US Army Corps of Engineers
Hydrologic Engineering Center

GENERALIZED COMPUTER PROGRAM

HEC-6

Scour and Deposition in Rivers and Reservoirs

User's Manual

September 1990

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CPD-6

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ASCE Manual 54

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CPD-6

FOREWORD

This September 1990 Version 4.0.0 of HEC-6, "Scour and Deposition in Rivers and Reservoirs," was developed by enhancing the version 3.2, dated October, 1986. The original computer program was developed by William A. (Tony) Thomas while at the Little Rock District and evolved into Version 2.7 while he was at the Hydrologic Engineering Center (HEC). The updates and enhancements of this version were initiated by Mr. Thomas while at HEC and the majority of the work was completed by Mr. Thomas and his staff at the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Some modifications were made under contract by Ford, Thorton and Norton Associates, Little Rock, Arkansas. This document was prepared by David Williams of W.E.S.T. Consultants, Inc. and finalized by HEC.

The present program has undergone major revisions since version 3.2, Modifications 50 and 51, and Error Corrections 01, 02, 03, and 04. While this version was under development, it was referred to as the "Network" version. Several applications have been made with the "Network" version and it has been thoroughly tested. Effort has been made to make version 4.0.0 "backwards compatible"; i.e., data developed for the prior versions can be used with minimum modifications. Because the movable bed width is now calculated differently, some computed results may differ from earlier versions.

This is the sixth in a special series of comprehensive programs, each of which is intended to be a major computational aid for solving programs associated with a particular area of hydrologic engineering. The programs currently in this series of comprehensive programs are:

HEC-1, Flood Hydrograph Package

HEC-2, Water Surface Profiles

HEC-3, Reservoir System Analysis (for Conservation)

HEC-4, Monthly Streamflow Simulation

HEC-5, Simulation of Flood Control and Conservation Systems

HEC-6, Scour and Deposition in Rivers and Reservoirs

Up-to-date information regarding availability of these and other programs is available from HEC. While the government is not responsible for the results obtained when using this program, identified errors will be eliminated in the program to the extent that time and funds are available. It is desired that users notify HEC of inadequacies in, or desirable modifications to the program.

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NOTATION

a = length of longest axis of a sediment particle

a_i = incremental area

A = total area of subsection

A, B, C = sediment transport coefficients developed using data

A_i = area of subsection

A_t = total area of cross section

A_1, A_2 = downstream and upstream area, respectively, of the cross sectional flow normal to the flow direction

b = length of intermediate axis of a sediment particle

B = coefficient of consolidation for silts or clay

B_s = width of the movable bed

B_{sp} = width of movable bed at point P

BSAE = coefficient used in calculation of transport under armor conditions

BSF = bed stability factor (coefficient)

c = length of smallest axis of a sediment particle

C = concentration at end of time period

C_e = loss coefficients for expansion or contraction

C_o = concentration at beginning of time period

CRT = critical section factor

CSAE = fraction of transport capacity sufficient to pass inflowing sediment discharge, used in armor layer calculations

d = grain diameter

d_a = smallest stable grain size in armor layer

d_i, d_{i+1} = the left and right depth of an incremental area, respectively

d_m = median grain diameter of the grain size class being tested

d_{mi} = median grain diameter for grain size class i

d_{84} = particle size in the streambed of which 84% of the bed is finer, in feet

D	=	water depth
D_{AL}	=	actual water depth for equilibrium depth calculations
D_{avg}	=	average water depth of each trapezoidal element
D_e	=	the minimum water depth for the condition of no sediment transport (i.e., equilibrium depth) for grain size d
D_{ely}	=	length difference between two sides of an incremental area
$D_s(i)$	=	effective depth occupied by sediment size i
D_{se}	=	depth of bed material which must be removed to reach equilibrium
D_{seold}	=	depth of active layer of previous discharge
D_{sm}	=	depth of sediment from bed surface to model bottom
D_J	=	either D_{AL} or $D1_{eq}$
DBN, DBI	=	weighting factors for hydraulic parameters at the downstream boundary
DD	=	duration of time increment
D,E	=	sediment transport coefficients developed using data
$D \bullet S_f$	=	depth-slope product
DECAY(i)	=	settling coefficient for sediment size class i
DIST	=	distance to upstream or downstream cross section
$D1_{eq}$, $D2_{eq}$	=	equilibrium depths corresponding to points on bed gradation curves
e	=	natural logarithm base
EFD	=	effective depth of a reach
EFW	=	effective width of a reach
ENTRLR	=	entrainment ratio
ETCON	=	entrainment coefficient
F_{SA}, F_{SL},	=	fractions of sand, silt, and clay, respectively, in the
F_{CL}	=	deposit
FSAE	=	transport capacity correction due to armoring
FTTS	=	flow through time through the reach
g	=	acceleration due to gravity

G	=	sediment load
G_u, G_d	=	sediment loads at the upstream and downstream cross sections, respectively
GP	=	sediment transport potential
GS	=	inflowing sediment discharge
h_e	=	energy head loss
h_f	=	head loss due to friction
h_o	=	form head loss
i	=	grain size class analyzed
i_t	=	total number of trapezoidal elements in a subsection
I	=	last sediment size class analyzed
j	=	total number of subsections across cross section
k'	=	$V_s P/2.3D$
K'	=	average conveyance/square root of length
K_i	=	conveyance of a subsection
K_t	=	sum of the subsection conveyances
K-1, K, K+1	=	downstream, midpoint, and upstream locations, respectively, of a reach
L_j	=	length of the jth strip between subsections
L_t	=	total number of trapezoidal elements in the subsection
L_u, L_d	=	length of the upstream and downstream reach, respectively, used in control volume computation
LTI	=	number of bed gradation recalculations within a discharge interval
M_1	=	erosion rate for particle scour
M_2	=	erosion rate for mass erosion
n	=	Manning's roughness coefficient
N	=	number of sediment grains on bed surface
NGS	=	number of grain sizes present
NSS	=	number of subsections
p_i	=	incremental wetted perimeter

P	=	wetted perimeter
P_d	=	porosity of deposits
P_i	=	wetted perimeter of subsection
P_r	=	probability that a floc will stick to bed $(1 - \tau_b/\tau_d)$
PC	=	percent of bed material coarser than size d
PI	=	fraction of bed composed of a grain size class
PIGS	=	percent of a grain size class required to transport inflowing sediment load
PROB	=	probability that grains will stay in the bed
q	=	water discharge per unit width of flow
Q	=	water discharge
R	=	hydraulic radius, in feet
R_i	=	hydraulic radius of subsection
R_1, R_2	=	downstream and upstream hydraulic radius, respectively
S_a	=	surface area exposed to scour
S_f	=	friction slope
SA	=	bed surface area
SAE	=	ratio of surface area of potential scour to total surface area
SD(i)	=	diameter of sediment size class i
SF	=	particle shape factor
SG	=	specific gravity of sediment particles
SLO	=	friction slope
SPI	=	see LTI
STO	=	multiplying factor of GP
t	=	time
T	=	time in years
TPIGS	=	total percent for all PIGS sizes
UBN, UBI	=	weighting factors for hydraulic parameters at the upstream boundary
UWD	=	unit weight of deposits

V	=	water velocity
V_f	=	volume of fluid in control volume
V_{se}	=	volume of bed material which must be removed to reach equilibrium
V_{sed}	=	volume of sediment in control volume
$V_s(i)$	=	settling velocity for particle size i
V_1, V_2	=	average velocities (total discharge ÷ total flow area) at ends of reach
VEL	=	weighted velocity of a reach
VOL_A	=	volume remaining in active layer
VOL_{SE}	=	total volume in active layer
VSF	=	volume shape factor
W	=	width of an incremental area
W_t	=	total water surface width
WTD	=	bed surface weight required to just transport inflowing sediment load
WTDT	=	weight of surface layer
WMB	=	width of movable bed
WS_1, WS_2	=	water surface elevations at ends of reach
x	=	distance along the channel
XID, XIN, XIU	=	weighting factors for hydraulic parameters
Y_s	=	depth of sediment in control volume
Y_{sp}, Y_{sp}	=	depth of sediment before and after time interval, respectively, at point P
ZSQ	=	computed section factor
0.047	=	Y-intercept of empirical data, from Shields (Vanoni, 1975)
2000	=	conversion from lbs to tons
α_1, α_2	=	velocity distribution coefficients for flow at ends of reach
γ	=	unit weight of water
γ_s	=	unit weight of sediment particles
$\gamma_{SA}, \gamma_{SL}, \gamma_{CL}$	=	unit weight of sand, silt, and clay, respectively
γ_{SC}	=	composite unit weight of deposits

γ_1	=	initial unit weight of the sediment deposit, usually after 1 year of consolidation
Δt	=	characteristic time of erosion
ρ_s	=	density of sand grains
ρ_f	=	density of water
τ_b	=	bed shear stress
τ_c	=	critical bed shear stress, after Meyer-Peter and Muller (1948)
τ_d	=	critical bed shear stress for deposition
τ_s	=	critical bed shear for particle scour
Ψ	=	transport intensity from Einstein's bed load function, related to the inverse of Shield's parameter

SECTION - 1

1. INTRODUCTION

1.1 Model Purpose and Philosophy

HEC-6 is a one-dimensional numerical model designed to analyze scour and deposition by simulating the interaction between the water-sediment mixture, the sediment material forming the stream's boundary and the hydraulics of flow. The model is intended to be used primarily for the evaluation of long-term river and reservoir responses rather than short-term, single event, floods. HEC-6 does not account for lateral channel migration or stream bank instability processes.

It is sometimes possible to separate sedimentation studies from those involving only the hydraulics of flow. For example, deposition in deep reservoirs can be studied from just the standpoint of a reduction in reservoir storage capacity because there is seldom reentrainment of material once it is deposited. On the other hand, sedimentation studies of shallow reservoirs or rivers downstream from dams treatment of the entire movable boundary problem because scour and/or deposition may affect the hydraulics. It is for this more general case of problems that HEC-6 is designed.

HEC-6 is not a watershed sediment yield program. It simulates the ability of a stream to transport sediment and considers the full range of conditions embodied in Einstein's Bed Load Function (Einstein, 1950), silt and clay transport and deposition, and the creation and destruction of an armor layer.

A reach of river with a sediment bed composed of the same type of sediment material as that moving in the stream is called an "alluvial reach" (Einstein, 1950). Einstein recognized that the "alluvial reach" provides a memory bank for the sediment (i.e., the bed surface of the stream) that has moved recently, perhaps even as recently as during the previous flood. By combining hydraulic properties of flow with characteristics of the sediment in that memory bank (which could be determined after the fact by analyzing samples of the streambed) one can calculate the rate of sediment transport which had occurred during that previous flood. HEC-6 utilizes a similar conceptual model to depict the movement of bed sediment materials for a temporal sequence of flows.

1.2 Applications of the Program

Nature maintains a delicate balance between the water-sediment mixture flowing in a natural stream, the size and gradation of sediment material forming the stream's boundary and the hydraulics of flow. When one constructs a reservoir, flood control features in the river, or maintains a minimum depth of flow for navigation, that balance is upset. This computer program can be used to predict the impact of changing one or more of the above parameters directly in terms of the water surface elevation and the water depth resulting from the change in streambed elevation.

HEC-6 is designed to simulate long-term trends of scour or deposition in a stream channel such as would result from modifying the frequency and duration of the water discharge and/or stage or from encroaching on floodplains. HEC-6 has the ability to evaluate reservoir deposition (both volume and location of deposits), channel contractions required to either maintain navigation depths or diminish the volume of maintenance dredging, influence that dredging has on the rate of deposition, scour during large flood events, and sedimentation within concrete channels.

1.3 Overview of Manual

This manual describes the fundamental concepts, program limitations and capabilities, methodologies, input requirements and output formats for HEC-6. A brief description of model capabilities and the organization of the manual is presented below. The section numbers after each heading refer to the manual's section that describes the information in detail.

Theoretical Basis For Movable Boundary Calculations (Section 2)

This section describes the theoretical basis for hydraulic and sediment computations used in the computer program HEC-6. It discusses the general capabilities of the program and how each computation is performed.

General Input Data Requirements (Section 3)

This section describes the general data requirements of HEC-6. It describes the necessary input requirements to implement specific HEC-6 capabilities.

Program Output (Section 4)

The program output section provides information on the various output levels for displaying the geometric, sediment and hydrologic data and for listing the initial and boundary conditions. It also describes how to display the desired information during a simulation.

HEC-6 Computations and Modeling Guidelines (Section 5)

General modeling guidelines and additional information on how HEC-6 performs its computations is presented in this section.

Example Problems (Section 6)

This section gives example applications of HEC-6. It covers single river and network situations as well as some commonly used features of the program.

1.4 Summary of Program Capabilities

General program capabilities are presented below. More detailed explanations of how the HEC-6 program calculates specific hydraulic and sediment transport quantities are presented in later sections of the manual.

1.4.1 Geometry

A system of main stem, tributary, and local inflow/outflow points can be simulated simultaneously. Such a system in which tributary sediment transport is calculated is called a network model. Sediment transport is calculated in primary tributaries as well as higher order tributaries. The total number of network branches, including the main stem and local inflow/outflow points, must not exceed 10.

1.4.2 Hydraulics

The one-dimensional energy equation is used for water surface profile computation using the standard step method and Manning's equation (U.S. Army Corps of Engineers, 1959). Manning's 'n' values for overbank and channel areas may be specified by discharge or elevation. Manning's 'n' for the channel can also be varied by Limerinos' (1970) method using the bed gradation of each cross section. Expansion and contraction losses are included in the determination of energy losses. The energy loss factors may be changed at any cross section.

For each discharge in the hydrograph, the downstream (starting) water surface elevation is determined by a rating curve or user specified water surface elevation. If desired, the downstream rating curve and any rating curves throughout the study reach can be changed in time by input of a new rating curve in the hydrology data set.

Conveyance limits, containment of the flow by levees, ineffective flow areas, and overtopping of levees, are simulated in a manner similar to HEC-2. Split flow computations are not done.

Supercritical flow is approximated by normal depth; therefore, sediment transport phenomena occurring in supercritical reaches are not explicitly computed by HEC-6.

HEC-6 can be executed in "fixed-bed" mode, similar to an HEC-2 application, in which only water surface profiles are computed. Sediment information such as inflowing sediment load and bed gradations are not needed to run in a "fixed-bed" mode.

1.4.3 Sediment

Sediment transport is calculated for grain sizes up to 64 mm. Sediment sizes larger than 64 mm may exist in the bed (used for sorting computations) but they are not transported.

For clay and silt sizes up to 0.0625 mm, Krone's (1962) method is used for deposition and Ariathurai's adaptation of Parthenaides' (1965) method is used for scour.

The sediment transport function for bed material load is selected by the user. Transport functions available in the program include the following:

a. Toffaleti's (1969)

b. Madden's (1963) modification (unpublished) of Laursen's (1958) relationship

c. Yang's Stream Power for Sands (Yang, 1972)

d. Duboys (Brown, 1950)

e. Ackers-White (1973)

f. Colby (1964)

g. Toffaleti (1969) and Schoklitsch (1930)

h. Meyer-Peter and Muller (1948)

i. Toffaleti (1969)/Meyer-Peter and Muller (1948) Combination

j. Madden's (1985) modification (unpublished) of Laursen's (1958) relationship

k. Parthenaides (1965)/Ariathurai (1976) and Krone (1962) for cohesive sediments.

l. User specification of transport coefficients based upon observed data.

The above methods, except for method (a), utilize the Colby (1964) method for adjusting the sediment transport potential when the wash load concentration is high.

Armoring and destruction of the armor layer is simulated based upon Gessler's (1970) approach.

For deposition or scour, each point within the movable bed (i.e., the area which is allowed to vertically change due to sediment activity) is raised or lowered. The depth of deposition can be limited to the depth of the water at each time step.

Simulation of geological controls such as bedrock or a clay layer is accomplished by specifying the lower limits (elevation) of the movable bed.

The movable bed limits may extend beyond the channel bank "limits". Deposition is allowed to occur in all wetted areas, even if the wetted areas are beyond the conveyance or movable bed limits. Scour occurs only within the movable bed limits. Sediment transport potential in these areas is based upon the hydraulic and sediment characteristics of the channel alone.

Sediment inflow rating curves for the main river channel, its tributaries, and local inflow/outflow points can be changed with time. HEC-6 has the capability to simulate diversion of water and sediment by grain size.

For the downstream-most cross section, a transmissive boundary condition may be specified where no scour or deposition is allowed to occur.

1.4.4 General

Output enhancements include the ability to print the total sediment discharge that has passed each cross section and the volume of deposits (or scour) accumulated at each cross section since the start of the simulation.

For a given dredging template, HEC-6 has the ability to simulate dredging activities. Dredging can be triggered by an allowable deposition depth before dredging is initiated or on a periodic basis. Dredging can also be performed based upon a required minimum navigation water depth.

If a network of main stem and tributaries is to be simulated, this version of HEC-6 makes use of exactly the same data set earlier versions would require if each river and tributary segment were being analyzed independently. Control Point data must be supplied to link the geometric segments together into a complete stream network. Data sets from earlier versions can be used with this version of HEC-6 if all **$TRIB** records are replaced by **$LOCAL** records and a water temperature is entered for each local inflow point.

1.5 Theoretical Assumptions and Limitations

HEC-6 is a one-dimensional continuous simulation model based on a sequence of steady flows to depict discharge hydrographs. There is no provision for simulating the development of meanders or specifying a lateral distribution of sediment load across a cross section. The cross section is subdivided into two parts with input data; that part which has a movable bed, and that which does not. The movable bed is constrained within the limits of the wetted perimeter and other limitations explained later. Usually the entire wetted part of the cross section is moved uniformly up or down; an option is available,however, which causes the bed elevation to be adjusted in horizontal layers for deposition conditions. Bed forms are not simulated except that 'n' values can be functions of discharge which indirectly permits a consideration of bed forms if the user can determine bed form effects from measured data. Density and secondary currents are not simulated.

There are three constraints on the formation of a model network containing tributaries for which sediment transport is calculated:

a. Sediment transport in distributaries is not possible.

b. Flow around islands, i.e., closed loops, cannot be directly accommodated.

c. Only one junction or local inflow point can occur between any two cross sections.

1.6 Single Event Analysis

HEC-6 is designed to analyze long-term scour and deposition. Single event analyses must be performed with caution. HEC-6 assumes that equilibrium conditions are reached within each time step (with certain restrictions explained later); however, the prototype is often influenced by unsteady non-equilibrium conditions during flood events. Equilibrium is never achieved under these conditions because of the continuously changing hydraulic and sediment conditions. If these situations predominate, single event analyses should be performed only on a qualitative basis. For gradually changing sediment and hydraulic conditions, such as for large rivers with slow rising and falling hydrographs, single event analyses may be performed with confidence.

SECTION - 2

2. THEORETICAL BASIS FOR MOVABLE BOUNDARY CALCULATIONS

2.1 General Overview of Approach and Capabilities

Section 2 presents the theories and ideas embodied in HEC-6. Detailed information on how these theories and ideas are implemented in HEC-6 are described in Section 3.

2.1.1 General

HEC-6 processes a discharge hydrograph as a sequence of (steady) flows of variable duration. Based on continuity of sediment, changes are calculated with respect to time and distance along the study reach for the following: total sediment load, volume and gradation of sediment that is scoured or deposited, armoring of the bed surface, and the resulting bed elevation. In addition, sediment outflow at the downstream end of the study reach is calculated. The location and amount of material that has to be dredged is calculated and printed out if desired.

2.1.2 Geometry

Geometry of the system is represented by cross sections which are specified by coordinate points (stations and elevations) and the distance between cross sections. HEC-6 raises or lowers cross section elevations to reflect deposition and scour. The horizontal locations of the channel banks are considered fixed and the floodplains on each side of the channel are considered as having fixed ground locations but can move vertically if within the movable bed.

2.1.3 Hydraulics and Hydrology

The water discharge hydrograph is approximated by a sequence of steady flow discharges, each of which each last for a specified period of time. Water surface profiles are calculated by using the standard step method to solve the energy and continuity equations (U.S. Army Corps of Engineers, 1959). Friction loss is calculated by the Manning's equation and expansion and contraction losses are included if the representative loss coefficients are specified. Hydraulic roughness is described by Manning's 'n' values and can vary from cross section to cross section. At each cross section 'n' values may vary vertically or by discharge.

It is necessary to specify the downstream water surface elevation for water surface profile calculations. In the case of a reservoir the operating rule may be utilized, but if open river conditions exist, a stage-discharge rating curve is usually specified as the downstream boundary condition. A rating curve or operating rule may be applied to any location along the main stem or tributaries.

2.1.4 Sediment Transport

Inflowing sediment loads are related to water discharge by sediment rating tables for the upstream ends of the main stem, tributaries and local inflow points. For realistic computation of scour and equilibrium conditions, the gradation of the material forming the stream bed must be measured. It can be specified at each cross section. If only deposition is expected, the gradation of material in the bed is less important and can be calculated by the program using the inflowing sediment load gradation.

Sediment mixtures are classified by grain size using the American Geophysical Union scale (Thomas, 1977). The program accommodates clay (particles less than 0.004 mm diameter), four classes of silt (0.004-0.0625 mm), five classes of sand (from very fine sand, 0.0625 mm, to very coarse sand, 2.0 mm), and five classes of gravel (from very fine gravel, 2.0 mm, to very coarse gravel, 64 mm).

Transport capacity is determined at each cross section by using hydraulic information from the water surface profile calculation (e.g., width, depth, energy slope, and flow velocity) and the gradation of bed material. Sediment is routed downstream after the backwater computations are made for each successive discharge.

2.2 Theoretical Basis for Hydraulic Calculations

The basis for water surface profile calculations is essentially Method II in U.S. Army Corps of Engineers (1959). Conveyance is calculated from average areas and average hydraulic radii for adjacent cross sections.

2.2.1 Equations for Basic Profile Calculations

The hydraulic parameters needed to calculate sediment transport capacity are velocity, depth, width and slope - all of which come from water surface profile calculations. The one-dimensional energy equation, shown below, is solved using the standard step method and the above hydraulic parameters are calculated at each cross section for each successive discharge. Figure 2.1 shows a representation of the terms in the energy equation.

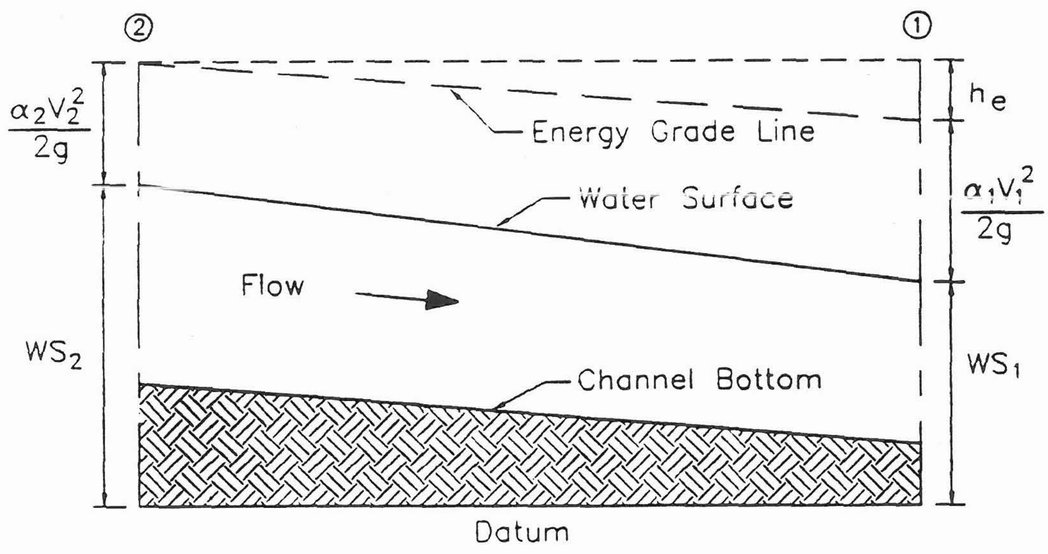

Figure 2.1. Representation of Terms in Energy Equation.

$$WS_2 + \frac{\alpha_2 V_2^2}{2g} = WS_1 + \frac{\alpha_1 V_1^2}{2g} + h_e \qquad (2\text{-}1)$$

where:

g	=	acceleration of gravity
h_e	=	energy loss
V_1, V_2	=	average velocities (total discharge ÷ total flow area) at ends of reach
WS_1, WS_2	=	water surface elevations at ends of reach (see Figure 2.1)
α_1, α_2	=	velocity distribution coefficients for flow at ends of reach

2.2.2 Hydraulic Losses

2.2.2.1 Friction Losses

Geometry is specified by cross sections and reach lengths; friction losses are calculated by Method II of U.S. Army Corps of Engineers (1959). The energy loss term, h_e, in equation 2-1 is composed of friction loss, h_f, and form losses, h_o, as shown in equation 2-2. Only contraction and expansion losses are considered in the geometric form loss term.

$$h_e = h_f = h_o \tag{2-2}$$

To approximate the transverse distribution of flow the river is divided into strips having similar hydraulic properties in the direction of flow. Each cross section is subdivided into portions that are referred to as subsections. Friction loss is calculated as shown below.

$$h_f = (Q/K')^2 \tag{2-3}$$

$$K' = \sum_{j=1}^{J} \left[\frac{1.48}{n_j}\right] \frac{\frac{(A_2 + A_1)_j}{2}\left[\frac{R_2 + R_1}{2}\right]_j^{1/2}}{L_j^{1/2}} \tag{2-4}$$

where:

A_1, A_2	=	downstream and upstream area, respectively, of the cross sectional flow normal to the flow direction
J	=	total number of subsections across cross section
K'	=	average conveyance ÷ square root of length between sections
L_j	=	length of the jth strip between subsections
n	=	Manning's roughness coefficient
Q	=	water discharge
R_1, R_2	=	downstream and upstream hydraulic radius, respectively

2.2.2.2 Other Losses

Energy losses due to contractions and expansions are computed by the following equation:

$$h_o = C_L \left| \frac{\alpha_2 V_2^2}{2g} - \frac{\alpha_1 V_1^2}{2g} \right| \qquad (2\text{-}5)$$

where:

C_L = loss coefficients for expansion or contraction

If the value within the absolute value notation is negative, flow is contracting and C_L is the coefficient of expansion. If the value is positive, flow is expanding and C_L is the coefficient of contraction.

2.2.3 Computation of Hydraulic Elements

Each cross section is defined by (X,Y) coordinates as shown in Figure 2.2

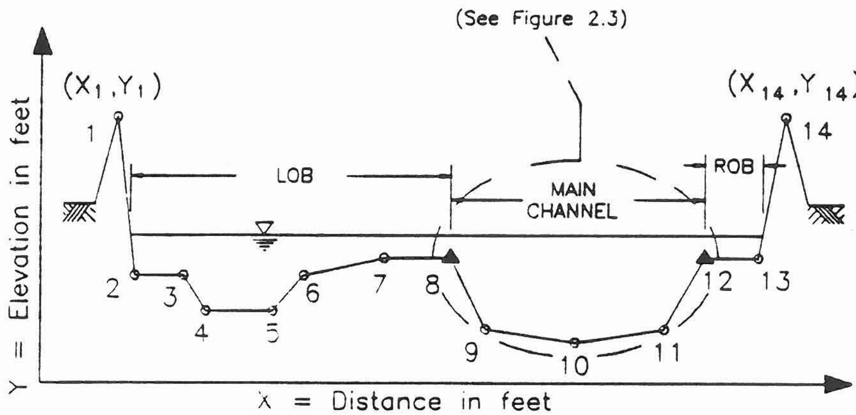

Figure 2.2. Typical Representation of a Cross Section.

For convenience of assigning 'n' values, reach lengths, etc., each cross section is divided into subsections, usually consisting of a main channel, with left and right overbanks.

2.2.3.1 Subsection Area

The area of each subsection is computed by summing incremental areas below the water surface between consecutive coordinates of the cross section. Fig. 2.3 illustrates the technique by using a subsection of Figure 2.2 with STCHL and STCHR as lateral boundaries of the subsection

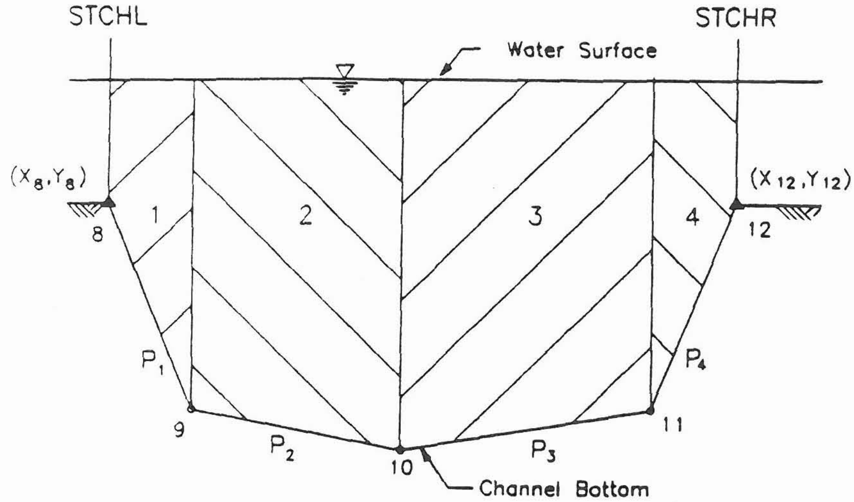

Figure 2.3. Incremental Areas in Subsection.

The area of a subsection, A, is:

$$A_i = a_1 + a_2 + a_3 + a_4 \tag{2-6}$$

where:

a_i	=	incremental area
A_i	=	area of subsection

The equation for an incremental area is:

$$a_i = \frac{(d_i + d_{i+1})\, W}{2} \tag{2-7}$$

where:

d_i, d_{i+1}	=	the left and right depth of each incremental area, respectively (see Figure 2.4)
W	=	width of an incremental area
D_{ely}	=	length difference between two sides of an incremental area

Normally, d_i, d_{i+1} and W are defined by two consecutive cross section coordinates, as shown in Figure 2.4. However at the first and last increments in each subsection, a subsection station defines one side of the incremental area. If the subsection station does not coincide with an X coordinate, straight line interpolation is used to compute the length of either d_i, d_{i+1}, or both.

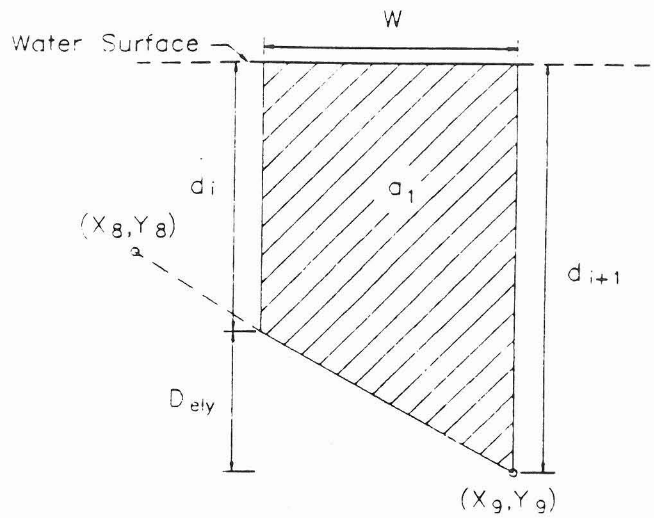

Figure 2.4. Incremental Area

2.2.3.2 Wetted Perimeter

The wetted perimeter, P, is computed as the length of cross section below the water surface. In the case of Figure 2.3, this is:

$$P = p_1 + p_2 + p_3 + p_4 \tag{2-8}$$

where:

p_i = incremental wetted perimeter

The equation for the wetted perimeter of the incremental area in Figure 2.4 is:

$$p_i = (D_{ely}^{\;2} + W^2)^{1/2} \tag{2-9}$$

Note that only the line between coordinate points is considered in p_i; d_i and d_{i+1} are not.

2.2.3.3 Hydraulic Radius

The hydraulic radius is calculated for each subsection by:

$$R_j = \frac{A_j}{P_j} \tag{2-10}$$

where:

A_j	=	area of subsection
P_j	=	wetted perimeter of subsection
R_j	=	hydraulic radius of subsection

2.2.3.4 Conveyance

The conveyance K_j, is computed for each subsection j by:

$$K_j = \frac{1.49}{n_j} A_j R_j^{2/3} \tag{2-11}$$

The total conveyance in the cross section is:

$$K_t = \sum_{j=1}^{NSS} K_j \tag{2-12}$$

where:

NSS = total number of subsections

2.2.3.5 Velocity Distribution Factor, Alpha

Alpha is an energy correction factor to account for the transverse distribution of velocity across the floodplains and channel. Large values of alpha (>2) may occur if the depth of flow on the overbanks is shallow, the conveyance is small, and the area is large. Alpha is computed as follows:

$$\alpha = \frac{\sum_{j=1}^{NSS} \left[\frac{K_j^3}{A_j^2}\right]}{\left[\frac{K_t^3}{A_t^2}\right]} \tag{2-13}$$

2.2.3.6 Effective Depth and Width

To account for the influence of non-rectangular cross section shapes on sediment transport capacity, a weighted depth, called the effective depth (EFD) is calculated. The effective width, EFW, is calculated from effective depth to preserve the proper $A(D^{2/3})$ for the cross section.

$$EFD = \frac{\sum_{i=1}^{i_t} D_{avg} . a_i . D_{avg}^{2/3}}{\sum_{i=1}^{i_t} a_i . D_{avg}^{2/3}} \qquad (2\text{-}14)$$

$$EFW = \frac{\sum_{i=1}^{i_t} a_i . D_{avg}^{2/3}}{EFD^{5/3}} \qquad (2\text{-}15)$$

where:

a_i = flow area of each trapezoidal element

D_{avg} = average water depth of each trapezoidal element

i_t = the total number of trapezoidal elements in a subsection

Since the sediment transport is based upon hydraulics of the main channel only, the hydraulic elements are from the geometry within the channel limits only.

2.2.3.7 Critical Depth Calculations

To assess if the backwater profiles remain above critical depth, the critical section factor (CRT), is computed using equation 2-16, and compared with the computed section factor at each cross section.

$$CRT = \frac{Q}{(g/\alpha)^{1/2}} \qquad (2\text{-}16)$$

A computed section factor, ZSQ, is calculated for comparison to CRT.

$$ZSQ = A_t(A_t/W_t)^{1/2} \qquad (2\text{-}17)$$

where:

A_t = total area of cross section

W_t = total water surface width

If CRT is less than ZSQ, subcritical flow exists and computations continue. Otherwise, critical depth is calculated by tracing the specific energy curve to the elevation of minimum total energy and the resulting water surface elevation is compared with the water surface elevation calculated by equation 2.1 to decide if flow is supercritical. If supercritical flow is indicated, flow depth is determined as described in Section 2.2.3.8.

2.2.3.8 Supercritical Flow

In the standard step method for water surface profile computations, calculations proceed from downstream to upstream based upon the reach's downstream boundary conditions and starting water surface elevation. As the calculations proceed upstream, HEC-6 examines the appropriate hydraulic parameters to determine if the reach is a subcritical or supercritical flow reach. If flow is subcritical, computations proceed upstream in the manner described in Section 2.2.1. If it is supercritical, HEC-6 approximates the channel geometry using the effective depth and width as described in Section 2.2.3.6 and determines the water surface elevation based upon the supercritical normal depth.

If a subcritical reach is eventually encountered, the downstream cross section of the reach is assumed to be at critical depth and backwater computations proceed upstream for assumed subcritical flow conditions. Note that for subcritical flow, M1 and M2 curves are possible in HEC-6 but under supercritical flow, S1 and S2 curves are not computed because only supercritical normal flow depths are calculated. An example of such a series of profiles is shown in Figure 2.5.

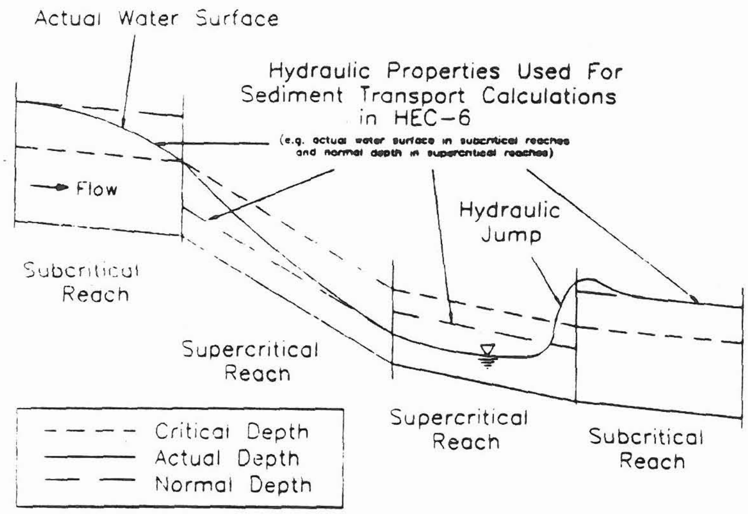

Figure 2.5. Examples of Subcritical, Critical, and Supercritical Flow Simulations in HEC-6.

2.2.3.9 Convergence Equations

Three major steps are used to converge computational trials to computed the upstream cross section water surface elevation. Figure 2.6 demonstrates the sequence of successive trials to converge the standard step method.

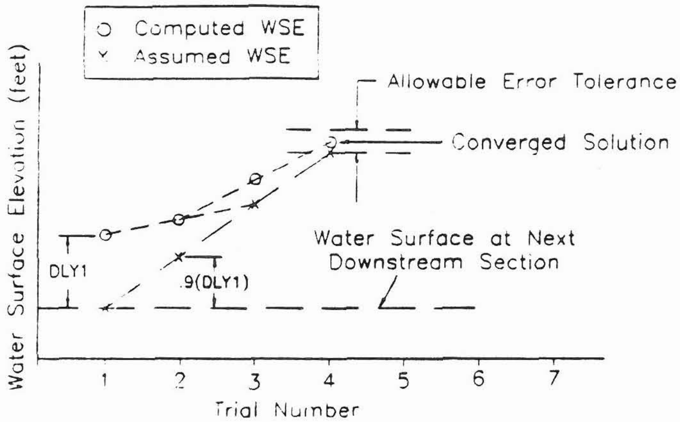

Figure 2.6. Convergence of Assumed and Computed Water Surface Elevations.

Computational Procedure:

Trial 1: Based on the previous water surface profile.

Trial 2: Assumed is 90% of DLY1

Trial 3: Trial 1 and 2 assumed are connected with a straight line and the computed trial 1 and 2 solutions are also connected with a straight line. The intersection of these lines becomes trial 3's assumed value.

Trial 4, etc.: This process continues until the assumed values and the computed value of WSE are within the allowable error tolerance. If they are, the computed WSE becomes the converged solution.

When an answer is forced, the program uses the last computed water surface elevation even though the allowable error between the trial and computed elevations has been exceeded. Oscillation between positive and negative "error" is permitted. A note is printed in the event a solution is "forced" (after 20 trials) even though the "error" is greater than the allowable error.

2.2.4 Representative Hydraulic Parameters Used in Sediment Calculations

Hydraulic parameters are converted into representative (weighted) values for each reach prior to calculating transport capacity. General equations are shown below. These weighting factors can be modified with input data.

Interior Point (section)

$$VEL = XID \cdot VEL(K-1)\ T\ XIN \cdot VEL(K) + XIU \cdot VEL(K+1) \qquad (2\text{-}18)$$

$$EFD = XID \cdot EFD(K-1) + XIN \cdot EFD(K) + XIU \cdot EFD(K+1) \qquad (2\text{-}19)$$

$$EFW = XID \cdot EFW(K-1) + XIN \cdot EFW(K) + XIU \cdot EFW(K+1) \qquad (2\text{-}20)$$

$$SLO = 0.5 \cdot [SLO(K) + SLO(K=1)] \qquad (2\text{-}21)$$

Upstream Point (section)

$$VEL = UBN \cdot VEL(K) + UBI \cdot VEL(K-1) \qquad (2\text{-}22)$$

$$EFD = UBN \cdot EFD(K) + UBI \cdot EFD(K-1) \qquad (2\text{-}23)$$

$$EFW = UBN \cdot EFW(K) + UBI \cdot EFW(K-1) \qquad (2\text{-}24)$$

$$SLO = SLO(K) \qquad (2\text{-}25)$$

Downstream Point (section)

$$VEL = DBN \cdot VEL(K) + DBI \cdot VEL(K+1) \qquad (2\text{-}26)$$

$$EFD = DBN \cdot EFD(K) + DBI \cdot EFD(K+1) \qquad (2\text{-}27)$$

$$EFW = DBN \cdot EFW(K) + DBI \cdot EFW(K+1) \qquad (2\text{-}28)$$

$$SLO = SLO(K) \qquad (2\text{-}29)$$

where:

DBN, DBI	=	coefficients for downstream reach boundary
K-1, K, K+1	=	downstream, midpoint, and upstream locations, respectively, of a reach
SLO	=	friction slope
UBN, UBI	=	coefficients for upstream reach boundary
VEL	=	weighted velocity of the reach
XID, XIN, XIU	=	downstream, interior, and upstream coefficients, respectively, for interior points

Several different weighting factors were investigated during the formulation of the computation scheme. The following table shows the one which appeared to give the most stable calculation and thereby permit the longest time steps (scheme 1) and also the one which is the most sensitive to changes in bed elevation but requires shorter time steps to be stable (scheme 2). Although scheme 1 is the most stable, it may cause the model to "smooth out" large bed elevation changes at adjacent cross sections which may not reflect actual prototype behavior.

Representative Hydraulic Parameter Weighting Factors

Scheme 1	DBI	DBN	XID	XIN	XIU	UBI	UBN	
	0.5	0.5	0.25	0.5	0.25	0.0	1.0	Most Stable
Scheme 2	0.0	1.0	0.0	1.0	0.0	0.0	1.0	Most Sensitive

The program defaults to scheme 2 but can be changed by using the **I5** record.

2.2.5 Hydraulic Roughness

Boundary roughness for an alluvial stream is closely tied to sediment transport and the movement of bed material. Energy losses for water surface profile calculations must include the effects of all losses: grain roughness of the movable bed, form roughness of the movable bed, bank irregularities, vegetation, contraction/expansion losses, bend losses and junction losses. All these losses except the contraction/expansion losses are embodied in a single roughness parameter, Manning's 'n'.

2.3 Theoretical Basis for Sediment Calculations

Sediment transport capacity is calculated at each time interval. The transport potential is calculated for each grain size class in the bed as though that size comprised 100 percent of the bed material. Transport potential is then multiplied by the fraction of each size class present in the bed to yield transport capacity for that size class. These fractions often change significantly during a time step, therefore an iteration technique is used to account for the effect of these changes on transport capacity. The primary controls on rate of scour are thickness of the active bed and amount of surface area armored. The active bed is the layer of material between the bed surface and a hypothetical depth at which no transport occurs for the given gradation of bed material and flow conditions. This is discussed in more detail in later sections. The thickness of the active bed is calculated at the beginning of each interval. The amount of surface area armored is proportional to the amount of active bed removed by scour. The basis for adjusting bed elevations for scour or deposition is the Exner equation. The basis for stability of the armor layer is the work by Gessler (1970).

2.3.1 Equation for Continuity of Sediment Material

2.3.1.1 The Control Volume

Each cross section represents a control volume. The control volume width is usually equal to the movable bed width and its depth extends from the water surface to top of bed rock or other geological control beneath the bed surface. In areas where no bed rock exists, an arbitrary model bottom or datum is assigned. This is illustrated in Figure 2.7.

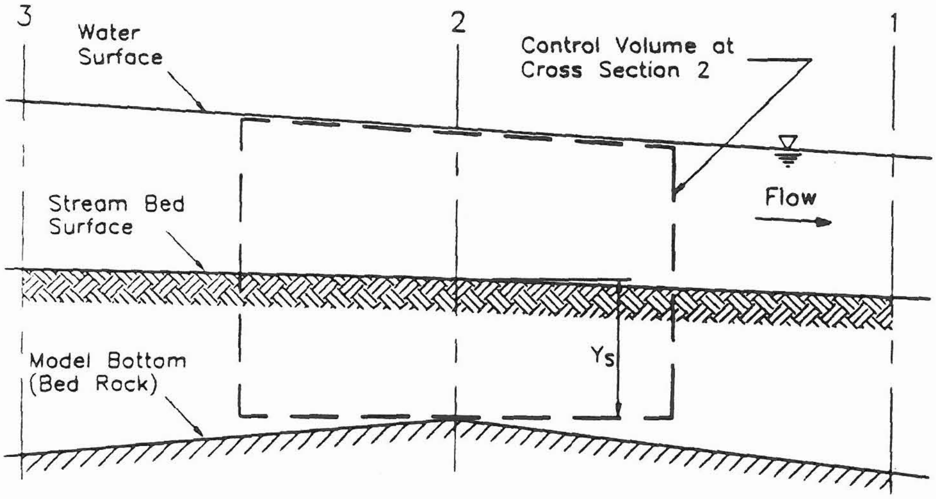

Figure 2.7. Control Volume for Bed Deposits.

The control volume for section 2 is represented by the heavy dashed lines. The control volumes for sections 1 and 3 join that for section 2, etc.

The continuity of sediment equation is written around this control volume; however, the energy equation is written between cross sections using the average end area concept. Since both mass continuity and energy should encompass the same space, and since the averaging of two cross sections tends to smooth the numerical results, the shape of the control volume is deformed as shown in Figure 2.8.

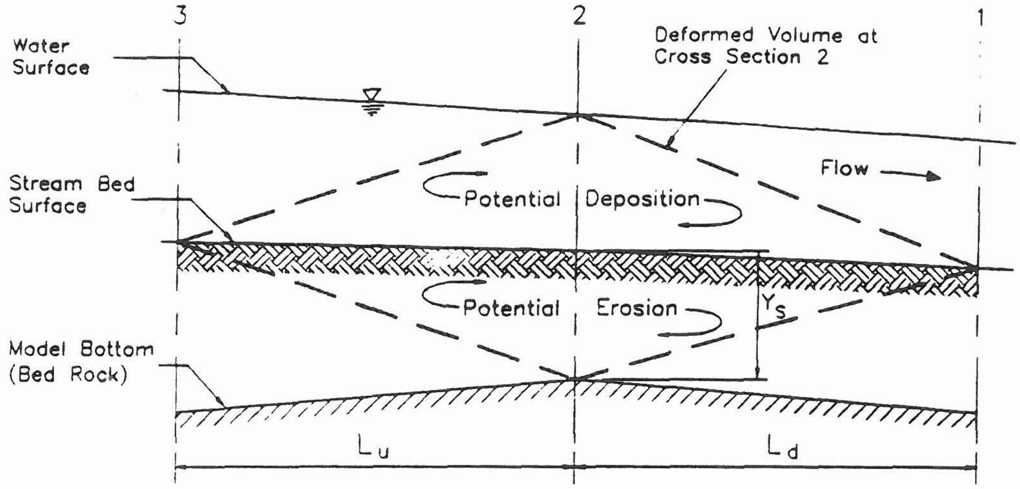

Figure 2.8. Deformed Control Volume For Bed Deposits.

The quantity of sediment in the stream bed, using an average end area approximation, is

$$V_{sed} = B_o \cdot (Y_s \cdot L_u/2 + Y_s \cdot L_d/2) \qquad (2\text{-}30)$$

where:

B_o	=	width of the movable bed
L_u, L_d	=	length of the upstream and downstream reach, respectively, used in control volume computation
V_{sed}	=	volume of sediment in control volume
Y_s	=	depth of sediment in control volume

For a water depth of D, the volume of fluid in the water column is

$$V_f = B_o \cdot [(D \cdot L_u/2) + (D \cdot L_d/2)] \qquad (2\text{-}31)$$

B_o and D are hydraulic parameters, width and depth, which are calculated by averaging over the same space used in solving the energy equation as described in section 2.2.1.

The solution to the continuity of sediment equation assumes that the initial concentration of suspended bed material is zero. That is, all bed material is contained in the sediment reservoir at the start of the computation interval and is returned to the sediment reservoir at the end of the computation interval. Therefore, no initial concentration of bed material load need be specified in the control volume. Another way of stating this is that it is assumed that the transport potential can be satisfied, if the sediment is available, within each time step within each control volume.

The hydraulic parameters, bed material gradation and calculated transport capacity are assumed to be uniform throughout the control volume. The inflowing sediment load is assumed to be mixed uniformly with sediment existing in the control volume. HEC-6 assumes instantaneous diffusion of all grain sizes classes on a control volume basis.

2.3.1.2 Concepts of the Bed-Sediment Reservoir

The alluvium deposit over which the water flows is called the sediment reservoir. The portion of the alluvium directly below the channel bed is called the "Bed Sediment Reservoir" and the portion on the sides is the "Bank Sediment Reservoir" as depicted in Figure 2.9. The river channel will erode sediment from either of those reservoirs or deposit sediment into either of them. HEC-6, however, only exchanges sediment with the bed sediment reservoir. Correct reproduction of a prototype system depends on the proper exchange of sediment between the flow field and the bed sediment reservoir. The physics of that exchange process is not well understood.

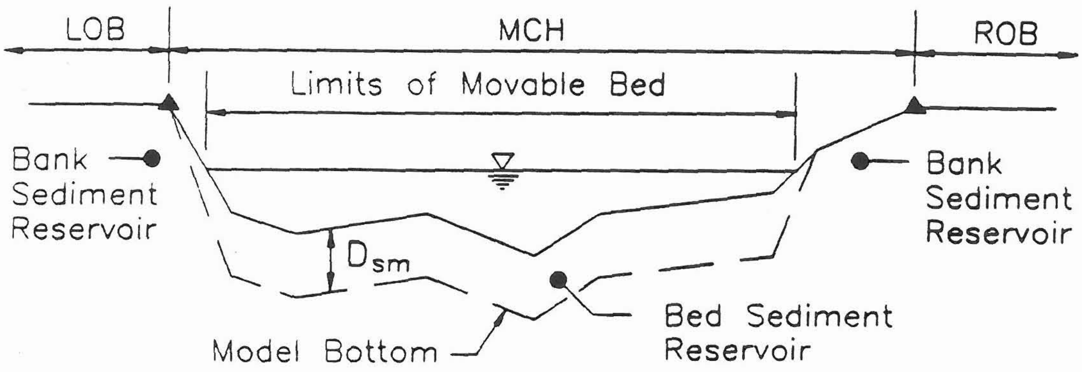

Figure 2.9. Sediment Material in the Streambed.

HEC-6 accounts for two sediment sources: the sediment concentration in the inflowing water and the bed-sediment reservoir in the channel bed. The inflowing sediment load is a boundary condition and is prescribed with input data. The bed sediment reservoir is the source-sink component of the numerical model and is also prescribed with input data.

Transport theory for sand relates the total sand load transport to the gradation of sediment particles on the bed surface. Armor calculations require the gradation of material beneath the bed surface. The depth to bed rock or some other material that might prevent degradation should also be given to limit the scour process. These requirements are addressed in HEC-6 by separately computing the surface gradation and the subsurface gradation.

Coordinates connected with the solid line in Fig. 2.9 define the initial cross section shape at the beginning of the simulation. For scour conditions, the difference between the inflowing sediment load and the reach's transport capacity is converted to a scour volume. After each time step the coordinates within the "movable bed" are lowered by an amount D_{sm}, which when multiplied by the movable bed width and the representative reach length, equals the required scour volume. If a model bottom elevation is not specified, a default value of 10 feet below the thalweg is used, which then becomes the maximum D_{sm} available for scour.

2.3.1.3 Exner Equation

The aforementioned physical description must be converted to computational algorithms. The basis for simulating vertical movement of the bed is the continuity equation for sediment material (the Exner equation):

$$\frac{\partial G}{\partial x} + B_o \cdot \frac{\partial Y_s}{\partial (DD)} = 0 \qquad (2\text{-}32)$$

where:

B_o	=	width of movable bed
DD	=	duration of time step
G	=	sediment discharge (ft^3/sec)
x	=	distance along the channel
Y_s	=	depth of sediment in control volume

This equation is expressed in finite difference form (see equations 2-33 and 2-34) for point P using the notation shown in Figure 2.10.

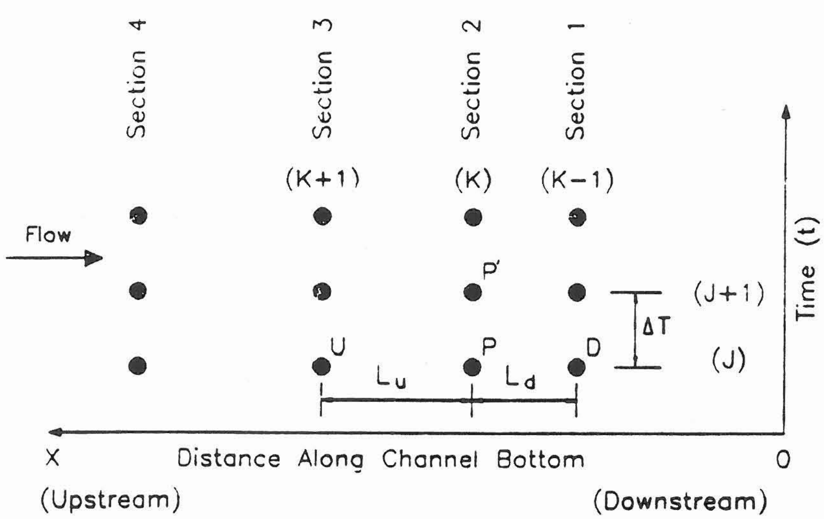

Figure 2.10. Computation Grid.

$$\frac{G_u - G_d}{VSF(L_d + L_u)} + \frac{B_{sp}(Y_{sp'} - Y_{sp})}{DD} = 0 \qquad (2\text{-}33)$$

$$Y_{sp'} = Y_{sp} - \frac{DD}{(0.5)B_{SP}} \cdot \frac{G_u - G_d}{L_d + L_u} \qquad (2\text{-}34)$$

where:

B_{sp}	=	width of movable bed at point P
G_u, G_d	=	sediment loads at the upstream and downstream cross sections, respectively Volume/time
L_u, L_d	=	upstream and downstream reach lengths, respectively, between cross sections
Y_{sp}, $Y_{sp'}$	=	depth of sediment before and after time step, respectively, at point P
VSF	=	volume shape factor as calculated from prismodial equation

The initial depth of bed material at point P defines the initial value of Y_{sp}. The sediment load, G_u is the amount of sediment, by grain size, entering the control volume from the upstream control volume. For the upstream-most reach, this is the inflowing load boundary condition provided by the user. The sediment leaving the control volume, G_d, becomes the G_u for the next downstream control volume.

The sediment load, G_d, is calculated by considering the transport capacity at point P, the sediment inflow, availability of material in the bed, and armoring. The difference between G_d and G_u is the amount of material deposited or scoured in the reach between points D and U during the time step, and is converted to a change in bed elevation using equation 2-34.

As shown in Figure 2.10, the transport capacity is calculated for the bed elevation at the beginning of the time interval and it is not recalculated during that interval. Therefore, it is important that each time interval be short enough so that changes in bed elevation due to scour or deposition during that time interval do not significantly influence the transport capacity by the end of the time interval. Fractions of a day are typical time steps for large water discharges and several days or even months may be satisfactory for low flows. The amount of change in bed elevation that can be tolerated in one time step is a matter of judgment. Good results have been achieved by using either one foot or ten percent of the water depth, whichever is less, as the allowable bed change in a computational time interval. The gradation of the bed material, however, is recalculated during the time interval because the amount of material transported is very sensitive to the gradation of bed material (see section 2.3.4.1).

2.3.2 Determination of the Active and Inactive Layer

HEC-6 incorporates the concept of an active and an inactive layer. The active layer is assumed to be continually mixed by the flow, but it can have a surface of slow moving particles that shield the finer particles from being entrained in the flow. Two different processes are assumed: (1) mixing that occurs between the bed sediment particles and the fluid-sediment mixture due to the energy in the moving fluid and, (2) mixing that occurs between the active layer and the inactive layer due to the distortion of the bed surface. The mixing mechanisms are attributed to macro-turbulence and bed shear stress from the moving water. The mixing depth, therefore, can be expressed as a function of flow intensity (i.e., unit discharge), energy slope, and particle size.

2.3.2.1 Equilibrium Depth

The minimum hydraulic condition at which a particular grain size will be immobile on the bed surface can be calculated by combining Manning's, Strickler's, and Einstein's equations, respectively:

$$V = \frac{1.486}{n} R^{2/3} S_f^{1/2} \qquad (2\text{-}35)$$

$$n = \frac{d^{1/6}}{29.3} \qquad (2\text{-}36)$$

$$\psi = \frac{\rho_s - \rho_f}{\rho_f} \cdot \frac{d}{DS_f} \qquad (2\text{-}37)$$

where:

d	=	grain diameter
D	=	water depth
V	=	water velocity
ρ_s	=	density of sand grains
ρ_f	=	density of water
Ψ	=	transport intensity from Einstein's bed load function, related to the inverse of Shield's parameter

(See ϕ vs. Ψ function in Eistein Bedload Formula)

For no transport, Ψ equals 30 or greater. Solving equation 2.37 in terms of S_f for a specific gravity of sand of 2.65 and with Ψ set at 30 yields

$$S_f = \frac{d}{18.18D} \qquad (2\text{-}38)$$

Combining this with the Manning and Strickler equations, in which R has been replaced with D_t and multiplying velocity by depth to get unit discharge yields:

$$q = \frac{(1.486)(29.3)D^{5/3}}{d^{1/6}} \left[\frac{d}{18.18D}\right]^{1/2} \qquad (2\text{-}39)$$

$$q = 10.21\, D^{7/6} d^{1/3} \qquad (2\text{-}40)$$

where:

q	=	water discharge per unit width of flow

The equilibrium depth for a given grain size and unit discharge is therefore;

$$D_e = D = \left[\frac{q}{10.21 d^{1.3}}\right]^{6/7} \tag{2-41}$$

where:

D_e = the minimum water depth for no sediment transport (i.e., equilibrium depth) for grain size d (particle is likely to be stable for D_0)

2.3.2.2 Scour Depth and Armoring

Where the bed material is a mixture of grain sizes, the scour depth required to accumulate a sufficient amount of coarse surface material to armor the bed is calculated as follows: The number of grains times the surface area shielded by each grain equals the total surface area of a vertical column, illustrated by Figure 2.11 and equations 2-42 and 2-43

$$SA = N\left[\frac{\pi d^2}{4}\right] \tag{2-42}$$

$$N = \frac{SA}{\left[\frac{\pi d^2}{4}\right]} \tag{2-43}$$

where:

D_{se} = depth of scour to reach equilibrium

N = number of sediment grains on bed surface

SA = bed surface area

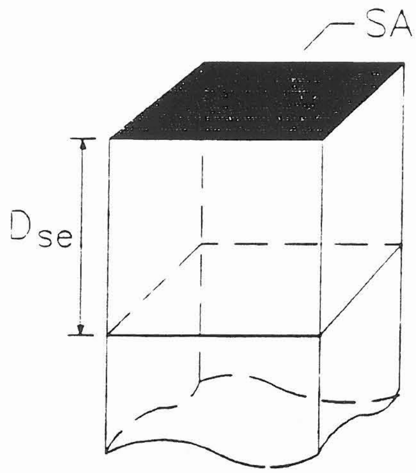

Figure 2.11. A Column of Bed Material Having Surface Area SA.

The surface area of the column may be partially shielded by a rock outcrop or an armor layer such that the potential scour area is less than the total surface area of the column. This reduces the number of grains exposed to scour as follows.

$$N = \frac{SA \cdot SAE}{\left[\frac{\pi d^2}{4}\right]} \tag{2-44}$$

where:

SAE = ratio of surface area of potential scour to total surface area

Assuming a heterogenous mixture, the depth of scour required to produce a volume of a particular grain size sufficient to completely cover the bed to a thickness of one grain diameter is:

$$V_{se} = PC \cdot SA \cdot D_{se} = N\left[\frac{\pi}{6} \cdot d_a^3\right] \tag{2-45}$$

where:

d_a = smallest stable grain size in armor layer

D_{se} = depth of bed material which must be removed to reach equilibrium in time stop

PC = percent of bed material coarser than size d

V_{se} = volume of bed material which must be removed to reach equilibrium in time step

Combining the surface area and volume equations and solving for the required depth of scour to fully develop the armor layer gives:

$$D_{se} = \left[\frac{\frac{SA \cdot SAE}{\pi d^2}}{4}\right] \cdot \left[\frac{\pi}{6} \cdot \frac{d^3}{PC \cdot SA}\right] \tag{2-46}$$

which reduces to:

$$D_{se} = (2/3)\left[\frac{SAE \cdot d}{PC}\right] \tag{2-47}$$

This equation is used with equation 2-41 to calculate an equilibrium depth for a mixture of grain sizes. In order to determine the PC to use in equation 2-47, the proper segment on the bed gradation curve is found by approximating the functional relationship between d and PC (the gradation curve) with a sequence of straight line segments as shown in Figure 2.12. The first step in locating the proper segment on the gradation curve is to calculate the equilibrium depths, $D1_{eq}$ and $D2_{eq}$ for the grain sizes at points 1 and 2, respectively, using equation 2-41. If the actual water depth, D_{AL}, is less than $D2_{eq}$, the straight line segment from 1 to 2 in Figure 2.12 defines the required functional relationship and the final equilibrium depth is calculated. If D_{AL} is greater than the equilibrium depth for grain size at point 2, computations move down the gradation curve to points 2 to 3, 3 to 4, etc., until either the proper segment is located or the smallest grain size is sufficient to armor the bed in which case scour will not occur.

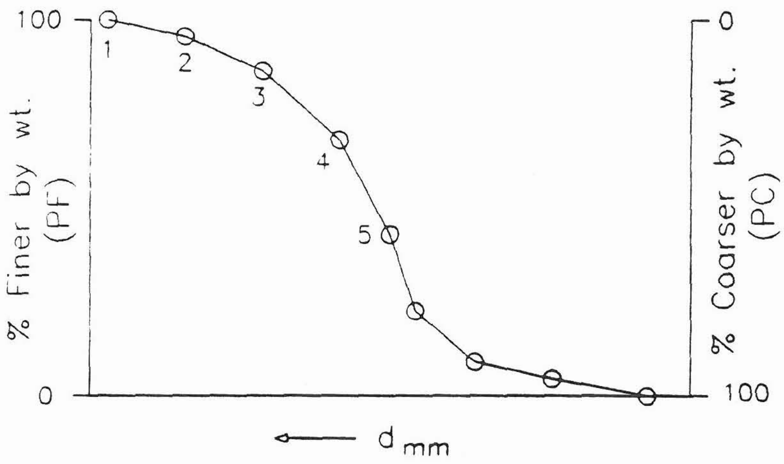

Figure 2.12. Gradation of Bed Material for Equilibrium Depth Computation.

Relating depth of scour and equilibrium depth requires consideration of two conditions as illustrated in Figure 2.13.

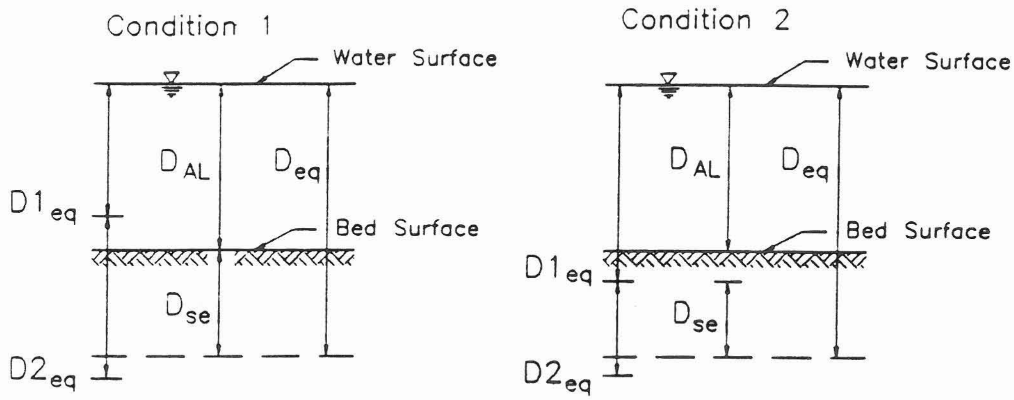

Figure 2.13. Equilibrium Depth Conditions.

When D_{AL}, the actual depth of flow, is between $D1_{eq}$ and $D2_{eq}$ (corresponding to equilibrium depths for points 1 and 2 of Figure 2.12), condition 1 is satisfied and

$$D_{eq} = D_{AL} + D_{se}$$

When D_{AL} is less than $D1_{eq}$, condition 2 is satisfied and

$$D_{eq} = D1_{eq} + D_{se} \tag{2-49}$$

A general expression is

$$D_u = D_u + D_{se} \tag{2-50}$$

where:

D_u = either D_{AL} or $D1_{eq}$

The technique for determining D_{eq} for a mixture of grain sizes is to first calculate D_{se} for $D2_{eq}$. Using equations 2-42 through 2-47, D_{se} is used to determine if there is a sufficient number of stable grains in V_{se} (see equation 2-45) to completely cover the bed surface. If not, $D2_{eq}$ is increased in increments until D_{se} provides enough volume of bed material so that 100 percent of the bed surface is covered by stable grains. When this occurs, $D2_{eq}$ equals D_{eq}.

HEC-6 designates the zone of material between the bed surface and equilibrium depth as the active layer and the zone from equilibrium depth to the model bottom as the inactive layer. The active layer provides the source of material forming the bed surface. The inactive layer has the same gradation as the parent bed. That gradation changes as material is deposited on the active layer and is exchanged with the inactive layer. The inactive layer is the bed sediment reservoir. Material is moved from one layer to the other layer as the active layer thickness changes with water depth, velocity and slope. Only the material in the active layer is subject to scour. HEC-6 allows sorting by grain size during the solution of the Exner Equation which requires continuous accounting of the percent of sediment in each size class within each time step. When all material is removed from the active layer, the bed is completely armored for that hydraulic condition. Details of how the active and inactive layer concepts work are presented in Section 2.3.3.

Assuming a heterogeneous mixture, the rate of armoring is proportional to the volume of material removed, and the surface area exposed for scour is:

$$SAE = \frac{VOL_A}{VOL_{SE}} \qquad \text{Exner 1} \qquad (2\text{-}51)$$

where:

VOL_A = volume remaining in active layer

VOL_{SE} = total volume in active layer

Leaching of the smaller particles from beneath the bed surface is prevented by adjusting the surface area exposed, SAE. If a grain size of bed sediment is smaller than the armor size, transport capacity is linearly decreased to zero as SAE decreases to 40% of the total bed surface (Harrison, 1950). Thereafter, the inflowing load of that grain size and smaller is transported through the reach. Particle sizes equal to and larger than the armor size are not constrained by this procedure.

2.3.3 Composition of the Active Layer

The thickness of the active layer is calculated by equating the resistance of the bed sediment particles to the imposed force from the flow field as described in Section 2.3.2.1. This defines an equilibrium depth - a flow depth at which the bed sediment particles are stable against the erosive forces of the flow. All particles within that layer are subject to being eroded provided there is sufficient transport capacity. The thickness of the active layer is D_{se} (see Figure 2.13).

The active layer's maximum thickness is not checked during a time step, however, it is important that the thickness change does not affect the hydraulic parameters (velocity, depth) enough to effect the sediment transport potential. Users must inspect their results for such conditions and adjust the time step accordingly (see Thomas, 1981). The thickness of the active layer is checked against a maximum allowable value (2 feet) at the start of each time step. The main consideration is to prevent large deposits during a time step that would cause the sorting concepts to fail. The 2 foot maximum allowable thickness of the active layer assumes that this is the maximum depth to which grains can interact within a computational interval.

2.3.3.1 The Cover Layer *Exner 3*

During erosion, HEC-6 stratifies the active layer into two sublayers; a cover layer and a sub-surface layer as shown in Figure 2.14. The concept of a cover layer is based upon the following; if a steady state water discharge continues for a sufficiently long period of time to develop an equilibrium sediment discharge, then an equilibrium condition will develop between the active layer and the sediment concentration in the water column. During the development of that equilibrium condition, the concentration of smaller particles in the flow, fine sands and silts, will decrease; however, the potential transport of those sizes will not change. That decrease is due to the removal of the smaller sizes from the bed surface layer because their transport rate is large relative to that for the larger sizes. Consequently, a cover layer of the coarser particles will grow over the bed surface and act like a slow moving shield that protects the finer particle sizes beneath it from the erosive forces. If the cover layer is replenished by deposition from the water column, it will remain as a shield. Otherwise, it will continue to slowly move in the direction of flow until a sufficient surface area of the bed is exposed to allow water forces to be in contact with the fines in the well mixed "Sub-surface Layer" beneath it. Harrison (1950) noticed this "armoring" occurring when as little as 40% of the bed surface was covered.

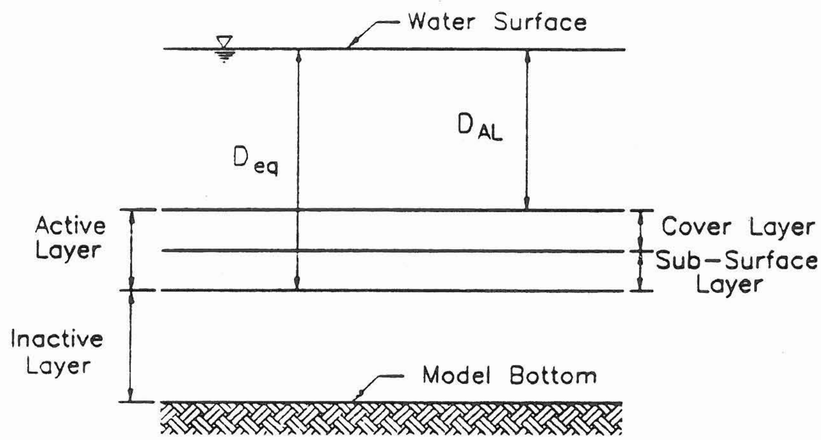

Figure 2.14. Composition of the Active Layer.

2.3.3.2 The Sub-Surface Layer

The sub-surface layer is composed of well mixed sediments brought up from the inactive layer plus sediment which has deposited from the water column. It will replenish the cover layer and thereby supply bed sediment as required to meet sediment transport capacity. When the weight in the sub-surface layer becomes less than the weight required to cover 100% of the bed surface to a depth of 2 times the size of the largest particle in transport, a new sub-surface layer is brought up from the inactive layer. Availability of material is a constraint. Thickness of the active layer is considered to be very important and is calculated as described earlier.

2.3.3.3 Rate of Replenishing the Active Layer *Exner 1*

A streambed having a gravel or cobble surface underlain by finer material is said to be armored. This condition does not reduce the stream's potential to transport sediment but rather reflects a limited supply of sediment material such that transport theory cannot be used for grain sizes finer than those in the armor layer because their rate of movement is limited by their availability and not the flow hydraulics. The armor layer forms when fines are transported away more rapidly than they are replaced by the inflowing load, allowing the coarser grain sizes to dominate the bed surface gradation and prevent further degradation.

The stability of the armor layer is based on a normal probability distribution function in which the ratio of critical to actual tractive force is the independent variable. Equations used for the two tractive forces are:

$$\tau_c = 0.047(\gamma_s - \gamma)d_m \qquad (2\text{-}52)$$

$$\tau_b = \gamma \cdot EFD \cdot S_f \qquad (2\text{-}53)$$

where:

d_m	=	median grain diameter of the grain size class being tested for stability
EFD	=	effective depth
S_f	=	friction slope
0.047	=	Y-intercept of empirical data, from Shields (Vanoni, 1975)
γ	=	unit weight of water
γ_s	=	unit weight of sediment particles
τ_b	=	bed shear stress
τ_c	=	critical bed shear stress, after Meyer-Peter and Muller (1948)

The probability relationship presented by Gessler (1970) is shown in Figure 2.15. According to Gessler, the stability of sediment particles on the bed surface is a probability relationship. Shields' deterministic curve for movement of sediment particles corresponds to a tractive force ratio (τ_c/τ) of 1.0 in Figure 2.15 and actually indicates a stability probability of 0.5. As the actual tractive force increases, the tractive force ratio decreases to reflect a lower probability that the grains will remain stationary. This does not guarantee particle movement nor do tractive force ratios greater than 1 guarantee that sediment particles will remain stationary in the bed. This relationship is used to calculate a bed stability coefficient which includes the particle size distribution of the bed material as follows:

$$BSF = \frac{\sum_{i=1}^{NGS} PROB \cdot PROB \cdot PI_i \cdot d_{mi}}{\sum_{i=1}^{NGS} PROB \cdot PI_i \cdot d_{mi}} \qquad \text{Exner 7} \quad (2\text{-}54)$$

where:

BSF	=	bed stability factor (coefficient)
d_{mi}	=	median grain diameter for grain size class i
i	=	grain size class analyzed
NGS	=	number of grain sizes present
PI	=	fraction of bed composed of a grain size class
PROB	=	probability that grains will stay in the bed

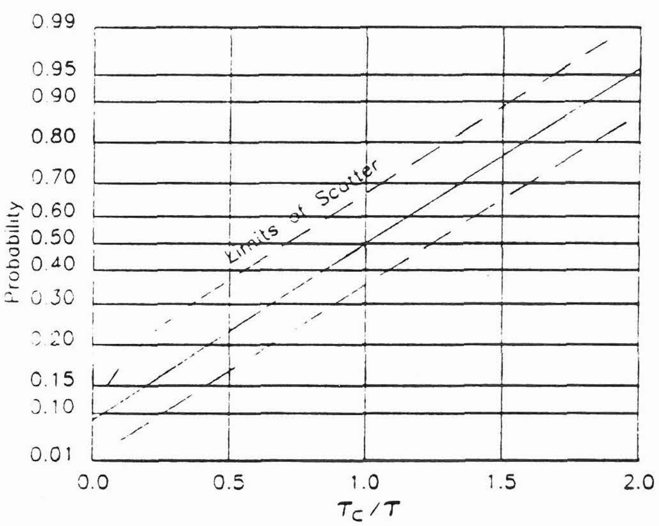

Figure 2.15. Probability of Grain Stability.

Work by Gessler (1970) proposed a stability factor equal to or greater than 0.65 be used to indicate a stable armor layer. If a partially armored bed is stable under a given hydraulic condition, material is taken from the active layer until enough stable grains are left to cover the bed to the depth of one stable grain size. If the armored bed is not stable, the layer is destroyed and a completely new active bed is calculated.

The probability function could be used to determine the amount of armor layer destroyed; however, a simple linear relationship is used. The amount of armor layer destroyed is related to the size of the stability coefficient as

$$SAE_{t+1} = 1.0 - \frac{BSF}{0.65}(1.0 - SAE_t) \quad \text{Exner 1} \qquad (2\text{-}55)$$

where subscripts t and t+1 represent beginning and ending of a computational interval. Material from the active layer is removed until the remaining stable grains are sufficient to cover the bed at the ending SAE.

2.3.3.4 Influence of Clay on the Active Layer

The presence of clay in the streambed can cause the bed's strength to be greater than the shear stress required to move individual particles. This results in a limiting of the entrainment rate under erosion conditions. HEC-6 attempts to emulate this process by first checking the percentage of clay in the bed. If more than 10% of bed is composed of clay, the entrainment rate of silts, sands and gravels is limited to the entrainment rate of the clay. This also prevents the erosion of silts, sands and gravels before the erosion of clay even if the bed shear were normally sufficient to erode those particles but not enough to erode the cohesive clay.

2.3.4 Movement of Sediment

2.3.4.1 Bed Gradation Recomputations Exner 1 & 3

HEC-6 solves the Exner equation for continuity of material. If transport capacity is greater than sediment discharge, available sediment is removed from the bed to satisfy continuity. Since transport capacity for a given size depends upon the fraction of bed material composed of that size, it is necessary to frequently recalculate fractions present as material is exchanged with the bed. The number of recalculations, LTI, is related to flow duration, velocity and reach length at each reach by:

$$LTI = \frac{DURATION \cdot VELOCITY}{REACH\ LENGTH} \qquad (2\text{-}56)$$

Often the number of recalculations can be less than this without significant changes in the results. The user should initially start with LTI=0 (use variable SPI in I1 input record) for extreme hydrologic events and observe the results. This should be the most stable (and computationally intensive) condition because the number of iterations is set by equation 2-56. Starting from SPI=50, decrease it in increments of 10 until the results become significantly different from the results with SPI=0. Use the SPI that gives answers close to those obtained with SPI=0.

2.3.4.2 Characteristic Rate of Entrainment *Exner 3 (1 Entrains instantly)*

The characteristic rate of entrainment is associated with flow turbulence. Turbulence simulation, however, is beyond the scope of this program. Since sediment entrainment is not instantaneous, a characteristic "flow-distance" was created to approximate a rate of entrainment. Using the distance one would need to sample equilibrium concentrations in a flume as a guide, the characteristic distance for entrainment was set at 30 times the flow depth. The entrainment ratio, associated with the rate at which a flow approaches its equilibrium load, is calculated by dividing the reach length by the characteristic distance for entrainment as follows:

$$ENTRLR = REACH\ LENGTH/(30 \cdot DEPTH) \qquad (2\text{-}57)$$

The entrainment coefficient, ETCON, is then defined by

$$ETCON = 1.368 - e^{-ENTRLR} \qquad (2\text{-}57)$$

where:

e	=	natural logarithm base
ENTRLR	=	entrainment ratio
ETCON	=	entrainment coefficient

ETCON is used to determine what percentage of the equilibrium concentration (for each grain size) is achieved in the channel reach, and has a maximum limit of 1.0.

Research is needed to substantiate this entrainment hypothesis in particular as well as the appropriate equation and coefficients.

2.3.4.3 Characteristic Rate for Deposition *Exner 3 (1 Deposits Instantly)*

Deposition occurs when the inflowing sediment discharge is greater than the transport capacity. Not all size classes in a mixture deposit; therefore, this process is calculated by size class. The rate at which sediment deposits from the flow field is controlled by particle settling velocity as follows:

$$DECAY(i) = \frac{V_s(i) \cdot DD}{D_s(i)} \qquad (2\text{-}59)$$

where:

$D_s(i)$	=	effective depth occupied by sediment size i
DD	=	duration of time increment
$V_s(i)$	=	settling velocity for particle size i

2.3.4.4 Influence of Armoring on Transport Capacity

All grain sizes are analyzed in each iteration. Before the next iteration, the surface area exposed for scour is calculated. In Einstein's relationship, the hiding factor adjusts transport capacity to account for armoring. In the other transport relationships, the transport capacity is corrected for armoring by a parabolic relationship which attempts to account for extra scour due to the presence of large individual sediment particles. The relationship used in HEC-6 is:

$$FSAE = CSAE + (1.0 - CSAE)SAE^{BSAE} \quad (2\text{-}60)$$

Exner 1

where:

BSAE = coefficient used in calculation of transport under armor conditions

CSAE = fraction of transport capacity sufficient to pass inflowing sediment discharge, used in armor layer calculations

FSAE = transport capacity correction due to armoring

The value of CSAE is the fraction of transport capacity just sufficient to pass the inflowing sediment discharge with no deposition. The program assigns the value of 0.5 for BSAE unless input data specifies otherwise.

2.3.4.5 Hard Bottom Channel

The special condition of a hard channel bottom (as with a concrete channel) is approximated by specifying 0 sediment depth in the bed sediment reservoir. This is accomplished by specifying the model bottom (EMB, field 2 on H record) equal to the initial thalweg elevation, less a small amount. No sediment is contributed to the flow of sediment at that cross section.

2.3.5 Unit Weight of Deposits

2.3.5.1 Initial Unit Weight

Unit weight is the weight per unit volume of a deposit expressed as dry weight.

$$\gamma_s = (1 - P_d) \cdot SG \cdot \gamma \quad (2\text{-}61)$$

where:

P_d = porosity of deposits

SG = specific gravity of sediment particles

γ = unit weight of water

γ_s = unit weight of sediment

Standard field tests are recommended when major decisions depend on the unit weight. Otherwise, use tables on pp 39-41 of Vanoni (1975) when field data is lacking at your project site.

Exner 1 - over 64 mm (use $EX Card, A-74)
3 - for all other (Default)

2.3.5.2 Composite Unit Weight

When dealing with mixtures of particle sizes, the composite unit weight of the mixture is computed using Colby's equation (Vanoni, 1975).

$$\gamma_{SC} = \frac{1}{\left[\frac{F_{SA}}{\gamma_{SA}} + \frac{F_{SL}}{\gamma_{SL}} + \frac{F_{CL}}{\gamma_{CL}}\right]} \tag{2-62}$$

where:

γ_{SC}	=	composite unit weight of deposits
γ_{SA}, γ_{SL}, γ_{CL}	=	unit weight of sand, silt, and clay, respectively
F_{SA}, F_{SL}, F_{CL}	=	fraction of sand, silt, and clay, respectively, in the deposit

2.3.5.3 Consolidated Unit Weight

Compaction of deposited sediments is caused by the grains reorienting themselves and the squeezing out the water trapped in the pores. The equation for consolidation (Vanoni, 1975) is:

$$\gamma = \gamma_1 + B \cdot \log_{10} T \tag{2-63}$$

where:

B	=	coefficient of consolidation for silts or clay
T	=	time in years
γ_1	=	initial unit weight of the sediment deposit, usually after 1 year of consolidation

Suggested values of γ_1 and B are given in Vanoni (1975).

The average consolidation unit weight over a time period T requires integration over time. This is computed using the following relationship developed by Miller (1953).

$$\gamma_{ave} = \gamma + B \cdot \left[\frac{T}{T-1}\right] \cdot \log_{10} T - 0.434\, B \tag{2-64}$$

These unit weights are used to convert sediment weight to volume for computation of the bed elevation change.

2.3.6 Sediment Particle Properties

Four basic sediment properties are important in sediment transport prediction: size, shape factor, specific gravity, and fall velocity. Grain size classification is fixed in HEC-6 and is described in section 3.3. Particle shape factor is defined by:

$$SF = \frac{c}{(a \cdot b)^{1/2}} \tag{2-65}$$

where:

a, b, c = the lengths of the longest, intermediate, and shortest, respectively, mutually perpendicular axes of a sediment particle

The particle shape factor of a perfect sphere is 1.0 and can be as low as 0.1 for very irregularly shaped particles. HEC-6 uses a shape factor default of 0.667 but it can be user specified. If a "sedimentation diameter" is used, which is determined by the particles' fall velocity characteristics, the particle shape factor of 1.0 should be used. If the actual sieve diameter is used, the actual shape factor should be used.

Specific gravity of a particle is governed by the mineral makeup of the sediment particle. In natural river systems, the bed material is dominated by quartz which has a specific gravity of 2.65. HEC-6 uses 2.65 as a default; however, values of specific gravities for sand, silt, and clay may be input.

Two particle fall velocity methods are used in HEC-6. Method 1 is based upon the fall velocities determined by Toffaleti (1966) and is similar to Rubey's method (Vanoni, 1975). This method assumes 0.9 is the shape factor. Method 2, which takes into consideration the particle shape factor, utilizes the procedure described in ICWR (1957), and is described in detail by Williams (1980). Method 2 is the default.

2.3.7 Scour Depth Calculation Sequence

The sequence of computations to determine depth of scour is as follows:

1. D_{se} is set to zero.
2. The active layer thickness is calculated.
3. The gradation of sediment in the active layer is calculated.
4. The Exner equation is solved, exchanging bed sediment material between the active layer and the flow field. These computations are made in units of tons.
5. Change in the active layer weight is converted to volume and new cross section coordinates are calculated. The next water discharge in the hydrograph is read.
6. A new water surface profile and associated hydraulic forces are calculated.
7. The new D_{se} is calculated.
8. When all sediment sizes cease to be transported the bed is completely armored for that

hydraulic event.

9. If the new D_{se} is greater than 0.0, it is compared to the total depth of the bed sediment reservoir. If the comparison indicates that more sediment is required to satisfy D_{se} than exists in the sediment reservoir, then D_{se} is set to the full sediment reservoir depth and a note is printed.

10. If there is enough sediment in the sediment reservoir, D_{se} is compared to the remains of the previous active layer, D_{seold}. If the difference (D_{se} - D_{seold}) is greater than 5 feet, the weight of sediment equivalent to a thickness of 5 feet is returned to the inactive layer. The reason an exchange is made is to keep the composition of the bed sensitive to the surface gradation because sediment transport calculations depend on the bed surface gradation.

11. If the difference (D_{se} - D_{seold}) is less than 2 feet, a new target weight of sediment is determined for the exchange between inactive and active layers in subsequent computations.

Earlier versions of HEC-6 allowed leaching of sediment from depths below the bed surface. This is prevented by subdividing the active layer into a sublayer updated LTI times for each discharge and maintaining a separate cover layer. This process is described in Section 2.3.3.

2.3.8 Bed Elevation Change

When scour or deposition occurs after a time step, HEC-6 adjusts channel elevations within the movable bed portion of the cross-section. For deposition, the streambed portion is moved vertically only if it is within the movable bed specified by the **H** or **HD** record and is below the water surface (i.e., wetted). Deposition is allowed outside of the conveyance limits defined by the **XL** record. Scour occurs only if it is within the movable bed, within the conveyance limits, within the effective flow limits defined by the **X3** record, and below the water surface. Once the scour or deposition limits are determined, the volume of scour or deposition is divided by the effective width and length of the cross section to obtain, Y_s, the bed elevation change. The vertical components of the coordinates within these scour/deposition limits are then adjusted as shown in Figure 2.9. An option for adjusting the geometry in a different manner for deposition is described in Section 3.7.4.

2.3.9 Silt and Clay Transport

2.3.9.1 Cohesive Sediment Deposition

The equation for silt and clay deposition (Krone, 1962) in a recirculating flume at slow aggregation rates and suspended sediment load concentrations less than 300 mg/l is

$$\log C/C_o = -k't \qquad (2\text{-}66)$$

or

$$C/C_o = e^{(-k't)}$$

where:

C = concentration at end of time period[1]

C_o = concentration at beginning of time period[1]

D = water depth

k' = $V_s P_r / 2.3D$

P_r = probability that a floc will stick to bed $(1 - \tau_b/\tau_d)$

t = time

V_s = settling velocity of sediment particles

τ_b = bed shear stress

τ_d = critical bed shear stress for deposition

This ratio is multiplied by the inflowing clay or silt concentration to obtain the transport potential. The concentration is converted to volume and deposited on the bed.

2.3.9.2 Cohesive Sediment Scour

Erosion is based upon work by Parthenaides (1965) and adapted by Ariathurai (1977). Particle erosion is determined by:

$$C = \frac{M_1 \cdot S_a}{Q \cdot \gamma} \cdot \left[\frac{\tau_b}{\tau_s} - 1\right] + C_o \qquad (2\text{-}68)$$

where:

C = concentration at end of time period

C_o = concentration at beginning of time period

M_1 = erosion rate for particle scour

Q = water discharge

S_a = surface area exposed to scour

τ_b = bed shear stress

τ_s = critical bed shear for particle scour

---

[1]Note: These and the subsequent relationships apply for sediment concentrations that are less than 300 mg/l, (see Krone, 1962).

γ = unit weight of water

As the bed shear stress increases, particle erosion gives way to mass erosion and the erosion rate increases. Because the mass erosion rate can theoretically be infinite, Ariathurai (1977) recommended that a 'characteristic time', Δt, be used. With a computational interval of DD, the mass erosion equation becomes:

$$C = \frac{M_2 S_e}{Q \gamma} \cdot \frac{\Delta t}{DD} + C_o \tag{2-69}$$

where:

DD = duration of time period

M_2 = erosion rate for mass erosion

Δt = characteristic time of erosion

Ariathurai (1977) gives guidance on how to obtain or estimate Δt, M_1, and M_2. Because erosion thresholds and rates for cohesive sediments are dependent on specific sediment particle and ambient water conditions such as mineralology, sodium adsorption ratio, cation exchange capacity, pH, salinity, and depositional history, in situ and/or laboratory testing are the recommended methods to determine the erosion characteristics of cohesive sediments.

2.3.10 Mudflow Constraint on Transport Potential

Because Einstein's concept of the "equilibrium concentration" is utilized for the non-cohesive load, no additional constraints are required. However, when cohesive sediments are included there is no equilibrium concentration. HEC-6 assumes erosion and entrainment will proceed until a maximum mudflow concentration has been reached. The maximum mudflow concentration (hyperconcentrated flow), based on two measurements at Mt. St. Helens, is considered to be 800,000 ppm. If the concentration of fines (i.e., silt and clay) at any cross section exceeds 50,000 ppm, a counter is incremented and a message will be printed at the end of the computer run stating the total number of times high concentrations were detected. When the concentration exceeds 800,000 ppm, each grain size concentration is proportionally reduced so that the total concentration is 800,000 ppm.

SECTION - 3

3. GENERAL INPUT REQUIREMENTS

3.1 General Description of Data Input

Input data are grouped into categories of geometry, sediment, hydrology, operating rule, program commands, and the network model as briefly described below. A description of input variables is contained in Appendix A. The alphanumerics in parentheses after each major heading refer to the input records that control the discussed data.

3.2 Geometric Data

This category includes cross sections, reach lengths and 'n' values existing at the beginning of the study, which are required for water surface profile calculations. In addition, the movable bed portion of each cross section and the depth of sediment material in the model bed are defined. The NC to H (or HD) records are used to define the model geometry. HEC-2 format is used for geometric data. In Fortran, this format is A2, F6.0, 9F8.0.

3.2.1 Cross Sections (X1, X3, GR)

Cross sections are specified for conditions existing at the beginning of the study and calculations are made directly from coordinate points (stations, elevations) - not from tables or curves of hydraulic elements. GR records are used to input the elevation-station coordinate pairs to establish an accurate description of the shape of a cross section (see Figure 2.2). Corrections for skew and changes in elevation are made, if desired, without re-entering coordinate points (X1 record).

Elevations may be positive, zero or negative. Cross section numbers must be positive and should increase in the upstream direction. If the water surface elevation exceeds the end elevations of a section, calculations continue by extending the end points vertically but ignoring the added wetted perimeter.

3.2.2 Subsections (X1)

Each cross section can be subdivided into parts called subsections - for example, left overbank, main channel and right overbank. Reach lengths and 'n' values are assigned to each subsection. The calculation of friction loss through the reach is made by averaging the end area of a subsection, averaging the end hydraulic radius and applying the subsection 'n' value and reach length to get a length-weighted subsection conveyance. Subsection conveyances are summed to get a total value for the reach which is used to calculate friction loss.

3.2.3 Reach Length (X1)

Each subsection must have a reach length. It extends from the previous (downstream) section to the present cross section. This enables the simulation of channel curves where the outer part of the bend, which is represented by an overbank area, has a reach length larger than the channel of the inside overbank area. For meandering rivers, the channel length is generally greater than the overbank reach lengths.

3.2.4 Manning 'n' Values (NC, NV, $KL, $KI)

A Manning 'n' value is required for each subsection and is utilized until it is changed. It is not possible to automatically change 'n' values with respect to time. The 'n' may vary with either discharge or elevation in the main channel and overbank areas. When 'n' varies with discharge, the first 'n' on the **NV** record should be a negative value. To change 'n' values utilizing Limerinos' relationship, the **$KL** record is placed in the hydrology data set. To return to the input 'n' values, a **$KI** record must be input.

3.2.5 Bridges

This model has no provision for calculating flow at bridges except by normal backwater calculations. Simulate piers by adjustment of **GR** points to reflect net flow area change if general scour information is of interest at the bridge. Be sure that the top elevations of the **GR** points used for piers are above the highest anticipated water surface elevation. This is to assure that "deposition" does not occur on the "piers". In most situations the user should ignore bridges and match water surface profiles by adjusting 'n' values and/or previously mentioned geometric changes to avoid the short time intervals required for analyzing general scour at bridges. All bridge routine records in original HEC-2 cross sections must be removed before use in HEC-6.

3.2.6 Movable and Fixed Bed (H, HD)

Each cross section is divided into movable and fixed bed portions. The movable bed can be specified beyond the channel limits. Scour and deposition will cause the movable bed to fall and rise by changing the cross section elevations after each time step.

3.2.7 Conveyance Limits (XL)

Sometimes water inundates areas that do not contribute to the water conveyance. Conveyance limits are specified by either entering a conveyance width to be centered between the channel limits or by input of two station locations that define the conveyance limits. Deposition is allowed to occur outside the conveyance limits (but within the movable bed); however, scour can occur only within the conveyance limits even if the movable bed limits are beyond the conveyance limits.

3.2.8 Ineffective Flow Area (X3)

When high ground or some other obstruction such as a levee prevents water from flowing into a subsection, the area up to that point is ineffective for conveying flow and is not used for hydraulic computations until the water surface exceeds the top elevation of the obstruction. The barrier can be a natural levee, man-made levee or some other structure. End area, wetted perimeter, n-value and conveyance computations are not made in the ineffective area portions of a cross section. This is similar to the ineffective flow option in HEC-2. Sediment computations will not be made for ineffective areas.

Three methods for ineffective flow area are available. Method 1 confines the water within the channel limits unless the water surface elevation is higher than the elevation of either channel limit. If either or both channel limit elevation is exceeded, that overbank area is used for hydraulic conveyance calculations (see Figure 3.1).

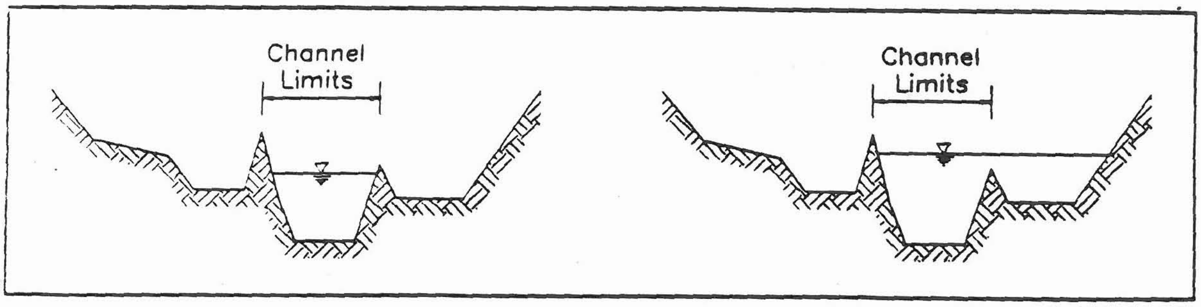

Figure 3.1. Examples of Ineffective Area, Method 1.

Method 2 is used to specify an effective area width of which the left and right limits are equidistance from the centerline of the channel. This is similar to Method 2 of the encroachment option in HEC-2. Method 2 may be used in conjunction with Method 1 as shown in Figure 3.2.

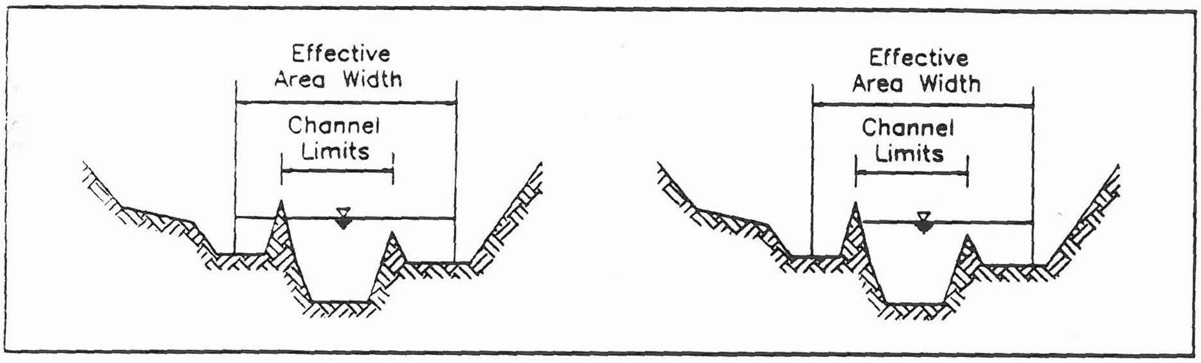

Figure 3.2. Examples of Ineffective Area, Method 2.

Method 3 uses the exact locations (STENCL and STENCR for left and right overbanks) and elevations (ELENCL and ELENCR for left and right overbanks) of ineffective areas for each overbank area are specified. This method is similar to Method 1 of the encroachment option in HEC-2 as demonstrated by Figure 3.3. Method 3 cannot be used together with Method 1 or 2.

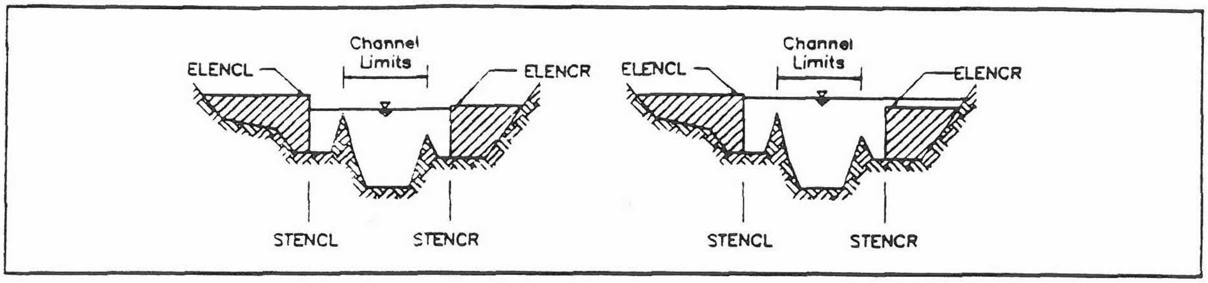

Figure 3.3. Examples of Ineffective Area, Method 3.

The program automatically tests the first and last points in the movable bed to ascertain if natural levees are forming during the computations. If this occurs, the program overrides the ineffective area methods specified by input data. In fact, natural levees formed by the movable bed are always considered to establish ineffective area even if that option was not selected by input data, as illustrated in Figure 3.4.

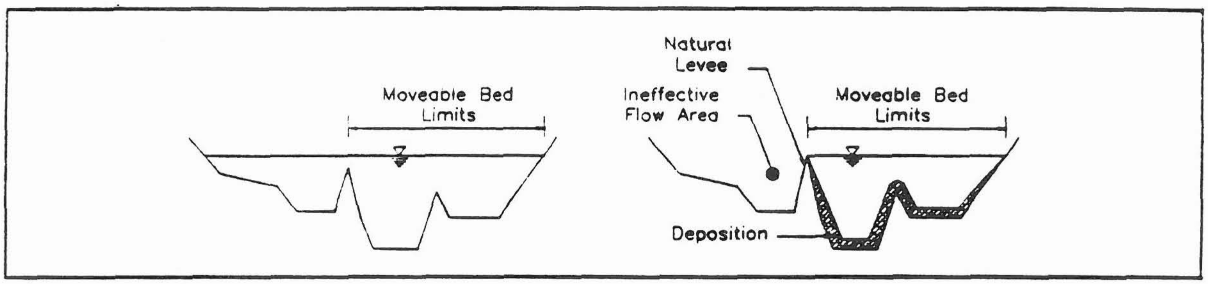

Figure 3.4. Ineffective Areas Due to Natural Levee Formation.

3.2.9 Dredging (H, HD, $DREDGE, $NODREDGE)

When the dredging option is used, part or all the movable bed portion of a cross section is lowered to the prescribed bed elevation. Outside of the dredged channel, the points are not changed. Sediment material is assumed to be removed from the channel and out of the system. The **H** or **HD** record is used to specify the bottom elevation, lateral limits, and the depth of overdredging. Dredging is initiated by the **$DREDGE** record in the hydrology data set and is assumed to be active for all discharges until a **$NODREDGE** record is encountered. This "on" dredging and "off" pair of records can be placed in the hydrology data set as often as required. Dredging can be activated any number of times during a long simulation by placing pairs of **$DREDGE, $NODREDGE** records in the hydrology.

The elevation of the channel bottom is calculated at the end of each computational cycle (DD). If the elevation is higher than the specified dredging elevation on the **H** or **HD** record, the channel invert is lowered to the specified dredging or overdredge depth, whichever is greater. An option is available to initiate dredging if the channel bottom elevation is still higher than a specified minimum draft depth (**$DREDGE** record). When this occurs, the channel is dredged to an elevation such that the minimum draft is achieved.

3.3 Sediment Data

Sediment data is specified on records I through N. This data includes the inflowing sediment load data, gradation of material in the stream bed, and information about fluid and sediment properties. The inflowing sediment load, transport capacity relationship, depth of sediment material in the bed, gradation of material in the bed, and unit weight of deposited material as well as fully consolidated deposits are input in this section.

The grain sizes of sediment particles commonly transported by rivers may range over 7 log cycles. Small sizes behave much differently from large sizes. Therefore, it is necessary to classify sediment material into groups for application of different transport theories. The three basic classes considered by HEC-6 are clay, silt and sand/gravel. The groups are identified and subdivided based on the American Geophysical Union (AGU) classification scale as shown in Table 3.1. HEC-6 accounts for 15 different sizes of material including 1 for clays, 4 silt sizes, 5 sand sizes, and 5 gravel sizes. The representative size of each class is the geometric size, which is the square root of the class ranges multiplied together. For example, the geometric size for medium silt is $(0.016 \cdot 0.032)^{1/2}$ or 0.023 mm.

Class Size No. used in HEC-6	Sediment Material	Class.	Grain Dia. (mm)
CLAY	Clay	(Clay)	0.004
SILT			
1.	Very Fine Silt	(Silt)	0.004 - 0.008
2.	Fine Silt		0.008 - 0.016
3.	Medium Silt		0.016 - 0.032
4.	Coarse Silt		0.032 - 0.0625
SAND AND GRAVEL			
1.	Very Fine Sand	(VFS)	0.0625 - 0.125
2.	Fine Sand	(FS)	0.125 - 0.250
3.	Medium Sand	(MS)	0.250 - 0.500
4.	Coarse Sand	(CS)	0.500 - 1.000
5.	Very Coarse Sand	(VCS)	1.000 - 2.000
6.	Very Fine Gravel	(VFG)	2.000 - 4.000
7.	Fine Gravel	(FG)	4.000 - 8.000
8.	Medium Gravel	(MG)	8.000 - 16.000
9.	Coarse Gravel	(CG)	16.000 - 32.000
10.	Very Coarse Gravel	(VCG)	32.000 - 64.000

Table 3.1. Grain Size Classification of Sediment Material.

3.3.1 Inflowing Sediment Load (L, LQ, LT, LF)

The aggradation or degradation of a stream bed profile depends upon the amount and size of sediment inflow relative to the transport capacity of the stream (see Section 2.3.1). The sediment entering the water inflow points of the geometric model (i.e., local inflow points, main stem and tributaries boundaries) are inflowing sediment loads and are expressed in tons/day. The sediment load should include both bed and suspended load (total load) and is expressed as a log-log function of water discharge in cfs vs. sediment load in tons/day as in Figure 3.5.

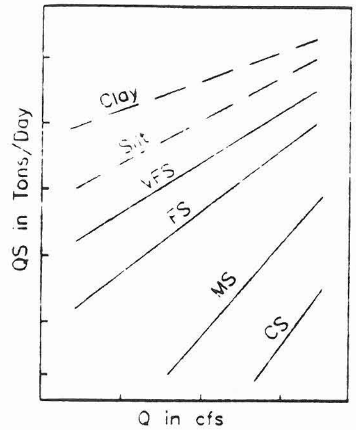

Figure 3.3. Water-Sediment Inflow Relationship.

Data is entered as a table of sediment load by grain size class for a given discharge. The range of discharges should encompass the full range expected in the simulation.

If the inflowing sediment load is essentially of one grain size, that size should be located in Table 3.1 and identified by its classification and assigned the number of its grain size class. For instance, if the representative size is 0.035 mm, its classification is medium sand and its sand size number is 3. This number is then input for variables IGS and LGS in the I4 record. But if the inflowing load is composed of a range of grain sizes, it is desirable to further subdivide sand and perhaps silt into the classifications shown in Table 3.1. Use as many of these classifications as are required to describe the problem. It is not necessary to start with the smallest size nor is it necessary to go to the coarsest size, but once a range of sizes is selected, all grain sizes within that range must be included. The above AGU classification in Table 3.1 is stored internally in the program and cannot be modified.

3.3.2 Sediment Material in the Streambed (N, PF, PFC)

Transport theory for sand relates the total sand and coarser load moving to the gradation of sediment particles on the bed surface. Armor calculations require the gradation of material beneath the bed surface and knowledge about the depth to bed rock or some other material that might prevent degradation.

These requirements are accommodated in the sediment program by assigning a depth of sediment material to each cross section and specifying the surface gradation and the subsurface gradation as illustrated in the following sketch.

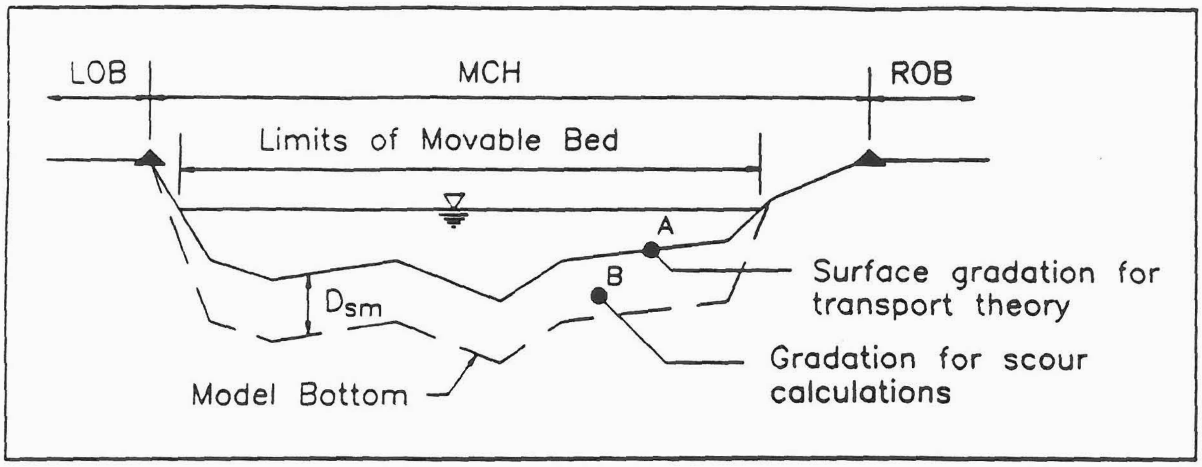

Figure 3.6. Sediment Material in the Streambed.

Coordinates connected with the solid line define the cross section at the beginning of the study. For scour conditions, the program lowers all coordinates within the "movable bed" by an amount D_{sm} and calculates the amount of sediment material available for transport from the cross sectional area defined by D_{sm}. If no model bottom elevation is specified, a default value of 10 feet is used for D_{sm}.

The gradation of sediment particles on the streambed, point A (Figure 3.6), and the distribution of sizes in the inflowing load are intimately related. One must complement the other in transport theory. The gradation for scour calculations, region around point B (Figure 3.6), is a completely different data source and easier to sample than the bed surface gradation. Therefore, in using the computer program it is customary to specify inflowing sediment load and gradation of the region identified by point B and have the program calculate the bed surface gradation which is required to transport the inflowing load. The bed gradation in region B is coded on the **N** or **PF** and **PFC** records.

The gradation of sediment material in the streambed is coded as percent finer versus grain size (**PF** records) or the fraction of material contained in each grain size class (**N** records). If **N** records are used to describe the bed gradation, one set is required for every cross section. If **PF** records are used, cross section numbers are used to identify the gradation cross section location within the geometric data set and gradations are linearly interpolated for those cross sections that do not have **PF** records for them.

3.3.3 Sediment Properties (I1, I2, I3, I4)

Five basic properties are considered: grain size, grain shape factor, specific gravity, unit weight of deposits and fall velocity. Grain size classifications are fixed in the program and are shown in Table 3.1. The program defaults to a specific gravity of 2.65 and the grain shape factor defaults to 0.667 if no values are specified. The fall velocity methods are input on the **I1** record (see Section 2.3.6).

3.3.4 Sediment Transport

3.3.4.1 Sand and Gravel Transport (I1)

There are several sand and gravel transport relationships available in HEC-6. The **I4** record is used to specify which of the following to use.

a. Toffaleti (1969)

b. User developed relationship

c. Madden's (1963) modification of Laursen's (1958) relationship

d. Yang's Stream Power for Sands. (Yang, 1972)

e. Duboys (Brown, 1950)

f. Ackers-White (1973)

g. Colby (1964)

h. Toffaleti (1969) and Schoklitsch (1930)

i. Meyer-Peter and Müller (1948)

j. Toffaleti (1969) and Meyer-Peter and Müller (1948)

k. Madden's (1985) modification of Laursen's (1958) relationship

Madden's (1963) and (1985) works are presently unpublished. For the options involving two sediment transport relationships, the transport potential for each sediment size is computed using both methods and the largest transport potential is utilized.

If there is enough field data to develop a functional relationship between hydraulic parameters and sediment transport by grain size, the user developed relationship using the **J** and **K** records should be considered. The functional relationship is:

$$GP = \left[\frac{D \cdot S_f - C}{A}\right]^B \qquad (3\text{-}1)$$

where:

$D \bullet S_f$	=	depth-slope product
A, B, C	=	sediment transport coefficients developed using data
GP	=	sediment transport potential

Often the transport potential is affected by variations in flow resistance. To account for this, the K record is used to define a factor, STO, which is multiplied by GP to determine the sediment transport potential. STO is defined by:

$$STO = 10^{-6} \cdot D \cdot n^{E} \tag{3-2}$$

where:

D,E	=	sediment transport coefficients developed using data
n	=	Manning's roughness coefficient
STO	=	multiplying factor of GP

3.3.4.2 Clay and Silt Transport (I2, I3)

Two methods for clay and silt transport are available in HEC-6. They are only applicable for flows with suspended sediment concentrations less than 300 mg/l (see Krone, 1962). The first method allows the deposition of clays and silts but does not allow scour (MTCL and MTSL = 1 in I2 and I3 records, respectively). This is the method used in previous HEC-6 versions. The second method (MTCL and MTSL = 2) allows for both deposition and scour as described in Section 2.3.9. When this method is used, an additional I2 record is required to provide information regarding critical shear stress thresholds for deposition and shear stress thresholds and erosion rates for both particle and mass erosion.

3.3.5 Transmissive Boundary ($B)

The user may specify transmissive boundary which will allow sediment reaching that boundary (cross section) to pass without changing that cross section. This is useful for situations where the conditions at a downstream boundary are anomalous (such as at a bridge, weir, drop structure, etc.) and may cause upstream computations to be in error if incorporated into the sediment transport/bed change computations.

3.4 Hydrologic Data

This category's data is are specified on records Q through W. The hydrologic data includes water discharges, temperatures, starting water surface elevations and flow duration.

Having specified the initial geometry (size, shape, and slope of the channel) and the sediment relationships for the stream, the final step in sediment calculations is to simulate the response of these data to hydrologic inputs and, perhaps, reservoir operation rules. A continuous simulation is needed for a water discharge hydrograph since both sediment transport and hydraulics of flow are nonlinear functions of water discharge. The operation rules for reservoirs vary with time and impact directly on hydraulics of flow. The lack of coincidence between main stem and tributary flood hydrographs makes it essential to enter flow from tributaries at their correct locations along the main stem.

The program treats a continuous hydrograph as a sequence of discrete steady flow events, each having a specified duration in days as illustrated in Figure 3.7. The reason for doing this is to attempt to minimize the number of time steps needed to simulate a given time period, and thus minimize computer time. A discharge hydrograph blocked out in this manner will be referred to as a computational histograph.

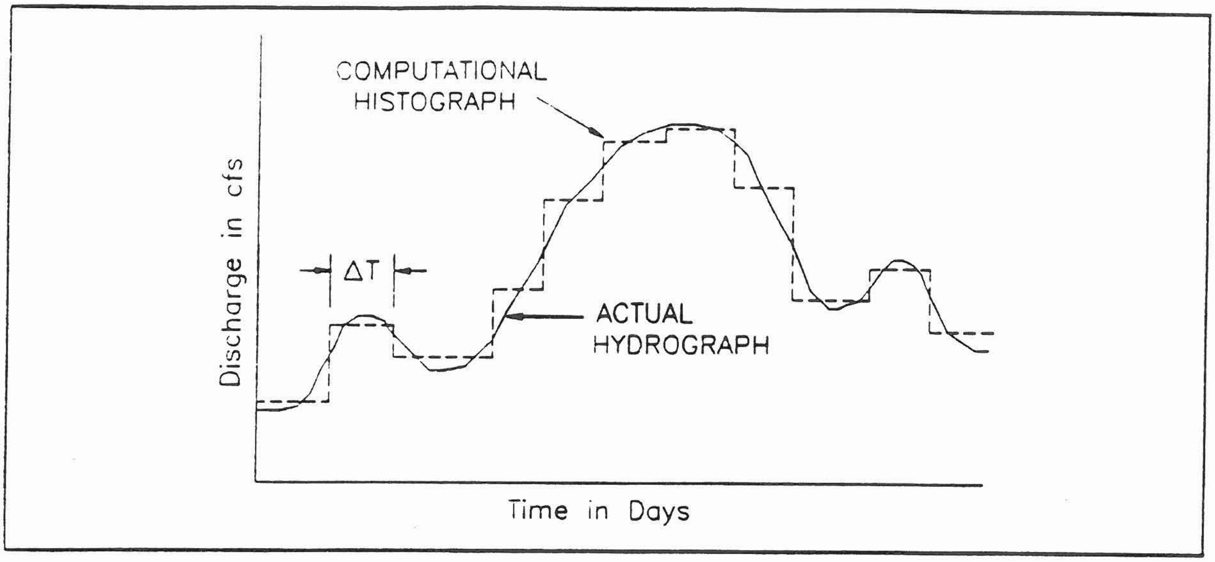

Figure 3.7. Example of Histograph Representation of a Hydrograph for HEC-6.

3.4.1 Water Discharges and Durations (Q, W, X)

An example hydrologic data set is shown in Table 3.2. The meaning of each record is explained in the following sections.

The **$HYD** record indicates that the hydrologic data follows. A * record is required for every discharge. This record contains user comments and also controls the level of printout for each discharge.

The water discharge, in cfs, is coded on a **Q** record and its duration, in days, is coded, on a **W** record. Sometimes a discharge at a long time increment may cause computational oscillations and it may be desirable to divide the time increment into smaller increments. In this case, instead of encoding entire sets of *, Q and W records, the **W** record is replaced by the **X** record. The **X** record is used to divide the time duration which is normally on the **W** record into smaller computational time increments.

```
——— Sediment Data ———
$HYD
$RATING
RC        3   100    0    0   520   525   528
*      AB COMMENT FOR EVENT NO. 1, AB LEVEL PRINTOUT
Q       100
T        60
W         1
*      COMMENT FOR EVENT NO. 2
Q       200
W         2
*      A COMMENT FOR EVENT NO. 3
Q       200
R       527
T        70
W         2
$RATING
RC        3   100    0    0   520   525   528
*      BB COMMENT FOR TIME STEP NO. 4
Q       200
W         1
$$END
```

Table 3.2. Example Hydrologic Input of HEC-6.

3.4.2 Water Temperature (T)

The water temperature is essential for the calculation of particle fall velocities. The temperature of the inflowing water is changed by inserting **T** records in the *****, **Q**, and **W** data set. New fall velocities are calculated each time a new **T** record is read. A water temperature (T) record is required for the first discharge. The temperature is assumed to be the same for subsequent discharges until another T record is encountered. Temperatures of tributaries and local inflows are also on the T record. The water temperature of the main stem is determined by discharge weighing of the tributary/local inflow and main stem temperatures.

3.4.3 Operating Rule

Operating rules are functional relationships between water surface elevations and time such as exhibited in the operation of a reservoir. This section deals with the simulation of these types of operations.

The starting water surface elevation is used by this program for the same purpose that it is used in HEC-2 for water surface profile computations. It is required at the downstream end of the geometric model (i.e., the downstream boundary). Operating rules may be imposed at up to 20 dams or other controls in the geometric data set to permit continuous analysis through reservoirs, weirs, etc., in series.

3.4.3.1 Downstream Boundary ($RATING, RC, R, S)

A starting water surface elevation must be specified at the downstream boundary of the model for every time step. HEC-6 provides three methods for prescribing this downstream boundary condition: using (1) a rating curve, (2) **R** records, or (3) a combination of a rating curve and **R** records.

The first method involves the use of a rating curve which can be specified using a **$RATING** record followed by a set of **RC** records containing the water surface elevation data as a function of discharge. The rating curve need only be specified once at the start of the hydrologic data and a water surface elevation will be determined by interpolation using the discharge given on the **Q** record for each time step. The rating curve may be temporarily modified using the **S** record or replaced by entering a new set of **$RATING** and **RC** records before any * record in the hydrologic data.

In method 2, **R** records can be used **instead** of a rating curve to define the water surface elevation. To use this method, an **R** record is required for the first time step. The elevation entered in field 1 of this record will be used for each succeeding time step until another **R** record is found with a non-zero value in field 1 to change it. In this way, you only insert **R** records to change water surface to a new value.

Method 3 is a combination of the first two methods. This method makes it possible to use the rating curve most of the time to determine the downstream water surface elevation while still allowing the user to specify the elevation exactly at given time steps. In this method, the **R** record's non-zero field 1 value for the downstream water surface elevation will override the rating curve for that timestep. Ont he next time step, the program will go back to using the rating curve unless another **R** record is found with a non-zero value in Field 1.

NOTE: **R** records have a secondary purpose. They can be used to define the water surface elevation at a certain internal control points in the geometry. The internal control points are defined using the **X5** record. **R** records are necessary to define the water surface at those internal control points where on the **X5** record the UPE option has not been set and a field value was given for the **R** record where the program would find a value for the water surface elevation.

3.4.3.2 Internal Control Points (X5, R)

A rule-curve type of option can be specified to establish a constant operating elevation of a navigation pool within the geometric set. This is accomplished with the use of an **X5** record in the geometry data which specifies a pool elevation and a head loss. When the tailwater elevation plus the head loss term is higher than the specified pool elevation, the pool rises. This option was originally developed for hinged pool operations which usually had constant head losses for all discharges. Users can specify an internal rating curve anywhere in the network by using a combination of **X5** and/or **R** records. This is helpful in modeling weirs and drop structures.

3.4.4 Example Hydrology Input

The following description refers to the example data shown in Table 3.2. The **$HYD** record follows the sediment data. At the beginning, the **$RATING** and **RC** records are used to input a discharge-elevation relationship. Every discharge must have *, **Q** and **W** (or **X**) records. A water temperature (**T**) record is **always** required for timestep number 1. The second timestep will use the same temperature (60°F). The **T** record in timestep no. 3 changes the temperature (70°F). This temperature is also used for timestep no. 4 since there is no **T** record in that timestep. The water surface elevation on the **R** record in event no. 3, 527 feet, is the starting water surface elevation for timestep no. 3. The rating curve (**$RATING** and **RC** records) just before event no. 4 is used to determine the starting water surface for timestep no. 4 and overrides elevation 527 from the **R** record in timestep 3. A **$$END** record is used to end the hydrology data as well as the entire HEC-6 input data set.

The A in column 5 and the B in column 6 of the * record for event no. 1 will produce A level printout of the water surface profile computations and B level print out of the sediment transport computation. The B in column 6 also causes information from this event to be written to a "solution file" for post-processing. Definitions of the print flags used on the * records are presented in Appendix A and described in Section 4.

3.5 Program Commands (EJ, $TRIB, $LOCAL, $HYD, $$END)

A command record structure was developed to enhance the flexibility of the program. The **EJ**, **$HYD**, and **$$END** records are used to delineate the geometric, sediment and hydrologic data sets of the program. These commands are required for all data sets. The **EJ** record identifies the end of geometric input. The **$HYD** record identifies the beginning of the hydrologic data. The **$$END** record identifies the end of the input. If tributaries or local inflow/outflow points are in the model, **$TRIB** and **$LOCAL** records, respectively, are required. The **$TRIB** and **$LOCAL** records are used to delineate tributary and local data from data for the main stream segment in the geometric and sediment data sets.

3.6 Network Model

A network system in which sediment transport in tributaries is calculated can be simulated. This section describes the required data sequence.

The network model is designed so that individual segments of the stream network can be analyzed independently to calibrate and confirm the model. With only minor changes, the user will be able to link the data sets together and perform the final analysis on the entire stream network.

The following are presented to define the terms used in this section.

Control point: For a main stem: its downstream end and any junction with a tributary. For a tributary: its junction with a higher order tributary. Each control point is designated by a circled number as in Figure 3.8, or by CP_n where n is the control point number, as in Figure 3.9.

Local inflow/outflow point: Points along any river segment at which water and sediment enters or exits that segment. Each local inflow/outflow point is designated by an arrow and $L_{n,m}$ where m is the sequence number (going upstream) of local inflow/outflow points along segment n, as in Figure 3.8.

River segment: A part of a river system which has an upstream water and sediment inflowing point and has a downstream termination at a control point. Sediment transport is calculated along a segment. A river segment's upstream most inflow point is designated by I_n where n is the segment number, as in Figure 3.8.

Tributary: A river segment other than the main stem in which sediment transport is calculated.

Main Stem: The primary river segment with its outflow at the downstream end of the model.

Methodology for labeling model segments is essential. The program saves information from the first title record in each geometric model as a label and prints it out as an identifier of the segment. Therefore, the stream's name and data model/test/run number code should be included on the T1 record. The date of the data set is also useful information.

3.6.1 Main Stem and Tributary Numbering

Segment and control points should not be numbered arbitrarily. To illustrate the numbering procedure, Figure 3.8 is used as an example and depicts a stream network. Arrows indicate local inflow/outflow points. The numbering of segments, inflow points, and control points should be according to these steps.

Step 1. Sketch out the stream network system.

Step 2. Number the control points 1, 2, and 3 along the main stem at the junctions with tributaries. With the main stem as segment 1, number segments 2 and 3. Number the main stem's upstream inflow point with I_1 and for segment 2, I_2 and for segment 3, I_3. Label the main stem's local inflow/outflow points, $L_{1,1}$ and $L_{1,2}$.

Step 3. Starting from the downstream most tributary (at control point 2) of the main stem, continue numbering control points 4 and 5. Number segments 4 and 5 coming off the control points and place inflow points I_4 and I_5. Label $L_{4,1}$ for the local inflow entering segment 4.

Step 4. Starting from the downstream most tributary of segment 2 (at control point 4), continue along segment 4, numbering control point 6, segment 6 and inflow point I_6. Since there are no tributaries on segment 6, check for tributaries segment 5 (next upstream tributary of segment 4). Since there are no tributaries on segment 5 and all tributaries from control point 2 are accounted for, go to step 5.

Step 5. Check next upstream segment of the main stem, segment 3, for tributaries. If there were tributaries, the procedure would have continued as in steps 3 and 4 with the next control point being 7. Since there are no more tributaries, the numbering is complete.

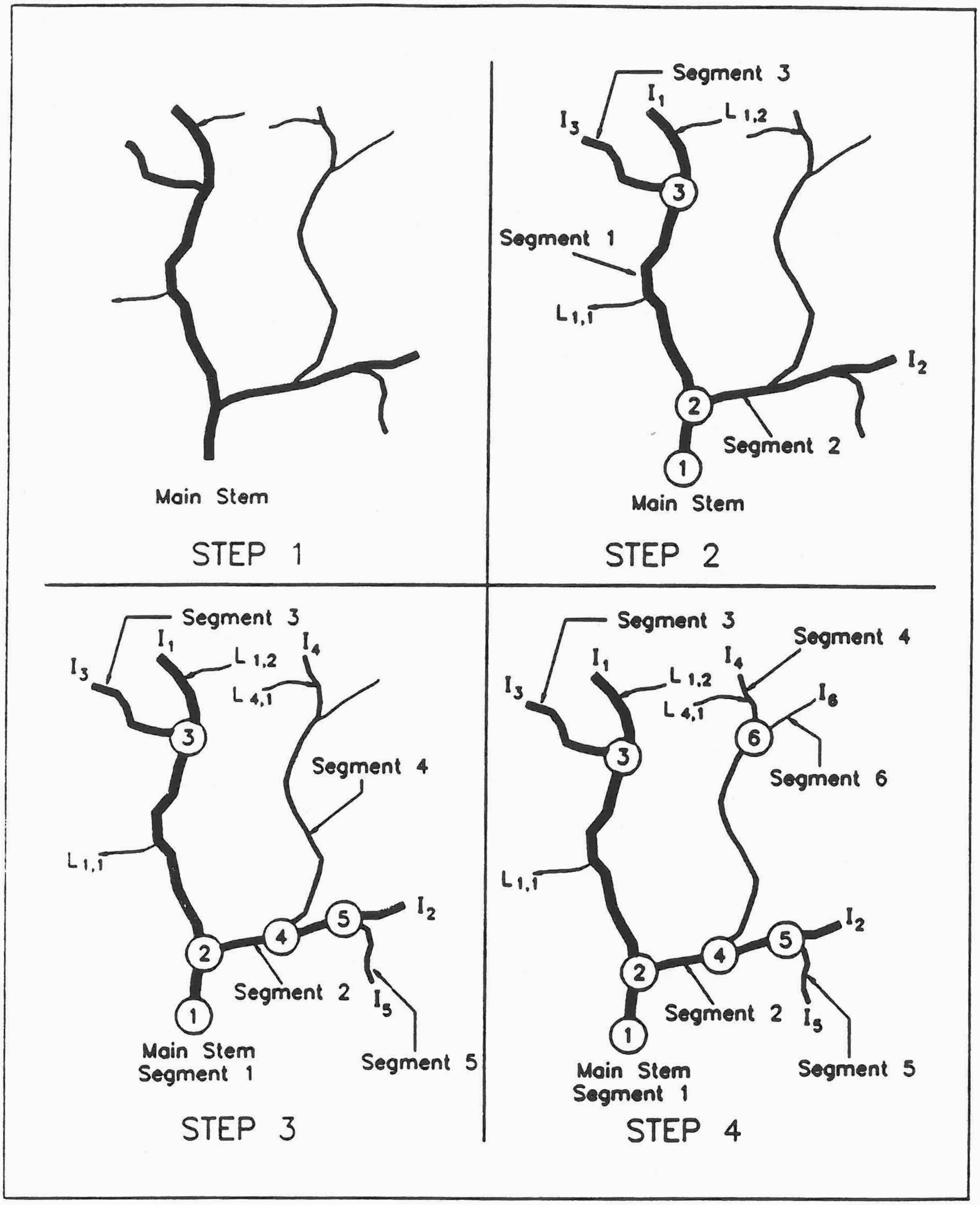

Figure 3.8. Example of Stream Network Numbering System.

3.6.2 Cross Section Data Sets of Main Stem and Tributaries

HEC-6 identifies segments by the order in which cross section sets are assembled in forming the geometric model. When the program reads the main stem geometry and eventually reaches the first **EJ** record in the geometric data set, the program will read one more record. If it is a **$TRIB** record the program recognizes that the following data set is for a segment in a stream network and assigns segment number 2 to it. This process is repeated until all geometric data sets representing river segments are read. The **CP** record following the **$TRIB** record identifies the control point number associated with the geometry information for each tributary segment data set. Table 3.3 illustrates these requirements for the network shown in Figure 3.8.

Figure 3.9 shows how to position cross sections at a control point. It is not necessary to treat the control point reach any differently than other reaches. The program will mix flow, temperature and sediment concentrations as though this were a normal river reach. There is no accounting of momentum losses due to impinging flows.

The location of the junction (control) points is specified by inserting a **QT** record just prior to the X1 record for the next cross section upstream from the control point location (e.g., 0.78 in Figure 3.9). The control point number must be coded on that **QT** record.

Record	Comment
T1	MAIN STEM GEOMETRY COMES FIRST, THEN TRIBUTARIES.
T2	EXAMPLE ILLUSTRATES GEOMETRIC SEQUENCE OF FIGURE 3.8.
T3	THIS RECORD TO EJ RECORD CONTAINS GEOMETRIC INFO.
———	Geometry of main stem, contains **QT** records for $L_{1,1}$, $L_{1,2}$ and segments 2 and 3.
EJ	End of main stem (Segment 1)
$TRIB	Warns program that geometry of a tributary segment follows.
CP 2	Indicates the following segment enters the network at control point 2.
T1	THIS PART IS FOR GEOMETRY OF SEGMENT 2 WHICH IS THE FIRST UPSTREAM
T2	TRIBUTARY FROM CONTROL POINT 1, STARTS AT CONTROL POINT 2 AND ENDS
T3	AT I2.
———	Geometry of Segment 2, contains **QT** records for segment 4 and 5.
EJ	End of Segment 2.
$TRIB	Indicates that data for additional tributary segments follow.
CP 3	Indicates that the following segment enters the network at control point 3.
T1	THIS PART IS FOR GEOMETRY OF SEGMENT 3 WHICH IS THE NEXT UPSTREAM
T2	TRIBUTARY FROM CONTROL POINT 2 ON THE MAIN STEM. STARTS AT CONTROL
T3	POINT 3 AND ENDS AT I3.
———	Geometry of Segment 3.
EJ	End of Segment 3.
$TRIB	Indicates that data for additional tributary segments follow.
CP 4	Indicates that the following segment enters the network at control point 4.
T1	THIS PART IS FOR GEOMETRY OF SEGMENT 4 WHICH IS THE DOWNSTREAM
T2	MOST TRIBUTARY OF SEGMENT 2. IT STARTS AT CONTROL POINT 4 AND ENDS
T3	AT I4.
———	Geometry of Segment 4, contains **QT** records for Segment 6 and $L_{4,1}$.
EJ	End of Segment 4.
T4	Sediment data follows.

Table 3.3. Sequence of Geometric Data Sets for Networks.

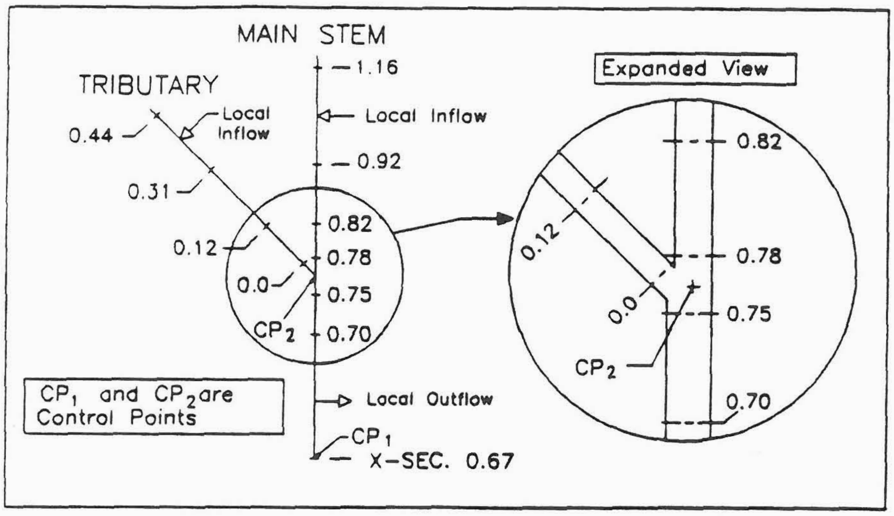

Figure 3.9. Example Cross Section Locations for Stream Networks.

3.6.3 Sediment Data

The main stem sediment data follows the geometric data in the job stream. The main stem data set fixes the fluid and sediment properties, number of grain size classes and unit weight of deposits for the entire network. If sediment properties in I1 through I5 records are present in the tributary data sets, they will be skipped by the program. Information on local inflows to a segment are input as a part of that segment's data set. These are identified with a $LOCAL record followed by inflow/outflow sediment discharge tables. Diversions are treated the same except negative discharges are used in the sediment discharge tables.

After the main stem sediment data set is entered, it is followed by a $TRIB record and then the first tributary sediment data set. It is not necessary to enter a control point number since the sediment data sets must be in the same sequence as the geometric sets described earlier. This is illustrated in Table 3.4 which is for the network shown in Figure 3.8.

Record	Comments
——	Previous geometric records.
T4-T8	T4-T8 records are used for comments on main stem.
——	Rest of sediment data of main stem are entered.
$LOCAL	Indicates information on local inflow points follows.
LQL LTL LFL LQL LTL LFL	Insert information on local sediment inflow on **LQL**, **LTL** and **LFL** records. Since there are two local inflow/outflow points in the segment ($L_{1,1}$ and $L_{1,2}$), two complete sets of these records are required with the set for $L_{1,1}$ first followed by $L_{1,2}$.
$TRIB	Sediment data set of segment 2 follows.
T4-T8	T4-T3 records are used for comments on segment 2.
——	Rest of sediment data of segment 2 are entered.
$TRIB	Sediment data set of segment 3 follows.
T4-T8	T4-T8 records are used for comments on segment 3.
——	Rest of sediment data of segment 3 are entered.
$TRIB	Sediment data set of segment 4 follows.
T4-T8	T4-T8 records are used for comments on segment 4.
——	Rest of sediment data of segment 4 are entered.
$LOCAL	Indicates information on local inflow/outflow points follows.
LQL LTL LFL	This set of records are for local inflow/outflow point $L_{4,1}$.
$TRIB	Sediment data set of segment 5 follows.
——	Enter sediment information on rest of segments in similar fashion.
$HYD	Start of hydrology.

Table 3.4. Sequence of Sediment Data Sets for Networks.

3.6.4 Hydrologic Data

The hydrologic data set depicted in Table 3.5 is for the stream network shown in Figure 3.8. In general the water discharge and temperatures (Q and T records) are entered in record fields in the order of the control point numbers. If the control point's segment contains local inflow/outflow points, their discharges and temperatures are entered in the fields after the control point information. The information for the next control point is then entered. An example of this procedure follows.

field	1	2	3	4	5	6	7	8	9
$HYD									
*	THIS ILLUSTRATES THE HYDROLOGIC DATA SEQUENCE.								
Q	Q_1	$Q_1L_{1,1}$	$Q_1L_{1,2}$	Q_2	Q_3	Q_4	$Q_4L_{4,1}$	Q_5	Q_6
T	T_1	$T_1L_{1,1}$	$T_1L_{1,2}$	T_2	T_3	T_4	$T_4L_{4,1}$	T_5	T_6
W	W_1								
*	Next Time Step								
——	Continue with sets of * to W records for all discharges								
$END	End of model data input								

Table 3.5. Hydrologic Data Input for Stream Networks.

The information in field 1 of the **Q** (Q_1) and **T** (T_1) records refers to segment 1 (see Figure 3.8). Information on these records is for the water exiting segment 1 at control point 1. Information in fields 2 ($Q_1L_{1,1}$ and $T_1L_{1,1}$) and 3 ($Q_1L_{1,2}$ and $T_1 L_{1,2}$) are for the local inflow points $L_{1,1}$ and $L_{1,2}$, respectively, which are on segment 1. Field 4 (Q_2 and T_2) contains the information on the water entering control point 2 from segment 2. Segment 3 information is entered in field 5 (Q_3 and T_3) and is for water entering control point 3 from segment 3. This procedure is continued for each control point and segment. The flow duration **W** record data remains constant for the entire stream network computation for that time step. Since HEC-6 does not "route" the water, it is necessary to process the hydraulic data for each segment and produce a single duration which best simulates the hydraulic and sediment processes of the whole system.

3.6.5 Summary of Data Input Sequence

The first data set in the data input is the geometric data. The main stem geometry is followed by a **$TRIB** command record, a **CP** record and then the geometric model for the first tributary, i.e., the stream segment joining the main stem at control point number 2. If more than one junction (control) point is present, each tributary data set must follow sequentially with a **$TRIB** command record followed by a **CP** record.

After all geometric data have been read, the program reads sediment data. Sediment data sets, one for each stream segment, must be arranged in the sequence of the control point numbers. A **$TRIB** command record precedes each tributary sediment data set. Hydrologic data follows the sediment data, but a different concept is utilized for entering hydrologic data than was used in the geometric and sediment data sets. No **$TRIB** command records are required. Instead, the main stem flow, local inflows and tributary junction flows are all entered on the same **Q** record. The starting water surface elevation is read or calculated for the downstream boundary (control point 1), water temperatures are read for each water discharge, and the flow duration is read.

3.6.6 Calculation Sequence of Network Systems

3.6.6.1 Hydraulic Computations for Network Systems

Water surface profiles are calculated for the main stem first and the elevation at each control point is saved. Each time the water discharge changes, the water discharges are mixed and new water temperatures are calculated for the main stem and tributaries. Upon reaching the upstream end of stream segment number 1, computations return to control point number 2, its starting water surface elevation is picked out of storage, and the hydraulic computations are made for stream segment number 2. Like the main stem, a tributary can have local inflows/diversions and tributary junctions. These are handled like the main stem, as presented above. Hydraulic computations are continued for segment 3 in a similar fashion until all stream segments have been analyzed; then sediment movement computations begin.

3.6.6.2 Sediment Computations

Whereas data input and hydraulic computations proceed through network segments in the same order in which the data was read, sediment computations are made in the reverse order. It is necessary for the program to process the most remote tributary first (highest segment number) to determine its sediment contribution to the next stream. After all sediment computations for the tributary are completed and results are printed, computations proceed to the next lower numbered segment. After the main stem calculations, the program cycles back to read the next discharge. The process is repeated until all water discharges have been analyzed.

3.7 Input Requirements for Other Options

3.7.1 Flow Resistance Relationships ($KL, $KI)

Limerinos' (1970) relationship is available for the determination of Manning's 'n' based upon bed gradation. This relationship is:

$$n = \frac{0.0926R^{1/6}}{1.16 + 2.0\,\log_{10}(R/d_{84})} \tag{3-3}$$

where:

d_{84} = particle size in the streambed of which 84% of the bed is finer, in feet

R = hydraulic radius, in feet

This option is initiated by the **$KL** record in the hydrologic data set and insertion of the **$KI** record returns the 'n' values to previous input values.

3.7.2 Fixed Bed Calculations

HEC-6 is capable of being executed as a "fixed bed" model similar to HEC-2. The minimum required records are: T1-T3, NC, X1, GR, H, EJ, **$HYD**, **Q**, **T**, **W** and **$$END**. The **H** record can be left blank. Optional records are NV, X3, X5, **$RATING** and **RC**. Note that no **T4** through **L** records are required. If these records are present, a "fixed bed" run is accomplished by moving the **$HYD** through **$$END** records to just after the **EJ** record of the geometry data set. "Fixed bed" runs are used to debug the geometry and analyze the hydraulic behavior of the model for a full range of flows. Calibrations and confirmation of the hydraulics are performed similar to procedures for HEC-2.

3.7.3 Multiple Fixed Bed Calculation

If there are no tributaries or local inflow/outflow points, up to 10 multiple profiles may be computed in one run. Table 3.6 contains an example of a run using 5 discharges from 100 to 10,000 cfs with starting water surface elevations ranging from 510 to 518 feet. Multiple profile runs are preferred over simple runs because the printout is more compact for the same number of discharges making it easier to make comparisons. If a **$RATING** record has been specified, the **R** record is not needed.

```
$HYD
*   A      5 DISCHARGES FROM LOW TO HIGH
Q100.     500.     1000.     5000.     10000.
R510.     512.      513.      516.       518.
T 70.      70.       70.       70.        70.
W  1.       1.        1.        1.         1.
$$END
```

Table 3.6. Example Hydrology Data Set for Multiple "Fixed Bed" Calculations.

3.7.4 Cross Section Shape Due to Deposition ($GR)

Previous versions of HEC-6 moved each y coordinate within the movable bed a constant amount after a time step as illustrated in Figure 3.6. Input of a **$GR** record in the hydrology data set causes the program to change the y coordinates to produce a horizontal deposition surface starting from the deepest part of the movable bed. The amount of deposition is limited to the water depth. Y-coordinate adjustment for erosion is uniform.

SECTION - 4

4. PROGRAM OUTPUT

4.1 Output Controls

The user must determine what information is needed and request a level of output that contains it. The program is defaulted to print out a minimum amount of information so that the user will know that computations are finished; however, it will not be sufficient to completely display model performance.

Each major data group (i.e., geometric, sediment and hydrologic) has a "normal" printout and one or more "options" for additional printout. These options are illustrated in the examples that follow and are summarized in Tables 4.1 and 4.2.

The records in parentheses after the major headings refer to the records that control the discussed printout.

4.2 Geometric Data and Hydraulic Calculations (T1, *)

The geometric information initially input is printed out using the printout option on the T1 record. This is helpful in debugging the geometry. After the geometric information is deemed to be correct, this option is usually turned off. For production runs, it is suggested that this option be used to document geometric input.

Since the entire water surface profile is calculated before the sediment calculations begin, an A-level hydraulic printout on the * record (column 5) for the first discharge calculations in the hydraulics model is useful for diagnosing data problems that might arise on the first pass. B, D and E-levels are increasingly detailed and may be required for unusual problems. Subsequently, the user should only request printout using the A-level only when interested in velocity information. Optional output from the hydraulic calculations is not particularly useful once geometric problems are resolved and the 'n' values are calibrated.

4.3 Sediment Data & Calculations (T4, *, $PRT, CP, PN, END)

Selection of output levels within the simulation level is essential for a complete understanding of model behavior. Use of the option in the T4 record causes the printout of initial conditions of the bed gradations and inflowing sediment loads. This is usually turned off after they have been checked for accuracy. The most useful sediment printout option is on the * record. Since this record is in the hydrology section, the option can be turned on or off at any point in the simulation. The B-level printout on the * record (record column 6) is the most common level and provides all the essential sediment information for calibration, confirmation and production runs. A C-level printout is recommended only for the first discharge and if unusual results are encountered. C, D, and E-levels should be used only for debugging purposes. When the * record printout option is exercised, the information for all the cross sections is printed out.

Often it is desirable to print out information only at selected points in time and for certain cross sections of interest. This is accomplished by inputting **$PRT**, **CP**, **PN** and **END** records in the hydrology data set. The **$PRT** record tells the program that instructions for selective printout is to follow, the **CP** record indicates which geometric segment of the model the printout applies, the **PN** records specify which cross sections in the segment are to have output, and the **END** record terminates this option for the discharge event.

Caution must be exercised when interpreting the bed change on the output. This change is related to the movement of the thalweg after scour and deposition and may not reflect the average bed elevation or sediment volume change of the cross section. To obtain this type of information, the **$VOL** option described in Section 4.4 should be utilized.

4.4 Accumulated Sediment Volumes ($VOL, VJ, VR)

The **$VOL** record in the hydrology data set causes the program to compute the cumulative bed and volume change of each cross section and sediment load that has passed each cross section. The sediment load information is for each grain size class. The **$VOL** record initiates the computation of an elevation-cumulative sediment volume table which is helpful for reservoir analysis. The elevation table displays the accumulated sediment volume between each parallel elevation planes specified by an elevation table which is defined by the **VJ** and **VR** records. In reservoir studies, these planes are usually horizontal but the program has the capability to determine the table based upon a user specified slope of the elevation planes.

4.5 Summary of Output Controls

Table 4.1 summarize the output controls for initial conditions printout. These controls affect the level of printout associated with what the user has input, such as geometry, inflowing sediment loads, bed gradations, and sediment characteristics. Table 4.2 summarizes the output controls for the simulation. These include volume of sediment entering and exiting the model, sediment trap efficiency, bed elevation changes, subsectional water velocities, water surface elevations, and other hydraulic and sediment information.

Record	Level	Description of Printout
T1	–	Normal printout. Prints **T1-NC** records and cross section identification numbers.
	B	Initial geometry and causes data edit to be made.
	C	Trace printout through subroutine GMOD.
T4	–	No printout.
	B	Initial condition of inflowing sediment loads and cross sectional bed gradations.

Table 4.1. Summary of Initial Conditions Printout Commands.

Record	Level	Description of Printout
*[1]	–	Discharge, starting water surface elevation, water temperature, flow duration.
	A	General hydraulic parameters of each cross section.
	B	Initial geometric data, distribution of hydraulic parameters across subsections.
	D	Trace information.
	E	Detailed trace information. Hydraulic information for each incremental area, each trial elevation in backwater computations for each cross section.
*[2]	–	No printout except B-level for last discharge.
	A	Volume of sediment entering and exiting model, trap efficiency.
	B	Bed elevation changes, water surface elevations, thalweg elevation, sediment load exiting model.
	C	Detailed printout of calculations.
$PRT[4]	N	Turn offprint out at all cross sections.
	A	Print out at all cross sections levels specified on * record.
CP	–	The control point number of the segment where printout is specified; used with **$PRT**, **PN** and **END** records.
PN	–	Cross section sequence number on segment specified; used with **$PRT**, **CP** and **END** records.
END	–	End of **PN** records, used with **$PRT**, **CP** and **PN** records.
$VOL[3]	–	Cumulative bed and volume change.
	X	Table of volume versus elevation.
$VOL[4]	A	Cumulative weight of sediment passing each cross section for each sediment size class.
VJ, **VR**	–	Input parameters for elevation-volume table; used with **$VOL** record.

[1] - Record Column 5
[2] - Record Column 6
[3] - Record Column 7
[4] - Record Column 8

Table 4.2. Summary of Continuous Simulation Printout Commands.

SECTION - 5

5. HEC-6 COMPUTATIONS AND MODELING GUIDELINES

5.1 General

Training Document No. 13 (Thomas, 1981), entitled "Guidelines for the Calibration and Application of Computer Program HEC-6," describes methods and procedures for calibrating and applying computer program HEC-6. Other useful documents for sediment transport modeling are Thomas (1977) and Gee (1984). Data requirements for river geometry, sediment characteristics and hydrology are discussed in these documents.

5.2 Establishing Geometry

With the study reach located on a topographic map, mark the upstream boundary, the downstream boundary, the lateral limits and the location of each cross section. Assign an identification number to each cross section; river-miles are recommended. Subdivide the floodplain into channel and overbank portions. These can be considered as subsections having similar hydraulic properties in the direction of flow. Within a subsection, flow conditions (depth, velocity, roughness) should be similar and representative 'n' values and reach lengths therefore can be assigned.

Plot each cross section as it appears at the starting time of the simulation, time zero, and divide each into two parts; the movable bed part in the main channel and the fixed bed. Mark the elevations of geologic controls such as bedrock and clay layers on each cross section. If none are present, the program will arbitrarily assign 10 feet below channel bottom to provide some finite depth of sediment material in the model. If more than 10 feet of scour is expected, assign a lower bottom elevation.

It is necessary to position the downstream end of the model where there is a stable rating curve or known water surface elevation. In reservoir degradation studies this may be several miles downstream from the dam at a rock outcrop or concrete weir. For studies in reservoirs the operating policy will establish the reservoir level for the water surface profile computations and the program will adjust the bed according to calculated results.

5.3 Sediment Data

5.3.1 Sediment Particle Characteristics

Only inorganic sediments are considered. The amount of organic sediments in samples should be measured, expressed as a percentage, and removed before testing for the inorganic properties presented below. If a significant quantity of organic particles are present, such as on the Big Sandy River where coal amounted to 40% of the sample by weight, a suitable procedure for correcting the calculations must be developed. In the Big Sandy River case the coal was represented by an equivalent sand size and treated as inorganic sediment having a specific gravity of 2.65.

5.3.2 Inflowing Sediment Load Synthesis

If the inflowing sediment load is not defined, the program can calculate it from gradation curves for the bed surface material. This procedure is less desirable than that discussed above because of the difficulty of obtaining representative sediment samples for the entire bed surface. However, simulating conditions along a segment of the river permits the use of indicators such as aggradation, degradation and fluctuation in sediment discharge from one cross section to another. Use of these indicators help make a better estimate of the noncohesive sediment load than can be made by applying transport theory at only a point on the river.

5.4 Hydrologic Data

It is important that the water discharges in the computational hydrograph reproduce the long term flow-duration curve (for long-term simulations). If a period of flow record is not available, an annual pattern hydrograph can be determined from knowledge about the duration curve and the annual sequence of flows. It is important to include a wet and dry year in addition to the average year.

It is desirable to repeat discharges at selected time intervals throughout the hydrologic data set to provide a common basis for comparing rates of change. For example, the ending of each year with the same discharge (of short duration) will permit the comparison of water surface and bed profiles at fixed time intervals as time progresses.

Representing the discharge hydrograph with a series of steady flows requires the preservation of total annual water and sediment volume while reproducing the shape and peak discharges in flood events. The duration of each discharge in the computational hydrograph should be at least long enough to permit the flow to pass through the model. For instance if the average water velocity of a discharge is 10 feet per second and the total model length is 10,000 feet, the minimum flow duration for the discharge is 10,000 ÷ 10 or 1000 seconds (0.278 days). Longer durations are acceptable; however, since this is an explicit formulation of the basic equations, care must be taken to insure that flow durations are not so long that oscillations are induced into the sediment bed and water surface profiles.

For moderate to large rivers, it is usually acceptable to approximate an annual hydrograph with 15 to 25 discharge segments. In general, the larger the discharge the shorter its duration must be because the larger discharges carry greater amounts of sediment and result in larger bed movements, increasing the possibility of oscillations. A large discharge can be entered as several successive constant discharge increments to satisfy the requirement for shorter durations.

6. EXAMPLE PROBLEMS

This section presents several example problems that illustrate the contents of input data and computed results files for several typical applications of HEC-6. Detailed descriptions of the input data records can be found in the Input Description (Appendix A), and will not be duplicated here. These example problems are not meant to provide engineering application guidance for use of HEC-6; such guidance can be found in Gee (1984) and Thomas et al. (1981). These examples are provided only to illustrate the type and sequence of data needed to model various situations. They encompass a range of situations from fixed bed backwater computation to simulation of the movement of sediment in a dendritic network of streams.

The example problems are derived from an actual engineering application of HEC-6; therefore, the values of the parameters used in these problems represent that situation only. They should not be used for other situations without field substantiation. Figure 6.1 shows a schematic of the river system that was the basis for these example problems. Each example builds upon previous examples, therefore, only the additional or changed data is described for each. The contents of the input and output files are described in the sequence in which they occur.

Some data can be entered in more than one way (an option); for example, the bed material gradation can be placed on either **N** or **PF** records (see Appendix A). The options used in the example problems were selected based on ease and frequency of use. Each analyst should select an appropriate option for their particular application. The selection should be based on study objectives, data availability and ease of use of the selected option.

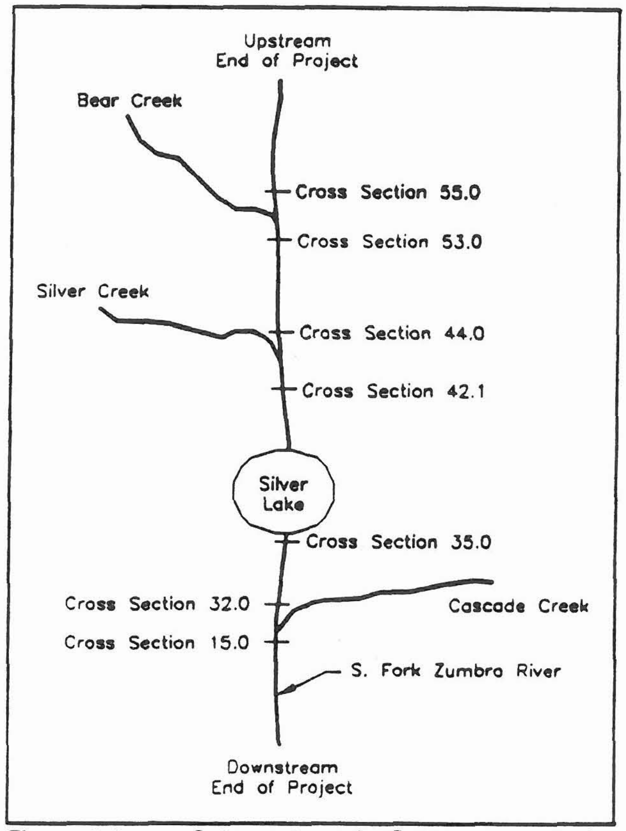

Figure 6.1 Schematic of System used for Example Problems

6.1 Problem 1 - Fixed Bed Application

When initially preparing geometric data and calibrating energy loss coefficients, it is often worthwhile to use HEC-6 as a fixed bed (backwater) model.

6.1.1 Input Data

An example of a data file used to operate HEC-6 as a fixed bed model is shown in Exhibit 6.1; note that the file is quite similar to an HEC-2 data file. Some data records (such as **QT** and **X5**) have different parameters for HEC-6 than for HEC-2; these differences are noted in the Input Description (Appendix A). The data file begins with three title records (**T1**, **T2**, **T3**). These are followed, in this example, by bed roughness data (**NC**) and the geometry for each cross section, beginning with the **X1** record. The **HD** (or **H**) records delineate the movable portion of the cross section; though irrelevant for fixed bed operation of HEC-6, they must be properly located in the data file. The **QT** records locate inflow/outflow points (tributaries or local flows); the values of the flows at these points are found on the **Q** records in the hydrology (flow) data. The cross sections are entered from downstream to upstream. In general, HEC-6 data records are position dependent.

At section 33.3 there are no **GR** data, this section is therefore a repeat of the downstream section, 33.2. Width and elevation modifications can be made to repeated sections similar to the HEC-2 procedure. Note that an **HD**, or **H**, record must be provided at the repeat section. Repeated sections are usually used to provide extra computational points for improving the accuracy of integration of the energy loss equation (USACE-HEC, 1986). Care must be taken to assure that repeat sections have sediment transport characteristics that reflect the theory of "reach representative" cross sections (Thomas, et al., 1981).

The distinguishing characteristic of an HEC-6 fixed boundary simulation data file is that there is no sediment data. The geometric data is followed by the flow data which begines with a **$HYD** record. The flow data for this example contains a rating curve (**$RATING & RC**), and flow information (*****, **Q**, **T**, and **W**). The temperature (**T**) and duration (**W**) data, while necessary in the data file, play no role in fixed bed computations. Problem 1 thus is a "multiple profile" run with two flow profiles being computed through a single reach.

EXHIBIT 6.1 Input - Fixed Bed

```
T1      EXAMPLE PROBLEM NO 1.  BASIC HYDRAULIC PROBLEM USING ROCHESTER DATA SET,
T2      MAINSTEM IS THE LOWER SOUTH FORK ZUMBRO RIVER, MN. 3 LOCAL INFLOWS
T3      ORIGINAL WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW
NC   .100     .100     .040       .1       .3
X1    1.0      31.  10077.0  10275.0       0.       0.       0.       0.       0.       0.
GR1004.0   9915.0   978.40  10002.0   956.00  10060.0   959.20  10077.0   959.30  10081.0
GR950.00  10092.0   948.48  10108.0   946.60  10138.0   944.70  10158.0   955.20  10225.0
GR956.20  10243.0   958.90  10250.0   959.80  10275.0   959.80  10300.0   959.90  10325.0
GR958.80  10350.0   957.40  10400.0   970.00  10700.0   966.00  10960.0   970.00  11060.0
GR968.00  11085.0   968.00  11240.0   970.00  11365.0   970.00  11500.0   970.00  11615.0
GR962.00  11665.0   962.00  12400.0   976.00  12550.0   980.00  12670.0   982.00  12730.0
GR984.00  12735.0
HD      1
X1   15.0      27.  10665.0  10850.0    8565.    7535.    8268.       0.       0.       0.
GR992.00   9570.0   982.00  10110.0   976.00  10300.0   976.00  10490.0   966.00  10610.0
GR964.70  10665.0   956.00  10673.0   953.00  10693.0   954.00  10703.0   955.60  10723.0
GR958.60  10750.0   959.30  10800.0   957.00  10822.0   957.30  10825.0   961.50  10850.0
GR962.00  10852.0   964.00  10970.0   966.00  11015.0   961.00  11090.0   962.00  11150.0
GR970.00  11190.0   972.00  11310.0   980.00  11410.0   984.00  11570.0   990.00  11770.0
GR990.00  11865.0  1000.00  12150.0
HD     15
QT
X1   32.0      29.  10057.0  10271.0    7429.    6654.    8240.       0.       0.       0.
GR998.00   9080.0   982.00   9250.0   982.00   9510.0   980.00   9600.0   980.01   9925.0
GR979.48  10000.0   978.50  10057.0   968.60  10075.0   959.82  10087.0   956.50  10097.0
GR956.80  10117.0   957.80  10137.0   959.40  10157.0   959.60  10177.0   959.82  10196.0
GR966.50  10225.0   971.20  10250.0   978.50  10271.0   978.50  10300.0   978.60  10350.0
GR978.91  10370.0   978.96  10387.0   980.00  10610.0   982.00  10745.0   982.00  11145.0
GR984.00  11150.0   992.00  11240.0  1000.00  11330.0   1008.0  11425.0
HD     32
X1   33.2      21.   1850.0   2150.0     130.     250.     320.       0.       0.       0.
GR1000.0    980.0   990.00   1060.0   980.00   1150.0   982.00   1180.0   982.00   1215.0
GR980.00   1260.0   982.00   1300.0   982.00   1350.0   980.00   1420.0   980.00   1540.0
GR982.00   1730.0   982.00   1830.0   984.41   1850.0   979.19   1851.0   961.00   1900.8
GR961.00   2099.2   976.00   2149.0   984.50   2150.0   982.00   2800.0   990.00   3100.0
GR1000.0   3170.0     0.00      0.0     0.00      0.0     0.00      0.0     0.00      0.0
HD   33.2
X1   33.3        0   1850.0   2150.0     155.     175.     175.      .95     1.49       0.
HD   33.3
X1   35.0      22.   9894.0  10155.0     105.     105.     105.       0.       0.       0.
X3     10
X5            974.      0.5
GR984.00   9035.0   980.00   9070.0   978.00   9135.0   980.00   9185.0   982.00   9270.0
GR980.00   9465.0   981.70   9595.0   983.70   9745.0   984.70   9894.0   963.40   9894.0
GR963.30   9954.0   967.10   9974.0   967.40  10004.0   968.20  10044.0   967.60  10054.0
GR973.40  10115.0   977.40  10120.0   983.70  10155.0   984.00  10245.0   982.00  10695.0
GR982.00  10895.0  1004.00  11085.0
HD     35
```

```
NC   .06      .06     .045
X1  42.1      32.   9880.0 10130.0    2070.    3965.    3005.      0.      0.      0.
GR996.00   7130.0   998.00  7310.0  998.00  7930.0  992.00  8205.0  990.00  8495.0
GR988.00   8780.0   986.00  8990.0  985.70  9570.0  986.45  9707.0  989.44  9857.0
GR990.00   9880.0   969.80  9881.0  969.80  9941.0  985.80  9941.0  985.80  9943.0
GR969.80   9943.0   969.80 10001.0  986.70 10001.0  986.70 10003.0  969.80 10003.0
GR969.80  10067.0   985.80 10067.0  985.80 10069.0  969.80 10069.0  969.80 10129.0
GR989.90  10130.0   989.50 10180.0  988.60 10230.0  987.60 10280.0  985.20 10430.0
GR986.80  11720.0   989.90 12310.0
HD 42.10
QT
X1  44.0      28.   9845.0 10127.0     290.     795.     495.      0.      0.      0.
GR1002.0   8035.0   992.00  8150.0  990.00  8305.0  990.00  8735.0  988.00  8835.0
GR996.00   9285.0   1017.6  9425.0  990.00  9505.0  986.00  9650.0  984.10  9788.0
GR980.60   9845.0   970.90  9868.0  972.20  9898.0  970.50  9968.0  967.50  9998.0
GR968.90  10028.0   967.40 10058.0  967.10 10078.0  971.90 10118.0  976.80 10127.0
GR977.80  10150.0   976.90 10193.0  982.00 10206.0  981.20 10300.0  979.20 10325.0
GR983.10  10400.0   999.80 10450.0 1002.40 10464.0
HD    44
X1  53.0      22.  10000.0 10136.0    3366.    2831.    2941.      0.      0.      0.
GR1004.0   7550.0  1000.00  7760.0  998.00  8440.0  996.00  8640.0  996.00  8780.0
GR994.00   8940.0   986.00  9245.0  986.30  9555.0  986.30  9825.0  983.80  9900.0
GR982.80  10000.0   978.20 10011.0  974.00 10041.0  972.20 10071.0  972.60 10101.0
GR978.20  10121.0   988.70 10136.0  989.30 10154.0  999.20 10200.0  1000.1 10320.0
GR1002.0  10470.0  1004.00 10700.0
HD    53
QT
X1  55.0      18.   9931.0 10062.0     275.    1430.     770.      0.      0.      0.
GR1004.0   7592.0  1000.00  7947.0  996.00  8627.0  990.00  9052.0  986.00  9337.0
GR984.30   9737.0   984.70  9837.0  985.50  9910.0  987.20  9931.0  978.10  9955.0
GR974.80   9975.0   974.20 10005.0  972.90 10035.0  973.20 10045.0  983.80 10062.0
GR985.80  10187.0   986.00 10307.0  990.00 10497.0
HD    55
X1  58.0      22.   9912.0 10015.0    1097.    1012.    1462.      0.      0.      0.
GR1006.0   8542.0  1004.00  8952.0 1000.00  9702.0  997.20  9812.0  996.30  9912.0
GR976.20   9944.0   975.40  9974.0  978.20  9991.0  990.40 10015.0  988.30 10062.0
GR988.80  10065.0   988.30 10065.0  989.30 10169.0  990.00 10172.0  992.00 10242.0
GR992.00  10492.0   988.00 10642.0  986.70 10852.0  988.00 11022.0  986.00 11097.0
GR986.00  11137.0   988.00 11192.0
HD    58
EJ
SHYD
SRATING
RC            40     2000        0        0    950.0    955.1    958.0    960.0    962.0
RC         963.6    965.1    966.2    967.0    967.7    968.3    968.9    969.4    969.8
RC         970.2    970.6    971.0    971.4    971.8    972.1    972.4    972.7    972.9
RC         973.1    973.3    973.5    973.7    973.8    973.9    974.0    974.1    974.2
RC         974.3    974.4    974.5    974.6    974.7    974.8    974.9    975.0
*   A   PROFILE 1 = AVERAGE ANNUAL DISCHARGE
Q  1200.     78.     151.     340.
T    60.     60.      60.      60.
W     1.
*   A   PROFILE 2 = BANK FULL FLOW
Q  2500.    150.     300.     650.
W     1.
SSEND
```

6.1.2 Output

The output from Example Problem 1 is shown in Exhibit 6.2. Various levels of output detail are available to the user. These are controlled by several input data items (see section 4); the output produced by these options will be described as encountered in the problems. The terminology for output is; default, "A-level", "B-level", etc., in increasing detail. Note that the default HEC-6 output provides the minimum level of information.

HEC-6 first gives information regarding program version and date, and the date and time of the run. The input and output file names are placed in the output file for the user's future reference. Information regarding the geometric data follows.

In Example Problem 1, the default (minimum) geometric output is presented. Additional information can be obtained via switches on the **T1** record, see Appendix A. Each cross section is denoted by the identification on the **X1** record. We suggest that river mile be used to identify cross sections. The "depth of bed sediment" is based on information on the **HD** record; since this is a fixed bed run, the values on this record are not used. Information regarding the repeated cross section at river mile 33.3 (see the **X1** record description in Appendix A) is echoed as well as the locations of tributaries/local inflow points and changes to the energy loss coefficients.

Following the geometric data is the flow data (for a fixed bed run). Example Problem 1 output shows an "A-level" output for hydraulic, or backwater, computations. This output is triggered by an A in column 5 of the * record which causes the discharge, water surface elevation, energy grade line elevation, velocity head, alpha, top width, average bed elevation, and average velocity in each subsection for each cross section to be written to the output file. The discharge value represents the subtraction of local inflows as the backwater computation proceeds upstream. Local flow data should be checked to assure that the main river discharge never becomes negative. The average bed elevation is the water surface elevation minus the effective depth (see Section 2.2.3.6). Subsection 1 is the left overbank, 2 the channel, and 3 the right overbank. Information regarding local flows, user supplied energy losses and water surface elevations at controls (**X5** record) are also provided. This hydraulic information is very useful when first assembling geometric data; once the data are verified and the loss coefficients are calibrated, the "A-level" output may be suppressed to save file space.

EXHIBIT 6.2 Output - Fixed Bed

```
*************************************************************          *******************************************
*  SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS            *          *  U.S. ARMY CORPS OF ENGINEERS           *
*   Version: 4.0.0  -  September 1990                       *          *  THE HYDROLOGIC ENGINEERING CENTER      *
*                                                           *          *  609 SECOND STREET                      *
*                                                           *          *  DAVIS, CALIFORNIA 95616-4687           *
*  RUN DATE 30NOV90       TIME 15:23:02                     *          *  (916) 756-1104                         *
*************************************************************          *******************************************


                         X     X XXXXXXX  XXXXX         XXXXX
                         X     X X       X     X       X     X
                         X     X X       X             X
                         XXXXXXX XXXX    X       XXXXX XXXXXX
                         X     X X       X             X     X
                         X     X X       X     X       X     X
                         X     X XXXXXXX  XXXXX         XXXXX


    ***************************************************************************************************
    *  MAXIMUM LIMITS FOR THIS VERSION ARE:                                                           *
    *                                                                                                 *
    *  Stream Segments (Main Stem + Tributaries) =   10          Control Points =   10               *
    *  Cross Sections =  150                                     Grain Sizes =   15                   *
    *                                                                                                 *
    ***************************************************************************************************


    ***************************************************************************************************
    *             INPUT FILE: EX1.DAT                                                                 *
    *             OUTPUT FILE: EX1.OUT                                                                *
    ***************************************************************************************************

T1      EXAMPLE PROBLEM NO 1.  BASIC HYDRAULIC PROBLEM USING ROCHESTER DATA SET,
T2      MAINSTEM IS THE LOWER SOUTH FORK ZUMBRO RIVER, MN, 3 LOCAL INFLOWS
T3      ORIGINAL WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW

NC  .1000   .1000   .0400   .1000   .3000

SECTION NO.  1 RIVER MILE=        1.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO       .000
```

```
SECTION NO.  2 RIVER MILE=      15.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

LOCAL INFLOW POINT  1 OCCURS JUST DOWNSTREAM FROM X-SECTION NO.    3

SECTION NO.  3 RIVER MILE=      32.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

SECTION NO.  4 RIVER MILE=      33.200
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

SECTION NO.  5 RIVER MILE=      33.300
...MULTIPLY ALL STATIONS(X) BY       .95
...ADD     1.49 TO EACH ELEVATION(Y)
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

SECTION NO.  6 RIVER MILE=      35.000
POOL ELEVATION, HEAD LOSS CRITERIA=X5        974.000     .500
INEFFECTIVE FLOW AREA REQUESTED BY X3-RECORD. LEFT OVERBANK   RIGHT OVERBANK
                                          STA #           10              19
                 INEFFECTIVE ELEVATION             984.700         983.700
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

NC  .0600   .0600   .0450   .0000   .0000

SECTION NO.  7 RIVER MILE=      42.100
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

LOCAL INFLOW POINT  2 OCCURS JUST DOWNSTREAM FROM X-SECTION NO.    8

SECTION NO.  8 RIVER MILE=      44.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

SECTION NO.  9 RIVER MILE=      53.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

LOCAL INFLOW POINT  3 OCCURS JUST DOWNSTREAM FROM X-SECTION NO.   10

SECTION NO. 10 RIVER MILE=      55.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

SECTION NO. 11 RIVER MILE=      58.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

NO. OF CROSS SECTIONS READ IN FOR THIS STREAM SEGMENT= 11
NO. OF INPUT DATA MESSAGES =    0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =   11
END OF GEOMETRIC DATA

================================================================================

FIXED BED MODEL

................................................................................

SRATING

DOWNSTREAM BOUNDARY CONDITION SPECIFIED BY A RATING CURVE

ELEVATION OF GAGE ZERO                                         .00
DISCHARGE CORRESPONDING TO LOWEST ELEVATION IN TABLE           .0
DISCHARGE INTERVAL                                          2000.0
NO. OF POINTS IN RATING TABLE                                   40
ELEVATIONS
    950.00   955.10   958.00   960.00   962.00   963.60   965.10   966.20   967.00   967.70
    968.30   968.90   969.40   969.80   970.20   970.60   971.00   971.40   971.80   972.10
    972.40   972.70   972.90   973.10   973.30   973.50   973.70   973.80   973.90   974.00
    974.10   974.20   974.30   974.40   974.50   974.60   974.70   974.80   974.90   975.00

================================================================================
```

```
*   A   PROFILE 1 = AVERAGE ANNUAL DISCHARGE

BOUNDARY CONDITION DATA, CONTROL POINT NO.  1

SEGMENT     INFLOW Q IN CFS...
   1    1200.0      78.0      151.0      340.0
  TIME STEP NO.        1
WATER     DISCHARGE=     1200.00
          ELEVATION=     953.060
        TEMPERATURE=      60.000
FLOW DURATION(DAYS)   1.000

****  N  DISCHARGE   WATER    ENERGY  VELOCITY   ALPHA     TOP      AVG       AVG VEL (by subsection)
          (CFS)     SURFACE    LINE     HEAD              WIDTH     BED      1      2      3

SEC NO.     1.000
****  1    1200.0    953.06    953.12       .06      1.00    122.96    948.15    .00  1.99    .00
                                                  FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    15.000
****  1    1200.0    959.39    959.54       .15      1.00    167.86    957.06    .00  3.06    .00
                                                  FLOW DISTRIBUTION (%) =     .0 100.0     .0

....LOCAL INFLOW POINT NO.  1,  Q=      78.00

   CONTINUING ON SEGMENT NO    1
       TEMPERATURE=      60.000

SEC NO.    32.000
****  1    1122.0    964.10    964.14       .04      1.00    133.53    958.97    .00  1.64    .00
                                                  FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    33.200
****  1    1122.0    964.20    964.24       .04      1.00    217.65    961.16    .00  1.70    .00
                                                  FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    33.300
****  1    1122.0    964.31    964.47       .16      1.00    198.82    962.56    .00  3.22    .00
                                                  FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    35.000
OPERATION RULE SPECIFIED
UPPER POOL ELEVATION (UPE) =    974.00    HEAD LOSS =       .50
****  1    1122.0    974.00    974.01       .01      1.00    221.75    967.05    .00   .73    .00
                                                  FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    42.100
****  1    1122.0    974.22    974.24       .02      1.00    242.44    969.84    .00  1.06    .00
                                                  FLOW DISTRIBUTION (%) =     .0 100.0     .0

....LOCAL INFLOW POINT NO.  2,  Q=     151.00

   CONTINUING ON SEGMENT NO    1
       TEMPERATURE=      60.000

SEC NO.    44.000
****  1     971.0    974.28    974.29       .01      1.00    262.34    969.86    .00   .84    .00
                                                  FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    53.000
****  1     971.0    975.11    975.69       .57      1.00     77.24    973.05    .00  6.08    .00
                                                  FLOW DISTRIBUTION (%) =     .0 100.0     .0

....LOCAL INFLOW POINT NO.  3,  Q=     340.00

   CONTINUING ON SEGMENT NO    1
       TEMPERATURE=      60.000

SEC NO.    55.000
****  1     631.0    977.38    977.46       .08      1.00     92.29    974.36    .00  2.27    .00
                                                  FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    58.000
```

```
**** 1     631.0     979.66     979.86        .20      1.00     55.38    976.48    .00  3.59    .00
                                                   FLOW DISTRIBUTION (%) =     .0 100.0     .0
```

```
*   A   PROFILE 2 = BANK FULL FLOW

BOUNDARY CONDITION DATA, CONTROL POINT NO.  1

SEGMENT    INFLOW Q IN CFS...
   1    2500.0      150.0      300.0      650.0
  TIME STEP NO.       2
WATER     DISCHARGE=     2500.00
          ELEVATION=     955.825
        TEMPERATURE=      60.000
FLOW DURATION(DAYS)  1.000

**** N  DISCHARGE   WATER    ENERGY  VELOCITY   ALPHA     TOP     AVG       AVG VEL (by subsection)
          (CFS)    SURFACE    LINE     HEAD              WIDTH    BED     1      2      3

SEC NO.     1.000
**** 1    2500.0     955.83     955.93       .10      1.00    151.14    949.38    .00  2.57    .00
                                                   FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    15.000
**** 1    2500.0     961.44     961.62       .17      1.02    215.62    957.34    .00  3.35    .20
                                                   FLOW DISTRIBUTION (%) =     .0  99.9     .1

....LOCAL INFLOW POINT NO.  1,  Q=    150.00

  CONTINUING ON SEGMENT NO   1
      TEMPERATURE=     60.000

SEC NO.    32.000
**** 1    2350.0     966.29     966.38       .09      1.00    145.83    959.53    .00  2.38    .00
                                                   FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    33.200
**** 1    2350.0     966.42     966.49       .06      1.00    231.09    961.41    .00  2.03    .00
                                                   FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    33.300
**** 1    2350.0     966.48     966.61       .14      1.00    211.35    962.72    .00  2.96    .00
                                                   FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    35.000
OPERATION RULE SPECIFIED
UPPER POOL ELEVATION (UPE) =    974.00   HEAD LOSS =       .50
**** 1    2350.0     974.00     974.04       .04      1.00    221.75    967.05    .00  1.53    .00
                                                   FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    42.100
**** 1    2350.0     974.82     974.88       .06      1.00    242.50    969.81    .00  1.94    .00
                                                   FLOW DISTRIBUTION (%) =     .0 100.0     .0

....LOCAL INFLOW POINT NO.  2,  Q=    300.00

  CONTINUING ON SEGMENT NO   1
      TEMPERATURE=     60.000

SEC NO.    44.000
**** 1    2050.0     974.99     975.03       .04      1.00    265.26    969.93    .00  1.53    .00
                                                   FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    53.000
**** 1    2050.0     977.02     977.64       .62      1.00     97.48    973.69    .00  6.31    .00
                                                   FLOW DISTRIBUTION (%) =     .0 100.0     .0

....LOCAL INFLOW POINT NO.  3,  Q=    650.00

  CONTINUING ON SEGMENT NO   1
      TEMPERATURE=     60.000
```

```
SEC NO.     55.000
**** 1      1400.0     979.11     979.27        .15      1.00     102.03     974.75    .00  3.14    .00
                                                         FLOW DISTRIBUTION (%) =      .0 100.0      .0

SEC NO.     58.000
**** 1      1400.0     981.66     982.01        .36      1.00      62.42     976.97    .00  4.79    .00
                                                         FLOW DISTRIBUTION (%) =      .0 100.0      .0
```

....

```
SSEND

      0   DATA ERRORS DETECTED.

TOTAL NO. OF TIMESTEPS READ=          2
TOTAL NO. OF WS PROFILES=          2
ITERATIONS IN EXNER EQ  =          0.
END OF JOB

JOB COMPLETED
RUN TIME =  0 HOURS,  0 MINUTES &  5.44 SECONDS
```

6.2 Problem 2 - Hydraulic and Geometric Options

This problem builds on Problem 1; it is also a fixed bed run and illustrates some of the more frequently used options for describing certain geometric and hydraulic conditions. The input file for Example Problem 2 is shown in Exhibit 6.3. Items that differ from Example Problem 1 are discussed below.

EXHIBIT 6.3 Input - Hydraulic Options

```
T1       EXAMPLE PROBLEM NO 2.  HYDRAULIC OPTIONS PROBLEM USING ROCHESTER DATA SET,
T2       MAINSTEM IS THE LOWER SOUTH FORK ZUMBRO RIVER, MN, 3 LOCAL INFLOWS
T3       ORIGINAL WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW
NC  .100     .100     .040       .1       .3
X1   1.0      31.  10077.0  10275.0       0.        0.       0.       0.       0.       0.
GR1004.0   9915.0   978.40  10002.0   956.00  10060.0   959.20  10077.0   959.30  10081.0
GR950.00  10092.0   948.48  10108.0   946.60  10138.0   944.70  10158.0   955.20  10225.0
GR956.20  10243.0   958.90  10250.0   959.80  10275.0   959.80  10300.0   959.90  10325.0
GR958.80  10350.0   957.40  10400.0   970.00  10700.0   966.00  10960.0   970.00  11060.0
GR968.00  11085.0   968.00  11240.0   970.00  11365.0   970.00  11500.0   970.00  11615.0
GR962.00  11665.0   962.00  12400.0   976.00  12550.0   980.00  12670.0   982.00  12730.0
GR984.00  12735.0
HD     1
NV    22     .045    965.6     .064    988.8
NV    12      .08    965.6      .13    988.8
NV    33       .1    965.6      .11    982.0      .12    988.8
X1  15.0      27.  10665.0  10850.0    8565.     7535.    8268.       0.       0.       0.
X3                            10700     961.    11000.     970.
GR992.00   9570.0   982.00  10110.0   976.00  10300.0   976.00  10490.0   966.00  10610.0
GR964.70  10665.0   956.00  10673.0   953.00  10693.0   954.00  10703.0   955.60  10723.0
GR958.60  10750.0   959.30  10800.0   957.00  10822.0   957.30  10825.0   961.50  10850.0
GR962.00  10852.0   964.00  10970.0   966.00  11015.0   961.00  11090.0   962.00  11150.0
GR970.00  11190.0   972.00  11310.0   980.00  11410.0   984.00  11570.0   990.00  11770.0
GR990.00  11865.0  1000.00  12150.0
HD    15
QT
NC    .1       .1      .05
X1  32.0      29.  10057.0  10271.0    7429.     6654.    8240.       0.       0.       0.
GR998.00   9080.0   982.00   9250.0   982.00   9510.0   980.00   9600.0   980.01   9925.0
GR979.48  10000.0   978.50  10057.0   968.60  10075.0   959.82  10087.0   956.50  10097.0
GR956.80  10117.0   957.80  10137.0   959.40  10157.0   959.60  10177.0   959.82  10196.0
GR966.50  10225.0   971.20  10250.0   978.50  10271.0   978.50  10300.0   978.60  10350.0
GR978.91  10370.0   978.96  10387.0   980.00  10610.0   982.00  10745.0   982.00  11145.0
GR984.00  11150.0   992.00  11240.0  1000.00  11330.0   1008.0  11425.0
HD    32
X1  33.2      21.   1850.0   2150.0     130.      250.     320.       0.       0.       0.
```

```
XL               250.
GR1000.0   980.0  990.00  1060.0  980.00  1150.0  982.00  1180.0  982.00  1215.0
GR980.00  1260.0  982.00  1300.0  982.00  1350.0  980.00  1420.0  980.00  1540.0
GR982.00  1730.0  982.00  1830.0  984.41  1850.0  979.19  1851.0  961.00  1900.8
GR961.00  2099.2  976.00  2149.0  984.50  2150.0  982.00  2800.0  990.00  3100.0
GR1000.0  3170.0    0.00     0.0    0.00     0.0    0.00     0.0    0.00     0.0
HD  33.2
X1  33.3       0  1850.0  2150.0    155.    175.    175.     .95    1.49      0.
X5                             2
HD  33.3
X1  35.0     22.  9894.0 10155.0    105.    105.    105.      0.      0.      0.
X3    10
X5          974.     0.5
GR984.00  9035.0  980.00  9070.0  978.00  9135.0  980.00  9185.0  982.00  9270.0
GR980.00  9465.0  981.70  9595.0  983.70  9745.0  984.70  9894.0  963.40  9894.0
GR963.30  9954.0  967.10  9974.0  967.40 10004.0  968.20 10044.0  967.60 10054.0
GR973.40 10115.0  977.40 10120.0  983.70 10155.0  984.00 10245.0  982.00 10695.0
GR982.00 10895.0 1004.00 11085.0
HD    35
NC   .06     .06    .045
X1  42.1     32.  9880.0 10130.0   2070.   3965.   3005.      0.      0.      0.
GR996.00  7130.0  998.00  7310.0  998.00  7930.0  992.00  8205.0  990.00  8495.0
GR988.00  8780.0  986.00  8990.0  985.70  9570.0  986.45  9707.0  989.44  9857.0
GR990.00  9880.0  969.80  9881.0  969.80  9941.0  985.80  9941.0  985.80  9943.0
GR969.80  9943.0  969.80 10001.0  986.70 10001.0  986.70 10003.0  969.80 10003.0
GR969.80 10067.0  985.80 10067.0  985.80 10069.0  969.80 10069.0  969.80 10129.0
GR989.90 10130.0  989.50 10180.0  988.60 10230.0  987.60 10280.0  985.20 10430.0
GR986.80 11720.0  989.90 12310.0
HD 42.10
QT
X1  44.0     28.  9845.0 10127.0    290.    795.    495.      0.      0.      0.
XL                          9850.  10200.
GR1002.0  8035.0  992.00  8150.0  990.00  8305.0  990.00  8735.0  988.00  8835.0
GR996.00  9285.0  1017.6  9425.0  990.00  9505.0  986.00  9650.0  984.10  9788.0
GR980.60  9845.0  970.90  9868.0  972.20  9898.0  970.50  9968.0  967.50  9998.0
GR968.90 10028.0  967.40 10058.0  967.10 10078.0  971.90 10118.0  976.80 10127.0
GR977.80 10150.0  976.90 10193.0  982.00 10206.0  981.20 10300.0  979.20 10325.0
GR983.10 10400.0  999.80 10450.0 1002.40 10464.0
HD    44
X1  53.0     22. 10000.0 10136.0   3366.   2831.   2941.      0.      0.      0.
GR1004.0  7550.0 1000.00  7760.0  998.00  8440.0  996.00  8640.0  996.00  8780.0
GR994.00  8940.0  986.00  9245.0  986.30  9555.0  986.30  9825.0  983.80  9900.0
GR982.80 10000.0  978.20 10011.0  974.00 10041.0  972.20 10071.0  972.60 10101.0
GR978.20 10121.0  988.70 10136.0  989.30 10154.0  999.20 10200.0  1000.1 10320.0
GR1002.0 10470.0 1004.00 10700.0
HD    53
QT
X1  55.0     18.  9931.0 10062.0    275.   1430.    770.      0.      0.      0.
GR1004.0  7592.0 1000.00  7947.0  996.00  8627.0  990.00  9052.0  986.00  9337.0
GR984.30  9737.0  984.70  9837.0  985.50  9910.0  987.20  9931.0  978.10  9955.0
GR974.80  9975.0  974.20 10005.0  972.90 10035.0  973.20 10045.0  983.80 10062.0
GR985.80 10187.0  986.00 10307.0  990.00 10497.0
HD    55
X1  58.0     22.  9912.0 10015.0   1097.   1012.   1462.      0.      0.      0.
GR1006.0  8542.0 1004.00  8952.0 1000.00  9702.0  997.20  9812.0  996.30  9912.0
GR976.20  9944.0  975.40  9974.0  978.20  9991.0  990.40 10015.0  988.30 10062.0
GR988.80 10065.0  988.30 10065.0  989.30 10169.0  990.00 10172.0  992.00 10242.0
GR992.00 10492.0  988.00 10642.0  986.70 10852.0  988.00 11022.0  986.00 11097.0
GR986.00 11137.0  988.00 11192.0
HD    58
EJ
SHYD
*   A   PROFILE 1 = ANNUAL DISCHARGE
Q  1200.     78.     151.     340.
R   953.    973.
T    60.     60.      60.      60.
W     1.
*   A   PROFILE 2 = FLOOD EVENT
Q 10000.    600.   1200.    2600.
R   963.    977.
W     1.
SSEND
```

6.2.1 Manning's n vs. Elevation

Some situations are better modeled by varying n-values vertically rather than horizontally; this is done in problem 2 at section 15.0 by using **NV** records (see Appendix A for details). These n vs. elevation functions are shown graphically on Figure 6.2. These functions will be used at all subsequent (upstream) cross sections until another **NV** or **NC** record is found. Elevations on **NV** records are constant for all subsequent cross sections, therefore, as the computation proceeds upstream they may become too low. In this example, the **NC** record at cross section 32.0 returns the computation to an n vs. subsection function. The **NV** record can also be used to vary n with discharge.

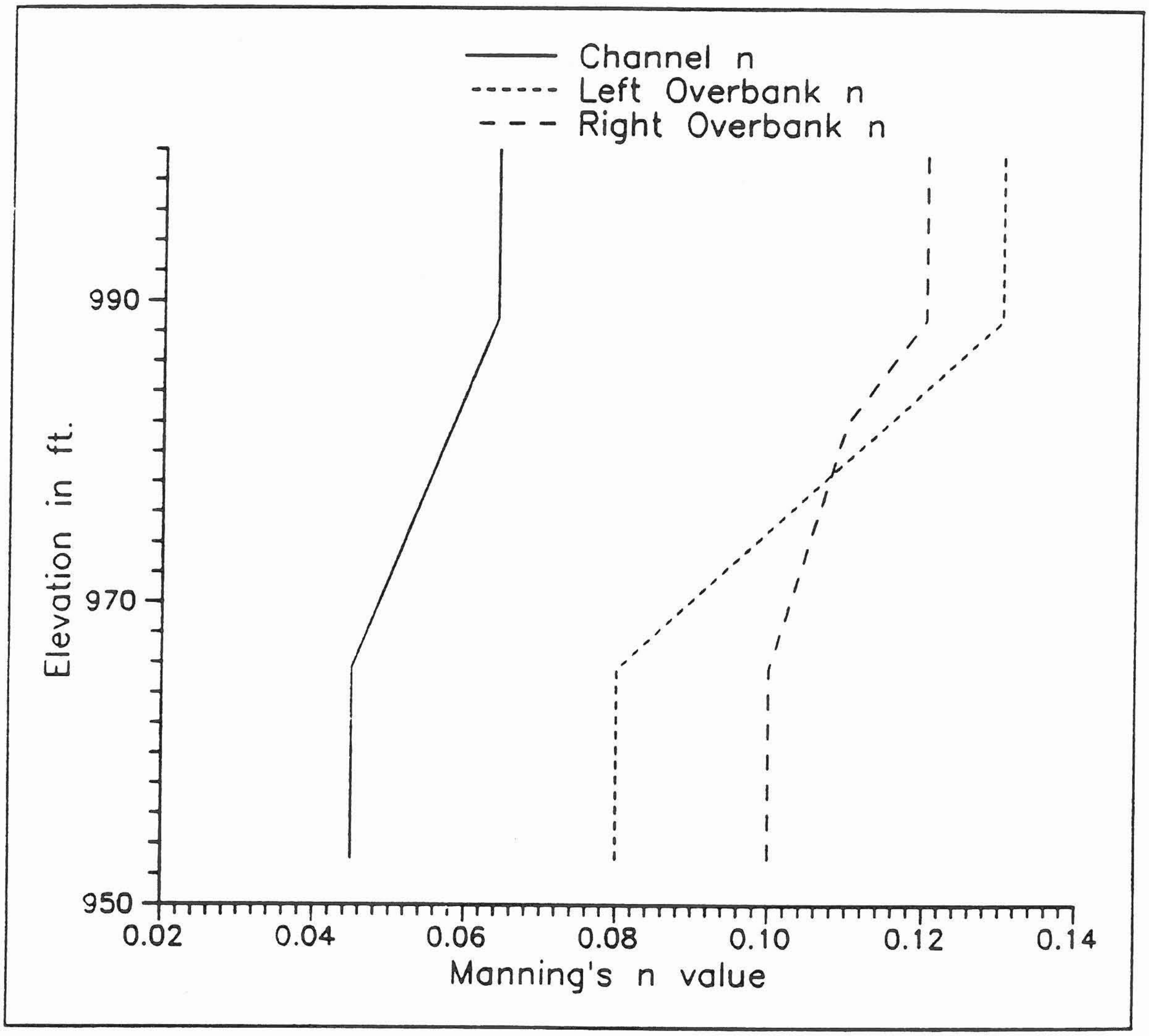

Figure 6.2 Manning's n vs. Elevation, Section 15, Problem 2

6.2.2 Ineffective Flow Area

A portion of section 15.0 is deemed to be ineffective; that is, it carries no flow. This is described with the **X3** records. The **X3** record allows easy modification of existing section data to reflect encroachments. In this case, the left encroachment starts at the intersection of the left bank and elevation 961 ft. and extends at that elevation to station 10700 ft. The right encroachment starts at station 11000 ft. and extends at elevation 970 ft. to the right bank. Computationally, this is equivalent to raising the **GR** points to lie along the top of the encroachments.

6.2.3 Conveyance Limits

Ineffective flow areas can also be specified with **XL** data. In this example cross section 33.2 has non-conveying areas centered about the channel on both sides, leaving a conveyance width of 250 ft. At cross section 44.0 the left conveyance limit is at station 9850 ft. and the right at 10200 ft., leaving a conveyance width of 350 ft. (not centered about the channel). The difference between the ineffective flow area and the conveyance limits options is that deposition may occur in wetted areas outside the conveyance limits, but not in ineffective flow areas. Although both methods may yield the same hydraulic conditions, sediment deposition may differ. Refer to sections 3.2.7 and 3.2.8.

6.2.4 Internal Hydraulic Control Points

Study reaches will occasionally contain internal hydraulic controls, such as weirs and gated structures, where the step backwater solution is not appropriate. The effects of such structures can be simulated using **X5** and **R** data. In example problem 2, section 33.3 is immediately upstream of a gated structure that can arbitrarily control the upstream water surface elevation. The "2" in field 4 of the **X5** record for section 33.3 causes the water surface elevation for that section to be read from field 2 of the **R** record in the flow data. Thus, for this example, the water surface elevation at section 33.3 will be 973 ft. for the first discharge and 977 ft. for the second. The larger of this water surface elevation or that computed by the step backwater is used.

6.2.5 Downstream Boundary Water Surface Elevation

In Example Problem 1, the downstream boundary water surface elevation was computed for each flow by interpolation within a rating curve (**RC**) table provided by the user. Alternately, when the downstream water surface elevation is independent of discharge, as with a reservoir pool elevation, the boundary condition can be specified as a time series of water surface elevations (i.e. a stage hydrograph). This is illustrated by the **R** records in the input data for Example Problem 2. For this problem the starting water surface elevation is 953 ft. for the first discharge and 963 ft. for the second.

6.2.6 Output

The "A-level" hydraulic output for Example Problem 2 is shown in Exhibit 6.4. This output is quite similar to that of Example Problem 1. Note that the water surface elevations at section 33.3 of 973 ft. and 977 ft. reflect the elevations on the **R** data. At cross section 35.0 for the second (larger) discharge, the minimum pool elevation of 974 ft. was submerged by tailwater and, therefore, a head loss of 0.5 ft. was added to the computed water surface elevation of 977 ft. Refer to the **X5** record for that section. That discharge was also large enough that the water surface elevations at sections 33.2 and 44.0 reached the encroachments; this can be seen in the column labelled "TOP WIDTH" where the values are 250 ft. and 350 ft. respectively for those two sections.

EXHIBIT 6.4 Output - Hydraulic Options

```
***************************************************************************************************
*              INPUT FILE: EX4.DAT                                                                 *
*              OUTPUT FILE: EX4.OUT                                                                *
***************************************************************************************************

T1       EXAMPLE PROBLEM NO 4.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
T2       SEDIMENT RUN W/OPTIONS, 3 LOCAL INFLOWS: CASCADE, SILVER, BEAR CREEKS
T3       ORIGINAL WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW

NC  .1000   .1000   .0400   .1000   .3000

SECTION NO.  1 RIVER MILE=      1.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO    10.000

NV   22.    .0450    966.    .0640    989.    .0000     0.    .0000     0.    .0000
NV   12.    .0800    966.    .1300    989.    .0000     0.    .0000     0.    .0000
NV   33.    .1000    966.    .1100    982.    .1200   989.    .0000     0.    .0000

SECTION NO.  2 RIVER MILE=     15.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO    10.000

LOCAL INFLOW POINT  1 OCCURS JUST DOWNSTREAM FROM X-SECTION NO.     3

NC  .1000   .1000   .0500   .0000   .0000

SECTION NO.  3 RIVER MILE=     32.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO    10.000

SECTION NO.  4 RIVER MILE=     33.200
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

SECTION NO.  5 RIVER MILE=     33.300
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

SECTION NO.  6 RIVER MILE=     35.000
POOL ELEVATION, HEAD LOSS CRITERIA=X5        974.000    .500
INEFFECTIVE FLOW AREA REQUESTED BY X3-RECORD. LEFT OVERBANK    RIGHT OVERBANK
                                   STA #             10               19
                   INEFFECTIVE ELEVATION          984.700          983.700
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

NC  .0600   .0600   .0450   .0000   .0000

SECTION NO.  7 RIVER MILE=     42.100
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO      .000

LOCAL INFLOW POINT  2 OCCURS JUST DOWNSTREAM FROM X-SECTION NO.     8

SECTION NO.  8 RIVER MILE=     44.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO     1.000

SECTION NO.  9 RIVER MILE=     53.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO    10.000

LOCAL INFLOW POINT  3 OCCURS JUST DOWNSTREAM FROM X-SECTION NO.    10

SECTION NO. 10 RIVER MILE=     55.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO    10.000

SECTION NO. 11 RIVER MILE=     58.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO     3.400

NO. OF CROSS SECTIONS READ IN FOR THIS STREAM SEGMENT= 11
NO. OF INPUT DATA MESSAGES =    0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =  11
END OF GEOMETRIC DATA
```

```
T4      MAIN STEM, SEGMENT 1, SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
T5      LOAD CURVE FROM USGS DATA AT USGS GAGE: 5 PERCENT ADDED FOR BED LOAD
T6      BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T7      ENCODED BY DAVID WILLIAMS, WES, SEPT 1982
T8      SEDIMENT TRANSPORT BY STREAM POWER: SEE ASCE JOURNAL (YANG 1971)
EXAMPLE PROBLEM NO 4.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
SEDIMENT RUN W/OPTIONS, 3 LOCAL INFLOWS: CASCADE, SILVER, BEAR CREEKS
ORIGINAL WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW


- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


SEDIMENT PARAMETER DATA
       SPI      IBG    MNQ       SPGF      ACGR     NFALL    IBSHER
I1      5.        0      1     1.000    32.174        2         1

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

 SAND AND/OR GRAVEL ARE PRESENT


       MTC      IASA     LASA      SPGS       GSF       BSAE       PSI     UWDLB
I4      4         1       10      2.650      .667       .500    30.000    93.000

FOLLOWING GRAIN SIZES UTILIZED
SAND:   .000288   .000580   .001160   .002319   .004639
        .009279   .018560   .037120   .074216   .148596

*****TRANSPORT CAPACITY RELATIONSHIP IS YANG*****                 *** MTC =  4

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED
        DBI      DBN      XID      XIN      XIU      UBI      UBN      JSL
I5     .500     .500     .250     .500     .250     .000    1.000      1

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


SEDIMENT LOAD TABLE FOR STREAM SEGMENT #   1
LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQ        * 1.00000     * 50.0000     * 1000.00     * 5800.00     * 90000.0     *
LF   VFS* .130900E-02* .178500     * 159.360     * 2299.50     * 232800.     *
LF    FS* .360800E-02* .492000     * 105.920     * 1377.00     * 112000.     *
LF    MS* .608300E-02* .829500     * 49.9200     * 693.000     * 44000.0     *
LF    CS* .100000E-19* .100000E-19* 3.52000     * 72.0000     * 8000.00     *
LF   VCS* .100000E-19* .100000E-19* 1.28000     * 36.0000     * 2000.00     *
LF   VFG* .100000E-19* .100000E-19* .100000E-19* 18.0000     * 800.000     *
LF    FG* .100000E-19* .100000E-19* .100000E-19* 4.50000     * 400.000     *
LF    MG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
LF    CG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
LF   VCG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
         ------------ ------------ ------------ ------------ ------------
   SUM=* .110000E-01* 1.50000     * 320.000     * 4500.00     * 400000.     *

VOLUME VS DEPTH OF DEPOSITS
  SEC NO.      REACH    MOVABLE       INITIAL BED-ELEVATIONS        ACCUMULATED CHANNEL DISTANCE
              LENGTH      BED    LEFT SIDE  THALWEG  RIGHT SIDE        FROM DOWNSTREAM
                         WIDTH                                        FEET            MILES
                  .00
   1.000                183.50    959.30    944.70    958.90           .00              .00
              8268.00
  15.000                242.00    961.00    954.00    962.00       8268.00             1.57
              8240.00
  32.000                219.50    968.60    956.50    978.50      16508.00             3.13
               320.00
  33.200                299.00    979.19    961.00    976.00      16828.00             3.19
               175.00
  33.300                299.00    979.19    961.00    976.00      17003.00             3.22
               105.00
```

35.000		276.00	963.30	963.30	983.70	17108.00	3.24
	3005.00						
42.100		154.50	969.80	969.80	969.80	20113.00	3.81
	495.00						
44.000		337.50	970.90	967.10	976.90	20608.00	3.90
	2941.00						
53.000		195.00	982.80	972.20	988.70	23549.00	4.46
	770.00						
55.000		204.00	987.20	972.90	983.80	24319.00	4.61
	1462.00						
58.000		176.50	996.30	975.40	990.40	25781.00	4.88

ED MATERIAL GRADATION (as computed from PF-records)

	SECID	SAE	DMAX	DXPI	XPI	TOTAL BED	BED MATERIAL FRACTIONS PER GRAIN SIZE (FINE TO COARSE)				
N	1.000	1.000	.105	.105	1.000	1.000	.010	.070	.290	.360	.120
							.060	.040	.015	.035	.000
N	15.000	1.000	.158	.158	1.000	1.000	.010	.070	.333	.368	.112
							.042	.032	.010	.020	.003
N	32.000	1.000	.210	.210	1.000	1.000	.010	.070	.375	.375	.105
							.025	.025	.005	.005	.005
N	33.200	1.000	.210	.210	1.000	1.000	.010	.068	.363	.380	.109
							.028	.026	.005	.006	.006
N	33.300	1.000	.210	.210	1.000	1.000	.009	.067	.356	.383	.112
							.030	.026	.005	.006	.006
N	35.000	1.000	.210	.210	1.000	1.000	.009	.067	.352	.384	.113
							.030	.026	.005	.007	.007
N	42.100	1.000	.210	.210	1.000	1.000	.006	.051	.237	.431	.154
							.058	.031	.003	.015	.015
N	44.000	1.000	.210	.210	1.000	1.000	.006	.048	.218	.439	.160
							.063	.032	.003	.016	.016
N	53.000	1.000	.210	.210	1.000	1.000	.002	.032	.105	.485	.200
							.090	.036	.001	.024	.024
N	55.000	1.000	.210	.210	1.000	1.000	.002	.028	.076	.497	.210
							.097	.038	.001	.026	.026
N	58.000	1.000	.210	.210	1.000	1.000	.000	.020	.020	.520	.230
							.110	.040	.000	.030	.030

.LOCAL INFLOW DATA...

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
AT LOCAL INFLOW POINT # 1

LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQL	* 1.00000	* 100.000	* 1000.00	* 10000.0	*
LFL	VFS* .265600E-02*	6.64000	* 7.50000	* 5940.00	*
LFL	FS* .828000E-03*	2.07000	* 122.500	* 5430.00	*
LFL	MS* .344000E-03*	.860000	* 302.500	* 3210.00	*
LFL	CS* .124000E-03*	.310000	* 26.0000	* 2940.00	*
LFL	VCS* .320000E-04*	.800000E-01*	19.5000	* 3810.00	*
LFL	VFG* .120000E-04*	.300000E-01*	10.0000	* 3480.00	*
LFL	FG* .400000E-05*	.100000E-01*	5.50000	* 2730.00	*
LFL	MG* .100000E-19*	.100000E-19*	5.50000	* 1590.00	*
LFL	CG* .100000E-19*	.100000E-19*	.100000E-19*	660.000	*
LFL	VCG* .100000E-19*	.100000E-19*	.100000E-19*	180.000	*
	------------	------------	------------	------------	
	SUM=* .400000E-02*	10.0000	* 499.000	* 29970.0	*

.LOCAL INFLOW DATA...

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
AT LOCAL INFLOW POINT # 2

LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQL	* 1.00000	* 100.000	* 1000.00	* 10000.0	*
LFL VFS*	.265600E-02*	6.64000	* 7.50000	* 5940.00	*
LFL FS*	.828000E-03*	2.07000	* 122.500	* 5430.00	*
LFL MS*	.344000E-03*	.860000	* 302.500	* 3210.00	*
LFL CS*	.124000E-03*	.310000	* 26.0000	* 2940.00	*
LFL VCS*	.320000E-04*	.800000E-01*	19.5000	* 3810.00	*
LFL VFG*	.120000E-04*	.300000E-01*	10.0000	* 3480.00	*
LFL FG*	.400000E-05*	.100000E-01*	5.50000	* 2730.00	*
LFL MG*	.100000E-19*	.100000E-19*	5.50000	* 1590.00	*
LFL CG*	.100000E-19*	.100000E-19*	.100000E-19*	660.000	*
LFL VCG*	.100000E-19*	.100000E-19*	.100000E-19*	180.000	*
	------------	------------	------------	------------	
SUM=*	.400000E-02*	10.0000	* 499.000	* 29970.0	*

.LOCAL INFLOW DATA...

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
AT LOCAL INFLOW POINT # 3

LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQL	* 1.00000	* 100.000	* 500.000	* 1000.00	* 30000.0	*
LFL VFS*	.402000E-03*	6.03000	* 39.0000	* 93.6000	* 3082.50	*
LFL FS*	.684000E-03*	10.2600	* 86.0000	* 210.000	* 4905.00	*
LFL MS*	.902000E-03*	13.5300	* 227.000	* 721.200	* 10710.0	*
LFL CS*	.200000E-05*	.300000E-01*	98.5000	* 170.400	* 3555.00	*
LFL VCS*	.100000E-19*	.100000E-19*	.100000E-19*	3.60000	* 180.000	*
LFL VFG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	45.0000	*
LFL FG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	22.5000	*
LFL MG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	
LFL CG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	
LFL VCG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	
	------------	------------	------------	------------	------------	
SUM=*	.199000E-02*	29.8500	* 450.500	* 1198.80	* 22500.0	*

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 4. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
DIMENSIONS OF BED SEDIMENT CONTROL VOLUMES, FEET.

SEC. NO. *	LENGTH	* MAX. WIDTH *	DEPTH	* VOLUME		*
*		*	*	* CU. FT.	* CU. YD.	*
1.000*	4134.00	* 203.000	* 10.0000	* .839202E+07*	310816.	*
15.000*	8254.00	* 228.490	* 10.0000	* .188596E+08*	698502.	*
32.000*	4280.00	* 227.710	* 10.0000	* .974600E+07*	360963.	*
33.200*	247.500	* 281.869	* .000000	* .000000	* .000000	*
33.300*	87.5000	* 299.000	* .000000	* .000000	* .000000	*
35.000*	1502.50	* 235.500	* .000000	* .000000	* .000000	*
42.100*	1750.00	* 197.899	* .000000	* .000000	* .000000	*
44.000*	1718.00	* 288.055	* 1.00000	* 494879.	* 18328.8	*
53.000*	1855.50	* 233.267	* 10.0000	* .432826E+07*	160306.	*
55.000*	1116.00	* 196.961	* 10.0000	* .219808E+07*	81410.4	*
58.000*	731.000	* 185.667	* 3.40000	* 461456.	* 17091.0	*

NO. OF INPUT DATA MESSAGES= 0
END OF SEDIMENT DATA

==

BEGIN COMPUTATIONS.
SHYD

....

SB 2

....

```
*   AB      FLOW 1 = BASE FLOW OF 500 CFS

BOUNDARY CONDITION DATA, CONTROL POINT NO.  1

SEGMENT     INFLOW Q IN CFS...
    1     500.0      61.0       29.0      128.0
  TIME STEP NO.        1
WATER     DISCHARGE=      500.00
          ELEVATION=     956.000
        TEMPERATURE=      65.000
FLOW DURATION(DAYS)  2.000

****  N  DISCHARGE   WATER    ENERGY  VELOCITY   ALPHA      TOP      AVG       AVG VEL (by subsection)
           (CFS)    SURFACE    LINE     HEAD              WIDTH     BED      1      2      3

SEC NO.     1.000
****  1      500.0    956.00    956.00       .00       1.00    154.50    949.52    .00    .50    .00
                                                      FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    15.000

SUPERCRITICAL
SEC NO.  15.000 TIME =    2.00 DAYS.
TRIAL     TRIAL        COMPUTED      CRITICAL
 NO.       WS             WS            WS
  0.      957.23        955.56
  1.      957.33        955.63        957.28
****  1      500.0    957.33    958.06       .73       1.00     46.55    955.76    .00   6.86    .00
                                                      FLOW DISTRIBUTION (%) =     .0 100.0     .0

....LOCAL INFLOW POINT NO.  1,  Q=      61.00

   CONTINUING ON SEGMENT NO    1
       TEMPERATURE=      64.027

SEC NO.    32.000
****  1      439.0    960.73    960.78       .04       1.00    114.10    958.43    .00   1.67    .00
                                                      FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    33.200

SUPERCRITICAL
SEC NO.  33.200 TIME =    2.00 DAYS.
TRIAL     TRIAL        COMPUTED      CRITICAL
 NO.       WS             WS            WS
  0.      961.57        961.45
  1.      961.59        961.42        961.54
****  1      439.0    961.59    961.80       .21       1.00    201.98    961.01    .00   3.71    .00
                                                      FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    33.300
****  1      439.0    962.33    962.38       .04       1.00    206.42    961.03    .00   1.64    .00
                                                      FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    35.000
OPERATION RULE SPECIFIED
UPPER POOL ELEVATION (UPE) =    974.00    HEAD LOSS =        .50
****  1      439.0    974.00    974.00       .00       1.00    221.75    967.05    .00    .29    .00
                                                      FLOW DISTRIBUTION (%) =     .0 100.0     .0

SEC NO.    42.100
****  1      439.0    974.02    974.02       .00       1.00    242.42    969.82    .00    .43    .00
                                                      FLOW DISTRIBUTION (%) =     .0 100.0     .0

....LOCAL INFLOW POINT NO.  2,  Q=      29.00

   CONTINUING ON SEGMENT NO    1
       TEMPERATURE=      63.605
```

```
SEC NO.    44.000
**** 1      410.0     974.02     974.02        .00       1.00    261.28    969.83    .00   .37   .00
                                                       FLOW DISTRIBUTION (%) =      .0 100.0    .0

SEC NO.    53.000

SUPERCRITICAL
SEC NO.  53.000 TIME =    2.00 DAYS.
TRIAL    TRIAL       COMPUTED     CRITICAL
 NO.       WS           WS           WS
  1.     973.79       973.64
  2.     973.88       973.71       973.83
**** 1      410.0     973.88     974.40        .52       1.00     62.55    972.75    .00  5.79   .00
                                                       FLOW DISTRIBUTION (%) =      .0 100.0    .0

....LOCAL INFLOW POINT NO.  3,  Q=     128.00

   CONTINUING ON SEGMENT NO   1
       TEMPERATURE=      62.064

SEC NO.    55.000
**** 1      282.0     975.22     975.35        .13       1.00     75.85    973.93    .00  2.88   .00
                                                       FLOW DISTRIBUTION (%) =      .0 100.0    .0

SEC NO.    58.000
**** 1      282.0     977.16     977.61        .45       1.00     42.45    975.93    .00  5.40   .00
                                                       FLOW DISTRIBUTION (%) =      .0 100.0    .0


TABLE SA-1.  TRAP EFFICIENCY ON STREAM SEGMENT #  1
             EXAMPLE PROBLEM NO 4.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
             ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*******************************************************************
                         *                                *
    TIME        ENTRY *                 SAND               *
    DAYS        POINT *     INFLOW    OUTFLOW    TRAP EFF  *
                         *                                *
    2.00       58.000 *         .03                        *
               53.000 *         .04                        *
   TOTAL=      53.000 *         .07         .76     -9.67  *
                         *                                *
*******************************************************************
    TIME        ENTRY *                 SAND               *
    2.00       53.000 *         .76                        *
               42.100 *         .00                        *
   TOTAL=      35.000 *         .76         .00      1.00  *
                         *                                *
*******************************************************************
    TIME        ENTRY *                 SAND               *
    2.00       35.000 *         .00                        *
               15.000 *         .00                        *
   TOTAL=       1.000 *         .00         .26    -59.23  *
                         *                                *
*******************************************************************
TABLE SB-1.                   TOTAL        AND LOAD BY GRAIN SIZEIN TONS/DAY
                                          VF           F            M            C            VC
SEDIMENT INFLOW
 SANDS & GRAVELS          28.81         9.03        10.94         8.84          .00          .00
                                          .00          .00          .00          .00          .00
SEDIMENT OUTFLOW
 SANDS & GRAVELS         260.08        16.61        36.23        96.75        80.54        26.57
                                         1.38         1.59          .41          .00          .00


 SECTION   BED CHANGE   WS ELEV   THALWEG        Q      SEDIMENT LOAD (TONS/DAY)
  ID NO       FEET        FEET    EL FEET       CFS         SAND
   58.000      -.71      977.16    974.69      282.          828.
   55.000       .05      975.22    972.95      282.          726.
   53.000       .00      973.88    972.20      410.            0.
   44.000       .56      974.02    967.66      410.            0.
   42.100       .00      974.02    969.80      439.            0.
   35.000       .00      974.00    963.30      439.            0.
```

```
      33.300          .00     962.33     961.00          439.          0.
      33.200          .00     961.59     961.00          439.          0.
      32.000         -.16     960.73     956.34          439.       1709.
      15.000          .08     957.33     954.08          500.        260.
       1.000          .00     956.00     944.70          500.        260.

.......................................................................................

SDREDGE

SDREDGE       0.

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .


STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 4.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN

SEC NO.     42.100
ELEVATION OF DREDGED CHANNEL INCLUDING    1.00 FEET OF OVER DREDGING=     969.80

SEC NO.     44.000
ELEVATION OF DREDGED CHANNEL INCLUDING    1.00 FEET OF OVER DREDGING=     968.00
TONS OF SEDIMENT DREDGED FROM THIS REACH=        2476.0 ACCUMULATED FROM DOWNSTREAM END=        2476.
                              CUBIC YARDS=        1972.1                                          1972.

=======================================================================================

*    B      FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE

COMPUTING FROM TIME=     2.000000 DAYS TO TIME=    52.000000 DAYS IN         20 COMPUTATION STEPS


BOUNDARY CONDITION DATA, CONTROL POINT NO.  1
  TIME STEP NO.        2
WATER    DISCHARGE=     2500.00
         ELEVATION=     965.000
       TEMPERATURE=      65.000
FLOW DURATION(DAYS)  2.500

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  1
            EXAMPLE PROBLEM NO 4.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*************************************************************
                     *                                *
    TIME      ENTRY  *              SAND              *
    DAYS      POINT  *    INFLOW   OUTFLOW  TRAP EFF  *
                     *                                *
   52.00     58.000  *     13.11                      *
             53.000  *     16.03                      *
   TOTAL=    53.000  *     29.14     37.71      -.29  *
                     *                                *
*************************************************************
    TIME      ENTRY  *              SAND              *
   52.00     53.000  *     37.71                      *
             42.100  *       .36                      *
   TOTAL=    35.000  *     38.06     13.86       .64  *
                     *                                *
*************************************************************
    TIME      ENTRY  *              SAND              *
   52.00     35.000  *     13.86                      *
             15.000  *       .99                      *
   TOTAL=     1.000  *     14.86       .62       .96  *
                     *                                *
*************************************************************
TABLE SB-1.               TOTAL        AND LOAD BY GRAIN SIZEIN TONS/DAY
                                      VF          F           M           C           VC
SEDIMENT INFLOW
 SANDS & GRAVELS        529.98      265.63      173.06       82.59        6.27        2.42
                                       .00         .00         .00         .00         .00
SEDIMENT OUTFLOW
 SANDS & GRAVELS         16.01        2.59        1.67        5.02        4.85        1.86
                                       .01         .00         .00         .00         .00
```

SECTION ID NO	BED CHANGE FEET	WS ELEV FEET	THALWEG EL FEET	Q CFS	SEDIMENT LOAD (TONS/DAY) SAND
58.000	-3.22	978.82	972.18	1400.	493.
55.000	-1.77	977.99	971.13	1400.	1051.
53.000	.00	976.37	972.20	2050.	0.
44.000	2.61	974.24	970.27	2050.	1879.
42.100	2.46	974.07	972.26	2200.	1053.
35.000	.00	974.00	963.30	2200.	0.
33.300	1.22	965.46	962.22	2200.	928.
33.200	1.22	965.39	962.22	2200.	813.
32.000	.27	965.39	956.77	2200.	300.
15.000	.18	965.03	954.18	2500.	16.
1.000	.00	965.00	944.70	2500.	16.

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 4. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN

SEC NO. 42.100
ELEVATION OF DREDGED CHANNEL INCLUDING 1.00 FEET OF OVER DREDGING= 969.80

SEC NO. 44.000
ELEVATION OF DREDGED CHANNEL INCLUDING 1.00 FEET OF OVER DREDGING= 968.00
TONS OF SEDIMENT DREDGED FROM THIS REACH= 5040.0 ACCUMULATED FROM DOWNSTREAM END= 5040.
CUBIC YARDS= 4014.3 4014.

* B FLOW 3 = NEAR BANK FULL DISCHARGE

BOUNDARY CONDITION DATA, CONTROL POINT NO. 1
TIME STEP NO. 3
WATER DISCHARGE= 1250.00
ELEVATION= 960.000
TEMPERATURE= 65.000
FLOW DURATION(DAYS) 1.000

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 4. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
53.00	58.000	13.18		
	53.000	16.13		
TOTAL=	53.000	29.32	37.91	-.29

TIME	ENTRY	SAND		
53.00	53.000	37.91		
	42.100	.36		
TOTAL=	35.000	38.27	13.86	.64

TIME	ENTRY	SAND		
53.00	35.000	13.86		
	15.000	1.00		
TOTAL=	1.000	14.86	.72	.95

TABLE SB-1. TOTAL AND LOAD BY GRAIN SIZEIN TONS/DAY

	TOTAL	VF	F	M	C	VC
SEDIMENT INFLOW						
SANDS & GRAVELS	149.81	66.90	53.32	29.58	.01	.00
		.00	.00	.00	.00	.00
SEDIMENT OUTFLOW						
SANDS & GRAVELS	204.33	67.74	26.17	51.88	42.76	15.33

.29	.18	.00	.00	.00

SECTION ID NO	BED CHANGE FEET	WS ELEV FEET	THALWEG EL FEET	Q CFS	SEDIMENT LOAD (TONS/DAY) SAND
58.000	-3.26	976.98	972.14	682.	260.
55.000	-1.76	376.37	971.14	682.	209.
53.000	.00	374.83	972.20	1022.	0.
44.000	-3.26	974.05	967.01	1022.	32.
42.100	.00	374.02	972.26	1100.	2.
35.000	.00	974.00	963.30	1100.	0.
33.300	.00	963.74	961.00	1100.	1230.
33.200	.00	963.26	961.00	1100.	4358.
32.000	-.38	962.21	956.12	1100.	21668.
15.000	.56	959.99	354.56	1250.	204.
1.000	.00	960.00	944.70	1250.	204.

. . . .

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 4. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN

....

SSED

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INFLOWING SEDIMENT LOAD TABLE MODIFIED BY:
LP          10.000       .000       .000       .000       .000       .000       .000       .000       .000

SEDIMENT LOAD TABLE FOR STREAM SEGMENT #   1
LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQ       * 1.00000     * 50.0000     * 1000.00     * 5800.00     * 90000.0     *
LF   VFS* .130900E-02* .178500     * 159.360     * 2299.50     * 232800.     *
LF    FS* .360800E-02* .492000     * 105.920     * 1377.00     * 112000.     *
LF    MS* .608300E-02* .829500     * 49.9200     * 693.000     * 44000.0     *
LF    CS* .379500E-02* .517500     * 3.52000     * 72.0000     * 8000.00     *
LF   VCS* .275000E-03* .375000E-01* 1.28000     * 36.0000     * 2000.00     *
LF   VFG* .550000E-04* .750000E-02* .100000E-19* 18.0000     * 800.000     *
LF    FG* .100000E-19* .100000E-19* .100000E-19* 4.50000     * 400.000     *
LF    MG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
LF    CG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
LF   VCG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
          ------------ ------------ ------------ ------------ ------------
   SUM=*  .151250E-01* 2.06250     * 320.000     * 4500.00     * 400000.     *
LP          12.000       .000       .000       .000       .000       .000       .000       .000       .000

SEDIMENT LOAD TABLE FOR STREAM SEGMENT #   1
                AT LOCAL INFLOW POINT #    2

LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQL      * 1.00000     * 100.000     * 1000.00     * 10000.0     *
LFL  VFS* .265600E-02* 6.64000     * 7.50000     * 5940.00     *
LFL   FS* .828000E-03* 2.07000     * 122.500     * 5430.00     *
LFL   MS* .344000E-03* .860000     * 302.500     * 3210.00     *
LFL   CS* .124000E-03* .310000     * 26.0000     * 2940.00     *
LFL  VCS* .320000E-04* .800000E-01* 19.5000     * 3810.00     *
LFL  VFG* .120000E-04* .300000E-01* 10.0000     * 3480.00     *
LFL   FG* .400000E-05* .100000E-01* 5.50000     * 2730.00     *
LFL   MG* .100000E-19* .100000E-19* 5.50000     * 1590.00     *
LFL   CG* .100000E-19* .100000E-19* .100000E-19* 660.000     *
LFL  VCG* .100000E-19* .100000E-19* .100000E-19* 180.000     *
          ------------ ------------ ------------ ------------
   SUM=*  .400000E-02* 10.0000     * 499.000     * 29970.0     *
```

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SRATING

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DOWNSTREAM BOUNDARY CONDITION SPECIFIED BY A RATING CURVE

ELEVATION OF GAGE ZERO                                          .00
DISCHARGE CORRESPONDING TO LOWEST ELEVATION IN TABLE            .0
DISCHARGE INTERVAL                                           2000.0
NO. OF POINTS IN RATING TABLE                                    40
ELEVATIONS
    950.00   955.10   958.00   960.00   962.00   963.60   965.10   966.20   967.00   967.70
    968.30   968.90   969.40   969.80   970.20   970.60   971.00   971.40   971.80   972.10
    972.40   972.70   972.90   973.10   973.30   973.50   973.70   973.80   973.90   974.00
    974.10   974.20   974.30   974.40   974.50   974.60   974.70   974.80   974.90   975.00

.............................................................................................

SPRT


PRINT AT SELECTIVE X-SECTIONS ONLY
PN          1.000      7.000      .000      .000      .000      .000      .000      .000      .000
END          .000       .000      .000      .000      .000      .000      .000      .000      .000

.............................................................................................

SNODREDG


=============================================================================================

*   AC     FLOW 4 = BASE FLOW OF 500 CFS

BOUNDARY CONDITION DATA, CONTROL POINT NO.  1

SEGMENT    INFLOW Q IN CFS...
   1     500.0     61.0     29.0     128.0
  TIME STEP NO.      4
WATER    DISCHARGE=      500.00
         ELEVATION=     965.000
       TEMPERATURE=      55.000
FLOW DURATION(DAYS)  1.000

****  N  DISCHARGE   WATER    ENERGY  VELOCITY   ALPHA     TOP      AVG       AVG VEL (by subsection)
           (CFS)    SURFACE    LINE     HEAD              WIDTH     BED      1      2      3

SEC NO.      1.000
****  1      500.0   965.00   965.00       .00      4.47   1330.15   951.52    .02    .17    .01
                                             FLOW DISTRIBUTION (%) =       .8   90.0    9.3

SEC NO.     -2.100
****  1      439.0   974.00   974.01       .00      1.00    242.95   970.70    .00    .55    .00
                                             FLOW DISTRIBUTION (%) =       .0  100.0     .0

EXAMPLE PROBLEM NO 4.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
FLOW # (N) =     1
FLOW...Q(N)=      282.0
TIMESTEP DURATION (DAYS) =     1.0000
ACCUMULATED TIME  (YRS)  =      .1479
WATER TEMPERATURE (DEG F)=   62.0638
***************************** FALL VELOCITY BY METHOD 2*****************************

                      DIAMETER      VELOCITY       REY. NO.          CD

                       .000288   .1341174E-01   .4491205        60.13548
                       .000580   .5773942E-01   2.836456        12.31433
                       .001160   .1329477       13.06215        4.645407
                       .002319   .2304031       55.07559        2.087675
                       .004639   .4807879       188.9094        1.420513
                       .009279   .7191504       565.1926        1.269958
                       .018560   1.039763       1634.511        1.215170
                       .037120   1.472924       4630.883        1.211086
                       .074216   2.082692       13091.77        1.211086
                       .148596   2.946998       37090.49        1.211086

SEDIMENT INFLOW (TONS/DAY)
```

```
                         TOTAL         AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY
 SANDS & GRAVELS        30.66        9.03        10.94        8.84        1.57        .29
                                      .00         .00          .00         .00        .00

THE FOLLOWING IS A LOCAL INFLOW
      L O C A L  INFLOW  POINT     : NO.  :     Q(CFS)      :TEMP(DEG-F):
                                   :   2  :                 :           :
             LOCAL      INFLOW     :   3  : 29.0000000      :      70.00:
             MAINSTEM  INFLOW      :   1  : 410.000000      :      63.60:
             TOTAL     OUTFLOW     :   1  : 439.000000      :      64.03:

***************************** FALL VELOCITY BY METHOD 2****************************

                        DIAMETER      VELOCITY       REY. NO.          CD

                        .000288  .1885611E-01  .4727185      57.33453
                        .000580  .5869588E-01  2.963424      11.91627
                        .001160  .1346745      13.59883      4.527048
                        .002319  .2822873      56.98364      2.059898
                        .004639  .4819037      194.6000      1.413942
                        .009279  .7197666      581.3678      1.267785
                        .018560  1.040157      1680.487      1.214248
                        .037120  1.472924      4759.336      1.211086
                        .074216  2.082692      13454.91      1.211086
                        .148596  2.946998      38119.32      1.211086

SEDIMENT INFLOW FROM LOCAL INFLOW POINT
                         TOTAL         AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY
 SANDS & GRAVELS        1.22         .81          .25          .10         .04         .01
                                     .00          .00          .00         .00         .00


*************************************************************************************************************
         THE FOLLOWING TABLE IS PRINTOUT FOR CROSS SECTION     42.100
         -------------------------------------------------------------


HYDRAULIC PARAMETERS:
         VEL            SLO            EFD            EFW            N-VALUE          TAU           USTARM          FROUDE
NO.
         .420           .000003        5.956          195.948        .0153            .00097        .02233
.030
BED SEDIMENT RESERVOIR COMPUTATIONS:
NEW SURFACE AREA (SQ FT):     TOTAL         K-PORTION       S-PORTION
                          324607.08       324607.08            .00
GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS
BED MATERIAL BY GRAIN SIZE FRACTION     .104572     .208994     .369921     .233720     .053457
                                        .017827     .009123     .000139     .002245     .000001
BED MATERIAL BY PERCENT FINER/100       .104572     .313567     .683488     .917207     .970665
                                        .988492     .997615     .997754     .999999     1.000000

SAND
** ARMOR LAYER **
STABILITY COEFFICIENT=      .94788
MIN.GRAIN DIAM       =     .001184
BED SURFACE EXPOSED  =     1.00000

         INACTIVE LAYER            ACTIVE LAYER
         Z         DEPTH         Z          DEPTH
 CLAY   .000000     .00       .000000        .00
 SILT   .000000     .00       .000000        .00
 SAND   .000000     .00      1.000000       2.46
TOTAL   .000000     .00      1.000000       2.46

      AVG. UNIT              AVG. UNIT
       WEIGHT                 WEIGHT

      .000000               .046500

**BED IS ARMORED**

    COMPOSITE UNIT WT OF ACTIVE LAYER T/CF=        .046500
    WEIGHT IN SURFACE LAYER(TONS),    WTSL=            .0
```

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     DEPTH OF NEW ACTIVE LAYER(FT),      DSE=           .0000
     WEIGHT IN NEW ACTIVE LAYER,       WTMXAL=            .0
     WEIGHT IN OLD ACTIVE LAYER,          WAL=        37098.2
     USEABLE WEIGHT, OLD INACTIVE LAY,    WIL=            .0
BED MATERIAL BY GRAIN SIZE FRACTION      .084731      .101697      .101697      .101697      .101697
                                         .101697      .101697      .101697      .101697      .101697
BED MATERIAL BY PERCENT FINER/100        .084731      .186427      .288124      .389820      .491517
                                         .593214      .694910      .796607      .898303     1.000000
** ACTIVE LAYER **
BED MATERIAL BY GRAIN SIZE FRACTION      .104572      .208994      .369921      .233720      .053457
                                         .017827      .009123      .000139      .002245      .000001
BED MATERIAL BY PERCENT FINER/100        .104572      .313567      .683488      .917207      .970665
                                         .988492      .997615      .997754      .999999     1.000000

C FINES, COEF(CFFML), MX POTENTIAL= .000000E+00 .100000E+01 .948240E+06

POTENTIAL TRANSPORT BY SIZE CLASS=  .100000E-06 .100000E-06 .100000E-06 .100000E-06 .100000E-06
                                    .100000E-06 .100000E-06 .100000E-06 .100000E-06 .100000E-06
BED MATERIAL BY GRAIN SIZE FRACTION      .104591      .208994      .369912      .233713      .053456
                                         .017826      .009123      .000139      .002245      .000001
BED MATERIAL BY PERCENT FINER/100        .104591      .313585      .683497      .917210      .970666
                                         .988492      .997615      .997754      .999999     1.000000
                             TOTAL          AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY
CALCULATED SEDIMENT LOAD, TONS/DAY
 SANDS & GRAVELS            .00         .00          .00          .00          .00          .00
                                        .00          .00          .00          .00          .00


*******************************************************************************************************
         THE FOLLOWING TABLE IS PRINTOUT FOR CROSS SECTION       1.000
         -------------------------------------------------------------


HYDRAULIC PARAMETERS:
          VEL             SLO             EFD             EFW           N-VALUE           TAU          USTARM          FROUDE
NO.
          .302         .000000          11.243         167.384            .0182          .00010          .00705
.016
BED SEDIMENT RESERVOIR COMPUTATIONS:
NEW SURFACE AREA (SQ FT):      TOTAL         K-PORTION       S-PORTION
                           954954.00         954954.00             .00

TRANSMISSIVE BOUNDARY CONDITION = TYPE      2
BED MATERIAL BY GRAIN SIZE FRACTION      .010000      .070000      .290000      .360000      .120000
                                         .060000      .040000      .015000      .035000      .000000
BED MATERIAL BY PERCENT FINER/100        .010000      .080000      .370000      .730000      .850000
                                         .910000      .950000      .965000     1.000000     1.000000
                             TOTAL          AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY
CALCULATED SEDIMENT LOAD, TONS/DAY
 SANDS & GRAVELS            .00         .00          .00          .00          .00          .00
                                        .00          .00          .00          .00          .00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  1
          EXAMPLE PROBLEM NO 4.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
          ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*****************************************************************
                       *                                *
    TIME        ENTRY  *              SAND              *
    DAYS        POINT  *    INFLOW    OUTFLOW  TRAP EFF *
                       *                                *
   54.00       58.000  *     13.20                      *
               53.000  *     16.15                      *
   TOTAL=      53.000  *     29.35     37.95      -.29  *
                       *                                *
*****************************************************************
    TIME        ENTRY  *              SAND              *
   54.00       53.000  *     37.95                      *
               42.100  *       .36                      *
   TOTAL=      35.000  *     38.31     13.86       .64  *
                       *                                *
*****************************************************************
    TIME        ENTRY  *              SAND              *
   54.00       35.000  *     13.86                      *
```

```
              15.000 *       1.00                        *
     TOTAL=    1.000 *      14.87         .72         .95 *
                     *                                    *
***********************************************************************
```

TABLE SB-1.	TOTAL	AND LOAD BY GRAIN SIZEIN TONS/DAY				
		VF	F	M	C	VC
SEDIMENT INFLOW						
SANDS & GRAVELS	30.66	9.03	10.94	8.84	1.57	.29
		.00	.00	.00	.00	.00
SEDIMENT OUTFLOW						
SANDS & GRAVELS	.00	.00	.00	.00	.00	00
		.00	.00	.00	.00	00

SECTION ID NO	BED CHANGE FEET	WS ELEV FEET	THALWEG EL FEET	Q CFS	SEDIMENT LOAD (TONS/DAY) SAND
58.000	-3.26	975.48	972.14	282.	20.
55.000	-1.77	974.96	971.13	282.	42.
53.000	.00	973.88	972.20	410.	0.
44.000	-3.22	974.01	964.78	410.	0.
42.100	.00	974.00	969.80	439.	0.
35.000	.00	974.00	963.30	439.	0.
33.300	.00	965.04	961.00	439.	0.
33.200	.00	965.04	961.00	439.	0.
32.000	-.38	965.04	956.12	439.	0.
15.000	.56	965.00	954.56	500.	0.
1.000	.00	965.00	944.70	500.	0.

ACCUMULATED WATER DISCHARGE FROM DAY ZERO(SFD)

MAIN	TRIB #1	TRIB #2	TRIB #3	....ETC
2750.0000				

....

SVOL A

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 4. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN

SUMMARY TABLE: MASS AND VOLUME OF SEDIMENT

SECTION	SEDIMENT PASSING SECTION IN TONS TOTAL	SAND	SILT	CLAY	SEDIMENT DEPOSITED IN REACH IN CUBIC YARDS TOTAL	ACCUMULATED	SAND	SILT	CLAY
INFLOW	26737.	26737.	0.	0.	21296.				
58.000	35457.	35457.	0.	0.	-6945.	-6945.	-6945.	0.	0.
55.000	44155.	44155.	0.	0.	-6928.	-13873.	-6928.	0.	0.
LOCAL	32721.	32721.	0.	0.	26062.				
53.000	76876.	76876.	0.	0.	0.	-13873.	0.	0.	0.
44.000	64482.	64482.	0.	0.	9871.	-4002.	9871.	0.	0.
LOCAL	733.	733.	0.	0.	583.				
42.100	28083.	28083.	0.	0.	29575.	25573.	29575.	0.	0.
35.000	28083.	28083.	0.	0.	0.	25573.	0.	0.	0.
33.300	28083.	28083.	0.	0.	0.	25574.	0.	0.	0.
33.200	28081.	28081.	0.	0.	1.	25575.	1.	0.	0.
32.000	32938.	32938.	0.	0.	-3868.	21707.	-3868.	0.	0.
LOCAL	2027.	2027.	0.	0.	1615.				
15.000	1464.	1464.	0.	0.	26684.	48391.	26684.	0.	0.
1.000	1464.	1464.	0.	0.	0.	48391.	0.	0.	0.

ACCUMULATED LOAD BY SIZE CLASS (fine to coarse, in TONS

INFLOW

SAND	13375.	8739.	4186.	315.	122.

```
                            0.        0.        0.        0.        0.
RIVER MILE =       58.000
                     SAND    13404.     8933.     4334.     5002.     2195.
                              1008.      364.        0.      217.        0.
RIVER MILE =       55.000
                     SAND    13337.     9190.     5091.     9958.     4272.
                              1351.      608.       10.      337.        0.
RIVER MILE =       53.000
                     SAND    16102.    15314.    22849.    16033.     4272.
                              1351.      608.       10.      337.        0.
RIVER MILE =       44.000
                     SAND    15348.    13536.    19465.    12040.     2992.
                               671.      342.        5.       83.        0.
RIVER MILE =       42.100
                     SAND    11798.     5993.     5857.     3399.     1017.
                                14.        5.        0.        0.        0.
RIVER MILE =       35.000
                     SAND    11798.     5993.     5857.     3399.     1017.
                                14.        5.        0.        0.        0.
RIVER MILE =       33.300
                     SAND    11798.     5993.     5857.     3399.     1017.
                                14.        5.        0.        0.        0.
RIVER MILE =       33.200
                     SAND    11798.     5993.     5857.     3399.     1017.
                                13.        4.        0.        0.        0.
RIVER MILE =       32.000
                     SAND     9833.     5774.     8892.     6491.     1917.
                                16.       14.        2.        0.        0.
RIVER MILE =       15.000
                     SAND      158.      176.      503.      455.      163.
                                 4.        3.        1.        0.        0.
RIVER MILE =        1.000
                     SAND      158.      176.      503.      455.      163.
                                 4.        3.        1.        0.        0.

..................................................................................................................

SSEND

     0   DATA ERRORS DETECTED.

TOTAL NO. OF TIMESTEPS READ=          4
TOTAL NO. OF WS PROFILES=          23
ITERATIONS IN EXNER EQ  =         920.
END OF JOB

JOB COMPLETED
RUN TIME =  0 HOURS,  0 MINUTES & 57.23 SECONDS
```

A portion of the "B-level" hydraulic output for Example Problem 2 for the second discharge at section 15.0 is shown in Exhibit 6.5. This output may be used to check the operation of the n vs. elevation function. In the section "REACH PROPERTIES BY STRIP", the n values used for the left overbank, channel, and right overbank are 0.0874, 0.0478, and 0.1021 respectively. These are interpolated from the input **NV** data at a water surface elevation of 969.015 ft. The **GR** data shown for section 15.0 reflect the **X3** encroachment. Elevations on the left side are kept above 961 ft. to station 10693 ft., which is the station before 10700 ft. The same is seen on the right side as elevations are kept at 970 ft. after station 11000 ft. until the original ground line is encountered.

EXHIBIT 6.5 B-Level Hydrualic Output

```
**********************************************************************************************
*            INPUT FILE: EX2B.DAT                                                            *
*            OUTPUT FILE: EX2B.OUT                                                           *
**********************************************************************************************

==================================================================================================

*   B   PROFILE 2 = FLOOD EVENT

BOUNDARY CONDITION DATA, CONTROL POINT NO.  1

SEGMENT     INFLOW Q IN CFS...
    1   10000.0     600.0     1200.0     2600.0
  TIME STEP NO.        2
WATER      DISCHARGE=    10000.00
           ELEVATION=     963.000
         TEMPERATURE=      60.000
FLOW DURATION(DAYS)   1.000

****  N  DISCHARGE   WATER    ENERGY  VELOCITY   ALPHA     TOP     AVG       AVG VEL (by subsection)
           (CFS)    SURFACE    LINE     HEAD              WIDTH    BED      1      2      3

SEC NO.      1.000
 X-SECTION COORDINATES (STA,ELEV)
         9915.000  1004.000  9915.000  1004.000 10002.000   978.400 10060.000   956.000 10077.000   959.200
        10081.000   959.300 10092.000   950.000 10108.000   948.480 10138.000   946.600 10158.000   944.700
        10225.000   955.200 10243.000   956.200 10250.000   958.900 10275.000   959.800 10300.000   959.800
        10325.000   959.900 10350.000   958.800 10400.000   957.400 10700.000   970.000 10960.000   966.000
        11060.000   970.000 11085.000   968.000 11240.000   968.000 11365.000   970.000 11500.000   970.000
        11615.000   970.000 11665.000   962.000 12400.000   962.000 12550.000   976.000 12670.000   980.000
        12730.000   982.000 12735.000   984.000

****  1    10000.0     963.00     963.23       .23      2.43   1243.42     951.52    .84  4.03   .44
                                              FLOW DISTRIBUTION (%) =    1.3   91.6   7.1

        REACH PROPERTIES BY STRIP               1           2           3
                     INEFF FLOW  EL     -99999.00   -99999.00   -99999.00
   U/S SECTION...     CONVEYANCE            6030.     422630.      32696.
                            AREA             155.       2273.       1612.
                      HYD RADIUS             4.23       11.20        1.59
   REACH...                    N            .1000       .0400       .1000
                         SQRT(L)            .0000       .0000       .0000
   D/S SECTION...           AREA               0.          0.          0.
                      HYD RADIUS              .00         .00         .00

   N-VALUE,SLOPE,EFW,EFD,VAG=    .040000     .000470     164.21      13.84      4.03

SEC NO.     15.000
 X-SECTION COORDINATES (STA,ELEV)
         9570.000   992.000  9570.000   992.000 10110.000   982.000 10300.000   976.000 10490.000   976.000
        10610.000   966.000 10665.000   964.700 10673.000   961.000 10693.000   961.000 10703.000   954.000
        10723.000   955.600 10750.000   958.600 10800.000   959.300 10822.000   957.000 10825.000   957.300
        10850.000   961.500 10852.000   962.000 10970.000   964.000 11015.000   970.000 11090.000   970.000
        11150.000   970.000 11190.000   970.000 11310.000   972.000 11410.000   980.000 11570.000   984.000
        11770.000   990.000 11865.000   990.000 12150.000  1000.000

****  .    10000.0     969.01     969.28       .27      1.58    434.03     958.47   1.02  4.44  1.31
                                              FLOW DISTRIBUTION (%) =    2.6   86.6  10.8

        REACH PROPERTIES BY STRIP               1           2           3
                     INEFF FLOW  EL     -99999.00   -99999.00   -99999.00
   U/S SECTION...     CONVEYANCE            8715.     287841.      35800.
                            AREA             257.       1951.        821.
                      HYD RADIUS             2.81       10.34        5.19
   REACH...                    N            .0874       .0478       .1021
                         SQRT(L)          92.5473     90.9285     86.8044
   D/S SECTION...           AREA             155.       2273.       1612.
                      HYD RADIUS             4.23       11.20        1.59

   N-VALUE,SLOPE,EFW,EFD,VAG=    .047807     .000732     175.88      11.09      4.44
```

```
....LOCAL INFLOW POINT NO.  1,  Q=     600.00

   CONTINUING ON SEGMENT NO    1
       TEMPERATURE=      60.000

...........................................................................................................

$$END


       0   DATA ERRORS DETECTED.

TOTAL NO. OF TIMESTEPS READ=           2
TOTAL NO. OF WS PROFILES=          2
ITERATIONS IN EXNER EQ  =         0.
END OF JOB

JOB COMPLETED
RUN TIME =  0 HOURS,   0 MINUTES &   6.26 SECONDS
```

6.3 Problem 3 - Movable Bed

The following example demonstrates how to add sediment data to the previously developed file. Existence of sediment data within the input file causes HEC-6 to compute sediment transport rates and modify the cross section geometry as described in section 2.3. Sediment related data consists of the delineation of the movable bed, characteristics and gradation of sediment within the bed, and inflowing/outflowing sediment loads and gradations. The sediment data is inserted between the EJ record of the geometry data and the $HYD record of the flow data. Exhibit 6.6 illustrates the input data file for Example Problem 3.

EXHIBIT 6.6 Input - Movable Bed

```
T1        EXAMPLE PROBLEM NO 3.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
T2        BASIC SEDIMENT RUN, 3 LOCAL INFLOWS: CASCADE, SILVER AND BEAR CREEKS
T3        ORIGINAL WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW
NC   .100     .100     .040       .1       .3
X1    1.0      31.  10077.0  10275.0       0.       0.       0.       0.       0.       0.
GR1004.0    9915.0   978.40  10002.0   956.00  10060.0   959.20  10077.0   959.30  10081.0
GR950.00   10092.0   948.48  10108.0   946.60  10138.0   944.70  10158.0   955.20  10225.0
GR956.20   10243.0   958.90  10250.0   959.80  10275.0   959.80  10300.0   959.90  10325.0
GR958.80   10350.0   957.40  10400.0   970.00  10700.0   966.00  10960.0   970.00  11060.0
GR968.00   11085.0   968.00  11240.0   970.00  11365.0   970.00  11500.0   970.00  11615.0
GR962.00   11665.0   962.00  12400.0   976.00  12550.0   980.00  12670.0   982.00  12730.0
GR984.00   12735.0
HD      1      10.    10081    10250
NV     22     .045    965.6     .064    988.8
NV     12     .080    965.6     .130    988.8
NV     33      .10    965.6      .11    982.0      .12    988.8
X1   15.0      27.  10665.0  10850.0    8565.    7535.    8268.       0.       0.       0.
X3                             10700      961    11000      970
GR992.00    9570.0   982.00  10110.0   976.00  10300.0   976.00  10490.0   966.00  10610.0
GR964.70   10665.0   956.00  10673.0   953.00  10693.0   954.00  10703.0   955.60  10723.0
GR958.60   10750.0   959.30  10800.0   957.00  10822.0   957.30  10825.0   961.50  10850.0
GR962.00   10852.0   964.00  10970.0   966.00  11015.0   961.00  11090.0   962.00  11150.0
GR970.00   11190.0   972.00  11310.0   980.00  11410.0   984.00  11570.0   990.00  11770.0
GR990.00   11865.0  1000.00  12150.0
HD     15      10.    10673    10852
QT
NC    .10      .10      .05
X1   32.0      29.  10057.0  10271.0    7429.    6654.    8240.       0.       0.       0.
GR998.00    9080.0   982.00   9250.0   982.00   9510.0   980.00   9600.0   980.01   9925.0
GR979.48   10000.0   978.50  10057.0   968.60  10075.0   959.82  10087.0   956.50  10097.0
GR956.80   10117.0   957.80  10137.0   959.40  10157.0   959.60  10177.0   959.82  10196.0
GR966.50   10225.0   971.20  10250.0   978.50  10271.0   978.50  10300.0   978.60  10350.0
GR978.91   10370.0   978.96  10387.0   980.00  10610.0   982.00  10745.0   982.00  11145.0
GR984.00   11150.0   992.00  11240.0  1000.00  11330.0   1008.0  11425.0
HD     32      10.    10075    10275
```

```
X1  33.2      21.  1850.0  2150.0    130.    250.    320.      0.      0.      0.
XL           250
GR1000.0   980.0  990.00  1060.0  980.00  1150.0  982.00  1180.0  982.00  1215.0
GR980.00  1260.0  982.00  1300.0  982.00  1350.0  980.00  1420.0  980.00  1540.0
GR982.00  1730.0  982.00  1830.0  984.41  1850.0  979.19  1851.0  961.00  1900.8
GR961.00  2099.2  976.00  2149.0  984.50  2150.0  982.00  2800.0  990.00  3100.0
GR1000.0  3170.0    0.00     0.0    0.00     0.0    0.00     0.0    0.00     0.0
HD  33.2       0    1851    2149
X1  33.3       0  1850.0  2150.0    155.    175.    175.      0.      0.      0.
HD  33.3       0    1851    2149
X1  35.0     22.  9894.0 10155.0    105.    105.    105.      0.      0.      0.
X3    10
X5          974.      .5
GR984.00  9035.0  980.00  9070.0  978.00  9135.0  980.00  9185.0  982.00  9270.0
GR980.00  9465.0  981.70  9595.0  983.70  9745.0  984.70  9894.0  963.40  9894.0
GR963.30  9954.0  967.10  9974.0  967.40 10004.0  968.20 10044.0  967.60 10054.0
GR973.40 10115.0  977.40 10120.0  983.70 10155.0  984.00 10245.0  982.00 10695.0
GR982.00 10895.0 1004.00 11085.0
HD    35       0    9954   10155
NC   .06     .06    .045
X1  42.1     32.  9880.0 10130.0   2070.   3965.   3005.      0.      0.      0.
GR996.00  7130.0  998.00  7310.0  998.00  7930.0  992.00  8205.0  990.00  8495.0
GR988.00  8780.0  986.00  8990.0  985.70  9570.0  986.45  9707.0  989.44  9857.0
GR990.00  9880.0  969.80  9881.0  969.80  9941.0  985.80  9941.0  985.80  9943.0
GR969.80  9943.0  969.80 10001.0  986.70 10001.0  986.70 10003.0  969.80 10003.0
GR969.80 10067.0  985.80 10067.0  985.80 10069.0  969.80 10069.0  969.80 10129.0
GR989.90 10130.0  989.50 10180.0  988.60 10230.0  987.60 10280.0  985.20 10430.0
GR986.80 11720.0  989.90 12310.0
HD 42.10       0    9881   10021
QT
X1  44.0     28.  9845.0 10127.0    290.    795.    495.      0.      0.      0.
XL                          9850   10200
GR1002.0  8035.0  992.00  8150.0  990.00  8305.0  990.00  8735.0  988.00  8835.0
GR996.00  9285.0  1017.6  9425.0  990.00  9505.0  986.00  9650.0  984.10  9788.0
GR980.60  9845.0  970.90  9868.0  972.20  9898.0  970.50  9968.0  967.50  9998.0
GR968.90 10028.0  967.40 10058.0  967.10 10078.0  971.90 10118.0  976.80 10127.0
GR977.80 10150.0  976.90 10193.0  982.00 10206.0  981.20 10300.0  979.20 10325.0
GR983.10 10400.0  999.80 10450.0 1002.40 10464.0
HD    44     10.    9868   10193
X1  53.0     22. 10000.0 10136.0   3366.   2831.   2941.      0.      0.      0.
GR1004.0  7550.0 1000.00  7760.0  998.00  8440.0  996.00  8640.0  996.00  8780.0
GR994.00  8940.0  986.00  9245.0  986.30  9555.0  986.30  9825.0  983.80  9900.0
GR982.80 10000.0  978.20 10011.0  974.00 10041.0  972.20 10071.0  972.60 10101.0
GR978.20 10121.0  988.70 10136.0  989.30 10154.0  999.20 10200.0  1000.1 10320.0
GR1002.0 10470.0 1004.00 10700.0
HD    53     10.   10000   10136
QT
X1  55.0     18.  9931.0 10062.0    275.   1430.    770.      0.      0.      0.
GR1004.0  7592.0 1000.00  7947.0  996.00  8627.0  990.00  9052.0  986.00  9337.0
GR984.30  9737.0  984.70  9837.0  985.50  9910.0  987.20  9931.0  978.10  9955.0
GR974.80  9975.0  974.20 10005.0  972.90 10035.0  973.20 10045.0  983.80 10062.0
GR985.80 10187.0  986.00 10307.0  990.00 10497.0
HD    55     10.    9931   10062
X1  58.0     22.  9912.0 10015.0   1097.   1012.   1462.      0.      0.      0.
GR1006.0  8542.0 1004.00  8952.0 1000.00  9702.0  997.20  9812.0  996.30  9912.0
GR976.20  9944.0  975.40  9974.0  978.20  9991.0  990.40 10015.0  988.30 10062.0
GR988.80 10065.0  988.30 10065.0  989.30 10169.0  990.00 10172.0  992.00 10242.0
GR992.00 10492.0  988.00 10642.0  986.70 10852.0  988.00 11022.0  986.00 11097.0
GR986.00 11137.0  988.00 11192.0
HD    58     3.4    9912   10015
EJ
T4        MAIN STEM. SEGMENT 1. SOUTH FORK ZUMBRO RIVER. ROCHESTER. MN
T5        LOAD CURVE FROM USGS DATA AT USGS GAGE: 5 PERCENT ADDED FOR BED LOAD
T6        BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T7        ENCODED BY DAVID WILLIAMS. WES. SEPT 1982
T8        SEDIMENT TRANSPORT BY STREAM POWER: SEE ASCE JOURNAL (YANG 1971)
I1      0       5
I4   SAND       4       1      10
I5             .5      .5     .25      .5     .25       0     1.0
LQ              1      50    1000    5800   90000
LT TOTAL    .0110     1.5     320   4500.  400000
LF    VFS    .119    .119    .498    .511    .582
LF     FS    .328     328    .331    .306    .280
```

```
LF     MS    .553     .553     .156     .154     .110
LF     CS    .000     .000     .011     .016     .020
LF    VCS    .000     .000     .004     .008     .005
LF    VFG    .000     .000     .000     .004     .002
LF     FG    .000     .000     .000     .001     .001
LF     MG    .000     .000     .000     .000     .000
LF     CG    .000     .000     .000     .000     .000
LF    VCG      .0       .0     .000     .000     .000
PF EXAMP      1.0      1.0     32.0     16.0     96.5      8.0     95.0      4.0     91.0
PFC  2.0     85.0      1.0     73.0       .5     37.0      .25      8.0     .125      1.0
PFC.0625      0.0
PF EXAMP     32.0      1.0     64.0     32.0     99.5     16.0     99.0      8.0     98.5
PFC  4.0     96.0      2.0     93.5      1.0     83.0      .50     45.5     .250      8.0
PFC .125      1.0    .0625      0.0
PF EXAMP     58.0      1.0     64.0     32.0     97.0     16.0     94.0      8.0     94.0
PFC  4.0     90.0      2.0     79.0      1.0     56.0      .50      4.0     .125      0.0
SLOCAL
LQL             1      100     1000    10000
LTLTOTAL    .0040       10      500    30000
LFL  VFS     .664     .664     .015     .198
LFL   FS     .207     .207     .245     .181
LFL   MS     .086     .086     .605     .107
LFL   CS     .031     .031     .052     .098
LFL  VCS     .008     .008     .039     .127
LFL  VFG    .0030    .0030    .0200    .1160
LFL   FG    .0010    .0010    .0110    .0910
LFL   MG    .0000    .0000    .0110    .0530
LFL   CG    .0000    .0000    .0000    .0220
LFL  VCG    .0000    .0000    .0000    .0060
LQL             1      100     1000    10000
LTLTOTAL    .0040       10      500    30000
LFL  VFS     .664     .664     .015     .198
LFL   FS     .207     .207     .245     .181
LFL   MS     .086     .086     .605     .107
LFL   CS     .031     .031     .052     .098
LFL  VCS     .008     .008     .039     .127
LFL  VFG    .0030    .0030    .0200    .1160
LFL   FG    .0010    .0010    .0110    .0910
LFL   MG    .0000    .0000    .0110    .0530
LFL   CG    .0000    .0000    .0000    .0220
LFL  VCG    .0000    .0000    .0000    .0060
LQL            1.     100.     500.    1000.   30000.
LTLTOTAL    .0020     30.0     500.     1200    22500
LFL  VFS     .201     .201     .078     .078     .137
LFL   FS     .342     .342     .172     .175     .218
LFL   MS     .451     .451     .454     .601     .476
LFL   CS     .001     .001     .197     .142     .158
LFL  VCS     .000     .000     .000     .003     .008
LFL  VFG    .0000    .0000    .0000    .0000    .0020
LFL   FG    .0000     .000    .0000    .0000    .0010
LFL   MG    .0000     .000    .0000    .0000    .0000
LFL   CG    .0000     .000    .0000    .0000    .0000
LFL  VCG    .0000     .000    .0000    .0000    .0000
SHYD
*   AB      FLOW 1 = BASE FLOW OF 500 CFS
Q    500      61       29      128
R   956.
T     65      72       70       67
W      2
*    B      FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE
Q 2500.0    300.     150.     650.
R   965.
W     50
*    B      FLOW 3 = NEAR BANK FULL DISCHARGE
Q  1250.    150.      78.     340.
R   960.
W     1.
*    C      FLOW 4 = BASE FLOW OF 500 CFS
Q   500.      61       29      128
R   965.
W     1.
SSEND
```

6.3.1 Movable Bed Limits

The **HD** records contain information regarding the movable bed for each cross section. For example, at section 1.0, only that portion of the cross section between stations 10081 and 10250 ft. is the 'movable bed'. The 'fixed' **GR** points are those on either side of the movable bed stations; that is, should a limit of the movable bed coincide with a **GR** point, that point is movable and the next point outward is fixed.

The vertical limits of the movable portion of the cross section must also be defined. In Example Problem 3, it was determined that the reach represented by cross section 58.0 had bedrock 3.4 ft. below the thalweg. Data describing the location of this bedrock is entered in field 2 of the **HD** record for that cross section. Cross sections 33.2, 33.3, 35.0 and 42.1 have either concrete or bedrock at the thalweg.

6.3.2 Sediment Title Records

Five records are required at the beginning of the sediment data; these records are available for user documentation of the sediment data.

6.3.3 Sediment Transport Control Parameters

Parameters governing the computation of sediment transport rates and selection of grain sizes are entered on the **I** records. For problem 3, the number of times that the bed material gradation is to be re-calculated within a time step is set to five (see section 2.3.4.1) on the **I1** record. Default values for the other parameters on this record will be used. Only sands and gravels are analyzed in problem 3. Since there are no clays or silts in either the bed or the inflowing load, there are no **I2** or **I3** records. All sand and gravel sizes are being analyzed (which is the default) as seen by the 1 in field 3 and 10 in field 4 of the **I4** record. The transport computation method chosen is that of Yang (4 in field 2 of the **I4** record). Default values for the other parameters were selected, by not providing data. It is important to remember that the range of grain sizes selected on the **I** records <u>must</u> encompass the entire range of sizes found in both the bed material and inflowing load, even though some of those sizes may be missing in either the bed or inflowing materials.

The 'most stable' weighting scheme for the hydraulic parameters has been selected via the **I5** record (see section 2.2.4).

6.3.4 Inflowing Sediment Loads

The inflowing sediment load at the upstream end of the main river is described with a table of sediment load vs. water discharge by grain size. This table is entered using the **LQ**, **LT**, and **LF** records. The **LQ** record contains the water discharges and the **LT** record contains the corresponding total inflowing sediment loads. The entire range of discharges in the hydrograph being simulated must be spanned by these data. For Example Problem 3, the range of water discharges in the load table is from 1 to 90,000 cfs and the related inflowing sediment loads vary from 0.011 to 400,000 tons/day. The distribution of grain sizes is described by the **LF** records which contain the <u>fraction</u> of the total load comprised of any particular grain size. These data are entered from fine to coarse and must correspond to the size ranges selected with the **I2** to **I4** data.

There are three local inflows of water and sediment in this problem; their locations are defined by the **QT** records in the geometric data. The tables of sediment load vs. local inflow are on **LQL**, **LTL**, and **LFL** records, analogous to the main river inflowing load data. The local flow load tables are entered in the same sequence as the geometric data; that is, downstream to upstream.

6.3.5 Bed Material Gradation

The initial gradation of material in the bed sediment reservoir is described with **PF** (percent finer) and **PFC** (percent finer continuation) records. In Example Problem 3, this data has only been provided at cross sections 1.0, 32.0, and 58.0 as noted in field 2 of the **PF** records. The selection of which, and how many, cross sections at which to provide this data depends on study objectives, field data, etc. For intermediate cross sections HEC-6 will linearly interpolate the bed material gradation. Note that the points in the gradation tables need not coincide with the size classes selected for computation. See Appendix A for the specific contents of these data records.

6.3.6 Flow Data

The flow data input structure is similar to that shown in the previous examples with the exception of the selection of a "B-level" output for sediment computations on the * record (see section 6.4.7). The values in the flow data, however, are extremely important to the results of a movable bed simulation. Particular care must be taken when selecting the period of record or hypothetical event to be simulated and time step sizes to be used. Water temperature may also be important in some instances. See Thomas, et al. (1981) and Gee (1984) for information regarding preparation of flow data.

EXHIBIT 6.7 Output - Movable Bed

```
*****************************************************************************************
*            INPUT FILE: EX3.DAT                                                        *
*            OUTPUT FILE: EX3.OUT                                                       *
*****************************************************************************************

==========================================================================================

T4       MAIN STEM, SEGMENT 1, SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
T5       LOAD CURVE FROM USGS DATA AT USGS GAGE: 5 PERCENT ADDED FOR BED LOAD
T6       BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T7       ENCODED BY DAVID WILLIAMS, WES, SEPT 1982
T8       SEDIMENT TRANSPORT BY STREAM POWER: SEE ASCE JOURNAL (YANG 1971)
EXAMPLE PROBLEM NO 3.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
BASIC SEDIMENT RUN, 3 LOCAL INFLOWS: CASCADE, SILVER AND BEAR CREEKS
ORIGINAL WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW


- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


SEDIMENT PARAMETER DATA
        SPI     IBG    MNQ       SPGF       ACGR      NFALL     IBSHER
I1       5.      0      1       1.000     32.174        2          1

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

 SAND AND/OR GRAVEL ARE PRESENT


        MTC     IASA     LASA      SPGS       GSF       BSAE        PSI      UWDLB
I4       4        1       10      2.650      .667       .500     30.000     93.000

FOLLOWING GRAIN SIZES UTILIZED
SAND:    .000288   .000580   .001160   .002319   .004639
         .009279   .018560   .037120   .074216   .148596

*****TRANSPORT CAPACITY RELATIONSHIP IS YANG*****                  *** MTC =  4

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED
          DBI       DBN       XID       XIN       XIU       UBI       UBN       JSL
I5       .500      .500      .250      .500      .250      .000     1.000        1
```

- -

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQ		* 1.00000	* 50.0000	* 1000.00	* 5800.00	* 90000.0 *
LF	VFS*	.130900E-02*	.178500	* 159.360	* 2299.50	* 232800. *
LF	FS*	.360800E-02*	.492000	* 105.920	* 1377.00	* 112000. *
LF	MS*	.608300E-02*	.829500	* 49.9200	* 693.000	* 44000.0 *
LF	CS*	.100000E-19*	.100000E-19*	3.52000	* 72.0000	* 8000.00 *
LF	VCS*	.100000E-19*	.100000E-19*	1.28000	* 36.0000	* 2000.00 *
LF	VFG*	.100000E-19*	.100000E-19*	.100000E-19*	18.0000	* 800.000 *
LF	FG*	.100000E-19*	.100000E-19*	.100000E-19*	4.50000	* 400.000 *
LF	MG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*
LF	CG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*
LF	VCG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*
	SUM=*	.110000E-01*	1.50000	* 320.000	* 4500.00	* 400000. *

VOLUME VS DEPTH OF DEPOSITS

SEC NO.	REACH LENGTH	MOVABLE BED WIDTH	INITIAL BED-ELEVATIONS LEFT SIDE	THALWEG	RIGHT SIDE	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM FEET	MILES
	.00						
1.000		163.50	959.30	944.70	958.90	.00	.00
	8268.00						
15.000		242.00	961.00	954.00	962.00	8268.00	1.57
	8240.00						
32.000		219.50	968.60	956.50	978.50	16508.00	3.13
	320.00						
33.200		299.00	979.19	961.00	976.00	16828.00	3.19
	175.00						
33.300		299.00	979.19	961.00	976.00	17003.00	3.22
	105.00						
35.000		276.00	963.30	963.30	983.70	17108.00	3.24
	3005.00						
42.100		154.50	969.80	969.80	969.80	20113.00	3.81
	495.00						
44.000		337.50	970.90	967.10	976.90	20608.00	3.90
	2941.00						
53.000		195.00	982.80	972.20	988.70	23549.00	4.46
	770.00						
55.000		204.00	987.20	972.90	983.80	24319.00	4.61
	1462.00						
58.000		176.50	996.30	975.40	990.40	25781.00	4.88

ED MATERIAL GRADATION (as computed from PF-records)

	SECID	SAE	DMAX	DXPI	XPI	TOTAL BED	BED MATERIAL FRACTIONS PER GRAIN SIZE (FINE TO COARSE)				
N	1.000	1.000	.105	.105	1.000	1.000	.010	.070	.290	.360	.120
							.060	.040	.015	.035	.000
N	15.000	1.000	.158	.158	1.000	1.000	.010	.070	.333	.368	.112
							.042	.032	.010	.020	.003
N	32.000	1.000	.210	.210	1.000	1.000	.010	.070	.375	.375	.105
							.025	.025	.005	.005	.005
N	33.200	1.000	.210	.210	1.000	1.000	.010	.068	.363	.380	.109
							.028	.026	.005	.006	.006
N	33.300	1.000	.210	.210	1.000	1.000	.009	.067	.356	.383	.112
							.030	.026	.005	.006	.006
N	35.000	1.000	.210	.210	1.000	1.000	.009	.067	.352	.384	.113
							.030	.026	.005	.007	.007
N	42.100	1.000	.210	.210	1.000	1.000	.006	.051	.237	.431	.154
							.058	.031	.003	.015	.015
N	44.000	1.000	.210	.210	1.000	1.000	.006	.048	.218	.439	.160
							.063	.032	.003	.016	.016

N	53.000	1.000	.210	.210	1.000	1.000	.002	.032	.105	.485	.200
							.090	.036	.001	.024	.024
N	55.000	1.000	.210	.210	1.000	1.000	.002	.028	.076	.497	.210
							.097	.038	.001	.026	.026
N	58.000	1.000	.210	.210	1.000	1.000	.000	.020	.020	.520	.230
							.110	.040	.000	.030	.030

.LOCAL INFLOW DATA...

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
AT LOCAL INFLOW POINT # 1

LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQL	* 1.00000	* 100.000	* 1000.00	* 10000.0	*
LFL VFS*	.265600E-02*	6.64000	* 7.50000	* 5940.00	*
LFL FS*	.828000E-03*	2.07000	* 122.500	* 5430.00	*
LFL MS*	.344000E-03*	.860000	* 302.500	* 3210.00	*
LFL CS*	.124000E-03*	.310000	* 26.0000	* 2940.00	*
LFL VCS*	.320000E-04*	.800000E-01*	19.5000	* 3810.00	*
LFL VFG*	.120000E-04*	.300000E-01*	10.0000	* 3480.00	*
LFL FG*	.400000E-05*	.100000E-01*	5.50000	* 2730.00	*
LFL MG*	.100000E-19*	.100000E-19*	5.50000	* 1590.00	*
LFL CG*	.100000E-19*	.100000E-19*	.100000E-19*	660.000	*
LFL VCG*	.100000E-19*	.100000E-19*	.100000E-19*	180.000	*
SUM=*	.400000E-02*	10.0000	* 499.000	* 29970.0	*

.LOCAL INFLOW DATA...

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
AT LOCAL INFLOW POINT # 2

LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQL	* 1.00000	* 100.000	* 1000.00	* 10000.0	*
LFL VFS*	.265600E-02*	6.64000	* 7.50000	* 5940.00	*
LFL FS*	.828000E-03*	2.07000	* 122.500	* 5430.00	*
LFL MS*	.344000E-03*	.860000	* 302.500	* 3210.00	*
LFL CS*	.124000E-03*	.310000	* 26.0000	* 2940.00	*
LFL VCS*	.320000E-04*	.800000E-01*	19.5000	* 3810.00	*
LFL VFG*	.120000E-04*	.300000E-01*	10.0000	* 3480.00	*
LFL FG*	.400000E-05*	.100000E-01*	5.50000	* 2730.00	*
LFL MG*	.100000E-19*	.100000E-19*	5.50000	* 1590.00	*
LFL CG*	.100000E-19*	.100000E-19*	.100000E-19*	660.000	*
LFL VCG*	.100000E-19*	.100000E-19*	.100000E-19*	180.000	*
SUM=*	.400000E-02*	10.0000	* 499.000	* 29970.0	*

.LOCAL INFLOW DATA...

SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 1
AT LOCAL INFLOW POINT # 3

LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQL	* 1.00000	* 100.000	* 500.000	* 1000.00	* 30000.0	*
LFL VFS*	.402000E-03*	6.03000	* 39.0000	* 93.6000	* 3082.50	*
LFL FS*	.684000E-03*	10.2600	* 86.0000	* 210.000	* 4905.00	*
LFL MS*	.902000E-03*	13.5300	* 227.000	* 721.200	* 10710.0	*
LFL CS*	.200000E-05*	.300000E-01*	98.5000	* 170.400	* 3555.00	*
LFL VCS*	.100000E-19*	.100000E-19*	.100000E-19*	3.60000	* 180.000	*
LFL VFG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	45.0000	*
LFL FG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	22.5000	*
LFL MG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	
LFL CG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	
LFL VCG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	

```
         ------------ ------------ ------------ ------------ ------------
   SUM=*  .199000E-02* 29.8500    * 450.500    * 1198.80    * 22500.0    *


STREAM SEGMENT #  1: EXAMPLE PROBLEM NO 3.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
DIMENSIONS OF BED SEDIMENT CONTROL VOLUMES, FEET.
SEC. NO. *   LENGTH    * MAX. WIDTH *   DEPTH    *        V O L U M E        *
         *             *            *            *   CU. FT.   *   CU. YD.   *
    1.000* 4134.00     * 203.000    * 10.0000    * .839202E+07* 310816.      *
   15.000* 8254.00     * 228.490    * 10.0000    * .188596E+08* 698502.      *
   32.000* 4280.00     * 227.710    * 10.0000    * .974600E+07* 360963.      *
   33.200* 247.500     * 281.869    * .000000    * .000000    * .000000      *
   33.300* 87.5000     * 299.000    * .000000    * .000000    * .000000      *
   35.000* 1502.50     * 235.500    * .000000    * .000000    * .000000      *
   42.100* 1750.00     * 197.899    * .000000    * .000000    * .000000      *
   44.000* 1718.00     * 288.055    * 10.0000    * .494879E+07* 183288.      *
   53.000* 1855.50     * 233.267    * 10.0000    * .432826E+07* 160306.      *
   55.000* 1116.00     * 196.961    * 10.0000    * .219808E+07* 81410.4      *
   58.000* 731.000     * 185.667    * 3.40000    * 461456.    * 17091.0      *

NO. OF INPUT DATA MESSAGES=     0
END OF SEDIMENT DATA

======================================================================================================

BEGIN COMPUTATIONS.
SHYD

======================================================================================================

*   AB      FLOW 1 = BASE FLOW OF 500 CFS

BOUNDARY CONDITION DATA, CONTROL POINT NO.  1

SEGMENT     INFLOW Q IN CFS...
   1     500.0       61.0       29.0      128.0
  TIME STEP NO.        1
WATER     DISCHARGE=       500.00
          ELEVATION=      956.000
        TEMPERATURE=       65.000
FLOW DURATION(DAYS)   2.000

****  N  DISCHARGE    WATER    ENERGY  VELOCITY   ALPHA     TOP     AVG       AVG VEL (by subsection)
           (CFS)     SURFACE    LINE     HEAD              WIDTH    BED      1      2      3

SEC NO.      1.000
****  1      500.0    956.00    956.00       .00      1.00   154.50   949.52    .00    .50    .00
                                                  FLOW DISTRIBUTION (%) =      .0 100.0     .0

SEC NO.     15.000

SUPERCRITICAL
SEC NO.  15.000 TIME =     2.00 DAYS.
TRIAL     TRIAL        COMPUTED      CRITICAL
 NO.        WS            WS            WS
  0.      957.23        956.49
  1.      957.33        956.55       957.28
****  1      500.0    957.33    958.06       .73      1.00    46.55   955.76    .00   6.86    .00
                                                  FLOW DISTRIBUTION (%) =      .0 100.0     .0

....LOCAL INFLOW POINT NO.  1,  Q=      61.00

   CONTINUING ON SEGMENT NO   1
      TEMPERATURE=      64.027

SEC NO.     32.000
****  1      439.0    962.97    962.98       .01      1.00   126.98   958.75    .00    .82    .00
                                                  FLOW DISTRIBUTION (%) =      .0 100.0     .0

SEC NO.     33.200
****  1      439.0    963.03    963.05       .02      1.00   210.65   961.07    .00   1.06    .00
                                                  FLOW DISTRIBUTION (%) =      0 100.0     .0
```

```
SEC NO.     33.300
**** 1      439.0     963.12     963.14         .02       1.00     211.16     961.08    .00  1.02    .00
                                                          FLOW DISTRIBUTION (%) =     .0 100.0    .0

SEC NO.     35.000
OPERATION RULE SPECIFIED
UPPER POOL ELEVATION (UPE) =     974.00    HEAD LOSS =       .50
**** 1      439.0     974.00     974.00         .00       1.00     221.75     967.05    .00   .29    .00
                                                          FLOW DISTRIBUTION (%) =     .0 100.0    .0

SEC NO.     42.100
**** 1      439.0     974.04     974.04         .00       1.00     242.42     969.84    .00   .43    .00
                                                          FLOW DISTRIBUTION (%) =     .0 100.0    .0

....LOCAL INFLOW POINT NO.  2,  Q=      29.00

   CONTINUING ON SEGMENT NO   1
       TEMPERATURE=     63.605

SEC NO.     44.000
**** 1      410.0     974.05     974.05         .00       1.00     261.36     969.85    .00   .37    .00
                                                          FLOW DISTRIBUTION (%) =     .0 100.0    .0

SEC NO.     53.000
**** 1      410.0     974.14     974.50         .36       1.00      66.12     972.85    .00  4.80    .00
                                                          FLOW DISTRIBUTION (%) =     .0 100.0    .0

....LOCAL INFLOW POINT NO.  3,  Q=     128.00

   CONTINUING ON SEGMENT NO   1
       TEMPERATURE=     62.064

SEC NO.     55.000
**** 1      282.0     976.18     976.22         .04       1.00      83.11     974.10    .00  1.63    .00
                                                          FLOW DISTRIBUTION (%) =     .0 100.0    .0

SEC NO.     58.000
**** 1      282.0     978.28     978.39         .11       1.00      50.53     976.22    .00  2.72    .00
                                                          FLOW DISTRIBUTION (%) =     .0 100.0    .0


TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  1
            EXAMPLE PROBLEM NO 3.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
****************************************************************
                      *                                    *
    TIME       ENTRY  *             SAND                   *
    DAYS       POINT  *    INFLOW   OUTFLOW   TRAP EFF     *
                      *                                    *
    2.00      58.000  *      .03                           *
              53.000  *      .04                           *
              42.100  *      .00                           *
   TOTAL=     35.000  *      .07       .00       1.00      *
                      *                                    *
****************************************************************
    TIME       ENTRY  *             SAND                   *
    2.00      35.000  *      .00                           *
              15.000  *      .00                           *
   TOTAL=      1.000  *      .00       .00        .29      *
                      *                                    *
****************************************************************
TABLE SB-1.                 TOTAL          AND LOAD BY GRAIN SIZEIN TONS/DAY
                                      VF          F            M             C            VC
SEDIMENT INFLOW
 SANDS & GRAVELS          28.81      9.03       10.94         8.84          .00          .00
                                      .00         .00          .00          .00          .00
SEDIMENT OUTFLOW
 SANDS & GRAVELS           3.07       .05         .21          .67          .85          .42
                                      .34         .43          .10          .00          .00


 SECTION    BED CHANGE    WS ELEV   THALWEG         Q       SEDIMENT LOAD (TONS/DAY)
```

ID NO	FEET	FEET	EL FEET	CFS	SAND
58.000	-.23	978.28	975.17	282.	346.
55.000	-.10	976.18	972.80	282.	562.
53.000	.00	974.14	972.20	410.	615.
44.000	.07	974.05	967.17	410.	6.
42.100	.00	974.04	969.80	439.	0.
35.000	.00	974.00	963.30	439.	0.
33.300	.00	963.12	961.00	439.	0.
33.200	.00	963.03	961.00	439.	0.
32.000	-.02	962.97	956.48	439.	178.
15.000	-.01	957.33	953.99	500.	399.
1.000	.03	956.00	944.73	500.	3.

* B FLOW 3 = NEAR BANK FULL DISCHARGE

BOUNDARY CONDITION DATA, CONTROL POINT NO. 1
TIME STEP NO. 3
WATER DISCHARGE= 1250.00
ELEVATION= 960.000
TEMPERATURE= 65.000
FLOW DURATION(DAYS) 1.000

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 3. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
53.00	58.000	13.18		
	53.000	16.13		
	42.100	.36		
TOTAL=	35.000	29.68	6.03	.80

TIME	ENTRY		SAND	
53.00	35.000	6.03		
	15.000	1.00		
TOTAL=	1.000	7.03	.04	.99

TABLE SB-1. TOTAL AND LOAD BY GRAIN SIZEIN TONS/DAY

	TOTAL	VF	F	M	C	VC
SEDIMENT INFLOW						
SANDS & GRAVELS	149.81	66.90	53.32	29.58	.01	.00
		.00	.00	.00	.00	.00
SEDIMENT OUTFLOW						
SANDS & GRAVELS	4.13	.47	.45	1.30	1.37	.52
		.00	.00	.00	.00	.00

SECTION ID NO	BED CHANGE FEET	WS ELEV FEET	THALWEG EL FEET	Q CFS	SEDIMENT LOAD (TONS/DAY) SAND
58.000	-1.86	979.31	973.54	682.	1408.
55.000	-.24	977.92	972.66	682.	2549.
53.000	-.10	975.33	972.10	1022.	9500.
44.000	.52	974.48	967.62	1022.	904.
42.100	2.35	974.37	972.15	1100.	39.
35.000	.79	974.00	964.09	1100.	10.
33.300	.02	965.08	961.02	1100.	507.
33.200	.32	965.00	961.32	1100.	575.
32.000	-.23	964.92	956.27	1100.	311.
15.000	.12	961.00	954.12	1250.	292.
1.000	.23	960.00	944.93	1250.	4.

6.3.7 Output

Exhibit 6.7 shows a portion of the output file generated from execution of Example Problem 3. The geometric data output is the same as in the previous example so is not repeated here. This is followed by sediment data; at this point no computations are being performed, the input data are being read and manipulated in preparation for the computations which begin when the flow data are read. The sediment title records are echoed followed by the information on the I records. Next is the main river inflowing load table; the sediment loads are in scientific notation because of the wide range of possible values. Note that a very small value is used instead of zero because log-log interpolation is used within these data tables.

The table headed "VOLUME VS DEPTH OF DEPOSITS" depicts the status of the bed sediment reservoir at the beginning of the simulation, as described by the input data. Note that the movable bed widths are not necessarily the same as given on the HD data. For example, at section 1.0, the movable bed was designated to be from station 10081 to station 10250 ft.; therefore, these are movable GR points. The width used for computations extends halfway to the next, fixed, GR points (10077 & 10275 ft.), which is a distance of 183.5 ft. [= ((10275+10250)/2) - ((10081+10077)/2)]. See Figure 2.9.

The table headed "BED MATERIAL GRADATION" contains the information on the PF and PFC records. That data has been translated into the format of N records, see Appendix A. Note that one set of "N" data is given for each cross section, this allows checking of the interpolation of the size distributions on the PF records.

The next section contains the load tables for the local inflows, these are similar to the table for the main river. This completes processing of the sediment data.

The following output is from the computations, beginning with an "A-level" hydraulic output table. Table "SA-1" shows cumulative (since the beginning of the simulation) values. The "ENTRY POINT" is the cross section at which an inflow occurs. Looking at the last SA-1 table we see that after 54 days, 13.2 acre-ft. of sands and gravels had entered the reach (section 58.0 is the upstream end of the reach). The total material passing section 35.0 is 6.03 acre-ft. The total input from the locals and the upstream end was 29.72 acre-ft., yielding a trap efficiency for that reach [(inflow-outflow)/inflow] of 80%.

Table SB-1 shows the instantaneous ("snap shot") sediment inflows and outflows by grain size in tons/day.

The following table is activated by a "B" in column 6 of the * record. It contains both cumulative and instantaneous information. The BED CHANGE is cumulative from time zero, the WS (water surface) ELEV, THALWEG, water and sediment discharges are for this time step. For example, the thalweg (minimum elevation GR point within the channel) at section 1.0 was initially 944.70 ft. After 54 days, there was a computed deposit of 0.23 ft. at section 1.0, resulting in a thalweg elevation of 944.93 ft. Note that, in general, the sediment output is from upstream to downstream which reflects the sequence in which the sediment computations are performed.

EXHIBIT 6.8

```
==========================================================================================

*    C      FLOW 4 = BASE FLOW OF 500 CFS

******************************************************************************************
        THE FOLLOWING TABLE IS PRINTOUT FOR CROSS SECTION       1.000
        ------------------------------------------------------------
```

```
HYDRAULIC PARAMETERS:
        VEL          SLO          EFD          EFW          N-VALUE         TAU          USTARM        FROUDE
NO.
        .279      .000001       11.321       166.989        .0400        .00039        .01416
.015
BED SEDIMENT RESERVOIR COMPUTATIONS:
NEW SURFACE AREA (SQ FT):     TOTAL        K-PORTION      S-PORTION
                          954954.00     954954.00           .00
GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS
BED MATERIAL BY GRAIN SIZE FRACTION      .012375    .071094    .291352    .358970    .119513
                                         .058680    .039121    .014669    .034226    .000000
BED MATERIAL BY PERCENT FINER/100        .012375    .083469    .374821    .733790    .853304
                                         .911983    .951104    .965774   1.000000   1.000000


SAND
** ARMOR LAYER **
STABILITY COEFFICIENT=     .95000
MIN.GRAIN DIAM      =     .000288
BED SURFACE EXPOSED  =     .00000

         INACTIVE LAYER          ACTIVE LAYER
         %          DEPTH        %         DEPTH
 CLAY  .000000       .00      .000000       .00
 SILT  .000000       .00      .000000       .00
 SAND 1.000000      9.70     1.000000       .52
TOTAL 1.000000      9.70     1.000000       .52

      AVG. UNIT             AVG. UNIT
       WEIGHT                WEIGHT

      .046500               .046500

**BED IS ARMORED**

    COMPOSITE UNIT WT OF ACTIVE LAYER T/CF=        .046500
    WEIGHT IN SURFACE LAYER(TONS),    WTSL=        13196.9
    DEPTH OF NEW ACTIVE LAYER(FT),     DSE=          .0000
    WEIGHT IN NEW ACTIVE LAYER,     WTMXAL=             .0
    WEIGHT IN OLD ACTIVE LAYER,        WAL=        23235.9
    USEABLE WEIGHT, OLD INACTIVE LAY,  WIL=       430856.7
BED MATERIAL BY GRAIN SIZE FRACTION      .010000    .070000    .290000    .360000    .120000
                                         .060000    .040000    .015000    .035000    .000000
BED MATERIAL BY PERCENT FINER/100        .010000    .080000    .370000    .730000    .850000
                                         .910000    .950000    .965000   1.000000   1.000000
** ACTIVE LAYER **
BED MATERIAL BY GRAIN SIZE FRACTION      .056418    .091374    .316420    .339864    .110485
                                         .034195    .022827    .008539    .019878    .000000
BED MATERIAL BY PERCENT FINER/100        .056418    .147792    .464212    .804076    .914561
                                         .948756    .971583    .980122   1.000000   1.000000

C FINES, COEF(CFFML), MX POTENTIAL= .000000E+00 .100000E+01 .108000E+07

POTENTIAL TRANSPORT BY SIZE CLASS=  .100000E-06 .100000E-06 .100000E-06 .100000E-06 .100000E-06
                                    .100000E-06 .100000E-06 .100000E-06 .100000E-06 .100000E-06
                              TOTAL          AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY
CALCULATED SEDIMENT LOAD, TONS/DAY
 SANDS & GRAVELS               .00         .00         .00         .00         .00         .00
                                           .00         .00         .00         .00         .00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  1
            EXAMPLE PROBLEM NO 3.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*****************************************************************
                       *                                  *
   TIME         ENTRY  *                SAND              *
   DAYS         POINT  *     INFLOW    OUTFLOW   TRAP EFF *
                       *                                  *
  54.00        58.000  *     13.20                        *
               53.000  *     16.15                        *
               42.100  *       .36                        *
  TOTAL=       35.000  *     29.72       6.03        .80  *
                       *                                  *
```

```
**********************************************************************
   TIME        ENTRY *            SAND            *
  54.00       35.000 *    6.03                    *
              15.000 *    1.00                    *
  TOTAL=       1.000 *    7.03          .04    .99 *
                     *                            *
**********************************************************************
TABLE SB-1.                 TOTAL          AND LOAD BY GRAIN SIZEIN TONS/DAY
                                        VF           F            M            C            VC
SEDIMENT INFLOW
 SANDS & GRAVELS          28.81        9.03        10.94         8.84          .00          .00
                                        .00          .00          .00          .00          .00
SEDIMENT OUTFLOW
 SANDS & GRAVELS            .00         .00          .00          .00          .00          .00
                                        .00          .00          .00          .00          .00


  SECTION   BED CHANGE   WS ELEV   THALWEG       Q       SEDIMENT LOAD (TONS/DAY)
   ID NO       FEET       FEET     EL FEET      CFS         SAND
   58.000     -1.86      977.23    973.54      282.          29.
   55.000      -.24      975.87    972.66      282.          27.
   53.000      -.15      974.36    972.05      410.         676.
   44.000       .56      974.10    967.66      410.          15.
   42.100      2.35      974.07    972.15      439.           0.
   35.000       .79      974.00    964.09      439.           0.
   33.300       .02      965.18    961.02      439.           0.
   33.200       .32      965.17    961.32      439.           0.
   32.000      -.23      965.16    956.27      439.           0.
   15.000       .12      965.02    954.12      500.           0.
    1.000       .23      965.00    944.93      500.           0.

ACCUMULATED WATER DISCHARGE FROM DAY ZERO(SFD)
      MAIN        TRIB #1       TRIB #2       TRIB #3        ....ETC
  127750.0000
.....................................................................................................
```

6.3.8 Detailed Sediment Output

More information regarding the sediment transport computations can be obtained at any time step by placing a "C" in column 6 of the * record. The resulting information is used primarily by the program developers; however, some of it can be of use for applications. An example of this "C-level" sediment information for section 1.0 for the last flow of Example Problem 3 is shown in Exhibit 6.8. The "HYDRAULIC PARAMETERS" table contains the velocity, energy slope, effective depth, effective width, Manning's n, TAU (the average bed shear stress, τ), USTARM (the shear velocity, u_*), and the Froude number. See Vanoni (1975) for definitions of these hydraulic variables. The "GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS" table shows the gradation of the bed material at this cross section at this time. The first data are the contents of the bed by grain size, as fractions, from fine to coarse. In this example there is 1.2% of very fine sand, 7.1% of fine sand, etc. These size classes were specified on the I records. The next items are cumulative; i.e. fraction finer of any particular grain size.

The armor layer STABILITY COEFFICIENT is described in section 2.3.3.3 and the MIN. GRAIN DIAM (ft.) is the minimum stable grain size as described in section 2.3.2.2. The following table shows that there are 9.70 ft. of sands and gravels in the inactive layer and 0.52 ft. in the active layer. This corresponds to the 0.23 ft. of deposition shown in the "B-level" print for this section. Note that the bed sediment reservoir is 10 ft. deep at this section (HD data) and arithmetic round-off explains the 0.01 ft. difference.

The POTENTIAL TRANSPORT BY SIZE CLASS (tons/day) is zero here because the bed is armored. The CALCULATED SEDIMENT LOAD, TONS/DAY is the potential transport rate of any grain size multiplied by the fraction of that grain size in the active layer.

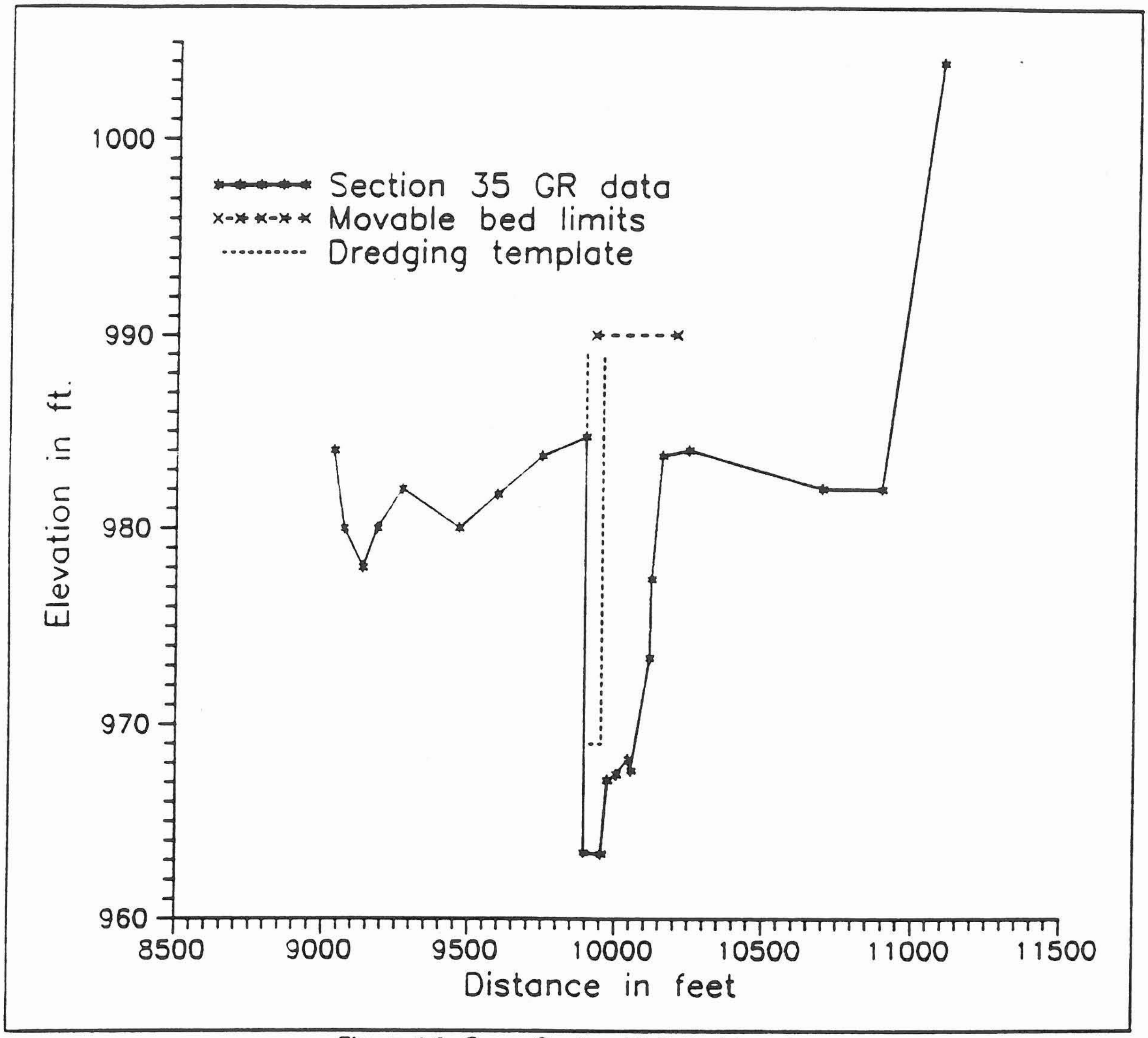

Figure 6.3 Cross Section 35.0, Problem 4

In this example, sections 35, 42.1, and 44 are to be dredged. The input data file is shown in Exhibit 6.9. The geometric data was modified via the **HD** record to identify the dredged channel template. Figure 6.3 shows cross section 35.0 for Example Problem 4. An **X5** record was added at section 53.0 to create output information regarding the quantities of material dredged. The dredging is activated by **$DREDGE** records in the flow data and deactivated by **$NODREDGE** records in the flow data.

EXHIBIT 6.9 Input - Sediment Options

```
T1       EXAMPLE PROBLEM NO 4.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
T2       SEDIMENT RUN W/OPTIONS, 3 LOCAL INFLOWS: CASCADE, SILVER, BEAR CREEKS
T3       ORIGINAL WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW
NC   .100     .100     .040       .1       .3
X1    1.0      31.  10077.0  10275.0       0.        0.        0.        0.        0.        0.
GR1004.0   9915.0   978.40  10002.0   956.00  10060.0   959.20  10077.0   959.30  10081.0
GR950.00  10092.0   948.48  10108.0   946.60  10138.0   944.70  10158.0   955.20  10225.0
```

```
GR956.20 10243.0  958.90 10250.0  959.80 10275.0  959.80 10300.0  959.90 10325.0
GR958.80 10350.0  957.40 10400.0  970.00 10700.0  966.00 10960.0  970.00 11060.0
GR968.00 11085.0  968.00 11240.0  970.00 11365.0  970.00 11500.0  970.00 11615.0
GR962.00 11665.0  962.00 12400.0  976.00 12550.0  980.00 12670.0  982.00 12730.0
GR984.00 12735.0
HD     1     10.   10081   10250
NV    22    .045   965.6    .064   988.8
NV    12    .080   965.6    .130   988.8
NV    33     .10   965.6     .11   982.0     .12   988.8
X1  15.0     27. 10665.0 10850.0   8565.   7535.   8268.      0.      0.      0.
X3                         10700     961   11000     970
GR992.00  9570.0  982.00 10110.0  976.00 10300.0  976.00 10490.0  966.00 10610.0
GR964.70 10665.0  956.00 10673.0  953.00 10693.0  954.00 10703.0  955.60 10723.0
GR958.60 10750.0  959.30 10800.0  957.00 10822.0  957.30 10825.0  961.50 10850.0
GR962.00 10852.0  964.00 10970.0  966.00 11015.0  961.00 11090.0  962.00 11150.0
GR970.00 11190.0  972.00 11310.0  980.00 11410.0  984.00 11570.0  990.00 11770.0
GR990.00 11865.0 1000.00 12150.0
HD    15     10.   10673   10852
QT
NC   .10     .10     .05
X1  32.0     29. 10057.0 10271.0   7429.   6654.   8240.      0.      0.      0.
GR998.00  9080.0  982.00  9250.0  982.00  9510.0  980.00  9600.0  980.01  9925.0
GR979.48 10000.0  978.50 10057.0  968.60 10075.0  959.82 10087.0  956.50 10097.0
GR956.80 10117.0  957.80 10137.0  959.40 10157.0  959.60 10177.0  959.82 10196.0
GR966.50 10225.0  971.20 10250.0  978.50 10271.0  978.50 10300.0  978.60 10350.0
GR978.91 10370.0  978.96 10387.0  980.00 10610.0  982.00 10745.0  982.00 11145.0
GR984.00 11150.0  992.00 11240.0 1000.00 11330.0  1008.0 11425.0
HD    32     10.   10075   10275
X1  33.2     21.  1850.0  2150.0    130.    250.    320.      0.      0.      0.
XL           250
GR1000.0   980.0  990.00  1060.0  980.00  1150.0  982.00  1180.0  982.00  1215.0
GR980.00  1260.0  982.00  1300.0  982.00  1350.0  980.00  1420.0  980.00  1540.0
GR982.00  1730.0  982.00  1830.0  984.41  1850.0  979.19  1851.0  961.00  1900.8
GR961.00  2099.2  976.00  2149.0  984.50  2150.0  982.00  2800.0  990.00  3100.0
GR1000.0  3170.0    0.00     0.0    0.00     0.0    0.00     0.0    0.00     0.0
HD  33.2       0    1851    2149
X1  33.3       0  1850.0  2150.0    155.    175.    175.      0.      0.      0.
HD  33.3       0    1851    2149
X1  35.0     22.  9894.0 10155.0    105.    105.    105.      0.      0.      0.
X3    10
X5          974.      .5
GR984.00  9035.0  980.00  9070.0  978.00  9135.0  980.00  9185.0  982.00  9270.0
GR980.00  9465.0  981.70  9595.0  983.70  9745.0  984.70  9894.0  963.40  9894.0
GR963.30  9954.0  967.10  9974.0  967.40 10004.0  968.20 10044.0  967.60 10054.0
GR973.40 10115.0  977.40 10120.0  983.70 10155.0  984.00 10245.0  982.00 10695.0
GR982.00 10895.0 1004.00 11085.0
HD    35       0    9954   10155             969    9894    9954       0       1
NC   .06     .06    .045
X1  42.1     32.  9880.0 10130.0   2070.   3965.   3005.      0.      0.      0.
GR996.00  7130.0  998.00  7310.0  998.00  7930.0  992.00  8205.0  990.00  8495.0
GR988.00  8780.0  986.00  8990.0  985.70  9570.0  986.45  9707.0  989.44  9857.0
GR990.00  9880.0  969.80  9881.0  969.80  9941.0  985.80  9941.0  985.80  9943.0
GR969.80  9943.0  969.80 10001.0  986.70 10001.0  986.70 10003.0  969.80 10003.0
GR969.80 10067.0  985.80 10067.0  985.80 10069.0  969.80 10069.0  969.80 10129.0
GR989.90 10130.0  989.50 10180.0  988.60 10230.0  987.60 10280.0  985.20 10430.0
GR986.80 11720.0  989.90 12310.0
HD 42.10       0    9881   10021           970.8    9881    9941       0       1
QT
X1  44.0     28.  9845.0 10127.0    290.    795.    495.      0.      0.      0.
XL                          9850   10200
GR1002.0  8035.0  992.00  8150.0  990.00  8305.0  990.00  8735.0  988.00  8835.0
GR996.00  9285.0  1017.6  9425.0  990.00  9505.0  986.00  9650.0  984.10  9788.0
GR980.60  9845.0  970.90  9868.0  972.20  9898.0  970.50  9968.0  967.50  9998.0
GR968.90 10028.0  967.40 10058.0  967.10 10078.0  971.90 10118.0  976.80 10127.0
GR977.80 10150.0  976.90 10193.0  982.00 10206.0  981.20 10300.0  979.20 10325.0
GR983.10 10400.0  999.80 10450.0 1002.40 10464.0
HD    44       1    9868   10193             969    9968   10028       0       1
X1  53.0     22. 10000.0 10136.0   3366.   2831.   2941.      0.      0.      0.
X5
GR1004.0  7550.0 1000.00  7760.0  998.00  8440.0  996.00  8640.0  996.00  8780.0
GR994.00  8940.0  986.00  9245.0  986.30  9555.0  986.30  9825.0  983.80  9900.0
GR982.80 10000.0  978.20 10011.0  974.00 10041.0  972.20 10071.0  972.60 10101.0
GR978.20 10121.0  988.70 10136.0  989.30 10154.0  999.20 10200.0  1000.1 10320.0
```

```
GR1002.0 10470.0 1004.00 10700.0
HD     53      10.   10000    10136
QT
X1  55.0      18.  9931.0 10062.0     275.    1430.     770.       0.       0.       0.
GR1004.0  7592.0 1000.00  7947.0  996.00  8627.0  990.00  9052.0  986.00  9337.0
GR984.30  9737.0  984.70  9837.0  985.50  9910.0  987.20  9931.0  978.10 [illegible]55.0
GR974.80  9975.0  974.20 10005.0  972.90 10035.0  973.20 10045.0 [illegible]3.80 [illegible]62.0
GR985.80 10187.0  986.00 10307.0  990.00 10497.0
HD     55      10.    9931    10062
X1  58.0      22.  9912.0 10015.0    1097.    1012.    1462.       0.       0.       0.
GR1006.0  8542.0 1004.00  8952.0 1000.00  9702.0  997.20  9812.0  996.30  9912.0
GR976.20  9944.0  975.40  9974.0  978.20  9991.0  990.40 10015.0  988.30 10062.0
GR988.80 10065.0  988.30 10065.0  989.30 10169.0  990.00 10172.0  992.00 10242.0
GR992.00 10492.0  988.00 10642.0  986.70 10852.0  988.00 11022.0  986.00 11097.0
GR986.00 11137.0  988.00 11192.0
HD     58     3.4     9912    10015
EJ
T4       MAIN STEM, SEGMENT 1, SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
T5       LOAD CURVE FROM USGS DATA AT USGS GAGE: 5 PERCENT ADDED FOR BED LOAD
T6       BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T7       ENCODED BY DAVID WILLIAMS, WES, SEPT 1982
T8       SEDIMENT TRANSPORT BY STREAM POWER: SEE ASCE JOURNAL (YANG 1971)
I1      0       5
I4  SAND        4       1      10
I5             .5      .5     .25      .5     .25       0     1.0
LQ              1      50    1000    5800   90000
LT TOTAL    .0110     1.5     320   4500.  400000
LF    VFS    .119    .119    .498    .511    .582
LF     FS    .328    .328    .331    .306    .280
LF     MS    .553    .553    .156    .154    .110
LF     CS    .000    .000    .011    .016    .020
LF    VCS    .000    .000    .004    .008    .005
LF    VFG    .000    .000    .000    .004    .002
LF     FG    .000    .000    .000    .001    .001
LF     MG    .000    .000    .000    .000    .000
LF     CG    .000    .000      00    .000    .000
LF    VCG      .0      .0       0    .000    .000
PF EXAMP      1.0     1.0       0    16.0    96.5     8.0    95.0     4.0    91.0
PFC   2.0    85.0     1.0 [illegible]3.0      .5    37.0     .25     8.0    .125     1.0
PFC.0625      0.0
PF EXAMP     32.0     1.0    64.0    32.0    93.5    16.0    99.0     8.0    98.5
PFC   4.0    96.0     2.0    93.5     1.0    83.0     .50    45.5    .250     8.0
PFC  .125     1.0   .0625     0.0
PF EXAMP     53.0     1.0    64.0    32.0    97.0    16.0    94.0     8.0    94.0
PFC   4.0    90.0     2.0    79.0     1.0    56.0     .50     4.0    .125     0.0
SLOCAL
LQL             1     100    1000   10000
LTLTOTAL    .0040      10     500   30000
LFL   VFS    .664    .664    .015    .198
LFL    FS    .207    .207    .245    .181
LFL    MS    .086    .086    .605    .107
LFL    CS    .031    .031    .052    .098
LFL   VCS    .008    .008    .039    .127
LFL   VFG   .0030   .0030   .0200   .1160
LFL    FG   .0010   .0010   .0110   .0910
LFL    MG   .0000   .0000   .0110   .0530
LFL    CG   .0000   .0000   .0000   .0220
LFL   VCG   .0000   .0000   .0000   .0060
LQL             1     100    1000   10000
LTLTOTAL    .0040      10     500   30000
LFL   VFS    .664     664    .015    .198
LFL    FS    .207    .207    .245    .131
LFL    MS    .086     086    .605    .107
LFL    CS    .031     031    .052    .098
LFL   VCS    .008     008    .039    .127
LFL   VFG   .0030    0030   .0200   .1160
LFL    FG   .0010   .0010   .0110   .0910
LFL    MG   .0000   .0000   .0110   .0530
LFL    CG   .0000   .0000   .0000   .0220
LFL   VCG   .0000   .0000   .0000   .0060
LQL            1.    100.    500.   1000.  30000.
LTLTOTAL    .0020    30.0    500.    1200   22500
LFL   VFS    .201    .201    .078     078    .137
```

```
LFL    FS    .342    .342    .172    .175    .218
LFL    MS    .451    .451    .454    .601    .476
LFL    CS    .001    .001    .197    .142    .158
LFL   VCS    .000    .000    .000    .003    .008
LFL   VFG   .0000   .0000   .0000   .0000   .0020
LFL    FG   .0000    .000   .0000   .0000   .0010
LFL    MG   .0000    .000   .0000   .0000   .0000
LFL    CG   .0000    .000   .0000   .0000   .0000
LFL   VCG   .0000    .000   .0000   .0000   .0000
SHYD
SB              2
SKL
*    AB      FLOW 1 = BASE FLOW OF 500 CFS
Q     500      61      29     128
R    956.
T      65      72      70      67
W       2
SDREDGE
*     B      FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE
Q 2500.0     300.    150.    650.
R    965.
X             2.5     50.
*     B      FLOW 3 = NEAR BANK FULL DISCHARGE
Q  1250.     150.     78.    340.
R    960.
W      1.
SSED
LP             10
LQ              1      50    1000    5800   90000
LT TOTAL    .0110     1.5     320   4500.  400000
LF    VFS    .119    .119    .498    .511    .582
LF     FS    .328    .328    .331    .306    .280
LF     MS    .553    .553    .156    .154    .110
LF     CS    .345    .345    .011    .016    .020
LF    VCS    .025    .025    .004    .008    .005
LF    VFG    .005    .005    .000    .004    .002
LF     FG    .000    .000    .000    .001    .001
LF     MG    .000    .000    .000    .000    .000
LF     CG    .000    .000    .000    .000    .000
LF    VCG      .0      .0    .000    .000    .000
SLOCAL
LP             12
LQL             1     100    1000   10000
LTLTOTAL    .0040      10     500   30000
LFL   VFS    .664    .664    .015    .198
LFL    FS    .207    .207    .245    .181
LFL    MS    .086    .086    .605    .107
LFL    CS    .031    .031    .052    .098
LFL   VCS     008    .008    .039    .127
LFL   VFG   .0030   .0030   .0200   .1160
LFL    FG   .0010   .0010   .0110   .0910
LFL    MG   .0000   .0000   .0110   .0530
LFL    CG   .0000   .0000   .0000   .0220
LFL   VCG   .0000   .0000   .0000   .0060
END
SRATING
RC             40    2000       0       0   950.0   955.1   958.0   960.0   962.0
RC          963.6   965.1   966.2   967.0   967.7   968.3   968.9   969.4   969.8
RC          970.2   970.6   971.0   971.4   971.8   972.1   972.4   972.7   972.9
RC          973.1   973.3   973.5   973.7   973.8   973.9   974.0   974.1   974.2
RC          974.3   974.4   974.5   974.6   974.7   974.8   974.9   975.0
SPRT
PN              1       7
END
SNODREDG
*    AC      FLOW 4 = BASE FLOW OF 500 CFS
Q    500.      61      29     128
R    965.
W      1.
SVOL   A
SSEND
```

This example problem uses a transmissive boundary condition (**$B**) at the downstream boundary. This merely passes all inflowing sediment through the downstream-most cross section without interaction with the bed.

The Limerinos (1970) function for bed form roughness is used in this example (**$KL** record). The value of Manning's n resulting from this computation can be found in the "C-level" sediment output. This computation overrides the roughness data (**N** records) in the geometric data.

The use of **X** rather than **W** data to select the time step is also illustrated in this problem. This allows a long period of constant flow to be subdivided automatically into multiple computational time steps without repeating *****, **Q**, **W** data. In this case, the program will use 20 time steps of 2.5 days each to simulate the constant bank full flow of 50 days duration.

Sometimes the inflowing water vs. sediment relationship will change in time due to land use changes or even seasonal variations in vegetation. Such changes, should they be known or predicted, can be described in the flow data by using the **$SED** option. Example Problem 4 illustrates the use of this option to change the main river and one local inflowing load curve prior to the last flow in the hydrograph. At this time, another change to the data is also illustrated by replacing the stage hydrograph (**R** records) with a rating curve (**$RATING**). In any study, selection and use of any of these options must be based on sound engineering analysis.

This data set also shows the use of output control to select output at specified cross sections (**$PRT** and **PN**) and request cumulative volumes of sediment passing each cross section (**$VOL**).

6.4.1 Output

The output from problem 4, as shown in Exhibit 6.10, reflects the transmissive boundary condition in that no scour or deposition was computed at section 1.0 (the downstream boundary). The output for the second flow shows that the 50 day duration of that flow was broken into 20 computational time steps (X record). Dredging was initiated at the second flow and terminated after the third flow. The table labelled "TONS OF SEDIMENT DREDGED FROM THIS REACH" indicates that 5040 tons (4014 yds^3) were dredged between sections 42.1 and 44.0 during this time step.

The inflowing load curves for the main river and the local inflow just downstream from section 44.0 as well as the rating curve at section 1.0 were changed just prior to the third flow. Tables echoing these data are provided.

At the last flow, output was only selected for sections 1.0 and 42.1. This is useful for limiting the output to only those places and times that are of interest. For example, the n-value calculated by the Limerinos equation at this time for section 42.1 is 0.0153.

Summary information regarding weight and volume of sediment (selected via the **$VOL** record) begins with the table labelled "SUMMARY TABLE: MASS AND VOLUME OF SEDIMENT". This table displays cumulative values since time zero. Under the "SEDIMENT PASSING SECTION IN TONS" heading are values for sediment passing each section. The difference between the sediment volume entering and leaving a section is scoured from or deposited into the control volume associated with that section. This value is given under the heading "SEDIMENT DEPOSITED IN REACH IN CUBIC YARDS"; negative values represent scour. Following that is a table showing cumulative load, in tons, passing each section by grain size fraction.

EXHIBIT 6.10

```
**************************************************************************************************
*              INPUT FILE: EX4.DAT                                                               *
*              OUTPUT FILE: EX4.OUT                                                              *
**************************************************************************************************
```

* B FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE

COMPUTING FROM TIME= 2.000000 DAYS TO TIME= 52.000000 DAYS IN 20 COMPUTATION STEPS

BOUNDARY CONDITION DATA, CONTROL POINT NO. 1
TIME STEP NO. 2
WATER DISCHARGE= 2500.00
ELEVATION= 965.000
TEMPERATURE= 65.000
FLOW DURATION(DAYS) 2.500

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 4. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
52.00	58.000	13.11		
	53.000	16.03		
TOTAL=	53.000	29.14	37.71	-.29
TIME	ENTRY		SAND	
52.00	53.000	37.71		
	42.100	.36		
TOTAL=	35.000	38.06	13.86	.64
TIME	ENTRY		SAND	
52.00	35.000	13.86		
	15.000	.99		
TOTAL=	1.000	14.86	.62	.96

TABLE SB-1. TOTAL AND LOAD BY GRAIN SIZEIN TONS/DAY

	TOTAL	VF	F	M	C	VC
SEDIMENT INFLOW						
SANDS & GRAVELS	529.98	265.63	173.06	82.59	6.27	2.42
		.00	.00	.00	.00	.00
SEDIMENT OUTFLOW						
SANDS & GRAVELS	16.01	2.59	1.67	5.02	4.85	1.86
		.01	.00	.00	.00	.00

SECTION ID NO	BED CHANGE FEET	WS ELEV FEET	THALWEG EL FEET	Q CFS	SEDIMENT LOAD (TONS/DAY) SAND
58.000	-3.22	978.82	972.18	1400.	493.
55.000	-1.77	977.99	971.13	1400.	1051.
53.000	.00	976.37	972.20	2050.	0.
44.000	2.61	974.24	970.27	2050.	1879.
42.100	2.46	974.07	972.26	2200.	1053.
35.000	.00	974.00	963.30	2200.	0.
33.300	1.22	965.46	962.22	2200.	928.
33.200	1.22	965.39	962.22	2200.	813.
32.000	.27	965.39	956.77	2200.	300.
15.000	.18	965.03	954.18	2500.	16.
1.000	.00	965.00	944.70	2500.	16.

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 4. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN

SEC NO. 42.100
ELEVATION OF DREDGED CHANNEL INCLUDING 1.00 FEET OF OVER DREDGING= 969.80

```
SEC NO.      44.000
ELEVATION OF DREDGED CHANNEL INCLUDING     1.00 FEET OF OVER DREDGING=      968.00
TONS OF SEDIMENT DREDGED FROM THIS REACH=        5040.0 ACCUMULATED FROM DOWNSTREAM END=          5040.
                               CUBIC YARDS=        4014.3                                                4014.
```

```
*    B     FLOW 3 = NEAR BANK FULL DISCHARGE

BOUNDARY CONDITION DATA, CONTROL POINT NO.  1
  TIME STEP NO.       3
WATER     DISCHARGE=     1250.00
            ELEVATION=    960.000
         TEMPERATURE=     65.000
FLOW DURATION(DAYS)  1.000

TABLE SA-1.  TRAP EFFICIENCY ON STREAM SEGMENT #  1
             EXAMPLE PROBLEM NO 4.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
             ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*****************************************************************
                      *                                  *
   TIME       ENTRY  *              SAND                *
   DAYS       POINT  *    INFLOW   OUTFLOW   TRAP EFF  *
                      *                                  *
  53.00      58.000  *     13.18                        *
             53.000  *     16.13                        *
  TOTAL=     53.000  *     29.32     37.91     -.29    *
                      *                                  *
*****************************************************************
   TIME       ENTRY  *              SAND                *
  53.00      53.000  *     37.91                        *
             42.100  *       .36                        *
  TOTAL=     35.000  *     38.27     13.86      64     *
                      *                                  *
*****************************************************************
   TIME       ENTRY  *              SAND                *
  53.00      35.000  *     13.86                        *
             15.000  *      1.00                        *
  TOTAL=      1.000  *     14.86       .72      .95    *
                      *                                  *
*****************************************************************
TABLE SB-1.                   TOTAL          AND LOAD BY GRAIN SIZEIN TONS/DAY
                                          VF            F            M            C            VC
SEDIMENT INFLOW
 SANDS & GRAVELS            149.81       56.90        53.32        29.58          01          .00
                                           00          .00          .00          .00          .00
SEDIMENT OUTFLOW
 SANDS & GRAVELS            204.33       67.74        26.17        51.88        42.76        15.33
                                          .29          .18          .00          .00          .00


  SECTION    BED CHANGE    WS ELEV    THALWEG        Q       SEDIMENT LOAD (TONS/DAY)
   ID NO        FEET         FEET     EL FEET       CFS            SAND
    58.000        -3.26      976.98     972.14       682.            260.
    55.000        -1.76      976.37     971.14       682.            209.
    53.000          .00      974.83     972.20      1022.              0.
    44.000        -3.26      974.05     967.01      1022.             32.
    42.100          .00      974.02     972.25      1100.              2.
    35.000          .00      974.00     963.30      1100.              0.
    33.300          .00      963.74     961.00      1100.           1230.
    33.200          .00      963.26     961.00      1100.           4358.
    32.000         -.38      962.21     956.12      1100.          21668.
    15.000          .56      959.99     954.56      1250.            204.
     1.000          .00      960.00     944.70      1250.            204.
```

. . . .

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 4. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN

. . . .

```
SSED


INFLOWING SEDIMENT LOAD TABLE MODIFIED BY:
LP           10.000       .000       .000       .000       .000       .000       .000       .000       .000

SEDIMENT LOAD TABLE FOR STREAM SEGMENT #   1
LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQ       * 1.00000     * 50.0000     * 1000.00     * 5800.00     * 90000.0     *
LF   VFS* .130900E-02* .178500     * 159.360     * 2299.50     * 232800.     *
LF    FS* .360800E-02* .492000     * 105.920     * 1377.00     * 112000.     *
LF    MS* .608300E-02* .829500     * 49.9200     * 693.000     * 44000.0     *
LF    CS* .379500E-02* .517500     * 3.52000     * 72.0000     * 8000.00     *
LF   VCS* .275000E-03* .375000E-01* 1.28000    * 36.0000     * 2000.00     *
LF   VFG* .550000E-04* .750000E-02* .100000E-19* 18.0000    * 800.000     *
LF    FG* .100000E-19* .100000E-19* .100000E-19* 4.50000    * 400.000     *
LF    MG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
LF    CG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
LF   VCG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
          ------------ ------------ ------------ ------------ ------------
   SUM=*  .151250E-01* 2.06250     * 320.000     * 4500.00     * 400000.     *
LP           12.000       .000       .000       .000       .000       .000       .000       .000       .000

SEDIMENT LOAD TABLE FOR STREAM SEGMENT #   1
               AT LOCAL INFLOW POINT #   2

LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQL      * 1.00000     * 100.000     * 1000.00     * 10000.0     *
LFL  VFS* .265600E-02* 6.64000     * 7.50000     * 5940.00     *
LFL   FS* .828000E-03* 2.07000     * 122.500     * 5430.00     *
LFL   MS* .344000E-03* .860000     * 302.500     * 3210.00     *
LFL   CS* .124000E-03* .310000     * 26.0000     * 2940.00     *
LFL  VCS* .320000E-04* .800000E-01* 19.5000     * 3810.00     *
LFL  VFG* .120000E-04* .300000E-01* 10.0000     * 3480.00     *
LFL   FG* .400000E-05* .100000E-01* 5.50000     * 2730.00     *
LFL   MG* .100000E-19* .100000E-19* 5.50000     * 1590.00     *
LFL   CG* .100000E-19* .100000E-19* .100000E-19* 660.000     *
LFL  VCG* .100000E-19* .100000E-19* .100000E-19* 180.000     *
          ------------ ------------ ------------ ------------
   SUM=*  .400000E-02* 10.0000     * 499.000     * 29970.0     *

.........................................................................................................

SRATING

DOWNSTREAM BOUNDARY CONDITION SPECIFIED BY A RATING CURVE

ELEVATION OF GAGE ZERO                                          .00
DISCHARGE CORRESPONDING TO LOWEST ELEVATION IN TABLE            .0
DISCHARGE INTERVAL                                          2000.0
NO. OF POINTS IN RATING TABLE                                   40
ELEVATIONS
    950.00    955.10    958.00    960.00    962.00    963.60    965.10    966.20    967.00    967.70
    968.30    968.90    969.40    969.80    970.20    970.60    971.00    971.40    971.80    972.10
    972.40    972.70    972.90    973.10    973.30    973.50    973.70    973.80    973.90    974.00
    974.10    974.20    974.30    974.40    974.50    974.60    974.70    974.80    974.90    975.00

.........................................................................................................

SPRT


PRINT AT SELECTIVE X-SECTIONS ONLY
PN           1.000      7.000       .000       .000       .000       .000       .000       .000       .000
END           .000       .000       .000       .000       .000       .000       .000       .000       .000

.........................................................................................................

SNODREDG
```

```
*    AC     FLOW 4 = BASE FLOW OF 500 CFS

BOUNDARY CONDITION DATA, CONTROL POINT NO.  1

SEGMENT     INFLOW Q IN CFS..
    1      500.0       61.0       29.0      128.0
  TIME STEP NO.        4
WATER    DISCHARGE=      500.00
          ELEVATION=    965.000
        TEMPERATURE=     65.000
FLOW DURATION(DAYS)  1.000

**** N  DISCHARGE   WATER    ENERGY  VELOCITY   ALPHA     TOP     AVG       AVG VEL (by subsection)
          (CFS)    SURFACE    LINE     HEAD              WIDTH    BED      1      2      3

SEC NO.      1.000
****  1     500.0     965.00    965.00        .00      4.47   1330.15    951.52   .02   .17   .01
                                                   FLOW DISTRIBUTION (%) =     .8  90.0   9.3

SEC NO.     42.100
****  1     439.0     974.00    974.01        .00      1.00    242.95    970.70   .00   .55   .00
                                                   FLOW DISTRIBUTION (%) =     .0 100.0    .0

EXAMPLE PROBLEM NO 4.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
FLOW # (N) =     1
FLOW...Q(N)=      282.0
TIMESTEP DURATION (DAYS) =     1.0000
ACCUMULATED TIME  (YRS)  =      .1479
WATER TEMPERATURE (DEG F)=   62.0638
***************************** FALL VELOCITY BY METHOD 2*****************************

                          DIAMETER       VELOCITY       REY. NO.          CD

                          .000288   .1841174E-01   .4491205       60.13548
                          .000580   .5773942E-01  2.836456        12.31433
                          .001160   .1329477      13.06215         4.645407
                          .002319   .2804031      55.07559         2.087675
                          .004639   .4807879     188.9094          1.420513
                          .009279   .7191504     565.1926          1.269958
                          .018560  1.039763     1634.511           1.215170
                          .037120  1.472924     4630.883           1.211086
                          .074216  2.082692    13091.77            1.211086
                          .148596  2.946998    37090.49            1.211086

SEDIMENT INFLOW (TONS/DAY)
                               TOTAL            AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY
 SANDS & GRAVELS           30.66          9.03          10.94         8.84          1.57         .29
                                           .00            .00          .00           .00          .00

THE FOLLOWING IS A LOCAL INFLOW
      L O C A L  INFLOW  POINT       :  NO.  :    Q(CFS)        :TEMP(DEG-F):
                                     :    2  :                  :           :
              LOCAL      INFLOW      :    3  : 29.0000000       :     70.00:
              MAINSTEM   INFLOW      :    1  : 410.000000       :     63.60:
              TOTAL      OUTFLOW     :    1  : 439.000000       :     64.03:

***************************** FALL VELOCITY BY METHOD 2*****************************

                          DIAMETER       VELOCITY       REY. NO.          CD

                          .000288   .1885611E-01   .4727185       57.33453
                          .000580   .5869588E-01  2.963424        11.91627
                          .001160   .1346745      13.59883         4.527048
                          .002319   .2822873      56.98364         2.059898
                          .004639   .4819037     194.6000          1.413942
                          .009279   .7197666     581.3678          1.267785
                          .018560  1.040157     1680.487           1.214248
                          .037120  1.472924     4759.336           1.211086
                          .074216  2.082692    13454.91            1.211086
                          .148596  2.946998    38119.32            1.211086
```

```
SEDIMENT INFLOW FROM LOCAL INFLOW POINT
                          TOTAL         AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY
 SANDS & GRAVELS          1.22       .81         .25         .10         .04         .01
                                     .00         .00         .00         .00         .00


****************************************************************************************************
        THE FOLLOWING TABLE IS PRINTOUT FOR CROSS SECTION     42.100
        -------------------------------------------------------


HYDRAULIC PARAMETERS:
        VEL           SLO           EFD           EFW           N-VALUE         TAU           USTARM        FROUDE
NO.
        .420        .000003        5.956        195.948          .0153         .00097         .02233
.030
BED SEDIMENT RESERVOIR COMPUTATIONS:
NEW SURFACE AREA (SQ FT):     TOTAL       K-PORTION      S-PORTION
                           324607.08    324607.08            .00
GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS
BED MATERIAL BY GRAIN SIZE FRACTION    .104572    .208994    .369921    .233720    .053457
                                       .017827    .009123    .000139    .002245    .000001
BED MATERIAL BY PERCENT FINER/100      .104572    .313567    .683488    .917207    .970665
                                       .988492    .997615    .997754    .999999   1.000000

SAND
** ARMOR LAYER **
STABILITY COEFFICIENT=      .94788
MIN.GRAIN DIAM       =     .001184
BED SURFACE EXPOSED  =     1.00000

         INACTIVE LAYER          ACTIVE LAYER
          %         DEPTH        %          DEPTH
 CLAY   .000000      .00      .000000        .00
 SILT   .000000      .00      .000000        .00
 SAND   .000000      .00     1.000000       2.46
TOTAL   .000000      .00     1.000000       2.46

      AVG. UNIT            AVG. UNIT
       WEIGHT               WEIGHT

       .000000             .046500

**BED IS ARMORED**

    COMPOSITE UNIT WT OF ACTIVE LAYER T/CF=       .046500
    WEIGHT IN SURFACE LAYER(TONS),    WTSL=            .0
    DEPTH OF NEW ACTIVE LAYER(FT),     DSE=         .0000
    WEIGHT IN NEW ACTIVE LAYER,     WTMXAL=            .0
    WEIGHT IN OLD ACTIVE LAYER,        WAL=       37098.2
    USEABLE WEIGHT, OLD INACTIVE LAY,  WIL=            .0
BED MATERIAL BY GRAIN SIZE FRACTION    .084731    .101697    .101697    .101697    .101697
                                       .101697    .101697    .101697    .101697    .101697
BED MATERIAL BY PERCENT FINER/100      .084731    .186427    .288124    .389820    .491517
                                       .593214    .694910    .796607    .898303   1.000000
** ACTIVE LAYER **
BED MATERIAL BY GRAIN SIZE FRACTION    .104572    .208994    .369921    .233720    .053457
                                       .017827    .009123    .000139    .002245    .000001
BED MATERIAL BY PERCENT FINER/100      .104572    .313567    .683488    .917207    .970665
                                       .988492    .997615    .997754    .999999   1.000000

C FINES, COEF(CFFML), MX POTENTIAL= .000000E+00 .100000E+01 .948240E+06

POTENTIAL TRANSPORT BY SIZE CLASS= .100000E-06 .100000E-06 .100000E-06 .100000E-06 .100000E-06
                                   .100000E-06 .100000E-06 .100000E-06 .100000E-06 .100000E-06
BED MATERIAL BY GRAIN SIZE FRACTION    104591     .208994    .369912    .233713    .053456
                                       .017826    .009123    .000139    .002245    .000001
BED MATERIAL BY PERCENT FINER/100      .104591    .313585    .683497    .917210    .970666
                                       .988492    .997615    .997754    .999999   1.000000
                          TOTAL         AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY
CALCULATED SEDIMENT LOAD, TONS/DAY
 SANDS & GRAVELS          .00        .00         .00         .00         .00         .00
                                     .00         .00         .00         .00         .00
```

****

THE FOLLOWING TABLE IS PRINTOUT FOR CROSS SECTION 1.000

HYDRAULIC PARAMETERS:

VEL	SLO	EFD	EFW	N-VALUE	TAU	USTARM	FROUDE NO.
.302	.000000	11.243	167.384	.0182	.00010	.00705	.016

BED SEDIMENT RESERVOIR COMPUTATIONS:

NEW SURFACE AREA (SQ FT):	TOTAL	K-PORTION	S-PORTION
	954954.00	954954.00	.00

TRANSMISSIVE BOUNDARY CONDITION = TYPE 2

BED MATERIAL BY GRAIN SIZE FRACTION	.010000	.070000	.290000	.360000	.120000
	.060000	.040000	.015000	.035000	.000000
BED MATERIAL BY PERCENT FINER/100	.010000	.080000	.370000	.730000	.850000
	.910000	.950000	.965000	1.000000	1.000000

	TOTAL	AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY				
CALCULATED SEDIMENT LOAD, TONS/DAY						
SANDS & GRAVELS	.00	.00	.00	.00	.00	.00
		.00	.00	.00	.00	.00

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 4. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
54.00	58.000	13.20		
	53.000	16.15		
TOTAL=	53.000	29.35	37.95	-.29
TIME	ENTRY		SAND	
54.00	53.000	37.95		
	42.100	.36		
TOTAL=	35.000	38.31	13.86	.64
TIME	ENTRY		SAND	
54.00	35.000	13.86		
	15.000	1.00		
TOTAL=	1.000	14.87	.72	.95

TABLE SB-1.	TOTAL	AND LOAD BY GRAIN SIZEIN TONS/DAY				
		VF	F	M	C	VC
SEDIMENT INFLOW						
SANDS & GRAVELS	30.66	9.03	10.94	8.84	1.57	.29
		.00	.00	.00	.00	.00
SEDIMENT OUTFLOW						
SANDS & GRAVELS	.00	.00	.00	.00	.00	.00
		.00	.00	.00	.00	.00

SECTION ID NO	BED CHANGE FEET	WS ELEV FEET	THALWEG EL FEET	Q CFS	SEDIMENT LOAD (TONS/DAY) SAND
58.000	-3.26	975.48	972.14	282.	20.
55.000	-1.77	974.96	971.13	282.	42.
53.000	.00	973.88	972.20	410.	0.
44.000	-3.22	974.01	964.78	410.	0.
42.100	.00	974.00	969.80	439.	0.
35.000	.00	974.00	963.30	439.	0.
33.300	.00	965.04	961.00	439.	0.
33.200	.00	965.04	961.00	439.	0.
32.000	-.38	965.04	956.12	439.	0.
15.000	.56	965.00	954.56	500.	0.

1.000	.00	965.00	944.70	500.	0.

ACCUMULATED WATER DISCHARGE FROM DAY ZERO(SFD)

MAIN	TRIB #1	TRIB #2	TRIB #3	....ETC
2750.0000				

....

SVOL A

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 4. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN

SUMMARY TABLE: MASS AND VOLUME OF SEDIMENT

SECTION	SEDIMENT PASSING SECTION IN TONS TOTAL	SAND	SILT	CLAY	SEDIMENT DEPOSITED IN REACH IN CUBIC YARDS TOTAL	ACCUMULATED	SAND	SILT	CLAY
INFLOW	26737.	26737.	0.	0.	21296.				
58.000	35457.	35457.	0.	0.	-6945.	-6945.	-6945.	0.	0.
55.000	44155.	44155.	0.	0.	-6928.	-13873.	-6928.	0.	0.
LOCAL	32721.	32721.	0.	0.	26062.				
53.000	76876.	76876.	0.	0.	0.	-13873.	0.	0.	0.
44.000	64482.	64482.	0.	0.	9871.	-4002.	9871.	0.	0.
LOCAL	733.	733.	0.	0.	583.				
42.100	28083.	28083.	0.	0.	29575.	25573.	29575.	0.	0.
35.000	28083.	28083.	0.	0.	0.	25573.	0.	0.	0.
33.300	28083.	28083.	0.	0.	0.	25574.	0.	0.	0.
33.200	28081.	28081.	0.	0.	1.	25575.	1.	0.	0.
32.000	32938.	32938.	0.	0.	-3868.	21707.	-3868.	0.	0.
LOCAL	2027.	2027.	0.	0.	1615.				
15.000	1464.	1464.	0.	0.	26684.	48391.	26684.	0.	0.
1.000	1464.	1464.	0.	0.	0.	48391.	0.	0.	0.

ACCUMULATED LOAD BY SIZE CLASS (fine to coarse, in TONS

INFLOW						
	SAND	13375.	8739.	4186.	315.	122.
		0.	0.	0.	0.	0.
RIVER MILE =	58.000					
	SAND	13404.	8933.	4334.	5002.	2195.
		1008.	364.	0.	217.	0.
RIVER MILE =	55.000					
	SAND	13337.	9190.	5091.	9958.	4272.
		1351.	608.	10.	337.	0.
RIVER MILE =	53.000					
	SAND	16102.	15314.	22849.	16033.	4272.
		1351.	608.	10.	337.	0.
RIVER MILE =	44.000					
	SAND	15348.	13536.	19465.	12040.	2992.
		671.	342.	5.	83.	0.
RIVER MILE =	42.100					
	SAND	11798.	5993.	5857.	3399.	1017.
		14.	5.	0.	0.	0.
RIVER MILE =	35.000					
	SAND	11798.	5993.	5857.	3399.	1017.
		14.	5.	0.	0.	0.
RIVER MILE =	33.300					
	SAND	11798.	5993.	5857.	3399.	1017.
		14.	5.	0.	0.	0.
RIVER MILE =	33.200					
	SAND	11798.	5993.	5857.	3399.	1017.
		13.	4.	0.	0.	0.
RIVER MILE =	32.000					
	SAND	9833.	5774.	8892.	6491.	1917.

```
                              16.        14.         2.         0.         0.
RIVER MILE =      15.000
                    SAND     158.       176.       503.       455.       163.
                               4.         3.         1.         0.         0.
RIVER MILE =       1.000
                    SAND     158.       176.       503.       455.       163.
                               4.         3.         1.         0.         0.

.....................................................................................................

SSEND


       0    DATA ERRORS DETECTED.

TOTAL NO. OF TIMESTEPS READ=          4
TOTAL NO. OF WS PROFILES=         23
ITERATIONS IN EXNER EQ  =        920.
END OF JOB

JOB COMPLETED
RUN TIME =  0 HOURS,  0 MINUTES & 57.23 SECONDS
```

6.5 Problem 5 - Reservoirs

HEC-6 simulates reservoirs by allowing the water surface elevation at the reservoir location to be a function of time, as defined by input data. The hydraulic computations are still steady state; therefore, there is no routing of the water (i.e outflow equals inflow at all times).

6.5.1 Reservoir Data

Problem 5 input is shown in Exhibit 6.11 and illustrates the data for a problem with two reservoirs; one at the downstream boundary (section 1.0) and one at section 35.0 (Silver Lake - the backwater from which extends much farther upstream than is illustrated in Figure 6.1). The reservoir at the downstream end is simulated simply by giving the time history of pool elevations on the **R** records in the flow data. The reservoir at section 35.0 is defined with an **X5** record which indicates that the pool elevations will be in field 2 of the R record. The **X5** record at section 33.3 causes sediment information to be computed between sections 1.0 and 33.3. Similarly the **X5** at section 53.0 causes information for the reach between sections 53.0 and 35.0 to be computed. Section 33.3 is at the approximate upstream extent of the pool for the downstream reservoir and section 53.0 is at the upstream end of Silver Lake. Thus the information produced can be used to analyze the behavior of the two reservoirs.

EXHIBIT 6.11 Input - Reservoir Model

```
T1       EXAMPLE PROBLEM NO 5.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
T2       2 RESERVOIRS, 3 LOCAL INFLOWS: CASCADE, SILVER AND BEAR CREEKS
T3       ORIGINAL WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW
NC   .100      .100      .040        .1        .3
X1    1.0       31.  10077.0  10275.0        0.        0.        0.        0.        0.        0.
GR1004.0    9915.0    978.40  10002.0    956.00  10060.0    959.20  10077.0    959.30  10081.0
GR950.00   10092.0    948.48  10108.0    946.60  10138.0    944.70  10158.0    955.20  10225.0
GR956.20   10243.0    958.90  10250.0    959.80  10275.0    959.80  10300.0    959.90  10325.0
GR958.80   10350.0    957.40  10400.0    970.00  10700.0    966.00  10960.0    970.00  11060.0
GR968.00   11085.0    968.00  11240.0    970.00  11365.0    970.00  11[illegible]0.0    970.00  11615.0
GR962.00   11665.0    962.00  12400.0    976.00  12550.0    980.00  12[illegible]70.0    982.00  12730.0
GR984.00   12735.0
HD      1       10.     10081     10250
NV     22       045     965.6      .064     988.8
NV     12      .080     965.6      .130     988.8
NV     33       .10     965.6       .11     982.0       .12     988.8
X1   15.0       27.  10665.0  10850.0     8565.     7535.     8268.        0.        0.        0.
X3                              10700       961     11000       970
GR992.00    9570.0    982.00  10110.0    976.00  10300.0    976.00  10490.0    966.00  10610.0
GR964.70   10665.0    956.00  10673.0    953.00  10693.0    954.00  10703.0    955.60  10723.0
```

```
GR958.60 10750.0  959.30 10800.0  957.00 10822.0  957.30 10825.0  961.50 10850.0
GR962.00 10852.0  964.00 10970.0  966.00 11015.0  961.00 11090.0  962.00 11150.0
GR970.00 11190.0  972.00 11310.0  980.00 11410.0  984.00 11570.0  990.00 11770.0
GR990.00 11865.0 1000.00 12150.0
HD     15      10.   10673   10852
QT
NC    .10      .10     .05
X1   32.0      29. 10057.0 10271.0    7429.   6654.   8240.      0.      0.      0.
GR998.00  9080.0  982.00  9250.0  982.00  9510.0  980.00  9600.0  980.01  9925.0
GR979.48 10000.0  978.50 10057.0  968.60 10075.0  959.82 10087.0  956.50 10097.0
GR956.80 10117.0  957.80 10137.0  959.40 10157.0  959.60 10177.0  959.82 10196.0
GR966.50 10225.0  971.20 10250.0  978.50 10271.0  978.50 10300.0  978.60 10350.0
GR978.91 10370.0  978.96 10387.0  980.00 10610.0  982.00 10745.0  982.00 11145.0
GR984.00 11150.0  992.00 11240.0 1000.00 11330.0  1008.0 11425.0
HD     32      10.   10075   10275
X1   33.2      21.  1850.0  2150.0     130.    250.    320.      0.      0.      0.
XL            250
GR1000.0   980.0  990.00  1060.0  980.00  1150.0  982.00  1180.0  982.00  1215.0
GR980.00  1260.0  982.00  1300.0  982.00  1350.0  980.00  1420.0  980.00  1540.0
GR982.00  1730.0  982.00  1830.0  984.41  1850.0  979.19  1851.0  961.00  1900.8
GR961.00  2099.2  976.00  2149.0  984.50  2150.0  982.00  2800.0  990.00  3100.0
GR1000.0  3170.0    0.00     0.0    0.00     0.0    0.00     0.0    0.00     0.0
HD   33.2        0    1851    2149
X1   33.3        0  1850.0  2150.0     155.    175.    175.      0.      0.      0.
X5
HD   33.3        0    1851    2149
X1   35.0      22.  9894.0 10155.0     105.    105.    105.      0.      0.      0.
X3     10
X5                               2
GR984.00  9035.0  980.00  9070.0  978.00  9135.0  980.00  9185.0  982.00  9270.0
GR980.00  9465.0  981.70  9595.0  983.70  9745.0  984.70  9894.0  963.40  9894.0
GR963.30  9954.0  967.10  9974.0  967.40 10004.0  968.20 10044.0  967.60 10054.0
GR973.40 10115.0  977.40 10120.0  983.70 10155.0  984.00 10245.0  982.00 10895.0
GR982.00 10895.0 1004.00 11085.0
HD     35        0    9954   10155
NC    .06      .06    .045
X1   42.1      32.  9880.0 10130.0    2070.   3965.   3005.      0.      0.      0.
GR996.00  7130.0  998.00  7310.0  998.00  7930.0  992.00  8205.0  990.00  8495.0
GR988.00  8780.0  986.00  8990.0  985.70  9570.0  986.45  9707.0  989.44  9857.0
GR990.00  9880.0  969.80  9881.0  969.80  9941.0  985.80  9941.0  985.80  9943.0
GR969.80  9943.0  969.80 10001.0  986.70 10001.0  986.70 10003.0  969.80 10003.0
GR969.80 10067.0  985.80 10067.0  985.80 10069.0  969.80 10069.0  969.80 10129.0
GR989.90 10130.0  989.50 10180.0  988.60 10230.0  987.60 10280.0  985.20 10430.0
GR986.80 11720.0  989.90 12310.0
HD 42.10         0    9881   10021
QT
X1   44.0      28.  9845.0 10127.0     290.    795.    495.      0.      0.      0.
XL                            9850   10200
GR1002.0  8035.0  992.00  8150.0  990.00  8305.0  990.00  8735.0  988.00  8835.0
GR996.00  9285.0  1017.6  9425.0  990.00  9505.0  986.00  9650.0  984.10  9788.0
GR980.60  9845.0  970.90  9868.0  972.20  9898.0  970.50  9968.0  967.50  9998.0
GR968.90 10028.0  967.40 10058.0  967.10 10078.0  971.90 10118.0  976.80 10127.0
GR977.80 10150.0  976.90 10193.0  982.00 10206.0  981.20 10300.0  979.20 10325.0
GR983.10 10400.0  999.80 10450.0 1002.40 10464.0
HD     44      10.    9868   10193
X1   53.0      22. 10000.0 10136.0    3366.   2831.   2941.      0.      0.      0.
X5
GR1004.0  7550.0 1000.00  7760.0  998.00  8440.0  996.00  8640.0  996.00  8780.0
GR994.00  8940.0  986.00  9245.0  986.30  9555.0  986.30  9825.0  983.80  9900.0
GR982.80 10000.0  978.20 10011.0  974.00 10041.0  972.20 10071.0  972.60 10101.0
GR978.20 10121.0  988.70 10136.0  989.30 10154.0  999.20 10200.0  1000.1 10320.0
GR1002.0 10470.0 1004.00 10700.0
HD     53      10.   10000   10136
QT
X1   55.0      18.  9931.0 10062.0     275.   1430.    770.      0.      0.      0.
GR1004.0  7592.0 1000.00  7947.0  996.00  8627.0  990.00  9052.0  988.00  9337.0
GR984.30  9737.0  984.70  9837.0  985.50  9910.0  987.20  9931.0  978.10  9955.0
GR974.80  9975.0  974.20 10005.0  972.90 10035.0  973.20 10045.0  983.80 10062.0
GR985.80 10187.0  986.00 10307.0  990.00 10497.0
HD     55      10.    9931   10062
X1   58.0      22.  9912.0 10015.0    1097.   1012.   1462.      0.      0.      0.
GR1006.0  8542.0 1004.00  8952.0 1000.00  9702.0  997.20  9812.0  996.30  9912.0
GR976.20  9944.0  975.40  9974.0  978.20  9991.0  990.40 10015.0  988.30 10062.0
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GR988.80 10065.0  988.30 10065.0  989.30 10169.0  990.00 10172.0  992.00 10242.0
GR992.00 10492.0  988.00 10642.0  986.70 10852.0  988.00 11022.0  986.00 11097.0
GR986.00 11137.0  988.00 11192.0
HD     58     3.4    9912   10015
EJ
T4       MAIN STEM, SEGMENT 1, SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
T5       LOAD CURVE FROM USGS DATA AT USGS GAGE: 5 PERCENT ADDED FOR BED LOAD
T6       BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T7       ENCODED BY DAVID WILLIAMS, WES, SEPT 1982
T8       SEDIMENT TRANSPORT BY STREAM POWER: SEE ASCE JOURNAL (YANG 1971)
I1       0          5
I4   SAND           4
I5                 .5        .5       .25        .5       .25         0       1.0
LQ                  1        50      1000      5800     90000
LT TOTAL        .0110       1.5       320     4500.    400000
LF    VFS        .119      .119      .498      .511      .582
LF     FS        .328      .328      .331      .306      .280
LF     MS        .553      .553      .156      .154      .110
LF     CS        .000      .000      .011      .016      .020
LF    VCS        .000      .000      .004      .008      .005
LF    VFG        .000      .000      .000      .004      .002
LF     FG        .000      .000      .000      .001      .001
LF     MG        .000      .000      .000      .000      .000
LF     CG        .000      .000      .000      .000      .000
LF    VCG          .0        .0      .000      .000      .000
PF EXAMP          1.0       1.0      32.0      16.0      96.5       8.0      95.0       4.0      91.0
PFC   2.0        85.0       1.0      73.0        .5      37.0       .25       8.0      .125       1.0
PFC.0625          0.0
PF EXAMP         32.0       1.0      64.0      32.0      99.5      16.0      99.0       8.0      98.5
PFC   4.0        96.0       2.0      93.5       1.0      83.0       .50      45.5      .250       8.0
PFC .125          1.0     .0625       0.0
PF EXAMP         58.0       1.0      64.0      32.0      97.0      16.0      94.0       8.0      94.0
PFC   4.0        90.0       2.0      79.0       1.0      56.0       .50       4.0      .125       0.0
$LOCAL
LQL                 1       100      1000     10000
LTLTOTAL        .0040        10       500     30000
LFL   VFS        .664      .664      .015      .198
LFL    FS        .207      .207      .245      .181
LFL    MS        .086      .086      .605      .107
LFL    CS        .031      .031      .052      .098
LFL   VCS        .008      .008      .039      .127
LFL   VFG       .0030     .0030     .0200     .1160
LFL    FG       .0010     .0010     .0110     .0910
LFL    MG        0000      0000     .0110      0530
LFL    CG       .0000     .0000     .0000     .0220
LFL   VCG       .0000     .0000     .0000     .0060
LQL                 1       100      1000     10000
LTLTOTAL        .0040        10       500     30000
LFL   VFS        .664      .664      .015      .198
LFL    FS        .207      .207      .245      .181
LFL    MS        .086      .086      .605      .107
LFL    CS        .031      .031      .052      .098
LFL   VCS        .008      .008      .039      .127
LFL   VFG       .0030     .0030     .0200     .1160
LFL    FG       .0010     .0010     .0110     .0910
LFL    MG       .0000     .0000     .0110     .0530
LFL    CG       .0000     .0000     .0000     .0220
LFL   VCG       .0000     .0000     .0000     .0060
LQL                1.      100.      500.     1000.    30000.
LTLTOTAL        .0020      10.0      500.      1200     22500
LFL   VFS        .201      .201      .078      .078      .137
LFL    FS        .342      .342      .172       175      .218
LFL    MS        .451      .451      .454      .601      .476
LFL    CS        .001      .001      .197      .142      .158
LFL   VCS        .000      .000      .000      .003      .008
LFL   VFG       .0000      .000     .0000     .0000     .0020
LFL    FG       .0000      .000     .0000     .0000     .0010
LFL    MG       .0000      .000     .0000     .0000     .0000
LFL    CG       .0000      .000     .0000     .0000     .0000
LFL   VCG       .0000      .000     .0000     .0000     .0000
$HYD
$VOL  X             0
VJ     16
```

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VR   944     946      948      950      952      954      956      958      960      962
VR   964     966      968      970      972      974
*    AB      FLOW 1 = BASE FLOW OF 500 CFS
Q    500      61       29      128
R   960.    974.0
T     65      72       70       67
W      2
*    B       FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE
Q 2500.0     300.     150.     650.
R   965.    975.0
X             2.5      50.
*    B       FLOW 3 = NEAR BANK FULL DISCHARGE
Q  1250.     150.      78.     340.
R   963.    975.0
W     1.
*    B       FLOW 4 = BASE FLOW OF 500 CFS
Q   500.      61       29      128
R   960.    974.5
W     1.
$VOL  XA
VJ    16       0
VR   944     946      948      950      952      954      956      958      960      962
VR   964     966      968      970      972      974
$$END
```

6.5.2 Data for Elevation-Surface Area and Elevation-Storage Tables

Output tables of elevation-surface area and elevation-storage can be obtained by use of the **$VOL**, **VJ**, and **VR** records in the flow data. For this example we are requesting that this information be computed for a series of horizontal planes extending from elevation 944 ft. (the approximate thalweg of section 1.0) to elevation 974 ft. (the approximate thalweg of section 53.0) in 2 foot increments. One should take care that the endpoints of each cross section are higher than these elevations; otherwise, the program will extend the ends of the sections vertically and the surface areas and volumes will be too small.

6.5.3 Output Elevation-Area and Elevation-Volume for Reservoirs

Portions of the output file for example 5 are shown in Exhibit 6.12. Much of the output is similar to that of previous examples. Tables are presented containing areas and volumes below each elevation specified on the **VR** records from each section to the downstream boundary. For example at section 33.2, which is at the upstream end of the downstream reservoir, the initial storage volume at elevation 968 ft. is 1582 acre-ft.; at the end it is 1575 acre-ft. This means that 7 acre-ft was deposited between sections 33.2 and 1.0 below elevation 968 ft. Similarly, this information could be found for Silver Lake by computing the differences between values at sections 35.0 and 53.0. One only needs to use information in the table for elevations above the thalweg of the section at the dam of interest. These tables can be used to construct elevation-deposition and deposition-distance relations.

EXHIBIT 6.12 Output - Reservoir Model

```
*****************************************************************************************
*              INPUT FILE: EX5.DAT                                                      *
*              OUTPUT FILE: EX5.OUT                                                     *
*****************************************************************************************

==========================================================================================

BEGIN COMPUTATIONS.
$HYD

..........................................................................................

$VOL   X          0
```

STREAM SEGMENT # 1: EXAMPLE PROBLEM NO 5. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN

SUMMARY TABLE: MASS AND VOLUME OF SEDIMENT

SECTION	SEDIMENT PASSING SECTION IN TONS				SEDIMENT DEPOSITED IN REACH IN CUBIC YARDS				
	TOTAL	SAND	SILT	CLAY	TOTAL	ACCUMULATED	SAND	SILT	CLAY
INFLOW	0.	0.	0.	0.	0.				
58.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
55.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
53.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
44.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
42.100	0.	0.	0.	0.	0.	0.	0.	0.	0.
35.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
33.300	0.	0.	0.	0.	0.	0.	0.	0.	0.
33.200	0.	0.	0.	0.	0.	0.	0.	0.	0.
32.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
15.000	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.000	0.	0.	0.	0.	0.	0.	0.	0.	0.

	ELEV	SURFACE AREA	VOLUME AC-FT	VOLUME CY
RIVER MILE	1.000			
	974.00	0.	0.	0.
RIVER MILE	15.000			
	944.00	0.	0.	0.
	946.00	2.	1.	2187.
	948.00	6.	9.	14910.
	950.00	9.	25.	40204.
	952.00	11.	45.	73087.
	954.00	12.	69.	110602.
	956.00	17.	98.	157542.
	958.00	26.	139.	223548.
	960.00	52.	214.	345548.
	962.00	123.	325.	524725.
	964.00	141.	589.	950996.
	966.00	156.	884.	1426941.
	968.00	196.	1222.	1972254.
	970.00	272.	1654.	2668188.
	972.00	287.	2214.	3571238.
	974.00	294.	2795.	4509757.
RIVER MILE	32.000			
	944.00	0.	0.	0.
	946.00	2.	1.	2187.
	948.00	6.	9.	14910.
	950.00	9.	25.	40204.
	952.00	11.	45.	73087.
	954.00	12.	69.	110602.
	956.00	20.	100.	161750.
	958.00	37.	153.	247166.
	960.00	76.	263.	424052.
	962.00	152.	427.	688610.
	964.00	180.	759.	1224057.
	966.00	202.	1137.	1835010.
	968.00	246.	1572.	2536276.
	970.00	341.	2109.	3402593.
	972.00	368.	2818.	4546617.
	974.00	380.	3566.	5753715.
RIVER MILE	33.200			
	944.00	0.	0.	0.
	946.00	2.	1.	2187.
	948.00	6.	9.	14910.
	950.00	9.	25.	40204.
	952.00	11.	45.	73087.
	954.00	12.	69.	110602.
	956.00	20.	100.	161750.
	958.00	37.	153.	247430.
	960.00	76.	264.	425136.

	962.00	153.	429.	692260.
	964.00	182.	763.	1231709.
	966.00	203.	1145.	1846942.
	968.00	248.	1582.	2552775.
	970.00	342.	2122.	3423962.
	972.00	370.	2835.	4573164.
	974.00	382.	3586.	5785705.
RIVER MILE	33.300			
	944.00	0.	0.	0.
	946.00	2.	1.	2187.
	948.00	6.	9.	14910.
	950.00	9.	25.	40204.
	952.00	11.	45.	73087.
	954.00	12.	69.	110602.
	956.00	20.	100.	161750.
	958.00	37.	153.	247430.
	960.00	76.	264.	425136.
	962.00	154.	430.	693566.
	964.00	182.	766.	1235743.
	966.00	204.	1149.	1853863.
	968.00	249.	1588.	2562738.
END AREA , U/S	0.	1955.	0.	
END AREA , D/S	582.	2474.	1768.	
	974.00	380.	3559.	5741354.
WIDTH , U/S	0.	193.	0.	
WIDTH , D/S	151.	185.	485.	
REACH LENGTH	7429.	8240.	6654.	
END AREA , U/S	0.	2331.	0.	
END AREA , D/S	860.	2844.	2713.	
RIVER MILE	33.200			
	944.00	0.	0.	0.
WIDTH , U/S	0.	0.	0.	
WIDTH , D/S	0.	0.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	0.	0.	
END AREA , D/S	0.	0.	0.	
	946.00	2.	1.	1591.
WIDTH , U/S	0.	0.	0.	
WIDTH , D/S	0.	0.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	0.	0.	
END AREA , D/S	0.	0.	0.	
	948.00	6.	8.	13117.
WIDTH , U/S	0.	0.	0.	
WIDTH , D/S	0.	0.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	0.	0.	
END AREA , D/S	0.	0.	0.	
	950.00	9.	23.	37329.
WIDTH , U/S	0.	0.	0.	
WIDTH , D/S	0.	0.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	0.	0.	
END AREA , D/S	0.	0.	0.	
	952.00	11.	43.	69743.
WIDTH , U/S	0.	0.	0.	
WIDTH , D/S	0.	0.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	0.	0.	
END AREA , D/S	0.	0.	0.	
	954.00	12.	66.	106816.
WIDTH , U/S	0.	0.	0.	
WIDTH , D/S	0.	0.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	0.	0.	
END AREA , D/S	0.	0.	0.	
	956.00	19.	97.	156100.
WIDTH , U/S	0.	0.	0.	

WIDTH , D/S	0.	0.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	0.	0.	
END AREA , D/S	0.	0.	0.	
958.00	36.	149.	240938.	
WIDTH , U/S	0.	0.	0.	
WIDTH , D/S	0.	49.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	0.	0.	
END AREA , D/S	0.	52.	0.	
960.00	76.	258.	415767.	
WIDTH , U/S	0.	0.	0.	
WIDTH , D/S	0.	111.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	0.	0.	
END AREA , D/S	0.	200.	0.	
962.00	153.	422.	681583.	
WIDTH , U/S	0.	204.	0.	
WIDTH , D/S	0.	122.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	197.	0.	
END AREA , D/S	0.	433.	0.	
964.00	182.	756.	1218876.	
WIDTH , U/S	0.	216.	0.	
WIDTH , D/S	0.	134.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	618.	0.	
END AREA , D/S	0.	589.	0.	
966.00	203.	1137.	1834338.	
WIDTH , U/S	0.	229.	0.	
WIDTH , D/S	0.	145.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	1063.	0.	
END AREA , D/S	0.	968.	0.	
968.00	248.	1575.	2540392.	
WIDTH , U/S	0.	241.	0.	
WIDTH , D/S	0.	158.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	1532.	0.	
END AREA , D/S	0.	1270.	0.	
970.00	342.	2115.	3411696.	
WIDTH , U/S	0.	253.	0.	
WIDTH , D/S	0.	171.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	2026.	0.	
END AREA , D/S	0.	1599.	0.	
972.00	370.	2827.	4560916.	
WIDTH , U/S	0.	265.	0.	
WIDTH , D/S	0.	183.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	2544.	0.	
END AREA , D/S	0.	1955.	0.	
974.00	382.	3579.	5773457.	
WIDTH , U/S	0.	277.	0.	
WIDTH , D/S	0.	193.	0.	
REACH LENGTH	130.	320.	250.	
END AREA , U/S	0.	3086.	0.	
END AREA , D/S	0.	2331.	0.	

RIVER MILE 33.300				
944.00	0.	0.	0.	
WIDTH , U/S	0.	0.	0.	
WIDTH , D/S	0.	0.	0.	
REACH LENGTH	155.	175.	175.	
END AREA , U/S	0.	0.	0.	
END AREA , D/S	0.	0.	0.	
946.00	2.	1.	1591.	
WIDTH , U/S	0.	0.	0.	
WIDTH , D/S	0.	0.	0.	
REACH LENGTH	155.	175.	175.	
END AREA , U/S	0.	0.	0.	
END AREA , D/S	0.	0.	0.	

```
.............................................................................................................
SSEND


        0    DATA ERRORS DETECTED.

TOTAL NO. OF TIMESTEPS READ=          4
TOTAL NO. OF WS PROFILES=         23
ITERATIONS IN EXNER EQ  =       1265.
END OF JOB

JOB COMPLETED
RUN TIME =  0 HOURS,  0 MINUTES & 57.07 SECONDS
```

6.5.4 Trap Efficiency

The computation of trap efficiency and interpretation of Table SA-1 was presented in section 6.4.7 for problem 3. Note that here the X5 records were used to delineate the upstream and downstream extent of the reservoirs causing trap efficiency to be computed for them. For example, Silver Lake extends from downstream of section 53.0 to section 35.0. So, from table SA-1 at the end of the simulation, 32.22 acre-ft. has entered Silver Lake from upstream, 0.34 acre-ft. from Silver Creek and 6.91 acre-ft have passed through Silver Lake giving it a trap efficiency of 79% at that time. The downstream reservoir has a trap efficiency of 100%. Negative trap efficiencies indicate scour.

6.6 Problem 6 - River Network System

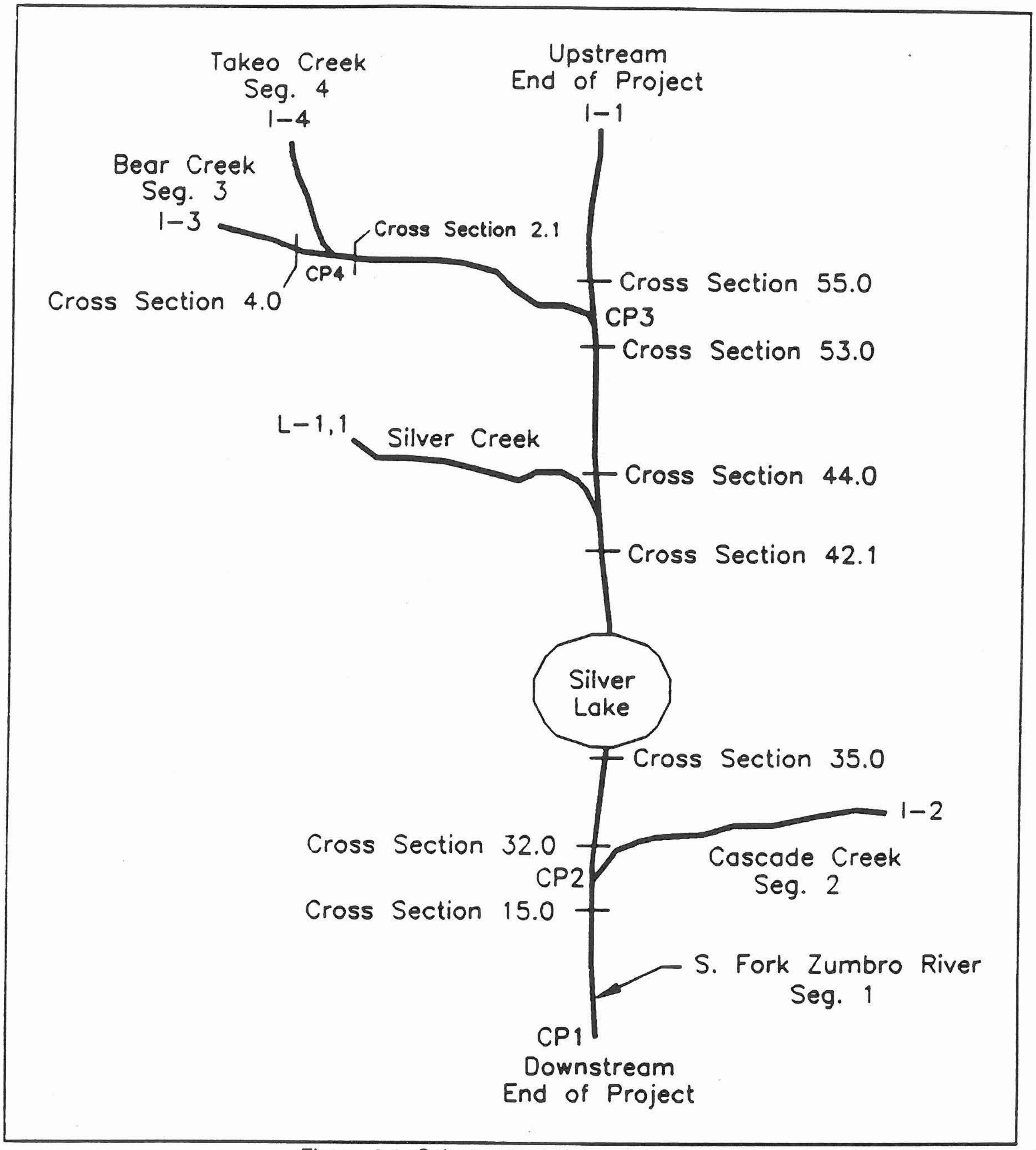

Figure 6.4 Schematic of Network System

This example problem adds tributaries to the existing problem. Tributaries are described with cross section and sediment data; therefore, sediment transport and bed movement is calculated for the tributaries as well as for the main stem. See section 3.6 for a detailed description of data preparation for network systems. It is suggested that the data for each segment of the system be tested and corrected separately so that any subsequent errors are due to the construction of the network system data and not due to errors in any individual segments. A schematic of the system is shown on Figure 6.4. Silver Creek is treated as a local inflow, all other segments are tributaries. Note that Takeo Creek is tributary to Bear Creek.

6.6.1 Network Layout and Numbering

The numbering of stream segments and control points must follow the scheme presented in section 3.6. This is shown for problem 6 in Figure 6.4. The stream segments, control points (CP), and inflows are numbered from downstream to upstream. The control points are numbered first, then each tributary is given a segment number that corresponds to the control point at its confluence with another segment or the main stem. The inflow points of each segment are then numbered corresponding to the segment number, e.g. the inflow to Bear Creek is designated I-3. Silver Creek is the only local inflow, so it is designated L-1,1, with the first number being the segment into which it flows and the second being which local it is on that segment.

EXHIBIT 6.13 Input - Network System

```
T1       EX. PB. #6., NETWORK, MAIN STEM: LOWER S. FORK ZUMBRO R., ROCHESTER, MN
T2       CASCADE AND BEAR CKS ARE TRIBS, TAKEO CK IS TRIB OF BEAR CK, SILVER CK
T3       IS LOCAL, ORIG. WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW
NC  .100    .100    .040      .1      .3
X1   1.0     31. 10077.0 10275.0      0.      0.      0.      0.      0.      0.
GR1004.0  9915.0  978.40 10002.0  956.00 10060.0  959.20 10077.0  959.30 10081.0
GR950.00 10092.0  948.48 10108.0  946.60 10138.0  944.70 10158.0  955.20 10225.0
GR956.20 10243.0  958.90 10250.0  959.80 10275.0  959.80 10300.0  959.90 10325.0
GR958.80 10350.0  957.40 10400.0  970.00 10700.0  966.00 10960.0  970.00 11060.0
GR968.00 11085.0  968.00 11240.0  970.00 11365.0  970.00 11500.0  970.00 11615.0
GR962.00 11665.0  962.00 12400.0  976.00 12550.0  980.00 12670.0  982.00 12730.0
GR984.00 12735.0
HD     1     10.   10081   10250
NV    12    .080   965.6    .130   988.8
NV    22    .045   965.6    .064   988.8
NV    33     .10   965.6     .11   982.0     .12   988.8
X1  15.0     27. 10665.0 10850.0   8565.   7535.   8268.      0.      0.      0.
X3                         10700     961   11000     970
GR992.00  9570.0  982.00 10110.0  976.00 10300.0  976.00 10490.0  966.00 10610.0
GR964.70 10665.0  956.00 10673.0  953.00 10693.0  954.00 10703.0  955.60 10723.0
GR958.60 10750.0  959.30 10800.0  957.00 10822.0  957.30 10825.0  961.50 10850.0
GR962.00 10852.0  964.00 10970.0  966.00 11015.0  961.00 11090.0  962.00 11150.0
GR970.00 11190.0  972.00 11310.0  980.00 11410.0  984.00 11570.0  990.00 11770.0
GR990.00 11865.0 1000.00 12150.0
HD    15     10.   10673   10852
QT     2
NC   .10     .10     .05
X1  32.0     29. 10057.0 10271.0   7429.   6654.   8240.      0.      0.      0.
GR998.00  9080.0  982.00  9250.0  982.00  9510.0  980.00  9600.0  980.01  9925.0
GR979.48 10000.0  978.50 10057.0  968.60 10075.0  959.82 10087.0  956.50 10097.0
GR956.80 10117.0  957.80 10137.0  959.40 10157.0  959.60 10177.0  959.82 10196.0
GR966.50 10225.0  971.20 10250.0  978.50 10271.0  978.50 10300.0  978.60 10350.0
GR978.91 10370.0  978.96 10387.0  980.00 10610.0  982.00 10745.0  982.00 11145.0
GR984.00 11150.0  992.00 11240.0 1000.00 11330.0  1008.0 11425.0
HD    32     10.   10075   10275
X1  33.2     21.  1850.0  2150.0    130.    250.    320.      0.      0.      0.
XL           250
GR1000.0   980.0  990.00  1060.0  980.00  1150.0  982.00  1180.0  982.00  1215.0
GR980.00  1260.0  982.00  1300.0  982.00  1350.0  980.00  1420.0  980.00  1540.0
GR982.00  1730.0  982.00  1830.0  984.41  1850.0  979.19  1851.0  961.00  1900.8
GR961.00  2099.2  976.00  2149.0  984.50  2150.0  982.00  2800.0  990.00  3100.0
GR1000.0  3170.0    0.00     0.0    0.00     0.0    0.00     0.0    0.00     0.0
HD  33.2       0    1851    2149
X1  33.3       0  1850.0  2150.0    155.    175.    175.      0.      0.      0.
HD  33.3       0    1851    2149
X1  35.0     22.  9894.0 10155.0    105.    105.    105.      0.      0.      0.
X3    10
X5                             2
GR984.00  9035.0  980.00  9070.0  978.00  9135.0  980.00  9185.0  982.00  9270.0
GR980.00  9465.0  981.70  9595.0  983.70  9745.0  984.70  9894.0  963.40  9894.0
GR963.30  9954.0  967.10  9974.0  967.40 10004.0  968.20 10044.0  967.60 10054.0
GR973.40 10115.0  977.40 10120.0  983.70 10155.0  984.00 10245.0  982.00 10695.0
```

```
GR982.00 10895.0 1004.00 11085.0
HD    35       0    9954   10155
NC   .06     .06    .045
X1  42.1     32.  9880.0 10130.0   2070.   3965.   3005.      0.      0.      0.
GR996.00  7130.0  998.00  7310.0  998.00  7930.0  992.00  8205.0  990.00  8495.0
GR988.00  8780.0  986.00  8990.0  985.70  9570.0  986.45  9707.0  989.44  9857.0
GR990.00  9880.0  969.80  9881.0  969.80  9941.0  985.80  9941.0  985.80  9943.0
GR969.80  9943.0  969.80 10001.0  986.70 10001.0  986.70 10003.0  969.80 10003.0
GR969.80 10067.0  985.80 10067.0  985.80 10069.0  969.80 10069.0  969.80 10129.0
GR989.90 10130.0  989.50 10180.0  988.60 10230.0  987.60 10280.0  985.20 10430.0
GR986.80 11720.0  989.90 12310.0
HD 42.10       0    9881   10021
QT
X1  44.0     28.  9845.0 10127.0    290.    795.    495.      0.      0.      0.
XL                          9850   10200
GR1002.0  8035.0  992.00  8150.0  990.00  8305.0  990.00  8735.0  988.00  8835.0
GR996.00  9285.0  1017.6  9425.0  990.00  9505.0  986.00  9650.0  984.10  9788.0
GR980.60  9845.0  970.90  9868.0  972.20  9898.0  970.50  9968.0  967.50  9998.0
GR968.90 10028.0  967.40 10058.0  967.10 10078.0  971.90 10118.0  976.80 10127.0
GR977.80 10150.0  976.90 10193.0  982.00 10206.0  981.20 10300.0  979.20 10325.0
GR983.10 10400.0  999.80 10450.0 1002.40 10464.0
HD    44     10.    9868   10193
X1  53.0     22. 10000.0 10136.0   3366.   2831.   2941.      0.      0.      0.
X5
GR1004.0  7550.0 1000.00  7760.0  998.00  8440.0  996.00  8640.0  996.00  8780.0
GR994.00  8940.0  986.00  9245.0  986.30  9555.0  986.30  9825.0  983.80  9900.0
GR982.80 10000.0  978.20 10011.0  974.00 10041.0  972.20 10071.0  972.60 10101.0
GR978.20 10121.0  988.70 10136.0  989.30 10154.0  999.20 10200.0  1000.1 10320.0
GR1002.0 10470.0 1004.00 10700.0
HD    53     10.   10000   10136
QT     3
X1  55.0     18.  9931.0 10062.0    275.   1430.    770.      0.      0.      0.
GR1004.0  7592.0 1000.00  7947.0  996.00  8627.0  990.00  9052.0  986.00  9337.0
GR984.30  9737.0  984.70  9837.0  985.50  9910.0  987.20  9931.0  978.10  9955.0
GR974.80  9975.0  974.20 10005.0  972.90 10035.0  973.20 10045.0  983.80 10062.0
GR985.80 10187.0  986.00 10307.0  990.00 10497.0
HD    55     10.    9931   10062
X1  58.0     22.  9912.0 10015.0   1097.   1012.   1462.      0.      0.      0.
GR1006.0  8542.0 1004.00  8952.0 1000.00  9702.0  997.20  9812.0  996.30  9912.0
GR976.20  9944.0  975.40  9974.0  978.20  9991.0  990.40 10015.0  988.30 10062.0
GR988.80 10065.0  988.30 10065.0  989.30 10169.0  990.00 10172.0  992.00 10242.0
GR992.00 10492.0  988.00 10642.0  986.70 10852.0  988.00 11022.0  986.00 11097.0
GR986.00 11137.0  988.00 11192.0
HD    58     3.4    9912   10015
EJ
STRIB               CASCADE GEOMETRY, SEGMENT 2, CONTROL POINT 2
CP     2
T1      EXAMPLE 6 (CONTINUED) CASCADE CREEK GEOMETRY, SEG. 2, CP2
T2      EXISTING CONDITIONS
T3      DAVID WILLIAMS, WES, OCT 1982, ADAPTED 1989 BY DAVID T. WILLIAMS
NC  .120    .120    .045      .1      .3
X1   1.0     25.  5000.0  5100.0      0.      0.      0.      0.      0.      0.
GR995.00  4570.0  980.00  4600.0  970.00  4690.0  968.00  4740.0  968.00  4850.0
GR965.24  4900.0  964.60  4950.0  964.00  4975.0  963.70  5000.0  961.50  5003.0
GR959.80  5014.0  960.20  5025.0  959.90  5038.0  960.10  5068.0  960.40  5073.0
GR962.50  5075.0  963.10  5083.0  968.90  5094.0  969.60  5100.0  970.30  5150.0
GR970.00  5260.0  972.00  5280.0  972.00  5400.0  980.00  5460.0   982.0   5780.
H      1            4925    5121
X1   3.0     24.  4942.0  5050.0    460.    280.    537.      0.      0.      0.
GR1000.0    4715   983.9    4897  982.90  4942.0  973.20  4959.0  973.00  4967.0
GR970.20  5000.0  964.78  5007.0  964.30  5017.0  965.10  5027.0  965.17  5027.0
GR968.70  5042.0  969.90  5050.0  969.40  5067.0  971.10  5092.0  970.30  5103.0
GR 972.7  5180.0     970    5207   972.8    5217   971.1    5242   970.7    5267
GR 975.2   5277.  976.56    5300     980    5360     982    5690
H      3   964.3    4942    5103
X1   4.0     18.  4950.0  5045.0    300.    280.    240.      0.      0.      0.
GR1000.0  4775.0  991.30  4875.0  988.10  4931.0  981.60  4941.0  981.70  4950.0
GR975.40  4961.0  972.90  4975.0  970.60  5004.0  968.30  5015.0  969.20  5025.0
GR969.40  5040.0  981.20  5045.0  981.20  5075.0  985.70  5082.0  985.90  5100.0
GR  980.    5270     982    5330     982    5700
H      4   968.3    4950    5047
X1   6.2     17.  5000.0  5130.0    405.    350.    474.      0.      0.      0.
X3   10.
```

```
GR994.00  4700.0  990.00  4720.0  986.00  4750.0  986.00  4940.0  987.40  5000.0
GR983.10  5000.0  979.00  5016.0  972.00  5032.0  972.00  5092.0  974.00  5100.0
GR976.00  5109.0  982.70  5126.0  987.50  5130.0  986.00  5210.0  980.00  5420.0
GR980.00  5830.0  982.00  5900.0    0.00     0.0    0.00     0.0    0.00     0.0
H   6.20     972    5000    5130
EJ
STRIB              BEAR CREEK GEOMETRY,  SEGMENT 3 CONTROL POINT 3
CP      3
T1       EXAMPLE 6 (CONTINUED) BEAR CREEK GEOMETRY, SEG. 3, CP3
T2       EXISTING CONDITIONS
T3       DAVID WILLIAMS, WES, OCT 1982, ADAPTED 1989, DAVID T. WILLIAMS
NC  .090    .090    .046      .3      .5
X1   1.0     19. 10115.0 10250.0      0.      0.      0.      0.      0.      0.
GR  996.   9020.    990.   9420.    988.   9550.    994.   9780.  985.30 10055.0
GR985.00 10115.0  978.18 10137.0  977.20 10147.0  977.00 10157.0  977.10 10200.0
GR978.20 10209.0  981.60 10216.0  982.80 10225.0  984.70 10250.0  985.90 10275.0
GR987.10 10300.0   988.0  10380.   990.0  10560.   1000.  10890.
H      1           10115   10275
X1   2.1     21.  1511.0  1629.0    210.    310.    260.      0.      0.      0.
GR 995.2    600.    992.    790.    990.    970.    990.    971.    990.    972.
GR    989    1000     988    1080     988    1290     990    1450   990.8    1490
GR 989.8    1493   986.7    1511   977.3    1516   977.3    1629   986.7    1629
GR 990.7    1650     988    1840     992    2000     994    2100     998    2450
GR  1002    2580
H   2.10            1511    1629
QT     4
X1   4.0     30. 10537.0 10660.0   1053.    533.    708.      0.      0.      0.
GR998.00  8370.0  997.00  8860.0  998.30  9100.0  994.50  9350.0  996.00  9480.0
GR999.00  9560.0  996.00  9640.0  994.00  9900.0  992.00  9980.0  993.90 10400.0
GR994.00 10425.0  995.20 10506.0  993.10 10523.0  986.30 10537.0  986.00 10550.0
GR985.80 10561.0  980.90 10570.0  978.70 10585.0  978.30 10595.0  978.40 10600.0
GR980.50 10625.0  980.80 10636.0  991.77 10657.0  992.30 10660.0  991.30 10675.0
GR991.40 10700.0  998.00 10970.0  998.00 11120.0 1000.00 11290.0  1006.0 11400.0
H      4   978.3   10537   10660
X1   6.0     29. 10100.0 10222.0    330.    570.    665.      0.      0.      0.
X3    10
GR998.00  8500.0  997.10  8650.0 1000.00  8900.0 1002.00  9110.0 1001.00  9400.0
GR999.80  9525.0 1002.00  9610.0 1002.00  9730.0 1000.00  9840.0  995.16 10000.0
GR995.60 10100.0  994.20 10109.0  990.80 10125.0  987.30 10140.0  985.80 10150.0
GR986.20 10161.0  985.24 10162.0  983.30 10172.0  983.30 10182.0  982.80 10202.0
GR985.24 10210.0  992.00 10222.0  992.20 10250.0  993.50 10300.0  994.20 10325.0
GR1000.0 10470.0  997.80 10640.0  998.00 10770.0 1004.60 10910.0
H      6   982.7   10100   10325
EJ
STRIB              TAKEO CREEK GEOMETRY, SEGMENT 4, CONTROL POINT 4
CP      4
T1       EXAMPLE 6 (CONTINUED) TAKEO CREEK GEOMETRY, SEG. 4, CP4
T2       EXISTING CONDITIONS
T3       DAVID WILLIAMS, WES, OCT 1982, ADAPTED 1989 BY DAVID T. WILLIAMS
NC  .090    .090    .046      .3      .5
X1   1.0     19. 10115.0 10250.0      0.      0.      0.      0.      2.      0.
GR  996.   9020.    990.   9420.    988.   9550.    994.   9780.  985.30 10055.0
GR985.00 10115.0  978.18 10137.0  977.20 10147.0  977.00 10157.0  977.10 10200.0
GR978.20 10209.0  981.60 10216.0  982.80 10225.0  984.70 10250.0  985.90 10275.0
GR987.10 10300.0   988.0  10380.   990.0  10560.   1000.  10890.
H      1           10115   10275
X1   2.1     21.  1511.0  1629.0    210.    310.    260.      0.      2.      0.
GR 995.2    600.    992.    790.    990.    970.    990.    971.    990.    972.
GR    989    1000     988    1080     988    1290     990    1450   990.8    1490
GR 989.8    1493   986.7    1511   977.3    1516   977.3    1629   986.7    1629
GR 990.7    1650     988    1840     992    2000     994    2100     998    2450
GR  1002    2580
H   2.10            1511    1629
X1   4.0     30. 10537.0 10660.0   1053.    533.    708.      0.      2.      0.
GR998.00  8370.0  997.00  8860.0  998.30  9100.0  994.50  9350.0  996.00  9480.0
GR999.00  9560.0  996.00  9640.0  994.00  9900.0  992.00  9980.0  993.90 10400.0
GR994.00 10425.0  995.20 10506.0  993.10 10523.0  986.30 10537.0  986.00 10550.0
GR985.80 10561.0  980.90 10570.0  978.70 10585.0  978.30 10595.0  978.40 10600.0
GR980.50 10625.0  980.80 10636.0  991.77 10657.0  992.30 10660.0  991.30 10675.0
GR991.40 10700.0  998.00 10970.0  998.00 11120.0 1000.00 11290.0  1006.0 11400.0
H      4   978.3   10537   10660
X1   6.0     29. 10100.0 10222.0    330.    570.    665.      0.      2.      0.
X3    10
```

```
GR998.00  8500.0  997.10  8650.0 1000.00  8900.0 1002.00  9110.0 1001.00  9400.0
GR999.80  9525.0 1002.00  9610.0 1002.00  9730.0 1000.00  9840.0  995.16 10000.0
GR995.60 10100.0  994.20 10109.0  990.80 10125.0  987.30 10140.0  985.80 10150.0
GR986.20 10161.0  985.24 10162.0  983.30 10172.0  983.30 10182.0  982.80 10202.0
GR985.24 10210.0  992.00 10222.0  992.20 10250.0  993.50 10300.0  994.20 10325.0
GR1000.0 10470.0  997.80 10640.0  998.00 10770.0 1004.60 10910.0
H       6   982.7   10100   10325
EJ
T4      MAIN STEM, SEGMENT 1, CONTROL POINT 1, S. FORK ZUMBRO R., ROCHESTER, MN
T5      LOAD CURVE FROM USGS DATA AT USGS GAGE: 5 PERCENT ADDED FOR BED LOAD
T6      BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T7      ENCODED BY DAVID WILLIAMS, WES, SEPT 1982
T8      SEDIMENT TRANSPORT BY STREAM POWER: SEE ASCE JOURNAL (YANG 1971)
I1      0       5
I4  SAND        4
I5             .5      .5     .25      .5     .25       0     1.0
LQ              1      50    1000    5800   90000
LT TOTAL    .0110     1.5     320   4500.  400000
LF   VFS     .119    .119    .498    .511    .582
LF    FS     .328    .328    .331    .306    .280
LF    MS     .553    .553    .156    .154    .110
LF    CS     .000    .000    .011    .016    .020
LF   VCS     .000    .000    .004    .008    .005
LF   VFG     .000    .000    .000    .004    .002
LF    FG     .000    .000    .000    .001    .001
LF    MG     .000    .000    .000    .000    .000
LF    CG     .000    .000    .000    .000    .000
LF   VCG       .0      .0    .000    .000    .000
PF EXAMP      1.0     1.0    32.0    16.0    96.5     8.0    95.0     4.0    91.0
PFC  2.0     85.0     1.0    73.0      .5    37.0     .25     8.0    .125     1.0
PFC.0625      0.0
PF EXAMP     32.0     1.0    64.0    32.0    99.5    16.0    99.0     8.0    98.5
PFC  4.0     96.0     2.0    93.5     1.0    83.0     .50    45.5    .250     8.0
PFC .125      1.0   .0625     0.0
PF EXAMP     58.0     1.0    64.0    32.0    97.0    16.0    94.0     8.0    94.0
PFC  4.0     90.0     2.0    79.0     1.0    56.0     .50     4.0    .125     0.0
$LOCAL
LQ              1     100    1000   10000
LT TOTAL    .0040      10     500   30000
LF   VFS     .664    .664    .015    .198
LF    FS     .207    .207    .245    .181
LF    MS     .086    .086    .605    .107
LF    CS     .031    .031    .052    .098
LF   VCS     .008    .008    .039    .127
LF   VFG    .0030   .0030   .0200   .1160
LF    FG    .0010   .0010   .0110   .0910
LF    MG    .0000   .0000   .0110   .0530
LF    CG    .0000   .0000   .0000   .0220
LF   VCG    .0000   .0000   .0000   .0060
$TRIB
T4      CASCADE CREEK, SEGMENT 2, AT CONTROL POINT 2
T5      FIRST TRIB ON MAIN STEM.  LOAD CURVE IS FROM USGS DATA WITH 5 PERCENT
T6      FOR BED LOAD.  BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN
T7      10 JUNE 1980.  DAVID WILLIAMS, WES, SEPT 1982
T8      ADAPTED BY DAVID WILLIAMS, 1989
LQL             1     100    1000   10000
LTLTOTAL    .0040      10     500   30000
LFL  VFS     .664    .664    .015    .198
LFL   FS     .207    .207    .245    .181
LFL   MS     .086    .086    .605    .107
LFL   CS     .031    .031    .052    .098
LFL  VCS     .008    .008    .039    .127
LFL  VFG    .0030   .0030   .0200   .1160
LFL   FG    .0010   .0010   .0110   .0910
LFL   MG    .0000   .0000   .0110   .0530
LFL   CG    .0000   .0000   .0000   .0220
LFL  VCG    .0000   .0000   .0000   .0060
PF  CASC      1.0     1.0     64.     32.     94.     16.     85.      8.     70.
PFC   4.      50.      2.     32.      1.     18.      .5      9.     .25      5.
PFC .125      2.5   .0625      0.
$TRIB
T4      BEAR CREEK, SEGMENT 3, AT CONTROL POINT 3,
T5      SECOND UPSTREAM TRIB ON MAIN STEM
```

```
T6      LOAD CURVE IS FROM USGS DATA WITH 5 PERCENT FOR BED LOAD
T7      BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T8      DAVID WILLIAMS, WES, SEPT 1982
LQL           1     100     500    1000   30000
LTLTOTAL  .0020    30.0    500.    1200   22500
LFL  VFS   .201    .201    .078    .078    .137
LFL   FS   .342    .342    .172    .175    .218
LFL   MS   .451    .451    .454    .601    .476
LFL   CS   .001    .001    .197    .142    .158
LFL  VCS   .000    .000   .000    .003    .008
LFL  VFG  .0000   .0000  .0000   .0000   .0020
LFL   FG  .0000    .000  .0000   .0000   .0010
LFL   MG  .0000    .000  .0000   .0000   .0000
LFL   CG  .0000    .000  .0000   .0000   .0000
LFL  VCG  .0000    .000  .0000   .0000   .0000
PF  BEAR     1.      1.      4.      2.    99.5      1.     99.      .5     93.
PFC  .25     27    .125      3.   .0625      0.
PF  BEAR     6.      1.      4.      2.    99.5      1.     99.      .5    89.5
PFC  .25   22.5    .125     2.5   .0625      0.
STRIB
T4      TAKEO CREEK, SEGMENT 4, AT CONTROL POINT 4
T5      FIRST TRIBUTARY ON BEAR CREEK
T6      LOAD CURVE IS FROM USGS DATA WITH 5 PERCENT FOR BED LOAD
T7      BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T8      DAVID WILLIAMS, WES, SEPT 1982
LQL           1     100     500    1000   30000
LTLTOTAL  .0020    30.0    500.    1200   22500
LFL  VFS   .201    .201    .078    .078    .137
LFL   FS   .342    .342    .172    .175    .218
LFL   MS   .451    .451    .454    .601    .476
LFL   CS   .001    .001    .197    .142    .158
LFL  VCS   .000    .000   .000    .003    .008
LFL  VFG  .0000   .0000  .0000   .0000   .0020
LFL   FG  .0000    .000  .0000   .0000   .0010
LFL   MG  .0000    .000  .0000   .0000   .0000
LFL   CG  .0000    .000  .0000   .0000   .0000
LFL  VCG  .0000    .000  .0000   .0000   .0000
PF TAKEO     1.      1.      4.      2.    99.5      1.     99.      .5     93.
PFC  .25    27.    .125      3.   .0625      0.
PF TAKEO     6.      1.      4.      2.    99.5      1.     99.      .5    89.5
PFC  .25   22.5    .125     2.5   .0625      0.
SHYD
*   AB     FLOW 1 = BASE FLOW OF 500 CFS
Q    500     29      61     128      90
R   956.   974.
T     65     70      72      67      73
W      2
SPRT
CP            1
PN  MAIN      7      11
CP            4
PN TAKEO      4
END
*   AC     FLOW 2 = 50 DAYS AT BANK FULL DISCHARGE
Q 2500.0    150     300     650     450
R   965.  975.0
X             5      50
*          FLOW 3 = NEAR BANK FULL DISCHARGE
Q  1250.     78     150    340.     250
R   960.   975.
W     1.
SPRT
CP            3
PN  BEAR      1
END
*   AC     FLOW 4 = BASE FLOW OF 500 CFS
Q    500     29      61     128      90
R   955.  974.5
W      2
SSEND
```

6.6.2 Geometric Data Structure

The input data file for problem 6 is shown in Exhibit 6.13. The main stem data is first, with **QT** records indicating locations of the tributaries (see section 3.6.2); an **EJ** record ends this data. The number in field 1 of the **QT** record is the control point associated with that tributary; thus, the first **QT** record encountered is for Cascade Creek which enters the main stem at control point 2. Another **QT** is between sections 42.1 and 44.0, since this is a local flow there is no control point on the record. The geometry for each tributary is entered in sequence by segment number following the main stem data. Therefore, the second set of cross section data is for Cascade Creek. Note the use of the **QT** record within the Bear Creek geometry to locate the confluence of Takeo Creek.

6.6.3 Sediment Data Structure

The sediment data are entered in a sequence similar to the geometric data. Note, however, that the local inflow load table follows the main stem sediment data. Thereafter the sediment data for each tributary follows in sequence of segment number. Each set of tributary data is begun with a **$TRIB** record.

6.6.4 Flow Data Structure

The flows and temperatures for local and tributary flows must be entered in the proper sequence on the Q and T records. The flows entering this system for the last (fourth) time step are shown on Figure 6.5. The first flow on the Q record is that leaving the downstream boundary of the main stem (500 cfs), the next is the local inflow (Silver Creek) to the main stem (29 cfs). Since there are no more local inflows on the main stem, field 3 contains the flow (61 cfs) for segment 2, Cascade Creek. Bear Creek flow (38 cfs) is in field 4 and Takeo Creek flow (90 cfs) in field 5.

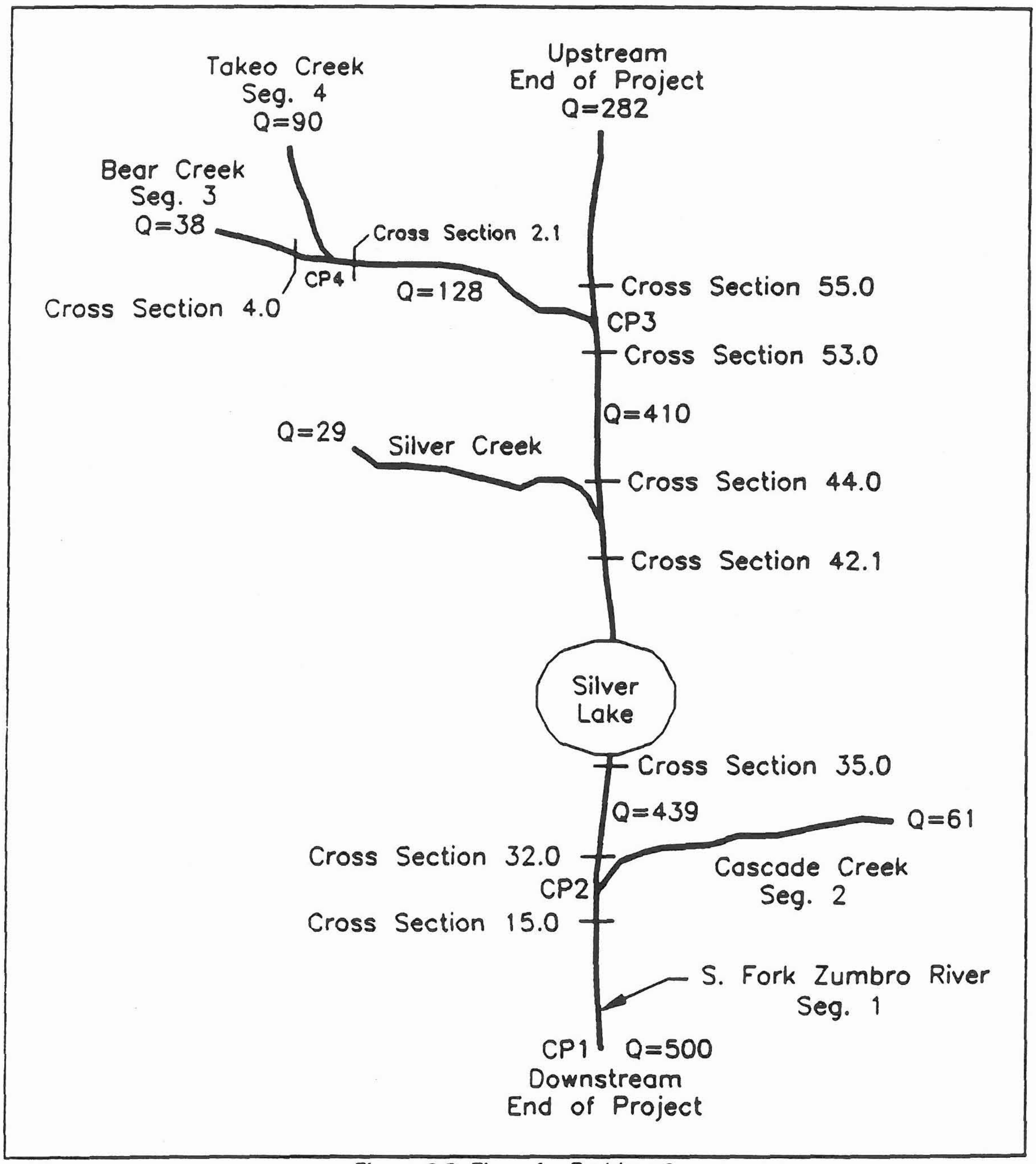

Figure 6.5 Flows for Problem 6

6.6.5 Selective Output

Output can be limited to specified cross sections on any stream segment. The type of output is governed by information on the * record. For example, for the third flow in problem 6, we are requesting A-level hydraulic and C-level sediment output at the seventh (42.1) and eleventh (58.0) sections on segment 1 and the fourth (6.0) section on segment 4 (Takeo Creek). This is done via the **$PRT**, **CP**, and **PN** records. For the fourth flow, AC level output is to be provided only for the first (1.0) section of the third segment (Bear Creek).

6.6.6 Network Output

The output is very similar to that of a single stream problem. The output file for problem 6 is shown in Exhibit 6.14. The geometric data is output in increasing segment order. Sediment data are then given for the main stem, the local inflow (Silver Creek), and the tributaries. The user is advised to take advantage of the title records to annotate the output file. The information from the **T1** records is used throughout the output so they should contain the name of each stream segment.

The A-level hydraulic data are output in the sequence in which the backwater computation is performed. Segment one is calculated first from downstream to upstream. The water surface elevation at each control point is printed; this then becomes the starting water surface elevation for the backwater computation for that tributary. The temperature in the main stem changes as differing water temperatures enter from the tributaries. For example, for the first flow, the inflow from Cascade creek is 61 cfs at 72 °F and the flow in the main stem below that confluence is 500 cfs at 65 °F (see Figure 6.5). Therefore, the flow in the main stem above the confluence is 439 cfs at 64.027 °F ($439*64.027 + 61*72 = 500*65$). Next, the hydraulics are calculated for segment 2 using as the starting water surface elevation the elevation calculated in segment 1 at the confluence.

Sediment output contains the same types of information previously discussed; identified primarily by cross section and segment.

EXHIBIT 6.14 Output - Network System

```
*****************************************************            **************************************
* SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS     *            * U.S. ARMY CORPS OF ENGINEERS       *
*  Version: 4.0.0  -  September 1990                *            * THE HYDROLOGIC ENGINEERING CENTER  *
*                                                   *            * 609 SECOND STREET                  *
*                                                   *            * DAVIS, CALIFORNIA 95616-4687       *
* RUN DATE 30NOV90      TIME 15:25:41               *            * (916) 756-1104                     *
*****************************************************            **************************************


                  X     X  XXXXXXX   XXXXX         XXXXX
                  X     X  X        X     X       X     X
                  X     X  X        X             X
                  XXXXXXX  XXXX     X       XXXXX XXXXXX
                  X     X  X        X             X     X
                  X     X  X        X     X       X     X
                  X     X  XXXXXXX   XXXXX         XXXXX


**********************************************************************************
* MAXIMUM LIMITS FOR THIS VERSION ARE:                                           *
*                                                                                *
* Stream Segments (Main Stem + Tributaries) =  10       Control Points =  10     *
* Cross Sections =  150                                 Grain Sizes =  15        *
*                                                                                *
**********************************************************************************


**********************************************************************************
*          INPUT FILE: EX6.DAT                                                   *
*          OUTPUT FILE: EX6.OUT                                                  *
```

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

T1      EX. PB. #6., NETWORK, MAIN STEM: LOWER S. FORK ZUMBRO R., ROCHESTER, MN
T2      CASCADE AND BEAR CKS ARE TRIBS, TAKEO CK IS TRIB OF BEAR CK, SILVER CK
T3      IS LOCAL, ORIG. WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW

NC  .1000   .1000   .0400   .1000   .3000

SECTION NO.  1 RIVER MILE=      1.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO   10.000

NV   12.   .0800    966.   .1300    989.   .0000     0.   .0000     0.   .0000
NV   22.   .0450    966.   .0640    989.   .0000     0.   .0000     0.   .0000
NV   33.   .1000    966.   .1100    982.   .1200   989.   .0000     0.   .0000

SECTION NO.  2 RIVER MILE=     15.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO   10.000

THIS IS JUNCTION NO  2 IN THE STREAM NETWORK.
TRIBUTARY ENTRY POINT  1 OCCURS JUST DOWNSTREAM FROM X-SECTION NO.   3

NC  .1000   .1000   .0500   .0000   .0000

SECTION NO.  3 RIVER MILE=     32.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO   10.000

SECTION NO.  4 RIVER MILE=     33.200
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO     .000

SECTION NO.  5 RIVER MILE=     33.300
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO     .000

SECTION NO.  6 RIVER MILE=     35.000
HYDRAULIC CONTROL POINT #  1
WATER SURFACE ELEVATION WILL BE READ FROM R-RECORD..FIELD=  2
INEFFECTIVE FLOW AREA REQUESTED BY X3-RECORD. LEFT OVERBANK   RIGHT OVERBANK
                                        STA #          10              19
               INEFFECTIVE ELEVATION             984.700         983.700
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO     .000

NC  .0600   .0600   .0450   .0000   .0000

SECTION NO.  7 RIVER MILE=     42.100
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO     .000

LOCAL INFLOW POINT  1 OCCURS JUST DOWNSTREAM FROM X-SECTION NO.   8

SECTION NO.  8 RIVER MILE=     44.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO   10.000

SECTION NO.  9 RIVER MILE=     53.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO   10.000

THIS IS JUNCTION NO  3 IN THE STREAM NETWORK.
TRIBUTARY ENTRY POINT  2 OCCURS JUST DOWNSTREAM FROM X-SECTION NO.  10

SECTION NO. 10 RIVER MILE=     55.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO   10.000

SECTION NO. 11 RIVER MILE=     58.000
SET THE DEPTH(FEET) OF BED SEDIMENT RESERVOIR TO    3.400

NO. OF CROSS SECTIONS READ IN FOR THIS STREAM SEGMENT= 11
NO. OF INPUT DATA MESSAGES =   0

CP     2     .000     .000     .000     .000     .000     .000     .000     .000     .000
T1      EXAMPLE 6 (CONTINUED) CASCADE CREEK GEOMETRY, SEG. 2, CP2
T2      EXISTING CONDITIONS
T3      DAVID WILLIAMS, WES, OCT 1982, ADAPTED 1989 BY DAVID T. WILLIAMS

NC  .1200   .1200   .0450   .1000   .3000
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SECTION NO.  1 RIVER MILE=      1.000

SECTION NO.  2 RIVER MILE=      3.000

SECTION NO.  3 RIVER MILE=      4.000

SECTION NO.  4 RIVER MILE=      6.200
INEFFECTIVE FLOW AREA REQUESTED BY X3-RECORD. LEFT OVERBANK   RIGHT OVERBANK
                                          STA #          6              14
               INEFFECTIVE ELEVATION           987.400        987.500

NO. OF CROSS SECTIONS READ IN FOR THIS STREAM SEGMENT=  4
NO. OF INPUT DATA MESSAGES =   0

CP     3      .000      .000      .000      .000      .000      .000      .000      .000      .000
T1      EXAMPLE 6 (CONTINUED) BEAR CREEK GEOMETRY, SEG. 3, CP3
T2      EXISTING CONDITIONS
T3      DAVID WILLIAMS, WES, OCT 1982, ADAPTED 1989, DAVID T. WILLIAMS

NC  .0900   .0900   .0460   .3000   .5000

SECTION NO.  1 RIVER MILE=      1.000

SECTION NO.  2 RIVER MILE=      2.100

THIS IS JUNCTION NO  4 IN THE STREAM NETWORK.
TRIBUTARY ENTRY POINT  1 OCCURS JUST DOWNSTREAM FROM X-SECTION NO.   3

SECTION NO.  3 RIVER MILE=      4.000

SECTION NO.  4 RIVER MILE=      6.000
INEFFECTIVE FLOW AREA REQUESTED BY X3-RECORD. LEFT OVERBANK   RIGHT OVERBANK
                                          STA #         12              23
               INEFFECTIVE ELEVATION           995.600        992.000

NO. OF CROSS SECTIONS READ IN FOR THIS STREAM SEGMENT=  4
NO. OF INPUT DATA MESSAGES =   0

CP     4      .000      .000      .000      .000      .000      .000      .000      .000      .000
T1      EXAMPLE 6 (CONTINUED) TAKEO CREEK GEOMETRY, SEG. 4, CP4
T2      EXISTING CONDITIONS
T3      DAVID WILLIAMS, WES, OCT 1982, ADAPTED 1989 BY DAVID T. WILLIAMS

NC  .0900   .0900   .0460   .3000   .5000

SECTION NO.  1 RIVER MILE=      1.000
...ADD      2.00 TO EACH ELEVATION(Y)

SECTION NO.  2 RIVER MILE=      2.100
...ADD      2.00 TO EACH ELEVATION(Y)

SECTION NO.  3 RIVER MILE=      4.000
...ADD      2.00 TO EACH ELEVATION(Y)

SECTION NO.  4 RIVER MILE=      6.000
...ADD      2.00 TO EACH ELEVATION(Y)
INEFFECTIVE FLOW AREA REQUESTED BY X3-RECORD. LEFT OVERBANK   RIGHT OVERBANK
                                          STA #         12              23
               INEFFECTIVE ELEVATION           997.600        994.000

NO. OF CROSS SECTIONS READ IN FOR THIS STREAM SEGMENT=  4
NO. OF INPUT DATA MESSAGES =   0

TOTAL NO. OF CROSS SECTIONS IN THE NETWORK =  23
END OF GEOMETRIC DATA
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T4      MAIN STEM, SEGMENT 1, CONTROL POINT 1, S. FORK ZUMBRO R., ROCHESTER, MN
T5      LOAD CURVE FROM USGS DATA AT USGS GAGE: 5 PERCENT ADDED FOR BED LOAD
T6      BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T7      ENCODED BY DAVID WILLIAMS, WES, SEPT 1982
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T8      SEDIMENT TRANSPORT BY STREAM POWER: SEE ASCE JOURNAL (YANG 1971)
EX. PB. #6., NETWORK, MAIN STEM: LOWER S. FORK ZUMBRO R., ROCHESTER, MN
CASCADE AND BEAR CKS ARE TRIBS, TAKEO CK IS TRIB OF BEAR CK, SILVER CK
IS LOCAL, ORIG. WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW
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SEDIMENT PARAMETER DATA
        SPI     IBG     MNQ      SPGF      ACGR     NFALL     IBSHER
I1       5.       0       1     1.000    32.174        2          1
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 SAND AND/OR GRAVEL ARE PRESENT


        MTC    IASA    LASA     SPGS       GSF      BSAE       PSI     UWDLB
I4       4       1      10     2.650      .667      .500    30.000    93.000

FOLLOWING GRAIN SIZES UTILIZED
SAND:   .000288   .000580   .001160   .002319   .004639
        .009279   .018560   .037120   .074216   .148596

*****TRANSPORT CAPACITY RELATIONSHIP IS YANG*****                *** MTC =  4
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COEFFICIENTS FOR COMPUTATION SCHEME WERE SPECIFIED
        DBI       DBN       XID       XIN       XIU       UBI       UBN       JSL
I5     .500      .500      .250      .500      .250      .000     1.000        1
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SEDIMENT LOAD TABLE FOR STREAM SEGMENT #   1
LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQ       * 1.00000     * 50.0000     * 1000.00     * 5800.00     * 90000.0     *
LF   VFS* .130900E-02* .178500     * 159.360     * 2299.50     * 232800.     *
LF    FS* .360800E-02* .492000     * 105.920     * 1377.00     * 112000.     *
LF    MS* .608300E-02* .829500     * 49.9200     * 693.000     * 44000.0     *
LF    CS* .100000E-19* .100000E-19* 3.52000     * 72.0000     * 8000.00     *
LF   VCS* .100000E-19* .100000E-19* 1.28000     * 36.0000     * 2000.00     *
LF   VFG* .100000E-19* .100000E-19* .100000E-19* 18.0000     * 800.000     *
LF    FG* .100000E-19* .100000E-19* .100000E-19* 4.50000     * 400.000     *
LF    MG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
LF    CG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
LF   VCG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
          ------------ ------------ ------------ ------------ ------------
   SUM=*  .110000E-01* 1.50000     * 320.000     * 4500.00     * 400000.     *

VOLUME VS DEPTH OF DEPOSITS
  SEC NO.      REACH     MOVABLE      INITIAL BED-ELEVATIONS        ACCUMULATED CHANNEL DISTANCE
               LENGTH    BED      LEFT SIDE  THALWEG  RIGHT SIDE        FROM DOWNSTREAM
                         WIDTH                                          FEET           MILES
                  .00
   1.000                 183.50    959.30    944.70    958.90            .00             .00
              8268.00
  15.000                 242.00    961.00    954.00    962.00        8268.00            1.57
              8240.00
  32.000                 219.50    968.60    956.50    978.50       16508.00            3.13
               320.00
  33.200                 299.00    979.19    961.00    976.00       16828.00            3.19
               175.00
  33.300                 299.00    979.19    961.00    976.00       17003.00            3.22
               105.00
  35.000                 276.00    963.30    963.30    983.70       17108.00            3.24
              3005.00
  42.100                 154.50    969.80    969.80    969.80       20113.00            3.81
               495.00
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   44.000                337.50    970.90    967.10    976.90    20608.00        3.90
            2941.00
   53.000                195.00    982.80    972.20    988.70    23549.00        4.46
             770.00
   55.000                204.00    987.20    972.90    983.80    24319.00        4.61
            1462.00
   58.000                176.50    996.30    975.40    990.40    25781.00        4.88


ED MATERIAL GRADATION (as computed from PF-records)
    SECID     SAE    DMAX    DXPI    XPI  TOTAL BED     BED MATERIAL FRACTIONS PER GRAIN SIZE (FINE TO COARSE)
N    1.000  1.000   .105    .105  1.000  1.000    .010    .070    .290    .360    .120
                                                  .060    .040    .015    .035    .000

N   15.000  1.000   .158    .158  1.000  1.000    .010    .070    .333    .368    .112
                                                  .042    .032    .010    .020    .003

N   32.000  1.000   .210    .210  1.000  1.000    .010    .070    .375    .375    .105
                                                  .025    .025    .005    .005    .005

N   33.200  1.000   .210    .210  1.000  1.000    .010    .068    .363    .380    .109
                                                  .028    .026    .005    .006    .006

N   33.300  1.000   .210    .210  1.000  1.000    .009    .067    .356    .383    .112
                                                  .030    .026    .005    .006    .006

N   35.000  1.000   .210    .210  1.000  1.000    .009    .067    .352    .384    .113
                                                  .030    .026    .005    .007    .007

N   42.100  1.000   .210    .210  1.000  1.000    .006    .051    .237    .431    .154
                                                  .058    .031    .003    .015    .015

N   44.000  1.000   .210    .210  1.000  1.000    .006    .048    .218    .439    .160
                                                  .063    .032    .003    .016    .016

N   53.000  1.000   .210    .210  1.000  1.000    .002    .032    .105    .485    .200
                                                  .090    .036    .001    .024    .024

N   55.000  1.000   .210    .210  1.000  1.000    .002    .028    .076    .497    .210
                                                  .097    .038    .001    .026    .026

N   58.000  1.000   .210    .210  1.000  1.000    .000    .020    .020    .520    .230
                                                  .110    .040    .000    .030    .030


.LOCAL INFLOW DATA...

SEDIMENT LOAD TABLE FOR STREAM SEGMENT #   1
                AT LOCAL INFLOW POINT #   1

LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQ       * 1.00000     * 100.000     * 1000.00     * 10000.0     *
LF   VFS* .265600E-02* 6.64000     * 7.50000     * 5940.00     *
LF    FS* .828000E-03* 2.07000     * 122.500     * 5430.00     *
LF    MS* .344000E-03* .860000     * 302.500     * 3210.00     *
LF    CS* .124000E-03* .310000     * 26.0000     * 2940.00     *
LF   VCS* .320000E-04* .800000E-01* 19.5000     * 3810.00     *
LF   VFG* .120000E-04* .300000E-01* 10.0000     * 3480.00     *
LF    FG* .400000E-05* .100000E-01* 5.50000     * 2730.00     *
LF    MG* .100000E-19* .100000E-19* 5.50000     * 1590.00     *
LF    CG* .100000E-19* .100000E-19* .100000E-19* 660.000     *
LF   VCG* .100000E-19* .100000E-19* .100000E-19* 180.000     *
          ------------ ------------ ------------ ------------
   SUM=* .400000E-02* 10.0000     * 499.000     * 29970.0     *

T4      CASCADE CREEK, SEGMENT 2, AT CONTROL POINT 2
T5      FIRST TRIB ON MAIN STEM.   LOAD CURVE IS FROM USGS DATA WITH 5 PERCENT
T6      FOR BED LOAD.  BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN
T7      10 JUNE 1980.  DAVID WILLIAMS, WES, SEPT 1982
T8      ADAPTED BY DAVID WILLIAMS, 1989
EXAMPLE 6 (CONTINUED) CASCADE CREEK GEOMETRY, SEG. 2, CP2
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EXISTING CONDITIONS
DAVID WILLIAMS, WES, OCT 1982, ADAPTED 1989 BY DAVID T. WILLIAMS


FOLLOWING GRAIN SIZES UTILIZED
SAND:   .000288   .000580   .001160   .002319   .004639
        .009279   .018560   .037120   .074216   .148596

*****TRANSPORT CAPACITY RELATIONSHIP IS YANG*****              *** MTC =  4

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SEDIMENT LOAD TABLE FOR STREAM SEGMENT #   2
LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQL      * 1.00000     * 100.000     * 1000.00     * 10000.0     *
LFL  VFS* .265600E-02* 6.64000     * 7.50000     * 5940.00     *
LFL   FS* .828000E-03* 2.07000     * 122.500     * 5430.00     *
LFL   MS* .344000E-03* .860000     * 302.500     * 3210.00     *
LFL   CS* .124000E-03* .310000     * 26.0000     * 2840.00     *
LFL  VCS* .320000E-04* .800000E-01* 19.5000     * 3810.00     *
LFL  VFG* .120000E-04* .300000E-01* 10.0000     * 3480.00     *
LFL   FG* .400000E-05* .100000E-01* 5.50000     * 2730.00     *
LFL   MG* .100000E-19* .100000E-19* 5.50000     * 1590.00     *
LFL   CG* .100000E-19* .100000E-19* .100000E-19* 660.000     *
LFL  VCG* .100000E-19* .100000E-19* .100000E-19* 180.000     *
         ------------ ------------ ------------ ------------
   SUM=*  .400000E-02* 10.0000     * 499.000     * 29970.0     *

VOLUME VS DEPTH OF DEPOSITS
  SEC NO.     REACH   MOVABLE      INITIAL BED-ELEVATIONS       ACCUMULATED CHANNEL DISTANCE
              LENGTH   BED     LEFT SIDE  THALWEG  RIGHT SIDE        FROM DOWNSTREAM
                       WIDTH                                       FEET          MILES
                  .00
    1.000              200.00    964.60    959.80    969.60          .00           .00
               537.00
    3.000              222.00    982.90    964.30    970.30       537.00           .10
               240.00
    4.000              114.50    981.70    968.30    981.20       777.00           .15
               474.00
    6.200              200.00    987.40    972.00    987.50      1251.00           .24

ED MATERIAL GRADATION (as computed from PF-records)
     SECID   SAE   DMAX   DXPI   XPI  TOTAL BED    BED MATERIAL FRACTIONS PER GRAIN SIZE (FINE TO COARSE)
N    1.000  1.000  .210   .210  1.000  1.000    .025   .025   .040   .090   .140
                                                .180   .200   .150   .090   .060

N    3.000  1.000  .210   .210  1.000  1.000    .025   .025   .040   .090   .140
                                                .180   .200   .150   .090   .060

N    4.000  1.000  .210   .210  1.000  1.000    .025   .025   .040   .090   .140
                                                .180   .200   .150   .090   .060

N    6.200  1.000  .210   .210  1.000  1.000    .025   .025   .040   .090   .140
                                                .180   .200   .150   .090   .060


T4      BEAR CREEK, SEGMENT 3, AT CONTROL POINT 3,
T5      SECOND UPSTREAM TRIB ON MAIN STEM
T6      LOAD CURVE IS FROM USGS DATA WITH 5 PERCENT FOR BED LOAD
T7      BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T8      DAVID WILLIAMS, WES, SEPT 1982
EXAMPLE 6 (CONTINUED) BEAR CREEK GEOMETRY, SEG. 3, CP3
EXISTING CONDITIONS
DAVID WILLIAMS, WES, OCT 1982, ADAPTED 1989, DAVID T. WILLIAMS


FOLLOWING GRAIN SIZES UTILIZED
SAND:   .000288   .000580   .001160   .002319   .004639
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       .009279   .018560   .037120   .074216   .148596

*****TRANSPORT CAPACITY RELATIONSHIP IS YANG*****                *** MTC =  4

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SEDIMENT LOAD TABLE FOR STREAM SEGMENT #    3
LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQL       * 1.00000      * 100.000      * 500.000      * 1000.00      * 30000.0      *
LFL  VFS* .402000E-03* 6.03000      * 39.0000      * 93.6000      * 3082.50      *
LFL   FS* .584000E-03* 10.2600      * 86.0000      * 210.000      * 4905.00      *
LFL   MS* .902000E-03* 13.5300      * 227.000      * 721.200      * 10710.0      *
LFL   CS* .200000E-05* .300000E-01* 98.5000      * 170.400      * 3555.00      *
LFL  VCS* .100000E-19* .100000E-19* .100000E-19* 3.60000      * 180.000      *
LFL  VFG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* 45.0000      *
LFL   FG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* 22.5000      *
LFL   MG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
LFL   CG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
LFL  VCG* .100000E-19* .100000E-19* .100000E-19* .100000E-19* .100000E-19*
          ------------ ------------ ------------ ------------ ------------
   SUM=* .199000E-02* 29.8500      * 450.500      * 1198.80      * 22500.0      *

VOLUME VS DEPTH OF DEPOSITS
  SEC NO.        REACH    MOVABLE      INITIAL BED-ELEVATIONS        ACCUMULATED CHANNEL DISTANCE
                 LENGTH   BED      LEFT SIDE  THALWEG  RIGHT SIDE          FROM DOWNSTREAM
                          WIDTH                                          FEET            MILES
                     .00
    1.000                  202.50    985.00    977.00    985.90           .00             .00
                  260.00
    2.100                  137.50    986.70    977.30    986.70        260.00             .05
                  708.00
    4.000                  137.50    986.30    978.30    992.30        968.00             .18
                  665.00
    6.000                  347.50    995.60    982.80    994.20       1633.00             .31


ED MATERIAL GRADATION (as computed from PF-records)
     SECID     SAE   DMAX    DXPI     XPI  TOTAL BED    BED MATERIAL FRACTIONS PER GRAIN SIZE (FINE TO COARSE)
N    1.000   1.000   .013    .013   1.000   1.000     .030     .240     .660     .060     .005
                                                      .005     .000     .000     .000     .000

N    2.100   1.000   .013    .013   1.000   1.000     .029     .234     .662     .066     .005
                                                      .005     .000     .000     .000     .000

N    4.000   1.000   .013    .013   1.000   1.000     .027     .216     .666     .081     .005
                                                      .005     .000     .000     .000     .000

N    6.000   1.000   .013    .013   1.000   1.000     .025     .200     .670     .095     .005
                                                      .005     .000     .000     .000     .000


T4       TAKEO CREEK, SEGMENT 4, AT CONTROL POINT 4
T5       FIRST TRIBUTARY ON BEAR CREEK
T6       LOAD CURVE IS FROM USGS DATA WITH 5 PERCENT FOR BED LOAD
T7       BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T8       DAVID WILLIAMS, WES, SEPT 1982
EXAMPLE 6 (CONTINUED) TAKEO CREEK GEOMETRY, SEG. 4, CP4
EXISTING CONDITIONS
DAVID WILLIAMS, WES, OCT 1982, ADAPTED 1989 BY DAVID T. WILLIAMS


FOLLOWING GRAIN SIZES UTILIZED
SAND:    .000288   .000580   .001160   .002319   .004639
         .009279   .018560   .037120   .074216   .148596

*****TRANSPORT CAPACITY RELATIONSHIP IS YANG*****                *** MTC =  4

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SEDIMENT LOAD TABLE FOR STREAM SEGMENT # 4
LOAD BY GRAIN SIZE CLASS (TONS/DAY)

LQL	* 1.00000	* 100.000	* 500.000	* 1000.00	* 30000.0 *
LFL VFS*	.402000E-03*	6.03000	* 39.0000	* 93.6000	* 3082.50 *
LFL FS*	.684000E-03*	10.2600	* 86.0000	* 210.000	* 4905.00 *
LFL MS*	.902000E-03*	13.5300	* 227.000	* 721.200	* 10710.0 *
LFL CS*	.200000E-05*	.300000E-01*	98.5000	* 170.400	* 3555.00 *
LFL VCS*	.100000E-19*	.100000E-19*	.100000E-19*	3.60000	* 180.000 *
LFL VFG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	45.0000 *
LFL FG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	22.5000 *
LFL MG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*
LFL CG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*
LFL VCG*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*	.100000E-19*
SUM=*	.199000E-02*	29.8500	* 450.500	* 1198.80	* 22500.0 *

VOLUME VS DEPTH OF DEPOSITS

SEC NO.	REACH LENGTH	MOVABLE BED WIDTH	INITIAL BED-ELEVATIONS LEFT SIDE	THALWEG	RIGHT SIDE	ACCUMULATED CHANNEL DISTANCE FROM DOWNSTREAM FEET	MILES
	.00						
1.000		202.50	987.00	979.00	987.90	.00	.00
	260.00						
2.100		137.50	988.70	979.30	988.70	260.00	.05
	708.00						
4.000		137.50	988.30	980.30	994.30	968.00	.18
	665.00						
6.000		347.50	997.60	984.80	996.20	1633.00	.31

ED MATERIAL GRADATION (as computed from PF-records)

	SECID	SAE	DMAX	DXPI	XPI	TOTAL BED	BED MATERIAL FRACTIONS PER GRAIN SIZE (FINE TO COARSE)				
N	1.000	1.000	.013	.013	1.000	1.000	.030	.240	.660	.060	.005
							.005	.000	.000	.000	.000
N	2.100	1.000	.013	.013	1.000	1.000	.029	.234	.662	.066	.005
							.005	.000	.000	.000	.000
N	4.000	1.000	.013	.013	1.000	1.000	.027	.216	.666	.081	.005
							.005	.000	.000	.000	.000
N	6.000	1.000	.013	.013	1.000	1.000	.025	.200	.670	.095	.005
							.005	.000	.000	.000	.000

STREAM SEGMENT # 1: EX. PB. #6., NETWORK, MAIN STEM: LOWER S. FORK ZUMBRO R., ROCHESTER, MN
DIMENSIONS OF BED SEDIMENT CONTROL VOLUMES, FEET.

SEC. NO. *	LENGTH	* MAX. WIDTH *	DEPTH	* VOLUME CU. FT. *	CU. YD. *
1.000*	4134.00	* 203.000	* 10.0000	* .839202E+07*	310816. *
15.000*	8254.00	* 228.490	* 10.0000	* .188596E+08*	698502. *
32.000*	4280.00	* 227.710	* 10.0000	* .974600E+07*	360963. *
33.200*	247.500	* 281.869	* .000000	* .000000	* .000000 *
33.300*	87.5000	* 299.000	* .000000	* .000000	* .000000 *
35.000*	1502.50	* 235.500	* .000000	* .000000	* .000000 *
42.100*	1750.00	* 197.899	* .000000	* .000000	* .000000 *
44.000*	1718.00	* 288.055	* 10.0000	* .494879E+07*	183288. *
53.000*	1855.50	* 233.267	* 10.0000	* .432826E+07*	160306. *
55.000*	1116.00	* 196.961	* 10.0000	* .219808E+07*	81410.4 *
58.000*	731.000	* 185.667	* 3.40000	* 461456.	* 17091.0 *

STREAM SEGMENT # 2: EXAMPLE 6 (CONTINUED) CASCADE CREEK GEOMETRY, SEG. 2, CP2
DIMENSIONS OF BED SEDIMENT CONTROL VOLUMES, FEET.

SEC. NO. *	LENGTH	* MAX. WIDTH *	DEPTH	* VOLUME CU. FT. *	CU. YD. *
1.000*	268.500	* 207.333	* 10.0000	* 556690.	* 20618.1 *
3.000*	388.500	* 205.864	* .000000	* .000000	* .000000 *
4.000*	357.000	* 145.465	* .000000	* .000000	* .000000 *
6.200*	237.000	* 171.500	* .000000	* .000000	* .000000 *

```
STREAM SEGMENT #  3: EXAMPLE 6 (CONTINUED) BEAR CREEK GEOMETRY, SEG. 3, CP3
DIMENSIONS OF BED SEDIMENT CONTROL VOLUMES, FEET.
SEC. NO. *   LENGTH    * MAX. WIDTH *   DEPTH     *       V O L U M E         *
         *             *            *             *   CU. FT.   *   CU. YD.   *
    1.000* 130.000     * 180.833    * 10.0000     * 235083.     * 8706.79     *
    2.100* 484.000     * 143.320    * 10.0000     * 693667.     * 25691.4     *
    4.000* 686.500     * 171.404    * .000000     * .000000     * .000000     *
    6.000* 332.500     * 277.500    * .100000E+00* 9226.87     * 341.736     *

STREAM SEGMENT #  4: EXAMPLE 6 (CONTINUED) TAKEO CREEK GEOMETRY, SEG. 4, CP4
DIMENSIONS OF BED SEDIMENT CONTROL VOLUMES, FEET.
SEC. NO. *   LENGTH    * MAX. WIDTH *   DEPTH     *       V O L U M E         *
         *             *            *             *   CU. FT.   *   CU. YD.   *
    1.000* 130.000     * 180.833    * 10.0000     * 235083.     * 8706.79     *
    2.100* 484.000     * 143.320    * 10.0000     * 693667.     * 25691.4     *
    4.000* 686.500     * 171.404    * .000000     * .000000     * .000000     *
    6.000* 332.500     * 277.500    * .100000E+00* 9226.87     * 341.736     *

NO. OF INPUT DATA MESSAGES=    0
END OF SEDIMENT DATA

=====================================================================================

BEGIN COMPUTATIONS.
$HYD

=====================================================================================

*   AB      FLOW 1 = BASE FLOW OF 500 CFS

BOUNDARY CONDITION DATA, CONTROL POINT NO.  1

SEGMENT     INFLOW Q IN CFS...
   1      500.0      29.0
  TIME STEP NO.       1
WATER     DISCHARGE=      500.00
          ELEVATION=     956.000
        TEMPERATURE=      65.000
FLOW DURATION(DAYS)  2.000

****  N  DISCHARGE   WATER    ENERGY  VELOCITY   ALPHA     TOP     AVG       AVG VEL (by subsection)
           (CFS)    SURFACE    LINE     HEAD              WIDTH    BED       1      2      3

SEC NO.     1.000
****  1     500.0     956.00    956.00        .00      1.00    154.50    949.52    .00    .50    .00
                                                  FLOW DISTRIBUTION (%) =      .0 100.0      .0

SEC NO.    15.000

SUPERCRITICAL
SEC NO.  15.000 TIME =    2.00 DAYS.
TRIAL    TRIAL        COMPUTED     CRITICAL
 NO.      WS             WS           WS
  0.     957.23       956.49
  1.     957.33       956.55       957.28
****  1     500.0     957.33    958.06        .73      1.00     46.55    955.76    .00   6.86    .00
                                                  FLOW DISTRIBUTION (%) =      .0 100.0      .0

JUNCTION...CONTROL POINT NO.=     2
                       TRIBUTARY DISCHARGE=       61.0
                       WATER SURFACE ELEV=     957.326

  CONTINUING ON SEGMENT NO.  1
WATER     DISCHARGE=      439.00
          ELEVATION=     957.326
        TEMPERATURE=      64.027
FLOW DURATION(DAYS)  2.000

****  N  DISCHARGE   WATER    ENERGY  VELOCITY   ALPHA     TOP     AVG       AVG VEL (by subsection)
           (CFS)    SURFACE    LINE     HEAD              WIDTH    BED
```

```
SEC NO.    32.000
**** 1     439.0    962.97    962.98     .01     1.00    126.98    958.75   .00   .82   .00
                                             FLOW DISTRIBUTION (%) =    .0 100.0    .0

SEC NO.    33.200
**** 1     439.0    963.03    963.05     .02     1.00    210.65    961.07   .00  1.06   .00
                                             FLOW DISTRIBUTION (%) =    .0 100.0    .0

SEC NO.    33.300
**** 1     439.0    963.12    963.14     .02     1.00    211.16    961.08   .00  1.02   .00
                                             FLOW DISTRIBUTION (%) =    .0 100.0    .0

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 4
            EXAMPLE 6 (CONTINUED) TAKEO CREEK GEOMETRY, SEG. 4, CP4
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
******************************************************************
                    *                                   *
   TIME      ENTRY  *              SAND                 *
   DAYS      POINT  *    INFLOW   OUTFLOW   TRAP EFF    *
                    *                                   *
   2.00      6.000  *      .02                          *
  TOTAL=     1.000  *      .02       .97     -40.21     *
                    *                                   *
******************************************************************
TABLE SB-1.              TOTAL         AND LOAD BY GRAIN SIZEIN TONS/DAY
                                   VF         F          M          C          VC
SEDIMENT INFLOW
 SANDS & GRAVELS        23.96      4.84       8.23      10.86       .02        .00
                                    .00        .00        .00       .00        .00
SEDIMENT OUTFLOW
 SANDS & GRAVELS       987.24     33.00     244.47     648.68     55.24       4.39
                                   1.46        .00        .00       .00        .00


  SECTION   BED CHANGE   WS ELEV   THALWEG      Q     SEDIMENT LOAD (TONS/DAY)
   ID NO       FEET       FEET     EL FEET     CFS        SAND
    6.000      -.10      986.41    984.70      90.        53.
    4.000       .01      981.50    980.31      90.        42.
    2.100      -.26      980.33    979.04      90.       307.
    1.000     -2.81      979.50    976.19      90.       987.

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 3
            EXAMPLE 6 (CONTINUED) BEAR CREEK GEOMETRY, SEG. 3, CP3
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
******************************************************************
                    *                                   *
   TIME      ENTRY  *              SAND                 *
   DAYS      POINT  *    INFLOW   OUTFLOW   TRAP EFF    *
                    *                                   *
   2.00      6.000  *      .00                          *
             2.100  *      .97                          *
  TOTAL=     1.000  *      .98      1.32       -.35     *
                    *                                   *
******************************************************************
TABLE SB-1.              TOTAL         AND LOAD BY GRAIN SIZEIN TONS/DAY
                                   VF         F          M          C          VC
SEDIMENT INFLOW
 SANDS & GRAVELS         3.96       .80       1.36       1.79       .00        .00
                                    .00        .00        .00       .00        .00
SEDIMENT OUTFLOW
 SANDS & GRAVELS      1334.14     59.22     373.42     826.29     67.93       5.39
                                   1.89        .00        .00       .00        .00


  SECTION   BED CHANGE   WS ELEV   THALWEG      Q     SEDIMENT LOAD (TONS/DAY)
   ID NO       FEET       FEET     EL FEET     CFS        SAND
    6.000      -.10      983.95    982.70      38.        33.
    4.000       .01      979.02    978.31      38.        26.
    2.100       .54      978.59    977.84     128.       463.
    1.000     -3.59      977.61    973.41     128.      1334.
```

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 2
EXAMPLE 6 (CONTINUED) CASCADE CREEK GEOMETRY, SEG. 2, CP2
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
2.00	6.200	.00		
TOTAL=	1.000	.00	.04	-7.90

TABLE SB-1.	TOTAL	AND LOAD BY GRAIN SIZEIN TONS/DAY VF	F	M	C	VC
SEDIMENT INFLOW						
SANDS & GRAVELS	4.32	2.87	.89	.37	.13	.03
		.01	.00	.00	.00	.00
SEDIMENT OUTFLOW						
SANDS & GRAVELS	38.44	3.86	2.85	4.02	8.70	13.44
		3.25	2.31	.00	.00	.00

SECTION ID NO	BED CHANGE FEET	WS ELEV FEET	THALWEG EL FEET	Q CFS	SEDIMENT LOAD (TONS/DAY) SAND
6.200	.00	972.74	972.00	61.	3.
4.000	.00	969.60	968.30	61.	3.
3.000	.00	965.96	964.30	61.	2.
1.000	-.11	960.34	959.69	61.	38.

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EX. PB. #6., NETWORK, MAIN STEM: LOWER S. FORK ZUMBRO R., ROCHESTER, MN
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	INFLOW	SAND OUTFLOW	TRAP EFF
2.00	58.000	.03		
	53.000	1.32		
TOTAL=	53.000	1.35	.06	.96

TIME	ENTRY		SAND	
2.00	53.000	.06		
	42.100	.00		
TOTAL=	35.000	.06	.00	1.00

TIME	ENTRY		SAND	
2.00	35.000	.00		
	15.000	.04		
TOTAL=	1.000	.04	.00	.92

TABLE SB-1.	TOTAL	AND LOAD BY GRAIN SIZEIN TONS/DAY VF	F	M	C	VC
SEDIMENT INFLOW						
SANDS & GRAVELS	28.81	9.03	10.94	8.84	.00	.00
		.00	.00	.00	.00	.00
SEDIMENT OUTFLOW						
SANDS & GRAVELS	3.07	.05	.21	.67	.85	.42
		.34	.43	.10	.00	.00

SECTION ID NO	BED CHANGE FEET	WS ELEV FEET	THALWEG EL FEET	Q CFS	SEDIMENT LOAD (TONS/DAY) SAND
58.000	-.23	978.28	975.17	282.	346.
55.000	-.10	976.18	972.80	282.	562.
53.000	2.38	974.14	974.58	410.	60.
44.000	.04	974.05	967.14	410.	0.
42.100	.00	974.04	969.80	439.	0.

```
   35.000         .00    974.00    963.30       439.         0.
   33.300         .00    963.12    961.00       439.         0.
   33.200         .00    963.03    961.00       439.         0.
   32.000        -.02    962.97    956.48       439.       178.
   15.000        -.01    957.33    953.99       500.       399.
    1.000         .03    956.00    944.73       500.         3.

..................................................................................................................

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  1
            EX. PB. #6., NETWORK, MAIN STEM: LOWER S. FORK ZUMBRO R., ROCHESTER, MN
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
*****************************************************************
                       *                                *
   TIME       ENTRY *              SAND                 *
   DAYS       POINT *    INFLOW   OUTFLOW   TRAP EFF    *
                       *                                *
   55.00     58.000 *     13.21                         *
             53.000 *     25.88                         *
   TOTAL=    53.000 *     39.10     44.94      -.15     *
                       *                                *
*****************************************************************
   TIME       ENTRY *              SAND                 *
   55.00     53.000 *     44.94                         *
             42.100 *       .36                         *
   TOTAL=    35.000 *     45.30     11.56       .74     *
                       *                                *
*****************************************************************
   TIME       ENTRY *              SAND                 *
   55.00     35.000 *     11.56                         *
             15.000 *       .95                         *
   TOTAL=     1.000 *     12.51       .05      1.00     *
                       *                                *
*****************************************************************
TABLE SB-1.                 TOTAL          AND LOAD BY GRAIN SIZEIN TONS/DAY
                                      VF          F           M           C          VC
SEDIMENT INFLOW
 SANDS & GRAVELS        28.81        9.03       10.94        8.84         .00        .00
                                      .00         .00         .00         .00        .00
SEDIMENT OUTFLOW
 SANDS & GRAVELS         6.97        1.04         .61        1.64        1.81        .83
                                      .41         .49         .13         .00        .00


  SECTION   BED CHANGE   WS ELEV   THALWEG        Q      SEDIMENT LOAD (TONS/DAY)
   ID NO       FEET        FEET    EL FEET       CFS         SAND
   58.000      -2.62     977.01    972.78       282.          71.
   55.000       -.17     975.58    972.73       282.          76.
   53.000       -.88     975.26    971.32       410.          53.
   44.000       2.61     974.59    969.71       410.           2.
   42.100       1.39     974.57    971.19       439.           0.
   35.000       2.95     974.50    966.25       439.           0.
   33.300        .08     963.26    961.08       439.         183.
   33.200        .58     963.07    961.58       439.         191.
   32.000       -.06     962.98    956.44       439.         392.
   15.000        .13     957.47    954.13       500.         717.
    1.000        .31     955.00    945.01       500.           7.

ACCUMULATED WATER DISCHARGE FROM DAY ZERO(SFD)
     MAIN        TRIB #1       TRIB #2       TRIB #3        ....ETC
  3250.0000

..................................................................................................................

SSEND


      0   DATA ERRORS DETECTED.

TOTAL NO. OF TIMESTEPS READ=          4
TOTAL NO. OF WS PROFILES=          13
ITERATIONS IN EXNER EQ  =      1495.
```

```
END OF JOB

JOB COMPLETED
RUN TIME =   0 HOURS,   1 MINUTES &   2.94 SECONDS
```

6.7 Problem 7 - Cohesive Sediment

This problem illustrates the deposition of clays and silts in an impoundment at the downstream end of a single stream segment. Subsequent lowering of the pool level in that impoundment causes erosion of the cohesive deposits. Exhibit 6.15 shows the input data file for this problem and Exhibit 6.16 the output file.

EXHIBIT 6.15 Input - Cohesive Sediment

```
T1       EXAMPLE PROBLEM NO 7.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
T2       COHESIVE SEDIMENT RUN, LOCAL INFLOWS ARE OUT, WILLIAMS LAKE IS FORMED
T3       ORIGINAL WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW
NC  .100     .100     .040       .1       .3
X1   1.0      31. 10077.0 10275.0       0.       0.       0.       0.       0.       0.
GR1004.0  9915.0  978.40 10002.0  956.00 10060.0  959.20 10077.0  959.30 10081.0
GR950.00 10092.0  948.48 10108.0  946.60 10138.0  944.70 10158.0  955.20 10225.0
GR956.20 10243.0  958.90 10250.0  959.80 10275.0  959.80 10300.0  959.90 10325.0
GR958.80 10350.0  957.40 10400.0  970.00 10700.0  966.00 10960.0  970.00 11060.0
GR968.00 11085.0  968.00 11240.0  970.00 11365.0  970.00 11500.0  970.00 11615.0
GR962.00 11665.0  962.00 12400.0  976.00 12550.0  980.00 12670.0  982.00 12730.0
GR984.00 12735.0
HD     1      10.   10081   10250
NV    22     .045   965.6    .064    988.8
NV    12     .080   965.6    .130    988.8
NV    33      .10   965.6     .11    982.0      .12    988.8
X1  15.0      27. 10665.0 10850.0    8565.    7535.    8268.       0.       0.       0.
X3                          10700      961    11000      970
GR992.00  9570.0  982.00 10110.0  976.00 10300.0  976.00 10490.0  966.00 10610.0
GR964.70 10665.0  956.00 10673.0  953.00 10693.0  954.00 10703.0  955.60 10723.0
GR958.60 10750.0  959.30 10800.0  957.00 10822.0  957.30 10825.0  961.50 10850.0
GR962.00 10852.0  964.00 10970.0  966.00 11015.0  961.00 11090.0  962.00 11150.0
GR970.00 11190.0  972.00 11310.0  980.00 11410.0  984.00 11570.0  990.00 11770.0
GR990.00 11865.0 1000.00 12150.0
HD    15      10.   10673   10852
NC   .10      .10     .05
X1  32.0      29. 10057.0 10271.0    7429.    5654.    8240.       0.       0.       0.
GR998.00  9080.0  982.00  9250.0  982.00  9510.0  980.00  9600.0  980.01  9925.0
GR979.48 10000.0  978.50 10057.0  968.60 10075.0  959.82 10087.0  956.50 10097.0
GR956.80 10117.0  957.80 10137.0  959.40 10157.0  959.60 10177.0  959.82 10196.0
GR966.50 10225.0  971.20 10250.0  978.50 10271.0  978.50 10300.0  978.60 10350.0
GR978.91 10370.0  978.96 10387.0  980.00 10610.0  982.00 10745.0  982.00 11145.0
GR984.00 11150.0  992.00 11240.0 1000.00 11330.0  1008.0 11425.0
HD    32      10.   10075   10275
NC   .06      .06    .045
X1  42.1      32.  9880.0 10130.0     2460     4495     3605       0.       0.       0.
GR996.00  7130.0  998.00  7310.0  998.00  7930.0  992.00  8205.0  990.00  8495.0
GR988.00  8780.0  986.00  8990.0  985.70  9570.0  986.45  9707.0  989.44  9857.0
GR990.00  9880.0  969.80  9881.0  969.80  9941.0  985.80  9941.0  985.80  9943.0
GR969.80  9943.0  969.80 10001.0  986.70 10001.0  986.70 10003.0  969.80 10003.0
GR969.80 10067.0  985.80 10067.0  985.80 10069.0  969.80 10069.0  969.80 10129.0
GR989.90 10130.0  989.50 10180.0  988.60 10230.0  987.60 10280.0  985.20 10430.0
GR986.80 11720.0  989.90 12310.0
HD 42.10        0    9881   10021
X1  44.0      28.  9845.0 10127.0     290.     795.     495.       0.       0.       0.
XL                           9850    10200
GR1002.0  8035.0  992.00  8150.0  990.00  8305.0  990.00  8735.0  988.00  8835.0
GR996.00  9285.0  1017.6  9425.0  990.00  9505.0  986.00  9650.0  984.10  9788.0
GR980.60  9845.0  970.90  9868.0  972.20  9898.0  970.50  9968.0  967.50  9998.0
GR968.90 10028.0  967.40 10058.0  967.10 10078.0  971.90 10118.0  976.80 10127.0
GR977.80 10150.0  976.90 10193.0  982.00 10206.0  981.20 10300.0  979.20 10325.0
GR983.10 10400.0  999.80 10450.0 1002.40 10464.0
HD    44      10.    9868   10193
X1  53.0      22. 10000.0 10136.0    3366.    2831.    2941.       0.       0.       0.
GR1004.0  7550.0 1000.00  7760.0  998.00  8440.0  996.00  8640.0  996.00  8780.0
```

```
GR994.00  8940.0  986.00  9245.0  986.30  9555.0  986.30  9825.0  983.80  9900.0
GR982.80 10000.0  978.20 10011.0  974.00 10041.0  972.20 10071.0  972.60 10101.0
GR978.20 10121.0  988.70 10136.0  989.30 10154.0  999.20 10200.0  1000.1 10320.0
GR1002.0 10470.0 1004.00 10700.0
HD     53     10.   10000   10136
X1  55.0     18.  9931.0 10062.0    275.   1430.    770.      0.      0.      0.
GR1004.0  7592.0 1000.00  7947.0  996.00  8627.0  990.00  9052.0  986.00  9337.0
GR984.30  9737.0  984.70  9837.0  985.50  9910.0  987.20  9931.0  978.10  9955.0
GR974.80  9975.0  974.20 10005.0  972.90 10035.0  973.20 10045.0  983.80 10062.0
GR985.80 10187.0  986.00 10307.0  990.00 10497.0
HD     55     10.    9931   10062
X1  58.0     22.  9912.0 10015.0   1097.   1012.   1462.      0.      0.      0.
GR1006.0  8542.0 1004.00  8952.0 1000.00  9702.0  997.20  9812.0  996.30  9912.0
GR976.20  9944.0  975.40  9974.0  978.20  9991.0  990.40 10015.0  988.30 10062.0
GR988.80 10065.0  988.30 10065.0  989.30 10169.0  990.00 10172.0  992.00 10242.0
GR992.00 10492.0  988.00 10642.0  986.70 10852.0  988.00 11022.0  986.00 11097.0
GR986.00 11137.0  988.00 11192.0
HD     58    3.4    9912   10015
EJ
T4          MAIN STEM, SEGMENT 1, SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
T5          LOAD CURVE FROM USGS DATA AT USGS GAGE: 5 PERCENT ADDED FOR BED LOAD
T6          BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T7          SILT/CLAY ARBITRARILY ADDED. ENCODED BY D. WILLIAMS, WEST CONSULTANTS
T8          SEDIMENT TRANSPORT BY STREAM POWER: SEE ASCE JOURNAL (YANG 1971)
I1      0       5
I2  CLAY        2
I2  CLAY        1     .02     .05      .1     1.5     60.
I2  CLAY        2     .02    .125     .25     2.0     32.
I3  SILT        2       1       4
I4  SAND        4
I5             .5      .5     .25      .5     .25       0     1.0
LQ              1      50    1000    5800   90000
LT TOTAL    .0220     3.0     640   9000.  800000
LF  CLAY      .10     .10     .10     .10     .15
LF SILT1        0       0       0       0       0
LF SILT2        0       0       0       0       0
LF SILT3      .30     .30     .20     .20     .25
LF SILT4        0       0       0       0       0
LF   VFS     .019    .019    .298    .311    .332
LF    FS     .228    .228    .231    .206    .130
LF    MS     .353    .353    .156    .154    .110
LF    CS     .000    .000    .011    .016    .020
LF   VCS     .000    .000    .004    .008    .005
LF   VFG     .000    .000    .000    .004    .002
LF    FG     .000    .000    .000    .001    .001
LF    MG     .000    .000    .000    .000    .000
LF    CG     .000    .000    .000    .000    .000
LF   VCG       .0      .0    .000    .000    .000
PF EXAMP      1.0     1.0    32.0    16.0    96.5     8.0    95.0     4.0    91.0
PFC  2.0     85.0     1.0    73.0      .5    37.0     .25     8.0    .125     1.0
PFC.0625      0.0
PF EXAMP     32.0     1.0    64.0    32.0    99.5    16.0    99.0     8.0    98.5
PFC  4.0     96.0     2.0    93.5     1.0    83.0     .50    45.5    .250     8.0
PFC .125      1.0   .0625     0.0
PF EXAMP     58.0     1.0    64.0    32.0    97.0    16.0    94.0     8.0    94.0
PFC  4.0     90.0     2.0    79.0     1.0    56.0     .50     4.0    .125     0.0
SHYD
*     B       FLOW 1 = WARM-UP BASE FLOW OF 500 CFS, WILLIAMS LAKE IMPOUNDED
Q     500
R     985
T      65
W       1
SPR
PN              3
END
*     C       FLOW 2 = 100 DAYS AT BANK FULL Q, WILLIAMS LAKE IMPOUNDED
Q  1250.
R     985
X              10     100
$RATING
RC             40    2000       0       0   950.0   955.1   958.0   960.0   962.0
RC          963.6   965.1   966.2   967.0   967.7   968.3   968.9   969.4   969.8
RC          970.2   970.6   971.0   971.4   971.8   972.1   972.4   972.7   972.9
```

```
RC          973.1   973.3   973.5   973.7   973.8   973.9   974.0   974.1   974.2
RC          974.3   974.4   974.5   974.6   974.7   974.8   974.9   975.0
SPR
PN              3
END
*   C       FLOW 3 = NEAR BANK FULL Q, WILLIAMS LAKE LOWERED TO NATURAL CONDITION
Q  1250.
W     .2
*   B       FLOW 4 = NEAR BANK FULL Q, WILLIAMS LAKE LOWERED TO NATURAL CONDITION
Q  1250.
X               1       20.
*   B       FLOW 5 = LAST FLOW, BASE FLOW OF 500 CFS, WILLIAMS LAKE IS LOWERED
Q   500.
X               2       20.
SSEND
```

6.7.1 Cohesive Sediment Data

This problem uses Method 2 (see sections 2.3.9, 3.3.4.2, and the I2 record in Appendix A) to compute the deposition and erosion rates for clay and silts. This method requires the addition of two **SPECIAL** I2 records to provide the data; in this case, one for the active layer and one for the inactive layer. The data for the active layer is described below.

The shear stress threshold above which clays and silts will not deposit is 0.02 lb/ft^2. The shear stress at which deposited cohesive material will scour is 0.05 lb/ft^2. The shear stress above which mass erosion occurs is 0.10 lb/ft^2. The erosion rate at that shear stress is 1.5 lb/ft^2/hr. The slope of the mass erosion rate curve is 60/hr. These values are depicted in Figure 6.6 for both the active and inactive layers. Note that the shear strength of the inactive layer is larger than that of the active layer and it erodes more slowly. This represents, perhaps, the effect of consolidation. The I3 record indicates that only one size of silt will be used in the computations.

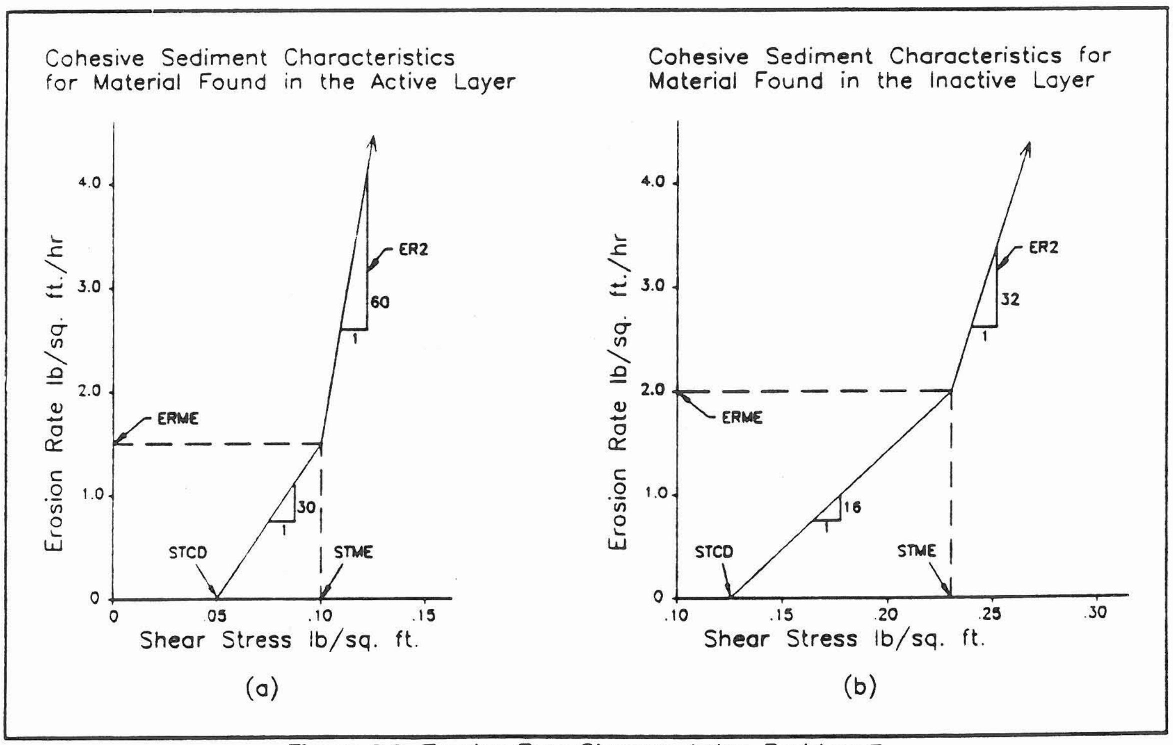

Figure 6.6 Erosion Rate Characteristics, Problem 7

Caution, the cohesive sediment values given in example 7 are not factual and should not be used under any circumstances without field verification. To determine these values, laboratory tests must be performed on the sediments to be simulated. These tests must be done under the same physical and chemical conditions as in the prototype, see section 2.3.9.

6.7.2 Output

The geometric and hydraulic output contains the same information as in previous examples. When the sediment data is read, the program produces tables of cohesive sediment properties under the headings "CLAY IS PRESENT" and "SILT IS PRESENT". The remainder of the input sediment data is output as before.

The first time step was for one day with the pool elevation at section 1.0 of 985 ft. The trap efficiency for clay was 11% and silt and sands 100%. From table SB-1, (under the heading "SEDIMENT LOAD") we see that clay begins to deposit at section 15.0 and silt at section 55.0. No silt is transported beyond section 32.0 for this flow and lake stage. Sands and gravels are immediately deposited at the upstream-most section (58.0).

The second time step was for 100 days at 10 day increments with the pool elevation also at 985 ft. A C-level sediment output was requested for cross section 32.0. Under the heading "POTENTIAL TRANSPORT BY SIZE CLASS" we see that 88.2 tons/day of clay and 71.5 tons/day of class 3 silt could potentially be transported (refer to data on the I2 and I3 records). Above this table is one labelled "SEDIMENT INFLOW (TONS/DAY)" which indicates that the rates at which clay and silt enter the control volume associated with section 32.0 are greater than the transport potential; therefore deposition occurs. The active and inactive layers now contain clay and silt since they have been deposited.

The third time step is preceded by a rating curve that represents channel control at the downstream-most section. The higher velocity at section 32.0 results in a bed shear stress of 0.3276 lb/ft^2, which, from Figure 6.6, results in mass erosion of both layers. The computed potential erosion rates for both clay and silt are 147790 and 43740 tons/day for the active and inactive layers respectively. The actual erosion rates will be limited by the availability of these materials.

EXHIBIT 6.16 Output - Cohesive Sediment

```
**************************************************************************************
*             INPUT FILE: EX7.DAT                                                    *
*             OUTPUT FILE: EX7.OUT                                                   *
**************************************************************************************

==========================================================================================


T4       MAIN STEM, SEGMENT 1, SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
T5       LOAD CURVE FROM USGS DATA AT USGS GAGE: 5 PERCENT ADDED FOR BED LOAD
T6       BED GRADATIONS FROM INTERPOLATION OF SAMPLES TAKEN 10 JUNE 1980
T7       SILT/CLAY ARBITRARILY ADDED. ENCODED BY D. WILLIAMS, WEST CONSULTANTS
T8       SEDIMENT TRANSPORT BY STREAM POWER: SEE ASCE JOURNAL (YANG 1971)
EXAMPLE PROBLEM NO 7.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
COHESIVE SEDIMENT RUN, LOCAL INFLOWS ARE OUT, WILLIAMS LAKE IS FORMED
ORIGINAL WORK BY DAVID T. WILLIAMS, WES, 1982: ADAPTED 1989, DTW


- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


SEDIMENT PARAMETER DATA
        SPI     IBG    MNQ        SPGF      ACGR     NFALL     IBSHER
I1      5.       0       1       1.000    32.174        2          1

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

CLAY IS PRESENT.

	MTCL	SPGC	PUCD	UWCL	CCCD
I2	2	2.650	78.000	30.000	16.000

DEPOSITION COEFFICIENTS BY LAYER

	LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS LB/SQ.FT.
ACTIVE LAYER	1	.0200
INACTIVE LAYER	2	.0200

EROSION COEFFICIENTS BY LAYER

	LAYER NO	PARTICLE EROSION SHEAR STRESS LB/SQ.FT.	MASS EROSION SHEAR STRESS LB/SQ.FT.	MASS EROSION RATE LB/SF/HR	SLOPE OF PARTICLE EROSION LINE=ER1 1/HR	SLOPE OF MASS EROSION LINE=ER2 1/HR
ACTIVE LAYER	1	.0500	.1000	1.5000	30.0000	60.0000
INACTIVE LAYER	2	.1250	.2500	2.0000	16.0000	32.0000

- -

SILT IS PRESENT

	MTCL	IASL	LASL	SGSL	PUSDLB	UWSDLB	CCSDLB
I3	2	1	4	2.650	82.000	65.000	5.700

DEPOSITION COEFFICIENTS BY LAYER

	LAYER NO.	DEPOSITION THRESHOLD SHEAR STRESS LB/SQ.FT.
ACTIVE LAYER	1	.0200
INACTIVE LAYER	2	.0200

EROSION COEFFICIENTS BY LAYER

	LAYER NO	PARTICLE EROSION SHEAR STRESS LB/SQ.FT.	MASS EROSION SHEAR STRESS LB/SQ.FT.	MASS EROSION RATE LB/SF/HR	SLOPE OF PARTICLE EROSION LINE=ER1 1/HR	SLOPE OF MASS EROSION LINE=ER2 1/HR
ACTIVE LAYER	1	.0500	.1000	1.5000	30.0000	60.0000
INACTIVE LAYER	2	.1250	.2500	2.0000	16.0000	32.0000

FINE-GRAIN SEDIMENT TYPES BY CROSS SECTION (XSEC,TYPE)

1.000	1	15.000	1	32.000	1	42.100	1	44.000	1
53.000	1	55.000	1	58.000	1				

- -

SAND AND/OR GRAVEL ARE PRESENT

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWDLB
I4	4	1	10	2.650	.667	.500	30.000	93.000

FOLLOWING GRAIN SIZES UTILIZED

CLAY:	.000009				
SILT:	.000018	.000036	.000072	.000144	
SAND:	.000288	.000580	.001160	.002319	.004639
	.009279	.018560	.037120	.074216	.148596

*****TRANSPORT CAPACITY RELATIONSHIP IS YANG*****   *** MTC = 4

```
BEGIN COMPUTATIONS.
SHYD
```

```
*    B      FLOW 1 = WARM-UP BASE FLOW OF 500 CFS, WILLIAMS LAKE IMPOUNDED

BOUNDARY CONDITION DATA, CONTROL POINT NO.  1
  TIME STEP NO.       1
WATER    DISCHARGE=      500.00
         ELEVATION=     985.000
       TEMPERATURE=      65.000
FLOW DURATION(DAYS)  1.000

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT #  1
            EXAMPLE PROBLEM NO 7.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
            ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT
**************************************************************************************************************************
******
                       *                                 *                                  *                                 *
    TIME       ENTRY *              CLAY                 *               SILT               *               SAND              *
    DAYS       POINT *    INFLOW  OUTFLOW  TRAP EFF *    INFLOW   OUTFLOW  TRAP EFF *    INFLOW   OUTFLOW  TRAP EFF *
                       *                                 *                                  *                                 *
    1.00      58.000 *       .03                         *      .03                         *      .05                        *
   TOTAL=      1.000 *       .03       .03       .11 *      .03       .00      1.00 *      .05       .00      1.00 *
                       *                                 *                                  *                                 *
**************************************************************************************************************************
******
TABLE SB-1.                  TOTAL          AND LOAD BY GRAIN SIZEIN TONS/DAY
                                        VF          F          M          C          VC
SEDIMENT INFLOW
          CLAY          18.50
          SILT          40.65          .00        .00      40.65        .00
 SANDS & GRAVELS       106.66        29.17      42.62      34.87        .00        .00
                                       .00        .00        .00        .00        .00
                     ------------
     TOTAL LOAD        165.81

SEDIMENT OUTFLOW
          CLAY          16.39
          SILT            .02          .00        .00        .02        .00
 SANDS & GRAVELS          .00          .00        .00        .00        .00        .00
                                       .00        .00        .00        .00        .00
                     ------------
     TOTAL LOAD         16.40


  SECTION   BED CHANGE   WS ELEV   THALWEG       Q      SEDIMENT LOAD (TONS/DAY)
   ID NO       FEET        FEET    EL FEET      CFS       CLAY       SILT       SAND
    58.000        .04     985.03    975.44     500.        18.        40.         0.
    55.000        .00     985.01    972.90     500.        18.        38.         0.
    53.000        .00     985.00    972.20     500.        18.        30.         0.
    44.000        .00     985.00    967.10     500.        18.        21.         0.
    42.100        .00     985.00    969.80     500.        18.        12.         0.
    32.000        .00     985.00    956.50     500.        18.         2.         0.
    15.000        .00     985.00    954.00     500.        17.         0.         0.
     1.000        .00     985.00    944.70     500.        16.         0.         0.

.......................................................................................................

SPR


PRINT AT SELECTIVE X-SECTIONS ONLY
PN            3.000       .000       .000       .000       .000       .000       .000       .000       .000
END            .000       .000       .000       .000       .000       .000       .000       .000       .000
```

```
*    C     FLOW 2 = 100 DAYS AT BANK FULL Q, WILLIAMS LAKE IMPOUNDED

COMPUTING FROM TIME=     1.000000 DAYS TO TIME=   101.000000 DAYS IN        10 COMPUTATION STEPS


BOUNDARY CONDITION DATA, CONTROL POINT NO.  1
  TIME STEP NO.       2
WATER      DISCHARGE=    1250.00
          ELEVATION=    985.000
        TEMPERATURE=     65.000
FLOW DURATION(DAYS)  10.00

EXAMPLE PROBLEM NO 7.  LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
FLOW # (N) =    1
FLOW...Q(N)=    1250.0
TIMESTEP DURATION (DAYS) =   10.0000
ACCUMULATED TIME  (YRS)  =     .2767
WATER TEMPERATURE (DEG F)=   65.0000
**************************** FALL VELOCITY BY METHOD 2****************************

                         DIAMETER      VELOCITY       REY. NO.          CD

                          .000009  .2105298E-04  .1671599E-04  1437286.
                          .000018  .8390687E-04  .1332435E-03  180969.5
                          .000036  .3337332E-03  .1059932E-02  22878.70
                          .000072  .1318051E-02  .8372224E-02  2933.566
                          .000144  .5112670E-02  .6495108E-01  389.9372
                          .000288  .1907676E-01  .4847001      56.01589
                          .000580  .5916453E-01  3.027370      11.72824
                          .001160  .1355234      13.86910      4.470513
                          .002319  .2832060      57.94010      2.046556
                          .004639  .4824399      197.4439      1.410801
                          .009279  .7200630      589.4511      1.266741
                          .018560  1.040348      1703.463      1.213804
                          .037120  1.472924      4823.523      1.211086
                          .074216  2.082692      13636.37      1.211086
                          .148596  2.346998      38633.42      1.211086

SEDIMENT INFLOW (TONS/DAY)
                          TOTAL          AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY
          CLAY          89.52
          SILT         179.04        .00         .00       179.04        .00
 SANDS & GRAVELS       625.68     268.22      203.80       139.42      10.33       3.91
                                     .00         .00          .00        .00        .00


********************************************************************************************
      THE FOLLOWING TABLE IS PRINTOUT FOR CROSS SECTION     32.000
      ------------------------------------------------------------


HYDRAULIC PARAMETERS:
      VEL            SLO            EFD            EFW            N-VALUE         TAU          USTARM         FROUDE
NO.
        .226       .000001        22.481        201.866          .0500         .00151         .02792
.008
BED SEDIMENT RESERVOIR COMPUTATIONS:
NEW SURFACE AREA (SQ FT):      TOTAL         K-PORTION       S-PORTION
                          1332433.75    1332433.75              .00
GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS
BED MATERIAL BY GRAIN SIZE FRACTION       .000125     .000000     .000000     .008748     .000000
                                          .009911     .069379     .371673     .371673     .104068
                                          .024778     .024778     .004956     .004956     .004956
BED MATERIAL BY PERCENT FINER/100         .000125     .000125     .000125     .008873     .008873
                                          .018784     .088163     .459836     .831508     .935577
                                          .960355     .985133     .990089     .995044    1.000000

CLAY TRANSPORT CAPACITY:
BED SHEAR STRESS, #/SQ FT    =    .0015
 FINE GRAIN SEDIMENT TYPE    =        1
              LAYER TYPE     =        1        2
DEPOSITION THRESHOLD #/SF    =    .0200     .0200
MASS EROSION THRESHOLD, #/SF=     .1000     .2500
```

```
 SIZE    FALL     DECAY    TRANSPORT
 CLASS   RATIO    RATIO    POTENTIAL
                             TONS

    1  .009853  .990195         88.

 SILT TRANSPORT CAPACITY:
 BED SHEAR STRESS, #/SQ FT =     .0015
  FINE GRAIN SEDIMENT TYPE =         1
               LAYER TYPE =         1        2
 DEPOSITION THRESHOLD #/SF =     .0200     .0200
 EROSION THRESHOLD, #/SF   =     .1000     .2500

 SIZE    FALL     DECAY    TRANSPORT     FALL
 CLASS   RATIO    RATIO    POTENTIAL   VELOCITY
                             TONS         FPS

    2  .039271  .961490          0.   .0000839
    3  .156198  .855389          0.   .0003337
    4  .616889  .539618         72.   .0013181
    5 2.392890  .091364          0.   .0051127

 SAND
 ** ARMOR LAYER **
 STABILITY COEFFICIENT=       .94947
 MIN.GRAIN DIAM       =     .000288
 BED SURFACE EXPOSED  =     1.00000

             INACTIVE LAYER            ACTIVE LAYER
               %          DEPTH        %          DEPTH
   CLAY    .000000          .00     .003270         .00
   SILT    .000000          .00     .228226         .13
   SAND   1.000000         9.70     .768504         .30
  TOTAL   1.000000         9.70    1.000000         .43

         AVG. UNIT                AVG. UNIT
          WEIGHT                   WEIGHT

          .046500                 .042075

 **BED IS ARMORED**

      COMPOSITE UNIT WT OF ACTIVE LAYER T/CF=       .042075
      WEIGHT IN SURFACE LAYER(TONS),    WTSL=       18413.5
      DEPTH OF NEW ACTIVE LAYER(FT),     DSE=         .0000
      WEIGHT IN NEW ACTIVE LAYER,     WTMXAL=            .0
      WEIGHT IN OLD ACTIVE LAYER,        WAL=       23960.2
      USEABLE WEIGHT, OLD INACTIVE LAY,  WIL=      601168.2
 BED MATERIAL BY GRAIN SIZE FRACTION       .000000     .000000     .000000     .000000     .000000
                                           .010000     .070000     .375000     .375000     .105000
                                           .025000     .025000     .005000     .005000     .005000
 BED MATERIAL BY PERCENT FINER/100         .000000     .000000     .000000     .000000     .000000
                                           .010000     .080000     .455000     .830000     .935000
                                           .960000     .985000     .990000     .995000    1.000000
 ** ACTIVE LAYER **
 BED MATERIAL BY GRAIN SIZE FRACTION       .003270     .000000     .000000     .228226     .000000
                                           .007685     .053795     .288189     .288189     .080693
                                           .019213     .019213     .003843     .003843     .003843
 BED MATERIAL BY PERCENT FINER/100         .003270     .003270     .003270     .231496     .231496
                                           .239181     .292976     .581165     .869354     .950047
                                           .969260     .988472     .992315     .996157    1.000000

 C FINES, COEF(CFFML), MX POTENTIAL= .656707E+02 .100000E+01 .269978E+07

 POTENTIAL TRANSPORT BY SIZE CLASS=  .882178E+02 .943262E-20 .792687E-20 .715250E+02 .284629E-21
                                     .100000E-06 .100000E-06 .100000E-06 .100000E-06 .100000E-06
                                     .100000E-06 .100000E-06 .100000E-06 .100000E-06 .100000E-06
                          TOTAL          AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY
 CALCULATED SEDIMENT LOAD, TONS/DAY
           CLAY        88.22
           SILT        71.52          .00          .00        71.52          .00
  SANDS & GRAVELS        .00          .00          .00          .00          .00          .00
                                      .00          .00          .00          .00          .00
```

TABLE SA-1. TRAP EFFICIENCY ON STREAM SEGMENT # 1
EXAMPLE PROBLEM NO 7. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
ACCUMULATED AC-FT ENTERING AND LEAVING THIS STREAM SEGMENT

TIME DAYS	ENTRY POINT	CLAY INFLOW	CLAY OUTFLOW	CLAY TRAP EFF	SILT INFLOW	SILT OUTFLOW	SILT TRAP EFF	SAND INFLOW	SAND OUTFLOW	SAND TRAP EFF
101.00	58.000	13.73			12.68			30.94		
TOTAL=	1.000	13.73	13.11	.04	12.68	.70	.94	30.94	.00	1.00

SRATING

DOWNSTREAM BOUNDARY CONDITION SPECIFIED BY A RATING CURVE

ELEVATION OF GAGE ZERO .00
DISCHARGE CORRESPONDING TO LOWEST ELEVATION IN TABLE .0
DISCHARGE INTERVAL 2000.0
NO. OF POINTS IN RATING TABLE 40
ELEVATIONS

950.00	955.10	958.00	960.00	962.00	963.60	965.10	966.20	967.00	967.70
968.30	968.90	969.40	969.80	970.20	970.60	971.00	971.40	971.80	972.10
972.40	972.70	972.90	973.10	973.30	973.50	973.70	973.80	973.90	974.00
974.10	974.20	974.30	974.40	974.50	974.60	974.70	974.80	974.90	975.00

SPR

PRINT AT SELECTIVE X-SECTIONS ONLY

PN	3.000	.000	.000	.000	.000	.000	.000	.000	.000
END	.000	.000	.000	.000	.000	.000	.000	.000	.000

* C FLOW 3 = NEAR BANK FULL Q, WILLIAMS LAKE LOWERED TO NATURAL CONDITION

BOUNDARY CONDITION DATA, CONTROL POINT NO. 1
TIME STEP NO. 3
WATER DISCHARGE= 1250.00
ELEVATION= 953.188
TEMPERATURE= 65.000
FLOW DURATION(DAYS) .2000

EXAMPLE PROBLEM NO 7. LOWER SOUTH FORK ZUMBRO RIVER, ROCHESTER, MN
FLOW # (N) = 1
FLOW...Q(N)= 1250.0
TIMESTEP DURATION (DAYS) = .2000
ACCUMULATED TIME (YRS) = .2773
WATER TEMPERATURE (DEG F)= 65.0000
***************************** FALL VELOCITY BY METHOD 2*****************************

DIAMETER	VELOCITY	REY. NO.	CD
.000009	.2105298E-04	.1671599E-04	1437286.
.000018	.8390687E-04	.1332435E-03	180969.5
.000036	.3337332E-03	.1059932E-02	22878.70
.000072	.1318051E-02	.8372224E-02	2933.566
.000144	.5112670E-02	.6495108E-01	389.9372
.000288	.1907676E-01	.4847001	56.01589
.000580	.5916453E-01	3.027370	11.72824
.001160	.1355234	13.86910	4.470513
.002319	.2832060	57.94010	2.046556
.004639	.4824399	197.4439	1.410801
.009279	.7200630	589.4511	1.266741
.018560	1.040348	1703.463	1.213804
.037120	1.472924	4823.523	1.211086
.074216	2.082692	13636.37	1.211086
.148596	2.946998	38633.42	1.211086

SEDIMENT INFLOW (TONS/DAY)

	TOTAL	AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY				
CLAY	89.52					
SILT	179.04	.00	.00	179.04	.00	
SANDS & GRAVELS	625.68	268.22	203.80	139.42	10.33	3.91
		.00	.00	.00	.00	.00

****

THE FOLLOWING TABLE IS PRINTOUT FOR CROSS SECTION 32.000

HYDRAULIC PARAMETERS:

VEL	SLO	EFD	EFW	N-VALUE	TAU	USTARM	FROUDE NO.
2.770	.001081	4.851	146.629	.0500	.32762	.41084	.222

BED SEDIMENT RESERVOIR COMPUTATIONS:

NEW SURFACE AREA (SQ FT):	TOTAL	K-PORTION	S-PORTION
	812541.25	812541.25	.00

GRADATION OF ACTIVE PLUS INACTIVE DEPOSITS

BED MATERIAL BY GRAIN SIZE FRACTION	.000139	.000000	.000000	.009714	.000000
	.009901	.069310	.371305	.371305	.103965
	.024754	.024754	.004951	.004951	.004951
BED MATERIAL BY PERCENT FINER/100	.000139	.000139	.000139	.009853	.009853
	.019755	.089065	.460370	.831675	.935640
	.960394	.985148	.990099	.995049	1.000000

CLAY TRANSPORT CAPACITY:

BED SHEAR STRESS, #/SQ FT	=	.3276	
FINE GRAIN SEDIMENT TYPE	=	1	
LAYER TYPE	=	1	2
DEPOSITION THRESHOLD #/SF	=	.0200	.0200
MASS EROSION THRESHOLD, #/SF	=	.1000	.2500

SIZE CLASS	EROSION RATE TONS/DAY ACTIVE LAYER	INACTIVE LAYER
1	147790.18	43719.65

SILT TRANSPORT CAPACITY:

BED SHEAR STRESS, #/SQ FT	=	.3276	
FINE GRAIN SEDIMENT TYPE	=	1	
LAYER TYPE	=	1	2
DEPOSITION THRESHOLD #/SF	=	.0200	.0200
EROSION THRESHOLD, #/SF	=	.1000	.2500

SIZE CLASS	EROSION RATE TONS/DAY ACTIVE LAYER	INACTIVE LAYER
2	147790.18	43719.65
3	147790.18	43719.65
4	147790.18	43719.65
5	147790.18	43719.65

SAND

** ARMOR LAYER **

STABILITY COEFFICIENT	=	.70824
MIN.GRAIN DIAM	=	.000288
BED SURFACE EXPOSED	=	1.00000

	INACTIVE LAYER %	DEPTH	ACTIVE LAYER %	DEPTH
CLAY	.000000	.00	.003543	.00
SILT	.000000	.00	.247306	.14
SAND	1.000000	9.70	.749151	.30
TOTAL	1.000000	9.70	1.000000	.44
	AVG. UNIT WEIGHT		AVG. UNIT WEIGHT	

```
          .046500                 .041743

     COMPOSITE UNIT WT OF ACTIVE LAYER T/CF=        .041743
     WEIGHT IN SURFACE LAYER(TONS),    WTSL=        11228.9
     DEPTH OF NEW ACTIVE LAYER(FT),     DSE=          .0025
     WEIGHT IN NEW ACTIVE LAYER,     WTMXAL=             .0
     WEIGHT IN OLD ACTIVE LAYER,        WAL=        14988.8
     USEABLE WEIGHT, OLD INACTIVE LAY,  WIL=       366602.8
BED MATERIAL BY GRAIN SIZE FRACTION    .000000    .000000    .000000    .000000    .000000
                                       .010000    .070000    .375000    .375000    .105000
                                       .025000    .025000    .005000    .005000    .005000
BED MATERIAL BY PERCENT FINER/100      .000000    .000000    .000000    .000000    .000000
                                       .010000    .080000    .455000    .830000    .935000
                                       .960000    .985000    .990000    .995000   1.000000
** ACTIVE LAYER **
BED MATERIAL BY GRAIN SIZE FRACTION    .003543    .000000    .000000    .247306    .000000
                                       .007492    .052441    .280932    .280932    .078661
                                       .018729    .018729    .003746    .003746    .003746
BED MATERIAL BY PERCENT FINER/100      .003543    .003543    .003543    .250849    .250849
                                       .258340    .310781    .591713    .872644    .951305
                                       .970034    .988763    .992508    .996254   1.000000

C FINES, COEF(CFFML), MX POTENTIAL= .587031E+04 .100000E+01 .268019E+07

POTENTIAL TRANSPORT BY SIZE CLASS=  .148060E+06 .147790E+06 .147790E+06 .167333E+06 .147790E+06
                                    .164320E+05 .471873E+04 .252230E+04 .178181E+04 .166995E+04
                                    .153141E+02 .106668E+02 .100000E-06 .100000E-06 .100000E-06
                             TOTAL          AND LOAD BY GRAIN SIZE (FINE TO COARSE) IN TONS/DAY
CALCULATED SEDIMENT LOAD, TONS/DAY
            CLAY       535.13
            SILT     38076.74        .00         .00    38076.74         .00
 SANDS & GRAVELS      2825.62     846.16      322.95      874.47      618.95      162.49
                                     .35         .25         .00         .00         .00
.............................................................................................................

SSEND


       0   DATA ERRORS DETECTED.

TOTAL NO. OF TIMESTEPS READ=          5
TOTAL NO. OF WS PROFILES=         42
ITERATIONS IN EXNER EQ  =      1680.
END OF JOB

JOB COMPLETED
RUN TIME =  0 HOURS,  1 MINUTES & 22.27 SECONDS
```

SECTION - 7

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Appendix A

Input Description

Section I

Geometry and Channel Properties

Summary

Summary of Geometry Records

The records described in this section are used to define the geometry of the river system being modeled. The title records (**T1-T3**) are required at the beginning of each stream segment. Each set of **X1** through **H** (or **HD**) records are used to describe the geometry and special features of a cross section along a stream segment. The **QT**, **$TRIB**, and **CP** records are used to combine single stream segments into a river network.

COMMAND	DESCRIPTION	PAGE
T1-T3	Title Records.	A-3
NC	Manning's N-values.	A-4
NV	Vary N-values by elevation of discharge.	A-5
QT	Tributary or local inflow/outflow.	A-7
X1	Cross section location.	A-8
X3	Encroachments.	A-10
X5	Hydraulic control point.	A-12
XL	Conveyance limits.	A-14
GR	Cross section coordinates.	A-15
H	Limits of movable bed.	A-16
HD	Bed sediment reservoir.	A-19
EJ	End of geometric data.	A-22
$TRIB	Tributary inflow point.	A-23
CP	Control point identification.	A-24

TITLE Records - 3 Required (T1, T2, T3)

Three title records are required to precede the geometry data for each stream segment in the network. The program expects a T in column 1. Additional printout of Geometric Data can be requested by specifying a B or C in Column 3 on the T1 record.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	T1	Record identification in Columns 1 and 2 is T1, T2 and T3 for the first, second and third title records, respectively.
Column 3 of T1, record only	ISI(1)	Blank (zero not allowed)	Normal printout lists data from title records and the NC record. Only the cross section identification number is listed for records X1 through EJ.
		B	This printout option prints the initial geometry of the model and causes a data edit[1] to be made.
		C	This printout option activates a trace[2] printout through subroutine GMOD.
1-10		Comments	Fields 1 through 10 (Columns 3-80) may be used for identification purposes such as labeling the data set, noting the date of the run, or other relevant information.

[1] Specifying a B in Column 3 invokes a Data Edit command. This causes the input records to be echoed in the output enabling the user to verify the initial geometry of the model. The B-level printout is normally not recommended but it may provide useful additional information when initially developing a data set.

[2] Specifying a C in Column 3 invokes a trace printout to occur. Use of this print option is not recommended. C-level trace printout is intended only for program debugging purposes.

NC

NC Record - Required for First Cross Section

Manning's N-Values

The NC record specifies the Manning's n-values and the expansion and contraction coefficients for transition losses. An NC is required prior to the first cross section definition (the first X1 record). When changing previously specified values additional NC records are required at those cross sections where n-values change. The NC record values are constant with depth and will be used until changed by the next NC record. NC records may be inserted before any X1 record. The n-values apply over the reach, and will be used starting in the reach in which the record appears in the data set. Expansion and/or contraction coefficients apply to the next upstream reach.

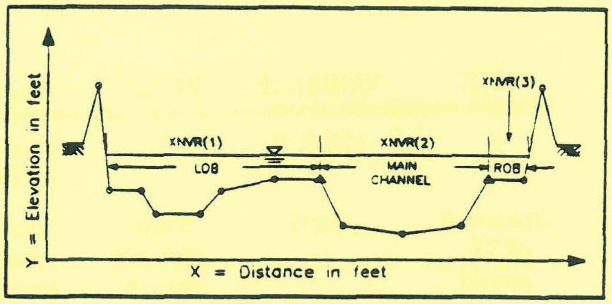

Figure A-1.

NOTE: HEC-6 applies n-values to the upstream reach whereas HEC-2 applies them halfway to the cross section on either side of the one for which they appear in the data set. However, results using either method are usually in close agreement without changing the n-values.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	NC	Record identification (in columns 1 and 2).
1	XNVR(1)	+	Manning's n-value for the **left overbank.**
		0	No change from previous n-value for the **left overbank.**
2	XNVR(3)	+	Manning's n-value for the **right overbank.**
		0	No change from previous n-value for the **right overbank.**
3	XNVR(2)	+	Manning's "n" value for the **channel.**
		0	No change from previous n-value for the **channel.**
4	CC	+	**Contraction coefficient** used in computing transition losses.
		0	No change in contraction coefficient.
5	CE	+	**Expansion coefficient** used in computing transition losses.
		0	No change in expansion coefficient.
6-10			Leave blank.

NV Record - Optional[3]

Vary N-Values by Elevation or Discharge

A table of Manning's n-values versus either elevations or discharges is entered on the **NV** record. The left overbank, the channel, and the right overbank are the three subsections in the model. A separate **NV** record must be entered for each subsection. Code values in order of **increasing elevation** or **discharge.** The values on this record will be used until changed by the next **NC** or **NV** record.

The program linearly interpolates when elevations or discharges are between values specified in the table. When elevations or discharges are outside the range of values specified in the table the extreme values are used, i.e., no extrapolation occurs.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	NV	Record identification.
1	NPAR,NCH	++	Enter subsection number in Column 7 and number of n-values in Column 8. Subsection numbers are: 1 = left overbank 2 = channel 3 = right overbank One to five n-values are permitted per subsection. (For example, 13 denotes that three n-values are coded for subsection #1, the left overbank.)
2	VALN(1)	+	Manning's n-value for lowest elevation in the table. A positive (+) n-value denotes that a "n versus elevation" table is being used.
		-	Manning's n-value for smallest discharge in the table. Enter the n-value on the record as a negative value for a "n versus discharge" table. **Note:** The (-) sign preceding the value denotes that an "n versus discharge" table is coded. A (+) sign or no sign denotes an "n versus elevation" table. Do not mix discharges and elevations at the same cross section.
3	ELQ(1)	-,0,+	Enter the elevation for +VALN(1) or the discharge for -VALN(1).

[3] This record is different from the HEC-2 program's **NV** record.

NV Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
4	VALN(2)	+	Enter the next n-value in the table. This can be blank if there is only one n-value for this subsection.
5	ELQ(2)	-,0,+	Enter the elevation or discharge for VALN(2).
6-10			Continue entering table values across the record. Code the fifth elevation or discharge value in Field 1 of a second NV record if five points are desired.
			Note: A maximum of five points may be entered per subsection.

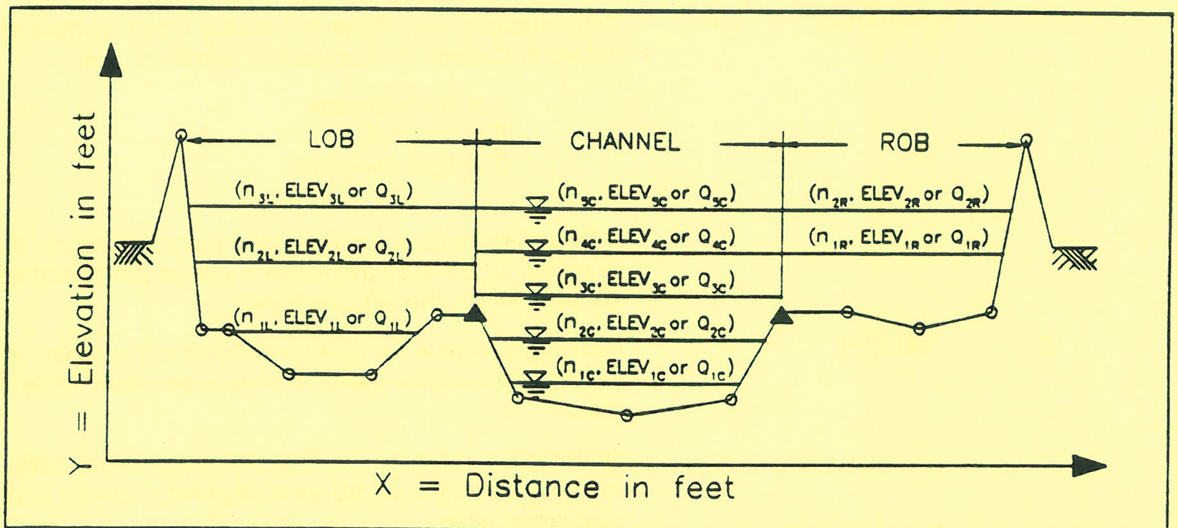

Figure A-2. An Illustration of VALN and ELQ.

Table A-1. Relationship of N Values to Elevations or Flows.

n vs. ELEVATION VALN(i)	n vs. ELEVATION ELQ(i)		n vs. DISCHARGE VALN(i)	n vs. DISCHARGE ELQ(i)
$+n_1$	$ELEV_1$		$-n_1$	Q_1
$+n_2$	$ELEV_2$	OR	$-n_2$	Q_2
$+n_3$	$ELEV_3$		$-n_3$	Q_3
$+n_4$	$ELEV_4$		$-n_4$	Q_4
$+n_5$	$ELEV_5$		$-n_5$	Q_5

QT Record - Optional

Tributary or Local Inflow/Outflow Location

This record identifies the location of a tributary or a diversion point. It should be placed immediately before the X1 record for the first cross section upstream from the tributary or local Inflow/Outflow location. See Section 3.6.2.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	QT	Record identification.
1	KQCH		A local inflow/diversion point.
		2-10	A tributary junction (control) point.
2-10			Leave blank.

NOTE: a.) When defining a local inflow/outflow point, leave field 1 blank. Any value greater than 1 entered for KQCH will indicate a tributary junction point.

b.) When defining a tributary junction point, a value must be entered in field 1. This value should be within the range 2 through 10.

X1

X1 Record - Required for Each Cross Section

Cross Section Location

This record is used to identify the cross section and define its location relative to its downstream neighbor.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	X1	Record identification.
1	SECID	-,0,+	Cross section identification number.
2	NXY	+	Total number of coordinate points used to describe the cross section's geometry on the **GR** records which follow. (5 ≤ NXY ≤ 100)
		0	**Repeat Cross Section Option.** The geometry of the previous (downstream) cross section (**GR** records) will be repeated for the present cross section. Therefore, no **GR** records will be entered for this section. Do not code a zero for the first cross section.
3	STCHL	-,+	Station of the **left** bank of the channel. Use top-bank when the bank roughness is included in channel n-values. Toe of bank is recommended when channel bank roughness is included in overbank n-values. STCHL does not need to equal one of the station values entered on the **GR** records for this cross-section.
		0	Omit when no **GR** records are present (i.e., enter blank or zero when NXY (**X1**.2) is 0).
4	STCHR	-,0,+	Station of the **right** bank of the channel. Same rules as for STCHL above.
5	RLL	+	**Reach length** of the **left** overbank between current cross section and the (previous) downstream cross section.
		0	Enter zero or leave blank for the first cross section or when there is no left overbank subsection.
6	RLR	0,+	**Reach length** of the **right** overbank. Same rules apply as for RLL above.
7	RLC	0,+	**Channel reach length.** The same rules apply as for overbank reach lengths above.
8	RX		**Cross Section Width Adjustment Factor.** Each station value defined in the **GR** data for this cross section will be **multiplied** by RX. For a repeat cross section, station values from the previous cross section will be changed before they are reused. For example, an RX value of 1.1 would increase each station by ten percent, and thereby effectively widen the entire cross section by ten percent.

X1 Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
			Note: The left and right channel stations, conveyance limits, ineffective area limits, movable bed limits, and limits of the dredged channel will all be adjusted by RX.
		+	Use a value for RX between 0.0 and 1.0 to narrow the cross section. Use a value greater than 1.0 to widen the cross section.
		0	No change to cross section stations.
9	DH		**Cross Section Elevation Adjustment Factor.** The constant DH will be **added** to each elevation value defined in the **GR** data for the cross section. For a repeat cross section, elevation values from the previous cross section will be changed before they are reused. For example, to code a 4000-foot long flume having a one-foot/thousand slope, just code the first **GR** data set and insert four repeat cross sections spaced 1000 feet apart with DH = 1. **Note:** If **NV** records are present, **elevations** will be changed, but the dredging template elevation, EDC, (**H** or **HD** record) is not changed.
		+	Constant will be added to all elevations.
		-	Constant will be subtracted from elevations.
		0	No change to cross section elevations.

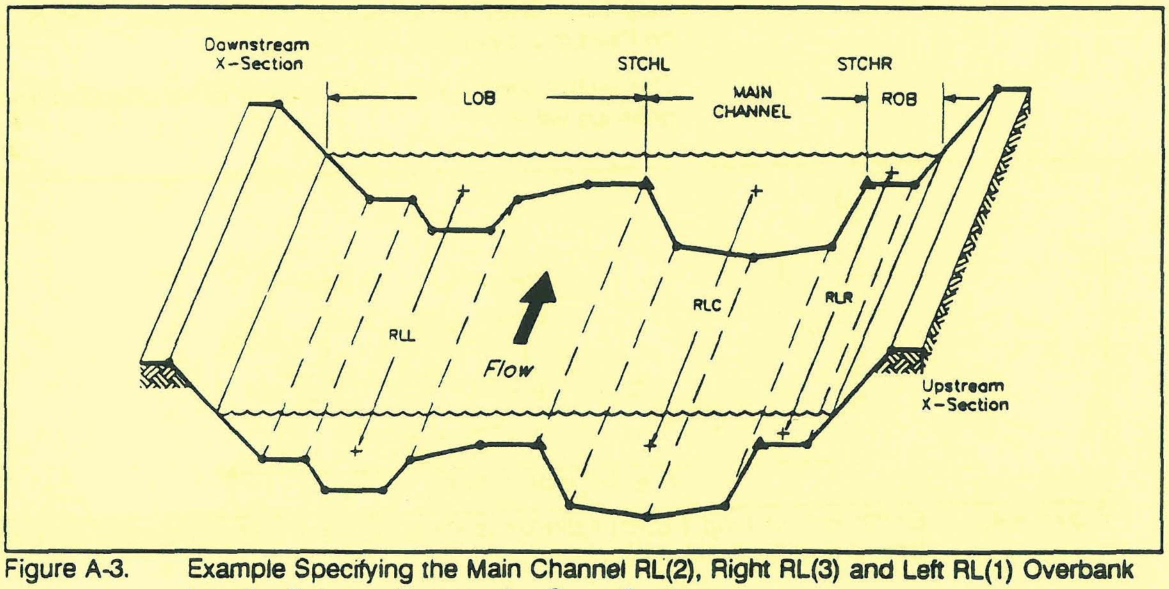

Figure A-3. Example Specifying the Main Channel RL(2), Right RL(3) and Left RL(1) Overbank Lengths Between Consecutive Cross Sections.

X3

X3 Record - Optional[4]

Encroachments

The **X3** record provides three methods for defining encroachments to a cross section. These methods are: (1) Ineffective flow area, defined using Field 1; (2) Effective width, defined using Field 3; and (3) Encroachment stations, defined using Fields 4-7.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	X3	Record identification.
1	MEID		**Method 1.** Ineffective flow area option.
		10	All water is confined to the channel, as defined by variables STCHL and STCHR on the **X1** record, until the calculated water surface elevation exceeds the channel bank elevation (the elevations corresponding to STCHL and STCHR on the **X1** record). The rest of this record may be left blank.
		0	No ineffective flow area. Total area of the cross section described on **GR** records below the water surface elevation is used in the computations.
2			Leave blank.
3	ENCFP		**Method 2.** Effective width for all flow.
		+	The program confines all flow to the width specified by ENCFP. It will be centered between the left and right bank stations of the channel (STCHL and STCHR on **X1** record). Side boundaries will be vertical and frictionless. Method 2 may be used in conjunction with Method 1.
		0	The width option is not being used or is not changed from previous value.

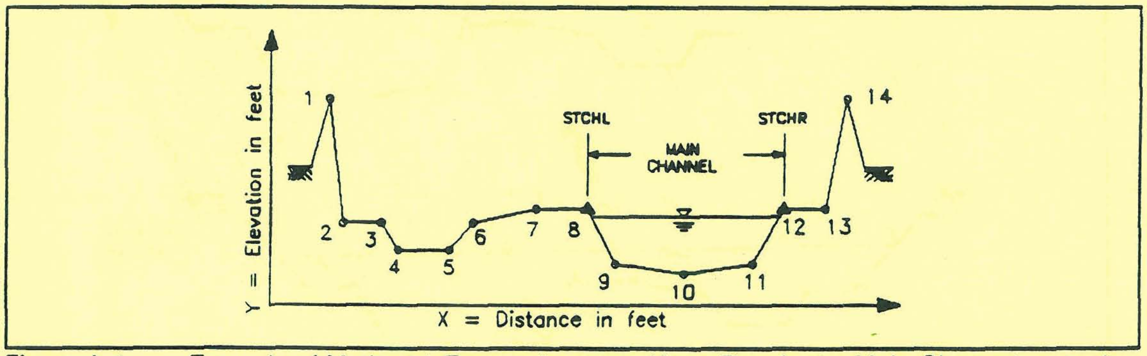

Figure A-4. Example of Method 1 Encroachment to Keep Flow in the Main Channel up to the Designated Bank Elevations.

[4] The HEC-6 **X3** record is different from the HEC-2 X3 record.

X3 Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
4	STENCL		**Method 3.** Encroachment station left. **Method 3 may not be used in conjunction with Methods 1 and/or 2.**
		-,+	STENCL sets a limit for flow on the **left** side of the channel. The side will be vertical and frictionless unless ELENCL is also used (see Field 5 below).
			Note: Do not enter a station value of zero since it will be treated as if no value was entered. Enter a small positive number like 0.01 instead.
5	ELENCL		**Method 3.** Encroachment elevation left.
		-,+	Enter the elevation at the top of the **left** encroachment. All cross section elevations for stations to the left of STENCL are raised to this elevation.
			Note: Do not enter a value of zero since it will be treated as if no value was entered as cautioned above.
6	STENCR		**Method 3.** Encroachment station right.
		-,+	Same rules and purpose as STENCL but for use on the **right** side of the channel.
7	ELENCR		**Method 3.** Encroachment elevation right.
		-,+	Same rules and purpose as ELENCL but for use on the **right** side of the channel.

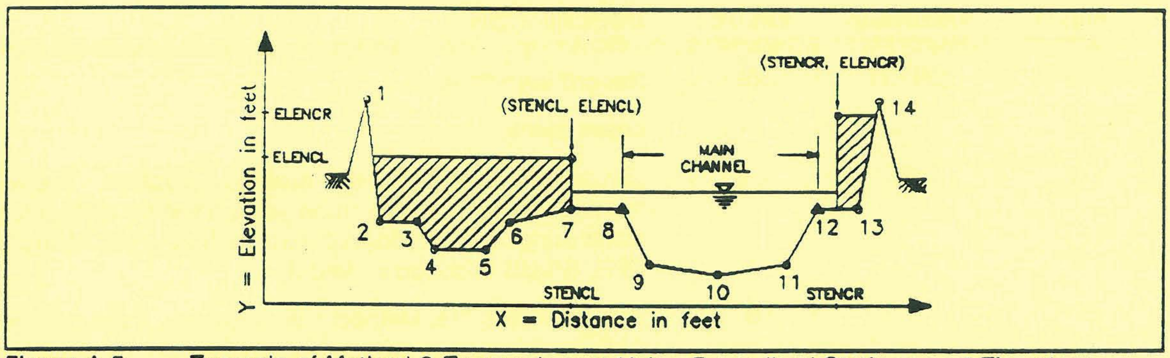

Figure A-5. Example of Method 3 Encroachment Using Prescribed Stations and Elevations (STENCL, ELENCL).

X5 Record - Optional[5]

Hydraulic Control Point

This record invokes two features: (1) It allows the water surface elevation to be prescribed at this section; (2) It establishes a control volume in which the program calculates trap efficiency.

Feature 1 provides two methods for specifying the water surface elevation. Method 1 is used to initially establish a starting water surface elevation at dams, weirs, bridges, etc. or to establish a control volume for trap efficiency computations by prescribing zero head loss and locating two sections very close together (e.g., one foot apart). It was originated for a system of navigation dams on the Trinity River so that hydraulic and sediment computations could start at the downstream end of the river and proceed all the way to the upstream end without starting and stopping at each dam.

Method 2 enables the user to prescribe the water surface elevation at a control point at any time step during the hydraulic computations. This is accomplished by specifying the field on the **R** record, where the water surface elevation for this control point can be found. Fields 2 through 10 are available on the **R** record for this purpose, therefore the user may not specify a value less than two nor greater than ten in Field 4 of the **X5** record. The effect of this **R** record field specification occurs each time an **R** record is encountered in the hydraulic data set with new values in any of the specified fields. When a new water surface elevation value is found in any of the specified fields, of the **R** record, then the initial water surface elevation for the associated cross section will be set to the new value at that time step.

Feature 2 provides a mechanism for obtaining trap efficiency at internal cross sections. This feature is invoked simply by the existence of the **X5** record in the cross section definition. If it is not desired to specify the water surface elevation but trap efficiency values are of interest, simply use an **X5** record with Fields 1-10 blank.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	X5	Record identification.
1			Leave blank.
2	UPE	-,+	**Method 1 - specified water surface elevation.** The water surface elevation at this cross section will be UPE unless the water surface at the downstream section + HLOS exceeds UPE. (HLOS is coded in field 3).
		0	Zero indicates that Method 1 is not used. If the desired water surface elevation is zero, enter a small positive value (e.g., 0.001).

[5] The HEC-6 **X5** record is different from the HEC-2 X5 record.

X5 Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
3	HLOS	0,+	**Head loss** between this section and the cross section immediately downstream. The specified water surface elevation is overridden when the tailwater elevation plus HLOS is higher.
4	ICSH	2-10	**Method 2 - R record field where initial water surface elevation will be specified.** Allows user specification of variable water surface elevation on R records in the hydrologic data set. **Note:** Do not use ICSH=1. Field 1 is reserved for specifying the water surface elevation at the downstream boundary control point. See the R record for a more detailed description.
		0	Zero indicates that Method 2 is not used. When using Method 2, allowable values are in the range from 2 to 10.

XL

XL Record - Optional

Conveyance Limits

Two methods are available for specifying conveyance limits. In Method 1, only a width is specified which is centered between the left and right bank stations specified on the **X1** record. Use Field 3 to specify this width and leave Fields 4 and 5 blank. In the second method both a left and right station must be specified to define the conveyance portion of the channel. Enter the left and right stations for the conveyance limits in Fields 4 and 5 and enter a zero in Field 3 or simply leave it blank.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	XL	Record identification.
1			Leave blank.
2			Leave blank.
3	CLC	+	**Method 1.** Enter the width of the conveyance channel. It will be centered between left and right bank stations (STCHL and STCHR on **X1** record).
		0	Use Method 2.
4	CLL	-,+	**Method 2.** Enter the cross section station for the **left** side of the conveyance channel. It does not have to coincide with a **GR** station point. It can be any place in the cross section, but it must be less than CLR. **Note:** Do not enter a value of zero since it will be interpreted as though no value was entered. Enter a small positive value (e.g., 0.001) when a value of zero is desired.
5	CLR	-,+	**Method 2.** Enter the cross section station on the right side of the conveyance channel. It does not have to coincide with a coordinate point. It can be any place in the cross section, but it must be greater than CLL. **Note:** Do not enter a value of zero since it will be interpreted as though no value was entered. Enter a small positive value (e.g., 0.001) when a value of zero is desired.
6-10			Leave blank.

GR Record - Required

Cross Section Coordinates

The data entered on the GR records is used to specify the cross section's two dimensional geometry in terms of a set of Y-X coordinate points. These coordinate points correspond to the elevation (Y) and station (X) along the cross section's ground profile. A set of GR records is required for each cross section unless NUMST (X1.2) is zero (or blank) indicating a repeat cross section. Code stations in increasing order. Enter five elevation/station pairs per GR record. A maximum of one hundred points (or twenty GR records) per cross section is permitted.

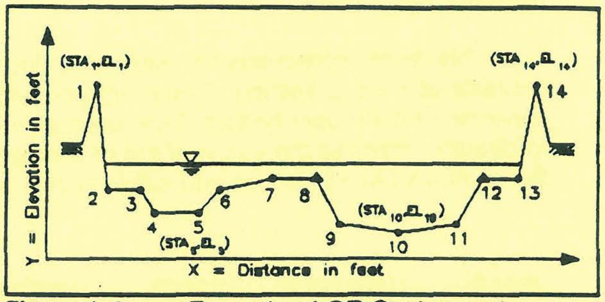

Figure A-6. Example of GR Station and Elevation Pairs Defining a Channel Cross Section.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	GR	Record identification.
1	EL(1)	-,0,+	Elevation of first coordinate point.
2	STA(1)	-,0,+	Station of first coordinate point.
3	EL(2)	-,0,+	Elevation of second coordinate point.
4	STA(2)	-,0,+	Station of second coordinate point.
5 - 10			Etc. Continue for up to one hundred coordinate point pairs. Each continuation record is identified with GR in Field 0, and the format is identical for all records.

H

H Record - Required If Not Using HD Record

Movable Bed Limits

This record prescribes the width and depth of the bed sediment reservoir and the dredging template at a cross section. The program computes the depth of sediment in the bed from the elevation of the model bottom, EMB defined in Field 2 of this record. The **HD** record allows the user to directly prescribe the depth of the bed sediment reservoir in Field 2. Other data on this record is the same as the **HD** record and either record is acceptable to the program.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	H	Record identification.
1	SECID	-,+	**Cross Section Identification Number.** Use the same value as previously entered in X1.1 for this cross section.
2	EMB		**Elevation of Model Bottom** (EMB) is used to calculate the depth of sediment material in the bed sediment reservoir at this cross section. EMB can be used to prescribe the elevation of geologic or concrete channel controls.
		-,+	Enter the desired elevation. Program will not scour bed below this elevation. Beware, a large depth of sediment can cause calculated volumes to be too large for computer word lengths, resulting in program failure.
		0	Program assigns EMB at 10 feet below the thalweg.
3	XSM		**Movable Bed Boundary, Left.** Cross section station at change from fixed to movable bed boundary; counterpart to XFM (H.4). Elevations at cross section coordinates between XSM and XFM will be adjusted vertically up or down for scour and deposition.
		-,+	Enter the station, **left** side of channel, where the fixed bed stops and the movable bed begins. This station need not coincide with an existing **GR** station point.
		0	Program will automatically set the movable bed limits according to the location of the water surface.

H Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
4	XFM		**Movable Bed Boundary, Right.** Cross section station at change from movable to fixed bed boundary, counterpart to XSM (H.3).
		-,+	Enter the station of the last movable bed point on the **right** side of channel.
		0	Program will automatically set the movable bed limits according to the location of the water surface.
5	DLYR		**Elevation correction** for movable bed at restart.
		-,+	In restarting a run it is desirable to enter a value for DLYR, causing program to correct all GR elevations within the movable bed limits by adding this value to the Y-coordinate.
		0,b	In most cases, leave this field blank.
6	EDC	-,+	**Elevation of Bottom of Dredged Channel.** Do not include overdredging here. (see H.10). This value should always be above the model bottom. (EMB in Field H.2.)
		0	Dredging is not desired at this cross section. If the desired elevation of the dredged channel bottom is zero, enter a small positive value (e.g. 0.001).
7	XSD		**Dredged Channel Boundary, Left.** The cross section station where dredging will begin if this value equals a station coded on the GR records. If it does not coincide with a GR station, dredging will begin at the next GR station after the value coded here. This value should be equal to or greater than XSM. No new cross section station is interpolated.
		-,+	Enter the station of the cross section coordinate point on the left side of the dredged channel, so that the elevation of coordinate points within the dredge channel (from XSD to XFD) can be corrected for dredging. XSD should always be greater than or equal to XSM.
		b,0	XSD is set equal to XSM, (HD.3).

H Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
8	XFD		**Dredged Channel Boundary, Right.** Cross section station beyond which no dredging is performed, counterpart to XSD.
		+	Enter the station of the cross section coordinate point at the right of dredged channel, so that the elevation coordinates of points outside the dredged channel boundaries will not be corrected for dredging. XFD **should always be less than or equal** to XFM.
		0	Either no dredging is required or XFD=XFM, (H.4).
9	XDM		Cross section **station of highest elevation** inside the dredge template. It is used to test the elevation of that point against the elevation of dredged channel to determine whether or not dredging is required.
		+	Enter the X-coordinate of the coordinate point having the highest elevation within the portion of channel to be dredged.
		0	Program uses the first (leftmost) station within the dredged channel portion of the cross section.
10	DOD		**Depth of Overdredging.** Used to establish some extra depth below the required bottom elevation.
		+	Enter the amount of overdredging desired at this cross section. Do not allow overdepth dredging below the bottom of the bed-sediment reservoir.
		0,b	Leave blank if overdredging is not required.

HD Record - Required If Not Using H Record

Movable Bed Limits

This record prescribes the width and depth of the bed sediment reservoir and the dredging template at a cross section. It replaces the H record and allows the depth of sediment in the bed to be prescribed directly with the variable DLY (HD.2) instead of implying it through the elevation of the model bottom, using EMB (H.2). All other fields of the HD record are the same as those on the H record and either record is acceptable to the program. **Do not use both H and HD at the same cross section.**

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	HD	Record identification.
1	SECID	-,+	**Cross Section Identification Number.** Use the same value as previously entered in X1.1 on the X1 record for this cross section.
2	DLY	0,+	**Depth of the Bed Sediment Reservoir** at this cross section. Negative values are not permitted. There is no default. Blank is the same as zero.
3	XSM		**Movable Bed Boundary, Left.** Cross section station at change from fixed to movable bed boundary; counterpart to XFM (H.4). Elevations at cross section coordinates will be adjusted vertically up or down for scour and deposition when the GR station falls between XSM and XFM.
		-,+	Enter the station, left side of channel, where the fixed bed stops and the movable bed begins. This station need not coincide with an existing GR station point.
		0	Program will automatically set the movable bed limits according to the location of the water surface.

HD Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
4	XFM		**Movable Bed Boundary, Right.** Cross section station at change from movable to fixed bed boundary, counterpart to XSM (H.3).
		-,+	Enter the station of the last movable bed point on the **right** side of channel.
		0	Program will automatically set the movable bed limits according to the location of the water surface.
5	DLYR		**Elevation correction** for movable bed at restart.
		-,+	In restarting a run it is desirable to enter a value for DLYR, causing program to correct all **GR** elevations within the movable bed limits by adding this value to the Y-coordinate.
		0,b	In most cases, leave this field blank.
6	EDC	-,+	**Elevation of Bottom of Dredged Channel.** Do not include overdredging here. (see **H**.10). This value should always be above the model bottom. (EMB in Field **H**.2.) **Note:** The bottom of the bed sediment reservoir is EMB = YMN - DLY, where YMN is the lowest elevation in the movable bed portion of the **GR** data and DLY is (**HD**.2) above.
		0	Dredging is not desired at this cross section. If the desired elevation of the dredged channel bottom is zero, enter a small positive value (e.g. 0.001).
7	XSD		**Dredged Channel Boundary, Left.** The cross section station where dredging will begin if this value equals a station coded on the **GR** records. If it does not coincide with a **GR** station, dredging will begin at the next **GR** station after the value coded here. This value should be equal to or greater than XSM. No new cross section station is interpolated.
		-,+	Enter the station of the cross section coordinate point on the left side of the dredged channel, so that the elevation of coordinate points within the dredge channel (from XSD to XFD) can be corrected for dredging. XSD should always be greater than or equal to XSM.
		b,0	XSD is set equal to XSM, (**HD**.3).

HD Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
8	XFD		**Dredged Channel Boundary, Right.** Cross section station beyond which no dredging is performed, counterpart to XSD.
		-,+	Dredging will stop at the GR station equal to, or to the left of this station. This value should be less than or equal to XFM.
		b,0	XFD is set equal to XFM, (HD.4).
9	XDM	-,+	The station of the cross section coordinate point having the highest elevation within the dredged channel. This is the station used to test whether or not dredging is required.
		0	The program uses the leftmost point inside the dredging template.
10	DOD		**Depth of overdredging.** Used to establish some extra depth below required bottom elevation.
		+	Enter the amount of overdredging desired at this cross section. Do not allow overdepth dredging below the bottom of the bed-sediment reservoir.
		0,b	There is no default, zero or blank means no dredging is required.

EJ

EJ Record - Required

End of geometric model data is established by an EJ record. This record must be the last geometry record entered for each stream segment described in the geometry section.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	EJ	Record identification.
1-10			Leave blank.

$TRIB Record - Optional

Tributary Inflow Point

This is the HEC-6 record which identifies the beginning of the geometry or sediment data set for each tributary in the stream network. The difference between a tributary and a local inflow is that the tributary is a branch in the network geometry data set whereas a local inflow point has no geometry. Refer to Section 3.6 for instructions on assembling data for tributary systems.

Place a **$TRIB** command in front of each tributary geometry data set and in front of each tributary sediment data set.

Important Note: A **$TRIB** record for this version of HEC-6 has a different meaning than a **$TRIB** record for prior versions. A **$TRIB** record from a data file setup to run under the prior version (all versions dated prior to October 1986) should be changed to a **$LOCAL** record in order to run the identical data file using this version.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	$TRIB	Record identification (Columns 1 - 5).
2-10			Leave blank.

CP

CP Record - Optional

Control Point Identification

The **CP** record is used to associate each tributary data set with the cross section where it enters the network. The value entered in Field 1 should equal that given on the Q record associated with the tributary.

A **CP** record must follow each **$TRIB** record used in the geometry data set. The appropriate records (described previously in this section) needed to detail the geometry of the tributary should follow the **CP** record.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	CP	Record identification.
1	JPNUM	+	Junction (control) point number.
2-10			Leave blank.

Section II

Sediment Properties

and

Transport Functions

Summary

Summary of Sediment Properties and Transport Functions

The initial sediment properties and quantities for the model are defined using the records in this section. Each stream segment in the river network must be described with a separate set of **T4-N** (or **PF**) records. Local inflow data (**$LOCAL** and **LQL-LFL** records) are entered after the complete set of records has been entered for the stream segment in which they are located and before the records for the next stream segment.

TITLE Records - Five Required (T4, T5, T6, T7, T8)

Comments

Five Title Records are required to precede the sediment data **for each segment** in the network. They each have a T in Column 1 and the sequence number in Column 2. The number four is suggested for the first sequence number. A Data Echo print option is available; see below for details.

Note: Column 4 of **T4** record reserved for program use.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	T4	**Record identification** in Columns 1 and 2. **T4, T5, T6, T7,** and **T8** for the first through fifth title records, respectively.
Column 4 of **T4** record only	ISI(2)	B	**Data Echo.** Each input record is echoed in the output file as it is read. This is available to help the user verify the initial conditions of the model and is not recommended for normal use. To exercise this option, enter **B** in Column 4 of the first title record (T4) of this group.
1-10[1]			**Fields** 1 through 10 (Columns 5-80) may be used for **identifying** the stream segment, project date, or any other **relevant** information.

[1] Column 4 of the first title record (T4) is reserved for requesting a printout option that echoes the input and should be left blank if a data echo is not required.

I1

I1 Record - Required

Sediment Properties

The I1 record contains sediment properties for the job.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	I1	Record identification.
1	ISI	Comment	Any alphanumeric characters or comments.
2	SPI		**Specify iterations** of the Exner computations.
		+	Specify the number of times during each time step for the program to recalculate the composition of material in the bed. **Note:** More than any other input variable, SPI affects computation time. When possible, specify one. If too small of a value is used, calculations may display oscillations in the amount of sediment being transported and in the bed profile. The value can be increased to twenty, fifty, etc., until values are essentially the same as those calculated with SPI left blank or zero.
		0	Program calculates the value. **Note:** The value of SPI computed by the program if the user does not specify a value for SPI can become very large for some problems. We suggest that users avoid using values greater than SPI = 50. A message will appear in your output if the computed SPI value is greater than fifty. If the user chooses to use the larger values; they must enter the desired SPI in Field 2 (I1.2) and re-execute the program. Refer to Training Document No. 13 (HEC 1981) for further discussion.

I1 Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
3	IBG		**Specify gradation calculation method.** Instructs program to calculate gradation in surface layer based upon transport capacity required to just transport the inflowing load with no scour or deposition if possible.
		0	Program uses gradation on N records to calculate transport capacity.
		+3	Program calculates gradation of surface layer based on inflowing load and sediment transport theory. Iterative process performed in three iterations (i.e., "IBG" iterations).
4	MNQ		**Number of parallel discharges.** (This option is rarely used.)
		+	Maximum number of discharges that will be analyzed in parallel. Any number up to ten is permissible when tributaries or diversions are not present. Otherwise use one.
		0	Program assigns one.
5	SPGF	+	**Specific gravity of fluid.** It is used with density and acceleration of gravity to calculate unit weight.
		0	Program assigns 1.0000 (Fresh water at 39.2 degrees F).
6	ACGR	+	**Acceleration due to gravity.**
		0	Program assigns 32.174 ft/sec^2 (standard at 45 degrees latitude, sea level).
7	NFALL		**Fall Velocity Computation Method.** Refer to Section 2.3.6, "Sediment Particle Properties" for a discussion of the available methods.
		0	Program defaults to Method 2.
		1	Original (TOFF) fall velocities.
		2	Federal Interagency Sedimentation Project (FISP) method for computing fall velocities.
8	IBSHER		**Bed shear stress computation method.**
		0,1	Program calculates bed shear stress as γDS for clay/silt erosion and deposition.
		2	Program uses U_* from smooth wall law to calculate bed shear stress for clay/silt erosion and deposition.

I2 Record - Optional

Parameters Required for Clay Transport

The presence of an **I2** record instructs the program to calculate transport of clay. The data included on this record provides parameters and guidelines within which to structure the computations for clay transport. **Note:** The following clay transport instructions were derived from experiments where the suspended sediment concentrations were less than 300 mg/l (see Krone, 1962). Applications to field situations where suspended sediment concentrations may be greater than 300 mg/l may exceed the intended range of applicability of the relationships. Also note that the relationships for clay deposition were derived from one-dimensional channels where the velocity and sediment concentration profiles are reasonably uniform. Users may experience difficulty with clay deposition rates in deep reservoirs.

If the **I2** record is used by itself, the program will compute deposition of clay only. However, if two **Special I2** records are used in addition to the first **I2**, both erosion <u>and</u> deposition of cohesive sediment (clay and silt) will be calculated.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	I2	Record identification.
1	ISI	Comment	Any alphanumeric characters or comments.
2	MTCL		**Clay Transport Method.**
		0,1	**Deposition** of clay using the original method is computed **only. No clay erosion** is computed.
		2	**Deposition and Erosion of Cohesive Sediments** are computed. Deposition is computed by the Krone equation and erosion by the Ariathurai method. **Note:** This method requires the addition of two **Special I2** records, as described on page A-32.
3	ICS	b,1	Initial size class interval for clay - there is only one clay size available, so enter 1 or leave blank.
4	LCS	b,1	Last size class interval for clay - there is only one clay size available, so enter 1 or leave blank.
5	SPGC	+	**Specific gravity** of clay particles.
		0	The default is 2.65.
6	DTCL	+	**The shear threshold for clay deposition.** This is the average bed shear stress in lbs/sq ft above which clay will not be deposited. This value is ignored when the **Special I2** records are used.
		0	The default is 0.02 lb/sq. ft.

I2 Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
7			Leave blank.
8	PUCD	+	The unit weight for fully compacted clay deposits, lb/cu. ft.
		0	The default is 78 lb/cu. ft.
9	UWCL	+	The initial (before compaction) unit weight for clay deposits, lb/cu. ft.
		0	The default is 30 lb/cu. ft.
10	CCCD	+	Compaction coefficient for clay deposits for the equation: $\gamma_{clay} = UWCL + [CCCD * \{Log_{10}(Time)\}]$ where Time is in years. See section 2.3.5.3.
		0	The default is 16 lb/cu. ft./yr.

Special I2

Special I2 Records - Optional

Cohesive Sediment Transport Method 2 - Supplemental Parameters

The **Special I2** records are used to code the depositional and erosional shear stress thresholds for fine grained cohesive sediment (clay and silt) to be used by Clay and Silt Transport Method 2 (MTCL-I2.2, MTSL-I3.2). Refer to Section 2.3.9. If used, two **Special I2** records must be employed (in addition to the first **I2** record described on the preceding pages): one to describe the active layer and one to describe the inactive layer. **Note:** The following clay transport instructions were derived from experiments where the suspended sediment concentrations were less than 300 mg/l (see Krone, 1962). Applications to field situations where suspended sediment concentrations may be greater than 300 mg/l may exceed the intended range of applicability of the relationships. Also note that the relationships for clay deposition were derived from one-dimensional channels where the velocity and sediment concentration profiles are reasonably uniform. Users may experience difficulty with clay deposition rates in deep reservoirs.

The erosion parameters defined on the **Special I2** records apply to silt as well as clay sediments. If erosion of silt sizes is desired then an **I3** record must follow the **I2** record.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	I2	Record identification.
1	ISI	Comment	Any alphanumeric characters or comments.
2	J	1	Data on this record applies to the active layer (the first **Special I2** record).
		2	Data on this record applies to the inactive layer (the second **Special I2** record).
3	DTCL	+	**The shear threshold for clay and silt deposition.** This is the average bed shear stress in lbs/sq. ft. above which clay and silt will not be deposited.
		0	The default is 0.02 lb/sq. ft.
4	STCD	+	**Shear stress threshold for erosion of clay and silt particles,** lb/sq. ft. This is the shear stress above which clay and silt material will be scoured from the bed[2].
5	STME	+	**Shear stress threshold for mass erosion**, lb/sq. ft.[2]
6	ERME	+	**Erosion rate of clay and silt** at STME, lb/sq. ft./hr.[2]
7	ER2	+	**Slope of the erosion rate curve** for mass erosion, 1/hr.[2]

[2] There is no default, user must enter a value.

I3 Record - Optional

Parameters Required for Silt Transport

The presence of an I3 record instructs the program that the mixture of sediment to be analyzed contains SILT size particles. The data included on this record provides parameters and guidelines within which to structure the computations for silt transport.

When modeling erosion of silts, you must provide an I2 and two **Special I2** records to define erosion parameters of silt grains. If no clay is present in the system, enter zero for clay in the LF and N (PF) records.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	I3	Record identification.
1	ISI	Comment	Any alphanumeric characters or comments.
2	MTSL		**Silt Transport Method**
		1	Original method for calculating deposition of silt.
		2	Method for including scour and deposition of silt. **Note:** This method requires the use of an I2 record and two **Special I2** records, as described on page A-30 and A-32.
3	IASL	+	ID number of the **smallest grain size classification** of silt to be transported (see Table A-2). IASL must always be less than LASL.
		0	Default IASL = 1.
4	LASL	+	ID number of the **largest grain size classification** of silt to be transported (see Table A-2).
		0	Default LASL = 4.

Table A-2.			
ID#	Classification	Grain Size (mm)	Geometric Mean (mm)
1	Very fine silt	.004 - .008	.005
2	Fine	.008 - .016	.011
3	Medium	.016 - .031	.022
4	Coarse	.031 - .0625	.044

I3 Record - Continued

The data in Table A-2 is built into HEC-6; IASL and LASL must be selected from this table. The program automatically includes all sizes between IASL and LASL if the I3 record is present in the input. If transport of clay is to be computed as well as silts, IASL should equal one to provide a continuous representation of grain classes from clay size to silt size classes. If transport of sands is to be computed as well as silts, LASL should equal four for the same reason. Grain sizes which are not found in the bed may be so noted (with zero values) in the bed material gradation specified on the **N** or **PF** records.

FIELD	VARIABLE	VALUE	DESCRIPTION
5	SGSL	+	**Specific gravity** of silt particles.
		0	Default = 2.65
6	DTSL		**Deposition threshold** for silt.
		+	The average bed shear stress in lb/sq. ft. above which silt material will not be deposited. This value is ignored if **Special I2** records are used.
		0	Default = 0.02 lb/sq. ft. (for lack of better data).
7			Leave blank.
8	PUSD	+	**Unit weight** of fully consolidated silt deposits in lb/cu. ft.
		0	Default = 82 lb/cu. ft.
9	UWSL	+	**Unit weight** of silt material at the moment it is deposited on the stream bed.
		0	Default = 65 lb/cu. ft.
10	CCSD	+	**Compaction coefficient** for silt deposits for the equation $$\gamma_{silt} = UWSL + [CCSD(\log_{10}(Time))]$$ where time is the accumulated simulation time expressed in years.
		0	Default = 5.7 lb/cu. ft./yr.

I4 Record - Optional

Parameters Required for Sand Transport

The presence of an I4 record instructs the program that sand sizes are present in the mixture of sediment to be analyzed. The data included on this record provides parameters and guidelines within which to structure the computations for sand transport.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	I4	Record identification.
1	ISI	Comment	Any alphanumeric characters or comments.
2	MTC[3]		**Transport capacity relationship** to be used by program to compute sediment load for a given water discharge.
		0,1	Toffaleti Method (1969).
		2	User Specified Transport Function. User must supply his own transport relationship in the form of DS versus transport coefficients (on records J and K), where DS is depth times slope. See instructions for the J and K records for a more complete description.
		3	Madden's (1963) modification of Laursen's (1958) relationship.
		4	Yang's streampower (1973).
		5	Duboys (Brown, 1950).
		6	Einstein ... not yet available.
		7	Ackers-White (1973).
		8	Colby (1964).
		9	Toffaleti and Schoklitsch.
		10	Meyer-Peter and Muller (1948).
		11	Not used.
		12	Toffaleti (1969) - Meyer-Peter and Muller (1948) combination.
		13	Madden's (1985) modification of Laursen's (1958) relationship.
		14	Copeland-Laursen ... not yet available.

[3] Users should refer to Chapter 2 of Vanoni's Sedimentation Engineering (1975), for information regarding the best transport function to use for specific types of rivers and bed material types.

I4 Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
3	IASA	+	ID number of the **smallest grain size classification** of sand to be transported in the calculations (see table below). IASA must always be less than LASA.
		0	Default IASA = 1.
4	LASA	+	ID number of the **largest grain size classification** of sand to be transported in the calculations (see table below).
		0	Default LASA = 10.

The following table of grain sizes is built into HEC-6. IASA and LASA must be selected from this table. All sizes between, and including, IASA and LASA will be transported. If transport of silts is to be computed as well as sands, IASA should equal one to provide a continuous representation of grain classes from silt to sand sizes even if the very fine sand sizes are not found in the bed. Grain sizes which are not found in the bed may be so noted in the bed material gradation specified on the **N** or **PF** records.

Table A-3. Grain Sizes.

ID#	Classification	Grain Size (mm)	Geometric Mean (mm)
1	Very fine sand	.062 - .125	.088
2	Fine sand	.125 - .250	.177
3	Medium sand	.250 - .500	.354
4	Coarse sand	.500 - 1.000	.707
5	Very coarse sand	1.000 - 2.000	1.414
6	Very fine gravel	2.000 - 4.000	2.828
7	Fine gravel	4.000 - 8.000	5.657
8	Medium Gravel	8.000 - 16.000	11.314
9	Coarse Gravel	16.000 - 32.000	22.627
10	Very Coarse Gravel	32.000 - 64.000	45.255

I4 Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
5	SPGS	+	**Specific gravity of sand particles.** (Not the unit weight of deposited material.)
		0	Default = 2.65.
6	GSF	+	**Grain shape factor.**
		0	Default = 0.667.
7	BSAE	+	**B coefficient in surface area exposed function.** Equation is as follows: $FSAE = ASAE(SAE^{BSAE}) + CSAE.$
		0	Default = 0.5.
8	PSI	+	**The parameter Ψ from Einstein's method,** used to approximate Ψ* for calculating equilibrium bed elevation.
		0	Default = 30.
9	UWD	+	**Unit weight of deposited sediment.** Specify in lb/cu. ft.
		0	Default UWD = 93 lb/cu. ft., a reasonable value for sand. Program does not change this value with time.

I5 Record - Optional

Weighting Factors for Numerical Integration Method

Use this record to enter the user selected hydraulic parameter weighting factors. Section 2.2.4 of the user's manual presents two sets or schemes of weighting factors for the numerical integration method used by the program. If the I5 record is omitted, the program defaults to the Scheme 2 weighting factors. If an I5 record is entered with fields 2 through 6 blank, the program will assume the desired weighting factors equal zero. There are no defaults.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	I5	Record identification.
1	ISI	Comment	Any alphanumeric characters or comments.
2	DBI	+	Weight assigned to hydraulic properties at second cross section when calculating at downstream boundary.
3	DBN	+	Weight assigned to hydraulic properties at downstream boundary for downstream boundary calculations. **Note:** if values are entered for DBI and DBN then DBI + DBN must equal 1.0.
4	XID	+	Weight assigned to hydraulic properties at cross section downstream of section of interest - interior point calculations.
5	XIN	+	Weight assigned to hydraulic properties at cross section of interest - interior point calculations.
6	XIU	+	Weight assigned to hydraulic properties at cross section upstream of section of interest - interior point calculations. **Note:** if values are entered for XID, XIN and XIU then XID + XIN + XIU must equal 1.0.
7	UBI	+	Weight assigned to hydraulic properties at next to last cross section for calculation at upstream boundary.
8	UBN	+	Weight assigned to hydraulic properties at upstream boundary. **Note:** if values are entered for UBI and UBN then UBI + UBN must equal 1.0.

J Record - Optional[4]

User Specified Transport Function

Use the J record to define the coefficients of the User Specified Transport Function. This function is expressed by the equation:

$$GP = ((DS-C)/A)^B$$

where DS is depth times slope and A, B and C are coefficients in tons/day/foot of width . A separate J record is required for each grain size fraction being evaluated. Enter data from fine to coarse. The data contained on the J and K records is relevant to the program only if the selected transport capacity relationship MTC (Field 2 of I4 record) equals two. If MTC is not equal to two, the program will simply ignore the data contained on these records. Section unknown contains a complete description of the user specified transport function option.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	J	Record identification in Column 1.
1	ISI	Comment	Comment information such as the name of the grain size classification to which the data on this record relates.
2	DSCO(1)	+	Coefficient corresponding to A in above equation.
3	DSCO(2)	+	Coefficient corresponding to B in above equation.
4	DSCO(3)	+	Coefficient corresponding to C in above equation.

[4] If the user decides to use the special transport function option, then he needs to provide **both** a set of J records as well as a K record in order to specify the required information and coefficients to use this option.

K

K Record - Optional[5]

User Specified Transport Function

Use the K record to define the coefficients of the function which is used to correct the User Specified Transport Function for variation in n-value. This correcting function is expressed by the equation:

$$STO = E/(Dn)$$

The data contained on the J and K records is relevant to the program only if the selected transport capacity relationship, MTC (Field 2 of I4 record), equals two. If MTC is not equal to two, the program will simply ignore the data contained on these records. Please see section **UNKNOWN**.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	K	Record identification in Column 1.
1	ISI	Comment	Comment information such as the name of the grain size classification to which the data on this record relates.
2	CNCO(1)		Coefficient corresponding to D in above equation.
3	CNCO(2)		Coefficient corresponding to E in above equation.

[5] If the user decides to use the special transport function option, then he needs to provide <u>both</u> a set of J records as well as a K record in order to specify the required information and coefficients to use this option.

LQ Record - Required

Water Discharge for the Water Discharge-Sediment Load Relationship

The inflowing sediment load is related to water discharge by prescribing the discharge in cfs on the **LQ** record, total sediment load in tons per day on the **LT** record and the fraction of the sediment load in each grain size class on **LF** records. Each **LF** record will describe one grain size fraction and they should be entered from fine to coarse. Enter the water discharge in cfs on the **LQ** record as follows.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	LQ	Record identification.
1	ISI	Comment	Any alphanumeric characters or comments.
2	QWATER	+	**Water discharge** in cfs. Enter the first discharge value[6] for the water discharge versus sediment load table. If the range of water discharges in the inflow hydrograph is beyond that specified in this table, the extreme values of sediment load from the table will be used (i.e. the program will not extrapolate beyond the ends of the table).
3	QWATER	+	The second water discharge for the water discharge versus sediment load table. Each consecutive water discharge must be greater in value than the previous one.
4-10	QWATER	+	Continue to enter increasing water discharge values in Fields 4 through 10. A maximum of nine water discharge values is permitted.

[6] QWATER cannot be zero or negative.

LT

LT Record - Required

Total Sediment Load for the Water Discharge-Sediment Load Relationship

The inflowing sediment load is related to water discharge by prescribing the discharge in cfs on the **LQ** record, total sediment load in tons per day on the **LT** record and the fraction of the sediment load in each grain size class on **LF** records. Each **LF** record will describe one grain size fraction and they should be entered from fine to coarse. Enter the total sediment load in tons per day on the **LT** record as follows.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	LT	Record identification.
1	ISI	Comment	Any alphanumeric characters or comments.
2	QS	+,0	**Total sediment load** in tons per day. This value corresponds to the water discharge entered in Field 2 of the **LQ** record.
3	QS	+,0	Total sediment load in tons per day. This value corresponds to the water discharge entered in Field 3 of the **LQ** record.
4-10	QS	+,0	Continue to enter the total sediment load values for each subsequent water discharge entered on the **LQ** record. A maximum of nine values is permitted.

LF Record - Required

Fraction of Load for the Water Discharge-Sediment Load Relationship

The inflowing sediment load is related to water discharge by prescribing the discharge in cfs on the LQ record, total sediment load in tons per day on the LT record and the fraction of the sediment load in each grain size class on LF records.

Each LF record will describe the sediment load of one grain size fraction. There must be one LF record for each grain size classification selected on records I2 through I4 even if the fraction of the load for any grain size equals zero. LF records should be entered from fine to coarse.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	LF	Record identification.
1	ISI	Comment	Any alphanumeric characters or comments. (It is recommended that the grain size class be entered in the comment field, i.e. CLAY, SILT1, SILT2, VFS, FS, ... VCG).
2	QSED	+,0	**The fraction for this grain size of the total sediment load** corresponding to the water discharge in Field 2 of the LQ record.
3	QSED	+,0	The fraction for this grain size of the total sediment load corresponding to the water discharge in Field 3 of the LQ record.
4-10	QSED	+,0	Continue to enter the fraction of the total sediment load corresponding to each subsequent water discharge entered on the LQ record. A maximum of nine values is permitted.

N

N Record - Required if Not Using PF Records

Bed Material Gradation - Fractions of Total Bed Load

Initial bed material composition by grain size fraction is required for each cross section. Up to four size fractions can be entered on the first record. If more than four grain sizes are present, use a continuation **N** record to finish coding size fractions. A fraction of the total load must be given for each grain size classification previously prescribed on the **I2 - I4** records even if that fraction is zero. Do not skip grain size classes that are prescribed on the **I2 - I4** records. Enter data for each cross section (even if the bed material gradation does not change between cross sections) from downstream to upstream.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	N	Record identification (Column 1).
1	ISI	Comment	Comment field (recommend cross section ID number always be used here).
2	SAE		The fraction of **surface area** of the bed that is not covered by armor layer at this cross section. Divide the surface area exposed to scour by the total surface area to obtain this value. This parameter is used to describe initial bed armoring conditions.
		Blank	Program uses 1.0 for initial value.
		.001-1.0	Program uses the value entered as the initial value rather than 1.0.
3	DMAX		**Maximum grain size** at this cross section. Obtain from the gradation curve the diameter for which one hundred percent (100%) is finer.
		+	Enter grain size in feet.
		0	Program uses the diameter of the largest grain size defined on the I2 - I4 records.
4	DXPI		**Grain size** in eighty (80%) to ninety-five percent (95%) finer range.
		+	Enter grain size in feet that is approximately ninety-five percent (95%) size on gradation curve. It should define the upper breakpoint in the gradation curve. Must be less than or equal to DMAX (N.3).
		0	Program uses DMAX (N.3).

N Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
5	XPI		**Percent finer** for DXPI (N.4) expressed as a decimal.
		+	Range is from 0 to 1.00.
		0	Program uses 0.95.
6	SFITOT	+	**Total of grain size fractions** in the bed at this particular cross section.
		0	Program sums all values that follow for individual grain sizes.
		1.0	Program considers SFITOT to equal one hundred percent of inactive deposits regardless of what the sum of individual values equals.
7	SFIL(1)	.001-1.0	The fraction of the total amount of bed material composing the smallest size classification present in the bed at this particular cross section.
		0	If this grain size is not present in bed, enter zero.
8-10	SFIL(2)		If more than one grain size is present in the bed, enter fractions across this record, from finest to coarsest, for each size classification. Continue in Field 2 of a second N record if needed.

To determine how many records might be required, let's say that there are sixty cross sections, with one clay, four silts and four sands defined on the I2 - I4 records (e.g., nine different size classifications). Since only four grain sizes will fit on the first N record, a second N record is be needed to provide the data required for the remaining grain size classifications. Thus, a total of one hundred and twenty N records (two N records per cross section) will be needed to fully define the bed material gradation for this stream network.

PF

PF Record - Required if Not Using N Records

Bed Material Gradation - Percent Finer

The **PF** record prescribes the gradation of the bed sediment reservoir (in percent finer) at each cross section. **PF** records may be used instead of **N** records to define the bed material gradation as a grain size distribution curve. The sediment computations expect gradation information for each cross section; however, it is not necessary to enter **PF** records for every cross section in the network. Specific rules are:

a. There must be at least one **PF** record for each stream segment in the network. If only one **PF** record is present, that gradation is used for all cross sections on that stream segment.

b. The cross section ID number (i.e. river mile) is coded in Field 2 to tell the program where that PF-data applies. The cross section ID number on each **PF** record should correspond to one used previously on an **X1** record. If more than one **PF** record is present, but not one for each cross section on the stream segment, a linear interpolation is made to fill in the missing data.

c. If the cross section ID number is omitted from a **PF** record, it will be assigned to the last cross section (i.e. the one most upstream), and values to the previous **PF** record will be interpolated.

d. The gradation for any cross sections after the final **PF** record will be assigned the values on that record.

e. Do not skip grain sizes when entering the data (i.e. set LASL = 4 (I3.4) and IGS = 1 (I4.3) if silts as well as sands are being transported). It is not necessary to calculate all fifteen sizes.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	PF	Record identification.
		PFC	Record identification, continuation records.
1	ISI	Comment	Comment on **PF** record; data on **PFC** records.
2	SECID	-,0,+	Cross section ID number (i.e. river mile). There is no default. Do not leave this field blank.
3	SAE	b,0	**The fraction of the bed surface** that is exposed to erosion. That is, a portion of the bed may be armored or partially covered with bed rock. Usually SAE is left blank in which case the program will default to 1.0.
		.001-1.0	The normal range.

PF Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
4	DMAX	+	**The diameter of the maximum particle size.** Code all diameters in millimeters[7]. Always code a value. The program assigns a percent finer (PFXIS(1)=100) to correspond with DMAX. Although not required for the program to execute, it is best if DMAX corresponds to a class interval boundary. DMAX is also known as DAXIS(1).
5	DAXIS(2)	+	**The grain size diameter** at the first coordinate point down the percent finer curve from DMAX. If this particle size is larger than 64 mm, choose a point that will approximate the PF-Curve with two straight line segments from DMAX to 64 mm. Note: it is not necessary that this or any PF-coordinate correspond to a grain size class interval boundary - although they can. Semi-log interpolation is used to calculate the percent finer at each class interval boundary and these are subtracted to calculate the fraction of sediment in each size class.
6	PFXIS(2)	0,+	**The percent finer** corresponding to DAXIS(2). Code as a percent[1] (e.g., enter ten for 10%, twenty for 20%, etc.).
7-10	DAXIS-PFAXIS	0,+	Continue to code points from the percent finer curve in (grain size diameter, percent finer) pairs. Use up to three continuation **PFC** records to code a maximum of sixteen points. Begin coding data in Field 1 of continuation records.

[7] Millimeters and percent finer are required by the **PF** records rather than feet and fraction as required by the **N** records.

$LOCAL

$LOCAL Record - Optional

Local Inflow

This is the HEC-6 record which indicates that a water-sediment discharge table comes next in the data stream. It is used to separate inflow/diversion data from other data in the data stream.

Place the **$LOCAL** record after the **N** or **PF** records in the sediment data to separate the sediment data for the current stream segment from the water-sediment discharge table information needed for the local inflow(s) on the same stream segment. Use only one **$LOCAL** record per branch of the network even though several sediment inflow/diversion data sets may be present on that stream segment.

A separate set of **LQL**, **LTL** and **LFL** records are required to specify **each** local inflow and/or diversion. Enter each set of **LQL**, **LTL** and **LFL** records in the same order as the local inflow points appear in the stream segments' geometry (downstream to upstream). The range of water discharges are specified on the **LQL** records, with corresponding sediment loads (for each water discharge) on the **LTL** records. Each **LFL** record specifies the sediment load fraction associated with each grain size defined by the **I2-I4** records.

Note: The **$LOCAL** record replaces the **$TRIB** record in old data sets.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	$LOCAL	Record identification (Columns 1 through 6).

LQL Record - Optional

Water Discharge for the Local Inflow/Outflow Specification

The discharge and related sediment load associated with local inflows and outflows are specified on LQL, LTL, and LFL records. The LQL record specifies the water discharge portion of the load curve associated with inflows and outflows. If only local inflow occurs, the data values on the LQL record are all positive and have the same format as specified on the LQ record. If an outflow (diversion) is to be modeled, two negative values must be entered that **bracket** the maximum and minimum diversion values in the hydrograph. These values are entered as negative numbers in Fields 2 and 3. Fields 4-10 are left blank. If the local flows are mixed with diversions and inflows at various times, then specify the range of the diversion flows with negative QWATER values in Fields 2 and 3 and positive QWATER values in fields 4 through 10 to specify the flow curve for the positive inflows.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	LQL	Record identification in Columns 1 through 3.
1	ISI	Comment	Any alphanumeric character comment.
Inflows			
2	QWATER	+	**Water Discharge** - Enter a positive discharge whose value is less than the smallest inflow value in the local hydrograph.
3-10		+	**Water Discharge** - Enter increasing water discharges for the local inflow curve.

Note: No continuation record is permitted. If flow values in the hydrograph are above the maximum (or minimum) discharge on the **LQL** record, the program will use the maximum (or minimum) discharge defined for the local discharge-sediment load table. When no diversions are entered, the program will use the minimum discharge in the table. However, if diversions are entered, they must fall between LQL.2 and LQL.3.

FIELD	VARIABLE	VALUE	DESCRIPTION
Outflows			
2	QWATER	-	**Water Discharge** - Enter a number that lies just above the maximum diversion value here. For example, if the maximum diversion value was 10, then one might enter -10.1. Note that the values entered in fields 2 and 3 **must be negative** to denote outflows.
3		-	Enter a number which lies just below the minimum diversion value. For example, if the minimum diversion value was 1, one might enter -0.9.
4-10			Leave blank.

LQL

LQL Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
Combined Diversions and Inflows			
2,3	QWATER	-	Enter negative values that lie on either side of the maximum and minimum divergence discharges (as in Outflows, above.)
4		+	**Water Discharge** - Enter a positive discharge whose value is less than the smallest inflow value in the local hydrograph (as in Inflows, above.)
5-10		+	**Water Discharge** - Continue entering increasing water discharges for the local inflow curve. Note that a maximum of seven values may be entered.

Note: No continuation record is permitted. If flow values in the hydrograph are above the maximum (or minimum) discharge on the **LQL** record, the program will use the maximum (or minimum) discharge in the rating table. When no diversions are entered, the program will use the minimum discharge defined for the local discharge-sediment load table. However, if diversions are entered, they must fall between LQL.2 and LQL.3.

LTL Record - Optional

Total Sediment Load for Local Inflow/Outflow Specification

The water discharge and sediment load associated with local inflows and outflows (diversions) are specified through the use of a set of **LQL**, **LTL**, and **LFL** records for each local flow. The total sediment load corresponding to discharges entered on the **LQL** record is entered on the **LTC** record in units of tons/day.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	LTL	Record identification in Columns 1 through 3.
1	ISI	Comment	Any alphanumeric characters or comments.
Inflows			
2-10	QS	+	**Total sediment load** (tons/day) corresponding to each water discharge given on the **LQL** record, for the local flow-sediment load table. A maximum of nine values is permitted.
Outflows/Diversions			
2,3	QS	1.0	If only outflows make up the local hydrograph, enter 1.0 in Fields 2 and 3 and leave Fields 4-10 blank.
4-10			Leave blank.
Combined Diversions and Inflows			
2,3	QS	1.0	If outflows are included in the local hydrograph, enter 1.0 in Fields 2 and 3.
4-10	QS	+	**Total sediment load** (tons/day) corresponding to each water discharge given on the **LQL** record, for the local flow-sediment load table. A maximum of seven values is permitted.

LFL

LFL Record - Optional

Sediment Grain Size Distribution for Local Inflow/Outflow

The water discharge and sediment load associated with local inflows and outflows (diversions) are specified through the use of a set of **LQL**, **LTL**, and **LFL** records for each local flow. The **LFL** records should be entered from fine to coarse with one **LFL** record for **each** of the sediment size classes specified on the **I2 - I4** records. Diversion points and combination inflow-diversion points require a slight variation from the upstream inflowing sediment load table. All diversions are prescribed by a ratio of the concentration of sediment in diverted water to that in the main channel just upstream from the diversion point.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	LFL	Record identification.
1	ISI	Comment	Any alphanumeric character comment. (It is recommended that the grain size class be entered in the comment field, i.e. CLAY, SILT1, SILT2, VFS, FS, ... VCG).
Inflows			
2-10	QSED	+,0	Enter the **fraction of the total sediment load** for this sediment size class corresponding to each water discharge specified on the **LQL** record.
Outflows/Diversions			
2,3	QSED		Enter the **diversion coefficient** (ratio of diverted sediment concentration to the ambient channel concentration) for the corresponding diversion (negative) discharge specified on the **LQL** record.
		+	When field data is available, calculate the ratio of $C_{Diverted}/C_{Ambient}$ and use that value.
		1.0	When field data is not available, use 1.0 for the diversion coefficient.
4-10			Leave blank.

LFL Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
Combined Diversions and Inflows			
2,3	QSED		Enter the **diversion coefficient** (ratio of diverted sediment concentration to the ambient channel concentration) for the corresponding diversion (negative) discharge specified on the **LQL** record.
		+	When field data is available, calculate the ratio of $C_{Diverted}/C_{Ambient}$ and use that value.
		1.0	When field data is not available, use 1.0 for the diversion coefficient.
4-10	QSED	+,0	Enter the **fraction of the total sediment load** or this sediment size class corresponding to each water discharge specified on the **LQL** record.

Section III

Hydrology

Summary

Summary of Hydrologic Data Records

The **$HYD** record is used only once to indicate the beginning of the hydrologic data section in the input file. The *****, **Q**, and **W** records are entered as a set for each timestep/discharge to be modelled in the hydrology data. The **T** record is required with the first timestep/discharge and is optional thereafter. All other records are optional and are to be added to the appropriate timestep(s). The **$$END** record should be entered as the last record of the input file and may also occur only once.

COMMAND	DESCRIPTION	PAGE
$HYD	Hydrologic model.	A-57
*****	Comment and print control.	A-58
Q	Water discharges in cfs.	A-60
R	Downstream water surface elevation boundary condition.	A-61
S	Rating shift.	A-63
T	Water temperature.	A-64
W	Duration.	A-65
X	Alternate format for coding duration data.	A-66
$$END	Last record in data file.	A-67

$HYD Record - Required

Hydrologic Model

The **$HYD** record marks the beginning of the hydrologic data. This record is required to precede discharge data records described on the following pages.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	$HYD	Record identification (Columns 1 through 4).

*

* Record - Required

Comment and Print Control

One comment record is required for each Q record in the hydrologic data. This record provides title information for each timestep defined in the hydrologic data. It also allows the user to specify various output printing options.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	*	Record identification (Column 1).

Print Control for Hydraulic Information

Column 5	ISI(3)		Optional output from **the hydraulic computations** (water surface profiles) is obtained by specifying one of the following codes in Column 5 on the * record.
		blank	Discharge, starting water surface elevation, water temperature and flow duration in days is printed. For this option, leave Column 5 blank, not zero. This is the standard hydraulic output option.
		A	Water surface and energy line elevations, velocity head, alpha, top width, average bed elevation, and velocity in each subsection are printed for each discharge at each cross section.
		B	Cross section coordinates at the current time and distribution of hydraulic data across the section for the final calculated water surface are printed.
		D	Trace information. (Not recommended for most users.)
		E	Detailed Trace Information. All of the above information plus coordinates, area and wetted perimeter for each trapezoidal area in each cross section and for each trial elevation at each cross section. (Not recommended for most users.)

NOTE: Printout levels D and E produce a very large amount of output. This output was designed primarily for debugging purposes. Execution time will increase if any of these options are used.

* Record - Continued

FIELD	VARIABLE	VALUE	DESCRIPTION
Print Control for Sediment Transport Information			
Column 6	ISI(4)		Optional output from **sediment transport computations.**
		blank	No printout except summary at end of job. For this option leave Column 6 blank, not zero.
		A	A table showing the volume of sediment entering and leaving each segment and the computed trap efficiency for each segment.
		B	In addition to A, the bed change from the initial elevation in feet, water surface elevation in feet, bed thalweg elevation in feet, sediment load passing in tons/day for clay, silt and sand. This and all higher level selections cause a "solution file" to be written at this time step for post-processing purposes.
		C	A detailed printout of calculations (in addition to the above).
		D	In addition to the above values from Toffaleti's procedure showing the detailed distribution by grain size fraction for the bed surface material at each cross section before the values are corrected by percentage present in the bed. (Not recommended for most users.)
		E	Detailed trace for debugging purposes (in addition to the above). (Not recommended for most users.)
Timestep Title Information			
2-10		Comment	Comment data for discharge-elevation-duration data that follows. Use the remainder of this record to provide title/comment information for this timestep.

NOTE: Printout levels C, D and E produce a very large amount of output. This output was designed primarily for debugging purposes. Execution time will increase if any of these options are used.

Q

Q Record - Required

Water Discharges in cfs

A Q record is required for each timestep defined in the hydrologic data set. The Q record provides the program with the outflow at the downstream boundary as well as flow conditions at each of the control points in the stream network. See Sections 3.4.1, 3.6 and 6.1 - 6.3 for a complete description of how to enter data on the Q record for a stream network.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	Q	Record identification (Column 1).
1	Q(1)	+	Outflow from downstream boundary of geometric model for this time step.
			If Tributaries, Local Inflows or Diversions <u>are</u> Present in the Geometric Data
2	Q(2)	0,+	Tributary discharge of first local inflow (diversion) point on main stem. If no local flows, enter discharge from stream segment at Control Point 2.
		-	Diversion flows are identified by a negative discharge. Otherwise, diversions and tributaries are subject to the same coding rules. They may be mixed but they both may not occur at the same time at the same cross section.
3-10	Q(3)-Q(10)	0,+,-	The discharge, inflow, or outflow of the next control/junction point defined in the network (see Sections 3.6 and 6.1 - 6.3 for details).
			If Tributaries, Local Inflows, and Divisions are <u>not</u> Present in the Geometric Data
2-10	Q(2)-Q(10)	+	Up to MNQ (I1.4) parallel discharges may be entered across the Q record.

R Record - Required[1]

Downstream Water Surface Elevation Boundary Condition

A starting water surface elevation must be specified at the downstream boundary of the model for every time step. HEC-6 provides three methods for prescribing this downstream boundary condition: using (1) a rating curve, (2) **R** records, or (3) a combination of a rating curve and **R** records.

The first method involves the use of a rating curve which can be specified using a **$RATING** record followed by a set of **RC** records containing the water surface elevation data as a function of discharge. The rating curve need only be specified once at the start of the hydrologic data (immediately following the **$HYD** record) and a water surface elevation will be determined by interpolation using the discharge given on the **Q** record for each time step. The rating curve may be temporarily modified using the **S** record or replaced by entering a new set of **$RATING** and **RC** records before any * record in the hydrologic data.

In Method 2, **R** records are used **instead** of a rating curve to define the water surface elevation. To use this method, an **R** record is required for the first time step. The elevation entered in Field 1 of this record will be used for each succeeding time step until another **R** record is found with a non-zero value in Field 1 to change it. In this way, you need only insert **R** records to change the water surface elevation to a new value.

Method 3 is a combination of the first two methods. This method makes it possible to use the rating curve most of the time to determine the downstream water surface elevation while still allowing the user to specify the elevation exactly at given time steps. In this method, the **R** record's non-zero Field 1 value for the downstream water surface elevation will override the rating curve for that timestep. On the next time step, the program will go back to using the rating curve unless another **R** record is found with a non-zero value in Field 1.

Water Surface Elevation at Internal Hydraulic Control Points

R records have a secondary purpose. They are used to define the water surface elevation at certain internal control points in the geometry. The location of internal control points is defined using **X5** records. **R** records are necessary to define the water surface at those internal control points where the UPE option on the **X5** record has not been set (X5.2) and the active field value is prescribed. The water surface elevation (UPE) for that timestep will be read from the **R** record at the field prescribed on the **X5** record (X5.4). Note that if a value is given for HLOS (head loss) on the **X5** record, that value will be used in conjunction with the water surface elevation (UPE) value found on the **R** record.

[1] An **R** record is required only if a Rating Table is not used, and then it's only required for the first timestep.

R Record - Continued

If Internal Control Sections are not Present in the Geometry

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	R	Record identification (Column 1).
1	WS(1)	+	Enter the value for the prescribed **water surface elevation** that corresponds to the outflow entered on the Q record in Field 1.
		0	When no internal control sections are present, then a zero in Field 1 **should not be used.** To define a water surface elevation at zero, input a small positive value (e.g. 0.001)
2-10			Leave blank.

If Internal Control Sections are Present in the Geometry

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	R	Record identification (Column 1).
1	WS(1)	+	Enter the value for the prescribed **water surface elevation** that corresponds to the outflow entered on the Q record in Field 1.
		0	When internal control sections are present (i.e., weirs or dams which are entered on **X5** records) and a rating curve exists, the water surface will be determined from the rating curve (**$RATING** and **RC** records). If a rating curve does not exist, the water surface from the previous timestep will be reused.
2-10	WS(n)	+	Enter the water surface elevation for the control point (weir or dam) for which ICSH (**X5.4**) = n, where n equals the current field. The program will set UPE = WS(n) at the control section defined by the **X5** record whose ICSH=n.
		0	Use the previous water surface value. To define a water surface elevation at zero, enter a small positive value (e.g., 0.001).

S Record - Optional

Rating Shift

This record allows the user to alter the starting water surface elevation by a constant value. This alteration will remain in effect for succeeding timesteps until another S record is read with a new shift value.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	S	Record identification (Column 1).
1	SHIFT	+,-	Enter the shift for starting water surface elevations in Field 1. All starting elevations will be shifted by this amount for this and subsequent Q's until a new shift value is read from an S record. To return to zero shift, enter an S record with Field 1 blank or zero.
		b,0	Use original water surface elevation. No alteration.
2-10			Leave blank.

T

T Record - Optional

Water Temperature

The T record provides water temperature data (refer to Section 3.4.2). This record is required only in the first timestep. Include subsequent T records only if the water temperature changes. The water temperature(s) entered on this record will remain in effect until another T record is entered to change it. Water temperature is important for computing sediment settling velocity (especially for fine materials).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	T	Record identification (Column 1).
1-10	WT(1)..WT(10)	+	**Water temperature,** in degrees Fahrenheit, corresponding to each Q that exists on the Q record. T.1 corresponds to Q.1, etc. Enter new values only if the water temperature changes from the values entered on the previous T record.

W Record - Required

Duration

The **W** record defines the duration of the flow for the present timestep. A **W** record is required for each timestep in the hydrologic data set (refer to Section 3.4 and Figure 3.7).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	W	Record identification (Column 1).
1-10	DD(1)..DD(10)	+	**The flow duration** in days or fractions of days, corresponding to each Q on the Q record.

X

X Record - Optional

Alternate Format for Coding Duration Data

The **X** record may be used in place of the **W** record to define the flow duration. The purpose, however, is to decrease the total flow duration timestep prescribed by the **W** record into shorter timesteps. This need arises when unstable computation steps are not detected until after the hydrologic data has been assembled using the traditional **W** record approach. The **X** record allows the computation time interval to be shortened without requiring additional timestep data sets (*****, **Q**, **W** record sets) to be inserted into the hydrologic data. To use this capability, replace the **W** record of the unstable timestep with an **X** record coded in one of the following two ways.

Coding Option #1

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	X	Record identification.
1			Leave blank.
2	DT	+	**Time Duration increment** in days. Must be less than the total duration of the original timestep (from **W** record).
3	DD	+	**The Total Duration** of the original timestep. This is the value previously coded in the **W** record: $DD \div DT$ equals the number of computational timesteps that will be used.
4-10			Leave blank.

Coding Option #2

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	X	Record identification
1	TCH	+	**The Total Accumulated Time** in days to be reached at the completion of this composite timestep. This value must be accurate and can be obtained from the output of the original data set using the **W** records. The total duration of this timestep equals TCH minus the accumulated time at the end of the previous timestep.
2	DT	+	**Time Duration Increment** in days. Must be less than the total duration of the original timestep. Total duration divided by DT equals the number of computational timesteps that will be used.
3-10			Leave blank.

$$END Record - Required

Last record in the data file.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	$$END	Record identification (Columns 1-5).

Section IV

Special Commands

and

Program Options

Summary

Summary of Special Program Commands

These commands are inserted into the HYDROLOGIC data after the **$HYD** command and immediately before any * record. They are entered one after another, inserted singularly, or used as many times as desired. Some require additional data as explained in the detailed instructions that follow this summary.

COMMAND	DESCRIPTION	PAGE
$B	Boundary condition. Use to specify transmissive boundary condition type.	A-71
$DREDGE	Initiates the dredging option.	A-72
$NODREDGE	Turns off dredging calculations.	A-73
$EX	Exner option. Allows access to original method for solving the Exner equation.	A-74
$GR	Cross section shape option.	A-75
$KL	Calculate hydraulic roughness (Manning's n-value) using Limerinos method.	A-76
$KI	Use Manning's n-values as read from input file.	A-76
$PRT	Select cross section(s) at which to print results. Use with **CP**, **PN**, and **END** records.	A-77
$RATING	A tailwater rating curve follows. Use with **RC** records.	A-81
$SED	Water Discharge-Sediment Load table(s) follow. Use with **$LOCAL**, **LP**, **LQ**, **LT**, **LF**, **LR**, and **END** records.	A-83
$VOL	Prints the accumulated sediment discharge passing each cross section and the accumulated volume of deposits (or scour) at each cross section since DAY 0. Use with **VJ** and **VR** records.	A-87

$B Record - Optional

Transmissive Boundary Condition

The **$B** record is used to change the sediment discharge crossing the downstream boundary from a calculated rate to the rate approaching from the next upstream section. Use this option when sediment deposits at the downstream boundary and there is no physical explanation for it (e.g., as in a supercritical flow reach when the sediment concentration is very high).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	$B	Record identification.
2	ISBT	1	Sediment discharge is calculated at the outflow boundary.
		2	Approaching sediment discharge is transmitted past the outflow boundary section without change.

$DREDGE

$DREDGE Record - Optional

Dredging Option

This command record initiates dredging calculations to be performed at all cross sections where dredging parameters have been specified (H.6 - H.10 or HD.6 - HD.10). When the depth of water required for navigation (draft) specified in Field 2 is not available, the program will determine dredging elevations and compute the volume of dredged material removed during dredging. The dredging option is initiated at the end of the timesteps (computational sequence) where the **$DREDGE** record occurs. It continues to operate until turned off by a **$NODREDGE** record later in the hydrologic data. (See Example ——.)

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	$DREDGE	Record identification (Columns 1 through 7).
2	DFT	+	Depth of water required for navigation.
		0,b	Program will compute dredging elevations.

$NODREDGE Record - Optional

Dredging Option

The presence of a **$NODREDGE** record stops the dredging option triggered previously by the **$DREDGE** record.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	$NODREDGE	Record identification (Columns 1 through 9).

$EX

$EX Record - Optional

Exner Options

This command allows the user access to the original method for solving the Exner equation. All restrictions on the original method still apply. To exercise this option, place the **$EX** record immediately after the **$HYD** record. Otherwise, the program will default to the most current method.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	$EX	Record identification in Columns 1 through 3.
Column 8	ISI(6)	1	Original method (used from 1972 - 1984).
		3	Current option for solving the Exner Equation. Used in all versions dated after November 1987.

$GR Record - Optional

Cross Section Shape Option

The original HEC-6 code retained the cross section shape coded on **GR** records and moved the Y-coordinates vertically by a constant amount after each timestep.

The **$GR** record allows the user to adjust the depth of deposit in a cross section to vary according to the depth of flow. Therefore, deeper portions of a cross section will receive more deposited material rather than a uniform depth of deposit. The Y-coordinates still move vertically but the amount of deposition depends on the depth of flow in the cross sections. Erosion is still a uniform value.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	$GR	Record identification (Columns 1 through 3).
Column 8		2	Vary the amount of deposition depending on depth.
		0	Move Y-coordinates by a constant amount after each computation.

$KL

$KL-$KI Records - Optional

Channel N Values by Relative Roughness

The model ignores the prescribed Manning's n-values for the channel (**NC** or **NV** records) when a **$KL** record is encountered and calculates bed roughness as a function of the bed material gradation via Limerinos' (1970) relative roughness method (see Section 3.7.1). To return to standard n-values insert a **$KI** record.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	$KL $KI	Record identification (Columns 1 through 3).

$PRT Record - Optional

Selective Printout Option

The **$PRT** command record is used alone to turn printout on or off for all cross sections. It is also used preceding **CP** and **PN** records to generate output at specified cross sections. An **END** record is required at the end of the **CP - PN** record set to mark the end of this optional printout request.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	$PRT	Record identification (Columns 1 through 4).
Column 8	ISI(6)	N	Turn output **off** at all sections.
		A	Turn output **on** at all sections.
		blank	Directs program to look for **CP** and **PN** records to determine selected sections.

CP

CP Record - See $PRT - Optional

Selective Printout

The **CP** record defines the stream segment for which the cross sections given on the **PN** record(s) apply. Each **CP** record must be followed by one or more **PN** records.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	CP	Record identification (Columns 1 and 2).
2	NGDS	+	Stream segment number.

PN Record - See $PRT - Optional

Selective Printout

Use the **PN** record to specify the cross sections where output is desired. Each set of **PN** records applies to the stream segment defined on the **CP** record immediately preceding it. Additional **PN** records may be used if more than nine cross sections per stream segment are requested. When specifying the desired cross sections for printing, use its index number, not its ID number. Index numbering of the cross sections begins at 1 for the downstream-most cross section on each stream segment.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	PN	Record identification.
1	ISI	Comment	Any alphanumeric characters or comments.
2-10	IPXS	+	Enter the index number of the desired cross section. The program generates output for the IPXSth cross section on segment NGDS (CP.2). **Note:** Do not enter the section ID number or river mile (SECNO) as given in Field 1 of the X1 record).

END

END Record - See $PRT - Optional

Selective Printout

The **END** record is required at the end of the **CP - PN** record sets. Place an **END** record in the data file after the last **PN** record.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	END	Record identification (Columns 1-3).

$RATING Record - Optional

Tailwater Rating

A starting water surface elevation must be specified at the downstream boundary of the model for every timestep. HEC-6 provides several methods for prescribing this downstream boundary condition. Specification of a tailwater rating curve is one of these methods. (Please refer to the R record description on page A-61 for a complete description of these methods.)

The rating curve is specified using a **$RATING** record followed by a set of **RC** records. The **$RATING** record indicates to the program that a set of **RC** records follows containing rating curve information. The rating curve can be input immediately after the **$HYD** record or before any * record in the hydrologic data. Once a rating curve has been input it can be changed by inputting a new rating curve (a new set of **$RATING** and **RC** records) before any * record later in the hydrologic data.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	$RATING	Record identification.

RC

RC Record

Tailwater Rating

The **RC** (rating curve) records prescribe the tailwater elevation as a Rating Curve. These records must be preceded by a **$RATING** command record. The set of **$RATING** and **RC** records may be located immediately before any * record in the hydrologic data.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	RC	Record identification (Columns 1 and 2).
1			Leave blank.
2	MNI	+	The number of water surface values that will be read. (May not exceed forty).
3	TINT	+	The **discharge interval** between water surface values in cfs. Use as small an interval as desired, but it must be a constant for the full range of water surface elevations that follow.
4	QBASE	+	If the **first discharge** in the table is not zero enter its value here in cfs.
5	GZRO	+	If the rating table is a stage-discharge curve rather than elevation-discharge, enter **gage zero** here.
6	RAT(1)	+	Lowest **water surface elevation or stage** goes here.
7-10	RAT(2)...RAT(MNI)		Continue entering **water surface elevation or stage values** defining the rating curve using Fields 7-10 on this record and Fields 2-10 on continuation **RC** records. A maximum of forty points can be entered to define the curve.

$SED Record - Optional

Water Discharge-Sediment Load Table

This program command option allows the user to change a sediment load table during a simulation. A change to a sediment load table can be made by either entering a new sediment load table definition on **LP**, **LQ**, **LT** and **LF** records or by altering the existing table with a ratio defined on **LP** and **LR** records.

A **$SED** command precedes a **LP**, **LQ**, **LT**, **LF** record combination that defines the discharge-sediment load rating curve. It can also precede a **LP**, **LR** record combination (see **LR** record). The **LP** record is used to specify the location where the modified sediment load table applies. It is required with either the **LQ**, **LT** and **LF** records or with the **LR** record. An **END** record is required as the last record to close the **$SED** option.

If the sediment load table for the mainstem or a tributary is to be replaced, see the input descriptions for the **LQ**, **LT** and **LF** records given on pages A-41 through A-43. However, if the sediment load table for a local inflow or outflow is to be replaced, refer to the input description for the **LQL**, **LTL**, and **LFL** on pages A-49 through A-53 instead (i.e. **LQ**, **LT**, **LF** records are used for the main channel and tributaries. The **LQL**, **LTL** and **LFL** records are used for local inflows and outflow).

Example Record Sequence - Replaces the Existing Table

```
$SED
$LOCAL
LP MAIN     10
LQ
LT
LF CLAY
.
.
.
LF VCS
END
```

Example Record Sequence - Using the Ratio Option

The following set of records are required to enter a change in the sediment discharge table using a ratio.

```
$SED
LP
LR
END
```

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	$SED	Record identification.

LP

LP Record - Optional

Inflow Point Identification for the Water Discharge-Sediment Load Table

The **LP** record[1] defines the stream segment and/or inflow point whose sediment load table will be modified by the succeeding **LQ**, **LT**, **LF**, or **LR** records.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	LP	Record identification (Columns 1 and 2).
1	ISI	Comment	Any alphanumeric character comment.
2	NGDS, NLOC		Enter a two-digit number which indicates the stream segment number in the first digit and the local inflow point number in the second digit. The main flow on a stream segment is considered inflow point zero. For example, a value of 10 would indicate the discharge-sediment load table change, defined on succeeding records, pertains to the main upstream flow (0) on the main stem (stream segment 1) of the network; 22 would indicate a change for the load table for local inflow point 2 on stream segment 2; and so on.
3-10			Leave blank.

[1] Use **LP** records only when changing the sediment discharge table in the Hydrologic Data (i.e., after the **$HYD** command). Do not use **LP** records in the Sediment Data.

LR Record - Optional

Ratio for the Water Discharge-Sediment Load Table

When changing the sediment discharge with the **$SED** option, the existing sediment-discharge load table can be modified by entering an **LR** record with a multiplier constant, rather than by entering a whole new table.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	LR	Record identification in Columns 1 and 2.
1	ISI	Comment	Any alphanumeric character comment.
2	NGDS	+	Stream segment number. This value should be the same as that used for the first digit (NGDS) of the code value given in Field 2 of the LP record.
3	RATIO	+	Existing sediment-discharge rating curve will be multiplied by RATIO.

END

END Record

Termination Record for the $SED Option

An **END** record is used to indicate the end of the changes made to the sediment load table(s). This record should be inserted after the last **LR** or **LF** record. If changes are to be made to more than one sediment load table sets of **LP**, **LR** or **LP**, **LQ**, **LT**, **LF** records may be stacked one after another. Insert the **END** record only after the last set of change records.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG	$END	Record identification.

$VOL Record - Optional

Compute Cumulative Volume and Deposits at all Sections

The **$VOL** command causes the program to calculate the cumulative bed change and load passing each cross section.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	$VOL	Record identification (Columns 1 through 4).
Column 7	ISI(5)	X	Causes the program to look for a **VJ** record immediately after the **$VOL** command and compute the storage volume for a table of elevations specified on succeeding **VR** records.
Column 8	ISI(6)	A	Additional printout showing cumulative weight of sediment passing each cross section by size class.
		B	"A" level printout plus extra trace information from the PRTVOL and STOVOL routines. (Not recommend for normal applications.)

VJ

VJ Record - See $VOL - Optional

Elevation Table for Cumulative Volume Computations

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	VJ	Record identification.
1	JM	1-30	The number of elevation values which are listed on the following VR records. Limited to thirty values.
2	AVGSLO	0	Compute volumes based on planes with no slope.
		+	Compute volumes based on planes having slope AVGSLO.

VR Record - See $VOL - Optional

Elevation Table for Cumulative Volume Computations

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ICG,IDT	VR	Record identification.
1	ELSTO(1)	-,0,+	Enter up to thirty elevations in Fields 1-10 on this and succeeding VR records.

Appendix B

Glossary

GLOSSARY

ACCURACY Degree of conformity of a measure to a standard or true value.

ACTIVE BED The active bed is the layer of material between the bed surface and a hypothetical depth at which no transport will occur for the given gradation of bed material and flow conditions. See also, ACTIVE LAYER.

ACTIVE LAYER The depth of material from bed surface to equilibrium depth continually mixed by the flow, but it can have a surface of slow moving particles that shield the finer particles from being entrained by the flow. See FIGURE B-1.

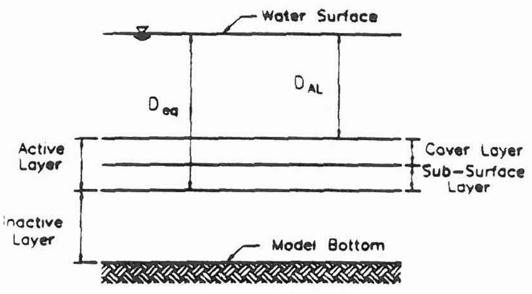

Figure B-1. Composition of the Active Layer

AGGRADATION The geologic process by which stream beds, floodplains, and the bottoms of other water bodies are raised in elevation by the deposition of material eroded and transported from other areas. It is the opposite of degradation.

ALGORITHM A procedure for solving a mathematical problem in a finite number of steps that frequently involves repetition of an operation. A step by step procedure for solving a problem or accomplishing an end. A set of numerical steps or routines to obtain a numerical output from a numerical input.

ALLUVIAL Pertains to alluvium deposited by a stream or flowing water.

ALLUVIAL CHANNEL See ALLUVIAL STREAM

ALLUVIAL DEPOSIT Clay, silt, sand, gravel, or other sediment deposited by the action of running or receding water.

ALLUVIAL REACH A reach of river with a sediment bed composed of the same type of sediment material as that moving in the stream.

ALLUVIAL STREAM A stream whose channel boundary is composed of appreciable quantities of the sediments transported by the flow, and which generally changes its bed forms as the rate of flow changes.

ALLUVIUM A general term for all detrital deposits resulting directly or indirectly from the sediment transported by (modern) streams, thus including the sediments laid down in river beds, floodplains, lakes, fans, and estuaries.

ANOMALY A deviation from a norm for which an explanation is not apparent on the basis of available data.

ARMOR LAYER See ARMORING.

ARMORING The process of progressive coarsening of the bed layer by removal of fine particles until it becomes resistant to scour. The coarse layer that remains on the surface is termed the 'armor layer'. Armoring is a temporary condition; higher flows may destroy an armor layer and it may re-form as flows decrease. Or simply, the formation of a resistant layer of relatively large particles resulting from removal of finer particles by erosion.

AVERAGE END CONCEPT The averaging of the two end cross sections of a reach in order to smooth the numerical results.

BACKWATER PROFILE Longitudinal profile of the water surface in a stream where the water surface is raised above its normal level by a natural or artificial obstruction.

BANK MIGRATION Lateral or horizontal movement of the banks of a streamcourse.

BANK SEDIMENT RESERVOIR The portion of the alluvium on the sides of a channel. See FIGURE B-2. (Note: HEC-6 only uses the BED SEDIMENT RESERVOIR as the source-sink of material.)

BED FORMS Irregularities found on the bottom (bed) of a stream that are related to flow characteristics. They are given names such as "dunes", "ripples", and "antidunes". They are related to the transport of sediment and interact with the flow because they change the roughness of the stream bed. An analog to stream bed forms are desert sand dunes (although the physical mechanisms for their creation and movement may be different).

BED LAYER An arbitrary term used in various procedures for computation of sediment transport. From observation of slow motion movies of laboratory flume experiments, H. Einstein defined the "bed layer" as: "A flow layer, 2 grain diameters thick, immediately above the bed. The thickness of the bed layer varies with the particle size."

BED LOAD Material moving on or near the stream bed by rolling, sliding, and sometimes making brief excursions into the flow a few diameters above the bed, i.e. jumping. The term "saltation" is sometimes used in place of "jumping". Bed load is bed material that moves in continuous contact with the bed; contrast with SUSPENDED LOAD.

BED LOAD DISCHARGE The quantity of bed load passing a cross section in a unit of time, i.e. the rate. Usually presented in units of tons per day. May be measured or computed. See BED LOAD.

BED MATERIAL The sediment mixture of which the moving bed is composed. In alluvial streams, bed material particles are likely to be moved at any moment or during some future flow condition. Bed material consists of both bed load and suspended load. Contrast with WASH LOAD.

BED MATERIAL DISCHARGE The total rate (tons/day) at which bed material (see BED MATERIAL) is transported by a given flow at a given location on a stream.

BED MATERIAL LOAD The total rate (tons/day) at which bed material is transported by a given location on a stream. It consists of bed material moving both as bed load and suspended load. Contrast with WASH LOAD.

BED ROCK A general term for the rock, usually solid, that underlies soil or other unconsolidated, surficial material.

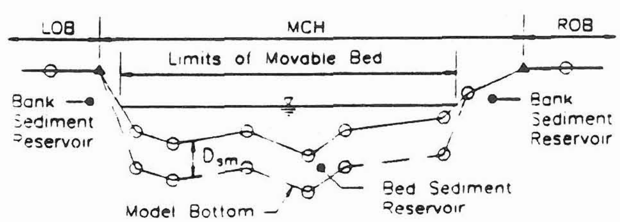

Figure B-2. Sediment Material in the Streambed

BED SEDIMENT RESERVOIR The portion of the alluvium directly below the channel bed. See FIGURE B-2. (Note: HEC-6 only uses the BED SEDIMENT RESERVOIR as the source-sink of material.)

BOUNDARY CONDITIONS Definition or statement of conditions or phenomena at the boundaries. Water levels, flows, concentrations, etc., that are specified at the boundaries of the area being modeled. A specified tail water elevation and incoming upstream discharge are typical boundary conditions.

BOUNDARY ROUGHNESS The roughness of the bed and banks of a stream or river. The greater the roughness, the greater the frictional resistance to flows; and, hence, the greater the water surface elevation for any given discharge.

BRAIDED CHANNEL A stream that is characterized by random interconnected channels divided by islands or bars. Bars which divide the stream into separate channels at low flows are often submerged at high flow.

CHANNEL A natural or artificial waterway which periodically or continuously contains moving water.

CHANNEL INVERT The lowest point in the channel.

CHANNEL STABILIZATION A stable channel is neither progressively aggrading nor degrading, or changing its cross sectional area through time. It could aggrade or degrade slightly, but over the period of a year, the channel would remain similar in shape and dimensions and position to previous times. Unstable channels are depositing or eroding in response to some exterior conditions. Stabilization techniques consist of bank protection and other measures that work to transform an unstable channel into a stable one.

CLAY See TABLE B-1.

COBBLES See TABLE B-1.

COHESIVE SEDIMENTS Sediments whose resistance to initial movement or erosion is affected mostly by cohesive bonds between particles.

COMPUTATIONAL HYDROGRAPH A continuous discharge hydrograph treated as a sequence of discrete steady flow events, each having a specified duration in days. The reason for doing this is to attempt to minimize the number of time steps needed to simulate a given time period, and, thus minimize computer time. See FIGURE B-3.

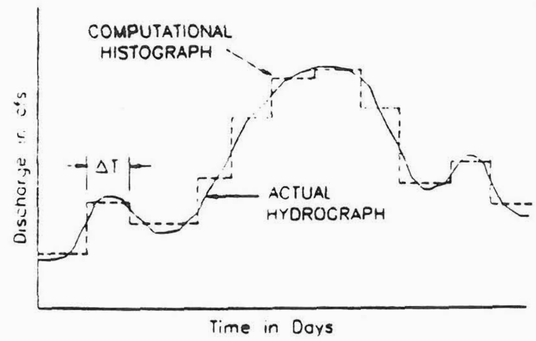

Figure B-3. Computational Hydrograph

CONCENTRATION OF SEDIMENT The dry weight of sediment per unit volume of water-sediment mixture, i.e. mg/l. (Note: In earlier writings, concentration was calculated as the ratio of the dry weight of sediment in a water-sediment mixture to the total weight of the mixture multiplied by 1,000,000. It was expressed as parts per million, i.e. ppm. Either method gives the same result, within 1 percent, for concentrations up to 16,000 mg/l. A correction is needed for concentrations in excess of that value.) The conversion to mg/l (miligrams per liter) from ppm (parts per million) is as follows:

$$mg/l = K \times (ppm) = K \times \frac{weight\ of\ sediment \times 1{,}000{,}000}{weight\ of\ water\text{-}sediment\ mixture}$$

where K is a correction factor.

CONCEPTUAL MODEL A simplification of prototype behavior used to demonstrate concepts.

CONSOLIDATION The compaction of deposited sediments caused by grain reorientation and by the squeezing out of water trapped in the pores.

CONTROL POINT For a main stem: its downstream end and any junction with a tributary. For a tributary: its junction with a higher order tributary. Each control point is designated by a circled number as in Figure B-4.

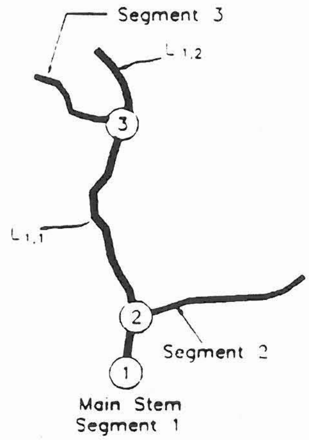

Figure B-4. Example of Control Point Numbering

CONVERGENCE The state of tending to a unique solution. A given scheme is convergent if an increasingly finer computational grid leads to a more accurate solution.

CONVEYANCE A measure of the carrying capacity of the channel section. Flow is directly proportional to conveyance for steady flow. From Manning's equation, the proportionality factor is the square root of the energy slope.

COVER LAYER One of the two sublayers of the active layer. It lies above the sub-surface layer (the second sublayer in the active layer). See FIGURE B-1.

CRITICAL BED SHEAR STRESS See CRITICAL TRACTIVE FORCE.

CRITICAL DEPTH If discharge is held constant and the water depth allowed to decrease, as in the case of water approaching a free overfall, velocity head will increase, pressure head will decrease, and total energy will decrease toward a minimum value where the rate of decrease in the pressure head is just counterbalanced by the rate of increase in velocity head. This is the critical depth. More generally, the critical depth is the depth of flow that would produce the minimum total energy head, and it depends on cross section geometry and water discharge.

CRITICAL FLOW The state of flow where the water depth is at the critical depth and when the inertial and gravitational forces are equal.

CRITICAL TRACTIVE FORCE The critical tractive force is the maximum unit tractive force that will not cause serious erosion of the material forming the channel bed on a level surface.

CROSS SECTION Depicts the shape of the channel in which a stream flows. Measured by surveying the stream bed elevation across the stream on a line perpendicular to the flow. Necessary data for the computation of hydraulic and sediment transport information.

CROSS-SECTIONAL AREA The cross-sectional area is the area of a cross section of the flow normal to the direction of flow.

DEGRADATION The geologic process by which stream beds, floodplains, and the bottoms of other water bodies are lowered in elevation by the removal of material from the boundary. It is the opposite of aggradation.

DEPTH OF FLOW The depth of flow is the vertical distance from the bed of a stream to the water surface.

DEPOSITION The mechanical or chemical processes through which sediments accumulate in a (temporary) resting place. The raising of the stream bed by settlement of moving sediment that may be due to local changes in the flow, or during a single flood event.

DISCHARGE The discharge Q is the volume of a fluid or solid passing a cross section of a stream per unit time.

DISTRIBUTARIES Diverging streams which do not return to the main stream, but discharge into another stream or the ocean.

DOMINANT DISCHARGE A particular magnitude of flow which is sometimes referred to as the "channel forming" discharge. Empirical relations have been developed between "equilibrium" stream width, depth, and slope and dominant discharge. It has been variously defined as the bank full flow, mean annual discharge, etc.

DRAFT DEPTH The depth measured perpendicularly from the water surface to the bottom of a boat, ship, etc. (i.e., a "clearance" depth).

DROP A structure in an open conduit or canal installed for the purpose of dropping the water to a lower level and dissipating its energy. It may be vertical or inclined; in the latter case it is usually called a chute.

EFFECTIVE (GRAIN) SIZE The diameter of the particles in an assumed rock or soil that would transmit water at the same rate as the rock or soil under consideration, and that is composed of spherical particles of equal size and arranged in a specific manner. The effective grain size is that single particle diameter that best depicts the bed material properties. The D50 grain size is often used as the effective grain size.

EFFECTIVE TRANSPORT DIAMETER See EFFECTIVE (GRAIN) SIZE.

EQUILIBRIUM DEPTH The minimum water depth for the condition of no sediment transport.

ENTRAINMENT The carrying away of the material produced by erosive action from bed and banks.

EQUILIBRIUM LOAD The amount of sediment that a system can carry for a given discharge without an overall accumulation (deposit) or scour (degradation).

EROSION The wearing away of the land surface by detachment and movement of soil and rock fragments through the action of moving water and other geological agents.

FALL VELOCITY The falling or settling rate of a particle in a given medium.

FINE MATERIAL See WASH LOAD.

FIXED BED MODEL Model in which the bed and side materials are nonerodible. Deposition does not occur as well.

FLOOD ROUTING The process of tracing, by calculation, the course and character of a flood as it progresses through a river reach or a reservoir.

FLOW DURATION CURVE A measure of the range and variability of a stream's flow. The flow duration curve represents the percent of time during which specified flow rates are exceeded at a given location. This is usually presented as a graph of flow rate (discharge) vs. percent of time that flows are greater than, or equal to, that flow.

FORMS See BED FORMS.

FREQUENCY The number of repetitions of a periodic process in a certain time period.

GEOLOGIC CONTROL A local rock formation or clay layer that limits (within the engineering time frame) the vertical and/or lateral movement of a stream at a particular point. Note that man-made controls such as drop structures also exist.

GEOLOGIC STRUCTURE See GEOLOGIC CONTROL.

GEOLOGY A science that deals with the history of the earth and its life, especially as recorded in rocks.

GEOPMORPHOLOGY The study of landform development under processes associated with running water.

GRADATION The proportion of material of each particle size, or the frequency distribution of various sizes, constituting a particulate material such as a soil, sediment, or sedimentary rock. The limits of each size are chosen arbitrarily. Four different gradations are significant: the gradation of the suspended load, the gradation of the bed load, the gradation of the material comprising the bed surface, and the gradation of material beneath the bed surface.

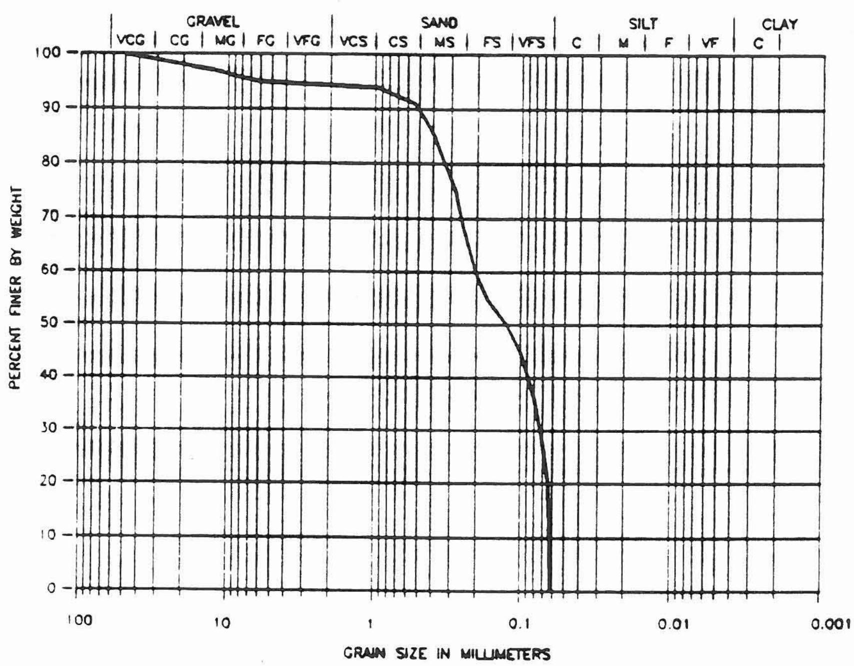

Figure B-5. Sample Gradation Curve

GRADATION CURVE Sediment samples usually contain a range of grain sizes, and it is customary to break this range into classes of percentages of the total sample weight contained in each class. After the individual percentages are accumulated, a graph, the "gradation curve", shows the grain size vs. the accumulated percent of material that is finer than that grain size. These curves are used by movable boundary models to depict the bed sediment material properties (e.g., grain size distribution of the bed material). See FIGURE B-5.

GRAIN SHAPE FACTOR See PARTICLE SHAPE FACTOR.

GRAIN SIZE See PARTICLE SIZE.

GRAIN SIZE DISTRIBUTION (GRADATION) A measure of the variation in grain (particle) sizes within a mixture. Usually presented as a graph of grain diameter vs. percent of the mixture that is finer than that diameter. See FIGURE B-5.

GRAVEL See TABLE B-1.

HISTORIC FLOWS The collection of recorded flow data for a stream during the period of time in which steam gages were in operation.

HYDRAULIC MODEL A physical scale model of a river used for engineering studies.

HYDRAULICS The study and computation of the characteristics, e.g. depth (water surface elevation), velocity and slope, of water flowing in a stream or river.

HYDROGRAPH A graph showing, for a given point on a stream or conduit, the discharge,water surface elevation, stage, velocity, available power, or other property of water with respect to time.

HYDROLOGY The study of the properties, distribution, and circulation of water on the surface of the land, in the soil, and in the atmosphere.

INACTIVE LAYER The depth of material beneath the active layer. See FIGURE B-1.

INCIPIENT MOTION The flow condition at which a given size bed particle just begins to move. Usually related to a "threshold" shear stress.

INEFFECTIVE FLOW When high ground or some other obstruction such as a levee prevents water from flowing into a subsection, the area up to that point is ineffective for conveying flow and is not used for hydraulic computations until the water surface exceeds the top elevation of the obstruction. The barrier can be a natural levee, man-made levee or some other structure.

INFLOWING LOAD CURVE See SEDIMENT RATING CURVE.

INITIAL CONDITIONS The value of water levels, velocities, concentrations, etc., that are specified everywhere in the mesh at the beginning of a model run. For an iterative solution, the initial conditions represent the first estimate of the variables the model is trying to solve.

IN SITU In (its original) place.

LEFT OVERBANK See OVERBANK.

LINEAR MODEL Mathematical model based entirely on linear equations.

LOCAL INFLOW/OUTFLOW POINT Points along any river segment at which water and sediment enter or exit that segment as a local flow. Each local inflow/outflow point is designated by an arrow and $L_{n,m}$ where n is the segment number and m is the sequence number (going upstream) of the local inflow/outflow points located along segment n, as shown in Figure B-6.

LOCAL SCOUR Erosion caused by an abrupt change in flow direction or velocity. Examples include erosion around bridge piers, downstream of stilling basins, at the ends of dikes, and near snags.

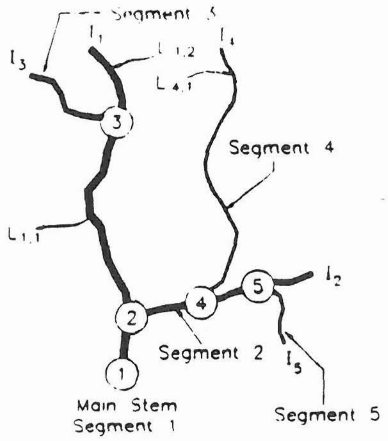

Figure B-6. Local Inflow/Outflow Points

M1 AND M2 CURVES M1 and M2 curves represent mild sloping water surface profiles.

MAIN STEM The primary river segment with its outflow at the downstream end of the model.

MANNING'S EQUATION The empirical Manning's equation commonly applied in water surface profile calculations defines the relationship between surface roughness, discharge, flow geometry, and rate of friction loss for a given stream location.

MANNING'S N-VALUE N is the coefficient of roughness with the dimensions of $T \times L^{-1/3}$. N accounts for energy loss due to the friction between the bed and the water. In fluvial hydraulics (movable boundary hydraulics), the Manning's n value includes the effects of all losses, such as grain roughness of the movable bed, form roughness of the movable bed, bank irregularities, vegetation, bend losses, and junction losses. Contraction and expansion losses are not included in Mannings n, but are typically accounted for separately.

MATHEMATICAL MODEL A model that uses mathematical expressions (i.e., a set of equations, usually based upon fundamental physical principles) to represent a physical process.

MEANDERING STREAM An alluvial stream characterized in planform by a series of pronounced alternating bends. The shape and existence of the bends in a meandering stream are a result of alluvial processes and not determined by the nature of the terrain (geology) through which the stream flows.

MESH The network of computational points (nodes) linked together to form a digital representation of the modeled area's geometry.

MITIGATION To make restitution for adverse project impacts.

MODEL A representation of a physical process or thing that can be used to predict the process's or thing's behavior or state.

Examples:
A conceptual model: If I throw a rock harder, it will go faster.
A mathematical model: F=ma
A hydraulic model: Columbia River physical model.

MOVABLE BED That portion of a river channel cross section that is considered to be subject to erosion or deposition.

MOVABLE BED LIMITS The lateral limits of the movable bed that define where scour or deposition occur. See FIGURE B-7.

MOVABLE BED MODEL Model in which the bed and/or side material is erodible and transported in a manner similar to the prototype.

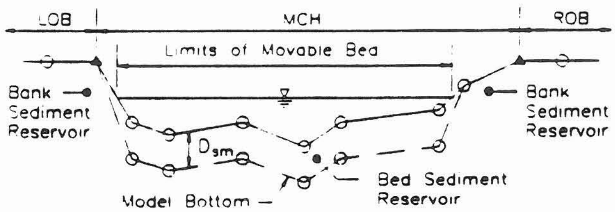

Figure B-7. Limits of Movable Bed

NETWORK Same as MESH.

NETWORK MODEL A network model is a network of main stem, tributary, and local inflow/outflow points that can be simulated simultaneously and in which tributary sediment transport can be calculated.

NORMAL DEPTH The depth that would exist if the flow were uniform is called normal depth.

NUMERICAL EXPERIMENTS Varying the input data, or internal parameters, of a numerical model to ascertain the impact on the output.

NUMERICAL MODEL A numerical model is the representation of a mathematical model as a sequence of instructions (program) for a computer. Given approximate data, the execution of this sequence of instructions yields an approximate solution to the set of equations that comprise the mathematical model.

ONE-DIMENSIONAL ENERGY EQUATION This equation has the same form as the Bernoulli Equation and the same terms are present. In addition, an α term has been added to correct for velocity distribution.

OPERATING POLICY See OPERATING RULE.

OPERATING RULE The rule that specifies how water is managed throughout a water resource system. Often they are defined to include target system states, such as storage, above which one course of action is implemented and below which another course is taken.

OVERBANK In a river reach, the surface area between the bank on the main channel and the limits of the floodplain. See FIGURE B-8.

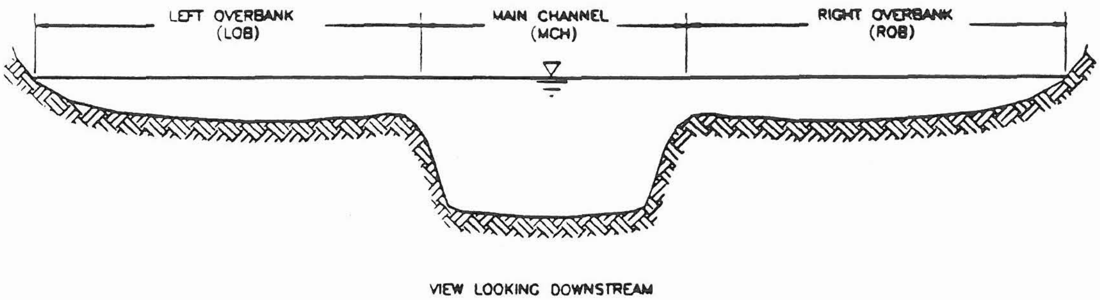

Figure B-8. Examples of Overbanks

OVERDREDGING The additional depth dredged beyond the minimum dredging depth used to provide sufficient navigational depth, to minimize redredging, and to help compensate for the sloughing off and resettling of sediment after dredging occurs

PARAMETER Any set of physical properties whose values determine the characteristics or behavior of something.

PARTICLE SHAPE FACTOR The particle shape factor of a perfect sphere is 1.0 and can be as low as 0.1 for very irregular shapes. It is defined by:

$$SF = \frac{c}{\sqrt{(a \times b)}}$$

where,

a,b,c = the lengths of the longest, intermediate, and shortest, respectively, mutually perpendicular axes on a sediment particle.

PARTICLE SIZE A linear dimension, usually designated as "diameter", used to characterize the size of a particle. The dimension may be determined by any of several different techniques, including sedimentation sieving, micrometric measurement, or direct measurement.

PERMEABILITY The property of a soil that permits the passage of water under a gradient of force.

PLANFORM The shape and size of channel and overbank features as viewed from directly above.

PRIMARY TRIBUTARY A tributary that is directly connected to or that joins with the main stem.

PROTOTYPE The full-sized structure, system process, or phenomenon being modeled.

QUALITATIVE Relating to or involving quality or kind.

QUANTITATIVE A relative measurement of a quantity or amount.

RATING CURVE See STAGE-DISCHARGE CURVE.

REACH (1) The length of a channel, uniform with respect to discharge, depth, area, and slope, e.g., "study reach", "typical channel reach" or "degrading reach", etc. (2) The length of a stream between two specified gaging stations.

REPLICATE To duplicate (a statistical experiment).

RIGHT OVERBANK See OVERBANK.

RIPPLE Small triangular-shaped bed forms that are similar to dunes but have much smaller heights and lengths of 0.3 m or less. They develop when the Froude number is less than approximately 0.3.

RIVER SEGMENT See STREAM SEGMENT.

ROUTING MODEL A model (see MATHEMATICAL MODEL and NUMERICAL MODEL) for performing flood routing (see FLOOD ROUTING).

S1 AND S2 CURVES S1 and S2 curves represent steep sloping water surface profiles.

SAND See TABLE B-1.

SATURATION The degree to which voids in soil are filled with water.

SCOUR The enlargement of a flow section by the removal of boundary material through the action of the fluid in motion.

SECONDARY CURRENTS (OR FLOW) The movement of water particles on a cross section normal to the longitudinal direction of the channel.

SEDIMENT (1) Particles derived from rocks or biological materials that have been transported by a fluid. (2) Solid material (sludges) suspended in or settled from water. A collective term meaning an accumulation of soil, rock and mineral particles transported or deposited by flowing water.

SEDIMENTATION A broad term that pertains to the five fundamental process responsible for the formation of sedimentary rocks: (1) ~~weathering,~~ [erosion] (2) ~~detachment,~~ [entrainment] (3) transportation, (4) deposition (sedimentation), and (5) ~~diagenesis;~~ [compaction] and to the gravitational settling of suspended particles that are heavier than water. ASTM definition.

See ASCE # 54

SEDIMENTATION DIAMETER The diameter of a sphere of the same specific weight and the same terminal settling velocity as the given particle in the same fluid.

SEDIMENT DISCHARGE The mass or volume of sediment (usually mass) passing a stream cross section in a unit of time. The term may be qualified, for example; as suspended-sediment discharge, bed load discharge, or total-sediment discharge. See SEDIMENT LOAD.

SEDIMENT LOAD A general term that refers to material in suspension and/or in transport. It is not synonymous with either discharge or concentration. It may also refer to a particular type of load; e.g. total, suspended, wash, bed, or material.

SEDIMENT PARTICLE Fragments of mineral or organic material in either a singular or aggregate state.

SEDIMENT RATING TABLES Tables which relate inflowing sediment loads to water discharge for the upstream ends of the main stem, tributaries, and local inflow points.

SEDIMENT TRANSPORT (RATE) See SEDIMENT DISCHARGE.

SEDIMENT TRANSPORT FUNCTION A formula or algorithm for calculating the sediment transport rate given the hydraulics and bed material at a cross section. Most sediment transport functions compute the bed material load capacity. The actual transport may be less than the computed capacity due to armoring, geologic controls, etc.

SEDIMENT TRANSPORT ROUTING The computation of sediment movement for a selected length of stream (reach) for a period of time with varying flows. Application of sediment continuity relations allow the computation of aggradation and deposition as functions of time.

SEDIMENT TRAP EFFICIENCY See TRAP EFFICIENCY.

SETTLING VELOCITY See FALL VELOCITY.

SHAPE FACTOR See PARTICLE SHAPE FACTOR.

SHEAR INTENSITY A dimensionless number that is taken from Einstein's bed load function. It is the inverse of Shield's parameter.

SHEAR STRESS Frictional force per unit of bed area exerted on the bed by the flowing water. An important factor in the movement of bed material.

SHIELD'S DETERMINISTIC CURVE A curve of the dimensionless tractive force plotted against the grain Reynolds number (ie., $U_{*} \cdot D_s/v$ where, U_{*} = turbulent shear velocity, D_s = characteristic or effective size of the grains or roughness elements, v = kinematic viscosity) and which is used to help determine the CRITICAL TRACTIVE FORCE.

SHIELD'S PARAMETER A dimensionless number referred to as a dimensionless shear stress. The beginning of motion of bed material is a function of this dimensionless number.

$$\frac{\tau_c}{(\gamma_s - \gamma)\, D_s}$$

where,

τ_c = critical tractive force
γ_s = specific weight of the particle
γ = specific weight of water
D_s = characteristic or effective size of the grains or roughness elements

SIEVE DIAMETER The smallest standard sieve opening size through which a given particle of sediment will pass.

SILT See TABLE B-1.

SILTATION An unacceptable term. Use sediment deposition, sediment discharge, or sediment yield as appropriate.

SIMULATE To express a physical system in mathematical terms.

SINUOSITY A measure of meander "intensity". Computed as the ratio of the length of a stream measured along its thalweg (or centerline) to the length of the valley through which the stream flows.

SORTING The dynamic process by which sedimentary particles having some particular characteristic (such as similarity of size, shape, or specific gravity) are naturally selected and separated from associated but dissimilar particles by the agents of transportation. Also, see GRADATION.

SPLIT FLOW Flow that leaves the main river flow and takes a completery different path from the main river [Case (a)]. Split flow can also occur in the case of flow bifurcation around an island [Case (b)]. See FIGURE B-9.

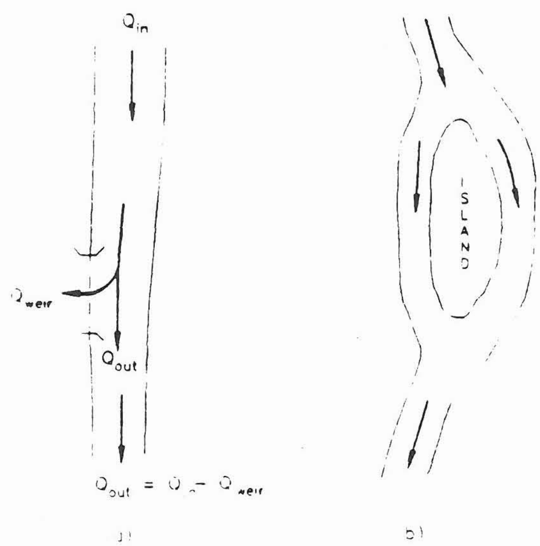

Figure B-9. Split Flow

STABLE CHANNEL A stream channel that does not change in planform or bed profile during a particular period of time. For purposes of this glossary the time period is years to tens of years.

STAGE-DISCHARGE (RATING) CURVE Defines a relationship beween discharge and water surface elevation at a given location.

STANDARD STEP METHOD Method where the total distance is divided into reaches by cross sections at fixed locations along the channel and, starting from one control, profile calculations proceed in steps from cross section to cross section to the next control.

STEADY STATE MODEL Model in which the variables being investigated do not change with time.

STREAM GAGE A device that measures and records flow characteristics such as water discharge and water surface elevation at a specific location on a stream. Sediment transport measurements are usually made at stream gage sites.

STREAM POWER The product of bed shear stress and mean cross-sectional velocity at a cross section for a given flow.

STREAM PROFOLE A plot of the elevation of a stream bed vs. distance along the stream.

STREAM SEGMENT A stream segment is a specified portion of a river with an upstream inflow point and with a downstream termination at a control point. Primary Inflow points are designated by I_n, where n is the segment number. Primary Inflow points are always at the upstream most end of a tributary or main stem segment. See FIGURE 3.8 in document.

SUBCRITICAL FLOW The state of flow where the water depth is above the critical depth. Here, the influence of gravity forces dominate the influences of inertial forces, and flow, having a low velocity, is often described as tranquil.

SUB-SURFACE LAYER The sub-surface layer is composed of well mixed sediments brought up from the inactive layer plus sediment which has deposited from the water column. It will replenish the cover layer and thereby supply bed sediment as required to meet sediment transport capacity. When the weight in the sub-surface layer becomes less than the weight required to cover 100% of the bed surface to a depth of 2 times the size of the largest particle in transport, a new sub-surface layer is brought up from the inactive layer. See FIGURE B-1.

SUPERCRITICAL FLOW The state of flow where the water depth is below the critical depth, inertial forces dominate the gravitational forces, and the flow is described as rapid or shooting.

SUSPENDED BED MATERIAL LOAD That portion of the suspended load that is composed of particle sizes found in the bed material.

SUSPENDED LOAD Inludes both suspended bed material load and wash load. Sediment that moves in suspension is continuously supported in the water column by fluid turbulence. Contrast with BED LOAD.

SUSPENDED-SEDIMENT DISCHARGE The quantity of suspended sediment passing a cross section in a unit of time usually given in tons/day. See SUSPENDED LOAD.

TAIL WATER The water surface elevation downstream from a structure, such as below a dam, weir or drop structure.

THALWEG The line following the lowest part of a valley, whether under water or not. Usually the line following the deepest part or middle of the bed or channel of a river.

TOTAL SEDIMENT DISCHARGE The total rate at which sediment passes a given point on the stream (tons/day). See TOTAL SEDIMENT LOAD.

TOTAL-SEDIMENT LOAD (TOTAL LOAD) Includes bed load, suspended bed material load, and wash load. In general, total sediment load cannot be calculated or directly measured.

TRACTIVE FORCE When water flows in a channel, a force is developed that acts in the direction of flow on the channel bed. This force, which is simply the pull of water on the wetted area, is known as the tractive force. In a uniform flow, the equation for the unit tractive force (i.e., the average value to the tractive force per unit wetted area) is

$$\tau_0 = wRS$$

where,

τ_o = unit tractive force
w = unit weight of water
R = the hydraulic radius
S = the slope of the channel.

TRANSMISSIVE BOUNDARY A boundary (cross section) that will allow sediment that reaches it to pass without changing that cross section.

TRANSPORTATION (SEDIMENT) The complex processes of moving sediment particles from place to place. The principal transporting agents are flowing water and wind.

TRANSPORT CAPACITY The ability of the stream to transport a given volume or weight of sediment material of a specific size per time for a given flow condintion. The units of transport capacity are usually given in Tons per day of sediment transported passed a given cross section for a given flow. Transport capacity for each sediment grain size is the transport potential for that size material multiplied by the actual fraction of each size class present in the bed and bank material.

TRANSPORT POTENTIAL Transport potential is the rate at which a stream could transport sediment of a given grain size for given hydraulic conditions if the bed and banks were composed entirely of material of that size.

TRAP EFFICIENCY Proportion of sediment inflow to a stream reach (or reservoir) that is retained within that reach (or reservoir). Computed as inflowing sediment volume minus outflowing sediment volume divided by inflowing sediment volume. Positive values indicate aggradation; negative values, degradation.

TRIBUTARY A river segment other than the main stem in which sediment transport is calculated. More generally, a stream or other body of water, surface or underground, that contributes its water to another and larger stream or body of water.

TURBULENCE In general terms, the irregular motion of a flowing fluid.

UNMEASURED LOAD Equipment used to measure sediment transport by sampling the concentration of suspended sediment cannot operate close to the stream bed. The material moving below the lowest point which the sampler can reach is termed "unmeasured load".

WASH LOAD That part of the suspended load that is finer than the bed material. Wash load is limited by supply rather than hydraulics. What grain sizes constitute wash load varies with flow and location in a stream. Sampling procedures that measure suspended load will include both wash load and suspended bed material load. Normally, that is of sediment particles smaller than 0.062 mm.

WATER COLUMN An imaginary vertical column of water used as a control volume for computational purposes. Usually the size of a unit area and as deep as the depth of water at that location in the river.

WATER DISCHARGE See STREAM DISCHARGE.

WATERSHED A topographically defined area drained by a river/stream or system of connecting rivers/streams such that all outflow is discharged through a single outlet. Also called a drainage area.

WEIR A small dam in a stream, designed to raise the water level or to divert its flow through a desired channel. A diversion dam.

WETTED PERIMETER The wetted perimeter is the length of the wetted contact between a stream of flowing water and its containing channel, measured in a direction normal to the flow.

TABLE B-1[1]

Scale for Size Classification of Sediment Particles

CLASS NAME	MILLIMETERS	MICRONS	PHI VALUE
Boulders	> 256	--	< -8
Cobbles	256 - 64	--	-8 to -6
Gravel	64 - 2 (5 partitions) 2, 4, 8, 16, 32, 64	--	-6 to -1
Very coarse sand	2.0 - 1.0	2000 - 1000	-1 to 0
Coarse sand	1.0 - 0.50	1000 - 500	0 to +1
Medium sand	0.50 - 0.25	500 - 250	+1 to +2
Fine sand	0.25 - 0.125	250 - 125	+2 to +3
Very fine sand	0.125 - 0.062	125 - 62	+3 to +4
Coarse silt	0.062 - 0.031	62 - 31	+4 to +5
Medium silt	0.031 - 0.016	31 - 16	+5 to +6
Fine silt	0.016 - 0.008	16 - 8	+6 to +7
Very fine silt	0.008 - 0.004	8 - 4	+7 to +8
Coarse clay	0.004 - 0.0020	4 - 2	+8 to +9
Medium clay	0.0020 - 0.0010	2 - 1	+9 to +10
Fine clay	0.0010 - 0.0005	1 - 0.5	+10 to +11
Very fine clay	0.0005 - 0.00024	0.5 - 0.24	+11 to +12
Colloids	< 0.00024	< 0.24	> +12

Divide By 2 for next grade

[1] TABLE B-1 is taken from EM 1110-2-4000, March 1988