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Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

PARTS OF SOUTH DISTRICT, SIKKIM

पूर्वी क्षेत्र, कोलकाता

Eastern Region, Kolkata

REPORT ON AQUIFER MAPPING STUDIES & MANAGEMENT PLAN IN PARTS OF SOUTH DISTRICT, SIKKIM AAP 2018-19

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1. INTRODUCTION

Groundwater is one of the prime sources of fresh water contributing significantly for the survival of mankind. However, overexploitation, surface runoff, subsurface groundwater discharge have depleted the fresh groundwater availability considerably. Assessing the groundwater potential zone is extremely important for the protection of water quantity & quality, and the management of groundwater system. In this context, the National Aquifer Mapping & Management Programme (NAQUIM) has been taken up by CGWB under XIIth Plan. As per the Action Plan under NAQUIM, ground water management studies in 6 blocks, eg. Namchi, Namthang, Melli, Jorethang, Temi Tarku, Sikip of South district in Sikkim, covering an area of approximately 280.32 sq. km. was taken up in this study. This report envisages the salient features of aquifer geometry, characteristics; ground water occurrences, availability, resource vis-a-vis quality, development & management scope of ground water etc. in present scenario.

1.1 Objective

The broad objective of the study is to establish the geometry of the underlying aquifer systems in horizontal and vertical domain, its resources potential in respect of quality & quantity, aquifer characterization, suggest suitable interventions for groundwater management and prepare groundwater management plan.

1.2 Scope of Study

The scope of the present study is broadly within the framework of National Aquifer Mapping & Management Programme (NAQUIM) being implemented by CGWB. There are three major activity components viz.:

(i) *Data collection / compilation*

Data compilation included collection, and wherever required procurement, of all maps from concerned Agencies, such as the Survey of India, Geological Survey of India, State Governments etc., computerization and analyses of all acquired data, and preparation of a knowledge base.

(ii) *Data generation*

Data generation included those of hydrometeorology, chemical quality of ground water, litho-logs and aquifer parameters. Generation of ground water chemical quality data was accomplished by collection of water samples and their laboratory analyses for all routine parameters, and some data of contamination by geogenic contaminants during recent special studies. Additional data pertaining to sub-surface lithology and aquifer parameters were obtained through drilling of additional exploratory wells by inhousing activities at sites.

(iii) *Preparation of aquifer maps and management plan to achieve the primary objective.*

Several GIS platforms such as Mapinfo, ArcGIS, and Google Earth Engine were used in preparation of thematic layers of the study area.

1.3 Approach and Methodology

An approach and methodology adopted to achieve the major objective have been shown below step-wise.

i) Compilation of existing data
ii) Preparation of thematic maps on GIS platform
iii) Preparation of 2D aquifer disposition maps
iv) Compilation of Aquifer Maps and Management Plan

1.4 Location, Extent and Accessibility of the study area

The study area **(Plate 1.4)** comprising 6 blocks and 1 subdivision of South district in Sikkim. The six blocks namely Namchi, Namthang, Melli, Jorethang, Temi Tarku, Sikip of Namchi subdivision of South Sikkim district, covering a total area of approximately 280.32 sq. Km was taken up in this study. This area is located in the southern part of the State. The area extends between North latitudes 88°00' and 89^{0}10’ and East longitudes 28°00' and 27^{0}50’.

The study area partly falls in the Survey of India Degree Sheet no.78A/7 & 78A/12.This area is connected by roads with State Capital Gangtok which is located at a distance of 85km. The nearest railway station from the study area is New Jalpaiguri and the nearest airport is Bagdogra, both of which are located in West Bengal.

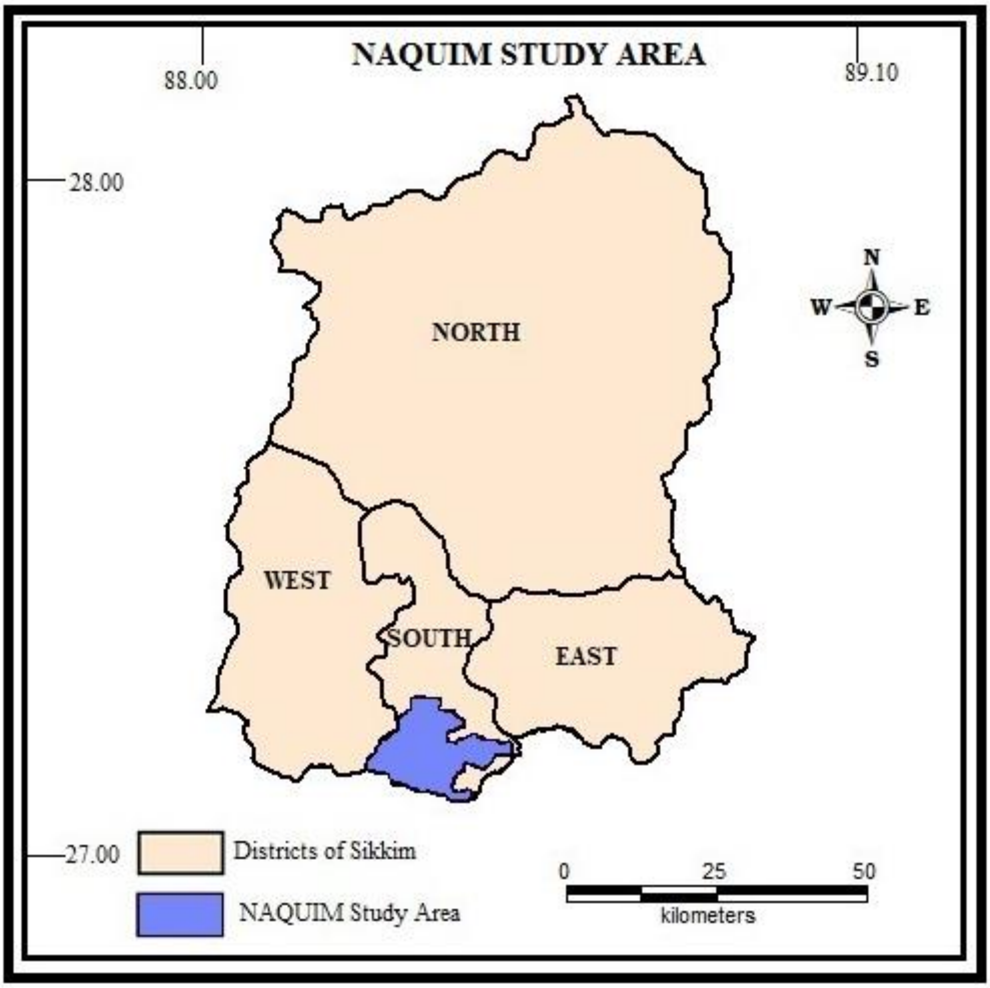

Plate 1.4: Aquifer mapping area in parts of South district of Sikkim

1.5 Administrative divisions and population

The study area covers 6 blocks namely Namchi, Namthang, Melli, Jorethang, Temi Tarku, Sikip of South district in Sikkim, covering an area of approximately 280.32 km^2 **(Plate 1.5).** Details of administrative divisions are summarized in Table 1.5.1.

Table 1.5.1: Administrative units of the study area

District	Sub-Division	Block	Area (km^2)	Villages
South Sikkim	Namchi	Namchi	120.22	24
		Namthang	61.39	33
		Melli	41.85	26
		Jorethang	38.57	25
		Temi Tarku	11.79	3
		Sikip	06.50	5
			280.32	116

The Total population of the Study area are presented in Table 1.5.2.

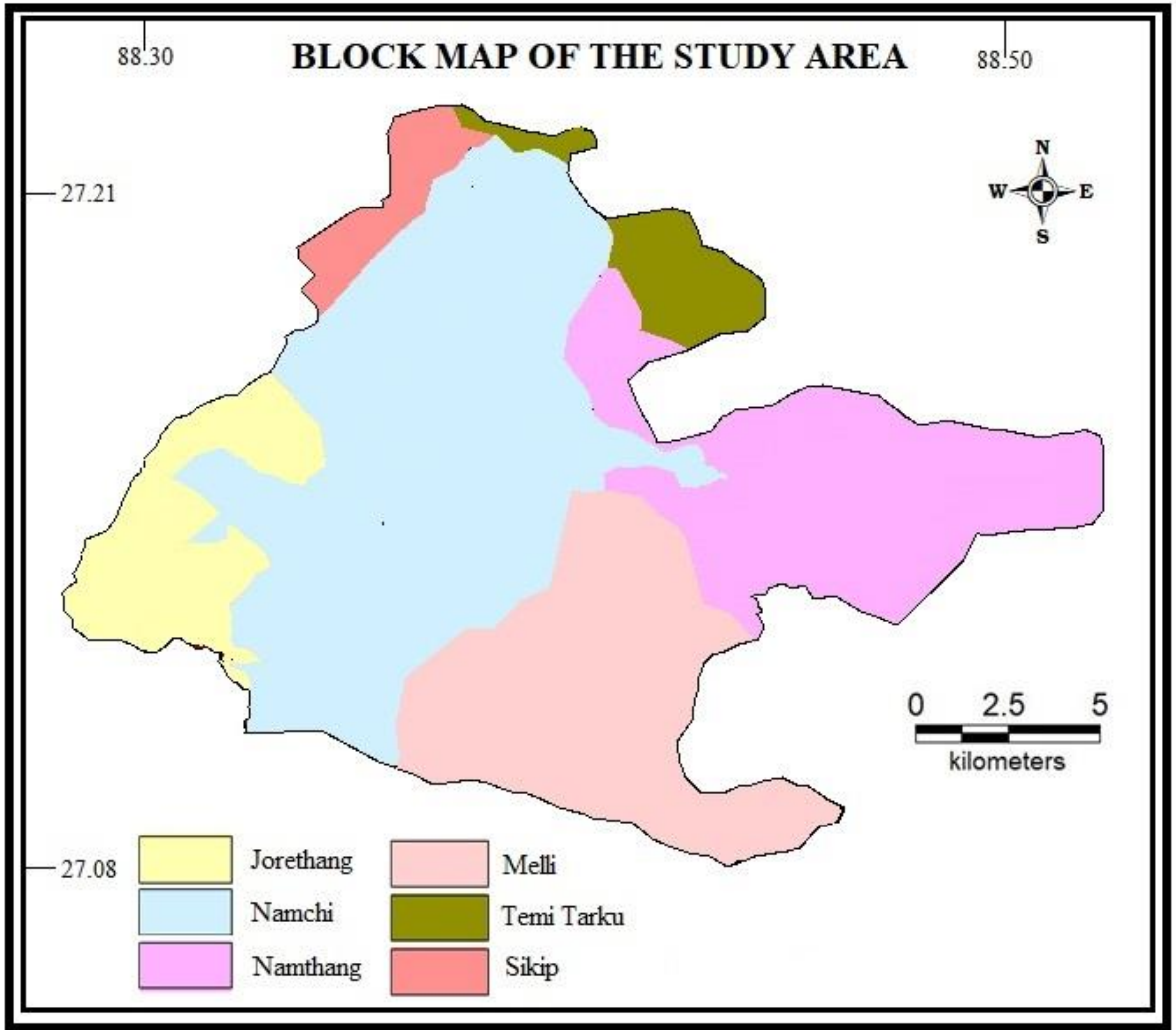

Plate 1.5: Block Map of the NAQUIM study area

Table 1.5.2: Population distribution in study area

Sub-Division	Rural Population			Urban Population			Total Population		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Namchi	40517	37179	77696	6166	6024	12190	46683	43203	89886

1.6 Land use, Irrigation and cropping pattern

Land Use: The land use/land cover of the study area is an important parameter which gives us information regarding the complex physical processes acting on the surface of the earth. Prominent five categories of land use/land cover were identifed in the study area **(Plate 1.5)** Evergreen forest, deciduous forest, fallow land, barren rocky land and settlement are identifed in the study area. The land use/land cover with vegetation has shown that the woody type plants with large root systems have helped in the improvement in the slope stability in an area. It is found that study area in general has a moderate vegetation cover with thick evergreen forest. Settlement area is seen to lie in some small pocket of the study area; it is the most fragile class as compared to other classes. Barren rocky surface, highly developed areas with network of roads, increases the probability of landslide occurrence in the study area. Land use map of the area has been shown in Plate 1.6.

Irrigation: Irrigation plays an important role for crop production and intensity of crops. The cultivation is done by both surface water as well as by rain water conservation. From age old times, irrigation depends mainly on springs and streams. The source of surface irrigation is Jhoras or streams (in Hilly area), river lift irrigation and storage tank. The district topography is rugged in nature with steep slope, and there is no such water supply system for irrigation except monsoon rainfall.

Cropping Pattern: Sikkim is primarily a state of rural and agricultural economy, where over 60 % of its population is directly engaged in agriculture. Principal food crops cultured in the study area include maize, paddy, barley, millet, wheat, buck wheat, beans etc. Important cash crops are cardamom, ginger, potato, soybean, fruit crops, and vegetables etc. Temi block of the study area is famous for organic tea plantation.

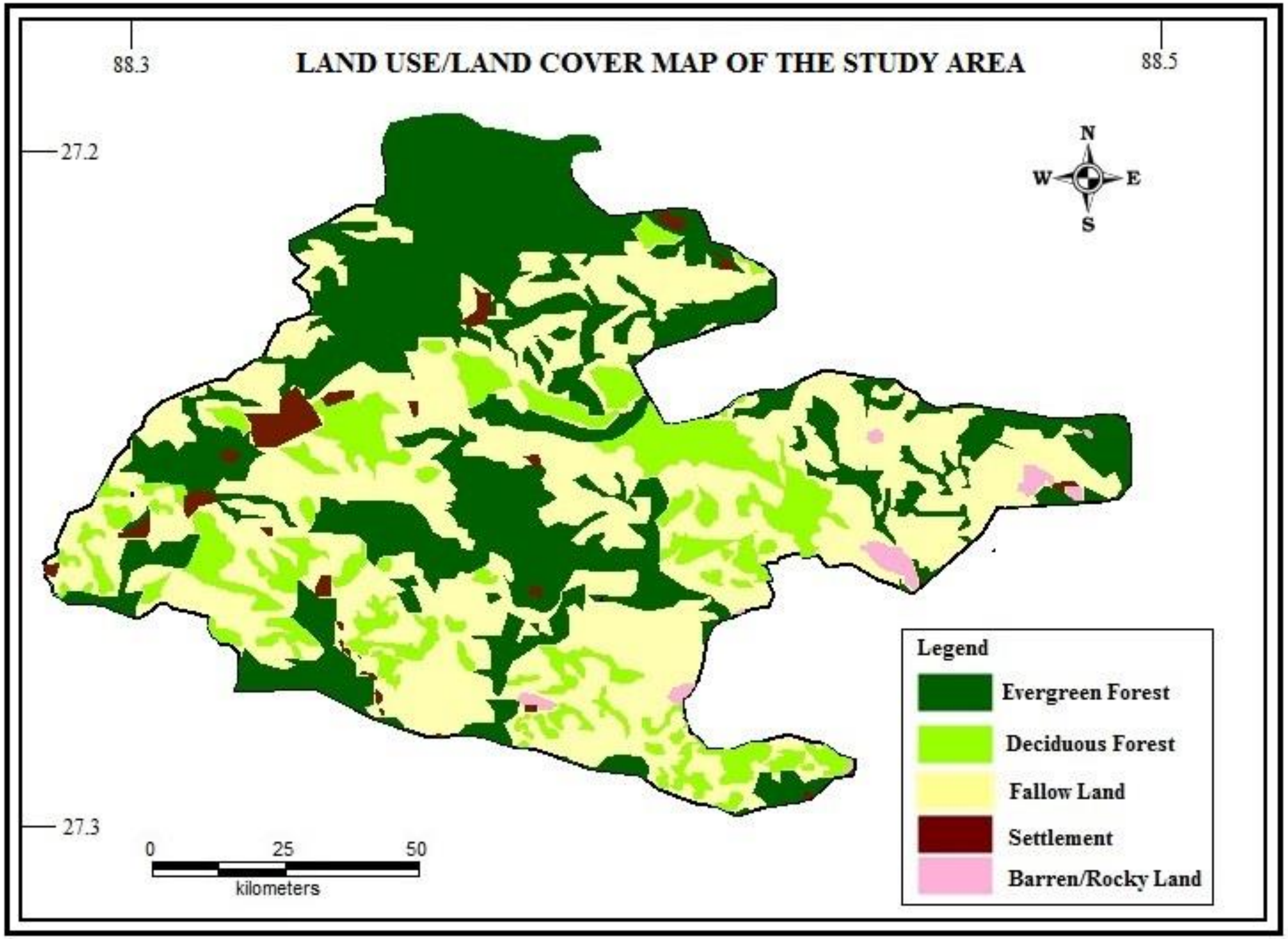

Plate 1.5 Land-use/Land-cover map of study area

1.7 Urban areas, Industries and Mining activities

Urban areas in the study area include only 1 town viz. Namchi in Namchi Sub Division in South Sikkim district, remaining entire study area comprises rural population. Small industries are set up in the study area in Jorethang and Namchi blocks. Mining activities are absent in this area.

2. CLIMATE

The climate depends on the landscape and landform pattern of any region. It is an important condition, which regulates the physical and biological activities. The spatial and temporal changes of environmental variables determine the climatic condition of an area. On the other hand, the elevation and slope are important factors that give rise to micro-climatic variation. The climate of the study area is characterized by hot and humid climate with adequate rainfall mainly derived from south-west monsoon, which starts from mid-June and continue upto September. The study area has four main seasons, as mentioned below.

1. Cold Winter Season: The winter season continues from middle of October to March. It gets very cold during winter months when temperature drops as low as below 0 degrees. The cold north-westerly wind blows over the region in this time.

2. Pre Monsoon Season: The season is prominent from late March to May. Thunderstorm and hailstorm are very common features at the time. These contribute a small amount ofrainfall. The days are bright and sunny.

3. Monsoon Season: From the mid June, the south-west monsoon brings heavy rainfall in South Sikkim. The rainfall is heavy and prolonged. The region is situated at the windward side of the Himalayas, as a result, the region receives quite heavy rainfall. But the amount of rainfall depends upon the situation of the slope and valleys that is why it varies from place to place. It is a season of fog, mist and torrential rain, which reduce the visibility causing the traffic hazards.

4. Post Monsoon Season: The fair weather is the main feature of the season and rainfall is mostly regular in this period also.

2.1 Rainfall

Month wise average rainfall for the year 2010 – 2017 in South Sikkim district in NAQUIM study area has presented in Table 2.1.1 below. Pre-monsoon showers are occasionally received in the month of March, April and May. Monsoon generally sets at the end of June and continuing up to October. Maximum rainfall takes place during the month of June to September.

The average annual rainfall is high but it varies from place to place due to variation of the slope. For example, Namchi block is situated at the lee-ward slope that is why it receives only 1500mm. of rainfall.

Normal Annual Rainfall in the district is to the tune of 1900 mm. Rainfall distribution map of the study area has been shown in Plate 2.1.

South Sikkim Rainfall (mm)														
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Mean**
2010	0	0	0	0	130	346.7	547.4	378.8	528.7	93.1	0.2	0	2024.9	168.7417
2011	11.5	5.4	90.4	117	152.7	308.5	663.3	513.4	318.2	13.9	28.6	1	2223.9	185.325
2012	10.1	3.6	9.1	122	187.5	367.2	372.1	359.7	385.1	16.9	0	0	1833.3	152.775
2013	4	25.7	66.2	111	263.8	288.4	297.8	339.6	189.2	141.5	2.2	13.5	1742.9	145.2417
2014	0	5.6	54.6	10	164.7	279.3	391.1	651.4	353.5	44.1	0	1.6	1955.9	162.9917
2015	2.4	9.2	74.4	155	269.9	394.8	625.8	377.3	448.5	84	30	3.8	2475.1	206.2583
2016	15.2	2.1	30.5	30.4	234.8	384.2	629.2	175.1	359.9	127.6	0	1.8	1990.8	165.9
2017	5.6	0	69	147.9	229	156.7	497.5	373	425.2	75.2	7	0	1986.1	165.5083

Table-2.1.1 Annual rainfall in South district of Sikkim for the period 2010-2017(mm)

Source: ENVIS Centre, Sikkim

2.2 Temperature

Summers in Namchi begin in March and end in the month of June. During this season the temperature hovers between 4°c - 12°c. During this time, the temperature can shoot up to 28° C, making the weather pretty warm yet bearable. Starting from July and stretching till September, the small town of Namchi experiences the Monsoon season. Temperature during this season ranges between 5°c - 13°c. The months starting from October to March witness the winter season. In this season, the weather in Namchi becomes a lot chilly with temperatures hovering between 8°c to -15°c.

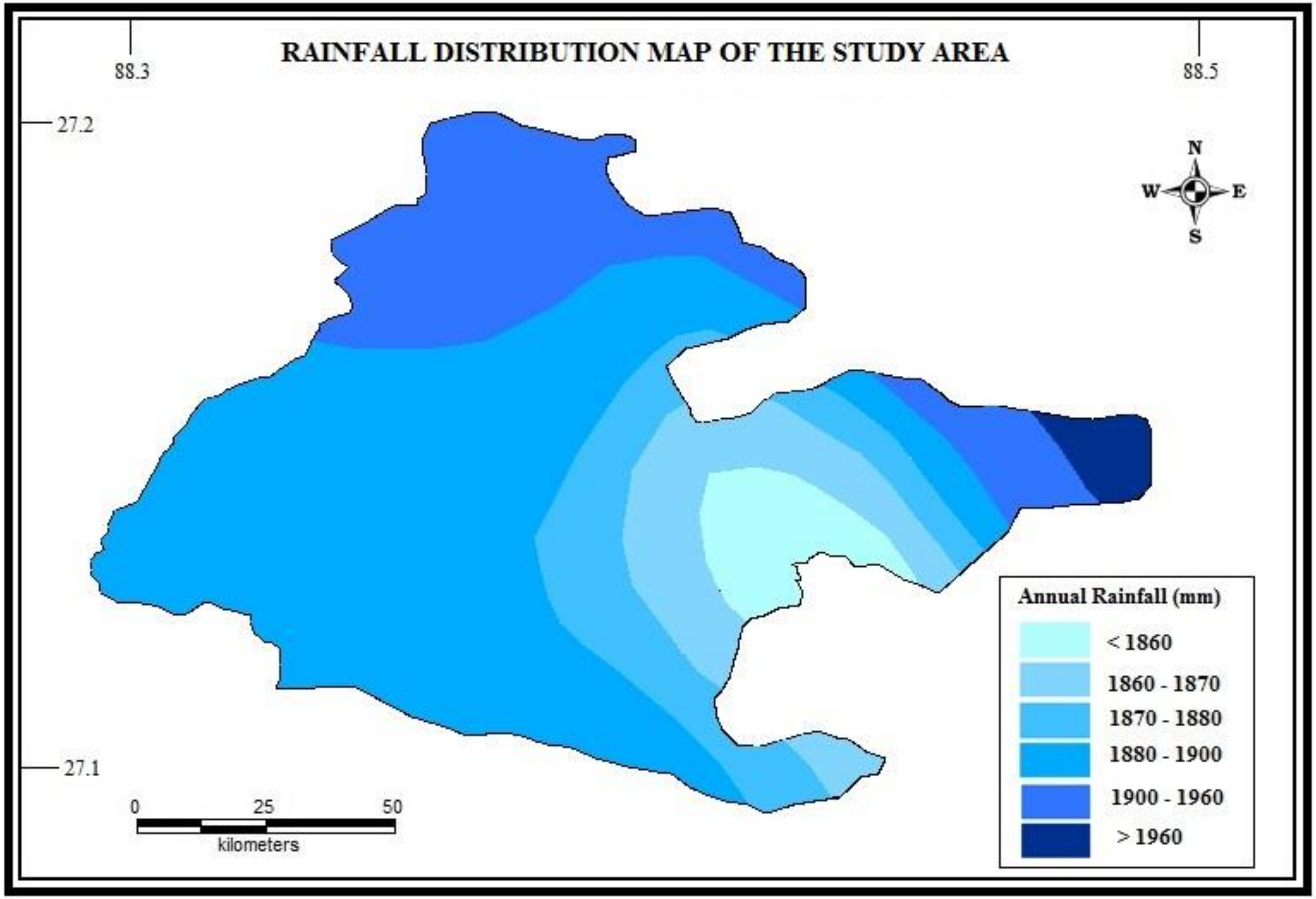

Plate 2.1 Rainfall distribution map of study area

3. PHYSIOGRAPHY

3.1 Geomorphology

The South District of Sikkim is predominantly mountainous forming part of the Eastern Himalayas. It is characterized by Himalayan topography with a series of crisscross ridges and ravines. The district topography is rugged in nature with steep slope and the altitude varies from 230 to 7000 m above MSL. The study area has moderate dissected hills and valleys to highly dissected valley as well as large number of denudational hill in the region. The State's climatic condition is determined almost exclusively by the difference in altitudes. Most of the rivers and streams in this area are in the boulder stage and have not attained a permanent regime even before entering the plains. While regular meandering courses, deep well defined beds and wide flood plains are the characteristics of stable rivers in the plains, the boulder rivers are having shallow beds and shifting braided and interlaced channels.

Urbanization in the road vicinity and also in the catchment areas is one of the major causes inducing unstable conditions, especially surface scour and thereby allowing water to percolate and create pore pressure conditions that cause movement of large scale debris creating blockage. The drainage basin of the present area is fan-shaped and has a greater run-off rate.

Several lineaments occur trending almost parallel to each other, implying that the stresses, which produce these features, were not local but acted in a large region to produce a number of failure or weak zones parallel to a particular direction. The strike ridges and valleys are the result of geological structure and lithology. Likewise, steep scarps, peaks and mass wasted scree slopes are the result of denudational processes. Differential weathering and erosion of various rock types has resulted in such relief variation. The low relief area is basically consisting of weaker rocks like schist and phyllites, while quartzite, gneiss give rise to higher relief with sharp crested ridge because of relatively resistant to weathering and erosion.

The Elevation Map of the study area is shown in **Plate.3.1a** and the Lineament density Map is shown in **Plate.3.1b**

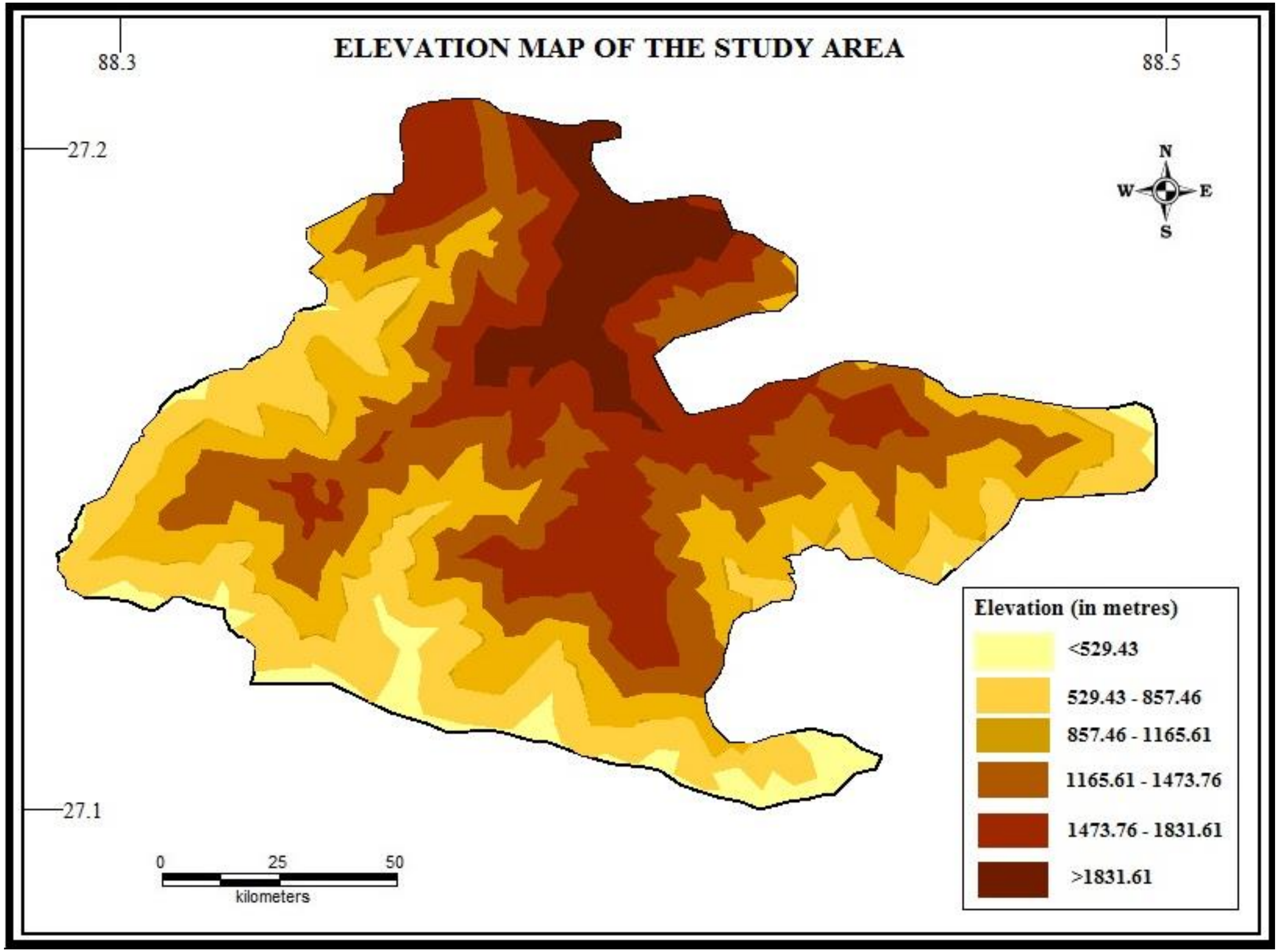

Fig. 3.1a: Elevation map of the NAQUIM study area

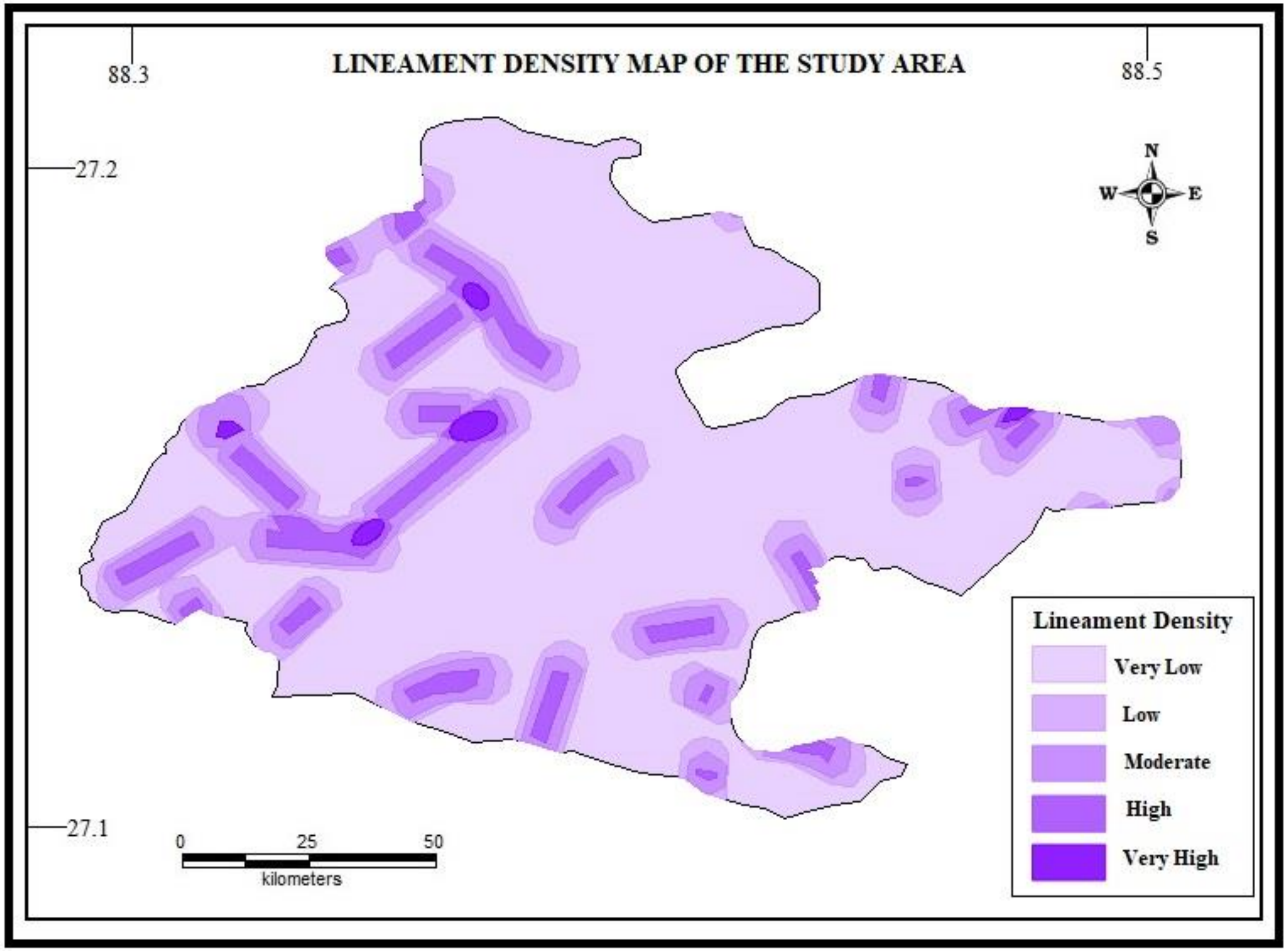

Fig. 3.1b: Lineament density map of the NAQUIM study area

3.2 Drainage

Drainage characteristics depend on the relief and geological structure of an area. The master stream of Sikkim as well as South Sikkim district is the Tista. The river Tista originates from a glacial lake, Chho Lhamo located at the north-eastern comer of the state, Sikkim. The river Tista enters in the South Sikkim district at the north-eastern corner near a place called Lingi. The river flows southwardly and makes a natural boundary of the study area in the east. Though in South Sikkim, the river Tista receives a numerous number of tributaries from both sides of the river bank. Among them, the river Rangit is one of the important right bank tributaries of South Sikkim, which forms a natural boundary of the district in the west.

The tributaries coming from the east of the district are more in number but shorter in length, whereas those coming from the west side of the district are very few in number but larger in length. The right bank tributaries of the river Tista are fed by the high mountain glaciers, that is why, they are perennial in character and more voluminous. But the left bank tributaries originate from seasonal rain and semi-permanent snow-fields, as a result of it, the tributaries are nonperennial in nature and less voluminous.

Another important river of South Sikkim is the river Rangit. It is one of the major tributaries of the river Tista. It originates from a comparatively low altitude area of South Sikkim, though its chief feeder, the Rathong Chhu originates from the Rathong glacier in the West district of Sikkim. The Rangit river ends her journey near Melli, where she meets with the river Tista.

The drainage pattern depends on the slope of land, underlying rock structure as well as the climatic conditions of the area. The rivers Tista and Rangit exhibit the sub-parallel drainage system along with its tributaries. Most of the strams also called Kholas have originated from the higher altitudes and flow down by cutting deep gorges in lower altitude where they ultimately join with the main river Tista. Ridges, ravines and deep “V” shaped valleys are the main features ofthe two main rivers and their tributaries.

3.3 Soil Characteristics

As the whole, South Sikkim has fine loamy sand to silty clay loam soil. The soils of the region contain almost 80% of slate and phyllite. In the tropical evergreen forest zone of study area, the soils are not rich in humus due to leaching by the heavy rainfall. These soils are acidic in nature and the pH is ranging from 4.3 to 6.4, with the mean value 5.37. But in the temperate deciduous forest zone, the soil with thick layer of leaf mound has been found. These soils are rich in organic matter and fertile in character. In the Tista and the Rangit valleys loamy to sandy loamy alluvial soils are found. These are clayey, alluvium and rich in organic matter. So, it can be said that the soil properties depend on landscape position.

Soils of the Namchi area are mainly composed of three major soil groups, as follows.

i. ***Entisols*:** (Lithic Udorthents and Typic Udorthents)

ii. ***Inceptisols*:** (Humic Pachic Dystrudepts, Humic Dystrudepts and Typic Dystrudepts)

iii. ***Mollisols:*** (Typic Paleudolls, Typic Argiudolls, Cumulic Hapludolls, Entic Hapludolls and Typic Hapludolls).

From the soil map **(Plate 3.3)** of the study area, it is observed that Inceptisols are dominant soil group (64.6%) followed by Entisols and Mollisols occupying 14.2% and 21.2%, respectively. Lithic Udorthents and Typic Udorthents are associated with coarse-grained excessively drained loamy–skeletal soils with strong surface stoniness and strong erosion; this soil group is severely prone to erosion. Entic Hapludolls is moderately deep, excessively drained, loamy–skeletal with moderate to strong erosion. Typic Hapludolls, Typic Argiudolls, Cumulic Hapludolls and Typic Paleudolls soils are well drained, fine–loamy to coarse–loamy, moderately shallow to deep, with moderate erosion, developed on steeply sloping hill side. Humic Pachic Dystrudepts, Humic Dystrudepts and Typic Dystrudepts are well to somewhat excessively drain coarse–loamy to fine–loamy soils, which is less prone to erosion.

However, the detailed Soil Map of this area is shown in **Plate- 3.3**

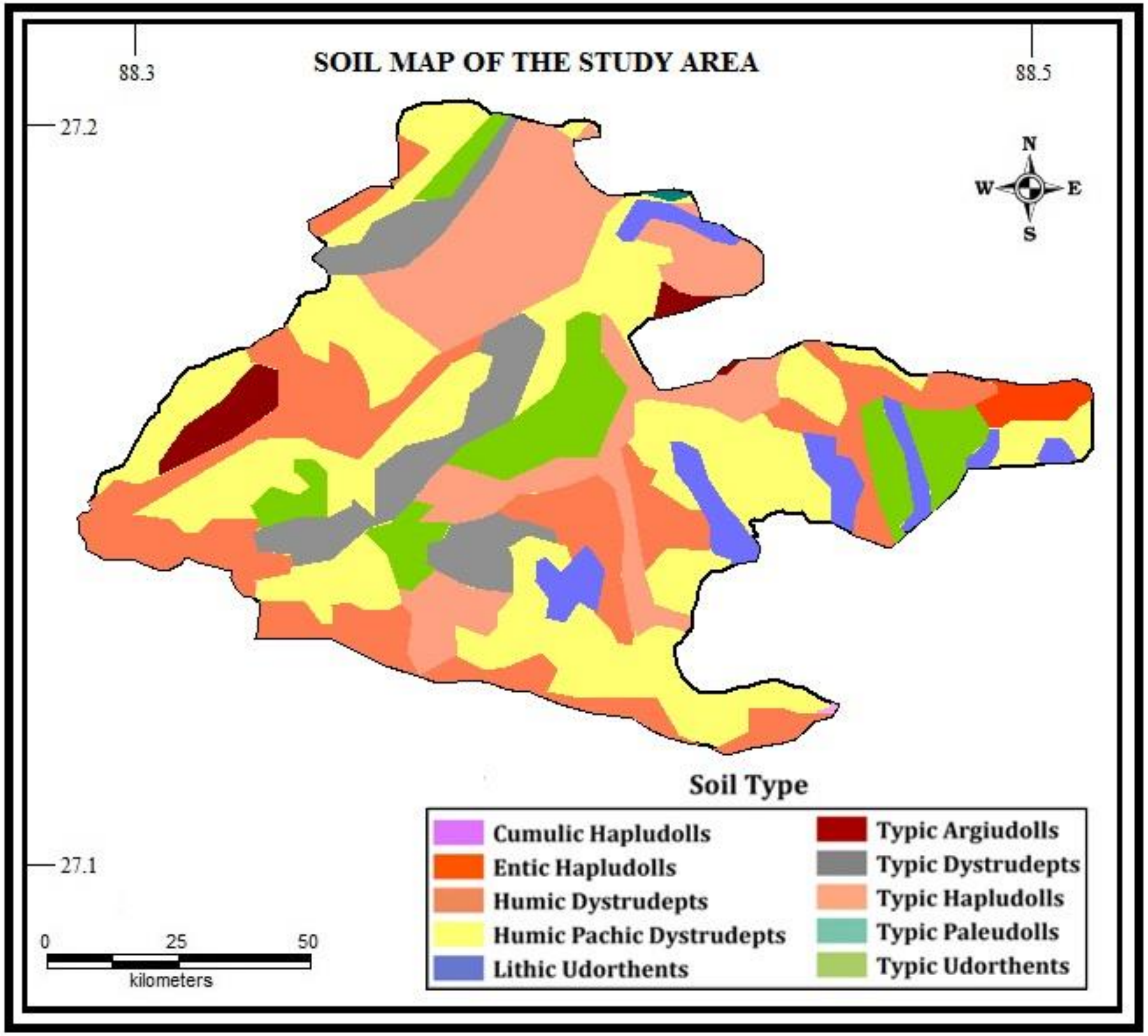

Plate. 3.3: Soil map of the study area

4. GEOLOGY

4.1 General Geology

The general geology of South Sikkim reflects that two groups of rocks are predominant in the region. These are as follows:

1. The Gneissic Group

The Gneissic group of rocks is the oldest, which constitutes the main body of the Himalayas. In South Sikkim, the gneiss is highly micaceous and frequently passes into mica schists. Both muscovite and biotite are predominant here.

2. The Dalings Group

"Dalings" - the name was given by the famous geologist, Mallet. Phyllites are the predominant rocks of the Dalings group. Dark clay slates with thick quartzite bands are encountered. In the south of Namchi (the district head quarter of South Sikkim) grit stones are dominant, whereas impure siliceous limestones are found in the north-east and north-west of Namchi and highly carbonaceous shales are visible at the Manpur Khola, just south of Namchi and at the east bank of the Rangiit. Igneous rocks are rare in the Dalings group of rock.

In the study of geology of South Sikkim one thing is mentionable, i.e., the *"Rangit Window". In the Rangit valley Gondwana and Buxa rocks occur inside a tectonic window called as the "Rangit Window".* The Rangit valley of South Sikkim, an outcrop of the Gondwana, is surrounded on all sides by the Daling schist and phyllite, which had been referred to as a tectonic window by Ghosh (1952). Continuous mapping across the 31 Rangit into South Sikkim brings out some important striking observations, i.e., a continuous stratigraphic sequence comprising Gondwana and Buxa rocks occurs, disclosing a systematic sequence of structural and metamorphic events. Following is the lithostratigraphic succession of the Rangit valley area **(Table 4.1)**.

Table 4.1: Lithostratigraphic Succession ofthe Rangit Valley Area

Stratigraphy	Lithostratigraphic Unit	Rock Types
Gondwana Super Group	Namchi Formation ≡ Part of Damuda Group	Grit, sand stone, carbonaceous shale, slate and coal with plant fossils of Glossopteris and Vertebraria
	Rangit Formation ≡ Talchir Formation	Pebble-slate, pebbly-quartzite, conglomerate, khaki-coloured slate, slate
Daling group	Buxa Formation ≡ UP. Daling Group	Dolomitic marble, impure pink phyllitic marble with slate partings, quartzite
	Gorubathan -Reyang Formations Lr.-Mid. Daling Group	Augen schist, chlorite-biotiteschist and phyllite with inter-bedded quartzite, hornblende schist and pegmatite

Source*: Gangopadhyay, P. K. and Ray, S (1982):* ***"Tectonic Framework ofthe 'Rangit Window' Around Namchi, South Sikkim"****, Jhingram, A G. and Verma, P. K. (eds.), "****Himalayan Geology"****, Wadia Institute ofHimalayan Geology. Dehra Dun, (VoL 10, pp. 338 - 351).*

Among the four lithostratigraphic units the Namchi, Rangit and Buxa formations occur inside the "Rangit Window" while the Gorubathan-Reyang formations form the cover-rock of the window and are now exposed surrounding it

The geology of the entire study area has been shown in plate **Plate – 4.1**.

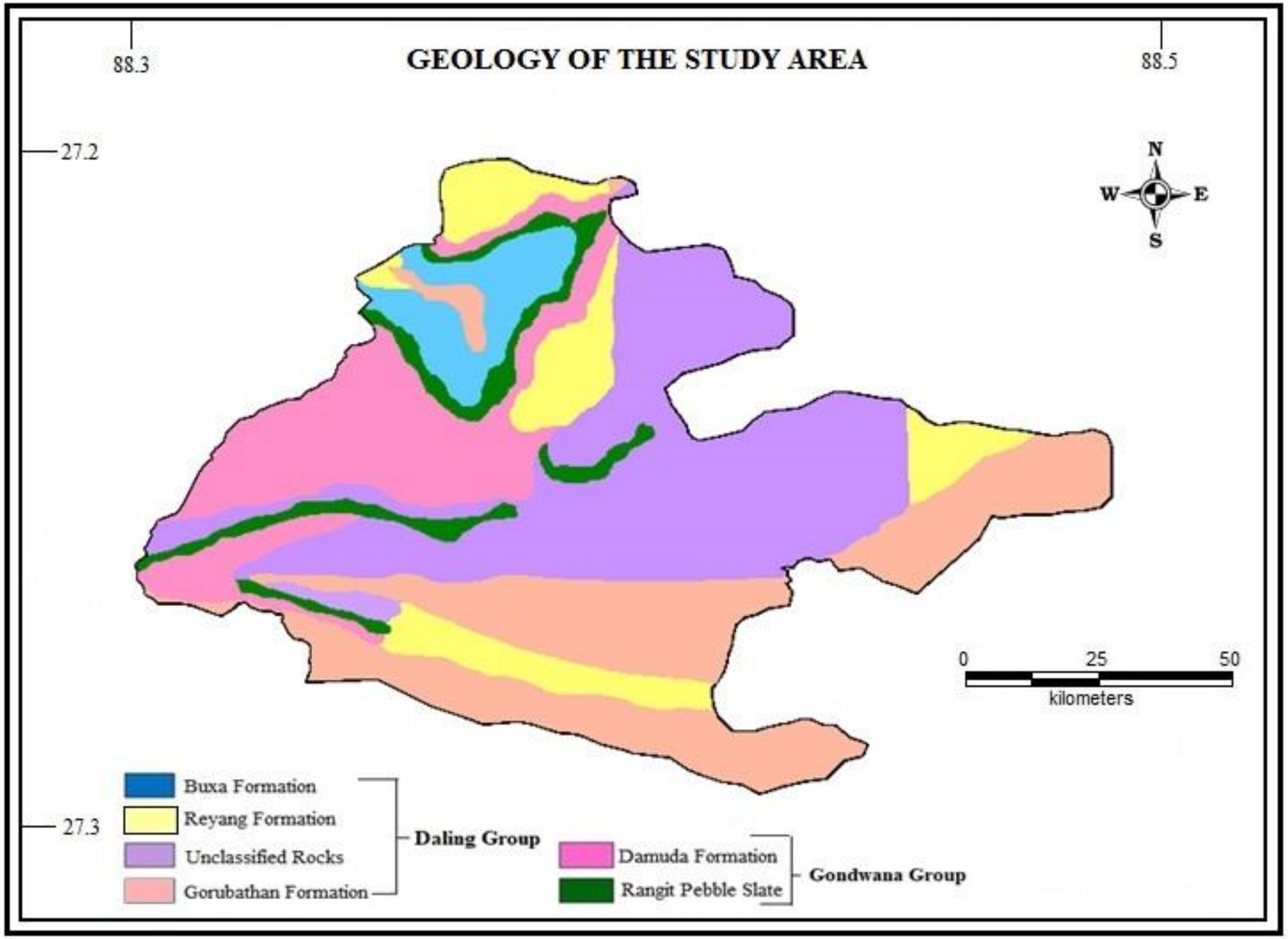

Plate 4.1: Geological Map of the Study Area

4.2 Sub Surface Geology

The geological formation of study area in South Sikkim district comprises Quaternary deposits of alluvium in river terraces which are developed sporadically along the streams and rivers. The Gondwana rocks occur in and around Namchi block. The predominant rock types are shale, sandstone, quartzite, coal. Among the Daling group Buxa formation is younger and consists of quartzites variegated slates, black slates and dolomite.

Location of Exploratory well are shown in **Plate – 4.2a.** All of the wells were exlplored through in-house activities of CGWB.

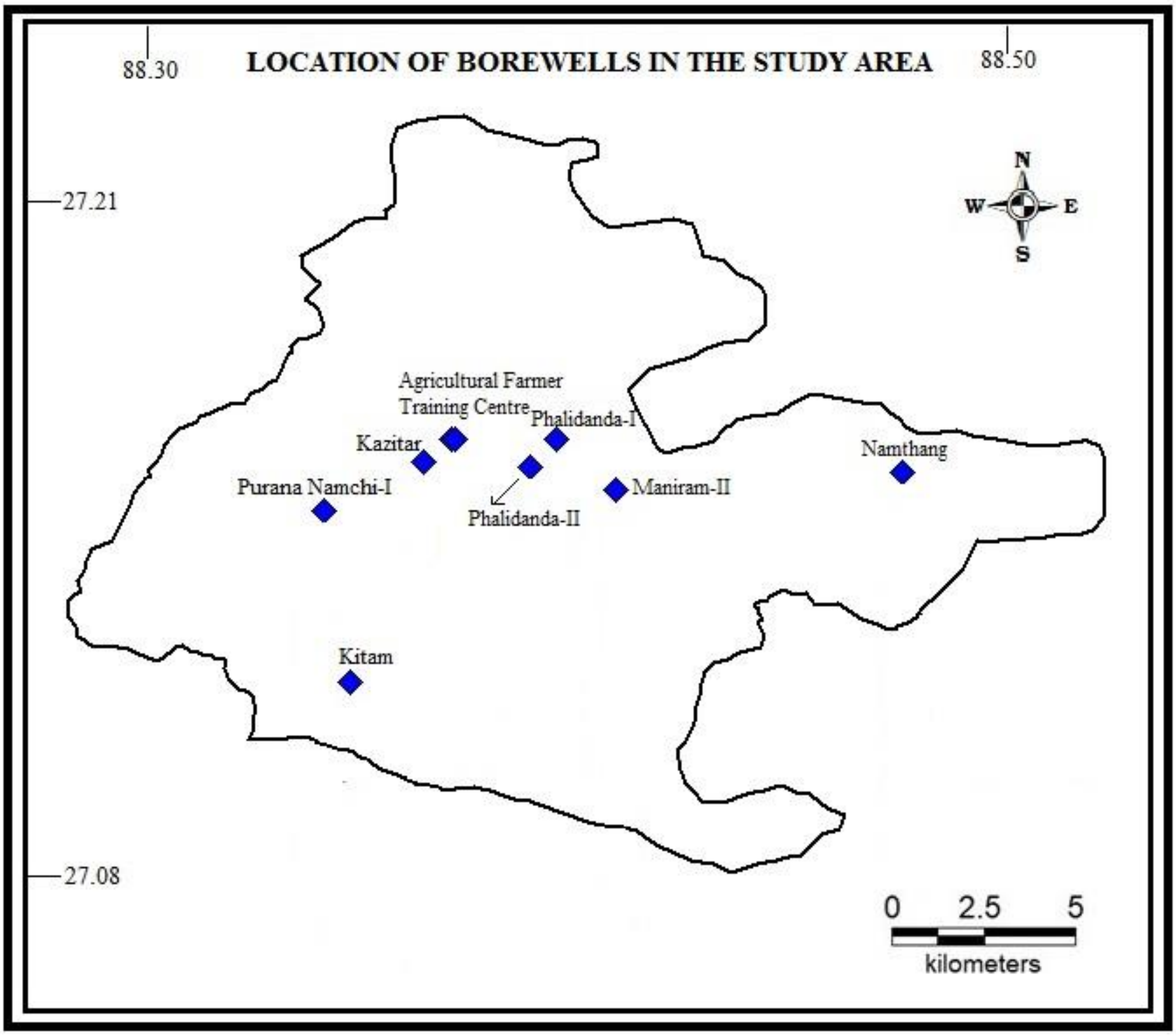

Plate-4.2a: Location of Exploratory wells in Parts of NAQUIM Area

CGWB has undertaken exploratory drilling at few locations within the study area during 1984-1990. This has revealed the existence of water bearing fractured horizons in the depth range 10m to 60m at suitable locales which are traversed by lineaments. This exploration studies have proved that groundwater is available in pockets, even at higher altitudes.

Unfortunately waterwell drilling couldnot get much attention and support in the difficuly terrain of Sikkim and this idea got prolonged for two decades.

A total of nine boreholes are encountered in the study area. The lithologs of these nine wells have been plotted to ascertain the subsurface geology as well to get a 2D projection of groundwater bearing zones in this area.

In **Plate - 4.2b**, lithologs encountered in exploratory wells have been shown in parts of NAQUIM area. In **Plate - 4.2c** aquifer disposition has been shown in correlation with the broad geology of the area.

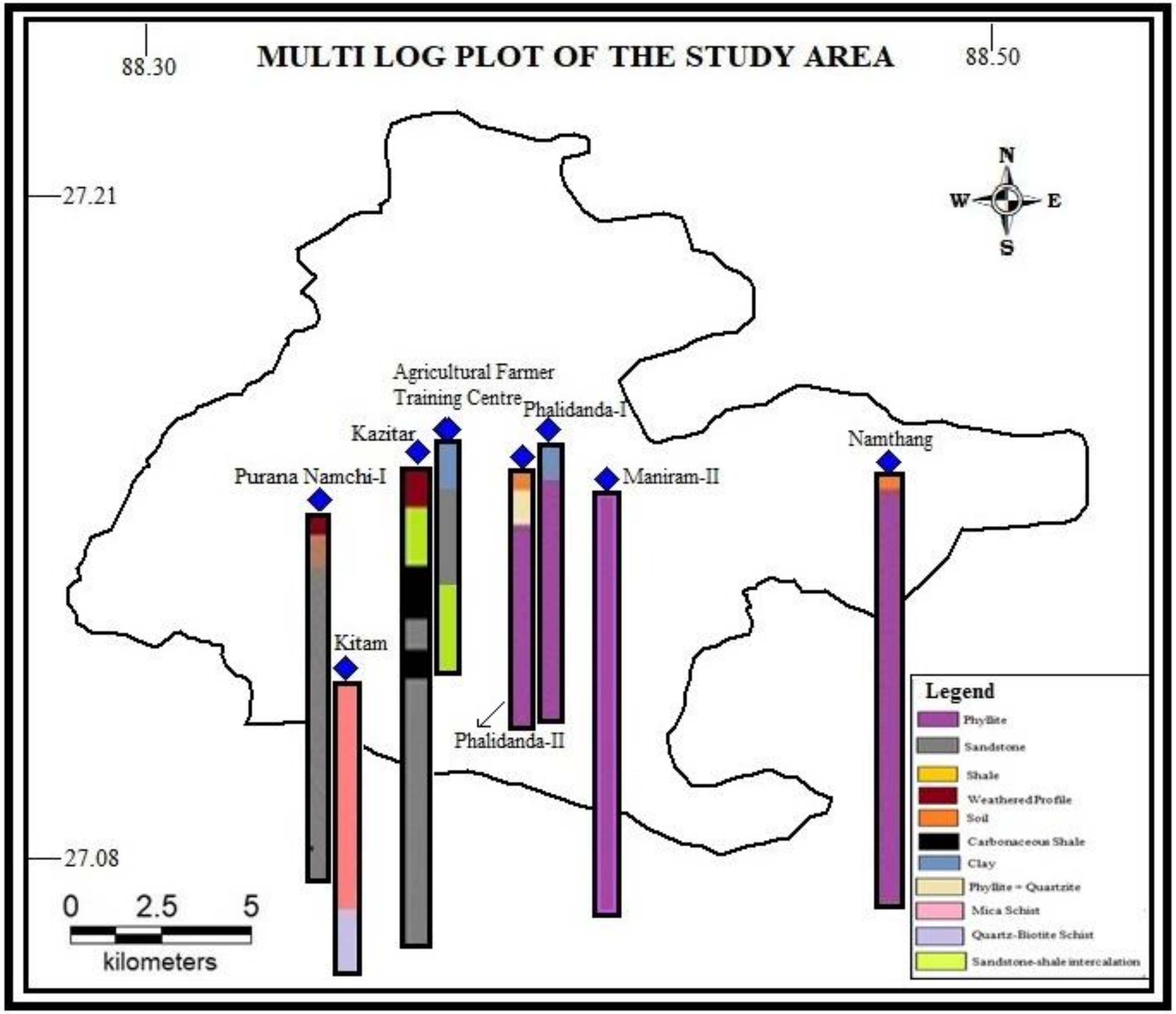

Plate – 4.2b: Lithologs of exploratory wells in the study area

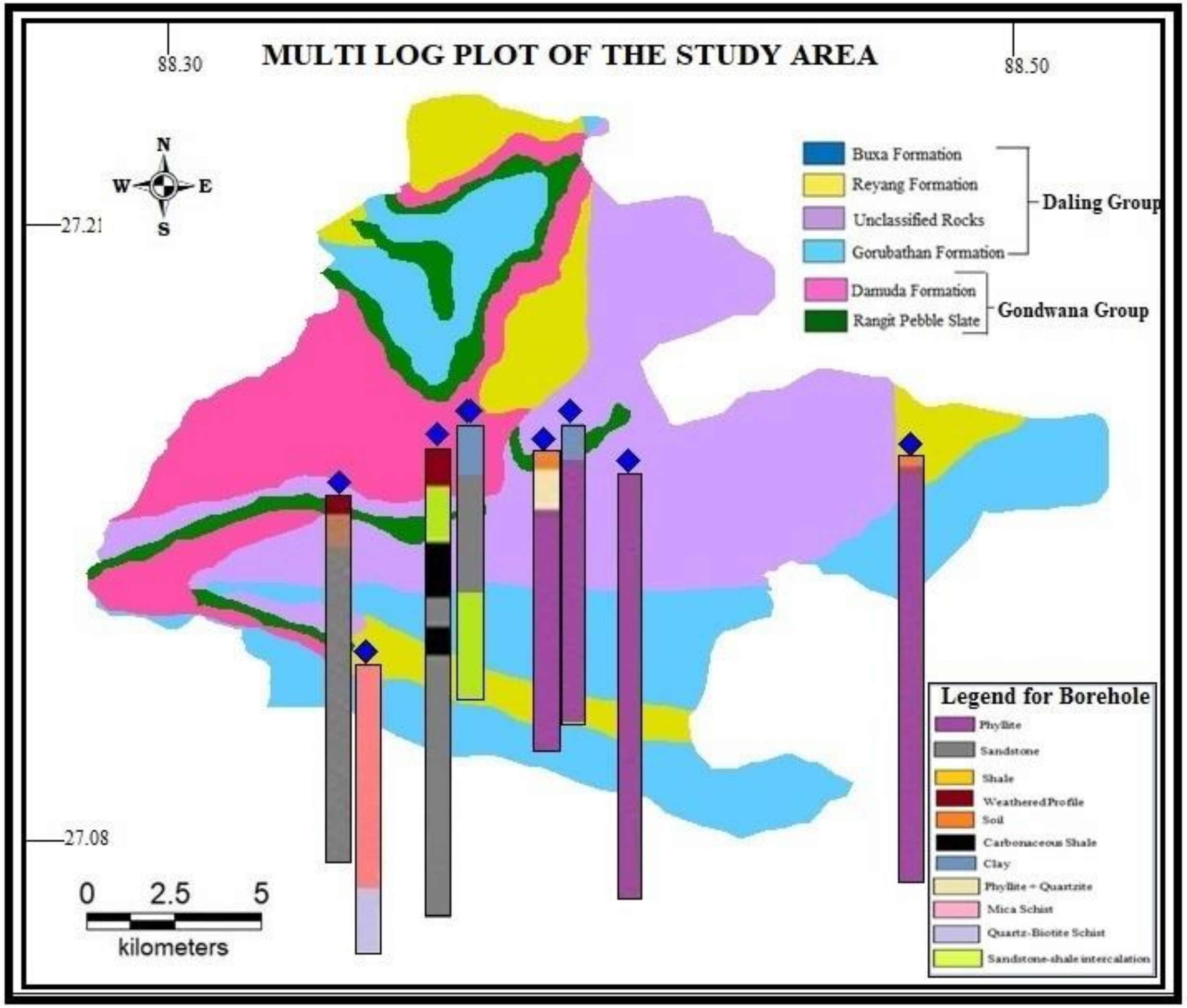

Plate – 4.2c: Lithologs of NAQUIM Area in correlation with general geology

5. HYDROGEOLOGY

5.1 Water bearing formations

The main repository of ground water in the the hilly state of Sikkim is fracture and joint plains. The presence of innumerable perennial springs with varied discharge is also suggestive of the occurrence of ground water in various rock formations and weathered zones in the phyllite, schist, gneisses and quartzite.

Due to higher relief and steeper gradient of the area, ground water comes out as seepages and springs, wherever the land surface intersects local ground water body. The area is characterized by high rainfall, with the result that the primary source of ground water is from natural precipitation. Direct infiltrations and percolation through joints, fractures, weathered zones of the rocky parts, and through soil covers are the principal mode of recharge of the springs. Due to high slope most of the precipitation in the area flows off as surface-run off through streams, 'kholas' and through intermittent springs. The movement of groundwater is mainly controlled by structural set up of the area and physiography.

Mainly two types of aquifers are encountered in the study area:

i. First type

- The first type of Aquifer occurs within the depth range 0.5 to 10m.
- These aquifers are disposed in varying slope ranging between 20o to 50o.
- It is mostly composed of colluviums and weathered mantle of pre-existing rocks.

ii. Second type

- This type of aquifer exists in some parts within Gondwana formation (sandstones) within depths varying from 15m to 60m.

In some parts of the area the second aquifer is constituted by fractured hardrocks i.e. in the Daling formation (schists/phyllites) which exists with depth range of 10m to 40m.

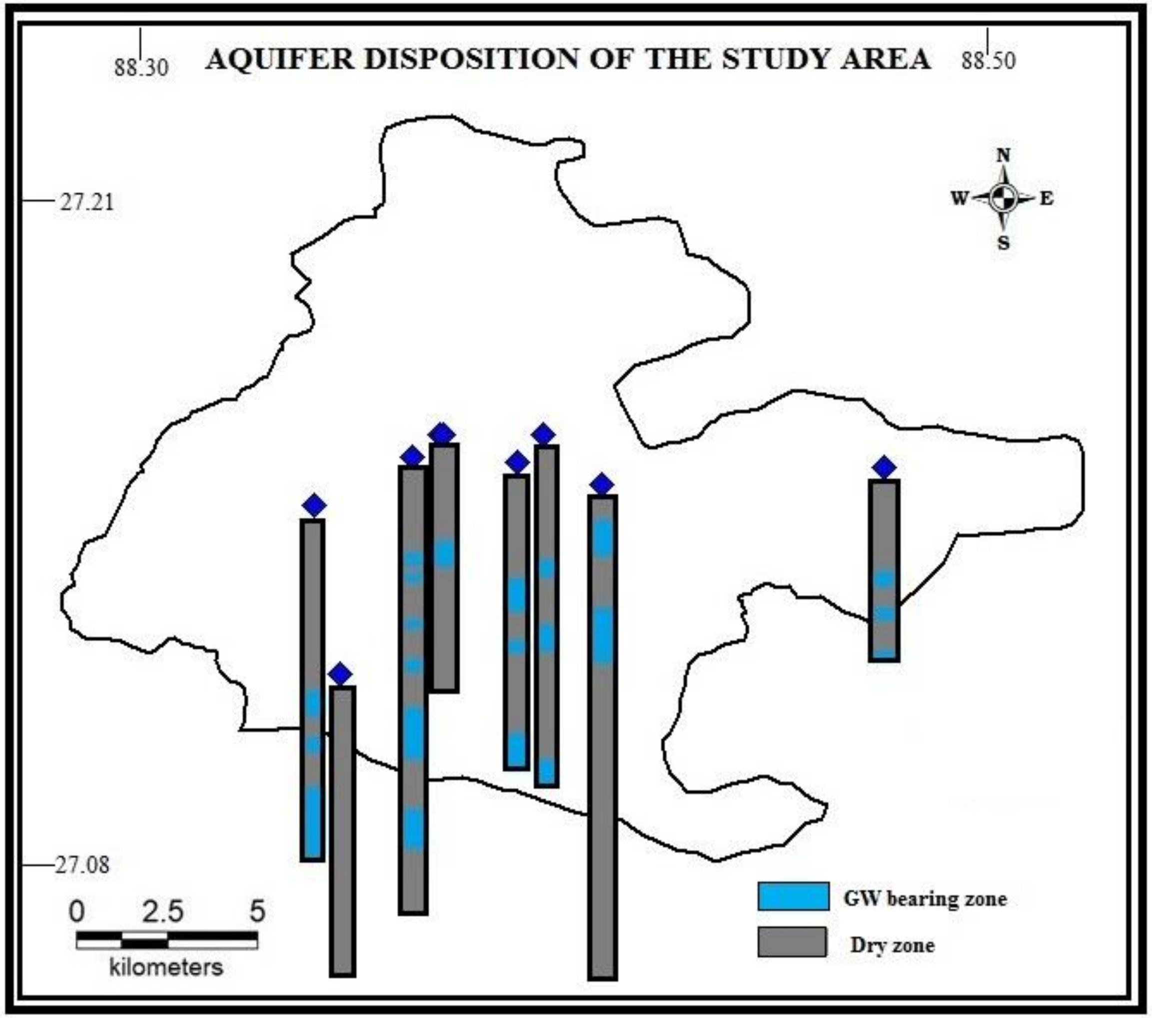

Plate-5.1: Occurrence of aquifers in the study area

Table- 5.1: Water bearing zones in the study area

Location	Type of Aquifer	Zone Tapped	
Purana Namchi-I	Gondwanas	34	40
		46	47
		51	63
Kitam	Daling Phyllite	-	-
Kazitar	Gondwanas	17	19
		22	22.8
		31	33.8
		38.2	41.5
		48	60
		70	75
Agricultural Farmer Training Centre	Gondwanas	14	15
Maniram-II	Buxa Phyllites	4	13
		24	36
Phalidanda-I	Daling Phyllite	17	19
		28	31
		45	47.8
Phalidanda-II	Daling Phyllite	13	17
		21	22.5
		34	38.5
Ghurpise	Gondwanas	32	34
Namthang	Daling Schist & Phyllite	16	17
		23.5	24
		29	30.5

5.2 Aquifer wise groundwater regime, depth to water level

The depth to water level of the groundwater bearing zones cannot be measured due to the absence of monitoring stations in the state of Sikkim.

5.3 Water Level Fluctuation

Water level fluctuation cannot be monitored due to the absence of monitoring stations in the state.

5.4 Occurrence, movement and distribution of ground water

Rainwater and snow melt water in high altitude percolate down through the soil horizon and cracks and fissures in the rocks. The groundwater thus formed flows along the slope and forms a water table. The water table often cuts the sloping surface at various altitudinal levels and emanates in the form of a spring. Depending upon rainfall, availability of snow melt water facilitated by the geological structure and formational characteristics of a rock, thickness and porosity of the soil horizon, the yield of the springs varies to a great extent. Springs are considered as the lifeline of the people dwelling in hilly and mountainous terrain as it facilitates as the chief source of water for drinking as also for irrigation.

Spring is a concentrated discharge of ground water appearing at the ground surface as flowing water. To be distinguished from springs are seepage areas which indicate a slower movement of ground water to the ground surface. Water in seepage area may pond and evaporates or flows, depending on magnitude of flow, the climate and the topography.

Gravity springs are the type of springs that result from water flowing under hydrostatic pressure and flow along slopes**.** Such types of springs are highly abundant in the study area.

5.5 Aquifers with yield prospects

From the In-house exploration of CGWB carried out during 1984-1990, two Aquifer Groups have been delineated down to a depth of 101 m bgl in the area under study.

The first type of Aquifer occurs within the depth range 0.5 to 10m, is disposed in varying slope ranging between 20^{o} to 50^{o} and is mostly composed of colluviums and weathered mantle of pre-existing rocks.

The second type of aquifer exists in some parts within Gondwana formation (sandstones) within depths varying from 15m to 60m. In some parts of the area the second aquifer is constituted by fractured hardrocks i.e. in the Daling formation (schists/phyllites) which exists with depth range of 10m to 40m

The Hydrogeological parameters of Exploratory Boreholes in the Study Area of South Sikkim district are given in the following Table-5.5.

Table- 5.5: Hydrogeological Details of Exploratory Boreholes in the Study Area of South Sikkim district

Location	Type of Well	Depth Drilled	Type of Aquifer	Zone Tapped		SWL (mbgl)	Discharge (lps)	Drawdown (m)	T (m^2/d)	Storativity	Chemical quality	Remarks
Purana Namchi-I site	EW	53.5	Gondwanas	34 46 51	40 47 63	-	4.0	-	-	-	-	-
Kitam	EW	70.0	Daling Phyllite	-	-	-	Dry	-	-	-		Abandoned
Kazitar/ Namchi Bazaar	EW	91.0	Gondwanas	17 22 31 38.2 48 70	19 22.8 33.8 41.5 60 75	14.23	1.43 (Auto flow after monsoon)	5.32	-	5.138 x 10^{-4}	Fe : 20.7 ppm	Iron removal necessary
Agricultural Farmer Training Centre	EW	27.0	Gondwanas	14	15	0.66	8.008	10.15	316.43	-	-	-
Maniram-II site	EW	101.0	Buxa Phyllites	4 24	13 36	-	0.12 (by compressor)	-	-	-	-	Abandoned for low yield as the discharge was very little, pump lowering was not possible but the well may operate as hand pump fitted well
Phalidanda-I	EW	47.80	Daling Phyllite	17 28 45	19 31 47.8	7.155	4.84	20.55	-	-	-	-
Phalidanda-II	EW	38.50	Daling Phyllite	13 21 34	17 22.5 38.5	15.10	5.169	9.736	181.49	-	EC:37, pH:7.0 HCO_3:12.2, Cl:70 TH:20	-
Ghurpise	EW	80.60	Gondwanas	32	34	40.50	0.12 (by compressor)	-	-	-	EC:378, pH:7.8 HCO_3:220, Cl:11 TH:190	Later filled up
Namthang	EW	30.50	Daling Schist & Phyllite	16 23.5 29	17 24 30.5	11.78	0.41 (by compressor)	-	-	-	-	Extensive caving in main well

6. GROUND WATER RESOURCES

Though the entire country has been assessed for its ground water resource through GEC '15 methodology, the same cannot be applied to Sikkim as it excludes its application in hilly areas with more than 20% slope. The entire state of Sikkim exhibits more than 20% slope. Moreover, as discussed earlier, Sikkim mostly lacks groundwater abstraction structures. The rural population is entirely dependent on spring sources; where as the urban and rural marketing centres are dependent on water supply schemes tapping major rivers, lakes or springs. This situation poses a major problem towards ground water resource estimation process initiated in the country.

However, it was observed from field studies that several springs are located at slopes more than 20%. Hence, an alternative approach of resource estimation through spring discharge quantification in areas having upto 50% slope was attempted. Recharge areas have been demarcated in each district which excluded the areas under permafrost and areas having >50%. Further, recharge has been computed using Rainfall Recharge method and discharge has been calculated from the values of both natural discharge as well as groundwater draft data. This was followed by calculations as per GEC’15 methodology.

District has been considered as ground water resource assessment unit. The dynamic groundwater resources of the South Sikkim district has been appended below in Table 6.

Table-6: Dynamic ground water resources of South Sikkim, as par 31st March 2017

District	Assessment Unit Name	Total Annual Ground Water Recharge (Ham)	Total Natural Discharges (Ham)	Annual Extractable Ground Water Recharge (Ham)	Current Annual Ground Water Extraction(Ham)				Annual GW Allocation for Domestic Use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)	Categorization (OE/Critical/Semi critical/Safe)
					Irrigation Use	Industrial Use	Domestic Use	Total Extraction				
South	South District	46740.48	39378.77	7361.71	0	41.66	0	41.66	340.83	6979.22	0.57	Safe

7. HYDROCHEMISTRY

In the entire study area ground water occurs mainly in the form of springs and from the chemical analysis it was observed that the ground water is of extremely good quality. The spring water is fresh, potent and suitable for domestic, irrigation and industrial uses.

7.1 General range of chemical parameter

From the analytical results as available from the chemical analysis of samples collected in the field area, the water quality is given below **(Table 7.1)**.

pH of ground water, in general, is around 8.2, Sp. Conductance varies between 26 to 287 µ/cm at 25°C. Total Hardness as CaCo3 varies between 15 to 130 ppm. Concentrations of Na and K are ranging from 0.2 to 0.7 mg/l and from 0.48 to 2.9 mg/1, respectively. Concentrations of Ca and Mg are ranging within 4-30 mg/1 and 1.21 to 7.29 mg/1 respectively. Concentrations of Fe and Si are ranging from 0.05 to 0.17 mg/l and from 5 to 13 mg/1, respectively. HCO_3 is present within range of 6-146 mg/1 and Cl is mostly in the range of 7-19 mg/1. SO_4 concentration varies within 0.43-4 mg/l. NO_3 concentration varies 1.37-2.03 mg/l. Fluoride concentration varies 0.12-0.29 mg/l.

Table - 7: Aquifer wise chemical parameters in study area of South Sikkim District

Chemical Constituents	Value of Spring Water
Ph	8.2
Sp. Conductance in µ/cm at 25°C	26 – 287
TDS (ppm)	NA
Total Hardness as CaCo3 (ppm)	15 – 130
Calcium (ppm)	4 – 30
Magnesium (ppm)	1.21 – 7.29
Sodium (ppm)	0.2 – 0.7
Potassium (ppm)	0.4 – 2.9
Iron (ppm)	0.05 – 0.17
Silicon (ppm)	5 – 13
Bi-carbonate (ppm)	6 – 146
Chloride (ppm)	7 – 19
Sulphate (ppm)	0.43 – 4
Nitrate (ppm)	1.37 – 2.03
Fluoride (ppm)	0.12 – 0.29

7.2 Ground water pollution

Periodic quality assessment of drinking water sources is necessary to guarantee the quality and security of water supply to people. All the water samples analysed in the laboratory reveal that all chemical parameters in collected water samples show values within permissible limit.

7.3 Ground Water Suitability for irrigation

Sikkim, being a hilly state with varying degree of slopes, constructing big irrigation canals running across the length & breadth of the State is also not feasible and entails a very high capital cost & maintenance cost, and since the majority of farmers are marginal farmers, they are not able to provide irrigation to the crops through costly means.

The Ground water is available in highly dynamic state and unavailable for useful purpose in the highly sloping topography. Hence extraction of groundwater for irrigation purpose is practically zero. Springs, both seasonal and perennial are the main source of available water. Availability of abundant stream water during the summer allows for growing of paddy which the farmers carry to their field through temporary channels. Otherwise almost all the crops are grown on rain conditions. The topography again is a big constraint in developing a suitable water application method. Design/ layout of drip irrigation, sprinklers etc., are difficult and entail high cost due to difference in pressure head in every terrace/ field.

Hence, a more pragmatic approach is to go for micro irrigation and better methods of water application, like small water harvesting structures, roof water harvesting and water saving application methods like sprinklers, drips, porous pipes etc.

8. AQUIFER MANAGEMENT PLAN

8.1 Desirable Management Interventions

To formulate the proper Aquifer Management Plan, it is required to understand the ground water resources, its quality and proper scientific development. The revival of traditional sources of water is extremely important for the sustainable conservation of water resources in the Himalayan context.

The following management plan has been conceptualised thorough understanding of the surface geology, geomorphology, rainfall pattern and groundwater disposition of the NAQUIM area.

- CGWB has undertaken exploratory drilling at few locations within the study area during 1984-1990. This has revealed the existence of water bearing fractured horizons in the depth range 10m to 60m at suitable locales which are traversed by lineaments. This exploration studies have proved that groundwater is available in pockets, even at higher altitudes. Unfortunately waterwell drilling couldnot get much attention and support in Sikkim and this idea got prolonged for two decades. Currently many borewells are being constructed for industrial purpose as well as in several hotels.

  From this aquifer mapping study, it is envisaged that for sustainable water supply, simultaneous recharging of the borewells should be practised.

- Springs are considered as lifeline in Sikkim. However, the springs are slowly losing their perenniality owing to factors such as climatic aberration, increasing population and urbanization. Thereafter idea of rejuvenation of the springs at their catchment through recharge of shallow aquifers is conceptualised from this study.

- Household-wise rainwater harvesting should be mandated.

8.2 Quantifiable Management Strategies for the study area

Most of the hilly terrain of Sikkim presents a paradoxical situation of scarcity amidst plenty on the water front. Though sufficient rainfall is received in most parts of the study area during monsoon season, majority of it flows down the steep slopes as runoff and is not available for practical use. Water harvesting and management therefore plays a key role in such hilly terrain.

The following management strategies are advised to be practiced in the study area for the conservation and management of groundwater.

1) **Contour Trenches**

Contour trenches are ditches dug along a hillside in such a way that they follow a contour and run perpendicular to the flow of water. The soil excavated from the ditch is used to form a berm on the downhill edge of the ditch. These trenches act as trap for the sunface runoff as well as to minimise soil erosion **(Fig.8.2.1a)**

Some of the immediate advantages of contour trenches are the following:

- The rain water does not immediately run off the hill
- Water does not evaporate uselessly
- Staggered contour trenches **(Fig.8.2.1b)** promotes Artificial Recharge
- Crops do not suffer later on from water shortage
- Fertile soil particles are not lost by water and wind erosion

Fig.8.2.1a Section of a Contour Trench

Fig.8.2.1b Staggered Trenches

2) **Rainwater Harvesting**

Rain Water harvesting should be made mandatory in hilly areas. Apart from roof-top rain water harvesting which is advised for most houses in the study area, building small tanks on slopes will also help the flowing down water to accumulate which can be used for plant or tree watering.

There is rainwater potential in the hilly areas to harvest for irrigation purposes because of its high annual average rainfall and availability of suitable landscape. In this type of condition, developing rainwater harvesting technologies for irrigation would be very useful for local agricultural production. By constructing small water reservoirs in upstream hilly canyon, **(Fig.8.2.2)** rainwater can be harvested to irrigate both hilltop and hillslope areas by pumping and the valley areas by gravity flow.

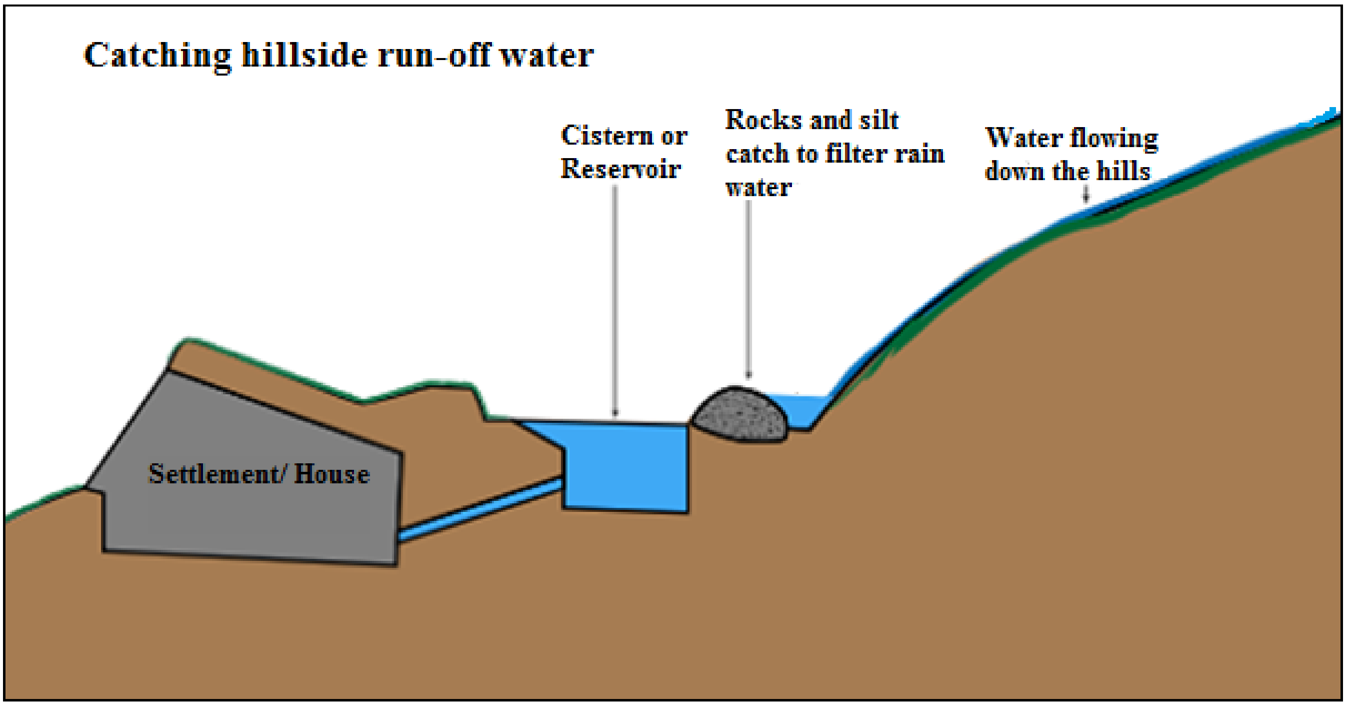

Fig.8.2.2 Rainwater Harvesting in hilly terrain

3) **Sustainable Irrigation Practices**

Usually because steep slopes rain-water that falls on them quickly leave the site down through the main valley. Rainwater, coming from the top of the mountain will has an enormous momentum going down owing to the force of gravity. As the water goes downwards, it accumulates much more water. So the force it produced is so enormous that can erode the soil whenever it touches.

To counter this scenario, we need to build a neutral ground, a step in the form of a terrace, to slow down or eradicate the momentum going downhill by the surface water. This practice is called **Terrace Farming** and is highly prevalent in hilly terrain. On every terrace, the water will just spill over another terrace until it reaches the lowest terrace down the mountain **(Fig.8.2.3)**.

What terracing does (when done correctly i.e following the contours) is spread the water from the valley to the ridges - effectively slowing down, pacifying and harvesting more rainwater and thus providing better crop irrigation. **Terracing** thus permits more intensive cropping than would otherwise be possible.

This is most useful for growing crops which are highly water intensive such as rice, wheat, barley and tea, all of which are cultivated in the study area.

Fig.8.2.3 Paddy cultivation in Terraced Farms of Sikkim

4) Spring water harvesting system

The rural and urban water supply in the study area is highly dependent on the spring water. However, in lean months the spring discharge dwindles and acute shortage is experienced especially in the rain shadow areas. The technology of Spring water harvesting system is recommended for those hilly areas where untapped perennial source of water (spring) is situated at higher elevation than the common place of storage in a targeted village so that water can be conveyed through low cost pipe under the influence of gravity.

For conservation of yield of natural springs and its supply to the downstream areas, **Spring Boxes** are constructed which can serve as collectors for spring water. They can be used as storage tanks when a small number of people are being served and the source is located nearby the users. When large numbers of people are served, the water collected in the spring box flows to larger storage tanks.

Fig.8.2.4a Spring Box in Namthang block, South Sikkim district

8.3 Groundwater Management Plan for Irrigation purpose

Sikkim, being a hilly state with varying degree of slopes, constructing big irrigation canals running across the length & breadth of the State is also not feasible and entails a very high capital cost & maintenance cost, and since the majority of farmers are marginal farmers, they are not able to provide irrigation to the crops through costly means. Ground water is available in highly dynamic state and unavailable for useful purpose in the highly sloping topography. Hence extraction of groundwater for irrigation purpose is practically zero. Springs, both seasonal and perennial are the main source of available water. Availability of abundant stream water during the summer allows for growing of paddy which the farmers carry to their field through temporary channels. Otherwise almost all the crops are grown on rain conditions. The topography again is a big constraint in developing a suitable water application method. Design/ layout of drip irrigation, sprinklers etc., are difficult and entail high cost due to difference in pressure head in every terrace/ field. Hence, a more pragmatic approach is to go for micro irrigation and better methods of water application, like small water harvesting structures, roof water harvesting and water saving application methods like sprinklers, drips, porous pipes etc.

8.4 Scope for Artificial Recharge in Study Area

Various measures such as rainwater and spring water harvesting, artificial recharge and water use efficiency are already suggested as above. However, for effective implementation of artificial recharge to groundwater, identification of appropriate location and structure is crucial.

Considering the administrative units (blocks and villages), geomorphology and location of springs, maximum portion of the study area is suitable for artificial recharge. Blockwise area suitable for artificial recharge is appended in Table 8.4. A map showing the areas demarcated for artificial recharge is shown in **Plate 8.3**

Table 8.3: Blockwise area suitable for Artificial Recharge in the study area

District	Block	Area (km^2)
South Sikkim	Namchi	108.20
	Namthang	49.01
	Melli	39.75
	Jorethang	37.79
	Temi Tarku	0
	Sikip	5.52

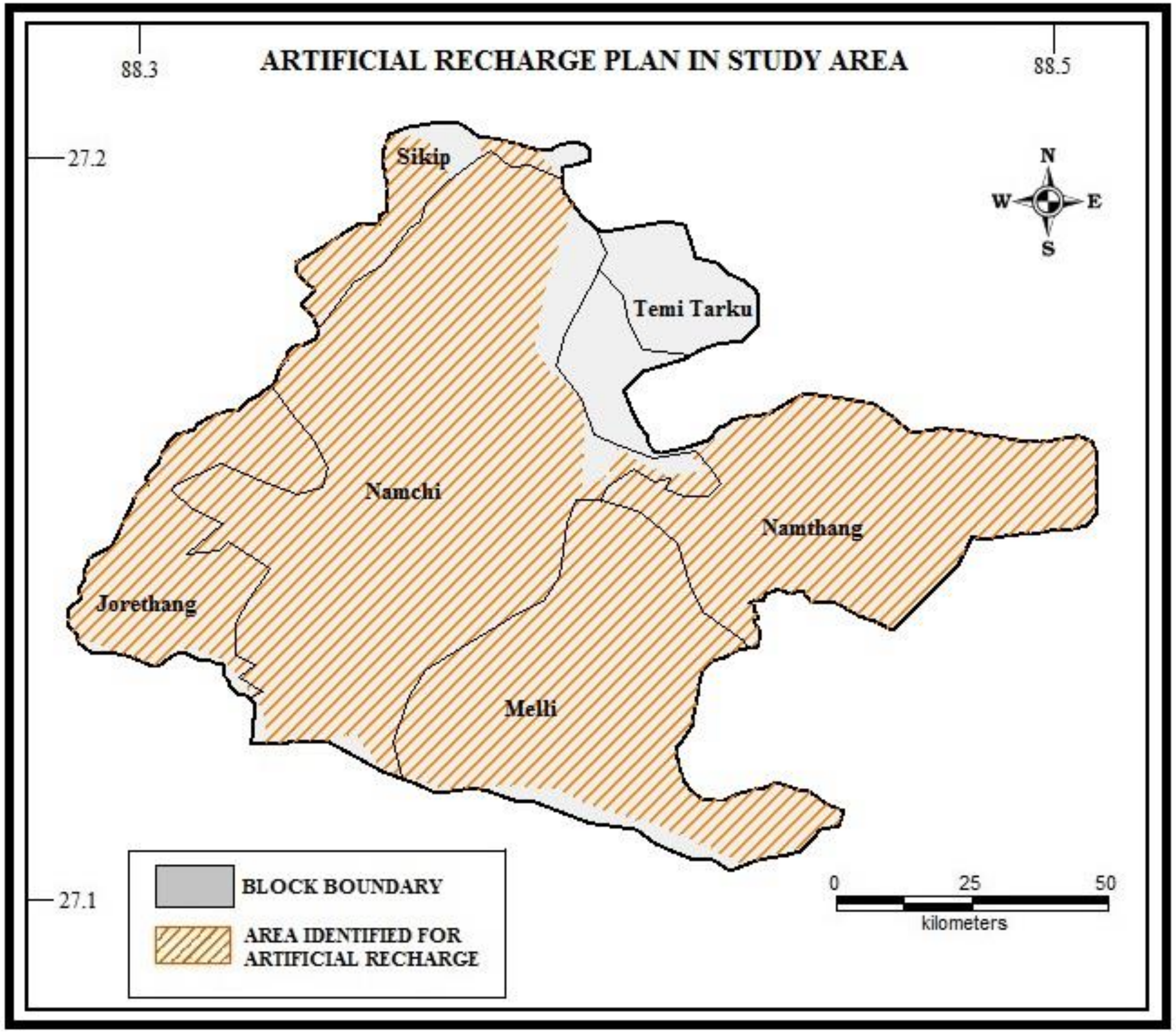

Plate 8.3: Blockwise Artificial Recharge plan in the study area