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

KARIMNAGAR (EASTWHILE) DISTRICT, TELANGANA

दक्षिणी क्षेत्र, हैदराबाद

Southern Region, Hyderabad

भारत सरकार
जल संसाधन नदी विकास एवम् गंगा संरक्षण मंत्रालय
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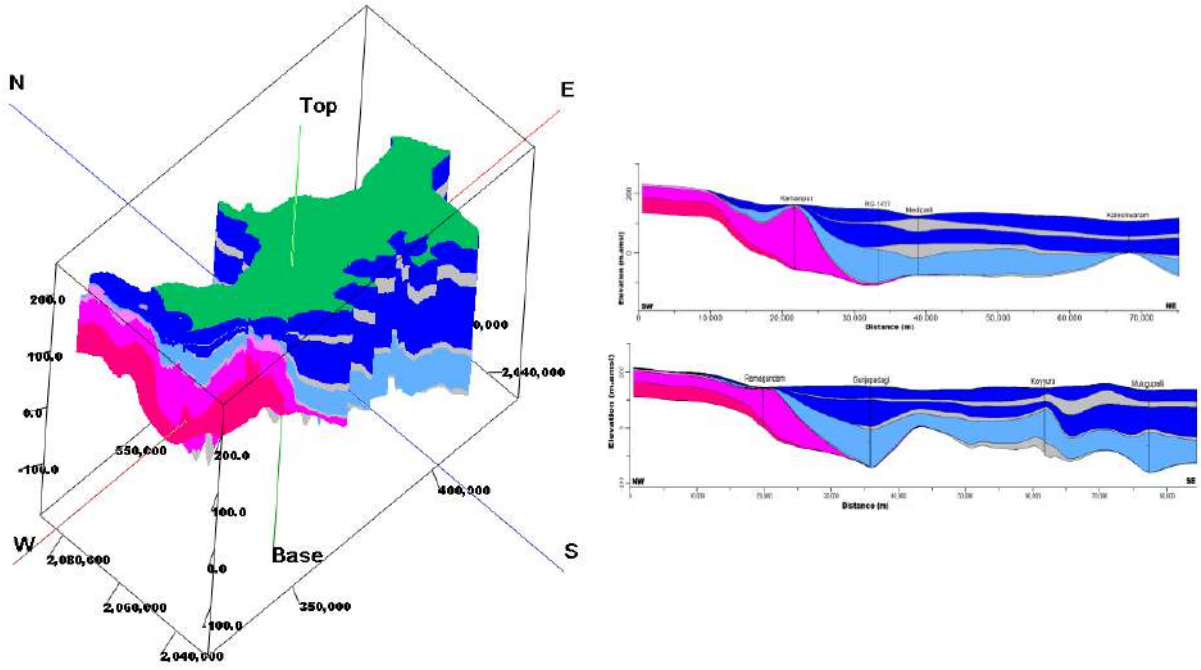
GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN SOFT ROCK AREA OF KARIMNAGAR (ERSTWHILE) DISTRICT, TELANGANA STATE



CENTRAL GROUND WATER BOARD
SOUTHERN REGION
HYDERABAD
JANUARY-2022

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN SOFT ROCK AREA OF KARIMNAGAR (ERSTWHILE) DISTRICT, TELANGANA STATE

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REPORT ON

AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN SOFT ROCK AREA OF KARIMNAGAR (ERSTWHILE) DISTRICT, TELANGANA STATE

AT A GLANCE

S.No.	Item		Particulars
1	Districts	:	Karimnagar (Erstwhile) Soft rock area
2	Revenue Divisions/ Mandals	:	12
3	Villages	:	222 Nos
4	Geographical area	:	2800 km^2
5	Population (2011 Census)	:	5.8 lakh.
6	Density of population (2011 Census)	:	207 persons/km^2.
7	Locations	:	North latitude 18°20´58"-18°52´51" East longitude 79°17´26"-80°20´44".
8	Rainfall (Normal)	:	~1033-1338 mm (avg: 1143 mm) (SW: 80 % & NE: 20 %) (During 2020-21 it received 1354 mm (18% excess than normal rainfall)
9	Geomorphology	:	Pediplain (50 %), pediment (22 %), Structural hills (15%), flood plains (8%).
10	Major Rivers	:	Godavari, Maner rivers
11	Watersheds	:	19 nos
12	Land Utilization (Ha)	:	Forest occupy 42%, Agriculture use ~43% of the total geographical area, wastelands ~ 9%.
13	Soils	:	Loamy soils (58 %), Fine mixed soils (30%) and Clayey soils (11 %)
14	Cropping Pattern (2019-20) (Gross Area:1,56,693 Ha)	:	Khariff: Paddy (36 %), Cereals & Millets (36%), Cotton (25%) Rabi: Paddy (49%), cereals & Millets (49%)
15	Irrigation	:	**Major project:** Sri Ram Sagar Project (SRSP), Ayacut of 49,797 Ha. **MI Tanks:** 1068 minor irrigation tanks
16	Prevailing Water Conservation/Recharge Practices	:	PT: 53 and CD: 75 and Farm ponds:195 Micro irrigation: 1797 Ha. Under Mission Kakatiya (Phase 1 to 4) silt is removed from 405 MI tanks.
17	Geology	:	Recent to Archaean age, Granites, Sandstone, Limestone, Shale, Quartzites, Conglomerates, etc.
18	Hydrogeological data points	:	38 hydrogeological data points (Exploration: 38 (CGWB: 28 and SCCL:10),VES: 30, 82 wells (CGWB:14, SGWD:26, SCCL:42).

<table>
<tr><td>20</td><td>Ground water yield (lps)</td><td>:</td><td>0.1 to 3 lps in Granites

1.0 to 25 lps in soft rocks

In Quartzites and Sandstone of Puranas abd Barren measures, yield varies from 1 to 5 lps.

Maleri and Kota Sandstone formations, Yield varies between 5 to 10 lps

Kota and Kamthi Sandstone formations show maximum yields varying between 10 to 25 lps.</td></tr>
<tr><td>21</td><td>Water Levels (10 years Average)

Depth to water levels (m bgl)</td><td>:

:</td><td>82 wells (CGWB:14, SGWD:42)

Water table elevations during pre-monsoon season varies from 93-182.3 m amsl and during post-monsoon season it varies from 70.3-182.8 amsl.

Pre-monsoon season: 1.2 to 26 m bgl (average: 8.6 m bgl) and majority are in the range of 2 - 10 m bgl (90 % area) followed by 10-20 mbgl (9% area). Deep water levels (> 20 mbgl) occupy ~1% of area.

Post-monsoon: 0.5- 25 m bgl (average: 6.8) and majority are in the range of 2-10 m bgl (92% area) followed by 10-20 mbgl (6 % area).</td></tr>
<tr><td>22</td><td>Water Level Fluctuations (May vs. November) (10 years Average)</td><td>:</td><td>-2.33 to 5.66 mbgl Out of 82 wells 74 wells shows rise in water levels and 8 wells shows fall in water levels.</td></tr>
<tr><td>23</td><td>Long term water level trends (2011-20)

(38 wells)</td><td>:</td><td>Pre-monsoon: Falling trends: 28 wells (0.01 to 1.77 m/yr) Rising trends: 10 wells shows 0.08-1.3m/yr.

Post-monsoon: Falling trends: 16 wells 0.01 to 1.64 m/yr) Rising trends: 22 wells shows 00 to 1.75 m/yr.</td></tr>
<tr><td>25</td><td>Hydrochemistry (2019)</td><td>:</td><td>Total 137 data points

Pre-monsoon (CGWB:05 nos, SGWD:66)

Post-monsoon (SGWD:66)</td></tr>
<tr><td>25.1</td><td>Electrical Conductivity (µ Siemens/cm)</td><td>:</td><td>Pre: 158-2300 µ Siemens/cm (avg:1047) in 86 % of area EC is within 1500 µ Siemens/cm.

Post: 199-2453 µ Siemens/cm (avg:986) In 95% of area EC is within 1500 µ Siemens/cm.</td></tr>
<tr><td>25.2</td><td>Nitrate mg/l</td><td>:</td><td>Pre: BDL to 350 mg/L and found 42% of samples are unfit for human consumption.

Post: BDL to 279 mg/L, 26% samples are unfit for human consumptions.</td></tr>
<tr><td>25.3</td><td>Fluoride mg/l</td><td>:</td><td>Pre: 0.05-2.52 mg/L, 8% of samples are unfit for human consumptions.

Post: 0.1-2.61 mg/L, 4% of samples are unfit for human consumptions.</td></tr>
<tr><td>26</td><td>Conceptualization</td><td></td><td><table><tr><th>Type of Aquifer</th><th>Depth range (m.bgl)</th></tr><tr><td>Unconfined Aquifer (Aquifer-I)</td><td>4 to 50</td></tr><tr><td>Confined Aquifer (Aquifer-II)</td><td>33 to 150</td></tr><tr><td>Confined Aquifer (Aquifer group-III)</td><td>140 to 300</td></tr></table></td></tr>
<tr><td>27</td><td>Aquifer Characterization</td><td>:</td><td>Unconfined Aquifer (Aquifer-I) : Ground water yield varies from <1 to 2</td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td>lps (avg: 1 lps) with transmissivity of 25 to 50 m^2/day in soft rocks and <0.1 to 2 lps (avg: 1 lps) in hard rocks.</td></tr>
<tr><td>27.1</td><td>Aquifer wise Ground water yield</td><td>:</td><td><table><tr><th>Type of Aquifer</th><th>Yield in lps</th></tr><tr><td>Unconfined Aquifer (Aquifer-I)</td><td><1 to 2 lps</td></tr><tr><td>Confined Aquifer (Aquifer-II)</td><td rowspan="2">1 to 25 lps</td></tr><tr><td>Confined Aquifer (Aquifer group-III)</td></tr></table></td></tr>
<tr><td>27.2</td><td>Transmissivity (m^2/day)</td><td>:</td><td>Aquifer-I : 25 to 50 m^2/day
Aquifer-II and III : 28 m^2/day to 668 m^2/day</td></tr>
<tr><td>27.3</td><td>Specific Yield</td><td>:</td><td>< 1 to 2 %</td></tr>
<tr><td>27.4</td><td>Storativity</td><td>:</td><td>0.0001 to $2.5x10^{-4}$</td></tr>
<tr><td>28</td><td>Ground water Resources (2020) MCM</td><td>:</td><td></td></tr>
<tr><td>28.1</td><td>Net Dynamic groundwater availability</td><td>:</td><td>311.39</td></tr>
<tr><td>28.2</td><td>Gross GW Draft</td><td>:</td><td>122.14</td></tr>
<tr><td>28.3</td><td>Provision for Domestic &Industrial (2025)</td><td>:</td><td>21.22</td></tr>
<tr><td>28.4</td><td>Average Stage of Ground water development (%)</td><td></td><td>39%</td></tr>
<tr><td>28.5</td><td>Net GW Availability for future irrigation</td><td>:</td><td>177.71</td></tr>
<tr><td>28.7</td><td>Categorization of mandals</td><td></td><td>All mandals are Safe</td></tr>
<tr><td>29</td><td>Major Ground Water Issues Identified</td><td>:</td><td>• Ground water Pollution (Geogenic: Fluoride (8% samples are unfit for human consumptions).(Anthropogenic: Nitrate 42 % samples are unfit for human consumptions).
• Declining water levels: Out of 38 wells analyzed, 28 wells shown falling trend in pre-monsoon and 16 during post-monsoon season.
• Over-extraction, paddy cultivation during rabi season (49% to total crops) ground water mining, limited artificial measures etc.</td></tr>
<tr><td>30</td><td>Management Strategies</td><td>:</td><td>Supply side measures
Ongoing Projects
• Mission Kakatiya: (Phase-1 to 4): silt is removed from 405 tanks which created additional surface storage and enhance ground water recharge.
Mission Bhagiratha:~21.24 MCM of water will be imported from surface sources this will save ~13 MCM and from this ~2160 ha of additional land can be brought under ID crops.
• 179 ARS (CD with recharge shafts: 93and PT:86)</td></tr>
</table>

			• Cost Rs ~31 Crores **Water Conservation measures (WCM) Farm Ponds** • The size of form ponds can be 10 x 10 x 3 m. Total 1551 farm ponds are recommended (20 in each village in 86 villages) with total cost of **3.8** crores. this can create an additional storage of 0.5 MCM **Demand side measure** **Ongoing work:** In the area till date a total ~1815 ha area is brought under micro-irrigation saving ~2.7 MCM of groundwater. **Other Recommendations** • ~3300 ha of additional land that can be brought under micro-irrigation (4 mandals) **Cost: 20** crores. With this ~6.6 MCM of ground water can be conserved over the traditional irrigation practices. • Change in cropping pattern from water intensive paddy to irrigated dry crops like pulses and millets are recommended particularly in 4 mandals viz, Kamanpur, Malharrao, Manthani and Mutharam Manthani, where paddy cultivated area is ~ 80% of the Gross cropped area. • • Roof top rainwater harvesting structures should be made mandatory to all Government/industrial buildings (new and existing). • Capacity building in power supply regulation (4 hour each in morning and evening) will increase the sustainability of wells • A participatory groundwater management (PGWM) approach in sharing of groundwater and monitoring resources on a constant basis along with effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002). • In urban and rural areas the underground sewerage line should be constructed to arrest leaching of nitrate
31	Expected Results and Out come	:	With the above interventions costing Rs **55** crores, the likely benefit would be the net saving of 11.9 MCM of ground water. This will bring down the stage of ground water development (SoGWD) by 1.5% (from 39 % to 37.5 %) for entire study area and will bring down the stage of ground water development by 6% (from 57% (4 mandals average SoGWD) to 51 %) in four mandals (852 Km^2 area) .

ABBREVATIONS

2D	:	2 Dimensional
3D	:	3 Dimensional
ARS	:	Artificial Recharge Structures
Avg	:	Average
BDL	:	Below Detection Level
BW	:	Bore Well
CD	:	Check dam
CGWB	:	Central Ground Water Board
Cr	:	Crore
DTW	:	Depth to water
DW	:	Dug well
EC	:	Electrical conductivity
EL	:	East Longitude
F	:	Fluoride
FP	:	Farm Pond
GEC	:	Ground Water Estimation committee
GW	:	Ground Water
Ha	:	Hector
Ha.m	:	Hector meter
ID	:	Irrigated dry
IMD	:	Indian Meteorological Department
Km^2	:	square kilometre
LPS	:	Litres per second
M	:	meter
M^3	:	Cubic meter
m bgl	:	Metres below ground level
MCM	:	Million cubic meter
Mg/l	:	Milligram per litre
MI	:	Micro irrigation
Min	:	Minimum
max	:	Maximum
MPT	:	Mini percolation tank
MSP	:	Minimum Support price
NL	:	North Latitude
NO_3	:	Nitrate
OE	:	Over Exploited
PGWM	:	Participatory ground water management
PT	:	Percolation tank
SGWD	:	State Ground Water Department
S	:	Storativity
Sy	:	Specific Yield
T	:	Transmissivity
WCM	:	Water conservation measures

EXECUTIVE SUMMARY

Karimnagar (erstwhile) soft rock area is ~2800 km^2. The area receives an average annual normal rainfall of 1143 mm of which 80% is contributed by SW monsoon and 20 % by north-east monsoon. During the year 2020-21, the district received 1354 mm (18% excess) rainfalls than normal annual rainfall. Administratively, the area is governed by 12 revenue mandals with 222 villages. The population of the study area is ~ 5.8 lakhs (2011 census) with average density of 207 persons/km^2.

Major part of the study area is underlain by Gondwana formation. Recent to Archaean age formations including Pakhal and Sullavai formations can be seen in the area. Archaean crystallines rocks occupy westen part of the district covering 15% of the area. Pediplain is the major landform covering about 1414 km^2 (50%) area. The other landforms observed are pediment (22%), Structural hills (15%), Flood plains (8%), residual hill, channel fill, etc. The study area form part of Pranahita sub-basin of Godavari river basin. Godavari river, and Maner river bifurcated into 19 watersheds.

The gross cropped area during 2019-20 is 1,56,693 ha. Forest occupies 42% of the total geographical area, waste lands occupies 9% of area. Paddy is main crop with 36% sown area in Khariff and 99% in Rabi, other main crops are Millets, Cereals and Cotton. The soils are loamy (58%) Mixed soils (30%) and clayey soils (11 %).

The registered ayacut under Sri Ram Sagar Project (SRSP) is 49797 ha. In the area there are 1038 minor irrigation tanks out of which~405 MI tanks are desilted and renovated under Mission Kakatiya. ~53 PT and 75 CD exist in the area.

Under Exploratory drilling CGWB hs drilled 28 wells, 02 well of shallow depth of 30 m, 05 wells of 30-100 m depth, 04 wells of 100-200m depth and 17 wells of 200-300 m depth**.** 10 representative exploratory well data of SCCL also utilized for the conceptualization of the Aquifer system in the area. Ground water yield varies from <0.1 to 3 lps in granite/gneisses. In soft rocks, the ground water yields vary from 1 to 25 lps. In Barren measures, Quartzites and Sandstone areas yield varies from 1 to 5 lps. In Maleri and Kota formations, Yield varies between 5 to 10 lps whereas Kota and Kamthi formations show maximum yields varying between 10 to 25 lps

Water levels are monitored through 82 wells during pre and post-monsoon season. The 10 years average DTW varies from 1.2 to 26 m bgl (average: 8.6) and 0.5- 25 m bgl

(average: 6.8) during pre and post-monsoon season respectively. During pre-monsoon season 2-10 m water levels is more predominant (90% of area) followed by 10-20 m (9% of area) > 20 m.bgl (1% of area). During post-monsoon season 2-10 m water levels is more predominant (92% of area) followed by 10-20 m (6% of area).The water level fluctuation (Nov Vs. May) data studied from 82 wells show that in 74 wells show a rise in water levels in the range of 0 to 5.66 m bgl (average:1.79 m) and in 8 wells show fall in water levels in the range of 0 to 2.33 m bgl. Long-term water levels trends analysed for 38 wells indicate that during pre-monsoon in 28 wells there is a falling trend varying from 0.01 to 1.77 m/yr and in 10 wells show a rising trend in the range of 0.08-1.3 m/yr. During post-monsoon season, 16 wells show falling trend in the range of 0.01 to 1.64 m/yr and 22 wells show rising trend in the range of 0.01 to 1.75 m/yr.

Geophysical data from 30 VES data (CGWB) reveals resistivity of different formations depth wise. The typical sequence of Pakhal formations showed clay (6 ohm m) shale (42 ohm m) quartzite (324 ohm m), shaly dolomite (40 ohm m) dolomite (180 ohm m). The sandstones have resistivity of 120 to 150 ohm m. Talchir formations exhibited a resistivity of 5 to 45 ohm m with thickness of 260 to 350 m.

Total 137 ground water samples (Pre-monsoon:71 and Post-monsoon: 66) were analysed for knowing the suitability of ground water for drinking purposes. In 86% of the samples and 95% of area EC is in the range of < 1500 µ Siemens/cm during pre and post-monsoon season respectively. During pre-monsoon season, concentration of NO_3 ranges from BDL to 350 mg/l and found that in 42% samples nitrate is beyond maximum permissible limit of BIS (45 mg/l) and F concentration varies from 0.05-2.52 mg/l in 8% of the samples it is beyond maximum permissible limits of BIS (1.5 mg/l). During post-monsoon season, concentration of NO_3 ranges from BDL to 279 mg/l and in 26% of the samples it is beyond maximum permissible limit of BIS (45 mg/l). The F concentration varies from 0.1-2.61 mg/l and in 4% of the samples it is beyond maximum permissible limit of BIS.

Based on 38 hydrogeological data points, In consolidated formation, Weathered zone is considered up to the maximum depth of weathering upto the first fracture (below weathered depth) and is generally down to ~20 m depth and the fractured zone (fractured granite) is considered up to the depth of deepest fracture below weathered zone. In unconsolidated formation aquifers are classified into 3 Aquifer units, viz. Unconfined Aquifer (Aquifer-I), Confined/Semiconfined Aquifer (Aquifer-II) and Confined Aquifer

group-III where the deeper aquifers are grouped into one unit due to inadequate aquifer wise data. Ground water yield of unconfined aquifer varies from <1 to 2 lps (avg: 1 lps) with transmissivity of 25 to 50 m^2/day. Ground water yield of weathered granite/gneiss aquifer varies from <0.1 to 2 lps (avg: 1 lps). Aquifer-II and Aquifer group-III are confined/semiconfined aquifer. Aquifer-II present below unconfined aquifer in the depth range of 30 to 150 m. saperated by clay layer with considerable thickness of 5 to 30 m. and Aquifer group-III present below aquifer-II in the depth range of 150 to 300 m. saperated by clay layer with thickness of 5 to 30 m. The transmissivity of these aquifers vary from 28 m^2/day to 668 m^2/day with storativity ranging from $5x10^{-4}$ to $2.5x10^{-4}$.

Net dynamic replenishable ground water availability is 311.39 MCM, gross ground water draft is 122.14 MCM, provision for drinking and industrial use for the year 2025 is 21.22 MCM and net available balance for future irrigation use is 177.7 MCM. The stage of ground water development varies from 14 to 61 % (avg: 39%).

Major issues identified are ground water pollution (both anthropogenic (NO_3) and geo-genic (F) and declining water levels in majority of hydrograph stations. Other issues identified are change in cropping pattern etc.

The management strategies mainly include both supply side and demand side. Under the supply side measure, the impact of ongoing works analysed, under Mission Kakatiya desilting from 405 tanks was done creating additional surface storage and enhance ground water recharge. Under Mission Bhagiratha, there is a plan to import ~21.24 MCM of water for drinking purposes which will save the present ~13 MCM of water drawing from ground water for drinking and domestic purposes and from this savings an additional ~2160 ha of land can be brought under ID crops.

Construction of 179 ARS with ~31 crores in 4 mandals viz. Kamanpur, Malharrao, Manthani and Mutharam Manthani are proposed where the stage of ground water development is 50% and above. 1551 farm ponds are recommended (20 in each of the 86 villages in four mandals) with total cost of **3.8** crores, which can conserve 0.46 MCM of surface water.

Demand side measure includes bringing ~3300 ha of land (from 4 mandals) under micro-irrigation with total cost of **20** crores. With this 6.6 MCM of ground water will be saved in both seasons by utilizing same units.

Other measure includes providing good quality seeds, improved procurement facilities, mandatory artificial recharge at every Govt and industrial units. Capacity building in power supply regulation, application of laser levelling technology in irrigated land, providing proper sewerage system and participatory groundwater management (PGWM) are the other measures recommended.

With the above interventions costing Rs 55 crores, the likely benefit would be the net saving of 11.9 MCM of ground water. This will bring down the stage of ground water development (SoGWD) by 1.5% (from 39 % to 37.5 %) for entire study area and will bring down the stage of ground water development by 6% (from 57% (4 mandals average SoGWD) to 51 %) in four mandals (852 Km^2 area).

NUMBER OF DATA POINTS USED FOR PREPARATION OF VARIOUS MAPS/FIGS- KARIMNAGAR DISTRICT, TELANGANA STATE

S. No.	Data	Aquifer	Total Data Points	Source		
				CGWB	SGWD	SCCL
1	Panel Diagram (3-D)	Combine	68	Expl:28 VES:30	-	10
2	Hydrogeological Sections	4 no	68	Expl:28 VES:30	-	10
3	Depth of weathering	1 no	68	Expl:28 VES:30	-	10
4	Depth of fracturing	1 no	68	Expl:28 VES:30	-	10
5	Groundwater Yield	Unconfined Aq.	38	28	-	10
		Conf/Semi conf. Aq	38	28	-	10
6	Transmissivity (m^2/day)	Unconfined Aq.	10	07	0	03
		Conf/Semi conf. Aq	10	07	0	03
7	Depth to Water Level Maps (10 Yr Avg)	Combine	82	14	26	42
8	Water Level Fluctuation	Combine	82	14	26	42
9	Long term water level trends	Combine	38	12	24	0
10	Water quality Pre-2019 Post-2019	Combine	137 Pre:71 Post:66	5 0	SGWD:66 SGWD:66	0 0

1. INTRODUCTION

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers. In recent past, there has been a paradigm shift from "**groundwater development**" to "**groundwater management**". As large parts of India particularly hard rocks have become water stressed due to rapid growth in demand for water due to population growth, irrigation, urbanization and changing life style. Therefore, in order to have an accurate and comprehensive micro-level picture of groundwater in India, aquifer mapping in different hydrogeological settings at the appropriate scale is devised and implemented to enable robust groundwater management plans. This will help in achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural and many parts of urban India. The aquifer mapping program is important for planning suitable adaptation strategies to meet climate change also. Thus the crux of National Aquifer Mapping (NAQUIM) is not merely mapping, but reaching the goal-that of ground water management through community participation.

The occurrence and movement of ground water in sedimentary rocks is controlled by the granular zones and their interconnectivity whereas in granites/hard rocks controlled by the degree of interconnection of secondary pores/voids developed by fracturing and weathering. Weathered zone is the potential recharge zone for deeper aquifers and excessive withdrawal from this zone leads to drying up of weathered zone in places and reducing the sustainability of deeper fractures. Besides these quantitative aspects, groundwater quality also represents a major challenge which is threatened by both geogenic and anthropogenic pollution. In some places, the aquifers have high level of geogenic contaminants, such as fluoride, rendering them unsuitable for drinking purposes. High utilization of fertilizers for agricultural productions and improper development of sewage system in rural/urban areas lead to point source pollution viz., nitrate and chloride.

1.1 Objectives: In view of the above challenges, an integrated hydrogeological study was taken up to develop a reliable and comprehensive aquifer map and to suggest suitable groundwater management plan on 1: 50,000 scale.

1.2 Scope of study: The main scope of study is summerised below.

1. Compilation of existing data from various departments (exploration, geophysical, groundwater level and groundwater quality),geo-referencing information and identification of principal aquifer units.
2. Periodic long term monitoring of ground water regime (for water levels and water quality) for creation of time series data base and ground water resource estimation.
3. Quantification of groundwater availability and assessing its quality.
4. To delineate aquifer in 3-D along with their characterization on 1:50,000 scale.
5. Capacity building in all aspects of ground water development and management through information, education and communication (IEC) activities, information dissemination, education, awareness and training.
6. Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable ground water management.

1.3 Area Details: The study area having geographical area of 2800 km^2, lies between north latitude 18°20´58"-18°52´51" and east longitude 79°17´26"-80°20´44". It is part of the River Godavari basin (**Fig.1.1**). The study area falls in newly carved two districts Peddapalli and Jayashanker Bhupalpalli.Administratively the area is governed by 12 revenue mandals with 222 villages, with a population of ~5.8 lakhs (2011 census), Population wise Palimela Mandal is the Smallest mandal with 7588 population and Ramagundam mandal is the biggest mandal with 2,42,979 population.

1.4 Climate and Rainfall: The climate of the district is characterised by hot summer and cool winters with good amount of rainfall. May is the hottest month with daily mean temperatures ranging from 29.4°C to 42.7°C and December is the coldest month with daily mean temperatures ranging from 14.6°C to 29.9°C. Normal annual rainfall varies between 1033 mm (Malharrao) to 1338 mm (Palmela) with average of 1143 mm (**Fig. 1.2**). SW monsoon contributes 80% and 20% is contributed by retreating monsoon (NE) season, winter and summer rainfall. Rainfall increses from Southwest to Northeast. As per the IMD rainfall data, during the year 2020, the study area received average rainfall of 1354 mm (18% excess rainfall than normal rainfall).

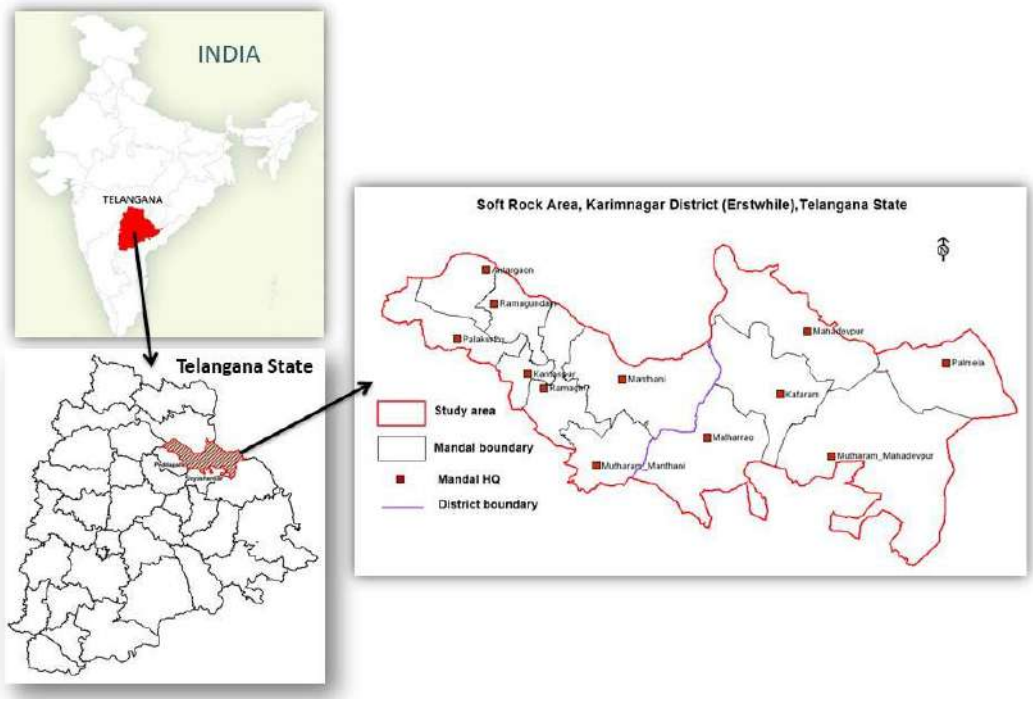


Fig.1.1: Location of Karimnagar district (Erstwhile) Soft rock area.

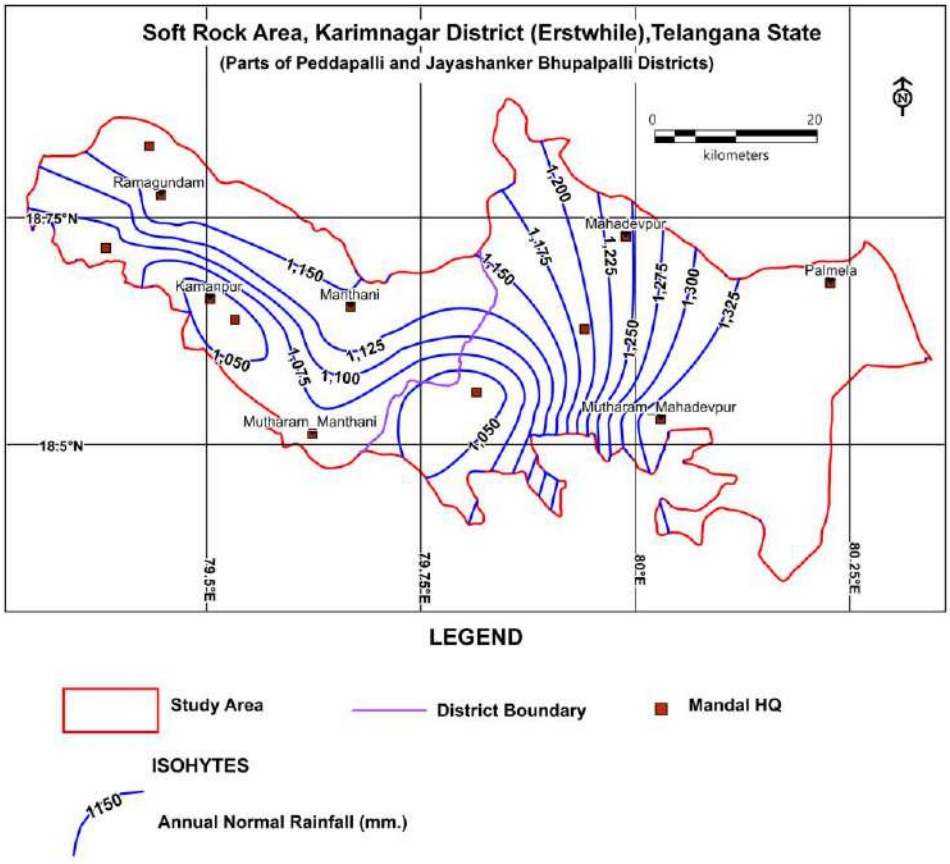


Fig.1.2: Isohyetal map of Karimnagar district (Erstwhile) Soft rock area.

1.5 Physiography : Physiographically, the area is represented by few hills in the western and southwestern parts near Ramagundam (420 m). The general surface elevation in the western parts is 223 m.amsl, at central parts it is 129 m and in eastern parts with 140 m.amsl. The raised plateau like structure in the eastern parts is occupied by thick forest cover. The low central part in the area is occupied with open cast coal mining and under ground coalmines.

1.6 Geomorphological Set up: Pediplain is the major landform covering about 1414 km^2 (50%) area. The other landforms observed are pediment (22%), Structural hills (15%), Flood plains (8%), residual hill, channel fill, etc. (**Fig.1.3**).

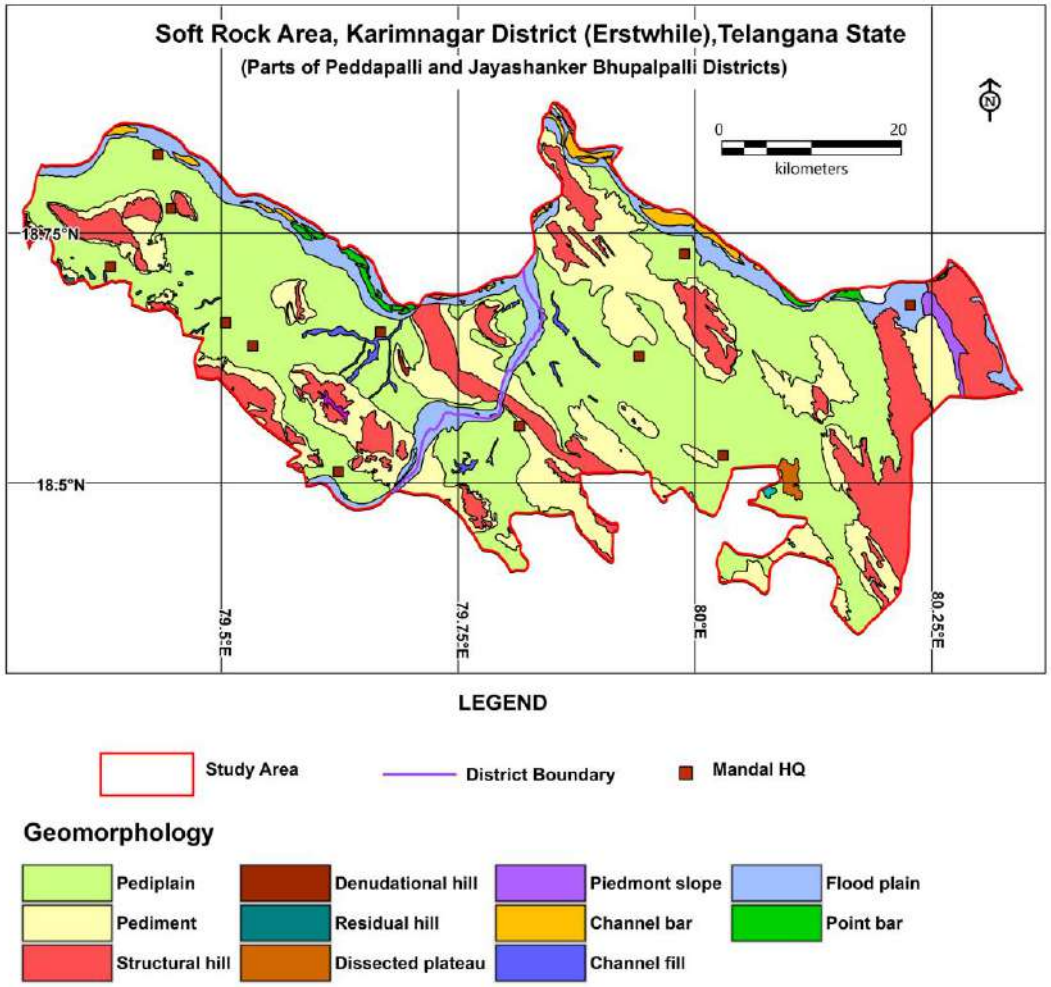


Fig.1.3: Geomorphology of Karimnagar district (Erstwhile) Soft rock area.

1.7 Drainage and Structures: The streams and smaller river in the area form part of Pranahita sub-basin of the Godavari river basin. Northern part of the area is bordered by meandering Godavari river, whereas the Maner River a tributary to river Godavari flow

through the central part from south to north. The Ramgiri hills and Kammampally reserve forest hills act as divide for sreams originating from them to flow in to Godavari and Maner rivers. Bokkala vagu is other recognizable stream flowing in the central part through Manthani town ultimately joining Godavari River in downsream side. The Maner is a perennial river except at times when draught-like conditions prevail than the river dries up in summer months. The drainage pattern in the study area is sub-dendritic and controlled by weathering of litho units and at places sub-parallel drainage is developed by structural elements and joints in the rock structures.These sub basin is further sub divided into 19 watersheds in the study area. Lineaments trend along SW-NE, NW-SE and N-S directions. Map depicting drainage, water bodies is presented in **Fig.1.4**.

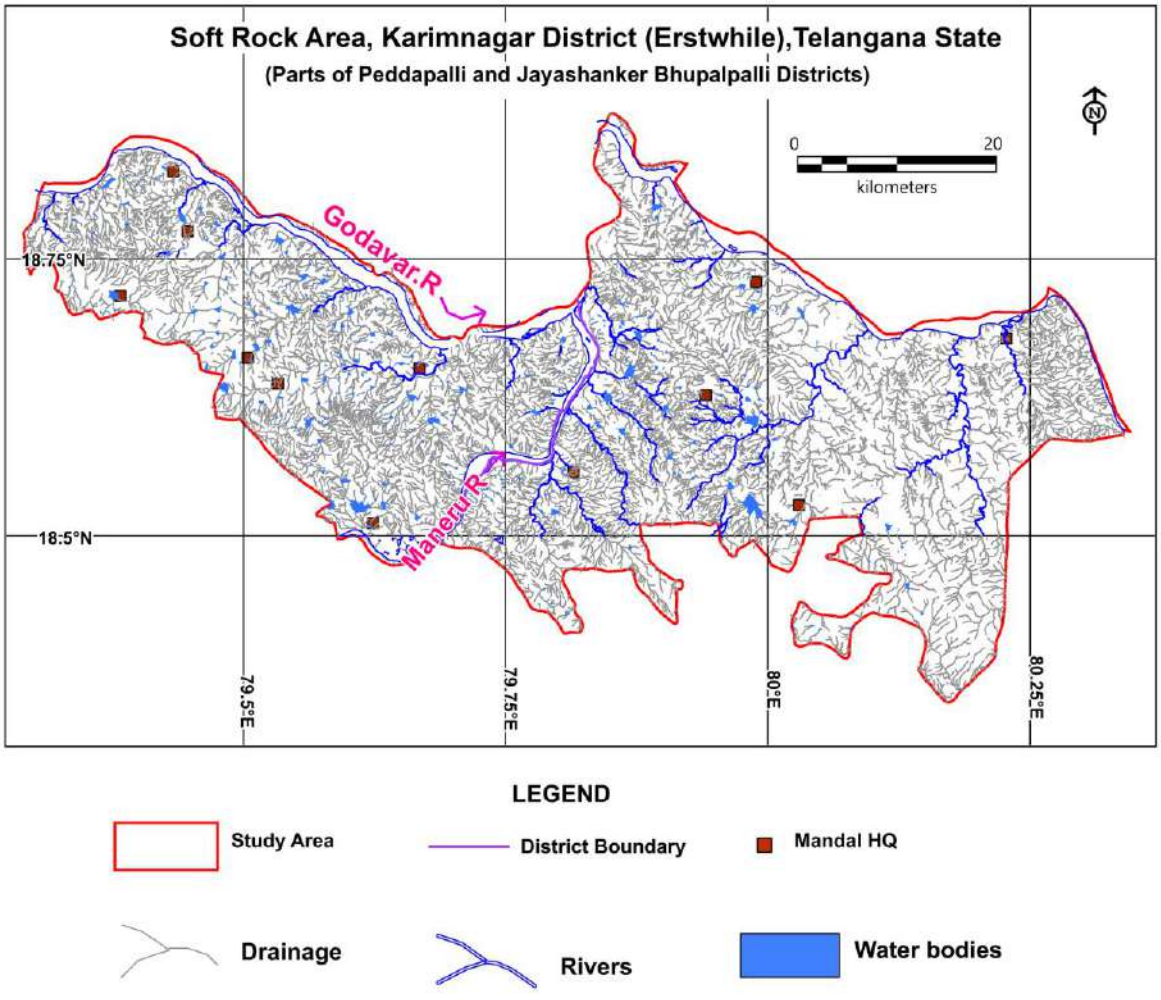


Fig.1.4: Drainage, lineaments and watershed boundaries, Karimnagar district (Erstwhile) Soft rock area.

1.8 Land use and cropping pattern (2019-20):

In the area, the land use can be grouped into 06 main classes (**Fig.1.5**). Forest occupies ~42% of the total geographical area, waste lands is 9%, agricultural use is 43%, river sandy area is 3%, Water channel area is 2%. The gross cropped area (2019-20) during khariff season is 1,19,763 ha and during rabi season is 36,930 ha (Total 1,56,693 ha). Main crops grown are paddy 43,064 ha (36%) of net sown area and 35,741 ha (49%) during khariff and rabi season respectively. Cereals & Millets are grown in 43,154 ha (36%) during Khariff and 36,059 ha (49%) during rabi, Cotton is grown in 30,009 ha (25%) during khariff season and Pulses are grown in 469 ha (1%) during rabi season. The other crops are spices and oil seeds (Fig:1.6).

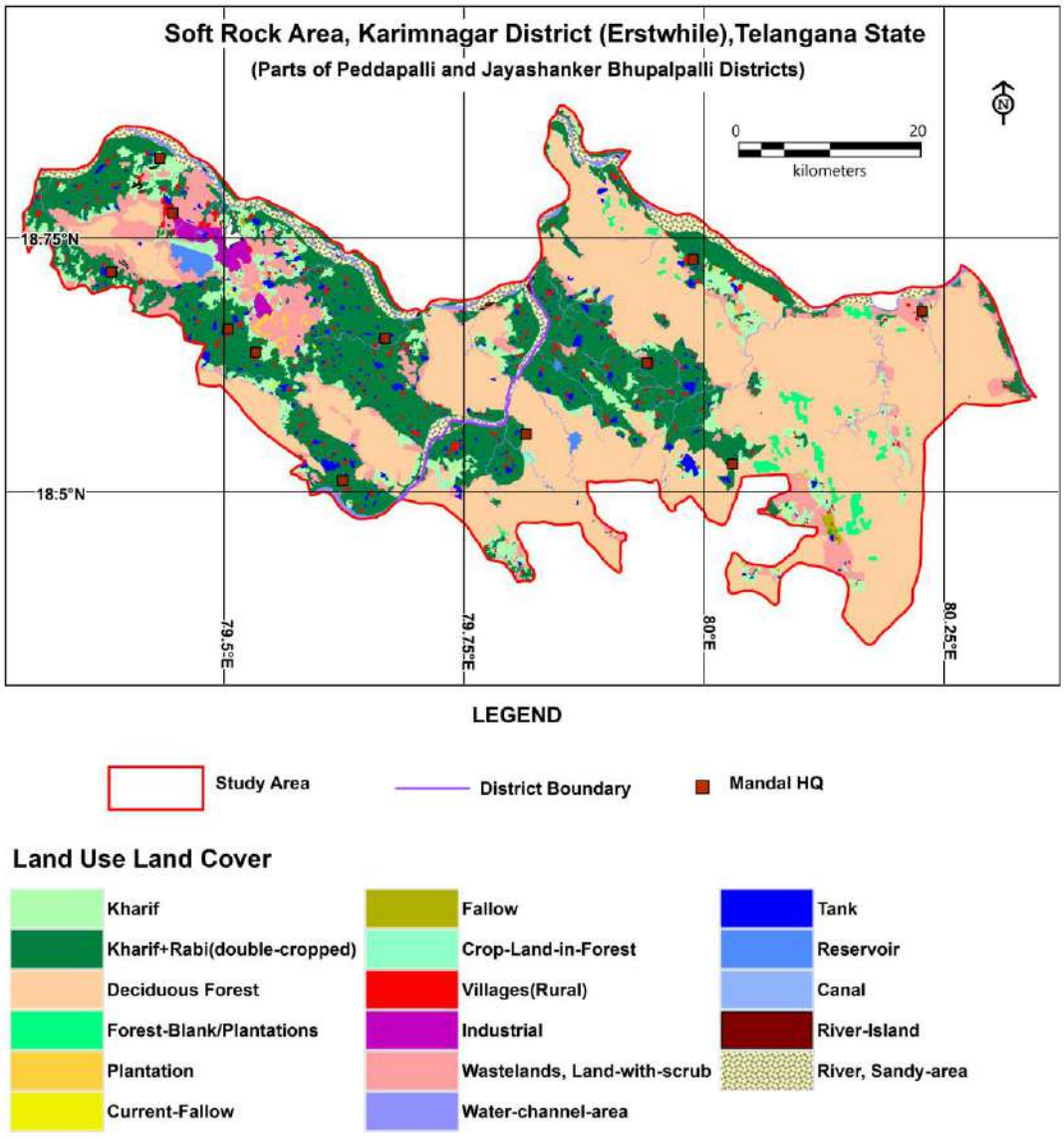


Fig.1.5: Land use and land cover of Karimnagar district (Erstwhile) Soft rock area.

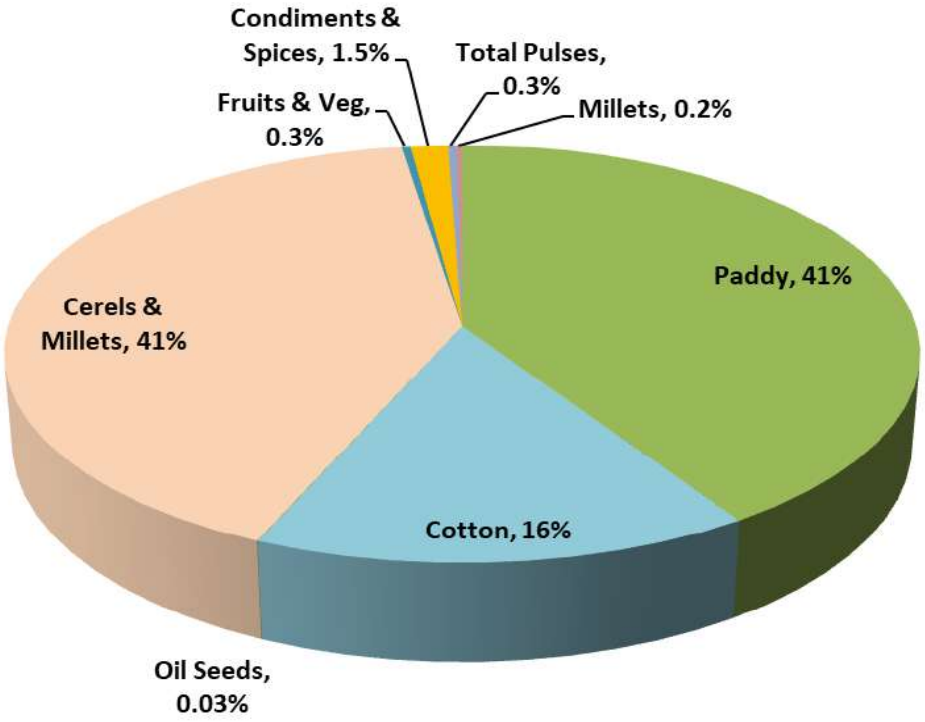


Fig.1.6: Cropping pattern of Karimnagar district (Erstwhile) Soft rock area.

1.9 Soils: The area is mainly occupied by red earths and black soils. The red earths include sandy loams, sandy clay loams.The red earthy soils occur in southwestern parts where as sandy clayey loams occur in kamanpur, Manthani, Mutharam mandals located in the central part.Sandy loams occur in Tadicherla and mutharam mandals. Black soils occupy parts of Manthani, Mahadevpur and Mahamutharam mandals.Loamy soils occupy 58% area, Rocky lands with clay occupy 11% area, Fine mixed soils occupy 30% of area. (**Fig.1.7**).

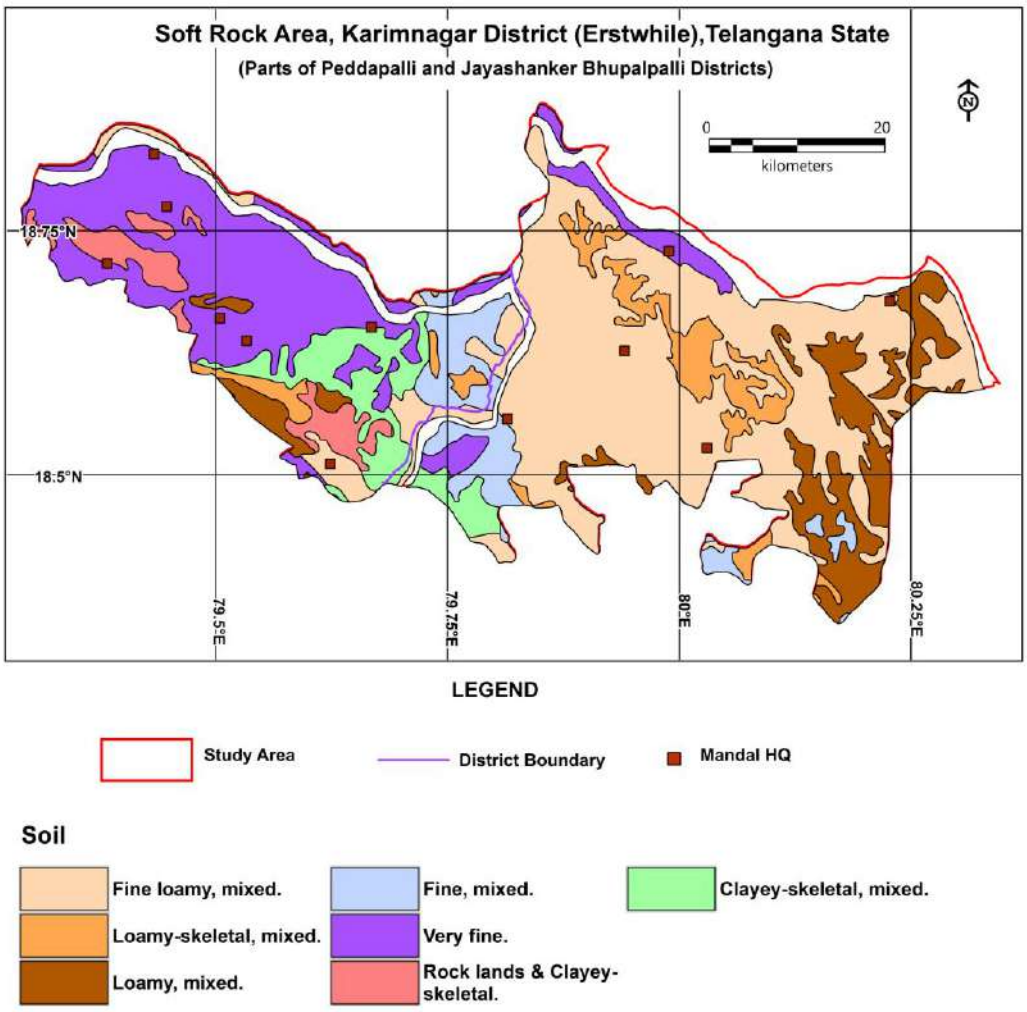


Fig.1.7: Soil map of Karimnagar district (Erstwhile) Soft rock area.

1.10 Irrigation:

The area receives the canal water from Sri Ram Sagar Project (SRSP) through Kakathiya Canal and its distributaries. The Sri Ram Sagar Project is built across Godavari River. The D-83 distributary is the biggest distributary feeder canal of the project with a length of 82 km with discharge capacity of 57 cu Mecs, serving mandals of Ramagundam, Peddapally, Kamanpur, Manthani and Manthani Mutharam. The localized extent of area under D-83 feeder canal is 49,797 ha out of which 30,904 ha is for wet crops and 18,893 ha is for irrigated dry crops. The index map of Sri Ram Sagar Project canal system is given in ***Fig-1.8***. The details of discharges, bed width and full supply depth of the two distributaries is presented in Table-1.1

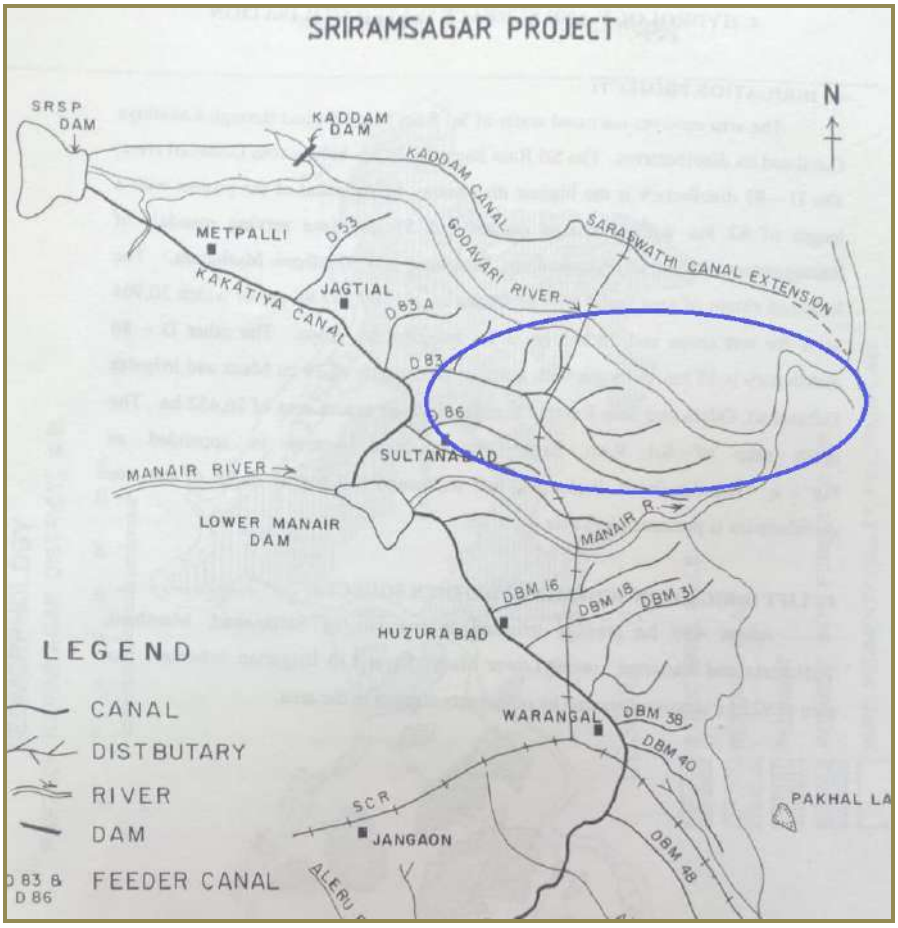


Fig-1.8 : Sri Ram Sagar Project canal system

Table-1.1 : Details of Distributary (D-83) of SRSP canal

Distributory	From Km to Km	Type of canal	Discharge (Cu mecs)	Bed width (BW)	Full Supply Depth
D-83	0.0 to 6.639	Lined	49.3583	6.09	3.11
			43.9236	5.49	3.04
	6.639 to 16.864	Lined	39.8084	16.15	2.37
	16.86 to 20.93	Lined	35.2105	15.54	2.215
	20.93 to 35.00	Lined	0	0	0
	35.00 to 43.20	Unlined	26.3028	10.62	2.155
RSB from Gundaram Tank	0.00 to 39.00	Unlined	11.9802	7.294	1.285
			5.8467	5.33	1.14
			3.7349	4.57	0.92

1.11 Prevailing Water Conservation/Recharge Practices: In the study area there are ~53 percolation tanks, 75 Check dams and 195 farm ponds. Under Mission Kakatiya (Phase-1 to Phase-4) 405 tanks were desilted and renovated under RRR (Repairs, restoration and Rejuvenation) schemes.

1.12 Geology:

Major part of the study area is underlain by Gondwana formation. Recent to Archaean age formations can be seen in the area. Archaean crystallines rocks occupy westen part of the district covering 15% of the area, represented by pink and grey granites, at places they are intruded by dolerite dyke rocks.

Pakhal Group of sediments, equivalent of upper Cuddapah rocks in age is represented by dolemitic limestones and conglomerates. These rocks occur in NW and west central parts of study area. The general strike of these rocks is NW-SE to NNW-SSE with dips of 5^0 to 20^0 to NE.

Sullavai formations belonging to Kurnool group of rocks are well represented in Central and NW part of the study area, represented by massive sandstones and shales forming hills in the central parts and in Ramagundam area. These rocks are brown to brick red in colour, quartzite to felspathic with general strike direction of NW-SE to WNW-ESE diping 10^0 to 30^0 towards NE.

Gondwana formations overlie the Pakhal group of rocks in the area. These rocks are divisible in to two groups. The Talchir, Brakar, Barren measures and Kamthi constitute Lower Gondwana whereas Maleri, Kota and Chikiala formations comprise the Upper Gondwanas Group. The lower group is well represented by Barakar sandstones, which are grayish white, fine to coarse at times to gritty feldspathic. These are intercalates with grey clays and coal seams. The workable coal seams are located in Ramagundam, Godavari Khani and Kamanpur areas. The Maximum thickness of these rocks is about 350 m as determined by boreholes data. The barren measures are represented by very coarse to coarse grained feldspathic sandstones with grey clays and carbonaceous clays without any coal deposits, these rocks are present below the Kamthi formations. The Kamthis are mainly ferrugineous sandstones and intermingled with clay zones, they are medium fine grained with cross bedding at places and form massive cliffs and escarpment of hills (east of Manthani). These rocks are covered by thick vegetations and often form raised mounds as in Mahadevpur, Kataram, Maha Mutharam and Manthani areas. The thickness of these formations is stated to be about 300 metres.

Maleri formations form narrow bands between Kamthi and Kota formations and comprise of coarse to gritty, pale grey to reddish sandstones occurring in Maha Mutharam area. Kota formations overlie Maleri formations. Their contact with Kamthis is structural and occurs

as low relief areas comprising shales and clays intercalated with fine to medium grained sandstones. These are exposed in Nashtarpalli, Chintakani, Gangaram areas of Mahadevpur and Maha Mutharam mandals. Chikialas form youngest formations of Gondwanas comprising light brown red buff coloured ferruginous sandstones and conglomerates intercalated with clays and shale beds. These rocks occur as narrow bands in eastern part of the area.

Gondwana formations represented by Barakar and Kamthi sandstones of Lower Gondwana age and Maleri and Kota formations of Upper Gondwana age are well represented in Kamanpur, Manthani, Ramagundam, Kattaram and Mahadevpur mandals.

Alluvial deposits of Recent in age consist of sands and clays occur along banks of the Maner and the Godavari rivers in the area. The sands are fine to medium grained mixed with gravel and silt. The thickness of alluvial deposits range from 3 to 16 m. at Mahadevpur. The general geological succession of the area is presented as ***Table-1.2.*** The Geology (Principal Aquifer) and Stratigraphy map of the studt area is given in ***Fig- 1.9*** and ***Fig- 1.10.***

Table-1.2 : General Geological Succession

ERA/Age	Group/System	Series	Lithology
Lower Cretaceous to Upper Triassic	Upper Gondwana	Kota	Sandstones, clays and limestones
		Maleri	Red clays and calcareous sandstones
Lower Triassic to Upper Carboneferous	Lower Gondwana	Kamthi	Ferroginous sandstones, grits, clays and shales
		Barren Measures	Feldspathic sandstones, shales, carbonaceous clay
		Barakars	Feldspathic sandstones, siltstones and coal seams
		Talchirs	Boulder bed and fine grained sandstone
Unconformity			
Lower Palaeozoic to Upper Pre-Cambrian	Vindhyan	Sullavai	Orkosic quartzites and sandstones
Upper Pre-Cambrian	Pakhals	-	Shale, dolomite, basal conglomerates
Unconformity			
Lower Pre-Cambrian	Dharwarian		Schists, banded heamatites and quartzites
	Archaean		Pink and grey granites & gneisses

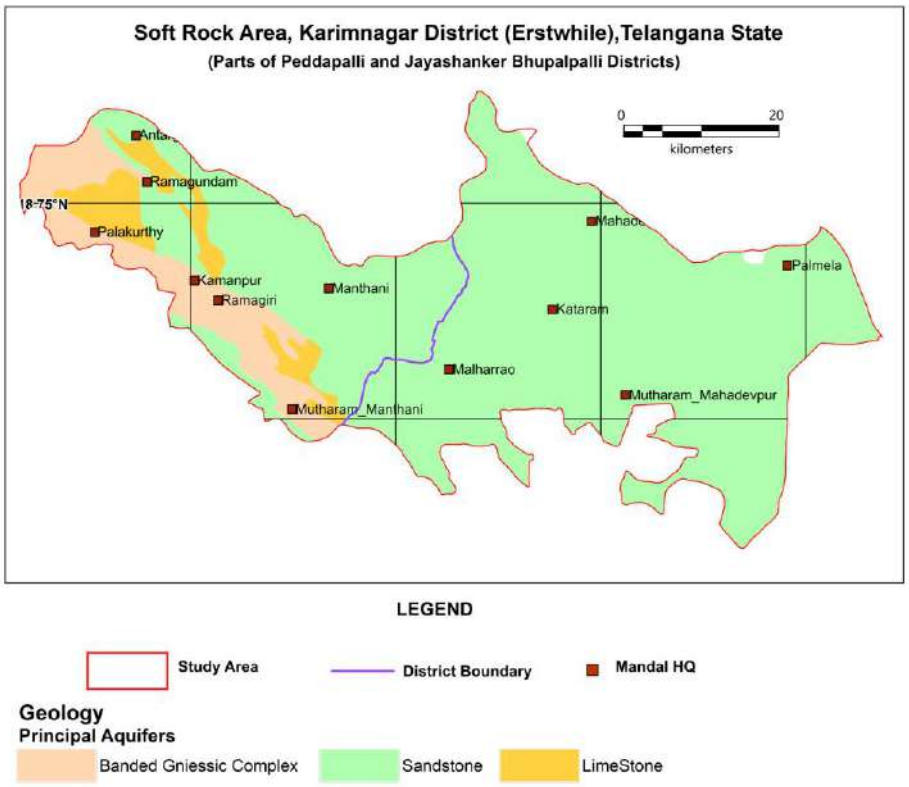


Fig.1.9: Geology – Principal Aquifer System.

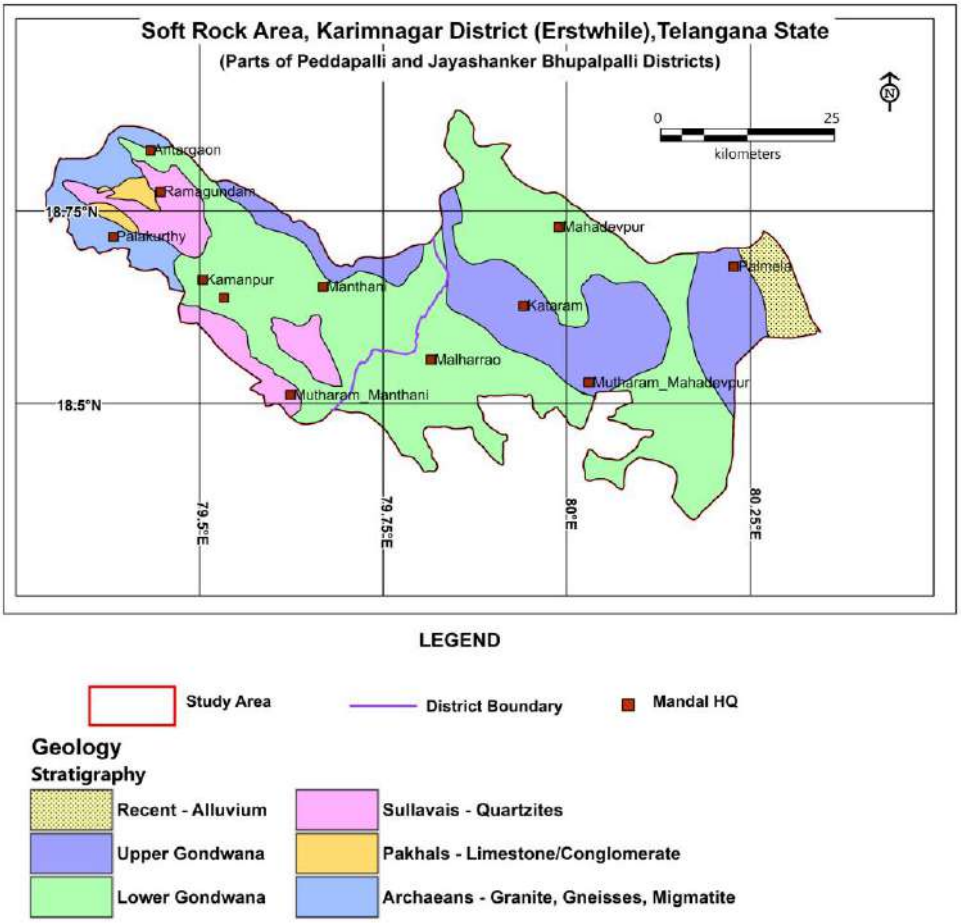


Fig.1.10: Geology – Stratigraphy

2. Data Collection and Generation

Collection and compilation of data for aquifer mapping studies is carried out in conformity with Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various data generation activities **(Table-2.1)**.

Table-2.1: Brief activities showing data compilation and generations.

S. No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc.
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
2.	Generation of Data	Generation of geological layers (1:50,000)	Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern.
		Surface and sub-surface geo-electrical and gravity data generation	Vertical Electrical Sounding (VES), bore-hole logging, 2-D imaging etc.
		Hydrological Parameters on groundwater recharge	Soil infiltration studies, rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of sub-surface hydrogeological sections.
		Generation of additional water quality parameters	Analysis of groundwater for general parameters including fluoride.
3.	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.
4.	Aquifer Management Plan	Preparation of aquifer management plan	Information on aquifer through training to administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain.

2.1 Hydrogeological Studies

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of ground water occurring in the subsurface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. The principal aquifers in the area are Sandstone, Granites and Limestone. The occurrence and movement of ground water in sedimentary rocks is controlled by the granular zones and their interconnectivity whereas in granites controlled by the degree of interconnection of secondary pores/voids developed by fracturing and weathering. Based on 68 hydrogeological data points (**Fig.2.1)** hydrogeological map is prepared.

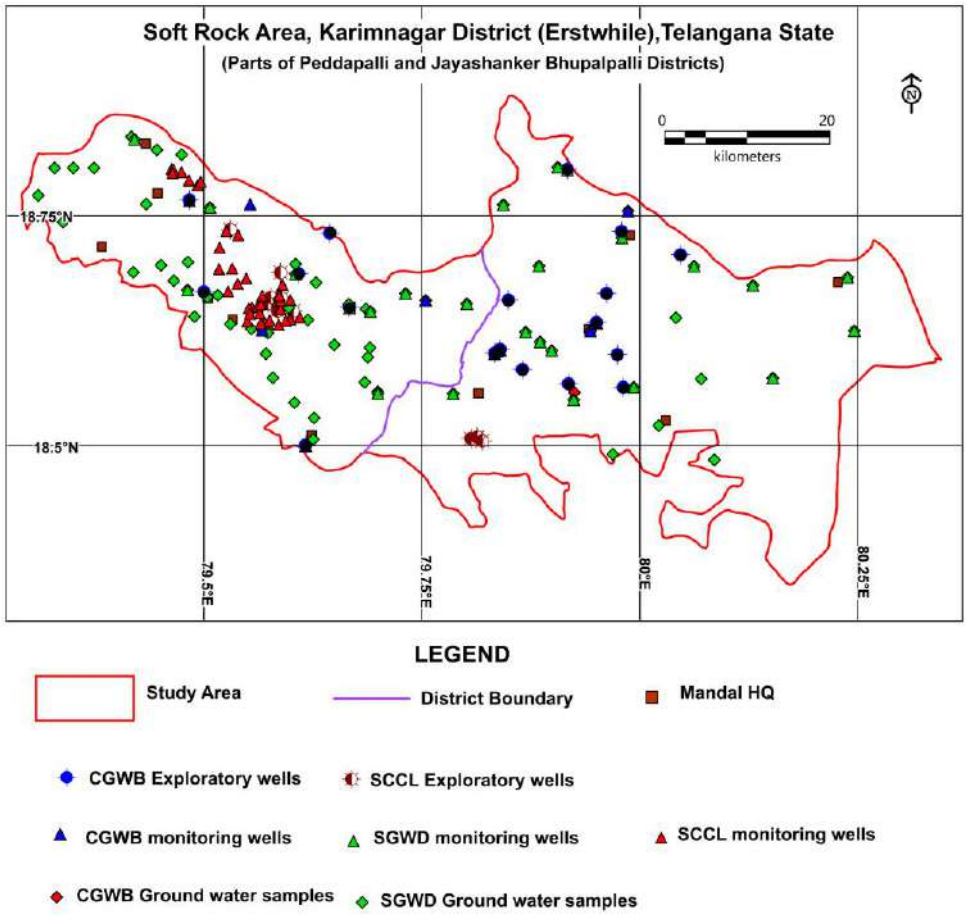


Fig. 2.1: Hydrogeological data availability.

2.1.1 Ground water occurrences and movement: Ground water occurs under unconfined and semi/confined conditions. On the basis of occurrence and movement of water in the subsurface, the aquifers in the area are grouped into two types i. Consolidated formations (Granites and Quartzites) and ii. Unconsolidated formation (Sedimentary rocks)

i. Consolidated formations : The consolidated aquifers include Granites and Quartzites of Precambrian age where the aquifers constitute the weathered zone at the top, followed by a discrete anisotropic fractured/fissured zone at the bottom, generally extending down to 200 m depth.

ii. Unconsolidated formation (Sedimentary rocks): The Unconsolidated formations include the sedimentary formations of Gondwana and recent alluvium deposits. These aquifers constitute the unconfined zone at the top, followed by confined aquifers saperated by clay layers which act as aquitards (confining beds). In the area two confined aqufers are demarcated upto a depth of 300 m. The hydrogeological map of the area is presented in **Fig. 2.2**.

2.1.2 Hydrogeology of Coal mine area : Ramagundam Coal belt comprises of 16 underground coal seams, they occur at 40 to 300 m in mine inclines in the geological horizons of Barakar sandstones and Barren measures of lower Gondwana group. The estimated thickness of subsurface geological formations based on coal exploration is given below in table. The aquifer tests conducted at three borewells with depth of 200 m. in Barakar sandstone shows groundwater discharge of 126 to 560 lpm with a drawdown of 41.8 to 51.4 m. The transmissivity varies from 2.19 m^2/day to 32.3 m^2/day with a storativity of $1.1x10^{-3}$ to $3.38x10^{-4}$.

Table: Details of Subsurface Geological formations

Geological Formation	Thickness (m)
Kamthi Sandstones	1600
Barren Measures	500
Barakar Sandstones	275
Talchir formations	200

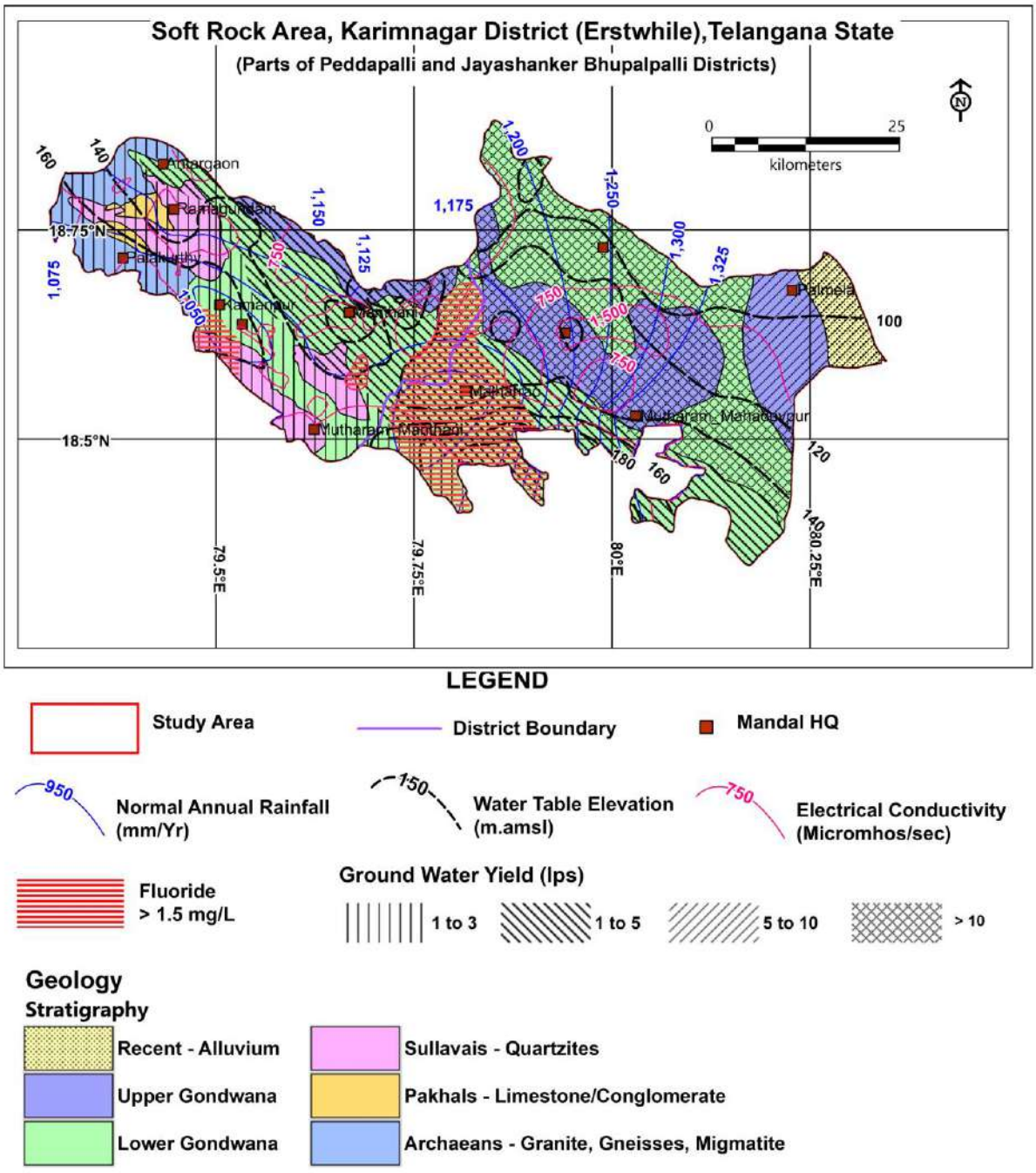


Fig.2.2: Hydrogeological map of Karimnagar district (Erstwhile) Soft rock area.

2.1.3 Exploratory Drilling: As on 31/03/2020, CGWB drilled 28 bore wells (exploratory, observation and piezometers) in the study area, out of which 26 wells are drilled in sedimentary formations and 02 wells were were drilled in granitic terrain. Tube well depth analysis of 28 exploratory wells indicates, 02 well are in shallow depth (30 m), 05 wells are in the depth range of 30-100 m, 04 wells are in the depth range of 100-200 m and 17 wells are in the depth range of 200-300 m depth**.** 10 representative exploratory well data of SCCL were also utilized for the conceptualization of the Aquifer system in the area.

2.1.4 Ground water Yield: Ground water yield in granitic aquifers varies from <1 to 3 lps (avg: 1.5 lps). In soft rocks, the ground water yields vary from 1 to 25 lps. In Barren measures, Quartzites and Sandstone areas yield varies from 1 to 5 lps. In Maleri and Kota formations, Yield varies between 5 and 10 lps where as Kota and Kamthi formations show maximum yields varying between 10 and 25 lps. (**Fig.2.2).**

2.2 Water Levels (10 Years Average): Ground water levels from 82 piezometers (CGWB:14, SGWD: 26 and SCCL :42) were analysed for pre-monsoon and post-monsoon season.

2.2.1 Water Table Elevations: During pre and post-monsoon season (May and November), the water-table elevation ranges from 93-182.3 and 70.3-182.8 meter above mean sea level (m amsl) respectively and general ground flow is towards river Maneru and towards river Godavari mostly from south to north. (**Fig.2.3**).

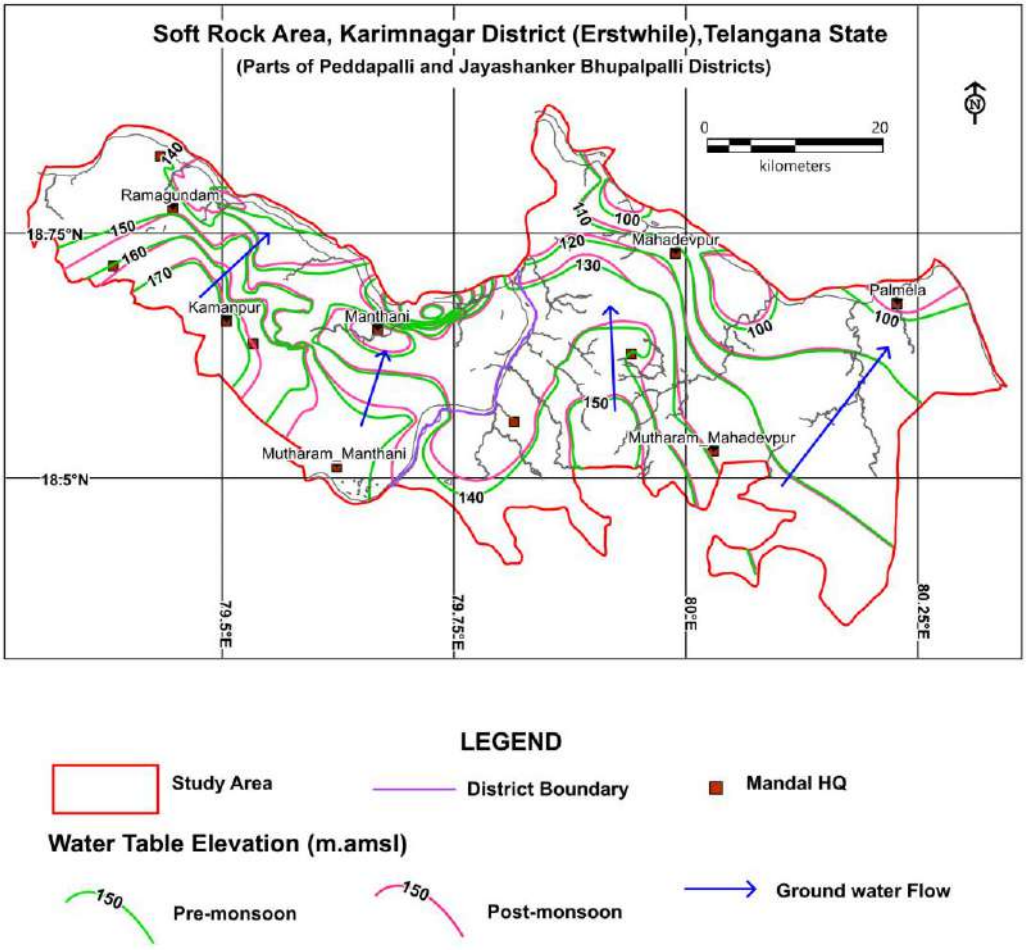


Fig.2.3: Water table elevations (m amsl) during pre and post-monsoon season.

2.2.2 Depth to Water Levels (DTW): The DTW varies from 1.2 to 26 meter below ground level (m bgl) (average: 8.6 m bgl) and 0.5- 25 m.bgl (average: 6.8) during pre and post-monsoon seasons respectively.

Pre-monsoon season:

Majority of the water levels during this season are in the range of 2-10 m covering 90% of the area, followed by 10-20 m.bgl (9%). Deep water levels in the range of 20-40 m.bgl occupy about < 1% of the area falling in parts of Ramgiri mandal (**Fig.2.4**). Shallow water levels (< 2 m.bgl) occupy about < 1% of the area in Mahadevpur mandal and 2 to 5 m.bgl occupy about 33% of the area in southeastern, central and isolated parts in weatsren parts of the area .

Post-monsoon season:

Majority of the water levels during this season are in the range of 2-10m covering 92% of the area, followed by 10-20 m.bgl (6%). Deep water levels in the range of 20-40 m.bgl occupy about < 1 % of the area falling in parts of Ramgiri mandal (**Fig.2.5**). Shallow water levels (< 2 mbgl) occupy about 2% of the area in Mutharam Mahadevpur, Ramagundam mandals and 2 to 5 m.bgl occupy about 67% of the area in southern parts of the area .

2.2.3 Water Level Fluctuations (May vs. November): The water level fluctuations vary from -2.33 to 5.66 m with average rise of 1.79 m (**Fig.2.6**). Eight wells (9%) registered fall in water levels and 74 wells (91%) show rise in water levels. Rise in water level in the range of 0 to 2m. cover majority of area (55%) followed by 2 to 5 m. covering 30% of area. Water level fall of 0 to 2 m. is observed in 15% of area mostly in southeaster, northern and central parts.

2.2.4 Long term water level trends: Trend analysis for the last 10 years (2011-2020) is studied from hydrograph stations of CGWB and SGWD. It is observed that during pre-monsoon season out of 38 wells, 28 wells (74%) shows falling trend (0.01 to 1.77 m/Yr) and 10 wells (26%) shows rising trend (0.08-1.3 m/yr). During post-monsoon season out of 38 wells, 16 wells (42%) show falling trend (0.01 to 1.64 m/Yr) and 22 wells (58%) shows rising trends (0.01 to 1.75 m/Yr). The long term water level trend map of pre-monsoon and post-monsoon is given in **Fig 2.7a** and **Fig 2.7b**.

2.3 Geophysical Studies

The Geophysical surveys are carriedout by CGWB, SGWD and NGRI in the area. Geophysical surveys conducted in 30 locations, including bore hole logging and VES by CGWB in the study area. Surveys indicated top soil upto 3 m with resistivity of 10 to 50 ohm m, weathered zone from 4 m to 18 m with resistivity of 30 to 80 ohm m. The fractured rock existed upto 22 m with a resistivity of 150 ohm m. The typical sequence of Pakhal formations showed clay (6 ohm m) shale (42 ohm m) quartzite (324 ohm m), shaly dolomite (40 ohm m) dolomite (180 ohm m) Sullavai sandstone with several intercalations of quartzite and sandstone proportions.The sandstones have resistivity of 120 to 150 ohm m in Sri Rampur and Manthani areas. Talchir formations exhibited a resistivity of 5 to 45 ohm m with thickness of 260 to 350 m. The sounding in Barakar and Barren measure formations at Khammanpalli, Tadicherla, Tundla and Ramakrishnapur showed intercalations of shale or underlying Talchir clays with a resistivity 60 ohm m. When thickness of sandstone is greater than shale the resistivity is about 86 ohm m. Vertical electrical soundings (VES) at Koyyuru, Yedlapalli, Rudraram and Medipalli in Kamthi sandstones showed a resistivity of 50 to 85 ohm m indicating productive aquifers. The Kamthi beds are found to occur at greater depths below clay horizons of Maleri and Kota formations at Medipally and Basavapuram villages. The sequences of formations at Nashtarpally, Dhanwada and Basvapuram showed the presence of clay stone with a resistivity of 6 to 20 ohm m and the resistive sandstone horizon with clay zone is well indicated as in Dhanwada village. The zones with greater than 100 ohm m resistivity are considered good aquifers for ground water development. The deep soundings conducted between Chintakani and Saranpalli revealed occurrence of thick sequence of clay zone down to 400 m depth.The VES at Mahadevpur and Bommapur indicated top soil 1-3 m, second layer is clayey sandstone with resistivity of 10 to 60 ohm m. Third layer of weathered sandstone with 30 m to 80 m thickness has resistivity of 60 to 215 ohm.m. 4^{th} layer is either coarse grained sandstone with resistivity of 240 ohm.m or sandy clay with 18 to 70 ohm.m.

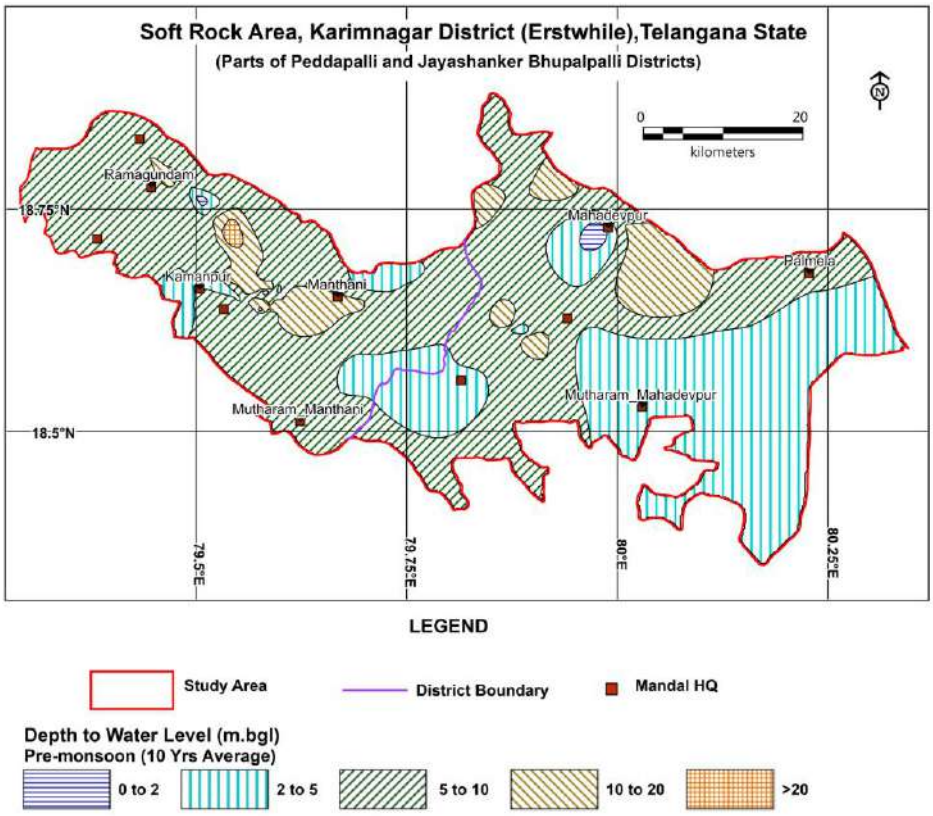


Fig.2.4: Depth to water levels Pre-monsoon (10 Yrs Average).

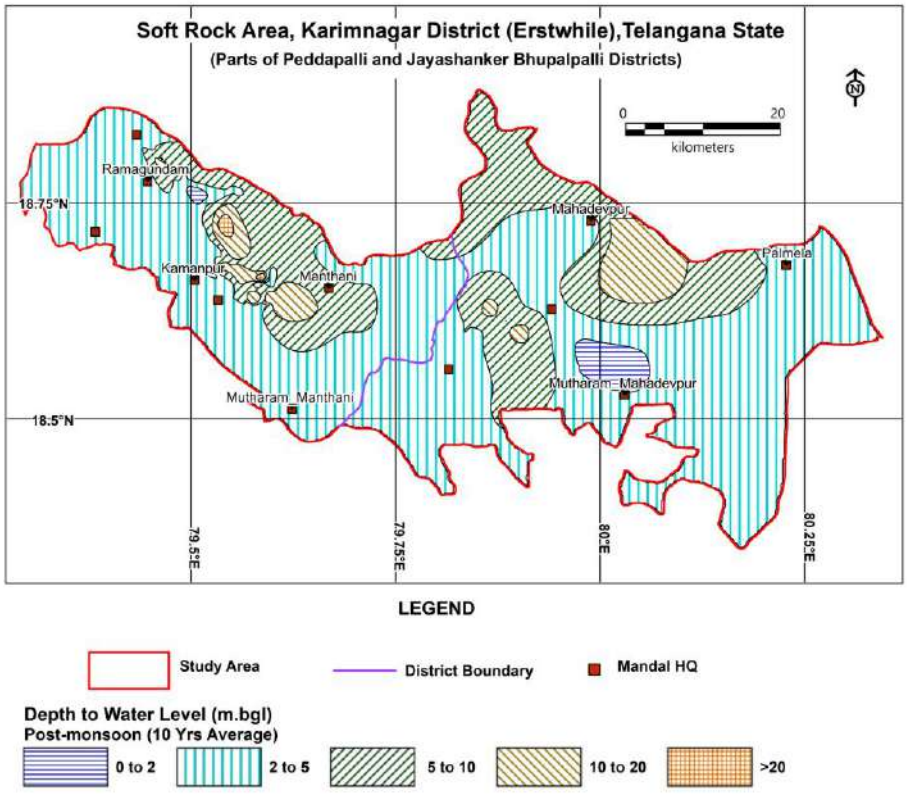


Fig.2.5: Depth to water levels Post-monsoon (10 Yrs Average).

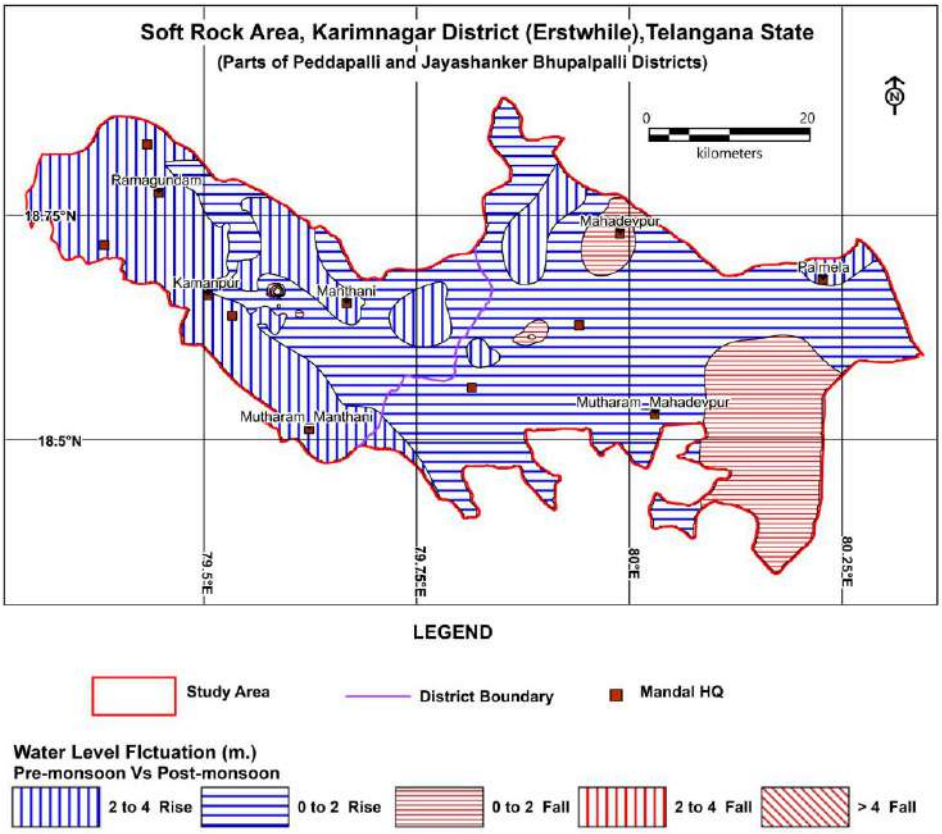


Fig.2.6: Water Level Fluctuations (m) (Nov with respect to May), 10 Yrs Average.

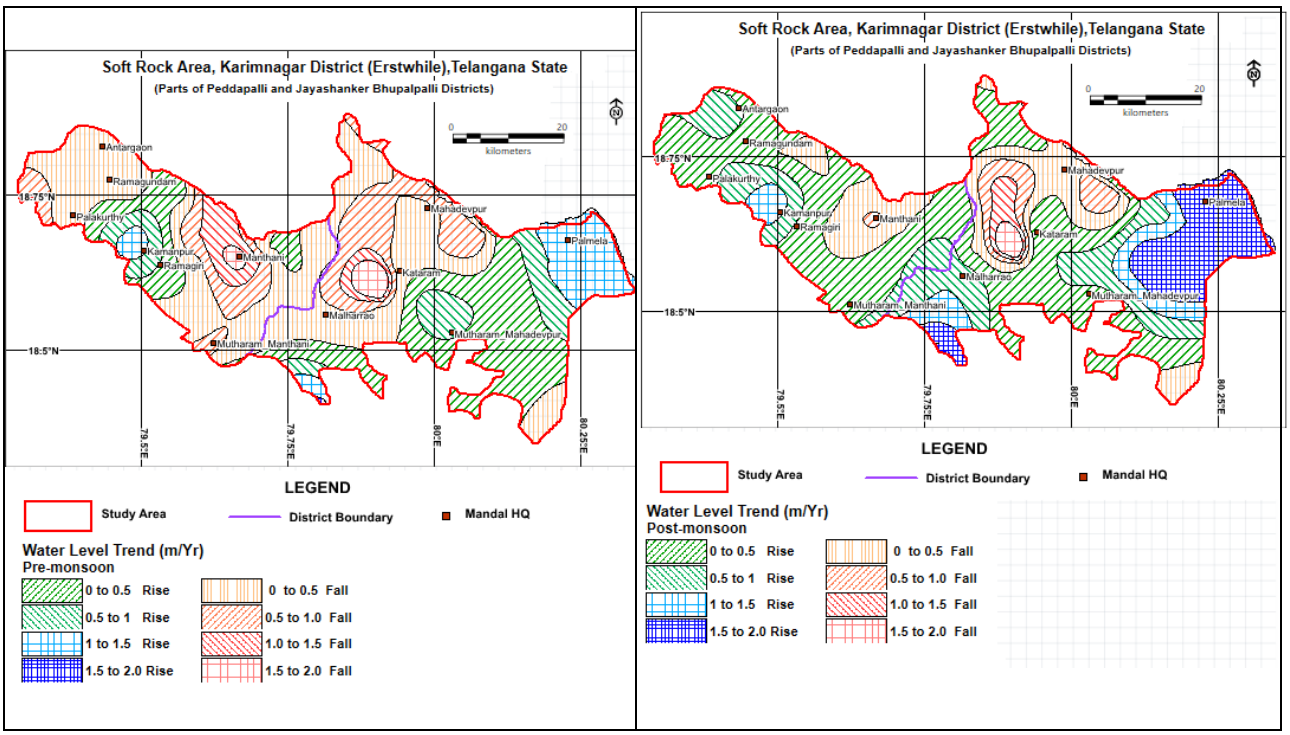


Fig. 2.7a-b: Long-term water level trends (2011-2020).

2.4 Hydro chemical Studies

To understand chemical nature of groundwater, total 137 data is utilized from ground water monitoring wells of CGWB and SGWD wells (Pre-monsoon:71 and post-monsoon:66) (mostly tapping combined aquifers Aq-1 and Aq-2) during the pre-monsoon and post-monsoon season of 2019. Parameters namely pH, EC (in µS/cm at 25 ° C), TH, Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, NO_3 and F were analyzed.

2.4.1 Pre-monsoon (Total 71samples were analyzed (CGWB: 5, SGWD:66):

Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 7.25-8.79 (Avg: 8.21). Electrical conductivity varies from 158-2300 (avg: 1047) µ Siemens/cm**.** In 86 % of area EC is within 1500 µ Siemens/cm, in 14 % area, it is 1500-3000 µ Siemens/cm **(Fig.2.8).** Average concentration of TDS is 667 mg/L and NO_3 ranges from 1-350 mg/L. Nitate concentration in 42% of samples is beyond permissible limits of 45 mg/L (**Fig.2.9**). Fluoride concentration varies from 0.05-2.52 (**Fig 2.10**), 92 % of samples are within permissible limits of BIS and rest is beyond permissible limit of 1.5 mg/L. High fluoride concentration is observed in southern and south-central parts of the area. Over all 34 samples (47%) are unfit for human consumption in the study area.

2.4.2 Post-monsoon (Total 66 samples were analyzed):

Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 7.17-8.69 (Avg: 8.17). Electrical conductivity varies from 199-2453 (avg: 986) µ Siemens/cm**.** In 95% of area EC is within 1500 µ Siemens/cm, in 05% of area EC is 1500 to 3000 µ Siemens/cm (**Fig.2.11).** Average concentration of TDS is 631 mg/L and NO_3 ranges from 1-279 mg/L. Nitate concentration in 26% of samples is beyond permissible limits of 45 mg/L (**Fig.2.12**). Fluoride concentration varies from 0.1-2.61 (**Fig 2.13**) and 96% of samples are within permissible limits of BIS and rest is beyond permissible limits of 1.5 mg/L. High fluoride concentration is observed in southern and south-central parts of the area. Over all 26% of samples are unfit for human consumption in the study area.

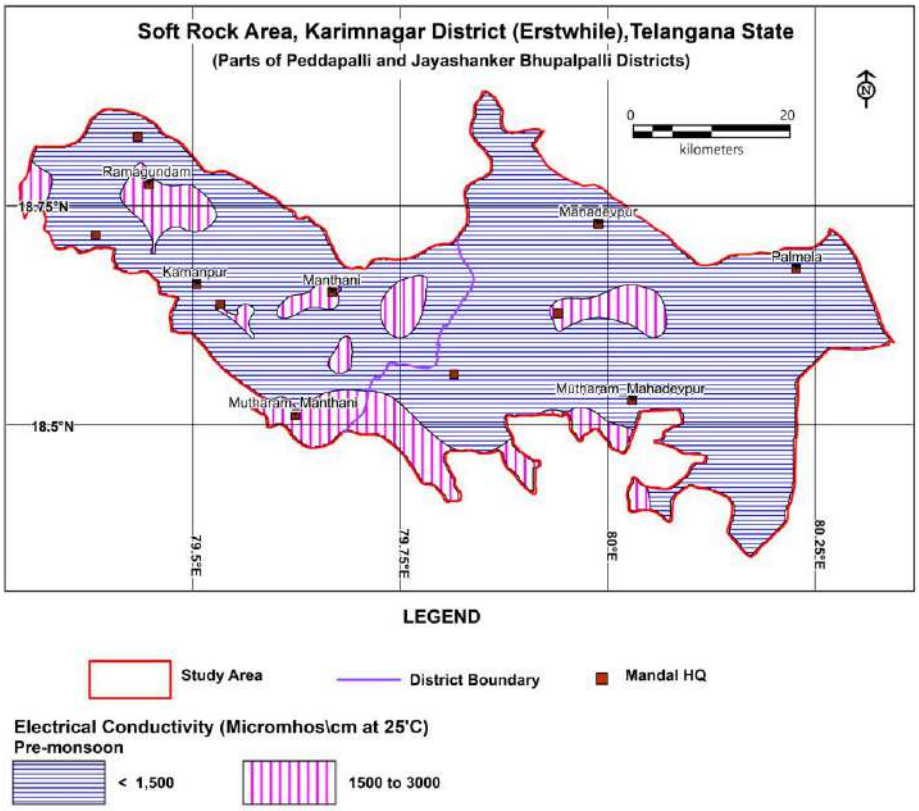


Fig.2.8: Distribution of Electrical conductivity (Pre-monsoon-2019).

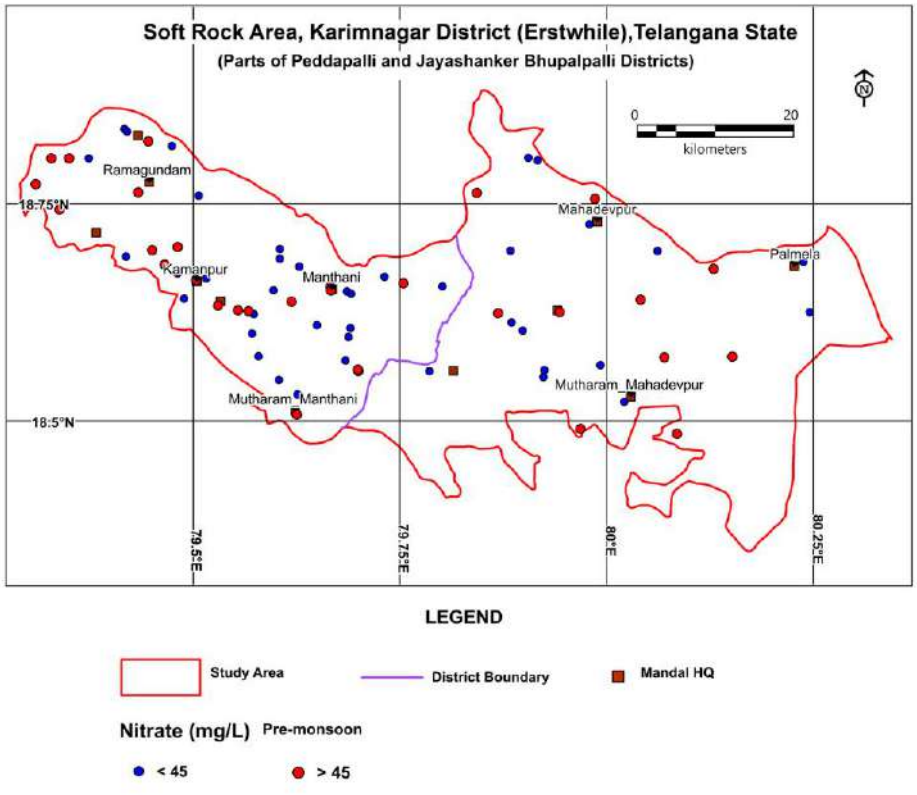


Fig.2.9: Distribution of Nitrate (Pre-monsoon-2019).

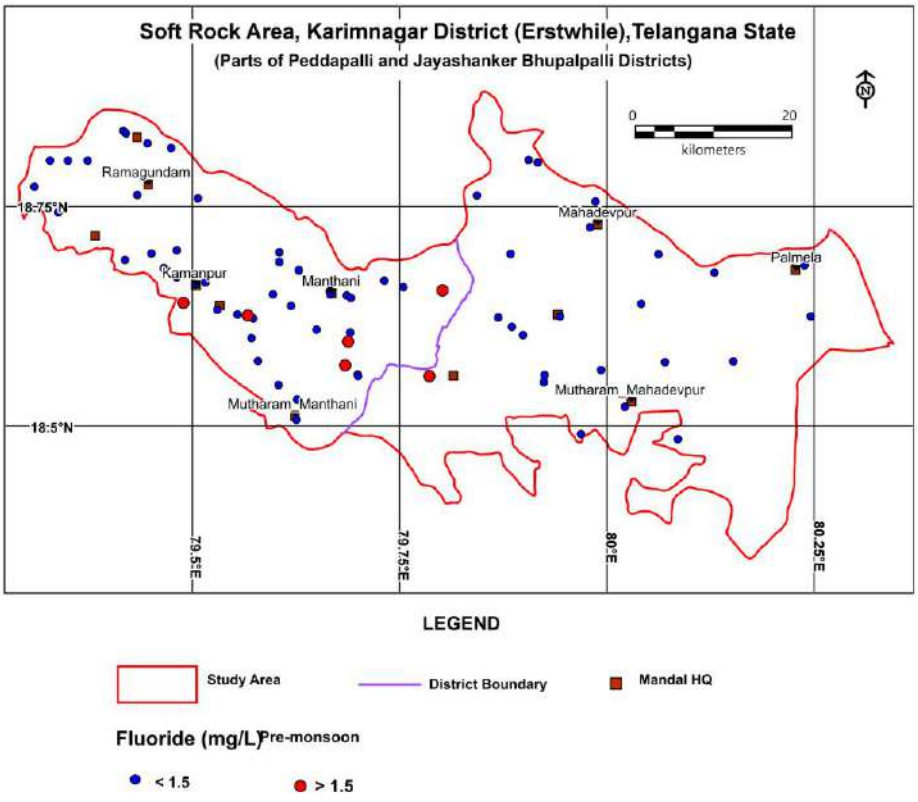


Fig.2.10: Distribution of Fluoride (Pre-monsoon-2016).

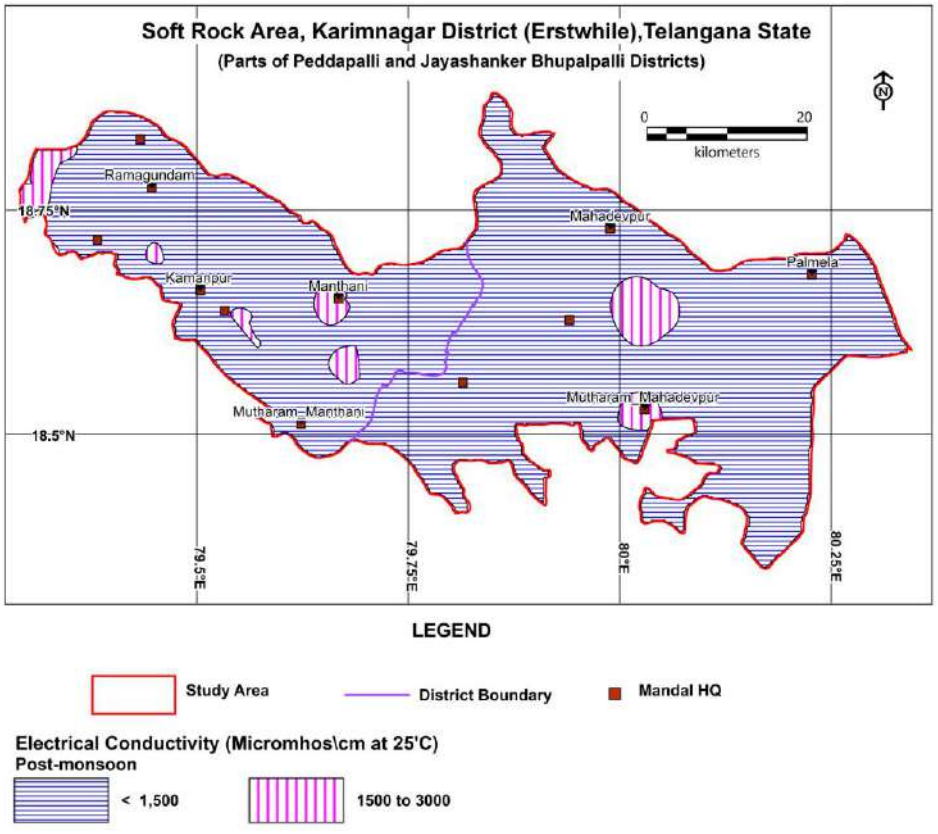


Fig.2.11: Distribution of Electrical conductivity (Post-monsoon-2019).

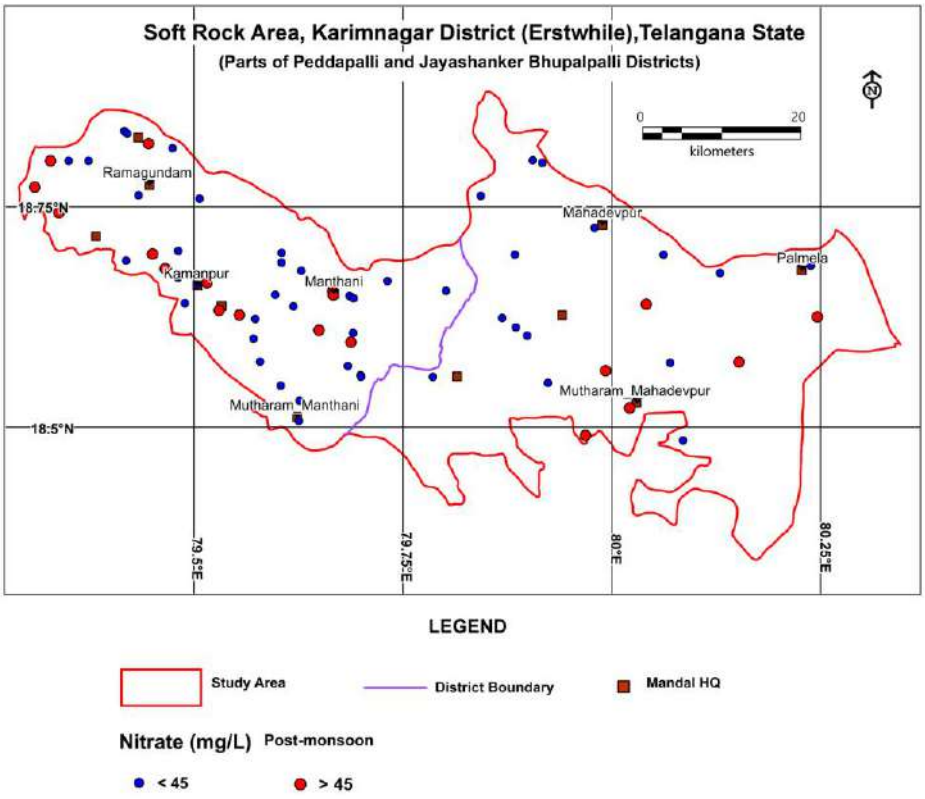


Fig.2.12: Distribution of Nitrate (Post-monsoon-2019).

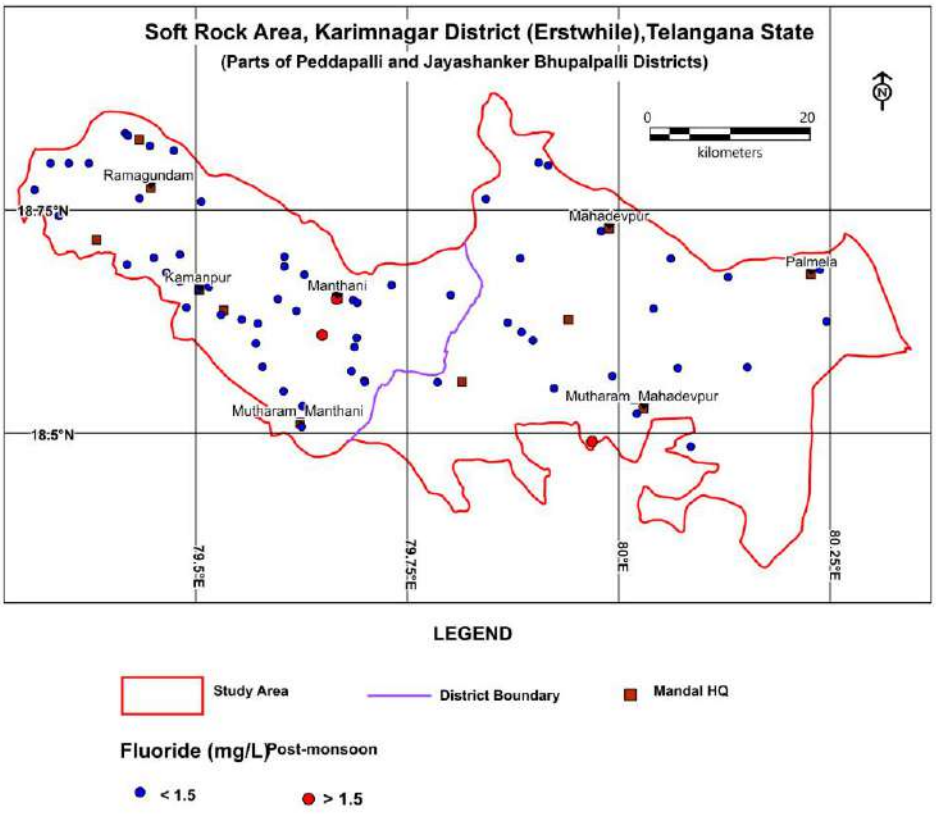


Fig.2.13: Distribution of Fluoride (Post-monsoon-2019).

3. DATA INTERPRETATION, INTEGRATION and AQUIFER MAPPING

Conceptualization of 3D hydrogeological model was carried out by interpreting and integrating representative 68 data points (both hydrogeological and geophysical data down to 300 m) for preparation of 3-D map, panel diagram and hydrogeological sections. The data (**Fig.2.1**) is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data. The perusal of the data indicates that there are multi aquifers in the area with intervening thick clay beds. Sandstone beds act as aquifers in the area and two to five distinct aquifers identified. Thin beds and pinched beds are neglected in making out the regional aquifer system. The lithological information was integrated by using the RockWorks-16 software and generated 3D map of the area (**Fig.3.1)** along with hydrogeological sections (**Fig.3.3a to 3.3d)**.

Type of Aquifer	Depth range (m.bgl)
Unconfined Aquifer (Aquifer-I)	4 to 50
Confined Aquifer (Aquifer-II)	33 to 150
Confined Aquifer (Aquifer group-III)	140 to 300

3.1 Conceptualization of aquifer system in 3D

Aquifers were characterized in terms of potential and quality based on integrated hydrogeological data and various thematic maps. In consolidated formation, Weathered zone is considered up to the maximum depth of weathering upto first fracture encountered (below weathered depth) generally down to ~20 m depth and the fractured zone (fractured granite) is considered up to the depth of deepest fracture encountered below weathered zone. In unconsolidated formation aquifers are classified into 3 Aquifer units, viz. Unconfined Aquifer (Aquifer-I), Confined/Semiconfined Aquifer (Aquifer-II) and Confined Aquifer group-III where the deeper aquifers are grouped into one unit due to inadequate aquifer wise data (**Fig.3.1)**.

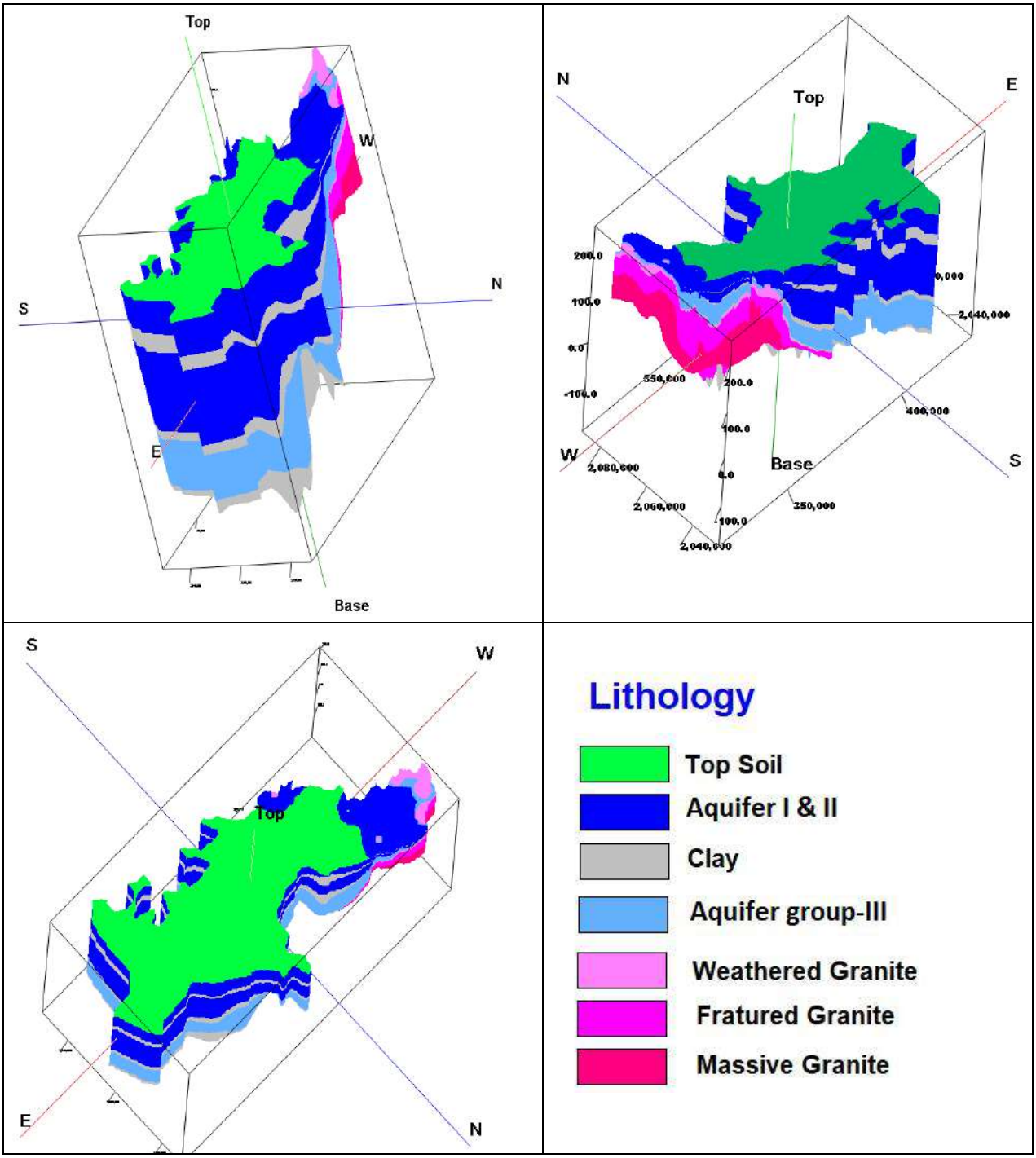


Fig.-3.1:3-D Model for study area.

3.2 Hydrogeological Sections

4 Hydrogeological sections are prepared in NW-SE, SW-NE,W-E and N-S directions (**Fig. 3.2**).

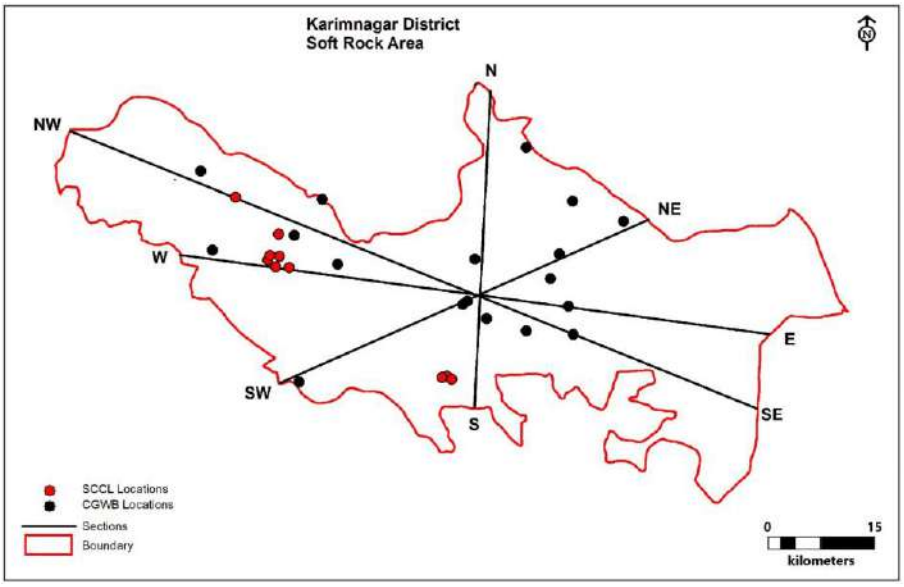


Fig.-3.2: Map showing orientation of various sections.

3.2.1 North-West and South-East Section: The section drawn along the NW-SE direction covering distance of ~90 kms (**Fig.3.3a**). It depicts weathered zone and fractured zone in Granites in north-western part extending from 0 to 25 km. and granular zones extend from 25 km to 90 km. Relatively thick clay beds are seen towards the southe-western parts. Thick Aquifer-II can be seen in central and southe-west of the section.

3.2.2 West-East Section: The section drawn along the W-E direction covering distance of ~90 kms (**Fig.3.3b**). It depicts weathered zone and fractured zone in Granites in north-western part extending from 0 to 25 km. and granular zones extend from 25 km to 90 km. Relatively thick clay beds are seen towards the southe-western parts. Thick Aquifer-II is seen at Nashatarpalli, in the eastern side, relatively thin granular zones noticed in the central par of the section near Manthani and Gangaram villages.

3.2.3 South-West and North-East Section: The section drawn along the SW-NE direction covering distance of ~80 kms (**Fig.3.3c**). It depicts weathered zone and fractured zone in Granites in south-western part extending from 0 to 25 km. and granular zones extend from 25 km to80 km. Relatively thick clay beds are seen in central part. Thickness of Aquifer-I & II is uniform through out the section except in central part near Medipalli village.

3.2.4 South-North Section: The section drawn along the S-N direction covering distance of ~22 kms (**Fig.3.3d**). It depicts the thickness of granular zones extending from south to north in the central part of the area. Relatively thick clay beds are seen in central part at

Medipalli village, Aquifer-I & II is uniform through out the section except in the central part.

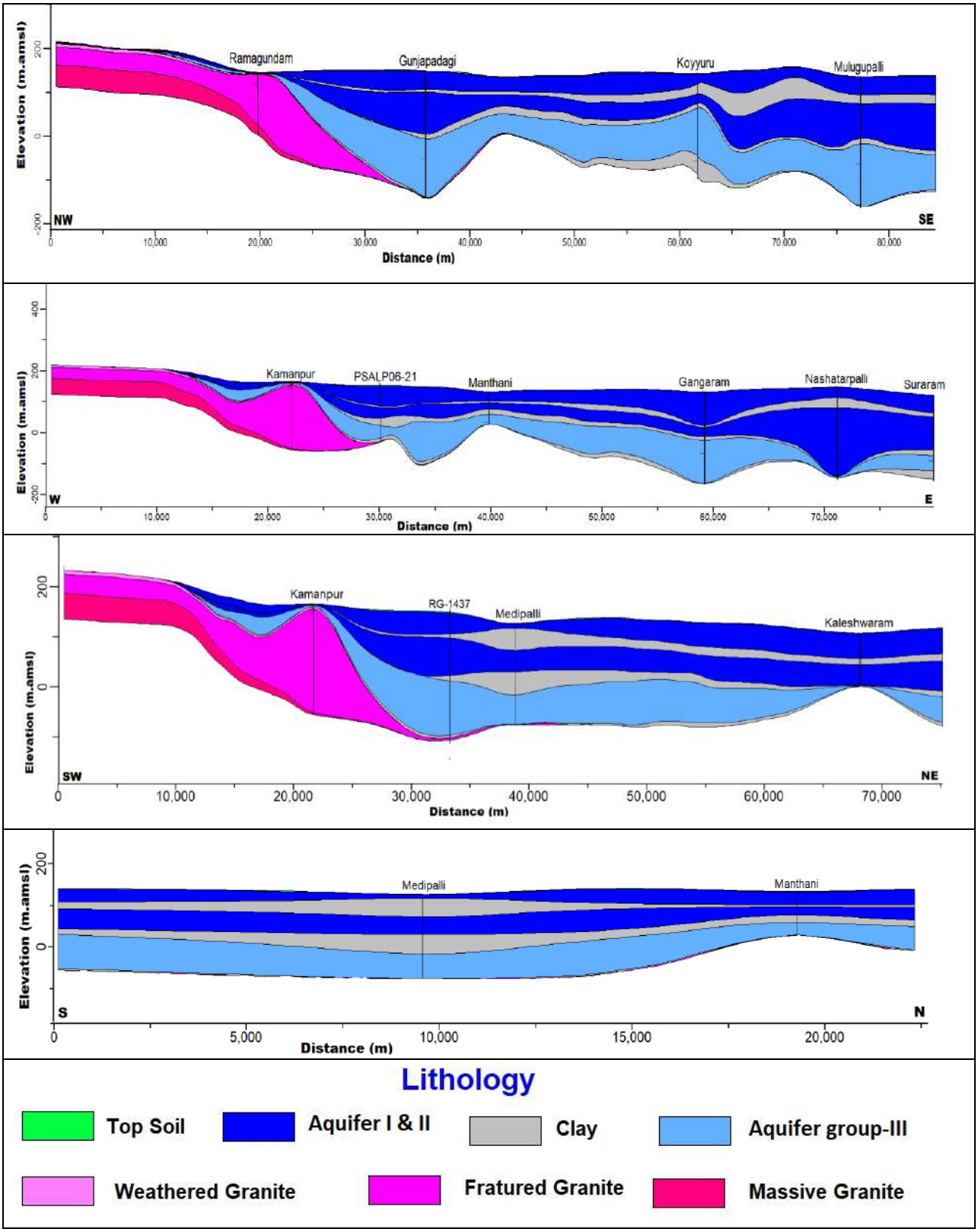


Fig.3.3 (a-d): Hydrogeological profile in different directions.

3.3 Aquifer Characterization

3.3.1 Aquifer-I/Unconfined Aquifer:

The unconfined aquifer thickness in unconsilodated (soft rock) formation range from 5 to 50 m. In hard rock area (Granitic formation) Weathered zone (~20 m) varies from meagre to 15 m.bgl.

Ground water yield of unconfined aquifer varies from <1 to 2 lps (avg: 1 lps) with transmissivity of 25 to 50 m^2/day. Ground water yield of weathered granite/gneiss aquifer varies from <0.1 to 2 lps (avg: 1 lps).

3.3.2 Confined/ Semiconfined Aquifers (Aquifer-II and Aquifer group-III):

Aquifer-II and Aquifer group-III are confined/semiconfined aquifer. Aquifer-II present below unconfined aquifer in the depth range of 30 to 150 m. saperated by clay layer with considerable thickness of 5 to 30 m. and Aquifer group-III present below aquifer-II in the depth range of 140 to 300 m. saperated by clay layer with thickness of 5 to 30 m. The transmissivity of these aquifers vary from 28 m^2/day to 668 m^2/day with storativity ranging from $5x10^{-4}$ to $2.5x10^{-4}$. The Aquifer with 160 m. thickness encountered at Koyyuru and Sthambampalli where potential aquifers with semi-artesian to artesian conditions. The yields of exploratory wells drilled in Kamthi formation range from 70 lpm to 120 lpm with transmissivity of 290 m^2/day to 668 m^2/day, where as the yields of Kota and Maleri sandstone range from 30 lpm to 35 lpm with transmissivity of 28 m^2/day to 50 m^2/day. The yields of exploratory wells drilled in Alluvial formation range up to 125 lpm.

3.4 Hydrogeology of Ramagundam coal mine area (SCCL)

The Ramagundam Coal Mine (RG Coal Mine) is formulated by amalgamating existing adjacent projects (viz., RG OC I Expansion Project, RG OC II Extension Project, Vakilpalli Mine, Adriyala Shaft Projects) and closed mines (i.e., Cluster of 10&10A) in Ramagundam area.

The Ramagundam Coal mine is located in the south eastern part of the Ramagundam coal belt, located in Ramagiri and Kamanpur Mandals of Peddapalli district, Telangana State. The Project is bounded by N latitude 18°36’48” to 18°41’31” and E longitudes 79°31’41” to 79°36’42” in the Survey of India Topo sheet No.56 N/10. The hydrogeology of the area

within 10km radius buffer zone around Ramagundam Coal mine (637.94 sq.km) has been studied by SCCL, The salient features of the study is given below.

- The buffer zone area covers 69 villages falling Ramagundam, Kamanpur, Ramagiri, Manthani, Muttaram (mnt), Peddapalli, Srirampur (Kaluva) and Palakurthi Mandals of Peddapalli District.

- The main crops cultivated in this area are Paddy, Cotton, Maize, Chilies, and Vegetables etc. The total area irrigated during Kharif and Rabi seasons are 13427.6 ha, 8416.6 ha respectively. Out of 21,844 ha total irrigated area, 7895 ha (36%) was irrigated by surface water and 13949 ha (64 %) by ground water.

- In buffer zone, there are 11 coal mines in operation, the water presently being pumped and its utility are given in table below. The total groundwater extracted from all the mines is 46,312 m^3/ day (16.9 MCM/Yr), out of which ground water used for mine requirement is 14234 m^3/ day (5.2 MCM/yr), Domestic use is 4915 m^3/ day (1.8 MCM/yr), Plantation is 1519 m^3/ day (0.55 MCM/yr), and excess water let out into streams and water bodies is 25644 m^3/ day (9.3 MCM/yr).

- The phreatic water levels varies from 1.97m.bgl to 10.80m.bgl during pre-monsoon season and 0.95m.bgl to 8.10m.bgl during post-monsoon season. The water level fluctuation varies from 0.03 to 6.68m with an average water level fluctuation of 3.21m.

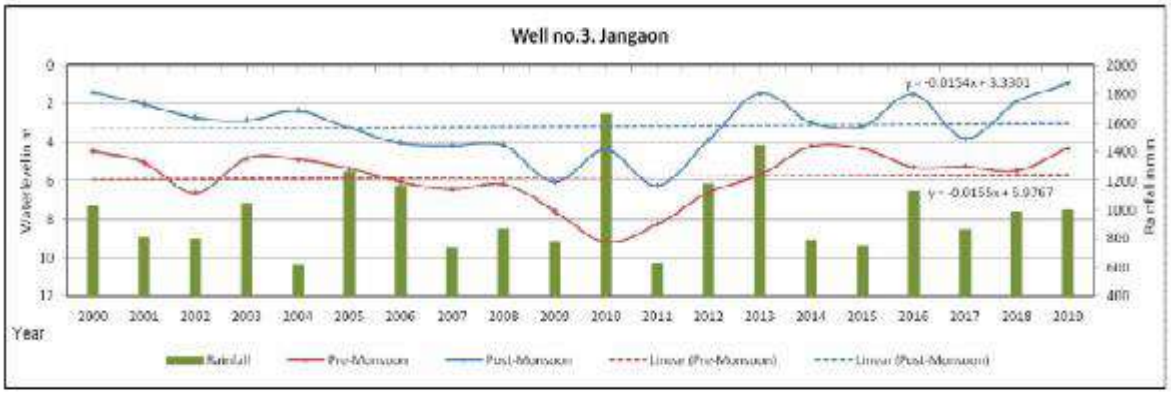
- The piezometric heads vary from 2.76 m.bgl to 26.15 m.bgl during pre-monsoon and 1.48m to 26.40m.bgl during post monsoon.

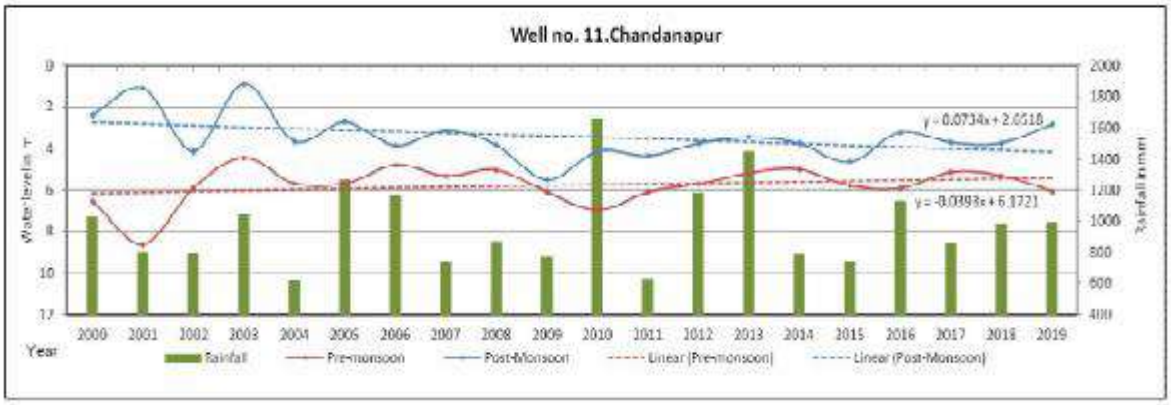
- The total groundwater draft in the buffer zone is about 15071.97 Ha.M/Year. Of this, draft from existing mines is about 1690.39 Ha.M/Year, while ground water used for irrigation is about 13017.59 (86% of total draft) Ha.M/Year.

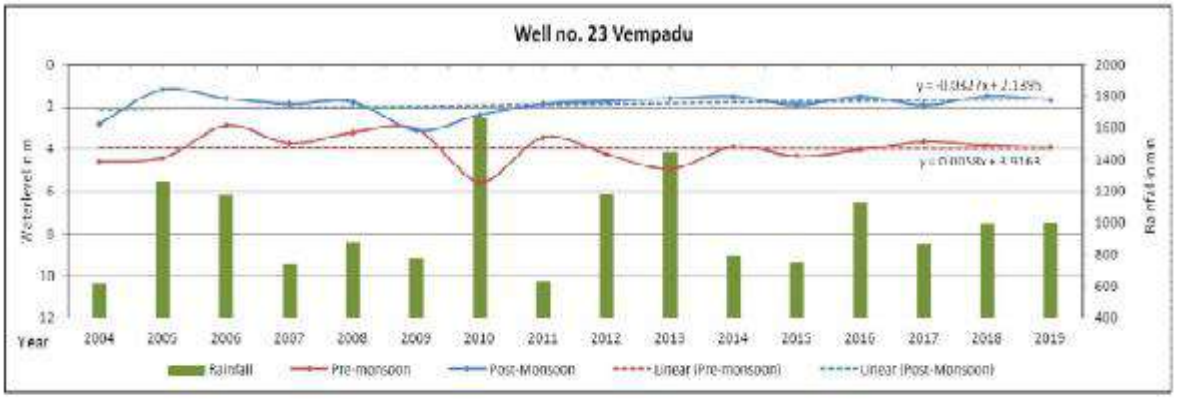
Mine-wise Ground water extraction and it's utility details in the buffer area

Sl. No.	Name of the Mine	Total quantity of water (m^3/day)				
		Pumped per day	Mine requirement	Domestic use	For plantation	Let out into streams
1	GDK 1&3	3067	1199	643	10	1215
2	GDK 2&2A	1800	1488	0	12	300
3	GDK 5	1100	700	0	400	0
4	GDK 7 LEP	3700	1200	500	200	1800
5	GDK 11	8360	3100	1500	20	3740
6	Vakilpalli	3250	750	500	200	1800
7	RGOCP-III	7896	1707	517	202	5470
8	GDK 10,10A	6834	3120	1200	400	2114
9	ALP	1605	20	30	5	1550
10	RGOCP-I	6900	700	20	50	6130
11	RG OC-II	1800	250	5	20	1525
	Total	46312	14234	4915	1519	25644

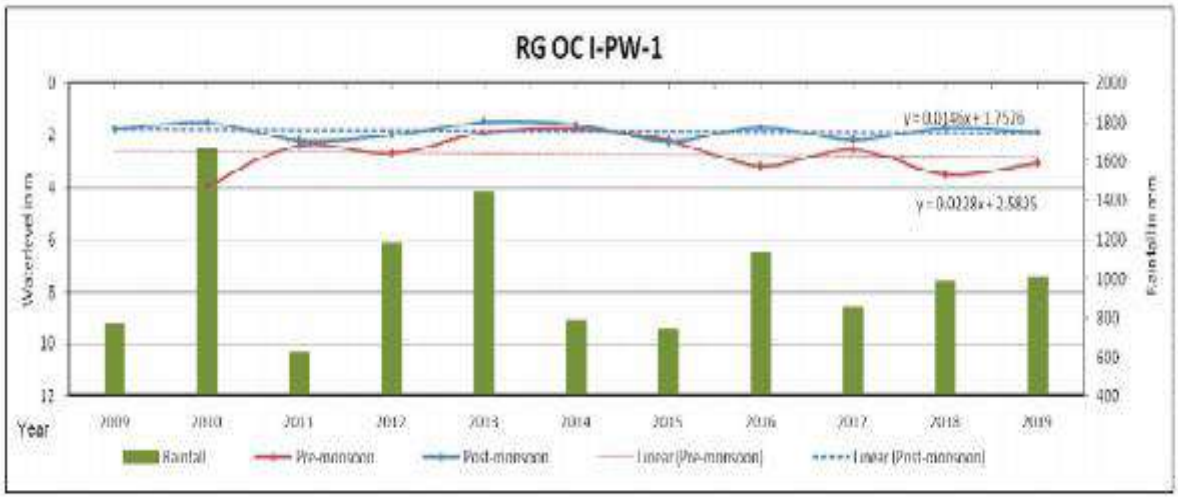
Hydrographs of Phreatic surface in the buffer area of RG Coal Mine

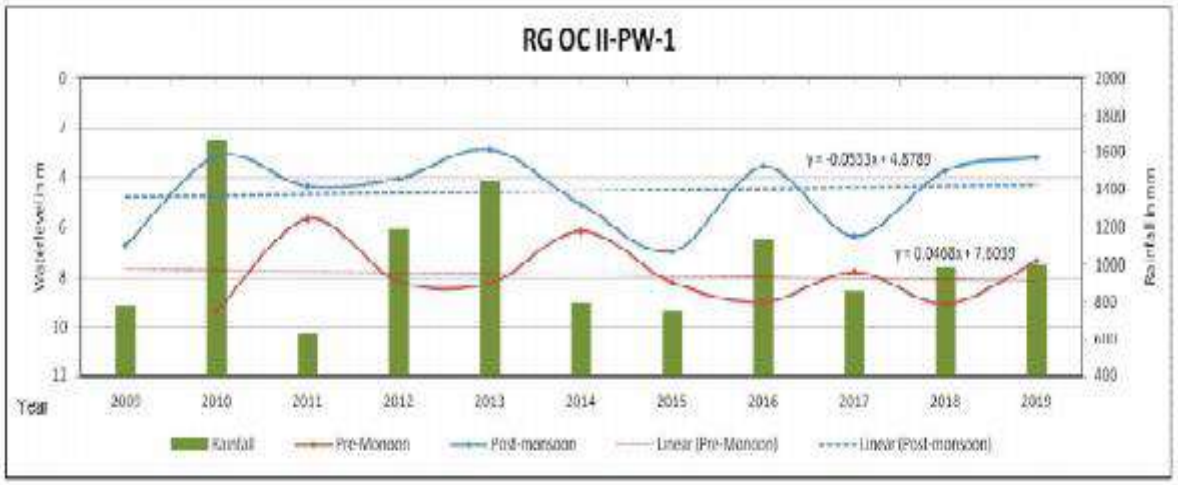


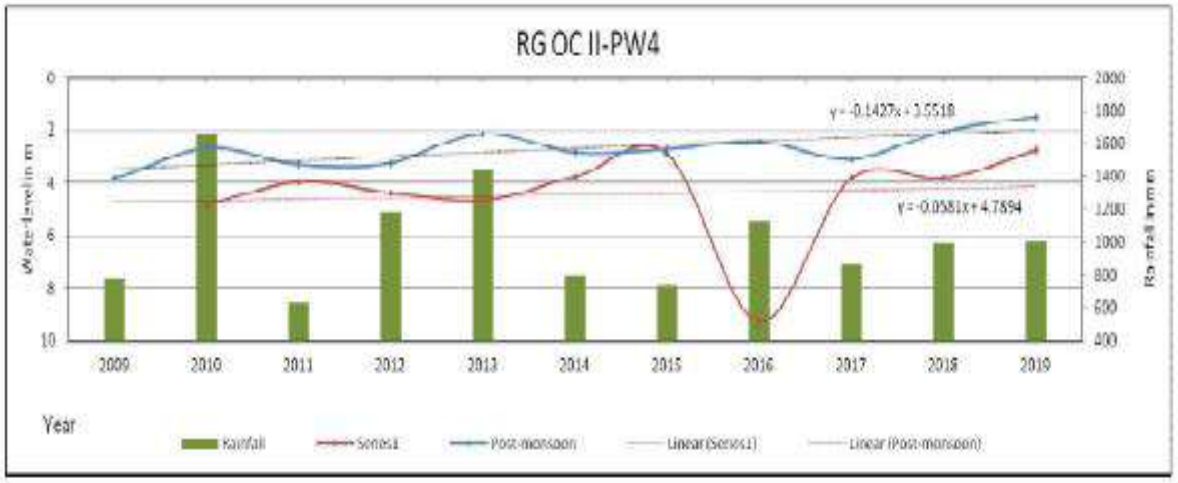




Hydrographs of Piezometric water levels in the buffer area of RG Coal Mine







4. GROUND WATER RESOURCES (2020)

Dynamic ground water resources are computed as per the guidelines laid down in GEC-15 methodology. As per 2020 GEC report, the net dynamic replenishable groundwater resources availability is 311.39 MCM, gross ground water draft for all uses 122.14 MCM and net annual ground water potential available for future irrigation needs is 177.7MCM. Stage of ground water development varies from 14% and 61 % with average of 39 %. All the mandals fall under safe category, with highest stage of extraction of 60% and 61% seen in Mutharam and Manthani mandals respectively. 91% (111.4 MCM) of gross ground water draft is utilized for irrigation purpose only. Computed Dynamic ground water resources of the study area are given in **Table-4.1**.

Table-4.1: Computed Dynamic ground water resources.

As per GEC 2020	MCM
Dynamic (Net GWR Availability)	**311.39**
• Monsoon recharge from rainfall	197.85
• Monsoon recharge from other sources	39.19
• Non-Monsoon recharge from rainfall	0
• Non-monsoon recharge from other sources	95.81
Gross GW Draft	**122.14**
• Irrigation	111.36
• Domestic and Industrial use	10.77
Provision for Drinking and Industrial use for the year 2025	21.22
Net GW availability for future irrigation	177.71
Stage of GW development (%)	**39%** Min : 14% (Mutharam_Mahadevpur & Ramagundam) Max : 61% (Manthani)

5. GROUND WATER RELATED ISSUES AND REASONS FOR ISSUES

5.1 Issues

Pollution (Geogenic and Anthropogenic)

1. Few mandals are fluorosis endemic where fluoride (geogenic) as high as 2.52 mg/L during pre-monsoon and 2.61 mg/L during post-monsoon season is found in groundwater. The high fluoride concentration (>1.5 mg/L) occur in 8% and 4 % of the samples during pre-monsoon and post-monsoon season of 2019, mostly in 4 mandals viz. Kamanpur, Malharrao, Manthani and Mutharam Manthani .
2. High nitrate (> 45 mg/L) due to anthropogenic activities is observed in 29 samples (42%) and 17 samples (26%) during pre-monsoon and post-monsoon season 2019.

Deep water levels

3. Deep water levels (> 20 m bgl) are observed during pre as well as post-monsoon season in < 1% of the area.
4. 74% wells during pre-monsoon, 42% wells during post-monsoon shown falling trend in the last 10 years (@0.01 to 1.77 and 0.01 to 1.64 m/yr) respectively. Majority of the wells show falling trend < 0.5 m/yr in both the seasons.

5.2 Reasons for Issues

Geo-genic pollution (Fluoride)

1. Higher concentration of fluoride in ground water is attributed due to source rock, rock water interaction where acid-soluble fluoride bearing minerals (fluorite, fluoro-apatite) gets dissolved under alkaline conditions.
2. Higher residence time of ground water in deeper aquifer.

Anthropogenic pollution (Nitrate)

3. Higher concentration is due to unscientific sewage disposal of treated and untreated effluents in urban and rural areas.Use of NPK fertilizers and nitrogen fixation by leguminous crops.

Deep water levels

4. Over-extraction, paddy cultivation during rabi season (49% to total crops), ground water mining, limited artificial measures etc.

6. MANAGEMENT STRATEGIES

High dependence on groundwater coupled with absence of augmentation measures has led to a steady fall in water levels and desaturation of weathered zone in some parts, especially in hard rock areas. Higher NO_3^- concentrations (> 45 mg/L) in unconfined aquifer is due to sewage contamination and higher concentration of F^- (>1.5 mg/L) in aquifers is due to local geology.

6.1 Management plan

The uneven distribution of groundwater availability and its utilization indicates that a single management strategy cannot be adopted and requires integrated hydrogeological aspects along with socio-economic conditions to develop appropriate management strategy.

In the study area 4413 MCM of unstaturated volume (below the depth of 5m) is avaialable during post-monsoon season having 110 MCM of recharge potential (2.5%). This can be utilized for implementing management strategy.

The study suggests notable measures for sustainable groundwater management, which involves a combination of various measures given below.

1. Supply side measures
2. Demand side measures
3. Regulatory measures
4. Institutional measures

6.1.1 Supply side measures:

Ongoing Projects

Repair Renovation and Restoration of existing tanks (Mission Kakatiya):

- De-silting of existing minor tanks (405 no) was taken under state Govt. sponsored Mission Kaktiya-Phase-1 to Phase-4 to remove silt and this has created additional surface storage and enhance ground water recharge.
- There is need to take remaining tanks (~1068 MI tanks and other smallwater bodies) for de-silting, this will greatly help in stabilisation of tank ayacut and ground water augmentation.

Mission Bhagiratha:

- Under Telangana Drinking Water Supply Project (TDWSP) also known as Mission Bhagiratha, all the villages and towns are proposed to be covered from the two water grids with intake from Yellamaplly reservoir and Bheemghanpur reservoir . The scheme is to enhance the existing drinking water scheme and to provide 100, 135 and 150 lpd/person of water in rural, municipal and Municipal Corporation respectively.

- The total water requirement as per 2011 census is 21.24 MCM and this imported water from surface sources will reduce the present utilized ~13 MCM of ground water (considering 60 lpcd). This can be effectively utilized to irrigate ~2160 ha of additional land under ID crops.

To be taken up

6.1.1.1 Artificial Recharge structures:

A total of 128 artificial recharge stuctures (CDs:75 and PTs:53) exist in the area. After considering the existing water conservation structures and other recharge measures, the feasibility of artificial recharge structures are studied based on the surplus runoff and recharge potential.

543 artificial recharge structures (ARS) are feasible (CDs: 289 and PTs: 254) in the study area. As the stage of ground water development in the area is 39% and all the mandals falling in safe category as per the GEC 2020 estimation, the artificial recharge structures are not proposed for entire area. However, 4 mandals viz. Kamanpur, Malharrao, Manthani and Mutharam Manthani are showing the stage of ground water development of 50% and above. To controle futher increase in stage of ground water development, artificial recharge structures are recommended in these four mandals only.

While formulating the village wise groundwater management plan, the unsaturated volume of aquifer is estimated by multiplying the area with specific yield and unsaturated thickness (post-monsoon water levels below 5 m). Potential surface run off is estimated by following standard procedures. On conservative side 20 % run off yield is considered as non-committed yield for recommending artificial recharge structures. In intermittent areas 50% of yield is considered and remaining 50% is recommended for implementing water conservation measures in recharge areas through MGNREGS. The pre-monsoon

groundwater quality is considered for categorising contaminated area (F >1.5 mg/l & EC >3000 µ S/cm). Nitrate is not considered here because it is point source pollution and localized. Based on hydrogeological characteristics like availability of unsaturated zone and water quality the area is sub-divided into following 8 categories (***Fig-6.1 and Table-6.1)*** for preparing management plan.

Table-6.1: Hydrogeological characteristics of area.

Category	**Hydrogeologic characterizations**
1	High EC with additional scope for artificial recharge.
2	High EC with no additional scope for artificial recharge.
3	High F with additional scope for artificial recharge.
4	High F with no additional scope for artificial recharge.
5	High EC and F with additional scope for artificial recharge.
6	High EC and F with no additional scope for artificial recharge.
7	Groundwater quality within permissible limits for drinking and irrigation with scope for artificial recharge.
8	Groundwater quality within permissible limits for drinking and irrigation with no scope for artificial recharge.

4 mandals covering 852 Km^2 is considered for recommending artificial recharge structures (ARS) where, 36.4 MCM recharge potential and 40.8 MCM utilizable yield is avaialable. For sustainable development and management of the groundwater resources the following recommendations are made and summarised in **Annexure-1**.

- 179 artificial recharge structures (93 CD's with 6 filling and 86 mini PT's with 1.5 fillings) with a total cost of 31 crores can be taken up.
- After effective utilization of this yield, there will be 4.8 MCM of ground water recharge.
- Roof top rainwater harvesting structures should be made mandatory to all Government buildings (new and existing).

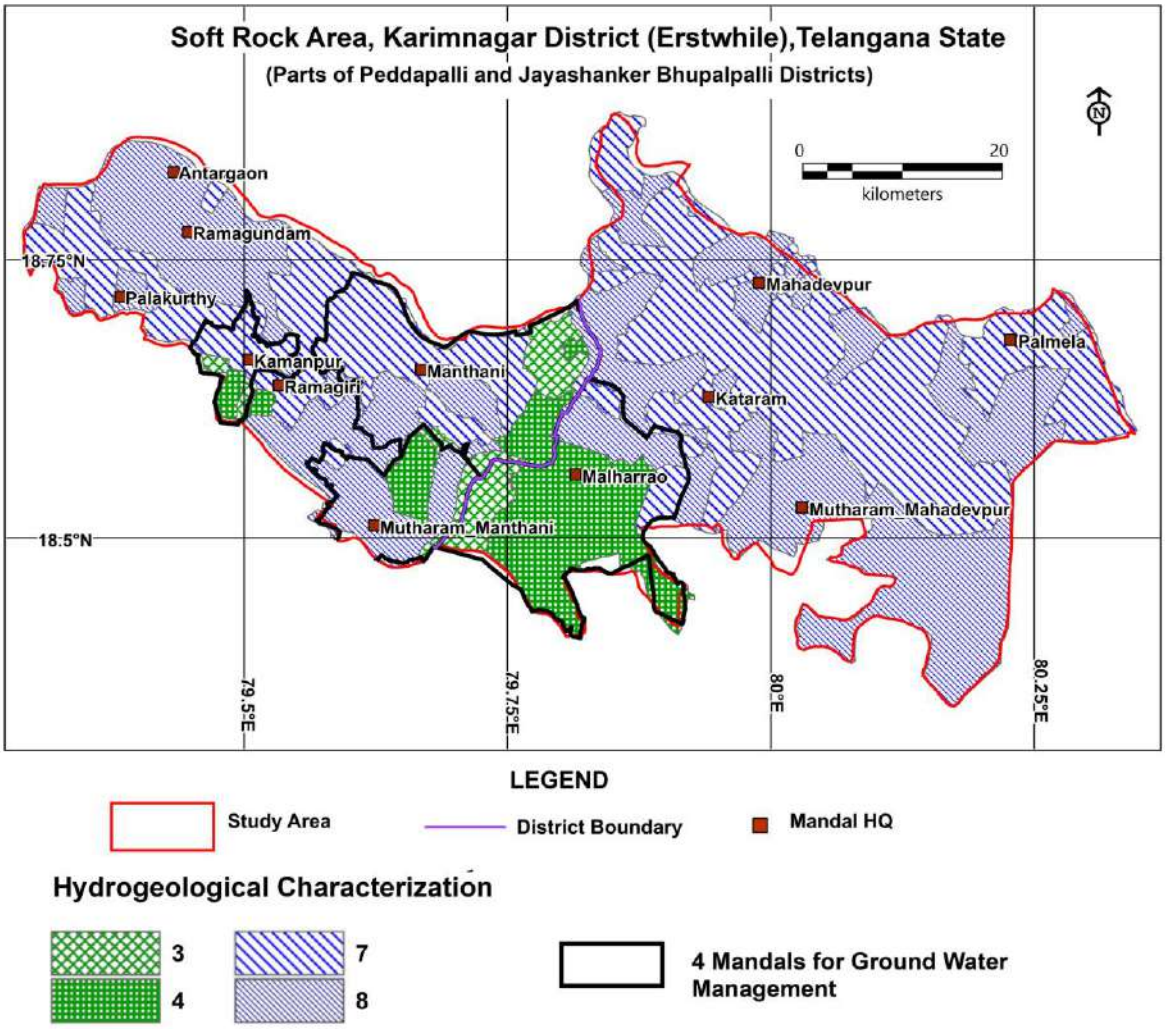


Fig.6.1: Hydrogeological characterization with 4 mandals for ground water management

Other supply side measures:

- Existing ARS like percolation tanks and check dams and dried dug wells can be de-silted involving people's participation through the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) (NREGA 2005). This will also help in sustainable management of groundwater resources.

- Some of de-silted tanks along river Maneru and river Godavari may be filled up with during lean monsoon period.

6.1.1.2 Water Conservation Measures (WCM) (Farm Ponds):

The farm ponds are the ideal water conservation structures, which are constructed in the low lying areas of the farm. The size of form ponds can be 10 x 10 x 3 m. In the district

total 198 farm ponds exist in 42 villages and additional 1551 farm ponds are recommended (20 in each village in 86 villages in four mandals) with total cost of **3.8** crores, which can conserve 0.46 MCM of surface water.

6.1.2 Demand side measures: In order to manage the available resources more effectively the following measures are recommended.

6.1.2.1 Ongoing Work

- In the area till date a total number of 1815 no's drip and sprinklers are sanctioned which has irrigated ~1797 ha under ID crops saving ~2.7 MCM of groundwater.

6.1.2.2 Proposed Work

- ~3300 ha of additional land that can be brought under micro-irrigation (@50 ha/village in 66 villages from 4 mandals) costing about 20 crores (considering 1 unit/ha @0.6 lakh/ha). With this 6.6 MCM of ground water can be conserved over the traditional irrigation practices.

- Change in cropping pattern from water intensive paddy to irrigated dry crops like pulses and millets are recommended particularly in 4 mandals viz, Kamanpur, Malharrao, Manthani and Mutharam Manthani, where paddy cultivated area is ~ 80% of the Gross cropped area.

- To avoid the interference of cone of depression between the productive wells, intermittent pumping of bore wells is recommended through regulatory mechanism.

- Power supply should be regulated by giving power in 4 hour spells two times a day in the morning and evening by the concerned department so that pumping of the bore well is carried out in phased manner to allow recuperations of the aquifer and increase sustainability of the bore wells.

6.1.3 Other measures

- A participatory groundwater management (PGWM) approach in sharing of groundwater and monitoring resources on a constant basis along with effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002) are the other measures suggested. Subsidy/incentives on cost involved in sharing of groundwater may be given to the farmers involved.

- In urban and rural areas the sewerage line should be constructed to arrest leaching of nitrate and the waste water may be treated and reused, particularly in urban areas.

- The other measure includes supplementary calcium and phosphorous rich food to the children in fluoride endemic 4 mandals. Creating awareness about safe drinking water habits, side effects of high fluoride and nitrate rich groundwater, improving oral hygiene conditions are recommended.

6.2 Expected Results and Out come

With the above interventions costing Rs 55 crores, the likely benefit would be the net saving of 11.9 MCM of ground water. This will bring down the stage of ground water development (SoGWD) by 1.5% (from 39 % to 37.5 %) in the entire study area and in four mandals (852 Km^2) area, where water conservation measures are proposed, the stage of ground water development will be improved by 6% (from 57% to 51 %).

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Annexure – I

Proposed Supply side interventions in 4 mandals, Karimnagar (Erstwhile) District, Soft Rock area

S.no	District	Mandal	Village	Existing PTs	Existing CDs	Proposed CDs	Proposed PTs
1	Jayashankar	Malhalrao	Ankanpalle	0	0	2	2
2	Jayashankar	Malhalrao	Ansanpalle	0	0	1	0
3	Jayashankar	Malhalrao	Chinna thoondla	0	0	1	0
4	Jayashankar	Malhalrao	Domala madaram	0	0	2	2
5	Jayashankar	Malhalrao	Dubbaghat	0	0	3	3
6	Jayashankar	Malhalrao	Gandharla	0	0	2	2
7	Jayashankar	Malhalrao	Kapuram	0	0	3	3
8	Jayashankar	Malhalrao	Kondampet	0	3	3	6
9	Jayashankar	Malhalrao	Korlakunta	0	6	0	0
10	Jayashankar	Malhalrao	Mallampalle	0	1	0	0
11	Jayashankar	Malhalrao	Mallaram	0	1	0	0
12	Jayashankar	Malhalrao	Mothkupally	0	0	3	3
13	Jayashankar	Malhalrao	Pedda thoondla	1	0	2	1
14	Jayashankar	Malhalrao	Rudraram	5	0	2	0
15	Jayashankar	Malhalrao	Shatrajpalle	0	0	3	3
16	Jayashankar	Malhalrao	Tadicherla	0	0	8	7
17	Jayashankar	Malhalrao	Tadwai	0	0	1	0
18	Jayashankar	Malhalrao	Vallamkunta	0	0	2	2
19	Peddapalle	Kamanpur	Jallipalle	0	0	1	1
20	Peddapalle	Kamanpur	Nagaram	0	3	0	0
21	Peddapalle	Kamanpur	Penchikalpet	0	1	0	0
22	Peddapalle	Manthani	Adavisomanpalle	0	0	6	6
23	Peddapalle	Manthani	Adrial	0	0	1	0
24	Peddapalle	Manthani	Akkepalle	0	0	1	1
25	Peddapalle	Manthani	Bitpalle(k)	0	0	2	2
26	Peddapalle	Manthani	Chinnaodela	0	0	2	1
27	Peddapalle	Manthani	Eklaspur	0	1	2	3
28	Peddapalle	Manthani	Gopalpur	0	0	2	2
29	Peddapalle	Manthani	Gumnoor	0	0	4	4
30	Peddapalle	Manthani	Gunjapadu	0	2	1	3
31	Peddapalle	Manthani	Kannala	0	0	2	2
32	Peddapalle	Manthani	Kasipet	3	4	0	0
33	Peddapalle	Manthani	Khanapur	0	0	1	0
34	Peddapalle	Manthani	Kuchirajpalle	0	0	1	0
35	Peddapalle	Manthani	Lakkapur	0	0	1	0

36	Peddapalle	Manthani	Maidipalle	0	0	3	3
37	Peddapalle	Manthani	Manthani (p.t.)	0	0	1	0
38	Peddapalle	Manthani	Peddaodela	0	0	1	1
39	Peddapalle	Manthani	Puttapaka	0	0	2	2
40	Peddapalle	Manthani	Siripuram	3	4	0	0
41	Peddapalle	Manthani	Uppatla	0	0	1	1
42	Peddapalle	Mutharam (Mnt)	Adavisrirampur	0	1	0	0
43	Peddapalle	Mutharam (Mnt)	Gaddalapalle	0	1	0	0
44	Peddapalle	Mutharam (Mnt)	Ippalapalle	0	1	3	4
45	Peddapalle	Mutharam (Mnt)	Khammampalle	0	0	17	16
46	Peddapalle	Mutharam (Mnt)	Mutharam	0	1	0	0
47	Peddapalle	Mutharam (Mnt)	Sarvaram	0	4	0	0
			Total	**12**	**34**	**93**	**86**