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APPLICATION OF RAINFLO MODEL ON MALAPRABHA CATCHMENT UPSTREAM OF KHANAPUR

BY

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PREFACE

Flood forecasting, reservoir design, watershed simulation, and comprehensive water resources projects generally utilize some form of routing technique. RAINFLO model is used to predict the temporal and spatial variations of a flood wave as it traverses a river reach or reservoir, or can be employed to predict the outflow hydrograph from a watershed subjected to a known amount of precipitation.

The RAINFLO model can be used to calculate regulatory and design discharges in ungauged watersheds, to complement statistical analyses in watersheds with scant or insufficient streamflow data, to calculate probable maximum flood based on the probable maximum precipitation, and when installed on a specific basin, for operational flood forecasting based on rainfall data in real time.

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This report has been prepared by Mr. A.V.Shetty, Scientist 'B', with the assistance of Mr. N.Varadharajan; R.A, under the guidance of Prof. V.M. Ponce, San Diego State University; U.S.A, during his visit to Hard Rock Regional Centre Belgaum.

Satish Chandra
(SATISH CHANDRA)

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1.Ø INTRODUCTION

RAINFLO is a comprehensive hydrologic computer software system to model the rainfall runoff process to forecast real time Flood in complex watersheds and river basin. The flood forecasting may be defined as "the prediction of stage, discharge, time of occurrence, and duration of flood; specifically of peak discharge of a specified point on a stream, resulting from precipitation". Flood forecasting may be defined in common usage that implies the estimation of stream flow before hand its occurrence. The forecast may be useful only when which satisfies the criteria of accuracy, reliability and timeliness. Flood forecasting is of fundamental importance to flood warning, flood control, or river regulation which can help the water resource managers to take necessary measures to mitigate flood damage.

The forecasting method should be designed according to the purpose of forecasting. If flood and damages are to be assessed, then forecast of flow stages at key locations. along the river are needed. For control of hydraulic structure, the forecast is in terms of river discharges prescribing the entire hydrograph. The flood forecast may include the time when the river will reach the flood level, the time and magnitude of peak flood, the time when the river will fall below the flood level and total amount of flood water. The available deterministic flood forecasting models can be divided into two parts: Flood routing models real time rainfall runoff models. An operational forecasting system may incorporate both types of model.

The RAINFLO model mainly has following four modules;

i. Network Topology

ii. Subwatershed Hydrograph Generation

iii Steam Channel Routing Module

iv. Reservoir Routing Module

ii). Subwatershed Hydrograph Generation

RAINFLO uses established SCS practices for subwatershed hydrograph generation, including the runoff curve number procedure for abstraction of flows, dimensionless storm distribution patters, and the dimensionless unit hydrograph.

Storm distribution can be read as actual rainfall amounts discretised at selected intervals, or total rainfall amounts for specified period of time. With the latter, you can supply a dimensionless storm distribution pattern or use one of seven RAINFLO built-in storm patterns.

The net precipitation is distributed using a phi-index approach or throughout the effective duration of rainfall calculated by SCS procedures and otherwise throughout the specified duration of rainfall(either 24-hr or 48-hr).

iii). Stream Channel Routing Module

RAINFLO features a diffusion wave routing method in which the routing parameters are calculated based on cross-sectional rating curves and geometric characteristics.

The diffusion wave method is limited to nonzero channel gradients. In the unlikely case that the channel gradient is effectively zero, the subreach in question would be considered a reservoir subreach, and therefore, subject to reservoir routing.

RAINFLO has two stream channel routing options:

a. a constant parameter method(Muskingum-Cunge); and

b. a variable parameter method (Muskingum-Cunge).

In the constant parameter method the subreach routing parameters are calculated at the start based on peak inflow values and kept constant throughout the computation in time. In the variable parameter method the routing parameters are allowed to vary in time as a function of the local flow values.

The variable parameter method is more computationally intensive than the constant parameter method. However, it will generally result in a more accurate routing, especially for routing overbank flows, long reaches and complex networks. RAINFLO has the capacity to abstract channel transmission losses during the subreach routing process. This feature is particularly suited for cases in which channel losses or gains are important and can be documented. Average infiltration velocities are needed by RAINFLO to account for the channel transmission losses or gains.

iv. Reservoir Routing Module

Reservoir routing method is based on the storage-indication technique. The system accepts set of elevation storage-storage-outflow values each reservoir or channel impoundment and uses this information, to calculate the outflow hydrograph for the reservoir subreach.

RAINFLO can accept at most one reservoir per stream reach. Two adjoining reservoirs must be configured into two reaches. Also a reservoir can span at most one stream reach. Therefore no network confluences are allowed within a reservoir.

To activate the reservoir routing element of RAINFLO, reservoir routing indicator is to be turned on. One or more reservoirs can also be considered. To deactivate the reservoir routing element of RAINFLO can be turned it off.

The RAINFLO model has been applied as an initial application to the Malaprabha basin upstream Khanapur. The data has been derived locally on the basis of on site gathering of information by the field visits made to the Malaprabha catchment upstream of Khanapur. The field visits and subsequent works in the office enable to develop a RAINFLO input file suited to the catchment upstream of Khanapur. The effort has been made to simulate the daily hydrograph and monthly discharge of wet months using the model.

2.0 MODEL DESCRIPTION

RAINFLO is a comprehensive hydrologic computer software system to model the rainfall runoff process in complex watersheds and river basins.

As a RAINFLO user, one can specify the stream channel network in terms of a set of topological numbers. Using these topological numbers, RAINFLO orders the sequence of computations to enable the subwatershed hydrograph generation and the routing of flows through the specified network of stream channels and reservoirs.

RAINFLO accepts rainfall input to the watershed or basin and converts it into streamflow. Flows are expressed at the basin outlet, and optionally, at any or all network confluences.

The total basin area is subdivided into two types of subwatershed units:

1) upland subwatersheds, neighboring the basin perimeter, which generate upland inflow hydrographs to the stream network; and
2) reach subwatersheds, adjacent to the stream channel reaches and generating lateral inflow to them.

Rainfall can be specified distinctly for each subwatershed. Storms can be input discretely in time or as a total amount for a given duration. In the latter case, you can supply the temporal storm pattern, or alternatively choose among several RAINFLO built-in SCS dimensionless storm patterns.

RAINFLO consists of three major modules:

1) subwatershed hydrograph generation;

2) stream channel routing; and

3) reservoir routing.

2.1.Ø. Network Topology

In RAINFLO, the basic unit of network simulation is the stream reach. The total number of stream reaches forms the channel network. The channel network is specified by a set of topological numbers. Each stream is assigned a topological number consisting of order-branch-channel information. The array of the topological numbers determines the connectivity of the stream network, enabling the routing of flows in time and space.

A topological number has five digits. The first digit is the order, varying from 1 to 9; the second and third digits are the branch number, from 1 to 99; and third digits are the branch number, from 1 to 99 and the fourth and fifth digits are the channel number, from 1 to 99.

The following steps are to be carried out for the determination of the topological numbers;

1. develop tree-like schematic of the stream network;
2. delineate all broaches;
3. assign steam orders to the various branches following RAINFLO procedures;
4. number of the branches following RAINFLO procedures;
5. number of the channels following RAINFLO procedures; and
6. combine order-branch-channel information for each stream reach into a five-digit topological(NTOPO) number.

All stream reaches with Ø1 as the last two digits of the NTOPO number are upland stream reaches, and consequently, accept upland subwatershed hydrograph inflow. Number all upland subwatersheds sequentially, in order of increasing upland stream reach NTOPO number, from 1 to number of upland watersheds.

In RAINFLO, confluence is the location where two stream reaches meet and join their flows. Multiple confluences can be configured in RAINFLO by using null reaches.

Rainflo stream reaches can be sub-divided in many as maximum number of subreaches per stream reach to account for cross-sectional nonuniformity. Within which stream reach, one subreach at most can be considered a reservoir subreach, and therefore, subject to reservoir routing.

2.2.Ø Subwatershed Hydrograph Generation

The subwatershed unit hydrograph calculation is based on current SCS practice. For watershed areas equal to or less than 6.2 square miles, the lag is estimated by the curve number method, provided the input (AMC 2.Ø) runoff curve number is within the range 5Ø-95. Otherwise, the lag is estimated as a percentage of the time of concentration. The latter is calculated based on the hydraulic length of the subwatershed and an estimation of the average velocity along the hydraulic length.

The duration of the unit hydrograph is estimated as the percentage of the lag. The unit hydrograph time-to-peak is estimated as a multiple of the unit hydrograph duration. The peak flow is calculated based on the subwatershed area and unit hydrograph time-to-peak. Based on peak flow and time-to-peak, the SCS dimensionless unit hydrograph is used to calculate the ordinates of the subwatershed unit hydrograph. The calculated unit hydrograph is convoluted with the effective storm pattern to generate the composite outflow hydrograph at each watershed outlet.

RAINFLO uses established SCS practices for subwatershed hydrograph generation, including the runoff curve number procedure for abstraction of flows, dimensionless storm distribution patterns, and the dimensionless unit hydrograph.

The SCS unit hydrograph is the dimensionless unit hydrograph developed by Victor Mockus in the 1950s. The hydrograph was developed based on the analysis of a large number of natural unit hydrographs from a wide range of catchment sizes and geographic locations. This method has been recognised as the SCS synthetic unit hydrograph and has been applied to mid size catchments throughout the world.

The SCS method uses constant rates of actual time base to time to peak, and also uses a dimensionless hydrograph function to provide a standard unit hydrograph shape.

The following two methods has been used to find out the catchment lag

i) The curve number method

ii) The velocity method.

2.2.1 Curve number method

The curve number method is limited to catchment of areas less than 8 km, but recent evidence suggests that it may be used up to the catchments area 16 square km. The subwatershed unit hydrograph calculation is based on current SCS practice. For watershed areas equal to or less than 6.2 square miles, the lag is estimated by the curve number method, provided the input (AMC 2.Ø) runoff curve number is within the range 5Ø-95.

2.2.2 Velocity Method

In the velocity method, the main stream divided into reaches and the two year flood or the bankfull discharge is to be estimated. It is also suggested for certain cases to use discharges corresponding to 1Ø year frequencies or more. The mean velocity is computed and the reach concentration time. is calculated by using the reach valley length (straight distance). The sum of the concentration time for all reaches is the concentration time for the catchment.

2.3.Ø Stream Channel Routing

The stream channel routing refers to a specific length of stream channel possessing certain translation and storage properties. The hydrograph at the upstream end of the reach is the inflow hydrograph at downstream end is the outflow hydrograph. Lateral contributions consists of point tributary inflow and distributed inflows. The stream channel routing is attributed for the application such as flood flow analysis, flood control design or flood forecasting.

The hydrologic and hydraulic approaches has been recognised in the stream channel routing. The hydraulic stream channel routing is based on the storage concept. Where as in the case of hydraulic stream channel routing is based on the principles of mass and momentum conservation.

The Muskingum-Cunge method is an alternative approach to hydraulic and hydrologic routing has emerged in recent years. The approach is similar in nature to the hydrologic routing method, yet contains sufficient physical information to compare favorably with the more complex hydraulic routing techniques.

The Muskingum-Cung method has been adopted for the stream channel flow routing mode in the RAINFLO. model.

The Muskingum-Cunge method is a physically based alternative to the Muskingum method. In this method the parameters are calculated based on flow and channel characteristics. It also limited to diffusion waves and is based on a single value rating and does not take into account strong flow non uniformity or unsteady flows exhibiting substantial loops in discharge stage rating. The Muskingum Cunge method is Kinematic in nature with a parameters being based on values evaluated at channel cross-sections rather than being reach averages. The Muskingum Cunge method has been calibrated using physical characteristics such as rating curve, cross sectional data, and channel slope.

2.4.Ø Reservoir Routing

The RAINFLO reservoir routing model is based on the storage-indication technique. The system accepts sets of elevation - storage outflow values for each reservoir channel exponent and uses the information together with starting reservoir elevation, to calculate the outflow hydrograph for the reservoir subreach.

The storage indication method of routing a hydrograph through a reservoir is also called the modified Plus method. A flood wave passing through a storage reservoir is both delayed and attenuated as it enters and spreads over the pool surface. Water stored in the reservoir is gradually released through turbines outlet works called principal spillways or in extreme floods over an emergency spillway. Flow over an ungated emergency spillway weir section or flow through a free outlet discharge pipe or some other may be estimated using proper flow equations. Storage value for various pool elevation in a reservoir are readily determined from computations of volume confined between various pool areas measured from topographic maps. Since storage and outflow both depend only on pool elevation, the resulting storage-elevation curve and the out flow and outflow-elevation relationship can be easily combined to for a storage outflow graph.

3.Ø APPLICATION OF THE MODEL ON MALAPRABHA CATCHMENT UPSTREAM OF KHANAPUR

3.1.Ø Introduction

The RAINFLO model has been tested as an initial application to the Malaprabha basin upstream of Khanapur (as shown in the figure 1.Ø) with locally derived data. This basin was selected because of its proximity. The field visits were made to the Malaprabha catchment for on sites assessed and gathering of preliminary data. The field visits and subsequent work in the office enabled to develop a RAINFLO input file suited to the Malaprabha basin upstream of Khanapur. The following data were collected and assembled in suitable form for computer utilisation.

1. Precipitation
2. Runoff curve no based on hydrologic soil type land use and treatment and hydrologic runoff condition.
3. Typical stream cross-sections,
4. Mannings 'n' for stream reaches
5. Discharge hydrograph at Khanapur.

The Malaprabha basin upstream of Khanapur was described into 2Ø catchments and 13 stream reaches and set of RAINFLO topological numbers developed. In turn, the 13 reaches were subdivided into several subreaches upto subreaches in the input files and a maximum of 2Ø subreaches internally generated by the model as shown in the figure 2.Ø,.

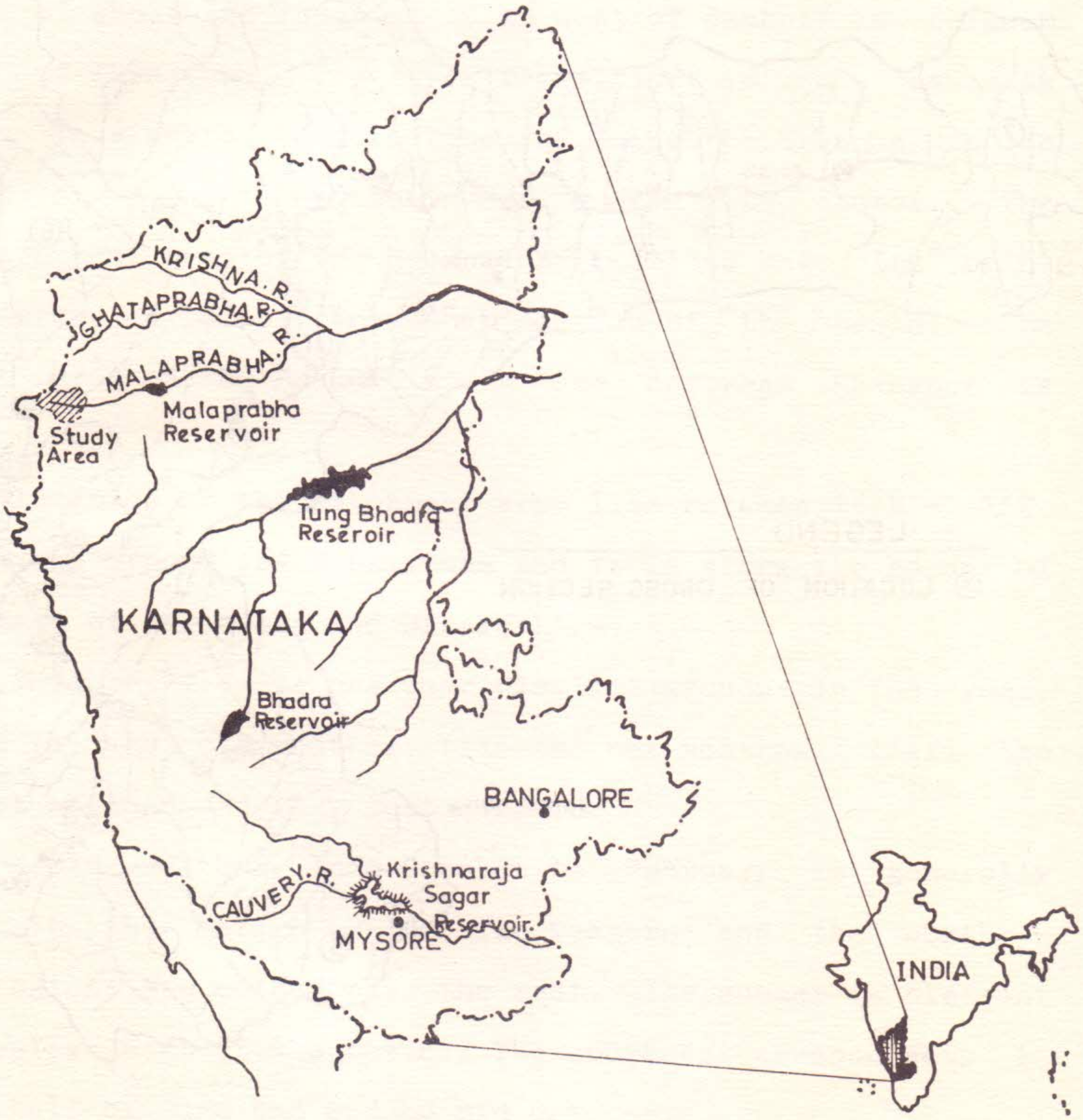


FIG.1. LOCATION MAP OF MALAPRABHA BASIN.

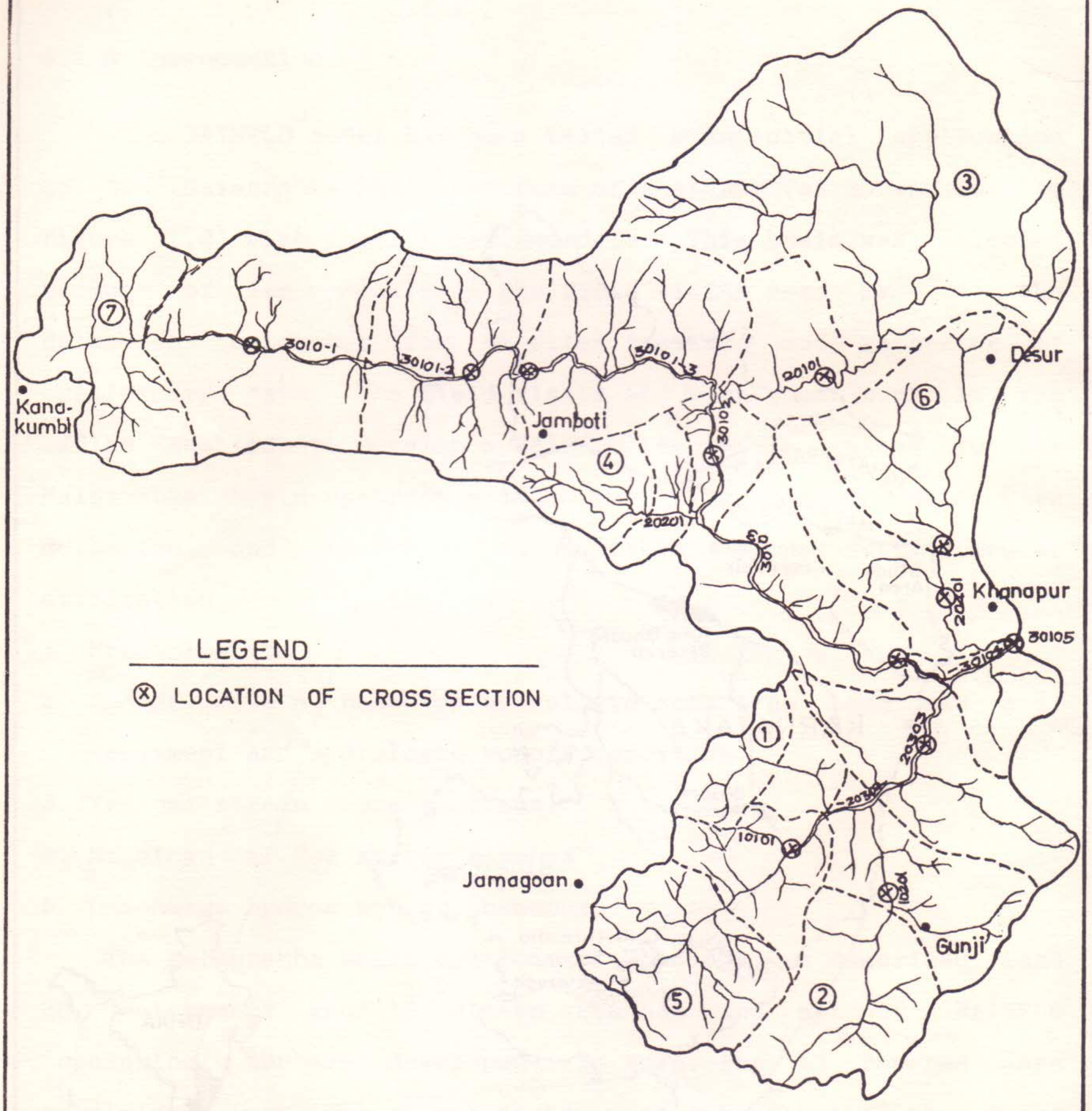


FIG. 2. MAP SHOWING UPLAND, REACHES, SUB-REACHES AND LOCATION OF CROSS SECTIONS.

3.2.0 Description of the Study area

The Malaprabha basin upstream of Khanapur located in the Western Ghats and sub-basin of Krishna river as shown in the fig:1

The Malaprabha rises at Kanakumbi in the western ghats at an altitude of about 793 in about 16 km west of Jamboti in Belgaum district of Karnataka. The river flows first in on easterly and then in a north direction and joins the Krishna at an elevation of about 488 m about 300 kms from its source. The total catchment area of the Malaprabha is 11549 km^2. Its principal source of supply from Ghat section of the basin. The catchment area of the Present study are upstream Khanapur is 520 km^2.

The location of the catchment area lies between 74°E - 75E Longitude and around 16° N Latitude and it is along the border of the states of Karnataka and Maharashtra.

The Malaprabha basin has four distinct seasons in the year. They are (1) the cold weather, (ii) the not weather, (iii) the south west monsoon and (iv) post monsoon.

The cold weather from October to February is generally pleasant in the entire basin. The western and the north-eastern regions are colder than the rest. The summer is pleasant in the western part of the basin. The southwest monsoon sets in by first half of June and end by mid October.

The red, black, and Laterite soils are the principal soils found in the study area.

3.3.Ø Modelling of the Catchment

3.3.1 Topology

The total basin area is sub divided into upland and reach watershed units. To the extent possible, the watershed units should be of the same order of magnitude in such a way that non of them should be too big and too small. The malaprabha basin upstream of khanapur was discretised into 2Ø subcatchments and 13 stream reaches as shown in the fig :3.Ø,. A set of RAINFLO topological numbers developed in which five digit number containing information on order-branch-channel. First digit indicates order of the stream, next two digits for the branch and last two digits which indicates the channel.

3.3.2 Landuse

Land use pertains to the watershed cover, including every kind of vegetation, litter and mulch, fallow as well as non-agricultural uses. Twenty subcatchments have been distinguished between cultivated land, grass lands, and wood and forests. For cultivated lands, it has been considered that as fallow, row crop, small grain, closed seed legumes, straight row fields, contoured fields, and terraced fields.

The Malaprabha basin upstream of Khanapur was sub-divided into 2Ø sub-catchments. Those sub-catchments were visited and classified into forest, agriculture, fallow and barren land. The percentage of respective classifications is identified and accordingly curve number has been selected.

3.3.3 Soils

All soils are classified into four hydrologic soil groups of

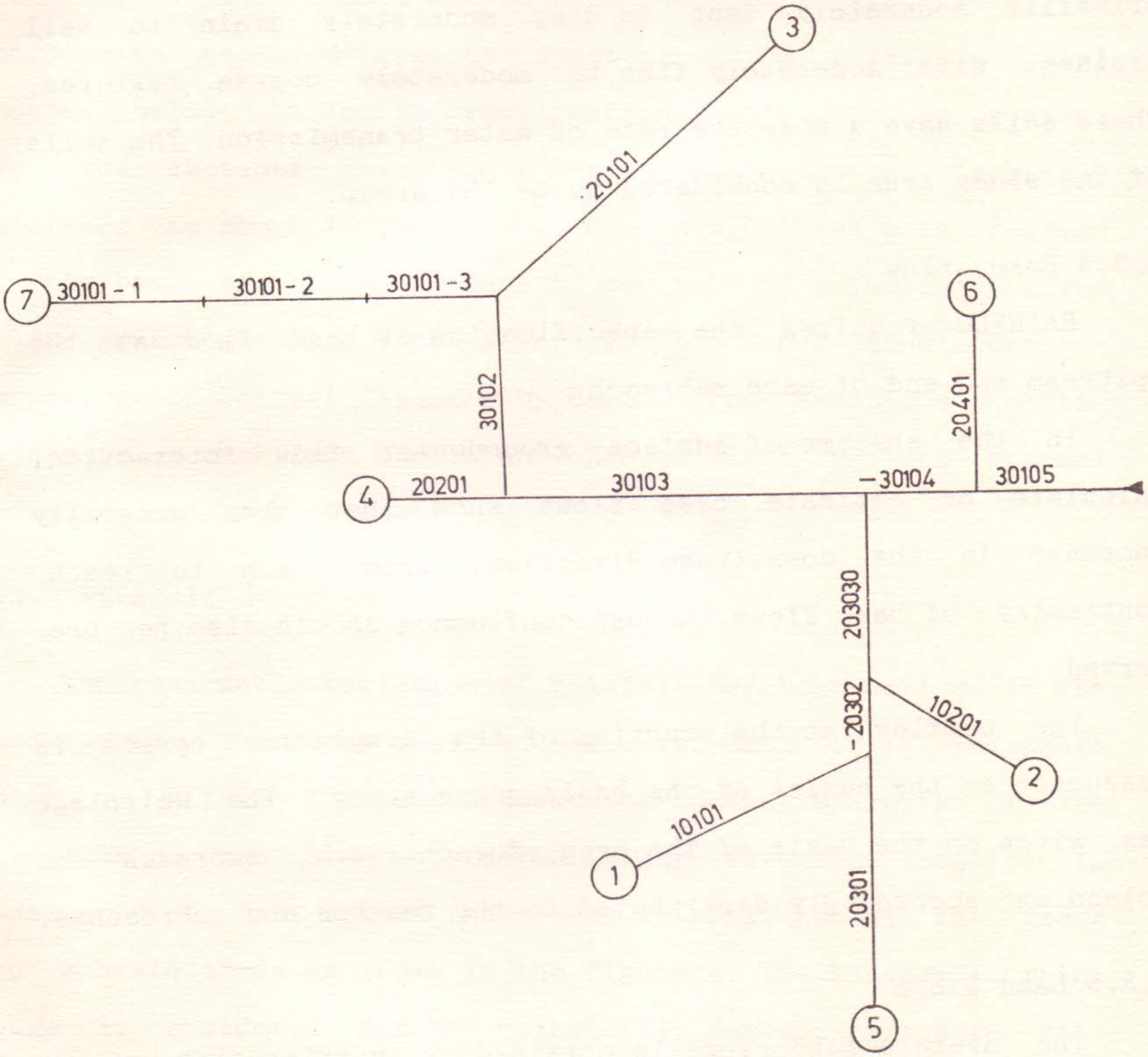


FIG. 3. NET WORK TOPOLOGY OF MALAPRABHA BASIN UPSTREAM OF KHANAPUR.

distinct runoff producing properties. These soil groups are labeled as A, B, C, and D. After the survey, the red loamy soils distributed in the study area. The red loamy which is of soil with moderate infiltration rates when wetted thoroughly, primarily moderately deep to deep, moderately drain to well drained, with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission. The soils of the study area is considered to be 'B' group.

3.3.4 Base Flow

RAINFLO requires the specification of base flow at the upstream and end of each subreach.

In the absence of surface- groundwater flow interaction, calculate or estimate base flows such that they generally increase in the downstream direction, from reach to reach. Continuity of base flows through confluence should also be preserved.

The outflow at the starting of the simulation period is measured at the outlet of the basin under study. The weightage was given on the basis of the area of each reach, subreach and upland and accordingly distributed to the reaches and subreaches.

3.3.5 Land Slope

The average land slope is obtained by superimposing square grid pattern over the catchment topographic map, evaluating the maximum land slope at each grid intersection within the catchment and averaging these values to obtain a representative value of the catchment land slope.

3.3.6 Cross-Sections

Cross-sectional data of X-Z coordinates has been measured. X-coordinates measured from a reference point located to the left of the left most cross-sectional point(looking downstream) and X-coordinate value should not be less than the previous one. Z-coordinates measured upwards starting at a reference point located below the lowest cross-sectional point. On an average two cross-sections have been taken in each reach and subreach watershed as shown in the fig: 2. Mannings 'n' has been derived on the basis of channel surface by the help of guidelines given by the Hydrologic Hand Book of Ven .T. Chow and Roughness Characteristics of Natural Channels by Barns. Three Manning's coefficients taken each from the inbank channel, left overbank channel and right overbank channel.

3.3.7 Rainfall

The remarkable variation of rainfall has been noticed in the study area. Therefore measured point rainfall of a raingauge which is within the subcatchment or in the vicinity of the subcatchment has been considered. Eight raingauge station is considered to take actual (measured) rainfall amounts for reach and subwatersheds as shown in the figure:4. The Kanakumbi raingauge is considered for the upland (7). Jamboti raingauge station is applied for three subwatersheds of reach 30101, upland (4), reach 20201and reach 30102. Desur has been considered for upland(3) and upland(6). Shanthibasthavad for the reach watershed 20101. Asoga for the reaches 30103, 20303, 30105, and upland(1). Khanapur raingauge station for reach watershed 30105 and 20401.

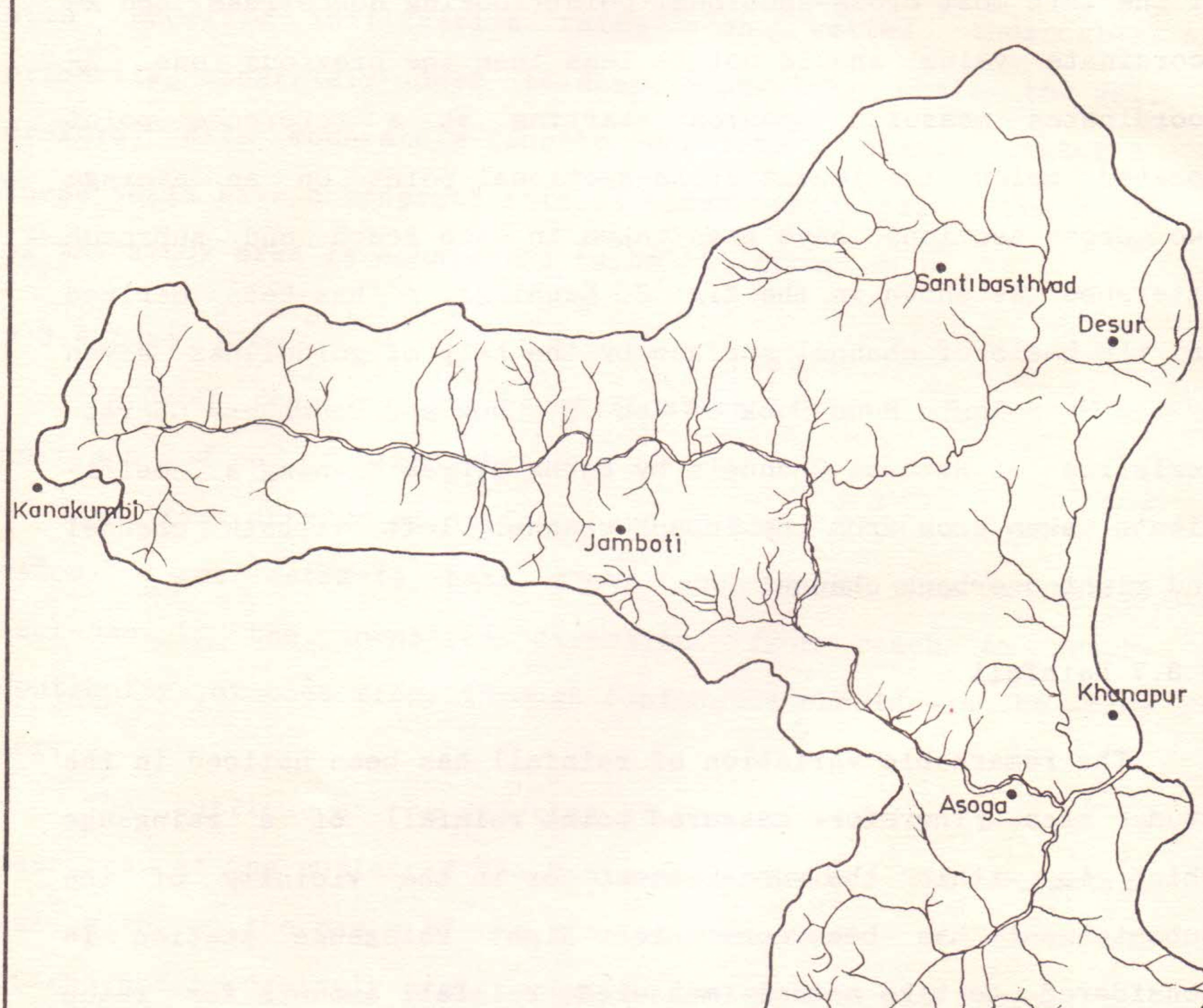


FIG. 4. LOCATION OF RAINGAUGE STATION WITH DRAINAGE SYSTEM.

Gunji raingauge is considered for the upland(2) reach watershed 10201 and 20301. Jamgaon has been considered for the upland(5).

3.3.8 Average Velocity Along Hydraulic Length

The average velocity is normally based on the bankfull flood plains where the depth of overbank flow may be 10 to 20 feet during a major flood event, it may be desirable to use correspondingly higher velocities for frequencies up to 100 years.

Either average velocity along hydraulic length or average land slope is used to calculate the subwatershed lag. Therefore, you can choose not to specify both velocity and slope. However, it has to be chosen this option, one must include a zero value in place of that not being used in the computation of the lag. For example, if the subwatershed area is 10 square miles, the average velocity method will be used; therefore, the average land slope should be specified as zero. The average velocity has been identified on the basis of bankfull discharge at a particular section in the specified upland.

4.0 RESULTS AND DISCUSSIONS

The rainflow model has been applied to simulate two high flow months in river Malaprabha which are in the month of August 1989 and July 1990. Nine test runs have been carried out to draw some conclusions especially to find the sensitiveness of the variable parameters which are incorporated in the model and to compare the output of the flow series by the model with the observed flow series in the river. In each test run, set of parameter values such as SCS curve number coefficient, slope, velocity, curve numbers, and Manning's 'n' have been selected.

Results:

Test Run One:

Year: 1989 Month: August

SCS CN Coefficient	: 0.2
Slope	: 10.3, 16.8
Velocity	: 0.5, 0.5, 0.3, 0.65, 0.5
Curve Number	: 74, 72, 73, 77, 75, 72, 78, 63, 74, 74, 75,- 73, 75, 66, 76, 71, 73, 71.
Manning's 'n'	: Initial(lower)

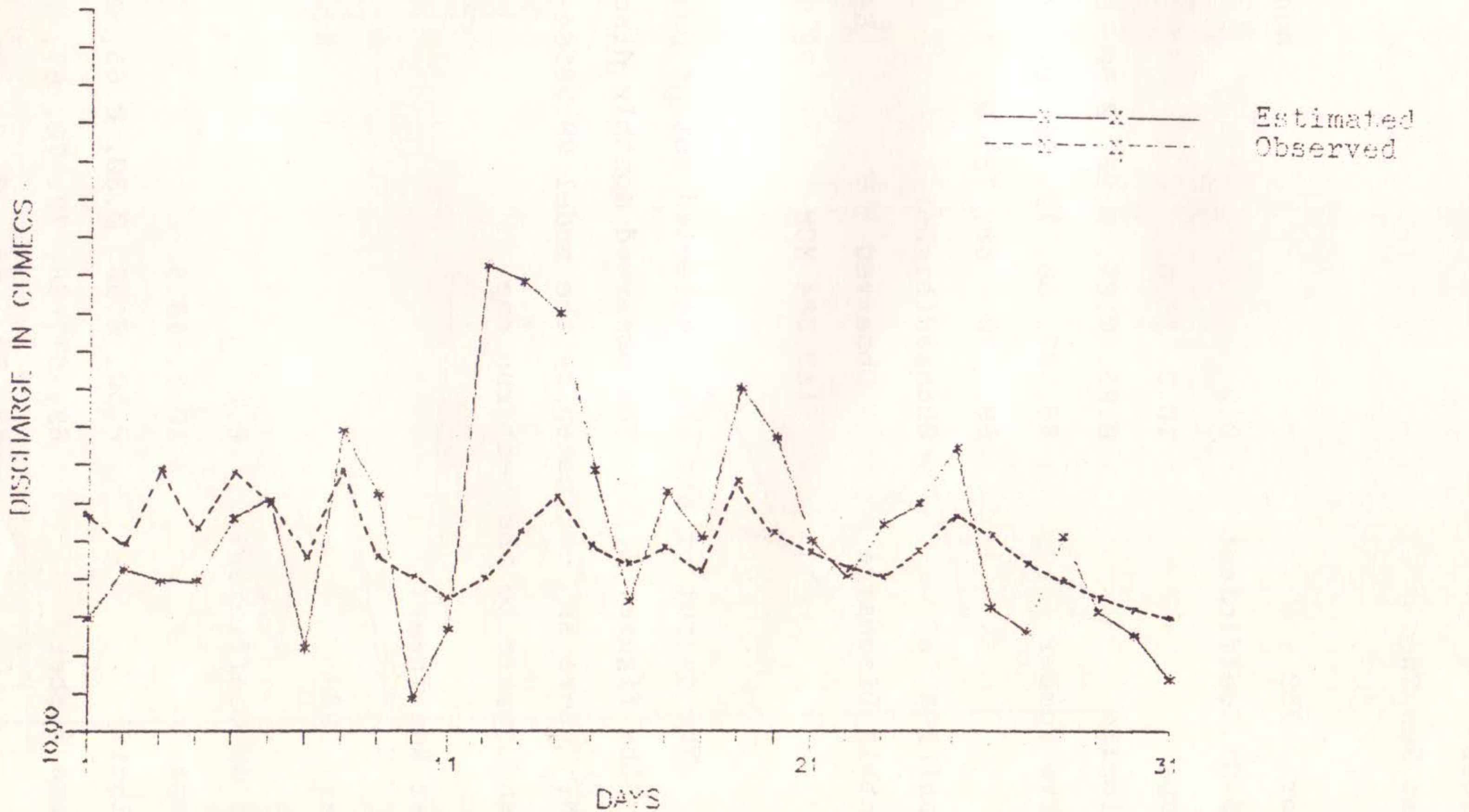
Monthly Discharge	Observed	Estimated
	159.0624 MCM	113.66388 MCM

As presented in the fig:5(i), the observed monthly discharge is 159.0624 MCM where as estimated discharge is 113.66388 MCM. The peaks observed and estimated hydrograph nearly follow the same trend. However higher magnitude of discharge is largely

FIGURE -5(a): DAILY HYDROGRAPH AT KHANAPUR

Year: 1989 Month: August

Monthly Discharge Observed 159.8824 MCM Estimated 113.66388 MCM



deviated and high peaks always higher in the case of simulated values.

Test Run Two:

Year: 1989		Month: August
SCS CN Coefficient	: Ø.2	
Slope	: 1Ø.3, 16.8,	
Velocity	: Ø.25, Ø.25, Ø.2Ø, Ø.5Ø, Ø.25	
Curve Number	: 69, 67, 68, 72, 7Ø, 67, 73, 58, 69, 69, 7Ø - 68, 7Ø, 61, 71, 66, 68, 66	
Manning's 'n'	: Changed(higher)	
Monthly Discharge	: Observed	Estimated
	159.Ø64 MCM	99.98564 MCM

The output of the above selected set of parameters as shown in the figure: 5(ii). The observed monthly discharge is 159.Ø64 MCM, where as estimated by the model 99.98564 MCM it is less, when compare to the test run one.

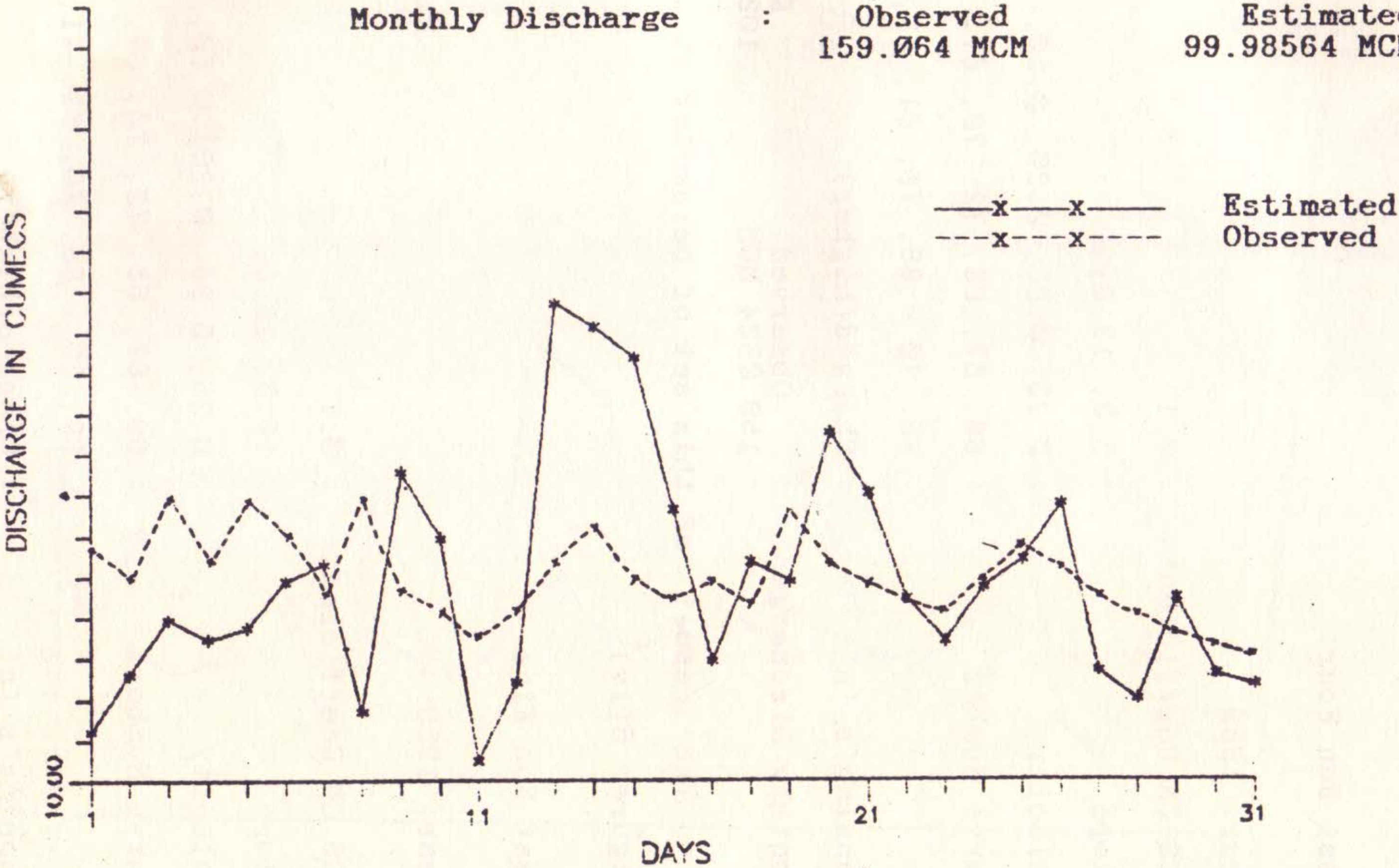
Test Run Three:

Year: 1989		Month: August
SCS CN Coefficient	: Ø.2	
Slope	: 1Ø.3, 16.8,	
Velocity	: Ø.5Ø, Ø.5Ø, Ø.3Ø, Ø.65, Ø.5Ø	
Curve Number	: 69, 67, 68, 72, 7Ø, 67, 73, 58, 69, 69, 7Ø - 68, 7Ø, 61, 71, 66, 68, 66	
Manning's 'n'	: Changed(higher)	

FIGURE - 5(b): DAILY HYDROGRAPH AT KHANAPUR

Year: 1989 Month: August

Monthly Discharge : Observed 159.064 MCM Estimated 99.98564 MCM



Monthly Discharge : Observed Estimated

159.Ø64 MCM 1ØØ.55355 MCM

As we can see from the figure: 5(iii), ordinates of the hydrograph almost have the same magnitude when compare to the other test run. However, there is variation in the discharge.

Test Run Four:

Year: 1989 Month: August

SCS CN Coefficient : Ø.1

Slope : 8.3, 13.3,

Velocity : Ø.25, Ø.25, Ø.2Ø, Ø.5Ø, Ø.25

Curve Number : 69, 67, 68, 72, 7Ø, 67, 73, 58, 69,

69, 7Ø - 68, 7Ø, 61, 71, 66, 68, 66

Manning's 'n' : Changed(higher)

Monthly Discharge : Observed Estimated

159.Ø624 MCM 1Ø2.77783 MCM

The result of this set of parameter is presented in the figure: 5(iv).

Test Run Five:

Year: 1989 Month: August

SCS CN Coefficient : Ø.1

Slope : 1Ø.3, 16.8,

Velocity : Ø.25, Ø.25, Ø.2Ø, Ø.5Ø, Ø.25

Curve Number : 69, 67, 68, 72, 7Ø, 67, 73, 58, 69,

69, 7Ø - 68, 7Ø, 61, 71, 66, 68, 66

Manning's 'n' : Changed(higher)

Monthly Discharge : Observed Estimated

FIGURE -5(c): DAILY HYDROGRAPH AT KHANAPUR

Year: 1989 Month: August

Monthly Discharge : Observed 159.064 MCM Estimated 100.55355 MCM

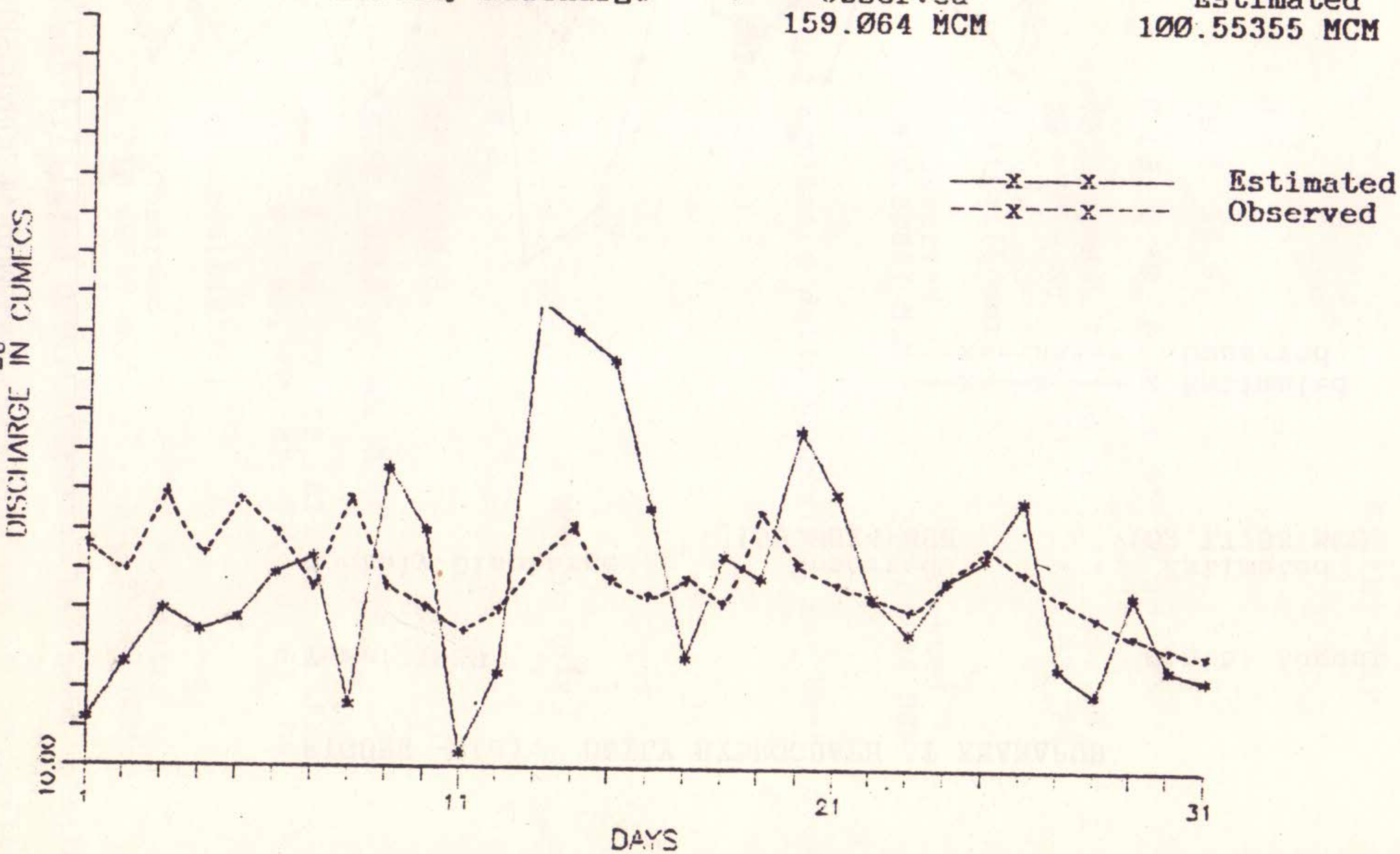
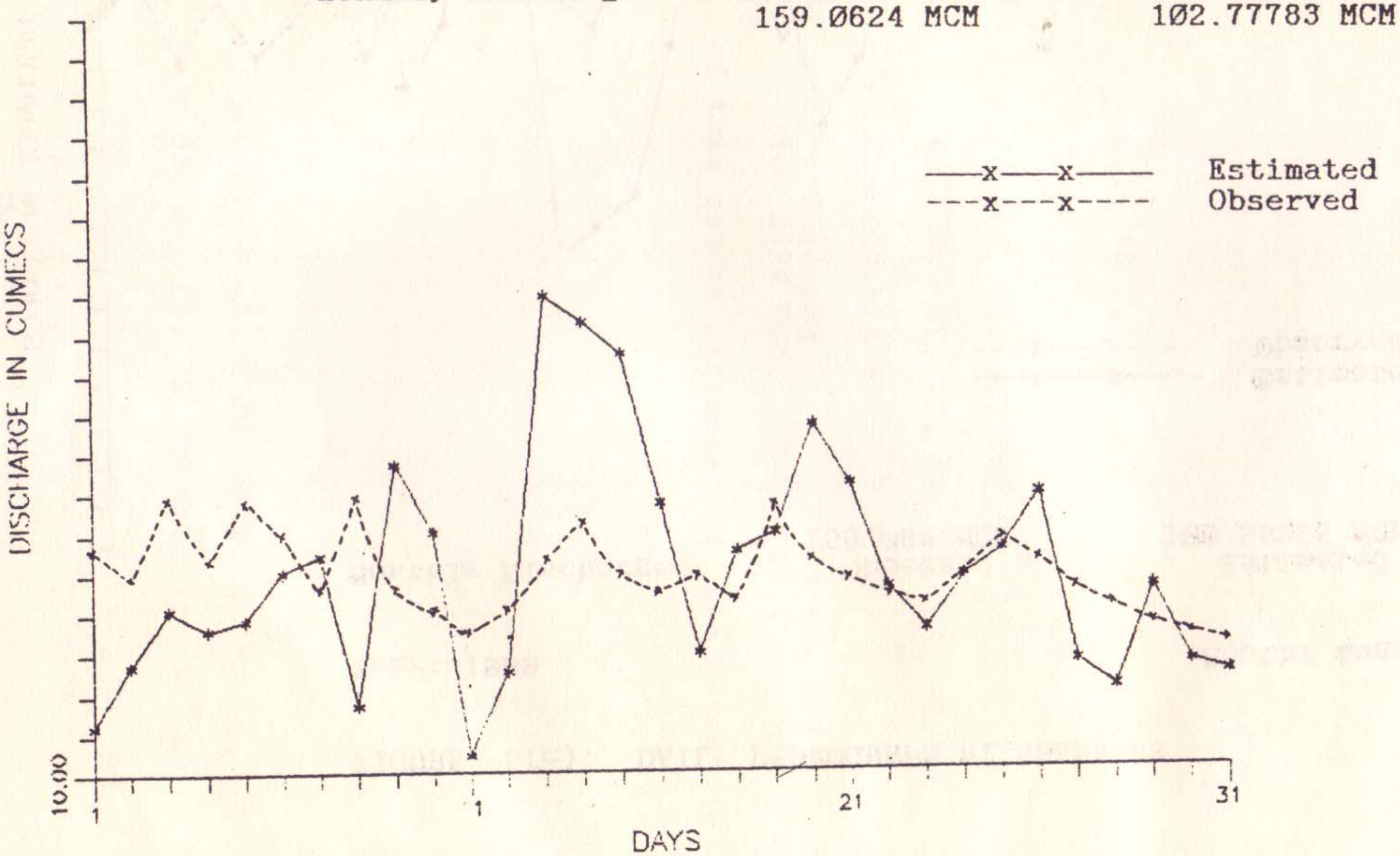


FIGURE -5(d): DAILY HYDROGRAPH AT KHANAPUR

Year: 1989 Month: August

Monthly Discharge	Observed	Estimated
	159.0624 MCM	102.77783 MCM



159.0624 MCM 102.77405 MCM

The simulated and observed values are presented in the figure: 5(v).

Test Run Six:

Year: 1990 Month: July

SCS CN Coefficient	: 0.2
Slope	: 10.3, 16.8,
Velocity	: 0.50, 0.50, 0.30, 0.65, 0.50
Curve Number	: 70, 67, 68, 72, 70, 67, 73, 58, 69, 69, 70 - 68, 70, 61, 71, 66, 68, 66
Manning's 'n'	: Initial(Lower)
Monthly Discharge	: Observed 310.60627 MCM — Estimated 346.05994 MCM

The observed and estimated daily hydrograph has been drawn as shown in the figure: 5(vi).

Test Run Seven:

Year: 1990 Month: July

SCS CN Coefficient	: 0.2
Slope	: 10.3, 16.8,
Velocity	: 0.50, 0.50, 0.30, 0.65, 0.50
Curve Number	: 70, 67, 68, 72, 70, 67, 73, 60, 69, 69, 70 - 68, 70, 61, 71, 66, 68, 66
Manning's 'n'	: Changed(higher)
Monthly Discharge	: Observed 310.60627 MCM — Estimated 345.89709 MCM

The observed and simulated daily discharge has been plotted as shown in the figure: 5(vii) using the above set of parameters

FIGURE -6(e): DAILY HYDROGRAPH AT KHANAPUR

Year: 1989 Month: Agust

Monthly Discharge : Observed 159.0624 MCM Estimated 102.77405 MCM

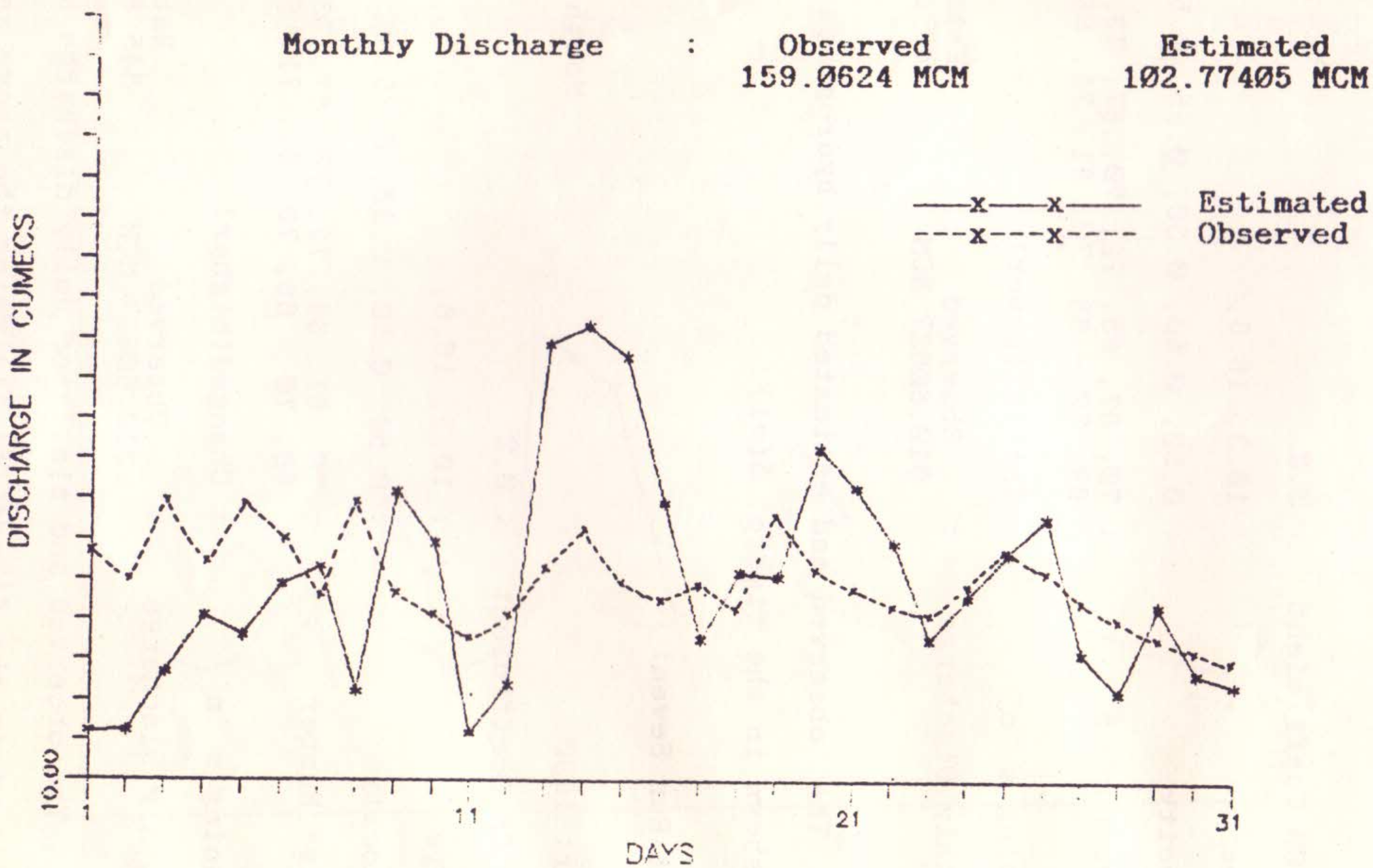


FIGURE -5(f): DAILY HYDROGRAPH AT KHANAPUR

Year: 1990 Month: July

Monthly Discharge	Observed	Estimated
	310.60627 MCM	346.05994 MCM

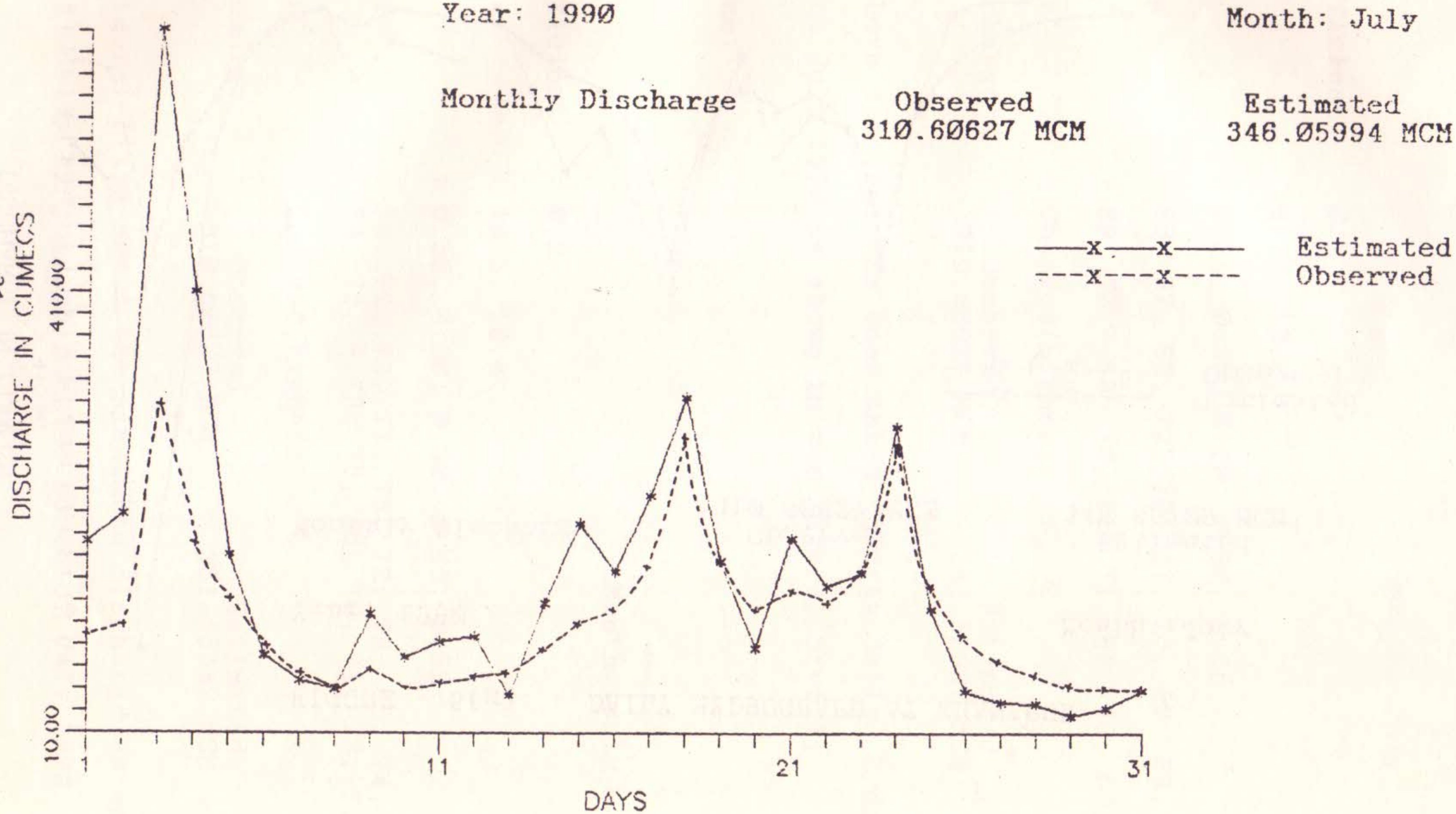
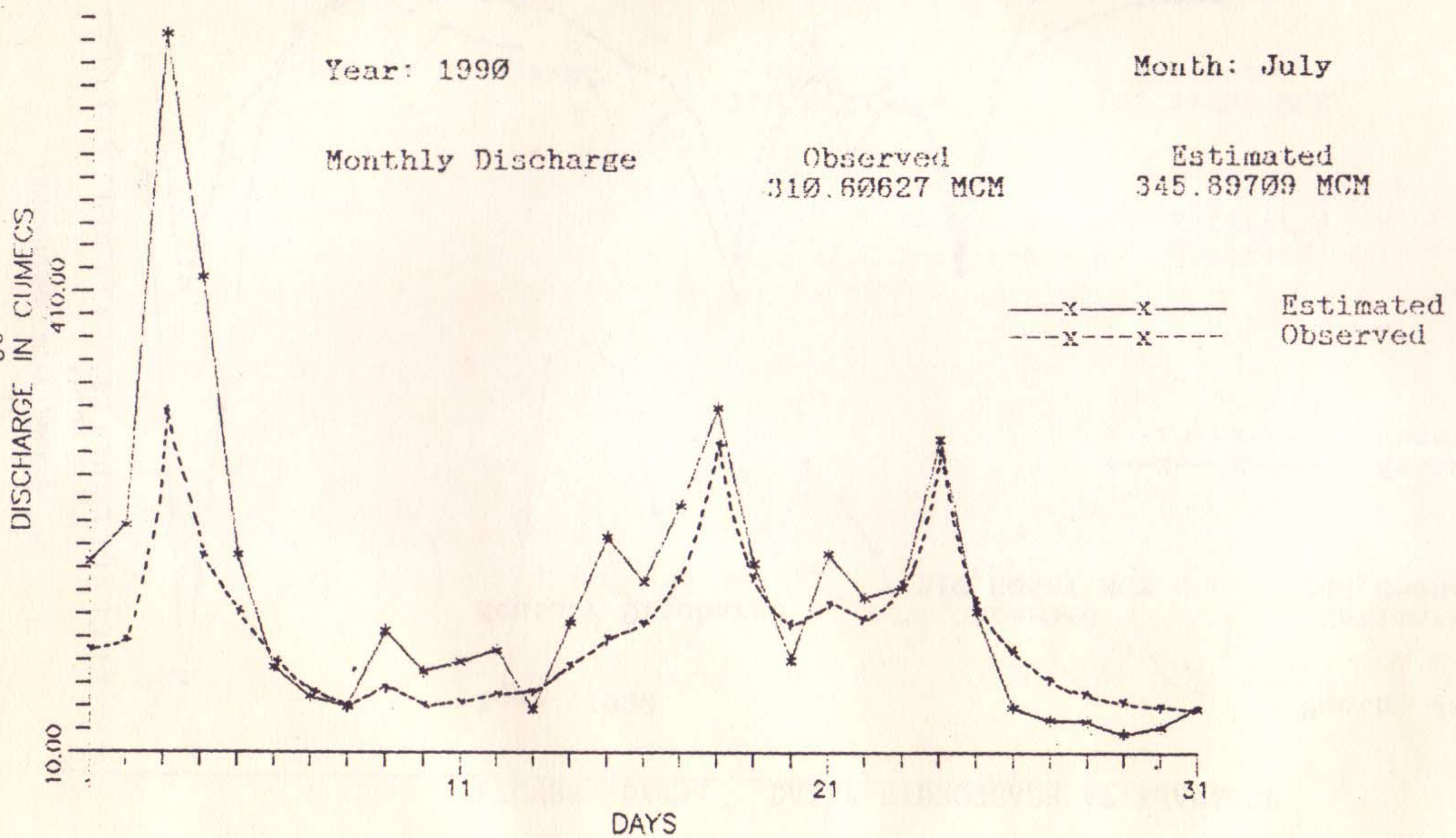


FIGURE - 5(g): DAILY HYDROGRAPH AT KHANAPUR

Year: 1990 Month: July

Monthly Discharge	Observed	Estimated
	310.60627 MCM	345.89709 MCM



in the RAINFLO model.

Test Run Eight:

Year: 1990		Month: July
SCS CN Coefficient	: 0.1	
Slope	: 8.30, 13.8,	
Velocity	: 0.25, 0.25, 0.20, 0.50, 0.25	
Curve Number	: 69, 67, 68, 72, 70, 67, 73, 58, 69, 69, 70 - 68, 70, 61, 71, 66, 68, 66	
Manning's 'n'	: Changed(higher)	
Monthly Discharge	: Observed 310.60627 MCM	Estimated 343.53997 MCM

The above data set has been taken to draw daily hydrograph for the month July 1990 as shown in the figure: 5(viii).

Test Run Nine:

Year: 1990		Month: July
SCS CN Coefficient	: 0.2	
Slope	: 10.3, 16.8,	
Velocity	: 0.50, 0.50, 0.30, 0.65, 0.50	
Curve Number	: 74, 72, 73, 77, 75, 72, 78, 63, 74, 74, 73, - 73, 75, 66, 76, 71, 73, 71	
Manning's 'n'	: Changed(higher)	
Monthly Discharge	: Observed 310.60627 MCM	Estimated 351.26442 MCM

The figure: 5(ix) shows the simulated discharge as well as the observed daily hydrograph for the month of July 1990.

FIGURE - 5(h): DAILY HYDROGRAPH AT KHANAPUR

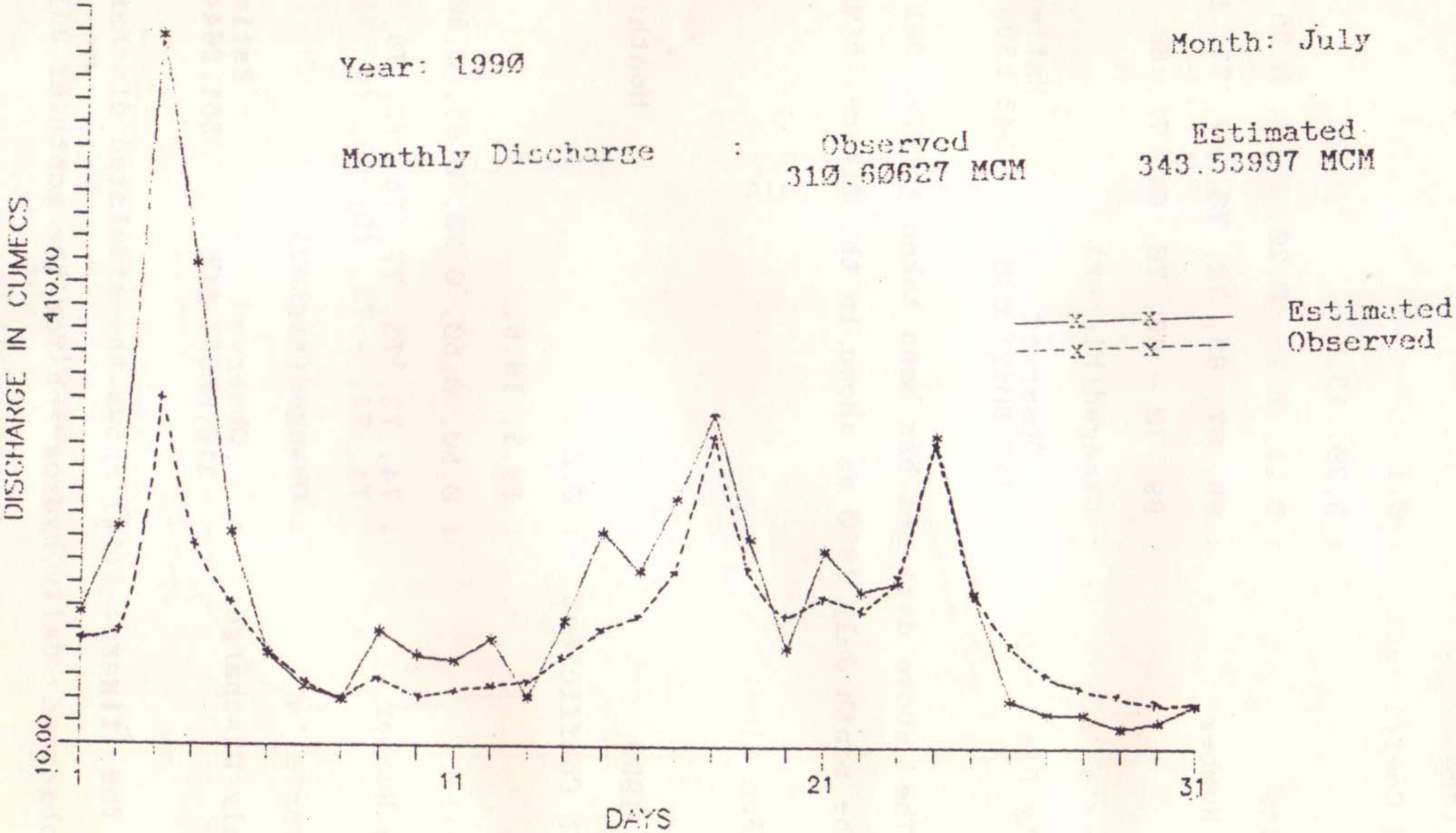
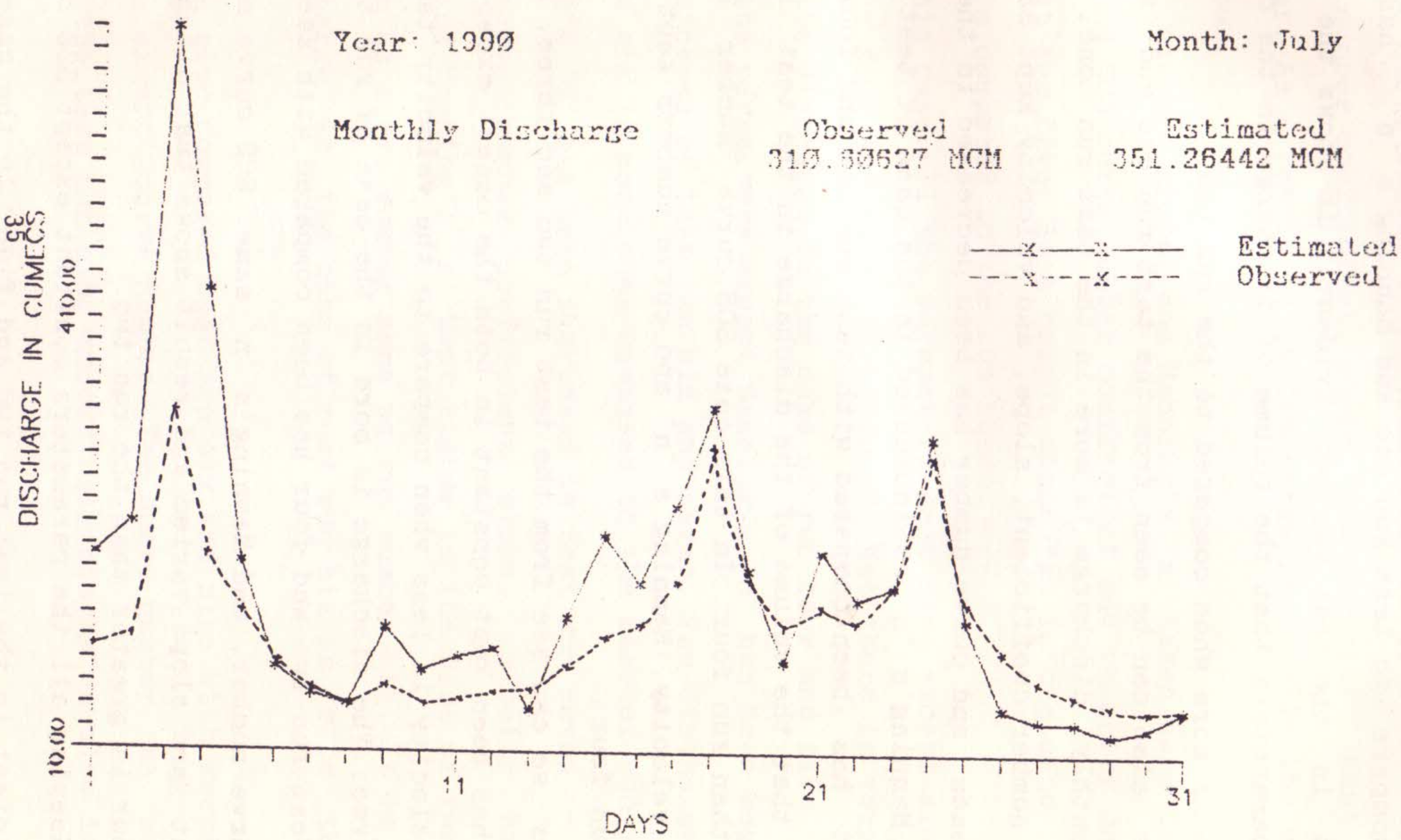


FIGURE - 5(i): DAILY HYDROGRAPH AT KHANAPUR



Discussions:

In the case of test run one and two, slope of the upland, SCS curve number coefficient has been kept constant with each other. Velocity and curve numbers of the test run two kept low when compare to test run one and Manning's 'n' has been increased in the test run two. Evidently it shows the effect of these parameters that the volume of discharge in the case of test run one is more when compared to the run two.

It also can be seen from the test run one and three that, the monthly discharge is more in the test run one. Where SCS curve number coefficient, slope, and velocity kept same in both the cases and curve number has been decreased in the test run three. Manning's 'n' is increased in the case of test run three.

It has been compared with test run one and four and also noted that the volume of the discharge in the test run one is more than run four. In this case SCS curve number coefficient, slope, velocity, Manning's 'n' and curve numbers kept low in the test run four.

As we can see from the test run two and three, all parameters has been kept constant in both the cases except velocity. The velocity is less when compare to the velocity taken in test run three. The discharge is more in the case of run three.

Test run two and four has been compared with keeping velocity, curve number, and Manning's 'n' same. SCS curve number coefficient and slope varied and result shows that discharge in the run four is greater than the run two.

Keeping all the parameters constant except SCS curve number coefficient in the test run two and five. In the case of run five

SCS curve number coefficient is decreased conversely discharge is more.

It is also compared run three and with test run four by keeping SCS curve number coefficient same in both the cases and SCS curve number coefficient, slope, and velocity kept low in the run four. As a result of it discharge is more in the case of test run four.

Curve number, slope, and Manning's 'n' taken same for both the cases and SCS curve number coefficient and velocity decreased in the test run five. As a output discharge in the case of run five is more compared to the run three.

In this case all the parameters kept same except slope for the test run four and five. It is found that there is very little change in the discharge in the case of run four and five.

All the parameters except Manning's 'n' has been kept same in both the cases of test run six and seven. The discharge in the case of run six is more when compared to the case of run seven as the Manning's 'n' has been increased in test run seven.

SCS curve number coefficient, slope, velocity has been decreased and Manning's 'n' kept higher in the case of run number eight where as curve number same as run number six. It is noticed that discharge in the case of test run six is more than run eight.

It is also compared test run six and nine with keeping all parameters except curve number. The curve number has been increased in the test run nine accordingly discharge also increased remarkably.

SCS curve number coefficient, slope, velocity has been decreased and Manning's 'n' increased in the case of test run eight. Curve number kept same for both the run seven and eight. As a result we got more discharge in the case of test run seven.

In an another comparison between test run seven and nine, all the parameters taken same in both the cases and curve number has been increased in the case of test run nine. It is noticed that discharge in the case of test run nine is more than test run seven.

It is also compared between test run eight and nine and all the parameters value has been increased in the case of test run nine. The discharge from run nine is more when compared to the run eight.

Conclusions:

The above discussions shows that, apart from the rainfall, parameters such as SCS curve number coefficient, slope, velocity, curve number, and Manning's 'n' has its role in the discharge. It is more clear and evident that curve number is more sensitive than any other parameters as we can see from all the test runs. It is also noticed that from the run three, four and five initial abstraction has edge over velocity. When compared with the run two and five initial abstraction is only the parameter for change in discharge, which is high in the case of test run number five. From the basis of the run two, three, four and five slope and velocity has very little effect in the RAINFLO model.

In the test run six and seven only Manning's 'n' has been changed and increased in the case of test run seven. It is also observed that discharge is less in the case of test run seven.

Hence Manning's 'n' is sensitive in the model.

As we observed from the simulated and observed ordinates of hydrograph and monthly discharge values, there is some magnitude of variation. It is mainly depends on how closely we modeled the natural system or catchment. At last we can conclude as follows;

The cross-sections of the channel are representative to the reach under consideration one and it need not be same throughout reach.

SCS dimensionless unit hydrograph has been used calculate ordinates of the subwatershed unit hydrograph which is developed in United States of America. It may not be true for Indian conditions. It is better to develop dimensionless unit hydrograph for Indian condition.

Uneven distribution of rainfall in space and time may have its own effect in attaining the peaks of observed with simulated values.

The selection of curve number, moisture conditions, base flow and initial abstraction coefficient should be very close to the natural system otherwise it may give unreliable simulated values.

In contrast, the values of ordinates of monthly hydrograph of observed and estimated using the model for the month of August 1989 and July 1990, July values are very close to the observed values as represented in the figures: 5(f) to (i). The following is the best suited set of parameters for the month of July.

SCS CN Coefficient : 0.1

Slope : 8.30, 13.8,

Velocity : 0.25, 0.25, 0.20, 0.50. 0.25

Hence Manning's 'n' is sensitive in the model.

As we observed from the simulated and observed ordinates of hydrograph and monthly discharge values, there is some magnitude of variation. It is mainly depends on how closely we modeled the natural system or catchment. At last we can conclude as follows;

The cross-sections of the channel are representative to the reach under consideration one and it need not be same throughout reach.

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Uneven distribution of rainfall in space and time may have its own effect in attaining the peaks of observed with simulated values.

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SCS CN Coefficient : 0.1

Slope : 8.30, 13.8,

Velocity : 0.25, 0.25, 0.20, 0.50. 0.25

Curve Number	:	69, 67, 68, 72, 70, 67, 73, 58, 69, 69, 70 - 68, 70, 61, 71, 66, 68, 66	
Manning's 'n'	:	Changed(higher)	
Monthly Discharge	:	Observed 310.60627 MCM	Estimated 343.53997 MCM

It is suggested that most reliable and close resultsmay be obtained taking finer cross-sections of channel reach, and by observing hourly rainfall values. The possibility of missing of peak flood values are quite common while taking the observation as genarally take reading at fixed times (once or twice in a day). Hence continuous recording of discharge data are not available. Therefore automatic stage recorder is advisable in this regard.

The output of the model when compared with the observed values are within the tolerance limit and the errors are found to be around 10%.

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APPENDIX

SAMPLE INPUT DATA FILE

```
'RØ2' 'NIH/BELGAUM REGIONAL CENTRE, MALAPRABHA BASIN, U/S OF KHANAPUR'
'RØ4' 'TEST RUN NO. 26, 13 JAN92, 31 DAYS(AUG1989), 1Ø:5Ø'
'R1Ø' Ø  -2  1  1Ø  Ø  Ø  Ø  Ø  1  1  1  Ø  1  13  744  744. 3ØØØ.
'R2Ø' Ø1  1Ø1Ø1 1
'R3Ø' Ø.66  2ØØØ.  Ø.ØØ25  Ø.Ø  6  Ø.Ø9  Ø.Ø7  Ø.Ø9  1ØØ.Ø  116.5
'R34' 5Ø.Ø  1Ø4.Ø  1ØØ.Ø  1ØØ.Ø  1Ø2.5  97.5  113.5  97.5  116.5  1ØØ.5
      15Ø.  1Ø4.Ø
'R4Ø' 69.  624.75  -1.  -1.  Ø.1
'R42' 31
'R44' Ø.38 Ø.4Ø Ø.34 Ø.26 Ø.18 Ø.56 Ø.42 Ø.3Ø Ø.38 Ø.18
      Ø.22 1.Ø2 Ø.5Ø Ø.78 Ø.4Ø Ø.6Ø Ø.66 Ø.72 1.Ø2 1.56
      Ø.76 Ø.24 Ø.62 Ø.78 Ø.62 Ø.26 Ø.94 Ø.76 Ø.16 Ø.36
      Ø.Ø6
'R2Ø' Ø2  1Ø2Ø1 1
'R3Ø' 2.31  45ØØ.  Ø.ØØ33  Ø.Ø  7  Ø.Ø9  Ø.Ø72  Ø.Ø9  1ØØ.Ø  123.5
'R34' 8Ø.Ø  1Ø2.Ø  1ØØ.Ø  1ØØ.Ø  1Ø6.Ø  97.Ø  113.5  96.5  121.Ø  97.Ø
      123.5  99.5  15Ø.Ø  1Ø3.Ø
'R4Ø' 67.  2232.Ø  -1.  -1.  Ø.1
'R42' 31
'R44' Ø.41 Ø.74 Ø.54 Ø.74 1.42 Ø.63 Ø.82 1.73 Ø.71 Ø.ØØ
      Ø.27 1.82 1.87 3.11 1.34 Ø.32 Ø.49 Ø.68 1.71 Ø.41
      Ø.83 1.22 Ø.83 1.84 Ø.85 1.13 Ø.51 1.61 Ø.96 Ø.41
      Ø.23
'R2Ø' Ø3  2Ø1Ø1 1
'R3Ø' 2.Ø2  75ØØ.  Ø.ØØ47  Ø.Ø  8  Ø.Ø9  Ø.Ø73  Ø.Ø9  1ØØ.Ø  126.Ø
'R34' 6Ø.Ø  11Ø.Ø  8Ø.Ø  1ØØ.Ø  1ØØ.Ø  1ØØ.Ø  1Ø2.5  95.Ø  124.5  95.Ø
      126.Ø  98.Ø  176.Ø  98.Ø  19Ø.Ø  1ØØ.Ø
'R4Ø' 68.  1925.Ø  -1.  -1.  Ø.1
'R42' 31
'R44' Ø.45 Ø.45 Ø.38 Ø.68 Ø.66 Ø.36 Ø.76 Ø.35 Ø.Ø5 Ø.2Ø
      1.75 1.4Ø 1.23 Ø.4Ø Ø.25 Ø.7Ø Ø.2Ø 1.6Ø Ø.35 Ø.6Ø
      1.61 Ø.66 Ø.35 2.1Ø Ø.3Ø Ø.Ø4 Ø.26 Ø.25 Ø.15 Ø.1Ø
      Ø.ØØ
'R2Ø' Ø4  2Ø2Ø1 1
'R3Ø' Ø.86  25ØØ.  Ø.ØØ4Ø  Ø.Ø  7  Ø.Ø9  Ø.Ø7  Ø.Ø9  1ØØ.Ø  125.Ø
'R34' 5Ø.Ø  1Ø1.Ø  1ØØ.Ø  1ØØ.Ø  1Ø6.Ø  97.Ø  112.Ø  96.5  118.Ø  97.Ø
      125.Ø  1Ø4.Ø  175.Ø  1Ø5.Ø
'R4Ø' 72.  65Ø.75  -1.  -1.  Ø.1
'R42' 31
'R44' 1.Ø4 1.28 1.34 1.16 1.14 1.2Ø Ø.2Ø 2.7Ø 1.46 Ø.1Ø
      1.Ø6 2.9Ø 2.9Ø 2.12 1.46 Ø.86 1.42 1.34 1.98 1.86
      1.54 Ø.98 Ø.88 1.2Ø 1.49 Ø.4Ø Ø.42 1.14 Ø.68 Ø.68
      Ø.4Ø
'R2Ø' Ø5  2Ø3Ø1 1
'R3Ø' 2.Ø8  6ØØØ.  Ø.ØØ17  Ø.Ø  8  Ø.Ø9  Ø.Ø73  Ø.Ø9  1ØØ.Ø  118.3
'R34' 8Ø.Ø  1Ø2.Ø  1ØØ.Ø  1ØØ.Ø  1Ø3.5  96.5  11Ø.2  96.Ø  116.8  96.5
      118.3  98.Ø  123.3  98.1  13Ø.Ø  1Ø1.Ø
'R4Ø' 7Ø.  2Ø75.Ø  -1.  -1.  Ø.1
'R42' 31
'R44' Ø.41 Ø.74 Ø.54 Ø.74 1.42 Ø.63 Ø.82 1.73 Ø.71 Ø.ØØ
      Ø.27 1.82 1.87 3.11 1.34 Ø.32 Ø.49 Ø.68 1.71 Ø.41
      Ø.83 1.22 Ø.83 1.84 Ø.85 1.13 Ø.51 1.61 Ø.96 Ø.41
      Ø.23
```

```
'R2Ø' Ø6 -2Ø3Ø2 1
'R2Ø' Ø7  2Ø3Ø3 1
'R3Ø' 6.5  7ØØØ.  Ø.ØØ1Ø  Ø.Ø  7  Ø.Ø7  Ø.Ø65  Ø.Ø7  1ØØ.Ø  145.Ø
'R34' 5Ø.Ø  1Ø1.Ø  1ØØ.Ø  1ØØ.Ø  1Ø5.Ø  95.Ø  12Ø.Ø  94.Ø  135.Ø  95.Ø
      145.Ø  1ØØ.Ø  195.Ø  1Ø1.Ø
'R4Ø' 67.  2912.5  -1.  -1.  Ø.1
'R42' 31
'R44' Ø.38 Ø.4Ø Ø.34 Ø.26 Ø.18 Ø.56 Ø.42 Ø.3Ø Ø.38 Ø.18
      Ø.22 1.Ø2 Ø.5Ø Ø.78 Ø.4Ø Ø.6Ø Ø.66 Ø.72 1.Ø2 1.36
      Ø.76 Ø.24 Ø.62 Ø.78 Ø.62 Ø.26 Ø.94 Ø.76 Ø.16 Ø.36
      Ø.Ø6
'R2Ø' Ø8  2Ø4Ø1 1
'R3Ø' 1.96  6ØØØ.  Ø.Ø133  Ø.Ø  7  Ø.Ø7  Ø.Ø6  Ø.Ø7  1ØØ.Ø  118.5
'R34' 5Ø.Ø  1Ø1.Ø  1ØØ.Ø  1ØØ.Ø  1Ø3.Ø  97.Ø  1Ø9.25  96.5Ø  115.5Ø  97.Ø
      118.5  1ØØ.Ø  168.5  1Ø1.Ø
'R4Ø' 73.  17Ø1.5  -1.  -1.  Ø.1
'R42' 31
'R44' Ø.31 Ø.2Ø Ø.13 Ø.2Ø Ø.25 Ø.5Ø Ø.2Ø Ø.45 Ø.3Ø Ø.ØØ
      Ø.24 1.Ø5 1.ØØ 1.Ø7 Ø.25 Ø.55 Ø.9Ø Ø.7Ø 1.17 1.58
      Ø.48 Ø.2Ø Ø.4Ø Ø.55 Ø.84 Ø.23 Ø.24 Ø.9Ø Ø.33 Ø.42
      Ø.2Ø
'R2Ø' Ø9  3Ø1Ø1 3
'R3Ø' 3.15  65ØØ.  Ø.ØØ15  Ø.Ø  8  Ø.Ø9  Ø.Ø7  Ø.Ø9  1ØØ.Ø  125.Ø
'R34'  5Ø.Ø  1Ø4.Ø  1ØØ.Ø  1ØØ.Ø  1Ø3.Ø  97.Ø  1Ø5.5  96.5  1Ø8.Ø  97.Ø
      123.Ø  97.Ø  125.Ø  1Ø1.Ø  175.Ø  1Ø5.Ø
'R3Ø' 5.19  8ØØØ.  Ø.ØØ13  Ø.Ø  8  Ø.Ø9  Ø.Ø72  Ø.Ø9  1ØØ.Ø  143.6
'R34' 93.Ø  1Ø4.Ø  97.Ø  1ØØ.Ø  1ØØ.Ø  1ØØ.Ø  1Ø4.Ø  96.Ø  139.6  96.Ø
      143.6  1ØØ.Ø  146.Ø  1ØØ.Ø  148.Ø  1Ø4.Ø
'R3Ø' 6.97  95ØØ.  Ø.ØØ21  Ø.Ø  7  Ø.Ø9  Ø.Ø75  Ø.Ø9  1ØØ.Ø  15Ø.Ø
'R34' 5Ø.Ø  1Ø2.Ø  1ØØ.Ø  1ØØ.Ø  1Ø5.5  94.5  125.5  92.5  145.5  94.5
      15Ø.Ø  1ØØ.Ø  18Ø.Ø  1Ø1.Ø
'R4Ø' 58.  11Ø86.Ø  -1.  -1.  Ø.1
'R42' 31
'R44' 1.Ø4 1.28 1.34 1.16 1.14 1.2Ø Ø.2Ø 2.7Ø 1.46 Ø.1Ø
      1.Ø6 2.9Ø 2.9Ø 2.12 1.46 Ø.86 1.42 1.34 1.98 1.86
      1.54 Ø.98 Ø.88 1.2Ø 1.49 Ø.4Ø Ø.42 1.14 Ø.68 Ø.68
      Ø.4Ø
'R2Ø' 1Ø  3Ø1Ø2 1
'R3Ø' 9.37  5ØØØ.  Ø.ØØ2Ø  Ø.Ø  8  Ø.Ø8  Ø.Ø6  Ø.Ø8  1ØØ.Ø  16Ø.Ø
'R34' 3Ø.Ø  12Ø.Ø  5Ø.Ø  1ØØ.Ø  1ØØ.Ø  1ØØ.Ø  118.Ø  94.Ø  133.Ø  92.25
      148.Ø  94.Ø  16Ø.Ø  1Ø6.Ø  18Ø.Ø  1Ø7.Ø
'R4Ø' 69.  811.Ø  -1.  -1.  Ø.1
'R42' 31
'R44' 1.Ø4 1.28 1.34 1.16 1.14 1.2Ø Ø.2Ø 2.7Ø 1.46 Ø.1Ø
      1.Ø6 2.9Ø 2.9Ø 2.12 1.46 Ø.86 1.42 1.34 1.98 1.86
      1.54 Ø.98 Ø.88 1.2Ø 1.49 Ø.4Ø Ø.42 1.14 Ø.68 Ø.68
      Ø.4Ø
'R2Ø' 11  3Ø1Ø3 2
'R3Ø' 1Ø.96  5ØØØ.  Ø.ØØ4  Ø.Ø  13  Ø.Ø7  Ø.Ø53  Ø.Ø7  1ØØ.Ø  179.Ø
'R34' 4Ø.Ø  116.Ø  7Ø.Ø  115.Ø  1ØØ.Ø  1ØØ.Ø  1Ø5.Ø  9Ø.Ø  11Ø.Ø  9Ø.Ø
      113.5  89.5  117.Ø  9Ø.Ø  147.Ø  9Ø.Ø  148.5  91.5  173.Ø  91.8
      179.Ø  97.8  2ØØ.Ø  1Ø4.Ø  2Ø2.Ø  1Ø9.Ø
'R3Ø' 11.96  65ØØ.  Ø.ØØ62  Ø.Ø  9  Ø.Ø7  Ø.Ø55  Ø.Ø7  1ØØ.Ø  164.Ø
'R34' 8Ø.Ø  1Ø1.Ø  1ØØ.Ø  1ØØ.Ø  1Ø2.5  95.Ø  117.25  94.Ø  132.Ø  95.Ø
      146.75  93.5  161.5  95.Ø  164.Ø  1ØØ.Ø  164.Ø  1Ø2.Ø
'R4Ø' 69.  3422.5  -1.  -1.  Ø.1
'R42' 31
```

```
'R44' Ø.38 Ø.4Ø Ø.34 Ø.26 Ø.18 Ø.56 Ø.42 Ø.3Ø Ø.38 Ø.18
      Ø.22 1.Ø2 Ø.5Ø Ø.78 Ø.4Ø Ø.6Ø Ø.66 Ø.72 1.Ø2 1.36
      Ø.76 Ø.24 Ø.62 Ø.78 Ø.62 Ø.26 Ø.94 Ø.76 Ø.16 Ø.36
      Ø.Ø6
'R2Ø' 12 -3Ø1Ø4 1
'R2Ø' 13  3Ø1Ø5 1
'R3Ø' 21.Ø8  3ØØØ.  Ø.ØØ17  Ø.Ø  8  Ø.Ø7  Ø.Ø5  Ø.Ø7  1ØØ.Ø  176.Ø
'R34' 8Ø.Ø  1Ø5.Ø  1ØØ.Ø  1ØØ.Ø  1Ø4.Ø  96.Ø  112.Ø  94.Ø  126.Ø  92.Ø
      164.Ø  94.Ø  176.Ø  1ØØ.Ø  19Ø.Ø  1Ø4.Ø
'R4Ø' 7Ø.  1325.Ø  -1.  -1.  Ø.1
'R42' 31
'R44' Ø.31 Ø.2Ø Ø.13 Ø.2Ø Ø.25 Ø.5Ø Ø.2Ø Ø.45 Ø.3Ø Ø.ØØ
      Ø.24 1.Ø5 1.ØØ 1.Ø7 Ø.25 Ø.55 Ø.9Ø Ø.7Ø 1.17 1.58
      Ø.48 Ø.2Ø Ø.4Ø Ø.55 Ø.84 Ø.23 Ø.24 Ø.9Ø Ø.33 Ø.42
      Ø.2Ø
'R5Ø' Ø1  68.  7Ø7.5  45ØØ.  8.3  Ø.Ø  Ø.1
'R52' 31
'R54' Ø.38 Ø.4Ø Ø.34 Ø.26 Ø.18 Ø.56 Ø.42 Ø.3Ø Ø.33 Ø.18
      Ø.22 1.Ø2 Ø.5Ø Ø.78 Ø.4Ø Ø.6Ø Ø.66 Ø.72 1.Ø2 1.36
      Ø.76 Ø.24 Ø.62 Ø.78 Ø.62 Ø.26 Ø.94 Ø.76 Ø.16 Ø.36
      Ø.Ø6
'R5Ø' Ø2  7Ø.  2375.  75ØØ.  Ø.Ø  Ø.25  Ø.1
'R52' 31
'R54' Ø.41 Ø.74 Ø.54 Ø.74 1.42 Ø.63 Ø.82 1.73 Ø.71 Ø.ØØ
      Ø.27 1.82 1.87 3.11 1.34 Ø.32 Ø.49 Ø.68 1.71 Ø.41
      Ø.83 1.22 Ø.33 1.34 Ø.85 1.13 Ø.51 1.61 Ø.96 Ø.41
      Ø.23
'R5Ø' Ø3  61.  9355.  8ØØØ.  Ø.Ø  Ø.25  Ø.1
'R52' 31
'R54' Ø.2Ø Ø.34 Ø.52 Ø.13 Ø.72 Ø.64 Ø.14 Ø.23 Ø.12 Ø.ØØ
      Ø.ØØ 1.2Ø 2.ØØ Ø.72 Ø.2Ø Ø.ØØ Ø.81 Ø.ØØ 1.36 Ø.52
      Ø.35 Ø.48 Ø.56 Ø.23 1.58 Ø.2Ø Ø.ØØ Ø.ØØ Ø.ØØ Ø.ØØ
      Ø.ØØ
'R5Ø' Ø4  71.  1Ø75.  5ØØØ.  13.8  Ø.Ø  Ø.1
'R52' 31
'R54' 1.Ø4 1.28 1.34 1.16 1.14 1.2Ø Ø.2Ø 2.7Ø 1.46 Ø.1Ø
      1.Ø6 2.9Ø 2.9Ø 2.12 1.46 Ø.86 1.42 1.34 1.98 1.86
      1.54 Ø.98 Ø.88 1.2Ø 1.49 Ø.4Ø Ø.42 1.14 Ø.68 Ø.68
      Ø.4Ø
'R5Ø' Ø5  66.  2Ø87.  7ØØØ.  Ø.Ø  Ø.2Ø  Ø.1
'R52' 31
'R54' 1.Ø4 1.28 1.34 1.16 1.14 1.2Ø Ø.2Ø 2.7Ø 1.46 Ø.1Ø
      1.Ø6 2.9Ø 2.9Ø 2.12 1.46 Ø.86 1.42 1.34 1.98 1.86
      1.54 Ø.98 Ø.88 1.2Ø 1.49 Ø.4Ø Ø.42 1.14 Ø.68 Ø.68
      Ø.4Ø
'R5Ø' Ø6  68.  2225.  6ØØØ.  Ø.Ø  Ø.5  Ø.1
'R52' 31
'R54' Ø.2Ø Ø.34 Ø.52 Ø.13 Ø.72 Ø.64 Ø.14 Ø.23 Ø.12 Ø.ØØ
      Ø.ØØ 1.2Ø 2.ØØ Ø.72 Ø.2Ø Ø.ØØ Ø.81 Ø.ØØ 1.36 Ø.52
      Ø.35 Ø.48 Ø.56 Ø.23 1.58 Ø.2Ø Ø.ØØ Ø.ØØ Ø.ØØ Ø.ØØ
      Ø.ØØ
'R5Ø' Ø7  66.  2841.  5ØØØ.  Ø.Ø  Ø.25  Ø.1
'R52' 31
'R54' 1.22 3.12 1.32 3.56 4.Ø4 6.Ø2 1.6Ø 4.Ø6 8.56 Ø.7Ø
      Ø.44 8.5Ø 4.86 8.78 9.1Ø 2.36 4.Ø8 3.6Ø 4.2Ø 5.ØØ
      Ø.84 1.78 5.88 2.9Ø 4.18 3.76 1.2Ø 1.9Ø 2.62 2.5Ø
      1.82
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28	69.60	67.35	63.14	54.75	46.64	45.29	47.27	45.83	28
29	43.68	42.99	39.63	35.21	30.92	25.70	22.30	19.84	29
30	18.15	17.44	16.56	16.27	15.85	15.67	15.55	15.40	30
31	15.66	16.55	19.69	26.16	32.80	33.72	31.70	32.56	31
32	33.80	33.02	33.67	34.09	33.71	34.26	34.10	34.18	32
33	34.42	34.28	34.57	34.45	34.57	34.59	34.60	34.66	33
34	37.43	44.20	52.52	66.95	81.04	83.58	81.70	84.67	34
35	88.83	90.54	95.66	101.55	107.01	113.66	117.90	121.10	35
36	123.44	124.48	125.84	126.33	127.01	127.34	127.60	127.94	36
37	126.62	124.50	124.49	125.34	125.27	125.81	126.05	126.66	37
38	127.03	127.40	127.19	126.39	125.16	123.87	122.86	122.33	38
39	122.11	122.00	122.00	122.05	122.06	122.10	122.17	122.23	39
40	123.03	124.40	123.68	119.89	114.98	113.50	115.23	114.20	40
41	112.77	113.20	112.75	113.03	114.32	114.86	115.80	116.09	41
42	115.93	116.01	115.66	115.66	115.42	115.30	115.22	115.03	42
43	113.31	108.97	103.59	95.44	88.48	87.35	87.57	85.88	43
44	83.91	83.17	81.79	80.69	80.30	79.40	79.10	78.73	44
45	78.32	78.22	77.88	77.81	77.58	77.49	77.46	77.36	45
46	77.95	78.31	75.53	70.17	66.22	65.66	66.43	65.35	46
47	64.05	62.92	60.27	56.69	52.80	48.60	45.64	43.59	47
48	42.32	41.64	40.92	40.66	40.40	40.27	40.23	40.09	48
49	40.49	41.57	43.49	47.13	50.90	51.77	51.37	52.26	49
50	53.56	54.19	55.69	57.38	58.83	60.61	61.77	62.68	50
51	63.38	63.70	64.11	64.30	64.55	64.67	64.74	64.85	51
52	64.92	65.15	65.60	66.40	66.89	66.50	65.96	65.73	52
53	65.36	64.61	63.98	63.25	62.36	61.69	61.03	60.57	53
54	60.32	60.11	59.88	59.65	59.57	59.47	59.34	59.32	54
55	60.52	63.46	66.97	72.46	77.55	78.76	79.15	80.88	55
56	82.86	84.20	86.27	88.21	89.71	91.49	92.71	93.74	56
57	94.51	94.86	95.37	95.73	96.00	96.15	96.29	96.49	57
58	97.70	99.00	96.69	92.93	91.06	90.48	90.05	88.95	58
59	87.79	86.66	85.54	84.65	84.18	83.62	83.26	83.04	59
60	82.64	82.37	82.24	82.11	81.82	81.68	81.67	81.49	60
61	79.14	75.07	74.46	74.39	72.69	72.14	71.85	71.58	61
62	70.94	70.32	68.67	66.44	63.99	61.46	59.46	58.18	62
63	57.36	56.87	56.49	56.22	56.05	55.98	55.95	55.91	63
64	54.29	51.30	49.61	46.41	42.05	41.45	42.88	42.64	64
65	42.01	43.08	43.17	43.33	44.21	44.51	45.04	45.26	65
66	45.35	45.57	45.48	45.60	45.59	45.65	45.61	45.59	66
67	46.70	48.42	47.83	45.96	45.19	45.21	45.67	45.45	67
68	45.62	46.32	47.45	49.23	51.59	53.81	55.63	56.79	68
69	57.49	57.91	58.17	58.37	58.47	58.57	58.67	58.71	69
70	59.32	61.11	64.37	69.77	74.26	74.53	73.53	74.17	70
71	74.63	73.65	73.14	71.93	69.90	68.59	67.07	66.08	71
72	65.65	65.18	65.09	64.89	64.75	64.62	64.63	64.65	72
73	64.27	63.55	62.45	61.46	61.54	62.50	63.00	63.61	73
74	64.61	65.93	67.56	69.45	71.45	73.25	74.71	75.87	74
75	76.72	77.27	77.72	78.10	78.41	78.63	78.82	78.97	75
76	77.65	74.64	71.29	64.41	56.38	54.49	55.73	54.04	76
77	51.56	50.97	48.75	46.59	45.24	43.18	42.15	41.14	77
78	40.19	39.77	38.97	38.74	38.36	38.08	37.88	37.66	78
79	39.24	41.85	41.48	40.31	40.53	40.25	40.32	39.83	79
80	39.44	38.99	38.13	36.50	35.06	33.72	32.53	31.90	80
81	31.31	30.98	30.93	30.81	30.77	30.55	30.48	30.66	81

82	30.51	31.52	35.71	42.13	47.25	48.23	[illegible]	[illegible]	82
83	49.85	49.92	51.01	52.10	52.36	53.25	53.74	[illegible]	83
84	54.34	54.56	54.87	54.61	54.76	55.09	[illegible]	[illegible]	84
85	52.95	49.02	46.23	42.12	[illegible]	37.47	[illegible]	[illegible]	85
86	36.11	36.36	36.13	36.19	36.23	36.12	36.56	[illegible]	86
87	36.73	36.77	36.41	36.66	36.91	[illegible]	[illegible]	[illegible]	87
88	37.37	37.91	36.90	35.85	35.85	[illegible]	[illegible]	[illegible]	88
89	35.15	34.83	34.73	34.71	34.39	[illegible]	[illegible]	[illegible]	89
90	34.18	34.23	34.04	34.10	34.08	[illegible]	[illegible]	[illegible]	90
91	33.12	31.77	30.62	28.48	26.39	[illegible]	[illegible]	[illegible]	91
92	25.46	25.65	25.34	24.66	24.17	23.76	[illegible]	[illegible]	92
93	22.80	22.79	22.76	22.73	22.72	22.72	[illegible]	[illegible]	93

TOTAL UPLAND SUBWATERSHED DIRECT RUNOFF VOLUME: 5.8137796E+07 CUBIC METERS

TOTAL REACH SUBWATERSHED DIRECT RUNOFF VOLUME: 6.6222288E+07 CUBIC METERS

TOTAL DIRECT RUNOFF VOLUME AT BASIN OUTLET: 1.0276610E+08 CUBIC METERS
