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RESEARCH PAPER

Morphometric analysis of shel dedumal watershed using remote sensing remote sensing and GIS

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Abstract : Morphometric analysis is the measurements and mathematical analysis of the land surface configuration, shape and dimension of the landforms. The efficiency of the drainage network is very important for understanding the processes of landform formation, soil physical properties and erosion characteristics. The present study is focused on the evaluation of morphometric parameters for conversation of soil and water on delineated in the basin. Furthermore, morphometric analysis of watershed using geospatial data and GIS techniques and slope analysis were also utilized to propose the suitable soil and water conservation measures in the basin. The results obtained in the analysis revealed that the Shel Dedumal basin tributaries is an 5th order drainage basin which describe that the texture is homogeneous or homogeneity still exist and lack of structural control in soil strata. The relief ratio (R h), the elevation difference (R h or H) and circularity ratio (R c) was found to be 10.73, 222.0 and 0.42, respectively which represents the basin having moderate relief and gentle to moderately high slope. Some areas of the basin are characterized by variation in Lithology and topography. The mean values of bifurcation ratio (R b) observed as 4.52 and circularity ratio (R c) observed as 0.42 of the entire basins shows a moderate but not strong structural control or structural disturbances. An extreme high value of ruggedness number (R n) observed as 11.83 which indicate the structural complexity of the terrain. The Moderate drainage density (D d) and circularity ratio (R c) was observed as 2.63 and 0.42, respectively which indicates the basin is highly permeable subsoil and vegetative cover. The form factor (F f), the elongation ratio (R e) and circularity ratio (R c) was observed as 0.39, 0.71 and 0.42 respectively which is indicating elongated basin with lower / flatter peak flows of longer duration than the average and also the elongation ratio (R e) values indicating moderate to slightly steep ground slope in basin which is indicating possibility for soil erosion and other soil and water conservation works.

Key Words : Morphometric analysis, Shel dedumal, Watershed using remote sensing, GIS

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INTRODUCTION

Rapid growth in industrialization and wide expansion of urbanization has created a great pressure on land and water resources in India. About 53 % of the geographical area of the India is subjected to soil erosion and other forms of land degradation due to deforestation and other natural and anthropogenic activities (Biswas *et al.,* 1999

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and Kumar *et al.*, 2011). Therefore, there is great need for sustainable land and water management especially in the arid and semi-arid regions where there is inequity in demand and supply of water. In arid and semi-arid environment, watershed management is one of the best approaches for management of natural resources. The real challenge in planning and management of available natural resources at a small scale is due to requirement of high precision in data. The study of the river basin morphometry analysis provides the useful parameter for the assessment of the groundwater potential, surface and groundwater resource management, runoff and geographic characteristics of the drainage system. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape, dimension of its landforms (Clarke, 1966). The morphometry analysis includes the linear aspects and aerial aspects, in the linear aspects the stream ordering, stream length, stream length ratio, and bifurcation ratio and in the aerial aspect the drainage density, stream frequency, form factor, circulatory ratio, and elongated ratio. Morphometric analysis is the measurements and mathematical analysis of the land surface configuration, shape and dimension of the landforms (Adi Narayana *et al*., 1995).The efficiency of the drainage network is very important for understanding the processes of landform formation, soil physical properties and erosion characteristics (Malik *et al.,* 2011; Okumara and Araujo, 2014 and Rodrigo-Comino *et al.*, 2016) as it determines the runoff discharge such as land management (Tavares *et al*., 2016; Keesstra *et al*., 2016 and Mass link *et al.*, 2017). Natural drainage system characteristics in the form of morphology, topography, soil properties, etc. have direct impact on the site selection and execution of land and water conservation measures Jayswal *et al.* (2021).The present study is focused on prioritization of sub-watersheds based on the evaluated morphometric parameters for conversation of soil and water on delineated sub-watersheds in the basin. Furthermore, prioritization of watershed using geospatial data and GIS techniques and slope analysis were also utilized to propose the suitable soil and water conservation measures in the basin.

Objective :

– To prepare stream order map and slope map for the Shell Dedumal River Basin.

– To study various morphometric parameters for the Shell Dedumal River Basin using GIS techniques

Material and Methods

Location of study area :

Amreli district is one of the 33 administrative districts of the state of Gujarat in western India. The district headquarters are located at Amreli. The district occupies an area of 6,760 km^2 and has a population of 1,514,190 of which 22.45% were urban (as of 2011). The average annual temperature in the Amreli is 26.8 °C ; 80.2 °F. Precipitation here is about 585 mm; 23.0 inch per year. The study area falls under this district with area of 168 Km^2 and relatively flat relief terrain. A dam has been constructed over the Shell River in year 1999 for the storage of the runoff water produced in the Monsoon season. The location map of the study is is as shown in Fig. A.

A DEM of 30 m resolution was downloaded from the Bhuvan portal with specified location. For morphometric analysis drainage network was prepared by using ArcMap software with hydrology tool. The

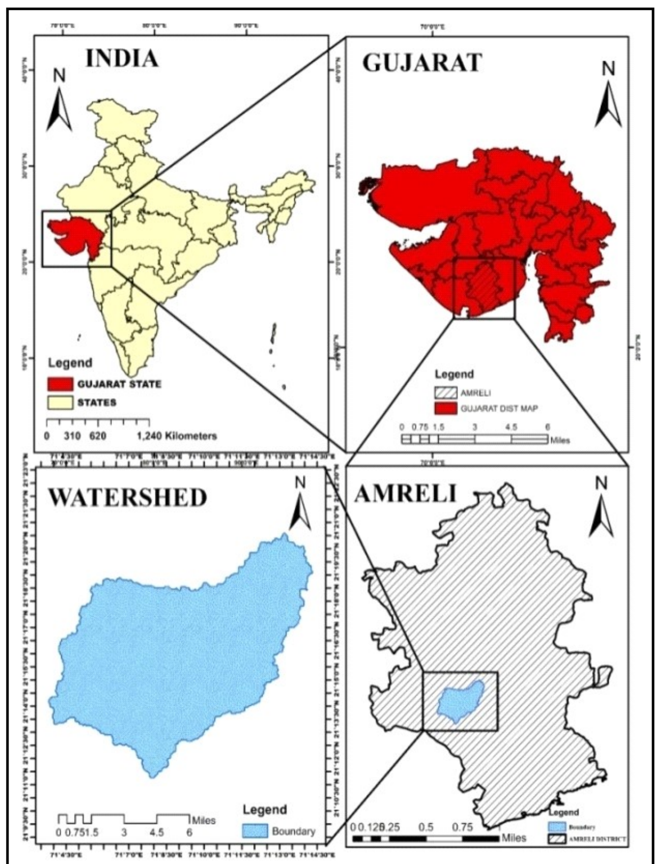

Fig. A : Location map

Table A : Morphometric parameters

Sr. No.	Morphometric parameters	Formula
1.	Stream order (N_u)	Hierarchical rank
2.	Stream length ratio (R_L)	$R_L=L_u/L_{u-1}$
3.	Bifurcation ratio (R_b)	$Rb=Nu/Nu_{+1}$
4.	Drainage density (Dd)	Dd=Lu/A
5.	Length of over land flow (L_g)	Lg=1/Dd*2
6.	Fitness ratio (R_{fn})	Rfn=Lb/p
7.	Circulatory ratio (R_c)	$R_c=4*pi*A/P^2$
8.	Elongation ratio (R_e)	$Re=(2/Lb)X(A/pi)^{0.5}$
9.	Form factor (R_f)	$R_f=A/L_b^2$
10.	Unity shape factor (R_u)	$Ru=Lb/A^{0.5}$
11.	Compactness co-efficient (C_c)	$Cc=0.2821*P/A^{0.5}$
12.	Drainage texture (R_t)	$R_t=Nu/P$
13.	Total relief (H)	$H=h_1-h_2$
14.	Relief ratio (R_h)	$R_h=H/L_b$
15.	Relative relief (R_p)	$R_p=H/P$

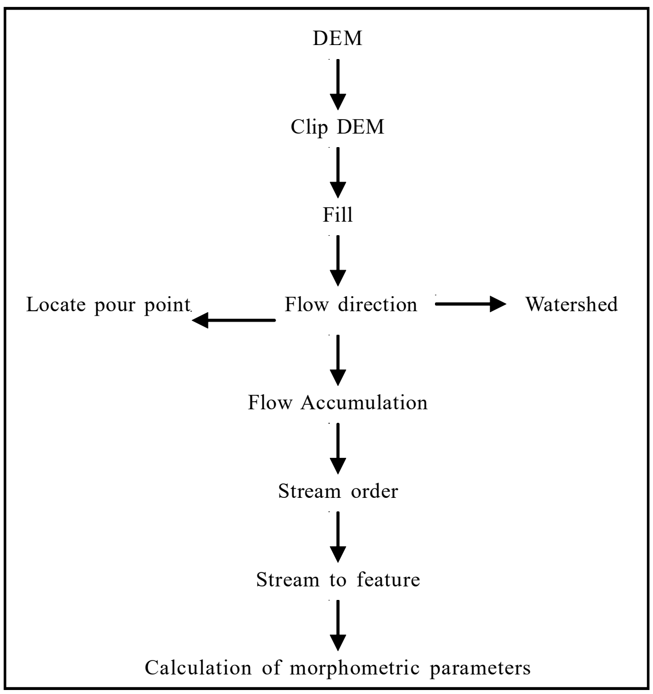

Fig. B: Flow chart for the steps of calculating morphometric parameters

process is shown in the flowchart Fig. B. various parameters were calculated using the standard formula for various morphometric parameters *i.e.,* stream orders, stream length ratio, unity shape factor, drainage texture by Horton (1945); bifurcation ratio, elongation ratio and relief ratio by Schumm (1956); drainage density, form factor, Horton (1932); fitness ratio, and relative relief by Melton(1957); circulatory ratio by Miller (1953); compactness coefficient by Strahler (1964)Total relief by Hardley and Schumm (1961). After drainage network preparation Morphometric tool was used for the further morphometric analysis using standard formula reviewed from the literature. The morphometric study was divided in to three parameter category as Liner aspect, Shape aspect and Relief aspect of the drainage basin.

Results and Discussion

The measurement and mathematical analysis of the configuration of the land forms, the shape and dimensions of its landform provides the basis of the investigation of maps for a geomorphological survey. This approach has recently been termed as Morphometry. The morphometric analysis of the Shell dedumal watershed was carried out scale 1:50,000 and ASTER-DEM with 30 m spatial resolution. The lengths of the streams, areas of the watershed were measured by using ArcGIS-10.5 software, and stream ordering has been generated using

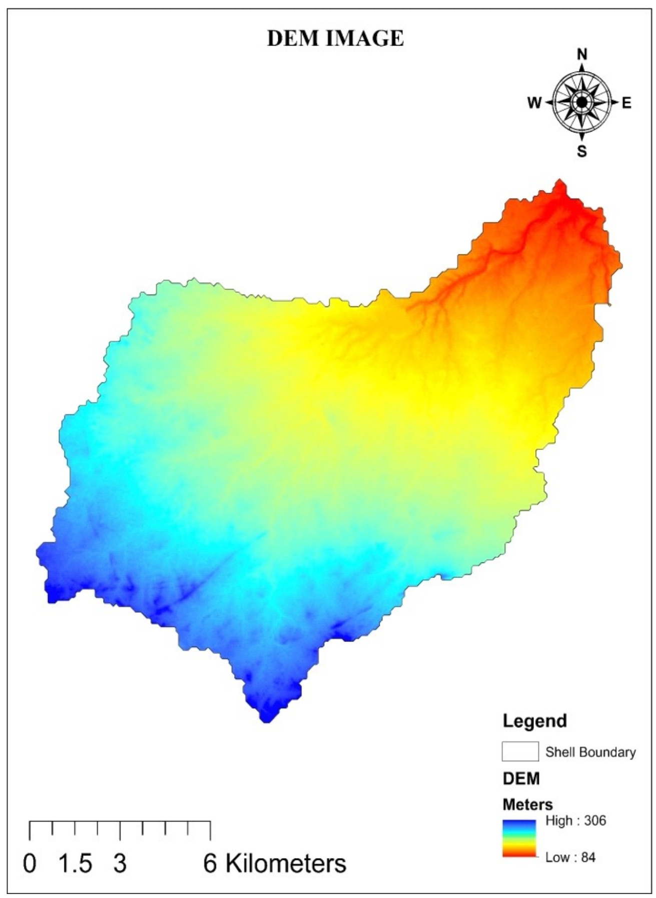

Fig. 1: Digital elevation model (DEM)

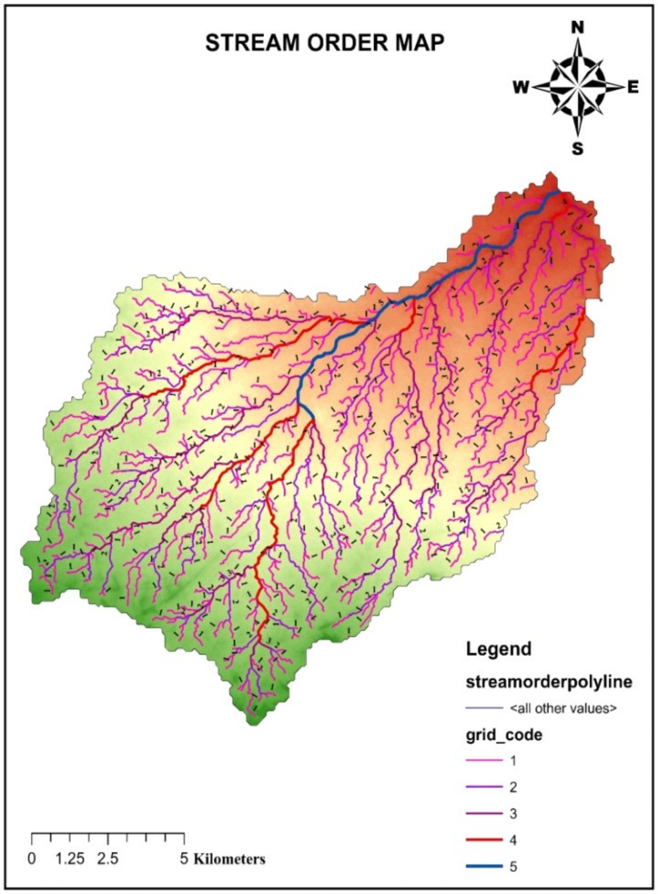

Fig. 2 : Stream order map of shell dedumal

Strahler (1953) system, and ArcHydro tool in ArcGIS-10.5 software. The morphometric parameters analysis was grouped into three categories related to their orientation in space. They are linear, aerial and relief aspects and calculated based on the formulae. The linear aspects were studied using the methods of Horton (1945), Strahler (1953), the areal aspects using those of Schumm (1956), Strahler (1956, 1968), Miller (1953) and Horton (1932), and the relief aspects employing the techniques of Horton (1945), Schumm (1954), and Strahler (1952). The linear aspect of the drainage basin, stream order, number of streams, length of stream, mean stream length and length of overland flow was calculated. The DEM Image for the study area is shown in Fig. 1, which shows the elevation distribution in the river basin.

The lowest elevation was as 84 m and the highest elevation was as 306 m. The stream was generated using DEM with ArcMap environment. The stream map was prepared using the drainage network as per shown in Fig 2. The estimated values of different parameters are as shown in Table 1. Stream ordering is the first step of quantitative analysis of the drainage basin.

The stream ordering systems was first advocated by Horton (1945), but Strahler (1952) has proposed some modification in ordering system. The designation of stream orders is the first step in drainage basin analysis and this stream ordering is based on the hierarchic ranking of streams proposed by Strahler (1964). In this first order streams have no tributaries, while second order streams have first order streams as a tributaries, third order streams have 1^{st} and 2^{nd} order streams as tributaries and so on. The drainage network in the study area was found as 5^{th} order. The total number of streams was found as 858. The number of streams of different orders in a watershed is counted and their length from mouth of the stream to the point on the drainage divide is measured with the help of ArcMap software.

Generally the total length of stream segment is maximum in first order streams and decreases as the stream order increases. The total length of the stream was found as 485.72 km and the length of the overland

Table 1 : Linear aspects of the shell dedumal river basin

Stream order	No of stream	Total length of streams (km)	Mean stream length	Length of overland flow
1	707	220.48	0.312	0.19
2	55	107.49	1.954	
3	42	71.78	1.709	
4	40	29.04	0.726	
5	14	12.57	0.898	
Total	858	485.72	-	

Table 2 : Bifurcation ratio and stream length ratio of the river basin

Bifurcation ratio (N_u/N_{u+1})					Stream length ratio (L_{u+1}/L_u)				
$1^{st}/2^{nd}$	$2^{nd}/3^{rd}$	$3^{rd}/4^{th}$	$4^{th}/5^{th}$	Mean	$2^{nd}/1^{st}$	$3^{rd}/2^{nd}$	$4^{th}/3^{rd}$	$5^{th}/4^{th}$	Mean
12.85	1.31	1.05	2.86	4.52	0.49	0.67	0.40	0.43	0.50

flow was observed as 0.19 km. The stream length ratio was found as 0.49, 0.67, 0.40, and 0.43 for 2nd/1st, 3rd/2nd, 4th/3rd and 5th/4th, respectively with mean stream length ratio as 0.50. The changes of stream length ratio from one order to another order are indicating their late youth stage of geomorphic development (Singh and Singh, 1997).

The high bifurcation value is the indication of complexity in structure (Nag and Chakroborty, 2003). Horton, 1945) considered the bifurcation ratio as an index of relief and dissections. The bifurcation ratio for 1st/2nd, 2nd/3rd, 3rd/4th and 4th/5th was 12.85, 1.31, 1.05, 2.86, respectively with the mean bifurcation ratio for the study area was observed as 4.52 for the drainage basin. The lower values of Rb are characteristics of the watersheds, which have suffered less structural disturbances (Strahler 1964) and the drainage pattern has not been distorted because of the structural disturbances (Nag, 1998). Irregularities in the bifurcation ratio are dependent on the geological ad lithological development of the drainage basin (Strahler, 1964). In the present study, the higher values of Rb indicates strong structural control on the drainage pattern, while the lower values indicative of watershed that are not affect by structural disturbances. The bifurcation ratio and stream length ratio are represented in Table 3 and 4.

In the aerial aspect of watershed study, parameters like drainage texture, fitness ratio, unity shape factor, drainage density, stream frequency, circulatory ratio, compactness co-efficient, form factor and elongation ratio was calculated. The values of different parameters related to aerial aspect are as per shown in Table 3.

Table 3: Aerial aspects of shell dedumal

Sr. No.	Parameter	Value
1.	Drainage texture (1/km)	12.07
2.	Fitness ratio	0.29
3.	Unity shape factor	1.60
4.	Drainage density (km/km^2)	2.63
5.	Stream frequency (1/km)	5.11
6.	Circulatory ratio	0.42
7.	Compactness co-efficient	1.55
8.	Form factor	0.39
9.	Elongation ratio	0.71
10.	Length of overland flow	0.19

Drainage texture is one of the important concept of geomorphology which means that the relative spacing of drainage lines. The drainage texture for watershed was found as 12.07. The texture ratio varies from 1.07 to 3.42. Texture ratio is classified into five classes *i.e.*, very coarse (greater than 2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (greater than 8). A watershed which has very fine texture or the highest value of drainage texture (>8) implies that it has more risk of soil erosion.Rate of water and sediment yield along the length and relief of the drainage basin is largely affected by the shape (Reddy *et al.,* 2015). It is the reciprocal of form factor. The shape index value of the watershed is 1.60.

Horton (1932) has introduced drainage density (Dd) as an expression to indicate the closeness of spacing of channels.Langbein (1947) stated that the significance of Drainage density as a factor determining the time of travel by water. Drainage density has a positive correlation with the stream frequency. Drainage density also gives an idea of the physical properties of the underlying rocks of the area. Drainage density in the area was found to be 2.63 km/km^2. High value of drainage density is indicative of less permeable material, sparse vegetative cover and moderate to high relief. Low drainage density generally results in areas of permeable sub-soil material, dense vegetation, low relief and coarse drainage texture (Nag, 1998) and Jayswal *et al*. (2021). High drainage density is resultant of impermeable subsurface medium, sparse vegetation, mountainous relief and fine drainage texture. Length of overland flow is a length of water over the ground before it gets concentrated into certain stream channels. Low value of Lg indicates high relief Vinutha (2014), short flow paths, more runoff and less infiltration, which leads to more vulnerable to the flash flooding Rai *et al.* (2017). Meanwhile, a high value of Lg means gentle slopes and long flow paths Rai *et al*. (2017), more infiltration, and reduced runoff Chandrashekar *et al.* (2015).

Compactness co-efficient denotes the relationship between actual hydrologic basins to the exact circular basin having the same area as that of the hydrologic basin. The $C\text{-}_c$ calculated for the study area was found

Table 4 : Relief aspects of shell dedumal

Relief parameters of basin			
Relief, m	Relief ratio	Relative relief	Ruggedness no
222.0	10.732	3.12	8.22

as 1.55. It is directly proportional to erosion risk assessment factor. A lower value of C_c signify less vulnerability risk factor, while higher values indicate great vulnerability and represents the need for implementation of conservation measures. Form factor value was calculated and it was found as 0.39 which indicates the elongated circular shape of basin and suggesting flatter peak flow with longer duration. The elongation ratio was calculated using standard formula and it was found as 0.71. According to Mustafa and Yusuf (1999), values of elongation ratio ranges from 0.4 to 1.0. Elongation ratio close to 1.0 is typically region of very low relief and sleep ground slope.T he change in slopes of the watershed can be classified according to Withanage et al. (2014) using elongation ratio, *i.e.* circular (0.9–0.10), oval (0.8–0.9), less elongated (0.7–0.8), elongated (0.5–0.7) and more elongated (less than 0.5) and also concluded that the Mustafa and Yusuf (1999) concluded that the flow of water in elongated shape basins is distributed over a longer period than in circular ones. The Shell Dedumal watershed found to be less elongated. Circulatory ratio for the basin was found to be 0.42, which suggests the basin is not perfectly circular in shape Jayswal *et al.* (2021).

The relief aspects of the watershed are related with three-dimensional features *i.e.* area, volume and altitude of topography to analyze different geo-hydrological characteristics. Difference in the elevation between the highest point of a watershed and the lowest point on the valley floor is known as relief of the water shed area and the ratio between relief and the longest dimension of the watershed parallel to the main drainage channel is known as relief ratio. Low value of relief ratios are due to resistant basement rock profile of the basin and very low degree slope. Relief ratio (Rr) gives indication of overall steepness of a drainage basin and the intensity of erosional process continued on the slope of the basin (Schumn 1956). The relief for the basin was found as 222.0 m and relief ration was estimated at 10.73. The maximum basin relief was obtained from the highest point on the watershed perimeter to the mouth of the stream. Relative relief for the basin comes to 3.12. The ruggedness number was found to be 8.22.

Conclusion :

Analysis of morphometry parameters comes to the following conclusions: The integral use of remote sensing data and GIS technique becomes helpful to find out the area which is affected by sedimentation process. From the morphometry analysis of basin, it has been found that the study area of Shell Dedumal basin tributaries is an 5th order drainage basin which describe that the texture is homogeneous or homogeneity still exist and lack of structural control in soil strata. From first to fifth order stream, stream length decreases hence gradient is increase from flat to steep as the stream order increases. The relief ratio (Rh), the elevation difference (Bh or H) and circularity ratio (Rc) represents the basin having moderate relief and gentle to moderately high slope. Some areas of the basin are characterized by variation in lithology and topography. The mean values of bifurcation ratio (Rb) and circularity ratio (Rc) of the entire basin shows a moderate but not strong structural control or structural disturbances. An extreme high value of ruggedness number (Rn) indicates the structural complexity of the terrain. The Moderate drainage density (Dd) and circularity ratio (Rc) indicates the basin is highly permeable subsoil and vegetative cover. The Form factor (Ff), the elongation ratio (Re) and circularity ratio (Rc) value indicating elongated basin with lower / flatter peak flows of longer duration than the average. The elongation ratio (Re) values indicating moderate to slightly steep ground slope. The overland flow (Lg) value of study area indicating old topography. This methodology should also have adopted for other neighbouring watershed areas which are also contributing erosion at Shel Dedumal watershed site.

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