A COMPARISON OF TECHNIQUES USED IN RAINFALL-RUNOFF MODELS: MODEL EFFICIENCY

by

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ABSTRACT

A suite of three underlying rainfall-runoff modeling techniques is applied to two data sets and the results used to compare model efficiencies for selected events. Linear regression, unit hydrograph, and quasi-physically based models make up the modeling suite. The two data sets come from a 7.2 KM^2 subwatershed (MCW) near Klingerstown, Pennsylvania and a 0.096 KM^2 subwatershed (R-5) near Chickasha, Oklahoma. Individual model efficiencies are determined on the basis of a sums of squares criterion. These efficiencies are surprisingly poor.

Results indicate that the most informative independent linear regression variables for MCW and R-5 are volume of rainfall and average rainfall intensity respectively. There is a general improvement in correlation coefficients and regression model efficiencies for both MCW and R-5 with increases in the number of selected events. The unit hydrograph and quasi-physically based models exhibited predictive prowess only for the R-5 events. The unit hydrograph technique is found to be strongly dependent upon an accurate estimate of spatially-variable excess rainfall. The efficiency of the physically-based, deterministic, distributed model was found to deteriorate drastically with increases in basin size due to the lumping of spatially-variable soil hydraulic properties.

Based on this work a definitively superior rainfall-runoff modeling technique is not suggested. Limitations of each of the three models and the efficiency criterion used for their evaluation are discussed. This work provides the foundation for a subsequent investigation to be carried out by the author, to determine if space-time tradeoffs exist across data sets of various rainfall-runoff modeling techniques. Future research will focus on the concept of data-worth and the question of model choice.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF TABLES--CONTINUED

Table | Page

LIST OF ILLUSTRATIONS

Figure | Page

LIST OF ILLUSTRATIONS--Continued

Figure Page

LIST OF ILLUSTRATIONS--Continued

Figure Page

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CHAPTER ONE

INTRODUCTION

Dooge (1972) describes the research hydrologist as one who is bound to be prolific in the production of all kinds of models, but one who must recognize the hardships the applied hydrologist faces attempting to choose the correct one for a given situation. Dooge (1978) notes that within the last two decades there has been an immense growth in the modeling literature dealing almost exclusively with description and recommendation, but hardly ever evaluation. This thesis and the research it represents is an attempt to evaluate, by comparison, the efficiencies of selected rainfall-runoff modeling techniques. A brief historical review of the development of hydrology and the types of models currently in use is presented in Linsley's (1981) overview of rainfall-runoff models.

This work underlies a subsequent investigation to determine if space-time tradeoffs exist across the data sets of various rainfall-runoff modeling techniques. Building upon this foundation, future research will focus on the concept of data-worth and the question of model choice.

Chapter One is introductory. It reviews the terminology and classification of hydrologic models; underlying modeling techniques in hydrology; and the concepts of space-time tradeoffs, data-worth and model choice as they are related to hydrologic modeling. At the end of this first chapter the general thesis objective is described. In Chapter Two, the three rainfall-runoff modeling techniques that are used in this study are fully described, and efficiency and comparison criteria are presented. Chapter Three describes the data sources and the methods used to select events from the available records. The simulations and their results are presented in Chapter Four. Conclusions and discussions of future research appear in Chapter Five.

1.1 Terminology and Classification of Hydrologic Models

Woolhiser (1973) describes a hydrologic model as an abstraction that replaces the original hydrologic system with a similar but simpler structure. Each of these models reflects some but not all the properties of the prototype. A great number of hydrologic models currently exist. These models are the result of attempts by research hydrologists both to expand theoretical understanding of hydrologic phenomena and to provide engineers with the necessary tools for decisions concerning operation and design.

As noted by Dooge (1978) the methods used in hydrologic research have not enjoyed a unified terminology in their classification. As a result, much of todays jargon is undercut with a confusing array of shared or conflicting definitions. The purpose of this section is to review, not introduce, hydrologic model classifications and their terminology. The focus of this review is exclusively on mathematical models rather than models of the sand-box or resistance-capacitance type. Many authors have attempted to classify the continuum of methods and models applied in hydrology. The most widely quoted classification schemes are: Amorocho and Hart (1964), and Clarke (1973).

Amorocho and Hart (1964) in their classic paper divided the modeling community into physical hydrology and systems investigation. Physical hydrology is directed towards a full understanding of mechanisms and interactions, while systems investigation deals with designing workable relationships between measurable parameters. Amorocho and Hart further characterize systems investigation as either parametric or stochastic. Following their definitions, parametric hydrology is the development of relationships among physical parameters involved in hydrologic events and the use of these relationships to generate synthetic sequences. Stochastic hydrology is the use of statistical characteristics of hydrologic variables to solve problems. This often involves the generation of sequences to which certain levels of probability can be attached. Kisiel (1967) states that parametric hydrology is concerned with discrete events while stochastic hydrology is concerned with the time sequences of these descrete events.

Dawdy and O'Donnell (1965) follow the delineations of Amorocho and Hart, labeling physical hydrology and system investigation as component and overall catchment modeling respectively. These two groups of models are obviously linked together, as the overall class gains additional information from the component class while the former provides feedback information to the latter. Kisiel (1967,1969) defines determinism as synonomous with causation and describes the stochastic approach as weaving uncertainty, by way of probability laws, into the fabric of the hydrodynamic and phenomenological relations of the system. Cornell (1964) describes a stochastic model as concerned not only with the central tendency values predicted by deterministic models, but also with the inherent and unexplained variation observed in physical phenomena. (Chow, 1964a) defines a model as deterministic if the chance of occurrence for the variable involved is ignored, and as stochastic or probabilistic if chance is taken into consideration and the concept of probability introduced.

Rosenblueth and Weiner (1945) separate models into two classes: material and symbolic. According to Woohiser (1973) a symbolic model is a mathematical description of an idealized situation that shares some of the structural properties of the real system. Woolhiser classifies mathematical models as empirical or theoretical, lumped or distributed, and deterministic or stochastic. In Woolhiser's judgement, an empirical model is based upon fact, having no predictive prowess under changing conditions, while the theoretical model hinges upon explanation of observation. According to Woolhiser, a lumped model can be represented in general, by an ordinary differential equation or a series of linked ordinary differential equations. A distributed model alternatively includes spatial variations in inputs, parameters and dependent variables, and would consist of a partial differential equation or linked partial differential equations. Under Woolhiser's classification, a model is deterministic if, when the initial conditions, boundary conditions and inputs are specified, the output is known with certainty. Woolhiser defines stochastic models as describing processes governed by probability laws.

Dooge (1968) defines a hydrologic system as a set of physical, chemical and/or biological processes acting upon input variables to convert them into output variables. According to Clarke (1973) a model is a simplified representation of a complex system. Clarke categorizes mathematical models into four major groups: Stochastic-conceptual, stochastic-empirical, deterministic-conceptual and deterministic-empirical. A model is regarded as stochastic if any of the variables in its mathematical expression are described by a probability distribution. A model is termed deterministic if all the variables are believed to be free from random variations so that the model involves no distributions in probability. Models are called conceptual if their mathematical expressions are derived from consideration of the physical processes, and empirical if they are not.

In Clarke's assessment, there are several sub-categorizations as well. A model is linear in the systems theory sense if the principle of superposition holds and linear in the statistical regression sense if linear in the parameters to be estimated. Clarke further identifies three sub-categories involving spatial variability of input variables. These are 1) lumped models, that do not account for spatial distribution, 2) probability-distributed models, that describe spatial variability without reference to geometrical configuration in the measurement network and 3) geometrically distributed models that express spatial variability in terms of orientation within the measurement network. Figure 1 shows Clarke's classification of hydrologic models, and references a few examples of each type.

Machado-Olive (1975) distinguishes between statistical and stochastic models. A model is statistical if it includes the concept of probability, with hydrologic variables subject to random fluctuations that are assumed to be independent for different observations. Stochastic models incorporate the

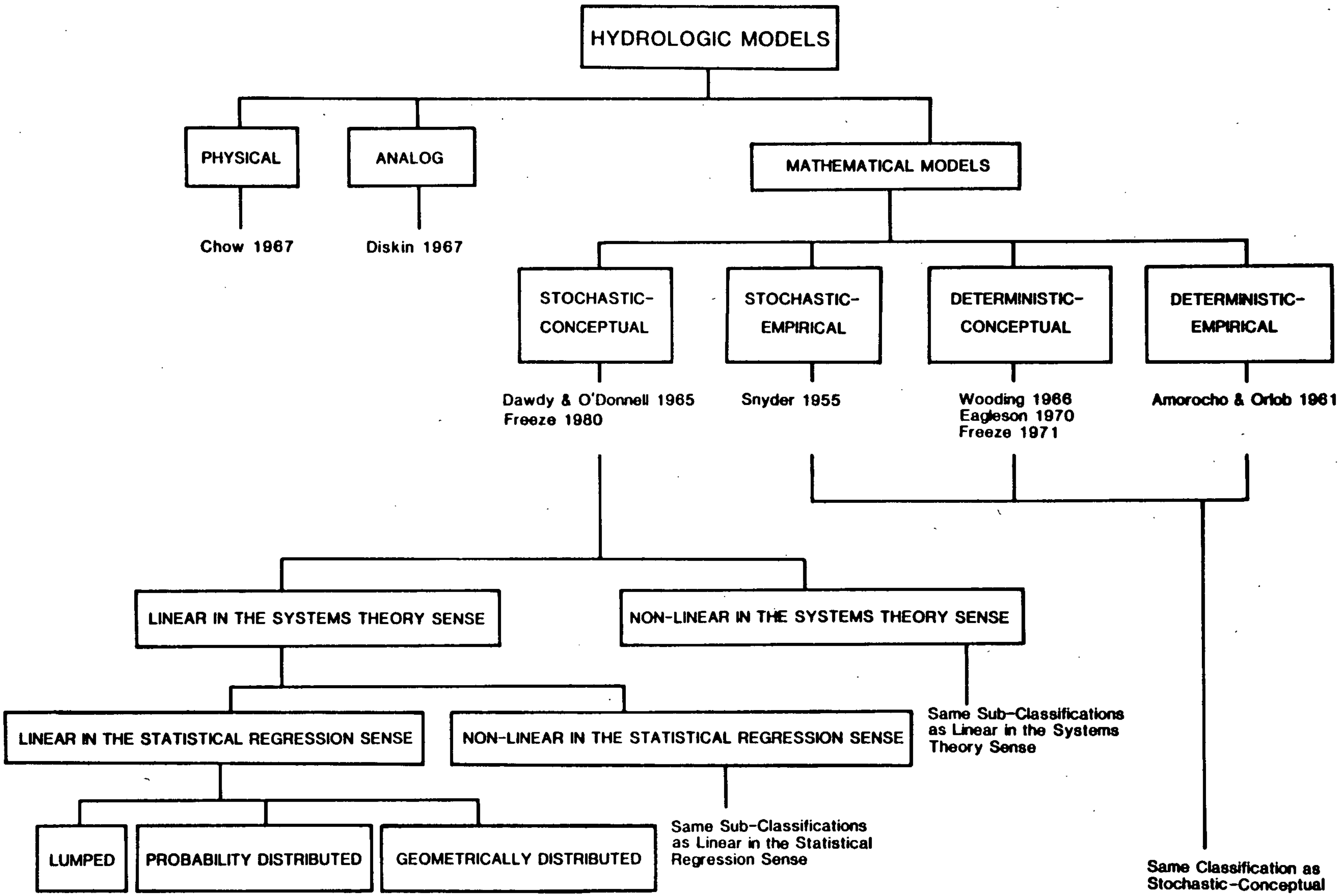

Figure 1. Flow chart of hydrologic model classification (abstracted from Clarke, 1973)

sequence with which hydrologic events occur within a time series and presume past events may influence future events.

Dooge (1972), Quimpo (1973) and Laurenson (1974) each discuss the combination of deterministic and stochastic model components into a unified type of model, classified as hybrid by Kisiel (1969). Klemes (1978) however, cautions that what often happens with such combinations is that the determinist has just included an error term while the stochasticist was only noticing mathematically similar models. Klemes adds, that unification of stochastic and deterministic models amounts to a "Don Quixotian" task, as any model can be classified as either depending upon whether its variables and parameters contain an element of randomness.

Outlining his own classification scheme, with the most decisive changes in terminology-interpretation seen yet, Klemes (1978) defines the term deterministic, as a one-to-one relationship dependent upon theory development, knowledge of initial conditions and accuracy of measurement. Klemes defines the term random, as a completely haphazard order, and finally, the term stochastic, as incorporating both an element of determinism and randomness. Klemes argues that with these definitions it follows that the two classifications, deterministic and random, are only special cases of the stochastic. Klemes further defines a probabilistic model as one that implies description and explanation, while a statistical model only involves description. Finally, Klemes addresses the arbitrariness of hierarchy in model classification and concludes that the most fundamental level of classification should be the conceptual-empirical division (Clarke, 1973; Kisiel, 1969) that has also been labeled synthetic-analytic (O'Donnell, 1966), genetic-statistical (Kartvelishvili, 1967), conceptual-analytic (Wood, 1973), descriptive-prescriptive (Jackson,1975), physically based-operational (Klemes, 1974) and empirical-theoretical (Woolhiser, 1973). The final level of classification for hydrologic models to be presented here differentiates between generic and site-specific models. Generic models are used to further the understanding of hydrologic phenomena, while site-specific models are used for operation and prediction.

What is evident for the foregoing classification schemes and their terminology, is that the range and scope of the various hydrologic models must be great to permit such diversity in model categorization. To insure continuity in terminology throughout the remainder of this thesis, Clarke's classification, which has been adopted by many authors and which is summarized in Figure 1, will be used exclusively.

1.2 Underlying Techniques used in Hydrologic Modeling

Clarke (1973) described the general hydrologic model as:

$$q_t=f(p_{t-1},p_{t-2},\cdots,q_{t-1},q_{t-2},\cdots,a_1,a_2,\cdots)+\xi_t \quad (1)$$

where, P_t = input variables

q_t = output variables

a_n = system parameters

ξ_t = residual error

f = functional form of the model

Variables and parameters are characteristics of the system being modeled. Variables change with time; parameters remain constant. The function can be either conceptual or empirical. The input and output variables as well as the system parameters and residual error can be either stochastic or deterministic. The purpose of this section is to review different techniques used in hydrologic modeling, concentrating upon those which will be employed in this study. In assessing any model for its efficiency in a given situation, as compared to another model, it is important to first recognize the basic structure and operational technique of the individual model with regard to the type of available or economically-obtainable data. The connection between the model classification described in the previous section, and the underlying modeling techniques discussed here, lies in the combinations of individual modeling techniques, inherent in the various hydrologic models, which satisfy various class definitions.

The underlying modeling techniques to be briefly described here are: Correlation analysis, partial system synthesis with linear analysis, and system synthesis. Other techniques used in various hydrologic modeling situations not pertinent to this research but to be included in future investigations include: Non-linear analysis (Amorocho, 1973), frequency analysis (Chow, 1964a), time-series analysis (Matalas, 1967; Kisiel, 1969), Monte Carlo simulation (Fiering and Jackson, 1971; Freeze, 1980) and Kriging (de Marsily, 1982). Delineation of modeling techniques in this manner is largely based upon the nomenclature of Amorocho and Hart (1964).

1.2.1 Correlation Analysis

Correlation analysis explores different combinations of dependent variables to determine the combination that most closely approximates the output function in terms of the recorded input function. Along with other arbitrary parameters, the correlation-analysis technique describes the best linear prediction equation. Often hydrologic systems that are naturally non-linear can be transformed and explained by linear models. Yevdjevich (1964) discusses when and why data transformations are necessary. Haan (1977) discusses many aspects of correlation analysis as related to its use in hydrologic modeling. Examples of correlation analysis are simple and multiple linear regression, multivariate statistical methods (Snyder, 1962; Wong, 1963; Wallis, 1965), and linear programing (Kolman and Beck, 1980).

Diskin (1970) concludes that the regression equation can be interpreted in terms of a simple three-element conceptual model for annual rainfall-runoff relationships. However, many authors believe that the use of correlation analysis as a direct tool in hydrologic modeling leads to unwarranted generalizations (Haan, 1977). Amorocho and Hart (1964) note that a great deal of subjectivity underlies the process of selecting a best model and there is no assurance that the optimum model has been considered. Correlation analysis is used extensively in the estimation of model parameters for other techniques. Correlation analysis is a stochastic-empirical aproach in Clarke's classification scheme.

1.2.2 Partial System Synthesis with Linear Analysis

Amorocho and Hart (1964) describe system analysis as a mathematical process used to define an input-output relationship, involving the use of measured input and output data only, without any attempt to describe the internal mechanisms of the system in explicit form. System synthesis is defined by Amorocho and Hart as an attempt to describe the system operation of components whose presence is presumed to exist and whose functions are known and predictable. Analysis has the form of unique function while synthesis does not.

The classical unit hydrograph (Sherman, 1932; Dooge, 1959) combines both synthesis and analysis as defined above into a technique that can be described as partial system synthesis with linear analysis. Rainfall excess and base flow separation functions combined with a linear convolution operation represent the unit hydrograph synthesis that is assumed equivalent to the operation of a watershed. Unit hydrograph theory can be summarized in six words: The system is linear and time-invariant.

The constrained linear system model proposed by Natale and Todini (1977) is another example of partial system synthesis with linear analysis. It relates effective precipitation to runoff for a time invariant linear system where constraints are placed on the parameters to be estimated. Partial system synthesis with linear analysis is either a deterministic-empirical or stochastic-empirical approach in Clarke's classification scheme, depending on whether there is a probability distribution associated with the parameters to be estimated.

1.2.3 System Synthesis

Amorocho and Hart (1964) describe the process of system synthesis as beginning with the postulation of a more-or-less complex model, whose structure is based upon qualitative and semi-qualitative knowledge of phenomena involved in the hydrologic cycle. Depending upon the level of sophistication, systems synthesis can vary from a black-box model to a fully conceptual model. System synthesis can be subdivided into two levels of abstraction. These are physically-based models and quasi-physically-based models which are discussed below. Clarke's four major classification groups are represented by various combinations of the sytem-synthesis technique.

1.2.3.1 Physically-Based Models

In their blue print, Freeze and Harlan (1969a) assess the feasibility of developing a rigorous physically-based mathematical model of the complete hydrologic system. Freeze and Harlan describe a physically-based model of the time-dependent hydrologic processes as being represented by a set of partial differential equations interrelated by the concepts of continuity of mass and momentum. These equations along with the respective boundary conditions comprise the boundary-value-problem that Freeze and Harlan call the hydrologic response model.

In response models of this type, the movement of water through the hydrologic system is governed by the Saint Venant equations in the overland and channel flow phases and the Darcian equation of groundwater flow in the subsurface flow phase (Freeze and Harlan, 1969a; Freeze, 1974; Freeze, 1978). Stehale (1966) however, has argued that while the purpose of mechanics is to provide a complete description of systems occurring in nature, that in hydrology this has not been accomplished and may never be. To date, Stehale has been proven correct as no physically-based model of the type described above has ever proven successful in field applications on any reasonable scale (Woolhiser, 1973; Klemes, 1978). Klemes (1979) also discusses the reasons why a hydrologic model in the form of a component boundary value problem cannot be considered the ultimate model.

1.2.3.2 Quasi-Physically-Based Models

Physically-based models are usually made up of a set of coupled partial differential equations. Quasi-physically-based models on the other hand use solutions to these equations.as operating algorithims. Such a model is described by Engman

(1974). The mathematical function used to describe the soil infiltrability is Philip's (1969) two-parameter solution to Richard's general flow equation. The kinematic approximation to the complete flow equation is used for the overland-flow and channel-flow components and the Manning relationships are assumed to hold (Brakensiek, 1966). The development of the kinematic form of the shallow-water equations is reviewed by Eagleson (1970). The kinematic approach does not have the same restrictive assumptions of linearity and time invariance seen in the unit hydrograph methods (Wooding, 1965; Kilber and Woolhiser, 1970).

Quasi-physically-based models often have non-physically based components. Components are linked and keyed by some sort of trigger that may or may not have physical basis. In such models, mathematical approximations representing complex natural mechanisms convert precipitation into stream flow. The influence of these mathematical functions, defining the model algorithims, are dependent upon the magnitude of calibrated parameters within the equations. Once the model parameters have been calibrated, a fixed budgeting framework for prediction exists. Uncertainties in this kind of synthesis are due to: Errors in recorded data, spatial distributions of parameters, imperfections in model structure and the non-uniqueness of the process. Freeze and Harlan (1969a) describe non-physically-based model components as storage elements and transmission routes, connected in parallel and in series by a set of decision points. A pot and pipeline structure, illustrated in Figure 2, is a fitting description for the way these models represent the hydrologic cycle. Along with unit hydrographs, various combinations of reservoir routing, channel routing, infiltration, snowmelt and base flow component techniques are used to explain complex natural mechanisms. Routing methods are reviewed by Chow (1959) and Henderson (1966).

Table 1 lists a number of the digital system-synthesis event simulation models in use. Table 2 differentiates between the component techniques used in these models (Viessman et al., 1977). Table 3 lists the techniques described in section 1.2, as they are used, and classifies them according to input requirements, nature of variables, model structure, spatial and temporal response and use.

1.3 Space-time Tradeoffs

Moss (1979) defines the space-time tradeoff of hydrologic data collection as the ability to substitute spatial coverage for temporal extensions of records. Freeze (1982b) defines a time-space tradeoff as the relative increase in efficiency that can be achieved through a lengthening of records as opposed to

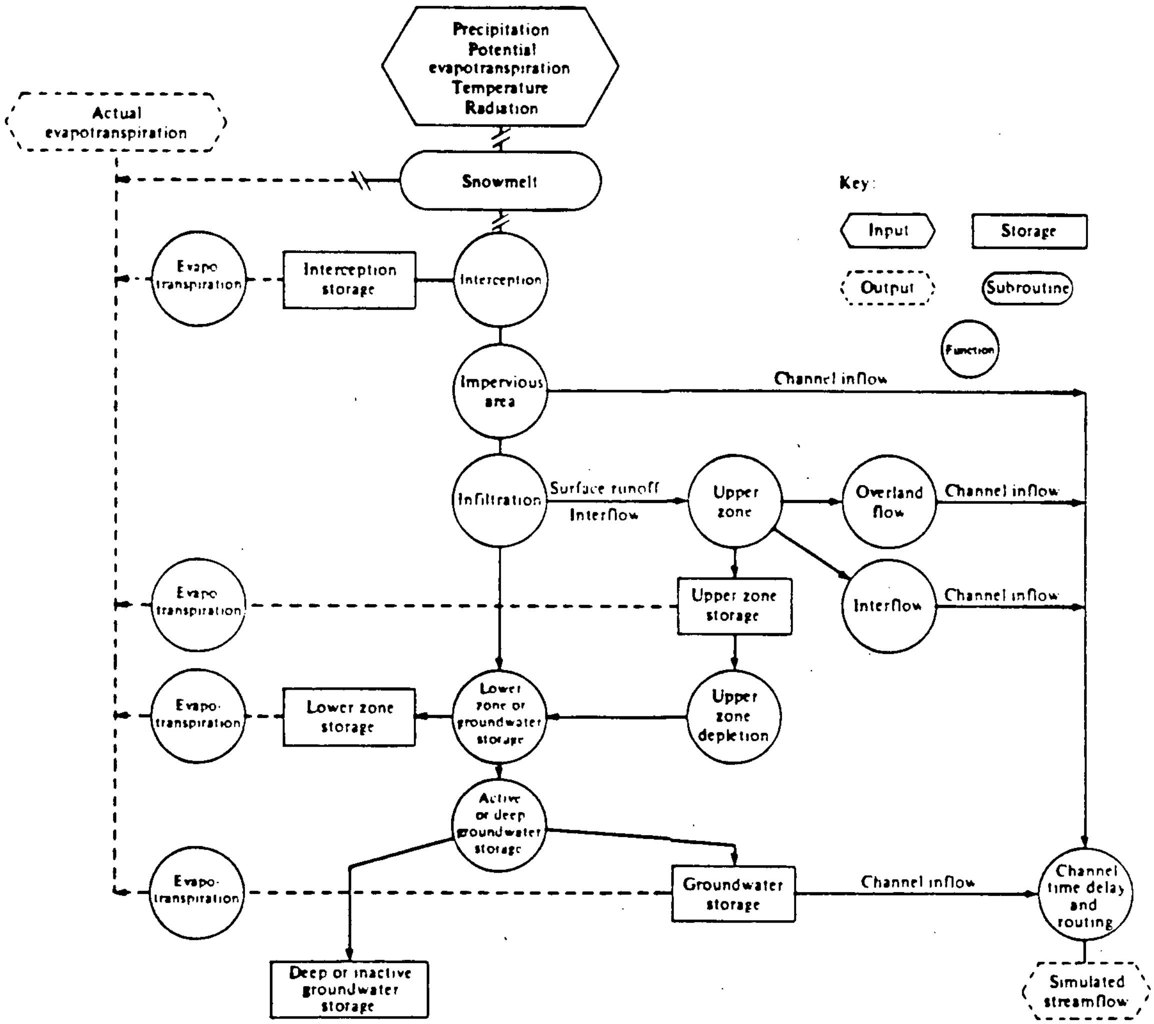

Figure 2. Flow chart illustrating the pot and pipeline structure of the Stanford Watershed Model IV (after Crawford and Linsley, 1966)

CODE NAME	MODEL NAME	AGENCY/ORGANIZATION
HEC-1	HEC-1 Flood Hydrograph Package	Army Corps of Engineers (1973)
TR-20	Computer Program for Project Hydrology	Soil Conservation Service (1974)
HYMO	Hydrologic Model Computer Language	Agricultural Research Service (Williams and Hann, 1973)
SWMM	Storm Water Management Model	Environmental Protection Agency (1971)
USGS	USGS Rainfall - Runoff Model	Geological Survey (Carrigan, 1973)

Table 1. Major rainfall-runoff event simulation models (after Viessman et al., 1977)

Modeled Components	HEC-1 (Corps)	TR-20 (SCS)	USGS (USGS)	HYMO (ARS)	SWMM (EPA)
	Model Code Names				
Infiltration and Losses					
Holtan's equation					
Horton's equation					X
Phillip's equation			X		
SCS curve number method		X		X	
Variable loss rate	X				
Standard capacity curves					X
Unit Hydrograph					
Input	X	X			
Clark's	X		X		
Snyder's	X				
2-parameter gamma response				X	
Dimensionless unit hydrograph		X			
River Routing					
Hydraulic					X
Muskingum	X				
Tatum	X				
Straddle-stagger	X				
Modified Puls	X				
Working R&D	X				
Variable storage coefficient	X			X	
Convex method		X			
Translation only			X		
Reservoir Routing					
Storage-indication	X	X		X	
Base Flow					
Input			X		
Constant value		X	X		
Recession equation	X				
Snowmelt Routine	Yes	No	No	No	No

Table 2. Hydrologic processes and options used by major event simulation models (from Viessman et al., 1977)

MODELING TECHNIQUE		INPUT REQUIREMENTS			NATURE OF VARIABLES		MODEL STRUCTURE		SPATIAL RESPONSE		TEMPORAL RESPONSE		USE		
		Streamflow	Precipitation	Watershed Parameters	Stochastic	Deterministic	Empirical	Conceptual	Lumped	Distributed	Time - Invariant	Time - Variant	Design Prediction	Design Forecast	Operational Forecast
RAINFALL - RUNOFF MODELS	Regression	●	●		●		●		●		●			●	
	Unit Hydrograph	●	●			●	●		●		●			●	●
	Quasi - Physically Based		●	●		●		●		●		●		●	●
STREAMFLOW ROUTING	Hydraulic Routing Using Open Channel Flow Equations	●				●		●		●		●			●

Table 3. Characterization of selected rainfall-runoff modeling techniques (after Freeze, 1982a)

an increase in the density of measuring points. Most documented examples of the aforementioned tradeoff have been for a single precipitation data set using only one model.

There is great promise for extending the space-time tradeoff idea across hydrologic data sets. This research underlies future work, by the author, which will address the possibility of improving hydrologic modeling efficiency by increasing geometrically distributed measurements of spatially-variable time-invariant watershed parameters on a one-time collection basis, and thereby, reducing the need for long continuous rainfall-runoff records.

1.4 Data-Worth and Model Choice

The concept of data worth is married to cost-benefit analysis. Hence, increases in model efficiency due to improvements in the data aquisition network are subject to economical justification. Dooge (1972) states that the use of incorrect methods leads to either economic waste due to conservative factors of safety, or economic loss resulting from faulty predictions. Davis et al.(1979) define the value of additional data as the incremental increase in expected payoff or reduction in expected loss.

If time-space tradeoffs exists, the demands of increasing individual model efficiencies can be evaluated economically based upon the cost and delay of obtaining the required data. Depending upon the situation, certain modeling techniques and their corresponding data sets may be preferred. The worth of this data will be directly related to the size and cost of a project. Also, delays in a project to obtain additional data, for specific model efficiency requirements, will be characterized by a decreasing marginal utility. In this research,the stage is being set for an initial assessment of data-worth as indicated by the efficiencies of individual rainfall-runoff-modeling techniques as it relates to space-time tradeoffs.

The data-worth concept as described here, along with adequate definition of the modeling problem, may become a basis for future model choice. A possible methodology for selection of a modeling technique that might be coupled with this type of data-worth assessment is shown in Figure 3.

1.5 Thesis Objective

The correct choice of a hydrologic modeling technique is often less than obvious. Criteria are needed to facilitate such decisions. These criteria must be functions not only of the

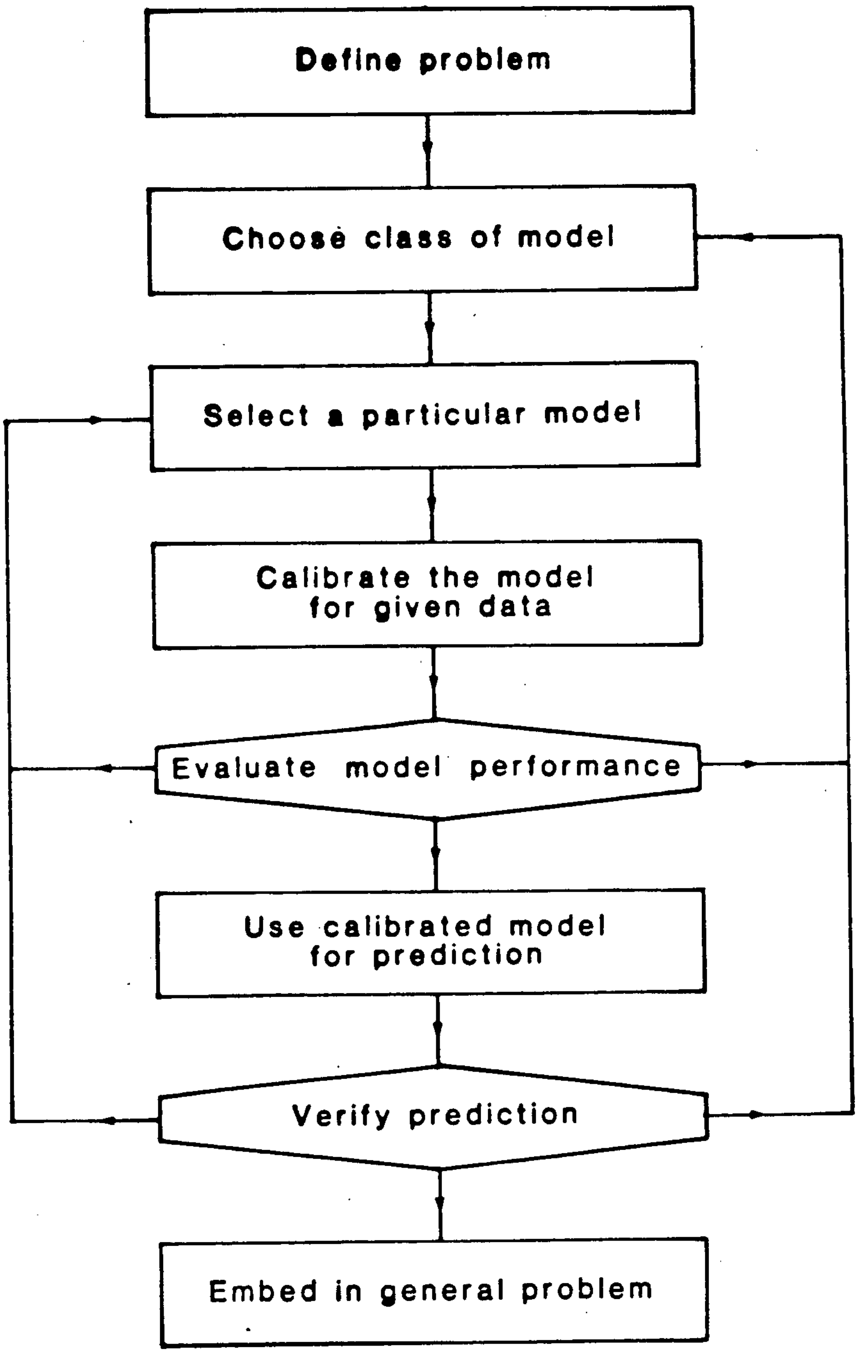

Figure 3. Possible methodology for selecting a rainfall-runoff modeling technique (after Dooge, 1978)

available models, but also the available data.

Freeze (1982a,b) proposes that it may be possible to increase modeling efficiency by a tradeoff of longer rainfall and stream flow records against additional measurements of spatially variable-soils information. The testing of this hypothesis requires simulations across a suite of modeling approaches with a variety of data sets.

The objective of the present research is to compare the efficiencies of various selected hydrologic modeling techniques on a limited suite of selected data sets. The scope of this work, in its initial phase as presented here, is limited to event-based rainfall-runoff modeling techniques. The selected techniques are linear and multiple regression, the unit hydrograph,and quasi-physically-based system synthesis.

Selected rainfall-runoff events, at experimental subwatersheds in Oklahoma and Pennsylvania are used to determine individual model efficiencies. Comparison of model efficiencies for the aforementioned techniques may be useful in future assessment of space-time-tradeoff potential and to gain an initial indication of data worth. The two subwatersheds were chosen because each maintained instrumentation and measurement programs compatible with the data requirements of the three selected modeling techniques.

If space-time tradeoffs across data sets have the potential to increase prediction efficiencies, then rainfall-runoff modeling techniques and data collection networks can conceivably be selected for given design or operational specifications, based upon model efficiency and cost-benefit analysis. Such criteria would be useful to the applied hydrologist.

CHAPTER TWO

MODELS AND COMPARISON

In this chapter the three established underlying rainfall-runoff-modeling techniques employed in this study are fully described. The efficiency and comparison criterion used for model evaluation are presented.

2.1 Regression

Models based on simple linear regression (SLR) with one independent variable, are commonly used in hydrology. A linear relationship of the form:

$$Y=\alpha+\beta X \tag{2}$$

is assumed between two variables X and Y, where X and Y are the independent and dependent variables respectively. A common example is for the independent variable to be precipitation and the dependent variable to be discharge. The regression line:

$$Y=a+bX \tag{3}$$

approximates Equation 2, where a and b are estimates of α and β respectively. The coefficient b and constant a are calculated from a set of data $[X_i]$, $[Y_i]$ with means $\overline{X}$ and $\overline{Y}$ as follows:

$$b=\Sigma x_i y_i/\Sigma x_i^2 \tag{4}$$

$$a=\overline{Y}-b\overline{X} \tag{5}$$

where,

$$x_i=X_i-\overline{X} \tag{6}$$

$$y_i=Y_i-\overline{Y} \tag{7}$$

This procedure of least squares is based upon minimizing the difference between the observed and predicted values:

$$\Sigma e_i^2=\Sigma(Y_i-\hat{Y}_i)^2 \tag{8}$$

The deviation between an observed value Y and the value predicted $\hat{Y}$ from the regression model described by Equation 3, is represented by a residual error term.

In order to determine if a regression line is the correct approach for a given set of data, some sort of evaluation is required. One approach is to determine how much of the variability in the dependent variable is explained by regression. The method commonly used is a ratio of the sum of squares due to regression and the sum of squares corrected for the mean, expressed as:

$$r_s^2=\Sigma(\hat{Y}_i-\overline{Y})^2/\Sigma y_i^2 \tag{9}$$

The range of r_s^2, which is known as the coefficient of determination, is between zero and one as hydrologic systems have positive correlation. When r_s^2 is equal to one, the regression equation is providing perfect predictions and $\Sigma e_i=0$. When r_s^2 is equal to zero the regression line is explaining none of the variation and $\Sigma e_i^2=\Sigma y_i^2$.

A SLR rainfall-runoff model could take any of the following forms:

$$\hat{V}_Q=a+bV_{PPT} \tag{10}$$

$$\hat{Q}_{PK}=a+b\overline{PPT} \tag{11}$$

$$T\hat{Q}_{PK}=a+bPPT_D \tag{12}$$

where, $\hat{V}_Q$ = predicted volume of runoff

V_{PPT} = observed volume of rainfall

$\hat{Q}_{PK}$ = predicted peak discharge

$\overline{PPT}$ = average observed rainfall intensity

$T\hat{Q}_{PK}$ = predicted time to peak discharge

PPT_D = observed duration of rainfall

Multiple linear regression (MLR) rainfall-runoff models are possible with combinations of independent variables or when more than one rain gage is available. In MLR the dependent variable is a function of several independent variables and unknown parameters expressed by:

$$Y=\beta_1 X_1+\beta_2 X_2+\cdots+\beta_P X_P \tag{13}$$

where, $\beta_1,\beta_2,\cdots,\beta_P$ are the unknown parameters. The SLR model is a special case of the MLR model. In practice, there would be n observations of the dependent variable and n corresponding observations of each independent variable. Subsequently, there will be n equations and p unknown parameters, where n should be greater than or equal to the number of independent variables. In practice n should be at least three or four times as large as p. The matrices of these n equations are written:

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \cdot \\ \cdot \\ \cdot \\ Y_n \end{bmatrix} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \cdot \\ \cdot \\ \cdot \\ \beta_P \end{bmatrix} \begin{bmatrix} X_{1,1} & X_{1,2} & \cdots & X_{1,P} \\ X_{2,1} & X_{2,2} & \cdots & X_{2,P} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ X_{n,1} & X_{n,2} & \cdots & X_{n,P} \end{bmatrix}$$

Written in matrix notation:

$$\underline{Y}=\underline{\beta}\ \underline{X} \tag{14}$$

Similar to the coefficient of determination seen in SLR, the multiple coefficient of determination is an evaluation of the usefulness of MLR for a given data set. Written in matrix notation, the multiple coefficient of determination is as follows:

$$r_M^2=\underline{\hat{\beta}}^T\underline{X}^T\underline{Y}-n\overline{Y}^2/\underline{Y}^T\underline{Y}-n\overline{Y}^2 \qquad (15)$$

where, $\underline{\hat{\beta}}^T, \underline{X}^T, \underline{Y}^T$ are the transpose of $\underline{\hat{\beta}}, \underline{X}, \underline{Y}$

n is the size of the Y vector

$\underline{\hat{\beta}}^T=(\underline{X}^T\underline{X})^{-1}\underline{X}^T\underline{Y}$

The range of r_M^2 is from zero to one, the closer to one the better the fit.

A correlation matrix should be computed before using the MLR technique to determine if a linear model can be used and what independent variables should be included. All the variables retained in a regression model should make a significant contribution. High correlation between two variables does not always mean there is a cause-and-effect relationship though, as external forces can be involved. Regression coefficient inferences, extrapolation and confidence intervals for MLR, as well as SLR, are discussed by Hann (1977). Johnston (1963) discusses the underlying assumptions and technique of MLR analysis in detail. Multivariate regression analysis is used to predict more than one dependent quantity from the same set of independent variables. Wallis (1965) discusses six multivariate statistical methods used in hydrology including regression analysis.

A MLR rainfall-runoff model has the following general form:

$$\hat{Y}=b_1X_1+b_2X_2+\cdots+b_MX_M+a \qquad (16)$$

where, $\hat{Y}$ = a predicted runoff variable

X_i = an observed rainfall variable at gage i

b_i = calculated coefficients

a = calculated constant

A MLR rainfall-runoff model can have any of the general forms shown in Equations 10, 11, and 12 with more than one independent variable.

In this study, the UBC Triangular Regression Package (TRP) is used for simple and multiple linear regression analysis. TRP calculated means, standard deviations, the correlation matrix of independent and dependent variables, as well as the coefficients of determination, residuals, predicted values and confidence intervals for the desired regression equation. Illustrative examples from the implementation of the TRP algorithm are shown in the TRP description (Le and Tenisci, 1977).

In a predictive mode SLR and MLR rainfall-runoff models require precipitation records in order to abstract various independent rainfall variables. The output produced from these models is in the form of runoff variables.

2.2 Unit Hydrograph

The regression rainfall-runoff models just described only allow for the estimation of runoff variables such as volume and peak flow. Often a rainfall-runoff model is desired that predicts the form of the storm hydrograph. The unit hydrograph is such a model.

Sherman (1932) defined the unit graph as follows:

> If a given one-day rainfall produces a one inch depth of runoff over the given drainage area, the hydrograph showing the rates at which runoff occurred can be considered a unit graph for that watershed.

Sherman's unit graph is a dimensionless routing model that is roughly linear and of unit volume. The unit hydrograph theory having evolved from the unit graph method incorporates unit time.

The unit hydrograph, despite being an approximate technique with many theoretical difficulties, has received considerable use by the hydrologic community, usually as a predictor of flood peaks. All unit hydrographs are based on the following two principles (Dooge, 1959): 1) Invariance-the hydrograph of surface runoff from a catchment due to a given pattern of rainfall excess is invariable. 2)Superposition-the hydrograph resulting from a given pattern of rainfall excess can be built by superimpositing the unit hydrographs due to the separate amounts of rainfall excess occurring in each period. This includes the principle of proportionality, by which the ordinates of the hydrograph are proportional to the volume of rainfall excess.

Dooge (1973) clearly states the implications of the linear assumptions in the unit hydrograph theory. Implicit to its linear assumption, the development of a unit hydrograph requires simultaneous data of excess rainfall and storm flow. Excess rainfall is defined here as total rainfall minus infiltration. Storm flow is defined as total runoff minus base flow. Base flow is generally accounted for by normal day-to-day groundwater contributions to stream flow. Excess rainfall and storm flow volumes for a selected event are equal.

Various base flow separation techniques used to estimate storm flow volumes are discussed by Viessman et al. (1977) and Dunne and Leopold (1978). The Soil Conservation Service curve number methodology, with empirical ratings based on soils and vegetation (U.S. Soil Conservation Service, 1972), is one method of establishing excess rainfall values. Other methods include the antecendent precipitation index (Viessman et al., 1977),the Φ and the W indices (Schultz, 1976).

Generally, the assumptions about uniform rainfall distribution are not met and variation in unit hydrograph ordinates for different storms should be expected. Averaging independently derived unit hydrographs is discussed by Linsley et al.(1975). Linsley et al.(1975), Viessman et al.(1977), and

Dunne and Leopold (1978) all show examples of unit hydrograph derivations. Figure 4 shows a flow chart of the basic operations involved in the unit hydrograph procedure.

An illustration of matrix methods used to define the unit hydrograph is presented in Viessman et al.(1977). Calculation of a design storm hydrograph is graphically demonstrated for a three period storm in Figure 5. In matrix notation the storm hydrograph is given by:

$$\underline{Q}=\underline{P}\ \underline{U} \tag{17}$$

where, $\underline{Q}$ = the existing storm hydrograph vector

$\underline{P}$ = known excess rainfall matrix

$\underline{U}$ = the unit hydrograph vector

The reverse of the process shown in Figure 5 is the basis of the matrix method. Subject to the restrictions of matrix algebra the solution for the unit hydrograph matrix becomes:

$$\underline{U}=(\underline{P}^T\underline{P})^{-1}\underline{P}^T\underline{Q} \tag{18}$$

Reproduction of initial storm hydrographs based on matrix methods are generally not exact. Adjustments are usually made by reducing the square of the errors. Matrix methods are discussed by Snyder (1955), Newton and Vinyard (1967) and Morel-Seytoux (1982).

The instantaneous unit hydrograph (IUH), traced to Clark (1945) is the hydrograph of one inch runoff spread uniformly

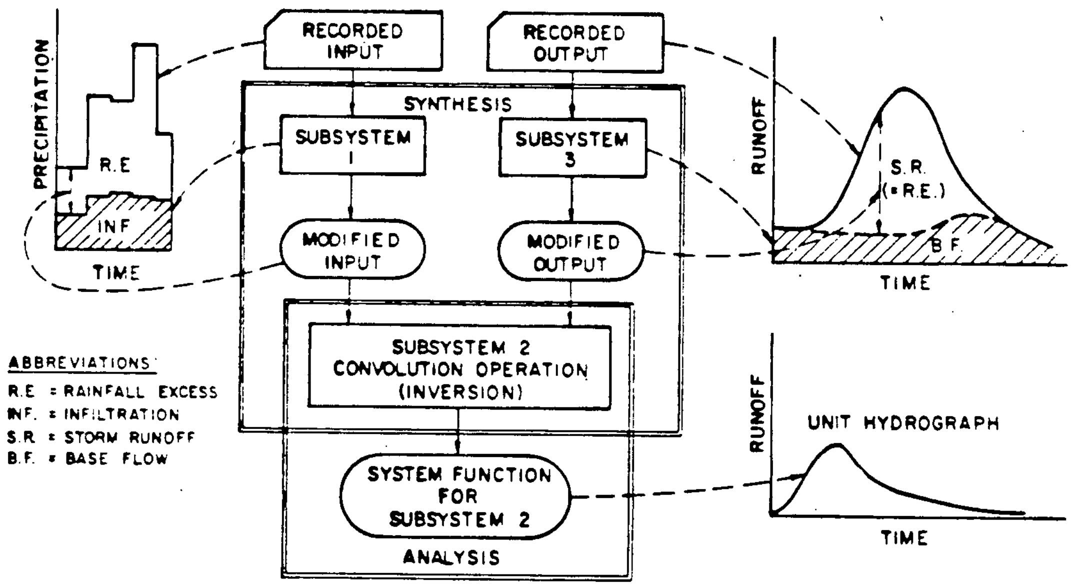

Figure 4. Flow chart of the operations involved in the unit hydrograph technique (from Amorocho and Hart, 1964)

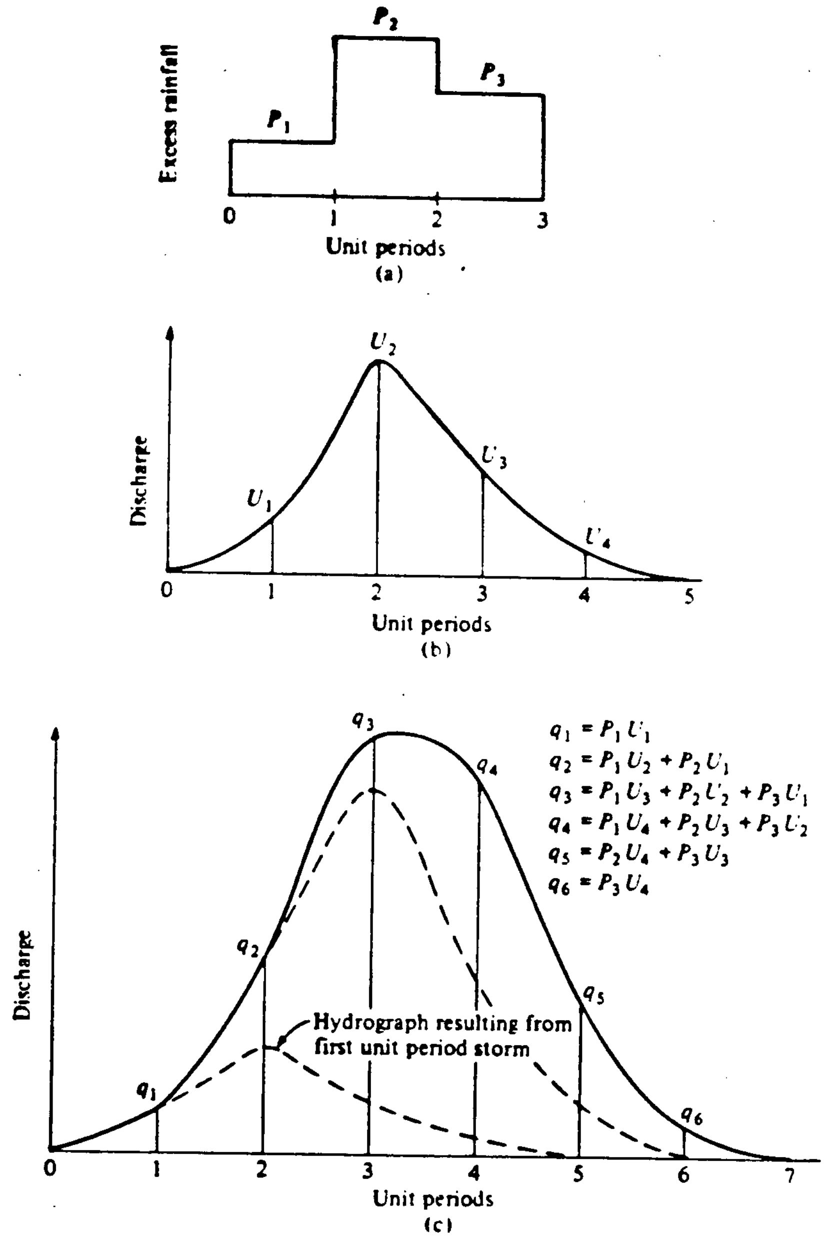

Figure 5. Determination of a design storm hydrograph: (a) Excess rainfall, (b) unit hydrograph, and (c) surface runoff hydrograph (from Viessman et al., 1977)

over an area generated in an infinitesimal time period. Mathematically, the IUH is the kernal function in the convolution relationship for a lumped linear time invariant causal system. The convolution integral has the following form:

$$y(t)=\int_{0}^{t_0} X(\lambda)h(t-\lambda)d\lambda \tag{19}$$

where, $y(t)$ = storm runoff hydrograph

$x(\lambda)$ = excess rainfall hyetograph

$h(t-\lambda)$ = unit hydrograph

Figure 6 shows the input, output and kernal functions.

Quimpo (1973) and Freeze (1982a) discuss the linkage of IUH and autoregressive stream flow models. The equation of continuity for any reservoir can be written as:

$$p-q=ds/dt \tag{20}$$

where, p = inflow

q = outflow

s = outflow storage

A linear reservoir is one in which the outflow is a linear function of the storage:

$$q=ks \tag{21}$$

where k is a watershed parameter. Combining equations 20 and 21 leads to the differential equation:

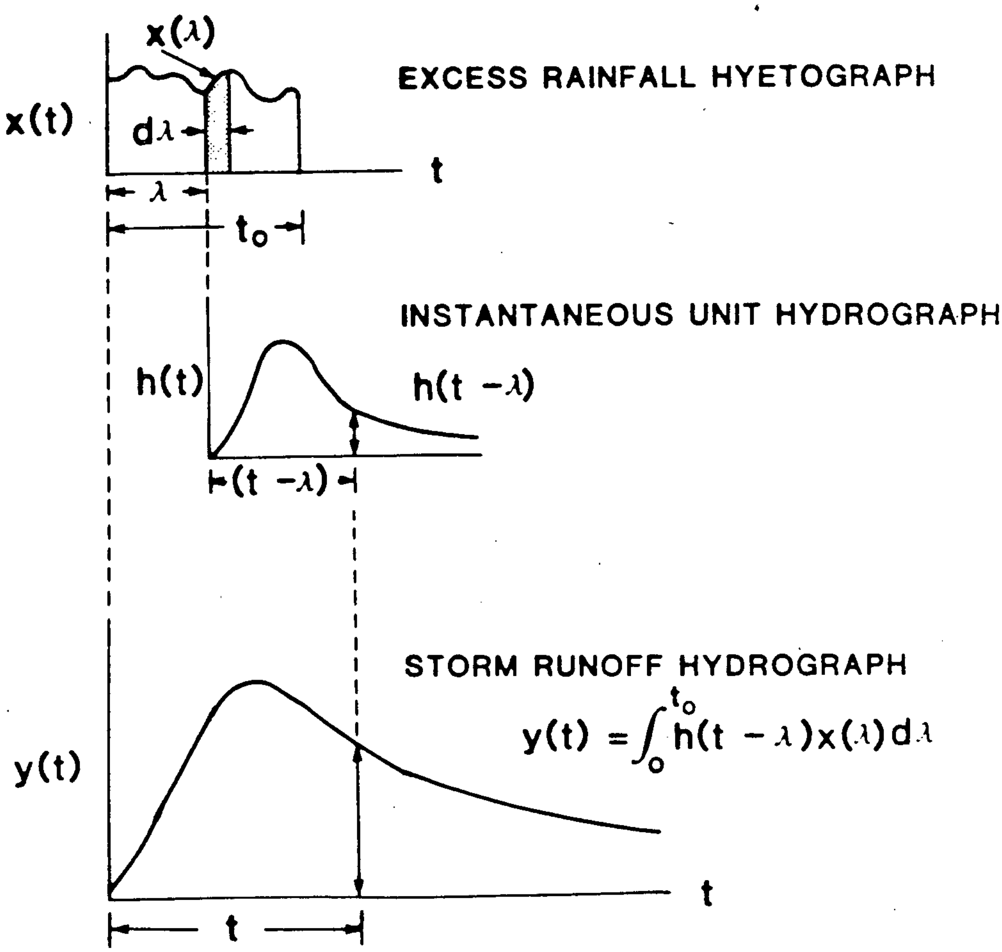

Figure 6. Instantaneous unit hydrograph: (a) input function, (b) kernel function, and output function (after Chow, 1964b)

$$(dq/dt)+kq=kp \tag{22}$$

The solution to this equation for the initial condition q=0 at t=0 is:

$$q(t)=\int_0^t ke^{-k(t-\lambda)}p(\lambda)d\lambda \tag{23}$$

Equations 19 and 23 are equivalent when

$$h(t)=(1/K)e^{-t/K} \tag{24}$$

where K = 1/k. Using Equation 24 as the IUH and Equation 19 as a rainfall-runoff predictor is equivalent to considering a watershed as a single linear reservoir. A conceptual model of the IUH described by Nash (1959) is shown in Figure 7. Nash proposed routing instantaneous rainfall through a series of successive linear reservoirs. For n linear resevoirs the IUH becomes:

$$h(t)=(1/k\Gamma(n))(t/K)^{n-1}e^{-t/K} \tag{25}$$

where $\Gamma(n)$ is the nth order gamma function. The approach here is linear as K is a constant that can be evaluated by the method of moments.

The calculation of unit hydrographs for experimental subwatersheds in this study was carried out with the computer program UNIT, which uses a matrix method employing optimization techniques, authored by Morel-Seytoux and Kimzey (1980). From the theory of linear systems, the instantaneous storm flow rate

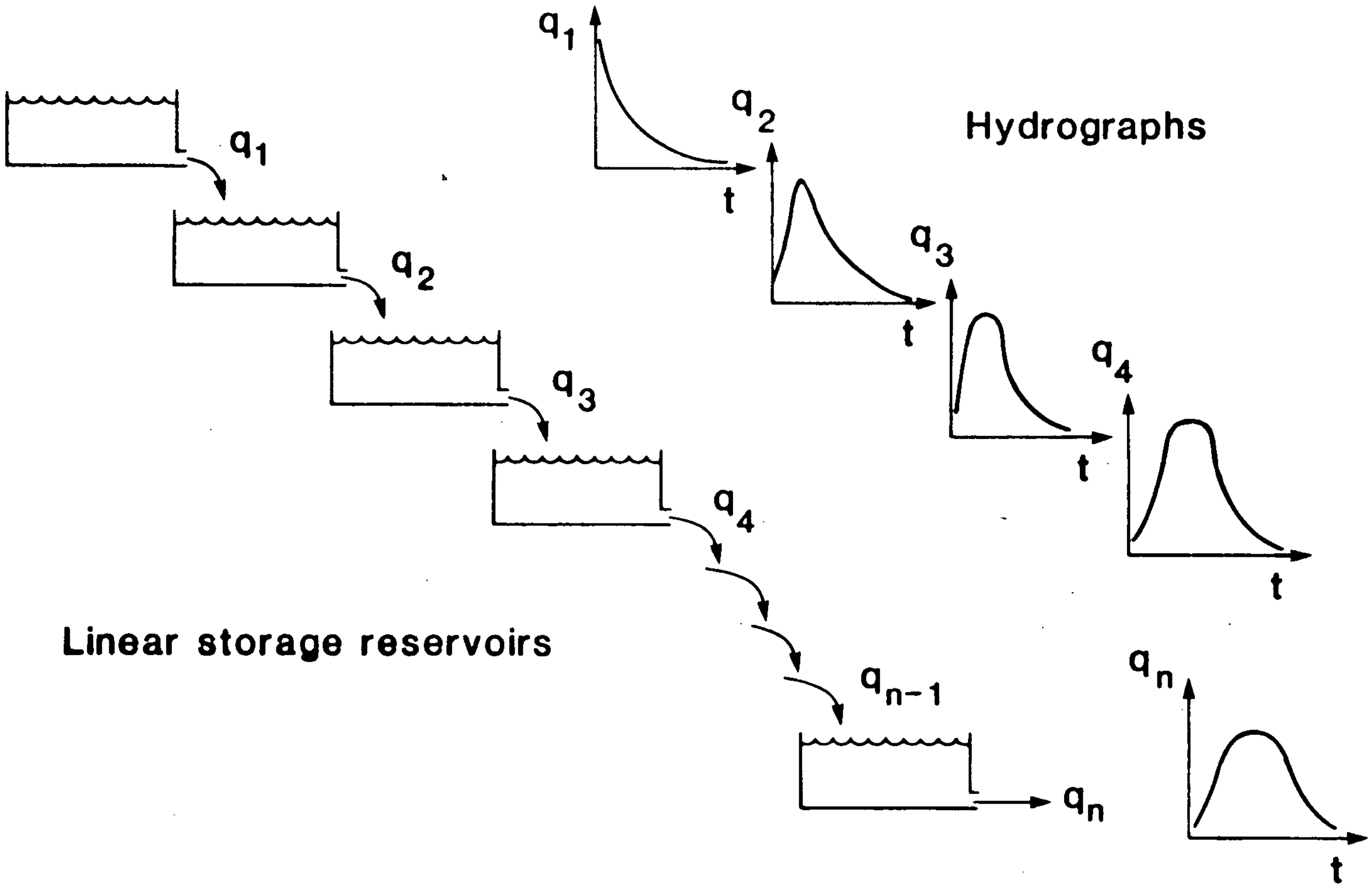

Figure 7. Nash's model for routing instantaneous rainfall through a series of linear storage resevoirs (after Chow, 1964b)

at the end of period n is given by the discrete equivalent to Equation 19:

$$q(n)=\sum_{j=1}^{n} \delta(n-j+1)\overline{r}(j) \qquad (26)$$

where, $\delta(m)$ = nth ordinate of the unit hydrograph

$\overline{r}(j)$ = mean excess rainfall rate during period j

Following the development of Morel-Seytoux and Kimzey (1980), the normal equations used in the equality-constrained least square method of UNIT are summarized in Table 4. The resulting system of linear equations is solved by gaussion elimination. The first M solutions are the desired unit hydrograph.

The UNIT code, or more specifically the technique it uses, is a practical choice for determining unit hydrographs in this study. Computer solution greatly reduces the computational time relative to hand calculation methods. The IUH method requires rainfall patterns to be known as continuous functions, which they rarely are. A listing of the UNIT code is given in Appendix A. Illustrative examples and hand computations verifying the UNIT program are found in the users manual (Morel-Seytoux and Kimzey, 1980).

To employ UNIT, excess rainfall and storm flow must be determined for selected events. The Φ index method of calculating excess rainfall is used in both experimental subwatersheds. The Φ index is defined as the amount of rainfall that is retained by the basin divided by the duration of the

$$\sum_{j=1}^{M+1} a_{ij} x_j = b_i \qquad i = 1,2,\ldots,M+1$$

where the a_{ij} and b_i are given by the formulae:

$$a_{ij} = \sum_{n=j}^{N}{}' \, \bar{r}(n-i+1)\bar{r}(n-j+1) \qquad \text{for } i = 1,2,\ldots,M \text{ and } j = 1,2,\ldots,M \text{ but with } j \geq i$$

For $j < i$ $\quad a_{ij} = a_{ji}$ (symmetry) $\quad i = 1,2,\ldots,M$

$$a_{i,M+1} = \frac{1}{2} \qquad i = 1,2,\ldots,M$$

$$a_{M+1,j} = 1 \qquad j = 1,2,\ldots,M$$

$$a_{M+1,M+1} = 0$$

$$b_i = \sum_{n=1}^{N}{}' \, \bar{r}(n-1+1)q(n) \qquad i = 1,2,\ldots,M$$

$$b_{M+1} = 1.$$

The prime indicates that the indices corresponding to periods with missing runoff are skipped in the summation. These equations guarantee that the discrete kernels add up to one but do not guarantee nonnegativity for them.

Table 4. Normal equations for the equality-constrained least squares technique used in the computer program UNIT (after Morel-Seytoux and Kimzey, 1980)

storm (Dunne and Leopold, 1978). The Φ index provides a means of replacing the time varying infiltration function by an average value. When data are insufficient to derive an infiltration curve, the Φ index is often used. The Φ index method is illustrated in Figure 8.

Storm flow is determined by separating base flow from the total observed hydrograph. Only one of the experimental subwatersheds considered in this study experiences base flow separation. The criteria used for separation in this study is the simple but objective technique described by Engman (1974). The procedure is illustrated in Figure 9, and in effect shows that no surface runoff is contributing to the hydrograph after the intersection of the base flow separation line and the hydrograph recession. The value of the slope α is chosen by analyzing several hydrographs from a study area with a subjective decision as to where the most rapid change in the recession curve occurs on the average.

The Φ index determined from a single storm is not generally applicable to other storms and therefore not considered a basin constant in this study. The slope α used for base flow separation is considered a basin constant in this study serving as a lynchpin between storm flow and calculated excess rainfall. In its predictive mode the unit hydrograph requires mean values of excess rainfall for unit periods as input and produces output in the form of a storm flow hydrograph.

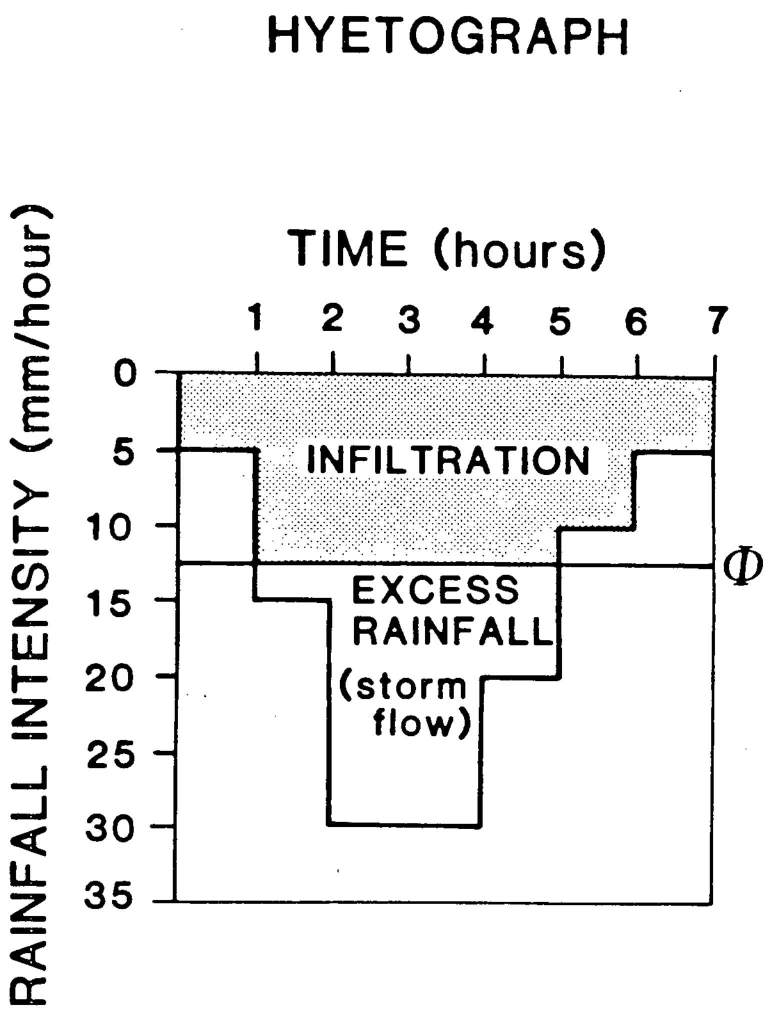

Figure 8. Φ index method of calculating excess rainfall

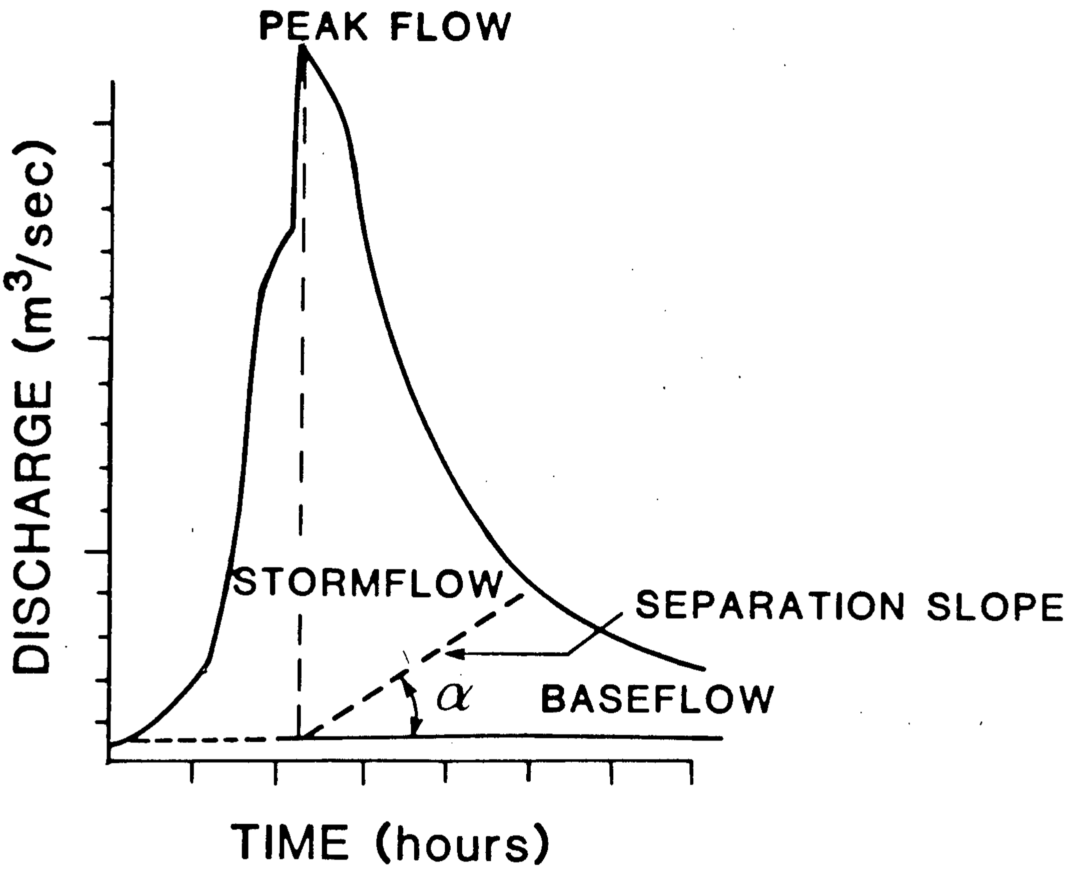

Figure 9. Base flow separation technique (after Engman, 1974)

2.3 Quasi-Physically-Based

Quasi-physically-based-rainfall-runoff models attempt to approximate the physical processes occurring within the hydrologic cycle illustrated in Figure 10. Many authors have attempted to describe the component mechanisms responsible for runoff. Rainfall-runoff processes are reviewed by Kirkby (1978) and Freeze (1974). A number of rainfall-runoff simulation models have been proposed to explain watershed physics. Common to all is the problem of accounting for natural watershed variability in terms of necessary input data as well as boundary and initial conditions.

The model chosen for use in this study (Engman, 1974) is based on partial area concepts (Betson, 1964) and emphasizes transformation of a natural heterogeneous system into a corresponding distributed system compatible with computer simulation. Hereafter, Engman's quasi-physically-based rainfall runoff modeling technique will be referred to as a distributed model.

Based on a dynamic watershed approach, illustrated in Figure 11, the distributed model may be divided into three parts (Engman and Rogowski, 1974a). The first part describes a physically based soil infiltrability calculation for developing the precipitation excess. The next two parts deal with kinematic routing phases: One for developing a lateral inflow

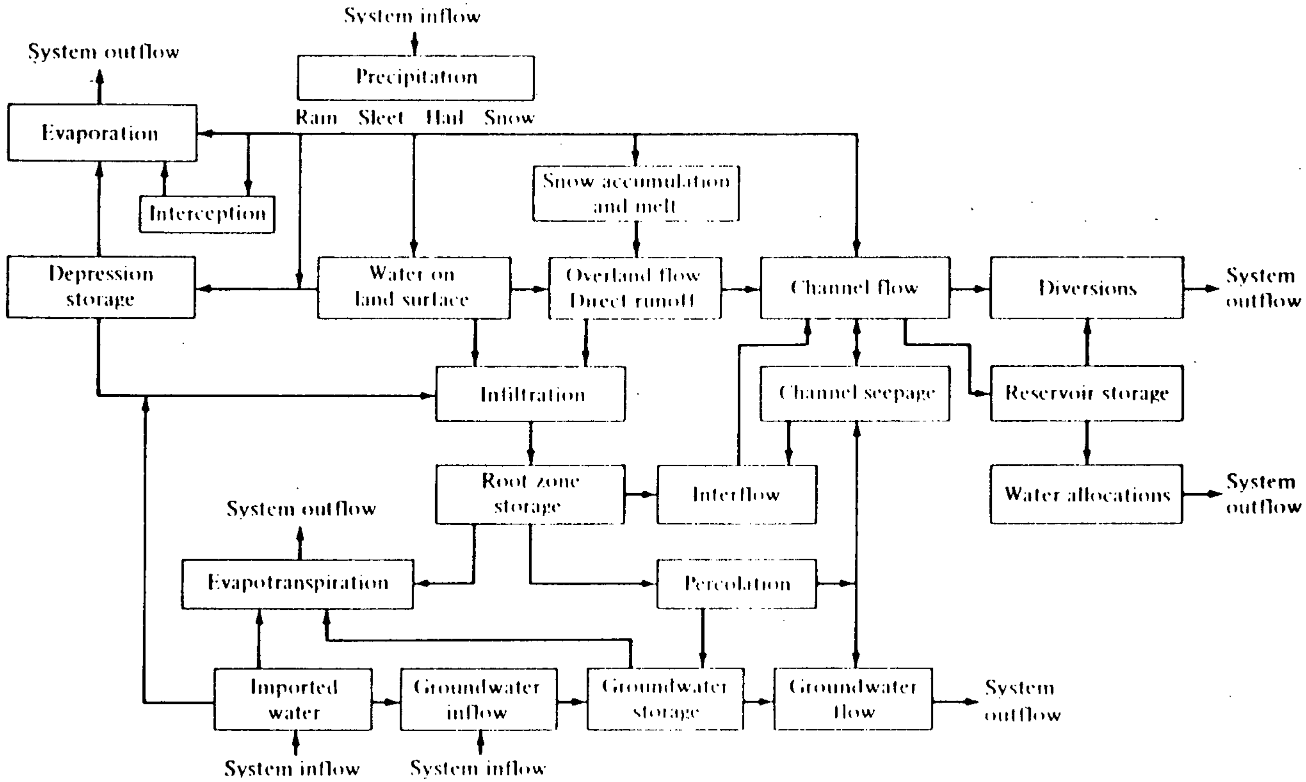

Figure 10. Systems representation of hydrologic cycle (from Viessman et al., 1977)

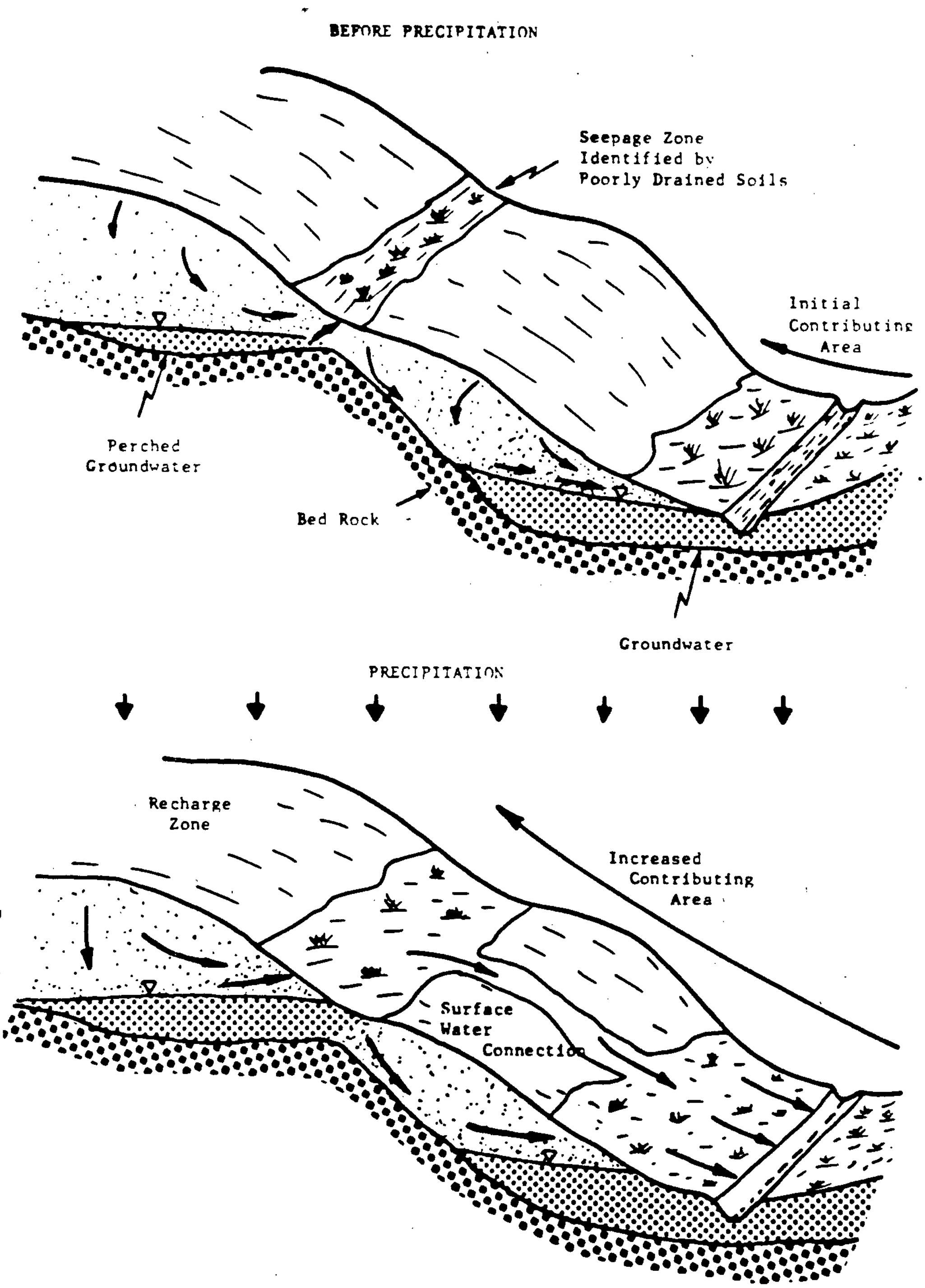

Figure 11. Schematic diagram of a dynamic watershed (from Engman, 1974)

hydrograph from the overland flow plane and one for routing the channel hydrograph. The model does not address possible origins of runoff other than those caused by the rainfall intensity exceeding the infiltration capacity. Application of the model is therefore limited to the prediction of the storm flow hydrograph from areas contributing overland flow without consideration of subsurface storm flow to the stream, direct groundwater discharge to the stream, or the evapotranspiration component mechanisms. A flow chart of the simulation model is shown in Figure 12.

The first computational step of the distributed model involves calculation of pertinent infiltration capacity and excess rainfall, as functions of time for the different soil series composing the watershed. The model simulates a two layer system. This step is based on Richard's (1931) one-dimensional infiltration equation for a unsaturated-saturated system:

$$(\partial/\partial z)\{K(\psi)((\partial\psi/\partial z)+1)\}=C(\psi)\partial\psi/\partial t \tag{27}$$

where, t = time

z = vertical distance from the soil surface downward

ψ = pressure head

$K(\psi)$, $C(\psi)$ are unsaturated functional relationships for hydraulic conductivity and specific moisture respectively.

Analytic and numeric solutions for one-dimensional infiltration boundary value problems are discussed by Philip (1957a,b,c,d,e,

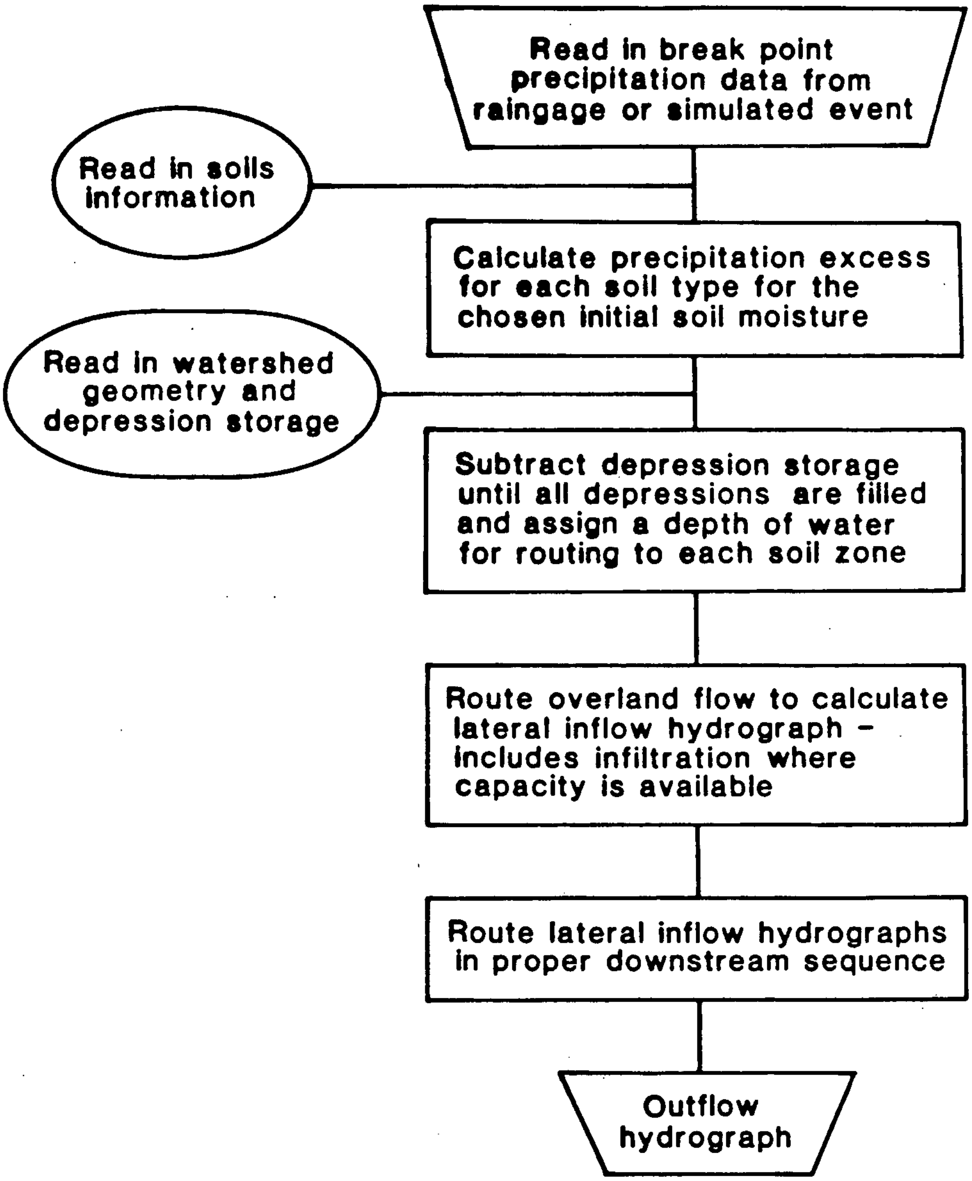

Figure 12. Flow chart for distributed model code (after Engman, 1974)

1958a,b) and Freeze (1969b) respectively.

In the model, infiltration capacity is described by Philip's (1969) two-parameter infiltration equation:

$$i=\tfrac{1}{2}St^{-\frac{1}{2}}+A \qquad (28)$$

where, i = infiltration rate

S = Sorptivity

A is a constant that is approximated by 1/2 the saturated hydraulic conductivity

Sorptivity values are computed from Parlange's (1972) approximation:

$$S=\{2\int_{\theta_0}^{\theta_1}(\theta-\theta_0)D\,d\theta\}^{\frac{1}{2}} \qquad (29)$$

where, θ = volumetric soil water content

θ_1 = soil water content of soil surface

θ_0 = initial soil water content

D = soil water diffusivity

The soil water diffusivity is described by:

$$D=K(\theta)(d\psi/d\theta) \qquad (30)$$

where K is hydraulic conductivity. The unsaturated characteristic curves of hydraulic conductivity and soil water pressure head as a function of soil water content are computed using modified models proposed by Rogowski (1971, 1972a,c,d) and Parlange (1972).

The input required for the first step of the distributed model is: 1) antecendent soil moisture for each soil, 2) the degree of saturation for each soil, 3)hydraulic conductivity at air entry for each soil, 4) sorptivity values for each soil, 5) the initial infiltration rate for each soil. The input required to determine soil characteristic curves with the methods described by Rogowski (1971, 1972a,c,d) and Parlange (1972) is: 1) the porosity of each soil, 2) soil moisture at 1.5 MPa for each soil, 3) the air entry value for each soil, 4) the water entry value of each soil, and 5) the hydraulic conductivity of each soil at air entry.

The second step of the distributed model routes excess surface water from contributing areas to the stream taking into account detention storage and reinfiltration.

Flow of water over a surface or in a channel is described by two differential equations based on the following assumptions (Chow, 1959): 1) velocity at any section is uniform and unidirectional, 2) channel slope is small, 3) streamline curvatures are small, 4) energy losses are represented by the slope of the energy gradient times the length of the channel reach. The continuity equation, based on the conservation of mass, is expressed as:

$$A(\partial V/\partial X)+V(\partial A/\partial X)+\partial A/\partial t=q \qquad (31)$$

The momentum equation, based on the concept that the sum of forces acting on an element of water is equal, is expressed as:

$$S_0 - S_f = (1/g)\{(\partial V/\partial t) + V(\partial V/\partial X) + (g/A)(\partial(A\bar{y})/\partial X) + Vq/A\} \tag{32}$$

where, A = cross sectional area of water

V = average velocity

X = horizontal distance

$\bar{y}$ = depth of water to centroid of volume

S_0 = bed slope of channel

S_f = friction slope

t = time

g = acceleration of gravity

q = source term

Equations 31 and 32, which are known as the, Saint Venant or shallow water equations, mathematically describe the propogation of a wave and cannot be solved in closed form for practical situations. (Ligget and Woolhiser, 1967; Strelkoff, 1969, 1970).

Kinematic approximations to the complete flow equations are used to simulate the overland flow hydrograph that results from rainfall excess. The kinematic equations take the form of first order differential equations, computationally much simpler than the complete hyperbolic shallow water equations. Kinematic routing has been analyzed by Kibler and Woolhiser (1970), Overton and Brakensiek (1970), and Smith and Woolhiser (1971). Kinematic flow occurs on a plane whenever a balance between gravitational and frictional forces is achieved. Under these conditions Equation 32 reduces to $S_0 = S_f$. S_f is defined by a stage discharge relationship. In their kinematic forms the equations of motion and continuity are given respectively by:

$$Q=Q_n \tag{33}$$

$$(\partial Q/\partial X)+\partial y/\partial t=q \tag{34}$$

where, Q = discharge

Q_n = normal discharge

y = depth of water

q = source term = precipitation excess, P_E

Turbulent flow is assumed in the distributed model, therefore Equation 33 is written in form:

$$Q=(1.0/n)y^{1.667}S_0^{\frac{1}{2}} \tag{35}$$

where n is Manning's roughness coefficient. The continuity equation in finite difference form is:

$$(\Delta Q/\Delta X)+\Delta y/\Delta t=P_E \tag{36}$$

Rewriting equation 36 in terms of the change in water depth:

$$\Delta y=((\Delta Q/\Delta X)-P_E)\Delta t \tag{37}$$

Equation 37 is solved numerically by explicit finite difference methods. For a discussion of the stability of the explicit method, parameter fitting and component verification of the surface water routing algorithm the reader is directed to Engman (1974).

The input requirements for the second step include: 1) a three-dimensional soil distribution of the watershed, 2) soil slopes, 3) depression storage, 4) Manning's n roughness values for overland flow, 5) average water surface widths, and 6) channel reach lengths.

In the third and final step of the distributed model surface runoff hydrographs become lateral inflow for channel routing. A kinematic flood routing program developed by Brakensiek (1966a) is used to synthesize the channel hydrograph in any given reach of a stream. The method is identical to that employed in step two, except that flow in a rectangular open channel is considered rather than flow across a plane.

The formulation of kinematic flood routing is composed of the continuity equation:

$$(\partial Q/\partial X)+\partial A/\partial t=q \tag{38}$$

The source term q is now the lateral inflow to the stream determined as output from the step-two simulation of overland flow. The equation of motion is now in the form of a rating function:

$$Q=Q(A) \tag{39}$$

Utilizing an algorithm developed by Brakensiek (1966b) a rating function is developed for each channel cross section so that:

$$\Delta Q=f(\Delta A) \tag{40}$$

Normal (turbulent) flow is assumed so that:

$$Q_n=(1.0/n)R^{0.667}AS_0^{\frac{1}{2}} \tag{41}$$

where R is the hydraulic radius of the channel (area/wetted perimeter). Simultaneous solutions of Equation 40 and the finite difference approximation of Equation 38 requires an iterative procedure. The numerical technique used is the method of false position (Kunz, 1957). Brakensiek (1967) reviews the application of the kinematic technique in flood routing.

As described by Engman (1974) Brakensiek's (1966a) flood routing program takes the upstream inflow hydrograph for any given reach, adds the lateral inflow hydrograph for that reach, and routes the two together to form the outflow hydrograph from the reach. This calculated outflow hydrograph becomes the inflow hydrograph for the next reach. Tributaries are treated as lateral inflow hydrographs over a very short reach. Dummy sections are used above and below short tributary sections to smooth the averaging done in the numerical solution.

The simulation philosophy of the distributed model proposed by Engman (1974), as described here, is that of a conceptually sound model that does not depend upon the calibration of watershed parameters with historical records. The selection of watershed parameters should be made on the basis of simple field measurements and values available in the literature.

The input required for the third step is: 1) channel reach lengths, 2) Manning's n roughness values for open channel flow, and 3) a normal flow rating function. The inputs required for the program used to develop the channel rating functions (Brakensiek, 1966b) are: 1) channel bed slopes, 2) Manning's n roughness values for open channel flow, and 3) channel cross section geometry. Listings of the four codes that define the distributed rainfall-runoff technique are found in Appendix B. Each of these codes was verified with the example output contained in the source documentation.

2.4 Model Efficiency

The model-calibration process is made up of calibration, verification, and prediction time periods (Freeze, 1982b). In the calibration period, model parameters are estimated on the basis of available rainfall-runoff records. During the verification period, the calibrated model is applied to the available rainfall records and computed runoff values are compared with the observed records in order to assess the predictive efficiency of the model. If the efficiency is adequate, the model can then be used for runoff prediction in the prediction period. The input data requirements for the techniques described in the previous section, relative to the calibration process, are summarized in Table 5.

The verification procedure, proposed by Nash and Sutcliffe (1970), is used in this study to compare relative model efficiencies. The efficiency (analogous to the coefficient of determination) of a given modeling technique is defined by:

$$R^2=(F_0^2-F^2)/F_0^2 \tag{42}$$

where the residual variance F and initial variance F_0 are defined as follows:

$$F^2=\Sigma(q'-q)^2 \tag{43}$$

$$F_0^2=\Sigma(q-\overline{q})^2 \tag{44}$$

where, q = observed runoff variable

q' = computed runoff variable

$\overline{q}$ = mean of observed runoff variables

Based on this sum of squares criterion, maximum model efficiency is achieved by maximizing R^2. The maximum value for model efficiency is one. This value would be reached only if the observed and computed runoff variables were identical. A negative efficiency infers that the model's predicted value is worse than simply using the observed mean.

INPUT REQUIREMENT	REGRESSION	UNIT HYDROGRAPH	DISTRIBUTED MODEL*			
			SOIL CHARACTERISTICS	OVERLAND FLOW ROUTING	CHANNEL RATING FUNCTION	OPEN CHANNEL ROUTING
Rainfall	CVP			P		
Excess Rainfall		CVP				
Runoff	CV					
Baseflow		CVP				
Stormflow		CV				
Porosity			P			
Soil Moisture 1.5 MPa			P			
Antecedent Soil Moisture				P		
Soil Moisture Frequency				P		
Degree of Saturation				P		
Pressure Air Entry			P			
Pressure Water Entry			P			
Hydraulic Conductivity, Air Entry			P	P		
Sorptivity				P		
Initial Infiltration Rate				P		
3-D Soil Distribution				P		
Depression Storage				P		
Soil Slope				P		
Manning n, Overland				P		
Manning n, Channel					P	P
Average Water Surface Width				P		
Channel Length				P		P
Channel Bed Slope					P	
Channel Geometry					P	
Normal Flow Ratings						P
Tolerance Levels				P		P
Time Step			P	P		P

C - Calibration mode V - Verification mode P - Prediction mode * - Ungaged basin

Table 5. Input requirements for selected modeling techniques relative to the calibration process

CHAPTER THREE

DATA SOURCES AND EVENT SELECTION

In this chapter, the two experimental subwatersheds chosen for this study are described and the available data from each are discussed. The criteria used for selecting rainfall-runoff events are also presented.

The selection of study areas for this research was restricted to North American experimental subwatersheds. It is felt by the author that the evaluation of rainfall-runoff modeling techniques must begin at the hillslope or subwatershed scale and progress to larger basin scales only after understanding the smaller scale. The experimental subwatershed data bases described here are used to compare the efficiencies of the selected modeling techniques described in Chapter Two. In order for an experimental subwatershed to be selected for this study, available records from the basin instrumentation program and data collection network had to be compatible with the input requirements of each underlying rainfall-runoff modeling technique being evaluated. Another limitation placed upon basin selection is that runoff not be generated from snowmelt.

Scientists at three Canadian experimental subwatersheds and ten experimental subwatersheds located in the United States were contacted to find data sets that included: 1) precipitation and stream flow records inclusive enough to allow abstraction of selected rainfall-runoff events, 2) soil surveys, 3) sufficient soil moisture measurements to allow for the estimates of antecedent soil water conditions for each selected runoff event, and 4) measurements of spatially variable, physically based parameters, including the characteristic curves of hydraulic conductivity and moisture content as functions of pressure head. The experimental subwatersheds contacted range in area from 80,000 M^2 to 10.4 KM^2. All thirteen subwatersheds have adequate rainfall-runoff data. Three otherwise acceptable data sets were eliminated becouse snowmelt was the principal source of runoff. The most restrictive data requirement, however turned out to be the measurement of spatially variable physical parameters, the lack of which eliminated seven more basins.

One of the three selected data sets, from a 132,000 M^2 subwatershed located in the Hubbard Brook Experimental Forest, New Hampshire, is not used in this study due to the necessity for considerable data reduction. This precious data set was obtained with the generous cooperation of the Northeastern Forest Experiment Station, Durham, N. H., (Federer, personal communication, 1982) and will certainly be included in future research.

The first of two subwatersheds used in this study is within the 420 KM^2 Mahantango Creek Watershed located in east-central Pennsylvania. The Agricultural Research Service (ARS) of the

United States Department of Agricultural (USDA) has a number of Watershed Research Centers throughout the United States. The Mahantango Creek Watershed, described by Pionke and Weaver (1977), is the research watershed for the Northeast Watershed Research Center (NWRC) of the ARS. Data collection programs at NWRC, and within the ARS in general, have been designed to facilitate specific research projects within the general areas of rainfall-runoff relationships, hydrology-water quality interactions, and mathematical modeling of hydrologic processes (Engman et al., 1971; Engman et al., 1974; Rogowski et al., 1974; Henninger et al., 1976; Gburek, 1977). The subwatershed data set, from the Mahantango Creek Watershed, used in this study was obtained from NWRC, University Park, Pa. (Gburek, personal communication, 1982).

The second subwatershed used in this study is within the ARS Southern Great Plains Research Watershed. A number of experimental watersheds are located near Chickasha, Oklahoma. The subwatershed chosen was recommended to the author, while inquiring about another facility, as meeting the data requirements of this study (Luxmoore, personal communication, 1981). The data set itself was obtained from the ARS at Chickasha (Gander, personal communication, 1981). The two experimental data sets used in this work are described in the following sections.

3.1 Mahantango Creek Subwatershed

The 7.2 KM^2 Mahantango Creek Subwatershed (MCW) shown in Figure 13 is located in the ridge and valley region near Klingerstown, Pennsylvania. The characteristic physiographic features of this region are long mountain ridges of fairly uniform elevation cut at intervals by water gaps. The major land uses are permanent pasture and cultivated fields.

Precipitation and stream flow records in break point form, covering the six year period 1971 through 1976, are used in this study. The locations of two rain gages and a dual notch weir with water level recorder, making up the continuous rainfall-runoff monitoring network, are shown in Figure 13. Carr (1973) describes the gages, the gage network and the data reduction procedure used.

Texturally, the soils are classified as shaly silt loams. The spatial distribution of soil type and the variation in land slopes are shown in Figure 14. Average topsoil and subsoil depth are listed in Table 6. Moisture characteristic, hydraulic conductivity, and soil water diffusivity curves for the modeled soils shown in Figure 14 were constructed using input parameters similar to the averaged values shown in Table 7. These parameters were either abstracted or estimated from the available literature (Engman and Rogowski, 1974a). Engman and Rogowski (1974b) discuss the selection of soil moisture

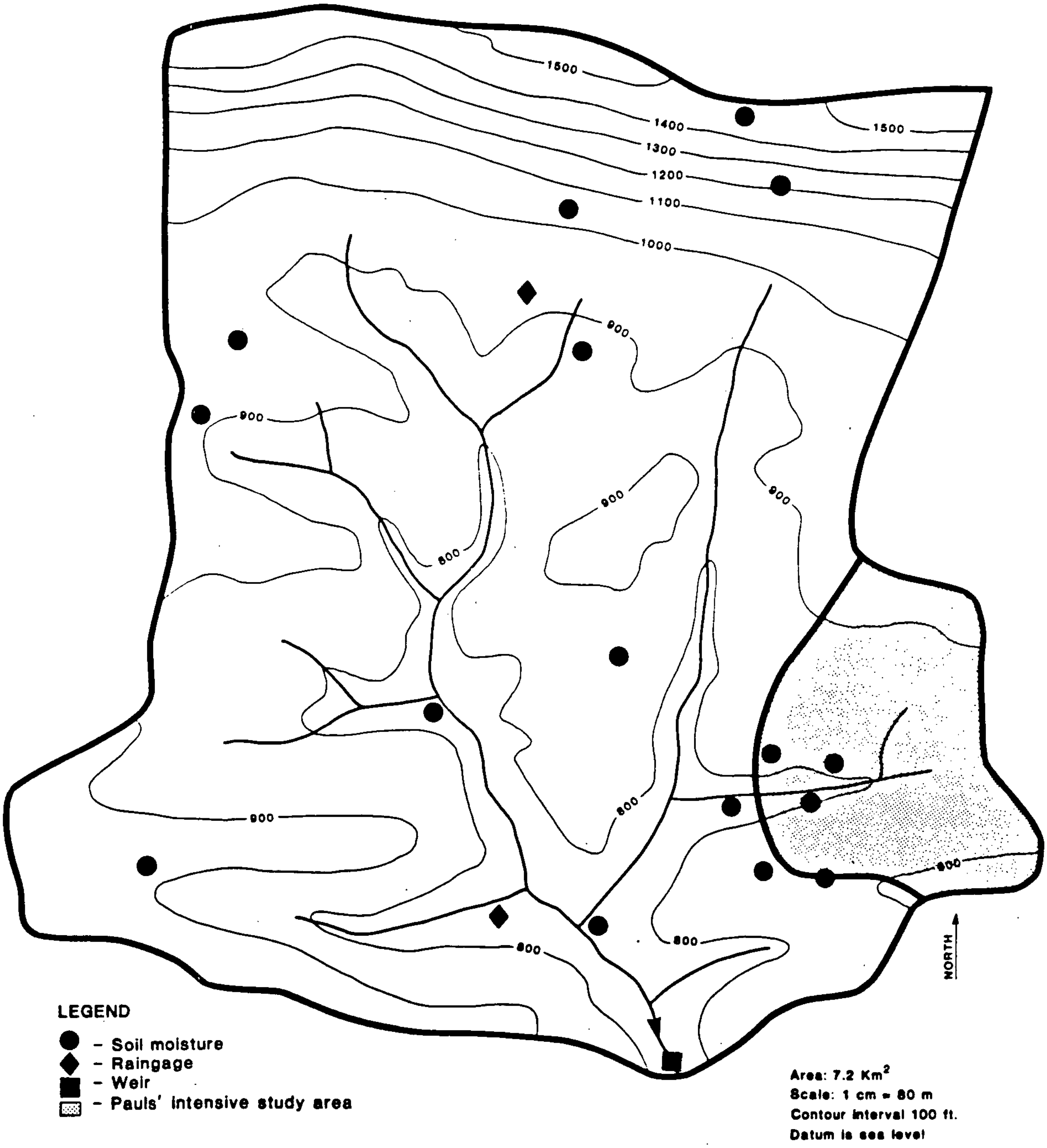

Figure 13. Mahantango Creek Subwatershed (Gburek, personal communication, 1982)

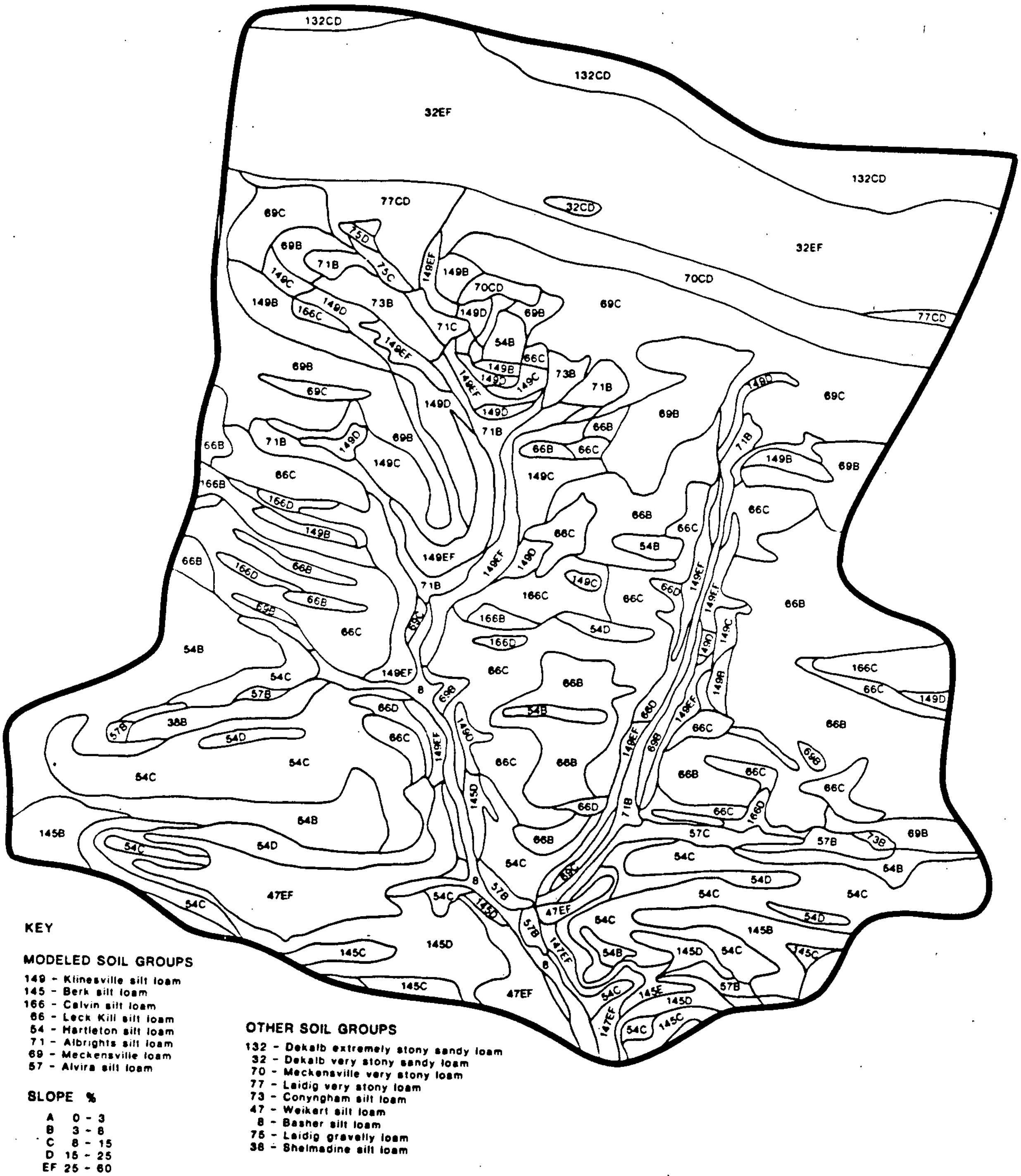

Figure 14. Spatial variation of soil type and land slope within the Mahantango Subwatershed (Gburek, personal communication, 1982)

SOIL NUMBER	SOIL NAME	DEPTH (m)	
		TOPSOIL	SUBSOIL
149	Klinesville	.23	.46
145	Berks	.23	.64
166	Calvin	.20	.71
66	Leck Kill	.20	.71
54	Hartleton	.23	.76
71	Albrights	.23	.52
69	Meckensville	.23	.61
57	Alvira	.23	.76

Table 6. Average soil depths within the Mahantango Creek Subwatershed (abstracted from Engman, 1974)

SOIL NUMBER	SOIL NAME	$K_e \times 10^4$ (M/S)	θ_o	θ_e	$\theta_{1.5}$
			(PERCENT BY VOLUME)		
149	Klinesville	3.0	47	38	11
145	Berks	3.0	47	38	11
166	Calvin	2.19	47	38	11
66	Leck Kill	2.19	37	30	12
54	Hartleton	1.6	42	34	12
71	Albrights	.64	43	34	14
69	Meckensville	.64	39	31	18
57	Alvira	.64	38	30	15

K_e - Averaged values of hydraulic conductivity at air entry (φ_e)
θ_o - Total pore space
θ_e - Soil water content at air entry
$\theta_{1.5}$ - Soilwater content at 1.5 MPa
φ_e - Estimated as 60 mm of water

Table 7. Soil characteristic parameters for the Mahantango Creek Subwatershed (after Engman and Rogowski, 1974a)

parameters.

The locations of a very limited amount of soil moisture data obtained for this study are shown in Figure 13. These data were measured by the neutron scattering method over a five year period. However, records of soil moisture proved to be inadequate for affixing initial conditions for each selected rainfall-runoff event. In order to estimate antecedent soil water contents for topsoil and subsoil layers, soil water frequency distributions similar to the ones shown in Figure 15 were used. The general approach to the seasonal soil water frequency distribution is outlined by Rogowski (1972bc). The employed distributions were developed with Henninger's (1972) soil moisture data, gathered in 1971. These data are summarized in Figure 16. The general assumption made in using these distributions is that the same or very similar soil moisture conditions will apply in any given year. Except for two events, no measurement of antecedent soil moisture was available. Therefore, initial conditions for the respective soils were set at their 50% probability level. For the two events in which measurements of soil moisture roughly coincide with the start of rainfall, the frequency of measured soil moisture associated with the most obvious source area was used for all other soils to estimate initial conditions. The most obvious source area is taken as the soil with the lowest hydraulic conductivity: Alvira silt loam in Figure 14. Table 8 summarizes the antecedent soil

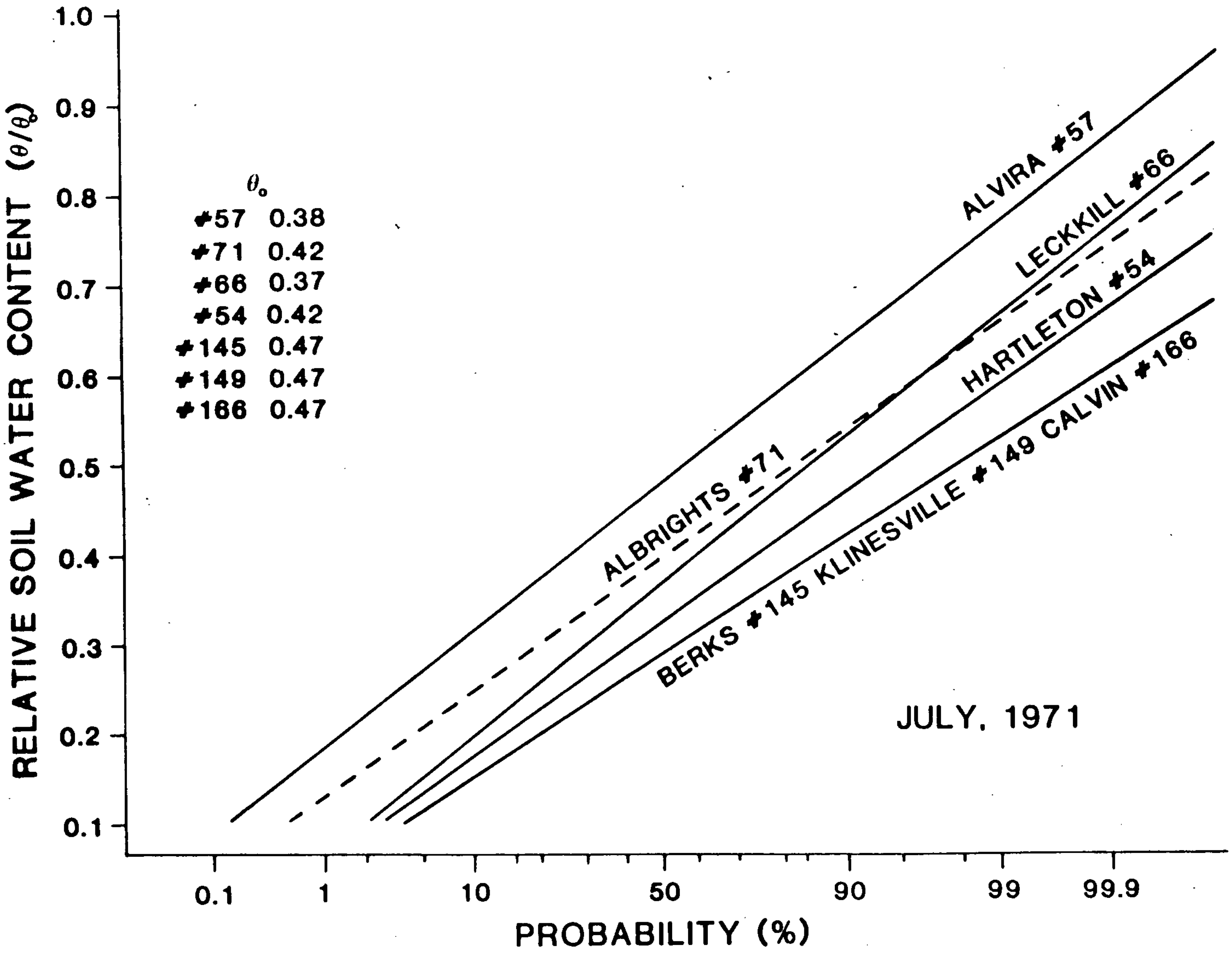

Figure 15. Example soil water frequency distributions (after Engman and Rogowski, 1974a)

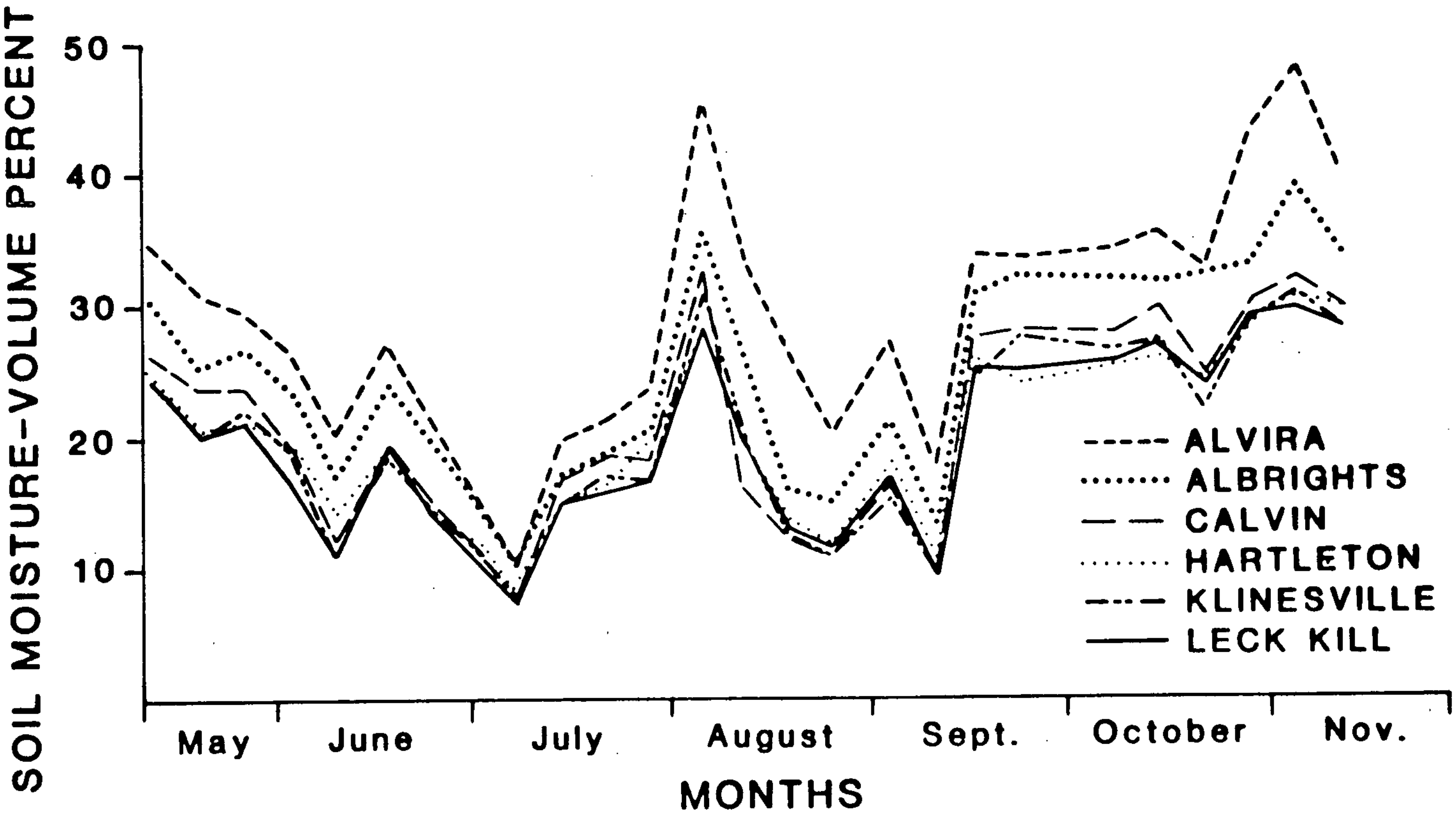

Figure 16. Soil moisture for 1971 within the Mahantango Creek Subwatershed (after Henninger, 1972)

SOIL NO.	SOIL NAME	SOIL LAYER	ANTECEDENT SOIL WATER CONTENT*	
			MCW	R-5
149	Klinesville	T S	.225 .225	
145	Berks	T S	.225 .225	
166	Calvin	T S	.237 .237	
66	Leck Hill	T S	.237 .237	
54	Hartleton	T S	.229 .229	
71	Albrights	T S	.258 .258	
69	Meckensville	T S	.278 .278	
57	Alvira	T S	.278 .278	
1	Kingfisher	T S		.218 .245
2	Grant	T S		.218 .245
3	Renfrow	T S		.218 .245

T - Topsoil
S - Subsoil
* - Initial soil moisture m^3 water/m^3 soil

Table 8. Antecedent soil water contents for the Mahantango Creek Subwatershed and the R-5 Subwatershed

water contents for MCW soils, at their 50% probability levels.

Huggins and Monke (1966) and Hiemstra (1968) propose that depression storage (Viessman et al., 1977) is a watershed constant for a given pattern of land use. Figure 17 illustrates the estimation of depression storage as a function of land slope and use as described by Hiemstra (1968). The average total depression storage for MCW is taken as 4 mm of water (Engman and Rogowski, 1974a).

Values of Manning's n of 0.35 and 0.05, for overland and channel flow respectively, are assumed (Engman, 1974). Engman determined the n value for the overland flow portion of the hydrograph by fitting Izzard's (1946) data for a sloping turf plane. The n value for channel flow was chosen by handbook procedures and verified with field measurements. Channel geometry was taken as prismatic triangular. Figure 18 shows the assumed channel cross section. The average water surface width is taken to be 3.0 M. Channel slopes were abstracted from topographic contour maps.

The base flow separation slope α, shown on Figure 9, is taken as $1.28*10^{-4} M^3/Sec^2$, based on the $1.79*10^{-5} M^3/Sec^2\text{-}KM^2$ relationship illustrated in Figure 19, that was established by Engman (1974) for the Mahantango Creek Watershed.

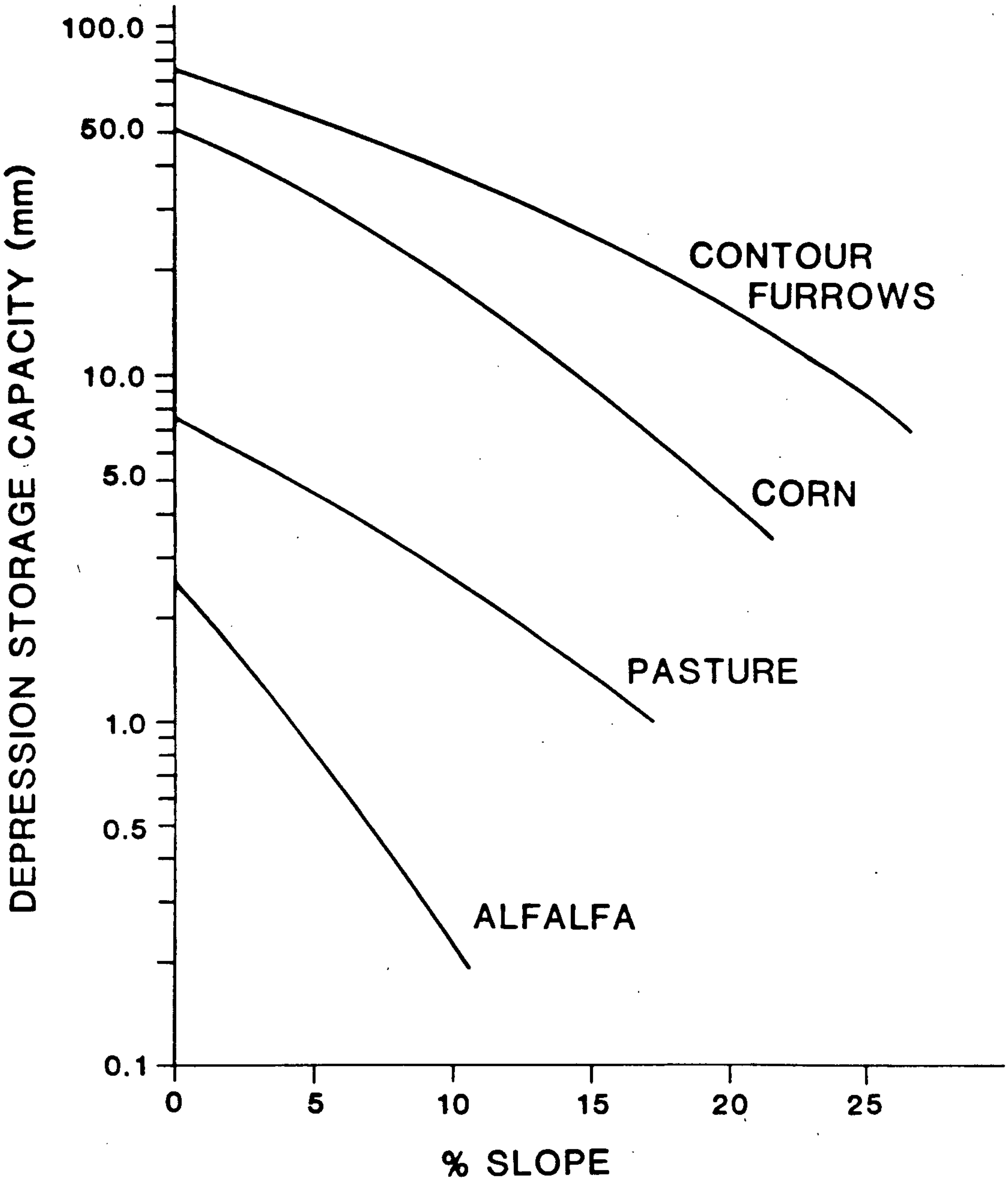

Figure 17. Depression storage as a function of land slope and use (after Hiemstra, 1968)

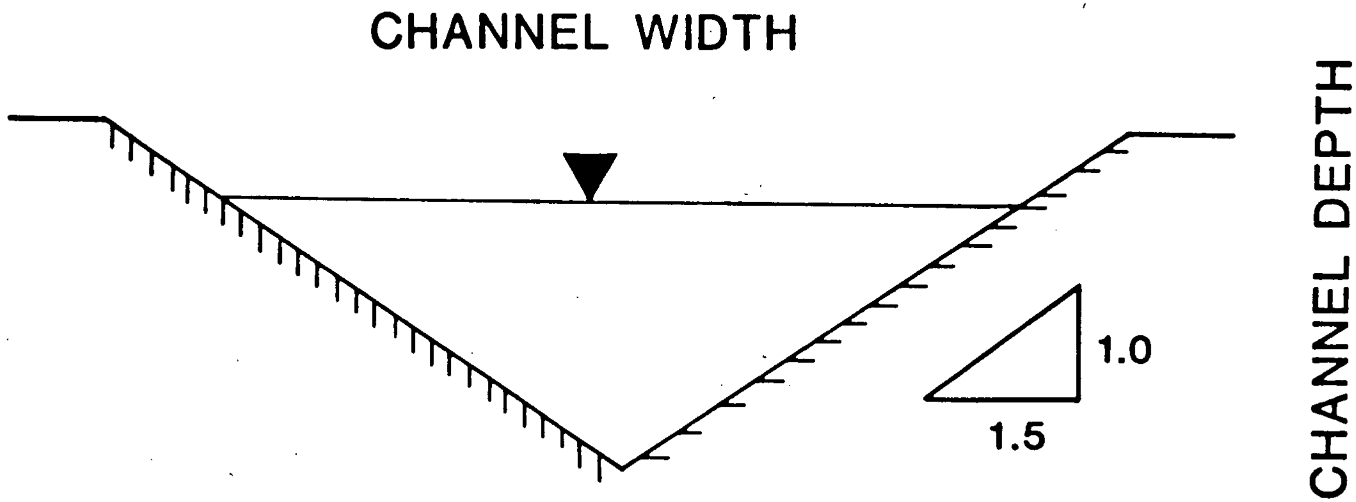

Figure 18. Open channel cross section

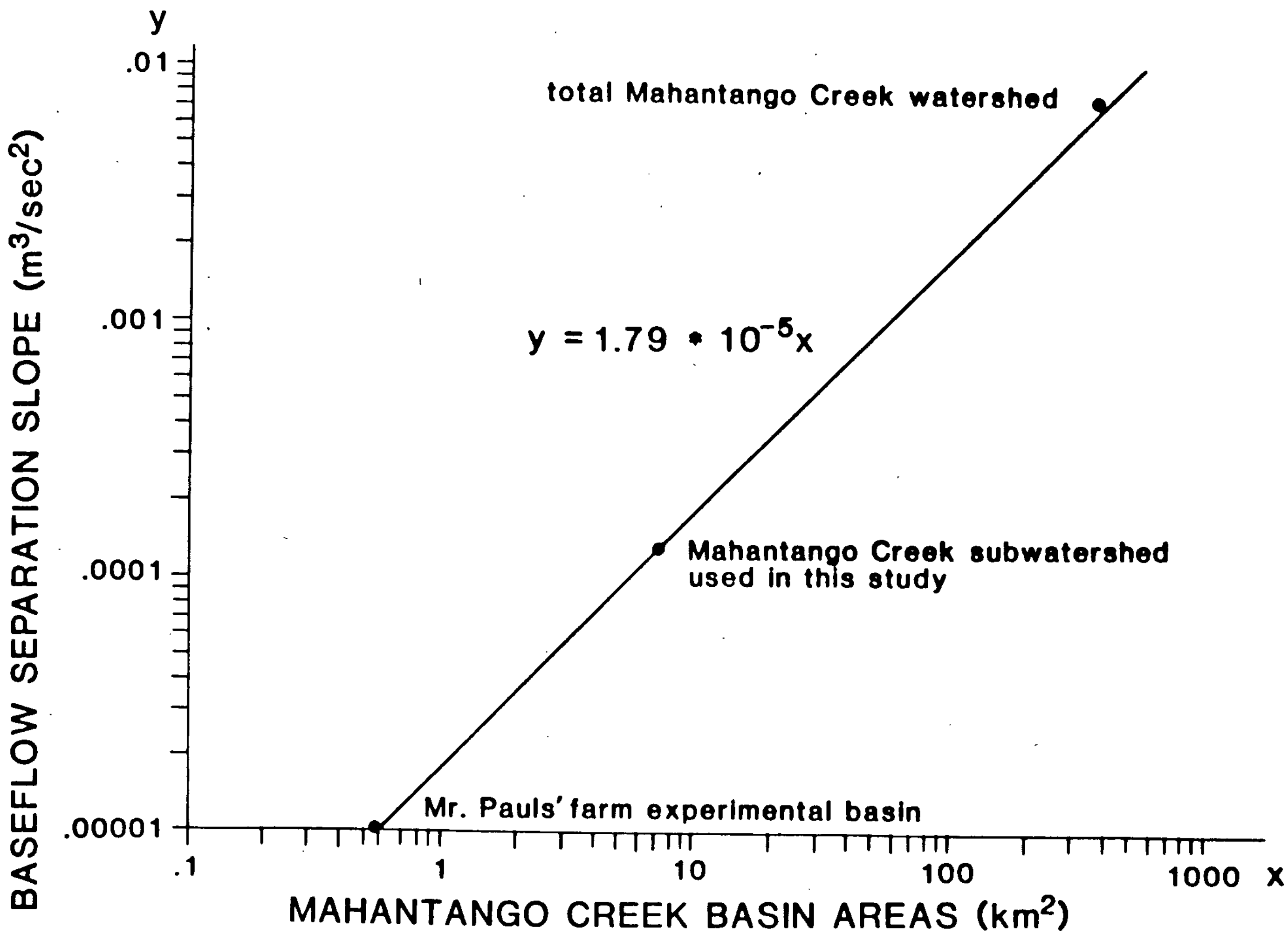

Figure 19. Base flow separation relationship for the Mahantango Creek Watershed (after Engman, 1974)

3.2 R-5 Subwatershed

The 96,000 M^2 R-5 subwatershed (R-5), shown in Figure 20, is located in rolling prairie grassland terrain in the Washita river valley, near Chickasha, Oklahoma. R-5 has been subjected to continuous well-managed grazing of beef cattle (Sharma et al., 1980).

Precipitation and stream flow records in break point form covering the eight-year period 1967 through 1974, are used in this study. Locations of the continuous recording rain gage and weir used in this study are shown in Figure 21.

Soil types and surface contours for R-5 are shown in Figure 20. Approximately 51% of the area is Renfrow silt loam, 43% Grant silt loam, and 6% Kingfisher silt loam (Sharma et al., 1980). Topsoil and subsoil depths are shown in Table 9. There is an overall gentle land slope of about 3%. Parameters used to construct soil characteristic curves are shown in Table 9. These data are taken from the reference soil parameters described by Luxmoore and Sharma (1980). Water retention and hydraulic conductivity data are discussed by Sharma and Luxmoore (1979) and Luxmoore and Sharma (1980). Based on standard statistical tests, no difference can be shown between the three soils (Sharma and Luxmoore, 1979).

The locations of soil moisture data, for topsoil and subsoil layers, from neutron scattering measurements are shown

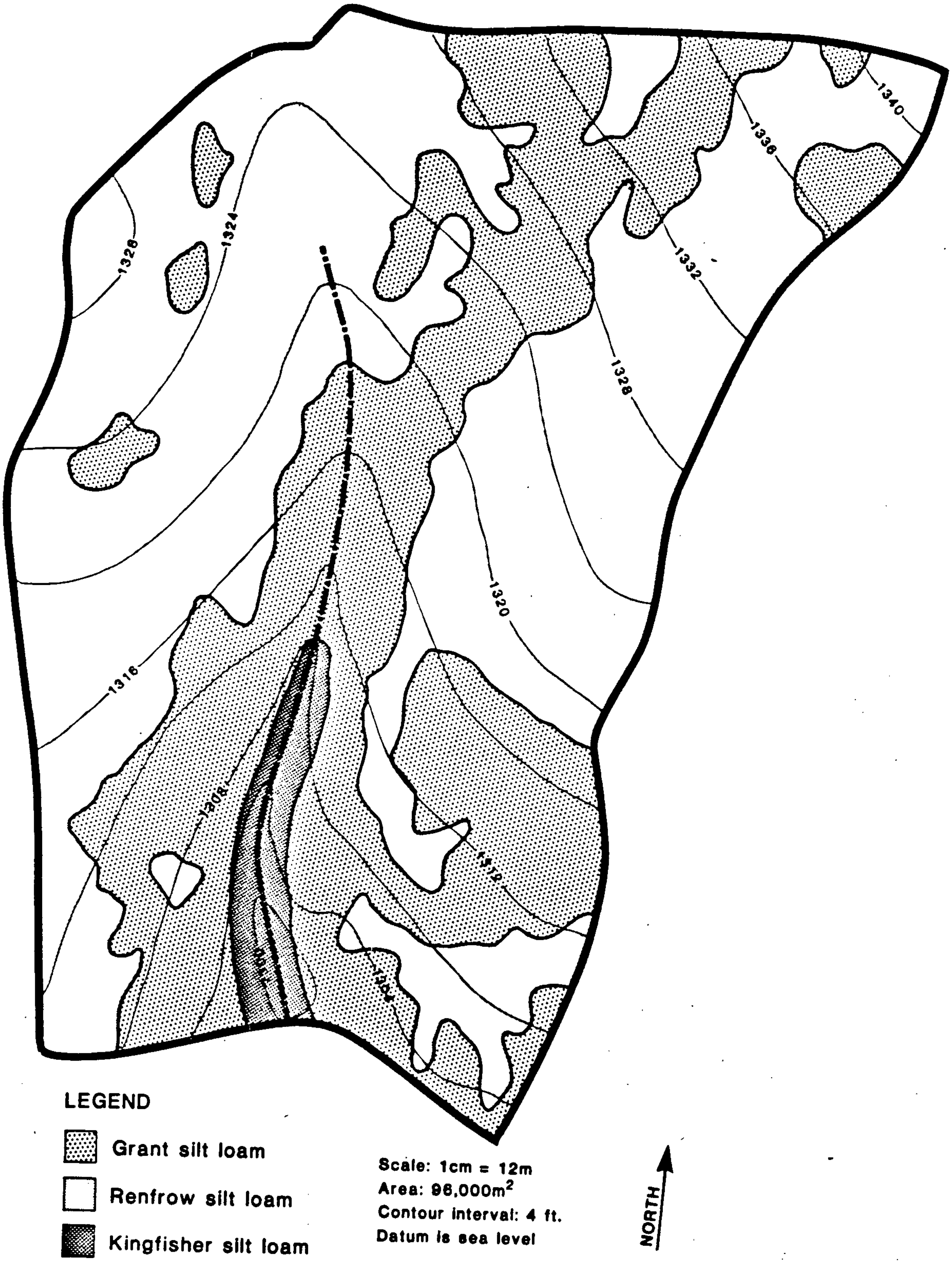

Figure 20. R-5 Subwatershed
(Gander, personal communication, 1981)

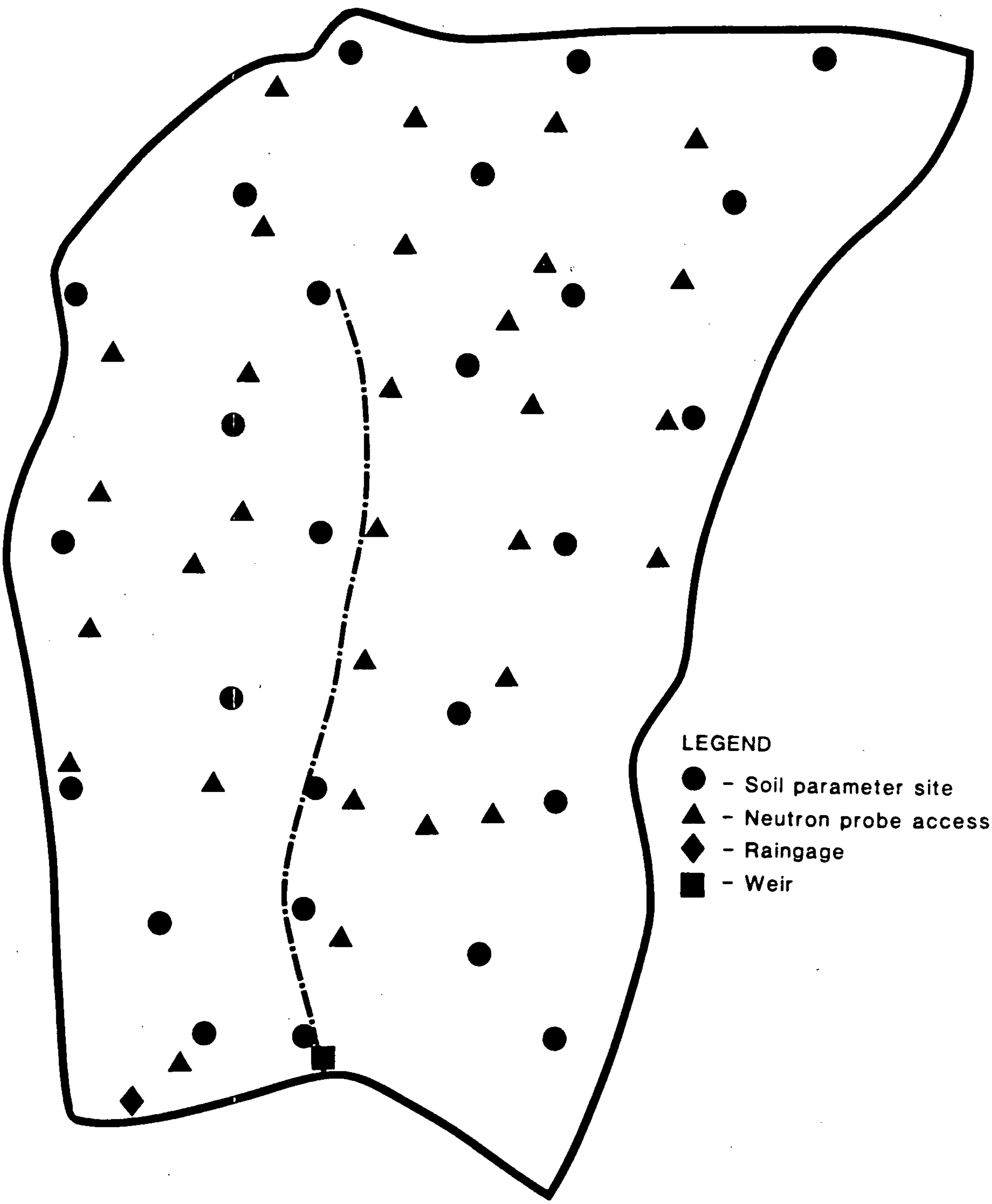

Figure 21. Location of instrumentation and soil parameter measurements within the R-5 Subwatershed (Gander, personal communication, 1981)

SOIL NUMBER	SOIL NAME	LAYER	$K_e \times 10^4$ (M/S)	θ_o	θ_e	$\theta_{1.5}$	DEPTH (m)
				(PERCENT BY VOLUME)			
1	Kingfisher Silt Loam	T	1.86	44	39.6	9	.2
		S	.31	44.3	39.9	14.5	.8
2	Grant Silt Loam	T	1.86	44	39.6	9	.2
		S	.31	44.3	39.9	14.5	1.30
3	Renfrow Silt Loam	T	1.86	44	39.6	9	.2
		S	.31	44.3	39.9	14.5	1.30

T - Topsoil
S - Subsoil
K_e - Estimated as 1/2K saturated
θ_e - Estimated as $0.9\theta_o$ (Rogowski, 1972b)

Table 9. Characteristic parameters and depths for R-5 Subwatershed soils

in Figure 21. These data represent measurements taken at 34 sites over a four year period and averaged values from a separate four year period.

Antecedent soil water contents for R-5 were estimated as the means of all measured values, taken from the two layers previously described, for the same six month period used in event selection. Assuming soil water content to be normally distributed (Rogowski, 1972b), this mean value is the same as the 50% frequency utilized at MCW. Table 8 summarizes the antecedent soil water contents used for R-5 soils.

Depression storage for R-5 is estimated, from Figure 17, as 10 mm. Manning n values are taken as 0.35 for overland flow (Engman, 1974) and 0.2 for channel flow (Luxmoore and Sharma, 1980). Channel geometry is taken as prismatic triangular. The average water surface width is assumed to be 1.5 M. The channel slope is constant at 2%. No base flow separation is considered as observed hydrographs exhibit a flashy response with little or no base flow (Luxmoore and Sharma, 1980).

3.3 Event Selection

In this section the criteria used for selecting individual rainfall-runoff events from the MCW and R-5 data sets are discussed. These selected rainfall-runoff events are simulated in Chapter Four, using the underlying modeling techniques described in Chapter Two. The observed events are used to compare the efficiencies of the individual models in Chapter Four.

Events were selected on the following basis: 1) Only events that show an obvious cause-and-effect rainfall-runoff relationship were chosen. 2) Only storms of simple structure were considered. 3) Only events occurring in the six month period April through September were considered, to avoid runoff due to snowmelt. 4) The duration of an individual rainfall event was restricted to a maximum of ten hours. The duration of a runoff event was taken from the start of the rainfall event until runoff had subsided to the prestorm rate. Both base flow separation and/or another rainfall event occurring in the tail of the hydrograph shorten this period. 5) An attempt was made to select storms that maintained a uniform intensity throughout the period of rainfall. The assumption was made that rainfall was uniformly distributed over the entire subwatershed. Simple arithmetic averages were used when the rainfall record for an event was available from two gages. 6) Only precipitation and stream flow records showing error free data were considered in the selection of an event, with no attempt to adjust records based on available error codes.

Nine events were selected from the R-5 data base. Twenty-one events, six of which have rainfall at two gages, were selected from the MCW data base. The selected rainfall-runoff events and their characteristics are summarized in Table 10.

	EVENT NO.	V_{PPT}	PPT	PPT_D	V_Q	Q_{PK}	V_Q^*	Q_{PK}^*	$T_{Q_{PK}}$
R-5	1	2804.	11.43	2.58	429.	.11			.51
	2	6071.	7.37	8.65	1958.	.58			1.56
	3	4170.	7.37	5.83	1367.	.48			5.19
	4	7510.	18.29	4.28	1002.	.26			1.65
	5	7754.	32.26	2.51	408.	.17			1.54
	10	8778.	63.50	1.44	4378.	1.79			.51
	12	3146.	17.02	1.92	1601.	.51			2.03
	14	4779.	7.87	6.25	974.	.22			2.95
	15	2780.	2.79	10.16	626.	.09			10.40
MCW	3	201865.	30.73	.91	6476.	.78	2346.	.77	1.33
	4	73405.	7.62	1.33	19465.	.56	1631.	.40	2.25
	15	128460.	5.59	3.25	73895.	1.76	4519.	1.37	1.58
	16	128460.	104.65	.17	17629.	1.08	1316.	1.02	.92
	17	146811.	35.05	.58	7034.	.59	1597.	.56	1.16
	**20	201865.	3.05	9.24	198326.	1.95	11799.	1.60	8.00
	21	293622.	5.33	7.54	43580.	2.86	9520.	2.81	3.92
	24	183514.	13.21	1.91	17479.	1.04	6082.	1.03	2.16
	25	403730.	14.48	3.83	206484.	5.76	35859.	5.67	2.00
	26	183514.	8.38	3.00	93602.	1.66	37129.	1.56	1.24
	32	238568.	10.41	3.17	66527.	1.20	19427.	1.13	2.41
	33	183514.	7.62	3.33	8569.	.46	2059.	.44	4.17
	42	128460.	3.56	5.08	80237.	.49	4121.	.31	6.07
	**43	128460.	4.06	4.42	8290.	.17	752.	.13	3.87
	**43b	110108.	2.82	5.50	63518.	.29	3534.	.22	6.11
	**44	73405.	3.30	3.17	9840.	.17	94.	.06	3.29
	**45	137635.	10.41	1.83	10676.	.63	1395.	.51	2.00
	**46	192689.	3.30	8.34	133564.	.59	2344.	.46	5.19
	47	201865.	11.94	2.33	97750.	1.84	13154.	1.75	2.41
	48	73405.	13.46	.75	6164.	.52	997.	.43	1.49
	49	201865.	4.06	6.92	132825.	1.24	5676.	1.08	1.94

V_{PPT} - Volume of rainfall, m^3

PPT - Average rainfall intensity, mm/hr

PPT_D - Duration of rainfall, hr

V_Q - Volume of runoff, m^3

Q_{PK} - Peak flow rate, m^3/sec

$T_{Q_{PK}}$ - Time to peak flow, hrs

* - With base flow separation

** - Rainfall records averaged from two rain gages

Table 10. Rainfall-runoff characteristics from the Mahantango Creek Subwatershed and the R-5 Subwatershed

CHAPTER FOUR

RESULTS AND DISCUSSION

In this chapter site-specific rainfall-runoff events are simulated for the selected Mahantango Creek and Chickasha subwatersheds. The purpose of this chapter is the presentation and discussion of these results. The underlying rainfall-runoff modeling techniques described in Chapter Two and the MCW and R-5 data sets presented in Chapter Three make up the suite of models and sets of data used in this study. Predicted runoff variables are evaluated with the efficiency criterion described in Chapter Two. This criterion is used to standardize model evaluation across the suite of modeling techniques under comparison. Levels of efficiency acceptability are not established in the present study for decisions concerning model use. Instead, calculated efficiencies are used as an index for a more general qualitative model interpretation. Efficiencies of less than zero, do arise in this study, but their values are set equal to zero. The efficiency values are therefore restricted to the range zero to one.

All simulations and most calculations in this work were done on the UBC AMDAHL V8-II computer operating under the Michigan Terminal System.

4.1 Regression Models

Independent rainfall variables and dependent runoff variables, from MCW and R-5, used to construct simple-and multiple-linear-regression rainfall-runoff models, as described in Chapter Two, are shown in Table 10. The regression-analysis scenario used in this study involved the following three steps: 1) construct a number of rainfall-runoff models based on less than the total number of events available; 2) use these models to predict the remainder of the events; and 3) incorporate all available events into new regression models. The determination of the coefficients and constants in the first step constitutes the calibration phase of the model calibration process, as described in Chapter Two. The second step constitutes the verification phase, wherein the established regression models are used to predict the dependent runoff variables. In the third or predictive phase, not included in this study, the regression models are used to predict runoff variables outside the combined set used in the first two phases. By repeating the first phase of model calibration, after incorporating the additional events, subsequent improvements in the regression models can be identified. The evaluation of linear regression models in this work is presented in terms of the efficiencies calculated for predicted runoff variables in the verification phase of model calibration.

The natural rainfall-runoff process shows only positive correlation. Therefore, only rainfall-runoff variables showing positive correlation are considered in this work. No other significance testing of rainfall-runoff variables is used in this study.

Correlation matrices for the six MCW linear regression variables (Table 10) are shown in Tables 11, 12, 13, and 14. The correlation coefficients in Tables 11 and 13 are based upon the observed rainfall-runoff variables, while those in Tables 12 and 14 result from dependent-variable data reduction, in the form of base flow separation as described in Chapter Two. The correlation coefficients in Tables 11 and 12 are based upon variables from 15 selected events, while those in Tables 13 and 14 result from the variables of 21 MCW selected events. Table 15 differentiates between Tables 11, 12, 13, and 14. The heavy lined boxes in Tables 11, 12, 13, and 14 separate out the nine correlations that represent rainfall-runoff relationships.

In Table 11 there are five positive correlations between rainfall-runoff variables: 1) Volume of rainfall and volume of runoff, 2) volume of rainfall and peak flow rate, 3) duration of rainfall and volume of runoff, 4) duration of rainfall and peak flow rate, and 5) duration of rainfall and time to peak flow. The closer these coefficients are to 1.0 the better the suggested rainfall-runoff relationship. Also in Table 11, there are four negative correlations between rainfall-runoff

	V_{PPT}	$\overline{PPT}$	PPT_D	V_Q	Q_{PK}	$^{T}Q_{PK}$
V_{PPT}	1.0					
$\overline{PPT}$	-.1174	1.0				
PPT_D	.2779	-.5730	1.0			
V_Q	.5585	-.2802	.5813	1.0		
Q_{PK}	.8723	-.0584	.2610	.7242	1.0	
$^{T}Q_{PK}$	-.0764	-.4816	.8423	.3858	-.1250	1.0

Table 11. Correlation matrix for Mahantango Creek Subwatershed rainfall-runoff variables based on 15 selected events without base flow separation

	V_{PPT}	$\overline{PPT}$	PPT_D	V_Q	Q_{PK}	$T_{Q_{PK}}$
V_{PPT}	1.0					
$\overline{PPT}$	-.1174	1.0				
PPT_D	.2779	-.5730	1.0			
V_Q	.8610	-.1711	.2657	1.0		
Q_{PK}	.8944	-.0367	.2294	.8664	1.0	
$T_{Q_{PK}}$	-.0764	-.4816	.8423	.0087	-.1533	1.0

Table 12. Correlation matrix for Mahantango Creek Subwatershed rainfall-runoff variables based on 15 selected events with base flow separation

	V_{PPT}	$\overline{PPT}$	PPT_D	V_Q	Q_{PK}	$T_{Q_{PK}}$
V_{PPT}	1.0					
$\overline{PPT}$	-.0696	1.0				
PPT_D	.3337	-.5153	1.0			
V_Q	.6045	-.2658	.6525	1.0		
Q_{PK}	.8541	-.0069	.1961	.6577	1.0	
$T_{Q_{PK}}$	-.0056	-.4419	.7702	.3840	-.1124	1.0

Table 13. Correlation matrix for Mahantango Creek Subwatershed rainfall-runoff variables based on 21 selected events without base flow separation

	V_{PPT}	$\overline{PPT}$	PPT_D	V_Q	Q_{PK}	$^{T}Q_{PK}$
V_{PPT}	1.0					
$\overline{PPT}$	-.0696	1.0				
PPT_D	.3337	-.5153	1.0			
V_Q	.8408	-.1127	.1942	1.0		
Q_{PK}	.8712	.0146	.1668	.8778	1.0	
$^{T}Q_{PK}$	-.0056	-.4419	.7702	.0109	-.1373	1.0

Table 14. Correlation matrix for Mahantango Creek Subwatershed rainfall-runoff variables based on 21 selected events with base flow separation

TABLE	SUBWATERSHED	NUMBER OF SELECTED EVENTS	BASE FLOW SEPARATION
11	MCW	15	NO
12	MCW	15	YES
13	MCW	21	NO
14	MCW	21	YES
17	R-5	6	NO
18	R-5	9	NO

Table 15. Summary of correlation matrix tables

variables: 1) Volume of rainfall and time to peak flow, 2) average rainfall intensity and volume of runoff, 3) average rainfall intensity and peak flow rate, and 4) average rainfall intensity and time to peak flow. The individual correlation coefficients in Tables 12, 13, and 14 show the same general positive and negative correlations described for Table 11.

The negative correlations in Tables 11, 12, 13, and 14 include every rainfall-runoff variable combination of average rainfall intensity. This suggests that the average rainfall intensity is not a useful rainfall-runoff regression model variable for MCW with comparable events and sample sizes. Tables 12 and 14 (with data reduction) when compared with Tables 11 and 13 (no data reduction) show increases in two positive correlation coefficients. Both of these increased correlation coefficients have the volume of rainfall as a component variable. This suggests that using the volume of rainfall as an independent variable in a rainfall-runoff regression model for MCW will be more informative for storm flow predictions. Again comparing Tables 12 and 14 with Tables 11 and 13, there are decreases in two positive correlation coefficients with data reduction. Both of these decreased correlation coefficients have the duration of rainfall as a component variable. This suggests that using the duration of rainfall as an independent variable in a rainfall-runoff regression model for MCW will be more informative for total flow predictions.

The seven MCW linear regression models included in this study, with and without data reduction, and their respective verification efficiencies are summarized in Table 16. The heavy lined boxes in Table 16 separate out the model verification efficiencies. The verification efficiencies of models based on 15 events without data reduction range from 0.0 to 0.83. The verification efficiencies of models based on 15 events with data reduction range from 0.0 to 0.48.

Table 16 also includes the coefficient of determination for each rainfall-runoff regression model. These regression model evaluations (calibration phase) are shown for both 15 event and 21 event models. The point should be made that even for calibrated data, model efficiencies will not be equal to one. A constant increase in the coefficient of determination is seen with data reduction, in all MCW models that include the rainfall volume as an independent variable. The coefficients of determination based on 21 events are greater than the coefficients of determination based on 15 events for runoff volume models, without data reduction, in every case suggesting stronger relationships for these models with increased sample sizes.

In Table 16, model number one (without data reduction) has a verification efficiency (0.48) that is greater than either of its coefficients of determination (0.31 and 0.37). Verification efficiencies higher than the coefficients of determination are

							NO SEPARATION			WITH BASEFLOW SEPARATION		
MODEL	V_{PPT}	$\overline{PPT}$	PPT_D	V_Q	Q_{PK}	$T_{Q_{PK}}$	r_1^2	R_2^2	r_3^2	r_4^2	R_5^2	r_6^2
1	●			●			.31	.48	.37	.74	.48	.71
2			●	●			.34	.68	.43	.07	.0	.04
3	●		●	●			.51	.83	.59	.74	.42	.72
4	●				●		.76	.48	.73	.80	.43	.76
5			●		●		.07	.0	.04	.05	.0	.03
6	●		●		●		.76	.43	.74	.80	.48	.78
7			●			●	.71	.0	.59	.71	.0	.59

$r^2_{1,4}$ - Regression (multiple) models based on events 3, 4, 15, 16, 17, 20, 21, 24, 25, 26, 32, 33, 42, 43, and 43b

$R^2_{2,5}$ - Predicting events 44, 45, 46, 47, 48, and 49 with $r_1(r_4)$ regression (multiple) models

$r^2_{3,6}$ - New regression (multiple) models based on all events

R - Model efficiency

r - Coefficient of determination

Table 16. Linear regression models and efficiencies for the Mahantango Creek Subwatershed

also seen in the other two MCW runoff volume models (without data reduction) in Table 16. These higher verification efficiencies for models 1, 2, and 3 are explained by the observed volumes of runoff being, by chance, close to the fitted regression line. The correlation coefficient interpretations, relating to data reduction, for MCW are also illustrated in Table 16. With data reduction the coefficient of determination values are shown to increase for models including the volume of rainfall and decrease for models including the duration of rainfall.

In general the predictive prowess of MCW regression models, that include the volume of rainfall as an independent variable, would appear to be fairly good within their calibrated ranges. This suggests that the volume of rainfall is the most useful independent variable for MCW rainfall-runoff regression models. It seems intuitive that there should be a strong correlation between rainfall-volumes and storm flow volumes. Dunne and Leopold (1978) describe the scatter that is usually found in regression models of this type as resulting from differences in rainfall intesity and duration as well as the antecedent moisture conditions of the basin from event to event.

The correlation matrices for the R-5 linear regression variables (Table 10) are shown in Tables 17 and 18. The correlation coefficients in Table 17 are based upon variables from six selected events, while those in Table 18 result from

	V_{PPT}	$\overline{PPT}$	PPT_D	V_Q	Q_{PK}	$^{T}Q_{PK}$
V_{PPT}	1.0					
$\overline{PPT}$	.7418	1.0				
PPT_D	-.2614	-.7032	1.0			
V_Q	.5223	.7162	-.1306	1.0		
Q_{PK}	.5364	.7861	-.2442	.9911	1.0	
$^{T}Q_{PK}$	-.3215	-.4690	.4566	-.1981	-.2103	1.0

Table 17. Correlation matrix for R-5 Subwatershed rainfall-runoff variables based on six selected events

	V_{PPT}	$\overline{PPT}$	PPT_D	V_Q	Q_{PK}	$^{T}Q_{PK}$
V_{PPT}	1.0					
$\overline{PPT}$	.7444	1.0				
PPT_D	-.3363	-.6743	1.0			
V_Q	.5159	.7395	-.2828	1.0		
Q_{PK}	.6156	.8126	-.3741	.9897	1.0	
$^{T}Q_{PK}$	-.5038	-.4973	.7336	-.3168	-.3520	1.0

Table 18. Correlation matrix for R-5 Subwatershed rainfall-runoff variables based on nine selected events

the variables of nine R-5 selected events. Table 15 differentiates between Tables 17 and 18. The heavy lined boxes in Tables 17 and 18 separate out the nine correlations that represent rainfall-runoff relationships. There are five positive and four negative correlations between rainfall-runoff variables shown in Tables 17 and 18. The positive correlations in Tables 17 and 18 are: 1) Volume of rainfall and volume of runoff, 2) volume of rainfall and peak flow rate, 3) average rainfall intensity and volume of runoff, 4) average rainfall intensity and peak flow rate, and 5) duration of rainfall and time to peak flow. The negative correlations in Tables 17 and 18 are: 1) Volume of rainfall and time to peak flow, 2) average rainfall intensity and time to peak flow, 3) duration of rainfall and volume of runoff, and 4) duration of rainfall and peak flow rate. The negative correlations shown in Tables 17 and 18 suggest that the duration of rainfall is not a useful rainfall-runoff model variable for R-5. There is a general increase in positive correlation coefficients from Table 17 to Table 18 suggesting greater model efficiencies with increased sample sizes as would be expected.

The seven R-5 linear regression models, included in this study, and their respective efficiencies are summarized in Table 19. The verification efficiencies of these models, based on six events, range from 0.14 to 0.99. The models that verify most efficiently all include the average rainfall intensity as an

MODEL	V_{PPT}	$\overline{PPT}$	PPT_D	V_Q	Q_{PK}	${}^{T}Q_{PK}$	r_1^2	R_2^2	r_3^2
1	●			●			.27	.14	.27
2		●		●			.51	.91	.55
3	●	●		●			.51	.92	.55
4	●				●		.29	.52	.31
5		●			●		.62	.98	.66
6	●	●			●		.62	.99	.67
7			●			●	.21	.37	.54

r_1^2 - Regression (multiple) model based on events 1, 2, 3, 4, 5, and 10.
R_2^2 - Predicting events 12, 14, and 15 with r_1 regression (multiple) models
r_3^2 - New regression (multiple) models based on all events

Table 19. Linear regression models and efficiencies for the R-5 Subwatershed

independent variable. These same models also have the highest coefficients of determination, suggesting that the average rainfall intensity variable may provide the best regression analysis information for R-5.

The seven MCW (with and without data reduction) and the seven R-5 linear regression models described thus far, represent only 33% of the rainfall-runoff linear regression relationships that could concievably be used as prediction models. The remainder were not analyzed because the correlation analysis on Tables 11, 12, 13, 14, 17, and 18 showed negative correlations. Verification efficiencies for R-5 regression models are in general much better than verification efficiencies for MCW regression models despite the smaller R-5 sample size. For MCW and R-5 the most informative independent regression variables would appear to be volume of rainfall and average rainfall intensity respectively.

Correlation matrices for nine linear regression variables (two rain gages) are presented in Appendix C for MCW data. These matrices are based on the six selected events flagged in Table 10. Following the positive correlation standard for rainfall-runoff variables, 168 MCW linear regression models are established and presented in Appendix C. The 168 models represent 44% of those possible. Coefficients of determination for MLR models, with and without data reduction, are in general very high. The analysis of these models is not taken any further, as more events with records at two rain gages, are needed to advance it to a verification mode.

The small sample sizes used in this study without question effects correlation coefficients and in turn must control, to some degree, the predictive efficiencies of rainfall-runoff regression models. In future work more rainfall-runoff events are necessary to uncover potential linear regression models and monitor the relative increase in model efficiencies for MCW and R-5. These additional events will require longer periods of record. There appears to be some promise for using MLR analysis where independent variables are abstracted from two rain-gage data sets. The standard test for the significance of a correlation coefficient, at a specific confidence level, could perhaps be used as a basis for setting standards of efficiency acceptability in future work.

4.2 Unit Hydrograph Model

In this section one-hour duration unit hydrographs are determined for MCW and R-5, as described in Chapter Two, using observed hydrographs and hyetographs from a set of rainfall-runoff events. These models are then used to simulate selected rainfall-runoff events. Φ index values are calculated for each of the MCW and R-5 selected events summarized in Table

10.

The calibration phase for unit hydrograph model calibration in this study consisted of three parts: 1) Calculating Φ index values for each selected event based on storm flow volumes, 2) averaging individually developed unit hydrographs, and 3) measuring the efficiency with which event storm flow hydrographs can be reconstructed with an average unit hydrograph model. In order to verify the form of a storm hydrograph predicted with the unit hydrograph model, excess precipitation must be determined for a rainfall event without knowledge of the storm runoff. In this study two methods used are: 1) a mean Φ index, and 2) a least-squares Φ index/excess-rainfall relationship. The predictive phase for unit hydrograph model calibration is not included in this study.

The MCW one-hour unit hydrograph determined in this study is shown in Figure 22. It is averaged from one-hour unit hydrographs developed for each of seven separate events. The calibration efficiencies for three runoff variables, based on the MCW events showing excess rainfall are summarized in the top line of the upper table of Table 20. The efficiency of the MCW unit hydrograph for reconstructing storm flow volumes and peak storm flows both show very high values.

Verification efficiencies for the MCW unit hydrograph model based on events showing excess rainfall are summarized in the heavy lined boxes of the upper table of Table 20. The mean MCW

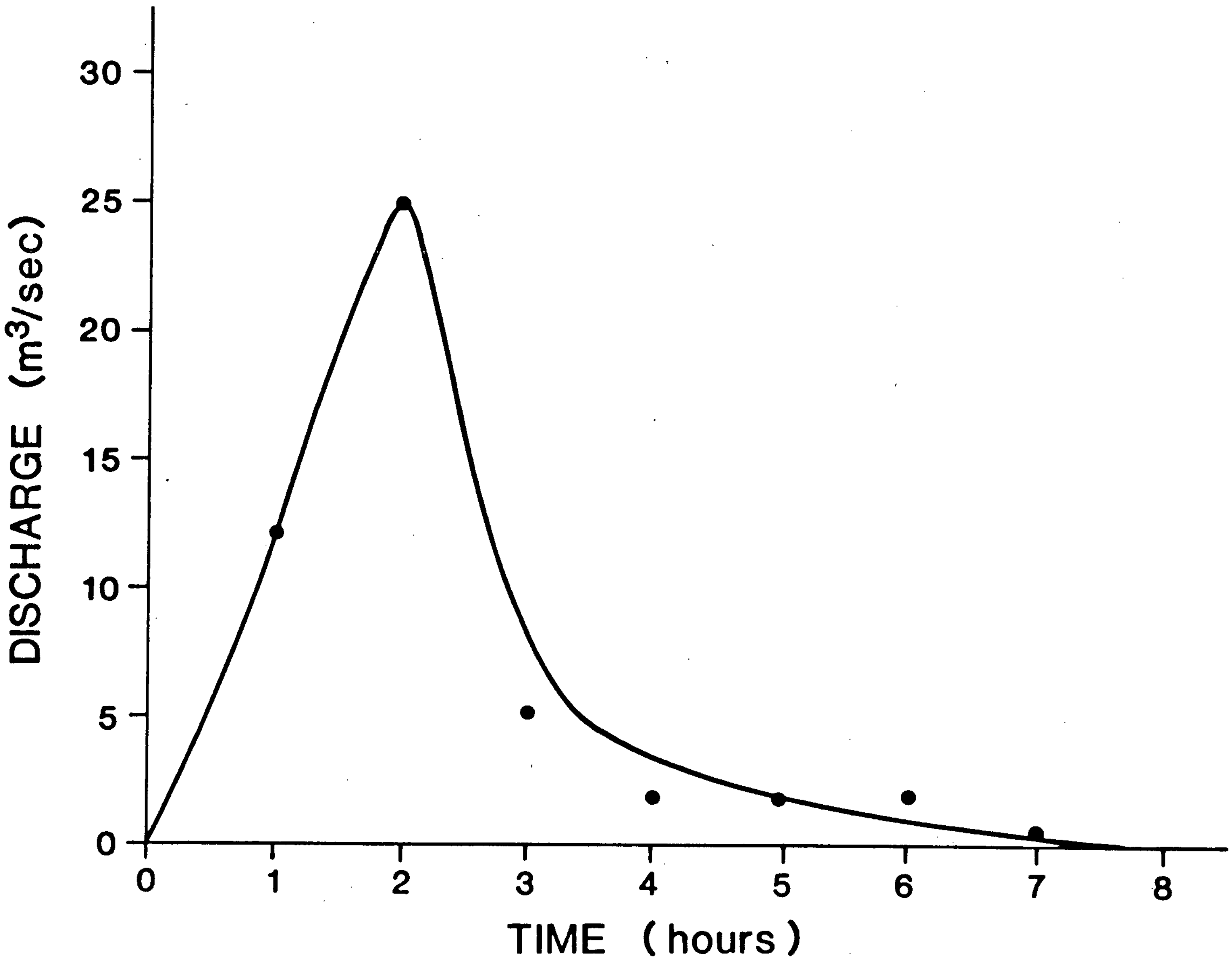

Figure 22. Averaged one-hour unit hydrograph for the Mahantango Creek Subwatershed (Component events 15, 24, 25, 32, 42, 47, and 49)

MCW

Φ	NO. OF EVENTS	R^2 V_Q	Q_{PK}	$T_{Q_{PK}}$
INDIVIDUALLY CALCULATED	19[1]	1.0	.70	.0
LINEAR RELATIONSHIP	10[2]	.0	.0	.0
AVERAGE RELATIONSHIP	10[2]	.0	.0	.0

R-5

Φ	NO. OF EVENTS	R^2 V_Q	Q_{PK}	$T_{Q_{PK}}$
INDIVIDUALLY CALCULATED	9	.81	.23	.0
LINEAR RELATIONSHIP	8[3]	.48	.19	.0
AVERAGE RELATIONSHIP	5[4]	.28	.30	.0

1 - Events 3, 4, 15, 16, 17, 20, 21, 24, 25, 26, 32, 33, 42, 43b, 45, 46, 47, 48, 49

2 - Events 3, 16, 17, 21, 25, 26, 32, 45, 47, 49

3 - Events 1, 2, 3, 5, 10, 12, 14, and 15

4 - Events 2, 4, 5, 10, and 12

Table 20. Unit hydrograph model efficiencies for the Mahantango Creek Subwatershed and R-5 Subwatershed

Φ index, based on 21 events, is 13.0 mm/hour. The linear index relationship for MCW is shown in Figure 23. The MCW unit hydrograph model now shows absolutely no predictive abilities and dramatically illustrates the importance of knowing the excess rainfall distribution before employing the model as a predictor. Example computer output from the implementation of the UNIT code for MCW event #25 is shown in Figure 24. This is one of the seven unit hydrographs used to get the MCW average unit hydrograph.

The R-5 one-hour-duration unit hydrograph used in this study, is shown in Figure 25. It is averaged from one-hour unit hydrographs from five events. The same calibration and verification scenario established for the MCW unit hydrograph model was used for the R-5 unit hydrograph model. The bottom table in Table 20 summarizes the calibration and verification efficiencies of the R-5 unit hydrograph model. Verification efficiencies are located in the heavy lined boxes. The mean R-5 Φ index, based on nine events, is 21 mm/hour. The linear Φ index relationship for R-5 is shown in Figure 26.

The R-5 unit hydrograph calibration efficiencies for storm flow volumes and peak storm flows are both lower than those described for MCW, although the former is still quite high. Verification efficiencies for the R-5 unit hydrograph model using the linear and average Φ index relationships, show greater promise than in the MCW case. This is especially so

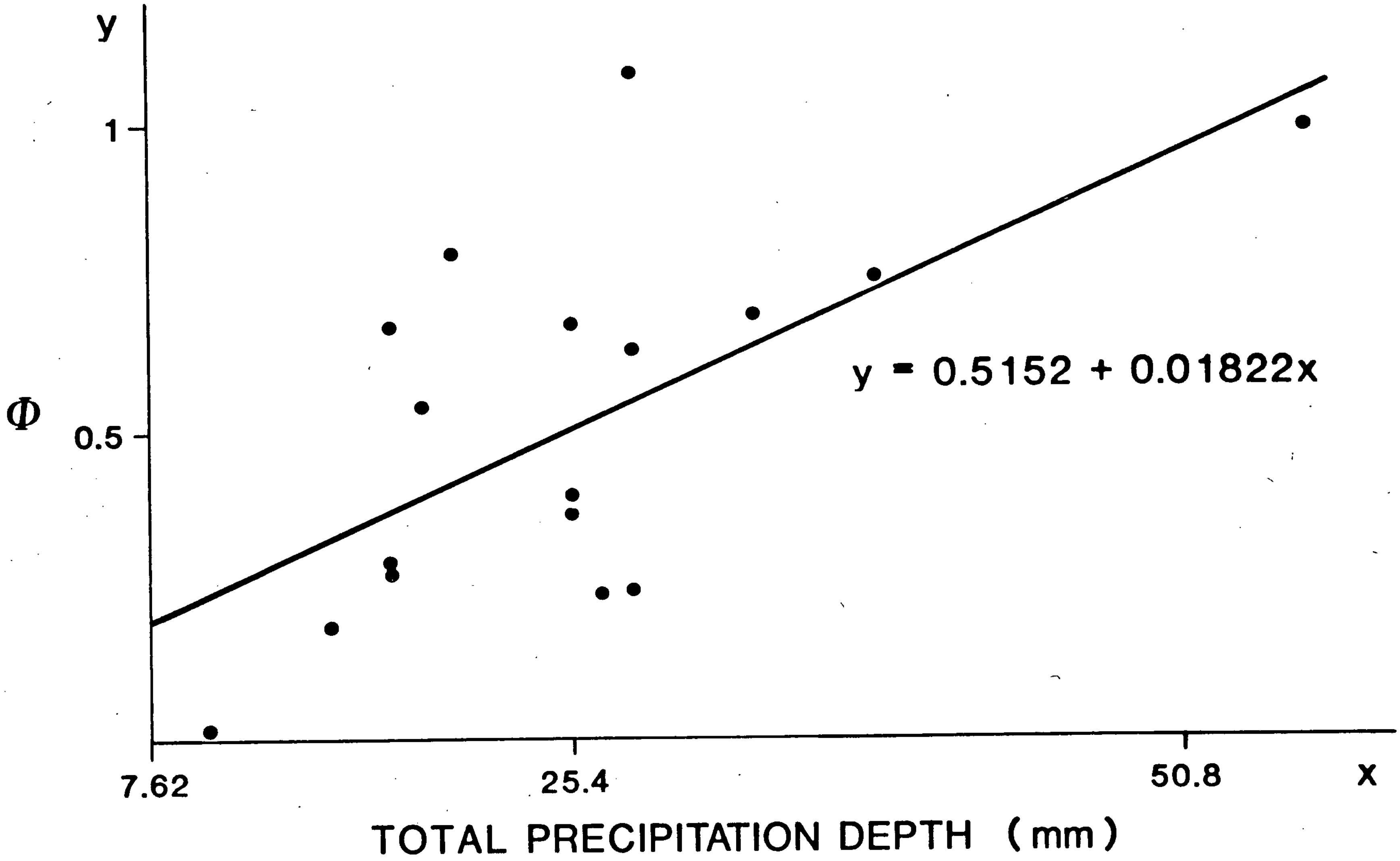

Figure 23. Linear Φ index relationship for the Mahantango Creek Subwatershed

UNIT HYDROGRAPH FOR MCW25-1HR

PERIOD NUMBER OF LAST NON-ZERO EXCESS RAINFALL = 1

PERIOD NUMBER OF LAST NON-ZERO RUNOFF = 5

MEMORY TIME = 5

TIME PERIOD	RAINFALL EXCESS	RUNOFF
1	0 20000	0.02133
2	0.0	0 11172
3	0.0	0.04905
4	0.0	0 02328
5	0.0	0 00947

DISCRETE KERNELS FOR UNIT HYDROGRAPH

I	
1	0.09180
2	0 54375
3	0.23040
4	0 10155
5	0 03250

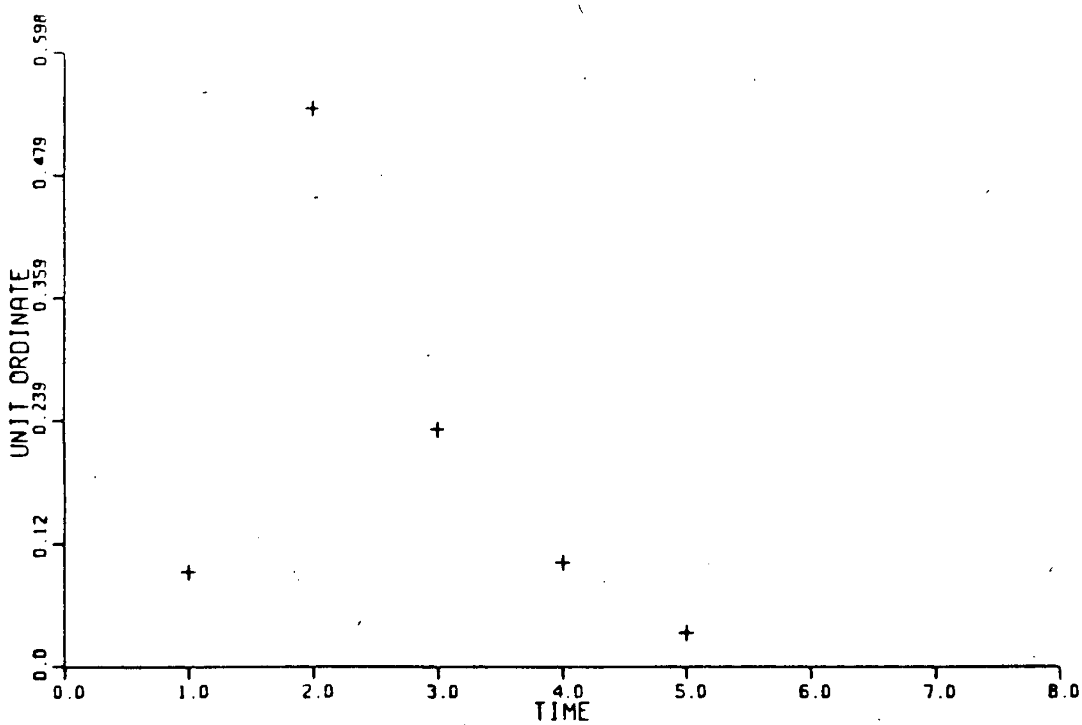

Figure 24. Example unit hydrograph

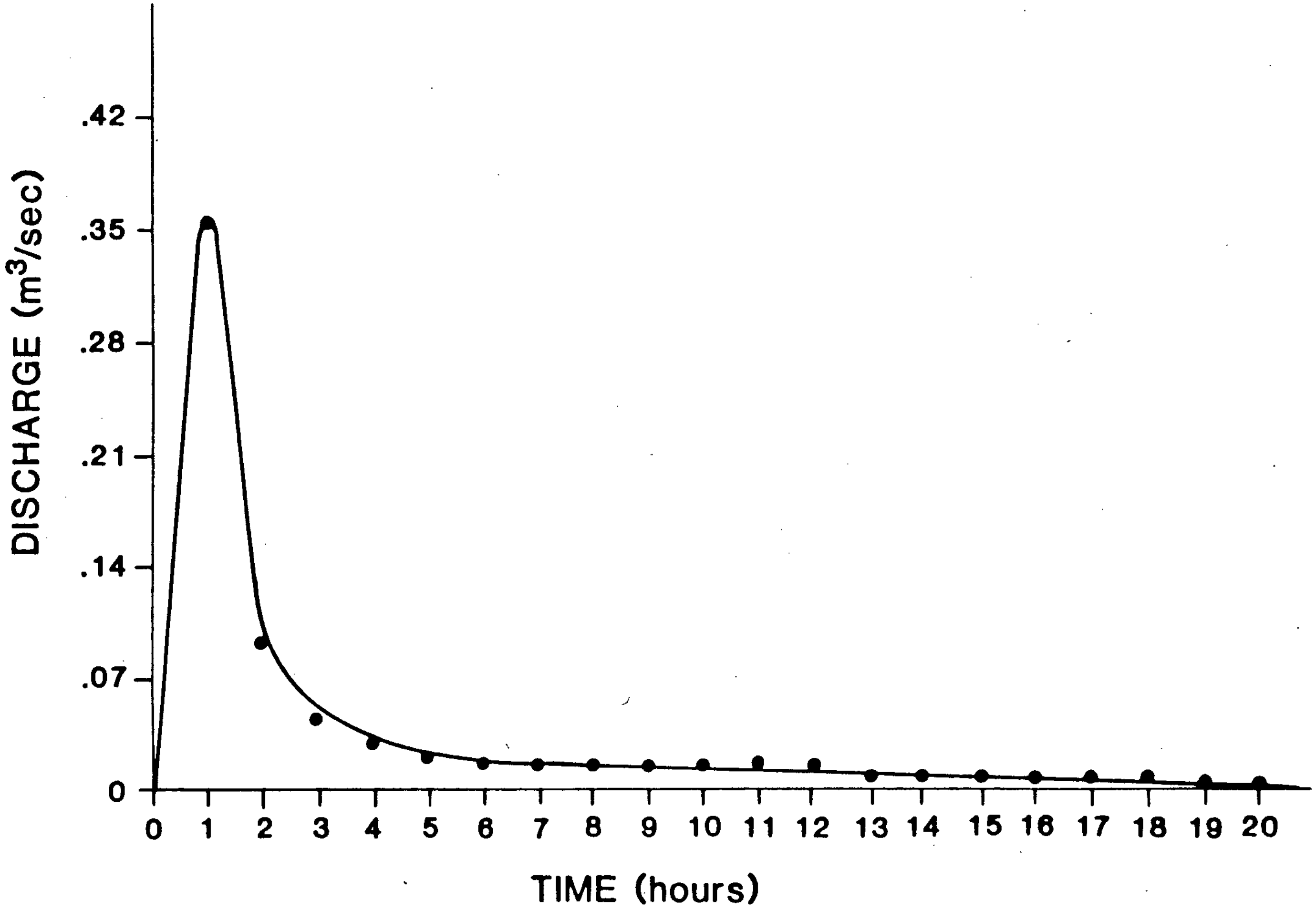

Figure 25. Averaged one-hour unit hydrograph for the R-5 Subwatershed (Component events 1, 5, 10, 12, and 15)

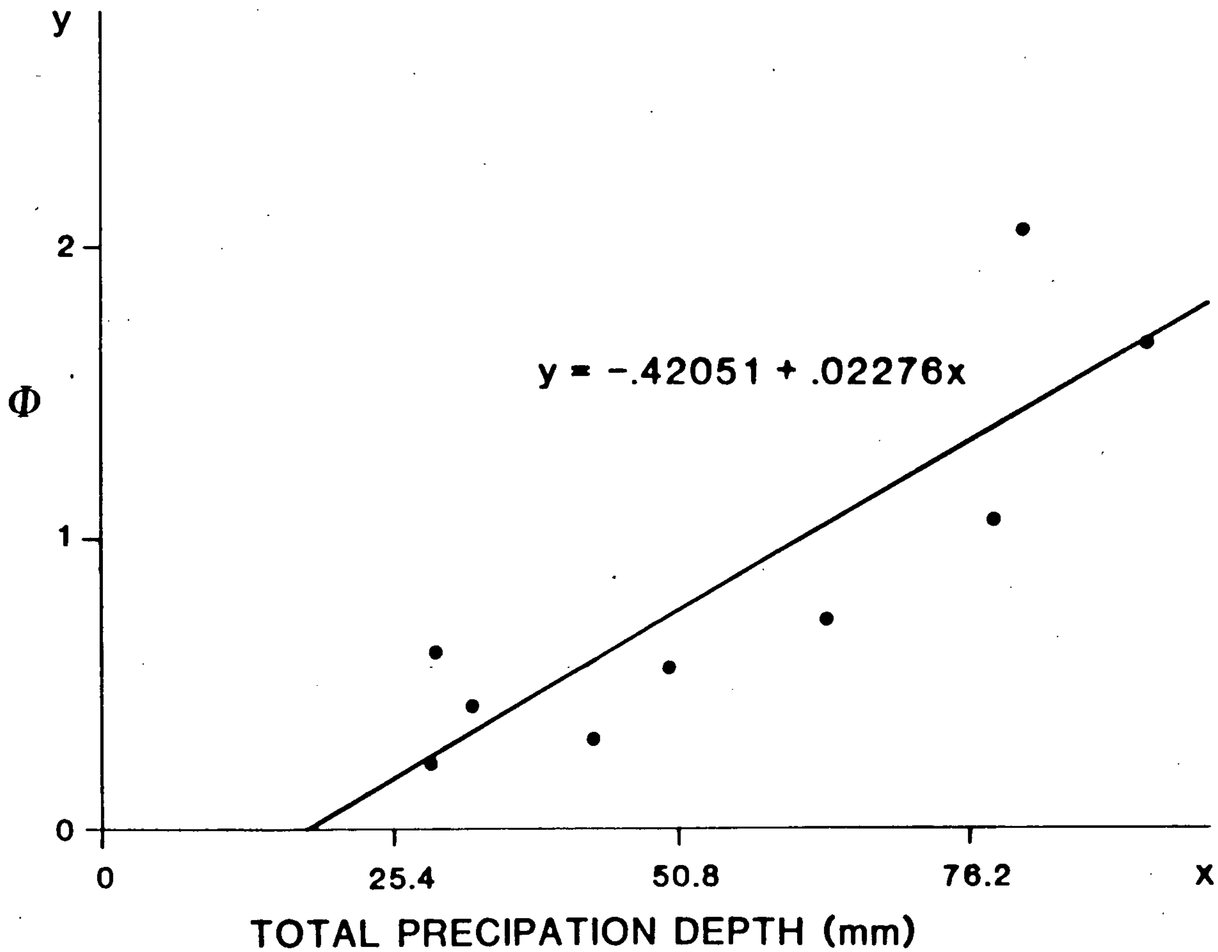

Figure 26. Linear Φ index relationship for the R-5 Subwatershed

when one considers the limited number of events included in the two Φ index standards used to calculate excess rainfall. The fact that R-5 is a smaller and more homogeneous basin than MCW may account for the fact that the R-5 unit-hydrograph model appears to have greater predictive prowess than the MCW unit-hydrograph model. In these models, excess rainfall is a lumped input parameter, whereas in reality, it is strongly variable over space due to differences in infiltration capacities. Smaller basins are less effected than larger basins by this variability. Linsley et al. (1975) suggest that unit-hydrograph models are best suited to basins of limited spatial variability.

Neither of the unit hydrograph models used in this study show any efficiency for reconstructing or predicting the time it takes for peak storm flows to occur. This may be the result of the way the models were constructed. The MCW and R-5 unit hydrographs are simple arithmetic averages of concurrent coordinates. Linsley et al. (1975) suggest that a more defensible procedure is to compute average peak flow and time to peak flow, then sketch the average unit hydrograph conforming to the general shape of the component graphs passing through the computed point. This recommendation will be tested in future work.

The results from MCW and R-5 unit-hydrograph models presented here illustrate that the technique may be dependent upon the averaging criterion used, and is strongly dependent upon the calculation of excess rainfall. Attempts to increase the sensitivity of the unit-hydrograph technique by calculating shorter duration models were stymied as excess-rainfall distributions, determined by the Φ index method, failed to correlate well with either MCW or R-5 storm flow hydrographs. The efficiency criterion adapted for this study is insufficient for evaluating the predicted form of the storm hydrograph simulated with the unit hydrograph technique.

4.3 Distributed Model

Results from simulations of MCW and R-5 rainfall-runoff events, using the distributed model described in Chapter Two, are presented and discussed in this section. The input data required by the distributed model is described in Chapter Two, the available MCW and R-5 data used to fill these requirements is presented in Chapter Three. There is no calibration phase required for the distributed model used in this study. Verification efficiencies for storm hydrographs predicted with the distributed model are calculated for two types of rainfall-runoff events: 1) Events that produced excess rainfall (lateral inflow hydrographs), and 2) events that did not generate excess rainfall. The predictive phase of model calibration is not addressed in this study for the distributed model.

The watershed segments used to transform MCW into overland flow planes compatible with the distributed model are shown in Figure 27. The size and orientation of the overland flow planes are based upon the MCW contributing areas described by Engman (1974). Table 21 summarizes the transformed subwatershed. The 16 major segments and their subdivisions were abstracted from Figure 14 and topographic contour maps. The major watershed segment lengths define routing reaches of equal channel slope and hydraulic behavior. The subdivisions of the major watershed segments characterize averaged soil zone dimensions and slope. These soil zones identify the areas over which particular infiltration curves apply in the calculation of excess precipitation. The reaches and tributaries describing the channel routing scenario used for MCW are illustrated in Figure 28.

The storm runoff volumes for each of the 21 selected MCW events were simulated in this study. The top table in Table 22 (Group A) shows that there is no predictive efficiency for the distributed model when all of these events are taken as a group. The dashes in Table 22 represent runoff variables not evaluated in the respective group of events. Inspection of individual simulations revealed that in more than one-half of all selected events no lateral inflow was being generated. This was due to

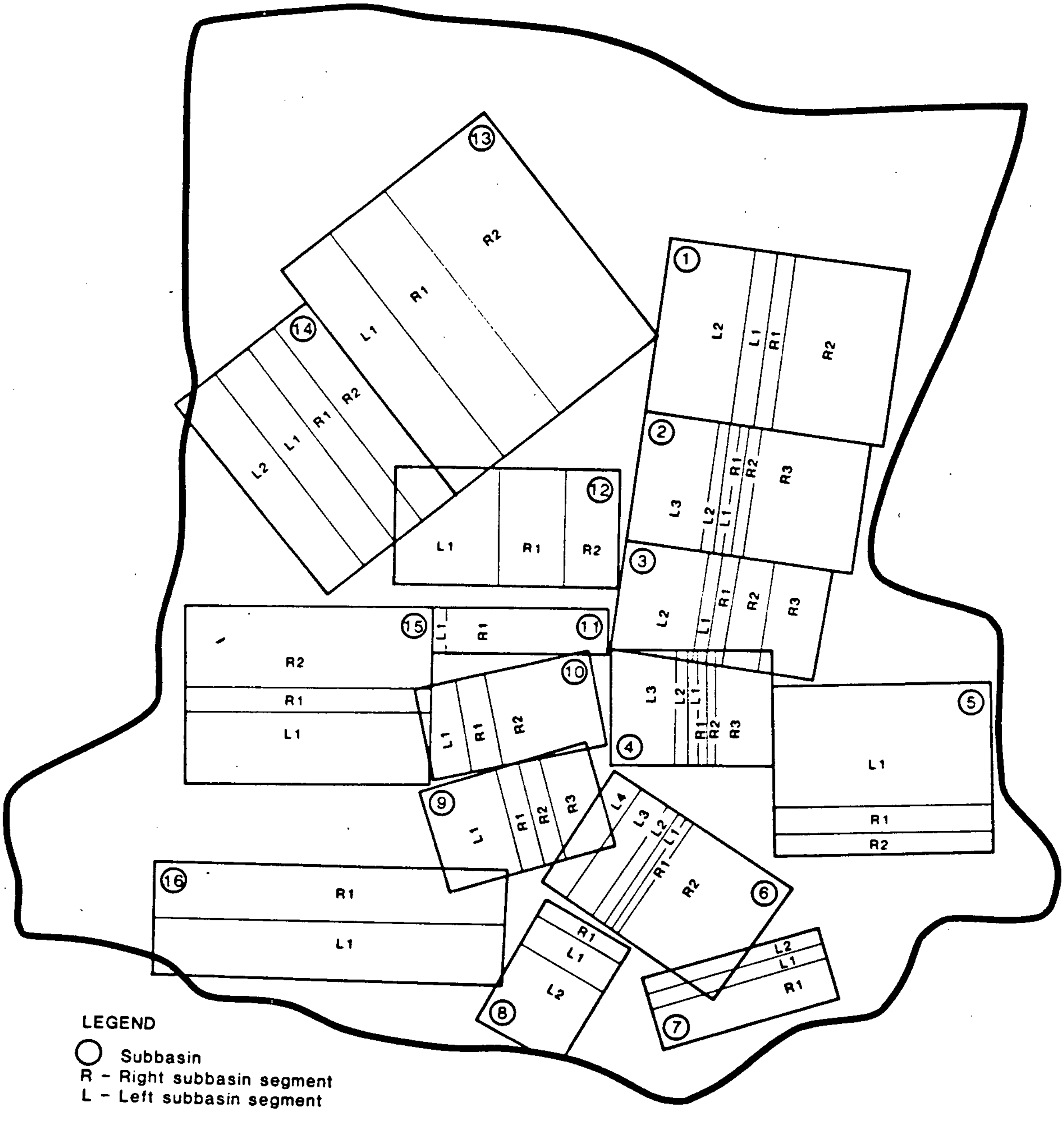

Figure 27. Watershed segments used to transform the Mahantango Creek Subwatershed into overland flow planes

SUBBASIN	LEFT SIDE				RIGHT SIDE				REACH LENGTH (m)	REACH SLOPE
	SEGMENT	SOIL TYPE	SOIL SLOPE	WIDTH (m)	SEGMENT	SOIL TYPE	SOIL SLOPE	WIDTH (m)		
1	1 2	145 71	.115 .115	67 335	1 2	71 69	.055 .115	43 396	533	.10
2	1 2 3	69 145 66	.2 .375 .055	31 55 287	1 2 3	71 145 66	.055 .115 .055	43 79 415	393	.03
3	1 2	145 66	.375 .115	43 299	1 2 3	69 145 66	.055 .115 .055	43 79 402	344	.02
4	1 2 3	69 145 66	.055 .375 .055	31 67 274	1 2 3	69 145 66	.055 .375 .055	31 55 226	357	.02
5	1	66	.115	372	1 2	57 54	.055 .115	91 159	649	.03
6	1 2 3 4	69 145 54 66	.115 .375 .115 .115	31 67 171 262	1 2	69 54	.115 .115	69 384	408	.02
7	1 2	57 54	.2 .115	55 104	1	145	.115	128	549	.06
8	1 2	54 145	.375 .2	104 341	1	54	.115	55	293	.02
9	1	54	.115	220	1 2 3	145 54 66	.2 .115 .115	79 140 293	332	.02
10	1	66	.115	116	1 2	145 66	.375 .115	91 415	293	.02
11	1	69	.115	37	1	66	.115	488	128	.02
12	1	145	.2	323	1 2	145 69	.2 .115	207 360	357	.02
13	1	145	.2	195	1 2	145 66	.2 .115	207 573	817	.07
14	1 2	69 66	.055 .115	116 256	1 2	145 69	.115 .055	104 220	725	.04
15	1	54	.115	232	1 3	54 66	.055 .055	79 305	725	.04
16	1	54	.375	183	1	54	.115	152	1055	.05

Table 21. Summary of the transformed Mahantango Creek Subwatershed

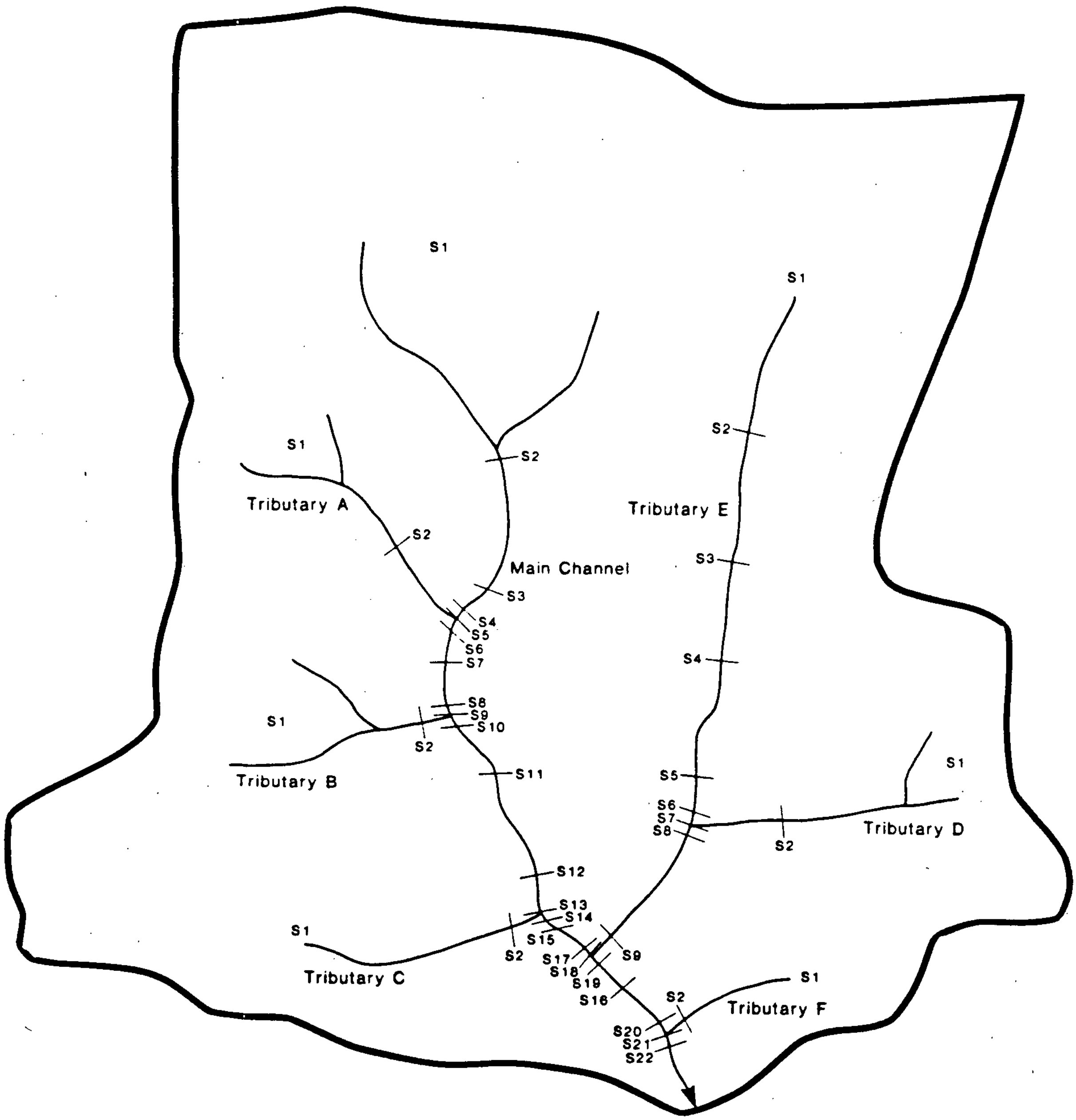

Figure 28. Channel routing scenario for the Mahantango Creek Subwatershed

MCW

GROUP	NO. OF EVENTS	R^2: V_Q	Q_{PK}	$T_{Q_{PK}}$
A	27[1]	.0	—	—
B	8[2]	.0	.0	.01

R-5

GROUP	NO. OF EVENTS	R^2: V_Q	Q_{PK}	$T_{Q_{PK}}$
A	9	.20	—	—
B	5[3]	.56	.81	1.0

1 - 15 events with 1 raingage and 6 events with 2 raingages
2 - Events 3, 16, 17, 21, 24, 25, 26, and 45
3 - Events 3, 4, 5, 10, and 12
A - Including all events
B - Including only events generating lateral inflow

Table 22. Distributed model efficiencies for the Mahantango Creek Subwatershed and R-5 Subwatershed

the way break point precipitation was distributed over the duration of the selected event. When the rainfall intensity was averaged over the entire events in these cases, it remained lower than the infiltration capacity thus preventing surface runoff. The eight MCW events in which lateral inflow was generated are taken as a subgroup of the total events. The top table in Table 22 (Group B) summarizes the lack of predictive efficiency the distributed model has for this subgroup of events.

These simulations draw attention to a specific limitation in the criterion being used to evaluate model efficiency in this study. Only groups of predicted runoff events can be evaluated, without any individual event evaluation. The evaluation of a given distributed model simulation is important for uncovering the type of events the model can or cannot handle efficiently.

The watershed segments used to transform R-5 into the overland flow planes, shown in Figure 29, were abstracted from Figure 20. The entire subwatershed was taken as a contributing area. Table 23 summarizes the transformed subwatershed. The storm runoff volumes for each of the nine selected R-5 events were simulated in this study. The bottom table in Table 22 (Group A) shows the relatively low predictive efficiency for the distributed model when all of these events are taken as a group. The five R-5 events generating lateral inflow are taken as a subgroup of the total events. The bottom table in Table 22

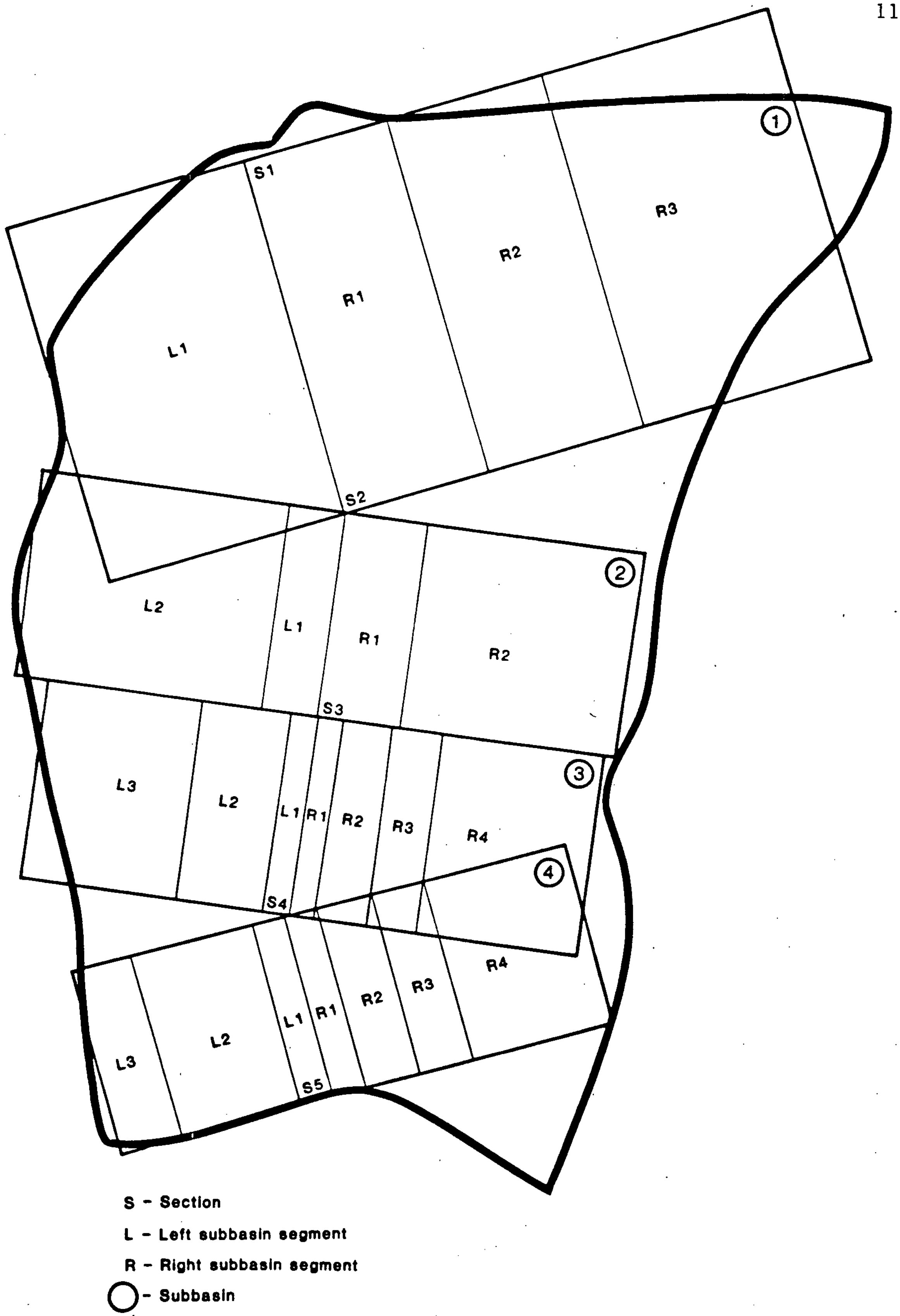

Figure 29. Watershed segments used to transform the R-5 Subwatershed into overland flow planes

SUBBASIN	LEFT SIDE			RIGHT SIDE			REACH LENGTH (m)
	SEGMENT	SOIL TYPE	WIDTH (m)	SEGMENT	SOIL TYPE	WIDTH (m)	
1	1	3	98	1 2 3	3 2 3	61 128 220	146
2	1 2	2 3	24 122	1 2	2 3	31 122	85
3	1 2 3	1 2 3	12 49 110	1 2 3 4	1 2 3 2	12 31 49 116	79
4	1 2 3	1 2 3	12 61 85	1 2 3 4	1 2 3 2	12 37 61 122	73

Table 23. Summary of the transformed R-5 Subwatershed

(Group B) summarizes the predictive efficiencies for this subgroup of events. Taken overall these values, used to verify the model, are quite high when compared with the MCW values.

The antecedent soil water contents for the MCW and R-5 selected events would appear to be the parameter of greatest uncertainty. The sensitivity of the antecedent soil water contents was investigated for a suite of seven MCW events. Table 24 summarizes the results of this analysis. Soil moisture frequencies, discussed in Chapter Three, of 20% and 80% are used as indicative of dry and wet conditions respectively. The dashes in Table 24 represent initial soil water contents not considered for specific events. For each event simulation two values are presented in Table 24: 1) Calculated storm runoff volumes, and 2) percentages of measured storm runoff volumes. Although the distributed model is sensitive to antecedent soil water content, selected MCW events are still poorly predicted using the soil moisture frequency criteria as shown in Table 24.

Using existing time series of soil moisture to produce initial moisture estimates, as a function of time of year, could be useful in future work. This author feels though, that improved estimates of antecedent soil water content, to be used as deterministic input parameters, will not necessarily increase the predictive efficiency of the distributed model due to the spatial variability of soil hydraulic properties. There are at least three reasons that could be advanced in explanation of the

EVENT NO.	MEASURED RUNOFF VOLUME (m^3)	SIMULATED RUNOFF VOLUMES (m^3) (PERCENTAGE OF MEASURED VALUES*) SOIL MOISTURE FREQUENCY			
		20%	50%	75%	80%
3	2346	462 19.7*	566 24.1*	—	800 34.1*
4	1631	8 0.5*	8 0.5*	—	8 0.5*
15	4519	14 0.3*	14 0.3*	—	14 0.3*
16	1316	1568 119.0*	—	2127 162.0*	2242 170.0*
17	1597	573 35.9*	—	—	878 55.0*
20	11799	23 0.2*	23 0.2*	—	23 0.2*
25	35859	1239 3.5*	3278 9.1*	—	4028 11.2*

Table 24. Effect of antecedent soil water content on simulated lateral inflow hydrograph volumes for selected Mahantango Creek Subwatershed events

poor predictive efficiencies of the distributed model. The next three paragraphs discuss each in turn.

First, subsurface storm flow (Whipky, 1965), has been shown to be an important component of the rainfall-runoff relationship for R-5 events (Sharma and Luxmoore, 1979; Luxmoore, 1982). As described in Chapter Two, the distributed model does not consider the subsurface storm flow component, thereby helping to explain why the simulated R-5 runoff volumes are too low.

Second, as previously described, the way in which a rainfall-intensity distribution is derived in the distributed model appears to be limited to high intensity storms of short duration. The efficiency of the distributed model is therefore strongly dependent upon the type of rainfall event being simulated.

Third, when concurrent stream reaches or tributaries are substantially different in length (MCW), the channel flow routing component of the distributed model does not satisfy conservation of mass going from one section to the next. The finite difference approximation used by the distributed model simply averages the concurrent reach/tributary lengths. It is suggested here that the incorporation of a weighting function may be necessary. Of course if all reaches are of similar lengths (R-5), weighting functions are not necessary as conservation of mass is already achieved. If a very large number of watershed segments were used for a big basin, the averaging and linear approximations made with the distributed model would be less subjective, but the amount of spatially variable input data required would be staggering.

Based on the results presented here and those of Engman (1974), the modeling efficiency of the distributed model, although promising for smaller basins, appears to degenerate with an increase in the number of overland flow planes necessary to simulate larger basins. It is felt by the author that uncalibrated, physically-based, deterministic, rainfall-runoff models will probably not provide satisfactory results for larger basins due to the spatial variability of the input data requirements. The efficiency of the distributed model may improve if a calibration phase is included. Parameters that might be calibrated against include the saturated hydraulic conductivity, depression storage and the roughness coefficients. As with the unit hydrograph technique, the efficiency criterion used in this study is not sufficient for analyzing the form of the storm flow hydrograph simulated by the distributed model.

Illustrative examples, in the form of sample computer output, for each of the four codes (Appendix B) making up the distributed model are presented in Appendix D. The simulated event used for these examples is MCW #16.

CHAPTER FIVE

CONCLUSIONS AND FUTURE RESEARCH

> The vitality of a false notion is often surprising. It is sometimes crushing to our faith in the survival of the fittest
> Chamberlin, 1884

In this study a suite of three underlying rainfall-runoff modeling techniques were applied to two data sets and the results were used to compare model efficiencies for selected events. Individual model efficiencies, based on a sum of squares criterion, were referenced to the three phases of model calibration. A toe hold for continuing research, this work establishes a framework for evaluating rainfall-runoff models. Future work will emphasize the quantitative investigation of space-time tradeoffs and data worth concepts. It will require an extension of the established data sets and a refined model efficiency criterion.

The efficiencies of the three underlying rainfall-runoff modeling techniques used in this study were found to be surprisingly poor. The results lead to the following qualitative conclusions:

a) The most informative independent variables for MCW and R-5 linear regression models appear to be volume of rainfall and average rainfall intensity respectively. There is a general improvement in correlation coefficients and regression-model efficiencies for both MCW and R-5 with increases in the number of selected events. The efficiencies are surprisingly high in some cases considering the small sample sizes. Positive and negative correlation coefficients for MCW and R-5 rainfall-runoff variables were presented in Tables 11, 12, 13, 14, 17, and 18. Efficiency values for MCW and R-5 regression models are shown in Tables 16 and 19. The effect of base flow separation on correlation coefficients and regression model efficiencies for MCW were summarized in Tables 11, 12, 13, 14, and 16.

b) With respect to the unit hydrograph model only the R-5 analysis demonstrated any predictive prowess. The unit hydrograph technique was found to be strongly dependent upon an accurate estimate of spatially variable excess rainfall. The efficiencies for MCW and R-5 unit hydrograph models were presented in Table 20.

c) The distributed modeling technique only exhibited predictive prowess for the R-5 events. It is believed by the author that the efficiency of the physically-based, deterministic, distributed-model deteriorates drastically with increases in basin size due to the lumping of spatially-variable soil hydraulic properties. The efficiencies with which the distributed model predicted selected MCW and R-5 rainfall-runoff events were summarized in Table 22.

d) The efficiencies determined for three rainfall-runoff modeling techniques used in this study do not uncover a definitively superior model. Limitations in each of the underlying modeling techniques were discussed in Chapter Four. Small sample sizes and spatial variability in input parameters were identified as the primary factors contributing to low predictive efficiencies. The regression model was found to be the only technique with any predictive efficiency for MCW. These regression model predictions are shrouded though by marginal calibration ranges and large confidence intervals. The unit hydrograph model and the distributed model were both found to be more efficient for the smaller R-5, but require improved estimates of spatially variable input parameters to reach acceptable levels.

e) Rainfall-runoff regression model efficiencies can be improved by increasing the number of selected events upon which they are based. Spatial variability of soil hydraulic properties is the reason for low predictive efficiencies for the unit hydrograph model and the distributed model. For R-5, these variabilities are smaller and the efficiencies of both modeling techniques are greater. Deterministic representation of model input parameters would appear to be the major pitfall of the distributed model used in this study.

f) The efficiency criterion itself is inadequate for: 1) Evaluating the form of a simulated storm flow hydrograph instead of selected runoff variables, 2) uncovering small sample biases, 3) evaluating a single event, and 4) establishing acceptable model standards.

This study has set the stage for continuing research by the author. The following discussion of future research is centered in three areas: 1) Modeling techniques, 2) model evaluation, and 3) additional data. The spatial variability of input parameters is the Achilles' heel of the comprehensive, physically-based, rainfall-runoff model at any practical spatial grid scale. Future research will focus upon determining effective values for these parameters. This will include: 1) assessing the worth of additional data points in estimating effective values, and 2) analyzing the influence of uncertainties in the estimates of effective values on runoff predictions. Optimization techniques, such as linear programming may be useful for calculating parameters such as depression storage, while the infiltration parameter might best be handled as a stochastic variable.

The spatial variability of soil hydraulic properties has been addressed by a number of authors. Future assessment of the distributed rainfall-runoff modeling technique will include the evaluation of various component techniques that are being used to describe soil hydraulic properties. These may include: Kriging (de Marsily, 1982), scaling methods (Warrick et al., 1977) and statistical analysis (Russo and Bresler, 1980).

Future evaluation of the quasi-physically based modeling technique will not be restricted to the model used in this study. A model similar to the one used in this work is described by Smith and Woolhiser (1971). Two recent approaches used in the distributed modeling technique are found in Freeze (1980) and Moore and Clarke (1981).

Various methods of calculating excess rainfall will be tested with the unit hydrograph technique. The linear-reservoir model, described in Chapter Two and the constrained linear system model (Natale and Todini, 1977) will also be added to the suite of underlying rainfall-runoff modeling techniques being evaluated. Regression analysis of rainfall-runoff variables will be facilitated in future work with increased sample sizes.

The major focus of future research will be determining if space-time tradeoffs exist across the data sets of various rainfall-runoff modeling techniques. The criterion used to establish tradeoffs will be model efficiency. The standard a model must meet to be considered suitably efficient is the key question in model evaluation. Moore and Clarke (1981) describe the present state of rainfall-runoff modeling as extremely fragmented with a bewilderingly large array of models to choose from. With so many models a standardized evaluation is indeed an important problem.

The model evaluation approach used in this study will continue to be employed in future research, but the simple criterion used here must be supplemented with new criteria for improved assessments. Future work will incorporate a quantitative index, based on Pearson product-moment coefficients, for comparing the form of computed and measured hydrographs (McCuen and Snyder, 1975). Future research will also concentrate on evaluating model components as described by Nash and Sutcliffe (1970). Sensitivity analysis, in the form of Monte Carlo simulation, may be useful for evaluating model components.

The future studies will employ data sets from three rather than two subwatersheds. In addition to R-5 and MCW, data from the Hubbard Brook Subwatershed, described in Chapter Three, will also be used. For the Pennsylvania watershed (MCW) a subwatershed known as Mr. Pauls' farm (Engman and Rogowski, 1974a) shown in Figure 13, will be emphasized in future investigation. The author hopes to visit each of the subwatersheds used in future study, in order to augment the respective data sets of soil hydraulic properties for specific needs. An extensive summary of published soil hydraulic properties is also now available to the author (Rawls, personal communication, 1981).

In order to estimate antecedent soil moisture conditions in future work all available soil moisture records need to be plotted into time series and seasonal soil-water frequency distributions. Finally, rainfall-runoff records need to be put into as complete a form as possible in order to increase the number of selected events and modeling options.

REFERENCES

Amorocho, J., and G. T. Orlob, Non-linear analysis of hydrologic systems, Univ. of Calif. Contrib. 40, Water Resourc. Cent., Berkeley, California, 1961.

Amorocho, J., and W. E. Hart, A critique of current methods in hydrologic systems investigation, Transactions American Geophysical Union, 45(2), 307-321, 1964.

Amorocho, J., Nonlinear hydrologic analysis, Advances in Hydroscience, 9, 203-251, 1973.

Betson, R. P., What is watershed runoff?, Journal of Geophysical Research, 69(8), 1541-1552, 1964.

Brakensiek, D. L., Storage routing without coefficients, ARS-41-122, Agricultural Research Service, USDA, Beltsville, Maryland, 1966a.

Brakensiek, D. L., Reduction of channel cross section coordinate data to hydraulic and geometric elements, Research Report No. 384, Agricultural Research Service, USDA, Beltsville, Maryland, 1966b.

Brakensiek, D. L., A technique for analysis of runoff hydrographs, Journal of Hydrology, 5, 21-32, 1967.

Carr, J. C., A system for collection, preparation, translation, and computer reduction of digital hydrologic data, ARS-NE-18, Agricultural Research Service, USDA, Washington, D. C., 1973.

Carrigan, P. H., Calibration of U.S. Geological Survey rainfall-runoff model for peak-flow synthesis-natural basins, U. S. Geological Survey Computer Report, Department of Commerce National Technical Information Service, 1973.

Chow, V. T., Open Channel Hydraulics, McGraw-Hill, New York, 1959.

Chow, V. T., Statistical and probability analysis of hydrologic data; Part I, frequency analysis, in Handbook of Hydrology, edited by V. T. Chow, pp. 8.1-8.42, McGraw-Hill, New York, 1964a.

Chow, V. T., Runoff, in Handbook of Hydrology, edited by V. T. Chow, pp. 14.1-14.54, McGraw-Hill, New York, 1964b.

Chow, V. T., Laboratory study of watershed hydrology, in Proc. Int. Hydrol. Symp., pp. 194-202, Fort Collins, Colorado, 1967.

Clark, C. O., Storage and the unit hydrograph, Trans. Amer. Soc. Civ. Eng., 110, 1419-1446, 1945.

Clarke, R. T., A review of some mathematical models used in hydrology, with observations on their calibration and use, Journal of Hydrology, 19, 1-20, 1973.

Cornell, C. A., Stochastic process models in structural engineering, Technical Report No. 24, Stanford University, Stanford, California, 1964.

Crawford, N. H., and R. K. Linsley, Jr., Digital simulation in hydrology: Stanford Watershed Model IV, Tech. Rept. No. 39, Department of Civil Engineering, Stanford University, Stanford California, 1966.

Diskin, M. H., A dispersion analogue model for watershed systems, Proc. Int. Hydrol. Symp., pp. 38-45, Fort Collins, Colorado, 1967.

Diskin, M. H., Definition and uses of the linear regression model, Water Resources Research, 6(6), 1668-1673, 1970.

Davis, D., L. Duckstein, and R. Krzysztofowicm, The worth of hydrologic data for non-optimal decision making, Water Resources Research, 15(6), 1733-1742, 1979.

Dawdy, D. R., and T. O'Donnell, Mathematical models of catchment behavior, J. Hydraul. Div. Amer. Soc. of Civ. Eng., 91(HY4), 123-131, 1965.

de Marsily, G., Krigin and the inverse problem, Hydrogeology Seminar, University of British Columbia, Vancouver, 1982.

Dooge, C. I., A general theory of the unit hydrograph, Journal of Geophysical Research, 64(2), 241-256, 1959.

Dooge, C. I., The hydrologic cycles as a closed system, Bull. Int. Sci. Hydrol., 13(1), 58-68, 1968.

Dooge, C. I., Mathematical models of hydrologic systems, International Symposium on Mathematical Modeling Techniques in Water Resource Systems, Ottawa, 1, pp. 171-189, Department of the Environment, 1972.

Dooge, C. I., Linear theory of hydrologic systems, Technical Bulletin No. 1468, Agricultural Research Service, USDA, Washington, D. C., 1973.

Dooge, C. I., General report on model structure and classification, in Logistics and Benefits of using Mathematical Model of Hydrologic and Water Resource Systems, edited by A. J. Askew, F. Greco, and J. Kindler, pp. 1-21, Pergamon, New York, 1978.

Dunne, T., and L. B. Leopold, Water in Environmental Planning, Freeman, San Francisco, 1978.

Eagleson, P. S., R. Meija, and F. March, Computation of optimum realizable unit hydrograph, Water Resources Research, 2(4), 755-764, 1965.

Eagleson, P. S., Dynamic Hydrology, McGraw Hill, New York, 1970.

Engman, E. T., W. T. Gburek, L. H. Parmele, and J. B. Urban, Scale problems in interdisciplinary water resource investigation, Water Resources Bulletin, 7(3), 495-505, 1971.

Engman, E. T., A partial area model for simulating surface runoff from small watersheds, Ph.D. thesis, Pennsylvania State University, University Park, 1974.

Engman, E. T., and A. S. Rogowski, A partial area model for storm flow synthesis, Water Resources Research, 10(3), 464-472, 1974a.

Engman, E. T., and A. S. Rogowski, Selection of soil moisture parameters for synthesizing storm hydrographs, reprint from Am. Soc. Civil Engrs. National Meeting of Water Resources Engineering, Los Angeles, 1974b.

Engman, E. T., L. H. Parmele, and W. J. Gburek, Hydrologic impact of tropical storm Agnes, Joual of Hydrology, 22, 179-193, 1974c.

Fiering, M. B. and B. B. Jackson, Synthetic streamflow, Water Resources Monograph 1, American Geophysical Union, Washington D. C., 1971.

Freeze, R. A. and R. L. Harlan, Blueprint for a physically-based, digitally-simulated hydrologic response model, Journal of Hydrology, 9, 237-258, 1969a.

Freeze, R. A., The mechanism of natural groundwater recharge and discharge: One dimensional, vertical, unsteady unsaturated flow above a recharging or discharging groundwater flow system, Water Resources Research, 5, 153-171, 1969b.

Freeze, R. A., Three-dimensional transient saturated-unsaturated flow in a grounwater basin, Water Resources Research, 7(2), 347-366, 1971.

Freeze, R. A., Streamflow generation, Reviews of Geophysics and Space Physics, 12(4), 627-647, 1974.

Freeze, R. A., Mathematical models of hillslope hydrology, in Hillslope hydrology, edited by M. J. Kirkby, pp. 177-225, Wiley-Interscience, New York, 1978.

Freeze, R. A., A stochastic-conceptual analysis of rainfall-runoff processes on a hillslope, Water Resources Research, 16(2), 391-408, 1980.

Freeze, R. A., Hydrological concepts in stochastic and deterministic rainfall-runoff models, in Recent Trends in Hydrogeology edited by T. N. Narasimhan, pp. 63-80, Geological Society of America, Boulder, Colo., 1982a.

Freeze, R. A., The influence of hillslope hydrological processes on the stochastic properties of streamflow in Statistical Analysis of Rainfall and Runoff, edited by V. P. Singh, pp. 155-172, Water Resources Publications, Littleton, Colo., 1982b.

Gburek, W. J., The Mahantango Creek Watershed-general hydrology and research results, in Watershed Research in North America, edited by D. L. Correll, Smithsonian Institution, Edgewater, Maryland, 1977.

Haan, C. T., Statistical Methods in Hydrology, Iowa State University Press, Iowa, 1977.

Henderson, F. M., Open Channel Flow, MacMillan, New York, 1962.

Henninger, D. L., Surface soil moisture within a watershed-variations, factors influencing, and relationships to runoff, M.Sc. thesis, Pennsylvania State University, University Park, 1972.

Henninger, D. L., G. W. Petersen, and E. T. Engman, Surface soil moisture within a watershed-variations, factors influencing, and relationships to surface runoff, J. Soil Sci. Soc. of Amer., 40, 773-776, 1976.

Hiemstra, L., Frequencies of runoff for small basins, Ph.D. thesis, Colorado State University, Fort Collins, 1968.

Huggins, L. F., and E. J. Monke, The mathematical simulation of the hydrology of small watersheds, Technical Report No. 1, Purdue University Water Resource Center, Lafayette, Indiana, 1966.

Izzard, C. F., Hydraulics of runoff from developed surfaces, Highway Research Board, 26, 129-150, 1946.

Jackson, B. B., The use of streamflow models in planning, Water Resources Research, 11(1), 54-63, 1975.

Johnston, J., Econometric Methods, McGraw-Hill, New York, 1963.

Kartvelishvili, N. A., "Teoriya veroyatnostnykh protsessov v gidrologii i regulirovanii rechnogo stoka." Gidrometeorologicheskoe Izdatel'stvo, Leningrad, 1967.

Kibler, D. F. and D. A. Woolhiser, The kinematic cascade as a hydrologic model, Hydrology Paper 39, Colorado State University, Fort Collins, Colorado, 1970.

Kirkby, M. J. (ED.), Hillslope Hydrology, Wiley-Interscience, New York, 1978.

Kisiel, C. C., Transformation of deterministic and stochastic processes in hydrology, in Proceedings of International Symposium on New Techniques in Hydrology, Fort Collins, Colorado, pp. 600-607, Water Resources Publications, Littleton, Colorado, 1967.

Kisiel, C. C., Time series analysis of hydrologic data, Advances in Hydroscience, 5, 1-119, 1969.

Klemes, V., The Hurst phenomenon: A puzzle?, Water Resources Research, 10(4), 675-688, 1974.

Klemes, V., Physically-based stochastic hydrologic analysis, Advances in Hydroscience, 11, 285-356, 1978.

Kolman, B. and R. E. Beck, Elementary Linear Programming with Applications, Academic Press, New York, 1980.

Kunz, K. S., Numerical Analysis, McGraw-Hill, New York, 1957.

Laurenson, E. M., Modeling of stochastic-deterministic hydraulic systems, Water Resources Research, 10(5), 955-961, 1974.

Le, C., and T. Tenisci, A General Computer Program for Regression Methods-TRP, University of British Columbia, Vancouver, 1977.

Liggett, J. A., and D. A. Woolhiser, Difference solutions to the shallow-water equation, J. Mech. Div. Amer. Soc. Civ. Eng., 93(EM3), 39-71, 1967.

Linsley, R. K., Jr., M. A. Kohler, and J. L. H. Paulhus, Hydrology for Engineers, (2nd Ed.), McGraw-Hill, New York, 1975.

Linsley, R. K., Jr., Rainfall-runoff models-An overview, in Rainfall-Runoff Relationship, edited by V. P. Singh, pp. 3-22, Water Resources Publications, Littleton, Colorado, 1982.

Luxmoore, R. J., and M. L. Sharma, Runoff responses to soil heterogeneity: Experimental and simulation comparisons for two contrasting watersheds, Water Resources Research, 16(4), 675-684, 1980.

Luxmoore, R. J., Simulated dynamics of variable contributing areas in relation to soil heterogenity, Water Resources Research (in press), 1982.

Machado-Olive, D., Probability-distributed parameters within conceptual catchment models, Ph.D. thesis, University of Lancaster, England, 1975.

Matalas, N. C., Time series analysis, Water Resources Research, 3(3), 817-829, 1967.

McCuen, R. H., and W. M. Snyder, A proposed index for comparing hydrographs, Water Resources Research, 11(6), 1021-1024, 1975.

Moore, R. J., and R. T. Clarke, A distribution function approach to rainfall-runoff modeling, Water Resources Research, 17(5), 1367-1382, 1981.

Morel-Seytoux, H. J., and J. Kimzey, User's manual for UNIT: A fortran IV program to identify unit hydrograph ordinates using a constrained least-squares approach, HYDROWAR Program Rep. CER80-81HJM-JK-FC16, Colorado State University, Fort Collins, 1980.

Morel-Seytoux, H. J., Optimization methods in rainfall-runoff modeling, in Rainfall-Runoff Relationships, edited by V. P. Singh, pp. 487-507, Water Resource Publications, Littleton, Colorado, 1982.

Moss, M. E., Some basic considerations in the design of hydrologic data networks, Water Resources Research, 15(6), 1797-1800, 1979.

Nash, J. E., Systematic determination of unit hydrograph parameters, Journal of Geophysical Research, 64(1), 111-115, 1959.

Nash, J. E., and J. V. Sutcliffe, River flow forecasting through conceptual models, Part 1, A discussion of principals, Journal of Hydrology, 10, 282-290, 1970.

Natale, L., and E. Todini, A constrained parameter estimation technique for linear models in hydrology, in Mathematical Models for Surface Water Hydrology, edited by T. A. Ciriani, U. Maione and J. R. Wallis, pp. 109-148, Wiley, New York, 1977.

Newton, D. W., and J. W. Vineyard, Computer-determined unit hydrograph from floods, J. Hydraul. Div. Amer. Soc. Civ. Eng., 93(HY5), 219-236, 1967.

O'Donnell, T., Methods of computation in hydrograph analysis and synthesis, in Recent Trends in Hydrograph Synthesis, 65-104, Committee for Hydrological Research TNO, The Hague, 1966.

Overton, D. E., and D. L. Brakensiek, A kinematic model of surface runoff response, International Symposium on the Results of Research on Representive and Experimental Basins, Int. Ass. Sci. Hydrol. Brussels Publ. 96, 100-112, 1970.

Parlange, J. Y., Analytical theory of water-movement in soils, Joint IAHR and ISSS Symposium on Fundamentals of Transport Phenomena in Porous Media, 1, pp. 222-236, Huddleston and Barney Ltd., Woodstock, Ont., 1972.

Philip, J. R., The theory of infiltration: 1. The infiltration equation and its solution, Soil Science, 83, 345-357, 1957a.

Philip, J. R., The theory of infiltration: 2. The profile at infinity, Soil Science 83, 435-448, 1957b.

Philip, J. R., The theory of infiltration: 3. Moisture profiles and relation to experiment, Soil Science, 84, 163-178, 1957c.

Philip, J. R., The theory of infiltration: 4. Sorptivity and algebraic infiltration equations, Soil Science, 84, 257-264, 1957d.

Philip, J. R., The theory of infiltration: 5. The influence of the initial soil moisture content, Soil Science, 84, 322-339, 1957e.

Philip, J. R., The theory of infiltration: 6. Effect of soil water depth over the soil, Soil Science, 85, 278-286, 1958a.

Philip, J. R., The theory of infiltration: 7., Soil Science, 85, 333-337, 1958b.

Philip, J. R., Theory of infiltration in Advances in Hydroscience, 5, 215-296, 1969.

Pionke, H. B., and R. N. Weaver, The Mahantango Creek Watershed-an interdisciplinary watershed research program in Pennsylvania, in Watershed Research in North America, edited by D. L. Correll, Smithsonian Institution, Edgewater, Maryland, 1977.

Quimpo, R.G., Link between stochastic and parametric hydrology, J. Hydraul. Div. Amer. Soc. Civ. Eng., 99(HY3), 461-170, 1973.

Rawitz, E., E. T. Engman, and G. D. Cline, Use of the mass balance method of examining the role of soils in controlling watershed performance, Water Resources Research, 6(4), 1115-1123, 1970.

Richards, L. A., Capillary conduction of liquids through porous mediums, Physics, 1, 318-333, 1931.

Rogowski, A. S., Watershed physics: Model of soil moisture characteristics, Water Resources Research, 7(6), 1575-1582, 1971.

Rogowski, A. S., Two-and three-point models of the soil moisture characteristic and hydraulic conductivity for field use, Joint IAHR and ISSS Symposium on Fundamentals of Transport Phenomena in Porous Media, 1, pp. 124-136, Huddleston and Barney Ltd., Woodstock, Ont., 1972a.

Rogowski, A. S., Watershed physics: Soil variability criteria, Water Resources Research, 8(4), 1015-1023, 1972b.

Rogowski, A. S., Variability of the soil water flow parameters and their effect on the computation of rainfall excess and runoff, in Proceedings of the International Symposium on Uncertainties in Hydrologic and Water Resource Systems, 1, edited by C. C. Kisiel and L. Duckstein, pp. 359-377, Department of Hydrology and Water Resources, University of Arizona, Tucson, 1972c.

Rogowski, A. S., Estimation of the soil moisture characteristic and hydraulic conductivity: Comparison of models, Soil Science, 114(6), 423-429, 1972d.

Rogowski, A. S., E. T. Engman, and E. L. Jacoby, Jr., Transient response to a layered sloping soil to natural rainfall in the presence of a shallow water table: Experimental results, ARS-NE-30, Agricultural Research Service, USDA, Hyattsville, Maryland, 1974.

Rosenblueth, A. and N. Wiener, The role of models in science, Philosophy of Science, 7(4), 316-321, 1945.

Russo, D., and E. Bresler, Field determinations of soil hydraulic properties for statistical analyses, Soil Sci. Soc. Amer. Proc., 44(4), 687-702, 1980.

Schultz, E. F., Problems in Applied Hydrology, Water Resource Publications, Littleton, Colorado, 1976.

Sharma, M. L., R. J. Luxmoore, Soil spatial variability and its consequences on simulated water balance, Water Resources Research, 15(6), 1567-1573, 1979.

Sharma, M. L., G. A. Gander, and C. G. Hunt, Spatial variability of infiltration in a watershed, Journal of Hydrology, 45,101-122, 1980.

Sherman, L. K., Streamflow from rainfall by unit graph method, Engineering News Record, 108, 501-505, 1932.

Smith, R. E., and D. A. Woolhiser, Mathematical simulation of infiltrating watersheds, Hydrology Paper 47, Colorado State University, Fort Collins, 1971.

Snyder, W. M., Hydrographanalysis by the method of least squares, J. Hydraul. Div. Amer. Soc. Civ. Eng., 81, 793.1-793.25, 1955.

Snyder, W. M., Some error properties of segmented hydrograph functions, Water Resources Research, 3(2), 359-374, 1962.

Stehale, P., Quantum Mechanics, Holden-Day, San Francisco, 1966.

Streikoff, T., One-dimensional equations of open-channel flow, J. Hydraul. Div. Amer. Soc. Civ. Eng., 95(HY3), 861-876, 1969.

Streikoff, T., Numerical solution of Saint-Venant equations, J. Hydraul. Div. Amer. Soc. Civ. Eng., 96(HY1), 223-252, 1970.

U. S. Army Corps of Engineers, HEC-1 Flood hydrograph package, Users and Programmers Manuals 723-X6-L2010, 1973.

U. S. Environmental Protection Agency, SWMM, Volume No. 1, Water Resources Engineers and Metcalf and Eddy Inc., 1971.

U. S. Soil Conservation Service, Computer program for project formulation hydrology, Tech. Release No. 20, 1973.

U. S. Soil Conservation Service, National Engineering Handbook, Section 4, Hydrology, Soil Conservation Service, USDA, Washington, D. C., 1972.

Viessman, W., Jr., J. W. Knapp, G. L. Lewis, and T. E. Harbaugh, Introduction to Hydrology, (2nd Ed.), Harper and Row, New York, 1977.

Wallis, J. R., Multivariate statistical methods in hydrology-a comparison using data of known function relationships, Water Resources Research, 1(4), 447-461, 1965.

Warrick, A. W., G. J. Mullen, and D. R. Nielsen, Scaling field-measured soil hydraulic properties using a similar media concept, Water Resources Research, 13(2), 355-362, 1977.

Williams, J. R., and R. W. Hann, HYMO: Problem-Oriented Computer Language for Hydrologic Modeling, USDA, Agricultural Research Service, 1973.

Wood, E. F., Digital catchment model based on subsurface flow, Ph.D. thesis, University of Canterbury, New Zealand, 1973.

Wooding R. A., A hydraulic model for the catchment-stream 1: Kinematic wave theory, Journal of Hydrology, 3, 254-267, 1965.

Wooding R. A., A hydrologic model for the catchment-stream problem 3: Comparison with runoff observations, Journal of Hydrology, 4, 21-37, 1966.

Woolhiser, D. A., Hydrologic and watershed modeling-state of the art, Trans. Amer. Soc. Eng., 16, 553-559, 1973.

Wong, S. T., A multivariate statistical model for predicting mean annual flood in New England, Annals Ass. Amer. Geographers, 53(3), 298-311, 1963.

Yevdjevich, V. M., Statistical and probability analysis of hydrologic data; Part II, Regression and correlation analysis, in Handbook of Hydrology, edited by V. T. Chow, pp. 8.43-8.67, McGraw-Hill, New York, 1964.

Personal Communication, Federer, C. A., USDA-Forest Service, Durham, New Hampshire, 1981.

Personal Communication, Gander, G. A., USDA-Agricultural Research Service, Chickasa, Oklahoma, 1981.

Personal Communication, Gburek, W. J., USDA-Agricultural Research Service, University Park, Pennsylvania, 1982.

Personal Communication, Luxmoore, R. J., Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1981.

Personal Communication, Rawls, W. J., USDA-Agricultural Research Service, Beltsville, Md., 1981.

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APPENDIX A

Unit hydrograph code UNIT

```
C     This code computes the coefficients A(I,J) and B(I) for a
C     system of linear equations used for identifying Unit
C     Hydrograph ordinates based on the method of least squares.
C       ie.  sum over J( A(I,J) * X(I)) = B(I)
C               where , I and J = 1,2,....,M+1
C
C     Original code , Morel-Seytoux and Kimzey (1980). The code
C     as shown in this theis was adapted , by Loague (1982) , for
C     use at UBC.
C
C     IMSL LIBRARY : subroutine LEQT1F
C
C     XRAIN = array for excess rainfall input
C     XRUN = array for runoff input
C        **NOTE**  for missing runoff data set XRUN(I)= -1.
C     IRAIN = period number of last non-zero excess rainfall
C     IRUN = period of last non-zero runoff
C     X(J) = unit hydrograph ordinate J = 1,2,...,M
C     M = memory time of watershed
C     T1,...,T10 = title
C
      DIMENSION B(700), A(700,700), XRAIN(700), XRUN(700), WKAREA(700),
     1          B1(700,1), X(700), Y(700)
C     read input data and information
      READ (5,160) IRAIN, IRUN, M, T1, T2, T3, T4, T5, T6, T7, T8, T9,
     1T10
      DO 10 J = 1, IRUN
        XRAIN(J) = 0.0
        XRUN(J) = 0.0
   10 CONTINUE
      DO 30 I = 1, IRUN
        READ (5,20) XRAIN(I), XRUN(I)
   20   FORMAT (F10.2, 1X, F10.2)
   30 CONTINUE
      MM = M + 1
      N = IRUN
C     calculate coefficients A(I,J) = sum over N=J,J+1,...,
C     M(XRAIN(N-I+1)*XRAIN(N-J+1)) , where I and J = 1,2,...,M
C     and J > I
C
C     initialize A-matrix
      DO 50 I = 1, 20
        DO 40 J = 1, 20
   40   A(I,J) = 0.
   50 CONTINUE
      IF (IRAIN .GE. N) GO TO 70
      KI = IRAIN + 1
      DO 60 I = KI, N
   60 XRAIN(I) = 0.
   70 DO 100 I = 1, M
        DO 90 J = I, M
          SUMIJ = 0.
          DO 80 JJ = J, N
            XRU = XRUN(JJ)
            IF (XRU .EQ. - 1.) GO TO 80
            II = JJ - I + 1
            JJJ = JJ - J + 1
            AIJ = XRAIN(II) * XRAIN(JJJ)
            SUMIJ = SUMIJ + AIJ
   80     CONTINUE
```

```
         A(I,J) = SUMIJ
C      completed 1 loop of J, now increase J by 1 and repeat
  90    CONTINUE
C      completed J loops for one I, now increase I by 1 and repeat
 100 CONTINUE
C      completed A(I,J) matrix for J > I, now complete rest of matrix
     A(MM,MM) = 0.
     DO 110 I = 1, M
       A(I,MM) = .5
       A(MM,I) = 1.
 110 CONTINUE
     DO 130 I = 2, M
       II = I - 1
       DO 120 J = 1, II
 120   A(I,J) = A(J,I)
 130 CONTINUE
C      calculate coefficient B(I) = sum over N = I,I+1,...,N (XRAIN
C      (N-I+1)*XRUN(N)) , where I = 1,2,...,M
     DO 150 I = 1, M
       SUMRQ = 0.
       DO 140 K = I, N
         IF (XRUN(K) .EQ. - 1.) GO TO 140
         RQ = XRAIN(K - I + 1) * XRUN(K)
         SUMRQ = SUMRQ + RQ
 140   CONTINUE
       B(I) = SUMRQ
C      completed loop for B(I) with K = I,N
 150 CONTINUE
     B(MM) = 1.
C      completed for all B(I) I = 1,M
C
C      print results
     WRITE (6,170) T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, IRAIN,
    1IRUN, M
 160 FORMAT (3I5, A4, A4, A4, A4, A4, A4, A4, A4, A4, A4)
 170 FORMAT ('1', 5X, A4, A4, A4, A4, A4, A4, A4, A4, A4, A4, /////,
    1        5X, 'PERIOD NUMBER OF LAST NON-ZERO EXCESS RAINFALL = ',
    2        1I5, //, 5X, 'PERIOD NUMBER OF LAST NON-ZERO RUNOFF = ',
    3        1I5, //, 5X, 'MEMORY TIME = ', 1I5, ////)
     WRITE (6,180)
     WRITE (6,190) (I,XRAIN(I),XRUN(I),I=1,IRUN)
 180 FORMAT (5X, 'TIME PERIOD', 10X, 'RAINFALL EXCESS', 14X, 'RUNOFF',
    1        /, 5X, '---- ------', 10X, '-------- ------', 14X,
    2        '------', ///)
 190 FORMAT (8X, 1I5, 17X, F10.5, 14X, F10.5)
     DO 200 I = 1, MM
 200 B1(I,1) = B(I)
     CALL LEQT1F(A, 1, MM, 700, B1, 0, WKAREA, IER)
     WRITE (6,220)
     WRITE (6,210) (I,B1(I,1),I=1,M)
 210 FORMAT (1X, I6, 5X, 1F9.5)
 220 FORMAT ('0', //, 10X, 'DISCRETE KERNELS FOR UNIT HYDROGRAPH', //,
    1        10X, '-------- ------- --- ---- ----------', //, 5X, 'I', /
    2        )
C      compute maximum discrete kernel
     AMAXB = 0.
     DO 230 I = 1, M
       IF (B1(I,1) .GT. AMAXB) AMAXB = B1(I,1)
 230 CONTINUE
C      plot resulting discrete kernels
```

```
      XMAX = FLOAT(M + 3)
      YMAX = AMAXB + (0.1*AMAXB)
      DO 240 I = 1, M
        X(I) = I
        Y(I) = B1(I,1)
240   CONTINUE
      CALL ALSIZE(8.0, 5.0)
      CALL ALAXIS('TIME', 4, 'UNIT ORDINATE', 13)
      CALL ALSCAL(0.0, XMAX, 0.0, YMAX)
      CALL ALGRAF(X, Y, M, -3)
      CALL PLOTND
      STOP
      END
```

APPENDIX B

Distributed model component codes:

B.1 Code used to determine soil characteristic curves.

B.2 Code used to synthesize storm hydrographs from partial source areas.

B.3 Code used to calculate normal discharge rating functions.

B.4 Code used for open channel flow routing.

APPENDIX B.1

```
C      The first part of the code performs computations of soil
C      hydraulic conductivity and difussivity as a function of
C      water content and/or pressure. The second part of the code
C      utilizes Parlanges' approximation to Philip's equations to
C      compute absorption rate, cumulative soil absorption,
C      infiltration rates and depth of the wetting front penetration.
C
C      Orginal code, Rogowski (1971). The code as shown in
C      this thesis was adapted, by Loague (1982), for use at UBC.
C
C      ID = sample identification
C      IEND = termination card (80 columns punched with 9's)
C      NC = number of incremented pore classes chosen for
C           calculating data (NC is limited to 99, dimensions
C           can be changed)
C      N = number of pore classes between THETA1 and THETAE
C      M = N+1
C      THETAE = water content at air entry pressure, (CM**3/CM**3)
C      CONE = experimentally obtained or estimated conductivity
C             (CM/DAY)
C      TF = field temperature in degrees centigrade
C      TM = tempeature at matching in degrees centigrade
C      PSI1 = initial pressure (CM of water),absolute value
C      PSIE = absolute value of air entry pressure, (CM)
C      PSI2 = water entry pressure =(1/2) PSIE
C      PSI15 = absolute value of 15-bar pressure, (CM)
C      THET15 = moisture content at 15-bar
C      STDINC = standard water content increment for calculated
C               values (CM**3/CM**3)
C      TINC = incremented THETA (CM**3/CM**3)
C      PSI = incremented PSI for respective TINC (CM OF WATER)
C      PCH = intermediate sum of products of coefficients and
C            heads in conductivity equation
C      SPCH = final sum of products
C      TAU = conversion factor that takes into account temperature
C            and gravity influences
C          = (325.4*TF+9671.7)/(325.4*TM+9671.7)
C      A = the exponent alpha in the PSI,THETA function
C      B = the exponent beta in the PSI, THETA function
C      PRESSURE = matric suction (CM of water), absolute value
C      THETA = water content (CM**3/CM**3)
C              upper limit = higher moisture, lower absolute pressure
C      CCAL = relative permability, of resistivity  ratio(W/WE)
C      CMAT = matched conductivity (CM/DAY), called 'CONDUCTIVITY'
C      DPSI = is the partial of PRESSURE (PSI) with respect to
C             THETA at a given value of THETA, (CM)
C      DIF = the diffusivity given as the product of K(THETA) and
C            the partial of PRESSURE (PSI) with respect to THETA at
C            a given value of THETA, (CM**2/DAY)
C      SORP = sorptivity (CM/HRS**0.5)
C      FS = sorptivity (FT/HRS**0.5)
C      PROS = initial inf. cap. after one sec. (CM/HRS)
C      F1 = initial inf. cap. after one sec. (FT/HRS)
C      ETA = THETA/THETA2
C      KE = conductivity in FT/HRS
C      PHI = solution of one dimensional absorption equation
C      SS = sorptivity ,Philip,1969,Advances in Hydroscience
C           5(237),CM/SEC**0.5
C      S = sorptivity,CM/DAY**0.5
C      SINC = normalized value of STDINC
```

```
C      CONE = conductivity at air entry =1/2 Ksat
C      HETA(I) = normalized value of THETA(I)
C      IDATE = date on which event occured
C      TSRT = starting time (HRS)
C      TEND = ending time (HRS)
C      MSOL = soil identification number
C      NM = denates initial soil water class in the
C           moisture characterist
C      NT = number of intervals a given time period
C           of rain is divided into
C
      DIMENSION ID(10), TINC(99), PSI(99), SPCH(99), CCAL(99), CMAT(99),
     1          DPSI(99), DIF(99), TIN(99), C(99), THETA(99), CP(99),
     2          D(99), F(99), G(99), H(99), PHI(99), SUM1(99), SUM2(99),
     3          S(99), T(99), TIME(99), CABS(99), ABSRT(99), VO(99),
     4          Z(99,99), SUM4(99,99), HETA(99), CPP(99), SUM11(99),
     5          SORP(99), PROS(99), ETA(99), HDF(99), FS(99), F1(99)
C      read input parameters and variables
   10 READ (5,20) ID1, ID2, ID3, ID4, ID5, ID6, ID7, ID8, ID9, ID10,
     1IEND
   20 FORMAT (10A4, 30X, I2)
      IF (IEND - 99) 30, 680, 30
   30 READ (5,40) NC, THET15, THETAE, THETA2, PSI15, PSI1, PSIE, PSI2,
     1CONE, TF, TM
   40 FORMAT (I3, 3(1X,F6.0), 2(1X,F7.0), 2(1X,F5.0), 2X, F8.0,
     1       2(1X,F4.0))
C      calculate exponent alpha
      A = (THET15 - THETAE) / ALOG(PSI15 - PSIE + 1)
C      calculate exponent beta
      B = (THETA2 - THETAE) / ALOG(PSIE - PSI2 + 1)
C      calculate initil moisture content corresponding to PSI1
      THETA1 = (ALOG(PSI1 - PSIE + 1)) * A + THETAE
C      calculate conversion factor
      TAU = (325.4*TF + 9671.7) / (325.4*TM + 9671.7)
C      calculate increment size
      RNC = NC
      STDINC = (THETA2 - THETA1) / RNC
C      initialize TINC array
      TINC(1) = THETA1
      TIN(1) = THETA1
      NCP1 = NC + 2
      DO 50 I = 2, NCP1
   50 TIN(I) = TIN(I - 1) + STDINC
C      calculate midpoint values of each increment for TINC
      DO 60 I = 2, NCP1
   60 TINC(I) = (TIN(I) + TIN(I - 1)) * 0.5
C      calculate adjusted PSI(I) values at midpoint of each
C      increment
      N = ((THETAE - THETA1)/STDINC) + 0.5
      DO 110 IIIII = 1, NCP1
        C(IIIII) = TINC(IIIII) - THETAE
        IF (C(IIIII)) 70, 70, 90
   70   CONTINUE
        DO 80 I = 1, N
          PSI(I) = PSIE - 1 + EXP((TINC(I) - THETAE)/A)
C      calculate partial of PRESSURE with respect to THETA
          DPSI(I) = (1./A) * EXP((TINC(I) - THETAE)/A)
          DPSI(I) = ABS(DPSI(I))
   80   CONTINUE
        GO TO 110
```

```
 90   CONTINUE
      M = N + 1
      DO 100 I = M, NCP1
        PSI(I) = PSIE + 1 - EXP((TINC(I) - THETAE)/B)
C     calculate partial of PRESSURE with respect to THETA
        DPSI(I) = (1./B) * EXP((TINC(I) - THETAE)/B)
 100  CONTINUE
 110 CONTINUE
C     calculate product of coefficient and 'HEAD' terms for
C     each pore class
     NC1 = NC + 1
     KL = NC1
     DO 130 J = 1, NC1
       NL = NCP1 - J
       PCH = 0.0
       DO 120 I = J, NC1
         PCH = PCH + (2*I + 1 - 2*J) * (1./PSI(NL)) ** 2
 120   NL = NL - 1
       SPCH(KL) = PCH
C     calculate W for a given water content and pressure
       CCAL(KL) = SPCH(KL)
 130 KL = KL - 1
     DO 140 I = 1, NC1
C     calculate relative conductivity
       CCAL(I) = CCAL(I) / CCAL(NC1) * ((THETAE/TINC(I))**2) * 2
C     calculate matched conductivity at each water content
       CMAT(I) = TAU * CONE * CCAL(I)
C     calculate diffusivity
       DIF(I) = CMAT(I) * DPSI(I)
       DIF(I) = ABS(DIF(I))
 140 CONTINUE
     WRITE (6,150) ID1, ID2, ID3, ID4, ID5, ID6, ID7, ID8, ID9, ID10
 150 FORMAT ('1', 20X, 10A4)
     WRITE (6,160)
 160 FORMAT ('0', ' NC THET15 THETAE  THETA2  PPSI15  PSI1  PSIE  PSI2
    1    CONE   TF   TM   ')
     WRITE (6,170)
 170 FORMAT (' ', '          (CM3/CM3)                (CM OF WATER)  (CM
    1/DAY) DEG.C    '/)
     WRITE (6,180) NC, THET15, THETAE, THETA2, PSI15, PSI1, PSIE, PSI2,
    1CONE, TF, TM
 180 FORMAT (' ', I3, 3(1X,F6.4), 2(1X,F7.1), 2(1X,F5.1), 1X, F8.4,
    1        2(1X,F4.1))
     WRITE (6,190)
 190 FORMAT ('0', ' CLASS PRESSURE THETA PERMEABILITY CONDUCTIVITY DIFF
    1USSIVITY    DPSI/DTHETA')
     WRITE (6,200)
 200 FORMAT (' ', '        (CM)     (CM3/CM3)            (CM/DAY)      (CM
    12/DAY   '/)
     DO 220 I = 1, NC1
       WRITE (6,210) I, PSI(I), TINC(I), CCAL(I), CMAT(I), DIF(I),
    1  DPSI(I)
 210   FORMAT (' ', I3, 2X, F9.1, 1X, F6.4, 2X, 1PE9.2, 4X, 1PE9.2, 6X,
    1          1PE9.2, 6X, 1PE9.2)
 220 CONTINUE
C     computation of sorptivity as a function of THETA/THETAE
C     Parlange, Guelph,Symp  equation 10
     WRITE (6,230)
 230 FORMAT ('1', '   SORPTIVITY AS A FUNCTION OF WATER CONTENT   '//)
     FE = CONE / (24.0*2.54*12.0)
```

```
      WRITE (6,240) THETAE, ID1, ID2, ID3, ID4, ID5, ID6, ID7, ID8, ID9,
     1ID10, FE
  240 FORMAT ('0', '  THETAE  =  ', F6.4, 5X, 10A4, '  KE(FT/HRS) =  ',
     1        1PE13.4, //)
      WRITE (6,250)
  250 FORMAT (' ', '  CLASS  INITIAL FLUX(CM/HRS)    SORPTIVITY(CM/HRS**
     10.5)   F1(FT/HRS) FS(FT/HRS**.5) THETA/THETA2 THETA MID.INT.', //)
      DO 260 I = 1, NC1
        ETA(I) = TIN(I) / THETA2
  260 CONTINUE
      NM = 1
  270 MN = NM + 1
      DO 280 I = NM, NC1
  280 HDF(I) = DIF(I) / 24.0
      DO 290 I = MN, NC1
  290 CPP(I) = (TINC(I) - TINC(NM)) * HDF(I) * STDINC
      SUM11(NM) = 0.0
      DO 300 I = MN, NC1
  300 SUM11(I) = SUM11(I - 1) + CPP(I)
      SORP(NM) = (2.0*SUM11(NC1)) ** 0.5
      FS(NM) = SORP(NM) / (2.54*12.0)
      PROS(NM) = (0.5*SORP(NM)/(1.0/60.0)) + (CONE/24.0)
      F1(NM) = PROS(NM) / (2.54*12.0)
      NM = NM + 1
      IF (NM - NC1) 270, 310, 310
  310 SORP(NC1) = 0.0
      DO 330 I = 1, NC1
        WRITE (6,320) I, PROS(I), SORP(I), F1(I), FS(I), ETA(I), TINC(I)
  320   FORMAT (' ', 2X, I3, 10X, 1PE9.2, 15X, E9.2, 10X, 2(3X,E9.2),
     1          6X, 0PE6.4, 9X, F6.4)
  330 CONTINUE
C      computation of PHI AND sorptivity from Parlange Soil Science
C      111(2)134,1971
      READ (5,340) NM, NT, TSTRT, TEND, IDATE, MSOL
  340 FORMAT (2I3, 2F5.2, I6, 3X, I3)
      MN = NM + 1
      HETA(NM) = 0.0
      IF (NC - MN) 10, 10, 350
C      normalize THETA and STDINC
  350 DO 360 I = MN, NC1
  360 HETA(I) = (TINC(MN - 1) - TINC(I)) / (TINC(MN - 1) - THETA2)
      SINC = STDINC / (THETA2 - TINC(MN - 1))
      DO 370 I = MN, NC1
        CP(I) = SINC * (DIF(I))
        D(I) = (HETA(I)) * (CP(I))
  370 CONTINUE
      SUM1(NM) = 0.0
      SUM2(NM) = 0.0
      DO 380 I = MN, NC1
        SUM1(I) = SUM1(I - 1) + CP(I)
        SUM2(I) = SUM2(I - 1) + D(I)
  380 CONTINUE
C      compute first term of equation 14 (Parlange,71)
      E = (2.0*SUM2(NC1)) ** 0.5
C      compute second term of equation 14 (Parlange,71)
      DO 390 I = MN, NC1
        F(I) = (HETA(I)) * SUM1(NC1)
        G(I) = CP(I) / F(I)
  390 CONTINUE
      H(NCP1) = 0.0
```

```
      MNN = NCP1 - MN
      DO 400 L = 1, MNN
        I = NCP1 - L
        H(I) = H(I + 1) + G(I)
 400  CONTINUE
C      compute PHI as a product of the first and second terms
C      of equation 14
      DO 410 I = MN, NC1
        PHI(I) = H(I) * E
 410  CONTINUE
C      integrate PHI to obtain sorptivity S on per day basis
      S(NM) = 0.0
      DO 420 I = MN, NC1
 420  S(I) = S(I - 1) + (STDINC*PHI(I))
C      compute sorptivity of per second basis
      SS = S(NC1) / 293.9388
      SSS = S(NC1) * 10.0 / 24.0 ** 0.5
      WRITE (6,430)
 430  FORMAT ('1', '       VALUES OF PHI AND SORPTIVITY   ', //)
      WRITE (6,440)
 440  FORMAT (' ', '       PSI(CM)  THETA(CM3/CM3)     THETA*    PHI', /
     1       /)
      DO 460 I = MN, NC1
        WRITE (6,450) I, PSI(I), TINC(I), HETA(I), PHI(I)
 450    FORMAT (' ', I3, 2X, F9.1, 5X, F6.4, 7X, F6.4, 7X, 1PE9.2)
 460  CONTINUE
      WRITE (6,470) S(NC1), SS, SSS
 470  FORMAT ('0', ' SORPTIVITY(CM/DAY**0.5) =  ', 1PE9.2,
     1       '          (CM/SEC**0.5)=  ', 1PE9.2,
     2       '       (MM/HRS**0.5)=', 1PE9.2, //)
      WRITE (6,480) A, B, SINC, STDINC
 480  FORMAT (4(4X,F7.4))
C      computation of infiltration capacity
C      using values of sorptivity SS(CM/HRS**0.5),and conductivity
C      at air entry, cone,and Philip's equation.
      TINT = (TEND - TSTRT) / 50.0
      TIME(1) = 0.0
C      sorptivity in CM/HRS**0.5 and hydraulic conductivity
C      in CM/HRS
      SS = S(NC1) / 24.0 ** 0.5
      CONE = CONE / 24.0
      DO 490 K = 2, 51
        TIME(K) = TIME(K - 1) + TINT
        T(K) = (TIME(K)) ** 0.5
        VO(K) = (0.5*SS/T(K)) + CONE
 490  CONTINUE
C      Parlange considers this VO negative and less than
C      cone,(Guelph,Symp.)
      WRITE (6,500)
 500  FORMAT ('1', '       INFILTRATION CAPACITY (CM/HRS) '//)
      WRITE (6,510)
 510  FORMAT (' ', '  K   TIME(HRS)  INF.CAPP.(CM/HRS) '//)
      DO 530 K = 2, 51
        L = K - 1
        WRITE (6,520) L, TIME(K), VO(K)
 520    FORMAT (' ', I3, 2(6X,1PE9.2))
 530  CONTINUE
      WRITE (6,540) IDATE, TSTRT, TEND, TINC(NM)
 540  FORMAT ('0', ' DATE ', I6, 'START TIME(HRS)=', F6.2,
     1       'END TIME(HRS)=', F6.2, 'THETA INITIAL(CM**3/CM**3)=',
```

```
    2       F6.4)
C     computation of moisture profiles, Parlange EQ.24
     DO 590 K = 2, 11
       MN = NM + 1
       DO 570 I = NM, NC
         Z(I,K) = (DIF(I)*STDINC) / ((CMAT(NC1)*TINC(I)) - CMAT(I))
         IF (Z(I,K)) 550, 560, 560
 550     Z(I,K) = (DIF(I)*STDINC) / ((CMAT(NC1)) - CMAT(I))
 560     CONTINUE
 570   CONTINUE
       TINT = (TEND - TSTRT) / 10.0
       TIME(1) = 0.0
       TIME(K) = TIME(K - 1) + TINT
       Z(NC1,K) = CONE * (TIME(K))
       SUM4(NCP1,K) = 0.0
       NMM = NCP1 - NM
       DO 580 I = 1, NMM
         NL = NCP1 - I
 580   SUM4(NL,K) = SUM4(NL + 1,K) + Z(NL,K)
 590 CONTINUE
     WRITE (6,600)
 600 FORMAT ('1', '  MOISTURE PROFILES           , Z(CM)   '//)
     WRITE (6,610)
 610 FORMAT ('0', '  I  THETA*   K=1         K=2         K=3         K=4
    1     K=5      THETA(CM**3/CM**3)     '//)
     DO 630 I = NM, NC1
       WRITE (6,620) I, HETA(I), (SUM4(I,K),K=2,6), TINC(I)
 620   FORMAT (' ', I3, 2X, F6.4, 5(2X,1PE9.2), 5X, 0PF6.4)
 630 CONTINUE
     WRITE (6,640)
 640 FORMAT ('0', '         MOISTURE ROFILES CONTINUED    ,Z(CM)     '//)

     WRITE (6,650)
 650 FORMAT ('0', '  I  THETA*   K=6         K=7         K=8         K=9
    1     K=10     THETA(CM**3/CM**3)     '//)
     WRITE (6,660) I, HETA(I), (SUM4(I,K),K=7,11), TINC(I)
 660 FORMAT (' ', I3, 2X, F6.4, 5(2X,1PE9.2), 5X, 0PF6.4)
 670 CONTINUE
     GO TO 10
 680 STOP
     END
```

APPENDIX B.2

```
C     This code is for the synthesis of storm hydrographs from
C     partial areas
C
C     Orginal code ,Engman (1974). The code as shown in
C     this thesis was adapted, by Loague (1982), for use at UBC.
C
C     MHR = hours from raingage chart
C     MIN = minutes from raingage chart
C     PACCUM = accumulated precip in inches from raingage chart
C     W = channel width in feet
C     SECLEN = delta x, incremental length of flow plane for routing
C     SECLEN2 = delta x for overland flow routing if changed
C     RCHLEN = length of main channel reach between xsects in feet
C     SLOPL1(),SLOPR() = average slope values for overland flow
C                        plane in each soil zone from SCS maps
C     DEPL(),DEPR() = total depth of depression storage
C                     for that soil zone in feet
C     WDTH() = perpendicular distance from stream to soil boundary
C     W = actual width of channel water surface in feet
C     XLLL = length of flow plane (maximum possible)
C     NEND = number of increments available for routing
C           ie. number of increments XLLL can be devided into
C     XEND = number of overland flow routing sections
C     XR(),XL() = the dimension of the soil zones on either
C                 side of the channel measured in feet from the
C                 channel to the farthest edge (should be even
C                 multiples of SECLEN)
C     TIMINC = computational time interval in seconds
C     XMANNN = mannings "N" for overland flow
C     SLPRNT = 0.0   infiltration and soils information not printed
C     DPPRNT = 0.0  the depths are not printed
C     PRPRNT = 0.0  the values of PRE() are not printed
C     XPUNCH = 0.0  QL cards are not punched
C     SOILNH = soil identification number
C     SOILDP = depth of top soil layer in feet
C     SOLDP2 = depth of second soil layer in feet
C     THETA2 = soil water content
C     THETAE = soil water content at air entry
C     DEGSAT = degree of saturation , THETA2/THETA(saturation)
C     FRQDEG = frequency of soil moisture from a probability
C              distribution
C     FS = sorptivity in ft/sec**.5
C     FK = conductivity at air entry in ft/sec
C     F1 = initial infiltration value in ft/sec
C     NTINT = length of array (ie. 1.5 times the length of
C             the storm so the hydrograph will have a full
C             recession and not be cut short)
C             * note * NTINT will always be 40 for short storms
C     PREX = the precipitation excess after depression storage
C            is subtracted
C     PRCP = rainfall intensity in inches/hour
C     DUR = duration of rainfall
C
      DIMENSION MHR(50), MIN(50), PACCUM(50), PTOT(50), ITTOT(50)
      DIMENSION THETA2(10), THETAE(10), DEGSAT(10), FRQDEG(10)
      DIMENSION XL(10), XR(10), PINF(500), WFRNT(500)
      DIMENSION PEX(10,500), QLLL(500), QLLR(500), QL(500), PREX(10,500)
      DIMENSION XLLL(500), XLLR(500)
      DIMENSION FS(10), FK(10), F1(10), THETAI(10)
      DIMENSION LISTL(10), LISTR(10)
```

```
      DIMENSION SOILDP(10), THETI2(10), THET22(10), THETE2(10),
     1          DEGST2(10), FRQDG2(10), FS2(10), FK2(10), F12(10),
     2          SOLDP2(10)
      DIMENSION SLOPL(10), SLOPR(10), DEPL(10), DEPR(10)
      INTEGER SOILN(10), SOIL2(10)
      COMMON PRE(500,500), FLO(500,500), DPTH(500,500), VO1(10,500),
     1       FTLONG(500), P(500), SLOP(500)
      LOGICAL*1 DATE(70)
      LOGICAL*1 GAGE(70)
      LOGICAL*1 SECTON(70)
   10 FORMAT (70A1)
   20 FORMAT (2I2, F14.7, I1)
   30 FORMAT (8F10.0)
   40 FORMAT (I3, 2X, 7F10.0, F4.0, I1)
   50 FORMAT ('1', 45X, '<<< SOIL PARAMETERS >>>'//)
   60 FORMAT (' ', 1X, I3, 8(2X,F12.5)///)
   70 FORMAT (' ', 1X, I3, 6X, I3, 5(2X,F12.5))
   80 FORMAT (' ', 'SOIL#', 06X, 'THETA2', 08X, 'THETAE', 08X, 'THETAI',
     1       08X, 'DEGSAT', 08X, 'FRQDEG', 07X, 'FS(FT/HR)', 05X,
     2       'FK(FT/HR)', 05X, 'F1(FT/HR)'/)
   90 FORMAT (' ', 'SECONDS PER TIMINT =  ', F5.0////)
  100 FORMAT (' ', 'SOIL#', 03X, 'TIMINT', 06X, 'VO1(FT)', 08X, 'P(FT)',
     1       08X, 'PEX(FT)', 07X, 'PINF(FT)', 7X, 'WFINC(FT)'/)
  110 FORMAT ('1', 5X, ' DIVISION OF TOTAL PRECIPITATION INTO INFILTRATI
     1ON AND EXCESS COMPONENTS USING SOIL PARAMETERS AND RAINGAGE DATA'/
     2       //)
  120 FORMAT (' ', 10X, 'DATE OF EVENT: ', 70A1//////)
  130 FORMAT (' ', 'ORIGINAL RAINFALL DATA FROM ', 70A1//)
  140 FORMAT (' ', 30X, 'TIME', 06X, 'INCHES'/)
  150 FORMAT (' ', 30X, 2I2, 1X, F10.2)
  160 FORMAT ('1', 'CALCULATION OF LATERAL INFLOW HYDROGRAPHS')
  170 FORMAT (' ', 'TOP LAYER SOIL DEPTH=', F5.3, 5X,
     1       'SECOND LAYER SOIL DEPTH=', F7.3)
C      initialize all arrays used in the precip breakdown
      DO 180 J = 1, 500
  180 SLOP(J) = 0.0
      DO 200 J = 1, 500
        DO 190 K = 1, 500
          DPTH(K,J) = 0.0
          FLO(K,J) = 0.0
          PRE(K,J) = 0.0
  190   CONTINUE
  200 CONTINUE
      DO 220 J = 1, 500
        DO 210 K = 1, 10
          PREX(K,J) = 0.0
          PEX(K,J) = 0.0
  210   CONTINUE
  220 CONTINUE
      DO 230 J = 1, 500
        XLLL(J) = 0.0
        PINF(J) = 0.0
        XLLR(J) = 0.0
        FTLONG(J) = 0.0
        P(J) = 0.0
        QLLR(J) = 0.0
        QLLL(J) = 0.0
        QL(J) = 0.0
  230 CONTINUE
      DO 240 J = 1, 50
```

```
        MIN(J) = 0.0
        MHR(J) = 0
        MIN(J) = 0
        PACCUM(J) = 0.0
        PTOT(J) = 0.0
        ITTOT(J) = 0.0
  240 CONTINUE
C      read the event date and raingage used
      READ (5,10) DATE
      READ (5,10) GAGE
C      read breakpoint raingage data; after last card, insert a card
C      of all 1's
      I = 1
  250 READ (5,20) MHR(I), MIN(I), PACCUM(I), NSTOP
      IF (NSTOP .NE. 0) GO TO 260
      I = I + 1
      GO TO 250
  260 NPINTS = I -- 2
C      read time interval of calculations in seconds
      READ (5,30) TIMINC, SECLEN, TOLR, XEND, SLPRNT, DPPRNT, PRPRNT,
     1XPUNCH
      NEND = XEND
      INCTIM = TIMINC
      XEND3 = XEND
      DELTX = SECLEN
C.     convert breakpoint data to precip depth vector
      NTSUM = 0
      DO 280 I = 1, NPINTS
        PTOT(I) = (PACCUM(I .+ 1) - PACCUM(1)) / 12.
        INCHR = MHR(I + 1) - MHR(I)
        INCMIN = MIN(I + 1) - MIN(I)
        IF (INCMIN .GE. 0) GO TO 270
        INCMIN = INCMIN + 60
        INCHR = INCHR - 1
  270   ITTOT(I) = (INCHR*3600) + (INCMIN*60) + NTSUM
  280 NTSUM = ITTOT(I)
      PSUM = 0.0
      PCUM = 0.0
      NSECSS = 0
      ITIME = 0
      ITSUM = 0
      I = 1
  290 NSECSS = NSECSS + INCTIM
      ITIME = ITIME + 1
      IF (NSECSS .GE. ITTOT(NPINTS)) GO TO 320
  300 IF (NSECSS .LE. ITTOT(I)) GO TO 310
      ITSUM = ITTOT(I)
      PSUM = PTOT(I)
      I = I + 1
      GO TO 300
  310 SECS = NSECSS
      TTOT = ITTOT(I)
      TSUM = ITSUM
      P(ITIME) = ((SECS - TSUM)/(TTOT - TSUM)) * (PTOT(I) - PSUM) +
     1PSUM - PCUM
      PCUM = PCUM + P(ITIME)
      GO TO 290
  320 P(ITIME) = PTOT(NPINTS) - PCUM
C      write heading,date,gage,and orginal precip data
      WRITE (6,110)
```

```
      WRITE (6,120) DATE
      WRITE (6,130) GAGE
      WRITE (6,90) TIMINC
      WRITE (6,140)
      NPREC = NPINTS + 1
      DO 330 K = 1, NPREC
  330 WRITE (6,150) MHR(K), MIN(K), PACCUM(K)
C      read soil input data
C
C      top soil layer
C      after last card insert card with all 3's
      I = 1
  340 READ (5,40) SOILN(I), THETA2(I), THETAE(I), DEGSAT(I), FRQDEG(I),
     1FS(I), FK(I), F1(I), SOILDP(I), MSTOP
      IF (MSTOP .GT. 2) GO TO 350
      I = I + 1
      GO TO 340
  350 I = 1
  360 CONTINUE
C      second soil layer read in data
C      after last card insert card with all 6's
      READ (5,40) SOIL2(I), THET22(I), THETE2(I), DEGST2(I), FRQDG2(I),
     1FS2(I), FK2(I), F12(I), SOLDP2(I), MSTOP
      IF (MSTOP .GT. 5) GO TO 370
      I = I + 1
      GO TO 360
  370 I = I - 1
C      calculate soil-time array of VO1, excess, and infiltration
C      print initial soil parameters and calculated output
      NTINT = 1.5 * ITIME + 1
      IF (NTINT .LT. 40) NTINT = 40
      DO 500 NSOIL = 1, I
        IF (FS(NSOIL)) 380, 380, 400
  380   DO 390 INP = 1, NTINT
  390   PEX(NSOIL,INP) = P(INP)
        GO TO 440
  400   CONTINUE
        THETAI(NSOIL) = DEGSAT(NSOIL) * THETA2(NSOIL)
        VO1(NSOIL,1) = F1(NSOIL) * TIMINC / 3600.
        PEX(NSOIL,1) = P(1) - VO1(NSOIL,1)
        IF (PEX(NSOIL,1) .GT. 0.0) PINF(1) = VO1(NSOIL,1)
        IF (PEX(NSOIL,1) .LE. 0.0) PINF(1) = P(1)
        WETFRT = PINF(1) / (THETAE(NSOIL) - THETAI(NSOIL))
        WFRNT(1) = WETFRT
        DO 410 INP = 2, NTINT
          RLTIME = INP * TIMINC / 3600.
          VO1(NSOIL,INP) = ((0.5*FS(NSOIL)/RLTIME**0.5) + FK(NSOIL)) *
     1    TIMINC / 3600.
          PEX(NSOIL,INP) = P(INP) - VO1(NSOIL,INP)
          IF (PEX(NSOIL,INP) .GT. 0.0) PINF(INP) = VO1(NSOIL,INP)
          IF (PEX(NSOIL,INP) .LE. 0.0) PINF(INP) = P(INP)
          WETFRT = WETFRT + PINF(INP) / (THETAE(NSOIL) - THETAI(NSOIL))
          WFRNT(INP) = WETFRT
          IINP = INP
C      checking to see if wetting front has proceeded below
C      the top soil.  if it has go to second layer which now
C      controls VO1
          IF (WETFRT .GT. SOILDP(NSOIL)) GO TO 420
  410   CONTINUE
  420   XWET = 1.0
```

```
      THETI2(NSOIL) = DEGST2(NSOIL) * THET22(NSOIL)
      DO 430 INP = IINP, NTINT
        RLTIME = INP * TIMINC / 3600.
        VO1(NSOIL,INP) = ((0.5*FS2(NSOIL)/RLTIME**0.5) + FK2(NSOIL)) *
     1    TIMINC / 3600.
        PEX(NSOIL,INP) = P(INP) - VO1(NSOIL,INP)
        IF (PEX(NSOIL,INP) .GT. 0.0) PINF(INP) = VO1(NSOIL,INP)
        IF (PEX(NSOIL,INP) .LE. 0.0) PINF(INP) = P(INP)
        WETFRT = WETFRT + PINF(INP) / (THETAE(NSOIL) - THETAI(NSOIL))
        WFRNT(INP) = WETFRT
 430  CONTINUE
      IF (SLPRNT .LE. 0.0) GO TO 490
 440  CONTINUE
      IF (FS(NSOIL)) 450, 450, 470
 450  WRITE (6,460)
 460  FORMAT (' ', 'LATERAL INFLOW FROM IMPERVIOUS AREA,PEX=PRECIP')
      GO TO 470
 470  CONTINUE
C     write orginal soils data
      WRITE (6,50)
      WRITE (6,80)
      WRITE (6,60) SOILN(NSOIL), THETA2(NSOIL), THETAE(NSOIL),
     1 THETAI(NSOIL), DEGSAT(NSOIL), FRQDEG(NSOIL), FS(NSOIL),
     2 FK(NSOIL), F1(NSOIL)
      WRITE (6,60) SOIL2(NSOIL), THET22(NSOIL), THETE2(NSOIL),
     1 THETI2(NSOIL), DEGST2(NSOIL), FRQDG2(NSOIL), FS2(NSOIL),
     2 FK2(NSOIL), F12(NSOIL)
      WRITE (6,170) SOILDP(NSOIL), SOLDP2(NSOIL)
C     write out infiltration,precipitation excess and depth
C     of the wetting front.
      WRITE (6,100)
      DO 480 INP = 1, NTINT
 480  WRITE (6,70) SOILN(NSOIL), INP, VO1(NSOIL,INP), P(INP),
     1 PEX(NSOIL,INP), PINF(INP), WFRNT(INP)
 490  CONTINUE
 500 CONTINUE
    NNSOIL = I
 510 CONTINUE
C     set arrays to zero
    DO 520 I = 1, 500
      DO 520 J = 1, 500
        PRE(I,J) = 0.0
 520 CONTINUE
    DO 530 L = 1, 10
      XL(L) = 0.0
      XR(L) = 0.0
      SLOPL(L) = 0.0
      SLOPR(L) = 0.0
      DEPL(L) = 0.0
      DEPR(L) = 0.0
      LISTL(L) = 0
 530 LISTR(L) = 0
    I = NNSOIL
C     read in watershed geometry
    READ (5,540) SECTON, IZSTOP
 540 FORMAT (70A1, 9X, I1)
    IF (IZSTOP - 9) 550, 1040, 550
 550 READ (5,560) (LISTL(L),L=1,10), (LISTR(L),L=1,10), LISTNL, LISTNR
 560 FORMAT (10I2, 10I2, I2, I2)
    READ (5,570) (XL(L),L=1,LISTNL), (XR(L),L=1,LISTNR)
```

```
 570 FORMAT (16F5.0)
     READ (5,570) (SLOPL(L),L=1,LISTNL), (SLOPR(L),L=1,LISTNR)
     READ (5,570) (DEPL(L),L=1,LISTNL), (DEPR(L),L=1,LISTNR)
     READ (5,30) RCHLEN, W, XMANNN, SECLN2, XEND2
     IF (SECLN2 .GT. 0.0) GO TO 580
     XEND = XEND3
     NEND = XEND
     SECLEN = DELTX
     GO TO 590
 580 SECLEN = SECLN2
     XEND = XEND2
     NEND = XEND
 590 CONTINUE
C     subtracting detention storage only when infiltration
C     is exceeded
     L = 1
 600 LIST = L
     NSOIL = LISTL(L)
     DETENT = DEPL(LIST)
     DO 630 INP = 1, NTINT
       DELDEP = 0.1 * DEPL(LIST)
       IF (PEX(NSOIL,INP) .LE. 0.0) GO TO 620
       IF (DETENT .LE. 0.0) GO TO 620
       IF (DELDEP .LE. PEX(NSOIL,INP)) GO TO 610
       DETENT = DETENT - PEX(NSOIL,INP)
       PREX(NSOIL,INP) = 0.0
       GO TO 630
 610   PREX(NSOIL,INP) = PEX(NSOIL,INP) - DELDEP
       DETENT = DETENT - DELDEP
       GO TO 630
 620   PREX(NSOIL,INP) = PEX(NSOIL,INP)
 630 CONTINUE
     L = L + 1
     IF (L .LE. LISTNL) GO TO 600
     XN2 = XEND
     LN2 = NEND
C     distributing SLOPE and PREX to each routing segment
C     in the flow plane
     DO 660 LIST = 1, LISTNL
       DO 650 ITINT = 1, NTINT
         XN1 = XN2 - XL(LIST) / SECLEN
         LN1 = XN1
         JOK = LISTL(LIST)
         DO 640 L = LN1, LN2
           SLOP(L) = SLOPL(LIST)
 640     PRE(L,ITINT) = PREX(JOK,ITINT)
 650   CONTINUE
       LN2 = LN1 - 1
 660 CONTINUE
     CALL SUROUT(TIMINC, NEND, SECLEN, XMANNN, ITIME, TOLR)
     DO 670 ITINT = 1, NTINT
       XLLL(ITINT) = FTLONG(ITINT)
 670 QLLL(ITINT) = FLO(NEND,ITINT)
 680 CONTINUE
C     exact duplicate of left side calculations
C     right side partial area
     DO 700 J = 1, 500
       DO 690 K = 1, 500
         PRE(K,J) = 0.0
 690   CONTINUE
```

```
700 CONTINUE
    DO 710 K = 1, 500
710 SLOP(K) = 0.0
    L = 1
720 LIST = L
    NSOIL = LISTR(L)
    DETENT = DEPR(LIST)
    DO 750 INP = 1, NTINT
      DELDEP = 0.1 * DEPR(LIST)
      IF (PEX(NSOIL,INP) .LE. 0.0) GO TO 740
      IF (DETENT .LE. 0.0) GO TO 740
      IF (DELDEP .LE. PEX(NSOIL,INP)) GO TO 730
      DETENT = DETENT - PEX(NSOIL,INP)
      PREX(NSOIL,INP) = 0.0
      GO TO 750
730   PREX(NSOIL,INP) = PEX(NSOIL,INP) - DELDEP
      DETENT = DETENT - DELDEP
      GO TO 750
740   PREX(NSOIL,INP) = PEX(NSOIL,INP)
750 CONTINUE
    L = L + 1
    IF (L .LE. LISTNR) GO TO 720
    XN2 = XEND
    LN2 = NEND
    DO 780 LIST = 1, LISTNR
      DO 770 ITINT = 1, NTINT
        XN1 = XN2 - XR(LIST) / SECLEN
        LN1 = XN1
        JOK = LISTR(LIST)
        DO 760 L = LN1, LN2
          SLOP(L) = SLOPR(LIST)
760     PRE(L,ITINT) = PREX(JOK,ITINT)
770   CONTINUE
      LN2 = LN1 - 1
780 CONTINUE
    CALL SUROUT(TIMINC, NEND, SECLEN, XMANNN, ITIME, TOLR)
    DO 790 ITINT = 1, NTINT
      XLLR(ITINT) = FTLONG(ITINT)
790 QLLR(ITINT) = FLO(NEND,ITINT)
C     total lateral inflow
C     sums left + right sides + channel precipitation
800 CONTINUE
    DO 810 INQQ = 1, NTINT
      QL(INQQ) = QLLL(INQQ) + QLLR(INQQ) + W * P(INQQ) / 3600.
810 CONTINUE
    QLT = 0.0
C     volume of precip excess
    DO 820 ITQL = 1, NTINT
      QLT = QLT + QL(ITQL) * TIMINC
820 CONTINUE
C     total volume of runoff from reach
    QLTT = QLT * RCHLEN
C     format for output
C     print out and punched card output
    WRITE (6,160)
    WRITE (6,10) SECTON
    WRITE (6,830) (DEPL(L),L=1,LISTNL)
830 FORMAT (' ', 'LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE', 5X,
   1        10(F6.4,3X))
    WRITE (6,840) (DEPR(L),L=1,LISTNR)
```

```
840 FORMAT (' ', 'RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE', 5X,
   1       10(F6.4,3X))
    WRITE (6,850) (SLOPL(L),L=1,LISTNL)
850 FORMAT (' ', 'LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE', 5X,
   1       10(F6.4,3X))
    WRITE (6,860) (SLOPR(L),L=1,LISTNR)
860 FORMAT (' ', 'RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE', 5X,
   1       10(F6.4,3X))
    WRITE (6,870) (XL(L),L=1,LISTNL)
870 FORMAT (' ', 'LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM', 5X,
   1       10(F6.1,3X))
    WRITE (6,880) (XR(L),L=1,LISTNR)
880 FORMAT (' ', 'RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM', 5X,
   1       10(F6.1,3X))
    WRITE (6,890) RCHLEN, W, XMANNN, SECLEN
890 FORMAT (' ', 'REACH LENGTH=', 5X, F7.2, 5X, 'STREAM WIDTH=', 5X,
   1       F5.2, 5X, 'MANNINGS N=', 5X, F8.6, 5X, 'DELTAX=', F7.2)
    WRITE (6,900) QLT
900 FORMAT (' ', 'VOLUME OF PRECIPITATION EXCESS=', F20.10, 5X,
   1       'CU FT')
    WRITE (6,910) QLTT
910 FORMAT (' ', 'TOTAL RUNOFF  VOLUME FROM REACH=', F20.10)
    WRITE (6,920)
920 FORMAT ('-', 30X, 'PRECIP EXCESS VALUES FOR EACH DELT')
    WRITE (6,930)
930 FORMAT (' ', '    QL CFS/FT              PRECIP DEPTH      LEFT SIDE
   1QL WIDTH OF CONTRIB AREA   RIGHT SIDE QL     WIDTH OF RIGHT SIDE')
    DO 940 I = 1, NTINT
940 WRITE (6,950) QL(I), P(I), QLLL(I), XLLL(I), QLLR(I), XLLR(I)
950 FORMAT (' ', 6(F14.7,5X))
    IF (XPUNCH .LE. 0.0) GO TO 990
    DO 960 I = 1, NTINT
960 PUNCH 970, QL(I)
970 FORMAT (20X, F12.7, 48X)
    DUMMY = 1111111.
    PUNCH 980, DUMMY
980 FORMAT (F10.0)
990 CONTINUE
    DO 1010 I = 1, NTINT
      WRITE (8,1000) QL(I)
1000  FORMAT (' ', 19X, F12.7, 48X)
1010 CONTINUE
    DUMMY = 1111111.
    WRITE (8,1020) DUMMY
1020 FORMAT (' ', F10.0)
1030 CONTINUE
    DPCT = 0.0
    GO TO 510
1040 STOP
    END
    SUBROUTINE SUROUT(TIMINC, NEND, SECLEN, XMANNN, ITIME, TOLR)
C     subroutine routes depth of precip excess over partial
C     area length usings simple kinematic formulation
    COMMON PRE(500,500), FLO(500,500), DPTH(500,500), VO1(10,500),
   1       FTLONG(500), P(500), SLOP(500)
    DUR = ITIME
    TINT = TIMINC / 60.
    NTINT = 1.5 * ITIME
    IF (NTINT .LT. 40) NTINT = 40
    NSECS = TIMINC * ITIME
```

```
      NTPL1 = NTINT + 1
      NTIMEP = NSECS / TIMINC
      INTER = NTIMEP + 1
      NTPLS = NTINT + 1
      DO 10 ITINT = 1, NTINT
   10 FTLONG(ITINT) = 0.0
      DO 30 ITINT = 1, NTPLS
        DO 20 ISECT = 1, NEND
   20   DPTH(ISECT,ITINT) = 0.0
   30 CONTINUE
      DO 50 ITINT = 1, NTINT
        DO 40 ISECT = 1, NEND
   40   FLO(ISECT,ITINT) = 0.0
   50 CONTINUE
C      set initial depth = precipitation excess
      DO 60 ISECT = 1, NEND
   60 DPTH(ISECT,1) = PRE(ISECT,1)
      DO 210 ITINT = 1, NTINT
C      calculates flow rate from manning's equation
        NTT = 0
        DO 80 ISECT = 1, NEND
          IF (DPTH(ISECT,ITINT) .LE. 0.0) GO TO 70
          FLO(ISECT,ITINT) = 1.486 * (DPTH(ISECT,ITINT)**1.67) * (SLOP(
     1    ISECT)**0.5) / XMANNN
          GO TO 80
   70     FLO(ISECT,ITINT) = 0.0
   80   CONTINUE
        ITPL1 = ITINT + 1
        DO 200 ISECT = 2, NEND
          ISMI1 = ISECT - 1
          QIN = FLO(ISMI1,ITINT)
          QOUT = FLO(ISECT,ITINT)
C      routing with continuity equation
          IF (PRE(ISECT,ITPL1) .LT. 0.0) GO TO 90
          PRP = PRE(ISECT,ITPL1)
          GO TO 100
   90     PRP = 0.0
  100     YDELT = ((QIN - QOUT)*60.*TINT/SECLEN) + PRP
C      calculating new depth
          DPTH(ISECT,ITPL1) = DPTH(ISECT,ITINT) + YDELT
          IF (PRE(ISECT,ITPL1) .GT. 0.0) GO TO 120
          DIF = PRE(ISECT,ITPL1) + DPTH(ISECT,ITPL1)
C      PRE is subtracted if PRE is negative
C      this amount to be re-infiltrated for this DELTAX
          IF (DIF .LT. 0.0) GO TO 110
          PRE(ISECT,ITPL1) = 0.0
          DPTH(ISECT,ITPL1) = DIF
          GO TO 120
  110     PRE(ISECT,ITPL1) = DIF
          DPTH(ISECT,ITPL1) = 0.0
  120     CONTINUE
          IF (DPTH(ISECT,ITPL1)) 130, 140, 140
  130     DPTH(ISECT,ITPL1) = 0.0
  140     IF (DPTH(ISMI1,ITPL1)) 150, 160, 160
  150     DPTH(ISMI1,ITPL1) = 0.0
  160     CONTINUE
C      check to see if DEPTH is not too large
          A = (DPTH(ISECT,ITPL1) - DPTH(ISECT,ITINT) + DPTH(ISMI1,ITPL1)
     1    -DPTH(ISMI1,ITINT)) * 0.5 / TIMINC
          B = (1.486*(SLOP(ISECT)**.5)/XMANNN) * (DPTH(ISECT,ITPL1)**1.
```

```
    1     33 - DPTH(ISMI1,ITPL1)**1.33)
          C = (PRE(ISECT,ITPL1) + PRE(ISECT,ITINT)) / 2.
          FH = A + B - C
          IF (FH .LT. TOLR) GO TO 180
          DFH = 0.5 / TIMINC + (1.486*5.*(SLOP(ISECT)**.5)/XMANNN*3.) *
    1     DPTH(ISECT,ITPL1) ** 0.67
          DPTH(ISECT,ITPL1) = DPTH(ISECT,ITPL1) - FH / DFH
          IF (DPTH(ISECT,ITPL1)) 170, 160, 160
170       DPTH(ISECT,ITPL1) = 0.0
          GO TO 160
180       CONTINUE
          IF (NTT .GT. 0) GO TO 200
          IF (DPTH(ISECT,ITPL1) .GT. 0.0) GO TO 190
          GO TO 200
190       FTLONG(ITPL1) = (NEND - ISECT) * SECLEN
          NTT = 1
200     CONTINUE
210   CONTINUE
      RETURN
      END
```

```
C      This code performs data reduction for channel
C      hydraulic studies.
C
C      The orginal code ,Brakensiel (1966), was modified by
C      Engman (1974). The code as shown in this thesis
C      was adapted , by Loague (1982), for use at UBC.
C
C      SLOPC = bed slope of channel
C      SLOPR = ground slope in direction of flow ,right bank
C      SLOPL = ground slope in direction of flow ,left bank
C      ZU1 = distance below zmax (zmax is maximum depth)
C      DELN = divisor for calculation an elevation increment
C      XR = channel manning's N divided by right bank N
C      XL = channel manning's N divided by left bank N
C      ZZ = card punch trigger (if .GT. 1.0 punching cards)
C      XID1 = watershed location
C      XID2 = identification of section
C      KODE = digit having value of 1 for last card
C      KODE1 = digit having value of 1 for left bank coordinate
C            = digit having value of 2 for right bank coordinate
C      YCOR(I) = horizontal distance of each survey point (referenced
C                to an orgin at centerline of channel)
C      ZCOR(I) = vertical elevation of each survey point
C
      DIMENSION YCOR(500), YCOR1(1), AREA(500,1), ZCOR(500), ZCOR1(1)
      DIMENSION WP(500,1), XLA(1), XLWP(1), XCA(1), XCWP(1), XRA(1)
      DIMENSION XRWR(1), AHZ(1), WPHZ(1), AMOD(1), WPMOD(1), TW(1)
      DIMENSION RH(1), RVR(1), RVC(1), RVL(1), RMOD(1), XKNHZ(1)
      DIMENSION XKNVR(1), XKNVC(1), XKNVL(1), XKNVT(1), XKNMO(1)
      DIMENSION XQNMO(1), XQNVT(1), XHYD(1)
      DIMENSION XQNHZ(1), XQNVR(1), XQNVC(1), XQNVL(1)
      DIMENSION YCOR3(500), ZCOR3(500), XRWP(1)
      DIMENSION DEPTH(1)
      XINT(C,D,E,F,G) = C + ((G - E)/(F - E)) * (D - C)
      XAREA(A,B,C,D,E) = (2.*A - B - C) * (D - E) / 2.
      XWP(A,B,C,D) = SQRT((A - B)*(A - B) + (C - D)*(C - D))
      XKN(A,B) = 1.486 * (A**0.67) * B
      XQN(A,B,C) = XKN(A,B) * SQRT(C)
   10 LL = 1
      IC1 = 0
      LS = 0
      IC = 0
   20 I = 0
      READ (5,30,END=630) SLOPC, SLOPR, SLOPL, ZU1, DELN, XR, XL, ZZ
   30 FORMAT (8F8.4)
C       READ IN SECTION DATA CARDS AND SET INDEXS FOR LEFT,RIGHT BANKS,
C            channel bottom and max left Y-CORRDINATE
   40 I = I + 1
      READ (5,50) XID1, XID2, KODE, KODE1, YCOR(I), ZCOR(I)
   50 FORMAT (2A4, 2I2, 2F8.2)
      IF (YCOR(I)) 90, 60, 70
   60 LS = LS + 1
      GO TO 90
   70 GO TO (80, 90), LS
   80 YCOR(I) = -YCOR(I)
   90 IF (YCOR(I)) 100, 110, 120
  100 YCOR2 = YCOR(I)
      GO TO 120
  110 ILOW = I
  120 IF (KODE1 - 1) 150, 130, 140
```

```
 130 ILOB = I
     GO TO 150
 140 IROB = I
 150 IF (KODE) 40, 40, 160
 160 NO = I
C     Y-CORRDINATE referenced to left most point of section
     NO1 = NO - 1
     YCOR3(1) = YCOR(1)
     ZCOR3(1) = ZCOR(1)
     NO2 = 1
     DO 190 I = 1, NO1
       J = I + 1
       YCOR3(J) = YCOR(J)
       ZCOR3(J) = ZCOR(J)
       IF (YCOR(J)) 170, 180, 170
 170   NO2 = NO2 + 1
       GO TO 190
 180   IZERO = NO2 + 1
 190 CONTINUE
     IZERO1 = IZERO - 1
     DO 200 K = 1, IZERO1
       J = IZERO - K
       YCOR(K) = YCOR3(J)
 200 ZCOR(K) = ZCOR3(J)
     K = IZERO
     DO 210 L = K, NO1
       M = L + 1
       YCOR(L) = YCOR(M)
 210 ZCOR(L) = ZCOR(M)
     ILOW = IZERO1
     ILOB = IZERO - ILOB
     IROB = IROB - 1
     NO = NO1
     DO 220 I = 1, NO
 220 YCOR(I) = YCOR(I) - YCOR2
C     Y-CORRDINATES of out-of-bank points,elev differnce in section,and
C     elev computation points
     YL = YCOR(ILOB)
     YR = YCOR(IROB)
     IF (ZCOR(ILOB) - ZCOR(IROB)) 230, 230, 240
 230 ZL = ZCOR(ILOB)
     GO TO 250
 240 ZL = ZCOR(IROB)
 250 IF (ZCOR(1) - ZCOR(NO)) 260, 260, 270
 260 ZMAX = ZCOR(1)
     GO TO 280
 270 ZMAX = ZCOR(NO)
 280 ZLOW = ZCOR(ILOW)
     ZU = ZMAX - ZU1
     DELZ1 = (ZMAX - ZLOW) / DELN
     DELZ = DELZ1
 290 GO TO (300, 10), LL
 300 I = 1
     IC1 = 0
     ZCOR1(I) = ZLOW + DELZ
     IF (ZCOR1(I) - ZMAX) 310, 320, 320
 310 DELZ = DELZ + DELZ1
     GO TO 330
 320 ZCOR1(I) = ZMAX
     LL = 2
```

```
C     initialize for section computations
 330 K = 1
     XRA(K) = 0.0
     XRWP(K) = 0.0
     XCA(K) = 0.0
     XCWP(K) = 0.0
     XLA(K) = 0.0
     XLWP(K) = 0.0
     TW(K) = 0.0
     TW1 = 0.0
     TW2 = 0.0
     TW3 = 0.0
     TW4 = 0.0
C     section computations for area,wetted perimeter,and top width
     N2 = NO
     N22 = N2 - 1
     DO 480 J = 1, N22
       IF (ZCOR(J) - ZCOR1(K)) 340, 350, 360
 340   IF (ZCOR(J + 1) - ZCOR1(K)) 370, 370, 380
 350   IF (ZCOR(J + 1) - ZCOR1(K)) 370, 400, 400
 360   IF (ZCOR(J + 1) - ZCOR1(K)) 390, 400, 400
 370   AREA(J,K) = XAREA(ZCOR1(K),ZCOR(J),ZCOR(J + 1),YCOR(J + 1),YCOR(
    1  J))
       WP(J,K) = XWP(YCOR(J + 1),YCOR(J),ZCOR(J + 1),ZCOR(J))
       TW1 = YCOR(J + 1) - YCOR(J)
       GO TO 410
 380   YCOR1(K) = XINT(YCOR(J),YCOR(J + 1),ZCOR(J),ZCOR(J + 1),ZCOR1(K)
    1  )
       AREA(J,K) = XAREA(ZCOR1(K),ZCOR1(K),ZCOR(J),YCOR1(K),YCOR(J))
       WP(J,K) = XWP(YCOR1(K),YCOR(J),ZCOR1(K),ZCOR(J))
       TW2 = YCOR1(K) - YCOR(J)
       GO TO 410
 390   YCOR1(K) = XINT(YCOR(J),YCOR(J + 1),ZCOR(J),ZCOR(J + 1),ZCOR1(K)
    1  )
       AREA(J,K) = XAREA(ZCOR1(K),ZCOR1(K),ZCOR(J + 1),YCOR(J + 1),
    1  YCOR1(K))
       WP(J,K) = XWP(YCOR(J + 1),YCOR1(K),ZCOR1(K),ZCOR(J + 1))
       TW3 = YCOR(J + 1) - YCOR1(K)
       GO TO 410
 400   AREA(J,K) = 0.0
       WP(J,K) = 0.0
       TW4 = 0.0
 410   IF (YCOR(J) - YL) 420, 440, 440
 420   IF (YCOR(J + 1) - YL) 430, 430, 440
 430   XLA(K) = XLA(K) + AREA(J,K)
       XLWP(K) = XLWP(K) + WP(J,K)
       GO TO 470
 440   IF (YCOR(J + 1) - YR) 450, 450, 460
 450   XCA(K) = XCA(K) + AREA(J,K)
       XCWP(K) = XCWP(K) + WP(J,K)
       GO TO 470
 460   XRA(K) = XRA(K) + AREA(J,K)
       XRWP(K) = XRWP(K) + WP(J,K)
 470   CONTINUE
       TW(K) = TW(K) + TW1 + TW2 + TW3 + TW4
       TW1 = 0.0
       TW2 = 0.0
       TW3 = 0.0
       TW4 = 0.0
 480 CONTINUE
```

```
C     section computations for total area,hydraulic radius,CVY*N,Q*N,
C     and hydraulic depths
      AHZ(K) = XLA(K) + XCA(K) + XRA(K)
      WPHZ(K) = XLWP(K) + XCWP(K) + XRWP(K)
      IF (ZCOR1(K) - ZU) 490, 510, 510
  490 IF (ZCOR1(K) - ZL) 510, 510, 500
  500 D = ZU - ZL
      D1 = ZCOR1(K) - ZL
      AD = AHZ(K) - XCA(K)
      WPD = WPHZ(K) - XCWP(K)
      AMOD(K) = XCA(K) + (D1/D) * AD
      WPMOD(K) = XCWP(K) + (D1/D) * (WPD)
      GO TO 520
  510 AMOD(K) = AHZ(K)
      WPMOD(K) = WPHZ(K)
  520 CONTINUE
      RH(K) = AHZ(K) / WPHZ(K)
      IF (XRWP(K)) 530, 530, 540
  530 RVR(K) = 0.0
      GO TO 550
  540 RVR(K) = XRA(K) / XRWP(K)
  550 IF (XLWP(K)) 560, 560, 570
  560 RVL(K) = 0.0
      GO TO 580
  570 RVL(K) = XLA(K) / XLWP(K)
  580 RVC(K) = XCA(K) / XCWP(K)
      RMOD(K) = AMOD(K) / WPMOD(K)
      XKNHZ(K) = XKN(RH(K),AHZ(K))
      XKNVR(K) = XKN(RVR(K),XRA(K))
      XKNVC(K) = XKN(RVC(K),XCA(K))
      XKNVL(K) = XKN(RVL(K),XLA(K))
      XKNVT(K) = XR * XKNVR(K) + XKNVC(K) + XL * XKNVL(K)
      XKNMO(K) = XKN(RMOD(K),AMOD(K))
      XQNHZ(K) = XQN(RH(K),AHZ(K),SLOPC)
      XQNVR(K) = XQN(RVR(K),XRA(K),SLOPR)
      XQNVC(K) = XQN(RVC(K),XCA(K),SLOPC)
      XQNVL(K) = XQN(RVL(K),XLA(K),SLOPL)
      XQNVT(K) = XR * XQNVR(K) + XQNVC(K) + XL * XQNVL(K)
      XQNMO(K) = XQN(RMOD(K),AMOD(K),SLOPC)
      DEPTH(K) = ZCOR1(K) - ZLOW
  590 XHYD(K) = AHZ(K) / TW(K)
      IC = IC + 1
      IC1 = IC1 + 1
      IF (ZZ .LE. 1.0) GO TO 610
      PUNCH 600, AHZ(I), XQNHZ(I)
  600 FORMAT (20X, 2F10.5, 50X)
  610 WRITE (6,620) ZCOR1(I), DEPTH(I), AHZ(I), XQNHZ(I), WPHZ(I),
     1TW(I), XID1, XID2, IC1, IC
  620 FORMAT (' ', F9.4, 5F10.5, 2X, A4, 2X, A4, 2X, I3, I3)
      GO TO 290
  630 STOP
      END
```

```
C     This code performs storage flood routing without coefficients
C
C     The orginal code ,Brakensiek (1966), was modified by
C     Engman (1974). The code as shown in this thesis
C     was adapted , by Loague (1982), for use at UBC.
C
C     C = lower bound for wanted table
C     D = upper bound for wanted table
C     E = lower bound for argument table
C     F = upper bound for argument table
C     G = argument
C     DELT = time increment used in routing computations
C            (constant) in seconds
C     DELT1 = same as DELT , saved for initialization
C     DELA = area increment in rating table , used to
C            establish an upper of lower bound
C     DELA = same as DELA , saved for initialization
C     TOLR = tolerance , iteration cutoff
C     N1 = number of inflow hydrograph entries
C     N2 = number of tabulated rating function entries
C     N5 = 0   read all lateral inflow cards
C        = 1   no input-lateral inflows all zero
C        = 2   laterla inflows all equal to one value (read)
C     ZZ = card punch trigger (if .GT. 1.0 punching cards)
C
      DIMENSION AREA1(2000), DISCH1(2000), Q1(2000), A1(2000),
     1          AREA2(2000)
      DIMENSION DISCH2(2000), Q2(2000), A2(2000), QL1(2000), QL2(2000)
      DIMENSION QN1(2000), QN2(2000)
      COMMON AREA1, N1, I, J, K, M, X1, DELT, DELT1
      COMMON N2, X4, X2, DELA, DELA1, ANEW, TOLR, X3
      COMMON A1, DELX, QL1, QL2
      COMMON QN1, QN2
   10 FORMAT (F5.0, F8.4)
   20 FORMAT (20X, F12.7, 48X)
   30 FORMAT (F5.3)
   40 FORMAT (20X, 2F10.5, 40X)
   50 FORMAT (20X, F12.7, 48X)
   60 FORMAT (4F5.0, F7.0, 3I3, F5.0)
      XINT(C,D,E,F,G) = C + ((G - E)/(F - E)) * (D - C)
      READ (5,60) DELT, DELT1, DELA, DELA1, TOLR, N1, N2, N5, ZZ
C      read first section rating and inflow
      DO 70 I = 1, N1
   70 READ (5,50) Q1(I)
      DO 80 I = 1, N2
   80 READ (5,40) AREA1(I), QN1(I)
      IF (N5 - 1) 90, 140, 160
   90 DO 130 I = 1, N1
        READ (5,20) QL1(I)
        IF (QL1(I) - 100.) 120, 100, 100
  100   IKE = I
        DO 110 IMP = IKE, N1
  110   QL1(IMP) = 0.0
        GO TO 180
  120   CONTINUE
  130 CONTINUE
      GO TO 180
  140 DO 150 I = 1, N1
  150 QL1(I) = 0.0
      GO TO 180
```

```
 160 READ (5,20) QL1(1)
     N7 = N1 - 1
     DO 170 I = 2, N7
 170 QL1(I) = QL1(1)
     QL1(N1) = 0.0
C     calculate first section areas
 180 READ (5,30) XN1
     WRITE (6,190) XN1
 190 FORMAT ('1', 15X, 'XN1=', F8.4)
     DO 200 I = 1, N2
 200 DISCH1(I) = QN1(I) / XN1
 210 DO 220 I = 1, N1
       CALL TBLLP(DISCH1, Q1)
 220 A1(I) = XINT(AREA1(K),AREA1(J),DISCH1(K),DISCH1(J),Q1(I))
C     read second section rating and lateral inflow
     LL1 = 0
     LL2 = 0
     N11 = N1
 230 M = N1
 240 I = 1
     DELT = DELT1
     N1 = N11
     J1 = N1 + 1
     IF (M - N1) 270, 270, 250
 250 DO 260 J = J1, M
 260 QL2(J) = 0.0
 270 CONTINUE
     DO 280 I = 1, N2
 280 READ (5,40,END=670) AREA2(I), QN2(I)
     IF (N5 - 1) 310, 360, 290
 290 READ (5,20) QL2(1)
     N7 = N1 - 1
     DO 300 I = 2, N7
 300 QL2(I) = QL2(1)
     QL2(N1) = 0.0
     GO TO 380
 310 DO 350 I = 1, N1
       READ (5,20) QL2(I)
       IF (QL2(I) - 100.) 340, 320, 320
 320   IPE = I
       DO 330 IMP = IPE, N1
 330   QL2(IMP) = 0.0
       GO TO 380
 340   CONTINUE
 350 CONTINUE
     GO TO 380
 360 DO 370 I = 1, N1
 370 QL2(I) = 0.0
C     read second section initial value ane delx
 380 I = 1
     READ (5,10) DELX, Q2(I)
     READ (5,30) XN2
     DO 390 I = 1, N2
 390 DISCH2(I) = QN2(I) / XN2
     I = 1
     CALL TBLLP(DISCH2, Q2)
     A2(I) = XINT(AREA2(K),AREA2(J),DISCH2(K),DISCH2(J),Q2(I))
     J = 1
     N1 = M
C     routing during inflow
```

```
 400 ALPHA = (A1(I) + A2(I)) / 2.
     I = J + 1
     BETA = (DELT/DELX) * Q1(I) + (-A1(I) + (DELT)*(QL1(I) + QL2(I))) /
    1 2.
     X1 = ALPHA + BETA
     IF (X1 - TOLR) 410, 410, 430
 410 Q2(I) = Q2(1)
     A2(I) = A2(1)
     DELT = DELT + DELT1
     I = I - J
     J = J + 1
     IF (J - N1) 400, 420, 420
 420 I = J
     GO TO 470
 430 CALL SOLVE(DISCH1, DISCH2, Q1, Q2, AREA2, A2)
     IF (Q2(I) - Q2(1) - TOLR) 440, 440, 450
 440 Q2(I) = Q2(1)
     A2(I) = A2(1)
 450 CONTINUE
     DELT = DELT1
     IF (I - N1) 460, 470, 470
 460 J = I
     GO TO 400
C     routing after inflow
 470 N3 = 0
 480 J = I
     N3 = N3 + 1
     IF (J - 1999) 510, 490, 490
 490 WRITE (6,500)
 500 FORMAT (' LATERAL INFLOW TOO LARGE,SUBSCRIPT I > 2000')
 510 ALPHA = (A1(N1) + A2(I)) / 2.
     I = J + 1
     BETA = (DELT/DELX) * Q1(N1) + (-A1(N1) + DELT*(QL1(N1) + QL2(N1)))
    1 / 2.
     X1 = ALPHA + BETA
     IF (X1 - TOLR) 520, 520, 530
 520 Q2(I) = Q1(N1)
     A2(I) = A1(N1)
     GO TO 550
 530 CALL SOLVE(DISCH1, DISCH2, Q1, Q2, AREA2, A2)
     IF (Q2(I) - Q1(N1) - TOLR) 520, 520, 540
 540 GO TO 480
 550 M = M + N3
     I2 = N1 + 1
     DO 560 I = I2, M
       QL1(I) = 0.0
       QL2(I) = 0.0
       A1(I) = A1(N1)
 560 Q1(I) = Q1(N1)
     LL1 = LL1 + 1
     LL2 = LL1 + 1
C     print out and interchange
     IF (LL1 .GT. 1) GO TO 580
     WRITE (6,570) TOLR, XN2, DELT1, DELA, DELX
 570 FORMAT (' ', 15X, 'TOLR=', F8.7, 5X, 'XN2=', F8.4, 5X, 'DELT=',
    1       F10.5, 5X, 'DELA=', F10.5, 5X, 'DELX=', F8.0, 5X///)
     GO TO 600
 580 WRITE (6,590) TOLR, XN2, DELT1, DELA, DELX
 590 FORMAT ('1', 15X, 'TOLR=', F8.7, 5X, 'XN2=', F8.4, 5X, 'DELT=',
    1       F10.5, 5X, 'DELA=', F10.5, 5X, 'DELX=', F8.0, 5X///)
```

```
 600 WRITE (6,610) LL1, LL2
 610 FORMAT (20X, 'IN SECTION NO =', I3, 14X, ' OUT SECTION NO =', I3)
     WRITE (6,620)
 620 FORMAT (24X, ' IN AREA', 6X, ' IN DISCH', 10X, ' OUT AREA', 5X,
    1        ' OUT DISCH', 10X, 'TOTAL TIME , SECONDS')
 630 FORMAT (20X, 2F13.5, 5X, 2F13.5, 15X, F10.0)
     DO 650 I = 1, M
       CUMT = DELT1 * FLOAT(I) - DELT1
       WRITE (6,630) A1(I), Q1(I), A2(I), Q2(I), CUMT
 640   QL1(I) = QL2(I)
       A1(I) = A2(I)
 650 Q1(I) = Q2(I)
C      interchange rating tables
     DO 660 I = 1, N2
       AREA1(I) = AREA2(I)
 660 DISCH1(I) = DISCH2(I)
     GO TO 240
 670 CONTINUE
     DO 690 I = 1, M
       WRITE (8,680) Q1(I)
 680   FORMAT (' ', 19X, F10.5, 50X)
 690 CONTINUE
     DO 710 I = 1, M
       IF (ZZ .LE. 1.0) GO TO 720
       PUNCH 700, Q1(I)
 700   FORMAT (20X, F10.5, 50X)
 710 CONTINUE
 720 STOP
     END
     SUBROUTINE SOLVE(DISCH1, DISCH2, Q1, Q2, AREA2, A2)
     DIMENSION AREA1(2000), DISCH1(2000), Q1(2000), A1(2000),
    1          AREA2(2000)
     DIMENSION DISCH2(2000), Q2(2000), A2(2000), QL1(2000), QL2(2000)
     DIMENSION QN1(2000), QN2(2000)
     COMMON AREA1, N1, I, J, K, M, X1, DELT, DELT1
     COMMON N2, X4, X2, DELA, DELA1, ANEW, TOLR, X3
     COMMON A1, DELX, QL1, QL2
     COMMON QN1, QN2
     XINT(C,D,E,F,G) = C + ((G - E)/(F - E)) * (D - C)
     AU = 0.
     FAU = 0.
     AL = 0.
     FAL = 0.
     DELA = DELA1
  10 A2(I) = A2(I - 1)
  20 CALL TBLLP(AREA2, A2)
     Q2(I) = XINT(DISCH2(K),DISCH2(J),AREA2(K),AREA2(J),A2(I))
     X2 = (DELT/DELX) * Q2(I) + (A2(I)) / 2.
     X2 = X2 - X1
     IF (X2) 70, 130, 30
  30 DELA = DELA1
     AU = A2(I)
     FAU = X2
     IF (AL) 110, 40, 110
  40 A2(I) = A2(I) - DELA
  50 IF (A2(I)) 60, 60, 20
  60 DELA = DELA * .5
     A2(I) = A2(I) + DELA
     GO TO 50
  70 DELA = DELA1
```

```
      AL = A2(I)
      FAL = -X2
      IF (AU) 110, 80, 110
   80 A2(I) = A2(I) + DELA
   90 IF (A2(I) - AREA2(N2)) 20, 20, 100
  100 DELA = DELA * .5
      A2(I) = A2(I) - DELA
      GO TO 90
  110 ANEW = AU - (FAU/(FAU + FAL)) * (AU - AL)
      X3 = ANEW - A2(I)
      X3 = ABS(X3)
      IF (X3 - TOLR) 130, 130, 120
  120 A2(I) = ANEW
      GO TO 20
  130 A2(I) = ANEW
      CALL TBLLP(AREA2, A2)
      Q2(I) = XINT(DISCH2(K),DISCH2(J),AREA2(K),AREA2(J),A2(I))
      RETURN
      END
      SUBROUTINE TBLLP(A, B)
C       A=argument table
C       B=argument
      DIMENSION A(2000), B(2000)
      DIMENSION AREA1(2000), DISCH1(2000), Q1(2000), A1(2000),
     1          AREA2(2000)
      DIMENSION DISCH2(2000), Q2(2000), A2(2000), QL1(2000), QL2(2000)
      DIMENSION QN1(2000), QN2(2000)
      COMMON AREA1, N1, I, J, K, M, X1, DELT, DELT1
      COMMON N2, X4, X2, DELA, DELA1, ANEW, TOLR, X3
      COMMON A1, DELX, QL1, QL2
      COMMON QN1, QN2
      X4 = B(I)
      IF (X4) 20, 10, 20
   10 J = 2
      K = J - 1
      RETURN
   20 DO 40 J = 2, N2
        IF (A(J) - X4) 40, 30, 30
   30   K = J - 1
        RETURN
   40 CONTINUE
      WRITE (6,50)
   50 FORMAT ('      WHOOPS!')
      RETURN
      END
```

APPENDIX C

Results from rainfall-runoff regression analysis of six Mahantango Creek Subwatershed events (two rain gages):

C.1 Correlation matrices of nine Mahantango Creek Subwatershed regression variables, with and without data reduction.

C.2 Summary of 168 Mahantango Creek Subwatershed linear regression models and their respective verification efficiencies.

APPENDIX C.1

Without base flow separation

	$V_{PPT}^{(B)}$	$V_{PPT}^{(E)}$	$\overline{PPT}^{(B)}$	$\overline{PPT}^{(E)}$	$PPT_D^{(B)}$	$PPT_D^{(E)}$	V_Q	Q_{PK}	${}^{T}Q_{PK}$
$V_{PPT}^{(B)}$	1.0								
$V_{PPT}^{(E)}$	.9708	1.0							
$\overline{PPT}^{(B)}$	.0138	.1626	1.0						
$\overline{PPT}^{(E)}$	.1614	.2875	.9795	1.0					
$PPT_D^{(B)}$	.7364	.6124	-.5926	-.4922	1.0				
$PPT_D^{(E)}$	.7066	.6491	-.5051	-.4517	.9427	1.0			
V_Q	.3758	.3283	-.3875	-.4189	.7467	.8553	1.0		
Q_{PK}	.8863	.9434	.1466	.2769	.4641	.5023	.0792	1.0	
${}^{T}Q_{PK}$	.1071	.0160	-.7734	-.7753	.6855	.6764	.6902	-.0818	1.0

With base flow separation

	$V_{PPT}^{(B)}$	$V_{PPT}^{(E)}$	$\overline{PPT}^{(B)}$	$\overline{PPT}^{(E)}$	$PPT_D^{(B)}$	$PPT_D^{(E)}$	V_Q	Q_{PK}	${}^{T}Q_{PK}$
$V_{PPT}^{(B)}$	1.0								
$V_{PPT}^{(E)}$	.9708	1.0							
$\overline{PPT}^{(B)}$	.0138	.1626	1.0						
$\overline{PPT}^{(E)}$	.1614	.2875	.9795	1.0					
$PPT_D^{(B)}$	.7364	.6124	-.5926	-.4922	1.0				
$PPT_D^{(E)}$	.7066	.6491	-.5051	-.4517	.9427	1.0			
V_Q	.8270	.8793	-.0616	.0576	.5639	.6121	1.0		
Q_{PK}	.8854	.9388	.1347	.2687	.4667	.4966	.9507	1.0	
${}^{T}Q_{PK}$	.1071	.0160	-.7734	-.7753	.6855	.6764	.1992	-.0750	1.0

APPENDIX C.2

$V_{PPT}^{(B)}$	$V_{PPT}^{(E)}$	$\overline{PPT}^{(B)}$	$\overline{PPT}^{(E)}$	$PPT_D^{(B)}$	$PPT_D^{(E)}$	V_Q	Q_{PK}	$^TQ_{PK}$	r_1^2	r_2^2
●	●			●	●	●			.88	.93
●	●			●		●			.76	.80
●	●				●	●			.84	.80
●				●	●	●			.84	.73
	●			●	●	●			.78	.85
●	●					●			.16	.79
●				●		●			.62	.69
●					●	●			.69	.84
	●			●		●			.77	.58
	●				●	●			.82	.78
				●	●	●			.76	.38
●						●			.68	.14
	●					●			.77	.11
				●		●			.32	.56
					●	●			.38	.73

$V_{PPT}^{(B)}$	$V_{PPT}^{(E)}$	$\overline{PPT}^{(B)}$	$\overline{PPT}^{(E)}$	$PPT_D^{(B)}$	$PPT_D^{(E)}$	V_Q	Q_{PK}	$T_{Q_{PK}}$	r_1^2	r_2^2
●	●	●	●				●		.99	.99
●	●	●		●			●		1.0	.99
●	●	●			●		●		1.0	1.0
●	●			●	●		●		.93	.93
●	●		●		●		●		1.0	1.0
●	●		●	●			●		.99	.98
●		●	●	●			●		.96	.96
●			●	●	●		●		.97	.97
	●	●	●	●			●		1.0	1.0
	●	●	●		●		●		1.0	.99
	●	●		●	●		●		1.0	1.0
	●		●	●	●		●		1.0	1.0
		●	●	●	●		●		1.0	1.0
●	●	●					●		.92	.90
●	●		●				●		.91	.90

$V_{PPT}^{(B)}$	$V_{PPT}^{(E)}$	$\overline{PPT}^{(B)}$	$\overline{PPT}^{(E)}$	$PPT_D^{(B)}$	$PPT_D^{(E)}$	V_Q	Q_{PK}	$^TQ_{PK}$	r_1^2	r_2^2
●	●			●			●		.91	.90
●	●				●		●		.92	.91
●		●	●				●		.80	.80
●			●	●			●		.95	.95
●				●	●		●		.89	.88
●		●		●			●		.93	.93
●		●			●		●		.82	.82
●			●		●		●		.82	.82
	●	●	●				●		.90	.89
	●	●		●			●		.99	1.0
	●	●			●		●		.96	.96
	●		●	●			●		.97	.98
	●			●	●		●		.90	.91
	●		●		●		●		.97	.98
		●	●	●			●		.61	.61

$V_{PPT}^{(B)}$	$V_{PPT}^{(E)}$	$\overline{PPT}^{(B)}$	$\overline{PPT}^{(E)}$	$PPT_D^{(B)}$	$PPT_D^{(E)}$	V_Q	Q_{PK}	$^{T}Q_{PK}$	r_1^2	r_2^2
		●	●		●		●		.73	.73
		●		●	●		●		.48	.80
			●	●	●		●		.58	.57
●	●						●		.91	.89
●		●					●		.80	.80
●			●				●		.80	.80
●				●			●		.86	.86
●					●		●		.82	.82
	●	●					●		.88	.89
	●		●				●		.89	.88
	●			●			●		.90	.91
	●				●		●		.91	.90
		●	●				●		.46	.48
		●		●			●		.49	.48
		●			●		●		.45	.47

$V_{PPT}^{(B)}$	$V_{PPT}^{(E)}$	$\overline{PPT}^{(B)}$	$\overline{PPT}^{(E)}$	$PPT_D^{(B)}$	$PPT_D^{(E)}$	V_Q	Q_{PK}	$^TQ_{PK}$	r_1^2	r_2^2
			●	●			●		.55	.55
			●		●		●		.57	.55
				●	●		●		.25	.25
●							●		.78	.79
	●						●		.88	.89
		●					●		.02	.02
			●				●		.07	.08
				●			●		.22	.22
					●		●		.25	.25
●	●			●	●			●	.99	.99
●	●			●				●	.83	.83
●	●				●			●	.79	.79
●				●	●			●	.83	.83
	●			●	●			●	.79	.79
●	●							●	.15	.15

$V_{PPT}^{(B)}$	$V_{PPT}^{(E)}$	$\overline{PPT}^{(B)}$	$\overline{PPT}^{(E)}$	$PPT_D^{(B)}$	$PPT_D^{(E)}$	V_Q	Q_{PK}	$^{T}Q_{PK}$	r_1^2	r_2^2
●				●				●	.82	.82
●					●			●	.73	.73
	●			●				●	.73	.73
	●				●			●	.77	.77
				●	●			●	.48	.48
●								●	.01	.01
	●							●	.0	.0
				●				●	.47	.47
					●			●	.46	.46

r – Coefficient of determination

r_1 – Regression (multiple) models for events 20, 43, 43b, 44, 45, and 46 with no baseflow separation

r_2 – Regression (multiple) models for events 20, 43, 43b, 44, 45, and 46 with baseflow separation

B,E – Rain gages

APPENDIX D

Example implementation of the distributed model:

D.1 Computer generated soil characteristic curved for the Mahantango Creek Subwatershed.

D.2 Computer generated lateral inflow hydrographs for

D.3 Computer generated normal discharge rating function for a 1:1.5 prismatic triangular open channel of 2% slope.

D.4 Computer generated open channel flow routing for Mahantango Creek Subwatershed selected event #16.

APPENDIX D.1

#2 BERKS (145) SILT LOAM

NC	THET15	THETAE	THETA2	PPSI15	PSI1	PSIE	PSI2	CONE	TF	TM
	(CM3/CM3)			(CM OF WATER)				(CM/DAY)	DEG.C	
48	0.1100	0.3800	0.4700	15306.0	15306.0	6.0	3.0	108.0000	20.0	20.0

CLASS	PRESSURE (CM)	THETA (CM3/CM3)	PERMEABILITY	CONDUCTIVITY (CM/DAY)	DIFFUSSIVITY (CM2/DAY	DPSI/DTHETA
1	15306.0	0.1100	1.03E-08	1.11E-06	6.09E-01	5.46E+05
2	13389.4	0.1138	4.16E-08	4.49E-06	2.14E+00	4.78E+05
3	10246.3	0 1213	9.47E-08	1.02E-05	3.74E+00	3.65E+05
4	7841.4	0.1288	1.81E-07	1.96E-05	5.47E+00	2.80E+05
5	6001.1	0.1363	3.18E-07	3.43E-05	7.34E+00	2.14E+05
6	4593.1	0.1438	5.32E-07	5.75E-05	9.41E+00	1.64E+05
7	3515.7	0.1513	8.67E-07	9.37E-05	1.17E+01	1.25E+05
8	2691.2	0.1587	1.39E-06	1.50E-04	1.44E+01	9.59E+04
9	2060.4	0.1662	2.22E-06	2.39E-04	1.76E+01	7.34E+04
10	1577.8	0.1737	3.51E-06	3.80E-04	2 13E+01	5.61E+04
11	1208.4	0.1812	5.56E-06	6.01E-04	2.58E+01	4.29E+04
12	925.8	0.1887	8.80E-06	9.50E-04	3.12E+01	3.29E+04
13	709.6	0.1962	1.39E-05	1.50E-03	3.78E+01	2.51E+04
14	544.1	0.2037	2.21E-05	2.38E-03	4.59E+01	1.92E+04
15	417.5	0.2112	3.50E-05	3.78E-03	5.57E+01	1.47E+04
16	320.7	0.2187	5.56E-05	6.01E-03	6.77E+01	1.13E+04
17	246.5	0.2262	8.84E-05	9.55E-03	8.23E+01	8.62E+03
18	189.8	0.2337	1.41E-04	1.52E-02	1.00E+02	6.60E+03
19	146.4	0.2412	2.24E-04	2.42E-02	1.22E+02	5.05E+03
20	113.2	0.2487	3.56E-04	3.84E-02	1.48E+02	3.86E+03
21	87.8	0.2562	5.64E-04	6.10E-02	1.80E+02	2.95E+03
22	68.4	0.2637	8.94E-04	9.65E-02	2.18E+02	2.26E+03
23	53.5	0.2712	1.41E-03	1.52E-01	2.64E+02	1.73E+03
24	42.1	0.2787	2.22E-03	2.39E-01	3.17E+02	1.32E+03
25	33.4	0.2862	3.46E-03	3.73E-01	3.78E+02	1.01E+03
26	26.7	0.2937	5.35E-03	5.78E-01	4.48E+02	7.75E+02
27	21.6	0.3012	8.19E-03	8.85E-01	5.25E+02	5.93E+02
28	17.7	0.3087	1.24E-02	1.34E+00	6.07E+02	4.54E+02
29	14.7	0.3162	1.85E-02	1.99E+00	6.93E+02	3.47E+02
30	12.4	0.3237	2.71E-02	2.92E+00	7.77E+02	2.66E+02
31	10.7	0.3312	3.89E-02	4.20E+00	8.55E+02	2.03E+02
32	9.4	0.3387	5.49E-02	5.92E+00	9.22E+02	1.56E+02
33	8.3	0.3462	7.57E-02	8.17E+00	9.73E+02	1.19E+02
34	7.6	0.3537	1.02E-01	1.10E+01	1.00E+03	9.11E+01
35	7.0	0.3612	1.35E-01	1.46E+01	1.02E+03	6.97E+01
36	6.5	0.3687	1.75E-01	1.89E+01	1.01E+03	5.33E+01
37	6.1	0.3762	2.22E-01	2.39E+01	3.48E+02	1.45E+01
38	5.9	0.3837	2.76E-01	2.98E+01	4.86E+02	1.63E+01
39	5.8	0.3912	3.37E-01	3.64E+01	6.66E+02	1.83E+01
40	5.7	0.3987	4.04E-01	4.37E+01	8.98E+02	2.06E+01
41	5.5	0.4062	4.78E-01	5.16E+01	1.19E+03	2.31E+01
42	5.3	0.4137	5.58E-01	6.02E+01	1.56E+03	2.59E+01
43	5.1	0.4212	6.44E-01	6.95E+01	2.02E+03	2.91E+01
44	4.9	0.4287	7.36E-01	7.95E+01	2.60E+03	3.26E+01
45	4.6	0.4362	8.36E-01	9.02E+01	3.31E+03	3.66E+01
46	4.3	0.4437	9.43E-01	1.02E+02	4.19E+03	4.11E+01
47	4.0	0.4512	1.06E+00	1.14E+02	5.28E+03	4.62E+01
48	3.6	0.4587	1.19E+00	1.28E+02	6.64E+03	5.18E+01
49	3.2	0.4662	1.33E+00	1.43E+02	8.34E+03	5.82E+01

THETAE = 0.3800 #2 BERKS (145) SILT LOAM KE(FT/HRS) = 1.4764E-01

CLASS	INITIAL FLUX(CM/HRS)	SORPTIVITY(CM/HRS**0.5)	FI(FT/HRS)	FS(FT/HRS**.5)	THETA/THETA2	THETA MID.INT.
1	9.58E+01	3.04E+00	3.14E+00	9.99E-02	0.2340	0.1100
2	9.53E+01	3.03E+00	3.13E+00	9.93E-02	0.2500	0.1138
3	9.42E+01	2.99E+00	3.09E+00	9.80E-02	0.2660	0.1213
4	9.30E+01	2.95E+00	3.05E+00	9.68E-02	0.2819	0.1288
5	9.18E+01	2.91E+00	3.01E+00	9.55E-02	0.2979	0.1363
6	9.07E+01	2.87E+00	2.97E+00	9.42E-02	0.3138	0.1438
7	8.95E+01	2.83E+00	2.94E+00	9.29E-02	0.3298	0.1513
8	8.83E+01	2.79E+00	2.90E+00	9.16E-02	0.3457	0.1587
9	8.70E+01	2.75E+00	2.86E+00	9.02E-02	0.3617	0.1662
10	8.58E+01	2.71E+00	2.81E+00	8.89E-02	0.3777	0.1737
11	8.45E+01	2.67E+00	2.77E+00	8.75E-02	0.3936	0.1812
12	8.32E+01	2.62E+00	2.73E+00	8.61E-02	0.4096	0.1887
13	8.19E+01	2.58E+00	2.69E+00	8.47E-02	0.4255	0.1962
14	8.06E+01	2.54E+00	2.64E+00	8.32E-02	0.4415	0.2037
15	7.92E+01	2.49E+00	2.60E+00	8.17E-02	0.4574	0.2112
16	7.79E+01	2.45E+00	2.55E+00	8.02E-02	0.4734	0.2187
17	7.65E+01	2.40E+00	2.51E+00	7.87E-02	0.4894	0.2262
18	7.50E+01	2.35E+00	2.46E+00	7.71E-02	0.5053	0.2337
19	7.36E+01	2.30E+00	2.41E+00	7.56E-02	0.5213	0.2412
20	7.21E+01	2.25E+00	2.37E+00	7.39E-02	0.5372	0.2487
21	7.06E+01	2.20E+00	2.32E+00	7.23E-02	0.5532	0.2562
22	6.91E+01	2.15E+00	2.27E+00	7.06E-02	0.5691	0.2637
23	6.75E+01	2.10E+00	2.21E+00	6.89E-02	0.5851	0.2712
24	6.59E+01	2.05E+00	2.16E+00	6.72E-02	0.6011	0.2787
25	6.43E+01	1.99E+00	2.11E+00	6.54E-02	0.6170	0.2862
26	6.26E+01	1.94E+00	2.05E+00	6.36E-02	0.6330	0.2937
27	6.09E+01	1.88E+00	2.00E+00	6.17E-02	0.6489	0.3012
28	5.92E+01	1.82E+00	1.94E+00	5.98E-02	0.6649	0.3087
29	5.75E+01	1.77E+00	1.89E+00	5.79E-02	0.6809	0.3162
30	5.57E+01	1.71E+00	1.83E+00	5.60E-02	0.6968	0.3237
31	5.39E+01	1.65E+00	1.77E+00	5.40E-02	0.7128	0.3312
32	5.20E+01	1.58E+00	1.71E+00	5.20E-02	0.7287	0.3387
33	5.01E+01	1.52E+00	1.64E+00	4.99E-02	0.7447	0.3462
34	4.82E+01	1.46E+00	1.58E+00	4.78E-02	0.7606	0.3537
35	4.63E+01	1.39E+00	1.52E+00	4.57E-02	0.7766	0.3612
36	4.43E+01	1.33E+00	1.45E+00	4.35E-02	0.7926	0.3687
37	4.22E+01	1.26E+00	1.39E+00	4.13E-02	0.8085	0.3762
38	4.01E+01	1.19E+00	1.32E+00	3.89E-02	0.8245	0.3837
39	3.78E+01	1.11E+00	1.24E+00	3.65E-02	0.8404	0.3912
40	3.55E+01	1.03E+00	1.16E+00	3.39E-02	0.8564	0.3987
41	3.30E+01	9.50E-01	1.08E+00	3.12E-02	0.8723	0.4062
42	3.04E+01	8.62E-01	9.96E-01	2.83E-02	0.8883	0.4137
43	2.76E+01	7.69E-01	9.05E-01	2.52E-02	0.9043	0.4212
44	2.46E+01	6.70E-01	8.07E-01	2.20E-02	0.9202	0.4287
45	2.14E+01	5.65E-01	7.03E-01	1.85E-02	0.9362	0.4362

#4 LECK KILL (66) SILT LOAM

NC	THET15	THETAE	THETA2	PPSI15	PSI1	PSIE	PSI2	CONE	TF	TM
	(CM3/CM3)				(CM OF WATER)			(CM/DAY)	DEG.C	
48	0.1200	0.3000	0.3700	15306.0	15306.0	6.0	3.0	79.0000	20.0	20.0

CLASS	PRESSURE (CM)	THETA (CM3/CM3)	PERMEABILITY	CONDUCTIVITY (CM/DAY)	DIFFUSSIVITY (CM2/DAY	DPSI/DTHETA
1	15305.9	0.1200	4.68E-09	3.70E-07	3.03E-01	8.19E+05
2	13315.0	0.1226	1.94E-08	1.53E-06	1.09E+00	7.13E+05
3	10076.4	0.1278	4.65E-08	3.68E-06	1.98E+00	5.39E+05
4	7625.9	0.1330	9.36E-08	7.39E-06	3.02E+00	4.08E+05
5	5771.6	0.1382	1.73E-07	1.36E-05	4.21E+00	3.09E+05
6	4368.5	0.1434	3.03E-07	2.40E-05	5.60E+00	2.34E+05
7	3306.8	0.1486	5.19E-07	4.10E-05	7.24E+00	1.77E+05
8	2503.4	0.1539	8.72E-07	6.89E-05	9.21E+00	1.34E+05
9	1895.5	0.1591	1.45E-06	1.15E-04	1.16E+01	1.01E+05
10	1435.5	0.1643	2.41E-06	1.90E-04	1.46E+01	7.66E+04
11	1087.5	0.1695	3.97E-06	3.14E-04	1.82E+01	5.79E+04
12	824.1	0.1747	6.55E-06	5.18E-04	2.27E+01	4.38E+04
13	624.8	0.1799	1.08E-05	8.53E-04	2.83E+01	3.32E+04
14	474.0	0.1851	1.78E-05	1.41E-03	3.53E+01	2.51E+04
15	359.9	0.1903	2.93E-05	2.32E-03	4.40E+01	1.90E+04
16	273.5	0.1955	4.84E-05	3.82E-03	5.49E+01	1.44E+04
17	208.2	0.2007	7.97E-05	6.29E-03	6.85E+01	1.09E+04
18	158.7	0.2059	1.31E-04	1.04E-02	8.53E+01	8.23E+03
19	121.3	0.2111	2.16E-04	1.70E-02	1.06E+02	6.23E+03
20	93.0	0.2164	3.54E-04	2.80E-02	1.32E+02	4.71E+03
21	71.6	0.2216	5.79E-04	4.57E-02	1.63E+02	3.57E+03
22	55.4	0.2268	9.43E-04	7.45E-02	2.01E+02	2.70E+03
23	43.1	0.2320	1.53E-03	1.21E-01	2.46E+02	2.04E+03
24	33.9	0.2372	2.46E-03	1.94E-01	3.00E+02	1.54E+03
25	26.8	0.2424	3.91E-03	3.09E-01	3.61E+02	1.17E+03
26	21.5	0.2476	6.16E-03	4.87E-01	4.31E+02	8.85E+02
27	17.5	0.2528	9.56E-03	7.55E-01	5.06E+02	6.69E+02
28	14.5	0.2580	1.46E-02	1.15E+00	5.84E+02	5.06E+02
29	12.2	0.2632	2.19E-02	1.73E+00	6.62E+02	3.83E+02
30	10.4	0.2684	3.21E-02	2.53E+00	7.34E+02	2.90E+02
31	9.1	0.2736	4.60E-02	3.63E+00	7.97E+02	2.19E+02
32	8.1	0.2789	6.44E-02	5.09E+00	8.44E+02	1.66E+02
33	7.3	0.2841	8.80E-02	6.95E+00	8.74E+02	1.26E+02
34	6.8	0.2893	1.18E-01	9.29E+00	8.83E+02	9.51E+01
35	6.3	0.2945	1.53E-01	1.21E+01	8.72E+02	7.19E+01
36	6.0	0.2997	1.96E-01	1.55E+01	3.05E+02	1.97E+01
37	5.9	0.3049	2.45E-01	1.94E+01	4.23E+02	2.18E+01
38	5.8	0.3101	3.01E-01	2.38E+01	5.75E+02	2.42E+01
39	5.6	0.3153	3.62E-01	2.86E+01	7.67E+02	2.68E+01
40	5.5	0.3205	4.29E-01	3.39E+01	1.01E+03	2.97E+01
41	5.3	0.3257	5.02E-01	3.97E+01	1.31E+03	3.30E+01
42	5.2	0.3309	5.81E-01	4.59E+01	1.68E+03	3.65E+01
43	5.0	0.3361	6.66E-01	5.26E+01	2.13E+03	4.05E+01
44	4.7	0.3414	7.56E-01	5.98E+01	2.68E+03	4.49E+01
45	4.5	0.3466	8.54E-01	6.75E+01	3.36E+03	4.98E+01
46	4.2	0.3518	9.59E-01	7.57E+01	4.18E+03	5.52E+01
47	3.9	0.3570	1.07E+00	8.47E+01	5.19E+03	6.12E+01
48	3.6	0.3622	1.20E+00	9.45E+01	6.41E+03	6.79E+01
49	3.2	0.3674	1.33E+00	1.05E+02	7.93E+03	7.52E+01

THETAE = 0.3000 #4 LECK KILL (66) SILT LOAM KE(FT/HRS) = 1.0799E-01

CLASS	INITIAL FLUX(CM/HRS)	SORPTIVITY(CM/HRS**0.5)	F1(FT/HRS)	FS(FT/HRS**.5)	THETA/THETA2	THETA MID.INT.
1	6.59E+01	2.09E+00	2.16E+00	6.85E-02	0.3243	0.1200
2	6.56E+01	2.08E+00	2.15E+00	6.81E-02	0.3384	0.1226
3	6.48E+01	2.05E+00	2.13E+00	6.73E-02	0.3525	0.1278
4	6.40E+01	2.02E+00	2.10E+00	6.64E-02	0.3666	0.1330
5	6.32E+01	2.00E+00	2.07E+00	6.55E-02	0.3806	0.1382
6	6.24E+01	1.97E+00	2.05E+00	6.46E-02	0.3947	0.1434
7	6.16E+01	1.94E+00	2.02E+00	6.38E-02	0.4088	0.1486
8	6.08E+01	1.92E+00	1.99E+00	6.29E-02	0.4229	0.1539
9	5.99E+01	1.89E+00	1.97E+00	6.19E-02	0.4369	0.1591
10	5.91E+01	1.86E+00	1.94E+00	6.10E-02	0.4510	0.1643
11	5.82E+01	1.83E+00	1.91E+00	6.01E-02	0.4651	0.1695
12	5.73E+01	1.80E+00	1.88E+00	5.91E-02	0.4792	0.1747
13	5.64E+01	1.77E+00	1.85E+00	5.81E-02	0.4932	0.1799
14	5.55E+01	1.74E+00	1.82E+00	5.71E-02	0.5073	0.1851
15	5.46E+01	1.71E+00	1.79E+00	5.61E-02	0.5214	0.1903
16	5.37E+01	1.68E+00	1.76E+00	5.51E-02	0.5355	0.1955
17	5.27E+01	1.65E+00	1.73E+00	5.41E-02	0.5495	0.2007
18	5.18E+01	1.62E+00	1.70E+00	5.30E-02	0.5636	0.2059
19	5.08E+01	1.58E+00	1.67E+00	5.19E-02	0.5777	0.2111
20	4.98E+01	1.55E+00	1.63E+00	5.08E-02	0.5918	0.2164
21	4.87E+01	1.51E+00	1.60E+00	4.97E-02	0.6059	0.2216
22	4.77E+01	1.48E+00	1.56E+00	4.85E-02	0.6199	0.2268
23	4.66E+01	1.44E+00	1.53E+00	4.74E-02	0.6340	0.2320
24	4.55E+01	1.41E+00	1.49E+00	4.62E-02	0.6481	0.2372
25	4.44E+01	1.37E+00	1.46E+00	4.50E-02	0.6622	0.2424
26	4.33E+01	1.33E+00	1.42E+00	4.37E-02	0.6762	0.2476
27	4.21E+01	1.29E+00	1.38E+00	4.25E-02	0.6903	0.2528
28	4.10E+01	1.26E+00	1.34E+00	4.12E-02	0.7044	0.2580
29	3.98E+01	1.22E+00	1.30E+00	3.99E-02	0.7185	0.2632
30	3.85E+01	1.17E+00	1.26E+00	3.85E-02	0.7325	0.2684
31	3.73E+01	1.13E+00	1.22E+00	3.72E-02	0.7466	0.2736
32	3.60E+01	1.09E+00	1.18E+00	3.58E-02	0.7607	0.2789
33	3.48E+01	1.05E+00	1.14E+00	3.44E-02	0.7748	0.2841
34	3.34E+01	1.00E+00	1.10E+00	3.30E-02	0.7888	0.2893
35	3.21E+01	9.60E-01	1.05E+00	3.15E-02	0.8029	0.2945
36	3.07E+01	9.15E-01	1.01E+00	3.00E-02	0.8170	0.2997
37	2.93E+01	8.67E-01	9.61E-01	2.84E-02	0.8311	0.3049
38	2.78E+01	8.17E-01	9.12E-01	2.68E-02	0.8452	0.3101
39	2.62E+01	7.64E-01	8.60E-01	2.51E-02	0.8592	0.3153
40	2.46E+01	7.09E-01	8.06E-01	2.33E-02	0.8733	0.3205
41	2.28E+01	6.51E-01	7.49E-01	2.14E-02	0.8874	0.3257
42	2.10E+01	5.90E-01	6.89E-01	1.94E-02	0.9015	0.3309
43	1.91E+01	5.26E-01	6.26E-01	1.73E-02	0.9155	0.3361
44	1.70E+01	4.57E-01	5.58E-01	1.50E-02	0.9296	0.3414
45	1.48E+01	3.85E-01	4.87E-01	1.26E-02	0.9437	0.3466

#5 HARTLETON (54) SILT LOAM

NC	THET15	THETAE	THETA2	PPSI15	PSI1	PSIE	PSI2	CONE	TF	TM
	(CM3/CM3)				(CM OF WATER)			(CM/DAY)	DEG.C	
48	0.1200	0.3400	0.4200	15306.0	15306.0	6.0	3.0	58.0000	20.0	20.0

CLASS	PRESSURE (CM)	THETA (CM3/CM3)	PERMEABILITY	CONDUCTIVITY (CM/DAY)	DIFFUSSIVITY (CM2/DAY	DPSI/DTHETA
1	15306.0	0.1200	6.39E-09	3.71E-07	2.48E-01	6.70E+05
2	13348.7	0.1231	2.62E-08	1.52E-06	8.88E-01	5.84E+05
3	10153.3	0.1294	6.17E-08	3.58E-06	1.59E+00	4.44E+05
4	7723.1	0.1356	1.22E-07	7.06E-06	2.39E+00	3.38E+05
5	5874.9	0.1419	2.20E-07	1.28E-05	3.28E+00	2.57E+05
6	4469.2	0.1481	3.80E-07	2.20E-05	4.30E+00	1.96E+05
7	3400.2	0.1544	6.37E-07	3.69E-05	5.49E+00	1.49E+05
8	2587.1	0.1606	1.05E-06	6.09E-05	6.89E+00	1.13E+05
9	1968.8	0.1669	1.72E-06	9.96E-05	8.56E+00	8.60E+04
10	1498.5	0.1731	2.79E-06	1.62E-04	1.06E+01	6.54E+04
11	1140.9	0.1794	4.53E-06	2.63E-04	1.31E+01	4.97E+04
12	868.9	0.1856	7.34E-06	4.26E-04	1.61E+01	3.78E+04
13	662.0	0.1919	1.19E-05	6.90E-04	1.98E+01	2.88E+04
14	504.7	0.1981	1.93E-05	1.12E-03	2.45E+01	2.19E+04
15	385.0	0.2044	3.13E-05	1.81E-03	3.02E+01	1.66E+04
16	294.0	0.2106	5.07E-05	2.94E-03	3.72E+01	1.27E+04
17	224.8	0.2169	8.23E-05	4.77E-03	4.59E+01	9.63E+03
18	172.2	0.2231	1.33E-04	7.74E-03	5.67E+01	7.32E+03
19	132.1	0.2294	2.16E-04	1.25E-02	6.99E+01	5.57E+03
20	101.7	0.2356	3.50E-04	2.03E-02	8.60E+01	4.23E+03
21	78.5	0.2419	5.65E-04	3.28E-02	1.06E+02	3.22E+03
22	60.9	0.2481	9.10E-04	5.28E-02	1.29E+02	2.45E+03
23	47.5	0.2544	1.46E-03	8.45E-02	1.57E+02	1.86E+03
24	37.3	0.2606	2.32E-03	1.35E-01	1.91E+02	1.42E+03
25	29.6	0.2669	3.66E-03	2.13E-01	2.29E+02	1.08E+03
26	23.7	0.2731	5.73E-03	3.32E-01	2.72E+02	8.19E+02
27	19.2	0.2794	8.84E-03	5.13E-01	3.20E+02	6.23E+02
28	15.8	0.2856	1.35E-02	7.80E-01	3.70E+02	4.74E+02
29	13.2	0.2919	2.01E-02	1.17E+00	4.21E+02	3.60E+02
30	11.3	0.2981	2.95E-02	1.71E+00	4.70E+02	2.74E+02
31	9.8	0.3044	4.24E-02	2.46E+00	5.13E+02	2.09E+02
32	8.6	0.3106	5.96E-02	3.46E+00	5.48E+02	1.59E+02
33	7.8	0.3169	8.19E-02	4.75E+00	5.73E+02	1.21E+02
34	7.1	0.3231	1.10E-01	6.38E+00	5.85E+02	9.17E+01
35	6.6	0.3294	1.44E-01	8.38E+00	5.84E+02	6.98E+01
36	6.1	0.3356	1.86E-01	1.08E+01	1.73E+02	1.61E+01
37	6.0	0.3419	2.34E-01	1.36E+01	2.43E+02	1.79E+01
38	5.8	0.3481	2.89E-01	1.68E+01	3.35E+02	1.99E+01
39	5.7	0.3544	3.51E-01	2.03E+01	4.52E+02	2.22E+01
40	5.6	0.3606	4.18E-01	2.43E+01	6.01E+02	2.48E+01
41	5.4	0.3669	4.92E-01	2.85E+01	7.87E+02	2.76E+01
42	5.2	0.3731	5.71E-01	3.31E+01	1.02E+03	3.08E+01
43	5.0	0.3794	6.56E-01	3.80E+01	1.30E+03	3.43E+01
44	4.8	0.3856	7.47E-01	4.33E+01	1.66E+03	3.82E+01
45	4.5	0.3919	8.46E-01	4.90E+01	2.09E+03	4.26E+01
46	4.3	0.3981	9.51E-01	5.52E+01	2.62E+03	4.74E+01
47	3.9	0.4044	1.07E+00	6.18E+01	3.27E+03	5.29E+01
48	3.6	0.4106	1.19E+00	6.91E+01	4.07E+03	5.89E+01
49	3.2	0.4169	1.33E+00	7.72E+01	5.07E+03	6.57E+01

THETAE = 0.3400 #5 HARTLETON (54) SILT LOAM KE(FT/HRS) = 7.9287E-02

CLASS	INITIAL FLUX(CM/HRS)	SORPTIVITY(CM/HRS**0.5)	FI(FT/HRS)	FS(FT/HRS**.5)	THETA/THETA2	THETA MID.INT.
1	6.20E+01	1.99E+00	2.03E+00	6.52E-02	0.2857	0.1200
2	6.16E+01	1.97E+00	2.02E+00	6.48E-02	0.3006	0.1231
3	6.09E+01	1.95E+00	2.00E+00	6.40E-02	0.3155	0.1294
4	6.02E+01	1.92E+00	1.97E+00	6.32E-02	0.3304	0.1356
5	5.94E+01	1.90E+00	1.95E+00	6.23E-02	0.3452	0.1419
6	5.86E+01	1.87E+00	1.92E+00	6.15E-02	0.3601	0.1481
7	5.79E+01	1.85E+00	1.90E+00	6.06E-02	0.3750	0.1544
8	5.71E+01	1.82E+00	1.87E+00	5.98E-02	0.3899	0.1606
9	5.63E+01	1.80E+00	1.85E+00	5.89E-02	0.4048	0.1669
10	5.55E+01	1.77E+00	1.82E+00	5.80E-02	0.4196	0.1731
11	5.46E+01	1.74E+00	1.79E+00	5.71E-02	0.4345	0.1794
12	5.38E+01	1.71E+00	1.77E+00	5.62E-02	0.4494	0.1856
13	5.30E+01	1.68E+00	1.74E+00	5.53E-02	0.4643	0.1919
14	5.21E+01	1.66E+00	1.71E+00	5.43E-02	0.4792	0.1981
15	5.12E+01	1.63E+00	1.68E+00	5.34E-02	0.4940	0.2044
16	5.03E+01	1.60E+00	1.65E+00	5.24E-02	0.5089	0.2106
17	4.94E+01	1.57E+00	1.62E+00	5.14E-02	0.5238	0.2169
18	4.85E+01	1.54E+00	1.59E+00	5.04E-02	0.5387	0.2231
19	4.76E+01	1.50E+00	1.56E+00	4.94E-02	0.5536	0.2294
20	4.66E+01	1.47E+00	1.53E+00	4.83E-02	0.5685	0.2356
21	4.56E+01	1.44E+00	1.50E+00	4.73E-02	0.5833	0.2419
22	4.46E+01	1.41E+00	1.46E+00	4.62E-02	0.5982	0.2481
23	4.36E+01	1.37E+00	1.43E+00	4.51E-02	0.6131	0.2544
24	4.26E+01	1.34E+00	1.40E+00	4.39E-02	0.6280	0.2606
25	4.15E+01	1.30E+00	1.36E+00	4.28E-02	0.6429	0.2669
26	4.04E+01	1.27E+00	1.33E+00	4.16E-02	0.6577	0.2731
27	3.93E+01	1.23E+00	1.29E+00	4.04E-02	0.6726	0.2794
28	3.82E+01	1.19E+00	1.25E+00	3.92E-02	0.6875	0.2856
29	3.71E+01	1.16E+00	1.22E+00	3.79E-02	0.7024	0.2919
30	3.59E+01	1.12E+00	1.18E+00	3.67E-02	0.7173	0.2981
31	3.48E+01	1.08E+00	1.14E+00	3.54E-02	0.7321	0.3044
32	3.36E+01	1.04E+00	1.10E+00	3.41E-02	0.7470	0.3106
33	3.23E+01	9.97E-01	1.06E+00	3.27E-02	0.7619	0.3169
34	3.11E+01	9.56E-01	1.02E+00	3.14E-02	0.7768	0.3231
35	2.98E+01	9.14E-01	9.79E-01	3.00E-02	0.7917	0.3294
36	2.85E+01	8.70E-01	9.36E-01	2.86E-02	0.8065	0.3356
37	2.72E+01	8.25E-01	8.92E-01	2.71E-02	0.8214	0.3419
38	2.58E+01	7.78E-01	8.45E-01	2.55E-02	0.8363	0.3481
39	2.43E+01	7.29E-01	7.96E-01	2.39E-02	0.8512	0.3544
40	2.27E+01	6.76E-01	7.45E-01	2.22E-02	0.8661	0.3606
41	2.11E+01	6.22E-01	6.91E-01	2.04E-02	0.8809	0.3669
42	1.93E+01	5.64E-01	6.34E-01	1.85E-02	0.8958	0.3731
43	1.75E+01	5.02E-01	5.74E-01	1.65E-02	0.9107	0.3794
44	1.55E+01	4.37E-01	5.10E-01	1.43E-02	0.9256	0.3856
45	1.35E+01	3.68E-01	4.42E-01	1.21E-02	0.9405	0.3919

#7 ALBRIGHTS (71) SILT LOAM

NC	THET15	THETAE	THETA2	PPSI15	PSI1	PSIE	PSI2	CONE	TF	TM
	(CM3/CM3)			(CM OF WATER)				(CM/DAY)	DEG.C	
48	0.1400	0.3400	0.4300	15306.0	15306.0	6.0	3.0	23.0000	20.0	20.0

CLASS	PRESSURE (CM)	THETA (CM3/CM3)	PERMEABILITY	CONDUCTIVITY (CM/DAY)	DIFFUSSIVITY (CM2/DAY	DPSI/DTHETA
1	15306.0	0.1400	3.84E-09	8.84E-08	6.52E-02	7.37E+05
2	13233.6	0.1430	1.60E-08	3.67E-07	2.34E-01	6.37E+05
3	9892.8	0.1491	3.87E-08	8.90E-07	4.24E-01	4.76E+05
4	7395.7	0.1551	7.88E-08	1.81E-06	6.45E-01	3.56E+05
5	5529.2	0.1611	1.48E-07	3.39E-06	9.03E-01	2.66E+05
6	4134.1	0.1672	2.64E-07	6.07E-06	1.21E+00	1.99E+05
7	3091.4	0.1732	4.60E-07	1.06E-05	1.57E+00	1.49E+05
8	2311.9	0.1793	7.90E-07	1.82E-05	2.02E+00	1.11E+05
9	1729.3	0.1853	1.34E-06	3.09E-05	2.57E+00	8.31E+04
10	1293.9	0.1914	2.28E-06	5.24E-05	3.25E+00	6.21E+04
11	968.4	0.1974	3.85E-06	8.85E-05	4.11E+00	4.64E+04
12	725.1	0.2034	6.50E-06	1.49E-04	5.19E+00	3.47E+04
13	543.2	0.2095	1.10E-05	2.52E-04	6.54E+00	2.59E+04
14	407.3	0.2155	1.85E-05	4.26E-04	8.25E+00	1.94E+04
15	305.7	0.2216	3.12E-05	7.19E-04	1.04E+01	1.45E+04
16	229.8	0.2276	5.27E-05	1.21E-03	1.31E+01	1.08E+04
17	173.0	0.2336	8.89E-05	2.04E-03	1.65E+01	8.09E+03
18	130.6	0.2397	1.50E-04	3.44E-03	2.08E+01	6.05E+03
19	98.9	0.2457	2.51E-04	5.78E-03	2.62E+01	4.52E+03
20	75.2	0.2518	4.21E-04	9.69E-03	3.27E+01	3.38E+03
21	57.4	0.2578	7.03E-04	1.62E-02	4.08E+01	2.53E+03
22	44.2	0.2639	1.16E-03	2.68E-02	5.06E+01	1.89E+03
23	34.3	0.2699	1.91E-03	4.40E-02	6.22E+01	1.41E+03
24	26.9	0.2759	3.12E-03	7.17E-02	7.56E+01	1.06E+03
25	21.4	0.2820	5.01E-03	1.15E-01	9.08E+01	7.89E+02
26	17.2	0.2880	7.92E-03	1.82E-01	1.07E+02	5.89E+02
27	14.1	0.2941	1.23E-02	2.83E-01	1.25E+02	4.41E+02
28	11.8	0.3001	1.87E-02	4.30E-01	1.42E+02	3.29E+02
29	10.1	0.3061	2.78E-02	6.39E-01	1.57E+02	2.46E+02
30	8.8	0.3122	4.03E-02	9.26E-01	1.70E+02	1.84E+02
31	7.9	0.3182	5.68E-02	1.31E+00	1.80E+02	1.38E+02
32	7.1	0.3243	7.82E-02	1.80E+00	1.85E+02	1.03E+02
33	6.6	0.3303	1.05E-01	2.41E+00	1.85E+02	7.68E+01
34	6.1	0.3364	1.37E-01	3.16E+00	4.60E+01	1.46E+01
35	6.0	0.3424	1.76E-01	4.05E+00	6.47E+01	1.60E+01
36	5.9	0.3484	2.20E-01	5.06E+00	8.88E+01	1.75E+01
37	5.8	0.3545	2.69E-01	6.20E+00	1.19E+02	1.93E+01
38	5.6	0.3605	3.24E-01	7.45E+00	1.57E+02	2.11E+01
39	5.5	0.3666	3.83E-01	8.81E+00	2.04E+02	2.32E+01
40	5.3	0.3726	4.47E-01	1.03E+01	2.62E+02	2.55E+01
41	5.2	0.3786	5.15E-01	1.19E+01	3.31E+02	2.79E+01
42	5.0	0.3847	5.89E-01	1.35E+01	4.15E+02	3.07E+01
43	4.8	0.3907	6.67E-01	1.53E+01	5.16E+02	3.36E+01
44	4.6	0.3968	7.50E-01	1.72E+01	6.37E+02	3.69E+01
45	4.4	0.4028	8.39E-01	1.93E+01	7.82E+02	4.05E+01
46	4.1	0.4089	9.34E-01	2.15E+01	9.55E+02	4.45E+01
47	3.8	0.4149	1.04E+00	2.38E+01	1.16E+03	4.88E+01
48	3.5	0.4209	1.15E+00	2.64E+01	1.41E+03	5.36E+01
49	3.2	0.4270	1.27E+00	2.92E+01	1.72E+03	5.88E+01

THETAE = 0.3400 #7 ALBRIGHTS (71) SILT LOAM KE(FT/HRS) = 3.1441E-02

CLASS	INITIAL FLUX(CM/HRS)	SORPTIVITY(CM/HRS**0.5)	F1(FT/HRS)	FS(FT/HRS**.5)	THETA/THETA2	THETA MID.INT.
1	3.54E+01	1.15E+00	1.16E+00	3.77E-02	0.3256	0.1400
2	3.52E+01	1.14E+00	1.16E+00	3.75E-02	0.3396	0.1430
3	3.48E+01	1.13E+00	1.14E+00	3.70E-02	0.3537	0.1491
4	3.44E+01	1.11E+00	1.13E+00	3.65E-02	0.3677	0.1551
5	3.39E+01	1.10E+00	1.11E+00	3.61E-02	0.3818	0.1611
6	3.35E+01	1.08E+00	1.10E+00	3.56E-02	0.3958	0.1672
7	3.30E+01	1.07E+00	1.08E+00	3.51E-02	0.4099	0.1732
8	3.26E+01	1.05E+00	1.07E+00	3.46E-02	0.4239	0.1793
9	3.21E+01	1.04E+00	1.05E+00	3.41E-02	0.4380	0.1853
10	3.17E+01	1.02E+00	1.04E+00	3.36E-02	0.4520	0.1914
11	3.12E+01	1.01E+00	1.02E+00	3.31E-02	0.4661	0.1974
12	3.07E+01	9.91E-01	1.01E+00	3.25E-02	0.4801	0.2034
13	3.02E+01	9.75E-01	9.91E-01	3.20E-02	0.4942	0.2095
14	2.97E+01	9.58E-01	9.75E-01	3.14E-02	0.5082	0.2155
15	2.92E+01	9.41E-01	9.58E-01	3.09E-02	0.5223	0.2216
16	2.87E+01	9.24E-01	9.41E-01	3.03E-02	0.5363	0.2276
17	2.82E+01	9.07E-01	9.24E-01	2.97E-02	0.5504	0.2336
18	2.76E+01	8.89E-01	9.06E-01	2.92E-02	0.5644	0.2397
19	2.71E+01	8.71E 01	8.88E-01	2.86E-02	0.5785	0.2457
20	2.65E+01	8.52E-01	8.70E-01	2.80E-02	0.5925	0.2518
21	2.60E+01	8.33E-01	8.52E-01	2.73E-02	0.6066	0.2578
22	2.54E+01	8.14E-01	8.33E-01	2.67E-02	0.6206	0.2639
23	2.48E+01	7.95E-01	8.14E-01	2.61E-02	0.6347	0.2699
24	2.42E+01	7.75E-01	7.94E-01	2.54E-02	0.6487	0.2759
25	2.36E+01	7.54E-01	7.74E-01	2.48E-02	0.6628	0.2820
26	2.30E+01	7.34E-01	7.54E-01	2.41E-02	0.6768	0.2880
27	2.23E+01	7.13E-01	7.33E-01	2.34E-02	0.6909	0.2941
28	2.17E+01	6.91E-01	7.12E-01	2.27E-02	0.7049	0.3001
29	2.10E+01	6.69E-01	6.90E-01	2.20E-02	0.7190	0.3061
30	2.04E+01	6.47E-01	6.69E-01	2.12E-02	0.7330	0.3122
31	1.97E+01	6.25E-01	6.46E-01	2.05E-02	0.7471	0.3182
32	1.90E+01	6.02E-01	6.24E-01	1.97E-02	0.7611	0.3243
33	1.83E+01	5.79E-01	6.01E-01	1.90E-02	0.7752	0.3303
34	1.76E+01	5.55E-01	5.77E-01	1.82E-02	0.7892	0.3364
35	1.69E+01	5.30E-01	5.53E-01	1.74E-02	0.8033	0.3424
36	1.61E+01	5.04E-01	5.28E-01	1.65E-02	0.8173	0.3484
37	1.53E+01	4.77E-01	5.01E-01	1.57E-02	0.8314	0.3545
38	1.44E+01	4.49E-01	4.74E-01	1.47E-02	0.8454	0.3605
39	1.36E+01	4.20E-01	4.45E-01	1.38E-02	0.8595	0.3666
40	1.26E+01	3.89E-01	4.14E-01	1.28E-02	0.8735	0.3726
41	1.17E+01	3.57E-01	3.83E-01	1.17E-02	0.8876	0.3786
42	1.06E+01	3.23E-01	3.49E-01	1.06E-02	0.9016	0.3847
43	9.57E+00	2.87E-01	3.14E-01	9.42E-03	0.9157	0.3907
44	8.43E+00	2.49E-01	2.77E-01	8.17E-03	0.9297	0.3968
45	7.23E+00	2.09E-01	2.37E-01	6.86E-03	0.9438	0.4028

#8 MECKENSVILLE (69) SILT LOAM

NC	THET15	THETAE	THETA2	PPSI15	PSI1	PSIE	PSI2	CONE	TF	TM
	(CM3/CM3)				(CM OF WATER)			(CM/DAY)	DEG.C	
48	0.1800	0.3100	0.3900	15306.0	15306.0	6.0	3.0	23.0000	20.0	20.0

CLASS	PRESSURE (CM)	THETA (CM3/CM3)	PERMEABILITY	CONDUCTIVITY (CM/DAY)	DIFFUSSIVITY (CM2/DAY	DPSI/DTHETA
1	15305.9	0.1800	1.45E-09	3.33E-08	3.78E-02	1.13E+06
2	13015.8	0.1822	6.20E-09	1.43E-07	1.37E-01	9.64E+05
3	9412.4	0.1866	1.59E-08	3.66E-07	2.55E-01	6.97E+05
4	6807.1	0.1909	3.46E-08	7.97E-07	4.02E-01	5.04E+05
5	4923.2	0.1953	6.98E-08	1.61E-06	5.85E-01	3.65E+05
6	3561.1	0.1997	1.35E-07	3.11E-06	8.19E-01	2.64E+05
7	2576.3	0.2041	2.55E-07	5.87E-06	1.12E+00	1.91E+05
8	1864.2	0.2084	4.76E-07	1.10E-05	1.51E+00	1.38E+05
9	1349.3	0.2128	8.83E-07	2.03E-05	2.02E+00	9.96E+04
10	977.0	0.2172	1.63E-06	3.75E-05	2.70E+00	7.20E+04
11	707.8	0.2216	3.00E-06	6.89E-05	3.59E+00	5.21E+04
12	513.1	0.2259	5.51E-06	1.27E-04	4.77E+00	3.77E+04
13	372.4	0.2303	1.01E-05	2.33E-04	6.33E+00	2.72E+04
14	270.7	0.2347	1.85E-05	4.26E-04	8.39E+00	1.97E+04
15	197.1	0.2391	3.39E-05	7.80E-04	1.11E+01	1.42E+04
16	143.9	0.2434	6.19E-05	1.42E-03	1.47E+01	1.03E+04
17	105.4	0.2478	1.13E-04	2.59E-03	1.93E+01	7.44E+03
18	77.6	0.2522	2.04E-04	4.70E-03	2.53E+01	5.38E+03
19	57.5	0.2566	3.68E-04	8.46E-03	3.29E+01	3.89E+03
20	43.0	0.2609	6.57E-04	1.51E-02	4.25E+01	2.81E+03
21	32.4	0.2653	1.16E-03	2.67E-02	5.43E+01	2.03E+03
22	24.8	0.2697	2.02E-03	4.64E-02	6.83E+01	1.47E+03
23	19.3	0.2741	3.45E-03	7.94E-02	8.44E+01	1.06E+03
24	15.4	0.2784	5.77E-03	1.33E-01	1.02E+02	7.69E+02
25	12.5	0.2828	9.41E-03	2.16E-01	1.20E+02	5.56E+02
26	10.4	0.2872	1.49E-02	3.43E-01	1.38E+02	4.02E+02
27	8.9	0.2916	2.29E-02	5.26E-01	1.53E+02	2.91E+02
28	7.8	0.2959	3.40E-02	7.82E-01	1.64E+02	2.10E+02
29	7.1	0.3003	4.89E-02	1.13E+00	1.71E+02	1.52E+02
30	6.5	0.3047	6.82E-02	1.57E+00	1.72E+02	1.10E+02
31	6.0	0.3091	9.22E-02	2.12E+00	3.62E+01	1.70E+01
32	5.9	0.3134	1.21E-01	2.79E+00	5.13E+01	1.84E+01
33	5.9	0.3178	1.55E-01	3.56E+00	7.07E+01	1.98E+01
34	5.8	0.3222	1.93E-01	4.44E+00	9.50E+01	2.14E+01
35	5.7	0.3266	2.35E-01	5.41E+00	1.25E+02	2.31E+01
36	5.6	0.3309	2.82E-01	6.47E+00	1.61E+02	2.49E+01
37	5.4	0.3353	3.32E-01	7.63E+00	2.05E+02	2.69E+01
38	5.3	0.3397	3.86E-01	8.88E+00	2.57E+02	2.90E+01
39	5.2	0.3441	4.44E-01	1.02E+01	3.19E+02	3.13E+01
40	5.1	0.3484	5.06E-01	1.16E+01	3.93E+02	3.37E+01
41	4.9	0.3528	5.72E-01	1.32E+01	4.79E+02	3.64E+01
42	4.7	0.3572	6.42E-01	1.48E+01	5.80E+02	3.93E+01
43	4.6	0.3616	7.16E-01	1.65E+01	6.98E+02	4.23E+01
44	4.4	0.3659	7.95E-01	1.83E+01	8.35E+02	4.57E+01
45	4.2	0.3703	8.79E-01	2.02E+01	9.96E+02	4.93E+01
46	3.9	0.3747	9.68E-01	2.23E+01	1.18E+03	5.32E+01
47	3.7	0.3791	1.06E+00	2.45E+01	1.40E+03	5.73E+01
48	3.4	0.3834	1.17E+00	2.68E+01	1.66E+03	6.19E+01
49	3.1	0.3878	1.28E+00	2.94E+01	1.96E+03	6.67E+01

THETAE = 0.3100 #8 MECKENSVILLE (69) SILT LOAM KE(FT/HRS) = 3.1441E-02

CLASS	INITIAL FLUX(CM/HRS)	SORPTIVITY(CM/HRS**0.5)	FI(FT/HRS)	FS(FT/HRS**.5)	THETA/THETA2	THETA MID.INT.
1	2.86E+01	9.21E-01	9.38E-01	3.02E-02	0.4615	0.1800
2	2.84E+01	9.15E-01	9.33E-01	3.00E-02	0.4728	0.1822
3	2.81E+01	9.04E-01	9.21E-01	2.97E-02	0.4840	0.1866
4	2.77E+01	8.93E-01	9.10E-01	2.93E-02	0.4952	0.1909
5	2.74E+01	8.81E-01	8.99E-01	2.89E-02	0.5064	0.1953
6	2.70E+01	8.69E-01	8.87E-01	2.85E-02	0.5176	0.1997
7	2.67E+01	8.57E-01	8.75E-01	2.81E-02	0.5288	0.2041
8	2.63E+01	8.45E-01	8.63E-01	2.77E-02	0.5401	0.2084
9	2.59E+01	8.33E-01	8.51E-01	2.73E-02	0.5513	0.2128
10	2.56E+01	8.21E-01	8.39E-01	2.69E-02	0.5625	0.2172
11	2.52E+01	8.08E-01	8.27E-01	2.65E-02	0.5737	0.2216
12	2.48E+01	7.95E-01	8.14E-01	2.61E-02	0.5849	0.2259
13	2.44E+01	7.82E-01	8.01E-01	2.57E-02	0.5962	0.2303
14	2.40E+01	7.69E-01	7.88E-01	2.52E-02	0.6074	0.2347
15	2.36E+01	7.55E-01	7.75E-01	2.48E-02	0.6186	0.2391
16	2.32E+01	7.42E-01	7.61E-01	2.43E-02	0.6298	0.2434
17	2.28E+01	7.28E-01	7.48E-01	2.39E-02	0.6410	0.2478
18	2.24E+01	7.13E-01	7.34E-01	2.34E-02	0.6522	0.2522
19	2.19E+01	6.99E-01	7.19E-01	2.29E-02	0.6635	0.2566
20	2.15E+01	6.84E-01	7.05E-01	2.24E-02	0.6747	0.2609
21	2.10E+01	6.69E-01	6.90E-01	2.20E-02	0.6859	0.2653
22	2.06E+01	6.54E-01	6.75E-01	2.15E-02	0.6971	0.2697
23	2.01E+01	6.38E-01	6.60E-01	2.09E-02	0.7083	0.2741
24	1.96E+01	6.22E-01	6.44E-01	2.04E-02	0.7196	0.2784
25	1.91E+01	6.06E-01	6.28E-01	1.99E-02	0.7308	0.2828
26	1.87E+01	5.90E-01	6.12E-01	1.94E-02	0.7420	0.2872
27	1.82E+01	5.73E-01	5.96E-01	1.88E-02	0.7532	0.2916
28	1.76E+01	5.56E-01	5.79E-01	1.83E-02	0.7644	0.2959
29	1.71E+01	5.39E-01	5.62E-01	1.77E-02	0.7756	0.3003
30	1.66E+01	5.21E-01	5.45E-01	1.71E-02	0.7869	0.3047
31	1.61E+01	5.04E-01	5.27E-01	1.65E-02	0.7981	0.3091
32	1.55E+01	4.85E-01	5.09E-01	1.59E-02	0.8093	0.3134
33	1.49E+01	4.66E-01	4.90E-01	1.53E-02	0.8205	0.3178
34	1.43E+01	4.46E-01	4.70E-01	1.46E-02	0.8317	0.3222
35	1.37E+01	4.25E-01	4.50E-01	1.40E-02	0.8429	0.3266
36	1.31E+01	4.04E-01	4.29E-01	1.33E-02	0.8542	0.3309
37	1.24E+01	3.82E-01	4.07E-01	1.25E-02	0.8654	0.3353
38	1.17E+01	3.59E-01	3.84E-01	1.18E-02	0.8766	0.3397
39	1.10E+01	3.34E-01	3.61E-01	1.10E-02	0.8878	0.3441
40	1.02E+01	3.09E-01	3.36E-01	1.01E-02	0.8990	0.3484
41	9.44E+00	2.83E-01	3.10E-01	9.28E-03	0.9103	0.3528
42	8.61E+00	2.55E-01	2.83E-01	8.37E-03	0.9215	0.3572
43	7.74E+00	2.26E-01	2.54E-01	7.42E-03	0.9327	0.3616
44	6.83E+00	1.96E-01	2.24E-01	6.42E-03	0.9439	0.3659
45	5.87E+00	1.64E-01	1.93E-01	5.37E-03	0.9551	0.3703

#9 ALVIRA (57) SILT LOAM

NC	THET15	THETAE	THETA2	PPSI15	PSI1	PSIE	PSI2	CONE	TF	TM
	(CM3/CM3)			(CM OF WATER)				(CM/DAY)	DEG.C	
48	0.1500	0.3000	0.3800	15306.0	15306.0	6.0	3.0	23.0000	20.0	20.0

CLASS	PRESSURE (CM)	THETA (CM3/CM3)	PERMEABILITY	CONDUCTIVITY (CM/DAY)	DIFFUSSIVITY (CM2/DAY	DPSI/DTHETA
1	15306.0	0.1500	2.22E-09	5.11E-08	5.02E-02	9.83E+05
2	13123.4	0.1524	9.38E-09	2.16E-07	1.82E-01	8.43E+05
3	9647.8	0.1572	2.35E-08	5.40E-07	3.34E-01	6.19E+05
4	7093.0	0.1620	4.95E-08	1.14E-06	5.19E-01	4.55E+05
5	5215.1	0.1668	9.65E-08	2.22E-06	7.43E-01	3.35E+05
6	3834.8	0.1716	1.80E-07	4.14E-06	1.02E+00	2.46E+05
7	2820.1	0.1764	3.27E-07	7.52E-06	1.36E+00	1.81E+05
8	2074.3	0.1811	5.86E-07	1.35E-05	1.79E+00	1.33E+05
9	1526.0	0.1859	1.04E-06	2.40E-05	2.34E+00	9.77E+04
10	1123.1	0.1907	1.85E-06	4.25E-05	3.05E+00	7.18E+04
11	826.8	0.1955	3.26E-06	7.50E-05	3.96E+00	5.28E+04
12	609.1	0.2003	5.76E-06	1.32E-04	5.14E+00	3.88E+04
13	449.0	0.2051	1.01E-05	2.33E-04	6.66E+00	2.85E+04
14	331.4	0.2099	1.79E-05	4.11E-04	8.62E+00	2.10E+04
15	244.9	0.2147	3.14E-05	7.23E-04	1.11E+01	1.54E+04
16	181.4	0.2195	5.53E-05	1.27E-03	1.44E+01	1.13E+04
17	134.6	0.2243	9.70E-05	2.23E-03	1.86E+01	8.33E+03
18	100.3	0.2291	1.70E-04	3.90E-03	2.39E+01	6.12E+03
19	75.0	0.2339	2.96E-04	6.80E-03	3.06E+01	4.50E+03
20	56.5	0.2386	5.12E-04	1.18E-02	3.90E+01	3.31E+03
21	42.8	0.2434	8.82E-04	2.03E-02	4.93E+01	2.43E+03
22	32.8	0.2482	1.50E-03	3.46E-02	6.17E+01	1.79E+03
23	25.4	0.2530	2.53E-03	5.81E-02	7.64E+01	1.31E+03
24	20.0	0.2578	4.19E-03	9.63E-02	9.30E+01	9.66E+02
25	16.0	0.2626	6.81E-03	1.57E-01	1.11E+02	7.10E+02
26	13.1	0.2674	1.08E-02	2.49E-01	1.30E+02	5.22E+02
27	11.0	0.2722	1.68E-02	3.86E-01	1.48E+02	3.83E+02
28	9.4	0.2770	2.53E-02	5.83E-01	1.64E+02	2.82E+02
29	8.2	0.2818	3.72E-02	8.55E-01	1.77E+02	2.07E+02
30	7.4	0.2866	5.29E-02	1.22E+00	1.85E+02	1.52E+02
31	6.7	0.2914	7.32E-02	1.68E+00	1.88E+02	1.12E+02
32	6.1	0.2961	9.87E-02	2.27E+00	3.68E+01	1.62E+01
33	6.0	0.3009	1.30E-01	2.98E+00	5.25E+01	1.76E+01
34	5.9	0.3057	1.66E-01	3.81E+00	7.30E+01	1.91E+01
35	5.8	0.3105	2.07E-01	4.75E+00	9.89E+01	2.08E+01
36	5.7	0.3153	2.52E-01	5.80E+00	1.31E+02	2.26E+01
37	5.6	0.3201	3.02E-01	6.95E+00	1.71E+02	2.45E+01
38	5.5	0.3249	3.56E-01	8.20E+00	2.19E+02	2.67E+01
39	5.3	0.3297	4.15E-01	9.54E+00	2.76E+02	2.90E+01
40	5.2	0.3345	4.77E-01	1.10E+01	3.46E+02	3.15E+01
41	5.0	0.3393	5.44E-01	1.25E+01	4.28E+02	3.42E+01
42	4.9	0.3441	6.14E-01	1.41E+01	5.26E+02	3.72E+01
43	4.7	0.3489	6.90E-01	1.59E+01	6.41E+02	4.04E+01
44	4.5	0.3536	7.70E-01	1.77E+01	7.77E+02	4.39E+01
45	4.2	0.3584	8.55E-01	1.97E+01	9.38E+02	4.77E+01
46	4.0	0.3632	9.46E-01	2.17E+01	1.13E+03	5.18E+01
47	3.7	0.3680	1.04E+00	2.40E+01	1.35E+03	5.63E+01
48	3.5	0.3728	1.15E+00	2.64E+01	1.62E+03	6.12E+01
49	3.2	0.3776	1.26E+00	2.90E+01	1.93E+03	6.65E+01

THETAE = 0.3000 #9 ALVIRA (57) SILT LOAM KE(FT/HRS) = 3.1441E-02

CLASS	INITIAL FLUX(CM/HRS)	SORPTIVITY(CM/HRS**0.5)	F1(FT/HRS)	FS(FT/HRS**.5)	THETA/THETA2	THETA MID.INT.
1	3.05E+01	9.84E-01	1.00E+00	3.23E-02	0.3947	0.1500
2	3.03E+01	9.78E-01	9.94E-01	3.21E-02	0.4073	0.1524
3	2.99E+01	9.66E-01	9.82E-01	3.17E-02	0.4200	0.1572
4	2.96E+01	9.54E-01	9.70E-01	3.13E-02	0.4326	0.1620
5	2.92E+01	9.41E-01	9.58E-01	3.09E-02	0.4452	0.1668
6	2.88E+01	9.29E-01	9.45E-01	3.05E-02	0.4578	0.1716
7	2.84E+01	9.16E-01	9.33E-01	3.00E-02	0.4704	0.1764
8	2.80E+01	9.03E-01	9.20E-01	2.96E-02	0.4830	0.1811
9	2.77E+01	8.90E-01	9.07E-01	2.92E-02	0.4956	0.1859
10	2.73E+01	8.76E-01	8.94E-01	2.88E-02	0.5082	0.1907
11	2.68E+01	8.63E-01	8.81E-01	2.83E-02	0.5208	0.1955
12	2.64E+01	8.49E-01	8.67E-01	2.79E-02	0.5334	0.2003
13	2.60E+01	8.35E-01	8.54E-01	2.74E-02	0.5461	0.2051
14	2.56E+01	8.21E-01	8.40E-01	2.69E-02	0.5587	0.2099
15	2.52E+01	8.07E-01	8.25E-01	2.65E-02	0.5713	0.2147
16	2.47E+01	7.92E-01	8.11E-01	2.60E-02	0.5839	0.2195
17	2.43E+01	7.77E-01	7.96E-01	2.55E-02	0.5965	0.2243
18	2.38E+01	7.62E-01	7.81E-01	2.50E-02	0.6091	0.2291
19	2.34E+01	7.47E-01	7.66E-01	2.45E-02	0.6217	0.2339
20	2.29E+01	7.31E-01	7.51E-01	2.40E-02	0.6343	0.2386
21	2.24E+01	7.15E-01	7.35E-01	2.34E-02	0.6469	0.2434
22	2.19E+01	6.98E-01	7.19E-01	2.29E-02	0.6595	0.2482
23	2.14E+01	6.82E-01	7.02E-01	2.24E-02	0.6721	0.2530
24	2.09E+01	6.65E-01	6.86E-01	2.18E-02	0.6848	0.2578
25	2.04E+01	6.47E-01	6.69E-01	2.12E-02	0.6974	0.2626
26	1.99E+01	6.30E-01	6.51E-01	2.07E-02	0.7100	0.2674
27	1.93E+01	6.12E-01	6.34E-01	2.01E-02	0.7226	0.2722
28	1.88E+01	5.94E-01	6.16E-01	1.95E-02	0.7352	0.2770
29	1.82E+01	5.75E-01	5.98E-01	1.89E-02	0.7478	0.2818
30	1.77E+01	5.57E-01	5.79E-01	1.83E-02	0.7604	0.2866
31	1.71E+01	5.38E-01	5.61E-01	1.76E-02	0.7730	0.2914
32	1.65E+01	5.18E-01	5.41E-01	1.70E-02	0.7856	0.2961
33	1.59E+01	4.98E-01	5.22E-01	1.63E-02	0.7982	0.3009
34	1.53E+01	4.77E-01	5.01E-01	1.57E-02	0.8109	0.3057
35	1.46E+01	4.55E-01	4.80E-01	1.49E-02	0.8235	0.3105
36	1.39E+01	4.33E-01	4.57E-01	1.42E-02	0.8361	0.3153
37	1.32E+01	4.09E-01	4.34E-01	1.34E-02	0.8487	0.3201
38	1.25E+01	3.85E-01	4.10E-01	1.26E-02	0.8613	0.3249
39	1.17E+01	3.59E-01	3.85E-01	1.18E-02	0.8739	0.3297
40	1.09E+01	3.32E-01	3.59E-01	1.09E-02	0.8865	0.3345
41	1.01E+01	3.04E-01	3.31E-01	9.98E-03	0.8991	0.3393
42	9.20E+00	2.75E-01	3.02E-01	9.02E-03	0.9117	0.3441
43	8.28E+00	2.44E-01	2.72E-01	8.00E-03	0.9243	0.3489
44	7.30E+00	2.11E-01	2.40E-01	6.94E-03	0.9369	0.3536
45	6.27E+00	1.77E-01	2.06E-01	5.81E-03	0.9496	0.3584

APPENDIX D.2

DATE OF EVENT: 21 JULY 72

ORIGINAL RAINFALL DATA FROM 2.77 SQUARE MILE MAHANTANGO SUB-WATERSHED

SECONDS PER TIMINT = 120.

TIME	INCHES
1750	3.20
1755	3.40
18 0	3.90

SOIL#	THETA2	THETAE	THETAI	DEGSAT	FRODEG	FS(FT/HR)	FK(FT/HR)	F1(FT/HR)
145	0.26300	0.37600	0.14912	0.56700	0.75000	0.06940	0.14720	2.09000
145	0.26300	0.37600	0.14912	0.56700	0.75000	0.06940	0.14720	2.33000

TOP LAYER SOIL DEPTH=0.750 SECOND LAYER SOIL DEPTH= 1.500

SOIL#	TIMINT	VO1(FT)	P(FT)	PEX(FT)	PINF(FT)	WFINC(FT)
145	1	0.06967	0.00667	-0.06300	0.00667	0.02938
145	2	0.00939	0.00667	-0.00272	0.00667	0.05877
145	3	0.00856	0.01167	0.00310	0.00856	0.09652
145	4	0.00807	0.01667	0.00859	0.00807	0.13211
145	5	0.00774	0.01667	0.00893	0.00774	0.16622
145	6	0.00749	0.0	-0.00749	0.0	0.16622
145	7	0.00730	0.0	-0.00730	0.0	0.16622
145	8	0.00715	0.0	-0.00715	0.0	0.16622
145	9	0.00702	0.0	-0.00702	0.0	0.16622
145	10	0.00691	0.0	-0.00691	0.0	0.16622
145	11	0.00682	0.0	-0.00682	0.0	0.16622
145	12	0.00674	0.0	-0.00674	0.0	0.16622
145	13	0.00666	0.0	-0.00666	0.0	0.16622
145	14	0.00660	0.0	-0.00660	0.0	0.16622
145	15	0.00654	0.0	-0.00654	0.0	0.16622
145	16	0.00649	0.0	-0.00649	0.0	0.16622
145	17	0.00644	0.0	-0.00644	0.0	0.16622
145	18	0.00640	0.0	-0.00640	0.0	0.16622
145	19	0.00636	0.0	-0.00636	0.0	0.16622
145	20	0.00632	0.0	-0.00632	0.0	0.16622
145	21	0.00629	0.0	-0.00629	0.0	0.16622
145	22	0.00626	0.0	-0.00626	0.0	0.16622
145	23	0.00623	0.0	-0.00623	0.0	0.16622
145	24	0.00620	0.0	-0.00620	0.0	0.16622
145	25	0.00617	0.0	-0.00617	0.0	0.16622
145	26	0.00615	0.0	-0.00615	0.0	0.16622
145	27	0.00613	0.0	-0.00613	0.0	0.16622
145	28	0.00610	0.0	-0.00610	0.0	0.16622
145	29	0.00608	0.0	-0.00608	0.0	0.16622
145	30	0.00606	0.0	-0.00606	0.0	0.16622
145	31	0.00604	0.0	-0.00604	0.0	0.16622
145	32	0.00603	0.0	-0.00603	0.0	0.16622
145	33	0.00601	0.0	-0.00601	0.0	0.16622
145	34	0.00599	0.0	-0.00599	0.0	0.16622
145	35	0.00598	0.0	-0.00598	0.0	0.16622

SOIL#	THETA2	THETAE	THETAI	DEGSAT	FRQDEG	FS(FT/HR)	FK(FT/HR)	F1(FT/HR)
66	0.27900	0.29500	0.21260	0.76200	0.75000	0.03210	0.09320	0.96500
66	0.27900	0.29500	0.21260	0.76200	0.75000	0.03470	0.10850	1.15500

TOP LAYER SOIL DEPTH=0.670 SECOND LAYER SOIL DEPTH= 2.330

SOIL#	TIMINT	V01(FT)	P(FT)	PEX(FT)	PINF(FT)	WFINC(FT)
66	1	0.03217	0.00667	-0.02550	0.00667	0.08090
66	2	0.00518	0.00667	0.00149	0.00518	0.14375
66	3	0.00480	0.01167	0.00687	0.00480	0.20198
66	4	0.00457	0.01667	0.01209	0.00457	0.25747
66	5	0.00442	0.01667	0.01225	0.00442	0.31107
66	6	0.00430	0.0	-0.00430	0.0	0.31107
66	7	0.00421	0.0	-0.00421	0.0	0.31107
66	8	0.00414	0.0	-0.00414	0.0	0.31107
66	9	0.00408	0.0	-0.00408	0.0	0.31107
66	10	0.00403	0.0	-0.00403	0.0	0.31107
66	11	0.00399	0.0	-0.00399	0.0	0.31107
66	12	0.00395	0.0	-0.00395	0.0	0.31107
66	13	0.00392	0.0	-0.00392	0.0	0.31107
66	14	0.00389	0.0	-0.00389	0.0	0.31107
66	15	0.00386	0.0	-0.00386	0.0	0.31107
66	16	0.00384	0.0	-0.00384	0.0	0.31107
66	17	0.00382	0.0	-0.00382	0.0	0.31107
66	18	0.00380	0.0	-0.00380	0.0	0.31107
66	19	0.00378	0.0	-0.00378	0.0	0.31107
66	20	0.00376	0.0	-0.00376	0.0	0.31107
66	21	0.00375	0.0	-0.00375	0.0	0.31107
66	22	0.00373	0.0	-0.00373	0.0	0.31107
66	23	0.00372	0.0	-0.00372	0.0	0.31107
66	24	0.00370	0.0	-0.00370	0.0	0.31107
66	25	0.00369	0.0	-0.00369	0.0	0.31107
66	26	0.00368	0.0	-0.00368	0.0	0.31107
66	27	0.00367	0.0	-0.00367	0.0	0.31107
66	28	0.00366	0.0	-0.00366	0.0	0.31107
66	29	0.00365	0.0	-0.00365	0.0	0.31107
66	30	0.00364	0.0	-0.00364	0.0	0.31107
66	31	0.00363	0.0	-0.00363	0.0	0.31107
66	32	0.00362	0.0	-0.00362	0.0	0.31107
66	33	0.00362	0.0	-0.00362	0.0	0.31107
66	34	0.00361	0.0	-0.00361	0.0	0.31107
66	35	0.00360	0.0	-0.00360	0.0	0.31107

SOIL#	THETA2	THETAE	THETAI	DEGSAT	FRQDEG	FS(FT/HR)	FK(FT/HR)	F1(FT/HR)
54	0.27200	0.33500	0.17816	0.65500	0.75000	0.04380	0.09320	1.32000
54	0.27200	0.33500	0.17816	0.65500	0.75000	0.04060	0.08000	1.30000

TOP LAYER SOIL DEPTH=0.750 SECOND LAYER SOIL DEPTH= 2.500

SOIL#	TIMINT	VO1(FT)	P(FT)	PEX(FT)	PINF(FT)	WFINC(FT)
54	1	0.04400	0.00667	-0.03733	0.00667	0.04251
54	2	0.00593	0.00667	0.00073	0.00593	0.08034
54	3	0.00542	0.01167	0.00625	0.00542	0.11487
54	4	0.00511	0.01667	0.01156	0.00511	0.14742
54	5	0.00489	0.01667	0.01177	0.00489	0.17863
54	6	0.00474	0.0	-0.00474	0.0	0.17863
54	7	0.00462	0.0	-0.00462	0.0	0.17863
54	8	0.00452	0.0	-0.00452	0.0	0.17863
54	9	0.00444	0.0	-0.00444	0.0	0.17863
54	10	0.00437	0.0	-0.00437	0.0	0.17863
54	11	0.00431	0.0	-0.00431	0.0	0.17863
54	12	0.00426	0.0	-0.00426	0.0	0.17863
54	13	0.00422	0.0	-0.00422	0.0	0.17863
54	14	0.00418	0.0	-0.00418	0.0	0.17863
54	15	0.00414	0.0	-0.00414	0.0	0.17863
54	16	0.00411	0.0	-0.00411	0.0	0.17863
54	17	0.00408	0.0	-0.00408	0.0	0.17863
54	18	0.00405	0.0	-0.00405	0.0	0.17863
54	19	0.00402	0.0	-0.00402	0.0	0.17863
54	20	0.00400	0.0	-0.00400	0.0	0.17863
54	21	0.00398	0.0	-0.00398	0.0	0.17863
54	22	0.00396	0.0	-0.00396	0.0	0.17863
54	23	0.00394	0.0	-0.00394	0.0	0.17863
54	24	0.00392	0.0	-0.00392	0.0	0.17863
54	25	0.00391	0.0	-0.00391	0.0	0.17863
54	26	0.00389	0.0	-0.00389	0.0	0.17863
54	27	0.00388	0.0	-0.00388	0.0	0.17863
54	28	0.00386	0.0	-0.00386	0.0	0.17863
54	29	0.00385	0.0	-0.00385	0.0	0.17863
54	30	0.00384	0.0	-0.00384	0.0	0.17863
54	31	0.00382	0.0	-0.00382	0.0	0.17863
54	32	0.00381	0.0	-0.00381	0.0	0.17863
54	33	0.00380	0.0	-0.00380	0.0	0.17863
54	34	0.00379	0.0	-0.00379	0.0	0.17863
54	35	0.00378	0.0	-0.00378	0.0	0.17863

SOIL#	THETA2	THETAE	THETAI	DEGSAT	FRQDEG	FS(FT/HR)	FK(FT/HR)	F1(FT/HR)
71	0.29400	0.34200	0.20374	0.69300	0.75000	0.03250	0.05900	0.97700
71	0.29400	0.34200	0.20374	0.69300	0.75000	0.02370	0.03130	0.74200

TOP LAYER SOIL DEPTH=0.750 SECOND LAYER SOIL DEPTH= 1.670

SOIL#	TIMINT	VO1(FT)	P(FT)	PEX(FT)	PINF(FT)	WFINC(FT)
71	1	0.03257	0.00667	-0.02590	0.00667	0.04822
71	2	0.00406	0.00667	0.00260	0.00406	0.07762
71	3	0.00368	0.01167	0.00799	0.00368	0.10423
71	4	0.00345	0.01667	0.01322	0.00345	0.12918
71	5	0.00329	0.01667	0.01337	0.00329	0.15301
71	6	0.00318	0.0	-0.00318	0.0	0.15301
71	7	0.00309	0.0	-0.00309	0.0	0.15301
71	8	0.00302	0.0	-0.00302	0.0	0.15301
71	9	0.00296	0.0	-0.00296	0.0	0.15301
71	10	0.00290	0.0	-0.00290	0.0	0.15301
71	11	0.00286	0.0	-0.00286	0.0	0.15301
71	12	0.00282	0.0	-0.00282	0.0	0.15301
71	13	0.00279	0.0	-0.00279	0.0	0.15301
71	14	0.00276	0.0	-0.00276	0.0	0.15301
71	15	0.00273	0.0	-0.00273	0.0	0.15301
71	16	0.00271	0.0	-0.00271	0.0	0.15301
71	17	0.00269	0.0	-0.00269	0.0	0.15301
71	18	0.00267	0.0	-0.00267	0.0	0.15301
71	19	0.00265	0.0	-0.00265	0.0	0.15301
71	20	0.00263	0.0	-0.00263	0.0	0.15301
71	21	0.00261	0.0	-0.00261	0.0	0.15301
71	22	0.00260	0.0	-0.00260	0.0	0.15301
71	23	0.00259	0.0	-0.00259	0.0	0.15301
71	24	0.00257	0.0	-0.00257	0.0	0.15301
71	25	0.00256	0.0	-0.00256	0.0	0.15301
71	26	0.00255	0.0	-0.00255	0.0	0.15301
71	27	0.00254	0.0	-0.00254	0.0	0.15301
71	28	0.00253	0.0	-0.00253	0.0	0.15301
71	29	0.00252	0.0	-0.00252	0.0	0.15301
71	30	0.00251	0.0	-0.00251	0.0	0.15301
71	31	0.00250	0.0	-0.00250	0.0	0.15301
71	32	0.00249	0.0	-0.00249	0.0	0.15301
71	33	0.00248	0.0	-0.00248	0.0	0.15301
71	34	0.00248	0.0	-0.00248	0.0	0.15301
71	35	0.00247	0.0	-0.00247	0.0	0.15301

SOIL#	THETA2	THETAE	THETAI	DEGSAT	FRQDEG	FS(FT/HR)	FK(FT/HR)	F1(FT/HR)
69	0.33700	0.31500	0.29016	0.86100	0.75000	0.01790	0.05900	0.53900
69	0.33700	0.31500	0.29016	0.86100	0.75000	0.01280	0.03130	0.41400

TOP LAYER SOIL DEPTH=0.750 SECOND LAYER SOIL DEPTH= 2.000

SOIL#	TIMINT	V01(FT)	P(FT)	PEX(FT)	PINF(FT)	WFINC(FT)
69	1	0.01797	0.00667	-0.01130	0.00667	0.26835
69	2	0.00312	0.00667	0.00354	0.00312	0.39402
69	3	0.00291	0.01167	0.00876	0.00291	0.51116
69	4	0.00278	0.01667	0.01388	0.00278	0.62321
69	5	0.00270	0.01667	0.01397	0.00270	0.73179
69	6	0.00263	0.0	-0.00263	0.0	0.73179
69	7	0.00258	0.0	-0.00258	0.0	0.73179
69	8	0.00254	0.0	-0.00254	0.0	0.73179
69	9	0.00251	0.0	-0.00251	0.0	0.73179
69	10	0.00248	0.0	-0.00248	0.0	0.73179
69	11	0.00246	0.0	-0.00246	0.0	0.73179
69	12	0.00244	0.0	-0.00244	0.0	0.73179
69	13	0.00242	0.0	-0.00242	0.0	0.73179
69	14	0.00240	0.0	-0.00240	0.0	0.73179
69	15	0.00239	0.0	-0.00239	0.0	0.73179
69	16	0.00238	0.0	-0.00238	0.0	0.73179
69	17	0.00236	0.0	-0.00236	0.0	0.73179
69	18	0.00235	0.0	-0.00235	0.0	0.73179
69	19	0.00234	0.0	-0.00234	0.0	0.73179
69	20	0.00233	0.0	-0.00233	0.0	0.73179
69	21	0.00232	0.0	-0.00232	0.0	0.73179
69	22	0.00232	0.0	-0.00232	0.0	0.73179
69	23	0.00231	0.0	-0.00231	0.0	0.73179
69	24	0.00230	0.0	-0.00230	0.0	0.73179
69	25	0.00229	0.0	-0.00229	0.0	0.73179
69	26	0.00229	0.0	-0.00229	0.0	0.73179
69	27	0.00228	0.0	-0.00228	0.0	0.73179
69	28	0.00228	0.0	-0.00228	0.0	0.73179
69	29	0.00227	0.0	-0.00227	0.0	0.73179
69	30	0.00226	0.0	-0.00226	0.0	0.73179
69	31	0.00226	0.0	-0.00226	0.0	0.73179
69	32	0.00226	0.0	-0.00226	0.0	0.73179
69	33	0.00225	0.0	-0.00225	0.0	0.73179
69	34	0.00225	0.0	-0.00225	0.0	0.73179
69	35	0.00224	0.0	-0.00224	0.0	0.73179

SOIL#	THETA2	THETAE	THETAI	DEGSAT	FRQDEG	FS(FT/HR)	FK(FT/HR)	F1(FT/HR)
57	0.28700	0.30400	0.21812	0.76000	0.75000	0.02570	0.05890	0.77100
57	0.28700	0.30400	0.21812	0.76000	0.75000	0.01870	0.03130	0.59200

TOP LAYER SOIL DEPTH=0.750 SECOND LAYER SOIL DEPTH= 2.500

SOIL#	TIMINT	VO1(FT)	P(FT)	PEX(FT)	PINF(FT)	WFINC(FT)
57	1	0.02570	0.00667	-0.01903	0.00667	0.07763
57	2	0.00362	0.00667	0.00304	0.00362	0.11981
57	3	0.00332	0.01167	0.00835	0.00332	0.15844
57	4	0.00314	0.01667	0.01353	0.00314	0.19496
57	5	0.00301	0.01667	0.01365	0.00301	0.23004
57	6	0.00292	0.0	-0.00292	0.0	0.23004
57	7	0.00285	0.0	-0.00285	0.0	0.23004
57	8	0.00279	0.0	-0.00279	0.0	0.23004
57	9	0.00275	0.0	-0.00275	0.0	0.23004
57	10	0.00271	0.0	-0.00271	0.0	0.23004
57	11	0.00267	0.0	-0.00267	0.0	0.23004
57	12	0.00264	0.0	-0.00264	0.0	0.23004
57	13	0.00261	0.0	-0.00261	0.0	0.23004
57	14	0.00259	0.0	-0.00259	0.0	0.23004
57	15	0.00257	0.0	-0.00257	0.0	0.23004
57	16	0.00255	0.0	-0.00255	0.0	0.23004
57	17	0.00253	0.0	-0.00253	0.0	0.23004
57	18	0.00252	0.0	-0.00252	0.0	0.23004
57	19	0.00250	0.0	-0.00250	0.0	0.23004
57	20	0.00249	0.0	-0.00249	0.0	0.23004
57	21	0.00248	0.0	-0.00248	0.0	0.23004
57	22	0.00246	0.0	-0.00246	0.0	0.23004
57	23	0.00245	0.0	-0.00245	0.0	0.23004
57	24	0.00244	0.0	-0.00244	0.0	0.23004
57	25	0.00243	0.0	-0.00243	0.0	0.23004
57	26	0.00242	0.0	-0.00242	0.0	0.23004
57	27	0.00241	0.0	-0.00241	0.0	0.23004
57	28	0.00241	0.0	-0.00241	0.0	0.23004
57	29	0.00240	0.0	-0.00240	0.0	0.23004
57	30	0.00239	0.0	-0.00239	0.0	0.23004
57	31	0.00238	0.0	-0.00238	0.0	0.23004
57	32	0.00238	0.0	-0.00238	0.0	0.23004
57	33	0.00237	0.0	-0.00237	0.0	0.23004
57	34	0.00237	0.0	-0.00237	0.0	0.23004
57	35	0.00236	0.0	-0.00236	0.0	0.23004

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 1
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150 0.1150
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.0550 0.1150
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 220.0 1100.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 140.0 1300.0
REACH LENGTH= 1750.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 2.3111543655 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 4044.5200195313

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0003071	0.0116667	0.0000394	1100.0000000	0.0002353	1300.0000000
0.0019133	0.0166667	0.0005720	1100.0000000	0.0012949	1300.0000000
0.0046056	0.0166667	0.0015763	1100.0000000	0.0029829	1300.0000000
0.0030786	0.0	0.0005912	1100.0000000	0.0024874	1300.0000000
0.0020887	0.0	0.0000477	1100.0000000	0.0020410	1300.0000000
0.0016400	0.0	0.0	1080.0000000	0.0016400	1280.0000000
0.0012818	0.0	0.0	1060.0000000	0.0012818	1260.0000000
0.0009651	0.0	0.0	1040.0000000	0.0009651	1240.0000000
0.0007058	0.0	0.0	1020.0000000	0.0007058	1220.0000000
0.0005586	0.0	0.0	1000.0000000	0.0005586	1200.0000000
0.0005656	0.0	0.0	980.0000000	0.0005656	1180.0000000
0.0005399	0.0	0.0	940.0000000	0.0005399	1140.0000000
0.0004394	0.0	0.0	920.0000000	0.0004394	1120.0000000
0.0003021	0.0	0.0	900.0000000	0.0003021	1100.0000000
0.0001677	0.0	0.0	880.0000000	0.0001677	1080.0000000
0.0000611	0.0	0.0	840.0000000	0.0000611	1040.0000000
0.0000024	0.0	0.0	0.0	0.0000024	80.0000000
0.0	0.0	0.0	0.0	0.0	0.0

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 2

LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE	0.0125	0.0125	0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE	0.0125	0.0125	0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE	0.2000	0.3750	0.0550
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE	0.0550	0.1150	0.0550
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM	100.0	180.0	940.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM	140.0	260.0	1360.0

REACH LENGTH= 1290.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 4.6148881912 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 5953.2031250000

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0008053	0.0116667	0.0005376	940.0000000	0.0002353	1360.0000000
0.0041353	0.0166667	0.0027940	940.0000000	0.0012949	1360.0000000
0.0093574	0.0166667	0.0063281	940.0000000	0.0029829	1360.0000000
0.0079914	0.0	0.0055040	940.0000000	0.0024874	1360.0000000
0.0067818	0.0	0.0047408	940.0000000	0.0020410	1360.0000000
0.0056747	0.0	0.0040348	920.0000000	0.0016400	1340.0000000
0.0013448	0.0	0.0000630	900.0000000	0.0012818	1320.0000000
0.0009992	0.0	0.0000341	880.0000000	0.0009651	1300.0000000
0.0006796	0.0	0.0000062	840.0000000	0.0006734	1260.0000000
0.0004050	0.0	0.0	0.0	0.0004050	80.0000000
0.0001926	0.0	0.0	0.0	0.0001926	60.0000000
0.0000534	0.0	0.0	0.0	0.0000534	20.0000000
0.0	0.0	0.0	0.0	0.0	0.0

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 3
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.3750 0.1150
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.0550 0.1150 0.0550
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 140.0 980.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 140.0 260.0 1320.0
REACH LENGTH= 1130.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 2.8512601852 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 3221.9238281250

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0003855	0.0116667	0.0000711	980.0000000	0.0002819	1320.0000000
0.0025444	0.0166667	0.0010329	980.0000000	0.0014652	1320.0000000
0.0062113	0.0166667	0.0028465	980.0000000	0.0033185	1320.0000000
0.0039540	0.0	0.0010676	980.0000000	0.0028863	1320.0000000
0.0025722	0.0	0.0000861	960.0000000	0.0024861	1320.0000000
0.0021158	0.0	0.0	940.0000000	0.0021158	1300.0000000
0.0017742	0.0	0.0	920.0000000	0.0017742	1280.0000000
0.0014606	0.0	0.0	880.0000000	0.0014606	1260.0000000
0.0011294	0.0	0.0	860.0000000	0.0011294	1220.0000000
0.0007709	0.0	0.0	0.0	0.0007709	100.0000000
0.0004668	0.0	0.0	0.0	0.0004668	80.0000000
0.0002397	0.0	0.0	0.0	0.0002397	60.0000000
0.0000888	0.0	0.0	0.0	0.0000888	20.0000000
0.0000098	0.0	0.0	0.0	0.0000098	0.0
0.0	0.0	0.0	0.0	0.0	0.0

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 4
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.0550 0.3750 0.0550
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.0550 0.3750 0.0550
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 100.0 220.0 900.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 100.0 180.0 740.0
REACH LENGTH= 1170.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 4.2111063004 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 4926.9921875000

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0005962	0.0116667	0.0002819	900.0000000	0.0002819	740.0000000
0.0029767	0.0166667	0.0014652	900.0000000	0.0014652	740.0000000
0.0066833	0.0166667	0.0033185	900.0000000	0.0033185	740.0000000
0.0057727	0.0	0.0028863	900.0000000	0.0028863	740.0000000
0.0049722	0.0	0.0024861	900.0000000	0.0024861	740.0000000
0.0042317	0.0	0.0021158	880.0000000	0.0021158	720.0000000
0.0033824	0.0	0.0016912	860.0000000	0.0016912	700.0000000
0.0025036	0.0	0.0012518	840.0000000	0.0012518	680.0000000
0.0018534	0.0	0.0009267	800.0000000	0.0009267	640.0000000
0.0011660	0.0	0.0005830	60.0000000	0.0005830	60.0000000
0.0006190	0.0	0.0003092	40.0000000	0.0003099	40.0000000
0.0002511	0.0	0.0001251	20.0000000	0.0001260	20.0000000
0.0000473	0.0	0.0000234	0.0	0.0000239	0.0
0.0	0.0	0.0	0.0	0.0	0.0

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 5
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.0550 0.1150
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 1220.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 300.0 520.0
REACH LENGTH= 2130.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 3.4995746613 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 7454.0937500000

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0005405	0.0116667	0.0002513	1220.0000000	0.0002568	520.0000000
0.0029334	0.0166667	0.0015131	1220.0000000	0.0013740	520.0000000
0.0067417	0.0166667	0.0035563	1220.0000000	0.0031391	520.0000000
0.0053478	0.0	0.0026755	1220.0000000	0.0026723	520.0000000
0.0041594	0.0	0.0019131	1200.0000000	0.0022463	500.0000000
0.0031252	0.0	0.0012670	1180.0000000	0.0018582	480.0000000
0.0022451	0.0	0.0007391	1160.0000000	0.0015060	440.0000000
0.0015246	0.0	0.0003360	1120.0000000	0.0011887	420.0000000
0.0009793	0.0	0.0000737	1100.0000000	0.0009056	300.0000000
0.0006569	0.0	0.0	0.0	0.0006569	300.0000000
0.0004433	0.0	0.0	0.0	0.0004433	280.0000000
0.0002662	0.0	0.0	0.0	0.0002662	260.0000000
0.0001282	0.0	0.0	0.0	0.0001282	220.0000000
0.0000345	0.0	0.0	0.0	0.0000345	180.0000000
0.0	0.0	0.0	0.0	0.0	0.0

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 6
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125 0.0125 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150 0.3750 0.1150 0.1150
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150 0.1150
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 100.0 220.0 560.0 860.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 100.0 1260.0
REACH LENGTH= 1340.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 5.2303237915 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 7008.6328125000

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0008477	0.0116667	0.0004077	860.0000000	0.0004077	1260.0000000
0.0042836	0.0166667	0.0021187	860.0000000	0.0021187	1260.0000000
0.0096434	0.0166667	0.0047985	860.0000000	0.0047985	1260.0000000
0.0083473	0.0	0.0041736	860.0000000	0.0041736	1260.0000000
0.0071898	0.0	0.0035949	840.0000000	0.0035949	1240.0000000
0.0061190	0.0	0.0030595	820.0000000	0.0030595	1220.0000000
0.0035175	0.0	0.0015988	800.0000000	0.0019187	1180.0000000
0.0017627	0.0	0.0008016	760.0000000	0.0009610	1160.0000000
0.0011186	0.0	0.0004886	740.0000000	0.0006300	100.0000000
0.0005359	0.0	0.0001920	40.0000000	0.0003439	80.0000000
0.0001665	0.0	0.0000322	0.0	0.0001343	60.0000000
0.0000170	0.0	0.0	0.0	0.0000170	20.0000000
0.0	0.0	0.0	0.0	0.0	0.0

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 7
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.2000 0.1150
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 180.0 340.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 420.0
REACH LENGTH= 1800.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 3.9879989624 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 7178.3945312500

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0005615	0.0116667	0.0004897	340.0000000	0.0000394	420.0000000
0.0032384	0.0166667	0.0026201	340.0000000	0.0005720	420.0000000
0.0076086	0.0166667	0.0059860	340.0000000	0.0015763	420.0000000
0.0056870	0.0	0.0050958	340.0000000	0.0005912	400.0000000
0.0043313	0.0	0.0042836	320.0000000	0.0000477	380.0000000
0.0035435	0.0	0.0035435	300.0000000	0.0	0.0
0.0028719	0.0	0.0028719	260.0000000	0.0	0.0
0.0022667	0.0	0.0022667	240.0000000	0.0	0.0
0.0017269	0.0	0.0017269	180.0000000	0.0	0.0
0.0012527	0.0	0.0012527	120.0000000	0.0	0.0
0.0001078	0.0	0.0001078	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 8
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.3750 0.2000
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 340.0 1120.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 180.0
REACH LENGTH= 960.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 3.3710384369 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 3236.1967773438

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0006130	0.0116667	0.0003737	1120.0000000	0.0002069	180.0000000
0.0038079	0.0166667	0.0024210	1120.0000000	0.0013407	180.0000000
0.0090562	0.0166667	0.0057987	1120.0000000	0.0032112	180.0000000
0.0064231	0.0	0.0041339	1100.0000000	0.0022892	180.0000000
0.0042516	0.0	0.0027363	1060.0000000	0.0015153	160.0000000
0.0024888	0.0	0.0016018	240.0000000	0.0008870	140.0000000
0.0011466	0.0	0.0007379	220.0000000	0.0004086	100.0000000
0.0002678	0.0	0.0001723	200.0000000	0.0000954	80.0000000
0.0	0.0	0.0	0.0	0.0	0.0

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 9
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.2000 0.1150 0.1150
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 720.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 260.0 460.0 960.0
REACH LENGTH= 1090.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 1.6612901688 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 1810.8061523438

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0002913	0.0116667	0.0002069	720.0000000	0.0000519	960.0000000
0.0021413	0.0166667	0.0013407	720.0000000	0.0007543	960.0000000
0.0053363	0.0166667	0.0032112	720.0000000	0.0020788	960.0000000
0.0030689	0.0	0.0022892	720.0000000	0.0007797	960.0000000
0.0015782	0.0	0.0015153	700.0000000	0.0000629	940.0000000
0.0008870	0.0	0.0008870	680.0000000	0.0	920.0000000
0.0004086	0.0	0.0004086	640.0000000	0.0	900.0000000
0.0000954	0.0	0.0000954	620.0000000	0.0	860.0000000
0.0	0.0	0.0	0.0	0.0	840.0000000

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 10
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.3750 0.1150
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 380.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 300.0 1360.0
REACH LENGTH= 960.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 2.1109523773 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 2026.5141601563

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0003548	0.0116667	0.0002513	380.0000000	0.0000711	1360.0000000
0.0025923	0.0166667	0.0015131	380.0000000	0.0010329	1360.0000000
0.0064491	0.0166667	0.0035563	380.0000000	0.0028465	1360.0000000
0.0037431	0.0	0.0026755	380.0000000	0.0010676	1360.0000000
0.0019992	0.0	0.0019131	360.0000000	0.0000861	1340.0000000
0.0012670	0.0	0.0012670	340.0000000	0.0	1320.0000000
0.0007391	0.0	0.0007391	320.0000000	0.0	1300.0000000
0.0003360	0.0	0.0003360	280.0000000	0.0	1260.0000000
0.0000737	0.0	0.0000737	260.0000000	0.0	1240.0000000
0.0	0.0	0.0	0.0	0.0	0.0

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 11
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 120.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 1600.0
REACH LENGTH= 420.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 4.1731872559 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 1752.7385253906

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0006913	0.0116667	0.0004077	120.0000000	0.0002513	1600.0000000
0.0036781	0.0166667	0.0021187	120.0000000	0.0015131	1600.0000000
0.0084011	0.0166667	0.0047985	120.0000000	0.0035563	1600.0000000
0.0068491	0.0	0.0041736	120.0000000	0.0026755	1600.0000000
0.0055080	0.0	0.0035949	120.0000000	0.0019131	1580.0000000
0.0043265	0.0	0.0030595	100.0000000	0.0012670	1560.0000000
0.0033046	0.0	0.0025656	80.0000000	0.0007391	1540.0000000
0.0014180	0.0	0.0010820	60.0000000	0.0003360	1500.0000000
0.0004582	0.0	0.0003845	40.0000000	0.0000737	1480.0000000
0.0001028	0.0	0.0001028	20.0000000	0.0	0.0
0.0000018	0.0	0.0000018	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 12
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.2000
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.2000 0.1150
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 1060.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 680.0 1180.0
REACH LENGTH= 1170.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 0.9140815735 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 1069.4753417969

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0001363	0.0116667	0.0000519	1060.0000000	0.0000519	1180.0000000
0.0015550	0.0166667	0.0007543	1060.0000000	0.0007543	1180.0000000
0.0042039	0.0166667	0.0020788	1060.0000000	0.0020788	1180.0000000
0.0015594	0.0	0.0007797	1040.0000000	0.0007797	1180.0000000
0.0001258	0.0	0.0000629	1000.0000000	0.0000629	1180.0000000
0.0	0.0	0.0	0.0	0.0	1160.0000000

CALCULATION OF LATERAL INFLOW HYDROGRAPHS

SECTION 13

LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125

RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125

LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.2000

RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.2000 0.1150

LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 640.0

RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 680.0 1880.0

REACH LENGTH= 2680.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00

VOLUME OF PRECIPITATION EXCESS= 0.9140815735 CU FT

TOTAL RUNOFF VOLUME FROM REACH= 2449.7385253906

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0001363	0.0116667	0.0000519	640.0000000	0.0000519	1880.0000000
0.0015550	0.0166667	0.0007543	640.0000000	0.0007543	1880.0000000
0.0042039	0.0166667	0.0020788	640.0000000	0.0020788	1880.0000000
0.0015594	0.0	0.0007797	620.0000000	0.0007797	1880.0000000
0.0001258	0.0	0.0000629	580.0000000	0.0000629	1860.0000000
0.0	0.0	0.0	0.0	0.0	1840.0000000

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 14
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.0550 0.1150
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150 0.0550
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 380.0 840.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 340.0 720.0
REACH LENGTH= 2380.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 2.7123842239 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 6455.4726562500

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0003537	0.0116667	0.0002819	840.0000000	0.0000394	720.0000000
0.0020835	0.0166667	0.0014652	840.0000000	0.0005720	720.0000000
0.0049411	0.0166667	0.0033185	840.0000000	0.0015763	720.0000000
0.0034776	0.0	0.0028863	840.0000000	0.0005912	720.0000000
0.0025338	0.0	0.0024861	820.0000000	0.0000477	720.0000000
0.0021158	0.0	0.0021158	800.0000000	0.0	720.0000000
0.0017742	0.0	0.0017742	780.0000000	0.0	700.0000000
0.0014606	0.0	0.0014606	740.0000000	0.0	680.0000000
0.0011746	0.0	0.0011746	720.0000000	0.0	680.0000000
0.0009162	0.0	0.0009162	380.0000000	0.0	660.0000000
0.0006859	0.0	0.0006859	380.0000000	0.0	640.0000000
0.0004844	0.0	0.0004844	360.0000000	0.0	620.0000000
0.0003130	0.0	0.0003130	340.0000000	0.0	600.0000000
0.0001737	0.0	0.0001737	300.0000000	0.0	580.0000000
0.0000698	0.0	0.0000698	280.0000000	0.0	540.0000000
0.0000082	0.0	0.0000082	240.0000000	0.0	500.0000000
0.0	0.0	0.0	0.0	0.0	0.0

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 15
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.0550 0.0550
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 760.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 260.0 1000.0
REACH LENGTH= 2380.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 2.0400657654 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 4855.3554687500

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0003824	0.0116667	0.0002069	760.0000000	0.0001431	1000.0000000
0.0023141	0.0166667	0.0013407	760.0000000	0.0009272	1000.0000000
0.0054782	0.0166667	0.0032112	760.0000000	0.0022208	1000.0000000
0.0038724	0.0	0.0022892	760.0000000	0.0015831	1000.0000000
0.0025632	0.0	0.0015153	740.0000000	0.0010479	1000.0000000
0.0015004	0.0	0.0008870	720.0000000	0.0006134	980.0000000
0.0006913	0.0	0.0004086	680.0000000	0.0002826	960.0000000
0.0001614	0.0	0.0000954	660.0000000	0.0000660	940.0000000
0.0	0.0	0.0	0.0	0.0	900.0000000

CALCULATION OF LATERAL INFLOW HYDROGRAPHS
SECTION 16
LEFT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125
RIGHT DEPRESSION STORAGE FOR EACH SOIL ZONE 0.0125
LEFT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.3750
RIGHT SIDE AVERAGE SLOPE FOR EACH SOIL ZONE 0.1150
LEFT SIDE DISTANCE OF SOIL ZONE FROM STREAM 600.0
RIGHT SIDE DISTANCE OF SOIL ZONE FROM STREAM 500.0
REACH LENGTH= 3460.00 STREAM WIDTH= 10.00 MANNINGS N= 0.350000 DELTAX= 20.00
VOLUME OF PRECIPITATION EXCESS= 3.3710384369 CU FT
TOTAL RUNOFF VOLUME FROM REACH= 11663.7929687500

PRECIP EXCESS VALUES FOR EACH DELT

QL CFS/FT	PRECIP DEPTH	LEFT SIDE QL	WIDTH OF CONTRIB AREA	RIGHT SIDE QL	WIDTH OF RIGHT SIDE
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0000185	0.0066667	0.0	0.0	0.0	0.0
0.0006130	0.0116667	0.0003737	600.0000000	0.0002069	500.0000000
0.0038079	0.0166667	0.0024210	600.0000000	0.0013407	500.0000000
0.0090562	0.0166667	0.0057987	600.0000000	0.0032112	500.0000000
0.0064231	0.0	0.0041339	580.0000000	0.0022892	500.0000000
0.0042516	0.0	0.0027363	540.0000000	0.0015153	480.0000000
0.0024888	0.0	0.0016018	500.0000000	0.0008870	460.0000000
0.0011466	0.0	0.0007379	480.0000000	0.0004086	420.0000000
0.0002678	0.0	0.0001723	460.0000000	0.0000954	400.0000000
0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX D.3

a	b	c	d	e	f
0.0835	0.08350	0.00996	0.00022	0.29121	0.23857
0.1670	0.16700	0.03984	0.00139	0.58244	0.47716
0.2505	0.25050	0.08964	0.00410	0.87364	0.71571
0.3340	0.33400	0.15937	0.00883	1.16487	0.95430
0 4175	0.41750	0.24901	0.01603	1.45607	1.19286
0.5010	0.50100	0.35858	0.02608	1.74729	1.43144
0.5845	0.58450	0.48806	0.03936	2.03849	1.67000
0.6680	0.66800	0.63747	0.05622	2.32972	1.90858
0.7515	0.75150	0.80742	0.07669	2.64151	2.17168
0.8350	0.83500	1.00037	0.10149	2.96609	2.45000
0.9185	0.91850	1.21657	0.13126	3.29067	2.72832
1.0020	1.00200	1.45600	0.16636	3.61527	3.00667
1.0855	1.08550	1.71868	0.20717	3.93985	3.28499
1.1690	1.16900	2.00460	0.25404	4.26446	3.56334
1.2525	1.25250	2.31375	0.30732	4.58904	3.84166
1.3360	1.33600	2.64584	0.36798	4.89924	4.10286
1.4195	1.41950	2.99839	0.43626	5.19044	4.34142
1.5030	1.50300	3.37086	0.51143	5.48167	4.58000
1.5865	1.58650	3.76325	0.59373	5.77287	4.81856
1.6700	1.67000	4.17556	0.68340	6.06410	5.05714
1.7535	1.75350	4.60779	0.78067	6.35530	5.29570
1.8370	1.83700	5.05994	0.88576	6.64652	5.53429
1.9205	1.92050	5.53201	0.99892	6.93772	5.77284
2 0040	2.00400	6.02400	1.12037	7.22895	6.01143
2.0875	2.08750	6.53592	1.25033	7.52015	6.24998
2.1710	2.17100	7.06775	1.38901	7.81138	6.48857
2.2545	2.25450	7.61951	1.53665	8.10258	6.72713
2.3380	2.33800	8.19118	1.69344	8.39380	6.96571
2.4215	2.42150	8.78278	1.85961	8.68500	7.20427
2.5050	2.50500	9.39430	2.03537	8.97623	7.44286
2.5885	2.58850	10.02573	2.22093	9.26743	7.68141
2.6720	2.67200	10.67709	2.41648	9.55866	7.92000
2.7555	2.75550	11.34910	2.61858	9.87204	8.18498
2.8390	2.83900	12.04417	2.82986	10.19664	8.46333
2.9225	2.92250	12.76248	3.05253	10.52122	8.74165
3.0060	3.00600	13.50402	3.28686	10.84580	9.01997
3.0895	3.08950	14.26881	3.53309	11.17040	9.29832
3.1730	3.17300	15.05684	3.79147	11.49498	9.57664
3.2565	3.25650	15.86812	4.06225	11.81959	9.85500
3.3400	3.34000	16.70222	4.34934	12.12818	10.11427
3.4235	3.42350	17.55672	4.65271	12.41941	10.35286
3.5070	3.50700	18.43112	4.96836	12.71061	10.59142
3.5905	3.59050	19.32549	5.29649	13.00183	10.83000
3.6740	3.67400	20.23975	5.63725	13.29303	11.06856
3.7575	3.75750	21.17392	5.99083	13.58426	11.30714
3.8410	3.84100	22.12802	6.35743	13.87546	11.54570
3.9245	3.92450	23.10207	6.73722	14.16669	11.78429
4.0080	4.00800	24.09599	7.13011	14.45862	12.02373
4.0915	4.09150	25.11029	7.53440	14.75744	12.27147
4.1750	4.17500	26.14532	7.95264	15.05625	12.51921
4.2585	4.25850	27.20102	8.38497	15.35508	12.76697
4.3420	4.34200	28.27740	8.83162	15.65390	13.01471
4.4255	4.42550	29.37448	9.29275	15.95273	13.26247
4.5090	4.50900	30.49223	9.76855	16.25154	13.51021
4.5925	4.59249	31.63068	10.25920	16.55037	13.75797
4.6760	4.67599	32.78979	10.76489	16.84917	14.00569
4.7595	4.75949	33.97002	11.28077	17.15988	14.26761
4.8430	4.84299	35.17253	11.81048	17.47537	14.53523
4.9265	4.92649	36.39743	12.35632	17.79089	14.80287
5.0100	5.00999	37.64464	12.91845	18.10640	15.07050

5.0935	5.09349	38.91418	13.49707	18.42191	15.33813
5.1770	5.17699	40.20607	14.09241	18.73740	15.60574
5.2605	5.26049	41.52034	14.70467	19.05290	15.87337
5.3440	5.34399	42.85660	15.34060	19.35561	16.12569
5.4275	5.42749	44.21303	15.99913	19.64684	16.36427
5.5110	5.51099	45.58940	16.67435	19.93803	16.60283
5.5945	5.59449	46.98572	17.36639	20.22925	16.84142
5.6780	5.67799	48.40195	18.07545	20.52045	17.07997
5.7615	5.76149	49.83806	18.80159	20.81168	17.31856
5.8450	5.84499	51.29410	19.54504	21.10287	17.55711
5.9285	5.92849	52.77011	20.30600	21.39410	17.79570
6.0120	6.01199	54.26599	21.08453	21.68529	18.03424
6.0955	6.09549	55.78178	21.88080	21.97650	18.27283
6.1790	6.17899	57.31754	22.69502	22.26772	18.51138
6.2625	6.26249	58.87321	23.52733	22.55893	18.74997
6.3460	6.34599	60.44879	24.37784	22.85013	18.98853
6.4295	6.42949	62.04428	25.24670	23.14136	19.22711
6.5130	6.51299	63.65970	26.13412	23.43256	19.46567
6.5965	6.59649	65.29507	27.04022	23.72379	19.70425
6.6800	6.67999	66.95030	27.96513	24.01498	19.94281
6.7635	6.76349	68.62645	28.88951	24.33157	20.21164
6.8470	6.84699	70.32573	29.82800	24.65616	20.48996
6.9305	6.93049	72.04829	30.78714	24.98073	20.76828
7.0140	7.01399	73.79405	31.76706	25.30533	21.04663
7.0975	7.09749	75.56303	32.76794	25.62991	21.32495
7.1810	7.18099	77.35530	33.79007	25.95451	21.60330
7 2645	7.26449	79.17082	34.83359	26.27908	21.88162
7.3480	7.34799	81.00899	35.91554	26.58450	22.13712
7.4315	7.43149	82.86737	37.03075	26.87570	22.37567
7.5150	7.51499	84.74570	38.16650	27.16693	22.61426
7.5985	7.59849	86.64398	39.32301	27.45811	22.85281
7.6820	7.68199	88.56215	40.50031	27.74934	23.09140
7.7655	7.76549	90.50021	41.69858	28.04054	23.32996
7.8490	7.84899	92.45822	42.91792	28.33177	23.56854
7.9325	7.93249	94.43619	44.15862	28.62297	23.80710
8.0160	8.01599	96.43404	45.42067	28.91418	24.04568
8.0995	8.09949	98.45172	46.70419	29.20538	24.28424
8.1830	8.18299	100.48947	48.00951	29.49660	24.52283
8.2665	8.26649	102.54700	49.33655	29.78781	24.76138
8.3500	8.34999	104.62466	50.68567	30.07903	24.99997
8.4335	8.43349	106.72200	52.05676	30.37022	25.23853
8.5170	8.51699	108.83945	53.45016	30.66145	25.47711
8.6005	8.60049	110.97665	54.86589	30.95265	25.71567
8.6840	8.68399	113.13397	56.30424	31.24388	25.95425
8.7675	8.76749	115.31209	57.73293	31.56204	26.22495
8.8510	8.85099	117.51358	59.17831	31.88663	26.50330
8.9345	8.93449	119.73811	60.64801	32.21121	26.78162
9.0180	9.01799	121.98613	62.14261	32.53580	27.05995
9.1015	9.10149	124.25716	63.66185	32.86040	27.33829
9.1850	9.18499	126.55159	65.20627	33.18497	27.61661
9.2685	9.26849	128.86909	66.77571	33.50957	27.89496
9.3520	9.35199	131.20941	68.39833	33.81337	28.14853
9.4355	9.43549	133.56967	70.06175	34.10458	28.38708
9.5190	9.51899	135.95003	71.74939	34.39580	28.62567
9.6025	9.60249	138.35013	73.46107	34.68700	28.86423
9.6860	9.68599	140.77037	75.19739	34.97820	29.10281
9.7695	9.76949	143.21028	76.95795	35.26942	29.34137
9.8530	9.85299	145.67036	78.74332	35.56062	29.57996
9.9365	9.93649	148.15013	80.55324	35.85185	29.81851
10.0200	10.01999	150.65005	82.38828	36.14305	30.05710

10.1035	10.10349	153.16966	84.24808	36.43427	30.29565
10.1870	10.18699	155.70943	86.13332	36.72546	30.53424
10.2705	10.27049	158.26888	88.04356	37.01668	30.77280
10.3540	10.35399	160.84846	89.97939	37.30789	31.01138
10.4375	10.43749	163.44775	91.94057	37.59909	31.24995
10.5210	10.52099	166.06721	93.92764	37.89032	31.48853
10.6045	10.60449	168.70634	95.94028	38.18152	31.72710
10.6880	10.68799	171.36563	97.97905	38.47275	31.96567
10.7715	10.77149	174.04581	99.99544	38.79253	32.23828
10.8550	10.85499	176.74945	102.03175	39.11711	32.51660
10.9385	10.93849	179.47609	104.09601	39.44170	32.79495
11.0220	11.02199	182.22618	106.18860	39.76627	33.07327
11.1055	11.10549	184.99930	108.30954	40.09087	33.35162
11.1890	11.18899	187.79593	110.45930	40.41545	33.62994
11.2725	11.27249	190.61551	112.63742	40.74005	33.90826
11.3560	11.35599	193.45781	114.88608	41.04224	34.15994
11.4395	11.43949	196.31999	117.18217	41.33347	34.39853
11.5230	11.52299	199.20238	119.50606	41.62466	34.63708
11.6065	11.60649	202.10442	121.85716	41.91588	34.87567
11.6900	11.68999	205.02660	124.23611	42.20708	35.11423
11.7735	11.77349	207.96846	126.64270	42.49831	35.35281
11.8570	11.85699	210.93053	129.07738	42.78951	35.59137
11.9405	11.94049	213.91223	131.53972	43.08073	35.82996
12.0240	12.02399	216.91408	134.03058	43.37192	36.06851
12.1075	12.10749	219.93562	136.54941	43.66315	36.30710
12.1910	12.19099	222.97740	139.09697	43.95435	36.54565
12.2745	12.27449	226.03877	141.67259	44.24556	36.78424
12.3580	12.35799	229.12030	144.27728	44.53677	37.02280
12.4415	12.44149	232.22151	146.91025	44.82799	37.26138
12.5250	12.52499	235.34300	149.57257	45.11920	37.49994
12.6085	12.60849	238.48405	152.26369	45.41042	37.73853
12.6920	12.69199	241.64526	154.98398	45.70163	37.97708
12.7755	12.77549	244.82751	157.66539	46.02301	38.25162
12.8590	12.85899	248.03334	160.37128	46.34760	38.52994
12.9425	12.94249	251.26207	163.10846	46.67215	38.80826
13.0260	13.02599	254.51427	165.87732	46.99675	39.08661
13.1095	13.10949	257.78906	168.67723	47.32133	39.36493
13.1930	13.19299	261.08765	171.50981	47.64594	39.64328
13.2765	13.27649	264.40918	174.37421	47.97052	39.92160
13.3600	13.35999	267.75342	177.32918	48.27112	40.17137
13.4435	13.44349	271.11743	180.33717	48.56235	40.40994
13.5270	13.52699	274.50171	183.37622	48.85355	40.64851
13.6105	13.61049	277.90576	186.44565	49.14478	40.88708
13.6940	13.69398	281.32959	189.54576	49.43597	41.12566
13.7775	13.77748	284.77344	192.67664	49.72720	41.36423
13.8610	13.86098	288.23706	195.83870	50.01840	41.60280
13.9445	13.94448	291.72095	199.03201	50.30963	41.84137
14.0280	14.02798	295.22534	202.25725	50.60083	42.07996
14.1115	14.11148	298.74854	205.51256	50.89204	42.31851
14.1950	14.19498	302.29248	208.80020	51.18326	42.55710
14.2785	14.27848	305.85547	212.11862	51.47446	42.79565
14.3620	14.36198	309.43896	215.46930	51.76567	43.03424
14.4455	14.44548	313.04224	218.85155	52.05688	43.27280
14.5290	14.52898	316.66553	222.26593	52.34808	43.51138
14.6125	14.61248	320.30859	225.71220	52.63931	43.74994
14.6960	14.69598	323.97168	229.19063	52.93051	43.98853
14.7795	14.77948	327.65576	232.60960	53.25348	44.26492
14.8630	14.86298	331.36353	236.05896	53.57808	44.54327
14.9465	14.94648	335.09448	239.54309	53.90265	44.82159
15.0300	15.02998	338.84839	243.06177	54.22723	45.09993

15.1135	15.11348	342.62573	246.61557	54.55182	45.37827
15.1970	15.19698	346.42676	250.20500	54.87640	45.65659
15.2805	15.28048	350.25049	253.82886	55.20102	45.93494
15.3640	15.36398	354.09619	257.56641	55.50002	46.18280
15.4475	15.44748	357.96240	261.36206	55.79121	46.42136
15.5310	15.53098	361.84863	265.19116	56.08244	46.65994
15.6145	15.61448	365.75464	269.05396	56.37363	46.89850
15.6980	15.69798	369.68042	272.94995	56.66486	47.13708
15.7815	15.78148	373.62622	276.88013	56.95605	47.37564
15.8650	15.86498	377.59180	280.84399	57.24728	47.61423
15.9485	15.94848	381.57764	284.84229	57.53848	47.85278
16.0320	16.03198	385.58301	288.87402	57.82970	48.09137
16.1155	16.11548	389.60864	292.94116	58.12090	48.32993
16.1990	16.19897	393.65356	297.04126	58.41209	48.56848
16.2825	16.28247	397.71875	301.17676	58.70328	48.80704
16.3660	16.36597	401.80396	305.34668	58.99449	49.04562
16.4495	16.44946	405.90918	309.55151	59.28569	49.28418
16.5330	16.53296	410.03418	313.79077	59.57690	49.52274
16.6165	16.61646	414.17896	318.06494	59.86810	49.76129
16.7000	16.69995	418.34375	322.37476	60.15929	49.99985
16.7000	16.70000	418.34668	322.37744	60.15945	50.00000

a Water Surface Elevation

b Water Depth

c Area of Section

d Normal Discharge

e Wetted Perimeter

f Top Width of Water Surface

TRIBUTARY A

APPENDIX D.4

XN1= 0.0500
TOLR=.0000010 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 2390.

IN SECTION NO = 1 OUT SECTION NO = 2

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.00421	0.00227	120.
0.0	0.0	0.00814	0.00513	240.
0.0	0.0	0.08836	0.11506	360.
0.0	0.0	0.52151	1.21723	480.
0.0	0.0	1.39103	4.43395	600.
0.0	0.0	1.72748	5.90446	720.
0.0	0.0	1.74276	5.97394	840.
0.0	0.0	1.57720	5.23466	960.
0.0	0.0	1.32530	4.16066	1080.
0.0	0.0	1.05482	3.07925	1200.
0.0	0.0	0.82899	2.24890	1320.
0.0	0.0	0.66121	1.67086	1440.
0.0	0.0	0.53472	1.25964	1560.
0.0	0.0	0.43777	0.96546	1680.
0.0	0.0	0.36237	0.75087	1800.
0.0	0.0	0.30311	0.59013	1920.
0.0	0.0	0.25571	0.47204	2040.
0.0	0.0	0.21758	0.37966	2160.
0.0	0.0	0.18643	0.31026	2280.
0.0	0.0	0.16097	0.25354	2400.
0.0	0.0	0.13974	0.21134	2520.
0.0	0.0	0.12199	0.17675	2640.
0.0	0.0	0.10715	0.14783	2760.
0.0	0.0	0.09457	0.12528	2880.
0.0	0.0	0.08377	0.10751	3000.
0.0	0.0	0.07451	0.09226	3120.
0.0	0.0	0.06656	0.07917	3240.
0.0	0.0	0.05974	0.06794	3360.
0.0	0.0	0.05380	0.05915	3480.
0.0	0.0	0.04855	0.05221	3600.
0.0	0.0	0.04393	0.04609	3720.
0.0	0.0	0.03984	0.04068	3840.
0.0	0.0	0.03624	0.03591	3960.
0.0	0.0	0.03305	0.03170	4080.
0.0	0.0	0.03024	0.02798	4200.
0.0	0.0	0.02776	0.02470	4320.
0.0	0.0	0.02557	0.02180	4440.
0.0	0.0	0.02359	0.01980	4560.
0.0	0.0	0.02177	0.01808	4680.
0.0	0.0	0.02011	0.01650	4800.
0.0	0.0	0.01860	0.01506	4920.
0.0	0.0	0.01722	0.01375	5040.
0.0	0.0	0.01596	0.01256	5160.

TRIBUTARY B

XN1= 0.0500
TOLR=.0000010 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 3460.

IN SECTION NO = 1 OUT SECTION NO = 2

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.00426	0.00256	120.
0.0	0.0	0.00829	0.00588	240.
0.0	0.0	0.13911	0.23501	360.
0.0	0.0	0.86791	2.66855	480.
0.0	0.0	2.35231	9.93426	600.
0.0	0.0	2.95526	13.53142	720.
0.0	0.0	3.01222	13.88944	840.
0.0	0.0	2.75582	12.30760	960.
0.0	0.0	2.34480	9.89285	1080.
0.0	0.0	1.89258	7.44598	1200.
0.0	0.0	1.50950	5.52281	1320.
0.0	0.0	1.22023	4.17019	1440.
0.0	0.0	0.99798	3.20417	1560.
0.0	0.0	0.82475	2.49745	1680.
0.0	0.0	0.68812	1.96976	1800.
0.0	0.0	0.57932	1.56843	1920.
0.0	0.0	0.49193	1.25988	2040.
0.0	0.0	0.42095	1.02339	2160.
0.0	0.0	0.36265	0.84040	2280.
0.0	0.0	0.31457	0.69315	2400.
0.0	0.0	0.27436	0.57974	2520.
0.0	0.0	0.24066	0.48585	2640.
0.0	0.0	0.21215	0.41097	2760.
0.0	0.0	0.18784	0.35045	2880.
0.0	0.0	0.16712	0.29884	3000.
0.0	0.0	0.14928	0.25714	3120.
0.0	0.0	0.13378	0.22340	3240.
0.0	0.0	0.12032	0.19409	3360.
0.0	0.0	0.10862	0.16862	3480.
0.0	0.0	0.09841	0.14727	3600.
0.0	0.0	0.08935	0.13056	3720.
0.0	0.0	0.08132	0.11574	3840.
0.0	0.0	0.07421	0.10261	3960.
0.0	0.0	0.06790	0.09097	4080.
0.0	0.0	0.06230	0.08064	4200.
0.0	0.0	0.05734	0.07149	4320.
0.0	0.0	0.05286	0.06467	4440.
0.0	0.0	0.04879	0.05864	4560.
0.0	0.0	0.04510	0.05318	4680.
0.0	0.0	0.04176	0.04822	4800.
0.0	0.0	0.03872	0.04373	4920.
0.0	0.0	0.03597	0.03966	5040.
0.0	0.0	0.03348	0.03596	5160.

XN1= 0.0500 TRIBUTARY C

TOLR=.0000010 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 2130.

IN SECTION NO = 1 OUT SECTION NO = 2

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.00421	0.00200	120.
0.0	0.0	0.00815	0.00450	240.
0.0	0.0	0.12083	0.15115	360.
0.0	0.0	0.66167	1.44825	480.
0.0	0.0	1.71089	5.04797	600.
0.0	0.0	2.20038	7.04662	720.
0.0	0.0	2.33831	7.63535	840.
0.0	0.0	2.26385	7.31753	960.
0.0	0.0	2.07050	6.49802	1080.
0.0	0.0	1.81943	5.47565	1200.
0.0	0.0	1.55367	4.44451	1320.
0.0	0.0	1.31110	3.55204	1440.
0.0	0.0	1.09998	2.81791	1560.
0.0	0.0	0.91472	2.21119	1680.
0.0	0.0	0.75236	1.71399	1800.
0.0	0.0	0.61316	1.30892	1920.
0.0	0.0	0.50065	0.99844	2040.
0.0	0.0	0.41350	0.77349	2160.
0.0	0.0	0.34490	0.60884	2280.
0.0	0.0	0.29040	0.48367	2400.
0.0	0.0	0.24656	0.38908	2520.
0.0	0.0	0.21095	0.31603	2640.
0.0	0.0	0.18170	0.25962	2760.
0.0	0.0	0.15766	0.21333	2880.
0.0	0.0	0.13747	0.17924	3000.
0.0	0.0	0.12050	0.15059	3120.
0.0	0.0	0.10624	0.12652	3240.
0.0	0.0	0.09410	0.10782	3360.
0.0	0.0	0.08363	0.09286	3480.
0.0	0.0	0.07462	0.07998	3600.
0.0	0.0	0.06686	0.06889	3720.
0.0	0.0	0.06017	0.05933	3840.
0.0	0.0	0.05434	0.05173	3960.
0.0	0.0	0.04918	0.04585	4080.
0.0	0.0	0.04460	0.04063	4200.
0.0	0.0	0.04054	0.03601	4320.
0.0	0.0	0.03695	0.03191	4440.
0.0	0.0	0.03376	0.02828	4560.
0.0	0.0	0.03094	0.02506	4680.
0.0	0.0	0.02844	0.02221	4800.
0.0	0.0	0.02622	0.01968	4920.
0.0	0.0	0.02422	0.01774	5040.
0.0	0.0	0.02239	0.01623	5160.

XN1= 0.0500

TRIBUTARY D

TOLR=.0000010 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 2380.

IN SECTION NO = 1 OUT SECTION NO = 2

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.00421	0.00227	120.
0.0	0.0	0.00813	0.00512	240.
0.0	0.0	0.08241	0.10526	360.
0.0	0.0	0.47416	1.07388	480.
0.0	0.0	1.26552	3.91208	600.
0.0	0.0	1.57378	5.21978	720.
0.0	0.0	1.63058	5.46716	840.
0.0	0.0	1.60034	5.33546	960.
0.0	0.0	1.52237	4.99585	1080.
0.0	0.0	1.41552	4.53580	1200.
0.0	0.0	1.29188	4.02166	1320.
0.0	0.0	1.15977	3.49063	1440.
0.0	0.0	1.02512	2.96774	1560.
0.0	0.0	0.89205	2.47244	1680.
0.0	0.0	0.76371	2.01762	1800.
0.0	0.0	0.64309	1.60956	1920.
0.0	0.0	0.53328	1.25504	2040.
0.0	0.0	0.43787	0.96575	2160.
0.0	0.0	0.36220	0.75040	2280.
0.0	0.0	0.30277	0.58929	2400.
0.0	0.0	0.25528	0.47097	2520.
0.0	0.0	0.21710	0.37859	2640.
0.0	0.0	0.18593	0.30915	2760.
0.0	0.0	0.16047	0.25244	2880.
0.0	0.0	0.13926	0.21039	3000.
0.0	0.0	0.12152	0.17584	3120.
0.0	0.0	0.10670	0.14696	3240.
0.0	0.0	0.09414	0.12458	3360.
0.0	0.0	0.08337	0.10684	3480.
0.0	0.0	0.07413	0.09163	3600.
0.0	0.0	0.06620	0.07858	3720.
0.0	0.0	0.05941	0.06739	3840.
0.0	0.0	0.05348	0.05873	3960.
0.0	0.0	0.04826	0.05182	4080.
0.0	0.0	0.04365	0.04572	4200.
0.0	0.0	0.03958	0.04034	4320.
0.0	0.0	0.03599	0.03559	4440.
0.0	0.0	0.03283	0.03140	4560.
0.0	0.0	0.03003	0.02770	4680.
0.0	0.0	0.02757	0.02444	4800.
0.0	0.0	0.02539	0.02156	4920.
0.0	0.0	0.02341	0.01964	5040.
0.0	0.0	0.02161	0.01792	5160.

XN1= 0.0500 TRIBUTARY E

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1750.

IN SECTION NO = 1 OUT SECTION NO = 2

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.00397	0.00340	120.
0.0	0.0	0.00744	0.00708	240.
0.0	0.0	0.06466	0.12015	360.
0.0	0.0	0.36153	1.18358	480.
0.0	0.0	0.91389	4.03215	600.
0.0	0.0	1.01636	4.64032	720.
0.0	0.0	0.94188	4.19830	840.
0.0	0.0	0.83965	3.61548	960.
0.0	0.0	0.73260	3.02372	1080.
0.0	0.0	0.62690	2.45960	1200.
0.0	0.0	0.52789	1.95709	1320.
0.0	0.0	0.44678	1.56903	1440.
0.0	0.0	0.39833	1.34305	1560.
0.0	0.0	0.36408	1.19462	1680.
0.0	0.0	0.32746	1.03595	1800.
0.0	0.0	0.28291	0.85348	1920.
0.0	0.0	0.23304	0.65711	2040.
0.0	0.0	0.18237	0.47640	2160.
0.0	0.0	0.13788	0.32860	2280.
0.0	0.0	0.10620	0.23099	2400.
0.0	0.0	0.08312	0.16833	2520.
0.0	0.0	0.06612	0.12396	2640.
0.0	0.0	0.05342	0.09261	2760.
0.0	0.0	0.04355	0.07198	2880.
0.0	0.0	0.03587	0.05595	3000.
0.0	0.0	0.02991	0.04349	3120.
0.0	0.0	0.02527	0.03380	3240.
0.0	0.0	0.02143	0.02804	3360.
0.0	0.0	0.01824	0.02326	3480.
0.0	0.0	0.01559	0.01929	3600.
0.0	0.0	0.01340	0.01600	3720.
0.0	0.0	0.01158	0.01328	3840.
0.0	0.0	0.01006	0.01101	3960.
0.0	0.0	0.00881	0.00913	4080.
0.0	0.0	0.00777	0.00758	4200.
0.0	0.0	0.00691	0.00629	4320.
0.0	0.0	0.00619	0.00529	4440.
0.0	0.0	0.00554	0.00473	4560.
0.0	0.0	0.00496	0.00423	4680.
0.0	0.0	0.00444	0.00379	4800.
0.0	0.0	0.00397	0.00339	4920.
0.0	0.0	0.00355	0.00304	5040.
0.0	0.0	0.00318	0.00272	5160.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1290.

IN SECTION NO = 2 OUT SECTION NO = 3

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00397	0.00340	0.00101	0.00048	120.
0.00744	0.00708	0.00303	0.00144	240.
0.06466	0.12015	0.08421	0.09369	360.
0.36153	1.18358	0.53188	1.08302	480.
0.91389	4.03215	1.56818	4.49923	600.
1.01636	4.64032	2.28178	7.39407	720.
0.94188	4.19830	2.58024	8.71588	840.
0.83965	3.61548	2.59719	8.79187	960.
0.73260	3.02372	2.23973	7.21460	1080.
0.62690	2.45960	1.93403	5.93780	1200.
0.52789	1.95709	1.66089	4.85097	1320.
0.44678	1.56903	1.41746	3.93502	1440.
0.39833	1.34305	1.21142	3.19994	1560.
0.36408	1.19462	1.04747	2.64265	1680.
0.32746	1.03595	0.91686	2.21818	1800.
0.28291	0.85348	0.80679	1.87938	1920.
0.23304	0.65711	0.70563	1.57707	2040.
0.18237	0.47640	0.61025	1.30084	2160.
0.13788	0.32860	0.52053	1.05150	2280.
0.10620	0.23099	0.43903	0.83938	2400.
0.08312	0.16833	0.36936	0.66686	2520.
0.06612	0.12396	0.31108	0.52860	2640.
0.05342	0.09261	0.26230	0.42304	2760.
0.04355	0.07198	0.22260	0.33848	2880.
0.03587	0.05595	0.18956	0.27477	3000.
0.02991	0.04349	0.16228	0.22217	3120.
0.02527	0.03380	0.13929	0.18231	3240.
0.02143	0.02804	0.12037	0.15037	3360.
0.01824	0.02326	0.10480	0.12409	3480.
0.01559	0.01929	0.09163	0.10430	3600.
0.01340	0.01600	0.08039	0.08823	3720.
0.01158	0.01328	0.07081	0.07454	3840.
0.01006	0.01101	0.06267	0.06290	3960.
0.00881	0.00913	0.05571	0.05329	4080.
0.00777	0.00758	0.04955	0.04627	4200.
0.00691	0.00629	0.04412	0.04008	4320.
0.00619	0.00529	0.03938	0.03468	4440.
0.00554	0.00473	0.03532	0.03005	4560.
0.00496	0.00423	0.03183	0.02608	4680.
0.00444	0.00379	0.02884	0.02267	4800.
0.00397	0.00339	0.02627	0.01974	4920.
0.00355	0.00304	0.02398	0.01754	5040.
0.00318	0.00272	0.02192	0.01584	5160.
0.00285	0.00243	0.02004	0.01430	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1130.

IN SECTION NO = 3 OUT SECTION NO = 4

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00101	0.00048	0.00327	0.00124	120.
0.00303	0.00144	0.00554	0.00211	240.
0.08421	0.09369	0.07354	0.06407	360.
0.53188	1.08302	0.48936	0.79146	480.
1.56818	4.49923	1.52493	3.54047	600.
2.28178	7.39407	2.42466	6.54712	720.
2.58024	8:71588	3.13253	9.26278	840.
2.59719	8.79187	3.56932	11.05712	960.
2.23973	7.21460	3.52487	10.86917	1080.
1.93403	5.93780	3.28673	9.88813	1200.
1.66089	4.85097	2.97388	8.63211	1320.
1.41746	3.93502	2.63752	7.32927	1440.
1.21142	3.19994	2.30379	6.11392	1560.
1.04747	2.64265	1.99270	5.04491	1680.
0.91686	2.21818	1.72204	4.15759	1800.
0.80679	1.87938	1.49807	3.45773	1920.
0.70563	1.57707	1.31546	2.91312	2040.
0.61025	1.30084	1.16174	2.47372	2160.
0.52053	1.05150	1.02767	2.10516	2280.
0.43903	0.83938	0.90778	1.78760	2400.
0.36936	0.66686	0.79791	1.51218	2520.
0.31108	0.52860	0.69856	1.27077	2640.
0.26230	0.42304	0.61115	1.06425	2760.
0.22260	0.33848	0.53393	0.88901	2880.
0.18956	0.27477	0.46717	0.74468	3000.
0.16228	0.22217	0.40935	0.62281	3120.
0.13929	0.18231	0.35949	0.52534	3240.
0.12037	0.15037	0.31647	0.44199	3360.
0.10480	0.12409	0.27885	0.37453	3480.
0.09163	0.10430	0.24666	0.31786	3600.
0.08039	0.08823	0.21911	0.27090	3720.
0.07081	0.07454	0.19503	0.23299	3840.
0.06267	0.06290	0.17406	0.19998	3960.
0.05571	0.05329	0.15587	0.17174	4080.
0.04955	0.04627	0.14002	0.14989	4200.
0.04412	0.04008	0.12618	0.13080	4320.
0.03938	0.03468	0.11405	0.11409	4440.
0.03532	0.03005	0.10339	0.09938	4560.
0.03183	0.02608	0.09379	0.08769	4680.
0.02884	0.02267	0.08512	0.07757	4800.
0.02627	0.01974	0.07734	0.06850	4920.
0.02398	0.01754	0.07049	0.06051	5040.
0.02192	0.01584	0.06455	0.05357	5160.
0.02004	0.01430	0.05936	0.04752	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1170.

IN SECTION NO = 4		OUT SECTION NO = 5		
IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00327	0.00124	0.00132	0.00050	120.
0.00554	0.00211	0.00363	0.00138	240.
0.07354	0.06407	0.05732	0.04513	360.
0.48936	0.79146	0.35887	0.52413	480.
1.52493	3.54047	1.11582	2.34520	600.
2.42466	6.54712	1.81326	4.45106	720.
3.13253	9.26278	2.50640	6.84633	840.
3.56932	11.05712	3.16935	9.40916	960.
3.52487	10.86917	3.68966	11.56597	1080.
3.28673	9.88813	3.88658	12.40812	1200.
2.97388	8.63211	3.83175	12.16952	1320.
2.63752	7.32927	3.60495	11.20777	1440.
2.30379	6.11392	3.29110	9.90605	1560.
1.99270	5.04491	2.94709	8.52563	1680.
1.72204	4.15759	2.60700	7.21458	1800.
1.49807	3.45773	2.29417	6.08041	1920.
1.31546	2.91312	2.02042	5.13785	2040.
1.16174	2.47372	1.78632	4.36439	2160.
1.02767	2.10516	1.58685	3.73116	2280.
0.90778	1.78760	1.41552	3.20728	2400.
0.79791	1.51218	1.26715	2.77108	2520.
0.69856	1.27077	1.13506	2.39904	2640.
0.61115	1.06425	1.01555	2.07299	2760.
0.53393	0.88901	0.90822	1.78869	2880.
0.46717	0.74468	0.81088	1.54468	3000.
0.40935	0.62281	0.72353	1.33047	3120.
0.35949	0.52534	0.64618	1.14550	3240.
0.31647	0.44199	0.57731	0.98745	3360.
0.27885	0.37453	0.51719	0.85102	3480.
0.24666	0.31786	0.46344	0.73682	3600.
0.21911	0.27090	0.41595	0.63672	3720.
0.19503	0.23299	0.37421	0.55386	3840.
0.17406	0.19998	0.33727	0.48229	3960.
0.15587	0.17174	0.30458	0.41982	4080.
0.14002	0.14989	0.27554	0.36870	4200.
0.12618	0.13080	0.24986	0.32348	4320.
0.11405	0.11409	0.22720	0.28364	4440.
0.10339	0.09938	0.20669	0.25135	4560.
0.09379	0.08769	0.18857	0.22283	4680.
0.08512	0.07757	0.17260	0.19768	4800.
0.07734	0.06850	0.15845	0.17541	4920.
0.07049	0.06051	0.14543	0.15735	5040.
0.06455	0.05357	0.13347	0.14086	5160.
0.05936	0.04752	0.12259	0.12585	5280.

TOLR=.0000100 XN2= 0.0500 DELI= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 5		OUT SECTION NO = 6		
IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00132	0.00050	0.00132	0.00050	120.
0.00363	0.00138	0.00345	0.00131	240.
0.05732	0.04513	0.05715	0.04493	360.
0.35887	0.52413	0.35832	0.52308	480.
1.11582	2.34520	1.11476	2.34222	600.
1.81326	4.45106	1.81234	4.44811	720.
2.50640	6.84633	2.50549	6.84300	840.
3.16935	9.40916	3.16849	9.40574	960.
3.68966	11.56597	3.68903	11.56330	1080.
3.88658	12.40812	3.88649	12.40772	1200.
3.83175	12.16952	3.83206	12.17091	1320.
3.60495	11.20777	3.60553	11.21023	1440.
3.29110	9.90605	3.29181	9.90897	1560.
2.94709	8.52563	2.94785	8.52862	1680.
2.60700	7.21458	2.60778	7.21743	1800.
2.29417	6.08041	2.29492	6.08301	1920.
2.02042	5.13785	2.02110	5.14013	2040.
1.78632	4.36439	1.78693	4.36634	2160.
1.58685	3.73116	1.58739	3.73282	2280.
1.41552	3.20728	1.41600	3.20870	2400.
1.26715	2.77108	1.26757	2.77232	2520.
1.13506	2.39904	1.13545	2.40013	2640.
1.01555	2.07299	1.01592	2.07399	2760.
0.90822	1.78869	0.90857	1.78958	2880.
0.81088	1.54468	0.81120	1.54550	3000.
0.72353	1.33047	0.72383	1.33120	3120.
0.64618	1.14550	0.64645	1.14615	3240.
0.57731	0.98745	0.57756	0.98803	3360.
0.51719	0.85102	0.51741	0.85152	3480.
0.46344	0.73682	0.46365	0.73727	3600.
0.41595	0.63672	0.41614	0.63711	3720.
0.37421	0.55386	0.37439	0.55420	3840.
0.33727	0.48229	0.33743	0.48259	3960.
0.30458	0.41982	0.30473	0.42010	4080.
0.27554	0.36870	0.27568	0.36894	4200.
0.24986	0.32348	0.24998	0.32370	4320.
0.22720	0.28364	0.22732	0.28382	4440.
0.20669	0.25135	0.20680	0.25152	4560.
0.18857	0.22283	0.18867	0.22298	4680.
0.17260	0.19768	0.17269	0.19782	4800.
0.15845	0.17541	0.15853	0.17553	4920.
0.14543	0.15735	0.14551	0.15746	5040.
0.13347	0.14086	0.13354	0.14096	5160.
0.12259	0.12585	0.12265	0.12594	5280.

TOLR=.0000100 XN2= 0.0500 DEL1= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 6 OUT SECTION NO = 7

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00132	0.00050	0.00389	0.00148	120.
0.00345	0.00131	0.00793	0.00348	240.
0.05715	0.04493	0.11819	0.11979	360.
0.35832	0.52308	0.68718	1.24354	480.
1.11476	2.34222	1.93688	4.85781	600.
1.81234	4.44811	2.80286	7.96488	720.
2.50549	6.84300	3.47363	10.65497	840.
3.16849	9.40574	4.03625	13.05937	960.
3.68903	11.56330	4.43015	14.80848	1080.
3.88649	12.40772	4.50460	15.14440	1200.
3.83206	12.17091	4.33748	14.39408	1320.
3.60553	11.21023	4.01997	12.98852	1440.
3.29181	9.90897	3.63169	11.32086	1560.
2.94785	8.52862	3.22561	9.63734	1680.
2.60778	7.21743	2.83215	8.07748	1800.
2.29492	6.08301	2.47742	6.74025	1920.
2.02110	5.14013	2.16829	5.64178	2040.
1.78693	4.36634	1.90625	4.75515	2160.
1.58739	3.73282	1.68518	4.03899	2280.
1.41600	3.20870	1.49622	3.45204	2400.
1.26757	2.77232	1.33418	2.96815	2520.
1.13545	2.40013	1.19230	2.55929	2640.
1.01592	2.07399	1.06522	2.20482	2760.
0.90857	1.78958	0.94930	1.89717	2880.
0.81120	1.54550	0.84728	1.63595	3000.
0.72383	1.33120	0.75563	1.40724	3120.
0.64645	1.14615	0.67318	1.21008	3240.
0.57756	0.98803	0.60158	1.04252	3360.
0.51741	0.85152	0.53810	0.89846	3480.
0.46365	0.73727	0.48284	0.77771	3600.
0.41614	0.63711	0.43267	0.67196	3720.
0.37439	0.55420	0.38988	0.58422	3840.
0.33743	0.48259	0.35094	0.50877	3960.
0.30473	0.42010	0.31715	0.44330	4080.
0.27568	0.36894	0.28735	0.38950	4200.
0.24998	0.32370	0.26033	0.34192	4320.
0.22732	0.28382	0.23650	0.29997	4440.
0.20680	0.25152	0.21589	0.26583	4560.
0.18867	0.22298	0.19673	0.23566	4680.
0.17269	0.19782	0.17983	0.20906	4800.
0.15853	0.17553	0.16486	0.18549	4920.
0.14551	0.15746	0.15202	0.16644	5040.
0.13354	0.14096	0.13950	0.14918	5160.
0.12265	0.12594	0.12810	0.13346	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 7		OUT SECTION NO = 8		
IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00389	0.00148	0.00637	0.00244	120.
0.00793	0.00348	0.01112	0.00564	240.
0.11819	0.11979	0.17039	0.19420	360.
0.68718	1.24354	0.97370	1.96192	480.
1.93688	4.85781	2.64800	7.36957	600.
2.80286	7.96488	3.66940	11.48031	720.
3.47363	10.65497	4.35378	14.46697	840.
4.03625	13.05937	4.84613	16.71371	960.
4.43015	14.80848	5.13096	18.05464	1080.
4.50460	15.14440	5.09431	17.88206	1200.
4.33748	14.39408	4.82565	16.61815	1320.
4.01997	12.98852	4.42100	14.76755	1440.
3.63169	11.32086	3.96132	12.73334	1560.
3.22561	9.63734	3.49587	10.74656	1680.
2.83215	8.07748	3.05082	8.93797	1800.
2.47742	6.74025	2.65536	7.39783	1920.
2.16829	5.64178	2.31234	6.14371	2040.
1.90625	4.75515	2.02231	5.14419	2160.
1.68518	4.03899	1.78040	4.34534	2280.
1.49622	3.45204	1.57528	3.69551	2400.
1.33418	2.96815	1.40083	3.16409	2520.
1.19230	2.55929	1.24919	2.71852	2640.
1.06522	2.20482	1.11244	2.33573	2760.
0.94930	1.89717	0.98987	2.00483	2880.
0.84728	1.63595	0.88338	1.72643	3000.
0.75563	1.40724	0.78640	1.48332	3120.
0.67318	1.21008	0.69993	1.27404	3240.
0.60158	1.04252	0.62560	1.09704	3360.
0.53810	0.89846	0.55880	0.94543	3480.
0.48284	0.77771	0.50203	0.81817	3600.
0.43267	0.67196	0.44921	0.70684	3720.
0.38988	0.58422	0.40529	0.61425	3840.
0.35094	0.50877	0.36446	0.53497	3960.
0.31715	0.44330	0.32913	0.46651	4080.
0.28735	0.38950	0.29903	0.41007	4200.
0.26033	0.34192	0.27069	0.36016	4320.
0.23650	0.29997	0.24568	0.31613	4440.
0.21589	0.26583	0.22498	0.28014	4560.
0.19673	0.23566	0.20479	0.24836	4680.
0.17983	0.20906	0.18697	0.22031	4800.
0.16486	0.18549	0.17119	0.19546	4920.
0.15202	0.16644	0.15846	0.17542	5040.
0.13950	0.14918	0.14547	0.15740	5160.
0.12810	0.13346	0.13356	0.14098	5280.

TOLR=.0000100   XN2= 0.0500   DELT= 120.00000   DELA= 10.00000   DELX= 1340.

IN SECTION NO = 8		OUT SECTION NO = 9		
IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00637	0.00244	0.0	0.0	120.
0.01112	0.00564	0.0	0.0	240.
0.17039	0.19420	0.15069	0.16460	360.
0.97370	1.96192	0.17634	0.20356	480.
2.64800	7.36957	0.73567	1.35950	600.
3.66940	11.48031	1.91512	4.78489	720.
4.35378	14.46697	3.07008	9.01454	840.
4.84613	16.71371	3.99706	12 88885	960.
5.13096	18.05464	4.58745	15.52472	1080.
5.09431	17.88206	4.95397	17.22139	1200.
4.82565	16.61815	5.11393	17.97444	1320.
4.42100	14.76755	5.05674	17.70522	1440.
3.96132	12.73334	4.83385	16.65590	1560.
3.49587	10.74656	4.50958	15.16726	1680.
3.05082	8.93797	4.13753	13.50007	1800.
2.65536	7.39783	3 74475	11.79889	1920.
2.31234	6.14371	3.36189	10.19651	2040.
2.02231	5.14419	3.00503	8.75595	2160.
1.78040	4.34534	2.68193	7.50000	2280.
1.57528	3.69551	2.39546	6.44024	2400.
1.40083	3.16409	2.14234	5.55136	2520.
1.24919	2.71852	1.92060	4.80324	2640.
1.11244	2.33573	1.72775	4.17595	2760.
0.98987	2.00483	1.55739	3.64042	2880.
0.88338	1.72643	1.40446	3.17478	3000.
0.78640	1.48332	1.26954	2 77812	3120.
0.69993	1.27404	1.14802	2.43532	3240.
0.62560	1.09704	1.03724	2.13057	3360.
0.55880	0.94543	0.93865	1.86890	3480.
0.50203	0.81817	0.84843	1.63882	3600.
0.44921	0.70684	0 76968	1.44141	3720.
0.40529	0.61425	0.69678	1.26650	3840.
0.36446	0.53497	0.63363	1.11551	3960.
0.32913	0.46651	0.57614	0.98480	4080.
0.29903	0.41007	0.52435	0.86726	4200.
0.27069	0.36016	0 47926	0.77018	4320.
0.24568	0.31613	0 43838	0.68400	4440.
0.22498	0.28014	0.40082	0.60542	4560.
0.20479	0.24836	0.36833	0.54248	4680.
0.18697	0.22031	0.33872	0.48510	4800.
0.17119	0.19546	0.31193	0.43319	4920.
0.15846	0.17542	0 28656	0.38811	5040.
0.14547	0.15740	0.26503	0.35019	5160.
0.13356	0.14098	0 24559	0.31597	5280.

XN1= 0.0500 TRIBUTARY F

TOLR=.0000010 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1800.

IN SECTION NO = 1 OUT SECTION NO = 2

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.00408	0.00271	120.
0.0	0.0	0.00774	0.00585	240.
0.0	0.0	0.11565	0.20139	360.
0.0	0.0	0.63468	1.93635	480.
0.0	0.0	1.59399	6.50069	600.
0.0	0.0	1.88059	8.08706	720.
0.0	0.0	1.85854	7.96170	840.
0.0	0.0	1.73741	7.28679	960.
0.0	0.0	1.57407	6.39446	1080.
0.0	0.0	1.39281	5.43953	1200.
0.0	0.0	1.20683	4.50323	1320.
0.0	0.0	1.02372	3.62822	1440.
0.0	0.0	0.73563	2.35471	1560.
0.0	0.0	0.53157	1.53042	1680.
0.0	0.0	0.39455	1.02762	1800.
0.0	0.0	0.29961	0.71207	1920.
0.0	0.0	0.23211	0.50627	2040.
0.0	0.0	0.18276	0.37012	2160.
0.0	0.0	0.14618	0.27432	2280.
0.0	0.0	0.11844	0.20807	2400.
0.0	0.0	0.09726	0.15887	2520.
0.0	0.0	0.08057	0.12514	2640.
0.0	0.0	0.06743	0.09857	2760.
0.0	0.0	0.05708	0.07764	2880.
0.0	0.0	0.04857	0.06382	3000.
0.0	0.0	0.04157	0.05251	3120.
0.0	0.0	0.03581	0.04321	3240.
0.0	0.0	0.03107	0.03556	3360.
0.0	0.0	0.02716	0.02926	3480.
0.0	0.0	0.02389	0.02459	3600.
0.0	0.0	0.02105	0.02130	3720.
0.0	0.0	0.01859	0.01844	3840.
0.0	0.0	0.01646	0.01597	3960.
0.0	0.0	0.01461	0.01383	4080.
0.0	0.0	0.01302	0.01198	4200.
0.0	0.0	0.01163	0.01037	4320.
0.0	0.0	0.01044	0.00898	4440.
0.0	0.0	0.00940	0.00778	4560.
0.0	0.0	0.00850	0.00673	4680.
0.0	0.0	0.00773	0.00583	4800.
0.0	0.0	0.00705	0.00505	4920.
0.0	0.0	0.00647	0.00437	5040.
0.0	0.0	0.00594	0.00395	5160.

MAIN CHANNEL

XN1= 0.0500
TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 2680.

IN SECTION NO = 1 | OUT SECTION NO = 2

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.00418	0.00291	120.
0.0	0.0	0.00803	0.00655	240.
0.0	0.0	0.03646	0.04775	360.
0.0	0.0	0.33091	0.87937	480.
0.0	0.0	0.99962	3.79918	600.
0.0	0.0	1.02317	3.91614	720.
0.0	0.0	0.79939	2.83609	840.
0.0	0.0	0.61835	2.02153	960.
0.0	0.0	0.48670	1.47016	1080.
0.0	0.0	0.38907	1.09015	1200.
0.0	0.0	0.31537	0.82305	1320.
0.0	0.0	0.25859	0.63405	1440.
0.0	0.0	0.21443	0.49309	1560.
0.0	0.0	0.17949	0.39012	1680.
0.0	0.0	0.15169	0.31048	1800.
0.0	0.0	0.12910	0.25224	1920.
0.0	0.0	0.11075	0.20493	2040.
0.0	0.0	0.09568	0.16821	2160.
0.0	0.0	0.08309	0.14069	2280.
0.0	0.0	0.07255	0.11767	2400.
0.0	0.0	0.06373	0.09842	2520.
0.0	0.0	0.05635	0.08250	2640.
0.0	0.0	0.04996	0.07134	2760.
0.0	0.0	0.04443	0.06169	2880.
0.0	0.0	0.03966	0.05334	3000.
0.0	0.0	0.03553	0.04612	3120.
0.0	0.0	0.03195	0.03988	3240.
0.0	0.0	0.02887	0.03448	3360.
0.0	0.0	0.02620	0.02982	3480.
0.0	0.0	0.02383	0.02639	3600.
0.0	0.0	0.02171	0.02373	3720.
0.0	0.0	0.01980	0.02133	3840.
0.0	0.0	0.01808	0.01917	3960.
0.0	0.0	0.01654	0.01723	4080.
0.0	0.0	0.01515	0.01549	4200.
0.0	0.0	0.01390	0.01392	4320.
0.0	0.0	0.01278	0.01252	4440.
0.0	0.0	0.01178	0.01125	4560.
0.0	0.0	0.01087	0.01011	4680.
0.0	0.0	0.01006	0.00909	4800.
0.0	0.0	0.00932	0.00817	4920.
0.0	0.0	0.00867	0.00735	5040.
0.0	0.0	0.00807	0.00660	5160.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1170.

IN SECTION NO = 2 OUT SECTION NO = 3

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00418	0.00291	0.00080	0.00030	120.
0.00803	0.00655	0.00253	0.00096	240.
0.03646	0.04775	0.01492	0.00821	360.
0.33091	0.87937	0.21863	0.27015	480.
0.99962	3.79918	0.94912	1.89668	600.
1.02317	3.91614	1.43405	3.26175	720.
0.79939	2.83609	1.53633	3.57558	840.
0.61835	2.02153	1.45191	3.31559	960.
0.48670	1.47016	1.29807	2.86198	1080.
0.38907	1.09015	1.13007	2.38507	1200.
0.31537	0.82305	0.97141	1.95584	1320.
0.25859	0.63405	0.83103	1.59520	1440.
0.21443	0.49309	0.71003	1.29820	1560.
0.17949	0.39012	0.60811	1.05734	1680.
0.15169	0.31048	0.52254	0.86316	1800.
0.12910	0.25224	0.45108	0.71076	1920.
0.11075	0.20493	0.39113	0.58664	2040.
0.09568	0.16821	0.34049	0.48852	2160.
0.08309	0.14069	0.29815	0.40851	2280.
0.07255	0.11767	0.26206	0.34497	2400.
0.06373	0.09842	0.23138	0.29095	2520.
0.05635	0.08250	0.20476	0.24831	2640.
0.04996	0.07134	0.18215	0.21271	2760.
0.04443	0.06169	0.16290	0.18242	2880.
0.03966	0.05334	0.14614	0.15834	3000.
0.03553	0.04612	0.13142	0.13803	3120.
0.03195	0.03988	0.11851	0.12023	3240.
0.02887	0.03448	0.10721	0.10465	3360.
0.02620	0.02982	0.09719	0.09166	3480.
0.02383	0.02639	0.08829	0.08128	3600.
0.02171	0.02373	0.08048	0 07217	3720.
0.01980	0.02133	0.07361	0.06415	3840.
0.01808	0.01917	0.06755	0.05708	3960.
0.01654	0.01723	0.06220	0.05083	4080.
0.01515	0.01549	0.05747	0.04531	4200.
0.01390	0.01392	0.05314	0.04114	4320.
0.01278	0.01252	0.04915	0.03742	4440.
0.01178	0.01125	0.04549	0.03402	4560.
0.01087	0.01011	0.04213	0.03089	4680.
0.01006	0.00909	0.03906	0.02803	4800.
0.00932	0.00817	0 03625	0.02542	4920.
0.00867	0.00735	0.03369	0.02304	5040.
0.00807	0.00660	0.03136	0.02087	5160.
0.00754	0.00594	0.02923	0.01889	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 3 OUT SECTION NO = 4

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00080	0.00030	0.00080	0.00030	120.
0.00253	0.00096	0.00236	0.00090	240.
0.01492	0.00821	0.01478	0.00811	360.
0.21863	0.27015	0.21803	0.26919	480.
0.94912	1.89668	0.94761	1.89267	600.
1.43405	3.26175	1.43293	3.25847	720.
1.53633	3.57558	1.53607	3.57478	840.
1.45191	3.31559	1.45214	3.31629	960.
1.29807	2.86198	1.29850	2.86326	1080.
1.13007	2.38507	1.13057	2.38646	1200.
0.97141	1.95584	0.97190	1.95716	1320.
0.83103	1.59520	0.83150	1.59637	1440.
0.71003	1.29820	0.71046	1.29921	1560.
0.60811	1.05734	0.60848	1.05819	1680.
0.52254	0.86316	0.52286	0.86387	1800.
0.45108	0.71076	0.45136	0.71136	1920.
0.39113	0.58664	0.39139	0.58714	2040.
0.34049	0.48852	0.34070	0.48894	2160.
0.29815	0.40851	0.29835	0.40886	2280.
0.26206	0.34497	0.26223	0.34527	2400.
0.23138	0.29095	0.23152	0.29121	2520.
0.20476	0.24831	0.20490	0.24853	2640.
0.18215	0.21271	0.18227	0.21290	2760.
0.16290	0.18242	0.16301	0.18258	2880.
0.14614	0.15834	0.14624	0.15847	3000.
0.13142	0.13803	0.13151	0.13816	3120.
0.11851	0.12023	0.11859	0.12034	3240.
0.10721	0.10465	0.10727	0.10474	3360.
0.09719	0.09166	0.09726	0.09174	3480.
0.08829	0.08128	0.08836	0.08136	3600.
0.08048	0.07217	0.08054	0.07223	3720.
0.07361	0.06415	0.07366	0.06420	3840.
0.06755	0.05708	0.06759	0.05713	3960.
0.06220	0.05083	0.06224	0.05088	4080.
0.05747	0.04531	0.05751	0.04535	4200.
0.05314	0.04114	0.05318	0.04117	4320.
0.04915	0.03742	0.04918	0.03746	4440.
0.04549	0.03402	0.04552	0.03405	4560.
0.04213	0.03089	0.04216	0.03092	4680.
0.03906	0.02803	0.03909	0.02806	4800.
0.03625	0.02542	0.03628	0.02544	4920.
0.03369	0.02304	0.03371	0.02306	5040.
0.03136	0.02087	0.03138	0.02088	5160.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 4 OUT SECTION NO = 5

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00080	0.00030	0.00374	0.00142	120.
0.00236	0.00090	0.00777	0.00338	240.
0.01478	0.00811	0.07038	0.06038	360.
0.21803	0.26919	0.49507	0.80349	480.
0.94761	1.89267	1.62251	3.84096	600.
1.43293	3.25847	2.23200	5.86378	720.
1.53607	3.57478	2.35917	6.30738	840.
1.45214	3.31629	2.26672	5.98476	960.
1.29850	2.86326	2.08746	5.36257	1080.
1.13057	2.38646	1.87665	4.65594	1200.
0.97190	1.95716	1.66360	3.96954	1320.
0.83150	1.59637	1.46085	3.34311	1440.
0.71046	1.29921	1.27167	2.78437	1560.
0.60848	1.05819	1.09809	2.29556	1680.
0.52286	0.86387	0.94046	1.87370	1800.
0.45136	0.71136	0.79984	1.51702	1920.
0.39139	0.58714	0.67542	1.21543	2040.
0.34070	0.48894	0.57071	0.97247	2160.
0.29835	0.40886	0.48610	0.78459	2280.
0.26223	0.34527	0.41768	0.64035	2400.
0.23152	0.29121	0.36038	0.52706	2520.
0.20490	0.24853	0.31448	0.43812	2640.
0.18227	0.21290	0.27499	0.36773	2760.
0.16301	0.18258	0.24164	0.30902	2880.
0.14624	0.15847	0.21463	0.26385	3000.
0.13151	0.13816	0.19074	0.22624	3120.
0.11859	0.12034	0.17024	0.19396	3240.
0.10727	0.10474	0.15254	0.16715	3360.
0.09726	0.09174	0.13667	0.14527	3480.
0.08836	0.08136	0.12361	0.12726	3600.
0.08054	0.07223	0.11225	0.11160	3720.
0.07366	0.06420	0.10236	0.09797	3840.
0.06759	0.05713	0.09282	0.08656	3960.
0.06224	0.05088	0.08449	0.07685	4080.
0.05751	0.04535	0.07714	0.06826	4200.
0.05318	0.04117	0.07124	0.06138	4320.
0.04918	0.03746	0.06602	0.05529	4440.
0.04552	0.03405	0.06130	0.04978	4560.
0.04216	0.03092	0.05703	0.04480	4680.
0.03909	0.02806	0.05225	0.04031	4800.
0.03628	0.02544	0.04789	0.03625	4920.
0.03371	0.02306	0.04429	0.03290	5040.
0.03138	0.02088	0.04103	0.02987	5160.
0.02925	0.01891	0.03806	0.02710	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 5 OUT SECTION NO = 6

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00374	0.00142	0.00649	0.00251	120.
0.00777	0.00338	0.01143	0.00585	240.
0.07038	0.06038	0.11275	0.11229	360.
0.49507	0.80349	0.72588	1.33608	480.
1.62251	3.84096	2.20971	5.78609	600.
2.23200	5.86378	2.93262	8.46809	720.
2.35917	6.30738	3.07644	9.03980	840.
2.26672	5.98476	2.97920	8.65327	960.
2.08746	5.36257	2.77612	7.86208	1080.
1.87665	4.65594	2.52810	6.92575	1200.
1.66360	3.96954	2.26603	5.98234	1320.
1.46085	3.34311	2.00625	5.09035	1440.
1.27167	2.78437	1.75700	4.27006	1560.
1.09809	2.29556	1.52266	3.53347	1680.
0.94046	1.87370	1.30558	2.88407	1800.
0.79984	1.51702	1.10797	2.32321	1920.
0.67542	1.21543	0.92935	1.84421	2040.
0.57071	0.97247	0.77567	1.45642	2160.
0.48610	0.78459	0.65252	1.16066	2280.
0.41768	0.64035	0.55450	0.93569	2400.
0.36038	0.52706	0.47591	0.76311	2520.
0.31448	0.43812	0.41176	0.62788	2640.
0.27499	0.36773	0.35812	0.52269	2760.
0.24164	0.30902	0.31315	0.43556	2880.
0.21463	0.26385	0.27589	0.36931	3000.
0.19074	0.22624	0.24469	0.31439	3120.
0.17024	0.19396	0.21704	0.26764	3240.
0.15254	0.16715	0.19289	0.22961	3360.
0.13667	0.14527	0.17334	0.19884	3480.
0.12361	0.12726	0.15692	0.17320	3600.
0.11225	0.11160	0.14083	0.15101	3720.
0.10236	0.09797	0.12687	0.13176	3840.
0.09282	0.08656	0.11545	0.11601	3960.
0.08449	0.07685	0.10589	0.10283	4080.
0.07714	0.06826	0.09679	0.09119	4200.
0.07124	0.06138	0.08858	0.08161	4320.
0.06602	0.05529	0.08132	0.07314	4440.
0.06130	0.04978	0.07479	0.06553	4560.
0.05703	0.04480	0.06894	0.05869	4680.
0.05225	0.04031	0.06369	0.05257	4800.
0.04789	0.03625	0.05898	0.04707	4920.
0.04429	0.03290	0.05488	0.04276	5040.
0.04103	0.02987	0.05069	0.03886	5160.
0.03806	0.02710	0.04687	0.03530	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 420.

IN SECTION NO = 6		OUT SECTION NO = 7		
IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00649	0.00251	0.0	0.0	120.
0.01143	0.00585	0.0	0.0	240.
0.11275	0.11229	0.11970	0.12187	360.
0.72588	1.33608	0.38402	0.57288	480.
2.20971	5.78609	1.40297	3.17039	600.
2.93262	8.46809	2.48125	6.75427	720.
3.07644	9.03980	3.05258	8.94494	840.
2.97920	8.65327	3.19004	9.49141	960.
2.77612	7.86208	3.08874	9.08872	1080.
2.52810	6.92575	2.83735	8.09749	1200.
2.26603	5.98234	2.55631	7.02901	1320.
2.00625	5.09035	2.28364	6.04371	1440.
1.75700	4.27006	2.02619	5.15717	1560.
1.52266	3.53347	1.78611	4.36370	1680.
1.30558	2.88407	1.56232	3.65559	1800.
1.10797	2.32321	1.35553	3.03091	1920.
0.92935	1.84421	1.16662	2.48739	2040.
0.77567	1.45642	0.99664	2.02281	2160.
0.65252	1.16066	0.84766	1.63689	2280.
0.55450	0.93569	0.72207	1.32699	2400.
0.47591	0.76311	0.61874	1.08148	2520.
0.41176	0.62788	0.53382	0.88876	2640.
0.35812	0.52269	0.46419	0.73841	2760.
0.31315	0.43556	0.40609	0.61593	2880.
0.27589	0.36931	0.35698	0.52048	3000.
0.24469	0.31439	0.31590	0.44088	3120.
0.21704	0.26764	0.28065	0.37771	3240.
0.19289	0.22961	0.25051	0.32463	3360.
0.17334	0.19884	0.22425	0.27900	3480.
0.15692	0.17320	0.20107	0.24250	3600.
0.14083	0.15101	0.18202	0.21251	3720.
0.12687	0.13176	0.16508	0.18583	3840.
0.11545	0.11601	0.14960	0.16309	3960.
0.10589	0.10283	0.13568	0.14391	4080.
0.09679	0.09119	0.12392	0.12769	4200.
0.08858	0.08161	0.11378	0.11372	4320.
0.08132	0.07314	0.10488	0.10144	4440.
0.07479	0.06553	0.09676	0.09115	4560.
0.06894	0.05869	0.08914	0.08227	4680.
0.06369	0.05257	0.08211	0.07406	4800.
0.05898	0.04707	0.07568	0.06656	4920.
0.05488	0.04276	0.06998	0.05991	5040.
0.05069	0.03886	0.06528	0.05442	5160.
0.04687	0.03530	0.06101	0.04945	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 7 OUT SECTION NO = 8

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.0	0.0	120.
0.0	0.0	0.0	0.0	240.
0.11970	0.12187	0.11923	0.12122	360.
0.38402	0.57288	0.38382	0.57249	480.
1.40297	3.17039	1.40150	3.16607	600.
2.48125	6.75427	2.47972	6.74868	720.
3.05258	8.94494	3.05206	8.94289	840.
3.19004	9.49141	3.19028	9.49239	960.
3.08874	9.08872	3.08937	9.09121	1080.
2.83735	8.09749	2.83808	8.10029	1200.
2.55631	7.02901	2.55701	7.03158	1320.
2.28364	6.04371	2.28431	6.04603	1440.
2.02619	5.15717	2.02683	5.15932	1560.
1.78611	4.36370	1.78673	4.36570	1680.
1.56232	3.65559	1.56292	3.65746	1800.
1.35553	3.03091	1.35611	3.03262	1920.
1.16662	2.48739	1.16718	2.48896	2040.
0.99664	2.02281	0.99717	2.02423	2160.
0.84766	1.63689	0.84816	1.63813	2280.
0.72207	1.32699	0.72251	1.32804	2400.
0.61874	1.08148	0.61912	1.08234	2520.
0.53382	0.88876	0.53413	0.88946	2640.
0.46419	0.73841	0.46447	0.73899	2760.
0.40609	0.61593	0.40632	0.61642	2880.
0.35698	0.52048	0.35719	0.52089	3000.
0.31590	0.44088	0.31607	0.44122	3120.
0.28065	0.37771	0.28082	0.37800	3240.
0.25051	0.32463	0.25065	0.32488	3360.
0.22425	0.27900	0.22439	0.27922	3480.
0.20107	0.24250	0.20119	0.24269	3600.
0.18202	0.21251	0.18212	0.21267	3720.
0.16508	0.18583	0.16517	0.18598	3840.
0.14960	0.16309	0.14969	0.16322	3960.
0.13568	0.14391	0.13576	0.14402	4080.
0.12392	0.12769	0.12399	0.12779	4200.
0.11378	0.11372	0.11385	0.11380	4320.
0.10488	0.10144	0.10493	0.10151	4440.
0.09676	0.09115	0.09681	0.09122	4560.
0.08914	0.08227	0.08920	0.08233	4680.
0.08211	0.07406	0.08216	0.07412	4800.
0.07568	0.06656	0.07573	0.06662	4920.
0.06998	0.05991	0.07002	0.05996	5040.
0.06528	0.05442	0.06531	0.05446	5160.
0.06101	0.04945	0.06104	0.04948	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 8		OUT SECTION NO = 9		
IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.00296	0.00112	120.
0.0	0.0	0.00647	0.00250	240.
0.11923	0.12122	0.15983	0.17758	360.
0.38382	0.57249	0.65972	1.17787	480.
1.40150	3.16607	2.09052	5.37282	600.
2.47972	6.74868	3.23884	9.69162	720.
3.05206	8.94289	3.77463	11.92523	840.
3.19028	9.49239	3.81782	12.10894	960.
3.08937	9.09121	3.59669	11.17287	1080.
2.83808	8.10029	3.22687	9.64250	1200.
2.55701	7.03158	2.85329	8.15875	1320.
2.28431	6.04603	2.51669	6.88400	1440.
2.02683	5.15932	2.21125	5.79148	1560.
1.78673	4.36570	1.93472	4.85058	1680.
1.56292	3.65746	1.68390	4.03487	1800.
1.35611	3.03262	1.45643	3.32950	1920.
1.16718	2.48896	1.25202	2.72662	2040.
0.99717	2.02423	1.06925	2.21553	2160.
0.84816	1.63813	0.91055	1.79454	2280.
0.72251	1.32804	0.77546	1.45589	2400.
0.61912	1.08234	0.66433	1.18890	2520.
0.53413	0.88946	0.57340	0.97857	2640.
0.46447	0.73899	0.49981	0.81350	2760.
0.40632	0.61642	0.43628	0.67956	2880.
0.35719	0.52089	0.38515	0.57506	3000.
0.31607	0.44122	0.34007	0.48771	3120.
0.28082	0.37800	0.30347	0.41788	3240.
0.25065	0.32488	0.27010	0.35912	3360.
0.22439	0.27922	0.24164	0.30902	3480.
0.20119	0.24269	0.21790	0.26899	3600.
0.18212	0.21267	0.19686	0.23588	3720.
0.16517	0.18598	0.17818	0.20646	3840.
0.14969	0.16322	0.16220	0.18131	3960.
0.13576	0.14402	0.14735	0.15999	4080.
0.12399	0.12779	0.13421	0.14189	4200.
0.11385	0.11380	0.12287	0.12624	4320.
0.10493	0.10151	0.11289	0.11249	4440.
0.09681	0.09122	0.10470	0.10119	4560.
0.08920	0.08233	0.09700	0.09143	4680.
0.08216	0.07412	0.08928	0.08243	4800.
0.07573	0.06662	0.08223	0.07420	4920.
0.07002	0.05996	0.07596	0.06688	5040.
0.06531	0.05446	0.07073	0.06078	5160.
0.06104	0.04948	0.06599	0.05525	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 9 OUT SECTION NO = 10

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00296	0.00112	0.00585	0.00222	120.
0.00647	0.00250	0.01014	0.00498	240.
0.15983	0.17758	0.19546	0.23366	360.
0.65972	1.17787	0.90531	1.78141	480.
2.09052	5.37282	2.70179	7.57633	600.
3.23884	9.69162	3.93847	12.63388	720.
3.77463	11.92523	4.45237	14.90781	840.
3.81782	12.10894	4.41177	14.72626	960.
3.59669	11.17287	4.08133	13.25550	1080.
3.22687	9.64250	3.59972	11.18567	1200.
2.85329	8.15875	3.13854	9.28668	1320.
2.51669	6.88400	2.73981	7.72249	1440.
2.21125	5.79148	2.39103	6.42403	1560.
1.93472	4.85058	2.07946	5.33576	1680.
1.68390	4.03487	1.80128	4.41250	1800.
1.45643	3.32950	1.55288	3.62654	1920.
1.25202	2.72662	1.33291	2.96440	2040.
1.06925	2.21553	1.13788	2.40693	2160.
0.91055	1.79454	0.96959	1.95103	2280.
0.77546	1.45589	0.82649	1.58382	2400.
0.66433	1.18890	0.70892	1.29553	2520.
0.57340	0.97857	0.61268	1.06773	2640.
0.49981	0.81350	0.53351	0.88805	2760.
0.43628	0.67956	0.46625	0.74275	2880.
0.38515	0.57506	0.41241	0.62925	3000.
0.34007	0.48771	0.36408	0.53423	3120.
0.30347	0.41788	0.32462	0.45778	3240.
0.27010	0.35912	0.28955	0.39337	3360.
0.24164	0.30902	0.25858	0.33884	3480.
0.21790	0.26899	0.23385	0.29530	3600.
0.19686	0.23588	0.21162	0.25910	3720.
0.17818	0.20646	0.19120	0.22697	3840.
0.16220	0.18131	0.17369	0.19940	3960.
0.14735	0.15999	0.15881	0.17597	4080.
0.13421	0.14189	0.14444	0.15599	4200.
0.12287	0.12624	0.13190	0.13869	4320.
0.11289	0.11249	0.12086	0.12348	4440.
0.10470	0.10119	0.11193	0.11116	4560.
0.09700	0.09143	0.10423	0.10054	4680.
0.08928	0.08243	0.09641	0.09075	4800.
0.08223	0.07420	0.08874	0.08180	4920.
0.07596	0.06688	0.08189	0.07381	5040.
0.07073	0.06078	0.07615	0.06711	5160.
0.06599	0.05525	0.07093	0.06102	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 960.

IN SECTION NO = 10 OUT SECTION NO = 11

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00585	0.00222	0.0	0.0	120.
0.01014	0.00498	0.05573	0.04355	240.
0.19546	0.23366	0.18543	0.21788	360.
0.90531	1.78141	0.49433	0.80195	480.
2.70179	7.57633	0.71412	1.30797	600.
3.93847	12.63388	1.78544	4.36154	720.
4.45237	14.90781	2.98322	8.66923	840.
4.41177	14.72626	3.79317	12.00364	960.
4.08133	13.25550	4.12089	13.42766	1080.
3.59972	11.18567	4.08734	13.28168	1200.
3.13854	9.28668	3.82986	12.16132	1320.
2.73981	7.72249	3.48441	10.69922	1440.
2.39103	6.42403	3.12800	9.24478	1560.
2.07946	5.33576	2.79237	7.92456	1680.
1.80128	4.41250	2.48327	6.76166	1800.
1.55288	3.62654	2.20012	5.75270	1920.
1.33291	2.96440	1.94225	4.87580	2040.
1.13788	2.40693	1.70961	4.11759	2160.
0.96959	1.95103	1.49985	3.46322	2280.
0.82649	1.58382	1.31268	2.90493	2400.
0.70892	1.29553	1.14642	2.43084	2520.
0.61268	1.06773	1.00099	2.03437	2640.
0.53351	0.88805	0.87551	1.70669	2760.
0.46625	0.74275	0.76871	1.43897	2880.
0.41241	0.62925	0.67579	1.21630	3000.
0.36408	0.53423	0.59868	1.03596	3120.
0.32462	0.45778	0.53164	0.88380	3240.
0.28955	0.39337	0.47484	0.76085	3360.
0.25858	0.33884	0.42603	0.65797	3480.
0.23385	0.29530	0.38223	0.56941	3600.
0.21162	0.25910	0.34495	0.49717	3720.
0.19120	0.22697	0.31319	0.43564	3840.
0.17369	0.19940	0.28445	0.38440	3960.
0.15881	0.17597	0.25861	0.33889	4080.
0.14444	0.15599	0.23683	0.30055	4200.
0.13190	0.13869	0.21711	0.26776	4320.
0.12086	0.12348	0.19915	0.23947	4440.
0.11193	0.11116	0.18254	0.21333	4560.
0.10423	0.10054	0.16783	0.19017	4680.
0.09641	0.09075	0.15552	0.17127	4800.
0.08874	0.08180	0.14459	0.15620	4920.
0.08189	0.07381	0.13436	0.14209	5040.
0.07615	0.06711	0.12470	0.12876	5160.
0.07093	0.06102	0.11598	0.11674	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1090.

IN SECTION NO = 11 OUT SECTION NO = 12

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.00410	0.00156	120.
0.05573	0.04355	0.00254	0.00097	240.
0.18513	0.21788	0.21026	0.25697	360.
0.49433	0.80195	0.78368	1.47650	480.
0.71412	1.30797	1.30607	2.88550	600.
1.78544	4.36154	1.22166	2.64146	720.
2.98322	8.66923	1.50684	3.48474	840.
3.79317	12.00364	2.23874	5.88727	960.
4.12089	13.42766	3.01782	8.80678	1080.
4.08734	13.28168	3.56526	11.03994	1200.
3.82986	12.16132	3.82622	12.14548	1320.
3.48441	10.69922	3.84001	12.20549	1440.
3.12800	9.24478	3.68742	11.55650	1560.
2.79237	7.92456	3.44643	10.54339	1680.
2.48327	6.76166	3.17108	9.41604	1800.
2.20012	5.75270	2.89183	8.30692	1920.
1.94225	4.87580	2.62234	7.27092	2040.
1.70961	4.11759	2.36673	6.33505	2160.
1.49985	3.46322	2.12784	5.50084	2280.
1.31268	2.90493	1.90704	4.75779	2400.
1.14642	2.43084	1.70510	4.10307	2520.
1.00099	2.03437	1.52134	3.52940	2640.
0.87551	1.70669	1.35536	3.03042	2760.
0.76871	1.43897	1.20664	2.59943	2880.
0.67579	1.21630	1.07572	2.23293	3000.
0.59868	1.03596	0.95807	1.92045	3120.
0.53164	0.88380	0.85516	1.65569	3240.
0.47484	0.76085	0.76480	1.42918	3360.
0.42603	0.65797	0.68554	1.23962	3480.
0.38223	0.56941	0.61730	1.07821	3600.
0.34495	0.49717	0.55686	0.94103	3720.
0.31319	0.43564	0.50364	0.82156	3840.
0.28445	0.38440	0.45753	0.72436	3960.
0.25861	0.33889	0.41721	0.63937	4080.
0.23683	0.30055	0.38052	0.56609	4200.
0.21711	0.26776	0.34830	0.50366	4320.
0.19915	0.23947	0.32012	0.44906	4440.
0.18254	0.21333	0.29498	0.40293	4560.
0.16783	0.19017	0.27182	0.36215	4680.
0.15552	0.17127	0.25040	0.32444	4800.
0.14459	0.15620	0.23158	0.29131	4920.
0.13436	0.14209	0.21491	0.26428	5040.
0.12470	0.12876	0.19993	0.24070	5160.
0.11598	0.11674	0.18613	0.21898	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 12		OUT SECTION NO = 13		
IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00410	0.00156	0.00403	0.00153	120.
0.00254	0.00097	0.00260	0.00099	240.
0.21026	0.25697	0.20922	0.25534	360.
0.78368	1.47650	0.78219	1.47277	480.
1.30607	2.88550	1.30548	2.88378	600.
1.22166	2.64146	1.22246	2.64369	720.
1.50684	3.48474	1.50631	3.48312	840.
2.23874	5.88727	2.23711	5.88159	960.
3.01782	8.80678	3.01623	8.80046	1080.
3.56526	11.03994	3.56418	11.03540	1200.
3.82622	12.14548	3.82572	12.14329	1320.
3.84001	12.20549	3.83998	12.20535	1440.
3.68742	11.55650	3.68772	11.55777	1560.
3.44643	10.54339	3.44692	10.54539	1680.
3.17108	9.41604	3.17166	9.41833	1800.
2.89183	8.30692	2.89244	8.30925	1920.
2.62234	7.27092	2.62293	7.27316	2040.
2.36673	6.33505	2.36731	6.33718	2160.
2.12784	5.50084	2.12841	5.50283	2280.
1.90704	4.75779	1.90759	4.75963	2400.
1.70510	4.10307	1.70562	4.10475	2520.
1.52134	3.52940	1.52184	3.53093	2640.
1.35536	3.03042	1.35583	3.03181	2760.
1.20664	2.59943	1.20708	2.60066	2880.
1.07572	2.23293	1.07611	2.23402	3000.
0.95807	1.92045	0.95844	1.92143	3120.
0.85516	1.65569	0.85550	1.65655	3240.
0.76480	1.42918	0.76510	1.42994	3360.
0.68554	1.23962	0.68582	1.24028	3480.
0.61730	1.07821	0.61755	1.07878	3600.
0.55686	0.94103	0.55708	0.94154	3720.
0.50364	0.82156	0.50385	0.82201	3840.
0.45753	0.72436	0.45771	0.72474	3960.
0.41721	0.63937	0.41737	0.63971	4080.
0.38052	0.56609	0.38068	0.56639	4200.
0.34830	0.50366	0.34844	0.50393	4320.
0.32012	0.44906	0.32024	0.44929	4440.
0.29498	0.40293	0.29510	0.40314	4560.
0.27182	0.36215	0.27193	0.36235	4680.
0.25040	0.32444	0.25050	0.32462	4800.
0.23158	0.29131	0.23167	0.29147	4920.
0.21491	0.26428	0.21499	0.26442	5040.
0.19993	0.24070	0.20001	0.24083	5160.
0.18613	0.21898	0.18620	0.21910	5280.

TOLR=.0000100   XN2= 0.0500   DELT= 120.00000   DELA= 10.00000   DELX= 1.

IN SECTION NO = 13   OUT SECTION NO = 14

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00403	0.00153	0.00686	0.00277	120.
0.00260	0.00099	0.00850	0.00387	240.
0.20922	0.25534	0.27674	0.37081	360.
0.78219	1.47277	1.27714	2.80045	480.
1.30548	2.88378	2.77102	7.84248	600.
1.22246	2.64369	3.16908	9.40808	720.
1.50631	3.48312	3.41772	10.42559	840.
2.23711	5.88159	3.79958	12.03072	960.
3.01623	8.80046	4.19164	13.74199	1080.
3.56418	11.03540	4.41822	14.75514	1200.
3.82572	12.14329	4.45139	14.90343	1320.
3.83998	12.20535	4.31441	14.29095	1440.
3.68772	11.55777	4.05973	13.16155	1560.
3.44692	10.54539	3.74417	11.79643	1680.
3.17166	9.41833	3.41288	10.40573	1800.
2.89244	8.30925	3.09057	9.09597	1920.
2.62293	7.27316	2.78741	7.90549	2040.
2.36731	6.33718	2.50771	6.85111	2160.
2.12841	5.50283	2.24960	5.92509	2280.
1.90759	4.75963	2.01155	5.10812	2400.
1.70562	4.10475	1.79626	4.39636	2520.
1.52184	3.53093	1.60123	3.77543	2640.
1.35583	3.03181	1.42621	3.23871	2760.
1.20708	2.60066	1.26922	2.77716	2880.
1.07611	2.23402	1.12989	2.38457	3000.
0.95844	1.92143	1.00726	2.05100	3120.
0.85550	1.65655	0.90041	1.76912	3240.
0.76510	1.42994	0.80413	1.52776	3360.
0.68582	1.24028	0.72135	1.32527	3480.
0.61755	1.07878	0.64931	1.15300	3600.
0.55708	0.94154	0.58607	1.00733	3720.
0.50385	0.82201	0.53011	0.88033	3840.
0.45771	0.72474	0.48223	0.77644	3960.
0.41737	0.63971	0.43911	0.68554	4080.
0.38068	0.56639	0.40165	0.60702	4200.
0.34844	0.50393	0.36703	0.53995	4320.
0.32024	0.44929	0.33705	0.48187	4440.
0.29510	0.40314	0.31166	0.43267	4560.
0.27193	0.36235	0.28714	0.38913	4680.
0.25050	0.32462	0.26430	0.34892	4800.
0.23167	0.29147	0.24418	0.31349	4920.
0.21499	0.26442	0.22765	0.28439	5040.
0.20001	0.24083	0.21151	0.25894	5160.
0.18620	0.21910	0.19664	0.23552	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 14		OUT SECTION NO = 15		
IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00686	0.00277	0.00866	0.00398	120.
0.00850	0.00387	0.01273	0.00673	240.
0.27674	0.37081	0.33909	0.48581	360.
1.27714	2.80045	1.71185	4.12481	480.
2.77102	7.84248	3.97525	12.79394	600.
3.16908	9.40808	4.72780	16.16896	720.
3.41772	10.42559	4.98515	17.36816	840.
3.79958	12.03072	5.15806	18.18219	960.
4.19164	13.74199	5.26358	18.68633	1080.
4.41822	14.75514	5.22024	18.47736	1200.
4.45139	14.90343	5.04829	17.66542	1320.
4.31441	14.29095	4.77329	16.37776	1440.
4.05973	13.16155	4.42069	14.76616	1560.
3.74417	11.79643	4.03366	13.04808	1680.
3.41288	10.40573	3.64890	11.39360	1800.
3.09057	9.09597	3.28549	9.88304	1920.
2.78741	7.90549	2.95023	8.53809	2040.
2.50771	6.85111	2.64687	7.36523	2160.
2.24960	5.92509	2.37013	6.34752	2280.
2.01155	5.10812	2.11518	5.45675	2400.
1.79626	4.39636	1.88624	4.68808	2520.
1.60123	3.77543	1.67929	4.02003	2640.
1.42621	3.23871	1.49416	3.44569	2760.
1.26922	2.77716	1.32927	2.95372	2880.
1.12989	2.38457	1.18369	2.53517	3000.
1.00726	2.05100	1.05609	2.18061	3120.
0.90041	1.76912	0.94349	1.88174	3240.
0.80413	1.52776	0.84317	1.62562	3360.
0.72135	1.32527	0.75691	1.41028	3480.
0.64931	1.15300	0.68037	1.22725	3600.
0.58607	1.00733	0.61507	1.07315	3720.
0.53011	0.88033	0.55582	0.93868	3840.
0.48223	0.77644	0.50676	0.82815	3960.
0.43911	0.68554	0.46086	0.73140	4080.
0.40165	0.60702	0.42114	0.64766	4200.
0.36703	0.53995	0.38563	0.57599	4320.
0.33705	0.48187	0.35387	0.51446	4440.
0.31166	0.43267	0.32690	0.46221	4560.
0.28714	0.38913	0.30236	0.41593	4680.
0.26430	0.34892	0.27811	0.37322	4800.
0.24418	0.31349	0.25670	0.33553	4920.
0.22765	0.28439	0.23900	0.30436	5040.
0.21151	0.25894	0.22301	0.27705	5160.
0.19664	0.23552	0.20708	0.25196	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 960.

IN SECTION NO = 15 OUT SECTION NO = 16

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00866	0.00398	0.0	0.0	120.
0.01273	0.00673	0.0	0.0	240.
0.33909	0.48581	0.13683	0.14549	360.
1.71185	4.12481	0.19426	0.23178	480.
3.97525	12.79394	1.41480	3.20517	600.
4.72780	16.16896	3.14610	9.31670	720.
4.98515	17.36816	4.24540	13.98235	840.
5.15806	18.18219	4.79608	16.48241	960.
5.26358	18.68633	5.06441	17.74132	1080.
5.22024	18.47736	5.18361	18.30247	1200.
5.04829	17.66542	5.18944	18.32993	1320.
4.77329	16.37776	5.09157	17.86920	1440.
4.42069	14.76616	4.89719	16.95409	1560.
4.03366	13.04808	4.62359	15.69061	1680.
3.64890	11.39360	4.30006	14.22676	1800.
3.28549	9.88304	3.95632	12.71159	1920.
2.95023	8.53809	3.61429	11.24727	2040.
2.64687	7.36523	3.28682	9.88851	2160.
2.37013	6.34752	2.98318	8.66907	2280.
2.11518	5.45675	2.70507	7.58896	2400.
1.88624	4.68808	2.44794	6.63235	2520.
1.67929	4.02003	2.21167	5.79294	2640.
1.49416	3.44569	1.99504	5.05275	2760.
1.32927	2.95372	1.79792	4.40172	2880.
1.18369	2.53517	1.61943	3.83149	3000.
1.05609	2.18061	1.45833	3.33537	3120.
0.94349	1.88174	1.31410	2.90911	3240.
0.84317	1.62562	1.18565	2.54067	3360.
0.75691	1.41028	1.07006	2.21768	3480.
0.68037	1.22725	0.96723	1.94475	3600.
0.61507	1.07315	0.87466	1.70458	3720.
0.55582	0.93868	0.79338	1.50082	3840.
0.50676	0.82815	0.71936	1.32049	3960.
0.46086	0.73140	0.65591	1.16877	4080.
0.42114	0.64766	0.59860	1.03577	4200.
0.38563	0.57599	0.54792	0.92076	4320.
0.35387	0.51446	0.50316	0.82055	4440.
0.32690	0.46221	0.46215	0.73411	4560.
0.30236	0.41593	0.42613	0.65818	4680.
0.27811	0.37322	0.39511	0.59435	4800.
0.25670	0.33553	0.36594	0.53783	4920.
0.23900	0.30436	0.33854	0.48476	5040.
0.22301	0.27705	0.31433	0.43784	5160.
0.20708	0.25196	0.29327	0.39993	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 16 OUT SECTION NO = 17

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.0	0.0	120.
0.0	0.0	0.0	0.0	240.
0.13683	0.14549	0.13623	0.14466	360.
0.19426	0.23178	0.19514	0.23316	480.
1.41480	3.20517	1.41288	3.19952	600.
3.14610	9.31670	3.14327	9.30549	720.
4.24540	13.98235	4.24382	13.97529	840.
4.79608	16.48241	4.79535	16.47905	960.
5.06441	17.74132	5.06405	17.73964	1080.
5.18361	18.30247	5.18342	18.30159	1200.
5.18944	18.32993	5.18943	18.32986	1320.
5.09157	17.86920	5.09175	17.87003	1440.
4.89719	16.95409	4.89753	16.95570	1560.
4.62359	15.69061	4 62409	15.69289	1680.
4.30006	14.22676	4 30066	14.22945	1800.
3.95632	12.71159	3.95698	12.71445	1920.
3.61429	11.24727	3.61496	11.25012	2040.
3.28682	9.88851	3.28749	9.89124	2160.
2.98318	8.66907	2.98381	8.67160	2280.
2.70507	7.58896	2.70568	7.59128	2400.
2.44794	6.63235	2.44853	6.63449	2520.
2.21167	5.79294	2.21223	5.79490	2640.
1.99504	5.05275	1 99557	5.05456	2760.
1.79792	4.40172	1.79843	4.40336	2880.
1.61943	3.83149	1.61991	3.83297	3000.
1.45833	3.33537	1.45877	3.33671	3120.
1.31410	2.90911	1.31451	2.91031	3240.
1.18565	2.54067	1.18604	2.54174	3360.
1.07006	2.21768	1.07043	2.21865	3480.
0.96723	1.94475	0.96755	1.94561	3600.
0.87466	1.70458	0.87497	1.70535	3720.
0.79338	1.50082	0.79365	1.50150	3840.
0.71936	1.32049	0.71961	1.32110	3960.
0.65591	1.16877	0.65613	1.16930	4080.
0.59860	1.03577	0.59881	1.03625	4200.
0.54792	0.92076	0.54811	0.92118	4320.
0.50316	0.82055	0.50333	0.82092	4440.
0.46215	0.73411	0.46231	0.73445	4560.
0.42613	0.65818	0.42627	0.65848	4680.
0.39511	0.59435	0 39524	0 59460	4800.
0.36594	0.53783	0.36606	0.53808	4920.
0.33854	0.48476	0.33866	0.48498	5040.
0.31433	0.43784	0.31443	0.43804	5160.
0.29327	0.39993	0.29337	0.40010	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 17 OUT SECTION NO = 18

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.0	0.0	120.
0.0	0.0	0.0	0.0	240.
0.13623	0.14466	0.19091	0.22651	360.
0.19514	0.23316	0.25604	0.33437	480.
1.41288	3.19952	1.63143	3.86843	600.
3.14327	9.30549	3.71710	11.68201	720.
4.24382	13.97529	5.21907	18.47169	840.
4.79535	16.47905	6.12452	22.91737	960.
5.06405	17.73964	6.63031	25.49876	1080.
5.18342	18.30159	6.90167	26.91064	1200.
5.18943	18.32986	6.97876	27.31673	1320.
5.09175	17.87003	6.86615	26.72351	1440.
4.89753	16.95570	6.58898	25.28561	1560.
4.62409	15.69289	6.19622	23.27930	1680.
4.30066	14.22945	5.73608	20.98276	1800.
3.95698	12.71445	5.24928	18.61736	1920.
3.61496	11.25012	4.76763	16.35179	2040.
3.28749	9.89124	4.31028	14.27248	2160.
2.98381	8.67160	3.89037	12.42461	2280.
2.70568	7.59128	3.51185	10.81413	2400.
2.44853	6.63449	3.17023	9.41266	2520.
2.21223	5.79490	2.86370	8.19879	2640.
1.99557	5.05456	2.58788	7.14458	2760.
1.79843	4.40336	2.33580	6.22544	2880.
1.61991	3.83297	2.10521	5.42206	3000.
1.45877	3.33671	1.89794	4.72730	3120.
1.31451	2.91031	1.71326	4.12934	3240.
1.18604	2.54174	1.54694	3.60825	3360.
1.07043	2.21865	1.39746	3.15420	3480.
0.96755	1.94561	1.26542	2.76600	3600.
0.87497	1.70535	1.14503	2.42694	3720.
0.79365	1.50150	1.03911	2.13553	3840.
0.71961	1.32110	0.94267	1.87957	3960.
0.65613	1.16930	0.85780	1.66231	4080.
0.59881	1.03625	0.78126	1.47044	4200.
0.54811	0.92118	0.71362	1.30676	4320.
0.50333	0.82092	0.65364	1.16335	4440.
0.46231	0.73445	0.59939	1.03755	4560.
0.42627	0.65848	0.55202	0.93006	4680.
0.39524	0.59460	0.51118	0.83745	4800.
0.36606	0.53808	0.47204	0.75496	4920.
0.33866	0.48498	0.43615	0.67930	5040.
0.31443	0.43804	0.40487	0.61337	5160.
0.29337	0.40010	0.37650	0.55823	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 18 OUT SECTION NO = 19

IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.0	0.0	120.
0.0	0.0	0.0	0.0	240.
0.19091	0.22651	0.24118	0.30821	360.
0.25604	0.33437	0.31314	0.43554	480.
1.63143	3.86843	1.83968	4.53606	600.
3.71710	11.68201	4.26179	14.05564	720.
5.21907	18.47169	6.13393	22.96487	840.
6.12452	22.91737	7.36240	29.35287	960.
6.63031	25.49876	8.08020	33.25601	1080.
6.90167	26.91064	8.48583	35.51849	1200.
6.97876	27.31673	8.62549	36.30301	1320.
6.86615	26.72351	8.49632	35.57712	1440.
6.58898	25.28561	8.14537	33.61618	1560.
6.19622	23.27930	7.64401	30.86664	1680.
5.73608	20.98276	7.05857	27.73714	1800.
5.24928	18.61736	6.44083	24.52139	1920.
4.76763	16.35179	5.83167	21.45457	2040.
4.31028	14.27248	5.25703	18.65475	2160.
3.89037	12.42461	4.72989	16.17856	2280.
3.51185	10.81413	4.25780	14.03779	2400.
3.17023	9.41266	3.83680	12.19152	2520.
2.86370	8.19879	3.46102	10.60325	2640.
2.58788	7.14458	3.12557	9.23510	2760.
2.33580	6.22544	2.82446	8.04795	2880.
2.10521	5.42206	2.55154	7.01155	3000.
1.89794	4.72730	2.30503	6.11825	3120.
1.71326	4.12934	2.08332	5.34869	3240.
1.54694	3.60825	1.88236	4.67506	3360.
1.39746	3.15420	1.70104	4.09002	3480.
1.26542	2.76600	1.53992	3.58662	3600.
1.14503	2.42694	1.39561	3.14875	3720.
1.03911	2.13553	1.26670	2.76975	3840.
0.94267	1.87957	1.14905	2.43821	3960.
0.85780	1.66231	1.04663	2.15549	4080.
0.78126	1.47044	0.95217	1.90478	4200.
0.71362	1.30676	0.86984	1.69248	4320.
0.65364	1.16335	0.79541	1.50591	4440.
0.59939	1.03755	0.72784	1.34077	4560.
0.55202	0.93006	0.66970	1.20174	4680.
0.51118	0.83745	0.61826	1.08039	4800.
0.47204	0.75496	0.57046	0.97191	4920.
0.43615	0.67930	0.52718	0.87369	5040.
0.40487	0.61337	0.48807	0.78875	5160.
0.37650	0.55829	0.45382	0.71654	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 19		OUT SECTION NO = 20		
IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.0	0.0	120.
0.0	0.0	0.0	0.0	240.
0.24118	0.30821	0.24080	0.30754	360.
0.31314	0.43554	0.31282	0.43492	480.
1.83968	4.53606	1.83572	4.52332	600.
4.26179	14.05564	4.25727	14.03542	720.
6.13393	22.96487	6.13084	22.94926	840.
7.36240	29.35287	7.36050	29.34264	960.
8.08020	33.25601	8.07910	33.25000	1080.
8.48583	35.51849	8.48522	35.51509	1200.
8.62549	36.30301	8.62528	36.30185	1320.
8.49632	35.57712	8.49652	35.57822	1440.
8.14537	33.61618	8.14590	33.61909	1560.
7.64401	30.86664	7.64478	30.87080	1680.
7.05857	27.73714	7.05949	27.74200	1800.
6.44083	24.52139	6.44182	24.52654	1920.
5.83167	21.45457	5.83270	21.45966	2040.
5.25703	18.65475	5.25803	18.65955	2160.
4.72989	16.17856	4.73085	16.18295	2280.
4.25780	14.03779	4.25868	14.04173	2400.
3.83680	12.19152	3.83761	12.19502	2520.
3.46102	10.60325	3.46178	10.60638	2640.
3.12557	9.23510	3.12627	9.23790	2760.
2.82446	8.04795	2.82512	8.05045	2880.
2.55154	7.01155	2.55216	7.01382	3000.
2.30503	6.11825	2.30562	6.12030	3120.
2.08332	5.34869	2.08387	5.35054	3240.
1.88236	4.67506	1.88286	4.67673	3360.
1.70104	4.09002	1.70151	4.09153	3480.
1.53992	3.58662	1.54036	3.58797	3600.
1.39561	3.14875	1.39602	3.14995	3720.
1.26670	2.76975	1.26706	2.77083	3840.
1.14905	2.43821	1.14940	2.43919	3960.
1.04663	2.15549	1.04695	2.15634	4080.
0.95217	1.90478	0.95246	1.90557	4200.
0.86984	1.69248	0.87011	1.69316	4320.
0.79541	1.50591	0.79566	1.50653	4440.
0.72784	1.34077	0.72807	1.34133	4560.
0.66970	1.20174	0.66990	1.20223	4680.
0.61826	1.08039	0.61845	1.08082	4800.
0.57046	0.97191	0.57064	0.97231	4920.
0.52718	0.87369	0.52734	0.87405	5040.
0.48807	0.78875	0.48823	0.78908	5160.
0.45382	0.71654	0.45395	0.71682	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 20		OUT SECTION NO = 21		
IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.0	0.0	0.00353	0.00134	120.
0.0	0.0	0.00700	0.00286	240.
0.24080	0.30754	0.29672	0.40599	360.
0.31282	0.43492	0.75296	1.40086	480.
1.83572	4.52332	2.74930	7.75898	600.
4.25727	14.03542	5.13187	18.05893	720.
6.13084	22.94926	6.90249	26.91493	840.
7.36050	29.34264	8.02916	32.97620	960.
8.07910	33.25000	8.64984	36.44162	1080.
8.48522	35.51509	8.96436	38.23184	1200.
8.62528	36.30185	9.02071	38.55263	1320.
8.49652	35.57822	8.81710	37.39368	1440.
8.14590	33.61909	8.35722	34.79987	1560.
7.64478	30.87080	7.78553	31.64049	1680.
7.05949	27.74200	7.15799	28.26088	1800.
6.44182	24.52654	6.51187	24.88783	1920.
5.83270	21.45966	5.88503	21.71794	2040.
5.25803	18.65955	5.29741	18.84944	2160.
4.73085	16.18295	4.76169	16.32454	2280.
4.25868	14.04173	4.28283	14.14972	2400.
3.83761	12.19502	3.85667	12.27798	2520.
3.46178	10.60638	3.47780	10.67209	2640.
3.12627	9.23790	3.13937	9.28998	2760.
2.82512	8.05045	2.83587	8.09179	2880.
2.55216	7.01382	2.56150	7.04801	3000.
2.30562	6.12030	2.31375	6.14861	3120.
2.08387	5.35054	2.09087	5.37399	3240.
1.88286	4.67673	1.88866	4.69619	3360.
1.70151	4.09153	1.70653	4.10768	3480.
1.54036	3.58797	1.54479	3.60161	3600.
1.39602	3.14995	1.40005	3.16180	3720.
1.26706	2.77083	1.27056	2.78112	3840.
1.14940	2.43919	1.15260	2.44816	3960.
1.04695	2.15634	1.04988	2.16411	4080.
0.95246	1.90557	0.95502	1.91234	4200.
0.87011	1.69316	0.87245	1.69904	4320.
0.79566	1.50653	0.79770	1.51165	4440.
0.72807	1.34133	0.72994	1.34579	4560.
0.66990	1.20223	0.67151	1.20608	4680.
0.61845	1.08082	0.61992	1.08416	4800.
0.57064	0.97231	0.57193	0.97524	4920.
0.52734	0.87405	0.52846	0.87659	5040.
0.48823	0.78908	0.48932	0.79138	5160.
0.45395	0.71682	0.45495	0.71892	5280.

TOLR=.0000100 XN2= 0.0500 DELT= 120.00000 DELA= 10.00000 DELX= 1.

IN SECTION NO = 21		OUT SECTION NO = 22		
IN AREA	IN DISCH	OUT AREA	OUT DISCH	TOTAL TIME , SECONDS
0.0	0.0	0.0	0.0	0.
0.00353	0.00134	0.00669	0.00265	120.
0.00700	0.00286	0.01120	0.00570	240.
0.29672	0.40599	0.34850	0.50404	360.
0.75296	1.40086	1.12250	2.36388	480.
2.74930	7.75898	3.55365	10.99086	600.
5.13187	18.05893	5.95888	22.08249	720.
6.90249	26.91493	7.64674	30.88135	840.
8.02916	32.97620	8.67954	36.61066	960.
8.64984	36.44162	9.20812	39.63403	1080.
8.96436	38.23184	9.43507	40.94933	1200.
9.02071	38.55263	9.41001	40.80409	1320.
8.81710	37.39368	9.13491	39.20976	1440.
8.35722	34.79987	8.56869	35.98148	1560.
7.78553	31.64049	7.92603	32.41075	1680.
7.15799	28.26088	7.25585	28.78011	1800.
6.51187	24.88783	6.58196	25.24936	1920.
5.88503	21.71794	5.93738	21.97636	2040.
5.29741	18.84944	5.33681	19.03944	2160.
4.76169	16.32454	4.79255	16.46619	2280.
4.28283	14.14972	4.30699	14.25778	2400.
3.85667	12.27798	3.87575	12.36098	2520.
3.47780	10.67209	3.49380	10.73782	2640.
3.13937	9.28998	3.15248	9.34210	2760.
2.83587	8.09179	2.84663	8.13315	2880.
2.56150	7.04801	2.57084	7.08220	3000.
2.31375	6.14861	2.32188	6.17694	3120.
2.09087	5.37399	2.09787	5.39746	3240.
1.88866	4.69619	1.89447	4.71566	3360.
1.70653	4.10768	1.71155	4.12383	3480.
1.54479	3.60161	1.54922	3.61525	3600.
1.40005	3.16180	1.40408	3.17366	3720.
1.27056	2.78112	1.27407	2.79142	3840.
1.15260	2.44816	1.15581	2.45712	3960.
1.04988	2.16411	1.05280	2.17188	4080.
0.95502	1.91234	0.95757	1.91913	4200.
0.87245	1.69904	0.87480	1.70491	4320.
0.79770	1.51165	0.79974	1.51676	4440.
0.72994	1.34579	0.73180	1.35024	4560.
0.67151	1.20608	0.67312	1.20993	4680.
0.61992	1.08416	0.62140	1.08751	4800.
0.57193	0.97524	0.57322	0.97816	4920.
0.52846	0.87659	0.52958	0.87914	5040.
0.48932	0.79138	0.49041	0.79368	5160.
0.45495	0.71892	0.45595	0.72103	5280.