केन्द्रीय 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

South Garo Hills District , Meghalaya

उत्तर पूर्वी क्षेत्र**,** गुवाहाटी
North Eastern Region, Guwahati

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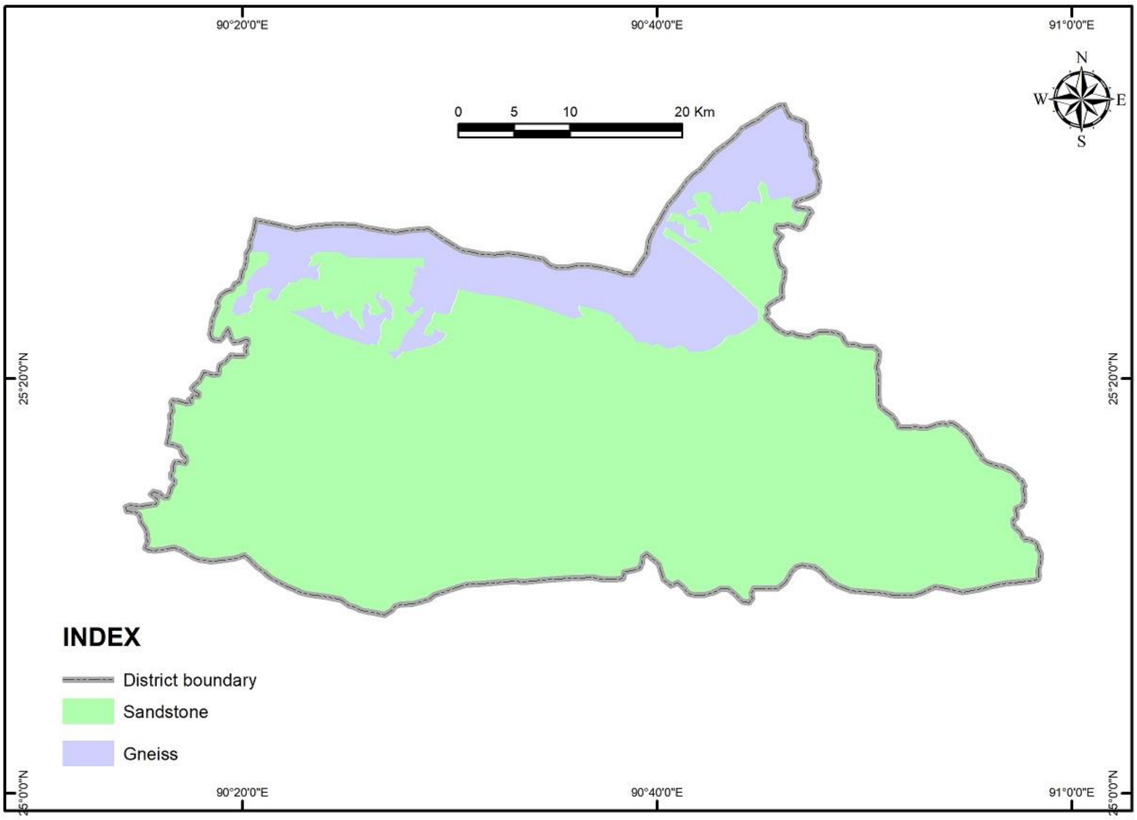
Department of Water Resources, River Development and Ganga Rejuvenation

केंद्रीय भूजल बोर्ड

CENTRAL GROUND WATER BOARD



दक्षिण गारो हिल्स जिला मेघालय की जलभृत मानचित्रण और प्रबंधन योजना पर प्रतिवेदन

REPORT ON
AQUIFER MAPPING AND MANAGEMENT PLAN OF SOUTH GARO HILLS DISTRICT, MEGHALAYA
(AAP 2020-21)

उत्तर पूर्वी क्षेत्र NORTH EASTERN REGION
गुवाहाटी GUWAHATI

सितंबर **SEPTEMBER 2021**

GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

REPORT
ON
"AQUIFER MAPPING AND MANAGEMENT PLAN OF SOUTH GARO HILLS DISTRICT, MEGHALAYA"
(AAP 2020-21)

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ABBREVIATION

AAP	Annual Action Plan
CGWB	Central Ground Water Board
NER	North Eastern Region
NAQUIM	National Aquifer Mapping and Management Plan
GL	Ground Level
GSI	Geological Survey of India
IMD	Indian Meteorological Department
LPM	Litres per minute
LPS	Litres per second
m	metre
mbgl	meters below ground level
MCM	Million Cubic Meter
Mm	Milli meter
mg/l	milligram/litre
m amsl	Metre above mean sea level
Sq.Km	Square Kilometre
µS/cm	Microsimens/centimetre
AMP	Aquifer Management Plan
AQM	Aquifer Mapping
BIS	Bureau of Indian Standards
BDL	Below detectable level
BCM	Billion Cubic Metres
DGM	Directorate of Geology and Mining
DTW	Depth to water table
DW	Dug Well
BW	Bore well
EC	Electrical Conductivity
EW	Exploratory Well
GEC	Ground water Estimation Committee
Ha	Hectare
Ham	Hectare meter
Km	Kilometer
MP	Measuring Point
OW	Observation Well
°C	Degree Celsius
Ppm	Parts per million equivalents to mg/l
Pz	Piezometer
SWL	Static water level
TDS	Total dissolved solid

EXECUTIVE SUMMARY

Aquifer Mapping Studies and Management Plan has been carried out in South Garo Hills district, Meghalaya under National Aquifer Mapping and Management Plan (NAQUIM) program with an objective to know the different aquifer system prevailing in the study area, to decipher the vertical and lateral extend of the aquifer down to the depth of 200 m, its characteristic, quantity as well as quality so as to bring a complete sustainable and effective aquifer management plan for ground water resources development in the study area. These studies have been done through multi-disciplinary approach so as to achieve the said objectives.

The total coverage area of aquifer mapping and management plan is 868 sq.km out of 1887 sq.km of the district and is underlain by consolidated rock of Gneiss and semi-consolidated rock of Sandstone.

Ground water occurs in the study area mainly in weathered and fractured sandstone and gneiss. The different hydrogeological data are generated through intensive field data collection and testing. The aquifers present in the district can be divided into a two aquifer system viz., first aquifer (shallow) and second aquifer (deeper). Shallow or first aquifer consists of weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells, shallow bore wells or hand pump. The second aquifer is the deeper aquifer constitute of fractured zones. Based on the study of litholog and analysis of depth of construction of dug wells and shallow bore wells, it is found that the first aquifer occurs within 2 to 30 m bgl. Ground water in the second aquifer occurs under semi-confined condition in the fractures zone upto the maximum depth of 142 m bgl.

Study of water level trend and its behaviour in phreatic aquifer were carried out in the aquifer mapping area. Study of spring was also carried out in the study area.

Surface Geophysical studies in the study area were carried out to delineate the subsurface geology. A total of 7 nos. of VES were conducted in South Garo Hills district during AAP 2010-11.

In order to study the chemical quality of ground water in the district, water samples from first aquifer (dug wells and springs) were collected during the course of field work. The samples were analyzed and found that there is a moderately high concentration of iron in almost all the dug well and spring. pH value is also low in some dug well and springs and needs to be treated before consumption. Based on the analysis using various method and chemical index such as sodium absorption ratio (SAR), sodium percentage(SP), residual

sodium carbonate (RSC), Kelly's ratio Permeability index and magnesium ratio, it is found that the ground water in the district is suitable for irrigation purpose.

Dynamic Groundwater Resources of the study area has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'2015). The net ground water availability was 8690 ham and the stage of ground water extraction was 2.98% which comes under safe category.

Finally, the aquifer map of the study area is generated based on the inputs from geological, hydrogeological and hydrochemical studies and a management plan was made with an emphasis in providing irrigation facilities through ground water development as agriculture is the main means of livelihood of the people living in the district.

1. INTRODUCTION

Central Ground Water Board, North Eastern Region has carried out Aquifer mapping and management plan in South Garo Hills district, Meghalaya during AAP 2020-21covering an entire area of 868sq.km (total district area is 1887 sq.km). Under National Aquifer Mapping and Management (NAQUIM) program, combination of geologic, geophysical, hydrologic and hydrochemical information is applied to characterize the quantity, quality and sustainability of ground water aquifers. Systematic aquifer mapping will improve our understanding of the geologic framework of aquifers, their hydrogeologic characteristics, quality and also quantifying the available ground water resources potential and proposing plans appropriate to the scale of demand and the institutional arrangements for management. Aquifer mapping at the appropriate scale can help to prepare, implement and monitor the efficacy of various management interventions aimed at long-term sustainability of our precious ground water resources, which, in turn, will help achieve drinking water security, improved irrigation facilities and sustainability in water resources development.

1.1 Objectives: The objectives of this project are to understand the aquifer systems up to 200 m depth, to define the aquifer geometry, type of aquifers, ground water regime behaviours, hydraulic characteristics and to establish groundwater quantity, quality, and sustainability, and to estimate the dynamic and static resources accurately through a multidisciplinary scientific approach on 1:50,000 scale and finally formulate a complete, sustainable and effective management plan for ground water development.

1.2 Scope of the Study: The activities of this Aquifer Mapping and management plan can be envisaged as follows:

1.2.1 Data Compilation & Data Gap Analysis: One of the important aspect of aquifer mapping program was the synthesis of the large volume of data already collected during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set generated that broadly describe an aquifer system. The data were assembled, analyzed, examined, synthesized and interpreted from available sources. These sources were predominantly non computerized data, which was converted into computer based GIS data sets. On the basis of available data, data gaps were identified.

1.2.2 Data Generation: There was also a strong need for generating additional data to fill the data gaps to achieve the task of aquifer mapping. This was achieved by multiple activities such as exploratory drilling, hydro-geochemical analysis, remote sensing, besides detailed hydrogeological and geophysical surveys to delineate multi aquifer system.

1.2.3 Aquifer Map Preparation: On the basis of integration of data generated from various studies of hydrogeology, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out characterization of Aquifers, which can be termed as Aquifer maps providing spatial variation (lateral & vertical) in reference to aquifer extremities, quality, water level, potential and vulnerability (quality & quantity).

1.2.4. Aquifer Management Plan Formulation: Aquifer Maps and ground water regime scenario are being utilized to identify a suitable strategy for sustainable development of the aquifer in the area.

1.3 Approach and Methodology: Aquifer mapping has been carried out by adopting a multi-disciplinary approach:

(i) Geophysical Surveys through Vertical Electrical Sounding (VES)

(ii) Exploratory drilling and construction of bore wells tapping various groups of aquifers

(iii) Ground Water Regime monitoring by establishing monitoring wells tapping different aquifers at different depths for long term monitoring of water level and quality

(iv) Pumping test of bore wells, soil infiltration test for determination of ground water recharge scope, intensity and potentials and also to determine the characteristics and performances of existing aquifers at various depths.

(v) Collection of various relevant technical data from the field in aquifer mapping area and also from the concerned State Govt. Agencies and other Institutes dealing with ground water and incorporating these data along with CGWB data for final output.

(vi) Preparations of a micro level mapping of existing aquifers, their potentials depth wise and sideways in 2D and 3D forms viewed from different angles by various GIS Layers.

(vii) Formulating a complete sustainable aquifer management plan for ground water development.

1.4 Area details: South Garo Hills district lies between E 90˚15’00” to E 91˚00’00” Longitude and N 25˚10’00” to N 25˚35’00” Latitude. The district is having an area of 1887 sq.km. Out of this, 868 sq.km of mappable area was covered under NAQUIM program during AAP 2020-21. Baghmara is the district headquarter of South Garo Hills District and is the only town in the district. The total population of the South Garo Hills district as per 2011 census is 142,334. The district has four C & RD blocks viz., Baghmara C& R.D. block, Chokpot C & R.D. block, Gasuapara C &R.D. block and Rongara C & R.D. block.

This area falls partly or fully in the quadrants of Survey of India Toposheets bearing nos. 78 K/7, 78 K/8, 78 K/10, 78 K/11, 78 K/12, 78 K/14, 78 K/15 and 78 K/16 and is bounded in the North by East Garo Hills, in the East by the west Khasi Hills district, in the West by West Garo Hills district and in the South by Bangladesh. The base map of the study area is shown in Fig.1.1.

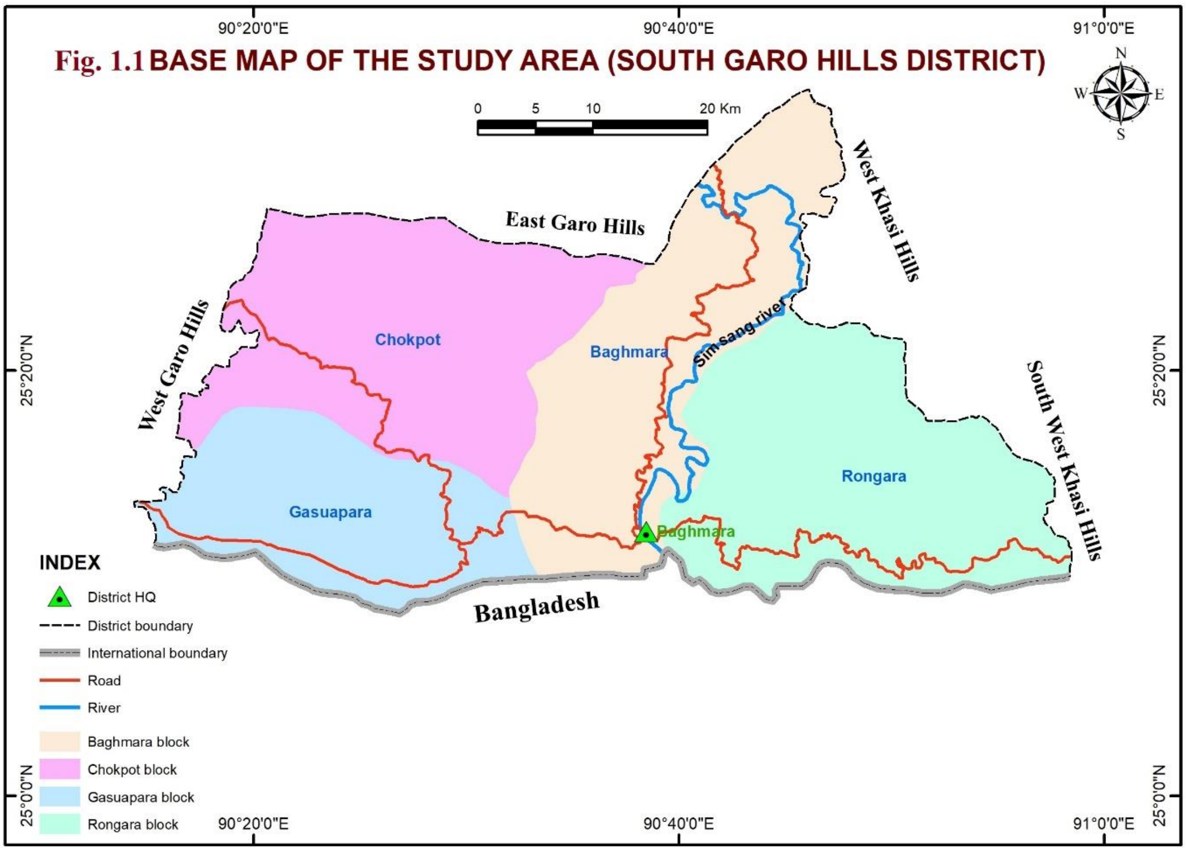


Fig. 1.1 BASE MAP OF THE STUDY AREA (SOUTH GARO HILLS DISTRICT)

1.5 Data availability, data adequacy and data gap analysis:

Aquifer mapping and management plan is carried out through collaborative of different data. The required data on various attributes of the study are collected from the available literatures of Central Ground Water Board, State Water Resources Department of Meghalaya and various Central and State Government agencies. The Data Requirement, Data Availability and Data Gap Analysis are presented in Fig1.2, table 1.1 and annexure 9.

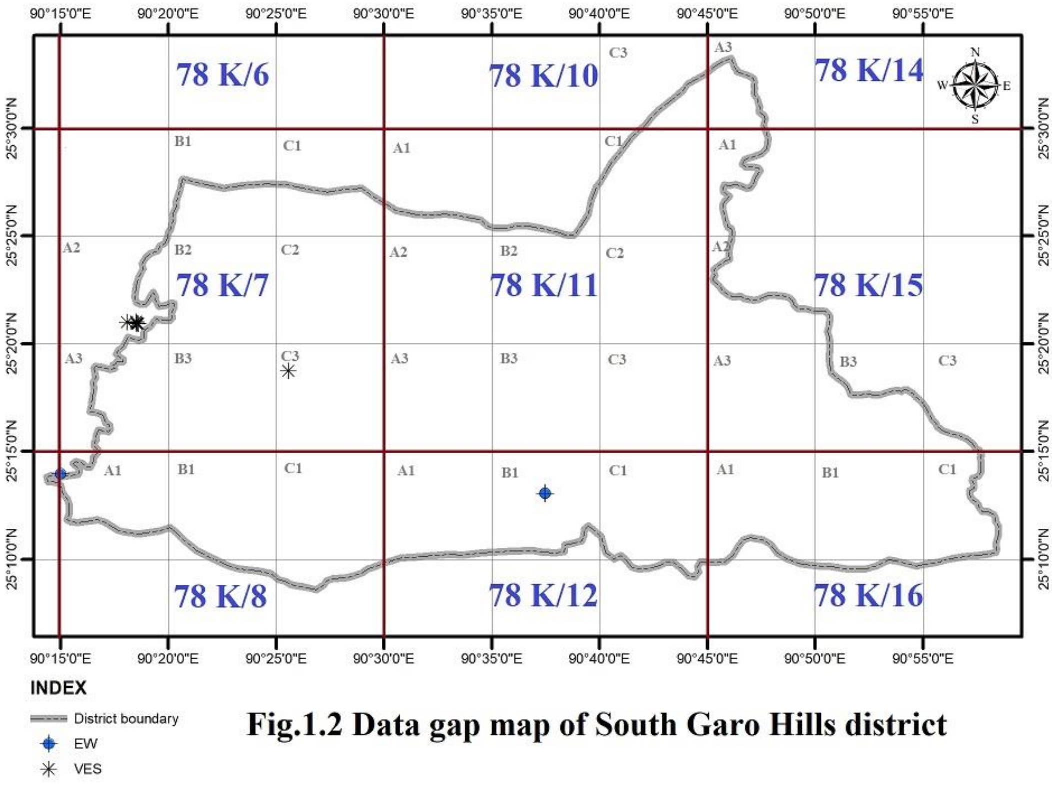


Fig.1.2 Data gap map of South Garo Hills district

Table1.1 Data Availability and Data Gap Analysis in Aquifer Mapping Studies

Sl. No.	Items	Data Requirement	Data Availability	Data Gap
1	Ground Water Exploration Data	Both first aquifer and second aquifer	2 EW	I Aquifer : 19 nos. of EW &19 nos. of OW. II Aquifer : 18 nos. of EW and 19 nos. of OW.
2	Geophysics	Geophysical data of the Study area	7 nos.	64 nos.
3	Ground Water Monitoring Regime	Representative Monitoring Wells well-distributed over the Study Area for both first and second aquifers.	Nil	I Aquifer : 32 nos. II Aquifer :19 nos.
4	Ground Water Quality	Representative well distributed Monitoring Wells over the study area for both first and second aquifers.	Nil	I Aquifer : 32 nos. II Aquifer : 19 nos.
5	Specific yield	Both aquifers	Nil	Entire study area
6	Climate	Season-wise Rainfall pattern	Till 2017	Monthly rainfall data for the past 10 years.
7	Soil	Soil map and Soil Infiltration Rate	Soil map	Soil Infiltration studies covering the entire study area
8	Land use	Latest Land Use pattern	Latest Land Use pattern	NA
9	Geomorphology	Detailed Information on Geomorphology of the area	District level information	NA
10	Recharge Parameters	Recharge parameters for different soil and aquifer types based on field studies	Recharge parameters given in Ground Water Resources Estimation	Entire study area

1.6 Demography: The total population of the South Garo Hills district are as per 2011 Census is 142334 with 73170 males and 69164 females.

South Garo Hills District	**Rural**	**Urban**	**Total**
Total population	129203	13131	142334
Male population	66470	6700	73170
Female population	62733	6431	69164

The block wise population of the community and Rural Development Blocks of South Garo Hills District as per the 2011 census is as below: -

Name of Block	Population		
	Male	Female	Total
Chokpot C & RD Block	20647	19831	40478
Gasuapara C & RD Block	14480	13736	28216
Baghmara C & RD Block	26156	24461	50617
Rongara C & RD Block	11887	11136	23023

1.7 Communication: The district is accessible through Williamnagar via Nongstoin-Nengkra-Rongjeng, and also via Jengjal (Tura-Williamnagar road) distance of about 115 Km from Tura. It is also approachable via NH-62 from Dudhnoi, Goalpara district, Assam which is 132 km from Baghmara.

1.8 Climate: The climate in the area is characterized by moderate temperature and is highly humid in nature. The climatic condition is accordingly much warmer than other districts of the State. Rainfall though inclined to be as heavy as in June – July months of each year is also much less than in the other districts to the east. The mean monthly temperature ranges from 17.58°C to 34.13°C. The coldest months in the district are December and January and the warmest months are June, July, August, September and October. Winter season starts in November and continues till the end of February. The months of March, April and May are the period of Pre-monsoon season. The temperature begins to rise from the month of March. The frequency of storms also increases during these months. During the monsoon period, due to heavy rainfall, the weather is suitable for crops growing in the hills and the plain areas. The Rainfall, Humidity and Temperature data of South Garo Hills District during 2002 to 2020 is presented in the table below,

Table 1.2 Rainfall, humidity and temperature data in South Garo Hills district during the period of 2002-2020

Sl No	Year	Rainfall (mm)	Humidity		Temperature	
			Max (%)	Min (%)	Max (ºC)	Min (ºC)
1.	2002	2724.2	80.23	69.30	31.66	19.41
2.	2003	2361.9	81	72.9	31.5	20.08
3.	2004	2531.8	80.67	68.98	30.33	19.91
4.	2005	2347.1	79.54	69.80	27.66	20.08
5.	2006	2005	85.66	51.5	33	23.25
6.	2007	2588.6	86.41	53.5	32.83	22.41
7.	2008	2391.9	84.58	55	33.08	22.58
8.	2009	1621.6	85.33	51.75	33.41	24
9.	2010	1660.82	83.75	51.41	33.5	23.75
10.	2011	2146.8	84.16	54.16	33.66	22.5
11.	2012	1841	84.33	52.66	33.16	23.25
12.	2013	1411	82.83	57.5	31.25	22.91
13.	2014	2,313.1	87.42	53.6	32.54	22.07
14.	2015	3,094	97.97	40.95	34.07	17.58
15.	2016	2,941.4	97.67	42.75	34.13	18.19
16.	2017	3,886.82	92.04	42.07	33.99	17.97
17.	2018	2248.6	89.8	46.81	32.99	18.21
18.	2019	3,538.6	88.12	41.2	33.72	16.49
19.	2020	4681.8	86.43	46.13	33.43	18.07

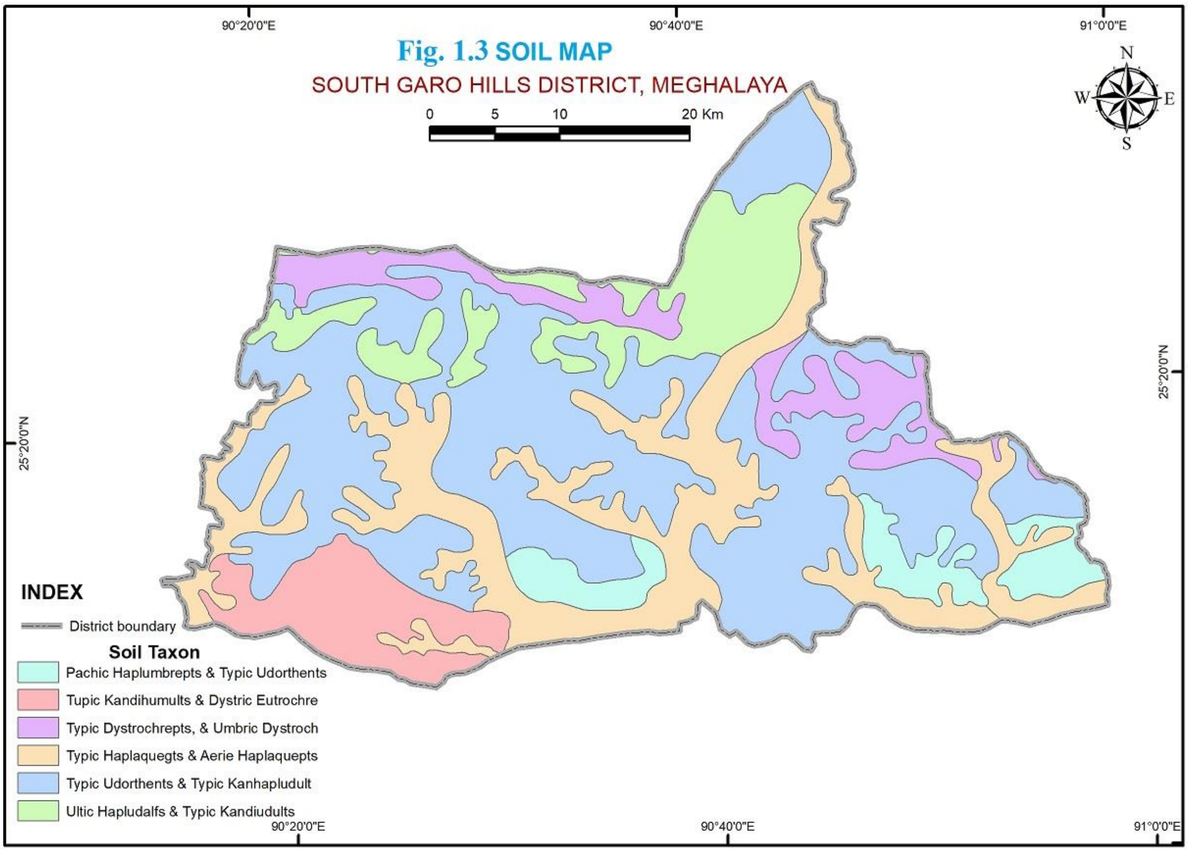
1.9 Land use: Land utilization statistics provide detailed information of the land use pattern in the area. The socio-cultural factor plays a dominant role in land use both in rural and urban areas. Landforms, slope, soil, natural calamities and natural resources are the important factors which control the land use pattern of the area. Based on the land utilization, the total area is divided into various types of landforms such as forest, cultivable land, fallows land, crops area etc. which in turn reflects the degree of development of agricultural activities and cultivation potential. The net sown area in the district is 13.49% of total geographical area. The land utilization statistics of South Garo Hills district is shown in the following Table1.3.

Table 1.3: Land use statistic in South Garo Hills, 2019-20

Sl.No.	Particulars	Area in Hectares
1	Total reporting area under land utilisation	188700
2	Forest land	102275
3	Not available for cultivation	11168
4	Other cultivated land	25383
5	Fallow land	24389
6	Net area sown	25472
7	Area sown more than once	5254
8	Gross cropped area	30726
9	Cropping intensity	120%

Source: District Statistical Office, South Garo Hills, Baghmara, Govt. of Meghalaya

1.10 Soil: The soils of the district are derived from gneissic complex parent materials; they are dark brown to dark reddish-brown in colour, varying in depth from 50-200 cm. The texture of soils varies from loamy to fine loamy. The soils of the alluvial plains adjacent to the northwest and southern plateau are very deep, dark brown to reddish-brown in colour and sandy-loam to silty-clay in texture. Soils are rich in organic carbon, which is a measure of nitrogen supplying potential of the soil, deficient in available phosphorous and medium to low in available potassium. The pH value of the soil varies from acidic (pH 5.0 to 6.0) to strongly acidic (pH 4.5 to 5.0). Most of the soils occurring on higher altitudes under high rainfall belt are strongly acidic due to intense leaching. Soil is one of the most important components of land through which an interaction of all natural factors is possible. The types of soil available in the district differ widely and three major types of soil are commonly found. They are (i) Laterite soil - found in the northern parts of the district. (ii) Red and yellow soil - the most prevalent one covering the entire parts of the district and (iii) Alluvial soil - found along the southern fringe of the district. Soil map of the area is given in Fig 1.3.



(*Source: Regional Center of National Bureau of Soil* Survey and Land *Use Planning*).

1.11 Agriculture: Agriculture is the main means of livelihood of the people in the district and about 90% of the population of South Garo Hills is dependent on agriculture. Rice is the most important food crop that is grown in the district, both in the plains and the hills. Other food crops that are widely grown in the district are maize, millet, jute, mesta, cotton, tur and pulses. Due to widespread practice of shifting cultivation and deforestation, the production of food crops is decreasing and Government has intervened to provide alternative measures of farming practices like terracing, contour farming etc. to the people. The area is endowed with diversified climatic condition thereby offering good scope for cultivation of temperate and subtropical crops. Broadly the low-lying areas were put under paddy during Kharif and with pulses, paddy, vegetables and oilseeds during the Rabi season depending on the availability of residual moisture and irrigation facilities. Gentle slopes up to 20% were put under other crops like paddy, maize, pulses, oilseeds, vegetables etc. Agricultural activities are by and large confined to the valleys and hill slopes. Kharif cultivation depends mainly on monsoon rainfall. The district is endowed with diversified climatic condition thereby offering good scope for cultivation of temperate and subtropical crops. Present area under different crops and their productivity is shown in table 1.4.

Table 1.4: Area under different crops and their productivity and yield in South Garo Hills district (2019-20)

Sl No.	**Types of Crops**	**TOTAL 2019-20**		
		Area (Hectare)	**Production (Metric tonnes)**	**Yield (Kg/Ha)**
1	<u>**Kharif:**</u>			
	Winter Paddy	3355	6460	1925
	Jhum Paddy	3610	5514	1527
2	Autumn Paddy	1230	2397	1949
3	Maize	610	1106	1814
4	Jute	496	3113	1130
5	Mesta	864	4994	1040
6	Cotton	110	77	119
7	Finger Millets	27	49	1840
8	Foxtail Millets	154	206	1336
9	Pearl Millets	60	81	1361
10	Sesamum	216	252	1166
11	Soyabean	29	61	2118
12	Tur(Arhar)	144	110	766
13	<u>**Rabi**</u>**:**			
	Spring Paddy	291	323	1110
14	Maize	530	964	1818
15	Gram Pulses	81	97	1203
16	Pea	121	564	4660
17	Lenthil	56	77	1370
18	Rapeseed & Mustard	337	332	985

Source: District Agriculture Department, South Garo Hills, Govt. of Meghalaya

1.12 Irrigation: There is no major or medium irrigation scheme in the district, agriculture is mainly rainfed. However, a few minor irrigation schemes based on surface water sources like Flow Irrigation Projects (FIP) and Lift Irrigation Project (LIP) exist. Flow Irrigation Projects (FIP) are gravity flow type which involves water diversion from rivers/streams and irrigating the field by the aid of gravitational flow. It is used widely where water is spread across land using basin, border and furrow method. Lift Irrigation Project (LIP) involves pumping/lifting water from the river using electric pump and irrigating the fields. Irrigation through ground water is not yet practiced. Not a single irrigation well could be traced in the district area during the course of present study. Irrigation statistics in South Garo Hills district are given in Table 1.5.

Table 1.5:Irrigation Statistics for the year 2019-20.

South Garo Hills	Net Irrigated Area (Ha)							Gross Irrigated Area (Ha)						
	Canal			Tank	Tube Well	Other Source	Total	Canal			Tank	Tube well	Other Source	Total
	Govt.	Private	Total					Govt.	Private	Total				
Total	2780	0	2780	0	0	0	2780	3413	0	3413	0	0	0	3413

Source: District Agriculture Office, South Garo Hills, Govt. of Meghalaya.

1.13 Industries: There are no major or minor industries in the district at present. The district is not industrially developed. Among the small scale industries, important industries are wooden furniture, bakery, tailoring, motor repairing, sawmills, cane and bamboo works, tyre rethreading, steel fabrication, etc.

1.14 Forest: The District is very rich in natural resources. Majority of the forests areas of this district falls under Tropical Moist Deciduous Forest Zone. These areas are rich in vegetation which ranges from tropical to temperate dense jungles clothe the higher summits. The valuable timbers, medicinal plants, hard and soft woods of various types are found in these areas of the district. Sals and teak are most important valuable timbers. A botanic curio shrub Nepenthes Khasian grows in and around Baghmara. As per Directorate of Economics and Statistics, the forest cover area is about 102275 ha (2019-20) which is about 54% of the total district area.

1.15 Geomorphology: Geomorphologically, the district is an undulatory terrain. In general, the district has a diversity of landscape such as hills, plateau, deep gorges and plain areas. Broadly, the district can be differentiated into the following geomorphic units,

i. Denudational Hills: It occupies the major part of the district comprised of gneissic rock and sandstone. These are the Archaean gneissic hills undergoing weathering and erosion. These have narrow to broad rounded crests. The hills have diverse orientations assuming isolated hummocky nature.

ii. Lower plateau: These are intermontane valley existing between hills. They get widen towards the eastern part.

iii. Structural hills: It is found in the central and western parts of the district and comprises mainly of tertiary group of rocks.

iv. Plateau: Small portion of plateau is found on the north-eastern corner of the district.

v. Upper plateau: It is found in the eastern corner of the district.

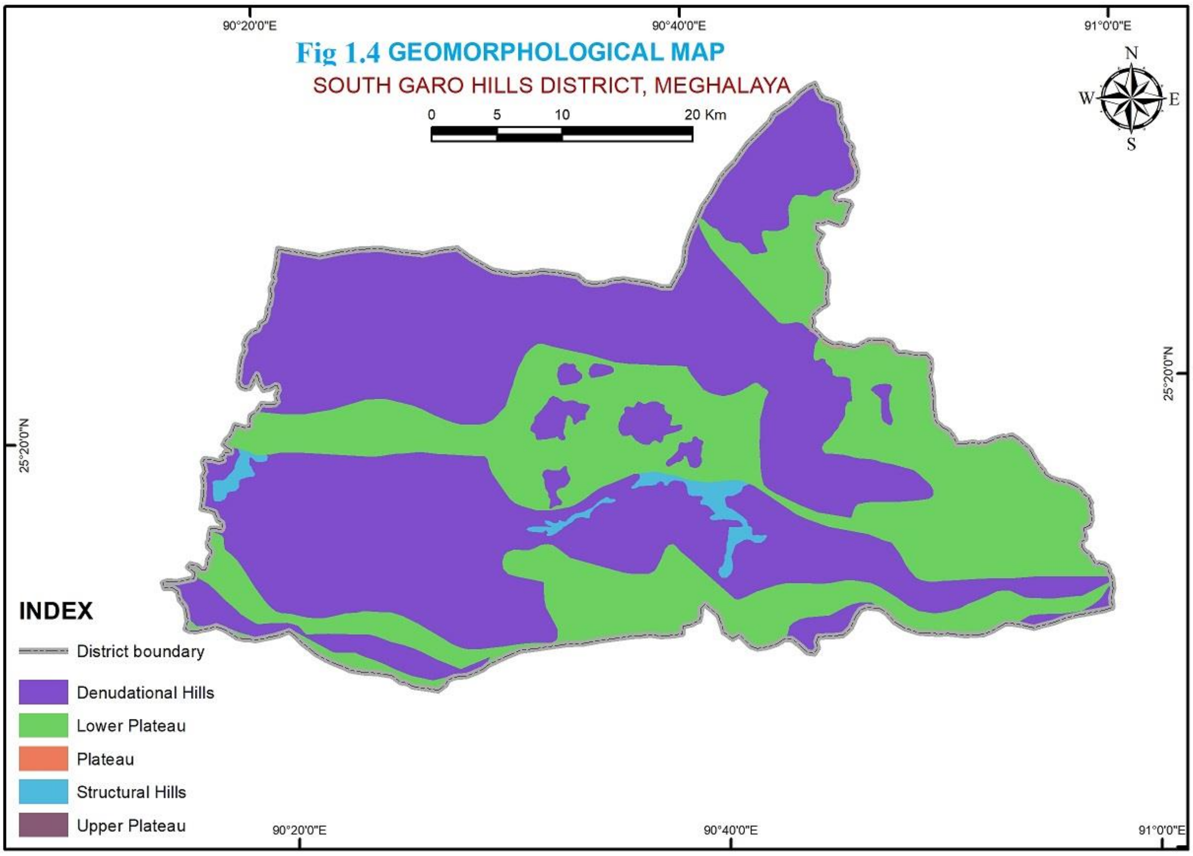
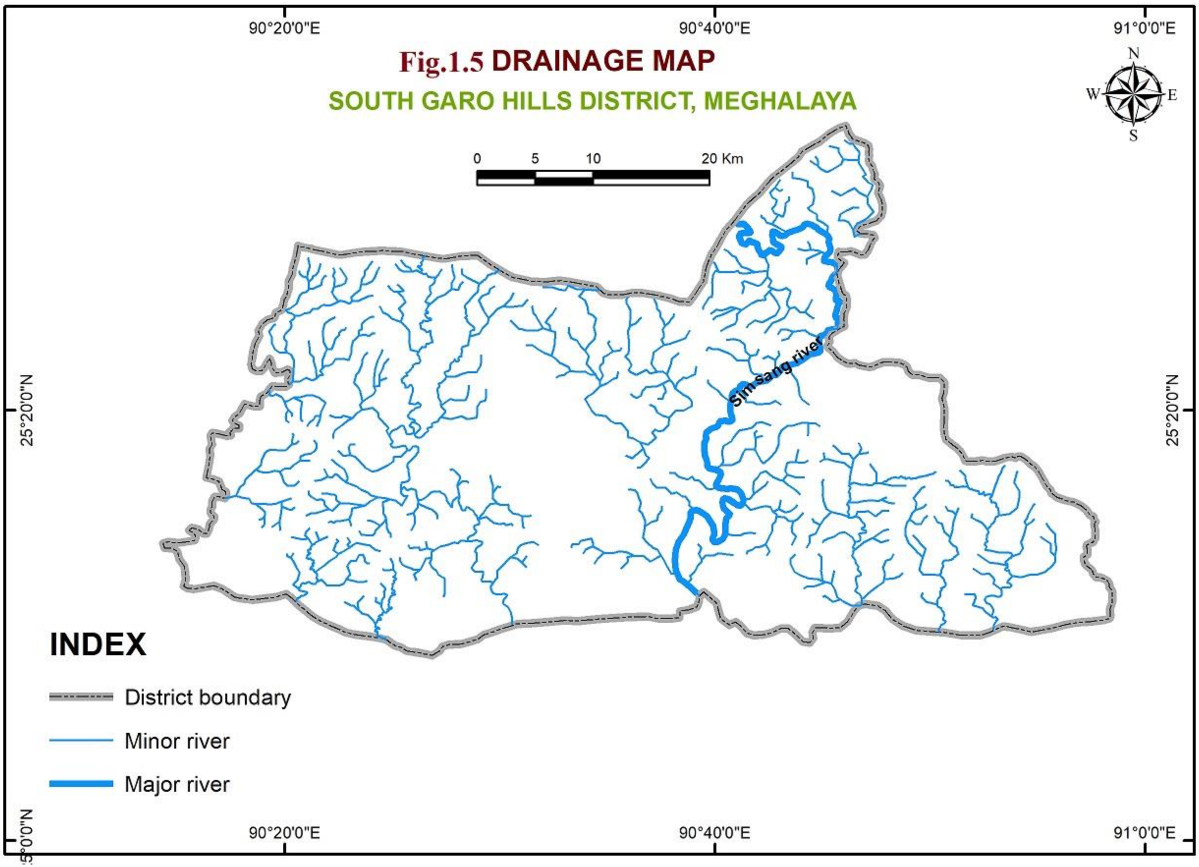


Fig 1.4 GEOMORPHOLOGICAL MAP
SOUTH GARO HILLS DISTRICT, MEGHALAYA

1.15 Drainage: The drainage system of the district is controlled mainly by physiographic features and geological structures, e.g., faults and joints, etc. The prevailing climate and environment in the district is characterised by heavy rainfall, which favours the action of streams to a considerable extent. Most of the rivers have their origin in the northern upland area in Tura Range and flow towards the south becoming wider. The drainage pattern varies from dendritic type to trellis pattern in lower orders, which indicates both topographic and structural control by topography. Main drainage in the district is the north-south flowingSimsang (Someswari) river which is the the biggest and longest river of Garo Hills covering a distance of about 62 km long in the district. The chief tributaries are Dadarek, Chibok, Rongdik, Rompha and Rongkhai rivers. Rongkhai and Rongdi rivers and Moheskhola river form part of the eastern boundary South Garo Hills district. Rangai and Bugi (Bhugai) rivers form the western boundary of South Garo Hills district. Some of the other rivers in the district are Mineng, Dabua, Khakija, Dareng and Nitai rivers to the west of Simsang river and Rongra, Rongdi, Kharnai (Khani), Mahadev and Moheskhola rivers to the east of Simsang river. All rivers flow due south and feed the Surma river in Bangladesh. After it is joined by the south flowing Someswari river, the Surma river is also non as the theBaulai river in Bangladesh. The drainage map is shown in Fig 1.5.



2. DATA COLLECTION AND GENERATION

One of the main objectives of the study was to collect various relevant technical data from the concerned State Government agencies and other Institutes dealing with ground water and incorporating these data along with CGWB data to generate strong data base. Based on the data availability and data gap analysis, the required sub-surface hydrogeological data, depth to groundwater level data and groundwater quality data were generated but the entire data required could not be generated due to unapproachable/inaccessible and difficult hilly terrain.

2.1 Hydrogeological: Occurrence of ground water in the study area is mainly of weathered and fractured gneiss and sandstone. The different hydrogeological data are generated through intensive field data collection and testing.

2.1.1 Water level monitoring: In the study area, only 12 dug wells and 7 spring were established as key wells to study the water level, quality and spring discharge. There was huge data requirement, but due to lack of groundwater abstraction structure in the study area only these could be established.

Phreatic aquifer: A total of 12 dug wells were established as key wells for periodical monitoring to know the water level trend and its behaviour. The key observation wells details are presented in Annexure 2. The pre-monsoon and post- monsoon depth to water level maps are depicted in Fig 3.4 and 3.5.

Confined/ Semi-confined aquifer: For study of piezometric head in the district, static water level of earlier 3 numbers of bore wells drilled under Ground Water Exploration programme of CGWB are taken into account. The exploratory wells location is shown in Fig 2.1.

Springs: A total of 7 springs were established and monitored to know the type, discharge and their behaviour. Pre-monsoon and post- monsoon spring discharge is shown in Fig 3.2 and 3.3. Details of spring monitored during NAQUIM (2019-2020) is given in Annexure 3.

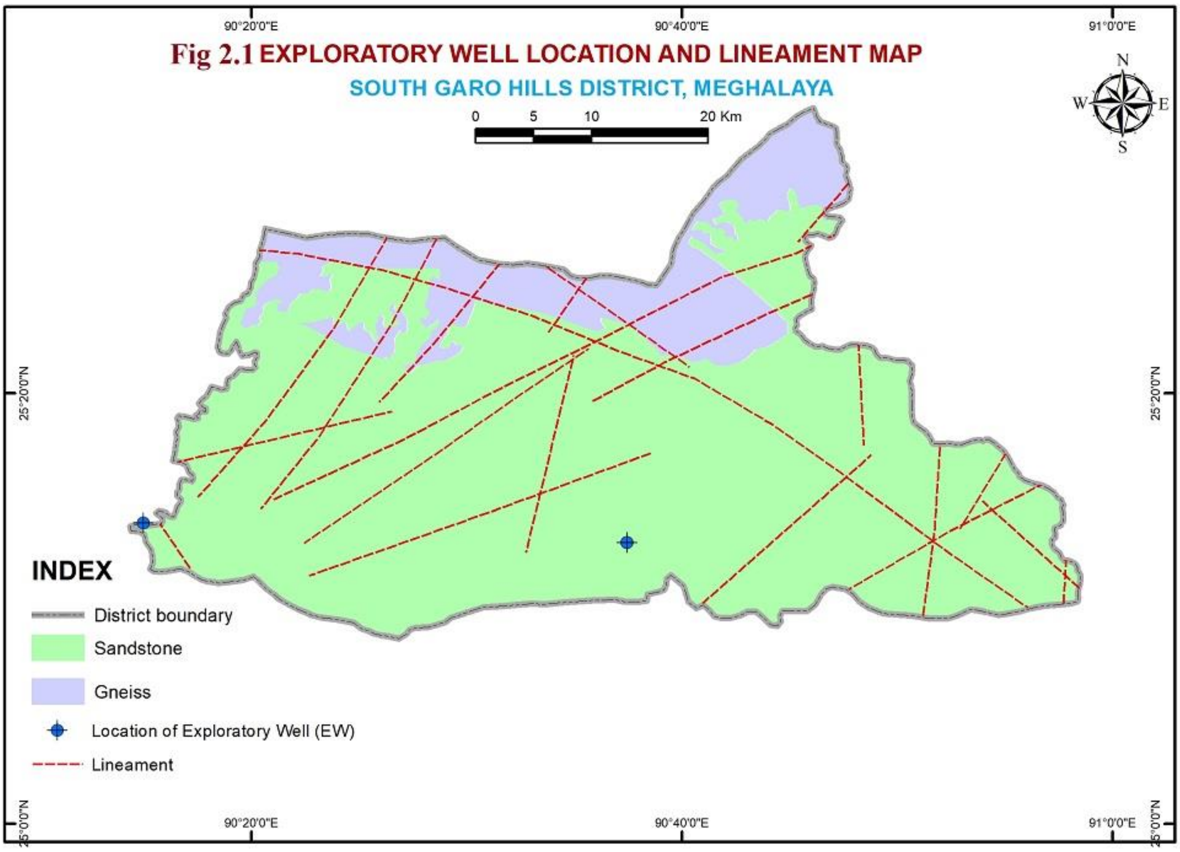
2.2 Hydrochemistry: The quality of ground water is as important as that of the quantity. In order to study the chemical quality of ground water in the district, water samples from first aquifer (dug wells and springs) were collected during the course of field work. Ground water samples were analysed in the regional chemical laboratory, Central Ground Water Board, North Eastern Region, Guwahati for 16 parameters. The analytical data are given in Annexure 4 & 5.

2.3 Ground water exploration studies: Ground water exploration has been carried out in different parts of the district to delineate the potential aquifers and their geometry and to determine the hydrogeological parameters of the aquifer systems. Before NAQUIM programme initiated in the district, 3 EWs were constructed. Details of the exploratory wells are presented below in the table 2.1.

Table 2.1 Exploratory wells constructed in South Garo Hills district

Sl. No.	Village/ Location	Taluka/ Block	Toposheet No.	Longitude	Latitude	Type of well (DW/BW /TW)	Drilled Depth (m bgl)
1	Baghmara I	Baghmara	78 K/12	92°37'15"	25°13'01"	BW	22.37
2	Baghmara I	Baghmara	78 K/12	92°37'28"	25°13'03"	BW	104
3	Dimapara	Gasuapara	78 K/8	92°15'00"	25°13'58"	BW	142

The exploratory wells which were constructed before NAQUIM are shown in fig 2.1.



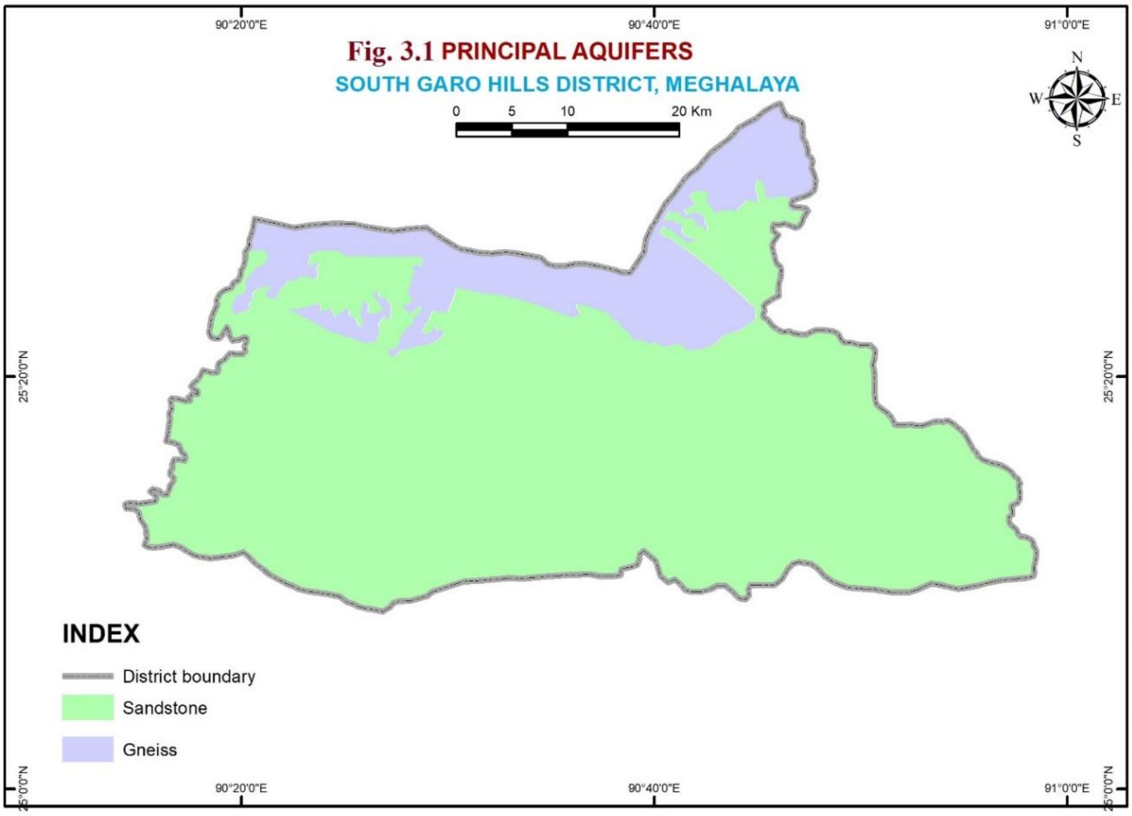
2.4 Geophysical studies: Surface Geophysical studies in the study area were carried out to delineate the subsurface geology as well as supplement the data gap under the assignment of Aquifer Mapping. A total of 7 nos. VES were conducted and HAK, HK, HKH, HAK, KQ, QH, A, K type VES curves were obtained. The inferences drawn on the basis of interpreted results could not be obtained for deeper formation due to the limitations of unavailability of large and straight stretch for current electrode separation. However, taking into account the interpreted results as well as the apparent resistivity, inferences have been approximated to shallow to deeper depth at few places. The detail results are given in annexure 7. The locations of the survey carried out are tabulated below.

Table 2.2: Location of VES survey carried out in West Garo Hills district

Sl. No.	Village	Location	Coordinates	General Geology
1	Dajibidrgre	100m south of VES-343.	N 25°18'44.0" E 90°25'34.5"	Jaintia Group(Sand Stone/Shale/Coal
2	Ashugre	50m S60°W of Sri Hollentro Sangma's house.	N 25°20'55.8" E 90°18'32.3"	Jaintia Group(Sand Stone/Shale/Coal
3	Ashugre	100m N15°W of VES-345.	N 25°20'58.6" E 90°18'31.3"	Jaintia Group(Sand Stone/Shale/Coal
4	Ashugre	100m N15°W of VES-346.	N 25°21'01.3" E 90°18'31.2"	Jaintia Group(Sand Stone/Shale/Coal
5	Ashugre	100m S65°E of VES-347.	N 25°21'01" E 90°18'05"	Jaintia Group(Sand Stone/Shale/Coal
6	Ashugre	100m S15°E of VES-348.	N 25°20'57.6" E 90°18'35.1"	Jaintia Group(Sand Stone/Shale/Coal
7	Ashugre	100m S15°E of VES-349.	N 25°20'55.7" E 90°18'35.9"	Jaintia Group(Sand Stone/Shale/Coal

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 General hydrogeology and occurrence of ground water: The hydrogeological formation of the study area comprised of Gneiss of Archean (?)- Proterozoic and Sandstone of Pleistocene-Eocene age. The presence of weak planes like fractures and joints in these hard rock formation forms the principal aquifer in the area. The ground water in the district occurs under unconfined and semi-confined conditions. Study of dug wells and ground water exploration data reveals the presence of phreatic/ shallow and deep fractured aquifers in the district. The principal aquifers in the district is shown in Fig 3.1.

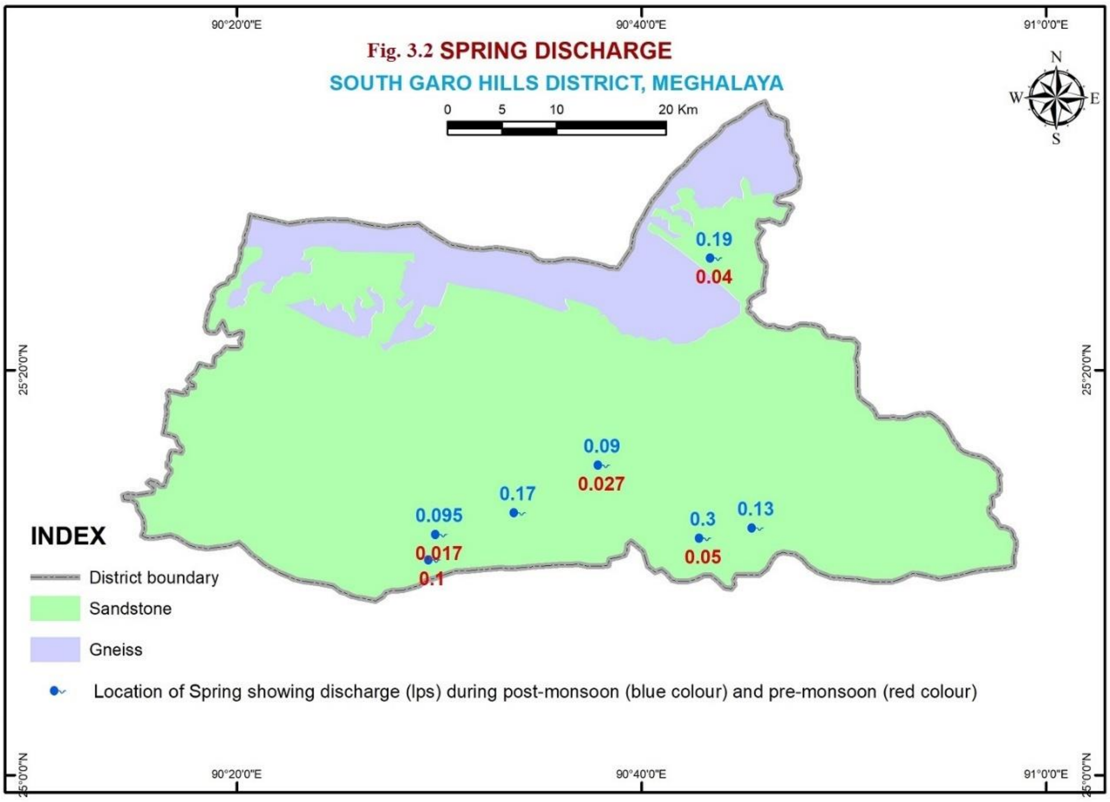


3.1.1 Occurrence of ground water in shallow aquifers: The depth of shallow aquifer in the district ranges from 2 to 30 meters. This shallow aquifer occurs under unconfined condition. Ground water from shallow aquifer is exploited through different types of ground water extraction structures such as dug wells (Kachha dug wells and ring well). This dug well tapped the unconfined aquifer generally down to 2 to 6 meters. This unconfined aquifer extends upto 30 meters which is the alluvium and weathered portion.

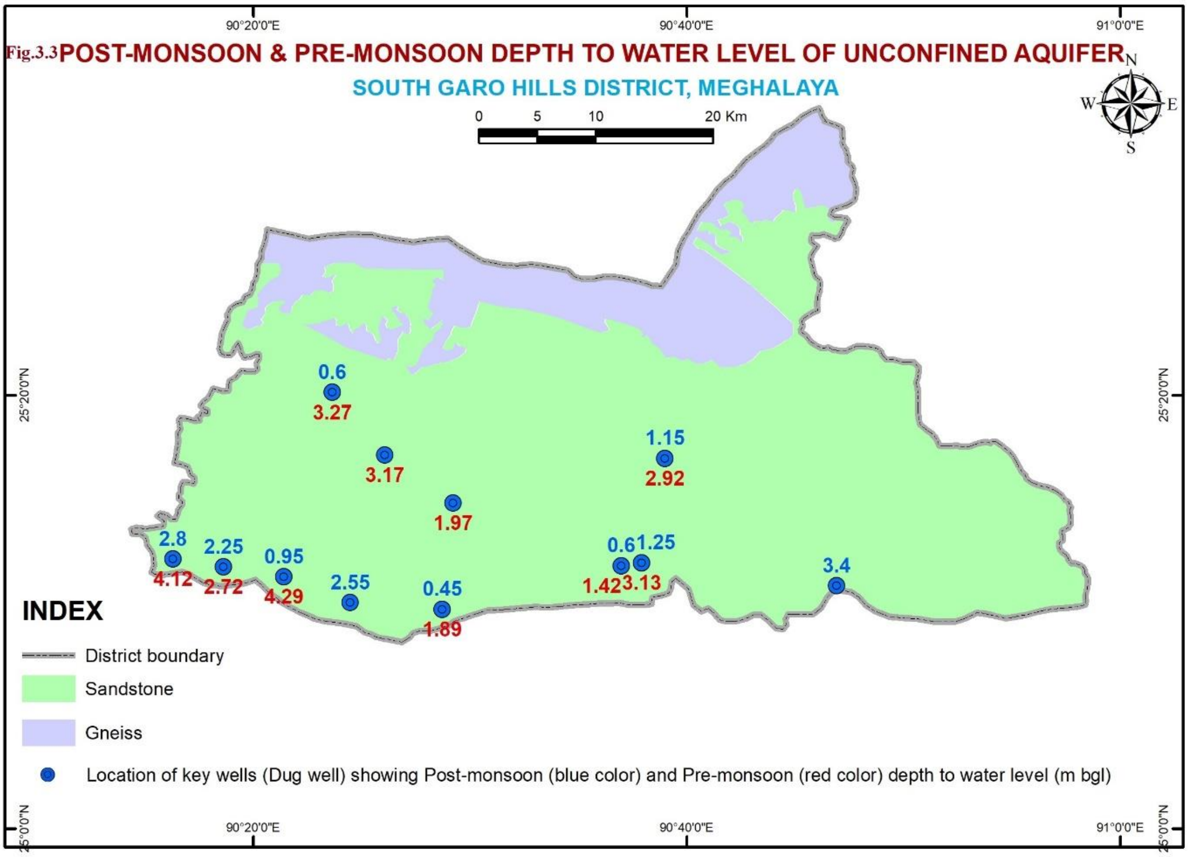
3.1.2 Occurrence of ground water in deeper aquifers: The deeper aquifer occurs as semi-confined condition where ground water is found in the fractured zone of consolidated Gneiss and Sandstone. The drilled depth of exploratory wells tapping this aquifer ranges from 22.37 to the explored depth of 142 m bgl. The number of fractures encountered varies from place to place which show the complexity of the hydrogeology of consolidated hard rock formation.

3.1.3 Springs: Spring is defined as a localized natural discharge of ground water appearing at the ground surface as a current of flowing water through well-defined outlets. The discharge may vary from a trickle to a stream. Groundwater flow from springs is governed mainly by three inter-related factors: geology (type, distribution and permeability characteristics of geologic units), topography (landforms and relief), and climate (timing and amount of precipitation). Topography drives the groundwater flow downhill and largely dictates the occurrence of the spring itself. Climate would influence the timing and amount of recharge to the flow system and the volume and variability of discharge. Groundwater obtained from spring is similar to water pumped from shallow wells. The study of spring has been carried out in the aquifer mapping area and it was found that the location of the spring is mainly restricted to foothills and intermontane valleys. A total of 7 springs were established and monitored periodically during the course of study. It was observed that the discharge of springs were 0.017 to 0.1 litre/second during pre-monsoon and 0.09 to 0.43 litre/minute during post-monsoon season which is shown in Fig 3.2. It has also been observed that the discharge of springs has been increased during monsoon season and gradually decreases in post-monsoon and pre-monsoon.

Fig. 3.2 SPRING DISCHARGE
SOUTH GARO HILLS DISTRICT, MEGHALAYA



3.2 Depth to Water Level: Study of water level and its behaviour both in phreatic and semi-confined condition were carried out in the aquifer mapping area. A total of 12dug well were established as key well for periodical monitoring to know the water level trend and its behavior in phreatic condition. The depth to water level in the phreatic aquifer vary from 1.42 to 4.29 m bgl during pre-monsoon and 0.45 to 3.4 m bgl during post-monsoon season and is shown in fig 3.3 and the average water level fluctuation is 1.5 m.



To study the piezometric head, 3 bore wells drilled by Central Ground Water Board previously were considered. The piezometric head ranges from 2.05 m bgl to 3.63 m bgl.

3.3 Aquifer System: The study area is mainly underlain by consolidated rocks of gneiss and sandstone. The aquifer system exists in all the rock formations. It also exists in both weathered formation as well as fractured system down to the explored depth of 142 m bgl. The depth of weathered zone varies from 2 to as high as 30 m below ground level. Thus, hydrogeologically, the study area can be categorized as (i) Gneiss aquifer and (ii) Sandstone aquifer. In Fig.3.4, disposition of fractures were shown however lateral extension of these fractures cannot be established.

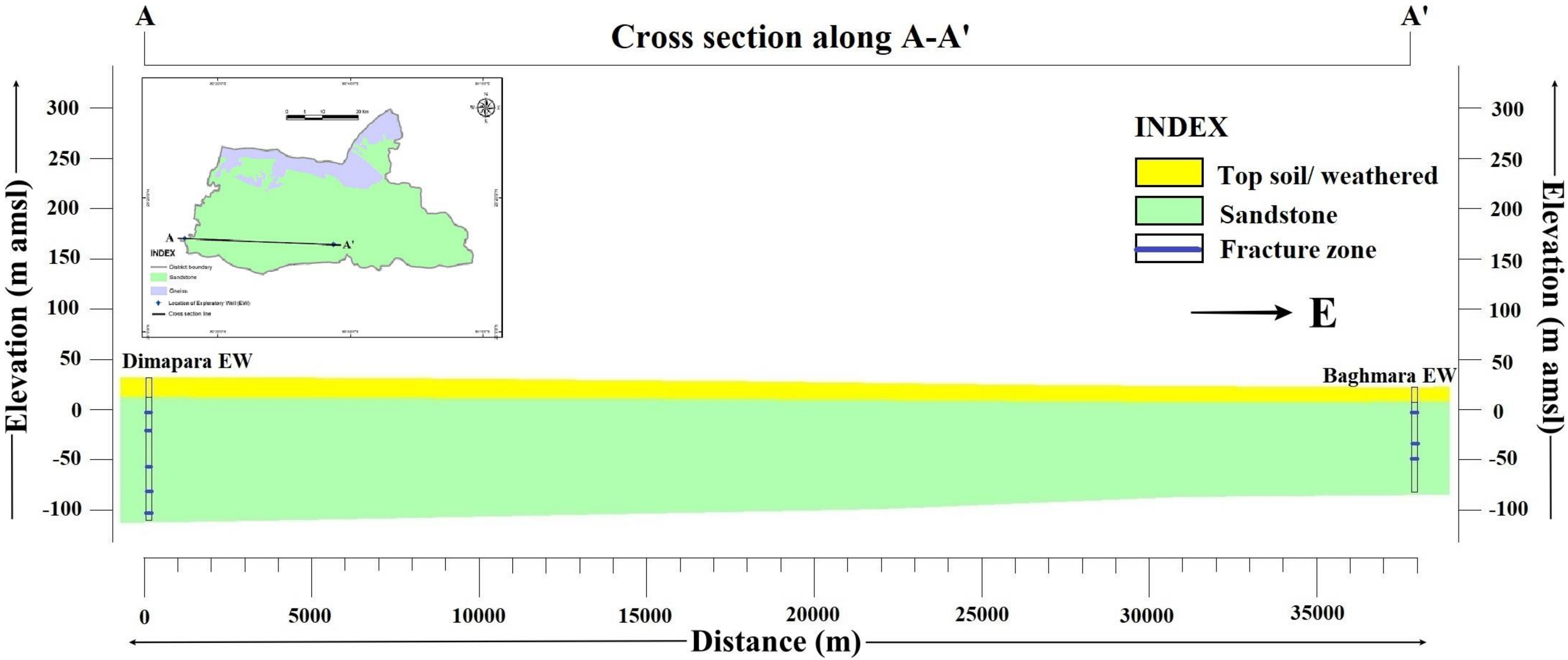


Fig 3.4 Hydrogeological cross section along A-A'

Formation wise hydrogeological behaviours in the district are discussed below:

3.3.1 Gneiss: The Gneisses are exposed in the northern part of the district. The occurrence of ground water in this formation is controlled by weathering and fractures/joints/weak planes patterns. Groundwater in these formations occurs under phreatic conditions in weathered mantle and under semi-confined conditions in the fractured rocks, which is governed by topography and drainage. CGWB has not constructed borewell in this formation in the district but the same formation has been explored in the other adjoining districts of the state and it is found that the average discharge from this formation is about 3 to 9 lps.

3.3.2 Sandstone: The major portion of the district is covered by Tertiary sandstone of Jaintia and Garo group. The occurrence of ground water in this formation is also controlled either by weathering and or by fractures patterns. Groundwater in these formations occurs under phreatic conditions in weathered mantle and under semi-confined to confine conditions in the fractured rocks, which is governed by topography and drainage. In this formation, depth of first aquifer ranges from 3 to 30 m bgl and the second aquifer ranges beyond 30 m bgl. So far, CGWB has drilled only three bore well in this formation and the discharge of the exploratory well are about 2 to 14.4 lps and Transmissivity ranges from 7 to 61 m^2/day. Distribution of fractures at various depth and cumulative discharge is tabulated in table 3.1.

Table 3.1 Location wise details of fracture encountered in Sandstone

Location	**Depth drilled in m bgl**	**Number of fractures encountered**					**Discharge (in lps)**
		0 to 50 m	**50 to 100 m**	**100 to 150 m**	**150 to 200 m**	**200 to 250 m**	
Dimapara	142	1	2	3	-	-	14.4
Baghmara I	22.37	1	-	-	-		2
Baghmara II	104	1	2	0	-	-	7.7

The above table reveals that 1 to 6 numbers of fractures were encountered within 150 m depth.

3.4 Aquifer Geometry: The aquifer system in this district can be divided into two aquifer system viz., first aquifer (shallow) and second aquifer (deeper). Shallow or first aquifer consists of weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells or shallow bore wells as hand pump. The second aquifer is the deeper aquifer which tapped the fractured zone. Based on the study of litholog and analysis of depth of construction of dug wells and shallow bore wells, it is found that the first aquifer occur within 2 to 30 m bgl. Ground water in the second aquifer occurs under semi-confined to confined condition in the fractures upto the maximum depth of 142 m bgl.

3.5 Aquifer Properties:

Aquifer I: It is the unconfined aquifer which occur between 2 to 30 m depth. Tapping of this Aquifer by the villagers were done through ground water extraction structures like kachha dug well or ring well. The properties of Aquifer-I could not be established due to unavailability of pump for conducting dug well pump test.

Aquifer II: This is the deeper aquifer which occurs as semi confine to confined condition where ground water is found in the fractured zone of consolidated sandstone and gneiss. The drilled depth of exploratory wells tapping this aquifer ranges from 22.37 to 142 m bgl. The number of fractures and zones of encountering fractures varies widely which show the complexity of the hydrogeology of consolidated hard rock formation. It was found that transmissivity values vary from 7 to 61 m^2/day and the discharge in these wells ranges from 2 to 14.4 lps.

3.6 Hydrochemistry:

The quality of ground water is as important as that of the quantity. In order to study the chemical quality of ground water in the district, a total of 19 numbers of ground water samples were collected and analyzed during the course of study. Out of these, 12 water samples from dug well and 7 sample from springs were analyzed for the parameters like pH, EC, Turbidity, TDS, CO_3, Cl, SO_4, Na, K, HCO_3, NO_3, F, Ca, Mg, TH, U, As and Fe. Table 3.2 and 3.3 summarizes the results of chemical analysis of groundwater samples from South Garo Hills district during pre-monsoon and post-monsoon season and the details of chemical analysis were given in the Annexure 4 and 5.

Table 3.2: Chemical quality of water samples from dug well and springs in South Garo Hills district during pre-monsoon

Sl. No.	Chemical constituents (Concentrations in mg/l except pH, EC, U and As)	Dug Well	Spring
		Range	
1	Ph	5.59 to 7.25	3.78 to 6.17
2	EC (µs/cm) 25°C	48.85 to 191.2	32.35 to 155.9
3	Turbidity (NTU)	BDL to 0.2	BDL to 0.2
4	TDS	25.91 to100.9	16.72 to 86.48
5	CO_3^{-2}	BDL	BDL
6	HCO_3^{-1}	42.73 to 128.2	24.42 to 61.05
7	TA (as $CaCO_3$)	42.73 to 128.2	24.42 to 61.05
8	Cl^-	63.81 to 180.8	56.72 to 113.44
9	SO_4^{-2}	1.62 to 5.01	2.1 to 6.73
10	NO_3^{-1}	0.08 to 0.98	0.1 to 1.09
11	F^-	0.04 to 0.43	BDL to 0.09
12	Ca^{+2}	10.01 to 72.06	8.01 to 10.01
13	Mg^{+2}	1.21 to 10.91	2.42 to 12.13
14	TH (as $CaCO_3$)	40 to 200	35 to 75
15	Na	6.83 to 48.92	20.67 to 38.25
16	K	2.45 to 27.25	7.26 to 20.75
17	Fe	0.002 to 15.59	0.02 to 1.26
18	As (µg/L)	BDL	BDL

Table 3.2: Chemical quality of water samples from dug well and springs in South Garo Hills district during post-monsoon

Sl. No.	Chemical constituents (Concentrations in mg/l except pH, EC, U and As)	Dug Well	Spring
		Range	
1	Ph	6.38 to 8.14	4.09 to 6.8
2	EC (μs/cm) 25°C	35.22 to 206.6	25.25 to 67.03
3	Turbidity (NTU)	BDL to 0.30	BDL to 0.3
4	TDS	19 to 112.5	13.62 to 33.58
5	CO_3^{-2}	BDL	BDL
6	HCO_3^{-1}	12.21 to 122.1	12.21 to 91.57
7	TA (as $CaCO_3$)	12.21 to 122.1	12.21 to 91.57
8	Cl^-	3.55 to 28.36	7.09 to 14.18
9	SO_4^{-2}	1.99 to 92.81	11.15 to 40.96
10	NO_3^{-1}	0.08 to 6.42	0.06 to 3.72
11	F^-	0.04 to 0.27	BDL to 0.12
12	Ca^{+2}	6 to 36.03	4 to 6
13	Mg^{+2}	2.42 to 10.91	1.21 to 8.49
14	TH (as $CaCO_3$)	25 to 110	20 to 50
15	Na	1.8 to 29.83	2.63 to 27.91
16	K	1.13 to 11.96	1.14 to 7.01
17	Fe	0.82 to 3.43	0.63 to 2.95
18	U (µg/L)	BDL to 0.28	BDL to 0.32
19	As (µg/L)	2.16 to 3.32	2.39 to 4.91

Table 3.3: Concentration of Fe and pH value in ground water during pre-monsoon

Type of Structure	No. of Sample analysed	Conc. of Iron (mg/l)			pH value	
		<0.3	0.3 to 1	>1	<6.5	6.5 to 8.5
Dug well	10	4	2	4	7	3
Spring	5	3	1	1	5	0

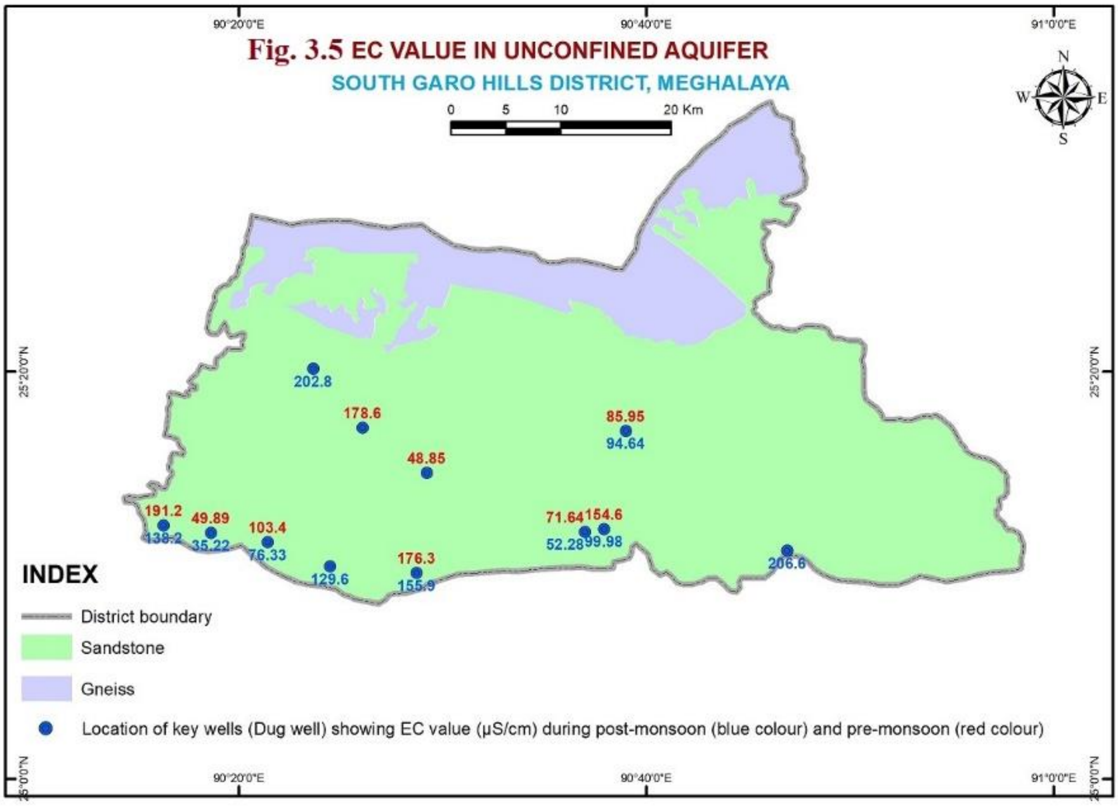
Table 3.4: Concentration of Fe and pH value in ground water during post-monsoon

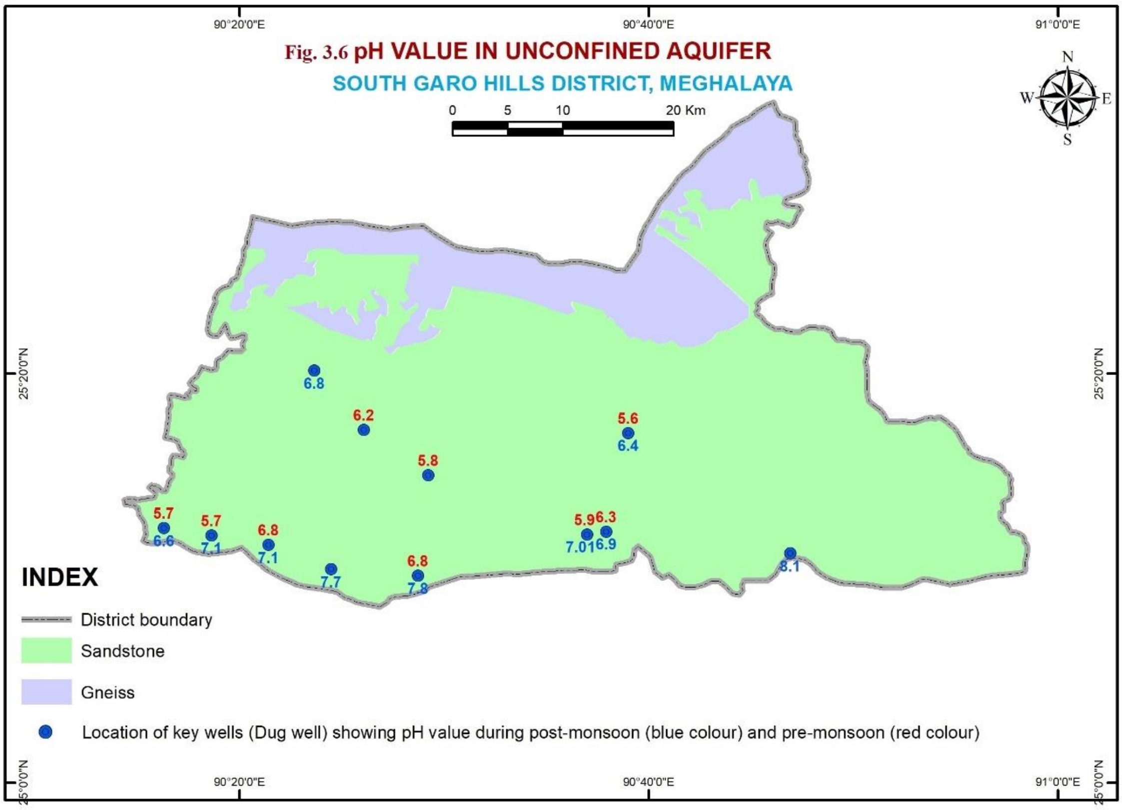
Type of Structure	No. of Sample analysed	Conc. of Iron (mg/l)			pH value	
		<0.3	0.3 to 1	>1	<6.5	6.5 to 8.5
Dug well	10	0	4	6	1	9
Spring	7	0	4	3	5	2

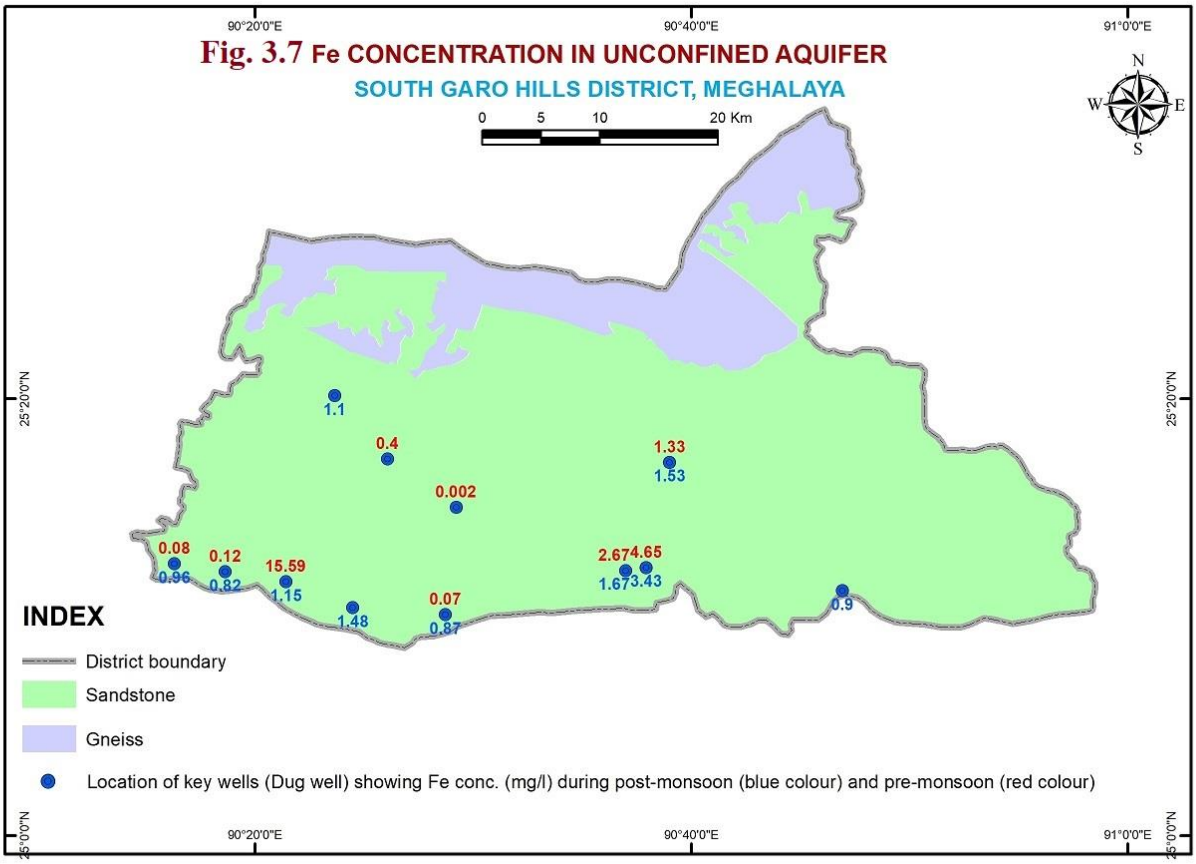
3.6.1 Ground water quality of unconfined aquifer:

A total of 10 ground water samples from dug well were collected during post-monsoon and 10 samples from dug well were collected pre-monsoon studies and the range of concentrations of different chemical constituents present in the ground water samples are given in table 3.2 and 3.3.

It is deciphered from table 3.2 and 3.3 that except pH and Fe, the other chemical parameters are within permissible limit. From the table 3.3 and 3.4, the concentration of Iron beyond permissible limit is found in 4 dug well during pre-monsoon and 6 dug wells during post-monsoon. The pH value less than 6.5 is found in 7 dug well during pre-monsoon and 1 dug wells during post-monsoon which indicates the water to be slightly acidic in nature. The EC values, pH and Fe conc. during pre-monsoon and post-monsoon are shown in fig 3.5, fig. 3.6 and fig. 3.7.

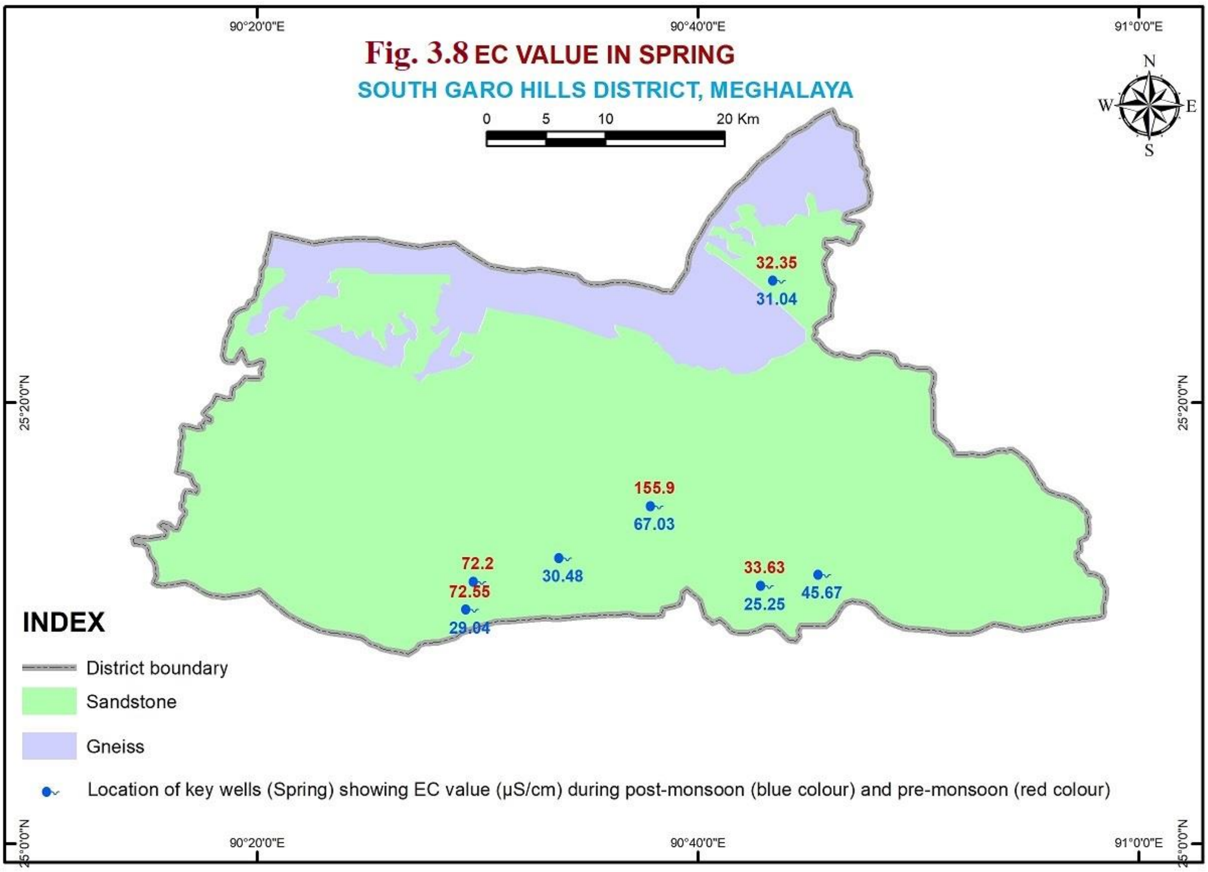


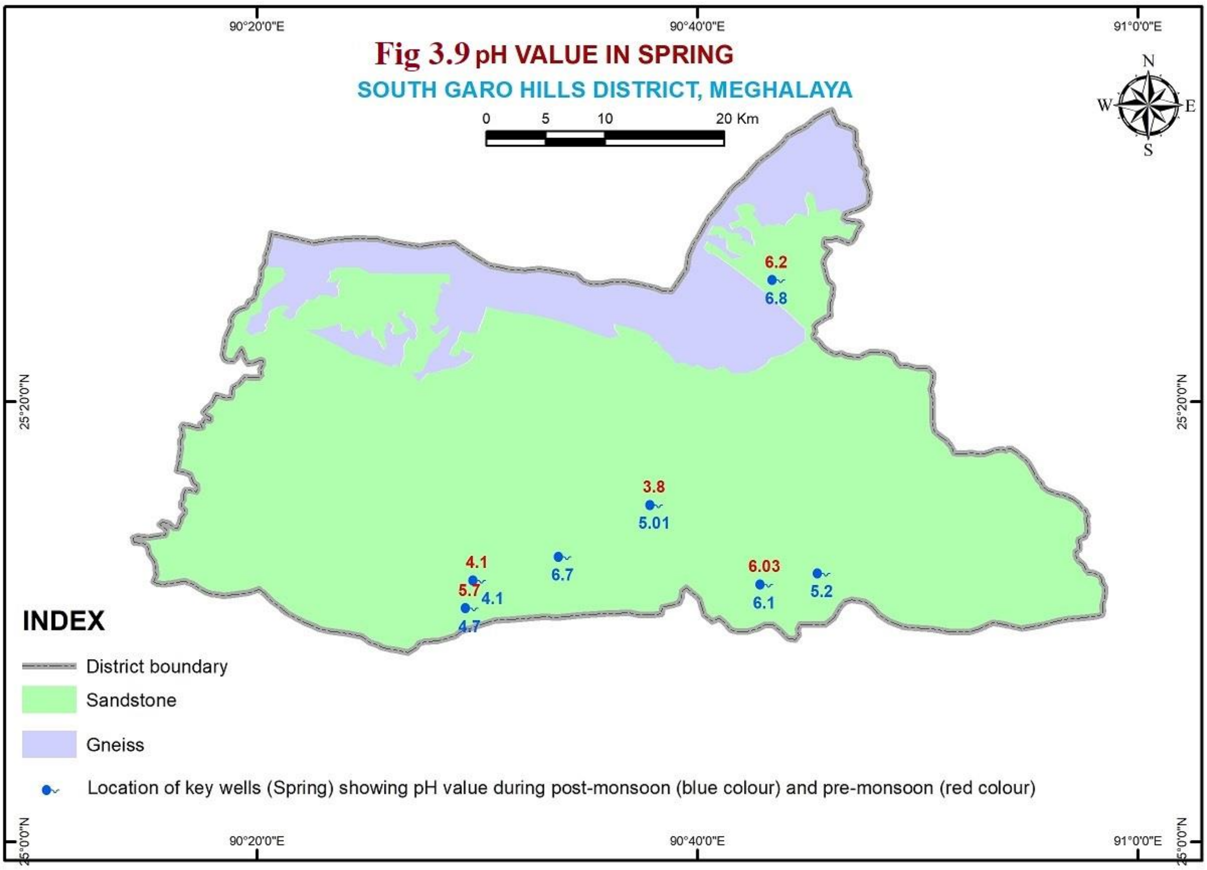


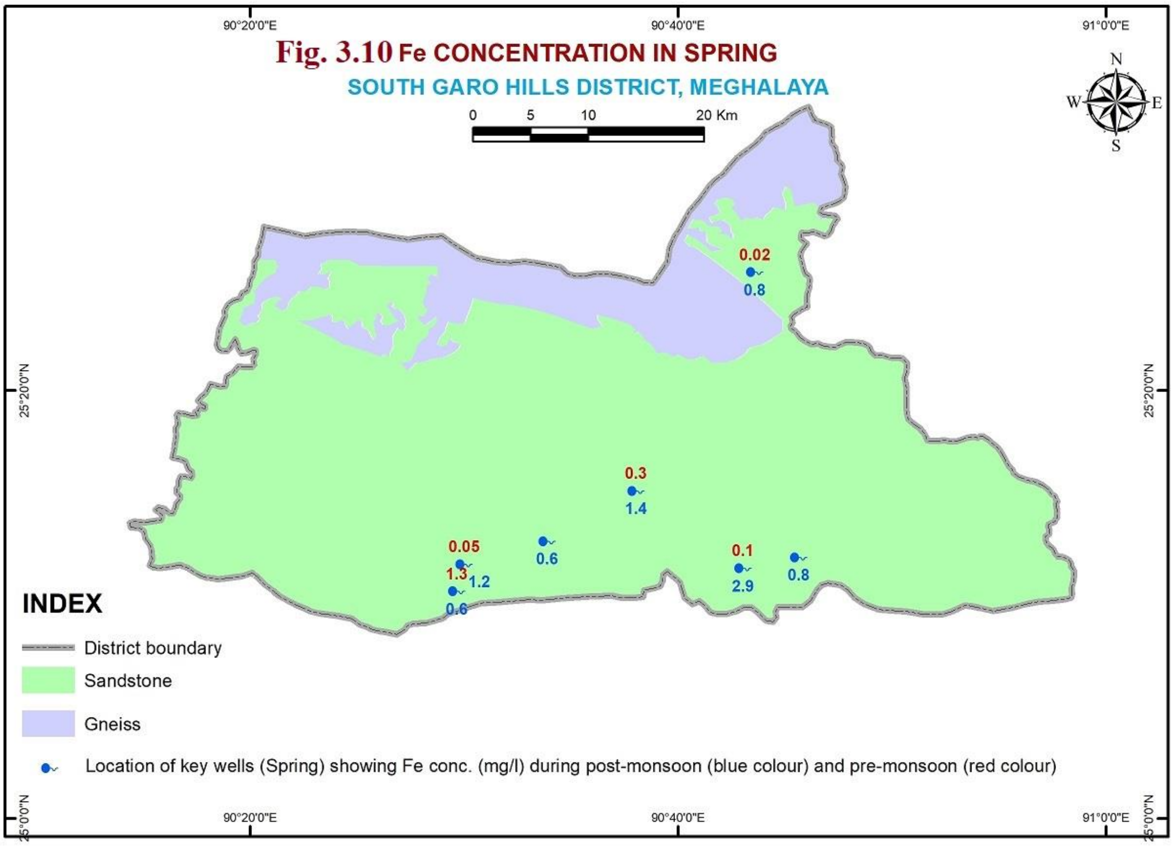


3.6.2 Water quality of springs: A total of 7 ground water samples from spring were collected during post-monsoon and 5 samples from spring were collected pre-monsoon studies and the range of concentrations of different chemical constituents present in the ground water samples are given in table 3.2 and 3.3.

It is deciphered from table 3.2 and 3.3 that except pH and Fe, the other chemical parameters are within permissible limit. From the table 3.3 and 3.4, the concentration of Iron beyond permissible limit is found in 1 spring during pre-monsoon and 3 springs during post-monsoon. The pH value less than 6.5 is found in 5 springs during pre-monsoon and 5 springs during post-monsoon which indicates the water to be slightly acidic in nature. The EC values, pH and Fe conc. during pre-monsoon and post-monsoon are shown in fig 3.8, fig. 3.9 and fig. 3.10.


90°20'0"E
90°40'0"E
91°0'0"E
Fig. 3.8 EC VALUE IN SPRING
SOUTH GARO HILLS DISTRICT, MEGHALAYA
0 5 10 20 Km
N
W
E
S
25°20'0"N
25°0'0"N
32.35
31.04
155.9
67.03
72.2
72.55
29.04
30.48
33.63
25.25
45.67
INDEX
District boundary
Sandstone
Gneiss
Location of key wells (Spring) showing EC value (µS/cm) during post-monsoon (blue colour) and pre-monsoon (red colour)


90°20'0"E
90°40'0"E
91°0'0"E
Fig 3.9 pH VALUE IN SPRING
SOUTH GARO HILLS DISTRICT, MEGHALAYA
0 5 10 20 Km
N
W
E
S
25°20'0"N
25°0'0"N
6.2
6.8
3.8
5.01
4.1
5.7
4.1
4.7
6.7
6.03
6.1
5.2
INDEX
District boundary
Sandstone
Gneiss
Location of key wells (Spring) showing pH value during post-monsoon (blue colour) and pre-monsoon (red colour)



3.6.3 Assessment of ground water quality with various graphical diagram:

Each ground water system in an area is known to have a unique chemistry, which depends on several factors such as soil-water interaction, dissolution of mineral species, duration of solid-water interaction and anthropogenic sources. Graphical approach was used to assess the quality of groundwater to recognise the various hydro-chemical types in a groundwater system. It further helps in evaluation of the suitability of groundwater for irrigation purpose. Ground water quality has been assessed with the help of various diagram such as Piper diagram and Wilcox diagram prepared with the help of Aquachem 9 software.

3.6.3.1 Piper diagram

A Piper diagram is a graphical representation of the chemistry of a water sample. The cations and anions are shown by separate ternary plots. The apexes of the cation plot are calcium, magnesium and sodium plus potassium cations. The apexes of the anion plot are sulphate, chloride and carbonate plus hydrogen carbonate anions. The two ternary plots are then projected onto a diamond. The diamond is a matrix transformation of a graph of the anions (sulfate + chloride / total anions) and cations (sodium + potassium /total cations).

In order to understand water composition and chemical relationship between dissolved ions, Pipers trilinear diagram for graphical analysis (Fig. 3.11 & 3.12) is used. This diagram reveals similarities and differences among water samples. During pre-monsoon most of the water samples analysed fall in sodium-chloride type and mixed type. Durin post monsoon most of the water samples analysed fall in mixed type.

The cations plotted in the diagram during pre-monsoon fall in Na-K type in majority of the samples. In case of anions, most of the samples are under chloride type. These trends are reflected in the central diamond of the diagram where most of the samples fall under the category of sodium-chloride type and mixed type. During post monsoon, both the cations and anions plotted in the diagram fall in no dominant type in majority of the samples. These trends are reflected in the central diamond of the diagram where most of the samples fall under the category of mixed type. The results suggest that mixed type are the dominant hydro chemical facies for the studied groundwater samples.

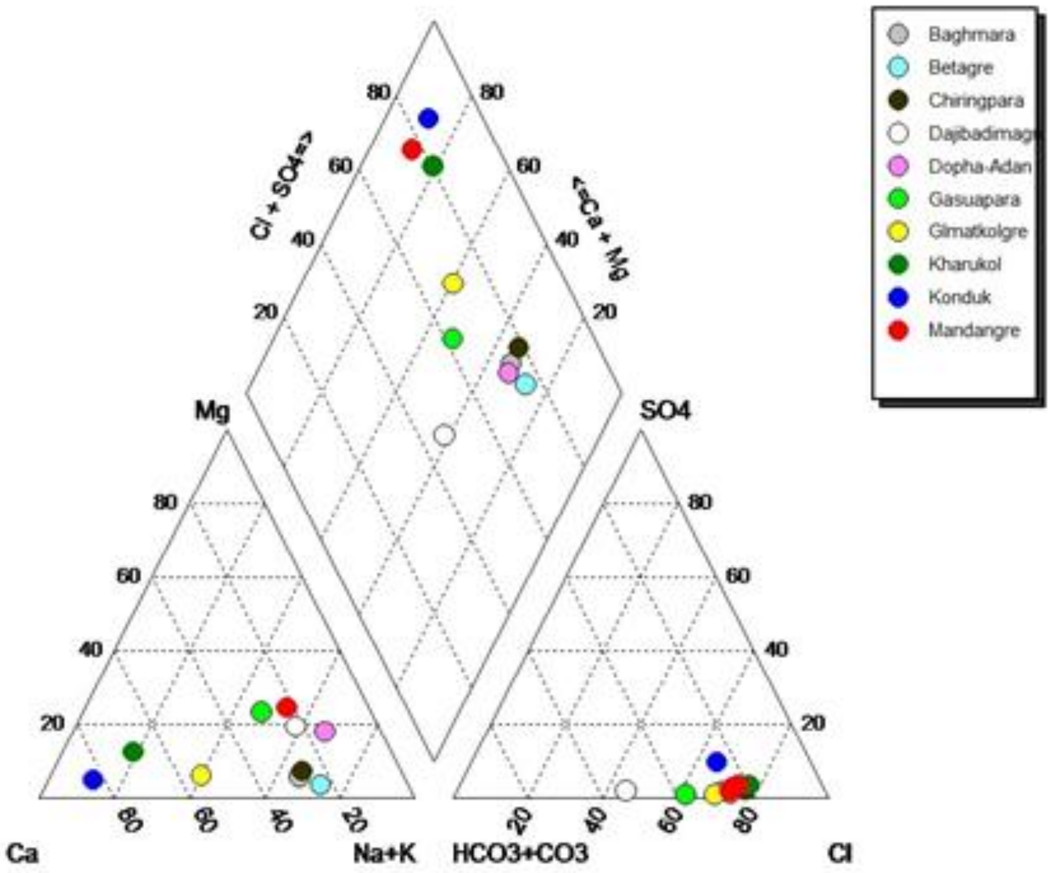


Fig. 3.11 Piper diagram for representing the analysis of ground water during Pre monsoon.

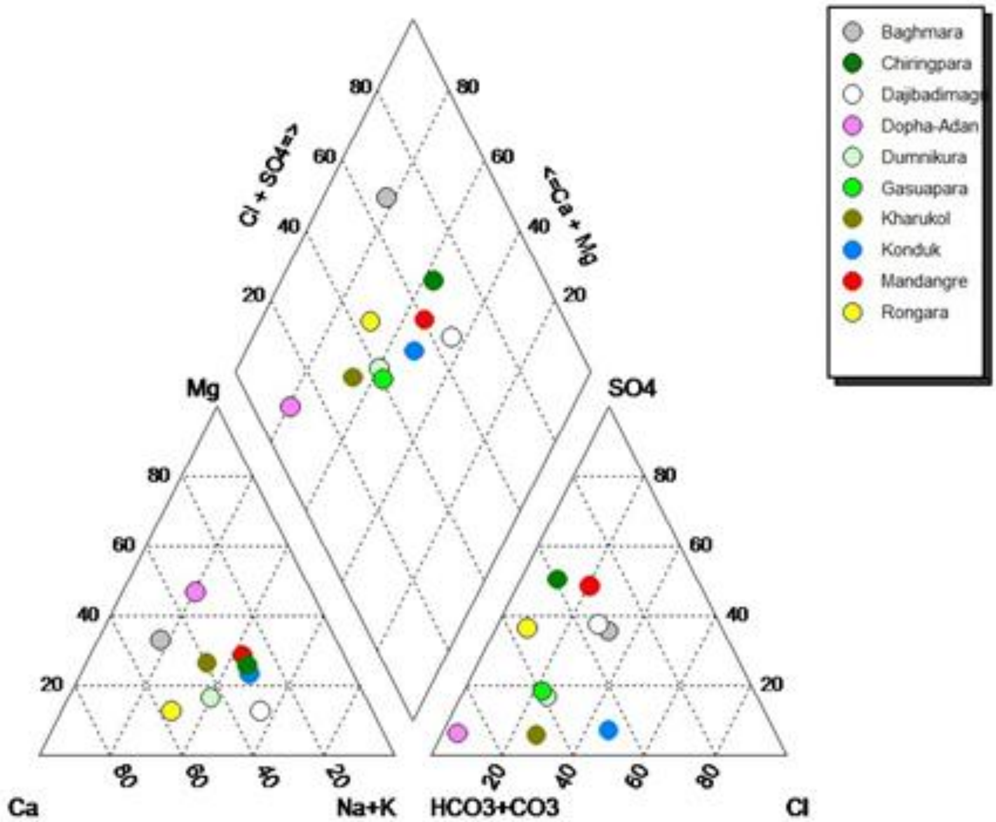


Fig.3.12 Piper diagram for representing the analysis of ground water during Post monsoon.

3.6.3.2 Wilcox diagram

Percentage of Sodium (Na+) is widely used for assessing the suitability of water for irrigation purposes. The sodium percentage is computed with respect to relative proportion of cations present in water.

According to Wilcox diagram (US Salinity Laboratory's diagram) in Fig.3.13 for pre monsoon samples, 78% of the samples analyzed falls in C1–S1which indicates low sodium and salinity hazard and 22 % of the samples fall in C2–S1 which indicates low sodium hazard and medium salinity hazard. During post monsoon in figure 3.14, 90% of the samples analyzed falls in C1–S1 which indicates low sodium and salinity hazard and 10 % of the samples fall in C2–S1 which indicates low sodium hazard and medium salinity hazard. The results indicate that water can be used directly for irrigation purpose. However, water samples falling in medium salinity and low sodium class(C2-S1) should be treated before using for irrigation purposes.

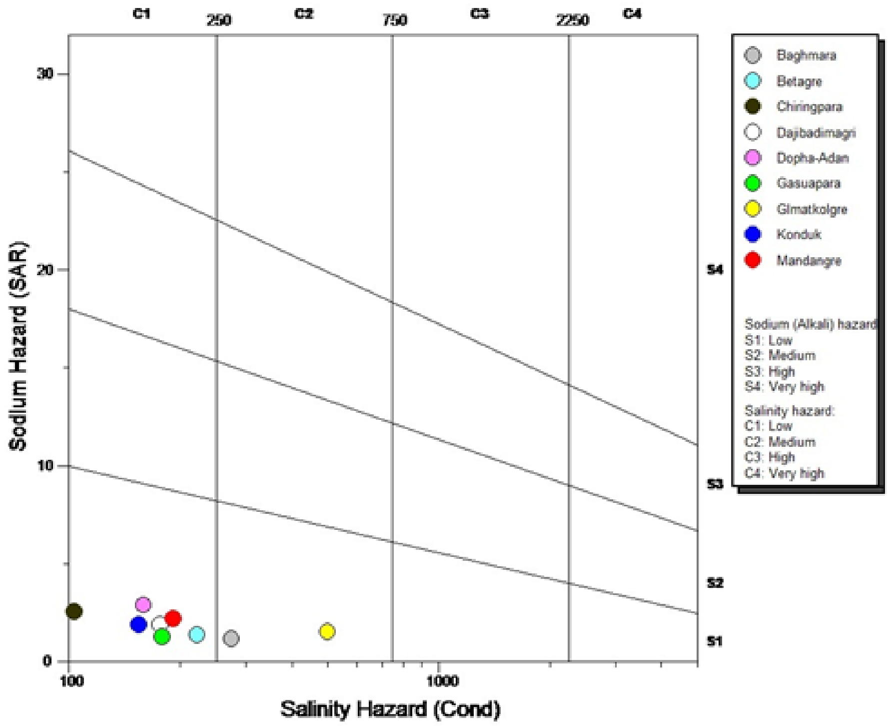


Fig. 3.13 Wilcox diagram to analyse the quality of water in relationship to salinity and sodium hazard during pre-monsoon.

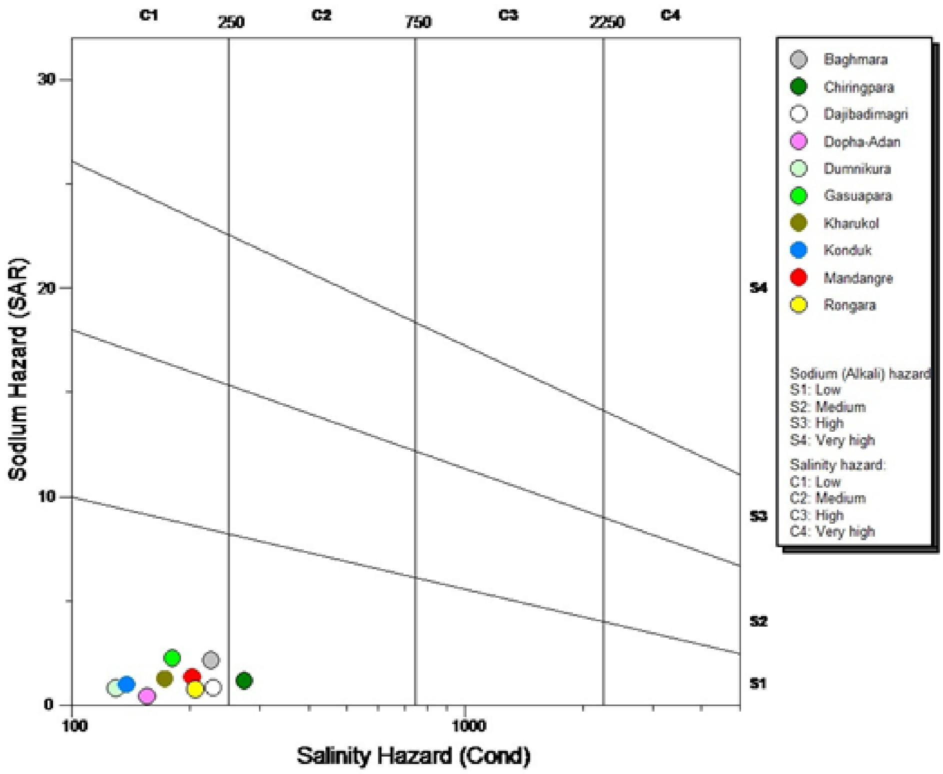


Fig. 3.14 Wilcox diagram to analyse the quality of water in relationship to salinity and sodium hazard during post-monsoon.

3.6.3.4 Water quality evaluation for irrigation purpose:

In order to study the water quality for irrigation purpose, 9 water samples during pre-monsoon and 10 samples during post monsoon from dug wells were collected and the suitability of water for irrigation purpose was analysed using various chemical index such as sodium absorption ratio (SAR), sodium percentage(SP), residual sodium carbonate (RSC), Kelly's ratio Permeability index and magnesium ratio were analyzed by adopting the standard procedures of water analysis. The irrigation suitability data of groundwater for pre monsoon and post monsoon is given in table 3.5 & 3.6 respectively.

Suitability of the groundwater for irrigation purpose was discussed by the following basic criteria.

Permeability Index

In the study area, 78% of the pre monsoon water samples and 90% of the post monsoon samples has permeability Index greater than 75 which indicated that the water is suitable for irrigation.

Sodium Absorption Ratio(SAR)

Irrigation water is classified on the basis of SAR. Hence, the assessment of sodium hazard is necessary while considering the suitability for irrigation. The SAR values of the groundwater samples from pre monsoon and post monsoon varies from 0-3 and 0.16-1.33 respectively. The SAR value of the water samples of the study area is less than 10 and are classified as excellent for irrigation.

Kelly's Index and Sodium Percentage

To determine the hazardous effect of sodium on water quality for irrigation, **Percent Sodium(%Na)** and **Kelly's Index** are calculated. The percent sodium (%Na) of pre monsoon and post monsoon samples varies from 18.75 – 73.24 % and 17.89 – 55.80 % respectively. Around 11% of the pre monsoon samples are categorized as excellent, while 44% of the samples as poor and 43 % of the samples as doubtful. During post monsoon 10% of the samples are categorized as excellent, while 30% of the samples as good and 60 % of the samples as poor.

Around 44% of the pre monsoon samples and 100% of the post monsoon samples has Kelly's Index less than 1 and are classified as suitable for irrigation.

Magnesium Ratio

In the study area, nearly 78% of the pre monsoon water samples and 90% of the post monsoon samples has Mg ratio less than 50 % which is suitable for irrigation, as magnesium ratio of more than 50% indicate that the soil is more alkaline which adversely effects the crop yield.

Residual Sodium Carbonate(RSC)

All the samples of pre monsoon and post monsoon have RSC value of less than 1.25 and are suitable for irrigation. The water with high RSC has high pH and land irrigated by such water becomes infertile owing to deposition of sodium carbonate as indicated by the black colour of the soil.

Table 3.5: Irrigation suitability data of ground water during Pre-monsoon

Location	Kelly ratio	Sodium %	Permeability Index	Sodium Absorption Ratio(SAR)	Magnesium Hazard	Residual Sodium Carbonate (RSC)
Chiringpara	1.4	66.48	93.05	2.17	16.67	-0.20
Gasuapara	2.37	73.24	103.49	3.01	12.5	0.00
Konduk	1.51	66.42	89.99	2.52	21.43	-0.30
Mandangre	1.08	58.56	98.36	1.87	46.67	0.60
Betagre	1.57	67.06	96.47	2.33	54.45	-0.10
Glmatkolgre	0.65	47.52	79.23	1.23	44.44	-0.40
Dajibadimagri	0.53	40.21	58.94	1.51	10	-1.80
Dopha-Adan	0	18.75	64.36	0	15.38	-0.60
Baghmara	1.01	53.67	79.47	1.85	52.94	-0.70

Table 3.6: Irrigation suitability data of ground water during Post- monsoon

Location	Kelly ratio	Sodium %	Permeability Index	Sodium Absorption Ratio(SAR)	Magnesium Hazard	Residual Sodium Carbonate (RSC)
Dopha-Adan	0.16	17.89	90.93	0.16	40	-0.30
Baghmara	0.69	42.79	86.68	0.97	50	-0.40
Kharukol	0.97	55.81	105.42	1.15	28.57	-0.10
Mandangre	0.22	20.63	86.28	0.41	58.82	0.30
Dumnikura	0.53	40.21	99.75	0.78	27.27	0.10
Konduk	0.65	42.81	107.18	0.82	50	0.00
Gasuapara	0.38	34.29	130.05	0.38	40	0.00
Chiringpara	0.72	47.62	99.66	0.97	44.44	-0.10
Dajibadimagri	0.68	45.82	78.91	1.33	47.36	-0.40
Rongara	0.34	30.85	71.02	0.72	18.18	-0.40

Based on the analysis using various chemical index such as sodium absorption ratio (SAR), sodium percentage(SP), residual sodium carbonate (RSC), Kelly's ratio Permeability index and magnesium ratio, it is found that the ground water in the district is suitable for irrigation purpose.

4. GROUNDWATER RESOURCES

Dynamic Groundwater Resources of South Garo Hills district has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'2015). The present methodology used for resources assessment is known as Ground Water Resource Estimation Methodology – 2015 (GEC'2015).GEC 2015 recommends estimation of Replenishable and in-storage ground water resources for both unconfined and confined aquifers. In GEC'2015, two approaches are recommended – water level fluctuation method and norms of rainfall infiltration method. The resources computed for the groundwater year 2019-20. The following sub-units are recommended for the computation of various figures in the methodology and these are considered in details below:

Hilly Area: Area with more than 20% slope has been excluded for the recharge computation. As per NESAC, total recharge worthy area in the district is 868 sq.km.

Command and Non-Command Area: The methodology envisages computation of various figures separately for command & non-command area. In the district, there is no major or medium canal irrigation scheme and thus the entire rechargeable area has been considered as a non-command area.

Recharge from Rainfall has been computed separately for monsoon and non-monsoon periods for the entire district. The recharge from rainfall during monsoon season has not been computed using water level fluctuation method (WLFM) as Ground Water Monitoring Wells (GWMW) in the district is very few. The rainfall recharge estimated for non-command area of the entire district and the details are shown in annexure 8.

Recharge from All Sources: Total recharge to groundwater has several components, rainfall being the major one. The other components include seepage from canals, return flow from surface water irrigation, return flow from groundwater irrigation, seepage from tanks/ ponds etc. Recharge from various sources has been calculated for monsoon as well as non-monsoon periods and details have been shown in table 4.1.

Table 4.1: Groundwater recharge from various sources (ham).

Assessment Unit/ District	Command/ Non-Command/ Total	Recharge from rainfall during monsoon season	Recharge from other sources during monsoon season	Recharge from rainfall during non-monsoon season	Recharge from other sources during non-monsoon season	Total Annual Ground Water Recharge	Provision for Natural Discharges	Annual Extractable Ground Water
South Garo Hills	Non-command	8018.55	61.7	1900.06	39.31	10019.62	1001.97	9017.65
	Total	8018.55	61.7	1900.06	39.31	10019.62	1001.97	9017.65

4.1 Groundwater extraction for Various Purposes: Groundwater extraction for domestic use has been estimated based on number of households using groundwater (Census 2011 data).Groundwater draft for irrigation is nil. It was found that groundwater draft for all uses in the district is 268.39 ham.

4.2 Stage of Groundwater extraction & Categorization of the district: The district falls under "**SAFE"** category. The stage of GW extraction is 2.98%. Summary of groundwater resources, stages of development and categorization are given in annexure 8.

4.3 Summarized results of dynamic ground water resources of South Garo Hills district as on March 2020: The summarized results of dynamic ground water resources estimation of South Garo Hills district as on March 2020 is shown in the table below,

Table 4.2:Summarized results of dynamic ground water resources of South Garo Hills district as on March 2020

Sl. No.	**ITEM**	**Year, 2019-20**
	Methodology	**GEC 2015 (in ham)**
1	Total Annual Ground Water Recharge	10019.62
2	Total Natural Discharges	1001.97
3	Annual Extractable Ground Water Resource	9017.65
4	Total annual Ground water extraction	268.39
5	Annual GW Allocation for for Domestic Use as on 2025	327.47
6	Net Ground Water Availability for future use	8690.18
7	Stage of GW Development (%)	2.98
8	Categorization of assessment unit i.e. district	Safe

5. GROUND WATER RELATED ISSUES

There is two major ground water related issues found in the study area.

5.1 Low stage of ground water development: As per ground water resource estimation 2020, the stage of ground water extraction is just 2.98 % and there is no utilization of ground water for irrigation in this area. All the irrigation schemes in the district are dependent upon the surface water resources. Therefore, there is enough scope for future development of ground water in the study area to bring more area under irrigation practice. At present the irrigation practice by utilizing ground water (constructing bore well) is not accepted by villagers due to small land holding, high cost for construction and running of a well compared to production outcome. Another major obstacle in accelerating ground water irrigation is the absence of power lines in most of the cultivated/cultivable area.

5.2 Ground Water Quality: As per water quality analysis data, it was found that there is a moderately high concentration of iron in almost all the dug well and spring. pH value is also low in some dug well and springs and needs to be treated before consumption.

6. MANAGEMENT STRATEGIES

The objective of management is to utilize the available ground water resources to fulfill human needs and also to boost economy of an area without hampering the interest of future generation. That objective can be achieved by finding out demand of various sectors and adjusting the demand with available resource.

As the area is characterized by undulatory terrain, the scope for development of ground water lies in low lying depression, and valley fills which hold good prospects for ground water development. Ground water development is being done through dug well and tube well/ bore well in the intermontane valley. The development of spring is seen mainly along the foothills. Therefore, there is ample scope for future development of ground water. The peneplain surfaces, buried pediments and valley fills are the most favorable localities for development of ground water. The fractures and lineament too hold prospect for the development of ground water. Moreover, the narrow and linear valleys offer ample scope of development of ground water. Structures like dug wells, shallow as well as deep tube wells are the feasible ground prospects for ground water. The weathered mantle holds good prospect for dug well within the depth range of 4 to 30 m depending on topographical setting. Large diameter dug wells can sustain moderately higher yield. Dug wells need to be properly lined with cement rings to avoid collapse of weathered zone. As very good quantity of dynamic ground water resources is available, dug wells are the preferred structures as of now in low-lying areas and valleys. The shallow water level condition gives scope to maintain sufficient water column in the dug wells. In future, if there are water crises, bore well within the depth of 100-150 m can be constructed.

As per dynamic ground water resource estimation of South Garo Hills District for 2020, annual extractable ground water is 9017.65 ham and stage of ground water extraction is only 2.98%. The district is having balance net ground water availability for future development in the tune of 8690 ham. If an irrigation plan is made to develop 60% of the balance dynamic ground water resources available, then 5214 ham of groundwater resources is available in the district for the future irrigation uses. Hence, there is ample scope for ground water development for irrigation purpose which will help the district in achieving self-reliance on food grain. In this district, net sown area is 25472 ha, area sown more than once is 5254 ha and cropping intensity is about 120%. The net sown area included field crops as well as horticulture and plantation crops on slopes and hills. Cropping intensity is calculated generally from field crops, which are of short duration whereas horticulture (like citrus, banana, pineapple) and plantation crops like spices are long duration crops. Moreover, crops grown on the hills like pineapple, turmeric and ginger are having negligible or nil irrigation requirements.

To use the groundwater for irrigation purpose a cropping plan has been designed for the district by using CROPWAT model developed by FAO. Cropping pattern data for the district is presented in table 6.1.

During kharif season, paddy (winter & autumn paddy) is cultivated in 4585 ha and during rabi season spring paddy is cultivated in 291 ha. The total area which remains fallow during rabi season is about 4294 ha. The intention of this plan is to bring this fallow land under assured irrigation during rabi season which will help to increase gross cropped area to 8588 ha and thereby increase cropping intensity up to 200%. In rice fallow, with the support of irrigation potato, mustard, pulses, millet and rabi vegetables can be grown. Present cropping pattern, proposed cropping pattern, intended increase in cropping intensity were shown in table 6.2a and 6.2b.

Crop-wise and month-wise irrigation water requirement (Precipitation deficit) has been taken from CROPWAT after giving necessary meteorological, soil, crop plan inputs and the same has been shown in table 6.3. Crop-wise and month-wise Irrigation water requirement in ham has been further calculated in table 6.4.

Table 6.1 **CROPPING PATTERN DATA**

Cropping pattern name: South Garo Hills

No.	Crop file	Crop name	Planting date	Harvest date	Area %
1	...Data\CROPWAT\data	Rice	04/06	01/10	15
2	...Data\CROPWAT\data	Rice	11/06	08/10	15
3	...Data\CROPWAT\data	Rice	18/06	15/10	10
4	...Data\CROPWAT\data	Rice	25/06	22/10	10
5	rape___mustard.CRO	Mustard	15/10	26/02	10
6	...a\CROPWAT\data\cr	Pulses	25/10	11/02	10
7	...a\CROPWAT\data\cr	MILLET	05/01	19/04	10
8	...\CROPWAT\data\cro	Potato	05/02	14/06	10
9	...CROPWAT\data\crop	Small Vegetables	10/02	15/05	10

Table 6.2a. Cropping pattern, proposed cropping pattern, intended cropping intensity, South Garo Hills District.

Cropping pattern (s)				
Rice based cropping pattern				
1. Rice-Mustard	Present Cultivated area	Area to be cultivated	Area to be cultivated (**ha**)	Irrigation requirement (**ham**)
2. Rice-Pulses	(**ha**)	(**%**)		
3. Rice-Millets				
4. Rice-Potato				
5. Rice-Vegetables				
	1	2 (= % of 1)	3	4
Rice (main crop)	4294		4294	548.01
Mustard		20	858.8	110.63
Pulses		20	858.8	105.02
Millet		20	858.8	69.49
Potato		20	858.8	61.17
Small vegetables		20	858.8	62.43
Net cultivated area	4294		**4294**	
Gross cultivated area (1+pulses/+Millet/+potato/+mustard/+Veg)			**8488**	
Total irrigation requirement				956.7
Cropping intensity	**100% (Present)**		**200% (Intended)**	
Total (South Garo Hills district)				**956.7**

Table 6.2b. Proposed cropping pattern with water deficit months and IWR, South Garo Hills district.

Rice based cropping pattern			
Crop	**Growing period (Months)**	**Periods/months of water deficit**	**Irrigation requirement (ham)**
Rice	4	2-3	548.01
Mustard	4	4	110.63
Pulses	4	4	105.02
Millet	3	3	69.49
Potato	4	3	61.17
Small vegetables	3	3	62.43

Table 6.3: Crop-wise and month-wise precipitation deficit (IWR) from CROPWAT 8, South Garo Hills District.

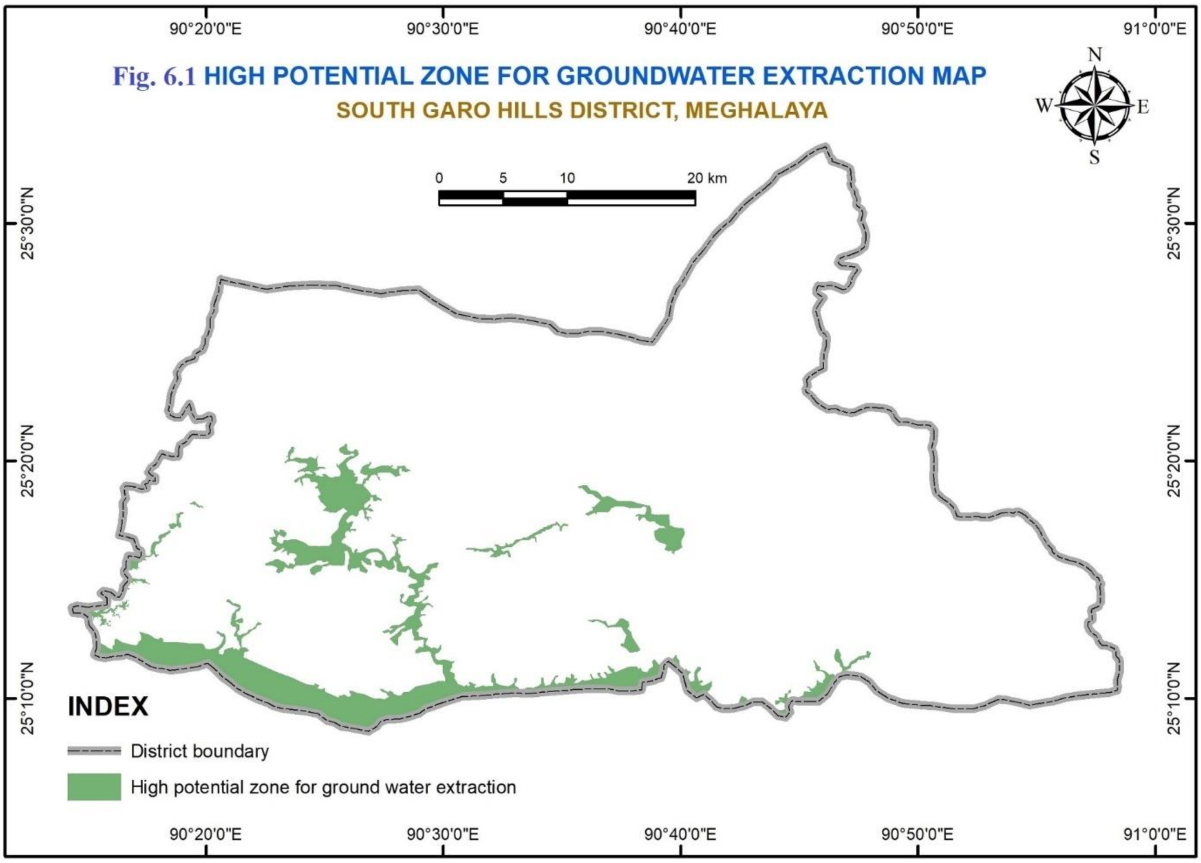
Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit (in mm)												
1. Rice	0	0	0	0	147.1	63.3	0	0	0	3	0	0
2. Rice	0	0	0	0	49.5	98	0	0	0	0	0	0
3. Rice	0	0	0	0	49.6	126.3	0	0	0	0	0	0
4. Rice	0	0	0	0	0	147.1	0	0	0	5.5	0	0
5. Mustard	50.1	25.8	0	0	0	0	0	0	0	0	50.2	49.5
6. Pulses	61.8	10.9	0	0	0	0	0	0	0	0	34.4	59.6
7. MILLET	18	44.6	47.7	0	0	0	0	0	0	0	0	0
8. Potato	0	17.2	39.3	40.6	0	0	0	0	0	0	0	0
9. Small Vegetables	0	24	46.3	28.8	0	0	0	0	0	0	0	0

Table 6.4: Irrigation Water Requirement (in ham),South Garo Hills District

Crops	% of total area of 4294 ha	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation deficit (ham)														
1. Rice	15	0	0	0	0	139.0	59.8	0	0	0	2.835	0	0	201.7
2. Rice	15	0	0	0	0	46.8	92.6	0	0	0	0	0	0	139.4
3. Rice	10	0.0	0.0	0.0	0.0	31.2	79.6	0.0	0.0	0.0	0.0	0.0	0.0	110.8
4. Rice	10	0.0	0.0	0.0	0.0	0.0	92.7	0.0	0.0	0.0	3.5	0.0	0.0	96.1
5. Mustard	10	31.6	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.6	31.2	110.63
6. Pulses	10	38.9	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.7	37.5	105.0
7.Millet	10	11.3	28.1	30.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.5
8.Potato	10	0.0	10.8	24.8	25.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.2
9.Small Vegetables	10	0.0	15.1	29.2	18.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.4
Total	100	81.8	77.2	84.0	43.7	217.0	324.7	0.0	0.0	0.0	6.3	53.3	68.7	956.7

Underground water exploration programme, CGWB has constructed 3 bore wells in this area and has established that the aquifer in most part of the district is having discharge ranging from 7.2 m^3/hr to 52 m^3/hr The average discharge of the well is about 28 m^3/hr from Sandstone formation.

The ground water potentiality of the area is good, especially in the low-lying valley areas which are feasible for sustainable ground water development. Therefore, those areas can be brought under irrigation by developing ground water through bore wells or large diameter dug wells of size 2 to 3 m (dia) X 10 to 15 m (depth) can be constructed. This type of dug wells can be used to irrigate 0.2 ha of land especially under Rabi vegetables. High ground water potential zone has been demarcated and is shown in the Fig. 6.1



A bore well in this area is expected to yield 20 m^3/hr. If such a bore well runs for 10 hrs/day for 120 days, then it will create a draft of 2.4 ham. Bore wells can be designed within a depth of 100-150 m, expected to encounter 2 – 3 fractures. Bore wells can be constructed by using 8// or 7// dia. and a casing pipe down to about 30 m.

In considered net sown area of 4294 ha, 1073 nos. of shallow bore wells can be constructed (considering 200 m distance between any two shallow bore well). 1073 nos. of bore wells can extract 2575 ham of water annually.

Annual irrigation water requirement is 956.7 ham while irrigation water requirement during dry season spanning from October to March is 371 ham. Again proportionate dynamic groundwater resources available for future irrigation use in the considered area are 5214 ham. Hence, this area can be brought under assured irrigation from groundwater sources. The demand of 371 ham can be harnessed by constructing 100 nos. of large diameter dug well (which can irrigate 20 ha) and 134 nos. of bore wells (which can irrigate 4274 ha). At possible places water harvesting methods should be employed.

When managing a precious and scarce resource such as groundwater, it is essential that the resource is not subjected to pollution. The chemical quality of ground water indicates that groundwater in the area have high iron concentration in some wells which are beyond the permissible limit, which warrant proper treatment before use. Removal of the iron is best effected by aeration process followed by sedimentation and filtration. Potassium permanganate or chlorine/chloride may be employed to oxidize the iron, which is then filtered from the waters. The process is applicable very much when bacteria is present in the water. Iron can also be removed by addition of a mixture of sodium carbonate and sodium phosphate to precipitate iron as insoluble, followed by settling and filtration. The pH value is also low in some dug well and spring which should be treated before consumption. This acidic water can be treated by acid neutralizing filters or chemical feed pump.

Rain Water Harvesting

The area receives an average annual rainfall of about 2500 mm. Hence there is ample scope for roof top rainwater harvesting. In roof top rainwater harvesting, rain water can be collected through gutters fitted on the edge of the roof and stored in reservoirs. Water collected from roofs should be stored in a PVC or Concrete tank. Water thus collected can be used for domestic purposes and in case of emergency can be used for drinking purposes, after proper treatment.

Spring Development and Rejuvenation Plan

Many villagers in the district are dependent on spring for drinking and domestic purpose. However, there is lack of proper development in those springs and some of the springs are drying up or giving very less discharge. Therefore, it is recommended to develop and construct spring tab chamber in all the existing springs which are presently being used by the villagers for drinking and domestic purposes. It is also recommended to take up Spring rejuvenation program in those springs which are slowly drying up or giving less discharge by construction of contour trenches/ staggered trenches in the upper reach of the source.

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Annexure I: Hydrogeological details of bore wells constructed by CGWB in Aquifer mapping area, South Garo Hills District

Sl No	Location	Long	Lat	Depth drilled (m bgl)	Depth of construction (m bgl)	Aquifer tapped	Static water level (m bgl)	Discharge m^3/hr	Draw down (M)	Transmissibility m^2/hr	Hydrolic conductivity m/day	Specific capacity	Storage co efficient	Remarks
1	Dimapara	92°15'00"	25°13'58"	142	142	Tertiary Sandstone	2.05	52	-	-				
2	Baghmara I	92°37'15"	25°13'01"	22.37	22.37	Tertiary Sandstone	3.63	7.2	8.74	7				
3	Baghmara II	92°37'28"	25°13'03"	104	104	Tertiary Sandstone	3.5	27.7	9	61				

Annexure II: Water level data, South Garo Hills District, 2020-21

S.No	State*	Block*	Village	Lat*	Long*	Well* Type	MP* (m)	RL* (m)	Depth* (mbgl)	Dia* (m)	Water Level (mbgl) Nov.-2020*	Water Level (mbgl)March-2021*
1	Meghalaya	Baghmara	Dopha-Adan	25°12'07.36"	90°36'58.27"	Dug Well	0.7	182	2.45	1	0.6	1.42
2	Meghalaya	Baghmara	Baghmara	25°12'15.52"	90°37'55.73"	Dug Well	0.9	19	4.95	0.9	1.25	3.13
3	Meghalaya	Baghmara	Kharukol	25°17'05.02"	90°38'59.65"	Dug Well	0.9	17	2.4	0.9	1.15	2.92
4	Meghalaya	Gasuapara	Mandangre	25°10'06.57"	90°28'42.58"	Dug Well	0.9	24	2.95	0.75	0.45	1.89
5	Meghalaya	Gasuapara	Dumnikura	25°10'25.20"	90°24'27.87"	Dug Well	1	14	4.25	0.85	2.55	4.94
6	Meghalaya	Gasuapara	Konduk	25°11'36.77"	90°21'25.19"	Dug Well	0.7	23	3.6	0.8	0.95	4.29
7	Meghalaya	Gasuapara	Gasuapara	25°12'03.92"	90°18'37.13"	Dug Well	0.85	35	3.05	0.9	2.25	2.72
8	Meghalaya	Gasuapara	Chiringpara	25°12'26.00"	90°16'17.00"	Dug Well	0.8	40	4.8	0.8	2.8	4.12
9	Meghalaya	Chokpot	Dajibadimagri	25°20'07.36"	90°23'38.33"	Dug Well	1.1	45	2.7	1.5	0.6	3.27
10	Meghalaya	Rongara	Rongara	25°11'11.69"	90°46'54.81"	Dug Well	0.75	3	5.15	0.85	3.4	4.1
11	Meghalaya	Chokpot	Betagre	25°15'1.699"	90°29'13.18"	Dug Well	0.7	29	3.89	0.93		1.97
12	Meghalaya	Chokpot	Glmatkolgre	25°17'13.462"	90°26'4.162"	Dug Well	0.85	19	5	0.89		3.17

Annexure III: Spring Discharge, South Garo Hills District, 2020-21

S.No	State*	District*	Block*	Village	Lat*	Long*	Spring* Type	RL* (m)	Discharge (lps)Nov.-2020*	Discharge (lps)March-2021*
1	Meghalaya	South Garo Hills	Baghmara	Dubagre	25°12'57.00"	90°33'52.74"	Depression	287	0.17	0.05
2	Meghalaya	South Garo Hills	Baghmara	Lotnagar	25°15'18.18"	90°38'01.68"	Fractured	193	0.09	0.027
3	Meghalaya	South Garo Hills	Baghmara	Jadi	25°25'30.90"	90°43'34.90"	Fractured	168	0.19	0.04
4	Meghalaya	South Garo Hills	Gasuapara	Sibbari	25°11'52.61"	90°29'59.98"	Depression	79	0.095	0.017
5	Meghalaya	South Garo Hills	Gasuapara	Dimagre	25°10'36.13"	90°29'39.05"	Depression	57	0.43	0.1
6	Meghalaya	South Garo Hills	Rongara	Wagekona	25°11'41.24"	90°43'02.54"	Fractured	226	0.3	0.05
7	Meghalaya	South Garo Hills	Rongara	Gaobari	25°12'11.58"	90°45'37.67"	Fractured	86	0.13	0.02

Annexure IV: Aquifer wise water quality data (post monsoon), South Garo Hills District

S.No.	Location	Block	Lat DMS	Long DMS	Aquifer type	Temp°C	pH	EC (µs/cm) 25C	Turbidity (NTU)	TDS	CO_3^{-2}	HCO_3^{-1}	TA (as $CaCO_3$)	Cl^-	SO_4^{-2}	NO_3^{-1}	F^-	Ca^{+2}	Mg^{+2}	TH (as $CaCO_3$)	Na	K	Fe	U	As
										mg/L														µg/L	
Shallow Aquifer (Dug well)																									
1	Dopha-Adan	Baghmara	25°12’07.36"	90°36’58.27”	Sandstone	24.20	7.01	52.28	BDL	28.21	BDL	12.21	12.21	7.09	10.56	0.18	0.11	6.00	2.42	25	1.80	1.13	1.67	0.28	2.16
2	Baghmara	Baghmara	25˚12'15.52"	90˚37'55.73"	Sandstone	24.50	6.92	99.98	BDL	54.35	BDL	36.63	36.63	14.18	45.07	0.08	0.09	10.01	6.06	50	15.88	2.27	3.43	0.18	2.86
3	Kharukol	Baghmara	25°17’05.02”	90°38’59.65”	Sandstone	27.70	6.38	94.64	BDL	51.18	BDL	36.63	36.63	17.73	31.62	0.49	0.04	10.01	2.42	35	15.64	7.95	1.53	0.16	2.86
4	Mandangre	Gasuapara	25°10’06.57”	90°28’42.58”	Sandstone	29.80	7.81	155.90	0.30	84.50	BDL	122.10	122.10	3.55	6.61	0.08	0.27	14.01	12.13	85	8.69	2.42	0.87	0.13	2.86
5	Dumnikura	Gasuapara	25°10’25.20”	90°24’27.87”	Sandstone	29.00	7.73	129.60	BDL	69.82	BDL	73.26	73.26	17.73	16.39	0.19	0.21	16.01	3.63	55	13.25	6.24	1.48	0.22	3.32
6	Konduk	Gasuapara	25°11’36.77”	90°21’25.19”	Sandstone	29.00	7.06	76.33	0.10	41.26	BDL	48.84	48.84	10.64	11.85	0.21	0.13	8.01	4.85	40	11.91	3.08	1.15	0.26	2.86
7	Gasuapara	Gasuapara	25°12’03.92”	90°18’37.13”	Sandstone	29.40	7.08	35.22	BDL	19.00	BDL	30.52	30.52	7.09	1.99	0.28	0.13	6.00	2.42	25	4.30	2.77	0.82	0.10	2.39
8	Chiringpara	Gasuapara	25°12’26.00”	90°16’17.00”	Sandstone	29.80	6.60	138.20	0.10	74.81	BDL	48.84	48.84	28.36	5.87	6.42	0.07	10.01	4.85	45	14.86	6.56	0.96	BDL	2.39
9	Dajibadimagri	Chokpot	25°20’07.36"	90°23’38.33”	Sandstone	26.10	6.76	202.80	0.10	109.60	BDL	91.57	91.57	14.18	92.81	3.17	0.07	20.02	10.91	95	29.83	11.96	1.10	0.08	2.86
10	Rongara	Rongara	25°11’11.69"	90°46’54.81”	Sandstone	28.30	8.14	206.60	BDL	112.50	BDL	109.89	109.89	10.64	57.67	0.92	0.20	36.03	4.84	110	17.50	8.64	0.92	0.19	2.63
Spring																									
1	Dubagre	Baghmara	25°12’57.00"	90°33’52.74”	Sandstone	25.20	6.71	30.48	BDL	16.46	BDL	18.31	18.31	10.64	11.15	0.23	0.12	4.00	3.64	25	4.96	1.37	0.68	0.32	2.39
2	Lotnagar	Baghmara	25°15’18.18”	90°38’01.68”	Sandstone	27.60	5.01	67.03	0.20	36.27	BDL	18.31	18.31	14.18	40.96	0.12	BDL	6.00	8.49	50	7.66	1.65	1.44	0.28	2.86
3	Jadi	Baghmara	25°25’30.90"	90°43’34.90”	Sandstone	26.40	6.80	31.04	BDL	16.76	BDL	24.42	24.42	7.09	14.93	3.72	0.07	4.00	8.49	45	2.63	1.14	0.82	0.27	2.86
4	Sibbari	Gasuapara	25°11’52.61”	90°29’59.98”	Sandstone	25.60	4.09	62.40	BDL	33.58	BDL	12.21	12.21	7.09	28.35	0.06	BDL	4.00	3.64	25	8.86	2.09	1.25	BDL	3.56
5	Dimagre	Gasuapara	25°10’36.13”	90°29’39.05”	Sandstone	28.00	4.69	29.04	0.30	15.67	BDL	18.31	18.31	10.64	13.24	0.18	0.01	6.00	1.21	20	10.69	1.33	0.63	0.09	3.56
6	Wagekona	Rongara	25°11’41.24”	90°43’02.54”	Sandstone	26.40	6.15	25.25	BDL	13.62	BDL	12.21	12.21	7.09	12.68	0.26	0.04	4.00	2.43	20	4.02	1.36	2.95	BDL	4.69
7	Gaobari	Rongara	25°12’11.58”	90°45’37.67”	Sandstone	26.70	5.16	45.67	BDL	24.78	BDL	91.57	91.57	7.09	27.84	0.17	0.01	4.00	6.07	35	27.91	7.01	0.77	0.00	4.92

Annexure V: Aquifer wise water quality data (Pre-monsoon), South Garo Hills District

Sl. No.	Location	Block	Lat DMS	Long DMS	Aquifer type	Temp °C	pH	EC (µs/cm) 25C	Turbidity (NTU)	TDS	CO_3^{-2}	HCO_3^{-1}	TA (as $CaCO_3$)	Cl^-	SO_4^{-2}	NO_3^{-1}	F^-	Ca^{+2}	Mg^{+2}	TH (as $CaCO_3$)	Na	K	Fe	As
										mg/L														in ppb
Shallow Aquifer (Dug well)																								
1	Chiringpara	Gasuapara	25°12’26”	90°16’17”	Sandstone	26.5	5.69	191.2	BDL	100.9	BDL	61.05	61.05	102.81	2.01	0.08	0.07	20.02	2.42	60	38.66	27.25	0.09	BDL
2	Gasuapara	Gasuapara	25°12’04”	90°18’37”	Sandstone	25.6	5.76	49.89	BDL	26.6	BDL	48.84	48.84	85.08	3.85	1.05	0.09	14.01	1.21	40	43.67	11.34	0.12	BDL
3	Konduk	Gasuapara	25°11’37”	90°21’25”	Sandstone	25.3	6.77	103.4	BDL	53.82	BDL	67.15	67.15	141.80	5.01	0.52	0.19	22.02	3.63	70	48.61	25.85	15.59	BDL
4	Mandangre	Gasuapara	25°10’07”	90°28’43”	Sandstone	27	6.85	176.3	0.1	93.17	BDL	128.20	128.20	63.81	3.48	0.08	0.35	16.01	8.49	75	37.26	19.46	0.07	BDL
5	Kharukol	Baghmara	25°17’05”	90°38’59”	Sandstone	25.7	5.59	85.95	BDL	46.32	BDL	42.73	42.73	81.54	4.72	0.13	0.04	54.04	2.40	145	6.83	2.45	1.33	BDL
6	Betagre	Chokpot	25°15’02”	90°29’04”	Sandstone	26.9	5.8	48.85	0.2	25.91	BDL	61.05	61.05	92.17	3.03	0.78	0.08	10.01	7.28	55	39.77	19.96	0.00	BDL
7	Glmatkolgre	Chokpot	25°17’13”	90°43’02”	Sandstone		6.16	178.6	BDL	96	BDL	85.47	85.47	81.54	1.62	0.43	0.12	20.02	9.70	90	26.95	17.91	0.40	BDL
8	Dajibadimagri	Chokpot	25°20’07"	90°23’38”	Sandstone	26.9	7.25	499.7	BDL	261.7	BDL	134.31	134.31	180.80	2.53	0.98	0.43	72.06	4.82	200	48.92	21.94	0.56	BDL
9	Dopha-Adan	Baghmara	25°12’07"	90°36’58”	Sandstone	26.6	5.9	71.64	BDL	36.49	BDL	42.73	42.73	99.26	5.83	0.17	0.06	22.02	2.42	65	37.33	11.85	2.67	BDL
10	Baghmara	Baghmara	25˚12'16"	90˚37'56"	Sandstone	26.8	6.27	154.6	BDL	80.95	BDL	61.05	61.05	102.81	3.60	0.11	0.11	16.01	10.91	85	39.3	9.95	4.65	BDL
Spring																								
1	Wagekona	Rongara	25°11’41”	90°43’02”	Sandstone	27.6	6.03	33.63	BDL	17.43	BDL	42.73	42.73	56.72	6.32	0.25	0.07	10.01	4.85	45	20.99	15.77	0.12	BDL
2	Lotnagar	Baghmara	25°15’18”	90°38’02”	Sandstone	27.7	3.78	155.9	0.2	86.48	BDL	36.63	36.63	113.44	6.73	0.42	BDL	10.01	12.13	75	36.99	18.51	0.31	BDL
3	Jadi	Baghmara	25°25’31"	90°43’35”	Sandstone	25.4	6.17	32.35	BDL	16.72	BDL	61.05	61.05	70.90	4.05	1.09	0.06	10.01	4.85	45	32.29	20.75	0.02	BDL
4	Dimagre	Gasuapara	25°10’36”	90°29’39”	Sandstone	26.2	5.7	72.55	BDL	38.11	BDL	54.94	54.94	77.99	2.10	0.11	0.09	10.01	2.42	35	38.25	18.82	1.26	BDL
5	Sibbari	Gasuapara	25°11’53”	90°30’00”	Sandstone	25.5	4.11	72.2	BDL	37.71	BDL	24.42	24.42	67.36	2.98	0.10	BDL	8.01	8.49	55	20.67	7.26	0.05	BDL

Annexure VI: Litholog of exploratory wells

Unique ID	
Village	Dimapara
Taluka/Block	Gasuapara
District	South Garo Hills
Toposheet No	78 K/8
Latitude	25°13’58”
Longitude	92°15’00”
RL (m amsl)	
Drilled Depth	142
Casing	15
SWL (mbgl)	2.05
Discharge (lps)	14.4
Date/year	1997-98

Depth range (mbgl)		Thickness (m)	Litholog
From	To		
0	20	20	Top Soil/Weathered
20	34	14	Sandstone, compact
34	35	1	Fractured
35	52	17	Sandstone, compact
52	53	1	Fractured
53	88	35	Sandstone, compact
88	89	1	Fractured
89	112	23	Sandstone, compact
112	113	1	Fractured
113	134	21	Sandstone, compact
134	135	1	Fractured
135	142	7	Sandstone, compact

Unique ID	
Village	Baghmara I
Taluka/Block	Baghmara
District	South Garo Hills
Toposheet No	78 K/12
Latitude	25°13’01”
Longitude	92°37’15”
RL (m amsl)	
Drilled Depth	22.37
Casing	15
SWL (mbgl)	3.63
Discharge (lps)	2
Date/year	1997-98

Depth range (mbgl)		Thickness (m)	Litholog
From	To		
0	10	10	Top Soil/Weathered
10	15	5	Sandstone, compact
15	16	1	Fractured
16	22.37	6.37	Sandstone, compact

Unique ID	
Village	Baghmara II
Taluka/Block	Baghmara
District	South Garo Hills
Toposheet No	78 K/12
Latitude	25°13’03”
Longitude	92°37’28”
RL (m amsl)	
Drilled Depth	104
Casing	6
SWL (mbgl)	3.5
Discharge (lps)	7.7
Date/year	1997-98

Depth range (mbgl)		Thickness (m)	Litholog
From	To		
0	15	15	Top Soil/Weathered
15	24	9	Sandstone, compact
24	25	1	Fractured
25	55	30	Sandstone, compact
55	56	1	Fractured
56	70	14	Sandstone, compact
70	71	1	Fractured
71	104	33	Sandstone, compact

Annexure VII: Geophysical data of South Garo Hills District

Sl. No.	Village	Location	Coordinates	General Geology	Layer Resistivity in Ohm-m					Layer Thickness in meters						Total Depth in m.
					ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	P_6	h_1	h_2	h_3	h_4	h_5	
1	Dajibidrgre	100m south of VES-343.	N 25°18’44.0” E 90°25’34.5”	Jaintia Group(Sand Stone/Shale/Coal	225	200	125	25			1	2	4			7
2	Ashugre	50m S60°W of Sri Hollentro Sangma’s house.	N 25°20’55.8” E 90°18’32.3”	Jaintia Group(Sand Stone/Shale/Coal	90	50	35	15			1	13	7			21
3	Ashugre	100m N15°W of VES-345.	N 25°20’58.6” E 90°18’31.3”	Jaintia Group(Sand Stone/Shale/Coal	75	35	90	10			1	5	12			18
4	Ashugre	100m N15°W of VES-346.	N 25°21’01.3” E 90°18’31.2”	Jaintia Group(Sand Stone/Shale/Coal	65	30	80	10			1	4	11			16
5	Ashugre	100m S65°E of VES-347.	N 25°21’01” E 90°18’05”	Jaintia Group(Sand Stone/Shale/Coal	120	50	110	15			1	4	9			14
6	Ashugre	100m S15°E of VES-348.	N 25°20’57.6” E 90°18’35.1”	Jaintia Group(Sand Stone/Shale/Coal	125	60	10				1	21				22
7	Ashugre	100m S15°E of VES-349.	N 25°20’55.7” E 90°18’35.9”	Jaintia Group(Sand Stone/Shale/Coal	140	40	15	5			1	24	15			40

Annexure VIII: Ground water resource

a) General Description of Ground Water Assessment in South Garo Hillsdistrict for 2019-20 (area in ha)

Name of Ground Water Assessment Unit	South Garo Hills
Type of Ground Water Assessment Unit	District
Type of rock formation	Gneiss and Sandstone
Total area of Groundwater Assessment Unit	188700
Hilly area	101929
Command area	0
Non-command area	86771
Poor ground water quality area	0
Area considered for groundwater recharge	86771

b) Ground Water Resource Potential in South Garo Hills district during 2019-20

Assessment Unit / District	South Garo Hills
Command/ Non-Command/ Total	Total
Recharge from rainfall during monsoon season	8018.55ham
Recharge from other sources during monsoon season	61.7ham
Recharge from rainfall during non-monsoon season	1900.06ham
Recharge from other sources during non-monsoon season	39.31ham
Total Ground Water Recharge	10019.62 ham
Annual extractable Ground Water	9017.65 ham

c) Ground Water extraction for All Uses in South Garo Hillsdistrict

District	South Garo Hills
Total extraction for domestic and industrial purpose (as per households)	268.39ham
Total extraction for irrigation	0ham
Total groundwater extraction	0 ham

d) Balance Ground Water Resources Available and Stage of Groundwater extraction in the Study Area as On 31st March 2020

Assessment Unit / District	South Garo Hills
Command/ Non-Command/ Total	Total
Net Annual Ground Water Availability	8690.18 ham
Existing Gross Ground Water extraction for Irrigation	0 ham
Existing Gross Ground Water extraction for domestic and industrial water supply	268.39 ham
Existing Gross Ground Water extraction for All Uses	268.39 ham
Provision for domestic, and industrial requirement supply to 2025	327.47 ham
Net Annual Ground Water Availability for future development	8690.18 ham
Stage of ground water extraction	2.98 %

e) Categorization for Ground Water Development of South Garo Hills district during 2019-20

Assessment/ Administrative Uint	Stage of Ground Water extraction %	Quantity Categorization (Safe/Semi-Critical/ Critical/ Over Exploited)	Quality Tagging	Validation of Assessment using GW Level Trends (Valid/To be Re-assessed)
South Garo Hills	2.98	Safe	Fresh	Could not validate , WL data not sufficient/ representative

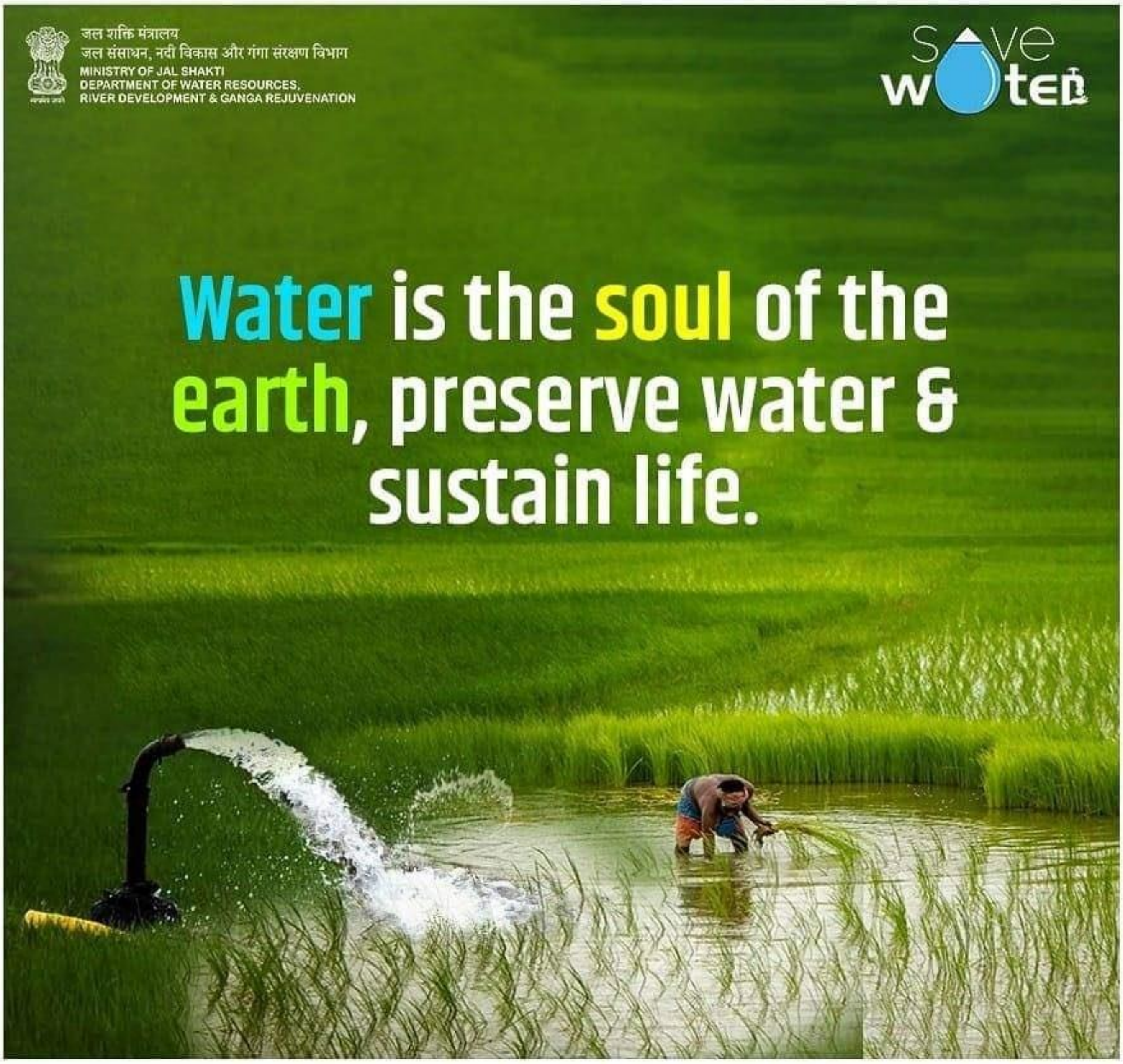
Annexure IX: Data gap and data requirement in South Garo Hills district

Toposheet No.	Grid	Data Existing										Data required									
		Aquifer I					Aquifer II					Aquifer I					Aquifer II				
		EW	OW	VES	CHE	WL	EW	OW	VES	CHE	WL	EW	OW	VES	CHE	WL	EW	OW	VES	CHE	WL
78 K/7	B1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/7	C1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/7	A2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/7	B2	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/7	C2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/7	A3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/7	B3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/7	C3	0	0	1	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/8	A1	0	0	0	0	0	1	0	0	0	0	1	1	0	1	1	0	1	2	1	1
78 K/8	B1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/8	C1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/10	C3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/11	A1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/11	C1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/11	A2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/11	B2	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/11	C2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/11	A3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/11	B3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/11	C3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/12	A1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/12	B1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/12	C1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/14	A3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/15	A1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/15	A2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/15	A3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/15	B3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/15	C3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/16	A1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/16	B1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/16	C1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
	TOTAL	0	0	1	0	0	2	0	0	0	0	19	19	0	32	32	18	19	64	19	19

FIELD PHOTOGRAPHS

Spring discharge measurement and water sample collection in South Garo Hills district

Water level measurement from dug well and water sample collection in South Garo Hills district



CENTRAL GROUND WATER BOARD,

NORTH EASTERN REGION,

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