

DEVELOPMENT AND TESTING OF A CROP DEPENDENT EVAPOTRANSPIRATION
FUNCTION IN THE KANSAS WATERSHED MODEL

by

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NOMENCLATURE

<u>Parameters</u>	<u>Description</u>
CKN (1) thru CKN (20)	6 hour incremental areas of the unitgraph.
SB1	The constant in the relation of surface storage to upper zone soil moisture.
SML	The slope in the relation of surface storage to upper zone soil moisture.
IB1	The constant in the relation of IA to UZS for $UZS \geq UZS_c$.
UZSC	The value of UZS for which the calculation of IA changes from one linear approximation to another.
UZS	Calculated current upper zone storage for area of current precipitation.
UZSO	Starting value for UZS.
IM1	The slope in the relation of IA to UZS for $UZS \geq UZS_c$.
UZSN	Nominal upper zone storage capacity (field capacity).
UBP	Constant in the equation for percolation from upper to lower soil zone.
UMP	Exponent in the equation for percolation from upper to lower soil zone.
UZMX	Values of UZS at which all water reaching the land surface becomes overland runoff. (saturated upper zone).
UZMN	Value of upper zone storage below which no evapo-transpiration occurs (wilting point).
LZMX	Maximum lower zone storage, uplands (saturated).
LZMN	Value of lower zone storage below which no evapo-transpiration occurs. Applies to both lower zones.
YSTRT	Number of first year in run.
IKR	Interflow recession constant.

RGWB	Constant in the calculation of groundwater recharge from the lower soil zone.
RGWM	Exponent in the calculation of groundwater recharge from the lower soil zone.
GWSN	An amount of groundwater storage below which no baseflow can take place.
BK	Baseflow recession constant.
AGW	Fraction of basin underlain by groundwater aquifer and lower zone.
PDY	Minimum amount of daily precipitation for which the hourly fraction will be read.
TLL	Number of precipitation stations.
LZSAN	"Nominal" lower zone storage in lowlands (field capacity).
LZSTN	"Nominal" lower zone storage in uplands (field capacity).
AREA	Total drainage area. Recalculated as drainage area exclusive of ponds.
LZSO	Starting value for LZSA and LZST (1) thru LZST (10).
GWSO	Starting value for GWS.
YREND	Number of last year in run.
GWRF	A constant combining conversion of STG to an area, GIGI to a slope, and permeability.
PORF	A constant to convert groundwater "EXCESS" to equivalent of a depth in feet.
IIA	Minimum value of initial abstraction by interception and ... (provided that at least that much precip. fell). Either hourly or daily.
PTPOND	The fraction of the streamflow that is available to go into pond storage.
FM	Minimum value of sum of interception, addition to depression storage, and infiltration (provided that at least that much precip. fell during the day or hour). Also minimum amount of infiltration, provided moisture is available.

POWER	Exponent used in calculation of interflow.
PWRE	Exponent in calculation of evapotranspiration from stream and bank storage.
QUANTY	Coefficients used in calculation of evapotranspiration from stream and bank storage.
B	The constant in the relation of IA to UZS for $UZS < UZS_{max}$.
C	The slope in the relation of IA to UZS for $UZS < UZS_{max}$.
PONDDP	Average depth of ponds.
PONDAR	Total area of ponds in basin.
ZZT	Signals whether or not to "CALL PLOTT". PLOTT will be called if $ZZT > 0.0$.

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INTRODUCTION

Thomas King, an engineer, epitomized the water problem in the following terms [1], "Of all the substances that are necessary to life as we know it, it is by far the most important, the most familiar and the most wonderful; yet most people know very little about it."

The earth's original supply of water is still in use: little has been added or lost in the hundreds of millions of years since the first cloud formed and the first rain fell. The same water has been pumped time and again from the oceans into the air, dropped upon the land and transferred back to the sea. This process -- the natural mechanism that evaporates ocean water, distributes it to every part of the earth, then returns it to the sea -- is known as the hydrologic cycle.

The most important links that complete the hydrologic cycle are complex processes of evaporation and transpiration. Evaporation is the conversion of water into vapor and its subsequent transfer from a soil or water surface to the atmosphere. Transpiration is the discharge of water to atmosphere as vapors by plants through their tissues. It is difficult to distinguish between free surface evaporation and transpiration from a soil in which plants are growing. The two processes are therefore lumped together and are termed evapotranspiration.

More than 70 percent of the 30 inch annual average precipitation of the United States is returned to the atmosphere in the form of evapotranspiration. Evapotranspiration cannot be ignored when considering such items as farm water management, irrigation requirements, potential moisture stress of crops, soil moisture estimates and ground water interaction with streams.

Estimates of evapotranspiration are useful in predicting the frequency and severity of agricultural droughts. It also permits more accurate calculations of soil moisture levels and better estimates of runoff, all of which improves river flow forecasts.

Research on evapotranspiration (ET), however, has historically concentrated on modeling ET when the soil has an adequate supply of water. Furthermore, most field investigations involve measuring ET indirectly from small plots of ground with single crops.

This research deals with a broader problem of improving the ET function of a watershed digital hydrologic simulation model originally developed at the University of Kansas [5], hereafter referred to as the Smith and Lumb model. The subroutine for calculating ET is altered so that it is more responsive to watershed cropping patterns and stage of plant growth.

The new ET function is basically an irrigation scheduling model applied to a natural watershed in which dryland agriculture predominates. The Smith and Lumb model is modified with the new evapotranspiration routine and the revised simulation package is applied to the Black Vermillion watershed. The simulated streamflows for a 14-year period are compared to recorded, (observed) flows in order to examine response characteristics and the fidelity of the new model. In addition, the new model performance is directly compared to that of the original Smith and Lumb model.

The major objective in altering the subroutine for calculating ET in the Smith and Lumb model is to develop a model capable of responding rapidly and accurately to daily climatological changes, and to provide the option of being able to predict the effect of changes in agricultural land use upon the overall watershed water budget. Another objective is to provide the framework

to generate low flow frequency curves for ungaged agricultural watersheds to aid water quality investigations.

This report briefly reviews the literature pertinent to the study and then describes the original Smith and Lumb model. The new ET model is subsequently introduced and the results of the testing and comparison between models for the Black Vermillion watershed are presented.

LITERATURE REVIEW

Much of the early work in modeling the hydrology of watersheds had, as the main objective, to predict the frequency of occurrence and magnitude of peak flood flows. This was particularly important for flood prevention planning on watersheds where a sufficient record of streamflow was not available. During periods of high surface runoff the evaporation from a watershed is a small portion of the total water budget, and any reasonable approach to predicting evapotranspiration was acceptable. The model developed by Huggins and Monke [2] lumps interception, surface storage and evapotranspiration all together as one function.

Attempts to model continuous streamflow over longer periods of time, particularly during extended dry periods, requires better estimates of evapotranspiration. These have been included in most new watershed models. However, in areas where predicting low flows is not important, an evapotranspiration component which gives adequate results over longer periods such as months or years is sufficient.

A hydrologic model based on antecedent soil moisture known as the Antecedent Precipitation Index (API) method was developed by Weather Bureau hydrologists and has been used and modified by others. This model has the advantage in that precipitation is the only input parameter required, and it gives satisfactory results of streamflow during periods of both high and low flows. However, the model contains a decay coefficient which has no direct relationship to any measurable physical parameter of the watershed and would not be useful in predicting the effects of future watershed changes.

One of the earliest and best known attempts to model the entire hydrologic cycle of a watershed is the Stanford Watershed Model [3]. This model

has been revised at least five times by its original developers and has been used as the basis for most of the other comprehensive models currently in existence, including the Smith and Lumb model [4,5].

In the Smith and Lumb model, the total evapotranspiration process is divided into direct surface evaporation, evapotranspiration from the unsaturated zone of the soil, evapotranspiration from groundwater, and direct evaporation from streams. It does not determine potential ET, but requires some estimate of potential ET as an input parameter. Pan evaporation data is generally used to compute a constant value of potential ET, which is multiplied by a linear temperature function to determine the daily potential ET rate. This method for determining potential ET uses temperature as the only climatic factor, although ET is strongly influenced by other factors, such as solar radiation, wind, and humidity.

The actual ET in the Smith and Lumb model is determined by multiplying the potential ET by an "evapotranspiration opportunity function." It is a function of the logarithm of the available soil moisture. The procedure does not include a function for the effect of the distribution of crops and stage of plant growth upon ET rates. This report presents a method whereby this factor can be included in the ET prediction.

The United States Department of Agriculture Hydrograph Laboratory model of watershed hydrology [6] divides the evapotranspiration process into direct evaporation from the soil and transpiration by plants. This model has been applied to micro-watersheds and the transpiration by plants was determined by lysimeters. The shortcoming is that it has not been applied to large watersheds where different crop patterns are encountered, and moreover, all of the climatic factors required for the ET routine were monitored locally.

The program adopted by the National Weather Service called the "River Forecast System Forecast Procedures" is quite similar to the Stanford Watershed Model [25]. Here the free water potential evapotranspiration is calculated based on Class A Pan evaporation modified by wind travel, water temperature, and a sinusoidal seasonal adjustment factor. This model has not taken into account the effect of crop pattern on yield from a watershed. It is not clear in [25] whether soil moisture availability is considered in calculating actual ET.

In scheduling irrigation many alternatives exist. In many areas, the climatic and soil moisture effects are disregarded in favor of irrigation on a rotational basis at constant intervals. This can result in low yields and low efficiencies. Due to the fact that evapotranspiration and precipitation are not uniform during the season, continuous irrigation flow systems are also inefficient. By controlling soil moisture, efficient irrigation can be achieved. In estimating soil moisture depletion, a time sharing computer program was developed by Jensen, Wright and Pratt [7] which helps to determine the number of days before the next irrigation and the amount of moisture that is needed. The program is a model which attempts to evaluate the complex climate-crop-soil moisture interrelations.

The basic principles employed by Jensen with respect to the use of a daily potential evapotranspiration model which responds rapidly to daily climatic changes were used in this study. Individual crop transpiration coefficients, which are input as functions of the stage of plant growth, are used to compute the actual ET. These adjustments were incorporated into the Smith and Lumb model.

QUANTITATIVE CONCEPTS OF KANSAS WATER BUDGET MODEL

The following are some general concepts of the Kansas Water Budget Model as described in Smith and Lumb [5]. The climatological parameters used in the model are the daily maximum and minimum temperatures and precipitation. In addition, approximately 50 input watershed parameters are necessary to describe the watershed.

The model can be generally described as follows: 1) it is a continuous model that generates daily outflows, 2) it is a lumped parameter model as distinguished from a distributed parameter model, which means that average watershed properties are used without regard to spatial distribution, 3) the general approach is to model as completely as possible the land phase of the hydrologic cycle, and 4) only readily available climatological, topographical, and soil data are used for model calibration and verification. The organization of the model is schematically presented in Figure 1.

Thiessen coefficients are used for obtaining the rainfall averages across the basin. After the initial deductions for interception and depression storage, part of the rainfall goes to surface runoff, while the rest infiltrates into the soil and increases the upper zone soil storage (UZS). If the moisture in the upper zone exceeds wilting point during the growing season, evapotranspiration continually operates to reduce the soil moisture in that zone. If the moisture in the upper zone exceeds field capacity, the excess percolates down and adds to the lower zone storage (LZS).

There are two sections in the lower zone, one is the area composed of valley alluvium and is called the lowland lower zone (LZSA), the other is known as upland (LZST) which comprises the basin upslope. Interflow is the flow of water from (LZST) when the moisture content in that zone exceeds the

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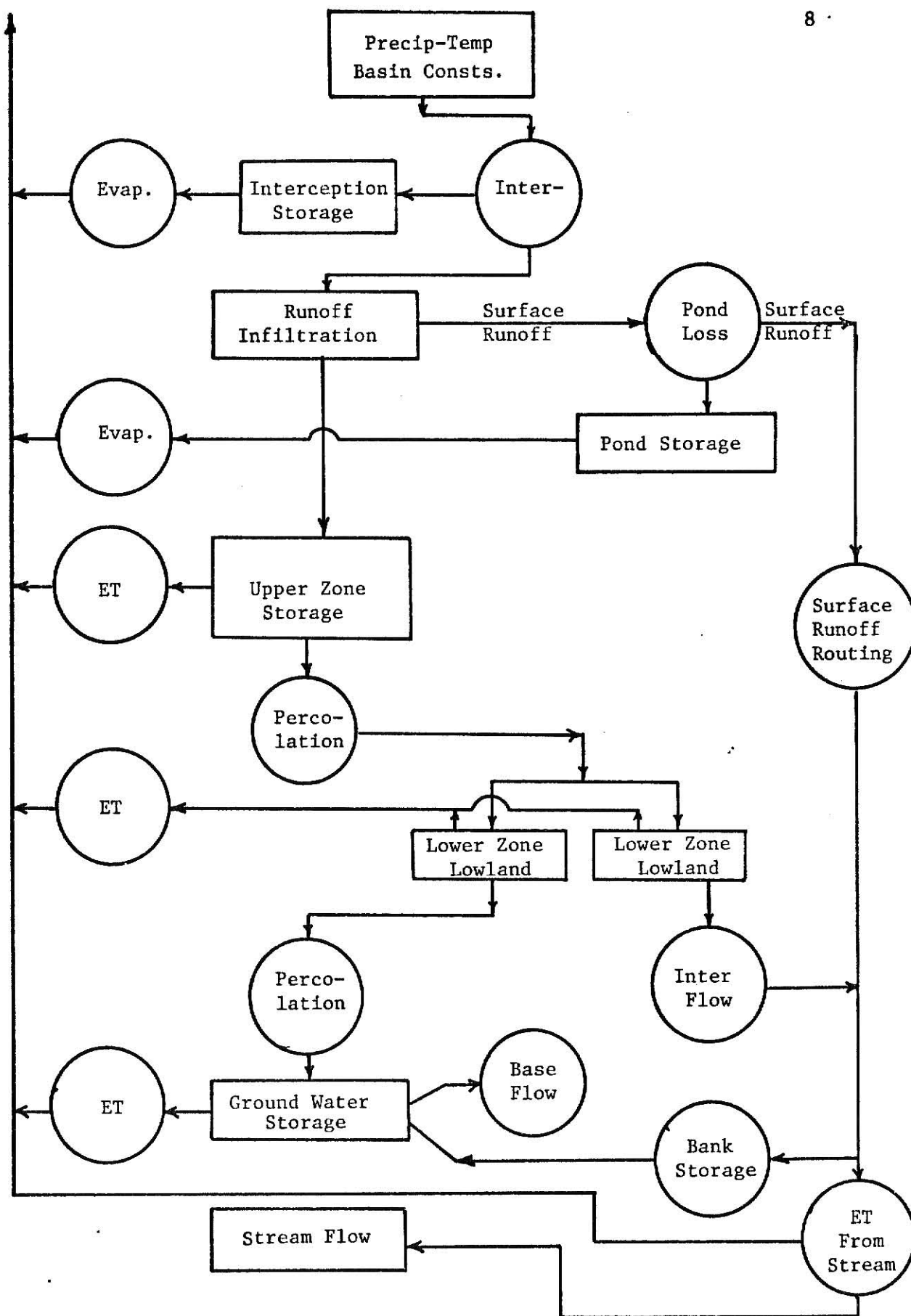


Figure 1. Flowchart of Kansas Water Budget Model.

field capacity. This water becomes surface runoff and flows directly to the stream. The loss of water from (LZSA) takes place by percolation to the groundwater storage (GWS) when the moisture content exceeds the field capacity. Water is also lost from both the upland and lowland lower zones by evapotranspiration. Water in groundwater storage feeds the streams as baseflow during dry periods and some storage may be lost by evapotranspiration of riparian vegetation along the stream banks.

The total discharge from the basin is determined by adding the surface runoff, interflow, and baseflow. Water is also lost from the stream and ponds by free surface evaporation.

The following is a brief description of the parameters and procedures involved in the original Smith and Lumb model. The streamflow routing procedures are not described since they were not required for a study of a relatively small watershed. For a complete and detailed description, see Knapp [8,27].

Precipitation

Daily precipitation is the primary input signal apart from temperature to the model and is distributed evenly across the entire basin by Thiessen weighting coefficients. If the daily precipitation at any station within watershed exceeds 0.1 inch, the precipitation rates for each hour are also provided since the entire rainfall-runoff response cycle for a storm on small watersheds occurs often in periods of less than 24 hours. Daily precipitation data is distributed by means of hourly precipitation fractions over one-hour periods throughout the rainy day. The hourly precipitation pattern at a single (sometimes two) hourly precipitation stations is assumed to adequately

describe the hourly variation over the entire watershed. The daily and hourly precipitation data is taken on a midnight to midnight basis from weather stations located within or near the basin.

Initial Abstraction

The initial abstraction is the quantity of moisture required during the early stages of a rainfall to wet leafy surfaces and ground surface depressions. This moisture is held by surface terrain until it is completely evaporated. The initial abstraction (IA) can be expressed as a linear function of the antecedent soil moisture according to Hamon [9]. Lumb [10] modified the linear relationship as described by Knapp [27;pp. 16-17].

Surface Evaporation

Moisture retained on the surface is lost to the atmosphere by evaporation which is assumed to be a linear function of temperature [10].

Surface evaporation is expressed as

$$ETSUR = ETR (T-30)/50$$

where

$ETSUR$ = Rate of evaporation from the surface, inches/hour (in/hr)

ETR = Rate of free surface evaporation at 80 °F, in/hr (a constant derived from pan evaporation records [27;pp. 44])

T = Daily mean temperature in °F; when the temperature is less than 30 °F, evaporation is zero.

Rainfall-Runoff Relation

The United States Soil Conservation Service [26] has attempted to estimate the amount of runoff that will result from a given amount of precipitation on

a specific area. The equation used is

$$\frac{P-IA-RO}{S} = \frac{RO}{P-IA} \quad (1)$$

where

RO = Direct runoff in inches,

P = Precipitation in inches,

IA = Initial abstraction,

S = Maximum potential difference between P and RO, in inches.

This relation is a mathematical expression of the assumption that the ratio of actual infiltration, (P-IA-RO), to potential infiltration, S, is equal to the ratio of actual runoff, RO, to potential runoff, (P-IA). Since S is a linear function of soil moisture, the upper zone soil moisture (UZS), is updated hourly to determine a new S as the storm progresses. Eq. (1) can then be solved directly for RO, as described in (26).

Surface Runoff Routing

The overland flow unit hydrograph method described by Linsley, et. al. [11;pp. 238-241] is used to temporarily distribute the surface runoff, RO, and to deliver it to the watershed outlet.

Infiltration and Storage

Infiltration through a soil depends upon the type of soil. It is maximum in sandy soils and minimum in clay-type soils. FM represents the minimum infiltration capacity. Ranges of FM for different soils have been obtained by Musgrave and Holton [12].

Upper Soil Zone

Infiltration from the surface adds to the moisture in the upper soil zone. UZMX denotes moisture at complete saturation. UZMN is moisture at wilting point and UZSN is the moisture at field capacity. Each of these values are dependent on soil texture. When moisture exceeds the wilting point, evapotranspiration takes place, and when the moisture exceeds the field capacity, percolation to the lower zone takes place.

Percolation

The following relationship is developed by Wilcox [13] computing percolation from upper zone to lower zone. Percolation will occur when the moisture is greater than field capacity, and is maximum at complete saturation.

$$\text{PERC} = K_1 (\overline{\text{UZS}})^{K_2} \quad (2)$$

where

PERC = Percolation,

K_1 = Permeability of the soil in the vertical direction, in/day,

K_2 = Parameteric constant for a soil,

$\overline{\text{UZS}} = (\text{UZS} - \text{UZSN}) / (\text{UZMX} - \text{UZSN})$.

Evapotranspiration from Upper Zone

Evapotranspiration being dependent upon atmospheric conditions and soil moisture, is calculated from a relationship presented by Lumb [10; pp. 38-44] and Smith and Lumb [5; pp. 11-15], and is as follows

$$\text{ETUZ} = \text{ET80} \left[\frac{(\log_{10}(\text{UZS}) - \log_{10}(\text{UZMN}))}{(\log_{10}(\text{UZMX}) - \log_{10}(\text{UZMN}))} \right]^{CX} \frac{(T-30)}{50} \quad (\text{PCU}) \quad (3)$$

where

ETUZ = Evapotranspiration actually taking place from upper soil zone,
in/day,

CX = Parametric constant of soil,

T = Daily average temperature, in °F,

PCU = Fraction of evapotranspiration from upper soil zone, and

ET80 = Potential evapotranspiration rate at 80 °F, in/day/°F.

When the temperature is less than 30 °F, evapotranspiration drops to zero. The potential ET (ET80) constant has values ranging from about 0.4 in/day in warm months to 0.1 in/day in cold months. In the Smith and Lumb model, the potential ET is computed by multiplying ET80 by the linear temperature $(T-30/50)$ function. Actual ET is assumed to be a logarithmic function of the available soil moisture.

Lower Soil Zone

The soil underlying upper soil zone is called the lower zone. It receives its moisture through percolation from the upper zone. It loses its water content either by ET or by downward percolation to the groundwater zone. The soil texture plays an important role in determining the quantity of moisture either lost by evapotranspiration or by recharging the aquifer. Sometimes, depending on the terrain of the watershed, water may be lost from lower zone through interflow. This flow only takes place when the profile of lower zone in the upland regions intersects the ground surface and water flows direct to the stream.

Evapotranspiration from Lower Zone

The same type of formula used for ET from upper zone is used to determine the evapotranspiration from lower zone, with a slight modification. The equation involved is as follows

$$ETLZ = ET80 \left[\frac{(\log_{10}(LZS) - \log_{10}(LZMN))}{(\log_{10}(LZMX) - \log_{10}(LZMN))} \right]^{CX} \frac{(T-30)}{50} PCL (FRAC) \quad (4)$$

where

PCL = Fraction of evapotranspiration attributed to lower zone and is equal to (1-PCU).

FRAC = This term controls the seasonal variation of evapotranspiration. It is zero for winter months when plants are dormant and transpiration ceases. It is equal to unity for summer months when the evapotranspiration is high. The transition period for values between zero to unity occurs when the growing season begins or is about to end.

Interflow

Water which enters the streamflow from lower zone without entering the groundwater zone is called interflow. This usually takes place from the uplands of the lower zone at a time when soil moisture exceeds field capacity. The following equation is used to determine interflow. (See Figure 2):

$$IFW = -\log_e (K_r) (\overline{LZS}) \quad (5)$$

where

IFW = Interflow rate, in/day,

K_r = Recession constant,

$\overline{LZS}$ = $LZS - LZSN$, in inches.

Groundwater Zone

The zone underlying lower zone is called the groundwater zone. It primarily derives its water content through recharge from the lower zone. It acts as storage reservoir and may be an aquifier if it can deliver a useful water supply. In Kansas, this zone is often hydraulically connected to the stream and maintains a baseflow to the stream during droughts.

Riparian Evapotranspiration

This factor has been introduced in the program to account for the loss of water from the groundwater zone near the interaction point with the stream. Plants grown on the banks of streams get moisture from the stream and the underlying groundwater zone. The following equation is used.

$$ETBF = ETSTR(RUNOFF)^{PWRE} \frac{(T-30)}{50} \text{FRAC} \quad (6)$$

where

$ETBF$ = Transpiration rate from streamflow, cfs/day,

$ETSTR$ = Potential transpiration rate from stream flow at 10,000 cfs and 80 °F, cfs/day,

$RUNOFF$ = Streamflow, cfs,

T = Average daily temperature, °F,

$PWRE$ = Parametric Constant (less than 1.0), and

$FRAC$ = Seasonal transpirational factor (0 or 1).

In the new model this factor has not been taken into account, although it could have been incorporated. Instead, evaporation from the stream has

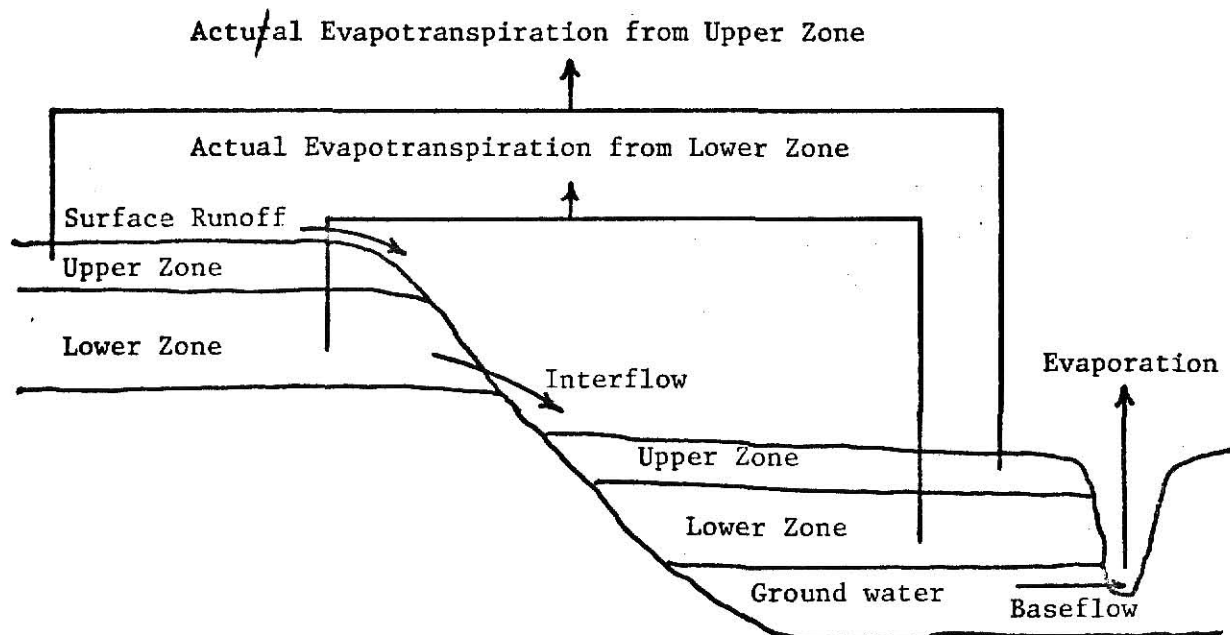


Figure 2. Profile of Ground Surface showing Interflow, (After Lumb).

been determined by taking it as part of the free surface available in addition to the ponds.

Streamflow

The total streamflow measured at a recording station is the sum of the direct surface runoff, interflow, and baseflow. These are calculated on a daily basis which are later summed into monthly and yearly values. These simulated daily flows are statistically compared with the observed daily discharges to determine the relative performance of the model.

DEVELOPMENT OF THE NEW EVAPOTRANSPIRATION MODEL

The daily actual evapotranspiration in the Smith and Lumb model described in the last section is determined by multiplying a constant potential ET rate (ET80) by a linear mean daily temperature function and a logarithmic soil moisture function. The primary advantage of this method is simplicity, in that it requires only temperature as a climatic factor. The ET80 constant can be adjusted so that long term ET rates (monthly and yearly) correspond to ordinarily accepted values. If the ET model is to be responsive on a daily or weekly basis, however, other important climatic factors which govern the process must be brought into the model. These factors are generally accepted to be solar radiation, humidity and wind speed. Similarly, the actual ET that occurs under a given set of climatic and soil moisture conditions is dependent upon the type of vegetation on the watershed and the stage of plant growth. An ET model which accounts for each of these factors is described in a paper by Jensen, Wright, and Pratt [7]. The Jensen model was selected for detailed study and was programmed into the Smith and Lumb model. The basic mathematical expressions are presented as follows:

$$ETA = ETP[(K_c)(K_s) + K_w] \quad (7)$$

where

ETA = actual ET in inches,

ETP = potential ET in inches,

K_c = a coefficient to account for the variation in water use by different types of crops in different seasons (crop coefficient),

K_s = a coefficient to account for differences in availability of water for evapotranspiration at different soil moisture contents, and

K_w = a coefficient indicating the presence of free water surfaces that would cause increased evaporation immediately following rainfall.

Penman Combination Equation

The potential evapotranspiration (ETP) was determined using the Penman Combination Equation. This equation has been used by researchers working on water use by irrigated [14], and is a compromise between a completely rigorous theoretical approach and a practical approach requiring limited data sources. It is a combination of the energy budget method and the mass transfer method for predicting evaporation, with empirical approximations for some factors, and is of the following form:

$$ETP = \frac{\Delta}{\Delta + \gamma}(RN - G) + \frac{\gamma}{\Delta + \gamma}(EA) \quad (8)$$

where

ETP = potential evapotranspiration in millimeters, converted to inches by dividing by 25.4,

G = heat flux to or from the soil in calories per square centimeter as a result of rapid changes in air temperature [G = (average air temperature minus the average air temperature for the three previous days in °F) x 5]. During the summer months where day-to-day temperatures do not change greatly and day-to-day radiation is similar, soil heat flux is relatively small and can be neglected. During the winter months, as

ET is inhibited, G's effect upon ET is small, and can be neglected, thus, $G = 0$ in the program,

RN = daily heat budget at the surface in millimeter of water,

Δ = slope of the saturation vapor pressure-temperature curve,
(de/dt),

γ = psychrometric constant,

EA = a function of wind speed and humidity as explained subsequently.

The first term to the right of the equal sign in Eq. (8) represents potential evaporation as a result of incoming solar radiation, while the second term represents the contribution of aerodynamic processes to evaporation. Hence the equation is called a combination equation.

Derivation of Parameters

$(\frac{\Delta}{\Delta+\gamma})$ and $(\frac{\gamma}{\Delta+\gamma})$ are mean air temperature weighting factors whose sum is 1.0. Table 1 summarizes these parameters versus mean air temperature as computed from the Smithsonian Meteorological Tables [24,14]. The derived values of $\Delta/(\Delta+\gamma)$ were plotted against temperature, T, in °F on logarithmic graph paper to derive an equation to be used in the new model (see Figure 3).

If $(\Delta/(\Delta+\gamma)) = a(T)^b$, then $\log (\Delta/(\Delta+\gamma)) = \log a(T)^b = \log a + b \log T$. When $T=1$, $\log (\Delta/(\Delta+\gamma)) = \log a$, hence $(\Delta/(\Delta+\gamma)) = a$ for $T = 1$ and $b =$ the slope of the line. The values for a and b were 0.039 and 0.673, respectively, as shown in Fig. 3. In the model $(\Delta/(\Delta+\gamma)) = \text{DELTA}$ and $(\gamma/(\Delta+\gamma)) = \text{GUM}$. So

$$\text{DELTA} = 0.039(T)^{0.673} \quad (9)$$

$$\text{GUM} = 1.0 - \text{DELTA} \quad (10)$$

Eq. (9) avoids the inconvenience of data tables and interpolation routines.

Table 1. Values of $\Delta/\Delta+\gamma$ and $\gamma/\Delta+\gamma$
Versus Temperature

Air Temperature			
Degrees Centigrade °C	Degrees Fahrenheit °F	$\Delta/\Delta+\gamma$	$\gamma/\Delta+\gamma$
1	33.8	0.417	0.583
5	41	0.478	0.522
10	50	0.552	0.448
15	59	0.621	0.379
20	68	0.682	0.318
25	77	0.735	0.265
30	86	0.781	0.219
35	95	0.819	0.181
40	104	0.851	0.149

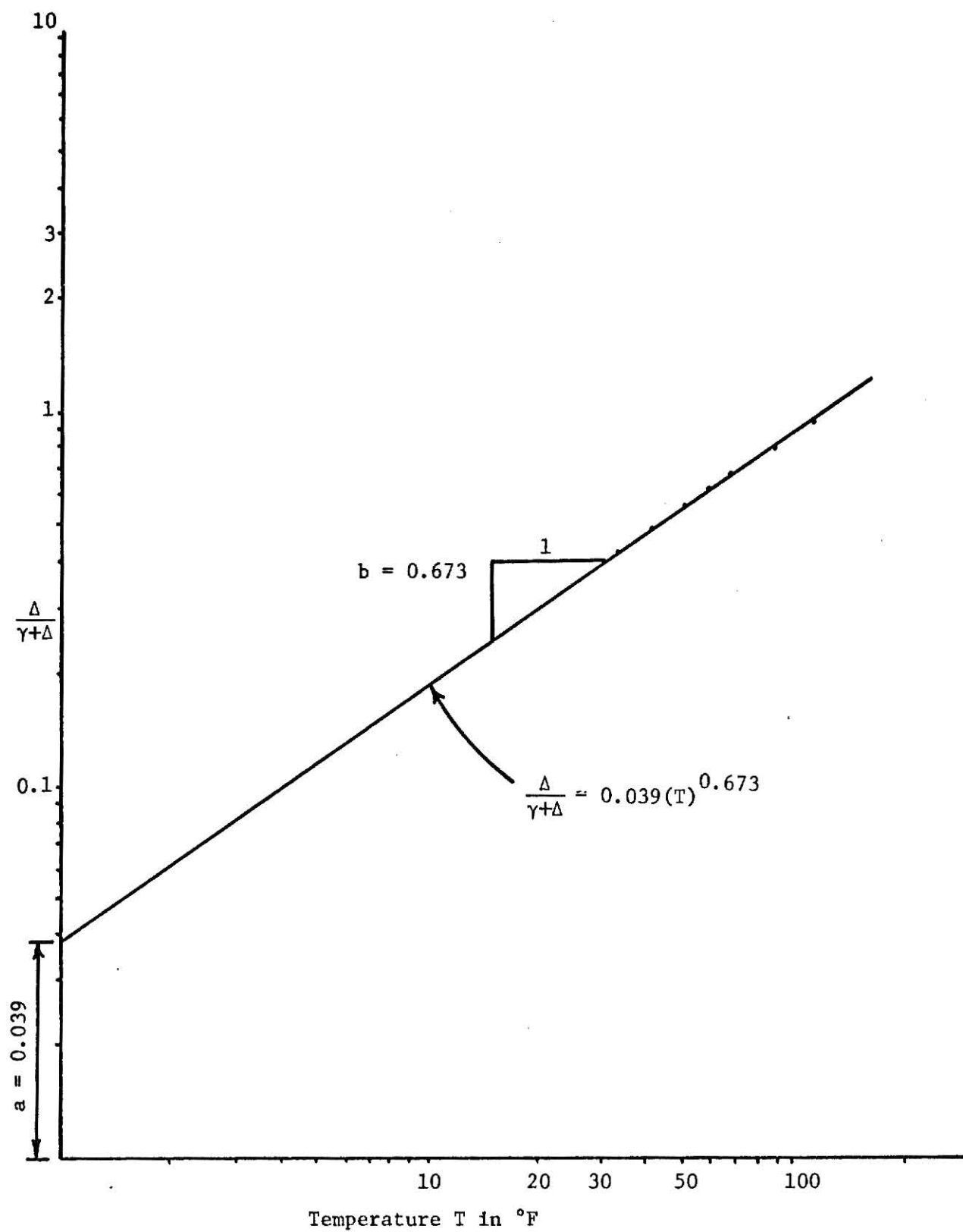


Figure 3. Mean Air Temperature Weighting Factor Versus Temperature.

The aerodynamic term in Eq. (8) is given as [15]:

$$EA = f(u)(ES - ESA) \quad (11)$$

where

$$\begin{aligned} f(u) &= \text{function of wind speed,} \\ &= 0.36(1.0 + 0.01 \text{ WVD}) \end{aligned} \quad (12)$$

WVD = mean wind velocity at 2 meters above the ground in miles per day,

= $W(\log 6.6 / \log h)$ where W is measured wind velocity in miles/day at height h in feet,

ES = mean saturation vapor pressure in millimeters of mercury, at mean daily air temperature. It is given by the following equation according to [28].

$$\log(ES/6.105) = (10.9533(ABST - 273.16)/ABST) - 5.31 \log(ABST/273.16) \quad (13)$$

where

ABST = temperature ($^{\circ}\text{K}$) absolute Kelvin.

Eq. (13) gives values in millibars. It is multiplied by 0.75007 to obtain millimeters of Mercury.

ESA = actual vapor pressure of the air. It is obtained from multiplying saturation vapor pressure by the mean relative humidity,

$$= ES \times \text{RHD.}$$

The heat budget term in Eq. (8) is a function of solar radiation as follows:

$$RN = (1 - R)RSI - RB \quad (14)$$

where

$$\begin{aligned} \text{RSI} &= \text{total solar radiation incident to the water surface,} \\ &= \text{RA(a+b)(PSUNS))} \end{aligned}$$

hence

$$\text{RN} = (1-\text{R}) \text{RA(a+b)(PSUNS))} - \text{RB} \quad (15)$$

where

R = mean daily shortwave reflectance or albedo and is taken as 0.20 to 0.25 for most green crops. In the program it is taken as 0.20,

RA = Extra-terrestrial solar radiation on a horizontal surface in millimeter of water evaporated per day. The following average monthly values of RA for 40° North Latitude [after Criddle 15] were used in the program: J - 6.0; F - 8.3; M - 11.0; A - 13.9; M - 15.9; J - 16.7; J - 16.3; A - 14.8; S - 12.2; O - 9.3; N - 6.7; D - 5.5.

PSUNS = Percentage of possible sunshine,

a, b = constants for different geographical locations. The values used are 0.22 and 0.54 respectively, which were obtained for Virginia [15]. These were the nearest application values available in the literature,

$$\begin{aligned} \text{RB} &= \text{Actual outgoing longwave radiation,} \\ &= \text{PE(1-E)(0.1 + 0.9(PSUNS))} \end{aligned} \quad (16)$$

where

$$\text{PE} = \sigma(\text{ABST})^4/58.1 \quad (17)$$

σ = Stefan-Boltzmann Constant (1.17×10^{-7} cal/cm²°K⁴/day),

E = emissivity, which is always a fraction, and stands for the emission characteristics of the surface. It relates to the black body radiation. The emissivity factor for water varies

from 0.906 to 0.985. According to Brunt [15], $E = a + b \sqrt{ESA}$ where a and b are empirically derived coefficients. The values for Kansas are taken for Oklahoma, being 0.40 and 0.047, as derived by Anderson in [15].

Thus combining Equations 15, 16 and 17, we obtain

$$RN = (0.8) RA [0.22 + 0.54(PSUNS)] - \left[\frac{\sigma(ABST)^4}{58.1} (0.4 - 0.047 \sqrt{ESA}) (0.1 + 0.9(PSUNS)) \right] \quad (18)$$

While the expanded form of the Penman Combination Equation (Eq. 8), is unusually cumbersome, only four climatological parameters are required for solution, namely, mean daily temperature, mean daily humidity, wind travel in miles per day, and daily percentage sunshine. While the latter three are regularly recorded at only five first-order stations in Kansas (Topeka, Concordia, Wichita, Dodge City, and Goodland), these stations cover the broad climatic regions of the state. Also, it is reasonable to assume that humidity, wind travel, and solar radiation are generally less variable than temperature across the state. Since temperature has a large influence and is usually locally available, the addition of the other three climate factors, although taken from a remote source, should enhance the weekly, and even daily, response of the model. Since there are only a few stations which have these records, the data collection and processing for the state also does not represent an overwhelming task. Thus, while the Penman approach appears unwieldy, once programmed, it is not significantly more difficult to handle than the Smith and Lumb method.

Computation of Actual Evapotranspiration

The actual evapotranspiration is determined in Eq. (7) by multiplying ETP by the dimensionless coefficient $[K_c K_s + K_w]$.

K_c is a coefficient to account for the variation in water use by different types of crops at different seasons. The values for Kansas are published by United States Department of Agriculture Soil Conservation Service [16].

K_s is a coefficient to account for difference in availability of water for evapotranspiration at different soil moisture contents. It is relative coefficient related to the available soil moisture. The value of K_s was calculated by a method suggested by Jensen [7]. It is assumed to be proportional to the logarithm of the percentage of remaining available soil moisture by the following relation;

$$K_s = \ln(\text{PSM}+1)/\ln(101) \quad (19)$$

where

PSM = Percentage available soil moisture in the upper and lower zones.

The maximum value of K_s is limited to 1.0 when the soil moisture in the upper and lower zones is equal to or greater than the field capacity. During a prolonged dry period, the crops and vegetation may reach the wilting point, in which case K_s falls to zero and evapotranspiration is completely inhibited.

K_w is a coefficient to account for the fact that evaporation occurs at a faster rate from a free water surface or a saturated soil surface. This factor would start out at a high value immediately following a rainfall period, and would decrease as the soil surface dries out, until it would eventually become negligible. K_w can be estimated as (7):

$$K_w = [1.0 - (K_c)(K_s)]e^{-\lambda t} \quad (20)$$

where

λ = a function of available moisture for direct surface evaporation. The value of λ is 0.3 in this model to give values comparable with those in Jensen [7].

t = The number of days since the last rainfall occurred. It is equal to zero on the day of rainfall and increases by one daily until the next rainfall.

The actual evapotranspiration is less than or equal to potential evapotranspiration so that the sum of $[(K_c)(K_s) + K_w]$ should always be less than or equal to 1.0.

For the purpose of deducting the soil moisture consumed as a result of actual evapotranspiration, it was assumed that 40 percent is taken from upper zone and 60 percent is taken from lower zone. For the daily computed values of upper and lower zone soil moistures, the ETA fractions are deducted to give a new value of upper and lower zone soil moisture for the next day. The allocations to upper and lower zones respectively are equivalent to PCU and PCL described in Knapp [8,27]. The free surface evaporation from ponds and streams is computed as

$$ETPS = ETP(PONDAR/AREA \times 640) \quad (21)$$

where

ETPS = Evaporation from pond surface, inches

PONDAR = Area of exposed open surfaces of water, acres

AREA = Area of the watershed, mile².

The total actual evapotranspiration is therefore given as follows:

$$ETA = ETP[(K_c)(K_s) + K_w] + ETPS \quad (22)$$

Equation (22) is a simple expression of the new ET model which was programmed into the Smith and Lumb model. This new model was tested and compared to the original Kansas Water Budget model on the Black Vermillion Watershed as described in the following section.

Figure 1 has been modified in Figure 4 by incorporating the additional input climatic parameters such as relative humidity, percentage of sunshine, solar radiation and wind velocity. Surface evaporation is now grouped together as collectively as from interception storage, pond storage and from the streamflow. The effect of crops have been added to determine actual evapotranspiration from the upper and lower zone. Total actual evapotranspiration is then the combination of surface evaporation and actual evapotranspiration from the upper and lower zones. Subroutines other than those relating to ET are the same as those presented by Knapp [7] for the original model, as discussed in the previous section.

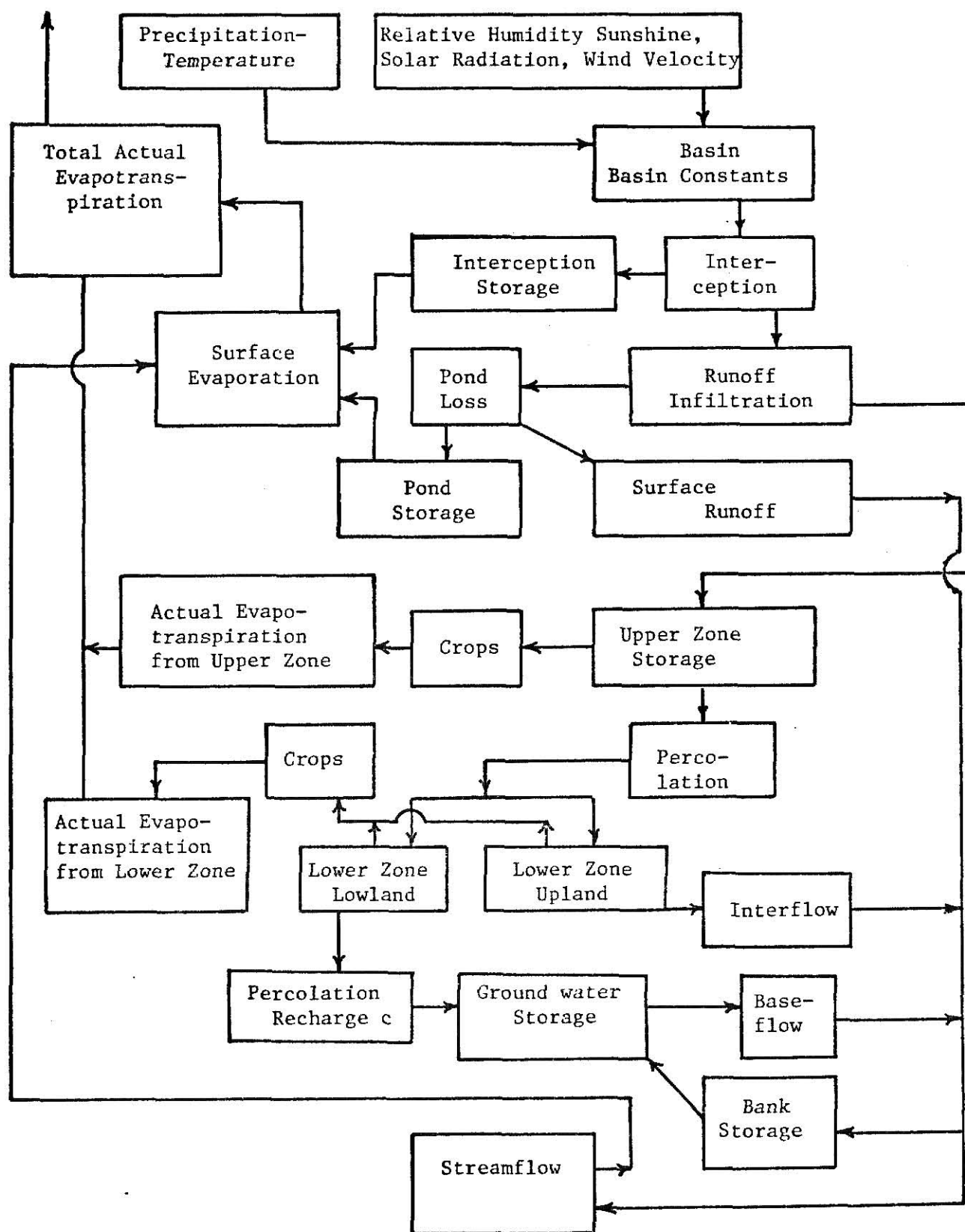


Figure 4. Flowchart of New Model.

TESTING OF THE NEW MODEL

In order to compare the performance of the new model compared to the Smith and Lumb model, both models were tested on the Black Vermillion basin for the time period 1954 through 1967. The only difference in model input parameters for the two models are the additional climate factors of relative humidity, wind velocity and percent sunshine data required for the new potential ET function, and the crop coefficients required for actual ET.

Description of Watershed

The Black Vermillion basin, as shown in Figure 5, is located in Northeastern Kansas near the Nebraska state border. It drains 412 square miles, of which 308 square miles are in Marshall county, 100 square miles in Nemaha county and about 4 square miles in Pottawatomie county.

The area is characterized by low topographic relief and includes large, extremely flat sections. The total relief is approximately 283 feet. Moderate annual precipitation of 32 inches characterizes its climate with a wide range in temperature, along with moderately high average wind velocity and comparatively rapid evaporation. The range of annual precipitation is less than 20 to more than 55 inches. The mean annual temperature is 54 °F with annual extremes of over 100 °F to below zero. The mean hourly wind speed is approximately 11 miles per hour. The average 6 a.m. relative humidity is approximately 80%.

Agricultural activity is prevalent throughout the area, with wheat, sorghum, corn, soy beans, pasture and alfalfa being the principal crops. Almost all of it during the study period was grown by dry farming techniques, and the yield depends on the water supplied by precipitation. The entire

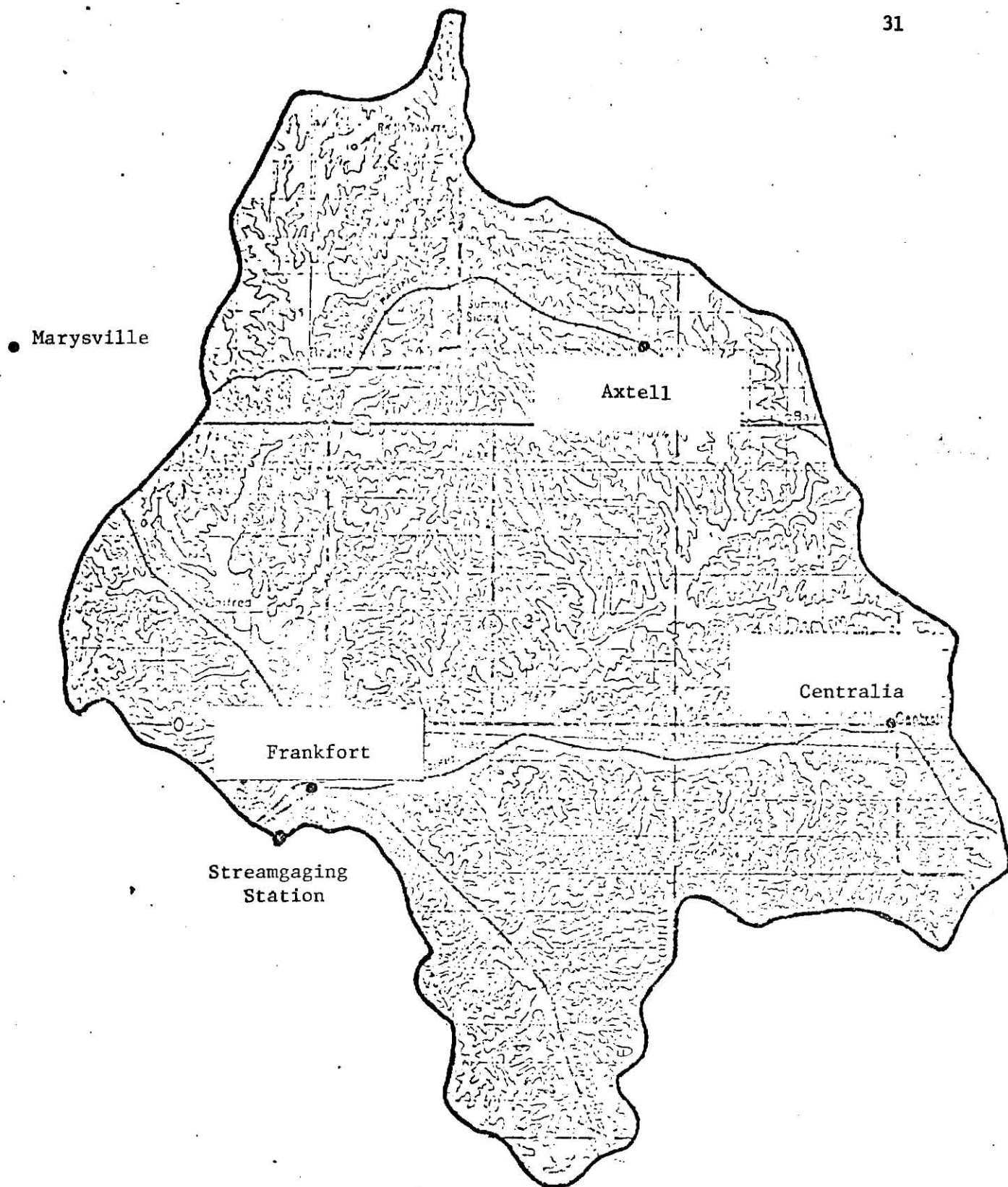


Figure 5. Sketch of the Black Vermillion Watershed.

watershed has a low well yield. Generalized tests performed gave well yields from 10 to 100 gallons per minute [17]). The saturated thickness of the unconsolidated deposits range between 40 to 80 feet [17]. The depth to water is generally 20 feet or less in the major stream valleys [17]. In the upland areas the depth ranges from 20 to 50 feet except in scattered local areas where it may exceed 100 feet. The estimated acre feet of water in storage is roughly 1.5 million [17] which is about 69 acre-inches per acre. Woodlands comprise less than 2 percent of watershed and therefore no special consideration was made for trees in the evapotranspiration model.

The Black Vermillion River has been gaged continuously since 1954 at Frankfort in Marshall county. These records were used for the comparison to computed basin discharge. Due to the watershed development construction activities which were begun in 1967, the new model was tested for the 1954-67 period in which the basin characteristics were relatively static.

Basin Data and Input Parameters

This section deals with the basic parametric input data required to test the model on the Black Vermillion. A complete listing of all the final input parameter values discussed in the following sections is included in Table 2. Some of the values were not used in the new program as a result of revising the ET functions as noted.

The minimum infiltration capacity, FM, is the smaller of the upper or lower soil zone percolation rates at complete saturation. It is dependent on soil type and is explained fully in [27]. The value used is given in Table 2. The maximum potential difference between precipitation and surface runoff, in inches, is termed storage. SBI and SMI are the parameters used to define the linear relationship between storage and upper zone soil moisture.

Its values were adjusted for the watershed as described in [27;pp. 46]. The values used are given in Table 2.

That portion of the moisture which neither contributes to surface runoff nor infiltration, and instead, is stored on the surface is termed Initial Abstraction. It is lost to the atmosphere by evaporation. The initial abstraction (IA) varies with upper zone soil moisture. It is expressed as the linear function of the antecedent soil moisture. The linear relationship was modified by Lumb [10] and is comprised of three straight-line segments. The upper left segment of the curve in Figure 6, which is at low values of soil moisture, includes the moisture lost to surface depression storage and interception. The relationship used is

$$IA = B-C(UZS) \quad (23)$$

The middle segment includes parameter IB1 and IM1 which marks the transition stage between initial abstraction and surface depression storage. The initial abstraction is in the form of wetting dry vegetation. The relationship used is

$$IA = IB1-IM1(UZS) \quad (24)$$

When the soil moisture level increases, the losses due to initial abstraction and from wetting the soil and vegetation surface are assumed to be a constant. The minimum value of IA is the IIA parameter. All the above values were adjusted for the watershed as described in [27;pp. 46-47]. The values used are given in Table 2.

The soil moisture at complete saturation in the upper and lower zone are termed UZMX and LZMX, respectively. Wilting point moisture levels are denoted by UZMN and LZMN for the upper and lower zone. Moisture at field capacity is represented by UZSN and LZSN. The soil moisture values are dependent on soil type. The Black Vermillion has predominantly Wymore and

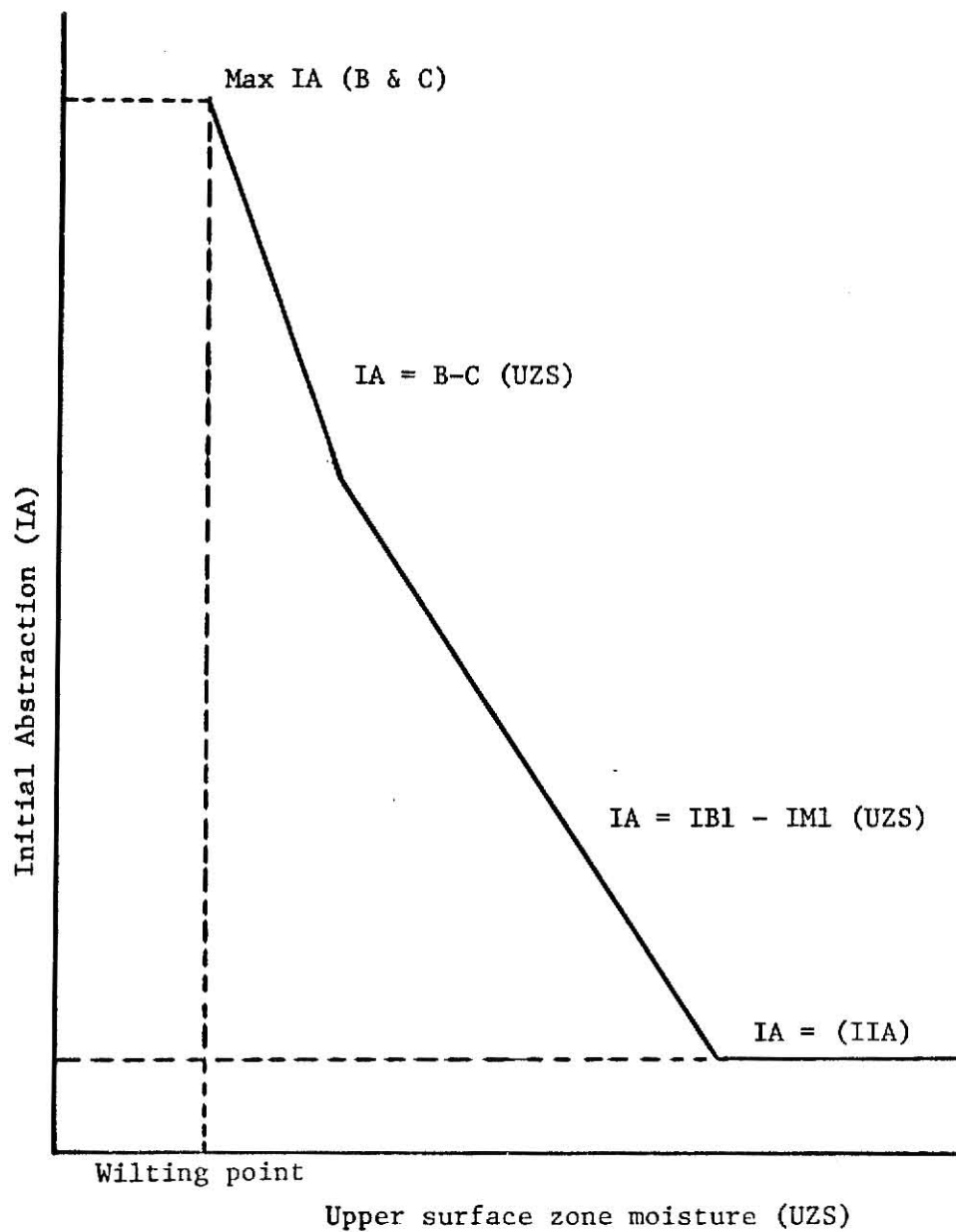


Figure 6. Variation of Initial Abstraction with Upper Soil Zone Moisture, (After Lumb).

Pawnee Soils. Wymore is a silty clay loam topsoil which is generally about 10 inches thick. Pawnee is a clay loam which comprises the lower zone in the watershed model.

The upper zone soil parameters for silty loam soil including the moisture content at wilting point, field capacity and saturation, were obtained from Table 7.4 of Israelsen and Hansen [18]

Percentage of Moisture by weight at wilting point = 15 %

Percentage of moisture by weight at field capacity = 31 %

Apparent specific gravity = A_s = 1.3

Pore space by volume = 51 %

Percentage of moisture by weight at saturation = $\frac{51}{1.3} = 39.2\%$

Depth of upper soil zone = 10 inches

UZMN = Moisture at wilting point

$$= \frac{15 \times 1.3 \times 10}{100} = 1.95 \text{ inches}$$

UZSN = Moisture at field capacity

$$= \frac{31 \times 1.3 \times 10}{100} = 4.03 \text{ inches}$$

UZMX = Moisture at saturation

$$= \frac{39.2 \times 1.3 \times 10}{100} = 5.096 \text{ inches .}$$

The lower zone soil is a clay loam and the values of moisture at wilting point, field capacity and saturation were calculated in the same way as the upper zone soil moisture.

Percentage of moisture by weight at wilting point = 13 %

Percentage of moisture by weight at field capacity = 27 %

$$\text{Apparent specific gravity} = A_s = 1.35$$

$$\text{Pore space by volume} = 49 \%$$

$$\text{Percentage of moisture by weight at saturation} = \frac{49}{1.35} = 36.30\%$$

$$\text{Depth of lower soil zone} = 30 \text{ inches}$$

$$\text{LZMN} = \text{Moisture at wilting point}$$

$$= \frac{13 \times 1.35 \times 30}{100} = 5.265 \text{ inches}$$

$$\text{LZSN} = \text{Moisture at field capacity}$$

$$= \frac{27 \times 1.35 \times 30}{100} = 10.935 \text{ inches}$$

$$\text{LZMX} = \text{Moisture at saturation}$$

$$= \frac{36.3 \times 1.35 \times 30}{100} = 14.7 \text{ inches}$$

The movement of water downwards from the upper zone to the lower zone is percolation. It only occurs when the moisture content in the upper zone exceeds the field capacity. PERC and RECGW are the functions governing this in the Smith and Lumb model. The parametric constants which govern PERC and RECGW for a particular type of soil are UBP, UMP, RGWB and RGWM, where UBP and RGWB are the upper and lower zone permeabilities, respectively, at complete saturation. UMP and RGWM are the exponents for the upper and lower zones for PERC and RECGW, respectively. RECGW is the recharge from the lower zone to the groundwater zone. The values used are given in Table 2, which can be determined from the study by Wilcox [13].

The lateral movement of water in the lower soil zone is interflow. It is dependent upon soil type and topography. The recession constant used in the interflow relation is IKR, and its value is taken as 0.98.

Table 2. List of Input Parameters for the Black Vermillion

Parameters	Value Used	Units
CKN (1) thru CKN (20)	0.010, 0.025, 0.065, 0.080, 0.085, 0.090, 0.100, 0.075, 0.065, 0.060, 0.055, 0.050, 0.045, 0.040, 0.035, 0.030, 0.025, 0.023, 0.021, 0.021	None
SBI	30.500	None
SMI	6.000	None
IBI	0.375	None
IMI	0.150	None
UZSN	4.030	Inches
UBP	9.000	None
UMP	2.000	None
UZMX	5.096	Inches
UZMN	1.950	Inches
LZMX	14.700	Inches
LZMN	5.265	Inches
ET80M (not used in new model)	0.220	None
CX (not used in new model)	0.900	None
YSTRT	54.000	None
IKR	0.980	None
PCL (not used in new model)	0.550	None
RGWB	6.000	None
RGWM	2.000	None
GWSN	69.000	Inches
BK	0.990	None
AGW	0.200	None
PDY	0.100	Inches
TLL	7.000	None
LZSAN	10.935	Inches
LZSTN	10.935	Inches
AREA	412.000	Sq. miles
UZSO	3.000	Inches
LZSO	9.100	Inches
GWSO	69.500	Inches
YREND	67.000	None
GWRP	0.000	None
PORF	0.0833	None
IIA	0.020	Inches
GWMN (not used in new model)	20.000	Inches
PTPOND	0.000	None
ETR (not used in new model)	0.010	Inches
FM	0.180	Inches
POWER	1.000	None
PWRE	0.100	None
QUANTY	0.600	None
B	1.260	None
C	0.700	None
PONDDP	0.500	Feet
PONDAR	500.000	Acres
ZZT	1.000	None

Snyder's [19] method was used for constructing the initial unit hydrograph for the basin. Since his method was developed for use in hilly Appalachian watersheds and the Black Vermillion has a relatively low relief, it was modified to delay the temporal distribution of surface runoff for its arrival at the Frankfort gaging station. CKN (1) through CKN (20) are the 6 hour incremental areas of the unitgraph given in Table 2.

The crop coefficients are additional parameters which are required for the new program and are not listed in Table 2. K_c was determined for different crops in the watershed using the percent of daylight hours at 38.5° North latitude. The values are given in Table D, pp. 66, of the "Kansas Irrigation Guide and Irrigation Planners Handbook" [16]. The values adopted are given in Table 3.

The affect of K_c is weighted by the crop's percentage coverage of the total watershed area. These percentages, along with the symbols used in the program, are given in Table 4 as an average for the 1954-67 time period. The principal crops grown in the basin are wheat, sorghum, corn, beans, pastures and alfalfa. The acreage of these crops were obtained from Kansas State Board of Agriculture Annual Reports [20].

Climatological Data

A watershed simulation package is calibrated by comparing a generated or simulated streamflows to observed streamflows using climatological records as input. The simulation is conducted on a daily basis for a given period of record (at least 10 years). For the Black Vermillion simulation, part of the historic climatological data was stored on magnetic tapes and part was stored on cards.

Table 3. Values of Crop Coefficients, K_c

Month	Wheat	Sorghum	Corn	Beans	Pastures	Alfalfa
January	0.30	----	----	----	----	----
February	0.40	----	----	----	----	----
March	0.60	----	----	----	----	----
April	0.85	----	----	----	0.50	0.55
May	1.10	----	0.15	----	0.65	0.70
June	1.06	0.25	0.45	0.35	0.90	0.90
July	----	0.85	1.00	0.95	0.85	1.00
August	----	1.10	1.00	0.75	0.85	1.00
September	----	0.75	0.85	----	0.90	0.85
October	0.45	0.30	0.60	----	0.55	0.60
November	0.40	----	----	----	----	----
December	0.30	----	----	----	----	----

Table 4. Average Crop Acreage for the
Black Vermillion as a Fraction
of Watershed Area (1954-67)

Crop	Symbol	Fraction of Watershed Area
Wheat	CKW	0.0882
Sorghum	CKSG	0.2346
Corn	CKC	0.0449
Beans	CKSB	0.0281
Pastures	CKP	0.5571
Alfalfa	CKA	0.0471

The magnetic tape record for the Black Vermillion basically consists of 14 one-year records of daily climate and streamflow data. A summary of the magnetic tape data organization is given in Table 5. A record for a given year begins with the Thiessen polygon coefficients, a leap year identifier, and ITHAW and IFREZ for the initiation and termination of evapotranspiration. These constant values are followed by the daily values of the date, streamflow, maximum and minimum temperature and the day's precipitation at each of the precipitation stations. If any of the precipitation stations record more than 0.1 inch on a given day, the hourly rainfall data describing the distribution of the precipitation over the 24 one-hour periods in the day are given. Four weather stations located within or near the watershed boundaries provided the daily precipitation records, while one station, Centralia, provided the daily temperatures for the 1954-67 period. The Frankfort precipitation record was used for the hourly data, while the streamgaging near Frankfort provided the daily streamflow records.

The climatological data on the cards from Topeka consists of daily extraterrestrial solar radiation on a horizontal surface for 40° North latitude, relative humidity at 6 a.m., 12 noon, 6 p.m. and midnight, the percentage of possible sunshine duration and the average wind velocity in miles per hour [21]. The RHD defined previously is the average of the four daily relative humidities. The wind velocities are recorded at a height above ground of 30 feet. These values were corrected to a height of two meters by the formula

$$WVD_{2 \text{ meters}} = WVD_{30 \text{ ft.}} \frac{\log(6.6)}{\log(30)} \quad (25)$$

for use in the ETP equation.

The Topeka data was readily available from the Weather Data Library of the Kansas State University Physics Department [21].

Table 5. Climatological Parameters

Black Vermillion River Climatological Data Base Variables

<u>Variable Identifier</u>	<u>Description</u>	<u>Units</u>
<u>Annual Data</u>		
TOTALM (LK, 8)	Estimated average monthly baseflow	cfs
CK	Thiessen polygon coefficient	
LY	= 1 during leap year = 0 for other years	
ITHAW	Initiates evapotranspiration	
IFREZ	Terminates evapotranspiration	
<u>Daily Data</u>		
	<u>On Tape</u>	
P24 (1)	Date identifier yr-mo-day	
P24 (2)	Daily streamflow (Frankfort)	cfs
P24 (3)	Blank	
P24 (4)	Centralia maximum temperature	°F
P24 (5)	Centralia minimum temperature	°F
P24 (6)	Frankfort daily precipitation	in.
P24 (7)	Blank	
P24 (8)	Centralia daily precipitation	in.
P24 (9)	Axtell daily precipitation	in.
P24 (10)	Marysville daily precipitation	in.
P24 (11)	Blank	
<u>Hourly Data</u>		
	<u>On Tape</u>	
(present only if P24 (6,8, 9 or 10) greater than 0.1 in.)		
PDATE	Date identifier	
P1 (1-24)	Frankfort hourly precipitation fractions	
<u>Daily Data</u>		
	<u>On Cards</u>	
RA	Extraterrestrial solar radiation	mm/day
RHD1	Relative humidity at 6 a.m.	
RHD2	Relative humidity at 12 noon	
RHD3	Relative humidity at 6 p.m.	
RHD4	Relative humidity at midnight	
PSUNS	Percentage of daily possible sunshine	
WVH	Average wind travel per hour	miles/hr

The model was calibrated by selecting the parameters in Table 2 from published ranges of values as in Knapp [8,27]. The model is then run for one or two years in order to get the best fit between calculated and observed discharges. This is a hand calibration procedure which depends very much upon the selection of several parameters which highly influenced the characteristics of the hydrograph. These important parameters are SB1, SM1, FM, AGW and all soil moisture coefficients.

SUMMARY OF RESULTS

The effects of the modification of the evapotranspiration function in the Kansas Water Budget Model are examined by comparing the results of history matching for the Black Vermillion Basin. The annual summary tabulations for the new model and the Smith and Lumb model, respectively, are given in Appendix B. Also in Appendix B is a computer printout of the revised program along with the history matching hydrographs for the year 1964.

Table 6 compares the values of the actual evapotranspiration obtained from the new model and the original Smith and Lumb model. Both the models behaved well with regard to long term evapotranspiration and responded well to soil moisture depletion. This can be judged from the results obtained by the new model for the drought years 1954 to 1956. Though the potential ET increases, the actual ET decreases as the soil moistures declined. Similar such fluctuations were reflected during the rest of the simulation period. Figures 7 and 8 are comparison plots of the computed annual and cumulative annual potential and actual evapotranspirations. The average value of potential evapotranspiration for the 14-year record is 45.1 inches, which corresponds closely to the average value of the free surface shallow lake evaporation of approximately 48 inches for this area. The average annual value of computed actual evapotranspiration, based on crop coefficients and available soil moisture is 26.8 inches. It is somewhat higher, as expected, than the value of 24.21 inches reported by Saxton [22] for Treynor, Iowa.

Figure 9 is a plot of cumulative observed and calculated total and baseflow discharges for the 14-year period. At the end of the simulation period, the new model has yielded 12.8 percent more discharge than the actual

Table 6. Summary of Potential and Actual Evapotranspiration
For the Black Vermillion (1954-67)

	Potential Evapotranspiration (New Model), in.	Basin Annual Precipitation, in.	Actual Evapotranspiration, in.	
			New Model	Smith & Lumb
1954	48.82	26.39	30.5	24
1955	49.69	23.46	27.68	20.1
1956	51.30	18.97	25.70	17.0
1957	47.01	34.08	26.98	23.15
1958	40.85	36.08	24.97	24.50
1959	44.53	41.80	28.45	26.10
1960	41.68	29.73	27.60	24.73
1961	42.33	38.62	27.37	24.60
1962	43.64	34.65	29.50	26.75
1963	48.40	21.91	24.47	22.70
1964	45.89	33.21	26.31	22.60
1965	41.24	36.00	26.23	25.10
1966	44.60	22.52	26.32	22.18
1967	41.30	35.37	24.38	23.82

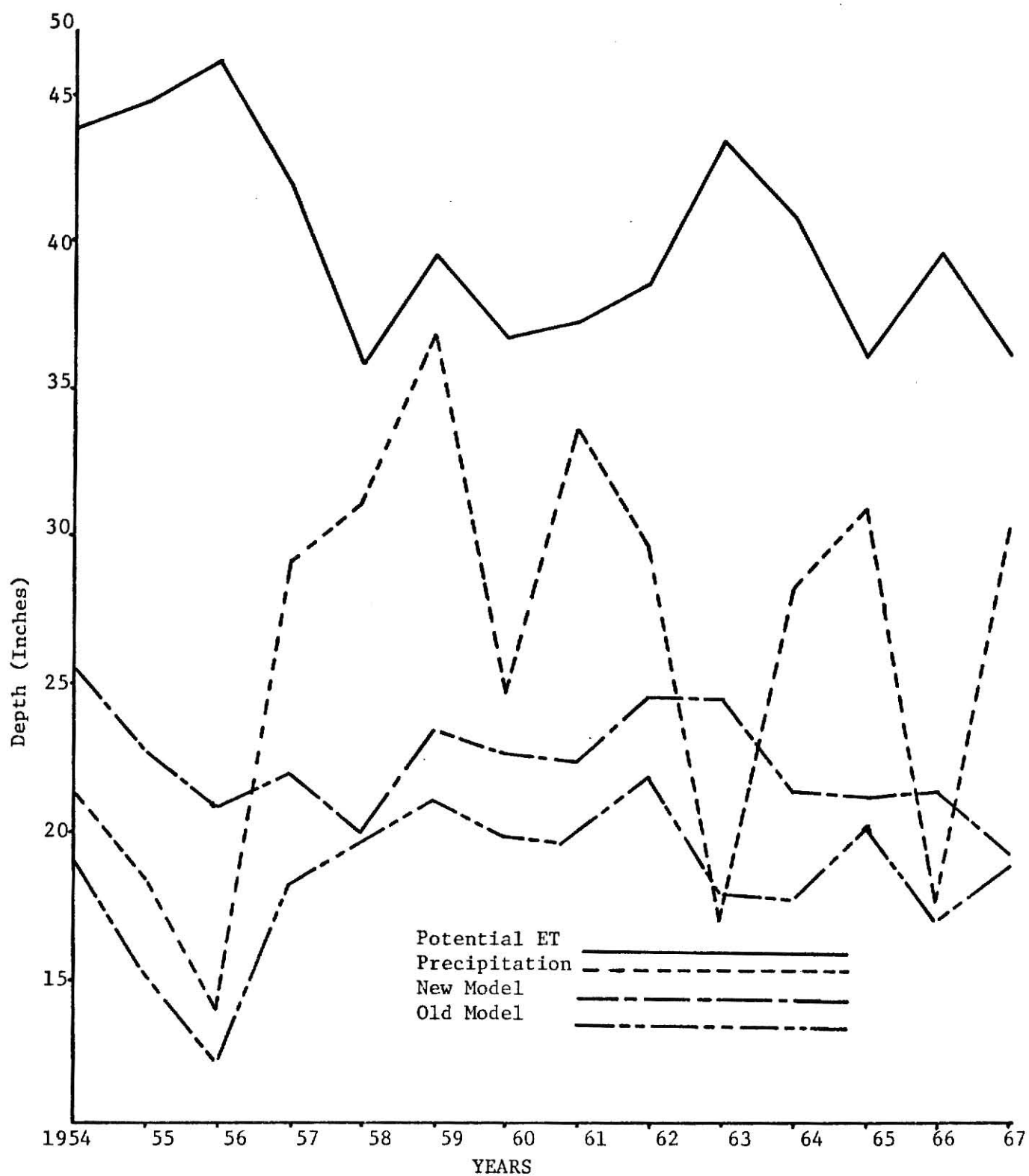


Figure 7. Comparison of Annual Precipitation, Potential Evapotranspiration, and Actual Evapotranspiration.

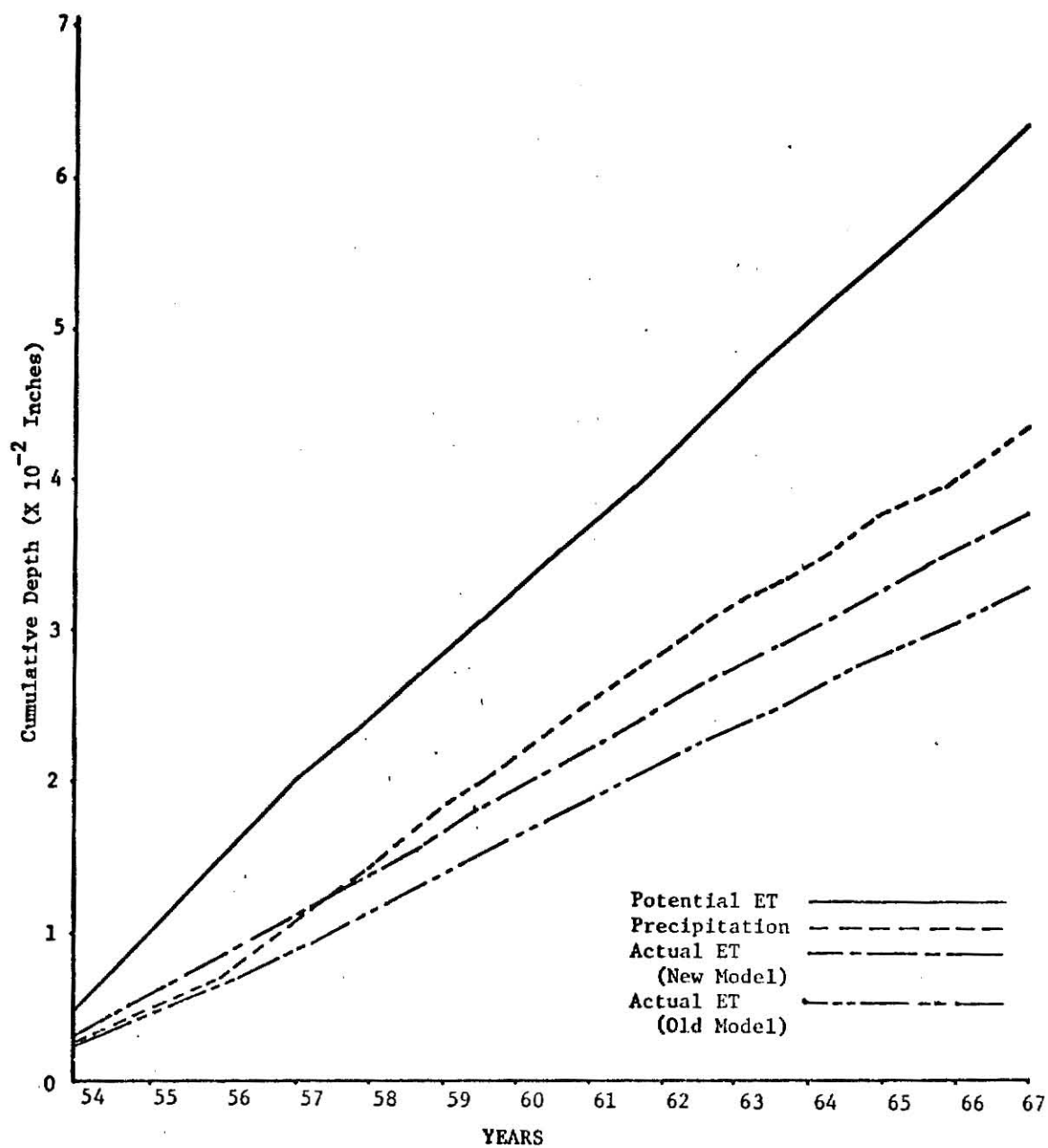


Figure 8. Comparison of Cumulative Precipitation, Potential Evapotranspiration and Actual Evapotranspiration.

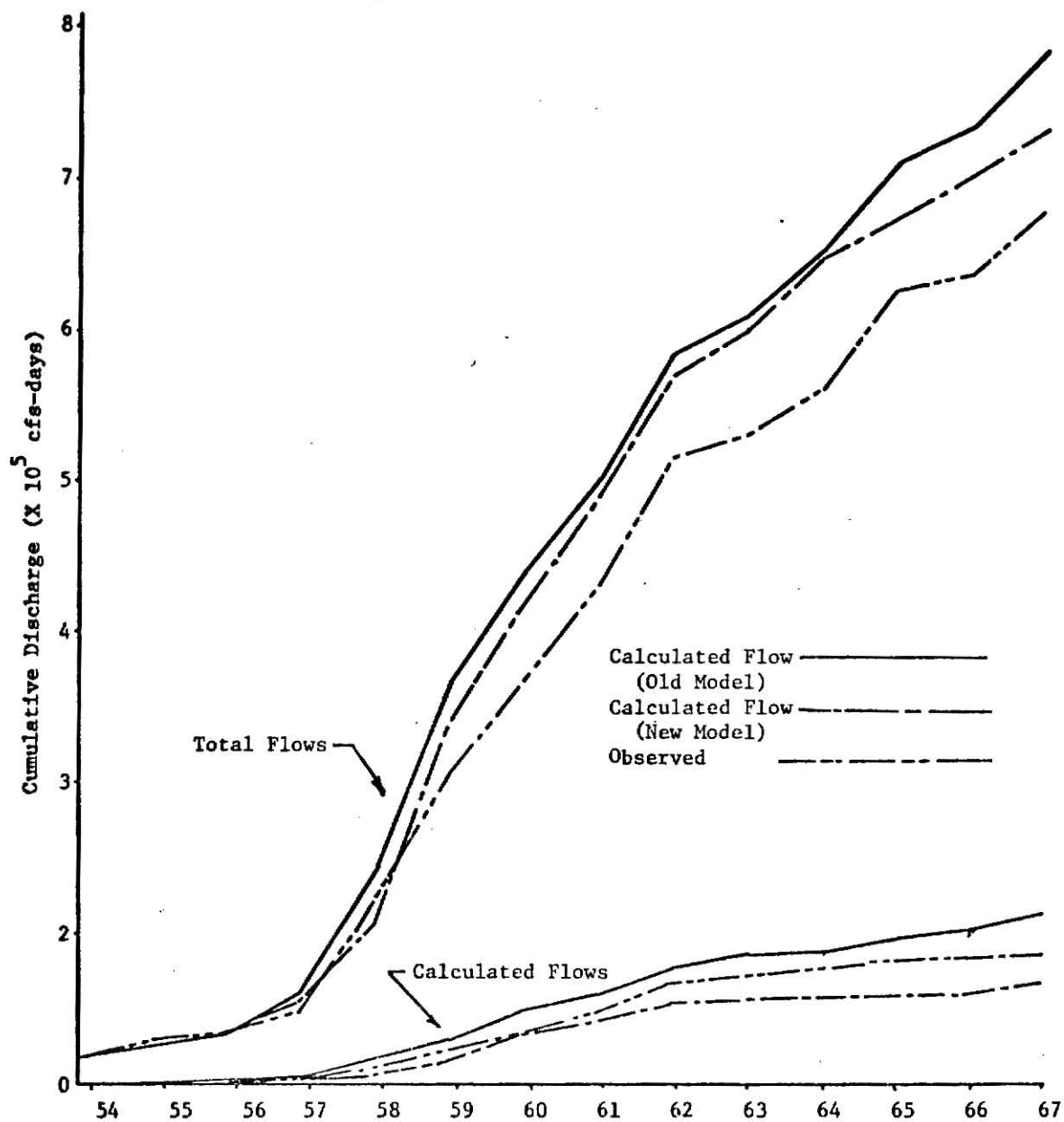


Figure 9. Plot of Cumulated Total and Baseflow Discharges.

basin. The high discharge can be traced to several very high values of interflow particularly during 1959 and 1963. The new model did as well as expected during the adjustment period, particularly 1954 when the response is dominated by the assumed starting conditions. During most of the simulation period the calculated hydrographs and peak runoffs closely matched the observed values. As can be seen from summary tables in Appendix B, both models under computed runoff as a result of winter storms. This is partly due to the fact that the stage-discharge relation at the Frankfort station is affected by ice, but primarily due to the fact that neither model has a snow accumulation or snowmelt function.

The relative performance of the two models is indicated by comparing the correlations of simulated to observed daily flows. This type of correlation indicates the degree to which simulated record follows the daily fluctuations of the observed record. That is, a high correlation coefficient indicates that the predicted flows rise and fall identically with the observed daily flow. Lower correlations result as predicted flows become "out of phase" with the observed flows.

The annual correlation coefficients for the two models are compared in Table 7 and Figure 10. The overall correlations of calculated to observed daily streamflows for the 1954 through 1967 study period were improved from 0.53 to 0.78 with the revised model. The correlations are computed by the formula

$$CCOREL = \frac{(DAC)(DSY)}{\sqrt{(DAC)^2 * (DSY)^2}} \quad (26)$$

where

CCOREL = correlation coefficient,

Table 7. Summary of Annual Correlation
Coefficients for the Black
Vermillion Simulation (1954-67)

Year	New Model	Smith & Lumb
1954	0.882	0.855
1955	0.722	0.149
1956	0.518	0.672
1957	0.811	0.618
1958	0.801	0.754
1959	0.798	0.575
1960	0.77	0.134
1961	0.784	0.484
1962	0.795	0.582
1963	0.833	0.617
1964	0.757	0.506
1965	0.733	0.551
1966	0.832	0.509
1967	0.873	0.498



Figure 10. Comparison of Annual Correlation Coefficients.

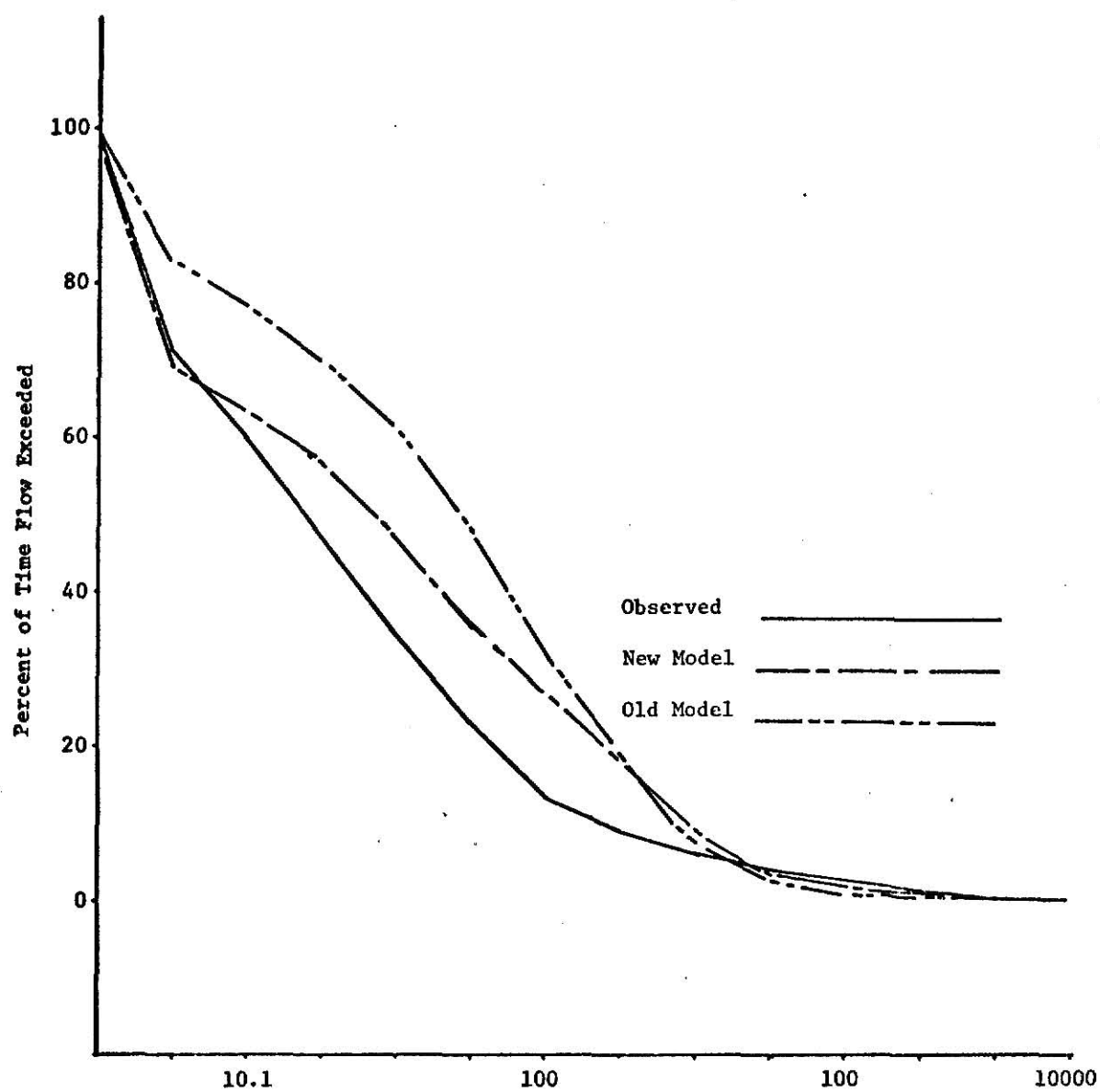


Figure 11. Daily Flow Duration Curves.

DAC = the difference between the daily observed streamflow and the daily average observed streamflow for a month,

DSY = the difference between the daily computed streamflow and the daily average computed streamflow for a month.

Figure 11 shows the various daily flow duration curves. It can be seen that during flows less than 10 cfs and more than 400 cfs, the computed curves closely matched the observed curve. For flows between 10 to 400 cfs the computed flows exceeded observed flows 12 percent for the new model and 20 percent for the Smith and Lumb model. This is again an apparent consequence of high interflows for both models.

The computer simulations were performed using the IBM 370-58 computer at Kansas State University. The cost of simulation is high due to the large quantities of data which must be handled in the processing. The cost of the 14 year simulation of the Smith and Lumb model was \$104 while the new model cost \$110. In view of the cost, not a great deal of time was spent in finely adjusting the parameters for the Black Vermillion, since the primary purpose was for relative comparison. But it is also noted that the new model is not much more expensive than the Smith and Lumb model.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

On the basis of the results obtained from this study, the following conclusions can be drawn.

The correlation coefficients are improved from 0.53 to 0.78 by altering the evapotranspiration function as adopted by the new model. It indicates that the new model is more responsive to the daily climatic changes over the basin and also to the crop patterns in the watershed. Thus, in the determination of actual evapotranspiration, the combined effects of relative humidity, sunshine, wind velocity, solar radiation and the crop patterns apparently improves the fidelity of the Smith and Lumb model.

The effect of the new evapotranspiration function on the digital model of the hydrologic cycle of the watershed was quite obvious. Both the new model and the Smith and Lumb model were tested on Black Vermillion watershed with the same basin input parameters. The new model gave low values of surface runoff as well as baseflow. The behavior could be attributed to the overall high values of actual evapotranspiration computed by the new model. This decreases the soil moisture in upper zone which increases infiltration and results in low runoff. Also more moisture is depleted from lower zone in the form of evapotranspiration, which reduces the recharge to the aquifer and results in lower baseflows in the Smith and Lumb model.

The Smith and Lumb model could be modified to increase evapotranspiration by changing the ET80 value, and both models can be adjusted to provide a better match of the long term runoff values. The primary advantage of the new model is the better response over short time periods, especially in dry periods during the growing season of days or weeks in length. More impor-

tantly, the model can be used as an improved generator of low flow frequency curves, and as a planning tool in the efficient utilization the water resources of an agricultural watershed.

Recommendations for Further Research

The following are recommendations for further research and improvements:

1. This model cannot be called a general one, for it needs to be tested on other watersheds within Kansas for which the climatic input parameters are easily available. This would make the new model more useful and beneficial.
2. The most important function in the model that needs consideration is the evaluation of interflow. It was not touched during this study, as attention was more given to the evapotranspiration function.
3. Both the models under computed runoff from winter storms. A function should be incorporated for the snow and snowmelt relationships during and following winter storms, even though precipitation and baseflows are small during these months. Efforts should be made to add snowmelt functions as pointed by Smith and Lumb and Knapp.

APPENDIX A

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APPENDIX B

1. Documentation of New Model.
2. Annual Summaries for New Model (1954-67).
3. Streamflow Hydrograph for 1964 (New Model).
4. Annual Summaries for Old Model (1954-67).

ILLEGIBLE DOCUMENT

**THE FOLLOWING
DOCUMENT(S) IS OF
POOR LEGIBILITY IN
THE ORIGINAL**

**THIS IS THE BEST
COPY AVAILABLE**


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1  $JNR      NAW,TIME=7,PAGES=300
2  DIMENSION SUSJ(10),RX(9,24)
3  COMMON  TOTAL(13,27),MCNH(15),CKN(20),MATH(12,6),CK(20),UZS(20),
4  1  PLTR(4,31),P2(20),CSF(24),SERP(24),SERAI(24),S(24),
5  2  CASI(24),SQERT(24),AVAR(24),AVER(24),PLI(24),P2(24),
6  3  DEPTH(20),PER(9),SEK(9),ICHR(12),LZST(10),IFL(10)
7  REAL IFM,IIA,LZSA,LZST,LZSN,LZTN,IA,IBI,IMI,LZSN
8  REAL LZSAN,LZSN,LZMX,LZMA,IKR,IFL,LZSTZ
9  REAL PA,PHD1,PHD2,PHD3,PHD4,PSUNS,MWH,ETP,ETA,T,APST
10 REAL TAU,H,ES,ESA,ENT,FTPH,CCKREL,TMAX,TWIN,ETPS
11 REAL LETA,XSU,KCW,KCSG,KCC,KCP,KCA,KCSR,K5
12 REAL KWK,KXSG,KVC,KWSB,KJP,KWA
13 INTEGER LY
14 READ(5,1010)(MCNH(K),K=1,13)
15 1010 FORMAT(13A6)
16 READ(5,1015)(MATH(J,K),K=1,6),J=1,12)
17 1015 FORMAT(12A1)
18 WRITE(6,1012)
19 1012 FORMAT(2H1 )
20 C THE CKN(J) ARRAY IS FOR THE 6-HOUR INCREMENTAL VALUES OF THE UNITGRAPH(1300)
21 READ(5,1009)(CKN(J),J=1,20)
22 1009 FORMAT(10F9.4)
23 READ(5,1008) AI,SBI,A2,SBI,A3,SBI,A4,IMI,A5,UZSN,A6,UHP,A7,UMP,A8,01700
24 1008 FORMAT(15A6,F10.4)
25 WRITE(6,1014)AI,SBI,A2,SBI,A3,IMI,A4,IMI,A5,UZSN,A6,UHP,A7,UMP,A8,02500
26 1014 FORMAT(15A6,F10.4)
27 WRITE(6,1020)AI,LZMX,A11,LZMN,A12,ETRO,A13,CK,A14,YSTRT,A15,IKR,C2600
28 1020 FORMAT(15A6,F10.4)
29 WRITE(6,1021)AI,PGWR,A18,PGMW,A19,GWSN,A20,PK,A21,AGW,A22,PDY,A23,TLL,C2700
30 1021 FORMAT(15A6,F10.4)
31 WRITE(6,1022)AI,LZSAN,A25,LZSTN,A26,AREA,A27,UZSC,A28,LZSO,A29,GWSD,A30,YREND,C2800
32 1022 FORMAT(15A6,F10.4)
33 WRITE(6,1023)AI,GMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100
34 1023 FORMAT(15A6,F10.4)
35 WRITE(6,1024)AI,PMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100
36 1024 FORMAT(15A6,F10.4)
37 WRITE(6,1025)AI,PMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100
38 1025 FORMAT(15A6,F10.4)
39 WRITE(6,1026)AI,PMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100
40 1026 FORMAT(15A6,F10.4)
41 WRITE(6,1027)AI,PMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100
42 1027 FORMAT(15A6,F10.4)
43 WRITE(6,1028)AI,PMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100
44 1028 FORMAT(15A6,F10.4)
45 WRITE(6,1029)AI,PMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100
46 1029 FORMAT(15A6,F10.4)
47 WRITE(6,1030)AI,PMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100
48 1030 FORMAT(15A6,F10.4)
49 WRITE(6,1031)AI,PMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100
50 1031 FORMAT(15A6,F10.4)

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EXTENSION LIMIT OF 5 CONTINUATION CARDS EXCEEDED

EXTENSION LIMIT OF 5 CONTINUATION CARDS EXCEEDED

1014 FORMAT(15A6,F10.4)

C CALCULATION OF CONSTANTS AND SETTING INITIAL VALUES

1015 FORMAT(12A1)

WRITE(6,1012)

1012 FORMAT(2H1)

C THE CKN(J) ARRAY IS FOR THE 6-HOUR INCREMENTAL VALUES OF THE UNITGRAPH(1300)

READ(5,1009)(CKN(J),J=1,20)

1009 FORMAT(10F9.4)

READ(5,1008) AI,SBI,A2,SBI,A3,SBI,A4,IMI,A5,UZSN,A6,UHP,A7,UMP,A8,01700

1008 FORMAT(15A6,F10.4)

WRITE(6,1014)AI,SBI,A2,SBI,A3,IMI,A4,IMI,A5,UZSN,A6,UHP,A7,UMP,A8,02500

1014 FORMAT(15A6,F10.4)

WRITE(6,1020)AI,LZMX,A11,LZMN,A12,ETRO,A13,CK,A14,YSTRT,A15,IKR,C2600

1020 FORMAT(15A6,F10.4)

WRITE(6,1021)AI,PGWR,A18,PGMW,A19,GWSN,A20,PK,A21,AGW,A22,PDY,A23,TLL,C2700

1021 FORMAT(15A6,F10.4)

WRITE(6,1022)AI,LZSAN,A25,LZSTN,A26,AREA,A27,UZSC,A28,LZSO,A29,GWSD,A30,YREND,C2800

1022 FORMAT(15A6,F10.4)

WRITE(6,1023)AI,GMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100

1023 FORMAT(15A6,F10.4)

WRITE(6,1024)AI,GMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100

1024 FORMAT(15A6,F10.4)

WRITE(6,1025)AI,GMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100

1025 FORMAT(15A6,F10.4)

WRITE(6,1026)AI,GMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100

1026 FORMAT(15A6,F10.4)

WRITE(6,1027)AI,GMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100

1027 FORMAT(15A6,F10.4)

WRITE(6,1028)AI,GMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100

1028 FORMAT(15A6,F10.4)

WRITE(6,1029)AI,GMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100

1029 FORMAT(15A6,F10.4)

WRITE(6,1030)AI,GMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100

1030 FORMAT(15A6,F10.4)

WRITE(6,1031)AI,GMRF,A32,PMRF,A33,IIA,A34,GWMN,A35,PTPOND,A36,ETP,A37,FM,A38,02100

1031 FORMAT(15A6,F10.4)

```

41 CET80U=ET80U**{(1.0-CX)
42 CFT80L=ET80L**{(1.0-CX)
43 WFI=ARFAY*{(-ALOS(IKR))
44 PER=(1.0-AGW)
45 L77TN=L77STN
46 FC=PEP/IL2MX**POWER-LZZTN**POWER)
47 (LPR=PER-ECT*(LZMX**POWER)
48 QIF=(LZMX-LZZTN)/10.
49 FB=A2*IX*AGW*(-ALOG(RK))
50 AF=L.0/(A=EA*AGW)
51 FCT2=C.97/(1.12.**POWER)
52 FCT22=(1.03)/(1.0010.-132.)
53 DO 3 L=6,LL
54 3 UZSL(J)=UZSO
55 DO 111 K=1,10
56 111 LZST(K)=LZSC
57 TAU=L.17E-07
58 L7SA=LZSC
59 GAS=GASO
60 DO 20 L=6,LL
61 20 DEPTH(L)=0.0
62 DO 309 K=1,7
63 309 PR2(K)=0.0
64 DO 903 J=1,24
65 CSEL(J)=0.0
66 CAS(J)=0.0
67 SFRS(J)=0.0
68 SERA(J)=0.0
69 S(J)=0.0
70 903 SQEP(J)=0.0
71 DO 919 L JIG=1,6
72 919 SUSU(JIG)=0.0
73 RAL=0.0
74 AIA=0.0
75 SEN=0.0
76 SSETHF=0.0
77 NV=0
78 CHZS=0.0
79 CLZS=0.0
80 TIME=C.0
81 P=0.20
82 RTCL=0.40
83 RTC2=0.60
84 C BEGIN YEARLY LOOP
85 DO 595 ANN=ASTRT,NENC
86 DO 901 KK=1,13
87 DO 901 K=1,27
88 901 TOTALM(KK,K)=0.0
89 AATA=0.0
90 EPV=0.0
91 YSDTD=0.0
92 YSDACQ=0.0
93 YSDSYN=0.0
94 READ(1,4444) (TOTALM(LK,8),LK=1,12)
95 WRITE(6,4444) (TOTALM(LK,8),LK=1,12)
96 4444 FORMAT(12F6.1)
97 C CK(J)=THIESSEN COEFFICIENTS
98 READ(1,220) (CK(J),J=6,LL),LY
99 220 FORMAT(7F10.4,8X,12)
100 DO 60 J=6,LL

```

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05200
05300
05400
05500
05600
05700
05800
05900
06000
06100
06200
06300
06400
06500

06900
07000
07100
07200
07300
07400
07500
07600
07700
07800
07900
08000
08100
08200
08300
08400
08500
08600

08700
08800
08900

09100
09200
09300
09400
09500
09600
09700

09900
10000
10100

```



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149 C CROP COEFFICIENTS FOR SOYBEANS
150 IF(NN.EQ.1.OR.NN.EQ.2.OR.NN.EQ.3.OR.NN.EQ.4.OR.NN.EQ.5) KCSR=0.0
151 IF(NN.EQ.9.OR.NN.EQ.10.OR.NN.EQ.11.OR.NN.EQ.12) KCSR=0.0
152 IF(NN.EQ.6) KCSR=0.35
153 IF(NN.EQ.7) KCSR=C.95
154 IF(NN.EQ.8) KCSR=0.75
155 C CROP COEFFICIENTS FOR PASTURES
156 IF(NN.EQ.1.OR.NN.EQ.2.OP.NN.EQ.3.OR.NN.EQ.11.OR.NN.EQ.12) KCP=0.0
157 IF(NN.EQ.4) KCP=0.50
158 IF(NN.EQ.5) KCP=C.65
159 IF(NN.EQ.6) KCP=0.90
160 IF(NN.EQ.7) KCP=C.85
161 IF(NN.EQ.9) KCP=0.85
162 IF(NN.EQ.10) KCP=0.90
163 IF(NN.EQ.11) KCP=C.55
164 C CROP COEFFICIENTS FOR ALFALFA
165 IF(NN.EQ.1.OR.NN.EQ.2.OP.NN.EQ.3.OR.NN.EQ.11.OR.NN.EQ.12) KCA=0.0
166 IF(NN.EQ.4) KCA=0.55
167 IF(NN.EQ.5) KCA=0.70
168 IF(NN.EQ.6) KCA=C.90
169 IF(NN.EQ.7) KCA=1.00
170 IF(NN.EQ.8) KCA=1.00
171 IF(NN.EQ.9) KCA=0.85
172 IF(NN.EQ.10) KCA=0.60
173 TOTALM(NN,8)=TOTALM(NN,8)
174 NDC2=NTD1+ICV-1
175 XICV=10V
176 XISV=1.07XIDY
177 SDIB=0.0
178 SDAC=0.0
179 SOSV=0.0
180 NCZ=0.0
181 C RGIN DAILY LOOP
182 DO 777 N=NTD1,NTD2
183 READ(5,50) RA,RHE1,RHD2,RHD3,RHD4,PSUNS,WVH
184 50 FORMAT(12X,F6.2)
185 READ(1,21)(P24(J),J=1,LL)
186 21 FORMAT(2X,F7.0,4X,F6.1,3X,F2.0,2X,F4.0,1X,F4.0,9(1X,F4.2))
187 DO 1111 J=C,LL
188 1111 IF(P24(J).GT.PDY) GO TO 1112
189 *EXTENSION* OTHER COMPILEPS MAY NOT ALLOW THIS STATEMENT TO END A DO-LOOP
190 GO TO 4265
191 1112 PEAC(1,607) PEATE,(PI(J),J=1,24)
192 607 FORMAT(1X,F7.0,2X,F3.2)
193 TIME=1
194 4269 NCZ=NCZ+1
195 TIME=TIME+1
196 NV=NV+1
197 DO 622 K=1,6
198 RPR(K)=RPR(K+1)
199 622 SPX(K)=0.0
200 613 TPERC=C.0
201 AUZS=0.0
202 TPA=0.0
203 C CALCULATION OF POTENTIAL EVAPOTRANSPIRATION BY MAEKES OF PENMAN
204 C COMBINATION EQUATION.
205 T=(P24(3)+P24(4)+P24(5))/2
206 IF(T.LT.0.0) T=0.0
207 CENT=1.33*(T-32)/180
208 ABST=CENT*273.16

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12100
12200
12300
12400
12500
12600
12700
12800
12900
13000

13100
13200
13300
13400
13500
13600

14200
14300
14400
14500
14700
14800

202	PE=ITAU*ABST**4)/58.1	15500
203	AE=(1-R)*RA*10.22*0.54*PSUNS1	15700
204	DE=10.953**((IARST-273.16)/ABST)-5.31*ALOG10(IARST/273.16)	15900
205	BE=10**DE	15900
206	ES=6.105**E	15900
207	ES=9.7507**ES	16000
208	RHC=(PHCI+RFD2+RHC3+RHC4)/4	16100
209	ESA=ES*RHC	16200
210	RB=PE*(0.40-0.047*SORT(ESA))*(0.1+0.9*PSUNS)	16300
211	PN=AL-PA	16400
212	DELTA=C-C39*I**0.673	16500
213	GUP=L-DELTA	16600
214	MVD=MVH*24	16800
215	MVD=MVD*(ALCG10(6.6)/ALOG10(30.))	16900
216	EA=0.36*(1.0+0.01*MVC)*(ES-ESA)	17000
217	EE=(DELTA**3N)*(GUP**EA)	17000
218	IF(EE.LT.0.0) EE=0.0	17100
219	ETP=EE/25.35958	17200
220	ETPS=ETP*(PCNDAR/(640*APEA))	17400
221	FIFSH=ETPS/24	17500
222	ON 623 L=6.11	17600
223	M=L-5	17700
224	IX(M,12)=0.0	17800
225	IF(P24(L).GT.PDV) GO TO 615	17900
226	TPA=TPA+P24(L)*CK(L)	17900
227	RAN=P24(L)	17900
228	IF(P24(L).LE.0.0) GO TO 22	17900
229	IA=IRI-IMI*UZS(L)	17900
230	IF(UZS(L).LT.UOZS) IA=B-C*UZS(L)	17900
231	IF(IA.LT.IIA) IA=IIA	17900
232	DIFF=IA-DEPTH(L)	17900
233	IF(DEPTH(L).GE.IA) DIFF=0.0	17900
234	IF(DIFF.GE.P24(L)) GO TO 23	17900
235	DEPTH(L)=DEPTH(L)+DIFF	17900
236	P24(L)=P24(L)-DIFF	17900
237	GO TO 22	17900
238	DEPTH(L)=DEPTH(L)+P24(L)	17900
239	P24(L)=0.0	17900
240	DEPTH(L)=DEPTH(L)-FTPS	17900
241	IF(DEPTH(L).LE.-C-C) DEPTH(L)=0.0	17900
242	IF(P24(L).LE.F4) GO TO 726	17900
243	SNA=SEL-SMI*UZS(L)	17900
244	IF(SNA.LT.0.0) SNN=0.0	17900
245	RX(M,12)=(P24(L)*P24(L))/(P24(L)+SNN)	17900
246	IF(P24(L)-RX(M,12)).LT.FM) PX(M,12)=P24(L)-FM	17900
247	SFX(12)=SPX(12)+RX(M,12)*CK(L)	17900
248	PERC=0.0	17900
249	ALIA=ALIA*(FAN-P24(L))*CK(L)	17900
250	EXCESS=UZS(L)-UZSN	17900
251	ON 873 K=1.10	17900
252	IF(EXCESS=PERC)B76,B76,B73	17900
253	PERC=PERC+UPP*(EXCESS=PERC)/(UZMX-UZSN)**0.67P/10.	17900
254	UZS(L)=UZS(L)+P24(L)-RX(M,12)-PERC	17900
255	TPERC=TPERC+PERC*CK(L)	17900
256	GO TO 729	17900
257	K99=0	17900
258	IF(M.LF.7) K99=0	17900
259	ON 728 J=1.24	17900
260	K9=J**99	17900
261	PI2=PI1K6)*P24(L)	17900

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262 TPA=TPA+PI2*CK(L)
263 RAN=PI2
264 IF(P12.LE.0.0) GO TO 5
265 IA=101-1M1*UZS(L)
266 IF(UZS(L).LT.0) IA=9-C*UZS(L)
267 IF(IA.LT.1) IA=11A
268 NIFF=IA-DEPTH(L)
269 IF(DEPTH(L).GE.1A) DIFF=0.0
270 IF(OTEE.GT.PI2) GO TO 6
271 DEPTH(L)=DEPTH(L)+DIFF
272 PI2=PI2-DIFF
273 GO TO 5
274 6 DEPTH(L)=DEPTH(L)+PI2
275 PI2=0.0
276 DEPTH(L)=DEPTH(L)-FTPSH
277 IF(DEPTH(L).LE.0.0) DEPTH(L)=0.0
278 RX(M,J)=0.0
279 IF(P12.LE.FM) GO TO 17
280 SNN=SRI-SM1*UZS(L)
281 IF(SNN.LT.0.0) SPN=0.0
282 PX(M,J)=(PI2*PI2)/(PI2+SNN)
283 IF(P12-RX(M,J).LT.FM) RX(M,J)=PI2-FM
284 IF(RX(M,J).LE.0.0) RX(M,J)=0.0
285 I=(J+51)/6
286 SRX(I)=SRX(I)+RX(M,J)*CK(L)
287 17 PERC=0.0
288 AATA=AATA+IPAN-PI2)*CK(L)
289 EXCESS=UZS(L)-UZSN
290 IF(EXCESS.GT.0.0) PERC=EXCESS/UELT)*WUMP/24.
291 UZS(L)=UZS(L)+PI2-RX(M,J)-PERC
292 IF(UZS(L)-UZMX) 3C,3C,40
293 4C FX(M,J)=RX(M,J)+UZS(L)-UZMX
294 I=(J+51)/6
295 SRX(I)=SRX(I)+(UZS(L)-UZMX)*CK(L)
296 UZS(L)=UZMX
297 30 TPERC=TPERC+PERC*CK(L)
298 728 CONTINUE
299 UZS(L)=UZS(L)-CUZS
300 IF(UZS(L).LT.0.0) UZS(L)=0.0
301 AUZS=AUZS+UZS(L)*CK(L)
302 623 CONTINUE
303 IF(AUZS.LE.UZMN) AUZS=0.0
304 A7=SRX(I)+SPX(21)+SRX(3)+SRX(4)
C ROUTING
305 IF(A7)83,83,84
306 84 DO 85 K=1,4
307 IF(SRX(K)) 85,85,87
308 87 DO 89 L=1,20
309 J=(K+L*2)/4
310 89 PPR(J)=PPR(J)+SRX(K)*CKN(L)
311 85 CONTINUE
C DETERMINATION OF ET POTENTIAL RELAZED
312 93 IF(N.GT.ITHAW-AND.N.LT.(ITHAW+25)) GO TO 207
313 IF(N.GE.(ITHAW+25).AND.N.LT.IFREZ) FRAC=1.0
314 IF(N.LE.ITHAW-OR.N.GE.IFREZ) FRAC=0.0
315 GO TO 206
316 207 XN=ITHAW
317 FRAC= X/25.0
318 206 CONTINUE
319 C INTERFLOW CALCULATIONS

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319 LZSTZ=LZSTN
320 IFW=0.0
321 PRT1=0.0
322 DO 100 K=1,10
323   IFL(K)=0.0
324   LZSTZ=LZSTZ+DIF
325   PRTZ=UPR+FCF*(LZSTZ**POWER)
326   PRT=PRT2-PRT1
327   EXCESS=LZST(K)-LZSTN
328   EXCESS=LZST(K)-LZSTZ+DIF
329   IF(EXCESS.GT.0.0.AND.LZST(K).GT.LZSTZ-DIF) IFL(K)=EXCESS*WFI
330   IFW=IFW+IFL(K)*PRT
331   IFL(K)=IFL(K)/AREAX
332   LZST(K)=LZST(K)+TPERC-IFL(K)-CLZS
333   IF(LZST(K).LT.0.0) LZST(K)=0.0
334   ALZST=LZST(K)
335   100 PRT1=PRT2
336   IF(ALZST.LE.LZMN) ALZST=0.0
337   C RECHARGE CALCULATIONS(NEXT 3 CARDS)
338   RECGW=0.0
339   EXCESS=LZSA-LZSAN
340   IF(EXCESS.LE.0.0) EXCESS=0.0
341   IF(EXCESS.GT.0.0) RECGW=RECGW*(EXCESS/DELTL)**RCGMM
342   LZSA=LZSA+TPERC-RECGW-CLZS
343   IF(LZSA.LT.0.0) LZSA=0.0
344   ALZSA=LZSA
345   IF(ALZSA.LE.LZMN) ALZSA=0.0
346   AVISM=AUZS+ALZST+ALZSA
347   FCSN=UZZX+LZMX+LZMX
348   PSM=AVISM/FCSN
349   C COEFFICIENT RELATED TO AVAILABLE SOIL MOISTURE
350   KS=LALG(PSM*.0)/ALCG(101.)
351   IF(KS.GT.1.0) KS=1.0
352   IF(KS.LT.0.0) KS=0.0
353   C COEFFICIENT WHEN SOIL SURFACE IS WETTED BY RAINFALL
354   KWS=(1-(KCSG*KS))*(2.72**(-(0.3*TIME)))
355   KWS=(1-(KCSG*KS))*(2.72**(-(0.3*TIME)))
356   KWS=(1-(KCSG*KS))*(2.72**(-(0.3*TIME)))
357   KWS=(1-(KCSG*KS))*(2.72**(-(0.3*TIME)))
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370   KWS=(1-(KCSG*KS))*(2.72**(-(0.3*TIME)))
371   KWS=(1-(KCSG*KS))*(2.72**(-(0.3*TIME)))

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372 LETA=RTD2*EYA*FRAC
373 CUZS=LETA
374 CLZS=LETA
375 ETA=ETPS*UFTA+LETA
C POND ROUTINE
376 PR=RR*(11)*AREAX
377 ETTT=(ETP*PCNDAR)/12
378 CFSIN=C.O
379 CFSOUT=0.0
380 CFSIN=PR+IFWTPA*PCNDAR*26.9/640.0
381 IF(CFSIN-LE.O.O) GO TO 333
382 CFSIN=CFSIN-PCND
383 CFSOUT=CFSIN-CFSIN
384 ACFT=CFSIN/0.5042
385 FREEVL=PCNDVL-STORGE
386 IF(FREEVL.GT.ACFT) GO TO 222
387 IF(FREEVL.LE.O.O) FREEVL=0.0
388 STORGE=STORGE+FREEVL
389 CFSIN=ACFT-FREEVL
390 GO TO 333
391 222 STORGE=STORGE+CFSIN
392 CFSIN=0.0
393 STORGE=STORGE-ETTT
394 IF(STORGE.LT.O.O) STORGE=0.0
395 OUTFLC=0.5042*CFSIN+CFSOUT
396 EPT=EPV*(CFSO-OUTFLC)/AREAX
397 IF(OUTFLC) 79,79,81
398 79 RR=0.0
399 IFW=0.0
400 GO TO 82
401 81 IFW=IFW*(OUTFLC/CFSO)
402 PR=PR*(OUTFLC/CFSO)
C STREAMFLOW-GROUNDWATER INTERACTION
C THE STATEMENTS THROUGH 784 REPRESENT A LINEAR APPROXIMATION OF
C THE STAGE DISCHARGE RELATIONSHIP. THEY MUST BE CHANGED FOR EACH NEW
C BASIN TO WHICH THE MODEL IS APPLIED.
82 Q=PR+IFW
STG=0.0
403 IF(LQ.LT.3400) STG=0.251*Q**0.539
404 IF(LQ.GE.3400) STG=3.72*Q**0.207
784 EXCESS=Q-S-GWSN
407 IF(EXCESS.LT.O.O) EXCESS=0.0
408 GIGI=STG-PORF*EXCESS-1.500
409 IF(GIGI.LT.O.O) GO TO 785
410 GRREC=GWSF*STG*GIGI
411 HF=0.0
412 GO TO 786
413 785 HF=EXCESS*FB
414 GRREC=0.0
415 786 RFIN=RF*AF
416 GWSIN=GWSF*STG*AF
417 C RUDGET EQUATIONS
418 IF(RR.LT.GWREC) GO TO 751
419 RR=RR-GWREC
420 RCRF=RR+IFW+BF
421 GO TO 753
422 751 IF(RR+IFW.LT.GWREC) GO TO 752
423 IFW=RR+IFW-GWREC
424 RF=0.0
425 ROBF=IFW+BF

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425 GO TO 753
427 752 GWRIN=(GR+IFW)*AF
428 FR=0.0
429 IFW=0.0
430 RORF=0.0
431 753 CONTINUE
432 IF(RORF.LE.0.0) GO TO 41
433 RORF1=RORF
434 IF(RORF) 29,29,31
435 29 RF=0.0
436 RF=0.0
437 IFW=0.0
438 GO TO 41
439 31 PRERF*(RCBF/RORF1)
440 IFW=IFW*(RCBF/RORF1)
441 PRERF*(RCBF/RORF1)
442 41 CC=TT/UF
443 GWS=GWS+RECG*GWRIN-RFIN
444 PLTR(1,NCZ)=RF
445 PLTP(2,NCZ)=IFW+RF
446 IF(PLTR(2,NCZ).GT.RORF) PLTR(2,NCZ)=RORF
447 PLTR(3,NCZ)=P24(2)
448 PLTR(4,NCZ)=RORF
449 C MONTHLY TOTALS
450 TOTAL(MNN,1)=TOTAL(MNN,1)+TPA
451 TOTAL(MNN,2)=TOTAL(MNN,2)+RORF
452 TOTAL(MNN,3)=TOTAL(MNN,3)+P24(2)
453 TOTAL(MNN,4)=TOTAL(MNN,4)+PR
454 TOTAL(MNN,5)=TOTAL(MNN,5)+P24(2)
455 TOTAL(MNN,6)=TOTAL(MNN,6)+IFW
456 TOTAL(MNN,7)=TOTAL(MNN,7)+RF
457 TOTAL(MNN,8)=TOTAL(MNN,8)+FTP
458 TOTAL(MNN,10)=TOTAL(MNN,10)+UETA
459 TOTAL(MNN,11)=TOTAL(MNN,11)+LETA
460 TOTAL(MNN,12)=TOTAL(MNN,12)+ETA
461 TOTAL(MNN,13)=TOTAL(MNN,13)+TPCK
462 TOTAL(MNN,14)=TOTAL(MNN,14)+T*IDY
463 C CORRELATION COEFFICIENT CALCULATIONS
464 AC=TOTAL(MNN,3)*TIDY
465 SYR=TOTAL(MNN,2)*TIDY
466 QAC=PLTR(3,NCZ)-ACM
467 DSY=PLTP(4,NCZ)-SYM
468 SDTO=SDTO+DAC*DSY
469 SDACQ=SDACQ+DAC*QAC
470 SDSYQ=SDSYQ+DSY*ESY
471 IF(SDACQ.LE.0.0) CR=SDSYQ/LE.0.0) GO TO 112
472 CCUREL=SDTO/SDRT(SDACQ*SDSYQ)
473 GO TO 113
474 112 CCUREL=0.0
475 113 TOTAL(MNN,15)=TOTAL(MNN,15)+CCUREL*TIDY
476 C FLCH DURATION CALCULATIONS
477 IF(MV-1.83) 777,777,108
478 108 ERR=RCBF-P24(2)
479 IF(P24(2).LT.1.0) IND=1.0
480 IF(P24(2).GE.1.0) IND=4.0-4*LOG10(P24(2))+2.0
481 CAS(IND)=CAS(IND)+1.0
482 IF(RORF.LT.1.0) ICN=1.0
483 IF(PORF.GE.1.0) ICN=4.0-4*LOG10(RORF)+2.0
484 CSE(IND)=CSE(IND)+1.0
485 SERR(IND)=SERR(IND)+ERR

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SERIAL(IND)=SERIAL(INC)+ABS(ERR)
SQER(IND)=SQER(INC)+ERR*ERR
AVER(IND)=SERIAL(INC)/CAS(IND)
AVAR(IND)=SERIAL(INC)/CAS(IND)
S(IND)=0.0
IF(CAS(IND).GT.1.0) S(IND)=SQRT((SQER(IND)-SERIAL(IND)**2/CAS(IND))/41800)
1(CAS(IND)-1.0))
777 CONTINUE
TOTALM(NN,5)=TOTALM(NN,5)-TOTALM(NN,8)
IF(TOTALM(NN,5).LT.0.0) TOTALM(NN,5)=0.0
C YEARLY TOTALS
DY=10Y
VL=LV+365
ON 806 K=1,8
806 TOTALM(13,K)=TOTALM(13,K)+TOTALM(NN,K)
DO 104 K=9,13
104 TOTALM(13,K)=TOTALM(13,K)+TOTALM(NN,K)
TOTALM(13,14)=TOTALM(13,14)+TOTALM(NN,14)*DY/VL
TOTALM(13,15)=TOTALM(13,15)+TOTALM(NN,15)*DY/VL
WRITE(6,1444) TOTALM(NN,15)
1444 FORMAT(5F13.4,2X)
501 IF(ZZT.LF.0.0) GO TO 868
502 CALL PLCT(10Y,PLTR,NN,MYTH)
503 CALL ZPT(NTD2+1)
504 C YEARLY OUTPUT
WRITE(6,1012)
WRITE(6,1013) NN
1013 FORMAT(13X,5HSUMMARY TABLE -- BLACK VERMILLION RIVER BASIN --
1,12/34X,5H)
WRITE(6,1002)
1002 FORMAT(1/13X,JAN. FEB. MAR. APR. MAY. TOTAL)
1 JUL. AUG. SEP. OCT. NOV. JUN.
WRITE(6,1003) ((TOTALM(J,K),J=1,13),K=1,15)
1003 FORMAT(9H PRECIP,13F9.2//17H CALCULATED TOTAL/9H RUNOFF,13F9.0//19H CALCULATED SURFACE/9H46300
1//15H OBSERVED TOTAL/9H RUNOFF,13F9.0//19H CALCULATED SURFACE/9H46300
2 RUNOFF,13F9.0//17H OBSERVED SURFACE/9H RUNOFF,13F9.0//18H CAL46400
3 CULATED INTER-/9H FLOW,13F9.0//11H CALCULATED/9H BASEFLOW,13F9.46500
4.0//9H OBSERVED/9H BASEFLOW,13F9.0//9H ETP,13F9.3//9H UE46600
5TA,13F9.3//9H LETA,13F9.3//9H ETA,13F9.3//6H PER-/9H
6COLLATION,13F9.3//9H TEMP.,13F9.1//18H CORRELATION COEFF-/9H FIC
7TEMPIS,13F9.3)
BALANCE=TOTALM(13,1)-TOTALM(13,2)/AREA*-TOTALM(13,12)
V=BALANCE-AAIA-EPY
WRITE(6,1006) BALANCE,AAIA,EPY,V
1006 FORMAT(1//19H DELTA STORAGE =,F10.3,8H INCHES/18H AAIA =
1 ,F10.3/18H PCMD STORAGE =,F10.3/28H-----
2-----/18H TOTAL CHANGE =,F10.3//)
SEW=SEW+EPY
BAL=BAL + BALANCE
AAIA=AAIA+AAIA
LDY=365+LY
SUSU(1)=SUSU(1)+TOTALM(13,2)
SUSU(2)=SUSU(2)+TOTALM(13,3)
SUSU(3)=SUSU(3)+TOTALM(13,4)+TOTALM(13,6)
SUSU(4)=SUSU(4)+TOTALM(13,5)
SUSU(5)=SUSU(5)+TOTALM(13,7)
SUSU(6)=SUSU(6)+TOTALM(13,8)
WRITE(6,15) SUSU(1),SUSU(2),SUSU(3),SUSU(4),SUSU(5),SUSU(6)
15 FORMAT(17X8,17HSUM CAL TOTAL =,F15.0/4X,17HSUM OBS TOTAL =,F15.8900
1-0.0/4X,17HSUM CAL SRINT =,F15.0/4X,15HSUM OBS SR =,F15.0/4X,14H49000
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528 2SUM,CAL,BF = ,F15.0/4X,14MSUM,CMS,BF = ,F15.0/()
529 999 CONTINUE
530 WRITE(4,1012)
531 C CALCULATIONS AND OUTPUT OF FLOW DURATION
532 WRITE(6,1015)
533 1019 FORMAT(11X,///41X,35HCAILY FLOW DURATION AND ERROR TABLE //11X,93HF49600
534 FLOW INTERVAL ACT.CASES PCT. CALC.CASES PCT. AVE.ERROR
535 2 AV.AES.FAROR STD.ERROR /)
536 SSTER=0.0
537 SSFRA=0.0
538 SSERR=0.0
539 SCASF=0.0
540 SCSC=0.0
541 DO 911 J=1,24
542 SCASF=SCASF+CAS(J)
543 SCSC=SCSC+SCSE(J)
544 SSERR=SSERR+SEPR(J)
545 SSFRA=SSFRA+SEPA(J)
546 911 SSTER=STER+S(J)
547 SCLS=SCASE
548 SCSE=SCSC
549 DO 912 J=1,24
550 IF(J.GT.2) GO TO 512
551 IF(J.EQ.1) FLOD=0.0
552 IF(J.EQ.2) FLOD=1.0
553 GO TO 913
554 912 FJ=J
555 PCWR=FJ/4.0-0.5
556 FLOD=1.0-PCWR
557 913 IF(SCASE.LE.0.0) GO TO 1447
558 PSCLS=100.0*SCLS/SCASE
559 GO TO 1448
560 1447 PSCLS=0.0
561 1448 CLS=CAS(J)
562 SCLS=SCLS+CLS
563 IF(SCSC.LE.0.0) GO TO 1449
564 PSCSE=100.0*SCSE/SCSC
565 GO TO 1450
566 1449 PSCSE=0.0
567 1450 SCL=SCSE(J)
568 SCSE=SCSE+SCL
569 IF(CLS.EQ.0.0) GO TO 980
570 SERACS=SERACS(J)/CLS
571 SERPCS=SERPCS(J)/CLS
572 IF(CLS.EQ.1.0) WRITE(6,1018)FLOC,CLS,PSCLS,SCL,PSCSE,SERACS
573 IF(CLS.GT.1.0) WRITE(6,1018)FLOC,CLS,PSCLS,SCL,PSCSE,SERPCS
574 1.5(J)
575 1018 FORMAT(12X,F10.1,1H-,F9.1,F11.3,F10.1,F11.3,F12.1,2F13.2)
576 GO TO 911
577 980 WRITE(6,1018) FLOC,CLS,PSCLS,SCL,PSCSE
578 981 CONTINUE
579 1020 FORMAT(12X,F10.1,1H-,F9.1,F11.3,F10.1,F11.3,F12.1,2F13.2)
580 C END OF CALCULATIONS
581 V=VAL-AIA-SEW
582 WRITE(6,1006) BAL,AIA,SEW,V
583 RETURN
584 END
585 SUBROUTINE PLCT(IDY,PLTR,NN,MWTH)
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581 DIMENSION ICHAR(122),PLTR(4,31),MMTH(12,6)
582 DATA THLANK,TOPS,ICAL,IDASH,IPDS,IZZA/1H,1H0,1H*,1H1,1H+,1HT/
583 DO 100 J=1,10V
584 DO 90 K=1,122
585 90 ICHAR(K)=IRLANK
586 DO 92 K=2,122,40
587 92 ICHAR(K)=IDASH
588 DO 94 L=1,4
589 94 IF(PLTR(L,J).LE.1.0) PLTR(L,J)=1.001
590 94=40.0*ALOG10(PLTR(1,J))+2.49
591 IF(INR.LT.122) GO TO 75
592 NR=NR-120
593 75 ICHAR(NR)=IZZA
594 NI=40.0*ALOG10(PLTR(2,J))+2.49
595 IF(NI.LT.122) GO TO 85
596 NI=NI-120
597 85 ICHAR(NI)=IPDS
598 NA=40.0*ALOG10(PLTR(3,J))+2.49
599 IF(NA.LE.122) GO TO 95
600 NA=NA-120
601 ICHAR(1)=ICAL
602 95 ICHAR(NA)=ICMS
603 NC=40.0*ALOG10(PLTR(4,J))+2.49
604 IF(NC.LE.122) GO TO 96
605 NC=NC-120
606 ICHAR(1)=ICAL
607 96 ICHAR(NC)=ICAL
608 MC=IRLANK
609 IF(J.LE.6) MC=MMTH(N,J)
610 100 WRITE(6,192) MC,J,(ICAR(NI,N=1,122)
611 192 FORMAT(3X,A1,13,1X,122A1)
612 RETURN
613 END

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SENTRY

SUMMARY TABLE -- BLACK VERMILLION RIVER BASIN -- 1954

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	0.00	1.66	0.40	1.69	7.39	2.32	3.15	6.94	1.04	1.34	0.01	0.44	26.39
CALCULATED TOTAL RUNOFF	297.	290.	164.	171.	3104.	5570.	1122.	6050.	586.	472.	23.	178.	18228.
CONSERVED TOTAL RUNOFF	103.	409.	178.	162.	2967.	8162.	74.	4408.	43.	11.	35.	165.	16718.
CALCULATED SURFACE RUNOFF	0.	81.	0.	55.	3055.	4564.	592.	5880.	205.	155.	0.	0.	14587.
CONSERVED SURFACE RUNOFF	10.	213.	8.	12.	2735.	7535.	17.	4126.	0.	5.	5.	0.	14667.
CALCULATED INTERFLOW	0.	0.	0.	0.	0.	464.	0.	0.	0.	0.	0.	0.	464.
CALCULATED BASEFLOW	297.	199.	164.	116.	49.	542.	530.	170.	381.	317.	234.	178.	3177.
CONSERVED BASEFLOW	93.	196.	171.	150.	232.	626.	56.	282.	48.	6.	30.	186.	2076.
ETP	1.029	2.199	2.896	4.880	4.737	7.294	7.923	6.026	5.863	2.883	2.009	1.089	49.817
UETA	0.050	0.167	0.352	1.143	1.542	2.420	2.742	2.196	1.432	0.742	0.029	0.153	12.567
LETA	0.000	0.000	0.000	0.864	2.312	3.629	4.113	3.295	2.147	1.080	0.000	0.000	17.441
ETA	0.052	0.172	0.357	2.016	3.863	6.063	6.871	5.502	3.590	1.828	0.033	0.155	30.501
PER-CCLATION	0.000	0.395	0.115	0.328	5.015	1.291	0.134	3.601	0.138	0.096	0.000	0.062	11.194
TEMP.	25.0	43.7	39.1	58.4	58.5	76.0	83.1	77.6	73.0	57.9	47.3	34.4	56.2
CORRELATION COEFFICIENTS	0.950	0.909	0.578	0.929	0.809	0.919	0.972	0.742	0.855	0.910	0.902	0.913	0.882

DELTA STORAGE = -5.758 INCHES

ADIA = 0.108

PCND STORAGE = 0.000

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1955

PRECIP	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
	1.66	2.07	0.35	3.23	2.73	4.05	2.97	0.91	2.97	1.96	0.09	0.47	23.46
CALCULATED TOTAL RUNOFF	275.	232.	75.	1425.	728.	1287.	2524.	203.	321.	241.	11.	8.	7331.
OBSERVED TOTAL RUNOFF	275.	7493.	874.	1622.	447.	842.	319.	7.	5.	4.	17.	45.	11545.
CALCULATED SURFACE RUNOFF	151.	152.	0.	1385.	694.	1261.	2506.	182.	307.	229.	2.	1.	6271.
OBSERVED SURFACE RUNOFF	120.	7238.	440.	1349.	341.	731.	294.	4.	2.	1.	5.	1.	10526.
CALCULATED INTERFLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CALCULATED BASEFLOW	123.	80.	75.	41.	34.	26.	18.	21.	14.	12.	10.	7.	460.
OBSERVED BASEFLOW	155.	255.	434.	273.	105.	111.	25.	3.	3.	3.	12.	43.	1423.
ETP	0.910	1.091	3.260	5.561	5.697	6.020	8.369	6.978	5.545	3.226	1.927	1.107	49.651
UETA	0.116	0.247	0.269	1.352	1.577	2.110	2.284	1.801	1.398	0.622	0.125	0.083	11.955
LETA	0.000	0.000	0.000	0.919	2.354	3.165	3.426	2.702	2.097	0.934	0.010	0.000	15.606
ETA	0.117	0.249	0.275	2.281	3.942	5.286	5.725	4.516	3.505	1.562	0.139	0.086	27.685
PERCOLATION	1.295	1.797	0.170	1.929	0.893	1.564	1.364	0.000	0.233	1.160	0.000	0.110	10.515
TEMP.	27.6	25.4	40.5	59.1	61.1	68.4	82.3	79.5	71.8	57.5	36.7	26.0	53.2
CORRELATION COEFFICIENTS	0.278	0.910	0.760	0.938	0.790	0.945	0.609	0.767	0.635	0.804	0.351	0.889	0.722

DELTA STORAGE = -4.835 INCHES
 AATA = 0.189
 POND STORAGE = 0.000

SUMMARY TABLE -- BLACK VERMILLION RIVER BASIN -- 1956

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	0.59	0.55	0.27	1.38	2.52	4.71	2.23	2.71	0.37	1.72	1.65	0.31	18.97
CALCULATED TOTAL RUNOFF	5.	43.	3.	443.	290.	3043.	1580.	1183.	103.	396.	234.	0.	7324.
OBSERVED TOTAL RUNOFF	51.	58.	89.	55.	120.	2426.	1037.	367.	0.	0.	1.	16.	4260.
CALCULATED SURFACE RUNOFF	0.	39.	0.	442.	289.	3042.	1580.	1183.	103.	395.	233.	0.	7311.
OBSERVED SURFACE RUNOFF	7.	13.	11.	20.	58.	2402.	975.	360.	0.	0.	0.	0.	3849.
CALCULATED INTER-FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CALCULATED BASEFLOW	5.	3.	3.	1.	1.	0.	0.	0.	0.	0.	0.	0.	15.
OBSERVED BASEFLOW	43.	45.	78.	75.	62.	24.	62.	6.	0.	0.	1.	16.	411.
ETP	1.044	1.306	3.474	4.650	6.256	6.918	7.007	7.147	6.523	4.232	1.731	0.964	51.294
UETA	0.059	0.094	0.041	0.914	1.561	2.018	2.092	2.185	1.300	0.832	0.213	0.056	11.433
LETA	0.000	0.000	0.000	0.044	1.873	3.027	3.137	3.277	1.950	0.863	0.000	0.000	14.171
EYA	0.101	0.097	0.047	0.567	3.446	5.058	5.242	5.475	3.262	1.703	0.216	0.087	25.702
PER-CORRELATION	0.398	0.442	0.212	0.395	1.036	2.403	0.833	0.191	0.000	0.038	0.715	0.104	6.768
TEMP.	24.8	31.0	41.7	51.3	66.9	75.8	78.7	79.6	71.8	63.6	42.5	35.3	55.3
CORRELATION COEFFICIENTS	0.559	0.527	0.987	0.499	0.385	0.670	0.582	0.807	0.000	0.000	-0.039	0.813	0.518

DELTA STORAGE = -7.398 INCHES
 AREA = 0.051
 POND STORAGE = 0.000

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1957

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	0.55	0.56	3.35	3.03	4.64	6.74	1.04	3.03	4.43	4.33	1.67	0.70	34.08
CALCULATED TOTAL RUNOFF	0.	0.	282.	170.	1186.	6541.	955.	537.	6457.	6172.	8.	0.	22308.
OBSERVED TOTAL RUNOFF	15.	58.	140.	1609.	2408.	4691.	497.	56.	1703.	2164.	829.	101.	14272.
CALCULATED SURFACE RUNOFF	0.	0.	282.	170.	1186.	6541.	955.	537.	6457.	6172.	8.	0.	22307.
OBSERVED SURFACE RUNOFF	0.	0.	47.	1468.	2321.	4553.	429.	56.	1667.	2074.	768.	8.	13390.
CALCULATED INTERFLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CALCULATED BASEFLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
OBSERVED BASEFLOW	16.	59.	93.	141.	87.	138.	68.	0.	36.	90.	63.	93.	863.
ETP	0.904	1.299	2.909	8.658	4.791	5.728	7.154	6.695	3.803	2.318	1.423	1.332	47.014
UETA	0.037	0.147	0.377	3.103	1.552	1.964	2.038	2.047	1.064	0.507	0.214	0.073	13.147
LETA	0.000	0.000	0.000	0.232	2.238	2.946	3.057	3.070	1.596	0.610	0.000	0.000	13.749
ETA	0.038	0.149	0.393	3.351	3.799	4.921	5.109	5.130	2.667	1.121	0.216	0.100	26.985
PER-CORRELATION	0.452	0.452	2.933	1.947	0.911	4.095	0.362	0.351	2.182	3.046	1.415	0.466	18.611
TEMP.	22.2	34.3	41.9	51.2	61.8	71.3	81.8	78.4	64.5	52.6	40.1	36.9	53.2
CORRELATION COEFFICIENTS	0.824	0.952	0.711	0.566	0.829	0.834	0.916	0.792	0.802	0.851	0.321	0.933	0.811

DELTA STORAGE = 5.077 INCHES
 AATA = 0.168
 POND STORAGE = 0.000

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1958

PRECIP	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
	1.67	1.43	1.54	0.72	3.97	3.30	11.67	2.14	7.93	0.27	1.05	0.39	36.08
CALCULATED TOTAL RUNOFF	0.	0.	0.	0.	3390.	647.	21377.	13846.	8849.	1242.	1087.	1232.	51720.
OBSERVED TOTAL RUNOFF	236.	5214.	4920.	478.	3278.	826.	29260.	8558.	18367.	688.	819.	594.	73238.
CALCULATED SURFACE RUNOFF	0.	0.	0.	0.	3278.	519.	21302.	13648.	8218.	0.	191.	0.	47156.
OBSERVED SURFACE RUNOFF	50.	5116.	4207.	148.	2937.	679.	28919.	7752.	17287.	37.	219.	36.	67387.
CALCULATED INTERFLOW	0.	0.	0.	0.	75.	0.	46.	61.	595.	644.	659.	796.	2875.
CALCULATED BASEFLOW	0.	0.	0.	0.	37.	128.	28.	137.	36.	598.	237.	486.	1688.
OBSERVED BASEFLOW	186.	98.	713.	330.	341.	147.	341.	806.	1080.	651.	600.	559.	5851.
ETP	0.857	1.160	1.581	3.558	5.472	6.043	5.448	5.670	4.024	3.343	1.897	0.997	40.849
UETA	0.144	0.106	0.281	1.044	1.644	2.116	2.011	2.033	1.462	0.749	0.180	0.343	11.210
LETA	0.000	0.000	0.000	0.003	1.648	3.173	3.017	3.050	2.193	0.000	0.000	0.000	13.084
ETA	0.145	0.109	0.285	1.054	3.302	5.301	5.038	5.094	3.663	0.755	0.184	0.042	24.972
PER-CORRELATION	1.539	1.337	1.363	0.013	2.359	0.867	6.229	0.622	5.118	0.030	0.426	0.075	19.977
TEMP.	29.6	74.8	35.6	51.6	64.7	71.2	74.3	76.1	69.1	59.6	45.6	29.6	52.7
CORRELATION COEFFICIENTS	0.845	0.663	0.562	0.944	0.738	0.475	0.840	0.896	0.842	0.949	0.973	0.864	0.801

DELTA STORAGE = 6.437 INCHES
 AAIA = 0.018
 PCNC STORAGE = 0.000

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1959

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	1.23	0.55	2.26	2.09	9.96	2.41	5.95	5.24	7.47	3.76	0.13	0.74	41.80
CALCULATED TOTAL RUNOFF	1876.	3824.	5336.	10072.	32762.	20649.	23366.	11626.	6679.	8941.	4013.	2633.	131777.
OBSERVED TOTAL RUNOFF	597.	6248.	2687.	2883.	24111.	2349.	11596.	454.	13086.	16354.	1550.	1487.	83781.
CALCULATED SURFACE RUNOFF	0.	3.	137.	571.	19486.	12099.	19363.	9089.	5065.	1550.	0.	4.	67367.
OBSERVED SURFACE RUNOFF	8.	5492.	1757.	1903.	22220.	849.	10821.	293.	12912.	14463.	410.	1050.	72177.
CALCULATED INTER-FLC	1458.	3821.	5199.	9501.	13276.	7661.	725.	0.	21.	7292.	4013.	2630.	55958.
CALCULATED BASEFLOW	18.	0.	0.	0.	0.	888.	3278.	2537.	1593.	98.	0.	0.	8413.
OBSERVED BASEFLOW	589.	756.	930.	960.	1891.	1500.	775.	161.	174.	1491.	1140.	837.	11604.
ETP	0.796	1.373	3.219	4.275	5.529	6.411	6.175	7.135	4.366	2.526	1.641	1.087	44.533
UETA	0.120	0.133	0.571	1.086	1.853	2.060	2.198	2.530	1.372	0.702	0.120	0.153	12.858
LETA	0.000	0.000	0.000	0.096	2.219	3.089	3.297	3.795	2.058	0.913	0.000	0.000	15.468
ETA	0.122	0.136	0.577	1.190	4.082	5.161	5.507	6.339	3.439	1.520	0.123	0.155	28.450
PER-CORRELATION	0.598	0.658	1.694	1.223	5.207	0.130	2.439	1.468	5.667	2.877	0.022	0.511	22.893
TEMP.	21.2	29.3	41.4	50.7	65.8	74.2	73.6	80.5	67.0	52.4	36.6	36.9	52.6
CORRELATION COEFFICIENTS	0.936	0.596	0.870	0.773	0.764	0.910	0.752	0.895	0.684	0.536	0.987	0.865	0.798

DELTA STORAGE = 1.435 INCHES
AAIA = 0.034
PCND STORAGE = 0.000

SUMMARY TABLE -- BLACK VEPMILLION RIVER BASIN -- 1960

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	1.94	1.88	1.78	2.08	2.75	5.47	4.05	3.21	3.97	1.42	0.46	0.53	25.73
CALCULATED TOTAL RUNOFF	7937.	9781.	13199.	9987.	7143.	8629.	5519.	3829.	3940.	2509.	1769.	1413.	75656.
RESERVED TOTAL RUNOFF	9116.	5748.	19715.	6373.	4758.	7622.	2669.	1711.	742.	471.	368.	506.	59800.
CALCULATED SURFACE RUNOFF	346.	29.	0.	71.	1845.	4885.	1799.	911.	2171.	191.	106.	172.	12526.
OBSERVED SURFACE RUNOFF	7907.	4068.	17979.	4363.	2991.	6272.	1863.	1447.	592.	370.	68.	10.	47862.
CALCULATED INTER- FLOW	7591.	9752.	13139.	9916.	3623.	1119.	0.	0.	0.	0.	0.	0.	42201.
CALCULATED BASEFLOW	0.	0.	0.	0.	1675.	2624.	3719.	2918.	1768.	2318.	1663.	1241.	17927.
RESERVED BASEFLOW	1209.	1680.	1736.	2010.	1767.	1350.	806.	264.	150.	171.	307.	496.	11938.
ETP	0.789	1.175	1.645	4.959	5.907	5.264	5.823	6.486	4.253	2.638	1.673	1.067	41.661
UEYA	0.119	0.244	0.326	1.172	1.503	1.851	2.016	2.297	1.349	0.663	0.191	0.142	12.272
LEYA	0.000	0.000	0.000	0.523	2.817	2.776	3.024	3.445	2.023	0.644	0.000	0.000	15.253
ETA	0.120	0.246	0.229	1.705	4.732	4.637	5.052	5.755	3.380	1.311	0.194	0.144	27.604
PER- COLATION	1.778	1.635	1.543	0.574	1.215	3.058	1.584	0.903	2.259	0.692	0.247	0.381	16.268
TEMP.	26.1	25.0	26.1	55.7	62.8	68.6	74.8	77.1	69.9	53.0	42.6	31.1	51.5
CORRELATION COEF- FICIENTS	0.629	0.711	0.822	0.766	0.759	0.804	0.773	0.631	0.803	0.679	0.922	0.940	0.770

DELTA STORAGE = -4.711 INCHES
 AATA = 0.075
 PCND STORAGE = 0.000

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1961

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	0.06	1.27	3.50	1.75	5.45	3.32	4.37	3.98	7.90	3.73	2.06	1.23	38.62
CALCULATED TOTAL RUNOFF	980.	656.	1514.	6156.	14953.	7204.	3937.	4678.	14470.	2882.	4885.	7855.	70409.
RESERVED TOTAL RUNOFF	423.	694.	5203.	5425.	9480.	3126.	1207.	1229.	15312.	10554.	8895.	2091.	63638.
CALCULATED SURFACE RUNOFF	0.	0.	586.	39.	2677.	1111.	2211.	3525.	13447.	1860.	616.	0.	26074.
RESERVED SURFACE RUNOFF	0.	274.	4490.	3835.	7217.	1986.	866.	1055.	14892.	9159.	5985.	45.	49804.
CALCULATED INTER- FLOW	0.	0.	528.	6356.	12276.	5625.	0.	0.	0.	0.	4269.	7855.	36909.
CALCULATED BASEFLOW	980.	656.	400.	0.	0.	468.	1726.	1152.	1022.	1022.	0.	0.	7426.
RESERVED BASEFLOW	434.	420.	713.	1590.	2263.	1140.	341.	174.	420.	1395.	2910.	2046.	13846.
ETP	1.025	1.303	2.590	4.395	5.138	6.246	6.986	5.764	3.961	3.108	1.174	0.636	42.325
UETA	0.010	0.134	0.608	1.038	1.496	2.236	2.549	2.004	1.463	0.836	0.162	0.099	12.685
LETA	0.000	0.000	0.000	0.000	1.270	3.354	3.824	3.006	2.194	0.960	0.000	0.000	14.608
ETA	0.012	0.186	0.612	1.047	2.776	5.603	6.387	5.021	3.664	1.802	0.164	0.100	27.374
PER- COLLATION	0.023	1.119	2.858	1.284	3.379	1.483	1.250	1.730	4.653	2.756	1.830	1.127	23.496
TEMP.	28.9	31.9	43.0	45.3	60.1	71.2	76.7	74.4	64.1	57.7	39.9	23.0	51.8
CORRELATION COEF- FICIENTS	0.573	0.863	0.826	0.729	0.749	0.767	0.855	0.683	0.715	0.754	0.580	0.913	0.784
DELTA STORAGE =	4.884												
ASIA =	0.078												
PCNC STORAGE =	0.000												

SUMMARY TABLE -- BLACK VERMILLION RIVER BASIN -- 1962

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	1.34	1.31	1.55	0.74	6.20	5.39	4.35	5.76	3.69	2.52	1.07	0.73	34.65
CALCULATED TOTAL RUNOFF	7468.	9519.	9758.	7834.	16484.	6385.	5476.	8480.	4678.	2350.	1302.	962.	74625.
RESERVED TOTAL RUNOFF	11514.	11942.	9967.	2312.	11104.	13097.	6518.	2262.	4854.	6537.	1239.	1104.	82750.
CALCULATED SURFACE RUNOFF	0.	0.	7.	54.	13643.	4333.	3312.	6518.	3794.	895.	35.	0.	32592.
RESERVED SURFACE RUNOFF	9809.	8482.	7177.	242.	10329.	10967.	5647.	1921.	4344.	5514.	219.	19.	64670.
CALCULATED INTERFLOW	7368.	8519.	9791.	7780.	956.	1099.	0.	0.	0.	0.	0.	0.	35513.
CALCULATED BASEFLOW	0.	0.	0.	0.	1864.	953.	2164.	1971.	884.	1455.	1267.	962.	11520.
RESERVED BASEFLOW	1705.	3360.	2790.	2070.	775.	2130.	1271.	341.	510.	1023.	1020.	1085.	18080.
ETP	0.730	1.121	2.534	4.667	7.421	5.761	6.332	6.897	3.425	2.530	1.417	0.806	43.641
UETA	0.089	0.234	0.458	1.013	2.228	2.062	2.305	2.398	1.231	0.689	0.242	0.107	13.054
LETA	0.000	0.000	0.000	0.391	3.197	3.093	3.457	3.597	1.846	0.783	0.000	0.000	16.364
ETA	0.090	0.236	0.462	1.413	5.439	5.166	5.774	6.008	3.084	1.476	0.244	0.108	29.501
PER-COLLATION	1.248	1.053	1.187	0.072	2.248	3.218	1.783	2.346	2.273	1.951	0.552	0.623	18.555
TEMP.	21.2	31.3	37.4	52.1	71.7	71.9	75.7	76.7	65.1	58.7	43.4	31.8	53.2
CORRELATION COEFFICIENTS	0.730	0.705	0.606	0.995	0.935	0.381	0.904	0.854	0.682	0.801	0.965	0.973	0.795

DELTA STORAGE = -2.053 INCHES
 AATA = 0.080
 PCND STORAGE = 0.000

SUMMARY TABLE -- BLACK VERMILLION RIVER BASIN -- 1963

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	0.51	0.00	2.50	1.47	4.46	2.79	2.27	3.26	2.03	1.42	0.94	0.27	21.91
CALCULATED TOTAL RUNOFF	703.	471.	6654.	5036.	5530.	6623.	1238.	1226.	830.	758.	418.	266.	29753.
OBSERVED TOTAL RUNOFF	750.	1384.	4393.	1311.	3231.	2494.	228.	168.	427.	121.	264.	117.	14689.
CALCULATED SURFACE RUNOFF	0.	0.	611.	131.	2477.	5354.	254.	604.	306.	355.	64.	0.	10161.
OBSERVED SURFACE RUNOFF	130.	489.	2567.	291.	2425.	1984.	63.	106.	367.	44.	144.	24.	9034.
CALCULATED INTER- FLOW	0.	0.	5999.	4905.	3053.	589.	0.	0.	0.	0.	0.	0.	14546.
CALCULATED BASEFLOW	703.	471.	43.	0.	0.	680.	984.	622.	524.	403.	351.	266.	5047.
OBSERVED BASEFLOW	620.	896.	1426.	1020.	806.	510.	164.	62.	60.	78.	120.	93.	5655.
ETP	0.663	1.672	3.595	4.866	5.499	6.905	7.620	6.706	4.324	3.958	1.765	0.823	48.395
UETA	0.091	0.024	0.617	1.301	1.812	2.382	2.536	2.180	1.426	0.723	0.244	0.061	13.357
LETA	0.000	0.000	0.000	0.060	2.136	3.573	3.805	3.270	2.138	0.999	0.090	0.000	15.981
ETA	0.062	0.027	0.624	1.370	3.959	5.969	6.356	5.462	3.572	1.729	0.247	0.063	29.470
PER- COLLATION	0.418	0.001	1.914	0.083	2.480	0.624	0.184	0.542	0.293	0.255	0.399	0.173	7.366
TEMP.	17.3	33.4	46.6	56.5	64.5	76.0	80.0	77.5	69.8	67.1	46.5	21.9	54.9
CORRELATION COEF- FICIENTS	0.949	0.727	0.567	0.977	0.807	0.947	0.932	0.939	0.460	0.875	0.912	0.398	0.833
DELTA STORAGE =	-10.247 INCHES												
AREA =	0.241												
POND STORAGE =	0.000												

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1964

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	0.24	0.40	1.30	5.12	2.77	10.92	1.37	5.29	1.72	0.51	2.61	0.94	33.21
CALCULATED TOTAL RUNOFF	154.	136.	171.	3658.	1189.	36000.	300.	2520.	1174.	78.	992.	14.	46464.
CONSERVED TOTAL RUNOFF	256.	277.	325.	3947.	1427.	21585.	569.	645.	844.	111.	366.	302.	30653.
CALCULATED SURFACE RUNOFF	0.	0.	65.	3658.	1138.	35985.	254.	2496.	1152.	54.	974.	1.	45782.
CONSERVED SURFACE RUNOFF	39.	67.	46.	3671.	931.	20865.	166.	552.	706.	0.	225.	127.	27394.
CALCULATED INTER-FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CALCULATED BASEFLOW	194.	136.	106.	40.	51.	15.	46.	23.	22.	24.	13.	14.	682.
CONSERVED BASEFLOW	217.	210.	279.	276.	496.	720.	403.	93.	139.	111.	141.	175.	3255.
FTP	1.424	1.706	3.239	4.610	6.549	5.658	7.468	6.122	3.895	2.906	1.554	0.759	45.890
UESTA	0.083	0.230	0.436	1.304	2.023	1.866	2.323	1.799	1.048	0.456	0.324	0.065	11.968
LETA	0.300	0.000	0.000	0.613	3.013	2.799	3.484	2.699	1.572	0.071	0.000	0.000	14.251
ETA	0.006	0.233	0.442	1.926	5.048	4.676	5.621	4.509	2.627	0.533	0.327	0.066	26.306
DEP-COLATION	0.100	0.260	0.672	3.497	0.675	6.239	0.000	1.658	0.893	0.081	1.926	0.845	17.048
TEMP.	32.6	32.9	39.6	55.7	67.9	71.9	81.3	73.7	67.7	55.6	45.5	29.1	54.4
CORRELATION COEFFICIENTS	0.550	0.987	0.738	0.802	0.757	0.725	0.694	0.787	0.300	0.688	0.846	0.817	0.757

DELTA STORAGE = 2.695 INCHES
 AREA = 0.049
 PCVD STORAGE = 0.900

SUMMARY TABLE -- BLACK VERMILLION RIVER BASIN -- 1965

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	1.55	2.28	1.47	1.47	2.44	8.08	4.43	2.44	9.34	0.56	0.08	1.85	36.00
CALCULATED TOTAL RUNOFF	411.	12.	506.	136.	1047.	3644.	3271.	399.	18175.	29.	1.	541.	28173.
OBSERVED TOTAL RUNOFF	430.	5202.	13210.	1139.	798.	10781.	8520.	161.	21155.	987.	650.	1071.	64083.
CALCULATED SURFACE RUNOFF	403.	5.	501.	133.	1046.	3643.	3270.	398.	18175.	27.	0.	541.	28141.
OBSERVED SURFACE RUNOFF	276.	4927.	12163.	237.	331.	10379.	7811.	39.	20861.	184.	4.	401.	57614.
CALCULATED INTER- FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CALCULATED BASEFLOW	9.	7.	4.	4.	2.	1.	1.	2.	0.	1.	1.	0.	32.
OBSERVED BASEFLOW	154.	274.	1047.	902.	468.	401.	709.	122.	284.	793.	646.	670.	6470.
ETP	0.779	1.206	1.990	4.183	6.276	5.607	6.377	5.871	3.531	2.870	1.406	1.145	41.242
UETA	0.151	0.171	0.391	1.134	1.911	1.990	2.309	2.083	1.326	0.659	0.382	0.119	12.324
LETA	0.000	0.000	0.000	0.008	1.893	2.986	3.463	3.124	1.988	0.364	0.000	0.000	13.926
ETA	0.152	0.173	0.395	1.149	3.816	4.987	5.784	5.218	3.321	1.023	0.084	0.121	26.229
PER- COLLATION	1.342	1.492	1.713	0.514	0.508	5.501	2.198	0.237	6.026	0.163	0.000	1.417	21.111
TEMP.	28.3	27.8	21.4	56.2	68.5	71.7	76.8	75.5	65.4	58.7	45.5	38.6	53.8
CORRELATION COEFF- FICIENTS	0.890	0.560	0.768	0.770	0.690	0.812	0.799	0.414	0.715	0.627	0.991	0.759	0.733

DELTA STORAGE = 7.221 INCHES
 AATA = 0.018
 PCND STORAGE = 0.000

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1966

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	0.53	0.83	0.23	1.24	2.35	3.91	3.54	3.56	4.54	0.83	0.05	0.92	22.52
CALCULATED TOTAL RUNOFF	177.	931.	1446.	1217.	3681.	3173.	2162.	2007.	11184.	260.	185.	140.	26556.
CRSEVED TOTAL RUNOFF	716.	725.	564.	459.	659.	3082.	1045.	431.	2220.	72.	132.	145.	10253.
CALCULATED SURFACE RUNOFF	74.	242.	0.	91.	1894.	2740.	1812.	1672.	11003.	0.	0.	0.	19526.
OBSERVED SURFACE RUNOFF	261.	365.	56.	68.	340.	2852.	973.	388.	2160.	0.	0.	0.	7503.
CALCULATED INTER-FLOW	68.	606.	1446.	844.	1538.	0.	0.	0.	0.	0.	0.	0.	4501.
CALCULATED BASEFLOW	35.	84.	0.	282.	249.	432.	349.	330.	181.	260.	185.	140.	2527.
CRSEVED BASEFLOW	455.	360.	468.	391.	319.	230.	73.	44.	61.	72.	133.	145.	2750.
ETP	0.928	1.362	3.663	3.529	6.193	6.009	7.669	5.729	3.478	3.310	1.485	0.950	44.603
UETA	0.155	0.186	0.310	0.911	1.833	2.077	2.721	1.995	1.047	0.555	0.073	0.061	12.025
LETA	0.000	0.000	0.000	0.011	1.931	3.115	4.082	2.993	1.571	0.505	0.000	0.000	14.207
ETA	0.157	0.198	0.317	0.929	3.776	5.203	6.818	4.999	2.625	1.166	0.076	0.064	26.316
PER-CCLATION	0.378	0.599	0.026	0.243	0.910	1.933	0.214	1.427	2.126	0.249	0.000	0.565	8.671
TEMP.	23.8	31.0	46.5	49.5	63.0	72.5	82.0	73.5	64.2	56.7	43.8	29.7	53.1
CORRELATION COEFFICIENTS	0.393	0.788	0.991	0.991	0.873	0.834	0.575	0.914	0.736	0.942	0.992	0.957	0.832

DELTA STORAGE = -6.156 INCHES
 AATA = 0.036
 PCND STORAGE = 0.000

SUMMARY TABLE -- BLACK VERMILLION RIVER BASIN -- 1967

	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
PRECIP	0.67	0.23	2.30	3.55	4.00	10.56	3.31	1.65	3.75	3.71	0.52	1.13	35.37
CALCULATED TOTAL RUNOFF	269.	71.	1343.	821.	297.	30742.	7014.	2538.	2354.	3312.	1114.	773.	50647.
OBSERVED TOTAL RUNOFF	430.	188.	646.	1528.	644.	30852.	1725.	537.	557.	4034.	502.	439.	42133.
CALCULATED SURFACE RUNOFF	176.	0.	1293.	794.	262.	21147.	909.	732.	1205.	2227.	213.	0.	26557.
OBSERVED SURFACE RUNOFF	282.	17.	470.	1210.	333.	29510.	785.	197.	356.	3747.	55.	0.	36962.
CALCULATED INTERFLOW	0.	0.	0.	0.	0.	9595.	5864.	0.	0.	0.	0.	0.	15459.
CALCULATED BASEFLOW	94.	71.	50.	26.	35.	0.	241.	1806.	1149.	1035.	902.	773.	6231.
OBSERVED BASEFLOW	149.	171.	176.	318.	311.	1342.	940.	340.	201.	336.	449.	439.	5170.
ETP	1.102	1.929	3.309	4.519	5.247	5.022	6.219	5.689	3.465	2.727	1.197	0.875	41.268
UETA	0.083	0.102	0.389	1.351	1.297	1.889	2.267	2.020	1.173	0.717	0.076	0.143	11.507
LETA	0.000	0.000	0.000	0.000	1.128	2.834	3.401.	3.029	1.760	0.647	0.000	0.000	12.799
ETA	0.085	0.106	0.395	1.359	2.435	4.733	5.680	5.060	2.939	1.369	0.078	0.144	24.304
PER-CORRELATION	0.588	0.127	1.659	2.514	2.113	7.362	0.722	0.257	1.799	2.612	0.461	0.912	21.127
TEMP.	28.6	32.1	45.6	56.7	60.2	71.7	74.9	73.1	64.9	55.2	40.6	31.7	53.0
CORRELATION COEFFICIENTS	0.974	0.977	0.955	0.676	0.769	0.727	0.806	0.882	0.912	0.916	0.980	0.988	0.873
DELTA STORAGE =	6.406	INCHES											
ATA =	0.068												
POND STORAGE =	0.000												

Streamflow Hydrograph for 1964 (New Model)

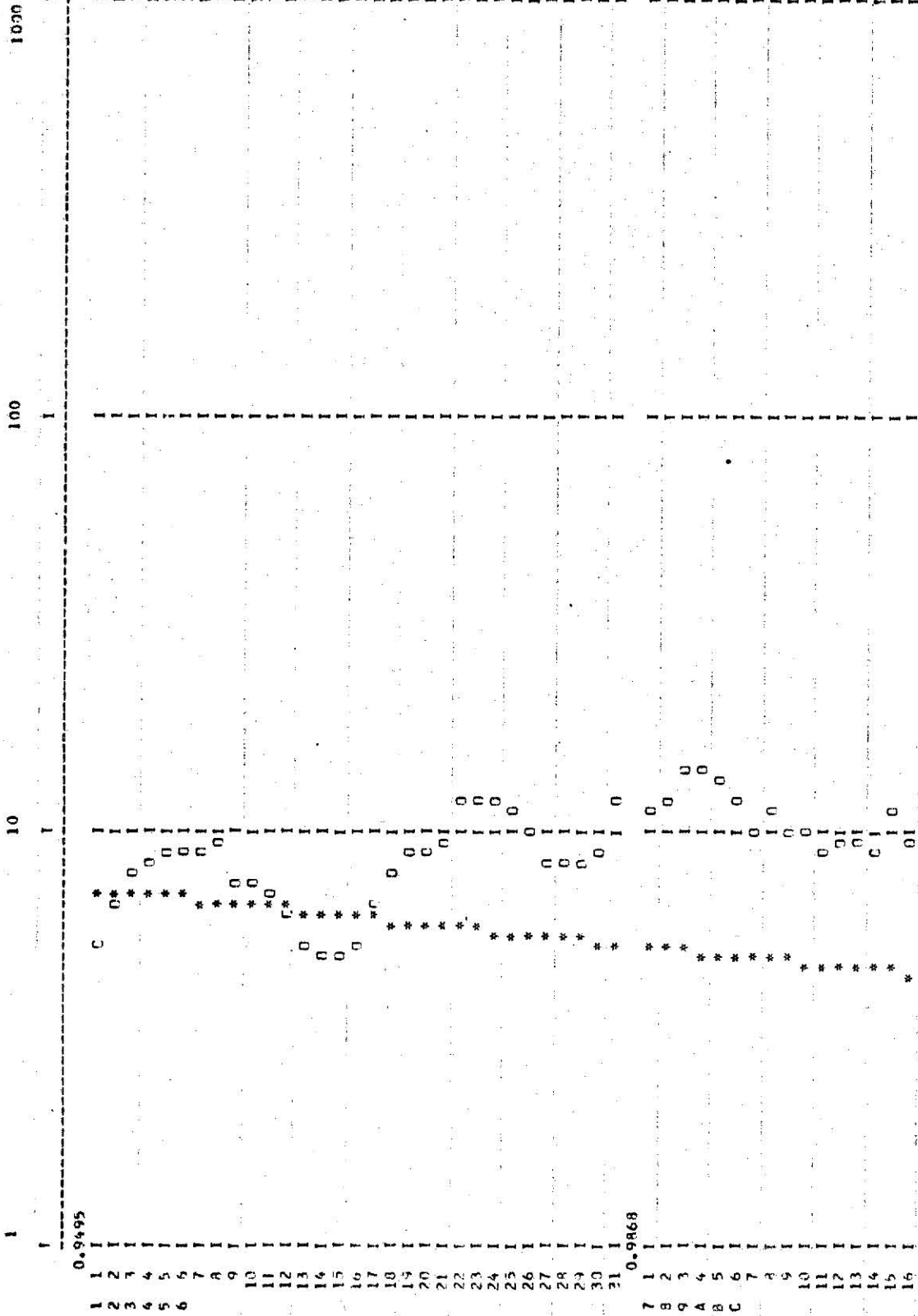
O - Observed Flows

*** - Simulated Flows**

+ - Interflow

YEARLY STREAMFLOW HYDROGRAPHS -- FROM JAN. 1, 1964 TO DECEMBER 31, 1964

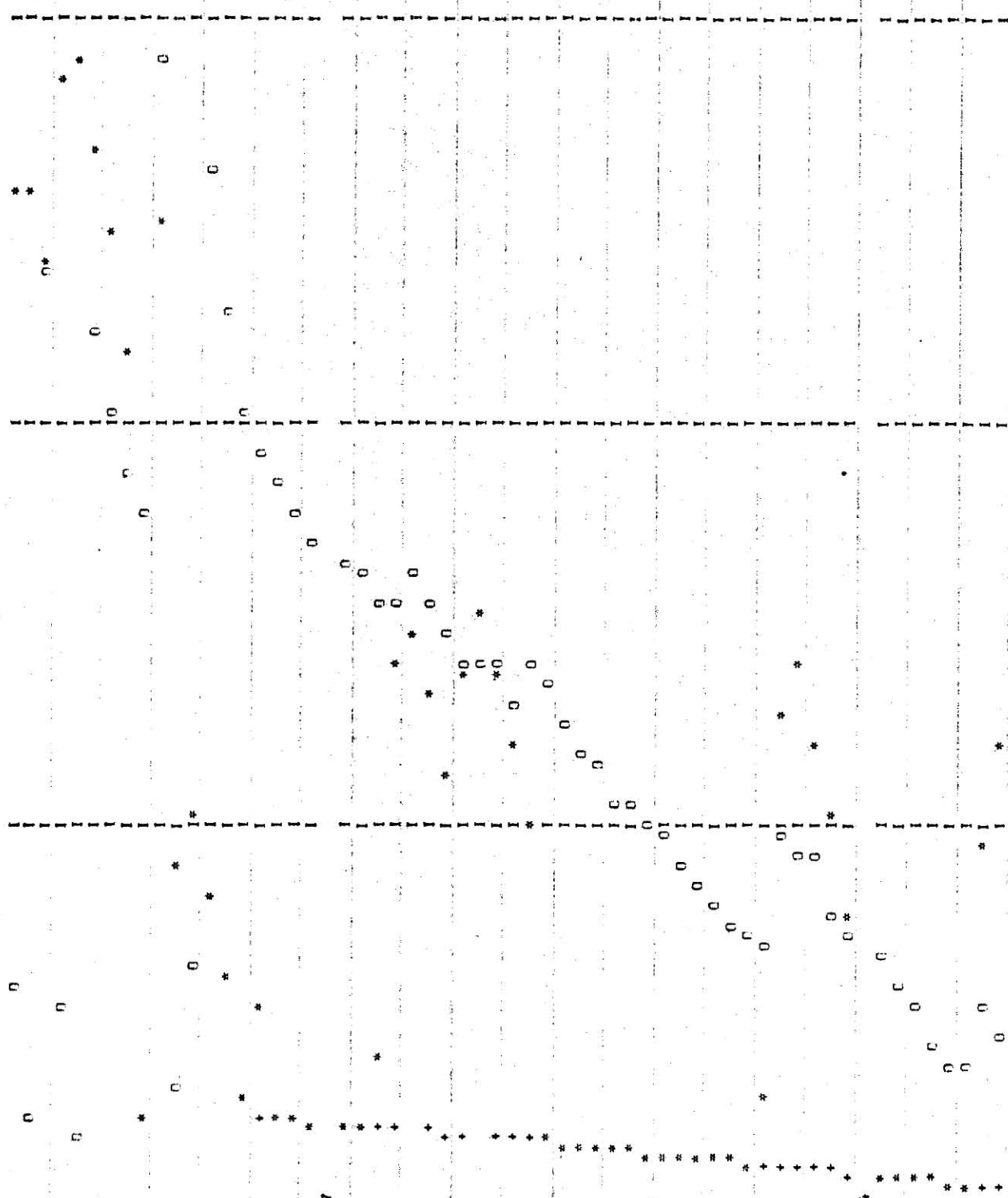
STREAMFLOW CFS



15	1	+	0	*
16	1	+	0	*
17	1	+	0	*
18	1	+	0	*
19	1	+	0	*
20	1	+	0	*
21	1	+	0	*
22	1	+	0	*
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24	1	+	0	*
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95	1	+	0	*
96	1	+	0	*
97	1	+	0	*
98	1	+	0	*
99	1	+	0	*
100	1	+	0	*

1. The first part of the paper is devoted to the study of the asymptotic behavior of the solutions of the system (1) as $t \rightarrow \infty$. It is shown that the solutions of the system (1) are bounded and tend to zero as $t \rightarrow \infty$ if the matrix A is stable. The second part of the paper is devoted to the study of the asymptotic behavior of the solutions of the system (1) as $t \rightarrow \infty$ if the matrix A is not stable. It is shown that the solutions of the system (1) are unbounded and tend to infinity as $t \rightarrow \infty$ if the matrix A is not stable.

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 C 1
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SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1954

PRECIP	0.00	1.66	0.40	1.69	7.39	2.32	3.15	6.94	1.04	1.34	0.01	0.44	26.39
CALCULATED TOTAL RUNOFF	297.	255.	164.	158.	2858.	5514.	1270.	5668.	608.	478.	268.	203.	17743.
OBSERVED TOTAL RUNOFF	133.	409.	178.	162.	2967.	8162.	74.	4408.	43.	11.	35.	165.	16719.
CALCULATED SURFACE RUNOFF	0.	56.	0.	44.	2810.	4337.	670.	5476.	179.	109.	0.	0.	13681.
OBSERVED SURFACE RUNOFF	10.	213.	8.	12.	2735.	7535.	17.	4126.	-5.	5.	5.	-21.	14641.
CALCULATED INTER-FLOW	0.	0.	0.	0.	2.	656.	0.	0.	0.	0.	0.	0.	656.
CALCULATED BASEFLOW	297.	199.	164.	113.	46.	521.	600.	192.	429.	370.	268.	203.	3404.
OBSERVED BASEFLOW	93.	196.	171.	150.	232.	626.	56.	282.	48.	6.	30.	186.	2076.
UZS	2.950	3.196	3.810	3.457	4.017	3.751	3.499	3.961	3.432	2.985	2.989	2.905	3.415
LZSA	9.100	9.146	9.254	9.075	9.953	10.481	8.630	8.582	8.204	7.137	6.876	6.876	8.605
LZST	9.100	9.146	9.254	9.075	9.953	11.351	9.219	8.973	8.473	7.329	7.047	7.047	8.826
LZST	9.100	9.146	9.254	9.075	9.953	11.435	9.308	9.033	8.515	7.359	7.074	7.074	8.856
LZST	9.100	9.146	9.254	9.075	9.953	11.505	9.375	9.078	8.547	7.392	7.094	7.094	8.880
LZST	9.100	9.146	9.254	9.075	9.953	11.560	9.423	9.110	8.569	7.398	7.109	7.109	8.897
LZST	9.100	9.146	9.254	9.075	9.953	11.592	9.449	9.129	8.582	7.407	7.117	7.117	8.906
LZST	9.100	9.146	9.254	9.075	9.953	11.597	9.454	9.132	8.584	7.409	7.118	7.118	8.908
LZST	9.100	9.146	9.254	9.075	9.953	11.597	9.454	9.132	8.584	7.409	7.118	7.118	8.908

LZST	9.100	9.146	9.254	9.C75	9.953	11.597	9.454	9.132	8.584	7.409	7.118	7.118	8.908
LZST	9.100	9.146	9.254	9.C75	9.953	11.597	9.454	9.132	8.584	7.409	7.118	7.118	8.908
LZST	9.100	9.146	9.254	9.075	9.953	11.597	9.454	9.132	8.584	7.409	7.118	7.118	8.908
GWS	69.427	69.316	69.235	69.172	69.137	70.298	70.056	69.875	69.729	69.541	69.397	69.292	69.540
PER- COLLATION	0.000	0.154	0.000	0.094	4.628	1.046	0.477	2.986	0.077	0.004	0.000	0.000	9.465
ETUZ	0.071	0.402	0.448	1.058	1.366	1.955	2.137	2.269	1.621	0.810	0.505	0.143	12.786
ETLZ	0.000	0.000	0.000	0.573	1.376	2.558	2.344	1.975	1.595	0.771	0.000	0.000	11.152
TEMP.	25.0	43.7	39.1	58.4	58.5	76.0	83.1	77.6	73.0	57.9	47.3	34.4	56.2
CORRELATION COEF- FICIENTS	0.746	0.758	-0.226	0.829	0.891	0.897	0.952	0.707	0.681	0.640	-0.620	-0.656	0.855

DELTA STORAGE = 0.808 INCHES
 AATA = 2.931
 POND STORAGE = 0.000
 ET BASEFLOW = 0.007

TOTAL CHANGE = -2.130

SUM CAL TOTAL = 17743.
 SUM OBS TOTAL = 16718.
 SUM CAL SPRINT = 14939.
 SUM OBS SQ = 14641.
 SUM CAL RF = 3404.
 SUM OBS RF = 2076.

155.0 254.8 434.0 273.0 105.4 111.0 24.8 3.1 3.0 3.1 12.0 43.4

53 306

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1955

PRECIP	1.66	2.07	0.35	3.23	2.73	4.03	2.97	0.91	2.97	1.96	0.09	0.47	23.46
CALCULATED TOTAL RUNOFF	214.	239.	84.	1024.	725.	1138.	2857.	160.	318.	175.	12.	9.	6956.
OBSERVED TOTAL RUNOFF	275.	7493.	874.	1622.	447.	842.	319.	7.	5.	4.	17.	45.	11949.
CALCULATED SURFACE RUNOFF	65.	149.	0.	978.	692.	1113.	2843.	145.	308.	165.	1.	1.	6461.
OBSERVED SURFACE RUNOFF	120.	7238.	440.	1349.	341.	731.	294.	4.	2.	1.	5.	1.	10526.
CALCULATED INTERFLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CALCULATED BASEFLOW	149.	90.	84.	46.	33.	25.	14.	15.	10.	10.	10.	8.	495.
OBSERVED BASEFLOW	155.	255.	434.	273.	105.	111.	25.	3.	3.	3.	12.	43.	1423.
UZS	3.831	4.099	3.848	3.802	3.719	3.868	3.689	2.929	2.811	3.685	3.201	3.366	3.568
LZSA	7.088	8.285	9.170	9.844	9.514	9.837	8.859	7.564	6.520	6.930	6.737	6.737	8.088
LZST	7.259	8.456	9.341	10.012	9.656	9.949	8.949	7.616	6.552	6.951	6.755	6.755	8.184
LZST	7.286	8.483	9.368	10.038	9.679	9.967	8.962	7.624	6.557	6.955	6.758	6.758	8.199
LZST	7.305	8.504	9.388	10.058	9.696	9.981	8.971	7.630	6.560	6.957	6.760	6.760	8.211
LZST	7.321	8.519	9.403	10.072	9.708	9.990	8.978	7.635	6.563	6.959	6.762	6.762	8.219
LZST	7.329	8.526	9.411	10.080	9.715	9.996	8.982	7.637	6.565	6.960	6.763	6.763	8.223
LZST	7.330	8.528	9.412	10.082	9.716	9.997	8.983	7.638	6.565	6.960	6.763	6.763	8.224
LZST	7.330	8.528	9.412	10.082	9.716	9.997	8.983	7.638	6.565	6.960	6.763	6.763	8.224

LZST	7.330	9.528	9.412	10.082	9.716	9.997	8.983	7.638	6.565	6.960	6.763	6.763	8.224
LZST	7.330	8.528	9.412	10.082	9.716	9.997	8.983	7.638	6.565	6.960	6.763	6.763	8.224
LZST	7.330	8.528	9.412	10.082	9.716	9.997	8.983	7.638	6.565	6.960	6.763	6.763	8.224
Gas	69.213	69.159	69.121	69.091	69.071	69.058	69.048	69.037	69.027	69.021	69.015	69.011	69.072
PER- CELLATION	0.425	1.863	0.009	1.423	0.885	1.436	1.332	0.000	0.243	0.967	0.000	0.000	8.583
ET02	0.079	0.059	0.538	1.269	1.341	1.709	2.268	1.424	0.920	1.194	0.302	0.108	11.211
ETL2	0.000	0.000	0.000	0.544	1.452	1.804	2.179	1.498	0.769	0.632	0.011	0.000	8.889
TEMP.	27.6	25.4	40.5	59.1	61.1	68.4	82.3	79.5	71.8	57.5	36.7	26.0	53.2
CORRELATION COEF- FICIENTS	0.089	0.826	0.742	0.891	0.782	0.882	0.042	0.702	0.244	0.716	-0.311	-0.258	0.149

DELTA STORAGE = 2.733 INCHES
 AATA = 2.635
 PCNO STORAGE = 0.000
 ET BASEFLOW = 0.006

 TOTAL CHANGE = 0.092

SUM CAL TOTAL = 24699.
 SUM OBS TOTAL = 28666.
 SUM CAL SRINT = 20800.
 SUM OBS SR = 25168.
 SUM CAL BF = 3899.
 SUM OBS BF = 3499.

43.4 44.8 77.5 75.0 62.0 24.0 62.0 6.2 0.0 0.0 0.6 15.5

115 300

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1956

PRECIP	3.59	0.55	0.23	1.38	2.52	4.71	2.23	2.71	0.37	1.72	1.65	0.31	18.97
CALCULATED TOTAL RUNOFF	6.	44.	3.	288.	230.	2633.	1437.	1037.	87.	388.	198.	0.	6352.
OBSERVED TOTAL RUNOFF	51.	58.	89.	95.	120.	2426.	1037.	367.	0.	0.	1.	16.	4260.
CALCULATED SURFACE RUNOFF	0.	40.	0.	286.	230.	2633.	1437.	1036.	87.	388.	198.	0.	6337.
OBSERVED SURFACE RUNOFF	7.	13.	11.	20.	58.	2402.	975.	360.	0.	0.	0.	0.	3849.
CALCULATED INTERFLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CALCULATED BASEFLOW	6.	4.	3.	2.	0.	0.	0.	0.	0.	0.	0.	0.	15.
OBSERVED BASEFLOW	43.	45.	78.	75.	62.	24.	62.	6.	0.	0.	1.	16.	411.
UZS	3.544	3.999	3.748	3.483	3.675	3.864	3.754	3.616	2.946	2.714	3.643	3.770	3.561
L25A	6.739	6.945	6.977	6.993	7.134	6.912	7.507	6.475	5.869	5.579	5.876	5.960	6.580
L25T	6.757	6.964	6.995	7.011	7.150	6.922	7.514	6.479	5.871	5.580	5.877	5.961	6.590
L25T	6.760	6.967	6.998	7.014	7.153	6.924	7.515	6.479	5.871	5.580	5.877	5.961	6.591
L25T	6.762	6.969	7.000	7.016	7.154	6.925	7.516	6.480	5.872	5.581	5.877	5.961	6.593
L25T	6.764	6.970	7.002	7.018	7.156	6.926	7.516	6.480	5.872	5.581	5.877	5.961	6.593
L25T	6.765	6.971	7.003	7.019	7.157	6.927	7.516	6.480	5.872	5.581	5.877	5.961	6.594
L25T	6.765	6.971	7.003	7.019	7.157	6.927	7.517	6.480	5.872	5.581	5.877	5.961	6.594
L25T	6.765	6.971	7.003	7.019	7.157	6.927	7.517	6.480	5.872	5.581	5.877	5.961	6.594

LZST	6.765	6.971	7.003	7.019	7.157	6.927	7.517	6.480	5.872	5.581	5.877	5.961	6.594
LZST	6.765	6.971	7.003	7.019	7.157	6.927	7.517	6.480	5.872	5.581	5.877	5.961	6.594
LZST	6.765	6.971	7.003	7.019	7.157	6.927	7.517	6.480	5.872	5.581	5.877	5.961	6.594
GHS	69.008	69.006	69.004	69.003	69.002	69.001	69.001	69.001	69.000	69.000	69.000	69.000	69.002
PER- COLLATION	0.009	0.231	0.000	0.021	0.528	1.977	0.601	0.042	0.000	0.000	0.439	0.000	3.848
ETUZ	0.094	0.162	0.542	0.819	1.556	2.039	2.149	2.091	1.172	0.771	0.499	0.325	12.220
ETLZ	0.000	0.000	0.000	0.014	0.748	0.992	1.409	0.902	0.410	0.172	0.000	0.000	4.647
TEMP.	24.8	31.0	41.7	51.3	66.9	75.8	78.7	79.6	71.8	63.6	42.5	35.3	55.3
CORRELATION COEFF- CIENTS	-0.135	0.052	0.691	0.891	0.582	0.726	0.539	0.769	0.000	0.000	-0.338	0.000	0.672

DELTA STORAGE = 1.524 INCHES
 AATA = 1.982
 PCHD STORAGE = 0.000
 ST BASEFLOW = 0.304

TOTAL CHANGE = -0.462

SUM CAL TOTAL = 31051.
 SUM OBS TOTAL = 32927.
 SUM CAL SRINT = 27137.
 SUM OBS SR = 29017.
 SUM CAL RF = 3915.
 SUM OBS BF = 3910.

15.5 58.8 93.0 141.0 86.8 130.0 68.2 0.0 36.0 89.9 63.0 93.0
 0
 104 298

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1957

PRECIP	0.55	0.56	3.35	3.03	4.64	6.74	1.04	3.03	4.43	4.33	1.67	0.70	34.08
CALCULATED TOTAL RUNOFF	0.	0.	227.	207.	1543.	6674.	2197.	1180.	6355.	6142.	439.	340.	25304.
OBSERVED TOTAL RUNOFF	15.	58.	140.	1609.	2408.	4691.	497.	56.	1703.	2164.	829.	101.	14272.
CALCULATED SURFACE RUNOFF	0.	0.	227.	207.	1408.	5856.	891.	564.	6098.	5742.	7.	0.	21000.
OBSERVED SURFACE RUNOFF	-0.	-0.	47.	1468.	2321.	4553.	429.	56.	1667.	2074.	766.	8.	13389.
CALCULATED INTERFLOW	0.	0.	0.	0.	105.	709.	519.	0.	0.	0.	8.	18.	1359.
CALCULATED BASEFLOW	0.	0.	0.	0.	31.	109.	787.	616.	757.	400.	424.	322.	2945.
OBSERVED BASEFLOW	16.	59.	93.	141.	87.	138.	68.	0.	36.	90.	63.	93.	883.
UZS	3.806	3.596	3.986	3.997	3.883	3.957	3.274	2.947	3.874	3.906	3.987	3.840	3.784
LZSA	5.979	6.217	7.014	10.651	10.780	11.020	9.995	8.014	8.407	9.064	10.135	10.713	9.010
LZST	5.980	6.218	7.015	10.652	10.862	11.539	10.802	8.547	8.776	9.356	10.410	10.969	9.274
LZST	5.980	6.218	7.015	10.652	10.882	11.656	10.983	8.680	8.870	9.430	10.482	11.060	9.339
LZST	5.980	6.218	7.015	10.652	10.886	11.703	11.121	8.783	8.943	9.488	10.538	11.115	9.364
LZST	5.980	6.218	7.015	10.652	10.886	11.724	11.228	8.863	8.999	9.533	10.581	11.158	9.417
LZST	5.980	6.218	7.015	10.652	10.886	11.737	11.297	8.914	9.036	9.562	10.609	11.186	9.439
LZST	5.980	6.218	7.015	10.652	10.886	11.739	11.323	8.933	9.049	9.573	10.619	11.196	9.447
LZST	5.980	6.219	7.015	10.652	10.886	11.739	11.324	8.933	9.050	9.573	10.619	11.197	9.447

LZST	5.980	6.218	7.015	10.652	10.886	11.739	11.324	8.933	9.050	9.573	10.619	11.197	9.447
LZST	5.980	6.218	7.015	10.652	10.886	11.739	11.324	8.933	9.050	9.573	10.619	11.197	9.447
LZST	5.980	6.218	7.015	10.652	10.886	11.739	11.324	8.933	9.050	9.573	10.619	11.197	9.447
GWS	69.000	69.000	69.000	69.000	69.105	69.757	70.518	70.147	69.995	69.825	69.628	69.462	69.540
PER- COLATION	0.136	0.281	2.531	2.037	2.263	3.797	0.300	0.418	2.034	2.053	1.038	0.066	16.955
EYUZ	0.075	0.244	0.563	0.966	1.468	1.902	1.849	1.360	1.543	1.032	0.465	0.358	11.824
ETLZ	0.000	0.000	0.000	0.310	1.664	2.352	2.884	1.914	1.343	0.861	0.000	0.000	11.320
TEMP.	22.2	34.3	41.9	51.2	61.8	71.3	81.8	78.4	64.5	52.6	40.1	36.9	53.2
CORRELATION COEFF- ICIENTS	0.000	0.000	0.418	0.892	0.602	0.781	0.910	0.792	0.737	0.832	-0.196	-0.845	0.618

DELTA STORAGE = 8.639 INCHES
 AATA = 3.023
 POND STORAGE = 0.000
 NET BASEFLOW = 0.006

 TOTAL CHANGE = 5.609

SUM CAL TOTAL = 56355.
 SUM ORS TOTAL = 47199.
 SUM CAL SINT = 49456.
 SUM ORS SP = 42406.
 SUM CAL RF = 6860.
 SUM ORS RF = 4793.

186.0 98.0 713.0 330.0 341.0 147.0 341.0 806.01080.0 651.0 600.0 558.0

0
 119 274

SUMMARY TABLE -- BLACK VERMILLION RIVER BASIN -- 1958

PRECIP	1.67	1.43	1.54	0.72	3.97	3.30	11.67	2.14	7.93	0.27	1.05	0.39	36.68
CALCULATED TOTAL RUNOFF	878.	1799.	6817.	4587.	8536.	2993.	23110.	16104.	8937.	3116.	2756.	2295.	81929.
OBSERVED TOTAL RUNOFF	216.	5214.	4920.	478.	3278.	826.	29260.	8558.	18367.	688.	819.	594.	73238.
CALCULATED SURFACE RUNOFF	0.	0.	0.	0.	3118.	473.	20429.	13335.	6960.	0.	113.	0.	44429.
RESERVED SURFACE RUNOFF	50.	5116.	4207.	148.	2937.	679.	28917.	7752.	17287.	37.	219.	36.	67367.
CALCULATED INTER- FLOW	710.	1799.	6817.	4587.	5418.	223.	2189.	1011.	1714.	1225.	691.	542.	26925.
CALCULATED BASEFLOW	168.	0.	0.	0.	0.	2297.	492.	1758.	263.	1892.	1951.	1754.	10575.
OBSERVED BASEFLOW	186.	98.	713.	330.	341.	147.	341.	806.	1080.	651.	600.	558.	5651.
UZS	4.073	4.063	4.047	3.708	3.866	3.774	3.960	3.739	3.996	3.456	3.127	3.333	3.760
L25A	11.072	11.151	11.220	11.023	11.118	9.809	10.532	10.237	10.800	10.908	10.927	10.971	10.813
L25T	11.494	12.001	12.807	12.118	12.147	10.664	11.453	11.124	11.638	11.546	11.280	11.160	11.618
L25T	11.647	12.252	13.114	12.458	12.489	10.958	11.697	11.370	11.866	11.927	11.606	11.509	11.898
L25T	11.717	12.438	13.397	12.778	12.823	11.248	11.940	11.613	12.086	12.103	11.928	11.856	12.159
L25T	11.773	12.613	13.652	13.095	13.155	11.538	12.183	11.855	12.301	12.376	12.250	12.203	12.416
L25T	11.812	12.775	13.911	13.408	13.485	11.827	12.426	12.094	12.515	12.650	12.571	12.550	12.669
L25T	11.825	12.976	14.134	13.703	13.806	12.113	12.664	12.330	12.725	12.920	12.890	12.896	12.907
L25T	11.825	12.981	14.253	13.941	14.098	12.383	12.891	12.558	12.925	13.181	13.199	13.235	13.116

LZST	11.825	12.882	14.359	14.173	14.387	12.651	13.116	12.782	13.119	13.392	13.411	13.468	13.300
LZST	11.825	12.882	14.448	14.395	14.671	12.917	13.339	13.001	13.306	13.579	13.599	13.655	13.472
LZST	11.825	12.882	14.515	14.803	14.948	13.177	13.559	13.213	13.479	13.741	13.761	13.817	13.631
GWS	69.612	70.565	72.195	72.677	73.365	73.367	73.046	73.511	73.268	73.375	72.334	71.519	72.412
PER- COLATION	1.401	1.074	1.130	0.002	2.055	0.642	5.514	0.464	4.331	0.000	0.073	0.003	16.690
ETU2	0.158	0.185	0.294	0.302	1.584	1.764	2.107	2.035	1.815	1.150	0.488	0.179	12.662
ETL2	0.000	0.000	0.000	0.002	1.597	2.347	2.711	2.800	2.333	0.000	0.000	0.000	11.790
TEMP.	29.6	24.8	35.6	51.6	64.7	71.2	74.3	76.1	69.1	58.8	45.6	29.6	52.7
CORRELATION COEFF- FICIENTS	0.746	0.767	-0.021	0.878	0.570	0.088	0.835	0.882	0.793	-0.840	-0.824	0.024	0.754

DELTA STORAGE = 4.226 INCHES
 AATA = 3.278
 PCND STORAGE = 0.000
 ET BASEFLOW = 0.006

TOTAL CHANGE = 0.942

SUM CAL TOTAL = 138284.
 SUM OBS TOTAL = 120437.
 SUM CAL SPRINT = 120850.
 SUM OBS SR = 109793.
 SUM CAL RF = 17434.
 SUM OBS RF = 10544.

589.0 756.0 930.0 960.01891.01500.0 775.0 161.2 174.01891.01140.0 837.0

112 301

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1959

PRECIP	1.23	0.55	2.26	2.09	9.96	2.41	5.95	5.24	7.47	3.76	0.13	0.74	41.80
CALCULATED TOTAL RUNOFF	1816.	3309.	4358.	8249.	29683.	18404.	23029.	12492.	6789.	8249.	2782.	3996.	123154.
OBSERVED TOTAL RUNOFF	597.	6248.	2687.	2863.	24111.	2349.	11596.	454.	13086.	16354.	1550.	1887.	83781.
CALCULATED SURFACE RUNOFF	0.	3.	125.	546.	18880.	11932.	18953.	9994.	4573.	1285.	0.	2.	66293.
OBSERVED SURFACE RUNOFF	8.	5492.	1757.	1903.	22220.	849.	10821.	293.	12912.	14463.	410.	1050.	72177.
CALCULATED INTER- FLOW	1070.	3307.	4234.	7703.	10802.	5604.	1013.	0.	647.	6964.	2782.	1548.	45673.
CALCULATED BASEFLOW	746.	0.	0.	0.	0.	967.	3062.	2498.	1570.	0.	0.	2446.	11188.
OBSERVED BASEFLOW	589.	756.	930.	960.	1891.	1500.	775.	161.	174.	1891.	1140.	837.	11604.
UZS	3.771	4.042	4.005	3.891	4.014	3.617	3.805	3.575	3.782	3.932	3.684	3.542	3.804
LZSA	11.080	11.169	11.169	11.185	11.248	10.191	10.127	9.032	9.546	11.043	10.719	10.720	10.600
LZST	11.249	11.691	11.772	12.401	13.029	12.075	11.248	9.765	10.164	12.903	11.951	11.428	11.631
LZST	11.611	12.060	12.144	12.775	13.383	12.389	11.526	9.983	10.331	13.130	12.140	11.758	11.935
LZST	11.972	12.428	12.516	13.149	13.738	12.704	11.804	10.201	10.498	13.356	12.430	12.087	12.239
LZST	12.333	12.796	12.887	13.522	14.093	13.021	12.084	10.420	10.663	13.576	12.717	12.416	12.543
LZST	12.694	13.154	13.259	13.896	14.449	13.339	12.364	10.639	10.828	13.791	13.001	12.743	12.845
LZST	13.054	13.531	13.631	14.270	14.805	13.658	12.644	10.858	10.993	14.004	13.284	13.069	13.148
LZST	13.411	13.897	14.001	14.643	15.162	13.978	12.923	11.077	11.158	14.217	13.568	13.395	13.450

LZST	13.688	14.220	14.348	15.003	15.512	14.296	13.200	11.293	11.323	14.431	13.851	13.722	13.738
LZST	13.900	14.498	14.671	15.351	15.856	14.612	13.474	11.507	11.486	14.635	14.130	14.046	14.011
LZST	14.063	14.719	14.962	15.682	16.192	14.925	13.743	11.717	11.647	14.828	14.403	14.367	14.268
GWS	71.077	71.615	72.140	73.460	75.263	76.938	75.986	74.538	73.689	75.795	76.006	75.677	74.364
PER- CULATION	0.456	0.673	1.283	1.077	4.698	0.227	2.349	1.448	4.944	2.331	0.000	0.008	19.493
ETUZ	0.044	0.168	0.616	0.923	1.726	1.782	1.967	2.088	1.593	1.047	0.378	0.298	12.628
STLZ	0.000	0.000	0.000	0.089	2.074	2.803	2.673	2.618	1.850	1.365	0.000	0.000	13.473
TEMP.	21.0	29.3	41.4	50.7	65.8	74.2	73.6	80.5	67.0	52.4	36.6	36.9	52.6
CORRELATION COEFF- FICIENTS	0.237	0.462	0.576	0.570	0.790	0.852	0.692	0.488	0.756	0.469	0.844	0.167	0.575

DELTA STORAGE = 4.563 INCHES
 ARIA = 3.385
 PCHP STORAGE = 0.000
 ET BASEFLOW = 0.007

TOTAL CHANGE = 1.170

SUM CAL TOTAL = 261438.
 SUM OBS TOTAL = 204219.
 SUM CAL SPINT = 232816.
 SUM OBS SP = 181971.
 SUM CAL BF = 28622.
 SUM OBS BF = 22248.

LZST	14.352	15.036	15.850	15.224	14.133	13.624	12.467	10.498	9.251	9.289	9.118	9.237	12.331
LZST	14.700	15.397	16.218	15.593	14.478	13.931	12.730	10.699	9.398	9.406	9.230	9.349	12.565
LZST	15.047	15.758	16.586	15.962	14.824	14.239	12.994	10.902	9.547	9.525	9.345	9.464	12.840
GWS	74.815	75.905	77.877	78.870	78.957	78.105	77.029	75.248	74.034	73.033	71.963	71.215	75.584
PER- COLATION	1.509	1.629	1.636	0.726	1.261	2.870	1.152	0.685	1.761	0.064	0.000	0.156	13.447
ETUZ	0.124	0.119	0.175	1.122	1.524	1.730	1.966	2.126	1.595	1.229	0.567	0.175	12.459
ETLZ	0.000	0.000	0.000	0.534	2.127	2.446	2.618	2.237	1.516	0.788	0.000	0.000	12.266
TEMP.	26.1	25.0	26.1	55.7	62.8	68.6	74.8	77.1	69.9	58.0	42.6	31.1	51.5
CORRELATION COEFF- FICIENTS	-0.101	-0.581	-0.156	0.536	0.527	0.590	0.422	-0.011	0.656	-0.134	-0.129	0.022	0.134

DELTA STORAGE = -1.569 INCHES
 AATA = 2.710
 PCND STORAGE = 0.000
 ET BASEFLOW = 0.007

TOTAL CHANGE = -4.286

SUM CAL TOTAL = 334177.
 SUM OBS TOTAL = 264019.
 SUM CAL SINT = 284634.
 SUM OBS SR = 229832.
 SUM CAL RF = 49544.
 SUM OBS RF = 34186.

434.0 420.0 713.01590.02263.01140.0 341.0 173.6 420.01395.02910.02046.0

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 122 299

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1961

PRECIP	0.06	1.27	3.50	1.75	5.45	3.32	4.37	3.98	7.90	3.73	2.06	1.23	39.62
CALCULATED TOTAL RUNOFF	1131.	758.	1163.	2861.	11273.	4745.	4303.	4480.	13360.	3413.	5139.	6954.	59579.
CONSERVED TOTAL RUNOFF	423.	694.	5203.	5425.	9480.	3126.	1207.	1229.	15312.	10554.	8895.	2091.	63638.
CALCULATED SURFACE RUNOFF	0.	0.	555.	31.	2633.	994.	2407.	3216.	11842.	1420.	462.	0.	23561.
CONSERVED SURFACE RUNOFF	-11.	274.	4490.	3835.	7217.	1986.	866.	1055.	14892.	9150.	5985.	45.	49793.
CALCULATED INTERFLOW	0.	0.	145.	2617.	8640.	3130.	0.	0.	339.	797.	4677.	6954.	27299.
CALCULATED BASEFLOW	1131.	758.	463.	213.	0.	620.	1896.	1264.	1178.	1196.	0.	0.	8719.
CONSERVED BASEFLOW	434.	420.	713.	1590.	2263.	1140.	341.	174.	420.	1395.	2910.	2046.	13846.
UZS	3.793	3.969	4.043	3.885	3.908	3.872	3.766	3.768	4.021	3.842	4.072	4.025	3.909
LZSA	8.335	8.637	10.220	11.202	11.249	10.513	9.334	9.438	10.648	10.916	11.253	11.181	10.250
LZST	8.551	8.833	10.455	12.169	13.061	11.854	10.176	10.043	11.137	11.488	12.429	12.540	11.072
LZST	8.649	8.951	10.564	12.379	13.342	12.141	10.416	10.219	11.298	11.714	12.716	12.869	11.281
LZST	8.748	9.051	10.666	12.570	13.612	12.423	10.654	10.394	11.456	11.330	12.998	13.194	11.485
LZST	8.849	9.151	10.768	12.755	13.879	12.705	10.891	10.571	11.608	12.110	13.249	13.503	11.681
LZST	8.952	9.254	10.871	12.898	14.121	12.976	11.122	10.743	11.748	12.258	13.473	13.798	11.863
LZST	9.057	9.359	10.976	13.043	14.365	13.248	11.354	10.917	11.884	12.390	13.678	14.082	12.041
LZST	9.164	9.467	11.084	13.187	14.608	13.520	11.584	11.091	12.020	12.511	13.859	14.354	12.216

L1ST	9.274	9.577	11.194	13.328	14.847	13.790	11.812	11.265	12.156	12.628	14.031	14.620	12.389
L2ST	9.386	9.689	11.306	13.450	15.036	14.035	12.023	11.426	12.283	12.734	14.163	14.856	12.545
L3ST	9.501	9.804	11.421	13.564	15.202	14.265	12.218	11.576	12.401	12.838	14.281	15.082	12.693
GAS	70.624	70.205	69.956	70.949	72.874	73.755	72.959	72.416	71.969	71.849	72.791	73.951	72.036
PER- CCLATION	0.000	0.686	2.513	1.192	3.064	1.236	1.488	1.650	3.987	2.126	1.497	0.970	20.410
ETU2	0.184	0.215	0.625	0.845	1.396	1.838	2.084	1.975	1.594	1.265	0.464	0.114	12.598
ETL2	0.000	0.000	0.000	0.000	1.228	2.573	2.552	2.343	1.903	1.404	0.000	0.000	12.003
TEMP.	28.8	31.9	43.0	49.3	60.1	71.2	76.7	74.4	64.1	57.7	39.9	23.0	51.8
CORRELATION COEFF- FICIENTS	0.568	-0.648	0.455	0.215	0.606	0.431	0.633	0.608	0.579	0.753	0.189	-0.697	0.484

DELTA STORAGE = 8.635 INCHES
 ARIA = 3.350
 PCNO STORAGE = 0.000
 ET BASEFLOW = 0.006

TOTAL CHANGE = 5.278

SUM CAL TOTAL = 393756.
 SUM OBS TOTAL = 327657.
 SUM CAL SPINT = 335493.
 SUM OBS SR = 279625.
 SUM CAL RF = 59263.
 SUM OBS RF = 48032.

SUMMARY TABLE -- BLACK VERMILLION RIVER BASIN -- 1962

PRECIP	1.34	1.31	1.55	0.74	6.20	5.39	4.35	5.76	3.69	2.52	1.07	0.73	34.65
CALCULATED TOTAL RUNOFF	6802.	7901.	9308.	7119.	18230.	7674.	6488.	9701.	5334.	3229.	2109.	1586.	85480.
OBSERVED TOTAL RUNOFF	11514.	11842.	9967.	2312.	11104.	13097.	6918.	2262.	4854.	6537.	1239.	1104.	82750.
CALCULATED SURFACE RUNOFF	0.	0.	6.	41.	14172.	4249.	2911.	6427.	3717.	745.	21.	0.	32291.
OBSERVED SURFACE RUNOFF	9804.	8482.	7177.	242.	10329.	10967.	5647.	1921.	4344.	5514.	219.	19.	64670.
CALCULATED INTER-FLOW	6802.	7901.	9302.	7078.	996.	2706.	488.	0.	101.	109.	0.	0.	35480.
CALCULATED BASEFLOW	0.	0.	0.	0.	3062.	718.	3089.	3274.	1517.	2375.	2088.	1586.	17709.
OBSERVED BASEFLOW	1705.	3360.	2790.	2070.	775.	2130.	1271.	341.	510.	1023.	1020.	1085.	18080.
U2S	4.068	4.050	4.030	3.617	3.429	3.912	3.800	3.642	3.968	3.665	3.517	3.802	3.790
L2SA	11.175	11.189	11.194	10.978	10.155	10.869	10.542	9.315	10.676	10.578	10.258	10.281	10.595
L2ST	12.361	12.615	12.669	12.254	10.903	11.778	11.120	9.719	10.966	10.868	10.548	10.570	11.354
L2ST	12.712	12.978	13.038	12.624	11.231	12.066	11.386	9.932	11.149	11.057	10.737	10.759	11.628
L2ST	13.061	13.339	13.407	12.995	11.561	12.357	11.652	10.143	11.325	11.228	10.905	10.927	11.897
L2ST	13.402	13.696	13.772	13.364	11.892	12.647	11.915	10.350	11.487	11.374	11.046	11.069	12.156
L2ST	13.735	14.049	14.136	13.732	12.222	12.939	12.175	10.554	11.644	11.505	11.172	11.194	12.409
L2ST	14.062	14.399	14.498	14.099	12.553	13.231	12.433	10.757	11.800	11.636	11.296	11.318	12.860
L2ST	14.383	14.745	14.857	14.465	12.885	13.524	12.689	10.558	11.957	11.767	11.420	11.443	12.910

L25T	14.701	15.089	15.216	14.830	13.218	13.818	12.944	11.158	12.112	11.897	11.545	11.567	13.160
L25T	15.003	15.425	15.570	15.193	13.550	14.112	13.194	11.354	12.266	12.026	11.667	11.690	13.406
L25T	15.300	15.758	15.923	15.556	13.882	14.406	13.441	11.546	12.418	12.154	11.789	11.812	13.650
GNS	74.711	75.891	76.944	77.772	77.186	77.002	76.283	74.738	74.005	73.132	72.099	71.278	75.079
PER- CCLATION	1.251	0.942	1.084	0.000	2.391	2.815	1.675	2.432	1.768	1.422	0.008	0.098	15.886
ETUZ	0.072	0.232	0.462	0.877	1.577	1.893	2.065	1.970	1.619	1.245	0.511	0.248	12.771
ETLZ	0.000	0.000	0.000	0.328	2.393	2.623	2.801	2.402	2.000	1.428	0.000	0.000	13.974
TEMP.	21.1	31.3	37.4	52.1	71.7	71.9	75.7	76.7	65.1	59.7	43.4	31.8	53.2
CORRELATION COEF- FICIENTS	0.902	0.176	0.120	0.881	0.828	0.230	0.853	0.316	0.481	0.747	0.148	-0.038	0.582

DELTA STORAGE = 0.174 INCHES
 AATA = 3.088
 PGND STORAGE = 0.000
 ET BASEFLOW = 0.008

 TOTAL CHANGE = -2.921

SUM CAL TOTAL = 479236.
 SUM DBS TOTAL = 410407.
 SUM CAL SRIAT = 403264.
 SUM DBS SR = 344295.
 SUM CAL BF = 75972.
 SUM DBS RF = 66112.

620.0 896.01426.01020.0 806.0 510.0 164.3 62.0 60.0 77.5 120.0 93.0

0
 113 302

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1963

PRECIP	9.51	0.00	2.50	1.47	4.46	2.79	2.27	3.26	2.03	1.42	0.94	0.27	21.91
CALCULATED TOTAL RUNOFF	1172.	812.	2561.	2030.	4127.	6498.	1444.	1480.	955.	714.	455.	309.	22556.
OBSERVED TOTAL RUNOFF	750.	1384.	4393.	1311.	3231.	2494.	228.	168.	427.	121.	264.	117.	14689.
CALCULATED SURFACE RUNOFF	0.	0.	463.	101.	2365.	5314.	269.	766.	241.	236.	48.	0.	9804.
OBSERVED SURFACE RUNOFF	130.	488.	2967.	291.	2425.	1984.	63.	106.	367.	44.	144.	24.	9034.
CALCULATED INTERFLOW	13.	36.	2028.	1928.	1194.	202.	0.	0.	0.	0.	0.	0.	5401.
CALCULATED BASEFLOW	1159.	777.	71.	0.	568.	982.	1175.	714.	714.	478.	407.	309.	7354.
OBSERVED BASEFLOW	620.	896.	1426.	1020.	806.	510.	164.	62.	60.	78.	120.	93.	5855.
U2S	4.051	3.916	3.954	3.468	3.907	3.663	3.259	3.423	3.625	3.014	3.432	3.667	3.613
L2SA	10.555	10.752	11.192	11.004	10.961	10.078	8.556	7.522	6.977	6.269	6.086	6.158	8.830
L2ST	10.842	11.005	11.887	11.703	11.419	10.534	8.876	7.726	7.110	6.355	6.156	6.229	9.141
L2ST	11.033	11.230	12.161	12.024	11.743	10.815	9.078	7.857	7.196	6.411	6.203	6.275	9.323
L2ST	11.202	11.399	12.373	12.312	12.051	11.088	9.275	7.986	7.281	6.467	6.249	6.321	9.488
L2ST	11.343	11.540	12.563	12.588	12.352	11.357	9.472	8.116	7.368	6.524	6.297	6.369	9.645
L2ST	11.468	11.666	12.738	12.855	12.648	11.623	9.668	8.246	7.456	6.582	6.345	6.417	9.797
L2ST	11.593	11.790	12.895	13.109	12.935	11.883	9.861	8.376	7.543	6.641	6.394	6.466	9.944
L2ST	11.717	11.914	13.042	13.353	13.215	12.136	10.049	8.503	7.630	6.699	6.443	6.515	10.089

L2ST	11.841	12.038	13.180	13.585	13.478	12.374	10.228	8.626	7.714	6.755	6.490	6.562	10.227
L2ST	11.964	12.161	13.304	13.723	13.619	12.514	10.333	8.698	7.764	6.789	6.518	6.591	10.319
L2ST	12.086	12.283	13.426	13.845	13.734	12.613	10.408	8.750	7.799	6.813	6.539	6.611	10.396
GWS	70.665	70.235	70.746	71.353	71.364	71.302	70.828	70.395	70.074	69.792	69.603	69.443	70.484
PER- CCLATION	0.389	0.002	1.568	0.007	2.066	0.641	0.223	1.084	0.068	0.000	0.103	0.000	6.151
ETUZ	0.068	0.236	0.768	1.012	1.599	1.905	1.784	1.812	1.635	1.100	0.602	0.126	12.645
ETLZ	0.000	0.000	0.000	0.062	1.721	2.582	2.283	1.651	1.084	0.673	0.000	0.000	10.057
TEMP.	17.1	33.4	46.6	56.5	64.5	76.0	80.0	77.5	69.8	67.1	46.5	21.9	54.8
CORRELATION COEFF- FICIENTS	0.871	0.255	0.325	0.626	0.544	0.809	0.541	0.968	0.374	0.818	0.567	0.414	0.617

DELTA STORAGE = -2.829 INCHES
 AATA = 2.531
 POND STORAGE = 0.000
 ET BASEFLOW = 0.007

TOTAL CHANGE = -5.367

SUM CAL TOTAL = 501794.
 SUM OBS TOTAL = 425296.
 SUM CAL SPRINT = 418469.
 SUM JAS SR = 353329.
 SUM CAL HF = 84325.
 SUM OBS AF = 71967.

217.0 210.0 279.0 276.0 496.0 720.0 403.0 93.0 138.0 110.9 140.7 175.4

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SUMMARY TABLE -- BLACK VERMILLION RIVER BASIN -- 1964

PRECIP	0.24	0.40	1.30	5.12	2.77	10.92	1.37	5.29	1.72	0.51	2.61	0.94	33.21
CALCULATED TOTAL RUNOFF	226.	156.	172.	3454.	1173.	35130.	1258.	3126.	1452.	507.	840.	280.	47773.
OBSERVED TOTAL RUNOFF	256.	277.	325.	3947.	1427.	21585.	569.	645.	844.	111.	366.	302.	30653.
CALCULATED SURFACE RUNOFF	0.	0.	49.	3404.	1120.	34331.	240.	2658.	994.	29.	581.	0.	43405.
OBSERVED SURFACE RUNOFF	39.	67.	46.	3671.	931.	20865.	166.	552.	706.	0.	225.	127.	27394.
CALCULATED INTER-FLOW	0.	0.	0.	0.	0.	782.	140.	0.	0.	0.	0.	0.	922.
CALCULATED BASEFLOW	226.	156.	123.	49.	53.	17.	878.	468.	459.	478.	259.	280.	3446.
OBSERVED BASEFLOW	217.	210.	279.	276.	496.	720.	403.	93.	138.	111.	141.	175.	3259.
UZS	3.653	3.713	3.847	3.997	3.755	3.996	3.275	3.436	3.753	3.227	3.781	4.021	3.703
LZSA	6.158	6.214	6.432	7.902	8.945	10.380	9.470	7.952	8.311	7.719	8.119	8.952	8.049
LZST	6.229	6.294	6.502	7.971	9.002	10.828	10.366	8.550	8.737	8.077	8.476	9.310	8.365
LZST	6.275	6.330	6.549	9.017	9.039	10.887	10.499	8.645	8.805	8.134	8.534	9.368	8.428
LZST	6.321	6.377	6.595	8.062	9.077	10.937	10.612	8.725	8.863	8.184	8.583	9.417	8.484
LZST	6.369	6.424	6.643	8.109	9.116	10.978	10.700	8.786	8.907	8.221	8.620	9.454	8.532
LZST	6.417	6.473	6.691	8.157	9.155	11.017	10.770	8.835	8.943	8.251	8.651	9.484	8.575
LZST	6.466	6.522	6.740	8.204	9.195	11.053	10.820	8.869	8.968	8.273	8.672	9.506	8.612
LZST	6.515	6.570	6.789	8.252	9.234	11.085	10.849	8.890	8.983	8.286	8.685	9.519	8.643

LZST	6.562	6.618	6.836	6.299	9.273	11.114	10.871	8.906	8.994	8.295	8.694	9.528	8.670
LZST	6.591	6.646	6.864	8.327	9.296	11.132	10.884	8.915	9.001	8.301	8.700	9.534	8.687
LZST	6.611	6.667	6.885	8.347	9.313	11.144	10.894	8.922	9.006	8.305	8.704	9.538	8.699
GWS	69.324	69.239	69.176	69.135	69.113	69.604	70.434	70.076	69.914	69.687	69.531	69.402	69.555
PER- COLATION	0.000	0.100	0.421	3.177	0.667	5.679	0.000	1.827	0.409	0.000	0.707	0.726	13.712
ETUJZ	0.231	0.177	0.421	1.185	1.652	1.949	1.833	1.613	1.629	0.893	0.686	0.167	12.436
ETLZ	0.000	0.000	0.000	0.308	1.609	2.211	2.686	1.706	1.491	0.138	0.000	0.000	10.150
TEMP.	32.6	32.9	38.6	55.7	67.9	71.9	81.3	73.7	67.7	55.6	45.5	29.1	54.4
CORRELATION COEF- FICIENTS	-0.488	0.867	0.158	0.602	0.182	0.515	0.624	0.455	0.104	-0.177	0.852	0.158	0.506
DELTA STORAGE = 6.301 INCHES													
ATAA = 2.914													
PCND STORAGE = 0.000													
EY BASEFLOW = 0.006													
TOTAL CHANGE = 3.380													
SUM CAL TOTAL = 549566.													
SUM OBS TOTAL = 455949.													
SUM CAL SRINT = 462756.													
SUM OBS SP = 380723.													
SUM CAL BF = 86771.													
SUM OBS RF = 75226.													
153.9 274.11047.2 901.8 467.5 401.3 708.6 122.3 293.7 783.2 646.0 670.0													
0 119 285													

SUMMARY TABLE -- BLACK VERMILION RIVER BASIN -- 1965

PRECIP	1.55	2.28	1.47	1.47	2.44	8.08	4.43	2.44	9.34	0.56	0.08	1.95	36.00
CALCULATED TOTAL RUNOFF	522.	358.	4375.	4065.	2634.	4951.	9063.	2781.	18284.	2458.	1788.	1485.	52764.
OBSERVED TOTAL RUNOFF	430.	5202.	13210.	1139.	798.	10781.	8520.	161.	21155.	967.	650.	1071.	64083.
CALCULATED SURFACE RUNOFF	340.	5.	457.	103.	963.	3235.	3032.	347.	16831.	24.	0.	199.	25538.
OBSERVED SURFACE RUNOFF	276.	4927.	12163.	237.	331.	10379.	7811.	39.	20861.	184.	4.	401.	57614.
CALCULATED INTER-FLOW	0.	197.	3918.	3961.	1195.	1142.	5413.	0.	945.	509.	111.	155.	17547.
CALCULATED BASEFLOW	182.	155.	0.	0.	476.	574.	618.	2434.	509.	1925.	1677.	1131.	9680.
OBSERVED BASEFLOW	154.	274.	1047.	902.	468.	401.	709.	122.	294.	783.	646.	670.	6470.
U25	4.052	4.077	4.069	3.902	3.782	1.949	3.836	3.432	4.058	3.594	3.040	3.276	3.753
L25A	9.842	10.798	11.269	11.084	10.613	10.841	10.663	8.700	10.032	10.511	10.415	10.481	10.433
L25T	10.207	11.144	12.600	12.262	11.314	11.424	12.324	9.749	10.917	11.311	11.075	11.072	11.282
L25T	10.257	11.233	12.811	12.550	11.625	11.702	12.594	9.977	11.096	11.546	11.374	11.407	11.515
L25T	10.306	11.290	12.978	12.814	11.924	11.971	12.860	10.203	11.273	11.777	11.658	11.721	11.733
L25T	10.344	11.329	13.117	13.063	12.214	12.233	13.122	10.425	11.449	11.990	11.874	11.939	11.927
L25T	10.374	11.359	13.236	13.302	12.498	12.487	13.379	10.643	11.623	12.195	12.079	12.145	12.113
L25T	10.396	11.380	13.347	13.536	12.779	12.738	13.633	10.858	11.796	12.392	12.276	12.342	12.294
L25T	10.408	11.393	13.425	13.747	13.047	12.916	13.879	11.068	11.965	12.578	12.460	12.526	12.461

LZST	10.418	11.403	13.461	13.924	13.292	13.192	14.108	11.266	12.124	12.738	12.618	12.684	12.608
LZST	10.424	11.408	13.484	14.083	13.524	13.390	14.324	11.454	12.272	12.869	12.748	12.815	12.740
LZST	10.428	11.413	13.488	14.121	13.621	13.473	14.469	11.591	12.379	12.964	12.842	12.908	12.815
GWS	69.305	69.255	70.825	71.642	71.717	71.644	73.645	72.857	72.407	72.375	71.488	70.843	71.515
PER- COLATION	1.115	1.408	1.707	0.264	0.372	4.824	1.953	0.172	5.180	0.015	0.000	0.271	17.283
ETUZ	0.154	0.181	0.240	1.166	1.722	1.906	2.139	1.757	1.682	1.190	0.489	0.323	12.951
ETLZ	0.000	0.000	0.000	0.010	1.569	2.503	3.102	2.337	1.908	0.677	0.600	0.000	12.107
TEMP.	28.3	27.9	31.4	56.2	68.5	71.7	76.8	75.5	65.4	58.7	45.5	38.6	53.8
CORRELATION COEFF- FICIENTS	0.859	0.388	0.072	0.849	0.481	0.966	0.644	0.233	0.600	-0.199	-0.104	0.621	0.551
DELTA STORAGE =	6.168	INCHES											
ATA =	3.432												
POND STORAGE =	0.000												
ET BASEFLOW =	0.006												

TOTAL CHANGE = 2.730

SUM CAL TOTAL = 602331.
 SUM OBS TOTAL = 520032.
 SUM CAL SPINT = 505880.
 SUM OBS SR = 438337.
 SUM CAL BF = 56451.
 SUM OBS RF = 81695.

455.4 350.5 467.9 390.7 319.3 229.8 72.6 43.9 60.7 72.3 132.5 145.3

118 289

L2ST	13.069	13.361	13.609	13.591	13.424	12.613	10.557	9.078	9.548	8.850	8.703	8.703	11.243
L2ST	13.200	13.491	13.754	13.754	13.601	12.772	10.678	9.164	9.612	8.902	8.753	8.753	11.354
L2ST	13.293	13.585	13.848	13.848	13.696	12.855	10.741	9.209	9.645	8.930	8.780	8.780	11.418
GWS	70.415	70.233	70.519	70.341	70.190	70.042	69.846	69.673	69.558	69.430	69.315	69.232	69.897
PER- CELLATION	0.261	0.472	0.002	0.006	0.716	1.797	0.422	1.417	1.833	0.000	0.000	0.000	6.926
ETUZ	0.109	0.221	0.742	0.720	1.447	1.775	2.097	1.958	1.484	1.021	0.441	0.139	12.154
ETLZ	0.000	0.000	0.000	0.005	1.436	2.420	2.492	1.648	1.414	0.602	0.000	0.000	10.018
TEMP.	23.6	31.0	46.5	49.5	63.0	72.5	82.0	73.5	64.2	56.7	43.8	29.7	53.1
CORRELATION COEF- FICIENTS	0.144	0.191	0.636	0.396	0.765	0.749	0.371	0.873	0.657	-0.813	-0.530	0.579	0.509

DELTA STORAGE = -2.061 INCHES
 AATA = 2.117
 POND STORAGE = 0.000
 ET BASEFLOW = 0.006

TOTAL CHANGE = -4.184

SUM CAL TOTAL = 628986.
 SUM OBS TOTAL = 530285.
 SUM CAL SPRINT = 527883.
 SUM OBS SP = 445840.
 SUM CAL RF = 101104.
 SUM OBS RF = 84445.

149.7 170.7 176.3 318.2 310.7 1342.1 939.8 340.0 201.0 336.3 447.5 439.0

0 122 292

SUMMARY TABLE -- BLACK VERMILLION RIVER BASIN -- 1967

PRECIP	0.67	0.23	2.30	3.55	4.00	10.56	3.31	1.65	3.75	3.71	0.52	1.13	35.37
CALCULATED TOTAL RUNOFF	235.	80.	985.	869.	881.	28954.	6007.	3268.	2625.	3296.	1481.	1081.	49764.
OBSERVED TOTAL RUNOFF	430.	198.	646.	1528.	644.	30852.	1725.	537.	557.	4084.	502.	439.	42133.
CALCULATED SURFACE RUNOFF	124.	0.	929.	647.	226.	19727.	859.	695.	924.	1767.	167.	0.	26064.
OBSERVED SURFACE RUNOFF	282.	17.	470.	1210.	313.	29510.	785.	197.	356.	3747.	55.	0.	36962.
CALCULATED INTER-FLOW	0.	0.	0.	143.	324.	9227.	4454.	8.	0.	0.	0.	0.	14156.
CALCULATED BASEFLOW	111.	80.	57.	79.	332.	0.	694.	2565.	1701.	1529.	1315.	1081.	9544.
OBSERVED BASEFLOW	149.	171.	176.	318.	311.	1342.	940.	340.	201.	336.	448.	439.	5170.
UZS	3.744	3.947	3.834	3.977	3.739	4.035	3.566	3.654	3.616	3.922	3.840	3.860	3.810
LZSA	8.102	8.267	8.479	10.771	10.897	11.368	9.945	8.587	7.686	9.083	9.466	9.535	9.353
LZST	8.149	8.314	8.527	10.885	11.225	13.565	12.160	10.018	8.726	9.900	10.258	10.327	10.179
LZST	8.230	8.395	8.607	10.993	11.438	13.806	12.424	10.246	8.897	10.036	10.391	10.460	10.335
LZST	8.312	8.478	8.690	11.084	11.608	14.020	12.675	10.460	9.059	10.166	10.517	10.586	10.480
LZST	8.397	8.562	8.774	11.168	11.716	14.189	12.906	10.659	9.210	10.287	10.635	10.704	10.610
LZST	8.482	8.647	8.860	11.254	11.799	14.330	13.124	10.848	9.354	10.404	10.749	10.818	10.732
LZST	8.569	8.734	8.947	11.340	11.883	14.455	13.334	11.031	9.494	10.518	10.860	10.929	10.851
LZST	8.655	8.820	9.033	11.426	11.966	14.578	13.541	11.210	9.632	10.630	10.969	11.038	10.968

LZST	8.739	8.904	9.117	11.510	12.048	14.687	13.738	11.380	9.764	10.738	11.074	11.143	11.381
LZST	8.790	8.955	9.168	11.561	12.097	14.769	13.919	11.537	9.886	10.938	11.171	11.240	11.172
LZST	8.817	8.982	9.194	11.588	12.123	14.834	14.088	11.682	9.999	10.931	11.262	11.331	11.247
GWS	69.170	69.128	69.095	69.176	69.525	72.230	74.286	73.482	72.384	71.779	71.108	70.552	71.006
PER- COLLATION	0.172	0.030	1.032	2.098	1.709	6.587	0.762	0.151	1.029	1.982	0.214	0.356	16.124
ETUZ	0.153	0.231	0.771	1.225	1.293	1.960	1.838	1.842	1.384	1.177	0.471	0.216	12.562
ETLZ	0.000	0.000	0.000	0.000	1.100	2.821	2.869	2.250	1.411	0.806	0.000	0.000	11.256
TEMP.	28.6	32.1	45.6	56.7	60.2	71.7	74.9	73.1	64.8	55.2	40.6	31.7	53.0
CORRELATION COEFF- FICIENTS	0.952	0.830	0.790	0.366	0.895	0.492	0.349	0.835	0.728	0.782	0.445	0.429	0.498

DELTA STORAGE = 7.052 INCHES
 ARIA = 3.894
 POND STORAGE = 0.000
 ET BASEFLOW = 0.036

 TOTAL CHANGE = 3.152

SUM CAL TOTAL = 678750.
 SUM OBS TOTAL = 572418.
 SUM CAL SPRINT = 568103.
 SUM TWS SP = 482802.
 SUM CAL RF = 110648.
 SUM OBS BF = 89615.

DEVELOPMENT AND TESTING OF A CROP DEPENDENT EVAPOTRANSPIRATION
FUNCTION IN THE KANSAS WATERSHED MODEL

by

AHMAD NAWAZ

B.E., Peshawar University, Pakistan, 1966

AN ABSTRACT OF A MASTER'S THESIS

Submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas U.S.A.

1975

ABSTRACT

A new evapotranspiration function for the Kansas Water Budget model is developed and tested on the Black Vermillion watershed in Northeastern Kansas. The purpose of the new ET function is to improve the response of Kansas model to daily climatic changes and to the distribution and stage of growth of crops on an agricultural watershed. The new function uses the Penman Combination equation modified by a three coefficients which account for, 1) the soil moisture availability, 2) the increased soil surface evaporation following rainfall, and 3) for the crop transpiration efficiency which varies with the crop and the stage of growth.

The new function was programmed into the present Kansas model and both the present and the revised models were applied to the Black Vermillion for comparison purposes. Improvements were noted in daily and weekly responses of the revised model. In particular, the overall correlations of calculated to observed daily streamflows for the 1954 through 1967 study period were improved from 0.58 to 0.78 with the revised model.

The significant improvement in streamflow simulation accuracy requires a modest increase in required input data and computer time. If planning efforts revolve around optimizing yields from agricultural watersheds, the extra cost would be warranted.