# SENSITIVITY OF PARAMETER VALUES OF A CONTINUOUS WATERSHED MODEL TO DATA ERRORS

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SENSITIVITY OF PARAMETER VALUES OF A CONTINUOUS WATERSHED MODEL TO DATA ERRORS

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# CHAPTER I

## INTRODUCTION

Information on streamflow, precipitation, and potential evapotranspiration is necessary input to a continuous watershed model. The data available to provide this information, however, contain inherent errors. These errors are introduced while measuring, recording and processing the basic data and in using that data to represent conditions pertaining to the watershed being modeled. The parameters which are sensitive to errors in the data would be difficult to correlate to physical characteristics of a watershed. This correlation is necessary for application of hydrologic models to ungaged watersheds. This study is therefore on the effects of data errors on model calibration rather than on the direct effects of the errors on simulation.

For example, there is no means to determine the true accuracy of point precipitation as measured by a gage (20). Rainfall, furthermore, is noted for its variability in space and time, and this often makes the determination of the total rainfall on a watershed from a gage placed at one point approximate. This spatial variability, which is more pronounced in short duration thunder storms, may not be entirely real, but instead may be a result of errors in point rainfall measurement (19). It is virtually impossible to make an accurate assessment on the error in estimating watershed precipitation from gage precipitation since the true precipitation on the watershed can not be determined. It is, however, methodologically easier and also important to assess error present in the point precipitation data.

Streamflow is the most reliable data of the three types previously mentioned. During normal flow periods the stream gage is usually representative of the actual flow which occurs. The stream gage has generally been calibrated for the cross-section within the immediate channel. However, when the cross-section is changed due to over-bank flow errors may be introduced in the extension of the stage-discharge curve for a particular gage. A major flood may also change the channel shape and therefore introduce errors into the total stage-discharge curve.

Potential evapotranspiration (PET) is different from the above two data types. PET may be estimated from various empirical equations such as Penman's equation and Hargreaves equation (8). Use of pan evaporation data is also a common method of evaluating the PET. The same problem is present in using pan data as with precipitation in that pan data may poorly represent PET over the watershed and the pan data itself may have errors. Still another method is a lysimeter which can be employed for directly measuring the evapotranspiration. Each of these methods may produce different results. At this point, a statement of which method is best would be impossible. It suffices to say that different methods are currently being used and that the results vary. This leads to the conclusion that the method used can affect the prediction process and the parameter values used in modeling. The degree to which this variation affects the model parameters and simulation will be discussed in the following chapters.

To determine the effects of errors in the data on model parameters, it is necessary to compare results between using true and erroneous values of the data. The strategy of this study is to develope an "error free" data set, and the parameters calibrated from this data are hereafter referred to as the "base set". These base set parameters serve as a control to compare with the variations caused by errors introduced in the data. As depicted in Figure 1, a base set of parameters is developed using precipitation and calculated PET data as input. The parameters are optimized using a pattern search procedure with minimum average absolute error between observed and predicted daily streamflow as the optimization criterion.

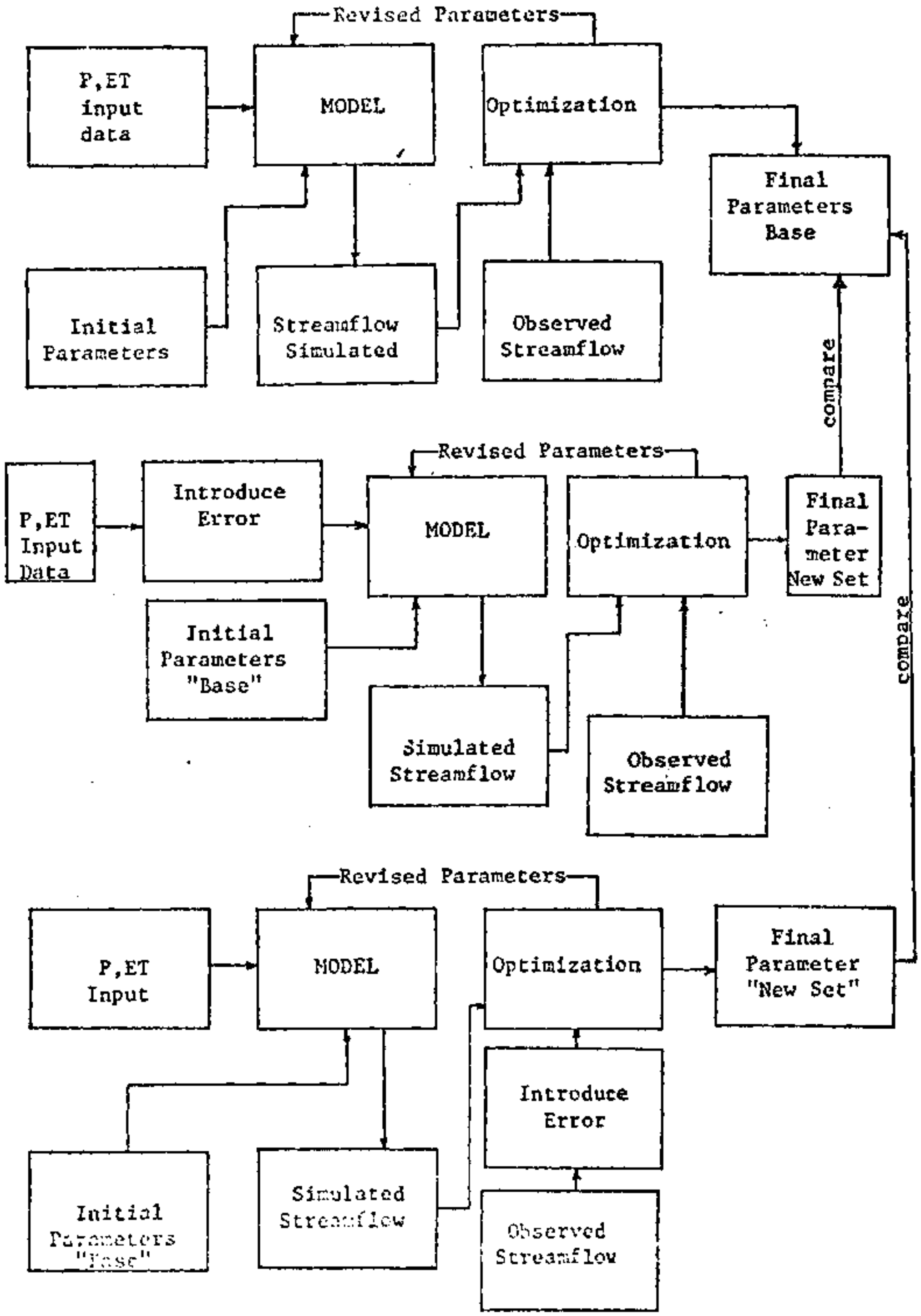



Figure 1. Flow Chart of Research Methodology

# CHAPTER II

# LITERATURE REVIEW

The major goal in hydrology is to predict watershed hydrological response. For an ungaged watershed, this implies the need to correlate the parameters of a hydrologic model to measureable watershed characterisitcs. However, the hydrologic data (i.e., precipitation, streamflow, and evapotranspiration) which are used to determine the above mentioned parameters contain errors as depicted on Figure 2. A great deal of research has been devoted to their origin and magnitude. The following sections discuss the findings and conclusions of this research on each of the three types of hydrologic data listed above.

## Precipitation

Precipitation measurements have often been accepted at face value although there is little known of how to assess the error in measurement due to the type of raingage used (20). The assumption that recorded data are entirely accurate is made by many people in everyday work. While there is no means of measuring, to a known high degree of accuracy, the quantity of precipitation that falls at a particular point on the earth's surface (20), being aware of the effect that errors will have on a prediction procedure is a must.

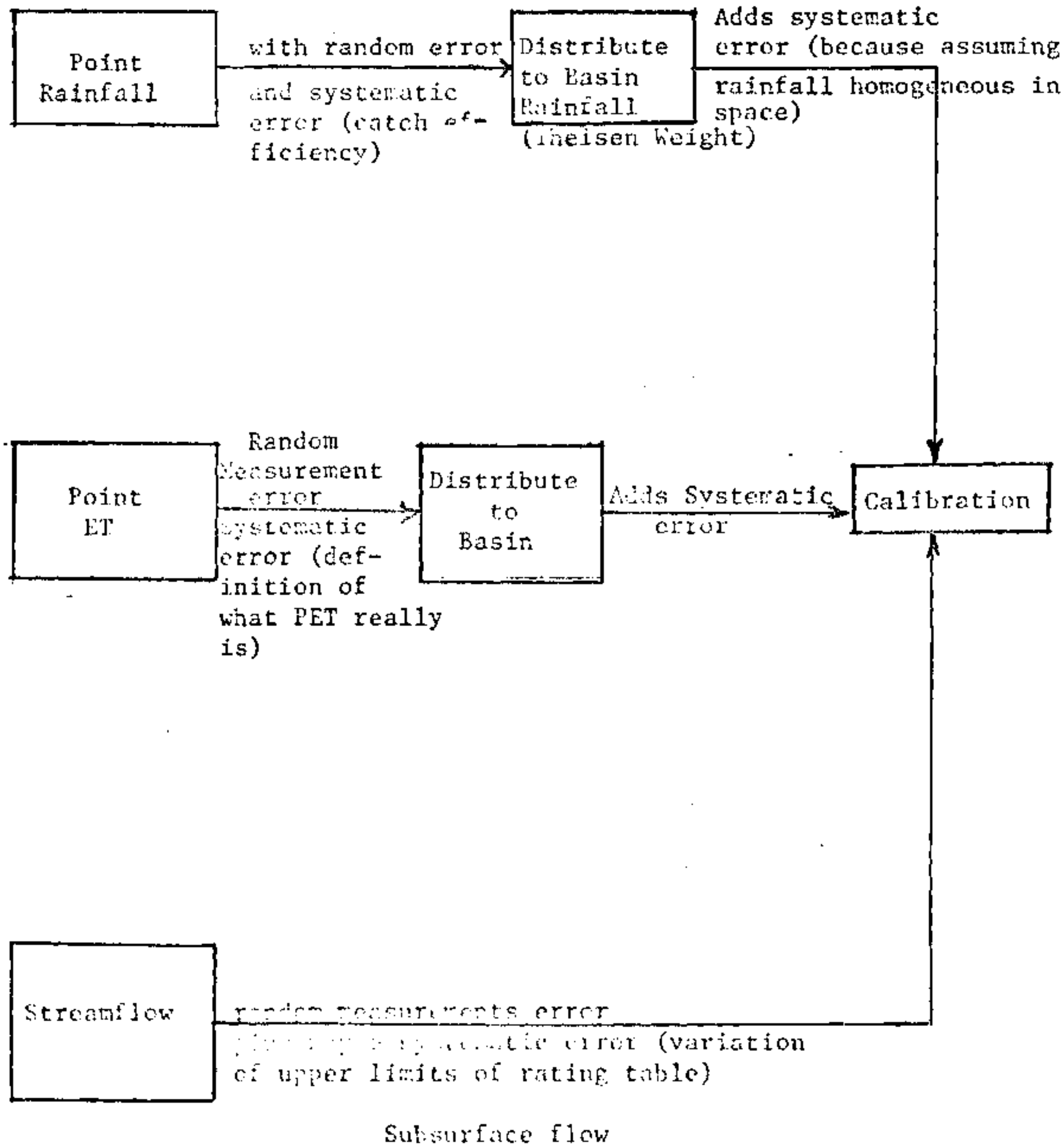



Figure 2. Types of errors Associated with Three Data Types

The effects of random errors in precipitation measurement have been the subject of considerable research although, according to Rodda (20), they tend to be compensating in the long run. Systematic errors appear to be less common but can induce more serious errors in optimized parameters. One case is the extrapolation of precipitation from a distant gage to a watershed (20). Rodda also discusses the difficulties with specific rain gage types and the errors associated with each. The main cause of systematic measurement error is wind which occurs during the period of precipitation. Kurtyka found wind caused errors to be negative (20).

Dawdy (6) has presented a fairly detailed analysis of the considerations for evaluating urban hydrologic models and has evaluated the effects of random errors in the data. He states, "If a fitting process is used the parameters will deviate from their true values in order to minimize the deviations between the simulated and observed records as specified in the objective function" (6). The fitted model parameters would then deviate from their population values because of the random errors in the data. Dawdy made has study by intoducing a random error with mean zero and standard deviation of 10 percent to all rainfall values. The adjusted data were used to calibrate a similation model to obtain a parameter set. This parameter set was then compared to an "optimum" parameter set based on the original rainfall data. Dawdy concluded that the impact of errors on the simulation process depends in part on whether the error is a random error of a quantity which is measured or whether the error is in the use of the index which is an approximation to something which cannot be measured (6). Point rianfall is measurable and is used as an index to basin rainfall. The model may have been calibrated to one set of precipitation data which determined the "best fit" of the parameters. Serious errors in simulation may develop when using these "best fit" parameters with another period of precipitation which contains events that are not adequately represented by the index.

Analysis of random data errors was also presented by Ibbitt (12). He assumed an "error free" set of precipitation data and obtained an optimum set of "base" parameters in the same method used by Dawdy. The error distribution was assumed to be normal with the mean being that of the "error free" data and a standard deviation of 10 percent. Negative values of precipitation were rejected and either zero or a value equal to the smallest non-zero quantity that could be measured was substituted (12). A major difference between Dawdy and Ibbitt was in the treatment of potential evapotranspiration as discussed in the last section of this chapter. A major conclusion by Ibbitt was that the variation in the final parameter values for fittings to error-contaminated data were no greater than for the error free case (12). The value of the fitting criterion was found to depend largely on the errors in the runoff record. This would stand to reason when the optimization function is some form of minimizing the difference between observed and simulated streamflow.

Huff and Changnon have presented data showing a definite variation in intensity over raingage networks in Illinois (11). The gage network is much more detailed than would normally be encountered in a hydrologic investigation. With this type of information it is apparent that distributing point rainfall from one or two gages can induce sizable errors, the sign of which would probably depend on the location of the gage relative to the storm center, and might be either random or systematic, depending on other factors such as orographic influences.

The effects of precipitation error on derivation of unit hydrographs was presented by Laurenson and O'Donnell (14). Their general approach was: (1) to set up a true rainfall-excess hyetogarph and a true unit hydrograph, both synthetic but of reasonable shape; (2) to determine the true surface runoff hydrograph by convolving the true hyetograph with the true unit hydrograph; (3) to introduce known reasonable errors into the true hyetograph or true runoff hydrograph, or both, thus producing an erroneous hyetograph or an erroneous runoff hydrograph or both; (4) to apply the various methods of derivation to the erroneous hyetograph or erroneous runoff hydrograph or both, thus deriving the erroneous unit hydrograph; and (5) to compare the derived erroneous unit hydrograph with the original true unit hydrograph, and to compute various measures of the error it contains.

Four methods of derivation of the unit hydrograph were then compared. These methods were 1) harmonic analysis method (O'Donnell 1966); 2) discrete Laguerre function method; 3) least squares regression analysis; and 4) two parameter gamma distribution method. In only one case, the use of the Laguerre function method, was the shape of the hyetograph a major contributor to error in the unit hydrograph derived.

Hershfield has investigated the pattern of the rain gage network in a watershed and the influences which this pattern has on the calculated rainfall distribution (10). The conclusion was that the location of the gages was more important than the gage density. This coincides with the conclusions of Rodda (20) as to placement of gages.

The effect of precipitation gage network density on storm pattern definition have been presented by Brandsetter and Morgan (2). A procedure was developed and presented for evaluating the gage network density. Storm evolution was investigated using a 20-gage network over a 10-square miles area. Brandsetter and Morgan conclude that any single gage within the watershed is as representative of the area means as any other, provided that there are no systematic effects (2). Their finding is that at the locations investigated, the density of gages required for urban storm drainage design does not have to be more than 1 gage per 10 square miles at the maximum (2).

## Streamflow

Of the three types of hydrologic data used, streamflow data is probably the least prone to error (20, 5). Measured streamflow data is compared with simulated streamflow data to determine the "goodness of fit" of a predicition model. In using deterministic models, the relationship of input to output is such that, once input is known, the output is wholly predictable. If there are errors in the observed data, there will naturally be errors in the simulated record.

Dawdy has investigated the significance of random errors in streamflow data on the parameters used in a simulation model (5). Dawdy first optimized a set of parameters to data which was assumed "error free". This data was used as a "base set" for later comparison. Random errors with mean zero and standard deviations of 5 and 10 percent were applied to the original record. These error distributions for the mean daily discharge were determined from the U.S. Geological Survey (1961) ratings of stream gages. The interpretation is that a gage rated as "good" will have a standard deviation in mean daily discharge of 5 percent. Peak discharge is measured less accurately than mean daily discharge. As stated by Dawdy, peaks that are "fairly well" defined by discharge measurements (peak flows are no more than twice the highest current meter reading) have a standard error of approximately 5 percent. When not so defined, the peak flows are computed by means other than extrapolating rating curves, such as by the slope area method. The standard error would then be about 10 percent.

It was concluded by Dawdy that estimates of model parameter values are not as sensitive to random errors in streamflow as they are to errors in precipitation. This may be explained by observing that errors in input (precipitation) may be magnified because a precipitation excess is used in the routing and any absolute error in input becomes an absolute error in the precipitation excess prior to routing. An example of error magnification would be when the excess is defined as all precipitation above a constant value. Another example of this magnification occurs with the use of the type of infiltration function shown in Figure 3. In either case, the error present in the precipitation data will represent a larger percentage in the excess than in the total precipitation.

On the other hand if the excess is defined as a percentage of the total precipitation, then errors in the precipitation will be transferred proportionally to the excess. The objective function for optimization is usually stated in terms of some comparison with streamflow. Therefore, error in the streamflow would be transfered proportionally to the output of the model (5).

Errors in input data cause errors in different portions of the model than do errors in output data. Random, unbiased errors in input usually are compensated by adjustments in the parameters associated with the loss function (infiltration, interception, and detention) if a long enough record is used (5). Similar errors in streamflow usually are compensated by parameters associated with

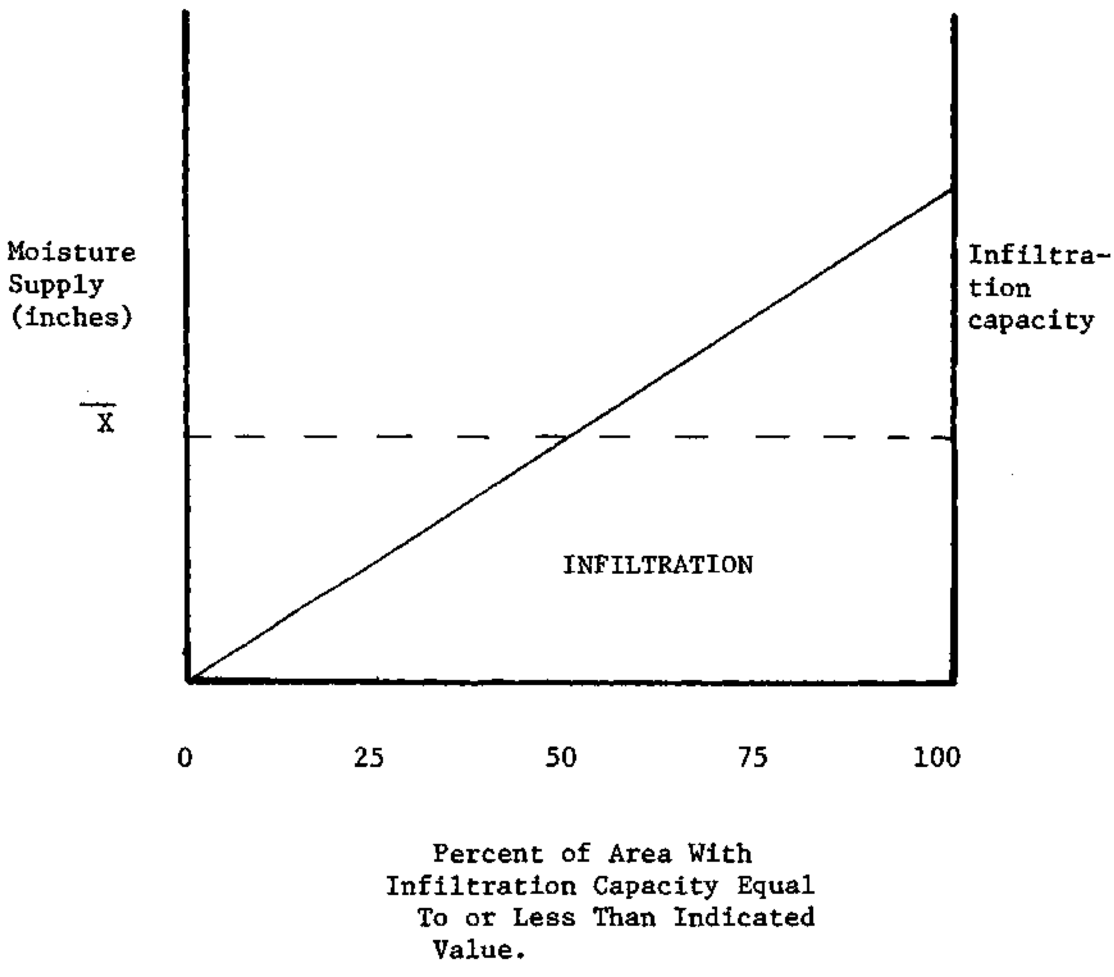



Figure 3. General Infiltration Function

the routing function.

Ibbitt has also investigated the effects of random data errors on the parameters of a watershed model (12). By using the data from Dawdy and O'Donnell (1965), Ibbitt introduced a random error. The adjusted value was taken from a normal distribution of 10 percent. Negative values in streamflow were treated in the same manner as those in precipitation discussed previously.

Ibbitt found that the larger errors were generated by errors in the streamflow data. It was noticed that the parameter values varied about the true parameters values based on the parameter sensitivity to output (12). This would stand to reason because the more sensitive parameters would tend to have larger perturbations about their means than the less sensitive ones.

## Evapotranspiration

Estimation of evaporative losses are becoming more important due to the increased use of water and because evaporation is a major factor in the availability of runoff. To properly simulate streamflow, estimates of potential evapotranspiration are essential.

Jobson (13) has investigated the effects of time averaging the meteorologic parameters of wind speed and temperature on the computed evaporation (13). Averages of 30 minute data over periods of 3 hours, 1 day and 1 month were used in conjunction with a mass transfer formula shown below.

$$e = Nu\,(e_o - e_a) \qquad (1)$$

where:

$e$ = evaporation rate

$N$ = mass transfer coefficient

$u$ = wind speed

$e_o$ = saturated vapor pressure corresponding to temperature of the water surface

$e_a$ = vapor pressure of the air

Due to the rapid fluctuations of the values on the right side of the equation, the use of average values could introduce a sizeable error. The conclusions reached were that using the 3-hour or 1-day averages produced very little effect on the mean error. Larger variations were indicated for the monthly averages (13). These larger errors were a result of the convariance of the wind speed and vapor pressure and temperature. The variance of the error (simulated minus observed) distribution was reported to increase by a factor of more than 6 as the averaging time increased from 3 hours to 1 day. For averaging time larger than 1 day the variance of the error distribution increased very slow.

In investigating constant bias errors and random errors in potential evapotranspiration (PET), Parmele found that a constant bias of 20 percent in PET has a cumulative effect and results in a considerable error in simulated hydrograph peaks (13). The use of a random error did not influence the streamflow prediciton to a measureable amount.

Using a positive bias of 10 percent on the PET decreased the total streamflow by 1 to 3 percent. A negative bias of 20 percent resulted in an increase in streamflow of 2 to 7 percent. When a random error of up to + 50 percent of daily ET was introduced along with the bias it did not significantly change the total predicted flow. The soil moisture conditions were either too low, resulting in an under prediction of flow from the positive bias, or too high resulting in an over prediction of flow from the negative bias. The results are not very different from those presented by Crawford and Linsley (1966), although Parmele's results are more detailed on the necessity of using representative PET data for streamflow simulation.

Both Ibbitt (12) and Dawdy (5) have treated errors in PET as random errors. Although Dawdy does not discuss the detailed affect of the PET error on model output, Ibbitt explains why the effects are much less by noting that the error will have no effect if the available soil moisture will allow evaporation of an amount less than that which could be evaporated (12). For example, if the correct value for PET is 3 millimeters (mm) and the error value is 2.7 mm, the error of 0.3 mm will have little effect if the available moisture will only allow an actual evaporation of 1.0 mm. In this aspect, not all the PET errors were actually used during the study.

# CHAPTER III

## Data Error Synthesis

This chapter explains the basic objectives of this research study in building on the previous research outlined in Chapter II. There is a definite need to investigate errors which may be introduced into runoff simulation due to poor calibration as a result of erroneous information on precipitation, streamflow, and/or evapotranspiration. If, within the present "state of the art", it can be determined that errors in the data do not affect the predicition process, then more effort could be directed toward improving the predicting model. If, after all points are considered, benefits from improved predictions are less than the cost of improving the model, then it would be a misuse of technology to attempt to sophisticate the process any further.

### Precipitation

The effects of random errors as discussed by Dawdy (5) and Rodda (20) have been investigated. Therefore, two additional types of errors are investigated in this study. To do this, adjustments to the hourly rainfall record associated with the largest storm of the year were made by multiplying the measured storm data by 0.7, 0.8, 1.1, and 1.2.

Since flood peaks are often of particular interest in hydrologic simulation and efforts to match them may strongly affect the estimates of parameter values made in model calibration, the effects of errors in measurement of precipitation during the largest storm was also explored.

A third type of error is the systematic type discussed by Rodda (20). This type of error could result from local meterological conditions, orographic effects, or consistently low rain gage catch efficiencies. For the purpose of the present study, adjustments to the existing precipitation record were made by multiplying the measured data by 0.8, 0.9, 1.1, and 1.2. This was to allow an assessment of the effects of errrors in basin precipitation of -20 percent, -10 percent, + 10 percent, and +20 percent.

## Streamflow

The effects of random errors in streamflow, as discussed previously and in the literature (5,20), is to increase the error between the simulated and measured hydrographs. If the random errors are not serially correlated and are introduced on a daily basis they will produce perturbations on the output hydrograph as shown in Figure 4. This type of error has been investigated rather thoroughly and shows generally that random errors may be compensated in the calibration process (5,20).

To build upon these investigations, it would be helpful to obtain some quantitative measure in those cases where extrapolation techniques were used to extend the rating curve for peak floods. It is possible that a systematic error could be introduced into the

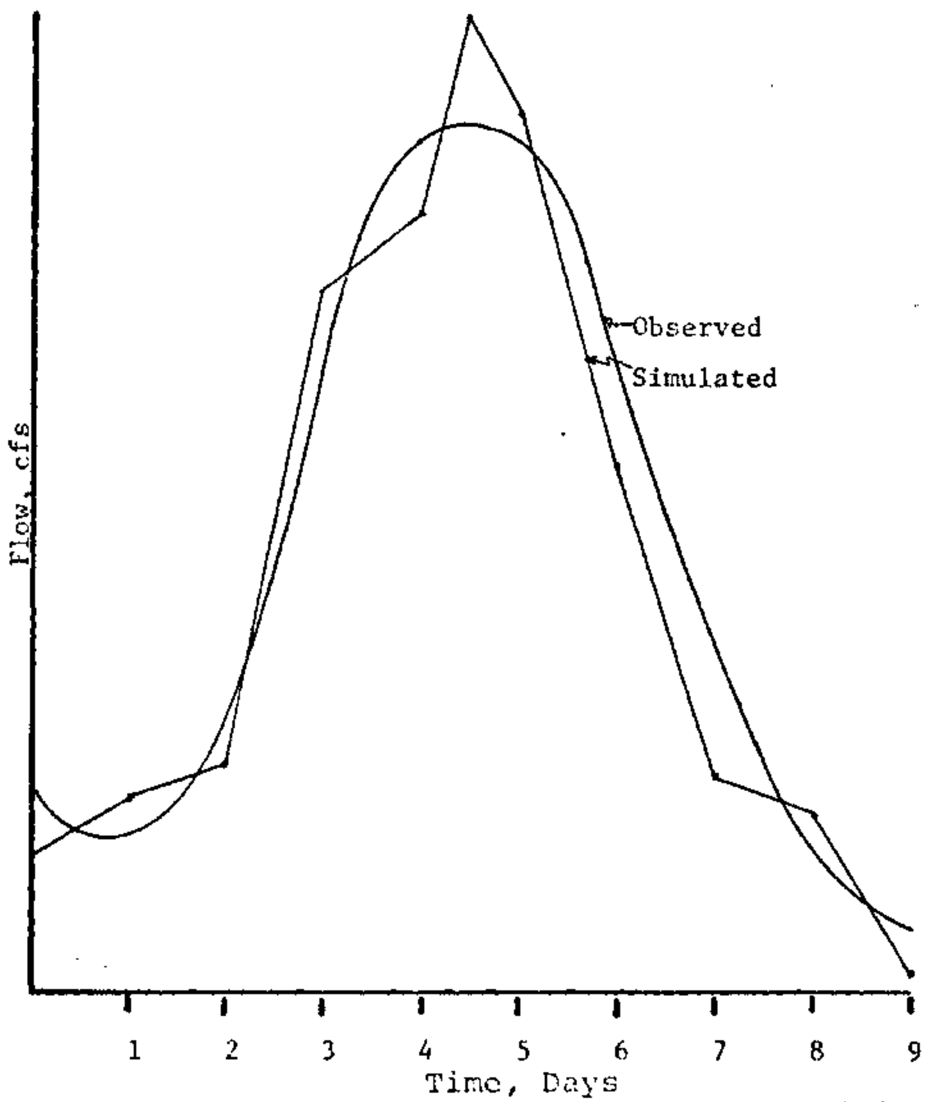


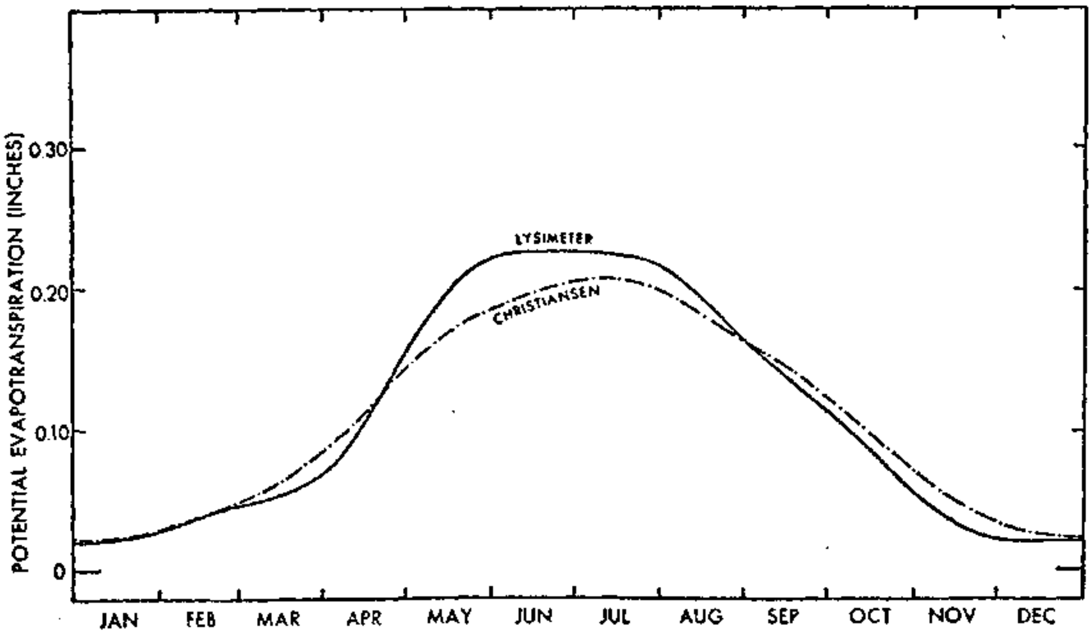

Figure 4. Effects of Random Daily Precipitation Error on Hydrograph

data by using an extrapolated rating curve. For this study, errors were introduced in the streamflow recorded for the three largest peak events during the year. Initially it was felt that a value of flow corresponding to the channel capacity should be used as a lower limit for the adjusted streamflow data. However, since the objective of this study is to assess the effect of errors in streamflow due to errors in extrapolating the stage-discharge curve, a lower bound for adjustment was selected so that at least three events within the year would be included. All flows above this lower bound were adjusted by + 20 percent and - 20 percent. The results of introducing the above errors into the streamflow record are presented by Chapter V.

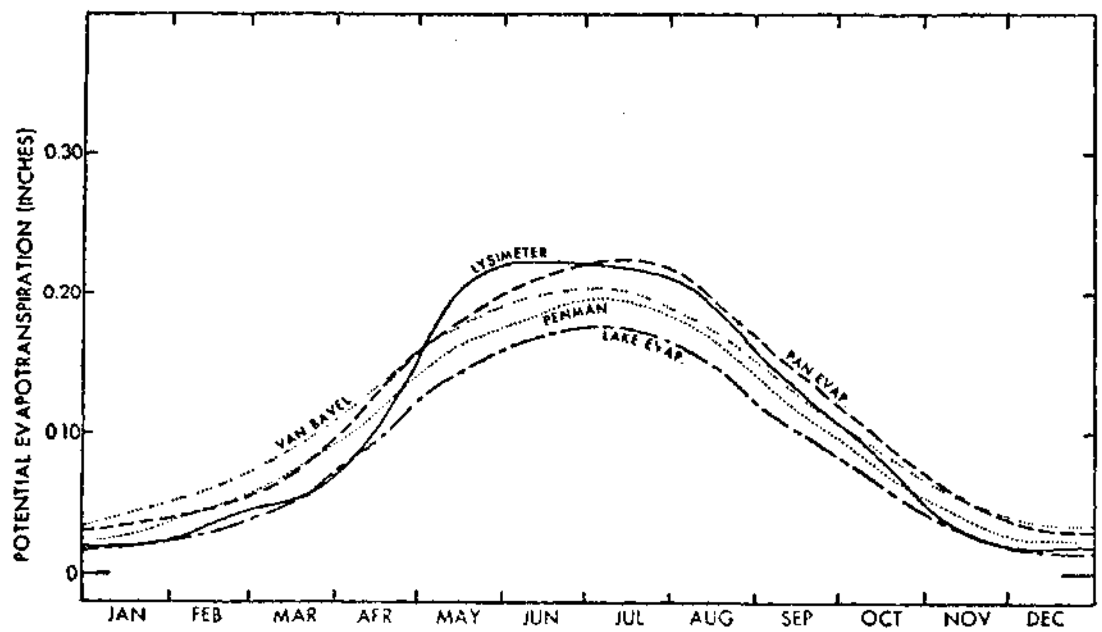
## Potential Evapotranspiration (PET)

The investigation of random errors in evaporation as discussed in the literature is helpful but does not give a practical insight into relaistic errors and their effects on the simulation process. As discussed in reference 1, there are various empirical methods of calculating potential evapotranspiration. The variation in each of the methods is illustrated on Figure 5 and 6.

Three forms of PET data were used in this study. These were, 1) computed daily PET (Hargreaves 1971), 2) 20-year daily average of the calculated PET, and 3) daily pan data. Comparisons of 2 and 3 with 1 are presented in Chapter 5. In addition, the pan data was adjusted so that the yearly total would equal that of the

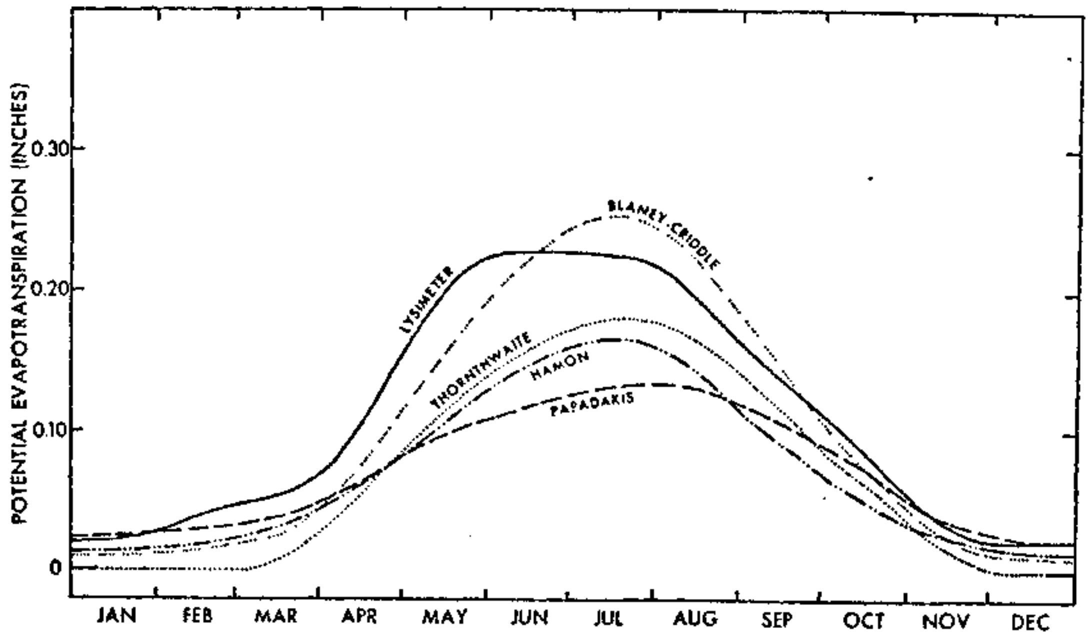



-Average daily potential evapotranspiration (*PET*) as estimated by a lysimeter growing deep-rooted grass-legume and

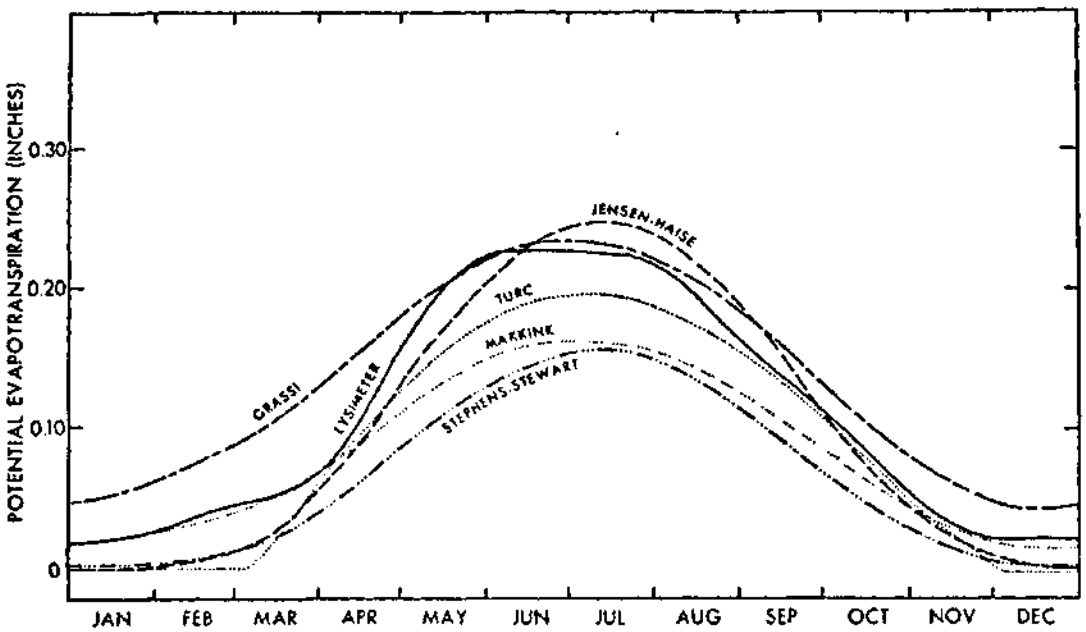



Average daily potential evapotranspiration (*PET*) as estimated by a lysimeter growing deep-rooted grass-legume and as computed by the Penman, van Bavel, and U.S. Weather Bureau methods.

Figure 5. Comparison of Daily ET Calculated by Various Methods (Reference 1)




Average daily potential evapotranspiration (*PET*) as estimated by a lysimeter growing deep-rooted grass-legume and as computed by the Thornthwaite, Blaney-Criddle, Hamon, and Papadakis methods.




Average daily potential evapotranspiration (*PET*) as estimated by a lysimeter growing deep-rooted grass-legume and as computed by the Grassi, Stephens-Stewart, Turc, Jensen-Haise, and Makkink methods.

Figure 6. Comparison of Daily
ET Calculated by Various Methods (Reference 1)

calculated data. This was done in an effort to determine the effects of the method of determining PET data and not the effects of annual bias.

# CHAPTER IV

## Data Preparation

This chapter describes the watershed, the simulation model, and the hydrologic data used. Detailed information concerning the simulation model is not included, but a brief description of the parameters used and the optimization criterion is provided.

## Watershed Description

The Camp Creek Watershed is located south of Atlanta, Georgia, covering parts of three counties (Fulton, Clayton, and Fayette), and has a total area of 17.0 square miles. The watershed extends north from State Highway 85, where the stream gage is located, to Godby Road and east and west from the town of Riverdale to National Highway (Figure 7).

The area is fairly hilly with an average elevation of 920 feet above sea level. The land ranges between a maximum elevation of 1,000 feet above sea level to a minimum of 840 feet above sea level.

Approximately 80 percent of the surface soil of the watershed is in the Appling-Cecil Association. The remaining 20 percent is mainly from the Congaree-Chewacb-Wickham association (22). The soil association and respective permeabilities are shown in Table 1.

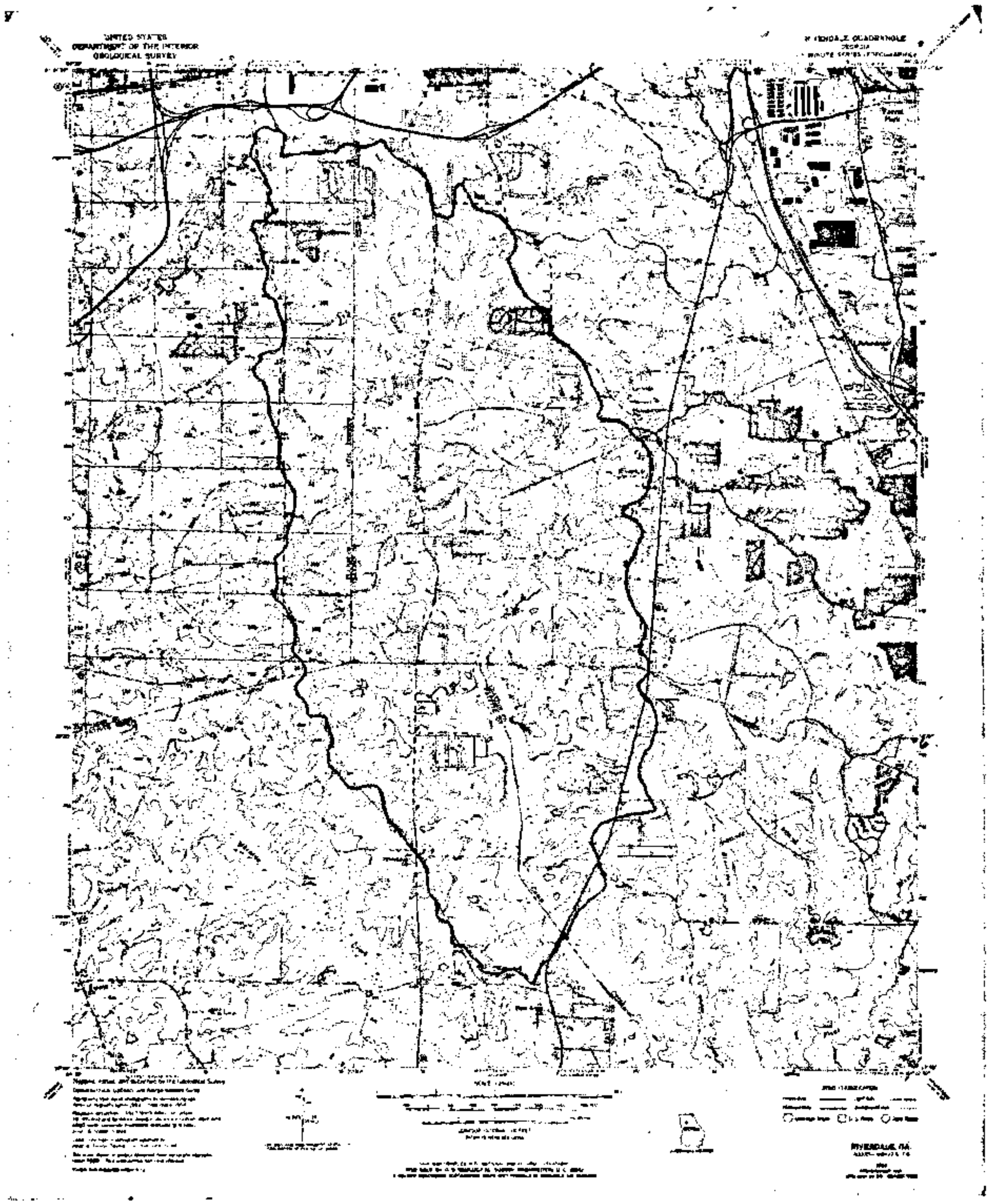


Figure 7. Map of Camp Creek Watershed

Table 1. Camp Creek Soil Associations and Permeabilities

| Soil | Permeability Class | Permeability in/hr |
|---|---|---|
| Cecil-Lloyd-Appling | Moderate | 0.6-2.0 |
| Appling-Cecil | Moderately Rapid | 2.0-6.0 |
| Congaree-Chewacb-Wickham | Rapid | 6.0-20.0 |

Camp Creek Watershed is located in the area which has relatively long, warm summers and short, mild winters, with moderately heavy rainfall (22). These conditions have been responsible for considerable leaching of soluable materials as bases. The less soluable material and collodial matter have been transfered down through the soil.

## Model Description

The continuous watershed model used is the Georgia Tech Model. The concepts of the model originated with the Stanford Model (3) and Kansas Model (17). The Georgia Tech Watershed Model was programmed by Dr. A. M. Lumb. The major elements of the model are shown on the attached flow chart, Figure 8.

Precipitation and potential evapotranspiration are the major data inputs to the model. Within the model, precipitation is stored in the three surface storage and three soil mositure storages depicted in Figure 8. A list of the input parameters and their definitions are included in Table 2.

The optimization objective used throughout this study was to minimize the sum of the absolute errors between the observed and the predicted daily streamflow. This objective function is used because the watershed has a fairly constant base flow with peaks throughout the year.

Optimization is accomplished through a direct search technique called Pattern Search (4). A flow chart of Pattern Search is included as Figure 9. The technique starts at an arbitrarily

Table 2. Definitions of Parameters used in Georgia Tech Watershed Model

| Parameter | Description |
| --- | --- |
| | AREA PARAMETERS |
| SWAREA, | SUBWATERSHED AREA (SQ. MI.) |
| IMPA, | FRACTION IMPERVIOUS AREA |
| FALZ, | FRACTION ALLUVIAL AREA |
| FHLZ, | FRACTION HILLSIDE AREA |
| PSRP, | MAXIMUM AREA FOR SRS (FRACTION) |
| PSDP, | AREA WHEN SDS+SDSN (FRACTION) |
| | STORAGE PARAMETERS - INCHES |
| ICMN, | WINTER INTERCEPTION STORAGE |
| ICMX, | SUMMER INTERCEPTION STORAGE |
| SRSN, | SURFACE RETENTION STORAGE CAPACITY |
| SDSN, | SURFACE DETENTION STORAGE CAPACITY |
| UZSN, | UPPER SOIL ZONE CAPACITY |
| LZSN, | LOWER SOIL ZONE CAPACITY |
| GWSF, | GROUND WATER STORAGE AT BASEFLOW |
| | DRAINAGE PARAMETERS - INCHES/HOUR |
| PPIF, | INFILTRATION PARAMETER |
| PSUP, | INFILTRATION FUNCTION SHAPE PARAMETER |
| PPUL, | UZS TO LZS PERCOLATION PARAMETER |
| PLGP, | LZD TO GWS PERCOLATION PARAMETER |
| PDGP, | UNDERFLOW FROM GWS PARAMETER |
| PLZU, | UNDERFLOW FROM LZS PARAMETER |
| YYM, | OVERLAND STORAGE CONSTANT (HOURS) |
| INFP, | INTERFLOW PARAMETER |
| KGWF, | BASEFLOW RECESSION CONSTANT (DAILY) |
| | EVAPOTRANSPIRATION PARAMETER |
| FIP, | INTERCEPTION EVAPORATION PARAMETER |
| EVP, | UZS-LZS EVAPORATION PARAMETER |
| FTGWP, | GROUND WATER TRANSPIRATION PARAMETER |
| SRS, SDS, UZS LZS, GWS | INITIAL STORAGE VALUES |

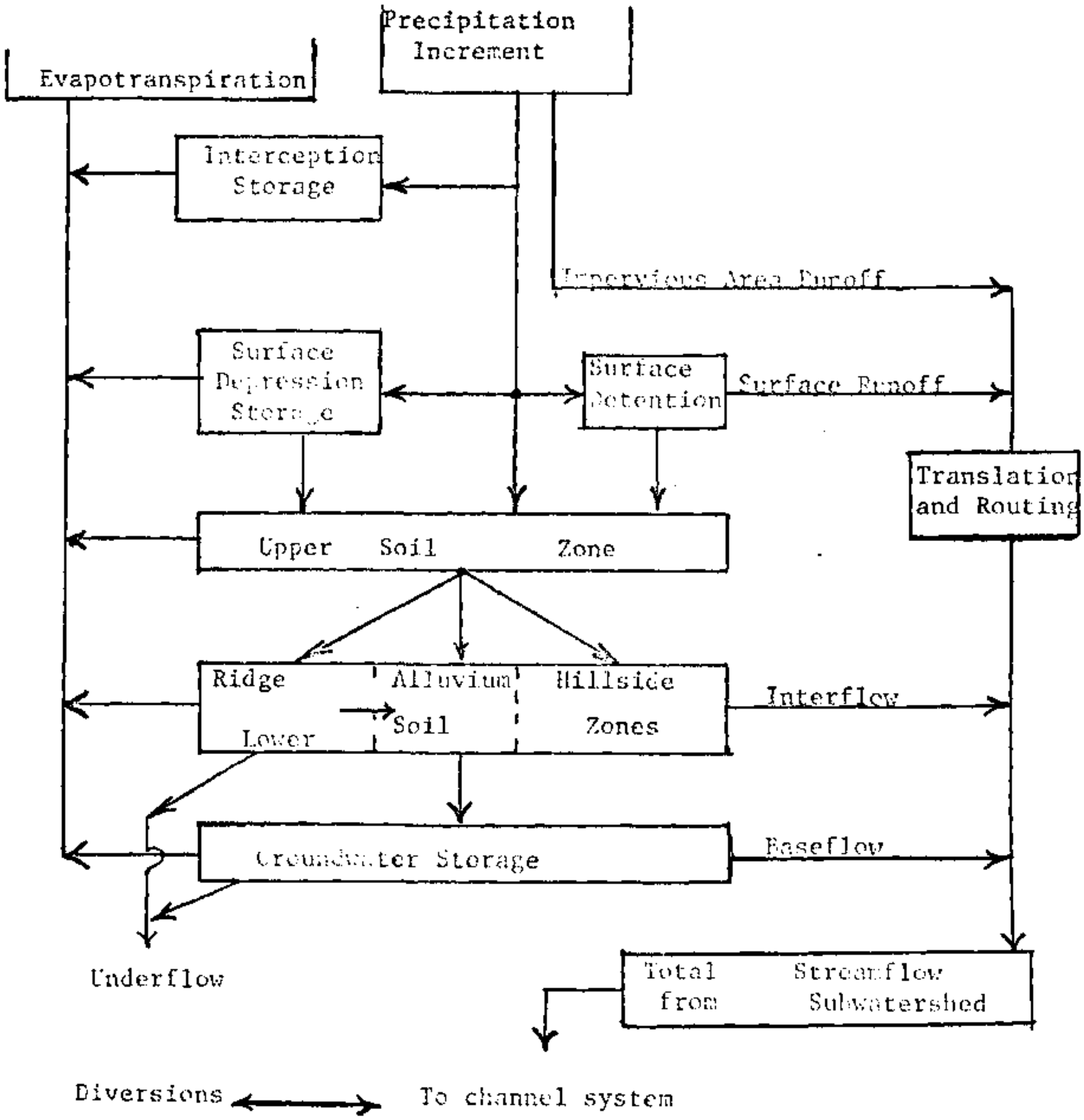



Figure 8. Flow Chart for the Geregia Tech Watershed Model

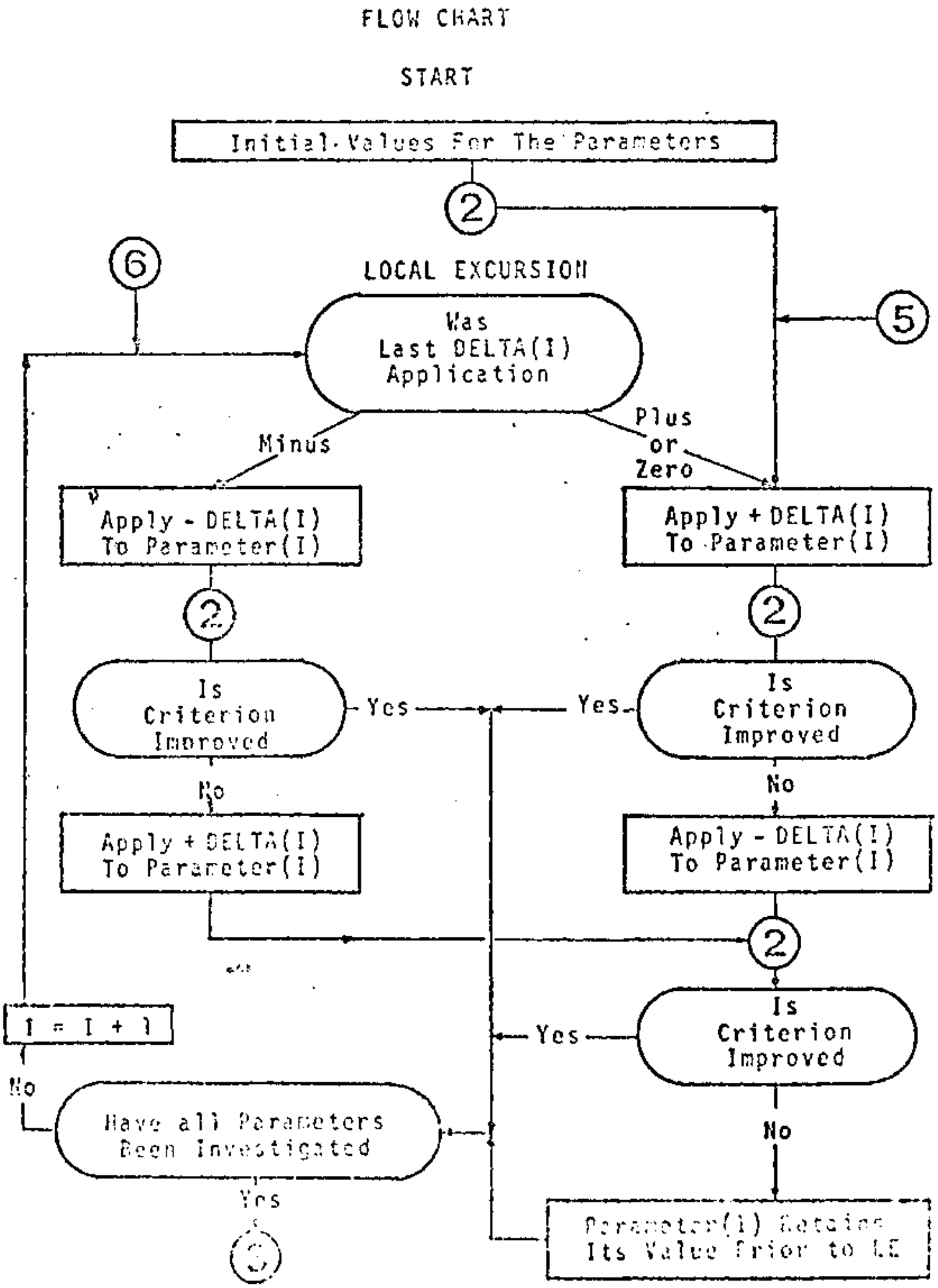



Figure 9. Flow Chart of Pattern Search (Reference 4)

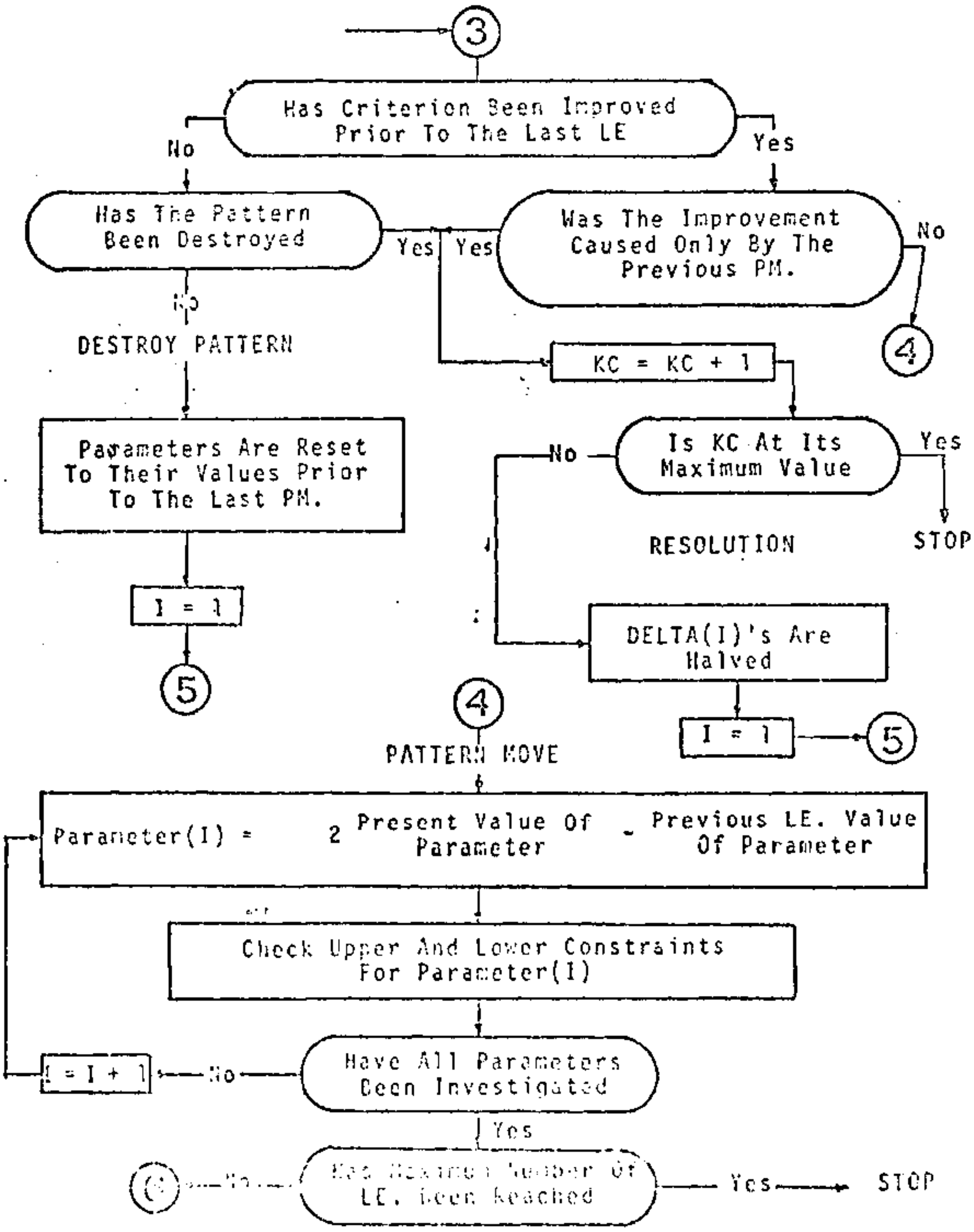



Figure 9. Flow Chart of Pattern Search (Cont)

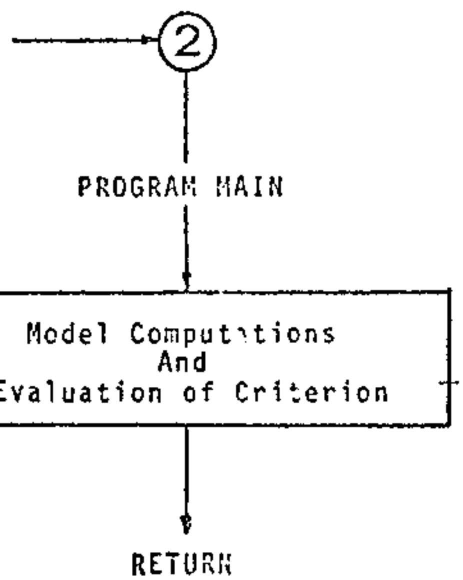



Figure 9. Flow Chart of Pattern Search (cont)

selected base point as defined by the initial parameter values. The distinguishing feature of Pattern Search is in the selection of trial points. There are two types of adjustments, local excursion (LE) and pattern move (PM).

The local excursion consists of a limited univariate search such that only a single parameter is adjusted by a small increment, DELTA. Upon completion of the local excursions for all parameters selected, a pattern move is made. The direction of the pattern move is determined from the information gathered from the local excursion for each parameter. Each parameter is altered in the direction indicated by the most successful local excursion. The process is repeated with the specified DELTA until the objective function can no longer be improved. At that point a resolution is made which divides the current DELTA by two and the procedure continued.

## Data Preparation

The streamflow, precipitation and evapotranspiration data for the Camp Creek watershed were stored in a Fastran drum file on a Univac 1108 computer.

Two precipitation gages were initially used, one located at the Atlanta Airport just north of the watershed and the other located at Jonesboro, Georgia. The airport gage is a continuous recording gage and the Jonesboro gage is a storage gage.

In conjunction with the Georgia Tech model, a data management program is used to weight precipitation by the Theisen method for up to 15 rain gages for a particular watershed. A flowchart of the data management process is shown in Figure 10. Other options which may be employed are reading data from cards or drum-file, eliminating various portion of data which are not desired, creating new files, punching cards in various formats for input, and weighting up to 15 precipitation gages with the end result being one set of precipitation data which represents the distributed rainfall over the watershed. The management program was used to weight the previously mentioned two gages and obtain one set of precipitation data.

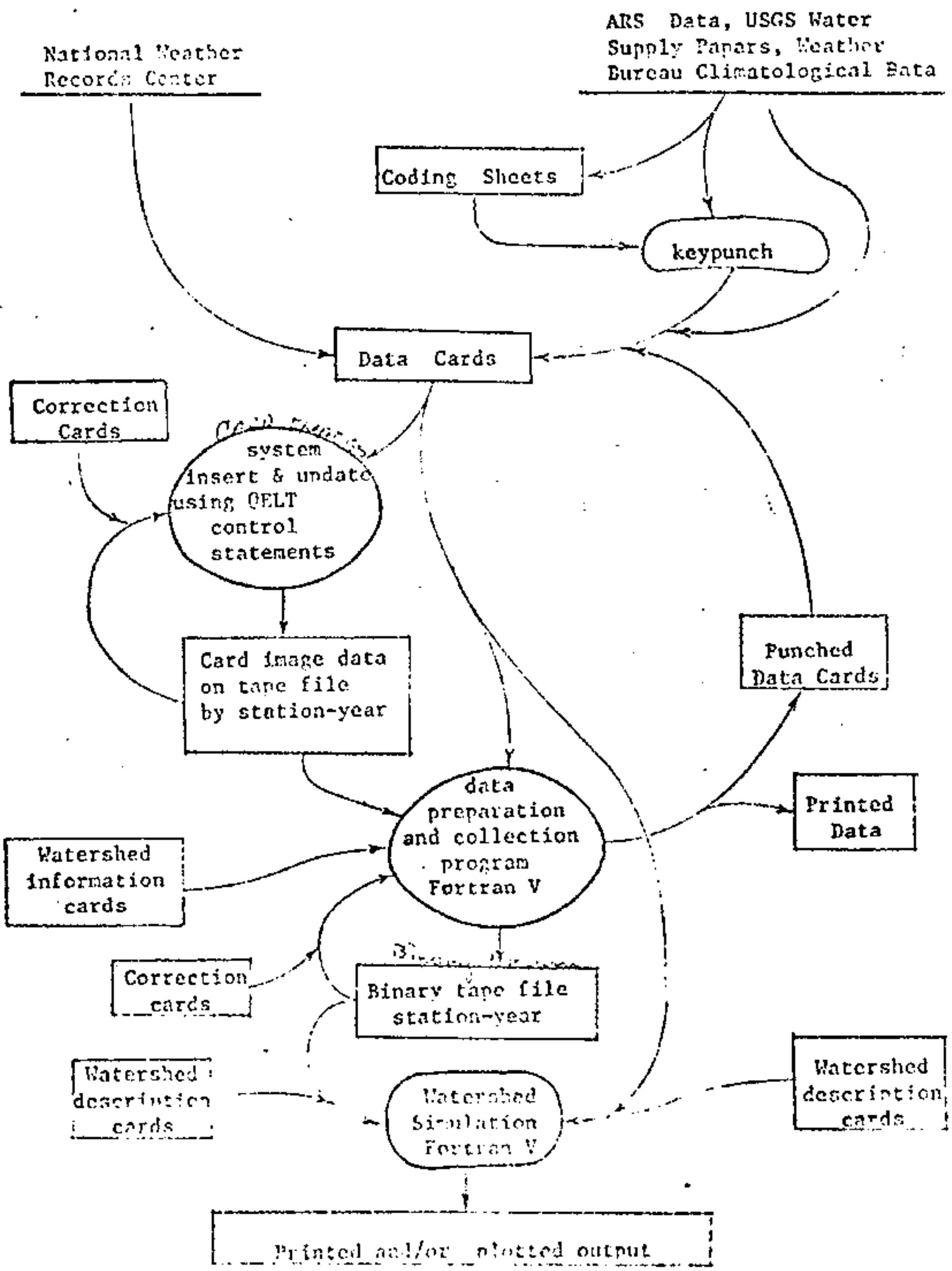



Figure 10. Flow Chart of Data Management Program

# CHAPTER V

## ANALYSIS OF RESULTS

In presenting the results it will be helpful to refer back to Chapter I which outlines the general objectives of this study. As discussed previously a "base set" of parameters was first obtained by optimization using precipitation and caluclated ET data as input to the Georgia Tech Watershed Model. Of the ten years of available data, water year 1961 was selected for this study because it contained the largest flood of record. The optimum parameter set is shown in Table 3 along with the associated average absolute error in daily flows (CFSD), the number of pattern moves necessary, and the number of resolutions performed on each parameter. A calcomp plot of the observed hydrograph and simulated hydrograph is included on Figure 11.

A resolution of 1 means that an improved value of the objective function could not be found with a DELTA of 10 percent for each parameter and that the current adjustments were at the 5 percent level. A resolution of 2 means the same as the above except at the 5 percent and 2.5 percent levels. For this study an accuracy of at least 10 percent was considered to balance the tradeoffs between improved values of the objective function and increased computer costs. variations in the parameter values less than 10 percent are assumed to result from parameter interaction and a lack of resolution of the

Table 3. Optimum Parameter Values for Camp Creek Watershed for Water Year 1961

Absolute Error = 6.1366

Number of Pattern Moves = 3

Number of Resolutions = 2

| Parameter | Optimum Value |
|---|---|
| IMPA | .015 |
| FALZ | .499 |
| FHLZ | .166 |
| PSRP | .3 |
| PSDP | .3 |
| ICMN | .05 |
| ICMX | .25 |
| SRSN | .50 |
| SDSN | .20 |
| UZSN | 1.708 |
| LZSN | 4.182 |
| GWSF | 0.0 |
| PPIF | 8.28 |
| PSUR | 5.4 |
| PPUL | 0.058 |
| PLGP | 0.195 |
| PDGP | 0.0 |
| PLZU | 0.0 |
| TTM | 0.50 |
| INFP | 0.088 |
| KGWF | 0.99 |
| EIP | 0.75 |
| EVP | 1.00 |
| ETGWP | 0.00 |
| SRS | 0.00 |
| SDS | 0.00 |
| UZS | 0.26 |
| LZS | 2.52 |
| GWS | 7.0 |

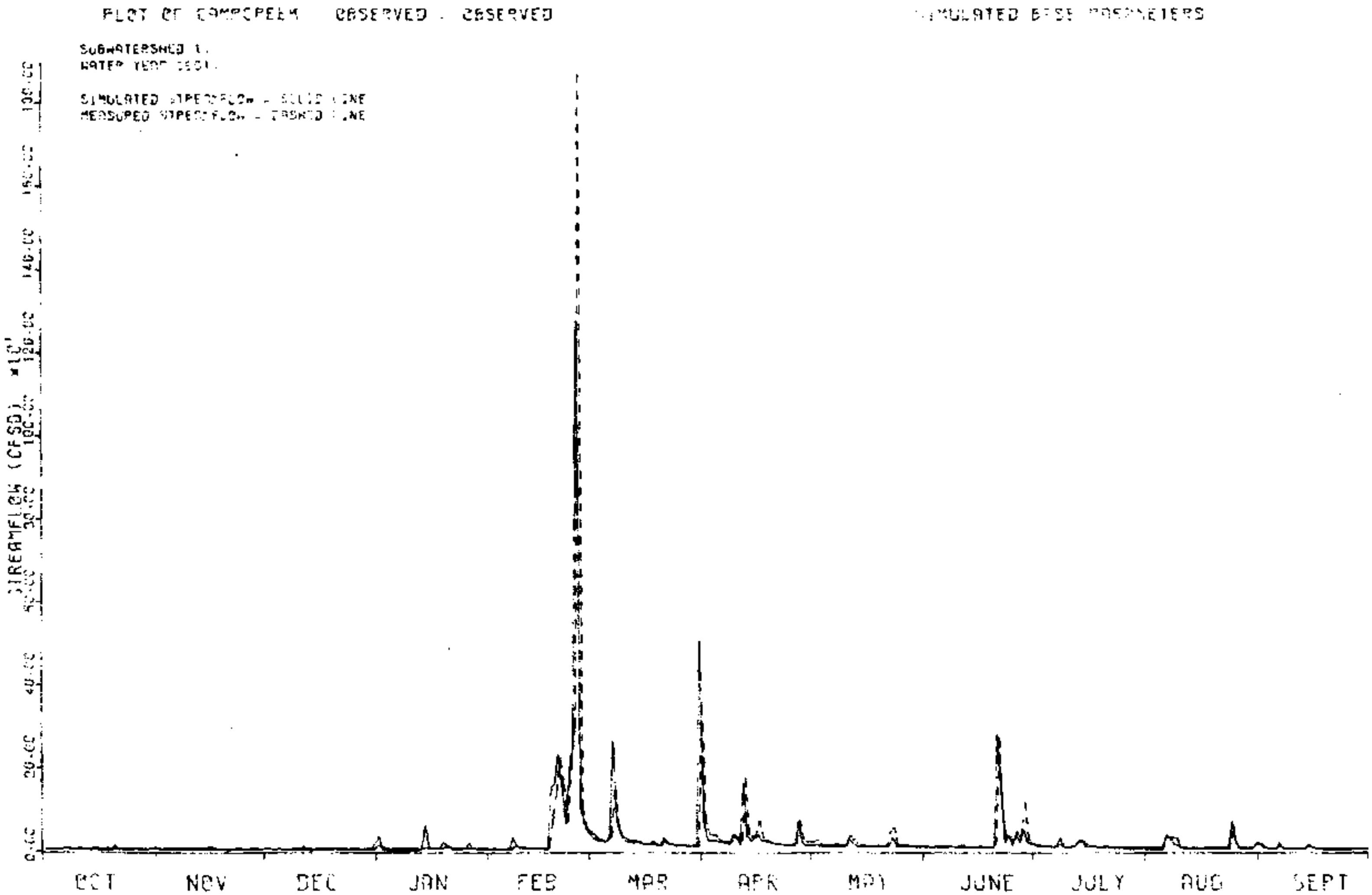



Figure 11. Plots of Simulated Hydrograph for Base Set and the Observed Hydrograph

optimization method rather than an improvement in the optimization function.

Five parameters are considered to be the most critical to model operation. These are FALZ, FHLZ, UZSN, LZSN and PPIF as defined in Table 2. The above parameters are responsible for allocation of water to the three soil zones discussed in Chapter IV. These five parameters were found to be the most sensitive during the initial phase of calibration. Of the parameters presented in Table 2, these five also have the best analogies to physical characteristics of the watershed.

A brief discussion of these five parameters and their significance within the model is necessary at this point. It must be noted that the five parameters interact extensively so that inferring any results through only one parameter may lead to erroneous conclusions.

The maximum infiltration rate at any point in time is calculated from

$$i_{max.} = \frac{PPIF}{2^{\left(PSUP \frac{UZS}{UZSN}\right)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Figure 12 illustrates the role of $i_{max}$, PPIF, and UZSN in allocating precipitation among surface runoff, interflow, and infiltration. If the maximum infiltration rate ($i_{max}$) were plotted versus the ratio of UZS to UZSN the resulting curve would look like those shown in Figure 13. Thus $i_{max}$ is the maximum infiltration rate at a given time and

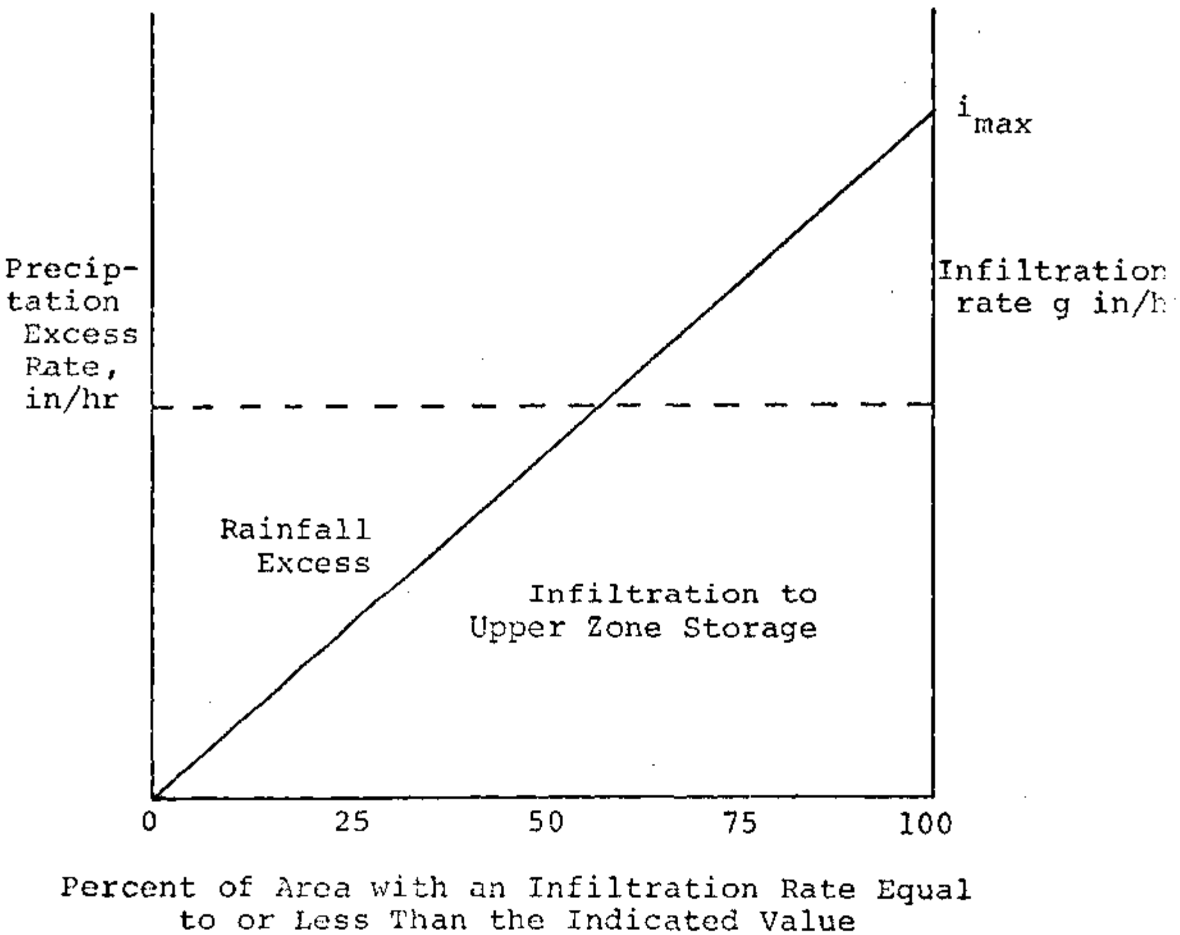



Figure 12. Infiltration Function

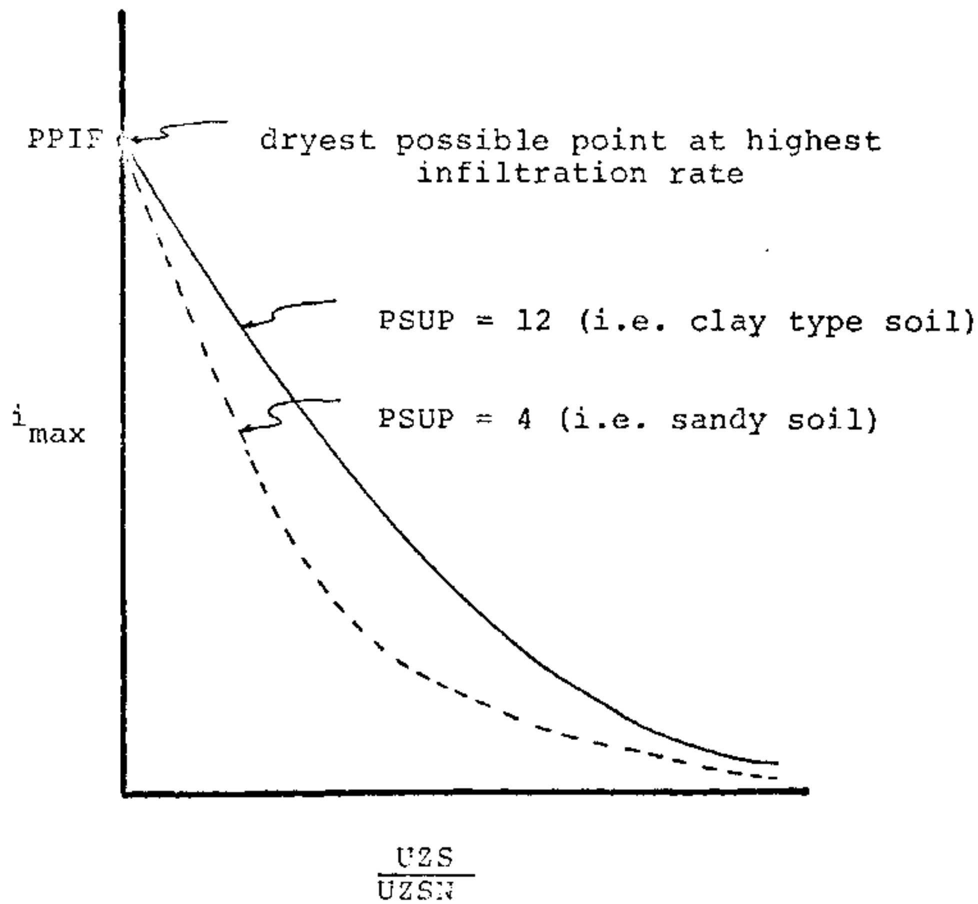



Figure 13. Comparison of Maximum Infiltration with the Ratio of UZS to UZSN

PPIF is the maximum infiltration rate in inches per hour when UZS is zero.

The parameters FALZ and FHLZ determine the fractional area of alluvium and hillside lower zone storages respectively. Another parameter, FRLZ, is calculated internally as

$$FRLZ = 1 - [FALZ + FHLZ] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

and refers to the fractional area of ridge lower zone storage. Removal of moisture from the LZSN zone through drainage is zero until a threshold is reached. Drainage from the ridge zone is added to the hillside and alluvial lower zones in proportion to the respective values of FHLZ and FALZ. FALZ directly relates to percolation from the lower zone to groundwater storage through the following equation.

$$PERC = PLGP\ [(ALZS/LZSN) - 0.5] \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where PLGP is the percolation to ground water parameter and ALZS is the alluvium lower zone soil moisture. Base flow is then calculated as

$$BFLO = (FALZ)\ (BFP)\ (GWS\text{-}GWSF) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where BFP is defined as

$$BFP = 1.0 - KGWF^{0.04167} \qquad \text{(6)}$$

and KGWF is the baseflow recession constant. GWSF is a threshold value for the initiation of baseflow.

Interflow is a function of the interactions of HLZS (hillside lower zone soil moisture), LZSN, FHLZ and a parameter INFP. Interflow (IFLO) drains from the hillside lower zone.

$$IFLO = (XLX)\ (FHLZ)\ (IAM2) \qquad \text{(7)}$$

where

$$XLX = [(INFP)\ (.8 + (.2)\ (W)\ ]\ W^2 \qquad \text{(8)}$$

$$W = [HLZS/LZSN] - 0.5 \qquad \text{(9)}$$

$$IAM2 = [1.0 - IMPA]^{0.7} \qquad \text{(10)}$$

IAM2 represents the remaining area of effective lower zone soil capacity when the fraction of impervious area is IMPA.

As can be seen from the previous brief discussion the interaction of the five parameters chosen for optimization and comparison is very complex. The following sections discuss the resulting effect on each parameter from the error introduced into the data.

## Precipitation

Two distinct cases will be presented. The first is for a systematic error introduced into the entire precipitation record. The second is for the particular error which may be associated with one or more large events during a year. In the first case adjustments of -20 percent, -10 percent, +10 percent and +20 percent were made to the entire precipitation record. The parameters were then optimized using the adjusted precipitation and compared to the original base set of parameters. This comparison is made in Table 4 and in Figure 14. Plots of the daily hydrographs are included for each adjustment in Figures 15 through 22. Figures 15, 17, 19 and 21, show the simulated hydrographs and the observed hydrographs. Figures 16, 18, 20, and 22 present the same simulated hydrograph with that simulated from the base set of parameters.

From Figure 14 the relative movements of each parameter resulting from the erroneous precipitation can be observed. The direction and size of the movement reflects the internal adjustment of the model to compensate for the precipitation error which was introduced.

In looking at positive adjustments to the precipitation, large changes in UZSN, LZSN, FALZ, and FHLZ are apparent. The best way for the model to absorb an increase in precipitation without additional runoff is to increase the storage capacity of the ridge zone. By increasing LZSN and UZSN and decreasing FHLZ and FALZ, the added precipitation is then allocated to the ridge zone where is has greater opportunity for evaporation. There are actually two

Table 4. Results of Adjustments to Total Precipitation Record

Adjustment = 0.8

| Parameter | Base | Adjusted Parameter | Change in Parameter | Change Base |
|---|---|---|---|---|
| FALZ | .49875 | .50947 | + .01072 | + .02149 |
| FHLZ | .16561 | .20839 | + .04278 | + .2583 |
| UZSN | 1.70775 | .84453 | - .86322 | - .50547 |
| LZSN | 4.18176 | 1.8382 | -2.34356 | - .5604 |
| PPIF | 8.28 | 9.95808 | +1.67808 | + .2027 |

Adjustment = 0.9

| Parameter | Base | Adjusted Parameter | Change in Parameter | Change Base |
|---|---|---|---|---|
| FALZ | .498755 | .54008 | - .04133 | + .0828 |
| FHLZ | .16561 | .1746 | - .00899 | + .05428 |
| UZSN | 1.70735 | 1.32165 | + .3861 | - .22608 |
| LZSN | 4.18176 | 2.8206 | +1.36116 | - .3255 |
| PPIF | 8.28 | 7.36 | + .92 | - .111 |

Adjustment = 1.1

| Parameter | Base | Adjusted Parameter | Change in Parameter | Change Base |
|---|---|---|---|---|
| FALZ | .49875 | .40976 | + .08899 | - .1784 |
| FHLZ | .16561 | .13602 | + .02959 | - .17 86 |
| UZSN | 1.70775 | 2.30522 | - .59747 | + .3498 |
| LZSN | 4.18176 | 5.4784 | -1.2966 | + .31007 |
| PPIF | 8.28 | 8.0224 | + .2576 | - .0311 |

Table 4. Results of Adjustments to Total Precipitation Record (Continuation)

Adjustment = 1.2

| Parameter | Base | Adjusted Parameter | Change in Parameter | Change Base |
|---|---|---|---|---|
| FALZ | .49875 | .22619 | + .27256 | + .5465 |
| FHLZ | .16561 | .05754 | + .10807 | - .6525 |
| UZSN | 1.70775 | 3.05399 | -1.34624 | + .788 |
| LZSN | 4.18176 | 6.2137 | -2.03194 | + .48.59 |
| PPIF | 8.28 | 9.20074 | - .9207 | + .1112 |

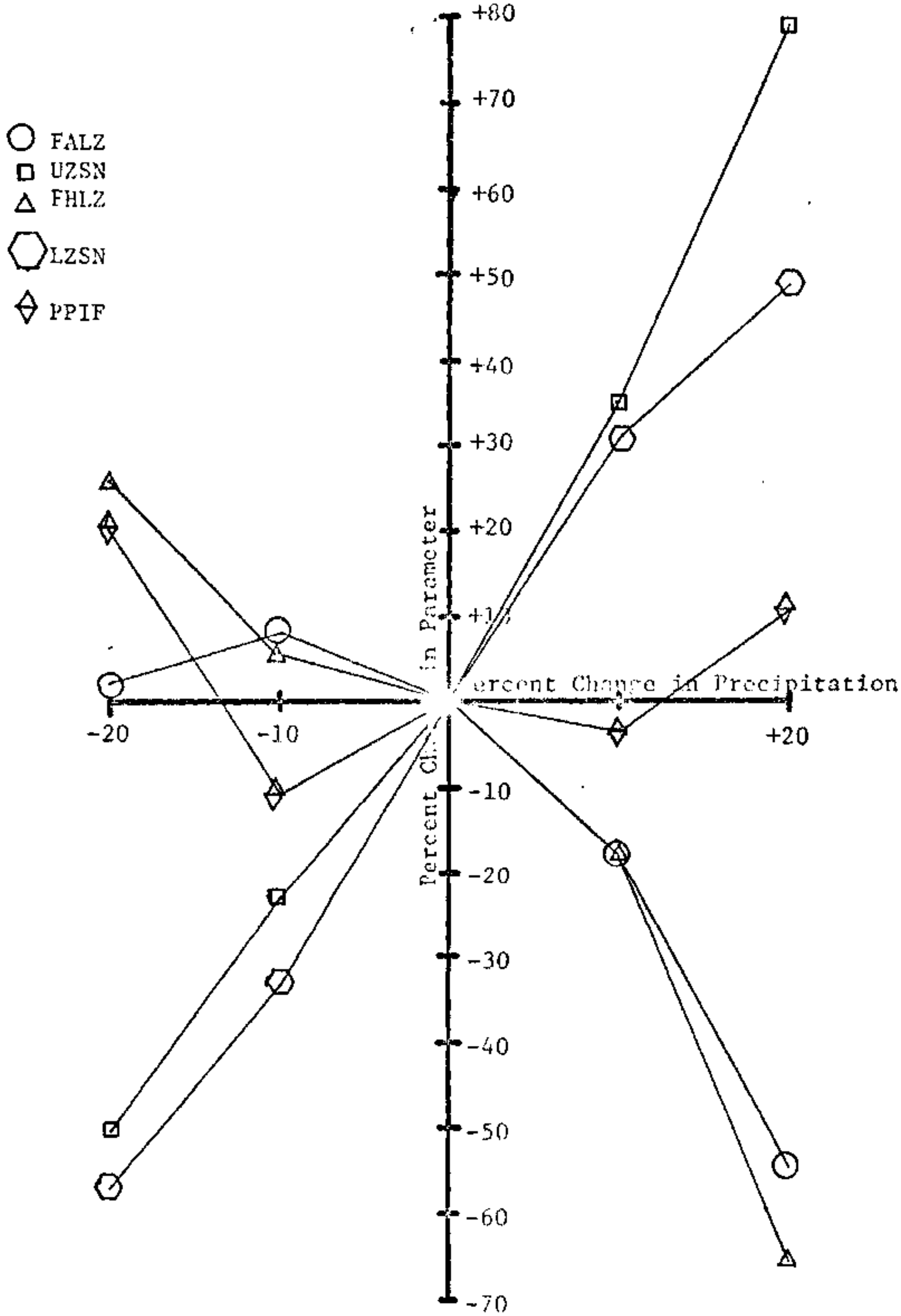



Figure 14. Results of Error Introduced into Total Precipitation Record

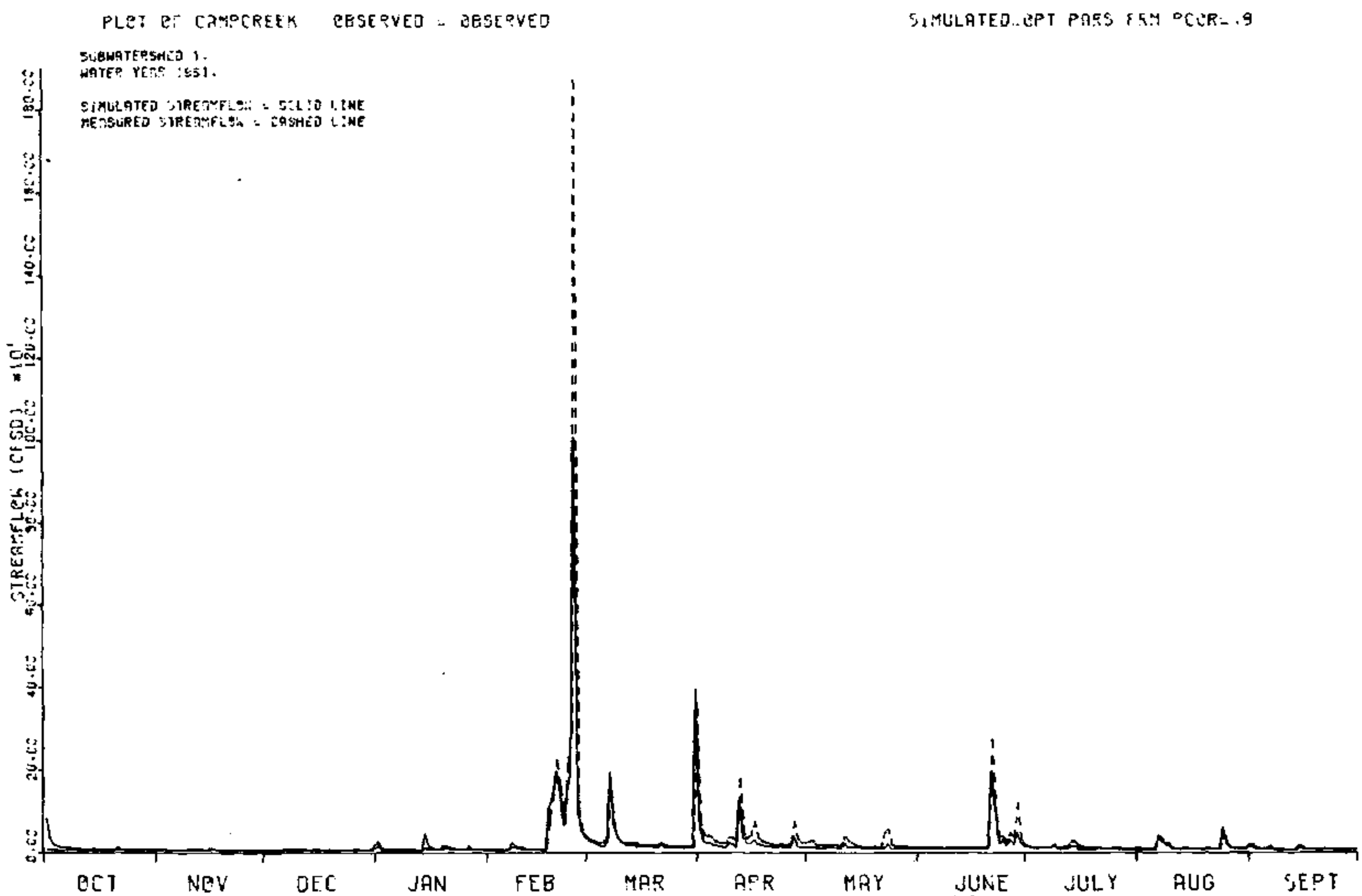



Figure 15. Plots of Simulated Hydrograph for a 0.8 Adjustment in Total Precipitation and the Observed Hydrograph

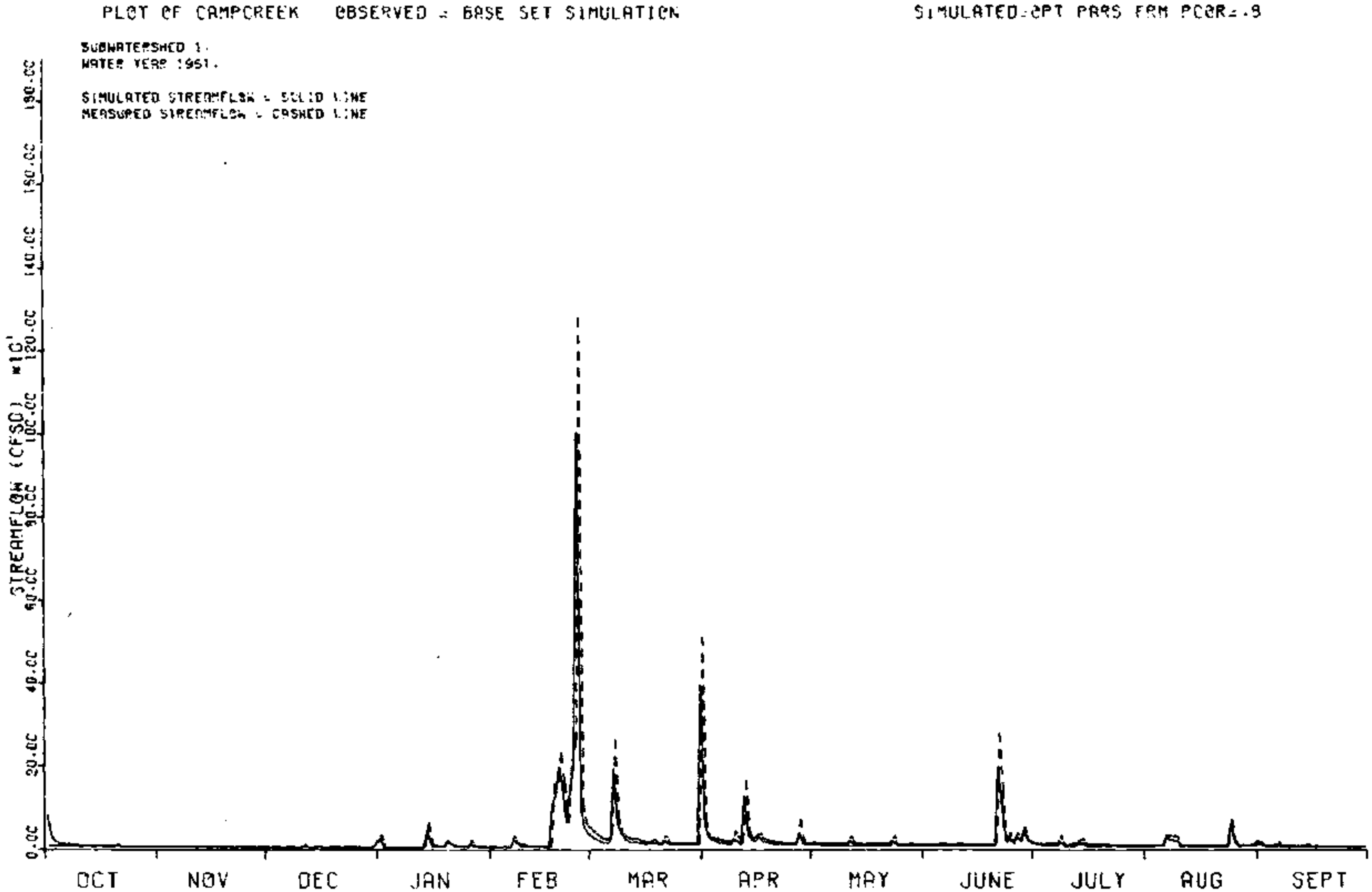



Figure 16. Plots of Simulated Hydrograph for a 0.8 Adjustment in Total Precipitation and the Simulated Hydrograph for the Base Set

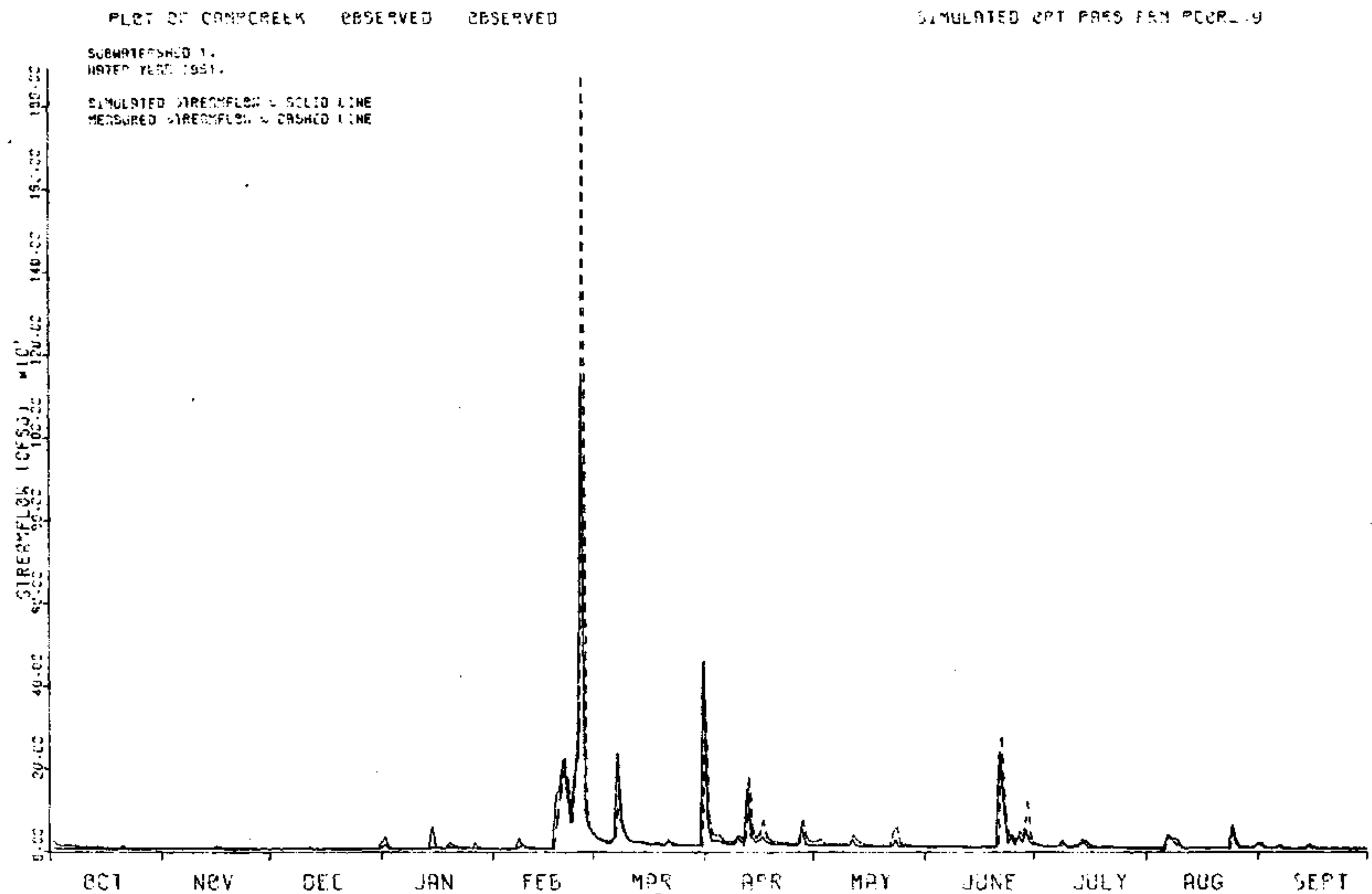



Figure 17. Plots of Simulated Hydrograph for a 0.9 Adjustment in Total Precipitation and the Observed Hydrograph

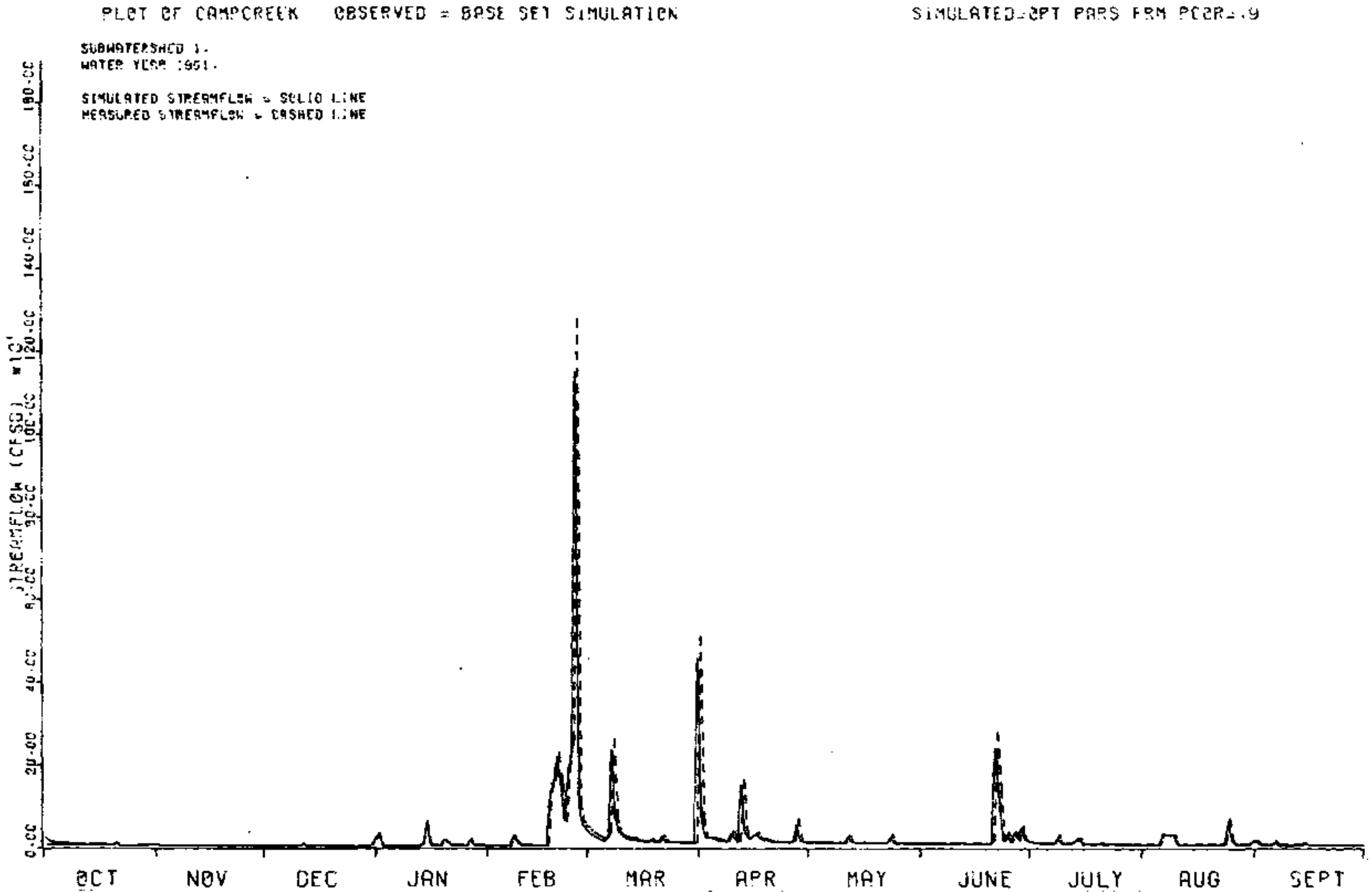



Figure 18. Plots of Simulated Hydrograph for a 0.9 Adjustment in Total Precipitation and the Simulated Hydrograph for the Base Set

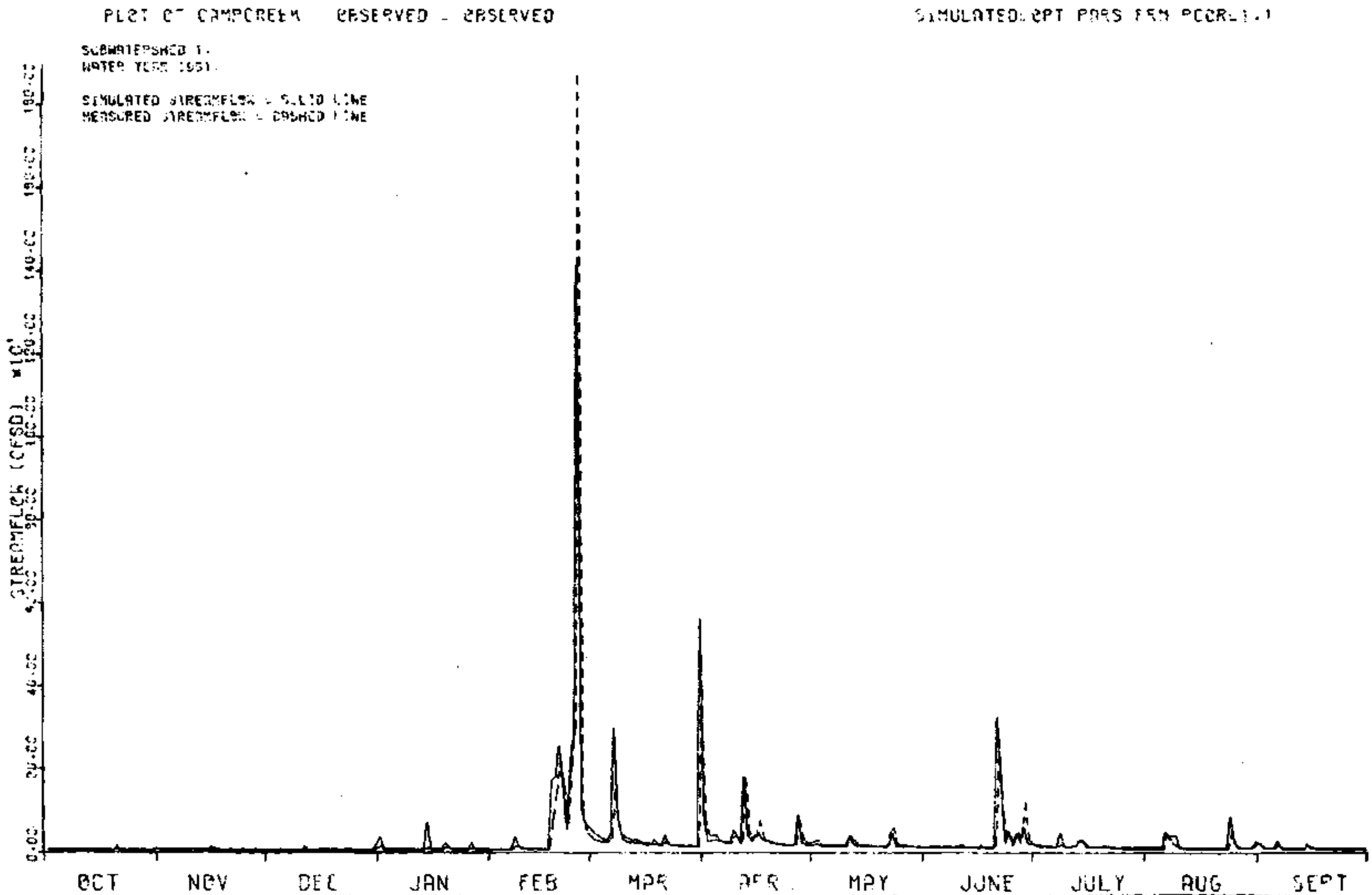


Figure 19. Plots of Simulated Hydrograph for a 1.1 Adjustment in Total Precipitation and the Observed Hydrograph

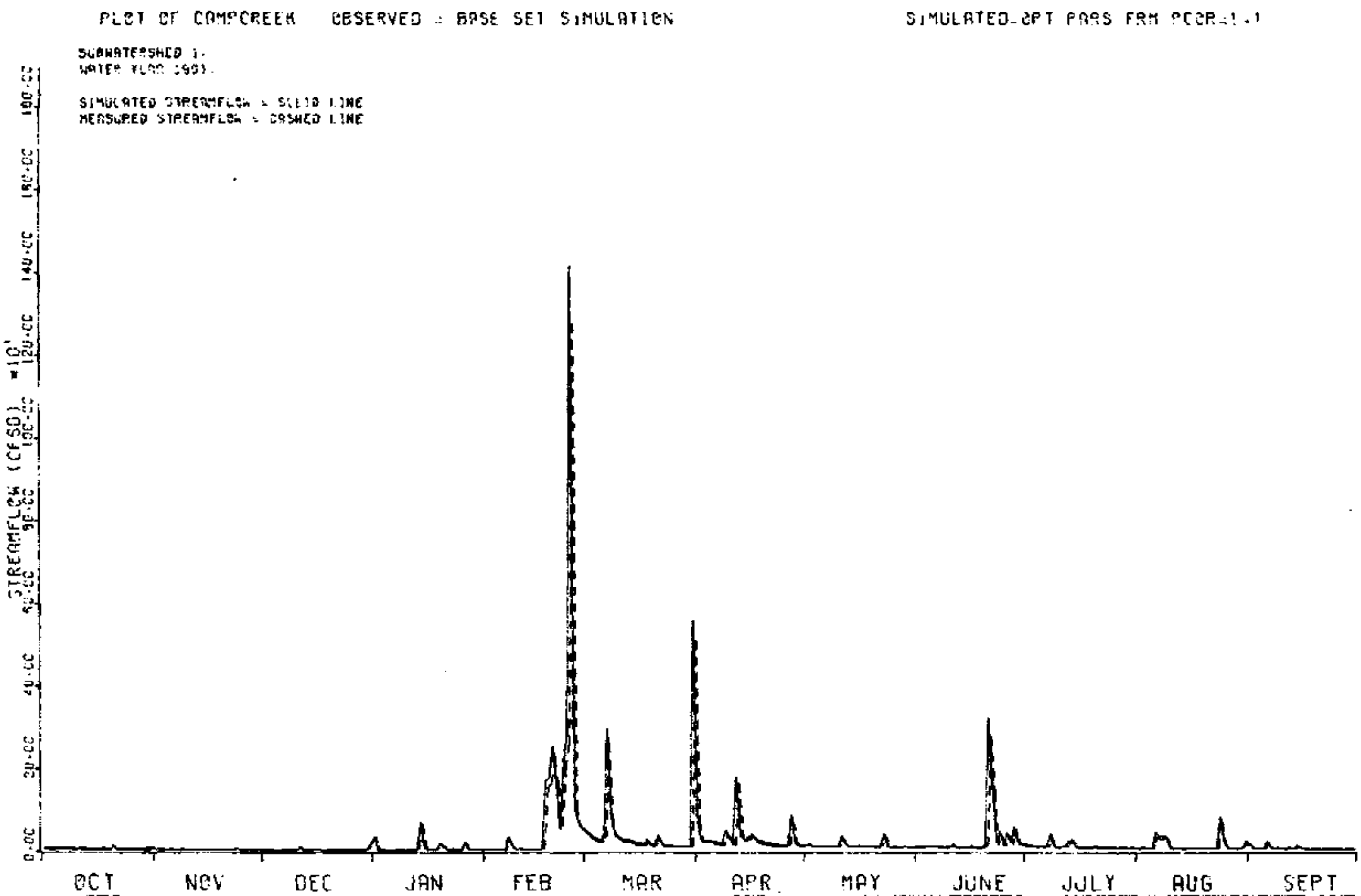


Figure 20. Plots of Simulated Hydrograph for a 1.1 Adjustment in Total Precipitation and the Simulated Hydrograph for the Base Set

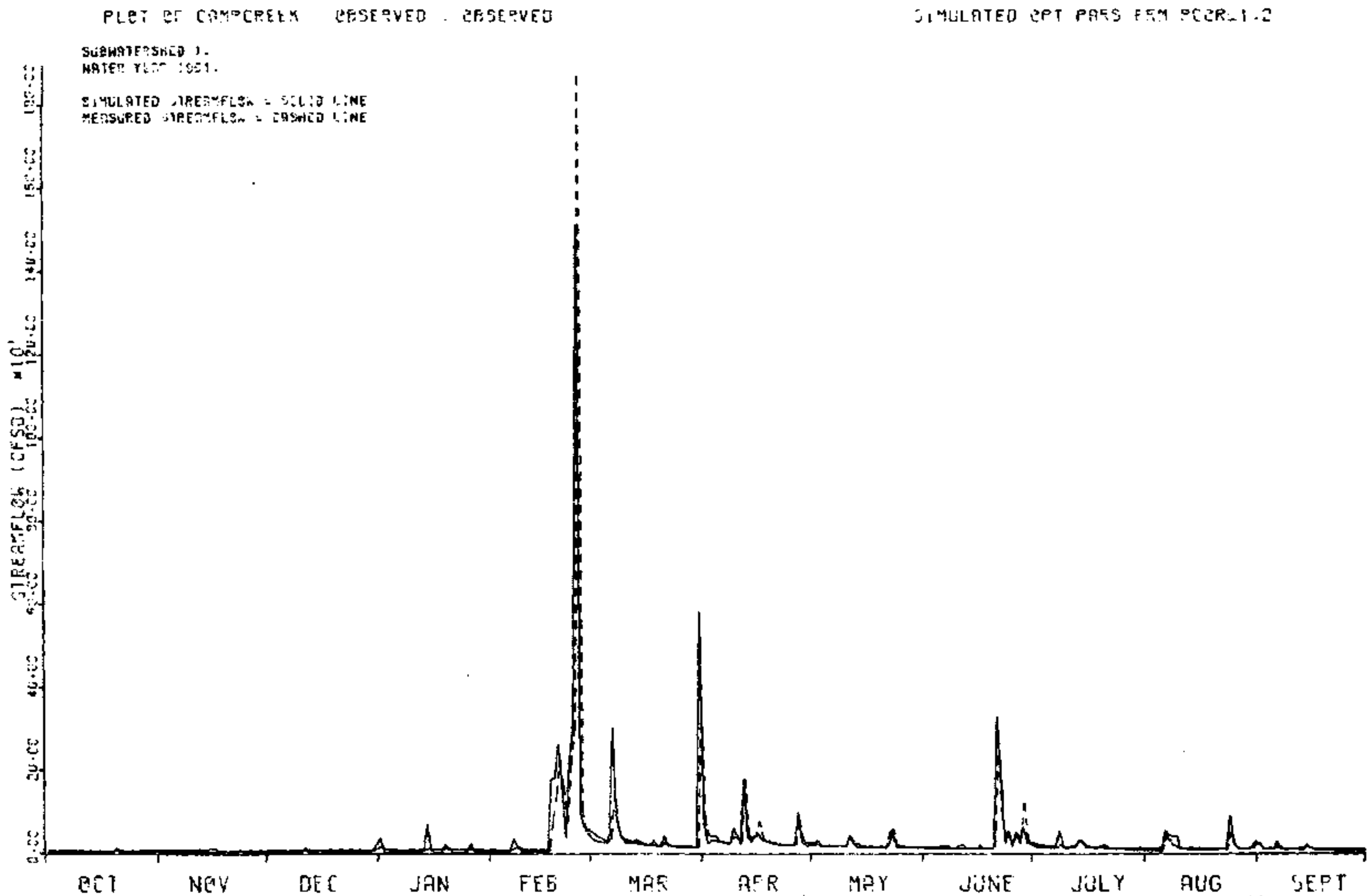



Figure 21. Plots of Simulated Hydrograph for a 1.2 Adjustment in Total Precipitation and the Observed Hydrograph

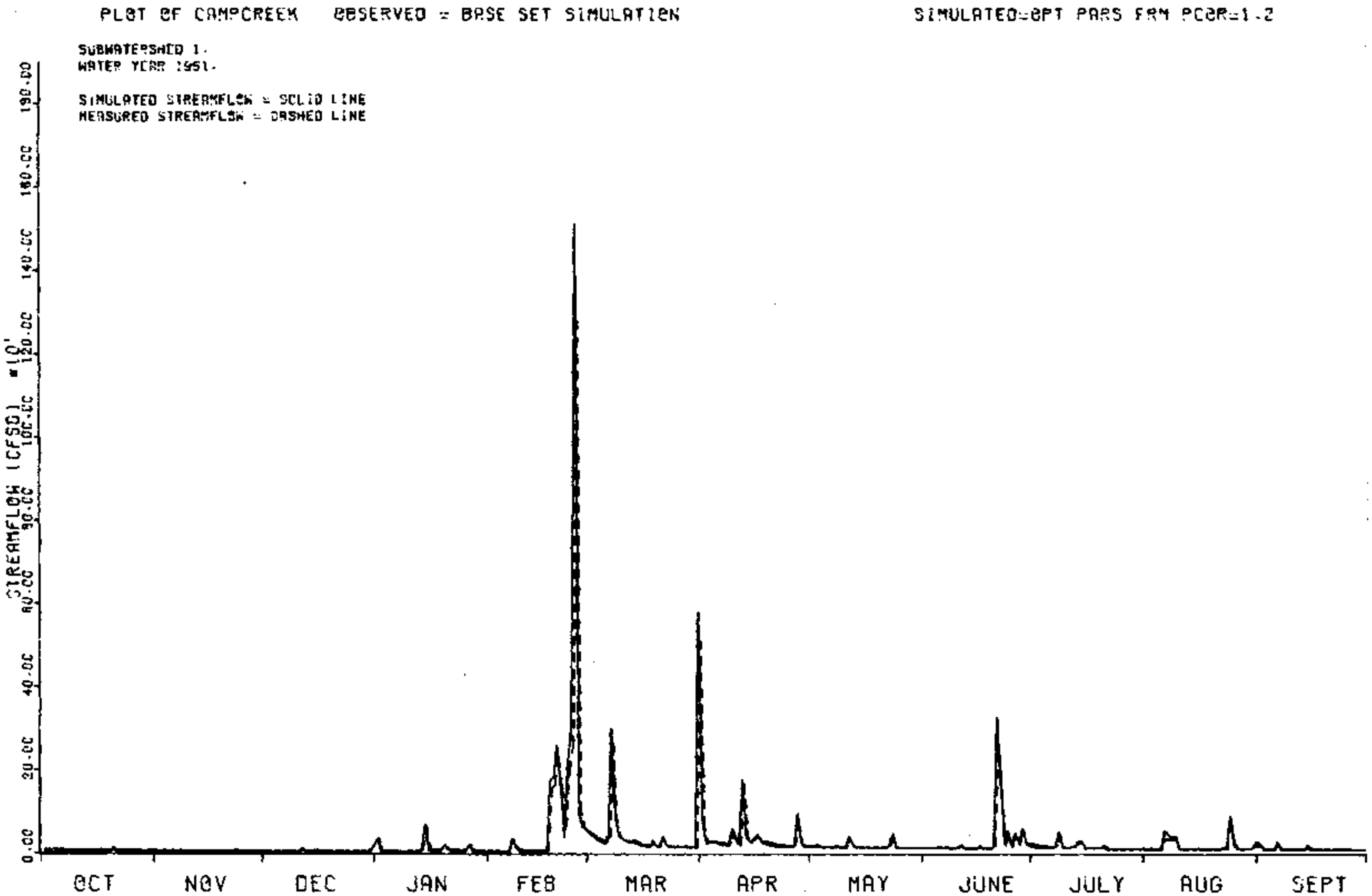



Figure 22. Plots of Simulated Hydrograph for a 1.2 Adjustment in Total Precipitation and the Simulated Hydrograph for the Base Set

effects involved. When precipitation is increased and the volume of streamflow is maintained approximately constant the evapotranspiration must increase. Therefore the first effect is an increase in UZSN and LZSN to afford a greater storage and thus a greater opportunity for evaporation. The second effect is for the zones FHLZ and FALZ to decrease to allow more precipitation to fall on the ridge zone. The ridge zone does not drain until a threshold is reached therefore keeping it wet to allow for higher evaportranspiration. This trend for the interaction of FALZ and FHLZ with UZSN and LZSN is quite apparent for all adjustments in precipitation. For the -20 percent adjustment the FALZ shift seems to be inconsistant. The can be attributed to the interdependency of PPIF, which increases rapidly between adjustments of -10 to -20 percent (Figure 14) allowing more water to infiltrate and drain to groundwater storage. Thus, too much low flow would be simulated unless FALZ is reduced. The small variations of PPIF about the horizontal axis result from parameter interaction and a resolution of only 10 percent used in the optimization. For additional detail on storage allocations, refer to Appendix A which contains the detailed storage and flow table from each simulation.

The second type of precipitation error which was analyzed was associated with a large event. All the rainfall associated with the largest precipitation event of the year was adjusted by -20 percent, -20 percent, +10 percent and +20 percent. This storm occurred over a two day period, February 25 and 26, 1961, and is associated with the largest peak of the ten-year record. The total precipitation for the two-day period was 5.7 inches preceeded by 6.23 inches in the previous 6 days. The results are shown in Table 5 and Figure 23. The calcomp plots of each adjustment are also included on Figures 24 through 31. Figure 24, 26, 28 and 30 compare the simulated hydrographs with the observed hydrographs while Figures 25, 27, 29 and 31 compare the hydrograph associated with base parameters with the hydrographs associated with the adjusted parameters. From Figure 23 slight variations outside the 10 percent level are present for PPIF on the positive and negative adjustments and for FHLZ on the neagtive adjustment. These variations are understandable since PPIF controls soil moisture conditions prior to the storm and FHLZ increases to supply more storm runoff through interflow when precipitation is decreased. PPIF moves in a direction to allow infiltration to increase so that, prior to the storm, UZS will be wetter and thus more runoff will be generated from the storm.

A more detailed analysis of the allocation of moisture by the model may be conducted by referring to the flow and storage allocation table in Appendix B.

## Streamflow

As discussed previously adjustments of +20 percent and -20 percent were made to the three largest peaks within the year. The results of these adjustments are included in Table 6 and on Figure 32. Also included are the calcomp plots of the hydrographs for the base set simulation compared to the simulation using the adjusted

Table 5. Results of Adjustments to Precipitation for the Largest Event

Adjustment = .7

| Parameter | Base | Adjusted Parameter | Change in Parameter | Change / Base |
|---|---|---|---|---|
| FALZ | .49875 | .49875 | - | - |
| FHLZ | .16561 | .18813 | -.02252 | +.1359 |
| UZSN | 1.70775 | 1.73745 | -.0297 | +.0174 |
| LZSN | 4.18176 | 4.18176 | - | - |
| PPIF | 8.28 | 9.2 | +.92 | +.111 |

Adjustment = 0.8

| Parameter | Base | Adjusted Parameter | Change in Parameter | Change / Base |
|---|---|---|---|---|
| FALZ | .49875 | .49875 | - | - |
| FHLZ | .16561 | .16944 | -.0038 | +.023 |
| UZSN | 1.70775 | 1.6038 | +.1039 | -.0608 |
| LZSN | 4.18176 | 4.18176 | - | - |
| PPIF | 8.28 | 9.2 | -.92 | +.111 |

Adjustment = 1.1

| Parameter | Base | Adjusted Parameter | Change in Parameter | Change / Base |
|---|---|---|---|---|
| FALZ | .49875 | .5225 | -.02375 | +.0476 |
| FHLZ | .16561 | .15521 | +.0104 | -.0628 |
| UZSN | 1.70775 | 1.6038 | +.104 | -.0608 |
| LZSN | 4.18176 | 4.18176 | - | - |
| PPIF | 8.28 | 7.36 | +.92 | -.111 |

Adjustment = 1.2

| Parameter | Base | Adjusted Parameter | Change in Parameter | Change / Base |
|---|---|---|---|---|
| FALZ | .49875 | .5225 | -.0237 | +.0476 |
| FHLZ | .16561 | .15521 | +.0104 | -.0628 |
| UZSN | 1.70775 | 1.6038 | +.104 | -.0608 |
| LZSN | 4.18176 | 4.18176 | - | - |
| PPIF | 8.28 | 7.36 | +.92 | -.111 |

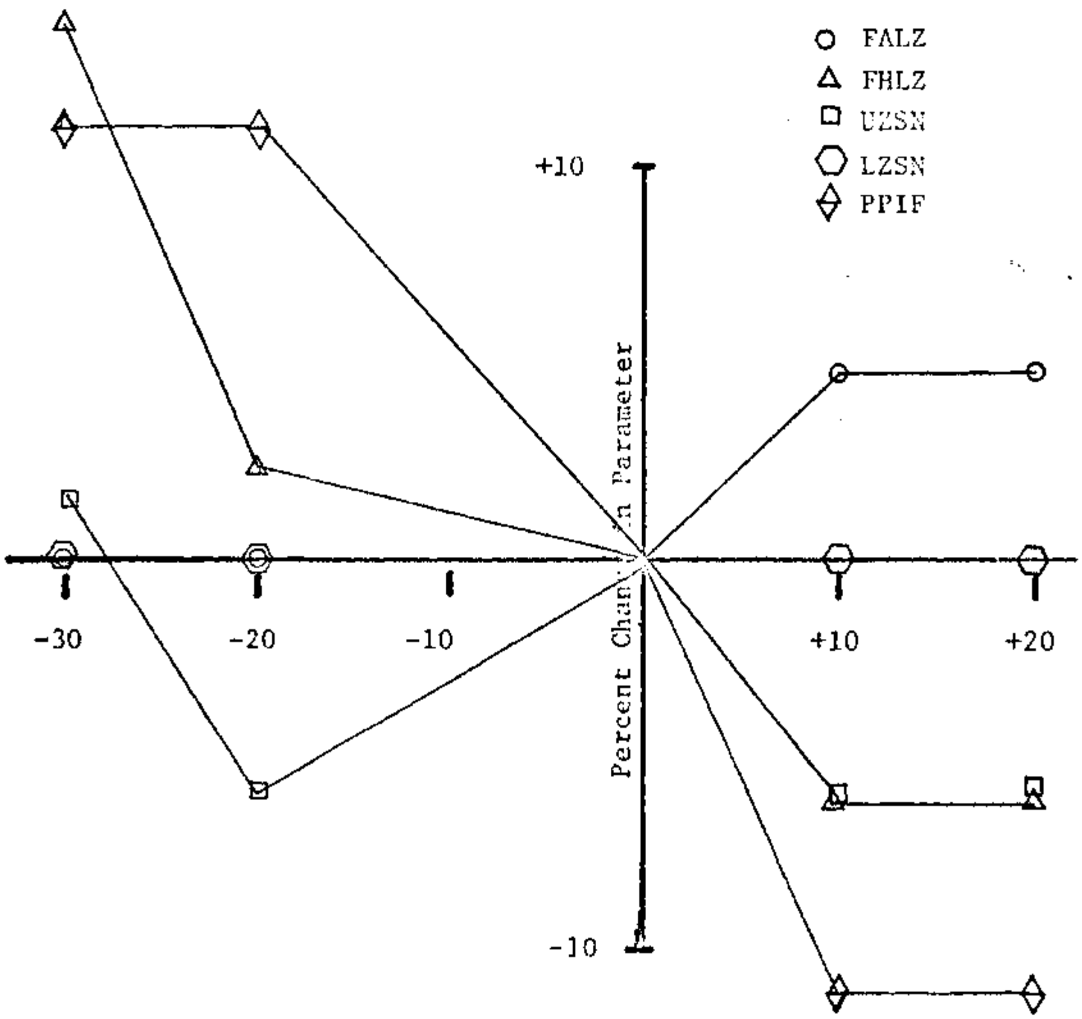



Figure 23. Results of Error Introduced into Largest Storm of Record

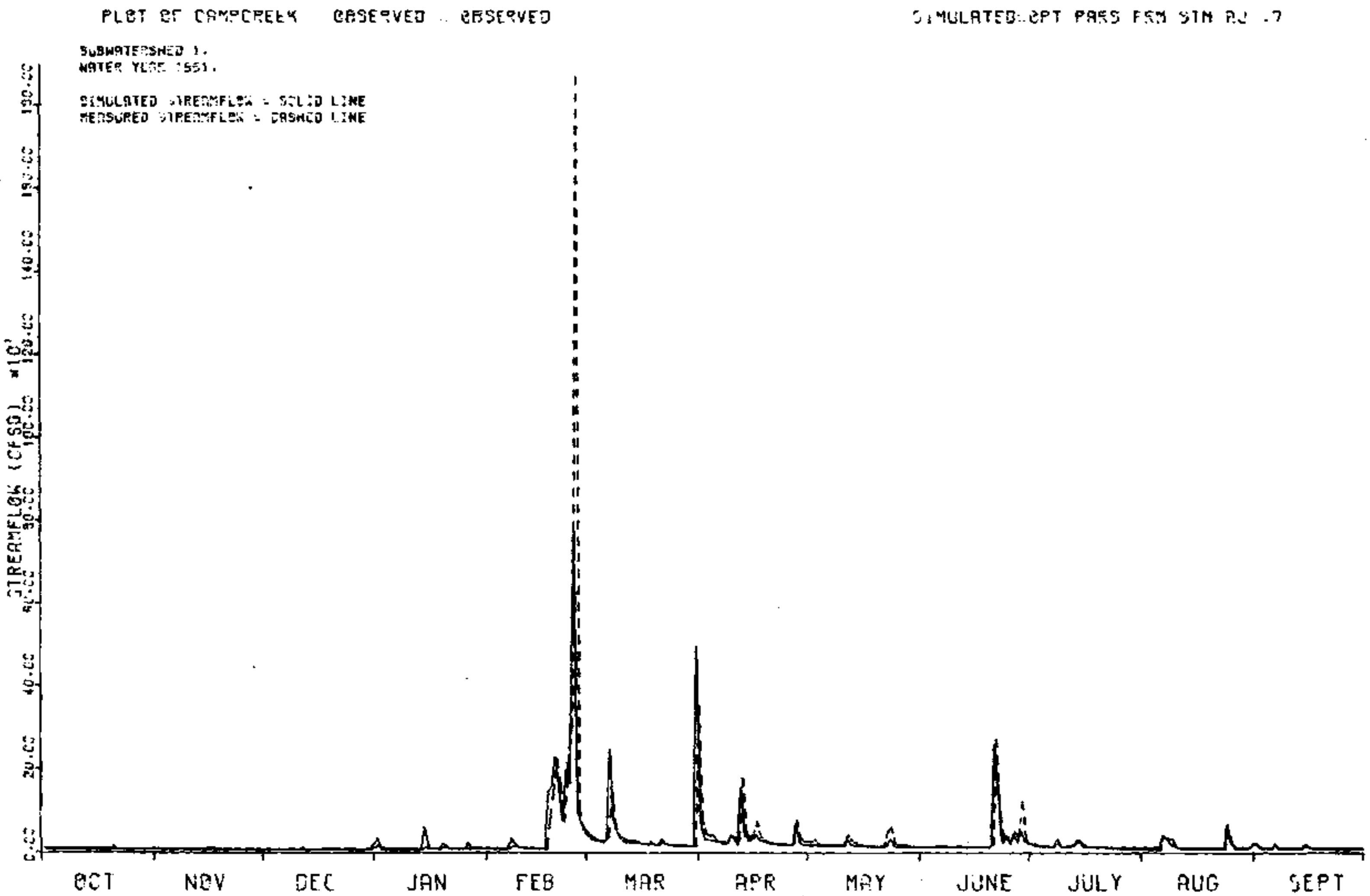



Figure 24. Plots of Simulated Hydrograph for a 0.7 Adjustment to Largest Storm of Record and the Observed Hydrograph

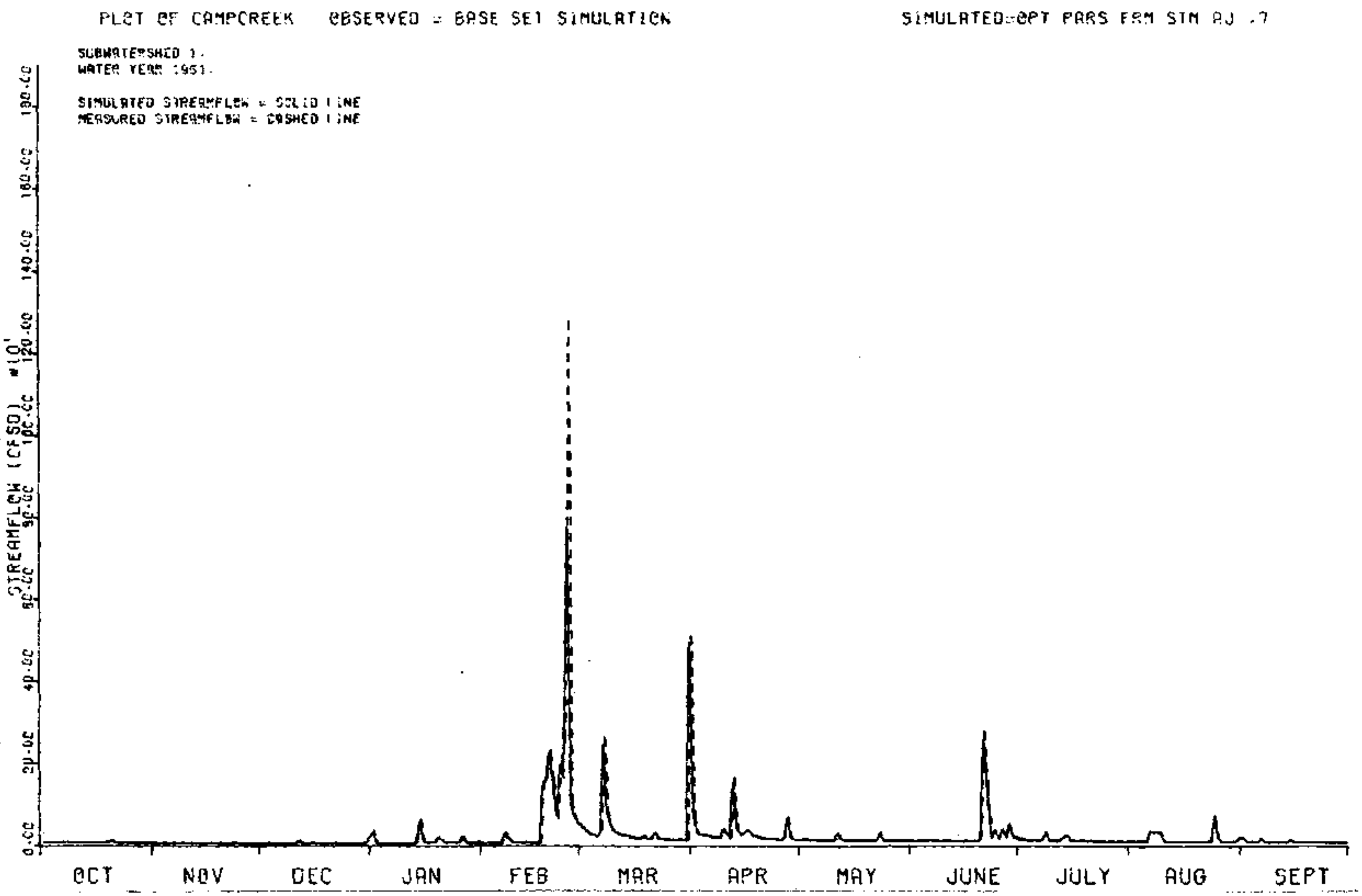



Figure 25. Plots of Simulated Hydrograph for a 0.7 Adjustment to Largest Storm of Record and the Simulated Hydrograph for the Base Set

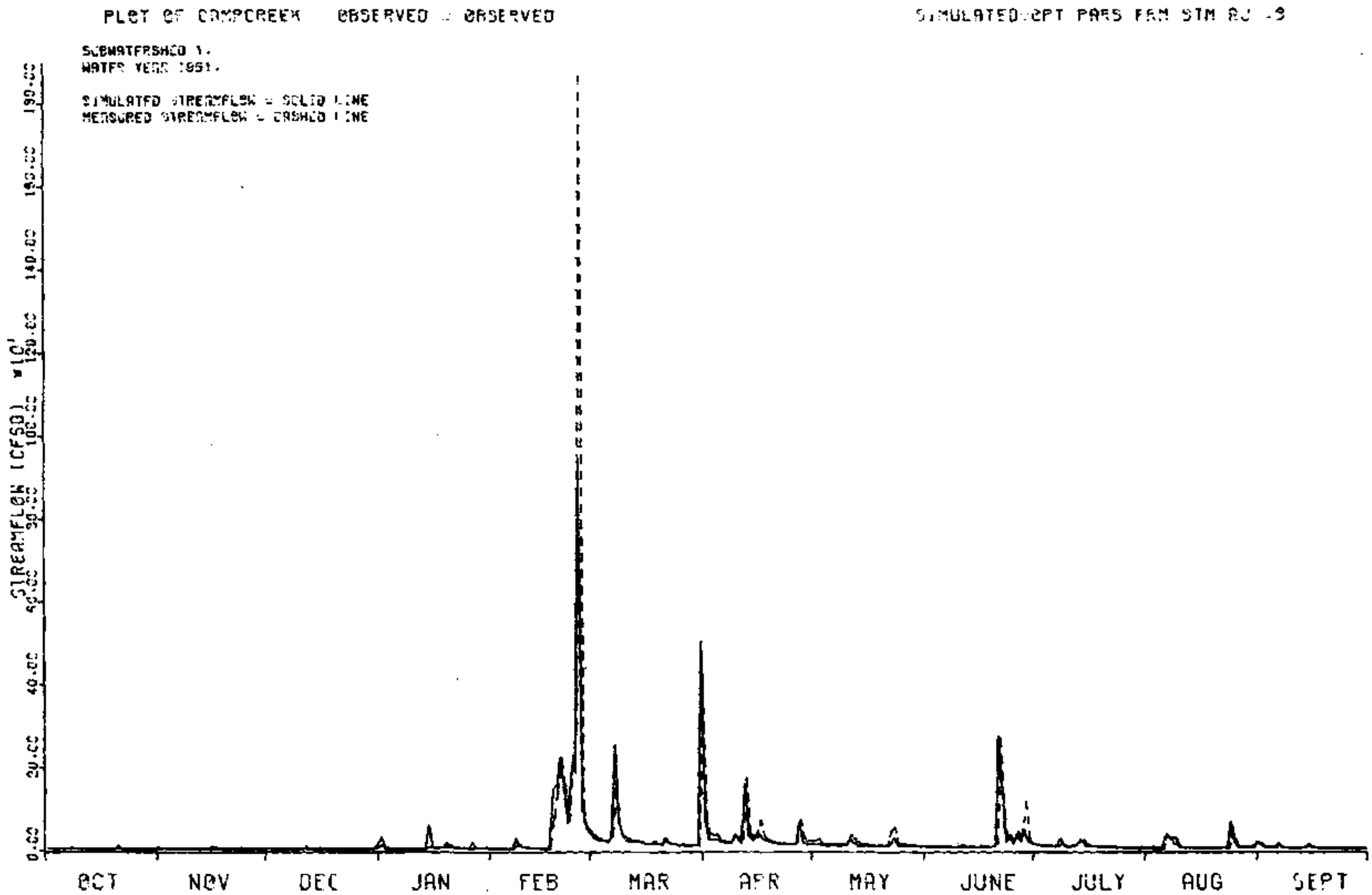



Figure 26. Plots of Simulated Hydrograph for a 0.9 Adjustment to Largest Storm of Record and the Observed Hydrograph

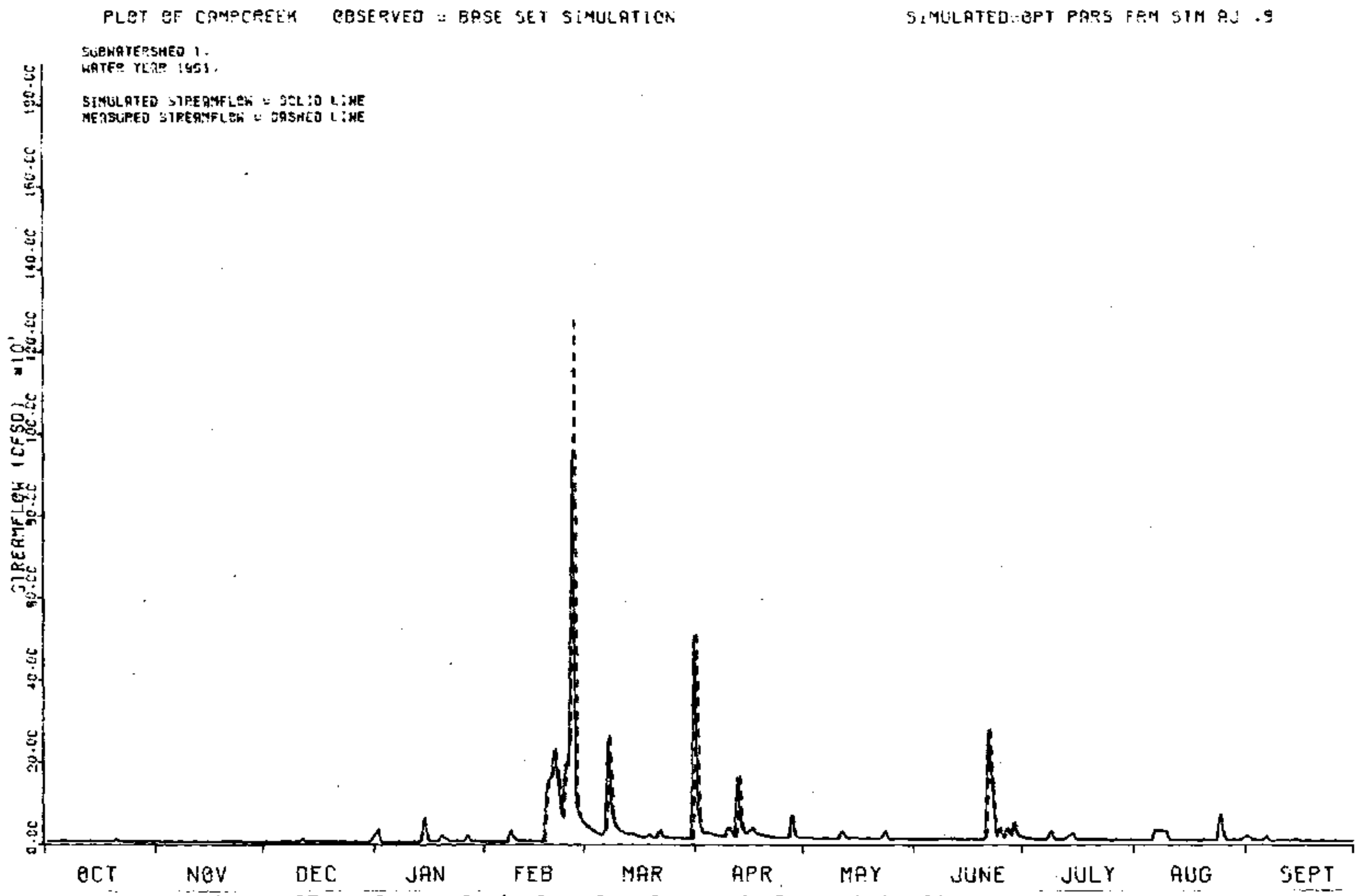



Figure 27. Plots of Simulated Hydrograph for a 0.9 Adjustment to Largest Storm of Record and the Simulated Hydrograph for the Base Set

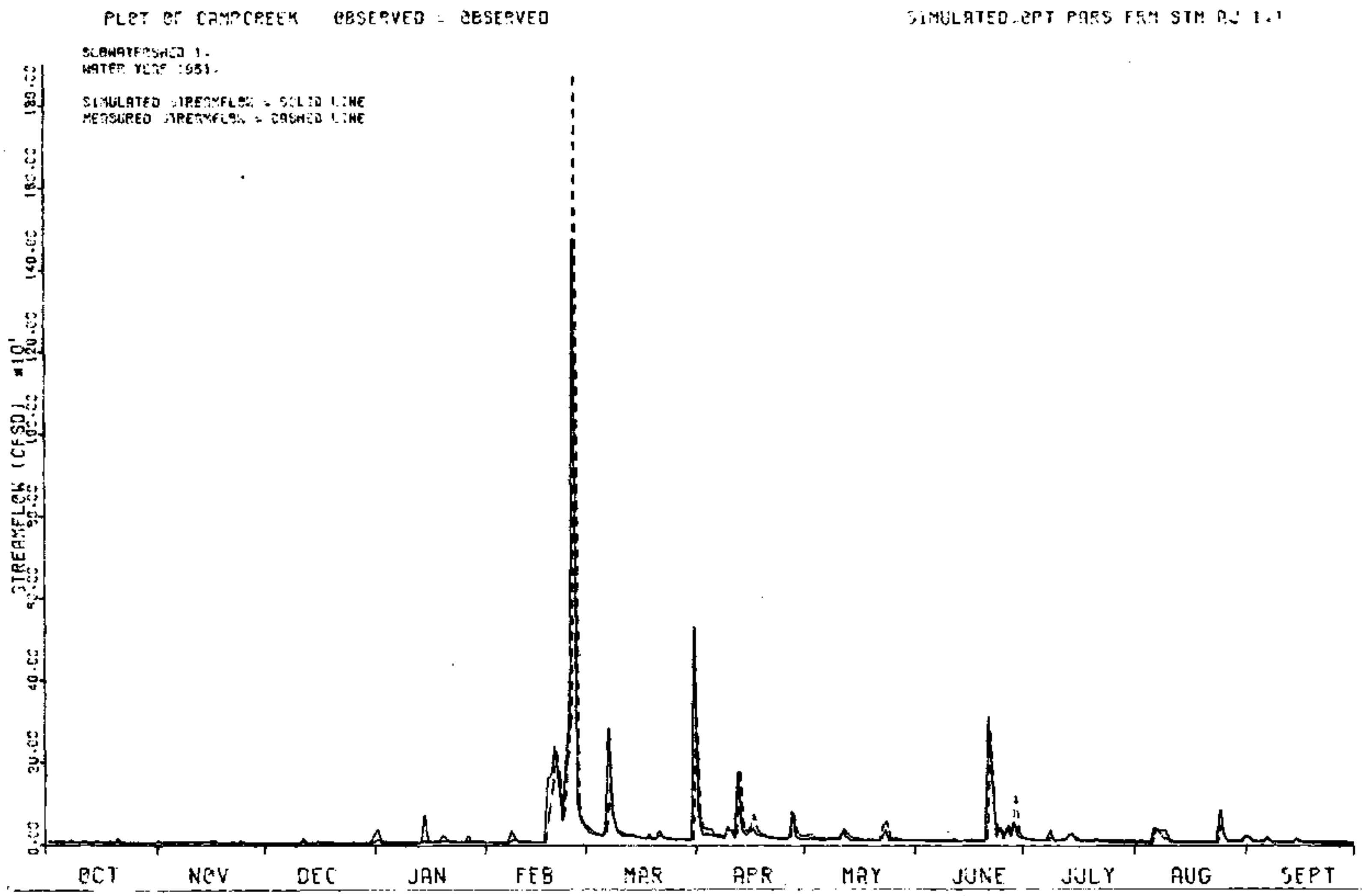



Figure 28. Plots of Simulated Hydrograph for a 1.1 Adjustment to Largest Storm of Record and the Observed Hydrograph

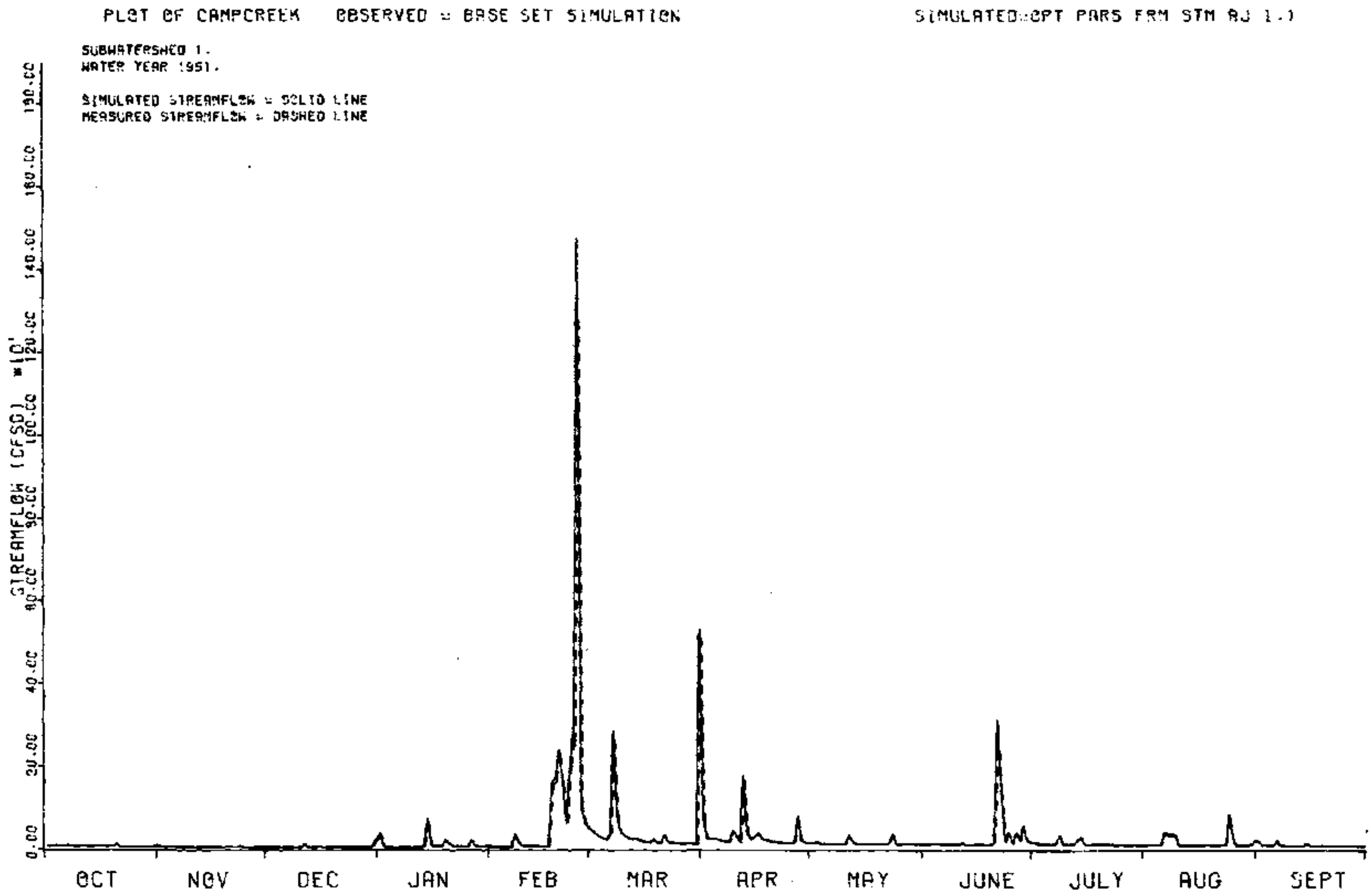



Figure 29. Plots of Simulated Hydrograph for a 1.1 Adjustment to Largest Storm of Record and the Simulated Hydrograph for the Base Set

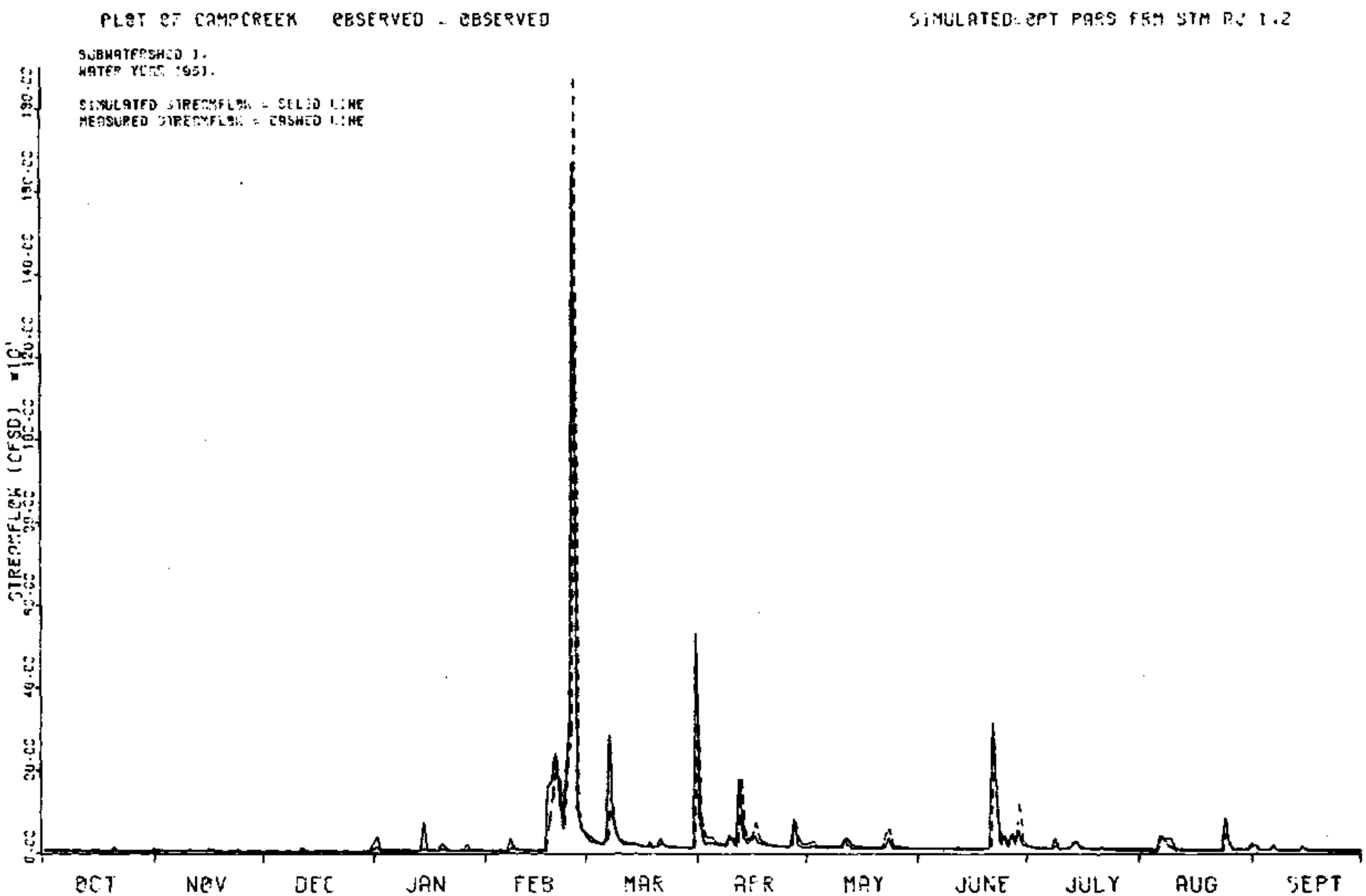



**Figure 30. Plots of Simulated Hydrograph for a 1.2 Adjustment to Largest Storm of Record and the Observed Hydrograph**

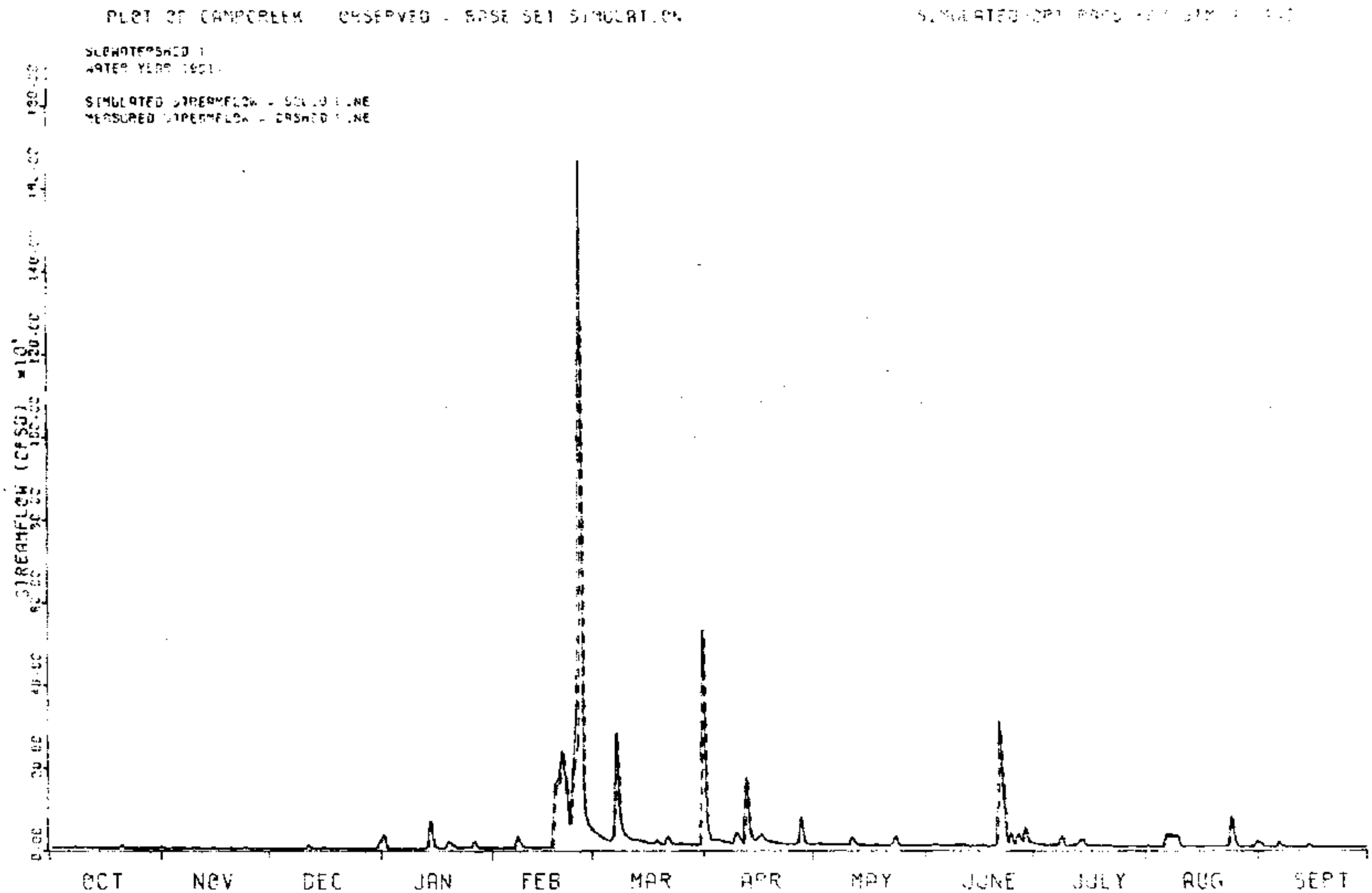



Figure 31. Plots of Simulated Hydrograph for a 1.2 Adjustment to Largest Storm of Record and the Simulated Hydrograph for the Base Set

Table 6. Results of Adjustments to Streamflow

Streamflow +.2

| Parameter | Base | Adjusted Parameter | Change in Parameter | Change / Base |
|---|---|---|---|---|
| FALZ | .49875 | .49266 | .00609 | -0.0122 |
| FHLZ | .16561 | .16975 | .00414 | +0.0250 |
| UZSN | 1.70775 | 1.74766 | .03991 | +0.0234 |
| LZSN | 4.18176 | 4.18176 | 0.0000 | 0.0000 |
| PPIF | 8.28 | 8.4985 | 0.2185 | +0.0264 |

Streamflow -.2

| Parameter | Base | Adjusted Parameter | Change in Parameter | Change / Base |
|---|---|---|---|---|
| FALZ | .49875 | .45125 | .0475 | -0.0952 |
| FHLZ | .16561 | .1455 | .0201 | -0.1214 |
| UZSN | 1.70775 | 1.6335 | .07425 | -0.0435 |
| LZSN | 4.18176 | 3.76358 | .41818 | -0.1000 |
| PPIF | 8.28 | 10.12 | 1.84 | +0.222 |

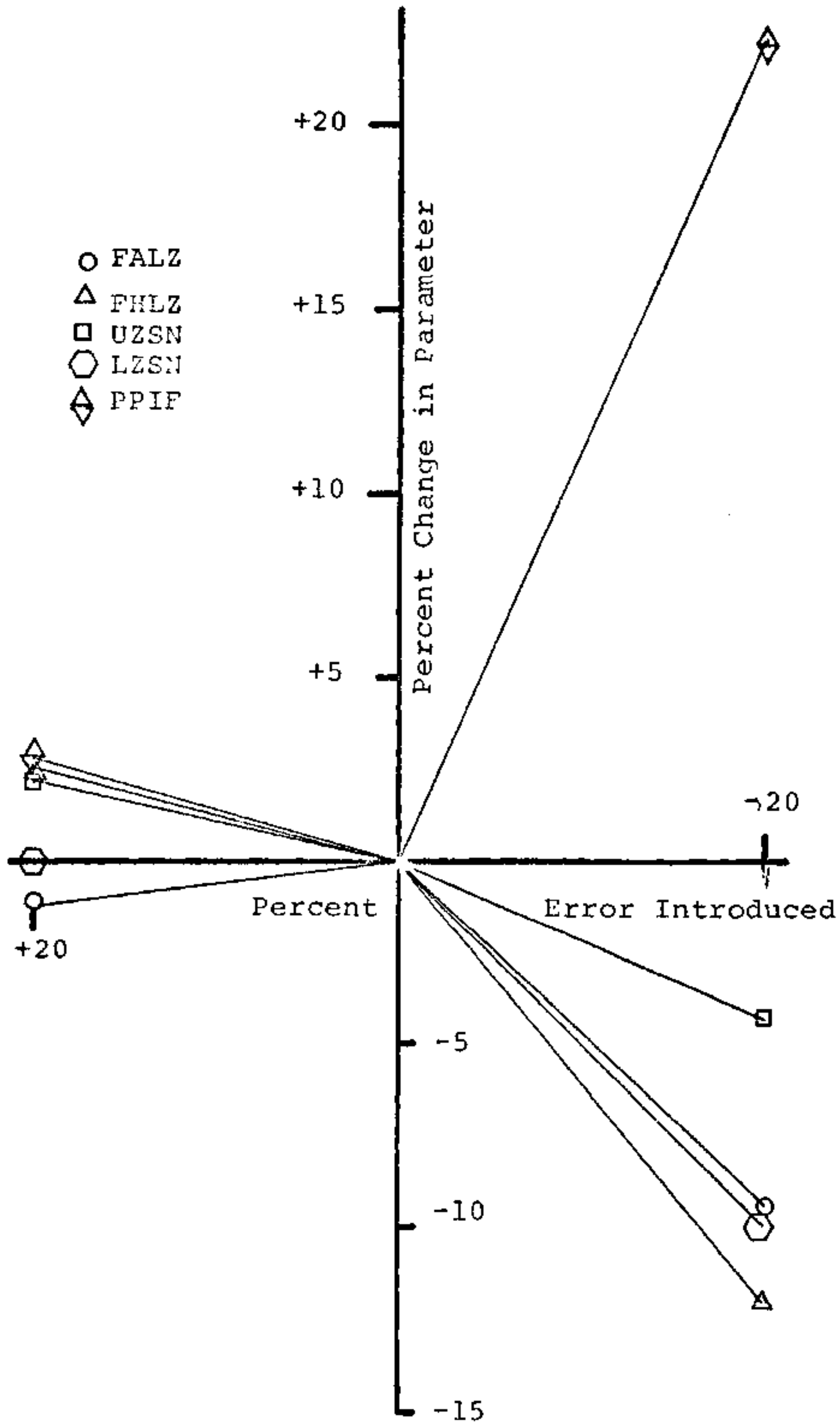



Figure 32. Results of Error Introduced into Streamflow Record

parameter set (Figures 33 and 35) and the observed hydrographs compared to simulated hydrographs using the adjusted parameters (Figures 34 and 36).

There were three events during the year which were adjusted. These occurred during (1) February 23 through 26 having original daily streamflow values of 215 cfs, 300 cfs, 1870 cfs and 106 cfs respectively, (2) April 12 having an original daily streamflow of 179 cfs and (3) June 21 having an original daily streamflow value of 274 cfs as shown in Table 7. The adjustments and adjusted streamflow values are also shown with the corresponding daily precipitation for each event. At this point it should be noted that the "base set" of parameters under simulated the yearly record by 0.89 inches. However by decreasing the observed streamflow (-20 percent adjustment) the model now has much more precipitation for the three events than the observed streamflow would indicate. In this case the model would allocate more moisture to the ridge zone by decreasing FHLZ and FALZ. Also by decreasing the streamflow, PPIF would increase and UZSN would decrease to increase the infiltration and decrease surface runoff to that of the adjusted peak flow. Although the decrease in LZSN is small, its decrease would allow a greater fraction of the evapotranspiration from the upper zone storage (UZS) so it would be dryer at the start of the storms and thus increase infiltration.

From Figure 32, it is apparent that larger variations of the parameters from the base set occur for a negative adjustment of

Table 7. Adjustment Values for Streamflow

| Event | Date | Original Streamflow | Adjustment | Adjusted Streamflow | Precipitation |
|---|---|---|---|---|---|
| 1 | Feb 23 | 215 | 1.2 | 258 | 0.86 |
| | 24 | 300 | 1.2 | 360 | 3.75 |
| | 25 | 1870 | 1.2 | 2244 | 1.95 |
| | 26 | 106 | 1.2 | 127.2 | 0.00 |
| 2 | April 12 | 179 | 1.2 | 214.8 | 1.49 |
| 3 | June 21 | 274 | 1.2 | 328.8 | 1.93 |
| | | | | | |
| 1 | Feb 23 | 215 | 0.8 | 172.0 | 0.86 |
| | 24 | 300 | 0.8 | 240.0 | 3.75 |
| | 25 | 1870 | 0.8 | 1496.0 | 1.95 |
| | 26 | 106 | 0.8 | 84.8 | 0.00 |
| 2 | April 12 | 179 | 0.8 | 143.2 | 1.49 |
| 3 | June 21 | 274 | 0.8 | 219.2 | 1.93 |

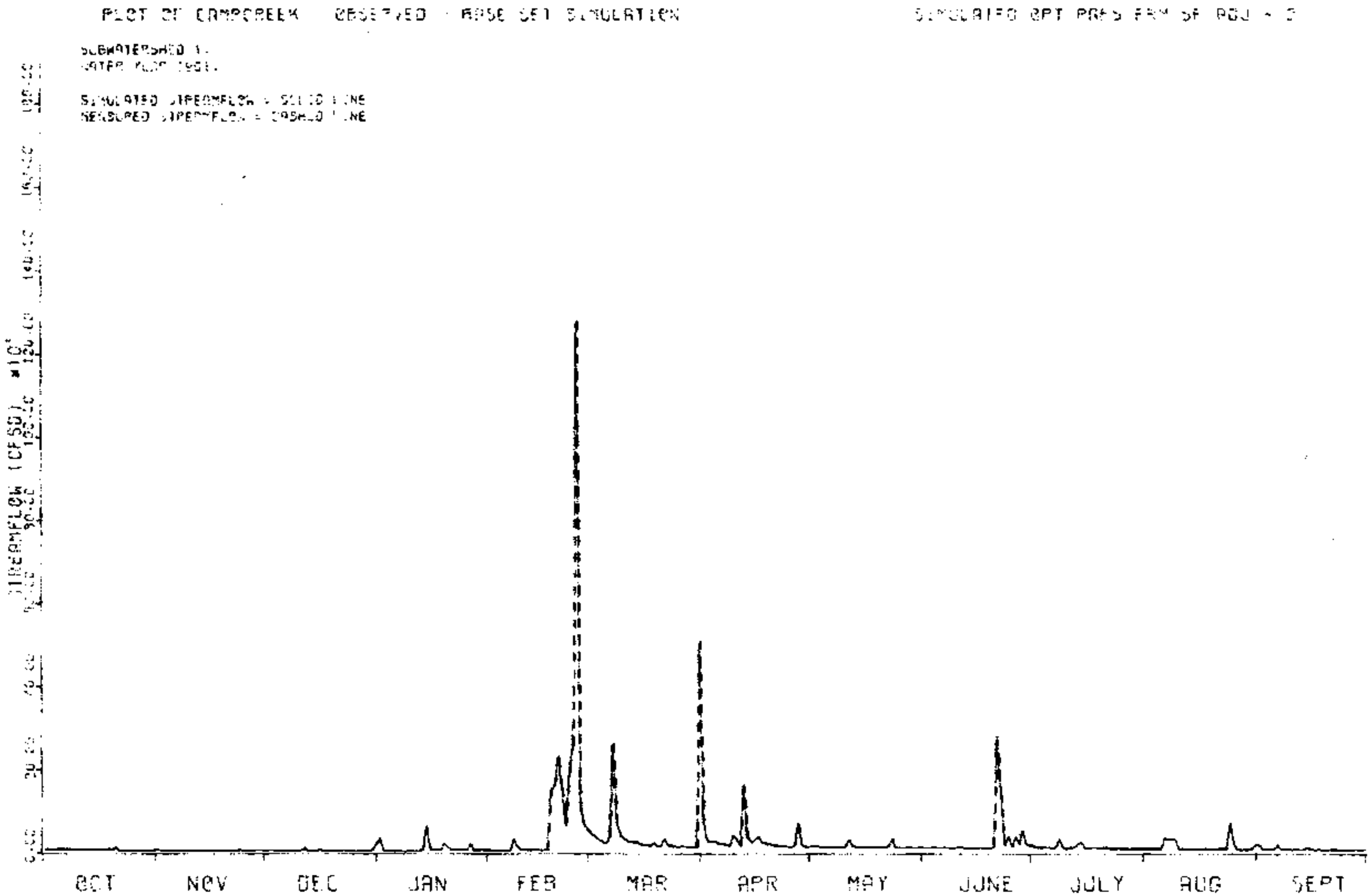



Figure 33. Plots of Simulated Hydrograph for a 1.2 Adjustment to Three Largest Peaks of the Year and Simulated Hydrograph for the Base Set

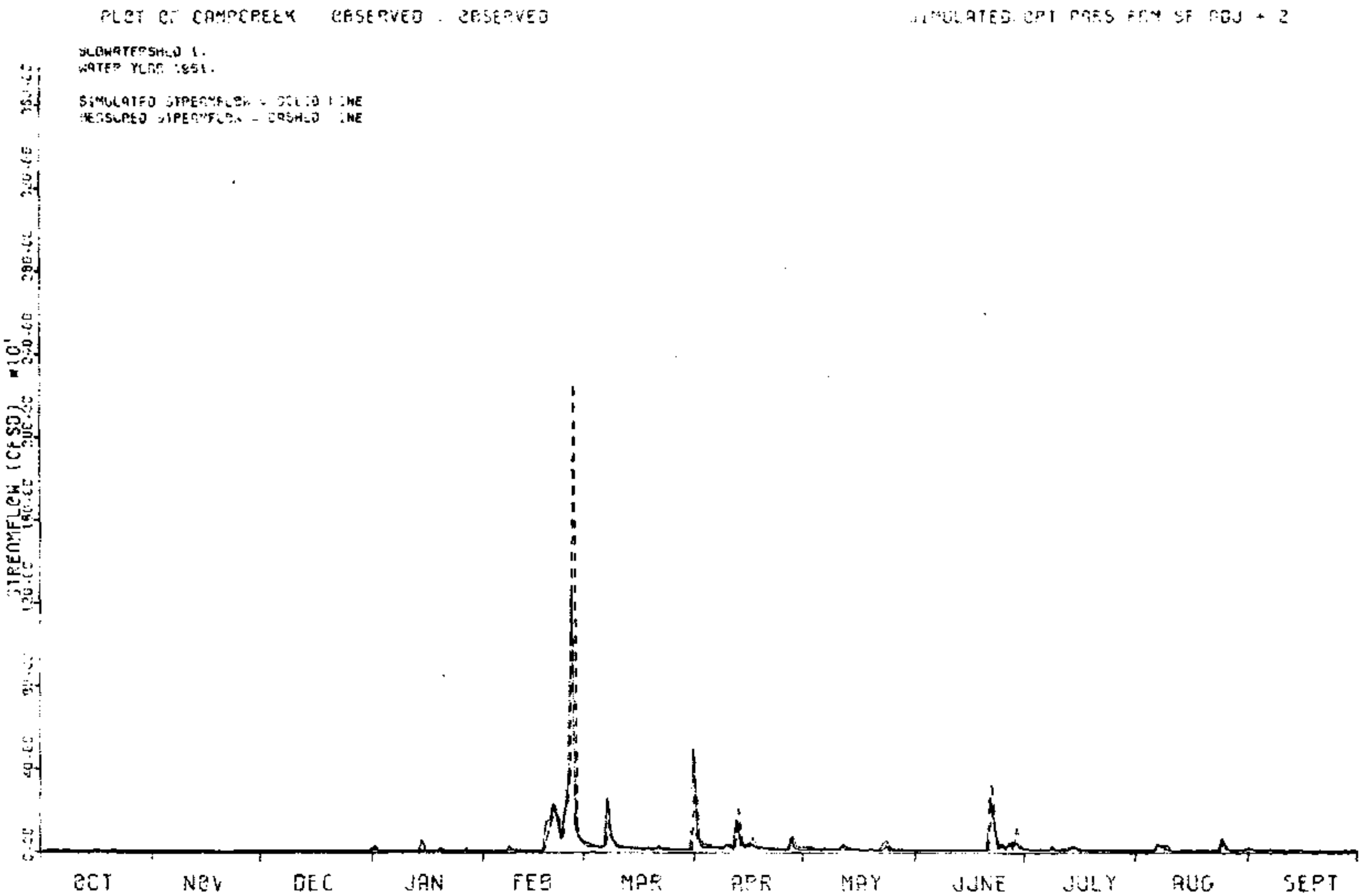



Figure 34. Plots of Simulated Hydrograph for a 1.2 Adjustment to Three Largest Peaks of the Year and the Observed Hydrograph

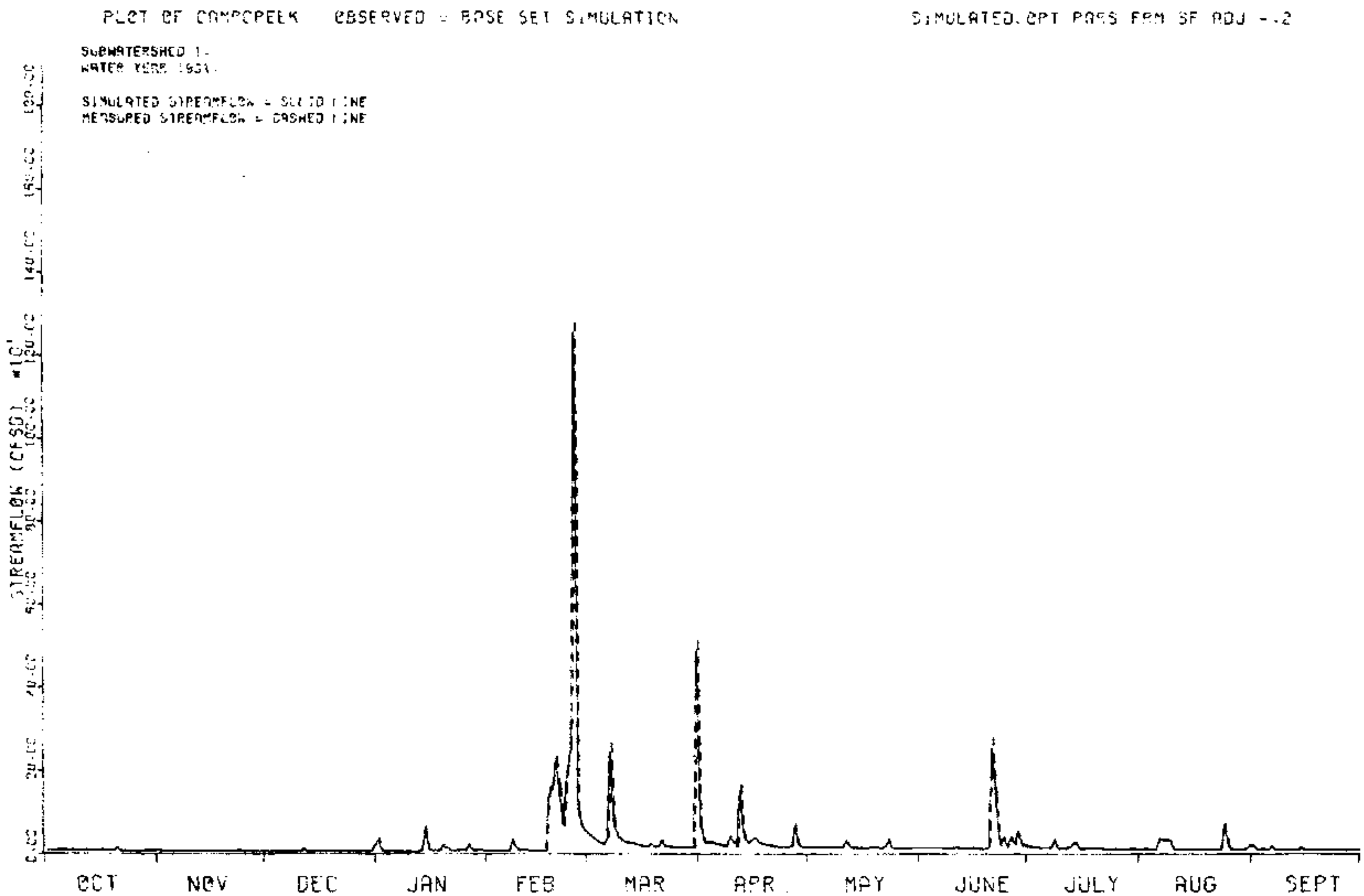



Figure 35. Plots of Simulated Hydrograph for a 0.8 Adjustment to Three Largest Peaks of the Year and the Simulated Hydrograph for the Base Set

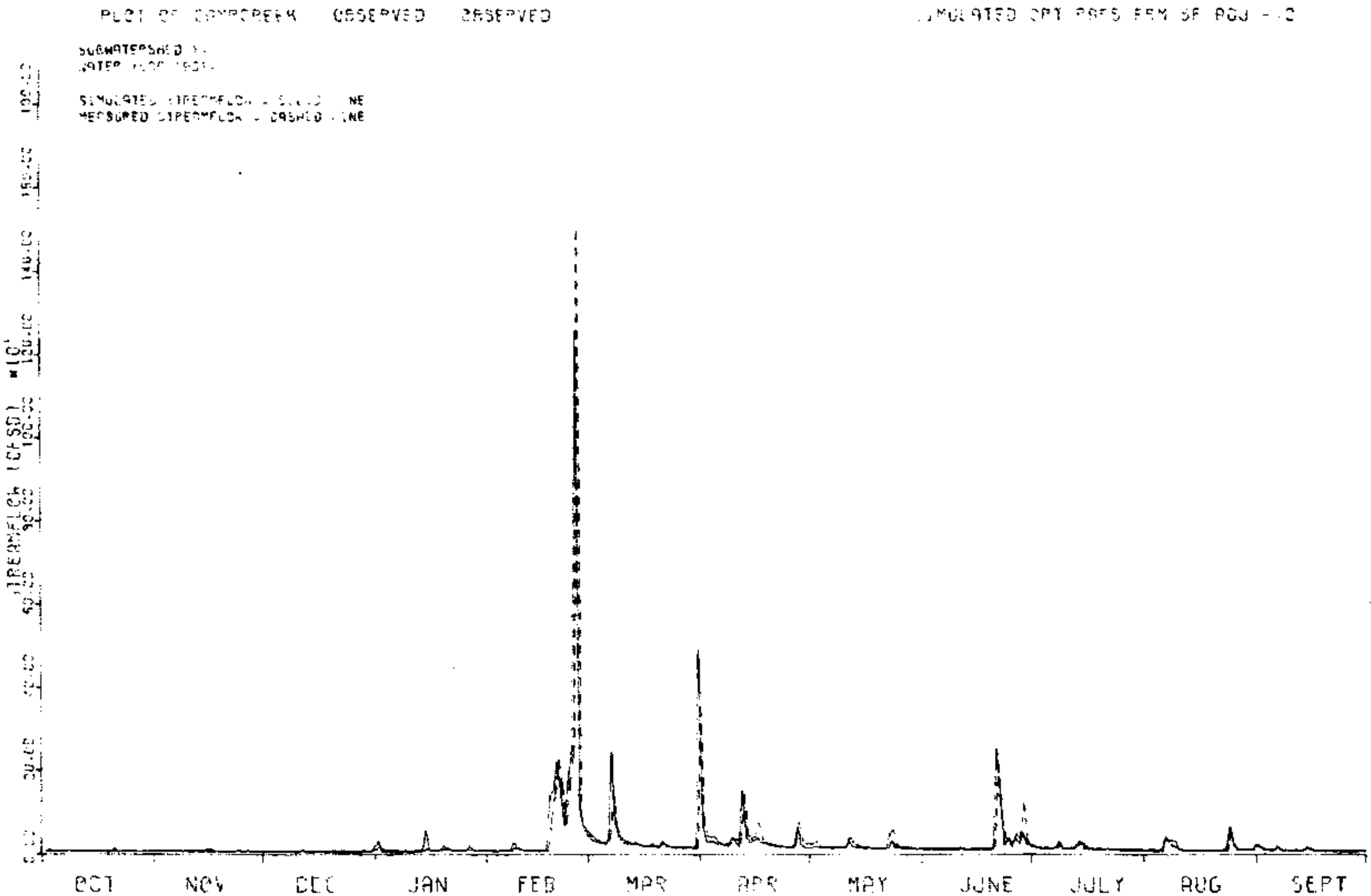



Figure 36. Plots of Simulated Hydrograph for a 0.8 Adjustment to Three Largest Peaks of the Year and the Observed Hydrograph

streamflow. The positive adjustments show variations that are within 10 percent and are considered insignificant as previously disucssed. It must be noted that streamflow is only used to evaluate the objective function for optimizations and is not required input for the simulation. The smaller changes in parameter values for the positive adjustments indicate that the parameter values are determined of more from their effect on antecedent moisture conditions than from any one peak event. Inceases in the three peak values cause smaller changes in the parameters than decrease because there is not enough precipitation to allocate in conjunction with the observed streamflow.

It appears that PPIF, relative to the other four parameters, is more sensitive to adjustments of selected rainfall events, whereas in overall adjustments of precipitation, UZSN, LZSN, FALZ and FHLZ seem most sensitive. This may be due to PPIF being determined mainly by major events during the year. However, in the case of the overall adjustments, minor perturbations of PPIF are masked in the variation of the remaining four parameters.

More detail may be obtained by referring to the detailed flow tables in Appendix C.

## Evaporation

As discussed in Chapter IV, three methods of estimating PET data were used to compare the effects of one method versus another. The three sources were (1) daily pan evaporation from

Rome, Georgia, 60 miles northwest of the watershed, (2) calculated daily PET from Hargreaves equation (8), and (3) a 20-year average of the Hargreaves calculated PET. The caluclated Hargreaves data was first used in obtaining the base set of parameters. Each data type was then used to replace the calculated PET and the parameters were optimized again. A comparison of the three types is presented in Table 8 and Figure 37. The relative position of each at the start of the water year should be noted. Pan evaporation is the lowest, the calculated monthly PET the next highest, and the 20-year monthly average being the highest. The difference between the pan evaporation and the Hargreaves calculated PET is greater than the difference between the 20-year average and the calculated PET. An adjustment was then made to the pan evaporation in order to adjust the yearly total to agree with that of the calcualted Hargreaves PET. The results of each of the above three data inputs on the five parameters are presented in Table 9 and Figure 38.

Calcamp plots for each adjustment are included in Figures 39 through 44. Figures 39, 41, and 43 show the hydrographs simulated using the adjusted parameters compared to the observed hydrographs while Figures 40, 42, and 44 have the simulated hydrographs (adjusted parameters) compared to the simulated hydrographs using the base set parameters.

By using the smaller PET values, the results should compare to the conditions of increased precipitation throughout the year. This is generally the case with a decrease in FALZ and FHLZ and an

Table 8. Monthly Total Potential Evapotranspiration for Water Year 1961

| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sept |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ROME PAN | 3.21 | 1.96 | 1.75 | .9 | 1.55 | 3.10 | 5.49 | 5.28 | 5.53 | 6.64 | 5.37 | 4.98 |
| Hargraves Calculated | 3.4 | 2.324 | 1.393 | 1.391 | 2.295 | 3.904 | 5.322 | 6.347 | 6.620 | 7.041 | 6.294 | 5.293 |
| 20-Year Average of Calculated | 3.49 | 2.01 | 1.28 | 1.37 | 1.88 | 3.43 | 5.22 | 6.7 | 7.19 | 7.0 | 6.58 | 5.13 |

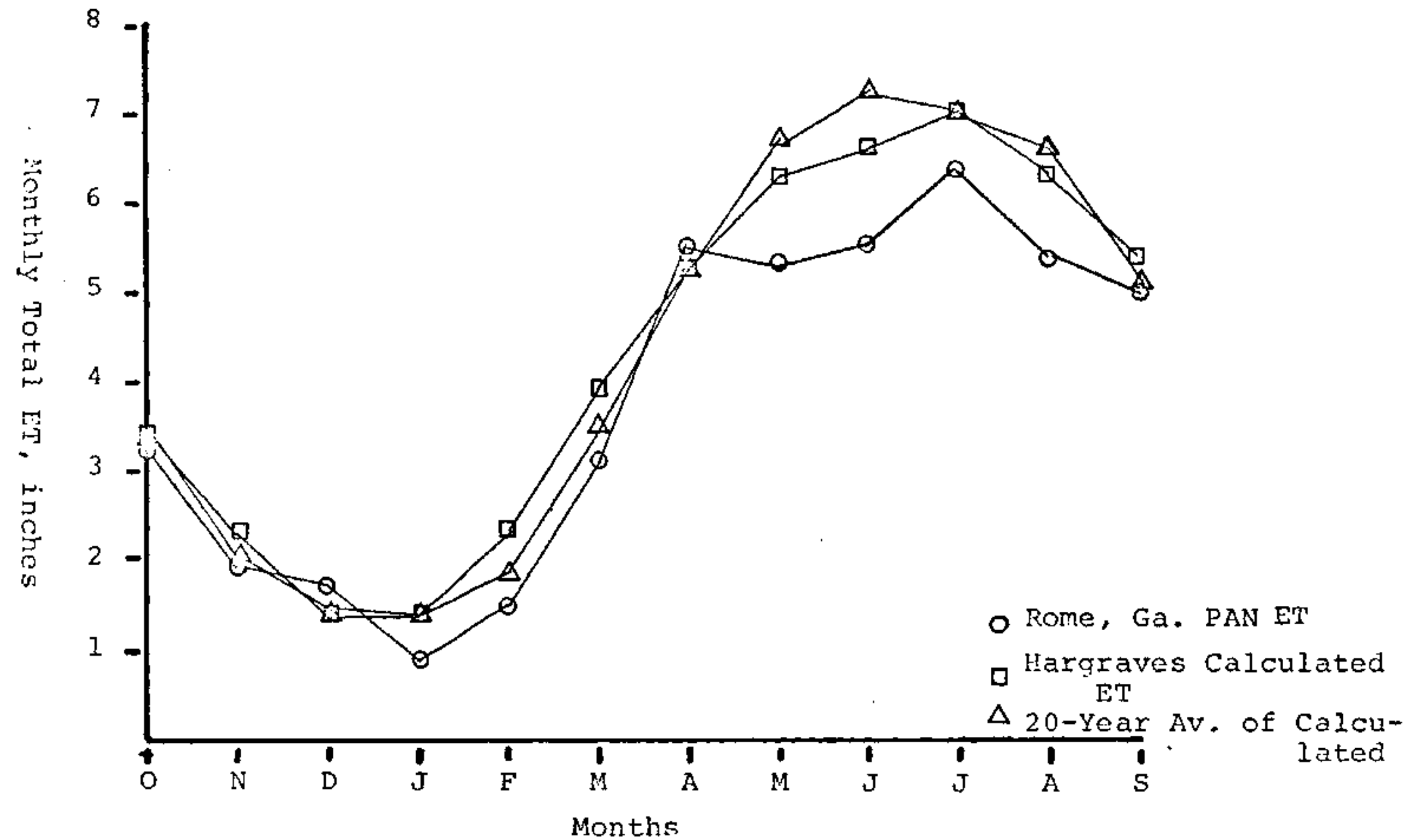



Figure 37. Comparison of Monthly Total Potential ET Data Available

Table 9. Results of Using the Two Sources of ET Data

| Parameter | Base | Adjusted Value | Change in Parameter | Change / Base |
|---|---|---|---|---|
| **Pan ET** | | | | |
| FALZ | .49875 | .40613 | .09262 | -.186 |
| FHLZ | .16561 | .13823 | .02738 | -.165 |
| UZSN | 1.70775 | 1.6335 | .0742 | -.043 |
| LZSN | 4.18176 | 4.5999 | .4131 | +.0999 |
| PPIF | 8.28 | 10.12 | 1.84 | +.222 |
| **Pan ET adjusted by 1.13** | | | | |
| FALZ | .49875 | .45006 | .0487 | -.0976 |
| FHLZ | .16561 | .14227 | .0233 | -.1409 |
| UZSN | 1.70775 | 1.47015 | .2376 | -.1391 |
| LZSN | 4.18176 | 4.18176 | .0000 | - |
| PPIF | 8.28 | 10.12 | 1.84 | +.222 |
| **20-Year Average ET** | | | | |
| FALZ | .49875 | .48094 | .01781 | -.0357 |
| FHLZ | .16561 | .12287 | .04274 | -.25807 |
| UZSN | 1.70775 | 1.30309 | .40466 | -.2369 |
| LZSN | 4.18176 | 4.18176 | 0.0 | - |
| PPIF | 8.28 | 8.855 | .575 | +.0694 |

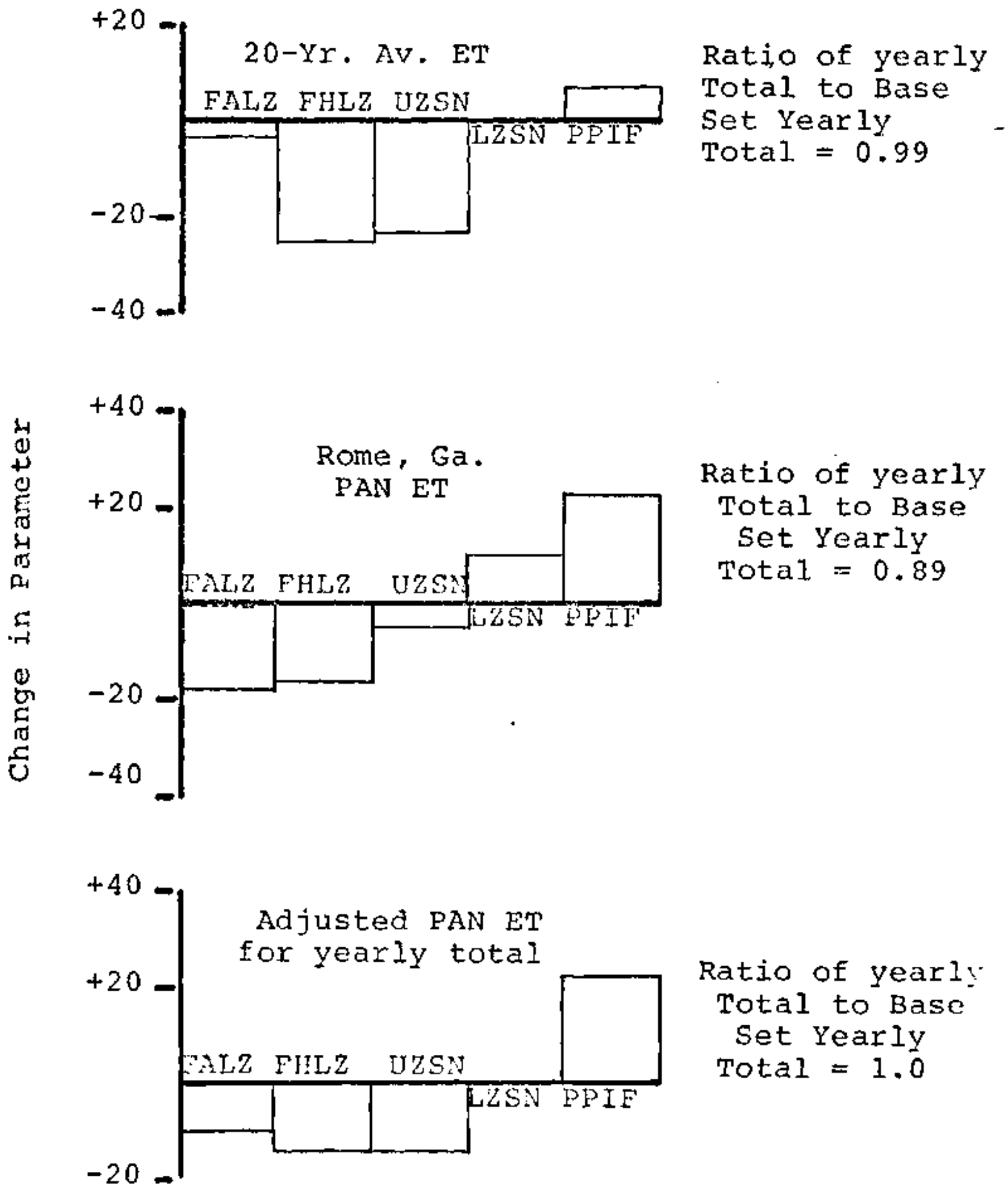



Figure 38. Results of Using the Two Sources of ET Data

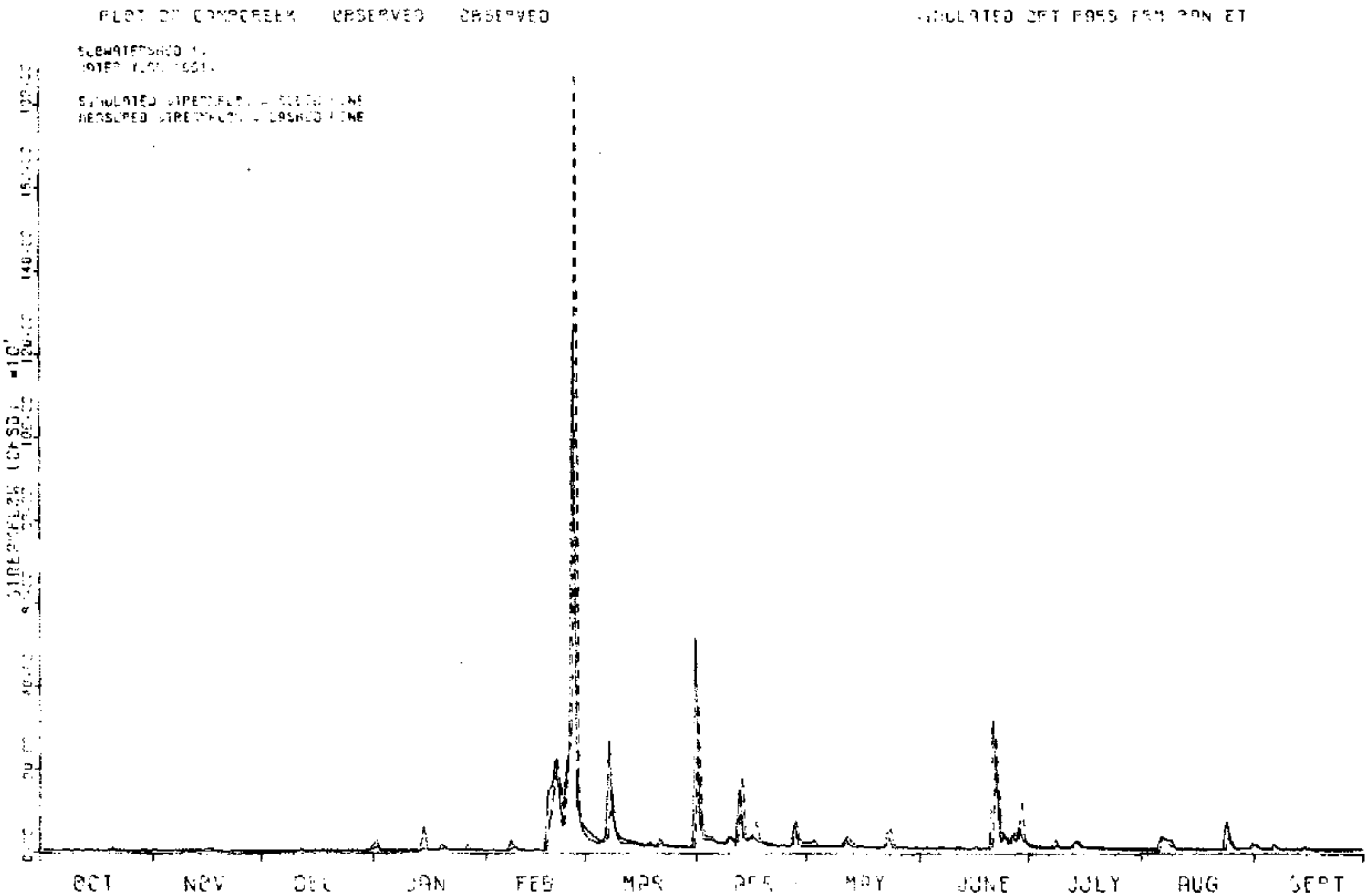



Figure 39. Plots of Simulated Hydrograph for Pan ET and the Observed Hydrograph

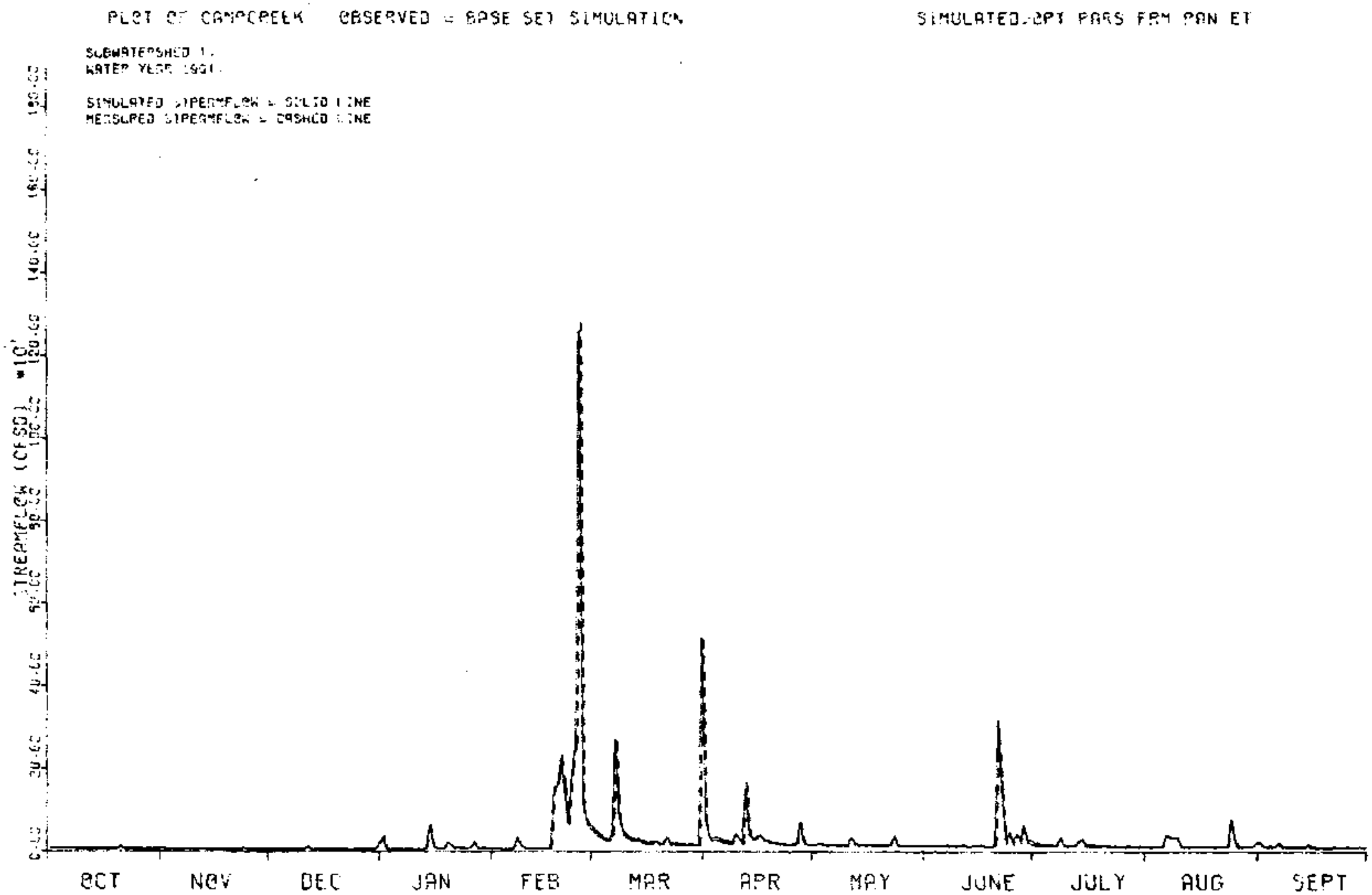



**Figure 40. Plots of Simulated Hydrograph for Pan ET and the Simulated Hydrograph for the Base Set**

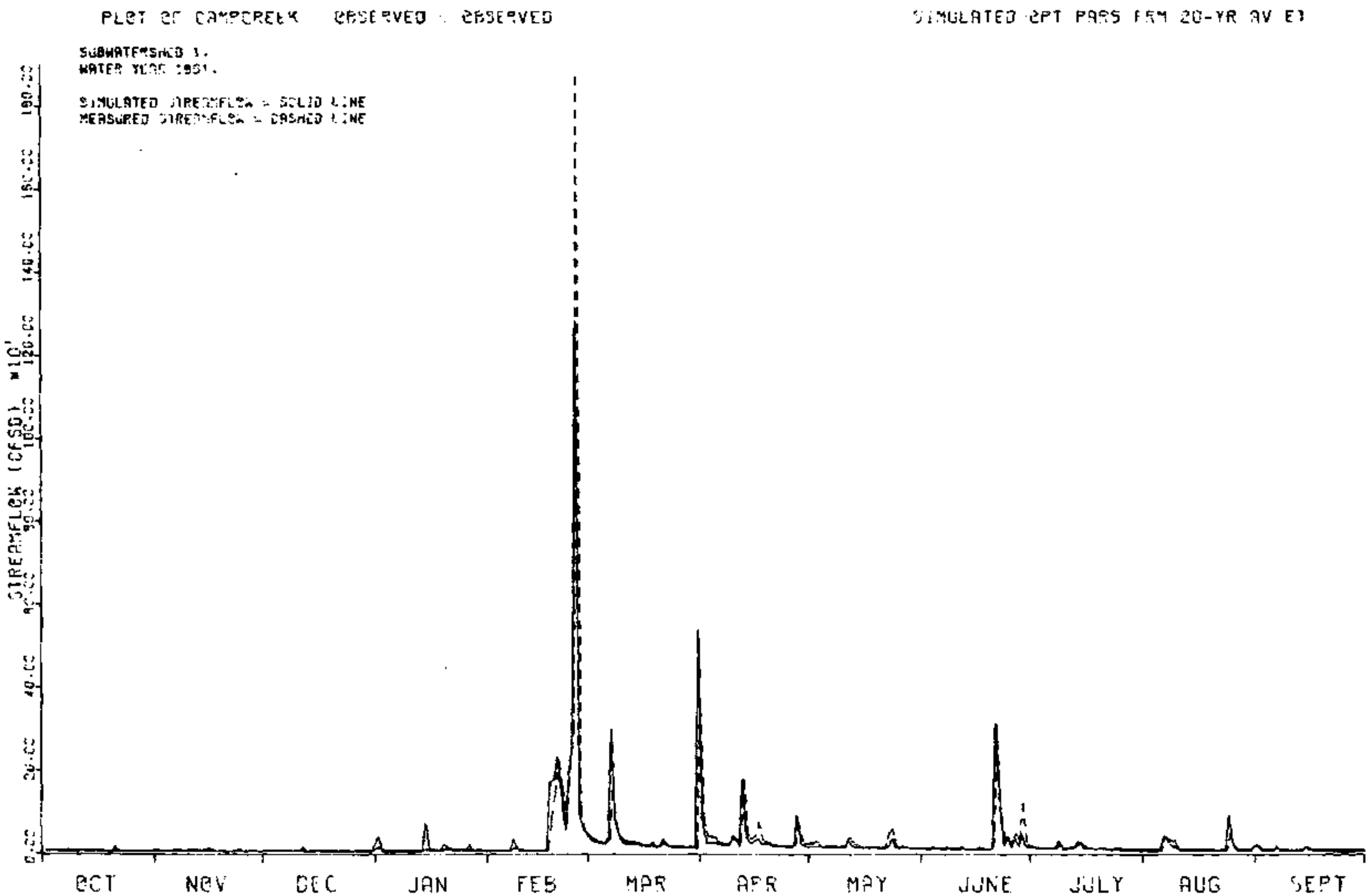



Figure 41. Plots of Simulated Hydrograph for 20-Year Average Calculated ET and the Observed Hydrograph

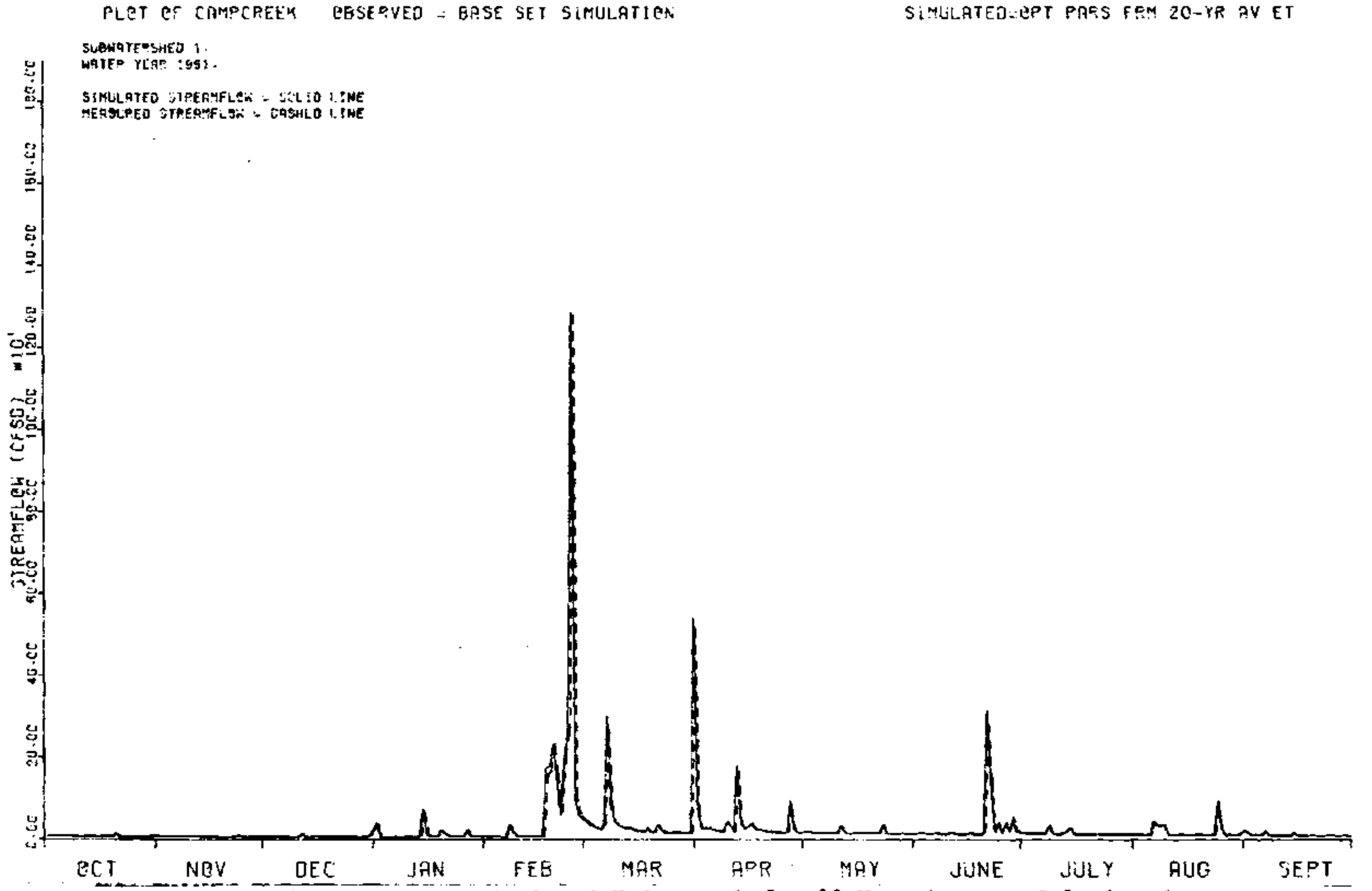



Figure 42. Plots of Simulated Hydrograph for 20-Year Average Calculated ET and the Simulated Hydrograph for the Base Set

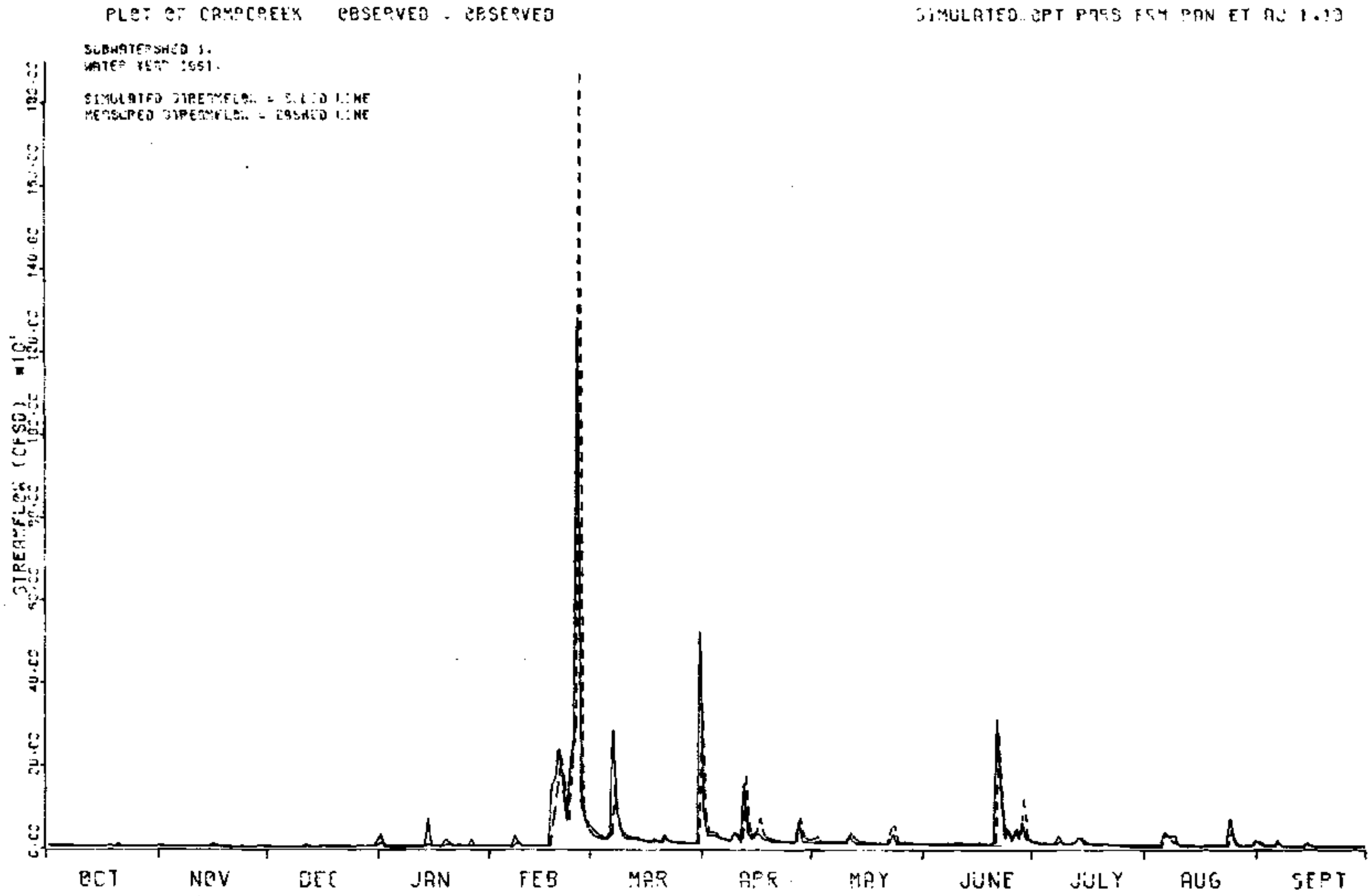



Figure 43. plots of Simulated Hydrograph for Adjusted Pan Et and the Observed Hydrograph

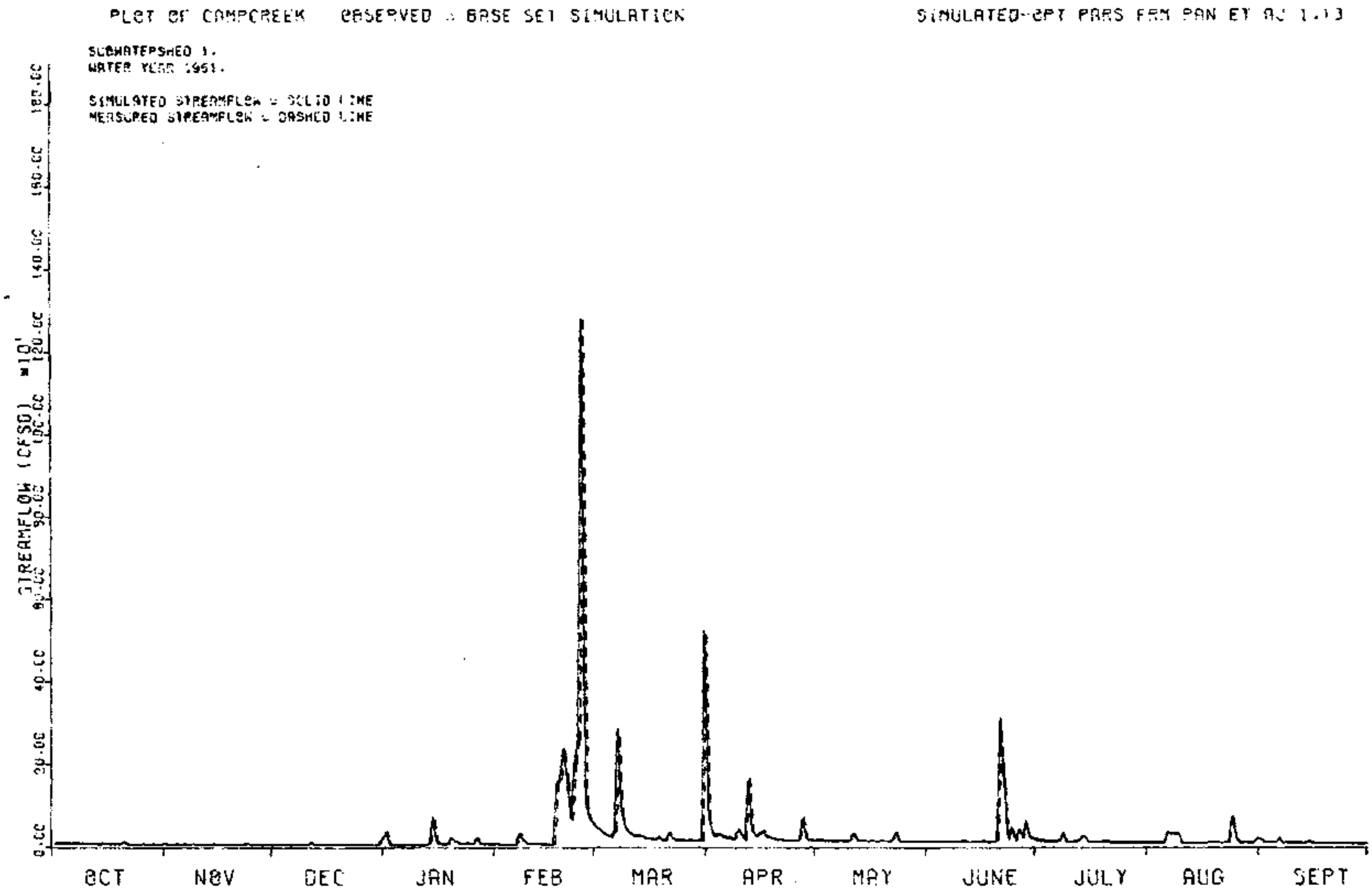



Figure 44. Plots of Simulated Hydrograph for Adjusted Pan ET and the Simulated Hydrograph for the Base Set

increase of PPIF. The change in direction of UZSN may reflect the accumulative effect of evapotranspiration on UZS relative to the major storm hydrographs. With a decreased PET the model has, in effect, too much precipitation. The decrease of UZSN is limiting the upper soil zone so as to store more moisture in the lower zones. FALZ and FHLZ are decreasing so that this moisture may be stored in the ridge storage (i.e., FRLZ is increasing). Generally LZSN is not as sensitive to the small variations in PET which are present. Only for the lowest data values (pan evaporation) does LZSN change and its movement is in the positive direction as would be expected. A more detailed analysis may be accomplished by referring to the flow tables in Appendix D.

# CHAPTER VI

# CONCLUSIONS AND RECOMMENDATIONS

## Conclusions

In conclusion, it is apparent that the most critical data errors are those made in precipitation systematically throughout the year. Variations of up to 70 or 80 percent for UZSN, FHLZ, LZSN, and FALZ for a 20 percent increase in precipitation (Figure 14) would be unacceptable on parameters with which correlations with the physical characteristics of a watershed were expected. It seems significant that an error of up to 30 percent in precipitation associated with a major event during the year (Figure 23) has little effect on parameter values. It is also true, however, that errors associated with individual major thunderstorms may be much larger than this. In order to assess the significance of an error one must look at both the probability of it happening and the consequence when it happens.

The effects of errors in streamflow on model parameters are still of some question. Parameter variations, such as those shown in Figure 39, may depend on whether the streamflow record used for calibration represents either a wet or dry year. The effects seem to be major only in two parameters, FHLZ and PPIF. However, these two parameters have a major effect on the moisture accounting in the model and the simulated streamflow.

The PET data comparison (Figure 37) has variations within it which assist in making assumptions about the five parameters. Of the five, LZSN seems to be the most stable in this case (Figure 38). PPIF will decrease in order to compensate for drier soil conditions due to greater evapotranspiration. Since FHLZ and UZSN are sensitive to the variations in PET it does not seem likely that they could be used as correlation parameters to watershed characteristics.

The adjustments which were applied to the total precipitation record are probably as large as could be expected although this would depend on gage performance. In adjusting the precipitation associated with a single event the errors involved could conceivably be much larger. This aspect was not investigated but, as discussed previously, errors in the order of twice the total rainfall over the watershed may occur. Adjustments of $\pm$ 20 percent to streamflow data are within the range which would be expected. This range could be caused by debris in the channel retarding the flow or by large storms causing over-bank flow at the stream gage. In examining the variations in potential evapotranspiration (PET) it is apparent from Figures 5 and 6 that larger variations could be expected. The variations in the PET data used are smaller than those in Figures 5 and 6, which is apparent from Figure 37.

## Recommendations

This study has brought to the surface several questions. It would be very interesting to observe the effects of random storm centers in conjunction with a varying rainfall distribution over a watershed. The distribution could be one in time and space over subwatersheds. This more sophisticated model would be, ar present, difficult to calibrate. Each subwatershed would have, in essense, a different rainfall and therefore have variations in the optimum parameter set obtained. The model would also become more complex which may not be advantageous at this time.

There are many aspects of the data which are still not understood. Point rainfall can not be measured to a known accuracy. The concept of potential evapotranspiration as used in watershed models is still somewhat vague as a tool in hydrology. This is an area for the theoretician and the practical engineer to work together in order to understand more fully the workings of nature. The number of years of streamflow data necessary for predicition of both low and high flows would also be an advantageous area to investigate.

## SUMMARY

This study has investigated the effects of the three basic types of hydrologic data, necessary for streamflow simulation, on the parameter values which are obtained through computerized optimization. By studying the calibration of a model to a watershed the general effects of data error on the calibration procedure were investigated.

As a result of this study, it appears that the most sensitive systematic data errors are in precipitation data. Systematic errors in streamflow and potential evapotranspiration produce similar effects on model parameters, although under certain conditions parameter values are more sensitive to errors in streamflow.

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# APPENDIX A

## Base Set

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTEVILLE GEORGIA — WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1,887 | 1,128 | 2,033 | 2,329 | 13,040 | 7,065 | 4,978 | 3,342 | 7,869 | 2,806 | 6,401 | 1,353 | 54,234 |
| LOSSES (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,897 | ,546 | ,259 | ,230 | ,529 | ,758 | 1,138 | 1,184 | 1,957 | 1,106 | 1,561 | ,628 | 10,792 |
| INFILTRATION-DIRECT | ,524 | ,556 | 1,559 | 1,755 | 5,581 | 3,496 | 2,908 | 1,960 | 4,230 | 1,472 | 4,126 | ,653 | 29,218 |
| -FROM SRS | ,011 | ,003 | ,037 | ,116 | 1,799 | ,632 | ,414 | ,045 | ,461 | ,056 | ,182 | ,018 | 3,769 |
| -FROM SDS | ,010 | ,062 | ,010 | ,016 | ,167 | ,109 | ,056 | ,022 | ,085 | ,030 | ,075 | ,008 | ,586 |
| SURFACE RETENTION | ,011 | ,003 | ,056 | ,093 | 1,884 | ,606 | ,258 | ,045 | ,469 | ,056 | ,186 | ,016 | 3,682 |
| PERCOLATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| UZS-LZS | ,000 | ,000 | ,529 | 1,978 | 6,711 | 2,712 | 2,577 | ,730 | 3,113 | ,500 | 2,133 | ,288 | 21,272 |
| LZS-GWS | ,163 | ,000 | ,000 | ,539 | 3,893 | 1,352 | 1,331 | ,000 | ,755 | ,000 | ,045 | ,069 | 8,147 |
| SEEPAGE RIDGE | ,000 | ,000 | ,009 | ,000 | 1,279 | ,682 | ,464 | ,000 | ,001 | ,000 | ,000 | ,000 | 2,447 |
| UNDERFLOW | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| STREAMFLOW (WATERSHED INCHES) | | | | | | | | | | | | | |
| IMPERVIOUS AREA | ,028 | ,017 | ,030 | ,034 | ,143 | ,105 | ,074 | ,049 | ,116 | ,042 | ,095 | ,020 | ,803 |
| SURFACE | ,017 | ,005 | ,119 | ,201 | 4,691 | 1,792 | ,545 | ,082 | 1,012 | ,101 | ,359 | ,029 | 8,954 |
| INTERFLOW | ,005 | ,000 | ,000 | ,106 | 1,067 | ,596 | ,401 | ,012 | ,116 | ,038 | ,006 | ,010 | 2,361 |
| BASEFLOW | ,526 | ,437 | ,387 | ,362 | ,458 | ,998 | 1,016 | ,951 | ,809 | ,806 | ,691 | ,389 | 8,010 |
| TOTAL FLOW | ,579 | ,459 | ,537 | ,704 | 6,389 | 3,491 | 2,035 | 1,095 | 2,053 | ,987 | 1,152 | ,448 | 20,127 |
| EVAPOTRANSPIRATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,741 | ,674 | ,237 | ,276 | ,527 | ,654 | 1,238 | 1,190 | 1,892 | 1,172 | 1,315 | ,874 | 10,792 |
| SRS | ,000 | ,000 | ,000 | ,001 | ,079 | ,012 | ,012 | ,000 | ,008 | ,000 | ,001 | ,000 | ,113 |
| UZS | ,633 | ,486 | ,385 | ,407 | ,634 | 1,165 | 1,419 | 1,619 | 1,306 | 1,728 | 1,266 | 1,342 | 12,390 |
| LZS | ,725 | ,349 | ,222 | ,332 | ,625 | 1,212 | 1,482 | 1,556 | 1,127 | 1,756 | 1,313 | 1,179 | 11,879 |
| GWS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| TOTAL | 2,100 | 1,509 | ,845 | 1,016 | 1,864 | 3,043 | 4,151 | 4,366 | 4,332 | 4,656 | 3,915 | 3,376 | 35,173 |
| POTENTIAL | 3,400 | 2,324 | 1,393 | 1,391 | 2,245 | 3,904 | 5,322 | 6,347 | 6,620 | 7,041 | 6,294 | 5,293 | 51,624 |
| END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES) | | | | | | | | | | | | | |
| INTC | ,158 | ,024 | ,056 | ,003 | ,005 | ,110 | ,008 | ,002 | ,068 | ,001 | ,250 | ,000 | |
| SDS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | |
| SRS | ,000 | ,000 | ,024 | ,000 | ,007 | ,171 | ,000 | ,000 | ,000 | ,000 | ,002 | ,000 | |
| UZS | ,640 | ,715 | 1,413 | ,908 | 1,169 | 1,475 | ,848 | ,519 | ,882 | ,201 | 1,179 | ,234 | |
| LZS(RIDGE) | 1,744 | 1,368 | 1,664 | 3,294 | 5,465 | 4,522 | 3,665 | 2,393 | 4,087 | 2,246 | 2,793 | 1,697 | |
| LZS(ALLUVIAL) | 1,497 | 1,165 | 1,488 | 2,086 | 2,465 | 2,490 | 1,967 | 1,410 | 2,085 | 1,187 | 2,104 | 1,192 | |
| LZS(HILLSIDE) | 1,702 | 1,333 | 1,634 | 2,634 | 4,184 | 3,061 | 2,448 | 1,631 | 2,971 | 1,512 | 2,337 | 1,379 | |
| GWS | 6,273 | 5,397 | 4,620 | 4,975 | 11,902 | 12,612 | 13,243 | 11,358 | 11,230 | 9,614 | 8,317 | 7,276 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS -1,066

CHANGE IN STORAGE EQUALS -1,066

## Adjustment to Total Precipitation Record of 0.8

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1,510 | ,903 | 1,627 | 1,864 | 10,432 | 5,652 | 3,983 | 2,674 | 6,295 | 2,245 | 5,121 | 1,083 | 43,387 |
| LOSES (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,246 | ,515 | ,259 | ,224 | ,516 | ,744 | 1,124 | 1,102 | 1,898 | 1,069 | 1,488 | ,610 | 10,400 |
| INFILTRATION-DIRECT | ,625 | ,372 | 1,226 | 1,435 | 4,998 | 2,939 | 2,286 | 1,480 | 3,334 | 1,083 | 3,159 | ,437 | 23,373 |
| -RECH SRS | ,005 | ,001 | ,017 | ,071 | 1,321 | ,440 | ,262 | ,016 | ,286 | ,018 | ,118 | ,005 | 2,560 |
| -RECH SPS | ,004 | ,001 | ,006 | ,010 | ,108 | ,066 | ,031 | ,009 | ,049 | ,012 | ,042 | ,003 | ,341 |
| SURFACE RETENTION | ,005 | ,001 | ,036 | ,053 | 1,379 | ,563 | ,154 | ,016 | ,291 | ,018 | ,119 | ,004 | 2,638 |
| PERCOLATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| UZS-LZS | ,000 | ,000 | ,423 | 1,384 | 5,705 | 2,149 | 1,639 | ,460 | 2,452 | ,279 | 1,952 | ,077 | 16,518 |
| LZS-GWS | ,617 | ,000 | ,000 | ,402 | 3,416 | ,695 | ,665 | ,000 | ,741 | ,000 | ,220 | ,000 | 7,156 |
| SEEPAGE RIDGE | ,107 | ,000 | ,000 | ,007 | 1,107 | ,415 | ,187 | ,000 | ,075 | ,000 | ,000 | ,000 | 1,896 |
| UNDERFLOW | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| STREAMFLOW (WATERSHED INCHES) | | | | | | | | | | | | | |
| IMPERVIOUS AREA | ,022 | ,013 | ,024 | ,028 | ,154 | ,084 | ,059 | ,040 | ,093 | ,033 | ,076 | ,016 | ,642 |
| SURFACE | ,007 | ,001 | ,077 | ,114 | 3,276 | 1,257 | ,329 | ,028 | ,630 | ,030 | ,237 | ,006 | 5,993 |
| INTERFLOW | ,275 | ,000 | ,000 | ,132 | 1,269 | ,362 | ,270 | ,000 | ,217 | ,010 | ,035 | ,006 | 2,595 |
| BASEFLOW | ,630 | ,524 | ,465 | ,423 | ,470 | ,905 | ,861 | ,789 | ,676 | ,685 | ,600 | ,515 | 7,546 |
| TOTAL FLOW | ,934 | ,539 | ,566 | ,697 | 5,169 | 2,608 | 1,519 | ,856 | 1,619 | ,758 | ,949 | ,543 | 16,776 |
| EVAPOTRANSPIRATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,690 | ,648 | ,232 | ,270 | ,515 | ,640 | 1,225 | 1,100 | 1,839 | 1,129 | 1,242 | ,862 | 10,400 |
| SRS | ,000 | ,000 | ,000 | ,000 | ,057 | ,008 | ,009 | ,000 | ,004 | ,000 | ,001 | ,000 | ,079 |
| UZS | ,707 | ,407 | ,354 | ,413 | ,638 | 1,124 | 1,299 | 1,279 | ,941 | 1,178 | ,815 | ,921 | 10,075 |
| LZS | ,764 | ,270 | ,143 | ,316 | ,585 | 1,032 | 1,248 | 1,022 | ,640 | 1,203 | ,992 | ,803 | 9,017 |
| GWS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| TOTAL | 2,161 | 1,326 | ,729 | ,999 | 1,795 | 2,803 | 3,779 | 3,409 | 3,425 | 3,510 | 3,050 | 2,586 | 29,570 |
| POTENTIAL | 3,400 | 2,324 | 1,393 | 1,391 | 2,255 | 3,904 | 5,322 | 6,347 | 6,620 | 7,041 | 6,294 | 5,293 | 51,624 |
| END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES) | | | | | | | | | | | | | |
| INTC | ,158 | ,023 | ,050 | ,003 | ,005 | ,110 | ,008 | ,002 | ,062 | ,001 | ,250 | ,000 | |
| SRS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | |
| SRS | ,000 | ,000 | ,019 | ,000 | ,001 | ,119 | ,000 | ,000 | ,000 | ,000 | ,001 | ,000 | |
| UZS | ,251 | ,717 | ,696 | ,411 | ,496 | ,671 | ,307 | ,070 | ,349 | ,000 | ,561 | ,000 | |
| LZS(RIDGE) | 1,050 | ,635 | ,845 | 1,816 | 2,825 | 2,074 | 1,315 | ,460 | 1,839 | ,419 | 1,197 | ,315 | |
| LZS(ALLUVIAL) | ,447 | ,244 | ,562 | ,898 | ,979 | 1,126 | ,727 | ,303 | ,876 | ,200 | ,851 | ,204 | |
| LZS(HILLSIDE) | ,578 | ,326 | ,620 | 1,077 | 1,543 | 1,505 | ,870 | ,339 | 1,207 | ,259 | 1,025 | ,251 | |
| GWS | 7,368 | 6,339 | 5,427 | 5,386 | 11,167 | 11,147 | 10,762 | 9,213 | 9,336 | 7,992 | 7,247 | 6,235 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS -2,959

CHANGE IN STORAGE EQUALS -2,959

## Adjustment to Total Precipitation Record of 0.9

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA — WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1,698 | 1,016 | 1,830 | 2,097 | 11,736 | 6,559 | 4,481 | 3,008 | 7,082 | 2,526 | 5,761 | 1,218 | 48,411 |
| LOSS (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,872 | ,532 | ,259 | ,227 | ,522 | ,751 | 1,132 | 1,143 | 1,928 | 1,087 | 1,529 | ,623 | 10,605 |
| INFILTRATION-DIRECT | ,771 | ,462 | 1,370 | 1,562 | 5,040 | 3,118 | 2,553 | 1,719 | 3,721 | 1,274 | 3,610 | ,542 | 25,750 |
| -FROM SRS | ,009 | ,002 | ,025 | ,107 | 1,618 | ,549 | ,368 | ,030 | ,390 | ,038 | ,156 | ,013 | 3,306 |
| -FROM SDS | ,008 | ,001 | ,008 | ,013 | ,131 | ,087 | ,044 | ,016 | ,066 | ,022 | ,058 | ,006 | ,459 |
| SURFACE RETENTION | ,009 | ,002 | ,050 | ,083 | 1,702 | ,714 | ,219 | ,030 | ,398 | ,038 | ,160 | ,010 | 3,415 |
| PERCOLATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| UZS-LZS | ,000 | ,000 | ,375 | 1,651 | 5,948 | 2,274 | 2,009 | ,478 | 2,635 | ,322 | 1,862 | ,153 | 17,725 |
| LZS-GWS | ,539 | ,000 | ,000 | ,450 | 3,726 | 1,053 | 1,004 | ,000 | ,686 | ,000 | ,052 | ,028 | 7,538 |
| SEEPAGE RIDGE | ,000 | ,000 | ,000 | ,000 | 1,099 | ,485 | ,283 | ,000 | ,005 | ,000 | ,000 | ,000 | 1,873 |
| UNDERFLOW | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| STREAMFLOW (WATERSHED INCHES) | | | | | | | | | | | | | |
| IMPERVIOUS AREA | ,025 | ,015 | ,027 | ,031 | ,174 | ,094 | ,066 | ,045 | ,105 | ,037 | ,085 | ,018 | ,722 |
| SURFACE | ,014 | ,003 | ,108 | ,181 | 4,166 | 1,595 | ,467 | ,055 | ,865 | ,057 | ,314 | ,019 | 7,055 |
| INTERFLOW | ,107 | ,000 | ,000 | ,108 | 1,056 | ,410 | ,298 | ,000 | ,124 | ,017 | ,004 | ,004 | 2,129 |
| BASEFLOW | ,621 | ,516 | ,458 | ,418 | ,476 | ,973 | ,954 | ,883 | ,752 | ,746 | ,641 | ,542 | 7,960 |
| TOTAL FLOW | ,766 | ,535 | ,593 | ,738 | 5,872 | 3,073 | 1,766 | ,983 | 1,046 | ,668 | 1,044 | ,583 | 16,666 |
| EVAPOTRANSPIRATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,716 | ,663 | ,235 | ,273 | ,521 | ,647 | 1,232 | 1,149 | 1,866 | 1,150 | 1,284 | ,869 | 10,605 |
| SRS | ,000 | ,000 | ,000 | ,001 | ,076 | ,012 | ,012 | ,000 | ,008 | ,000 | ,001 | ,000 | ,109 |
| UZS | ,683 | ,468 | ,386 | ,432 | ,669 | 1,219 | 1,457 | 1,598 | 1,188 | 1,612 | 1,114 | 1,243 | 12,069 |
| LZS | ,736 | ,319 | ,186 | ,307 | ,572 | 1,059 | 1,287 | 1,208 | ,809 | 1,400 | 1,071 | ,939 | 9,893 |
| GWS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| TOTAL | 2,135 | 1,450 | ,806 | 1,013 | 1,838 | 2,936 | 3,987 | 3,956 | 3,870 | 4,163 | 3,470 | 3,052 | 32,676 |
| POTENTIAL | 3,400 | 2,324 | 1,393 | 1,391 | 2,295 | 3,904 | 5,322 | 6,347 | 6,620 | 7,041 | 6,294 | 5,293 | 51,624 |
| END-OF-MONTH-STORAGES (PERVIOUS SUB-AREA INCHES) | | | | | | | | | | | | | |
| INTC | ,158 | ,026 | ,050 | ,003 | ,065 | ,110 | ,008 | ,002 | ,065 | ,001 | ,250 | ,000 | |
| SDS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | |
| SRS | ,000 | ,000 | ,025 | ,000 | ,008 | ,160 | ,000 | ,000 | ,000 | ,000 | ,002 | ,000 | |
| UZS | ,430 | ,427 | 1,088 | ,681 | ,836 | 1,101 | ,593 | ,277 | ,636 | ,027 | ,893 | ,045 | |
| LZS(RIDGE) | 1,570 | 1,143 | 1,274 | 2,562 | 3,935 | 3,054 | 2,291 | 1,157 | 2,740 | 1,118 | 1,711 | -,790 | |
| LZS(ALLUVIAL) | ,866 | ,620 | ,843 | 1,398 | 1,541 | 1,699 | 1,213 | ,673 | 1,372 | ,563 | 1,372 | ,596 | |
| LZS(HILLSIDE) | 1,131 | ,806 | ,995 | 1,721 | 2,584 | 2,101 | 1,495 | ,795 | 1,925 | ,738 | 1,517 | ,681 | |
| GWS | 6,849 | 5,893 | 5,045 | 5,103 | 11,121 | 11,267 | 11,360 | 9,725 | 9,603 | 8,221 | 7,132 | 6,181 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS -2,552

CHANGE IN STORAGE EQUALS -2,552

## Adjustment to Total Precipitation Record of 1.1

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA — WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 2,076 | 1,241 | 2,237 | 2,562 | 14,344 | 7,772 | 5,476 | 3,676 | 8,656 | 3,087 | 7,041 | 1,409 | 59,650 |
| **LOSSES (WATERSHED INCHES)** | | | | | | | | | | | | | |
| INTERCEPTION | ,922 | ,559 | ,259 | ,233 | ,534 | ,766 | 1,144 | 1,210 | 1,981 | 1,124 | 1,581 | ,632 | 10,945 |
| INFILTRATION-DIRECT | 1,075 | ,650 | 1,729 | 1,919 | 5,903 | 3,802 | 3,199 | 2,193 | 4,643 | 1,647 | 4,545 | ,756 | 32,058 |
| -FROM SRS | ,014 | ,004 | ,039 | ,136 | 2,020 | ,733 | ,483 | ,066 | ,560 | ,081 | ,239 | ,027 | 4,403 |
| -FROM SCS | ,012 | ,002 | ,013 | ,020 | ,143 | ,134 | ,072 | ,030 | ,108 | ,040 | ,100 | ,011 | ,735 |
| SURFACE RETENTION | ,014 | ,004 | ,065 | ,112 | 2,113 | ,919 | ,316 | ,066 | ,570 | ,081 | ,243 | ,024 | 4,526 |
| **PERCOLATION (WATERSHED INCHES)** | | | | | | | | | | | | | |
| UZS-LZS | ,000 | ,000 | ,523 | 2,253 | 7,181 | 2,978 | 3,062 | ,921 | 3,454 | ,639 | 2,315 | ,426 | 23,753 |
| LZS-GWS | ,000 | ,000 | ,600 | ,453 | 3,630 | 1,756 | 1,619 | ,064 | ,760 | ,015 | ,099 | ,092 | 6,487 |
| SEEPAGE RIDGE | ,000 | ,000 | ,000 | ,000 | 1,560 | 1,069 | ,855 | ,000 | ,065 | ,002 | ,000 | ,000 | 3,591 |
| UNDERFLOW | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| **STREAMFLOW (WATERSHED INCHES)** | | | | | | | | | | | | | |
| IMPERVIOUS AREA | ,031 | ,018 | ,033 | ,038 | ,212 | ,115 | ,081 | ,054 | ,128 | ,046 | ,104 | ,022 | ,883 |
| SURFACE | ,021 | ,008 | ,138 | ,241 | 5,389 | 2,036 | ,666 | ,124 | 1,227 | ,149 | ,467 | ,045 | 10,511 |
| INTERFLOW | ,000 | ,000 | ,000 | ,053 | ,934 | ,773 | ,491 | ,036 | ,109 | ,072 | ,015 | ,021 | 2,503 |
| BASEFLOW | ,413 | ,343 | ,304 | ,284 | ,357 | ,949 | 1,010 | ,965 | ,823 | ,823 | ,707 | ,611 | 7,566 |
| TOTAL FLOW | ,465 | ,369 | ,475 | ,616 | 6,891 | 3,873 | 2,247 | 1,179 | 2,286 | 1,090 | 1,293 | ,699 | 21,464 |
| **EVAPOTRANSPIRATION (WATERSHED INCHES)** | | | | | | | | | | | | | |
| INTERCEPTION | ,766 | ,684 | ,240 | ,279 | ,532 | ,662 | 1,244 | 1,216 | 1,913 | 1,193 | 1,336 | ,879 | 10,945 |
| SRS | ,000 | ,000 | ,000 | ,001 | ,084 | ,014 | ,013 | ,000 | ,010 | ,000 | ,001 | ,000 | ,123 |
| UZS | ,603 | ,495 | ,397 | ,420 | ,655 | 1,211 | 1,493 | 1,732 | 1,458 | 1,890 | 1,470 | 1,435 | 13,258 |
| LZS | ,621 | ,319 | ,210 | ,311 | ,622 | 1,281 | 1,575 | 1,740 | 1,335 | 1,983 | 1,502 | 1,345 | 12,845 |
| GWS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| TOTAL | 1,990 | 1,499 | ,847 | 1,011 | 1,893 | 3,167 | 4,325 | 4,688 | 4,715 | 5,067 | 4,309 | 3,659 | 37,171 |
| POTENTIAL | 3,400 | 2,324 | 1,393 | 1,391 | 2,295 | 3,904 | 5,322 | 6,347 | 6,620 | 7,041 | 6,294 | 5,293 | 51,624 |
| **END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES)** | | | | | | | | | | | | | |
| INTC | ,158 | ,031 | ,050 | ,003 | ,005 | ,110 | ,008 | ,002 | ,071 | ,001 | ,250 | ,000 | |
| SCS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | |
| SRS | ,000 | ,000 | ,026 | ,000 | ,009 | ,183 | ,000 | ,000 | ,000 | ,000 | ,003 | ,000 | |
| UZS | ,830 | ,994 | 1,868 | 1,261 | 1,546 | 2,034 | 1,220 | ,850 | 1,255 | ,482 | 1,596 | ,512 | |
| LZS(RIDGE) | 1,893 | 1,570 | 1,886 | 3,836 | 6,660 | 5,857 | 5,079 | 3,827 | 5,511 | 3,642 | 4,170 | 2,999 | |
| LZS(ALLUVIAL) | 1,893 | 1,570 | 1,886 | 2,747 | 3,456 | 3,193 | 2,699 | 2,124 | 2,821 | 1,937 | 2,800 | 1,866 | |
| LZS(HILLSIDE) | 1,893 | 1,570 | 1,886 | 3,446 | 6,038 | 3,992 | 3,455 | 2,545 | 4,114 | 2,387 | 3,229 | 2,224 | |
| GWS | 5,993 | 5,156 | 4,414 | 4,828 | 12,616 | 14,786 | 16,274 | 14,078 | 13,920 | 11,947 | 10,462 | 9,195 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS 1,003

CHANGE IN STORAGE EQUALS 1,003

# Adjustment to Total Precipitation Record of 1.2

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 2,264 | 1,354 | 2,440 | 2,795 | 15,648 | 8,478 | 5,974 | 4,010 | 9,443 | 3,368 | 7,681 | 1,624 | 65,081 |
| LOSSES (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,947 | ,566 | ,259 | ,235 | ,535 | ,773 | 1,149 | 1,232 | 2,001 | 1,142 | 1,601 | ,637 | 11,079 |
| INFILTRATION-DIRECT | 1,237 | ,754 | 1,937 | 2,142 | 6,603 | 4,340 | 3,631 | 2,468 | 5,279 | 1,865 | 5,093 | ,672 | 36,222 |
| -FROM SRS | ,019 | ,004 | ,042 | ,133 | 2,163 | ,801 | ,478 | ,075 | ,597 | ,093 | ,258 | ,030 | 4,687 |
| -FROM SDS | ,013 | ,003 | ,015 | ,024 | ,236 | ,166 | ,087 | ,036 | ,131 | ,049 | ,123 | ,013 | ,896 |
| SURFACE RETENTION | ,014 | ,004 | ,062 | ,113 | 2,249 | ,965 | ,331 | ,075 | ,605 | ,093 | ,262 | ,027 | 0,000 |
| PERCOLATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| UZS-LZS | ,000 | ,000 | ,406 | 2,532 | 7,890 | 3,329 | 3,576 | 1,076 | 3,862 | ,775 | 2,491 | ,553 | 26,489 |
| LZS-GWS | ,000 | ,000 | ,000 | ,249 | 3,296 | 2,629 | 2,096 | ,073 | ,827 | ,178 | ,133 | ,074 | 9,554 |
| SEEPAGE RIDGE | ,000 | ,000 | ,000 | ,000 | 2,647 | 2,169 | 1,769 | ,000 | ,533 | ,058 | ,000 | ,000 | 7,176 |
| UNDERFLOW | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| STREAMFLOW (WATERSHED INCHES) | | | | | | | | | | | | | |
| IMPERVIOUS AREA | ,034 | ,028 | ,036 | ,041 | ,232 | ,125 | ,068 | ,059 | ,140 | ,050 | ,114 | ,024 | ,963 |
| SURFACE | ,020 | ,007 | ,130 | ,240 | 5,793 | 2,111 | ,668 | ,139 | 1,286 | ,168 | ,468 | ,051 | 11,121 |
| INTERFLOW | ,000 | ,000 | ,000 | ,018 | ,686 | ,774 | ,505 | ,037 | ,104 | ,112 | ,018 | ,021 | 2,275 |
| BASEFLOW | ,228 | ,189 | ,168 | ,155 | ,217 | ,894 | 1,028 | 1,010 | ,859 | ,887 | ,768 | ,601 | 7,063 |
| TOTAL FLOW | ,281 | ,217 | ,334 | ,454 | 6,928 | 3,904 | 2,309 | 1,247 | 2,388 | 1,217 | 1,388 | ,757 | 21,422 |
| EVAPOTRANSPIRATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,791 | ,691 | ,241 | ,281 | ,534 | ,669 | 1,249 | 1,238 | 1,930 | 1,214 | 1,356 | ,883 | 11,079 |
| SRS | ,000 | ,000 | ,000 | ,000 | ,080 | ,012 | ,011 | ,000 | ,008 | ,000 | ,001 | ,000 | ,113 |
| UZS | ,603 | ,519 | ,427 | ,463 | ,728 | 1,341 | 1,666 | 1,939 | 1,665 | 2,136 | 1,701 | 1,618 | 14,607 |
| LZS | ,515 | ,277 | ,182 | ,276 | ,607 | 1,309 | 1,623 | 1,864 | 1,495 | 2,130 | 1,637 | 1,495 | 15,410 |
| GWS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| TOTAL | 1,909 | 1,486 | ,851 | 1,021 | 1,948 | 3,332 | 4,548 | 5,042 | 5,099 | 5,481 | 4,695 | 3,996 | 39,409 |
| POTENTIAL | 3,600 | 2,324 | 1,393 | 1,391 | 2,295 | 3,904 | 5,322 | 6,347 | 6,620 | 7,041 | 6,294 | 5,293 | 51,624 |
| END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES) | | | | | | | | | | | | | |
| INTC | ,158 | ,032 | ,050 | ,003 | ,005 | ,110 | ,008 | ,002 | ,074 | ,001 | ,250 | ,000 | |
| SDS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | |
| SRS | ,000 | ,000 | ,020 | ,000 | ,006 | ,159 | ,000 | ,000 | ,000 | ,000 | ,003 | ,000 | |
| UZS | ,995 | 1,209 | 2,419 | 1,712 | 2,102 | 2,748 | 1,686 | 1,243 | 1,731 | ,813 | 2,115 | ,841 | |
| LZS(RIDGE) | 1,959 | 1,720 | 1,946 | 4,221 | 7,814 | 6,673 | 5,967 | 4,965 | 6,431 | 4,730 | 5,417 | 4,299 | |
| LZS(ALLUVIAL) | 1,995 | 1,720 | 1,946 | 3,129 | 5,292 | 3,695 | 3,114 | 2,618 | 3,695 | 2,453 | 3,208 | 2,378 | |
| LZS(HILLSIDE) | 1,999 | 1,720 | 1,946 | 3,912 | 8,665 | 4,848 | 4,284 | 3,196 | 5,929 | 3,092 | 3,925 | 2,868 | |
| GWS | 5,993 | 5,156 | 4,414 | 4,829 | 18,441 | 26,112 | 30,835 | 26,690 | 26,599 | 23,416 | 20,607 | 18,015 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS 4,250

CHANGE IN STORAGE EQUALS 4,250

# APPENDIX B

# Adjustment to Largest Storm of 0.7

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA — WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1,867 | 1,128 | 2,033 | 2,329 | 11,314 | 7,065 | 4,978 | 3,342 | 7,869 | 2,806 | 6,401 | 1,353 | 52,508 |
| **LOSSES (WATERSHED INCHES)** | | | | | | | | | | | | | |
| INTERCEPTION | ,897 | ,546 | ,259 | ,230 | ,529 | ,758 | 1,138 | 1,184 | 1,957 | 1,106 | 1,561 | ,628 | 10,792 |
| INFILTRATION-DIRECT | ,926 | ,557 | 1,578 | 1,785 | 5,801 | 3,623 | 2,978 | 1,975 | 4,339 | 1,490 | 4,189 | ,658 | 29,903 |
| -FROM SRS | ,010 | ,003 | ,030 | ,104 | 1,377 | ,607 | ,379 | ,040 | ,429 | ,051 | ,164 | ,016 | 3,210 |
| -FROM SGS | ,009 | ,002 | ,010 | ,016 | ,133 | ,111 | ,056 | ,021 | ,084 | ,029 | ,072 | ,008 | ,552 |
| SURFACE RETENTION | ,010 | ,003 | ,050 | ,084 | 1,425 | ,768 | ,236 | ,040 | ,436 | ,051 | ,167 | ,014 | 3,265 |
| **PERCOLATION (WATERSHED INCHES)** | | | | | | | | | | | | | |
| UZS-LZS | ,000 | ,000 | ,516 | 2,003 | 6,522 | 2,730 | 2,612 | ,726 | 3,170 | ,501 | 2,144 | ,289 | 21,214 |
| LZS-GWS | ,163 | ,000 | ,000 | ,551 | 3,734 | 1,234 | 1,339 | ,002 | ,795 | ,000 | ,056 | ,072 | 7,947 |
| SEEPAGE RIDGE | ,000 | ,000 | ,000 | ,000 | 1,184 | ,590 | ,474 | ,000 | ,012 | ,000 | ,000 | ,000 | 2,259 |
| UNDERFLOW | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| **STREAMFLOW (WATERSHED INCHES)** | | | | | | | | | | | | | |
| IMPERVIOUS AREA | ,028 | ,017 | ,030 | ,034 | ,167 | ,105 | ,074 | ,049 | ,116 | ,042 | ,095 | ,020 | ,777 |
| SURFACE | ,015 | ,005 | ,106 | ,180 | 3,259 | 1,700 | ,496 | ,072 | ,936 | ,089 | ,317 | ,026 | 7,200 |
| INTERFLOW | ,010 | ,000 | ,000 | ,124 | 1,167 | ,618 | ,461 | ,015 | ,142 | ,047 | ,009 | ,013 | 2,606 |
| BASEFLOW | ,526 | ,437 | ,387 | ,363 | ,439 | ,961 | ,985 | ,924 | ,788 | ,792 | ,679 | ,580 | 7,860 |
| TOTAL FLOW | ,578 | ,458 | ,524 | ,702 | 5,032 | 3,383 | 2,016 | 1,060 | 1,982 | ,970 | 1,100 | ,639 | 18,444 |
| **EVAPOTRANSPIRATION (WATERSHED INCHES)** | | | | | | | | | | | | | |
| INTERCEPTION | ,741 | ,674 | ,237 | ,276 | ,527 | ,654 | 1,238 | 1,190 | 1,892 | 1,172 | 1,315 | ,874 | 10,792 |
| SRS | ,000 | ,000 | ,000 | ,000 | ,046 | ,011 | ,010 | ,000 | ,007 | ,000 | ,001 | ,000 | ,075 |
| UZS | ,634 | ,488 | ,387 | ,411 | ,652 | 1,175 | 1,436 | 1,638 | 1,320 | 1,749 | 1,304 | 1,337 | 12,531 |
| LZS | ,718 | ,347 | ,220 | ,329 | ,630 | 1,190 | 1,459 | 1,536 | 1,118 | 1,739 | 1,307 | 1,173 | 11,765 |
| GWS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| TOTAL | 2,094 | 1,508 | ,845 | 1,017 | 1,855 | 3,029 | 4,143 | 4,364 | 4,336 | 4,660 | 3,926 | 3,384 | 35,162 |
| POTENTIAL | 3,400 | 2,324 | 1,393 | 1,391 | 2,295 | 3,904 | 5,322 | 6,387 | 6,620 | 7,041 | 6,294 | 5,293 | 51,624 |
| **END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES)** | | | | | | | | | | | | | |
| INTC | ,158 | ,028 | ,050 | ,003 | ,005 | ,110 | ,008 | ,002 | ,068 | ,001 | ,250 | ,000 | |
| SGS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | |
| SRS | ,000 | ,000 | ,021 | ,000 | ,001 | ,154 | ,000 | ,000 | ,000 | ,000 | ,002 | ,000 | |
| UZS | ,641 | ,716 | 1,442 | ,925 | 1,065 | 1,509 | ,664 | ,531 | ,699 | ,208 | 1,200 | ,241 | |
| LZS(RIDGE) | 1,751 | 1,377 | 1,662 | 3,319 | 5,298 | 4,558 | 3,703 | 2,416 | 4,132 | 2,288 | 2,840 | 1,738 | |
| LZS(ALLUVIAL) | 1,563 | 1,173 | 1,484 | 2,066 | 2,328 | 2,512 | 1,978 | 1,420 | 2,090 | 1,201 | 2,108 | 1,200 | |
| LZS(HILLSIDE) | 1,708 | 1,342 | 1,631 | 2,640 | 4,026 | 3,093 | 2,456 | 1,641 | 3,000 | 1,528 | 2,357 | 1,395 | |
| GWS | 6,273 | 5,397 | 4,621 | 4,997 | 11,604 | 12,153 | 12,863 | 11,015 | 11,031 | 9,443 | 8,194 | 7,175 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS -1,098

CHANGE IN STORAGE EQUALS -1,098

## Adjustment to Largest Storm of 0.8

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA — WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1,887 | 1,128 | 2,033 | 2,329 | 11,894 | 7,065 | 4,978 | 3,342 | 7,869 | 2,806 | 6,401 | 1,353 | 53,088 |
| LOSSES (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,897 | ,546 | ,259 | ,230 | ,529 | ,758 | 1,138 | 1,184 | 1,957 | 1,106 | 1,561 | ,628 | 10,792 |
| INFILTRATION-DIRECT | ,925 | ,556 | 1,567 | 1,775 | 5,739 | 3,554 | 2,944 | 1,971 | 4,271 | 1,485 | 4,155 | ,658 | 29,599 |
| -FROM SRS | ,011 | ,003 | ,031 | ,109 | 1,533 | ,621 | ,395 | ,041 | ,449 | ,052 | ,174 | ,016 | 3,436 |
| -FROM SGS | ,009 | ,002 | ,010 | ,016 | ,142 | ,109 | ,056 | ,021 | ,085 | ,029 | ,073 | ,008 | ,560 |
| SURFACE RETENTION | ,011 | ,003 | ,053 | ,087 | 1,593 | ,789 | ,247 | ,041 | ,457 | ,052 | ,177 | ,014 | 3,524 |
| PERCOLATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| UZS-LZS | ,000 | ,005 | ,614 | 1,996 | 6,650 | 2,782 | 2,623 | ,786 | 3,207 | ,542 | 2,256 | ,301 | 21,762 |
| LZS-GWS | ,142 | ,000 | ,000 | ,569 | 3,867 | 1,297 | 1,339 | ,007 | ,793 | ,000 | ,072 | ,072 | 8,177 |
| SEEPAGE RIDGE | ,000 | ,000 | ,000 | ,000 | 1,279 | ,635 | ,463 | ,000 | ,007 | ,000 | ,000 | ,000 | 2,403 |
| UNDERFLOW | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| STREAMFLOW (WATERSHED INCHES) | | | | | | | | | | | | | |
| IMPERVIOUS AREA | ,028 | ,017 | ,030 | ,034 | ,176 | ,105 | ,074 | ,049 | ,116 | ,042 | ,055 | ,020 | ,766 |
| SURFACE | ,016 | ,005 | ,113 | ,187 | 3,715 | 1,751 | ,521 | ,075 | ,984 | ,093 | ,341 | ,026 | 7,828 |
| INTERFLOW | ,009 | ,000 | ,000 | ,117 | 1,090 | ,579 | ,414 | ,013 | ,127 | ,040 | ,009 | ,012 | 2,411 |
| BASEFLOW | ,525 | ,437 | ,367 | ,365 | ,444 | ,989 | 1,009 | ,946 | ,807 | ,808 | ,694 | ,594 | 8,005 |
| TOTAL FLOW | ,578 | ,459 | ,531 | ,703 | 5,425 | 3,424 | 2,018 | 1,084 | 2,034 | ,982 | 1,138 | ,652 | 19,029 |
| EVAPOTRANSPIRATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,741 | ,674 | ,237 | ,276 | ,527 | ,654 | 1,238 | 1,190 | 1,892 | 1,172 | 1,315 | ,678 | 10,792 |
| SRS | ,000 | ,000 | ,000 | ,000 | ,058 | ,011 | ,011 | ,000 | ,007 | ,000 | ,001 | ,000 | ,088 |
| UZS | ,631 | ,485 | ,376 | ,391 | ,616 | 1,118 | 1,362 | 1,552 | 1,261 | 1,657 | 1,223 | 1,271 | 11,942 |
| LZS | ,748 | ,357 | ,231 | ,348 | ,657 | 1,252 | 1,533 | 1,610 | 1,162 | 1,816 | 1,367 | 1,222 | 12,304 |
| GWS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| TOTAL | 2,120 | 1,515 | ,844 | 1,016 | 1,858 | 3,035 | 4,144 | 4,352 | 4,322 | 4,645 | 3,907 | 3,367 | 35,120 |
| POTENTIAL | 3,400 | 2,324 | 1,393 | 1,391 | 2,295 | 3,904 | 5,322 | 6,347 | 6,620 | 7,041 | 6,294 | 5,293 | 51,624 |
| END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES) | | | | | | | | | | | | | |
| INTC | ,158 | ,028 | ,050 | ,003 | ,005 | ,110 | ,008 | ,002 | ,068 | ,001 | ,250 | ,000 | |
| SGS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | |
| SRS | ,000 | ,000 | ,023 | ,000 | ,002 | ,161 | ,000 | ,000 | ,000 | ,000 | ,002 | ,000 | |
| UZS | ,644 | ,716 | 1,344 | ,849 | 1,000 | 1,369 | ,790 | ,480 | ,822 | ,180 | 1,117 | ,213 | |
| LZS(RIDGE) | 1,720 | 1,341 | 1,714 | 3,342 | 5,343 | 4,554 | 3,660 | 2,377 | 4,107 | 2,223 | 2,832 | 1,692 | |
| LZS(ALLUVIAL) | 1,478 | 1,143 | 1,543 | 2,064 | 2,358 | 2,516 | 1,976 | 1,412 | 2,002 | 1,177 | 2,111 | 1,173 | |
| LZS(HILLSIDE) | 1,660 | 1,308 | 1,685 | 2,637 | 4,091 | 3,104 | 2,453 | 1,033 | 2,583 | 1,496 | 2,374 | 1,370 | |
| GWS | 6,270 | 5,395 | 4,618 | 5,028 | 11,892 | 12,510 | 13,170 | 11,288 | 11,260 | 9,439 | 6,392 | 7,346 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS -1,067

CHANGE IN STORAGE EQUALS -1,067

## Adjustment to Largest Storm of 1.1

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTEVILLE GEORGIA — WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1,887 | 1,128 | 2,033 | 2,329 | 13,604 | 7,065 | 4,978 | 3,342 | 7,869 | 2,806 | 6,401 | 1,353 | 54,798 |
| **LOSSES (WATERSHED INCHES)** | | | | | | | | | | | | | |
| INTERCEPTION | ,857 | ,546 | ,259 | ,230 | ,529 | ,758 | 1,138 | 1,184 | 1,957 | 1,106 | 1,561 | ,628 | 10,792 |
| INFILTRATION-DIRECT | ,916 | ,553 | 1,529 | 1,711 | 5,305 | 3,330 | 2,806 | 1,938 | 4,065 | 1,445 | 4,024 | ,646 | 28,270 |
| -FROM SRS | ,014 | ,004 | ,035 | ,135 | 1,934 | ,661 | ,464 | ,051 | ,508 | ,064 | ,211 | ,021 | 4,102 |
| -FROM SGS | ,011 | ,002 | ,011 | ,016 | ,166 | ,106 | ,057 | ,023 | ,086 | ,031 | ,078 | ,008 | ,593 |
| SURFACE DETENTION | ,014 | ,004 | ,065 | ,106 | 2,038 | ,854 | ,288 | ,051 | ,518 | ,064 | ,216 | ,016 | 4,236 |
| **PERCOLATION (WATERSHED INCHES)** | | | | | | | | | | | | | |
| UZS-LZS | ,000 | ,004 | ,592 | 1,944 | 6,554 | 2,667 | 2,503 | ,766 | 3,063 | ,519 | 2,172 | ,292 | 21,156 |
| LZS-GWS | ,169 | ,000 | ,000 | ,559 | 3,920 | 1,339 | 1,305 | ,000 | ,747 | ,000 | ,039 | ,070 | 8,147 |
| SEEPAGE RIDGE | ,000 | ,000 | ,000 | ,000 | 1,183 | ,633 | ,429 | ,000 | ,000 | ,000 | ,000 | ,000 | 2,246 |
| UNDERFLOW | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| **STREAMFLOW (WATERSHED INCHES)** | | | | | | | | | | | | | |
| IMPERVIOUS AREA | ,028 | ,017 | ,030 | ,034 | ,201 | ,105 | ,074 | ,049 | ,116 | ,042 | ,095 | ,020 | ,811 |
| SURFACE | ,022 | ,007 | ,140 | ,231 | 5,365 | 1,912 | ,616 | ,097 | 1,127 | ,119 | ,427 | ,034 | 10,096 |
| INTERFLOW | ,008 | ,000 | ,000 | ,098 | ,954 | ,534 | ,346 | ,010 | ,099 | ,032 | ,005 | ,008 | 2,094 |
| BASEFLOW | ,550 | ,457 | ,406 | ,379 | ,454 | 1,015 | 1,026 | ,959 | ,815 | ,811 | ,695 | ,591 | 8,159 |
| TOTAL FLOW | ,608 | ,481 | ,576 | ,743 | 6,974 | 3,566 | 2,062 | 1,115 | 2,157 | 1,003 | 1,222 | ,653 | 21,161 |
| **EVAPOTRANSPIRATION (WATERSHED INCHES)** | | | | | | | | | | | | | |
| INTERCEPTION | ,741 | ,674 | ,237 | ,276 | ,527 | ,654 | 1,238 | 1,190 | 1,892 | 1,172 | 1,315 | ,874 | 10,792 |
| SRS | ,000 | ,000 | ,000 | ,001 | ,092 | ,014 | ,015 | ,000 | ,010 | ,000 | ,001 | ,000 | ,134 |
| UZS | ,630 | ,483 | ,375 | ,391 | ,603 | 1,119 | 1,360 | 1,552 | 1,258 | 1,655 | 1,223 | 1,270 | 11,919 |
| LZS | ,746 | ,356 | ,230 | ,344 | ,634 | 1,239 | 1,513 | 1,586 | 1,138 | 1,773 | 1,328 | 1,197 | 12,083 |
| GWS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| TOTAL | 2,117 | 1,513 | ,843 | 1,011 | 1,856 | 3,027 | 4,126 | 4,328 | 4,298 | 4,600 | 3,868 | 3,341 | 34,928 |
| POTENTIAL | 3,400 | 2,324 | 1,393 | 1,391 | 2,295 | 3,904 | 5,322 | 6,347 | 6,620 | 7,041 | 6,294 | 5,293 | 51,624 |
| **END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES)** | | | | | | | | | | | | | |
| INTC | ,158 | ,028 | ,050 | ,003 | ,005 | ,110 | ,008 | ,002 | ,068 | ,001 | ,250 | ,000 | |
| SGS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | |
| SRS | ,000 | ,000 | ,030 | ,000 | ,012 | ,194 | ,000 | ,000 | ,000 | ,000 | ,004 | ,000 | |
| UZS | ,639 | ,713 | 1,328 | ,849 | 1,060 | 1,375 | ,790 | ,479 | ,822 | ,179 | 1,112 | ,212 | |
| LZS(RIDGE) | 1,726 | 1,340 | 1,691 | 3,273 | 5,431 | 4,475 | 3,651 | 2,345 | 3,975 | 2,136 | 2,716 | 1,615 | |
| LZS(ALLUVIAL) | 1,478 | 1,142 | 1,521 | 2,064 | 2,398 | 2,465 | 1,948 | 1,392 | 2,079 | 1,161 | 2,102 | 1,168 | |
| LZS(HILLSIDE) | 1,660 | 1,307 | 1,663 | 2,626 | 4,159 | 3,020 | 2,426 | 1,611 | 2,941 | 1,477 | 2,318 | 1,344 | |
| GWS | 6,270 | 5,395 | 4,618 | 4,962 | 11,596 | 12,215 | 12,749 | 10,914 | 10,783 | 9,231 | 7,975 | 6,977 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS -1,290

CHANGE IN STORAGE EQUALS -1,290

## Adjustment to Largest Storm of 1.2

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA     WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1,867 | 1,128 | 2,033 | 2,329 | 14,174 | 7,065 | 4,978 | 3,342 | 7,869 | 2,804 | 6,401 | 1,353 | 55,368 |
| LOSSES (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,897 | ,546 | ,259 | ,230 | ,529 | ,758 | 1,138 | 1,184 | 1,957 | 1,106 | 1,561 | ,628 | 10,792 |
| INFILTRATION-DIRECT | ,916 | ,553 | 1,529 | 1,711 | 5,291 | 3,329 | 2,806 | 1,938 | 4,065 | 1,445 | 4,024 | ,646 | 28,255 |
| -FROM SRS | ,014 | ,004 | ,035 | ,135 | 1,998 | ,663 | ,464 | ,051 | ,508 | ,064 | ,211 | ,021 | 4,167 |
| -FROM SGS | ,011 | ,002 | ,011 | ,016 | ,177 | ,106 | ,057 | ,023 | ,066 | ,031 | ,078 | ,008 | ,604 |
| SURFACE RETENTION | ,014 | ,004 | ,065 | ,106 | 2,168 | ,855 | ,288 | ,051 | ,518 | ,064 | ,216 | ,018 | 4,307 |
| PERCOLATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| UZS-LZS | ,006 | ,004 | ,592 | 4,944 | 6,648 | 2,676 | 2,543 | ,766 | 3,063 | ,519 | 2,172 | ,292 | 21,219 |
| LZS-GWS | ,169 | ,000 | ,000 | ,559 | 3,951 | 1,358 | 1,305 | ,000 | ,747 | ,000 | ,039 | ,070 | 8,197 |
| SEEPAGE RIDGE | ,000 | ,000 | ,000 | ,000 | 1,192 | ,645 | ,429 | ,000 | ,000 | ,000 | ,000 | ,000 | 2,267 |
| UNDERFLOW | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| STREAMFLOW (WATERSHED INCHES) | | | | | | | | | | | | | |
| IMPERVIOUS AREA | ,028 | ,017 | ,030 | ,034 | ,210 | ,105 | ,074 | ,049 | ,116 | ,042 | ,095 | ,020 | ,819 |
| SURFACE | ,022 | ,007 | ,140 | ,231 | 5,859 | 1,913 | ,616 | ,097 | 1,127 | ,119 | ,427 | ,034 | 10,591 |
| INTERFLOW | ,008 | ,000 | ,000 | ,098 | ,962 | ,541 | ,346 | ,010 | ,099 | ,032 | ,005 | ,008 | 2,109 |
| BASEFLOW | ,550 | ,457 | ,406 | ,379 | ,454 | 1,022 | 1,032 | ,964 | ,819 | ,815 | ,699 | ,594 | 8,192 |
| TOTAL FLOW | ,608 | ,481 | ,576 | ,743 | 7,485 | 3,581 | 2,068 | 1,120 | 2,161 | 1,007 | 1,225 | ,656 | 21,712 |
| EVAPOTRANSPIRATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,741 | ,674 | ,237 | ,276 | ,527 | ,654 | 1,238 | 1,190 | 1,892 | 1,172 | 1,315 | ,874 | 10,792 |
| SRS | ,000 | ,000 | ,000 | ,001 | ,097 | ,014 | ,015 | ,000 | ,010 | ,000 | ,001 | ,000 | ,139 |
| UZS | ,630 | ,483 | ,375 | ,391 | ,601 | 1,120 | 1,360 | 1,552 | 1,258 | 1,655 | 1,223 | 1,270 | 11,918 |
| LZS | ,746 | ,356 | ,230 | ,344 | ,632 | 1,240 | 1,513 | 1,586 | 1,138 | 1,773 | 1,328 | 1,197 | 12,081 |
| GWS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| TOTAL | 2,117 | 1,513 | ,843 | 1,011 | 1,858 | 3,028 | 4,126 | 4,328 | 4,298 | 4,600 | 3,868 | 3,341 | 38,930 |
| POTENTIAL | 3,400 | 2,324 | 1,393 | 1,391 | 2,295 | 3,904 | 5,322 | 6,347 | 6,620 | 7,041 | 6,294 | 5,293 | 51,624 |
| END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES) | | | | | | | | | | | | | |
| INTC | ,158 | ,028 | ,050 | ,003 | ,005 | ,110 | ,008 | ,002 | ,068 | ,001 | ,250 | ,000 | |
| SGS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | |
| SRS | ,000 | ,000 | ,030 | ,000 | ,014 | ,154 | ,000 | ,000 | ,000 | ,000 | ,004 | ,000 | |
| UZS | ,639 | ,713 | 1,328 | ,849 | 1,069 | 1,375 | ,790 | ,479 | ,822 | ,179 | 1,112 | ,212 | |
| LZS(RIDGE) | 1,720 | 1,340 | 1,691 | 3,273 | 5,459 | 4,475 | 3,651 | 2,345 | 3,975 | 2,136 | 2,716 | 1,615 | |
| LZS(ALLUVIAL) | 1,478 | 1,142 | 1,521 | 2,084 | 2,409 | 2,465 | 1,948 | 1,392 | 2,079 | 1,161 | 2,102 | 1,168 | |
| LZS(HILLSIDE) | 1,680 | 1,307 | 1,663 | 2,626 | 4,181 | 3,020 | 2,426 | 1,611 | 2,941 | 1,477 | 2,318 | 1,344 | |
| GWS | 6,270 | 5,395 | 4,618 | 4,962 | 11,654 | 12,296 | 12,819 | 10,974 | 10,835 | 9,275 | 8,013 | 7,009 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS -1,273

CHANGE IN STORAGE EQUALS -1,273

# APPENDIX C

# Adjustment to Streamflow of 0.8

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA — WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1.647 | 1.128 | 2.633 | 2.329 | 13.640 | 7.065 | 4.478 | 3.342 | 7.069 | 2.806 | 6.941 | 1.353 | 54.234 |
| **LOSSES (WATERSHED INCHES)** | | | | | | | | | | | | | |
| INTERCEPTION | .697 | .546 | .259 | .230 | .529 | .758 | 1.134 | 1.184 | 1.957 | 1.186 | 1.561 | .628 | 10.792 |
| INFILTRATION-DIRECT | .930 | .558 | 1.587 | 1.804 | 5.032 | 3.076 | 3.020 | 1.990 | 4.395 | 1.538 | 4.228 | .663 | 30.291 |
| -FROM SRS | .000 | .092 | .028 | .097 | 1.721 | .063 | .352 | .038 | .413 | .045 | .153 | .014 | 3.480 |
| -FROM SDS | .000 | .002 | .010 | .016 | .167 | .116 | .055 | .020 | .083 | .027 | .069 | .008 | .577 |
| SURFACE RETENTION | .009 | .002 | .047 | .078 | 1.795 | .753 | .224 | .036 | .419 | .045 | .155 | .013 | 3.578 |
| **PERCOLATION (WATERSHED INCHES)** | | | | | | | | | | | | | |
| UZ-LZ | .000 | .000 | .546 | 1.995 | 6.065 | 2.819 | 2.598 | .721 | 3.213 | .501 | 2.208 | .276 | 21.859 |
| LZ-GWS | .237 | .000 | .000 | .535 | 4.111 | 1.476 | 1.473 | .015 | .017 | .002 | .166 | .066 | 8.742 |
| SEEPAGE RIDGE | .000 | .000 | .000 | .000 | 1.771 | .076 | .029 | .000 | .074 | .001 | .000 | .000 | 3.351 |
| UNDERFLOW | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| **STREAMFLOW (WATERSHED INCHES)** | | | | | | | | | | | | | |
| IMPERVIOUS AREA | .028 | .017 | .030 | .034 | .193 | .105 | .074 | .049 | .110 | .042 | .095 | .020 | .863 |
| SURFACE | .013 | .024 | .100 | .167 | 4.624 | 1.603 | .468 | .063 | .098 | .076 | .294 | .022 | 8.195 |
| INTERFLOW | .025 | .000 | .000 | .119 | 1.150 | .568 | .415 | .011 | .140 | .041 | .013 | .014 | 2.507 |
| BASEFLOW | .489 | .406 | .360 | .340 | .624 | 1.624 | 1.046 | .961 | .637 | .036 | .731 | .619 | 8.004 |
| TOTAL FLOW | .555 | .427 | .490 | .661 | 6.181 | 3.300 | 2.003 | 1.104 | 1.991 | .996 | 1.122 | .670 | 19.588 |
| **EVAPOTRANSPIRATION (WATERSHED INCHES)** | | | | | | | | | | | | | |
| INTERCEPTION | .749 | .674 | .237 | .276 | .527 | .654 | 1.538 | 1.198 | 1.092 | 1.172 | 1.315 | .874 | 10.792 |
| SRS | .005 | .000 | .000 | .000 | .071 | .010 | .009 | .000 | .006 | .000 | .001 | .000 | .097 |
| UZS | .601 | .542 | .396 | .420 | .657 | 1.200 | 1.654 | 1.650 | 1.518 | 1.749 | 1.281 | 1.342 | 12.653 |
| LZS | .731 | .356 | .219 | .338 | .638 | 1.210 | 1.681 | 1.537 | 1.183 | 1.757 | 1.319 | 1.166 | 11.845 |
| GWS | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| TOTAL | 2.133 | 1.522 | .853 | 1.034 | 1.893 | 3.074 | 4.186 | 4.378 | 4.310 | 4.677 | 3.916 | 3.382 | 35.367 |
| POTENTIAL | 3.400 | 2.524 | 1.593 | 1.391 | 2.065 | 3.404 | 5.322 | 6.347 | 6.020 | 7.041 | 6.244 | 5.243 | 51.624 |
| **END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES)** | | | | | | | | | | | | | |
| INTC | .159 | .028 | .050 | .003 | .005 | .110 | .001 | .082 | .068 | .001 | .250 | .000 | |
| SRS | .000 | .000 | .009 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | |
| SDS | .090 | .030 | .019 | .000 | .003 | .145 | .000 | .000 | .000 | .000 | .001 | .000 | |
| UZS | .616 | .677 | 1.375 | .064 | 1.644 | 1.420 | .797 | .400 | .333 | .154 | 1.134 | .106 | |
| LZS(UPLAND) | 1.711 | 1.324 | 1.632 | 3.265 | 5.093 | 4.192 | 3.320 | 2.103 | 3.783 | 2.001 | 2.047 | 1.549 | |
| LZS(ALLUVIAL) | 1.319 | 1.006 | 1.359 | 1.875 | 2.516 | 2.319 | 1.594 | 1.244 | 1.091 | 1.045 | 1.933 | 1.022 | |
| LZS(TOTAL STOR) | 1.579 | 1.216 | 1.539 | 2.378 | 3.673 | 2.669 | 2.211 | 1.439 | 2.780 | 1.329 | 2.191 | 1.217 | |
| GWS | 6.446 | 5.546 | 4.748 | 5.180 | 13.351 | 14.653 | 15.079 | 12.938 | 12.095 | 11.043 | 9.081 | 8.459 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS -.721

CHANGE IN STORAGE EQUALS -.721

## Adjustment to Streamflow of 1.2

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA — WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1.607 | 1.128 | 2.033 | 2.329 | 13.040 | 7.065 | 4.978 | 3.342 | 7.869 | 2.806 | 6.401 | 1.393 | 54.234 |
| LOSSES (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | .897 | .546 | .259 | .230 | .529 | .758 | 1.138 | 1.184 | 1.957 | 1.106 | 1.541 | .628 | 10.792 |
| INFILTRATION-DIRECT | .925 | .556 | 1.567 | 1.765 | 5.649 | 3.539 | 2.934 | 1.964 | 4.274 | 1.478 | 4.150 | .659 | 29.456 |
| -FROM SRS | .011 | .003 | .031 | .112 | 1.735 | .625 | .401 | .043 | .449 | .054 | .175 | .018 | 3.706 |
| -FROM SDS | .009 | .002 | .010 | .016 | .164 | .110 | .056 | .022 | .085 | .030 | .079 | .009 | .597 |
| SURFACE RETENTION | .011 | .003 | .053 | .090 | 1.869 | .793 | .250 | .043 | .456 | .054 | .179 | .015 | 3.815 |
| PERCOLATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| UZS-LZS | .000 | .000 | .502 | 1.986 | 6.754 | 2.720 | 2.583 | .715 | 3.119 | .491 | 2.110 | .265 | 21.266 |
| LZS-GWS | .151 | .000 | .000 | .551 | 3.885 | 1.359 | 1.336 | .000 | .756 | .000 | .043 | .069 | 8.150 |
| SEEPAGE RIDGE | .000 | .000 | .000 | .000 | 1.300 | .697 | .497 | .000 | .004 | .000 | .000 | .000 | 2.498 |
| UNDERFLOW | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| STREAMFLOW (WATERSHED INCHES) | | | | | | | | | | | | | |
| IMPERVIOUS AREA | .028 | .017 | .030 | .034 | .193 | .105 | .074 | .049 | .116 | .042 | .095 | .020 | .803 |
| SURFACE | .016 | .005 | .114 | .194 | 4.638 | 1.760 | .527 | .079 | .981 | .097 | .343 | .028 | 8.782 |
| INTERFLOW | .009 | .000 | .000 | .109 | 1.137 | .620 | .419 | .013 | .121 | .045 | .006 | .011 | 2.454 |
| BASEFLOW | .519 | .432 | .383 | .358 | .453 | .994 | 1.013 | .948 | .807 | .805 | .690 | .597 | 7.969 |
| TOTAL FLOW | .572 | .453 | .527 | .694 | 6.371 | 3.479 | 2.032 | 1.090 | 2.026 | .984 | 1.134 | .656 | 20.008 |
| EVAPOTRANSPIRATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | .741 | .674 | .237 | .276 | .527 | .654 | 1.238 | 1.190 | 1.492 | 1.172 | 1.315 | .879 | 10.792 |
| SRS | .000 | .000 | .000 | .000 | .077 | .012 | .011 | .000 | .008 | .000 | .001 | .000 | .109 |
| UZS | .634 | .487 | .380 | .413 | .649 | 1.182 | 1.441 | 1.644 | 1.323 | 1.755 | 1.310 | 1.342 | 12.562 |
| LZS | .717 | .347 | .220 | .328 | .619 | 1.199 | 1.467 | 1.541 | 1.119 | 1.743 | 1.302 | 1.170 | 11.772 |
| GWS | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| TOTAL | 2.093 | 1.508 | .845 | 1.017 | 1.867 | 3.047 | 4.157 | 4.376 | 4.342 | 4.671 | 3.929 | 3.386 | 35.235 |
| POTENTIAL | 3.400 | 2.324 | 1.393 | 1.391 | 2.295 | 3.904 | 5.322 | 6.347 | 6.620 | 7.041 | 6.294 | 5.293 | 51.624 |
| END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES) | | | | | | | | | | | | | |
| INTC | .158 | .028 | .050 | .003 | .005 | .110 | .008 | .002 | .068 | .001 | .250 | .000 | |
| SDS | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | |
| SRS | .000 | .000 | .023 | .000 | .096 | .165 | .000 | .000 | .000 | .000 | .002 | .000 | |
| UZS | .640 | .715 | 1.444 | .931 | 1.134 | 1.512 | .870 | .535 | .005 | .210 | 1.205 | .243 | |
| LZS(RIDGE) | 1.753 | 1.380 | 1.652 | 3.294 | 5.460 | 4.532 | 3.695 | 2.408 | 4.110 | 2.275 | 2.809 | 1.719 | |
| LZS(ALLUVIAL) | 1.504 | 1.175 | 1.474 | 2.087 | 2.410 | 2.495 | 1.971 | 1.414 | 2.087 | 1.196 | 2.104 | 1.200 | |
| LZS(HILLSIDE) | 1.710 | 1.344 | 1.621 | 2.636 | 4.197 | 3.068 | 2.453 | 1.636 | 2.081 | 1.523 | 2.338 | 1.399 | |
| GWS | 6.273 | 5.398 | 4.621 | 4.973 | 11.980 | 12.719 | 13.374 | 11.449 | 11.346 | 9.713 | 8.400 | 7.349 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS -1.009

CHANGE IN STORAGE EQUALS -1.009

# APPENDIX D

# Calculated 20-Year Average Potential Evapotranspiration

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA — WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1,867 | 1,128 | 2,033 | 2,329 | 13,040 | 7,065 | 4,978 | 3,342 | 7,869 | 2,806 | 6,401 | 1,353 | 54,238 |
| LOSSES (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,939 | ,537 | ,251 | ,216 | ,567 | ,770 | 1,178 | 1,288 | 2,161 | 1,199 | 1,761 | ,645 | 11,511 |
| INFILTRATION-DIRECT | ,876 | ,559 | 1,536 | 1,734 | 5,430 | 3,295 | 2,771 | 1,860 | 3,964 | 1,396 | 3,845 | ,640 | 27,905 |
| -FROM BRS | ,033 | ,005 | ,035 | ,133 | 1,854 | ,669 | ,455 | ,043 | ,478 | ,051 | ,200 | ,016 | 3,953 |
| -FROM SDS | ,010 | ,002 | ,011 | ,016 | ,156 | ,102 | ,055 | ,021 | ,082 | ,028 | ,075 | ,006 | ,565 |
| SURFACE RETENTION | ,013 | ,005 | ,065 | ,104 | 1,913 | ,861 | ,287 | ,043 | ,487 | ,051 | ,204 | ,015 | 4,048 |
| PERCOLATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| UZS-LZS | ,000 | ,147 | ,828 | 1,976 | 6,842 | 3,011 | 2,583 | ,816 | 3,018 | ,551 | 2,258 | ,277 | 22,306 |
| LZS-GWS | ,157 | ,000 | ,000 | ,660 | 4,191 | 1,769 | 1,234 | ,000 | ,571 | ,000 | ,036 | ,000 | 8,619 |
| SEEPAGE RIDGE | ,000 | ,000 | ,000 | ,000 | 1,657 | ,960 | ,476 | ,000 | ,000 | ,000 | ,000 | ,000 | 3,093 |
| UNDERFLOW | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| STREAMFLOW (WATERSHED INCHES) | | | | | | | | | | | | | |
| IMPERVIOUS AREA | ,028 | ,017 | ,030 | ,034 | ,193 | ,105 | ,074 | ,049 | ,116 | ,042 | ,095 | ,020 | ,805 |
| SURFACE | ,020 | ,009 | ,141 | ,226 | 4,800 | 1,933 | ,614 | ,080 | 1,058 | ,091 | ,401 | ,027 | 9,402 |
| INTERFLOW | ,006 | ,000 | ,009 | ,114 | ,895 | ,565 | ,285 | ,008 | ,059 | ,012 | ,002 | ,001 | 1,947 |
| BASEFLOW | ,507 | ,421 | ,370 | ,365 | ,450 | 1,088 | 1,095 | 1,019 | ,861 | ,830 | ,712 | ,595 | 8,318 |
| TOTAL FLOW | ,561 | ,447 | ,545 | ,740 | 6,338 | 3,691 | 2,067 | 1,157 | 2,095 | ,975 | 1,210 | ,642 | 20,470 |
| EVAPOTRANSPIRATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | ,789 | ,635 | ,253 | ,264 | ,534 | ,686 | 1,266 | 1,296 | 2,130 | 1,251 | 1,536 | ,891 | 11,511 |
| SRS | ,000 | ,000 | ,000 | ,001 | ,052 | ,015 | ,015 | ,000 | ,009 | ,000 | ,002 | ,000 | ,095 |
| UZS | ,608 | ,388 | ,302 | ,340 | ,410 | ,823 | 1,152 | 1,409 | 1,218 | 1,401 | 1,126 | 1,078 | 10,254 |
| LZS | ,831 | ,325 | ,254 | ,416 | ,567 | 1,204 | 1,690 | 1,870 | 1,349 | 1,854 | 1,465 | 1,203 | 13,026 |
| GWS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| TOTAL | 2,228 | 1,348 | ,809 | 1,020 | 1,563 | 2,728 | 4,122 | 4,576 | 4,684 | 4,507 | 4,130 | 3,172 | 34,887 |
| POTENTIAL | 3,490 | 2,010 | 1,280 | 1,370 | 1,680 | 3,430 | 5,220 | 6,700 | 7,190 | 7,000 | 6,580 | 5,130 | 51,280 |
| END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES) | | | | | | | | | | | | | |
| INTC | ,153 | ,052 | ,050 | ,001 | ,014 | ,099 | ,010 | ,001 | ,055 | ,001 | ,250 | ,000 | |
| SDS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | |
| BRS | ,000 | ,005 | ,031 | ,000 | ,007 | ,186 | ,000 | ,000 | ,000 | ,000 | ,002 | ,000 | |
| UZS | ,619 | ,650 | 1,109 | ,671 | ,863 | 1,098 | ,638 | ,333 | ,625 | ,141 | ,887 | ,185 | |
| LZS(RIDGE) | 1,633 | 1,433 | 2,000 | 3,519 | 5,502 | 4,531 | 3,720 | 2,171 | 3,550 | 1,796 | 2,397 | 1,358 | |
| LZS(ALLUVIAL) | 1,398 | 1,239 | 1,032 | 2,070 | 2,469 | 2,496 | 2,007 | 1,304 | 2,032 | 1,071 | 1,957 | 1,107 | |
| LZS(HILLSIDE) | 1,597 | 1,463 | 1,974 | 2,600 | 4,345 | 3,115 | 2,496 | 1,507 | 2,758 | 1,359 | 2,155 | 1,216 | |
| GWS | 6,273 | 5,397 | 4,621 | 5,234 | 13,013 | 14,428 | 14,717 | 12,599 | 11,994 | 10,268 | 8,664 | 7,626 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS -1,122

CHANGE IN STORAGE EQUALS -1,122

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA — WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1,887 | 1,128 | 2,033 | 2,329 | 13,040 | 7,065 | 4,978 | 3,342 | 7,869 | 2,806 | 6,401 | 1,353 | 54,234 |
| **LOSSES (WATERSHED INCHES)** | | | | | | | | | | | | | |
| INTERCEPTION | ,929 | ,517 | ,269 | ,160 | ,377 | ,633 | 1,148 | 1,136 | 1,679 | 1,039 | 1,597 | ,559 | 10,043 |
| INFILTRATION-DIRECT | ,698 | ,562 | 1,569 | 1,834 | 5,953 | 3,605 | 2,994 | 1,996 | 4,373 | 1,553 | 4,314 | ,723 | 30,195 |
| -FROM SRS | ,010 | ,004 | ,030 | ,110 | 1,798 | ,652 | ,383 | ,048 | ,506 | ,052 | ,176 | ,017 | 3,785 |
| -FROM SDS | ,009 | ,002 | ,010 | ,017 | ,168 | ,110 | ,055 | ,023 | ,092 | ,029 | ,075 | ,009 | ,598 |
| SURFACE RETENTION | ,010 | ,004 | ,049 | ,090 | 1,632 | ,611 | ,229 | ,048 | ,509 | ,052 | ,179 | ,015 | 3,527 |
| **PERCOLATION (WATERSHED INCHES)** | | | | | | | | | | | | | |
| UZS-LZS | ,000 | ,094 | ,595 | 2,231 | 7,307 | 3,152 | 2,757 | 1,067 | 3,628 | ,689 | 2,448 | ,440 | 24,400 |
| LZS-GWS | ,060 | ,000 | ,000 | ,606 | 4,105 | 1,249 | 1,514 | ,063 | 1,005 | ,024 | ,224 | ,090 | 9,619 |
| SEEPAGE RIDGE | ,000 | ,000 | ,000 | ,000 | 2,053 | 1,206 | ,824 | ,000 | ,279 | ,006 | ,000 | ,000 | 4,366 |
| UNDERFLOW | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| **STREAMFLOW (WATERSHED INCHES)** | | | | | | | | | | | | | |
| IMPERVIOUS AREA | ,028 | ,017 | ,030 | ,034 | ,193 | ,105 | ,074 | ,049 | ,116 | ,042 | ,095 | ,020 | ,803 |
| SURFACE | ,014 | ,007 | ,105 | ,194 | 4,518 | 1,803 | ,479 | ,090 | 1,099 | ,092 | ,342 | ,028 | 8,769 |
| INTERFLOW | ,001 | ,000 | ,000 | ,124 | 1,173 | ,760 | ,479 | ,030 | ,209 | ,064 | ,035 | ,033 | 2,946 |
| BASEFLOW | ,418 | ,347 | ,308 | ,301 | ,393 | 1,039 | 1,091 | 1,025 | ,883 | ,912 | ,792 | ,691 | 8,199 |
| TOTAL FLOW | ,460 | ,370 | ,443 | ,653 | 6,277 | 3,726 | 2,122 | 1,193 | 2,307 | 1,130 | 1,264 | ,771 | 20,717 |
| **EVAPOTRANSPIRATION (WATERSHED INCHES)** | | | | | | | | | | | | | |
| INTERCEPTION | ,762 | ,655 | ,251 | ,208 | ,362 | ,540 | 1,252 | 1,138 | 1,622 | 1,098 | 1,351 | ,805 | 10,043 |
| SRS | ,000 | ,000 | ,000 | ,000 | ,030 | ,003 | ,004 | ,000 | ,003 | ,000 | ,001 | ,000 | ,042 |
| UZS | ,535 | ,379 | ,475 | ,238 | ,391 | ,854 | 1,327 | 1,240 | 1,059 | 1,526 | 1,047 | 1,166 | 10,236 |
| LZS | ,702 | ,304 | ,334 | ,243 | ,484 | 1,118 | 1,758 | 1,507 | 1,235 | 2,024 | 1,341 | 1,390 | 12,440 |
| GWS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 |
| TOTAL | 1,998 | 1,338 | 1,059 | ,689 | 1,267 | 2,516 | 4,341 | 3,885 | 3,919 | 4,648 | 3,740 | 3,361 | 32,761 |
| POTENTIAL | 3,210 | 1,960 | 1,750 | ,900 | 1,550 | 3,100 | 5,490 | 5,280 | 5,530 | 6,640 | 5,370 | 4,960 | 45,760 |
| **END-OF-MONTH-STORAGES (PERVIOUS SUB-AREA INCHES)** | | | | | | | | | | | | | |
| INTC | ,170 | ,031 | ,050 | ,002 | ,016 | ,110 | ,005 | ,002 | ,001 | ,001 | ,250 | ,000 | |
| SDS | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | ,000 | |
| SRS | ,000 | ,000 | ,020 | ,000 | ,004 | ,161 | ,000 | ,000 | ,000 | ,000 | ,001 | ,000 | |
| UZS | ,711 | ,827 | 1,376 | ,660 | 1,083 | 1,450 | ,789 | ,546 | ,835 | ,245 | 1,129 | ,258 | |
| LZS(RIDGE) | 1,797 | 1,578 | 1,835 | 3,814 | 6,059 | 5,191 | 3,942 | 3,152 | 4,682 | 2,810 | 3,666 | 2,422 | |
| LZS(ALLUVIAL) | 1,683 | 1,480 | 1,753 | 2,268 | 2,806 | 2,869 | 2,116 | 1,853 | 2,307 | 1,492 | 2,315 | 1,415 | |
| LZS(HILLSIDE) | 1,791 | 1,573 | 1,831 | 2,930 | 5,071 | 3,633 | 2,705 | 2,182 | 3,666 | 1,857 | 2,814 | 1,715 | |
| GWS | 6,119 | 5,265 | 4,507 | 5,257 | 14,396 | 16,390 | 17,431 | 15,063 | 15,562 | 13,374 | 11,975 | 10,496 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS ,757

CHANGE IN STORAGE EQUALS ,756

Pan Evapotranspiration Adjusted by 1.13

FLOW AND STORAGE TABLE FOR CAMPCREEK NEAR FAYETTVILLE GEORGIA — WATER YEAR 1961 (VALUES IN INCHES)

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION | 1.087 | 1.128 | 2.033 | 2.329 | 13.040 | 7.065 | 4.978 | 3.342 | 7.869 | 2.806 | 6.401 | 1.353 | 54.234 |
| LOSSES (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | .950 | .533 | .279 | .167 | .401 | .650 | 1.205 | 1.167 | 1.761 | 1.072 | 1.879 | .590 | 10.843 |
| INFILTRATION-DIRECT | .876 | .569 | 1.596 | 1.780 | 5.626 | 3.475 | 2.908 | 1.963 | 4.257 | 1.517 | 4.025 | .699 | 29.243 |
| -FROM SRS | .009 | .003 | .030 | .127 | 1.860 | .667 | .411 | .049 | .515 | .053 | .178 | .018 | 3.921 |
| -FROM SCS | .008 | .002 | .010 | .017 | .163 | .109 | .055 | .023 | .089 | .029 | .074 | .000 | .587 |
| SURFACE RETENTION | .009 | .003 | .053 | .104 | 1.967 | .844 | .237 | .049 | .519 | .053 | .180 | .016 | 3.977 |
| PERCOLATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| UZS-LZS | .000 | .000 | .375 | 2.135 | 6.921 | 2.038 | 2.453 | .803 | 3.286 | .490 | 2.067 | .320 | 21.697 |
| LZS-GWS | .164 | .000 | .000 | .546 | 4.095 | 1.532 | 1.329 | .000 | .885 | .000 | .052 | .062 | 8.665 |
| SEEPAGE RIDGE | .000 | .000 | .000 | .000 | 1.365 | .763 | .468 | .000 | .039 | .000 | .000 | .000 | 2.676 |
| UNDERFLOW | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| STREAMFLOW (WATERSHED INCHES) | | | | | | | | | | | | | |
| IMPERVIOUS AREA | .026 | .017 | .030 | .034 | .193 | .105 | .074 | .049 | .116 | .042 | .095 | .020 | .803 |
| SURFACE | .014 | .005 | .115 | .227 | 4.750 | 1.883 | .500 | .091 | 1.126 | .094 | .347 | .030 | 9.181 |
| INTERFLOW | .008 | .000 | .000 | .110 | 1.131 | .658 | .388 | .005 | .154 | .038 | .006 | .011 | 2.509 |
| BASEFLOW | .526 | .437 | .388 | .363 | .444 | 1.047 | 1.069 | .991 | .847 | .854 | .732 | .622 | 8.319 |
| TOTAL FLOW | .576 | .459 | .532 | .734 | 6.518 | 3.693 | 2.030 | 1.136 | 2.243 | 1.027 | 1.181 | .683 | 20.812 |
| EVAPOTRANSPIRATION (WATERSHED INCHES) | | | | | | | | | | | | | |
| INTERCEPTION | .784 | .675 | .256 | .215 | .388 | .555 | 1.310 | 1.169 | 1.710 | 1.124 | 1.834 | .826 | 10.843 |
| SRS | .000 | .000 | .000 | .000 | .039 | .005 | .006 | .000 | .004 | .000 | .001 | .000 | .054 |
| UZS | .614 | .435 | .566 | .299 | .483 | 1.060 | 1.625 | 1.512 | 1.230 | 1.791 | 1.228 | 1.371 | 12.209 |
| LZS | .766 | .321 | .307 | .240 | .477 | 1.108 | 1.718 | 1.376 | 1.098 | 1.865 | 1.205 | 1.249 | 11.729 |
| GWS | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| TOTAL | 2.163 | 1.427 | 1.129 | .754 | 1.387 | 2.728 | 4.659 | 4.056 | 4.041 | 4.780 | 3.667 | 3.446 | 34.437 |
| POTENTIAL | 3.621 | 2.211 | 1.974 | 1.015 | 1.748 | 3.497 | 6.193 | 5.956 | 6.238 | 7.490 | 6.057 | 5.617 | 51.617 |
| END-OF-MONTH STORAGES (PERVIOUS SUB-AREA INCHES) | | | | | | | | | | | | | |
| INTC | .168 | .026 | .050 | .001 | .018 | .110 | .003 | .001 | .053 | .001 | .250 | .000 | |
| SCS | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | |
| SRS | .000 | .000 | .024 | .000 | .008 | .183 | .000 | .000 | .000 | .000 | .002 | .000 | |
| UZS | .610 | .753 | 1.408 | .891 | 1.180 | 1.499 | .765 | .501 | .852 | .151 | 1.147 | .167 | |
| LZS(RIDGE) | 1.700 | 1.354 | 1.402 | 3.203 | 5.567 | 4.610 | 3.311 | 2.336 | 4.129 | 2.126 | 2.739 | 1.592 | |
| LZS(ALLUVIAL) | 1.856 | 1.151 | 1.238 | 2.070 | 2.451 | 2.537 | 1.723 | 1.396 | 2.074 | 1.101 | 2.034 | 1.109 | |
| LZS(HILLSIDE) | 1.661 | 1.322 | 1.376 | 2.611 | 4.270 | 3.147 | 2.244 | 1.678 | 3.013 | 1.433 | 2.289 | 1.289 | |
| GWS | 6.276 | 5.399 | 4.622 | 4.969 | 12.308 | 13.280 | 13.802 | 11.815 | 11.893 | 10.181 | 8.817 | 7.698 | |

ANNUAL PRECIPITATION MINUS EVAPOTRANSPIRATION MINUS STREAMFLOW MINUS UNDERFLOW EQUALS -1.015

CHANGE IN STORAGE EQUALS -1.015