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ESTIMATION OF GEOMORPHOLOGY PARAMETERS FOR SMALL CATCHMENTS USING GIS

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PREFACE

Quantitative analysis of landforms has acquired significance in the recent past for various developmental projects concerning hydrology, geology, soil erosion and conservation, forestry and agriculture. The physical features of a watershed help in predicting the stage of its development and runoff and soil loss productivity characteristics. It also helps in inter comparison of watersheds for the purpose of deciding priority areas in developmental planning and execution.

In this study geomorphologic characteristics of various bridge catchments of a subzone have been determined using GIS approach. For the present study Luni subzone 1(a) has been selected. The morphological parameters have been estimated using GIS for five catchments located in the subzone. Efforts have been made by many investigators to provide linkage between the response function in the form of Instantaneous hydrograph (IUH) and the various geomorphological characteristics. This approach is termed as Geomorphological Inatantaneous Unit Hydrograph (GIUH) approach. In one of the above bridge catchments GIUH based approach for design flood estimation has been applied.

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ABSTRACT

Stream channel morphology is literally the study of stream channel form and structure, but generally it is taken to mean their form and structures regarded as a whole or their collective morphology features. Systematic analysis of morphometry of any drainage basin and its stream system is of great importance in understanding hydrological behaviour of the basin. Geomorphologists have developed parameters, which describe the topology, the structure, the planform and the relief of stream networks.

The important geomorphological parameters which represent the linear, areal and slope aspects of the catchment are required to be evaluated either from Survey of India toposheets or from existing maps. Application of Geographic Information Systems (GIS) package provides an efficient and accurate means for evaluation of these characteristics. In this study geomorphologic characteristics of various bridge catchments using GIS, have been determined using GIS. For the present study Luni subzone 1(a) has been selected. The morphological parameters have been estimated using GIS for five catchments located in the subzone. GIUH based approach has been applied for one of the catchments and design flood has been estimated. The peak value of unit hydrograph obtained using this approach is comparable with the value given in Fllod estimation report for Luni sub zone 1(a) prepared by CWC.

1.0 INTRODUCTION

A river basin is made up of two interrelated systems: the channel network and the hillslopes. The hillslopes control the production of storm water runoff which, in turn, is transported through the channel network toward the basin outlet. The runoff-contributing areas of the hill-slopes are both a cause and an effect of the drainage network growth and development. The linking of the geomorphological parameters with the hydrological characteristics of the basin provides a simple way to understand the hydrologic behaviour of the different basins particularly of the ungauged basins. Before taking up the studies related with hydrologic simulations using the geomorphologic characteristics, the important geomorphological properties have to be quantified from the available topographical map of the basin.

In many hydrological studies such as design flood estimation, water availability studies and runoff estimation, geomorpho-logical characteristics have been frequently used, particularly in the regional studies, in order to make the required estimates for ungauged catchments. Some of the hydrological studies, wherein the different aspects of the geomorphological characteristics are utilized include: Regional unit hydrograph studies using geomorphological and physical characteristics of catchment, regional flood frequency analysis using geomorphological characteristics, development of geomorphological Instantaneous Unit Hydrograph (GIUH), application of geomor-phological parameters and physiographic characteristics in model studies.

The geomorphological properties which are important from the hydrological studies point of view include the linear, areal and relief aspect of the watersheds. The linear aspect includes stream order, stream number and length. The areal aspect includes stream area, length of overland flow, drainage density, and stream frequency. While Relief aspect includes channel gradient, composite profile, relief ratio and ruggedness number.

The quantitative analysis of channel networks began with Horton's (1945) method of classifying streams by order. He developed a system for ordering stream networks and derived laws relating the number and length of streams of different order. Strahler (1957) slightly revised Horton's classification scheme in which ordering procedure is based on the following rules:

i. Channels that originate at a source are defined to be first-order streams.

ii. When two streams of order ω join, a stream of order ω +1 is created.

iii. When two streams of different order join, the channel segment immediately downstream has the higher of the orders of the two combining streams.

The quantitative expressions of Horton's laws are:

Laws of stream numbers

$$N\omega/N\omega{+}1 = R_B$$

Laws of stream length

$$L\omega/L\omega{+}1 = R_L$$

Laws of stream areas

$$A\omega/A\omega{+}1 = R_A$$

Where Nω ia the number of streams of order ω , Where Lω is the mean length of the streams of order ω and Aω is the mean area of the basins of order ω, R_B, R_L and R_A represent the bifurcation ratio, the length ration and the area ratio whose values in nature are normally between 3 and 5 for R_B, between 1.5 and 3.5 for R_L and between 3 and 6 for R_A

Computation of the parameters required for morphometric analysis using manual methods like area measurement using dot grid method or using planimeter and length measurement using curvimeter are very tedious and time consuming. It is more difficult if the map is on higher scale like 1:50,000 and 1:25,000. The ordering, lengths, area and perimeter etc. can be easily estimated using Geographic Information System (GIS) technique. Use of GIS can not only make this task relatively easy but accurate as well.

In GIUH based approach, a unifying synthesis of the hydrological response of a catchment to surface runoff is attempted by linking the instantaneous unit hydrograph (IUH) with the geomorphological parameters of a basin. Equations of general character are derived which express the IUH as a function of Horton's numbers i.e. area ratio (R_a), bifurcation ratio (R_b) and length ratio (R_l) (Strahler, 1957); an internal scale parameter L_W denoting the length of highest order stream; and the peak velocity of streamflow V expected during the storm. The IUH is time varying in character for different storms.

The geomorphological theory of unit hydrograph (GIUH) was originated by Rodriguez-Iturbe and Valdes (1979), who rationally interpreted the runoff hydrograph in the frame work of travel time distribution explicitly accounting for geopmorphological structure of a basin. They have derived the basic equations for the GIUH of a third-order basin. The equations for higher-order can be derived with exactly the same framework. However, for basins of any order the peak q_{pg} and the time to peak t_{pg} , which are the most important characteristics of the GIUH, are worked out from the derived functional relationship of the GIUH as:

$$q_{pg} = 1.31 \quad R_L^{0.43} \; \left(\frac{V}{L_\Omega}\right) \qquad \text{...........(1)}$$

$$t_{pg} = 0.44 \quad R_L^{-0.38} \; \left(\frac{R_B}{R_A}\right)^{0.55} \; \left(\frac{L_\Omega}{V}\right) \qquad \text{...........(2)}$$

The above equations represent general relationships which allow the estimation of the peak and time to peak of the IUH for any watershed.

On multiplying Eq.(1) and Eq.(2) we get a non-dimensional term q_{pg}* t_{pg} as:

$$q_{pg} * t_{pg} = 0.5764 \quad \left(\frac{R_B}{R_A}\right)^{0.55} \; (R_L)^{0.05}$$

This term is not dependent upon the velocity and thereby on the storm characteristics and hence is a function of only the catchment characteristics.

For the dynamic parameter velocity (V), Rodriquez et al. (1979) in their studies assumed that the flow velocity at any given moment during the storm can be taken as constant throughout the basin. The characteristic velocity for the basin as a whole changes throughout as the storm progresses. For the derivation of GIUH, this can be taken as the velocity at the peak discharge time for a given rainfall-runoff event in a basin. However, for ungauged catchments the peak discharge is not known and so this criterion for estimation of velocity cannot be applied. In such a situation one possible approach could be estimation of velocity by using the relationship developed between the velocity and the rainfall excess intensity.

One advantage of the geomorpihc instantaenous unit hydrograph (GIUH) approach is the potential of deriving the UH using only the information obtainable from topographic maps or remote sensing, possibly linked with geographic information system (GIS) and digital elevation model (DEM). The input to a GIS may be remotely sensed data, digital models of the terrain, or point or aerial data compiled in the forms of maps, tables or reports. GIS provide a digital representation of watershed characterisation used in hydrologic modelling. Hydrologic applications of GIS have ranged from synthesis and characterization of hydrologic tendencies to prediction of response to hydrologic events (Tao and Kouwen,1989). A GIS can provide the basis for hydrologic modelling of ungauged catchments and for studying the hydrologic impact of physical changes within a catchment. The integration of GIS into hydrologic models follows one of the two approaches (i) to develop hydrologic models that operate within a GIS framework (Moore et al., 1987), (ii) to develop GIS techniques that partially parameterize existing hydrologic models (DeRoo et al.1989).

2.0 THE STUDY AREA AND DATA USED

2.1 The Study area

For the present study Luni basin subzone 1(a) has been chosen. The Luni basin subzone 1(a) lies approximately between East longitudes 68^0 and 76^0 and North latitudes 22^0 45' and 30^0.The subzone 1(a) is bounded by international boundary between India and Pakistan in the west, subzone 1(e) in the north, sub zone 3(a) in the south and sub zone 1(b) in the east.

The sub zone comprises of the Luni river basin covering 20% of the sub zonal area, Thar desert in the north region covering about 60% of the sub zonal area and "Rann of Kachch" in the south region covering remaining 20% of the sub zonal area. The sub zone being mostly arid, river channels in the region are generally small and shallow. All the rivers flowing through the sub zone either disappear in the sandy waters or the marshy land in "Runnof Kutch". The sub zone 1(a) has a total area of 2,05,624 Km, out of which 202422 Km lies in Rajasthan State and the remaining area of 3,202 Km lies in Gujarat State.

The Luni River is the only major river in the sub zone. It originates in Arvali hills and flows through the deserts of Western Rajasthan. It has the total basin area of 36,527 Km. This constitutes approximately 20% of the sub zonal area and the rest of the area (80%) comprises of Thar desert and marshy land. It covers a length of 482 Km and flowing towards east, disappears in the "Great Rann of Kachch.".

The catchment areas of major tributaries of the Luni river and its free drainage area are given in Table 1.

Table 1: Major tributories of Luni river

Sl.No.	Tributary	Catchment area in Km
1.	Jojri	1,453
2.	Gunai Mata-Khari	3,150
3.	Sagi	940
4.	Guhiya	3,652

5.	Khari-Hemawas	1,124
6.	Mithri	1,075
7.	Jawai	3,499
8.	Bandi	1,373
9.	Sukri	1,787

The extreme north west portion of sub zone has an elevation less than 150 meters. It increases towards east and the middle portion of the north east sector has an elevation ranging between 150 and 300 meters. It continues to increase further towards northeast and southeast, where the elevation varies between 300 and 600 meters. Towards extreme southwest fringe of the sub zone, where the "Great Runn of Kutch" is located, the elevation decreases and becomes less than 150 meters.

The southwest monsoon causes the rainfall in the sub zone from July to October. The normal annual rainfall varies from 175 to 800 mm. The variation of the mean annual temperature in the sub zone is not much. The mean annual temperature in the sub zone is of the order of 25.6 ^{0}C with slightly lower at Ajmer where it is around 25 ^{0}C. The Thar Desert contains mainly Rhegosolic soils with small pockets of Lithosolic soils in the areas adjoining Bikaner and Jaisalmer districts. The Luni catchment mainly contains submotane soils and strip of old alluvial soils from Alor to "Rann of Kachch".

The marshy land of the Rann of Kutch basically covers deltaic alluvial soils and a small area of red sandy soils and deep black soils towards south of the Kachch. The sub zone 1(a) has considerable area of wasteland. It has a small area of forests where the annual rainfall is of the order of 400 mm. The area adjoining Pakistan is most fertile with wheat as the major crop in addition to little areas of rice fields. Other major crops grown are millets and pulses.

For the present studies five-bridge catchment located in subzone 1(A) are taken and shown in Figure 1. The details of these catchments are given in Table 2.

Table 2: Bridge catchments of Luni subzone 1(a)

Sl. No.	Name of stream	Name of section where bridge is located	Railway bridge No./Site No.	G. Site Location	
				Long.	Lat.
1	Sukri	Beawar-Pali	Mot-3	73°43'51"	25°56'09"
2	Ungti	Pali-Sanderav	Mot-4	73°13'00"	25°21'15"
3	Gauriandi	Ajmer-Palanpur	527	73°57'35"	25°58'55"
4	Ungti	Ajmer-Palanpur	639	73°17'12"	25°18'36"
5	Balwana	Ajmer-Palanpur	672	73°17'40"	25°06'40"

2.2 Data used

For the present studies all the data base have been prepared using Survey of India toposheets at a scale of 1:50,000

The toposheets used for the present study are given in the following table

Table 3: Toposheets for the bridge catchments

Sl. No.	Bridge catchment No.	Toposheets No.
1	527	45 G/13, 45 K/1
2	672	45 G/4
3	639	45G/7
4	MOT3	45G/9,13, 45 K/1
5	MOT4	45 G/3,7

For applying GIUH based approach, storm data of bridge no. 527 was taken from

3.0 METHODOLOGY

In the present study morphological characteristics of five bridge catchments located in Luni sub zone has been carried out. GIUH based approach has been applied for one of these catchments.

3.1 ESTIMATION OF MORPHOLOGICAL/TOPOGRAPHICAL PARAMETERS

The GIS software used in the present study is Integrated Land and Water Information System (ILWIS). ILWIS stands for Integrated Land and Water Information System. It was developed at ITC, Enschede, and The Netherlands. ILWIS is a GIS that integrates image processing capabilities, tabular databases and conventional GIS characteristics. Data acquisition from aerospace images, an integral part of the system, enables effective monitoring. This is important in regions in which data is scarce or difficult to gather. The conceptualization of the system takes into account that not all GIS users have a thorough knowledge of computers.

A conversion program allows the importation of the remote sensing data, tabular data, raster maps and vector files in several other formats. Analog data can be transformed into vector format by means of a digitizing program, of which on screen digitizing, with any raster map of image as on screen underlay is one of the most important feature.

The 'Map Calculator' can execute complex modelling of features. The map calculator includes an easy to use modelling language and the possibility of using mathematical functions and macros. It integrates tabular and spatial databases. Complex procedures can be executed rapidly on portions of study area on the video memory. After evaluation and assessment of results, the procedure can be applied to the entire area. Tabular and spatial databases can be used independently and on integrated bases. The Table Calculator can perform calculations, queries and simple statistical analysis. Computational procedures and efficient use of system are improved by the appropriate use of modelling processes. Fast overlay procedures constitute one of the main characteristics of the system.

Image processing capabilities integrated with spatial modelling and tabular databases constitute a powerful tool. Together they enable a kind of analysis, which was not possible until recently. ILWIS also incorporates conventional image processing techniques such as filtering, geometric corrections and classification procedures. Special features of interpolation of point data and contour lines are also available to create DEMs (Digital Elevation Models). Special filters and functions are available to produce slope and aspect maps.

Data processing several basic image analysis capabilities, such as histogram manipulation, automatic stretch display, user defined filters, transfer function manipulation and other standard functions. It includes calculation of covariance and correlation matrices, eigenvalues and eigenvectors and other statistics. A user friendly sampling program allows sampling by pixel, feature space plot analysis and sample and class statistics. Several classifier algorithms can be used. Before classifying an entire image, the behaviour of the different classifiers can be compared through an interactive pixel classification routine.

The ILWIS menu is subdivided in several modules and submodules. A brief description of the functioality of the modules, sub-modules and menu options is given. There is not always a one-to-one relationship between menu options and program names and that some menu options can be found in different modules. There are six main modules namely Input, Vector, Raster, Tables, Output and Command. These modules are described below:

The boundary of all the four catchment and all the streams have been mapped at a scale of 1:50,000 from Survey of India toposheets. Also a contour map at the same scale was prepared. Both these maps were then converted to digital form using digitization and stored in ILWIS. Digitization, which is the most time consuming part of the analysis, was carried in parts to minimise the digitization errors. Then the digitized map was corrected for any type of error such as proper joining of the streams, proper overlaying of the segments etc. The system then edits the coverage and splits the stream of the higher order automatically at the point where they meet. Individual stream (segment) lengths are computed by default and stored in the order table alongwith the order of each stream. The area and perimeter of the basin can be computed after converting segment (boundary) map to polygon map. After converting the contour map into digital form, it was rasterised. Then interpolation from isolines was carried out on this map. This interpolated map gives the elevation at each point (pixel) in the basin.

3.2 EVALUATION OF GEOMORPHOLOGICAL CHARACTERISTICS

For stream order, Strahler's ordering system, has been followed. According to this ordering system, which is applied through ILWIS over the entire drainage network of the study area it is found that it is a seventh order basin. In the system, length of each stream is stored in a table. Then after adding length of each stream for a order we can get the total stream lengths of each order. The total stream length divided by the number of stream segment (N_u) of that order gives the mean stream length L_u for that order. The plot of logarithm of mean stream length (ordinate) as a function of order (abscissa) yields a set of points lying essentially along a straight line.

Horton's law of stream number states that the number of stream segments of each order is in inverse geometric sequence with order number i.e.

$$N_u = R_b^{u-k} \qquad \text{.......(1)}$$

Where k is the order of trunk segment, u is the stream order, N_u is the number of stream of order u and R_b is a constant called the bifurcation ratio. When logarthim of the number of streams is plotted against order it shows a linear relationship.

Horton inferred that mean drainage basin areas of progressively higher order should increase in a geometric sequence, as do stream lengths. The law of stream areas may written as :

$$A_u = A_1 R_a^{u-1} \qquad \text{.......(2)}$$

Where A_u is the mean area of basin of order u. The areas of fourth and higher order streams have been found by ILWIS. The areas of lower order basin was estimated using the relationship between area of any order and area of highest order as given below:

$$A_u = A_1\, R_b^{\,u-1}\, (R_{lb}^{\,u}-1)/(R_{lb}-1) \qquad \text{.......(3)}$$

Where A_1 is the mean area of first order basin R_b is the bifurcation ratio and R_{lb} is Horten's term for the length ratio to bifurcation ratio. In this relationship, only A_1 is unknown, so A_1 can be calculated. Now using the value of A_1 the other mean areas are computed.

Bifurcation, length and area ratios are calculated as the slope of the best fit lines through these plotted points given by the Horton's laws of stream numbers, lengths and areas respectively.

3.3 TIME AREA DIAGRAM

The time area methods were developed in recognition of the importance of the time distribution of rainfall on run-off in the hydrologic design of storage and regulation of works. The central idea in these methods is a time contour or an isochrone, The time area diagram, indicates the distribution of travel time of different parts of the watershed. In GIS environment the derivaton of TA diagram is significantly easier. Maidment (1993) used the GIS approach for derivation of TA diagram. In this study direction and velocity maps were generated in spatial form. A grid of flow direction was defined using a DEM of the watershed. In the present study due to non-availability of velocity components the above approach could not be adopted. The time area diagrams were prepared using the following approach:

- Measure the distance from the most upstream point in the basin to the outflow location along the principal watercourse.
- Preparation of time-area diagram is done by assuming that the time of travel between any two points is proportional to the distance and inversely proportional to the square root of the slope between them.

  $$T = KL/\sqrt{S} \qquad \text{.......(4)}$$

  Where t is time of travel

  L is the length of the stream

  S is the slope of the stream

  K is propotionality constant

- An initial estimate of the time of concentration may be obtained using the Kirpich's formula.

  $$t_c = 0.06628L^{0.77}H_{0.305} \qquad \text{.......(5)}$$

  Where t is concentration time in hours

  L is the length of stream in km

  H is the average slope of the stream

  Substituting the values of L and H in the above equation we get the value of time of concentration tc for each catchment

- This value of tc may be substituted in the above equation and then may be rearranged in the form:

  $$K = tc\sqrt{S_A}/L \qquad \text{.......(6)}$$

Substituting the known values of tc, L and SA in this equation the value of K may be computed.

- Knowing the value of constant of proportionality K the equation (5) may be used to calculate time of travel between the two points in the catchment. Starting from the basin outlet the time of travel of various points over the catchment is thus progressively calculated.
- All the values of the time of travels for each stream are then denoted on the map at the beginning of the stream. Now these points were transferred in the digital form. Using interpolation technique a map of time distribution was then drawn through these points.
- From the time distribution map values a map at an interval of 60 minutes was prepared. The area for each time interval was measured and these values were tabulated.

3.4 COMPUTATION OF DESIGN STORM

Since the rainfall-runoff records for this catchment is not available, recourse is made to obtain the synthetic unit hydrograph based on the regionalised regression equations recommended by the Central Water Commission, India. Catchment under study was located on plate -9 showing 50-yr 24-hr point rainfall (CWC,). The point rainfall was found to be 20.00 cm. The conversion factor of 0.668 was read from the report to convert the 50-yr 24-hr point rainfall to 50-yr 5-hr point rainfall. 50-yr 5-hr point rainfall was 13.6 cm. Areal reduction factor of 0.82 corresponding to the catchment area of 77.0 km2 for TD = 5-hr. was interpolated from the standard table for conversion of point rainfall to areal rainfall. 50-yr 5-hr areal rainfall thus worked out to be 11.15 cm.

The 50-yr 5-hr areal rainfall was split in to 1-hr rainfall increments using time distribution coefficients and the values are given in Table 3.

Table 4: Hourly rainfall increments

Duration	Distribution coefficient	Storm rainfall	Rainfall increments	Effective rainfall increments
1	0.56	6.24	6.24	5.74
2	0.76	8.47	2.24	1.74
3	0.88	9.81	1.34	0.84
4	0.95	10.60	0.79	0.29
5	1.00	11.15	0.55	0.05

3.5 GIUH BASED CLARK MODEL

In this study, the peak characteristics of the IUH as obtained in Eqs. (1) & (2) given in chapter 1, are utilised for the evaluation of Clark model parameters. Once the parameters of this GIUH based Clark model are known, the complete IUH may be derived. The step-by-step explanation of the procedure for estimating the design flood using the proposed approach is given here under:

- Excess rainfall hyetograph is computed either by uniform loss rate procedure or by SCS curve number method (Soil Conservation Service, 1971) or by any other suitable method.
- As mentioned above, the direct determination of the velocity, V, in Eqs. (1) & (2) is not possible for ungauged catchments. And so, a relationship between the equilibrium velocity and the excess rainfall intensity is developed. It is assumed that the velocities corresponding to discharges passing through the gauging section at different depths of water flow are known from observations. The steps involved in this approach are given below.
  (i) Let these velocities and discharges be the equilibrium velocities V and the corresponding equilibrium discharges Q_e.
  (ii) For these Q_e find the corresponding intensities i of excess rainfall from the expression:

$$i = \frac{Q_e}{0.2778A} \qquad \ldots\ldots(6)$$

Where A is the area of the catchment in km^2.

(iii) From the pairs of such V and i, develop the relationship between the equilibrium velocity and the rainfall excess intensity in the form: $V = a\, i^b$.

It is to be noted here that this approach though requires the information of discharges and velocities at the gauging site does not mean that it can be applied for the gauged catchments only. For the ungauged catchments too, this information may easily be obtained by gauging the stream intermittently for all ranges of depth of flow during one or two monsoon seasons. Also, it has been assumed here that the flow at the outlet is contributed from the whole catchment at the time of peak flow. This is a condition, which would invariably be satisfied for the design floods for any catchment.

- compute the time of concentration, T_c (in hours) using the equation:

$$T_c = 0.2778 \frac{L}{V} \qquad ......(7)$$

where L is the length of the main channel in kms..

V is the estimated velocity m/sec..

- Taking the time of concentration as computed in step(c), obtain the time-area diagram for the catchment at an hourly time interval with the help of non-dimensionalised plot between percent cumulative isochronal area and the percent time of travel.
- Compute the peak discharge (q_{pg}) of GIUH given by Eq.(1).
- Using Newton-Raphson's iterative procedure compute the value of the storage coefficient R such that the peak of the IUH by Clark model is equal to q_{pg} (within tolerable limits) obtained in step(e).
- Compute the instantaneous unit hydrograph (IUH) using the GIUH based Clark Model with the help of final values of storage coefficient (R) obtained in step (f) above, time of concentration (T_c) and the time-area diagram.
- Compute the D-hour unit hydrograph (UH) using the relationship between IUH and UH of D-hour.
- Convolute the design storm rainfall excess hyetograph with the unit hydrograph obtained in step (h) to obtain the standard project flood hydrograph.

3.6 COMPUTATION OF DESIGN FLOOD

The design storms computed using the method discussed under section 5.1 are used as inut to the GIUH model to compute the design flood hydrograph. The geomorphological parameters such as length of the main stream, bifurcation ratio, length ratio and area ratio alongwith the tiem area diagram are supplied to the model. Flood hydrograph corresponding to the supplied design storm are computed using the principle of superposition and principle of propotionality of the unit hydrograph. The computation for design flood direct surface runoff is performed using the convolution equation, which is given as

$$Q_i = \sum_{j=1}^{i} X_j U_{i-j+1} = \sum_{j=1}^{i} U_j X_{i-j+1} \qquad ....(8)$$

Where

X is the rainfall excess and U is the unit hydrograph ordinate.

i is the number of pulses of input

The excess rainfall is computed using the design loss rate over the design storm hydrograph. The computation of direct surface runoff uses the equtation No. 8 is added with design base flow to compute the design flood hydrograph ordinate.

4.0 ANALYSIS AND RESULTS

4.1 Morphological parameters

Different parameters for five bridge catchments have been prepared using the capability of ILWIS GIS package. The drainage network map and digital elevation model (DEM) of these catchments has been developed and shown in Fig. 2 to 11.

Table 4 to 8 given below provides the details of these geomorphological characteristics for all the bridge catchment. The values of bifurcation ration, length ratio and area ratios, which are non-dimensional characteristics, are within the limits, which have been reported in the literature.

Table 5 Geomorphological characteristics of bridge No. 527 catchment

Order	No. of streams	Average Length	Average area	Value of constants
1	204	0.526	0.1473	R_b=4.04 R_l=1.85 R_a=4.64
2	51	0.815	0.8676	
3	124	1.761	4.009	
4	34	6.29	17.13	
5	8	4.07	71.03	

Table 6 Geomorphological characteristics of bridge no. 672 catchment

Order	No. of streams	Average Length	Average area	Value of constants
1	48	0.543	0.2096	R_b=3.51 R_l=1.88 R_a=4.38
2	13	0.666	1.13	
3	5	1.328	4.708	
4	1	3.55	17.93	

Table 7 Geomorphological characteristics of bridge no. 639 catchment

Order	No. of streams	Average Length	Average area	Value of constants
1	22	1.05	0.686	R_b=4.69
2	5	2.11	5.23	R_l=2.94
3	1	9.04	30.44	R_a=6.661

Table 8 Geomorphological characteristics of bridge no. Mot 3 catchment

Order	No. of streams	Average Length	Average area	Value of constants
1	1101	0.467	0.1248	R_b=4.27 R_l=2.40 R_a=4.93
2	230	0.869	0.832	
3	58	1.62	4.275	
4	12	5.400	19.979	
5	2	28.655	89.455	
6	1	20.91	391.91	
7	1	16.82	712.66	

Table 9 Geomorphological characteristics of bridge no. Mot 4 catchment

Order	No. of streams	Average Length	Average area	Value of constants
1	2221	0.561	0.1476	R_b=3.65 R_l=1.88 R_a=4.032
2	523	0.751	0.8162	
3	124	1.790	3.50	
4	34	3.880	13.76	
5	8	4.850	52.05	
6	3	20.069	190.01	
7	1	16.82	712.66	

4.2 APPLICATION OF GIUH MODEL

From the bridge catchment for which geomorphological characteristics are described as above, one catchment no. 527 is considered for design flood estimation. For this GIUH based approach has been applied. The geomorphological parameters required for the present study i.e. Area, Length and Bifurcation ratios are already computed.

The time area diagram is one of the important inputs for running the GIUH based Clark model. It provides the shape of IUH without considering the storage effects of the catchment. The DEM data generated from ILWIS for catchment no. 527 are utilized to develop isochronal map for the catchment in which the isochrone are plotted at hourly interval. A time area diagram for Jawai dam catchment has been prepared taking the contributing area on Y- axis and time of travel on X-axis. For preparing the time area diagram also the capability of ILWIS package is utilized. The time area diagram for this catchment is shown in Fig. 12. In order to provide the flexibility in the interpolation of time area diagram a non-dimensional time area has been prepared taking t/tc on X-axis and a/ac (ratio of total contributing area and the catchment area) on Y-axis (Fig.13). The ordinate of the non-dimensional curves is used as input for the time area diagram. The data for design storm has been prepared using the methodology discussed in the chapter 3 under section 5.4

Each set of design storm data together with geomorphological characteristics, time area diagram and in initial parameter values are supplied to the GIUH based model and the model has been run. The velocity is one of the important parameter in the GIUH model. Methodology has been prepared elsewhere (Chowdhry et. al.) for the computation of the velocity using the limited stage discharge observations and hydraulic characteristics of Main River channel. Unfortunately for this site no historical records were available and also the information regarding the hydraulic characteristics were inadequate for evaluating the velocity. Under the circumstances reasonable values of velocity between 4 -5 m/s is utilised. The design flood estimated for the catchment no. 527 is 482.06 cumec and the flood hydrograph is shown in figure no 14. From the result we can see that the value of IUH peak is 100.33 cumec while GIUH peak is 100.36 cumec. From the CWC report the value of unit hydrograph peak is 130.49 cumec, which is comparable with the estimated value.

5.0 CONCLUSIONS

In the present study, morphological parameters for bridge catchments located in Luni zone has been estimated using GIS. Various morphological parameters, which are required for many hydrological studies, have been evaluated using GIS. The estimation of these parameters can be handled easily and more accurately using GIS system which otherwise is very tedious using manual methods.

In one of the catchment no. 527 of the Luni Sub-zone, GIUH based approach has been applied for computation of design flood. The peak of the design flood is comparable with the value given in the report prepared by CWC. Therefore it is observed that the GIUH and GIS based approach has potential application for the estimation of the design flood particularly for the ungauged catchments. This approach has added advantage over the conventional regional unit hydrograph technique as it derives the time variant unit hydrograph considering the storm characteristics and avoids the cumbersome procedure of developing the regional unit hydrograph.

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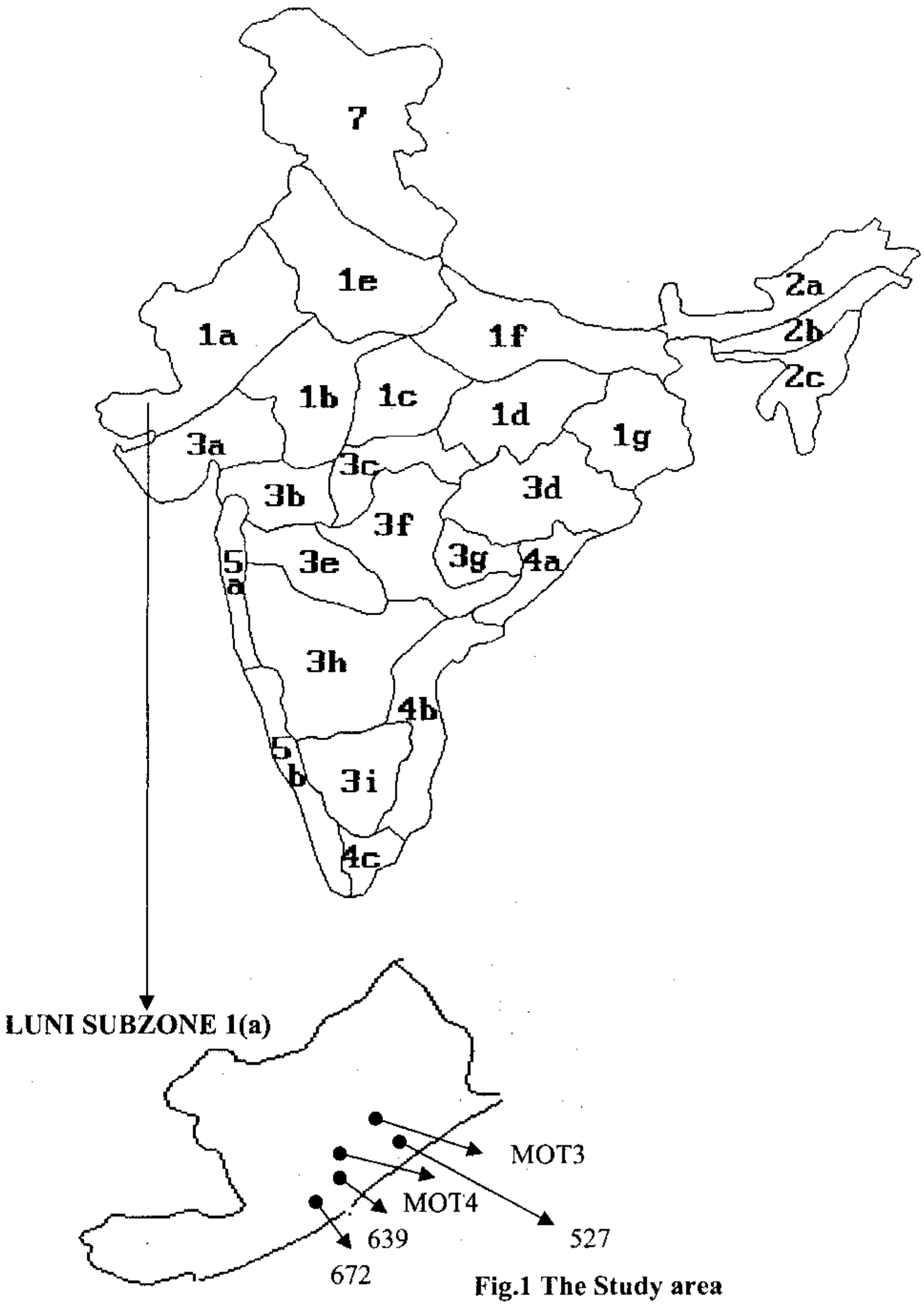


Fig.1 The Study area

Fig. 13 Time area diagram of bridge catchment no. 527

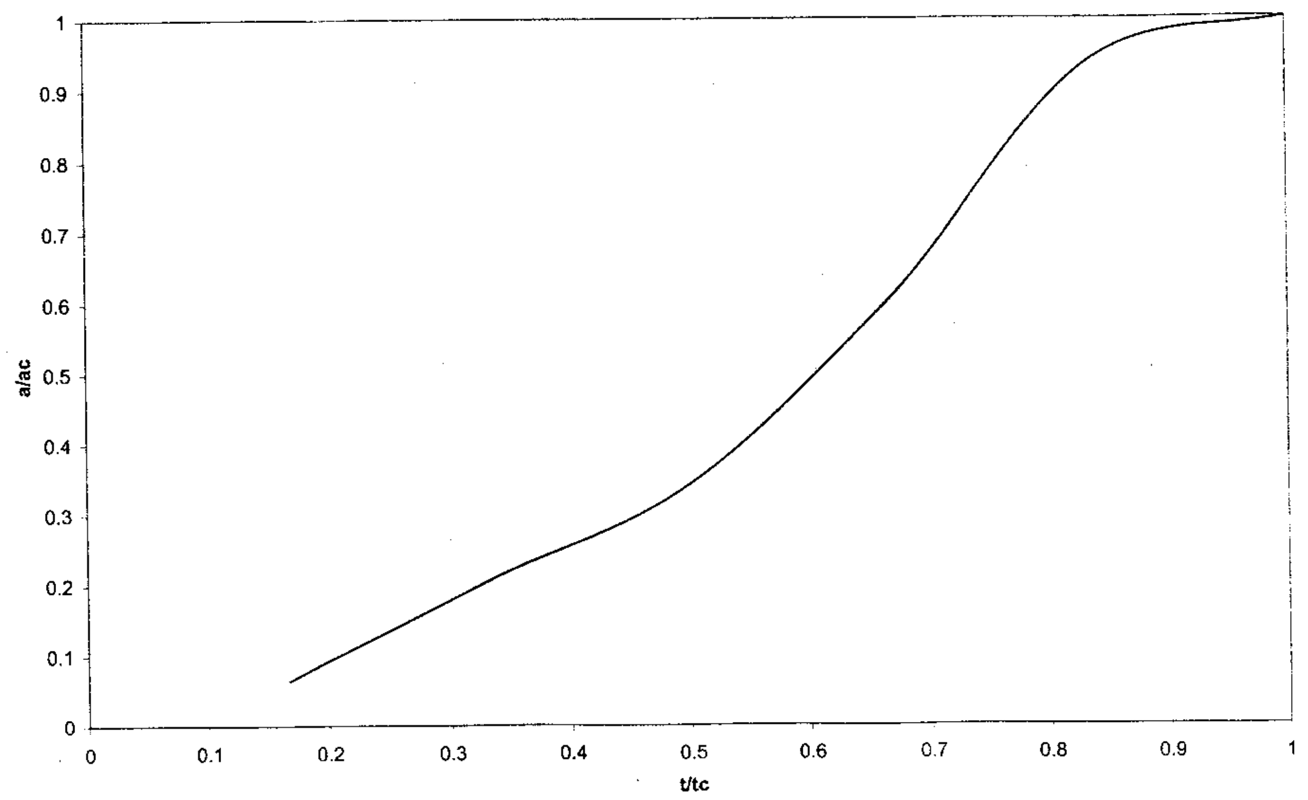
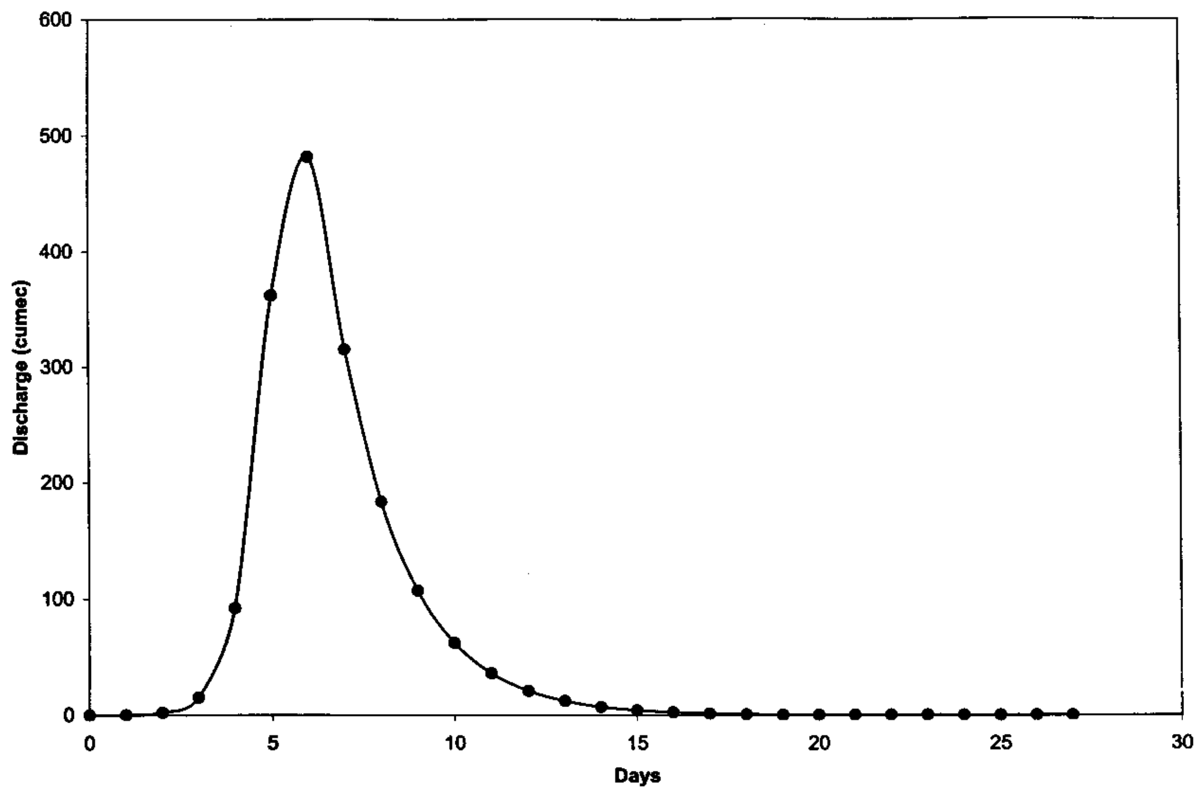


Fig. 14 Design flood hydrograph for bridge no. 527



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