केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

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 WEST SIKKIM DISTRICT, SIKKIM

पूर्वी क्षेत्र, कोलकाता

Eastern Region, Kolkata

सत्यमेव जयते

REPORT ON
AQUIFER MAPPING STUDIES & MANAGEMENT PLAN IN PARTS OF WEST SIKKIM DISTRICT
SIKKIM

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Executive Summary

Groundwater is one of the prime sources of freshwater contributing significantly to the survival of mankind. However, overexploitation, surface runoff, and subsurface groundwater discharge have depleted fresh groundwater availability considerably. Assessing the groundwater potential zone is extremely important for the protection of water quantity & quality, and the management of the 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, groundwater management studies in 6 blocks namely Yuksom, Gyalshing, Dentam of Gyalshing sub-division and Kaluk, Soreng, Daramdin of Soreng sub-division of West Sikkim, covering a total area of approximately 481 sq. km was taken up in this study. This study envisages the salient features of aquifer geometry, characteristics; groundwater occurrences, availability, resource vis-a-vis quality, development & management scope of groundwater. The approach and methodology adopted to achieve the major objective included a compilation of existing data followed by the preparation of thematic maps on the GIS platform and the preparation of a groundwater prospect map to ultimately conceptualize an Aquifer Management Plan for that area.

Hydrogeological studies were conducted in the study area wherein huge existing data pertinent to geology, hydrology, hydrochemistry, spring discharge, etc was collected, synthesized and analyzed to bring out this report. This report mainly projects the groundwater prospect zones in the study area, which will be useful to undertake future groundwater exploration and management studies in this area. From a thorough understanding of the sub-surface geology, geomorphology, rainfall pattern, occurrence of springs and groundwater disposition in that area, an aquifer management plan has been conceptualized for the study area through which the groundwater needs can be fulfilled rationally. Rainwater harvesting is one of the most important management strategies to be adopted in the hills. Also, several site-specific quantifiable management strategies were suggested.

Considering the administrative units (blocks and villages), geomorphology and location of springs, a Block-wise artificial recharge plan is mentioned in the report. However, it is also suggested to consider the slope stability for applying all the recommended management strategies to avoid the triggering of landslides. A slope's stability is dependent upon various factors such as bed-rock geology, vegetation cover, the impact of human activity, etc, which are to be considered while implementing the interventions.

REPORT ON AQUIFER MAPPING STUDIES & MANAGEMENT PLAN IN PARTS OF WEST DISTRICT, SIKKIM AAP 2019-20

TABLE OF CONTENTS

List of Plates

List of Tables

1. INTRODUCTION

Groundwater is one of the prime sources of fresh water contributing significantly to the survival of mankind. However, over exploitation, surface runoff, and 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 the 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, groundwater management studies in 6 blocks, eg. Yuksom, Gyalshing, Dentam, Kaluk, Soreng, Daramdin of Westdistrict in Sikkim, covering an area of approximately 481 sq. km. was taken up in this study. The west district forms the second largest district of Sikkim with a total geographical area of 1467 sq km. This report envisages the salient features of aquifer geometry, characteristics; groundwater occurrences, availability, resource vis-a-vis quality, development & management scope of groundwater.

1.1 Objective

Aquifer Mapping has been taken up in the hilly terrain of West Sikkim. Almost the entire district is part of the Lesser Himalayas and is an assemblage of complex landforms of varying slopes in association with mountains, hills, ridges, escarpments, cliffs and precipitous slopes and valleys.

The broad objective of the study is to establish the geometry of the underlying aquifer systems which exist in the undulated hilly area, its resource potential in respect of quality & quantity, and aquifer characterization to be able to suggest suitable interventions for groundwater management and a comprehensive groundwater management plan.

1.2 Scope of Study

The scope of the present study is broadly within the framework of the 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, the chemical quality of groundwater, litho-logs and aquifer parameters. Generation of groundwater chemical quality data was accomplished by a 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 the drilling of additional exploratory wells by in-housing 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 the 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 the 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 west district falls in the Survey of India toposheets Nos 78A/3, 78A/4, 78A/7 and 78/A/8 and lies between the latitudes 27°06’38” and 27°40’40” N and longitudes 88°01’00” and 88°21’40” E. The west district covers part of the western and whole of the south-western area of Sikkim. West District of Sikkim lies at an altitude of 400 meters to 2500 meters with unique countryside escape of endless waves of agricultural fields and the terraced slopes, intercepted by spring patched forests. The study area **(Plate 1.4)** comprises 6 blocks namely Yuksom, Gyalshing, Dentam of Gyalshing sub-division and Kaluk, Soreng, Daramdin of Soreng sub-division of West Sikkim, covering a total area of approximately 481 sq. km. This area is located in the eastern part of the West district. The study area extends between north latitudes 88°06'and 88^{0}35'and East longitudes 27°11'and 27^{0}41'.This area is connected by roads with State Capital Gangtok which is located at a distance of about 120 km. The nearest railway station is New Jalpaiguri (NJP) (around 140 km) and the nearest Airport is Bagdogra (around 145 km) from Gyalshing, both of which are located in West Bengal.

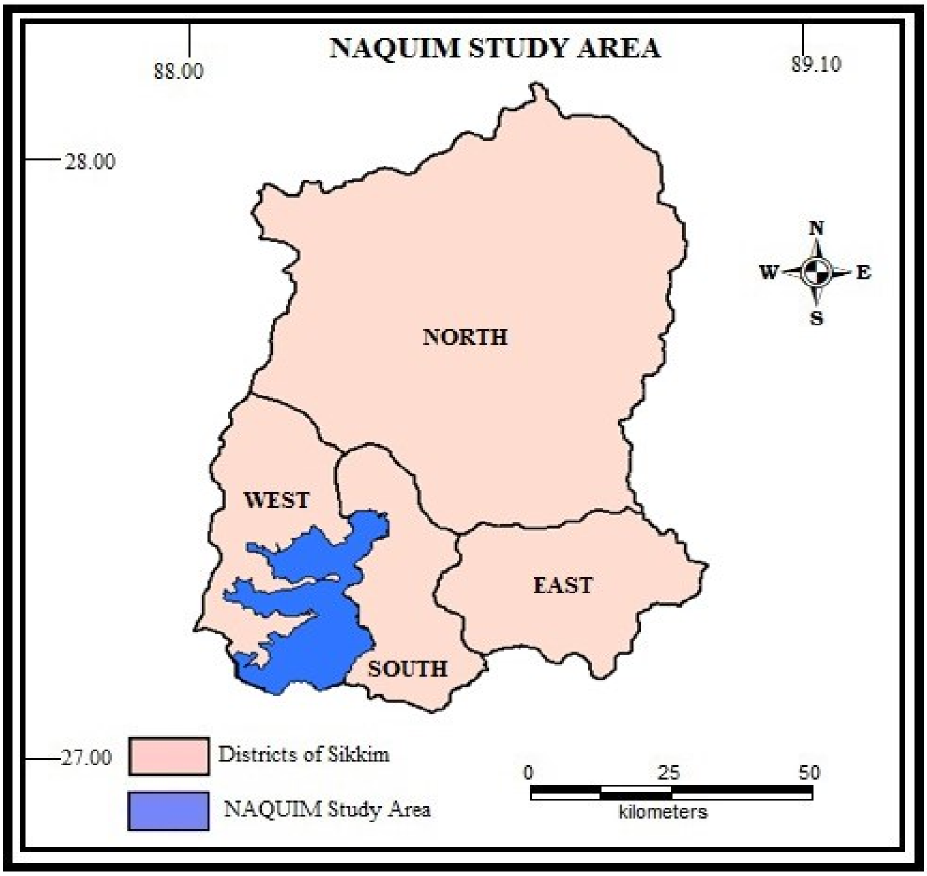


Plate 1.4: Aquifer mapping area in parts of West district of Sikkim

1.5 Administrative divisions and population

The study area covers 6 blocks namely Yuksom, Gyalshing, Dentam of Gyalshing sub-division and Kaluk, Soreng, Daramdin of Soreng sub-division of West Sikkim, covering an area of approximately 481km^2 **(Plate 1.5).** Details of administrative divisions are summarized in Table 1.5.1.

Table1.5.1: Administrative units of the study area

District	Sub-Division	Block	MappableArea (km^2)	No. of Villages
West	**Gyalshing**	Yuksom	109.0	12
		Gyalshing	73.7	16
		Dentam	68.0	20

	Soreng	Kaluk	70.3	12
		Soreng	109.0	10
		Daramdin	51.0	12
		Total Area	**481.0**	**82**

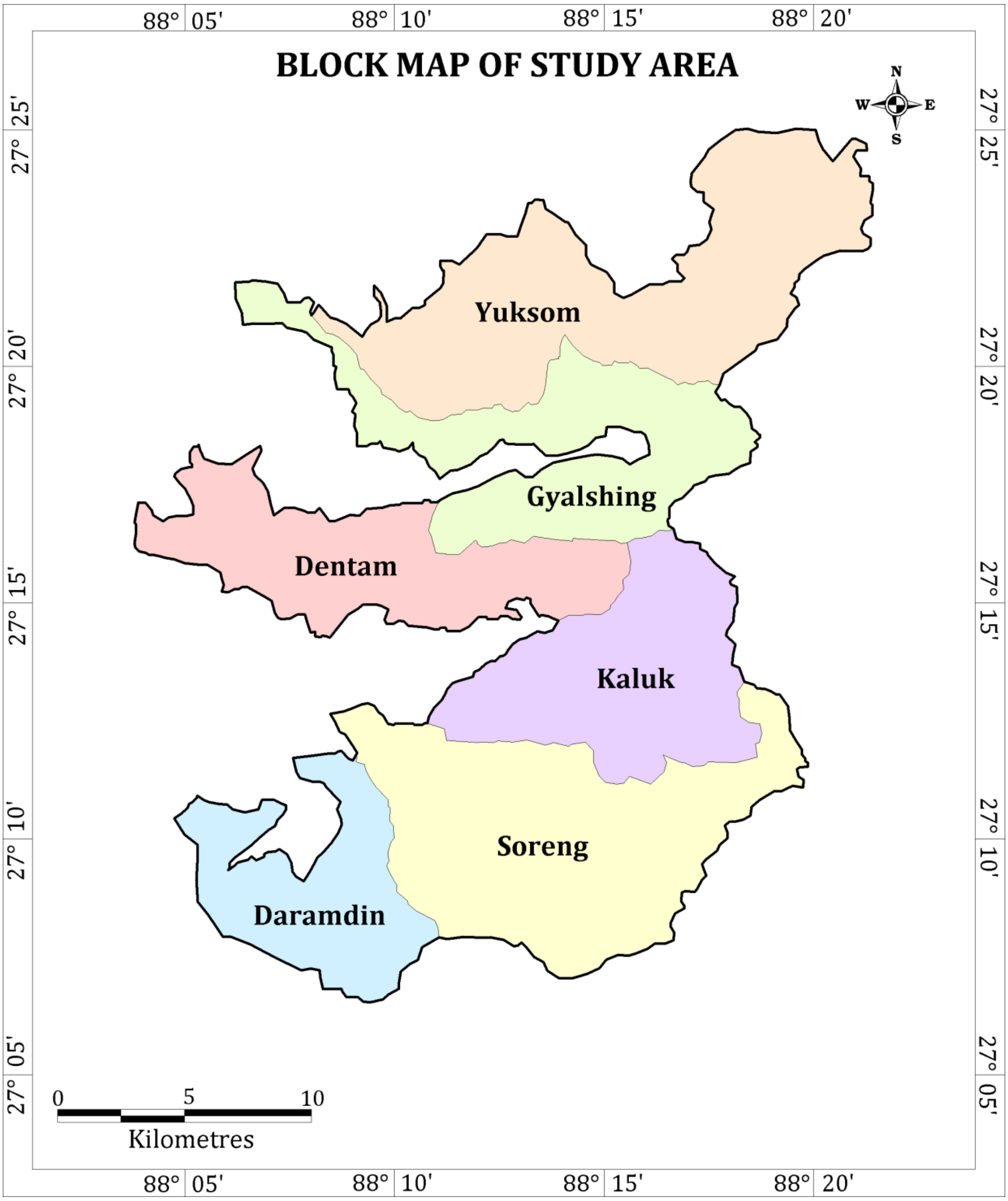


Plate 1.5: Block Map of the NAQUIM study area in West Sikkim

The Total population of the study area is presented in Table 1.5.2 while the household distribution is presented in Table 1.5.3.

Table 1.5.2: Population distribution in the study area

Sub-Division	Rural Population			Urban Population			Total Population		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Gyalshing	35,123	32,539	67,662	2054	1959	4013	37,177	34,498	71,675
Soreng	32,405	31,120	63,525	656	579	1235	33,061	31,699	64,760

(Source: Census Report of India 2011)

Table 1.5.3: Household distribution in the study area

Sub-Division	Rural Household	Urban Household	Total Household
Gyalshing	13,428	881	14,309
Soreng	13,462	252	23,714

(Source: Census Report of India 2011)

1.6 Landuse, Irrigation and Cropping Pattern

Land Use: The land use/land cover of the study area is an important parameter that gives us information regarding the complex physical processes acting on the surface of the earth. Prominent four categories of land use/land cover as Cultivable land; Reserved forest, Rural, and Urban Settlement are identified in the study area. The land-use pattern in the Gyalshing subdivision is still traditional. There is of course, evidence of conversion of rural land to non-agricultural usages such as urban development, transportation network, and other utility services. The concept of multiple and sequential Land-use rather than permanent and exclusive use exists in the rural community and its practice is common in agriculture and horticulture. Land-use planning on a regional scale doesn't exist in Sikkim. However, at the local or individual land-owner scale, some basic elements of

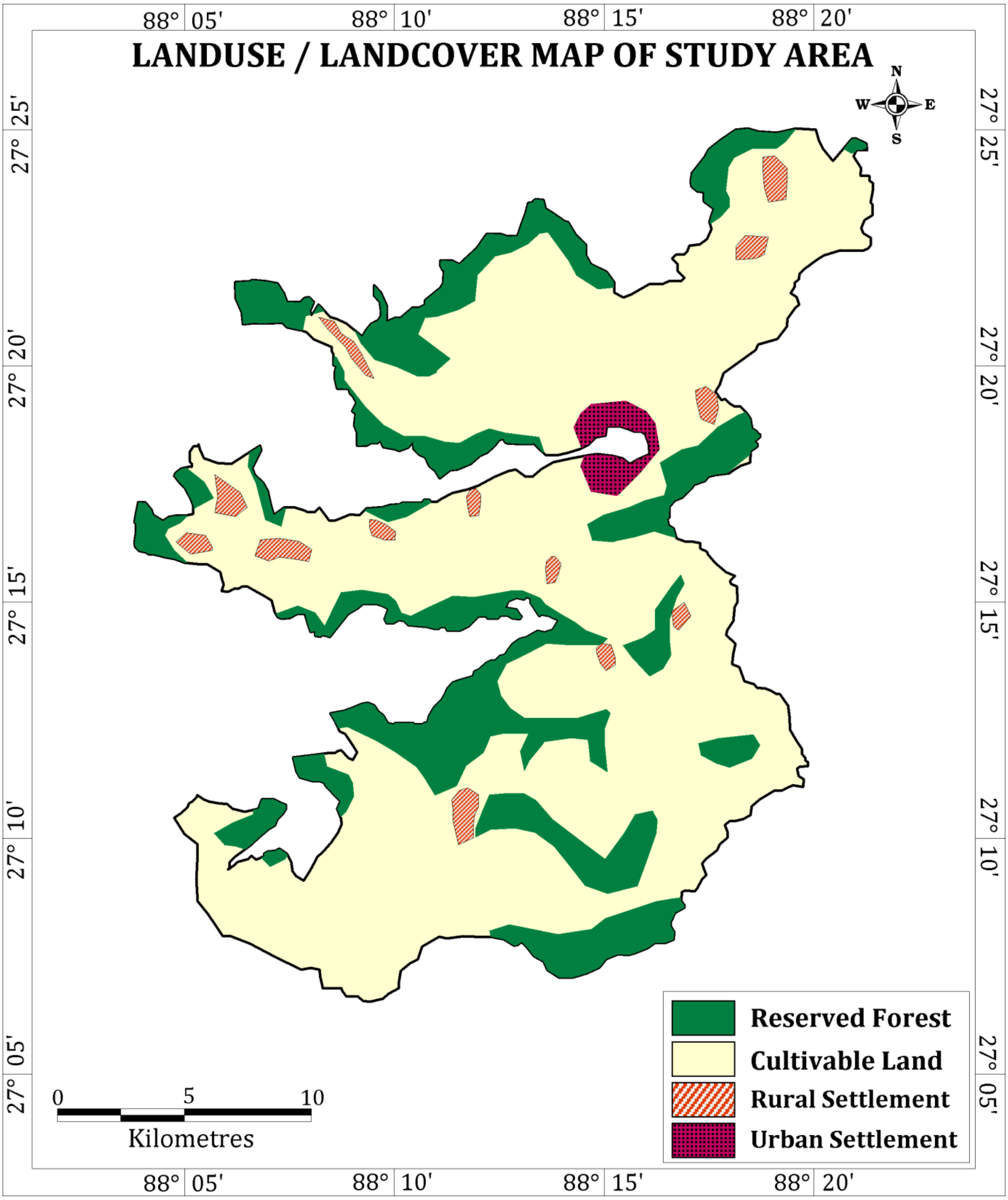
the Land-use plan seem to exist knowingly or otherwise. Uncontrolled and unscientific growth is evident around Pelling, Gyalshing bazaar area because of tourism. Certain concrete buildings within the Gyalshing bazaar area and Pelling are at risk to themselves and others.

Most of the study area is covered by cultivable land which includes Wet cultivation (Khet), Dry cultivation (Bari), and Forest cover which includes mixed forests, shrubs, and bamboos. The occurrence of urban settlement is mostly localized in the Gyalshing subdivision. Rural settlements are found to occur in small patches all over the area. Barren rocky surface, and highly developed areas with a network of roads, increases the probability of landslide occurrence in the study area.The land use map of the area has been shown in **Plate 1.6**.

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

Cropping Pattern: Sikkim is primarily a state of a rural and agricultural economy. In Sikkim, over 60 % of its population is directly engaged in agriculture. Principal food crops and cash crops cultured in the study area include the following:

- <u>Kharif crops</u> :
  Maize, Rice, Blackgram, Finger millet,
- <u>Rabi crops</u> :
  Buckwheat, Mustard, Wheat, Barley and other Pulses.
- <u>Fruits</u> :
  Oranges
- <u>Spices</u> :
  Large Cardamom, Ginger and Turmeric



(Source: Forest & Environment dept, Govt. of Sikkim)

Plate 1.6 Land-use/Land-cover map of the study area

1.7 Urban areas, Industries and Mining activities

Urban areas in the study area include only one (1) town viz. Gyalshing in Gyalshing Sub Division in West Sikkim district comprises 881 urban households while the remaining entire study area comprises a rural population. Both Industrial and 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 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. Being an entirely hilly terrain, the climate of the study area is characterized by a temperate climate. The study area has three main seasons, as mentioned below.

1. Summer Season: The winter season continues from the middle of April to June. Summers are cool and pleasant and bring out the best panoramas in West Sikkim. Temperature ranges from 10°-28°C, and the snow from winter starts to melt giving way to greener sceneries, which are ideal for all sorts of outdoor activities.

2. Monsoon Season: Monsoons begin in July and last well into September. This is the least favored time to visit West Sikkim because of the danger that torrential rains cause. The rainfall is heavy and prolonged. Landslides or boulder drops are frequent, and the winding mountain roads become too slippery for movement. It is a season of fog, mist and torrential rain, which reduce the visibility causing the traffic hazards.

3. Winter Season: The winter season continues from October to March. When the sun is up, it is lukewarm on the skin, with the mercury around 17°-22°C, but it starts to drop after sundown and by the end of November, the temperature quickly plummets to subzero levels. December is full-fledged winter, with frequent snowfall and shivering cold throughout, and so is January. It goes down to as much as -4° to -6°C, which is not an ideal situation to find yourself in, especially in the lap of the Himalayas which is covered in white powdery snow. The jovial Kanchenjunga festival is also held during this time, during the last week of December.

2.1 Rainfall

Month-wise average rainfall for the year 2011 – 2018 in West Sikkim district in the NAQUIM study area has presented in Table 2.1 below. Pre-monsoon showers are occasionally received in March, April and May. The monsoon generally sets at the end of June and continues up to October. Maximum rainfall takes place during June to September. The average annual rainfall is moderate and it varies from place to place due to variation of the slope.

Normal Annual Rainfall in the district is to the tune of 1620 mm. The rainfall distribution map of the study area has been shown in Plate 2.1.

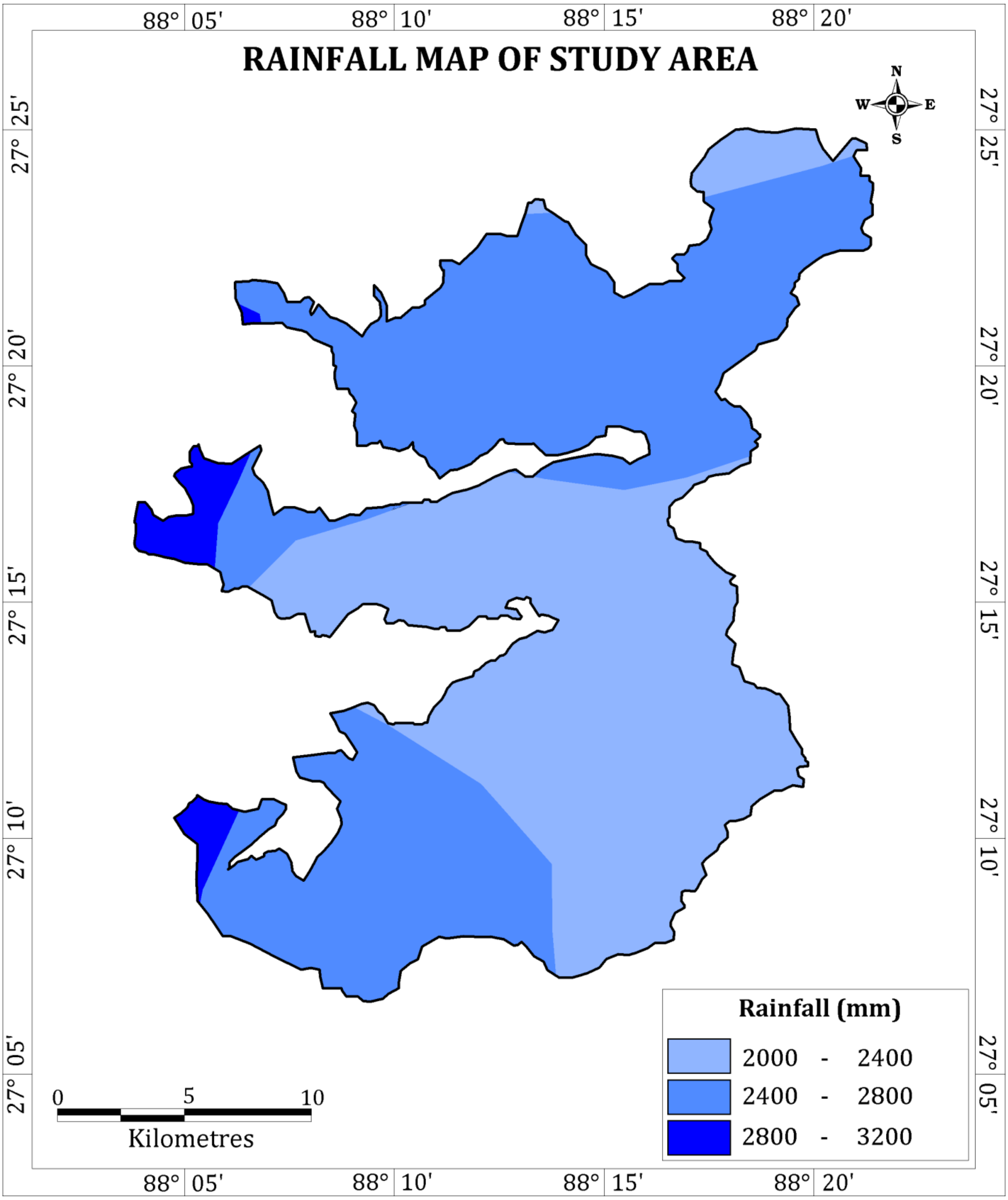
Table-2.1 Annual rainfall (mm) in Gyalshing West Sikkim district from 2011 to 2018

West Sikkim Rainfall (mm)														
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Mean**
2011	-	-	-	-	-	-	85.5	449	241	57	38	6	876.5	73.04
2012	16	5	21	126	240	486	376	520	548	81	0	10	2429	202.42
2013	8	43	79	155	354	241	583	459.2	374.5	153	3.2	8.7	2461.6	205.13
2014	0	1.3	41.3	59.8	204	543.3	204.7	439	109	66.5	6	1.7	1676.6	139.72
2015	7	23.5	38.5	121	240.5	446.6	351	273	466.5	56	1	4	2028.6	169.05
2016	11.2	4.5	70	84.5	234.5	401.7	501.5	176.7	585.1	110.5	0	0	2180.2	181.68
2017	-	-	-	77.1	181.7	278	642.4	602.6	602.1	69.2	6.2	0	2459.3	204.94
2018	2.9	18.5	39.5	105.8	194.8	335.2	548.8	555.7	200.1	45.5	0	14.3	2061.1	171.75

Data Source: IMD, Govt. of India

2.2 Temperature

Summers in the study area begin in April and end in June. During this season the temperature hovers between 10°-25°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 study area experiences the Monsoon season. The temperature during this season ranges between 5°c to 13°c.The months starting from October to March witness the winter season. During this season, the weather in this area becomes a lot chilly with temperatures hovering between 8°c to as low as -6°c.



(Source: http://www.sikenvis.nic.in/)

Plate 2.1 Rainfall distribution map of study area

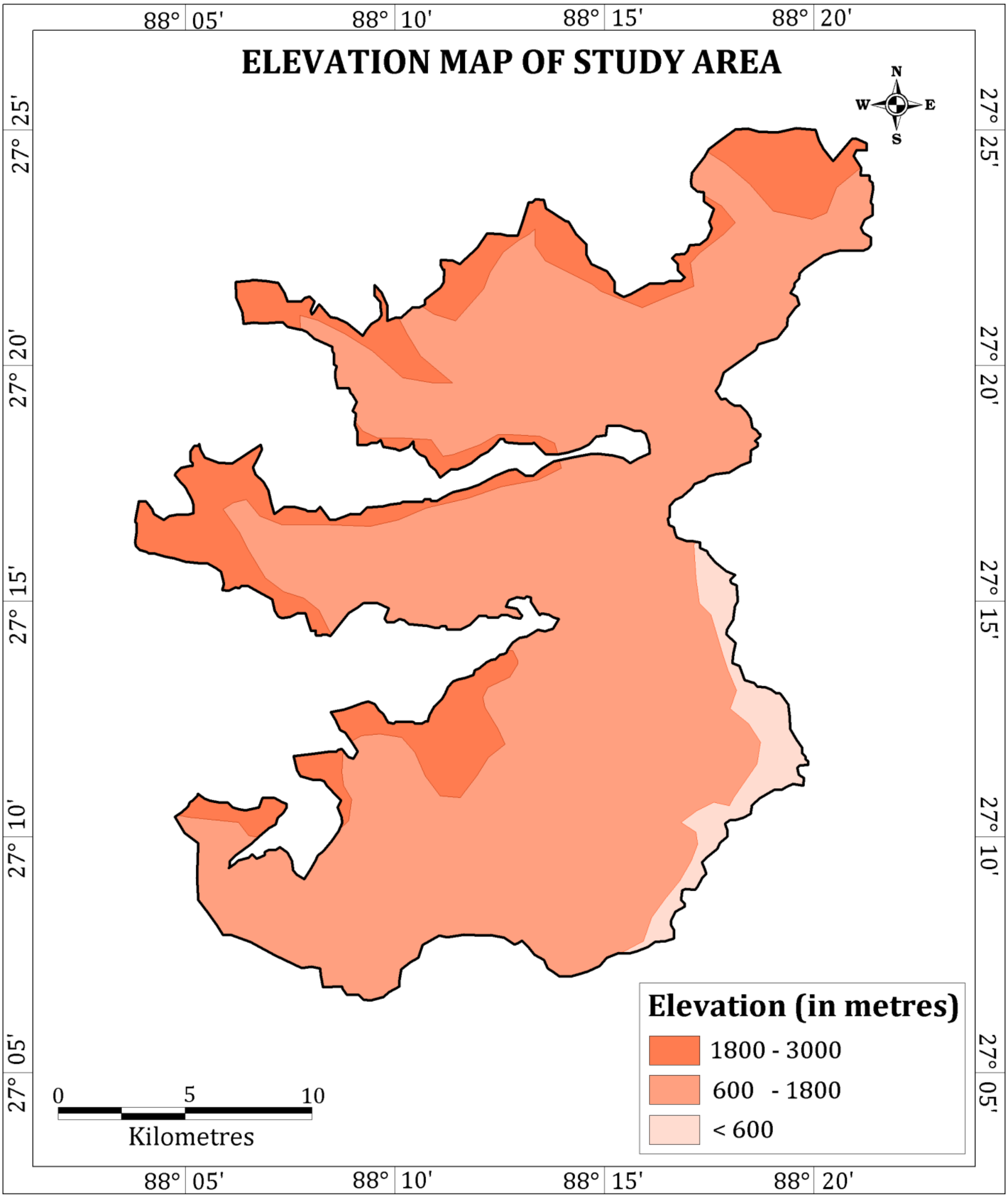
3. PHYSIOGRAPHY

3.1 Geomorphology

The West District of Sikkim is predominantly mountainous forming part of the Eastern Himalayas. It is characterized by Himalayan topography with cliffs, deep gorges and valleys and a series of crisscross ridges and ravines. Amongst all the stupendous hammocks that span across the entire terrain, Kanchenjunga is recorded to be the highest. Another feature possessed by the Sikkim geography is that a vast number of streams that speed across the terrain of Sikkim give rise to many exquisite river valleys. The water that runs through most of these streams is generally procured by the snow that crowns the stupendous mountains. These newly formed river valleys are confined to the southern and eastern fringe of the study area. The terrain that forms an exceedingly important portion of the geography of the study area is not significantly fertile. The main reason that lies behind this abnormality is the fact that there is an abundance of extremely rocky and precipitous slopes which present a tough look to the landscape.

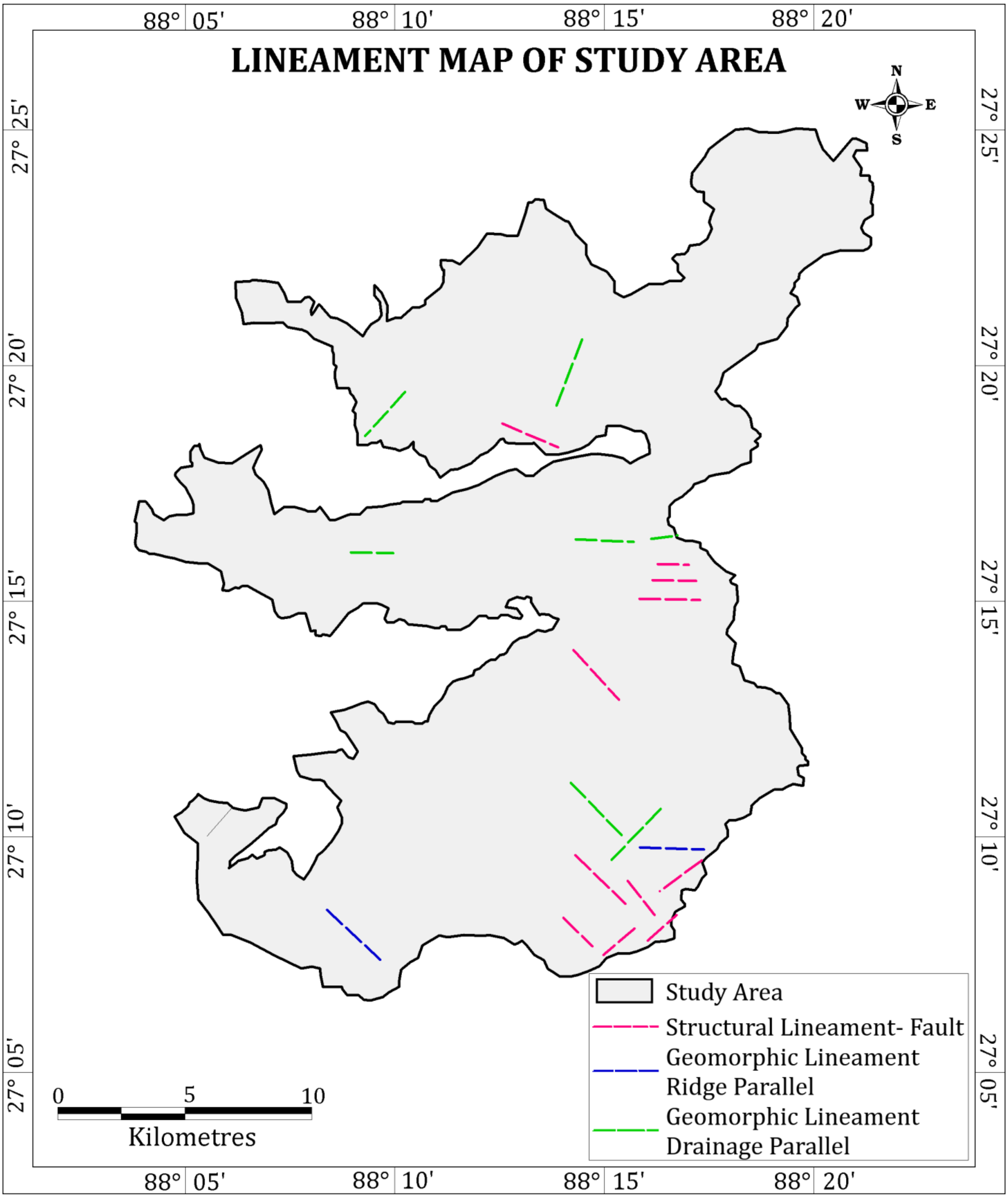
The district topography is rugged with steep slopes and the altitude varies from approximately 200 to 5000 m above MSL. The study area has moderate dissected hills and valleys to the highly dissected valleys as well as a large number of denudational hills. Most of the rivers and streams in this area 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.

The Elevation Map is shown in **Plate.3.1a** and the Lineament Map is shown in **Plate.3.1b**



(Source: Forest & Environment dept, Govt. of Sikkim)

Fig. 3.1a: Elevation map of the study area



(Source: NRSC, https://www.nrsc.gov.in/ Govt. of India)

Fig. 3.1b: Lineament map of the study area

3.2 Drainage

Drainage characteristics depend on the relief and geological structure of an area. The master stream of Sikkim is the Tista. The entire state of Sikkim occurs in the upper part of the Tista basin. River Tista receives tributaries from both sides of the river bank. Among them, the river Rangit is one of the important right bank tributaries of West Sikkim. The Rangit River originates in the Himalayan Mountains in the West Sikkim district (**Plate 3.2a**). The river also forms the boundary between Sikkim and Darjeeling districts. Rangit is a perennial river that is fed by the melting snow of the Himalayas in early summer and the monsoon rains from June to September. The River Rangit flows southwardly and makes a natural boundary of the study area in the east. The study area can be divided into Upper Rangit and Lower Rangit sub-basins which encompass several distributaries or smaller streams. They have dissected the land so intricately that there is no sizeable portion of level land in the study area.

Plate.3.2a Rangit River in West Sikkim

The Drainage and River Basin Map of the study area is shown in **Plate.3.2b**

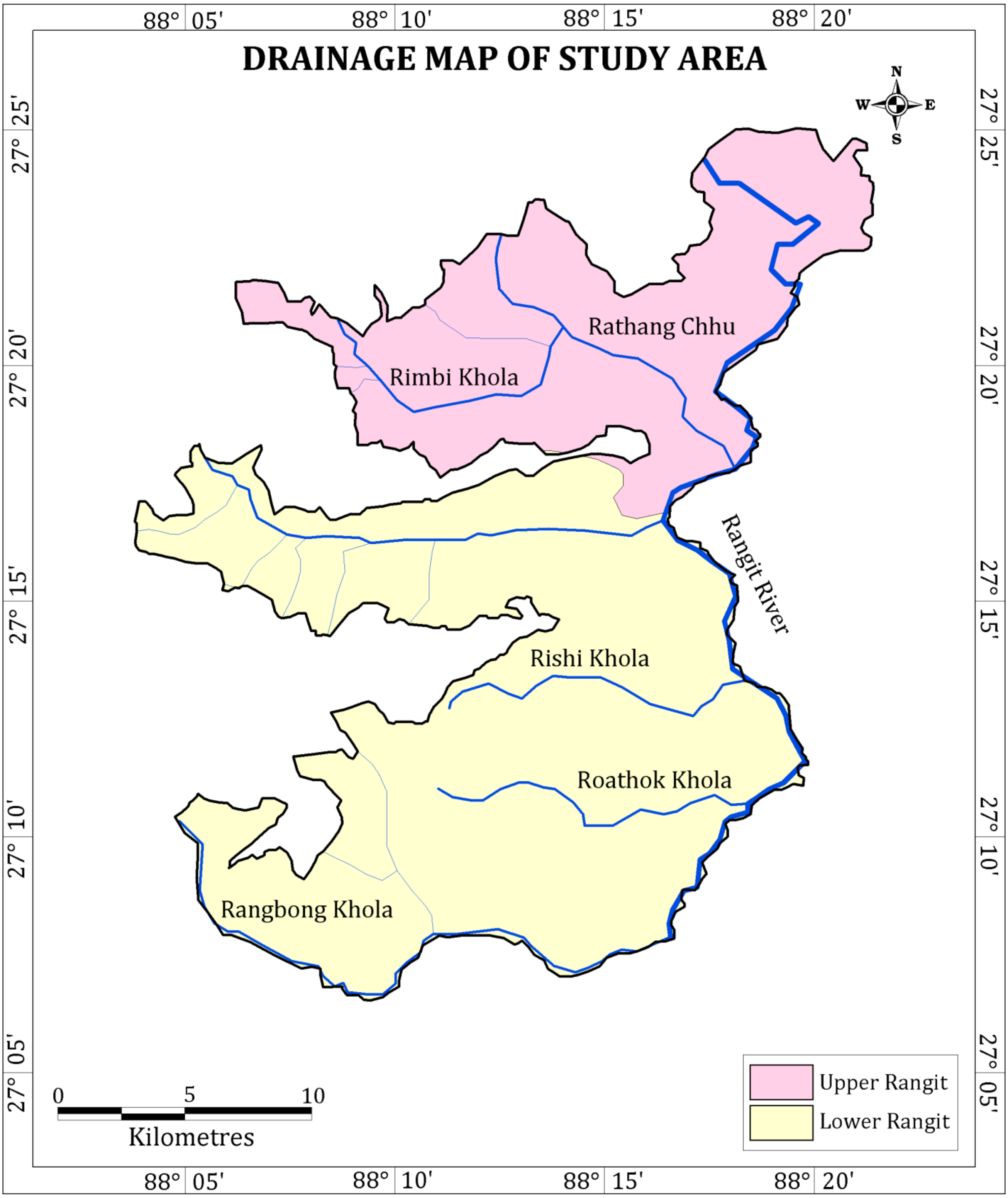


Fig. 3.2: Drainage map of the study area

3.3 Soil Characteristics

As the whole, West Sikkim has shallow to medium coarse loamy soils. In the tropical evergreen forest zone of the study area, the soils are not rich in humus due to leaching by the heavy rainfall. These soils are acidic but in the temperate deciduous forest zone, the soils with a thick layers of leaf mounds are found. These soils are rich in organic matter and fertile. In 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 study area are mainly composed of three major soil groups, as follows.

i. ***Entisols*****:** (Loamy-skeletal Lithic Cryothents)

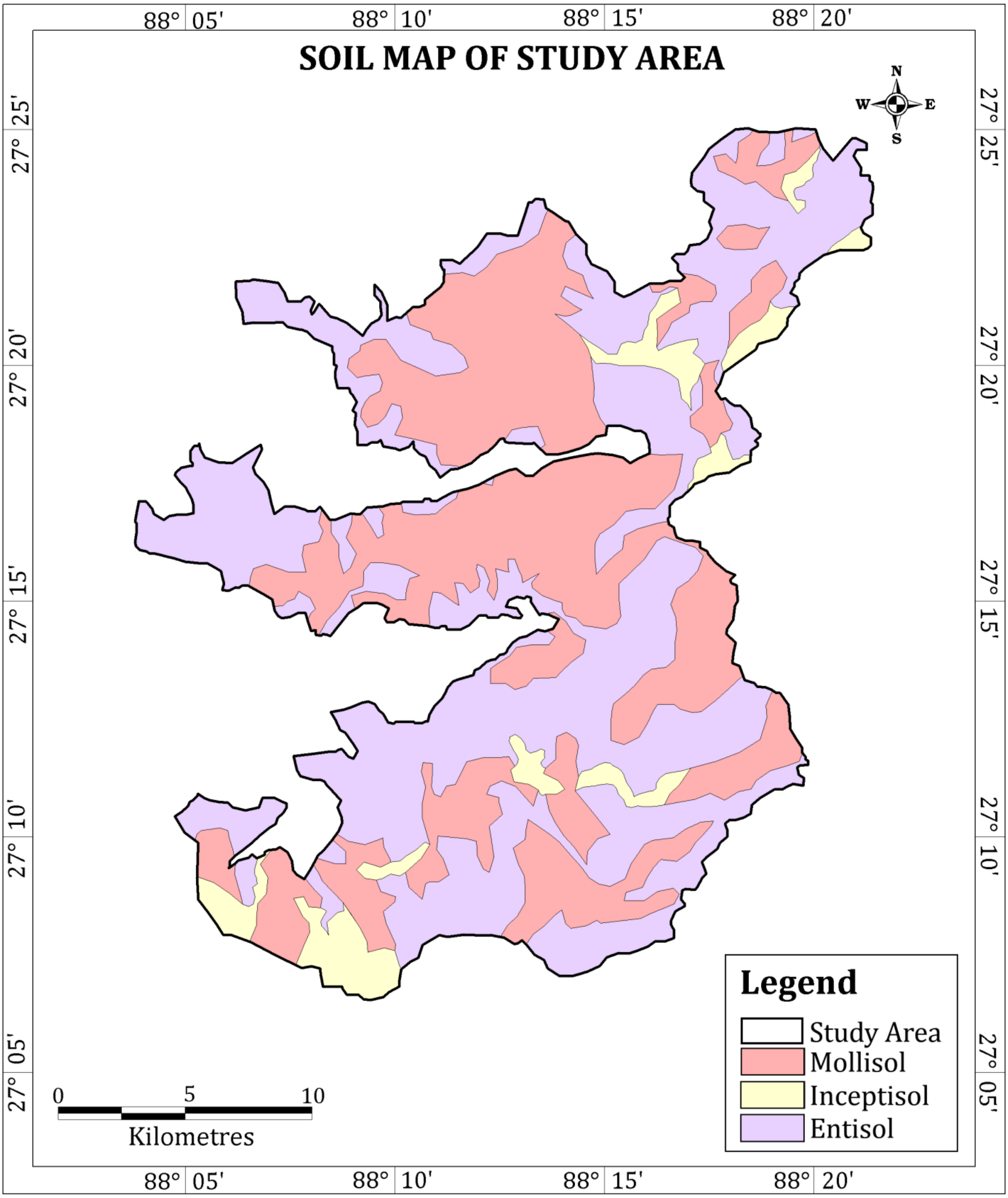
ii. ***Inceptisols*****:** (Coarse-loamy HumicPachicDystrudepts, Fine-loamy TypicDystrudepts)

*iii.****Mollisols:*** (Fine-loamyTypicArgiudolls, Coarse-loamy TypicHapludolls)

From the soil map **(Plate 3.3)** of the study area, it is observed that Entisols are the dominant soil group (55%) followed by Mollisolsoccupying 35% and andInceptisols occupying 10%, respectively.

Soil infiltration refers to the ability of soil to allow water movement into and through the soil profile which ultimately reaches the groundwater bearing layer. Soil texture (percentage of sand, silt, and clay) is the major factor affecting infiltration. Water moves more quickly through large pores of sandy soil than it does through small pores of clayey soil, especially if clay is compacted and has little or no structure or aggregation.

The detailed Soil Map of this area is shown in **Plate- 3.3**



(Data source: ENVIS, Govt.of Sikkim)

Plate 3.3: Soil map of the study area

4. GEOLOGY

4.1 General Geology

There are four (4) Groups of lithostratigraphic units encountered in the study area which are as mentioned below.

i. ***Kanchenjunga Group***: The Kanchenjunga Group of rocks consists of Augen Gneisses, Quartzite, Amphibolites and Migmatitic Gneisses belonging to Early Pre Cambrian Age.

ii. ***Chungthang Group***: Chungthang Group consists of Biotite Muscovite gneiss, quartzites, marbles, and graphitic schist belonging to the Early Pre Cambrian Age.

iii. ***Darjeeling Group***: The Darjeeling Group consists of Migmatitic Gneisses with cal Silicates lenses belonging to the Early Pre Cambrian Age.

iv. ***Daling Group***: Daling Group consists of Purple colored phyllite and variegated slates of massive grey quartzite and sericite schists belonging to Proterozoic Age.

The metapelites of the Daling Group along with gneisses of the Darjeeling Group are the most dominant rock types of the study area followed by rocks of Kanchenjunga Group and Chungthang Group.

(Source: GEOLOGICAL SURVEY OF INDIA, Miscellaneous Publication No. 30, Part XIX – SIKKIM)

Table 4.1: Stratigraphy of West Sikkim

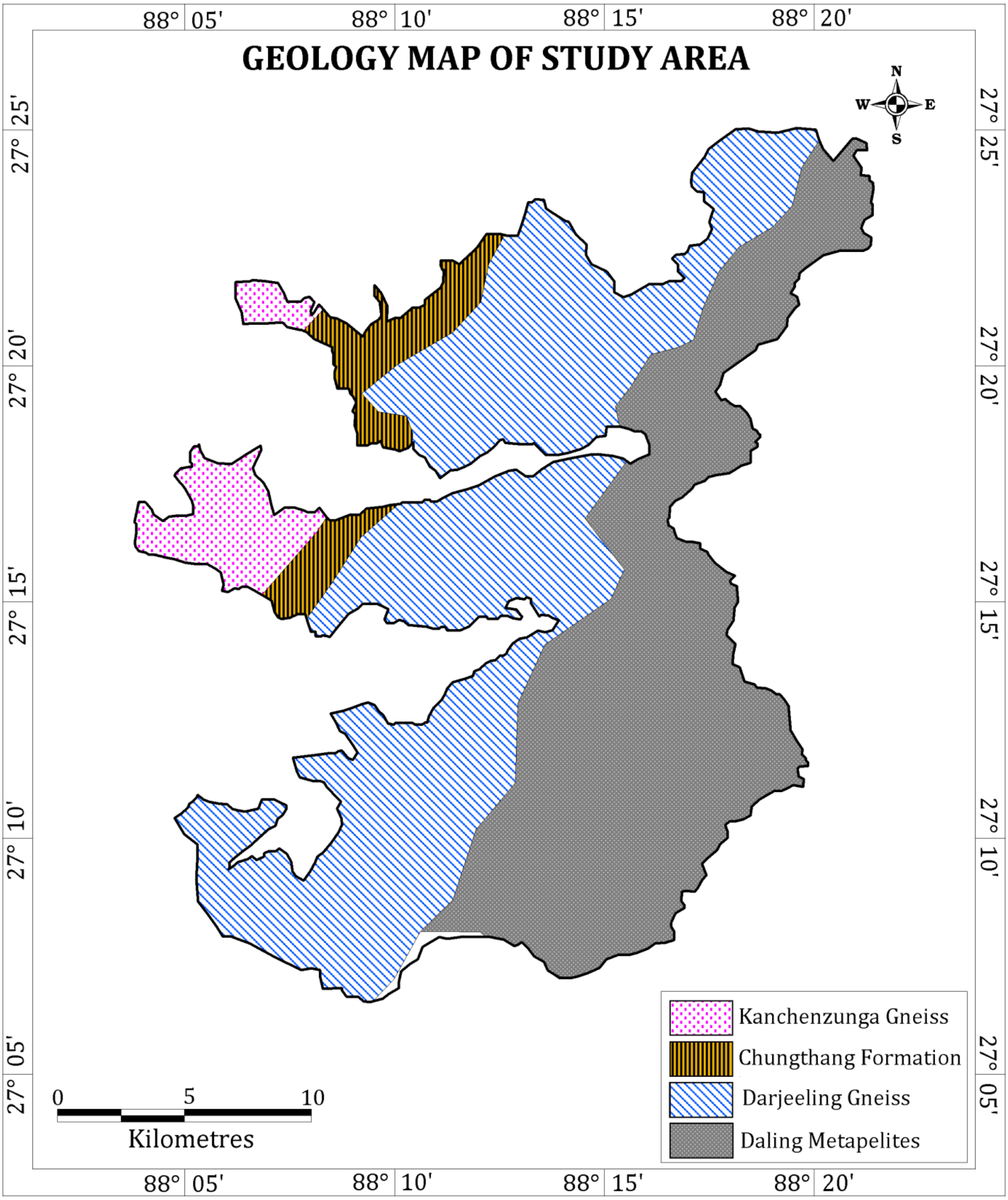
Stratigraphy of West Sikkim			
Group	Formation	Rock Type	Age
Lower Gondwana Group	Rangit Pebble Slate	Shale and coal pebbly cum boulder Slate	Upper Carboniferous to Permian
Thrust Contact			
Buxa Formation	Buxa	Greyish coloured dolomite with purple coloured quartzite and Phyllites, some black Slates	Early Palaeozoic
Daling Group	Reyang and Garubathan	Purple coloured phyllite and variegated slates massive grey	Proterozoic

Stratigraphy of West Sikkim			
Group	Formation	Rock Type	Age
		quartzite and sericite schists	
Thrust Contact			
Lingtse Group	Granite Gneiss	Highly sheared porphyroblastic granite Gneiss	Pre Cambrian
Thrust Contact			
Chungthang Group		Biotite Muscovite gneiss, quartzites, marbles, graphitic schist	Early Pre Cambrian
Darjeeling Group		Migmatitic Gneisses with cal Silicates lenses	Early Pre Cambrian
Kanchenjunga Group		Augen Gneisses, Quartzite, Amphibolites and Migmatitic Gneisses	Early Pre Cambrian

(Reference: GEOLOGICAL SURVEY OF INDIA, Miscellaneous Publication No. 30, Part XIX – SIKKIM; Report on Hydrogeology and Groundwater Resources of Sikkim by A K Mishra, 1995)

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

Plate – 4.1a Field photograph of Sericite Schist at Pelling, Gyalshing block, West Sikkim



(Source: Geological Suvey of India)

Plate 4.1b: Geological Map of the Study Area

5. HYDROGEOLOGY

5.1 Water bearing formations:

Groundwater occurs in a largely disconnected localized body under favourable geological conditions such as joints, fracture zones and weathered zones of various lithological units. The groundwater is available only from several perennial springs and 'jhoras' located in all types of geological formations at various altitudes in the study area. The main repository of groundwater are fracture zones. The presence of innumerable perennial springs with varied discharge is also suggestive of the occurrence of groundwater in various rock formations and weathered zones in the phyllite, schist, gneisses and quartzite.

Due to the high relief and steep gradient of the study area, the subsurface groundwater flow comes out as seepages and springs, wherever the land surface intersects the local groundwater body. The study area is characterized by high rainfall (natural precipitation), which is the primary source of groundwater. Direct infiltrations and percolation through secondary porosities like joints, fractures, weathered zones of the rocky parts, and through soil covers are the principal mode of recharge of the groundwater and hence the springs. Only a small fraction of precipitation is percolated down through thickly vegetative cover of permeable soil and through high ridges, saddles, spurs, stream terrain forming the potential recharge zones/areas. While the steeper hill slopes dominantly form the areas of spring discharge.
The movement of groundwater is mainly controlled by the structural set-up of the area and physiography as shown in **Plate 5.1a**.

There has not been any groundwater exploration activity in the West district of Sikkim. As a result, the exact demarcation of groundwater bearing zones along with information regarding the yield of the aquifers could not be mentioned. However, in the absence of exploration wells, a lineament map has been plotted of the study area using both geomorphic and structural lineament data from the National Remote Sensing Centre. Based on this data, groundwater prospect map has been prepared where the study area has been categorized as Good, Moderate and Poor. The areas having the highest lineament density are categorized as the Good groundwater prospect zone and with fair lineament density are categorized as the Moderate groundwater prospect zone, followed by the Poor groundwater prospect zone where there is a minimum lineament density.

The groundwater prospect map of the study area is shown in **Plate 5.1b.**

Plate-5.1a: Flow of springwater controlled by physiography and structural features (bedding plane)

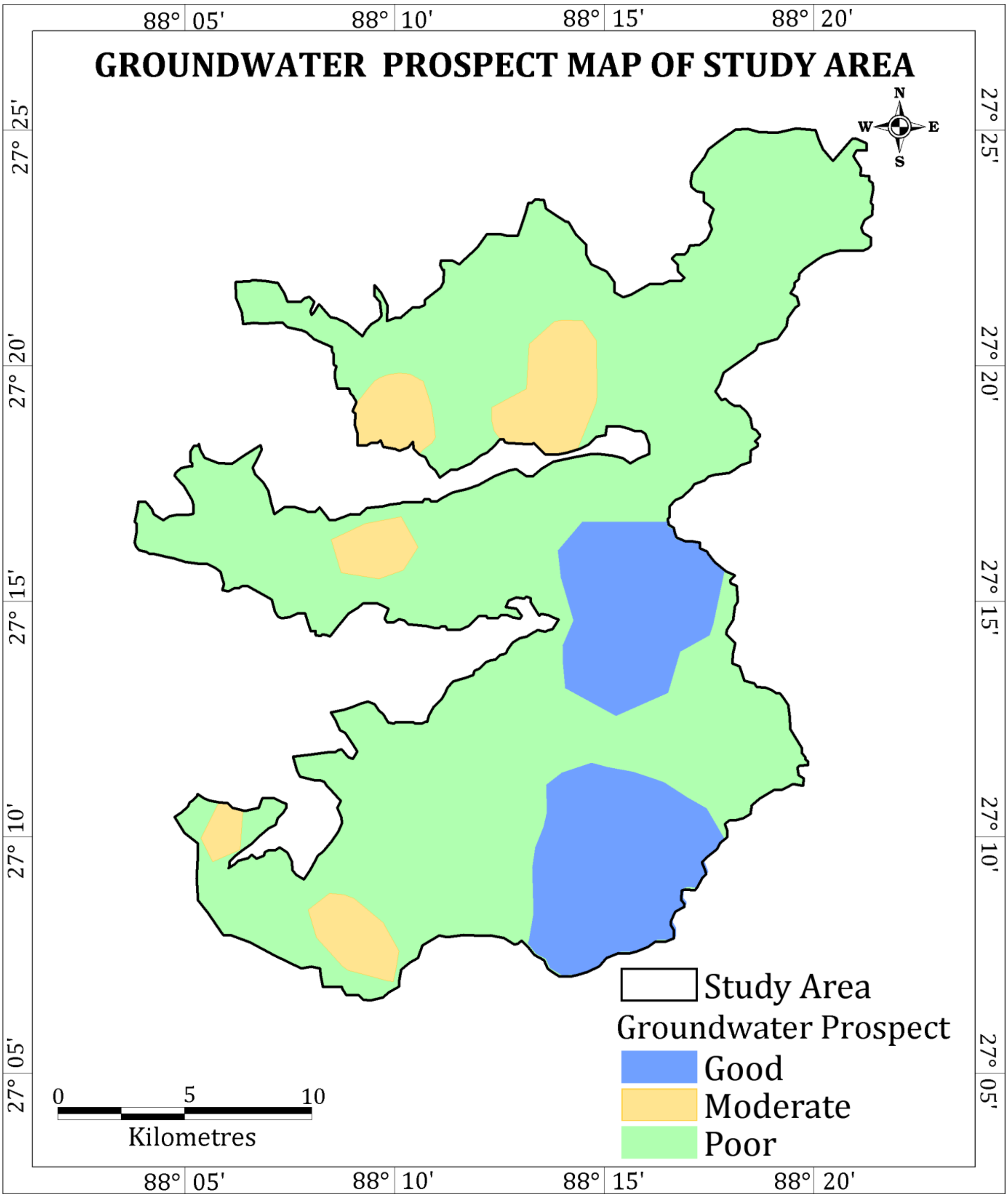


Plate-5.1b: Groundwater prospect map of the study area

5.2 Aquiferwise 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 Occurrence, movement and distribution of groundwater:

Rainwater and snow meltwater in high altitudes 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 meltwater facilitated by the geological structure and formational characteristics of rock, thickness and porosity of the soil horizon, the yield of the springs varies to a great extent. Springs are considered the lifeline of the people dwelling in hilly and mountainous terrain as it facilitates the chief source of water for drinking as also for irrigation.

To be distinguished from springs are seepage areas which indicate a slower movement of groundwater to the ground surface. Water in seepage area may pond and evaporates or flows, depending on the magnitude of flow, the climate and the topography.

The springs in the study area are generally gravity type. **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.

Plate 5.3 Field photograph of a huge spring on Pelling-Rimbi road, West Sikkim

Two types of gravity springs are identified in the West District viz. (i) Depression springs and (ii) Fracture springs.

The depression springs are formed where the land surface intersects the water table and fracture springs are formed in the hard relatively impermeable formations by connecting the local or perched groundwater body. These develop secondary porosity due to tectonic movements. At places, some seepages also occur, which indicates a slower movement of groundwater through fissures and fracture planes at hard rocks overlain by a thick weathered mantle. The structurally weak planes like joints, fractures and small scale faults are the good avenues for groundwater movements. The catchment area is characterized by the soil covered by dense forest. Also, the upper part of the catchment area is more or less flat or depressed and extends both in length and breadth like a saucer-shaped body. The large and extended catchment area forms the reservoir for the groundwater supply for springs and 'kholas'. During the monsoon period all the catchment areas get saturated and form the permanent aquifer.

Discharge of the springs occurring in various types of rock formations at different altitudes in the district is in the range of 1 to 50 lpm, through higher discharges of the 'jhoras/kholas'are also recorded. Discharge of the springs in the monsoon period generally increases 50-70% from that of the pre-monsoon period. Several hot springs have also been located in the eastern part of the district. The categorization of the spring discharge found in the study area is as below:

Table 5.3-: Categorization of Spring Discharge in the study area of West Sikkim

Serial No	Discharge of springs (lpm)	Number of springs
1	1-5	160
2	>5-10	150
3	>10-20	192
4	>20-50	117
5	>50-100	16
6	>100-200	6
7	>200-500	1
8	>500	2

(Source: Groundwater Information Booklet of West Sikkim,,CGWB May 2013)

6. GROUNDWATER RESOURCES

Though the entire country has been assessed for its groundwater 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; whereas 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 groundwater 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% slope. 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.

The groundwater resource assessment (in 2020) for the State of Sikkim has been carried out as per GEC 2015 guidelines through 'IN-GRES', with Districts as primary assessment units. The Total Annual Groundwater Recharge for West District has been estimated at 11897 Ham and the Annual Extractable Groundwater Resource has been estimated at 10707.30 Ham. The Current Annual Groundwater Extraction for all uses has been estimated at 316.20 Ham, which translates into a Stage of Groundwater Extraction at 1.16% and as per the present assessment, the assessment unit of the West district falls under 'SAFE' category.

As compared to the 2017 assessment, in the West district, the Annual Extractable Groundwater Resource was reduced from 20854.41 Ham to 10707.30 Ham. The Annual Groundwater Extraction from all sources though has increased to 316.20 Ham. As a result, the Stage of Groundwater Extraction marginally increased to 1.16 %.

A decrease in annual rainfall resulted in a decrease in recharge, which is reflected in the decrease in Annual Extractable resources. The increase in Annual Groundwater Extraction is attributed to the domestic use in the districts, utilizing groundwater, resulting in a marginal increase in the Stage of Groundwater Extraction.

The district has been considered as groundwater resource assessment unit. The dynamic groundwater resources of the West Sikkim district have been appended below in Table 6.

Table-6: Dynamic Groundwater Resources of West Sikkim as of 31st March 2017 and 31st March 2020

District	Assessment Unit Name	Total Annual Groundwater Recharge (Ham)	Total Natural Discharges (Ham)	Annual Extractable Groundwater Recharge (Ham)	Current Annual Groundwater Extraction (Ham)				Annual GW Allocation (Ham) for Domestic Use as on 2025	Net Groundwater Availability for future use (Ham)	Stage of Groundwater Extraction (%)	Categorization (OE/Critical/Semi critical/Safe)
					Irrigation Use	Industrial Use	Domestic Use	Total Extraction				
West	West District	74511.68	53657.27	20854.41	0	0	0	0	316.58	20537.83	0	Safe
West	West District	11897	1189.70	10707.30	0	0	124.53	124.53	316.20	10391.10	1.16	Safe

The **West district of Sikkim** has been categorized as **"Safe"** as per the **Groundwater Resource Estimation of 2017 & 2020**

7. HYDROCHEMISTRY

7.1 General range of chemical parameters

In the entire study area, groundwater occurs mainly in the form of springs and from the general literature it was found that the groundwater is of extremely good quality. The spring water is fresh, potent and suitable for domestic, irrigation and industrial uses. The Chemical quality of spring water in the state shows that it is fresh and fit for both drinking and irrigation purposes. The concentrations of different chemical constituents present in the groundwater are well within the desirable limit as stipulated for drinking water by the Bureau of Indian Standard (BIS). However, it is observed that spring water is very much vulnerable to surface pollution which necessitates effective and proper measures to prevent any contamination. In such a situation Chlorination is desirable before spring water is used for drinking purposes. Bacterial contamination is very common in spring water, especially in the hilly terrain and appropriate safeguards and remedial measures have to be taken to avoid any type of infection. The ranges of chemical constituents of the spring water samples collected from the west Sikkim district are given below:

Table 7.1: Chemical Quality of Spring Water of Study Area

Sl No.	Chemical Constituents/Parameters	Units	Range	BIS Drinking Water Standards IS- 10500-2012	
				Desirable Limits	Maximum Permissible Limits
1	Electronic Conductivity (µs/cm at 25°)	(µs/cm at 25°)	22-292		
2	pH	mg/l	6.79-7.94 mg/l	6.5	8.5
3	Total Dissolved Solid (TDS)	mg/l	19-65 mg/l	500	2000
4	Total Hardness as $CaCO_3$	mg/l	7-175 mg/l	200	600
5	Calcium	mg/l	1.6-44 mg/l	75	200
6	Magnesium	mg/l	0.24-9.7 mg/l	30	100
7	Sodium	mg/l	0.6-4.80 mg/l	-	-
8	Potassium	mg/l	0.1-1.30 mg/l	-	-

Sl No.	Chemical Constituents/Parameters	Units	Range	BIS Drinking Water Standards IS- 10500-2012	
				Desirable Limits	Maximum Permissible Limits
9	Iron	mg/l	<0.01-0.56 mg/l	0.30	No Relaxation
10	Bicarbonate	mg/l	11-171 mg/l	-	-
11	Chloride	mg/l	1.40-16 mg/l	250	1000
12	Fluoride	mg/l	0.12-0.29 mg/l	1.0	1.5
13	Sulphate	mg/l	0.43-14 mg/l	200	400
14	Nitrate	mg/l	0.37-2.03 mg/l	45	No Relaxation

(Source: Groundwater Information Booklet of West Sikkim, by Dr Indranil Roy, Sc-C May 2013)

7.2 Groundwater pollution:

Periodic quality assessment of drinking water sources is necessary to guarantee the quality and security of water supply to people. From the general literature, it was found that reveals that all chemical parameters in the groundwater of West Sikkim show values within the permissible limits.

7.3 Groundwater Suitability for irrigation:

Sikkim, being a hilly state with varying degrees 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 Groundwater is available in a highly dynamic state and unavailable for useful purposes in the highly sloping topography. Hence extraction of groundwater for irrigation purposes 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 the growing of paddy which the farmers carry to their field through temporary channels. Otherwise almost all the crops are grown in rainy 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 differences 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 groundwater resources, their 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 potential of the NAQUIM area.

- Springs are considered a 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 conceptualized in this study.

- Household-wise rainwater harvesting should be mandated. Harvesting rainwater in such hilly terrain will be very useful during the dry season & it will save unnecessary wastage of money in making water available during summer.

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 waterfront. Though sufficient rainfall is received in most parts of the study area during the monsoon season, the majority of it flows down the steep slopes as runoff and is not available for practical use. Water harvesting and management, therefore, play 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) **Sustainable Irrigation Practices**
   Usually, because of steep slopes rainwater that falls on them quickly leaves the site down through the main valley. Rainwater, coming from the top of the mountain will have an enormous momentum going down owing to the force of gravity. As the water

goes downwards, it accumulates much more water. So the force is 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.8.2.1).

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 that are highly water-intensive such as rice, wheat, barley and tea, all of which are cultivated in the study area.

Fig.8.2.1 Paddy cultivation at Gyalsingh Terraced Farms of West Sikkim

2) Springwater harvesting system

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

For conservation of the yield of natural springs and their supply to the downstream areas Spring, Boxes are constructed which can serve as collectors for spring water (Fig.8.2.2). 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.8.2.2 Spring Box at Darap in Gyalshing block, West Sikkim

8.3 Groundwater Management Plan for Irrigation purpose

Sikkim, being a hilly state with varying degrees 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.Groundwater is available in a highly dynamic state and unavailable for a useful purposes in the highly sloping topography. Hence extraction of groundwater for irrigation purposes is practically zero. Springs, both seasonal and perennial are the main source of available water. The availability of abundant stream water during the summer allows for the growing of paddy which the farmers carry to their fields through temporary channels. 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 costs due to differences 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.

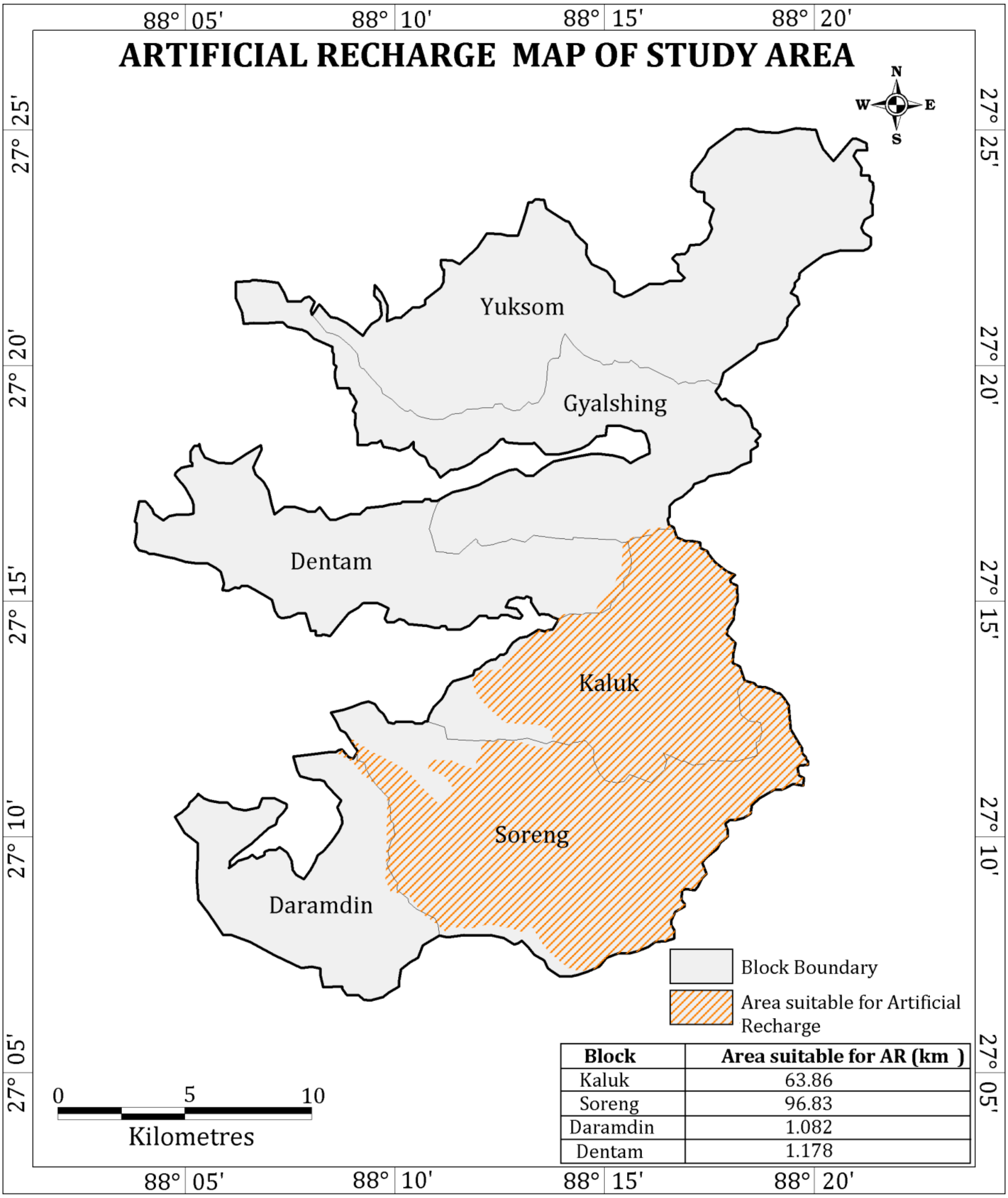
8.4 Scope for Artificial Recharge in Study Area:

No water conservation or artificial recharge structure has been constructed by CGWB, so far, in the West Sikkim district as this hilly hard rock terrain is not suitable for those types of structures in view of high cost-benefit ratio of making any such structure and the danger of soil erosion and/or landslide on the slope and valleys. Sikkim, being a hilly state with varying degrees 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. In hilly terrain, artificial recharge to groundwater body by rainwater is not recommendable because the injected rainwater before recharging the groundwater might find its way to a strem or it may come out through cracks, joints, fault planes, fractures etc. Including damages like landslides, and cracks/collapsing of buildings. However, rain water harvesting schemes may be taken up in small magnitudes for catering for the need of domestic use in localized areas. Conservation structures for rain water as well as spring water above the ground such as gabions, nala bundhs/cement plugging may also be constructed for providing assured supply of water during dry seasons. 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, the 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: Blockwisearea suitable for Artificial Recharge in the study area

District	Block	Area(km^2)
West Sikkim	Kaluk	63.86
	Soreng	96.83
	Daramdin	1.082
	Dentam	1.178
	Total Area	**162.95**

However, it is suggested to consider the slope stability for applying all the recommended management strategies to avoid the triggering landslides. A slope's stability is dependent upon various factors such as bed-rock geology, vegetation cover, the impact of human activity etc which are to be considered while implementing the interventions.



Block	Area suitable for AR (km)
Kaluk	63.86
Soreng	96.83
Daramdin	1.082
Dentam	1.178

Plate 8.3: Blockwise Artificial Recharge plan in the study area

9. GROUNDWATER RELATED ISSUES & PROBLEMS

9.1 Water Scarcity

In this study area, due to adverse soil conditions and inadequate infiltration of scanty rainfall into the ground in the months of February and March the discharge of springs become meager and the villagers use to face an acute crisis of drinking water, which is an inherent and common problem in this study area. Some of the reported water scare villages are Geling, Samsingh Khani, Shirbong, Kamling, Mabong, Chakung, Chungbong, Jhum, Kaluk, and Rinchingpong.

9.2 Drilling problems

In general, the rocks prevailing in the district are very hard and massive and thus may be problematic to be penetrated even by the DTH rig operated by pneumatic pressure. During drilling operation, the loss of air (which helps in hammering the rock formation for piercing) through the dry and wide fractures encountered. Moreover, the water already obtained in such fracture/weathered zone may be lost by draining through the fracture zones encountered at greater depth due to the possible interconnection of the later zone with some springs or streams situated at a further lower level. Above all, there is the universal problem of finding any suitable site/ location for placing the drilling machine in the recommended potential area due to the lack of proper communication road for transportation of rig and other materials/machines. However, the rocks in some areas in the district are very fragile in nature. The Daling schist and phyllites are sometimes interbedded with massive quartzites, which are not much less jointed. The quartzites are probably impeding the groundwater movement by acting as barriers.

9.3 Risk to natural disaster

The existing rugged and hilly topography of the area do not favor the construction of a large scale multipurpose irrigation scheme. The soil in this study area is very loose and non-cohesive. Therefore, the irrigation practice in agricultural fields, which are unterraced, partly terraced or unlevelled terraced, should be kept very limited to avoid the danger of soil erosion and the consequential landslide, which is a common phenomenon of sloppy surfaces in a hilly undulated terrain.

10. AWARENESS & TRAINING ACTIVITIES

10.1 Mass Awareness Programme & Water Management Training by CGWB

No mass awareness programs & water management training have been conducted by CGWB till date.

11. AREA NOTIFIED BY CGWB/CGWA

No area of the study area has been identified to be notified by CGWB/CGWA

11. RECOMMENDATIONS

In the hilly terrain of the study area of Sikkim special planning for the withdrawal/ harnessing of groundwater should be chalked out:

1. As the groundwater in a hilly area occurs mainly in the secondary porosity/structure, the potential conduits in the form of fractures, joints, faults, weathered mantle etc. Have to be delineated precisely with the help of detailed structural studies, remote sensing and geophysical prospecting such as spot resistivity surveys with 'SP' profiles and radial vertical electric sounding (RVES) etc, which in turn will help to demarcate the areas having hydrogeologically favourable locations/ sites for groundwater exploration followed by deploying a suitable drilling machine (DTH Rig) for construction of tube wells/bore wells.

2. The Gondwanas restricted in a very small area in southeastern part of the study area consists mainly of coarse-grained sandstones. The sandstones along with the pebble beds are the potential zones for successful dug wells. The dug wells and bore wells located in flat areas near the springs can yield the appreciable amount of water. In a small area in the southernmost fringe of the study area, the thickness of the loose weathered overburden is considerably high. So deployment of the suitable rig in this area may be planned for groundwater extraction and development.

3. In higher hilly areas where construction of any groundwater structure is not feasible, the perennial springs have to properly develop for sustainable water supply. As far as practicable, the spring source has to be cleaned periodically, storage tanks of adequate capacity are to be built up, wastage of spring water before collection in chamber/storage tank as well as during pipelined home distribution, thereafter, should have to be minimized and some treatment (chemical and anti-bacterial) has to be carried out before the use for drinking. The spring water is tapped at a relatively higher altitude than the habitation and collected in a chamber/ artificial tank in the topographically low area. As the water may have some suspended particles, the water, thus collected, is to be led to a second chamber, where it is filtered and then to be

guided to travel down towards the village by the main supply pipe and ultimately enters into a storage tank constructed at an elevation near the concerned village.

4. The agricultural land in the study area is mostly without any source of irrigation water. There may be some potential zone in the surrounding which can be explored for irrigation water through the construction of bore wells. There may be substantial scope for slow but steady transformation from the existing sole rain-fed irrigation system to a conjunctive system of using both rainwaters (during rainy season) and groundwater (in lean/dry season) which can help to change the mono-cropped land to double-cropped as far as feasible after taking in to account the other parameters like agro-climatic conditions, land use, cropping pattern etc.

5. Rooftop rainwater harvesting should be adopted particularly in areas where groundwater is scarce and the access to reach the groundwater source is very difficult due to highly rugged topography and dense forest. This method can be very easily practiced by villagers who are having homes with a sloping roofs of considerable size. The rainwater from the roof is to be collected and stored in reservoirs (may be cemented or PVC Tank) and then can be utilised for drinking and other domestic purposes on non-rainy days. Before use, the stored water may have to be treated with bleaching powder if consumed after a long time. Thus collecting rainwater from a large number of buildings will contribute a substantial quantity of water for domestic uses. Technical guidance in this respect, if necessary, can be sought out from the Eastern Regional office of the Central Groundwater Board at Kolkata.