

# Morphometric and Hydrological Analysis of North East Punjab Region: With Special Reference to Groundwater Management

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**Abstract-** Water is extremely crucial for the human being and economy of the country. Almost every industry from agriculture, hydropower and industrial manufacturing to production of readymade food and tourism relies on water to grow. Continuous population growth and economic development has significantly increased the agricultural and industrial water demand. Watershed development and management is one of solutions to such problems. To prepare a comprehensive watershed development plan, it becomes necessary to understand the topography, erosional status and drainage pattern of the area. A comprehensive study of watershed for south west Punjab region was carried out. This watershed region has the total area of approximately 4161.132 km<sup>2</sup>. The morphometric parameters are computed by using Geographic Information system (GIS). GIS was used in evaluation of linear and aerial aspects of morphometric parameters. The drainage patterns of the basin are dendritic and include a third order stream. In this study an attempt has been made to develop a recharge plan for the entire study area by locating the suitable site of recharge and recharge structures.

## I. INTRODUCTION

In most of the regions of the world water is already over-appropriated. Approximately one-third of the world's population roughly 2.4 billion people, live in water-stressed countries and by 2025 the number is expected to rise to two-thirds (UN-FAO, 2007). In India Punjab region is one of the most agricultural productive region. It is located in the North West part of India and has an area of about 50,362 km<sup>2</sup> and having an annual rainfall of 780 mm. Entire Punjab state is underlain by thick quaternary alluvium. Due to continuous escalating population and water demand most of the surface and groundwater resources are depleting very fast. Groundwater tables and river levels are receding in many parts of the Punjab due to human water use. One of the major reasons for increasing the water scarcity in the region is changes in precipitation patterns and intensity. Drastically reduced precipitation in some regions has causes exponentially larger depletion in groundwater tables. Temperature increase changes like precipitation patterns, frequent severe weather events, and prolonged droughts are affecting the agriculture production.

In near future it will be difficult to satisfy the growing water and food demand because climate change is escalating problems like soil salinity, soil erosion, and desertification.

Moreover continuous depletion in water table is recorded along with deterioration in water quality.

The decrease in the crop yield will further increase the already increased food inflation in India. This condition can only be improved by preventing the depletion of water resources and increasing the crop yield. In this study morphometric analysis of a minor watershed of North east Punjab region was carried out. This paper locates the suitable location of artificial groundwater recharge in the study areas to satisfy the demand of water for domestic, irrigational and industrial sector. The paper also suggests a road map for long-term and near-term mitigation and adaptation strategies for minimizing the impact of climate change on water resources.

## II. OBJECTIVES

**Some of the major objects of the study area are as follows:**

- To derive the different drainage aspects of North east Punjab region and to understand the relationship of the drainage networking.
- To study the quantitative analysis of drainage system.
- To develop a recharge plan for entire watershed basin and describe different morphometric analysis.
- To develop a road map for long term and near-term mitigation and adaptation plan for water resource management of the region.

## III. WATERSHED AREA

Geologically most of the area of the Punjab state is represented by the Quaternary sediments differentiated into older alluvium and younger alluvium. The soils in the watershed area are micaceous. The average annual rainfall in Punjab is around 780 mm. Punjab is also called state of lakes and rivers. There are five rivers namely Beas, Sutlej, Ravi, Chenab and Jhelum in Punjab that drains the fertile lands. Despite plenty of water resources in Punjab the state fails to satisfy the growing demand of water. Figure 1 shows the location of selected water in the Indian continent. The watershed taken for the study covers an area of 4161.132 km<sup>2</sup>.

## IV. METHODOLOGY

For the morphometric analysis a minor-watershed basin area was taken. Watershed map was modified using GIS software

Roita Geomatica 10.3.2 and stream orders were calculated by following standard drainage network analysis method described by laws of Horton (1945) and Strahler (1964). The quantitative analysis of the basin which include stream orders, stream numbers, stream lengths, bifurcation ratio, basin circularity, drainage density, drainage frequency, drainage texture, etc., have

been analyzed through use of a Geomatica software that determines the geomorphic stage of development of the area. Figure 1 shows watershed map of the North east Punjab region and suitable location of different recharge structures.

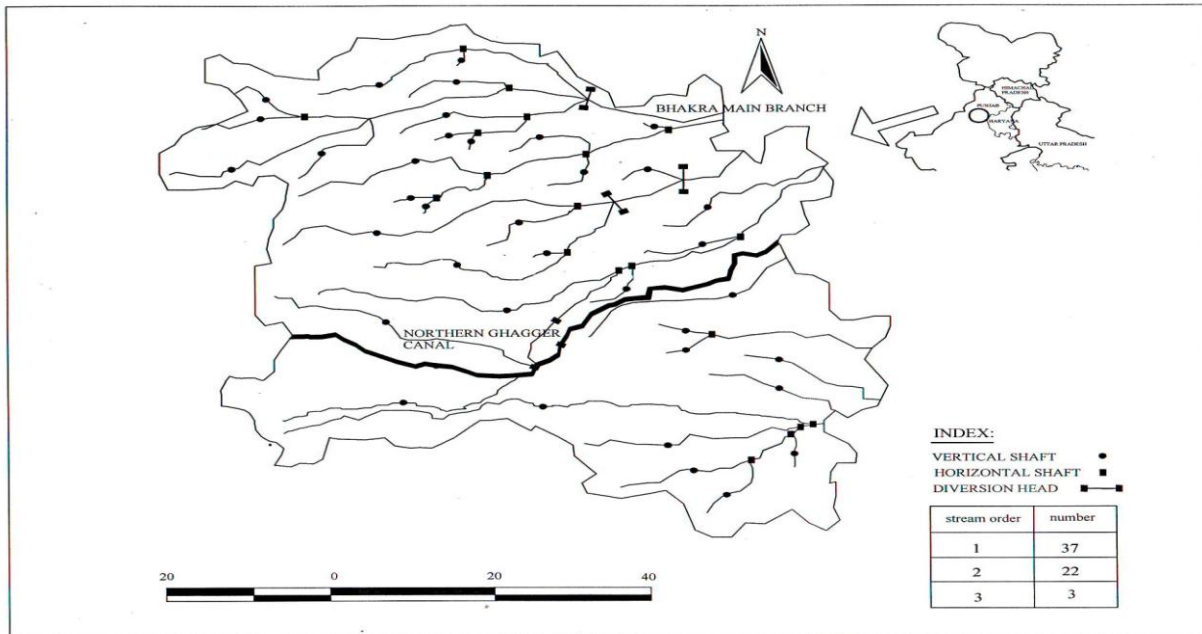


Figure 1. Drainage map of north east Punjab region, showing natural and man-made drainage (Source: Base maps Google Image).

## V. SOME IMPORTANT ASPECTS OF MORPHOMETRIC ANALYSIS

### Stream Order:

The streams of the basin have been ranked according to the method described by Strahler, when two first order streams join, a stream segment of second order is formed; when two second order streams join, a segment of third order is formed, and so on. The study area is a third order drainage basin.

### Bifurcation ratio:

Bifurcation ratio is the ratio of the number of streams of an order to the number streams of the next higher order (Horton, 1945), Bifurcation ratios are related to the structural control on the drainage (Nautiyal, 1994; Strahler, 1964; Chow, 1964). The bifurcation ratio for 2<sup>nd</sup> order, and 3<sup>rd</sup> order, streams measured are 1.68 and 7.33 respectively.

### Stream Length (Lu):

It is one of the most significant hydrological features of the basin as it gives surface runoff characteristics of streams. Longer lengths of streams are generally indicative of flatter gradients. Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases. Total stream lengths of different streams are mentioned in table 1.

### Basin area:

The basin area (A) is defined as the total area projected upon a horizontal plane contributing to cumulate of all order of basins. Basin area is extremely important from the hydrological point of view as it directly affects the size of the storm hydrograph and the magnitudes of peak and mean runoff. It is interesting that the maximum flood discharge per unit area is inversely related to size. The total area of the watershed was recorded 4161 km<sup>2</sup>.

### Drainage Density (D):

Drainage density (D) is an important indicator of the linear scale of land form elements in stream eroded topography (Horton 1932). It is the ratio of total channel segment lengths cumulated for all orders within a basin to the basin area. It indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. The total drainage density (D) for watershed area was recorded around 0.122

### Texture Ratio (T):

It is one of the important factors in the drainage morphometric analysis that depends on the underlying lithological conditions, porosity and permeability, infiltration capacity and topography of the terrain. In the present study the texture ratio of the watershed area was recorded 0.1436. Table 2

shows the outcome of different morphometric parameters recorded for the North-east Punjab region watershed.

**Table 1. Outcome of measurement of total stream length and bifurcation ratio**

STREAM ORDER	NO. OF STREAMS	NO. OF STREAM %	TOTAL LENGTH (Km)	MEAN LENGTH (Km)	BIFURCATION RATIO
1	37	59.68	318.17	8.60	—
2	22	35.48	158.93	7.22	1.68
3	3	4.84	30.56	10.19	7.33
TOTAL	62		507.66		

**Table 2. Different morphometric parameters of North-east Punjab region watershed.**

S.No.	Morphometric Parameters	Symbol / Formula	Values
1.	Area (sq. km)	A	4161.132
2.	Perimeter (km)	P	257.634
3.	Drainage density (km/sq. km)	$D = Lu \div A$	0.122
4.	Stream frequency	$F_s = Nu \div A$	0.015
5.	Texture ratio	$T = N1 \div P$	0.1436
6.	Basin length	Lb	65.88
7.	Elongation ratio	$Re = (A/\pi)^{0.5} / Lb$	0.552
8.	Circulatory ratio	$Rc = 4\pi A / (P)^2$	0.78
9.	Form factor ratio	$Rf = A \div (Lb)^2$	0.95

#### VI. AVAILABILITY OF WATER RESOURCES IN THE REGION

Punjab state is located just above the Haryana state and is mainly underlain by quaternary alluvium of considerable thickness. States average annual rainfall is approximately 780 mm. Punjab state is also called state of lakes and rivers. There are five rivers namely Beas, Sutlej, Ravi, Chenab and Jhelum in Punjab that drains the fertile lands. Despite the presence of several rivers and other water resources Punjab fails to satisfy the growing demand of water for domestic, irrigational and industrial purposes. To fulfill the escalating demand and preventing the continuous degradation of ground water resource in Punjab, ground water recharge and management is the only solution. Out of the total 138 of the state, 93 blocks have turned Dark (critical blocks) where the under ground water development has crossed 100%.

**Table 3. Available water resources of Punjab district (Source: Jain, A.K. and Raj Kumar, 2010)**

Annual canal water available at H/w	1.79 M ha-m
Annual canal water available at outlets	1.45 M ha-m
Annual ground water available	2.03 M ha-m
Total annual available water resources	3.48 M ha-m
Annual water demand	4.76 M ha-m
<b>Annual water deficit</b>	<b>1.28 M ha-m</b>

**Table 4. Escalation of over-exploited, critical and semi-critical blocks in study area ((Source: Jain, A.K. and Raj Kumar, 2010).**

CATEGORY	2000	2005	2010
Over-exploited (Dark)	73	103	110
Critical	11	5	3
Semi Critical	16	4	2
Safe	38	25	23

Punjab is one of the most intensively cultivated and an irrigated area of India with approximately 84% of the total geographical area under agricultural use. About 35% area is suffering with some kinds of soil degradation problems along with decreasing water table problems. In some areas especially in the central Punjab water table has gone down below critical depth of 10m with 3% in 1973, 25% in 1990 and 46% in 1994. It's now become imperative to take urgent steps to conserve the available ground water and increasing the recharge of ground water resources.

#### VII. CONCLUSION AND RECOMMENDATION

Declining water quality is an acute problem with notable decrease in agricultural and industrial production, coupled with a lack of adequate wastewater treatment. Many rivers in the Punjab

are so badly polluted that not even industry can use the water. Rising water demand and the lack of water management schemes have badly affected the region. The watershed area shows that the entire catchment area of the watershed is the part of fluvial system and is dominated by 1<sup>st</sup> and 2<sup>nd</sup> order stream. The development of the stream segments in the watershed area is more or less affected by rainfall. The general topographic gradient of the entire area is towards north east.

The findings of the study demonstrated following points:

- In entire study area natural water storage capacity has decreased and subsequently long-term water availability has also reduced
- Entire watershed area is facing frequent droughts and flood situation. Water scarcity problems has increased manifold, due to changes in precipitation patterns and intensity. Both droughts and episodes of regional-scale flooding can both be linked to the large-scale atmospheric circulation patterns in the region and often occur simultaneously in different parts of the study area compounding their impact on human activities.
- Depletion of water resources has affected the agriculture production that has gone down and food inflation has escalated manifold.
- A comprehensive recharge plan is needed for entire Punjab region

The following recommendations are proposed to tackle the existing problems:

- More research is needed to improve existing capabilities of weather forecast related with short- and long-term drought conditions and to make this information more useful and timely for decision making.
- With time, significant land-cover changes have occurred in response to persistent droughts, and the role of land-cover changes in amplifying or damping drought conditions should be thoroughly analyzed.
- To increase the awareness about the ecological impacts and affect of over drafting of water withdrawal and discharge should be thoroughly studied.
- More studies are required for agricultural sector and adaptation of improved irrigation techniques to cope with drought, and new plant varieties which are resistant to drought or to salt water.
- Increase practice of recycling and reuse of wastewater especially for irrigational purposes. It should be implemented in the entire study area.
- Artificial recharge structures should be constructed. Awareness should also be raised among the people by taking the help of media and NGO's regarding climate and water conservation education and development
- There has been drastic change in the land use and land cover of study area. To minimize further changes in

land-use pattern strict rules and regulations should be formed and adopted.

#### ACKNOWLEDGEMENT

We would like to thank all the faculty members of the Department of Civil and Environmental Engineering, ITM University for providing working facilities and continuous encouragement. We would also like to thank to Mr. Vikas Kumar, Lab Assistant in the department for his continuous support and help. The **National Institute of Design, Ministry of small and medium enterprises, Govt. of India Ahmedabad** is acknowledged for financial assistance (**Project No.SDP-12-87**).

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