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DEVELOPMENT OF MODEL FOR SIMULATION OF FLOWS OF NON MONSOON SEASON

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PREFACE

The rainfall runoff modelling is widely used for the estimation of floods and flood forecasting. The data requirements in most of the model is high at the same time some models are limited by the separation of the base flow in oder to account for nonlinearity of the process in to a linear form.

The present simple linear model is developed by the separation of rainfall in to two components as the rainfall used to meet the soil moisture storage demand and the component of rainfall causing the direct runoff. For the separation of rainfall, the maximum soil moisture in tension storage is estimated based on the average soil type and depth. Finally the maximum soil moisture in tension storage is iterated to achieve the maximum efficiency of the model. The methodology not only yields the constants of the model but also results in average soil moisture status in the catchment on ten daily and monthly basis. Since, the soil moisture data of the catchment was not known, the verification of the estimated soil moisture could not be carried out. The application of the model is limited due to availability of time.

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ABSTRACT

In planning and design of water resources development schemes, reliable estimates of available water at the site of interest are required. For this purpose a long term stream flow data may be needed. It is generally observed that the desired stream flow data for long term period are lacking. Therefore, application of rainfall runoff model is useful to simulate flows and to have the accountability of soil water deficit during few forthcoming months.

This report presents a simple deterministic model, based on water balance technique, developed for Banjar sub basin of upper Narmada catchment. The rainfall is separated in to two components; One being the linear part which is causing direct runoff and other being the non linear component of rainfall absorbed to meet the requirement for soil moisture deficit. The hydrological drought is defined and then modelled using Cordery's approach which evaluates soil water deficit. The model can be used to estimate probability distribution of soil water deficits for each month of the year. From a given initial value it is then possible to estimate the distribution of soil water deficit in subsequent months. This means that from the current soil water deficit, probability of being above or below a chosen value during future months, can be determined.

1.0 INTRODUCTION

The ever increasing demand for water, properly distribution in space and time has forced hydrologists and engineers to propose more and more complex and combitious plans for water resources management. The planning, design and operation of water resources projects need flow data of reasonable length. Especially for this the quantitative information on water available at a particular site is essential. Even though historic data is used for assessing the capabilities of the projects, the probability of its occurrence in future is in significant.

The studies reported in literature indicate that mostly the emphasis has been given towards meteorological drought followed by agricultural drought. There is a need to study hydrological aspects of drought using hydrological variables. The stream flow represents runoff from the basin and reflects the basic effects of rainfall deficiency as well as the changes in the basin both natural and man made due to drought conditions. The drought phenomenon, can therefore be better studied by analysing low stream flows of a basin for which local singularities are also eliminated. The deterministic or statistical study of stream flow may lead to drought characteristics related to soil water deficit and flow parameters.

In semi arid region, the stream flow is mostly concentrated during monsoon period spread over 3 to 4 month. In such cases, water resources engineers choose to use a time period less than a month (say Ten-daily) for monsoon and monthly periods in non-monsoon flow analysis. In arid, semi arid and tropical regions in which the significant portion of rain is utilized to satisfy the initial soil moisture requirements, the estimated runoff can be treated as representative of soil moisture. The application of simple linear models to such an areas may be useful. This study relates to modelling of monthly flows using Cordery (1983) approach. Through this work an attempt has been made to develop a simple deterministic monthly rainfall runoff model based on water balance approach. The present model is developed by the separation of rainfall in to two components as the rainfall used to meet the soil moisture storage demand and the component of rainfall causing the direct runoff. For the separation of rainfall, the maximum soil moisture in tension storage is estimated based on the average soil type and depth. Finally the maximum soil moisture in tension storage is iterated to achieve the maximum efficiency of the model. The methodology not only yields the constants of the model but also results in average soil moisture status in the catchment on monthly basis. Since, the soil moisture data of the catchment was not known, the verification of the estimated soil moisture could not be carried out. The developed model has been applied to make prediction of monthly flows and soil moisture deficits during non-monsoon period.

The present model has been developed, for Banjar sub basin of upper Narmada. It can also be used to fulfil the following requirements.

a) assessing the monthly stream flow at unguaged sites.

b) computing the flow at sites where measuring operations has been suspended.

2.0 DEFINITION OF DROUGHT

Studies on the incidence of droughts as well as its prediction and undertaking of measures to combat it are extremely vital for countries like India (Krishna 1979). Inspite of technological advanced marks made in the word and move so in India, the drought still continues to be a major factor of uncertainty. There are more than about 60 definitions, given by various researchers for drought, each advanced on a different consideration related particularly to the nature of water requirement and the time of its need. However, no universally accepted definition of drought has so far been developed (Hounam et. aL. 1975). Non - specific definitions have commonly been used in quite specific circumstances Cordery (1983). Presently a very wide range of definitions is being used (Krishnan 1979). on one extreme, drought is defined as a state of low annual rainfall. The above definition may probably a good one for aridity, but has little to do with drought as investigated here. Some workers have defined drought in terms of the 'normal' rainfall and have suggested that drought occurs when the rainfall is less than an arbitrarily chosen proportion of the long term average. Gibbs et.al (1967) defined drought in terms of deciles of observed rainfalls. In their definition drought occurs at a location when the observed rainfall for any season or year is in the lowest 10 percent of all observed historical rainfalls for that time period. India meteorological Department (IMD) defined drought as the occasion when annual rainfall is less than 75% of normal rainfall.

All the above definitions are concerned with meteorological droughts. A hydrological drought is defined as the situation with marked depletion in surface water storage, cessation of spring flows and fall in ground water level. Agricultural drought occurs when soil moisture and rainfall are inadequate during the growing season to support healthy crop growth to maturity and cause extreme crop stress and wilt. Hydrological drought based on theory of run was first defined by Yevjevich (1967). He briefly stated, a 'drought is defined as a period of time that a consecutive sequence of stream flow below a chosen level called truncation level.

A number of workers have produced drought indices which takes some account of storage of water in the soil and loss of this water by evapotranspiration. A fairly complex index of agricultural drought was suggested by palmer (1965), though he called it meteorological drought, and this has found widespread use. Some attempt have been made to examine the frequency of drought as defined by Palmer index,using stochastic data generation techniques (Padmnabhan and Rao, 1979). Simpler indices of hydrological drought have been proposed by Rodda (1965), Wigley and Atkinson, 1977), and Tabony (1977). Dracup et al (1980) have attempted to provide a background for defining drought for semi arid and arid regions on the basis of a statistical analysis of multi year stream flow event. However as Jackson (1981) has pointed out to be really meaningful, drought needs to be defined in terms of normal or expected human activities in the region. Definitions in terms of normal or average levels of rainfall, stream flow or even soil water have little meaning unless they are related to the expectations of the area's population and effects in the regional economy. This type of definition was suggested by Gibbs (1967). Gibbs stated that the impact of drought is dependent on the nature and extent animal and plant communities using water, and therefore the concept of drought can not be divorced from the uses to be made of the water. Cordery (1983) stated that a hydrological drought may be defined as the lack of water in the surface streams,

The above definition of hydrological drought, as given by Cordery (1983), will be considered in this study. To simulate stream flow in nonmonsoon season and to predict the hydrological drought a simple deterministic model is developed which takes account of input, output and storage of water in the basin. At any instant the storage of water within the basin is determined by the recent meteorological history and the storage capacity by soil crop root zone. In turn, the storm runoff is directly influenced by both precipitation and the amount of water stored in the soil.

3.0 REVIEW

There are several models in respect of rainfall runoff relationship. A comprehensive literature search would no doubt disclose the existence of several hundred (thousand ?) models and the number of unpublished models probably exceeds the published ones (Singh 1981). It is not possible to include an exhaustive review of all these models here, but few of these are discussed below.

3.1 Rainfall runoff relationship

A number of models are applied to represent the process of rainfall and runoff by making a separation of daily/ten-daily rainfall into rainfall utilized to meet the soil moisture tension storage and rainfall causing runoff. The separation for soil moisture tension storage is based on initial soil moisture and potential evaporative demand. An algebraic cumulation of separated portion of rainfall to meet the tension water storage and its loss due to evaporative demand, result in current state of available soil moisture in tension.

The literature indicates that in the catchments located in arid and semi arid regions the non linearly in rainfall runoff relationship is due to the tension water storage, in which a significant part of the precipitation is used to satisfy tension water requirement of the soil and does not appear as river flow. The second non linear component which is relatively less dominant in fast responding catchments is the free water. A little portion of free water meets the evaporative demand and the major portion of free water emerges as inter flow and base flow and later joins the river flow introducing non linearity.

Hydrologic models as defined by Synder and Stall (1965) are symbolic or mathematical representations of known or assumed functions expressing the relationship of segments of the hydrologic cycle or expressing the effects of a watershed on the runoff portion of the hydrologic cycle.

Simple linear models are widely used to model rainfall runoff process. The simplest one is rational formula, which defines a linear relation between rainfall and runoff. The first overall model of hydrologic cycle was developed by Folse (1929). Sherman (1932) proposed the theory of unit hydrograph, by which runoff can be estimated from rainfall in the basin under some assumptions. Subsequently, many hydrologists have studied and proposed various types of rainfall-runoff models. In this series the TVA model (Synder 1963), Hamon model (Hamon, 1963), SCS model (Soil Conservation Service, USA, 1964, 1973), Tank model

(Sugawarw, 1967), Haan model (Haan, 1972), S-D model (Singh and Dickinson, 1975) etc. are widely used.

Van Der Beken and Byloos (1977) developed a monthly water balance model and applied it to Grote Nete basin in Belgium to compute direct runoff, water storage in the catchment, total stream flow and percolation etc. Singh (1993) developed a monthly water balance model (MWATBAL) for simulation of monthly rainfall-runoff. This model is a lumped conceptual deterministic model which comprises the surface storage, sub surface storage and ground water storage components.

Kachroo (1986) applied a linear model to fifteen catchments of different country for estimation of flow. He observed that soil moisture deficit and variation in evaporation are the significant factors influencing rainfall runoff process. It was suggested that the improvement in the results can only be done by adding a component of water balance to account for soil moisture deficit and evaporation. He observed poor model efficiency in all cases and indicates that the assumption of linearity and time invariance were the reasons for poor efficiency.

Kachroo (1992) observed that the simple linear model generally over estimates the flow, of the low flow region and under estimates the flow, in the high flow region because of the varying soil moisture conditions of the catchment. He proposed a simple linear rainfall runoff model and observed the evidence of non linearly. Also he tried to relate the soil moisture conditions with the estimated river flow in order to improve the model efficiency. Ahsan Mainul (1994) applied a simple linear rainfall runoff model in the same five catchment considered by Kachroo

(1992). He re-scaled the estimated outflows to represent catchment wetness index and the gain factor is varied in accordance with estimated wetness index based on the estimated flow.

A Multi input single output simple linear model was suggested by Liang (1994) for runoff modeling with variable gain factor model. He used runoff at two sites as input to the model and obtained the estimated runoff at third point as output. Wang (1986) used a simple linear input output model and suggested the method for the estimation of model parameters.

3.2 Prediction of drought

Flow forecasting has greater role to play in operational aspects of water resources management during the period of drought i.e. when stream flows are not able to meet the draft need of the area. On the basis of flow forecasts, the extent of expected drought damage and water scarcity or storage can be estimated in advance. This would help in deciding or updating water distribution policy, fixing of water allocation priorities for intended uses and reservoir operation and management in the event of drought. Many workers have suggested possible methods of forecasting drought, but as yet none of these suggestions have led to successful. Most of the studies discuss mean of assessing the current state of drought and of comparing the current drought with historical droughts. This is the case in the work of Palmer (1965), Rodda (1967), Gibbs et.al (1967), Taboney (1977) and Krishnan (1979). A wide ranging examination of the definition of drought, its causes and effects and some thoughts on forecasting have also been given by Houman (1975). Millan and Yevjevich (1970) carried out an extensive simulation study and have provided some empirical fitting about the probabilities of criterial drought in stream flow sequences. Taking observed rainfall and evaporation data, Cordery (1983) suggested a simple water balance model to evaluate soil water deficit (SWD) and to estimate probability distribution of soil water deficits for each month of the year. He estimated the distribution of soil water deficits in subsequent months using a given initial value of SWD and made probabilistic forecasts of SWD for shorter duration (ie. period of 3 to 4 months in humid zones and up to 15 months in sub humid zones).

4.0 DESCRIPTION OF STUDY AREA

The river Banjar is one of the major tributary of Narmada river in upper Narmada sub catchment. The Banjar sub catchment rises in the Satpura range in the Durg district of Madhya Pradesh at an elevation of 600 m at latitude 21^{o} 42' North and longitude 80^{o}22' East. It flows in North West direction for a total length of 184 km. to join the Narmada from the left near Mandla at 287th km. of its run. The Banjar sub catchment drains a total area of 3626 sq. km.

Climate of the basin can be classified as sub tropical semi arid with normal annual rainfall of 1178 mm. The south west monsoon is the principal rainy season (June to October) accounting for nearly 90% of the annual rainfall. The catchment receives about 60% of its annual rainfall during July and August months. The estimated values of evapotranspiratio range between 4mm/day to 8mm/day. The climatic characteristics of Banjar sub basin are shown in Table 1. The catchment comprises of both flat and undulating lands covered with timber, grass and cultivated agriculture. These lands consist of mainly the black soils and mixed red soils.

Table: 1. Climatic Characteristics of Banjar sub basin

Month	Median rainfall	90^{th} percentile of rainfall	median evaporation	90^{th} percentile of evaporation
Jan.	8.80	45.10	75.30	86.80
Feb.	14.90	58.57	109.20	120.40
Mar.	3.60	30.20	186.00	229.40
Apr.	5.90	24.80	276.00	291.00
May	6.2	29.29	359.60	465.00
June	142.09	241.68	288.00	321.00
July	352.90	581.80	139.50	210.50
Aug.	458.94	718.17	105.40	116.30
Sept.	122.80	266.10	111.00	123.00
Oct.	31.80	58.40	112.20	124.00
Nov.	3.90	8.20	93.00	102.45
Dec.	6.10	25.37	74.40	83.70

5.0 THE DATA USED

To develop a simple linear model between rainfall and runoff, the daily rainfall and runoff data is utilized in addition to the daily pan evaporation and the soil type of the area under consideration. The data availability of Banjar basin is listed below in Table 2.

Table 2: Data availability of Hridaynagar of Narmada basin.

Type of data	Period
1. Monthly Discharge	1982to 1992
2. Monthly rainfall	
1. Mandla	1982 to 1992
2. Manot	1982 to 1992
3. Palhera	1982 to 1992
3. Monthly pan evaporation at Mandla	1982 to 1992
4. Average soil type	Deep, Medium and shallow black soil, Mixed red and black soil

6.0 WATER BALANCE MODEL

To estimate and predict hydrological drought a water balance model was chosen which would keep an account of the soil water storage, and which would clearly distinguish between water lost from the storage by runoff and by evapotranspiration. In this model, drought is defined in terms of the water stored in the soil. The soil water deficit (SWD) is the difference between the actual water storage and the maximum storage that can be sustained. Since a high soil water deficit means the soil is very dry, numerically the SWD has a large negative value. That is, an SWD of - 100 mm which may be referred to as a large value of SWD, means that 100 mm of water is required to bring the soil to a state of zero deficit, or saturation.

Drought is assumed to occur when there is a large value of SWD. However, terms like severe drought or slight drought are very qualitative and will not be used. As suggested by Rodda (1965), if the SWD can be calculated for a long continuous period of record then it is possible to determine the proportion of time the SWD has been above a particular value and to gain some comparative understanding of the severity of the drought situation. For example, it may be that the SWD calculated for last March was the third highest value for any March in the 100 years for which records are available. This use of a comparative index has also been used by Tabony (1977) and Wigley and Atkinson (1977). The definition of drought suggested here is similar, in a statistical sense, to the definition of meteorological drought used by Gibbs and Maher (1967) with the difference that in addition to rainfall also, hydrological drought takes account of evapotranspiration and runoff data, and provides for storage of water within the soil.

6.1 Model Structure

The process of rainfall runoff is highly non linear specially in arid, semi arid and drought prone regions. In such areas, the major cause of non linearity in the process is due to the combined effect of interception, depression storage and soil moisture storage. The application of a simple water balance models to such areas is possible by splitting the total rainfall into non linear and linear components. The non linear component is absorbed and released back to atmosphere and the linear component causes the runoff.

The underlying philosophy of the model is that while water is readily available in the root zone, it will be transpired at close to the potential rate. When the root zone storage is depleted significantly evapotranspiration will continue, but at a very much reduced rate. In the wetting phase precipitation is taken up by the soil until the root zone reaches saturation. Once saturation is reached any further precipitation runs off. It is assumed that there are parts of all catchments which have no soil water storage capacity (impermeable surfaces), and that any precipitation on these areas runs off immediately.

This model was developed by Mr. I. Cordery for prediction of hydrological drought. This model is a monthly water balance model to estimate soil water deficit and with the help of this model, monthly runoff has been estimated. The structure of the model used is shown in Fig. 2.

To obtain the SWD for the catchment the model must be run separately to obtain the SWD for each root zone capacity area and then the catchment average SWD is obtained by weighting these values according to area. It should be noted that this is a simple model and that it requires calibration. The variable 'A' which indicates that a small proportion of all precipitation runs off without loss, the proportion of the total area having particular root zone capacities (SWD "limit")m, and the value of the exponent 'g' for each of these zones must be determined by some fitting technique. All three factors have pseudo physical meaning and so some intuitive estimation assisted in the fitting process. The exponent "g" was adopted as a means of achieving very restricted evapotranspiration once the soil became dry.

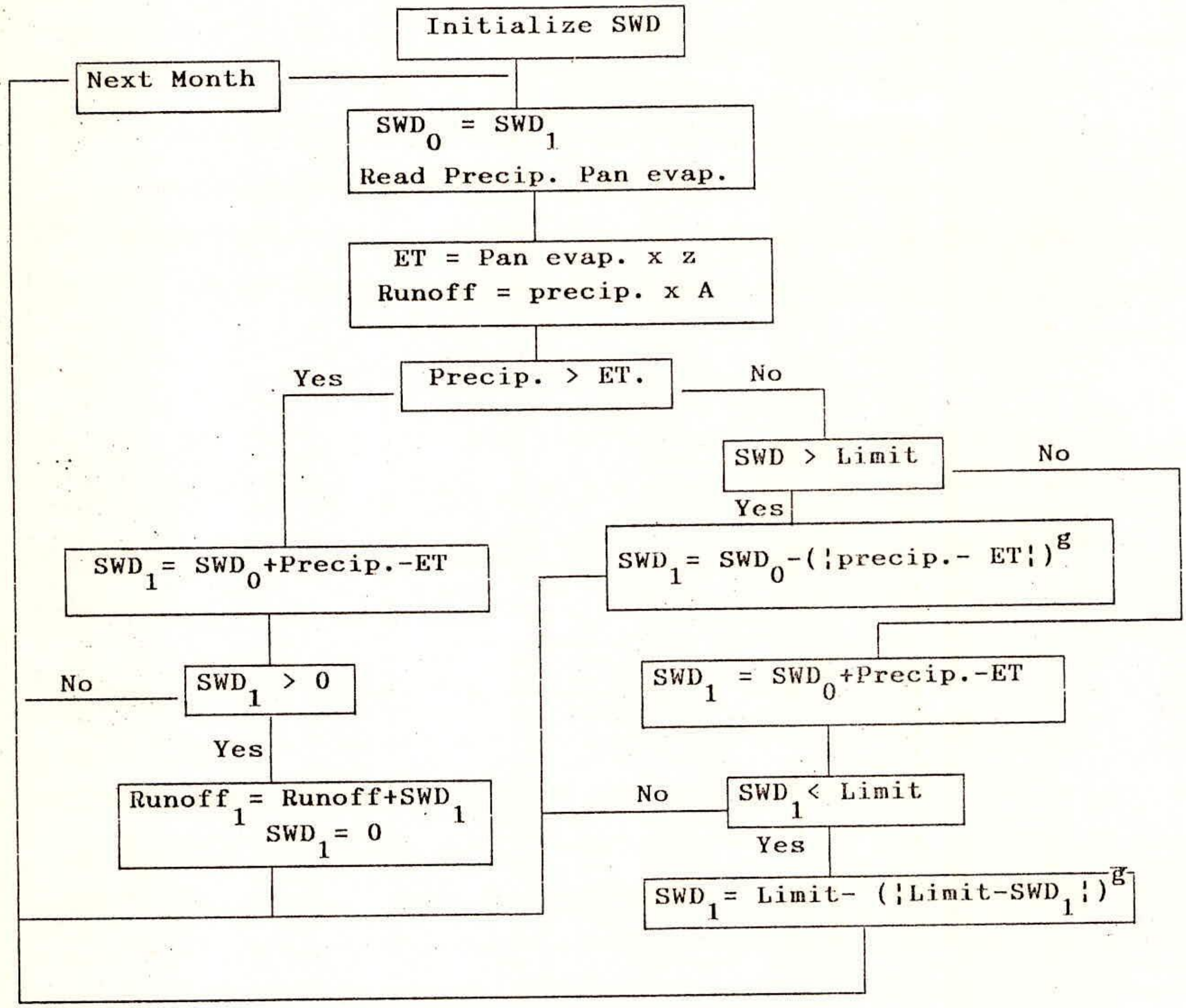

Fig. 2 Flow chart of water balance model

7.0 METHODOLOGY

A monthly model was initially chosen because only monthly estimates of evaporation were available and to avoid the large amounts of data handling that would have been involved with a daily model. The monthly model gave satisfactory results and so use of a daily model could not attempted. This model is based on the monthly water balance approach as suggested by Cordery (1983) for ecasting of hydrological drought.

7.1 Model Calibration

Using the rainfall, stream flow and the evaporation data for the period from 1982 to 1987 the model is calibrated for Banjar catchment up to Hridaynager. The data used for the study were the Thiessen weighted monthly rainfall of three stations namely Hridaynagar, Palhera and Manot. The catchment mean monthly evapotranspiration has been taken as pan evaporation recorded at Mandla. The calibration was achieved by assuming physically reasonable initial values of some of the parameters (selected by trial runs for fitting of variables/parameters). The iteration procedure is applied for the separation of soil moisture in tension storage and fitting of developed model for obtaining the model parameters and to achieve maximum model efficiency. The model parameters like 'A', which indicates that small portion of precipitation runs off without loss (runoff coefficient), 'L' (SWD limit) the maximum soil water deficit limit proportion in the total area having particular root zone capacities, and 'g' the exponent for each of the zones are estimated, using "Rosenbrock" optimization technique, after minimizing the sum of the squares of the differences between monthly observed and computed runoff for the calibration period. A computer programme CAL.FOR (Annexer I) is used for calibration of model parameter A, XL and g.

The values of initial SWD i.e. SWD_o has been adopted as -80 mm after several trial runs of the programme. The maximum SWD limit has been fixed as -150 mm on the basis of available soil type of catchment after calculation of the field capacity and permanent wilting point.

With variations of model structure and fitting parameters many trial runs of the programme was exercised to achieve the model which was physically realistic and could reproduce runoff for a period of six years to an acceptable level of accuracy.

7.2 Model Validation

The calibrated model was subsequently applied to reproduce the observed runoff for the period from 1988 to 1992. During the validation of the model, the optimized model parameters are used to simulate the monthly runoff using the monthly rainfall and evapotranspiration for the validation period as input to the model. A computer programme VAL.FOR (Annexer II) is used for validation of the model.

The efficiency of the model for calibration as well as validation period is calculated from the following relationship.

$$R = \frac{F_o - F_i}{F_o} \qquad \text{(i)}$$

Where, $F_o = \sum_{i=1}^{n} (CRUN_i - \overline{CRUN})^2$

and $F_i = \sum_{i=1}^{n} (CRUN_i - \hat{CRUN}_i)^2$

$\overline{CRUN}$ = Mean of observed 'n' cumulative runoff values.

$CRUN_i$ = Observed cumulative runoff for the i^{th} time period.

$\hat{CRUN}_i$ = Estimated cumulative runoff from the model for i^{th} time period.

n = Number of data taken in to consideration during calibration or validation of model.

In this model it is assumed that all parts of the catchment have got the same type of soil and the same values of parameters A, L, g, SWD_o for the catchment. These assumptions were made due to non-availability of sufficient data for the study area.

8.0 DISCUSSIONS

The modeling of total response simple linear rainfall runoff process considering that the rainfall is a complex process by virtue of its non linearly due to soil moisture storage release and due to the percolation of free water and its reappearance. The moisture storage in the system is in the form of tension water and free water, which are dependent on incident moisture condition. The water under tension storage is released back to atmosphere through evapotranspiration and is a non linear component to rainfall runoff process, while the second component, the free water percolates and travels as base flow to appear in the river and is relatively less nonlinear.

Using step lengths and convergence criteria for optimization, the monthly values of rainfall, evaporation, observed runoff, initial soil water deficit (SWD_0) which was calculated from soil type of the catchment and trial runs, and initial values of A, XL, and g were input to the model. The values of parameters after optimization were found to be: A =0.268, Xl = -119.92, g = 0.88 and SWD_0= -80 mm.

The efficiency of the model in calibration and validation phases are found to be 84.53% and 76.34% respectively.

The hydrograph of calibration period and validation period are plotted and compared with hydrograph of observed runoff values and shown in Fig. 7.1 and Fig. 7.2 respectively. Also, the similar hydrograph is compared for nonmonsoon months (excluding the months of July, August and September) as shown in Fig. 7.5 and Fig. 7.6. It is observed that the hydrographs of observed flows and simulated flows are matching to an acceptable extent. The hydrograph developed based on computed flows does not show much deviation from the observed hydrograph. The little difference in the computed flows and observed flows may be due to :

(i) Actual evapotranspiration loss for all parts of the catchment and all types of vegetation are not readily available.

(ii) It is assumed here that the soil type is same in the entire catchment and soil water deficit is same in all parts of the catchment, which may not be true.

(iii) The parameter values as 'A', 'XL' and 'g' are assumed to be the same over the entire catchment, which may vary from place to place within the catchment.

The observed runoff and simulated runoff during calibration and validation period are plotted along the line of equality as shown in figure 7.3 and 7.4 respectively.

Since soil moisture is being hardly measured in the basin, the simulation approach is applied for computing soil water deficit to evaluate drought conditions. The soil water deficits for validation period (1988-92) were computed and present in Annexer- III. The estimates of SWDs show that in the nonmonsoon months SWD becomes greater and crops face large water stress.

9.0 CONCLUSIONS

The simple monthly rainfall-runoff model evolved and applied to Banjar sub basin will be useful for computing the stream flows in the unguaged sites for the purpose of water resources planning, development and management. This is especially significant because the basin has a number of raingauge stations and in the entire basin the stream gauging stations are few only.

It is also possible to estimate the distribution of soil water deficits for the subsequent months, if the initial value of SWD is known. This approach could be of great use in planning drought management measures in advance.

This model in the present form may be useful for simulation of flows in sub catchments of upper Narmada basin. However, further modification in model structure to consider different values of model parameters for different type of soils may provide better results.

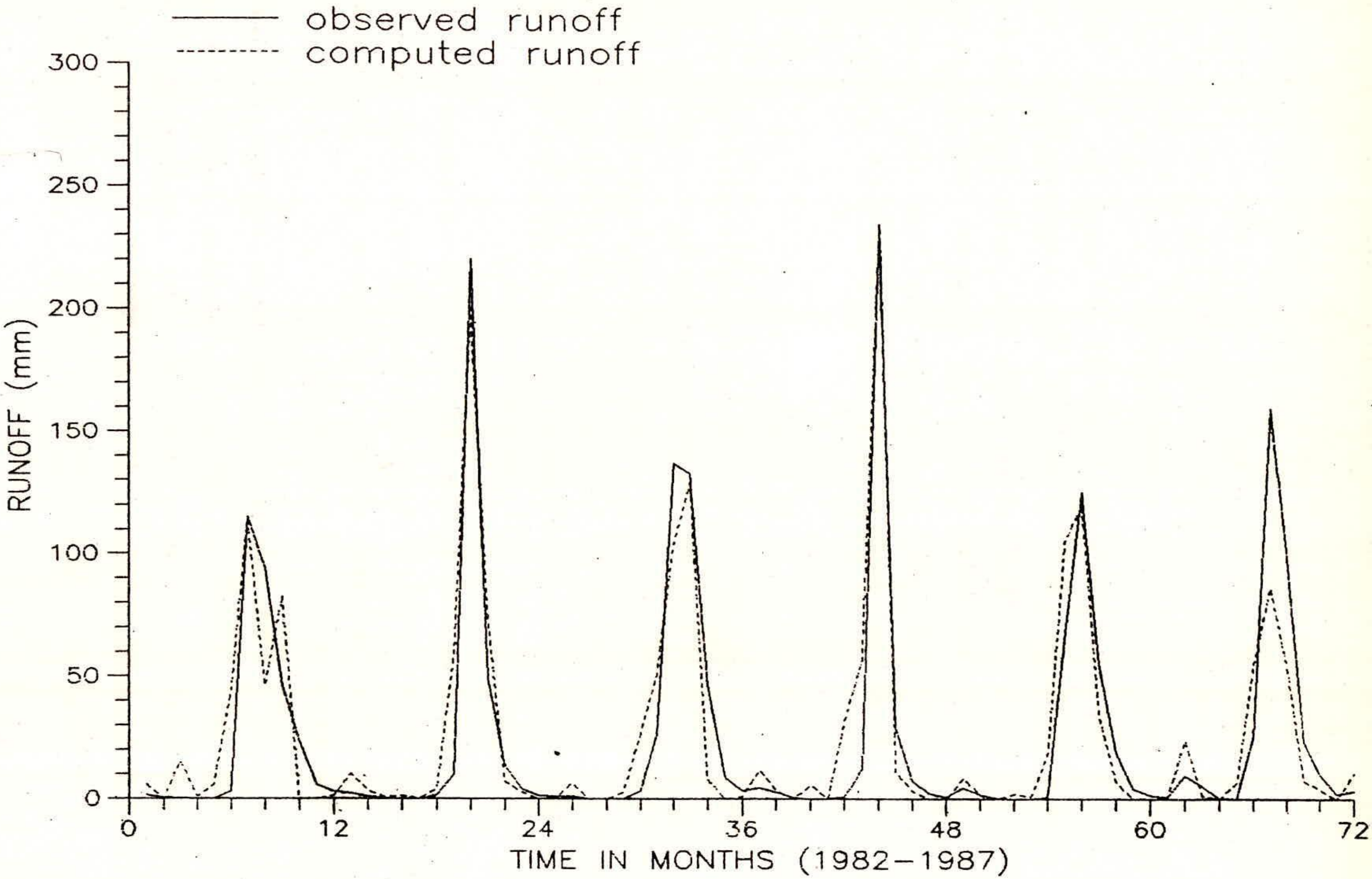

Fig. 7.1 Comparison of observed and computed runoff for calibration period (1982–1987)

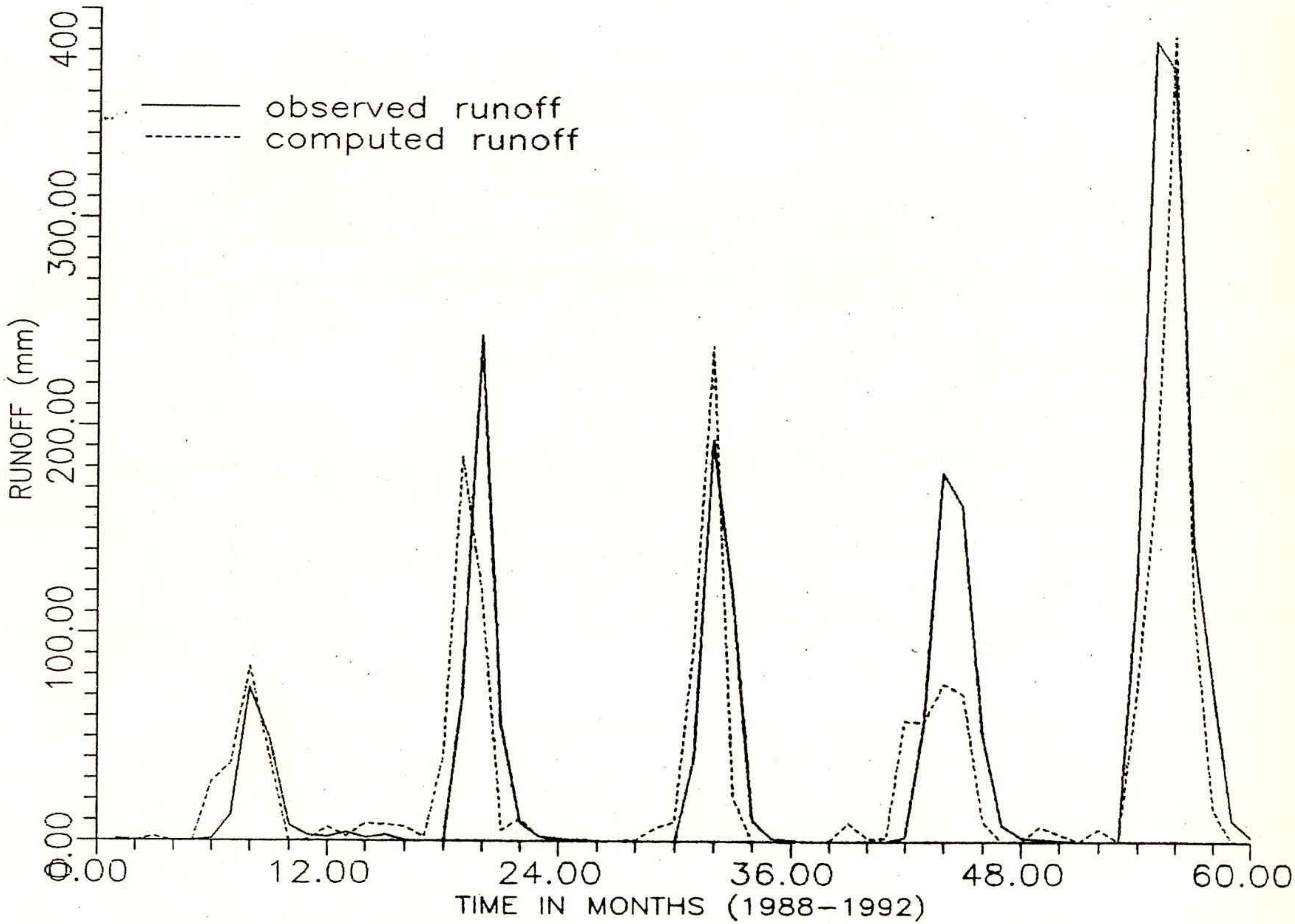

Fig. 7.2 Comparison of observed and computed runoff for validation period (1988–1992)

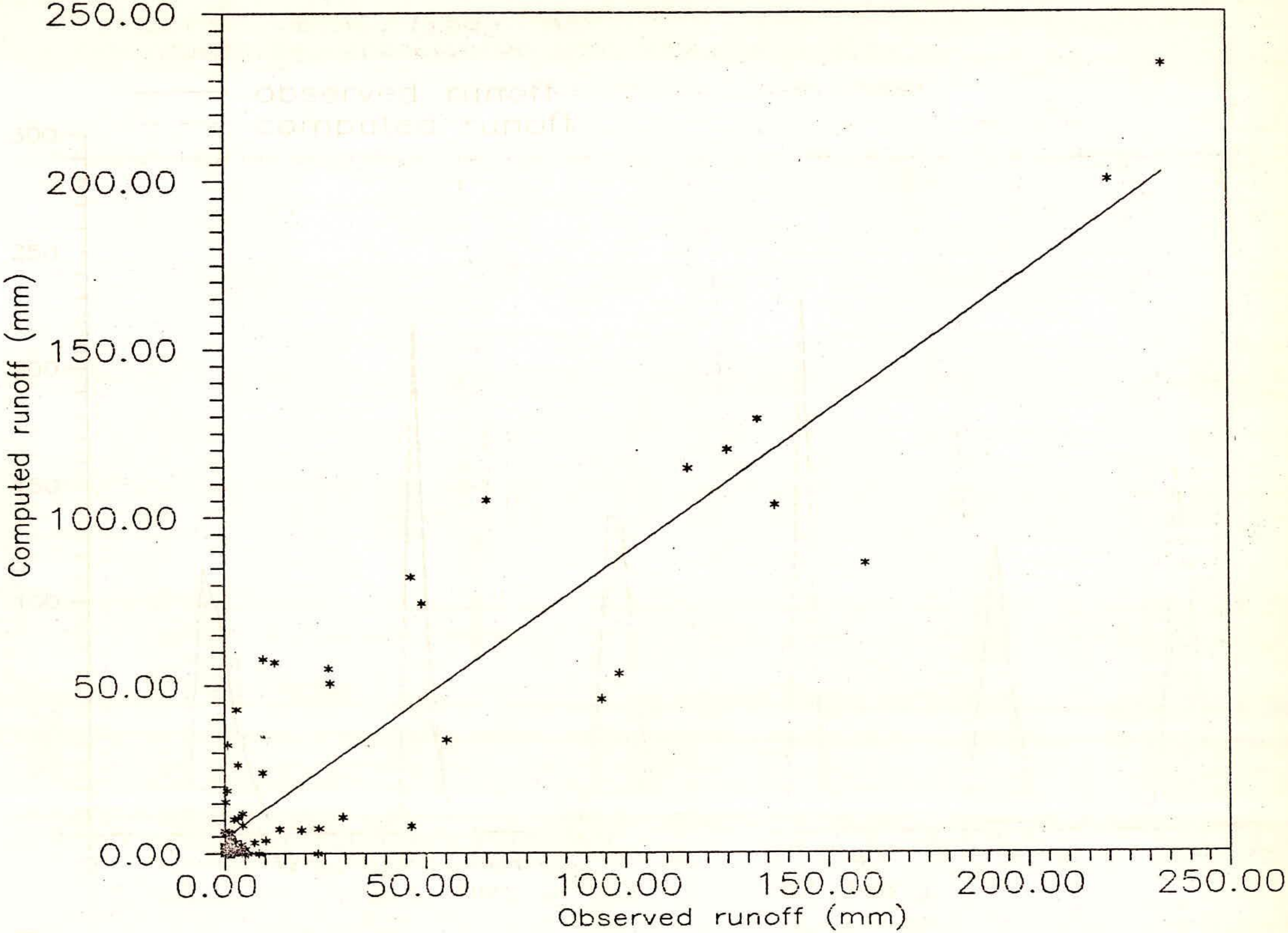

Fig. 7.3 Plot of observed and computed runoff for calibration period

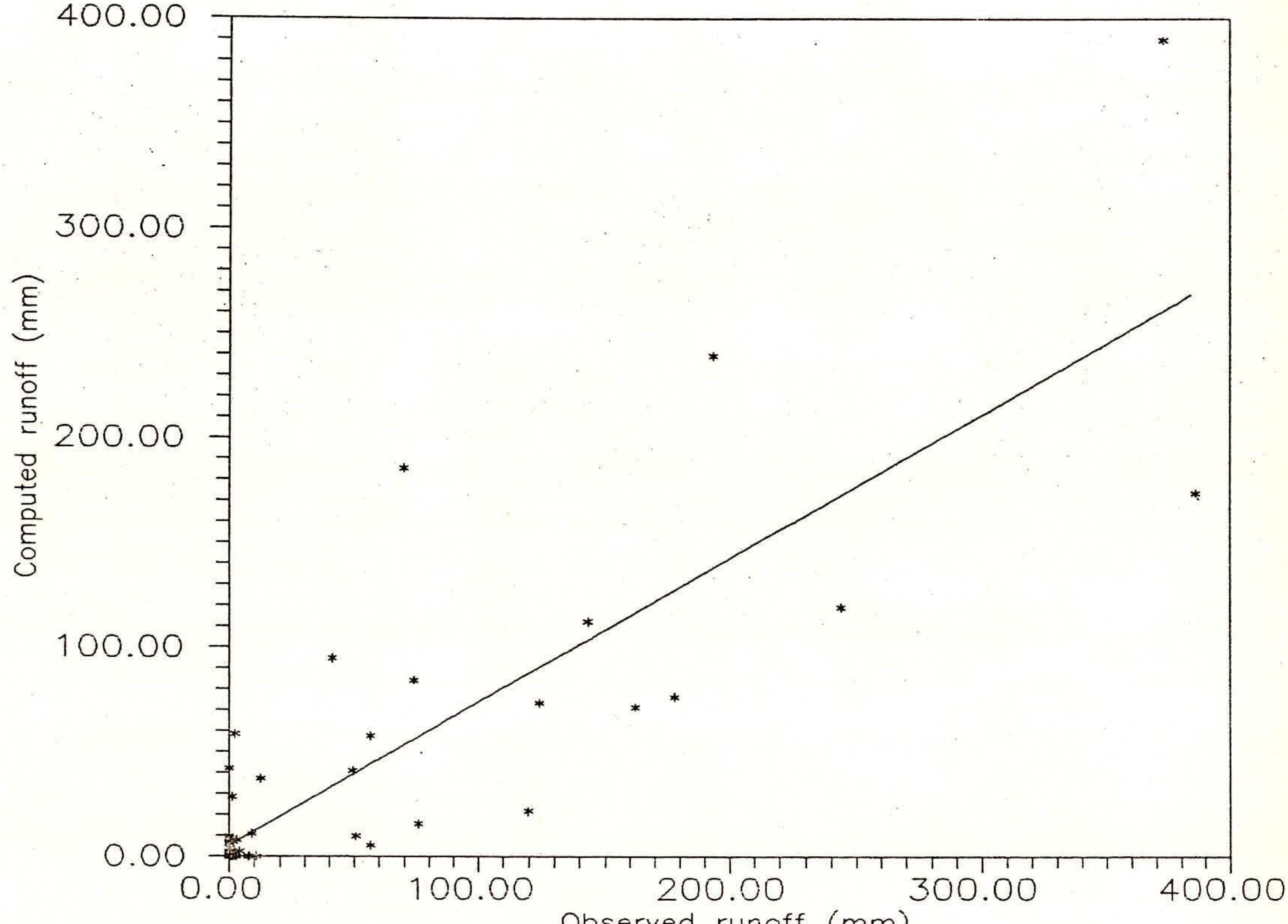

Fig. 7.4 Plot of observed and computed runoff for validation period

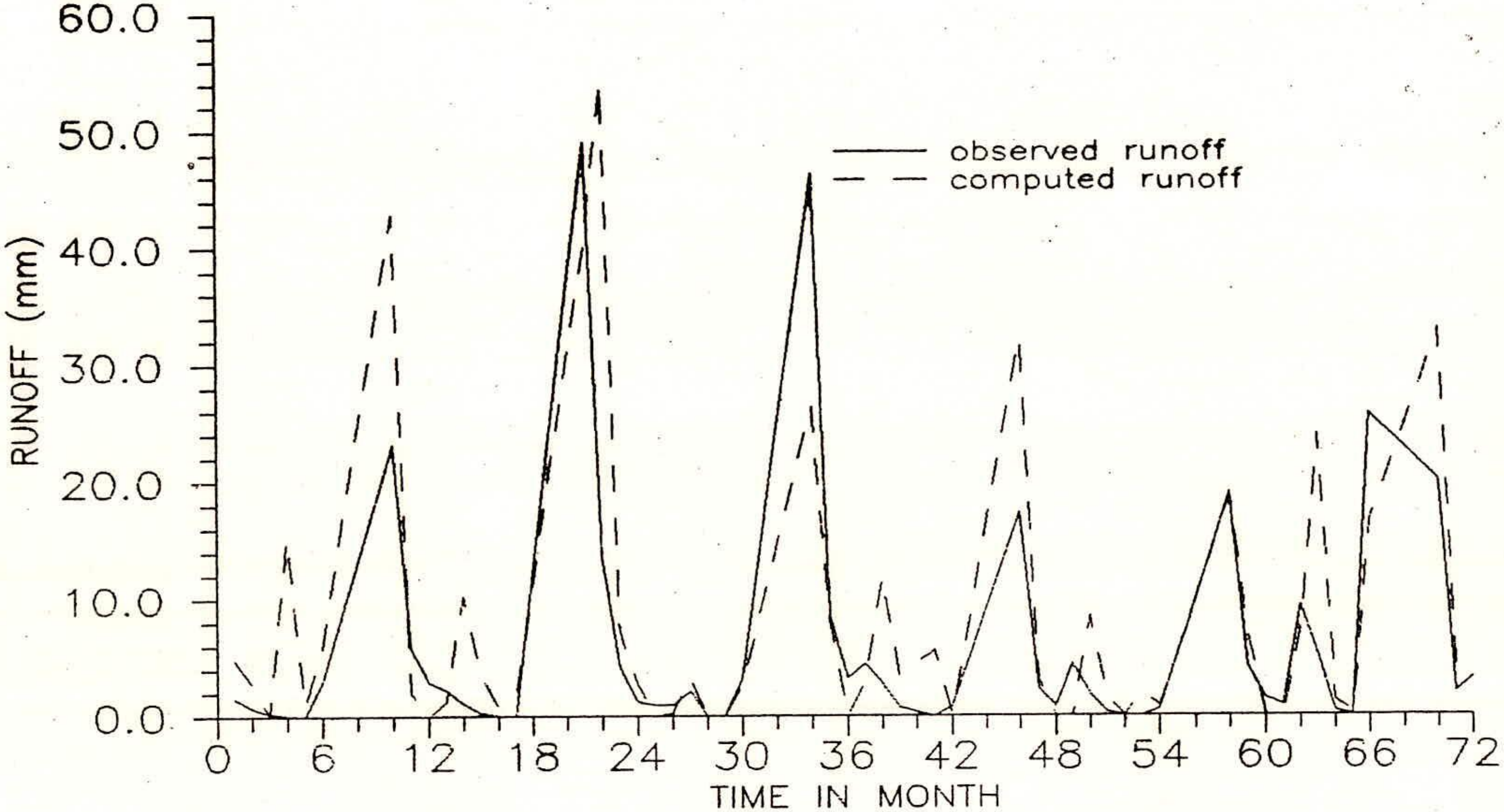

Fig. 7.5 Comparison of observed and computed runoff in non-momsoon months of calibration period (1982–87)

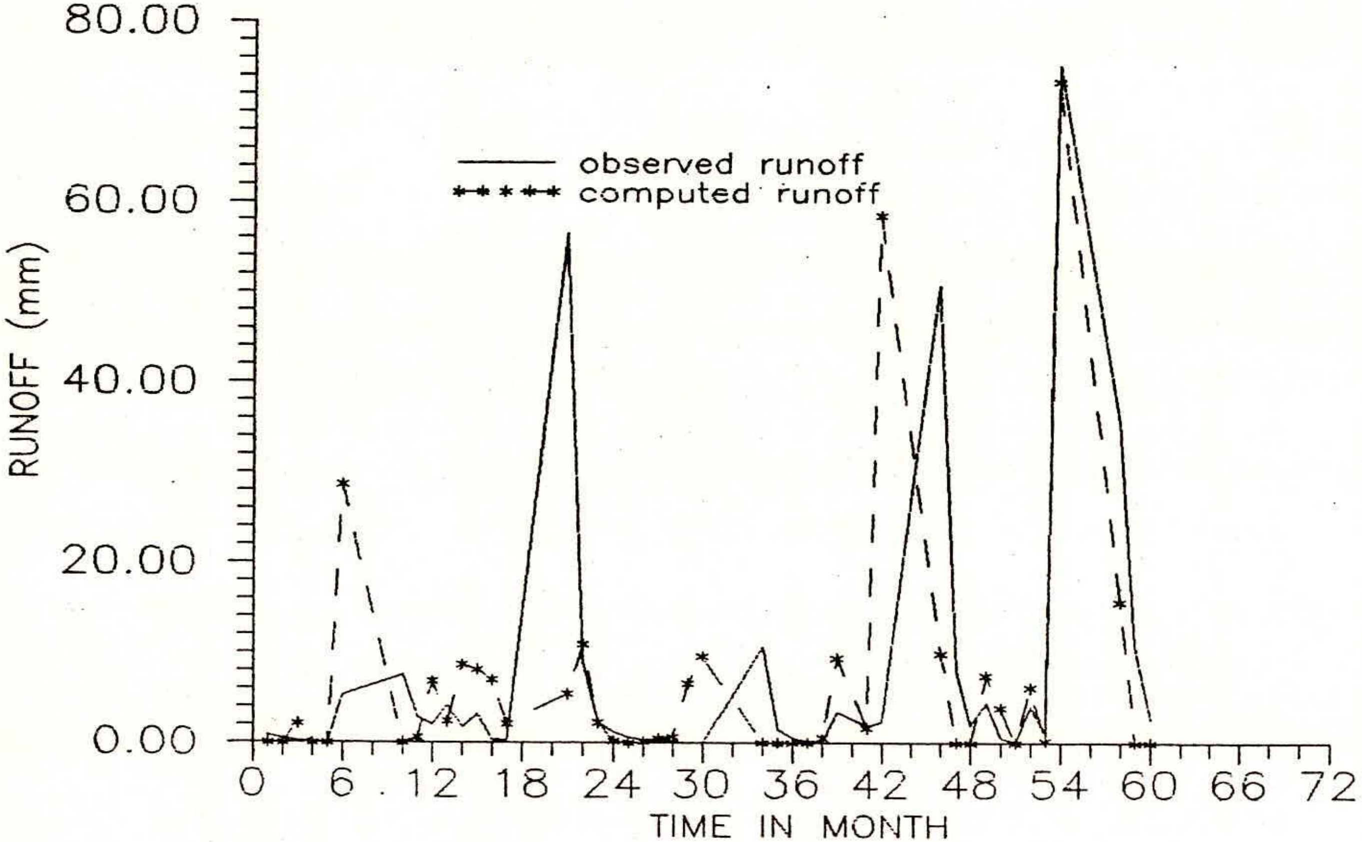

Fig. 7.6 Comparison of observed and computed runoff in non-momsoon months of validation period (1988-92)

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ANNEXURE -I

CAL.FOR

```
$LARGE
      INCLUDE  'FGRAPH.Fi'
C     PROGRAM FOR MONTHLY WATER BALANCE MODEL CALIBRATION USING
C     ROSENBROCK HILLCLIMB TECHNIQUE
      COMMON PRPN(150),EVP(150),RUNF(150),ORUN(150),NOBS,SWD1
      COMMON KOUNT
      DIMENSION X(3),E(3),V(3,3),SA(3),D(3),G(3),H(3),AL(3),
     1 PH(3),A(3,3),B(3,3),BX(3),DA(1),VV(3,3),EINT(3),VM(3),
     2 OORUN(144),RRUNF(144),Q1(12),QE1(12),TIME1(12),R1(12)
      CHARACTER*12 ibns*1
      INTEGER P
      INTEGER PR
      INTEGER R
      INTEGER C
      REAL LC
      NI=50
      NO=66
      OPEN(UNIT=1,FILE='GRA.DAT',STATUS='OLD')
      OPEN(UNIT=NI,FILE='PARA7.DAT',STATUS='OLD')
      OPEN(UNIT=NO,FILE='PARA7.OUT',STATUS='UNKNOWN')
   99 FORMAT(3F10.2)
   98 FORMAT(5X,2F10.2)
      READ(NI,*)SWD1,NOBS
C      WRITE(NO,*)SWD1,NOBS
      READ(NI,99)(PRPN(I),ORUN(I),EVP(I),I=1,NOBS)
C      WRITE(NO,99)(PRPN(I),ORUN(I),EVP(I),I=1,NOBS)
      READ(NI,*) M,P,L,LOOPY,PR,ND,NDATA,NSTEP
      WRITE(NO,*) M,P,L,LOOPY,PR,ND,NDATA,NSTEP
C     M=1 for maximization of objective function,
C     M=-1 for minimization
C     L= No for parameters having explicit constraints
C     P= Total parameters to be optimized
C     LOOPY= No of computions to be performedfor each cycle
C     PR=1 for every step computation printing,
C     PR=0 for summary of results
C     ND=1 for storage of computed results in previous step,
C     ND=0 for not storing
C     NDATA= No of data items to be stored
C     NSTEP=0 for supplied user length,
C     NSTEP=1 for step length computed in the program
C     AN= No linear reservoir
C
  001 FORMAT (8I5)
  002 FORMAT (1E10.4)
   10 DO 100 K=1,P
      READ (NI,*) X(K)
C      WRITE(NO,*) X(K)
  100 CONTINUE
      DO 200 J=1,P
      READ (NI,*) E(J)
C      WRITE(NO,*) E(J)
```

```
  200 CONTINUE
      WRITE (NO,013)
  013 FORMAT (1H1,10X,30HROSENBROCK HILLCLIMB PROCEDURE)
C
      IF (ND -1) 30, 20, 30
   20 DO 300 KA=1,NDATA
      READ (NI,*) DA(KA)
      WRITE(NO,*) DA(KA)
  300 CONTINUE
C
   30 LAP=PR-1
      LOOP=0
      ISW=0
      INIT=0
      KOUNT=0
      TERM=0.0
      DELY=1.0E-10
      F1=0.0
      NPAR=NDATA
      N=L
      DO 40 K=1,L
   40 AL(K)=(CH(X,DA,N,NPAR,K)-CG(X,DA,N,NPAR,K))*.00001
      DO 60 I=1,P
      DO 60 J=1,P
      V(I,J)=0.0
      IF(I-J) 60,61,60
   61 V(I,J)=1.0
   60 CONTINUE
      DO 65 KK=1,P
      EINT(KK)=E(KK)
   65 CONTINUE
C
C
 1000 DO 70 J=1,P
      IF (NSTEP.EQ.0)  E(J)=EINT(J)
      SA(J)=2.0
   70 D(J)=0.0
      FBEST=F1
   80 I=1
      IF(INIT.EQ.0)GO TO 120
   90 DO 110 K=1,P
  110 X(K)=X(K)+E(I)*V(I,K)
      DO 50 K=1,L
   50 H(K)=F0
C
C
  120 F1=F(X,DA,N,NPAR)
      F1=M*F1
      IF(ISW.EQ.0) F0=F1
      ISW=1
      IF(ABS(FBEST-F1)-DELY) 122,122,125
  122 TERM=1.0
      GO TO 450
  125 CONTINUE
C
```

```
C
      J=1
C
  130 XC=CX(X,DA,N,NPAR,J)
      LC=CG(X,DA,N,NPAR,J)
      UC=CH(X,DA,N,NPAR,J)
      IF(XC.LE.LC) GO TO 420
      IF(XC.GE.UC) GO TO 420
      IF(F1.LT.F0) GO TO 420
      IF(XC.LT.LC+AL(J)) GO TO 140
      IF(XC.GT.UC-AL(J)) GO TO 140
      H(J)=F0
      GO TO 210
C
C
  140 CONTINUE
C
      BW=AL(J)
C
      IF(XC.LE.LC.OR.UC.LE.XC) GO TO 150
      IF(LC.LT.XC.AND.XC.LT.LC+BW) GO TO 160
      IF(UC-BW.LT.XC.AND.XC.LT.UC) GO TO 170
      PH(J)=1.0
      GO TO 210
C
C
  150 PH(J)=0.0
      GO TO 190
  160 PW=(LC+BW-XC)/BW
      GO TO 180
  170 PW=(XC-UC+BW)/BW
  180 PH(J)=1.0-3.0*PW+4.0*PW*PW-2.0*PW*PW*PW
C
  190 F1=H(J)+(F1-H(J))*PH(J)
C
  210 CONTINUE
      IF(J.EQ.L)GO TO 220
      J=J+1
      GO TO 130
C
  220 INIT=1
      IF(F1.LT.F0)GO TO 420
      D(I)=D(I)+E(I)
      E(I)=3.0*E(I)
      F0=F1
      IF(SA(I).GE.1.5)  SA(I)=1.0
C
  230 DO 240 JJ=1,P
      IF(SA(JJ).GE.0.5) GO TO 440
  240 CONTINUE
C
C     AXES ROTATION
C
      DO 250 R=1,P
      DO 250 C=1,P
```

```
  250 VV(C,R)=0.0
      DO 260 R=1,P
      KR=R
      DO 260 C=1,P
      DO 265 K=KR,P
  265 VV(R,C)=D(K)*V(K,C)+VV(R,C)
  260 B(R,C)=VV(R,C)
      BMAG=0.0
      DO 280 C=1,P
      BMAG=BMAG+B(1,C)*B(1,C)
  280 CONTINUE
      BMAG=SQRT(BMAG)
      BX(1)=BMAG
      DO 310 C=1,P
  310 V(1,C)=B(1,C)/BMAG
C
      DO 390 R=2,P
C
      IR=R-1
      DO 390 C=1,P
      SUMVM=0.0
      DO 320 KK=1,IR
      SUMAV=0.0
      DO 330 KJ=1,P
  330 SUMAV=SUMAV+VV(R,KJ)*V(KK,KJ)
  320 SUMVM=SUMAV*V(KK,C)+SUMVM
  390 B(R,C)=VV(R,C)-SUMVM
      DO 340 R=2,P
      BBMAG=0.0
      DO 350 K=1,P
  350 BBMAG=BBMAG+B(R,K)*B(R,K)
      BBMAG=SQRT(BBMAG)
      DO 340 C=1,P
  340 V(R,C)=B(R,C)/BBMAG
      LOOP=LOOP+1
      LAP=LAP+1
      IF(LAP.EQ.PR) GO TO 450
      GO TO 1000
C
  420 IF (INIT.EQ.0) GO TO 450
      DO 430 IX=1,P
  430 X(IX)=X(IX)-E(I)*V(I,IX)
      E(I) = -0.5*E(I)
      IF (SA(I).LT.1.5) SA(I)=0.0
      GO TO 230
C
  440 CONTINUE
      IF (I.EQ.P) GOTO 80
      I=I+1
      GO TO 90
C
  450 WRITE (NO,003)
  003 FORMAT (//,2X,5HSTAGE,8X,8HFUNCTION,12X,8HPROGRESS,9X,
     116HLATERAL PROGRESS)
      WRITE (NO,004) LOOP, F0,BMAG,BBMAG
```

```
  004 FORMAT (1H,I5,3E20.8)
      WRITE (NO,014)KOUNT
  014 FORMAT (/,2X,33HNUMBER OF FUNCTION EVALUATIONS= ,I8)
      WRITE (NO,005)
  005 FORMAT (/,2X,25HVALUES OF X AT THIS STAGE)
C     PRINT CURRENT VALUES OF X
      WRITE (NO,006) (JM, X(JM), JM=1,P)
C  006 FORMAT (/,2X,3(2HX(,I2,4H) = ,1PE14.6,4X))
  006 FORMAT (/,2X,3(2HX(,I2,4H) = ,1F10.4,4X))
C
      LAP =0
      IF  (INIT.EQ.0) GO TO 470
      IF  (TERM.EQ.1.0) GO TO 480
      IF  (LOOP.GE.LOOPY) GO TO 480
      GO TO 1000
C
  470 WRITE (NO,007)
  007 FORMAT (///,2X,81HTHE STARTING POINT MUST NOT VIOLATE THE CONSTRAI
     1NTS.  IT APPEARS TO HAVE DONE SO.)
  480 CONTINUE
  490 WRITE (NO,008)
  008 FORMAT (///,2X,29HFINAL DIRECTION VECTOR MATRIX)
      DO 500 J=1,P
  500 WRITE (NO,009) (J, I, V(J,I), I=1,P)
  009 FORMAT (/,2X,3(2HV(,I2,1H,,I2,4H) = ,F10.8,4X))
      WRITE (NO,011)
  011 FORMAT (//,2X,16HFINAL STEP SIZES)
      WRITE (NO,012) (J, E(J), J=1,P)
  012 FORMAT (/,2X,3(2HS(,I2,4H) = ,1PE14.6,4X))
C
      SUM=0.0
        NT=0
      DO 102 I=1,NOBS
      WRITE(NO,98)ORUN(I),RUNF(I)
        IF(ORUN(I).EQ.-1.00)GO TO 102
        NT=NT+1
        SUM=SUM+ORUN(I)
        OORUN(NT)=ORUN(I)
        RRUNF(NT)=RUNF(I)
  102 CONTINUE
        AVM=SUM/NT
        SUM=0.0
        S=0.0
        DO 103 I=1,NT
        SUM=SUM+(OORUN(I)-RRUNF(I))**2
        S=S+(OORUN(I)-AVM)**2
103     CONTINUE
        EFF=(S-SUM)/S
        EFF=EFF*100.0
        WRITE(NO,*)'EFFICIENCY (%)=',EFF
        WRITE(*,*)'EFFICIENCY (%)=',EFF
C     ****************************************************
      write(*,*)'do you want to plot the graph(y/n)?'
      read(*,1235)ibns
 1235 format(a1)
```

```
      if(ibns.eq.'y'.or.ibns.eq.'Y')then
      write(*,*)'about to draw graph...'
      read(*,*)
      call grasub1
      IS=0
      IG=12
      IJ=IG
      DO 1234 I=1,NOBS
      R1(I-IS)=PRPN(I)
      Q1(I-IS)=OORUN(I)
      QE1(I-IS)=RRUNF(I)
      TIME1(I-IS)=I-IS
C       write(2,99)q1(i-is),qe1(i-is),time1(i-is)
      IF(I-IJ)1234,1232,1232
 1232 ij=ij
      call grasub2(Q1,QE1,TIME1,IG)
C       call grasub2(Q1,R1,TIME1,IG)
      WRITE(*,'('' Enter key for next graph'')')
      read(*,*)
      IS=IS+IG
      IJ=IJ+IG
 1234 continue
      end if
C     **************************************************
      stop
      END
      FUNCTION F(X,DA,N,NPAR)
      COMMON PRPN(150),EVP(150),RUNF(150),ORUN(150),NOBS,SWD
      COMMON  KOUNT
      DIMENSION X(N), DA(NPAR)
      XA=X(1)
      XL=X(2)
      XG=X(3)
      SWD1=SWD
      WRITE(*,*)'XA=',XA,'XL=',XL,'XG=',XG
      DO 201 I=1,NOBS
201   RUNF(I)=0.0
      DO 101 I=1,NOBS
      SWD0=SWD1
      RUNF(I)=PRPN(I)*XA
      IF(PRPN(I).GT.EVP(I))GO TO 3000
      GO TO 5000
 3000 SWD1=SWD0+PRPN(I)-EVP(I)
      IF(SWD1.LE.0)GO TO 101
      RUNF(I)=RUNF(I)+SWD1
      SWD1=0
      GO TO 101
 5000 IF(SWD0.LT.XL)GO TO 7000
      GO TO 8000
 7000 SWD1=SWD0-(ABS(PRPN(I)-EVP(I)))**XG
      GO TO 101
 8000 SWD1=SWD0+PRPN(I)-EVP(I)
      IF(SWD1.LT.XL)THEN
      SWD1=XL-(ABS(XL-SWD1)**XG)
      END IF
```

```
  101 CONTINUE
      SUM=0.0
      DO 102 I=1,NOBS
C      WRITE(*,*)'RUNOFF=',ORUN(I),RUNF(I)
      if(orun(i).eq.-1.00)go to 102
      SUM=SUM+(ORUN(I)-RUNF(I))**2
  102 CONTINUE
      F=SUM
        write(*,*)'f=',f
       UNT=KOUNT+1
      R  URN
      END
      FUNCT ON CX (X,DA,N,NPAR,K)
C
      DIMENSION X(N), DA(NPAR)
C
      CX=X(K)
      RETURN
      END
      FUNCTION CG (X,DA,N,NPAR,K)
C
       DIMENSION X(N), DA(NPAR)
C
      GO TO (1,2,1),K
    1 CG=0.0
      GO TO 3
    2 CG=-150.0
    3 RETURN
      END

      FUNCTION CH (X,DA,N,NPAR,K)
C
      DIMENSION X(N), DA(NPAR)
C
      GO TO (1,2,1),K
C
   1  CH   = 1.0
      GO TO 3
   2  CH =0.0
C
   3  RETURN
      END
C       ***********************************************************
C       General purpose graphics program
        subroutine grasub1
        INCLUDE  'FGRAPH.FD'
        character*50 Title, xtit*40, ytit*10
        common/x/ cxmin,cxmax,cymin,cymax,npx,nspx,npy,nspy,iswitch
        common/t/ title, xtit, ytit
        read(1,1) Title
        read(1,1) xtit
        read(1,1) ytit
1       format(a)
c       Switch for prescribing own extremes.
        write(*,'('' Enter 1 for manual formatting of graph :  '',$)')
```

```
      read(*,*) ians
      IF (ians.EQ.1) THEN
      write(*,*) ' Enter values of : cxmin,cxmax,cymin,cymax :
      read(*,*) cxmin,cxmax,cymin,cymax
      write(*,'('' Enter no. of parts on x-axis :  '',$)')
      read(*,*) npx
      write(*,'('' Enter no. of smaller divisions on a part :  '',$)')
      read(*,*) nspx
      write(*,'('' Enter no. of parts on y-axis :  '',$)')
      read(*,*) npy
      write(*,'('' Enter no. of smaller divisions on a part :  '',$)')
      read(*,*) nspy
      iswitch = 1
      ELSE
      read(1,*) npx,nspx,npy,nspy
      iswitch = 0
      ENDIF
      RETURN
      END
C
C
      SUBROUTINE GRASUB2(yy,yy1,xx,nn)
        INCLUDE  'FGRAPH.FD'
        DIMENSION XX(366),YY(366),YY1(366)
      Integer*2   dummy
        character*50 Title, xtit*40, ytit*10
        common/x/ cxmin,cxmax,cymin,cymax,npx,nspx,npy,nspy,iswitch
        common/t/ title, xtit, ytit
      CALL graphicsmode()
      CALL drawlines(yy,yy1,xx,nn)
      READ (*,*)                           ! Wait for ENTER key
      call clearscreen ($GCLEARSCREEN)
      dummy = setvideomode( $DEFAULTMODE )
      RETURN
      END
C     ***************************************************************
C
      SUBROUTINE graphicsmode()
C     ***************************************************************
C      This subroutine finds the video mode of the monitor.
C     ****************************************************************
C       Output :
C             maxx = min. dimension in horizontal direction
C             maxy = max dimension in vertical direction
C********************************************************************
      INCLUDE  'FGRAPH.FD'
      INTEGER*2               dummy, maxx, maxy
      RECORD /videoconfig/ myscreen
      COMMON/gmod/            maxx, maxy
C     Find graphics mode.
      CALL getvideoconfig( myscreen )
      SELECT CASE( myscreen.adapter )
         CASE( $CGA )
            dummy = setvideomode( $HRESBW )
         CASE( $OCGA )
```

```
            dummy = setvideomode( $ORESCOLOR )
         CASE( $EGA, $OEGA )
            IF( myscreen.monitor .EQ. $MONO ) THEN
                dummy = setvideomode( $ERESNOCOLOR )
            ELSE
                dummy = setvideomode( $ERESCOLOR )
            END IF
         CASE( $VGA, $OVGA, $MCGA )
            dummy = setvideomode( $VRES2COLOR )
         CASE( $HGC )
            dummy = setvideomode ( $HERCMONO )
         CASE DEFAULT
            dummy = 0
      END SELECT
      IF( dummy .EQ. 0 ) STOP 'Error:  cannot set graphics mode'
C     Determine the minimum and maximum dimensions.
      CALL getvideoconfig( myscreen )
      maxx = myscreen.numxpixels - 1
      maxy = myscreen.numypixels - 1
      RETURN
      END
C
C
      SUBROUTINE drawlines(yy,yy1,xx,nn)
C*******************************************************************
C          This subroutine draws various parts of the graph          *
C*******************************************************************
C          Input :                                                   *
C*              cxmin = minimum abscissa.                            *
C*              cxmax = maximum abscissa.                            *
C*              cymin = minimum ordinate.                            *
C*              cymin = minimum ordinate.                            *
C*                npx = no. of parts on x-axis.                      *
C*               nspx = no. of smaller parts of a division on x-axis.*
C*                npy = no. of parts on y-axis.                      *
C*               nspy = no. of smaller parts of a division on y-axis.*
C*               gtit = title of the graph.                          *
C*               xtit = title of x-axix.                             *
C*               ytit = title of y-axis.                             *
C*            iswitch = switch for whether the option is for automatic or *
C*                      manual formatting.                           *
C*********************************************************************
      INCLUDE  'FGRAPH.FD'
      EXTERNAL          newx,newy
        DIMENSION XX(366),YY(366),YY1(366)
      COMMON/gmod/           maxx, maxy
        common/x/ cxmin,cxmax,cymin,cymax,npx,nspx,npy,nspy,iswitch
        common/t/ gtit, xtit, ytit
      INTEGER*2         dummy, newx, newy, maxx, maxy
      INTEGER*2 dummy2
      INTEGER*4 dummy4
      INTEGER*4 bkcolor(8) /
     +              $BLACK, $BLUE, $GREEN, $CYAN,
     +              $RED, $MAGENTA, $BROWN, $WHITE /
      CHARACTER*50 gtit, xtit*40, ytit*10, str*9
```

```
      RECORD /xycoord/ xy
      dummy2 = selectpalette (0)
      dummy4 = setbkcolor(bkcolor(2))
      xmin=10000000
      xmax=-999999
      ymin=xmin
      ymax=xmax
      do 5 i=1,nn
         if(xx(i).lt.xmin) xmin=xx(i)
         if(xx(i).gt.xmax) xmax=xx(i)
         if(yy(i).lt.ymin) ymin=yy(i)
         if(yy(i).gt.ymax) ymax=yy(i)
         if(yy1(i).lt.ymin) ymin=yy1(i)
5     IF (yy1(i).gt.ymax) ymax=yy1(i)
      IF (iswitch.EQ.1) then
         xmin = cxmin
         xmax = cxmax
         ymin = cymin
         ymax = cymax
      ELSE
         xmin=int(xmin/npx)*npx
         xmax=nint(xmax/npx)*npx
         ymin=int(ymin/npy)*npy
         ymax=nint(ymax/npy)*npy
      ENDIF
      ixnew=maxx*0.15
      iynew=maxy*0.85
      CALL  setvieworg( ixnew, iynew, xy)
      CALL  setlinestyle( #FFFF)
      CALL  moveto( 0, 0, xy )
      ixl = maxx*0.75
      ixl = ixl/100
      ixl = ixl*100
      dummy = lineto( ixl, 0 )
      CALL  moveto( 0, 0, xy )
      iyl = maxy*0.7
      iyl = iyl/100
      iyl = iyl*100
      dummy = lineto( 0, -iyl )
      tm = ixl/npx
      CALL  settextposition( 28,8, xy)
      write(str,'(f7.0)') xmin
      CALL outtext(str)
      do i = 1,npx
         do j = 1,nspx-1
            ptm = (i-1+j/float(nspx))
            CALL moveto(ptm*tm, 0, xy)
            dummy = lineto(ptm*tm, 4)
         end do
         CALL  setlinestyle( #8888 )
         CALL  moveto( i*tm,-iyl, xy)
         dummy = lineto(i*tm, 0)
         CALL  setlinestyle( #FFFF)
         dummy = lineto(i*tm, 7)
         CALL  settextposition( 28,int2(8+50*i/npx), xy)
```

```
         write(str,'(f7.0)') xmin+(xmax-xmin)*i/npx
         CALL outtext(str)
      enddo
      tm = iyl/npy
      CALL  settextposition( 26,3, xy)
      write(str,'(f7.0)') ymin
      CALL outtext(str)
      do i = 1,npy
         do j = 1,nspy-1
            ptm = (i-1+j/float(nspy))
            CALL moveto(0,-ptm*tm, xy)
            dummy = lineto(-4,-ptm*tm)
         end do
         CALL  setlinestyle( #8888)
         CALL  moveto( ixl, -i*tm, xy)
         dummy = lineto(0, -i*tm)
         CALL  setlinestyle( #FFFF)
         dummy = lineto(-7,-i*tm)
         CALL  settextposition(int2(26-19*i/npy),3, xy)
         write(str,'(f7.0)') ymin+(ymax-ymin)*i/npy
         CALL outtext(str)
      enddo
      xr = ixl/(xmax-xmin)
      yr = iyl/(ymax-ymin)
      CALL moveto(xr*(xx(1)-xmin),-yr*(yy(1)-ymin),xy)
      do 10 i=1,nn
         ixn = xr * ( xx(i) - xmin)
         iyn = yr * ( yy(i) - ymin)
10    dummy = lineto( ixn, -iyn)
      CALL  setlinestyle( #AA00)
      CALL moveto(xr*(xx(1)-xmin),-yr*(yy1(1)-ymin),xy)
      do 11 i=1,nn
         ixn = xr * ( xx(i) - xmin)
         iyn = yr * ( yy1(i) - ymin)
11    dummy = lineto( ixn, -iyn)
      CALL  settextposition( 2, 20, xy)
      CALL  outtext(gtit)
      CALL  settextposition( 29, 35, xy)
      CALL  outtext(xtit)
      CALL  settextposition( 5, 5, xy)
      CALL  outtext(ytit)
      READ (*,*)                          ! Wait for ENTER key
      CALL clearscreen ($GCLEARSCREEN)
      dummy = setvideomode( $DEFAULTMODE )
      RETURN
      END
```

VAL.FOR

```
$LARGE,
C       PROGRAM FOR MONTHLY WATER BALANCE MODEL VALIDATION USING
        DIMENSION PRPN(100),EVP(100),RUNF(100),ORUN(100),EVPT(100),
       1RPP(100)
        CHARACTER*12 INFIL,OUFIL
        WRITE(*,21)
   21   FORMAT(5X,'INPUT FILE NAME')
        READ(*,32)INFIL
   32   FORMAT(A)
        WRITE(*,22)
   22   FORMAT(5X,'OUTPUT FILE NAME')
        READ(*,32)OUFIL
        OPEN(UNIT=1,FILE='PRID.DAT',STATUS='OLD')
        OPEN(UNIT=2,FILE='PRID.OUT',STATUS='UNKNOWN')
   98   FORMAT(5X,3F10.2)
   99   FORMAT(3F10.2)
        READ(1,*)SWD1,NOBS
        WRITE(2,*)SWD1,NOBS
        READ(1,*)(PRPN(I),ORUN(I),EVP(I),I=1,NOBS)
C        WRITE(2,99)(PRPN(I),ORUN(I),EVP(I),I=1,NOBS)
        XA=0.268
        XL=-119.72
        XG=.88
        DO 201 I=1,NOBS
201     CONTINUE
        RUNF(I)=0.0
        DO 103 I=1,NOBS
        SWD0=SWD1
        RUNF(I)=PRPN(I)*XA
        EVPT(I)=EVP(I)*0.7
        IF(PRPN(I).GT.EVPT(I))GO TO 3000
        GO TO 5000
 3000   SWD1=SWD0+PRPN(I)-EVPT(I)
        IF(SWD1.LE.0)GO TO 101
        RUNF(I)=RUNF(I)+SWD1
        SWD1=0
        GO TO 101
 5000   IF(SWD0.LT.XL)GO TO 7000
        GO TO 8000
 7000   SWD1=SWD0-(ABS(PRPN(I)-EVPT(I)))**XG
        GO TO 101
 8000   SWD1=SWD0+PRPN(I)-EVPT(I)
        IF(SWD1.LT.XL)THEN
        SWD1=XL-(ABS(XL-SWD1)**XG)
        END IF
  101   RPP(I)=SWD1
C        WRITE(2,98)ORUN(I),RUNF(I),RPP(I)
  103   CONTINUE
        DO 102 I=1,NOBS
        WRITE(*,*)'RUNOFF=',ORUN(I),RUNF(I)
        if(orun(i).eq.-1.00)go to 102
```

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      WRITE(2,98)ORUN(I),RUNF(I),RPP(I)
  102 CONTINUE
C      WRITE(2,98)ORUN(I),RUNF(I),SWD1
      SO=0.0
      SE=0.0
      DO 104  I=1,NOBS
      SO=SO+ORUN(I)
  104 SE=SE+RUNF(I)
      SAMO=SO/5
      SAME=SE/5
      VR=100*(SE/SO)
      VI=100*(SO-SE)/SO
      WRITE(2,98)SO,SE
      WRITE(2,98)SAMO,SAME
      WRITE(2,98)VI,VR
      STOP
      END
```

COMPARISON OF OBSERVED AND COMPUTED RUNOFF FOR CALIBRATION AND VALIDATION PERIOD

MONTH	Calibration Period (1982-87)		Validation Period (1988-92)		
	Observed Runoff	Computed Runoff	Observed Runoff	computed Runoff	Soil Water Deficit
1	1.58	5.87	.88	.00	-129.59
2	.68	.00	.46	.00	-175.53
3	.25	15.41	.19	2.10	-244.26
4	.04	.91	.08	.00	-344.63
5	.00	5.83	.00	.00	-483.70
6	2.99	42.85	1.25	28.62	-524.64
7	115.35	114.44	12.45	37.30	-465.32
8	93.94	45.85	73.91	84.15	-219.01
9	46.23	82.24	49.34	40.94	-120.09
10	23.20	.00	7.54	.00	-159.19
11	5.87	.00	2.87	.59	-207.55
12	2.92	1.21	1.97	6.80	-257.25
13	2.28	10.26	4.19	2.36	-285.65
14	1.09	3.55	1.67	8.63	-315.48
15	.29	.82	3.16	8.09	-362.57
16	.03	1.34	.33	6.97	-460.88
17	.00	.14	.00	2.09	-577.17
18	1.48	4.14	.00	41.97	-640.74
19	9.71	57.89	69.85	185.32	-53.61
20	220.17	200.09	243.88	119.08	.00
21	49.08	74.39	56.47	5.36	-62.74
22	13.65	7.24	8.96	10.88	-100.68
23	4.15	2.75	2.30	2.20	-142.28
24	1.22	.00	1.14	.11	-174.93
25	.94	.29	.56	.00	-204.95
26	.96	6.31	.38	.11	-242.90
27	.12	.00	.35	.48	-304.92
28	.00	.00	.14	.64	-411.42
29	.00	2.59	.04	6.57	-507.70
30	3.35	26.42	.00	9.57	-594.53
31	26.28	50.63	40.98	94.58	-382.68
32	136.81	103.42	193.43	238.82	.00
33	132.63	129.02	120.00	21.76	-4.90
34	46.33	8.06	10.68	.00	-89.53
35	8.57	.00	1.47	.00	-136.36
36	3.24	.89	.51	.00	-168.77
37	4.45	11.89	.21	.00	-205.88
38	2.73	3.39	.06	.54	-250.26

39	.68	.24	.01	9.35	-320.63
40	.07	5.66	.00	1.45	-412.89
41	.00	.00	.00	1.66	-539.74
42	.79	32.33	2.35	58.48	-541.82
43	12.57	56.93	56.45	57.59	-418.06
44	233.79	234.36	177.89	76.22	-213.95
45	29.36	10.74	162.06	71.31	-17.15
46	7.39	3.17	50.78	9.92	-58.27
47	2.34	.00	7.97	.00	-122.85
48	.84	.00	2.02	.00	-156.44
49	4.42	8.50	1.22	7.48	-168.96
50	1.85	1.61	.52	3.86	-210.94
51	.31	.00	.15	.00	-284.59
52	.00	2.00	.00	6.11	-376.57
53	.00	.90	.00	.24	-538.74
54	.59	18.81	124.20	73.41	-466.44
55	65.30	105.03	386.17	173.63	.00
56	125.18	119.92	372.89	559.97	.00
57	55.30	33.74	143.19	112.39	.00
58	19.07	6.90	75.80	15.65	-28.40
59	4.25	.00	10.74	.00	-97.70
60	1.53	.00	2.66	.00	-139.70
61	.87	.65			
62	9.46	24.05			
63	5.19	1.30			
64	.40	.20			
65	.00	6.67			
66	25.84	55.00			
67	159.47	86.25			
68	98.45	53.51			
69	23.46	7.42			
70	10.15	3.85			
71	2.03	.00			
72	3.28	10.62			

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