Sustainable Water Management using Rainfall Runoff Modeling: A Geospatial Approach

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Abstract

In earth crust, precipitation is one of the dynamic hydrologic cycle. It is an ideal unit of natural resource like water from precipitation. In present days, Remote Sensing technology (RS) in association with Geographic Information system (GIS) has become a very important in innovation of technology in all fields of Engineering. Because these techniques enable us results with high accuracy in less time. Digital Elevation Model (DEM) is one of the most effective models, to delineate stream network map with flow direction, stream density and watersheds. The rainfall runoff is estimated by using Lacy's and Rational formula. To identify the feasible locations for excess precipitation water to the ground water regime by the help of Rain Water Harvesting systems (RWH), evaluate total recharge potential through these systems and its impact on ground water regime. This research paper provides a scientific approach to arrest the maximum possibility of precipitation runoff during rainfall event and also the conservation of water with ground water recharge, in the area of studied.

Introduction

Precipitation runoff is one of the most dynamic hydrologic variables of Hydrologic Cycle. It is an ideal unit for the supervision of natural resources like water from precipitation & for reduction of the impact of natural disaster for achieving sustainable development. Calculation of surface runoff is indispensable for estimation of discharge possible of each watershed, planning of water conservation measures and ground water recharge structures.

In India, maximum of agriculture, domestic and industrial sectors are mainly depending up on the surface water and ground water sources. During rainy season the surface water, river water, dam water etc. are the main sources. For the reaming seasons totally ground water is the only main source. In the areas where the surface water sources such as ponds/lakes are not available, the ground water is the only main source. Now a days, the demand for the ground water for the purpose of agriculture, domestic and industrial uses is beyond imagination. As per available statics (GEC, 1997), the water reserves are of four types, namely safe, semi-critical, critical & over exploited. In 2004 (GWRA, 2004) the statics are as follows, safe-1, semi-critical-0, critical-3 & over exploited-8. In 2017 (GWRA 2017), safe-0, semi-critical-4, critical-5 & over exploited-3. In view of this above statics, it is evident that the pressure on ground water source in India tremendously increasing.

During rainy season, runoff is hardly available in most of places in India. When we capture excess runoff from rainfall i.e, after full fill of ponds/lakes/reservoirs and flood water etc. It would be very useful for recharge water to the ground water regime by the help of rainwater harvesting structures/artificial recharge reservoirs. Rainwater-harvesting structures at this point can serve the purpose of arresting rainwater runoff in the area. In India, most of the watersheds are ungauged, without having historical records of calculated runoff, and accurate runoff data are hardly available (Sarangi et al., 2005). For the development of watershed and management programmes in India, need to be evaluate the rainfall runoff amounts in all catchments (Zade et al., 2005). Due to non-availability of rainfall runoff records in Indian watersheds, few techniques have been developed for estimation of surface runoff from basins (Chattopadhyay and Choudhury, 2006). Several rainfall-runoff methods have been evolved over the years, and a few of them were widely-used. All rainfall runoff methods have their own advantages and limitations; the Lacye's (Garg, 1976) & Rational (Rahunath, 2006; Kuichling 1889) methods have received a great consideration Xand implementation due to easiness, easy applicability and consistency in obtaining results.

Udaipur district, Rajasthan is an ungauged catchment. There are many seasonal rivers flowing during rainy season and as per physiographic gradient transporting large amounts of surface water runoff from these seasonal river catchments. These seasonal rivers also act as transporter for sediment yield from the river catchment. The capacity of the ponds/lakes/reservoirs have been reduced over the years due to sedimentation and its water quality has been degraded drastically. Estimation of surface runoff is very imperative for this ungauged catchment for planning and management of soil and water resources of the catchment. Unfortunately, no systematic studies have been conducted to estimate surface runoff in the catchment area. Therefore, in present study, surface runoff of seasonal River catchments is estimated by Rational (Rahunath, 2006; Kuichling 1889) & Lacy's (Garg, 1976) model using integrated Remote Sensing and GIS techniques (Trotter, 1991).

2. Study area:

The study area, Udaipur is also known as "Lake city of Rajasthan" (IMD, 2013), it is a major city in Rajasthan state as shown in Fig.1. It lies between 23° 48' 05.79" to 25° 06' 16.75" North latitude and 73° 01' 23.10" to 74° 26' 20.87" East longitude covering an approximate area of 11,773 sq kms (CGWB, 2017), located in the southern part Rajasthan state and bounded by Aravalli Range.

The location Headquarters with railway & road network map is shown in Fig.2. The elevation ranges between 155 to 1313 m above mean sea level as given in Fig.3.

The important rivers are Jokham, Sabarmati, Som, Berach and Sei which are parts of three major river basins of Rajasthan viz. Sabarmati, Mahe, Banas and Luni (CGWB, 2017). In addition to there are a huge number of local streams creating from Aravalli range. These are all seasonal rivers. The distribution of stream network with water bodies are shown in Fig. 4. The area is subtropical with sub-humid to semi-arid climatic conditions. The normal rainfall for the period of 1901 to 2019 is 632.7 mm. (WRD, 2019 & IMD, 2013).

3. Objectives of the study:

The main objectives are as hereunder:

a. Estimating of rainfall runoff from all catchments at average rainfall, max daily rainfall & peak daily rainfall intensity.
b. Calculation of highest water column developed in each catchment area.
c. To identify feasible site for Artificial Recharge system with design aspects.
d. To evaluate total recharge potential thorough proposed RWH structures.
e. To assess the Impact on ground water regime due to artificial recharge system.

4. Data Base and Methodology:

Throughout the study both primary and secondary data has been used. The core data has been created in the form of vector map by using ArcGIS 10.5, secondary has been collected from published and unpublished sources mainly from Water Resource Department (WRD), Raj., Indian Metrological Department (IMD), Central Ground Water Board (CGWB) India. The Methodology adopted is given in Fig.5.

Results And Discussions

As per the DEM (Sanders, 2007 and Prasad et al, 2016), the water flow direction in drainage/streams orders (Fig.6) are derived and then the watersheds are derived. These watersheds are again classified into sub-watersheds. Out of these all catchments only large catchments are selected for high rainfall runoff, the balance catchments are neglected due to less area of rainfall runoff from those areas. The area distribution of derived watershed & sub-watersheds are shown in Fig.7 & 8 and the area of the controlling catchments are tabulated in Table-1.

5.1. Rainfall Runoff:

In present study, surface runoff from all selected catchments are estimated by average of both Lacy's (Garg, 1976) & Rational (Rahunath, 2006; Kuichling 1889). The followings empirical relationship was used for estimation of runoff. A brief description is given below:

5.1.1. Lacey's Formula:

This formula connects rainfall(P) with the yield (Q) by the equation (Garg, 1976):

$$\boldsymbol{R} = \frac{\boldsymbol{p}}{1 + \left(\frac{304 \cdot 8f}{ps}\right)} \qquad (1)$$

Where

R = Daily Runoff in cm

P = Peak rainfall in cm

f = Monsoon duration factor (**Table-2**) &

s = Catchment factor (**Table-3**)

$$\boldsymbol{Q = R\ X\ A} \qquad (2)$$

Where

Q = Runoff in m^3

R = Daily runoff in m

A = Catchment area in m^2

5.1.2. Rational Method:

It is based on a simple formula that relates runoff-producing potential (Rahunath, 2006; Kuichling 1889) of the watershed, the average intensity of rainfall for a particular length of time (the time of concentration), and the watershed drainage area. The formula is

$$\boldsymbol{Q = C\ X\ P\ X\ A} \qquad (3)$$

Where

Q = Runoff in m^3

C = Runoff coefficient (Table-4)

P = Peak daily rainfall in m

A = Catchment area in m^2

The normal rainfall for the area is 632.7 mm (IMD, 2013). The normal annual rainy days in the Udaipur district is about 96 days, it means the daily rainfall would be 6.59 mm. The lowest (58) rainy days were observed during in 2000 and the highest (145) days in 1961 (IMD, 2013). As per characteristic features of hourly rainfall in India (N.R. Deshpande et al., 2012), the peak intensity of daily rainfall event for the studied area is varies between 40-50 cm. Considering 25 % safety factor of average peak rainfall of 45 cm would be 56.25 cm. The average rainfall runoff generated from all catchments are tabulated in Table-5 at different rainfall events (Norbiato, 2009; Sepaskhan & Fard, 2010; and Zakai, 2006).

5.2. Highest Flood Level:

During rainfall event, flood point is the level at which a build of water surface has increased to a satisfactory level to cause sufficient inundation of areas that are not generally covered by water, causing an inopportuneness or a hazard to life and property. When a body of water rises to this level, it is measured a flood occurrence. The level of flood occurrence is said to be as highest flood level. Generally, in excess/peak rainfall events there is more chances of occurrence of floods. The relation between Runoff generated at peak daily rainfall water in a particular area and total area of the stream/river/pond is the highest flood level. The highest flood level of selected catchments is tabulated in Table-6.

5.3. The design criteria of Artificial Recharge System:

The design criteria of proposed artificial recharge systems are designed at peak daily rainfall event. Because at peak daily rainfall, the maximum runoff will be occurred in a single storm/intensity of rainfall, in that cause may flood will occur. Hence, the proposed system is designed at peak daily rainfall event. Here we are proposing artificial recharge system (Chiew et al, 1992; Osterkamp et al, 1995; Bredenkamp et al, 1995; Finch, 1998; Amitha, 2000; Xianfeng Sun, 2005 & Jain, 2008) like check dam/anicuts are feasible because for implementation of these systems are economically very low in cost (B.H. Ramathilagam et al., 2017). The purpose of this system is arresting the rainfall runoff and allowing to store as well as allowing the rainfall water to the ground water regime and then excess water will go through overflow provision to another artificial recharge system at a certain distance. It means the all systems are formed in step by step formation in river/stream.

The height of anicut would be as flood level develop in the catchment at peak daily rainfall but as per the Water Resources Department of the Rajasthan state has already issued directions not to allow implement of anicuts more than 2 m height (WRD, 2012). Hence, we are considering the height of the anicut is 2 m with foundation depth must be at least half of effective height. It means, the height is 2 m and as such, foundation may be kept as 1 m. The Thickness for a smaller check dams should be 1:0.3 ratio for base to spillway. The thickness of the base of check dam should be 2 times of the height. The thickness at spillway (top of check dam) will be 1/3 of the base. Therefore, the thickness of spill way would be nearly 0.7 m. Hence, Bottom thickness is 2 m & top thickness would be 0.7 m. The material used should be stone masonry/cement concrete in 1:4 mix of cement and coarse sand.

The stream density network map is shown in Fig.9 & the proposed locations of anicuts are given in Fig.10. As per the density of stream and stream orders the location of RWH structures are propose. Considering average width of the each anicut is 15 m and having average water column of 1 m and water spread area is around 40 m. Therefore, the average water holding capacity of each anicut is around 600 m^3. The stored water in anicuts are very useful for irrigation, thus the pressure of ground water regime will be free during monsoon & post-monsoon period.

Based on the rainfall runoff generated at average rainfall, there would be a balance runoff after full fill of existing water bodies and storage capacity of proposed anicuts in the studied area. The data has been tabulated in Table.7. As per CGWA guidelines, the recharge potential through bed is three time of the half of the storage capacity (Table-8).

For fast recharge/to develop ground water level/ground water quality of ground water regime, we need to implement/install a couple number of percolation pits/recharge shafts. Before going to propose these systems, we need to understand the hydrogeological properties of the area. Such as, geological, geomorphological formation, depth to bed rock, type of aquifer as well as intake capacity of the water by the aquifer as determined by recharge test (CGWB, 2000).

In Udaipur district, the most of central part is occupied by the formation of Aravalli super group of Proterozoic age. Little portion of central part and western portion is also occupied by Delhi and remining portion i.e eastern is covered by Bhilwara super group of Archean age (CGWB, 2017). The formation of Geology types and sub types are given in Fig.11 & 12. The geomorphology of the area is mostly by hills (structural/linear/denudational), eastern & southern as well as in central portion in the form of pockets the Denudational origins and very small pockets of Fluvial origins are occupied (CGWB, 2017). The distribution of types and sub types of geomorphological formations are shown in Fig.13 & 14.

In the studied area, the availability of ground water is mainly controlled by the topographic and structureal features present in the geological formations. Mainly ground water occures in under unconfined to semi-confined condition in the saturated portion of the rock formation (CGWB, 2017). BGC (Banded Gneissic Complex), Granite, Phyllite, Quartizite and Schist are main aquifers in the studied area (**Fig.14**). The estern part is covered by BGC, central portion having Phullite and western portion is occupied by Schist, Quartzite and Granite (CGWB, 2017). The avaerage yield from BGC, Quartzite & Phyllite is 40 m^3/day and Granite & Schist is 50 m^3/day, taping depth is 30 m below the ground level. The depth to bed rock is shown in **Fig.15**. It represents that, the depth of alluvium zone from the surface level.

5.4. Recharge Test

In this test, the known volume of water was injected under gravity (slug) into the selected tube wells of different aquifers and water level measurements were carried out at the start of the test and at short intervals immediately after the known volume of water was injected into the well (CGWB, 2007). It has been found that, the recharge capacities of each aquifers are tabulated in Table-8 and the plot between time v/s drawn down cure for all aquifer are shown in Fig.16. The total recharge potential through injection system is tabulated in Table-9.

In the above proposed RWH structure (Ravi Shankar and Mohan, 2005; De Winnaar et al, 2007; Mbilinyi et al, 2007; Ghayoumian et al, 2007), the dimensional parameter of percolation pit is kept as 1 m (length) x 1 m (width) x 2 m (depth) with 8” dia. injection well of 30 m depth having 8” plain pipe up to 6 m depth Thereafter, 7” dia. necked borehole in rock may be made up to 10 m depth by DTH drilling machine. Each structure capable of recharging 42.4 m^3/day by each pit. The inlet of the structure may be kept 1 m above anicut bed leaving, 1 m water column for settlement of silt/dust etc. The annual cleaning/ removal of silt/ dust from the pond bed is suggested before monsoon for efficient working of system. The schematic design of percolation pit in the RWH pond is shown in **Fig.17** and the relation to the anicuts and depth to bed rock is given in **Fig.18**.

5.5. Impact on Ground Water Regime:

It doesn't allow adverse impact on ground water regime of the area. It helps in controlling declining trends of water level and it helps in maintaining existing water quality of ground water and prevent from deterioration.

Conclusion

This paper will be helpful to arrest the maximum precipitation runoff during rainfall events. As per hydrogeological condition of the area, these techniques have provided a scientific approach for planning of water conservation measures with ground water recharge measures. This concept is less expensive than any other technique of artificial recharge. The innovatively designed structures are simple, easy to construct, operate and maintain. It shows a positive result of rise in water level or reducing decline in water level and improvement in water quality within short time. Even these systems are may be avoided occurrence of flood problem of area, because the systems are designed at Peak Intensity rainfall. Besides, it may turn out to be lifeline in surviving supplementary water requirement.

Declarations

Compliance with Ethical Standards:

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Conflict of Interest: Authors declares that he/she has no conflict of interest.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors

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Tables

Table-1: The area of the controlling catchments.

Watershed Code	Sub-Watershed No.	Catchment area of Watershed in sq.m.	Catchment area of Watershed in sq.km.
A	0	1,43,49,28,883.92	1,434.93
	1	15,29,23,826.00	152.92
	2	14,43,41,603.32	144.34
	3	4,50,60,709.17	45.06
	4	42,43,55,665.52	424.36
D	5	61,54,20,762.92	615.42
	6	36,18,69,793.78	361.87
	7	17,70,36,639.52	177.04
	8	4,59,87,756.48	45.99
	9	1,59,00,95,222.29	1,590.10
C	10	10,90,88,715.44	109.09
	11	4,31,44,108.62	43.14
	12	7,67,09,703.33	76.71
	13	39,58,37,698.98	395.84
	14	2,94,33,77,225.29	2,943.38
	15	10,68,26,544.78	106.83
	16	1,23,98,87,279.63	1,239.89
Total Area		**9,90,68,92,138.98**	**9,906.89**

Table-2: Different values of Monsoon duration factors (f):

Si. No.	Duration of Monsoon	Monsoon duration factor “f”
1	Bad Year	0.5
2	Normal Year	1.2
3	Good Year	1.5

Table-3: Different values of catchment factors (s) for different types of catchments

Si. No.	Class of Catchment	Description of catchment	Value of “s”
1	A	Flat cultivated, absorbent soils	0.25
2	B	Flat, partly cultivated stiff soils	0.60
3	C	Average catchments	1.00
4	D	Hills & plains with little cultivation	1.70
5	E	Very hilly & steep catchment with little or no cultivation	3.45

Table-4: Different values of catchment factors (C) for different types of catchments:

Si. No.	Type of catchment	Value of catchment factor “C”
1	Rocky & impermeable	0.8 - 1.0
2	Slightly permeable, bare	0.6 – 0.8
3	Cultivated or covered with vegetation	0.4 – 0.6
4	Cultivated absorbent soil	0.3 – 0.4
5	Sandy soil	0.2 – 0.3
6	Heavy forest	0.1 - 0.2

Table-5: The average rainfall runoff generated from all catchments.

Watershed No.	Catchment area of in m^2	Runoff generated at Peak Daily Rainfall m^3	Runoff generated at Peak intensity Rainfall m^3
0	1,43,49,28,883.92	7,43,790.18	21,61,32,230.86
1	15,29,23,826.00	79,267.51	2,30,33,732.22
2	14,43,41,603.32	74,818.95	2,17,41,058.45
3	4,50,60,709.17	23,357.06	67,87,145.84
4	42,43,55,665.52	2,19,963.22	6,39,17,409.21
5	61,54,20,762.92	3,19,001.12	9,26,96,065.92
6	36,18,69,793.78	1,87,573.90	5,45,05,646.02
7	17,70,36,639.52	91,766.30	2,66,65,658.68
8	4,59,87,756.48	23,837.59	69,26,779.79
9	1,59,00,95,222.29	8,24,220.09	23,95,03,735.36
10	10,90,88,715.44	56,545.74	1,64,31,188.82
11	4,31,44,108.62	22,363.59	64,98,463.13
12	7,67,09,703.33	39,762.20	1,15,54,188.85
13	39,58,37,698.98	2,05,181.04	5,96,21,968.66
14	2,94,33,77,225.29	15,25,688.91	44,33,38,128.53
15	10,68,26,544.78	55,373.15	1,60,90,455.56
16	1,23,98,87,279.63	6,42,691.07	18,67,54,623.71

Table-6: Highest flood levels of selected all catchments.

Watershed No.	Average Rainfall Runoff in m^3 (A)	Total available water Storage in water bodies in m^3 (B)	Available Balance Runoff in m^3 (C)	Total Area of the river/stream in m^2 (D)	Highest Flood Level in m (C/D)
0	21,61,32,230.86	9,94,00,433.60	11,67,31,797.27	2,03,78,216.36	5.73
1	2,30,33,732.22	1,36,97,462.72	93,36,269.50	14,59,239.67	6.40
2	2,17,41,058.45	1,50,50,641.55	66,90,416.90	1,99,162.87	33.59
3	67,87,145.84	41,80,841.57	26,06,304.27	64,508.76	40.40
4	6,39,17,409.21	23,27,363.45	6,15,90,045.77	38,56,107.82	15.97
5	9,26,96,065.92	19,17,714.55	9,07,78,351.36	73,08,853.46	12.42
6	5,45,05,646.02	5,09,329.28	5,39,96,316.75	38,63,004.60	13.98
7	2,66,65,658.68	0.00	2,66,65,658.68	21,17,227.90	12.59
8	69,26,779.79	12,80,526.50	56,46,253.29	3,41,456.86	16.54
9	23,95,03,735.36	1,66,16,379.73	22,28,87,355.63	2,75,60,023.41	8.09
10	1,64,31,188.82	23,74,944.12	1,40,56,244.70	8,47,141.37	16.59
11	64,98,463.13	0.00	64,98,463.13	6,94,890.90	9.35
12	1,15,54,188.85	0.00	1,15,54,188.85	6,66,746.67	17.33
13	5,96,21,968.66	5,40,79,884.25	1,03,27,621.17	2,69,68,702.99	0.38
14	44,33,38,128.53	37,61,98,755.82	7,82,82,146.84	5,40,91,756.71	1.45
15	1,60,90,455.56	3,31,703.47	1,57,58,752.09	2,70,27,637.79	0.58
16	18,67,54,623.71	14,16,70,787.55	4,50,83,836.16	2,91,84,062.10	1.54

Table-7: Balance runoff after full fill of existing water bodies & proposed storage capacity in anicuts and recharge potential through anicut beds.

Watershed No.	Total rainfall runoff at annual rainfall in m³	Water stored in Water bodies in m³	No. of proposed RWH structures	Total proposed storage of the anicut in a year in m³	Total Recharge potential through anicut bed in m3	Balance Runoff
0	18,08,01,039	9,94,00,434	35	6,32,80,36,378	3,16,40,18,189	8,13,37,606
1	1,92,68,402	1,36,97,463	11	21,19,52,423	10,59,76,211	55,51,139
2	1,81,87,042	1,50,50,642	3	5,45,61,126	2,72,80,563	31,31,000
3	56,77,649	41,80,842	3	1,70,32,948	85,16,474	14,91,408
4	5,34,68,814	23,27,363	8	42,77,50,511	21,38,75,255	5,11,27,050
5	7,75,43,016	19,17,715	10	77,54,30,161	38,77,15,081	7,56,07,302
6	4,55,95,594	5,09,329	4	18,23,82,376	9,11,91,188	4,50,79,065
7	2,23,06,617	0	5	11,15,33,083	5,57,66,541	2,22,97,617
8	57,94,457	12,80,527	4	2,31,77,829	1,15,88,915	45,06,731
9	20,03,51,998	1,66,16,380	21	4,20,73,91,958	2,10,36,95,979	18,36,97,818
10	1,37,45,178	23,74,944	3	4,12,35,534	2,06,17,767	1,13,64,834
11	54,36,158	0	2	1,08,72,315	54,36,158	54,32,558
12	96,65,423	0	1	96,65,423	48,32,711	96,63,623
13	4,98,75,550	4,92,94,347	4	19,95,02,200	9,97,51,100	5,74,003
14	37,08,65,530	36,50,55,982	18	6,67,55,79,547	3,33,77,89,773	57,77,149
15	1,34,60,145	3,31,703	2	2,69,20,289	1,34,60,145	1,31,24,841
16	15,62,25,797	14,16,70,788	11	1,71,84,83,770	85,92,41,885	1,45,35,210
Total	**1,24,82,68,410**	**71,37,08,457**	**145**	**21,02,15,07,872**	**10,51,07,53,936**	**53,42,98,952**

Table-7: Recharge capacity of different aquifers.

Si. No.	Type of Aquifer	Recharge capacity in m³/day
1.	BGC	35.29
2.	Granite	42.60
3.	Phyllite	61.01
4.	Quartizite	52.17
5.	Schist	23.30

Table-8: Recharge potential through percolation pits

Watershed No.	Total no. of percolation pit	Considering average recharge capacity of the aquifer 42.4 m^3/day	No. of average recharging days in a year	Total Recharge potential through percolation pit in m^3/annum
0	35	1484	96	1,42,464
1	11	466		44,774
2	3	127		12,211
3	3	127		12,211
4	8	339		32,563
5	10	424		40,704
6	4	170		16,282
7	5	212		20,352
8	4	170		16,282
9	21	890		85,478
10	3	127		12,211
11	2	85		8,141
12	1	42		4,070
13	4	170		16,282
14	18	763		73,267
15	2	85		8,141
16	11	466		44,774
Total	**145**	**6148**		**5,90,208**

Table-9: Total Recharge potential.

Watershed No.	Recharge through anicut bed	Recharge through Percolation pit
0	31,500.00	1,42,464
1	9,900.00	44,774
2	2,700.00	12,211
3	2,700.00	12,211
4	7,200.00	32,563
5	9,000.00	40,704
6	3,600.00	16,282
7	4,500.00	20,352
8	3,600.00	16,282
9	18,900.00	85,478
10	2,700.00	12,211
11	1,800.00	8,141
12	900.00	4,070
13	3,600.00	16,282
14	16,200.00	73,267
15	1,800.00	8,141
16	9,900.00	44,774
Total recharge	**1,30,500.00**	**5,90,208**
Grand Total	**7,20,708 m^3/annum**	

Figures

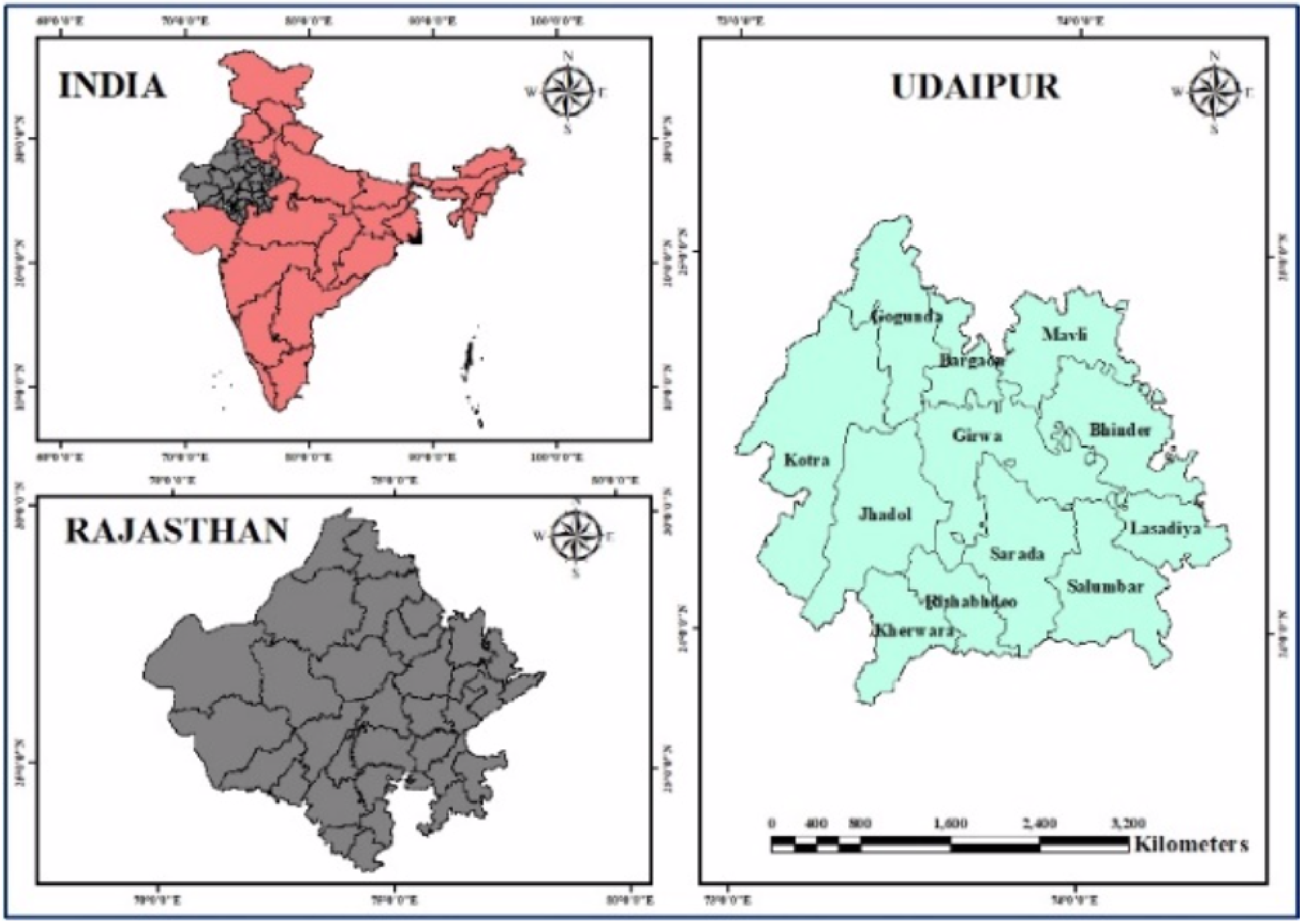

Figure 1

Location of studied area Map.

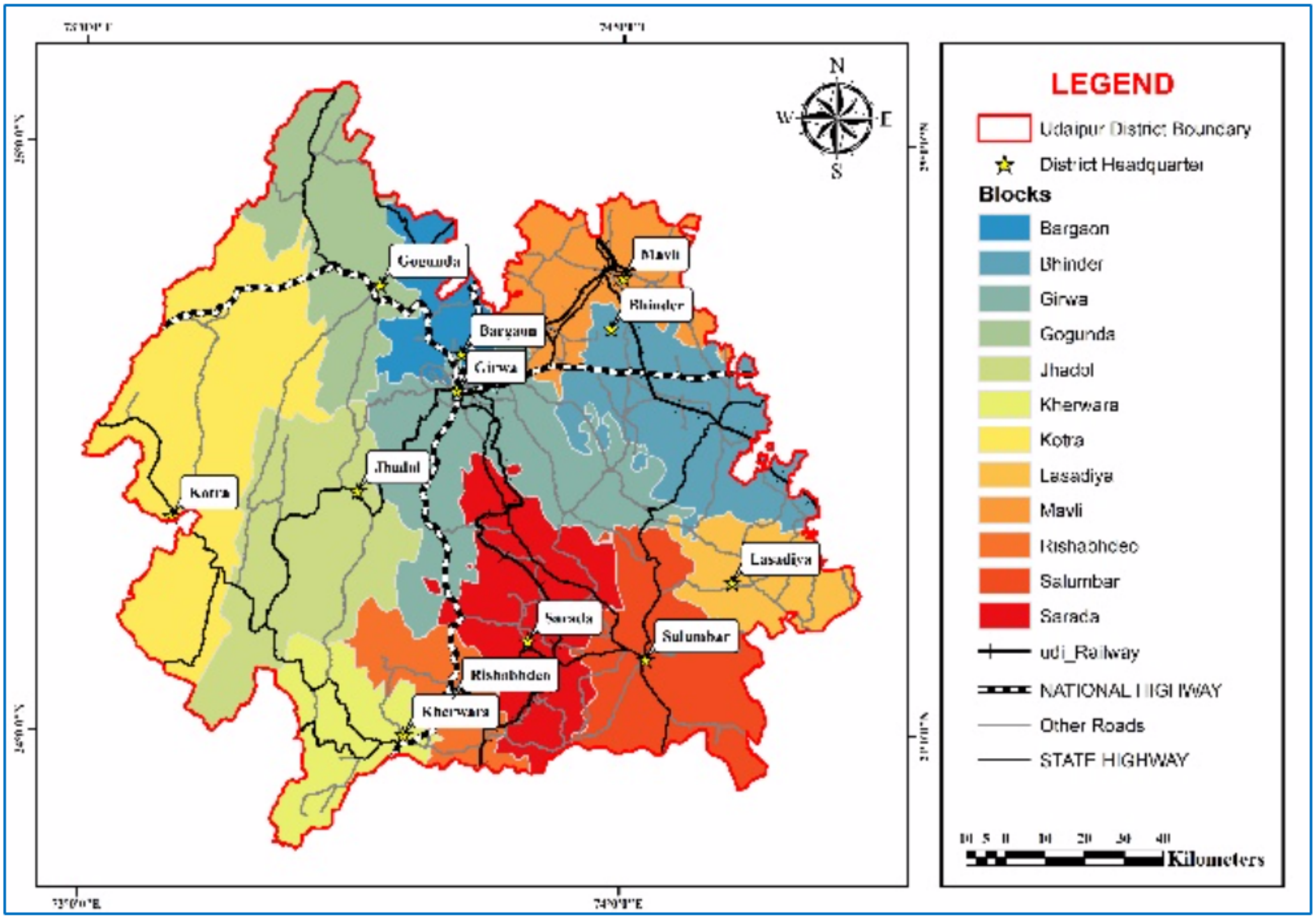

Figure 2

Headquarters with railway & road network map.

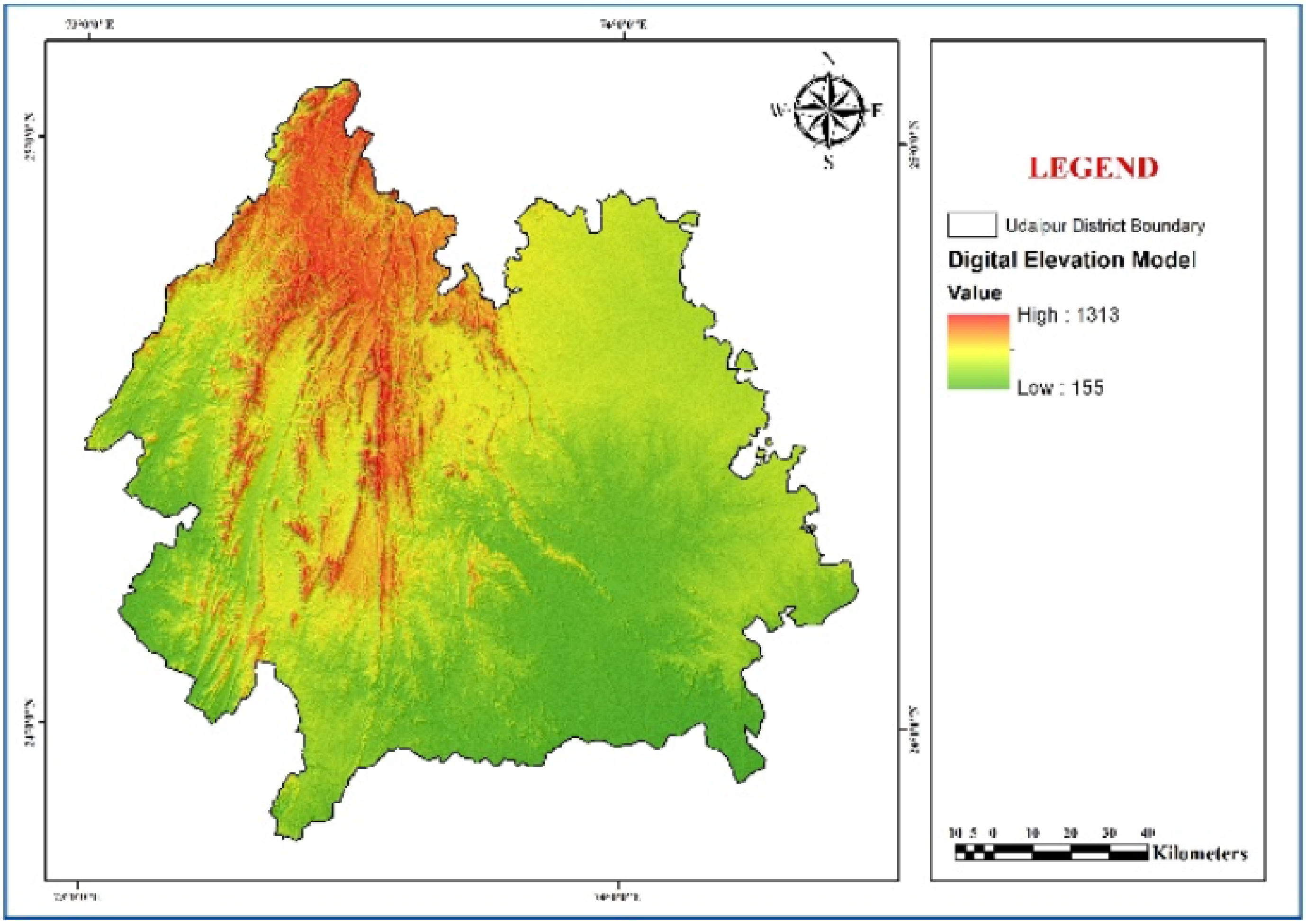

Figure 3

Elevation Map.

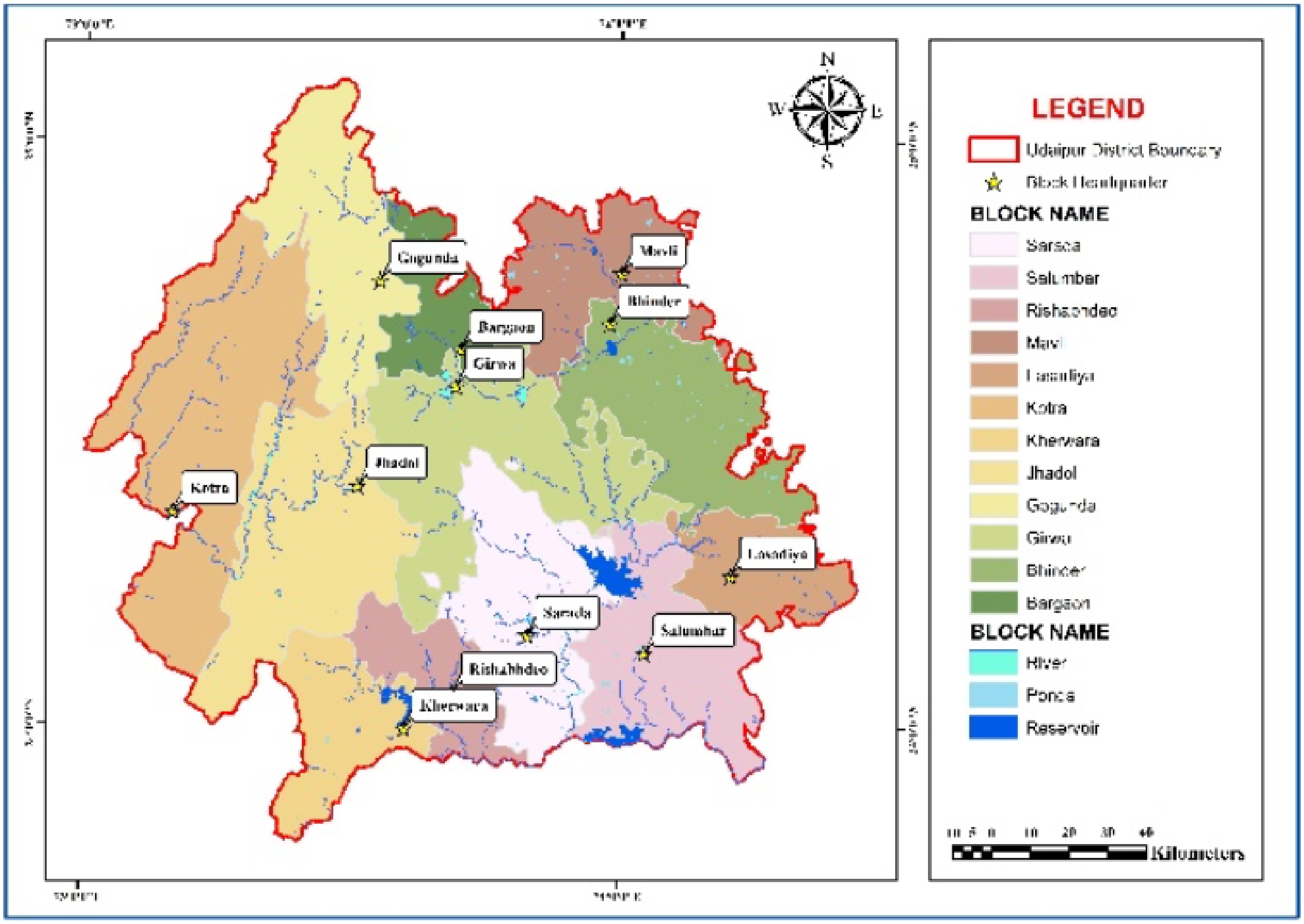

Figure 4

The distribution of stream network with water bodies.

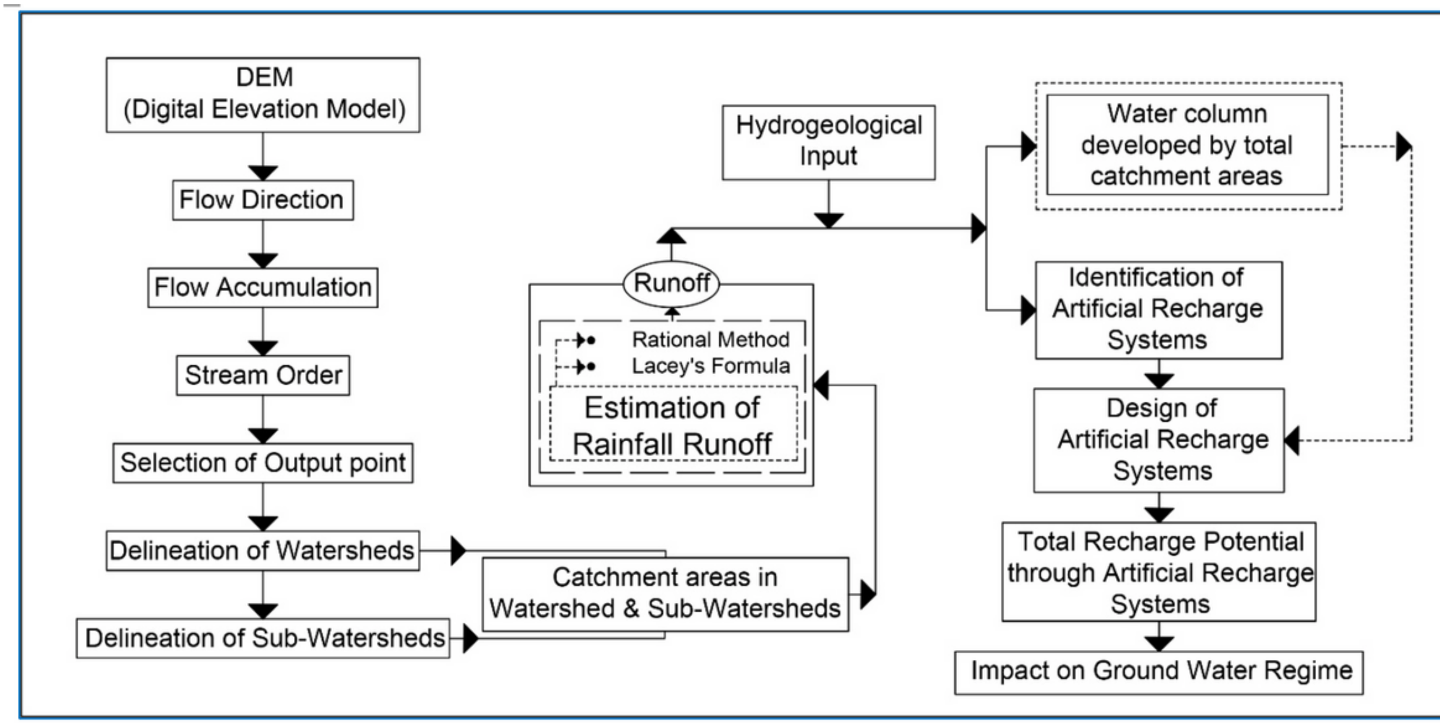

Figure 5

The Methodology adopted.

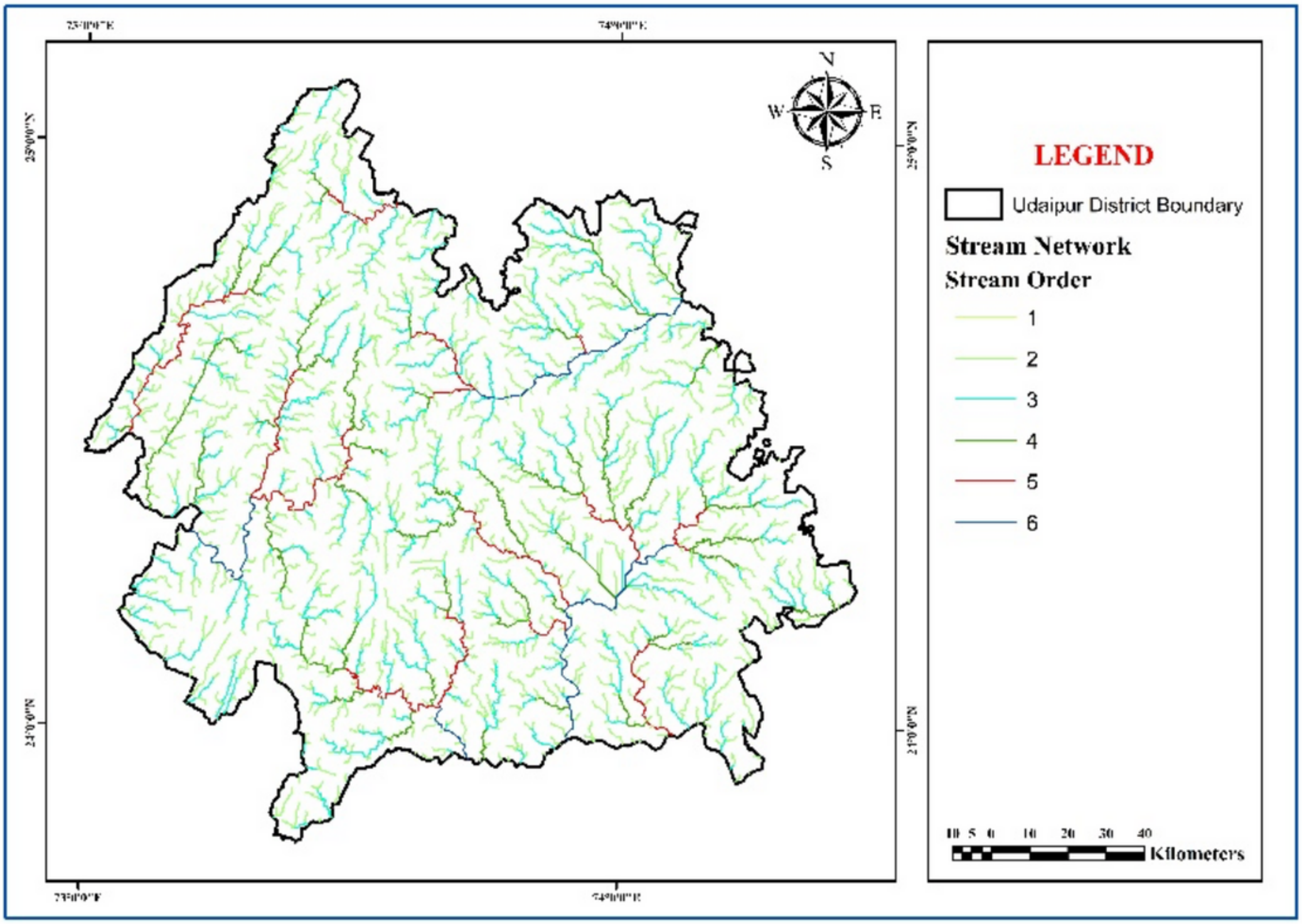

Figure 6

Distribution of Stream order network.

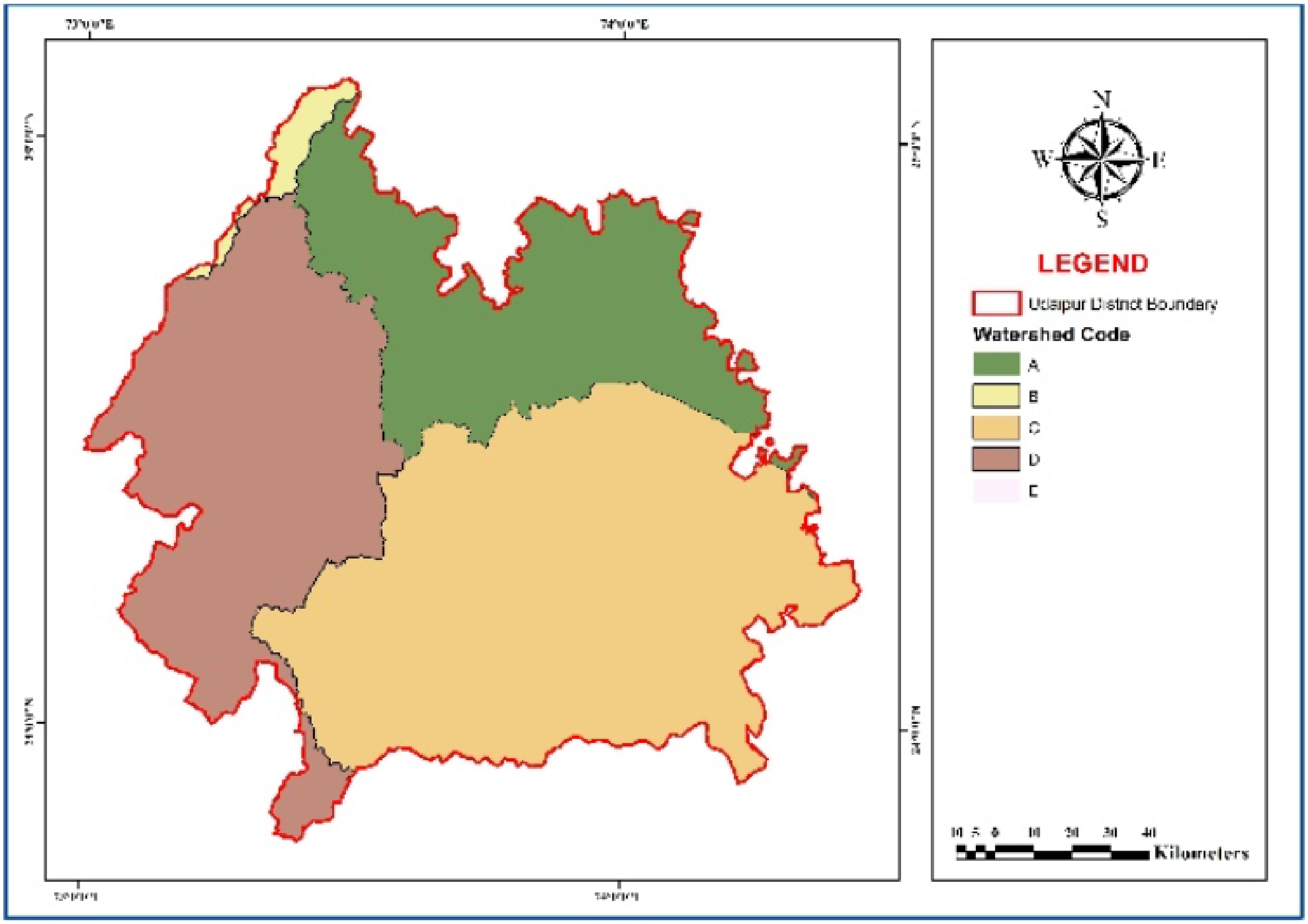

Figure 7

Distribution of Watershed Map.

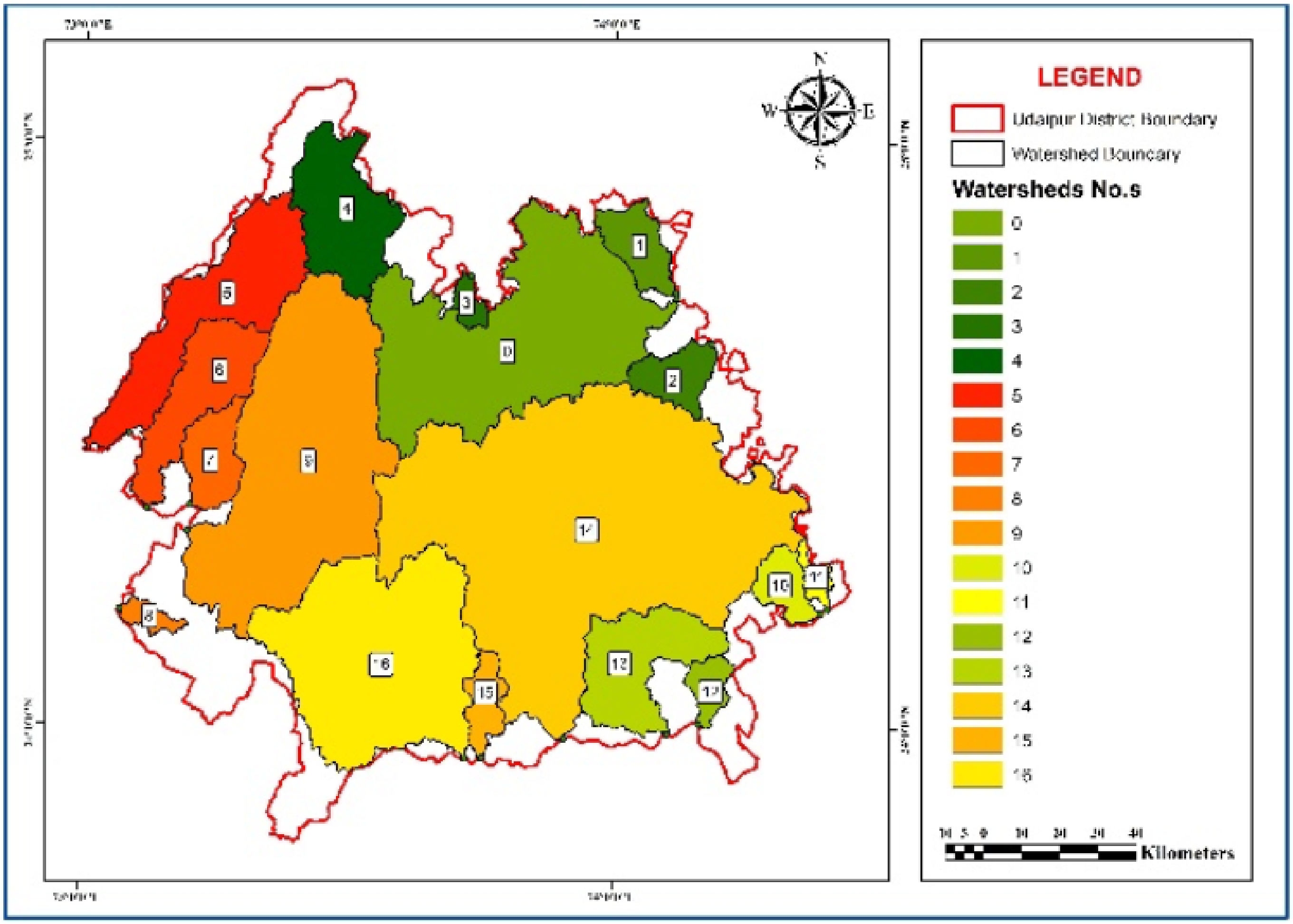

Figure 8

Distribution of Sub-Watershed Map.

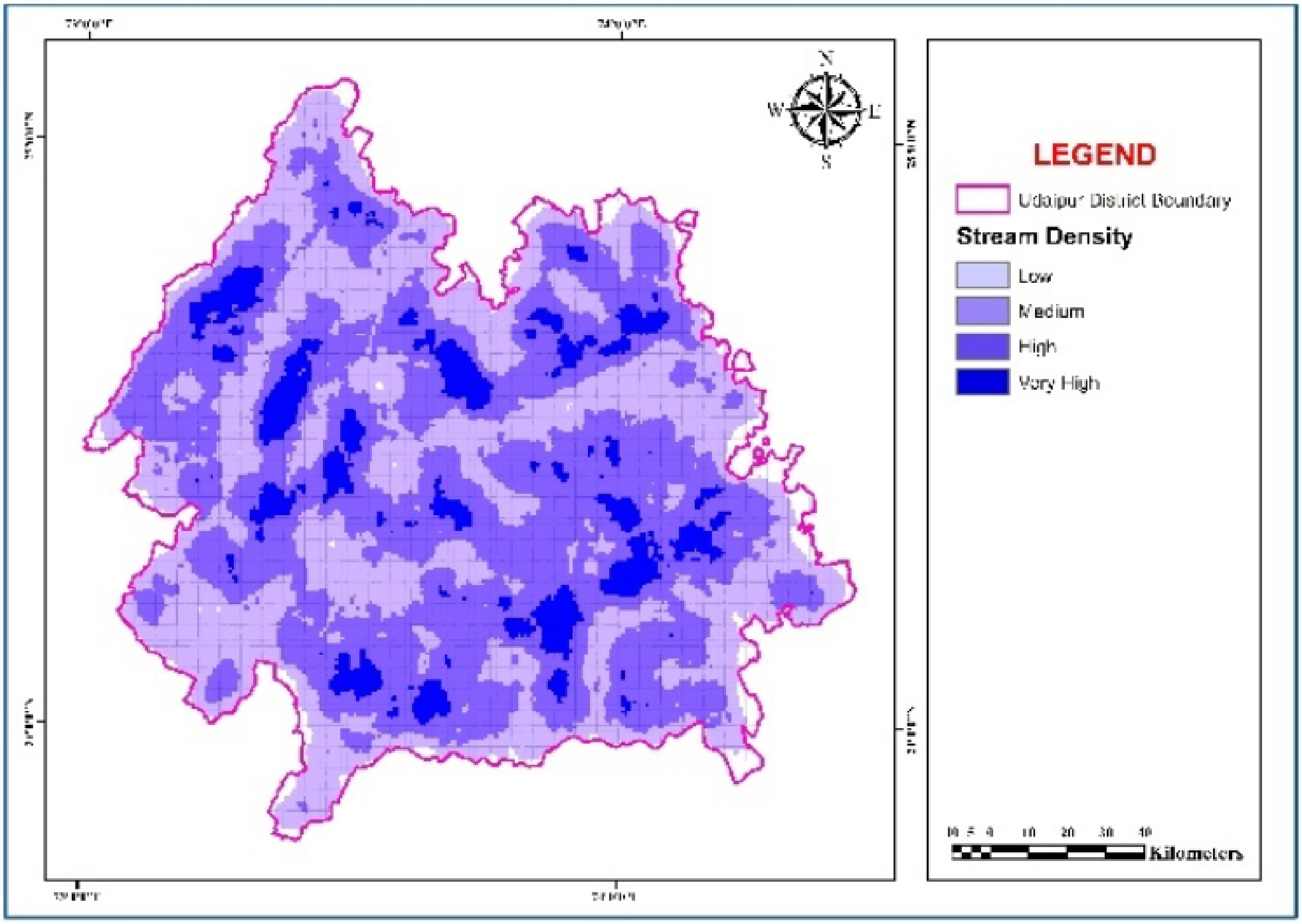

Figure 9

Distribution of Stream density network Map.

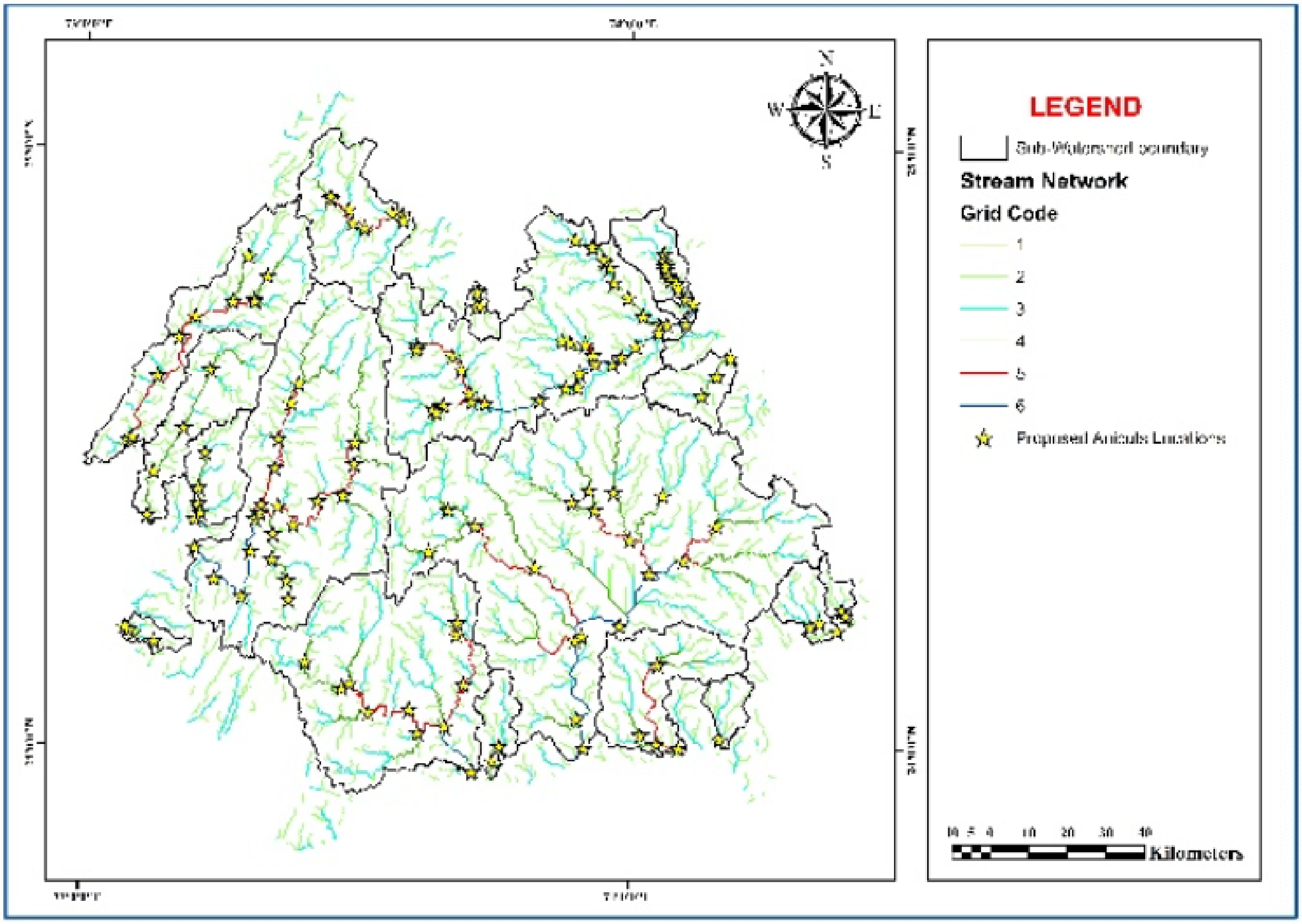

Figure 10

Location of proposed RWH structures.

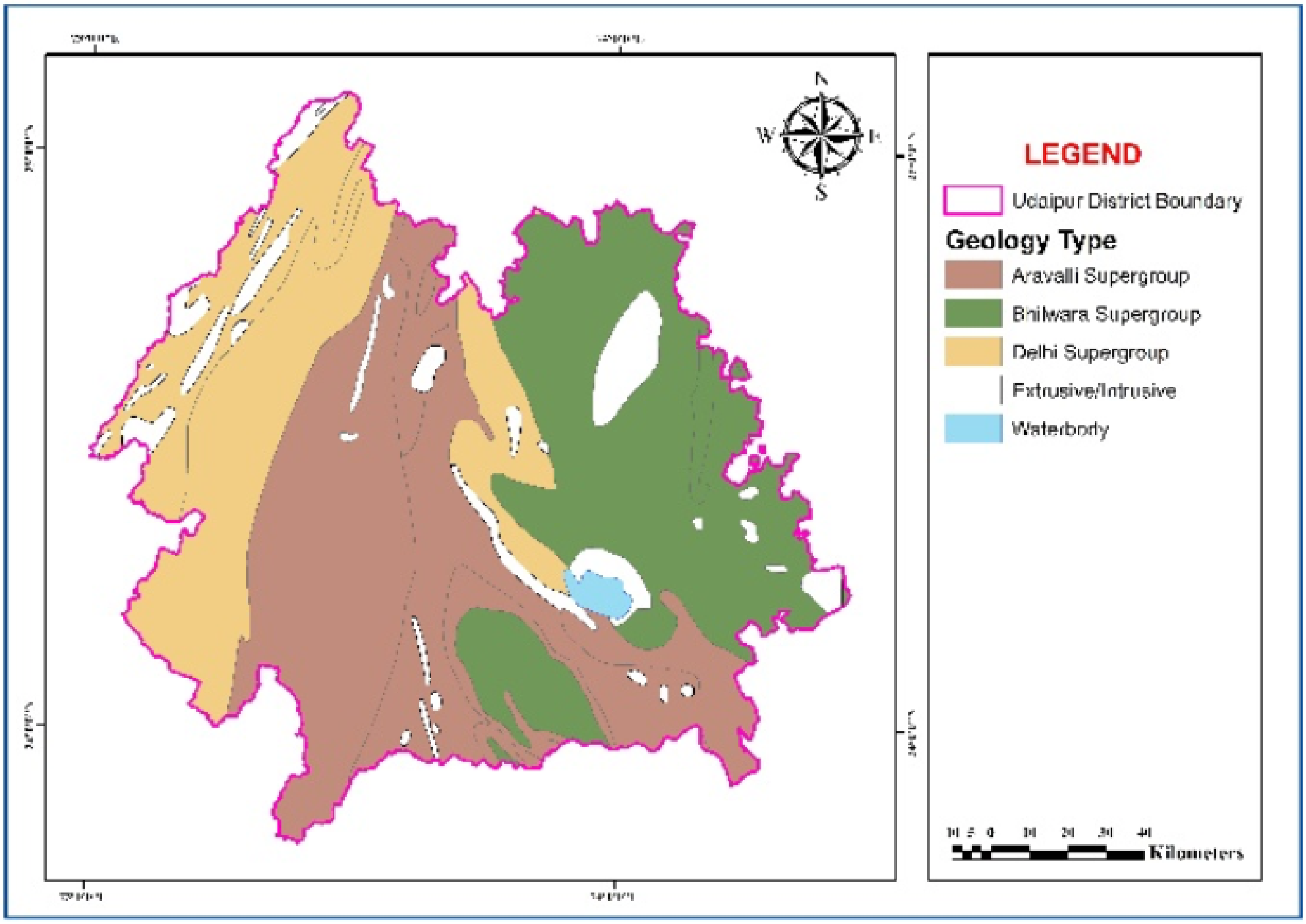

Figure 11

Types of Geological formation Map.

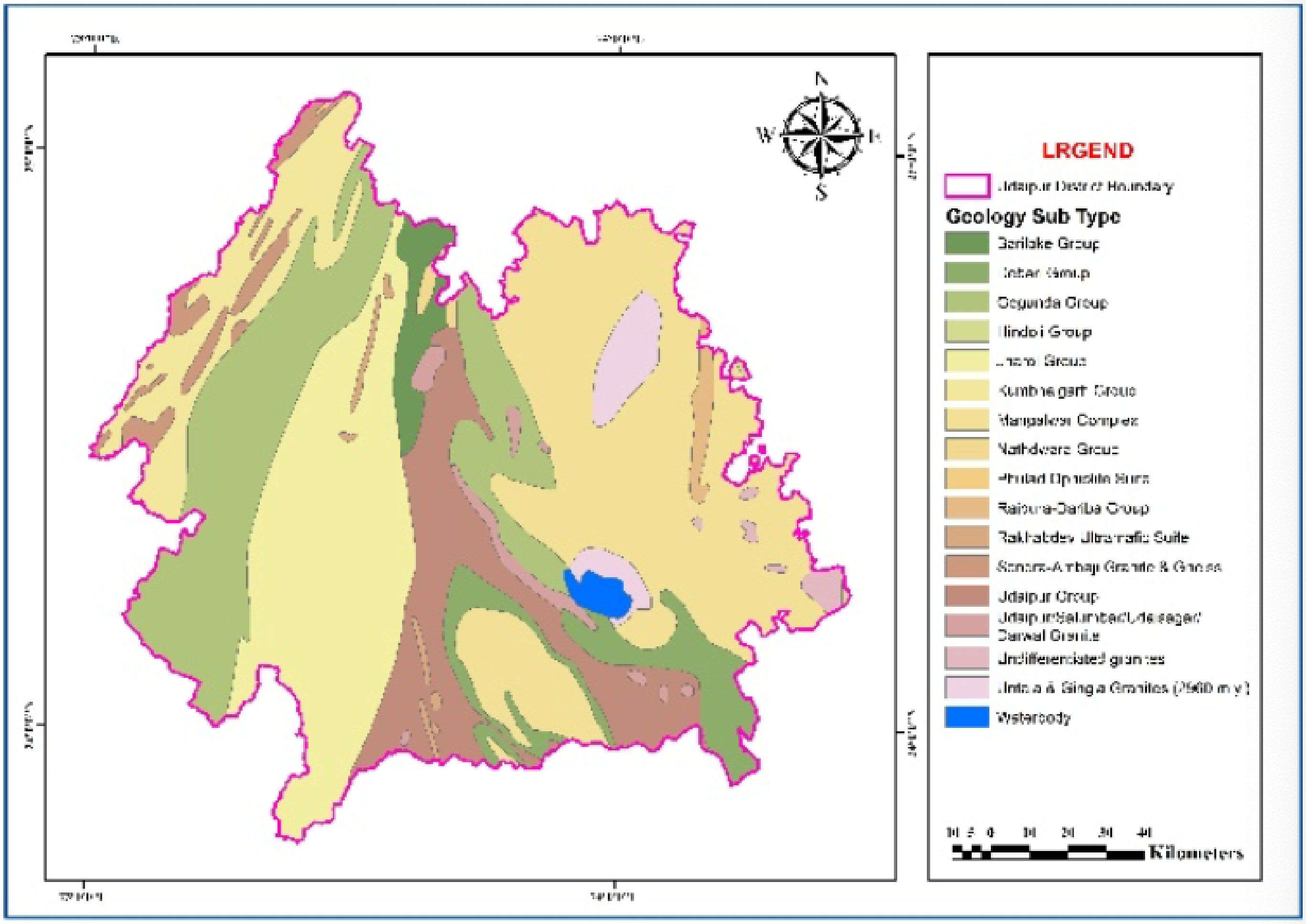

Figure 12

Sub-Types of Geological formation Map.

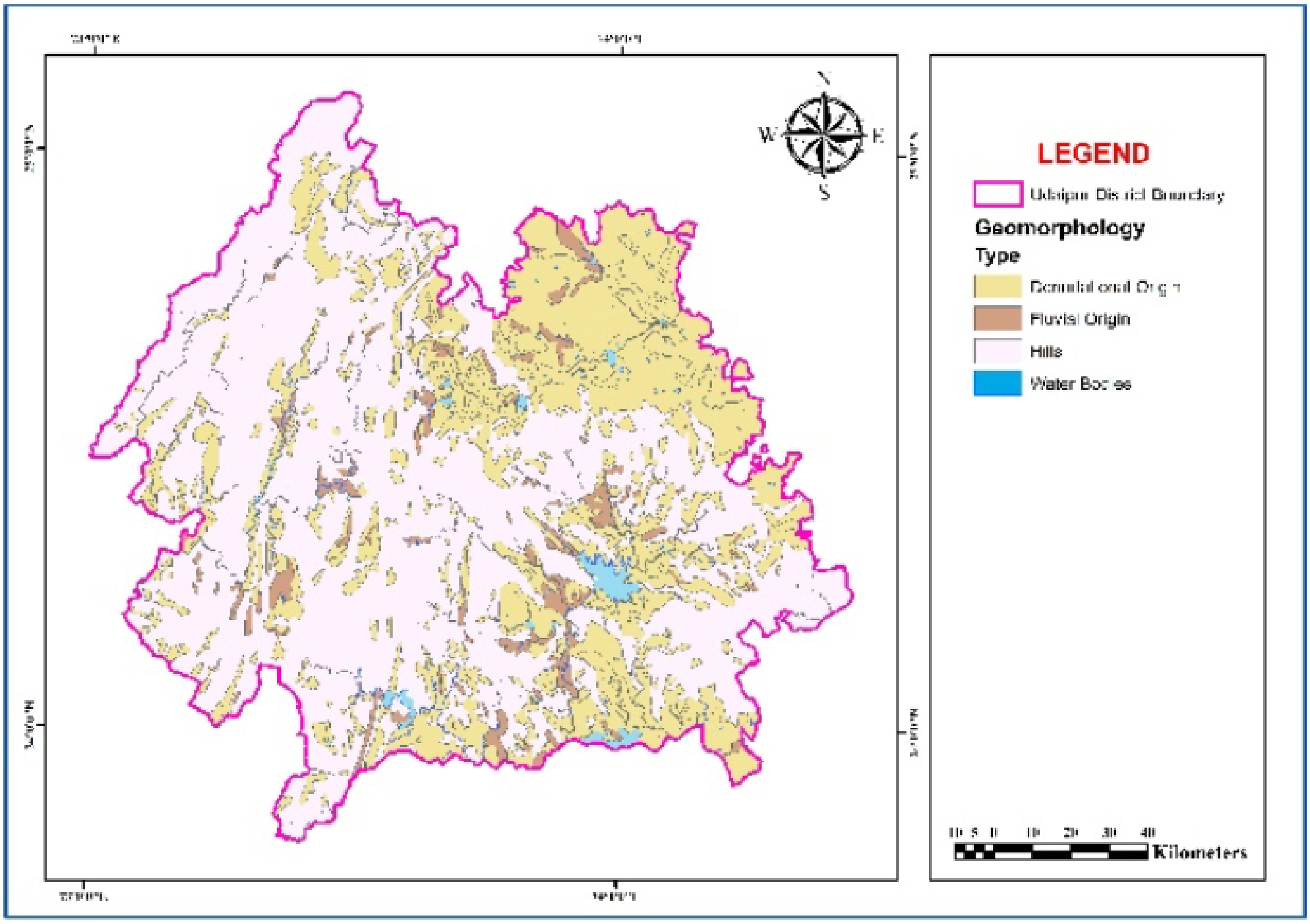

Figure 13

Types of Geomophological formation map.

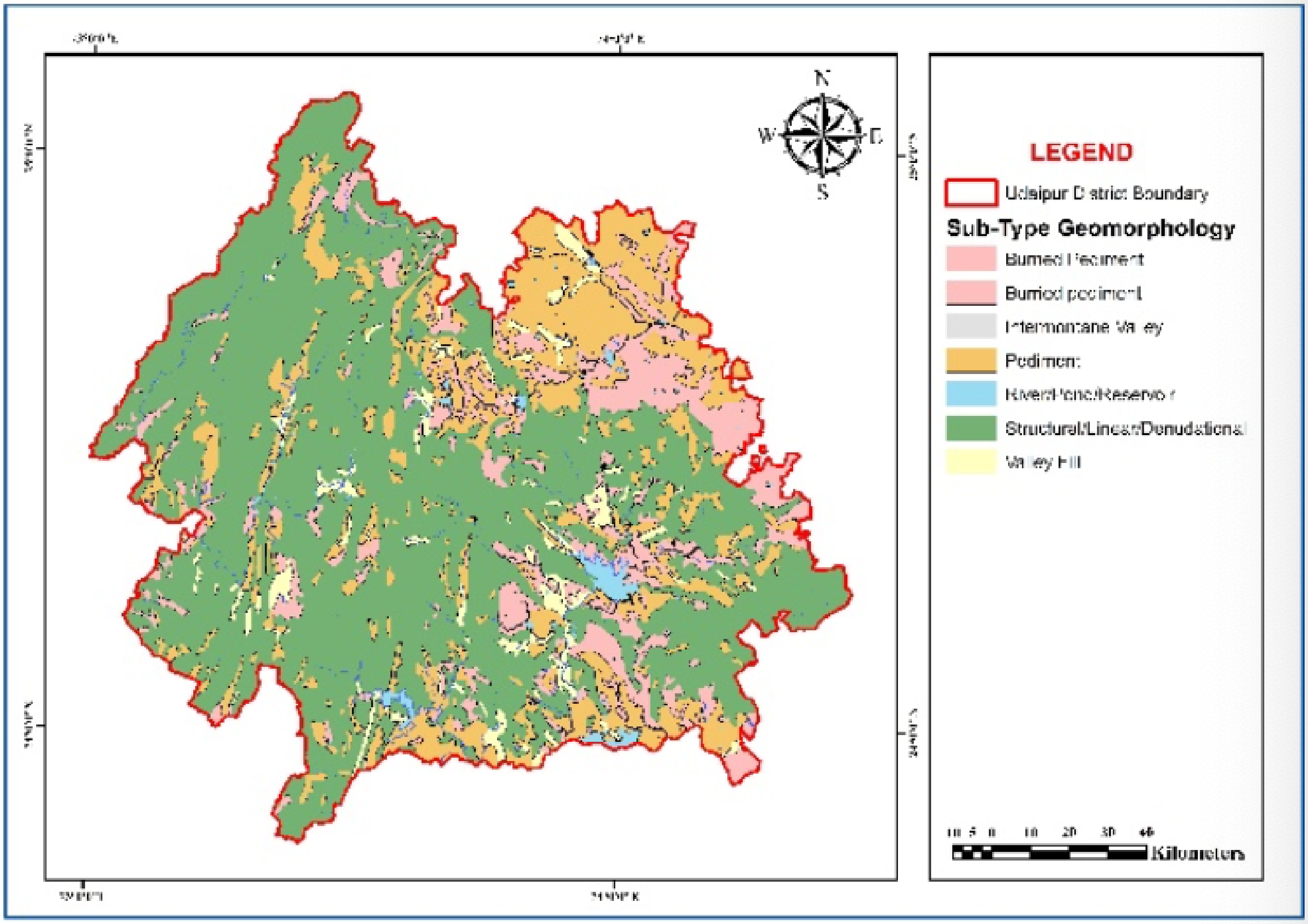

Figure 14

(F.13.2) Sub-Types of Geomorphological formation map.

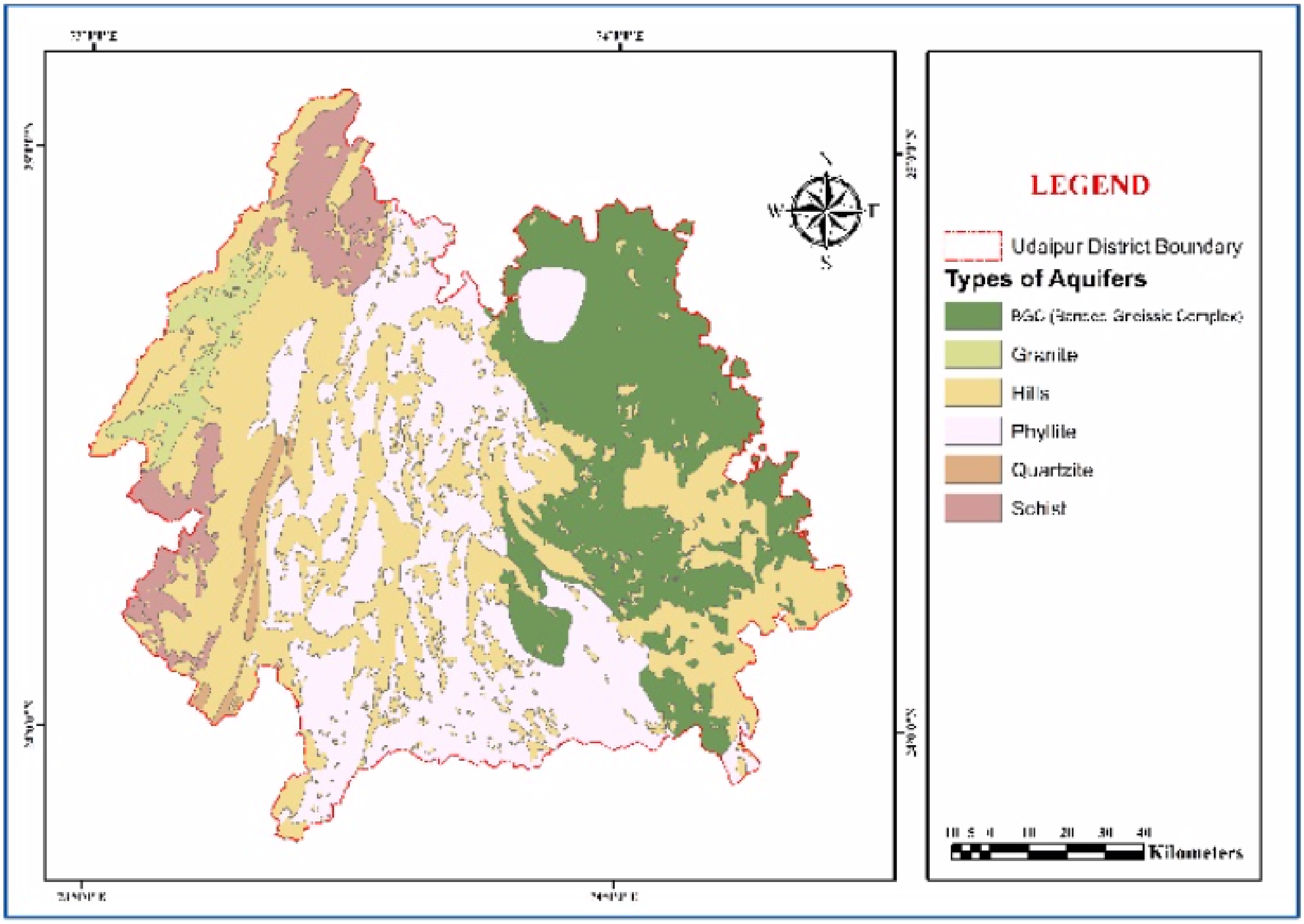

Figure 15

(Fig.14) Aquifer distribution Map.

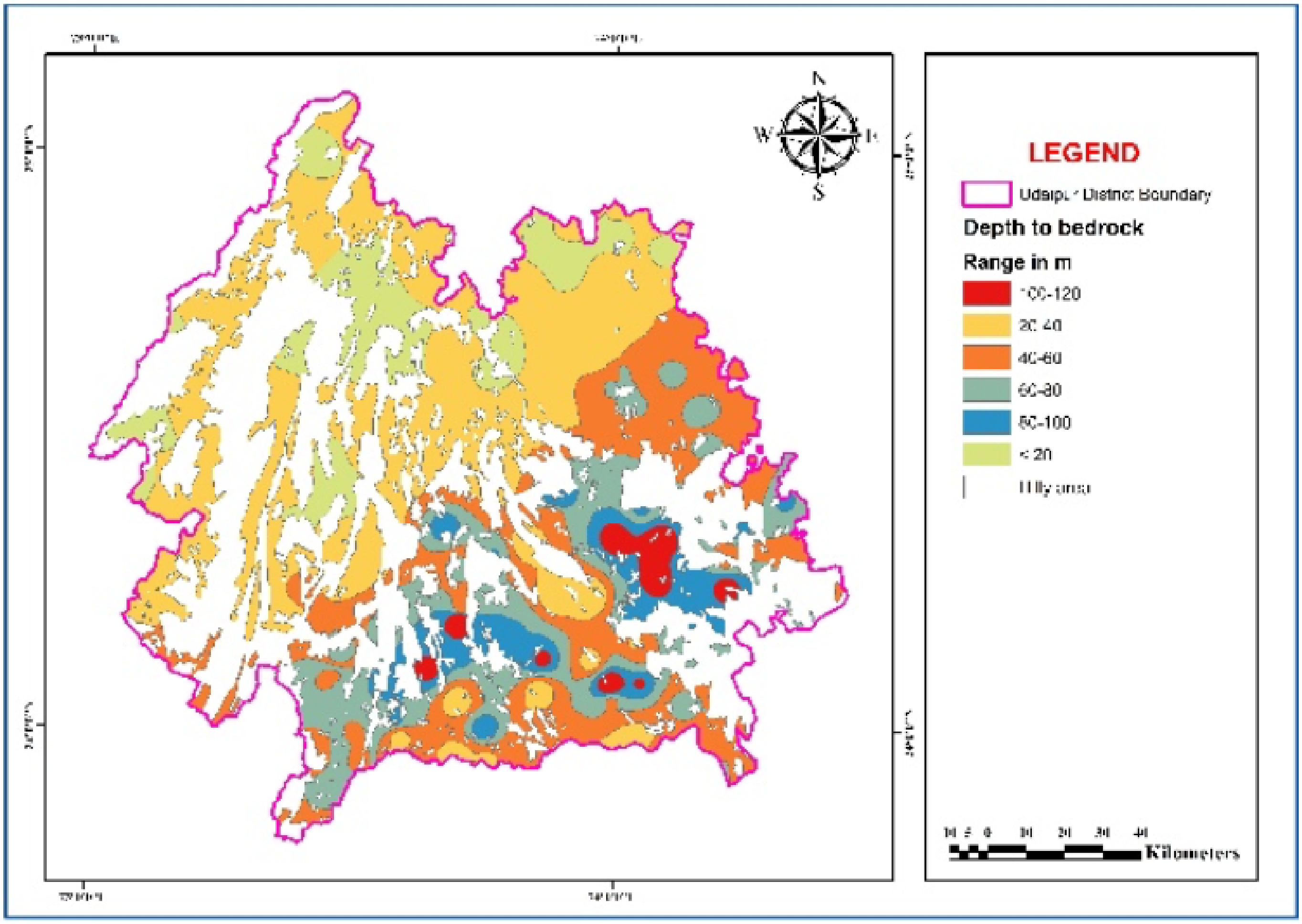

Figure 16

(Fig.15) Depth to Bed rock Map

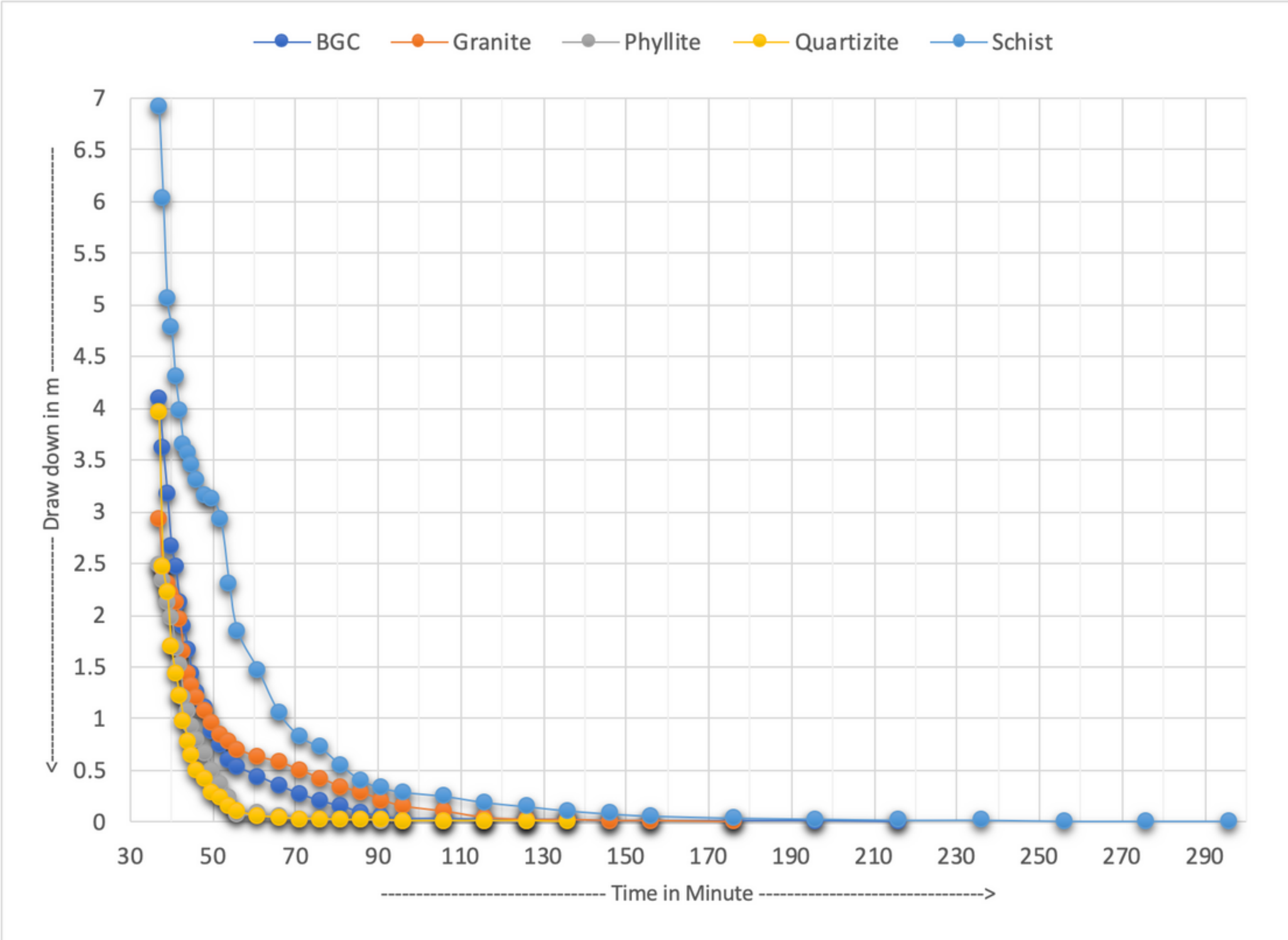

Figure 17

(Fig.16) Recharge Test Curve plot between time v/s drawn down cure for all aquifer.

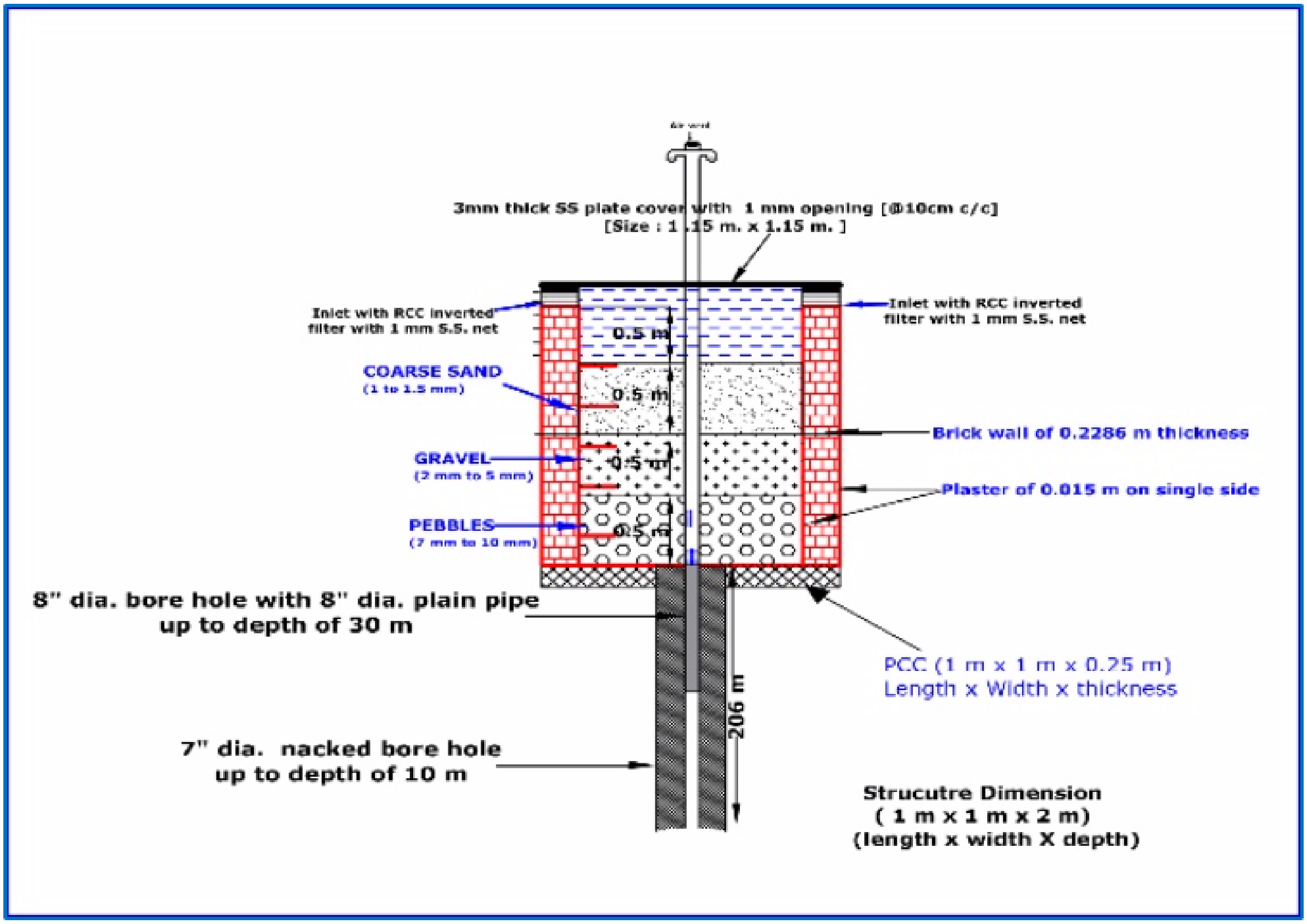

Figure 18

(Fig.17) Schematic design of percolation pit in the RWH pond

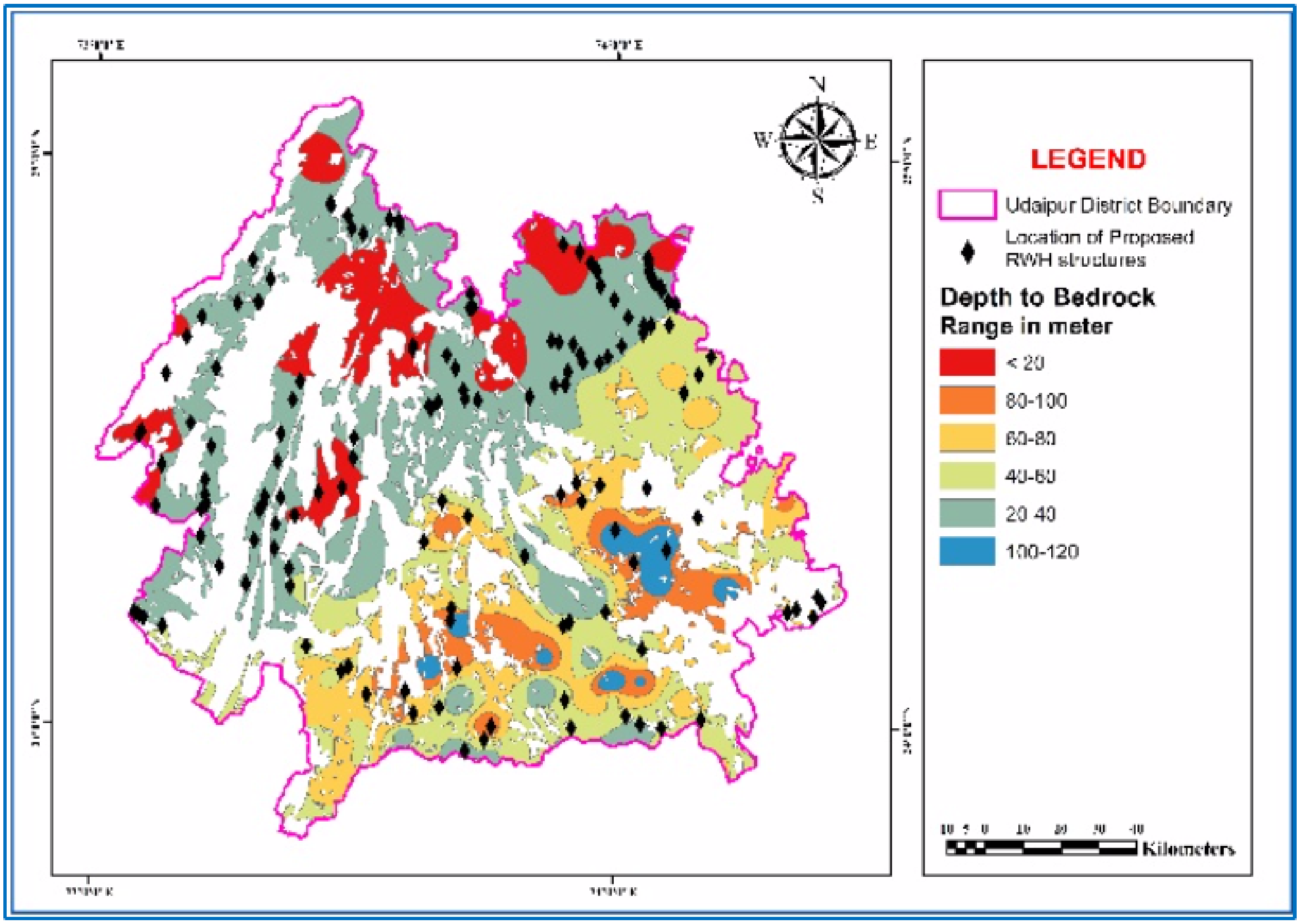

Figure 19

(Fig.18) Anicuts with relation to depth to bedrock.