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Regional Analysis : Satluj, Lohit and Barak

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Chapter 1 : APPROACH FOR ESTIMATING NATURAL FLOW USING SWAT

1.1 MODELLING APPROACH ADOPTED FOR BARAK, LOHIT AND SUTLEJ

The objective of the regional analysis is to enable a designer to develop a time series of flow at the project site, where the flow observation information is not available. Under the given objective, the study aims to develop relationships to enable computation of monthly yield series for small ungauged sub-basins in the Barak, Lohit and Sutlej river system this report gives a comprehensive assessment of the water resource availability through spatial and temporal analysis for the above basin of India. A detailed sub-basin wise assessment has been undertaken using Soil and Water Assessment Tool (SWAT). Further, empirical relation has been developed using data on soil, sub-basin characteristics, land use and spatially distributed climate parameters with flow.

The parameters chosen for developing relations are as follows:

Climate parameters

Precipitation and temperature i.e. mean annual snowfall, rainfall, temperature, monthly precipitation, monthly temperature are chosen as climatic parameters.

Land use parameters

Percent Cropped area and Forest area in the basin is used as land use parameter.

Basin characteristic

The sub-basin characteristics are:

a) Area of the sub-basin
b) Total relief of the sub-basin defined as the maximum difference in elevation between the highest point and outlet of the basin.

In this study, an attempt has been made to develop a monthly relationship between flow and climatic parameters, basin characteristics and land use. The relationship can be written as:

Monthly flows = f (Climatic Variables, Basin characteristics, Land use)

To develop a meaningful relationship between flows and various physical parameters, model that is distributed, comprehensive, continuous in time, conceptual, and has the capability to successfully simulate land phase of the hydrological cycle is applied. SWAT, a physically-based, time continuous model, has been chosen to simulate the land phase of the hydrological cycle. In keeping with the above objective, the various stages of Modeling from dataset preparation, analysis, and application of SWAT for estimating Natural flow series has been discussed in the Report. The results of analyses and conclusion have subsequently been presented.

1.2 MODEL INPUT FOR SIMULATION

Major inputs to the integrated model are categorized into spatial and non-spatial data. Spatial datasets pertain to topography, land use, and soil type. Non-spatial inputs include data on weather, soil properties, land use/cover characteristics, and crops.

Automatic delineation of watershed into sub-basins is done using digital elevation model (DEM). The DEM theme is further used to generate additional themes on flow direction and flow accumulation. This process facilitates to develop drainage network, basin and sub-basin boundaries and extract basin parameters such as basin area, slope, elevation, length of main channel and tributaries etc. with their locations.

Further, land use and soil map are overlaid in SWAT on delineated watersheds to define multiple Hydrologic Response Units (HRUs) for each sub-basin. HRU captures the land use and soil characteristics accounting for the spatial diversity, within the boundaries of the sub-basins.

The land cover/use map accounting for the spatial variability in forest and other vegetation characteristics was processed as raster data and include categories like agriculture, forest, built-up, rangeland, grass, barren etc. The database already developed in SWAT contains landuse/land cover and plant growth specific data such as Mannings 'n', SCS Curve number for various hydrologic groups, maximum leaf area index, maximum rooting depth, maximum canopy height, energy to biomass conversion, optimum and base temperatures for plant growth. The SWAT model uses runoff curve numbers to estimate runoff.

The soil database consisting of soil map and attribute information developed by FAO has been used to characterize soils in the study area. The physical properties of soil which govern the movement of water through the soil profile includes Soil Hydrologic Group determined by SCS runoff Curve number 'CN', soil permeability, land use and antecedent moisture conditions besides parameters like maximum rooting depth of soil profile, depth from soil surface to bottom of layer for each layer of soil, available capacity of the soil layer, also defined as plant available water.

The meteorological inputs are daily precipitation, daily temperature (maximum and minimum), solar radiation, wind velocity and dew point. SWAT picks the precipitation and temperature data located nearest to the centroid of the sub-basin. Evapotranspiration potential has been estimated using Penmann-Montieth method. SWAT computes evaporation from soil and plants separately. Maximum soil moisture evaporation is estimated as a function of potential evapotranspiration adjusted for evaporation of free water in the canopy and soil cover index. Soil cover index is a function of above ground biomass and residue. Actual soil evaporation is estimated by using exponential functions of soil depth and water content. A calibration parameter ESCO allows the user to modify the depth distribution used to meet the soil evaporative demand. As ESCO tends from 1 towards 0, the model is able to extract more of the evaporative demand from the lower layers. Plant water evaporation is simulated as a function of potential evapotranspiration, leaf area index and root depth, limited by the soil water content. A plant evaporation water uptake factor (EPCO) allows the user to modify the depth distribution used to meet the plant water uptake demand. As EPCO approaches 1 from 0, the model allows more of water uptake demand to be met by lower layers in the soil.

Table 1.1: Input files for simulating land phase of the hydrological cycle in SWAT

File name	Input file property
A.	***Watershed-level file***
.cio	Control input/output file. This file contains names of input files for all watershed-level variables and sub-basin-level variables.
.bsn	Basin input file. It defines values or options used to model physical processes uniformly over the entire watershed and contains coefficient related to Water Balance. Surface runoff, storage in reach segment, routing options. The inputs include evaporation factors, baseflow factors, leaf Area index, initial soil water contents etc.
.pcp	Precipitation input file. This file contains daily measured precipitation for measuring gages in mm.
.tmp	Temperature input file. This file contains daily measured maximum and minimum temperatures for measuring gages in degree Celsius.
.fig	Watershed configuration file. This file defines the routing network in the watershed.
crop.dat	Land cover/ plant growth database file. This file contains plant growth parameters for all land covers simulated in the watershed.
B.	**Sub-basin-level file**
.sub	Sub-basin input file. Required file for sub-basin level parameters that defines climatic inputs, tributary channel attributes, number and type of HRU's include area, land and channel slopes and length, manning's n, and hydraulic conductivity.
.wgn	Weather generator input file. This file contains statistical data such as long-term mean monthly precipitation, minimum and maximum temperature, solar radiation, and wind speed needed to generate representative daily climate data for the sub-basins.
.wus	Water use input file. This file contains information for consumptive water use in a sub-basin.
C.	**HRU-level file**

File name	Input file property
.hru	HRU input file. Required file for HRU-level parameters. Information includes lateral flow travel time, slope length for lateral subsurface flow, irrigation option, irrigation source location, irrigation diversion and irrigation use, and urban option.
.mgt	Management input file. This file contains management scenarios and specifies the land cover simulated in the HRU. Management operations include planting, harvest, irrigation applications, nutrient applications, and tillage operations.
.sol	Soil input file. This file contains information about the physical characteristics of the soil in the HRU that include layer wise depth, bulk density, available water capacity, particle sizes, saturated conductivity, organic carbon, and maximum rooting depth.
.gw	Groundwater input file. Required file which contains information about shallow and deep aquifer in the subbasin. Because land covers differ in their interaction with the shallow aquifer, information in this input file is allowed to be varied at the HRU level. Parameters includes initial depth of shallow and deep aquifer, ground water delay, base flow alpha factor, threshold depth of water in the shallow aquifer for evaporation or percolation to occur, evaporation coefficient, deep aquifer percolation fraction etc.

1.3 SNOWMELT AND GLACIER MELT ROUTING ALGORITHM IN SWAT

Mean daily air Temperature is the indicator for precipitation in SWAT, and the boundary temperature (Ts-r) is used to categorize precipitation as rain or snow by the user. It is defined in such a way that if the mean daily air temperature is below the boundary temperature, the precipitation will be modeled as snow. Similarly, if the temperature is above the boundary temperature, precipitation will be considered in the form of liquid rain. Snowfall is stored at the ground surface in the form of an accumulating snow pack, and the amount of water stored there is reported as snow water equivalent. The snow pack will increase with additional snowfall or decrease with snowmelt or sublimation.

The snowpack increases with additional snowfall, but decreases with snowmelt or sublimation. The mass balance for the snowpack is computed as:

$$SNO_i = SNO_{i-1} + R_{sfi} - E_{subi} - SNO_{mlti}$$

Where,

SNO_i and SNO_{i-1} are the water equivalents of the snowpack on the current day (i) and previous day ($i-1$), respectively

R_{sfi} is the water equivalent of the snow precipitation on day i

E_{subi} is the water equivalent of the snow sublimation on day i

SNO_{mlti} is the water equivalent of the snowmelt on day i.

All of these variables are reported in terms of the equivalent water depth (mm) over the total HRU area.

Subbasins are categorized into two major classes based on the presence of glaciers. THe HRU's located within glaciers were treated as solid ice. The temperature index approach was used for glacier melt modeling where it is assumed that the melt rate is a linear function of daily positive air temperature. Surface melt rate is calculated as :

$$M = F_M + r_{ice/snow} I) T \quad : T > 0^O C$$

$$= 0 \quad : T \leq 0^O C$$

where, F_M indicates the melt factor, $r_{ice/snow}$ is the radiation factor of ice and snow, I denotes the clear sky radiation. Daily air temperatures for each elevation band are computed using a lapse rate dT/dZ and similarly, precipitation lapse rate dP/dZ also computed assuming a linear increase with elevation.

1.4 SNOWMELT PARAMETERS IN SWAT

A watershed is subdivided into a number of subbasins for modeling purposes. In SWAT, snowmelt hydrology is realized on an HRU (hydrologic response unit) basis. The following parameters have been used in calibration of the snowmelt modeling:

A. SFTMP: When the mean daily air temperature is less than the snowfall temperature, as specified by the variable SFTMP, the precipitation within an HRU is classified as snow and the liquid water equivalent of the snow precipitation is added to the snowpack. The snowpack is rarely uniformly distributed over the total area. Some fraction of area is also bare of snow. In SWAT, the areal coverage of snow over the total HRU area is defined using an areal depletion curve, which describes the seasonal growth and recession of the snowpack and is a function of:

   i. sno_{covi} = Fraction of the HRU area covered by snow on the current day (*i*),
   ii. SNOCOVMX = Minimum snow water content that corresponds to 100% snow cover (mm H_2O),
   iii. cov_1 , cov_2 = Coefficients that define the shape of the curve and are derived from 95% coverage at 95% SNOCOVMX, and 50% coverage at a fraction of SNOCOVMX, specified by SNO50COV.

The value of sno_{covi} is assumed to be equal to 1.0 once the water content of the snowpack exceeds SNOCOVMX, indicating uniform depth of snow over the HRU area. The areal depletion curve affects snowmelt only when the snowpack water content is between 0.0 and SNOCOVMX. A small value for SNOCOVMX will assume a minimal impact of the areal depletion curve on snowmelt, whereas as the value of SNOCOVMX increases, the curve will assume a more important role in approximating the snowmelt process.

B. TIMP: Defined by Snowpack temperature lag factor. The snowpack temperature is a function of the mean daily temperature during the preceding days and varies as a dampened function of air temperature. The influence of the previous day's snowpack temperature on the current day's snowpack temperature is described by a lag factor, specified by the variable TIMP, which implicitly accounts for snowpack density, water content, and exposure.

The snowpack temperature is calculated as:

$$Tsp_i = Tsp_{i-1}(1\text{-}TIMP) + TIMP.Ta_i$$

Where,

Tsp_i and Tsp_{i-1} are the snowpack temperatures on the current day (i) and the previous day ($i-1$), respectively, and

Ta_i is the mean air temperature on day i.

As TIMP approaches 1.0, Ta_i exerts an increasingly greater influence on Tsp_i; conversely, as TIMP moves away from 1.0, Tsp_{i-1} becomes more important.

C. SMFMAX and SMFMN : The maximum and minimum snowmelt factors which defines the melt factor on day i (mm $H_2O/^0C$-day). The amount of snowmelt on the current day (i), $SNOmlt_i$, expressed in terms of the equivalent amount of water in mm, or melting rate, is calculated in SWAT from maximum and minimum snowmelt factors (SMFMAX and SMFMN) , Maximum air temperature on day i (^0C), Base temperature above which snowmelt is allowed (SMTMP) (^0C) .

1.5 DATASET FOR MODEL

SWAT 2009 (Neitsch et al., 2002) in MAPWINDOW was used to delineate the boundaries of the Godavari and its sub-basins and generation of its river network. The following datasets were prepared for SWAT analysis:

1. A Digital Elevation Model (DEM) with a spatial resolution of 1 km (from USGS),
2. Land-use map from USGS Global Land Cover characterisation (GLCC) database
3. Soil map from Global FAO
4. Flow data from CWC G&D stations
5. Climate data from Weather files (available in Indian SWAT dataset available on public domain)
6. IMD raingauge stations and IMD gridded rainfall data (Daily) at 0.5º X 0.5º for the basin. Additionally SWAT Global daily gridded rainfall® and At-Site rainfall data from IMD for the same period.
7. The temperature data for the same period at 1º X 1º and Global Data source of SWAT

1.6 MODEL CALIBRATION AND VALIDATION

The values for the standard soil and land use parameters used to configure the model were estimated from datasets by the SWAT interface. The model sets default values for all the parameters. Providing known or measured values to these parameters enables to improve model representation. Model calibration and validation is performed once initial results are obtained and compared with observed data.

In the calibration period, with known inputs and outputs, parameters are allowed to vary until an acceptable fit to measured data is obtained. The composite water balance in calibration is achieved by adjusting the calibration parameters in order to obtain a close match of simulated water budget components to observed values while maximizing the agreement between the observed and predicted record of flows at annual and monthly time interval. The model is then run using the adjusted parameters for the validation period and performance is determined.

1.6.1 Performance Criteria

The Total Water Yield (TWY) is calculated on monthly, annual and monsoon time interval from the model output. The objective of calibration is to minimize the standard error between the observed and simulated water budget components while maximizing the monthly and annual model efficiencies. In the present case, observed and simulated TWY on monthly and annual resolution is compared under the measures for the goodness of fit, defined by:

i) Coefficient of determination (R^2). :

$$R^2 = \sigma^2 = \frac{\left[(Q_m - \overline{Q}_m)(Q_s - \overline{Q}_s)^2 \right]}{\sum (Q_m - \overline{Q}_m)^2 \sum (Q_s - \overline{Q}_s)^2}$$

Where,

Q_m = Measured discharge, Q_s= Simulated discharge

The R^2 value measures how well the simulated versus observed regression line approaches an ideal match and ranges from 0 to 1, with the value of 0 indicating no correlation and value of 1 represents that the computed value equals the observed value. The development of reliable regression requires a fairly large data series. The scale of correlation values for an acceptable relationship can be above 0.75.

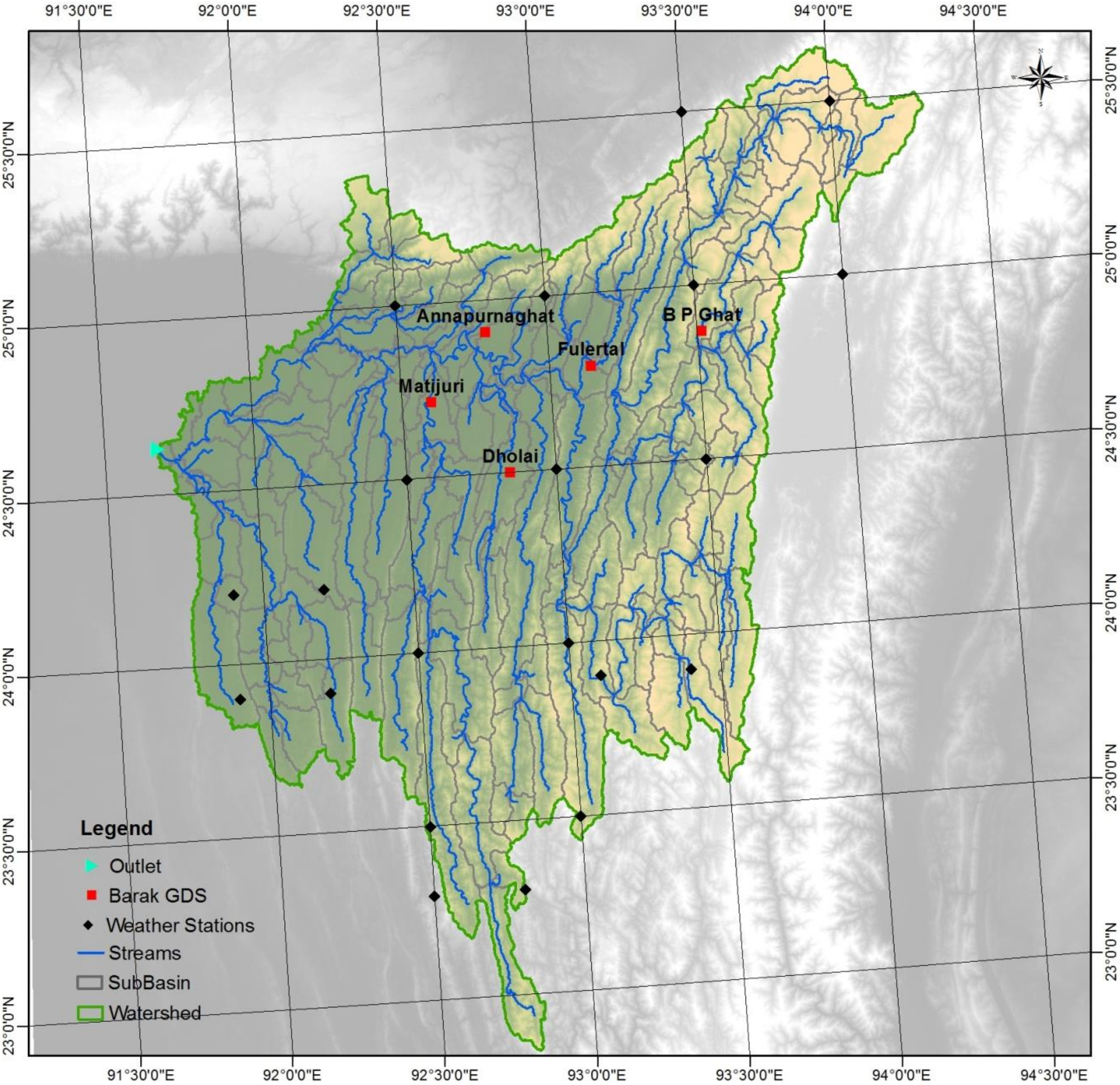
ii) Nash Sutcliffe Index (NSI):

$$NSI = 1 - \frac{\Sigma(Q_m - Q_s)^2}{\Sigma(Q_m - \overline{Q}_m)^2}$$

The NSI ranges from –α to 1 and measures how well the simulated verses observed data match (Nash and Sutcliffe, 1970). Nash and Sutcliffe coefficient values above 0.6 are generally acceptable and values near unity indicate a close relationship between predicted and measured yields.

® The National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) designed and executed as a global high resolution coupled atmosphere-Ocean-land surface-sea ice system to provide the best estimate of the state of these coupled domains(reference : global weather.tamu.edu)

Chapter 2 : REGIONAL MODELING OF BARAK BASIN



2.1 INTRODUCTION: BARAK BASIN

Barak and others is one of the major rivers basins of North Eastern India, draining parts of six states Meghalaya (24.1%), Manipur (20.4%), Mizoram (18.7%), Assam (16.7%) , Tripura (18.3%) and Nagaland (1.8%) and then flowing further in Bangladesh. (Refer Figure 2.1). It covers an area of 45,622.12 Sq.km and comprises of three sub-basins viz. Barak, Kynchiang and Naochchara. The Barak river system is the second largest in the North-east. The main river Barak, rises from the Manipur hills, south of Mao in Senapati district of Manipur at the border of Nagland and Manipur, south east of Javpo peak. From the source, it runs westward for some distance along the boundary of the two states and turns southward till it reaches Tipaimukh. Thereafter, it takes a sharp north turn and forms the boundary between Manipur and Mizoram. After flowing for some 60 km northward through Nagaland-Manipur hilly terrains, it turns west at Jhirimukh and flows through Cachar district of Assam. The Barak sub-basin covers a catchment of 27,658 sq km.

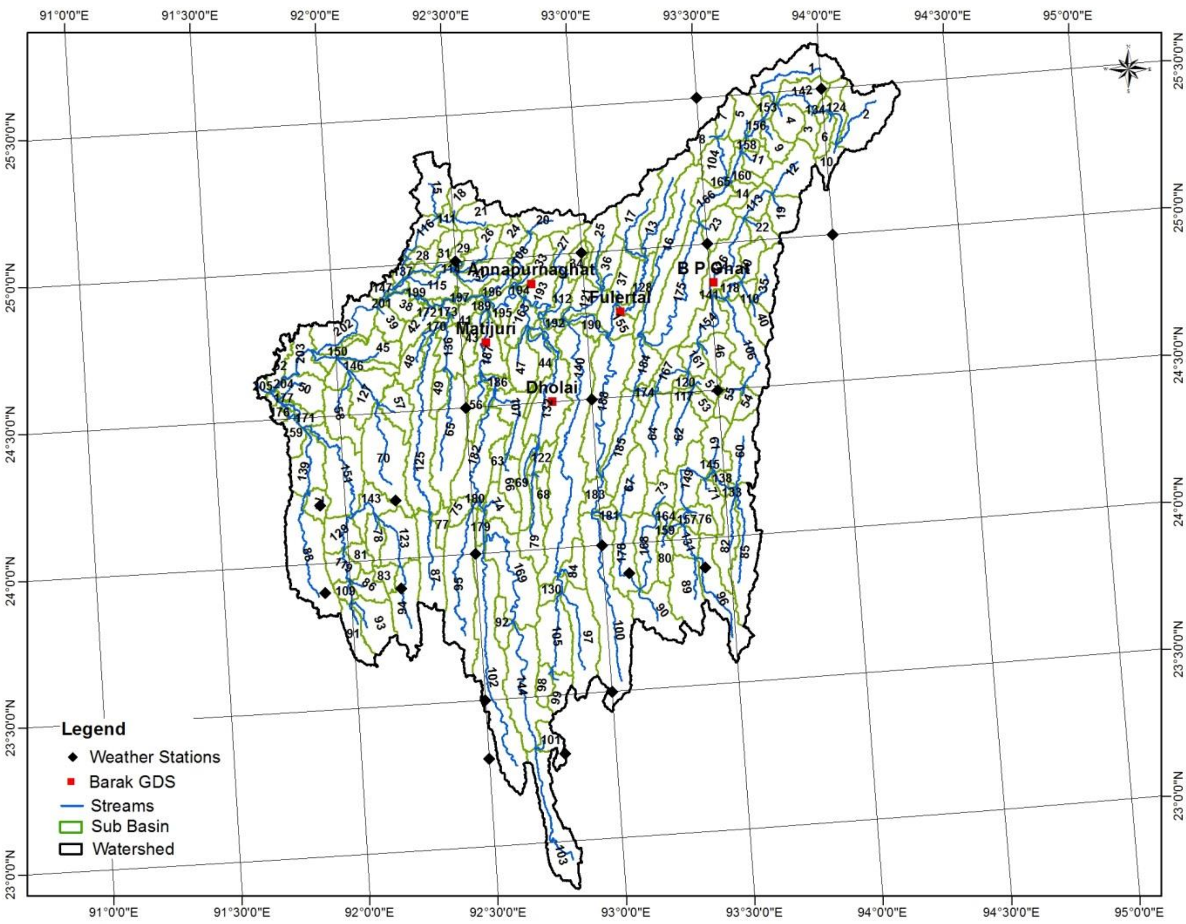


Figure 2. 1: Barak Basin with weather stations

2.2 SUB BASIN CHARACTERISTICS

2.2.1 Topography

The Barak basin is fan shaped with two distinct regime – the hilly catchment and the alluvial plain. The hill ranges which surround the valley are among the youngest in the world. The basin is bounded by Barail hills of Maghalaya range, Naga and Lushai hills and Mizo hills of

Purvanchal range in the south. The Barail range separates it from the Brahmaputra region in the north.

The plains of Cachar are formed by the alluvial sediments of the floods of the Barak, which flows through the area from east to west. The upper portion of the sub-basin of Barak mainly Nagaland area falls in the range up to 3000 m height. Around 1% of the catchment covers an area above El. 2000 m. But around 25% of sub-basin area lies above 850 m and 50% area of the sub-basin lies above 350 m elevation range.

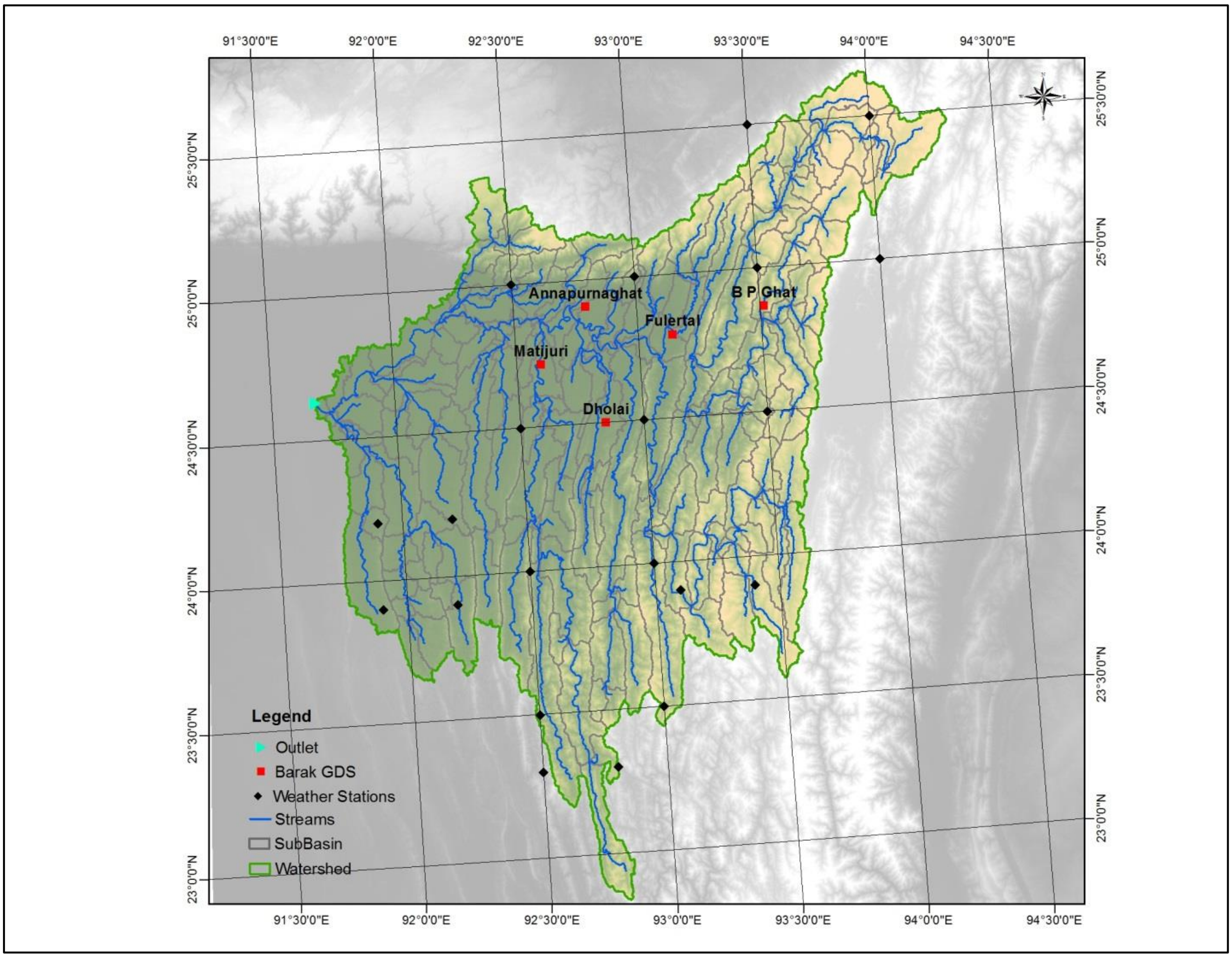


Figure 2.2: Barak basin with Outlet location and stream network

2.2.2 Rainfall

At-site daily rainfall data for the Basin are available for Monierkhal, Dholai and Lakhipur from 1990 to 2006. Considering the inadequacy of the dataset to represent the basin, spatial modeling has been done with 0.5 ^{0} X 0.5 ^{0} Gridded daily data of IMD from 1990 to 2005. With reference to the given precipitation information, the Barak sub-basin has received normal rainfall of 2750 mm with maximum of 3340 mm in 1991 and minimum of 2430 mm in 1992, as shown in ***Figure 2.3***. Comparison of Monsoon precipitation (refer ***Figure 2.4***) calculated in SWAT with CWC Weighted precipitation calculation (Reference: Barak and Other Basins by CWC and NRSC, Mar 2014) shows a considerable variation, part of it can be attributed to the time period of analysis taken as 1971 to 2005 in CWC calculation.

The analysis of Gridded precipitation data reveals that it does not cover high altitude snowfall. The model therefore, does not simulate snowmelt processes for the Barak catchment.

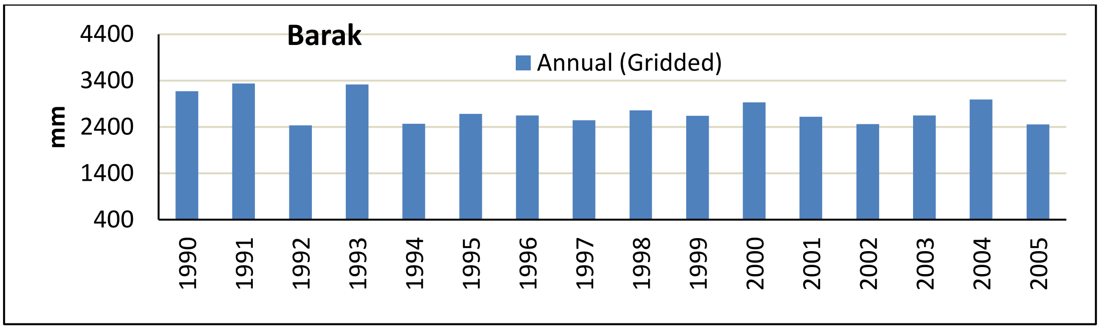


Figure 2. 3: Annual gridded rainfall

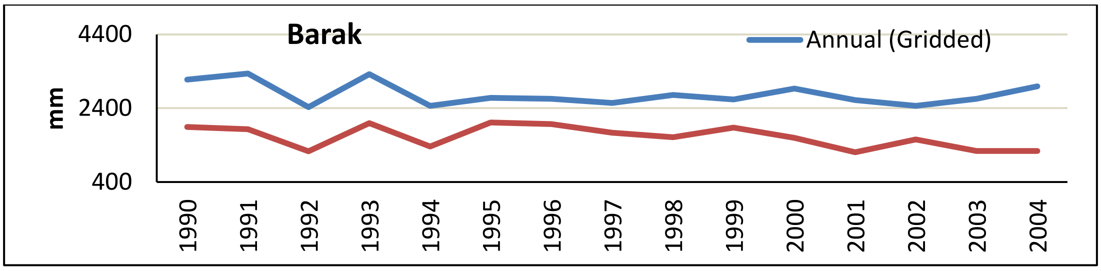


Figure 2. 4: Comparison of CWC and gridded rainfall for Barak basin

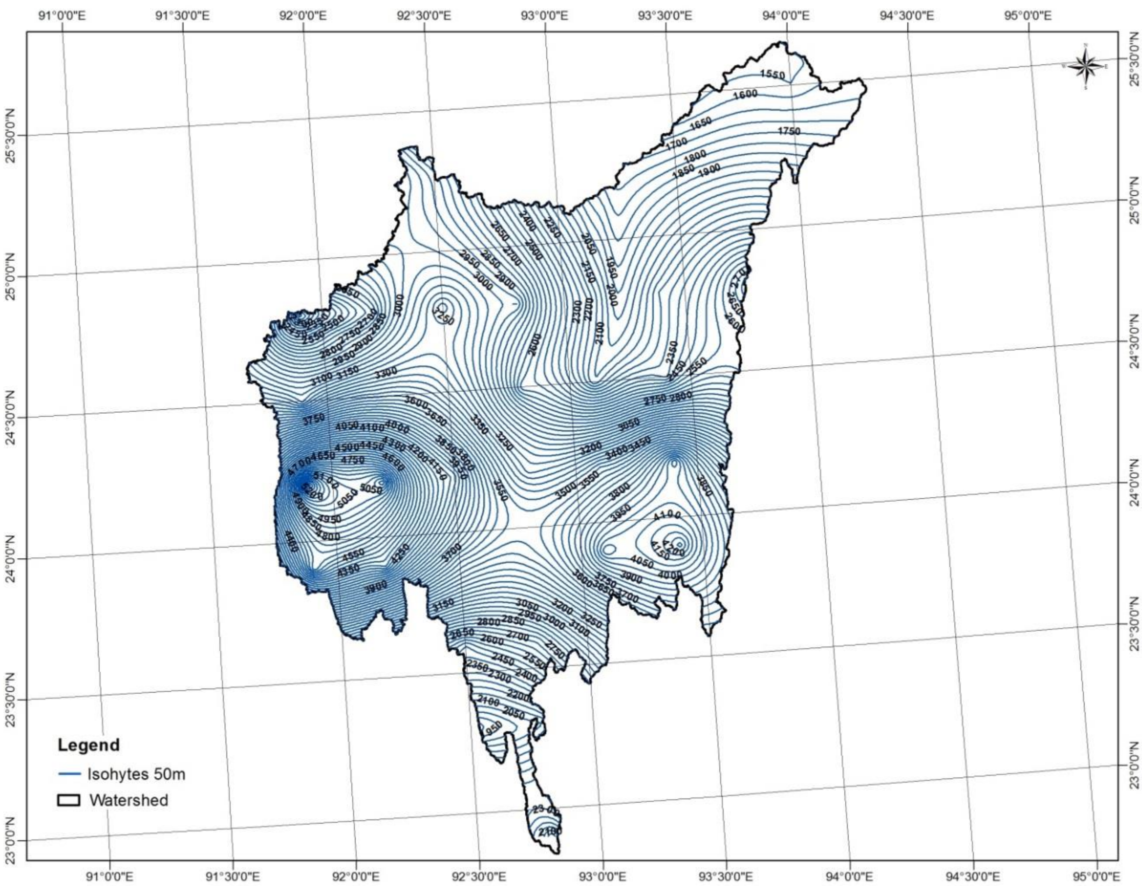


Figure 2. 5: Isohyet generated for Barak basin

2.2.6 Soil

The soil of Barak sub-basin is predominantly of Clay, loamy clay, loam and rock as per FAO classification. Refer ***Figure 2.6.***

Table 2. 1:Soil Classification for Barak Sub basin

Sl. No.	Soil Group	District covered under soil group
1	Loam	North Tripura and Dhalai (Tripura), Karimganj, Hailakandi in Assam Kolasib, Mamit and Lunglie in Mizoram
2	Loamy clay	Aizwal (Mizoram),; Tamenglong and Churachandpur in Manipur , parts of Kohima and Dimapur (Nagaland) and Senapati in Manipur.
3	Clay	Cachar, Karimganj and Hailakandi districts of Assam

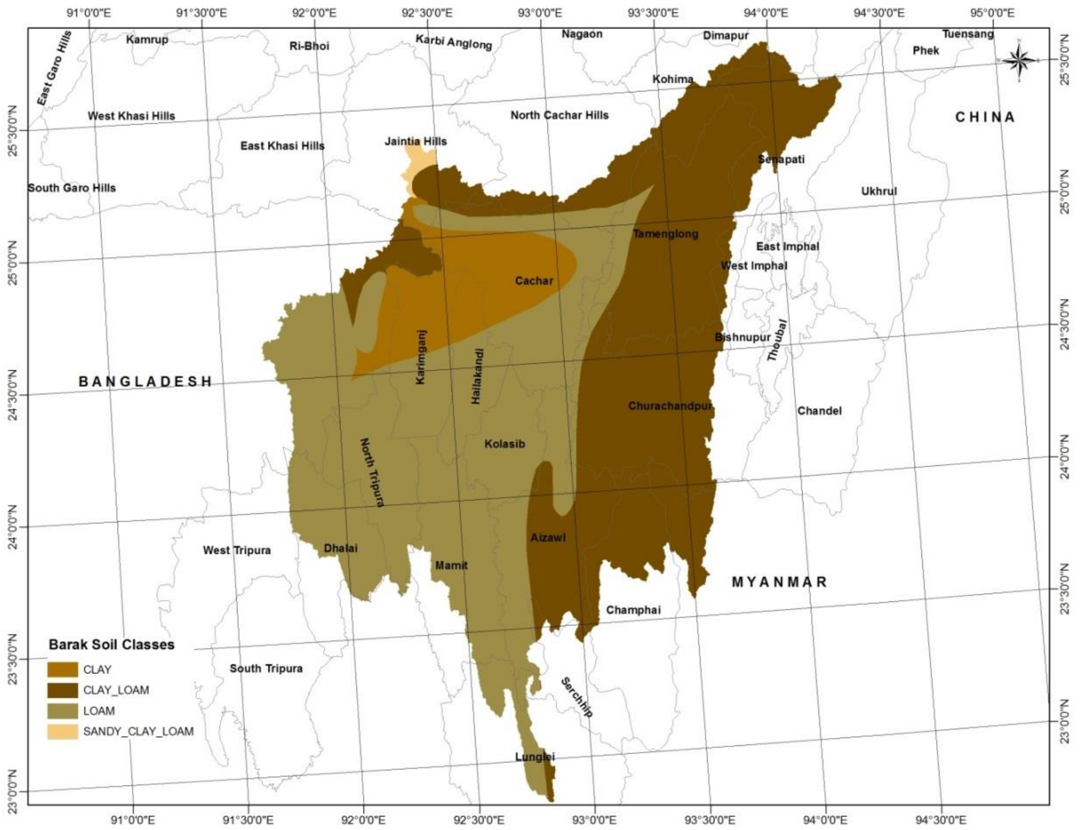


Figure 2. 6: Soil map of Barak basin

2.2.6 Land use

Referring to the landuse figures, the forest land coverage in the Barak sub-basin is 86% and 13% of the area belongs to culturable land category as shown in ***Table 2.2.*** The spatial distribution is indicated in ***Figure 2.7.***

Table 2. 2: Land use Classification of Barak Sub basin

Sl. No.	Land use classification	% of total basin area
1	Built up land	0.02
2	Forest	86.13
3	Pasture and grassland, grazing land	0.58
4	Agriculture	13
5	Wasteland	0.02
6	Water bodies	0.25
	Total	100

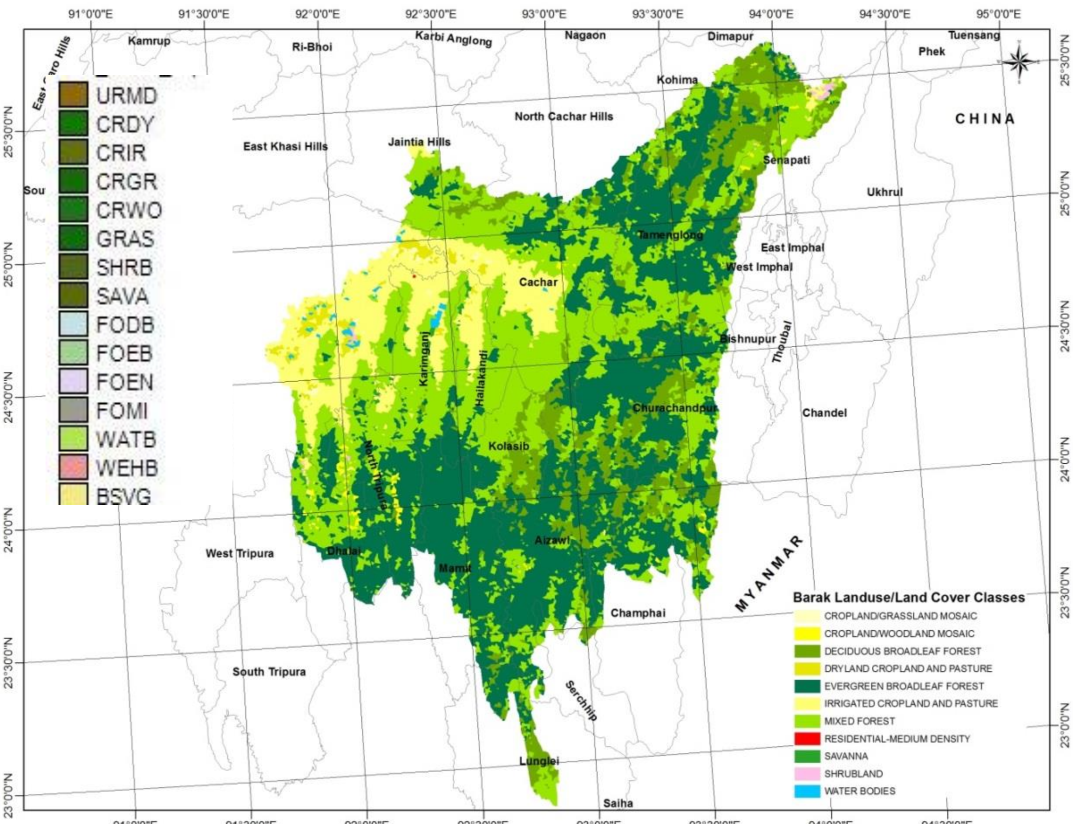


Figure 2. 7: Land use and land cover map of Barak sub-basin

2.2.6 Natural flow data

The observed daily flow data in Barak are available at the following G&D sites from May 1990 to December 2006.

Table 2. 3: Station name and catchment area

Sr. No.	**Station**	**Catchment Area (sq km)**
1	B. P.Ghat	24216

2	Annapurna Ghat	18721
3	Matijuri	7770
4	Fulertal	14450
5	Dholai	562

No major irrigation project is existing in the catchment during the period of analysis 1990 - 2005. As per the records available in **Barak and Others Basin Report** and WRIS site (http://www.india-wris.nrsc.gov.in), the Barak basin has 6 medium projects. 2 Irrigation projects viz Khowai and Khoupam Medium Irrigation Projects are completed in 2010 and 1980 respectively. Others are Gumti, Manu and Jiri-Assam and Jiri Manipur Irrigation Projects which are ongoing .

Three Hydropower projects viz. Loktak (Storage), Myntdu (Run of the river) and Gumti (Storage) are existing in the basin.

No significant utilization data is envisaged for Natural flow estimation for above discharge data series during the simulation period of 1990-2005.

2.2.6 Import/ Export

Import and export does not exist during the considered calibration and validation period.

2.2.7 Calibration and validation period

Considering the limited length of data, Calibration period therefore, has been considered from 1990-91 to 2004-2005 and no validation period considered for Modeling. The simulated data of the same period has been considered to develop the database for Empirical Relation.

2.3 RESULTS AND ANALYSIS

A significant number of flow data is available in the basin. A basin level modeling has been done using 0.5 ^{0} X 0.5 ^{0} Gridded IMD data. A progressive multi-site spatial calibration would require higher resolution climate information. Considering those limitations, a regional approach has been taken up for database simulation. For this, B P Ghat flow which represents the basin flow of Barak is the main calibration station and other gauging sites have been taken for further validation of spatial distribution of flow seasonal flow variability.

The output results of calibration for the Badarpur Ghat G & D are presented in ***Figure 2.8, Figure 2.9* and *Figure 2.10*** in terms of comparisons of simulated and observed natural flows. The model performance criteria values have been shown in ***Table 2.4***

Table 2. 4: Model performance for simulation of flow: Barak Basin

Component	Model performance (Calibration)		Model performance (Validation)	
	R^2	Nash and Sutcliffe	R^2	Nash and Sutcliffe

Stream flow (Annual)				
Badarpur Ghat G & D	0.83	0.73	0.70	0.58
AnnapurnaGhat	0.41	0.38	0.44	-0.07
Fulertal	0.46	0.17	0.47	0.46
Matijuri	0.63	0.48	0.26	-4.0
Dholai	0.39	0.80	0.93	0.87
Stream flow (Monthly)				
Badarpur G & D (u/s)	0.86	0.86	0.9	0.89
AnnapurnaGhat	0.77	0.77	0.88	0.75
Fulertal	0.77	0.74	0.85	0.84
Matirjuri	0.81	0.80	0.89	0.88
Dholai	0.78	0.74	0.85	0.84

The analysis Results of model at B P Ghat, the main calibration station is found to be within acceptable range as indicated by the efficiency coefficients namely, R^2 and NSI. For other stations the annual flow correlation coefficient lie in the range of 0.4 to 0.9 while the monthly flow coefficient variability is in the range of 0.77 to 0.86 which can be considered acceptable for further analysis. The lower values of acceptance for those stations indicate a need for higher spatial resolution of precipitation and climate time series to drive efficient sub-basin level simulation. The plot of observed and simulated monthly flow for other stations are shown in ***Figure 2.11*** to ***Figure 2.14***

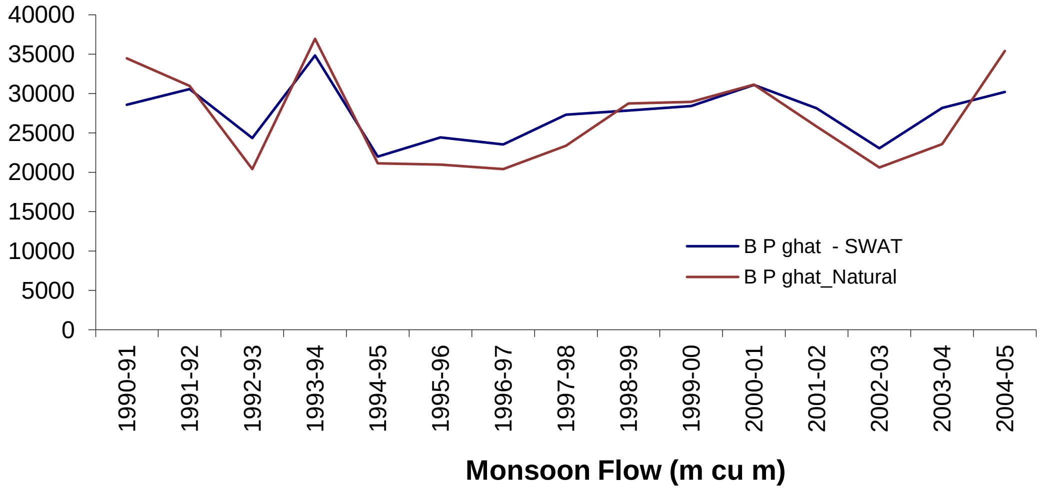


Figure 2. 8: Plot of observed, simulated flow at B. P. Ghat Station

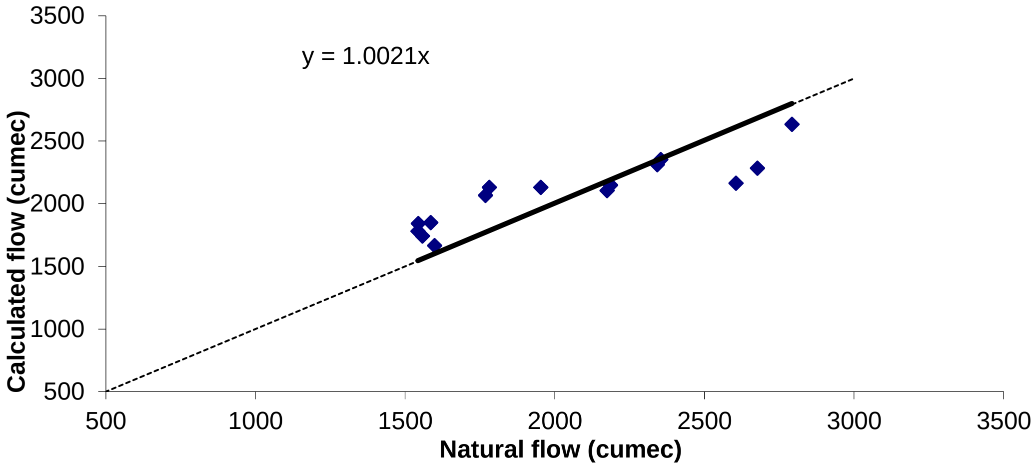


Figure 2. 9: Comparison of natural flow (NWDA) and natural flow (SWAT) at B P Ghat

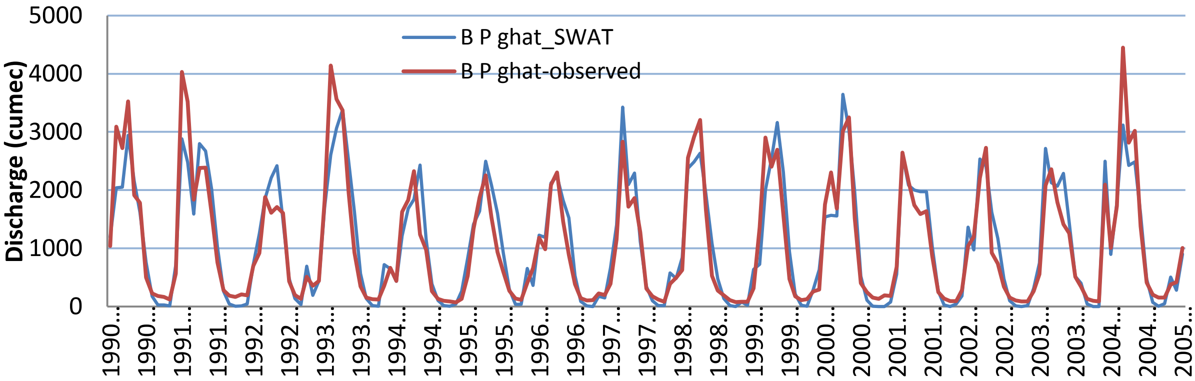


Figure 2.10: Comparison of natural flow (NWDA) and natural flow (SWAT) at B. P. Ghat Station

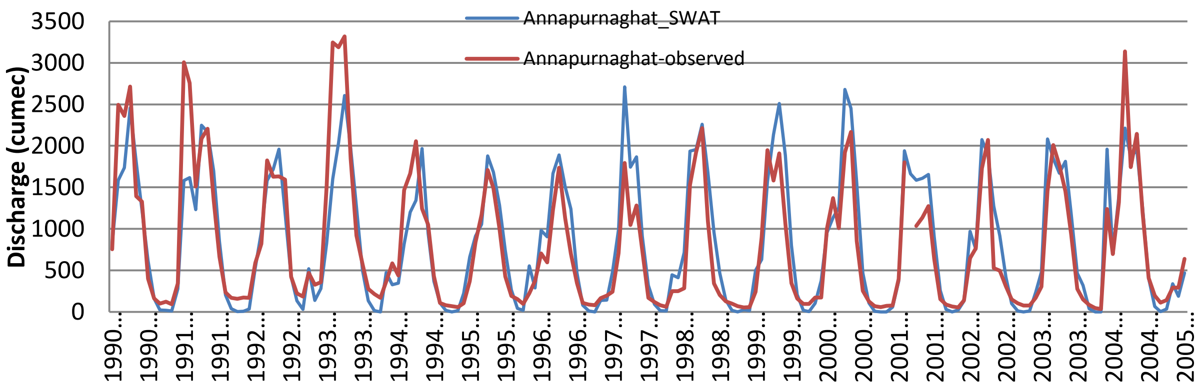


Figure 2. 11 : Plot of observed vs. simulated monthly flow of A. P. Ghat

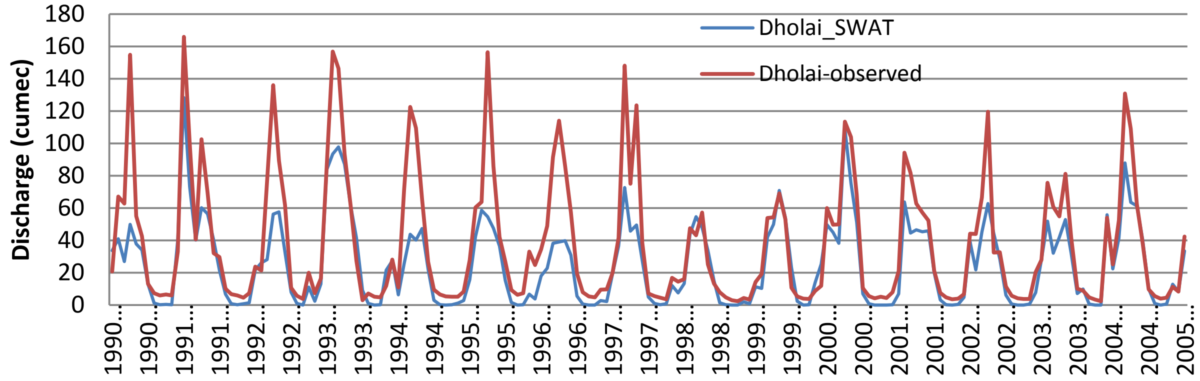


Figure 2. 12 : Plot of observed vs. simulated monthly flow of Dholai

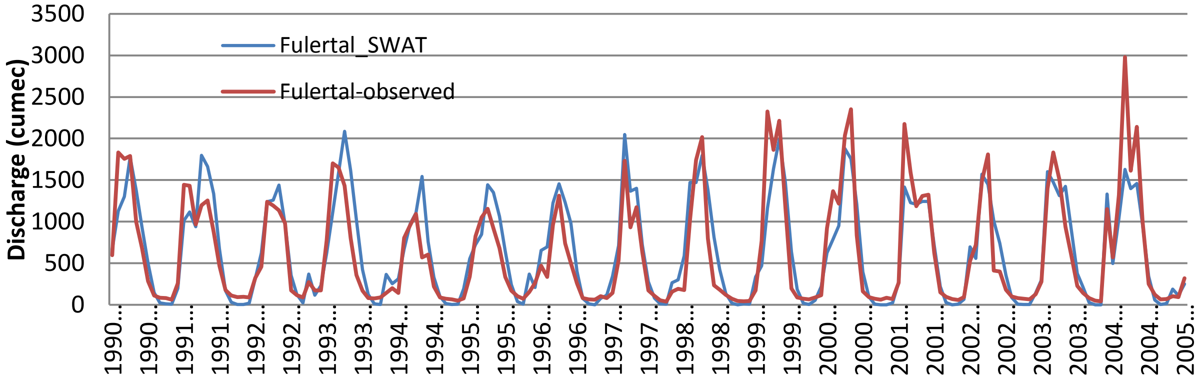


Figure 2. 13 : Plot of observed vs. simulated monthly flow of Fulertal

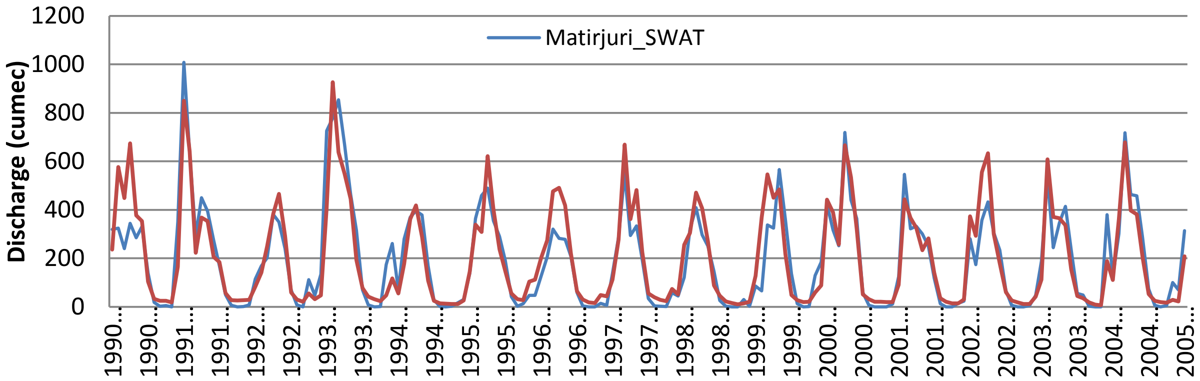


Figure 2. 14 : Plot of observed vs. simulated monthly flow of Matirjuri

The total and average runoff volumes (MCM) of flow observation at B P Ghat are also in agreement with those simulated by SWAT in ***Table 2.5.***

Table 2. 5: Comparison of Observed and SWAT simulated Runoff and Precipitation for Barak sub-basin

Barak upto Badarpur Ghat G&D site

Catchment Area : **24216 sq km**

S. No.	Year	Observed runoff CWC	Observed monsoon runoff CWC	Natural Monsoon runoff CWC	Natural Monsoon runoff SWAT	Natural monsoon runoff CWC	Natural monsoon runoff SWAT	Observed monsoon runoff CWC	Weighted Annual Precipitation CWC	Weighted Annual Precipitation SWAT	Remarks
		(MCM)	(MCM)	(MCM)	(MCM)	(mm)	(mm)	(mm)	(mm)	(mm)	
1	1990-91	49444	34440	34440	28581	1422	1180	1422	1894.8	3171.9	
2	1991-92	37413	30964	30964	30545	1279	1261	1279	1831.5	3338.9	
3	1992-93	30543	20419	20419	24344	843	1005	843	1233.2	2430.3	
4	1993-94	42490	36915	36915	34813	1524	1438	1524	1997.5	3317.0	
5	1994-95	24437	21134	21134	21992	873	908	873	1361.1	2467.4	
6	1995-96	29772	20963	20963	24435	866	1009	866	2013.1	2683.9	
7	1996-97	24371	20399	20399	23518	842	971	842	1970.1	2650.2	
8	1997-98	29017	23378	23378	27305	965	1128	965	1733.3	2543.1	
9	1998-99	31531	28748	28748	27814	1187	1149	1187	1615.8	2760.4	
10	1999-00	37201	28913	28913	28387	1194	1172	1194	1874.2	2638.9	
11	2000-01	36166	31124	31124	31095	1285	1284	1285	1599.7	2928.8	
12	2001-02	32917	25822	25822	28137	1066	1162	1066	1207.1	2618.0	
13	2002-03	24649	20601	20601	23029	851	951	851	1550.1	2462.7	
14	2003-04	34643	23550	23550	28142	973	1162	973	1239.0	2650.6	
15	2004-05	42460	35400	35400	30179	1462	1246	1462	1238.4	2990.6	
	AVG. RUNOFF	**33804**	**26851**	**26851**	**27488**	**1109**	**1135**	**1109**	**1624**	**2777**	

Based on the successful calibration and validation of SWAT, input data sets for regional analysis for all the 205 sub-basins of Barak basin have been developed and appended in a tabular form as ***Annex 2.1***. The calibration parameters provided sub-basin and HRU wise for Barak is given in ***Appendix 1***. The statistical characteristics of the dataset are shown in ***Table 2.6***. The precipitation and yield values in this table are 15 year average values for the period 1990-91-2004-05 derived from SWAT database. These datasets from 1990-91 to 2004-05 are further applied in Cluster Analysis and subsequent development of Empirical Equations after dividing them into calibration and validation period .

Table 2. 6: Statistical Characteristic of SWAT database for the Barak Sub basins

	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
Mean	441.70	27.15	1048.87	19.97	75.93	242.80	406.93
Min.	320.28	26.81	942.31	0.00	0.00	0.00	0.47
Max.	718.51	27.66	1330.71	70.64	100.00	518.00	1380.00
SD.	70.87	0.31	76.35	18.77	22.56	136.27	301.61

2.4 CLUSTERING PROCEDURE AND ESTIMATING NUMBER OF CLUSTERS

2.4.1 Analysis of data

Six dimensions viz. precipitation (mm), percentage cropped area, percentage forest area, mean temperature (^{0}C), relief (m), and catchment area (km^2) have been used as clustering variables. Multiple regression analysis was undertaken on the data set of 205 sub-basins. The correlation matrix of these variables with average natural runoff is shown in ***Table 2.7***. The multiple R obtained was 0.98, and R^2 is 0.97.

Table 2. 7: Correlation matrix and regression parameters used in clustering

	Natural flow mm	Average Temp oC	Average Precip. mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
Natural flow mm	1						
Average Temperature ^{o}C	-0.004	1					
Average Precipitation mm	0.985	-0.038	1				
Forest Area %	-0.383	-0.294	-0.33	1			
Cropped Area %	0.387	0.292	0.334	-0.999	1		
Relief, m	-0.531	-0.422	-0.476	0.712	-0.711	1	
Unit Area, sq.km.	0.019	0.063	0.039	0.259	-0.26	0.263	1

Regression Statistics

Multiple R	0.988
R Square	0.976
Adjusted R Square	0.975
Standard Error	162.973
Observations	205

2.4.2 Standardization

The principal components are dependent on the units used to measure the original variables as well as range of values that they assume. Data should always be standardized prior to using PCA. A common standardization method is to transform all the data to have zero mean and unit standard deviation by applying the relation $(x_i-\mu)/\sigma$, where μ and σ are the mean and standard deviation of x_i's.

2.4.3 Computation of covariance matrix

Covariance matrix is a matrix with all possible covariance values between the different dimensions. If there is an *n* dimensional dataset, then the matrix has n rows and *n* columns (so is square) and each entry in the matrix is the result of calculating the covariance between two separate dimensions. For the present case a 6*6 matrix is obtained by using Data Analysis Tool Add-in in excel (***Table 2.8***).

Table 2. 8: Covariance matrix data set

	Average Temp. oC	Average Precip. mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
Average Temp. oC	0.995	-0.038	-0.292	0.291	-0.420	0.063
Average Precip. mm	-0.038	0.995	-0.328	0.332	-0.474	0.039
Forest Area %	-0.292	-0.328	0.995	-0.994	0.708	0.258
Cropped Area %	0.291	0.332	-0.994	0.995	-0.707	-0.259
Relief, m	-0.420	-0.474	0.708	-0.707	0.995	0.262
Unit Area, sq.km.	0.063	0.039	0.258	-0.259	0.262	0.995

2.4.4 Computation of eigenvalue and eigenvector from covariance matrix

The eigenvectors of a square matrix are the non-zero vectors that, after being multiplied by the matrix, remain parallel to the original vector. For each eigenvector, the corresponding eigenvalue is the factor by which the eigenvector is scaled when multiplied by the matrix. Eigenvectors are for square matrices only and there are n eigenvectors for an n x n matrix.

The mathematical expression of this idea is as follows: if A is a square matrix, a non-zero vector v is an eigenvector of A if there is a scalar λ (lambda) such that $AV= \lambda v$

The scalar λ (lambda) is said to be the eigenvalue of A corresponding to v. For the present analysis the Eigenvalues shown in ***Table 2.9*** were considered. STATA has been used for Eigen's calculation.

Table 2. 9: Eigenvalue dataset

	Eigenvalues	Difference	Proportion	Cumulative
Comp 1	3.053	1.989	0.5113	0.5113
Comp 2	1.064	0.039	0.1782	0.6893
Comp 3	1.025	0.426	0.1717	0.8612
Comp 4	0.599	0.370	0.1003	0.9615
Comp 5	0.229	0.228	0.0384	0.9998
Comp 6	0.001	0.001	0.0002	1.0000
Sum	**5.97**			

Table 2. 10: Eigenvector dataset

Variables	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6
Average Temp. oC	0.244	-0.642	0.496	-0.398	-0.352	0.001
Average Precip. mm	0.280	-0.031	-0.778	-0.409	-0.384	0.005
Forest Area %	-0.535	-0.056	-0.044	-0.430	0.153	-0.708
Cropped Area %	0.535	0.058	0.041	0.428	-0.163	-0.707
Relief, m	-0.506	0.073	0.038	0.324	-0.795	0.005
Unit Area, sq.km.	-0.186	-0.759	-0.378	0.449	0.214	-0.002

2.4.5 Computation of covariance matrix

After eigenvectors are found from the covariance matrix, the next step is to order them by eigenvalues, highest to lowest. This arranges the components in order of significance, which helps in deciding to ignore the components of less significance. To be precise, if the original data have (D) dimensions, there will be (D) eigenvectors and eigenvalues, and if one choose only the first d eigenvector, then the final data set has only (d) dimensions. For the present analysis, 6 eigenvalues are taken.

2.4.6 Deriving new dataset

The standardized data series is multiplied with the chosen eigenvectors to derive principal components as shown in ***Table 2.11***.

Table 2. 11: New generated data set

Sub basins	PC1	PC2	PC3	PC4	PC5	PC6
1	-2.44	-0.77	0.54	1.33	-1.08	0.00
2	-1.36	-0.93	0.46	1.28	-0.07	0.01
3	-1.77	0.51	1.17	0.25	-0.83	0.00
4	-2.06	0.22	1.03	0.57	-1.07	0.00
5	-1.60	0.19	1.26	0.41	-0.18	0.00
6	-1.13	0.40	1.11	-0.14	0.18	0.00

Sub basins	PC1	PC2	PC3	PC4	PC5	PC6
7	-1.33	0.39	1.36	0.07	0.16	0.00
8	-1.28	0.39	1.36	0.15	0.12	0.00
9	-1.93	0.36	1.10	0.43	-0.98	0.00
10	-1.05	0.31	1.30	0.03	0.09	-0.01
11	-1.74	0.41	1.37	0.34	-0.45	0.00
12	-1.92	-0.47	0.91	0.96	-0.70	0.00
13	-1.86	-0.65	0.51	0.68	-0.57	0.00
14	-1.30	0.39	1.03	-0.15	-0.41	0.00
15	-0.30	-0.47	-0.28	0.20	-0.28	-0.01
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
196	3.29	0.86	0.45	0.95	-0.05	-0.03
197	3.05	0.68	0.35	0.93	0.01	-0.03
198	3.34	0.81	0.42	0.94	0.05	-0.03
199	3.27	0.72	0.38	0.96	0.09	0.02
200	3.35	0.85	0.45	0.91	0.05	-0.03
201	3.34	0.82	0.43	0.93	0.06	-0.03
202	2.86	-0.59	-0.28	1.68	0.45	0.03
203	3.52	-0.62	-1.20	0.05	-0.70	0.09
204	4.10	0.29	-0.74	-0.22	-1.00	-0.02
205	4.06	0.15	-0.80	-0.14	-0.97	-0.02

2.5 K MEANS CLUSTERING

K-means is a prototype-based, simple partitioned clustering technique which attempts to find a user-specified k number of clusters. These clusters are represented by their centroids. A cluster centroid is typically the mean of the points in the cluster. The algorithm consists of two separate phases: the first phase is to select k centers randomly, where the value k is fixed in advance. The next phase is to assign each data object to the nearest centers. Euclidean distance is generally considered to determine the distance between each data object and the cluster centers. The iterative process continues repeatedly until the criterion function becomes minimum (Tajunisha & Saravanan 2011).

Step 1: Dimension reduction and finding initial centroid using PCA

Step 2 : Assigning data-points to clusters

i) Compute the distance of each data-point p_i ($1 \le i \le n$) to all the centroids q_j ($1 \le j \le k$) using Euclidean distance formula.

In general, for (d) dimensional space, the Euclidean distance is calculated as

$$ED\ (p,q) = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2 + \cdots + \cdots (p_d - q_d)^2}$$

ii) For each data object p_i, find the closest centroid q_j and assign p_i to the cluster with the nearest centroid q_j.

Table 2. 12: Computation of sum of minimum distance

Sub basins	Dist. To centroid -1	Dist. To centroid-2	Dist. To centroid -3	Dist. To centroid-4	Cluster	Min Dist.
1	1.448	2.679	2.620	5.794	Cluster 1	1.448
2	1.097	2.081	1.683	4.667	Cluster 1	1.097
3	1.539	1.260	1.983	4.900	Cluster 2	1.260
4	1.405	1.721	2.154	5.222	Cluster 1	1.405
5	1.381	0.847	1.750	4.631	Cluster 2	0.847
6	1.683	0.001	1.660	4.230	Cluster 2	0.001
7	1.731	0.383	1.796	4.383	Cluster 2	0.383
8	1.704	0.418	1.711	4.315	Cluster 2	0.418
9	1.454	1.519	2.071	5.081	Cluster 1	1.454
10	1.683	0.296	1.550	4.132	Cluster 2	0.296
11	1.576	1.028	1.951	4.794	Cluster 2	1.028
12	1.011	1.850	1.960	5.116	Cluster 1	1.011
13	0.522	1.804	1.875	5.112	Cluster 1	0.522
14	1.444	0.615	1.629	4.452	Cluster 2	0.615
15	1.407	1.932	1.046	3.823	Cluster 3	1.046
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
196	5.145	4.635	3.531	0.855	Cluster 4	0.855
197	4.873	4.405	3.271	0.829	Cluster 4	0.829
198	5.184	4.672	3.576	0.849	Cluster 4	0.849
199	5.106	4.617	3.504	0.823	Cluster 4	0.823
200	5.207	4.681	3.597	0.849	Cluster 4	0.849
201	5.193	4.677	3.585	0.849	Cluster 4	0.849
202	4.748	4.724	3.370	2.032	Cluster 4	2.032
203	5.309	5.380	4.103	3.066	Cluster 4	3.066
204	5.886	5.683	4.524	2.872	Cluster 4	2.872
205	5.826	5.665	4.476	2.877	Cluster 4	2.877
Sum						**349.606**

iii) In K-means algorithm the objective is to minimise the sum of minimum distance i.e., distances to the nearest cluster centers.

$$\sum_{j=1}^{k}\sum_{i=1}^{n}[x_i^j - c_j]^2 \ldots\ldots\ldots\ldots\ldots\ldots$$

where , x_i^j is the data point belonging to the cluster j and c_j is the cluster center.

iv) The minimization is done with the help of 'Solver' tool available with MS-Excel. A 'Solver' basically solves an optimization problem (minimization or maximization problem) subjected to a set of constraints.. Here the objective function is to minimize distance by changing the cluster centroid. The minimum distance derived and allocation of cluster membership to individual sub-basins for k=2 can be seen in ***Table 2.13.*** The coordinates of the new centroid for the same, are shown in the ***Table 2.14*** .

v) Continue to follow the steps from i) to iv) for various values of k i.e., k=1, 2, 3, 4, 5, 6 etc. and plot a graph between k (x-axis) and optimized sum of the results of clusters (encircled in Table 2.13)

vi) Finally choose the number of clusters based on the point that shows a sudden change in the slope of the curve (as depicted by arrow corresponding to k=2 in ***Figure 2.15***).

Table 2. 13: Optimized results of clusters

Sub basins	Dist. To centroid -1	Dist. To centroid-2	Dist. To centroid -3	Dist. To centroid-4	Cluster	Min Dist.
1	2.215	2.355	3.838	5.826	Cluster 1	2.215
2	1.365	1.863	2.858	4.710	Cluster 1	1.365
3	3.040	1.185	2.958	5.042	Cluster 2	1.185
4	2.859	1.514	3.278	5.330	Cluster 2	1.514
5	2.663	1.030	2.707	4.820	Cluster 2	1.030
6	2.850	0.779	2.098	4.406	Cluster 2	0.779
7	2.914	0.992	2.441	4.606	Cluster 2	0.992
8	2.891	0.985	2.435	4.539	Cluster 2	0.985
9	2.944	1.360	3.139	5.204	Cluster 2	1.360
10	2.840	0.927	2.175	4.331	Cluster 2	0.927
11	2.964	1.172	2.921	4.989	Cluster 2	1.172
12	2.139	1.658	3.178	5.206	Cluster 2	1.658
13	1.714	1.484	2.868	5.134	Cluster 2	1.484
14	2.839	0.687	2.247	4.569	Cluster 2	0.687
15	1.899	1.495	1.410	3.639	Cluster 3	1.410
-	-	-	-	-	-	-
-	-	-	-	-	-	-

Sub basins	Dist. To centroid -1	Dist. To centroid-2	Dist. To centroid -3	Dist. To centroid-4	Cluster	Min Dist.
-	-	-	-	-	-	-
-	-	-	-	-	-	-
196	5.487	4.652	3.704	0.452	Cluster 4	0.452
197	5.181	4.408	3.441	0.216	Cluster 4	0.216
198	5.495	4.694	3.712	0.417	Cluster 4	0.417
199	5.394	4.632	3.639	0.323	Cluster 4	0.323
200	5.531	4.706	3.726	0.453	Cluster 4	0.453
201	5.508	4.700	3.717	0.428	Cluster 4	0.428
202	4.555	4.639	3.638	1.619	Cluster 4	1.619
203	5.260	5.174	3.673	2.214	Cluster 4	2.214
204	6.105	5.546	4.128	2.073	Cluster 4	2.073
205	6.005	5.518	4.092	2.055	Cluster 4	2.055
Sum						**281.496**

Table 2. 14: Coordinates of new centroid

	PC1	PC2	PC3	PC4	PC5	PC6
Median value -1	-1.402	-1.850	-0.368	0.742	0.144	0.001
Median value -2	-1.242	0.416	0.421	-0.002	-0.125	0.000
Median value -3	0.350	-0.357	0.087	-0.897	0.181	0.002
Median value -4	3.087	0.539	0.297	0.792	0.051	-0.005

2.5.1 Choosing number of clusters for Barak basin

Following the above methodology for Barak sub basin, ***Figure 1.8*** shows the selection of the number of clusters.

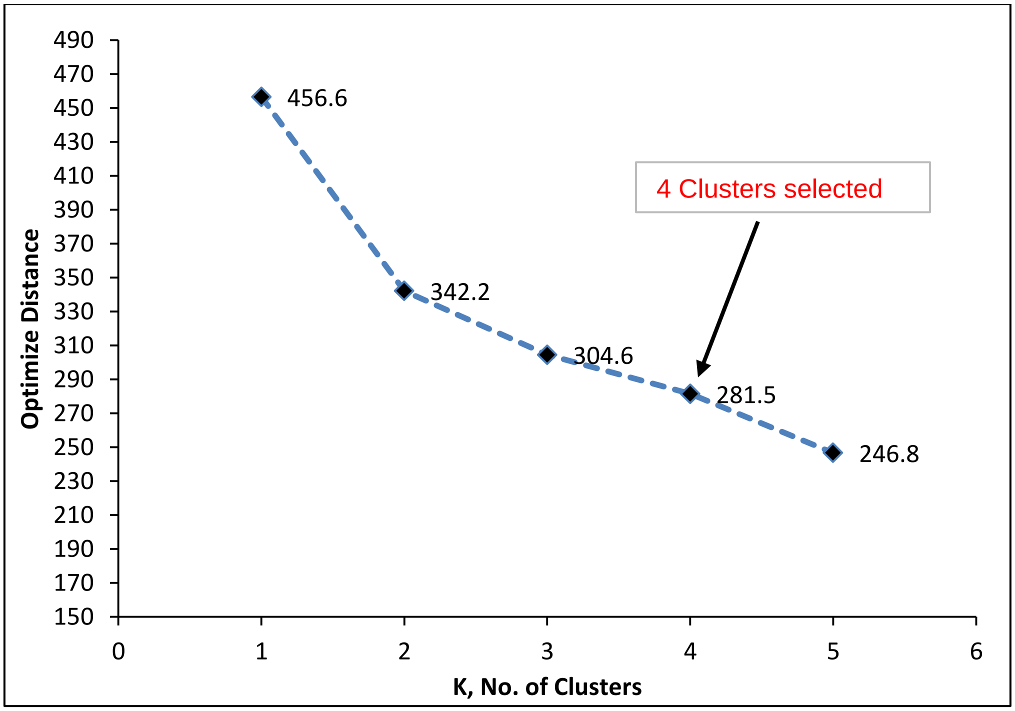


Figure 2. 15: Choosing number of clusters for middle Barak basin

Given the above analysis, 4 clusters are selected for Barak sub basin for formulation of empirical relationships using regression analysis.

2.5.2 Membership of formed clusters

All the 205 sub basins are identified to form 4 clusters of greatest possible distinction by using the 6 variable clustering schemes, chosen on the basis of Eigen values discussed in Sections 1.4.4 and 1.4.5.

The membership of Cluster formed by Cluster Analysis using K-means algorithm are shown in ***Tables 2.15, Table 2.16, Table 2.17 and 2.18.***

Table 2. 15: Cluster 1 Dataset

Sub basins	Natural flow mm	Average Temp. oC	Average Precip. mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
1	482.29	22.77	1658.44	98.55	1.46	2571.00	375.55
2	482.83	22.77	1658.44	84.71	14.56	1647.00	399.05
16	708.24	22.98	1948.82	99.99	0.00	2007.00	496.57
64	1692.78	24.09	3121.45	100.00	0.00	1424.00	332.99
65	1579.70	24.98	2575.61	89.22	10.77	581.00	481.14
88	3006.52	24.14	4735.18	93.50	6.49	467.00	606.45
95	1215.08	23.08	2545.31	100.01	0.00	1198.00	635.21
97	1317.78	21.50	2574.05	100.00	0.00	1740.00	412.15
100	2694.46	19.95	4193.82	99.99	0.00	1785.00	877.66

Sub basins	Natural flow mm	Average Temp. oC	Average Precip. mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
102	1291.56	23.32	2631.77	99.99	0.00	1266.00	865.59
103	837.98	22.14	1876.60	98.62	0.00	1246.00	428.48
106	1037.96	22.08	2307.13	100.00	0.00	1819.00	385.41
125	1577.97	24.98	2575.61	89.04	10.97	375.00	594.78
132	1759.99	24.09	3121.45	79.54	20.46	464.00	444.15
140	1753.01	24.09	3121.45	89.92	9.99	1295.00	1100.30
144	1298.65	23.32	2631.77	99.98	0.02	1469.00	547.01
169	1219.20	23.08	2545.31	99.99	0.00	1454.00	538.51
175	710.31	22.98	1948.82	100.01	0.00	1524.00	661.51
182	1582.07	24.98	2575.61	95.19	4.81	589.00	435.48
185	1698.19	24.09	3121.45	100.01	0.00	1174.00	314.49
188	1724.85	24.09	3121.45	100.00	0.00	1056.00	658.59

Table 2. 16: Cluster 2 Dataset

Sub basins	Natural flow mm	Average Temp. oC	Average Precip. mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
3	493.41	22.77	1658.44	100.01	0.00	2056.00	78.75
4	479.75	22.77	1658.44	100.00	0.00	2333.00	148.68
5	199.98	22.77	1279.36	98.55	1.45	1677.00	142.71
6	483.87	22.77	1658.44	99.96	0.04	1217.00	82.26
7	287.25	22.77	1279.36	99.94	0.06	1345.00	89.03
8	297.79	22.77	1279.36	97.40	2.59	1368.00	92.95
9	476.94	22.77	1658.44	99.99	0.00	2220.00	115.36
10	389.61	22.98	1487.05	95.20	4.80	1276.00	89.43
11	264.44	22.77	1279.36	100.00	0.00	1863.00	97.00
12	388.20	22.98	1487.05	95.27	4.73	2141.00	282.87
13	728.35	22.98	1948.82	99.93	0.06	1974.00	313.00
14	706.95	22.98	1948.82	100.00	0.00	1578.00	73.02
17	1196.49	22.92	2429.55	99.87	0.13	1774.00	299.97
18	1910.12	22.92	3245.85	100.00	0.00	1529.00	99.80
19	352.55	22.98	1487.05	100.00	0.00	1977.00	159.70
20	1263.23	22.92	2429.55	100.00	0.00	1532.00	189.14
21	1895.33	22.92	3245.85	100.00	0.00	1611.00	182.51
22	764.75	22.98	1948.82	100.01	0.00	1902.00	100.41
23	705.01	22.98	1948.82	100.00	0.00	1639.00	155.76
24	1961.10	22.92	3245.85	100.00	0.00	1601.00	78.44
25	1497.05	22.92	2429.55	99.98	0.03	1688.00	206.18
26	1881.68	22.92	3245.85	85.51	14.49	1530.00	153.16
27	1506.54	22.92	2429.55	98.65	1.35	1700.00	160.34
29	2220.88	22.92	3245.85	89.02	10.98	1272.00	86.88

Sub basins	Natural flow mm	Average Temp. oC	Average Precip. mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
30	714.70	22.98	1948.82	100.00	0.00	1453.00	119.04
33	1486.67	22.92	2429.55	88.80	11.20	1263.00	131.39
34	1496.73	22.92	2429.55	100.00	0.00	1313.00	83.82
35	708.11	22.98	1948.82	98.80	1.20	1886.00	180.64
36	1489.20	22.92	2429.55	100.00	0.00	997.00	132.43
40	1063.97	22.08	2307.13	100.00	0.00	1578.00	101.21
46	1038.13	22.08	2307.13	100.01	0.00	1584.00	149.51
51	1060.64	22.08	2307.13	100.00	0.00	1404.00	85.86
53	1057.61	22.08	2307.13	100.00	0.00	1310.00	74.14
54	1095.58	22.08	2307.13	100.00	0.00	1433.00	80.19
55	1049.28	22.08	2307.13	100.00	0.00	1114.00	164.88
60	1093.75	22.08	2307.13	100.00	0.00	1308.00	284.25
61	1080.95	22.08	2307.13	100.00	0.00	1425.00	187.32
62	1052.37	22.08	2307.13	99.99	0.00	1647.00	307.33
67	1431.90	19.95	2662.87	100.00	0.00	1374.00	244.39
68	1483.04	19.95	2662.87	100.00	0.00	970.00	81.90
69	1319.94	23.08	2545.31	100.00	0.00	1031.00	144.21
71	3002.19	18.29	4376.94	100.00	0.00	1148.00	121.55
73	1406.30	19.95	2662.87	100.00	0.00	1069.00	148.86
74	1212.53	23.08	2545.31	100.00	0.00	1030.00	151.59
76	2871.18	18.29	4376.94	100.00	0.00	1476.00	88.71
79	1349.17	23.08	2545.31	99.99	0.00	1174.00	219.16
80	2712.80	19.95	4193.82	100.01	0.00	1527.00	107.80
82	2841.66	18.29	4376.94	100.00	0.00	1072.00	231.42
84	1411.20	19.95	2662.87	99.99	0.00	1654.00	121.00
85	2984.73	18.29	4376.94	96.88	3.13	1362.00	380.67
89	2865.79	18.29	4376.94	99.00	1.01	1591.00	312.37
90	2699.47	19.95	4193.82	100.00	0.00	1863.00	294.54
92	1229.46	23.08	2545.31	100.00	0.00	1310.00	94.89
96	2920.45	18.29	4376.94	100.00	0.00	1723.00	360.48
98	1342.82	23.32	2631.77	100.00	0.00	1236.00	88.45
99	1315.68	21.50	2574.05	100.00	0.00	1327.00	101.70
101	785.27	22.14	1876.60	99.99	0.00	1270.00	113.01
104	187.45	22.77	1279.36	100.00	0.00	1901.00	193.52
105	1318.84	21.50	2574.05	98.80	1.21	1218.00	345.52
110	713.48	22.98	1948.82	100.00	0.00	1486.00	53.06
113	712.96	22.98	1948.82	100.00	0.00	1628.00	121.46
117	1057.69	22.08	2307.13	99.99	0.00	684.00	16.16
118	715.80	22.98	1948.82	100.00	0.00	1243.00	54.11
120	1064.30	22.08	2307.13	100.00	0.00	872.00	36.77
121	1486.64	22.92	2429.55	65.93	33.37	1335.00	188.33
124	518.96	22.77	1658.44	96.37	3.62	2014.00	119.51
126	767.82	22.98	1948.82	100.01	0.00	1503.00	280.10

Sub basins	Natural flow mm	Average Temp. oC	Average Precip. mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
130	1411.22	19.95	2662.87	99.99	0.00	1361.00	74.03
131	3005.04	18.29	4376.94	100.00	0.00	1509.00	105.47
133	2909.65	18.29	4376.94	100.00	0.00	628.00	5.62
134	492.03	22.77	1658.44	97.47	2.54	1721.00	42.65
138	2923.76	18.29	4376.94	100.00	0.00	763.00	50.63
141	719.22	22.98	1948.82	100.00	0.00	1011.00	13.87
142	495.15	22.77	1658.44	99.99	0.00	2361.00	190.75
145	1053.33	22.08	2307.13	100.00	0.00	640.00	8.17
149	2858.24	18.29	4376.94	100.01	0.00	1517.00	229.99
152	463.75	22.77	1658.44	100.01	0.00	644.00	1.57
153	457.51	22.77	1658.44	95.22	4.78	1368.00	37.03
154	1043.36	22.08	2307.13	99.99	0.00	1217.00	188.05
156	206.49	22.77	1279.36	100.00	0.00	1437.00	56.89
157	2878.98	18.29	4376.94	99.99	0.00	1430.00	50.20
158	199.34	22.77	1279.36	100.00	0.00	1245.00	42.20
159	2885.32	18.29	4376.94	100.00	0.00	1120.00	27.69
160	765.96	22.98	1948.82	100.00	0.00	1794.00	91.38
161	1022.39	22.08	2307.13	99.99	0.00	1314.00	107.09
164	2878.44	18.29	4376.94	100.01	0.00	925.00	56.45
165	766.02	22.98	1948.82	100.00	0.00	977.00	2.61
166	770.47	22.98	1948.82	100.00	0.00	1699.00	169.27
167	1059.84	22.08	2307.13	100.01	0.00	1319.00	136.65
168	2716.92	19.95	4193.82	100.00	0.00	1436.00	235.37
178	2715.91	19.95	4193.82	98.85	1.15	1610.00	272.97
181	1442.11	19.95	2662.87	100.00	0.00	1272.00	53.38
183	1378.48	19.95	2662.87	100.00	0.00	1311.00	123.84

Table 2. 17: Cluster 3 Dataset

Sub basins	Natural flow mm	Average Temp. oC	Average Precip. mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
15	1817.20	22.92	3245.85	80.36	19.65	1177.00	265.24
31	2211.53	22.92	3245.85	60.05	39.94	1296.00	126.33
32	2279.15	22.92	3245.85	44.62	55.38	880.00	197.14
37	1488.36	22.92	2429.55	99.25	0.75	230.00	144.26
41	2196.38	22.92	3245.85	63.17	36.83	136.00	85.61
42	1977.35	22.92	3245.85	49.84	50.16	129.00	131.16
43	1571.91	24.98	2575.61	70.62	29.37	145.00	101.87
44	2095.73	24.09	3121.45	78.21	21.78	244.00	141.09
47	1581.94	24.98	2575.61	91.77	8.24	162.00	199.82
48	1613.60	24.98	2575.61	49.26	50.74	214.00	151.88
49	1632.07	24.98	2575.61	48.81	51.18	137.00	98.62

Sub basins	Natural flow mm	Average Temp. oC	Average Precip. mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
56	1581.27	24.98	2575.61	77.58	22.42	294.00	132.75
57	1582.45	24.98	2575.61	89.54	10.47	191.00	180.66
63	1584.40	24.98	2575.61	100.00	0.00	534.00	73.35
66	1243.40	23.08	2545.31	100.00	0.00	770.00	132.70
70	4132.46	24.03	5236.33	82.99	17.01	371.00	520.39
72	3723.26	24.17	5564.12	93.50	6.50	211.00	92.60
75	1580.85	23.08	2545.31	100.00	0.00	535.00	74.15
77	1210.79	23.08	2545.31	100.00	0.00	665.00	72.49
78	4114.92	24.03	5236.33	95.63	4.37	239.00	108.03
81	2942.57	24.14	4735.18	93.75	6.25	270.00	79.12
83	2698.70	23.66	4391.92	100.00	0.00	459.00	72.36
86	2684.63	23.66	4391.92	94.52	5.49	526.00	115.65
87	2709.00	23.66	4391.92	100.00	0.00	766.00	328.28
91	2959.26	24.14	4735.18	100.00	0.00	407.00	160.56
93	2688.01	23.66	4391.92	99.63	0.37	703.00	240.17
94	2709.33	23.66	4391.92	97.14	2.86	866.00	337.00
107	1582.87	24.98	2575.61	99.49	0.50	501.00	234.97
108	2280.90	22.92	3245.85	61.39	38.61	1060.00	194.24
109	3024.11	24.14	4735.18	99.14	0.85	442.00	57.80
111	2248.48	22.92	3245.85	99.99	0.00	993.00	44.73
116	1884.83	22.92	3245.85	89.06	9.61	1016.00	144.82
119	3017.18	24.14	4735.18	91.79	8.21	405.00	129.10
122	1790.03	24.09	3121.45	100.00	0.00	723.00	85.02
123	3374.91	24.03	5236.33	90.42	9.57	621.00	278.76
127	3673.55	24.03	5236.33	44.31	53.31	122.00	251.03
128	1488.30	22.92	2429.55	100.00	0.00	601.00	151.02
129	4460.58	24.17	5564.12	85.01	14.99	328.00	168.39
136	1572.56	24.98	2575.61	43.57	41.56	103.00	184.01
139	4539.73	24.17	5564.12	53.82	46.19	122.00	249.10
143	4115.29	24.03	5236.33	98.72	1.28	228.00	161.09
148	1206.59	23.08	2545.31	100.00	0.00	187.00	7.99
151	4452.77	24.17	5564.12	66.81	33.21	285.00	443.83
155	1488.55	22.92	2429.55	100.00	0.00	452.00	157.04
163	2273.51	22.92	3245.85	53.34	46.67	104.00	126.69
174	1746.32	24.09	3121.45	100.00	0.00	621.00	46.48
179	1582.43	23.08	2545.31	100.00	0.00	731.00	48.31
180	1227.16	23.08	2545.31	100.00	0.00	343.00	10.34
184	1724.88	24.09	3121.45	100.00	0.00	1152.00	178.28
186	1632.28	24.98	2575.61	55.26	44.75	74.00	58.25
190	1529.90	22.92	2429.55	70.38	29.61	309.00	79.32

Table 2. 18: Cluster 4 Dataset

Sub basins	Natural flow mm	Average Temp. oC	Average Precip. mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
28	2279.59	22.92	3245.85	34.49	63.12	731.00	78.99
38	1976.03	22.92	3245.85	23.41	76.31	42.00	106.17
39	1946.05	22.92	3245.85	34.85	58.50	68.00	113.48
45	1274.98	24.98	2575.61	22.86	75.18	166.00	201.56
50	3946.88	24.17	5564.12	27.69	71.26	65.00	206.35
52	3939.69	24.17	5564.12	0.00	100.00	13.00	86.26
58	4539.57	24.17	5564.12	34.51	63.98	316.00	246.83
59	3940.26	24.17	5564.12	27.04	72.96	59.00	105.48
112	1483.34	22.92	2429.55	49.11	50.89	84.00	115.99
114	2271.95	22.92	3245.85	0.00	100.00	0.00	0.01
115	2268.70	22.92	3245.85	0.02	99.98	45.00	210.45
135	1978.02	22.92	3245.85	0.00	100.00	10.00	17.62
137	1973.51	22.92	3245.85	0.00	92.22	10.00	48.22
146	1274.96	24.98	2575.61	36.27	60.10	196.00	145.11
147	1976.57	22.92	3245.85	0.00	100.00	12.00	59.68
150	3930.84	24.17	5564.12	13.64	86.36	51.00	76.89
162	1519.53	22.92	2429.55	0.00	100.00	5.00	0.19
170	1976.43	22.92	3245.85	0.00	100.00	23.00	17.38
171	3940.60	24.17	5564.12	16.14	83.86	46.00	77.23
172	1974.57	22.92	3245.85	15.98	84.02	39.00	17.13
173	1978.25	22.92	3245.85	0.00	100.00	14.00	32.75
176	3946.84	24.17	5564.12	0.00	100.00	13.00	38.59
177	3948.16	24.17	5564.12	0.00	100.00	15.00	20.52
187	1612.18	24.98	2575.61	29.25	70.75	102.00	239.98
189	2275.00	22.92	3245.85	24.35	75.65	144.00	37.70
191	1530.86	22.92	2429.55	0.00	83.91	21.00	4.62
192	1526.43	22.92	2429.55	0.00	100.00	20.00	39.88
193	1520.07	22.92	2429.55	38.63	61.37	129.00	146.02
194	1520.49	22.92	2429.55	17.93	82.07	41.00	13.82
195	2272.12	22.92	3245.85	38.30	61.70	106.00	152.86
196	2276.29	22.92	3245.85	0.00	100.00	92.00	1.83
197	2269.69	22.92	3245.85	5.44	94.56	125.00	39.15
198	1978.29	22.92	3245.85	0.00	100.00	15.00	11.56
199	1965.36	22.92	3245.85	0.00	97.37	16.00	29.89
200	1978.59	22.92	3245.85	0.00	100.00	10.00	1.82
201	1978.17	22.92	3245.85	0.00	100.00	10.00	8.62
202	1910.04	22.92	3245.85	2.06	94.63	40.00	320.29
203	3938.38	24.17	5564.12	8.09	86.49	52.00	197.28
204	3949.28	24.17	5564.12	0.00	100.00	11.00	2.05
205	3948.38	24.17	5564.12	0.00	100.00	21.00	33.06

2.5.3 Correlation matrix development

After dividing the dataset into clusters and choosing the sub-basin which is part of the same cluster, a correlation matrix was computed for each of the clusters. The correlation matrix for each cluster is shown in ***Table 2.19, Table 2.20, Table 2.21 and 2.22.***

Table 2. 19: Correlation of Matrix Parameters of Cluster 1

	Natural flow mm	*Average Temp. oC*	*Average Precip. mm*	*Forest Area %*	*Cropped Area %*	*Relief, m*	*Unit Area, sq.km.*
Natural flow mm	1.000						
Average Temp. oC	0.123	1.000					
Average Precip. mm	0.982	0.056	1.000				
Forest Area %	-0.116	-0.418	-0.050	1.000			
Cropped Area %	0.135	0.434	0.070	-0.999	1.000		
Relief, m	-0.537	-0.692	-0.437	0.525	-0.531	1.000	
Unit Area, sq.km.	0.354	-0.096	0.367	-0.003	0.012	-0.082	1.000

Table 2. 20: Correlation of Matrix Parameters of Cluster 2

	Natural flow mm	*Average Temp. oC*	*Average Precip. mm*	*Forest Area %*	*Cropped Area %*	*Relief, m*	*Unit Area, sq.km.*
Natural flow mm	1.000						
Average Temp. oC	-0.822	1.000					
Average Precip. mm	0.994	-0.838	1.000				
Forest Area %	-0.032	-0.150	0.015	1.000			
Cropped Area %	0.033	0.150	-0.014	-1.000	1.000		
Relief, m	-0.263	0.249	-0.258	-0.004	0.005	1.000	
Unit Area, sq.km.	0.213	-0.137	0.211	-0.071	0.071	0.402	1.000

Table 2. 21: Correlation of Matrix Parameters of Cluster 3

	Natural flow mm	*Average Temp. oC*	*Average Precip. mm*	*Forest Area %*	*Cropped Area %*	*Relief, m*	*Unit Area, sq.km.*
Natural flow mm	1.000						
Average Temp. oC	0.131	1.000					
Average Precip. mm	0.965	0.109	1.000				
Forest Area %	-0.083	-0.126	0.033	1.000			
Cropped Area %	0.095	0.107	-0.024	-0.995	1.000		
Relief, m	-0.165	-0.454	-0.096	0.295	-0.286	1.000	
Unit Area, sq.km.	0.494	0.131	0.453	-0.168	0.166	0.103	1.000

Table 2. 22: Correlation of Matrix Parameters of Cluster 4

	Natural flow mm	*Average Temp.oC*	*Average Precip. mm*	*Forest Area %*	*Cropped Area %*	*Relief, m*	*Unit Area, sq.km.*
Natural flow mm	1.000						
Average Temp. oC	0.515	1.000					
Average Precip. mm	0.987	0.551	1.000				
Forest Area %	-0.081	0.215	-0.116	1.000			
Cropped Area %	0.113	-0.200	0.146	-0.980	1.000		
Relief, m	-0.008	0.087	-0.070	0.541	-0.542	1.000	
Unit Area, sq.km.	0.097	0.398	0.087	0.506	-0.513	0.275	1.000

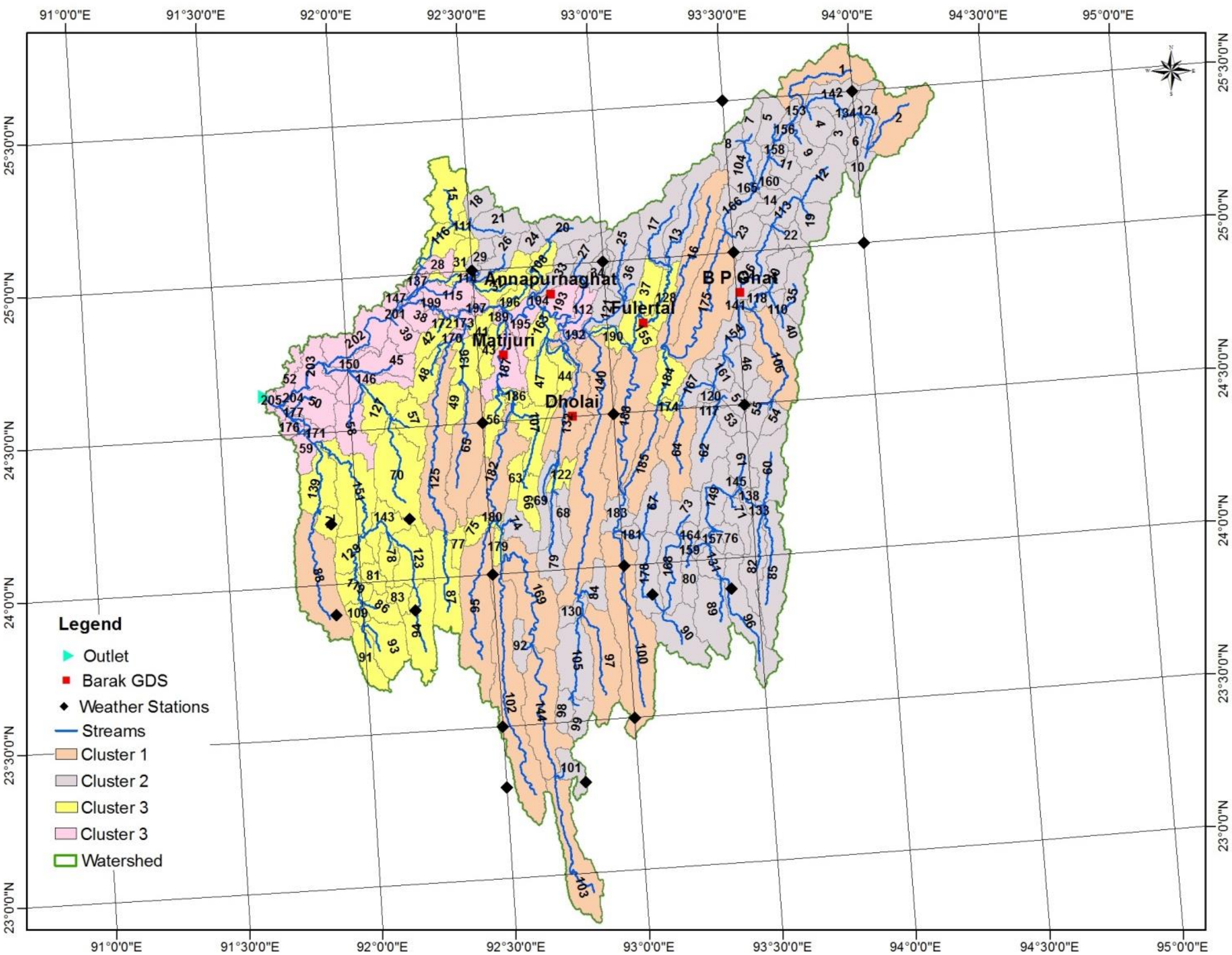


Figure 2. 16: Cluster wise map Barak basin

2.6 COMPUTATION OF EMPIRICAL EQUATION

Separate empirical equations have been computed for entire monsoon season (June to September) and each monsoon month i.e. for June, July, August and September. The approach considered for computation of empirical equations for the clusters of Barak basin is detailed as below:

2.6.1 Approach for month and cluster wise equation formulation

i. "Discharge", "Precipitation", "Temperature", "Relief", "% Crop Area", "% Forest Area" and "Sub basin Area" Parameters of each sub-basin of a cluster have been arranged month-wise.

ii. The correlation coefficient matrix for the above data has been derived.

iii. Calculate the parameters for the following equation (Equation 1.1), which has been chosen to relate the dependent variable "monthly discharge (Q_{sim})" with the independent variables namely "Precipitation" (PCP), "Temperature" (TEMP), "Relief"(RL), "% Crop Area"(%CA), "% Forest Area (%FA)" and "Sub basin Area/ Catchment area of the sub basin" (SA):

$$Q_{sim} = \beta_1\times (PCP) + \beta_2\times(TEMP) + \beta_3\times(SA) + \beta_4\times(\%CA) + \beta_5\times (\%FA) + \beta_6\times (RL) - CONS \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (1.1)$$

where coefficient, β_{1-6} and CONS are the coefficients that has been determined, such that the root mean square error (RMSE) between the observed discharge and simulated discharge is minimum.

iv. Similarly, an empirical equation is computed for the entire monsoon season using the above steps (i) to (iii).

The results of the optimization for various months and monsoon season for Barak basin are provided in sections below. For each month, a set of best 2 or 3 equations for each cluster, chosen in the order of importance/significant parameters are formulated. The criteria for selection are based on Coefficient of Determination, correlation coefficient, parameter significance estimated from p-value and t-statistic, sign conventions of independent variables with respect to dependant variables and the ease of applicability. The t-statistic is a measure of how strongly a particular independent variable explains variation in the dependant variable given by $t_i = b_i / se(b_i)$ where, b_i is the coefficient of the independent variable and $se(b_i)$ is its standard error . The larger the t-statistic, higher is the independent variables explanatory power in the equation. The p-value is used to interpret the t-stat. It is the probability that the independent variable is significant. For a p-value less than 0.05, it implies that there is a 5% chance that the independent variable is unrelated to dependant variable. If the p-value is higher thsn 0.1, this can be a strong reason to eliminate the independent variable from the model because it is not statistically significant.

2.6.2 Equation formulation

Based on the analysis as described in the preceding sections, the Empirical Equation derived is presented. The formulation is explained by Q_{SIM} = Discharge (mm); PCP = Total precipitation during the period/ month (mm); PCP1= Precipitation in the previous month ; PCP2= Precipitation in the 2nd previous month ; PCP3= Precipitation in the 3rd previous month; TEMP = Average temperature during the month (^{0}C); SA = sub basin or catchment area (km^2); %CA = Percentage Cropped area; %FA = Percentage Forest area; RL = Relief i.e. difference between maximum and minimum elevation (m).

The flow computed using the Empirical relation at sample HRU's in each cluster has been shown in ***Annex 2.2*** at calibration period (1990-91 to 1999-00) and Validation period (2000-01 to 2004-05) for Barak basin.

EQN NO	EQUATION (CL-I) - Barak	R
	MONSOON (CL-I)	
1	Q_{SIM} = -8163.1955 + 0.7766 X (PCP) + 80.0989 X (%FA) + 76.1756 X (%CA) - 0.1484 X (RL) Equation valid for monsoon PCP > 840 mm	0.97
2	Q_{SIM} = -9303.9022 + 0.8057 X (PCP) + 88.7701 X (%FA) + 92.0145 X (%CA) Equation valid for monsoon PCP > 710 mm	0.96
3	Q_{SIM} = -641.715 + 0.785 X (PCP) + 4.727 X (%FA) -0.1523 X (RL) Equation valid for monsoon PCP > 840 mm	0.97
	JUNE (CL-I)	
1	Q_{SIM} = -2369.0325 + 24.7665 X (%FA) + 25.2322 X (%CA) -0.0452 X (RL) + 0.0006 X (PCP^2) Equation valid for June PCP > 135 mm	0.93
2	Q_{SIM} = 107.4411 -0.0475 X (RL) + 0.0006 X (PCP^2) Equation valid for June PCP > 195 mm	0.93
3	Q_{SIM} = -2594.9404 + 26.2768 X (%FA) + 28.8847 X (%CA) + 0.0007 X (PCP^2) Equation valid for June PCP > 140 mm	0.92
	JULY (CL-I)	
1	Q_{SIM} = -102.6985 + 0.6011 X (PCP) -0.0195 X (RL) + 0.1977 X (PCP1) Equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 135 mm . The weights are w1 = 0. 1977; w2 = 0. 6011.	0.93
2	Q_{SIM} = -28.1747 + 0.6693 X (PCP) -0.0367 X (RL) Equation is valid for PCP > 115 mm	0.90

EQN NO	EQUATION (CL-I) - Barak	R
3	Q_{SIM} = -139.8803 + 0.6093 X (PCP) + 0.2165 X (PCP1) Equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 170 mm. The weights are w1 = 0. 2165; w2 = 0. 093	0.92
	AUGUST (CL-I)	
1	Q_{SIM} = -28.9648 + 0.6542 X (PCP) -1.2876 X (%CA) -0.0412 X (RL) + 0.1382 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 120 mm. The weights are w1 = 0. 1382; w2 = 0. 6542.	0.97
2	Q_{SIM} = -44.9039 + 0.6528 X (PCP) -0.0336 X (RL) + 0.1422 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 120 mm. The weights are w1 = 0. 1422; w2 = 0. 6528.	0.96
3	Q_{SIM} = -4011.1029 + 0.6497 X (PCP) + 39.1979 X (%FA) + 40.1041 X (%CA) + 0.1528 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 125 mm. The weights are w1 = 0. 1528; w2 = 0. 6497.	0.96
	SEPTEMBER (CL-I)	
1	Q_{SIM} = -21.1696 + 0.5571 X (PCP) -0.0244 X (RL) + 0.0359 X (UA) + 0.1572 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP August + w2× PCP September)> 75 mm. The weights are w1 = 0.1572; w2 = 0.5571.	0.95
2	Q_{SIM} = -5.3542 + 0.5628 X (PCP) -0.0248 X (RL) + 0.1627 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP August + w2 × PCP September) > 75 mm. The weights are w1 = 0.1627; w2 = 0.5628.	0.95

EQN NO	EQUATION (CL-I) - Barak	R
3	Q_{SIM} = -74.195 + 0.5342 X (PCP) + 0.0315 X (UA) + 0.0866 X (PCP2) + 0.1374 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2 x PCP August + w3×PCP September) > 95 mm. The weights are w1 = 0. 0866; w2 = 0. 1374; w3 =0.5342.	0.95
	OCTOBER (CL-I)	
1	Q_{SIM} = -66.1333 + 0.5028 X (PCP) + 0.0349 X (UA) + 0.0893 X (PCP2) + 0.2308 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP August + w2×PCP September + w3×PCP October) > 65 mm. The weights are w1 = 0. 0893; w2 = 0. 2308; w3 = 0. 5028.	0.95
2	Q_{SIM} = -53.0911 + 0.5506 X (PCP) + 0.0401 X (UA) + 0.2734 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP September + w2×PCP October) > 50 mm. The weights are w1 = 0. 2734; w2 = 0. 5506.	0.94
3	Q_{SIM} = -38.0978 + 0.5032 X (PCP) -0.0088 X (RL) + 0.0917 X (PCP2) + 0.2346 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP August + w2×PCP September + w3 x PCP October) > 65 mm. The weights are w1 = 0. 0917; w2 = 0. 2346; w3 = 0.5032.	0.95

EQN NO	EQUATION (CL-II) - Barak	R
	MONSOON (CL-II)	
1	Q_{SIM} = -379.9425 + 0.8309 X (PCP) -0.0985 X (RL) + 0.2864 X (UA) The above equation is valid for monsoon PCP > 685 mm for	0.98
2	Q_{SIM} = -400.287 + 0.8385 X (PCP) -0.0669 X (RL) The above equation is valid for monsoon PCP > 685 mm .	0.98

EQN NO	EQUATION (CL-II) - Barak	R
3	Q_{SIM} = -411.3513 + 0.8396 X (PCP) + 8.1848 X (%CA) -0.0669 X (RL) The above equation is valid for monsoon PCP > 685 mm	0.98
	JUNE (CL-II)	
1	Q_{SIM} = 303.9786 -2.6016 X (%FA) -0.0143 X (RL) + 0.0007 X PCP^2 The equation is mostly for June PCP > 90 mm	0.95
2	Q_{SIM} = 280.8858 + 0.0007 X PCP^2 -2.582 X (%FA) The equation is mostly for June PCP > 85 mm	0.95
3	Q_{SIM} = 45.1065 -0.0138 X (RL) + 0.0007 X (PCP^2) The equation is mostly for June PCP > 90 mm	0.95
	JULY (CL-II)	
1	Q_{SIM} = -57.171 -3.2957 X (TEMP) + 0.632 X (PCP) + 0.2142 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 145. The weights are w1 = 0. 2142; w2 = 0. 632.	0.96
2	Q_{SIM} = -150.4315 + 0.6492 X (PCP) + 0.2194 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 170 mm. The weights are w1 = 0. 2194; w2 = 0. 6492.	0.96
3	Q_{SIM} = 43.796 + 0.6523 X (PCP) -1.9579 X (%FA) + 0.2142 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 150 mm. The weights are w1 = 0. 2142; w2 = 0.6523.	0.96
	AUGUST (CL-II)	
1	Q_{SIM} = 14.6211 -3.6713 X (TEMP) + 0.661 X (PCP) -0.0163 X (RL) + 0.156 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 120 mm. The weights are w1 = 0. 156; w2 = 0. 661.	0.97

EQN NO	EQUATION (CL-II) - Barak	R
2	Q_{SIM} = -85.1675 + 0.6793 X (PCP) -0.0195 X (RL) + 0.1624 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 125 mm. The weights are w1 = 0. 1624; w2 = 0. 6793.	0.97
3	Q_{SIM} = -78.6026 + 0.6736 X (PCP) -0.0305 X (RL) + 0.1004 X (UA) + 0.1577 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 130 mm. The weights are w1 = 0. 1577; w2 = 0. 6736.	0.98
	SEPTEMBER (CL-II)	
1	Q_{SIM} = -17.0649 + 0.5918 X (PCP) -0.0404 X (RL) + 0.1095 X (UA) + 0.174 X (PCP1) The above equation is valid for total weighted precipitation (w1X PCP August + w2×PCP September) > 60 mm. The weights are w1 = 0. 174; w2 = 0. 5918.	0.97
2	Q_{SIM} = -23.3619 + 0.5972 X (PCP) -0.0286 X (RL) + 0.1791 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP August + w2×PCP September) > 85 mm. The weights are w1 = 0. 1791; w2 = 0. 5972.	0.96
3	Q_{SIM} = -82.0385 + 0.581 X (PCP) + 0.0335 X (UA) + 0.0616 X (PCP2) + 0.1614 X (PCP1) The above equation is valid for total weighted precipitation (w1X PCP July+ w2×PCP August + w3 x PCP September) > 90 mm taken together for the months of August, and September for sub-basins under Cluster 2. The weights are w1 = 0. 0616; w2 = 0. 1614; w3 = 0.581.	0.97
	OCTOBER (CL-II)	
1	Q_{SIM} = 143.9751 -7.2392 X (TEMP) + 0.5283 X (PCP) + 0.0275 X (UA) + 0.2324 X (PCP1) The above equation is valid for total weighted precipitation (w1 X PCP September + w2×PCP October) > 45 The weights are w1 = 0. 2324; w2 = 0. 5283.	0.96
2	Q_{SIM} = 10.3942 + 0.5265 X (PCP) -0.0396 X (RL) + 0.1011 X (UA) + 0.2675 X (PCP1) The above equation is valid for total weighted precipitation (w1 X PCP September+ w2 X PCP October) > 35. The weights are w1 = 0.2675; w2 = 0. 5265.	0.96

EQN NO	EQUATION (CL-II) - Barak	R
3	QSIM = 65.0971 + 0.8468 X (PCP) -0.0538 X (RL) + 0.1581 X (UA) The equation is mostly for October precipitation > 25 mm for sub-basins under cluster 2	0.93

EQN NO	EQUATION (CL-III) - Barak	R
	MONSOON (CL-III)	
1	Q_{SIM} = -404.1621 + 0.8564 X (PCP) -0.1196 X (RL) + 0.4773 X (UA) The above equation is valid for monsoon PCP > 840 mm	0.97
2	Q_{SIM} = -497.0941 + 0.8634 X (PCP) + 4.1614 X (%CA) -0.0423 X (RL) + 0.2921 X (UA) The above equation is valid for monsoon PCP > 840 mm	0.98
3	Q_{SIM} = -463.1198 + 0.8608 X (PCP) + 0.4198 X (UA) The above equation is valid for monsoon PCP > 840 mm	0.97
	JUNE (CL-III)	
1	Q_{SIM} = 576.0151 -11.6339 X (TEMP) -1.643 X (%FA) + 0.121 X (UA) + 0.0005 X PCP^2 The equation valid for June PCP > 155 mm	0.93
2	Q_{SIM} = 125.0971 -0.0391 X (RL) + 0.1626 X (UA) + 0.0006 X PCP^2 The equation is mostly for June PCP > 180 mm.	0.92
3	Q_{SIM} = 106.991 + 1.7194 X (%CA) -0.005 X (RL) + 0.0006 X PCP^2 The equation is mostly for June PCP > 155 mm.	0.93
	JULY (CL-III)	
1	Q_{SIM} = -136.2291 + 0.7903 X (PCP) -0.0424 X (RL) + 0.1017 X (UA) + 0.1081 X (PCP1) The is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 135 mm. The weights are w1 = 0. 1081; w2 = 0. 7903.	0.95

EQN NO	**EQUATION (CL-III) - Barak**	**R**
2	Q_{SIM} = -162.6259 + 0.8124 X (PCP) + 1.2018 X (%CA) + 0.0899 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 165 mm. The weights are w1 = 0. 0899; w2 = 0. 8124.	0.96
3	Q_{SIM} = -131.602 + 0.8009 X (PCP) -0.0387 X (RL) + 0.1127 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 170 mm taken together for the months of June and July for sub-basins under Cluster 3. The weights are w1 = 0.1127; w2 = 0.8009.	0.95
	AUGUST (CL-III)	
1	Q_{SIM} = -109.2246 + 0.7583 X (PCP) + 0.9866 X (%CA) + 0.0397 X (UA) + 0.101 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 125 mm. The weights are w1 = 0. 101; w2 = 0. 7583.	0.97
2	Q_{SIM} = -96.1784 + 0.7495 X (PCP) + 0.076 X (UA) + 0.1046 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 125 mm. The weights are w1 = 0. 1046; w2 = 0. 7495.	0.97
3	Q_{SIM} = -86.1088 + 0.7467 X (PCP) -0.0201 X (RL) + 0.086 X (UA) + 0.1038 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 125 mm. The weights are w1 = 0. 1038; w2 = 0.7467.	0.97
	SEPTEMBER (CL-III)	
1	Q_{SIM} = -57.0366 + 0.7122 X (PCP) -0.0174 X (RL) + 0.1205 X (UA) + 0.0989 X (PCP1) The above equation is valid for total weighted precipitation (w1X PCP August + w2×PCP September) > 55. The weights are w1 = 0. 0989; w2 = 0.7122.	0.97
2	Q_{SIM} = -51.5239 + 0.7215 X (PCP) -0.0123 X (RL) + 0.1093 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP August + w2×PCP September) > 75 mm. The weights are w1 = 0. 1093; w2 = 0. 7215.	0.97
3	Q_{SIM} = -65.7038 + 0.7142 X (PCP) + 0.1114 X (UA) + 0.1003 X (PCP1) The above equation is valid for total weighted precipitation (w1X PCP August + w2 x PCP September) > 55 mm. The weights are w1 = 0. 1003; w2 = 0. 7142.	0.97
	OCTOBER (CL-III)	

EQN NO	EQUATION (CL-III) - Barak	R
1	Q_{SIM} = 227.1286 -10.5514 X (TEMP) + 0.6898 X (PCP) + 0.032 X (UA) + 0.1917 X (PCP1) The above equation is valid for total weighted precipitation (w1 X PCP September + w2×PCP October) > 70 mm. The weights are w1 = 0. 1917; w2 = 0. 6898.	0.96
2	Q_{SIM} = -47.9818 + 0.6721 X (PCP) + 0.0198 X (RL) + 0.2181 X (PCP1) The above equation is valid for total weighted precipitation (w1 X PCP September+ w2 X PCP October) > 50 mm. The weights are w1 = 0.2181; w2 = 0. 6721.	0.96
3	Q_{SIM} = 119.0767 + 0.6724 X (PCP) -1.5378 X (%FA) -1.7632 X (%CA) + 0.2162 X (PCP1) The above equation is valid for total weighted precipitation (w1 X PCP September+ w2 X PCP October) > 50 mm. The weights are w1 = 0.2162; w2 = 0. 6724.	0.97

EQN NO	EQUATION (CL-IV) - Barak	R
	MONSOON (CL-IV)	
1	Q_{SIM} = -813.0319 + 0.8779 X (PCP) + 3.7843 X (%FA) + 4.1352 X (%CA) + 0.336 X (RL) The above equation is valid for monsoon PCP > 860 mm.	0.99
2	Q_{SIM} = -413.2682 + 0.88 X (PCP) + 0.3086 X (RL) The above equation is valid for monsoon PCP > 860 mm.	0.99
3	Q_{SIM} = -389.5027 + 0.8777 X (PCP) + 0.0692 X (UA) The above equation is valid for monsoon PCP > 860 mm.	0.99
	JUNE (CL-IV)	
1	Q_{SIM} = 887.1181 -28.7408 X (TEMP) + 0.5747 X (%CA) + 0.2102 X (RL) + 0.0005 X PCP^2 The equation is mostly for June PCP > 160 mm.	0.95
2	Q_{SIM} = 167.4812 + 0.1699 X (RL) -0.0811 X (UA) + 0.0005 X PCP^2 The equation is mostly for June PCP > 160 mm.	0.94
3	Q_{SIM} = 83.4329 + 0.885 X (%CA) + 0.2146 X (RL) + 0.0005 X PCP^2 The equation is mostly for June PCP > 255 mm.	0.93

EQN NO	EQUATION (CL-IV) - Barak	R
	JULY (CL- IV)	
1	Q_{SIM} = 210.6702 -12.301 X (TEMP) + 0.8182 X (PCP) + 0.0581 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 125 mm. The weights are w1 = 0. 0581; w2 = 0. 8182.	0.97
2	Q_{SIM} = -132.2232 + 0.8219 X (PCP) + 0.1007 X (RL) + 0.0606 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 125 mm. The weights are w1 = 0. 0606; w2 = 0. 8219.	0.97
3	Q_{SIM} = -132.0165 + 0.8214 X (PCP) + 0.466 X (%FA) + 0.0634 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 125 mm. The weights are w1 = 0.0634; w2 = 0.8214.	0.97
	AUGUST (CL- IV)	
1	Q_{SIM} = -85.2345 + 0.7868 X (PCP) + 0.2263 X (%CA) + 0.0801 X (RL) + 0.057 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 120 mm. The weights are w1 = 0. 057; w2 = 0. 7868.	0.98
2	Q_{SIM} = -65.5218 + 0.787 X (PCP) + 0.0648 X (RL) + 0.0582 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 120 mm. The weights are w1 = 0. 0582; w2 = 0. 787.	0.98
3	Q_{SIM} = -180.6437 + 0.7852 X (PCP) + 1.3775 X (%FA) + 1.2116 X (%CA) + 0.0573 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 120 mm. The weights are w1 = 0. 0573; w2 = 0.7852.	0.98
	SEPTEMBER (CL- IV)	
1	Q_{SIM} = -55.0265 + 0.7398 X (PCP) + 0.0388 X (RL) + 0.1134 X (PCP1) The above equation is valid for total weighted precipitation (w1X PCP August + w2×PCP September) > 55 mm. The weights are w1 = 0. 1134; w2 = 0.7398.	0.99
2	Q_{SIM} = -61.2134 + 0.7292 X (PCP) + 0.0392 X (RL) + 0.027 X (PCP2) + 0.1029 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2 x PCP August + w3 × PCP September) > 40 mm. The weights are w1 = 0. 027; w2 = 0. 1029; w3 = 0.7292.	0.99
3	QSIM = -51.533 + 0.7393 X (PCP) + 0.1129 X (PCP1)	0.99

EQN NO	EQUATION (CL-IV) - Barak	R
	The above equation is valid for total weighted precipitation (w1X PCP August + w2 x PCP September) > 55 mm. The weights are w1 = 0. 1129; w2 = 0. 7393.	
	OCTOBER (CL- IV)	
1	Q_{SIM} = -25.3882 + 0.7224 X (PCP) -0.0585 X (RL) + 0.0282 X (UA) + 0.1907 X (PCP1) The above equation is valid for total weighted precipitation (w1 X PCP September + w2×PCP October) > 35 mm. The weights are w1 = 0. 1907; w2 = 0. 7224.	0.98
2	Q_{SIM} = -23.8517 + 0.7227 X (PCP) -0.0532 X (RL) + 0.1913 X (PCP1) The above equation is valid for total weighted precipitation (w1 X PCP September+ w2 X PCP October) > 35 mm. The weights are w1 = 0.1913; w2 = 0. 7227.	0.98
3	Q_{SIM} = -34.2235 + 0.6862 X (PCP) -0.0516 X (RL) + 0.0571 X (PCP2) + 0.1645 X (PCP1) The above equation is valid for total weighted precipitation (w1 X PCP August + w2 x PCP September + w3 X PCP October) > 40 mm The weights are w1 = 0.0571; w2 = 0. 1645; w3 = 0.6862.	0.98

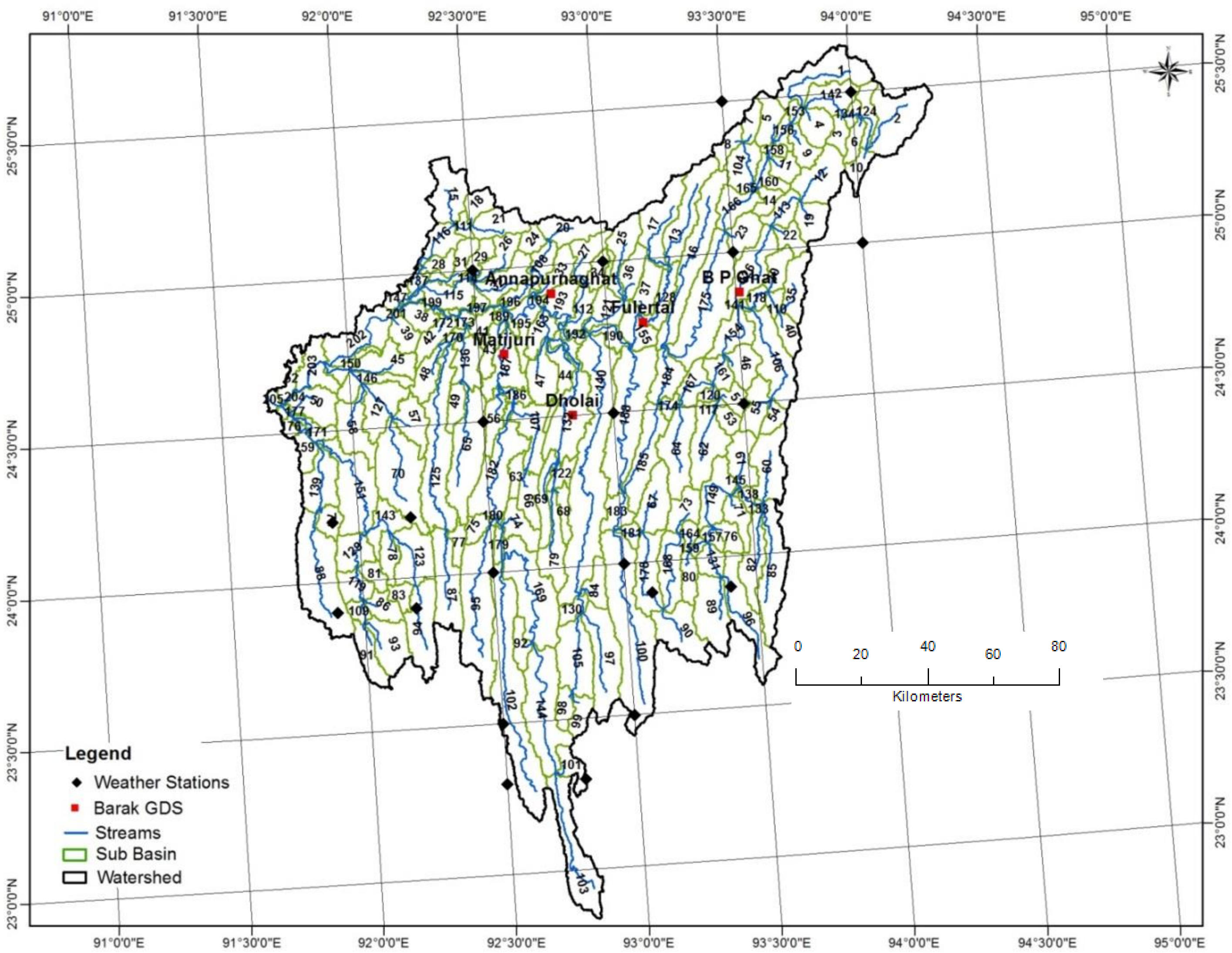


Figure 2. 17: HRU map of Barak basin

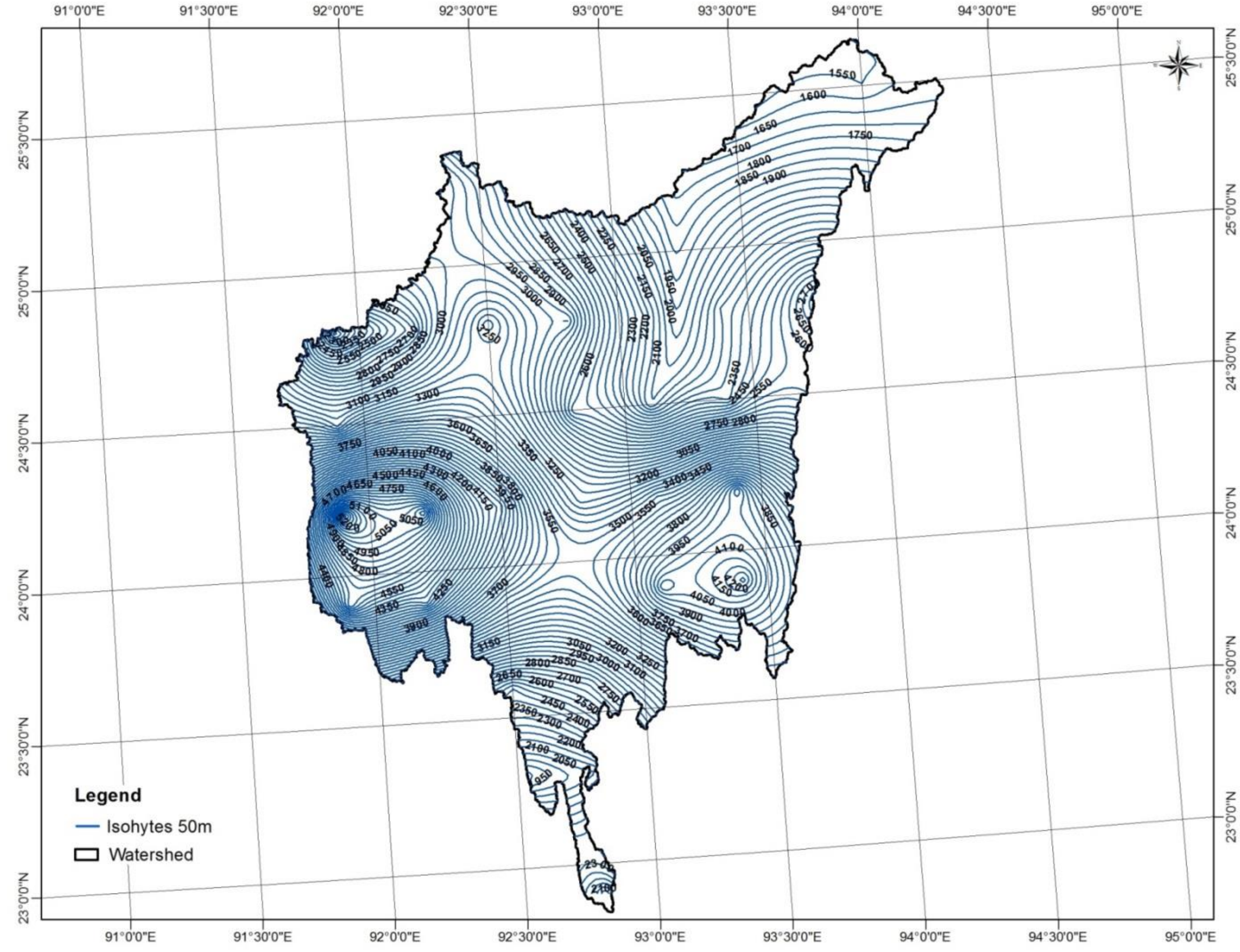
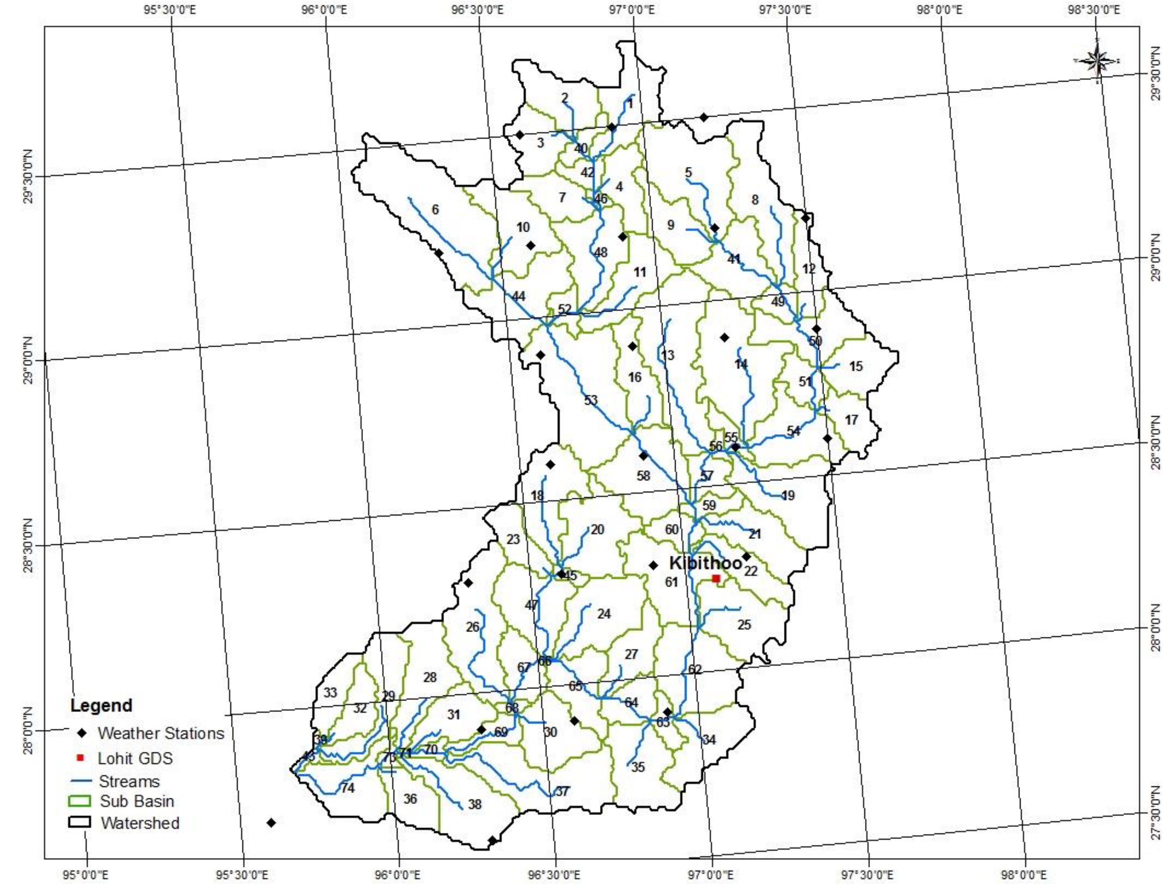


Figure 2. 18: Isohyetal map of Barak Basin

Chapter 3 : MODELING OF LOHIT SUB-BASIN , ANALYSIS AND RESULTS



3.1 INTRODUCTION: LOHIT SUB-BASIN

The Lohit river, a tributary of Brahmaputra river, is the easternmost river basin of India. It rises from the snow covered peaks in Eastern Tibet at an elevation of 6190 m. The river enters India through Kibithoo area. Known in the upper reaches as Krawnaon and flowing westwards, it is joined by a tributary called Chalum Susning flowing from Indo-Burma Border. The combined flow is known as Tellu or Lohit river. The Lohit River after crossing the Sadiya town in Assam is joined by Dibang and Dihang river near Kobo. The river system are then known as Brahmputra river. The total catchment area of Lohit basin including Tibet is 29,487 sq.km shown in ***Figure 3.1.*** The river drainage area in India is 14,453 km^2.

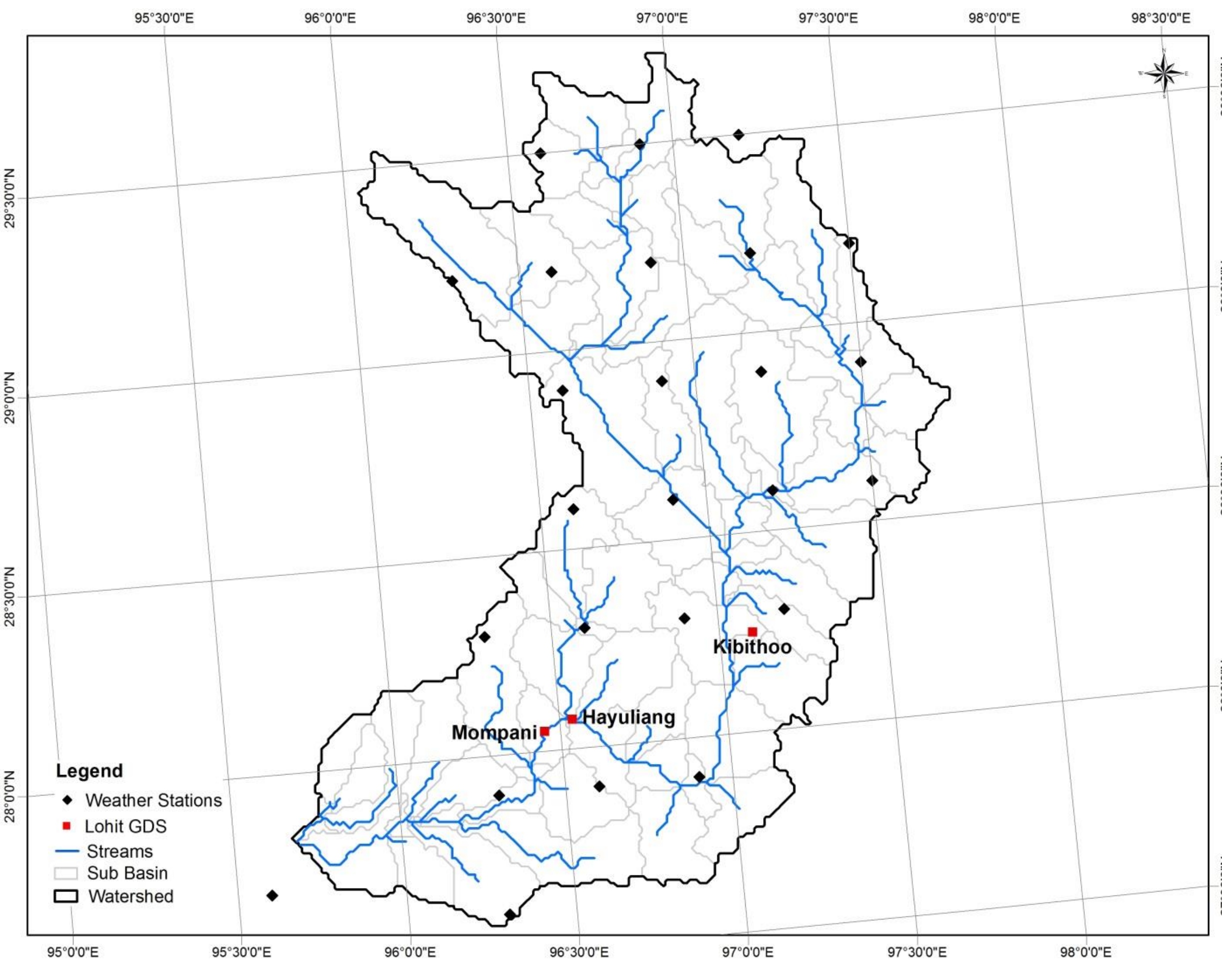


Figure 3.1 : Lohit Basin

3.2 SUB BASIN CHARACTERISTICS

3.2.1 Topography

The Lohit river has a length of 413 km from its source in Tibet to its confluence with the Dihang near Kobo. Out of 243 km length in India, 111km lies in the hilly terrain and the balance of 132 km lies in the plain. The basin is curvilinear in shape with uniform width. There is wide variation in elevation ranging from 6190 m at the source to 76 m at the outlet. About 80% of the catchment lies above 2000m and 10% lies above 5000 m. The upper reaches is characterized by hills with steep gorges, deep rugged valleys of dentritic pattern, water falls and rapids with streams feeding the tributaries of the Lohit river system. As River Lohit enters the state of Arunachal Pradesh after traversing through Tibet, it flows through Mishmi hills. Rivers Dau, Dalai and Tidding are its major tributaries on the right bank and river Lang is the major tributary on the left bank. After descending from the gorges of Mishmi hills into the plains near Brahamkund, it flows in a westerly direction. It meets Noa-Dihing, Kamlang, Tabang and Tengapani River on the left bank and Digaru, Balijan and Kundli on the right bank. River Lohit is then joined by river Dibang, another important tributary of river Brahmaputra on its right bank and combined flow confluences with river Dihang near Kobo.

3.2.2 Precipitation

At- site or Gridded precipitation data is not available for Lohit sub-basin from any Indian source. Spatial modeling has therefore been done using Global precipitation data of ***NCEP-CFSR*** available from ***http://globalweather.tamu.edu/home***. The analysis of Gridded data indicate high spatial variability of precipitation. An isohyetal map has been developed from annual precipitation averaged over a period from 1985-86 to 2004-05 (refer ***Figure 3.2***). The map shows a marked variation in precipitation with values ranging from 300mm in the Central East to 5000mm in the South East of the sub-basin. The snowfall mainly occurs in the higher reaches in north and central area as seen from ***Figure 3.3*** .

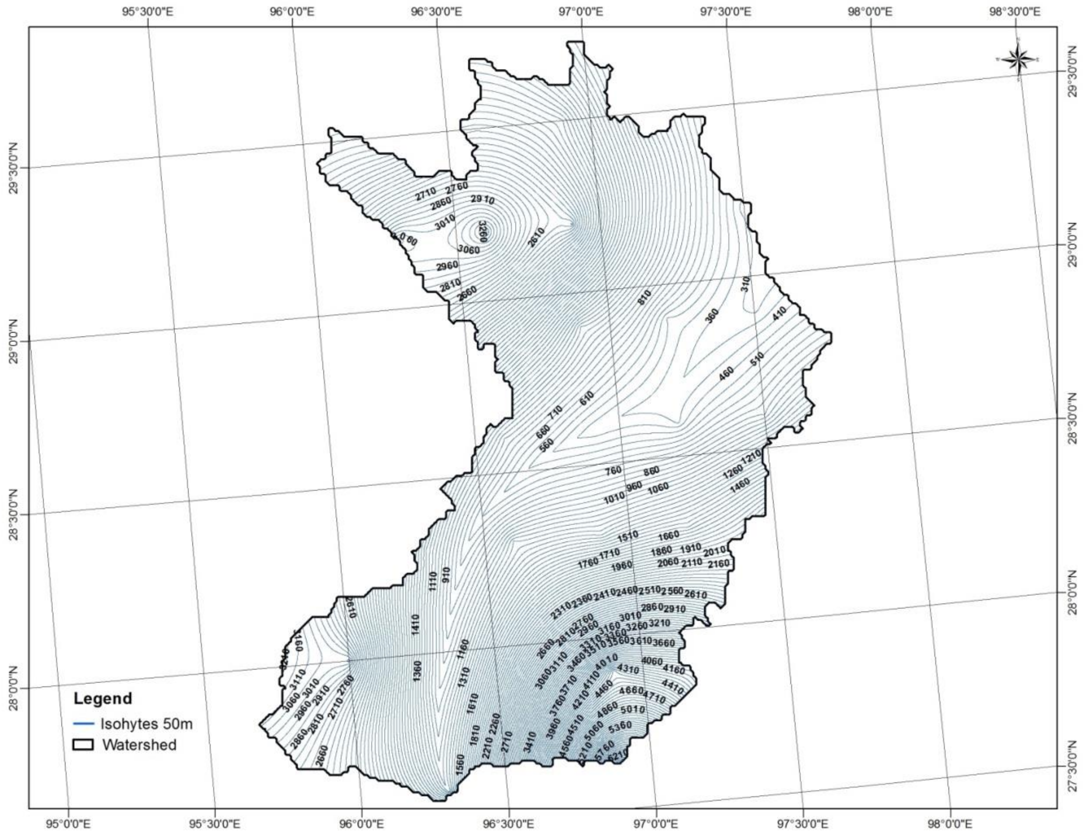


Figure 3. 2: Isohyetal Map of Lohit basin

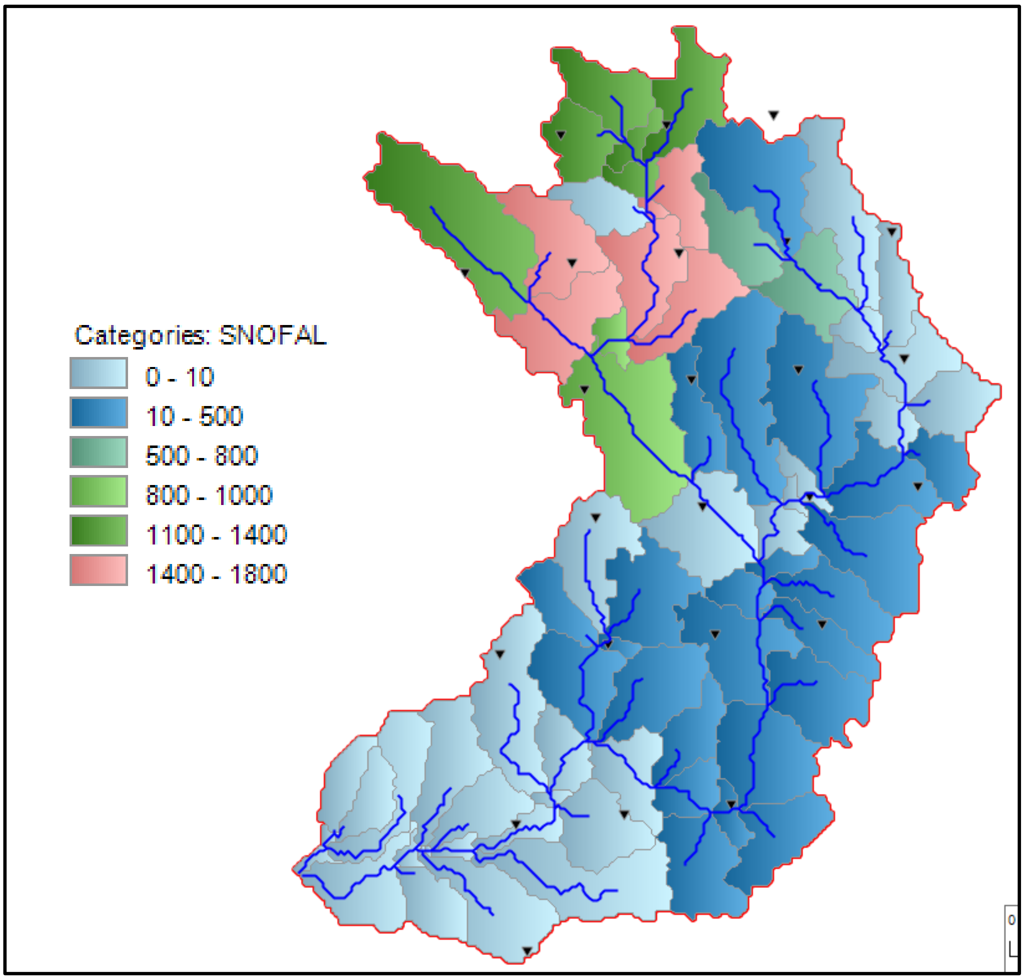


Figure 3.3: HRU wise distributed snowfall (mm) developed in MWSWAT for Lohit basin

The monthly variation of snow and precipitation as seen from *Figure 3.4* reveal that precipitation occurs in Winter Season (December to February) mostly in the form of snow. In the pre-monsoon season (March to May), 25% of precipitation occurs of which snowfall contribution is 49%. The monsoon season (June to September) receives the highest precipitation of 57% with only 2% snowfall in the upper reaches. The post-monsoon season experiences little precipitation to the order of 8.5%.

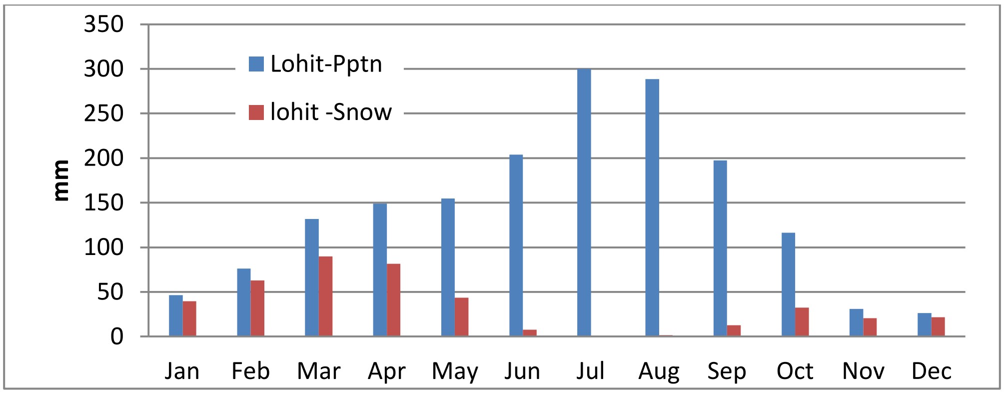


Figure 3.4 : Monthly average Precipitation and snowfall in Lohit catchment

The Lohit sub-basin received average annual precipitation (***period from 1985-86 to 2004-05)*** of 1741mm (Refer ***Figure 3.5***). The average snowfall in the same duration occurring in the catchment is 418 mm which is about 24% of the total precipitation. The maximum precipitation received is 2342mm in 1989-90 and 1357 mm in 1987-88

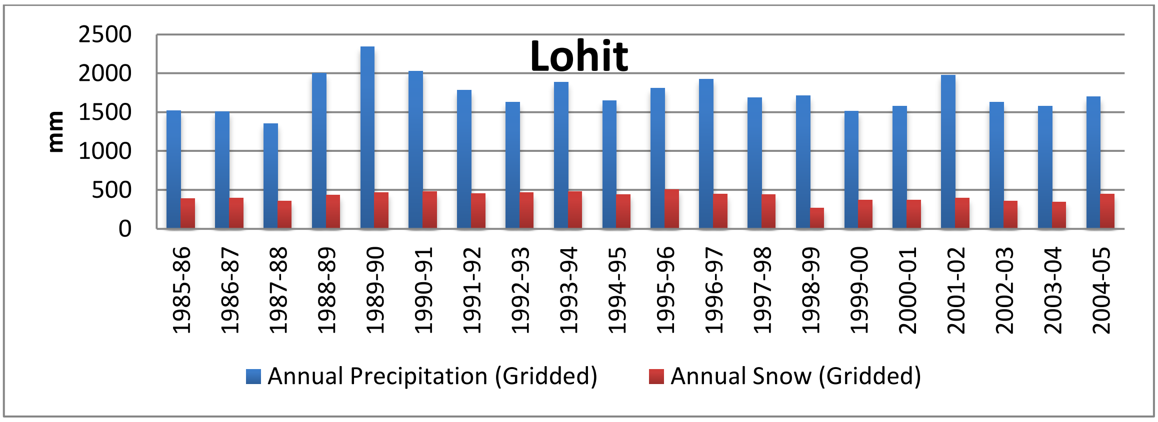


Figure 3.5 : Annual Average Precipitation and snowfall in Lohit catchment

For the Lohit sub-basin lying within the Indian boundary, the precipitation received is mostly in the form of rainfall. The normal value is 1895 mm out of which 73% occurs in the monsoon. The maximum precipitation is 2581mm received in 1989-90 and 1378 mm in 1987-88. The average annual snowfall is 51 mm (2.7% of total precipitation).

3.2.3 Soil

The soil of Lohit sub-basin is predominantly Loamy in the upper reaches The lower reaches have clay loam and sandy clay loam soil cover. The map covering the sub-basin with soil Classification is shown in ***Figure 3.6*** :

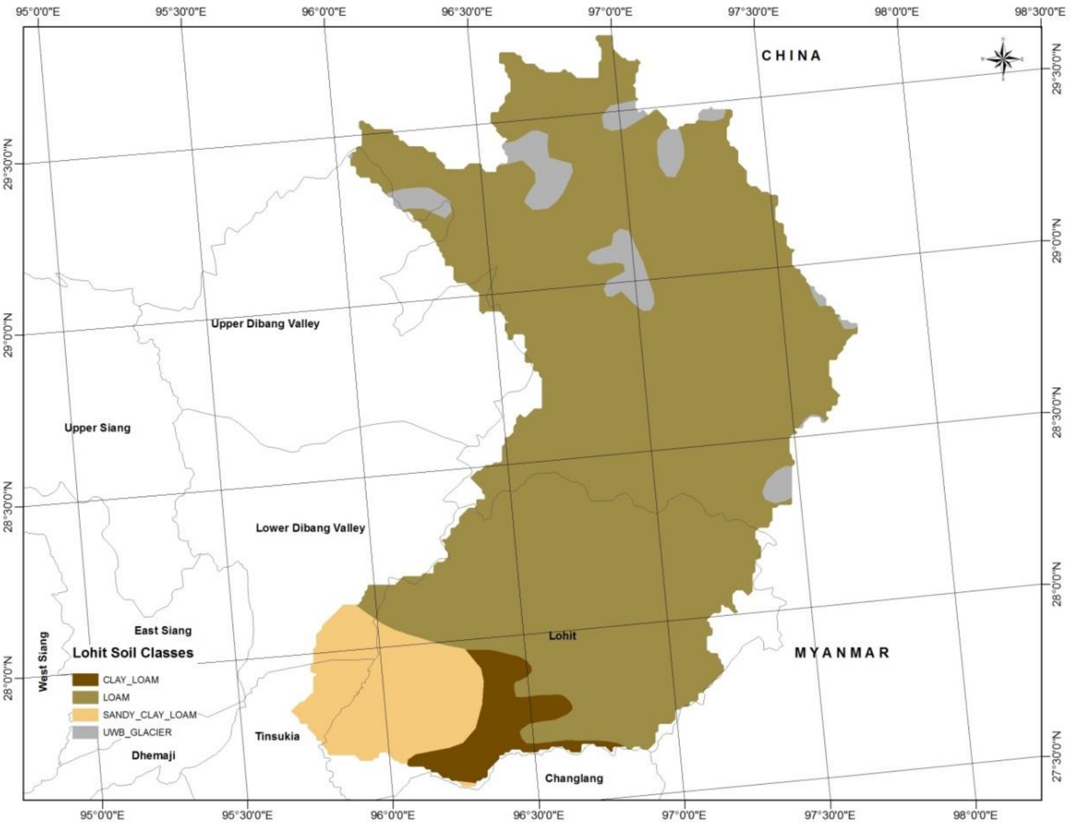


Figure 3.6: Soil map of Lohit basin

3.2.4 Landuse

Referring to the landuse spatial distribution as indicated in ***Figure .3.7***, the forest land coverage in the Lohit sub-basin is 49% and 7% of the area belongs to agricultural land category. The % distribution is shown in ***Table 3.1***.

Table 3. 1: Land use Classification for Lohit Sub basin

Sl. No.	Land use classification	% of total basin area
1	Built up land	0.00
2	Forest	49.0
3	Pasture and grassland, grazing land	36.6
4	Agriculture	7
5	Barren/Sparsely Vegetated	3.7
6	Water bodies	3.7
	Total	100

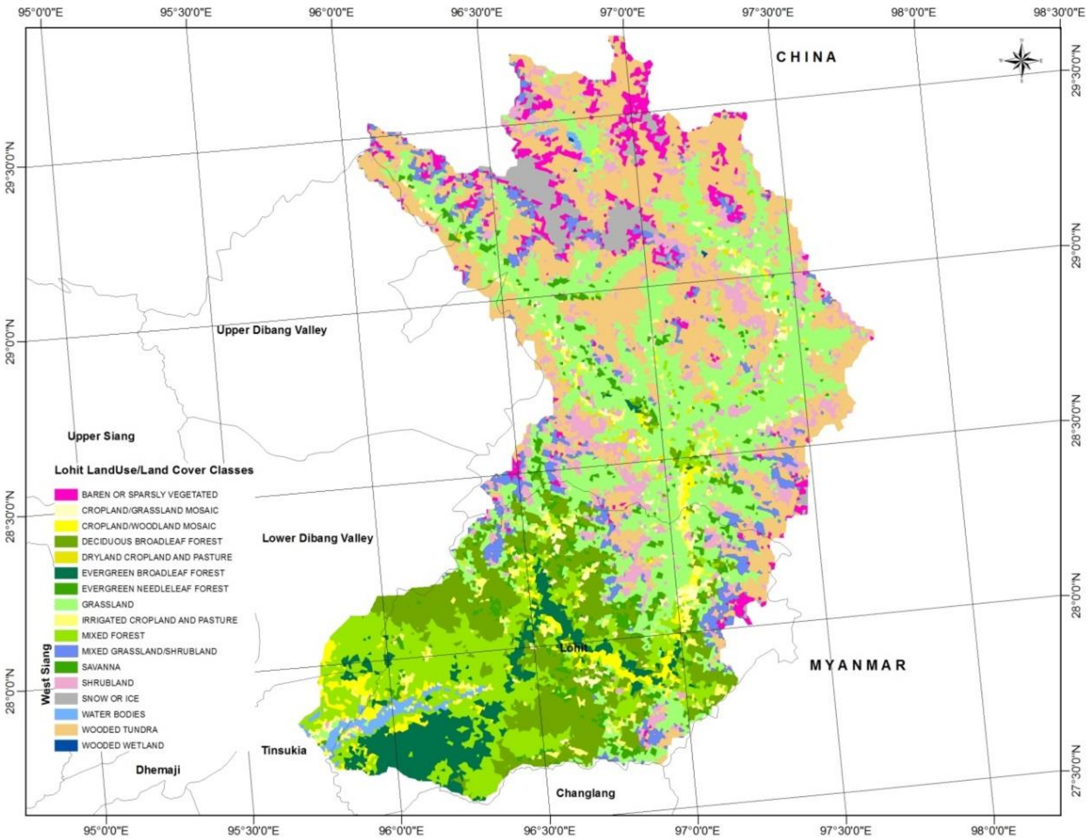
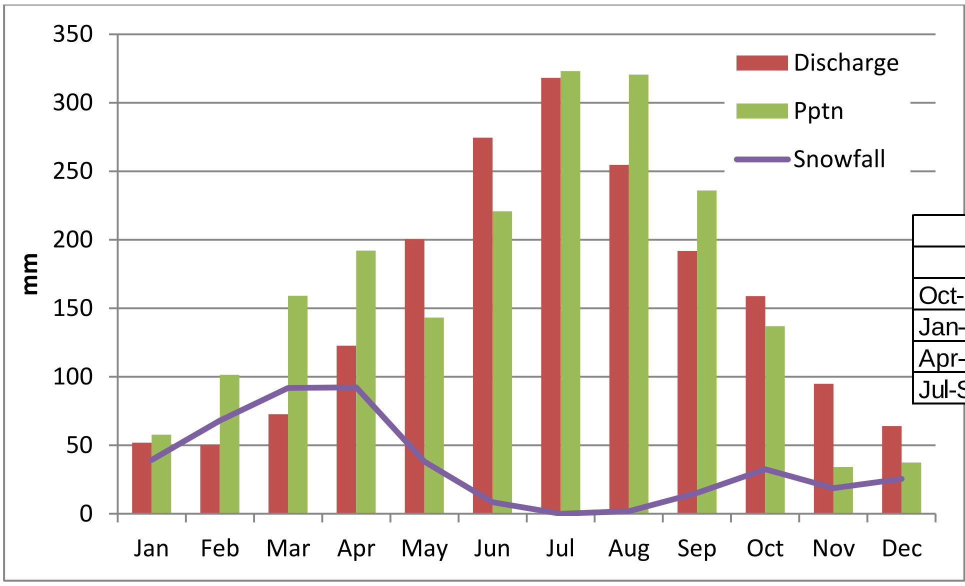


Figure 3.7 : Landuse and Landcover map of Lohit basin

3.2.5 Natural flow data

10-day discharge is available at Hayuliang G&D stations of catchment area 17600 sq km. from January 1985 to December 1993. Further downstream, 10 day flow is available at Mompani G&D station with catchment area 18947 sq km ,from January 1987 to December 2004. A detailed analysis of Mompani and Hayuliang series show that the average annual flow for the common period at Hayuliang and Mompani are 35040 M cu m and 44243 M cu m respectively . The differential flow volume works out to 9202 M cu m equivalent to 6831 mm depth, which qualifies for further investigation before adopting for any calibration. Hayuliang has therefore been considered for calibration.

A monthly analysis of flow and areal averaged precipitation at Hayuliang as shown in ***Figure 3.8*** highlights the temporal variability in discharge. The snowmelt contribution starts from March and continues till June/July followed by glacial melt. The pre-monsoon season experiences high flow due to snow melt. During monsoon, the flow contribution enhances in response to heavy rainfall. During winter, snowmelt contribution to flow is less as melting conditions are not adequate. Flow occurs mostly from sub-surface discharge.



	Flow %	Precipitation %
Oct-Dec	17.1	10.6
Jan-Mar	9.4	16.2
Apr-Jun	32.2	28.3
Jul-Sept	41.2	44.8

Figure 3.8 : Monthly Precipitation and flow at Hayuliang : Lohit basin

However, with limited length of data available, the complete series from 1985 to 1993 is analysed under calibration time period. The model simulation has been carried out from 1985 to 2005 for data-set generation. There is no significant utilization /import/Export in the catchment during the simulation period.

3.3 RESULTS AND ANALYSIS

The model performance criteria values (R^2 and NSI) have been shown in ***Table 3.2.*** The output results for Lohit sub-basin simulation are presented in ***Figure 3.9, Figure 3.10*** and ***Table 3.4*** in terms of comparison of simulated and observed natural flows which shows a moderately acceptable result which leaves scope for further improvement. The limitations of the model lies in inadequate representation of precipitation which is completely dependant on Global information source. A better representation of Lohit Indian part of the catchment can be achieved when concurrent flow series for Kibithoo and downstream flow station at Hayuliang is available for adequate period of time along with precipitation records in the basin.

Table 3. 2: Model Performance Comparisons For Simulation Of Flows: Lohit Sub Basin

Component	Model performance (Calibration)		Model performance (Validation)	
	R^2	Nash and Sutcliffe	R^2	Nash and Sutcliffe
Monthly Stream flow at Hayuliang	0.76	0.71	-	-

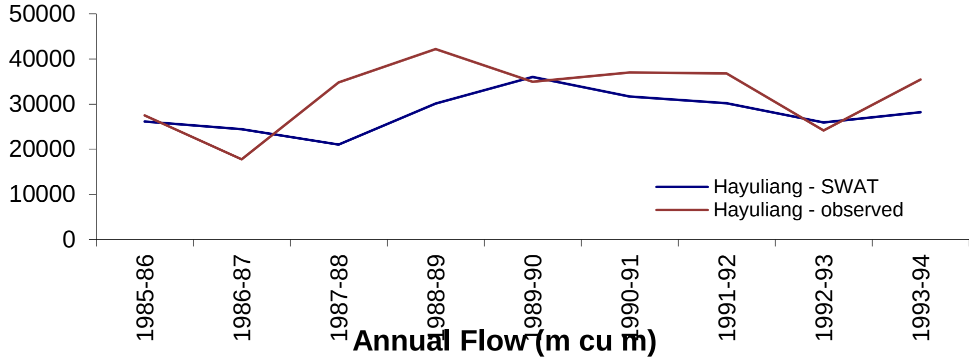


Figure 3. 9: Plot of Observed and Simulated Annual Flow at Hayuliang in Lohit Basin

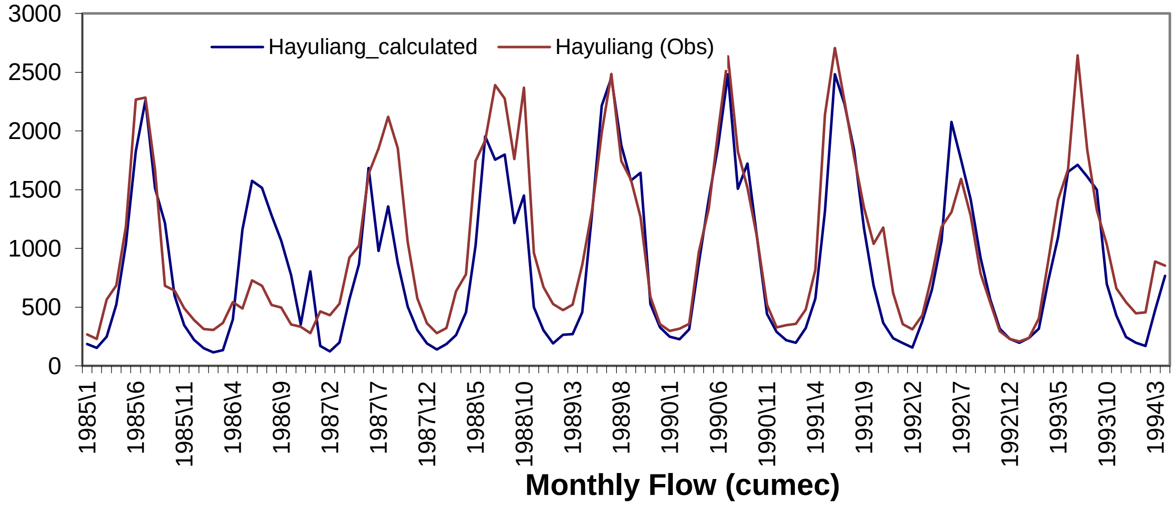


Figure 3. 10 : Comparison of Monthly observed Flow at Hayuliang and SWAT Flow in Lohit Sub Basin

Snowmelt contribution

The percentage of snow-covered area with respect to the total drainage area changes with location. The average snow and glacial contribution to the annual flow of Lohit at Hayuliang is assessed using the water balance approach (long term averaged value) as outlined in the Report ***Snow and Glacier contribution in the Satluj river at Bhakra Dam by NIH*** given by :

snow and glacial runoff = observed flow – (Rainfall-Evapotranspiration)

where, losses from rain and snowmelt in the form of infiltration is reflected within a period of 10 years for volume computation. Therefore, baseflow is not considered separately in the Water Balance. The Components calculated at Hayuliang is Tabulated as :

Runoff	Rainfall	Evapo-transpiration loss	Rain contribution to runoff		Snow and glacier contribution to runoff	
mm	mm	mm	mm	%	mm	%
1854.4	1373.9	316	1057.9	57.0	796.6	43.0

The analysis indicate that the Snow and Glacier contribution is about 43% at Hayuliang. It is further stated that Lohit will have higher snowmelt contribution in the flow at locations upstream of Hayuliang.

Notwithstanding the limited calibration results achieved in modeling the Lohit catchment, generated data sets of all the 74 sub-basins of Lohit basin have been considered for development of Empirical Equations. The data-set is appended in a tabular form as ***Annexure 3.1***. The precipitation and yield values in this table are average values for the period 1985-2005 derived from SWAT database. The statistical characteristics of the dataset are shown in ***Table 3.3***. The calibration parameters for each of the sub-basin and HRU's are provided in ***Appendix 2***. The precipitation and yield values in this table are 20 year average values for the period 1985-86 to 2004-05 derived from SWAT database. These datasets from 1985-86 to 2004-05 are further applied in Cluster Analysis and subsequent development of Empirical Equations after dividing them into calibration and validation period .

Table 3. 3: Statistical Characteristics of SWAT Dataset in Lohit Basin

	Natural flow mm	Average Temp °C	Average Precipitation mm	Forest Area %	Cropped Area %	Relief m	Unit Area sq.km.	Snowfall mm
Mean	1226	5.1	1655	84.58	9.11	2399.74	333.86	358.8
Min.	0	-5.8	279	20.00	0.00	57.00	3.57	0.0
Max.	4000	19.9	4461	100.00	42.11	4636.00	1009.80	1620.7
SD.	1177	8.3	1170	16.39	9.77	1156.57	233.35	476.28

Table 3. 4: Comparison of Runoff and Weighted Precipitation for Lohit Sub Basin

Lohit : Hayuliang G&D site

Catchment Area : 17600 sq km

S. No.	Year	Observed Runoff	Observed Monsoon Runoff	Monsoon Runoff SWAT	Observed Runoff	Observed Monsoon Runoff	Monsoon Runoff SWAT	Weighted Annual Precipitation SWAT	Weighted Monsoon Precipitation SWAT	Annual Snowfall in Lohit
		(MCM)	(MCM)	(MCM)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
1	1985-86	27449.8	19937.6	19608	1560	1133	1114	1766.6	1162.9	393.9
2	1986-87	17771.0	7345.6	16417	1010	417	933	1730.4	1103.4	397.7
3	1987-88	34822.5	22505.9	14283	1979	1279	812	1548.4	901.4	362.1
4	1988-89	42197.0	28318.0	21612	2398	1609	1228	2140.6	1418.8	435.7
5	1989-90	34928.1	23981.5	25823	1985	1363	1467	2572.3	1676.7	466.9
6	1990-91	36989.0	24013.5	22967	2102	1364	1305	2205.7	1383.4	480.6
7	1991-92	36827.6	24124.4	22211	2092	1371	1262	2032.7	1253.5	457.1
8	1992-93	24176.6	14555.5	17811	1374	827	1012	1811.4	1074.5	468.1
9	1993-94	35445.8	22504.7	18967	2014	1279	1078	2005.2	1160.4	477.9
	AVERAGE	32290	20810	19966	1835	1182	1134	1979	1237	438

3.4 CLUSTERING PROCEDURE AND ESTIMATING NUMBER OF CLUSTERS

3.4.1 Analysis of Data

Seven dimensions viz. natural flow (mm), precipitation (mm), percentage cropped area, percentage forest area, mean temperature (^{0}C), relief (m), catchment area (km^2) and snowfall (mm) have been used as clustering variables. Multiple regression analysis was undertaken on the data set of 74 sub-basins. The correlation matrix of these variables with average natural runoff is shown in ***Table 3.5***. The multiple R obtained was 0.976, and R^2 is 0.95.

Table 3. 5: Correlation Matrix and Regression Statistics of Parameters used in Clustering

	Natural flow mm	Avg. Temp. (^{0}C)	Avg. Precip. (mm)	Forest Area (%)	Cropped Area (%)	*Relief, m*	*Unit Area, sq.km.*	*SNFL, mm*
Natural flow mm	1.000							
Avg. Temp. (^{0}C)	-0.225	1.000						
Avg. Precip. (mm)	0.940	-0.127	1.000					
Forest Area (%)	0.187	-0.342	0.013	1.000				
Cropped Area (%)	-0.091	0.402	-0.062	-0.525	1.000			
Relief, (m)	0.378	-0.316	0.317	0.496	-0.187	1.000		
Unit Area, (sq.km.)	0.167	-0.253	0.107	0.419	-0.313	0.604	1.000	
Snowfall,(mm)	0.500	-0.727	0.365	0.193	-0.388	0.141	0.179	1.000

Regression Statistics	
Multiple R	0.976
R Square	0.953
Adjusted R Square	0.948
Standard Error	266.487
Observations	74

3.4.2 Standardisation

The principal components are dependent on the units used to measure the original variables as well as range of values that they assume. Data should always be standardized prior to using PCA. A common standardization method is to transform all the data to have zero mean and unit standard deviation by applying the relation $(x_i-\mu)/\sigma$, where μ and σ are the mean and standard deviation of x_i's.

3.4.3 Computation of covariance matrix

Covariance matrix is a matrix with all possible covariance values between the different dimensions. If there is an *n* dimensional dataset, then the matrix has n rows and *n* columns (so is square) and each entry in the matrix is the result of calculating the covariance between two separate dimensions. For the present case a '7 x 7' matrix is obtained by using Data Analysis Tool Add-in in excel (***Table 3.6***).

Table 3. 6: Covariance matrix dataset

	Avg. Temp. (^{0}C)	Avg. Precip. (mm)	Forest Area (%)	Cropped Area (%)	Relief, (m)	Unit Area, (sq.km.)	Snowfall (mm)
Avg. Temp. (^{0}C)	0.986	-0.126	-0.338	0.395	-0.313	-0.249	-0.716
Avg. Precip. (mm)	-0.126	0.986	0.012	-0.061	0.312	0.106	0.360
Forest Area (%)	-0.338	0.012	0.986	-0.518	0.489	0.414	0.190
Cropped Area (%)	0.395	-0.061	-0.518	0.986	-0.185	-0.308	-0.383
Relief, (m)	-0.313	0.312	0.489	-0.185	0.986	0.595	0.139
Unit Area, (sq.km.)	-0.249	0.106	0.414	-0.308	0.595	0.986	0.177
Snowfall,(mm)	-0.716	0.360	0.190	-0.383	0.139	0.177	0.986

3.4.4 Computation of eigenvalues and eigenvector of covariance matrix

The eigenvectors of a square matrix are the non-zero vectors that, after being multiplied by the matrix, remain parallel to the original vector. For each eigenvector, the corresponding eigenvalue is the factor by which the eigenvector is scaled when multiplied by the matrix. Eigenvectors are for square matrices only and there are n eigenvectors for an n x n matrix.

The mathematical expression of this idea is as follows: if A is a square matrix, a non-zero vector v is an eigenvector of A if there is a scalar λ (lambda) such that $AV = \lambda v$

The scalar λ (lambda) is said to be the eigenvalue of A corresponding to v. For the present analysis the Eigenvalues shown in ***Table 3.7*** were considered. STATA has been used for Eigen's calculation.

Table 3. 7: Eigenvalues of dataset

	Eigenvalues	Difference	Proportion	Cumulative
Comp 1	2.878	1.5690	0.4170	0.4170
Comp 2	1.309	0.2100	0.1897	0.6066
Comp 3	1.099	0.4370	0.1592	0.7659
Comp 4	0.662	0.1640	0.0959	0.8618
Comp 5	0.498	0.2100	0.0722	0.9339
Comp 6	0.288	0.1200	0.0417	0.9757
Comp 7	0.168		0.0243	1.0000
Sum	**6.902**			

Table 3. 8: Eigenvector of dataset

Variables	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6	Comp 7

Avg. Temp. (^{0}C)	-0.431	0.377	0.170	0.455	-0.225	-0.248	0.569
Avg. Precip. (mm)	0.204	-0.271	0.732	0.495	0.008	-0.079	-0.312
Forest Area (%)	0.410	0.336	-0.272	0.278	0.530	-0.530	-0.074
Cropped Area (%)	-0.388	0.034	0.440	-0.574	0.354	-0.445	-0.042
Relied (m)	0.398	0.392	0.385	-0.186	0.296	0.500	0.409
Unit Area (sq km)	0.382	0.423	0.140	-0.292	-0.666	-0.299	-0.193
Snowfall (mm)	0.387	-0.581	-0.001	-0.146	-0.108	-0.337	0.605

3.4.5 Choosing components

After eigenvectors are found from the covariance matrix, the next step is to order them by eigenvalues, highest to lowest. This arranges the components in order of significance, which helps in deciding to ignore the components of less significance. To be precise, if the original data have (D) dimensions, there will be (D) eigenvectors and eigenvalues, and if one choose only the first d eigenvector, then the final data set has only (d) dimensions. For the present analysis, 6 eigenvalues are taken.

3.4.6 Deriving new data set

The standardized data series is multiplied with the chosen eigenvectors to derive principal components as shown in ***Table 3.9***.

Table 3.9: new generated data set

Sub basins	PC1	PC2	PC3	PC4	PC5	PC6	PC7
1	1.654	-1.577	-0.888	0.099	-0.460	-0.811	-0.261
2	1.691	-1.892	-0.797	0.265	-0.193	-0.844	-0.204
3	1.436	-2.138	-0.694	0.222	-0.230	-0.465	-0.082
4	1.452	-2.508	-0.350	0.285	-0.314	-0.409	0.066
5	1.418	0.437	-0.902	-0.647	-0.896	-0.139	-0.408
6	3.150	-0.091	1.051	-0.473	-1.646	-1.059	-0.176
7	-0.152	-1.412	0.970	0.343	-0.888	2.063	-1.426
8	0.932	0.993	-1.432	-0.451	-0.316	0.078	-0.587
9	1.169	-0.248	-0.850	-0.334	0.255	0.431	-0.016
10	2.942	-1.689	1.315	-0.280	-0.307	0.536	1.056
11	2.326	-1.634	0.342	-0.168	-0.242	0.247	0.617
12	0.391	0.374	-1.724	0.025	0.585	0.386	-0.389
13	2.167	1.196	-0.120	-1.135	-0.904	-0.057	-0.145
14	1.626	1.323	-1.046	-0.854	-0.841	-0.148	-0.618
15	0.423	0.355	-1.697	-0.103	0.413	0.252	-0.543
16	1.339	0.127	-0.811	-0.122	0.597	0.435	0.141
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
62	0.554	0.502	2.918	0.168	-0.154	-0.257	-0.580

Sub basins	PC1	PC2	PC3	PC4	PC5	PC6	PC7
63	-0.595	-0.625	2.550	0.710	1.065	0.056	-0.407
64	-0.824	-0.544	2.992	0.120	0.810	-0.146	-0.483
65	-0.904	0.608	1.648	-0.073	0.336	-0.107	-0.080
66	-0.834	-0.411	-0.681	2.373	0.582	-0.418	-0.648
67	-0.616	1.295	-0.395	0.898	0.327	0.104	0.723
68	-1.611	0.384	-0.858	1.214	0.558	-0.290	0.381
69	-1.486	0.612	-0.477	0.816	0.202	-0.096	0.471
70	-3.005	-0.736	-0.583	0.658	-0.874	0.155	0.057
71	-5.197	-1.489	1.322	-1.644	-0.868	0.041	0.121
72	-3.487	-1.528	-0.563	0.792	-2.154	1.701	0.270
73	-3.452	-1.161	-0.346	0.437	-1.517	0.845	0.152
74	-2.835	-0.005	0.223	-0.518	-1.518	-0.723	-0.236

3.5 K-MEANS CLUSTERING

K-means is a prototype-based, simple partitioned clustering technique which attempts to find a user-specified k number of clusters. These clusters are represented by their centroids. A cluster centroid is typically the mean of the points in the cluster. The algorithm consists of two separate phases: the first phase is to select k centers randomly, where the value k is fixed in advance. The next phase is to assign each data object to the nearest centers. Euclidean distance is generally considered to determine the distance between each data object and the cluster centers. The iterative process continues repeatedly until the criterion function becomes minimum (Tajunisha & Saravanan 2011).

Step 1: Dimension reduction and finding initial centroid using PCA

Step 2 : Assigning data-points to clusters

vii) Compute the distance of each data-point p_i ($1 \le i \le n$) to all the centroids q_j ($1 \le j \le k$) using Euclidean distance formula.

In general, for (d) dimensional space, the Euclidean distance is calculated as

$$ED(p,q) = \sqrt{(p_{1-}\ q_1)^2 + (p_{2-}\ q_2)^2 + \cdots + \cdots (p_{d-}\ q_d)^2}$$

ii) For each data object p_i, find the closest centroid q_j and assign p_i to the cluster with the nearest centroid q_j.

Table 3. 10: Computation of sum of minimum distance

Sub basins	Dist. To centroid -1	Dist. To centroid-2	Dist. To centroid -3	Cluster	Min Dist.

Sub basins	Dist. To centroid -1	Dist. To centroid-2	Dist. To centroid -3	Cluster	Min Dist.
1	4.144	2.994	2.307	Cluster 3	2.307
2	4.278	3.274	2.714	Cluster 3	2.714
3	4.177	3.323	2.842	Cluster 3	2.842
4	4.418	3.643	3.237	Cluster 3	3.237
5	3.618	1.578	0.006	Cluster 3	0.006
6	5.591	3.527	2.930	Cluster 3	2.930
7	4.216	3.809	4.034	Cluster 2	3.809
8	3.193	1.519	1.132	Cluster 3	1.132
9	3.173	1.738	1.559	Cluster 3	1.559
10	5.550	4.096	3.851	Cluster 3	3.851
11	4.687	3.300	2.917	Cluster 3	2.917
12	2.663	2.006	2.157	Cluster 2	2.006
13	4.431	2.051	1.436	Cluster 3	1.436
14	3.991	1.839	0.969	Cluster 3	0.969
15	2.730	1.911	1.951	Cluster 2	1.911
16	3.174	1.721	1.800	Cluster 2	1.721
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
62	4.196	3.127	4.076	Cluster 2	3.127
63	3.625	3.658	4.777	Cluster 1	3.625
64	3.956	3.863	4.966	Cluster 2	3.863
65	2.457	2.343	3.727	Cluster 2	2.343
66	2.348	3.408	4.158	Cluster 1	2.348
67	1.207	1.914	3.218	Cluster 1	1.207
68	0.731	2.857	3.925	Cluster 1	0.731
69	0.056	2.386	3.574	Cluster 1	0.056
70	2.319	4.066	4.802	Cluster 1	2.319
71	5.324	6.549	7.329	Cluster 1	5.324
72	4.143	5.508	5.963	Cluster 1	4.143
73	3.299	4.809	5.426	Cluster 1	3.299
SUM					158.253

iii) In K-means algorithm the objective is to minimise the sum of minimum distance i.e., distances to the nearest cluster centers.

$$\sum_{j=1}^{k}\sum_{i=1}^{n}[x_i^j - c_j]^2 \ldots\ldots\ldots\ldots\ldots\ldots$$

where , x_i^j is the data point belonging to the cluster j and c_j is the cluster center.

iv) The minimization is done with the help of 'Solver' tool available with MS-Excel. A 'Solver' basically solves an optimization problem (minimization or maximization problem) subjected to a set of constraints.. Here the objective function is to minimize distance by changing the cluster centroid. The minimum distance derived and allocation of cluster membership to individual sub-basins for k=3 can be seen in ***Table 3.10*** The coordinates of the new centroid for the same, are shown in the ***Table 3.12 .***

v) Continue to follow the steps from i) to iv) for various values of k i.e., k=1, 2, 3, 4, 5, 6 etc. and plot a graph between k (x-axis) and optimized sum of the results of clusters (encircled in ***Table 3.11)***

vi) Finally choose the number of clusters based on the point that shows a sudden change in the slope of the curve (as depicted by arrow corresponding to k=3 in ***Figure 3.8***).

Table 3. 11: Optimized results of clusters

Sub basins	Dist. To centroid -1	Dist. To centroid-2	Dist. To centroid -3	Cluster	Min Dist.
1	4.103	2.853	0.938	Cluster 3	0.938
2	4.227	3.107	0.747	Cluster 3	0.747
3	4.068	3.137	0.443	Cluster 3	0.443
4	4.247	3.473	0.605	Cluster 3	0.605
5	3.693	1.559	2.749	Cluster 2	1.559
6	5.507	3.637	3.384	Cluster 3	3.384
7	3.799	3.720	3.669	Cluster 3	3.669
8	3.454	1.393	3.348	Cluster 2	1.393
9	3.262	1.356	2.065	Cluster 2	1.356
10	5.412	3.943	2.617	Cluster 3	2.617
11	4.587	3.103	1.412	Cluster 3	1.412
12	3.028	1.665	3.132	Cluster 2	1.665
13	4.477	2.118	3.586	Cluster 2	2.118
14	4.156	1.877	3.646	Cluster 2	1.877
15	3.023	1.609	3.068	Cluster 2	1.609
16	3.407	1.277	2.401	Cluster 2	1.277
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Sub basins	Dist. To centroid -1	Dist. To centroid-2	Dist. To centroid -3	Cluster	Min Dist.
62	3.827	3.314	4.286	Cluster 2	3.314
63	3.127	3.675	4.129	Cluster 1	3.127
64	3.270	3.956	4.501	Cluster 1	3.270
65	1.936	2.521	4.136	Cluster 1	1.936
66	2.860	3.302	3.737	Cluster 1	2.860
67	2.132	1.888	4.077	Cluster 2	1.888
68	1.649	2.817	4.166	Cluster 1	1.649
69	1.235	2.409	4.072	Cluster 1	1.235
70	1.990	4.140	4.828	Cluster 1	1.990
71	4.355	6.713	7.262	Cluster 1	4.355
72	3.881	5.542	5.845	Cluster 1	3.881
73	2.868	4.884	5.387	Cluster 1	2.868
74	2.115	4.037	5.112	Cluster 1	2.115
Sum					134.091

Table 3. 12: Coordinates of new centroid

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Median value -1	-1.855	0.057	0.082	0.023	0.150	-0.182	0.111
Median value -2	0.642	0.783	-0.299	-0.120	0.039	0.113	-0.046
Median value -3	1.553	-1.959	-0.384	0.190	-0.129	-0.309	0.057

3.5.1 Choosing number of Clusters for Lohit Basin

Following the above methodology for Lohit sub basin, ***Figure 3.11*** shows the selection of the number of clusters.

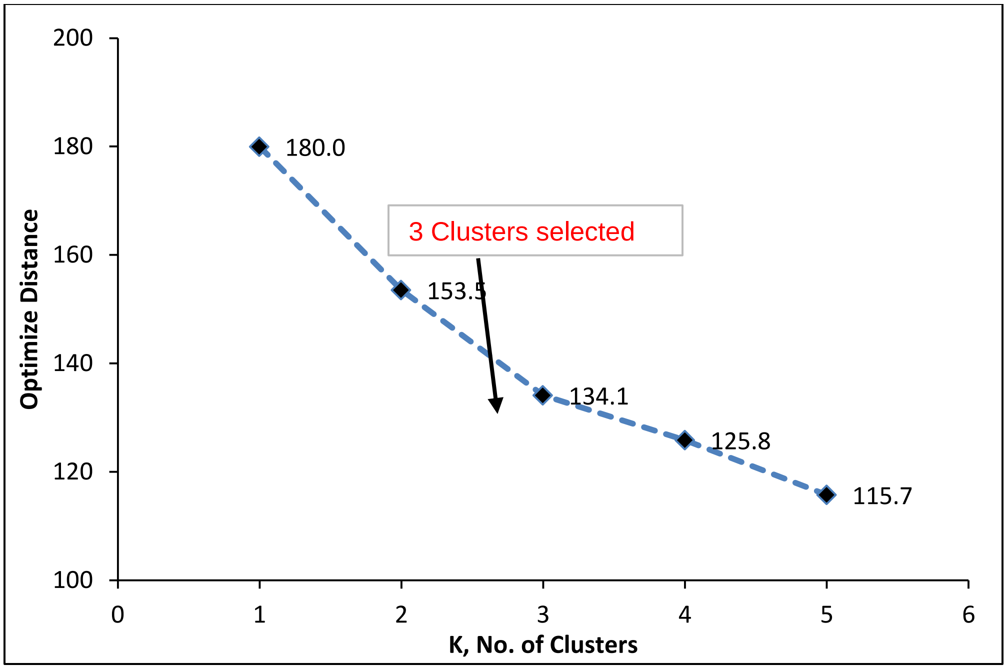


Figure 3. 11: Choosing number of clusters for Lohit basin

Given the above analysis, 3 clusters are selected for Lohit sub basin for formulation of empirical relationships using regression analysis.

3.5.2 Membership of formed clusters

All the 74 sub basins are identified to form 3 clusters of greatest possible distinction by using the 6 variable clustering schemes, chosen on the basis of Eigen values discussed in Sections 3.4.4 and 3.4.5.

The membership of Cluster formed by Cluster Analysis using K-means algorithm are shown in ***Tables 3.13***, ***Table 3.14, and Table 3.15*** and ***Figure 3.12***

Table 3.13: Cluster 1 dataset

Sub basins	Natural flow (mm)	Avg.Temp. (⁰C)	Avg. Precip. (mm)	Forest Area (%)	Cropped Area (%)	Relief, (m)	Unit Area, (sq.km.)	Snowfall (mm)
29	503.22	16.72	1009.30	84.20	14.01	2581.00	395.89	0.00
31	503.90	16.72	1009.30	82.95	10.41	2038.00	309.20	0.00
32	504.45	16.72	1009.30	80.09	19.91	1110.00	210.90	0.00
33	504.33	16.72	1009.30	76.35	23.66	1387.00	200.18	0.00
36	490.64	19.86	1223.42	93.62	5.67	396.00	252.01	0.00
39	515.13	16.72	1009.30	57.89	42.11	62.00	16.98	0.00
43	515.03	16.72	1009.30	67.50	7.50	61.00	35.75	0.00

Sub basins	Natural flow (mm)	Avg.Temp. (⁰C)	Avg. Precip. (mm)	Forest Area (%)	Cropped Area (%)	Relief, (m)	Unit Area, (sq.km.)	Snowfall (mm)
45	788.61	8.10	1243.56	79.60	20.41	2777.00	43.79	50.60
49	119.13	-1.93	308.66	74.64	25.38	1933.00	119.75	128.44
56	149.38	1.78	409.69	80.95	19.04	2119.00	37.53	169.97
57	149.86	1.78	409.69	77.97	22.04	2465.00	166.22	169.97
59	1141.51	3.64	1561.56	61.94	38.05	2455.00	100.98	418.81
60	878.95	5.64	1303.48	80.37	19.65	3002.00	150.13	208.64
63	3950.57	7.50	4460.79	78.25	21.74	3030.00	102.77	190.25
64	3967.99	7.50	4460.79	72.12	27.87	3045.00	201.96	190.25
65	2143.01	11.46	2658.62	78.11	21.89	3025.00	330.65	4.75
66	1992.93	11.46	2658.62	100.00	0.00	668.00	3.57	4.75
68	557.32	16.72	1009.30	92.11	7.89	1395.00	33.96	0.00
69	558.67	16.72	1009.30	85.81	9.25	1844.00	144.77	0.00
70	504.73	16.72	1009.30	56.89	10.35	101.00	51.83	0.00
71	0.00	16.72	1009.30	20.00	40.00	60.00	4.47	0.00
72	0.00	16.72	1009.30	25.00	0.00	57.00	3.57	0.00
73	0.00	16.72	1009.30	37.78	8.89	79.00	40.21	0.00
74	336.30	16.72	1009.30	55.53	21.70	254.00	420.01	0.00

Table 3.14: Cluster 2 dataset

Sub basins	Natural flow (mm)	Avg. Temp. (⁰C)	Avg. Precip. (mm)	Forest Area (%)	Cropped Area (%)	Relief, (m)	Unit Area, (sq.km.)	Snowfall (mm)
5	626.05	-2.27	861.65	91.53	1.30	2407.00	685.43	495.31
8	96.40	-1.19	279.36	97.95	1.10	2396.00	569.25	122.32
9	771.80	-3.74	1060.08	91.84	1.84	2847.00	339.59	579.69
12	96.28	-1.19	279.36	99.27	0.72	2215.00	247.54	122.32
13	821.09	-2.22	1082.82	93.94	4.32	3717.00	869.52	519.51
14	250.19	-2.30	465.01	98.32	1.67	2798.00	802.50	241.00
15	102.85	-1.93	308.66	98.53	1.48	2052.00	301.16	128.44
16	821.94	-2.22	1082.82	98.58	1.40	3261.00	318.14	519.51
17	474.29	-0.29	777.72	100.00	0.91	2371.00	224.31	285.16
18	513.49	5.01	892.55	97.26	2.73	3523.00	491.51	185.28
19	474.43	-0.29	777.72	94.61	2.92	2845.00	580.87	285.16
20	746.99	8.10	1243.56	95.70	4.30	3423.00	519.21	50.60
21	1132.13	3.64	1561.56	97.00	2.99	2858.00	387.84	418.81
22	1150.14	3.64	1561.56	94.66	5.33	2711.00	268.09	418.81
23	748.32	8.10	1243.56	93.31	6.69	3390.00	226.99	50.60
24	786.28	8.10	1243.56	93.08	6.92	4057.00	503.12	50.60
25	1153.86	3.64	1561.56	88.07	10.99	2809.00	479.89	418.81
26	801.46	11.27	1258.13	96.05	3.96	3996.00	654.15	4.91
27	3999.87	7.50	4460.79	95.95	4.07	3753.00	285.97	190.25
28	528.38	16.72	1009.30	90.74	7.64	3276.00	444.14	0.00
30	2175.23	11.46	2658.62	97.51	2.49	3367.00	394.10	4.75
34	3960.99	7.50	4460.79	90.96	9.05	3489.00	404.82	190.25

Sub basins	Natural flow (mm)	Avg. Temp. (⁰C)	Avg. Precip. (mm)	Forest Area (%)	Cropped Area (%)	Relief, (m)	Unit Area, (sq.km.)	Snowfall (mm)
35	3957.72	7.50	4460.79	90.19	9.81	3426.00	464.70	190.25
37	2155.96	11.46	2658.62	96.16	3.86	3902.00	695.26	4.75
38	630.94	19.86	1223.42	96.29	3.54	2184.00	529.93	0.00
41	785.21	-3.74	1060.08	88.25	10.20	2857.00	403.04	579.69
47	735.78	8.10	1243.56	85.18	14.83	3563.00	452.19	50.60
50	108.73	-1.93	308.66	91.04	8.72	2402.00	389.63	128.44
51	109.52	-1.93	308.66	89.75	10.25	2481.00	174.26	128.44
53	1795.21	-0.35	2043.00	89.76	10.25	3248.00	967.82	779.07
54	449.01	-0.29	777.72	91.03	8.96	2859.00	458.44	285.16
55	148.63	1.78	409.69	91.51	8.49	2275.00	94.73	169.97
58	193.04	3.54	452.00	85.73	14.26	2853.00	595.17	153.08
61	874.60	5.64	1303.48	91.92	8.08	2848.00	530.83	208.64
62	3910.81	7.50	4460.79	80.43	19.58	3670.00	584.45	190.25
67	526.43	16.72	1009.30	94.47	5.53	2850.00	242.18	0.00

Table 3. 15: Cluster 3 dataset

Sub basins	Natural flow (mm)	Avg. Temp. (⁰C)	Avg. Precip. (mm)	Forest Area (%)	Cropped Area (%)	Relief, (m)	Unit Area, (sq.km.)	Snowfall (mm)
1	1825.39	-5.31	2012.27	94.80	0.00	1278.00	429.84	1171.89
2	2131.18	-5.83	2280.70	96.20	0.25	1256.00	352.10	1262.59
3	2180.27	-5.83	2280.70	88.71	0.00	1347.00	285.07	1262.59
4	2501.26	-5.59	2673.50	84.13	0.34	1400.00	259.16	1401.21
6	3009.72	-2.31	3210.42	93.55	3.27	3117.00	1009.80	1199.85
7	0.00	-5.40	3419.83	49.10	0.00	2262.00	247.54	0.00
10	3296.68	-5.40	3419.83	79.32	0.79	4337.00	453.97	1620.70
11	2519.23	-5.59	2673.50	83.94	0.00	3269.00	394.99	1401.21
40	1881.20	-5.31	2012.27	88.60	0.00	1194.00	101.88	1171.89
42	1882.94	-5.31	2012.27	85.95	3.51	1235.00	101.88	1171.89
44	3315.85	-5.40	3419.83	90.56	4.64	4636.00	520.10	1620.70
46	2517.25	-5.59	2673.50	100.00	0.00	934.00	29.49	1401.21
48	2518.56	-5.59	2673.50	70.44	0.39	3993.00	459.34	1401.21
52	1766.90	-0.35	2043.00	97.40	2.61	2400.00	102.77	779.07

3.5.3 Correlation matrix development

After dividing the dataset into clusters and choosing the sub-basin which is part of the same cluster, a correlation matrix was computed for each of the clusters. The correlation matrix for each cluster is shown in ***Table 3.16, Table 3.17, Table 3.18.***

Table 3. 16: Correlation matrix of parameters of cluster 1

	Natural flow (mm)	*Avg.Temp. (⁰C)*	*Avg. Precip.*	*Forest Area (%)*	*Cropped Area (%)*	*Relief, (m)*	*Unit Area, (sq.km.)*	*Snowfall (mm)*

			(mm)					
Natural flow (mm)	1.000							
Avg.Temp. (⁰C)	-0.242	1.000						
Avg. Precip. (mm)	0.980	-0.119	1.000					
Forest Area (%)	0.291	-0.203	0.163	1.000				
Cropped Area (%)	0.123	-0.347	0.080	-0.276	1.000			
Relief, (m)	0.518	-0.638	0.400	0.510	0.229	1.000		
Unit Area, (sq.km.)	0.096	0.145	0.067	0.307	0.017	0.329	1.000	
Snowfall (mm)	0.354	-0.786	0.268	0.079	0.450	0.587	-0.098	1.000

Table 3. 17: Correlation matrix of parameters of cluster 2

	Natural flow (mm)	*Avg.Temp. (⁰C)*	*Avg. Precip. (mm)*	*Forest Area (%)*	*Cropped Area (%)*	*Relief, (m)*	*Unit Area, (sq.km.)*	*Snowfall (mm)*
Natural flow (mm)	1.000							
Avg.Temp. (⁰C)	0.309	1.000						
Avg. Precip. (mm)	0.996	0.380	1.000					
Forest Area (%)	-0.273	-0.037	-0.274	1.000				
Cropped Area (%)	0.318	0.150	0.326	-0.932	1.000			
Relief, (m)	0.544	0.401	0.570	-0.185	0.241	1.000		
Unit Area, (sq.km.)	0.099	-0.027	0.091	-0.138	0.068	0.354	1.000	
Snowfall (mm)	0.026	-0.659	-0.022	-0.132	-0.028	-0.126	0.264	1.000

Table 3. 18: Correlation matrix of parameters of cluster 3

	Natural flow (mm)	*Avg.Temp. (⁰C)*	*Avg. Precip. (mm)*	*Forest Area (%)*	*Cropped Area (%)*	*Relief, (m)*	*Unit Area, (sq.km.)*	*Snowfall (mm)*
Natural flow (mm)	1.000							
Avg.Temp. (⁰C)	-0.019	1.000						
Avg. Precip. (mm)	0.244	-0.097	1.000					
Forest Area (%)	0.521	0.289	-0.476	1.000				
Cropped Area (%)	0.346	0.472	0.210	0.242	1.000			
Relief, (m)	0.488	0.122	0.698	-0.291	0.406	1.000		
Unit Area, (sq.km.)	0.460	0.173	0.523	-0.004	0.323	0.568	1.000	
Snowfall (mm)	0.924	-0.289	0.002	0.546	0.137	0.274	0.228	1.000

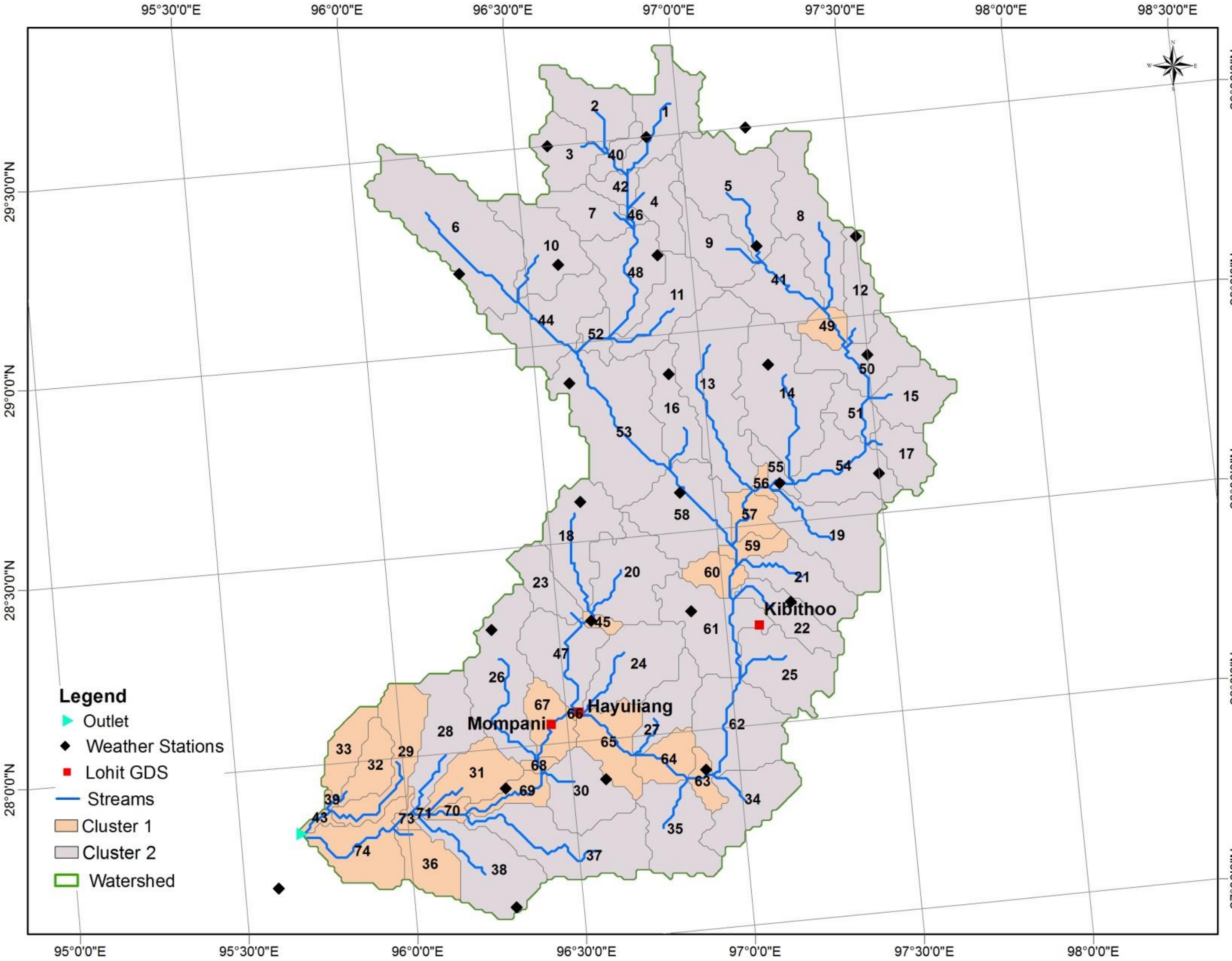


Figure 3. 12: Cluster wise map of Lohit basin

3.6 COMPUTATION OF EMPIRICAL EQUATION

Separate empirical equations have been computed for entire year (January to December). The approach considered for computation of empirical equations for the clusters of Lohit basin is detailed as below:

3.6.1 Approach For Month-wise Cluster-wise Equation Formulation

v. “Discharge”, “Precipitation”, “Temperature (max.)”, “Relief”, “% Crop Area”, “% Forest Area”, “Sub basin Area”, “Snowfall” and “Snowmelt” Parameters of each sub-basin of a cluster has been arranged month-wise.

vi. The correlation coefficient matrix for the above data has been derived.

vii. Calculate the parameters for the following equation (Equation 3.1), which has been chosen to relate the dependent variable "monthly discharge (Q_{sim})" with the independent variables namely “Precipitation” (PCP), “Temperature” (TEMP), “Relief”(RL), “% Crop Area”(%CA), “% Forest Area (%FA)” , “Snowfall”, and “Snowmelt” and “Sub basin Area/ Catchment area of the sub basin” (SA):

$Q_{sim} = \beta_1\times (PCP) + \beta_2\times(TEMP) + \beta_3\times(SA) + \beta_4\times(\%CA) + \beta_5\times (\%FA) + \beta_6\times (RL) - CONS$ ………………… (8.1)

where coefficient, β_{1-6} and CONS are the coefficients that has been determined, such that the root mean square error (RMSE) between the observed discharge and simulated discharge is minimum.

viii. Similarly, an empirical equation is computed for the entire monsoon season using the above steps (i) to (iii).

The results of the optimization for various months and monsoon season for Lohit basin are provided in sections below. For each month, a set of best 2 or 3 equations for each cluster, chosen in the order of importance/significant parameters are formulated. The criteria for selection are based on Coefficient of Determination, correlation coefficient, parameter significance estimated from p-value and t-statistic, sign conventions of independent variables with respect to dependant variables and the ease of applicability. The t-statistic is a measure of how strongly a particular independent variable explains variation in the dependant variable given by $t_i = b_i / se(b_i)$ where, b_i is the coefficient of the independent variable and $se(b_i)$ is its standard error . The larger the t-statistic, higher is the independent variables explanatory power in the equation. The p-value is used to interpret the t-stat. It is the probability that the independent variable is significant. For a p-value less than 0.05, it implies that there is a 5% chance that the independent variable is unrelated to dependant variable. If the p-value is higher thsn 0.1, this can be a strong reason to eliminate the independent variable from the model because it is not statistically significant.

3.6.2 Equation formulation

Based on the analysis as described in the preceding sections, the Empirical Equation derived is presented. The formulation is explained by Q_{SIM} = Discharge (mm); PCP = Total precipitation during the period/ month (mm); PCP1= Precipitation in the previous month ; PCP2= Precipitation in the 2nd previous month ; PCP3= Precipitation in the 3rd previous month; SNFL = Snowfall during the period ; SNMT = Snowmelt during the period ; TEMP = Average temperature during the month (^{0}C); SA = sub basin or catchment area (km^2); %CA = Percentage Cropped area; %FA = Percentage Forest area; RL = Relief i.e. difference between maximum and minimum elevation (m).

The flow computed using the Empirical relation at sample HRU's in each cluster has been shown in ***Annex 3.2*** at calibration period (1985-86 to 1999-00) and Validation period (2000-01 to 2004-05) for Lohit basin.

EQN NO	EQUATION (CL-I) - Lohit	R
	March (CL-I)	
1	Q_{SIM} = -20.045 + 0.618 X (PCP) + 0.0044 X (RL) +0.283 X (SNMT) The equation is valid for March PCP > 20 mm	0.92
2	Q_{SIM} = -33.31 + 0.629 X (PCP) + 0.259 X (%FA) + 0.32 X (SNMT) The equation is valid for March PCP > 20 mm	0.92
	April (CL-I)	
1	Q_{SIM} = -35.1822 + 0.6603 X (PCP) + 0.0094 X (RL) + 0.5275 X (SNMT) The equation is valid for April PCP > 40 mm	0.95
2	Q_{SIM} = -26.44 + 0.7075 X (PCP) + 0.5725 X (SNMT) The equation is valid for April PCP > 40 mm	0.94
	May (CL-I)	
1	Q_{SIM} = -50.84 + 0.672 X (PCP) + 0.0249 X (RL) - 0.0679 X (UA) The equation is valid for May PCP > 50 mm	0.94
2	Q_{SIM} = -57.0406 +0.6755 X (PCP) + 0.0224 X (RL) The equation is mostly for May PCP > 65 mm	0.93
	June (CL-I)	
1	Q_{SIM} = -94.2984 + 0.7529 X (PCP) + 0.0255 X (RL) The equation is valid for June PCP > 60 mm	0.98
2	Q_{SIM} = -92.2543 + 0.7528 X (PCP) – 0.0353 X (%FA) + 0.0258 X (RL) The equation is valid for June PCP > 60 mm	0.98
3	Q_{SIM} = -157.4835 + 0.7918 X (PCP) + 0.9221 X (%FA) + 1.5777 X (%CA) The equation is valid for June PCP > 125 mm	0.97

EQN NO	EQUATION (CL-I) - Lohit	R
	July (CL-I)	
1	Q_{SIM} = -145.0318 + 0.7861 X (PCP) +0.0416 X (RL) The equation is valid for July PCP > 75 mm	0.97
2	Q_{SIM} = -185.4434 + 0.7853 X (PCP) + 0.8902 X (%FA) + 0.0381 X (RL) -0.1218 X (UA) The equation is valid for July PCP > 175 mm	0.97
3	Q_{SIM} = -211.2449 + 0.6141 X (PCP) + 1.6282 X (%FA) + 0.3348 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 180 mm. The weights are w1 = 0. 3348; w2 = 0. 6141.	0.97
	August (CL-I)	
1	Q_{SIM} = -128.5088 + 0.8392 X (PCP) + 0.0357 X (RL) The equation is valid for August PCP > 150 mm	0.97
2	Q_{SIM} = -210.3852 + 0.7527 X (PCP) + 1.6593 X (%FA) + 0.1346 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 125 mm. The weights are w1 = 0. 1346; w2 = 0. 7527.	0.98
3	Q_{SIM} = -190.2958 + 0.7204 X (PCP) + 0.9391 X (%FA) + 0.0274 X (RL) + 0.1392 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 170 mm. The weights are w1 = 0. 1392; w2 = 0. 7204.	0.98
	September (CL-I)	
1	Q_{SIM} = -134.9622 + 0.7293 X (PCP) + 1.1151 X (%FA) + 0.0358 X (PCP2) + 0.1339 X (PCP1) The equation is valid for total weighted precipitation (w1X PCP July+ w2×PCP August + w3 x PCP September) > 50 mm. The weights are w1 = 0. 0358; w2 = 0. 1339; w3 = 0.7293.	0.98
2	Q_{SIM} = -57.9141 + 0.7537* (PCP) + 0.1628 X (PCP1) The above equation is valid for total weighted precipitation (w1X PCP August + w2 x PCP September) > 65 mm. The weights are w1 = 0. 1628; w2 = 0. 7537.	0.97

EQN NO	EQUATION (CL-I) - Lohit	R
3	Q_{SIM} = -81.0691 + 0.6886 X (PCP) + 0.0204 X (RL) + 0.1779 X (PCP1) The equation is valid for total weighted precipitation (w1X PCP August + w2 x PCP September) > 80 mm. The weights are w1 = 0. 1779; w2 = 0. 6886.	0.98
	October (CL-I)	
1	Q_{SIM} = -104.4446 + 0.7259 X (PCP) + 1.1006 X (%FA) + 0.2988 X (PCP1) The above equation is valid for total weighted precipitation (w1X PCP September + w2 x PCP October) > 20 mm. The weights are w1 = 0. 2988; w2 = 0. 7259.	0.97
2	Q_{SIM} = -90.8424 + 0.971 X (PCP) + 1.3477 X (%FA) The equation is valid for October PCP > 15 mm .	0.93
3	Q_{SIM} = -126.1353 + 0.7208 X (PCP) + 1.2414 X (%FA) + 0.8614 X (%CA) + 0.2962 X (PCP1) The equation is valid for total weighted precipitation (w1X PCP September + w2 x PCP October) > 40 mm. The weights are w1 = 0. 2962; w2 = 0. 7208.	0.97
	November (CL-I)	
1	Q_{SIM} = -55.9056 + 1.631 X (PCP) + 0.4377 X (%FA) + 0.0083 X (RL) + 1.8633 X (Tmax) The equation is valid for November PCP > 10 mm	0.77

EQN NO	EQUATION (CL-II) - Lohit	R
	March (CL-II)	
1	Q_{SIM} = -98.1274 + 0.545 X (PCP) + 0.0239 X (RL) + 0.4648 X (SNMT) The equation is valid for March PCP > 90mm	0.84
2	Q_{SIM} = -76.097 + 0.6046 X (PCP) + 0.019 X (RL)	0.79

EQN NO	EQUATION (CL-II) - Lohit	R
	The equation is valid for March PCP > 55 mm	
	April (CL-II)	
1	Q_{SIM} = -29.7462 + 0.7228 X (PCP) – 0.005 (%FA) + 0.4619 X (SNMT) The equation is mostly for April PCP > 25 mm	0.91
2	Q_{SIM} = 71.1103 + 0.7053 X (PCP) – 0.0217 X (RL) The equation is valid for April PCP > 35 mm	0.77
	May (CL-II)	
1	Q_{SIM} = -19.5404 + 0.793 X (PCP) + 0.6769 X (SNMT) The equation is valid for May PCP > 20 mm	0.97
	June (CL-II)	
1	Q_{SIM} = 855.2151 + 0.7983 X (PCP) – 8.7474 X (%FA) – 9.308 X (%CA) The equation is validfor June PCP > 30 mm	0.96
2	Q_{SIM} = -8.6214 + 0.7883 X (PCP) – 1.1754 X (%CA) The equation is valid for June PCP > 15 mm	0.96
3	Q_{SIM} = -4.0442 + 0.7788 X (PCP) -0.109 X (%FA) The equation is valid for June PCP > 25 mm	0.95
	July (CL-II)	
1	Q_{SIM} = -17.6136 + 0.7644 X (PCP) -0.0114 X (RL) + 0.1559 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 50 mm taken together for the months of June and July. The weights are w1 = 0. 1559; w2 = 0. 7644.	0.98
2	Q_{SIM} = -100.8103 + 0.7522 X (PCP) + 0.5572 X (%FA) + 0.1546 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP June + w2×PCP July) > 55 mm. The weights are w1 = 0. 1546; w2 = 0. 7522.	0.99
3	Q_{SIM} = 403.4161 + 0.8772 X (PCP) -4.3275 X (%FA) -4.7968 X (%CA) -0.0081 X (RL) The equation is valid for July precipitation > 60 mm	0.98
	August (CL-II)	
1	Q_{SIM} = -86.7925 + 0.8416 X (PCP) + 0.3979 X (%FA) + 0.0647 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 55 mm. The weights are w1 = 0. 0647; w2 = 0. 8416.	0.99

EQN NO	EQUATION (CL-II) - Lohit	R
2	Q_{SIM} = -21.9917 + 0.8446 X (PCP) -0.0102 X (RL) + 0.0738 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 50 mm. The weights are w1 = 0. 0738; w2 = 0. 8416.	0.99
3	Q_{SIM} = 142.1463 + 0.9125 X (PCP) -1.6918 X (%FA) -2.1608 X (%CA) -0.0072 X (RL) The equation is valid for August precipitation > 55 mm	0.99
	September (Cl-II)	
1	Q_{SIM} = -32.9955 + 0.7471 X (PCP) + 0.1532 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP August + w2×PCP September) > 35 mm. The weights are w1 = 0. 1532; w2 = 0. 7471.	0.99
2	Q_{SIM} = -211.1953 + 0.9319 X (PCP) + 1.8381 X (%FA) + 2.0632 X (%CA) The equation is valid for September precipitation > 35 mm	0.99
3	Q_{SIM} = -24.8085 + 0.7465 X (PCP) -0.003 X (RL) + 0.1574 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP August + w2×PCP September) > 35 mm. The weights are w1 = 0.1574; w2 = 0. 7465.	0.99
	October (CL-II)	
1	Q_{SIM} = 56.6904 + 0.7957 X (PCP) -0.8588 X (%FA) + 0.6883 X (Tmax) + 0.2333 X (PCP1) The equation is valid for total weighted precipitation (w1×PCP September + w2×PCP October) > 25. The weights are w1 = 0. 2333; w2 = 0. 7957.	0.98
2	Q_{SIM} = -6.2845 + 1.016 X (PCP) -0.8462 X SNMT + 1.1142 X (Tmax) The equation is valid for October precipitation > 20 mm	0.99
3	Q_{SIM} = -12.6908 + 1.033 X (PCP) + 0.0276 X (UA) The equation is valid for October precipitation > 10 mm	0.96
	November (CL-II)	
1	Q_{SIM} = -51.3543 + 1.3839 X (PCP) + 0.0157 X (RL) + 1.8536 X (Tmax) The equation is valid for November precipitation > 10 mm	0.79
2	Q_{SIM} = -68.0653 + 1.2795 X (PCP) + 0.0265 X (RL) The equation is mostly for November precipitation > 10 mm for sub-basins under cluster 2	0.75

EQN NO	EQUATION (CL-III) – Lohit	R
	March (CL-III)	

EQN NO	EQUATION (CL-III) – Lohit	R
1	Q_{SIM} = 20.54 + 0.0256 X (PCP) + 2.301 (Tmax) The equation is mostly for March precipitation > 5 mm for sub-basins under cluster 3.	0.45
	April (CL-III)	
1	Q_{SIM} = 0.822 + 0.023 X (PCP) + 0.824 X (SNMT) The equation is mostly for April precipitation > 5 mm for sub-basins under cluster 3.	0.98
	May (CL-III)	
1	Q_{SIM} = -69.3672 + 0.1575 X (PCP) + 0.0027 X (RL) + 0.9677 X (SNMT) The equation is mostly for May precipitation values > 265 mm for sub-basins under cluster 3.	0.98
	June (CL-III)	
1	Q_{SIM} = -139.3852 + 0.4662 X (PCP) + 0.0337 X (RL) + 0.9073 X (SNMT) The equation is mostly for June precipitation values > 235 mm for sub-basins under cluster 3.	0.96
2	Q_{SIM} = -311.1338 + 0.7608 X (PCP) + 26.1031 X (Tmax)+ 0.9208 X (SNMT) The equation is mostly for June precipitation values > 255 mm for sub-basins under cluster 3.	0.96
3	Q_{SIM} = -268.7886 + 0.6779 X (PCP) + 1.3656 X (%FA) + 31.4876 X (%CA) + 0.9088 X SNMT The equation is mostly for June precipitation values > 305 mm for sub-basins under cluster 3.	0.97
	July (CL-III)	
1	Q_{SIM} = -101.3746 + 0.5584 X (PCP) + 1.01 X SNMT + 16.9202 X (Tmax) The equation is mostly for July precipitation values > 415 mm for sub-basins under cluster 3.	0.94
2	Q_{SIM} = -706.2782 + 0.5217 X (PCP) + 7.6742 X (%FA) + 0.0525 X (RL) + 0.9016 X SNMT The equation is mostly for July precipitation values > 420 mm for sub-basins under cluster 3.	0.98
3	Q_{SIM} = -50.1231 + 0.3572 X (PCP) + 0.0371 X (RL) + 0.9815 X (SNMT) + 10.6521 X (Tmax)	0.95

EQN NO	EQUATION (CL-III) – Lohit	R
	The equation is mostly for July precipitation values > 420 mm for sub-basins under cluster 3.	
	August (CL-III)	
1	Q_{SIM} = 77.0938 + 0.3519 X (PCP) + 0.0353 X (RL) + 1.0453 X (SNMT) The equation is mostly for August precipitation values > 140 mm for sub-basins under cluster 3.	0.75
2	Q_{SIM} = -457.4167 + 6.7192 X (%FA) + 0.0792 X (RL) + 0.9328 X (SNMT) The equation is mostly for August precipitation values > 505 mm for sub-basins under cluster 3.	0.85
3	Q_{SIM} = -660.3027 + 0.77 X (PCP) + 7.575 X (%FA) + 1.0651 X (SNMT) The equation is mostly for August precipitation values > 225 mm for sub-basins under cluster 3.	0.89
	September (CL-III)	
1	Q_{SIM} = -462.6303 + 0.4466 X (PCP) + 5.2769 X (%FA) + 0.0317 X (RL) + 0.9975 X SNMT The equation is mostly for September precipitation values > 385 mm for sub-basins under cluster 3.	0.88
2	Q_{SIM} = -472.7727 + 0.4171 X (PCP) + 5.2555 X (%FA) + 1.0001 X (SNMT) + 0.2354 X (PCP1) The equation is mostly for September precipitation values > 255 mm for sub-basins under cluster 3.	0.85
	October (CL-III)	
1	Q_{SIM} = -205.6716 + 0.1356 X (PCP) + 2.6561 X (%FA) + 0.9489 X (SNMT) + 0.0721 X (PCP2) + 0.119 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP August + w2×PCP September + w3 x October) > 90 mm. The weights are w1 = 0. 119; w2 = 0. 0721; w3 = 0.1356.	0.83
2	Q_{SIM} = 39.8121 + 0.0888 X (UA) + 0.2783 X (PCP) + 0.9449 X (SNMT) + 6.8802 X (Tmax) The equation is mostly for October precipitation values > 245 mm for sub-basins under cluster 3.	0.79
3	Q_{SIM} = -56.8173 + 1.7303 X (%FA) + 0.0779 X (PCP) + 1.2461 X (SNMT) The equation is mostly for October precipitation values > 5 mm for sub-basins under cluster 3.	0.77
	November (CL-III)	
1	Q_{SIM} = -46.0389 + 1.0107 X (%FA) + 0.0604 X (UA) + 0.1767 X (PCP) The equation is mostly for November precipitation values > 50 mm for sub-basins under cluster 3.	0.67

Snowmelt SNMT (mm) for the above equations is derived from the relation given as :

i. For Cluster I and Cluster II

a) Average snowfall value less than 200 mm

$$SNMT = 0.935 + 0.001 \times SNFL_i + 1.383 \times \sum SNFL_{i,i-1} + 0.064 \times \sum SNFL_{i,i-1,i-2} + 0.001 \times Tmax$$

for $SNFL_{Annual} \geq 200$ mm

b) Average snowfall value greater than 200 mm

$$SNMT = -2.875 + 0.5861 \times SNFL_i + 0.3097 \times \sum SNFL_{i,i-1} + 0.1524 \times Tmax$$

for $SNFL_{Annual} < 200$ mm

ii. For Cluster III

$$SNMT = -104.4938 + 0.292 \times \sum SNFL_{i,i-1,i-2,i-3} + 0.9078 \times \sum SNFL_{i,i-1,i-2} + 7.898 \times Tmax$$

An attempt has been made to evaluate the discharge Q of Lohit flow at the point of its entry in the Indian territory. The relation has been evaluated (location corresponding to the outlet point of HRU 60) and provided below :

Month	Equation	R
April	Q = 97.644 + 0.1798 X (PCP) + 2.851 X (SNMT) + 27.6 X (Tavg) Above equation valid for April PCP > 110 mm.	0.96
May	Q = -157.625 + 1.0496 X (PCP) + 4.094 X (SNMT) + 77.79 X (Tavg) Above equation valid for May PCP > 85 mm.	0.98
June	Q = -418.285 + 3.051 X (PCP) +5.702 X (SNMT) + 31.955 X (Tavg) Above equation valid for June PCP > 105 mm.	0.98
July	Q = -61.6517 + 3.58 X (PCP) + 5.056 X (Tavg) Above equation valid for July PCP > 165 mm.	0.99
August	Q = -531.761 + 3.981 X (PCP) + 6.764 X (SNMT) + 48.671 X (Tavg) Above equation valid for August PCP > 170 mm.	0.96
September	Q = -326.108 + 2.2176 X (PCP) + 10.2224 X (SNMT) + 87.82 X (Tavg) Above equation valid for September PCP > 75 mm.	0.96
October	Q = 181.98 + 1.591 X (PCP) + 5.4895 X (SNMT) Above equation valid for October precipitation value > 45 mm.	0.92

Where Q is in cumec. and PCP (mm) is areal average precipitation of the catchment. The Snowmelt (SNMT) is based on two, three and four months snowfall (SNFL) values.

$$SNMT = -20.372 - 0.5348 \times \sum SNFL_{i,i-1} + 0.2017 \times \sum SNFL_{i,i-1,i-2} + 0.5427 \times \sum SNFL_{i,i-1,i-2,i-3} + 1.68 \times Tmax$$

SNMT – Weighted average snowmelt in mm

SNFL – Weighted average snowfall in mm

Tmax – Weighted average maximum monthly temperature in deg. C.

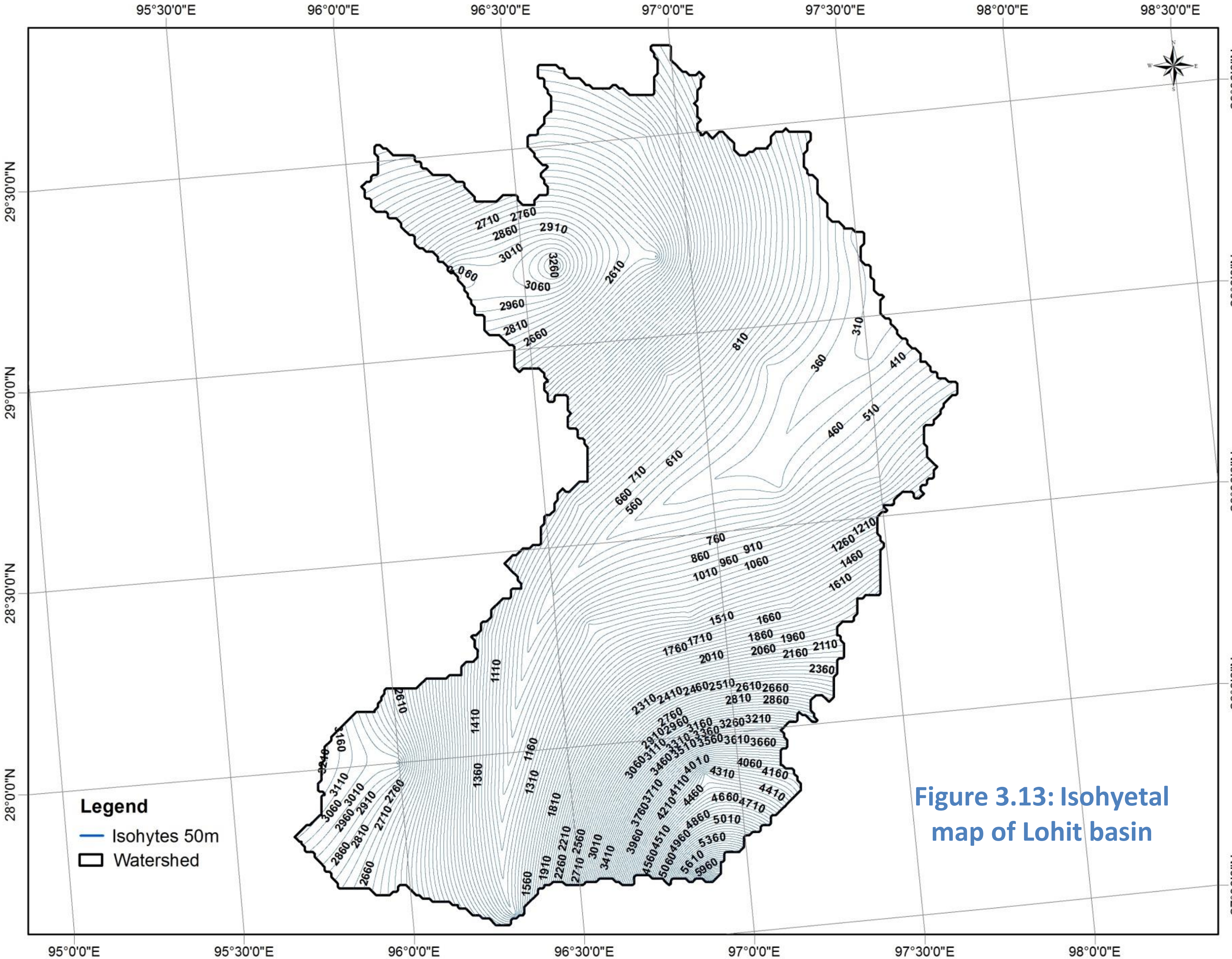


Figure 3.13: Isohyetal map of Lohit basin

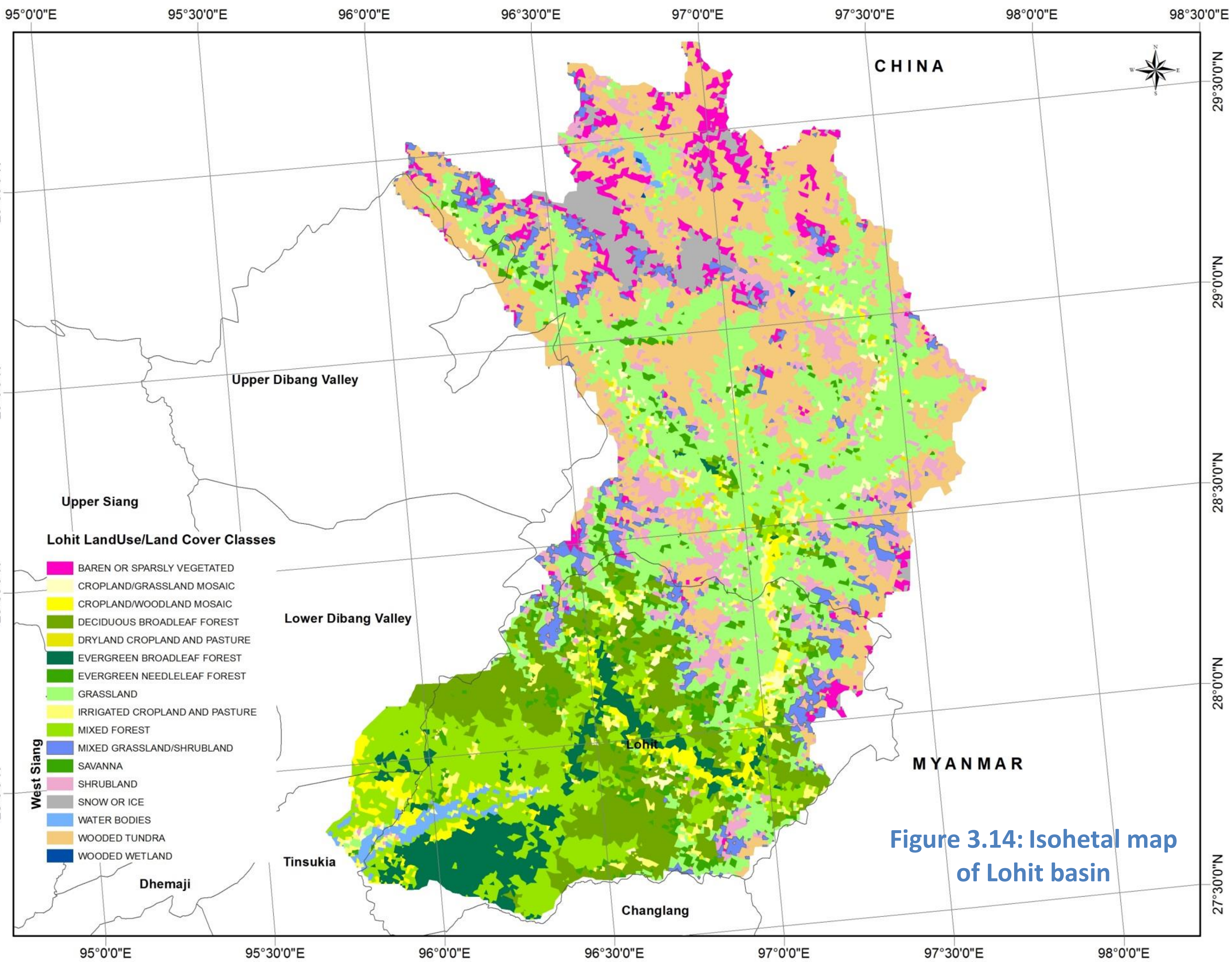


Figure 3.14: Isohetal map of Lohit basin

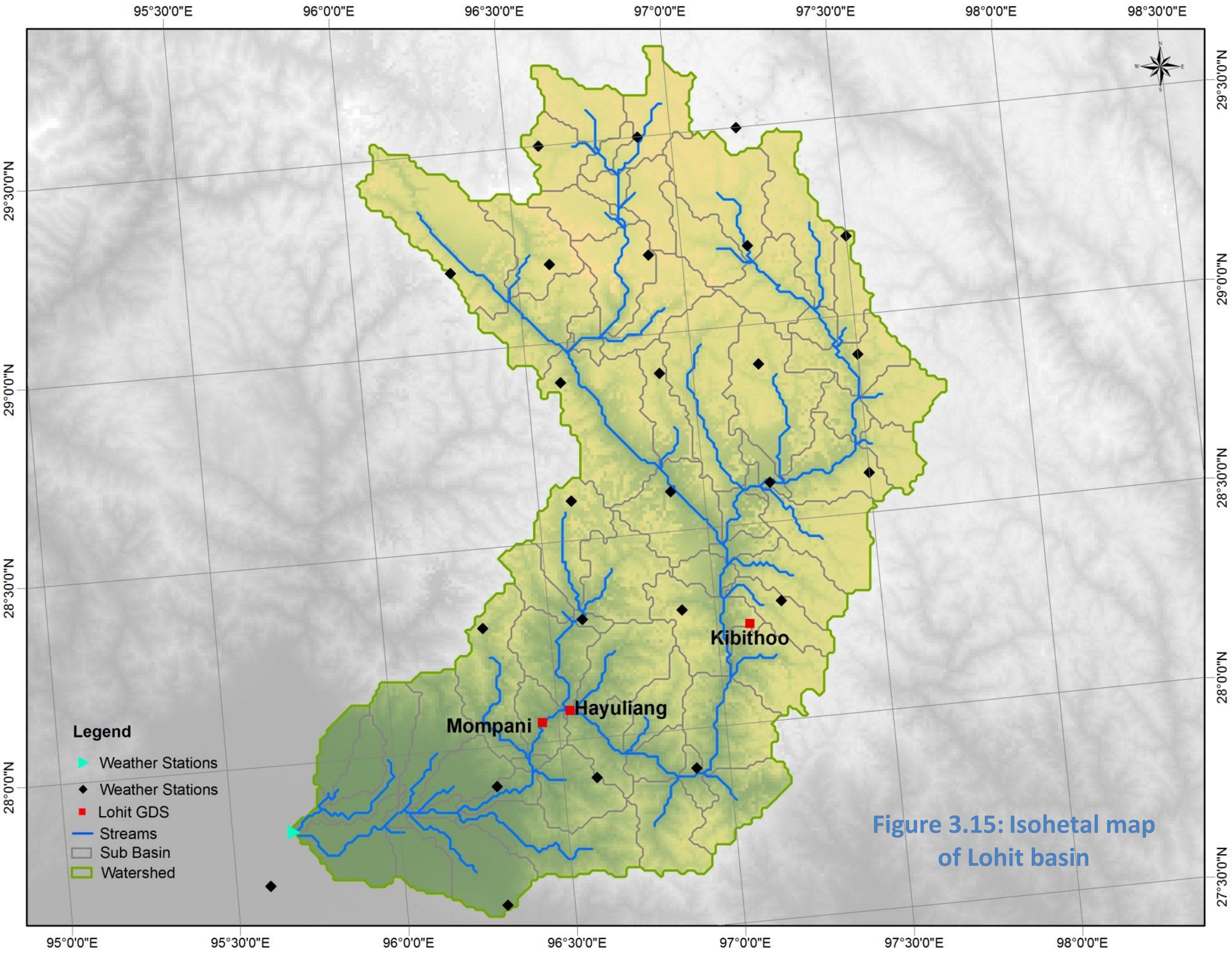


Figure 3.15: Isohetal map of Lohit basin

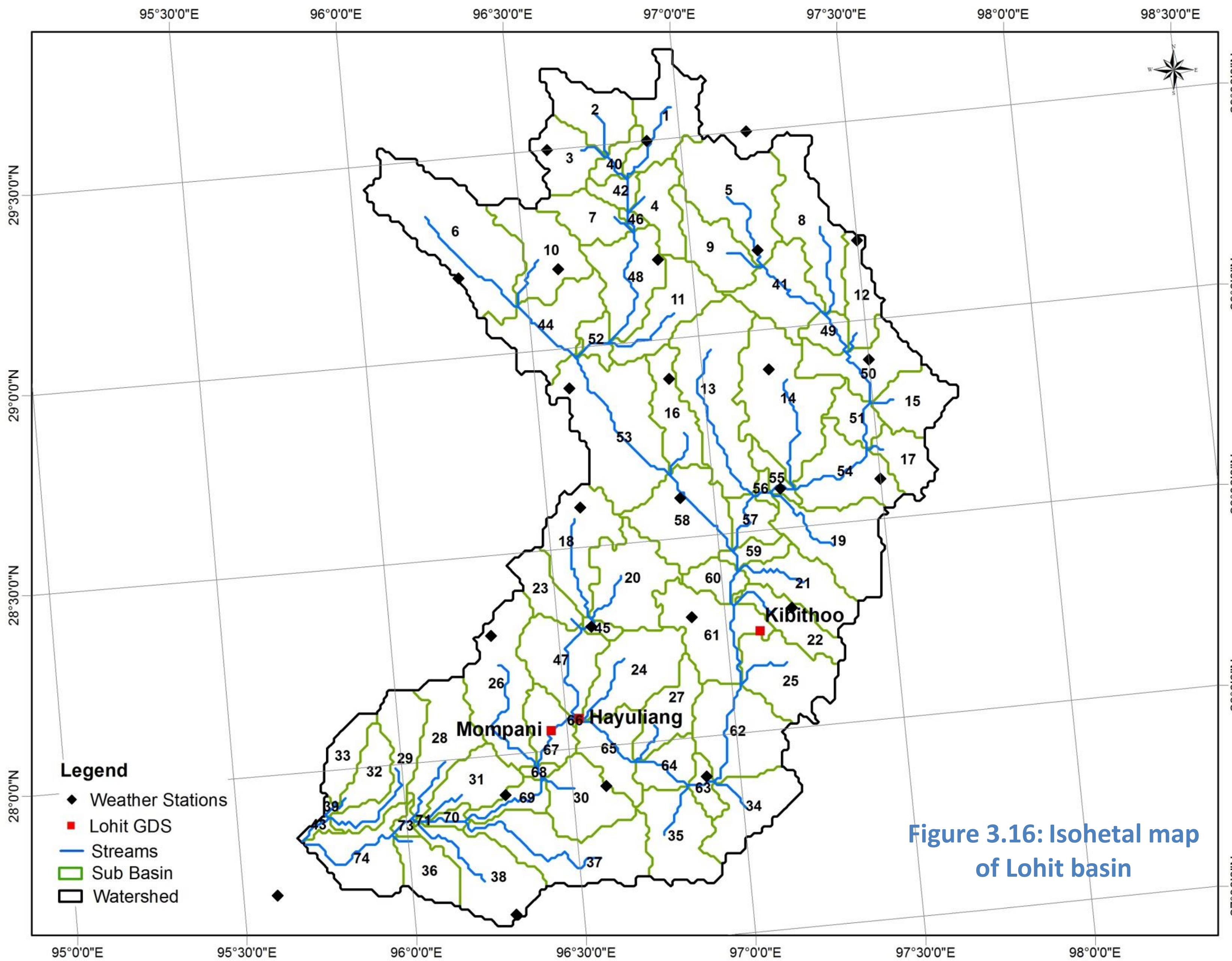
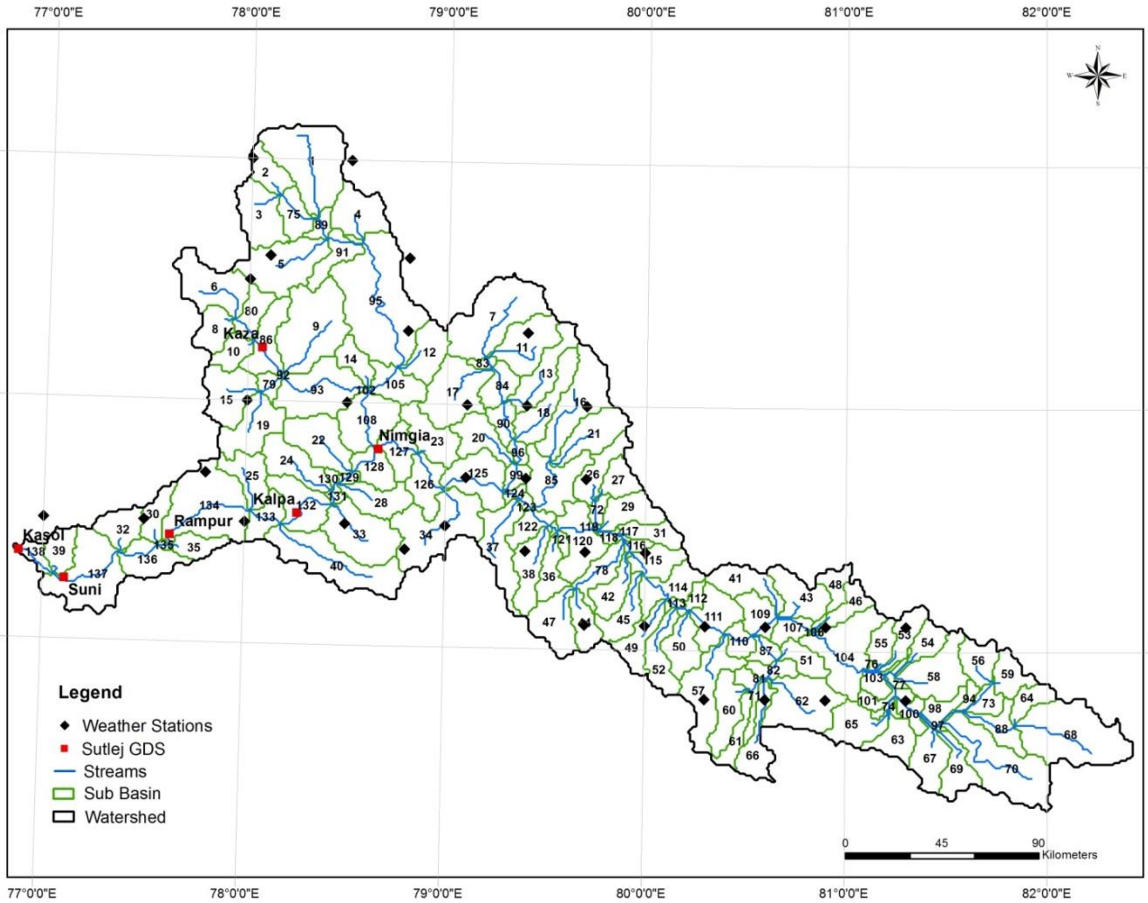


Figure 3.16: Isohetal map of Lohit basin

Chapter 4 : MODELING OF SATLUJ SUB-BASIN, ANALYSIS AND RESULTS



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4.1. INTRODUCTION: SATLUJ BASIN

The Satluj river rises in the lakes of Mansarovar and Rakastal in the Tibet plateau at an elevation of about 6,572 m and forms one of the main tributaries of Indus. In the Tibetan region, it flows for some 320 km in the north-west direction cutting through snow and glacier in the cold desert. Then, it turns south-west and covers a length of about another 320 km upto the Bhakhra gorge, where the 225.55 m high Bhakhra/Gobind Sagar Dam has been constructed. The total catchment of Satluj upto Bhakra reservoir is about 56,500 km^2 out of which 22,275 km^2 lies in India. The catchment of Satluj upto Kasol upstream of Bhakra is shown in ***Figure 4.1.***

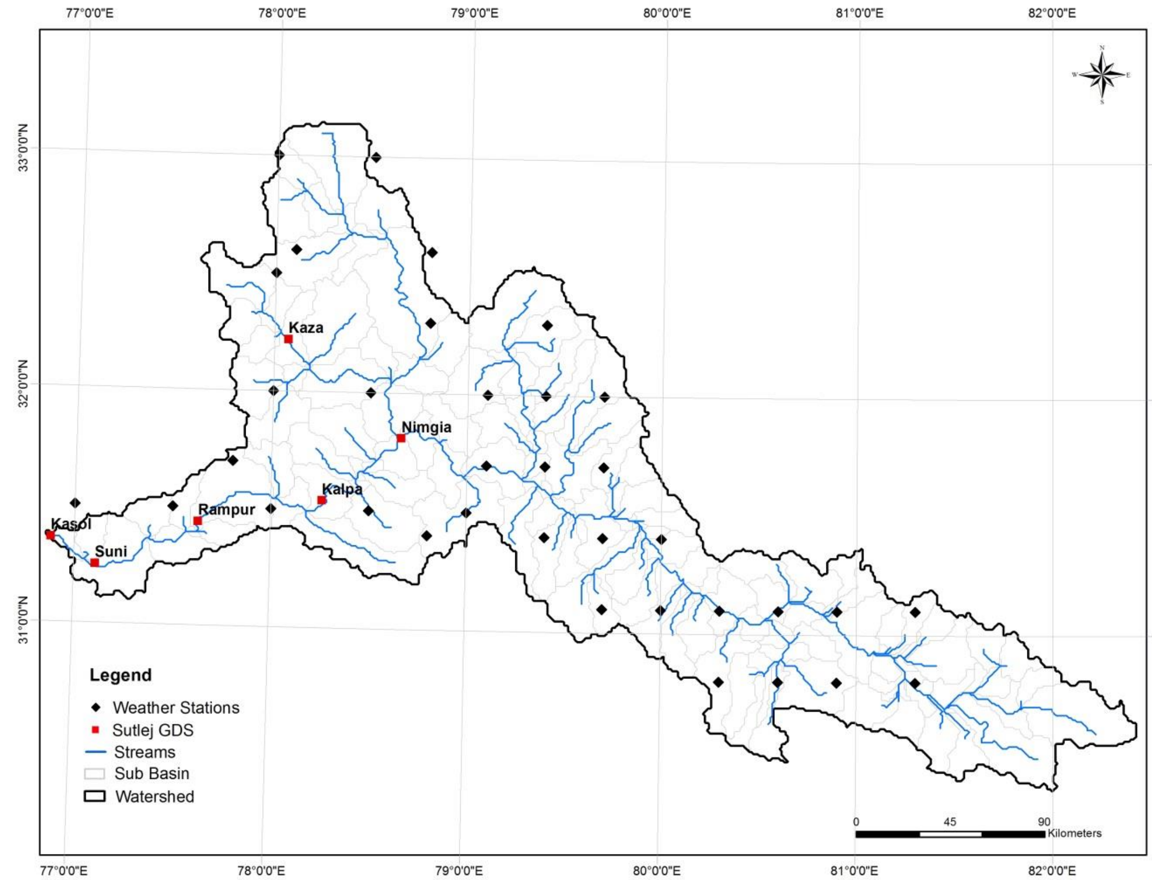


Figure 4.1: Satluj basin

4.2. SUB BASIN CHARACTERISTICS

4.2.3. Topography

The upper reaches of the Satluj catchment lies in the Tibetan region which experiences cold desert climate. Immediately after entering the Indian territory, the river is joined by a major tributary Spiti, at Nimgia near Shipki. Further, it flows downstream through Kinnaur district of Himachal Pradesh which receives heavy rainfall and snow. Numerous glaciers drain directly along the course. The Indian part of the Satluj basin is elongated in shape and covers outer Himalayas (Siwalik ranges), middle Himalayas (Dhauladhar range) and greater Himalayas including Zaskar range. The major part of the catchment covers Greater Himalayan range of Spiti, Baspa and Upper Satluj sub-basins where heavy snow is experienced.

The elevation of the Upper Satluj catchment varies widely from 636 m to 6572 m. The mean elevation is 4600 m. It is steep at the source with area above 6000m covering only 1% of the catchment. About 90 % of the basin area lies at an elevation range from 3800 m to 6000m. The permanent snowline line in this part of the range is about 5400m (Reference : BBMB, 1988).

4.2.4. Precipitation

The spatial modeling of Satluj basin has been undertaken with the 0.5^0 X 0.5^0 Gridded data available from ***IMD and Gridded Global precipitation data of NCEP-CFSR.*** The analysis shows that Satluj sub-basin received annual precipitation (averaged from 1990 to 2005) of 690 mm with only 40% received during the monsoon season. The average snowfall occurring during the same period in the catchment was 440 mm which is nearly 60% of total precipitation. The maximum precipitation was 888 mm received in 1995 and 440 mm in 2001. ***Figure 4.2*** shows annual precipitation and snowfall for the Satluj basin. An isohyetal map has been developed (refer ***Figure 4.3***) which shows high spatial variation in the catchment with values ranging from 300mm in the upper plateau area to 1300 mm near outlet in the valley part of the sub-basin.

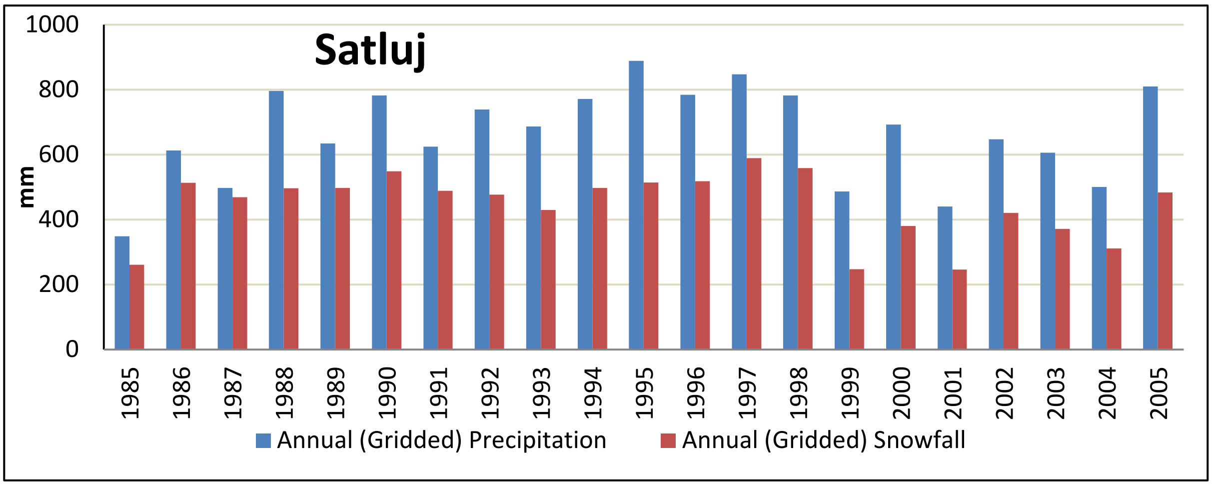


Figure 4.2 : Annual Precipitation and Snowfall in Satluj Catchment

The monthly plot as seen in ***Figure 4.4*** indicate that precipitation is high in the winter season from December to March which occurs mostly in the form of snow in Greater and Middle Himalayas. The pre-monsoon season (April – June) experiences transition from winter to monsoon with receding rainfall and snow at higher elevations. During the mosoon season (July – September), the lower Himalayas receive high rainfall over the Indian plains. The Post – monsoon season of October and November sees the driest period.

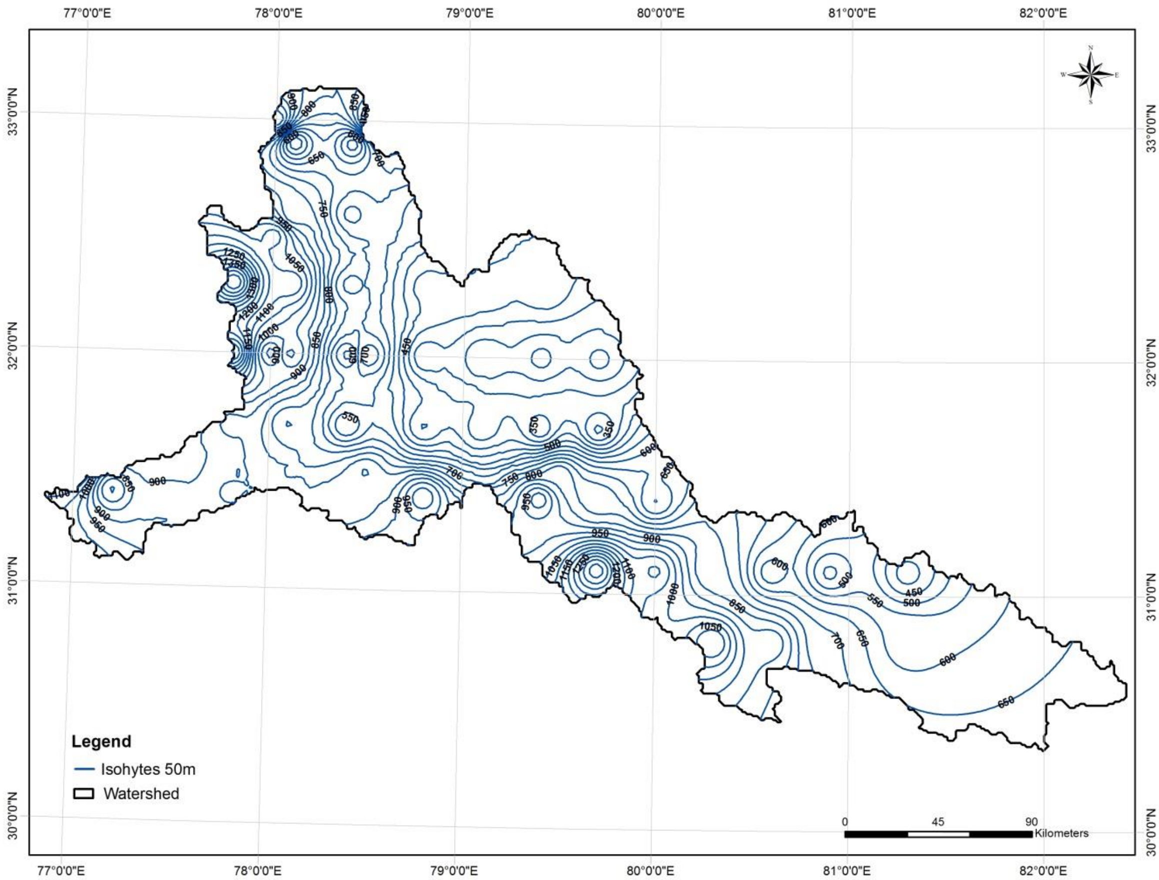


Figure 4.3: Isohyetal Map of Satluj (upper) basin

The sub-basin level spatial distribution of snowfall analysed from the model is shown in ***Figure 4.5***. The map indicates a progressive increase in snowfall with elevation in Spiti and Baspa region. The upper catchment in the Tibetan region show a high Snowfall vs. Precipitation ratio.

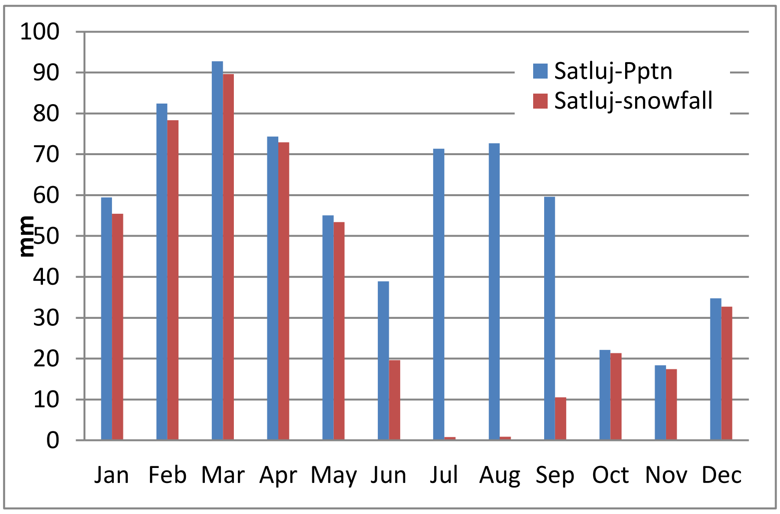


Figure 4.4:Monthly Precipitation and snowfall in Satluj catchment

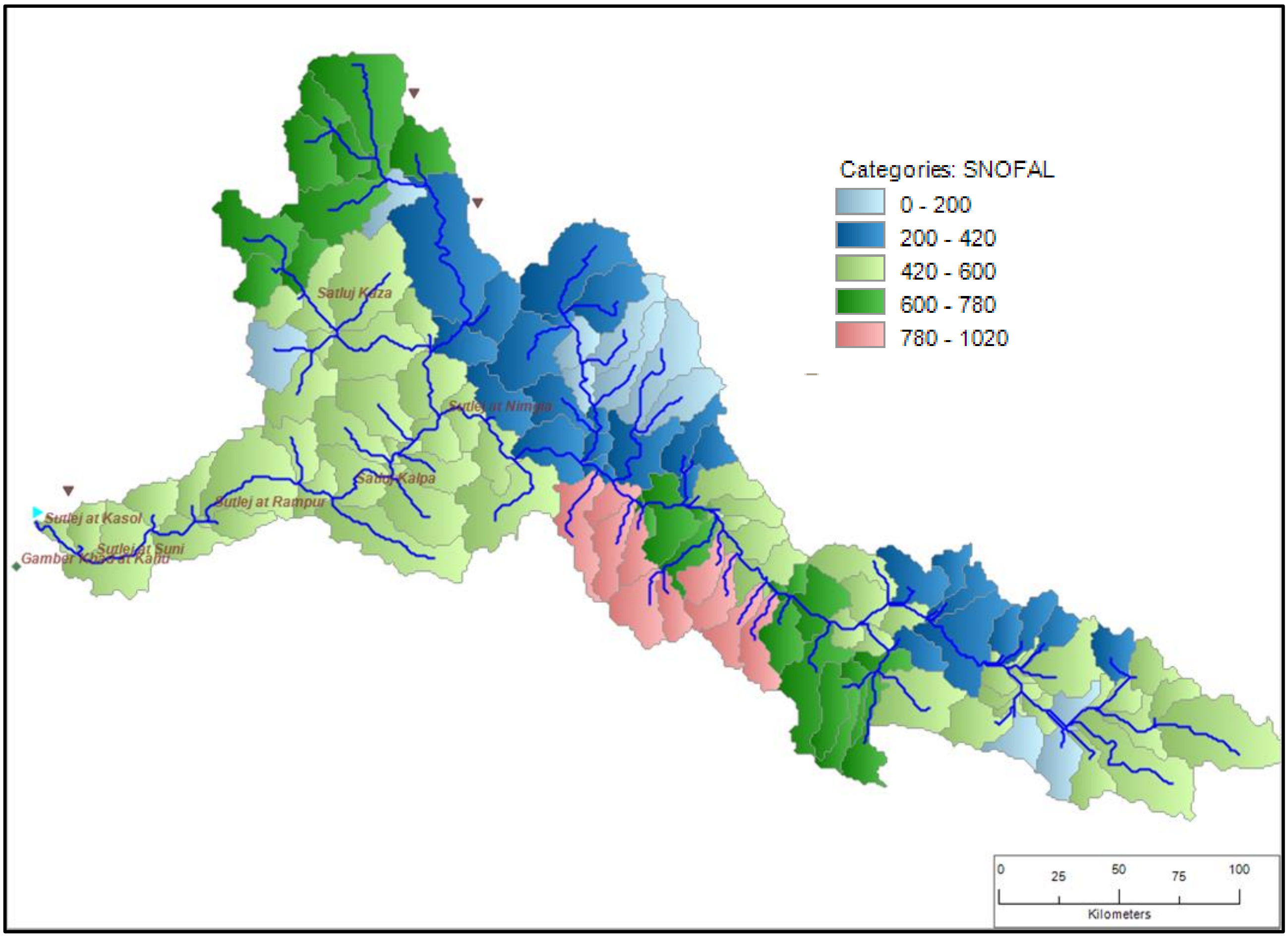


Figure 4.5: Sub-basin level snowfall (mm) in Satluj basin developed in MWSWAT

For the Satluj sub-basin lying within the Indian boundary, the annual precipitation averaged for the years from 1990 to 2005 is 807 mm out of which 50% occur in the monsoon. The maximum precipitation is 1024mm received in 1997 and 529 mm in 2003. The average annual snowfall for the same time duration is 455 mm (60 % of annual precipitation). The plot is shown in ***Figure 4.6***.

A comparison of Gridded data based Areal precipitation with the Annual Precipitation series documented in the Report '***Indus Basin, March 2014, by CWC and NRSC***' for the Upper Satluj sub-basin (Indian territory) show significant variation as seen from Figure 4.6. This is understood to be attributed to different source and resolution of data considered. Notwithstanding this difference, the spatial modeling of Satluj basin has been carried out with the available information database.

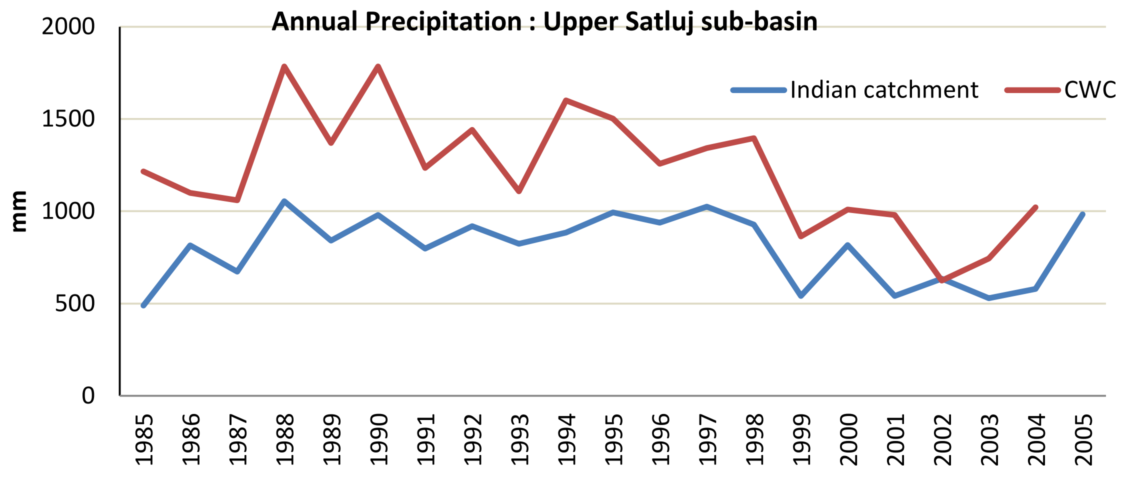


Figure 4.6 : Annual Average Precipitation and Snowfall in Satluj Catchment

4.2.3. Soil

The soil of Upper Satluj sub-basin is predominantly Loamy in about 80% of the catchment. Clay-loam soil is restricted to the valley portion of the Indian catchment. A significant portion of the sub-basin is waterbody and glacier constituting more than 12% of the area as seen in ***Figure 4.7***:

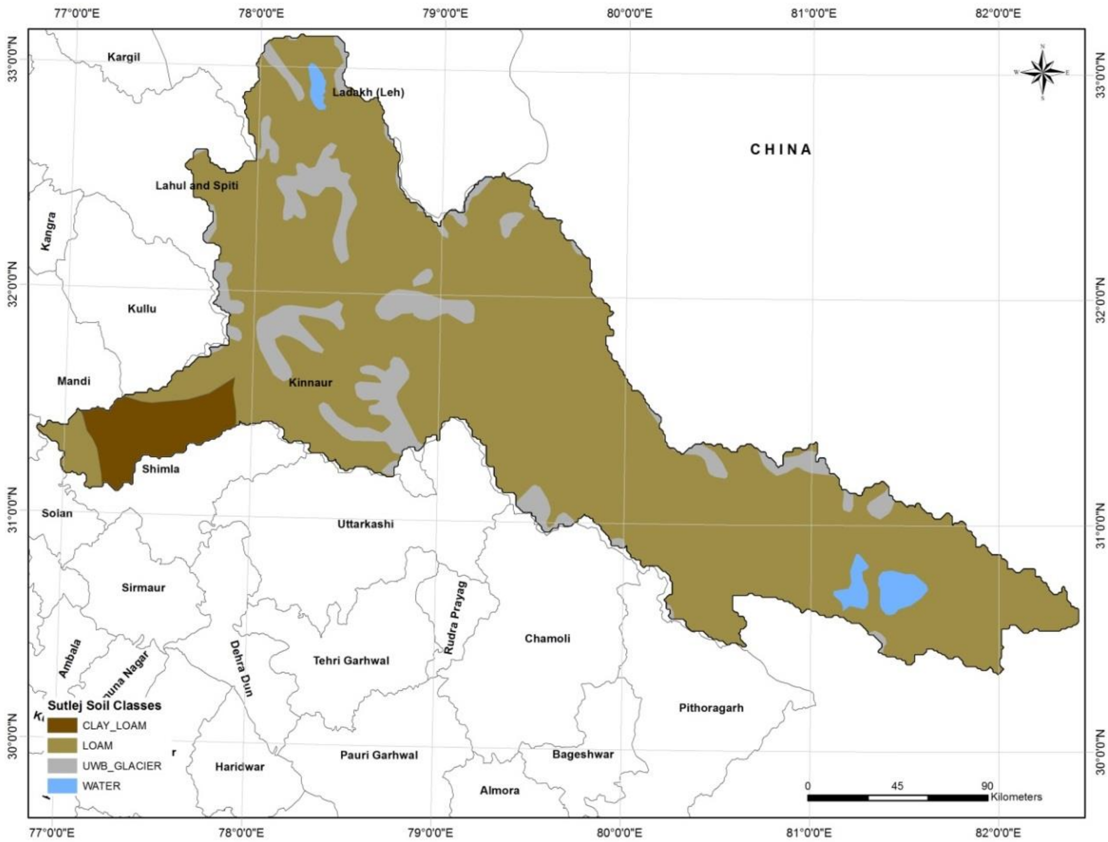


Figure 4.7: Soil map of Satluj (Upper) sub-basin

4.2.4. Land use

With reference to the land use data used in modeling Upper Satluj sub-basin as shown in ***Figure 4.8***, the % distribution is shown in ***Table 4.1.***

Table 4.1: Land use classification for Upper Satluj Sub basin

Sl. No.	Land use classification	% of total basin area
1	Glacier/Water bodies/ Wooded Tundra	7.77
2	Forest	0.58
3	Grassland / Shrubland / Savannah	66.16
4	Barren	21.03
5	Cropland	4.46
	Total	100

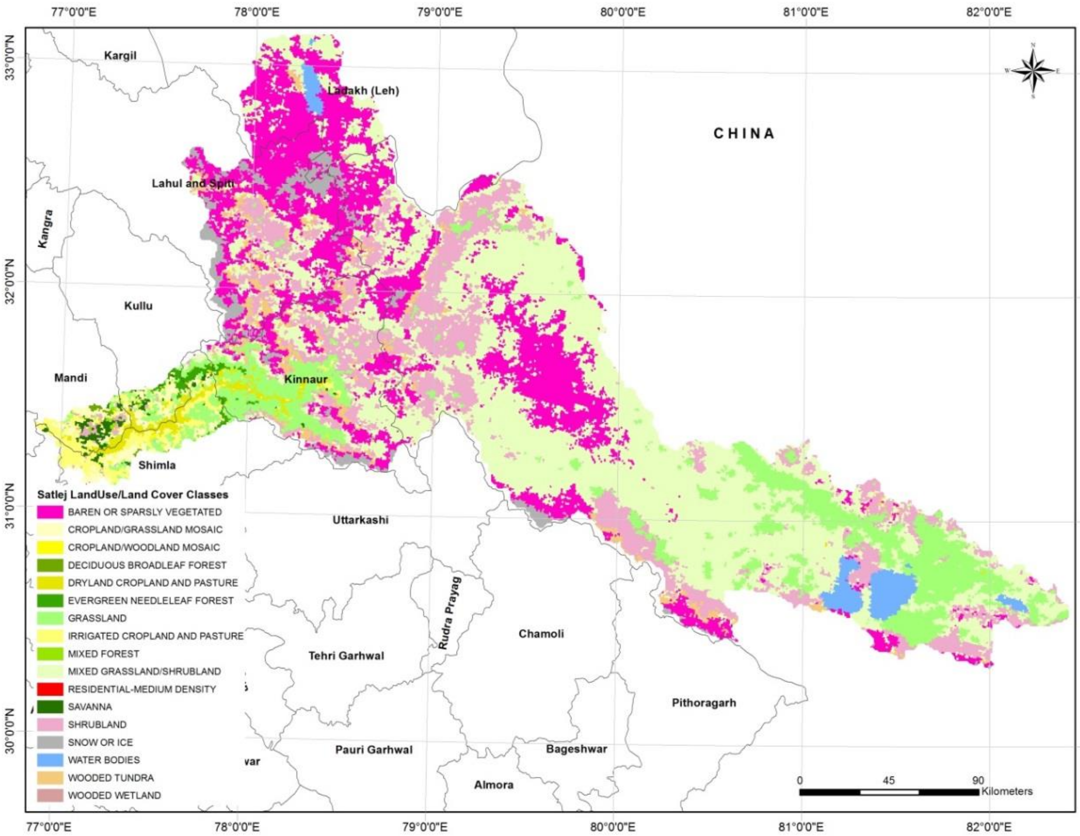


Figure 4. 8: Land use and land cover map of Satluj sub basin

4.2.5. Natural flow data

Flow records on 3 G&D sites viz. Kasol, Rampur, Suni on Satluj maintained by BBMB are available for modeling,. Further upstream, flow measurement is available on Nimgia station on Spiti confluence. The details of the stations are tabulated below :

	G&D gauging station	CA (sq km)	Period of data available
1	Nimgia	12490	Jan 1990-Aug 2010 *
2	Kasol	52350	Jan 1990-Aug 2010
3	Rampur	49550	Jan 1990-Aug 2010
4	Suni	51660	Jan 1990-Aug 2010

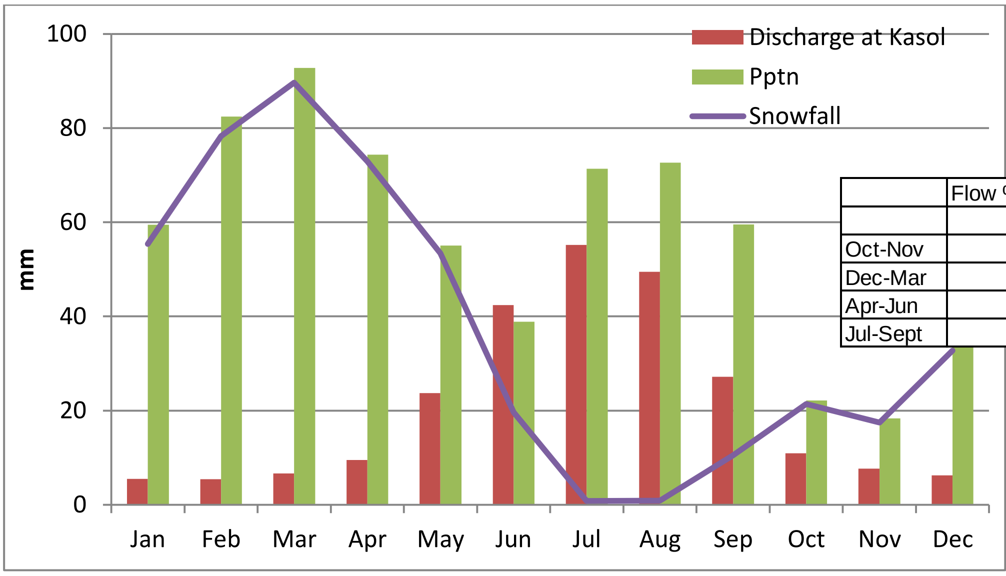
* missing records

With the given duration of flow records available, the model is simulated from 1990-91 to 1999-00 under calibration time period and 2000-01 to 2004-05 under validation.

The flow series at Nimgia for the said period show several missing records in observations. Therefore, it could not be considered for model testing.

As per current records, there are 3 dams, 2 weirs and 1 barrage in the Upper Satluj sub-basin viz. Nathpa Jhakri dam, Karcham Wangtoo dam, Karchham (Jaypee) dam, Baspa Barrage, Sanjay Bhabha and Ghanvi weirs. For the simulation period, no regulation or utilization for any of the dams have been considered for yield assessment. There is no import/export from the satluj sub-basin during the simulation period.

A monthly analysis of flow and areal averaged precipitation at Kasol as shown in ***Figure4.9*** highlights the temporal variability in discharge. The snowmelt contribution starts gradually from April and continues till August followed by glacial melt. The pre-monsoon season experiences flow mostly from sub-surface discharge. During monsoon, the flow contribution enhances in response to heavy snowmeltl. During winter, snowmelt contribution to flow is less as melting conditions are not adequate.



	Flow %	Precipitation %
Oct-Nov	7.5	5.9
Dec-Mar	9.5	39.5
Apr-Jun	30.3	24.7
Jul-Sept	52.8	29.9

Figure 4. 9: Monthly Flow and Precipitation at Kasol in Satluj sub basin

4.3. RESULTS AND ANALYSIS

The model performance criteria values (R^2 and NSI) have been shown in ***Table 4.2.*** The annual correlation coefficient and NSI at Kasol observation station is 0.43 and 0.51 respectively. The results of Satluj model simulation observed at other stations are presented in ***Figure 4.10, Figure 4.11*** and ***Table 4.2*** for comparison of simulated and observed flow which show a limited acceptability with a scope for further improvement. The limitations of the model lies in precipitation records which is largely dependent on Global information source as the major catchment lies outside the Indian boundary. The Indian part of the catchment suffers from low spatial resolution of precipitation data. A better model representation of Satluj Indian part of the catchment is proposed for improved result which will require flow series for a station observing records of Satluj near Nimgia and downstream flow station at Kasol, along with higher spatial resolution concurrent precipitation records in the basin.

Table 4.2: Model performance comparison for simulation flow: Satluj sub basin

Component	Model performance (Calibration)		Model performance (Validation)	
	R^2	Nash and Sutcliffe	R^2	Nash and Sutcliffe
Stream flow (Monthly)				
Kasol	0.75	0.66	0.62	0.49
Seoni	0.74	0.61	0.60	0.51
Rampur	0.73	0.57	0.57	0.47

Notwithstanding the limited acceptability of model performance measure, Empirical relation has been developed with the generated dataset. The model simulation has been carried out from 1985 to 2005 for data-set generation with calibration period considered from 1985-86 to 1999-00.

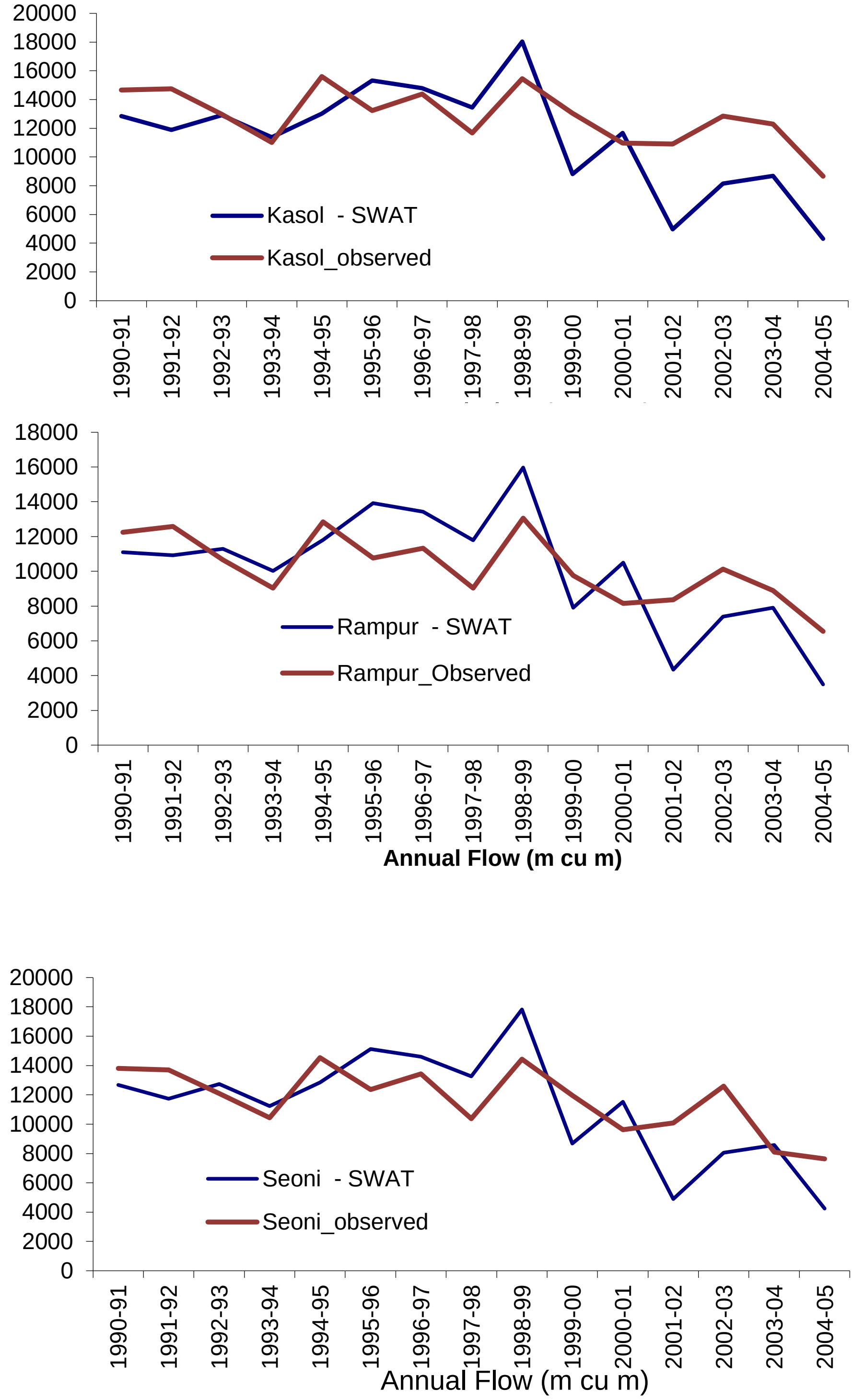


Figure 4.10: Plot of observed and simulated flow (Annual) – Satluj sub basin

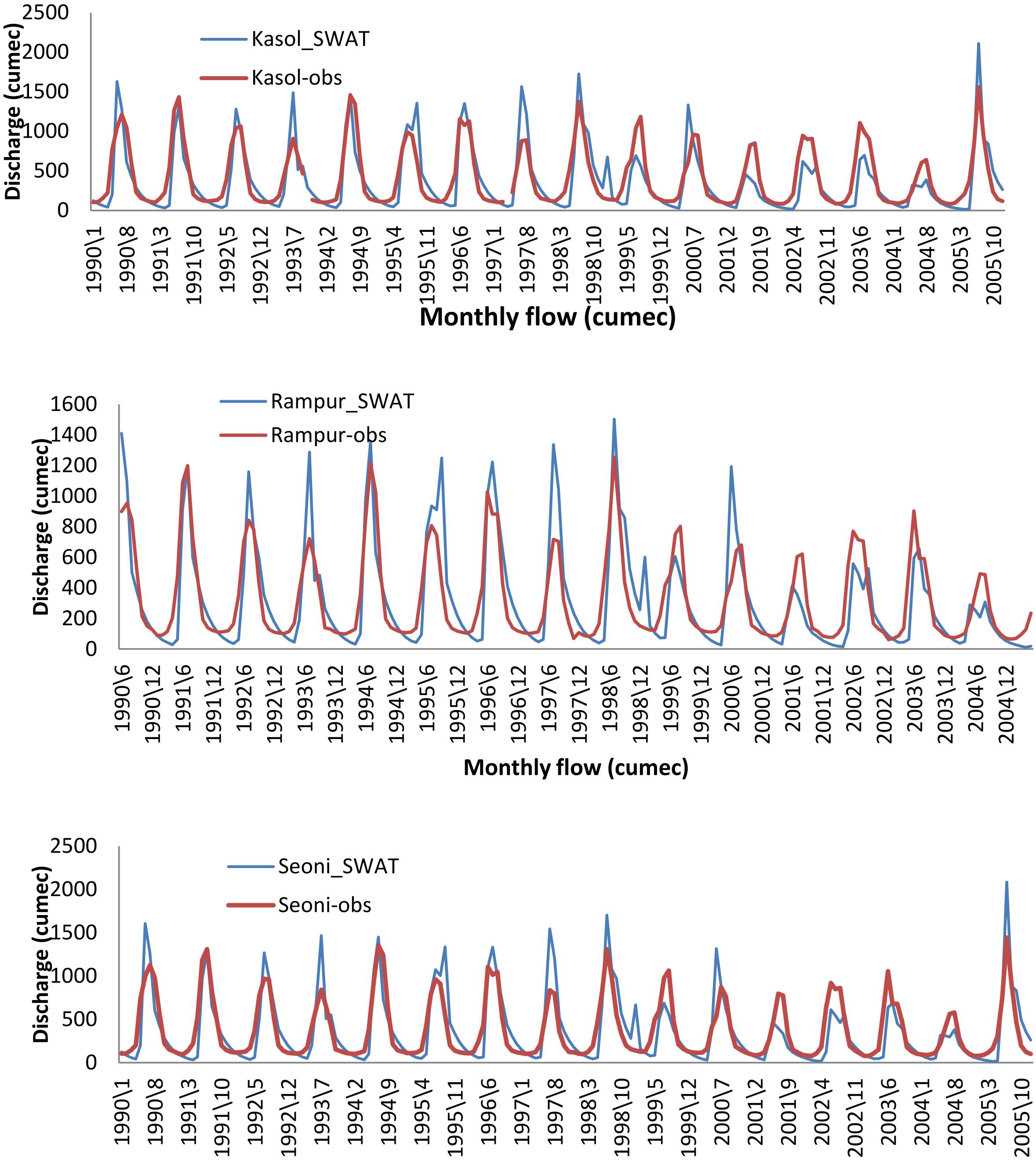


Figure 4. 11: Comparison of simulated natural flow (SWAT) with observed flow for Satluj sub basin

The average snow and glacial contribution to the annual flow if Satluj is assessed using the water balance approach (mm) as outlined in the Report ***Snow and Glacier Contribution in the Satluj river at Bhakra Dam by NIH*** given by:

Snow and Glacial Runoff = Observed flow – (Rainfall-Evapotranspiration) where, losses from rain and snowmelt in the form of infiltration is reflected within a period of 15 years for volume computation. Therefore, baseflow is not considered separately in the Water Balance. The Resource Components calculated at Kasol is Tabulated as :

Runoff	**Rainfall**	**Evapo-transpiration loss**	**Rain contribution to runoff**		**Snow and glacier contribution to runoff**	
mm	mm	mm	mm	%	mm	%
249.9	250.5	224	26.5	10.6	223.4	89.4

Therefore, the snow and glacier contribution in the Satluj flow at Kasol is about 89%

The upstream sites will have higher contribution than 89%.

Table 4.3: Comparison of monsoon runoff and weighted monsoon precipitation for Lohit sub basin

Satluj upto Kasol G&D site

Catchment Area : 52350 sq km

S. No.	Year	Observed runoff	Observed monsoon runoff	Observed runoff SWAT	Observed runoff	Observed monsoon runoff	Observed runoff SWAT	Weighted Annual Precipitation	Weighted Monsoon Precipitation	Weighted Snowfall
		(MCM)	(MCM)	(MCM)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
1	1990-91	14660	10978	12841.88	280	210	245	788	240	561
2	1991-92	14745	11571	11888.84	282	221	227	622	139	471
3	1992-93	12987	9871	12903.11	248	189	246	721	277	451
4	1993-94	11019	9024	11374.97	210	172	217	716	252	465
5	1994-95	15602	12385	13021.20	298	237	249	744	293	467
6	1995-96	13231	9574	15331.68	253	183	293	918	411	552
7	1996-97	14383	11081	14789.83	275	212	283	688	316	435
8	1997-98	11674	7920	13441.53	223	151	257	894	345	618
9	1998-99	15465	11324	18047.54	295	216	345	593	366	353
10	1999-00	13047	9674	8806.00	249	185	168	619	271	398
11	2000-01	10977	8405	11673.73	210	161	223	578	326	258
12	2001-02	10914	7329	4969.46	208	140	95	590	180	402
13	2002-03	12854	9251	8152.83	246	177	156	619	253	376
14	2003-04	12284	9894	8688.29	235	189	166	471	209	253
15	2004-05	8671	5761	4310.82	166	110	82	729	253	543
	AVERAGE	**12834**	**9603**	**11349**	**245**	**183**	**217**	**686**	**275**	**440**

Input data sets for regional analysis of all the 138 sub-basins of Satluj basin have been considered for development of Empirical Equations. The data-set is appended in a tabular form as ***Annex 4.1***. The calibration parameters of the sub-basins of Satluj are provided in Appendix 3. The precipitation and yield values in this table are average values for the period 1985-2005 derived from SWAT database. The statistical characteristics of the dataset are shown in ***Table 4.4***. These datasets are further applied in Cluster Analysis and subsequent development of Empirical Equations.

Table 4. 4: Statistical characteristics of SWAT dataset for Satluj Sub basin

	Natural flow mm	Average Temperature oC	Average Precipitation mm	Elevation m asl	Forest Area %	Cropped Area %	Relief m	Unit Area sq.km.
Mean	242.84	26.76	869.71	549.12	4.47	92.90	123.75	418.61
Min.	101.32	26.06	663.87	337.91	0.00	41.69	10.00	2.82
Max.	542.79	27.22	1180.90	708.78	53.48	100.01	318.00	2461.07
SD.	107.15	0.30	121.69	95.27	8.69	12.01	66.75	406.51

4.4. CLUSTERING PROCEDURE AND ESTIMATING NUMBER OF CLUSTERS

4.4.1. Analysis of data

Six dimensions viz. precipitation (mm), percentage forest area, mean temperature (^{0}C), relief (m), catchment area (km^2), snowfall (mm) have been used as clustering variables. Multiple regression analysis was undertaken on the data set of 138 sub-basins as shown in ***Table 4.5***. The correlation matrix of these variables with average natural runoff is shown and the multiple R obtained was 0.98, and R^2 is 0.97.

Table 4.5 : Correlation matrix and regression statistics used in clustering

	Natural flow mm	*Average Temperature oC*	*Average Precipitation mm*	*Forest Area %*	*Relief, m*	*Unit Area, sq.km.*	*SNFL, mm*
Natural flow mm	1.000						
Average Temperature oC	0.112	1.000					
Average Precipitation mm	0.917	0.100	1.000				
Forest Area %	-0.211	-0.035	-0.289	1.000			
Relief, m	0.305	0.113	0.229	-0.096	1.000		
Unit Area, sq.km.	0.069	-0.051	0.033	0.032	0.450	1.000	
SNFL, mm	0.846	0.054	0.808	0.150	0.120	0.015	1.000

Regression Statistics	
Multiple R	0.947
R Square	0.896
Adjusted R Square	0.891
Standard Error	46.311
Observations	138

4.4.2. Standardization

The principal components are dependent on the units used to measure the original variables as well as range of values that they assume. Data should always be standardized prior to using PCA. A common standardization method is to transform all the data to have zero mean and unit standard deviation by applying the relation (xi-μ)/σ, Where μ and σ are the mean and standard deviation of xi's.

4.4.3. Computation of covariance matrix

Covariance matrix is a matrix with all possible covariance values between the different dimensions. If there is an *n* dimensional dataset, then the matrix has n rows and *n* columns (so is square) and each entry in the matrix is the result of calculating the covariance between two separate dimensions. For the present case a 6*6 matrix is obtained by using Data Analysis Tool Add-in in excel (***Table 4.6***).

Table 4.6: Covariance matrix of dataset

	Average Temperature oC	Average Precipitation mm	Forest Area %	Relief, m	Unit Area, sq.km.	SNFL, mm
Average Temperature oC	0.993	0.099	-0.034	0.112	-0.050	0.053
Average Precipitation mm	0.099	0.993	-0.286	0.228	0.033	0.802
Forest Area %	-0.034	-0.286	0.993	-0.095	0.032	0.149
Relief, m	0.112	0.228	-0.095	0.993	0.447	0.119
Unit Area, sq.km.	-0.050	0.033	0.032	0.447	0.993	0.015
SNFL, mm	0.053	0.802	0.149	0.119	0.015	0.993

4.4.4. Computation of eigenvector and eigenvalues of covariance matrix

The eigenvectors of a square matrix are the non-zero vectors that, after being multiplied by the matrix, remain parallel to the original vector. For each eigenvector, the corresponding eigenvalue is the factor by which the eigenvector is scaled when multiplied by the matrix. Eigenvectors are for square matrices only and there are n eigenvectors for an n x n matrix.

The mathematical expression of this idea is as follows: if A is a square matrix, a non-zero vector v is an eigenvector of A if there is a scalar λ (lambda) such that AV= λv.

The scalar λ (lambda) is said to be the eigenvalue of A corresponding to v. For the present analysis the Eigenvalues shown in Table 3.8 were considered.

Table 4.7: Eigenvalues of dataset

	Eigenvalues:	Difference	Proportion	Cumulative
Comp 1	1.933	0.574	0.325	0.325
Comp 2	1.359	0.253	0.228	0.553
Comp 3	1.106	0.126	0.186	0.738
Comp 4	0.98	0.485	0.165	0.903
Comp 5	0.495	0.412	0.083	0.986

	Eigenvalues:	Difference	Proportion	Cumulative
Comp 6	0.083	0.083	0.014	1.000
Sum	**5.956**			

Table 4.8: Eigenvector of dataset

Variables	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6
Comp 1	-0.141	0.019	0.314	-0.918	0.196	-0.019
Comp 2	-0.662	0.239	0.087	0.138	0.071	0.688
Comp 3	0.141	0.035	-0.858	-0.351	-0.14	0.317
Comp 4	-0.358	-0.598	0.05	-0.09	-0.708	-0.051
Comp 5	-0.191	-0.694	-0.203	0.086	0.658	-0.001
Comp 6	-0.598	0.318	-0.338	0.008	0.056	-0.651

4.4.5. Choosing components (Principle Component Analysis)

After eigenvectors are found from the covariance matrix, the next step is to order them by eigenvalues, highest to lowest. This arranges the components in order of significance, which helps in deciding to ignore the components of less significance. To be precise, if the original data have (D) dimensions, there will be (D) eigenvectors and eigenvalues, and if one choose only the first d eigenvector, then the final data set has only (d) dimensions. For the present analysis, 6 eigenvalues are taken.

4.4.6. Deriving new dataset

The standardized data series is multiplied with the chosen eigenvectors to derive principal components as shown in ***Table 4.9***

4.5. K-MEANS CLUSTERING

K-means is a prototype-based, simple partitioned clustering technique which attempts to find a user-specified k number of clusters. These clusters are represented by their centroids. A cluster centroid is typically the mean of the points in the cluster. The algorithm consists of two separate phases: the first phase is to select k centers randomly, where the value k is fixed in advance. The next phase is to assign each data object to the nearest center.

Table 4.9 : New generated dataset

Sub basins	PC1	PC2	PC3	PC4	PC5	PC6
1	-2.059	-1.268	-0.298	0.186	1.750	0.172
2	-1.339	1.045	-0.477	-0.275	0.166	0.474
3	-0.337	0.203	-1.915	2.970	0.054	-0.285
4	-1.470	0.321	-0.593	-0.257	0.444	0.444
5	-0.843	-0.710	-1.118	3.359	0.288	-0.656

Sub basins	PC1	PC2	PC3	PC4	PC5	PC6
6	-2.079	-0.375	-0.051	0.029	0.494	0.313
7	0.873	-2.103	-1.086	1.024	1.138	0.060
8	-1.960	0.427	0.815	0.172	-0.240	0.085
9	-1.073	-2.217	-0.263	-0.149	0.870	-0.044
10	-0.683	0.153	0.265	-0.308	-0.663	0.003
11	1.286	-0.795	-0.766	0.907	0.250	0.076
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
132	-1.181	-1.718	0.415	-0.349	-1.287	-0.084
133	-1.348	-0.810	0.329	-0.408	-1.619	-0.053
134	-2.942	-3.229	2.167	-4.482	0.936	-0.481
135	-0.844	1.425	4.056	1.321	0.564	-0.927
136	-1.486	-0.397	2.714	0.804	0.044	-0.581
137	-2.437	-1.078	2.423	1.171	1.690	0.307
138	-1.986	0.914	3.926	1.358	0.255	-0.034

Euclidean distance is generally considered to determine the distance between each data object and the cluster centers. The iterative process continues repeatedly until the criterion function becomes minimum (Tajunisha & Saravanan 2011).

Step 1: Dimension reduction and finding initial centroid using PCA

Step 2 : Assigning data-points to clusters

i) Compute the distance of each data-point p_i ($1 \leq i \leq n$) to all the centroids q_j ($1 \leq j \leq k$) using Euclidean distance formula.

In general, for (d) dimensional space, the Euclidean distance is calculated as

$$ED(p,q) = \sqrt{(p_1 - q_1)^{2} + (p_2 - q_2)^{2} + \cdots + \cdots (p_d - q_d)^{2}} \quad .$$

ii) For each data object p_i, find the closest centroid q_j and assign p_i to the cluster with the nearest centroid q_j.

Table 4.10: Computation of sum of minimum distance

Sub basins	Dist. To centroid -1	Dist. To centroid-2	Dist. To centroid -3	Cluster	Min Dist.
1	3.738	4.137	4.337	Cluster 1	3.738
2	3.819	1.689	3.026	Cluster 2	1.689
3	5.289	4.033	3.828	Cluster 3	3.828

4	3.713	2.252	3.126	Cluster 2	2.252
5	4.673	4.699	4.376	Cluster 3	4.376
6	3.090	3.173	3.805	Cluster 1	3.090
7	4.975	4.465	3.111	Cluster 3	3.111
8	2.323	2.834	3.764	Cluster 1	2.323
9	3.776	4.328	3.887	Cluster 1	3.776
10	3.015	2.185	2.580	Cluster 2	2.185
11	4.545	3.242	1.645	Cluster 3	1.645
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
132	3.240	4.185	3.986	Cluster 1	3.240
133	3.225	3.628	3.824	Cluster 1	3.225
134	6.252	7.742	7.916	Cluster 1	6.252
135	2.498	4.933	5.345	Cluster 1	2.498
136	0.039	4.337	4.536	Cluster 1	0.039
137	2.239	5.228	5.456	Cluster 1	2.239
138	2.013	5.136	5.723	Cluster 1	2.013
				SUM	**294.35**

iii) In K-means algorithm the objective is to minimise the sum of minimum distance i.e., distances to the nearest cluster centers.

$$\sum_{j=1}^{k}\sum_{i=1}^{n}[x_i^j - c_j]^2 \ldots\ldots\ldots\ldots\ldots\ldots$$

where , x_i^j is the data point belonging to the cluster j and c_j is the cluster center.

iv) The minimization is done with the help of 'Solver' tool available with MS-Excel. A 'Solver' basically solves an optimization problem (minimization or maximization problem) subjected to a set of constraints.. Here the objective function is to minimize distance by changing the cluster centroid. The minimum distance derived and allocation of cluster membership to individual sub-basins for k=3 can be seen in ***Table 4.11*** The coordinates of the new centroid for the same, are shown in the ***Table 4.12*** .

v) Continue to follow the steps from i) to iv) for various values of k i.e., k=1, 2, 3, 4, 5, 6 etc. and plot a graph between k (x-axis) and optimized sum of the results of clusters (encircled in Table 4.11)

vi) Finally choose the number of clusters based on the point that shows a sudden change in the slope of the curve (as depicted by arrow corresponding to k=3 in ***Figure 4.12***).

4.5.1. Choosing the number of clusters for Satluj sub basin

Following the above methodology in plotting the relation in ***Figure 4.12***, it can be seen that three clusters have been selected for Satluj basin for formulation of empirical relationships using regression analysis.

Table 4.11: Optimize result of clusters

Sub basins	Dist. To centroid -1	Dist. To centroid-2	Dist. To centroid -3	Cluster	Min Dist.
1	2.455	3.893	4.064	Cluster 1	2.455
2	1.379	2.130	3.493	Cluster 1	1.379
3	3.748	3.955	3.836	Cluster 1	3.748
4	1.053	2.357	3.330	Cluster 1	1.053
5	3.812	4.459	4.079	Cluster 1	3.812
6	1.169	3.112	3.709	Cluster 1	1.169
7	3.547	3.572	2.222	Cluster 3	2.222
8	1.350	2.929	3.859	Cluster 1	1.350
9	2.367	3.662	3.153	Cluster 1	2.367
10	0.891	1.812	2.598	Cluster 1	0.891
11	2.946	2.272	0.926	Cluster 3	0.926
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
132	1.979	3.572	3.258	Cluster 1	1.979
133	1.619	3.236	3.398	Cluster 1	1.619
134	6.176	7.327	7.458	Cluster 1	6.176
135	4.902	4.881	5.615	Cluster 2	4.881
136	3.105	4.013	4.334	Cluster 1	3.105
137	3.788	4.994	5.207	Cluster 1	3.788
138	4.549	5.145	5.842	Cluster 1	4.549
				SUM	**235.8**

Table 4.12: Coordinates of new centroids

	PC1	PC2	PC3	PC4	PC5	PC6
Median value -1	-1.264	-0.147	-0.138	-0.143	-0.249	0.062
Median value -2	0.694	0.901	-0.130	-0.320	0.155	-0.0343
Median value -3	1.540	-0.774	-0.258	0.250	-0.062	-0.0032

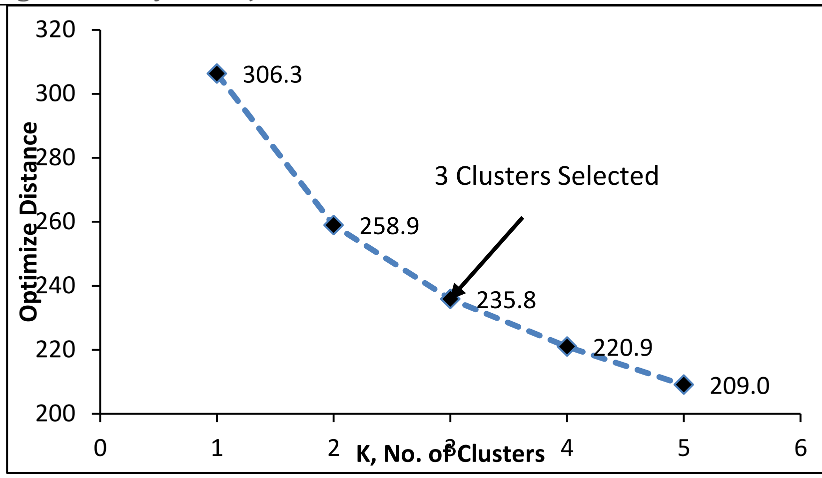


Figure 4.12: Choosing the number of clusters for Lohit sub basin

4.5.2. Membership of formed clusters

All the 138 sub basins are identified to form 3 clusters characterised by distinct properties by using the 7 variable clustering scheme, chosen on the basis of eigen values discussed in Sections *3.4*

The membership of Cluster formed by Cluster Analysis using K-means algorithm are shown in ***Tables 4.13*** to ***4.15*** and ***Figure 4.13***.

Table 4.13: Cluster 1 dataset

Sub basins	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Relief, m	Unit Area, sq.km.	SNFL, mm
1	397.15	-6.17	1064.52	83.21	1835.00	1080.07	649.06
2	364.98	-6.17	1091.12	100.00	1356.00	274.43	664.79
3	270.64	-10.03	790.67	99.63	1259.00	532.19	691.98
4	366.87	-6.17	1064.52	100.00	1620.00	487.11	649.06
5	276.46	-10.03	790.67	77.55	1816.00	750.76	691.98
6	421.31	-6.17	1130.38	85.11	2197.00	644.91	659.20
8	424.69	-6.17	1130.38	70.37	2235.00	291.09	659.20
9	363.24	-6.17	747.47	88.30	2673.00	1038.91	483.38
10	250.35	-6.17	819.68	87.73	2260.00	215.62	529.25
14	213.10	-6.17	747.47	90.35	3045.00	223.46	483.38
19	256.29	-6.17	819.68	85.35	2117.00	535.13	529.25
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
131	260.80	-6.17	759.20	85.71	2328.00	41.16	462.92
132	253.51	-6.17	759.20	83.80	3930.00	490.05	462.92
133	313.40	-6.17	846.00	87.07	3693.00	257.77	539.83

Sub basins	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Relief, m	Unit Area, sq.km.	SNFL, mm
134	256.04	-0.80	835.51	67.52	4351.00	1107.51	529.60
136	336.41	-6.17	935.58	27.96	2420.00	389.10	510.00
137	540.35	-6.17	1276.57	28.24	1934.00	916.39	503.35
138	579.09	-6.17	1276.57	5.04	1685.00	136.23	503.35

Table 3. 14 : Cluster 2 dataset

Sub basins	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Relief, m	Unit Area, sq.km.	SNFL, mm
29	162.92	-5.64	599.23	100.00	1861.00	352.84	457.16
31	144.72	-5.64	599.23	100.00	1883.00	247.97	457.16
41	150.12	-6.32	575.47	100.00	1217.00	394.98	427.90
50	261.11	-6.28	808.95	100.00	1148.00	357.74	607.67
51	93.95	-6.92	445.10	100.00	584.00	232.28	327.92
59	160.54	-6.88	586.98	100.00	796.00	274.43	436.68
62	198.57	-5.73	712.18	100.00	724.00	739.98	517.21
64	160.08	-6.88	586.98	100.00	1027.00	213.66	436.68
65	175.79	-5.73	712.18	83.92	857.00	414.58	517.21
69	140.61	-6.88	586.98	88.76	1206.00	331.27	436.68
71	315.94	-5.86	939.52	100.00	586.00	175.44	667.89
72	38.77	-5.33	292.79	100.00	612.00	90.17	225.68
73	158.92	-6.88	586.98	98.87	904.00	173.48	436.68
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
121	229.37	-5.60	774.01	100.00	650.00	66.65	595.72
123	54.47	-5.20	315.87	100.00	553.00	43.12	245.50
124	55.59	-5.20	315.87	100.00	844.00	54.89	245.50
129	248.69	-6.17	759.20	98.11	2132.00	51.95	462.92
135	329.64	-6.17	935.58	0.00	851.00	21.56	510.00

Table 4.15: Cluster 3 dataset

Sub basins	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Relief, m	Unit Area, sq.km.	SNFL, mm
7	75.72	-7.85	445.10	100.00	1620.00	1036.95	301.92
11	85.22	-7.85	445.10	100.00	1357.00	561.60	301.92
12	96.36	-8.65	423.04	100.00	2183.00	392.04	348.39
13	28.32	-7.25	234.38	100.00	1667.00	463.59	181.70
15	0.00	-6.17	819.68	69.87	2192.00	530.23	0.00
16	23.26	-6.66	235.69	100.00	2009.00	769.38	174.71
17	34.11	-7.05	253.16	100.00	1533.00	714.49	203.92
18	28.30	-7.25	234.38	100.00	1721.00	468.49	181.70
20	33.53	-7.05	253.16	100.00	1605.00	378.32	203.92
21	23.26	-6.66	235.69	100.00	1952.00	479.27	174.71
23	40.11	-7.05	253.16	92.83	3123.00	437.12	203.92
26	40.98	-5.33	292.79	100.00	1687.00	333.23	225.68
27	43.48	-5.33	292.79	100.00	1864.00	246.01	225.68
43	89.53	-6.92	445.10	100.00	1294.00	439.08	327.92
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
91	0.00	-10.03	790.67	67.61	1703.00	278.35	0.00
95	91.11	-8.65	423.04	93.65	2607.00	1713.21	348.39
98	0.00	-6.88	586.98	40.41	1043.00	189.16	0.00
104	94.38	-6.92	445.10	100.00	1528.00	823.28	327.92
105	96.63	-8.65	423.04	98.06	3064.00	353.82	348.39
125	78.93	-5.82	366.78	100.00	1598.00	545.92	288.03

4.5.3. Correlation matrix development

After dividing the dataset into clusters and choosing the sub-basin parameters, a correlation matrix was computed for each of the clusters. The correlation matrix for each cluster is shown in ***Table 4.16, 4.17*** and ***Table 4.18***.

Table 4.16: Correlation matrix – Cluster 1 dataset

	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Relief, m	Unit Area, sq.km.	SNFL, mm
Natural flow mm	1.000						
Average Temperature oC	-0.110	1.000					
Average Precipitation	0.890	-0.088	1.000				

mm							
Forest Area %	-0.397	-0.150	-0.269	1.000			
Relief, m	-0.275	0.396	-0.448	-0.147	1.000		
Unit Area, sq.km.	-0.072	0.188	-0.119	0.002	0.215	1.000	
SNFL, mm	0.533	-0.347	0.717	0.285	-0.535	-0.134	1.000

Table 4.17: Correlation matrix – Cluster 2 dataset

	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Relief, m	Unit Area, sq.km.	SNFL, mm
Natural flow mm	1.000						
Average Temperature oC	-0.148	1.000					
Average Precipitation mm	0.906	-0.157	1.000				
Forest Area %	0.005	0.176	-0.140	1.000			
Relief, m	-0.016	0.067	-0.088	0.197	1.000		
Unit Area, sq.km.	0.003	0.041	-0.015	0.205	0.452	1.000	
SNFL, mm	0.884	-0.160	0.835	0.302	0.024	0.108	1.000

Table 4.18: Correlation matrix – Cluster 3 dataset

	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Relief, m	Unit Area, sq.km.	SNFL, mm
Natural flow mm	1.000						
Average Temperature oC	-0.139	1.000					
Average Precipitation mm	0.110	-0.242	1.000				
Forest Area %	0.481	0.055	-0.636	1.000			
Relief, m	-0.032	-0.217	-0.071	0.150	1.000		
Unit Area, sq.km.	0.336	-0.075	0.151	0.119	0.284	1.000	
SNFL, mm	0.899	-0.048	-0.166	0.710	0.066	0.408	1.000

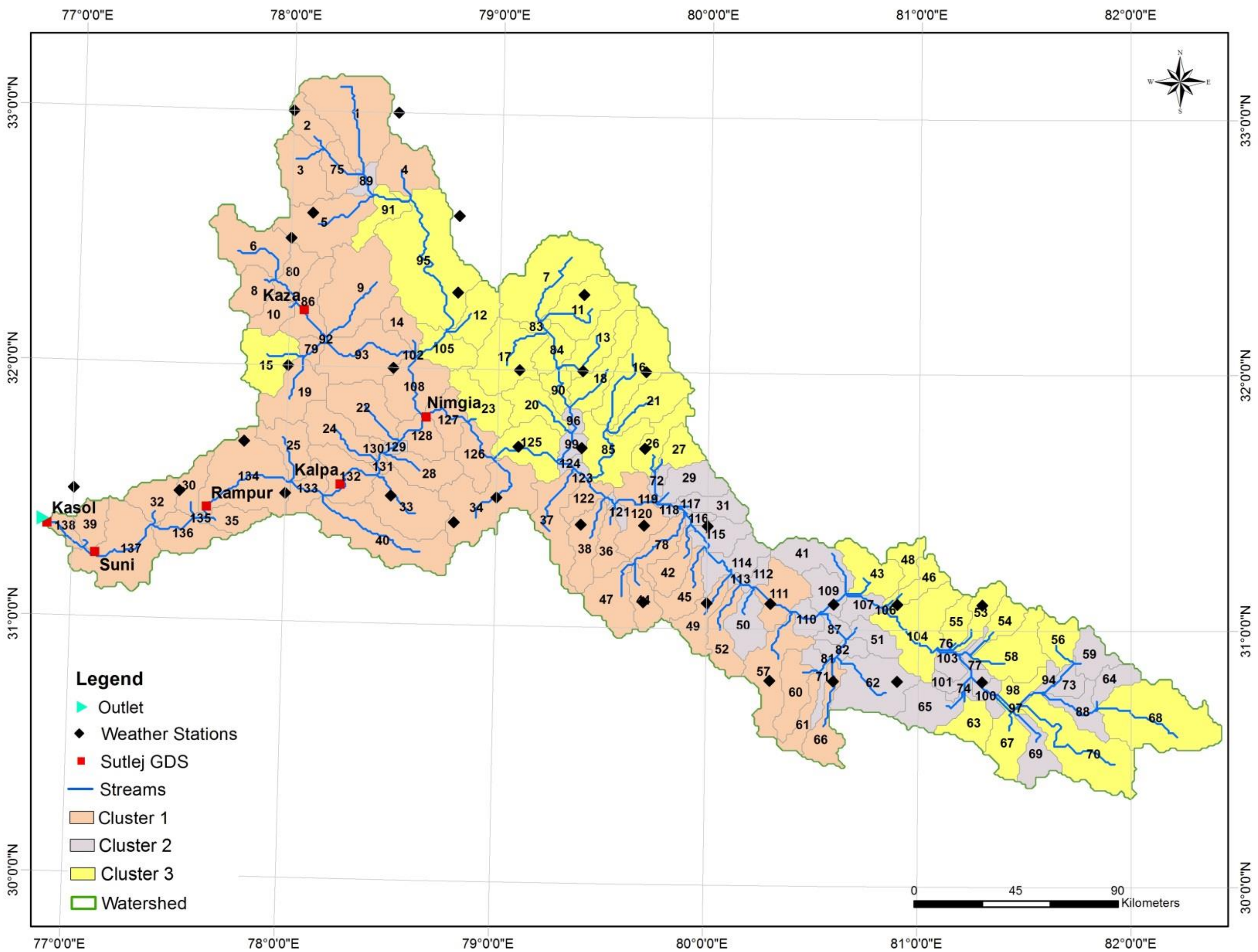


Figure 4.13: Cluster wise map for satluj sub basin

4.6. FORMULATION OF EMPIRICAL EQUATIONS

Separate empirical equations have been computed for months May, June, July, August, September. The approach considered for computation of empirical equations for the clusters of Sutlej Basin is detailed as below:

4.6.1. Approach for cluster wise empirical equation formulation

i. “Discharge”, “Precipitation”, “Temperature”, “Relief”, “% Forest Area”, “Sub basin Area”, “Snowfall” Parameters of each sub-basin of a cluster has been arranged month-wise.

ii. The correlation coefficient matrix for the above data have been derived.

iii. Calculate the parameters for the following equation which has been chosen to relate the dependent variable "monthly discharge (Q_{sim})" with the independent variables namely “Precipitation” (PCP), “Max. Temperature” (Tmax.), “Relief”(RL), “% Forest Area (%FA)”, “Sub basin Area/ Catchment area of the sub basin” (SA) “Snowfall (SNFL)” and “Snowmelt (SNMT)”:

$Q_{sim} = \beta_1 \times (PCP) + \beta_2 \times (Tmax) + \beta_3 \times (SA) + \beta_4 \times (\%FA) + \beta_5 \times (\%RL) + \beta_6 \times (SNFL) + \beta_7 \times (SNMT) – CONS$

Where coefficient, β_{1-7} and CONS are the coefficients that has been determined, such that the root mean square error (RMSE) between the observed discharge and simulated discharge is minimum.

iv. Similarly, an empirical equation is computed for the entire monsoon season using the above steps (i) to (iii).

The results of the optimization for various months and monsoon season for Manjra basin are provided in sections below. For each month, a set of best 3 equations for each cluster, chosen in the order of importance/significant parameters are formulated. The criteria for selection are based on Coefficient of Determination, correlation coefficient, parameter significance estimated from p-value and t-statistic, sign conventions of independent variables with respect to dependant variables and the ease of applicability. The t-statistic is a measure of how strongly a particular independent variable explains variation in the dependant variable given by $t_i = b_i / se(b_i)$ where, b_i is the coefficient of the independent variable and $se(b_i)$ is its standard error . The larger the t-statistic, higher is the independent variables explanatory power in the equation. The p-value is used to interpret the t-stat. It is the probability that the independent variable is significant. For a p-value less than 0.05, it implies that there is a 5% chance that the independent variable is unrelated to dependant variable. If the p-value is higher thsn 0.1, this can be a strong reason to eliminate the independent variable from the model because it is not statistically significant.

Based on the analysis as described in the preceding sections, the Empirical Equation derived is presented. The formulation is explained by Q_{SIM} = Discharge (mm); PCP = Total precipitation during the period/ month (mm); PCP1= Precipitation in the previous month ; PCP2= Precipitation in the 2nd previous month ; PCP3= Precipitation in the 3rd previous month; TEMP = Average temperature during the month (^{0} C); SA = sub basin or catchment area (km^2); %CA = Percentage Cropped area; %FA = Percentage Forest area; RL = Relief i.e. difference between maximum and minimum elevation (m).

The flow computed using the Empirical relation at sample HRU's in each cluster has been shown in ***Annex 4.2*** at calibration period (1985-86 to 1999-00) and Validation period (2000-01 to 2004-05) for Sutlej Basin.

Cluster 1 (CL-1) : Sutlej Basin

EQN NO	EQUATION (CL-I) Sutlej Basin	R
	MAY (CL-I)	
1	Q_{SIM} = -7.542 + 0.0408 X (PCP) + 0.0018 X (RL) + 0.1467X SNMT The above equation is valid for may PCP > 35 mm .	0.80
2	Q_{SIM} = -2.513 + 0.0311X SNFL + 0.1501 X SNMT The above equation is valid for may PCP > 35 mm.	0.79
	JUNE (CL-I)	
1	Q_{SIM} = -89.4403 + 0.3493 X (PCP) + 0.009 X (RL) + 0.2263 X SNMT + 5.6935 X Tmax The equation is mostly for June PCP > 55 mm.	0.74
2	Q_{SIM} = -49.4981 + 0.0088 X (RL) + 0.0527 X SNFL + 0.2416 X SNMT + 2.0565 X Tmax The equation is mostly for June SNFL > 85 mm.	0.66
	JULY (CL-I)	
1	Q_{SIM} = -89.9009 + 0.5325 X (PCP) + 0.0093 X (RL) + 0.2728 X SNMT + 4.215 X Tmax The equation is mostly for July PCP > 35 mm .	0.86
2	Q_{SIM} = -60.4664 + 0.5283 X (PCP) + 0.2595 X SNMT + 3.8768 X Tmax The equation is mostly for July PCP > 5 mm .	0.85
	AUGUST (CL-I)	
1	Q_{SIM} = -26.8335 + 0.4409 X (PCP) + 0.2557 X SNMT + 2.7113 X Tmax + 0.0329 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP July + w2×PCP August) > 20 mm. The weights are w1 = 0. 0329; w2 = 0. 4409.	0.90
2	Q_{SIM} = -25.9252 + 0.4553 X (PCP) + 0.2542 X SNMT + 2.8471 X Tmax The equation is mostly for August PCP > 20 mm.	0.90
	SEPTEMBER (CL-I)	
1	Q_{SIM} = -5.0204 + 0.3938 X (PCP) -0.1007 X SNMT + 1.1987 X Tmax + 0.1043 X (PCP1) The above equation is valid for total weighted precipitation (w1×PCP August + w2×PCP September) > 15 mm . The weights are w1 = 0. 1043; w2 = 0. 3938.	0.81

EQN NO	EQUATION (CL-I) Sutlej Basin	R
2	Q_{SIM} = 10.8557 + 0.4182 X (PCP) -0.0035 X (RL) + 1.2986 X Tmax The equation is valid for September PCP > 5 mm	0.77

For applying above equations, Snowmelt series can be derived as a function of three month snowfall SNFL (mm) and maximum monthly Temperature Tmax given by :

$$SNMT = -43.965 + 1.7047 \times \sum SNFL_{i,i-1,i-2} + 3.4635 \times Tmax$$

Where,

SNMT = Snowmelt in mm

SNFL = Snowfall in mm

Tmax = Weighted average maximum monthly temperature in deg. C.

For Tavg < 0.5 degree C, SNMT = 0.0

An attempt has been made to compute discharge Q of Satluj at the point of its entry to the Indian territory. The location of flow evolved is corresponding to HRU 127. The set of equations derived are :

Month	Equation	R
June	Q = -323.08 + 2.8048 X (PCP) + 1.7985 X (SNMT) + 94.47 X (Tavg) Above equation valid for June precipitation value > 10 mm.	0.90
July	Q = -104.59 + 1.842 X (PCP) + 2.22X (SNMT) + 33.0 (Tavg) Above equation valid for July precipitation value > 20 mm.	0.80
August	Q = 95.33 + 2.17 X (PCP) + 4.16 X (SNMT) Above equation valid for August precipitation value > 20 mm.	0.90
September	Q = 182.75 + 2.24 X (PCP) – 6.1388 X (SNMT) Above equation valid for September precipitation value > 10 mm.	0.77

Where Q is in cumec, PCP = Area Averaged Precipitation (mm) for the Catchment upto HRU 127, SNMT = Averaged Snowmelt (mm) for Catchment at HRU 127

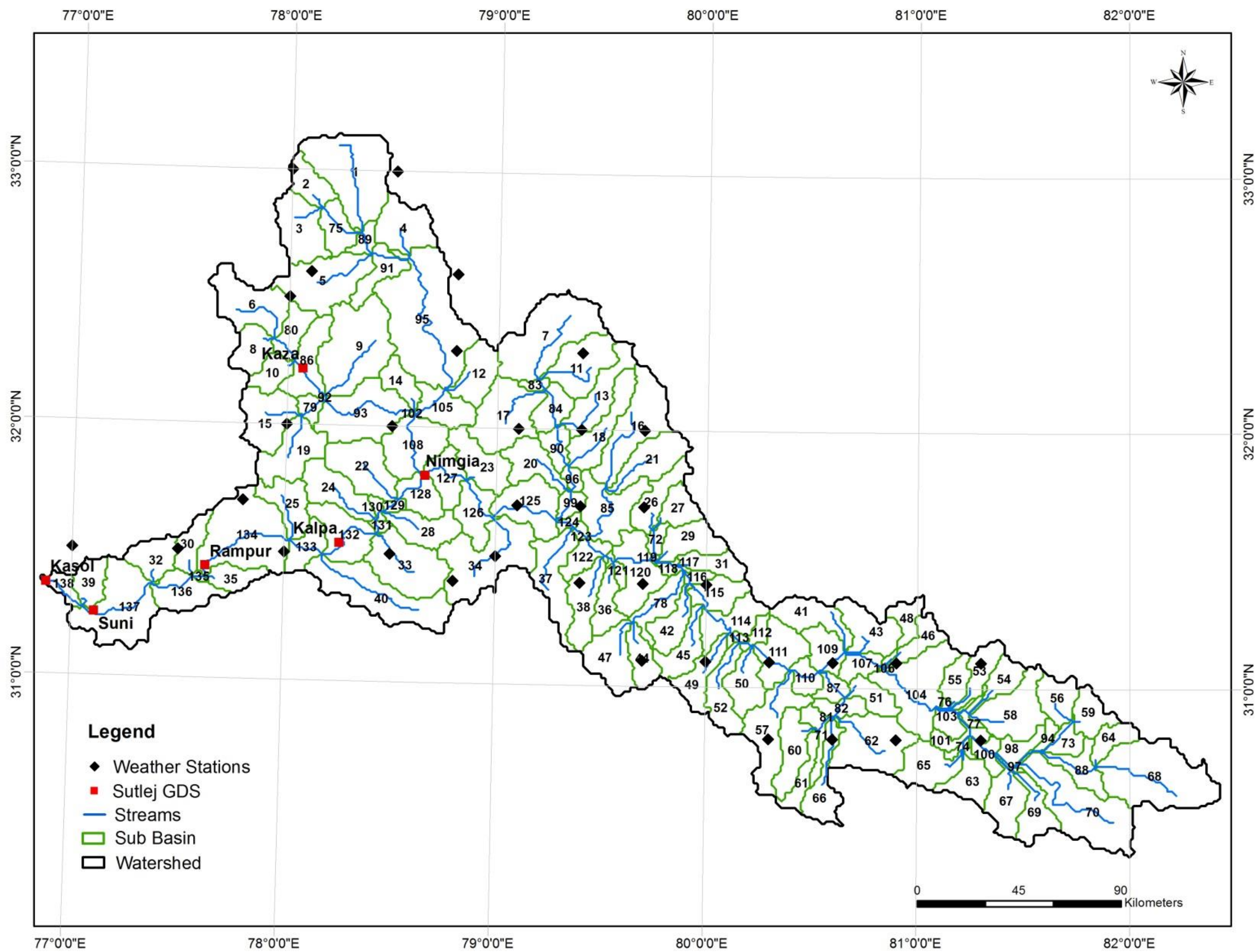
The Snowmelt (SNMT) for the above sets of eqn can be derived from :

$$SNMT = -78.5034 - 0.10897 \times \sum SNFL_{i,i-1,i-2} + 0.95553 \times \sum SNFL_{i,i-1,i-2,i-3} + 10.495 \times Tmax$$

SNMT – Weighted average snowmelt (mm) of catchment at HRU 127 outlet

SNFL – Weighted average snowfall (mm) of catchment at HRU 127 outlet

Tmax – Weighted average maximum monthly temperature in deg. C.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31°0'0"N
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Kalpa
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Streams
Sub Basin
Watershed
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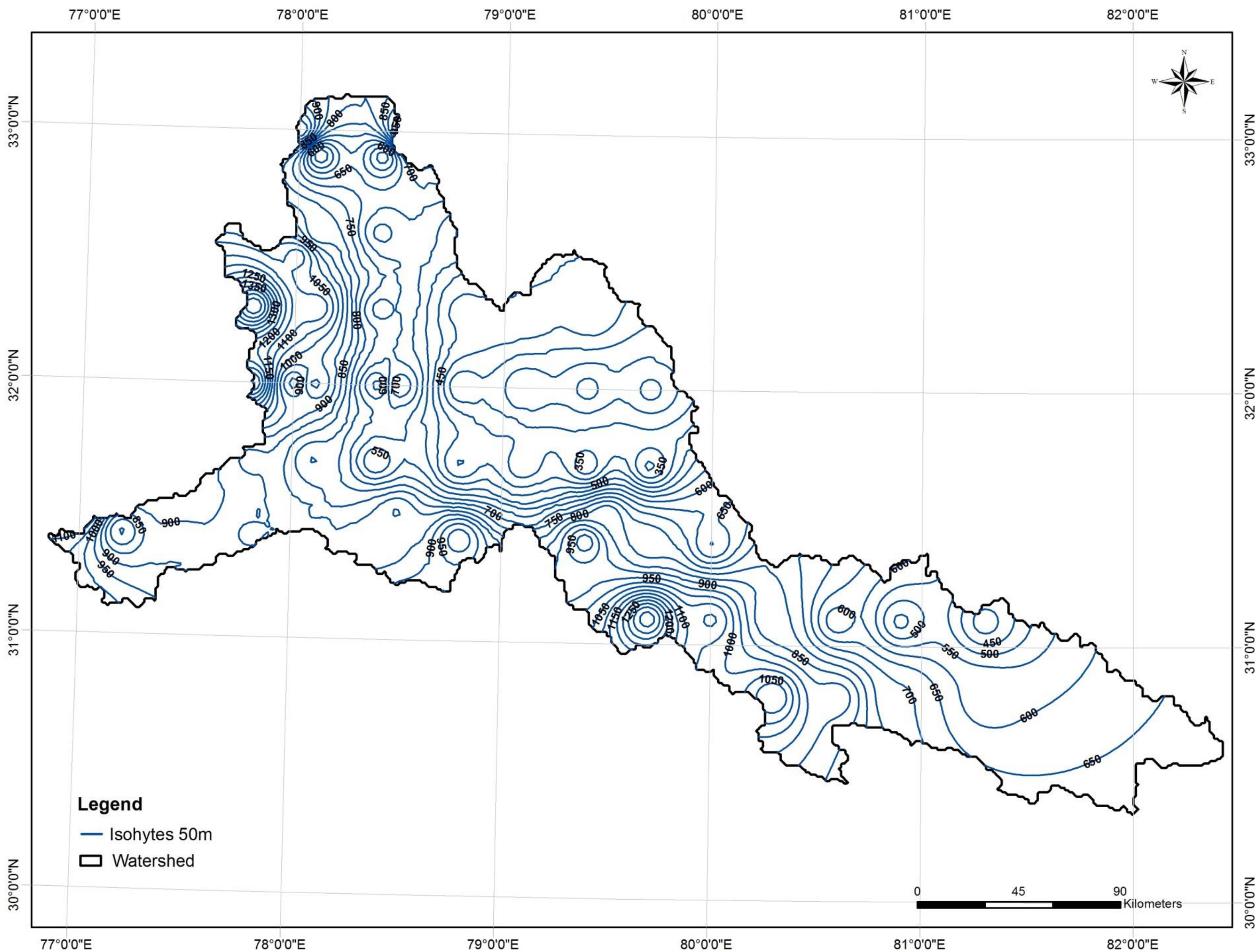
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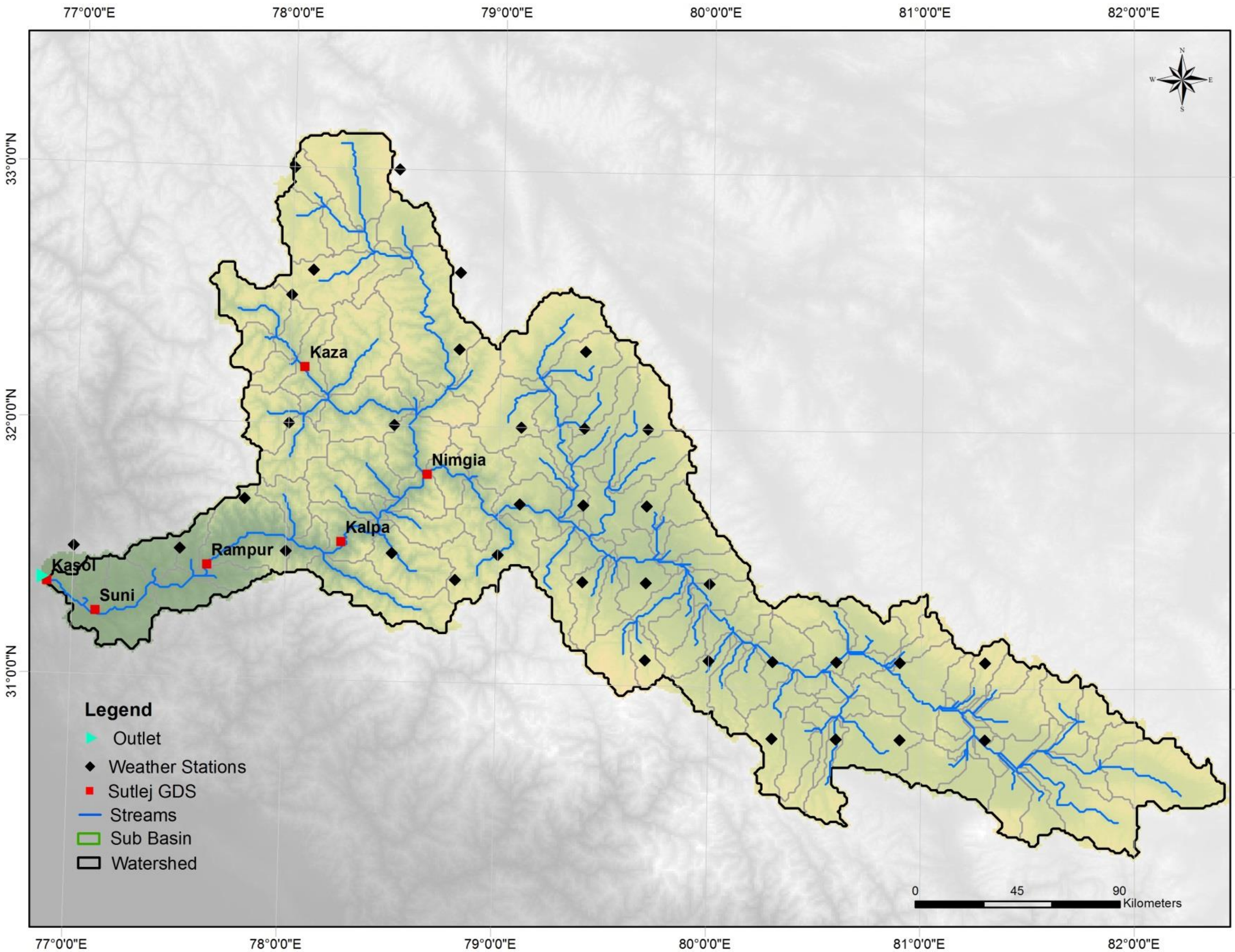


Figure 3. 14: Elevation map of Satluj sub basin

Input Data set for Barak Sub-basin

Sub basins	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.
1	482.29	22.77	1658.44	98.55	1.46	2571.00	375.55
2	482.83	22.77	1658.44	84.71	14.56	1647.00	399.05
3	493.41	22.77	1658.44	100.01	0.00	2056.00	78.75
4	479.75	22.77	1658.44	100.00	0.00	2333.00	148.68
5	199.98	22.77	1279.36	98.55	1.45	1677.00	142.71
6	483.87	22.77	1658.44	99.96	0.04	1217.00	82.26
7	287.25	22.77	1279.36	99.94	0.06	1345.00	89.03
8	297.79	22.77	1279.36	97.40	2.59	1368.00	92.95
9	476.94	22.77	1658.44	99.99	0.00	2220.00	115.36
10	389.61	22.98	1487.05	95.20	4.80	1276.00	89.43
11	264.44	22.77	1279.36	100.00	0.00	1863.00	97.00
12	388.20	22.98	1487.05	95.27	4.73	2141.00	282.87
13	728.35	22.98	1948.82	99.93	0.06	1974.00	313.00
14	706.95	22.98	1948.82	100.00	0.00	1578.00	73.02
15	1817.20	22.92	3245.85	80.36	19.65	1177.00	265.24
16	708.24	22.98	1948.82	99.99	0.00	2007.00	496.57
17	1196.49	22.92	2429.55	99.87	0.13	1774.00	299.97
18	1910.12	22.92	3245.85	100.00	0.00	1529.00	99.80
19	352.55	22.98	1487.05	100.00	0.00	1977.00	159.70
20	1263.23	22.92	2429.55	100.00	0.00	1532.00	189.14
21	1895.33	22.92	3245.85	100.00	0.00	1611.00	182.51
22	764.75	22.98	1948.82	100.01	0.00	1902.00	100.41
23	705.01	22.98	1948.82	100.00	0.00	1639.00	155.76
24	1961.10	22.92	3245.85	100.00	0.00	1601.00	78.44
25	1497.05	22.92	2429.55	99.98	0.03	1688.00	206.18
26	1881.68	22.92	3245.85	85.51	14.49	1530.00	153.16
27	1506.54	22.92	2429.55	98.65	1.35	1700.00	160.34
28	2279.59	22.92	3245.85	34.49	63.12	731.00	78.99
29	2220.88	22.92	3245.85	89.02	10.98	1272.00	86.88
30	714.70	22.98	1948.82	100.00	0.00	1453.00	119.04
31	2211.53	22.92	3245.85	60.05	39.94	1296.00	126.33
32	2279.15	22.92	3245.85	44.62	55.38	880.00	197.14
33	1486.67	22.92	2429.55	88.80	11.20	1263.00	131.39
34	1496.73	22.92	2429.55	100.00	0.00	1313.00	83.82
35	708.11	22.98	1948.82	98.80	1.20	1886.00	180.64
36	1489.20	22.92	2429.55	100.00	0.00	997.00	132.43
37	1488.36	22.92	2429.55	99.25	0.75	230.00	144.26
38	1976.03	22.92	3245.85	23.41	76.31	42.00	106.17
39	1946.05	22.92	3245.85	34.85	58.50	68.00	113.48
40	1063.97	22.08	2307.13	100.00	0.00	1578.00	101.21
41	2196.38	22.92	3245.85	63.17	36.83	136.00	85.61

Input Data set for Barak Sub-basin

42	1977.35	22.92	3245.85	49.84	50.16	129.00	131.16
43	1571.91	24.98	2575.61	70.62	29.37	145.00	101.87
44	2095.73	24.09	3121.45	78.21	21.78	244.00	141.09
45	1274.98	24.98	2575.61	22.86	75.18	166.00	201.56
46	1038.13	22.08	2307.13	100.01	0.00	1584.00	149.51
47	1581.94	24.98	2575.61	91.77	8.24	162.00	199.82
48	1613.60	24.98	2575.61	49.26	50.74	214.00	151.88
49	1632.07	24.98	2575.61	48.81	51.18	137.00	98.62
50	3946.88	24.17	5564.12	27.69	71.26	65.00	206.35
51	1060.64	22.08	2307.13	100.00	0.00	1404.00	85.86
52	3939.69	24.17	5564.12	0.00	100.00	13.00	86.26
53	1057.61	22.08	2307.13	100.00	0.00	1310.00	74.14
54	1095.58	22.08	2307.13	100.00	0.00	1433.00	80.19
55	1049.28	22.08	2307.13	100.00	0.00	1114.00	164.88
56	1581.27	24.98	2575.61	77.58	22.42	294.00	132.75
57	1582.45	24.98	2575.61	89.54	10.47	191.00	180.66
58	4539.57	24.17	5564.12	34.51	63.98	316.00	246.83
59	3940.26	24.17	5564.12	27.04	72.96	59.00	105.48
60	1093.75	22.08	2307.13	100.00	0.00	1308.00	284.25
61	1080.95	22.08	2307.13	100.00	0.00	1425.00	187.32
62	1052.37	22.08	2307.13	99.99	0.00	1647.00	307.33
63	1584.40	24.98	2575.61	100.00	0.00	534.00	73.35
64	1692.78	24.09	3121.45	100.00	0.00	1424.00	332.99
65	1579.70	24.98	2575.61	89.22	10.77	581.00	481.14
66	1243.40	23.08	2545.31	100.00	0.00	770.00	132.70
67	1431.90	19.95	2662.87	100.00	0.00	1374.00	244.39
68	1483.04	19.95	2662.87	100.00	0.00	970.00	81.90
69	1319.94	23.08	2545.31	100.00	0.00	1031.00	144.21
70	4132.46	24.03	5236.33	82.99	17.01	371.00	520.39
71	3002.19	18.29	4376.94	100.00	0.00	1148.00	121.55
72	3723.26	24.17	5564.12	93.50	6.50	211.00	92.60
73	1406.30	19.95	2662.87	100.00	0.00	1069.00	148.86
74	1212.53	23.08	2545.31	100.00	0.00	1030.00	151.59
75	1580.85	23.08	2545.31	100.00	0.00	535.00	74.15
76	2871.18	18.29	4376.94	100.00	0.00	1476.00	88.71
77	1210.79	23.08	2545.31	100.00	0.00	665.00	72.49
78	4114.92	24.03	5236.33	95.63	4.37	239.00	108.03
79	1349.17	23.08	2545.31	99.99	0.00	1174.00	219.16
80	2712.80	19.95	4193.82	100.01	0.00	1527.00	107.80
81	2942.57	24.14	4735.18	93.75	6.25	270.00	79.12
82	2841.66	18.29	4376.94	100.00	0.00	1072.00	231.42
83	2698.70	23.66	4391.92	100.00	0.00	459.00	72.36
84	1411.20	19.95	2662.87	99.99	0.00	1654.00	121.00
85	2984.73	18.29	4376.94	96.88	3.13	1362.00	380.67
86	2684.63	23.66	4391.92	94.52	5.49	526.00	115.65

Input Data set for Barak Sub-basin

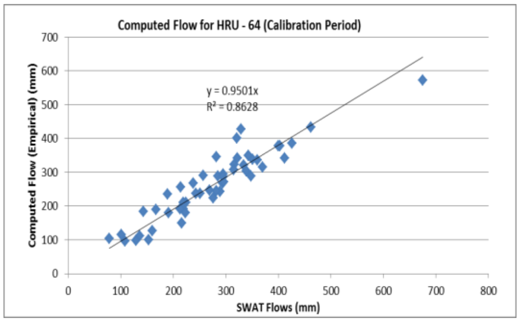
87	2709.00	23.66	4391.92	100.00	0.00	766.00	328.28
88	3006.52	24.14	4735.18	93.50	6.49	467.00	606.45
89	2865.79	18.29	4376.94	99.00	1.01	1591.00	312.37
90	2699.47	19.95	4193.82	100.00	0.00	1863.00	294.54
91	2959.26	24.14	4735.18	100.00	0.00	407.00	160.56
92	1229.46	23.08	2545.31	100.00	0.00	1310.00	94.89
93	2688.01	23.66	4391.92	99.63	0.37	703.00	240.17
94	2709.33	23.66	4391.92	97.14	2.86	866.00	337.00
95	1215.08	23.08	2545.31	100.01	0.00	1198.00	635.21
96	2920.45	18.29	4376.94	100.00	0.00	1723.00	360.48
97	1317.78	21.50	2574.05	100.00	0.00	1740.00	412.15
98	1342.82	23.32	2631.77	100.00	0.00	1236.00	88.45
99	1315.68	21.50	2574.05	100.00	0.00	1327.00	101.70
100	2694.46	19.95	4193.82	99.99	0.00	1785.00	877.66
101	785.27	22.14	1876.60	99.99	0.00	1270.00	113.01
102	1291.56	23.32	2631.77	99.99	0.00	1266.00	865.59
103	837.98	22.14	1876.60	98.62	0.00	1246.00	428.48
104	187.45	22.77	1279.36	100.00	0.00	1901.00	193.52
105	1318.84	21.50	2574.05	98.80	1.21	1218.00	345.52
106	1037.96	22.08	2307.13	100.00	0.00	1819.00	385.41
107	1582.87	24.98	2575.61	99.49	0.50	501.00	234.97
108	2280.90	22.92	3245.85	61.39	38.61	1060.00	194.24
109	3024.11	24.14	4735.18	99.14	0.85	442.00	57.80
110	713.48	22.98	1948.82	100.00	0.00	1486.00	53.06
111	2248.48	22.92	3245.85	99.99	0.00	993.00	44.73
112	1483.34	22.92	2429.55	49.11	50.89	84.00	115.99
113	712.96	22.98	1948.82	100.00	0.00	1628.00	121.46
114	2271.95	22.92	3245.85	0.00	100.00	0.00	0.01
115	2268.70	22.92	3245.85	0.02	99.98	45.00	210.45
116	1884.83	22.92	3245.85	89.06	9.61	1016.00	144.82
117	1057.69	22.08	2307.13	99.99	0.00	684.00	16.16
118	715.80	22.98	1948.82	100.00	0.00	1243.00	54.11
119	3017.18	24.14	4735.18	91.79	8.21	405.00	129.10
120	1064.30	22.08	2307.13	100.00	0.00	872.00	36.77
121	1486.64	22.92	2429.55	65.93	33.37	1335.00	188.33
122	1790.03	24.09	3121.45	100.00	0.00	723.00	85.02
123	3374.91	24.03	5236.33	90.42	9.57	621.00	278.76
124	518.96	22.77	1658.44	96.37	3.62	2014.00	119.51
125	1577.97	24.98	2575.61	89.04	10.97	375.00	594.78
126	767.82	22.98	1948.82	100.01	0.00	1503.00	280.10
127	3673.55	24.03	5236.33	44.31	53.31	122.00	251.03
128	1488.30	22.92	2429.55	100.00	0.00	601.00	151.02
129	4460.58	24.17	5564.12	85.01	14.99	328.00	168.39
130	1411.22	19.95	2662.87	99.99	0.00	1361.00	74.03
131	3005.04	18.29	4376.94	100.00	0.00	1509.00	105.47

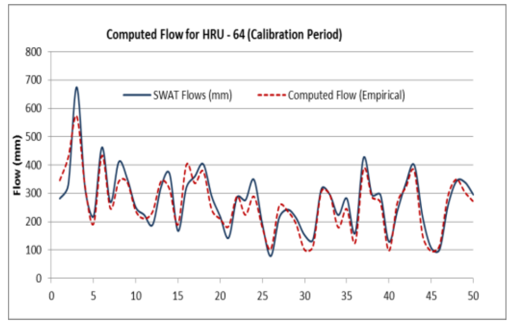
Input Data set for Barak Sub-basin

132	1759.99	24.09	3121.45	79.54	20.46	464.00	444.15
133	2909.65	18.29	4376.94	100.00	0.00	628.00	5.62
134	492.03	22.77	1658.44	97.47	2.54	1721.00	42.65
135	1978.02	22.92	3245.85	0.00	100.00	10.00	17.62
136	1572.56	24.98	2575.61	43.57	41.56	103.00	184.01
137	1973.51	22.92	3245.85	0.00	92.22	10.00	48.22
138	2923.76	18.29	4376.94	100.00	0.00	763.00	50.63
139	4539.73	24.17	5564.12	53.82	46.19	122.00	249.10
140	1753.01	24.09	3121.45	89.92	9.99	1295.00	1100.30
141	719.22	22.98	1948.82	100.00	0.00	1011.00	13.87
142	495.15	22.77	1658.44	99.99	0.00	2361.00	190.75
143	4115.29	24.03	5236.33	98.72	1.28	228.00	161.09
144	1298.65	23.32	2631.77	99.98	0.02	1469.00	547.01
145	1053.33	22.08	2307.13	100.00	0.00	640.00	8.17
146	1274.96	24.98	2575.61	36.27	60.10	196.00	145.11
147	1976.57	22.92	3245.85	0.00	100.00	12.00	59.68
148	1206.59	23.08	2545.31	100.00	0.00	187.00	7.99
149	2858.24	18.29	4376.94	100.01	0.00	1517.00	229.99
150	3930.84	24.17	5564.12	13.64	86.36	51.00	76.89
151	4452.77	24.17	5564.12	66.81	33.21	285.00	443.83
152	463.75	22.77	1658.44	100.01	0.00	644.00	1.57
153	457.51	22.77	1658.44	95.22	4.78	1368.00	37.03
154	1043.36	22.08	2307.13	99.99	0.00	1217.00	188.05
155	1488.55	22.92	2429.55	100.00	0.00	452.00	157.04
156	206.49	22.77	1279.36	100.00	0.00	1437.00	56.89
157	2878.98	18.29	4376.94	99.99	0.00	1430.00	50.20
158	199.34	22.77	1279.36	100.00	0.00	1245.00	42.20
159	2885.32	18.29	4376.94	100.00	0.00	1120.00	27.69
160	765.96	22.98	1948.82	100.00	0.00	1794.00	91.38
161	1022.39	22.08	2307.13	99.99	0.00	1314.00	107.09
162	1519.53	22.92	2429.55	0.00	100.00	5.00	0.19
163	2273.51	22.92	3245.85	53.34	46.67	104.00	126.69
164	2878.44	18.29	4376.94	100.01	0.00	925.00	56.45
165	766.02	22.98	1948.82	100.00	0.00	977.00	2.61
166	770.47	22.98	1948.82	100.00	0.00	1699.00	169.27
167	1059.84	22.08	2307.13	100.01	0.00	1319.00	136.65
168	2716.92	19.95	4193.82	100.00	0.00	1436.00	235.37
169	1219.20	23.08	2545.31	99.99	0.00	1454.00	538.51
170	1976.43	22.92	3245.85	0.00	100.00	23.00	17.38
171	3940.60	24.17	5564.12	16.14	83.86	46.00	77.23
172	1974.57	22.92	3245.85	15.98	84.02	39.00	17.13
173	1978.25	22.92	3245.85	0.00	100.00	14.00	32.75
174	1746.32	24.09	3121.45	100.00	0.00	621.00	46.48
175	710.31	22.98	1948.82	100.01	0.00	1524.00	661.51
176	3946.84	24.17	5564.12	0.00	100.00	13.00	38.59

Input Data set for Barak Sub-basin

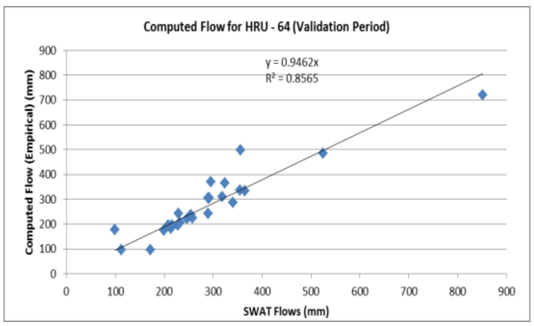
177	3948.16	24.17	5564.12	0.00	100.00	15.00	20.52
178	2715.91	19.95	4193.82	98.85	1.15	1610.00	272.97
179	1582.43	23.08	2545.31	100.00	0.00	731.00	48.31
180	1227.16	23.08	2545.31	100.00	0.00	343.00	10.34
181	1442.11	19.95	2662.87	100.00	0.00	1272.00	53.38
182	1582.07	24.98	2575.61	95.19	4.81	589.00	435.48
183	1378.48	19.95	2662.87	100.00	0.00	1311.00	123.84
184	1724.88	24.09	3121.45	100.00	0.00	1152.00	178.28
185	1698.19	24.09	3121.45	100.01	0.00	1174.00	314.49
186	1632.28	24.98	2575.61	55.26	44.75	74.00	58.25
187	1612.18	24.98	2575.61	29.25	70.75	102.00	239.98
188	1724.85	24.09	3121.45	100.00	0.00	1056.00	658.59
189	2275.00	22.92	3245.85	24.35	75.65	144.00	37.70
190	1529.90	22.92	2429.55	70.38	29.61	309.00	79.32
191	1530.86	22.92	2429.55	0.00	83.91	21.00	4.62
192	1526.43	22.92	2429.55	0.00	100.00	20.00	39.88
193	1520.07	22.92	2429.55	38.63	61.37	129.00	146.02
194	1520.49	22.92	2429.55	17.93	82.07	41.00	13.82
195	2272.12	22.92	3245.85	38.30	61.70	106.00	152.86
196	2276.29	22.92	3245.85	0.00	100.00	92.00	1.83
197	2269.69	22.92	3245.85	5.44	94.56	125.00	39.15
198	1978.29	22.92	3245.85	0.00	100.00	15.00	11.56
199	1965.36	22.92	3245.85	0.00	97.37	16.00	29.89
200	1978.59	22.92	3245.85	0.00	100.00	10.00	1.82
201	1978.17	22.92	3245.85	0.00	100.00	10.00	8.62
202	1910.04	22.92	3245.85	2.06	94.63	40.00	320.29
203	3938.38	24.17	5564.12	8.09	86.49	52.00	197.28
204	3949.28	24.17	5564.12	0.00	100.00	11.00	2.05
205	3948.38	24.17	5564.12	0.00	100.00	21.00	33.06

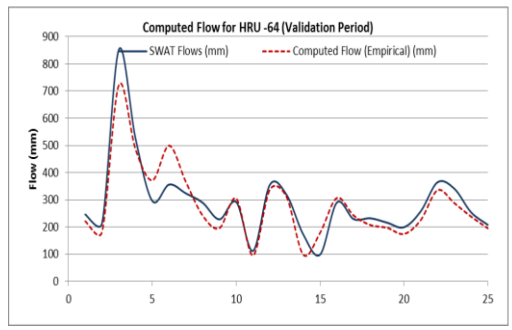




Observed and Computed Flow for HRU -64 (Calibration Period)

Flow Series for HRU -64 (Calibration Period)





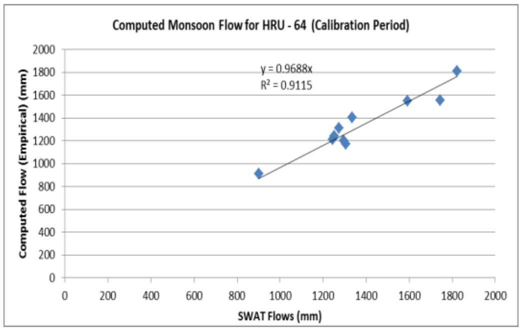
Observed and Computed Flow for HRU -64 (Validation Period)

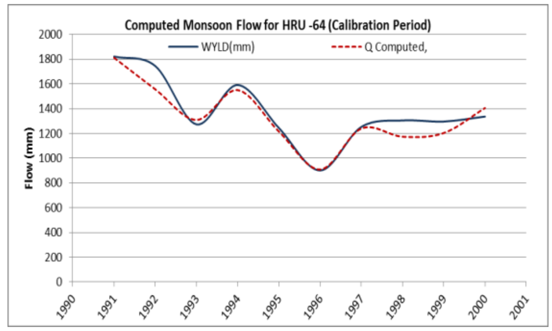
Flow Series for HRU -64 (Validation Period)

Cluster **I**

Equation:

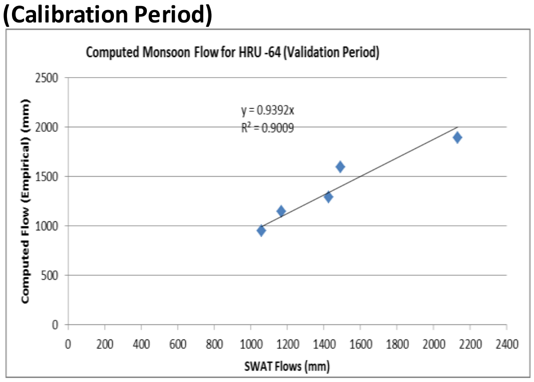
Q_{SIM}	**=**	**-2594.9404 + 26.2768 X (%FA) + 28.8847 X (%CA) + 0.0007 X (PCP^2)**	**: June**
Q_{SIM}	**=**	**-102.6985 + 0.6011 X (PCP) -0.0195 X (RL) + 0.1977 X (PCP1)**	**:July**
Q_{SIM}	**=**	**-28.9648 + 0.6542 X (PCP) -1.2876 X (%CA) -0.0412 X (RL) + 0.1382 X (PCP**	**: August**
Q_{SIM}	**=**	**-21.1696 + 0.5571 X (PCP) -0.0244 X (RL) + 0.0359 X (UA) + 0.1572 X (PCP1)**	**: September**
Q_{SIM}	**=**	**-66.1333 + 0.5028 X (PCP) + 0.0349 X (UA) + 0.0893 X (PCP2) + 0.2308 X (PCP1)**	**: October**
Basin	**:**	**Barak**	

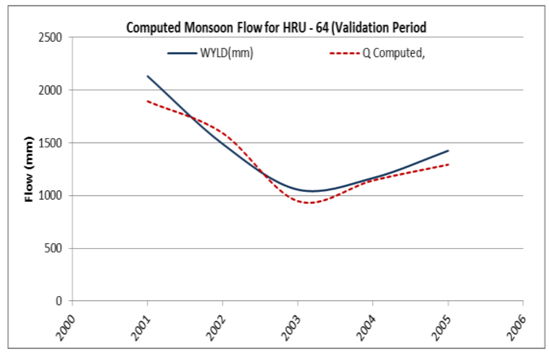




Observed and Computed Flow for HRU -64 (Calibration Period)

Flow Series for HRU -64 (Calibration Period)





Observed and Computed Flow for HRU -64 (Validation Period)

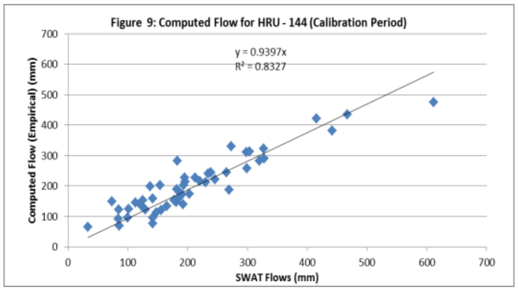
Flow Series for HRU -64 (Validation Period)

Cluster **I**

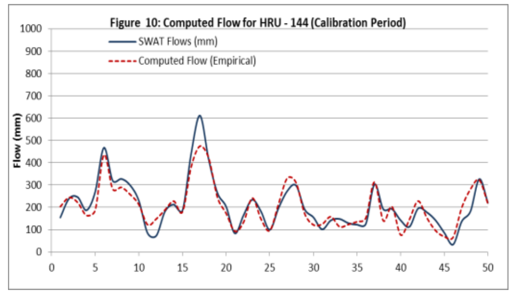
Equation:

Q_{SIM} **=** **-641.715 + 0.785 X (PCP) + 4.727 X (%FA) -0.1523 X (RL)** **Monsoon**

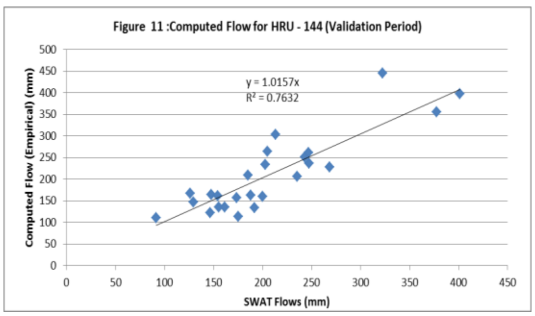
Basin **:** **Barak**



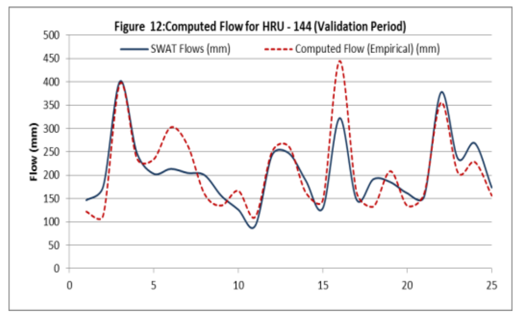
Observed and Computed Flow for HRU -144 (Calibration Period)



Flow Series for HRU -144(Calibration Period)



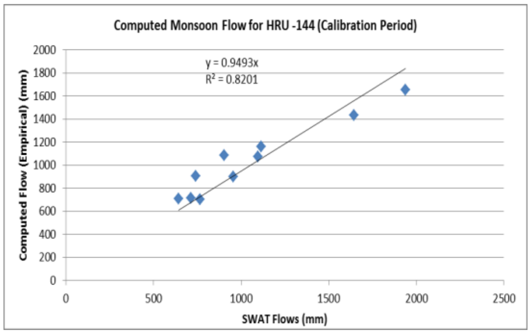
Observed and Computed Flow for HRU -144 (Validation Period)



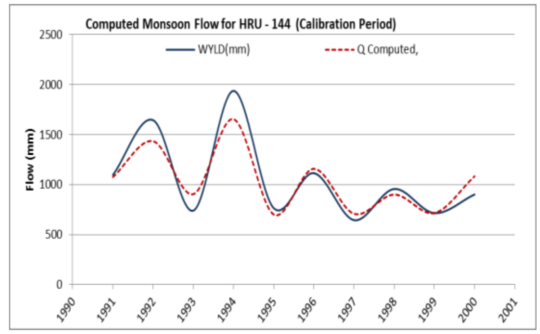
Flow Series for HRU -144 (Validation Period)

Cluster Equation: **I**

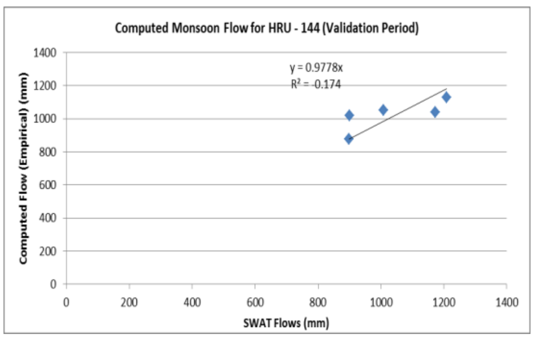
Q_{SIM}	=	-2594.9404 + 26.2768 X (%FA) + 28.8847 X (%CA) + 0.0007 X (PCP^2)	: June
Q_{SIM}	=	-102.6985 + 0.6011 X (PCP) -0.0195 X (RL) + 0.1977 X (PCP1)	:July
Q_{SIM}	=	-28.9648 + 0.6542 X (PCP) -1.2876 X (%CA) -0.0412 X (RL) + 0.1382 X (PCP	: August
Q_{SIM}	=	-21.1696 + 0.5571 X (PCP) -0.0244 X (RL) + 0.0359 X (UA) + 0.1572 X (PCP1)	: September
Q_{SIM}	=	-66.1333 + 0.5028 X (PCP) + 0.0349 X (UA) + 0.0893 X (PCP2) + 0.2308 X (PCP1)	: October
Basin	:	**Barak**	



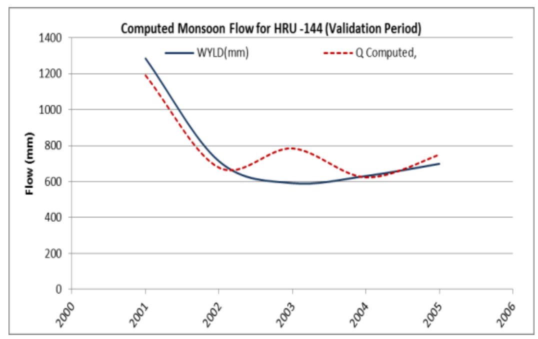
Observed and Computed Flow for HRU -144 (Calibration Period)



Flow Series for HRU -144 (Calibration Period)



Observed and Computed Flow for HRU -144 (Validation Period)



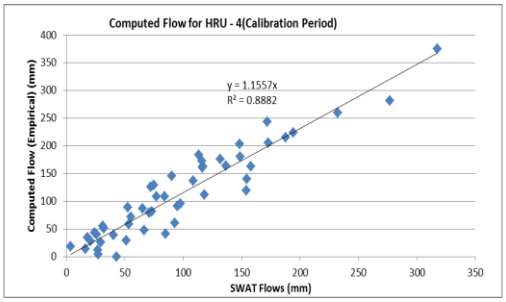
Flow Series for HRU -144 (Validation Period)

Cluster **I**

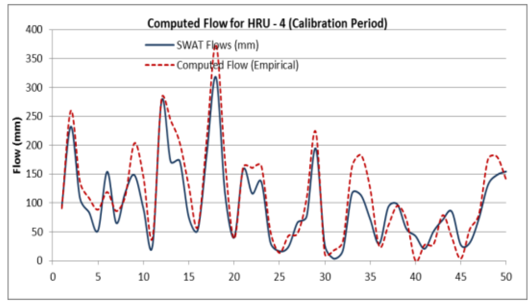
Equation:

Q_{SIM} = -641.715 + 0.785 X (PCP) + 4.727 X (%FA) -0.1523 X (RL) Monsoon

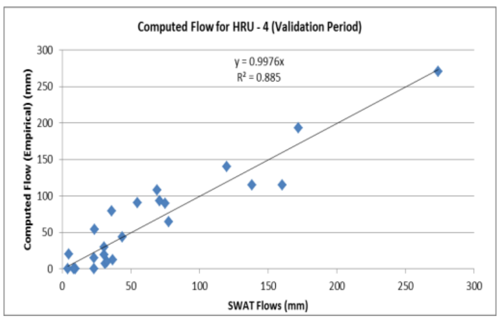
Basin : Barak



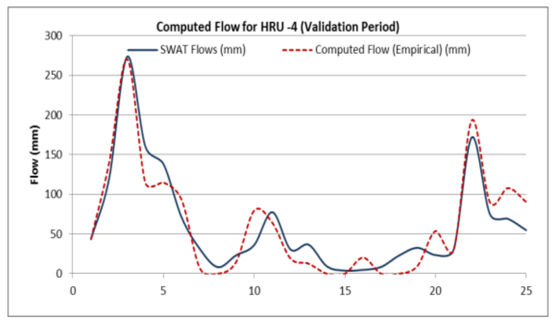
Observed and Computed Flow for HRU -4 (Calibration Period)



Flow Series for HRU -4(Calibration Period)

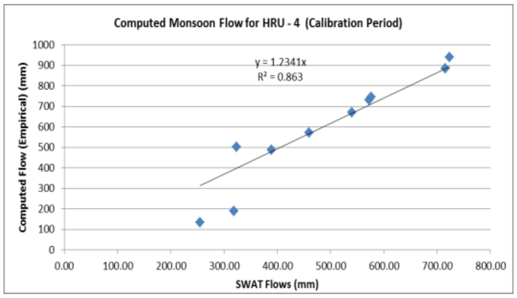


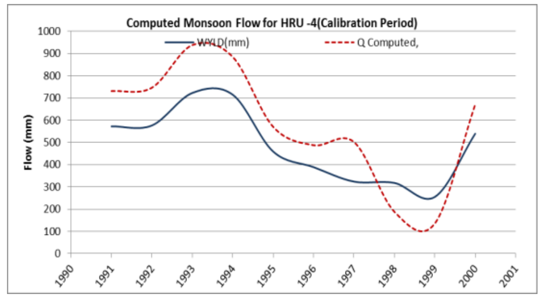
Observed and Computed Flow for HRU -4 (Validation Period)



Flow Series for HRU -4 (Validation Period)

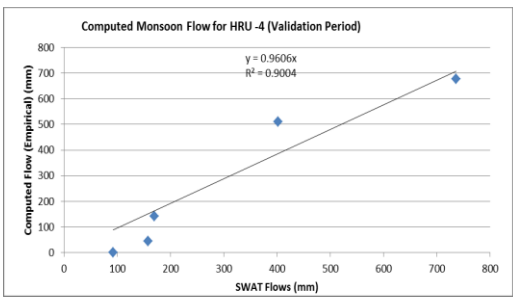
Cluster		**II**	
Equation:			
Q_{SIM}	=	**45.1065 -0.0138 X (RL) + 0.0007 X (PCP^2)**	**: June**
Q_{SIM}	=	**43.796 + 0.6523 X (PCP) -1.9579 X (%FA) + 0.2142 X (PCP1)**	**:July**
Q_{SIM}	=	**-78.6026 + 0.6736 X (PCP) -0.0305 X (RL) + 0.1004 X (UA) + 0.1577 X (PCP1)**	**: August**
Q_{SIM}	=	**QSIM = -17.0649 + 0.5918 X (PCP) -0.0404 X (RL) + 0.1095 X (UA) + 0.174 X (PCP1)**	**: September**
Q_{SIM}	=	**65.0971 + 0.8468 X (PCP) -0.0538 X (RL) + 0.1581 X (UA)**	**: October**
Basin	**:**	**Barak**	

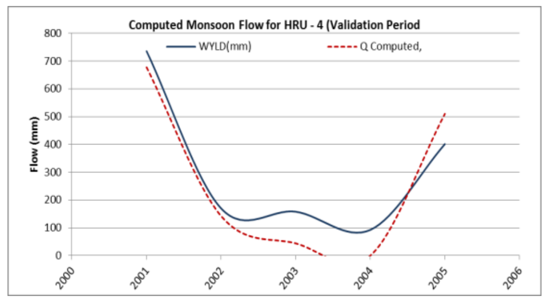




Observed and Computed Flow for HRU -4 (Calibration Period)

Flow Series for HRU -4 (Calibration Period)





Observed and Computed Flow for HRU -4 (Validation Period)

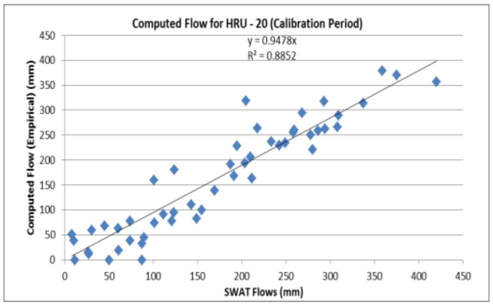
Flow Series for HRU -4 (Validation Period)

Cluster **II**

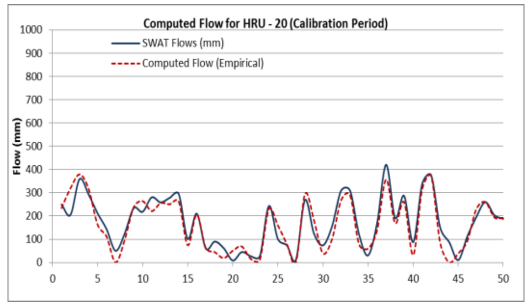
Equation:

Q_{SIM} = -411.3513 + 0.8396 X (PCP) + 8.1848 X (%CA) -0.0669 X (RL) Monsoon

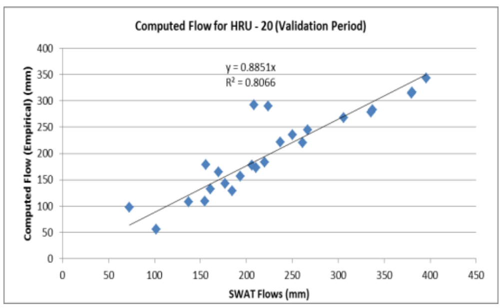
Basin : Barak



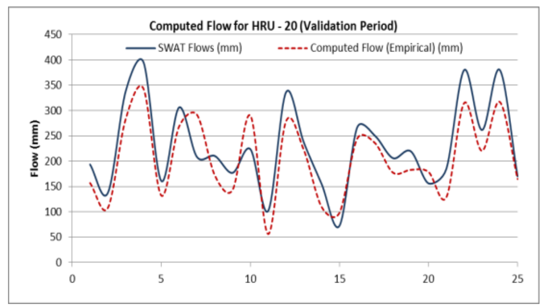
Observed and Computed Flow for HRU -20 (Calibration Period)



Flow Series for HRU -20(Calibration Period)



Observed and Computed Flow for HRU -20 (Validation Period)

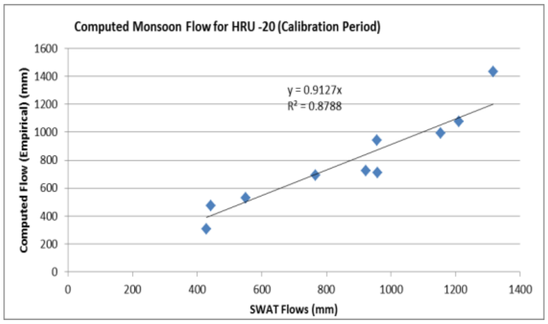


Flow Series for HRU -20 (Validation Period)

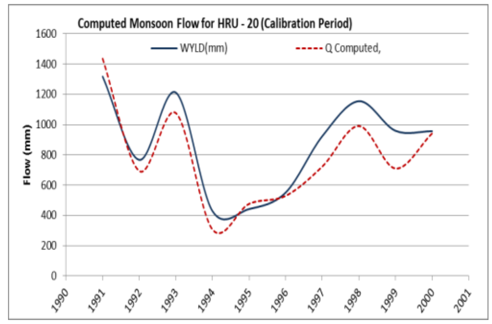
Cluster **II**

Equation:

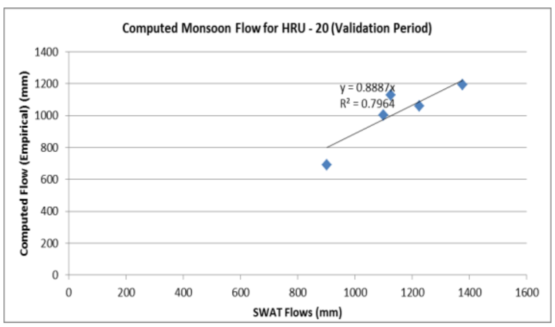
Q_{SIM}	**=**	**45.1065 -0.0138 X (RL) + 0.0007 X (PCP^2)**	**: June**
Q_{SIM}	**=**	**43.796 + 0.6523 X (PCP) -1.9579 X (%FA) + 0.2142 X (PCP1)**	**:July**
Q_{SIM}	**=**	**-78.6026 + 0.6736 X (PCP) -0.0305 X (RL) + 0.1004 X (UA) + 0.1577 X (PCP1)**	**: August**
Q_{SIM}	**=**	**QSIM = -17.0649 + 0.5918 X (PCP) -0.0404 X (RL) + 0.1095 X (UA) + 0.174 X (PCP1)**	**: September**
Q_{SIM}	**=**	**65.0971 + 0.8468 X (PCP) -0.0538 X (RL) + 0.1581 X (UA)**	**: October**
Basin	**:**	**Barak**	



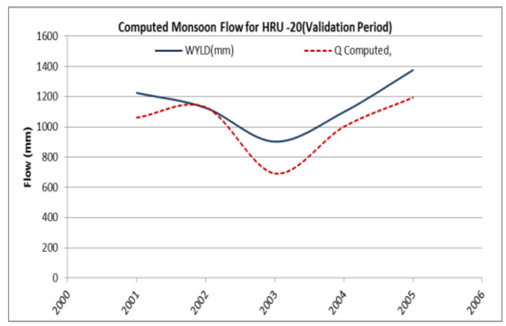
Observed and Computed Flow for HRU -20 (Calibration Period)



Flow Series for HRU -20 (Calibration Period)



Observed and Computed Flow for HRU -20 (Validation Period)



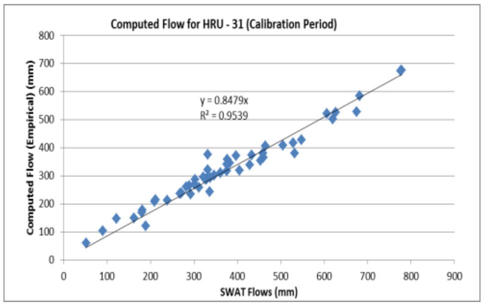
Flow Series for HRU -20 (Validation Period)

Cluster **II**

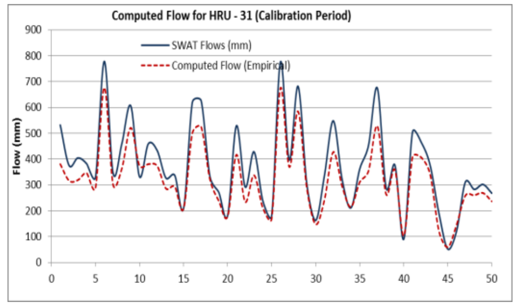
Equation:

Q_{SIM} = -411.3513 + 0.8396 X (PCP) + 8.1848 X (%CA) -0.0669 X (RL) Monsoon

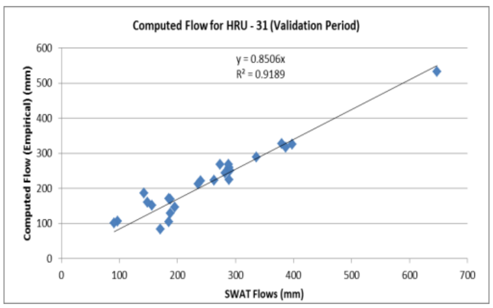
Basin : Barak



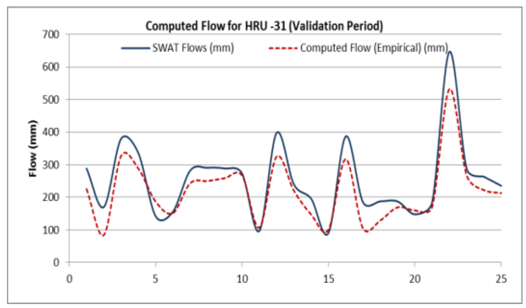
Observed and Computed Flow for HRU -31 (Calibration Period)



Flow Series for HRU -31(Calibration Period)



Observed and Computed Flow for HRU -31 (Validation Period)



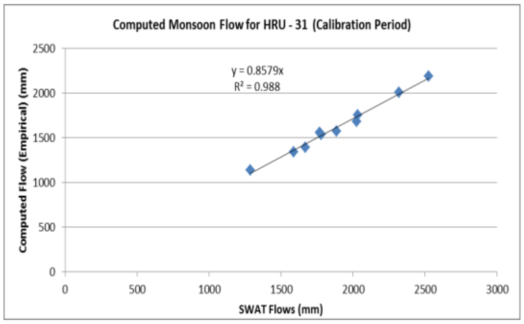
Flow Series for HRU -31 (Validation Period)

Cluster **III**

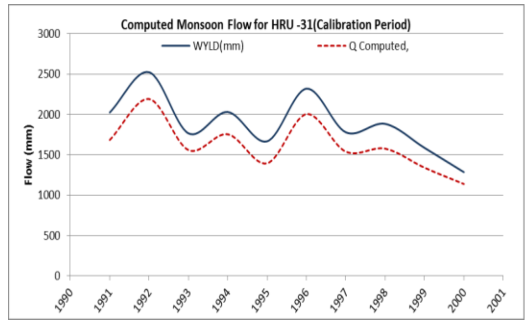
Equation:

Q_{SIM}	=	125.0971 -0.0391 X (RL) + 0.1626 X (UA) + 0.0006 X (PCP^2)	: June
Q_{SIM}	=	-136.2291 + 0.7903 X (PCP) -0.0424 X (RL) + 0.1017 X (UA) + 0.1081 X (PCP1)	:July
Q_{SIM}	=	-86.1088 + 0.7467 X (PCP) -0.0201 X (RL) + 0.086 X (UA) + 0.1038 X (PCP1)	: August
Q_{SIM}	=	-57.0366 + 0.7122 X (PCP) -0.0174 X (RL) + 0.1205 X (UA) + 0.0989 X (PCP1)	: September
Q_{SIM}	=	119.0767 + 0.6724 X (PCP) -1.5378 X (%FA) -1.7632 X (%CA) + 0.2162 X (PCP1)	: October

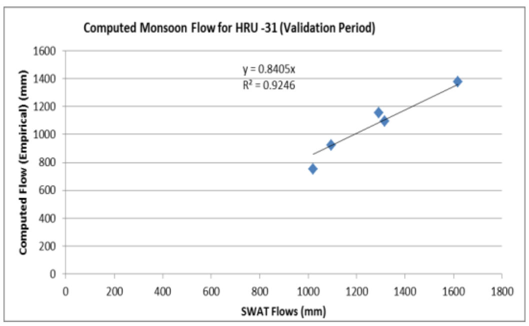
Basin : **Barak**



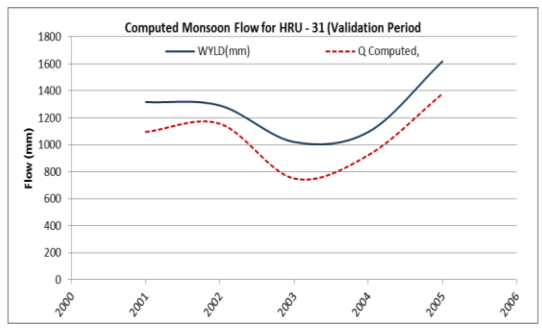
Observed and Computed Flow for HRU -31 (Calibration Period)



Flow Series for HRU -31 (Calibration Period)



Observed and Computed Flow for HRU -31 (Validation Period)



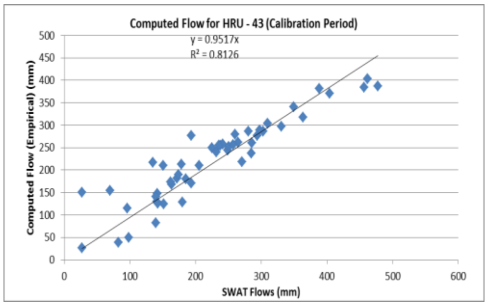
Flow Series for HRU -31 (Validation Period)

Cluster **III**

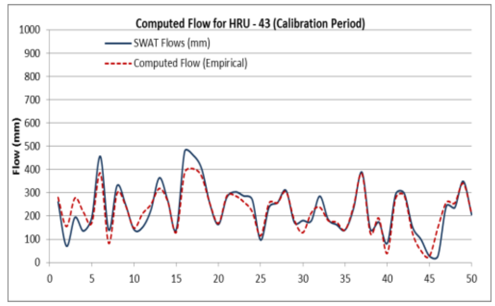
Equation:

Q_{SIM} **=** **-404.1621 + 0.8564 X (PCP) -0.1196 X (RL) + 0.4773 X (UA)** **Monsoon**

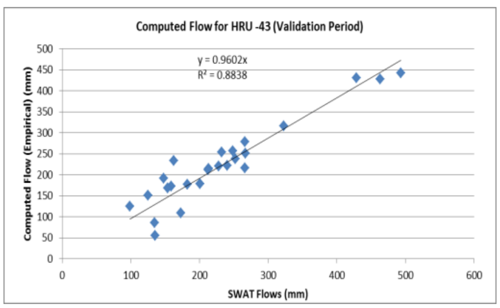
Basin : Barak



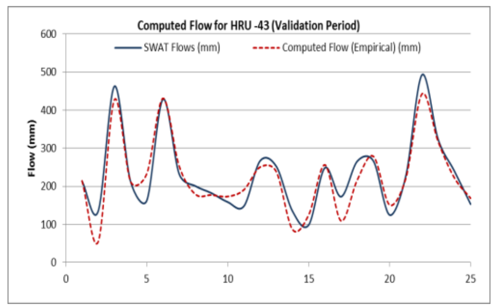
Observed and Computed Flow for HRU -43 (Calibration Period)



Flow Series for HRU -43(Calibration Period)

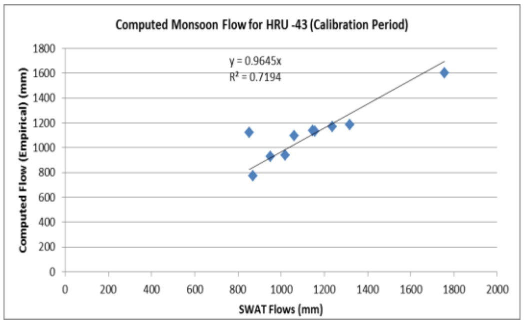


Observed and Computed Flow for HRU -43 (Validation Period)

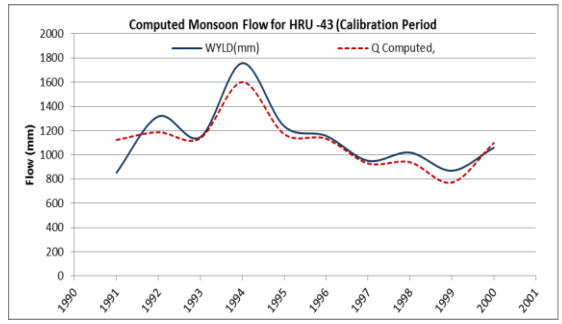


Flow Series for HRU -43(Validation Period)

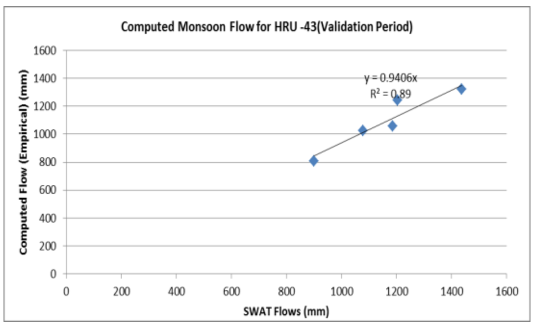
Cluster		**III**	
Equation:			
Q_{SIM}	=	125.0971 -0.0391 X (RL) + 0.1626 X (UA) + 0.0006 X (PCP^2)	: June
Q_{SIM}	=	-136.2291 + 0.7903 X (PCP) -0.0424 X (RL) + 0.1017 X (UA) + 0.1081 X (PCP1)	:July
Q_{SIM}	=	-86.1088 + 0.7467 X (PCP) -0.0201 X (RL) + 0.086 X (UA) + 0.1038 X (PCP1)	: August
Q_{SIM}	=	-57.0366 + 0.7122 X (PCP) -0.0174 X (RL) + 0.1205 X (UA) + 0.0989 X (PCP1)	: September
Q_{SIM}	=	119.0767 + 0.6724 X (PCP) -1.5378 X (%FA) -1.7632 X (%CA) + 0.2162 X (PCP1)	: October
Basin	:	**Barak**	



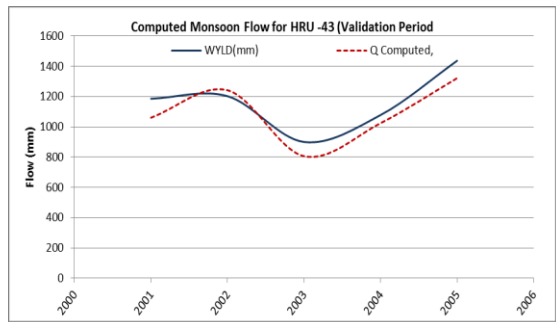
Observed and Computed Flow for HRU -43 (Calibration Period)



Flow Series for HRU -43 (Calibration Period)



Observed and Computed Flow for HRU -43 (Validation Period)



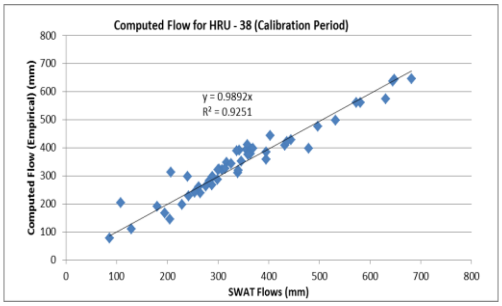
Flow Series for HRU -43 (Validation Period)

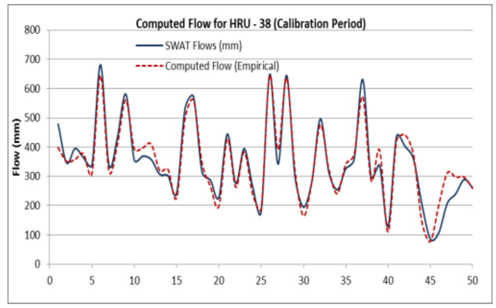
Cluster **III**

Equation:

Q_{SIM} = -404.1621 + 0.8564 X (PCP) -0.1196 X (RL) + 0.4773 X (UA) Monsoon

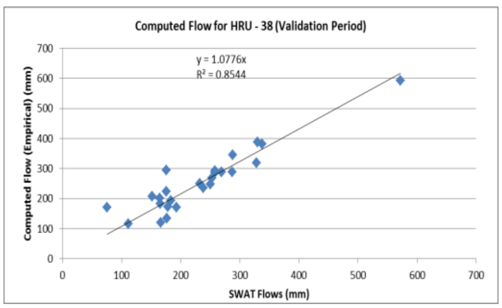
Basin : Barak

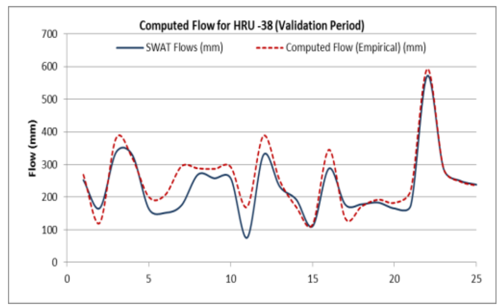




Observed and Computed Flow for HRU -38 (Calibration Period)

Flow Series for HRU -38(Calibration Period)





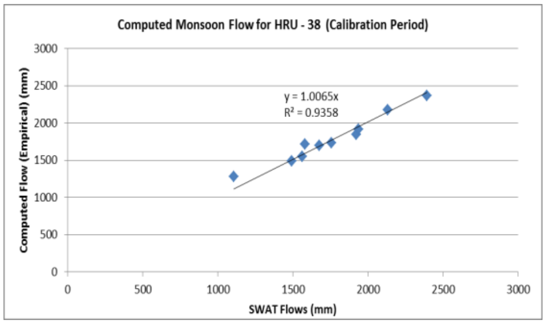
Observed and Computed Flow for HRU -38 (Validation Period)

Flow Series for HRU -38(Validation Period)

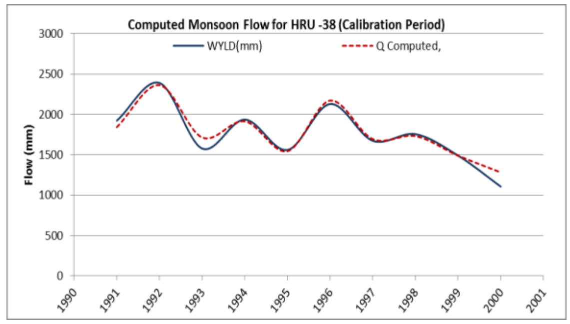
Cluster **IV**

Equation:

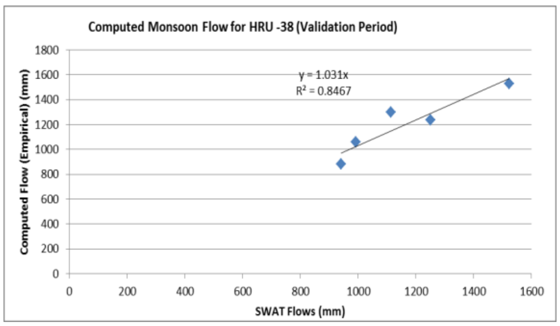
Q_{SIM}	=	83.4329 + 0.885 X (%CA) + 0.2146 X (RL) + 0.0005 X (PCP^2)	: June
Q_{SIM}	=	-132.2232 + 0.8219 X (PCP) + 0.1007 X (RL) + 0.0606 X (PCP1)	:July
Q_{SIM}	=	-180.6437 + 0.7852 X (PCP) + 1.3775 X (%FA) + 1.2116 X (%CA) + 0.0573 X (PCP1)	: August
Q_{SIM}	=	-55.0265 + 0.7398 X (PCP) + 0.0388 X (RL) + 0.1134 X (PCP1)	: September
Q_{SIM}	=	-25.3882 + 0.7224 X (PCP) -0.0585 X (RL) + 0.0282 X (UA) + 0.1907 X (PCP1)	: October
Basin	:	**Barak**	



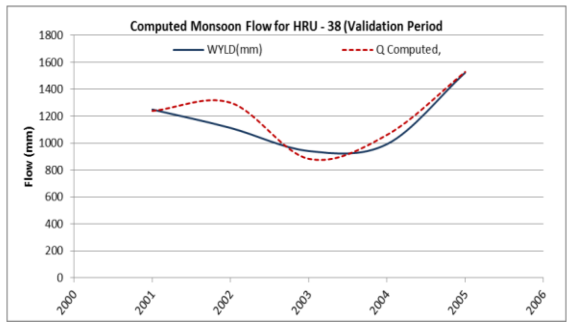
Observed and Computed Flow for HRU -38 (Calibration Period)



Flow Series for HRU -38 (Calibration Period)



Observed and Computed Flow for HRU -38 (Validation Period)



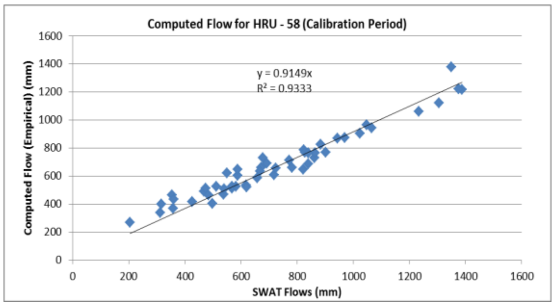
Flow Series for HRU -38 (Validation Period)

Cluster **IV**

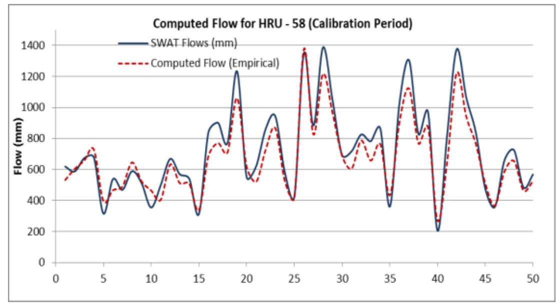
Equation:

Q_{SIM} = -413.2682 + 0.88 X (PCP) + 0.3086 X (RL) **Monsoon**

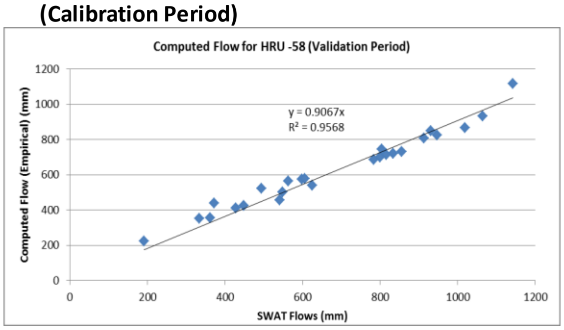
Basin : Barak



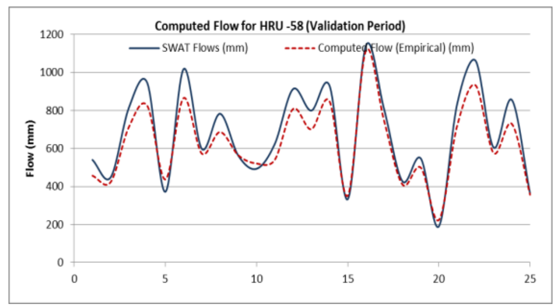
Observed and Computed Flow for HRU -58 (Calibration Period)



Flow Series for HRU -58(Calibration Period)



Observed and Computed Flow for HRU -58 (Validation Period)



Flow Series for HRU -58(Validation Period)

Cluster **IV**

Equation:

Q_{SIM} = **83.4329 + 0.885 X (%CA) + 0.2146 X (RL) + 0.0005 X (PCP^2)** **: June**

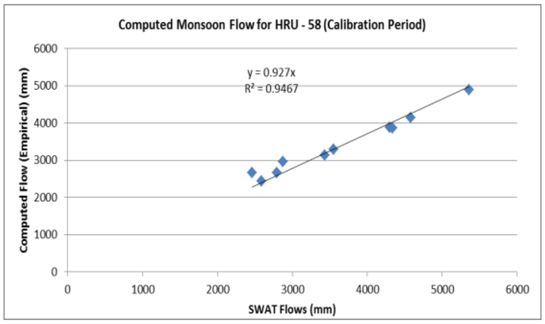
Q_{SIM} = **-132.2232 + 0.8219 X (PCP) + 0.1007 X (RL) + 0.0606 X (PCP1)** **:July**

Q_{SIM} = **-180.6437 + 0.7852 X (PCP) + 1.3775 X (%FA) + 1.2116 X (%CA) + 0.0573 X (PCP1)** **: August**

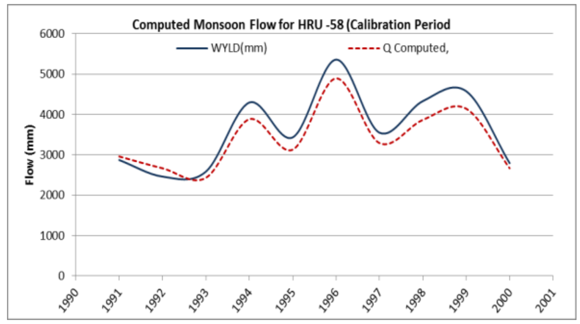
Q_{SIM} = **-55.0265 + 0.7398 X (PCP) + 0.0388 X (RL) + 0.1134 X (PCP1)** **: September**

Q_{SIM} = **-25.3882 + 0.7224 X (PCP) -0.0585 X (RL) + 0.0282 X (UA) + 0.1907 X (PCP1)** **: October**

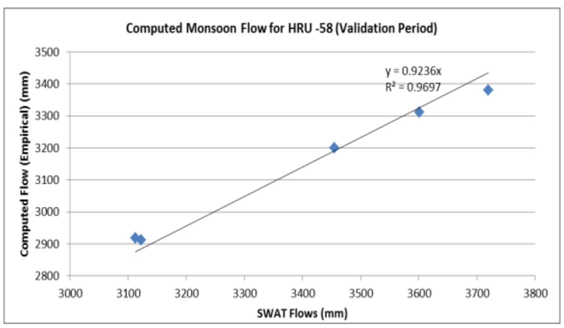
Basin **:** **Barak**



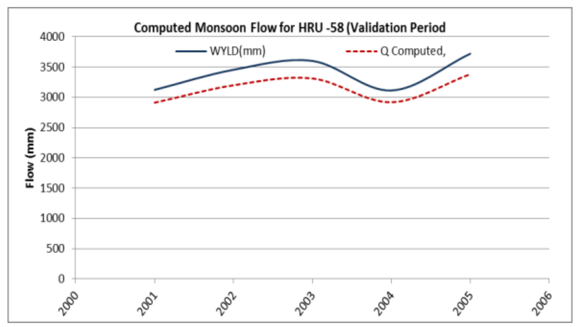
Observed and Computed Flow for HRU -58 (Calibration Period)



Flow Series for HRU -58 (Calibration Period)



Observed and Computed Flow for HRU -58 (Validation Period)



Flow Series for HRU -58 (Validation Period)

Cluster **IV**

Equation:

Q_{SIM} = -413.2682 + 0.88 X (PCP) + 0.3086 X (RL) **Monsoon**

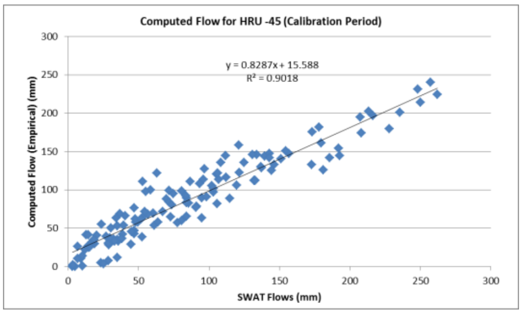
Basin : Barak

Input Data set for Lohit Sub-basin

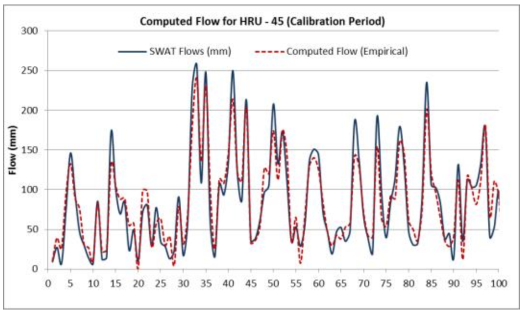
Sub basins	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.	SNFL, mm
1	1825.4	-5.312	2012.27	94.80	0.00	1278.00	429.84	1171.89
2	2131.2	-5.834	2280.70	96.20	0.25	1256.00	352.10	1262.59
3	2180.3	-5.834	2280.70	88.71	0.00	1347.00	285.07	1262.59
4	2501.3	-5.589	2673.50	84.13	0.34	1400.00	259.16	1401.21
5	626.0	-2.273	861.65	91.53	1.30	2407.00	685.43	495.31
6	3009.7	-2.307	3210.42	93.55	3.27	3117.00	1009.80	1199.85
7	0.0	-5.402	3419.83	49.10	0.00	2262.00	247.54	0.00
8	96.4	-1.185	279.36	97.95	1.10	2396.00	569.25	122.32
9	771.8	-3.737	1060.08	91.84	1.84	2847.00	339.59	579.69
10	3296.7	-5.402	3419.83	79.32	0.79	4337.00	453.97	1620.70
11	2519.2	-5.589	2673.50	83.94	0.00	3269.00	394.99	1401.21
12	96.3	-1.185	279.36	99.27	0.72	2215.00	247.54	122.32
13	821.1	-2.223	1082.82	93.94	4.32	3717.00	869.52	519.51
14	250.2	-2.303	465.01	98.32	1.67	2798.00	802.50	241.00
15	102.8	-1.928	308.66	98.53	1.48	2052.00	301.16	128.44
16	821.9	-2.223	1082.82	98.58	1.40	3261.00	318.14	519.51
17	474.3	-0.287	777.72	100.00	0.91	2371.00	224.31	285.16
18	513.5	5.005	892.55	97.26	2.73	3523.00	491.51	185.28
19	474.4	-0.287	777.72	94.61	2.92	2845.00	580.87	285.16
20	747.0	8.103	1243.56	95.70	4.30	3423.00	519.21	50.60
21	1132.1	3.638	1561.56	97.00	2.99	2858.00	387.84	418.81
22	1150.1	3.638	1561.56	94.66	5.33	2711.00	268.09	418.81
23	748.3	8.103	1243.56	93.31	6.69	3390.00	226.99	50.60
24	786.3	8.103	1243.56	93.08	6.92	4057.00	503.12	50.60
25	1153.9	3.638	1561.56	88.07	10.99	2809.00	479.89	418.81
26	801.5	11.267	1258.13	96.05	3.96	3996.00	654.15	4.91
27	3999.9	7.504	4460.79	95.95	4.07	3753.00	285.97	190.25
28	528.4	16.721	1009.30	90.74	7.64	3276.00	444.14	0.00
29	503.2	16.721	1009.30	84.20	14.01	2581.00	395.89	0.00
30	2175.2	11.459	2658.62	97.51	2.49	3367.00	394.10	4.75
31	503.9	16.721	1009.30	82.95	10.41	2038.00	309.20	0.00
32	504.4	16.721	1009.30	80.09	19.91	1110.00	210.90	0.00
33	504.3	16.721	1009.30	76.35	23.66	1387.00	200.18	0.00
34	3961.0	7.504	4460.79	90.96	9.05	3489.00	404.82	190.25
35	3957.7	7.504	4460.79	90.19	9.81	3426.00	464.70	190.25
36	490.6	19.862	1223.42	93.62	5.67	396.00	252.01	0.00
37	2156.0	11.459	2658.62	96.16	3.86	3902.00	695.26	4.75
38	630.9	19.862	1223.42	96.29	3.54	2184.00	529.93	0.00
39	515.1	16.721	1009.30	57.89	42.11	62.00	16.98	0.00
40	1881.2	-5.312	2012.27	88.60	0.00	1194.00	101.88	1171.89

Input Data set for Lohit Sub-basin

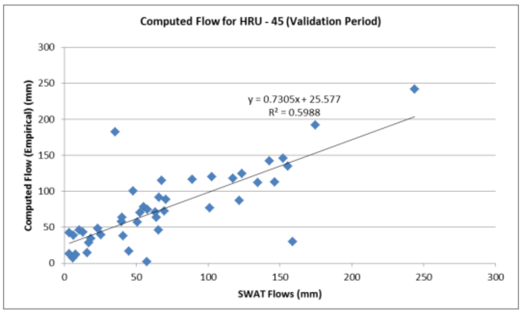
41	785.2	-3.737	1060.08	88.25	10.20	2857.00	403.04	579.69
42	1882.9	-5.312	2012.27	85.95	3.51	1235.00	101.88	1171.89
43	515.0	16.721	1009.30	67.50	7.50	61.00	35.75	0.00
44	3315.8	-5.402	3419.83	90.56	4.64	4636.00	520.10	1620.70
45	788.6	8.103	1243.56	79.60	20.41	2777.00	43.79	50.60
46	2517.2	-5.589	2673.50	100.00	0.00	934.00	29.49	1401.21
47	735.8	8.103	1243.56	85.18	14.83	3563.00	452.19	50.60
48	2518.6	-5.589	2673.50	70.44	0.39	3993.00	459.34	1401.21
49	119.1	-1.928	308.66	74.64	25.38	1933.00	119.75	128.44
50	108.7	-1.928	308.66	91.04	8.72	2402.00	389.63	128.44
51	109.5	-1.928	308.66	89.75	10.25	2481.00	174.26	128.44
52	1766.9	-0.347	2043.00	97.40	2.61	2400.00	102.77	779.07
53	1795.2	-0.347	2043.00	89.76	10.25	3248.00	967.82	779.07
54	449.0	-0.287	777.72	91.03	8.96	2859.00	458.44	285.16
55	148.6	1.781	409.69	91.51	8.49	2275.00	94.73	169.97
56	149.4	1.781	409.69	80.95	19.04	2119.00	37.53	169.97
57	149.9	1.781	409.69	77.97	22.04	2465.00	166.22	169.97
58	193.0	3.543	452.00	85.73	14.26	2853.00	595.17	153.08
59	1141.5	3.638	1561.56	61.94	38.05	2455.00	100.98	418.81
60	878.9	5.640	1303.48	80.37	19.65	3002.00	150.13	208.64
61	874.6	5.640	1303.48	91.92	8.08	2848.00	530.83	208.64
62	3910.8	7.504	4460.79	80.43	19.58	3670.00	584.45	190.25
63	3950.6	7.504	4460.79	78.25	21.74	3030.00	102.77	190.25
64	3968.0	7.504	4460.79	72.12	27.87	3045.00	201.96	190.25
65	2143.0	11.459	2658.62	78.11	21.89	3025.00	330.65	4.75
66	1992.9	11.459	2658.62	100.00	0.00	668.00	3.57	4.75
67	526.4	16.721	1009.30	94.47	5.53	2850.00	242.18	0.00
68	557.3	16.721	1009.30	92.11	7.89	1395.00	33.96	0.00
69	558.7	16.721	1009.30	85.81	9.25	1844.00	144.77	0.00
70	504.7	16.721	1009.30	56.89	10.35	101.00	51.83	0.00
71	0.0	16.721	1009.30	20.00	40.00	60.00	4.47	0.00
72	0.0	16.721	1009.30	25.00	0.00	57.00	3.57	0.00
73	0.0	16.721	1009.30	37.78	8.89	79.00	40.21	0.00
74	336.3	16.721	1009.30	55.53	21.70	254.00	420.01	0.00



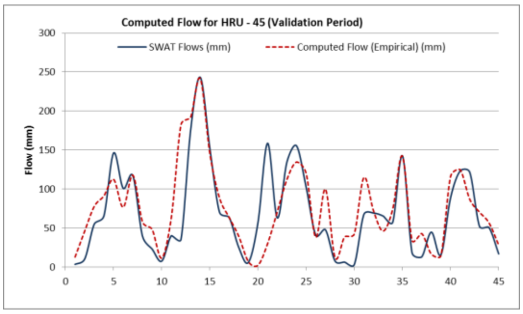
Observed and Computed Flow for HRU -45 (Calibration Period)



Flow Series for HRU -45 (Calibration Period)



Observed and Computed Flow for HRU -45 (Validation Period)



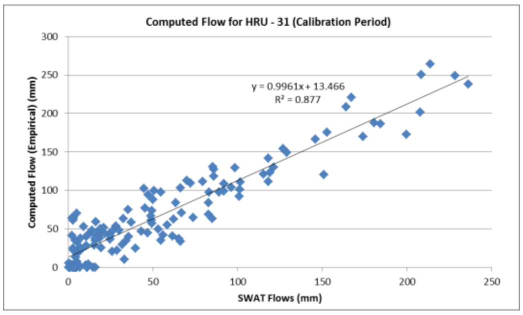
Flow Series for HRU -45 (Validation Period)

Cluster **I**

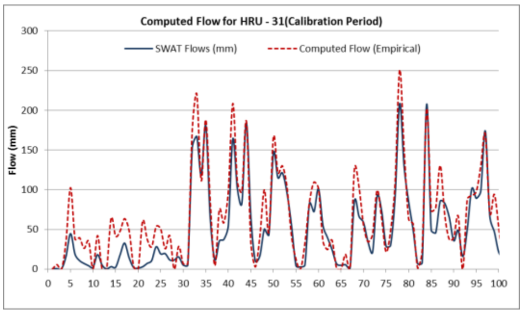
Equation:

Q_{SIM}	**=**	**-33.31 + 0.629 X (PCP) + 0.259X (%FA) + 0.32 X SNMT**	**: March**
Q_{SIM}	**=**	**-26.4463 + 0.7055 X (PCP) + 0.5725 X SNMT**	**: April**
Q_{SIM}	**=**	**-57.0406 + 0.6755 X (PCP) + 0.0224 X (RL)**	**: May**
Q_{SIM}	**=**	**-92.2543 + 0.7528 X (PCP) -0.0353 X (%FA) + 0.0258 X (RL)**	**: June**
Q_{SIM}	**=**	**-211.2449 + 0.6141 X (PCP) + 1.6282 X (%FA) + 0.3348 X (PCP1)**	**:July**
Q_{SIM}	**=**	**-210.3852 + 0.7527 X (PCP) + 1.6953 X (%FA) + 0.1346 X (PCP1)**	**: August**
Q_{SIM}	**=**	**-81.0691 + 0.6886 X (PCP) + 0.0204 X (RL) + 0.1779 X (PCP1)**	**: September**
Q_{SIM}	**=**	**-101.4446 + 0.7259 X (PCP) + 1.1006 X (%FA) + 0.2988 X (PCP1)**	**: October**
Q_{SIM}	**=**	**-55.9056 + 1.631 X (PCP) + 0.4377 X (%FA) + 0.0083 X (RL) + 1.8633 X Tmax**	**: November**

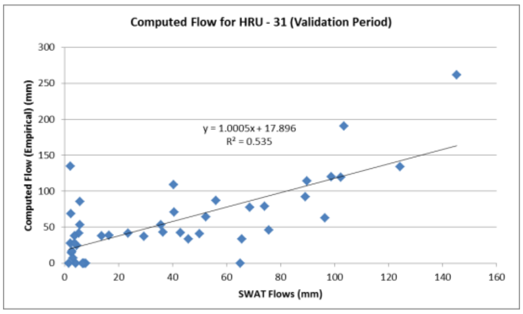
Basin **:** **Lohit**



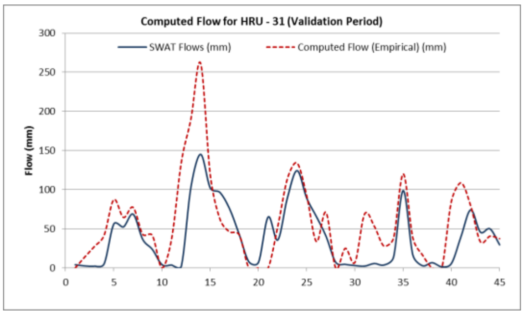
Observed and Computed Flow for HRU -31 (Calibration Period)



Flow Series for HRU -31 (Calibration Period)



Observed and Computed Flow for HRU -31 (Validation Period)

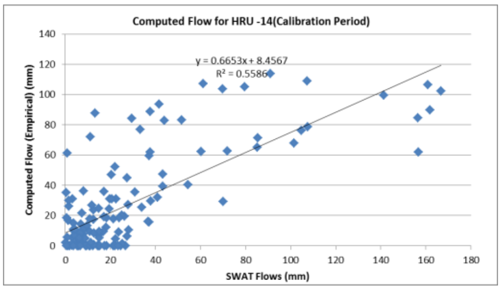


Flow Series for HRU -31 (Validation Period)

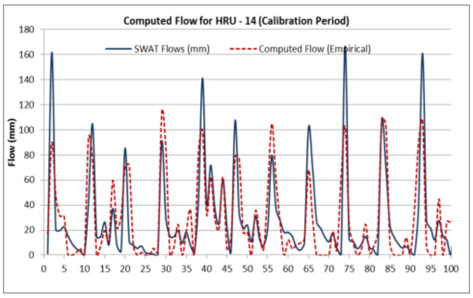
Cluster **I**

Equation:

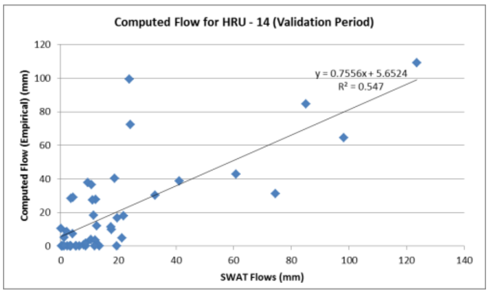
Q_{SIM}	=	-33.31 + 0.629 X (PCP) + 0.259X (%FA) + 0.32 X SNMT	: March
Q_{SIM}	=	-26.4463 + 0.7055 X (PCP) + 0.5725 X SNMT	: April
Q_{SIM}	=	-57.0406 + 0.6755 X (PCP) + 0.0224 X (RL)	: May
Q_{SIM}	=	-92.2543 + 0.7528 X (PCP) -0.0353 X (%FA) + 0.0258 X (RL)	: June
Q_{SIM}	=	-211.2449 + 0.6141 X (PCP) + 1.6282 X (%FA) + 0.3348 X (PCP1)	:July
Q_{SIM}	=	-210.3852 + 0.7527 X (PCP) + 1.6953 X (%FA) + 0.1346 X (PCP1)	: August
Q_{SIM}	=	-81.0691 + 0.6886 X (PCP) + 0.0204 X (RL) + 0.1779 X (PCP1)	: September
Q_{SIM}	=	-101.4446 + 0.7259 X (PCP) + 1.1006 X (%FA) + 0.2988 X (PCP1)	: October
Q_{SIM}	=	-55.9056 + 1.631 X (PCP) + 0.4377 X (%FA) + 0.0083 X (RL) + 1.8633 X Tmax	: November
Basin	:	Lohit	



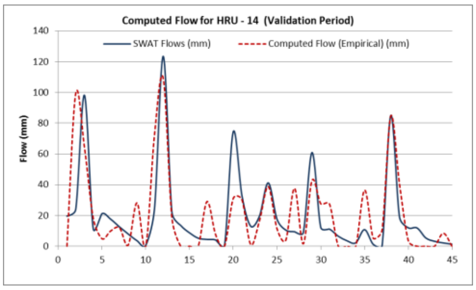
Observed and Computed Flow for HRU -14 (Calibration Period)



Flow Series for HRU -14 (Calibration Period)



Observed and Computed Flow for HRU -14 (Validation Period)

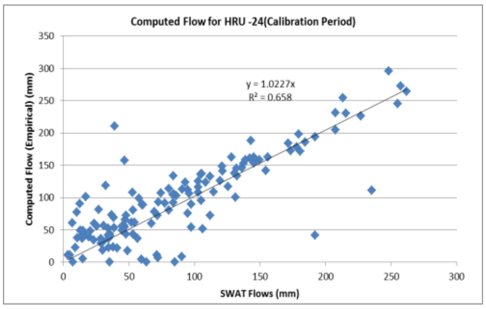


Flow Series for HRU -14 (Validation Period)

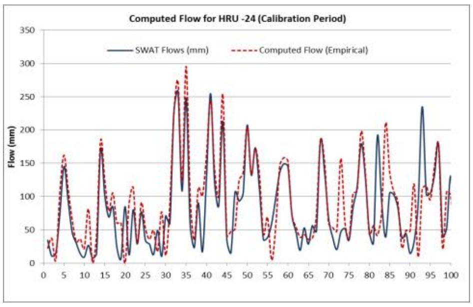
Cluster **II**

Equation:

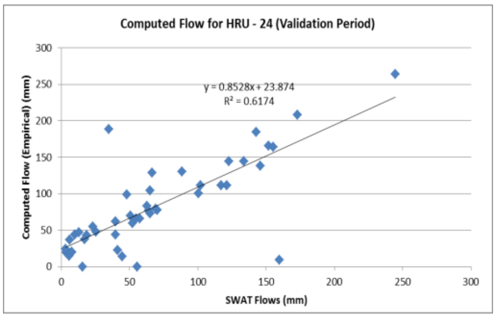
Q_{SIM}	=	-98.1274 + 0.545 X (PCP) + 0.0239 X (RL) + 0.4648 X SNMT	: March
Q_{SIM}	=	-29.7462 + 0.7228 X (PCP) -0.005 X (%FA) + 0.4619 X SNMT	: April
Q_{SIM}	=	-19.5404 + 0.793 X (PCP) + 0.6769 X SNMT	: May
Q_{SIM}	=	-4.0442 + 0.7788 X (PCP) -0.109 X (%FA)	: June
Q_{SIM}	=	-17.6136 + 0.7644 X (PCP) -0.0114 X (RL) + 0.1559 X (PCP1)	:July
Q_{SIM}	=	-86.7925 + 0.8416 X (PCP) + 0.3979 X (%FA) + 0.0647 X (PCP1)	: August
Q_{SIM}	=	-24.8085 + 0.7465 X (PCP) -0.003 X (RL) + 0.1574 X (PCP1)	: September
Q_{SIM}	=	-6.2845 + 1.016 X (PCP) -0.8462 X SNMT + 1.1142 X Tmax	: October
Q_{SIM}	=	-51.3543 + 1.3839 X (PCP) + 0.0157 X (RL) + 1.8536 X Tmax	: November
Basin	:	Lohit	



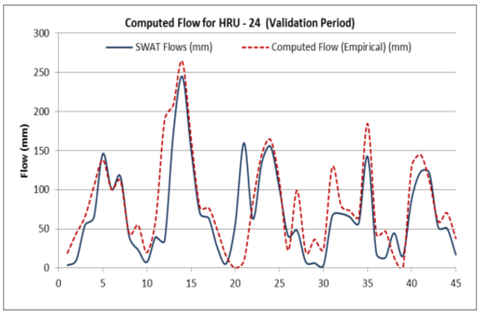
Observed and Computed Flow for HRU -24 (Calibration Period)



Flow Series for HRU -24 (Calibration Period)



Observed and Computed Flow for HRU -24 (Validation Period)

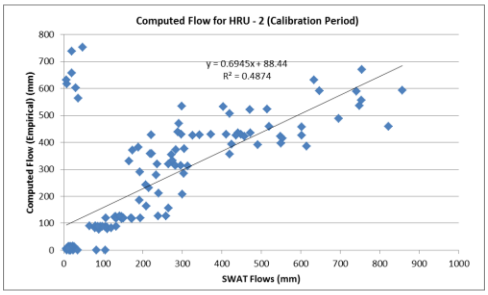


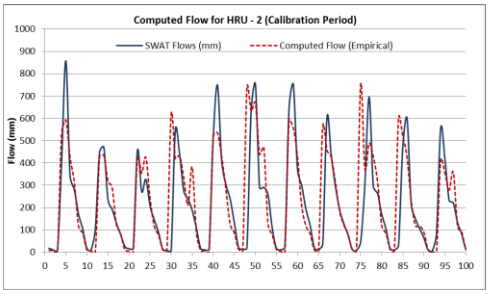
Flow Series for HRU -24 (Validation Period)

Cluster **II**

Equation:

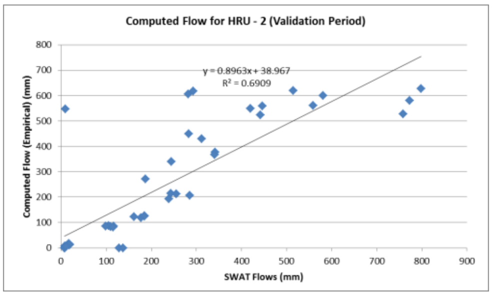
Q_{SIM}	=	-98.1274 + 0.545 X (PCP) + 0.0239 X (RL) + 0.4648 X SNMT	: March
Q_{SIM}	=	-29.7462 + 0.7228 X (PCP) -0.005 X (%FA) + 0.4619 X SNMT	: April
Q_{SIM}	=	-19.5404 + 0.793 X (PCP) + 0.6769 X SNMT	: May
Q_{SIM}	=	-4.0442 + 0.7788 X (PCP) -0.109 X (%FA)	: June
Q_{SIM}	=	-17.6136 + 0.7644 X (PCP) -0.0114 X (RL) + 0.1559 X (PCP1)	:July
Q_{SIM}	=	-86.7925 + 0.8416 X (PCP) + 0.3979 X (%FA) + 0.0647 X (PCP1)	: August
Q_{SIM}	=	-24.8085 + 0.7465 X (PCP) -0.003 X (RL) + 0.1574 X (PCP1)	: September
Q_{SIM}	=	-6.2845 + 1.016 X (PCP) -0.8462 X SNMT + 1.1142 X Tmax	: October
Q_{SIM}	=	-51.3543 + 1.3839 X (PCP) + 0.0157 X (RL) + 1.8536 X Tmax	: November
Basin	:	Lohit	

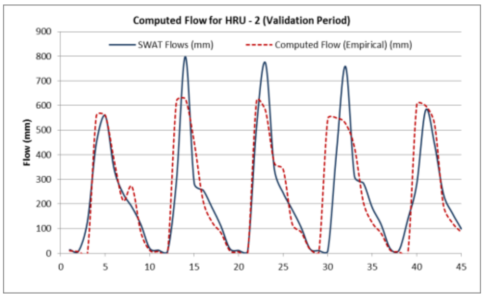




Observed and Computed Flow for HRU -2 (Calibration Period)

Flow Series for HRU -2 (Calibration Period)





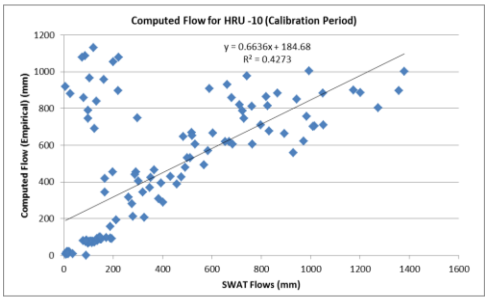
Observed and Computed Flow for HRU -2 (Validation Period)

Flow Series for HRU -2 (Validation Period)

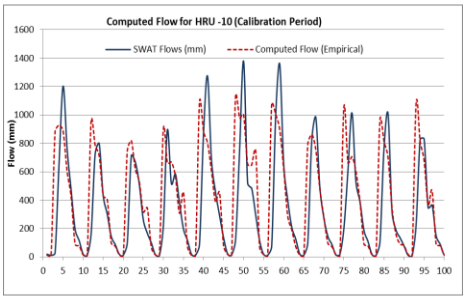
Cluster **III**

Equation:

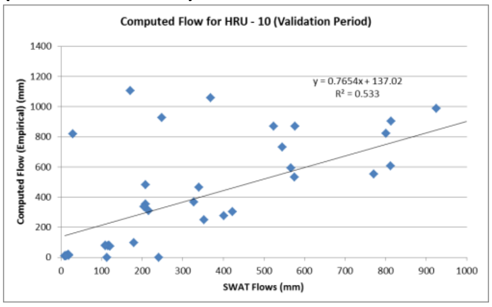
Q_{SIM}	=	20.5457 + 0.0256 X SNFL + 2.3018 X Tmax	: March
Q_{SIM}	=	0.822 + 0.0231 X SNFL + 0.8242 X SNMT	: April
Q_{SIM}	=	-69.3672 + 0.1575 X (PCP) + 0.0027 X (RL) + 0.9677 X SNMT	: May
Q_{SIM}	=	-139.3852 + 0.4662 X (PCP) + 0.0337 X (RL) + 0.9073 X SNMT	: June
Q_{SIM}	=	-50.1231 + 0.3572 X (PCP) + 0.0371 X (RL) + 0.9815 X SNMT + 10.6521 X Tmax	:July
Q_{SIM}	=	-724.3954 + 0.5582 X (PCP) + 8.0793 X (%FA) + 0.0469 X (RL) + 0.954 X SNMT	: August
Q_{SIM}	=	-462.6303 + 0.4466 X (PCP) + 5.2769 X (%FA) + 0.0317 X (RL) + 0.9975 X SNMT	: September
Q_{SIM}	=	-56.8173 + 1.7303 X (%FA) + 0.0779 X SNFL + 1.2461 X SNMT	: October
Q_{SIM}	=	-46.0389 + 1.0107 X (%FA) + 0.0604 X (UA) + 0.1767 X PCP	: November
Basin	:	Lohit	



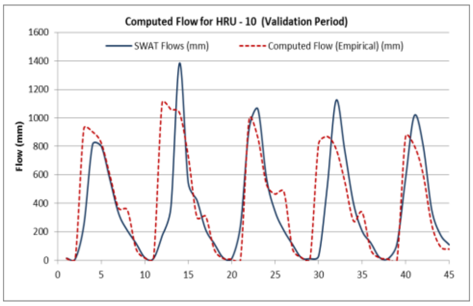
Observed and Computed Flow for HRU -10 (Calibration Period)



Flow Series for HRU -10 (Calibration Period)



Observed and Computed Flow for HRU -10 (Validation Period)



Flow Series for HRU -10 (Validation Period)

Cluster **III**

Equation:

Q_{SIM}	=	20.5457 + 0.0256 X SNFL + 2.3018 X Tmax	: March
Q_{SIM}	=	0.822 + 0.0231 X SNFL + 0.8242 X SNMT	: April
Q_{SIM}	=	-69.3672 + 0.1575 X (PCP) + 0.0027 X (RL) + 0.9677 X SNMT	: May
Q_{SIM}	=	-139.3852 + 0.4662 X (PCP) + 0.0337 X (RL) + 0.9073 X SNMT	: June
Q_{SIM}	=	-50.1231 + 0.3572 X (PCP) + 0.0371 X (RL) + 0.9815 X SNMT + 10.6521 X Tmax	:July
Q_{SIM}	=	-724.3954 + 0.5582 X (PCP) + 8.0793 X (%FA) + 0.0469 X (RL) + 0.954 X SNMT	: August
Q_{SIM}	=	-462.6303 + 0.4466 X (PCP) + 5.2769 X (%FA) + 0.0317 X (RL) + 0.9975 X SNMT	: September
Q_{SIM}	=	-56.8173 + 1.7303 X (%FA) + 0.0779 X SNFL + 1.2461 X SNMT	: October
Q_{SIM}	=	-46.0389 + 1.0107 X (%FA) + 0.0604 X (UA) + 0.1767 X PCP	: November
Basin	:	Lohit	

Input Data set for Satluj Sub-basin

Sub basins	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Relief, m	Unit Area, sq.km.	SNFL, mm
1	397.15	-6.17	1064.52	83.21	1835.00	1080.07	649.06
2	364.98	-6.17	1091.12	100.00	1356.00	274.43	664.79
3	270.64	-10.03	790.67	99.63	1259.00	532.19	691.98
4	366.87	-6.17	1064.52	100.00	1620.00	487.11	649.06
5	276.46	-10.03	790.67	77.55	1816.00	750.76	691.98
6	421.31	-6.17	1130.38	85.11	2197.00	644.91	659.20
7	75.72	-7.85	445.10	100.00	1620.00	1036.95	301.92
8	424.69	-6.17	1130.38	70.37	2235.00	291.09	659.20
9	363.24	-6.17	747.47	88.30	2673.00	1038.91	483.38
10	250.35	-6.17	819.68	87.73	2260.00	215.62	529.25
11	85.22	-7.85	445.10	100.00	1357.00	561.60	301.92
12	96.36	-8.65	423.04	100.00	2183.00	392.04	348.39
13	28.32	-7.25	234.38	100.00	1667.00	463.59	181.70
14	213.10	-6.17	747.47	90.35	3045.00	223.46	483.38
15	0.00	-6.17	819.68	69.87	2192.00	530.23	0.00
16	23.26	-6.66	235.69	100.00	2009.00	769.38	174.71
17	34.11	-7.05	253.16	100.00	1533.00	714.49	203.92
18	28.30	-7.25	234.38	100.00	1721.00	468.49	181.70
19	256.29	-6.17	819.68	85.35	2117.00	535.13	529.25
20	33.53	-7.05	253.16	100.00	1605.00	378.32	203.92
21	23.26	-6.66	235.69	100.00	1952.00	479.27	174.71
22	230.96	-6.17	747.47	98.97	3132.00	569.44	483.38
23	40.11	-7.05	253.16	92.83	3123.00	437.12	203.92
24	452.71	-6.17	846.00	92.42	2958.00	452.81	539.83
25	490.55	-6.17	846.00	86.98	3589.00	376.36	539.83
26	40.98	-5.33	292.79	100.00	1687.00	333.23	225.68
27	43.48	-5.33	292.79	100.00	1864.00	246.01	225.68
28	247.60	-6.17	759.20	99.74	3175.00	380.28	462.92
29	162.92	-5.64	599.23	100.00	1861.00	352.84	457.16
30	349.94	-6.17	935.58	45.78	3931.00	244.04	510.00
31	144.72	-5.64	599.23	100.00	1883.00	247.97	457.16
32	338.36	-6.17	935.58	42.45	2191.00	311.67	510.00
33	249.40	-6.17	759.20	96.39	3617.00	733.11	462.92
34	267.37	-6.17	838.88	100.00	2221.00	959.52	463.27
35	301.97	-6.17	846.00	57.02	3838.00	223.46	539.83
36	332.09	-6.61	1024.82	100.00	2048.00	257.77	787.07
37	377.62	-6.61	1024.82	100.00	2439.00	554.74	787.07
38	342.33	-6.61	1024.82	100.00	2063.00	412.62	787.07
39	573.77	-6.17	1276.57	35.94	1833.00	250.91	503.35
40	257.06	-6.17	759.20	84.61	4232.00	948.74	462.92
41	150.12	-6.32	575.47	100.00	1217.00	394.98	427.90
42	601.96	-7.35	1421.61	100.00	1679.00	294.03	1020.42
43	89.53	-6.92	445.10	100.00	1294.00	439.08	327.92
44	534.62	-7.35	1421.61	96.64	2061.00	262.67	1020.42
45	420.70	-6.64	1105.41	100.00	1822.00	328.33	821.34
46	96.20	-6.92	445.10	100.00	1588.00	237.18	327.92

Input Data set for Satluj Sub-basin

47	551.69	-7.35	1421.61	78.85	2133.00	477.31	1020.42
48	94.91	-6.92	445.10	100.00	1367.00	216.60	327.92
49	356.81	-6.64	1105.41	100.00	1379.00	332.25	821.34
50	261.11	-6.28	808.95	100.00	1148.00	357.74	607.67
51	93.95	-6.92	445.10	100.00	584.00	232.28	327.92
52	354.64	-6.64	1105.41	100.00	1305.00	369.50	821.34
53	139.50	-7.78	386.86	100.00	1417.00	263.65	277.01
54	139.02	-7.78	386.86	100.00	1346.00	228.36	277.01
55	75.03	-7.78	386.86	100.00	1312.00	204.84	277.01
56	75.90	-7.78	386.86	100.00	945.00	301.87	277.01
57	442.19	-6.36	1153.93	98.05	1727.00	652.75	785.75
58	151.87	-6.88	586.98	100.00	1168.00	600.80	436.68
59	160.54	-6.88	586.98	100.00	796.00	274.43	436.68
60	442.13	-6.36	1153.93	99.51	1367.00	400.86	785.75
61	276.45	-5.86	939.52	97.61	1234.00	204.84	667.89
62	198.57	-5.73	712.18	100.00	724.00	739.98	517.21
63	0.00	-6.88	586.98	42.07	649.00	302.85	0.00
64	160.08	-6.88	586.98	100.00	1027.00	213.66	436.68
65	175.79	-5.73	712.18	83.92	857.00	414.58	517.21
66	276.53	-5.86	939.52	97.42	1376.00	379.30	667.89
67	0.00	-6.88	586.98	61.35	1608.00	393.02	0.00
68	151.74	-6.88	586.98	94.10	1242.00	1195.72	436.68
69	140.61	-6.88	586.98	88.76	1206.00	331.27	436.68
70	156.53	-6.88	586.98	90.17	1386.00	1027.14	436.68
71	315.94	-5.86	939.52	100.00	586.00	175.44	667.89
72	38.77	-5.33	292.79	100.00	612.00	90.17	225.68
73	158.92	-6.88	586.98	98.87	904.00	173.48	436.68
74	130.23	-6.88	586.98	54.39	356.00	55.87	436.68
75	274.42	-10.03	790.67	99.64	1499.00	271.49	691.98
76	149.16	-6.88	586.98	100.00	79.00	18.62	436.68
77	155.80	-6.88	586.98	100.00	840.00	64.69	436.68
78	238.60	-5.60	774.01	100.00	1874.00	295.99	595.72
79	267.67	-6.17	819.68	100.00	1952.00	111.73	529.25
80	418.96	-6.17	1130.38	97.72	2210.00	257.77	659.20
81	315.87	-5.86	939.52	100.00	0.00	0.98	667.89
82	276.54	-5.86	939.52	100.00	467.00	169.56	667.89
83	34.34	-7.05	253.16	100.00	312.00	56.85	203.92
84	29.24	-7.25	234.38	100.00	1575.00	258.75	181.70
85	53.86	-5.20	315.87	100.00	1056.00	572.38	245.50
86	246.85	-6.17	819.68	97.49	2289.00	429.28	529.25
87	131.94	-6.32	575.47	100.00	614.00	137.21	427.90
88	157.95	-6.88	586.98	98.98	1159.00	287.17	436.68
89	247.95	-10.03	790.67	95.76	970.00	115.65	691.98
90	29.45	-7.25	234.38	100.00	1140.00	185.24	181.70
91	0.00	-10.03	790.67	67.61	1703.00	278.35	0.00
92	250.12	-6.17	819.68	100.00	462.00	5.88	529.25
93	212.01	-6.17	747.47	97.27	2859.00	789.96	483.38
94	158.53	-6.88	586.98	78.05	1040.00	80.37	436.68
95	91.11	-8.65	423.04	93.65	2607.00	1713.21	348.39
96	59.07	-5.20	315.87	100.00	1156.00	80.37	245.50
97	0.00	-6.88	586.98	0.00	0.00	0.98	0.00
98	0.00	-6.88	586.98	40.41	1043.00	189.16	0.00

Input Data set for Satluj Sub-basin

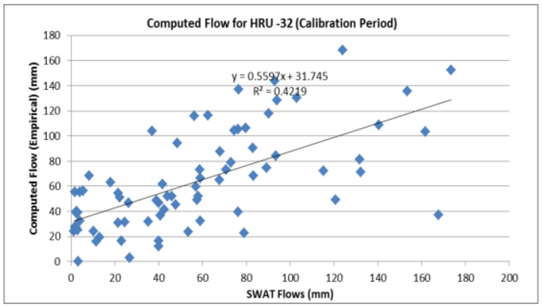
Sub basins	Natural flow mm	Average Temperature oC	Average Precipitation mm	Forest Area %	Cropped Area %	Relief, m	Unit Area, sq.km.	SNFL, mm
99	55.20	-5.20	315.87	100.00	978.00	123.49	245.50
100	267.53	-6.88	586.98	75.68	203.00	145.05	436.68
101	151.17	-6.88	586.98	80.49	802.00	160.74	436.68
102	193.65	-6.17	747.47	100.00	623.00	4.90	483.38
103	149.50	-6.88	586.98	94.12	711.00	149.96	436.68
104	94.38	-6.92	445.10	100.00	1528.00	823.28	327.92
105	96.63	-8.65	423.04	98.06	3064.00	353.82	348.39
106	85.70	-6.92	445.10	100.00	263.00	2.94	327.92
107	131.56	-6.32	575.47	100.00	590.00	181.32	427.90
108	219.48	-6.17	747.47	97.47	3414.00	581.20	483.38
109	149.19	-6.32	575.47	100.00	990.00	288.15	427.90
110	133.07	-6.32	575.47	100.00	689.00	173.48	427.90
111	228.85	-6.28	808.95	100.00	1402.00	449.87	607.67
112	229.46	-6.28	808.95	100.00	1471.00	98.99	607.67
113	263.08	-6.28	808.95	100.00	396.00	27.44	607.67
114	144.46	-5.64	599.23	100.00	1690.00	394.00	457.16
115	143.87	-5.64	599.23	100.00	1319.00	300.89	457.16
116	142.34	-5.64	599.23	100.00	736.00	73.51	457.16
117	136.13	-5.64	599.23	100.00	261.00	16.66	457.16
118	197.33	-5.60	774.01	100.00	306.00	48.02	595.72
119	224.25	-5.60	774.01	100.00	0.00	8.82	595.72
120	228.64	-5.60	774.01	100.00	1085.00	535.13	595.72
121	229.37	-5.60	774.01	100.00	650.00	66.65	595.72
122	374.95	-6.61	1024.82	100.00	1658.00	224.44	787.07
123	54.47	-5.20	315.87	100.00	553.00	43.12	245.50
124	55.59	-5.20	315.87	100.00	844.00	54.89	245.50
125	78.93	-5.82	366.78	100.00	1598.00	545.92	288.03
126	251.95	-6.17	838.88	100.00	2421.00	366.56	463.27
127	224.45	-6.17	747.47	99.37	3461.00	312.65	483.38
128	248.74	-6.17	759.20	99.66	3145.00	290.11	462.92
129	248.69	-6.17	759.20	98.11	2132.00	51.95	462.92
130	257.07	-6.17	759.20	88.46	2359.00	50.97	462.92
131	260.80	-6.17	759.20	85.71	2328.00	41.16	462.92
132	253.51	-6.17	759.20	83.80	3930.00	490.05	462.92
133	313.40	-6.17	846.00	87.07	3693.00	257.77	539.83
134	256.04	-0.80	835.51	67.52	4351.00	1107.51	529.60
135	329.64	-6.17	935.58	0.00	851.00	21.56	510.00
136	336.41	-6.17	935.58	27.96	2420.00	389.10	510.00
137	540.35	-6.17	1276.57	28.24	1934.00	916.39	503.35
138	579.09	-6.17	1276.57	5.04	1685.00	136.23	503.35

Input Data set for Satluj Sub-basin

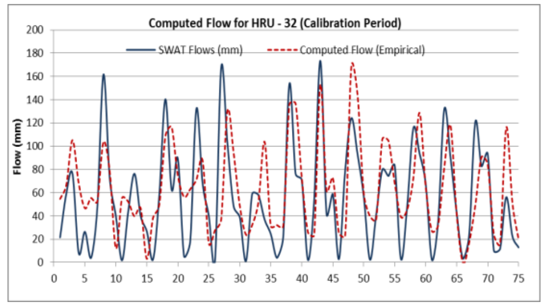
1	1825.4	-5.312	2012.27	94.80	0.00	1278.00	429.84	1171.89
2	2131.2	-5.834	2280.70	96.20	0.25	1256.00	352.10	1262.59
3	2180.3	-5.834	2280.70	88.71	0.00	1347.00	285.07	1262.59
4	2501.3	-5.589	2673.50	84.13	0.34	1400.00	259.16	1401.21
5	626.0	-2.273	861.65	91.53	1.30	2407.00	685.43	495.31
6	3009.7	-2.307	3210.42	93.55	3.27	3117.00	1009.80	1199.85
7	0.0	-5.402	3419.83	49.10	0.00	2262.00	247.54	0.00
8	96.4	-1.185	279.36	97.95	1.10	2396.00	569.25	122.32
9	771.8	-3.737	1060.08	91.84	1.84	2847.00	339.59	579.69
10	3296.7	-5.402	3419.83	79.32	0.79	4337.00	453.97	1620.70
11	2519.2	-5.589	2673.50	83.94	0.00	3269.00	394.99	1401.21
12	96.3	-1.185	279.36	99.27	0.72	2215.00	247.54	122.32
13	821.1	-2.223	1082.82	93.94	4.32	3717.00	869.52	519.51
14	250.2	-2.303	465.01	98.32	1.67	2798.00	802.50	241.00
15	102.8	-1.928	308.66	98.53	1.48	2052.00	301.16	128.44
16	821.9	-2.223	1082.82	98.58	1.40	3261.00	318.14	519.51
17	474.3	-0.287	777.72	100.00	0.91	2371.00	224.31	285.16
18	513.5	5.005	892.55	97.26	2.73	3523.00	491.51	185.28
19	474.4	-0.287	777.72	94.61	2.92	2845.00	580.87	285.16
20	747.0	8.103	1243.56	95.70	4.30	3423.00	519.21	50.60
21	1132.1	3.638	1561.56	97.00	2.99	2858.00	387.84	418.81
22	1150.1	3.638	1561.56	94.66	5.33	2711.00	268.09	418.81
23	748.3	8.103	1243.56	93.31	6.69	3390.00	226.99	50.60
24	786.3	8.103	1243.56	93.08	6.92	4057.00	503.12	50.60
25	1153.9	3.638	1561.56	88.07	10.99	2809.00	479.89	418.81
26	801.5	11.267	1258.13	96.05	3.96	3996.00	654.15	4.91
27	3999.9	7.504	4460.79	95.95	4.07	3753.00	285.97	190.25
28	528.4	16.721	1009.30	90.74	7.64	3276.00	444.14	0.00
29	503.2	16.721	1009.30	84.20	14.01	2581.00	395.89	0.00
30	2175.2	11.459	2658.62	97.51	2.49	3367.00	394.10	4.75
31	503.9	16.721	1009.30	82.95	10.41	2038.00	309.20	0.00
32	504.4	16.721	1009.30	80.09	19.91	1110.00	210.90	0.00
33	504.3	16.721	1009.30	76.35	23.66	1387.00	200.18	0.00
34	3961.0	7.504	4460.79	90.96	9.05	3489.00	404.82	190.25
35	3957.7	7.504	4460.79	90.19	9.81	3426.00	464.70	190.25
36	490.6	19.862	1223.42	93.62	5.67	396.00	252.01	0.00
37	2156.0	11.459	2658.62	96.16	3.86	3902.00	695.26	4.75
38	630.9	19.862	1223.42	96.29	3.54	2184.00	529.93	0.00
39	515.1	16.721	1009.30	57.89	42.11	62.00	16.98	0.00
40	1881.2	-5.312	2012.27	88.60	0.00	1194.00	101.88	1171.89
41	785.2	-3.737	1060.08	88.25	10.20	2857.00	403.04	579.69
42	1882.9	-5.312	2012.27	85.95	3.51	1235.00	101.88	1171.89
43	515.0	16.721	1009.30	67.50	7.50	61.00	35.75	0.00
44	3315.8	-5.402	3419.83	90.56	4.64	4636.00	520.10	1620.70

Input Data set for Satluj Sub-basin

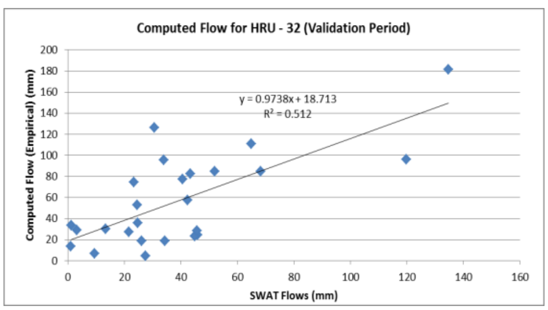
45	788.6	8.103	1243.56	79.60	20.41	2777.00	43.79	50.60
46	2517.2	-5.589	2673.50	100.00	0.00	934.00	29.49	1401.21
47	735.8	8.103	1243.56	85.18	14.83	3563.00	452.19	50.60
48	2518.6	-5.589	2673.50	70.44	0.39	3993.00	459.34	1401.21
49	119.1	-1.928	308.66	74.64	25.38	1933.00	119.75	128.44
50	108.7	-1.928	308.66	91.04	8.72	2402.00	389.63	128.44
51	109.5	-1.928	308.66	89.75	10.25	2481.00	174.26	128.44
52	1766.9	-0.347	2043.00	97.40	2.61	2400.00	102.77	779.07
53	1795.2	-0.347	2043.00	89.76	10.25	3248.00	967.82	779.07
54	449.0	-0.287	777.72	91.03	8.96	2859.00	458.44	285.16
55	148.6	1.781	409.69	91.51	8.49	2275.00	94.73	169.97
56	149.4	1.781	409.69	80.95	19.04	2119.00	37.53	169.97
57	149.9	1.781	409.69	77.97	22.04	2465.00	166.22	169.97
58	193.0	3.543	452.00	85.73	14.26	2853.00	595.17	153.08
59	1141.5	3.638	1561.56	61.94	38.05	2455.00	100.98	418.81
60	878.9	5.640	1303.48	80.37	19.65	3002.00	150.13	208.64
61	874.6	5.640	1303.48	91.92	8.08	2848.00	530.83	208.64
62	3910.8	7.504	4460.79	80.43	19.58	3670.00	584.45	190.25
63	3950.6	7.504	4460.79	78.25	21.74	3030.00	102.77	190.25
64	3968.0	7.504	4460.79	72.12	27.87	3045.00	201.96	190.25
65	2143.0	11.459	2658.62	78.11	21.89	3025.00	330.65	4.75
66	1992.9	11.459	2658.62	100.00	0.00	668.00	3.57	4.75
67	526.4	16.721	1009.30	94.47	5.53	2850.00	242.18	0.00
68	557.3	16.721	1009.30	92.11	7.89	1395.00	33.96	0.00
69	558.7	16.721	1009.30	85.81	9.25	1844.00	144.77	0.00
70	504.7	16.721	1009.30	56.89	10.35	101.00	51.83	0.00
71	0.0	16.721	1009.30	20.00	40.00	60.00	4.47	0.00
72	0.0	16.721	1009.30	25.00	0.00	57.00	3.57	0.00
73	0.0	16.721	1009.30	37.78	8.89	79.00	40.21	0.00
74	336.3	16.721	1009.30	55.53	21.70	254.00	420.01	0.00



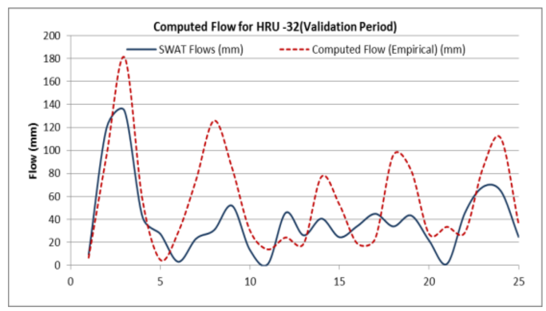
Observed and Computed Flow for HRU -32 (Calibration Period)



Flow Series for HRU -32(Calibration Period)



Observed and Computed Flow for HRU -32 (Validation Period)

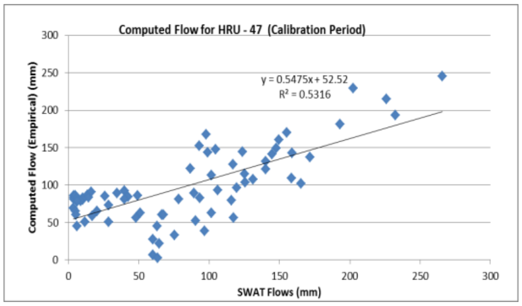


Flow Series for HRU -32(Validation Period)

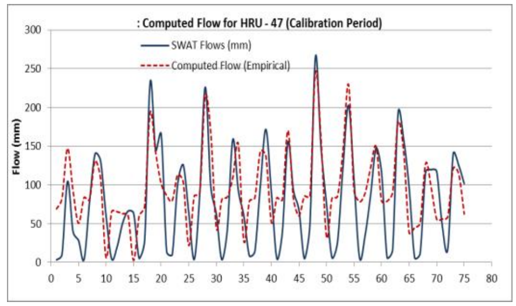
Cluster **I**

Equation:

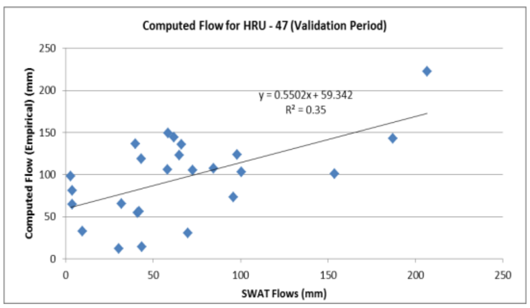
Q_{SIM}	**=**	**-7.542 + 0.0408 X (PCP) + 0.0018 X (RL) + 0.1467X SNMT**	**: May**
Q_{SIM}	**=**	**-89.4403 + 0.3493 X (PCP) + 0.009 X (RL) + 0.2263 X SNMT + 5.6935 X Tmax**	**:June**
Q_{SIM}	**=**	**-89.9009 + 0.5325 X (PCP) + 0.0093 X (RL) + 0.2728 X SNMT + 4.215 X Tmax**	**: July**
Q_{SIM}	**=**	**-26.8335 + 0.4409 X (PCP) + 0.2557 X SNMT + 2.7113 X Tmax + 0.0329 X (PCP1)**	**: August**
Q_{SIM}	**=**	**-5.0204 + 0.3938 X (PCP) -0.1007 X SNMT + 1.1987 X Tmax + 0.1043 X (PCP1)**	**: September**
Basin	**:**	**Sutlej**	



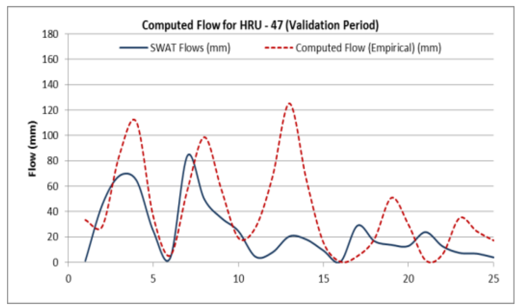
Observed and Computed Flow for HRU -32 (Calibration Period)



Flow Series for HRU -32(Calibration Period)



Observed and Computed Flow for HRU -32 (Validation Period)



Flow Series for HRU -32(Validation Period)

Cluster **I**

Equation:

Q_{SIM}	=	-7.542 + 0.0408 X (PCP) + 0.0018 X (RL) + 0.1467X SNMT	: May
Q_{SIM}	=	-89.4403 + 0.3493 X (PCP) + 0.009 X (RL) + 0.2263 X SNMT + 5.6935 X Tmax	:June
Q_{SIM}	=	-89.9009 + 0.5325 X (PCP) + 0.0093 X (RL) + 0.2728 X SNMT + 4.215 X Tmax	: July
Q_{SIM}	=	-26.8335 + 0.4409 X (PCP) + 0.2557 X SNMT + 2.7113 X Tmax + 0.0329 X (PCP1)	: August
Q_{SIM}	=	-5.0204 + 0.3938 X (PCP) -0.1007 X SNMT + 1.1987 X Tmax + 0.1043 X (PCP1)	: September
Basin	:	**Sutlej**	

Sub Basin and HRU wise Calibration Parameter (Barak)

OID	SUB BASIN	HRU	LANDUSE	SOIL	HRU_FR	SLSUBBSN	HRU_SLP	OV_N	ESCO	EPCO	GW_DELAY	ALPHA_BF	GWQMN	GW_REVAP	REVAPMN	CN2	TEXTURE	SOL_Z1	SOL_AWC1	SOL_K1	SOL_Z2	SOL_BD2	SOL_AWC2	SOL_K2
0	1	1	FODB	Bh16-2-3c-4301	1	30	0.439	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
1	2	2	FOMI	Ao76-2-3c-4276	1	30	0.336	0.1	0.7	1	31	0.048	2000	0.18	1	79	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
2	3	3	FODB	Bh16-2-3c-4301	1	30	0.515	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
3	4	4	FODB	Bh16-2-3c-4301	1	30	0.406	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
4	5	5	FOEB	Bh16-2-3c-4301	1	30	0.413	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
5	6	6	FOMI	Ao76-2-3c-4276	1	30	0.337	0.1	0.7	1	31	0.048	2000	0.18	1	79	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
6	7	7	FOMI	Ao76-2-3c-4276	1	30	0.392	0.1	0.7	1	31	0.048	2000	0.18	1	79	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
7	8	8	FOMI	Ao76-2-3c-4276	1	30	0.428	0.1	0.7	1	31	0.048	2000	0.18	1	79	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
8	9	9	FODB	Bh16-2-3c-4301	1	30	0.361	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
9	10	10	FOMI	Ao76-2-3c-4276	1	30	0.317	0.1	0.7	1	31	0.048	2000	0.18	1	79	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
10	11	11	FODB	Bh16-2-3c-4301	1	30	0.442	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
11	12	12	FODB	Bh16-2-3c-4301	1	30	0.419	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
12	13	13	FOEB	Ao76-2-3c-4276	1	30	0.401	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
13	14	14	FOEB	Bh16-2-3c-4301	1	30	0.398	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
14	15	15	FOMI	Ao74-2b-3646	1	30	0.153	0.1	0.7	1	31	0.048	2000	0.18	1	73	SANDY_CLAY_	300	0.175	8.45	1000	1.4	0.175	5.16
15	16	16	FOEB	Bh16-2-3c-4301	1	30	0.354	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
16	17	17	FOEB	Ao76-2-3c-4276	1	30	0.415	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
17	18	18	FOMI	Ao74-2b-3646	1	30	0.348	0.1	0.7	1	31	0.048	2000	0.18	1	73	SANDY_CLAY_	300	0.175	8.45	1000	1.4	0.175	5.16
18	19	19	FOMI	Bh16-2-3c-4301	1	30	0.477	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
19	20	20	FOMI	Ao76-2-3c-4276	1	30	0.38	0.1	0.7	1	31	0.048	2000	0.18	1	79	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
20	21	21	FOMI	Ao78-3c-3649	1	30	0.388	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
21	22	22	FOEB	Bh16-2-3c-4301	1	30	0.511	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
22	23	23	FOEB	Bh16-2-3c-4301	1	30	0.367	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
23	24	24	FODB	Ao78-3c-3649	1	30	0.399	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
24	25	25	FOMI	Ge53-3a-3708	1	30	0.356	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY	300	0	23.11	1000	1.5	0	2.55
25	26	26	FOMI	Ao78-3c-3649	1	30	0.287	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
26	27	27	FOEB	Ge53-3a-3708	1	30	0.37	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY	300	0	23.11	1000	1.5	0	2.55
27	28	28	CRIR	Ge53-3a-3708	1	30	0.094	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
28	29	29	FOMI	Ge53-3a-3708	1	30	0.297	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY	300	0	23.11	1000	1.5	0	2.55
29	30	30	FOEB	Bh16-2-3c-4301	1	30	0.436	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
30	31	31	FOMI	Ge53-3a-3708	1	30	0.205	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY	300	0	23.11	1000	1.5	0	2.55
31	32	32	CRIR	Ge53-3a-3708	1	30	0.118	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
32	33	33	FOEB	Gd25-2a-3701	1	30	0.206	0.1	0.7	1	31	0.048	2000	0.18	1	77	LOAM	300	0	5.42	1000	1.5	0	3.73
33	34	34	FOEB	Ge53-3a-3708	1	30	0.199	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY	300	0	23.11	1000	1.5	0	2.55
34	35	35	FOEB	Bh16-2-3c-4301	1	30	0.437	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
35	36	36	FOMI	Gd25-2a-3701	1	30	0.16	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
36	37	37	FOMI	Gd25-2a-3701	1	30	0.079	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
37	38	38	CRIR	Ao78-3c-3649	1	100	0.018	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
38	39	39	CRIR	Bd61-2c-3665	1	90	0.024	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
39	40	40	FOMI	Ao76-2-3c-4276	1	30	0.378	0.1	0.7	1	31	0.048	2000	0.18	1	79	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4

OID	SUB BASIN	HRU	LANDUSE	SOIL	HRU_FR	SLSUBBSN	HRU_SLP	OV_N	ESCO	EPCO	GW_DELAY	ALPHA_BF	GWQMN	GW_REVAP	REVAPMN	CN2	TEXTURE	SOL_Z1	SOL_AWC1	SOL_K1	SOL_Z2	SOL_BD2	SOL_AWC2	SOL_K2
40	41	41	FOMI	Ge53-3a-3708	1	60	0.046	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY	300	0	23.11	1000	1.5	0	2.55
41	42	42	CRIR	Ao78-3c-3649	1	60	0.031	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
42	43	43	FOMI	Ge53-3a-3708	1	60	0.038	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY	300	0	23.11	1000	1.5	0	2.55
43	44	44	FOMI	Gd25-2a-3701	1	30	0.073	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
44	45	45	CRIR	Bd61-2c-3665	1	90	0.026	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
45	46	46	FOMI	Bh16-2-3c-4301	1	30	0.41	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
46	47	47	FOMI	Gd25-2a-3701	1	60	0.04	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
47	48	48	CRIR	Ge53-3a-3708	1	60	0.037	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
48	49	49	CRIR	Gd25-2a-3701	1	60	0.033	0.15	0.7	1	31	0.048	2000	0.18	1	85.5	LOAM	300	0	5.42	1000	1.5	0	3.73
49	50	50	CRIR	Ge51-2a-3707	1	100	0.019	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.175	12.9	1000	1.4	0.175	4.78
50	51	51	FOEB	Bh16-2-3c-4301	1	30	0.448	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
51	52	52	CRIR	Ge51-2a-3707	1	100	0.011	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.175	12.9	1000	1.4	0.175	4.78
52	53	53	FOEB	Bh16-2-3c-4301	1	30	0.416	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
53	54	54	FOMI	Ao76-2-3c-4276	1	30	0.394	0.1	0.7	1	31	0.048	2000	0.18	1	79	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
54	55	55	FOEB	Bh16-2-3c-4301	1	30	0.362	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
55	56	56	FOMI	Gd25-2a-3701	1	30	0.073	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
56	57	57	FOMI	Gd25-2a-3701	1	60	0.046	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
57	58	58	CRIR	Gd25-2a-3701	1	60	0.03	0.15	0.7	1	31	0.048	2000	0.18	1	85.5	LOAM	300	0	5.42	1000	1.5	0	3.73
58	59	59	CRIR	Ge51-2a-3707	1	90	0.022	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.175	12.9	1000	1.4	0.175	4.78
59	60	60	FOMI	Ao76-2-3c-4276	1	30	0.331	0.1	0.7	1	31	0.048	2000	0.18	1	79	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
60	61	61	FOMI	Bh16-2-3c-4301	1	30	0.417	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
61	62	62	FOEB	Bh16-2-3c-4301	1	30	0.337	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
62	63	63	FOMI	Gd25-2a-3701	1	30	0.154	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
63	64	64	FOEB	Bh16-2-3c-4301	1	30	0.356	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
64	65	65	FOMI	Gd25-2a-3701	1	30	0.079	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
65	66	66	FOMI	Bd61-2c-3665	1	30	0.197	0.1	0.7	1	31	0.048	2000	0.18	1	73	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
66	67	67	FODB	Bh16-2-3c-4301	1	30	0.422	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
67	68	68	FODB	Bd61-2c-3665	1	30	0.379	0.1	0.7	1	31	0.048	2000	0.18	1	77	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
68	69	69	FOMI	Bd61-2c-3665	1	30	0.274	0.1	0.7	1	31	0.048	2000	0.18	1	73	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
69	70	70	FOMI	Gd25-2a-3701	1	30	0.058	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
70	71	71	FODB	Bh16-2-3c-4301	1	30	0.388	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
71	72	72	FOMI	Bd61-2c-3665	1	30	0.056	0.1	0.7	1	31	0.048	2000	0.18	1	73	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
72	73	73	FOEB	Bh16-2-3c-4301	1	30	0.401	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
73	74	74	FOEB	Bd61-2c-3665	1	30	0.194	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
74	75	75	FOEB	Gd25-2a-3701	1	30	0.148	0.1	0.7	1	31	0.048	2000	0.18	1	77	LOAM	300	0	5.42	1000	1.5	0	3.73
75	76	76	FOEB	Bh16-2-3c-4301	1	30	0.446	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
76	77	77	FOEB	Bd61-2c-3665	1	30	0.182	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
77	78	78	FOEB	Gd25-2a-3701	1	30	0.093	0.1	0.7	1	31	0.048	2000	0.18	1	77	LOAM	300	0	5.42	1000	1.5	0	3.73
78	79	79	FODB	Bd61-2c-3665	1	30	0.327	0.1	0.7	1	31	0.048	2000	0.18	1	77	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
79	80	80	FOEB	Bh16-2-3c-4301	1	30	0.465	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
80	81	81	FOEB	Bd61-2c-3665	1	30	0.098	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
81	82	82	FOEB	Bh16-2-3c-4301	1	30	0.332	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54

OID	SUB BASIN	HRU	LANDUSE	SOIL	HRU_FR	SLSUBBSN	HRU_SLP	OV_N	ESCO	EPCO	GW_DELAY	ALPHA_BF	GWQMN	GW_REVAP	REVAPMN	CN2	TEXTURE	SOL_Z1	SOL_AWC1	SOL_K1	SOL_Z2	SOL_BD2	SOL_AWC2	SOL_K2
82	83	83	FOEB	Bd61-2c-3665	1	30	0.168	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
83	84	84	FOEB	Bh16-2-3c-4301	1	30	0.413	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
84	85	85	FODB	Bh16-2-3c-4301	1	30	0.324	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
85	86	86	FOEB	Bd61-2c-3665	1	30	0.132	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
86	87	87	FOEB	Bd61-2c-3665	1	30	0.208	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
87	88	88	FOMI	Bd61-2c-3665	1	30	0.082	0.1	0.7	1	31	0.048	2000	0.18	1	73	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
88	89	89	FOEB	Bh16-2-3c-4301	1	30	0.404	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
89	90	90	FOEB	Bh16-2-3c-4301	1	30	0.42	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
90	91	91	FOEB	Bd61-2c-3665	1	30	0.146	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
91	92	92	FOEB	Bd61-2c-3665	1	30	0.402	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
92	93	93	FOEB	Bd61-2c-3665	1	30	0.144	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
93	94	94	FOEB	Bd61-2c-3665	1	30	0.207	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
94	95	95	FOEB	Bd61-2c-3665	1	30	0.257	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
95	96	96	FOMI	Bh16-2-3c-4301	1	30	0.393	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
96	97	97	FOEB	Bh16-2-3c-4301	1	30	0.43	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
97	98	98	FOEB	Bh16-2-3c-4301	1	30	0.363	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
98	99	99	FOEB	Bh16-2-3c-4301	1	30	0.394	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
99	100	100	FOEB	Bh16-2-3c-4301	1	30	0.416	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
100	101	101	FOEB	Bd61-2c-3665	1	30	0.36	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
101	102	102	FOEB	Bd61-2c-3665	1	30	0.376	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
102	103	103	FODB	Bd61-2c-3665	1	30	0.383	0.1	0.7	1	31	0.048	2000	0.18	1	77	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
103	104	104	FOEB	Bh16-2-3c-4301	1	30	0.407	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
104	105	105	FOEB	Bh16-2-3c-4301	1	30	0.409	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
105	106	106	FOMI	Bh16-2-3c-4301	1	30	0.416	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
106	107	107	FOMI	Gd25-2a-3701	1	30	0.115	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
107	108	108	CRIR	Ge53-3a-3708	1	30	0.189	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
108	109	109	FOMI	Bd61-2c-3665	1	30	0.109	0.1	0.7	1	31	0.048	2000	0.18	1	73	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
109	110	110	FOEB	Bh16-2-3c-4301	1	30	0.42	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
110	111	111	FOMI	Gd25-2a-3701	1	30	0.345	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
111	112	112	FOMI	Ge53-3a-3708	1	90	0.028	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY	300	0	23.11	1000	1.5	0	2.55
112	113	113	FOEB	Bh16-2-3c-4301	1	30	0.453	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
113	114	114	CRIR	Ge53-3a-3708	1	120	0	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
114	115	115	CRIR	Ge53-3a-3708	1	120	0.009	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
115	116	116	FOMI	Ao78-3c-3649	1	30	0.297	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
116	117	117	FOEB	Bh16-2-3c-4301	1	30	0.378	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
117	118	118	FOEB	Bh16-2-3c-4301	1	30	0.417	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
118	119	119	FOMI	Bd61-2c-3665	1	30	0.091	0.1	0.7	1	31	0.048	2000	0.18	1	73	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
119	120	120	FOEB	Bh16-2-3c-4301	1	30	0.464	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
120	121	121	FOMI	Ge53-3a-3708	1	30	0.067	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY	300	0	23.11	1000	1.5	0	2.55
121	122	122	FOMI	Bd61-2c-3665	1	30	0.259	0.1	0.7	1	31	0.048	2000	0.18	1	73	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
122	123	123	FOEB	Bd61-2c-3665	1	30	0.096	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
123	124	124	FOMI	Ao76-2-3c-4276	1	30	0.418	0.1	0.7	1	31	0.048	2000	0.18	1	79	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4

OID	SUB BASIN	HRU	LANDUSE	SOIL	HRU_FR	SLSUBBSN	HRU_SLP	OV_N	ESCO	EPCO	GW_DELAY	ALPHA_BF	GWQMN	GW_REVAP	REVAPMN	CN2	TEXTURE	SOL_Z1	SOL_AWC1	SOL_K1	SOL_Z2	SOL_BD2	SOL_AWC2	SOL_K2
124	125	125	FOMI	Gd25-2a-3701	1	30	0.056	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
125	126	126	FOEB	Bh16-2-3c-4301	1	30	0.475	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
126	127	127	CRIR	Bd61-2c-3665	1	90	0.028	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
127	128	128	FOMI	Gd25-2a-3701	1	30	0.186	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
128	129	129	FOMI	Gd25-2a-3701	1	30	0.073	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
129	130	130	FOEB	Bh16-2-3c-4301	1	30	0.392	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
130	131	131	FODB	Bh16-2-3c-4301	1	30	0.393	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
131	132	132	FOMI	Bd61-2c-3665	1	30	0.095	0.1	0.7	1	31	0.048	2000	0.18	1	73	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
132	133	133	FOMI	Bh16-2-3c-4301	1	30	0.311	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
133	134	134	FODB	Bh16-2-3c-4301	1	30	0.48	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
134	135	135	CRIR	Ao78-3c-3649	1	120	0.005	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
135	136	136	FOMI	Ge53-3a-3708	1	60	0.037	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY	300	0	23.11	1000	1.5	0	2.55
136	137	137	CRIR	Ao78-3c-3649	1	120	0.006	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
137	138	138	FOMI	Bh16-2-3c-4301	1	30	0.383	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
138	139	139	CRIR	Gd25-2a-3701	1	90	0.029	0.15	0.7	1	31	0.048	2000	0.18	1	85.5	LOAM	300	0	5.42	1000	1.5	0	3.73
139	140	140	FODB	Bd61-2c-3665	1	30	0.254	0.1	0.7	1	31	0.048	2000	0.18	1	77	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
140	141	141	FOEB	Bh16-2-3c-4301	1	30	0.439	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
141	142	142	FODB	Bh16-2-3c-4301	1	30	0.514	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
142	143	143	FOEB	Gd25-2a-3701	1	30	0.082	0.1	0.7	1	31	0.048	2000	0.18	1	77	LOAM	300	0	5.42	1000	1.5	0	3.73
143	144	144	FOEB	Bd61-2c-3665	1	30	0.416	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
144	145	145	FOEB	Bh16-2-3c-4301	1	30	0.37	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
145	146	146	CRIR	Bd61-2c-3665	1	90	0.025	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
146	147	147	CRIR	Ao78-3c-3649	1	120	0.01	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
147	148	148	FOEB	Bd61-2c-3665	1	30	0.136	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
148	149	149	FOEB	Bh16-2-3c-4301	1	30	0.387	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
149	150	150	CRIR	Ge51-2a-3707	1	100	0.019	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.175	12.9	1000	1.4	0.175	4.78
150	151	151	FOMI	Gd25-2a-3701	1	60	0.049	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
151	152	152	FOEB	Bh16-2-3c-4301	1	30	0.503	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
152	153	153	FOEB	Bh16-2-3c-4301	1	30	0.474	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
153	154	154	FOMI	Bh16-2-3c-4301	1	30	0.44	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
154	155	155	FOMI	Gd25-2a-3701	1	30	0.098	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
155	156	156	FOEB	Bh16-2-3c-4301	1	30	0.439	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
156	157	157	FOEB	Bh16-2-3c-4301	1	30	0.42	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
157	158	158	FOEB	Bh16-2-3c-4301	1	30	0.407	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
158	159	159	FOEB	Bh16-2-3c-4301	1	30	0.435	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
159	160	160	FOEB	Bh16-2-3c-4301	1	30	0.435	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
160	161	161	FOEB	Bh16-2-3c-4301	1	30	0.465	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
161	162	162	CRIR	Ge53-3a-3708	1	120	0.003	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
162	163	163	CRIR	Ge53-3a-3708	1	90	0.03	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
163	164	164	FOEB	Bh16-2-3c-4301	1	30	0.417	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
164	165	165	FOEB	Bh16-2-3c-4301	1	30	0.363	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
165	166	166	FOEB	Ao76-2-3c-4276	1	30	0.453	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4

OID	SUB BASIN	HRU	LANDUSE	SOIL	HRU_FR	SLSUBBSN	HRU_SLP	OV_N	ESCO	EPCO	GW_DELAY	ALPHA_BF	GWQMN	GW_REVAP	REVAPMN	CN2	TEXTURE	SOL_Z1	SOL_AWC1	SOL_K1	SOL_Z2	SOL_BD2	SOL_AWC2	SOL_K2
166	167	167	FOEB	Bh16-2-3c-4301	1	30	0.414	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
167	168	168	FOEB	Bh16-2-3c-4301	1	30	0.467	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
168	169	169	FOEB	Bd61-2c-3665	1	30	0.288	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
169	170	170	CRIR	Ao78-3c-3649	1	120	0.005	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
170	171	171	CRIR	Ge51-2a-3707	1	100	0.018	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.175	12.9	1000	1.4	0.175	4.78
171	172	172	CRIR	Ao78-3c-3649	1	100	0.016	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
172	173	173	CRIR	Ao78-3c-3649	1	120	0.008	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
173	174	174	FOEB	Bh16-2-3c-4301	1	30	0.342	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
174	175	175	FOEB	Bh16-2-3c-4301	1	30	0.381	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
175	176	176	CRIR	Ge51-2a-3707	1	100	0.012	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.175	12.9	1000	1.4	0.175	4.78
176	177	177	CRIR	Ge51-2a-3707	1	100	0.012	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.175	12.9	1000	1.4	0.175	4.78
177	178	178	FOEB	Bh16-2-3c-4301	1	30	0.457	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
178	179	179	FOEB	Gd25-2a-3701	1	30	0.305	0.1	0.7	1	31	0.048	2000	0.18	1	77	LOAM	300	0	5.42	1000	1.5	0	3.73
179	180	180	FOEB	Bd61-2c-3665	1	30	0.316	0.1	0.7	1	31	0.048	2000	0.18	1	70	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
180	181	181	FODB	Bh16-2-3c-4301	1	30	0.495	0.1	0.7	1	31	0.048	2000	0.18	1	77	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
181	182	182	FOMI	Gd25-2a-3701	1	30	0.126	0.1	0.7	1	31	0.048	2000	0.18	1	79	LOAM	300	0	5.42	1000	1.5	0	3.73
182	183	183	FOEB	Bh16-2-3c-4301	1	30	0.409	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
183	184	184	FOMI	Bh16-2-3c-4301	1	30	0.295	0.1	0.7	1	31	0.048	2000	0.18	1	73	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
184	185	185	FOEB	Bh16-2-3c-4301	1	30	0.386	0.1	0.7	1	31	0.048	2000	0.18	1	70	CLAY_LOAM	300	0.063	20.33	1000	1.2	0.063	12.54
185	186	186	CRIR	Gd25-2a-3701	1	60	0.036	0.15	0.7	1	31	0.048	2000	0.18	1	85.5	LOAM	300	0	5.42	1000	1.5	0	3.73
186	187	187	CRIR	Ge53-3a-3708	1	90	0.022	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
187	188	188	FOMI	Bd61-2c-3665	1	30	0.275	0.1	0.7	1	31	0.048	2000	0.18	1	73	LOAM	300	0.158	22.59	1000	1.2	0.158	15.91
188	189	189	CRIR	Ge53-3a-3708	1	60	0.033	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
189	190	190	CRIR	Gd25-2a-3701	1	30	0.078	0.15	0.7	1	31	0.048	2000	0.18	1	85.5	LOAM	300	0	5.42	1000	1.5	0	3.73
190	191	191	CRIR	Gd25-2a-3701	1	100	0.014	0.15	0.7	1	31	0.048	2000	0.18	1	85.5	LOAM	300	0	5.42	1000	1.5	0	3.73
191	192	192	CRIR	Gd25-2a-3701	1	90	0.023	0.15	0.7	1	31	0.048	2000	0.18	1	85.5	LOAM	300	0	5.42	1000	1.5	0	3.73
192	193	193	CRIR	Ge53-3a-3708	1	60	0.033	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
193	194	194	CRIR	Ge53-3a-3708	1	90	0.025	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
194	195	195	CRIR	Ge53-3a-3708	1	60	0.031	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
195	196	196	CRIR	Ge53-3a-3708	1	60	0.038	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
196	197	197	CRIR	Ge53-3a-3708	1	60	0.031	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY	300	0	23.11	1000	1.5	0	2.55
197	198	198	CRIR	Ao78-3c-3649	1	100	0.017	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
198	199	199	CRIR	Ao78-3c-3649	1	90	0.02	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
199	200	200	CRIR	Ao78-3c-3649	1	100	0.018	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
200	201	201	CRIR	Ao78-3c-3649	1	100	0.011	0.15	0.7	1	31	0.048	2000	0.18	1	81	CLAY_LOAM	300	0.094	21.89	1000	1.2	0.094	14.17
201	202	202	CRIR	Ge51-2a-3707	1	100	0.013	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.175	12.9	1000	1.4	0.175	4.78
202	203	203	CRIR	Ge51-2a-3707	1	100	0.014	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.175	12.9	1000	1.4	0.175	4.78
203	204	204	CRIR	Ge51-2a-3707	1	90	0.021	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.175	12.9	1000	1.4	0.175	4.78
204	205	205	CRIR	Ge51-2a-3707	1	100	0.014	0.15	0.7	1	31	0.048	2000	0.18	1	81	LOAM	300	0.175	12.9	1000	1.4	0.175	4.78

Parameters	**Details**
HRU	Hydrological Response Unit Number
LANDUSE	Land use cover simulated in HRU

SOIL	Name of the soil simulated in HRU
HRU_FR	Fraction of total watershed in HRU
SLSUBBSN	Average slope length (m)
HRU_SLP	Average slope steepness (m/m)
OV_N	Manning's 'n' value for overland flow
ESCO	Soil water compensation factor
EPCO	Plant uptake compensation factor
GW_DELAY	Groundwater delays (days)
ALPHA_BF	Baseflow alpha factor (days)
GW_REVAP	Groundwater revap coefficient
REVAPMN	Threshold depth of water in the shallow aquifer for revap to occur (mm)
CN2	Initial SCS runoff curve number for moisture condition II
SOL_Z1	Depth to bottom of first soil layer (mm/mm)
SOL_AWC1	Available water capacity first soil layer (mm/mm)
SOL_K1	Saturated hydraulic conductivity of first soil layer (mm/hr)
SOL_Z2	Depth to bottom of second soil layer (mm/mm)
SOL_AWC2	Available water capacity second soil layer (mm/mm)
SOL_K2	Saturated hydraulic conductivity of second soil layer (mm/hr)

HRU Attribute Input Data in sub basin (Barak)

OID	SUBBASIN	SUB_KM	SUB_LAT	SUB_ELEV	IRGAGE	ITGAGE	CH_L1	CH_S1	CH_W1	HRUTOT
1	1	375.55	25.56	1723.62	13	13	60.419	0.039	45.226	1
2	2	399.05	25.40	1545.45	13	13	43.772	0.033	46.903	1
3	3	78.75	25.36	1590.36	13	13	18.692	0.076	17.715	1
4	4	148.68	25.40	1776.06	13	13	20.601	0.105	25.938	1
5	5	142.71	25.43	981.93	12	12	22.949	0.046	25.309	1
6	6	82.26	25.34	1465.31	13	13	26.550	0.041	18.184	1
7	7	89.03	25.42	1212.15	12	12	23.801	0.057	19.069	1
8	8	92.95	25.35	1292.99	12	12	18.239	0.074	19.568	1
9	9	115.36	25.33	1529.51	13	13	25.579	0.065	22.276	1
10	10	89.43	25.25	1359.45	11	11	21.898	0.025	19.120	1
11	11	97.00	25.27	1166.89	12	12	16.357	0.105	20.075	1
12	12	282.87	25.22	1481.54	11	11	29.904	0.053	38.154	1
13	13	313.00	25.15	823.75	10	10	59.137	0.031	40.543	1
14	14	73.02	25.16	1204.46	10	10	13.946	0.094	16.929	1
15	15	265.24	25.26	796.45	8	8	36.527	0.029	36.709	1
16	16	496.57	25.00	605.13	10	10	89.041	0.017	53.478	1
17	17	299.97	25.12	833.92	9	9	60.112	0.028	39.522	1
18	18	99.80	25.22	727.87	8	8	18.569	0.076	20.420	1
19	19	159.70	25.09	1458.69	11	11	22.222	0.068	27.076	1
20	20	189.14	25.11	605.12	9	9	28.264	0.021	29.968	1
21	21	182.51	25.15	994.76	8	8	30.596	0.048	29.333	1
22	22	100.41	25.03	1319.72	10	10	19.352	0.093	20.496	1
23	23	155.76	25.06	1110.79	10	10	24.160	0.045	26.672	1
24	24	78.44	25.09	606.76	8	8	15.499	0.024	17.673	1
25	25	206.18	25.04	609.26	9	9	43.403	0.033	31.560	1
26	26	153.16	25.04	360.06	8	8	39.467	0.039	26.404	1
27	27	160.34	25.03	520.82	9	9	36.494	0.043	27.140	1
28	28	78.99	25.03	73.73	8	8	21.710	0.034	17.748	1
29	29	86.88	25.04	344.56	8	8	24.721	0.050	18.790	1
30	30	119.04	24.93	848.79	10	10	22.695	0.059	22.699	1
31	31	126.33	25.03	233.99	8	8	39.555	0.031	23.523	1
32	32	197.14	24.97	98.88	8	8	39.516	0.009	30.722	1
33	33	131.39	24.98	224.00	9	9	35.653	0.035	24.084	1
34	34	83.82	24.97	235.91	9	9	22.356	0.059	18.390	1
35	35	180.64	24.87	1297.16	10	10	35.845	0.052	29.153	1
36	36	132.43	24.96	163.31	9	9	30.563	0.031	24.199	1
37	37	144.26	24.90	79.80	9	9	29.043	0.006	25.473	1
38	38	106.17	24.86	22.05	8	8	20.317	0.000	21.192	1
39	39	113.48	24.80	23.94	8	8	19.045	0.003	22.057	1
40	40	101.21	24.72	1139.58	7	7	21.439	0.061	20.593	1
41	41	85.61	24.81	33.08	8	8	18.683	0.006	18.626	1
42	42	131.16	24.79	33.25	8	8	28.434	0.003	24.059	1
43	43	101.87	24.74	34.35	5	5	31.504	0.002	20.674	1
44	44	141.09	24.63	54.64	6	6	60.628	0.002	25.136	1
45	45	201.56	24.72	26.04	5	5	34.648	0.002	31.134	1
46	46	149.51	24.63	948.37	7	7	19.521	0.057	26.025	1
47	47	199.82	24.63	44.35	5	5	31.505	0.001	30.973	1
48	48	151.88	24.67	37.86	5	5	33.460	0.001	26.272	1
49	49	98.62	24.56	35.70	5	5	27.604	0.002	20.276	1
50	50	206.35	24.59	20.05	19	20	26.180	0.002	31.576	1
51	51	85.86	24.52	683.51	7	7	16.513	0.043	18.657	1
52	52	86.26	24.69	14.46	19	20	29.050	0.000	18.710	1
53	53	74.14	24.45	695.72	7	7	19.639	0.062	17.086	1
54	54	80.19	24.44	1174.87	7	7	17.531	0.053	17.909	1
55	55	164.88	24.49	994.80	7	7	23.941	0.038	27.599	1
56	56	132.75	24.51	61.48	5	5	38.757	0.002	24.233	1
57	57	180.66	24.51	43.76	5	5	27.719	0.003	29.154	1
58	58	246.83	24.50	32.14	19	20	47.697	0.001	35.158	1
59	59	105.48	24.45	24.33	19	20	35.190	0.001	21.110	1
60	60	284.25	24.29	1006.45	7	7	38.960	0.034	38.265	1
61	61	187.32	24.32	1023.61	7	7	26.202	0.027	29.795	1
62	62	307.33	24.37	541.02	7	7	41.583	0.030	40.101	1
63	63	73.35	24.32	148.33	5	5	17.644	0.025	16.975	1
64	64	332.99	24.36	477.68	6	6	44.743	0.022	42.077	1
65	65	481.14	24.40	82.73	5	5	68.825	0.002	52.475	1
66	66	132.70	24.24	206.17	3	3	29.985	0.026	24.228	1
67	67	244.39	24.20	668.71	4	4	36.914	0.021	34.949	1
68	68	81.90	24.18	463.82	4	4	28.076	0.035	18.137	1
69	69	144.21	24.23	307.62	3	3	41.903	0.025	25.467	1
70	70	520.39	24.35	61.99	20	21	62.285	0.003	55.003	1
71	71	121.55	24.12	998.10	18	19	30.800	0.020	22.985	1
72	72	92.60	24.20	77.08	19	20	22.894	0.009	19.524	1
73	73	148.86	24.16	1009.04	4	4	24.728	0.030	25.957	1

OID	SUBBASIN	SUB_KM	SUB_LAT	SUB_ELEV	IRGAGE	ITGAGE	CH_L1	CH_S1	CH_W1	HRUTOT
74	74	151.59	24.15	187.92	3	3	28.411	0.033	26.242	1
75	75	74.15	24.15	135.27	3	3	18.311	0.022	17.087	1
76	76	88.71	24.06	1030.70	18	19	19.309	0.035	19.027	1
77	77	72.49	24.11	209.11	3	3	20.731	0.030	16.856	1
78	78	108.03	24.08	108.07	20	21	25.755	0.006	21.414	1
79	79	219.16	24.07	395.87	3	3	47.235	0.018	32.737	1
80	80	107.80	23.94	1125.10	17	18	27.007	0.057	21.388	1
81	81	79.12	24.02	111.13	15	16	19.000	0.013	17.765	1
82	82	231.42	23.98	1008.99	18	19	51.219	0.016	33.825	1
83	83	72.36	23.94	173.49	16	17	17.515	0.026	16.838	1
84	84	121.00	23.94	681.22	4	4	28.061	0.036	22.922	1
85	85	380.67	23.94	1049.54	18	19	66.501	0.014	45.595	1
86	86	115.65	23.91	151.77	16	17	22.937	0.023	22.309	1
87	87	328.28	23.98	229.22	16	17	54.572	0.012	41.719	1
88	88	606.45	24.02	108.45	15	16	67.636	0.003	60.293	1
89	89	312.37	23.82	1186.36	18	19	36.940	0.029	40.494	1
90	90	294.54	23.76	987.02	17	18	35.385	0.042	39.091	1
91	91	160.56	23.75	171.98	15	16	32.759	0.006	27.163	1
92	92	94.89	23.76	642.85	3	3	17.074	0.064	19.812	1
93	93	240.17	23.79	189.46	16	17	30.300	0.009	34.586	1
94	94	337.00	23.84	239.87	16	17	45.216	0.007	42.381	1
95	95	635.21	23.89	338.54	3	3	87.546	0.011	61.993	1
96	96	360.48	23.80	1174.58	18	19	56.911	0.017	44.128	1
97	97	412.15	23.69	712.73	2	2	53.437	0.016	47.822	1
98	98	88.45	23.54	715.96	1	1	19.383	0.048	18.994	1
99	99	101.70	23.51	729.66	2	2	21.377	0.058	20.653	1
100	100	877.66	23.78	811.22	17	18	95.626	0.015	75.264	1
101	101	113.01	23.34	696.76	14	15	26.645	0.031	22.002	1
102	102	865.59	23.59	490.24	1	1	122.127	0.007	74.641	1
103	103	428.48	23.06	672.15	14	15	74.129	0.015	48.950	1
104	104	193.52	25.28	1080.20	12	12	26.760	0.019	30.383	1
105	105	345.52	23.70	550.84	2	2	42.681	0.021	43.020	1
106	106	385.41	24.64	909.08	7	7	55.683	0.033	45.935	1
107	107	234.97	24.45	92.20	5	5	44.430	0.011	34.134	1
108	108	194.24	24.97	180.33	8	8	49.890	0.015	30.450	1
109	109	57.80	23.90	118.68	15	16	14.174	0.005	14.714	1
110	110	53.06	24.83	834.96	10	10	13.176	0.083	13.978	1
111	111	44.73	25.15	407.05	8	8	11.150	0.089	12.616	1
112	112	115.99	24.85	32.14	9	9	22.552	0.004	22.348	1
113	113	121.46	25.13	1105.59	10	10	20.610	0.045	22.974	1
114	114	0.01	24.97	19.00	8	8	0.134	0.000	0.076	1
115	115	210.45	24.92	19.45	8	8	39.565	0.000	31.951	1
116	116	144.82	25.10	304.81	8	8	26.104	0.004	25.532	1
117	117	16.16	24.51	481.46	7	7	8.348	0.042	6.849	1
118	118	54.11	24.84	635.73	10	10	18.790	0.049	14.144	1
119	119	129.10	23.98	97.00	15	16	20.986	0.009	23.831	1
120	120	36.77	24.54	510.90	7	7	12.106	0.070	11.218	1
121	121	188.33	24.86	72.11	9	9	51.609	0.026	29.892	1
122	122	85.01	24.31	239.79	6	6	17.019	0.012	18.548	1
123	123	278.76	24.07	120.09	20	21	33.931	0.018	37.821	1
124	124	119.51	25.43	1568.75	13	13	17.489	0.094	22.753	1
125	125	594.78	24.41	64.84	5	5	92.030	0.004	59.594	1
126	126	280.10	24.95	788.01	10	10	45.854	0.012	37.929	1
127	127	251.03	24.57	27.61	20	21	34.081	0.002	35.516	1
128	128	151.02	24.87	150.89	9	9	44.885	0.012	26.182	1
129	129	168.39	24.10	78.71	19	20	28.397	0.011	27.950	1
130	130	74.03	23.86	508.03	4	4	16.588	0.064	17.070	1
131	131	105.47	23.99	945.02	18	19	17.971	0.003	21.109	1
132	132	444.15	24.52	83.49	6	6	72.337	0.003	50.016	1
133	133	5.62	24.17	770.88	18	19	3.246	0.000	3.634	1
134	134	42.65	25.43	1384.17	13	13	13.199	0.112	12.262	1
135	135	17.62	24.93	17.55	8	8	7.418	0.001	7.213	1
136	136	184.01	24.70	30.45	5	5	25.941	0.000	29.478	1
137	137	48.22	24.98	18.01	8	8	16.527	0.000	13.198	1
138	138	50.63	24.19	838.36	18	19	14.859	0.043	13.591	1
139	139	249.10	24.33	38.06	19	20	39.467	0.000	35.352	1
140	140	1100.31	24.32	280.08	6	6	141.762	0.009	86.198	1
141	141	13.87	24.82	550.97	10	10	5.914	0.009	6.249	1
142	142	190.75	25.49	1417.15	13	13	27.216	0.087	30.121	1
143	143	161.09	24.18	86.33	20	21	26.519	0.003	27.217	1
144	144	547.01	23.54	609.54	1	1	67.050	0.010	56.675	1
145	145	8.17	24.21	732.71	7	7	5.676	0.012	4.549	1
146	146	145.11	24.65	26.00	5	5	33.633	0.005	25.563	1
147	147	59.68	24.92	17.65	8	8	14.726	0.000	14.999	1
148	148	7.99	24.17	80.17	3	3	5.259	0.001	4.489	1
149	149	229.99	24.21	947.54	18	19	36.673	0.038	33.699	1

OID	SUBBASIN	SUB_KM	SUB_LAT	SUB_ELEV	IRGAGE	ITGAGE	CH_L1	CH_S1	CH_W1	HRUTOT
150	150	76.89	24.71	17.71	19	20	33.413	0.000	17.463	1
151	151	443.83	24.31	51.85	19	20	62.404	0.000	49.994	1
152	152	1.57	25.46	624.43	13	13	2.016	0.089	1.694	1
153	153	37.03	25.45	902.47	13	13	11.529	0.070	11.265	1
154	154	188.05	24.73	619.52	7	7	27.734	0.000	29.864	1
155	155	157.04	24.77	78.16	9	9	25.050	0.001	26.804	1
156	156	56.89	25.38	913.11	12	12	16.562	0.085	14.576	1
157	157	50.20	24.06	827.09	18	19	10.191	0.131	13.521	1
158	158	42.20	25.33	819.98	12	12	12.269	0.093	12.184	1
159	159	27.69	24.04	738.17	18	19	8.528	0.013	9.462	1
160	160	91.38	25.24	864.15	10	10	16.784	0.029	19.368	1
161	161	107.09	24.61	622.63	7	7	13.727	0.017	21.303	1
162	162	0.19	24.76	23.24	9	9	1.393	0.000	0.473	1
163	163	126.69	24.78	30.61	8	8	26.088	0.002	23.563	1
164	164	56.45	24.08	771.67	18	19	11.962	0.036	14.507	1
165	165	2.61	25.20	515.98	10	10	2.440	0.400	2.295	1
166	166	169.27	25.15	873.25	10	10	28.045	0.048	28.037	1
167	167	136.65	24.57	490.66	7	7	30.905	0.039	24.658	1
168	168	235.37	23.97	830.57	17	18	38.049	0.029	34.170	1
169	169	538.51	23.92	372.47	3	3	68.434	0.015	56.144	1
170	170	17.38	24.78	21.60	8	8	8.080	0.000	7.156	1
171	171	77.23	24.51	20.87	19	20	31.921	0.001	17.509	1
172	172	17.13	24.80	23.19	8	8	11.000	0.000	7.094	1
173	173	32.75	24.84	21.52	8	8	8.505	0.001	10.464	1
174	174	46.48	24.51	265.58	6	6	15.189	0.020	12.911	1
175	175	661.51	24.84	570.46	10	10	81.835	0.004	63.520	1
176	176	38.59	24.52	14.66	19	20	12.756	0.001	11.547	1
177	177	20.52	24.57	12.97	19	20	8.309	0.001	7.906	1
178	178	272.97	23.96	674.14	17	18	38.359	0.028	37.348	1
179	179	48.31	24.09	268.87	3	3	15.520	0.026	13.214	1
180	180	10.34	24.17	192.58	3	3	5.833	0.015	5.240	1
181	181	53.38	24.10	613.97	4	4	14.947	0.080	14.028	1
182	182	435.48	24.33	100.45	5	5	62.419	0.008	49.428	1
183	183	123.84	24.17	458.84	4	4	24.349	0.031	23.244	1
184	184	178.28	24.60	312.44	6	6	29.360	0.002	28.923	1
185	185	314.49	24.35	386.71	6	6	42.856	0.012	40.659	1
186	186	58.25	24.58	41.12	5	5	22.268	0.003	14.782	1
187	187	239.98	24.67	30.26	5	5	46.604	0.002	34.569	1
188	188	658.59	24.49	257.80	6	6	87.440	0.007	63.352	1
189	189	37.70	24.82	29.42	8	8	14.426	0.003	11.387	1
190	190	79.32	24.75	53.87	9	9	24.515	0.002	17.792	1
191	191	4.62	24.77	28.51	9	9	4.946	0.001	3.230	1
192	192	39.88	24.77	25.71	9	9	27.507	0.001	11.777	1
193	193	146.02	24.88	31.70	9	9	27.112	0.004	25.659	1
194	194	13.82	24.89	25.37	9	9	6.851	0.001	6.237	1
195	195	152.86	24.81	28.22	8	8	36.416	0.001	26.373	1
196	196	1.83	24.86	29.79	8	8	1.938	0.006	1.851	1
197	197	39.15	24.87	25.32	8	8	25.605	0.000	11.648	1
198	198	11.56	24.86	22.08	8	8	7.017	0.001	5.602	1
199	199	29.89	24.89	20.77	8	8	27.396	0.000	9.907	1
200	200	1.82	24.89	18.54	8	8	3.402	0.001	1.845	1
201	201	8.62	24.87	18.13	8	8	5.324	0.000	4.696	1
202	202	320.29	24.81	17.11	8	8	49.293	0.000	41.107	1
203	203	197.28	24.71	15.55	19	20	38.569	0.000	30.736	1
204	204	2.05	24.60	12.79	19	20	3.331	0.001	1.984	1
205	205	33.06	24.61	13.70	19	20	9.519	0.001	10.524	1

Parameters	**Details**
SUB_KM	Sub basin area in sq.km.
SUB_LAT	Sub basin latitude
SUB_ELEV	Elevation of the sub basin
IRGAGE	Number of precipitation gauge used in sub basin
ITGAGE	Number of temperature gauge used in sub basin
CH_L1	Longest tributary channel length in sub basin (km)
CH_S1	Average slope of tributary channel (m/m)
CH_W1	Average width of tributary channel (m)
HRUTOT	Total number of HRU modeled in the sub basin

Sub Basin and HRU wise Calibration Parameter (Lohit)

OID	HRU	LANDUSE	SOIL	HRU_FR	SLSUBBSN	HRU_SLP	OV_N	ESCO	EPCO	GW_ DELAY	ALPHA_BF	GWQMN	GW_REVAP	REVAPMN	CN2	TEXTURE	SOL_Z1	SOL_ AWC1	SOL_ K1	SOL_ Z2	SOL_ BD2	SOL_ AWC2	SOL_K2
0	1	TUWO	I-K-U-2c-3724	1	30	0.21	0.13	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.064	14.38	1000	1.3	0.064	7.68
1	2	TUWO	I-K-U-2c-3724	1	30	0.21	0.13	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.064	14.38	1000	1.3	0.064	7.68
2	3	TUWO	GLACIER-6998	1	30	0.21	0.13	0	0	68.27	0.3	0	0.02	1	87.4	UWB	1524	0.01	99	0	0	0	0
3	4	TUWO	I-Bh-U-2c-3967	1	30	0.21	0.13	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.064	33.91	1000	1.3	0.064	8.25
4	5	TUWO	I-Bh-U-2c-3967	1	30	0.29	0.13	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.064	33.91	1000	1.3	0.064	8.25
5	6	TUWO	I-Be-2c-3963	1	30	0.32	0.13	0	0	68.27	0.3	0	0.02	1	87.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
6	7	ICES	GLACIER-6998	1	30	0.25	0.01	0	0	68.27	0.3	0	0.02	1	98	UWB	1524	0.01	99	0	0	0	0
7	8	TUWO	I-Bh-U-2c-3967	1	30	0.33	0.13	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.064	33.91	1000	1.3	0.064	8.25
8	9	TUWO	Jc55-2ab-4391	1	30	0.35	0.13	0	0	68.27	0.3	0	0.02	1	87.4	LOAM	300	0.175	6.57	1000	1.4	0.175	7.86
9	10	TUWO	Jc55-2ab-4391	1	30	0.52	0.13	0	0	68.27	0.3	0	0.02	1	87.4	LOAM	300	0.175	6.57	1000	1.4	0.175	7.86
10	11	TUWO	I-Be-2c-3963	1	30	0.52	0.13	0	0	68.27	0.3	0	0.02	1	87.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
11	12	TUWO	I-Bh-U-2c-3967	1	30	0.29	0.13	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.064	33.91	1000	1.3	0.064	8.25
12	13	TUWO	I-Be-2c-3963	1	30	0.39	0.13	0	0	68.27	0.3	0	0.02	1	87.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
13	14	TUWO	I-Be-2c-3963	1	30	0.36	0.13	0	0	68.27	0.3	0	0.02	1	87.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
14	15	TUWO	I-Bh-U-2c-4362	1	30	0.24	0.13	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
15	16	TUWO	I-Be-2c-3963	1	30	0.39	0.13	0	0	68.27	0.3	0	0.02	1	87.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
16	17	TUWO	I-Bh-U-2c-4362	1	30	0.26	0.13	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
17	18	GRAS	I-Be-2c-3963	1	30	0.40	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
18	19	TUWO	I-Bh-U-2c-4362	1	30	0.28	0.13	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
19	20	GRAS	I-Be-2c-3963	1	30	0.41	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
20	21	GRAS	I-Af-Bd-2-4351	1	30	0.34	0.15	0	0	68.27	0.3	0	0.02	1	86.9	LOAM	300	0.122	23.09	1000	1.3	0.122	8.46
21	22	TUWO	I-Bh-U-2c-4362	1	30	0.34	0.13	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
22	23	GRAS	I-Be-2c-3963	1	30	0.39	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
23	24	FODB	I-Be-2c-3963	1	30	0.44	0.10	0	0	68.27	0.3	0	0.02	1	91.3	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
24	25	TUWO	I-Bh-U-2c-4362	1	30	0.39	0.13	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
25	26	FODB	I-Af-Bd-2-4351	1	30	0.40	0.10	0	0	68.27	0.3	0	0.02	1	84.7	LOAM	300	0.122	23.09	1000	1.3	0.122	8.46
26	27	GRAS	I-Be-2c-3963	1	30	0.39	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
27	28	FODB	I-Af-Bd-2-4351	1	30	0.23	0.10	0	0	68.27	0.3	0	0.02	1	84.7	LOAM	300	0.122	23.09	1000	1.3	0.122	8.46
28	29	FOMI	Af48-2ab-3637	1	30	0.14	0.10	0	0	68.27	0.3	0	0.02	1	80.3	SANDY_CLAY_LOAM	300	0.175	11.02	1000	1.4	0.175	5.2
29	30	FODB	Ao76-2-3c-4276	1	30	0.35	0.10	0	0	68.27	0.3	0	0.02	1	91.3	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
30	31	FOMI	Af48-2ab-3637	1	30	0.12	0.10	0	0	68.27	0.3	0	0.02	1	80.3	SANDY_CLAY_LOAM	300	0.175	11.02	1000	1.4	0.175	5.2
31	32	FOMI	Af48-2ab-3637	1	90	0.03	0.10	0	0	68.27	0.3	0	0.02	1	80.3	SANDY_CLAY_LOAM	300	0.175	11.02	1000	1.4	0.175	5.2
32	33	FOMI	Af48-2ab-3637	1	60	0.04	0.10	0	0	68.27	0.3	0	0.02	1	80.3	SANDY_CLAY_LOAM	300	0.175	11.02	1000	1.4	0.175	5.2
36	34	FODB	I-Bh-U-2c-4362	1	30	0.44	0.10	0	0	68.27	0.3	0	0.02	1	84.7	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
37	35	FODB	I-Bh-U-2c-4362	1	30	0.39	0.10	0	0	68.27	0.3	0	0.02	1	84.7	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
38	36	FOEB	Af48-2ab-3637	1	90	0.02	0.10	0	0	68.27	0.3	0	0.02	1	77	SANDY_CLAY_LOAM	300	0.175	11.02	1000	1.4	0.175	5.2
42	37	FODB	I-Bh-U-2c-4362	1	30	0.29	0.10	0	0	68.27	0.3	0	0.02	1	84.7	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
43	38	FOEB	Ao76-2-3c-4276	1	30	0.06	0.10	0	0	68.27	0.3	0	0.02	1	84.7	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
44	39	FOMI	Ao79-a-3650	1	90	0.03	0.10	0	0	68.27	0.3	0	0.02	1	80.3	SANDY_CLAY_LOAM	300	0.175	8.75	1000	1.4	0.175	5.51
48	40	TUWO	GLACIER-6998	1	30	0.17	0.13	0	0	68.27	0.3	0	0.02	1	87.4	UWB	1524	0.01	99	0	0	0	0
49	41	GRAS	Jc55-2ab-4391	1	30	0.34	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.175	6.57	1000	1.4	0.175	7.86
50	42	TUWO	GLACIER-6998	1	30	0.20	0.13	0	0	68.27	0.3	0	0.02	1	87.4	UWB	1524	0.01	99	0	0	0	0
54	43	FOMI	Ao79-a-3650	1	90	0.03	0.10	0	0	68.27	0.3	0	0.02	1	80.3	SANDY_CLAY_LOAM	300	0.175	8.75	1000	1.4	0.175	5.51

OID	HRU	LANDUSE	SOIL	HRU_FR	SLSUBBSN	HRU_SLP	OV_N	ESCO	EPCO	GW_DELAY	ALPHA_BF	GWQMN	GW_REVAP	REVAPMN	CN2	TEXTURE	SOL_Z1	SOL_AWC1	SOL_K1	SOL_Z2	SOL_BD2	SOL_AWC2	SOL_K2
55	44	GRAS	Jc55-2ab-4391	1	30	0.42	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.175	6.57	1000	1.4	0.175	7.86
56	45	FODB	I-Be-2c-3963	1	30	0.37	0.10	0	0	68.27	0.3	0	0.02	1	91.3	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
60	46	TUWO	I-Be-2c-3963	1	30	0.16	0.13	0	0	68.27	0.3	0	0.02	1	87.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
61	47	FODB	I-Af-Bd-2-4351	1	30	0.38	0.10	0	0	68.27	0.3	0	0.02	1	84.7	LOAM	300	0.122	23.09	1000	1.3	0.122	8.46
62	48	TUWO	I-Be-2c-3963	1	30	0.41	0.13	0	0	68.27	0.3	0	0.02	1	87.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
66	49	GRAS	I-Bh-U-2c-3967	1	30	0.32	0.15	0	0	68.27	0.3	0	0.02	1	86.9	LOAM	300	0.064	33.91	1000	1.3	0.064	8.25
67	50	GRAS	I-Bh-U-2c-4362	1	30	0.36	0.15	0	0	68.27	0.3	0	0.02	1	86.9	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
68	51	GRAS	I-Bh-U-2c-4362	1	30	0.40	0.15	0	0	68.27	0.3	0	0.02	1	86.9	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
72	52	GRAS	Jc55-2ab-4391	1	30	0.38	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.175	6.57	1000	1.4	0.175	7.86
73	53	GRAS	I-Be-2c-3963	1	30	0.44	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
33	54	GRAS	Jc55-2ab-4391	1	30	0.40	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.175	6.57	1000	1.4	0.175	7.86
34	55	GRAS	Jc55-2ab-4391	1	30	0.25	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.175	6.57	1000	1.4	0.175	7.86
35	56	GRAS	Jc55-2ab-4391	1	30	0.27	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.175	6.57	1000	1.4	0.175	7.86
39	57	GRAS	Jc55-2ab-4391	1	30	0.51	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.175	6.57	1000	1.4	0.175	7.86
40	58	GRAS	I-Be-2c-3963	1	30	0.40	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
41	59	GRAS	I-Af-Bd-2-4351	1	30	0.29	0.15	0	0	68.27	0.3	0	0.02	1	86.9	LOAM	300	0.122	23.09	1000	1.3	0.122	8.46
45	60	GRAS	I-Be-2c-3963	1	30	0.24	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
46	61	GRAS	I-Be-2c-3963	1	30	0.37	0.15	0	0	68.27	0.3	0	0.02	1	92.4	LOAM	300	0.071	7.99	1000	1.4	0.071	4.17
47	62	FOMI	I-Af-Bd-2-4351	1	30	0.42	0.10	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.122	23.09	1000	1.3	0.122	8.46
51	63	FOMI	I-Bh-U-2c-4362	1	30	0.47	0.10	0	0	68.27	0.3	0	0.02	1	80.3	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
52	64	FODB	I-Bh-U-2c-4362	1	30	0.39	0.10	0	0	68.27	0.3	0	0.02	1	84.7	LOAM	300	0.078	33.91	1000	1.3	0.078	8.25
53	65	FODB	I-Af-Bd-2-4351	1	30	0.39	0.10	0	0	68.27	0.3	0	0.02	1	84.7	LOAM	300	0.122	23.09	1000	1.3	0.122	8.46
57	66	SAVA	I-Af-Bd-2-4351	1	30	0.18	0.15	0	0	68.27	0.3	0	0.02	1	84.2	LOAM	300	0.122	23.09	1000	1.3	0.122	8.46
58	67	FODB	I-Af-Bd-2-4351	1	30	0.37	0.10	0	0	68.27	0.3	0	0.02	1	84.7	LOAM	300	0.122	23.09	1000	1.3	0.122	8.46
59	68	FOMI	Ao76-2-3c-4276	1	30	0.27	0.10	0	0	68.27	0.3	0	0.02	1	86.9	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
63	69	FOMI	Ao76-2-3c-4276	1	30	0.21	0.10	0	0	68.27	0.3	0	0.02	1	86.9	CLAY_LOAM	300	0.077	7.61	1000	1.3	0.077	8.4
64	70	FOMI	Af48-2ab-3637	1	90	0.03	0.10	0	0	68.27	0.3	0	0.02	1	80.3	SANDY_CLAY_LOAM	300	0.175	11.02	1000	1.4	0.175	5.2
65	71	WATB	Af48-2ab-3637	1	60	0.03	0.01	0	0	68.27	0.3	0	0.02	1	98	SANDY_CLAY_LOAM	300	0.175	11.02	1000	1.4	0.175	5.2
69	72	WATB	Af48-2ab-3637	1	90	0.03	0.01	0	0	68.27	0.3	0	0.02	1	98	SANDY_CLAY_LOAM	300	0.175	11.02	1000	1.4	0.175	5.2
70	73	WATB	Af48-2ab-3637	1	90	0.03	0.01	0	0	68.27	0.3	0	0.02	1	98	SANDY_CLAY_LOAM	300	0.175	11.02	1000	1.4	0.175	5.2
71	74	FOEB	Af48-2ab-3637	1	100	0.02	0.10	0	0	68.27	0.3	0	0.02	1	77	SANDY_CLAY_LOAM	300	0.175	11.02	1000	1.4	0.175	5.2

Parameters	**Details**
HRU	Hydrological Response Unit Number
LANDUSE	Land use cover simulated in HRU
SOIL	Name of the soil simulated in HRU
HRU_FR	Fraction of total watershed in HRU
SLSUBBSN	Average slope length (m)
HRU_SLP	Average slope steepness (m/m)
OV_N	Manning's 'n' value for overland flow
ESCO	Soil water compensation factor
EPCO	Plant uptake compensation factor
GW_DELAY	Groundwater delays (days)
ALPHA_BF	Baseflow alpha factor (days)
GW_REVAP	Groundwater revap coefficient
REVAPMN	Threshold depth of water in the shallow aquifer for revap to occur (mm)

CN2	Initial SCS runoff curve number for moisture condition II
SOL_Z1	Depth to bottom of first soil layer (mm/mm)
SOL_AWC1	Available water capacity first soil layer (mm/mm)
SOL_K1	Saturated hydraulic conductivity of first soil layer (mm/hr)
SOL_Z2	Depth to bottom of second soil layer (mm/mm)
SOL_AWC2	Available water capacity second soil layer (mm/mm)
SOL_K2	Saturated hydraulic conductivity of second soil layer (mm/hr)

HRU Attribute Input Data in sub basin (Lohit)

SUBBASIN	SUB_KM	SUB_LAT	SUB_ELEV	IRGAGE	ITGAGE	CH_L1	CH_S1	CH_W1	HRUTOT
1	429.84	29.56	5095.43	23	23	45.97	0.02	49.04	1
2	352.10	29.59	4909.18	22	22	38.41	0.01	43.51	1
3	285.07	29.48	4809.49	22	22	26.83	0.00	38.33	1
4	259.16	29.33	4950.27	19	19	30.84	0.03	36.20	1
5	685.43	29.35	4857.54	24	24	55.72	0.04	64.89	1
6	1009.82	29.32	4108.26	17	17	66.64	0.04	81.87	1
7	247.54	29.32	5005.81	18	18	33.84	0.03	35.22	1
8	569.25	29.26	4598.00	21	21	60.38	0.03	58.05	1
9	339.59	29.22	4662.15	20	20	40.46	0.05	42.58	1
10	453.97	29.25	4476.15	18	18	39.19	0.06	50.68	1
11	394.99	29.07	4510.29	19	19	46.36	0.06	46.62	1
12	247.54	29.06	4391.37	21	21	37.95	0.03	35.22	1
13	869.52	28.86	3993.62	14	14	70.91	0.05	74.84	1
14	802.50	28.82	4062.23	15	15	57.93	0.05	71.33	1
15	301.16	28.78	4344.63	16	16	31.33	0.05	39.62	1
16	318.14	28.81	3870.01	14	14	45.25	0.06	40.94	1
17	224.31	28.64	4248.48	12	12	27.00	0.09	33.20	1
18	491.51	28.51	3495.58	9	9	53.14	0.05	53.15	1
19	580.87	28.45	4215.94	12	12	49.66	0.05	58.75	1
20	519.21	28.40	3359.63	6	6	39.58	0.06	54.93	1
21	387.84	28.35	3909.64	8	8	44.37	0.05	46.11	1
22	268.09	28.26	3898.28	8	8	42.25	0.05	36.95	1
23	226.99	28.41	3218.71	6	6	31.24	0.08	33.43	1
24	503.12	28.18	2753.18	6	6	48.71	0.07	53.90	1
25	479.89	28.13	3587.38	8	8	35.34	0.08	52.39	1
26	654.15	28.18	2432.55	5	5	69.02	0.04	63.10	1
27	285.97	28.07	3001.89	4	4	42.42	0.08	38.40	1
28	444.14	28.06	974.24	2	2	49.26	0.06	50.02	1
29	395.89	28.02	665.19	2	2	59.96	0.04	46.68	1
30	394.10	27.87	1905.06	3	3	32.50	0.09	46.55	1
31	309.20	27.94	529.21	2	2	37.92	0.05	40.25	1
32	210.90	27.99	237.81	2	2	30.22	0.04	31.99	1
33	200.18	28.03	282.95	2	2	31.56	0.04	31.01	1
34	404.82	27.81	2809.94	4	4	32.34	0.05	47.31	1
35	464.70	27.76	2983.77	4	4	32.67	0.07	51.39	1
36	252.01	27.73	234.10	1	1	36.68	0.01	35.60	1
37	695.26	27.75	1627.00	3	3	68.86	0.05	65.45	1
38	529.93	27.71	396.92	1	1	52.88	0.03	55.61	1
39	16.98	27.91	127.63	2	2	7.63	0.01	7.06	1
40	101.88	29.46	4796.22	23	23	23.38	0.04	20.67	1
41	403.04	29.09	4335.30	20	20	36.52	0.08	47.18	1
42	101.88	29.38	4756.36	23	23	18.26	0.04	20.67	1
43	35.75	27.86	119.43	2	2	14.64	0.00	11.03	1
44	520.10	29.06	3916.23	18	18	37.14	0.08	54.98	1
45	43.79	28.29	2472.71	6	6	13.30	0.20	12.46	1
46	29.49	29.31	4619.39	19	19	9.29	0.04	9.83	1
47	452.19	28.22	2097.72	6	6	38.24	0.08	50.56	1
48	459.34	29.16	4589.36	19	19	42.25	0.06	51.03	1
49	119.75	28.98	3962.43	16	16	21.32	0.08	22.78	1
50	389.63	28.89	4118.30	16	16	37.69	0.05	46.24	1
51	174.26	28.76	3759.92	16	16	24.32	0.08	28.53	1
52	102.77	29.02	3732.29	13	13	17.31	0.15	20.78	1
53	967.82	28.80	3526.31	13	13	53.11	0.04	79.81	1
54	458.44	28.62	3676.35	12	12	45.09	0.06	50.98	1
55	94.73	28.64	2858.78	11	11	17.87	0.11	19.79	1
56	37.53	28.60	2538.81	11	11	10.79	0.16	11.36	1
57	166.22	28.53	2802.30	11	11	22.04	0.02	27.73	1
58	595.17	28.55	3088.62	10	10	51.38	0.05	59.62	1
59	100.98	28.45	2937.52	8	8	24.00	0.10	20.57	1
60	150.13	28.39	2752.51	7	7	21.03	0.13	26.09	1
61	530.83	28.27	3281.29	7	7	47.08	0.05	55.66	1

SUBBASIN	SUB_KM	SUB_LAT	SUB_ELEV	IRGAGE	ITGAGE	CH_L1	CH_S1	CH_W1	HRUTOT
62	584.45	28.00	2906.62	4	4	31.88	0.03	58.97	1
63	102.77	27.87	2331.90	4	4	14.64	0.17	20.78	1
64	201.96	27.94	2090.12	4	4	20.70	0.14	31.17	1
65	330.65	27.99	1948.73	3	3	35.18	0.08	41.90	1
66	3.57	28.07	1001.25	3	3	2.84	0.24	2.77	1
67	242.18	28.06	1645.01	2	2	29.51	0.10	34.76	1
68	33.96	27.95	1073.29	2	2	8.90	0.16	10.69	1
69	144.77	27.88	639.21	2	2	30.84	0.01	25.53	1
70	51.83	27.85	180.24	2	2	16.14	0.01	13.78	1
71	4.47	27.85	145.60	2	2	2.84	0.02	3.17	1
72	3.57	27.85	138.25	2	2	2.28	0.00	2.77	1
73	40.21	27.85	152.38	2	2	13.14	0.01	11.84	1
74	420.01	27.78	146.44	2	2	46.04	0.00	48.37	1

Parameters	**Details**
SUB_KM	Sub basin area in sq.km.
SUB_LAT	Sub basin latitude
SUB_ELEV	Elevation of the sub basin
IRGAGE	Number of precipitation gauge used in sub basin
ITGAGE	Number of temperature gauge used in sub basin
CH_L1	Longest tributary channel length in sub basin (km)
CH_S1	Average slope of tributary channel (m/m)
CH_W1	Average width of tributary channel (m)
HRUTOT	Total number of HRU modeled in the sub basin

Sub basin within the watershed (Lohit)

GRIDCODE	Subbasin	Area	Slo1	Len1	Sll	Csl	Wid1	Dep1	Lat	Long_	Elev	ElevMin	ElevMax
1	1	42984.49	0	45968.95	0	16.92	49.04	0	29.56	96.96	5095.43	-999999	999999
2	2	35209.75	0	38406.31	0	13.07	43.51	0	29.59	96.74	4909.18	-999999	999999
3	3	28507.38	0	26832.97	0	3.73	38.33	0	29.48	96.65	4809.49	-999999	999999
4	4	25915.80	0	30843.67	0	32.55	36.20	0	29.33	96.93	4950.27	-999999	999999
5	5	68542.83	0	55718.80	0	36.56	64.89	0	29.35	97.14	4857.54	-999999	999999
6	6	100982.27	0	66643.36	0	37.00	81.87	0	29.32	96.29	4108.26	-999999	999999
7	7	24754.06	0	33841.85	0	32.92	35.22	0	29.32	96.70	5005.81	-999999	999999
8	8	56925.40	0	60378.27	0	30.01	58.05	0	29.26	97.36	4598.00	-999999	999999
9	9	33958.64	0	40459.16	0	52.25	42.58	0	29.22	97.07	4662.15	-999999	999999
10	10	45397.34	0	39189.44	0	60.65	50.68	0	29.25	96.56	4476.15	-999999	999999
11	11	39499.26	0	46360.51	0	55.63	46.62	0	29.07	96.92	4510.29	-999999	999999
12	12	24754.06	0	37947.56	0	31.39	35.22	0	29.06	97.49	4391.37	-999999	999999
13	13	86951.99	0	70911.26	0	46.16	74.84	0	28.86	97.04	3993.62	-999999	999999
14	14	80249.63	0	57933.85	0	45.81	71.33	0	28.82	97.23	4062.23	-999999	999999
15	15	30115.95	0	31330.25	0	47.30	39.62	0	28.78	97.62	4344.63	-999999	999999
16	16	31813.88	0	45252.99	0	58.18	40.94	0	28.81	96.90	3870.01	-999999	999999
17	17	22430.58	0	26995.17	0	87.27	33.20	0	28.64	97.58	4248.48	-999999	999999
18	18	49150.66	0	53140.02	0	53.74	53.15	0	28.51	96.59	3495.58	-999999	999999
19	19	58087.15	0	49655.25	0	54.37	58.75	0	28.45	97.36	4215.94	-999999	999999
20	20	51920.97	0	39581.01	0	62.68	54.93	0	28.40	96.73	3359.63	-999999	999999
21	21	38784.34	0	44374.84	0	48.95	46.11	0	28.35	97.25	3909.64	-999999	999999
22	22	26809.45	0	42254.81	0	53.44	36.95	0	28.26	97.20	3898.28	-999999	999999
23	23	22698.67	0	31235.24	0	83.05	33.43	0	28.41	96.47	3218.71	-999999	999999
24	24	50312.41	0	48709.92	0	74.65	53.90	0	28.18	96.72	2753.18	-999999	999999
25	25	47988.92	0	35340.94	0	75.10	52.39	0	28.13	97.16	3587.38	-999999	999999
26	26	65415.06	0	69020.60	0	43.97	63.10	0	28.18	96.32	2432.55	-999999	999999
27	27	28596.75	0	42417.00	0	75.51	38.40	0	28.07	96.81	3001.89	-999999	999999
28	28	44414.33	0	49263.69	0	56.80	50.02	0	28.06	96.13	974.24	-999999	999999
29	29	39588.62	0	59958.87	0	38.51	46.68	0	28.02	95.97	665.19	-999999	999999
30	30	39409.89	0	32504.95	0	93.92	46.55	0	27.87	96.53	1905.06	-999999	999999
31	31	30920.23	0	37919.73	0	45.78	40.25	0	27.94	96.21	529.21	-999999	999999
32	32	21090.10	0	30222.73	0	36.79	31.99	0	27.99	95.91	237.81	-999999	999999
33	33	20017.72	0	31559.62	0	40.02	31.01	0	28.03	95.84	282.95	-999999	999999
34	34	40482.27	0	32342.76	0	54.63	47.31	0	27.81	97.02	2809.94	-999999	999999
35	35	46469.72	0	32667.15	0	68.45	51.39	0	27.76	96.80	2983.77	-999999	999999
36	36	25200.89	0	36677.84	0	10.91	35.60	0	27.73	96.05	234.10	-999999	999999
37	37	69525.85	0	68858.41	0	52.89	65.45	0	27.75	96.48	1627.00	-999999	999999
38	38	52993.35	0	52882.81	0	33.94	55.61	0	27.71	96.23	396.92	-999999	999999
39	39	1697.93	0	7629.82	0	8.13	7.06	0	27.91	95.78	127.63	-999999	999999
40	40	10187.59	0	23376.04	0	44.28	20.67	0	29.46	96.80	4796.22	-999999	999999
41	41	40303.54	0	36515.65	0	78.24	47.18	0	29.09	97.27	4335.30	-999999	999999
42	42	10187.59	0	18257.82	0	40.20	20.67	0	29.38	96.80	4756.36	-999999	999999
43	43	3574.59	0	14638.70	0	3.83	11.03	0	27.86	95.74	119.43	-999999	999999
44	44	52010.34	0	37136.59	0	79.68	54.98	0	29.06	96.56	3916.23	-999999	999999

GRIDCODE	Subbasin	Area	Slo1	Len1	Sll	Csl	Wid1	Dep1	Lat	Long_	Elev	ElevMin	ElevMax
45	45	4378.88	0	13301.80	0	195.31	12.46	0	28.29	96.63	2472.71	-999999	999999
46	46	2949.04	0	9291.10	0	44.67	9.83	0	29.31	96.84	4619.39	-999999	999999
47	47	45218.61	0	38244.11	0	81.53	50.56	0	28.22	96.50	2097.72	-999999	999999
48	48	45933.53	0	42254.81	0	59.52	51.03	0	29.16	96.81	4589.36	-999999	999999
49	49	11974.89	0	21323.19	0	75.04	22.78	0	28.98	97.39	3962.43	-999999	999999
50	50	38963.07	0	37690.35	0	53.25	46.24	0	28.89	97.48	4118.30	-999999	999999
51	51	17426.14	0	24321.37	0	84.45	28.53	0	28.76	97.44	3759.92	-999999	999999
52	52	10276.96	0	17312.49	0	148.45	20.78	0	29.02	96.70	3732.29	-999999	999999
53	53	96782.12	0	53112.19	0	42.59	79.81	0	28.80	96.72	3526.31	-999999	999999
54	54	45844.16	0	45090.80	0	57.86	50.98	0	28.62	97.40	3676.35	-999999	999999
55	55	9472.67	0	17866.26	0	110.10	19.79	0	28.64	97.18	2858.78	-999999	999999
56	56	3753.32	0	10790.20	0	164.87	11.36	0	28.60	97.15	2538.81	-999999	999999
57	57	16621.86	0	22039.14	0	17.42	27.73	0	28.53	97.11	2802.30	-999999	999999
58	58	59516.98	0	51383.72	0	48.28	59.62	0	28.55	96.91	3088.62	-999999	999999
59	59	10098.23	0	23996.99	0	98.97	20.57	0	28.45	97.11	2937.52	-999999	999999
60	60	15013.29	0	21026.63	0	125.98	26.09	0	28.39	96.99	2752.51	-999999	999999
61	61	53082.72	0	47076.47	0	45.22	55.66	0	28.27	96.95	3281.29	-999999	999999
62	62	58444.61	0	31884.01	0	31.30	58.97	0	28.00	97.00	2906.62	-999999	999999
63	63	10276.96	0	14638.70	0	168.80	20.78	0	27.87	96.89	2331.90	-999999	999999
64	64	20196.45	0	20702.24	0	141.53	31.17	0	27.94	96.79	2090.12	-999999	999999
65	65	33064.99	0	35178.75	0	80.42	41.90	0	27.99	96.63	1948.73	-999999	999999
66	66	357.46	0	2835.99	0	235.54	2.77	0	28.07	96.53	1001.25	-999999	999999
67	67	24217.87	0	29506.77	0	96.59	34.76	0	28.06	96.45	1645.01	-999999	999999
68	68	3395.86	0	8899.54	0	156.75	10.69	0	27.95	96.41	1073.29	-999999	999999
69	69	14477.10	0	30843.67	0	14.88	25.53	0	27.88	96.33	639.21	-999999	999999
70	70	5183.16	0	16137.79	0	6.38	13.78	0	27.85	96.13	180.24	-999999	999999
71	71	446.82	0	2835.99	0	22.57	3.17	0	27.85	96.05	145.60	-999999	999999
72	72	357.46	0	2282.23	0	0.00	2.77	0	27.85	96.03	138.25	-999999	999999
73	73	4021.42	0	13139.61	0	6.24	11.84	0	27.85	96.00	152.38	-999999	999999
74	74	42001.48	0	46036.13	0	2.35	48.37	0	27.78	95.87	146.44	-999999	999999

Parameters	**Details**
Slo1	Sub basin slop (%)
Dep1	Sub basin tributary reach depth (m)
Len1	Longest path with in the sub basin (m)
Lat	Latitude
Sil	Field slope length (m)
Long	Longitude
Csl	Sub basin tributary reach slope (%)
Elev	Elevation
Wid1	Sub basin tributary reach width (m)

Sub Basin and HRU wise Calibration Parameter (Sutlej)

OID	HRU	LANDUSE	SOIL	HRU_FR	SLSUBBSN	HRU_SLP	OV_N	ESCO	EPCO	GW_DELAY	ALPHA_BF	GWQMN	GW_REVAP	REVAPMN	CN2	TEXTURE	SOL_Z1	SOL_AWC1	SOL_K1	SOL_Z2	SOL_BD2	SOL_AWC2	SOL_K2
0	1	MIGS	I-B-U-2c-3713	1	30	0.151	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.135	21.3	1000	1.3	0.135	7.5
1	1	BSVG	I-B-U-2c-3713	1	30	0.184	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.135	21.3	1000	1.3	0.135	7.5
2	1	BSVG	Be78-2c-3679	1	30	0.142	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
3	1	BSVG	I-B-U-2c-3713	1	30	0.115	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.135	21.3	1000	1.3	0.135	7.5
4	1	BSVG	Be78-2c-3679	1	30	0.237	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
5	1	BSVG	Be78-2c-3679	1	30	0.309	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
6	1	SHRB	I-B-U-2c-3713	1	30	0.141	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.135	21.3	1000	1.3	0.135	7.5
7	1	BSVG	Be78-2c-3679	1	30	0.337	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
8	1	BSVG	GLACIER-6998	1	30	0.278	0.15	0.7	0	83.7	0.048	100	0.16	250	72	UWB	1524	0.017	99	0	0	0.000	0
9	1	BSVG	Be78-2c-3679	1	30	0.324	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
10	1	MIGS	I-X-2c-3731	1	30	0.098	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
11	1	MIGS	I-B-U-2c-3713	1	30	0.271	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.135	21.3	1000	1.3	0.135	7.5
12	1	MIGS	I-X-2c-3731	1	30	0.094	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
13	1	BSVG	Be78-2c-3679	1	30	0.339	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
14	1	ICES	GLACIER-6998	1	30	0.309	0.01	0.7	0	83.7	0.048	100	0.16	250	82.8	UWB	1524	0.017	99	0	0	0.000	0
15	1	MIGS	I-X-2c-3731	1	30	0.095	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
16	1	SHRB	I-X-2c-3731	1	30	0.124	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
17	1	MIGS	I-X-2c-3731	1	30	0.087	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
18	1	BSVG	Be78-2c-3679	1	30	0.291	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
19	1	SHRB	I-K-U-2c-3723	1	30	0.139	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
20	1	MIGS	I-X-2c-3731	1	30	0.088	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
21	1	BSVG	Be78-2c-3679	1	30	0.357	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
22	1	SHRB	I-Bh-U-c-3717	1	30	0.264	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
23	1	BSVG	GLACIER-6998	1	30	0.319	0.15	0.7	0	83.7	0.048	100	0.16	250	72	UWB	1524	0.017	99	0	0	0.000	0
24	1	GRAS	GLACIER-6998	1	30	0.386	0.15	0.7	0	83.7	0.048	100	0.16	250	75.6	UWB	1524	0.017	99	0	0	0.000	0
25	1	BSVG	I-X-2c-3731	1	30	0.090	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
26	1	MIGS	I-X-2c-3731	1	30	0.113	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
27	1	MIGS	I-Bh-U-c-3717	1	30	0.329	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
28	1	MIGS	I-X-2c-3731	1	30	0.106	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
29	1	CRGR	Bd29-3c-3661	1	30	0.361	0.15	0.7	0	83.7	0.048	100	0.16	250	72.9	CLAY_LOAM	300	0.147	22.3	1000	1.1	0.147	23
30	1	MIGS	I-K-U-2c-3723	1	30	0.111	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
31	1	CRGR	Bd29-3c-3661	1	30	0.282	0.15	0.7	0	83.7	0.048	100	0.16	250	72.9	CLAY_LOAM	300	0.147	22.3	1000	1.1	0.147	23
32	1	MIGS	I-Bh-U-c-3717	1	30	0.343	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
33	1	MIGS	I-Bh-U-c-3717	1	30	0.237	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
34	1	GRAS	Bd29-3c-3661	1	30	0.350	0.15	0.7	0	83.7	0.048	100	0.16	250	71.1	CLAY_LOAM	300	0.147	22.3	1000	1.1	0.147	23
35	1	MIGS	I-Bh-U-c-3717	1	30	0.119	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3

OID	HRU	LANDUSE	SOIL	HRU_FR	SLSUBBSN	HRU_SLP	OV_N	ESCO	EPCO	GW_DELAY	ALPHA_BF	GWQMN	GW_REVAP	REVAPMN	CN2	TEXTURE	SOL_Z1	SOL_AWC1	SOL_K1	SOL_Z2	SOL_BD2	SOL_AWC2	SOL_K2
36	1	MIGS	I-X-2c-3731	1	30	0.196	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
37	1	MIGS	I-Bh-U-c-3717	1	30	0.179	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
38	1	CRIR	Be72-2c-3670	1	30	0.205	0.15	0.7	0	83.7	0.048	100	0.16	250	76.9	LOAM	300	0.188	5.45	1000	1.4	0.188	4.5
39	1	GRAS	I-Bh-U-c-3717	1	30	0.347	0.15	0.7	0	83.7	0.048	100	0.16	250	71.1	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
40	1	MIGS	I-X-2c-3731	1	30	0.118	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
41	1	MIGS	I-X-2c-3731	1	30	0.076	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
42	1	GRAS	I-K-U-2c-3723	1	30	0.094	0.15	0.7	0	83.7	0.048	100	0.16	250	71.1	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
43	1	BSVG	I-Bh-U-c-3717	1	30	0.208	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
44	1	MIGS	I-X-2c-3731	1	30	0.105	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
45	1	MIGS	I-X-2c-3731	1	30	0.165	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
46	1	MIGS	I-Bh-U-c-3717	1	30	0.199	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
47	1	MIGS	I-X-2c-3731	1	30	0.118	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
48	1	SHRB	I-Bh-U-c-3717	1	30	0.116	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
49	1	MIGS	I-X-2c-3731	1	30	0.072	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
50	1	MIGS	I-X-2c-3731	1	30	0.079	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
51	1	SHRB	I-Bh-U-c-3717	1	30	0.108	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
52	1	SHRB	GLACIER-6998	1	30	0.186	0.15	0.7	0	83.7	0.048	100	0.16	250	72	UWB	1524	0.017	99	0	0	0.000	0
53	1	SHRB	GLACIER-6998	1	30	0.183	0.15	0.7	0	83.7	0.048	100	0.16	250	72	UWB	1524	0.017	99	0	0	0.000	0
54	1	GRAS	I-X-2c-3731	1	30	0.113	0.15	0.7	0	83.7	0.048	100	0.16	250	75.6	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
55	1	GRAS	I-X-2c-3731	1	30	0.143	0.15	0.7	0	83.7	0.048	100	0.16	250	75.6	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
56	1	MIGS	I-X-2c-3731	1	30	0.098	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
57	1	MIGS	I-X-2c-3731	1	30	0.104	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
58	1	GRAS	I-X-2c-3731	1	30	0.137	0.15	0.7	0	83.7	0.048	100	0.16	250	75.6	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
59	1	MIGS	I-X-2c-3731	1	30	0.079	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
60	1	BSVG	I-Bh-U-c-3717	1	30	0.125	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
61	1	MIGS	I-X-2c-3731	1	60	0.040	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
62	1	WATB	WATER-6997	1	90	0.029	0.01	0.7	0	83.7	0.048	100	0.16	250	82.8	WATER	25	0.000	99	0	0	0.000	0
63	1	GRAS	I-X-2c-3731	1	30	0.135	0.15	0.7	0	83.7	0.048	100	0.16	250	75.6	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
64	1	MIGS	I-Bh-U-c-3717	1	30	0.053	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
65	1	BSVG	I-Bh-U-c-3717	1	30	0.129	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
66	1	WATB	I-Bh-U-c-3717	1	30	0.099	0.01	0.7	0	83.7	0.048	100	0.16	250	82.8	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
67	1	MIGS	I-X-2c-3731	1	30	0.110	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
68	1	GRAS	I-Bh-U-c-3717	1	30	0.071	0.15	0.7	0	83.7	0.048	100	0.16	250	71.1	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
69	1	GRAS	I-X-2c-3731	1	30	0.088	0.15	0.7	0	83.7	0.048	100	0.16	250	75.6	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
70	1	MIGS	I-X-2c-3731	1	60	0.039	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
71	1	BSVG	I-K-U-2c-3723	1	30	0.081	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
72	1	GRAS	I-X-2c-3731	1	30	0.095	0.15	0.7	0	83.7	0.048	100	0.16	250	75.6	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
73	1	MIGS	I-Bh-U-c-3717	1	60	0.034	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
74	1	BSVG	Be78-2c-3679	1	30	0.193	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
75	1	MIGS	I-X-2c-3731	1	100	0.015	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
76	1	GRAS	I-X-2c-3731	1	100	0.020	0.15	0.7	0	83.7	0.048	100	0.16	250	75.6	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
77	1	MIGS	I-X-2c-3731	1	30	0.108	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9

OID	HRU	LANDUSE	SOIL	HRU _FR	SLSUB BSN	HRU_ SLP	OV_N	ESCO	EPCO	GW_ DELAY	ALPH A_BF	GWQMN	GW_REV AP	REVAPMN	CN2	TEXTURE	SOL_Z1	SOL_ AWC1	SOL_K1	SOL_ Z2	SOL_BD2	SOL_ AWC2	SOL_K2
78	1	MIGS	Be78-2c-3679	1	30	0.313	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
79	1	SHRB	Be78-2c-3679	1	30	0.267	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
80	1	MIGS	I-X-2c-3731	1	120	0.000	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
81	1	MIGS	I-K-U-2c-3723	1	30	0.057	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
82	1	MIGS	I-X-2c-3731	1	60	0.030	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
83	1	MIGS	I-X-2c-3731	1	30	0.148	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
84	1	BSVG	I-X-2c-3731	1	30	0.073	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
85	1	SHRB	Be78-2c-3679	1	30	0.278	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
86	1	MIGS	I-K-U-2c-3723	1	30	0.076	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
87	1	GRAS	I-X-2c-3731	1	30	0.089	0.15	0.7	0	83.7	0.048	100	0.16	250	75.6	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
88	1	BSVG	I-B-U-2c-3713	1	30	0.154	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.135	21.3	1000	1.3	0.135	7.5
89	1	MIGS	I-X-2c-3731	1	30	0.177	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
90	1	ICES	GLACIER-6998	1	30	0.209	0.01	0.7	0	83.7	0.048	100	0.16	250	82.8	UWB	1524	0.017	99	0	0	0.000	0
91	1	MIGS	Be78-2c-3679	1	30	0.147	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
92	1	BSVG	Be78-2c-3679	1	30	0.332	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.156	7.99	1000	1.4	0.156	4.5
93	1	GRAS	I-X-2c-3731	1	30	0.102	0.15	0.7	0	83.7	0.048	100	0.16	250	75.6	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
94	1	BSVG	I-B-U-2c-3713	1	30	0.233	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.135	21.3	1000	1.3	0.135	7.5
95	1	MIGS	I-X-2c-3731	1	30	0.230	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
96	1	WATB	WATER-6997	1	120	0.000	0.01	0.7	0	83.7	0.048	100	0.16	250	82.8	WATER	25	0.000	99	0	0	0.000	0
97	1	WATB	WATER-6997	1	90	0.024	0.01	0.7	0	83.7	0.048	100	0.16	250	82.8	WATER	25	0.000	99	0	0	0.000	0
98	1	BSVG	I-X-2c-3731	1	30	0.142	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
99	1	SHRB	WATER-6997	1	90	0.023	0.15	0.7	0	83.7	0.048	100	0.16	250	72	WATER	25	0.000	99	0	0	0.000	0
100	1	MIGS	I-X-2c-3731	1	30	0.065	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
101	1	BSVG	I-B-U-2c-3713	1	30	0.218	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.135	21.3	1000	1.3	0.135	7.5
102	1	MIGS	I-X-2c-3731	1	30	0.060	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
103	1	MIGS	I-X-2c-3731	1	30	0.086	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
104	1	MIGS	I-B-U-2c-3713	1	30	0.278	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.135	21.3	1000	1.3	0.135	7.5
105	1	MIGS	I-K-U-2c-3723	1	30	0.092	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
106	1	MIGS	I-K-U-2c-3723	1	30	0.068	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
107	1	MIGS	I-Bh-U-c-3717	1	30	0.323	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
109	1	MIGS	I-X-2c-3731	1	30	0.074	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
110	1	MIGS	I-K-U-2c-3723	1	30	0.093	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
111	1	MIGS	I-K-U-2c-3723	1	30	0.093	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
112	1	MIGS	I-K-U-2c-3723	1	30	0.099	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
113	1	MIGS	I-X-2c-3731	1	30	0.097	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
114	1	MIGS	I-K-U-2c-3723	1	30	0.108	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
115	1	MIGS	I-K-U-2c-3723	1	30	0.100	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
116	1	MIGS	I-K-U-2c-3723	1	30	0.070	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
117	1	BSVG	I-K-U-2c-3723	1	30	0.054	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
118	1	BSVG	I-K-U-2c-3723	1	30	0.050	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
119	1	BSVG	I-X-2c-3731	1	120	0.000	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
120	1	BSVG	I-X-2c-3731	1	30	0.063	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
121	1	BSVG	I-X-2c-3731	1	30	0.083	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9

OID	HRU	LANDUSE	SOIL	HRU_FR	SLSUBBSN	HRU_SLP	OV_N	ESCO	EPCO	GW_DELAY	ALPHA_BF	GWQMN	GW_REVAP	REVAPMN	CN2	TEXTURE	SOL_Z1	SOL_AWC1	SOL_K1	SOL_Z2	SOL_BD2	SOL_AWC2	SOL_K2
122	1	MIGS	I-X-2c-3731	1	30	0.122	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
123	1	MIGS	I-K-U-2c-3723	1	30	0.138	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	14.4	1000	1.3	0.111	7.7
124	1	BSVG	I-X-2c-3731	1	30	0.162	0.15	0.7	0	83.7	0.048	100	0.16	250	72	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
125	1	MIGS	I-X-2c-3731	1	30	0.186	0.15	0.7	0	83.7	0.048	100	0.16	250	73.8	LOAM	300	0.123	6.24	1000	1.5	0.123	2.9
126	1	MIGS	I-Bh-U-c-3717	1	30	0.316	0.15	0.7	0	83.7	0.048	100	0.16	250	68.8	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
127	1	SHRB	I-Bh-U-c-3717	1	30	0.384	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
128	1	SHRB	I-Bh-U-c-3717	1	30	0.393	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
129	1	SHRB	I-Bh-U-c-3717	1	30	0.389	0.15	0.7	0	83.7	0.048	100	0.16	250	66.6	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
130	1	GRAS	I-Bh-U-c-3717	1	30	0.333	0.15	0.7	0	83.7	0.048	100	0.16	250	71.1	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
131	1	GRAS	I-Bh-U-c-3717	1	30	0.364	0.15	0.7	0	83.7	0.048	100	0.16	250	71.1	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
132	1	GRAS	I-Bh-U-c-3717	1	30	0.394	0.15	0.7	0	83.7	0.048	100	0.16	250	71.1	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
133	1	GRAS	I-Bh-U-c-3717	1	30	0.431	0.15	0.7	0	83.7	0.048	100	0.16	250	71.1	LOAM	300	0.111	33.9	1000	1.3	0.111	8.3
134	1	GRAS	Bd29-3c-3661	1	30	0.383	0.15	0.7	0	83.7	0.048	100	0.16	250	71.1	CLAY_LOAM	300	0.147	22.3	1000	1.1	0.147	23
135	1	CRDY	Bd29-3c-3661	1	30	0.221	0.15	0.7	0	83.7	0.048	100	0.16	250	72.9	CLAY_LOAM	300	0.147	22.3	1000	1.1	0.147	23
136	1	CRIR	Bd29-3c-3661	1	30	0.273	0.15	0.7	0	83.7	0.048	100	0.16	250	72.9	CLAY_LOAM	300	0.147	22.3	1000	1.1	0.147	23
137	1	CRGR	Bd29-3c-3661	1	30	0.221	0.15	0.7	0	83.7	0.048	100	0.16	250	72.9	CLAY_LOAM	300	0.147	22.3	1000	1.1	0.147	23
138	1	CRIR	Be72-2c-3670	1	30	0.272	0.15	0.7	0	83.7	0.048	100	0.16	250	76.9	LOAM	300	0.188	5.45	1000	1.4	0.188	4.5

Parameters	**Details**
HRU	Hydrological Response Unit Number
LANDUSE	Land use cover simulated in HRU
SOIL	Name of the soil simulated in HRU
HRU_FR	Fraction of total watershed in HRU
SLSUBBSN	Average slope length (m)
HRU_SLP	Average slope steepness (m/m)
OV_N	Manning’s ‘n’ value for overland flow
ESCO	Soil water compensation factor
EPCO	Plant uptake compensation factor
GW_DELAY	Groundwater delays (days)
ALPHA_BF	Baseflow alpha factor (days)
GW_REVAP	Groundwater revap coefficient
REVAPMN	Threshold depth of water in the shallow aquifer for revap to occur (mm)
CN2	Initial SCS runoff curve number for moisture condition II
SOL_Z1	Depth to bottom of first soil layer (mm/mm)
SOL_AWC1	Available water capacity first soil layer (mm/mm)
SOL_K1	Saturated hydraulic conductivity of first soil layer (mm/hr)
SOL_Z2	Depth to bottom of second soil layer (mm/mm)
SOL_AWC2	Available water capacity second soil layer (mm/mm)
SOL_K2	Saturated hydraulic conductivity of second soil layer (mm/hr)

HRU Attribute Input Data in sub basin (Sutlej)

SUBBASIN	SUB_KM	SUB_LAT	SUB_ELEV	IRGAGE	ITGAGE	CH_L1	CH_S1	CH_W1	HRUTOT
1	1080.070	32.992	5180.631	35	35	63.911	0.015	85.243	1
2	274.428	32.946	5252.854	34	34	32.641	0.026	37.467	1
3	532.194	32.765	5177.541	24	24	38.751	0.021	55.748	1
4	487.110	32.783	4901.338	35	35	35.441	0.045	52.865	1
5	750.757	32.563	5329.725	24	24	58.932	0.022	68.531	1
6	644.906	32.471	4920.386	33	33	56.132	0.025	62.559	1
7	1036.946	32.365	5131.357	23	23	56.782	0.015	83.185	1
8	291.090	32.287	5144.172	33	33	31.481	0.051	38.816	1
9	1038.906	32.309	5110.656	32	32	62.142	0.043	83.279	1
10	215.622	32.194	5018.109	31	31	28.681	0.079	32.419	1
11	561.597	32.257	4847.548	23	23	56.711	0.018	57.576	1
12	392.040	32.212	5133.838	22	22	32.881	0.065	46.407	1
13	463.587	32.140	4692.025	20	20	62.892	0.023	51.318	1
14	223.463	32.173	4860.465	32	32	30.831	0.082	33.122	1
15	530.234	32.022	4980.837	31	31	34.621	0.028	55.625	1
16	769.379	32.018	4754.448	21	21	65.791	0.024	69.546	1
17	714.493	32.050	5045.623	19	19	49.371	0.026	66.526	1
18	468.488	32.017	4490.042	20	20	58.182	0.030	51.643	1
19	535.135	31.886	4775.495	31	31	40.391	0.030	55.933	1
20	378.319	31.864	4719.754	19	19	41.211	0.040	45.426	1
21	479.269	31.886	4707.045	21	21	51.012	0.031	52.352	1
22	569.438	31.836	4516.735	32	32	44.662	0.057	58.057	1
23	437.125	31.867	4824.803	19	19	31.001	0.093	49.540	1
24	452.806	31.743	4476.201	28	28	47.151	0.056	50.598	1
25	376.358	31.686	4200.448	28	28	38.581	0.087	45.285	1
26	333.234	31.740	4500.976	18	18	47.052	0.033	42.096	1
27	246.005	31.699	4634.590	18	18	26.701	0.046	35.088	1
28	380.279	31.604	4831.387	29	29	42.201	0.063	45.567	1
29	352.836	31.570	4553.161	14	14	38.411	0.042	43.565	1
30	244.045	31.519	2463.880	27	27	34.621	0.109	34.920	1
31	247.965	31.481	4670.549	14	14	34.381	0.036	35.255	1
32	311.672	31.464	2106.494	27	27	27.931	0.078	40.440	1
33	733.115	31.456	4760.461	29	29	46.161	0.066	67.561	1
34	959.518	31.490	4791.521	30	30	60.332	0.028	79.400	1
35	223.463	31.396	2519.518	28	28	32.811	0.117	33.122	1
36	257.766	31.316	4684.954	12	12	38.751	0.047	36.085	1
37	554.737	31.415	4862.809	12	12	70.613	0.027	57.153	1
38	412.622	31.323	4884.881	12	12	47.321	0.040	47.854	1
39	250.906	31.362	1755.105	26	26	30.661	0.060	35.506	1
40	948.737	31.340	4545.860	29	29	71.292	0.039	78.864	1
41	394.980	31.279	5010.494	8	8	54.562	0.020	46.616	1
42	294.030	31.240	4490.477	5	5	41.791	0.030	39.050	1
43	439.085	31.231	4789.359	9	9	33.801	0.028	49.673	1
44	262.667	31.108	5304.881	5	5	32.571	0.047	36.495	1
45	328.334	31.147	4714.854	6	6	45.001	0.039	41.723	1
46	237.184	31.189	5236.347	9	9	38.821	0.025	34.327	1
47	477.309	31.107	5541.526	5	5	38.751	0.044	52.224	1
48	216.602	31.257	5278.452	9	9	41.282	0.025	32.508	1
49	332.254	31.042	4693.664	6	6	42.781	0.028	42.022	1
50	357.737	31.015	4581.153	7	7	39.401	0.027	43.927	1
51	232.284	30.969	4824.996	9	9	33.631	0.006	33.900	1
52	369.498	30.975	4729.708	6	6	51.351	0.020	44.787	1
53	263.647	31.075	5323.364	10	10	43.771	0.023	36.577	1
54	228.363	31.039	5393.966	10	10	37.491	0.029	33.556	1
55	204.841	31.036	5083.651	10	10	36.091	0.026	31.437	1
56	301.871	30.967	5302.039	10	10	28.271	0.028	39.672	1
57	652.747	30.835	4838.670	1	1	67.022	0.016	63.014	1
58	600.801	30.920	4999.347	4	4	51.691	0.013	59.955	1
59	274.428	30.906	5282.368	4	4	25.471	0.025	37.467	1
60	400.861	30.756	4907.824	1	1	48.891	0.026	47.031	1
61	204.841	30.654	5022.029	2	2	41.381	0.020	31.437	1
62	739.976	30.786	4692.409	3	3	43.841	0.003	67.939	1
63	302.851	30.640	4701.285	4	4	30.421	0.021	39.749	1
64	213.662	30.805	5194.583	4	4	30.831	0.023	32.242	1
65	414.582	30.702	4760.466	3	3	41.791	0.005	47.991	1

SUBBASIN	SUB_KM	SUB_LAT	SUB_ELEV	IRGAGE	ITGAGE	CH_L1	CH_S1	CH_W1	HRUTOT
66	379.299	30.629	5069.127	2	2	56.061	0.014	45.497	1
67	393.020	30.563	4989.716	4	4	44.591	0.024	46.477	1
68	1195.722	30.661	5158.740	4	4	68.832	0.009	90.608	1
69	331.274	30.520	4919.728	4	4	46.062	0.010	41.947	1
70	1027.145	30.540	5077.791	4	4	87.372	0.010	82.712	1
71	175.438	30.814	4732.793	2	2	35.951	0.016	28.646	1
72	90.169	31.575	4025.761	18	18	21.511	0.028	19.214	1
73	173.478	30.800	4979.147	4	4	23.731	0.014	28.454	1
74	55.866	30.760	4704.105	4	4	15.571	0.011	14.417	1
75	271.488	32.771	5118.794	24	24	25.471	0.024	37.225	1
76	18.622	30.942	4676.421	4	4	8.160	0.003	7.458	1
77	64.687	30.913	4718.909	4	4	19.531	0.043	15.743	1
78	295.990	31.319	4350.070	13	13	48.551	0.039	39.206	1
79	111.731	32.065	4451.719	31	31	17.721	0.112	21.852	1
80	257.766	32.362	4689.061	33	33	32.061	0.054	36.085	1
81	0.980	30.887	4616.000	2	2	1.400	0.000	1.275	1
82	169.557	30.927	4711.439	2	2	16.900	0.018	28.066	1
83	56.846	32.174	4562.759	19	19	13.930	0.022	14.568	1
84	258.746	32.080	4569.674	20	20	21.850	0.032	36.167	1
85	572.378	31.694	4226.337	17	17	46.981	0.023	58.237	1
86	429.284	32.246	4676.121	31	31	52.002	0.039	49.005	1
87	137.214	31.001	4695.621	8	8	20.931	0.010	24.719	1
88	287.169	30.692	4941.348	4	4	44.591	0.021	38.501	1
89	115.652	32.728	4882.034	24	24	16.900	0.000	22.309	1
90	185.239	31.934	4411.032	20	20	29.501	0.037	29.596	1
91	278.348	32.597	5203.549	24	24	37.831	0.040	37.787	1
92	5.881	32.107	3829.000	31	31	3.960	0.117	3.735	1
93	789.961	32.047	4577.830	32	32	59.342	0.030	70.657	1
94	80.368	30.809	4889.732	4	4	28.751	0.032	17.932	1
95	1713.215	32.421	4913.280	22	22	91.813	0.019	112.429	1
96	80.368	31.809	4259.402	17	17	14.751	0.016	17.932	1
97	0.980	30.699	4658.000	4	4	1.400	0.000	1.275	1
98	189.159	30.769	4700.363	4	4	34.521	0.030	29.970	1
99	123.493	31.709	4039.587	17	17	21.681	0.045	23.205	1
100	145.055	30.747	4687.318	4	4	25.781	0.000	25.557	1
101	160.736	30.813	4808.652	4	4	21.101	0.006	27.181	1
102	4.901	32.050	3574.800	32	32	2.970	0.152	3.348	1
103	149.955	30.874	4783.719	4	4	20.280	0.000	26.072	1
104	823.284	31.008	4829.820	9	9	45.411	0.014	72.430	1
105	353.816	32.077	4950.781	22	22	35.271	0.074	43.637	1
106	2.940	31.079	4553.000	9	9	3.380	0.078	2.464	1
107	181.319	31.091	4588.551	8	8	19.701	0.009	29.218	1
108	581.199	31.926	4408.363	32	32	32.471	0.037	58.774	1
109	288.149	31.153	4771.303	8	8	36.671	0.023	38.580	1
110	173.478	31.040	4591.593	8	8	19.870	0.021	28.454	1
111	449.866	31.140	4671.612	7	7	35.851	0.024	50.401	1
112	98.990	31.215	4686.228	7	7	22.091	0.067	20.321	1
113	27.443	31.196	4359.429	7	7	9.560	0.007	9.411	1
114	394.000	31.259	4530.102	14	14	41.282	0.041	46.547	1
115	300.891	31.366	4438.264	14	14	39.641	0.031	39.595	1
116	73.508	31.428	4230.973	14	14	18.711	0.039	16.998	1
117	16.662	31.459	3973.294	14	14	7.170	0.012	6.976	1
118	48.025	31.468	3985.327	13	13	11.300	0.000	13.166	1
119	8.821	31.497	3903.000	13	13	4.780	0.000	4.763	1
120	535.135	31.445	4175.319	13	13	28.851	0.012	55.933	1
121	66.647	31.451	4114.897	13	13	18.711	0.032	16.027	1
122	224.443	31.501	4280.061	12	12	30.901	0.054	33.209	1
123	43.124	31.603	3967.000	17	17	8.980	0.031	12.343	1
124	54.886	31.636	4038.214	17	17	14.100	0.036	14.265	1
125	545.916	31.697	4364.433	16	16	41.621	0.013	56.606	1
126	366.557	31.667	4454.043	30	30	39.641	0.050	44.573	1
127	312.652	31.806	4429.122	32	32	32.641	0.077	40.516	1
128	290.110	31.728	4317.824	29	29	27.691	0.098	38.737	1
129	51.945	31.689	3384.774	29	29	11.950	0.109	13.801	1
130	50.965	31.681	3561.750	29	29	13.350	0.166	13.644	1
131	41.164	31.610	3253.524	29	29	9.730	0.239	12.003	1
132	490.050	31.577	3812.550	29	29	36.431	0.022	53.056	1
133	257.766	31.519	3472.452	28	28	26.051	0.105	36.085	1

SUBBASIN	SUB_KM	SUB_LAT	SUB_ELEV	IRGAGE	ITGAGE	CH_L1	CH_S1	CH_W1	HRUTOT
134	1107.513	31.560	3012.145	15	15	63.712	0.064	86.536	1
135	21.562	31.392	1287.955	27	27	7.750	0.110	8.143	1
136	389.100	31.331	1855.028	27	27	42.611	0.057	46.198	1
137	916.394	31.265	1624.394	26	26	44.591	0.015	77.239	1
138	136.234	31.334	1251.619	26	26	26.701	0.013	24.613	1

Parameters	**Details**
SUB_KM	Sub basin area in sq.km.
SUB_LAT	Sub basin latitude
SUB_ELEV	Elevation of the sub basin
IRGAGE	Number of precipitation gauge used in sub basin
ITGAGE	Number of temperature gauge used in sub basin
CH_L1	Longest tributary channel length in sub basin (km)
CH_S1	Average slope of tributary channel (m/m)
CH_W1	Average width of tributary channel (m)
HRUTOT	Total number of HRU modeled in the sub basin

Sub basin within the watershed (Sutlej)

GRIDCODE	Subbasin	Area	Slo1	Len1	Sll	Csl	Wid1	Dep1	Lat	Long_	Elev	ElevMin	ElevMax
1	1	108007.02	0	63910.79	0	14.93	85.24	0	32.99	78.28	5180.63	-999999	999999
2	2	27442.8	0	32640.86	0	25.92	37.47	0	32.95	78.08	5252.85	-999999	999999
3	3	53219.43	0	38750.71	0	21.16	55.75	0	32.77	78.04	5177.54	-999999	999999
4	4	48710.97	0	35441.00	0	45.34	52.86	0	32.78	78.54	4901.34	-999999	999999
5	5	75075.66	0	58931.64	0	22.40	68.53	0	32.56	78.17	5329.72	-999999	999999
6	6	64490.58	0	56131.50	0	25.40	62.56	0	32.47	77.81	4920.39	-999999	999999
7	7	103694.58	0	56781.79	0	15.13	83.18	0	32.37	79.23	5131.36	-999999	999999
8	8	29108.97	0	31481.00	0	50.92	38.82	0	32.29	77.82	5144.17	-999999	999999
9	9	103890.6	0	62141.86	0	43.01	83.28	0	32.31	78.32	5110.66	-999999	999999
10	10	21562.2	0	28680.86	0	78.83	32.42	0	32.19	77.92	5018.11	-999999	999999
11	11	56159.73	0	56711.43	0	18.09	57.58	0	32.26	79.40	4847.55	-999999	999999
12	12	39204	0	32881.07	0	64.84	46.41	0	32.21	78.90	5133.84	-999999	999999
13	13	46358.73	0	62891.64	0	22.98	51.32	0	32.14	79.48	4692.03	-999999	999999
14	14	22346.28	0	30830.71	0	81.93	33.12	0	32.17	78.53	4860.46	-999999	999999
15	15	53023.41	0	34620.86	0	27.87	55.63	0	32.02	77.91	4980.84	-999999	999999
16	16	76937.85	0	65791.29	0	24.08	69.55	0	32.02	79.65	4754.45	-999999	999999
17	17	71449.29	0	49371.36	0	26.21	66.53	0	32.05	79.03	5045.62	-999999	999999
18	18	46848.78	0	58181.86	0	29.58	51.64	0	32.02	79.50	4490.04	-999999	999999
19	19	53513.46	0	40391.00	0	29.98	55.93	0	31.89	78.03	4775.49	-999999	999999
20	20	37831.86	0	41211.14	0	39.72	45.43	0	31.86	79.17	4719.75	-999999	999999
21	21	47926.89	0	51011.64	0	31.46	52.35	0	31.89	79.73	4707.04	-999999	999999
22	22	56943.81	0	44661.57	0	56.60	58.06	0	31.84	78.36	4516.73	-999999	999999
23	23	43712.46	0	31000.57	0	93.06	49.54	0	31.87	78.92	4824.80	-999999	999999
24	24	45280.62	0	47151.14	0	55.86	50.60	0	31.74	78.24	4476.20	-999999	999999
25	25	37635.84	0	38580.86	0	86.86	45.28	0	31.69	78.02	4200.45	-999999	999999
26	26	33323.4	0	47051.64	0	33.13	42.10	0	31.74	79.76	4500.98	-999999	999999
27	27	24600.51	0	26700.86	0	46.07	35.09	0	31.70	79.87	4634.59	-999999	999999
28	28	38027.88	0	42201.14	0	62.56	45.57	0	31.60	78.67	4831.39	-999999	999999
29	29	35283.6	0	38411.00	0	42.49	43.56	0	31.57	79.93	4553.16	-999999	999999
30	30	24404.49	0	34620.86	0	108.89	34.92	0	31.52	77.56	2463.88	-999999	999999
31	31	24796.53	0	34380.64	0	36.07	35.26	0	31.48	80.04	4670.55	-999999	999999
32	32	31167.18	0	27931.07	0	78.44	40.44	0	31.46	77.39	2106.49	-999999	999999
33	33	73311.48	0	46161.14	0	65.79	67.56	0	31.46	78.58	4760.46	-999999	999999
34	34	95951.79	0	60331.71	0	28.41	79.40	0	31.49	78.96	4791.52	-999999	999999
35	35	22346.28	0	32810.71	0	116.97	33.12	0	31.40	77.77	2519.52	-999999	999999
36	36	25776.63	0	38750.71	0	47.07	36.08	0	31.32	79.53	4684.95	-999999	999999
37	37	55473.66	0	70612.64	0	27.09	57.15	0	31.41	79.29	4862.81	-999999	999999
38	38	41262.21	0	47321.00	0	39.96	47.85	0	31.32	79.42	4884.88	-999999	999999
39	39	25090.56	0	30660.86	0	59.78	35.51	0	31.36	77.09	1755.11	-999999	999999
40	40	94873.68	0	71292.07	0	38.81	78.86	0	31.34	78.46	4545.86	-999999	999999
41	41	39498.03	0	54561.57	0	20.49	46.62	0	31.28	80.50	5010.49	-999999	999999
42	42	29403	0	41791.07	0	30.01	39.05	0	31.24	79.84	4490.48	-999999	999999
43	43	43908.48	0	33800.71	0	28.25	49.67	0	31.23	80.77	4789.36	-999999	999999
44	44	26266.68	0	32570.50	0	46.82	36.49	0	31.11	79.70	5304.88	-999999	999999
45	45	32833.35	0	45001.29	0	39.11	41.72	0	31.15	79.89	4714.85	-999999	999999

GRIDCODE	Subbasin	Area	Slo1	Len1	Sll	Csl	Wid1	Dep1	Lat	Long_	Elev	ElevMin	ElevMax
46	46	23718.42	0	38821.07	0	25.24	34.33	0	31.19	81.01	5236.35	-999999	999999
47	47	47730.87	0	38750.71	0	43.92	52.22	0	31.11	79.56	5541.53	-999999	999999
48	48	21660.21	0	41281.50	0	25.44	32.51	0	31.26	80.94	5278.45	-999999	999999
49	49	33225.39	0	42781.07	0	28.47	42.02	0	31.04	79.98	4693.66	-999999	999999
50	50	35773.65	0	39401.00	0	26.83	43.93	0	31.02	80.19	4581.15	-999999	999999
51	51	23228.37	0	33630.86	0	6.36	33.90	0	30.97	80.80	4825.00	-999999	999999
52	52	36949.77	0	51351.36	0	20.27	44.79	0	30.97	80.09	4729.71	-999999	999999
53	53	26364.69	0	43771.07	0	22.91	36.58	0	31.07	81.30	5323.36	-999999	999999
54	54	22836.33	0	37491.36	0	29.02	33.56	0	31.04	81.40	5393.97	-999999	999999
55	55	20484.09	0	36091.29	0	26.18	31.44	0	31.04	81.18	5083.65	-999999	999999
56	56	30187.08	0	28270.79	0	27.66	39.67	0	30.97	81.66	5302.04	-999999	999999
57	57	65274.66	0	67021.50	0	15.74	63.01	0	30.83	80.31	4838.67	-999999	999999
58	58	60080.13	0	51691.07	0	12.57	59.96	0	30.92	81.46	4999.35	-999999	999999
59	59	27442.8	0	25470.64	0	24.81	37.47	0	30.91	81.82	5282.37	-999999	999999
60	60	40086.09	0	48890.93	0	26.06	47.03	0	30.76	80.41	4907.82	-999999	999999
61	61	20484.09	0	41381.00	0	19.53	31.44	0	30.65	80.46	5022.03	-999999	999999
62	62	73997.55	0	43841.43	0	2.76	67.94	0	30.79	80.79	4692.41	-999999	999999
63	63	30285.09	0	30420.64	0	21.33	39.75	0	30.64	81.25	4701.28	-999999	999999
64	64	21366.18	0	30830.71	0	23.45	32.24	0	30.80	81.92	5194.58	-999999	999999
65	65	41458.23	0	41791.07	0	4.88	47.99	0	30.70	81.05	4760.47	-999999	999999
66	66	37929.87	0	56061.14	0	14.22	45.50	0	30.63	80.57	5069.13	-999999	999999
67	67	39302.01	0	44591.21	0	24.00	46.48	0	30.56	81.42	4989.72	-999999	999999
68	68	119572.2	0	68831.64	0	9.12	90.61	0	30.66	82.12	5158.74	-999999	999999
69	69	33127.38	0	46061.64	0	10.01	41.95	0	30.52	81.55	4919.73	-999999	999999
70	70	102714.48	0	87372.29	0	10.17	82.71	0	30.54	81.78	5077.79	-999999	999999
71	71	17543.79	0	35950.57	0	16.30	28.65	0	30.81	80.52	4732.79	-999999	999999
72	72	9016.92	0	21510.64	0	28.45	19.21	0	31.57	79.76	4025.76	-999999	999999
73	73	17347.77	0	23730.86	0	13.95	28.45	0	30.80	81.70	4979.15	-999999	999999
74	74	5586.57	0	15570.64	0	11.17	14.42	0	30.76	81.20	4704.11	-999999	999999
75	75	27148.77	0	25470.64	0	23.79	37.23	0	32.77	78.21	5118.79	-999999	999999
76	76	1862.19	0	8160.21	0	3.31	7.46	0	30.94	81.13	4676.42	-999999	999999
77	77	6468.66	0	19530.64	0	43.01	15.74	0	30.91	81.26	4718.91	-999999	999999
78	78	29599.02	0	48551.21	0	38.60	39.21	0	31.32	79.78	4350.07	-999999	999999
79	79	11173.14	0	17720.50	0	111.85	21.85	0	32.07	78.11	4451.72	-999999	999999
80	80	25776.63	0	32060.93	0	53.59	36.08	0	32.36	78.02	4689.06	-999999	999999
81	81	98.01	0	1400.07	0	0.00	1.27	0	30.89	80.60	4616.00	-999999	999999
82	82	16955.73	0	16900.36	0	18.11	28.07	0	30.93	80.64	4711.44	-999999	999999
83	83	5684.58	0	13930.36	0	21.54	14.57	0	32.17	79.18	4562.76	-999999	999999
84	84	25874.64	0	21850.36	0	32.31	36.17	0	32.08	79.26	4569.67	-999999	999999
85	85	57237.84	0	46981.29	0	22.75	58.24	0	31.69	79.54	4226.34	-999999	999999
86	86	42928.38	0	52001.64	0	39.33	49.00	0	32.25	78.10	4676.12	-999999	999999
87	87	13721.4	0	20930.71	0	10.22	24.72	0	31.00	80.60	4695.62	-999999	999999
88	88	28716.93	0	44591.21	0	21.44	38.50	0	30.69	81.77	4941.35	-999999	999999
89	89	11565.18	0	16900.36	0	0.00	22.31	0	32.73	78.35	4882.03	-999999	999999
90	90	18523.89	0	29501.00	0	36.68	29.60	0	31.93	79.28	4411.03	-999999	999999
91	91	27834.84	0	37831.07	0	40.10	37.79	0	32.60	78.42	5203.55	-999999	999999
92	92	588.06	0	3960.00	0	116.67	3.73	0	32.11	78.18	3829.00	-999999	999999
93	93	78996.06	0	59341.71	0	29.78	70.66	0	32.05	78.36	4577.83	-999999	999999
94	94	8036.82	0	28751.21	0	32.28	17.93	0	30.81	81.60	4889.73	-999999	999999
95	95	171321.48	0	91812.71	0	18.96	112.43	0	32.42	78.65	4913.28	-999999	999999
96	96	8036.82	0	14750.50	0	16.20	17.93	0	31.81	79.36	4259.40	-999999	999999
97	97	98.01	0	1400.07	0	0.00	1.27	0	30.70	81.46	4658.00	-999999	999999
98	98	18915.93	0	34521.36	0	30.21	29.97	0	30.77	81.48	4700.36	-999999	999999
99	99	12349.26	0	21680.50	0	45.11	23.20	0	31.71	79.35	4039.59	-999999	999999
100	100	14505.48	0	25781.21	0	0.00	25.56	0	30.75	81.34	4687.32	-999999	999999
101	101	16073.64	0	21100.57	0	6.26	27.18	0	30.81	81.20	4808.65	-999999	999999
102	102	490.05	0	2970.00	0	152.19	3.35	0	32.05	78.59	3574.80	-999999	999999
103	103	14995.53	0	20280.43	0	0.00	26.07	0	30.87	81.16	4783.72	-999999	999999
104	104	82328.4	0	45411.36	0	14.40	72.43	0	31.01	81.00	4829.82	-999999	999999
105	105	35381.61	0	35271.14	0	74.11	43.64	0	32.08	78.74	4950.78	-999999	999999
106	106	294.03	0	3380.07	0	77.81	2.46	0	31.08	80.83	4553.00	-999999	999999
107	107	18131.85	0	19700.50	0	8.68	29.22	0	31.09	80.73	4588.55	-999999	999999
108	108	58119.93	0	32471.00	0	36.86	58.77	0	31.93	78.60	4408.36	-999999	999999
109	109	28814.94	0	36671.21	0	22.74	38.58	0	31.15	80.56	4771.30	-999999	999999
110	110	17347.77	0	19870.36	0	20.89	28.45	0	31.04	80.47	4591.59	-999999	999999
111	111	44986.59	0	35851.07	0	23.96	50.40	0	31.14	80.35	4671.61	-999999	999999
112	112	9899.01	0	22090.57	0	66.59	20.32	0	31.22	80.24	4686.23	-999999	999999

GRIDCODE	Subbasin	Area	Slo1	Len1	Sll	Csl	Wid1	Dep1	Lat	Long_	Elev	ElevMin	ElevMax
113	113	2744.28	0	9560.29	0	7.22	9.41	0	31.20	80.16	4359.43	-999999	999999
114	114	39400.02	0	41281.50	0	40.94	46.55	0	31.26	80.12	4530.10	-999999	999999
115	115	30089.07	0	39641.21	0	31.33	39.59	0	31.37	80.06	4438.26	-999999	999999
116	116	7350.75	0	18710.50	0	38.53	17.00	0	31.43	79.96	4230.97	-999999	999999
117	117	1666.17	0	7170.21	0	11.99	6.98	0	31.46	79.88	3973.29	-999999	999999
118	118	4802.49	0	11300.07	0	0.00	13.17	0	31.47	79.82	3985.33	-999999	999999
119	119	882.09	0	4780.14	0	0.00	4.76	0	31.50	79.76	3903.00	-999999	999999
120	120	53513.46	0	28850.71	0	11.51	55.93	0	31.45	79.67	4175.32	-999999	999999
121	121	6664.68	0	18710.50	0	32.44	16.03	0	31.45	79.58	4114.90	-999999	999999
122	122	22444.29	0	30901.07	0	53.66	33.21	0	31.50	79.42	4280.06	-999999	999999
123	123	4312.44	0	8980.36	0	31.29	12.34	0	31.60	79.41	3967.00	-999999	999999
124	124	5488.56	0	14100.21	0	36.45	14.26	0	31.64	79.35	4038.21	-999999	999999
125	125	54591.57	0	41621.21	0	12.78	56.61	0	31.70	79.16	4364.43	-999999	999999
126	126	36655.74	0	39641.21	0	49.52	44.57	0	31.67	78.90	4454.04	-999999	999999
127	127	31265.19	0	32640.86	0	76.71	40.52	0	31.81	78.76	4429.12	-999999	999999
128	128	29010.96	0	27690.86	0	97.79	38.74	0	31.73	78.64	4317.82	-999999	999999
129	129	5194.53	0	11950.36	0	108.95	13.80	0	31.69	78.52	3384.77	-999999	999999
130	130	5096.52	0	13350.43	0	165.54	13.64	0	31.68	78.44	3561.75	-999999	999999
131	131	4116.42	0	9730.14	0	239.26	12.00	0	31.61	78.45	3253.52	-999999	999999
132	132	49005	0	36431.00	0	22.43	53.06	0	31.58	78.28	3812.55	-999999	999999
133	133	25776.63	0	26050.57	0	105.45	36.08	0	31.52	78.11	3472.45	-999999	999999
134	134	110751.3	0	63711.79	0	63.58	86.54	0	31.56	77.82	3012.15	-999999	999999
135	135	2156.22	0	7750.14	0	109.80	8.14	0	31.39	77.61	1287.95	-999999	999999
136	136	38909.97	0	42611.21	0	56.79	46.20	0	31.33	77.53	1855.03	-999999	999999
137	137	91639.35	0	44591.21	0	15.05	77.24	0	31.26	77.23	1624.39	-999999	999999
138	138	13623.39	0	26700.86	0	12.58	24.61	0	31.33	76.96	1251.62	-999999	999999

Parameters	**Details**
Slo1	Sub basin slop (%)
Dep1	Sub basin tributary reach depth (m)
Len1	Longest path with in the sub basin (m)
Lat	Latitude
Sil	Field slope length (m)
Long	Longitude
Csl	Sub basin tributary reach slope (%)
Elev	Elevation
Wid1	Sub basin tributary reach width (m)