TECHNICAL MEMORANDUM

PEAK RUNOFF ESTIMATION FROM UNDEVELOPED LANDS

by

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EXECUTIVE SUMMARY

This memorandum presents comprehensive documentation of the computer model PEAKQ (formerly known as WSHS1). PEAKQ estimates peak runoff rates from undeveloped lands and is the model that was used to develop the peak runoff rate curves as presented in the South Florida Water Management District's publication, Management and Storage of Surface Waters, PERMIT INFORMATION MANUAL, VOLUME IV (1988).

In the solution algorithm of PEAKQ two simultaneous equations, Manning's overland flow equation (Manning's equation for very wide channels) and the continuity equation, are solved to determine the runoff rate and depth of water on the watershed at discrete time intervals. The highest runoff rate during the period of simulation is identified as the peak runoff rate for the watershed for the given storm conditions. Optionally, the runoff and stage hydrographs for the period of simulation may be written to a file.

Two abstractions are accounted for by the model: depression storage and infiltration. Evapotranspiration is considered negligible. Infiltration is modeled by Horton's equation.

Several user inputs are necessary to the model: the 24-hr rainfall amount, the surface area of the watershed, the average slope of the watershed, the overland flow length, and the depth of available groundwater storage. There are several optional inputs to the model: the depression storage, Manning's roughness coefficient, the rainfall duration, and the infiltration constants for the Horton equation. If values for these optional parameters are not specified, default values are assumed. The shape of the rainfall hyetograph is assumed by the model.

Recently Capece et al (1986) compared several models, (i.e., a slightly modified PEAKQ, Cypress Creek Formula, CREAMS, SCS-Chart, and SCS Unit Hydrograph) to field data from five small undeveloped watersheds in the lower Kissimmee River basin and in the Taylor Creek-Nubbin Slough basin. Overall the modified PEAKQ made the best estimates of the peak runoff rate of the five models.

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ABSTRACT

Comprehensive documentation of the computer model PEAKQ (formerly known as WSHS1) is presented. PEAKQ estimates peak runoff rates from undeveloped lands and is the model that was used to develop the peak runoff rate curves as presented in the South Florida Water Management District's publication, Management and Storage of Surface Waters, PERMIT INFORMATION MANUAL, VOLUME IV (1988).

I. INTRODUCTION

This memorandum presents comprehensive documentation of the computer model PEAKQ (formerly known as WSHS1). PEAKQ estimates peak runoff rates from undeveloped lands and is the model that was used to develop the peak runoff rate curves as presented in the South Florida Water Management District's publication, Management and Storage of Surface Waters, PERMIT INFORMATION MANUAL, VOLUME IV (1988).

The South Florida Water Management District has charge of permitting all surface water management systems within its boundaries. Where the District does not have other specific basin discharge criteria for the receiving waters, all post-development discharges must be less than or equal to pre- development discharges as defined in Rule 40E-4.091 of the Florida Administrative Code (SFWMD, 1987).

In these cases, proper design of a surface water management system requires knowledge of the highest rate at which water is expected to be discharged from the area to be developed prior to its being developed. This highest discharge rate is known as the peak runoff rate.

For many projects it is not practical or cost effective to do a detailed hydrologic investigation of the project site to determine the peak runoff rate. A simple model was developed by the SFWMD (Higgins, 1979) to provide an estimate of the peak runoff rate from an undeveloped area for a particular design storm. This model, with certain modifications[1], was used to develop the peak runoff curves for undeveloped watersheds found in Part C of Management and Storage of Surface Waters, PERMIT INFORMATION MANUAL, VOLUME IV (SFWMD, 1988).

PEAKQ is a user friendly, micro computer version of the model used to develop the runoff curves in Volume IV and can be used in place of the runoff curves. The main advantage of PEAKQ over the runoff curves is that any case may be analyzed without interpolation between curves. The computer version requires the same input as the runoff curves. Additionally parameters that were assumed in creating the runoff curves may be changed by the user from those assumed values. A user's manual for execution of the micro-computer version of the model is included as an appendix to this report.

A. Applicability of the Model to South Florida

PEAKQ is a simple model and does not actually mimic the physical processes of overland runoff. Values of peak runoff rates obtained from PEAKQ will be approximate and in some cases these values will greatly overestimate or underestimate the actual peak runoff rate. Better results could be obtained by more sophisticated models. In general, however, neither time nor money is available in the permitting process to collect the data for and to implement these models.

[1]Some of the original parameter estimates recommended by Higgins were changed. These estimates are discussed in a second technical memorandum entitled "A Procedure for the Estimation of Sheetflow Runoff in the South Florida Water Management District" (Gauthier, 1980). This document and Higgin's original work are available on request.

In our opinion, it is sufficient to expect that the results obtained from a simple model such as PEAKQ to be on average "conservative". For PEAKQ's particular regulatory use, conservative can be defined as underestimating the actual peak runoff rate on average for a particular drainage basin. To verify that PEAKQ is indeed conservative, the results of the model should be compared with field data under a variety of rainfall and watershed conditions and should be calibrated and re-verified as required. To our knowledge, no such comparisons were made prior to the use of this model to develop the peak runoff curves for undeveloped watersheds found in Part C of Management and Storage of Surface Waters, PERMIT INFORMATION MANUAL, VOLUME IV (SFWMD, 1988).

Recently Capece et al. (1986) compared several models, (i.e., a modified PEAKQ, Cypress Creek Formula, CREAMS, SCS-Chart, and SCS Unit Hydrograph) to field data from five small undeveloped watersheds in the Lower Kissimmee River Basin and in the Taylor Creek-Nubbin Slough Basin. For these tests, PEAKQ was modified from the version used by the District in an effort to calibrate the model to the rain events that occurred during the period of the study. Of the modifications to PEAKQ, the most significant was a reduction in the depression storage from 2.0 inches to 0.25 inches.

Overall the modified PEAKQ made the best estimates of peak runoff rate of the five models. It was the only model to under-predict runoff from any of the watersheds (three out of five). In one case however the model greatly over-predicted (by 479 percent) the runoff. This particular watershed had a very short length in comparison to its width. Note that since the District's version of PEAKQ uses a greater value of depression storage than the version tested by Capece et al., the estimates of peak runoff rate made by the District's version are probably lower (and more conservative) than those made by the version of PEAKQ used by Capece et al.

The work done by Capece et al. suggests that in general the District's version of PEAKQ underestimates peak runoff rates from flatwoods watersheds and is conservative. Peak runoff rates from watersheds with very short runoff lengths may still be over-predicted by the model, however.

Note that the data set used by Capece et al. was limited to small rainfall events. For larger rainfall events, in particular those used in design of surface water management systems, PEAKQ remains untested. Capece et al., recommended, and we concur, that further analysis is necessary with a more extensive data set to truly test the applicability of any of the five models to the watershed and rainfall conditions of South Florida.

I. BASIC CONCEPTS

Several things happen to rain after it falls to earth: it may seep into the ground, it may evaporate, it may be transpired by vegetation, it may be stored as surface water, or it may flow overland to another location. At the beginning of a rain event, most of the rain falling to earth will seep into the ground. This seeping of rainwater into the ground is known as infiltration. As the pore space in the ground fills up with rainwater, the rate at which infiltration occurs gradually decreases. When the rate at which the rain falls exceeds the infiltration rate, rainwater will begin to pool on the ground surface. Because the rainwater collects in small depressions on the ground surface, this pooling is known as depression storage. These depressions have only a limited storage volume, and when their capacity is exceeded, the excess water will flow overland to the nearest stream or canal. That part of the rainfall that "runs off" the soil surface is termed surface runoff or overland flow. Although evaporation and transpiration (i.e., evapotranspiration) are important factors in the overall water budget of any area, they are probably at a minimum during a rain event.

Infiltration, depression storage, and evapotranspiration are known as abstractions. The sum of the abstractions and runoff equals the amount of rainfall. For our purposes here, evapotranspiration will be considered negligible during the rain event relative to infiltration, depression storage, and surface runoff.

The infiltration rate varies in time and is a function of the amount of water already in the soil and the characteristics of the soil. Soil characteristics affect the amount of water that can be stored in the soil and the rate at which water will pass through the soil at various degrees of saturation.

Depression storage is usually considered to be constant in time. It is a function of the topography of the watershed, and the type and extent of vegetative cover.

The area for which we wish to determine the peak runoff rate is known as a watershed. It is assumed that all of the runoff from the watershed is discharged to the same canal or stream. The rate at which runoff is discharged from a watershed varies in time and is a function of characteristics of the watershed: the size and the slope of the watershed, the roughness of the surface of the watershed, and the depth of water on the watershed. The plot of rate of runoff versus time is known as a hydrograph (Figure 1).

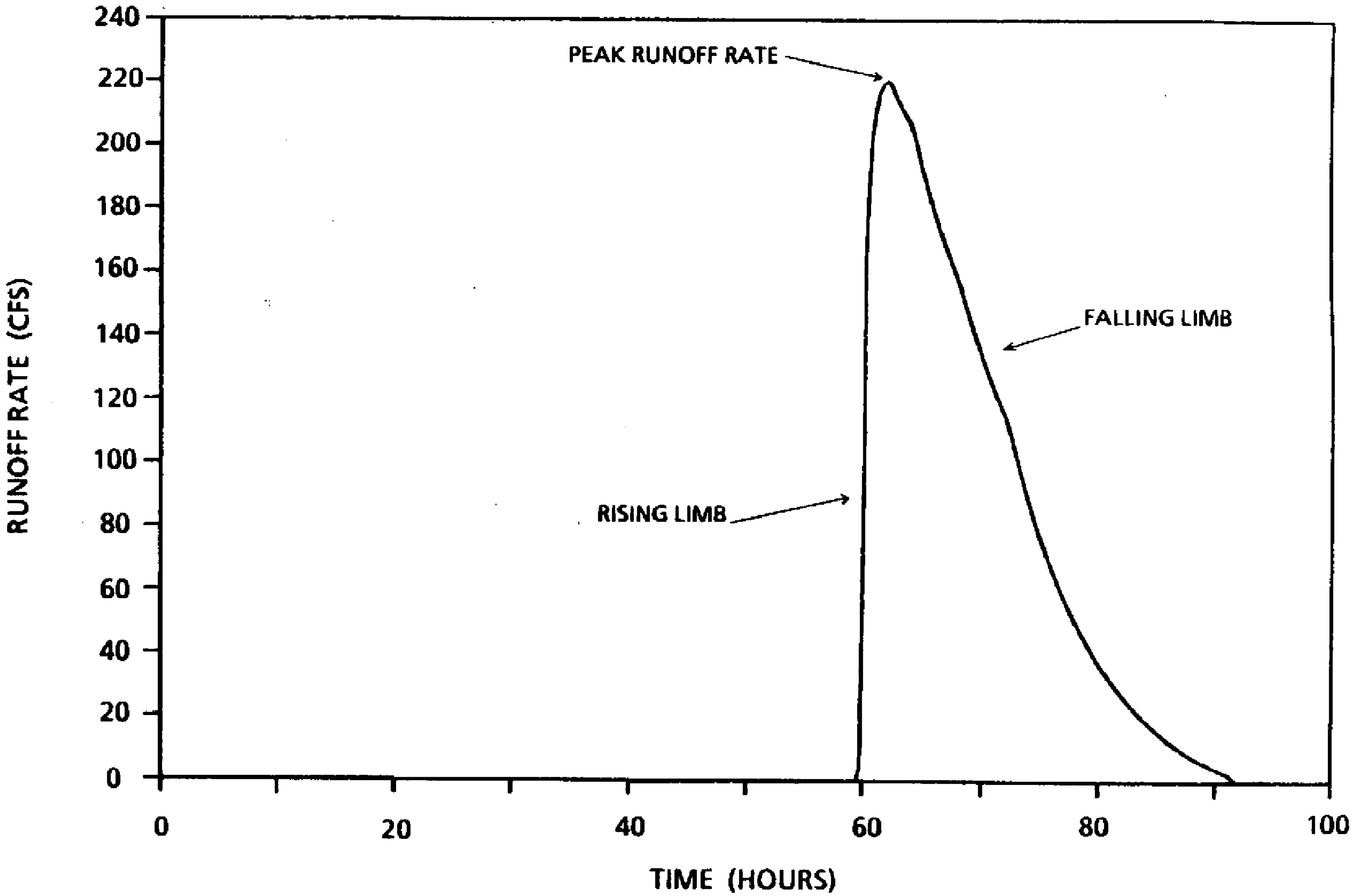


FIGURE 1. A Runoff Hydrograph

III. THE MODEL

A real watershed usually has heterogeneous characteristics. The shape is generally irregular, the soil properties and amount of depression storage vary from place to place, and the relative roughness of the surface is not uniform. To make the issue more complex, the rain falling on the watershed is not distributed uniformly in time or space. Although accounting for these inherent heterogeneities in the watershed characteristics and in the rainfall distribution would make for a more accurate estimate of the peak runoff rate, the computations would be necessarily complex and time consuming. A simpler calculation, although possibly less accurate, is usually more practical. The model described here is based on simplifications of and assumptions about the rainfall distribution and watershed and about the physics of overland flow.

A. Time Intervals

Time is assumed to occur in discrete intervals, or steps, rather than continuously. During each interval of time, all parameters affecting flow on the watershed are assumed to be constant, although these parameters may change from one time step to the next. The time step is assumed to be 15 minutes in this model.

B. Rainfall Distribution

Rainfall intensity is assumed to be the same everywhere in the basin at any given time, but the intensity is assumed to vary with time. The distribution of rainfall intensity with time is termed a hyetograph (Figure 2). Hyetographs of severe storms occurring in South Florida may be of differing magnitudes, but they tend to have similar shapes for storms of the same duration. Because of the similarities in shape, "normalized" hyetographs for various storm durations can be created that are typical by shape of severe storms in South Florida. District runoff models use normalized hyetographs for one- ,three-, and five-day storms. (SFWMD, 1987). To obtain a storm hyetograph of a given duration, the ordinates of the normalized hyetograph of appropriate duration are multiplied by the maximum 24-hour precipitation for the storm.

The model requires as input the amount of the maximum 24-hour precipitation for the storm. The model assumes a three-day storm, but optionally, the user may specify either a one- or five-day storm.

C. Watershed Model

To model the actual watershed, several simplifying assumptions are made (Figure 3). The purpose of these simplifying assumptions is to represent the actual watershed as a wide channel so that Manning's Equation can be used to calculate the flow (see **Governing Equations** below). The watershed is transformed from one

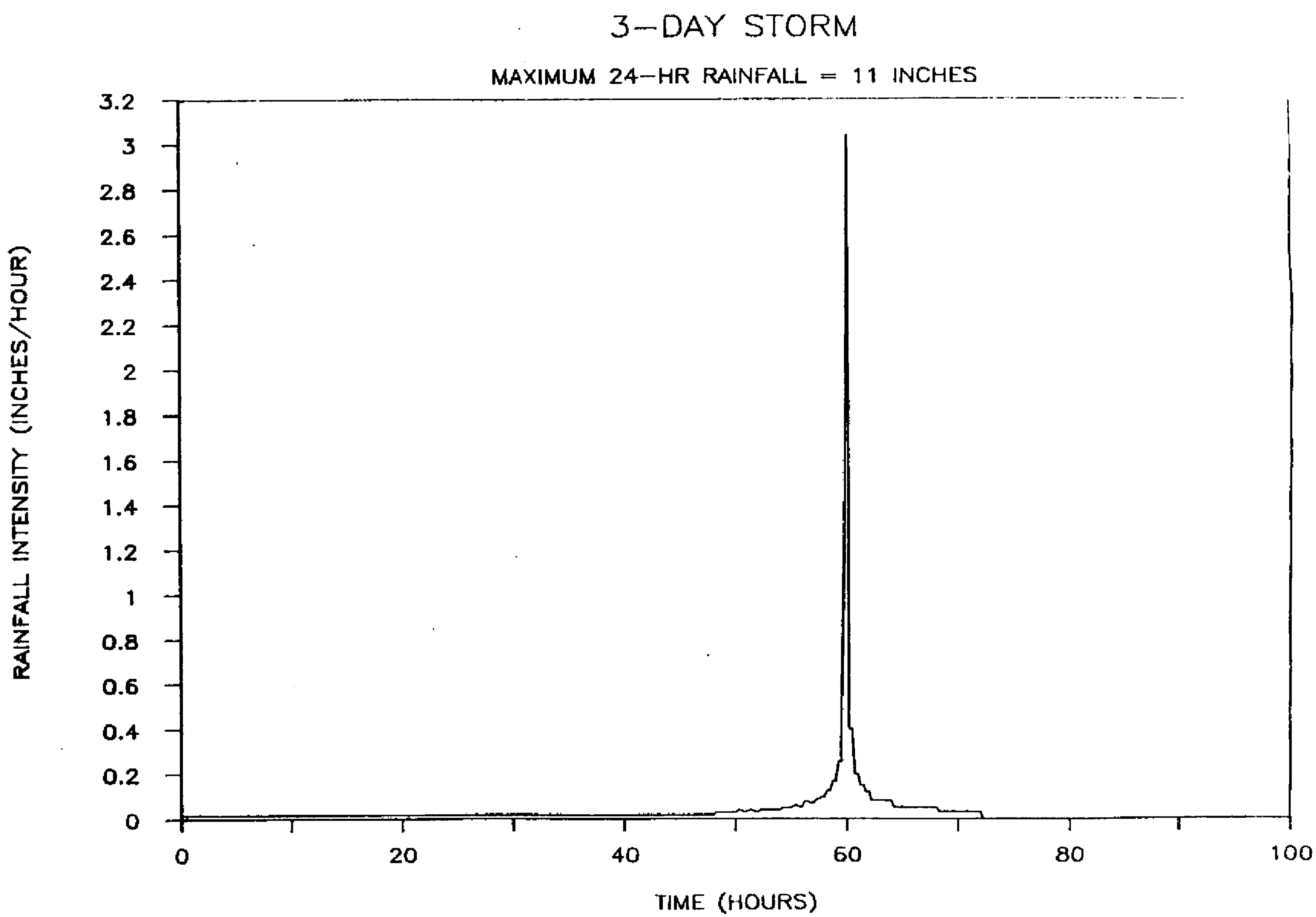


FIGURE 2. A Rainfall Hyetograph

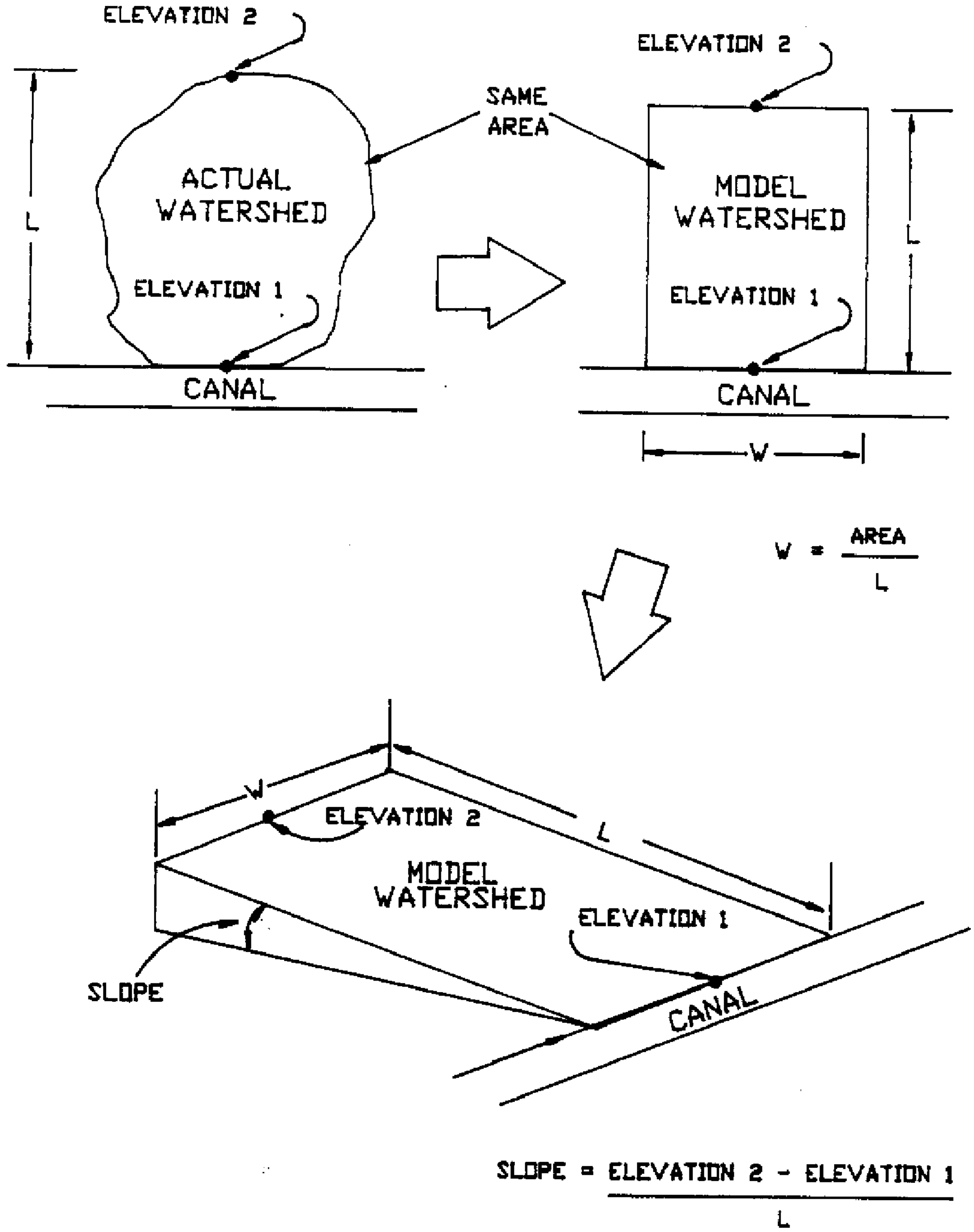


FIGURE 3. Simplification of the Watershed.

of irregular shape to one that is rectangular. The total runoff length, L, and the area, A, of the original watershed are retained. The width, W, of the rectangular model of the watershed is calculated by dividing the area by the runoff length. The slope of the model watershed is assumed to be uniform along its length. It is further assumed that there is no slope across the watershed. The model watershed, then, is the inclined plane shown in Figure 3. It is assumed to have uniform roughness.

The model requires input of the watershed area, the maximum runoff length for the watershed, and the average slope of the watershed. A Manning's roughness coefficient of 0.25 (Higgins,1979) is assumed by the model, although optionally the user may change the value of this parameter from its default value.

D. Hydrologic Abstractions

Two abstractions are accounted for by this model: depression storage and infiltration. A third abstraction, evapotranspiration is assumed to be negligible during a rain event.

i. Depression storage - Actual depression storage occurs in small depressions in the surface of the watershed (Figure 4). Since the model watershed is represented by an inclined plane, the depression storage is averaged over the surface of the plane in a thin sheet of uniform depth, D_d (Figure 5). The depression storage depth is assumed to be 2.0 inches by the model (please refer to section **III. E. A Note on the Parameter Values Assumed by the Model**). The user may change the value of this parameter at his or her option.

ii. Infiltration - Infiltration is modeled by Horton's equation:

$$f_t = f_c + (f_o - f_c)e^{-kt} \tag{1}$$

where f_t is the potential infiltration rate at time t, f_o is the initial (i.e., dry soil) infiltration rate, f_c is the final (i.e., saturated soil) infiltration rate, and k is a decay constant. The potential infiltration for any discrete time interval is found by integrating Equation 1 over the time interval. Thus

$$F_{\Delta t} = F_{t_2 - t_1}$$

$$= [f_c t_2 - \frac{(f_o - f_c)e^{-k_{t_2}}}{k}] - [f_c t_1 - \frac{(f_o - f_c)e^{-k_{t_1}}}{k}] \tag{2}$$

where t_1 is the time at the beginning of the interval, and t_2 is the time at the end of the interval.

The infiltration rate as defined by Horton's equation decreases with time (Figure 6). The infiltration rate approaches the saturated soil infiltration rate f_c asymptotically at a rate determined by the value of the decay constant k. The initial and final infiltration rates depend on the initial water content of the soil and on the

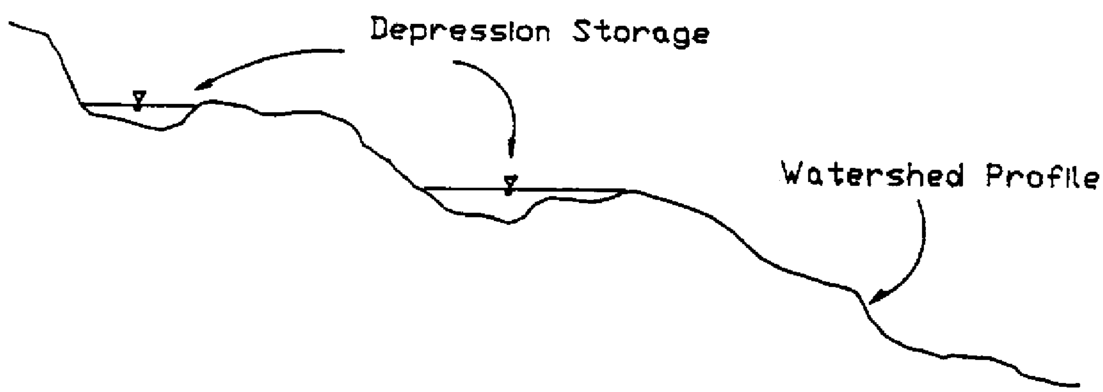


FIGURE 4. Actual Depression Storage.

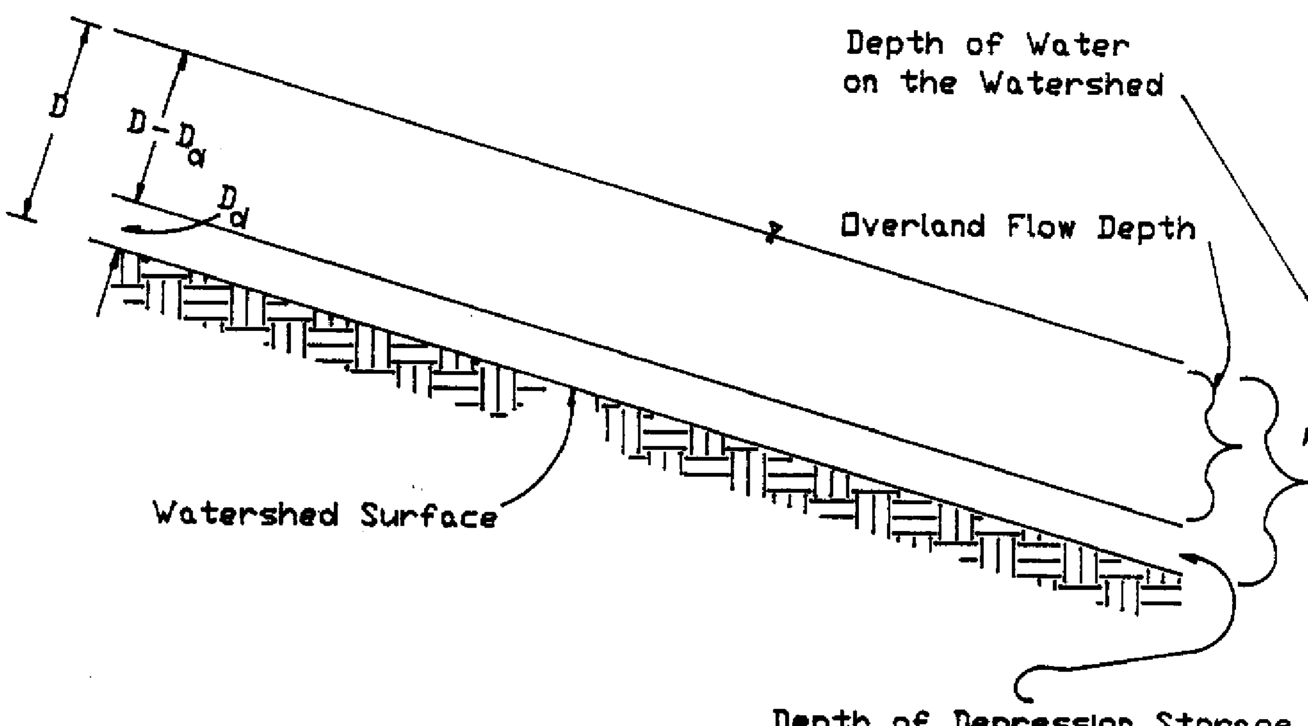


FIGURE 5. Relationship of the Overland Flow Depth to the Depth of Depression Storage in the Simplified Model

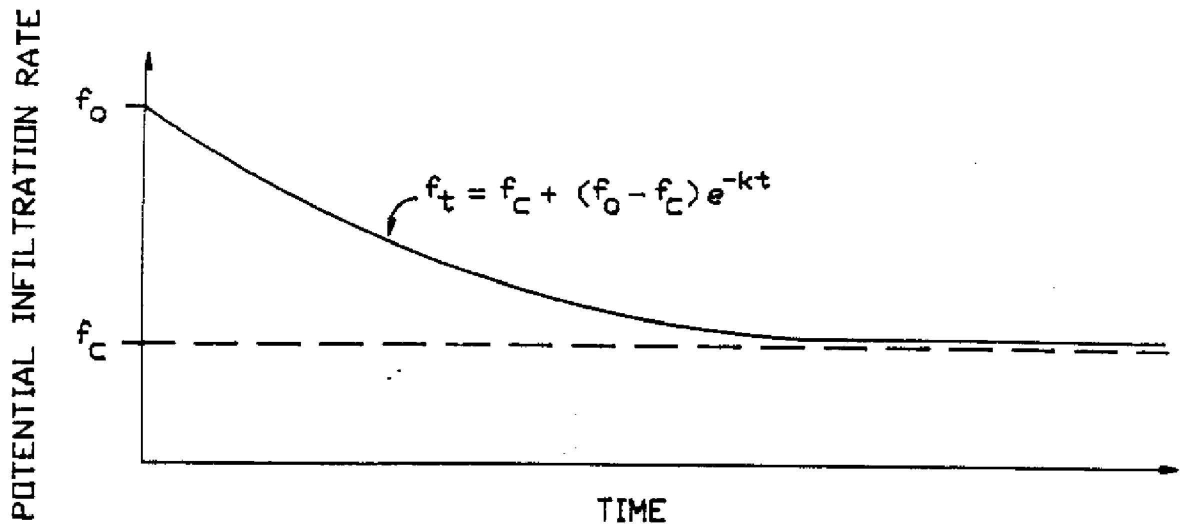


FIGURE 6. Potential Infiltration as Defined by Horton's Equation.

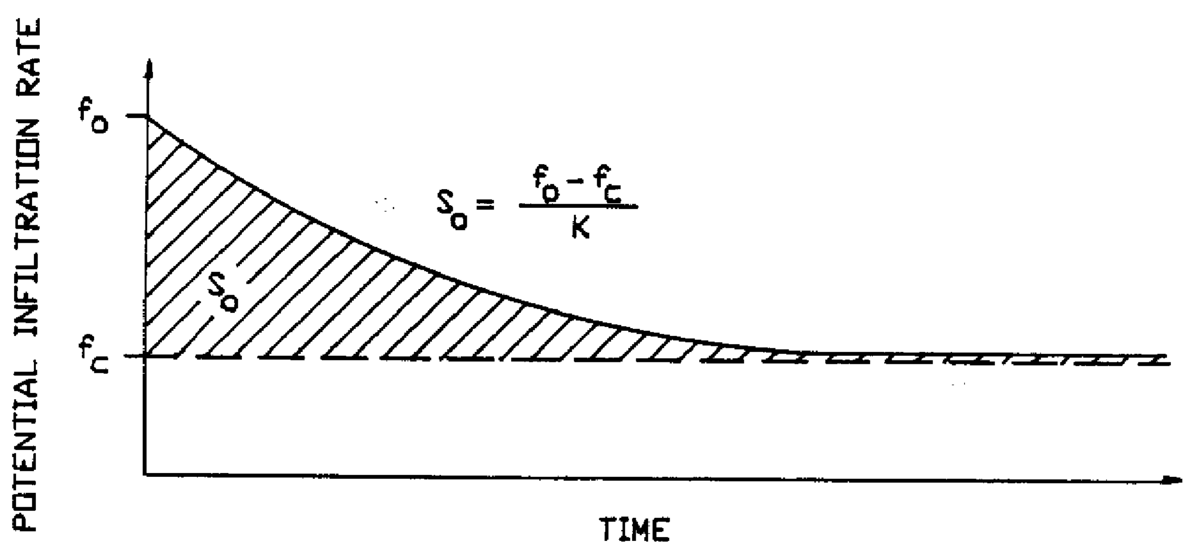


FIGURE 7. Initial Soil Storage Defined in Terms of Horton's Equation.

physical properties of the soil. The decay constant k is a soil parameter which describes the rate of decrease of the infiltration rate. It depends only on the soilstorage available at the beginning of the rain event and on the infiltration constants f_o and f_c. Available soil storage is a function of the volume of empty pore space in the soil above the water table. A typical relationship between cumulative soil storage and depth to the water table is given in Figure 8 (SFWMD, 1987, page C-37). Defined in terms of infiltration, the available soil storage at the beginning of a rain event is equal to the total volume of infiltration as time goes to infinity less the volume of infiltration occurring through the saturated soil below the water table. The initial available soil storage is given by S_0 and is represented by the shaded area under the curve in Figure 7.

It is implicitly assumed in the application of Horton's equation that there is sufficient available water from rainfall and from depression and detention storage[2] to satisfy the potential infiltration (as calculated by Horton's equation). If there is not sufficient available water, soil storage will be depleted at a rate slower than predicted. Further, Horton's equation will underestimate the potential infiltration rate for time $t + \Delta t$ if at time t the available water did not satisfy the potential infiltration. These errors are cumulative.

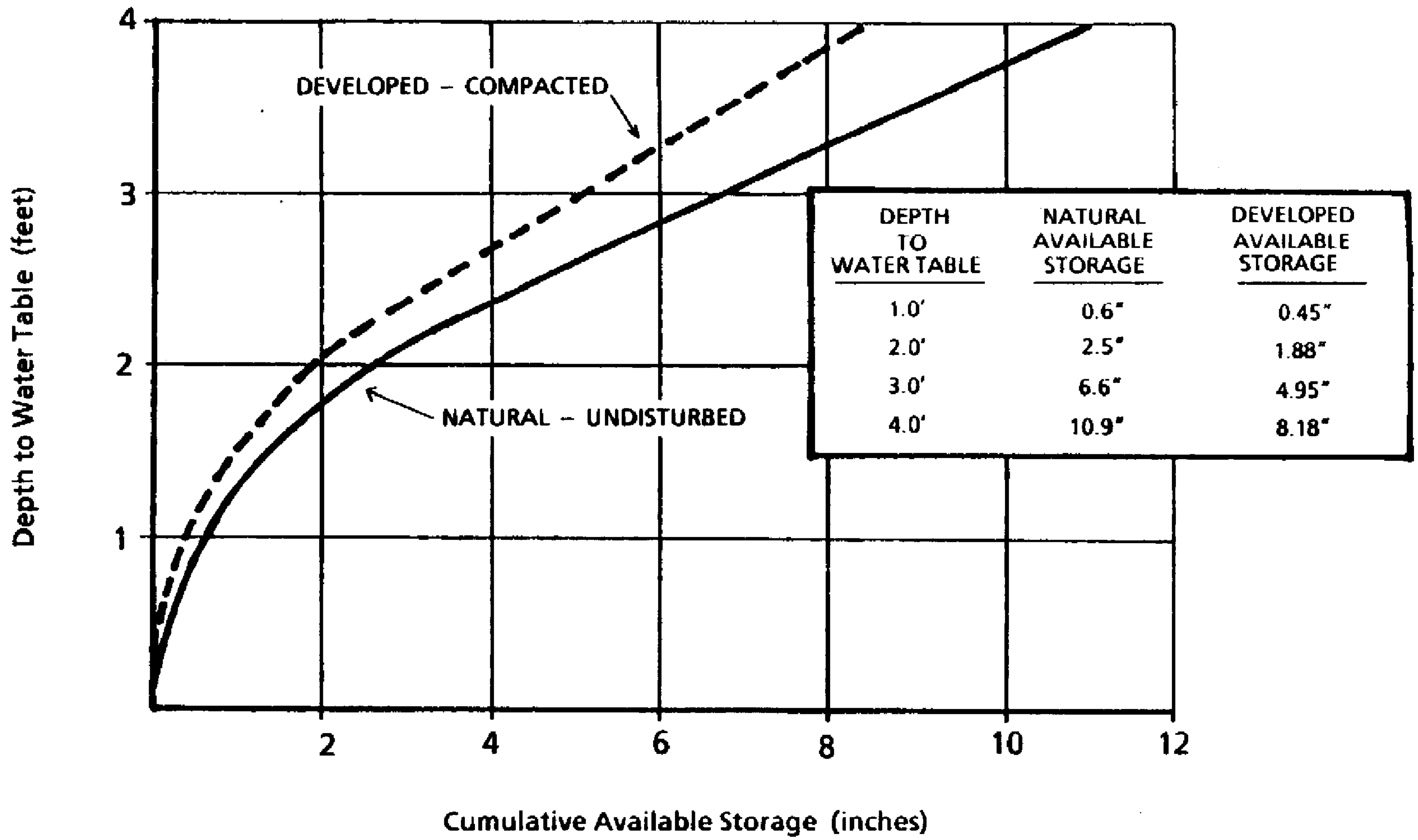
The difficulty with Horton's equation may be overcome by assuming that for any time interval where the potential infiltration exceeds available water, the calculation of the potential infiltration rate for the beginning of the next time interval is a function of the actual infiltration during the previous interval rather than of time. The model implements this by the method shown graphically in Figure 9.

Refer to Figure 9a and assume that the rain that fell during the time interval Δt does not satisfy the infiltration potential as calculated by Equation 2. All of the rain falling during Δt is assumed to infiltrate the soil and is assumed to be equal to the actual infiltration $I_{\Delta t}$. $I_{\Delta t}$ is less than the potential infiltration $F_{\Delta t}$ predicted by Horton's equation. Note that for the actual amount of infiltration $I_{\Delta t}$ occurring during Δt, the infiltration rate at the end of the interval should be $i_{\Delta t}$. Horton's equation underestimates the infiltration rate at the end of the interval to be $f_{\Delta t}$.

Since the actual infiltration rate at time t, i_t, is not the infiltration rate predicted by Horton's equation to occur at time t, the parameters affecting Horton's equation must be re-initialized to make Horton's equation valid in the next time step. This is shown in Figure 9b. For the next time step, the initial infiltration rate f_o is set equal to the infiltration rate i_t at the end of the last interval. For calculation of the potential infiltration rate only, time must be re-initialized to zero. Two clocks are kept in the model, one for model time, t, and one for Horton's equation calculations, t_H.

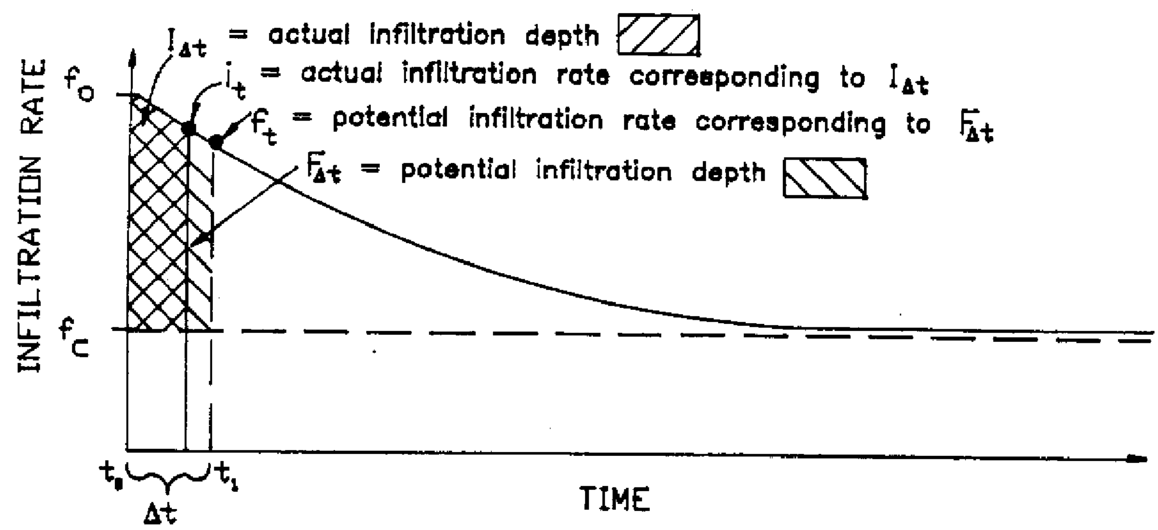
To implement the method outlined above, it is necessary to be able to calculate the new initial infiltration rate f_o as a function of the accumulated actual

[2]Detention storage is used here to refer to surface water on the watershed in excess of depression storage. This water is in the process of "running off" the watershed.

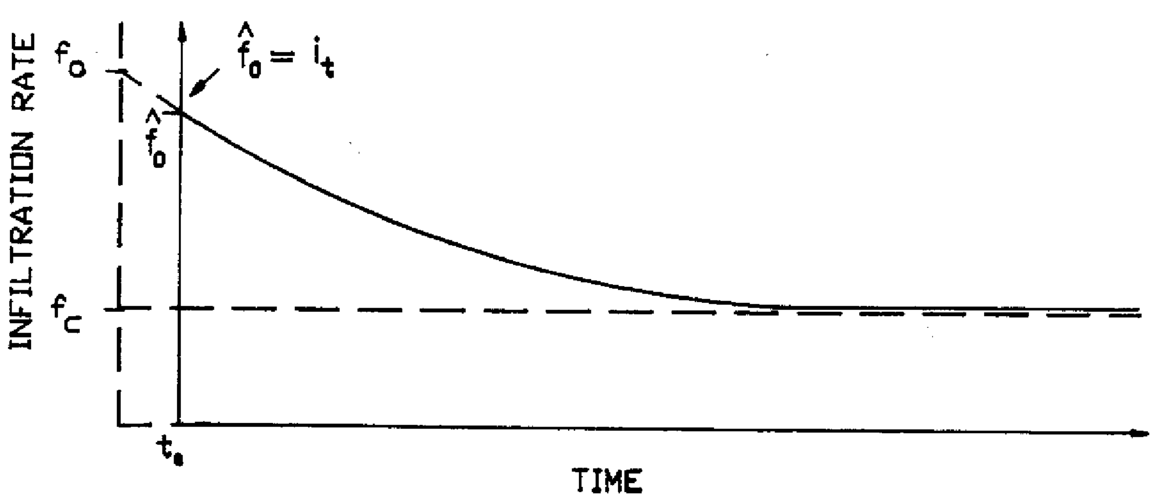


DEPTH TO WATER TABLE	NATURAL AVAILABLE STORAGE	DEVELOPED AVAILABLE STORAGE
1.0'	0.6"	0.45"
2.0'	2.5"	1.88"
3.0'	6.6"	4.95"
4.0'	10.9"	8.18"

FIGURE 8. Cumulative Soil Moisture Storage



(a) Initial Horton's Parameters



(b) Reinitialized Horton Parameters

FIGURE 9. Modification of the Application of Horton's Equation to Account for Time Intervals Were Available Water Does Not Exceed the Potential Infiltration.

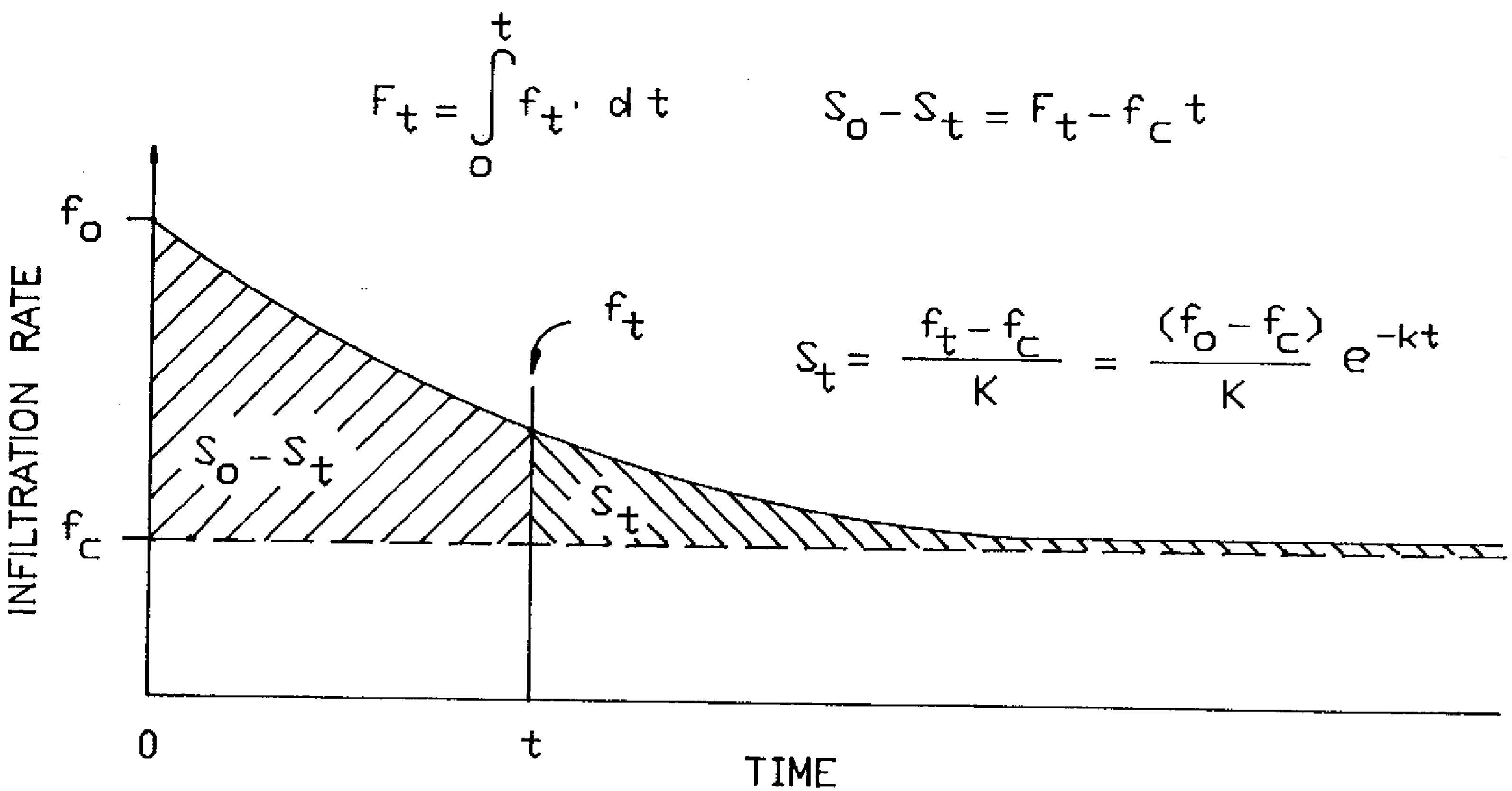


FIGURE 10. Relationships of the Infiltration Rate f_t, the Cumulative Infiltration F_t, and Available Soil Storage S_t.

infiltration. This calculation is equivalent to calculating the infiltration rate f_t as a function of cumulative infiltration F_t (Figure 10). Alternatively, since the available soil storage limits the amount of infiltration possible, f_t may be calculated as a function of the available soil storage S_t. The following is the derivation of a functional relationship to calculate f_t as a function of S_t.

We can define the soil storage available at the end of any time interval ($S_{t+\Delta t}$) as a function of the cumulative infiltration during the interval ($F_\Delta t$) and the available soil storage at the beginning of the interval (S_t)

$$S_{t+\Delta t} = S_t - (F_{\Delta t} - f_c \Delta t) \qquad (3)$$

In terms of the groundwater storage available at the beginning of the storm (S_0),

$$S_t = S_o - (F_t - f_c t) \qquad (4)$$

The relationship between available soil storage and the infiltration rate at time t is derived as follows. F_t in Equation 4 is obtained by integrating Equation 1 with respect to time for the limits t = 0 to t = t,

$$F_t = f_c t + \frac{(f_o - f_c)}{k}(1 - e^{-kt}) \qquad (5)$$

Substituting Equation 5 into Equation 4 and simplifying.

$$S_t = S_o - \frac{(f_o - f_c)}{k}(1 - e^{-kt})$$

or

$$S_o - S_t = \frac{(f_o - f_c)}{k}(1 - e^{-kt}) \qquad (6)$$

Taking the limit as t goes to infinity of Equation 6,

$$S_o = \frac{f_o - f_c}{k} \qquad (7)$$

then equating Equations 4 and 6,

$$S_o - S_t = F_t - f_c t = \frac{(f_o - f_c)}{k}(1 - e^{-kt}) \qquad (8)$$

and substituting Equation 7 into Equation 8 and solving for S_t,

$$S_t = \frac{(f_o - f_c)e^{-kt}}{k} = \frac{f_t - f_c}{k} \quad (9)$$

Solving for f_t,

$$f_t = (k)(S_t) + f_c \quad (10)$$

which is the desired relationship.

For calculation of the infiltration rate, the model requires values for f_o, f_c, and S_o. The value for k is calculated by way of Equation 7.

The model assumes that for the sandy soils typically found within the District, f_c is equal to 0.01 inches per hour (United States Army, Corps of Engineers, 1952) and f_o is equal to 3.1 inches per hour (please refer to section **III. E. A Note on the Parameter Values Assumed by the Model**).

S_o can be determined from the depth to the water table. The relationship between cumulative soil storage and depth to the water table for the sandy soils typically found within the District is given in Figure 8 (SFWMD, 1988, page C-37).

E. A Note on the Parameter Values Assumed by the Model

Certain parameter values were assumed by the model in the construction of the runoff curves used in Volume IV. An attempt was made by Higgins (1979) and Gauthier (1980) to justify these values. In two cases, examination of the cited references failed to verify the selection of parameter values. However, as long as the parameter values are within realistic limits, it is the overall performance of the model that is important. Parameter values could in fact be used to calibrate the model.

IV. GOVERNING EQUATIONS

The governing equations used in this model are Manning's Equation for steady, uniform flow in a channel of uniform cross section,

$$Q_{out} = \frac{1.486}{n} R^{0.667} S_o^{0.5} A_c \qquad (11)$$

and the continuity equation,

$$Q_{out} = Q_{in} - \frac{(VOL_2 - VOL_1)}{\Delta t} \qquad (12)$$

where Q_{out} is the average rate of discharge of water from the channel during a time interval, Q_{in} is the average rate of inflow of water to the channel during a time interval, n is Manning's Roughness Coefficient, R is the hydraulic radius of the channel, S_o is the slope of the channel, A_c is the cross-sectional area of flow in the channel, VOL_1 is the amount of water stored in the channel at the beginning of a time interval, VOL_2 is the amount of water stored in the channel at the end of the time interval, and Δt is the length of the time interval. Because we have assumed that the watershed can be considered to be a wide channel, these equations can be rewritten so that the hydraulic radius and the storage in the channel are functions of water depth D on the watershed. There are then two unknowns, Q_{out} and D. The two equations can be solved simultaneously for these two unknowns at each time step. The following is a derivation of the functional relationship used in the model to determine values of Q_{out} and D at each time step. The functional relationship is a single equation in one unknown. The unknown value ΔD is the change in depth of water on the watershed during the time interval. The solution to the equation is determined numerically by a root finding algorithm, the Newton-Raphson Method. Q_{out} and D are subsequently determined from the change in depth.

A. Derivation of the Functional Equation

Since it has been assumed that the watershed can be approximated by a very wide channel, the hydraulic radius can be assumed to be equal to the water depth in the channel (i.e., on the watershed) minus the depression storage, D_d, (Figure 5)

$$R = D - D_d \qquad (13)$$

where D is the average water depth on the watershed during a time interval. Rewriting Equation 11,

$$Q_{out} = \frac{1.486}{n} (D - D_d)^{0.667} S_o^{0.5} (D - D_d) W$$

$$= \frac{1.486}{n} (D - D_d)^{1.667} S_o^{0.5} W \qquad (14)$$

where W is the width of the watershed, and $A_c = W(D-D_d)$. Since n, S_o, W and the area of the watershed, A, are all constants, let

$$Z = \frac{1.486}{n} S_o^{0.5} \frac{W}{A} \quad (15)$$

Then Equation 14 becomes

$$Q_{out} = Z(D-D_d)^{1.667} A \quad (16)$$

Since D is the average depth of water on the watershed during the interval, we can write

$$D = \frac{D_1 + D_2}{2}$$

$$= D_1 + \Delta D/2 \quad (17)$$

where D_1 is the depth of water on the watershed at the beginning of the time interval, D_2 is the depth of water on the watershed at the end of the time interval, and ΔD is the change in depth of water on the watershed during the interval. Now Equation 16 can be rewritten as

$$Q_{out} = Z[(D_1 + \Delta D/2) - D_d]^{1.667} A \quad (18)$$

Q_{in} is a function of the depth of rainfall on the watershed minus the depth of water lost to infiltration, the area of the watershed, and the length of the time interval.

$$Q_{in} = \frac{(P_{\Delta t} - I_{\Delta t})A}{\Delta t} \quad (19)$$

where $P_{\Delta t}$ is the rainfall during the interval, and $I_{\Delta t}$ is the infiltration during the interval, and Δt is the length of the time interval.

If it is assumed that the storage on the watershed is equal to the product of the depth of water and the area of the watershed, and if Equation 19 is substituted into Equation 12,

$$Q_{out} = \frac{(P_{\Delta t} - I_{\Delta t})A - (D_2 - D_1)A}{\Delta t}$$

$$= \frac{(P_{\Delta t} - I_{\Delta t})A - (\Delta D)A}{\Delta t} \quad (20)$$

Equating the right hand sides of Equations 18 and 20, rearranging,and simplifying yields

$$(\Delta t)Z[(D_1+\Delta D/2)-D_d]^{1.667} - (P_{\Delta t}-I_{\Delta t}) + \Delta D = 0$$

which is the functional equation used by the model. This functional equation is solved for ΔD by the Newton-Raphson Method.

B. Solution by the Newton-Raphson Method

The Newton-Raphson method is a widely used root finding algorithm (Gerald and Wheatly, 1985, page 15). It may be used with monotonic functions that are either concave up or concave down. An initial estimate, x_0, of the root of the function is made, and the tangent to the function at x_0 is extrapolated to its intersection with the x-axis at x_1 (Figure 11). x_1 is taken as a new estimate of the actual root, x^*. This procedure is continued until the function is sufficiently close to zero or successive x-values are sufficiently close.

Referring to Figure 11,

$$x_1 = x_0 - \Delta x$$

$$\frac{f(x_0)}{\Delta x} = \text{slope of the tangent line} = f'(x_0)$$

then

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} \qquad (22)$$

The functional equation, f(x), we wish to solve is given by Equation 21 where ΔD is the unknown value. The derivative f'(x)of the functional equation is given by

$$f'(\Delta D) = 0.833(\Delta t)Z[(D_1 + \Delta D/2)-D_d]^{0.667} + 1 \qquad 23$$

The convergence criterion used in the model is

$$|\Delta D_1 - \Delta D_0| \leq 0.001\Delta D_1 \qquad (24)$$

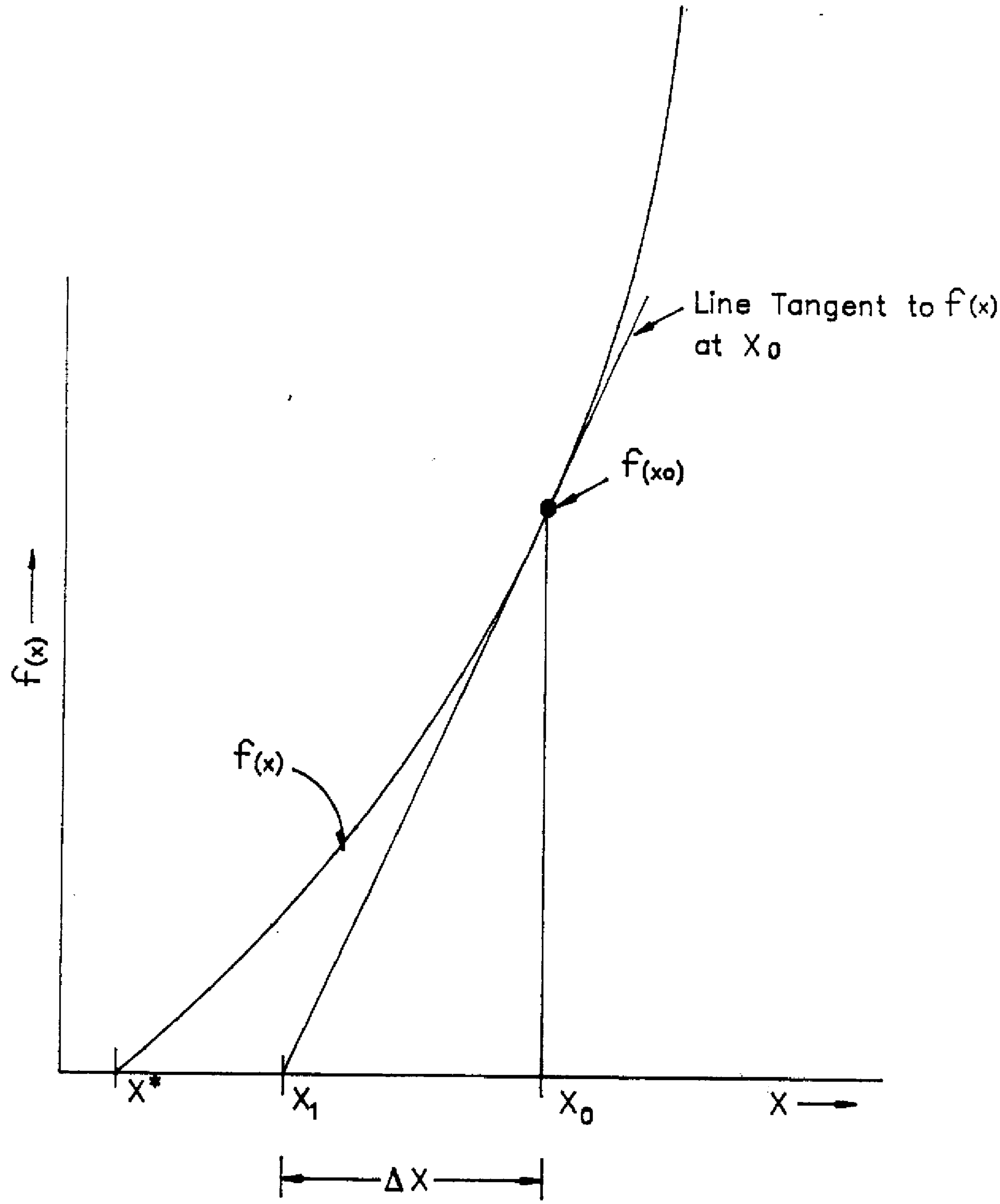


FIGURE 11. Root Finding by the Newton Raphson Method.

V. OVERLAND FLOW MODEL ALGORITHM

The model requires as input: the area of the watershed, the length of the watershed, the average slope of the watershed, the available soil storage, and the maximum 24- hour rainfall amount. Other parameters (i.e., storm duration, depression storage, Manning's "n", and Horton's infiltration constants) are assumed in the model, but may be changed at the users option.

The solution algorithm follows the following steps (Figure 12 is a flow chart of the algorithm and Figure 13 illustrates the three infiltration/runoff cases of the algorithm):

A. Step 1

The depth of water available (D_{aw}) for infiltration and runoff during each interval is determined by adding the depth of rain falling ($P_{\Delta t}$) during the interval to the depth of water on the watershed (D_t) at the beginning of the interval,

$$D_{aw} = D_t + P_{\Delta t} \tag{25}$$

B. Step 2

The potential infiltration for the time interval is calculated from Horton's equation (Equation 2). If D_{aw} does not exceed the potential infiltration for the watershed, all available water infiltrates, D_t for the next interval is set equal to zero, D_{aw} is subtracted from the available soil storage, f_o is re-initialized by Equation 10, t is incremented, time for calculation of infiltration (t_H) is set to zero, and control returns to Step 1. If available water exceeds potential infiltration, the actual infiltration is equal to the potential infiltration and is subtracted from the available water D_{aw}. The depth of water (D_{xs}) in excess of infiltration is available for depression storage and runoff.

$$D_{xs} = D_{aw} - F\Delta t \tag{26}$$

C. Step 3

If D_{xs} is less than the depth of the depression storage (D_d), all excess water is stored in depression storage and is unavailable for runoff. The depth of water on the watershed D_t for the next interval is set equal to D_{xs}, t and t_H are incremented, and control returns to step 1. If D_{xs} exceeds D_d, then water is available for runoff. The change in depth of water on the watershed is calculated from Equation 21. The average outflow from the watershed during the interval and the new depth of water on the watershed at the end of the interval are determined, t and t_H are incremented, and control is returned to step 1.

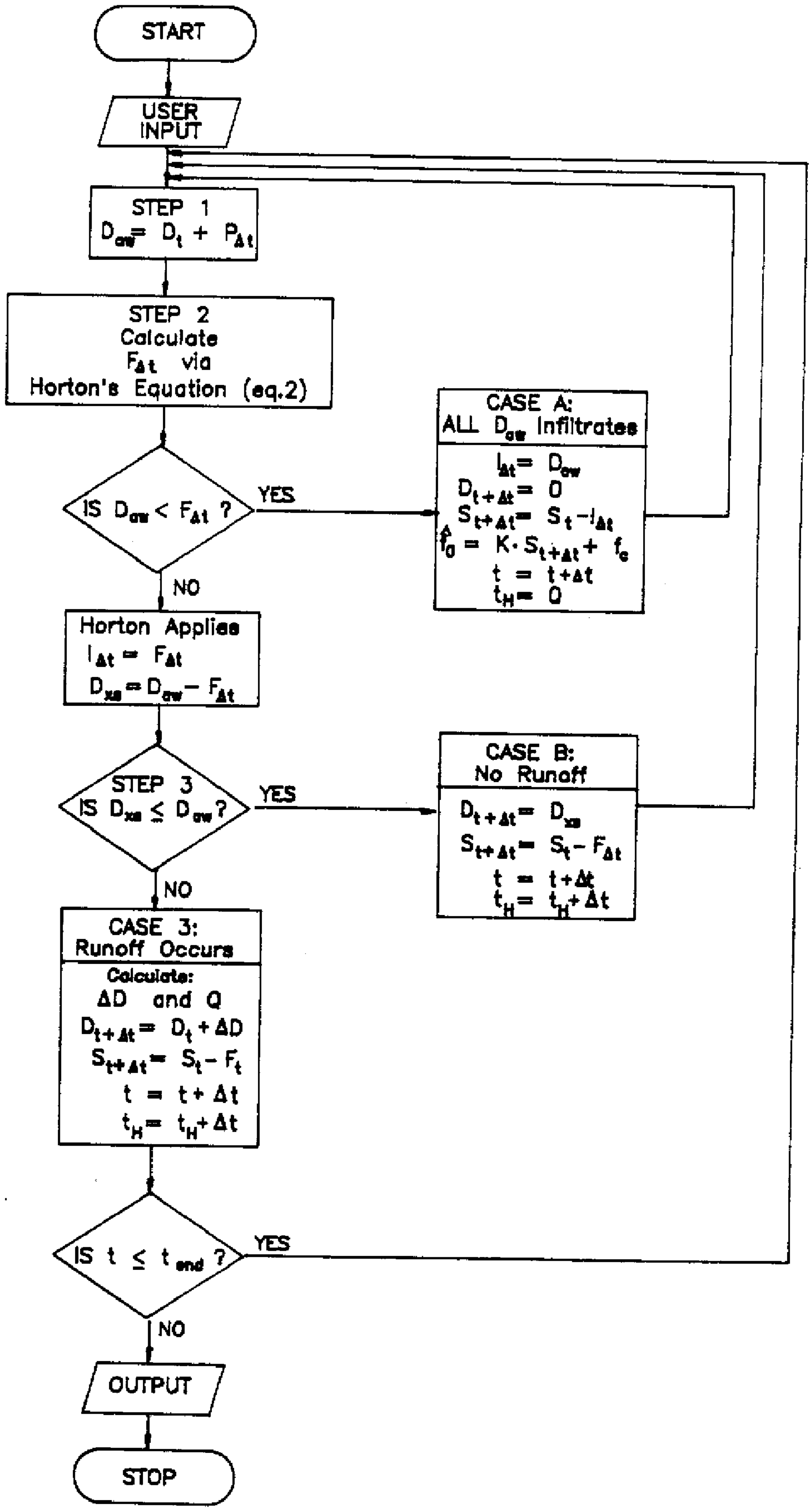


Figure 12. Flow Chart of the Overland Flow Model Algorithm.

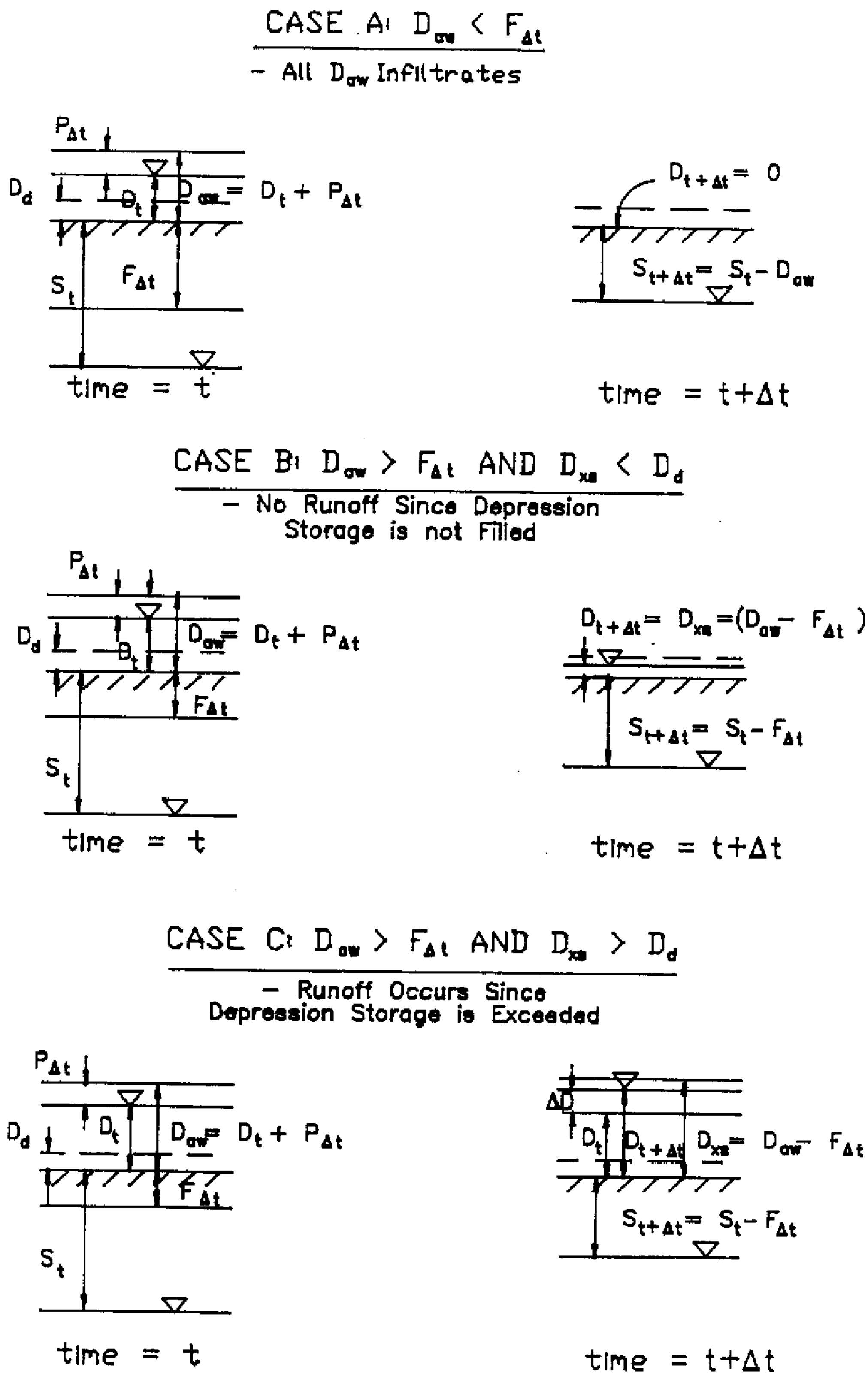


Figure 13. Cases A,B, and C of the Overland Flow Model Algorithm.

VII. REFERENCES

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APPENDIX A

USERS MANUAL

Installing PEAKQ

The program PEAKQ may be executed from a directory on your fixed disk or from a floppy disk. In either case, the command file ANSI.SYS must be present in Random Access Memory (RAM). This may be accomplished by copying ANSI.SYS to an accessible directory on your hard drive or to the floppy disk from which you boot your machine. ANSI.SYS must be specified as a device in your CONFIG.SYS file. Be sure to include the path name in your specification. For example, if you load ANSI.SYS into a subdirectory of drive C: called UTIL, the configuration command in your CONFIG.SYS file would look like this:

```
DEVICE = C:\UTIL\ANSI.SYS
```

After changing your CONFIG.SYS file, reboot your machine to load ANSI.SYS into RAM.

When PEAKQ is executed the following menu of input options will appear on the screen.

```
                INPUT MODEL PARAMETERS AND OUTPUT FILE OPTIONS
INPUT PARAMETERS:
     1.  ALL
     2.  PROJECT NAME (                    )
     3.  REVIEWERS NAME (                   )
     4.  MAXIMUM 24-HR RAINFALL AMOUNT ( 0.00 INCHES)
     5.  BASIN AREA (    0.00 ACRES)
     6.  SLOPE OF WATERSHED ( 0.00 FEET PER MILE)
     7.  LENGTH OF WATERSHED (    0.00 FEET)
     8.  DEPTH OF GROUND STORAGE ( 0.000 INCHES)
     9.  OPTIONAL PARAMETERS (DEFAULT VALUES)
OUTPUT FILE:
     10. FILE NAME (         )
     11. PRINT INTERVAL ( 0.00 HOURS)
END EDITING AND EXECUTE PROGRAM:
     12. GO
SELECTION:
```

To make a selection from this menu simply type the number of your selection and press return. You will be prompted for the desired information. For example, if you select item 4, the following prompt will appear on the screen below the menu

```
ENTER THE MAXIMUM 24-HOUR RAINFALL AMOUNT IN INCHES:
```

Type in the desired information, press return, and you will be returned to the main menu. The value you have entered will be displayed in the menu in parenthesis following the parameter. If you have entered the value incorrectly, simply select the item again and enter the correct value.

If you select item 1 (ALL) you will be sequentially prompted for the project name, the reviewers name, the 24-hr rainfall amount, the basin area, the average slope of the watershed, the length of the watershed, and the depth of groundstorage. You will also be asked if you wish to have incremental values of rainfall, runoff, and infiltration rates written to an output file (Figure C-1)

If you opt to write incremental values to an output file, you will be asked to specify a print interval. The program calculates incremental values of runoff at quarter hour intervals. You may specify any integer multiple of one-quarter hour as your print interval.

If you select item 9, the following menu of optional parameters will appear on your screen.

OPTIONAL PARAMETERS

THE FOLLOWING PARAMETERS MAY BE CHANGED FROM THEIR DEFAULT VALUES. NOTE HOWEVER THAT CHANGING THESE PARAMETERS WILL PRODUCE RESULTS THAT CAN NOT BE OBTAINED FROM THE NOMOGRAPHS IN "VOLUME IV"

```
     1.   DEPRESSION STORAGE (2.000 INCHES)
     2.   MANNING'S "n" (0.250)
     3.   RAINFALL DURATION ( 3 DAYS)
     4.   HORTON'S EQUATION INFILTRATION CONSTANTS
          (INITIAL RATE:    3.10 INCHES PER HOUR)
           (FINAL RATE:     0.01 INCHES PER HOUR)
     5.    RETURN TO MAIN MENU
SELECTION:
```

You may change parameter values here exactly as you would for the main menu. The program will use the default values shown unless you specify otherwise. Be advised, however, that the nomographs used in "Volume IV" were generated assuming these default values in all cases. If you change any of these values you will not obtain results that could be obtained from the nomographs in "Volume IV". If any of these values are changed from their default values, item 9 in the main menu will be changed to read:

PROJECT: TEST

REVIEWER: RICK COOPER

DATE: Fri. 06/24/88 04:47:03

TIME (HR)	RAIN (IN)	TOTAL RAIN (IN)	RUNOFF RATE (CFS)	TOTAL RUNOFF (AC-FT)	INFILT (IN)	TOTAL INFILT (IN)	WATER DEPTH (IN)
.25	.017	.017	.00	.00	.017	.017	.000
.50	.017	.033	.00	.00	.017	.033	.000
.75	.017	.050	.00	.00	.017	.050	.000
1.00	.017	.067	.00	.00	.017	.067	.000
1.25	.017	.084	.00	.00	.017	.084	.000
1.50	.017	.100	.00	.00	.017	.100	.000
1.75	.017	.117	.00	.00	.017	.017	.000
2.00	.017	.134	.00	.00	.017	.134	.000
2.25	.017	.151	.00	.00	.017	.151	.000
2.50	.017	.167	.00	.00	.017	.167	.000
2.75	.017	.184	.00	.00	.017	.184	.000
2.50	.017	.167	.00	.00	.017	.167	.000
2.75	.017	.184	.00	.00	.017	.184	.000
3.00	.017	.201	.00	.00	.017	.201	.000
3.25	.017	.217	.00	.00	.017	.217	.000
3.50	.017	.234	.00	.00	.017	.234	.000
3.75	.017	.251	.00	.00	.017	.251	.000
4.00	.017	.268	.00	.00	.017	.268	.000
4.25	.017	.284	.00	.00	.017	.284	.000
4.50	.017	.301	.00	.00	.017	.301	.000
4.75	.017	.318	.00	.00	.017	.318	.000
5.00	.017	.335	.00	.00	.017	.335	.000
5.25	.017	.351	.00	.00	.017	.351	.000
5.50	.017	.368	.00	.00	.017	.368	.000
5.75	.017	.385	.00	.00	.017	.385	.000
6.00	.017	.401	.00	.00	.017	.401	.000
6.25	.017	.418	.00	.00	.017	.418	.000
6.50	.017	.435	.00	.00	.017	.435	.000
6.75	.017	.452	.00	.00	.017	.452	.000
7.00	.017	.468	.00	.00	.017	.468	.000
7.25	.017	.485	.00	.00	.017	.485	.000
7.50	.017	.502	.00	.00	.017	.502	.000
7.75	.017	.519	.00	.00	.017	.519	.000
8.00	.017	.535	.00	.00	.017	.535	.000
8.25	.017	.552	.00	.00	.017	.552	.000
8.50	.017	.569	.00	.00	.017	.569	.000
8.75	.017	.586	.00	.00	.017	.586	.000
9.00	.017	.586	.00	.00	.017	.586	.000

Figure 14. Header Page of an Example Output File of Incremental Values of Rainfall, Runoff, and Infiltration.

to warn you that the default values will not be used if the program is executed.

When you are satisfied with your input, select item 12 to execute the program. When the program has completed execution the peak runoff rate will be printed to the screen below the menu.

THE PEAK RUNOFF RATE FROM THE WATERSHED IS XX CFS.
DO YOU WISH TO WRITE THE INPUT AND THE PEAK FLOW TO A FILE? (Y/N):

If you are satisfied with the results of the run, you may save the input and the output generated to a file (Figure C-2). If you wish to write this information to an output file answer yes to the query, and you will be prompted for the required information. Finally you will be asked if you wish to make another run.

DO YOU WISH TO MAKE ANOTHER RUN? (Y/N):

If you answer yes, you will be returned to the main menu. All of the parameter values selected from the main menu for the previous run have been saved and will be displayed in the main menu. Optional parameter values have been returned to their default values. You may change any or all of these values before executing the next run.

PROJECT: TEST

REVIEWER: RICK COOPER

DATE: Wed. 06/15/88 08:54:06am

INPUT PARAMETERS

MAXIMUM 24-HR RAINFALL AMOUNT	11.000 INCHES
RAINFALL DURATION	3 DAYS
BASIN AREA	640.000 ACRES
SLOPE OF WATERSHED	5.000 FEET PER MILE
LENGTH OF WATERSHED	5280.000 FEET
MANNINGS "n"	.250
DEPRESSION STORAGE	2.000 INCHES
DEPTH OF GROUND STORAGE	10.900 INCHES
HORTON EQUATION INFILTRATION CONSTANTS:	
INITIAL RATE	3.100 INCHES/HOUR
FINAL RATE	.010 INCHES/HOUR

FINAL OUTPUT

THE PEAK RUNOFF RATE FOR THE WATERSHED IS 48 CFS.

Figure 15. Example of Final Output File From PEAKQ.

APPENDIX B - SOURCE CODE

PEAKQ

```
C
C***********************************************************************
C                                 PEAKQ
C
C           ORIGINAL ALGORITHM AND PROGRAM BY ROBERT HIGGINS
C                                  1979
C
C          REWRITTEN, MODIFIED, AND COMMENTED BY RICHARD COOPER
C                                  1988
C
C      THIS PROGRAM CALCULATES THE PEAK STORM RUNOFF RATE FOR UNDEVELOPED
C      WATERSHEDS.  THE ALGORITHM SOLVES TWO SIMULTANEOUS EQUATIONS,
C      MANNING'S OVERLAND FLOW EQUATION AND THE CONTINUITY EQUATION,
C      TO DETERMINE THE RUNOFF RATE AND THE DEPTH OF WATER ON THE
C      WATERSHED AT DISCRETE TIME INTERVALS.
C
C      THERE ARE SEVERAL NECESSARY USER INPUTS TO THE MODEL: THE 24-HR
C      RAINFALL AMOUNT, THE SURFACE AREA OF THE WATERSHED, THE AVERAGE
C      SLOPE OF THE WATERSHED, THE OVERLAND FLOW LENGTH, AND THE DEPTH OF
C      AVAILABLE GROUNDWATER STORAGE.  THERE ARE SEVERAL OPTIONAL
C      INPUTS TO THE MODEL: THE RETENTION DEPTH (DEPRESSION STORAGE),
C      MANNING'S ROUGHNESS COEFFICIENT, THE RAINFALL DURATION, AND THE
C      INFILTRATION CONSTANTS FOR HORTON'S EQUATION.  IF VALUES FOR
C      THESE OPTIONAL PARAMETERS ARE NOT SPECIFIED, DEFAULT VALUES ARE
C      ASSUMED.  THE SHAPE OF THE RAINFALL HYETOGRAPH IS ASSUMED BY THE
C      MODEL.
C
C      LINKS REQUIRED (MS-FORTRAN): FORTRAN.LIB, 8087.LIB, STATPAC.LIB,
C      CHECKER.OBJ, SCREEN.OBJ.  CONTACT RICHARD COOPER FOR COPIES OF
C      CHECKER.OBJ, SCREEN.OBJ, AND THE STATPAC.LIB.
C
C      NOTE: TO RUN THIS PROGRAM, THE FILE ANSI.SYS MUST BE PRESENT ON
C      YOUR MACHINE IN AN ACCESSIBLE DIRECTORY AND MUST BE SPECIFIED AS
C      A DEVICE IN THE CONFIG.SYS FILE.
C***********************************************************************
C
```

```
C
C^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
C      LIST OF MAJOR VARIABLES:
C
C      USER INPUT
C
C         PROJNAM    THE PROJECT NAME
C         REVIEW     THE REVIEWERS NAME
C         AMOUNT     THE 24-HR RAINFALL AMOUNT (INCHES)
C         AREA       THE AREA OF THE WATERSHED (ACRES)
C         SLOP       THE AVERAGE SLOPE OF THE WATERSHED (FEET/MILE)
C         LSHED      THE OVERLAND FLOW LENGTH (FEET)
C         STOR       THE DEPTH OF AVAILABLE GROUNDWATER STORAGE (INCHES)
C         DEPSTO     THE RETENTION DEPTH (INCHES)
C         NPERV      MANNING'S ROUGHNESS COEFFICIENT
C         IRF        THE RAINFALL DURATION (DAYS)
C         FC(I)      THE CONSTANTS USED IN HORTONS EQUATION (INCHES/HOUR)
C                    FC(1) = fo - THE INITIAL INFILTRATION RATE
C                    FC(2) = fc - THE FINAL INFILTRATION RATE
C                    FC(3) = k  - THE DECAY CONSTANT, INITIALIZED TO
C                                 ZERO, AND CALCULATED FROM THE AVAILABLE
C                                 SOIL STORAGE AND THE INITIAL AND FINAL
C                                 INFILTRATION RATES.
C
C      RAINFALL DISTRIBUTION
C
C         RNDAT1(I,J) THE HYETOGRAPH FOR THE 1-DAY RAIN EVENT
C         RNDAT3(I,J) THE HYETOGRAPH FOR THE 3- AND 5-DAY EVENTS
C
C^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
C
```

```
      PROGRAM PEAKQ
C
C-----------------------------------------------------------------------
C                                    TYPE STATEMENTS
C-----------------------------------------------------------------------
C
      CHARACTER PROJNAM*40,REVIEW*40,FNAME*15
      REAL LSHED,NPERV
      INTEGER*2 STORM,FLAG,FLAG1
C
C-----------------------------------------------------------------------
C                                    COMMON BLOCKS
C-----------------------------------------------------------------------
C
      COMMON/RAINDAT/RNDAT(2,100),RNDAT1(2,50),RNDAT3(2,54),
     1                NUMPTS(3)
      COMMON/PARAM/AREA,STOR,DEPSTO,NPERV,IRF,STORM,AMOUNT,SLOP,
     1              LSHED,RDT,FLAG,FLAG1,PROJNAM,REVIEW,FNAME
      COMMON/INFILDAT/FC(3)
C
C-----------------------------------------------------------------------
C                                    DISPLAY TITLE
C-----------------------------------------------------------------------
C
      CALL CLRON
      CALL TITLE
10    CONTINUE
C
C-----------------------------------------------------------------------
C                                    USER INPUT
C-----------------------------------------------------------------------
C
      CALL INPUT
C
C-----------------------------------------------------------------------
C                           CALCULATE INCREMENTAL RUNOFF
C-----------------------------------------------------------------------
C
      CALL INCRUN(QPEAK)
C
C-----------------------------------------------------------------------
C                                    OUTPUT
C-----------------------------------------------------------------------
C
      CALL OUTPUT(QPEAK)
C
C-----------------------------------------------------------------------
C                          DETERMINE IF ANOTHER RUN IS DESIRED
C                                OR TERMINATE EXECUTION
C-----------------------------------------------------------------------
C
      CALL END
      GOTO 10
      END
```

```
C***********************************************************************
C                           RAINFALL HYETOGRAPHS
C
C     THIS SUBPROGRAM SPECIFIES THE RAINFALL UNIT HYETOGRAPHS FOR
C     CALCULATION OF INCREMENTAL RAINFALL AMOUNTS.
C***********************************************************************
C
      BLOCK DATA
C
C-----------------------------------------------------------------------
C                              COMMON BLOCKS
C-----------------------------------------------------------------------
C
      COMMON/RAINDAT/ RNDAT(2,100),RNDAT1(2,50),RNDAT3(2,54),
     1                NUMPTS(3)
C
C-----------------------------------------------------------------------
C        NUMBER OF DATA POINTS FOR 1-, 3-, AND 5-DAY RAIN EVENTS
C-----------------------------------------------------------------------
C
      DATA NUMPTS/50,52,54/
C
C-----------------------------------------------------------------------
C                      HYETOGRAPH FOR 1-DAY RAIN EVENT
C-----------------------------------------------------------------------
C
      DATA RNDAT1/00.0,0.000,00.5,0.005,01.0,0.011,01.5,0.017,
     1 02.0,0.022,02.5,0.029,03.0,0.035,03.5,0.042,04.0,0.048,
     2 04.5,0.056,05.0,0.064,05.5,0.072,06.0,0.080,06.5,0.090,
     3 07.0,0.100,07.5,0.110,08.0,0.120,08.5,0.134,09.0,0.147,
     4 09.5,0.163,10.0,0.181,10.5,0.204,11.0,0.235,11.5,0.283,
     5 11.75,0.387,12.0,0.663,12.5,0.735,13.0,0.772,13.5,0.799,
     6 14.0,0.820,14.5,0.835,15.0,0.850,15.5,0.865,16.0,0.880,
     7 16.5,0.889,17.0,0.898,17.5,0.907,18.0,0.916,18.5,0.925,
     8 19.0,0.934,19.5,0.943,20.0,0.952,20.5,0.958,21.0,0.964,
     9 21.5,0.970,22.0,0.976,22.5,0.982,23.0,0.988,23.5,0.994,
     A 24.0,1.00/
C
C-----------------------------------------------------------------------
C                 HYETOGRAPH FOR 3- AND 5-DAY RAIN EVENTS
C-----------------------------------------------------------------------
C
      DATA RNDAT3/00.0,0.000,24.0,0.146,48.0,0.359,48.5,0.364,
     1 49.0,0.370,49.5,0.376,50.0,0.381,50.5,0.388,51.0,0.394,
     2 51.5,0.401,52.0,0.407,52.5,0.415,53.0,0.423,53.5,0.431,
     3 54.0,0.439,54.5,0.449,55.0,0.459,55.5,0.469,56.0,0.479,
     4 56.5,0.493,57.0,0.506,57.5,0.522,58.0,0.540,58.5,0.563,
     5 59.0,0.594,59.5,0.642,59.75,0.746,60.0,1.022,60.5,1.094,
     6 61.0,1.131,61.5,1.158,62.0,1.179,62.5,1.194,63.0,1.209,
     7 63.5,1.224,64.0,1.239,64.5,1.248,65.0,1.257,65.5,1.266,
     8 66.0,1.275,66.5,1.284,67.0,1.293,67.5,1.302,68.0,1.311,
     9 68.5,1.317,69.0,1.323,69.5,1.329,70.0,1.335,70.5,1.341,
     A 71.0,1.347,71.5,1.353,72.0,1.359,96.0,1.472,120.0,1.568/
      END
```

```
C
C***********************************************************************
C                             SUBROUTINE TITLE
C
C     THIS SUBROUTINE DISPLAYS THE PROGRAM NAME AND ACKNOWLEDGES THE
C     DISTRICT AND THE WATER RESOURCES DIVISION.
C***********************************************************************
C
      SUBROUTINE TITLE
      CALL CLS
      CALL MOVECUR(9,1)
      WRITE(*,10)
10    FORMAT(12X,'PEAK RUNOFF RATE ESTIMATION FOR ',
     1       'UNDEVELOPED WATERSHEDS',//
     2    12X,'        SOUTH FLORIDA WATER MANAGEMENT DISTRICT',/
     3    12X,'             RESOURCE PLANNING DEPARTMENT',/
     4    12X,'               WATER RESOURCES DIVISION')
      CALL DELAY(500)
      CALL CLS
      RETURN
      END
```

```
C
C*************************************************************************
C                              SUBROUTINE  INPUT
C
C     THIS SUBROUTINE DISPLAYS A MENU OF REQUIRED AND OPTIONAL USER
C     INPUT TO THE PROGRAM.  IT READS THE USER'S SELECTION AND CALLS THE
C     PROPER SUBROUTINE TO PROMPT FOR THE DESIRED INPUT.
C*************************************************************************
C
      SUBROUTINE INPUT
C
C-------------------------------------------------------------------------
C                              TYPE STATEMENTS
C-------------------------------------------------------------------------
C
      CHARACTER PROJNAM*40,REVIEW*40,FNAME*15,OPTYN*21
      INTEGER*2 STORM,FLAG,FLAG1,ERR
      REAL LSHED,NPERV
C
C-------------------------------------------------------------------------
C                              COMMON BLOCKS
C-------------------------------------------------------------------------
C
      COMMON/PARAM/AREA,STOR,DEPSTO,NPERV,IRF,STORM,AMOUNT,SLOP,
     1             LSHED,RDT,FLAG,FLAG1,PROJNAM,REVIEW,FNAME
      COMMON/INFILDAT/ FC(3)
C
C-------------------------------------------------------------------------
C                       INITIALIZE OPTIONAL PARAMETERS
C-------------------------------------------------------------------------
C
      DEPSTO=2.0
      NPERV=0.25
      IRF=3
      STORM=2
      FC(1)=3.10
      FC(2)=0.01
      OPTYN='DEFAULT VALUES'
      FNAME='NO OUTPUT FILE'
      FLAG=0
      RDT=0.25
```

```
C
C----------------------------------------------------------------------
C                          DISPLAY EDITOR OPTIONS
C----------------------------------------------------------------------
C
10     CONTINUE
       CALL CLS
       WRITE(*,20) PROJNAM,REVIEW,AMOUNT,AREA,SLOP,LSHED,STOR,
      1            OPTYN,FNAME,RDT
20     FORMAT(16X,'INPUT MODEL PARAMETERS AND OUTPUT FILE OPTIONS',//
      1    10X,'INPUT PARAMETERS:',/
      1    10X,'        1. ALL',/
      2    10X,'        2. PROJECT NAME (',A,')',/
      3    10X,'        3. REVIEWERS NAME (',A,')',/
      4    10X,'        4. MAXIMUM 24-HR RAINFALL AMOUNT (',
      +    F6.2,' INCHES)',/
      5    10X,'        5. BASIN AREA (',F10.2,' ACRES)',/
      6    10X,'        6. SLOPE OF WATERSHED (',F6.2,' FEET PER MILE)',/
      7    10X,'        7. LENGTH OF WATERSHED (',F10.2,' FEET)',/
      8    10X,'        8. DEPTH OF GROUND STORAGE (',F6.3,' INCHES)',/
      9    10X,'        9. OPTIONAL PARAMETERS (',A,')',/
      A    10X,'INCREMENTAL OUTPUT FILE:',/
      B    10X,'       10. FILE NAME (',A,')',/
      C    10X,'       11. PRINT INTERVAL (',F5.2,' HOURS)',/
      D    10X,'END EDITING AND EXECUTE PROGRAM:',/
      E    10X,'       12. GO',/
      F    10X,'SELECTION:  ',\)
C
C----------------------------------------------------------------------
C          READ SELECTION AND EXECUTE APPROPRIATE SUBROUTINE(S)
C----------------------------------------------------------------------
C
       READ(*,*,IOSTAT=ERR) NN
       IF(ERR.GT.0) GOTO 10
       IF(NN.EQ.1) THEN
          CALL CLS
          CALL MOVECUR(12,1)
          CALL SAVECUR
          CALL A(PROJNAM)
          CALL CLS
          CALL B(REVIEW)
          CALL CLS
          CALL C(AMOUNT)
          CALL CLS
          CALL D(AREA)
          CALL CLS
          CALL E(SLOP)
          CALL CLS
          CALL F(LSHED)
          CALL CLS
          CALL G(STOR)
          CALL CLS
          CALL H(FNAME,FLAG,RDT)
          CALL CLS
```

```
        IF(FLAG.EQ.1) THEN
           CALL I(RDT)
        ENDIF
        GOTO 10
     ENDIF
     CALL MOVECUR(20,1)
     CALL SAVECUR
     IF(NN.EQ.2) THEN
        CALL A(PROJNAM)
     ELSEIF(NN.EQ.3) THEN
        CALL B(REVIEW)
     ELSEIF(NN.EQ.4) THEN
        CALL C(AMOUNT)
     ELSEIF(NN.EQ.5) THEN
        CALL D(AREA)
     ELSEIF(NN.EQ.6) THEN
        CALL E(SLOP)
     ELSEIF(NN.EQ.7) THEN
        CALL F(LSHED)
     ELSEIF(NN.EQ.8) THEN
        CALL G(STOR)
     ELSEIF(NN.EQ.9) THEN
        CALL OPTION(OPTYN)
     ELSEIF(NN.EQ.10) THEN
        CALL H(FNAME,FLAG,RDT)
     ELSEIF(NN.EQ.11) THEN
        IF(FLAG.EQ.0)THEN
           WRITE(*,30)
30         FORMAT(/,10X,'AN OUTPUT FILE HAS NOT BEEN SPECIFIED')
           CALL DELAY(300)
        ELSE
           CALL I(RDT)
        ENDIF
     ELSEIF(NN.EQ.12) THEN
        RETURN
     ELSE
     ENDIF
     GOTO 10
     END
```

```
C
C***********************************************************************
C                              INPUT SUBROUTINES
C
C     THE FOLLOWING SUBROUTINES PROMPT FOR VARIOUS REQUIRED USER INPUT.
C***********************************************************************
C
C-----------------------------------------------------------------------
C                               PROJECT NAME
C-----------------------------------------------------------------------
C
      SUBROUTINE A(PROJNAM)
      CHARACTER PROJNAM*40
      INTEGER ERR
10    CALL RESTCUR
      WRITE(*,20)
20    FORMAT(10X,'ENTER THE PROJECT NAME:  ',\)
      READ(*,'(A)',IOSTAT=ERR) PROJNAM
      IF(ERR.GT.0) GOTO 10
      RETURN
      END
C
C-----------------------------------------------------------------------
C                              REVIEWERS NAME
C-----------------------------------------------------------------------
C
      SUBROUTINE B(REVIEW)
      CHARACTER REVIEW*40
      INTEGER ERR
10    CALL RESTCUR
      WRITE(*,20)
20    FORMAT(10X,'ENTER THE REVIEWERS NAME:  ',\)
      READ(*,'(A)',IOSTAT=ERR) REVIEW
      IF(ERR.GT.0) GOTO 10
      RETURN
      END
C
C-----------------------------------------------------------------------
C                          24-HOUR RAINFALL AMOUNT
C-----------------------------------------------------------------------
C
      SUBROUTINE C(AMOUNT)
      INTEGER ERR
10    CALL RESTCUR
      WRITE(*,20)
20    FORMAT(10X,'ENTER THE MAXIMUM 24-HOUR RAINFALL AMOUNT IN',
     1           ' INCHES:  ',\)
      READ(*,*,IOSTAT=ERR) AMOUNT
      IF(ERR.GT.0) GOTO 10
      RETURN
      END
```

```
C
C-----------------------------------------------------------------------
C                              BASIN AREA
C-----------------------------------------------------------------------
C
      SUBROUTINE D(AREA)
      INTEGER ERR
10    CALL RESTCUR
      WRITE(*,20)
20    FORMAT(10X,'ENTER THE AREA OF THE WATERSHED IN ACRES:  ',\)
      READ(*,*,IOSTAT=ERR) AREA
      IF(ERR.GT.0) GOTO 10
      RETURN
      END
C
C-----------------------------------------------------------------------
C                           AVERAGE BASIN SLOPE
C-----------------------------------------------------------------------
C
      SUBROUTINE E(SLOPE)
      INTEGER ERR
10    CALL RESTCUR
      WRITE(*,20)
20    FORMAT(10X,'ENTER THE WATERSHEDS AVERAGE SLOPE IN',
     1          ' FEET/MILE:  ',\)
      READ(*,*,IOSTAT=ERR) SLOPE
      IF(ERR.GT.0) GOTO 10
      RETURN
      END
C
C-----------------------------------------------------------------------
C                         LENGTH OF THE WATERSHED
C-----------------------------------------------------------------------
C
      SUBROUTINE F(LSHED)
      REAL LSHED
      INTEGER ERR
10    CALL RESTCUR
      WRITE(*,20)
20    FORMAT(10X,'ENTER THE RUNOFF LENGTH OF THE WATERSHED IN',
     1          ' FEET:  ',\)
      READ(*,*,IOSTAT=ERR) LSHED
      IF(ERR.GT.0) GOTO 10
      RETURN
      END
```

```
C-----------------------------------------------------------------
C                      AVAILABLE GROUNDWATER STORAGE
C-----------------------------------------------------------------
C
      SUBROUTINE G(STOR)
      INTEGER ERR
10    CALL RESTCUR
      WRITE(*,20)
20    FORMAT(10X,'ENTER THE AVAILABLE GROUNDWATER STORAGE IN',
     1          ' INCHES:  ',\)
      READ(*,*,IOSTAT=ERR) STOR
      IF(ERR.GT.0) GOTO 10
      RETURN
      END
C
C-----------------------------------------------------------------
C                      INCREMENTAL OUTPUT FILE NAME
C-----------------------------------------------------------------
C
      SUBROUTINE H(FNAME,FLAG,RDT)
      INTEGER FLAG,FLAG1,ERR
      LOGICAL FLAG2,FILECHK
      CHARACTER FNAME*15, CHK*1
      CHK=' '
20    CONTINUE
      CALL RESTCUR
      WRITE(*,30)
30    FORMAT(10X,
     1    'DO YOU WANT INCREMENTAL VALUES OF RUNOFF, INFILTRATION',/
     2    10X,'AND RAINFALL WRITTEN TO AN OUTPUT FILE? (Y/N):  ',\)
      READ(*,'(A)',IOSTAT=ERR) CHK
      IF(ERR.GT.0) GOTO 20
      CALL RESTCUR
      CALL CLL
      CALL CLL
      CALL RESTCUR
      CALL CHKYN(CHK,FLAG2)
      IF(FLAG2) GOTO 20
      IF(CHK.EQ.'y'.OR.CHK.EQ.'Y') THEN
         FLAG=1
40       WRITE(*,50)
50       FORMAT(10X,'ENTER THE INCREMENTAL OUTPUT FILE NAME:  ',\)
         READ(*,'(A15)',IOSTAT=ERR) FNAME
         CALL RESTCUR
         CALL CLL
         CALL RESTCUR
         IF(ERR.GT.0) GOTO 40
         CALL CHKFILE(FNAME,FLAG2)
         IF(FLAG2) GOTO 40
      ELSE
         FLAG=0
         FNAME='NO OUTPUT FILE'
      ENDIF
      RETURN
      END
```

```
C
C-----------------------------------------------------------------------
C                                PRINT INTERVAL
C-----------------------------------------------------------------------
C
      SUBROUTINE I(RDT)
      INTEGER ERR
      RDT=0.25
10    CALL RESTCUR
      WRITE(*,20)
20    FORMAT(10X,'ENTER THE PRINT INTERVAL IN QUARTER',
     1           ' HOUR INCREMENTS: ',\)
      READ(*,*,IOSTAT=ERR) RDT
      IF(ERR.GT.0) GOTO 10
      RETURN
      END
```

```
C
C**************************************************************************
C                              SUBROUTINE OPTION
C
C     THIS SUBROUTINE DISPLAYS A MENU OF OPTIONAL USER INPUT.  IT READS
C     THE USERS SELECTION AND CALLS THE PROPER SUBROUTINE TO PROMPT FOR
C     THE DESIRED INPUT.
C**************************************************************************
C
      SUBROUTINE OPTION(OPTYN)
C
C-------------------------------------------------------------------------
C                              TYPE STATEMENTS
C-------------------------------------------------------------------------
C
      CHARACTER PROJNAM*40,REVIEW*40,FNAME*15,OPTYN*21
      INTEGER*2 STORM,FLAG,FLAG1,ERR
      REAL LSHED,NPERV
C
C-------------------------------------------------------------------------
C                              COMMON BLOCKS
C-------------------------------------------------------------------------
C
      COMMON/PARAM/AREA,STOR,DEPSTO,NPERV,IRF,STORM,AMOUNT,SLOP,
     1            LSHED,RDT,FLAG,FLAG1,PROJNAM,REVIEW,FNAME
      COMMON/INFILDAT/ FC(3)
C
C-------------------------------------------------------------------------
C                           DISPLAY EDITOR OPTIONS
C-------------------------------------------------------------------------
C
10    CALL CLS
      WRITE(*,20) DEPSTO,NPERV,IRF,FC(1),FC(2)
20    FORMAT(30X,'OPTIONAL PARAMETERS',//
     1   10X,'THE FOLLOWING PARAMETERS MAY BE CHANGED FROM THEIR',/
     2   10X,'DEFAULT VALUES.  NOTE HOWEVER THAT CHANGING THESE',/
     3   10X,'PARAMETERS WILL PRODUCE RESULTS THAT CAN NOT BE',/
     4   10X,'OBTAINED FROM THE NOMOGRAPHS IN "VOLUME IV"',//
     5   10X,'      1. DEPRESSION STORAGE (',F5.3,' INCHES)',/
     6   10X,'      2. MANNINGS "n" (',F5.3,')',/
     7   10X,'      3. RAINFALL DURATION (',I2,' DAYS)',/
     8   10X,'      4. HORTON EQUATION INFILTRATION CONSTANTS',/
     9   10X,'             (INITIAL RATE: ',F10.2,' INCHES PER HOUR)',/
     A   10X,'             (FINAL RATE:   ',F10.2,' INCHES PER HOUR)',/
     B   10X,'      5. RETURN TO MAIN MENU',//
     C   10X,'SELECTION:  ',\)
```

```
C
C-----------------------------------------------------------------------
C             READ SELECTION AND CALL APPROPRIATE SUBROUTINE
C-----------------------------------------------------------------------
C
      READ(*,*,IOSTAT=ERR) NN
      IF(ERR.GT.0) GOTO 10
      CALL MOVCUR(17,1)
      CALL SAVECUR
      IF(NN.EQ.1) THEN
         CALL AA(DEPSTO)
       ELSEIF(NN.EQ.2) THEN
         CALL BB(NPERV)
      ELSEIF(NN.EQ.3) THEN
         CALL CC(IRF,STORM)
      ELSEIF(NN.EQ.4) THEN
         CALL DD(FC)
      ELSEIF(NN.EQ.5) THEN
         IF(DEPSTO.EQ.2.0.AND.NPERV.EQ.0.25.AND.IRF.EQ.3.AND.
     1      FC(1).EQ.3.1.AND.FC(2).EQ.0.01) THEN
            OPTYN='^[[36mDEFAULT VALUES'
         ELSE
            OPTYN='^[[31mUSER VALUES^[[36m'
         ENDIF
         RETURN
      ELSE
      ENDIF
      GOTO 10
      END
```

```
C
C***************************************************************************
C                        OPTIONAL INPUT SUBROUTINES
C
C     THE FOLLOWING SUBROUTINES PROMPT FOR VARIOUS OPTIONAL USER INPUT.
C     IF USER VALUES ARE NOT SPECIFIED, DEFAULT VALUES ARE ASSUMED.
C***************************************************************************
C
C---------------------------------------------------------------------------
C                         DEPRESSION STORAGE DEPTH
C                           DEFAULT = 2.0 INCHES
C---------------------------------------------------------------------------
C
      SUBROUTINE AA(DEPSTOR)
      REAL DEPSTOR
      INTEGER ERR
10    CALL RESTCUR
      WRITE(*,20)
20    FORMAT(10X,'ENTER THE DEPRESSION STORAGE IN INCHES:  ',\)
      READ(*,*,IOSTAT=ERR) DEPSTOR
      IF(ERR.GT.0) GOTO 10
      RETURN
      END
C
C---------------------------------------------------------------------------
C                               MANNING'S "n"
C                              DEFAULT = 0.25
C---------------------------------------------------------------------------
C
      SUBROUTINE BB(NPERV)
      REAL NPERV
      INTEGER ERR
10    CALL RESTCUR
      WRITE(*,20)
20    FORMAT(10X,'ENTER MANNINGS "n" FOR THE WATERSHED:  ',\)
      READ(*,*,IOSTAT=ERR) NPERV
      IF(ERR.GT.0) GOTO 10
      RETURN
      END
```

```
C
C----------------------------------------------------------------------
C                                  STORM DURATION
C                                 DEFAULT = 3 DAYS
C----------------------------------------------------------------------
C
      SUBROUTINE CC(IRF,STORM)
      INTEGER*2 STORM,ERR
20    CALL RESTCUR
      STORM=0
      WRITE(*,30)
30    FORMAT(10X,'ENTER THE RAINFALL DISTRIBUTION TYPE',/
     1       10X,'1 = 24-HOUR;  3 = 3-DAY;  5 = 5-DAY',/
     2       10X,'SELECTION:  ',\)
      READ(*,*,IOSTAT=ERR) IRF
      IF(ERR.GT.0) GOTO 20
      IF(IRF.EQ.1) STORM=1
      IF(IRF.EQ.3) STORM=2
      IF(IRF.EQ.5) STORM=3
      IF(STORM.EQ.0) GOTO 20
      RETURN
      END
C
C----------------------------------------------------------------------
C                      CONSTANTS FOR HORTON'S EQUATION
C             DEFAULT INITIAL INFILTRATION RATE = 3.1 INCHES/HOUR
C              DEFAULT FINAL INFILTRATION RATE = 0.01 INCHES/HOUR
C----------------------------------------------------------------------
C
      SUBROUTINE DD(FC)
      INTEGER ERR
      LOGICAL FLAG2
      DIMENSION FC(3)
10    CALL RESTCUR
      WRITE(*,30)
30    FORMAT(10X,'THIS PROGRAM DETERMINES THE INFILTRATION RATE',/
     1       10X,'BY HORTONS EQUATION USING THESE VALUES',/
     2       10X,'FOR THE INITIAL AND FINAL INFILTRATION RATES:',/
     3       10X,'   INITIAL:          3.10 INCHES PER HOUR',/
     4       10X,'   FINAL:            0.01 INCHES PER HOUR',/
     5       10X,'DO YOU WANT TO CHANGE THESE VALUES? (Y/N):   ',\ )
      READ(*,'(A)',IOSTAT=ERR) CHK
      IF(ERR.GT.0) GOTO 10
      CALL RESTCUR
      DO 35 I=1,6
         CALL CLL
35    CONTINUE
      CALL RESTCUR
      CALL CHKYN(CHK,FLAG2)
      IF(FLAG2) GOTO 10
```

```
      IF(CHK.EQ.'Y'.OR.CHK.EQ.'y') THEN
40       CALL RESTCUR
         CALL CLL
         CALL RESTCUR
         WRITE(*,50)
50       FORMAT(10X,'ENTER THE INITIAL INFILTRATION RATE:  ',\)
         READ(*,*,IOSTAT=ERR) FC(1)
         IF(ERR.GT.0) GOTO 40
70       CALL RESTCUR
         CALL CLL
         CALL RESTCUR
         WRITE(*,80)
80       FORMAT(10X,'ENTER THE FINAL INFILTRATION RATE:',\)
         READ(*,*,IOSTAT=ERR) FC(2)
         IF(ERR.GT.0) GOTO 70
      ELSE
         FC(1)=3.10
         FC(2)=0.01
      ENDIF
      RETURN
      END
```

```
C
C***********************************************************************
C                          SUBROUTINE INCRUN
C
C     THIS SUBROUTINE DETERMINES THE RUNOFF FROM THE WATERSHED DURING
C     EACH TIME STEP AND INTIALIZES THE POTENTIAL INFILTRATION, THE
C     AVAILABLE GROUNDWATER STORAGE, AND THE WATER DEPTH ON THE
C     WATERSHED FOR THE NEXT TIME STEP.
C
C     LIST OF VARIABLES:
C
C     USER INPUT
C
C        PROJNAM     THE PROJECT NAME
C        REVIEW      THE REVIEWERS NAME
C        AMOUNT      THE 24-HR RAINFALLAMOUNT (INCHES)
C        AREA        THE AREA OF THE WATERSHED (ACRES)
C        SLOP        THE AVERAGE SLOPE OF THE WATERSHED (FEET/MILE)
C        LSHED       THE OVERLAND FLOW LENGTH (FEET)
C        STOR        THE DEPTH OF AVAILABLE GROUNDWATER STORAGE (INCHES)
C        DEPSTO      THE RETENTION DEPTH (INCHES)
C        NPERV       MANNING'S ROUGHNESS COEFFICIENT
C        IRF         THE RAINFALL DURATION (DAYS)
C        FC(I)       THE CONSTANTS USED IN HORTONS EQUATION (INCHES/HOUR)
C                    FC(1) = fo - THE INITIAL INFILTRATION RATE
C                    FC(2) = fc - THE FINAL INFILTRATION RATE
C                    FC(3) = k  - THE DECAY CONSTANT, INITIALIZED TO
C                                 ZERO, AND CALCULATED FROM THE AVAILABLE
C                                 SOIL STORAGE AND THE INITIAL AND FINAL
C                                   INFILTRATION RATES.
C
C     RAINFALL DISTRIBUTION
C
C        RNDAT1(I,J) THE HYETOGRAPH FOR THE 1-DAY RAIN EVENT
C        RNDAT3(I,J) THE HYETOGRAPH FOR THE 3- AND 5-DAY EVENTS
C
C     SUBROUTINE VARIABLES
C
C       TIME VARIABLES
C
C        DT          TIME INTERVAL IN SECONDS
C        DTM         TIME INTERVAL IN MINUTES
C        DTH         TIME INTERVAL IN HOURS
C        TIMERUN     ELAPSED MODEL TIME IN HOURS ( MEASURED AT THE END
C                    OF EACH INTERVAL
C        TIMEPRT     PRINT INTERVAL IN HOURS
C        TIME1       ELAPSED TIME IN HOURS FOR INFILTRATION CALCULATIONS
C                    (MEASURED AT THE END OF EACH INTERVAL)
C        TIME2       ELAPSED TIME IN HOURS FOR INFILTRATION CALCULATIONS
C                    (MEASURED AT THE BEGINNING OF EACH INTERVAL)
```

```
C
C       WATERSHED VARIABLES
C
C        ASHED        AREA OF THE WATERSHED (SQUARE FEET)
C        WSHED        WIDTH OF THE WATERSHED (FEET)
C        SLOPE        AVERAGE SLOPE OF THE WATERSHED (FEET/FEET)
C        DEPSTOR      RETENTION DEPTH (FEET)
C
C       TRANSIENT VARIABLES
C
C        INCRAIN      RAINFALL DURING THE INTERVAL (FEET)
C        FILTI        POTENTIAL INFILTRATION DURING THE TIME INTERVAL
C                     (INCHES)
C        FILTF        POTENTIAL INFILTRATION DURING THE TIME INTERVAL
C                     (FEET)
C        AFILT        ACTUAL INFILTRATION DURING THE TIME INTERVAL
C                     (INCHES)
C        GDSTOR       GROUNDWATER STORAGE AVAIALABLE AT EACH TIME
C                     INTERVAL (INCHES)
C        DEPTH        DEPTH OF WATER ON THE WATERSHED DURING THE
C                     INTERVAL (FEET)
C        RDEPTH       DEPTH OF WATER ON THE WATERSHED CONTRIBUTING TO
C                     RUNOFF (FEET)
C        DELD         CHANGE IN DEPTH OF WATER ON THE WATERSHED DURING
C                     THE INTERVAL
C        DELDEST      ESTIMATE OF CHANGE IN DEPTH OF WATER ON THE
C                     WATERSHED DURING NEWTON-RAPHSON ITERATIONS
C        AWATER       AVAILABLE WATER - EQUAL TO DEPTH OF WATER ON THE
C                     WATERSHED AT THE BEGINNING OF THE TIME INTERVAL
C                     PLUS THE INCREMENTAL RAINFALL
C        XSWATER      AVAILABLE WATER MINUS INFILTRATION
C        XSRAIN       INCREMENTAL RAINFALL MINUS INCREMENTAL INFILTRATION
C        QINC         RUNOFF RATE DURING AN INTERVAL (CFS)
C
C       OUTPUT VARIABLES
C
C        QPEAK        PEAK RUNOFF RATE (CFS)
C        TQINC        TOTAL DISCHARGE FROM THE WATERSHED (AC-FT)
C        TFILT        TOTAL ACTUAL INFILTRATION (INCHES)
C        TRAIN        TOTAL RAINFALL (INCHES)
C*************************************************************************
C
```

```
      SUBROUTINE INCRUN(QPEAK)
C
C-----------------------------------------------------------------------
C                              TYPE STATEMENTS
C-----------------------------------------------------------------------
C
      CHARACTER CHK*1,PROJNAM*40,REVIEW*40,FNAME*15
      CHARACTER HMS*10,WKDAY*4,MDY*8,FNAME1*15
      LOGICAL FLAG2,FILECHK
      REAL LSHED,NPERV,INCRAIN
      INTEGER*2 STORM,FLAG,FLAG1,ERR,RNSTOP
      DIMENSION RAINFL(480)
C
C-----------------------------------------------------------------------
C                              COMMON BLOCKS
C-----------------------------------------------------------------------
C
      COMMON/RAINDAT/ RNDAT(2,100),RNDAT1(2,50),RNDAT3(2,54),
     1                NUMPTS(3)
      COMMON/PARAM/AREA,STOR,DEPSTO,NPERV,IRF,STORM,AMOUNT,SLOP,
     1             LSHED,RDT,FLAG,FLAG1,PROJNAM,REVIEW,FNAME
      COMMON/INFILDAT/ FC(3)
C
C-----------------------------------------------------------------------
C                      INITIALIZE SUBROUTINE VARIABLES
C-----------------------------------------------------------------------
C
C.......................................................................
C                            RAIN DATA VARIABLES
C.......................................................................
C
      DEPTH = 0.0
      DO 10 I=1,2
         DO 10 J=1,100
           RNDAT(I,J)=0.0
10    CONTINUE
C
C.......................................................................
C                              TIME VARIABLES
C.......................................................................
C
      DT=900.
      DTM=DT/60.
      DTH=DT/3600.
      TIME1=0.
      TIMERUN=0.0
      TIMEPRT=RDT
```

```
C
C.............................................................................
C                              WATERSHED VARIABLES
C.............................................................................
C
      ASHED=AREA*43560.
      WSHED=ASHED/LSHED
      SLOPE=SLOP/5280.
      DEPSTOR=DEPSTO/12.
C
C.............................................................................
C                              INFILTRATION VARIABLES
C.............................................................................
C
      GDSTOR=STOR
      C1=FC(2)
      C2=(FC(1)-FC(2))
      FC(3)=(FC(1)-FC(2))/GDSTOR
C
C.............................................................................
C                              CALCULATION VARIABLES
C.............................................................................
C
      Z=(1.486/NPERV)*(SLOPE**0.5)*WSHED/ASHED
      DELDEST=0.0
      DELD=0.0
C
C.............................................................................
C                              OUTPUT VARIABLES
C.............................................................................
C
      QPEAK=0.0
      TQINC=0.0
      TFILT=0.0
      TRAIN=0.0
C
C-----------------------------------------------------------------------------
C        IF NECESSARY OPEN INCREMENTAL OUTPUT FILE AND WRITE HEADER
C-----------------------------------------------------------------------------
C
      IF(FLAG.EQ.1) THEN
         OPEN(2,FILE=FNAME,STATUS='NEW')
         CALL TIME(HMS)
         CALL DATE(WKDAY,MDY)
         WRITE (2,20) PROJNAM,REVIEW,WKDAY,MDY,HMS
20       FORMAT(4X,'PROJECT:   ',A40,//,
     1          4X,'REVIEWER:   ',A40,//,
     2          4X,'DATE:   ',A4,3X,A8,10X,A10,//,
     3          4X,'TIME',4X,'RAIN',3X,'TOTAL',2X,'RUNOFF',1X,
     4             '  TOTAL',2X,'INFILT',1X,'  TOTAL',3X,'WATER',/
     5          4X,'    ',4X,'    ',3X,' RAIN',2X,'  RATE',1X,
     6             ' RUNOFF',2X,'      ',1X,' INFILT',3X,'DEPTH',/
     7          4X,'(HR)',4X,'(IN)',3X,' (IN)',2X,' (CFS)',1X,
     8             '(AC-FT)',2X,'  (IN)',1X,'   (IN)','    (IN)'//)
      ENDIF
```

```
C
C---------------------------------------------------------------------
C                    DETERMINE RAINFALL DISTRIBUTION TYPE
C---------------------------------------------------------------------
C
      IF(STORM.EQ.1) THEN
         DO 30 I=1,2
            DO 30 J=1,50
               RNDAT(I,J)=RNDAT1(I,J)
30       CONTINUE

      ELSE
         DO 40 I=1,2
            DO 40 J=1,NUMPTS(STORM)
               RNDAT(I,J)=RNDAT3(I,J)
40       CONTINUE
      ENDIF
C
C---------------------------------------------------------------------
C                    CALCULATE THE RAINFALL DISTRIBUTION
C---------------------------------------------------------------------
      CALL RNFALL(RNDAT,STORM,RAINFL,AMOUNT,DTM,RNSTOP)
C
C---------------------------------------------------------------------
C                 DETERMINE THE RUNOFF DURING EACH TIME STEP
C---------------------------------------------------------------------
C
C.....................................................................
C                      DETERMINE INCREMENTAL RAINFALL
C.....................................................................
C
      DO 100 I=1,2000
         IF(I.GT.RNSTOP) THEN
           INCRAIN=0.0
         ELSE
           INCRAIN=RAINFL(I)/12.
         ENDIF
         TIME1=TIME1+DTH
         TIMERUN=TIMERUN+DTH
         TRAIN=TRAIN+INCRAIN
C
C.....................................................................
C           COMPUTE AVERAGE INFILTRATION DURING TIME INTERVAL
C.....................................................................
C
         FILTI=C1*DTH
         EXP1=-FC(3)*TIME1
         TIME2=TIME1-DTH
         EXP2=-FC(3)*TIME2
         IF(EXP1.GT.-170.) THEN
            FILTI=(C1*TIME1-C2/FC(3)*EXP(EXP1))-
     1           (C1*TIME2-C2/FC(3)*EXP(EXP2))
         ENDIF
         FILTF=FILTI/12.
```

```
C
C.......................................................................
C                                 CASE A
C     IF AVAILABLE WATER IS LESS THAN POTENTIAL INFILTRATION LOSS THEN
C     ALL AVAILABLE WATER IS INFILTRATED
C.......................................................................
C
        AWATER=DEPTH+INCRAIN
        IF(AWATER.LE.FILTF) THEN
           QINC=0.0
           GDSTOR=GDSTOR-AWATER*12.
           GDSTOR1=GDSTOR
           IF(GDSTOR.LT.0.) GDSTOR=0.
           C2=GDSTOR*FC(3)
           TIME1=0.
           AFILT=INCRAIN*12.
           DEPTH=0.0
C
C.......................................................................
C                              CASES B AND C
C        ELSE COMPUTE CHANGE IN DEPTH OF WATER ON WATERSHED
C.......................................................................
C
        ELSE
           GDSTOR1 = GDSTOR1 - FILTI
           XSWATER=AWATER-FILTF
           AFILT=FILTI
C
C.......................................................................
C                                 CASE B
C    IF AVAILABLE WATER MINUS INFILTRATION IS LESS THAN OR EQUAL TO THE
C    DEPRESSION STORAGE DEPTH, THEN NO RUNOFF OCCURS, INFILTRATION EQUALS
C    THE POTENTIAL INFILTRATION, AND THE DEPTH OF WATER ON THE WATERSHED
C    IS EQUAL TO THE AVAILABLE WATER MINUS INFILTRATION
C.......................................................................
C
           IF(XSWATER.LE.DEPSTOR) THEN
              QINC = 0.0
              DEPTH = XSWATER
```

```
C
C.......................................................................
C                                  CASE C
C        IF AVAILABLE WATER MINUS INFILTRATION IS GREATER THAN
C        DEPRESSION STORAGE DEPTH, THEN CALCULATE INCREMENTAL RUNOFF AND
C        NEW WATER DEPTH FOR THE WATERSHED
C.......................................................................
C
            ELSE
               XSRAIN=INCRAIN-FILTF
               DO 60 J=1,20
                  RDEPTH=DEPTH-DEPSTOR+0.5*DELDEST
                  IF(RDEPTH.LT.0.0) RDEPTH=0.0
                  FUNC=DT*(Z*RDEPTH**1.6666667)-XSRAIN+DELDEST
                  DFUNC=DT*(0.83333333*Z*RDEPTH**0.6666667)+1.0
                  DELD=DELDEST-FUNC/DFUNC
                  IF(J.NE.1) THEN
                     IF((ABS(DELD-DELDEST)).LT.(ABS(0.001*DELDEST)))
     1                 GOTO 70
                  ENDIF
                  DELDEST=DELD
                  IF(J.EQ.20) THEN
                     CALL MOVECUR(20,1)
                     CALL CLL
                     CALL CLL
                     CALL CLL
                     CALL MOVECUR(20,1)
                     WRITE(*,55)
55                   FORMAT(5X,'            **ERROR**',/
     1                      5X,' CANNOT CONVERGE ON A SOLUTION',/
     2                      5X,'  PLEASE CHECK YOUR INPUT DATA',/
     3                      5X,'  BEFORE RESUBMITTING YOUR JOB')
                     CALL DELAY(500)
                     CALL MOVECUR(20,1)
                     CALL CLL
                     CALL CLL
                     CALL CLL
                     CALL CLL
                     CALL MOVECUR(20,1)
                     CALL END
                  ENDIF
60             CONTINUE
70             DELDEST=0.0
               QINC=(XSRAIN-DELD)*ASHED/DT
               IF(QINC.LT.0.0) QINC = 0.0
               DEPTH=DEPTH+DELD
            ENDIF
         ENDIF
```

```
C
C...........................................................................
C              DETERMINE THE PEAK RUNOFF FOR THE RAIN EVENT
C...........................................................................
C
      IF(QINC.GT.QPEAK) QPEAK=QINC
      TQINC=TQINC+QINC*900/43560
      TFILT=TFILT+AFILT
C
C...........................................................................
C                   WRITE INCREMENTAL OUTPUT TO A FILE
C...........................................................................
C
      IF(FLAG.EQ.1) THEN
         IF(TIMERUN.EQ.TIMEPRT) THEN
            WRITE(2,80) TIMERUN,INCRAIN*12,TRAIN*12,QINC,TQINC,AFILT,
     1                  TFILT,DEPTH*12
80          FORMAT(F8.2,2(F8.3),2(F8.2),3(F8.3))
            TIMEPRT=TIMEPRT+RDT
         ENDIF
      ENDIF
      CALL MOVECUR(20,1)
      WRITE(*,90) TIMERUN,TRAIN*12,TQINC
90    FORMAT(5X,'PROCESSING.....................................',//,
     1    5X,'TIME: ',F6.2,' HRS.  TOTAL RAIN: ',F6.2,' IN.  TOTAL',
     2    ' RUNOFF: ',F8.2,' AC-FT')
      IF(FLAG.EQ.1) THEN
        ALPHA=0.01
      ELSE
        ALPHA=0.95
      ENDIF
      IF(QINC.LT.QPEAK*ALPHA) RETURN
100   CONTINUE
      RETURN
      END
```

```
C
C***************************************************************************
C                               SUBROUTINE RNFALL
C
C     THIS SUBROUTINE DETERMINES THE INCREMENTAL RAINFALL FROM THE
C     UNIT HYETOGRAPH AND THE 24-HOUR RAINFALL AMOUNT.
C***************************************************************************
C
      SUBROUTINE RNFALL(RNDAT,STORM,RAINFL,RAIN,DTM,RNSTOP)
      DIMENSION RAINFL(480),RNDAT(2,100)
      INTEGER STORM,RNSTOP
      IF(STORM.EQ.1) NN=50
      IF(STORM.EQ.2) NN=52
      IF(STORM.EQ.3) NN=54
      DO 10 I=1,480
         RAINFL(I)=0.
10    CONTINUE
      J=1
      DO 20 I=1,NN-1
         TIMERUN=RNDAT(1,I+1)-RNDAT(1,I)
         AMNT=RNDAT(2,I+1)-RNDAT(2,I)
         IT=TIMERUN*60/DTM
         FRAC=AMNT/IT
         DO 20 K=1,IT
            RAINFL(J)=FRAC*RAIN
            J=J+1
20    CONTINUE
      RNSTOP=J-1
      RETURN
      END
```

```
C
C***********************************************************************
C                        SUBROUTINE OUTPUT
C
C     THIS SUBROUTINE WRITES THE FINAL OUTPUT FILE IF SPECIFIED BY THE
C     USER.
C***********************************************************************
C
      SUBROUTINE OUTPUT(QPEAK)
C
C-----------------------------------------------------------------------
C                              TYPE STATEMENTS
C-----------------------------------------------------------------------
C
      CHARACTER CHK*1,PROJNAM*40,REVIEW*40,FNAME*15
      CHARACTER HMS*10,WKDAY*4,MDY*8,FNAME1*15
      LOGICAL FLAG2,FILECHK
      REAL LSHED,NPERV
      INTEGER*2 STORM,FLAG,FLAG1,IROW,ICOL,IPAGE,ERR
      DIMENSION RAINFL(480)
C
C-----------------------------------------------------------------------
C                              COMMON BLOCKS
C-----------------------------------------------------------------------
C
      COMMON/RAINDAT/ RNDAT(2,100),RNDAT1(2,50),RNDAT3(2,54),
     1                NUMPTS(3)
      COMMON/PARAM/AREA,STOR,DEPSTO,NPERV,IRF,STORM,AMOUNT,SLOP,
     1             LSHED,RDT,FLAG,FLAG1,PROJNAM,REVIEW,FNAME
      COMMON/INFILDAT/ FC(3)
C
C------------------------------------------------------------------
C                        WRITE PEAK RUNOFF TO SCREEN
C------------------------------------------------------------------
C
      IQPEAK=QPEAK+.5
      CALL MOVECUR(20,1)
      CALL CLL
      CALL CLL
      CALL CLL
      CALL MOVECUR(20,1)
      WRITE(*,20)IQPEAK
20    FORMAT(10X,'THE PEAK RUNOFF RATE FROM THE WATERSHED',
     1          ' IS ',I7,' CFS.')
C
C------------------------------------------------------------------
C               IF NECESSARY CLOSE INCREMENTAL OUTPUT FILE
C------------------------------------------------------------------
C
      IF(FLAG.EQ.1) CLOSE(2,STATUS='KEEP')
```

```
C
C-----------------------------------------------------------------
C              DETERMINE IF A FINAL OUTPUT FILE IS DESIRED
C-----------------------------------------------------------------
C
      CALL MOVECUR(21,1)
      CALL SAVECUR
30    WRITE(*,40)
40    FORMAT(10X,'DO YOU WISH TO WRITE THE INPUT AND ',
     1          'THE PEAK FLOW TO A FILE? (Y/N):  ',\)
      READ(*,'(A)',IOSTAT=ERR) CHK
      IF(ERR.GT.0) GOTO 30
      CALL RESTCUR
      CALL CLL
      CALL RESTCUR
      CALL CHKYN(CHK,FLAG2)
      IF(FLAG2) GOTO 30
      IF(CHK.EQ.'y'.OR.CHK.EQ.'Y') THEN
C
C.....................................................................
C                 PROMPT FOR FINAL OUTPUT FILE NAME
C.....................................................................
C
60       WRITE(*,70)
70       FORMAT(10X,'ENTER THE FINAL OUTPUT FILE NAME:  ',\)
         READ(*,'(A15)',IOSTAT=ERR) FNAME1
         IF(ERR.GT.0) GOTO 60
         CALL RESTCUR
         CALL CLL
         CALL RESTCUR
         CALL CHKFILE(FNAME1,FLAG2)
         IF(FLAG2) GOTO 60
         OPEN(4,FILE=FNAME1,STATUS='NEW')
```

```
C
C.....................................................................
C                    WRITE TO THE FINAL OUTPUT FILE
C.....................................................................
C
      WRITE(*,80) FNAME1
80    FORMAT(10X,'WRITING ',A,'..........')
      CALL TIME(HMS)
      CALL DATE(WKDAY,MDY)
      WRITE (4,90) PROJNAM,REVIEW,WKDAY,MDY,HMS,AMOUNT,IRF,
     1              AREA,SLOP,LSHED,NPERV,DEPSTO,STOR,FC(1),
     2              FC(2),IQPEAK
90   FORMAT(////,10X,'PROJECT:  ',A40,//,
     1 10X,'REVIEWER:  ',A40,//,
     2 10X,'DATE:  ',A4,3X,A8,10X,A10,///,
     3 10X,'                 INPUT PARAMETERS',//
     4 10X,'  MAXIMUM 24-HR RAINFALL AMOUNT.. ',F10.3,' INCHES',/
     5 10X,'  RAINFALL DURATION.............. ',I6,'     DAYS',/
     6 10X,'  BASIN AREA..................... ',F10.3,' ACRES',/
     7 10X,'  SLOPE OF WATERSHED............. ',F10.3,' FEET PER',
     + ' MILE',/
     8 10X,'  LENGTH OF WATERSHED............ ',F10.3,' FEET',/
     9 10X,'  MANNINGS "n"................... ',F10.3,/
     A 10X,'  DETENTION POTENTIAL............ ',F10.3,' INCHES',/
     B 10X,'  DEPTH OF GROUND STORAGE........ ',F10.3,' INCHES',/
     C 10X,'  HORTON EQUATION INFILTRATION CONSTANTS:',/
     D 10X,'     INITIAL RATE................ ',F10.3,' INCHES/HOUR',/
     E 10X,'     FINAL RATE.................. ',F10.3,' INCHES/HOUR',
     + ///
     F 10X,'                 FINAL OUTPUT',//
     G 10X,'THE PEAK RUNOFF RATE FROM THE WATERSHED IS ',I7,' CFS.')
      CALL DELAY(200)
     ENDIF
     RETURN
     END
```

```
C
C*************************************************************************
C                              SUBROUTINE END
C
C     DETERMINE IF ANOTHER RUN IS DESIRED. TERMINATE THE PROGRAM IF
C     REQUIRED.
C*************************************************************************
C
      SUBROUTINE END
      CHARACTER CHK*1
      LOGICAL FLAG
      INTEGER*2 ERR
10    CALL RESTCUR
      CALL CLL
      CALL RESTCUR
      WRITE(*, 20)
20    FORMAT(10X,'DO YOU WISH TO MAKE ANOTHER RUN? (Y/N):  ',\)
      READ(*,'(A)',IOSTAT=ERR) CHK
      IF(ERR.GT.0) GOTO 10
      CALL RESTCUR
      CALL CLL
      CALL RESTCUR
      CALL CHKYN(CHK,FLAG)
      IF(FLAG) GOTO 10
      IF(CHK.EQ.'N'.OR.CHK.EQ.'n')  THEN
C        CALL CLROFF
         CALL CLS
         STOP
      ENDIF
      RETURN
      END
```