City of Sacramento

User's Manual for

Sacramento Stormwater Management Model (SSWMM96)

January 1996

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Stormwater Management Model
(SSWMM96)
User's Manual

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SECTION 1

BACKGROUND

This section of the SSWMM96 User's Manual gives a brief history of the evolution of the EPA SWMM model into the RUNOFF and EXTRAN blocks that make up SSWMM96. Figure 1-1 is a schematic illustrating the way that the RUNOFF and EXTRAN blocks are related.

As indicated in the figure, the RUNOFF block watershed simulation is first used to develop runoff hydrographs for each subcatchment in the watershed. Then, the RUNOFF block conveyance simulation may optionally be used to perform hydrologic routing through various conveyance elements. Finally, the EXTRAN block is used to dynamically route the hydrographs through the remainder of the conveyance system, usually the major interceptors and trunk lines.

Figure 1-2 is a conceptual view of the relationship between RUNOFF and EXTRAN. As shown in the figure, RUNOFF is used to simulate the hydrologic parameters for areas A_1 and A_2, along with the gutter or pipe hydrologic routing through A_2. These hydrologic parameters, in combination with a precipitation hyetograph, are used by RUNOFF to develop runoff hydrographs Q_1 and Q_2 for areas A_1 and A_2. The hydrograph from A_1 is routed through the gutter and combined with the hydrograph from A_2 to yield the resultant hydrograph Q_{12}.

The combination hydrograph represented by Q_{12} is used as input to the EXTRAN block and is then dynamically routed through the major trunk line to the storm drain outfall.

1.1 HISTORY OF SSWMM96

1.1.1 RUNOFF Block

The RUNOFF block was first developed as one part of the EPA Stormwater Management Model (SWMM). It simulated both the quality and quantity of runoff from urban drainage basins, along with hydrologic routing of the flows through conveyance systems. Hydrologic Engineering Center and the Missouri River Division (MRD) of the U.S. Army Corps of Engineers modified a quantity only version of the original RUNOFF block to correct deficiencies that had been encountered in the model. This version of the RUNOFF block simulated only the quantity of stormwater and not the quality. Boyle Engineering Corporation (BEC) made a further revision to the MRD version, allowing it to be run on personal computers.

Montgomery Watson Americas, Inc. (MW) has further modified the RUNOFF block for SSWMM96. These modifications mostly affected the input data formatting and output data

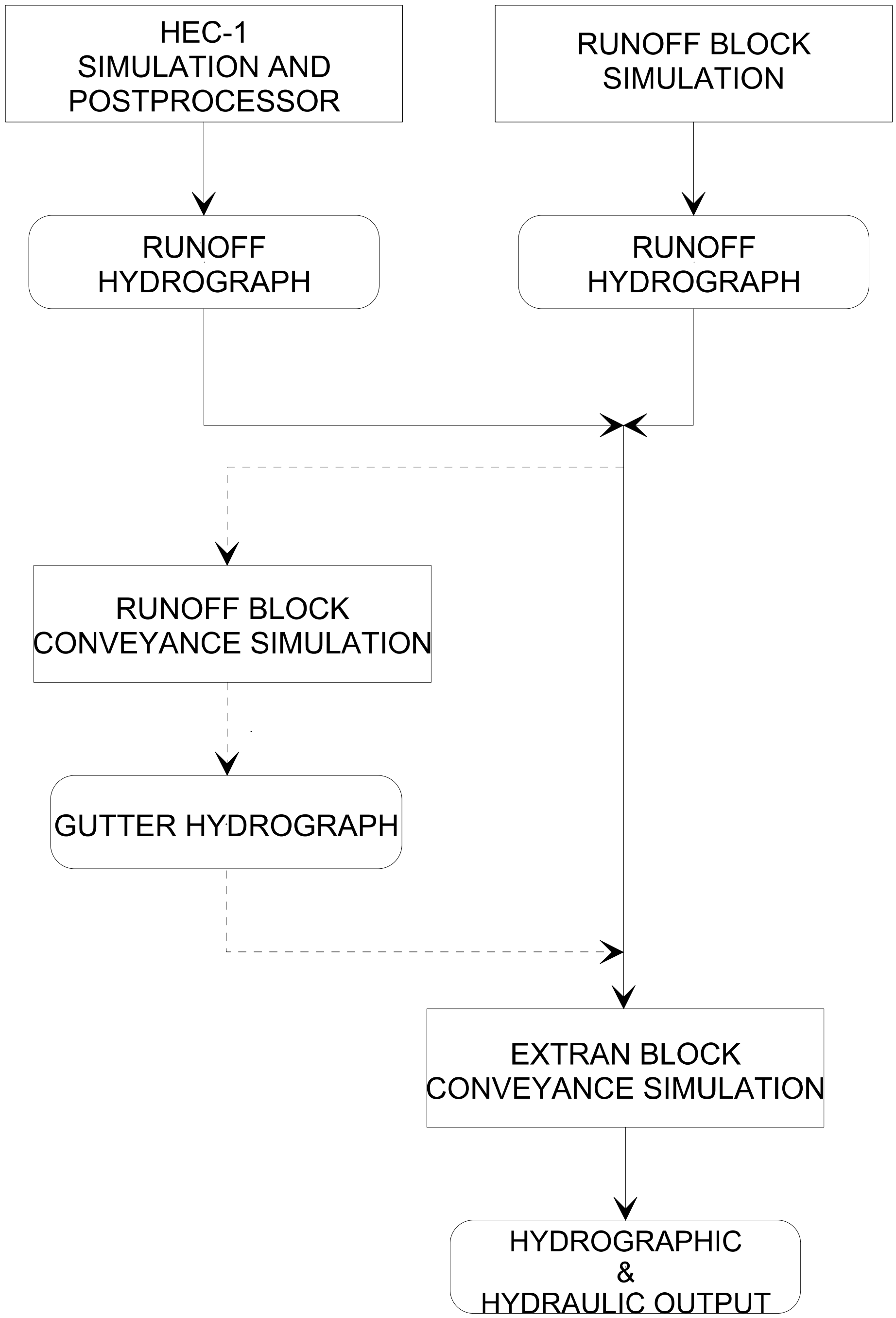
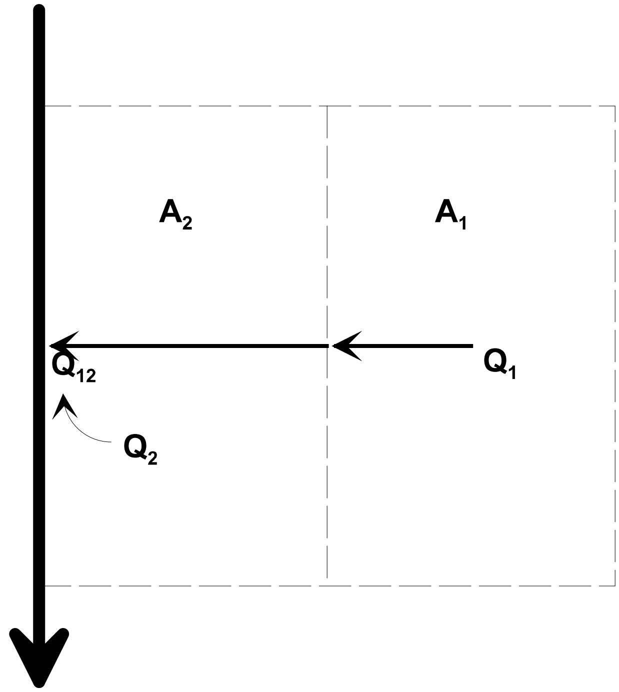


FIGURE 1-1
MW-SWMM HYDROGRAPH SIMULATION SCHEMATIC



Options to Estimate Flow Q_{12} from Areas A_1 and A_2

1) Estimate Q_{12} from a combined area, A_1 plus A_2, using the watershed element in the RUNOFF Block.

2) Estimate Q_1 and Q_2 separately, then route Q_1 and combine it with Q_2.
Routing Options: i) Conveyance Element in RUNOFF Block
ii) EXTRAN Block

3) Major Trunk Routing in EXTRAN Block

FIGURE 1-2
CONCEPTUAL RELATIONSHIP OF RUNOFF AND EXTRAN

presentation. Input is now free format with input variable descriptions in the input itself. Output formats were clarified and expanded to meet the needs of the City.

1.1.2 EXTRAN Block

The EXTRAN block used in SSWMM96 was originally developed by Water Resources Engineers (WRE)[1] for the City of San Francisco in 1973. In 1974 EPA acquired this model and incorporated it into the SWMM package, calling it the Extended Transport Model - EXTRAN -- to distinguish it from the TRANSPORT Module developed by the University of Florida as part of the original SWMM package.

Extensive modifications were made to the EXTRAN block by BEC during their work on the City of Sacramento's combined sewer system. These modifications included overflow simulation components to simulate street flooding; simulation of various pumping plant configurations; and a modified numerical solution technique for quicker, more accurate results.

Montgomery Watson has further modified the EXTRAN block for SSWMM96. These modifications included new input and output data formats that make it easier to develop, debug, and understand the results of EXTRAN simulations. Major modifications were made in the way EXTRAN handles weirs and separated pipes. Pumpback storage and downstream boundary conditions have also been added. Output graphics for plotting flow and stage hydrographs, and an HEC-1 post-processor to allow HEC-1 to be used to develop runoff hydrographs for use in EXTRAN were also developed as part of these modifications.

[1]Camp Dresser & McKee

SECTION 2

RUNOFF BLOCK

2.1 INTRODUCTION

The purpose of the RUNOFF block is to transform precipitation into runoff that then enters the storm drainage or combined sewer system being modeled. It represents a watershed as a number of smaller subbasins or subcatchments and their associated conveyance systems. The subcatchments and conveyances are idealized for ease in describing their characteristics.

The RUNOFF block uses precipitation in the form of rainfall hyetographs that give the rainfall intensity in inches per hour for each timestep in the model. The program uses these rainfall hyetographs to make a step by step accounting of rainfall infiltration losses in previous areas, surface retention, overland flow, and gutter flow, leading to the calculation of hydrographs.

The drainage basin is subdivided into subcatchment areas that produce runoff hydrographs. These hydrographs may be used directly as input for the EXTRAN block, or may be routed (in RUNOFF) through gutters or pipes to compute hydrographs at the inlet points to the major storm drain conveyance system. Overbank floodway sections may be used in conjunction with gutters and pipes. Detention basins with a specified storage-outflow relationship may be used. Also, RUNOFF allows the user to specify a flow diversion table for routing elements. Pipes, gutters, diversions, and detentions are referred to as "conveyance elements" in this manual.

Two types of elements are available to the RUNOFF user:

1. Subcatchment elements (overland flow)

2. Conveyance elements (channel flow, pipe flow, storage, etc.)

These two elements are analyzed as separate operations in RUNOFF. That is, if the user intends to create overland flow hydrographs and then route them through RUNOFF conveyance elements, he will need to use RUNOFF twice. The first RUNOFF simulation will calculate the runoff hydrographs, and second one will use the calculated hydrographs as input for routing through conveyance elements.

The subcatchment elements receive rainfall, account for infiltration loss using Horton's equation, permit surface storage such as ponding or retention on grass or shrubbery, and route excess rainfall to develop overland flows. The results from the subcatchment (overland flow) analysis are saved to a file for future routing. The overland flows may then be routed through the conveyance elements of the study watershed. Pipes and initial channel sections are permitted to surcharge when full or, if desired, overflow sections may be provided to convey the flow exceeding the pipe or the initial channel capacity. The routing is based on a kinematic wave approach that utilizes Manning's equation both for subcatchment and conveyance elements.

2.2 SUBCATCHMENT PARAMETERS

Subcatchments can be thought of as idealized areas with a uniform slope and uniform ground cover. This ground cover may represent one actual type of ground cover such as impervious asphalt paving or pervious turf, or it may represent a mix of impervious and pervious ground cover types. Important information required to characterize a subcatchment includes area, width, ground slope, percent imperviousness, roughness coefficients, surface retention depth (depression losses), and soil infiltration coefficients. Since the subcatchments encountered in the real world are not rectangular areas with uniform characteristics, some approximations must be made in order to represent the subcatchments in the model.

The important subcatchment parameters that are required in order to describe subcatchments for use by the RUNOFF block are described in the following paragraphs.

2.2.1 Drainage Area

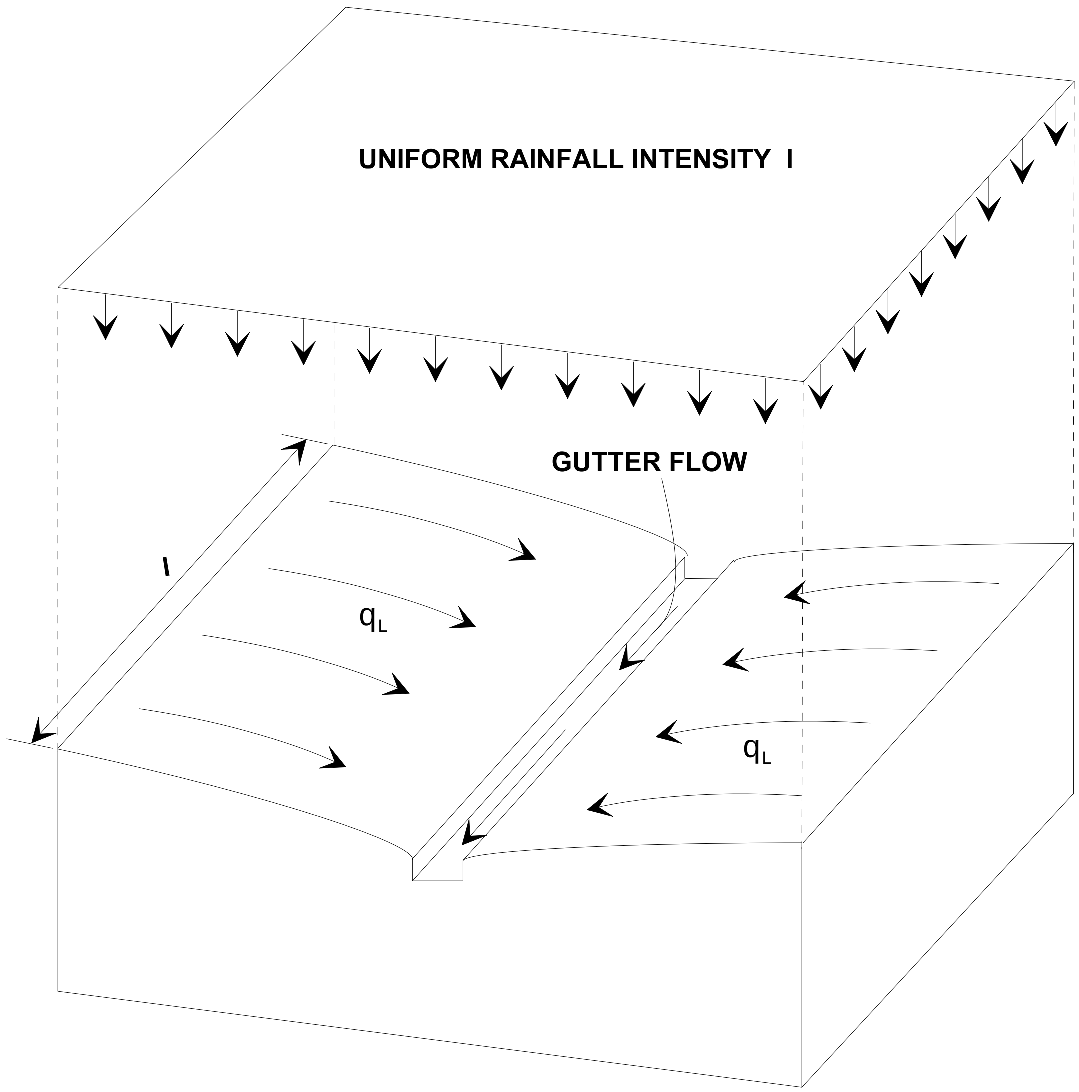
This is the total area of the subcatchment and it is typically measured from a topographic map of the area being modeled, with the subcatchment boundaries overlaid on top. It is important to understand the topography of the subcatchment, as well as any conveyance elements that carry runoff into or out of the subcatchment, prior to delineating the subcatchments on the map. The topography will determine the subcatchment boundaries except where conveyance structures may divert water into or out of the subcatchment.

Subcatchments should be chosen to coincide with different land uses and with drainage divides as described above if possible.

2.2.2 Subcatchment Width

If overland flow in a subcatchment is visualized as occurring in an idealized, rectangular subcatchment such as the one shown in Figure 2-1, then the width of the subcatchment is the physical width of the overland flow. Since the overland flow per unit width (q_l) occurs along a length ℓ, the total flow is equal to q_l multiplied by the width. In the idealized example shown in Figure 2-1 the two sides of the subcatchment are symmetrical, giving total width that is twice the length of the gutter flow (2ℓ). If the subcatchment in question was just one side of the subcatchment shown in Figure 2-1, the width would simply be ℓ.

Subcatchments in the real world are rarely consistent with the idealized situation shown in Figure 2-1. Most of them will be irregular in shape and will have a drainage channel that is not centered in the basin as shown in Figure 2-2. A simple way to handle this case is to compute a skew factor:



q_L = RATE OF OVERLAND FLOW/UNIT WIDTH

W = 2 l = TOTAL WIDTH OF OVERLAND FLOW

FIGURE 2-1
IDEALIZED SUBCATCHMENT-GUTTER ARRANGEMENT SHOWING SUBCATCHMENT WIDTH

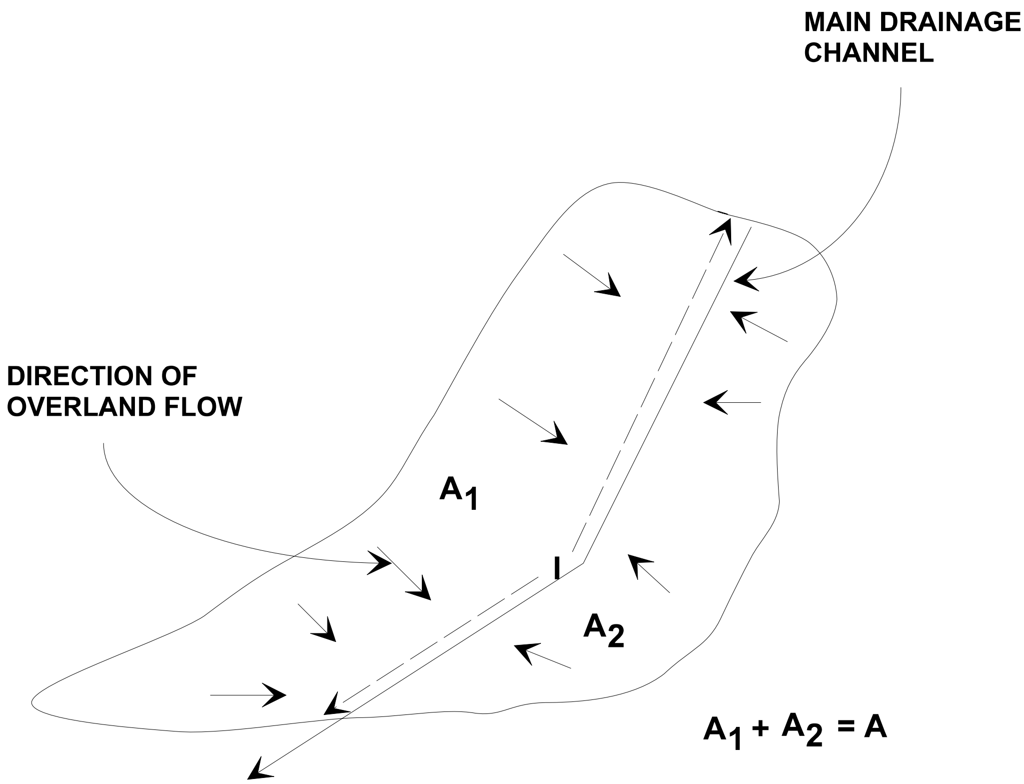


FIGURE 2-2
CALCULATING BASIN WIDTH FOR IRREGULAR SHAPED SUBCATCHMENTS

$$\gamma = \left| \frac{A_2 - A_1}{A} \right|$$

where γ = skew factor, $0 \le \gamma \le 1.0$
A_1 = area to one side of channel
A_2 = area to other side of channel
A = total area

Then, the width, W is:

$$W = (2 - \gamma)\ell$$

where W = subcatchment width
ℓ = length of main drainage conveyance

2.2.3 Slope

The subcatchment slope should reflect the average along the pathway of overland flow to inlet locations. For simple geometry (e.g., rectangular subcatchments as illustrated in Figure 2-1) the calculation is simply the elevation difference divided by the straight-line length of flow. For the more complex situations encountered in the real world, several overland flow paths may be determined, their slopes calculated, and a weighted slope computed using a path-length weighted average.

2.2.4 Imperviousness

The percent imperviousness of a subcatchment is obtained by using aerial photos or land use maps to determine the extent of each particular land use that exists in a subcatchment. Although this extent can be measured accurately with a planimeter or some other method, it is more common to use visual estimates of the percentage of a subcatchment that is occupied by each land use. Table 2-1 presents a list of City of Sacramento land uses and their suggested percentage of imperviousness for use in the RUNOFF block. Remember that these percentages are just suggestions, and actual percentages, especially for schools and parks, could vary widely depending on the specific site.

Care must be taken to insure that impervious areas are hydraulically connected to the drainage system. For instance, if rooftops drain onto adjacent pervious areas, they should not be treated as impervious. On the other hand, if a driveway drains to a street and then to a storm drain inlet, the driveway would be considered to be hydraulically connected. Rooftops with downspouts connected directly to the storm drain or discharging onto adjacent impervious areas are hydraulically connected.

TABLE 2-1
LAND USES AND PERCENT IMPERVIOUSNESS

Land Use	Suggested Percent Impervious*
Commercial/Highways/Parking	95-99
Apartments/Offices/Trailers	75-90
Condominiums/Schools/Industry	70
Residential: 8-10 units/acre	60
Residential: 6-8 units/acre	50
Residential: 4-6 units/acre	40
Residential: 3-4 units/acre	30
Residential: 2-3 units/acre	25
Residential: 1-2 units/acre	20
Residential: .5-1 units/acre	15
Residential: .2-.5 units/acre	10
Residential: <.2 units/acre	5
Open Space/Grassland/Cropland	2
Open Space/Woodland	1

(*Table 2-5, Sacramento City/County Drainage Manual (1991))

Note: These percentages may be used as default values, but actual percentages should be determined for each development.

If rooftops are treated as draining to pervious areas, then those pervious areas will be subject to more incoming water than they would get from rainfall alone. This will probably produce more runoff from the pervious area quicker than if rainfall alone was considered. If this effect is considered to be important, it can be modeled by altering the infiltration parameters (lowering infiltration rates) for the pervious areas receiving roof runoff. For example, if all downspouts in a residential area with type C soils are designed to discharge to the lawns around the homes, then the pervious area infiltration coefficient could be changed from 0.11 to 0.10 or 0.09.

2.2.5 Roughness Coefficient (Manning's n)

Values of roughness coefficient (n) are not as easily determined for subcatchment overland flow as they are for conveyance elements because of the variability in ground cover and small depths that occurs in overland flow situations. It is recommended that suggested values in Table 2-2 be used to estimate the roughness of the subcatchment because they have been found to work reasonably well in urban situations. Resistance factors for the pervious and impervious areas of the subcatchment are specified separately, with default values of 0.25 and 0.013 for pervious and impervious overland flow, respectively.

TABLE 2-2
SUBCATCHMENT OVERLAND FLOW ROUGHNESS COEFFICIENTS

Ground Cover	Suggested Manning's n for Overland Flow
Impervious:	
Smooth Asphalt	0.016
Asphalt or concrete paving	0.020
Pervious:	
Native grass	0.20
Urban lawns	0.25
Dense shrubbery and forest litter	0.40

2.2.6 Depression Storage

Rainfall that is collected and held in small depressions and does not become part of the general surface runoff is call depression storage or retention. Most of this water eventually infiltrates (on pervious areas) or evaporates. Depression storage also includes water intercepted by trees and bushes and water that is detained on the surface and does not run off. Depression storage will depend on specific subcatchment conditions, but Table 2-3 gives suggested values for typical depression storage for various types of land cover.

TABLE 2-3
TYPICAL DEPRESSION STORAGE FOR VARIOUS LAND COVERS

Land Cover	Typical Depression and Detention Storage Values (inches)	Recommended Storage Values (inches)
Impervious Areas		
Large Paved Areas	0.05 - 0.15	0.10
Roofs - Flat	0.10 - 0.30	0.10
Roofs - Sloped	0.05 - 0.10	0.05
Pervious Areas		
Lawn Grass	0.2 - 0.5	0.35
Wooded Areas and Open Fields	0.2 - 0.6	0.40

In RUNOFF, depression storage may be used as a calibration parameter, particularly to adjust runoff volumes. If runoff volumes from a subcatchment or basin being calibrated appear to be too high or too low, the depression storage values being used in RUNOFF may be adjusted within the ranges given in Table 2-3

2.2.7 Infiltration Coefficients

Infiltration from pervious areas is calculated using the Horton infiltration equation:

$$f = f_o + (f_i - f_o) * e^{-at}$$

where: f = infiltration rate (inches/hour)
f_i = initial (maximum) infiltration rate (inches/hour)
f_o = final infiltration rate (inches/hour)
e = natural logarithm base
a = decay coefficient
t = time in seconds

The U.S. Soil Conservation Service (SCS) has classified most soils into Hydrologic Soil Groups, A, B, C, and D, describing their infiltration capacities. They are as follows:

- Group A - Low runoff potential. Group A is made up of soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well- to excessively-drained sands or gravels.

- Group B - Moderately low runoff potential. Group B contains soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with fine to moderately coarse textures. These soils have a moderate rate of water transmission.

- Group C - Moderately high runoff potential. Group C is comprised of soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

- Group D - High runoff potential. Group D includes soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

- Urban - High runoff potential. Urban soils have been disturbed and recompacted, usually having slow infiltration rates when thoroughly wetted. These soils have a slow rate of water transmission and should be handled the same as Group D soils.

Soil types for a particular area in the City of Sacramento can be determined from the SCS Soil Survey maps that are available from the local SCS office. Recommended values for f_i, f_o, and a are listed in Table 2-4.

TABLE 2-4
RECOMMENDED INFILTRATION COEFFICIENTS

SCS Soil Type	Initial Infiltration f_i (in/hr)	Final Infiltration f_o (in/hr)	Infiltration Decay Coefficient a
A	1.0	0.35	0.0007
B	1.0	0.19	0.0018
C	1.0	0.11	0.0018
D	1.0	0.08	0.0018

Note: The infiltration decay coefficient used in the combined system model is 0.000362

2.3 CONVEYANCE PARAMETERS

There are five standard types of conveyance elements and three special flow routing conveyance elements that are used in RUNOFF.

2.3.1 Conveyance Elements

The RUNOFF Block has eight conveyance elements available for routing flows. Figure 2-3 illustrates general conveyance element configurations. The five standard conveyance elements are:

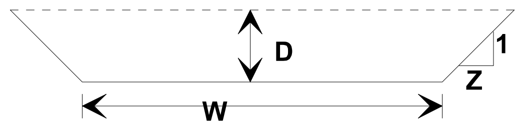
1. Channel. A trapezoidal channel used to represent or approximate an open channel/gutter condition. The channel is defined by its bottom width and side slope.

2. Pipe. A circular pipe of any diameter.

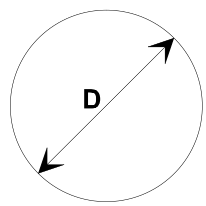
3. Direct flow. This element provides only instantaneous direct translation of the flows from the upstream to the downstream conveyance element and does not modify the hydrograph.

4. Channel with overflow channel. Same as the channel element above except that a larger trapezoidal channel is also specified to accept the flows exceeding the capacity of the initial channel cross-section.

1. TRAPEZOIDAL CHANNEL



2. CIRCULAR PIPE



3. DIRECT FLOW (NOT SHOWN)

4. CHANNEL WITH OVERFLOW

5. PIPE WITH OVERFLOW CHANNEL

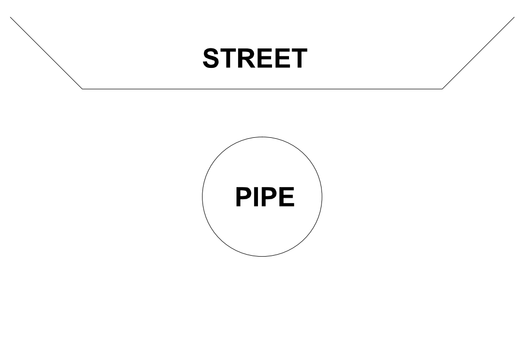


FIGURE 2-3
GENERAL CONVEYANCE ELEMENT CONFIGURATIONS

5. Pipe with overflow channel. Same as the pipe element above except that a trapezoidal channel is also specified to accept the flows exceeding the capacity of the pipe.

2.3.2 Special Flow Routing Elements

The three special flow routing conveyance elements, shown in Figure 2-4, are as follows:

1. Diversion. A table of flows in a conveyance element versus the flow diverted to another conveyance element may be specified using this option.

2. Storage reservoir (detention basin). A table of reservoir storage in acre-feet versus outflow in cubic feet per second (cfs) may be specified using this option. This operation may be used in conjunction with the "pipe" routing element. The pipe capacity has to be exceeded before the storage-outflow function is utilized.

3. Inflow hydrograph. This option may be used to specify an input hydrograph table of time in hours versus the flow in cfs for any routing element.

2.3.3 Manning's n

For hydrologic routing through the conveyance elements described above, the resistance (Manning's n) coefficients should not be the same as those that would be used for the same type of conveyance element where hydraulic calculations are being performed. Studies have shown that increasing the "typical" values of Manning's n by approximately 25 percent provides more realistic results when using RUNOFF. For example, when doing hydraulic calculations a concrete gutter would normally have n = 0.013. That same gutter when being used for hydrologic routing in RUNOFF would have n = 0.016.

Hydrologic routing in streets is approximated using the trapezoidal sections illustrated in Figure 2-5.

2.4 PRECIPITATION

Precipitation for use with RUNOFF may come from two different sources:

- Historical Storm Data
- Design Storm Data

The precipitation data may be input for any time interval desired, but it is best to keep the time intervals between 5 to 30 minutes for the best storm definition without having excessive precipitation values. Each value in a precipitation hyetograph is the average intensity, in inches per hour, that took place during the timestep.

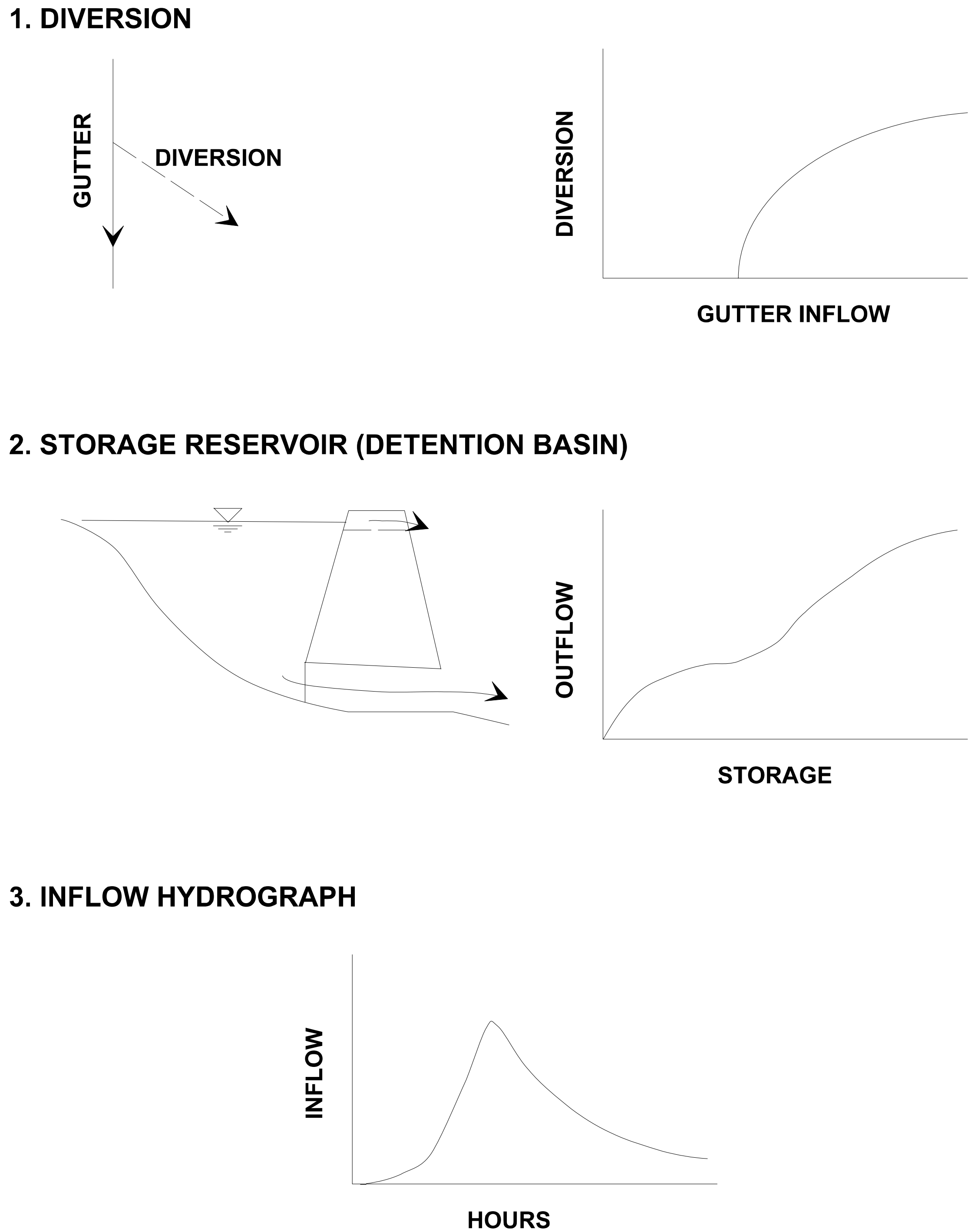
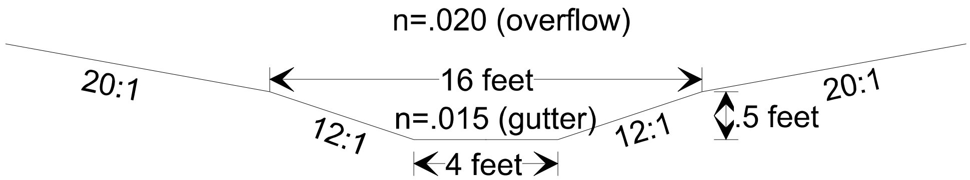
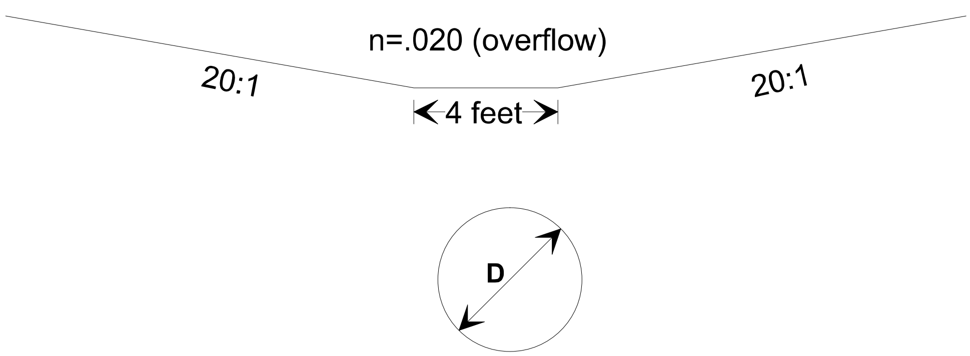


FIGURE 2-4
SPECIAL FLOW ROUTING CONVEYANCE ELEMENTS



FULL STREET (TWO GUTTER) W/O STORM SEWER
(FOR ONE GUTTER USE ONE-HALF OF SECTION)



FULL STREET WITH STORM SEWER

FIGURE 2-5
TRAPEZOIDAL APPROXIMATIONS FOR STREETS

2.5 INPUT DATA PREPARATION

The input data format for the RUNOFF block has been designed to be flexible and to allow the user to insert notes and comments as part of the input. RUNOFF ignores any input line beginning with an asterisk (*) in the first column. The user may place comment lines at any point in the input except where the program is expecting a certain number of input values such as during the specification of a pump curve.

All input variables are entered in free format, meaning that the precise column in which a particular variable is entered is not important. What is important is the order in which the data is entered, the grouping in which it is entered, and presence of a space or comma between each data value. For each type of data (i.e., subcatchment data or rainfall data), RUNOFF expects each line to contain a specified number of data values. If more than that number of values are entered, they will be ignored. If less than the expected number of values are entered, RUNOFF will read the remaining input values from the next line of input.

2.5.1 Default Values

Many variables used by the RUNOFF block have default values that will be used in the computations if the variable in question is not specified (i.e., a zero). Where default values are supplied in the model they will be noted in this manual as part of the input parameters' description.

The standard defaults incorporated in the RUNOFF block may not be applicable in all situations. Methods are available in RUNOFF to change any of the default values to match individual situations. Multiplication ratios may also be added for any of the subcatchment parameters enabling the user to change all subsequent subcatchments by a given amount. For example, as part of a calibration procedure the maximum infiltration rate for a series of subcatchments could be multiplied by a factor of 1.1 to decrease the volume of runoff produced by a given amount of rainfall.

2.5.2 Overland Flow Input Data Template

Table 2-5 is a sample input file illustrating the input format and layout of a typical overland flow RUNOFF input data file for use in creating hydrographs. The input is divided into sections as follows:

- Title Section
- System Parameters Section
- Rainfall Parameters Section
- Subcatchment Data Section

Each of these sections and its associated input variables will be discussed in detail.

TABLE 2-5
RUNOFF SUBCATCHMENT SIMULATION INPUT TEMPLATE

```
*This is a subcatchment (overland flow) simulation input file for the RUNOFF block of SSWMM96
*
*TITLE SECTION
 SSWMM96 DOCUMENTATION EXAMPLE DATA
 RUNOFF BLOCK - SUBCATCHMENT OVERLAND FLOW HYDROGRAPHS
*
*SYSTEM PARAMETERS SECTION- free input format
     0              *IOPT = 0 for overland flow
   179              *NSTEP = Number of timesteps to be calculated
     8,55           *NHR,NMN = Hour and minutes of start of storm
   5.0              *DELT = Integration period (min.)
     1              *NRGAG = Number of rain gage hyetographs
  75.0              *PCTZER = Percent of impervious area with zero detention
     1              *IPFlag(1) = 1 for rainfall parameters printout
     1              *IPFlag(2) = 1 for subarea data printout
     1              *IPFlag(3) = 1 for output hydrographs printout
     1              *IPKCHK = 1 for printed summary of peak flows
*
*RAINFALL PARAMETERS SECTION - This section required for subcatchment (overland flow) simulation.
    50              *NHISTO = No. of data points for each hyetograph
    10.0            *THISTO = Time interval between values
*Rainfall data - ten-year storm
*Intensity in inches/hour for each timestep
     0     0     0     0     0     0  0.13  0.13  0.13  0.13
  0.13  0.13  0.16  0.16  0.16  0.16  0.16  0.16  0.28  0.30
  0.36  0.52  1.98  0.48  0.36  0.36  0.36  0.36  0.36  0.36
  0.20  0.20  0.20  0.20  0.20  0.20  0.16  0.16  0.16  0.16
  0.16  0.16     0     0     0     0     0     0     0     0
*
*SUBCATCHMENT DATA SECTION
*One line for each subcatchment
*  JK      N    NGOTO  WWIDTH  WAREA   PCIMP  WSLOPE      W5         W6         W7        W8     WLMAX WLMIN   DECAY
*Hyeto-  Sub-  Convey.  Sub-    Sub-     %      Sub-   Manning's  Manning's  Storage  Storage  |-Infiltration---|
*graph   catch. Elem.  catch.  catch.  Imper-  catch.      n          n         on       on                    Decay
* No.     No.    No.   Width    Area   vious   Slope     Imperv.     Perv.    Imperv.   Perv.    Max.   Min.  Rate
*                       (ft)    (ac)          (ft/ft)                          (in)     (in)    --(in/hr)--
   1     1031    103    1100    13.9     45     .001      .016       0.05      .100     .250    3.00  0.50  0.0018
   1     1051    105    1800    13.0     45     .001      .016       0.05      .100     .250    3.00  0.50  0.0018
   1     1061    106    1960    24.6     45     .001      .016       0.05      .100     .250    3.00  0.50  0.0018
   1     1062    106    1800    34.5     40     .001      .016       0.05      .100     .250    3.00  0.50  0.0018
*Comments are allowed in the subcatchment data section
   1     1071    107    1750    30.1     70     .001      .016       0.05      .100     .250    3.00  0.50  0.0018
   1     1072    107     770    11.2     70     .001      .016       0.05      .100     .250    3.00  0.50  0.0018
   1     1081    108    2520    26.1     90     .001      .016       0.05      .100     .250    3.00  0.50  0.0018
   1     1082    108    1300     7.3     90     .001      .016       0.05      .100     .250    3.00  0.50  0.0018
   1     1083    108    1600    10.3     80     .001      .016       0.05      .100     .250    3.00  0.50  0.0018
*
*To indicate end of subcatchment data, enter 99999 (or blank)
99999
*
*Subcatchment Save And Print Control
    1               *N7 - If > 0, hydrographs saved for routing in RUNOFF Block
    0               *N21 - If > 0, hydrographs saved for routing in EXTRAN Block
    9               *NPRNT - No. of subcatchments for which hydrographs are printed
    3               *INTERV - No. of timesteps between printings
* Enter subbasin numbers if NPRNT > 0
   1031 1051 1061 1062 1071 1072 1081 1082 1083
ENDPROGRAM
```

2.5.2.1 Title Section. The title section is two lines containing up to 80 characters in each line. The title should be descriptive, but may be anything the user wants.

2.5.2.2 System Parameters Section. This section of the input contains the overall simulation parameters that control the length of the simulation, timestep size, etc. Descriptions of each of the system parameters are given below. No comment lines are allowed inside the System Parameters Section.

Name	Description	Default
IOPT	Indicates whether subcatchment hydrographs will be simulated in RUNOFF or if they will be input from another source. For subcatchment (overland flow) simulation, IOPT = 0. 0 = subcatchment hydrographs will be simulated in RUNOFF. The hydrographs may be routed through RUNOFF conveyance elements before being saved but that is not required.	none
NSTEP	Number of timesteps to be calculated. Should be sufficient to insure that most of the runoff occurs. Depends on the size of the watershed, the length of the precipitation, and the size of the timestep	none
NHR,NMN	Hour and minutes of start of the storm. May be 0,0.	none
DELT	Size of the computation timestep in minutes. For all but very small subcatchments, DELT = 5 minutes is adequate.	none
NRGAG	Number of rain gage hyetographs provided. Up to 10 hyetographs are allowed.	none
PCTZER	Percentage of the impervious area that has no depression storage depth and runs off immediately.	25
IPFLAG	Input data print echo switches: 0 = off 1 = on IPFLAG(1) = Rainfall parameters printout IPFLAG(2) = Subarea data printout IPFLAG(3) = Output hydrographs printout printout	none
IPKCHK	Peak flow and depth of flow summary table flag. 0 = No summary table 1 = Print peak flow and depth of flow summary table at end of run	none

2.5.2.3 Rainfall Parameters Section. The Rainfall Parameters Section contains the parameters controlling the size and time intervals for the precipitation hyetographs, as well as the hyetographs themselves.

Name	Description	Default
NHISTO	Number of data points for each rainfall hyetograph (maximum of 399)	none
THISTO	Time interval in minutes for each value of the hyetograph. Does not have to be the same as the computation timestep (DELT).	none
RAIN(x)	Rainfall intensity values for each timestep in the hyetograph. May have as many values as wanted on a line, only requirement is that values be separated by either a blank or a comma. For ease in error checking, use the same format on each line as shown in Table 2-5.	none

2.5.2.4 Subcatchment Data Section. The Subcatchment Data Section contains the data describing each of the subcatchments being simulated. All the data values for a subcatchment are placed on one line. Comment lines are allowed between subcatchment data lines so long as the data lines contain all the data values for a subcatchment.

Global changes in default values, for any subcatchment variable for which default a value is defined, may be made through the use of N = -2 in the Subcatchment Data Section as described below. It is also possible to substitute N = -1 which will alter all subsequent subcatchment values by specified modification ratios, as described below.

Name	Description	Default
JK	Hyetograph number for use with this subcatchment. A number is given to each hyetograph based on the order in which they are read.	none
N	The unique subcatchment identification number. Also used to control subcatchment default values and modification ratios. >0= Subcatchment identification number -2 = Modify default values for each variable based on values entered on this line. Any non-zero value entered on a line with N = -2, will replace the current default value for that variable. -1 = Alter subsequent values for a variable by the modification ratio entered on this line for that variable.	none
NGOTO	The identification number of the conveyance element in the conveyance module of RUNOFF, or the junction element, in EXTRAN, to which the subcatchment connects.	none

WWIDTH	The subcatchment width in feet. This represents the width of the downstream side of the idealized sloping rectangular subcatchment area. When the subcatchment conveyance element approximately bisects the subcatchment (Figure 2-1), use twice the length of the conveyance element for WWIDTH.	none
WAREA	Area of the subcatchment in acres.	none
PCIMP	Percent of the subcatchment that is impervious, such as paved roads, paved parking lots, roofs, sidewalks, driveways, etc.	45
WSLOPE	The average ground slope of the subcatchment normal to the tributary width, in feet/foot.	0.001
W5	Manning's n (resistance factor) for the impervious surfaces in the subcatchment (Table 2-2, default is smooth asphalt).	0.016
W6	Manning's n (resistance factor) for the pervious surfaces in the subcatchment (Table 2-2, default is urban lawns).	0.250
W7	Depression storage on impervious surfaces, in inches. Saved as WSTORE(1) (Table 2-3, default is paved area or flat roof).	0.010
W8	Depression storage on pervious surfaces, in inches. Saved as WSTORE(2) (Table 2-3, default is lawn grass).	0.35
WLMAX	Initial (maximum) infiltration rate, f_i in Horton's equation, in inches/hour (Table 2-4).	1.0
WLMIN	Final (minimum) infiltration rate, f_o in Horton's equation, in inches/hour (Table 2-4).	0.08
DECAY	Decay rate of infiltration per second, a, in Horton's equation (Table 2-4).	0.0018
99999	A blank line or 99999 indicates the end of the Subcatchment Data Section	none

Subcatchment Save and Print Control contains the parameters to control the disposition and printing of the subcatchment hydrographs created by RUNOFF.

Name	Description	Default
N7	If N7 $\geq$ 1, hydrographs from each subcatchment are to be saved for subsequent conveyance routing in RUNOFF.	none
N21	If N21 $\geq$ 1, hydrographs from each subcatchment are to be saved for subsequent routing in EXTRAN.	none
NPRNT	Number of subcatchments for which hydrographs are to be printed and sent to file for use with plot program.	none
INTERV	Number of timesteps between printing	1
IPRNT(x)	If NPRNT > 0, Subcatchment numbers for which values are to be printed and sent to file for use with plot program.	none

2.5.3 Routing Input Data Template

Table 2-6 is a sample input file illustrating the input format and layout of a typical RUNOFF routing input data file for use in routing previously created hydrographs. The input is divided into sections as described below.

- Title Section
- System Parameters Section
- Conveyance Element Data Section

Each of these sections and its associated input variables will be discussed in detail below.

2.5.3.1 Title Section. The title section is two lines containing up to 80 characters in each line. The title should be descriptive, but may be anything the user wants.

2.5.3.2 System Parameters Section. This section of the input contains the overall simulation parameters that control the length of the simulation, timestep size, etc. Descriptions of each of the system parameters are given below. No comment lines are allowed inside the System Parameters Section.

Name	Description	Default
IOPT	Indicates whether subcatchment hydrographs will be simulated in RUNOFF or if they will be input from another source. For hydrograph routing, IOPT = 1. 1 = subcatchment hydrographs are input from another source. This option is used when subcatchment hydrographs from a previous RUNOFF simulation or from HEC-1 are to be input for routing through RUNOFF conveyance elements.	none
NSTEP	Number of timesteps to be calculated. Should be sufficient to insure that most of the runoff occurs. Depends on the size of the watershed, the length of the precipitation, and the size of the timestep	none
NHR,NMN	Hour and minutes of start of the storm. May be 0,0.	none
DELT	Size of the computation timestep in minutes. For all but very small subcatchments, DELT = 5 minutes is adequate.	none
IPFLAG	Input data print echo switches: 0 = off 1 = on IPFLAG(1) = Rainfall parameters printout IPFLAG(2) = Subarea data printout IPFLAG(3) = Output hydrographs printout printout	none

TABLE 2-6
RUNOFF CONVEYANCE ROUTING INPUT TEMPLATE

```
*This is a conveyance routing input file for the RUNOFF block of SSWMM96
*
*TITLE SECTION
 SSWMM96 DOCUMENTATION EXAMPLE DATA
 RUNOFF BLOCK - CONVEYANCE ROUTING
*
*SYSTEM PARAMETERS SECTION- free input format
     1             *IOPT = 1 for routing only
   179             *NSTEP = Number of timesteps to be calculated
     8,55          *NHR,NMN = Hour and minutes of start of storm
   5.0             *DELT = Integration period (min.)
     1             *IPFlag(1) = 1 for rainfall parameters printout
     1             *IPFlag(2) = 1 for subarea data printout
     1             *IPFlag(3) = 1 for output hydrographs printout
     1             *IPKCHK = 1 for printed summary of peak flows and stages
*
*Subcatchment-Conveyance Element Relationships
*One line for each subcatchment hydrograph being read in,
*indicating conveyance element associated with each subcatchment.
*  N       IDGUT
*  Sub-   Convey.
*catch.   Element
*  No.      No.
  1031      103
  1051      105
  1061      106
  1062      106
  1071      107
*
*To indicate end of subcatchment data, enter 99999 (or blank)
99999
*
*CONVEYANCE ELEMENT DATA SECTION
*One line for each conveyance element
*  JK       N      NGOTO    NDP     NP     GWIDTH    GLEN    GSLOPE   GS1      GS2      GS      DFULL
*Special  Convey.  Next     No.    Type    Bottom   Length   Invert   Left     Right   Mannings  Depth
*Routing  Element  Elem.   Added  Convey.   Width   Convey.   Slope   Side     Side      n        or
*Element   No.      No.    Value  Element  or Dia.  Element           Slope    Slope              Dia.
*                                           (ft)     (ft)    (ft/ft) (ft/ft) (ft/ft)             (ft)
   0       103      0       0       1        10      450       .01      .5      .5       .02       5
 345       105      0       5       2         4      600       .01      0       0        .018      4
*If NDP > 0 and JK >0.
*  Element  Divert.  Element  Divert.  Element  Divert.  Element  Divert.  Element  Divert.
*   (cfs)    (cfs)    (cfs)    (cfs)    (cfs)    (cfs)    (cfs)    (cfs)    (cfs)    (cfs)
      0        0       10        5       20       10       30       15       40       20
   0      106       0       5       2         4      800       .01      0       0        .018      4
*If NDP > 0 and JK = 0.
*  Storage  Outflow  Storage  Outflow  Storage  Outflow  Storage  Outflow  Storage  Outflow
*  (ac-ft)   (cfs)   (ac-ft)   (cfs)   (ac-ft)   (cfs)   (ac-ft)   (cfs)   (ac-ft)   (cfs)
      0        0        2        5        4       10        6       15       10       20
  -1      107       0       5       1        10      350       .01      .5      .5       .025      6
*If NDP > 0 and JK = -1
*    Time    Inflow    Time    Inflow    Time    Inflow    Time    Inflow    Time    Inflow
*   (hrs)    (cfs)    (hrs)    (cfs)    (hrs)    (cfs)    (hrs)    (cfs)    (hrs)    (cfs)
      0        0        1        5        2       10        3       15        4       20
   0      108       0       0       4        10      450       .01      .5      .5       .02       5
*Overflow channel
                                              5      450       .05      .01     .01      .025     10
*
*To indicate end of conveyance element data, enter 99999 (or blank)
99999
*
*Conveyance Element Save And Print Control
    1              *N21 - If > 0, hydrographs saved for routing in EXTRAN Block
    5             *NPRNT - No. of conveyance elements for which hydrographs are to be printed
    3             *INTERV - No. of timesteps between printings
* Enter conveyance element numbers if NPRNT > 0
   103 105 106 107 108
*
ENDPROGRAM
```

IPKCHK	Peak flow and depth of flow summary table flag. 0 = No summary table 1 = Print peak flow and depth of flow summary table at end of run	none

2.5.3.3 Subcatchment-Conveyance Element Relationships Section. This section lists the subcatchment hydrographs and their associated conveyance element. The hydrograph read in from the subcatchment will be routed through the conveyance element on the same line.

Name	Description	Default
N	Subcatchment number for which a hydrograph will be read in.	none
IDGUT	Conveyance element number through which the subcatchment hydrograph will be routed.	none

2.5.3.3 Conveyance Element Data Section. The Conveyance Element Data Section contains the data describing any of the RUNOFF conveyance elements being simulated. All the data values for a specified conveyance element are put on one line unless the special conveyance element or overflow options are used.

For the special conveyance element option, additional lines are required to describe the diversion; detention; or input hydrograph. For the overflow option, an additional line is required to describe the overflow channel.

Name	Description	Default
JK	If the variable NDP = 0, JK is ignored. If NDP > 0 then values of JK are as follows: >0= a diversion from this conveyance element to the conveyance element indicated by JK. Must be followed by line(s) with a table of Total Q (cfs) versus Diverted Q (cfs). NDP is the number of sets of tabular values 0 = a detention basin at this location. Must be followed by line(s) with a table of Detention Storage (ac-ft) versus Basin Outflow Capacity (cfs). -1 = an inflow hydrograph will be specified for this location. Must be followed by line(s) with a table of Time (hrs) versus Inflow (cfs). NDP is the number of sets of tabular values.	none

N	Unique identification number of the conveyance element. Also used to control conveyance element default values and modification ratios. >0= Conveyance element identification number -2 = Modify default values for each variable based on values entered on this line. Any non-zero value entered on a line with N = -2, will replace the current default value for that variable. -1 = Alter subsequent values for a variable by the modification ratio entered on this line for that variable.	none
NGOTO	Identification number of the conveyance element downstream of conveyance element N. This may be the manhole number in EXTRAN into which the hydrograph from this conveyance element will be put for dynamic routing.	none
NDP	Normally zero, unless one of the special routing element options explained for JK is to be used. In that case, NDP is a positive number equal to the number of sets of tabular values to be input under the JK option.	none
NP	Type of conveyance element: 1 = channel 2 = pipe 3 = direct flow (no routing) 4 = channel with overflow channel 5 = pipe with overflow channel	none
GWIDTH	Bottom width of channel or pipe diameter, in feet.	0.001
GLEN	Length of conveyance element, in feet.	none
GSLOPE	Invert slope, in feet/foot.	0.001
GS1	Left-hand (looking downstream) side slope, in feet/foot.	0.001
GS2	Right-hand (looking downstream) side slope, in feet/foot.	0.001
GS	Manning's n (resistance factor) for the channel or pipe	0.020
DFULL	Depth of channel when full or the pipe diameter, in feet. When an overflow section has been specified, the depth at which overflow begins. If an overflow channel has been specified (NP = 4 or 5), variables GWIDTH, GLEN, GSLOPE, GS1, GS2, GS, and DFULL must be specified for the overflow channel, on the next line.	10

Diversion Option Input Line(s) (JK > 0 and NDP > 0). NDP data pairs describing flow in the element versus diverted flow. JK is conveyance element number receiving the diverted flow.

SD,QD	SD = Flow in conveyance element N, in cfs. QD = Flow diverted to conveyance element JK, in cfs.

Detention Basin Option Input Line(s) (JK = 0 and NDP > 0). NDP data pairs describing detention basin storage versus outflow discharge.

SD,QD	SD = Storage in detention basin, in acre-feet. QD = Outflow from detention basin, in cfs.	

Inflow Hydrograph Option Input Line(s) (JK = -1 and NDP > 0). NDP data pairs of time versus inflow.

SD,QD	SD = Time, in hours. QD = Inflow to the conveyance element, in cfs.	
99999	A blank line or 99999 indicates the end of the Conveyance Element Data Section	none

Conveyance Element Save and Print Control contains the parameters to control the disposition and printing of the conveyance element hydrographs created by RUNOFF. <u>This section is required for all runs using conveyance elements.</u>

Name	Description	Default
N21	If N21 $\geq$ 1, hydrographs from each conveyance element are to be saved for subsequent routing in EXTRAN.	none
NPRNT	Number of conveyance elements for which hydrographs are to be printed.	none
INTERV	Number of timesteps between printing	1
IPRNT(x)	If NPRNT > 0, conveyance element numbers for which values are to be printed.	none

End of Input Line

CNAME	"ENDPROGRAM" indicates the end of input data.	none

2.6 OUTPUT DESCRIPTION

Every effort has been made to make the output from the RUNOFF block easy to understand, with headings for each of the output sections that are complete and concise. Table 2-7 is a sample output file for subcatchment simulation in the RUNOFF block. Table 2-8 is a sample output file for conveyance routing in the RUNOFF block. The output shown in Tables 2-7 and 2-8 has been abridged, but still shows all the major headings and output data. The following paragraphs describe each of the output headings, and follow the sample output in Tables 2-7 and 2-8.

2.6.1 RUNOFF Subcatchment Simulation Output

The first page of RUNOFF subcatchment simulation output begins with a title block describing the evolution of the program. This title block is followed by a second title block describing the particular RUNOFF input being run. It is made up of the two-line title block from the RUNOFF input data. Also on the first page is a reiteration of the major control parameters as well as the rainfall hyetographs for the subcatchment simulation.

The second page begins with the two-line title block and then summarizes the input data. This input data consists of the subcatchment (subarea) descriptions for subcatchment simulations or conveyance element descriptions for conveyance routing.

The third and succeeding pages of the subcatchment simulation output (shown in Table 2-7) contain the printed hydrographs requested in the Subcatchment Print and Control Section in the input data. The last page of the output gives the results of a continuity check on the subcatchment (overland flow) simulation. The continuity indicates the difference between the total rainfall on the watershed and the abstractions from the watershed (infiltration, watershed outflow, and depression storage). This difference, shown as percent of rainfall that is not accounted for, indicates how well the program has simulated the rainfall/runoff characteristics of the entire watershed. Values of the continuity error should not exceed 1 to 2 percent. A simulation that results in higher values than these should be checked carefully for problems.

2.6.2 RUNOFF Conveyance Routing Output

The first page of the RUNOFF conveyance routing output, shown in Table 2-8, begins with a title block describing the evolution of the program. This title block is followed by a second title block describing the particular RUNOFF input being run. It is made up of the two-line title block from the RUNOFF input data. Also on the first page is the number of time steps in the simulation and the routing time interval in minutes.

The second page of the RUNOFF conveyance routing output contains a listing of the hydrographs (from RUNOFF subcatchment simulation or from HEC-1) that are being used as input to the simulation. The hydrographs are listed for each subcatchment for all timesteps.

The third page reiterates the conveyance element input data including element number; downstream connection, if any; NDP, the number of special data sets associated with the JK option; the type of conveyance element; the width or diameter, length, invert slope, side slopes, and Manning's n of the conveyance element; the depth at which overflow begins; and JK, the special routing element description. The total number of conveyance elements in the simulation is listed at the bottom of page 3.

The fourth page begins with the title block, as do all pages of the output. After the title block, each conveyance element is listed, along with conveyance elements and subareas that are tributary to it. The total drainage area upstream of the conveyance element is also listed. Following the connectivity table, the hydrograph data for each conveyance element selected for printing in the Conveyance Element Save and Print Control Section of the input data file are listed. These data include the discharge through the conveyance as the upper number and then one of the following, depending on the type of conveyance

TABLE 2-7
RUNOFF SUBCATCHMENT SIMULATION OUTPUT FILE

Page 1 --

```
                RUNOFF BLOCK OF SSWMM96

                DEVELOPED BY        METCALF + EDDY, INC.

                                    UNIVERSITY OF FLORIDA

                                    WATER RESOURCES ENGINEEERS, INC. (SEPTEMBER 1970)

                UPDATED BY          UNIVERSITY OF FLORIDA (JUNE 1973)

                                    HYDROLOGIC ENGINEERING CENTER, CORPS OF ENGINEERS

                                    MISSOURI RIVER DIVISION, CORPS OF ENGINEERS (SEPTEMBER 1974)

                                    BOYLE ENGINEERING CORPORATION (JULY 1985)

                                    MONTGOMERY WATSON AMERICAS, INC (JAN 1996)

  SSWMM96 DOCUMENTATION EXAMPLE DATA
  RUNOFF BLOCK - SUBCATCHMENT OVERLAND FLOW HYDROGRAPHS

 OVERLAND FLOW WILL BE CALCULATED (IOPT=0)

 NUMBER OF TIME STEPS (NSTEP) =  179
 THE STORM BEGINS AT  8:55 (NHR,NMN)
 INTEGRATION TIME INTERVAL IN MINUTES (DELT) =  5.00

 75.0 PERCENT OF IMPERVIOUS AREA HAS ZERO DETENTION DEPTH (PCTZER)
 FOR  50 RAINFALL STEPS (NHISTO), THE TIME INTERVAL IS 10.00 MINUTES (THISTO)
 FOR RAINGAGE NUMBER  1, RAINFALL HISTORY IN INCHES PER HOUR
```

.00	.00	.00	.00	.00	.00	.13	.13	.13	.13
.13	.13	.16	.16	.16	.16	.16	.16	.28	.30
.36	.52	1.98	.48	.36	.36	.36	.36	.36	.36
.20	.20	.20	.20	.20	.20	.16	.16	.16	.16
.16	.16	.00	.00	.00	.00	.00	.00	.00	.00

Page 2 --

```
  SSWMM96 DOCUMENTATION EXAMPLE DATA
  RUNOFF BLOCK - SUBCATCHMENT OVERLAND FLOW HYDROGRAPHS
```

SUBAREA	CONVEY.	WIDTH	AREA	PERCENT	SLOPE	RESISTANCE FACTOR		SURFACE STORAGE(IN)		INFILTRATION RATE(IN/HR)			GAGE
NUMBER	ELEMENT	(FT)	(AC)	IMPERV.	(FT/FT)	IMPERV.	PERV.	IMPERV.	PERV.	MAXIMUM	MINIMUM	DECAY RATE	NO.
1031	103	1100.	13.9	45.0	.0010	.016	.050	.100	.250	3.00	.50	.00180	1
1051	105	1800.	13.0	45.0	.0010	.016	.050	.100	.250	3.00	.50	.00180	1
1061	106	1960.	24.6	45.0	.0010	.016	.050	.100	.250	3.00	.50	.00180	1
1062	106	1800.	34.5	40.0	.0010	.016	.050	.100	.250	3.00	.50	.00180	1
1071	107	1750.	30.1	70.0	.0010	.016	.050	.100	.250	3.00	.50	.00180	1
1072	107	770.	11.2	70.0	.0010	.016	.050	.100	.250	3.00	.50	.00180	1
1081	108	2520.	26.1	90.0	.0010	.016	.050	.100	.250	3.00	.50	.00180	1
1082	108	1300.	7.3	90.0	.0010	.016	.050	.100	.250	3.00	.50	.00180	1
1083	108	1600.	10.3	80.0	.0010	.016	.050	.100	.250	3.00	.50	.00180	1

```
 TOTAL NUMBER OF SUBCATCHMENTS,    9
 TOTAL TRIBUTARY AREA (ACRES),    171.00
```

TABLE 2-7 (continued)

Page 3 --

```
 SSWMM96 DOCUMENTATION EXAMPLE DATA
 RUNOFF BLOCK - SUBCATCHMENT OVERLAND FLOW HYDROGRAPHS


HYDROGRAPHS ARE LISTED FOR THE FOLLOWING   9 SUBCATCHMENTS - AVERAGE VALUES WITHIN TIME INTERVALS

TIME(HR:MIN)  1031      1051      1061      1062      1071      1072      1081      1082      1083

 9:00          .00       .00       .00       .00       .00       .00       .00       .00       .00

 9:15          .00       .00       .00       .00       .00       .00       .00       .00       .00

 9:30          .00       .00       .00       .00       .00       .00       .00       .00       .00
  .
  .     Output has been abridged
  .
11:30          .87       .89      1.55      1.79      2.35       .93      2.88       .94      1.17

11:45          .94       .92      1.66      1.97      2.69      1.05      3.22      1.00      1.25

12:00         1.05      1.04      1.87      2.23      3.09      1.20      3.66      1.12      1.40

12:15         1.48      1.50      2.62      3.09      4.24      1.65      5.04      1.58      1.98

12:30         2.05      2.10      3.63      4.26      5.84      2.27      6.95      2.20      2.75
```

Page 4 --

```
SUBCATCHMENT HYDROGRAPHS (CONTINUED)
TIME(HR:MIN)  1031      1051      1061      1062      1071      1072      1081      1082      1083
12:45         7.28      8.27     12.92     14.28     17.97      7.20     22.42      7.99      9.95

13:00         4.58      3.90      8.11     10.30     15.41      5.82     17.50      4.75      5.97

13:15         2.98      2.48      5.26      6.94     11.23      4.11     12.18      3.05      3.84

13:30         2.52      2.21      4.45      5.80      9.43      3.43     10.15      2.60      3.27
  .
  .     Output has been abridged
  .
23:15          .00       .00       .01       .01       .04       .01       .03       .00       .00

23:30          .00       .00       .01       .01       .03       .01       .03       .00       .00

23:45          .00       .00       .01       .01       .03       .01       .02       .00       .00
```

Page 5 --

```
 SSWMM96 DOCUMENTATION EXAMPLE DATA
 RUNOFF BLOCK - SUBCATCHMENT OVERLAND FLOW HYDROGRAPHS


*** CONTINUITY CHECK FOR SUBCATCHMEMT SIMULATION, SSWMM96 RUNOFF BLOCK ***

WATERSHED AREA (ACRES)                          171.000

TOTAL RAINFALL (INCHES)                           1.663

TOTAL INFILTRATION (INCHES)                        .630

TOTAL WATERSHED OUTFLOW (INCHES)                   .995

TOTAL SURFACE STORAGE AT END OF STORM (INCHES)     .036

ERROR IN CONTINUITY, PERCENTAGE OF RAINFALL        .142
```

TABLE 2-7 (continued)

Page 6 --

```
SSWMM96 DOCUMENTATION EXAMPLE DATA
RUNOFF BLOCK - SUBCATCHMENT OVERLAND FLOW HYDROGRAPHS


*** PEAK FLOWS FROM SUBCATCHMENTS ***

  SUBCATCHMENT    PEAK     TIME
    ELEMENT       (CFS)   (HR/MIN)

      1031         7.48     12:50
      1051         8.27     12:45
      1061        13.25     12:50
      1062        15.26     12:50
      1071        20.09     12:50
      1072         7.93     12:50
      1081        24.47     12:50
      1082         8.06     12:50
      1083        10.07     12:50
```

TABLE 2-8
RUNOFF CONVEYANCE ROUTING OUTPUT FILE

Page 1 ---

```
                RUNOFF BLOCK OF SSWMM96

                DEVELOPED BY        METCALF + EDDY, INC.

                                    UNIVERSITY OF FLORIDA

                                    WATER RESOURCES ENGINEEERS, INC. (SEPTEMBER 1970)

                UPDATED BY          UNIVERSITY OF FLORIDA (JUNE 1973)

                                    HYDROLOGIC ENGINEERING CENTER, CORPS OF ENGINEERS

                                    MISSOURI RIVER DIVISION, CORPS OF ENGINEERS (SEPTEMBER 1974)

                                    BOYLE ENGINEERING CORPORATION (JULY 1985)

                                    MONTGOMERY WATSON AMERICAS, INC (JAN 1996)

  SSWMM96 DOCUMENTATION EXAMPLE DATA
  RUNOFF BLOCK - CONVEYANCE ROUTING

 HYDROGRAPH ROUTING ONLY (IOPT=1)

 NUMBER OF TIME STEPS (NSTEP) =  179

 ROUTING TIME INTERVAL IN MINUTES (DELT) =  5.00
```

Page 2 ---

```
  SSWMM96 DOCUMENTATION EXAMPLE DATA
  RUNOFF BLOCK - CONVEYANCE ROUTING

 HYDROGRAPHS FROM SSWMMM95 RUNOFF ARE LISTED FOR THE FOLLOWING   9 SUBCATCHMENTS (AVERAGE VALUES WITHIN TIME INTERVALS)

 TIME(HR:MIN)  1031      1051      1061      1062      1071      1072      1081      1082      1083

   8:55        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
   9:00        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
   9:05        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
   9:10        0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
   .
   .     Output has been abridged
   .
  23:35        0.00      0.00      0.01      0.01      0.03      0.01      0.03      0.00      0.00
  23:40        0.00      0.00      0.01      0.01      0.03      0.01      0.03      0.00      0.00
  23:45        0.00      0.00      0.01      0.01      0.03      0.01      0.03      0.00      0.00
```

Page 3 ---

```
  SSWMM96 DOCUMENTATION EXAMPLE DATA
  RUNOFF BLOCK - CONVEYANCE ROUTING

                                                           WIDTH                            INVERT          SIDE  SLOPES
OVERBANK/SURCHARGE
 ELEMENT    ELEMENT       NDP        NP                    OR DIAM    LENGTH    SLOPE    HORIZ TO VERT   MANNING      DEPTH
JK
 NUMBER    CONNECTION                                       (FT)      (FT)     (FT/FT)      L     R          N          (FT)

  103         105          0          1      CHANNEL         10.0      450.    0.0100      0.5   0.5       0.020        5.00
0
  105          0           5          2      PIPE             4.0      600.    0.0100      0.0   0.0       0.018        4.00
345
               DIVERSION TO CONVEYANCE ELEMENT NUMBER 345 - TOTAL Q VS DIVERTED Q IN CFS
                          0.0     0.0     10.0     5.0      20.0    10.0      30.0    15.0      40.0    20.0
  106          0           5          2      PIPE             4.0      800.    0.0100      0.0   0.0       0.018        4.00
0
                     RESERVOIR STORAGE IN ACRE-FEET VS SPILLWAY OUTFLOW
                          0.0     0.0      2.0     5.0       4.0    10.0       6.0    15.0      10.0    20.0
  107          0           5          1      CHANNEL         10.0      350.    0.0100      0.5   0.5       0.025        6.00
-1
                     TIME IN HRS VS INFLOW IN CFS
```

```
                         0.0     0.0       1.0     5.0       2.0    10.0       3.0   15.0       4.0    20.0
  108           0           0           4      CHANNEL        10.0       450.    0.0100       0.5   0.5      0.020        5.00
0
                                                OVERFLOW      5.0       450.    0.0100      0.0   0.0      0.025       10.00

 TOTAL NUMBER OF CONVEYANCE ELEMENTS: ,   5
```

TABLE 2-8 (continued)

Page 4 --

```
  SSWMM96 DOCUMENTATION EXAMPLE DATA
  RUNOFF BLOCK - CONVEYANCE ROUTING


 ARRANGEMENT OF SUBCATCHMENTS AND CONVEYANCE ELEMENTS

CONVEYANCE
   ELEMENT             TRIBUTARY  CONVEYANCE  ELEMENT                                                       TRIBUTARY  SUBAREA
D.A.(AC)

       103     0    0    0    0    0    0    0    0    0    0      1031    0    0    0    0    0    0    0    0    0    13.9

       105   103    0    0    0    0    0    0    0    0    0      1051    0    0    0    0    0    0    0    0    0    26.9

       106     0    0    0    0    0    0    0    0    0    0      1061 1062    0    0    0    0    0    0    0    0    59.1

       107     0    0    0    0    0    0    0    0    0    0      1071    0    0    0    0    0    0    0    0    0    30.1

       108     0    0    0    0    0    0    0    0    0    0      1072    0    0    0    0    0    0    0    0    0    11.2

  RUNOFF BLOCK - CONVEYANCE ROUTING


 HYDROGRAPHS ARE LISTED FOR THE FOLLOWING   5 CONVEYANCE ELEMENTS

          THE UPPER NUMBER IS DISCHARGE IN CFS
          THE LOWER NUMBER IS ONE OF THE FOLLOWING CASES:
                    ( ) DENOTES DEPTH ABOVE INVERT IN FEET
                    (S) DENOTES STORAGE IN AC-FT FOR DETENTION DAM.  DISCHARGE INCLUDES SPILLWAY OUTFLOW.
                    (I) DENOTES CONVEYANCE ELEMENT INFLOW IN CFS FROM SPECIFIED INFLOW HYDROGRAPH
                    (D) DENOTES DISCHARGE IN CFS DIVERTED FROM THIS CONVEYANCE  ELEMENT
                    (O) DENOTES STORAGE IN AC-FT FOR SURCHARGED CONVEYANCE ELEMENT

 TIME(HR/MIN)   103       105       106       107       108

   9  0.00     0.00      0.00      0.00     25.29      0.00
               0.0(O)    0.0(D)    0.0(S)   20.0(I)    0.0(O)
   .
   .     Output has been abridged
   .

  11 30.00     1.42      2.79      5.51     24.15      1.60
               0.0(O)    1.4(D)    0.0(S)   20.0(I)    0.0(O)

  11 45.00     1.47      2.88      5.76     24.52      1.73
               0.0(O)    1.4(D)    0.0(S)   20.0(I)    0.0(O)
   .
   .     Output has been abridged
   .
```

Page 5 --

```
  SSWMM96 DOCUMENTATION EXAMPLE DATA
  RUNOFF BLOCK - CONVEYANCE ROUTING


 *** PEAK FLOWS, STAGES AND STORAGE OF CONVEYANCE ELEMENTS AND DETENTION DAMS ***

   CONVEYANCE   PEAK      STAGE      STORAGE     TIME
     ELEMENT    (CFS)      (FT)      (AC-FT)   (HR/MIN)

        1        14.       0.4                 12  45.
        5        14.       0.4                 12  50.
        4        57.       1.0                 12  45.
        3        53.       2.0                 12  45.
        2        29.       1.4                 12  45.
```

element: 1) depth of flow above the invert; 2) storage in acre-feet for a detention dam; 3) conveyance element inflow in cfs from a specified inflow hydrograph; 4) discharge diverted from the conveyance element; and 5) storage in acre-feet for a surcharged conveyance element. The data are listed for each timestep.

Page 5 of the output contains a summary of the peak flows, stages, and storage of the conveyance elements and detention dams. This summary includes the time at which the peak flow occurred.

2.7 DEBUGGING AND STABILIZATION HINTS

The preceding subsections of this section have described in detail the data input procedure to be used when running the RUNOFF Block of SSWMM96. This subsection will describe important limitations inherent to the RUNOFF Block, along with a description of calibration and a listing of RUNOFF warning and error messages and their probable causes and solutions.

The following list describes the output data items that need to be checked first when debugging a RUNOFF model input data set:

1. Total Drainage Area. Make sure that the total drainage area listed in the output is the same as the actual size of the drainage area being simulated in the RUNOFF Block. This will quickly indicated whether there are input data errors.

2. Imperviousness. Check the input data for each subcatchment to insure that the correct percent impervious has been entered.

3. Rainfall amount and time distribution. Make sure that the total rainfall amount listed in the continuity check output data equals the intended total rainfall for the storm. Check the rainfall time interval and the history printed in the output data.

4. Continuity. The last item in the continuity check output data is the percent error in continuity. This error should be very small, always less than 10 percent. A large error probably indicates an input data error

2.7.1 Important Limitations

All models have limitations because they use mathematical formulas to represent physical processes. RUNOFF is no exception to this rule and it is important to take these limitations into account when using RUNOFF to solve real-world problems. Some of the important limitations are:

1. RUNOFF is based on a kinematic wave simulation in which the subcatchment is viewed as a plane that is represented in the model as rectangular in shape. Schematizing the irregular shape of an actual subcatchment area into a rectangular shape with subcatchment width and length can be quite difficult and hard to conceptualize. Methods have been provided in this manual to make the job easier, but it can still be difficult to resolve a real-world subcatchment into a subcatchment that can be used in the model.

2. The kinematic wave simulation works well when a large area is modeled using a number of small subcatchments. In that case, any timing and magnitude errors tend to cancel out when the small area hydrographs are summed to represent the larger area. When a large area is represented as only one subcatchment the timing errors will not be canceled out and may be significant. Maximum size for subcatchments in RUNOFF modeling should be on the order of 200 to 400 acres. Subcatchments larger than 100 to 150 acres should probably include a RUNOFF Conveyance Routing step before using the output in EXTRAN.

3. As with all hydrologic models, the most sensitive input parameter in RUNOFF is the percent impervious. This parameter can be very difficult to estimate accurately, and changes in percent impervious can yield significant differences in the volume of runoff from a subcatchment.

4. Another hydrologic parameter that is difficult to estimate is the subcatchment slope. In RUNOFF, the subcatchment slope is assumed to be the slope of the subcatchment plane. In the real-world, the subcatchment is comprised of numerous small planes with widely varying slopes.

2.7.2 Calibration

Calibration or verification of a model is an important step that leads to more trust in the model results. It is also a very difficult step to accomplish in many instances. For small, urban subcatchments there is usually very little data with which to calibrate the RUNOFF model. Adequate amounts of both precipitation and flow data are necessary in order to calibrate the model. This may involve large amounts of data because precipitation and runoff patterns can vary widely within even the smallest subcatchment, especially during the smaller, more frequent storm events.

Even when data is available, it is essential that the data be analyzed carefully to insure that it really represents what happened in the basin during the storm. In particular, rain gages used for calibration should be inside the subcatchment that is being calibrated. Flow data must be checked to determine whether there are any unknown factors that are acting to change the flow (i.e. pumps, plugged inlets, etc.).

Calibration basically involves two steps:

1. Compare the observed and computed volumes of runoff from the subcatchment. Computed volumes can be adjusted by modifying the percent impervious and the infiltration rates for the subcatchment. In changing these parameters, one must be careful to maintain their values within representative ranges.

2. Compare the timing and shape of the observed and computed hydrographs. Hydrograph timing and shape are controlled mostly by the basin shape and roughness coefficient, and by any routing that occurs in the subcatchment. In general, the longer the basin width, the sharper and faster the hydrograph peak.

   Manning's n roughness factor can also be used to control hydrograph peaks. The lower the roughness coefficient, the higher and faster the peak. The user always needs to remember that the roughness coefficient used in RUNOFF will generally be higher than that used in a hydraulic model such HEC-2 because of the shallow overland flow, debris, and irregular slopes that occur in a subcatchment.

The following list describes the important output variable to check during the verification and calibration procedure

2.7.3 Warnings and Error Messages

2.7.3.1 Subcatchment Warnings and Error Messages.

1. `**** WARNING 1 **** CHECK RESULTS.  NO CONVERGENCE IN SUBCATCHMENT SIMULATION.` - Errors have occurred in the kinematic wave overland flow equations in the WSHED subroutine , preventing convergence. Check the results printout and look for values in the subcatchment hydrographs that are unstable or seem to be excessively high or low.

2.7.3.2 Conveyance Element Routing Warnings and Error Messages.

1. `**** ERROR 1 **** THE GIVEN DELT IS DIFFERENT FROM THAT USED IN THE INPUT HYDROGRAPH.` - the integration time increment (DELT) specified in the System Parameters Section is not the same as the integration time at which the input hydrographs were saved. Change either the integration timestep for the hydrograph input or for the routing.

2. `**** ERROR 2 **** THE HYDROGRAPH OF SUBCATCHMENT` *`XX`* `WAS NOT STORED` - The user specified subcatchment *XX* in the Subcatchment-Conveyance Element Relationships section. A hydrograph for this subcatchment is not found in the input hydrograph data for this run. Check

input data and modify Subcatchment-Conveyance Element Relationships section as needed.

3. `**** ERROR 3 **** STOPPED BY UNMATCHING CONVEYANCE ELEMENT NO.` *`XX`* - Conveyance element *XX* was specified in the Conveyance Element Data Section for which there is no corresponding input hydrograph or vice versa. Check input data and either remove conveyance element *XX* or change input hydrograph number.

4. `**** ERROR 4 **** STOPPED BY MORE THAN 10 CONVEYANCE ELEMENTS CONNECTING TO CONVEYANCE ELEMENT NO.` *`XX`* - Up to 10 conveyance elements may connect (be tributary to) another conveyance element. Conveyance element *XX* has more than 10 tributary conveyance elements. Check input data and modify connecting conveyance elements.

5. `**** WARNING 2 **** ORDER OF TREE STRUCTURE (NGUT VALUE) DECREASES THROUGH DIVERSION FROM CONVEYANCE ELEMENT` *`XX`* `TO CONVEYANCE ELEMENT` *`YY`* `COMPUTATION THROUGH DIVERSION WILL LAG ONE TIME STEP UNLESS CONVEYANCE ELEMENT DATA ARE MODIFIED TO REVERSE DIVERSION.` - Diversion specified from conveyance element *XX* to conveyance element *YY* in the Conveyance Element Data Section may be in the wrong direction. Check input data and modify as necessary.

6. `**** WARNING 3 **** CHECK RESULTS.  NOT CONVERGED IN CONVEYANCE ELEMENT ROUTING.` - Errors have occurred in the kinematic routing equations in subroutine GUTTER and they did not converge on a suitable result. Check results for location of error

2.8 RUNOFF GRAPHS

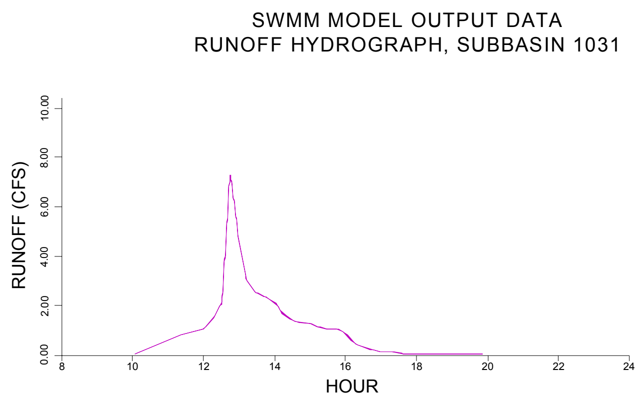
In the Subcatchment or Conveyance Element Save and Print control sections of the input data, the user specifies subcatchments or conveyance elements to be printed out (NPRNT, IPRNT(i)). RUNOFF also saves these same hydrographs to a special hydrograph plotting file that is saved with the extension of .PLH. The graphics program supplied with SSWMM96, SWMGRAPH, can plot the hydrographs saved in the .PLH file. Table 2-9 contains the commands that were used to plot an example hydrograph. Required user input is underlined in the table. The graphics program will display each of the available hydrograph plots one at a time.

TABLE 2-9
HYDROGRAPH PLOTTING EXAMPLE

```
Windows;C:\SWMM\GRAPHICS>SWMGRAPH

 Initialize Program for Screen Viewing:
         1. Monochrome screen
         2. Color screen
Enter Number> 2
Enter Name of Input Data File For Plotting> RUNOFF.PLH
READY TO DISPLAY DRAWING.
Press <return> when ready to continue.
```

Example RUNOFF Graph




```
Hardcopy?                                       (Y/N)> N
Would You Like Plots from Different Data?(Y/N)> N
Stop - Program terminated.
```

SECTION 3

EXTRAN BLOCK

3.1 INTRODUCTION

EXTRAN is a dynamic flow routing model that routes inflow hydrographs through an open channel and/or closed conduit system, based on a solution of the full dynamic equation for gradually varied flow. The EXTRAN Block receives hydrograph input at specified model locations by file transfer from the RUNOFF Block or from HEC-1, and/or by direct input in the EXTRAN input file. Figure 3-1 illustrates the operation of the EXTRAN Block.

EXTRAN performs dynamic routing of stormwater flows through the major storm drainage system to the points of outfall to the receiving water system. The program simulates branched or looped networks, backwater due to tidal or non-tidal conditions, free-surface flow, pressure flow or surcharge, flow reversals, flow transfers by weirs, orifices and pumping facilities, and storage at on or off-line facilities. Types of channels that can be simulated include circular, rectangular, horseshoe, elliptical, and arch pipes, plus trapezoidal channels. Simulation output takes the form of water surface elevations and discharge at selected system locations.

For junctions, invert and ground elevations are required. The various types of flow structures such as storage, diversion weirs, pumps, and outfalls, are specified at junctions.

The original version of EXTRAN lacked the capability of handling overflow conditions resulting from inadequate conveyance capacities. When the hydraulic head exceeded the ground elevation at a junction, the program assumed that the excess water that overflowed onto the ground became lost from the system. To overcome this deficiency, the SSWMM96 EXTRAN block was modified to allow for the simulation of overflows in streets, and reentrance of the overflow water back into the system through inlets and manholes.

As developed by WRE, EXTRAN solved the continuity and Saint-Venant flow equations using the modified Euler explicit numerical scheme. An implicit numerical solution scheme was developed and incorporated into the modified version of EXTRAN to cut the execution time required for a simulation in half without impairing the accuracy of results. At the same time, provision for up to ten different pumping rates at a pump station was added to the model.

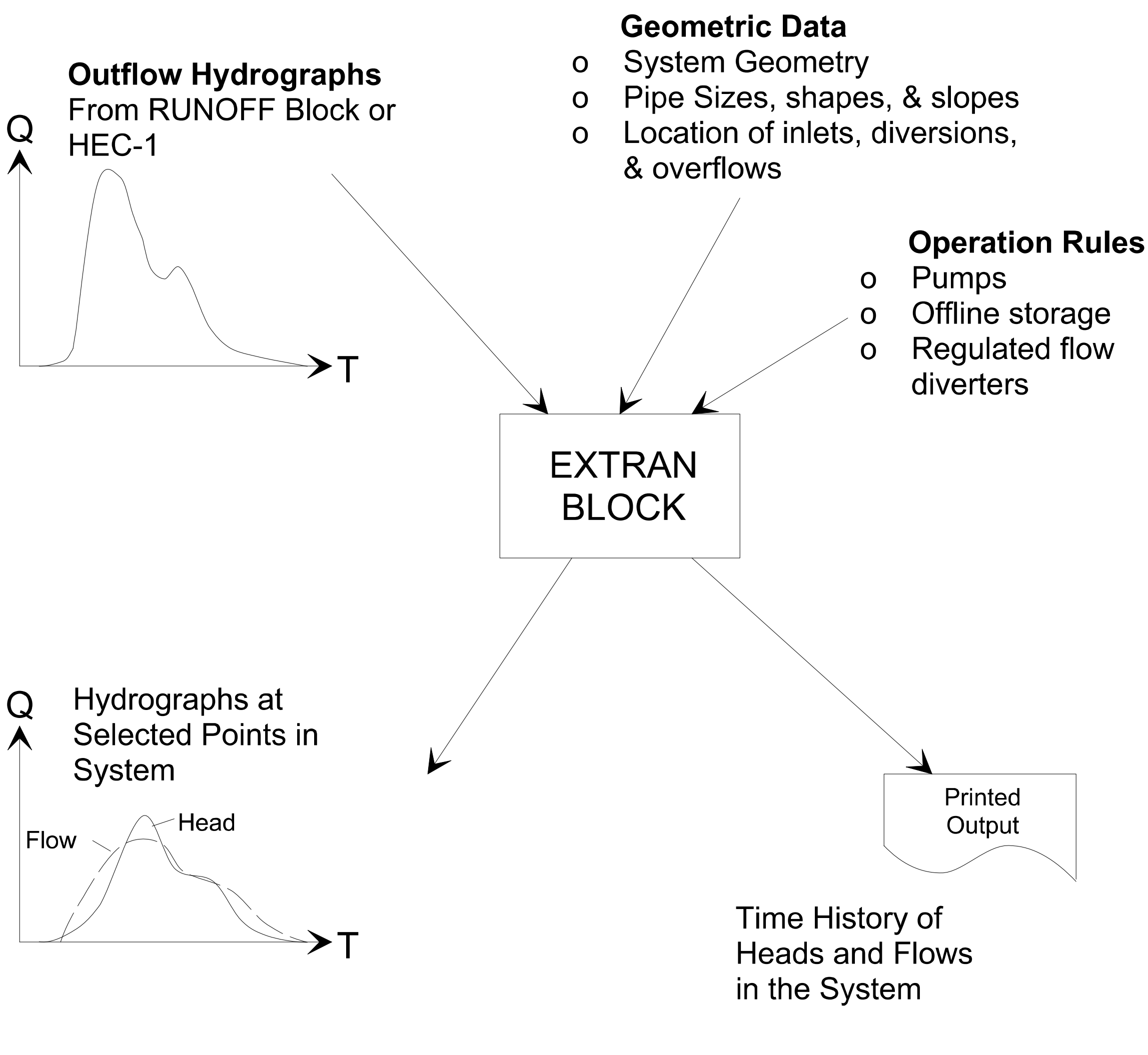


FIGURE 3-1
OPERATION OF THE EXTRAN BLOCK

Recent modifications to EXTRAN for SSWMM96 have included:

- Specification of simulation duration rather than a specified number of timesteps
- Specification of time cycles for hydrograph output
- Weir flow modifications to handle surcharged conditions
- Modifications to overflow simulation:
  - User may specify whether or not overflow to streets or reentrance from streets will occur at a given junction
  - Replacing the linear approximation of the flow equation for overflow sections with an iteration scheme that solves the nonlinear flow equation
  - Street flooding depth is limited to ten feet
- Irregular shaped storage/detention junctions
- Hot start feature, allowing model runs to begin where a previous run ended
- Control of inflow from RUNOFF
- Detailed water balance at a junction
- Pumpback from storage
- Stage hydrograph boundary condition

The hot start or restart capability allows a file to be read and/or created to establish the initial conditions for a run. This capability is often used to avoid re-running of lengthy dry weather stabilization time periods prior to the start of a storm event simulation.

The detailed water balance at a junction keeps track of:

- Watershed Inflow -- inflows from RUNOFF module or from user created inflow (.gut) file
- Node Storage -- storage at the junction resulting from inflows greater than user defined inflow capacity
- Hydrograph Excess -- inflows that can't enter the system due to limited downstream pipe capacity
- System Inflow -- difference between the watershed inflow and the hydrograph excess
- System Outflow -- flows out of the system, i.e., free outfalls
- Inflow from Flooding -- flows entering the system through street inlets from flooding in the streets
- Surcharge to Street -- flows entering the streets due to pipe surcharging
- Volume in the Street -- total volume in the street at the junction

Pumpback from storage allows the user to define storage locations that pumpback to the pipe conveyance system based on the available capacity in a designated pipe. Pumpback should be used in those locations where storage will be required to prevent overflows and where the storage will likely require a pump to return it to the system. If a location can be fed and discharged by gravity, then a storage junction should be used rather than the pumpback option.

3.2 CONVEYANCE ELEMENTS

The basic conveyance element input data required in EXTRAN are specifications for shape, size, length, hydraulic roughness, connecting junctions, and invert distances referenced from the junction invert as shown in Figure 3-2.

3.2.1 Conduits

The various types of conduits are circular, rectangular, horseshoe, elliptical, arch, and trapezoidal channels. These types of conduits are illustrated in Figure 3-3.

The elevation of each end of a conduit is described in relation to the invert of the junction to which the end of the conduit is connected as shown in Figure 3-2. The junction invert elevation is specified in the Junction Elements Data Section of the input file. The distance ZP is the height of the invert of the connecting conduit above the invert of the junction. The lowest conduit connected to a junction must have a ZP of zero. If it didn't, the junction would act as a sink in the simulation, and all water entering the junction would leave the system. Because of this problem, the program will generate an error message and terminate if the input data contains junctions where all conduits have ZPs greater than zero.

3.2.2 Overflow Sections

It is assumed a street configuration for simulation of overflow in the street can be approximated by a trapezoidal section shown in Figure 3-4. The longitudinal slope of the overflow section is based on the junction rim elevations of junctions connected by conduits.

3.3 JUNCTION ELEMENTS

To perform flow routing with EXTRAN, it is required that the sewer system be idealized as a series of conduits which are connected at nodes or junctions. Junction points should be identified at each

- Upstream terminal points in the system,
- Outfall and discharge points,
- Pump stations, storage junctions, orifice and weir diversions,
- Junctions where inflow hydrographs will be input (either by EXTRAN input or hydrographs from RUNOFF),
- Pipe junctions,
- Points where pipe size and/or shape changes significantly,
- Points where pipe slope changes significantly, and
- Points where pipe inverts are significantly different.

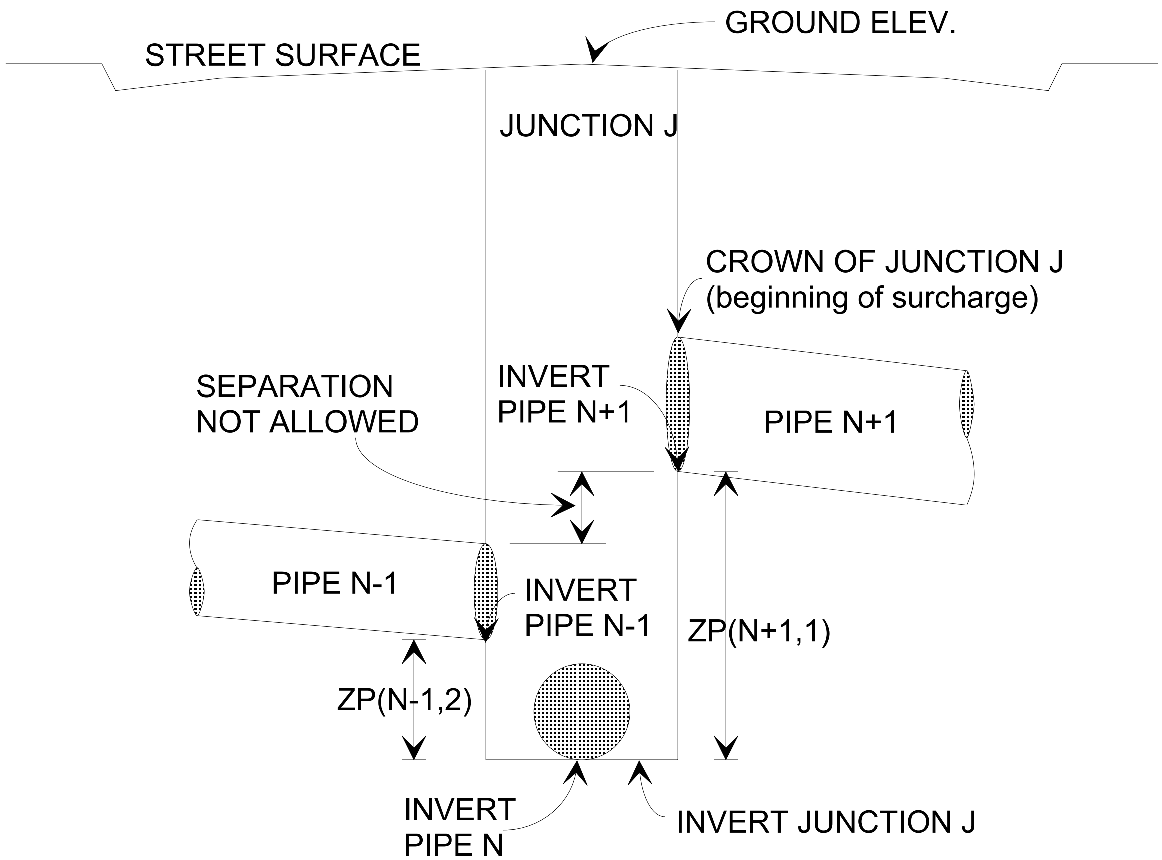
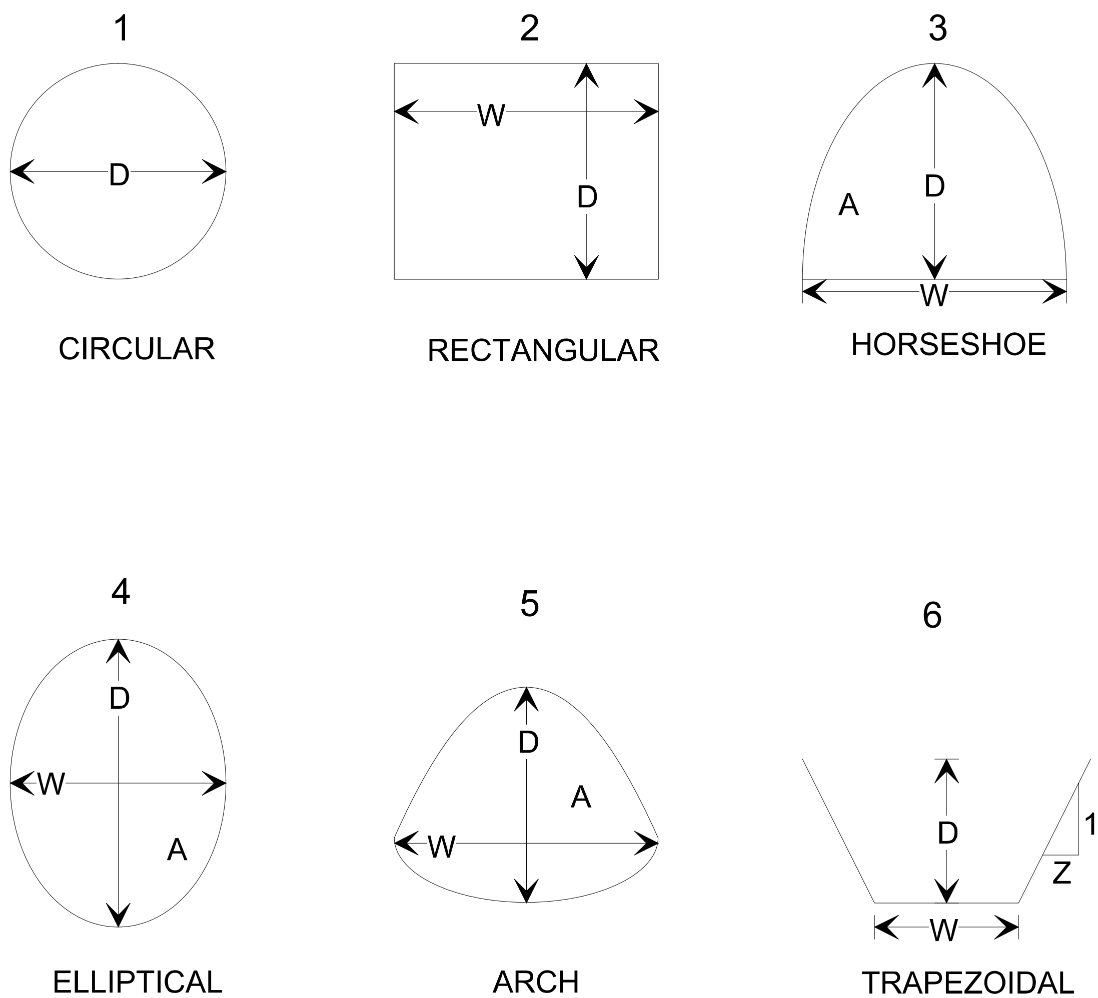
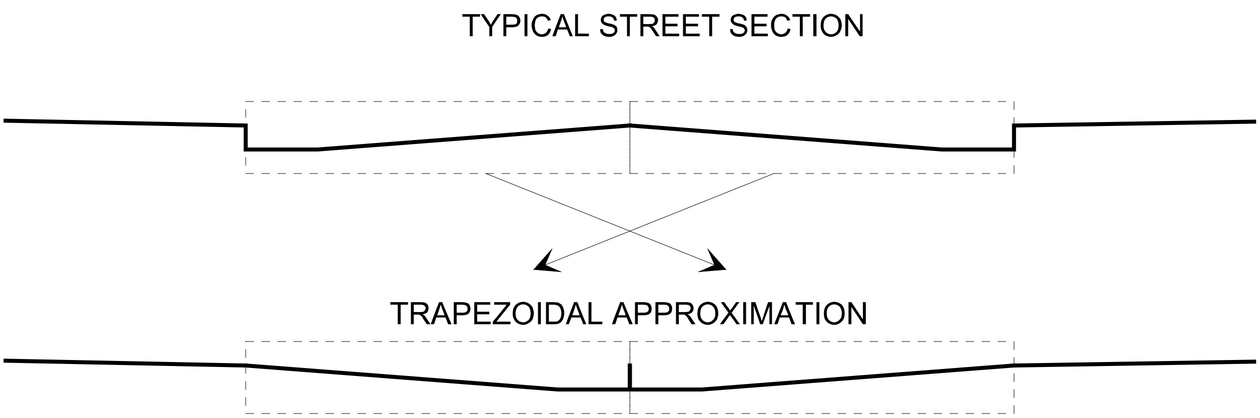


FIGURE 3-2
DEFINITIONS OF TERMS FOR PIPE JUNCTIONS

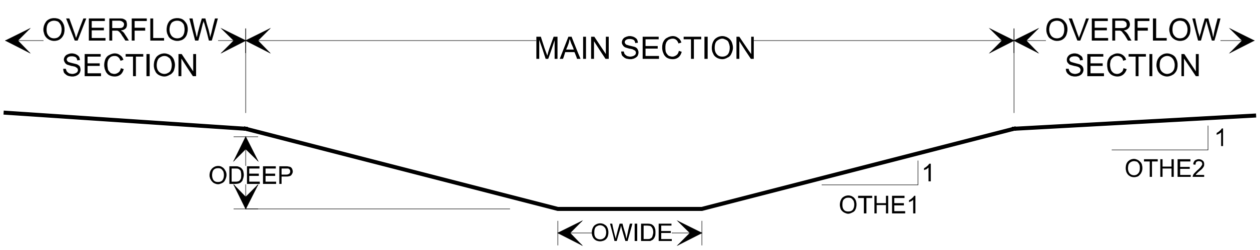


A = AREA OF CONDUIT
D = VERTICAL DEPTH OF CONDUIT
W = MAXIMUM WIDTH OF CONDUIT (bottom width for trapezoidal))
Z = SIDE SLOPE OF TRAPEZOIDAL (horizontal/vertical)

FIGURE 3-3
TYPES OF CONDUITS IN EXTRAN



TRANSFORMING TYPICAL STREET SECTION TO TRAPEZOIDAL APPROXIMATION



DEFINITIONS

FIGURE 3-4
STREET OVERFLOW SECTION

3.3.1 Storage Junctions

Conceptually, storage junctions may be either tanks of constant surface area, over their depth or irregular shaped detention basins. Storage may be placed at any junction in the system, either in-line or off-line. The elevation of the top of the storage is specified in the storage junction data and must be at least as high as the highest pipe crown at the junction. If this condition is violated, the system will go into simulated surcharge before the highest pipe is flowing full.

Irregular shaped detention basins are described in EXTRAN by defining data pairs containing surface area and depth information. These data pairs can define storage of any shape and size and are not limited to the regular constant surface area of a storage "tank" junction.

3.3.2 Orifices

EXTRAN simulates orifices as equivalent pipes (created automatically by the program). The term equivalent pipes means that for a given head at a junction, the flow in the equivalent pipe created by the system will be the same as the flow that would pass through the orifice for the same head at the junction. Data entry is straightforward. For sump (bottom) orifices the program automatically sets the invert of the orifices one diameter <u>below</u> the junction invert so that the orifice is flowing full before there is any discharge (overflow) to conduits downstream of the junction containing the orifice. Figure 3-5 illustrates the use of orifices.

3.3.3 Weirs

Weirs may be specified as either transverse or side-flow in SSWMM96. Flow at the weir may be below the weir crest, over the weir from either side, or surcharged from either side. Weirs are often put into systems to provide wet weather relief when levels in a junction go above the level of the weir crest as shown in Figure 3-5.

3.3.4 Pumps

Pumps may be of three types, off line, on-line and pumpback. The characteristics of these pumps are as follows:

1. <u>Off-line pump station with a wet well:</u> the rate of pumping depends upon the volume (level) of water in the wet well. If the inflow rate to the wet well exceeds the maximum pump capacity and the volume (level) in the wet well approaches the maximum volume, the inflow to the wet well will be reduced to the maximum pump rate. This inflow reduction will cause the hydraulic grade line upstream of the wet well to rise. No flooding will occur at the wet well junction.

   A Type 1 pump may have only one influent pipe entering the pump junction.

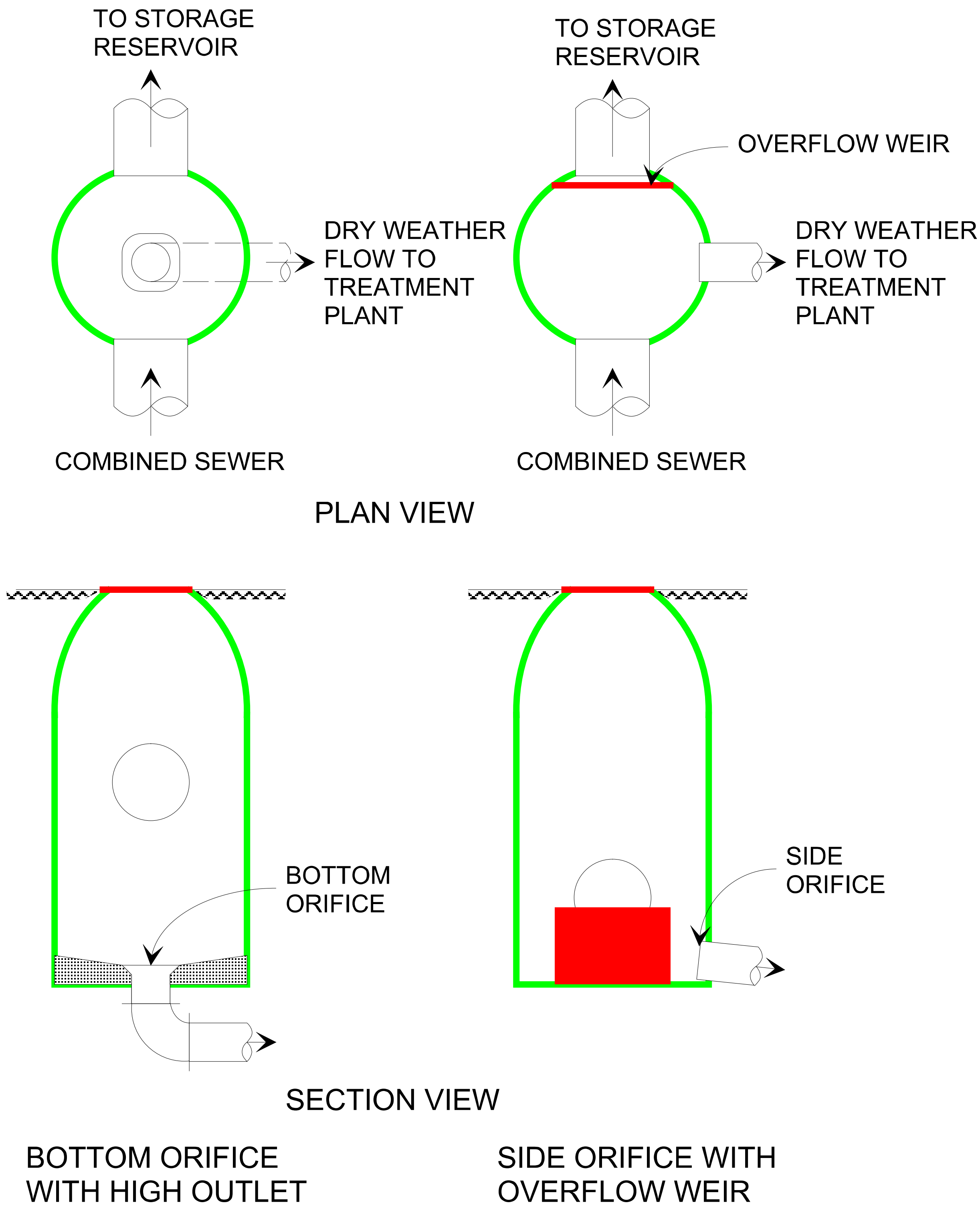


FIGURE 3-5
WEIRS AND ORIFICES

2. On-line lift station: The lift station pumps according to the level of the water surface at the junction being pumped. When the inflow rate to the pump junction exceeds the maximum pump capacity and the level of the water surface at the junction is higher than the ground surface, overflow will occur at the pump junction.

   A Type 2 pump may have multiple influent pipes entering the pump junction.

3. Pumpback from storage pump station: At this station the rate of pumping from storage back into the system depends on the excess capacity of a specified conveyance element. When flow in the conveyance element is lower than its capacity and the storage is not empty, the pump will begin pumping at a rate equal to the difference between the available capacity and the actual flow rate in the pipe, but always less than a specified maximum pumping rate.

   A Type 3 pump may have only one influent pipe entering the pump/storage junction.

Two types of pump operation curves, illustrated in Figure 3-6, are available for the Type 1 and Type 2 pumps:

1. A stage-capacity pump operation curve (or volume-capacity for a Type 1 pump) describes the operation of a variable speed pump. The capacity of the pump will vary according to the stage (or volume) at the pump junction. The stage capacity curve can vary in a stepwise fashion or in a smooth curve.

2. The other type of pump operation curve describes a pump or pumps with on and off pump settings. As shown in Figure 3-6, the pump can have different on and off settings as well as having variable speed characteristics that increase the capacity with increase in stage.

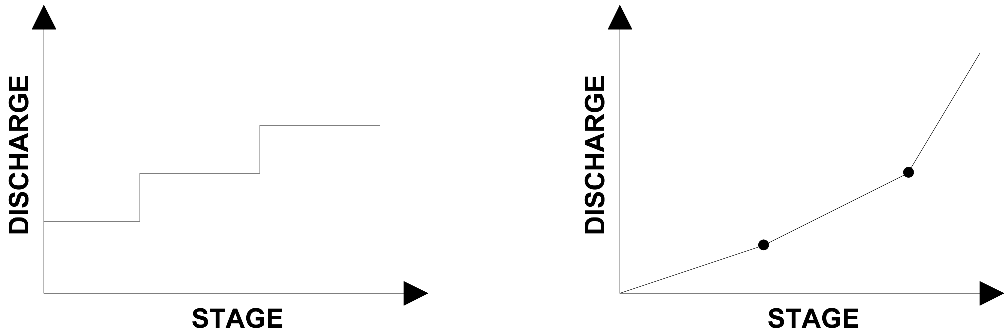
As described above, pump operation for the Type 3 pump is controlled solely by the capacity of the specified pumpback conduit and the specified maximum pump capacity.

3.3.5 Free Outfalls

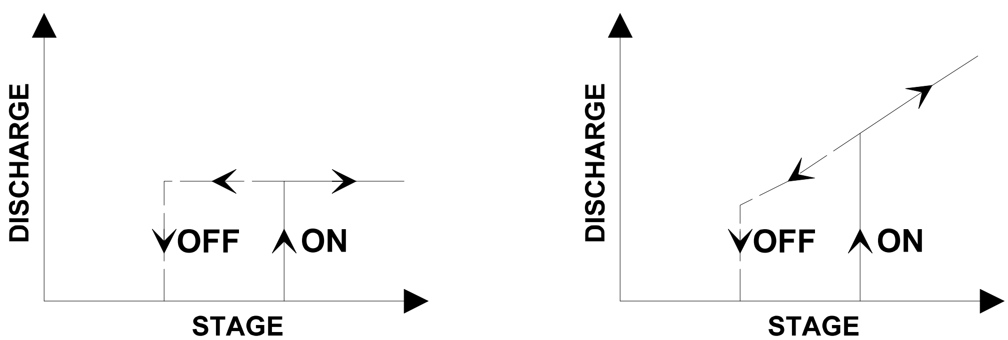
A free outfall is simply an outfall junction which discharges based on given backwater conditions. If the elevation of the receiving water is low enough, the outfall will be simulated using either critical or normal depth in the conduit, whichever is less. If backwater exists, the receiving water surface elevation is used for the water surface elevation at the free outfall. Only one conduit may be connected to a free outfall.

3.3.6 Flap (Tide) Gates

Flap gates (sometimes called tide gates) are simulated in EXTRAN by specifying the outfall junction numbers for pipes with flap gates. A flap gate functions in EXTRAN to prevent



STAGE AND CAPACITY RELATIONSHIPS



ON AND OFF PUMP SETTINGS

FIGURE 3-6
PUMP OPERATION CURVES

flow from moving from the outfall junction into the system even though the water surface elevation at the outfall junction is greater than that in the system. Outflow from the system will be zero if the elevation downstream of the junction is higher than the incoming water surface elevation.

3.4 INPUT DATA PREPARATION

3.4.1 Default Values

Most variables used by the EXTRAN block do not have default values. This means that the value for each variable must be explicitly defined. Where default values are supplied in the model they will be noted in this manual as part of the input parameters description.

3.4.2 Input Data Template

Table 3-1 is a sample input file illustrating the input format and layout of a typical EXTRAN input data file. The input is divided into sections as follows:

- Title Section
- System Parameters Section
- Conveyance Elements Data Section
- Junction Elements Data Section
- Storage Junction Data Section
- Orifice Data Section
- Weir Data Section
- Pump Data Section
- Free Outfalls Data Section
- Outfalls with Flap Gates (Tide Gates) Data Section
- Initial Flow Data Section
- User Defined Inflow Hydrograph Section

Each of these sections and its associated input variables will be discussed in detail below.

3.4.2.1 Title Section. The title section is two lines containing up to 80 characters in each line. The title should be descriptive, but may be anything the user wants.

3.4.2.2 System Parameters Section. This section of the input contains the overall simulation parameters which control the length of the simulation, timestep size, etc. Hot start and output control switches are also located in the System Parameters Section of the input data. Descriptions of each of the system parameters are given below. No comment lines are allowed inside the System Parameters Section.

TABLE 3-1
EXTRAN INPUT TEMPLATE

```
*This is an input file for the EXTRAN block of SSWMM96
*
*TITLE SECTION (2 lines)
 SSWMM96 DOCUMENTATION EXAMPLE DATA
 EXTRAN BLOCK
*
*SYSTEM PARAMETERS SECTION - free input format
    30.0        * DELT - Length of integration step in seconds
    9.00        * TZERO - Start of simulation, decimal hours
   19.00        * TEND  - End of simulation, decimal hours
      15        * NHPRT - No. of junctions for detailed printing of head output
       4        * NWPRT - No. of junctions for detailed water balance
      14        * NQPRT - No. of conduits for detailed printing of discharge
       1        * PSTART - First time-step to begin print cycle
      30        * DINTER - Interval between print cycles for all junctions and conduits
      20        * HINTER - Interval between print cycles for detailed printouts
       0        * NJSW - No. of input junctions
     100        * MAXIT - Maximum number of iterations per timestep
       0        * JREDO  - Hot Start Control 0=No;1=Yes;2=New;3=Yes & New
       1        * IPFlag(1) = 1 for conduit parameters printout
       1        * IPFlag(2) = 1 for junction parameters printout
       1        * IPFlag(3) = 1 for miscellaneous input data printout
       0        * IPFlag(4) = 1 for junctions and conduits summary printout
       1        * IPFlag(5) = 1 for hydraulic grade line summary printout
       1        * IPFlag(6) = 1 for summary statistics for junctions printout
       1        * IPFlag(7) = 1 for flow and velocity summary printout
       1        * IPFlag(8) = 1 for summary statistics for conduits printout
*
*Node (junction) numbers where heads are to be printed (NHPRT junctions)
        20 101 102 103 104 105 106 107 108 109 110 150 151 152 153
*
*Node (junction) numbers for detailed water balance (NWPRT junctions)
        105 106 107 108
*
*Conduit numbers where flows are to be printed (NQPRT conduits)
       201 202 203 204 205 206 207 208 209 210 251 252 253 254
*
*CONVEYANCE ELEMENTS DATA SECTION
* Con-  Up-   Down-  Con-          Conduit            Up-   Down-       1st    2nd   |---------------Overflow---------------|
* duit  strm  strm   duit  |-----------------------|  strm  strm   "N"  Side   Side                      Main  Over.  Main   Over.
*  No.  Node  Node   Type  Area  Depth  Width  Length  ZP    ZP         Slope  Slope  Depth  Width   "N"   "N"   Slope  Slope
*                          (ft2)  (ft)   (ft)   (ft)  (ft)  (ft)      (ft/ft)(ft/ft)  (ft)  (ft)                (ft/ft) (ft/ft)
* Circular conduit
  201   101    20     1      0    5.0     0     900    0.    0.    0    0      0      0.5    0.5  0.016  0.020    37.    50.
* Rectangular conduit
  202   102   101     2      0    5.0    6.0    850    0.    0.    0    0      0      0.5    0.5  0.016  0.020    37.    50.
* Horseshoe conduit
  203   103   102     3   13.3    5.0    4.0    850    0.    0.    0    0      0      0.5    0.5  0.016  0.020    37.    50.
* Elliptical conduit
  204   104   103     4   15.7    5.0    4.0    950    0.    0.    0    0      0      0.5    0.5    0.     0.     37.    50.
* Arch conduit
  205   105   104     5   19.6    3.8    6.1    850    0.    0.    0    0      0      0.58   0.5  0.016  0.020    38.    50.
* Trapezoidal conduit
  206   106   105     6      0    5.0    3.0    900    0.    0.  .015  2.0    2.5    0.58   0.5  0.016  0.020    38.    50.
  207   107   106     1      0    5.0     0    1000    0.    0.    0    0      0      0.58   0.5  0.016  0.020    38.    50.
  208   108   107     1      0    5.0     0     900    0.  0.03    0    0      0      0.58   0.5  0.016  0.020    38.    50.
  209   109   108     1      0    5.0     0     900    0.  0.11    0    0      0      0.58   0.5  0.016  0.020    38.    50.
  210   110   109     1      0    5.0     0     800    0.  0.01    0    0      0      0.58   0.5  0.016  0.020    38.    50.
*To indicate end of Conduit Data Section, enter 99999
99999
*
*JUNCTION ELEMENTS DATA SECTION - free input format
* Junc-            In-   Const.          Inlet
* tion   Grnd.    vert     In-    Inlet   weir     Inlet
*  No.   Elev.    Elev.   flow   Length  Coeff.  Capacity
*        (ft)     (ft)   (cfs)    (ft)            (cfs)
   20    21.70  -4.86     .07      12.    3.1       0
* No overflow to street and no return flow to junction
  101    20.16  -4.66      0       0.    0.        0
* Overflow to street, but no return flow to junction
  102    17.99  -4.04      0      12.    0.        0
* Overflow to street and return flow to junction
  103    17.49  -3.61     .10      12.    3.1       0
* Control of inflow from RUNOFF to 15 cfs
  104    16.09  -2.09      0      12.    3.1      15
  105    13.90  -1.60     .11      12.    3.1       0
  106    12.24   -.58     .47      12.    3.1       0
* Comments allowed in Junction Data Section
  107    12.87   -.30     .12      12.    3.1       0
  108    12.65   -.02     .13      12.    3.1       0
  109    14.46    .33      0       12.    3.1       0
```

TABLE 3-1 (continued)

```
  110    14.39    .53     .12      12.    3.1       0
*To indicate end of Junction Data Section, enter 99999
99999
*
*STORAGE JUNCTION DATA SECTION
* Junc.  Crown   Storage     Number of
*  No.   Elev.   Vol.         Stages
*                (cf/ft)    (0 = reg. storage)
*  Regular Storage Junction
* 34     45       200          0
*  Irregular Storage Junction
* 7046    35.0     -1           5
*  Area   Stage    Area   Stage    Area   Stage    Area   Stage    Area   Stage
* (ft2)    (ft)   (ft2)    (ft)   (ft2)    (ft)   (ft2)    (ft)   (ft2)    (ft)
*   1        1     3000     5     10000     10    15000     15    20000    20
*To indicate end of Storage Junction Data Section, enter 99999
99999
*
*ORIFICE DATA SECTION
* Up-    Down-
* strm   strm   |-------Orifice-------|
* Junc.  Junc.  Type  Area  Coeff.  ZP
* Side orifice (type 1)
* 316     325    1    7.37   0.6   3.85
* Bottom orifice (type 2)
* 317     326    2    1.49   0.6   0.0
*To indicate end of Orifice Data Section, enter 99999
99999
*
*WEIR DATA SECTION
*  Up-   Down-            Weir
*stream stream    Type  Ht    Ht    Length  Coeff
* Junc.  Junc.          Bot   Top
* Type of weir: 1=transverse, 2=transverse w/flap gate; 3=side; 4=side w/flap gate
* 791    5711      3    2.50  7.50   30      2.8
*To indicate end of Weir Data Section, enter 99999
99999
*
*PUMP DATA SECTION
*Data for Pump Stations with on and off switch operation
*        Down-         Wet   No.
* Junc.  strm   Pump  well   of      On     Off     Capacity=a+(b*depth)
*  No.   Junc.  Type  Vol   Pumps   Stage  Stage          a      b
*
* Type 1 pump, On and off stages represent wet well volume
   20      0      1  100     1     160     120        230.0    0.0
* Type 2 pump, on and off stages represent depth above invert of junction
   20      0      2     0.    3
                                    4.1    2.0        114.0    0.0
                                    5.2    2.0        114.0    0.0
                                    6.3    3.0        114.0    0.0
*Data for Pump Stations with variable speed pumps
*        Down-         Wet
* Junc.  strm   Pump  well   Enter
*  No.   Junc.  Type  Vol.   Zero      Stage   Cap.
*
* Type 1 pump, stages represent wet well volume
*   20      0      1   120.    0
*                                    120.       0.
*                                    130.0      0.
*                                    150       93.
*                                    200.0    294.
*                                    300.0    720.
* Type 2 pump, stages represent depth above invert of junction
*   20      0      2     0.    0
*                                      0.       0.
*                                      3.86     0.
*                                      5.86    93.
*                                      6.83   294.
*                                      7.86   720.
*                                     10.86   928.
* Type 3 pump, pumpback from storage
*                  Beginning        Maximum
*        Down-       Storage        Storage               Maximum
* Junc.  strm   Pump  Volume   Enter  Volume    Pumpback  Pumpback
*  No.   Junc.  Type (cu.ft.)  Zero  (cu.ft.)   Conduit    Rate
*89002   9071    3      0.0     0
*                                   1000000      51        10
*To indicate end of Pump Data Section, enter 99999
99999
*
```

TABLE 3-1 (continued)

```
*FREE OUTFALL DATA SECTION
* Junction  Sequence
*  Number    Number
     20         1
*
*To indicate end of Free Outfall Data Section, enter 99999 (or blank line)
99999
*
*OUTFALLS WITH FLAP GATES (TIDE GATES) DATA SECTION
*one outfall junction number per line
* Junction  Sequence
*  Number    Number
*    35         4
*
*To indicate end of for Outfalls W/Flap Gates Data Section, enter 99999 (or blank line)
99999
*
*TIDE OR STAGE BOUNDARY DATA SECTION
*If no water surface elevation at outfall, Ntide=1
*  Ntide
*    1
*If constant water surface elevation at outfall, Ntide=2
*  Ntide     A1
*    2       47
*If tide coefficients provided by user, Ntide=3
*                                                        Tidal
*  NTide     A1     A2     A3     A4     A5     A6     A7  Period
*    3        1      4      5      7    1.5      2      2    25
*If tide coefficients to be computed by program, Ntide=4
*               Tidal
*  Ntide       Period
*    4           25
*    KO        Number      Print
*              Points      Flag
*     1          4          1
*   Time    Tide     Time     Tide      Time     Tide     Time     Tide
*     1      34       8        37        14       33       21       31
*If stage history boundary condition, Ntide=5
*  Ntide
*    5
*   Number      Print
*   Points      Flag
*     10          0
*   Time     Stage     Time     Stage     Time     Stage     Time     Stage     Time     Stage
*     0       34        1       34.5        3      35.5        4      36.0        5      37.0
*     6      38.0       7       37.5        8      36.5        9      36.0       10      35.5
*
*To indicate end of Tide or Stage Boundary Data Section, enter 99999 (or blank line)
99999
*
*INITIAL FLOW DATA SECTION
*If entering initial flow data, must enter initial flows for each conduit
*(real and internal) in the order specified n the Conveyance Element Data Section
*   Q      V      Q      V      Q      V      Q      V      Q      V
* (cfs)  (fps)  (cfs)  (fps)  (cfs)  (fps)  (cfs)  (fps)  (cfs)  (fps)
*
*Must also enter initial depths for each junction (real and internal) in the order
*specified in the Junction Element Data Section
*  Depth  Depth  Depth  Depth  Depth  Depth  Depth  Depth  Depth  Depth
*  (ft)   (ft)   (ft)   (ft)   (ft)   (ft)   (ft)   (ft)   (ft)   (ft)
*To indicate end of Initial Flow Data Section, enter 99999
99999
*
*INPUT HYDROGRAPHS SECTION
*Required only if NJSW > 0 (System Parameters Section). Enter junctions for which
*hydrographs are being input.
*  Junc.(1)  Junc.(2)  Junc.(3)  Junc.(4)  Junc.(5)  Junc.(6)  Junc.(7)  ...
*
*Enter time and flows for each junction and each time in hydrograph.
*  Time   Q(1)   Q(2)   Q(3)   Q(4)   Q(5)   Q(6)   Q(7)  ...
* (hrs)  (cfs)  (cfs)  (cfs)  (cfs)  (cfs)  (cfs)  (cfs)
END PROGRAM
```

Name	Description	Default
DELT	Length of integration timestep in seconds. This variable is critical to the stability of the EXTRAN block and must be selected carefully. First, compute t_c, the time for a surface wave to travel from one end of the shortest conveyance element in the system to the other: $$t_c = \frac{L}{\sqrt{gD}}$$ where: t_c = time for a surface wave to travel from one end of a conduit to the other, in seconds, L = length of shortest conduit, in feet, g = 32.2 feet/second, and D = channel depth or pipe diameter, in feet. The timestep may exceed t_c by a factor of 1.5 to 2.0, but only for a few, widely separated conveyance elements. For most problems, conduit lengths will allow a timestep of 15 to 20 seconds.	none
TZERO	Start of simulation, in decimal hours. May be set to zero.	none
TEND	End of simulation, in decimal hours. Must be a non-zero number, because this sets the number of timesteps used in the simulation.	none
NHPRT	Number of junctions selected for detailed printing of head output.	none
NWPRT	Number of junctions selected for printing of detailed water balance.	none
NQPRT	Number of conveyance elements selected for detailed printing of discharge.	none
PSTART	Time to begin detailed printing, in decimal hours.	none
DINTER	Time between printing cycles for all conveyance and junction elements, in minutes. DINTER = 0 indicates no printout.	none
HINTER	Time between detailed printing cycles for specified conveyance and junction elements, in minutes. HINTER = 0 indicates no printout.	none
NJSW	Number of input junctions for user defined inflow hydrographs. If NJSW > 0, NJSW inflow hydrographs must be defined later in input.	none
MAXIT	Maximum number of iterations per timestep. EXTRAN assumes a minimum number of 100 iterations.	100

Name	Description	Default
JREDO	Hot start option control 0 = No hot start operations 1 = Use existing hot start file to begin this run 2 = Create a new hot start file at the end of this run 3 = Use existing hot start file to begin this run and create a new hot start file at the end of the run	none
IPFLAG	Input and output data print switches: 0 = off 1 = on IPFLAG(1) = Conduit parameters printout IPFLAG(2) = Junction parameters printout IPFLAG(3) = Miscellaneous input data printout IPFLAG(4) = Junctions and conduits summary printout IPFLAG(5) = Hydraulic grade line summary printout IPFLAG(6) = Summary statistics for junctions printout IPFLAG(7) = Flow and velocity summary printout IPFLAG(8) = Summary statistics for conduits printout	none

Junction and Conveyance Elements for Detailed Printout.

JPRT(i)	Junction element numbers for detailed hydraulic grade line printout.	none
KPRT(i)	Junction element numbers for detailed water balance printout.	none
CPRT(i)	Conveyance element numbers for detailed flow and velocity printout.	none

3.4.2.3 Conveyance Elements Section. Conveyance elements include conduits (various shapes of pipes, and trapezoidal channels) as illustrated in Figure 3-3, and their associated overflow sections. This section of the input data gives a complete description of each conduit, including size, upstream and downstream junction elements, Manning's n (resistance factor), slope (from upstream and downstream invert elevations), and overflow channel section description.

All the data values for a conveyance element are placed on one line. Comment lines are allowed between conveyance element data lines so long as the each data lines contains all the data values for a conveyance element. A sample input line for each type of conveyance element is given in the Conveyance Element Section in Table 3-1.

Name	Description	Default
NCOND	Unique conduit identification number	none
NJUNC(1)	Junction number at upstream end of conduit	none
NJUNC(2)	Junction number at downstream end of conduit	none

Name	Description	Default
NKLASS	Type of conduit shape: 1 = circular 2 = rectangular 3 = horseshoe 4 = elliptical 5 = arch 6 = trapezoidal channel	none
AFULL	Cross sectional area of the conduit, in square feet. This value is required only for conduit types 3, 4, and 5. AFULL may be set to zero for conduit types 1, 2, and 6.	none
DEEP	Vertical depth of conduit, in feet.	none
WIDE	Maximum width of conduit, in feet. For the trapezoidal channel (type 6) it is the bottom width, in feet.	none
LEN	Length of the conduit between the junctions, in feet.	none
ZP(1)	Distance of the conduit invert above the junction invert at the upstream junction (NJUNC(1)).	none
ZP(2)	Distance of the conduit invert above the junction invert at the downstream junction (NJUNC(2)).	none
ROUGH	Manning's n (roughness coefficient or resistance factor) for the conduit. The n should include adjustments for entrance and exit losses at the manholes.	0.014
STHETA	Slope of one side of trapezoidal channel (horizontal/vertical; 0 = vertical), in feet/feet. Set to zero for conduit types 1 through 5.	none
SPHI	Slope on the other side of trapezoidal channel (horizontal/vertical; 0 = vertical), in feet/foot. Set to zero for conduit types 1 through 5.	none

Overflow section data (continues on same line), see Figure 3-4 for description of elements.

Name	Description	Default
ODEEP	Depth of the main trapezoidal section, in feet.	none
OWIDE	Bottom width of the main trapezoidal section, in feet. This represents total gutter width (both sides of the street).	none
ORN1	Manning's n coefficient for the main trapezoidal section.	none
ORN2	Manning's n coefficient for the overflow trapezoidal section	none
OTHE1	Average slope of both sides of the main trapezoidal section (horizontal/vertical), in feet/foot. This slope corresponds to the street cross slope and is used with ODEEP to determine: street width. = ODEEP*OTHE1*2	none
OTHE2	Average slope of both sides of the overflow trapezoidal section (horizontal/vertical), in feet/foot. This slope corresponds to the slope of the ground outside the street.	none
99999	A blank line or 99999 indicates the end of the Conveyance Element Data Section	none

3.4.2.4 Junction Elements Data Section. A line with junction element data is required for each of the following junction element types in the network:

- regular junctions,
- storage and diversion junctions,
- pump junctions, and
- outfall junctions.

It is very important to remember that the junction invert elevation must equal the lowest invert elevation of the conduits connecting to the junction (ZP = 0). Program execution will terminate with an error message if this condition is not met.

The explanation of ground and invert elevations is shown in Figure 3-1. The ground elevation is the elevation at which the assumption of pressure flow is no longer valid. Normally this will be the street or ground elevation of the top of the manhole because when the depth in the manhole exceeds that elevation overflow onto the ground begins. If the manholes are bolted down, the ground elevation should be set high enough that the simulated water surface elevation does not exceed it. Alternatively, the junction may be defined such that overflows are not allowed, as described below and shown in the Junction Elements Data Section in Table 3-1.

The inflow capacity control option allows the user to select the maximum flow rate that will be allowed into the system, from the RUNOFF hydrograph file, at the inflow junction. All flows in excess of this rate will be stored at the junction and can be allowed to enter the system when capacity is available or can be assumed to be lost from the system. The inflow capacity control simulates the operation of storage facilities before the flows enter the pipe conveyance system.

Name	Description	Default
JUN	Unique junction identification number.	none
GRELEV	Ground elevation at the top of the junction, in feet msl.	none
Z	Junction elevation, in feet msl.	none
QINST	Net constant flow into the junction (may be negative), in cfs. In a combined sewer system this could be the sanitary sewage contribution. Could also be infiltration and inflow coming into the system.	none
CLEN	Sum of the length of curb inlets per thousand feet (both sides of the street) into the system in the area of influence of the junction. The area of influence is defined as ½ the distance along each conduit connected to the junction. Example: if the two conduits connecting to the junction have an average of one 3-foot inlet on each side of the street every 500 feet, then: $CLEN = \left(\left(\frac{3}{500}\right) * 2 * 1000\right) = 12$	none

Name	Description	Default
OWEIRC	Average curb inlet weir coefficient for the inlets in the conduits connecting to the junction. A typical number for this coefficient is 3.1.	none

A combination of CLEN and OWEIRC is also used to provide better control of overflow from and inlet inflow to each junction, as follows:

	Flow out to Street	Flow into Junction
1. CLEN = 0 OWEIRC = 0	No*	No
2. CLEN > 0 OWEIRC = 0	Yes	No
3. CLEN > 0 OWEIRC > 0	Yes	Yes

* Head may become greater than ground elevation.

CLEN and OWEIRC act only as switches for cases A and B shown above, and may be any positive value or zero. For case C, the values used for CLEN and OWEIRC must represent the actual inlet situation as described above.

QCAP — This parameter controls the inflow capacity (from RUNOFF) of the junction
0 = No restrictions on inflow from RUNOFF
>0 = Inflow restricted to specified peak flow. Excess sent to storage and then added to system as capacity allows.
<0 = Inflow restricted to specified peak flow. Excess is sent to storage and then lost from system.

A blank line or 99999 indicates the end of the Junction Data — Default: none

3.4.2.5 Storage Junction Data Section. Regular storage junctions in EXTRAN are defined as uniform "tanks" that can be described by a crown elevation and a storage capacity in cubic feet per foot of junction height. Irregular storage junctions can have any shape and are represented by a table of area-depth data pairs. Input data for both types of storage junction are illustrated in the Storage Junction Data Section in Table 3-1

Name	Description	Default
JSTORE	Identification number of Junction containing storage facility. Must already have been listed in the Junction Elements Data Section	none
ZCROWN	Junction crown elevation, in feet. This elevation must be higher than the crown of any pipe that enters the storage junction.	none
ASTORE	Storage volume parameter >0 = Storage volume per foot of junction height, in cubic feet for a regular storage junction. -1 = Irregular storage junction. Area-stage data pairs follow.	none
NUMV	Number of area-stage data pairs for irregular storage junction. 0 = Required for regular storage junctions. >0 = Number of area-stage data pairs on next lines.	none
VCURVE	For irregular storage junction, NUMV area-stage data pairs. Area in square feet and stage in feet above junction invert.	
99999	A blank line or 99999 indicates the end of the Storage Junction Data	none

3.4.2.6 Orifice Data Section. Orifices in EXTRAN are described as equivalent pipes. Each orifice is defined between two junctions. Two types of orifice, side and bottom discharge may be used in EXTRAN. Orifice data is entered on one line per orifice. Comment lines are allowable between orifice data lines. Use of both types of orifice is illustrated in the Orifice Data Section in Table 3-1.

Name	Description	Default
NJUNC(1)	Junction containing the orifice. Must already have been listed in the Junction Elements Data Section.	none
NJUNC(2)	Junction to which the orifice discharges. Must already have been listed in the Junction Elements Data Section.	none
NKLASS	Type of orifice as shown in Figure 3-5: 1 = side outlet orifice 2 = bottom outlet orifice	none
AORIF	Orifice area, in square feet.	none
CORIF	Orifice discharge coefficient. Typical value for discharge coefficient is around 0.6.	none
ZP	Distance of orifice invert above junction invert. Set to zero for bottom orifice.	none
99999	A blank line or 99999 indicates the end of the Orifice Data Section	none

3.4.2.7 Weir Data Section. Weirs in EXTRAN may be of two types, side flow or transverse. Data is entered on one line per weir, with comment lines allowable between weir data lines. Weir parameters are given in the Weir Data Section of Table 3-1 and are illustrated in Figure 3-7.

Name	Description	Default
NJUNC(1)	Junction at which the weir is located. Must already have been listed in the Junction Elements Data Section.	none
NJUNC(2)	Junction to which the weir discharges. Must already have been listed in the Junction Elements Data Section.	none
KWEIR	Type of weir: 1 = transverse 2 = transverse with flap gate 3 = side flow 4 = side flow with flap gate	none
YCREST	Height of weir crest above invert of junction, in feet.	none
YTOP	Height of top of weir opening above invert of junction, in feet. This is the level at which the weir surcharges and begins to operate as an orifice.	none
WLEN	Weir length, in feet.	none
COEF	Coefficient of discharge for the weir. A typical value for the discharge coefficient would be around 2.8.	none
99999	A blank line or 99999 indicates the end of the Weir Data Section	none

3.4.2.8 Pump Data Section. Pumps in EXTRAN may be of three types, an off-line pump station with a wet well (storage junction), an on-line lift station, or a pump for use in pumpback from storage. Pump operation for the Type 1 and Type 2 pumps may be either on-off operation or variable speed. Type 3 pump operation is dependent on the flow in the specified pumpback conduit. Input data for the three types of pumps is illustrated in the Pump Data Section of Table 3-1.

Name	Description	Default
NJUNC(1)	Junction in which the pump is located. Note that for a Type 1 pump (wet well), only one influent pipe may be connected to the pump junction. Junction must already have been listed in the Junction Elements Data Section.	none
NJUNC(2)	Junction to which the pump is discharging. Must already have been listed in the Junction Elements Data Section. Enter zero if the pump is discharging out of the system.	none

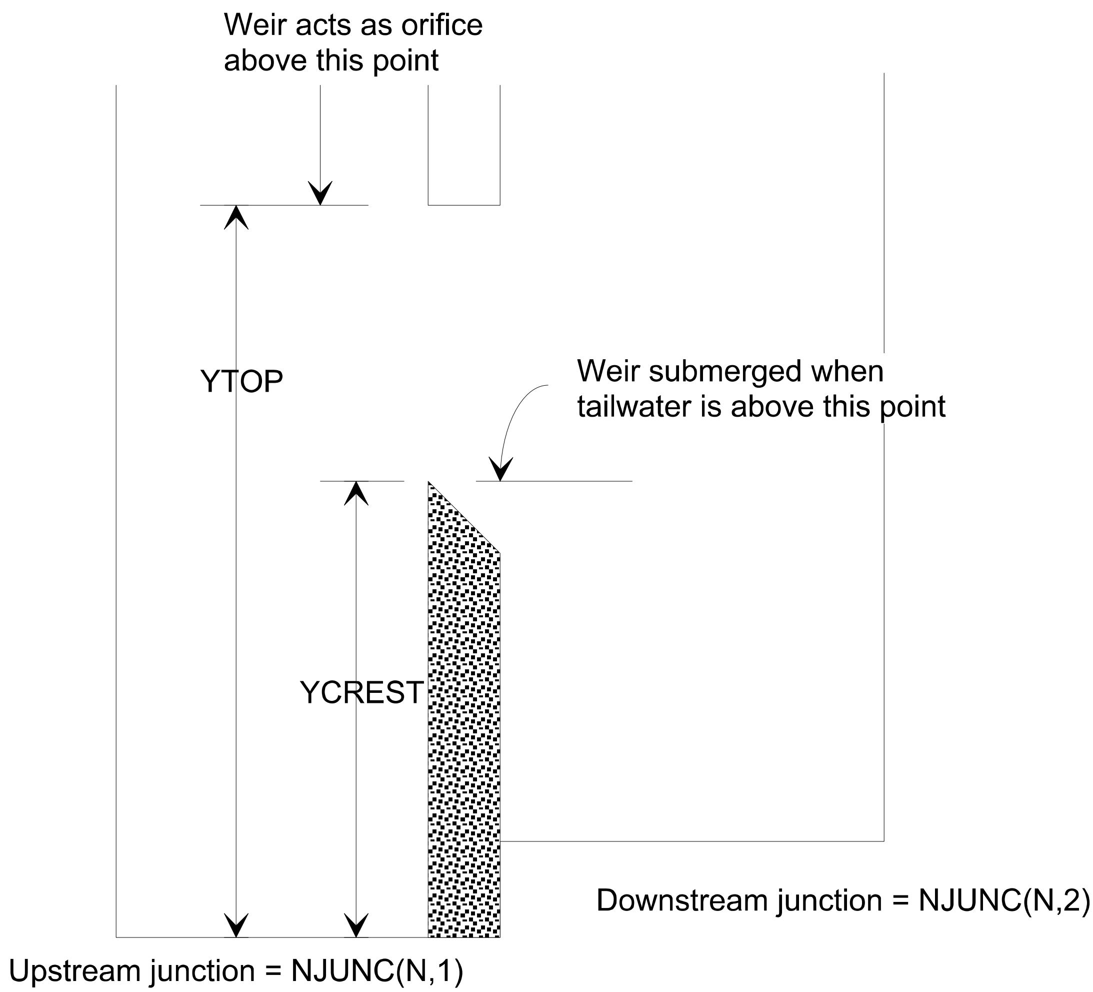


FIGURE 3-7
WEIR INPUT DEFINITIONS

Name	Description	Default
IPTYP	Type of pump: 1 = off-line pump with wet well. No flooding will occur when inflow exceeds pump capacity. On-off or variable speed operation will be based on the volume of stormwater in the wet well. 2 = on-line lift pump. Flooding may occur at pump junction when inflow exceeds pump capacity. On-off or variable speed operation will be based on the stage at the junction. 3 = pumpback from storage. Pumping rate is determined by available capacity in the specified pumpback conduit. Flows exceeding the specified maximum storage volume will not be allowed to enter the junction.	none
VWELL	For: Type 1 pump = Initial wet well volume, in cubic feet. Type 2 pump = 0 (zero). Type 3 pump = Initial volume in storage, in cubic feet.	none
MPUMP	Type of pump operation: >0= On-off operation. MPUMP indicates the number of pumps for which on-off operation is defined. One line of pump operation data is required for each pump. 0 = Variable speed pump. Up to ten paired values of stage (or volume for Type 1 pump) and pump capacity required on next lines. 0 = Pumpback from storage. Maximum storage volume, pumpback conduit, and maximum pumpback rate required on next line.	none

<u>On-Off Pump Operation Data. MPUMP lines of data, one for each pump.</u>

PSON	Stage (or volume) for pump to come on, in feet or cubic feet.	none
PSOFF	Stage (or volume) for pump to go off, in feet or cubic feet.	none
PRATE	Base pump capacity, in cubic feet per second.	none

Name	Description	Default
VRATE	Variable pump capacity, in cubic feet per second per foot. Total pump capacity is based on equation: $Q_t = Q_p + (Q_v * S)$ where: Q_t = Total pump capacity at a given stage in cubic feet per second; Q_p = Base pump capacity (PRATE) in cubic feet per sec; Q_v = Variable pump capacity (VRATE) in cubic feet per second per foot or cubic feet per second per cubic foot; S = Stage (volume) in pump junction feet or cubic feet	

Variable Speed Pump Operation Data. Up to 10 lines with paired values of stage (volume) and pumping capacity.

VRATE	Stage (or volume for Type 1 pump), in feet (or cubic feet).	none
PRATE	Pump capacity corresponding to VRATE, in cubic feet per second.	none

Pumpback from Storage Pump Operation Data. One line of data.

VMax	Maximum storage volume in cubic feet.	none
PBCond	Conduit number where available capacity will be used to determine pumpback rate.	none
PBMax	Maximum pumpback rate in cubic feet per second.	
99999	A blank line or 99999 indicates the end of the Pump Data Section	none

3.4.2.9 Free Outfall Data Section. Free outfalls are outfalls without flap gates. The water surface elevation at the terminal junction determines the outflow from the outfall junction. The information for each free outfall is listed on a separate line. Comments are allowable between free outfall data lines. Only one conduit may be connected to a free outfall. Sample input is illustrated in the Free Outfall Data Section in Table 3-1.

Name	Description	Default
JFREE	Junction from which the outfall occurs. Must already have been listed in the Junction Elements Data Section. Only one conduit may be connected to the free outfall junction.	none
NBCF	Location of tide or stage information in Tide or Stage Boundary Information Section	none
99999	A blank line or 99999 indicates the end of the Free Outfall Data Section	none

3.4.2.10 Outfall with Flap Gate Data Section. Outfalls with flap gates are a special case of the free outfall. Flow will not leave the system at an outfall with a flap gate if the water surface elevation at the flap gate is higher than the water surface at the outfall.

Name	Description	Default
JGATE	Junction from which the outfall with a flap gate occurs. Must already have been listed in the Junction Elements Data Section. One outfall junction number per line.	none
NBCG	Location of tide or stage information in Tide or Stage Boundary Information Section	none
99999	A blank line or 99999 indicates the end of the Outfall with Flap Gate Data.	none

.4.2.11 Tide or Stage Boundary Data Section. This section may contain up to 20 tide or stage boundary descriptions. All tide or stage data are on one line except if NTIDE = 4 or 5.

Name	Description	Default
NTIDE	Tide index: 1 = no water surface elevation at outfalls 2 = outfall control water surface at constant elevation A1 3 = tide control coefficients provided by user 4 = program will compute tide coefficients 5 = stage history of water surface elevation boundary condition	none
A1 to A7	for NTIDE = 1, 4, or 5, A1 to A7 not required for NTIDE = 2, A1 = outfall control water surface elevation; A2 to A7 not required for NTIDE = 3, A1 to A7 = tidal coefficients for computing the current tide elevation using the following equation:	none

$$H_{TIDE} = A_1 + A_2 \sin \omega T + A_3 \sin 2\omega T + A_4 \sin 3\omega T + A_5 \cos \omega T + A_6 \cos 2\omega T + A_7 \cos 3\omega T$$

Name	Description	Default
W	For NTIDE = 3 or 4, tidal period, in hours. Typical tidal periods are 12.5 and 25 hours, but any value may be used.	none

For NTIDE = 4, Tide coefficient calculation control line.

Name	Description	Default
KO	KO = 1, four information points for tide coefficient development. KO > 1, NI information points for tide coefficient development.	none
NI	Number of information points for developing tide coefficients: NI = 4 if KO = 1 NI < 50 if KO > 1	none
NCHTID	NCHTID = 1, will print out information on tide coefficient development. NCHTID = 0, no print out.	none
TT(i)	Time of information point, in hours.	none
YY(i)	Tidal stage, in feet.	none

For NTIDE = 5, Stage history boundary condition

NI	Number of stage history point pairs:	none
NCHTID	NCHTID = 1, will print out information on stage history boundary condition. NCHTID = 0, no print out.	none

Stage history point pairs, time and stage. NI point pairs total. No comments allowed in stage history data.

TT(i)	Time of stage data point, in hours.	none
YY(i)	Stage, in feet.	none
99999	A blank line or 99999 indicates the end of the Tide or Stage Boundary Information Data.	none

3.4.2.12 Initial Flows, Velocities, and Heads Data Section. In some situations it is desirable to begin a simulation with initial flows and velocities in the conduits and stages in the junctions. These initial flows, velocities, and stages represent the antecedent flow conditions just prior to the storm being simulated. The initial flow data section allows the user to input initial flow data, but if this option is used, data must be input for every conduit and every junction in the system.

The initial discharge and velocity must be specified for all real conduits plus all internal links. (There is one internal link for each orifice, weir, pump, and outfall in the system. In a complex network, the total number of real plus internal conduits is best determined from the conduit connectivity summary in a trial run with EXTRAN.) As an example, in a system of 25 real conduits, 28 junctions, 2 orifices, 3 weirs, and 1 free outfall, we have a total of 31 links. The specification of initial discharges requires that flow and velocity pairs be input for each of the 31 links.

Similarly, the initial depths (not elevations) must be specified for all real and internal junctions. Internal junctions are specified automatically by EXTRAN for each weir in the system. Thus, in the example above we would input depth values for a total of 31 junctions.

Name	Description	Default
Q(i), V(i)	Initial discharge and velocity pair for each conduit (real and internal) in the system, in cubic feet per second and feet per second, respectively. Must be entered in the order that the conduits were specified in the Conveyance Elements Data Section.	none
Y(i)	Initial depth of flow in each junction (real and internal) in the system, in feet above junction invert. Must be entered in the order that the junctions were specified in the Junction Elements Data Section.	none
99999	A blank line or 99999 indicates the end of the Initial Flow Data Section	none

3.4.2.13 User-Defined Inflow Hydrograph Section. . EXTRAN provides for the input of user-defined inflow hydrographs where it is desirable to run EXTRAN alone without prior use of the RUNOFF program or when the user wants to add additional input hydrographs, either at the same or different junctions, to those computed by RUNOFF. The individual junctions receiving user-defined hydrographs are specified on the first line(s) of this section of the input.

After the junctions receiving hydrographs have been specified, the times and discharges for all points on the hydrographs are input next. The time of each discharge point is given in decimal hours, i.e., 10:45 am is 10.75. Hydrograph time input points can be specified at any convenient time as long as a discharge is included for each junction specified. The hydrographs used by EXTRAN are constructed by interpolating between consecutive time input points for each time step.

<u>These input lines required only if NJSW > 0 (Program Parameters Section)</u>

Name	Description	Default
JSW(i)	Junctions for NJSW input hydrographs. All the junctions must already have been listed in the Junction Elements Data Section.	none
TEO	Time in decimal hours for hydrograph point.	none

Name	Description	Default
QCARD(i)	Flow rate at each of NJSW nodes in the order specified for JSW, in cubic feet per second	

99999	A blank line or 99999 indicates the end of the Initial Flow Data Section	none

3.5 OUTPUT DESCRIPTION

Every effort has been made to make the output from the EXTRAN block easy to understand, with headings for each of the output sections that are complete and concise. Table 3-2 is a sample output file from the EXTRAN block. The output shown in Tables 3-2 has been abridged, but still shows all the major headings and output data. The following paragraphs describe each of the output headings, and follow the sample output in Table 3-2.

3.5.1 Definition of Output Variables

The word "page," in the following output description, is used to describe a section of output that contains specific output data. The data on a "page" may cover more than one physical page in the output file.

Page 1. The first page of EXTRAN output begins with a title block describing the evolution of the program. This title block is followed by a second title block describing the particular EXTRAN input being run. It is made up of the two-line title block from the EXTRAN input data file. Also on the first page is a reiteration of the major control parameters such as the number of integration cycles, length of integration timestep, starting time, and the conduit and junction numbers for detailed printout.

Pages 2 through 4. The second and third pages begin with the two-line title block and then summarize the conduit and junction input data respectively. The fourth page of the EXTRAN output contains the internal connectivity information. This information is extremely important because it indicates how the program thinks the system is set up based on the users input data. The internal connectivity information is a good way to check for input errors by verifying that the system connectivity matches the system the user is trying to simulate.

Page 5. The fifth page of the EXTRAN output contains the summary printout for the junctions and conduits at the print cycle specified in the System Parameters Section of the input data. The cycle description includes simulation time, flow differential in the surcharged area, and the iterations required to solve the flow equations for that timestep.

TABLE 3-2
SAMPLE EXTRAN OUTPUT

```
ENTRY MADE TO EXTENDED TRANSPORT MODEL

 UPDATED BY MONTGOMERY WATSON, JANUARY 1996
```

Page 1 --

```
* SACRAMENTO STORMWATER MANAGEMENT MODEL (SSWMM96) *
*** EXTENDED TRANSPORT PROGRAM (EXTRAN BLOCK) ***

DATE OF THIS RUN : 02/25/94

 SSWMM96 DOCUMENTATION EXAMPLE DATA
 EXTRAN BLOCK

INTEGRATION CYCLES 1200

LENGTH OF INTEGRATION STEP IS   30. SECONDS

PRINTING FOR ALL CONDUITS AND NODES STARTS IN CYCLE   40 AND PRINTS AT INTERVALS OF   60 CYCLES

INITIAL TIME  9.00 HOURS

SURCHARGE VARIABLES: ITMAX =   99999
                     SURTOL =   .050

PRINTED OUTPUT AT THE FOLLOWING 11 JUNCTIONS

                20       101       102       103       104       105       106       107       108
               109       110

WATER BALANCE AT THE FOLLOWING  4 JUNCTIONS

               105       106       107       108

          AND FOR THE FOLLOWING 10 CONDUITS

               201       202       203       204       205       206       207       208       209       210
```

Page 2 --

```
* SACRAMENTO STORMWATER MANAGEMENT MODEL (SSWMM96) *
*** EXTENDED TRANSPORT PROGRAM (EXTRAN BLOCK) ***

 SSWMM96 DOCUMENTATION EXAMPLE DATA
 EXTRAN BLOCK
```

CONDUIT INPUT DATA

	CONDUIT NUMBER	LENGTH (FT)	SLOPE (FT/FT)	CLASS	AREA (SQ FT)	MANNING COEF.		MAX WIDTH (FT)	DEPTH (FT)	JUNCTIONS AT ENDS		INVERT HEIGHT ABOVE JUNCTIONS		TRAPEZOID SIDE SLOPE	
1	201	900.	0.00022	CIRCULAR	19.63	0.014		5.00	5.00	101	20	0.00	0.00		
				OVERFLOW		0.016	0.020	0.50	0.50					37.	50.

Output Abridged in This Section

9	209	900.	0.00027	CIRCULAR	19.63	0.014		5.00	5.00	109	108	0.00	0.11		
				OVERFLOW		0.016	0.020	0.50	0.58					38.	50.
10	210	800.	0.00020	CIRCULAR	19.63	0.014		5.00	5.00	110	109	0.00	0.01		
				OVERFLOW		0.016	0.020	0.50	0.58					38.	50.

Page 3 --

```
* SACRAMENTO STORMWATER MANAGEMENT MODEL (SSWMM96) *
*** EXTENDED TRANSPORT PROGRAM (EXTRAN BLOCK) ***

 SSWMM96 DOCUMENTATION EXAMPLE DATA
 EXTRAN BLOCK
```

JUNCTION INPUT DATA

	JUNCTION NUMBER	GROUND ELEV.	CROWN ELEV.	INVERT ELEV.	QINST (CFS)	INLET LENGTH	INLET COEF.	INFLOW CAP. (CFS)	CONNECTING CONDUITS	
1	20	21.70	0.14	-4.86	0.07	11.	3.10	99999.0	201	

Output Abridged in This Section

9	108	12.65	5.09	-0.02	0.13	22.	3.10	25.0	208	209
10	109	14.46	5.34	0.33	0.00	20.	3.10	99999.0	209	210
11	110	14.39	5.50	0.50	0.12	10.	3.10	99999.0	210	

TABLE 3-2 (continued)

```
_______________________________________________________________PUMP DATA_____________________________________________________________
        JUNCTIONS        TYPE         INITIAL VOLUME      CONST RATE,CFS          VARIABLE      DEPTH     DEPTH
      FROM     TO                                                             RATE/DEPTH      ON        OFF
 1     20       0          2                 0.             114.                  0.            4.        2.
                                                            114.                  0.            5.        2.
                                                            114.                  0.            6.        3.
```

Page 4 --

```
* SACRAMENTO STORMWATER MANAGEMENT MODEL (SSWMM96) *
*** EXTENDED TRANSPORT PROGRAM (EXTRAN BLOCK) ***

  DOCUMENTATION EXAMPLE DATA
 EXTRAN BLOCK

______________________________________________ INTERNAL CONNECTIVITY INFORMATION_____________________________________________

         CONDUIT     JUNCTION     JUNCTION

           201          101           20
           202          102          101
```

Output Abridged in this Section

```
           210          110          109
         90011           20            0
```

Page 5 --

```
 SSWMM96 DOCUMENTATION EXAMPLE DATA
 EXTRAN BLOCK

________________________________________ SUMMARY OF INITIAL HEADS, FLOWS AND VELOCITIES _________________________________________

INITIAL HEADS, FLOWS AND VELOCITIES ARE ZERO

* SACRAMENTO STORMWATER MANAGEMENT MODEL (SSWMM96) *
*** EXTENDED TRANSPORT PROGRAM (EXTRAN BLOCK) ***

 SSWMM96 DOCUMENTATION EXAMPLE DATA
 EXTRAN BLOCK

___________________________________ SUMMARY PRINTOUT FOR ALL JUNCTIONS AND CONDUITS___________________________________

CYCLE    60      TIME    9 HRS - 30.00 MIN  FLOW DIFFERENTIAL IN SURCHARGED AREA=  0.00CFS  ITERATIONS REQUIRED= 1

JUNCTIONS:  MANHOLE DEPTH, FLOODING DEPTH

    20:   0.14    0.00    101:   0.00    0.00    102:   0.01    0.00    103:   0.10    0.00    104:   0.03    0.00
   105:   0.24    0.00    106:   0.27    0.00    107:   0.14    0.00    108:   0.16    0.00    109:   0.05    0.00
   110:   0.21    0.00

CONDUITS:  CONDUIT FLOW, OVERFLOW

   201:   0.00    0.00     202:   0.00    0.00     203:   0.02    0.00     204:   0.01    0.00     205:   0.12    0.00
   206:   0.42    0.00     207:   0.07    0.00     208:   0.07    0.00     209:   0.01    0.00     210:   0.07    0.00
 90011:   0.00    0.00

CYCLE   120      TIME   10 HRS -  0.00 MIN  FLOW DIFFERENTIAL IN SURCHARGED AREA=  0.00CFS  ITERATIONS REQUIRED= 1

JUNCTIONS:  MANHOLE DEPTH, FLOODING DEPTH

    20:   0.26    0.00    101:   0.02    0.00    102:   0.08    0.00    103:   0.29    0.00    104:   0.25    0.00
   105:   0.43    0.00    106:   0.29    0.00    107:   0.24    0.00    108:   0.23    0.00    109:   0.16    0.00
   110:   0.24    0.00

CONDUITS:  CONDUIT FLOW, OVERFLOW

   201:  -0.03    0.00     202:   0.02    0.00     203:   0.19    0.00     204:   0.46*   0.00     205:   0.64    0.00
   206:   0.56*   0.00     207:   0.19*   0.00     208:   0.15    0.00     209:   0.07    0.00     210:   0.13    0.00
 90011:   0.00    0.00
```

.

. Output Abridged in This Section

.

TABLE 3-2 (continued)

```
CYCLE  1200      TIME   19 HRS -   0.00 MIN  FLOW DIFFERENTIAL IN SURCHARGED AREA=  0.00CFS  ITERATIONS REQUIRED= 1

JUNCTIONS:  MANHOLE DEPTH, FLOODING DEPTH

    20:   3.85    0.00    101:   3.65    0.00    102:   3.04    0.00    103:   2.58    0.00    104:   1.05    0.00
   105:   0.65    0.00    106:   0.49    0.00    107:   0.57    0.00    108:   0.42    0.00    109:   0.21    0.00
   110:   0.22    0.00

CONDUITS:  CONDUIT FLOW, OVERFLOW

   201:  -0.48    0.00     202:  -1.26    0.00     203:  -0.95    0.00     204:   1.27    0.00     205:   1.89    0.00
   206:   1.68*   0.00     207:   1.07    0.00     208:   0.57    0.00     209:   0.13*   0.00     210:   0.12    0.00
 90011:   0.00    0.00
```

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```
* SACRAMENTO STORMWATER MANAGEMENT MODEL (SWMM) *
*** EXTENDED TRANSPORT PROGRAM (EXTRAN BLOCK) ***

SSWMM96 DOCUMENTATION EXAMPLE DATA
 EXTRAN BLOCK
```

CONTINUITY BALANCE IN CU-FT AT END OF RUN

JUNCTION	WATERSHED INFLOW	MAX STORAGE	HYDROGRAPH EXCESS	SYSTEM INFLOW	SYSTEM OUTFLOW	INFLOW FROM FLOODING	SURCHARGE TO STREET
20	2520.	0.	0.	2520.	947340.	0.	0.
101	0.	0.	0.	0.	0.	0.	0.
102	0.	0.	0.	0.	0.	0.	0.
103	66274.	0.	0.	66274.	0.	0.	0.
104	0.	0.	0.	0.	0.	0.	0.
105	63197.	0.	0.	63197.	0.	0.	0.
106	265067.	0.	0.	265067.	0.	0.	0.
107	272718.	0.	0.	272718.	0.	0.	0.
108	352002.	51786.	404.	351598.	0.	404.	0.
109	0.	0.	0.	0.	0.	0.	0.
110	4320.	0.	0.	4320.	0.	0.	0.
TOTAL	1026099.	51786.	404.	1025695.	947340.	404.	0.

```
VOLUME LEFT IN PIPE    =          49390. CU FT
VOLUME LEFT IN STREET  =              0. CU FT
VOLUME LEFT IN STORAGE =              0. CU FT

ERROR IN CONTINUITY, PERCENT =  3.03
(INFLOW-OUTFLOW-VOLUME LEFT)/INFLOW
```

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```
* SACRAMENTO STORMWATER MANAGEMENT MODEL (SWMM) *
*** EXTENDED TRANSPORT PROGRAM (EXTRAN BLOCK) ***

SSWMM96 DOCUMENTATION EXAMPLE DATA
 EXTRAN BLOCK
```

CUMULATIVE INFLOW AND OUTFLOW IN CU-FT

TIME HR : MIN	WATERSHED INFLOW	NODE STORAGE	HYDROGRAPH EXCESS	SYSTEM INFLOW	SYSTEM OUTFLOW	INFLOW FROM FLOODING	SURCHARGE TO STREET	VOLUME IN ST.	PUMPBACK VOLUME
0:20	1260.	0.	0.	1260.	0.	0.	0.	0.	0.
0:40	2520.	0.	0.	2520.	0.	0.	0.	0.	0.
1:00	3803.	0.	0.	3803.	0.	0.	0.	0.	0.
1:20	7962.	0.	0.	7962.	0.	0.	0.	0.	0.
1:40	18766.	0.	0.	18766.	0.	0.	0.	0.	0.
2:00	36073.	0.	0.	36073.	0.	0.	0.	0.	0.
2:20	59726.	0.	0.	59726.	0.	0.	0.	0.	0.
2:40	87630.	0.	0.	87630.	20520.	0.	0.	0.	0.
3:00	117804.	0.	0.	117804.	44460.	0.	0.	0.	0.
3:20	159295.	0.	0.	159295.	75240.	0.	0.	0.	0.
3:40	228325.	1585.	0.	226740.	116280.	0.	0.	0.	0.
4:00	424381.	42607.	404.	381371.	205200.	193.	0.	211.	0.
4:20	539914.	51652.	404.	487858.	287280.	404.	0.	0.	0.
4:40	626418.	50427.	404.	575588.	383040.	404.	0.	0.	0.
5:00	704580.	46641.	404.	657535.	478800.	404.	0.	0.	0.
5:20	764910.	36719.	404.	727788.	557460.	404.	0.	0.	0.
5:40	813294.	22790.	404.	790099.	632700.	404.	0.	0.	0.
6:00	857311.	7566.	404.	849341.	701100.	404.	0.	0.	0.
6:20	896276.	0.	404.	895872.	762660.	404.	0.	0.	0.
6:40	931730.	0.	404.	931326.	813960.	404.	0.	0.	0.

TABLE 3-2 (continued)

7:00	965304.	0.	404.	964900.	855000.	404.	0.	0.	0.
7:20	986728.	0.	404.	986324.	892620.	404.	0.	0.	0.
7:40	998500.	0.	404.	998096.	909720.	404.	0.	0.	0.
8:00	1006049.	0.	404.	1005645.	919980.	404.	0.	0.	0.
8:20	1011386.	0.	404.	1010982.	926820.	404.	0.	0.	0.
8:40	1015454.	0.	404.	1015050.	933660.	404.	0.	0.	0.
9:00	1018734.	0.	404.	1018330.	940500.	404.	0.	0.	0.
9:20	1021503.	0.	404.	1021099.	940500.	404.	0.	0.	0.
9:40	1023925.	0.	404.	1023521.	947340.	404.	0.	0.	0.
10:00	1026099.	0.	404.	1025695.	947340.	404.	0.	0.	0.

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```
* SACRAMENTO STORMWATER MANAGEMENT MODEL (SWMM) *
*** EXTENDED TRANSPORT PROGRAM (EXTRAN BLOCK) ***

SSWMM96 DOCUMENTATION EXAMPLE DATA
 EXTRAN BLOCK

________________________________________NODE   108 INFLOW AND OUTFLOW IN CU-FT________________________________________
```

TIME HR : MIN	WATERSHED INFLOW	NODE STORAGE	HYDROGRAPH EXCESS	SYSTEM INFLOW	SYSTEM OUTFLOW	INFLOW FROM FLOODING	SURCHARGE TO STREET	VOLUME IN ST.	PUMPBACK VOLUME
0:20	156.	0.	0.	156.	0.	0.	0.	0.	
0:40	312.	0.	0.	312.	0.	0.	0.	0.	
1:00	477.	0.	0.	477.	0.	0.	0.	0.	
1:20	1716.	0.	0.	1716.	0.	0.	0.	0.	
1:40	5456.	0.	0.	5456.	0.	0.	0.	0.	
2:00	11625.	0.	0.	11625.	0.	0.	0.	0.	
2:20	20138.	0.	0.	20138.	0.	0.	0.	0.	
2:40	30199.	0.	0.	30199.	0.	0.	0.	0.	
3:00	41063.	0.	0.	41063.	0.	0.	0.	0.	
3:20	56117.	0.	0.	56117.	0.	0.	0.	0.	
3:40	81406.	1585.	0.	79820.	0.	0.	0.	0.	
4:00	152427.	42607.	404.	109417.	0.	193.	0.	211.	
4:20	191472.	51652.	404.	139417.	0.	404.	0.	0.	
4:40	220247.	50427.	404.	169417.	0.	404.	0.	0.	
5:00	246462.	46641.	404.	199417.	0.	404.	0.	0.	
5:20	266539.	36719.	404.	229417.	0.	404.	0.	0.	
5:40	282611.	22790.	404.	259417.	0.	404.	0.	0.	
6:00	297387.	7566.	404.	289417.	0.	404.	0.	0.	
6:20	310518.	0.	404.	310114.	0.	404.	0.	0.	
6:40	322518.	0.	404.	322114.	0.	404.	0.	0.	
7:00	333956.	0.	404.	333552.	0.	404.	0.	0.	
7:20	341031.	0.	404.	340627.	0.	404.	0.	0.	
7:40	344687.	0.	404.	344283.	0.	404.	0.	0.	
8:00	346907.	0.	404.	346503.	0.	404.	0.	0.	
8:20	348399.	0.	404.	347994.	0.	404.	0.	0.	
8:40	349484.	0.	404.	349080.	0.	404.	0.	0.	
9:00	350314.	0.	404.	349910.	0.	404.	0.	0.	
9:20	350979.	0.	404.	350574.	0.	404.	0.	0.	
9:40	351531.	0.	404.	351127.	0.	404.	0.	0.	
10:00	352002.	0.	404.	351598.	0.	404.	0.	0.	

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```
* SACRAMENTO STORMWATER MANAGEMENT MODEL (SWMM) *
*** EXTENDED TRANSPORT PROGRAM (EXTRAN BLOCK) ***

DATE OF THIS RUN:  02/25/94
 SSWMM96 DOCUMENTATION EXAMPLE DATA
 EXTRAN BLOCK

  * * * * * * * * * * * * * * * * * * * *   T I M E   H I S T O R Y   O F   H. G. L.   * * * * * * * * * * * * * * * * * * * *
                                                   (VALUES IN FEET)
```

	JUNCTION 20 GRND 21.70			JUNCTION 101 GRND 20.16			JUNCTION 102 GRND 17.99			JUNCTION 103 GRND 17.49			JUNCTION 104 GRND 16.09			JUNCTION 105 GRND 13.90		
TIME HR : MIN	HGL ELEV	HGL DEPTH	FLOOD DEPTH	HGL ELEV	HGL DEPTH	FLOOD DEPTH	HGL ELEV	HGL DEPTH	FLOOD DEPTH	HGL ELEV	HGL DEPTH	FLOOD DEPTH	HGL ELEV	HGL DEPTH	FLOOD DEPTH	HGL ELEV	HGL DEPTH	FLOOD DEPTH
0:20	-4.76	0.10	0.00	-4.66	0.00	0.00	-4.04	0.00	0.00	-3.54	0.07	0.00	-2.08	0.01	0.00	-1.48	0.12	0.00
0:40	-4.67	0.19	0.00	-4.66	0.00	0.00	-4.02	0.02	0.00	-3.48	0.13	0.00	-2.01	0.08	0.00	-1.24	0.36	0.00

Output Abridged in this Section

10:00	-1.01	3.85	0.00	-1.01	3.65	0.00	-1.00	3.04	0.00	-1.03	2.58	0.00	-1.04	1.05	0.00	-0.95	0.65	0.00

TABLE 3-2 (continued)

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* SACRAMENTO STORMWATER MANAGEMENT MODEL (SSWMM96) *
*** EXTENDED TRANSPORT PROGRAM (EXTRAN BLOCK) ***

SSWMM96 DOCUMENTATION EXAMPLE DATA
EXTRAN BLOCK

* * * * * * * * * * * * * * * * S U M M A R Y   S T A T I S T I C S   F O R   J U N C T I O N S * * * * * * * * * * * * * * * *

JUNCTION NUMBER	GROUND ELEVATION (FT)	UPPERMOST PIPE CROWN ELEVATION (FT)	MAXIMUM COMPUTED DEPTH (FT)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM WATER SURFACE ELEVATION	FEET MAX. DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	MAXIMUM FLOODED VOLUME (AF)	FLOODING DEPTH (FT)	TIME OF OCCURENCE HR	MIN.	LENGTH OF FLOODING (MIN)
20	21.70	0.14	5.05	13	15	0.19	21.51	1.	0.00	0.00	0	0	0.

Output Abridged in this Section

110	14.39	5.50	13.59	12	56	14.09	0.30	21.	0.00	0.00	0	0	0.

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* SACRAMENTO STORMWATER MANAGEMENT MODEL (SSWMM96) *
*** EXTENDED TRANSPORT PROGRAM (EXTRAN BLOCK) ***

SSWMM96 DOCUMENTATION EXAMPLE DATA
EXTRAN BLOCK

* * * * * * * * * * * * * * * T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y * * * * * * * * * * * * * * *
Q(CFS), VEL(FPS)

TIME	CONDUIT 201			CONDUIT 202			CONDUIT 203			CONDUIT 204			CONDUIT 205			CONDUIT 206		
HR . MIN	CONDUIT FLOW	VEL	FLOODING FLOWS	CONDUIT FLOW	VEL	FLOODING FLOWS	CONDUIT FLOW	VEL	FLOODING FLOWS	CONDUIT FLOW	VEL	FLOODING FLOWS	CONDUIT FLOW	VEL	FLOODING FLOWS	CONDUIT FLOW	VEL	FLOODING FLOWS
0:20	0.00	0.00	0.00	0.00	0.19	0.00	0.01	0.26	0.00	0.00	0.04	0.00	0.03	0.37	0.00	0.20	0.86	0.00
0:40	0.00	0.00	0.00	0.00	0.19	0.00	0.04	0.39	0.00	0.07	0.46	0.00	0.29	0.85	0.00	0.48	0.91	0.00

Output Abridged in This Section

10:00	-0.48	-0.03	0.00	-1.26	-0.10	0.00	-0.95	-0.05	0.00	1.27	0.20	0.00	1.89	0.86	0.00	1.68	1.33	0.00

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SSWMM96 DOCUMENTATION EXAMPLE DATA
EXTRAN BLOCK

* * * * * * * * * * * * * * * * * * S U M M A R Y   S T A T I S T I C S   F O R   C O N D U I T S * * * * * * * * * * * * * * * * * *

CONDUIT NUMBER	UP NODE	DOWN NODE	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL SIZE (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM ELEV. UP NODE (FT)	DOWN NODE (FT)	MAXIMUM FLOODING FLOW (CFS)	TIME OF OCCURENCE HR	MIN.
201	101	20	36.0	1.8	60.0	123.9	13	16	14.2	13	3	3.4	7.30	0.19	0.	0	0
202	102	101	65.3	3.3	60.0	115.9	12	58	5.9	12	58	1.8	9.21	7.30	0.	0	0

Output Abridged in This Section

210	110	109	34.2	1.7	60.0	-21.2	12	56	-1.1	12	56	-0.6	14.09	13.37	0.	0	0

* * * * * EXTENDED TRANSPORT MODEL SIMULATION ENDED * * * * *

The data for each junction is: junction number, depth of flow in the manhole (junction), and the street flooding depth at that junction. An asterisk (*) next to a manhole depth number indicates that the manhole is surcharged (the hydraulic grade line in the manhole is above the highest pipe crown in the manhole). A plus sign (+) next to a manhole depth number indicates that an overflow into the street is occurring at this manhole.

The data for each conduit is: conduit number, flow in the conduit, and overflow in the street above the conduit. An asterisk (*) next to the conduit flow number indicates that the differences in water surface elevation between the upstream and downstream junctions could not be solved explicitly. The upstream end is solved using normal depth.

Page 6. Page six of the output is the continuity balance in cubic feet at each junction in the system at the end of the run. The continuity balance lists, for each junction, the total watershed inflow, maximum storage, hydrograph excess, system inflow, system outflow, inflow from flooding, and the surcharging to the street. The definitions of the items in the continuity balance are:

- Watershed Inflow -- total of all inflows from RUNOFF module or from user created .gut file
- Maximum Storage -- maximum total storage at all junction resulting from inflows greater than user defined inflow capacities
- Hydrograph Excess -- total of inflows that didn't enter the pipe conveyance system from RUNOFF due to limited downstream pipe capacity
- System Inflow -- difference between the watershed inflow and the hydrograph excess
- System Outflow -- total flow out of the system
- Inflow from Flooding -- total flow entering the pipe conveyance system through street inlets from flooding in the streets
- Surcharge to Street -- total flow entering the streets due to pipe surcharging

The continuity balance also takes into account the volume of stormwater left in the pipes, in the street, and in storage at the end of the simulation. If the error in continuity is more than 10 percent, this is an indication that problems are occurring in the system and a careful study of the output is necessary to determine the location of the problems and possible solutions.

Page 7. Page seven is the cumulative inflow and outflow summary. For each print cycle, the cumulative watershed inflow, node storage, hydrograph excess, system inflow, system outflow, inflow from flooding, surcharge to street, volume in street, and pumpback volume. The definition of the headings in the cumulative inflow and outflow summary are:

- Watershed Inflow -- cumulative inflow at all junctions from RUNOFF module or from user created .gut file
- Node Storage -- timestep storage at all junction resulting from inflows greater than user defined inflow capacities

- Hydrograph Excess -- sum of all watershed inflows that didn't enter the pipe conveyance system from RUNOFF due to limited downstream pipe capacity
- System Inflow -- cumulative difference between the watershed inflow and the hydrograph excess and node storage
- System Outflow -- cumulative flow out of the system
- Inflow from Flooding -- cumulative flow entering the pipe conveyance system through street inlets from flooding in the streets
- Surcharge to Street -- cumulative flow entering the streets due to pipe surcharging
- Volume in Street -- cumulative volume in street
- Pumpback Volume -- cumulative volume in pumpback storage

Page 8. Page eight is the detailed water balance time history for junctions (nodes) selected for detailed water balance printout. For each print cycle, the watershed inflow, node storage, hydrograph excess, system inflow, system outflow, inflow from flooding, surcharge to street, volume in street, and pumpback volume are given. The definition of the headings in the detailed water balance are the same as for the cumulative inflow and outflow summary, but are for one junction only.

Page 9. The detailed Time History Of The Hydraulic Grade Line, for each of the junctions specified for detailed printouts, is on page nine of the output. Each junction is described with a number and ground elevation. Three columns of results are given for each junction: water surface elevation, depth, and overflow flooding depth in the street. These results are printed for each print cycle.

Page 10. Page ten of the output contains the Summary Statistics for Junctions. The summary statistics are given in one line for each junction in the model. The values summarized for each junction in the system are:

- Junction number;
- Junction ground elevation;
- Crown elevation of the uppermost pipe in the junction;
- Maximum computed depth and its time of occurrence;
- Maximum water surface elevation;
- Number of feet the maximum computed depth is below the ground elevation;
- Length of time the junction is surcharged (water surface elevation above the crown elevation of the uppermost pipe in the junction); and
- Maximum flooded volume and depth in the street above the junction, time of occurrence of the maximum flooding depth, and the length of flooding (flood depth >0). The area of influence of the flooding information is defined as half the length of each overflow section (conduit) connected to the junction.

Page 11. The detailed flow history for each of the conduits specified for detailed printouts, is on page eleven of the output. Three values are given at each timestep for the specified conduits: flow and velocity in the conduit, and overflow flooding flows in the street above the conduit. Negative numbers for the any of the values indicate flows that are going counter to the direction of the conduit indicated in the Internal Connectivity Information on page four.

Page 12. Page twelve of the output contains the Summary Statistics for Conduits. The summary statistics are given in one line for each junction in the model. The values summarized for each junction in the system are:

- Conduit number and upstream and downstream junctions (nodes);
- Design flow (cfs) and velocity (fps) for the conduit (conduit flowing full, no surcharging);
- Vertical size of the conduit (ft);
- Maximum computed flow (cfs) and time of occurrence;
- Maximum computed velocity (fps) and time of occurrence;
- Ratio of the maximum computed flow to the design flow;
- Maximum water surface elevation at the upstream and downstream junctions (nodes); and
- Maximum overflow flooding flows (cfs)in the street above the conduit and time of occurrence.

3.6 DEBUGGING AND STABILIZATION HINTS

This section has described in detail the individual data elements that make up the input file for the EXTRAN Block of SSWMM96. Carefully following the instructions given in preceding sections will help to ensure that the input data file is as error-free and correct as possible.

3.6.1 Important Limitations

It is important to remember that EXTRAN has limitations which must be taken into account when using the model to solve a real-world problem. Overstepping the bounds set by these limitations can result in the model "blowing up" or becoming unstable and terminating execution. Even more serious, the model may run to completion but the output data may be erroneous. Some of the significant limitations are:

1. Headloss at manholes, expansions, contractions, bends, etc. are not explicitly accounted for in EXTRAN. These losses must be simulated by adjusting the value of Manning's friction factor (n) in the conduits upstream and/or downstream of the junction at which the losses occur.

2. Changes in hydraulic grade line due to rapid expansions or contractions are neglected. At expansions, the headloss will tend to equalize the heads, but at contractions the headloss could aggravate the problem.

3. EXTRAN is not capable of simulating water quality transport.

3.6.2 Calibration

EXTRAN was developed using the full dynamic flow equations, which have been proved to give reasonably accurate results in simulating surcharged and unsurcharged flow in conveyance systems. Unlike RUNOFF, EXTRAN has few estimated parameters and assumptions. The simulation is based on a description of the physical system being modeled. During the model testing and calibration, the following elements should be checked:

1. Connectivity. Errors in EXTRAN are very often a result of input data errors. Some important parameters to check are: pipe invert elevations, pipe sizes, ZPs, and pump specifications. The internal connectivity summary in the output data must be carefully checked to insure that conduit and junction connections are correct. Many problems encountered during calibration can be traced back to input data problems.

2. Input Data Verification. During model verification, all system description parameters must be checked carefully to insure that they match the actual system being modeled.

3. Continuity. One of the best indicators of proper model operation is the percent error in continuity listed at the bottom of page six of the output from EXTRAN. This error should always be less than ten percent. If it is greater than five percent it is suggested that the input data be checked carefully for input data errors (see 1 above) or instabilities (see 3 below).

4. Oscillations. Large and rapid oscillations in junction water surface elevations or in flow and velocity in conduits are also good indicators of numerical instabilities in the EXTRAN simulation. Check for conduits that are too short and/or rerun the simulation with a lower ΔT.

5. Excessively High Velocity. At times the numerical solution to the flow equations will result in conduit velocities that are not feasible. It is always a good idea to check the conduit design velocity in the Summary Statistics for Conduits in the output data against the maximum computed velocity. If the maximum computed velocity is significantly higher than the design velocity, it is likely that the model has become numerically unstable at that location.

6. Total Inflow. If there are big differences between the observed and computed hydrographs, many times they are due to problems that are carried over from RUNOFF. Be sure to check the RUNOFF output carefully before attempting to calibrate or verify EXTRAN.

Other items that are important to consider when calibrating an EXTRAN model are:

1. Steady Flows. The first simulation to try with a newly created EXTRAN input data set is a steady flow simulation. First, run the simulation with steady flows and free outfalls. This may highlight many problems in the input data. Second, add any pumps to the simulation and run again with steady flows. Finally, when both of these simulations work, add the inflow hydrographs from RUNOFF. Remember, if it doesn't work with steady flow, it certainly won't work with unsteady inflow hydrographs.

2. Junction Losses. The EXTRAN block ignores junction losses as mentioned above as a limitation. To correct for junction losses where needed, the user should increase the Manning's n roughness coefficient for the pipe downstream of the junction. In this way the losses in the pipe can be adjusted to represent the junction losses that would otherwise occur.

3. Flow and Depth Measurements. Accurate calibration of EXTRAN requires both flow and depth measurements. Depth measurements are relatively easy to obtain by installing automatic stage recorders at various locations. Flows, on the other hand, require measurement of both velocity and depth, which can be very difficult, especially in pipes flowing full. Velocities may vary widely across the pipe section and velocity instruments are prone to failure and inaccuracy. For this reason, calibration is normally achieved by comparing depth only. In many areas this may provide satisfactory results.

3.6.3 Fatal Error Messages

The following error messages are "fatal" and will cause EXTRAN to terminate prematurely.

1A. `**** ERROR 1A **** CONDUIT` *`XX`* `HAS FLOW AREA EQUAL TO ZERO.` There is an error in the input data for conduit *XX*. The diameter has been set to zero. Check input data and set conduit diameter or depth to a number greater than zero.

1B. `**** ERROR 1B **** CONDUIT` *`XX`* `HAS LENGTH EQUAL TO ZERO.` There is an error in the input data for conduit *XX*. The length has been set to zero. Check input data and set conduit length to a number greater than zero.

2. `**** ERROR 2 **** JUNCTION` *`XX`* `IS ASSOCIATED WITH MORE THAN 8 PIPES.` Each junction may have up to eight pipes connected to it. Junction *XX* has passed that limit. Check the input data and renumber junctions and required.

3. `**** ERROR 3 **** JUNCTION` *`XX`* `IS ASSOCIATED WITH MORE THAN 8 PIPES INCLUDING ORIFICES.` See (2) above.

4. `**** ERROR 4 **** JUNCTION` *`XX`* `IS ASSOCIATED WITH MORE THAN 8 PIPES INCLUDING WEIRS.` See (2) above.

5. `**** ERROR 5 **** JUNCTION` *`XX`* `IS ASSOCIATED WITH MORE THAN 8 PIPES INCLUDING PUMPS.` See (2) above.

6. `**** ERROR 6 **** JUNCTION` *`XX`* `IS ASSOCIATED WITH MORE THAN 8 PIPES INCLUDING FREE OUTFALLS.` See (2) above.

7. `**** ERROR 7 **** JUNCTION` *`XX`* `ON CONDUIT` *`YY`* `IS NOT CONTAINED IN JUNCTION DATA.` The input data indicates that conduit *YY* is connected to Junction *XX*. Junction *XX* is not in the Junction Elements Data Section. Check input data.

8. `**** ERROR 8 **** CONDUIT XX HAS CAUSED ZCROWN OF JUNCTION YY TO LIE ABOVE THE SPECIFIED GROUND ELEV.` The elevation of the junction YY invert, plus the ZP for conduit XX, plus the diameter or depth of conduit XX, results in a top-of -conduit elevation higher than the ground elevation specified for junction YY. Check input data.

9. `**** ERROR 9 **** ALL CONDUITS CONNECTING` *`XX`* `TO JUNCTION` *`YY`* `LIE ABOVE THE JUNCTION INVERT.` EXTRAN requires that at least one of the conduits connecting to a junction have the same invert elevation as the junction (ZP=0). Check input data.

10. `**** ERROR 10 **** STORAGE JUNCTION` *`XX`* `IS NOT CONTAINED IN JUNCTION DATA.` A storage junction was specified that was not described as part of the Junction Data Section. Check the input data and either correct the storage junction number or add the storage junction to the junction data.

11. `**** ERROR 11 **** ORIFICE JUNCTION` *`XX`* `IS NOT CONTAINED IN JUNCTION DATA.` An orifice junction was specified that was not described as part of the Junction Data Section. Check the input data and either correct the orifice junction number or add the orifice junction to the Junction Data Section.

12. `**** ERROR 12 **** ORIFICE TOP LIES ABOVE GROUND ELEVATION AT JUNCTION` *`XX`*`.` The specified orifice diameter, plus the specified distance above the junction invert, when added to the junction invert elevation, is higher than the specified ground elevation for Junction *XX*. Check input data.

13. `**** ERROR 13 **** WEIR JUNCTION` *`XX`* `IS NOT CONTAINED IN JUNCTION DATA.` All weir junctions must be described in the Junction Elements Data Section. Check input data and either correct the weir junction number or add the weir junction to the Junction Elements Data Section.

14. `**** ERROR 14 **** PUMP JUNCTION` *`XX`* `IS NOT CONTAINED IN JUNCTION DATA.` All pump junctions must be described in the Junction Elements Data Section. Check input data and either correct the pump junction number or add the pump junction to the Junction Elements Data Section.

15. `**** ERROR 15 **** FREE OUTFALL JUNCTION` *`XX`* `IS NOT CONTAINED IN JUNCTION DATA.` All free outfall junctions must be described in the Junction Elements Data Section. Check input data and either correct the free outfall junction number or add the free outfall junction to the Junction Elements Data Section.

16. `**** ERROR 16 **** FLAP (TIDE) GATE JUNCTION` *`XX`* `IS NOT CONTAINED IN JUNCTION DATA.` All flap (tide) gate junctions must be described in the Junction Elements Data Section. Check input data and either correct the flap gate junction number or add the flap gate junction to the Junction Elements Data Section.

17. `**** ERROR 17 **** FLAP (TIDE) GATE JUNCTION` *`XX`* `IS ASSOCIATED WITH MORE THAN 1 PIPE.` A flap (tide) gate junction may be connected to only one pipe. Check input data and remove the extra pipe(s), or if required add a junction and pipe upstream of the flap gate junction.

18. `**** ERROR 18 **** JUNCTION` *`XX`* `REQUESTED FOR PRINTOUT IS NOT CONTAINED IN JUNCTION DATA.` All junctions requested for printout must be described in the Junction Elements Data Section. Check input data and correct the junction number in the junction printout section.

19. `**** ERROR 19 **** MORE THAN ONE PIPE IS INFLUENT TO PUMP JUNCTION` *`XX`*`.` The pump type for junction *XX* was specified as an off-line pump. Off-line pumps are allowed to have only one influent pipe. Check input data and either change the pump type to on-line, or remove influent pipes until there is only one influent pipe to the junction.

20. `**** ERROR 20 **** FREE OUTFALL JUNCTION` *`XX`* `IS ASSOCIATED WITH MORE THAN 1 PIPE.` A free outfall junction may be connected to only one pipe. Check input data and remove the extra pipe(s), or if required add a junction and pipe upstream of the free outfall junction.

21. `**** ERROR 21 **** CONDUIT` *`XX`* `REQUESTED FOR PRINTOUT IS NOT CONTAINED IN CONDUIT DATA.` All conduits requested for

printout must be described in the Conveyance Elements Data Section. Check input data and correct the conduit number in the conduit printout section.

22. `**** ERROR 22 **** "NI" IN THE TIDAL DATA SHOULD BE LESS THAN 50.` Reduce the number of tidal information points to less than 50.

23. `**** ERROR 23 **** PROGRAM CANNOT MATCH HYDROGRAPH AT NODE` *XX* `TO JUNCTION DATA.` An inflow hydrograph has been specified at node (junction) *XX*. This junction number does not exist in the Junction Elements Data Section. Check input and either add the junction to the Junction Elements Data Section, or change the output node number in the RUNOFF block input data and rerun RUNOFF to create the correct inflow hydrographs.

24. `**** ERROR 24 **** "NJO" IN COMMON.INC SHOULD BE GREATER THAN` *XX*. The number of junctions that have been specified as input to this simulation is greater than the dimensioned number of junctions (NJO). The parameter NJO in the file COMMON.INC must be increased, and the EXTRAN block must be recompiled and relinked if it is necessary to run a simulation with the current number of junctions.

25. `**** ERROR 25 **** "NSTORO" IN COMMON.INC SHOULD BE GREATER THAN` *XX*. The number of storage junctions specified in the input data is greater than the allowable dimension (NSTORO). If the number of storage junctions specified in the input data is required for this simulation, the parameter NSTORO in COMMON.INC must be increased and the entire EXTRAN block must be recompiled and relinked before running the simulation.

26. `**** ERROR 26 **** "NORIFO" IN COMMON.INC SHOULD BE GREATER THAN` *XX*. The number of orifices specified in the input data exceeds the allowable dimension (NORIFO). If the number of orifices specified in the input is required for this simulation, the parameter NORIFO in COMMON.INC must be increased and the entire EXTRAN block must be recompiled and relinked before running the simulation.

27. `**** ERROR 27 **** "NPUMPO" IN COMMON.INC SHOULD BE GREATER THAN` *XX*. The number of pumps specified in the input data exceeds the allowable dimension (NPUMPO). If the number of pumps specified in the input is required for this simulation, the parameter NPUMPO in COMMON.INC must be increased and the entire EXTRAN block must be recompiled and relinked before running the simulation.

28. `**** ERROR 28 **** "NFREEO" IN COMMON.INC SHOULD BE GREATER THAN` *XX*. The number of free outfalls specified in the input data

exceeds the allowable dimension (NFREEO). If the number of free outfalls specified in the input is required for this simulation, the parameter NFREEO in COMMON.INC must be increased and the entire EXTRAN block must be recompiled and relinked before running the simulation.

29. `**** ERROR 29 **** "NGATEO" IN COMMON.INC SHOULD BE GREATER THAN` *`XX`*`.` The number of flap (tide) gates specified in the input data exceeds the allowable dimension (NGATEO). If the number of flap gates specified in the input is required for this simulation, the parameter NGATEO in COMMON.INC must be increased and the entire EXTRAN block must be recompiled and relinked before running the simulation.

30. `**** ERROR 30 **** "NWEIRO" IN COMMON.INC SHOULD BE GREATER THAN` *`XX`*`.` The number of weirs specified in the input data exceeds the allowable dimension (NWEIRO). If the number of weirs specified in the input is required for this simulation, the parameter NWEIRO in COMMON.INC must be increased and the entire EXTRAN block must be recompiled and relinked before running the simulation.

31. `**** ERROR 31 **** TOTAL NUMBER OF JUNCTIONS (INCLUDING WEIRS) EXCEED PROGRAM DIMENSIONS, NJ=`*`XX`*`.` Total number of junctions, including weirs, orifices, pumps, and outfalls, specified in the input data exceeds the allowable dimension. If the number of junctions specified in the input is required for this simulation, the parameter NJO in COMMON.INC must be increased and the entire EXTRAN block must be recompiled and relinked before running the simulation

32. `**** ERROR 32 **** TOTAL NUMBER OF CONDUITS EXCEEDS, PROGRAM DIMENSIONS, NTLO=`*`XX`*`.` Total number of conduits specified in the input data exceeds the allowable dimension. If the number of conduits specified in the input is required for this simulation, the parameter NCO in COMMON.INC must be increased and the entire EXTRAN block must be recompiled and relinked before running the simulation

33. `**** ERROR 33 **** ORIFICE OUTLET AT JUNCTION` *`XX`* `IS HIGHER THAN INLET.` The ZP of the junction specified as the outlet to orifice *XX* is higher than the orifice inlet. Either raise the orifice or lower the outlet junction.

34. `**** ERROR 34 **** THE INVERT OF CONDUIT` *`XX`* `LIES ABOVE THE CROWN OF ALL OTHER CONDUITS AT JUNCTION` *`YY`*`.` A gap between the crown of a conduit and the invert of the next highest conduit is not allowed at a junction. One solution to the problem is to bridge the gap with a "dummy" pipe that has an invert below the crown of the lower pipe and a crown above the invert of the high pipe. The "dummy" pipe leads to a junction

with no outlet. Another solution to the problem is to designate the junction as a storage junction. Gaps are allowed to occur at storage junctions.

35. `**** ERROR 35 **** CONDUIT` *`XX`* `IS LISTED TWICE IN INPUT DATA.` Two lines of conduit data have been given the same number. Check your data file and renumber one of the conduits.

36. `**** ERROR 36 **** JUNCTION` *`XX`* `IS LISTED TWICE IN INPUT DATA.` Two lines of junction data have been given the same number. Check your data file and renumber one of the junctions.

37. `**** ERROR 37 **** CONDUIT` *`XX`* `SPECIFIED FOR PUMPBACK IS NOT CONTAINED IN CONDUIT DATA.` The conduit specified in the pumpback option to be used for determining the pumpback rate from storage is not contained in the conduit data. Check your data and either enter the correct conduit information to the conveyance element data section, or change the pumpback conduit number in the pumpback data.

38. `**** ERROR 38 **** JUNCTION` *`XX`* `SPECIFIED FOR PUMPBACK STORAGE CANNOT BE IN DETAILED HEAD PRINTOUT.` Detailed head printout is not applicable to the junctions at which pumpback to the system is implemented. Remove the reference to junction *XX* from the list of junctions where heads are to be printed.

39. `**** ERROR 39 **** ERROR READING THE HOT START FILE.` The file specified as the hot start file was not found or was not a legal hot start file. Check the file name and type, then rerun EXTRAN.

40. `**** ERROR 40 **** ERROR WRITING THE HOT START FILE.` An error occurred while writing the hot start data to a file. The probable cause for this error is insufficient room on the disk. Check your disk and rerun EXTRAN.

41. `**** ERROR 41 **** JUNCTION XX TIDE OR STAGE BOUNDARY CONDITION YY NOT INPUT CORRECTLY.` A tide or stage boundary condition was specified but not supplied in the tide or stage data.

42. `**** ERROR 42 **** FOUR TIDE POINTS DO NOT FALL IN THE TIDAL PERIOD.` The tide data given for calculating the tidal coefficients is outside of the specified tidal period.

3.6.3 Termination of Execution Error Message

`**** EXECUTION TERMINATED BECAUSE OF XX DATA ERROR(S) ****.` A total of XX errors have been found in the input data for this simulation. Program execution was terminated. Check input data error descriptions in output file. Correct errors and rerun EXTRAN.

3.6.4 Warning Messages

The following warning messages will not cause EXTRAN to terminate, but may cause the program to produce erroneous results. The user should carefully check the input data for the conduits and junctions specified in the warning message(s) and should make the appropriate changes. The output at the specified locations should also be checked carefully for instabilities and other possible problems.

1. `**** WARNING 1 **** (C*DELT/LEN) IN CONDUIT` *XX* `IS` *YY.Y* `AT FULL DEPTH.` The length of conduit *XX* is probably too short for the given timestep (DELT). Either shorten the timestep, or lengthen the pipe as required. Otherwise, check the output around conduit XX for instability.

2. `**** WARNING 2 **** JUNCTION` *XX* `IS NOT ASSOCIATED WITH ANY PIPE.` A junction was specified in the Junction Elements Data Section but was not connected to a conduit in the Conveyance Elements Data Section

3. `**** WARNING 3 **** JUNCTION` *XX* `IS NOT ASSOCIATED WITH ANY OVERFLOW CONVEYANCES.` No overflow sections have been specified for the conduits connected to this junction. Overflow routing will not occur at this junction unless overflow sections are added to the conduits.

4. `**** WARNING 4 **** AT STORAGE JUNCTION` *XX* `AREA DECREASES BETWEEN STAGES` *YY* `AND` *ZZ*. Area must increase with increasing stage in the irregular storage junction.

5. `**** WARNING 5 **** SIMULATION STARTS BEFORE TIME HISTORY OF STAGE BEGINS FOR STAGE BOUNDARY CONDITION XX; PROGRAM DEFAULTS TO THE FIRST STAGE VALUE.` The simulation start time is earlier than the start time specified in the stage boundary condition input data. The program will use the first given stage data point for all simulation times prior to the first point.

6. `**** WARNING 6 **** SIMULATION CONTINUES AFTER THE TIME HISTORY OF STAGE ENDS FOR STAGE BOUNDARY CONDITION XX; PROGRAM DEFAULTS TO THE LAST STAGE VALUE.` The simulation end time is past the end of the data in the stage boundary condition input data. The program will use the last given stage data point for all simulation times after the last point.

3.7 EXTRAN GRAPHS

In the System Parameters Section of the EXTRAN input data, the user specifies junctions or conveyance elements to be printed out (NHPRT, JPRT(i), NQPRT, CPRT(i)). EXTRAN also saves these same hydrographs to special junction and conduit plotting files that are saved with the extensions of .PLJ and .PLC, respectively. The graphics program supplied with SSWMM96, SWMGRAPH, can plot the junction water surface elevation data saved in the .PLJ file as well as the conduit discharge data saved in the .PLC file. It can also plot the inflow hydrographs found in the .GUT files created by RUNOFF. Table 3-3 contains the commands that were used to plot an example junction water surface elevation graph. Required user input is underlined in the table. The graphics program will display each of the available data plots one at a time.

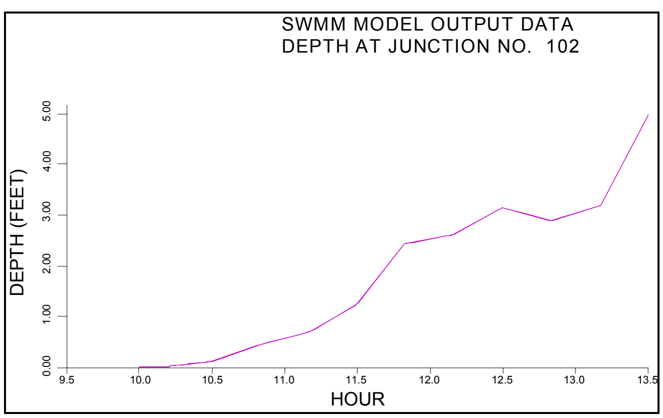
TABLE 3-3
HYDROGRAPH PLOTTING EXAMPLE

```
Windows;C:\SWMM\GRAPHICS>SWMGRAPH

 Initialize Program for Screen Viewing:
         1. Monochrome screen
         2. Color screen
Enter Number> 2

Enter Name of Input Data File For Plotting> EXTRAN.PLJ
Plot Elevation or Depth?(E/D)> D
READY TO DISPLAY DRAWING.
Press <return> when ready to continue.↵
```

Example EXTRAN Graph




```
Hardcopy? (Y/N)> N
Would You Like Other Plots from the Same Data?(Y/N)> N
Would You Like Plots from Different Data?(Y/N)> N
Stop - Program terminated.
```

SECTION 4

HEC-1 HYDROGRAPHS

4.1 INTRODUCTION

The HEC-1 model developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) is designed to simulate the surface runoff response of a watershed to precipitation. This is accomplished by representing the watershed as an interconnected system of hydrologic and hydraulic components. Each model component represents a specific aspect of the rainfall-runoff processes occurring in a portion of the watershed. A component may represent the runoff occurring in a subbasin, the routing of flows down a stream channel, or the routing of flows through a reservoir. Description of the components of a model requires estimation of a set of parameters that describes the hydrologic and hydraulic characteristics of the components. Parameters describing the various components of the model are based on land use, soils, vegetation, and topography. For example, the land use in a subbasin will determine the percent of that subbasin that is impervious and the average condition of the drainage channels. The end result of the modeling process is the computation of streamflow hydrographs (including peak flows) at specified locations throughout the watershed.

HEC-1 provides a wide variety of rainfall-runoff simulation methods, including:

- Synthetic Unit Hydrographs
  - Clark Unit Hydrograph
  - Snyder Unit Hydrograph
  - SCS Dimensionless Unit Hydrograph
  - User-defined Unit Hydrograph
- Kinematic Wave Overland Flow Routing

Land surface interception, depression storage, and infiltration are referred to in the HEC-1 model as precipitation losses. The losses may be represented in a variety of ways:

- Initial and Uniform Loss Rate
- Exponential Loss Rate
- SCS Curve Number
- Holtan Loss Rate
- Green and Ampt Infiltration Function

The output file from HEC-1 is run through a post-processor (POSTHEC1) that prepares hydrograph input files for use with either RUNOFF or EXTRAN.

4.2 INPUT DATA PREPARATION

Detailed instructions for preparing HEC-1 input data are given in the "HEC-1 Flood Hydrograph Package User's Manual" (HEC 1990). This section of the SSWMM96 User's Manual will describe the procedure used to modify HEC-1 hydrograph output for use in SSWMM96.

In order for the hydrographs from HEC-1 to be used in either RUNOFF or EXTRAN, each subbasin for which a SSWMM96 hydrograph is wanted must have a KO card with a 1 in the first field indicating that all output should be printed for that subbasin. Care must be taken to insure that the names (on the KK card for each subbasin) used to describe the hydrograph locations correspond to the proper location in the SSWMM96 programs. For routing in RUNOFF, the name should be the same as the subcatchment number.

A program (POSTHEC1) has been developed to modify HEC-1 output and put it into a form usable by RUNOFF or EXTRAN, as needed. This program reads in the HEC-1 output and then, depending on the instructions from the user, processes it into a form that RUNOFF or EXTRAN can use as inflow hydrographs.

4.3 EXAMPLE

Table 4-1 illustrates the sequence of commands to run POSTHEC1 for creation of a RUNOFF or EXTRAN inflow hydrograph file. User inputs are underlined for clarity.

TABLE 4-1
HEC-1 POSTPROCESSOR EXAMPLE

```
C:>POSTHEC1
 HEC-1 SSWMM96 Post-Processor
 Montgomery Watson Americas, Inc., January 1996

Enter the HEC-1 Output File Name> HEC1.OUT
HEC1.gut     Already exists. Overwrite?(Y,N)> Y
Are Hydrographs to be used in 1) RUNOFF or
                              2) EXTRAN? > 2
Delt=       5.000000
NHR,NMN=           8           55
Intervals=         179
Reading Hydrograph for Subcatchment        1031
Reading Hydrograph for Subcatchment        1051
Reading Hydrograph for Subcatchment        1061
Reading Hydrograph for Subcatchment        1082
Reading Hydrograph for Subcatchment        1083
Stop - Program terminated.
```