A Major Project Report on

Development of Physiographic Parameters and Design Flood Estimation of DOIMUKH Hydro Electric Project Using Remote Sensing & GIS

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IN

CIVIL ENGINEERING

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HYDRAULICS AND WATER RESOURCES ENGINEERING

BY

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Certificate

This is to certify that the project report entitled "**Development of Physiographic Parameters and Design Flood Estimation of DOIMUKH Hydro Electric Project Using Remote Sensing & GIS**" is a bona fide record of work carried out by Kailash Chandra Singh (2K15/HFE/17) under my guidance and supervision, during the session 2015-17 in partial fulfilment of the requirement for the degree of Master of Technology (Hydraulics and Water Resource Engineering) from Delhi Technological university, Delhi. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university/Institute for the award of any Degree or Diploma.

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Kailash Chandra Singh

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ABSTRACT

The most widely used method for the estimation of flood hydrograph which is derived from a known storm in a catchment area uses historical rainfall-runoff data and unit hydrographs developed from them. These techniques are highly unreliable because of the physical and climatic changes in the catchment and their uses to ungauged catchments. These drawbacks can be overcome by use of the synthetic unit hydrograph (SUH), which is a physically based rainfall-runoff estimation method. The physiographic parameters of the Doimukh basin were estimated from 30 m ASTER (Advanced Space Borne Thermal Emission and Reflection Radiometer Sensor) DEM and using ARC-GIS 10.2, 3DEM, and GeoHMS Software. The aim of this study was to estimate the development of Physiographic Parameters for River Dicrang with special reference to DOIMUKH Hydro Electric Project's watershed, of the site situated at Itanagar , Arunachal Pradesh. This Report provides an overview of estimation of physiographic parameter, the Development of Synthetic Unit Hydrograph (SUH) & subsequently Design flood of the project. The same result has been compare with different method of convention approach i.e flood frequency analysis. The flood frequency method is based on statistical approach in which the past year data has been used for calculate the design flood for different return period. The return period is depending on the importance of the structure, their storage and economy of the structure.

Keyword;- Geomorphologic parameter, Geographic information System(GIS), Remote sensing , Digital elevation Model (DEM), Synthetic Unit hydrograph (SUH),Standard Project Flood (SPF),Annual Peak Discharge, Return Period, , Flood Frequency Analysis

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CHAPTER -1

1 INTRODUCTION

1.1 General

Flood evaluation play vital role in planning of Hydro Power Projects (HEP), including the disaster management plan for floods. Hydrology of any catchment is depend upon a no. of factor like; climatic factor, edaphic factor, land use pattern and topography of that area. These factors vary with the time. These physical variation caused by human interference as well as natural change in environment. It is not feasible to estimate all these parameters regularly at many locations at different time interval over a long period of the entire catchment. It is also not economical as well as cumbersome process for an ungauged catchment. To overcome this, many researchers are trying to correlate the relationship between runoff discharges to geomorphology of the basin. Geomorphology of a river gives the idea of natural features of that catchment, and its connection of hydrology of the catchment basin. Geomorphology depicts the geometric as well topographic feature of the catchment & its stream network. Hydrologic processes such as rainfall, runoff & their application in flood routing etc. are controlled by it.

Previous works have helped to understanding the catchment geomorphology-hydrology connection by empirical relationships (Snyder, 1938; Horton, 1945; Taylor and Schwartz, 1952; Jain and Sinha, 2003; etc.). Snyder (1938) illustrate the synthetic unit hydrograph approach (SUH) for ungauged basin as a function of basin area& its shape, catchment topography, streams slope & density; and derived the basin coefficient by taking average of other parameters. Conventionally these parameters were obtained through Survey of India topo sheets by manually developing catchment area and river tracings. Understanding of basin geomorphology-hydrology association can also be obtained through empirical relationships.

Mainly three models are used to derive the Synthetic Unit Hydrograph. It is categorized in following criteria: 1) model based on watershed storage (e.g., Nash, 1957, 1958, 1959; Dooge, 1959; etc.); 2) model based on hydrograph characteristics. (e.g., Snyder, 1938;) and 3) model based on unit hydrograph (e.g., Soil Conservation Service, 1972). In our study, we have satellite image of catchment area. Using Snyder's approach we developed the Geomorphologic feature based unit Hydrograph.

The convention method likes Gumble, Log normal distribution, & Log Pearson Type III is based on flood frequency method. These method using observed annual peak flow & complex statistical formula which has a large no. of statistical parameter like mean values, standard deviations, variance, skewness, and return period etc are involved. These statistical data are then used to construct frequency distributions, likelihood of various discharges as a function of recurrence interval or exceedence probability. Due to these complexity and these methods are highly unreliable & lack of accuracy.

The uncertainties & inaccuracy involved in conventional approach, led the hydrologists/ interested to find a more scientific approach which gives more reliable & accurate design flood for a catchment area. Using the conventional manual approach to find the centroidal lenth, total length of river and slope of river bed may affect the result. Further the chances of error may get scaled up if topo- sheet is not well prepared and not available on required scale.

The advantage of Geomorphologic Instantaneous Unit Hydrograph (GIUH) approach directly used for ungauged or lesser number of gauged basin where runoff data are scarcely available. Another advantage of GIUH method is easily extracted physical parameter from the digital elevation model (DEM) using remote sensing technology.

1.2 Remote sensing & GIS application in Catchment Geomorphology analysis

The catchment area and its hydrological characteristic is an important factor for planning, management of water resource projects. Till now, catchment areas of a particular rivers or entire rivers systems and presented in thematic maps. With the help of GIS and digital terrain models it is now possible to delineate the catchment area for each individual river. With ArcGIS-Tool "Catchment area" the hydrologic catchment area can be extracted by defining a definite pouring point in a river network. Catchment area can be shown in ArcGIS. Catchment Geometry & the important physical feature of the catchment like area, altitude, main stream and sub stream & their sub catchment, land use and other geographic information are easily extracted.

1.3 Objectives

Objectives of the present study are to evaluate the design flood by using remote sensing & GIS and same design flood has been verified with convection approach. The objective of the study of this paper is to find the more scientific approach to find the design flood which is more reliable and accurate and compare these results with different conventional method. The objective has been summarized in following three head:

I. To Develop the Geomorphologic Instantaneous Unit Hydrograph (GIUH) based on catchment Response.
II. Estimate the design flood discharge using GIUH.
III. Estimate the Design Discharge by Convention Flood Frequency method.

1.4 Overview of Thesis

This dissertation compromises of six chapters. Chapter 1 is introduction, which gives general introduction of subject followed by objectives of the present study and structure of the dissertation. Chapter 2 titled Literature Review summarizes literature regarding the geomorphologic parameter using GIS & Remote Sensing technology estimate the design flood based on Hydro-metrological approach & Statistical approach. Chapter 3 is all about geographical region of study area & Doimukh project & data, software used for the analysis. Chapter 4 contain Methodology in which procedure adopted for processing the data for study carried out is elaborated. Chapter 5 is result and discussion this chapter include discussion of the detailed result based on methodology underlined in chapter 4 and conclusion of the study are given in Chapter 6.

CHAPTER 2

2 LITERATURE REVIEW

The Design Flood has an important role in water resource field. Planning & management of infrastructure development work like large Hydropower project is heavily dependent on it. Due to improper calculation of design flood various dams has failed in past years. The failure not only damage the project structure also effect the downstream life and property. The conventional approach of flood frequency method often fails to record an extreme event. These method is depend on past record hydrological data i.e annual observed peak flow & complex statistical formula. Where the chances of reliability of the results are sustainably reduced.

S. W. Franks *et al.* (in 2015) in their research paper "**Estimating extreme flood events – assumptions, uncertainty and error"** explained the risk, reliability and dependency on these convention flood frequency approach. They explained why the historical observed peak flood data, used in conventional method is not reliable. In their research paper they described the conventional method where the past trend of annual peak of discharge has been used, not always follow the same trend especially in present scenario where climatic factor played an important role. They further emphasis the problem associated with this method is implicit of hydrological stationary.

Remote sensing technology & geographic information system (GIS) has become the key tool for flood estimation in recent years. Many research paper advocates the using the new techniques over the conventional approach keeping in mind of its advantage and reliability.

B Supraja, *et al*. has worked on Estimation of Peak Discharge in an Ungauged catchment using Geomorphologic Instantaneous Unit Hydrograph (GIUH) Model Supported with GIS and Remote Sensing. Geomorphologic Instantaneous Unit Hydrograph (GIUH) is a workable approach based on GIS & Remote sensing techniques, which directs used to an ungauged catchment for estimation of runoff response. It does not require generally applied old methods of regional specific unit hydrograph; wherein, the historical rainfall runoff data of well established gauged catchments has been used. Because of these advantages, GIUH will be more adaptive in near future. Further, they supported to use of GIUH based approach particularly in case of developing countries like India where adequate number of discharge sites are not established & accuracy of runoff data is huge concern.

Kumari Priyanka . *et al.* in 2016 has worked on estimation of Design Flood for rivers of Saurashtra area which is merging into the Gulf of Khambhat. Design discharge of these rivers by both the approaches like hydro metrological (deterministic approach) & flood frequency method (**s**tatistical approach) has been compared and since the percentage difference is very less between SUH and flood frequency method. They suggested for design purpose one with higher value should be used. They further suggested in case of large difference the other empirical regional flood formula (RFF) may not be applicable.

Himanshu S.K. *et al.* in 2013 carried out geomorphologic studies and estimated the design flood calculation of Himalayan River basin (Joshimath, Uttarakhand). Their study of geomorphologic parameters of the basin was estimated from 30 m ASTER (Advanced Space Borne Thermal Emission and Reflection Radiometer Sensor) DEM and Landsat imageries using ARC-GIS 9.3 and ERDAS IMAGINE 9.3 Software. Their aim of study was to estimate the design flood of the site situated at Joshimath, district Chamoli, Uttarakhand along with few Geomorphological parameters which will provide us with feasibility of designing of the hydraulic component like dams, spillways in future in that catchment area.

Snyder (1938) proposed that catchment area, shape of basin, topography, channel slope, stream density and channel storage affects the shape of hydrograph. On that basis, he proposed an empirical equation of unit hydrograph (called synthetic unit hydrograph-SUH) based on catchment area, shape of the basin and averaging out other parameters with a coefficient.

Chapter 3

3 STUDY AREA AND DATA USED

3.1 Project Study Area

The Doimukh Hydroelectric Project is situated in Papumpare district (Arunachal Pradesh). It is proposed on river Dikrang near Chiputa village, about 2 km d/s of Pare H.E Project. The Dikrang River is the right bank tributary of Brahmputra River. It originates at an elevation of EL 2579 M near the border of Lower Subansiri District and East Kameng District in Arunachal Pradesh and ultimately falls into Brahmaputra river. It drains the area covering a part of lower hills of Arunachal Pradesh and Lakhimpur District of Assam. The dam site is located at Latitude 27°11' 15"N, Longitude 93°47' 09"E, about 15 km north of Itanagar . The total length of Dikrang River is 145 km. Out of which for a distance of about 113 km, it flows through the hilly region of Arunachal Pradesh and for remaining 32 km, it flows through the plains of Assam. Location of the project has been indicated in the Fig no 3.1 .

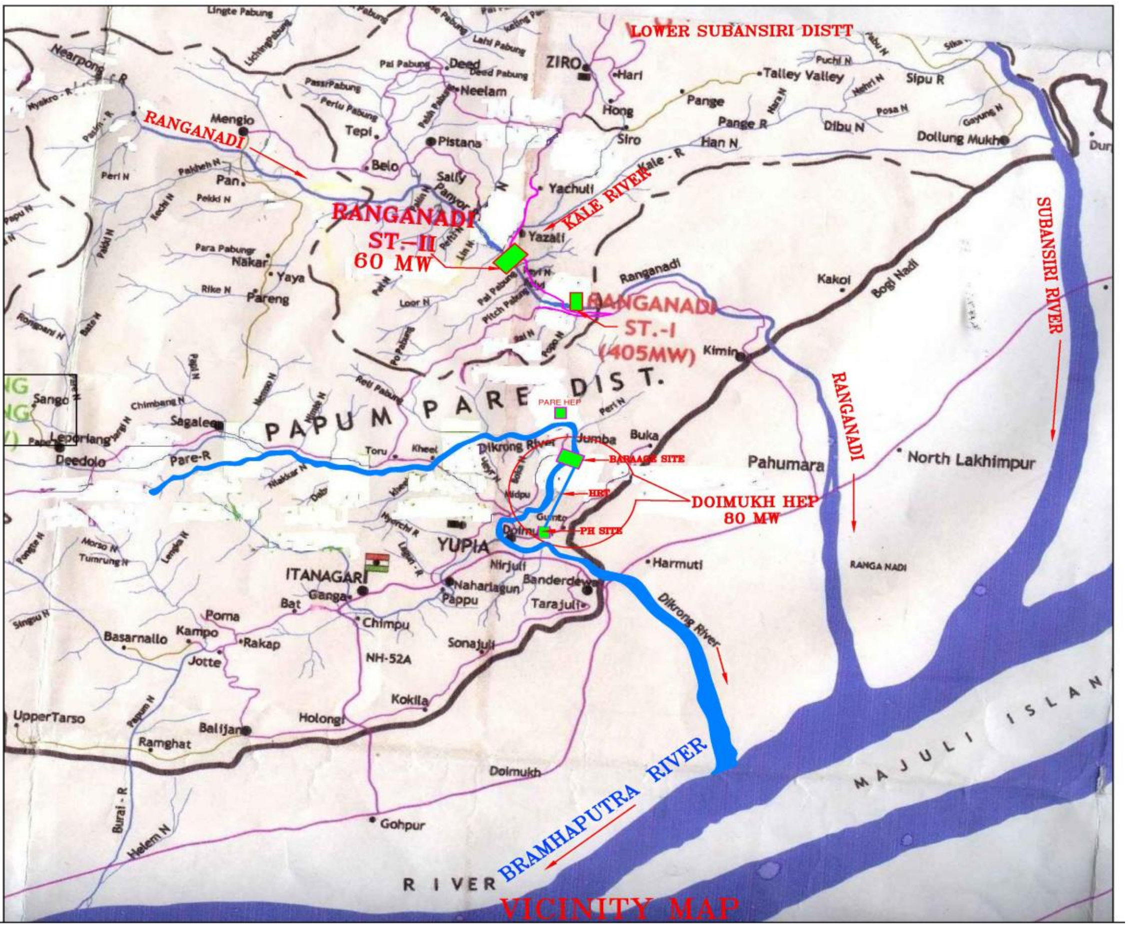

Fig. 3.1 Location map of Doimukh Project

3.2 Brief description of Doimukh Project & its Catchment Characteristics

The Doimukh project has proposal of construction of 20 m high Dam on Dikrang River with a live storage of 2.01 million cubic metres (mcm) and a gross storage capacity of 4.742 million cubic metres (mcm) at Flood reservoir elevation 163.2 m. The submergence area is estimated as 0.97 Sq.km at Flood reservoir level (FRL) whereas the reservoir length is measured as around 1.8 km. The Doimukh Hydro-electric Project proposes to utilize the waters of rivers Dikrong and tail water discharge from Ranganadi Hydroelectric Project, Stage I (RHEP-I) for Power generation. The water of Ranganadi after passing through Head Race Tunnel, generate power at RHEP-I (Power House located at Dikrong) near Yayee village on the bank of river Dikrong and then through tail race meeting Dikrong upstream of proposed Dam structure of Doimukh HEP. Thus regulated discharges from RHEP-I (Dikrong Power House) and those of the Dikrong/ Pare River itself shall be available for further hydropower potential under Doimukh H.E. Project.

The Doimukh H.E. Project is part of overall development of Panyor-Dikrong basin which envisages two projects on the Ranganadi (Panyor) river and two projects across the Dikrong River as shown in table 1 :-

Table 1 development Status of hydropower Project on river Dickrong

Hydroelectric Project	Status of Development
Ranganadi Stage I (405 MW)	Already commissioned
Ranganadi Stage II (130 MW)	Preparation of DPR in progress.
Pare H.E. Project	DPR taken up by CES.
Doimukh H.E. Project	Preparation of DPR in progress.

The Project is located in the Papumpare district of Arunachal Pradesh (long. 93°47’09” E lat. 27°14’13”). The Distt. Head quarter Ziro is around 35 km. in the North. The shape of catchment is elongated with average width of valley varying from about 20 km in initial reaches to around 18 Km above dam site. The catchment boundary of project is shown in Fig. No. 3.2

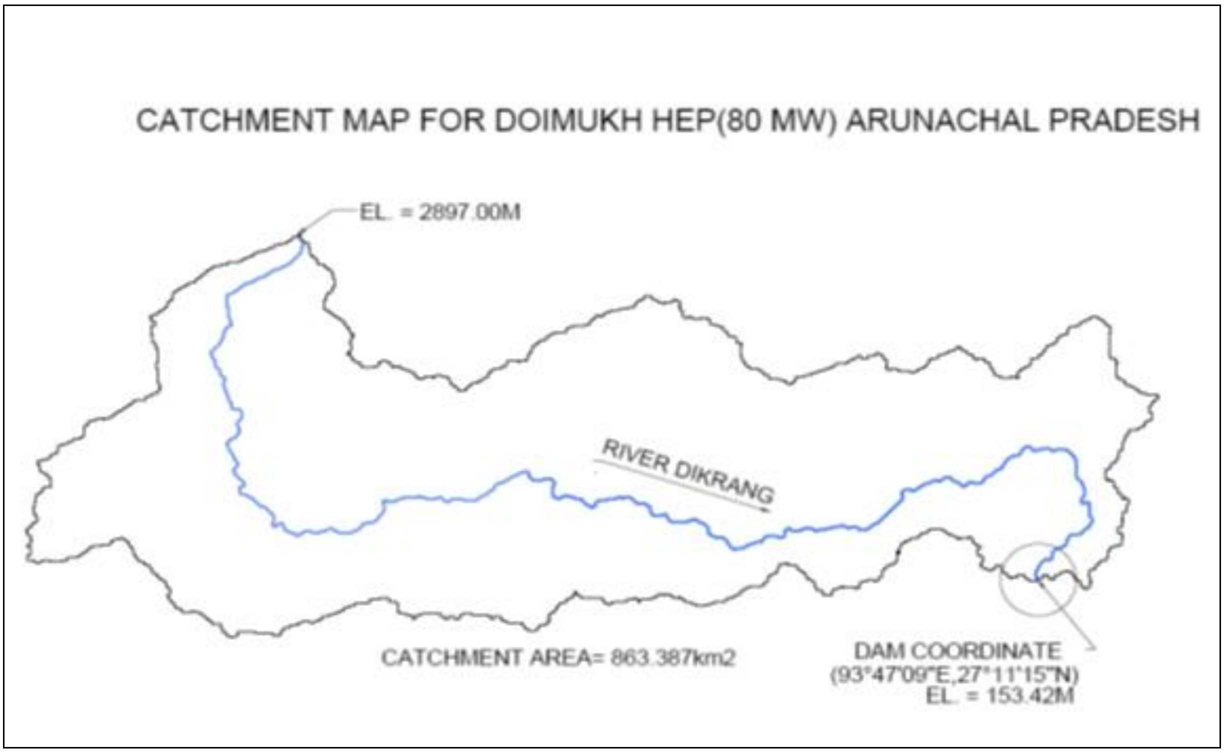

Fig 3.2 Catchment Map of Doimukh Project

3.3 Study Area-Data Characteristics

The ASTER 30m resolution Satellite DEM image of the study area and nearby area has downloaded from the NASA websites. To find out the geomorphologic features of the basin with the help of Digital Elevation Model (DEM) image of the river basin has been processed in the ArcGIS 10.2 & with some additives tools perform to delineate the basin boundaries and the drainage networks. The stream & Catchment extraction is established by performing the various ArcGIS command mentioned in chapter 4 subsection (4.1.1) in sequential order.

3.4 Software Used For Geomorphological Parameter extraction from DEM

I. **ArcGIS -** is a Geographic Information System (GIS) tool which helps to understand the maps and their geographic information. It is used for: creating and using maps; compiling geographic feature ; analysis of mapped information; sharing and discovering geographic information; using maps and geographic information in a number of applications; and managing geographic information in a database.

II. **3DEM**- is additive tool which helps in

a. Creates a practical terrain surface

b. Convert the projection to WGS 84 UTM system of coordinate.

c. Used to cut-out the related portion of the downloaded DEM ASRER file.

III. The Arc Hydro Toolset

The Arc Hydro Toolset is a additive tools to arc-GIS which provides the creation, manipulation, & step wise hydrological analysis of catchment ArcGIS. The tools provide raster, vector, and time series functionality, which also help in catchment analysis.

IV. HEC-GeoHMS

HEC-GeoHMS identify the drainage network by combining the drainage paths and catchment boundaries into a hydrologic data structure. The tools help in visualize spatial information, extracting catchment boundary, their sub basins and sub-streams.

3.5 Hydrological Field Data

3.5.1 Design Storm

Value of Design Storm is taken from Indian Metrological Department. The 1-day Standard Project Storm (SPS) is 35.5 cm and Probable Maximum Precipitation (PMP) of the project as provided by IMD is 42.2 cm respectively. The 1-day design storm values are enhanced by 15% (as recommended by IMD). The 24-hour SPS values for the project have been estimated to 40.82 cm. The temporal distribution of the design storm as provided by **IMD.**

3.5.2 Loss Rate of runoff

The design loss rate of runoff for the project has been assumed to be 0.24 cm/hr as per mention in Central Water Commission report of **"Flood estimation report for North Brahmaputra Basin (Subzone -2 (a)".**

3.5.3 Annual Peak Flood

The flood for the proposed project has been computed using annual peaks for the period 1973-2012 at Doimukh Dam site. The flood for various return periods is calculated using Gumbel distribution, Log normal distribution**,** Log-Pearson Type-III method, is given in below table 2:

Table 2 Observed Annual Peak flow

Sr No	**YEAR**	**Observed peak (cumecs)**	**Instantaneous peaks(cumecs)**
1	1973	1424	1851
2	1974	1901	2471
3	1975	358	465
4	1976	422	549
5	1977	345	449
6	1978	335	436
7	1979	381	495
8	1980	395	514
9	1981	814	1058
10	1982	517	672
11	1983	961	1249
12	1984	943	1226
13	1985	350	455
14	1986	384	499
15	1987	414	538
16	1988	329	428
17	1989	490	637
18	1990	612	796
19	1991	303	394
20	1992	640	832
21	1993	709	922
22	1994	571	742
23	1995	841.6	1094
24	1996	660.2	858
25	1997	642.1	835
26	1998	643.1	836
27	1999	611.6	795
28	2000	642.2	835
29	2001	642.2	835
30	2002	1151	1496
31	2003	730.8	950
32	2004	1223	1590
33	2005	999.4	1299
34	2006	468	608
35	2007	403.9	525
36	2008	877.3	1140
37	2009	598.8	778
38	2010	483.4	628
39	2011	1143.4	1486
40	2012	754.2	980

Chapter 4

4 METHODOLOGY

To accomplish the objective of the present study, the methodology is broadly divided in three steps as given below and explained further:

a) Catchment , Sub-catchment Delineation Stream & Sub-Stream Profile analysis

b) Collection of hydrological field data & calculate the design flood by hydro metrological approach

c) Verify the design discharge with statistical approach of flood frequency method

4.1 Catchment, Sub-catchment Delineation, Stream & Sub-Stream Profile analysis

Although Catchment area is easily delineate and analyze on a topographic sheet map, but GIS based delineation is less manpower intensive, more reproducible, and less dependent on manual judgment. The GIS delineation process involve a no of command function which must be run sequentially starts with a grid representation of an area called a digital elevation model (DEM, Figure 4.1).

(The methodology for each command & their function is explained in subsection 4.1.1 and their respective result is mention in Chapter 5 of results & Discussion.)

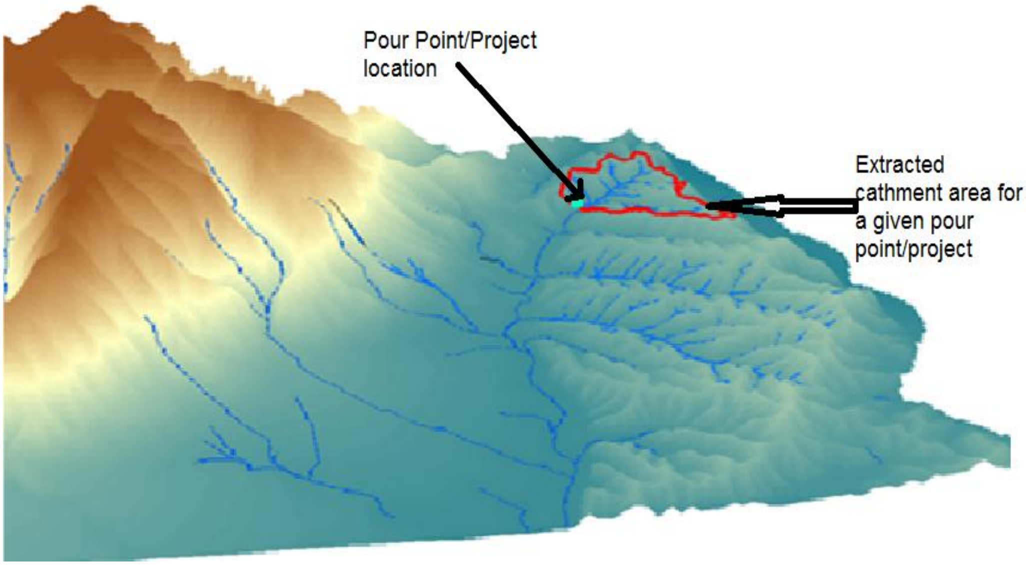

Fig. 4.1 Typical Representation of a DEM, a Pour Point & the Watershed Boundary

4.1.1 Step involved in Extraction of physiographic parameter through Arc-GIS:-

A. Terrain Pre-processing

i. Fill Sinks

Fills sinks command provide the flatness in surface where cause of undulation the flow is not smooth. Due to unevenness in surface the flow is not smooth. These are problematic because the grid cells contained in these features have no down slope in adjacent area, which is the basis for DEM flow-path.

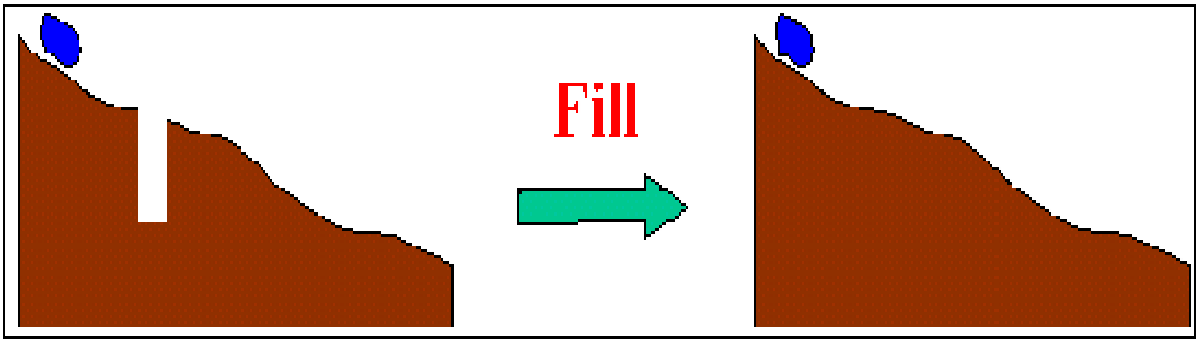

Fig 4.2 Fill Sink Concept

ii. Flow Direction

Flow direction identifies the slope from the cell. The flow occurs along the steepest slope of connecting cell. It is shown in Fig 4.3.

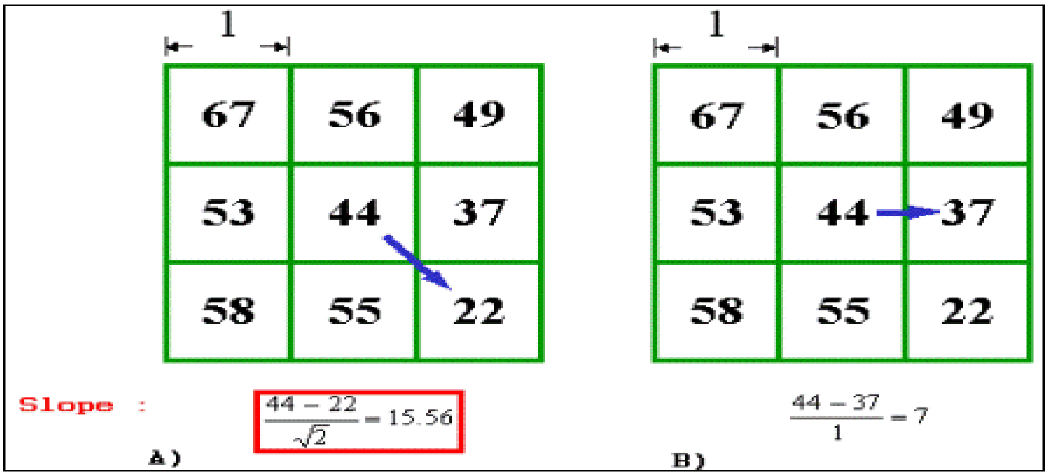

Fig. 4.3 Flow Direction Concept

iii. **Flow Accumulation**

This command evaluates the different pouring point in the catchment accordingly flow direction and slope. Subsequently all interconnected pouring point is flow toward the lowest elevation in catchment area. It is shown in Fig 4.4.

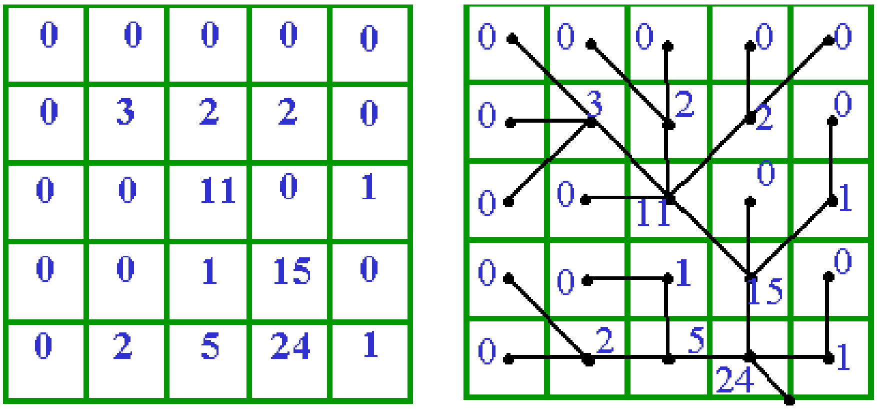

Fig 4.4 Flow Accumalation Concept

iv. **Stream Definition**

After identifying the accumulation grid the very next step is stream definition. Using the stream definition command those flow accumulation value is greater than particular number is considered stream. Stream definition shown in Fig. no 4.5.

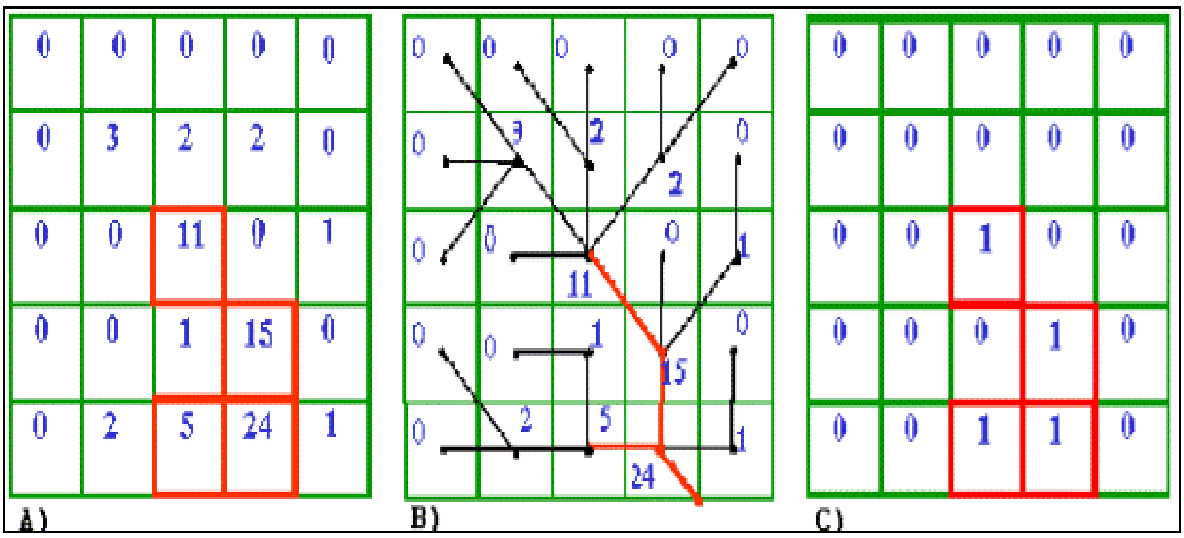

Fig 4.5 Stream Definition

v. **Stream Segmentation**

The next step is to divide the stream network into distinct stream segments – this is useful if the purpose of the delineation to the single Catchments. If only the overall catchment is desired, the Catchment grid delineation function should be used.

vi. **Catchment Grid Delineation**

This function generates a grid in which every cell carries a value referring to which catchment the cell belongs. The value with respect to the value assigned by the stream segment that drains that area, described in the stream segment link grid.

vii. **Catchment Polygon Processing**

The three functions Catchment Polygon Processing, Drainage Line Processing and Adjoin Catchment Processing change the raster data into vector format.

Drainage Line Processing

This function changes the input Stream Link grid into a Drainage Line feature class. Each line in the feature class carries the identifier of the catchment in which it resides.

B. Project Setup

Selecting the project setup command in arcGis hydro tool below mention three thing to be specify the user:-

I. Data management
II. Define a new project – add a project
III. Generate project

In these step, we define the dam location in catchment area. Accordingly Arc gis generate the project and extracted the area which one is contributing the discharge in the basin & it delineated the specific area only.

C. **Extracting Basin Characteristics**

Using HEC-GeoHMS tools these phyigographic parameter has been obtained. Mainly four physiographic parameter is listed below extracted from the basin -

a) Longest Path of river
b) centroid of catchment
c) Longest Centroidal Flow Path
d) Average slope of river.

The all arc-GIS step which is explained above under section 4.1.1 shown through flow chart diagram in Fig.4.6

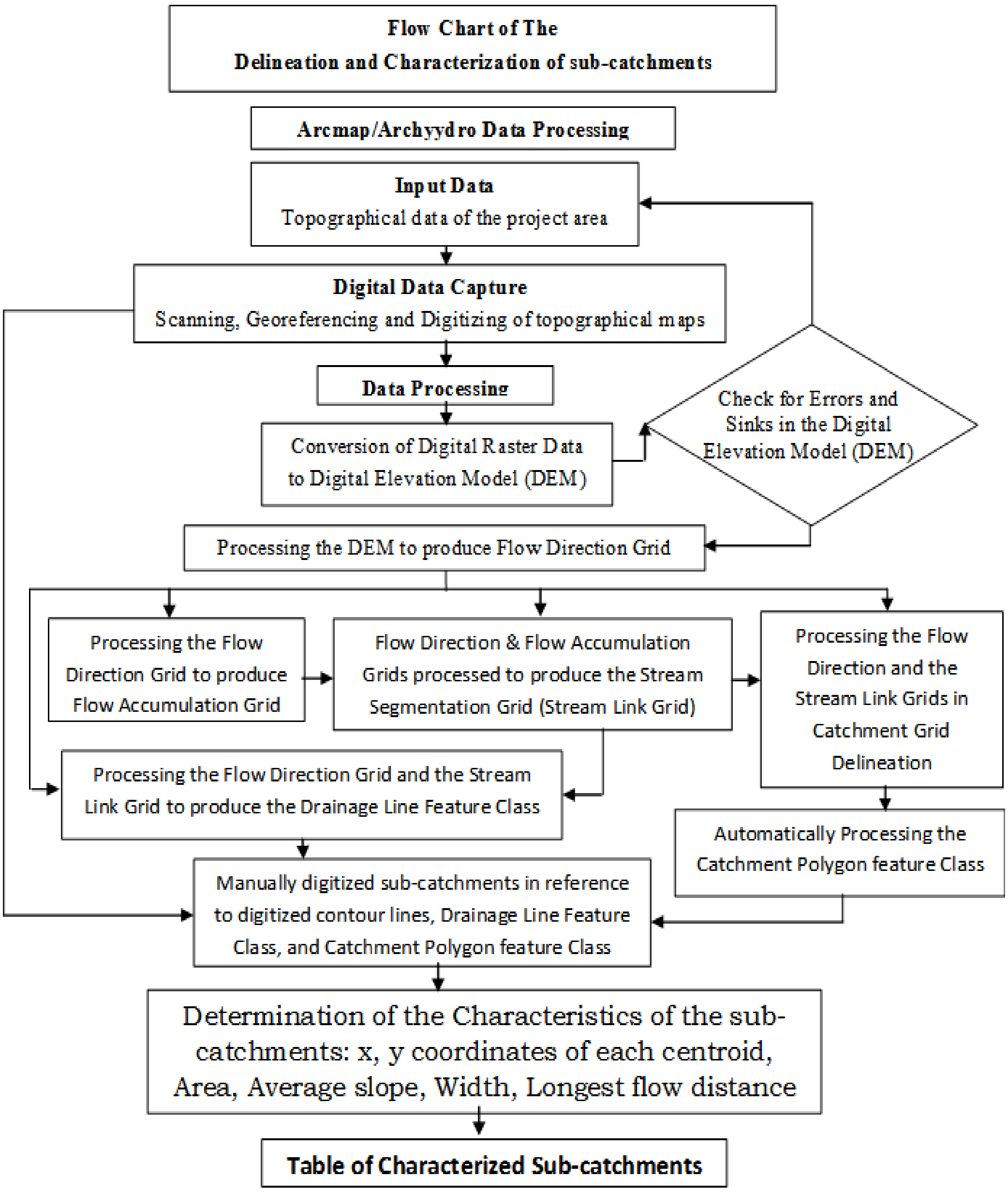

Fig 4.6 Flow chart of Catchment Delineation & Stream Profile analysis

4.2 Hydro-Meteorological Approach

Generally following two methods is used for the flood calculation:

- PMF and SPF by the hydro meteorological approach.
- Calculation of a flood of a given frequency by statistical approach

The method for calculating the PMF and SPF comes under the hydro meteorological approach, using the unit hydrograph theory. Flood of a given frequency (or return period) is obtained using the statistical approach, commonly known as flood frequency analysis. In every method, sufficient data for carrying out the calculations are required. The data which are required include long term annual flood peaks, catchment physiographic characteristics, etc. The criteria for choosing the design flood for various types of hydraulic structures depend on purpose, life and economy of the structure.

Due to vastness of our country not possible to observe the data for every stream. There are a large number of such ungauged catchments in India which has to depend on synthetically developed flood formulae. India is classified into 7 zones and 26 hydro-meteorologically homogeneous sub-zones, for each one of which flood estimation guidelines have been published. These reports contain ready to use chart and formulae for computing floods of 25, 50 and 100 year return period of ungauged basins in the respective regions. The criteria for choosing the design flood for various types of hydraulic structures depend on purpose, life and economy of the structure.

<u>Following steps and parameter for Hydro-Meteorological Approach are used:-</u>

A. Catchment Area

Catchment area is delineated and measure through ASTER image by using arc-GIS tools.

B. Parameters of the Main Stream (L &L_c)

River length (L) is the longest length of the main stream river from the dam site to catchment boundary.

Whereas Lc is defined as the centroidal length of main stream .but it doesn't mean that the centre of gravity passes through it. It is measured from the dam site to near of centroidal point of catchment.

C. Equivalent Stream Slope (S)

Formula applied to evaluate the equivalent slope (S).

$$S = \frac{£\ L_i(D_{(i-1)} + Di)}{L^2}$$

Where,

$D_{(i-1)}$ = Downstream slope of i^{th} stream

D_i. = Upstream slope of i^{th} stream

D. Derivation of Unit Hydrograph

Unit hydrograph is developed as per the guidelines given in the flood Estimation report for North Brahmaputra Basin (sub zone 2a). This guideline report is prepared by Central Water Commission.

The detail parameters of a synthetic unit hydrograph (SUH) are described in **Figure 4.7 below** for understanding the important inputs of design flood computations.

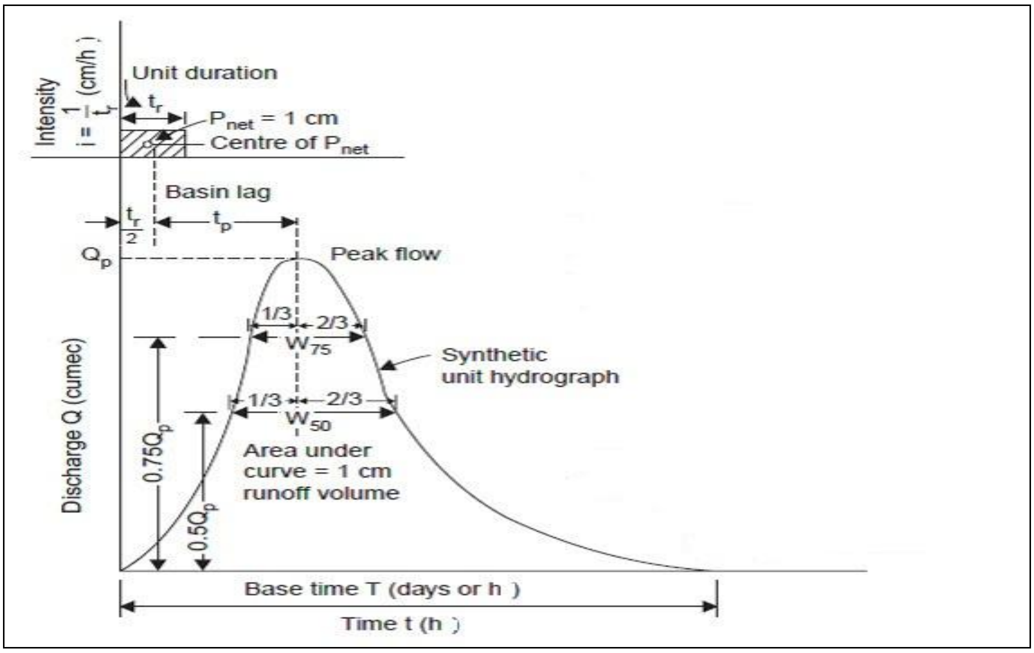

Fig 4.7 Parameters of SUH

The formula of the above stated parameters for deriving unit hydrograph has been given in Table 3 below:

Table 3 Unit Hydrograph Parameters

Parameters	**Formula**
qp	$2.272 * (LL_c)^{-0.409}$ S
tp	$2.164 * (q_p)^{-0.940}$
tm	$t_p + 0.5$
W**50**	$2.084 * (q_p)^{-1.065}$
W**75**	$1.028 * (q_p)^{-1.071}$
W**R50**	$0.856 * (q_p)^{-0.865}$
W**R75**	$0.44 * (q_p)^{-0.918}$
T**B**	$5.428 * (t_p)^{0.852}$
Q**p**	q_px A_r

Where;

A =Catchment area in km^2

L =Length of main river in km

L_c= length of main river from dam site to centroid of catchment

S_{eq} = Equivalent slope of stream (m/km)

t_r = Unit duration in hour

t_p = duration between centre of effective rain to the peak of Unit Hydrograph

t_m = Time to reach the peak in hour

T_b = Base width of U.G. in hour

q_p = Peak Discharge per unit area in m^3/sec/ km^2

Q_p = Unit hydrograph Peak Discharge in m^3/sec

W_{50} = Width at 50% of Peak Discharge in hour

W_{75} = Width of at 75% of peak discharge in hour

W_{R50} = Width of the rising limb @ 50% of Peak Discharge in hour

W_{R75} = Width of the rising limb @ 75% of Peak Discharge in hour

4.3 Statistical Approach: Flood Frequency method

The statistical approach for design flood estimation, also known as flood frequency analysis, performed on the past recorded data of annual flood peak discharges.

Flood frequency analysis, analyse the past records of flood & predict the future possibility of flood. It also estimates the magnitude of an event corresponding to a specific return period.

The following assumptions are generally assumed for the collected past data:

a) The sample is representative in nature. Thus, it is assumed that though only a limited years' data of peak flow has been recorded, the same type of trend was carried forward in predication of future.
b) The data are not depending on each other they are basically independent. The data is assumed to be random. So in this process the value of the variant does not affect the previous or next values.

Flood frequency analysis starts by checking the evenness of the data and finding the presence of characteristics such as trend, jump, etc. Trend is the continuing shift in the annual peak flood data, either in the increasing or decreasing order. This may occurs due to human interference, ex. afforestation or deforestation of the region . Jump means "exceptional values" which may be – high or low, depend on the factors like forest fire, earthquake, landslide, cloudburst or any other unforeseen event etc. Jump change the river's flow characteristics temporarily.

Various flood frequency method is used in estimating the Design discharge. Mainly following three method practically used for calculation of design discharge is-

I. Gumbel method
II. Log – normal method
III. Pearson Type III

4.3.1 Gumble method

Steps involved in frequency analysis by the Gumbel method are as follows:

(i) Arrange annual floods (x) in descending order of magnitude.

(ii) Assign rank ‘m’, m = 1 for highest value and so on. Total no of data is =n

(iii) Calculate return period (T) and/or probability of exceedence (P) by equations n + 1/m and m/n +1 respectively. These values together with respective flood magnitude give plotting positions.

(iv) Using tabular form calculate x2 and ∑x and Ex2.

(v) Now calculate mean x; squared mean x2; mean of squares x2 and standard deviation S.

(vi) From the Table 4 of frequency factors for Gumbel method read if values for desired return periods and the available sample size.

(vii) Using relation x = x + KS calculate flood values for different return periods.

Table 4 Frequency Factor for Gumble method

Frequency factors for Gumbel method

Sample size	Return priod (T) in years										
n	*5*	*10*	*15*	*20*	*25*	*30*	*50*	*60*	*75*	*100*	*1,000*
15	0.967	1.703	2.117	2.410	2.632	2.823	3.321	3.501	3.721	4.005	6.265
20	0.919	1.625	2.023	2.302	2.517	2.690	3.179	3.352	3.563	3.836	6.006
25	0.888	1.575	1.963	2.235	2.444	2.614	3.088	3.257	3.463	3.729	5.842
30	0.866	1.541	1.922	2.18	2.393	2.560	3.026	3.191	3.393	3.653	5.727
35	0.851	1.516	1.891	2.152	2.354	2.520	2.979	3.142	3.341	3.598	
40	0.838	1.495	1.866	2.126	2.326	2.489	2.943	3.104	3.301	3.554	5.576
45	0.829	1.478	1.847	2.104	2.303	2.464	2.913	3.078	3.268	3.520	
50	0.820	1.466	1.831	2.086	2.283	2.443	2.889	3.027	3.241	3.491	5.478
55	0.813	1.455	1.818	2.071	2.267	2.426	2.869	3.027	3.219	3.467	
60	0.807	1.455	1.818	2.071	2.267	2.426	2.869	3.008	3.219	3.467	
65	0.801	1.446	1.806	2.059	2.253	2.411	2.852	2.992	3.200	3.446	
70	0.797	1.437	1.796	2.048	2.241	2.398	2.837	2.979	3.183	3.429	
75	0.792	1.430	1.788	2.038	2.230	2.387	2.824	2.9.67	3.169	3.413	5.359
80	0.788	1.423	1.780	2.029	2.220	2.377	2.812	2.956	3.155	3.400	
85	0.785	1.413	1.767	2.020	2.212	2.368	2.802	2.946	3.145	3.387	
90	0.782	1.409	1.762	2.007	2.205	2.353	2.785	2.938	3.125	3.367	
95	0.780	1.405	1.757	2.002	2.193	2.347	2.777	2.930	3.116	3.357	
100	0.779	1.401	1.172	1.998	2.187	2.341	2.770	2.922	3.109	3.349	5.261

4.3.2 Log-Normal Distribution method

The same procedure of normal distribution is applied for the lognormal distribution expects that the logarithm of data is used to calculate mean and standard deviation.

4.3.3 Pearson III Frequency method

The Log-Pearson Type III is the very common distribution used in stream discharge frequency study. But there is no significant analytical method for this distribution so practitioners almost always go for Pearson Type III frequency factor approach, using log-transformed data.

4.4 Return Period for Doimukh Project

The height of the dam is 20 m, which lies between 12-30 m. The IS: 11223-1985 has prescribed the following criteria for design storm.

Table 5 Classification of Dam (According to IS: 11223-1985)

Classification of Dam	Gross Storage (Mm^3)	Hydraulic Head (m)
Small	Between 0.5 – 10	Between 7.5 m – 12.5 m
Intermediate	Between 10 – 60	Between 12 m – 30 m
Large	Grater than 60	Greater than 30 m

The inflow design flood prescribed for safety of the dam is prescribed as under:

Table 6 Inflow Design Flood (According to IS: 11223-1985)

Classification of Dam	Inflow design flood
Small	100 year flood
Intermediate	SPF
Large	PMF

Floods of larger or smaller magnitude may be used if the hazard involved in the eventuality of a failure is high or low. The relevant parameters to be considered in judging the hazard in addition to the size would be:

(i) Distance to and location of human habitation on the downstream after considering likely future developments.

(ii) Maximum hydraulic capacity of the d/s channel at a level at which catastrophe is not expected

It is proposed to design the dam **for inflow design flood of Standard Project Flood.**

CHAPTER 5

5 RESULTS AND DISCUSSIONS

5.1 Geomorphologic Parameters Estimation of Catchment:

5.1.1 Catchment Characteristics obtained By Arc-GIS

First , The satellite image is downloaded from the NASA websites. The ASTER 30m resolution Satellite DEM image of the study area and nearby area is shown in Fig 5.1.

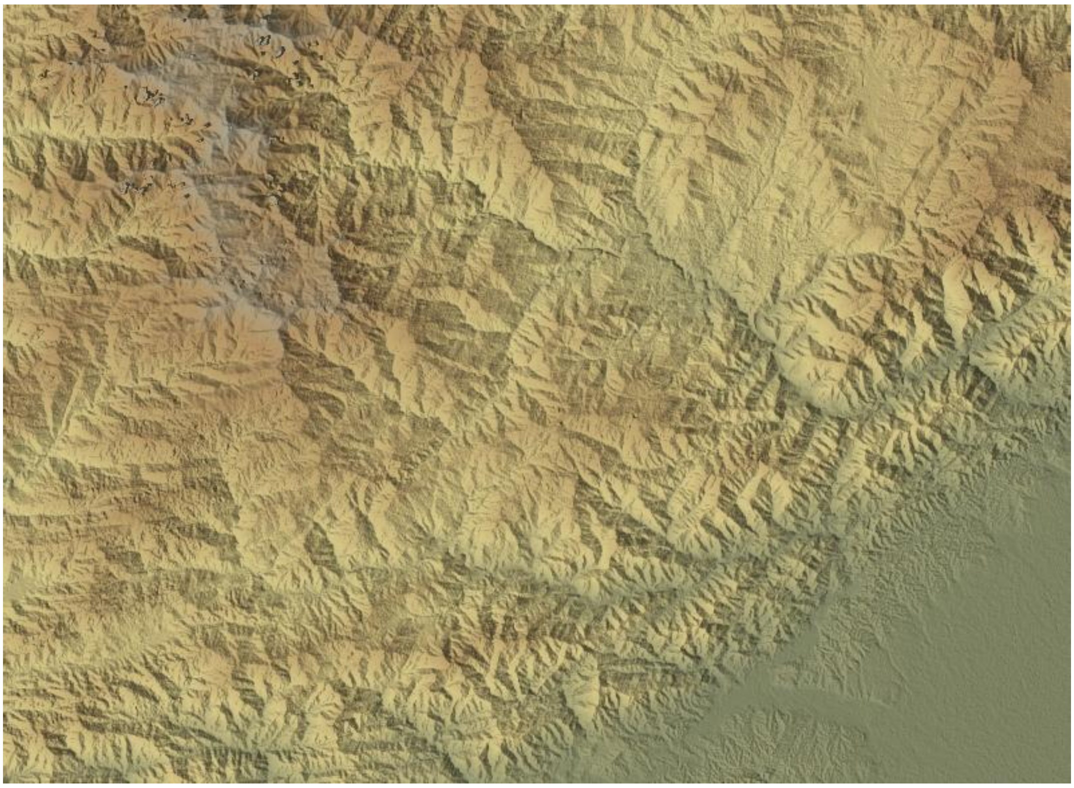

Fig 5.1 ASTER 30m resolution Raw Satellite DEM image of the project region

The satellite image capture large area & bulky in nature. From this raw image project location and area of interest is extracted using the 3DEM Software. The image is in correspond to UTM Zone 46. The DEM is available in WGS 84 coordinate system. Coordinate of WGS84 system to convert into UTM system. The converted image in UTM System is shown in **Fig. 5.2**. This segment of UTM of transformed DEM has been further proceeds on ARC-GIS map to get the physiographic parameter.

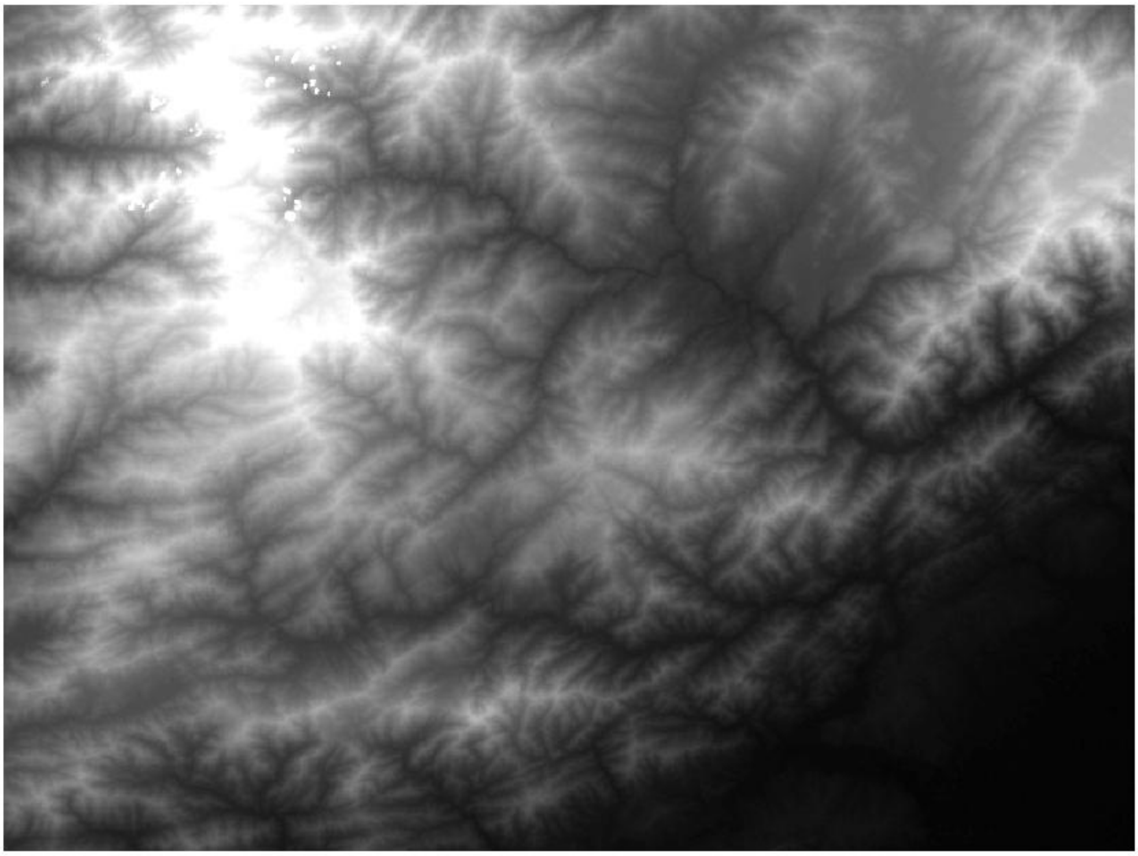

Fig 5.2 Extracted ASTER 30 m Resolution Satellite DEM image In UTM System

5.1.2 Extraction of Raw data through Arc-GIS:-

A. Terrain Pre-processing

i. Fill Sinks

The main function of fill sink command is fill the depression and allow the flow be smooth. After application of fill sink command in DEM image fill the undulation and same image is shown in Fig 5.3.

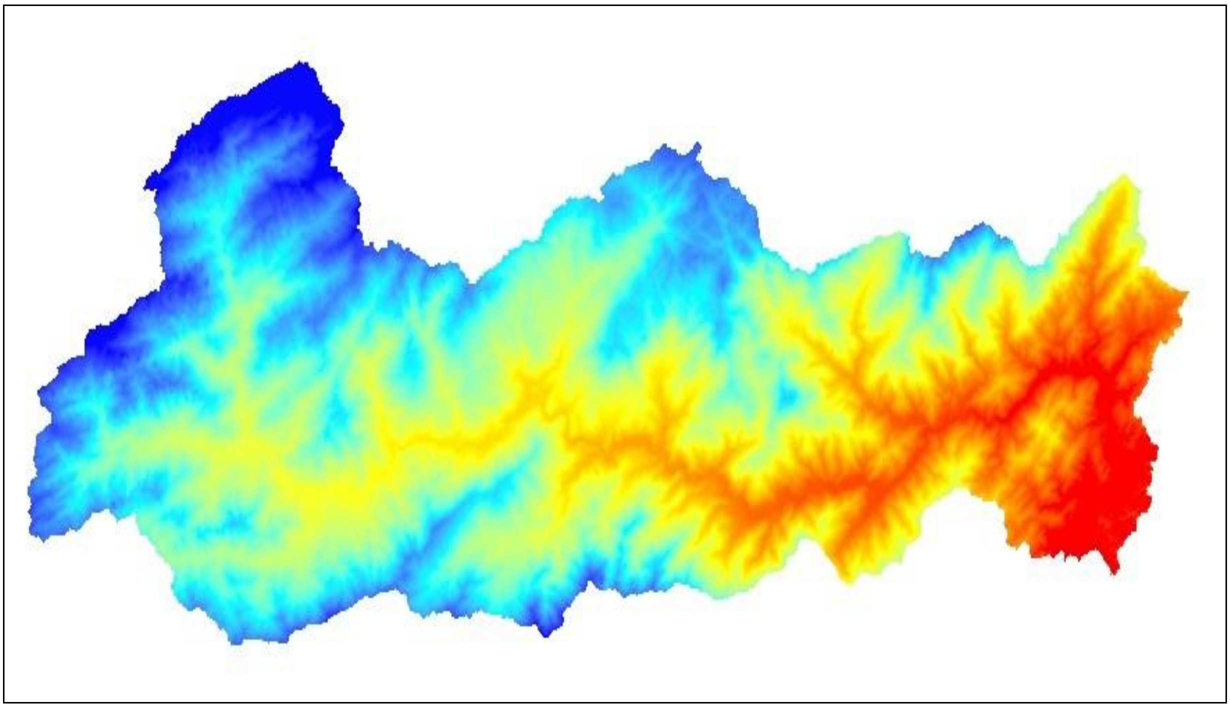

Fig 5.3 Sink image of Doimukh Cathment

ii. Flow Direction

These commands identify the slope of all part catchment. these slope play key role to define the flow direction . The processed image comes out after applying flow Direction command is shown in Fig. 5.4

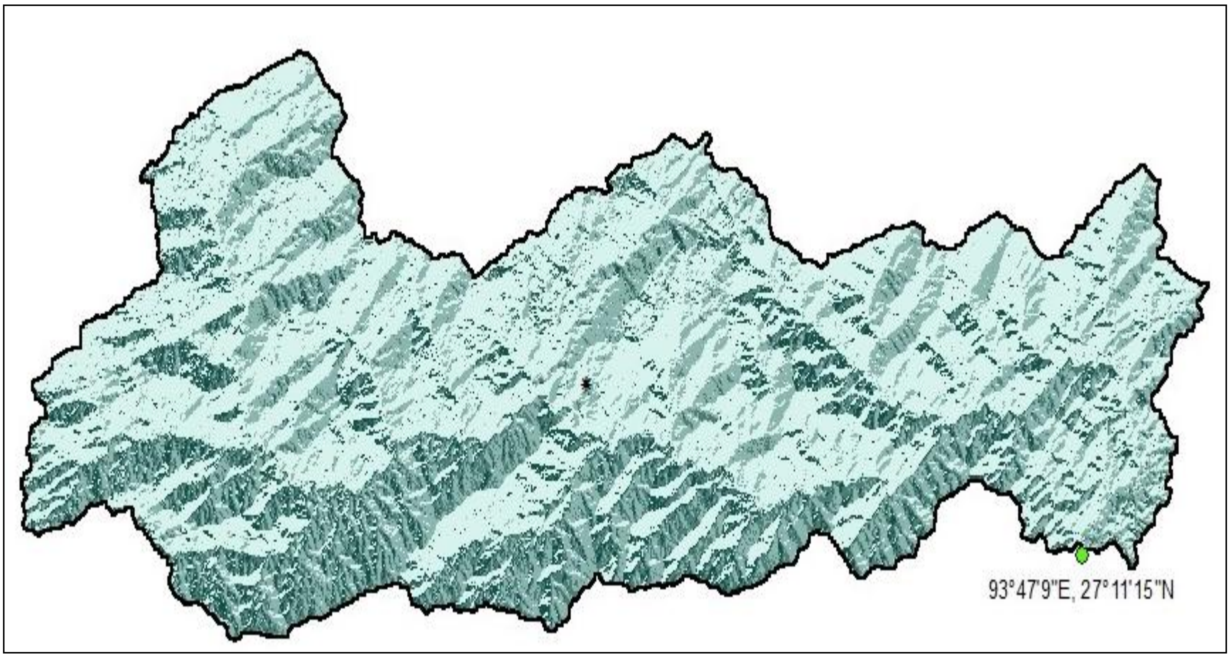

Fig. 5.4 Flow Direction Image of Doimukh Catchment

iii. **Flow Accumulation**

Flow accumulation command locates the pouring point of the entire minor stream. The image extracted from the applying this command visualizes the flow direction as well collection point of different sub stream.

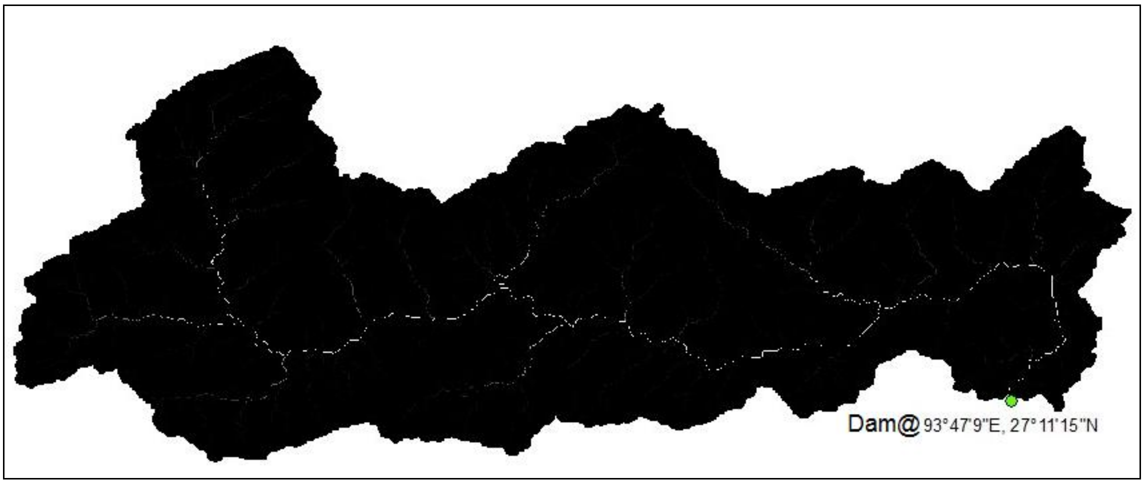

Fig. 5.5 Flow Accumulation map of Doimukh Catchment

iv. Stream Definition

Stream Definition from the Flow Accumulation Grid define the all the stream in catchment as well as nearby area. The extracted & substream is shown in figure 5.6 & 5.7.

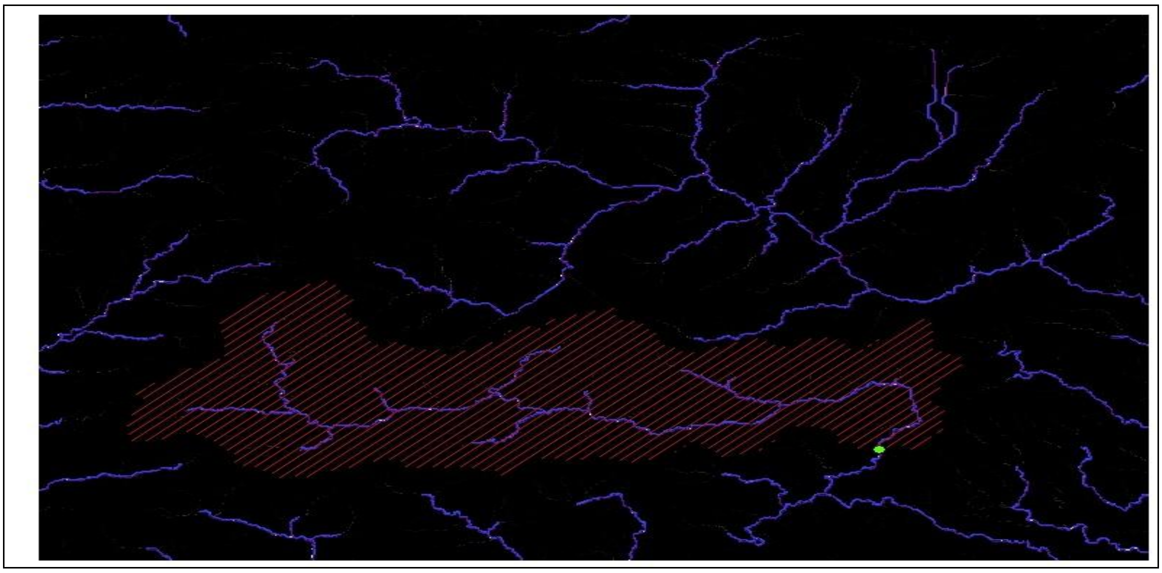

Fig 5.6 Stream Definition map of Doimukh Cathment &Surronding Area

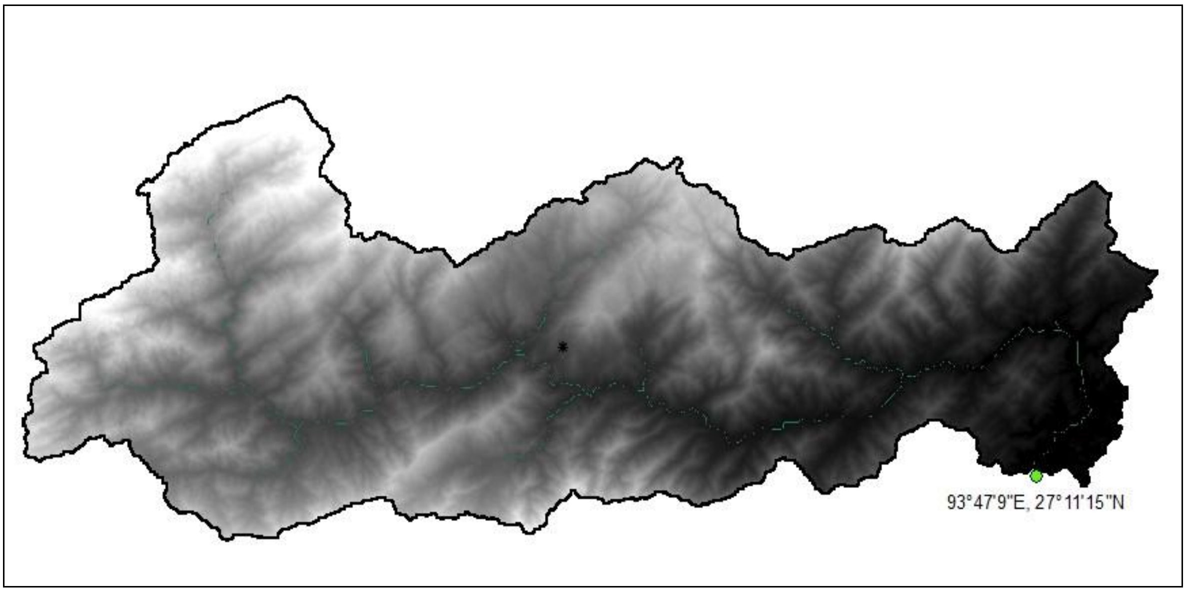

Fig 5.7 Stream Defined map of Doimukh Cathmen

v. Stream Segmentation

The next step is to divide the stream network into distinct stream segments – this is useful if the purpose of the delineation is to determine the individual Catchments.

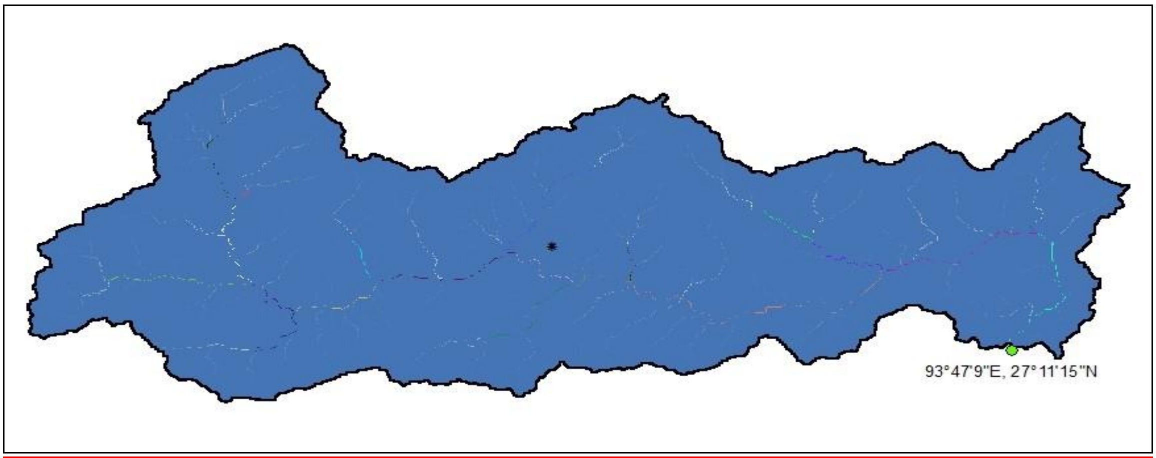

Fig 5.8 Stream Segmentation map of Doimukh Catchment

vi. Catchment Grid Delineation

This function creates a grid in which each cell carries a value (grid code) indicating to which catchment the cell belongs. The value corresponds to the value carried by the stream segment that drains that area, defined in the stream segment link grid.

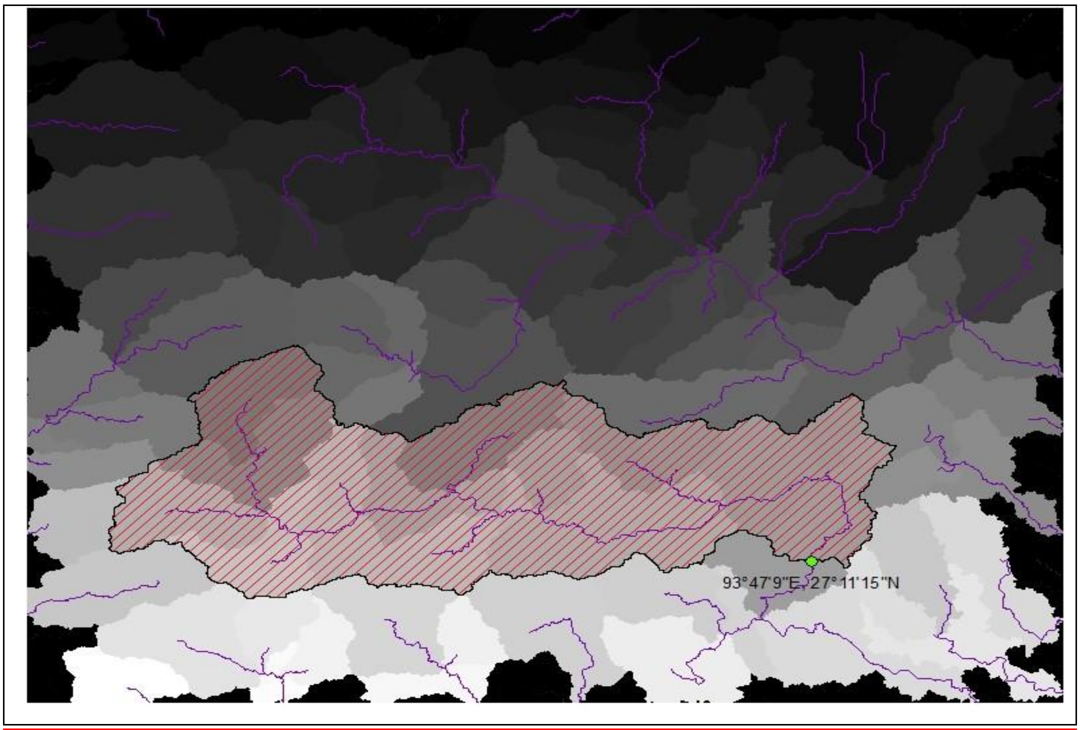

Fig 5.9 Cathment grid Deliention map from surrounding Geographical Region

vii. **Catchment Polygon Processing**

This command identifies the sub-catchment from the catchment.

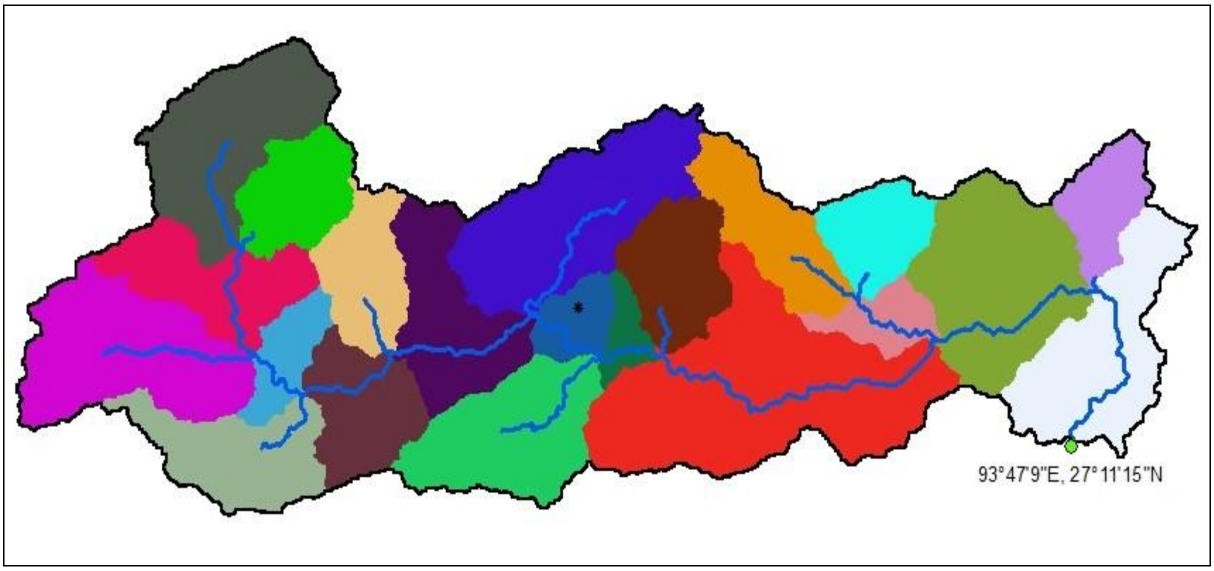

Fig. 5.10 Map of Sub Catchment of Doimukh Cathment

viii. **Drainage Line Processing**

This command differentiate individual stream as per their location in catchment.

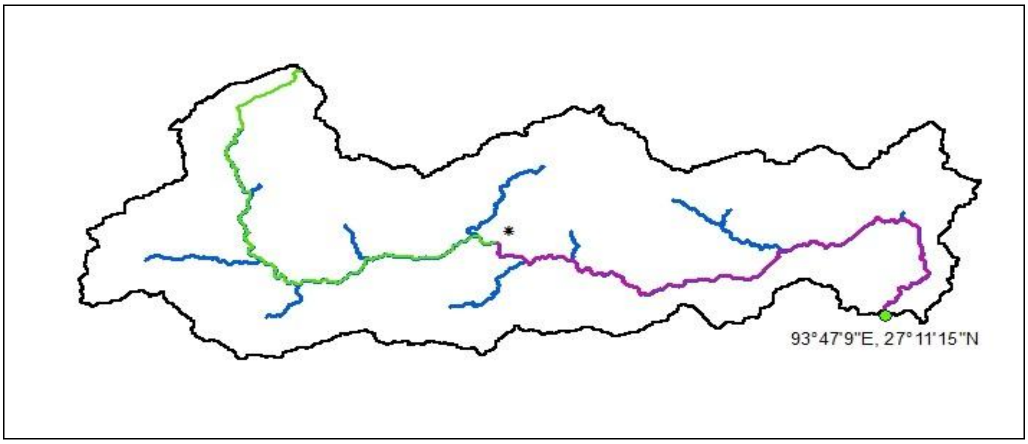

Fig 5.11 Drainage line Map of Doimukh Cathment

B. Project Setup

I. Data management
II. Define a new project – add a project
III. Generate project

In project set up we define the dam location in catchment area. Accordingly Arc gis generate the project and extracted the area which one is contributing the discharge in the basin. it delineated the specific area only.

C. **Basin processing-**

Merge Basins: This process merges two or more adjacent basins into Single one.

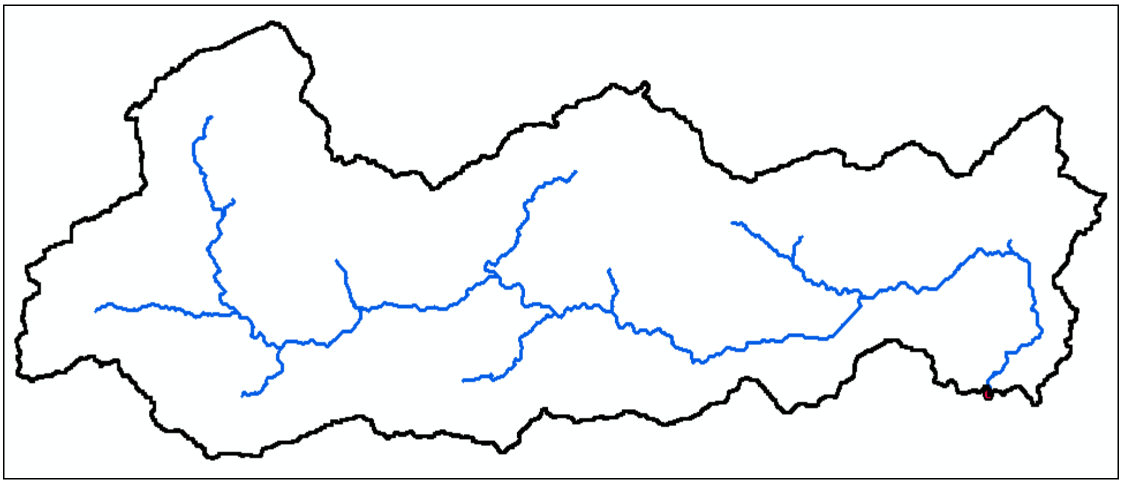

Fig 5.12 Doimuh Catchment Basin After merge the Sub catchments

D. **<u>Basin Characteristics</u>**

The basin characterstitic like length, centroid position &distance from the dam site is analysed by using Arc-GIS & same in shown in figure 5.13 & Fig 5.14.

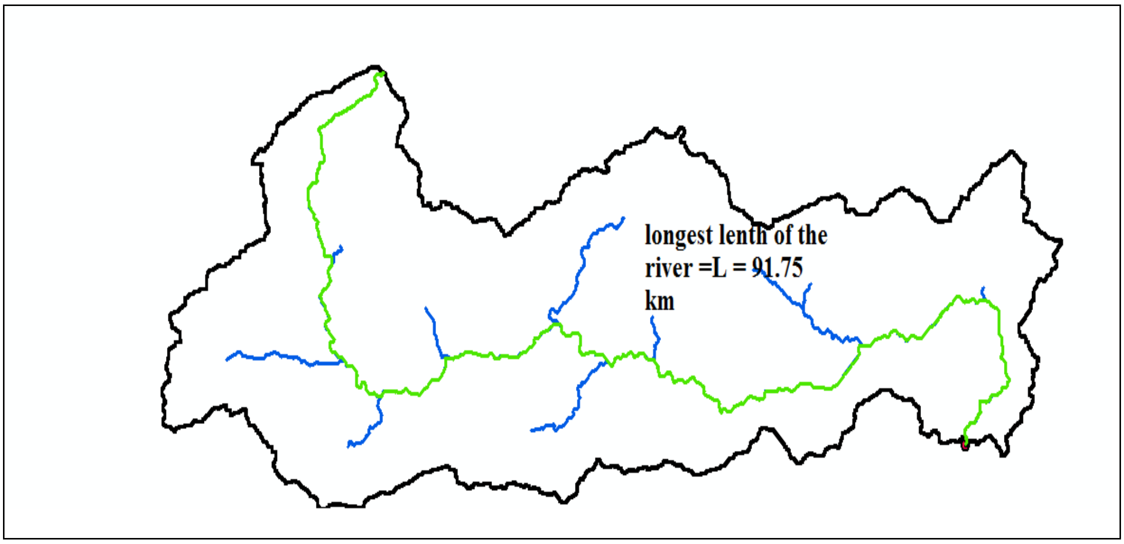

Fig 5.13 longest Flow path Contributing to the Doimukh HEP

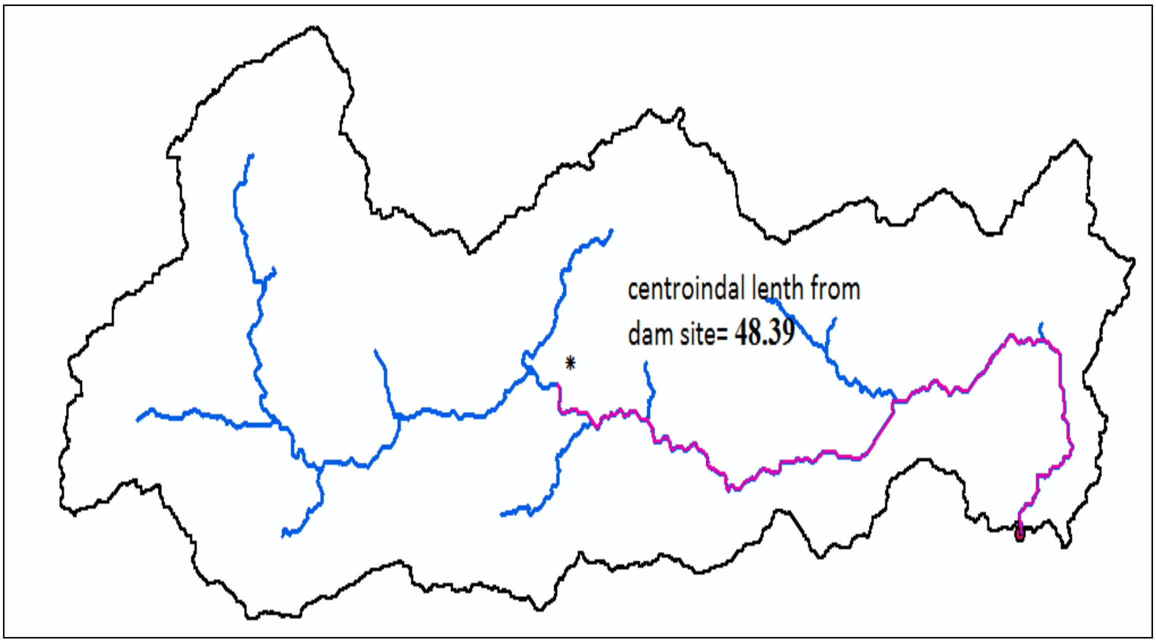

Fig 5.14 Location of Centroid & Centroidal longest path of Doimukh HEP

After using these entire steps, finally we get the physiographic parameter value which is summarized as:-

I. Catchment area of proposed dam site is "**A**" = 864 km^2 ,

II. longest length of the main river L = 91.75 km

III. Equivalent Stream Slope S = 28.74 m/km.

IV. The Centroidal Distance from outlet= 48.39

Based on these physiographic characteristics we further developed the SUH which is further used for develop the design flood hydrograph.

5.2 Design flood by Hydro-Metrological Approach

5.2.1 Derivation of Unit Hydrograph

The numerical value of unit hydrograph is listed below in Table no 7. The typical sketch & abbreviation of term is explained in under subsection head 4.2 of methodology (Chapter4).

Table 7 Numerical value of Unit Hydrograph Parameters

Parameters	Formula	Values
qp	$2.272 * \left(\frac{LL_c}{\sqrt{S}}\right)^{-0.409}$	0.29 Cumecs/Km^2
tp	$2.164 * (q_p)^{-0.940}$	6.94 hrs
tm	$t_p + 0.5$	7.45 hrs
W**50**	$2.084 * (q_p)^{-1.065}$	7.81 hrs
W**75**	$1.028 * (q_p)^{-1.071}$	3.88 hrs
W**R50**	$0.856 * (q_p)^{-0.865}$	2.50 hrs
W**R75**	$0.44 * (q_p)^{-0.918}$	1.37 hrs
T**B**	$5.428 * (t_p)^{0.852}$	28.30 hrs
Q**p**	$q_p x A_r$	249.67 cumecs

Derived Unit Hydrograph

The 1-hour Derived Unit Hydrograph of the Catchment for Doimukh H.E. Project. (As per numerical value obtained in Table no 7.)

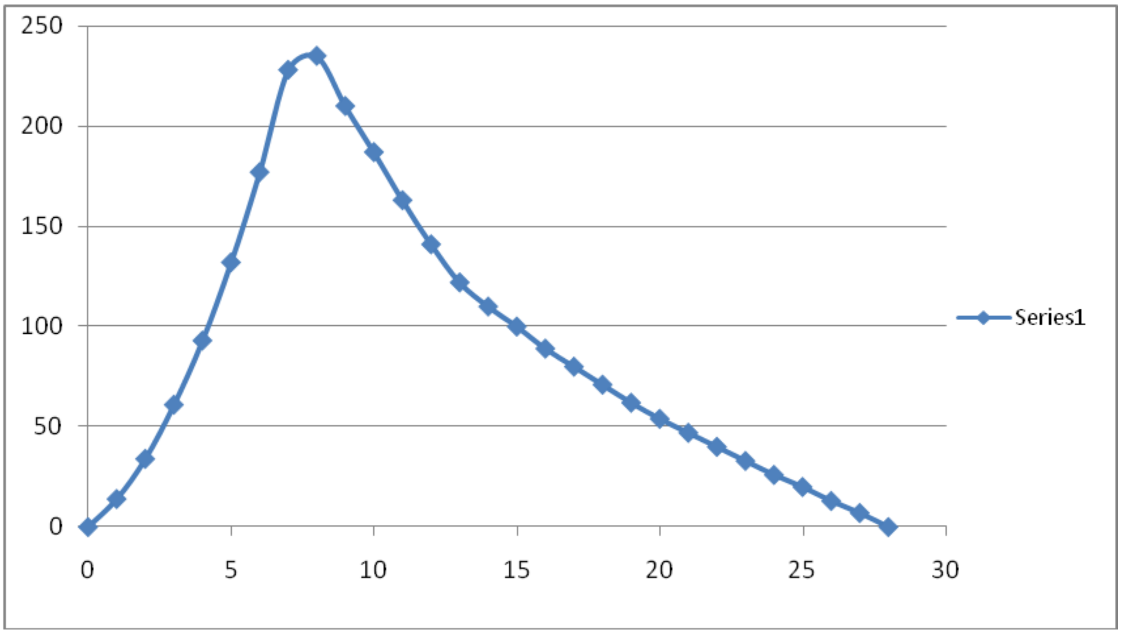

Fig 5.15 1-hour Derived Unit Hydrograph

Table 8 Ordinate of Derived Unit hydrograph

Time	Derived Hourly UG coordinates
0	0
1	14
2	34
3	61
4	93
5	132
6	177
7	228
8	235
9	210
10	187
11	163
12	141
13	122
14	110

Time	Derived Hourly UG cordinates
15	100
16	89
17	80
18	71
19	62
20	54
21	47
22	40
23	33
24	26
25	20
26	13
27	7
28	0
	2549

Adopted Unit Hydrograph

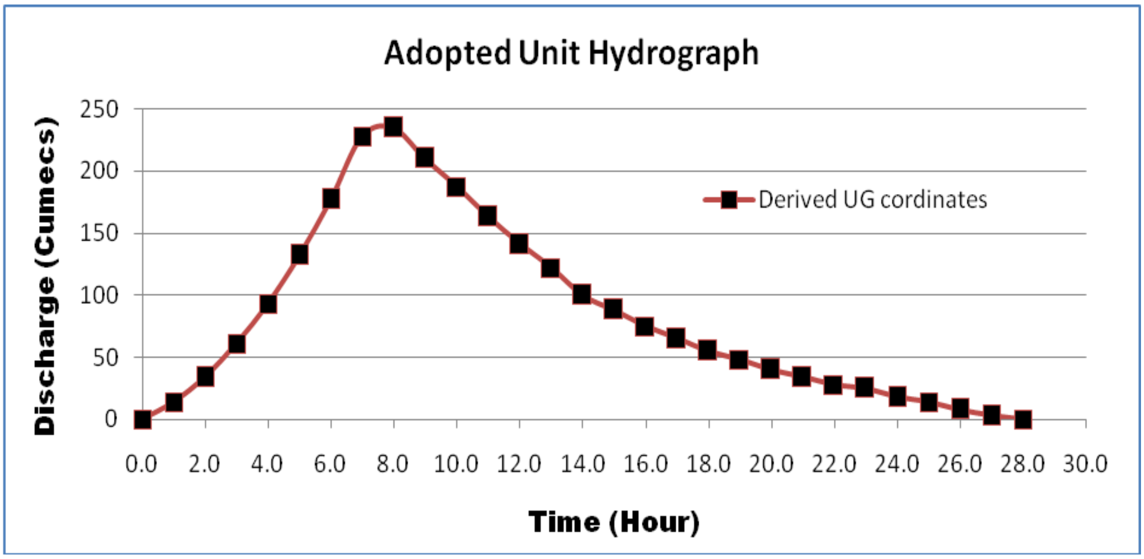

Fig 5.16 Adopted Unit Hydrograph

Table 9 ordinate of Adopted Unit Hydrograph Coordinates

After Adjustment		After Adjustment	
Time	UG coordinates	Time	UG cordinates
0.0	0	15	88
1.0	14	16	75
2.0	34	17	65
3.0	61	18	55
4.0	93	19	48
5.0	132	20	40
6.0	177	21	34
7.0	228	22	28
8.0	235	23	25
9.0	210	24	18
10	187	25	14
11	163	26	8
12	141	27	3
13	122	28	0
14	100		2398

5.2.2 Design value of Storm

IMD provides the 24 hours Standard Project Storm (SPS) and 24 hour Probable Maximum Precipitation (PMP) values for the the project area. As provided by IMD value of SPS is 35.5 cm and PMP is 42.2 cm. The 1-day design storm values are enhanced by 15% (as recommended by IMD) to convert them into any 24-hour value. The 24-hour SPS values for the project have been estimated to 40.82 cm. The temporal distribution of the design storm as provided by IMD is given Table 10**.**

Table 10 Temporal Distribution of 24-hour Design Storm

Time Distribuition Coefficient	
Duration	**% of 24 Hours Design Storm**
1	17
2	30
3	41
4	48
5	54
6	57
7	62
8	65
9	69
10	71
11	74
12	78

Time Distribuition Coefficient	
Duration	**% of 24 Hours Design Storm**
13	80
14	82
15	85
16	87
17	89
18	91
19	92
20	93
21	96
22	97
23	98
24	100

a) <u>Distribution of Design Storm</u>

Two bells of 12 hrs each have been considered as per current practices.

- 1^{st} Bell (78% of 24 hr rainfall).
- 2^{nd} Bell (22% of 24 hr rainfall).

b) <u>Loss Rate of runoff</u>

The design loss rate for the project has been assumed to be 0.24 cm/hr as per report of Subzone-2a.

c) **Rainfall Critical Sequencing**

It is done as per the prevailing practice. The critical Sequencing is done to keep the highest Rainfall next to maximum ordinate of Unit Hydrograph. for maximum peak this sequence must be reversed. The calculation for same is shown in Table-11.

Table 11 Critical & Reverse Critical Sequence of Rainfall Excess

1 day SPS =		35.5	cm	(Increased by 15% to convert 1-day values into 24-hour values**)**
24 hr SPS =		40.83	cm	
1st bell	78%	31.84	cm	
2nd bell	22%	8.982	cm	
Design loss rate as per sub zone 2a report=		0.24	cm/hr	

1st bell

Time (hrs)	% Distribution 12hrs	Cumulative Rainfall (cm)	Rainfall Incremental (cm)	Rainfall Excess Incremental (cm)	Critical	Reverse Critical
1	22	7.03	7.03	6.79	0.90	0.71
2	39	12.35	5.32	5.08	1.22	1.12
3	53	16.74	4.39	4.15	2.15	1.16
4	61	19.48	2.75	2.51	5.08	1.34
5	69	21.87	2.39	2.15	6.79	1.83
6	73	23.27	1.40	1.16	4.15	2.51
7	80	25.34	2.07	1.83	2.51	4.15
8	84	26.71	1.36	1.12	1.83	6.79
9	88	28.17	1.46	1.22	1.34	5.08
10	91	29.12	0.95	0.71	1.16	2.15
11	95	30.27	1.14	0.90	1.12	1.22

12	100	31.84	1.58	1.34	0.71	0.90
		2nd bell				
Time (hrs)	% Distribution 12hrs	Cumulative Rainfall (cm)	Rainfall Increment al (cm)	Rainfall Excess Incremental (cm)	Critical	Reverse Critical
1	22	1.98	1.98	1.74	0.08	0.03
2	39	3.48	1.50	1.26	0.17	0.14
3	53	4.72	1.24	1.00	0.43	0.15
4	61	5.50	0.77	0.53	1.26	0.21
5	69	6.17	0.67	0.43	1.74	0.34
6	73	6.56	0.39	0.15	1.00	0.53
7	80	7.15	0.58	0.34	0.53	1.00
8	84	7.53	0.38	0.14	0.34	1.74
9	88	7.95	0.41	0.17	0.21	1.26
10	91	8.21	0.27	0.03	0.15	0.43
11	95	8.54	0.32	0.08	0.14	0.17
12	100	8.98	0.45	0.21	0.03	0.08

d) <u>Base flow</u>

The base flow is taken @ 0.05 cumec/km^2 as specified in the report of subzone-2a. A Design discharge of 160 m^3/s from tail race of RHEP I is also added in the flood hydrograph to get inflow hydrographs. The base flow for the catchment has been estimated to 203 (43.17 + 160) cumec.

e) <u>Surface Flow Hydrograph</u>

Surface Flow Hydrograph has been evaluated by convoluting rainfall excess increments with Unit Hydrograph. Firstly Rainfall excess increments have been organized in a critical sequence. And then each of the individual incremental hydrographs has been lagged 1-hour from the previous one in the assumed critical sequence and added to find the surface flow hydrograph.

f) <u>Flood Hydrograph</u>

Flood hydrograph is generated by summing up the Base flow into surface hydrograph. Flood hydrograph for SPF thus obtained has been given in **Annexure-I.**

The Standard Project flood at the project site has been estimated to be **6000** cumec.

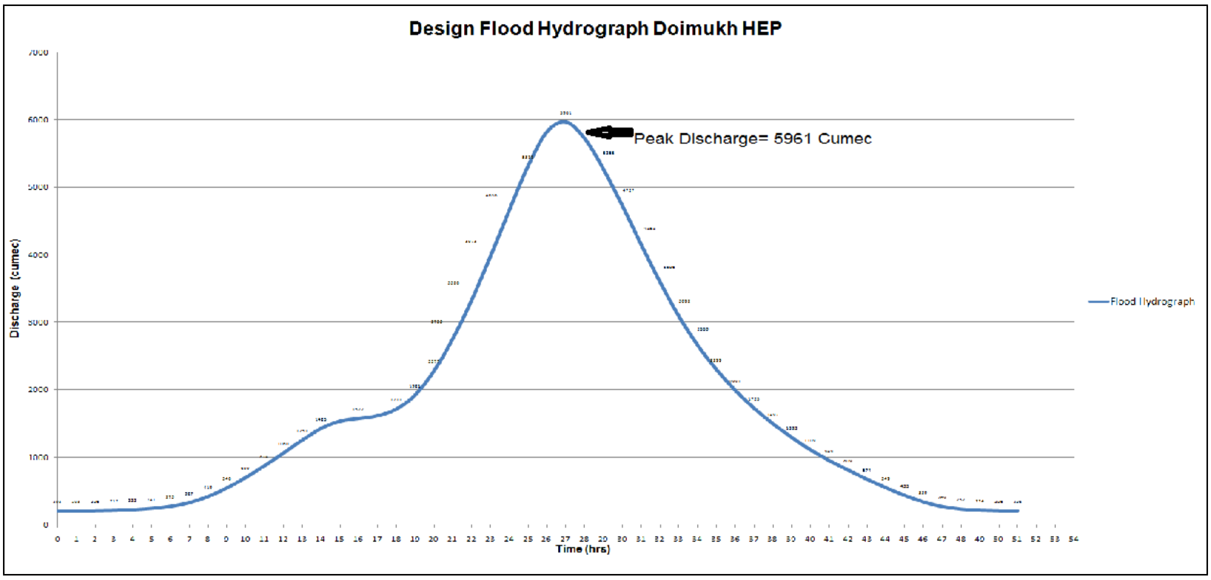

Fig 5.17 Flood Hydrograph of the Project

5.3 Design flood by Statistical Approach

Based upon the sample statistics the following frequency distribution has been considered:

1) Gumbel distribution (Attached as ***Annex-II***)
2) Log Normal distribution (Attached as ***Annex-III***)
3) Perason type III(Attached as ***Annex-IV***)

The result of all these above mentioned method for design flood, calculated from using the observed annual peak flood and it is presented in ***annexure - II, III & IV***. There comparison is also tabulated in ***annexure- V***.

CHAPTER 6

6 CONCLUSION

- From ASTER DEM image we delineated the catchment which contributes their discharge to our proposed project. Further we have identified the sub catchment. It helps in identify the sub stream & main stream of river.

- The geometry & geomorphologic parameters are precisely traced out in Arc-GIS. The catchment area, main stream, sub stream & their feature like length, slope is precisely found out with application of Arc-GIS. In convention method the centroid is located by Plumbline and Pin method. This may not be exact centroid.

- The chance of error is very less in case of using GIS & remote sensing Techniques if it is properly used.

- The design Flood discharge from Statistical method come out 2700 & 4100 cumec cumec (return period with 100 & 1000 years respectively) however in case of hydro metrological approach its come out approx 6000 cumec. This gives safer design discharge for design of structure. For safely design we adopt this value.

- In case of ungauged station the development of SUH and GIS techniques are only way to find out the satisfactory result of design discharge. The convention method not reliable at that particular situation.

It has acknowledge successfully that remote sensing and GIS can give the suitable platform for convergent of large volume of multi-disciplinary data. Various Catchments of the Indian as well as of developing countries do not have enough past records hydrological Data and detailed Catchment knowledge needed for analysis of conventional method. In that situation SUH can give a improved result for flood studies. Method of Arc-GIS & SUH based design flood evaluation is very helpful in fixation of capacity of reservoir, design of different component of hydrological structure of hydroelectric power project. Manpower as well time involve in analysis is substantially reduced so this technique is also beneficial in term of economics. It has high accuracy in finding the flood hydrograph for any basin / catchment (gauged or ungauged) as it utilizes DEM of the catchment that can be easily available from NASA website.

ANNEXURE

Annexure-I: Convolution of Unit Hydrograph with rainfall excess

Convolution of UG with rainfall excess

Catchment Area= 863.39 sqkm
Base Flow 0.05 cumecs/sqkm
Base Flow 43.17 cumecs

DIRECT SURFACE RUNOFF

Time	U.G	0.03	0.14	0.15	0.21	0.34	0.53	1.00	1.74	1.26	0.43	0.17	0.08	0.71	1.12	1.16	1.34	1.83	2.51	4.15	6.79	5.08	2.15	1.22	0.9	DSRO	Baseflow	time (hrs)	Flood hydrograph ordinates(cumecs)
0.0	0	0.0																								0	203	0	203
1.0	14	0.4	0.0																							0	203	1	203
2.0	34	1.0	2.0	0.0																						3	203	2	206
3.0	61	1.8	4.8	2.1	0.0																					9	203	3	212
4.0	93	2.8	8.5	5.1	2.9	0.0																				19	203	4	222
5.0	132	4.0	13.0	9.2	7.1	4.8	0.0																			38	203	5	241
6.0	177	5.3	18.5	14.0	12.8	11.6	7.4	0.0																		70	203	6	273
7.0	228	6.8	24.8	19.8	19.5	20.7	18.0	14.0	0.0																	124	203	7	327
8.0	235	7.1	31.9	26.6	27.7	31.6	32.3	34.0	24.4	0.0																216	203	8	419
9.0	210	6.3	32.9	34.2	37.2	44.9	49.3	61.0	59.2	17.6	0.0															343	203	9	546
10	187	5.6	29.4	35.3	47.9	60.2	70.0	93.0	106.1	42.8	6.0	0.0														496	203	10	699
11	163	4.9	26.2	31.5	49.4	77.5	93.8	132.0	161.8	76.9	14.6	2.4	0.0													671	203	11	874
12	141	4.2	22.8	28.1	44.1	79.9	120.8	177.0	229.7	117.2	26.2	5.8	1.1	0.0												857	203	12	1060
13	122	3.7	19.7	24.5	39.3	71.4	124.6	228.0	308.0	166.3	40.0	10.4	2.7	9.9	0.0											1048	203	13	1251
14	100	3.0	17.1	21.2	34.2	63.6	111.3	235.0	396.7	223.0	56.8	15.8	4.9	24.1	15.7	0.0										1222	203	14	1425
15	88	2.6	14.0	18.3	29.6	55.4	99.1	210.0	408.9	287.3	76.1	22.4	7.4	43.3	38.1	16.2	0.0									1329	203	15	1532
16	75	2.3	12.3	15.0	25.6	47.9	86.4	187.0	365.4	296.1	98.0	30.1	10.6	66.0	68.3	39.4	18.8	0.0								1369	203	16	1572
17	65	2.0	10.5	13.2	21.0	41.5	74.7	163.0	325.4	264.6	101.1	38.8	14.2	93.7	104.2	70.8	45.6	25.6	0.0							1410	203	17	1613
18	55	1.7	9.1	11.3	18.5	34.0	64.7	141.0	283.6	235.6	90.3	40.0	18.2	125.7	147.8	107.9	81.7	62.2	35.1	0.0						1508	203	18	1711
19	48	1.4	7.7	9.8	15.8	29.9	53.0	122.0	245.3	205.4	80.4	35.7	18.8	161.9	198.2	153.1	124.6	111.6	85.3	58.1	0.0					1718	203	19	1921
20	40	1.2	6.7	8.3	13.7	25.5	46.6	100.0	212.3	177.7	70.1	31.8	16.8	166.9	255.4	205.3	176.9	170.2	153.1	141.1	95.1	0.0				2074	203	20	2277
21	34	1.0	5.6	7.2	11.6	22.1	39.8	88.0	174.0	153.7	60.6	27.7	15.0	149.1	263.2	264.5	237.2	241.6	233.4	253.2	230.9	71.1	0.0			2550	203	21	2753
22	28	0.8	4.8	6.0	10.1	18.7	34.5	75.0	153.1	126.0	52.5	24.0	13.0	132.8	235.2	272.6	305.5	323.9	331.3	386.0	414.2	172.7	30.1	0.0		3123	203	22	3326
23	25	0.8	3.9	5.1	8.4	16.3	29.2	65.0	130.5	110.9	43.0	20.7	11.3	115.7	209.4	243.6	314.9	417.2	444.3	547.8	631.5	309.9	73.1	17.1	0.0	3770	203	23	3973
24	18	0.5	3.5	4.2	7.1	13.6	25.4	55.0	113.1	94.5	37.8	17.0	9.8	100.1	182.6	216.9	281.4	430.1	572.3	734.6	896.3	472.4	131.2	41.5	12.6	4453	203	24	4656
25	14	0.4	2.5	3.8	5.9	11.6	21.2	48.0	95.7	81.9	32.3	15.0	8.0	86.6	157.9	189.1	250.6	384.3	589.9	946.2	1201.8	670.6	200.0	74.4	30.6	5108	203	25	5311
26	8	0.2	2.0	2.7	5.3	9.5	18.0	40.0	83.5	69.3	28.0	12.8	7.0	71.0	136.6	163.6	218.4	342.2	527.1	975.3	1548.1	899.2	283.8	113.5	54.9	5612	203	26	5815
27	3	0.1	1.1	2.1	3.8	8.5	14.8	34.0	69.6	60.5	23.7	11.1	6.0	62.5	112.0	141.5	188.9	298.3	469.4	871.5	1595.7	1158.2	380.6	161.0	83.7	5758	203	27	5961
28	0	0.0	0.4	1.2	2.9	6.1	13.3	28.0	59.2	50.4	20.6	9.4	5.2	53.3	98.6	116.0	163.5	258.0	409.1	776.1	1425.9	1193.8	490.2	215.9	118.8	5516	203	28	5719
			0.0	0.5	1.7	4.8	9.5	25.0	48.7	42.8	17.2	8.2	4.4	46.2	84.0	102.1	134.0	223.3	353.9	676.5	1269.7	1066.8	505.3	278.2	159.3	5062	203	29	5265
				0.0	0.6	2.7	7.4	18.0	43.5	35.3	14.6	6.8	3.8	39.1	72.8	87.0	117.9	183.0	306.2	585.2	1106.8	950.0	451.5	286.7	205.2	4524	203	30	4727
					0.0	1.0	4.2	14.0	31.3	31.5	12.0	5.8	3.2	34.1	61.6	75.4	100.5	161.0	251.0	506.3	957.4	828.0	402.1	256.2	211.5	3948	203	31	4151
						0.0	1.6	8.0	24.4	22.7	10.8	4.8	2.7	28.4	53.8	63.8	87.1	137.3	220.9	415.0	828.4	716.3	350.5	228.1	189.0	3393	203	32	3596
							0.0	3.0	13.9	17.6	7.7	4.3	2.2	24.1	44.8	55.7	73.7	119.0	188.3	365.2	679.0	619.8	303.2	198.9	168.3	2889	203	33	3092
								0.0	5.2	10.1	6.0	3.1	2.0	19.9	38.1	46.4	64.3	100.7	163.2	311.3	597.5	508.0	262.3	172.0	146.7	2457	203	34	2660
									0.0	3.8	3.4	2.4	1.4	17.8	31.4	39.4	53.6	87.8	138.1	269.8	509.3	447.0	215.0	148.8	126.9	2096	203	35	2299
										0.0	1.3	1.4	1.1	12.8	28.0	32.5	45.6	73.2	120.5	228.3	441.4	381.0	189.2	122.0	109.8	1788	203	36	1991
											0.0	0.5	0.6	9.9	20.2	29.0	37.5	62.2	100.4	199.2	373.5	330.2	161.3	107.4	90.0	1522	203	37	1725
												0.0	0.2	5.7	15.7	20.9	33.5	51.2	85.3	166.0	325.9	279.4	139.8	91.5	79.2	1294	203	38	1497
													0.0	2.1	9.0	16.2	24.1	45.8	70.3	141.1	271.6	243.8	118.3	79.3	67.5	1089	203	39	1292
														0.0	3.4	9.3	18.8	32.9	62.8	116.2	230.9	203.2	103.2	67.1	58.5	906	203	40	1109
															0.0	3.5	10.7	25.6	45.2	103.8	190.1	172.7	86.0	58.6	49.5	746	203	41	949
																0.0	4.0	14.6	35.1	74.7	169.8	142.2	73.1	48.8	43.2	606	203	42	809
																	0.0	5.5	20.1	58.1	122.2	127.0	60.2	41.5	36.0	471	203	43	674
																		0.0	7.5	33.2	95.1	91.4	53.8	34.2	30.6	346	203	44	549
																			0.0	12.5	54.3	71.1	38.7	30.5	25.2	232	203	45	435
																				0.0	20.4	40.6	30.1	22.0	22.5	136	203	46	339
																					0.0	15.2	17.2	17.1	16.2	66	203	47	269
																						0.0	6.5	9.8	12.6	29	203	48	232
																							0.0	3.7	7.2	11	203	49	214
																								0.0	2.7	3	203	50	206
																									0.0	0	203	51	203

Annexure-II : Gumbel's Distribution

Yn at N=40	0.5436
Sn at N=40	1.1413
Mean=	881.21
Std deviation	440.62

Sr. No.	Value of X	Value of ln(X)	Plotting Position (%) according to WEIBULL	Tp	Yt	Kt	Xt
1	2471.3	7.81	2.44	41	3.7	3.22	2302.2
2	1851.2	7.52	4.88	20.5	3	2.52	1991.24
3	1589.9	7.37	7.32	13.67	2.58	2.1	1806.92
4	1496.3	7.31	9.76	10.25	2.28	1.8	1674.37
5	1464.3	7.29	12.2	8.2	2.04	1.56	1570.13
6	1299.3	7.17	14.63	6.83	1.84	1.37	1483.74
7	1249.3	7.13	17.07	5.86	1.68	1.2	1409.62
8	1225.9	7.11	19.51	5.13	1.53	1.05	1344.42
9	1118.4	7.02	21.95	4.56	1.39	0.92	1286.01
10	1094.1	7.00	24.39	4.1	1.27	0.8	1232.9
11	1058.2	6.96	26.83	3.73	1.16	0.69	1184.03
12	958.3	6.87	29.27	3.42	1.06	0.58	1138.63
13	950.1	6.86	31.71	3.15	0.96	0.49	1096.1
14	921.7	6.83	34.15	2.93	0.87	0.4	1055.97
15	858.3	6.75	36.59	2.73	0.79	0.31	1017.86
16	836.1	6.73	39.02	2.56	0.7	0.23	981.46
17	834.9	6.73	41.46	2.41	0.62	0.15	946.52
18	834.9	6.73	43.9	2.28	0.55	0.07	912.83
19	834.7	6.73	46.34	2.16	0.47	0	880.19
20	832	6.72	48.78	2.05	0.4	-0.07	848.43
21	795.6	6.68	51.22	1.95	0.33	-0.14	817.42
22	795.1	6.68	53.66	1.86	0.26	-0.21	787.01
23	756.4	6.63	56.1	1.78	0.19	-0.28	757.07

24	742.3	6.61	58.54	1.71	0.13	-0.35	727.49
25	672.1	6.51	60.98	1.64	0.06	-0.42	698.15
26	637	6.46	63.41	1.58	-0.01	-0.48	668.92
27	606.3	6.41	65.85	1.52	-0.07	-0.55	639.68
28	586.3	6.37	68.29	1.46	-0.14	-0.61	610.29
29	548.6	6.31	70.73	1.41	-0.21	-0.68	580.61
30	538.2	6.29	73.17	1.37	-0.27	-0.75	550.46
31	513.5	6.24	75.61	1.32	-0.34	-0.82	519.65
32	502.9	6.22	78.05	1.28	-0.42	-0.89	487.91
33	499.2	6.21	80.49	1.24	-0.49	-0.97	454.95
34	495.3	6.21	82.93	1.21	-0.57	-1.05	420.34
35	465.4	6.14	85.37	1.17	-0.65	-1.13	383.5
36	455	6.12	87.8	1.14	-0.74	-1.22	343.57
37	448.5	6.11	90.24	1.11	-0.84	-1.32	299.15
38	435.5	6.08	92.68	1.08	-0.96	-1.44	247.8
39	427.7	6.06	95.12	1.05	-1.11	-1.58	184.29
40	393.9	5.98	97.56	1.03	-1.31	-1.79	93.25

Gumbel's Distribution

Return Pd	Yt	KT	Xt(Flood Value)
10	2.25	1.77	1662.91
25	**3.2**	**2.72**	**2080.69**
100	4.6	4.12	2698.27
500	6.21	5.74	3409.19
1000	6.91	6.43	3714.83
10000	9.21	8.73	4729.6

Annexure-III: ***Flood frequency as per log normal distribution***

Mean of Log(X)	2.9						
Std. Dev of Log(X)	0.194						
Skew of Log(X)	0	Assumed as in normal distribution skew is zero					
1	2	3	4	5	6	7	
∑p	K	X=Avg+KS	Y=10^x	Oi	pi	Ei=n*pi	Tp
0.9999	-3.719	2.178	151	0	0.0001	0.004	1
0.9995	-3.2905	2.2612	182	0	0.0004	0.016	1
0.999	-3.0902	2.3001	200	0	0.0005	0.02	1
0.998	-2.8782	2.3413	219	0	0.001	0.04	1
0.995	-2.5758	2.4	251	0	0.003	0.12	1.01
0.99	-2.3264	2.4485	281	0	0.005	0.2	1.01
0.98	-2.0538	2.5015	317	0	0.01	0.4	1.02
0.975	-1.96	2.5197	331	0	0.005	0.2	1.03
0.96	-1.7507	2.5603	363	0	0.015	0.6	1.04
0.95	-1.6449	2.5809	381	0	0.01	0.4	1.05
0.9	-1.2816	2.6515	448	3	0.05	2	1.11
0.8	-0.8416	2.7369	546	8	0.1	4	1.25
0.7	-0.5244	2.7986	629	3	0.1	4	1.43
0.6	-0.2534	2.8512	710	2	0.1	4	1.67
0.5704	-0.1773	2.866	734	0	0.0296	1.184	1.75
0.5	0	2.9004	795	2	0.0704	2.816	2
0.4296	0.1773	2.9349	861	7	0.0704	2.816	2.33
0.4	0.2534	2.9496	891	1	0.0296	1.184	2.5
0.3	0.5244	3.0023	1005	3	0.1	4	3.33
0.2	0.8416	3.0639	1159	3	0.1	4	5
0.1	1.2816	3.1494	1411	3	0.1	4	10
0.05	1.6449	3.22	1659	3	0.05	2	20
0.04	1.7507	3.2405	1740	0	0.01	0.4	25

0.025	1.96	3.2812	1911	1	0.015	0.6	40
0.02	2.0538	3.2994	1992	0	0.005	0.2	50
0.01	2.3264	3.3523	2251	0	0.01	0.4	100
0.005	2.5758	3.4008	2517	1	0.005	0.2	200
0.002	2.8782	3.4595	2881	0	0.003	0.12	500
0.001	3.0902	3.5007	3168	0	0.001	0.04	1000
0.0005	3.2905	3.5397	3465	0	0.0005	0.02	2000
0.0001	3.719	3.6229	4197	0	0.0004	0.016	10000
0	---				0.0001	0.004	
	3.71902			40	1		

Log Normal Distribution (LN II) (Cs=0)				
Return Pd.		**Kz**	**Xz**	**Y=10^x(Flood)**
10		1.2816	3.1494	1411
25		1.7507	3.2405	1740
100		2.3264	3.3523	2251
500		2.8782	3.4595	2881
1000		3.0902	3.5007	3168
10000		3.719	3.6229	4197

Annexure-IV ***Flood frequency analysis as per Log-Pearson III Distribution***

Mean of Log(X)	2.9
Std. Dev of Log(X)	0.194
Skew ofLog(X)	0.442

1	2	3	4	5	6	7	
∑p	**K**	**X=Avg+KS**	**Y=10^x**	**Oi**	**pi**	**Ei=n*pi**	**Tp**
0.9999	-2.8991	2.3373	217	0	0.0001	0.004	1
0.9995	-2.6539	2.3849	243	0	0.0004	0.016	1
0.999	-2.5326	2.4084	256	0	0.0005	0.02	1
0.998	-2.3994	2.4343	272	0	0.001	0.04	1
0.995	-2.2009	2.4729	297	0	0.003	0.12	1.01
0.99	-2.0293	2.5062	321	1	0.005	0.2	1.01
0.98	-1.8336	2.5442	350	0	0.01	0.4	1.02
0.975	-1.7643	2.5577	361	0	0.005	0.2	1.03
0.96	-1.6057	2.5885	388	1	0.015	0.6	1.04
0.95	-1.5236	2.6045	402	0	0.01	0.4	1.05
0.9	-1.2311	2.6613	458	3	0.05	2	1.11
0.8	-0.8551	2.7343	542	5	0.1	4	1.25
0.7	-0.5687	2.79	617	1	0.1	4	1.43
0.6	-0.3136	2.8395	691	5	0.1	4	1.67
0.5704	-0.2404	2.8537	714	2	0.0296	1.184	1.75
0.5	-0.0665	2.8875	772	2	0.0704	2.816	2
0.4296	0.11154	2.9221	836	0	0.0704	2.816	2.33
0.4	0.18916	2.9372	865	2	0.0296	1.184	2.5
0.3	0.47228	2.9922	982	3	0.1	4	3.33
0.2	0.81638	3.059	1146	6	0.1	4	5
0.1	1.31671	3.1562	1433	4	0.1	4	10
0.05	1.75048	3.2405	1740	1	0.05	2	20
0.04	1.88039	3.2657	1844	0	0.01	0.4	25
0.025	2.14202	3.3165	2073	1	0.015	0.6	40
0.02	2.26133	3.3397	2186	1	0.005	0.2	50
0.01	2.61539	3.4085	2562	1	0.01	0.4	100
0.005	2.949	3.4733	2974	0	0.005	0.2	200
0.002	3.36566	3.5542	3583	0	0.003	0.12	500

0.001	3.66608	3.6126	4098	0	0.001	0.04	1000
0.0005	3.95605	3.6689	4666	0	0.0005	0.02	2000
0.0001	4.59687	3.7934	6215	0	0.0004	0.016	10000
0	---				0.0001	0.004	
	7.37151			**39**	**1**	40	

Log Pearson Type III (Cs= 0.4)			
Return Pd.	**Kz**	**Xz**	**Y=10^x(Flood)**
10	1.31671	3.1562	1433
25	1.8804	3.2657	1844
100	2.6154	3.4085	2562
500	3.3657	3.5542	3583
1000	3.6661	3.6126	4098
10000	4.5969	3.7934	6215

Annexure V Comparison of Flood frequency Results for different Return period

Return Period	Acc To Gumbel(EVI)	Acc. To Log Normal Type II	Acc. Log Pearson Type III
10	1662.91	1411	1433
25	2080.69	1740	1844
100	2698.27	2251	2562
500	3409.19	2881	3583
1000	3714.83	3168	4098
10000	4729.6	4197	6215

References

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1) ***Himanshu S.K., FISCA, Garg N., Rautela S., Anuja K.M. and Tiwari M*** *(Department of Civil Engineering, GEU, Dehradun, UK, INDIA) -" Remote Sensing and GIS Applications in Determination of Geomorphological Parameters and Design Flood for a Himalyan River Basin, India*

2) ***Priyanka Kumari and Sushil Kumar Himanshu*** *Estimation of Design Flood for Rivers of Saurashtra Region Contributing into the Gulf of Khambhat* **.**

3) ***S. W. Franks, C. J. White, and M. Gensen "****Estimating extreme flood events – assumptions, uncertainty and error"*

4) ***B Supraja, T Hemalatha and C Mahesh Babu*** *:- Estimation of Peak Discharge in an Ungauged Watershed Using GIUH Model Supported With GIS and RS.*

5) ***Luna Moni Dasa, Zahid Husain Qureshib*** *Flood Frequency Analysis for Jiya Dhol River of Brahmaputra Valley*

6) ***Bhadra A, Pnigrahi N, Singh R, Raghuwanshi NS, Mal BC, Tripathi MP.*** *Development of geomorphological instantaneous unit hydrograph model for scantly gauged watersheds, Environmental Modelling & Software. 2008; 23:1013-1025.*

7) ***Never Mujere*** *:Flood Frequency Analysis Using the Gumbel Distribution*

8) *Flood Frequency Analysis: Manual of hydrology Part-3 geological survey water supply paper*

9) *Flood estimation report for North Brahmaputra Basin (Subzone -2 (a) Prepared by* ***Central water Commission.***

10) *Engineering Hydrology by* ***K Subramanya***

11) *http://nptel.ac.in/courses/105102015/gis%20done/case%20study/watershed%20delineation%20by%20archydro.html*

12) ***Aster 30m resolution satellite data from NASA website*** *http://reverb.echo.nasa.gov/reverb/#utf8=%E2%9C%93&spatial_map=satellite&spatial_type=rectangle&spatial=26.083%2C%2093.772%2C%228.285%2C%2090.945*

13) ***Snyder FF.*** Synthetic Unit graphs, Transactions of American Geophysics Union, 19th Annual Meeting report,