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

MANCHERIAL DISTRICT, TELANGANA

दक्षिणी क्षेत्र, हैदराबाद
Southern Region, Hyderabad

भारत सरकार

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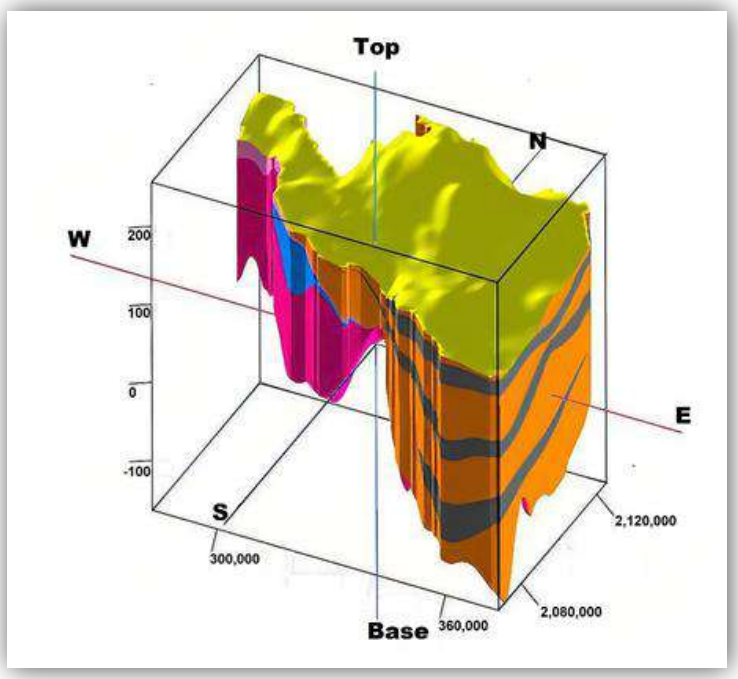
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION
CENTRAL GROUND WATER BOARD

REPORT ON

AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN MANCHERIAL DISTRICT, TELANGANA STATE



CENTRAL GROUND WATER BOARD
SOUTHERN REGION
HYDERABAD
NOVEMBER 2021

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN MANCHERIAL DISTRICT, TELANGANA STATE

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AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN MANCHERIAL DISTRICT, TELANGANA STATE

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REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN MANCHERIAL DISTRICT, TELANGANA STATE

At a glance

S.No.	Item		Particulars
1	Districts	:	Mancherial
2	Revenue Divisions/ Mandals	:	18
3	Villages	:	382 villages
4	Geographical area	:	4016 km^2
5	Population (2011 Census)	:	8.07 lakhs
6	Density of population (2011 Census)	:	200 persons/km^2
7	Locations	:	North latitude: 19°9'34.56"N to 19°24'11.83"N East longitude: 79°30'53.58"E to 79°41'10.56"E
8	Rainfall (Normal)	:	~635 mm -1276 mm (avg: 1078 mm) (SW: 80 % & NE: 20%)
9	Geomorphology	:	Pediplain (31% of the area), Pediment (32%of the area), and Structural hills (25% of the area)
10	Major Rivers	:	Godavari, Pranhita
11	Land Utilization (Ha)	:	Forest occupies nearly 45.14% of the area; agricultural land occupies nearly 41.58% of the area. Remaining area is occupied by water bodies, waste land, built up etc. Gross cropped area during the year 2019-20 is 188627 ha. Net sown area is 148320 ha
12	Soils	:	Fine soil (44%), loamy soil (34 %) and montmorillonite soil (22%)
13	Cropping Pattern (2019-20) (Gross Area:188627Ha)	:	Major crops grown during khariff season are Cotton (49%) and Paddy (19%), etc. Rabi season crops include Paddy(95.80%), Pulses and(1.12%), etc.
14	Mining and Indutries		The principal mineral deposits of the Mancherial district include Coal, Limestone, Sowing stone.
15	Irrigation	:	Major Projects: Kadam Narayan Reddy project (ayacut: 57,841 acres), Sriramasagar Project (ayacut: 138 acres)

			Medium Projects: PP Rao Project (ayacut: 1231 acres). Ongoing: Gollavagu Project (ayacut: 955 hectares), Peddavagu project (at Jagganathpur ayacut :3283 acres, at Nilwai ayacut:13000 acres), Ralivagu project (ayacut: 2428 acres)
16	Prevailing Water Conservation/Recharge Practices	:	~1278 percolation tanks, ~31 Check dams, Under Mission Kakatiya (Phase 1, 2, 3,4) 405 tanks have been desilted and rejuvenated.
17	Geology	:	About 76% of the area is underlain by Sandstones of Precambrian to Jurrasic period, Banded Gneissic Complex (19%), Limestone (4%) & Basalt (1 %)
18	Hydrogeology		Hard rock (Consolidated formations):24% area Soft rock (semiconsolidated to unconsolidated formations):76% of the area
19	Hydrogeological data points		
	Exploratory drilling data points	:	(Exploration: 35 (CGWB: 34),(SGWD:1)
	Water Level data points		33 wells (CGWB:15, SGWD:18)
	Hydrochemical Points		Pre-monsoon: 66 (CGWB: 7, SGWD: 18, RWS: 41) post-monsoon: 47 (SGWD: 18, RWS:29)
	Geophysical		VES: 7 (CGWB)
20	**DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING**		
20.1	**Ground water Level Scenario**		
	Water Levels Depth to water level(m bgl)	: :	Water table elevations during pre-monsoon season vary from 118-231m amsl and during post-monsoon season it varies from 123-236 m amsl. Pre-monsoon season: 1.75 to 19.54m bgl and majority are in the range of 5 to 10m bgl (88% area) followed by 10-20 mbgl (10% area). Post-monsoon: 0.55-13.30 and majority are in <3 m bgl (47% area) followed by 3-5 mbgl (42% area), 5-10 mbgl (11 % area) , >10 mbgl (1%)
	Water Level Fluctuations (May vs. November)	:	All the wells show rise in water level 0-5 m: 89%, 5-10 m: 11%, 10-20: 1 %
	Long term water level trends (2010-19) (16 wells)	:	Pre-monsoon season :11 wells shows falling trend in the range of (>0.5m: 2, 0-0.5m: 9 wells) and 5 wells shows rising trend in range of (0-0.5m) Post-monsoon season: 7 wells show falling trend in range of (0-0.5m) and 9 wells shows rising trends in range of (0-0.5m)
20.2	**Ground Water Quality**		

	Electrical Conductivity (µ Siemens/cm)	:	Pre: 555-11250 (avg: 1656) micro Siemens/cm. In 48% of area EC is within 1500 µ Siemens/cm, 1500-3000 µ Siemens in 49 % area, >3000 µ Siemens/cm in 2 % area. Post: 388-2287 (avg: 1307) micro Siemens/cm. In 84% of area EC is within 1500 µ Siemens/cm and 1500-3000 µ Siemens in 16 % area.			
	Nitrate mg/l	:	Pre: 1.3-304 mg/L and 2 no. of samples are unfit for human consumption having NO_3 > 45 mg/L. Post: <1.2-82 mg/L and 2 no. of samples are unfit for human consumption having NO_3 > 45 mg/L			
28	Fluoride mg/l	:	Pre: 0.19-4.61mg/L, 80% of samples are is within permissible limits of BIS and rest is beyond permissible limit of 1.5 mg/L. Post: 0.03-3.27 mg/L. 78 % of sample is within permissible limit of BIS and rest is beyond permissible limit of 1.5 mg/L which is unfit for human consumptions			
20.3	**Aquifer Mapping**					
	Geology		Archean Crystalline		Gondwana Formation	
	Prominent Lithology		Granite, Gneiss		Sandstone, Shale, Clay	
	Aquifers	:	Aquifer-1 (Weathered Zone)	Aquifer-2 (Fracture Zone)	Aquifer-1 (Unconfined aquifer)	Aquifer-II to IV (Semiconfined/ Confined aquifer)
	Thickness range	:	6- 26 m	8-87.5 m	6 to 60 m	Upto 300m at different depth ranges
	Range of yield potential	:	<0.01 to 1.5 lps (avg: 0.4 lps)		1.2 to 16.2 lps (avg: 4 lps)	
	Transmissivity (m2/day)	:	0.04 to 29.4 m^2/day		1.34-115 m2/day	
	Storativity		0.0001 to 0.00001		1.2 to 0.0001	
	Specific Capacity (lpm/mdd)		Upto 31.85		3.15 to 93.42	
21	**Ground Water Resources**					
1	Ground water Resources (2020) MCM	:				
	Net Dynamic groundwater availability	:	855.10 MCM			

	Gross GW Draft	:	272.07 MCM
	Provision for Domestic & Industrial (2025)		65.7
	Average Stage of Ground water development (%)		32%
	Net GW Availability for future irrigation	:	583.02 MCM
	Categorization of mandals		Safe: 18
22	Major Ground Water Issues Identified	:	• Few mandals are fluorosis endemic where fluoride (geogenic) as high as 4.61 mg/L during pre-monsoon and 3.27 mg/L during post-monsoon season is found in groundwater. The high fluoride concentration (>1.5 mg/L) occur in 4 % and 6 % of the area during pre and post-monsoon season. • High nitrate (> 45 mg/L) due to anthropogenic activities is observed in 2 no. of samples during pre and post-monsoon. • The high concentration of EC (> 3000 micro-seimens/cm) in 2 % of the area is observed during pre-monsoon seasons. • Low ground water potential (< 1 lps) areas have been identified in ~430 sq.km. area in western and southwestern parts mostly due to granitic terrain
23	Management Strategies	:	**Supply side measures** **State Government Project** • **Mission Kakatiya:** De-silting of existing minor tanks (405 no) was taken under state Govt. sponsored Mission Kaktiya (Phase-1 to 4) to remove 2.04 MCM of silt and this has created an additional surface storage. This will contribute ~ 0.51 MCM to groundwater (considering 25 % of recharge) and with this additional ~85 ha land can be brought under irrigated dry (ID) crops in the tank ayacut. • **Mission Bhagiratha:** ~40.78 MCM of water will be imported from surface sources will reduce the present utilized ~22 MCM of ground water (considering 60 lpcd). This can be effectively utilized to irrigate ~3666 ha of additional land under ID crops. **To be taken up (Artificial Recharge Structure)** 146 artificial recharge structures (90 CD's and 56 mini PT's) with a total cost of 24.70 crores **Demand side measure** • **Ongoing work:** In the area till date a total number of 1624 no's drip

			and sprinklers are sanctioned which has irrigated ~1826.82 ha under ID crops saving 3.28 MCM of groundwater from the basin. **Other Recommendations** • As a mandatory measure, every groundwater user should recharge rainwater through artificial recharge structures in proportionate to the extraction • Declaration of Minimum Support Price in advance (before start of season) and improved facilities at procurement centres. • Capacity building in power supply regulation (4 hour each in morning and evening) will increase the sustainability of wells in areas where groundwater potential is less. • 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).
24	Expected Results and Out come	:	With the above interventions costing Rs 40.75 crores (excluding the cost involved in Mission Kakatiya and Mission Bhagiratha), the likely benefit would be net saving of 31.74 MCM of ground. This will bring down the stage of groundwater development by 3% (from 41% to 38%).

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	:	Hectare
Ha.m	:	Hectare 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

The Mancherial district having geographical area of 4016 km^2, lies between north latitude 19°9'34.56"N to 19°24'11.83"N and east longitude 79°30'53.58"E to 79°41'10.56"E located in the north-east of Telangana State. Administratively the district is governed by 18 revenue mandals and 382 villages with a population of ~8.07 lakhs (2011 census). The density of population in the district is 200 per Sq.km.

The area is underlain by various geological formation from the oldest Archaean rocks comprising granite/gneisses to Purana, Gondwana to the recent alluvium. The Gondwana succession rest unconformabely over Lower Palaeozoic and Archeans. About 76% of the area is underlain by Sandstones, 19% by Banded Gneissic Complex, 4% Limestone & 1% by Basalt .

Pediment is the major landform covering about 1269 km2 (32 %) area. The other landforms observed are pedeplain (31%), structural hills (25 %), flood plain (5%), denudation hills, residual hills channel fill, dissected plateau, intermontane valley etc. The area is mainly occupied by clayey soils (44%), Loamy soils (34%) and montmorillonite soil (22%).

Out of the total geographical area of 4016 km^2, forest and agriculture are the prominent land use pattern in Mancherial district and forms 45.14% and 41.58% of total area respectively followed by the industrial and built-up structures. The gross cropped area (2019-20) during khariff season is 148320 ha and during rabi season is 40307 ha (Total 188627 ha).

The registered ayacut under the major irrigation project (completed) like Kadam Narayan Reddy project, Sriram Sagar project is 57,979 acres. The registered ayacut under the medium irrigation project (completed) like P.P. Rao (Yerravagu) project is 1231 acres. The ongoing medium irrigation project have irrigation potential of 28211 acres. In the district there are of 910 minor irrigation tanks, 20,404 irrigation wells (9,390 dugwells and 11,014 borewells), ~1278 percolation tanks and 31 check dams exist. Under Mission Kakatiya (Phase 1 to 4), 405 tanks have been desilted and rejuvenated/restored ..

Water level is monitored through 33 groundwater monitoring stations of both CGWB and SGWD during pre and post-monsoon season of 2019. The premonsoon depth to water level ranges from 1.75 (Neelwai) and 19.54 mbgl (Kundaram). The postmonsoon depth to water levels ranges from 0.55 (Neelwai) and 13.30 mbgl (Bellampally). The water table elevation ranges from 118.97 to 229.9 m.amsl during premonsoon period and 123.14 to 236.36 m.amsl during postmonosoon period. The groundwater flow is mainly towards Pranhita and Godavari River in the southeastern direction.

The study area records rise in water level. The seasonal water level fluctuations vary from 1.20 to 14.63 m rise. Rise in water level range of 5-10 m cover majority of area with 89%, followed by 5 to 10 m covering 11% of area. Water level rise of >5 m is observed Jaipur, Mandmarri, Tandur, Jannaram and Bheemini mandal.

Trend analysis for the last 10 years (2010-2019) is studied from 16 hydrograph stations of CGWB . However, there is no significant change in decadal water level trend. It is observed that during pre-monsoon and post monsoon water level trend ranges from -0.5 m/yr to 0.5 m/yr.

On the basis of occurrence and movement of ground water, mainly rock units of the Mancherial district can be broadly classified into two categories: consolidated formation (Archean crystalline and metasedimentary formation) which occupies 24% of the area and semi-consolidated formation (Sedimentary rock) which occupies 76 % of the area.

In consolidated formations, weathered zone forms the unconfined aquifer. The weathered zone (~30 m) consisting of upper saprolite and lower sap rock .Thickness of weathered zone is in the range of 10-20 m in most part of area covering ~75 % of area, shallow weathering (< 10 m) occurs in 24 % of the area and deep weathering (> 20 m) occurs in rest of the area. The depth of fracturing varies from 8 m to 87.5m (deepest fracture encountered at Luxetipeth). Ground water yield from fractured granite/gneiss varies from <0.01 to 1.5 lps. (avg: 0.4 lps). The transmissivity varies from 0.04-29.4 m2/day and storativity varies from 0.0001 to 0.00001. The specific capacity ranges upto 31.85 lpm/mdd.

Semiconsolidated formations , mainly comprises of Sandstone. Multiple aquifer system (1 to 4 aquifers) occurs in the sandstone formations with intervening clay beds. The first aquifer is unconfined whereas the deeper aquifers are in semi-confined/ confined condition. The thickness of Aquifers are varying depending upon the disposition of Sandstones and intervening clay beds. The thickness of Aquifer-I varies from 6-60m. The unconfined zone extend from bottom of the soil layer to top of the first clay layer. Unlike Aquifer-I, ground water occurs under confined to semi-confined condition in Aquifer-II to IV. The deeper aquifers identified upto a depth of 300m. Ground water yield of sandstone aquifers varies from 1.2 to 16.2 lps (avg: 4.0 lps). The transmissivity varies from 1.34-115 m2/day and storaivity varies from 0.12 to 0.00049. The specific capacity ranges between 3.15 to 93.42 lpm/mdd

Total 113 ground water samples (Pre-monsoon:66 and Post-monsoon:47) were analysed for understanding groundwater quality of the district. In 48 % and 84 % 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 1.3-304 mg/L and found that in 2 no. samples nitrate is beyond maximum permissible limit of BIS (45 mg/l) and F concentration varies from 0.19-4.61 mg/l and found that in 20% samples it is beyond maximum permissible limits of BIS (1.5 mg/l). During post-monsoon season, concentration of NO_3 ranges from **<**1.2-82 mg/L and found that in 2 no. of samples it is beyond maximum permissible limit of BIS (45 mg/l). The F concentration varies from 0.03-3.27 mg/l and found that in 22% it is beyond maximum permissible limit of BIS.

Net dynamic replenishable ground water availability is 855.10 MCM, gross ground water draft is 272.07 MCM, provision for drinking and industrial use for the year 2025 is 65.17

MCM and net available balance for future irrigation use is 583.02 MCM. The stage of ground water development is 32 % .

Major issues identified are low ground water potential (< 1 lps) in some areas particularly in consolidated granitic formation, high fluoride concentration (>1.5 mg/L) occur in 4 % and 6 % of the area during pre and post-monsoon season, high EC concentration (> 3000 micro-seimens/cm) in 2 % of the area is observed during pre-monsoon seasons.

The overall groundwater scenario and regime of the district is good with high potential nature of groundwater formations except a minor quality issues and few areas of low groundwater potentiality. However, considering the dependency on groundwater and further to maintain the sustainability, few supply side and demand side measures have been recommended. The sandstone aquifers though potential, the groundwater occurs at depths, which requires high input costs in tubewell drilling and expertise to tap potential zones in Aquifer-II to Aquifer-IV. It is imperative to recommend few artificial recharge structures under supply side to recharge Aquifer-I of Sandstone which is mainly unconfined. In the granitic area, the artificial recharge structures recommended to improve the overall sustainability and recharge the Aquifer-I which is mainly of weathering part.

The management strategies mainly include supply side management. The supply side measure includes ongoing work under Mission Kakatiya where ~2.04 MCM of silt has been removed from existing 405 tanks. This will contribute ~0.51 MCM of ground water by recharge, with this additional ~85 ha land can be brought under irrigated dry (ID) crops in tank ayacut.

Under Mission Bhagiratha, there is plan to import ~40.78 MCM of water for drinking purposes which will save the present ~22 MCM of water for drinking and domestic purposes and with this additional ~3666 ha of land can be brought under ID crops.

Construction of 146 artificial recharge structures (90 CD’s and 56 mini PT’s) with a total cost of 24.70 cores are recommended as supply side measures.

Other measure includes strict implementation of WALTA and participatory groundwater management (PGWM).

With the above interventions, the likely benefit would be the net saving of 29.52 MCM of ground water, which can bring down the stage of ground water development by 1 % (from 32 % to 31 %).

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

S.No.	Data	Aquifer	Total Data Points	Source	
				CGWB	SGWD/SCCL/RWS
1	Panel Diagram (3-D)	Combine	42	Expl:34 VES:7	1
2	Hydrogeological Sections	3 no	42	Expl:34 VES:7	1
3	Fence/ panel Diagrams	2 no	42	Expl:34 VES:7	1
4	Hydrogeological Map	Combined	35	34	1
5	Depth to Water Level Maps (2019)	Combine	33	15	18
6	Water Level Fluctuation	Combine	33	15	18
7	Long term water level trends	Combine	16	16	-
8	Water quality Pre-2019 Post-2019	Combine	Pre:66 Post:47	7 0	SGWD:18 RWS : 41) SGWD:18 RWS : 29)

1 INTRODUCTION

National Aquifer Mapping (NAQUIM) had been taken up by CGWB to create robust database of hydrogeological information at 1:50,000 scale for sustainable groundwater. Aquifer mapping is a multidisciplinary and a holistic scientific approach wherein a combination of geologic, geophysical, hydrologic and chemical analysis is applied to characterize the quantity, quality and sustainability of ground water in aquifers. It had been taken up by CGWB to carry out detailed hydrogeological investigation on toposheet scale of 1:50,000. The vagaries of rainfall, inherent heterogeneity & unsustainable nature of hard rock aquifers, over exploitation of aquifers, insufficient regulation mechanism has a detrimental effect on ground water scenario of the country in last decade or so. Thus, prompting the paradigm shift from "**traditional groundwater development concept**" to "**modern groundwater management concept**".

Varied and diverse hydrogeological settings demand precise and comprehensive mapping of aquifers down to the optimum possible depth at appropriate scale to arrive at the robust and implementable ground water management plans. The proposed management plans will provide necessary inputs and reccomendations for ensuring sustainable management of groundwater resources of district. The aquifer maps and management plans will be shared with the Administration of Mancherial district, TS for its effective implementation.

1.1 Objective and Scope

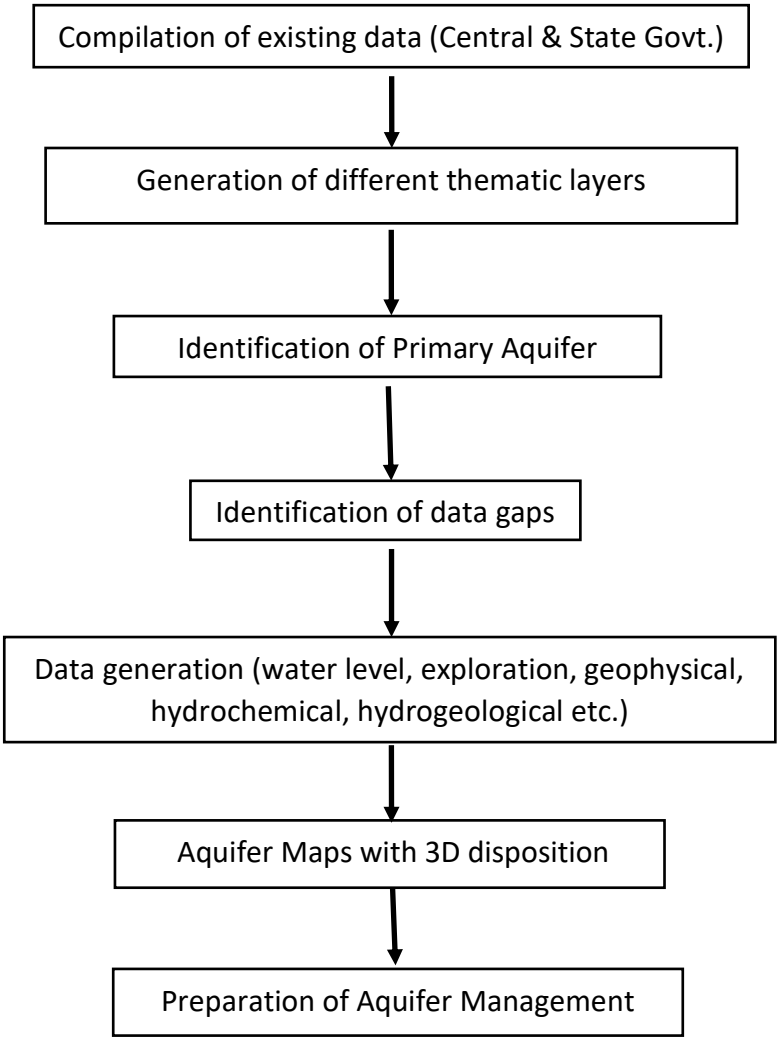
An integrated hydrogeological study was taken up to develop a reliable and comprehensive aquifer map and to suggest suitable groundwater management plan on 1: 50,000 scale. The activities under NAQUIM are aimed at:

- Identifying the aquifer geometry
- Aquifer characteristics and their yield potential
- Groundwater quality
- Aquifer wise assessment of ground water resources
- Preparation of aquifer maps in 3D and 2D
- Formulate ground water management plan

1.2 Approach and Methodology

The ongoing activities of NAQUIM include toposheet wise micro-level hydrogeological data acquisition supported by geophysical and hydro-chemical investigations supplemented with ground water exploration down to the depths of 200- 300 meters.

Considering the objectives of the NAQUIM, the data on various components was segregated, collected and brought on GIS platform by geo-referencing the available information for its utilization for preparation of various thematic maps. The approach and methodology followed for Aquifer mapping is as given below:



1.3 Study area

The Mancherial district having geographical area of 4016 km^2, lies between north latitude 19°9'34.56"N to 19°24'11.83"N and east longitude 79°30'53.58"E to 79°41'10.56"E located in the north-east of Telangana State. The location map of the study area is presented in **Fig.1.1**.The district is bounded on the north by Kumaram Bheem district, on the south by Peddapalli and Jagital district, on the west by Nirmal district and on the East by Gadchiroli district of Maharashtra. It is part of the Godavari and Pranhita river basin . Administratively the district is governed by 18 revenue mandals and 382 villages with a population of ~8.07 lakhs (2011 census). The density of population in the district is 200 per Sq.km.

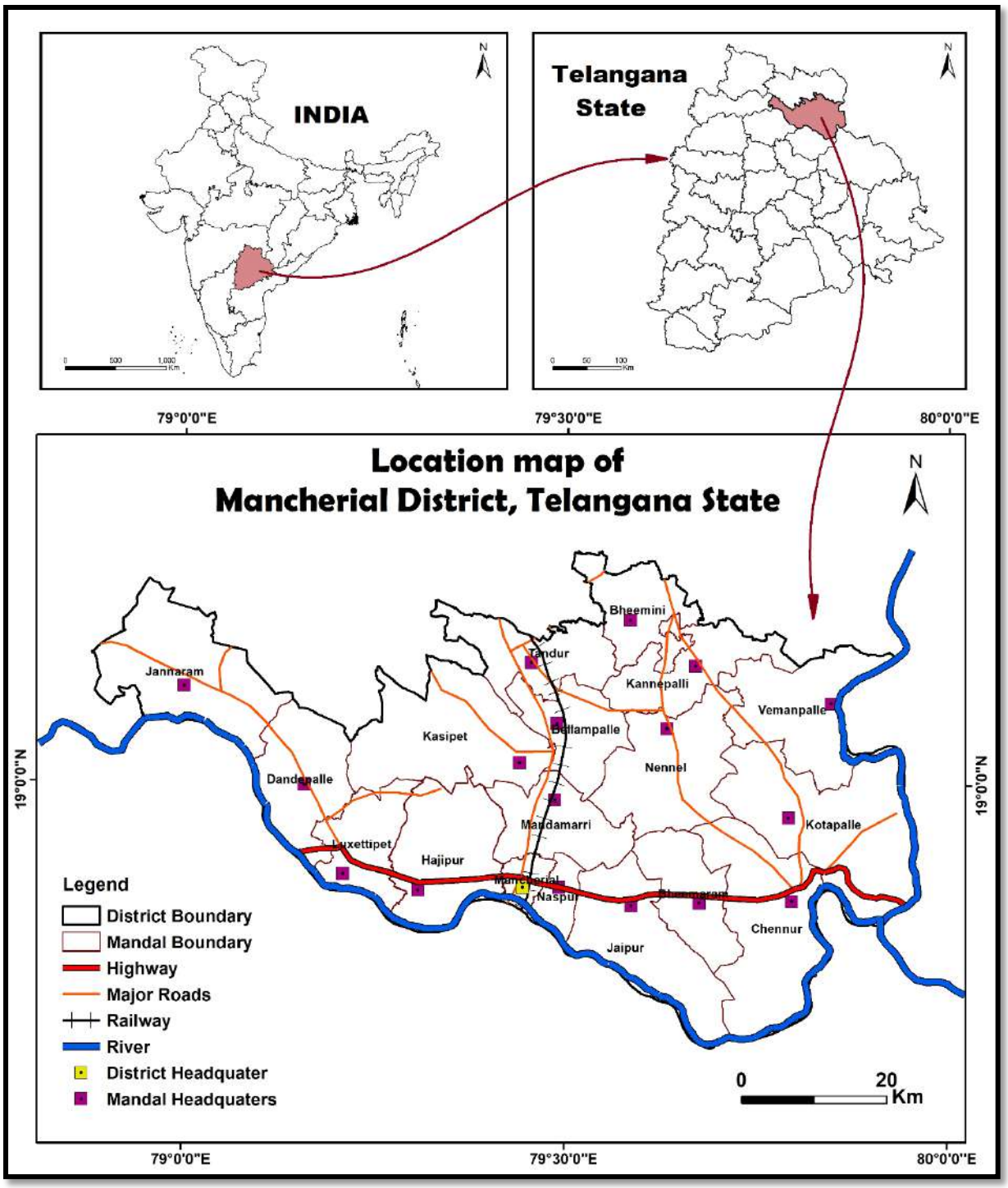


Fig.1.1: Location map of Mancherial district.

1.4 Climate and Rainfall

The climate of the district is characterised by hot summer and cool winters with a fairly good amount of seasonal rainfall. The normal mean daily minimum and maximum temperature of 29.4 °C and 42.6 °C during May and 14.6 °C and 29 °C during December. The normal annual rainfall of the area is 1078 mm. The area receives more than 80 % of the annual rainfall by southwest monsoon between June and September and the rest during the northeast monsoon from October to November. As per district statistical abstract, during

the year 2020, it received average rainfall of 1276 mm (18% more rainfall than normal rainfall). The isohyetal map of the study area is presented in Fig.**1.2a**.

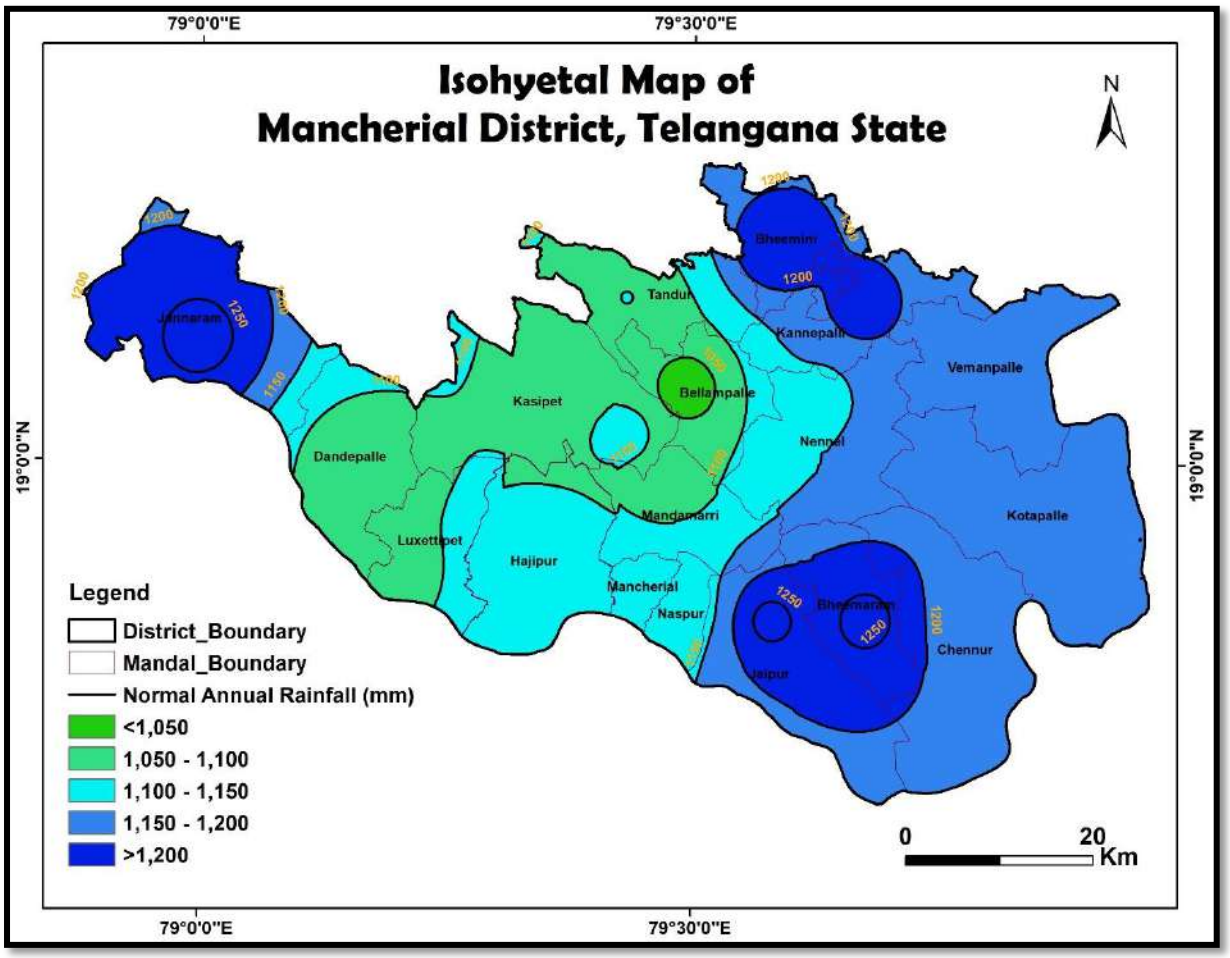


Fig.1.2a: Isohyetal map of Mancherial district.

Analysis of long term rainfall data of 16 years from 2005 to 2020 shows increasing trend in annual rainfall by 8.3 mm/year. District received excess rainfall (+20% & above normal) in 2013 & 2016, deficient rainfall (-20% & below normal) in 2007, 2009, 2011 & 2017 and normal rainfall (-19% to +19%) in remaining 10 years. The monthly rainfall time series analysis for 16 years from 2005 to 2020 shows increasing trend in monthly rainfall for June, August & October months (6.3, 3.8 & 2.7 mm/Year respectively) and decreasing trend for September (-3.2 mm/year) (**Fig.1.2b & 1.2c**).

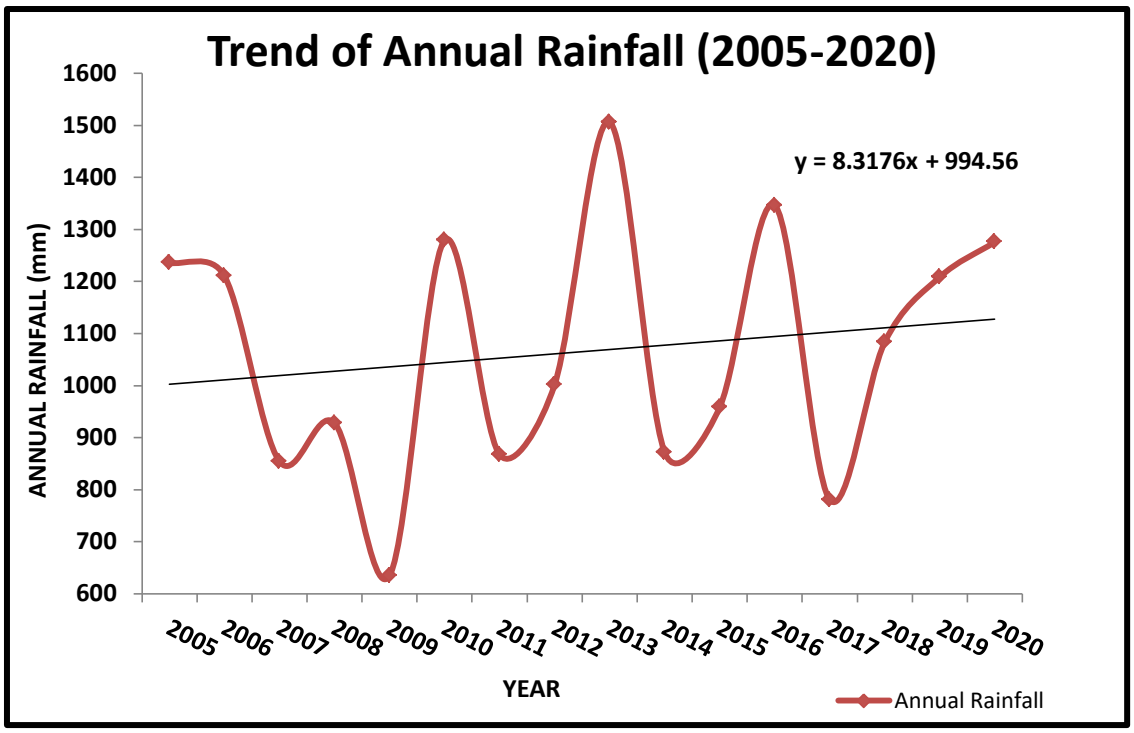


Fig.1.2b: Annual rainfall trend (2005-2020)

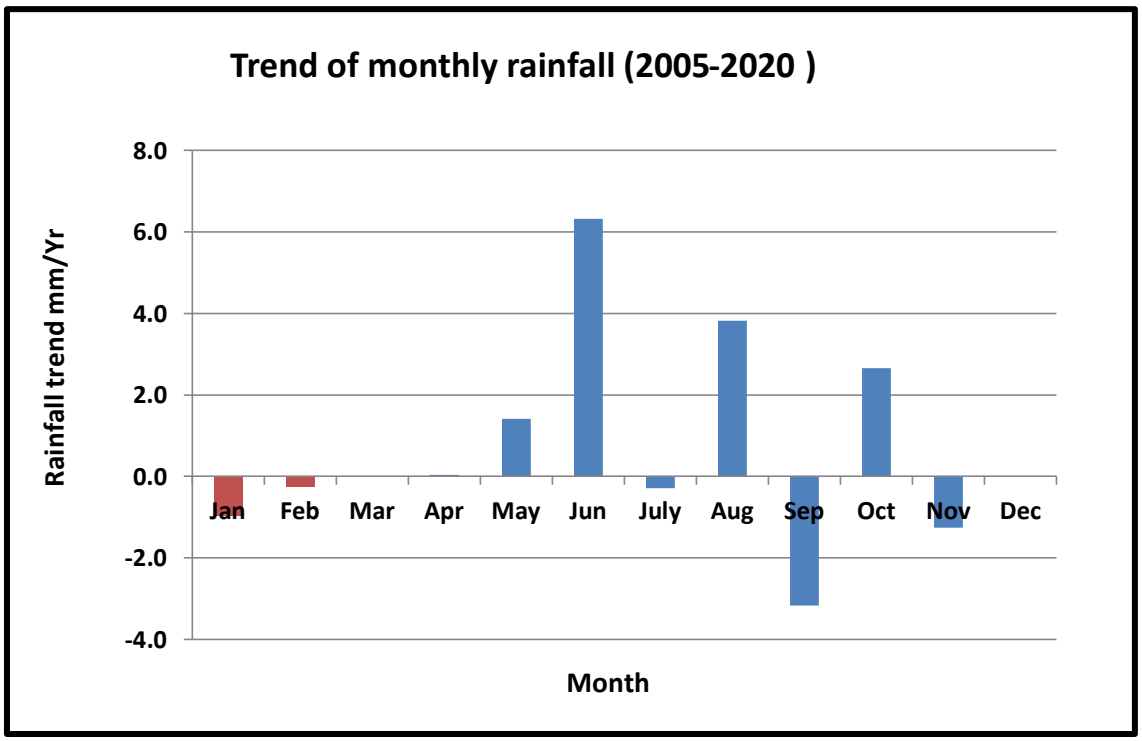


Fig.1.2c: Monthly rainfall trend (2005-2020)

1.5 Geomorphological Set up

The area forms part of peninsular plateau and is characterised by rolling and rugged topography comprising scattered hill ranges, undulating plains and interstream area. The hills rise to the height of 390 to 660 m amsl in the western part of the area, whereas in the eastern part, the hills rising to the height of 215 to 411 m amsl. The general slope of the area is north to south and northwest to southeasterly directions.

Pediment is the major landform covering about 1269 km^2 (32 %) area. The other landforms observed are pedeplain (31%), structural hills (25 %), flood plain (5%), denudation hills, residual hills channel fill, dissected plateau, intermontane valley etc. The geomorphology map of the study area is presented in **Fig.1.3**.

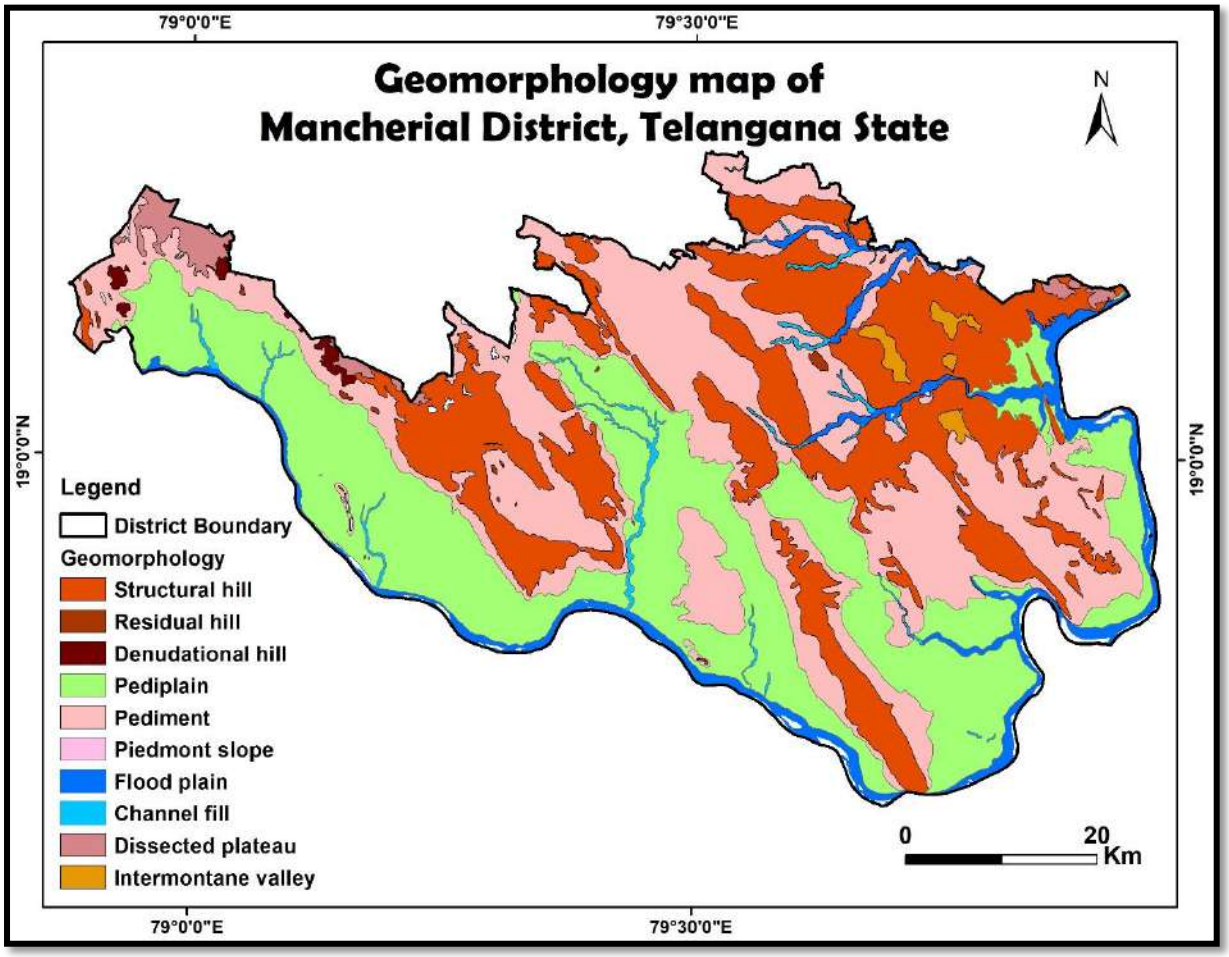


Fig.1.3: Geomorphology map of Mancherial district.

1.6 Drainage and Structures

The area surveyed forms a part of Godavari and Pranhita river basin and the important rivers that drains in the area the Godavari and Pranhita. The Godavari river forms the south and south eastern border while the Pranhita river forms the eastern boundary of the area. The river Pranhita joins the river Godavari between Rawalpalli and Wadgudem in toposheet no.56N/13 in the area. The other important

streams and streamlets which joins the Godavari are Raja Vagu, Parkkiloddivagu, Peddara vagu, Gudem vagu in the western part. The Ralla vagu and Ralivagu drains in the central part. The Golla vagu and Pedda vagu in the eastern part of the area. The drainage pattern in the area is dendritic to sub-dendritic in nature. Map depicting drainage, water bodies, lineaments and river is presented in **Fig.1.4.**

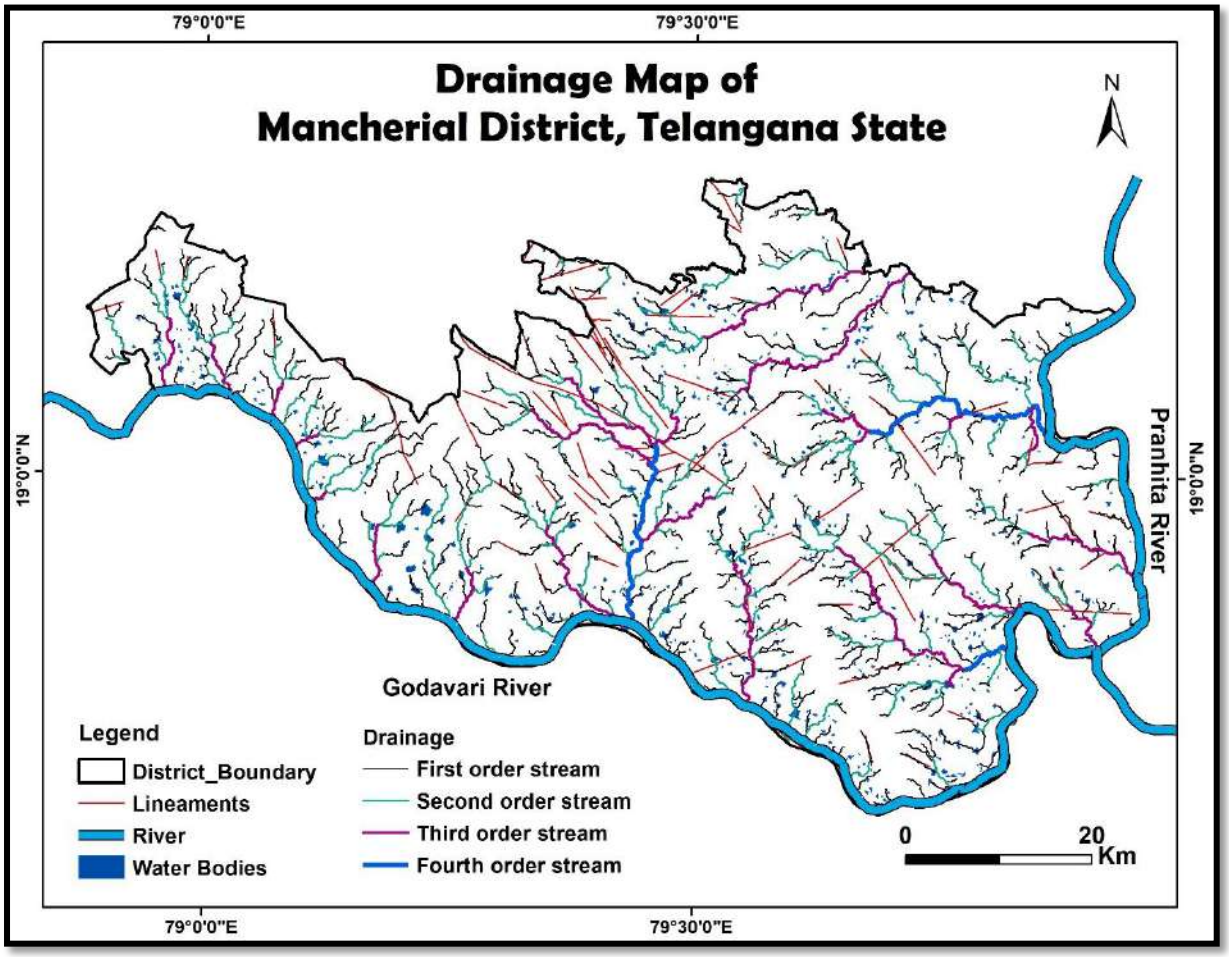


Fig.1.4: Drainage map of Mancherial district

1.7 Land use and cropping pattern (2019-20)

Out of the total geographical area of 4016 km2, forest and agriculture are the prominent land use aspects in Mancherial district and forms 45.14% and 41.58% of total area respectively followed by the industrial and built-up structures. About 3.46 % constitute the barren and uncultivable land. The land put to non-agricultural use is 4.15%, 1.17 % of the area is formed by permanent pasture and 9.02 % of the other fallow land. The current fallows are about 5.95 %. Nearly 1.48 lakh hectares are under cultivation, out of which 21 % of the area is under double cropping. The spatial distribution of land use is presented in **Fig. 1.5.**

The gross cropped area (2019-20) during khariff season is 148320 ha and during rabi season is 40307 ha (Total 188627 ha). Main crops grown are Cotton 73114 ha (49%) followed by Paddy 65137 ha (19%) , Fruits and Vegetables 7776 ha (5%), Pulses 1517 ha (1%), Condiments and Spices 446 ha (0.30 ha), Millets 249 ha (0.17%) and others 81 ha (0.05%)

during khariff season and Paddy 38616 ha (95.80 %), Pulses 451 ha (1.12 %), Fruits and Vegetables 382 ha (0.99%), Millets 740 ha (1.92 %), Others 118 ha (0.31%) during Ravi season. Season wise cropping pattern is given in **Fig.1.6a** and **Fig.1.6b**.

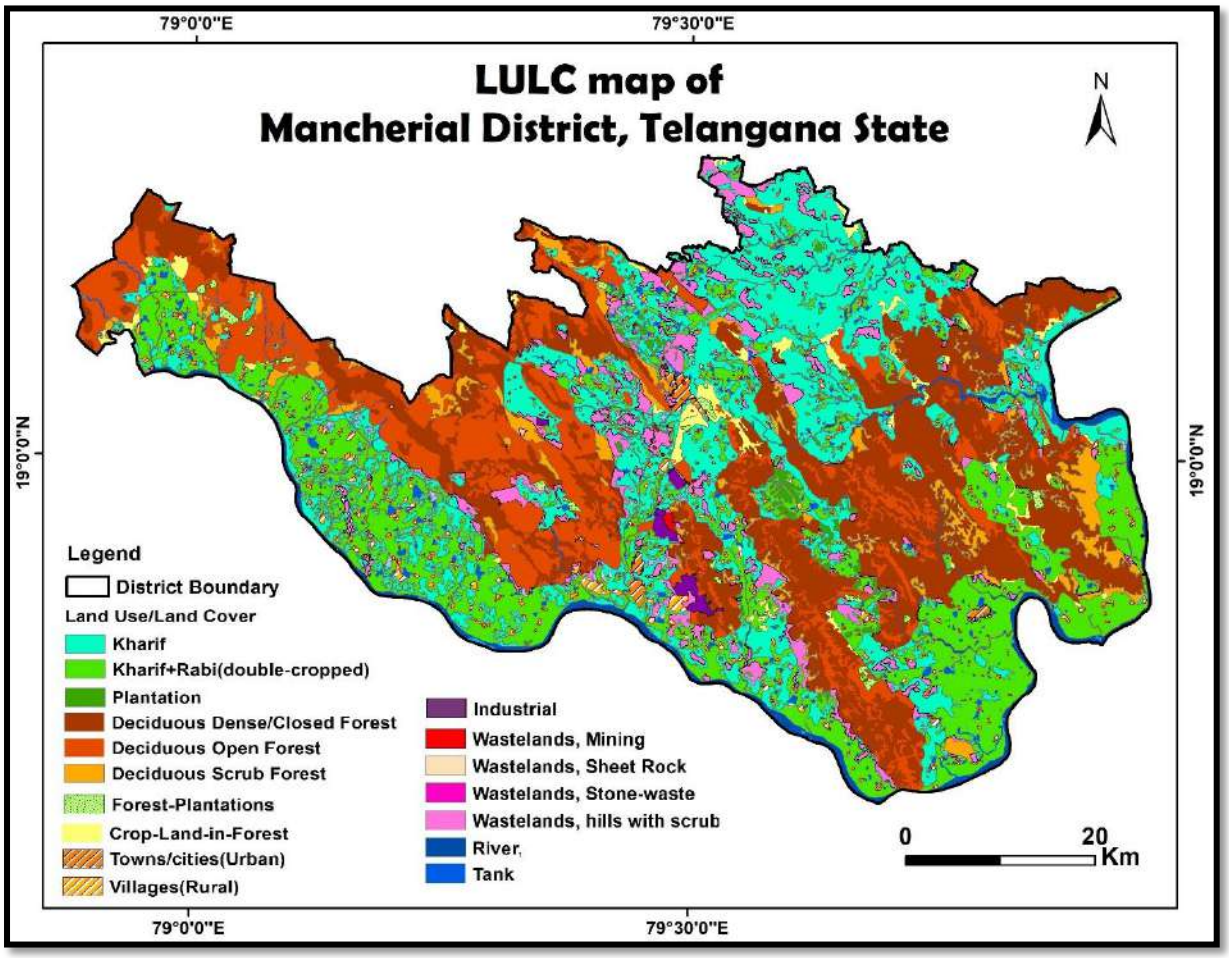


Fig.1.5: Land use and land cover of Mancherial district.

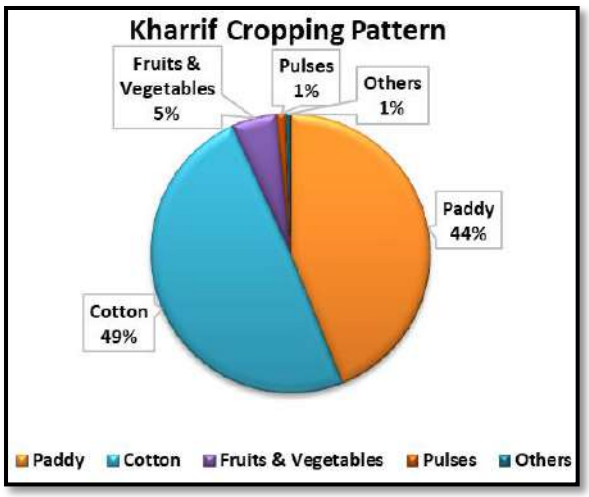


Fig.1.6a: Cropping pattern in Khariff

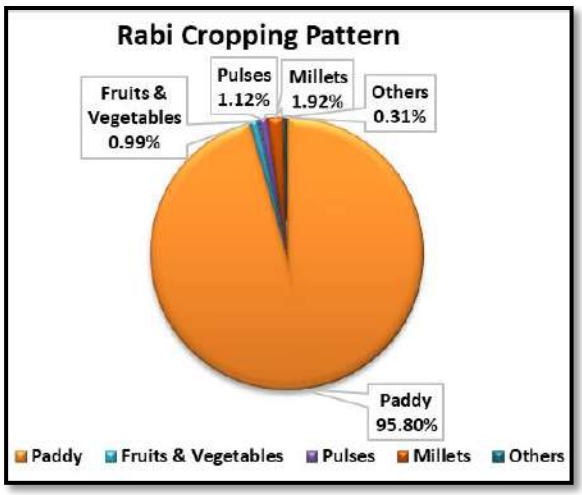


Fig.1.6b: Cropping pattern in Rabi

1.8 Soils

The area is mainly occupied by clayey soils (44%) (Deep, well drained, gravelly clay with low available water content (AWC)), Loamy soils (34%) (Red and sandy soils, which are shallow with low water holding capacity) and montmorillonite soil (22%) (calcareous, moderately drained, high AWC). Red loamy soils are predominant in central and western parts of the district, clayey soils are mostly seen in eastern and small areas in western part of the district and montmorillonite soil are mostly observed in northern part of the district (**Fig.1.7**).

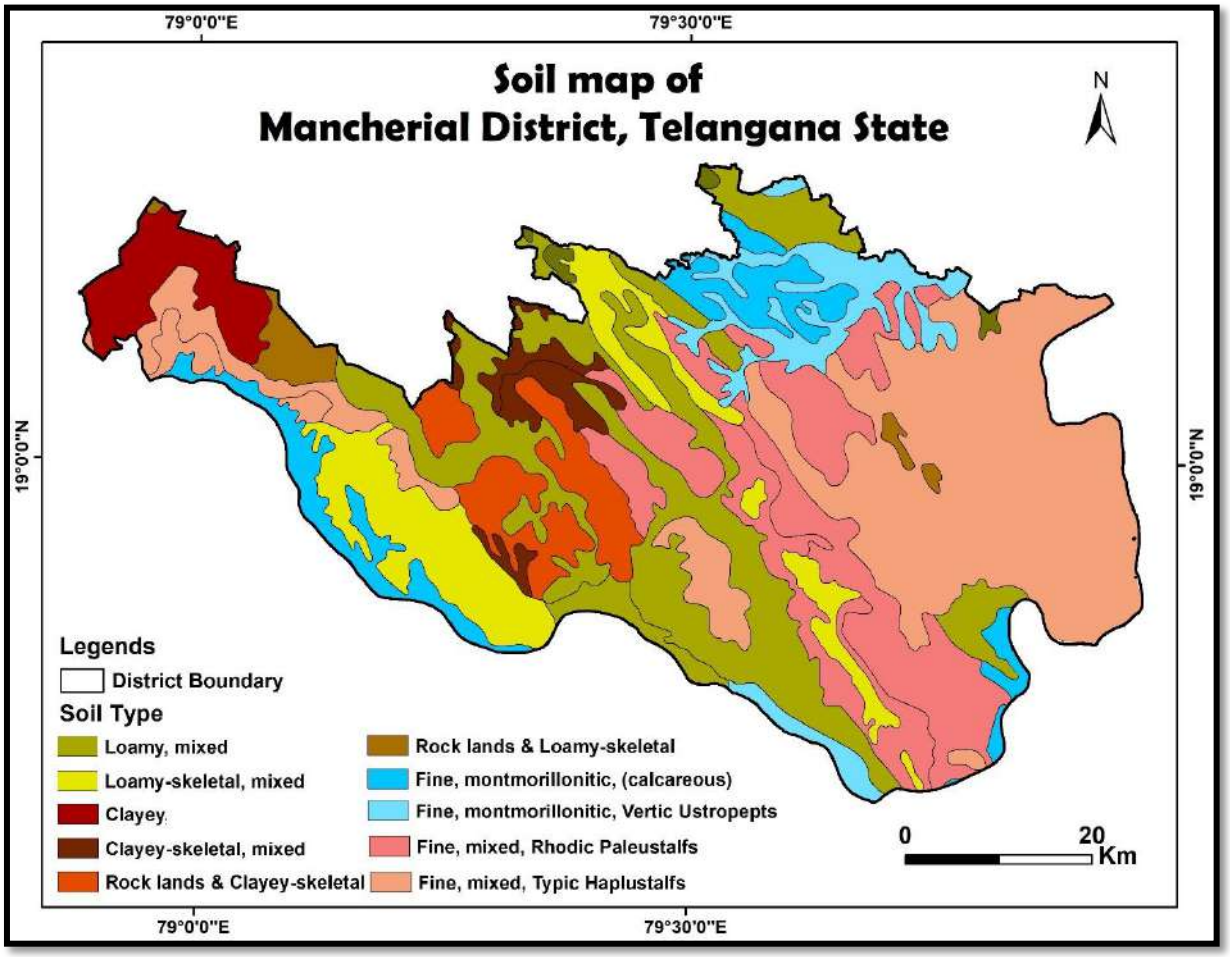


Fig.1.7: Soil map of Mancherial district

1.9 Irrigation

Major Irrigation Project:

Kadam Narayan Reddy project was constructed across Kadam river a tributary of Godavari river. This project is having an ayacut area of 57841 acres. The mandals benefited from this projects are Jannaram, Dandepalli, Luxettipet, Mancherial of Mancherial district.

Sriram Sagar project, also known as Pochampad project of Nizamabad district also provide an irrigation potential of 138 acres to Mancherial district (Source: bhuvan portal/twris).

Medium Irrigation Projects:

The Palavi Purushotam Rao project constructed across Yerravagu stream near Kalwada village of Asifabad district. The project provides irrigation to an extent of 1231 acres in Bheemini and Vemanpally mandal of Mancherial district

The ongoing major irrigation projects are Gollavagu project at Bheemaram village (& mandal) with an ayacut of 1231 acres, Peddavagu project at Nilwai village Vemanpally mandal with an ayacut of 13,000 acres , at Jaganathpur village with an ayacut of 3283 acres, Ralivagu project at Mulakalla village in Mancherial mandal with an ayacut area of 2267 acres (Source: bhuvan portal/twris).

A total of 910 minor irrigation tanks exist in the district with an ayacut of 59,408 acres. In the district there are 20,404 irrigation wells (9,390 dugwells and 11,014 borewells). There are 9 Lift Irrigation Scheme commissioned in the district which created Irrigation potential of 17,105 acres (Source: Telangana state statistical abstract-2020).

1.10 Prevailing Water Conservation/Recharge Practices

In the district there are ~1278 percolation tanks and 31 check dams exist. Under Mission Kakatiya (Phase 1 to 4), 405 tanks have been undertaken under RRR (Repairs, restoration and Rejuvenation) schemes.

1.11 Geology

The area is underlain by various geological formation from the oldest Archaean rocks comprising granite/gneisses to Purana, Gondwana to the recent alluvium. The general geological succession of the area is presented in the **Table-1.1** About 76% of the area is underlain by Sandstones, Banded Gneissic Complex (19%), Limestone (4%) & Basalt (1 %). (**Fig1.8**).

Table-1.1: Stratigraphic Succession of Mancherial district

Era	Period	Formation		Lithological Description
Quaternary	Recent	Alluvium		Loose and coarse grained sand, gravels and river alluvium
Mesozoic	Jurassic to Upper Carboniferous	Upper Gondwanas	Chikkialas Kota Maleris	Sandstone, Clay, Grit and Limestone
		Lower Gondwanas	Kamthis Barren Measures Barakars Talchirs	Sandstones, Shales and Clays, Coal seams and boulder beds
Unconformity				

Palaeozoic	Lower Palaeozoic to Upper Precambrian	Sullavais		Grit, Conglomerates and Sandstones
		Pengangas		Shales, Limestones and Sandstones
Azoic	Archaeans	Archaeans		Granites and Gneisses

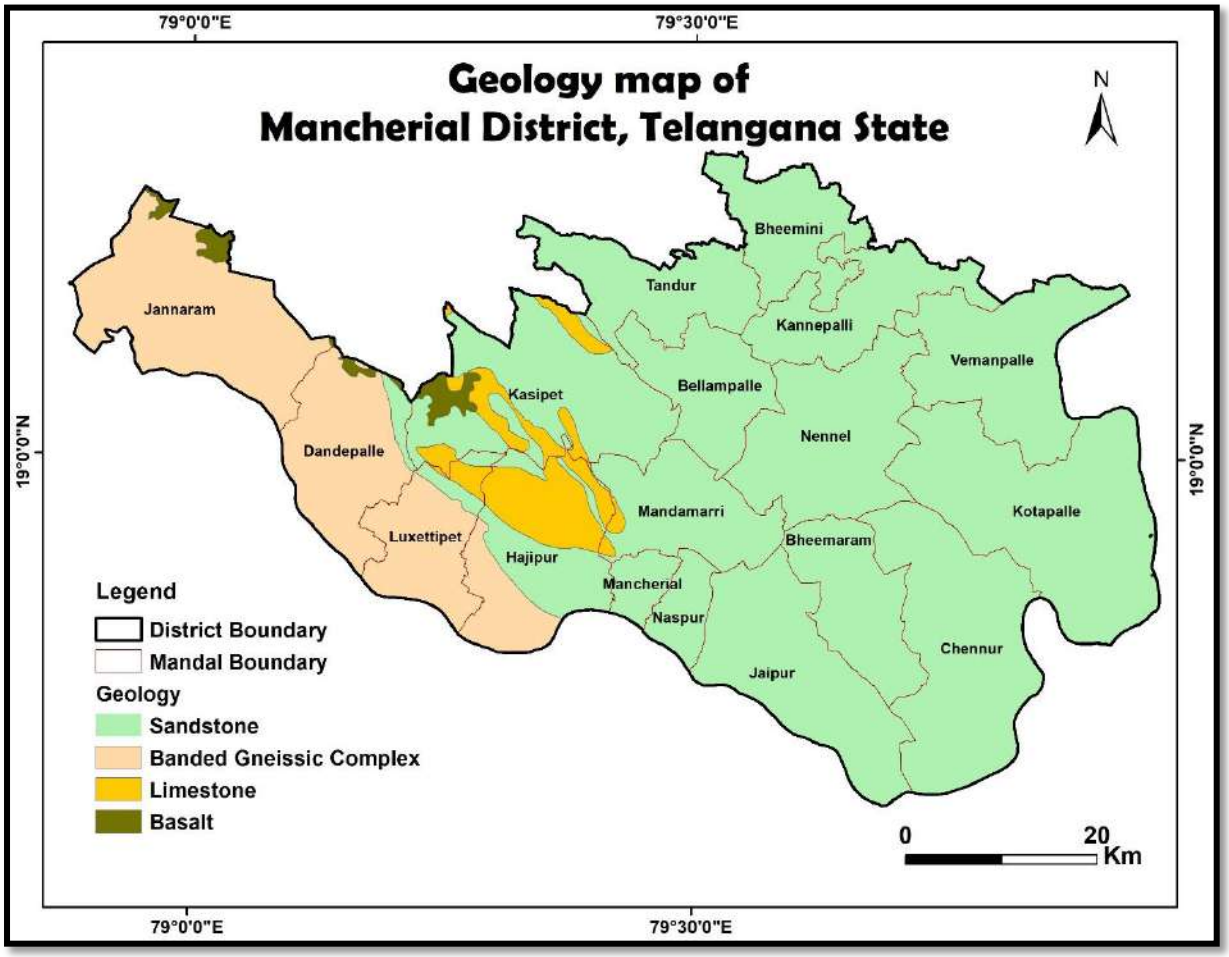


Fig.1.8: Geology map of Mancherial district.

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)**. The historically available data of the study area on Geology, Geophysics, Hydrogeology and Hydrochemistry generated under various studies by the CGWB by Systematic Hydrogeologial studies, Reappraisal Hydrogeological studies, Groundwater Management studies, Exploratory drilling and special studies have been utilized for data gap analysis in conjunction with the data collected from various State and Central government departments.

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 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	Analysis of data and preparation of GIS layers and preparation	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.

	(1:50,000 scale)	of aquifer maps	
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.

The aquifer geometry for shallow and deeper aquifer has been established through hydro geological studies, exploration, surface and subsurface geophysical studies in the district. The data used for the integration and interpretation includes:

2.1 Ground Water Exploration

So far, CGWB had constructed**,** 34 borewells at different depths in the Mancherial district. Out of these, 26 borewells were drilled in semiconsolidated/unconsolidated formation and 8 borewells were drilled in consolidated formation. SGWD drilled 1 exploratory well in the district. Data analysed from CGWB wells indicates that 3 wells of shallow depth (<30 m), 3 nos (30-100 m) 17 nos (100-200 m), 8 nos (200-300 m) and 3 nos (>300 m) depth. Deepest fracture was encountered at 87.5 m.bgl at Luxettipeth in consolidated granitic formation. The locations of exploratory wells are shown in **Fig. 2.1**.

Table-2.2: Ground Water Exploration wells

Source	Exploratory wells/ Observation wells	Piezometers
CGWB	28	6
SGWD	1	-

2.2 Ground Water Monitoring Wells

Water level monitoring wells of CGWB and SGWD is utilized for the Aquifer Mapping studies. Current and historical water levels along with water level trend data of 33 **(CGWB: 15, SGWD: 18).** monitoring wells were utilized for pre-monsoon and post-monsoon season. CGWB wells are being monitored four times (January, April, August and November) in a year whereas; the monitoring wells of State Ground Water Department (SGWD) are being monitored every month. These groundwater monitoring wells were used in order to understand the spatio-temporal behaviour of the groundwater regime.The locations of monitoring wells are shown in **Fig. 2.1.**

Table-2.3: Ground Monitoring wells

Source	No. of wells
CGWB	15
SGWD	18

2.3 Ground Water Quality

To understand chemical nature of groundwater, 66 water sample data for premonsoon season and 47 data for postmonsoon season are utilized from ground water monitoring wells of CGWB, SGWD and RWS wells. The details are given in **Table 2.4**. Parameters namely pH, EC (in µS/cm at 25° C), TH, Ca, Mg, Na, K, CO3, HCO3, Cl, SO4, NO3 and F were analyzed. The locations of sampling wells are shown in **Fig. 2.1.**

Table-2.4: Ground Water Sampling wells

Source	Premonsoon	Postmonsoon
CGWB	7	-
SGWD	18	18
RWS	41	29

2.4 Geophysical Studies

Geophysical data on VES and profiling are used to extract information on the weathered thickness, fracture depth, thickness of fracture etc. of hard rock area. For the interpretation of the aquifer geometry geophysical data in conjunction with the available groundwater exploration data is utilised. The data from 7 Vertical Electrical Soundings (VES) employing the Schlumberger electrode configuration with the maximum electrode separation (AB) of 400 meters is used for the aquifer mapping studies (**Fig. 2.1).** The data was processed and interpreted by IPI2Win software enveloped by Moscow State University, after marginally modifying the manually interpreted results in corroboration with geology and hydrogeology.

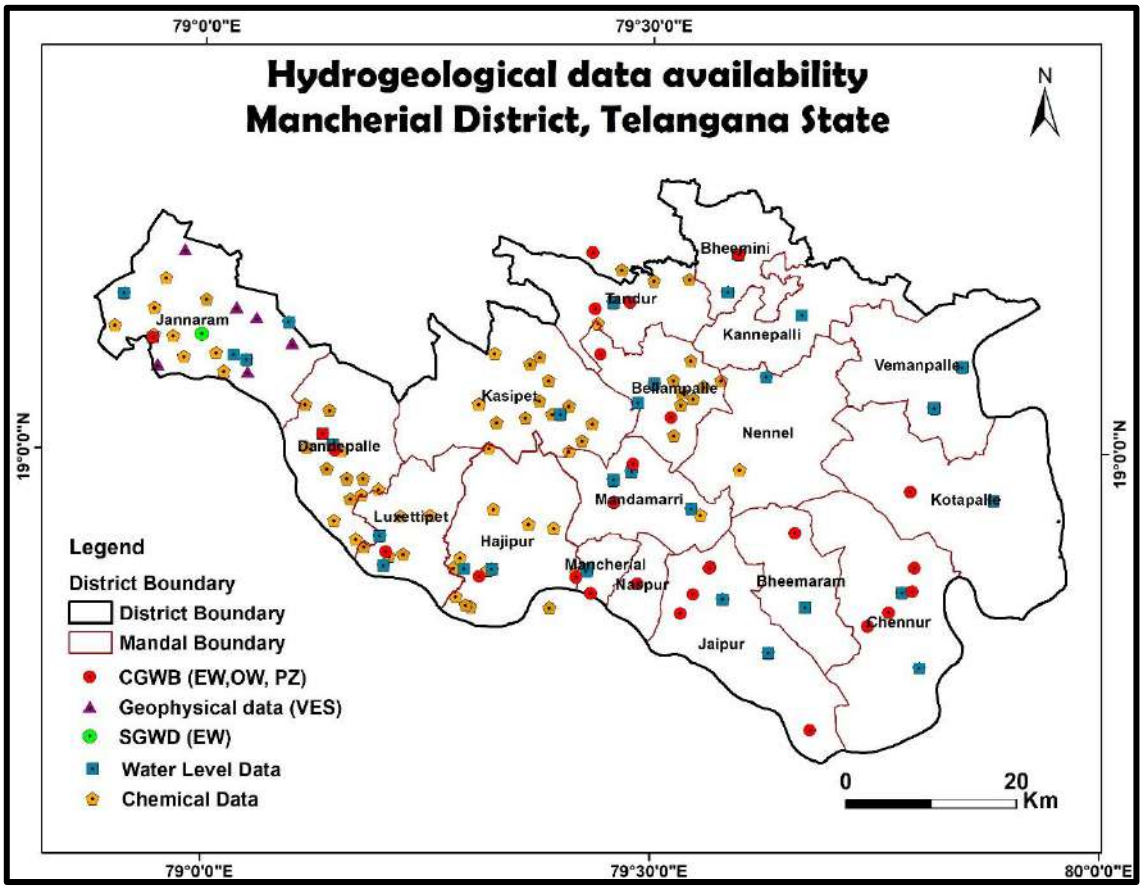


Fig.2.1: Data availability

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The data collected and generated on various parameters viz., water levels, water quality, exploration, aquifer parameters, geophysical, hydrology, hydrometeorology, irrigation, was interpreted and integrated. Based on this the various thematic layers hydrogeology, water level scenario of both current and long term scenarios, aquifer wise ground water quality, 2-D and 3-D sub surface disposition of aquifers by drawing fence and lithological sections, yield potential, groundwater resources, were generated and discussed in details.

3.1 Water Level Scenario

The present depth to water level scenario for premonsoon and postmonsoon season was generated by utilizing water level data of 33 (CGWB: 15, SGWD: 18) monitoring wells.

The premonsoon depth to water levels during May 2019 ranged between 1.75 (Neelwai) and 19.54 mbgl (Kundaram). The shallow water levels of within <3 m bgl are observed in parts of Vemanpalle mandal (< 1% of area), whereas water levels between 5-10 m bgl are observed in major parts of the district (88 % of area). The deeper water levels of 10-20 m bgl are observed in parts of Tandur, Bellampally, Bheemaram, Jaipur, Kasipet, Mandmari and Nennel mandals (10% of area). The pre-monsoon depth to water level map is given in **Fig.3.1**

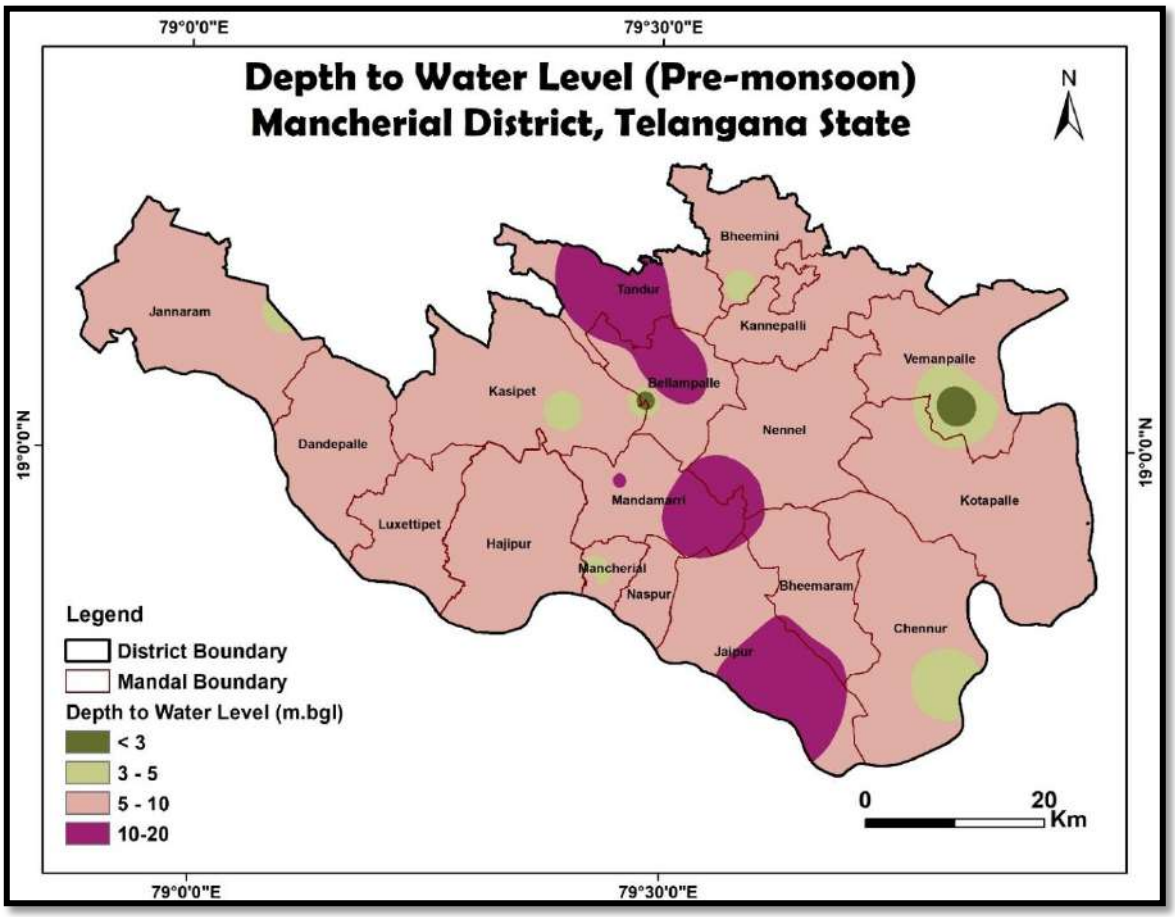


Fig.3.1: Depth to water level map of pre-monsoon season (May-2019)

The postmonsoon depth to water levels during November 2019 ranged between 0.55 (Neelwai) and 13.30 mbgl (Bellampally). The shallow water levels of <3 mbgl are observed in majority part of the district (47% of area). Moderate water levels between 3-5 mbgl are observed in 42 % of area, whereas water level of 5-10 m are observed in parts of Tandur, Bellampally, Mandmarri and Kotapalle mandals (11% of the area). The deeper water levels of 10-20 mbgl are observed as isolated patch in Bellampally mandal (<1% of area). The post-monsoon depth to water level map is given in **Fig.3.2.**

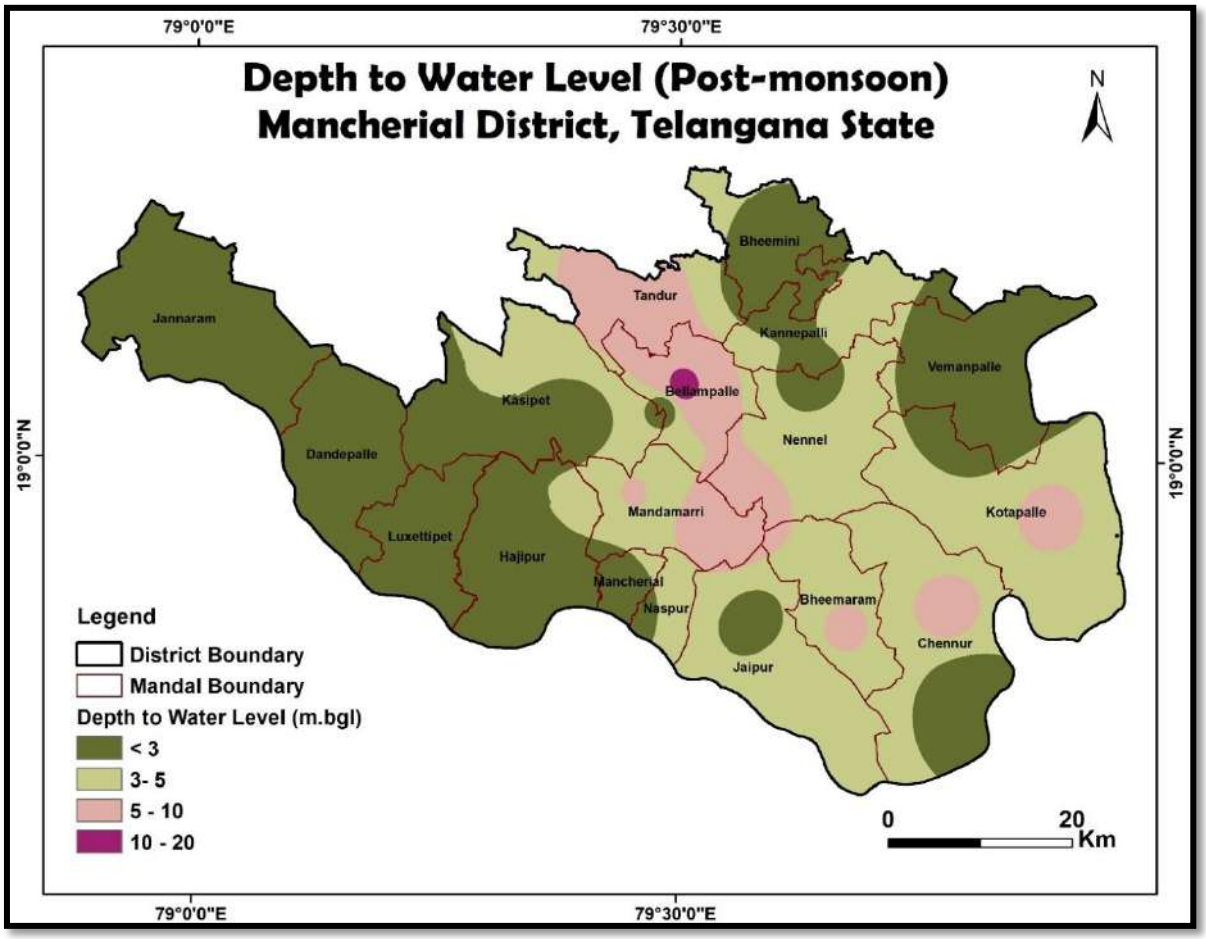


Fig.3.2: Depth to water level map of post-monsoon season (November-2019)

3.1.1 Water Level Fluctuation

The water level measured during pre and post monsoon period (2019) was used to compute the seasonal fluctuation. 100% (33 no's) of the wells show rise in water level and no wells show fall in water level. The analysis of water level fluctuation data indicated that minimum water level fluctuation was observed at Neelwai (1.20m) while maximum water level fluctuation was observed at Kundaram (14.63 m). The water level fluctuations were grouped under three categories i.e., less, moderate and high and the % of wells in each category was analysed (**Table-3.1**).

Table-3.1: Analysis of Water Level Fluctuation

S. No.	Category	Fluctuation Range	% of area
1.	Less water level fluctuation	0 to 5 m	89 %
2.	Moderate water level fluctuation	5 to 10 m	11%
3.	High water level fluctuation	10-20 m	1%

The analysis indicates that majority of the area (89%) are falling in less fluctuation range indicating good aquifer storage, whereas moderate water level fluctuation are observed in 11 % area and high water level fluctuation were observed in 1 % area. The seasonal fluctuation map is presented as **Fig. 3.3**, the perusal of map indicates that fluctuation of upto 5 m is observed in major part of the district, whereas higher fluctuation of more than 5 m is observed as isolated patches in parts of Jaipur, Mandmarri, Tandur, Jannaram and Bheemini mandal and low potential areas occurring as isolated patch in the southern part of the Mancherial district.

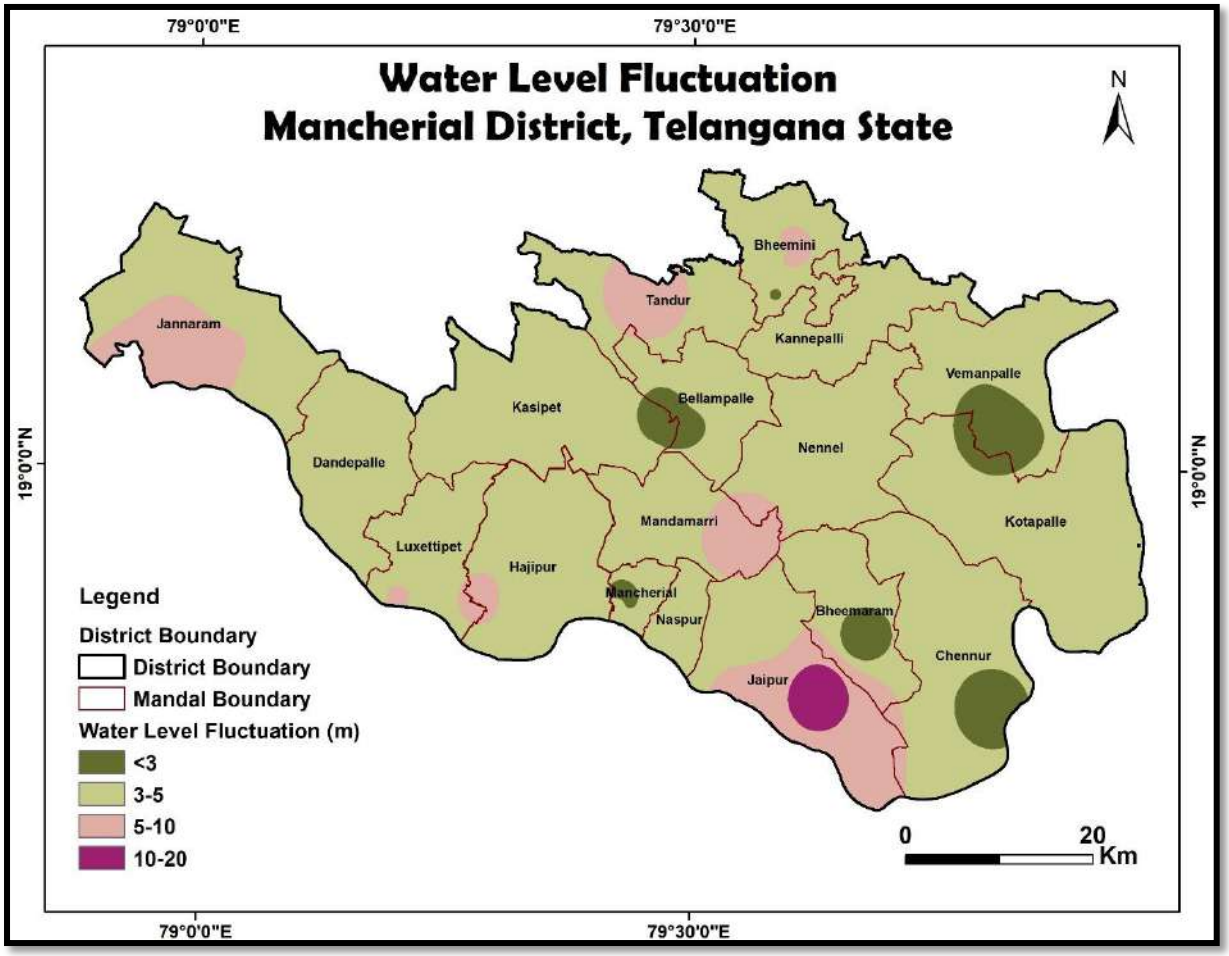


Fig.3.3: Water Level Fluctuations (m) (Nov-2019 with respect to May-2019)

3.1.2 Water Table Elevation

The water table elevation map for premonsoon and postmonsoon period (2019) was also prepared (**Fig.3.4**) to understand the ground water flow directions. The water table elevation ranges from 119 to 230 m.amsl during premonsoon period and 123 to 236 m.amsl during postmonsoon period. The groundwater flow is mainly towards Pranhita and Godavari River in the southeastern direction.

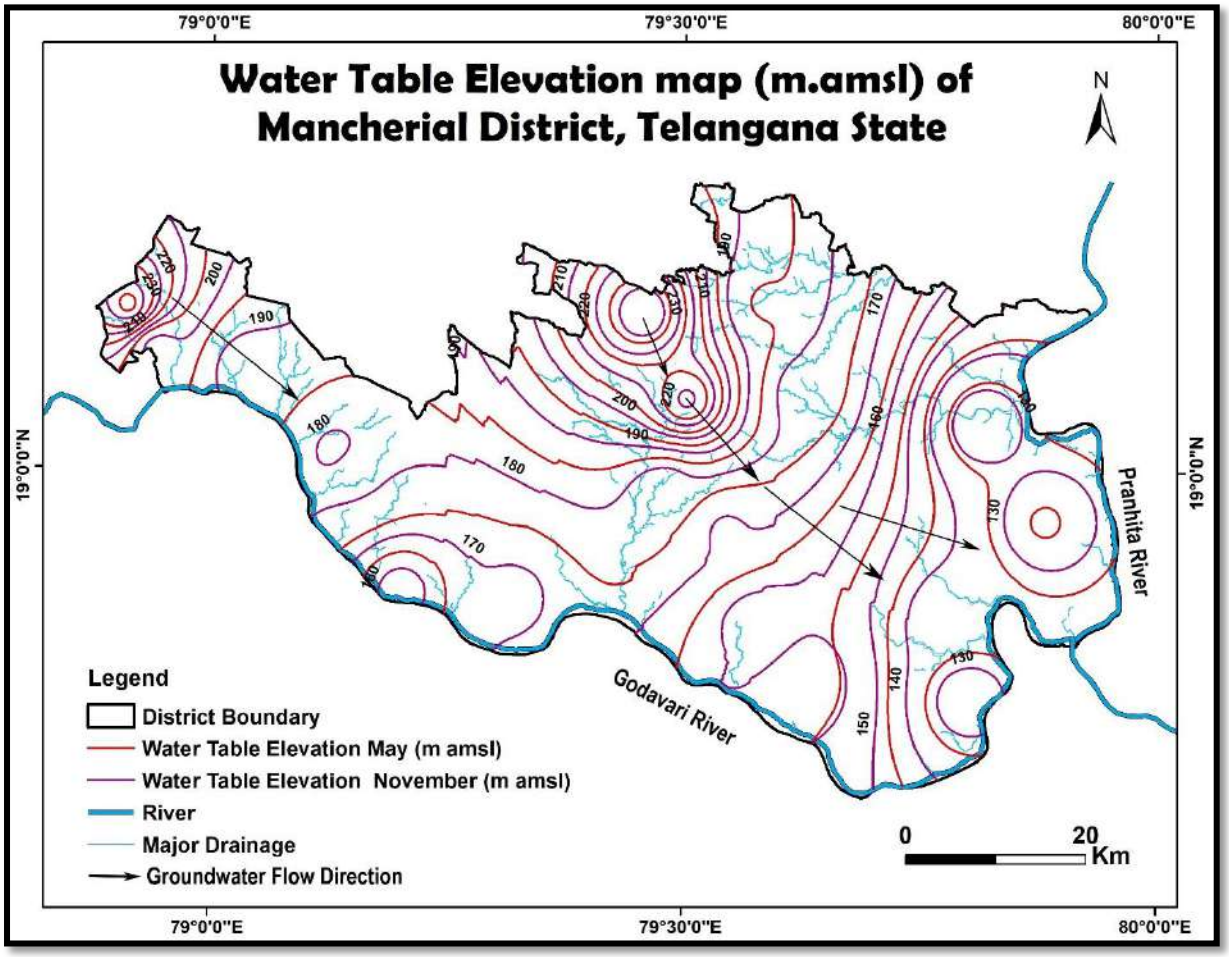


Fig.3.4: Water table elevations (m.amsl) during pre and post-monsoon seasons (2019)

3.1.3 Long Water Level Trend (2010-19)

In order to study long term behavior of the water levels and also the effect of various developmental activities with time, the data from 16 hydrograph station of CGWB for the period 2010-19 have been computed and analyzed. The decadal premonsoon water level trend analysis indicates that during pre-monsoon period, 11 wells shows falling trend (>0.5m: 2, 0-0.5m: 9 wells) (max fall: 0.65 m/yr) and 5 wells shows rising trend (0-0.5: 5 wells) (max rise: 0.28 m/yr). During post-monsoon season 7 wells show falling trend 0-0.5m.:7) (maximum fall: 0.33 m/Yr) and 9 wells shows rising trends (0-0.5m: 9 wells) (max rise: 0.47 m/yr). The graphical representation of fall and rise is shown in **Fig.3.5** and spatial distribution map is shown in **Fig.3.6** and **3.7.**

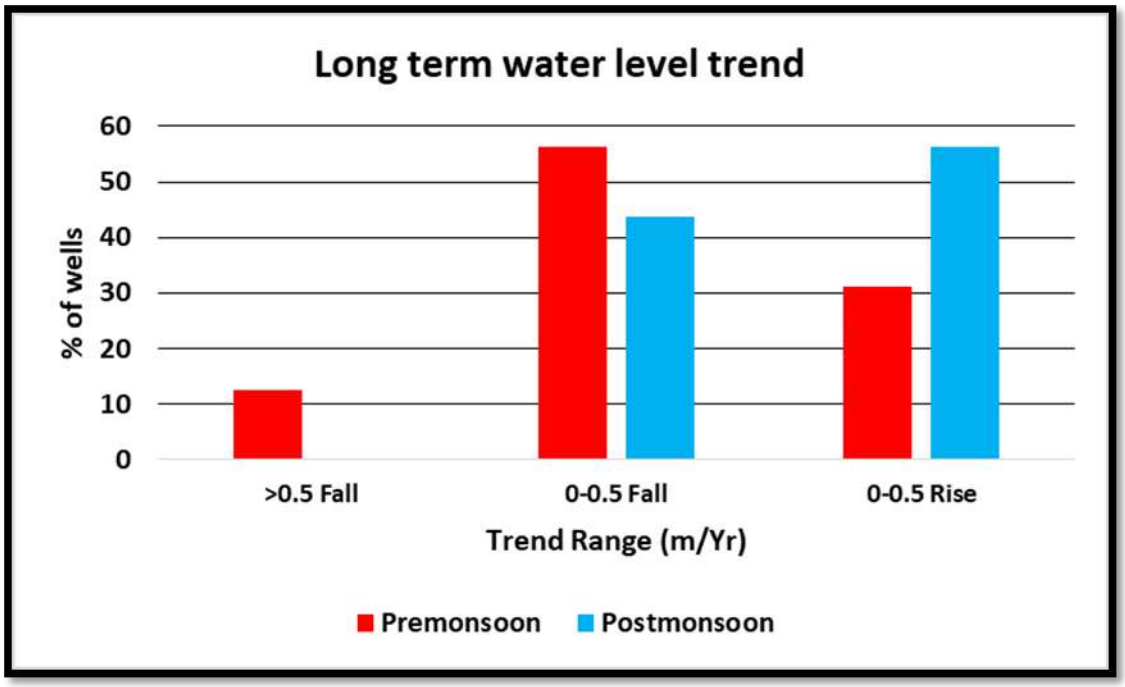


Fig. 3.5: Graphical representation of water level trends (2010-2019)

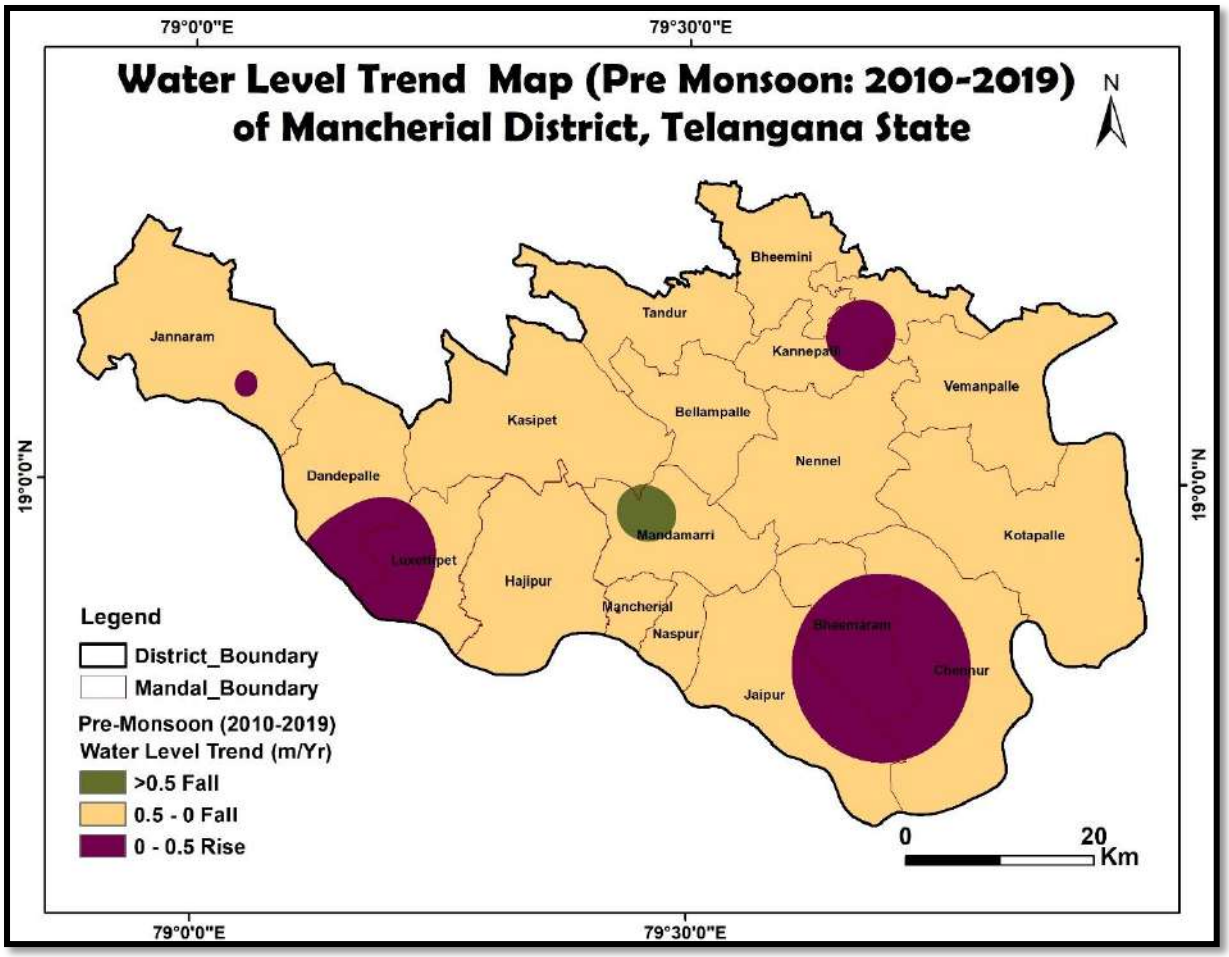


Fig. 3.6: Long-term water level trend-Premonsoon (2010-2019)

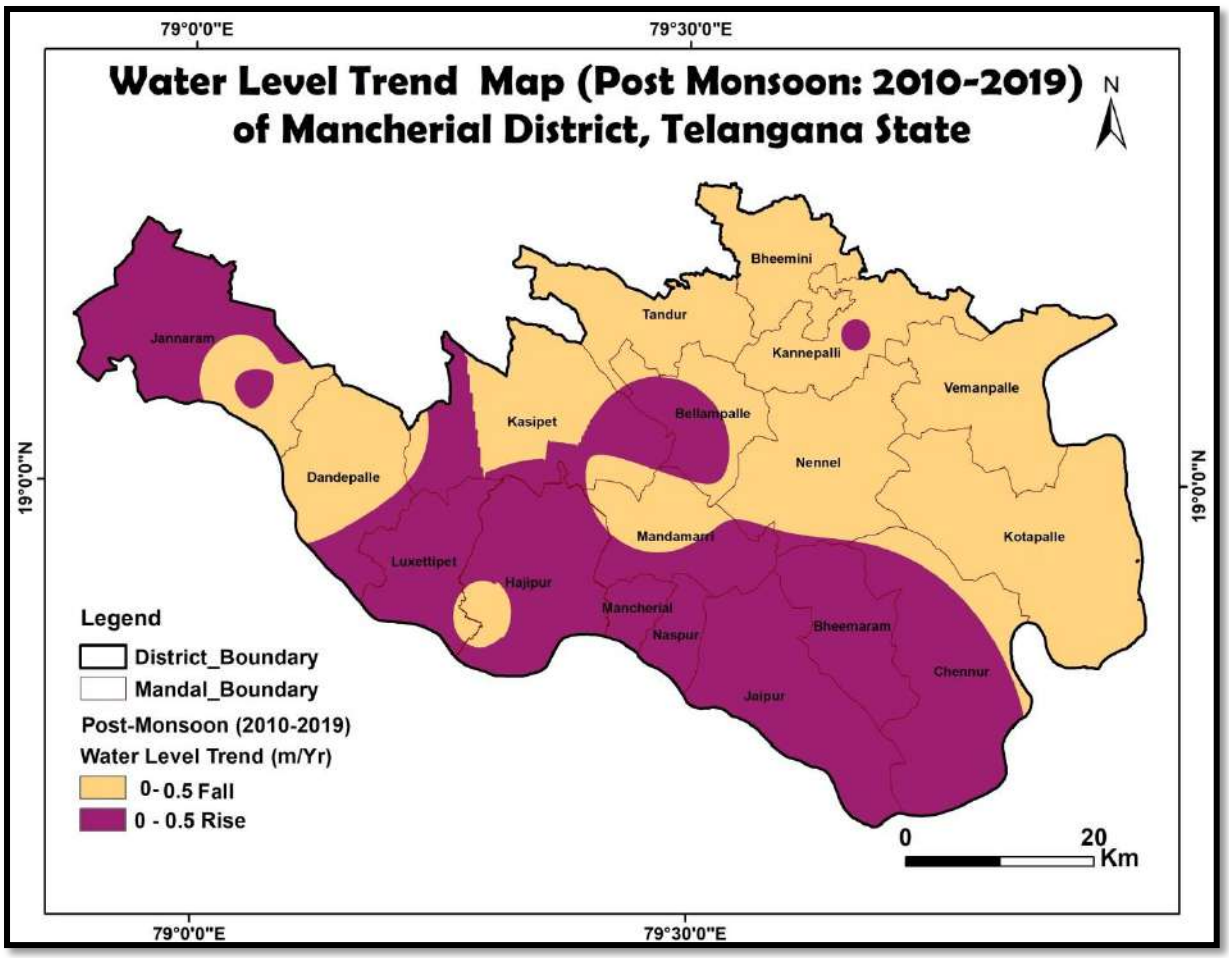


Fig. 3.7: Long-term water level trend-Postmonsoon (2010-2019)

3.2 Ground Water Quality

The suitability of ground water for drinking/irrigation/industrial purposes is determined keeping in view the effects of various chemical constituents present in water on the growth of human being, animals, various plants and also on industrial requirement. Though many ions are very essential for the growth of plants and human body but when present in excess, have an adverse effect on health and growth. For assessment of ground water quality, 113 samples (Pre-monsoon:66 and post-monsoon:47) were utilised from monitoring wells of CGWB, SGWD and RWS for the year 2019. The ground water samples were analysed for major chemical constituents. Parameters namely pH, EC (in µS/cm at 25° C), TH, Ca, Mg, Na, K, CO3, HCO3, Cl, SO4, NO3 and F were analysed.

3.2.1 Pre-Monsoon

A total of 66 samples were analyzed (CGWB:7, SGWD:18 and RWS:41).Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 7.03-8.71(Avg:7.37). Electrical conductivity varies from 555-11250 (avg: 1656) µ Siemens/cm. In 48 % of area EC is within 1500 µ Siemens/cm, in 49% area, it is 1500-3000 µ Siemens/cm and in 2 % area, it is > 3000 µ Siemens/cm (**Fig.3.8**). Nitrate concentration in 2 sample is beyond permissible limits of 45 mg/L (**Fig.3.9**). Fluoride concentration varies from 0.19-4.61 mg/L (**Fig 3.10**) and

80 % of samples are within permissible limits of BIS and rest is beyond permissible limit of 1.5 mg/L. High fluoride concentration is observed mostly in Jaipur, Bheemaram, Chennur, mandmarri, Hazipur, Kasipet, Kotapalle, Jannaram mandal and in small areas in Dandepally, Bheemini parts of the district.

3.2.2 Post-Monsoon

A total of 47 samples were analyzed (SGWD:18 and RWS:29). Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 7.2-8.58 (Avg:7.46). Electrical conductivity varies from 388-2287 (avg: 1307) µ Siemens/cm. In 84 % of area EC is within 1500 µ Siemens/cm, in 16% of area EC is 1500 to 3000 µ Siemens/cm (**Fig.3.11**). Nitrate concentration in 2 of samples is beyond permissible limits of 45 mg/L (**Fig.3.12**). Fluoride concentration varies from 0.3-3.27 mg/L (**Fig 3.13**) and 78 % of samples are within permissible limit of BIS and rest is beyond permissible limit of 1.5 mg/L.

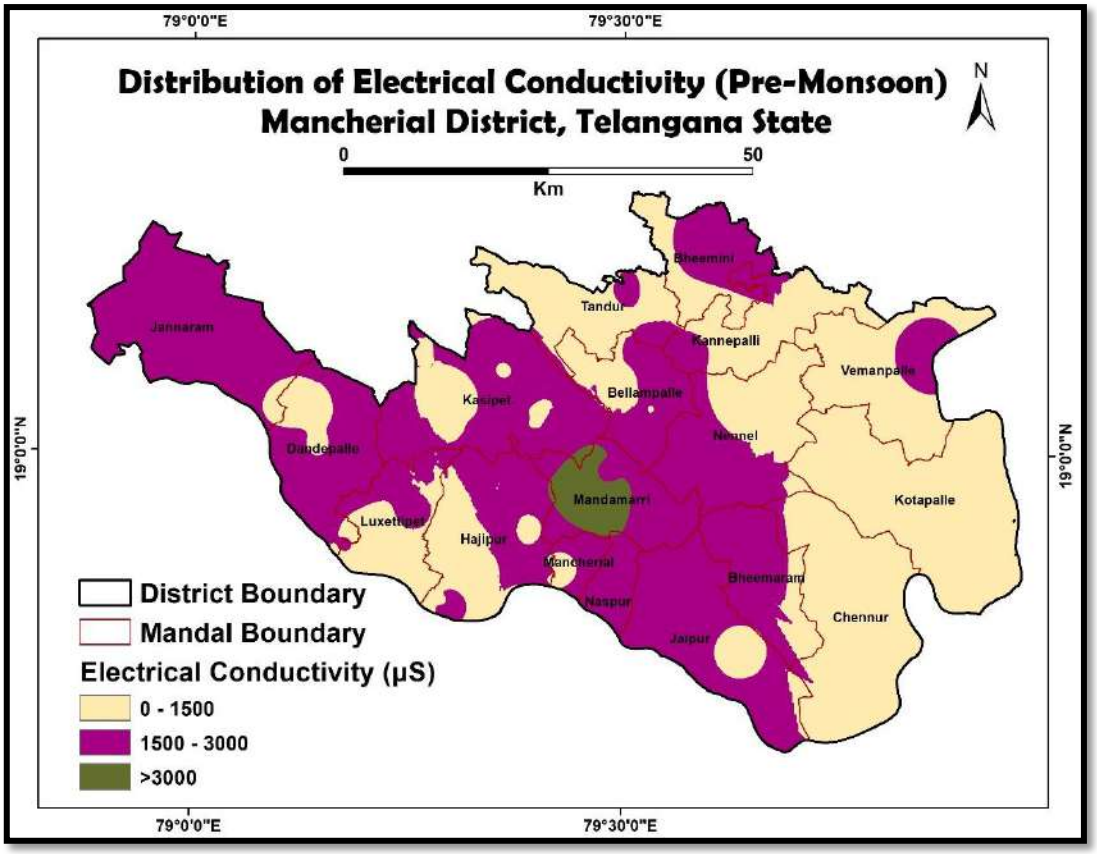


Fig.3.8: Distribution of Electrical conductivity (Pre-monsoon 2019).

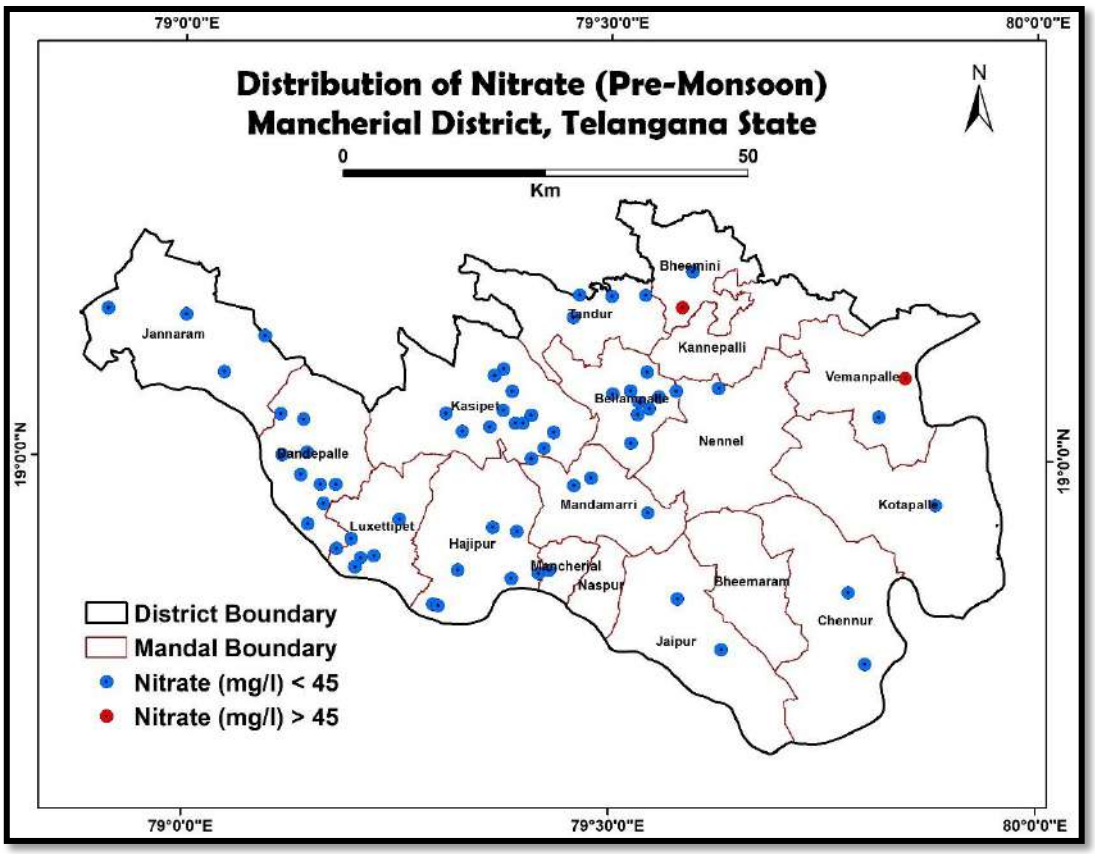


Fig.3.9: Distribution of Nitrate (Pre-monsoon 2019)

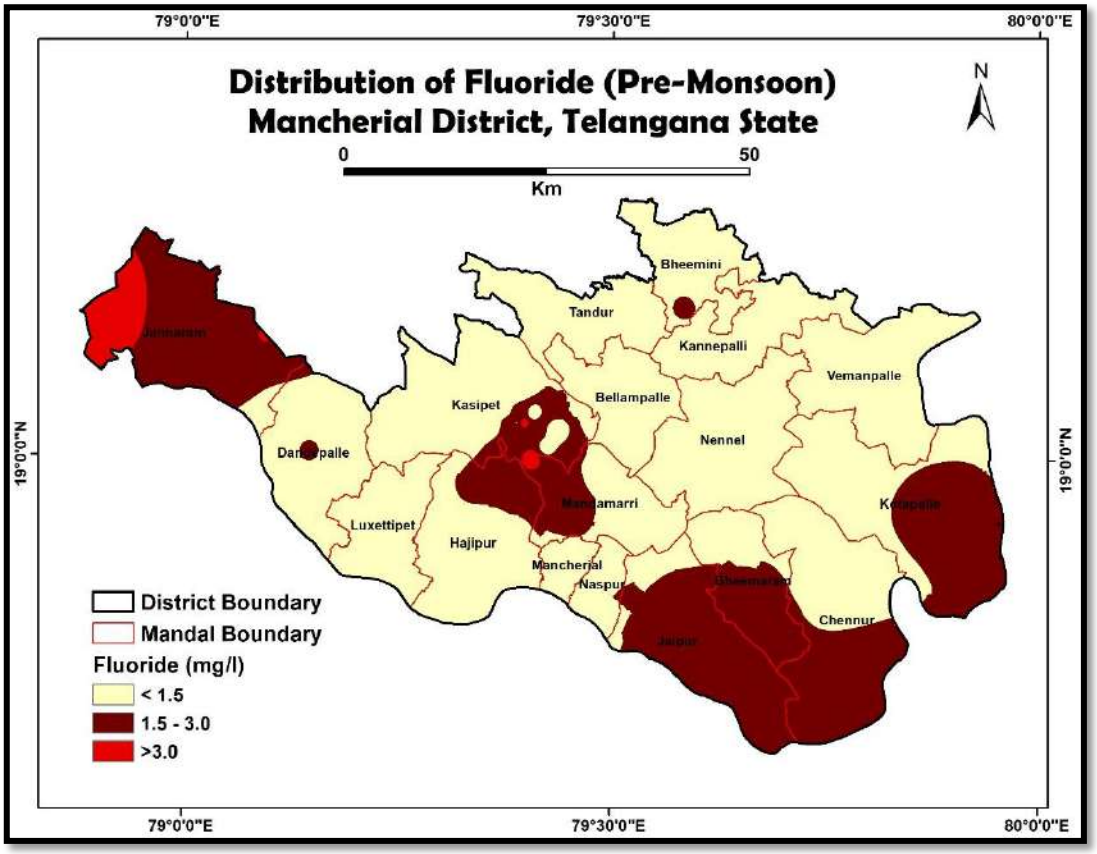


Fig.3.10: Distribution of Fluoride (Pre-monsoon 2019)

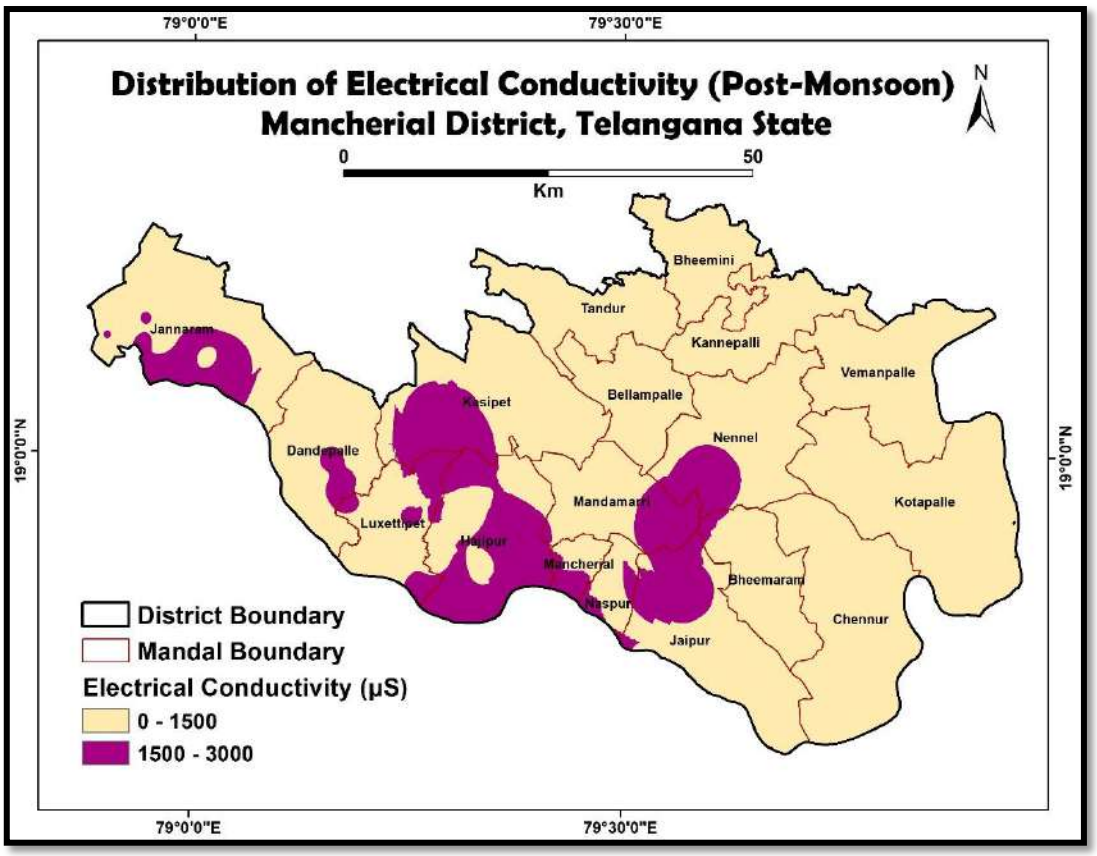


Fig.3.11: Distribution of Electrical conductivity (Post-monsoon 2019)

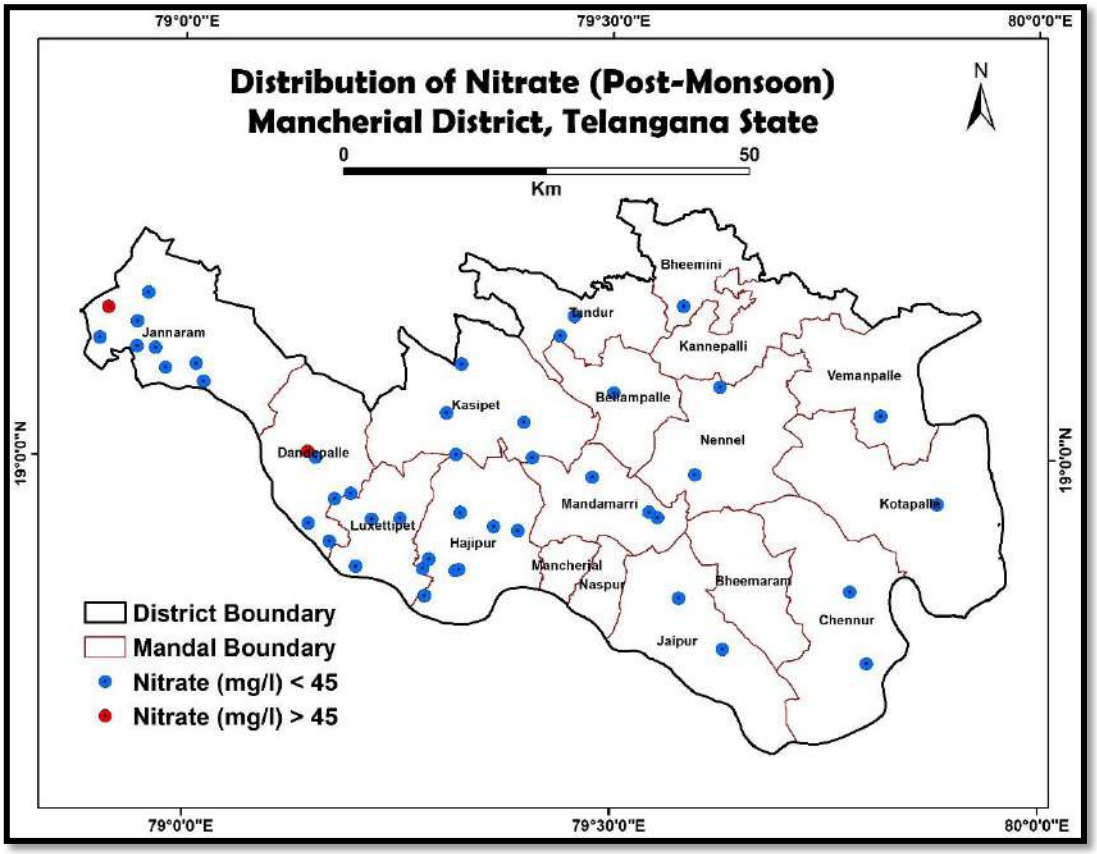


Fig.3.12: Distribution of Nitrate (Post-monsoon 2019)

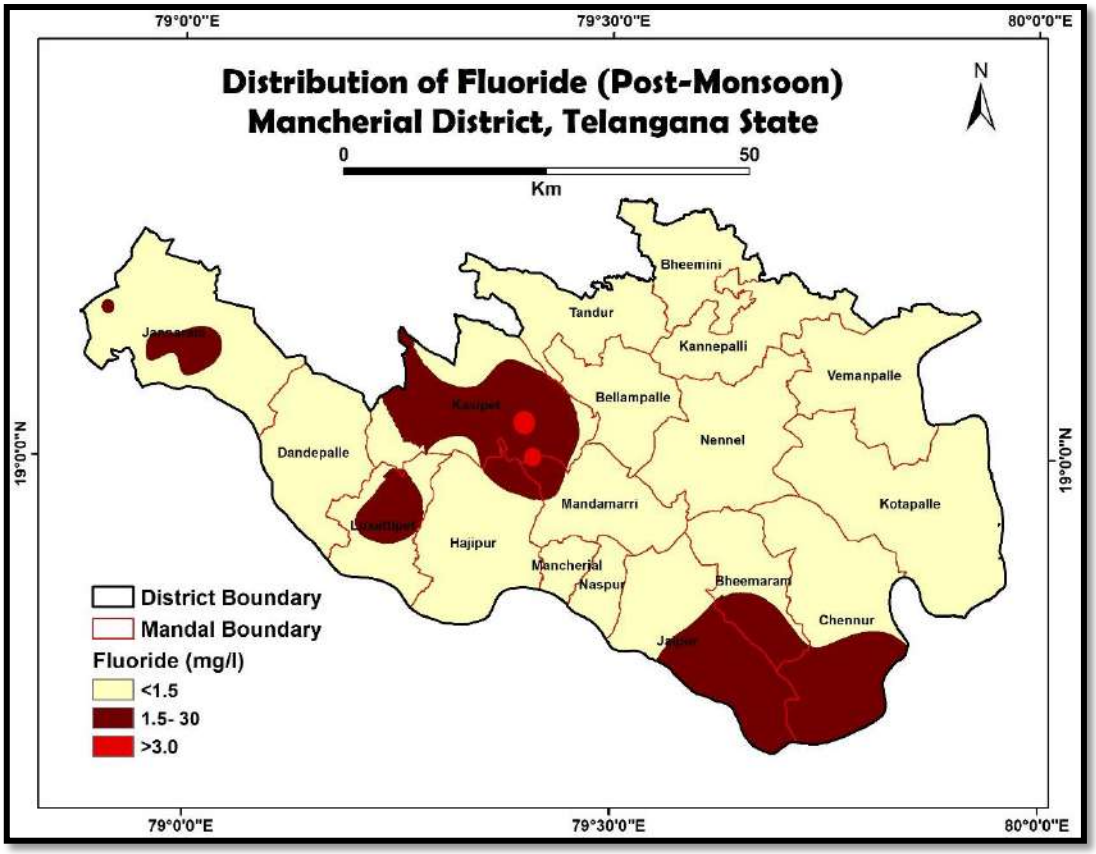


Fig.3.13: Distribution of Fluoride (Post-monsoon 2019)

3.3 Aquifer Mapping

The aquifer geometry for shallow and deeper aquifer has been established through hydro geological studies, exploration, the surface and subsurface geophysical studies in the district covering all geological formations. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks. It depends on rock type, depth of weathering and extension of weak zones like fractures, joints etc., in hard rocks, while in sedimentary rocks it depends on porosity, granularity, cementing matrix, permeability, bedding plains and faults etc. Based on 37 hydrogeological data points hydrogeological map is prepared and presented in **Fig 3.14**.

On the basis of occurrence and movement of ground water, mainly rock units of the Mancherial district can be broadly classified into two categories: consolidated formation (Archean crystalline and metasedimentary formation) which occupies 24% of the area and semi-consolidated to unconsolidated formation (Sedimentary rock) which occupies 76 % of the area.

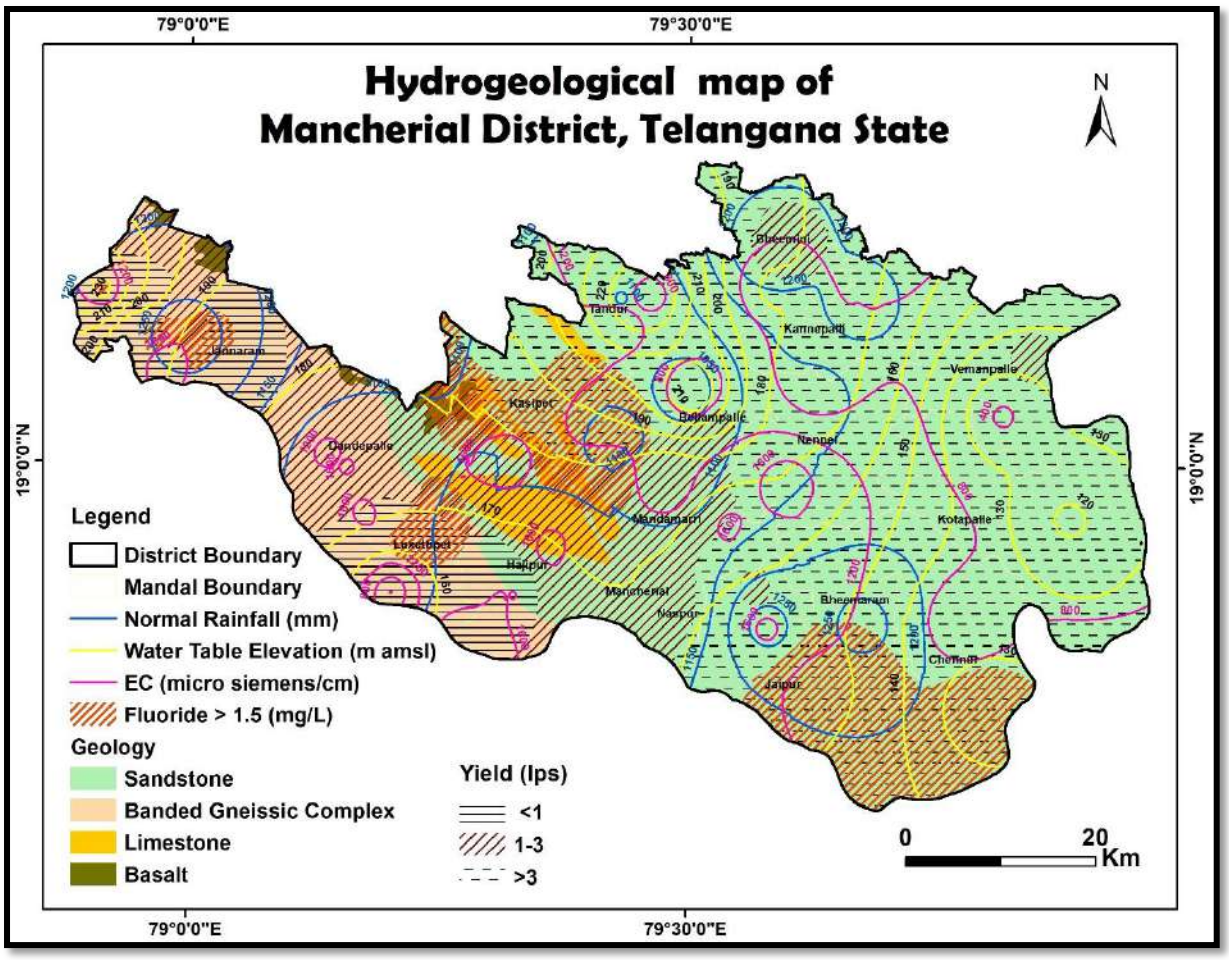


Fig.3.14: Hydrogeological map of Mancherial district

3.3.1 Aquifer system in consolidated formation

Consolidated formation consist of Archean crystalline formation. The crystalline granites and gneisses are devoid of primary porosity. However, subsequent weathering, fracturing and fissuring developed secondary porosity. The main 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.

3.3.1.1 Weathered Zone (Aquifer -I)

It consists of weathered residum where ground water occurs under unconfined conditions in the intergranular pore spaces of weathered mantle and is mainly developed by construction of dug wells or shallow bore wells as hand pumps The storage in granite rocks is primarily confined to the weathered zone and it has been used mainly for irrigation purpose. It extends upto depth of 26m in Mancherial district. Thickness of weathered zone is in the range of 10-20 m in most part of area covering ~75 % of area, shallow weathering (< 10 m) occurs in 24 % of the area and deep weathering (> 20 m) occurs in rest of the area.

3.3.1.2 Fractured Zone (Aquifer -II)

In the fractured zone ground water occurs under semi-confined to confined conditions. The fractured zone is considered from depth of first fracture to the depth of deepest fracture. Ground water in fractured zone is developed through construction of shallow/deep bore wells and dug-cum- borewells. The depth of fracturing varies from 8 m to 87.5m (deepest fracture encountered at Luxetipeth). Ground water yield from fractured granite/gneiss varies from <0.01 to 1.5 lps. (avg: 0.4 lps). The transmissivity varies from 0.04-29.4 m2/day and storativity varies from 0.0001 to 0.00001. The specific capacity ranges upto 31.85 lpm/mdd.

3.3.2 Aquifer system in semiconsolidated /unconsolidated formation

These are Gondwana formations which consist of sandstones, shales and clays, forming a thick sequence of sediments. They are generally bedded deposits with well-defined lithologic units and are effected by structural disturbances, the area show lateral and vertical variation with in short distances, due to which the hydrogeological properties of the formation vary widely. The sandstones are generally medium to coarse, friable and loose due to weathering. The sandstones form the principal aquifers except where they occurs as thin intercalations of clays. The ferruginous kankary material formed on the surface due to weathering augments the infiltration and saturates the underlying sandstones. The groundwater in the Gondwana formations occurs under both water table and confined conditions.

Multiple aquifer system (1 to 4 aquifers) are found in the sandstone formations with intervening clay beds. The first aquifer is unconfined whereas the deeper aquifers are in semi-confined/ confined condition. Depth of aquifers are decided based on the depth of bottom clay layers.

3.3.2.1 Unconfined aquifer (Aquifer-I)

In the Aquifer-I, groundwater occurs under phreatic/unconfined condition. The thickness of Aquifer-I varies from 6-60m. The unconfined zone extend from bottom of the soil layer to top of the first clay layer. Thickness of the unconfined zone consisting in range of <10m occurs in 19 % of the area, 10-20m in 42 % , 20-30 in 25 % , 30-40m in 8% and >40m occurs in 6 % of the area .

3.3.2.2 Confined/Semiconfined aquifer (Aquifer-I to Aquifer-IV)

Unlike Aquifer-I, ground water occurs under confined to semi-confined condition in these aquifers. The occurrence of ground water depends on porosity, granularity, cementing matrix, permeability, bedding plains and faults etc. The deeper aquifers identified upto a depth of 300m. The aquifers are mainly composed of fine to coarse grained sandstone.

Ground water yield of sandstone aquifers varies from 1.2 to 16.2 lps (avg: 4.0 lps). The transmissivity varies from 1.34-115 m^2/day and storaivity varies from 1.12 to 0.0001. The specific capacity ranges between 3.15 to 93.42 lpm/mdd.

Table 3.2 Salient features of Aquifer system in Mancherial district

	Archean Crystalline		Gondwana Formation	
Prominent Lithology	Granite, Gneiss		Sandstone	
Aquifers	Weathered Zone (Aquifer-1)	Fracture Zone (Aquifer-2)	Unconfined Zone (Aquifer-1)	Semiconfined/ Confined Zone (Aquifer-II to IV)
Thickness range	6-26 m	8-87.5 m	6 to 60 m	Upto 300 m at different depth ranges
Range of yield potential	<0.01 to 1.5 lps (avg: 0.4 lps)		1.2 to 16.2 lps (avg: 4 lps)	
Transmissivity (m^2/day)	0.04 to 29.4 m^2/day		1.34-115 m^2/day	
Storativity	0.0001 to 0.00001		1.2 to 0.0001	
Specific Capacity (lpm/mdd)	Upto 31.85		3.15 to 93.42	
Quality(Suitabilty of Irrigation)	Yes	Yes	Yes	Yes
Suitabilty of domestic purposes	Yes	Yes	Yes	Yes

3.4 3D and 2D Aquifer Disposition

The data generated from ground water monitoring wells, hydrogeological inventories, exploratory wells and geophysical studies, various thematic layers were utilized to decipher the aquifer disposition of the area. This particularly includes the information on 3D geometry of aquifers, panel diagram and hydrogeological information of these aquifers. RockWorks-16 software was used for this purpose. The data is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data. The 3-D representation of Aquifer disposition is presented in **Fig. 3.15**

The fence diagram indicating the disposition of various aquifers is presented in **Fig.3.16 & 3.17**. In western part of the area the presence of granites/gneiss can be seen. The disposition of weathered and fractured zone followed by massive granite/gneiss can be observed in the Fence. In the central and eastern parts multi-aquifers system of sandstone can be seen separated by intervening clay layers.

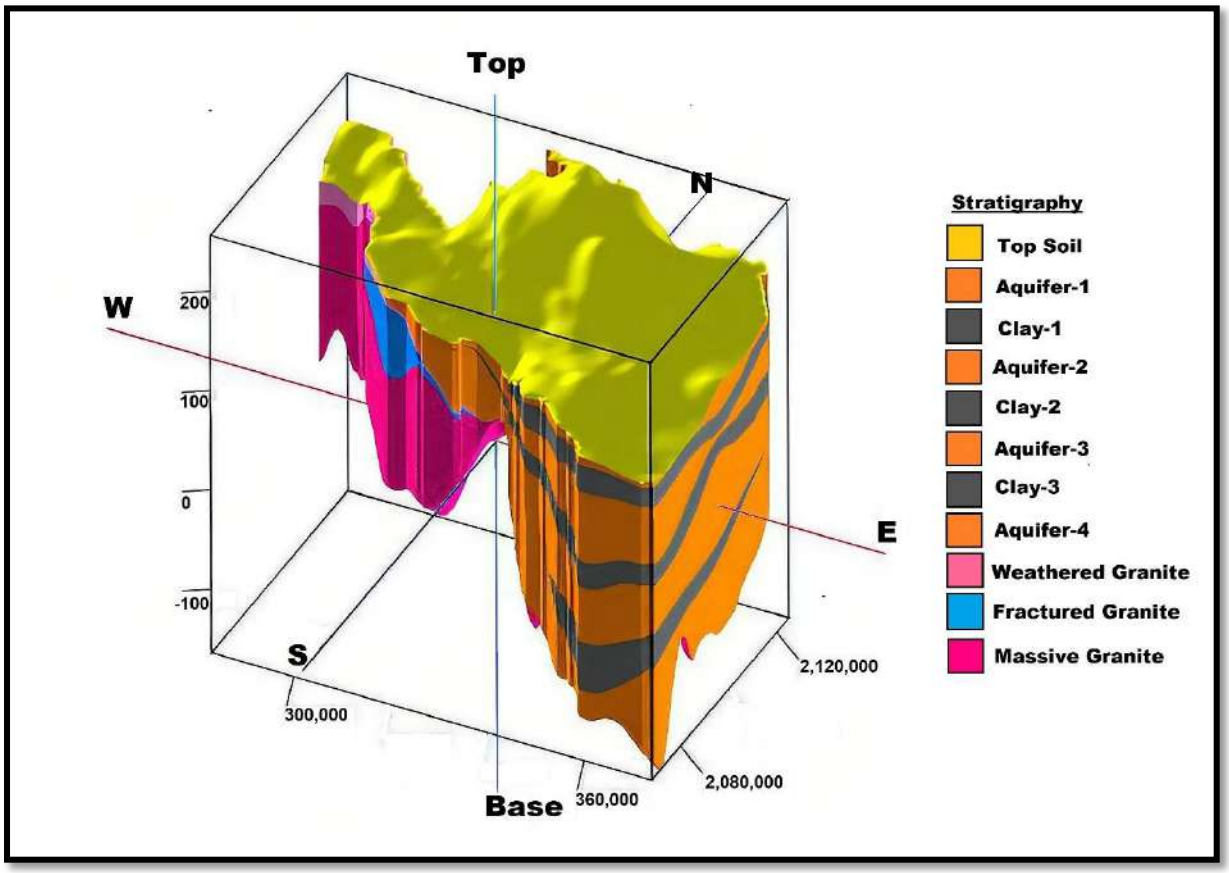


Fig.-3.15: 3-D disposition of Aquifers

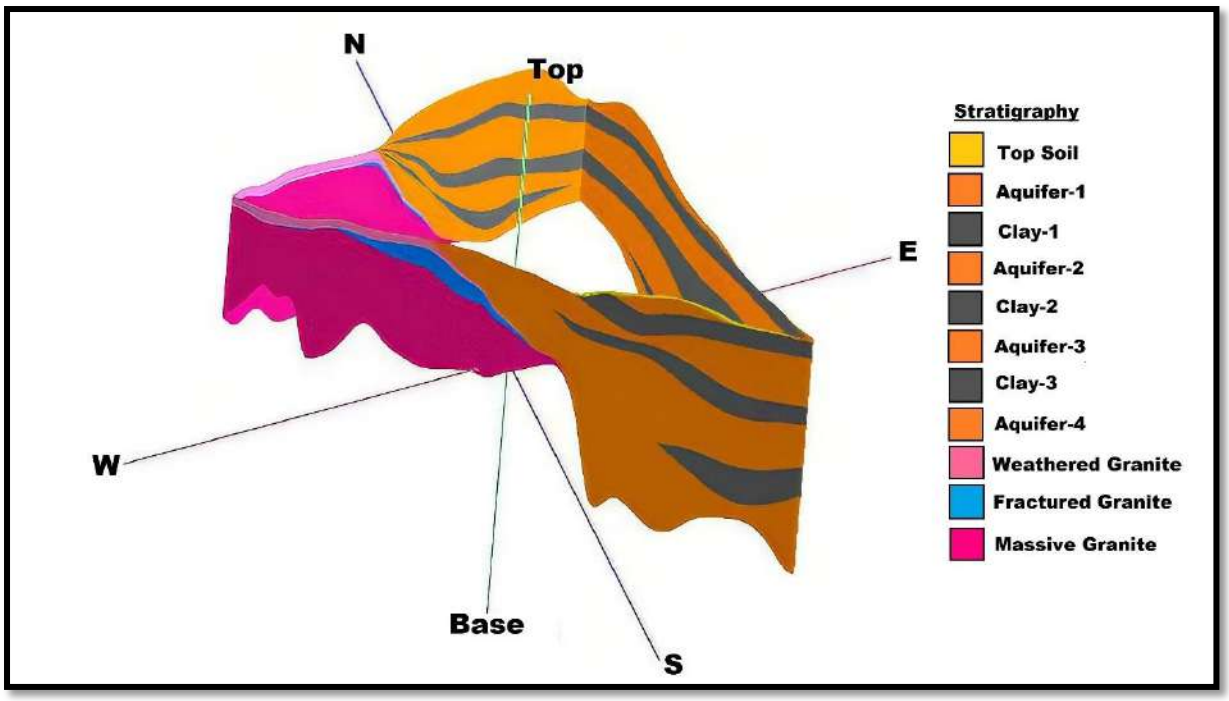


Fig.-3.16: Fence diagram-1

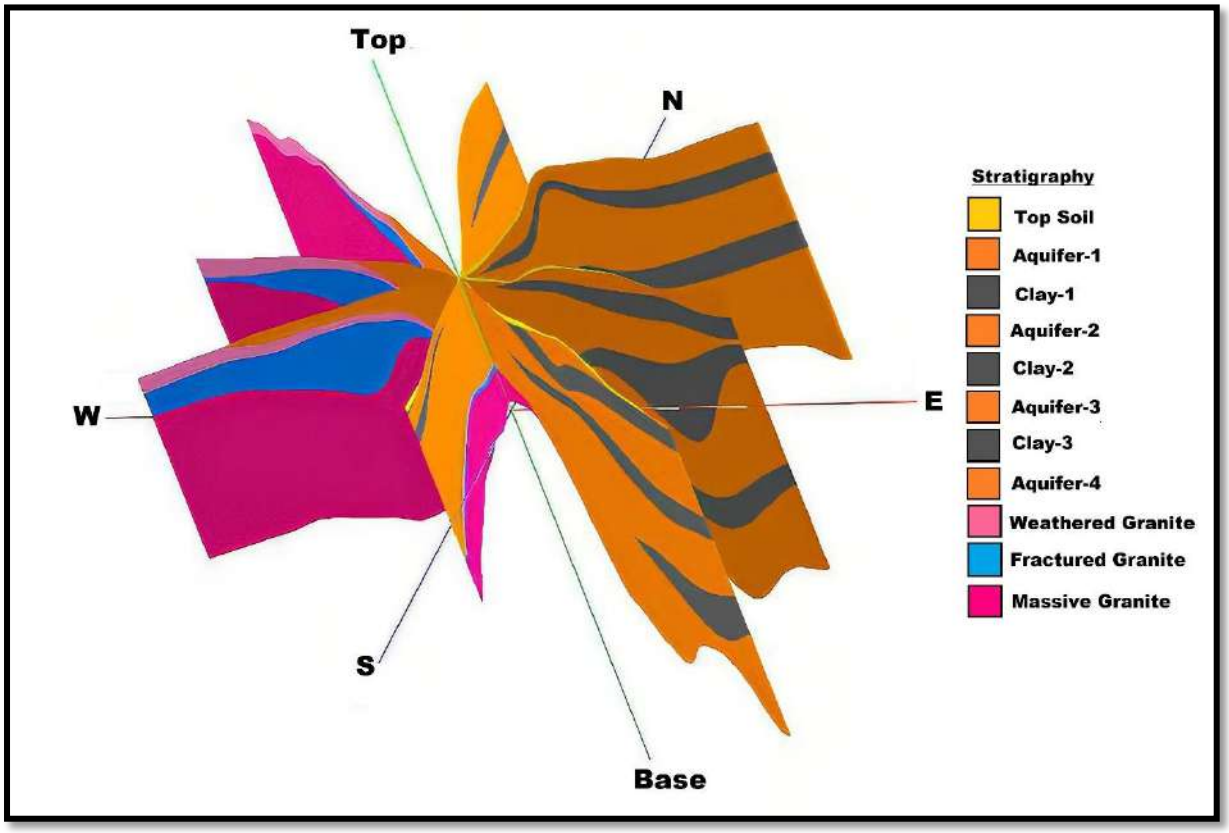


Fig.-3.17: Fence diagram-2

3.4.1 Hydrogeological Cross Sections

To study the aquifer disposition in detail, various hydrogeological cross section indicating aquifer geometry has been prepared viz. NW-SE, W-E and SW-NE directions (**Fig. 3.18**).

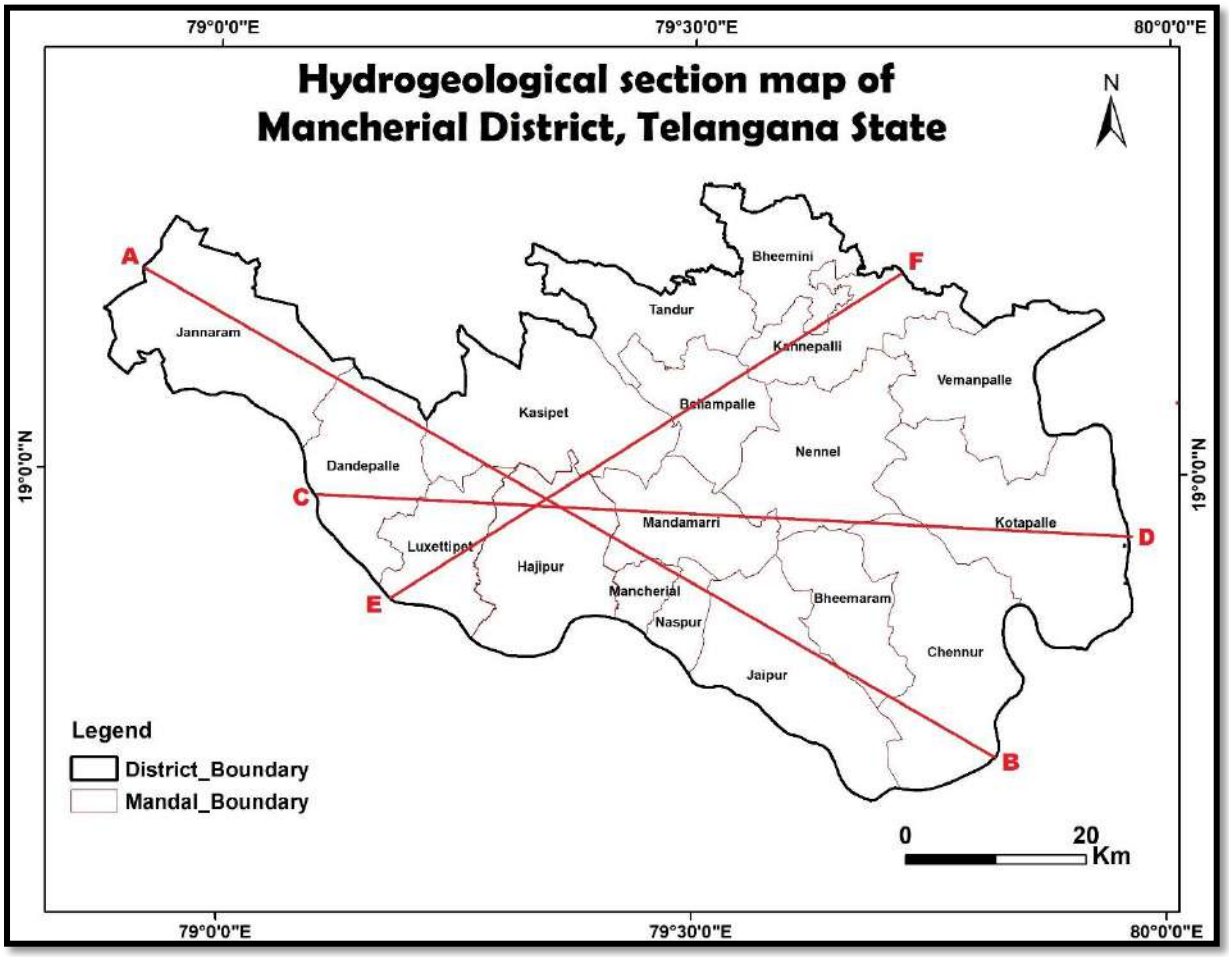


Fig. 3.18: Map showing orientation of hydrogeological sections

3.4.1.1 Hydrogeological Cross Section A-B

Hydrogeological cross section A-B (**Fig.3.19**) represents northwest-southeast direction covering a distance of ~106 kms. It can be clearly seen from the section that as we move from northwest to southeast direction i.e. from Kawal to Pokkur, the formation changes from granite/gneiss to sandstone. The maximum depth of weathering ranging from 8.9 m.bgl at Kawal to 12 m.bgl at Dandepalli, whereas fracture depth is 44.50 m.bgl at Dandepalli. As many as 3 aquifers are demarcated in the sandstone formation, separated by 3-intervening clay layers. At Mittapalli, two aquifers found with two intervening clay layers. Three aquifers present at Pokkur with three intervening clay layers.

3.4.1.2 Hydrogeological Cross Section C-D

Hydrogeological cross section C-D (**Fig.3.20**) represents west–east direction covering a distance of ~70 kms. In this section as we move from west to east direction i.e., from Dandepalli to Kottapalle, the formation changes from granite/gneiss to sandstone. Shallow depth of weathering and fracturing is observed in western part underlain by massive

granite. In the eastern part 4 aquifers are identified separated by 3 clay layers. In the central part 3 aquifers are identified at Mandmarri area separated by 2 clay layers.

3.4.1.3 Hydrogeological Cross Section E-F

Hydrogeological cross section C-D (**Fig.3.21**) represents southwest–northeast direction covering a distance of ~73 kms. In this section as we move from southwest to northeast direction i.e., from Luxettipet to Bellampalle, the formation changes from granite/gneiss to sandstone. Shallow depth of weathering and deep fracturing (~87 m) is found at Luxettipet. At Bellampally area, three aquifers are demarcated separated by two clay layers.

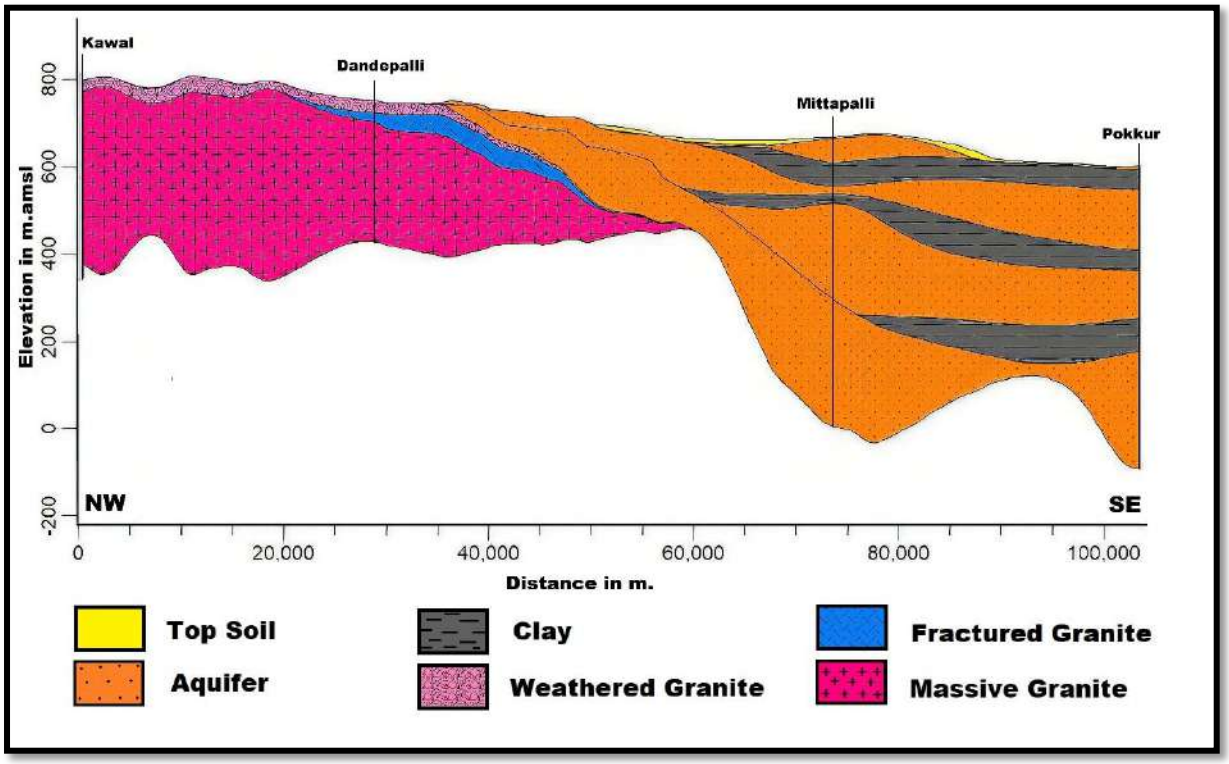


Fig.3.19: Hydrogeological cross section A-B

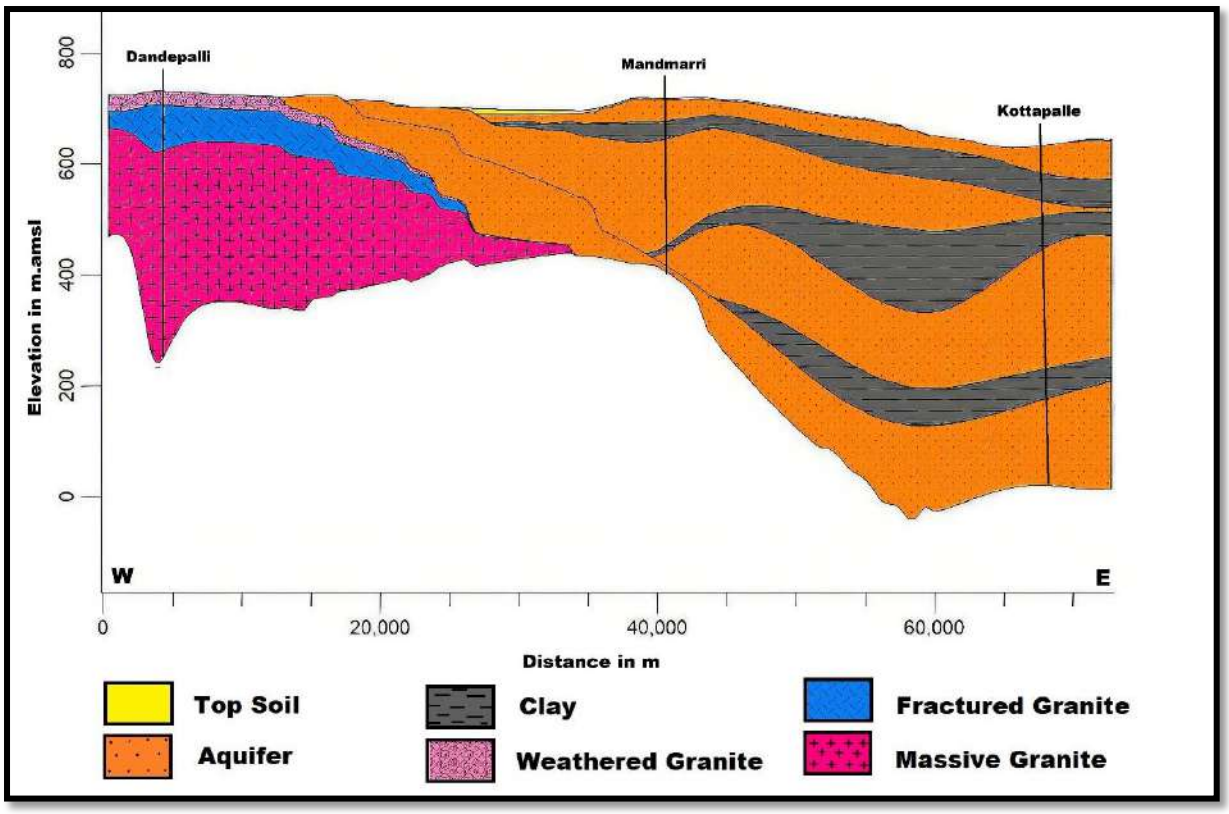


Fig.3.20: Hydrogeological cross section C-D

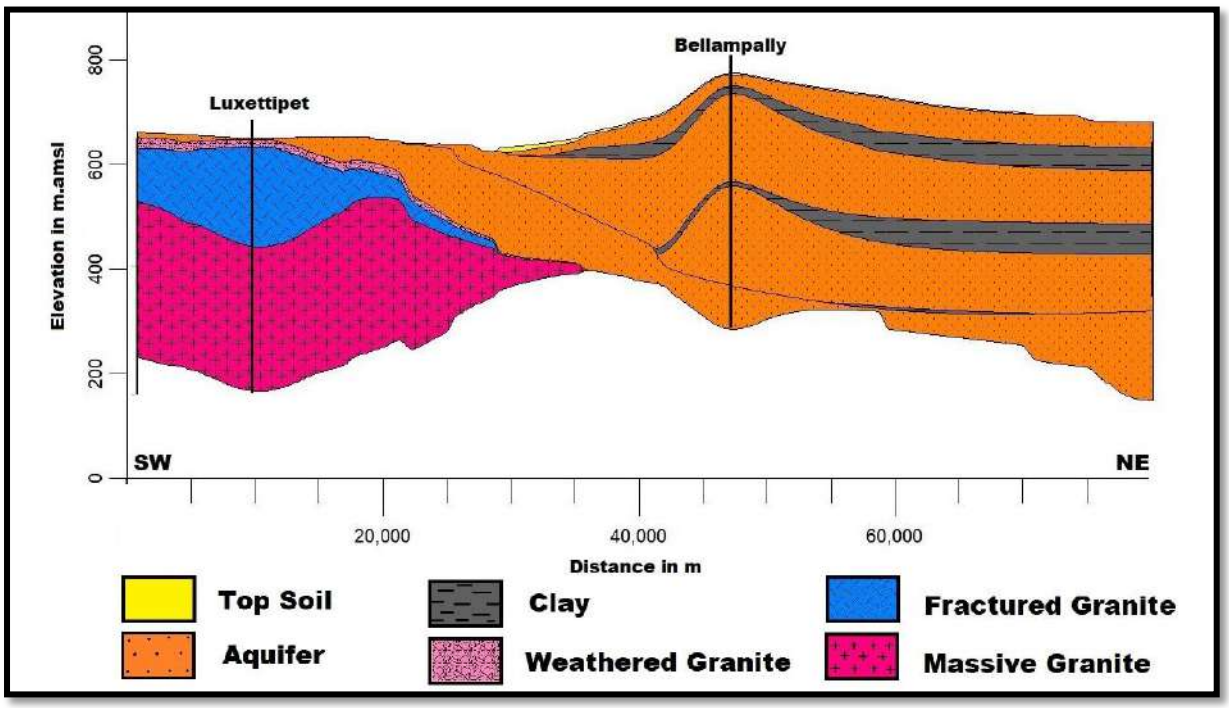


Fig.3.21: Hydrogeological cross section E-F

3.5 MINING HYDROGEOLOGY

Among the mining activities coal mining is the major industry in the area. The mining activity taking place in Mancherial, Mandamarri, Kasipet, Bellampalli, Jaipur and Naspur mandals in the study area.

M/S Singareni Collieries Company Limited is the sole lessee of coal mining. These mining areas are divided into sub areas. They are Mandamarri area, Bellampally area, Srirampur project area, Ramakrishnapuram project area. Presently coal is being mined from a maximum depth of about 350 m.

The Barakars formation of the Lower Gondawana is the main coal bearing formation.This formation is mainly arenaceous with fine to medium grained sandstones, shales and clays and 4 to 10 coal seams. This is overlain by Barren Measures formation, which comprises medium to coarse grained and pebbly sandstones with red clay and siltstones.

Extent of Mine Dewatering:

It is observed that the seepage of water into the mine workings depend on several factors like the permeability of overlying sandstone formations, its structure, number of seams/sections being mined, depth and aerial extent of the mine etc. The present inflow of water into the coalmine workings of area in underground mines is generally ranges from 500 to 900 m^3/day. Most of this water is being used for drinking purpose, industrial plantation and supply to adjacent tanks and streams. (Source: M/s SCCL and GWMS report in southeastern part of Adilabad district, CGWB).

Ground Water Withdrawal Structures:

The major quality of water seepage into the mine workings that accumulates in the under ground sumps is pumped out onto the surface in stages. In addition, a few 6"/8" dia dewatering wells are also constructed in the dip side area to pump out the water accumulated in the sump. The assembly of these wells contain only plain pipes and the well is not gravel packed. The discharge through these wells varies widely in proportion to the seepage. The total discharge from the 17 wells existing in the area is 46,264 m^3/day. The major part of the mine water is being used for domestic purposes and other water supply , which is 17,336 m3/day (37.47 % to total discharge). The water used for industrial use and plantation purpose is 8205 m3/day and 1747 m3/day, the remaining 18,976 m3/day (41 % to total discharge) water is being let out into streams. The mine-wise details are presented in **Table-3.3.**

Table-3.3: Discharge of water from mines and its distribution

Sl.No.	Name of the Mine	Average quantity of water pumping (m^3/day)					
		Pumped per day	Mine requirement	Domestic use	For plantation	Other purposes (water supply to colony etc.)	Let out into streams
1	Shantikhani mine	3970	40	0	70	2835	1025
2	Kasipet mine	2450	720	150	180	1400	0
3	Kasipet-2 incline	540	200	50	15	0	275
4	KK OCP	3800	500	24	300	0	2976
5	KK-1 Incline	1384	140	0	0	700	544
6	KK-5 Incline	1960	18	40	5	886	1011
7	RK-1A Incline	2380	270	150	180	1400	380
8	RK OCP	3120	1460	0	60	0	1600
9	RK-5 Incline	1560	20	40	20	0	1480
10	RK-6 Incline	1934	50	40	100	0	1744
11	RK-7 Incline	2080	250	30	100	1000	700
12	RK-8 INC	2256	813	25	50	1368	0
13	RK-NT Incline	2152	1380	80	100	592	0
14	SRP-3&3A Incline	2578	78	80	80	2002	338
15	SRP-OCP-II	5000	1086	22	400	0	3492
16	IK-1A inc.	5000	520	65	80	4335	0
17	IKOCP	4100	660	22	7	0	3411
	Total	**46264**	**8205**	**818**	**1747**	**16518**	**18976**

(Source: M/s SCCL)

Impact of Pumping on Ground Water Levels:

To study the impact of mining on ground waters regime, water levels is being periodically monitoring on long term basis in 27 observatory wells located within and adjacent to the mining zone of Mandmarri area by Singareni Collieries Company Limited. The depth of these shallow open wells range from 4.60m to 14.50m with a dia. of 1.00m to 6.00m. In these wells, SCCL is monitoring the phreatic surface four times in a year i.e., winter (January), pre-monsoon (May), monsoon (August) and post-monsoon (November) seasons since 1997. During 2019, the depth to water varied from 1.94m to 12.66m during pre-monsoon season and 1.29m to 12.58m during post-monsoon season.

The long term change in phreatic water level (2009-2019) of these wells furnished in **Table-3.4.** In the 20 year period, the raise /fall is insignificant in 6 wells (22%) and 3 wells (11%) show raise in water levels (up to 3 meters). 18 wells (67%) show 4m decline in water levels,

of which only 5 wells are located at a distance of 5 km to 10km from the edge of mine workings.

It is observed that, water level fluctuation ranges from 0.03m to 3.00m. The fluctuation is attributed to normal and natural seasonal effects based on rainfall during monsoon period. The observation also corroborates that water levels in this coal belt area is unaffected by coal mining.

Table-3.4: Change in water level in wells in 20 years (1999-2019)

Raise / Fall		Pre-Monsoon Observation well distance from mine					Post-Monsoon Observation well distance from mine				
		Upto 1km	1 to 2 km	2 to 5 km	5 to 10 km	Total Wells	Upto 1km	1 to 2 km	2 to 5 km	5 to 10 km	Total Wells
▲	>4	-	-	-	-	-	-	1	-	-	1
	3	-	1	-	-	1	-	-	-	-	-
	2	1	-	1	-	2	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	1	1
	0	2	2	2	-	6	3	3	4	-	10
	-1	-	2	-	1	3	-	2	-	-	2
	-2	1	2	2	2	7	1	-	-	2	3
	-3	-	1	1	1	3	-	2	1	1	4
▼	>-4	2	1	1	1	5	2	1	2	1	6
Total Wells		**6**	**9**	**7**	**5**	**27**	**6**	**9**	**7**	**5**	**27**

(Source: M/s SCCL)

Also, there are fifteen piezometric wells around Kasipet U/G mine, KKOC and RKOC projects up to a distance of 1km. The piezometric surface is being monitored during four seasons in a year. The depth to water varied from 1.98m to 20.27m during pre-monsoon season and 1.37m to 19.76m during post-monsoon season of 2019.

Impact of Pumping on Ground Water Quality:

The Singareni Collieries Company Limited also collecting water samples and analyzing to know about the chemical quality of water from the effluents of mines. The chemical quality is generally food for domestic and irrigation purposes.

4. GROUND WATER RESOURCES

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 855.10 MCM, gross ground water draft for all uses 272.07 MCM and net annual ground water potential available for future irrigation needs is 583.02 MCM. Stage of ground water development varies from 15.35% and 62.42 % with average of 32 %. All the mandals fall under safe category, with highest stage of extraction of 62.48% and 62.29% seen in Naspur and Bheemini mandals respectively. 75.49% (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)	**855.10**
• Monsoon recharge from rainfall	528.83
• Monsoon recharge from other sources	219.50
• Non-Monsoon recharge from rainfall	4.46
• Non-monsoon recharge from other sources	177.38
• Natural Discharge	75.08
Gross GW Draft	**272.07**
• Irrigation	205.41
• Domestic and Industrial use	66.66
Provision for Drinking and Industrial use for the year 2025	65.17
Net GW availability for future irrigation	583.02
Stage of GW development (%)	**32%** Min : 15.35% (Jannaram) Max : 62.42% (Naspur)

5 GROUND WATER RELATED ISSUES

5.1 Low groundwater potential

In Mancherial district, low ground water potential (< 1 lps) areas have been identified in ~430 sq.km. area in western and southwestern parts mostly due to granitic terrain (absence of primary porosity, negligible development of secondary porosity) and restricted depth of weathering (< 10 m) as seen in **Fig. 5.1**. The occurrence of less rainfall and urbanization also affects the potential. Sustainability of the aquifer is limited and the wells normally sustain pumping for 0.5 to 2 hours only.

5.2 Inferior groundwater quality

- Few mandals are fluorosis endemic where fluoride (geogenic) as high as 4.61 mg/L during pre-monsoon and 3.27 mg/L during post-monsoon season is found in groundwater. The high fluoride concentration (>1.5 mg/L) occur in 4 % and 6 % of the area during pre and post-monsoon season.

  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 and higher residence time of ground water in deeper aquifer.

- High nitrate (> 45 mg/L) due to anthropogenic activities is observed in 2 samples during pre and post-monsoon.

  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.

- The high concentration of EC (> 3000 micro-seimens/cm) in 2 % of the area is observed during pre-monsoon seasons. However, this areas are restricted to central part and the probable cause may be due to its close vicinity to industrial/mining hub.

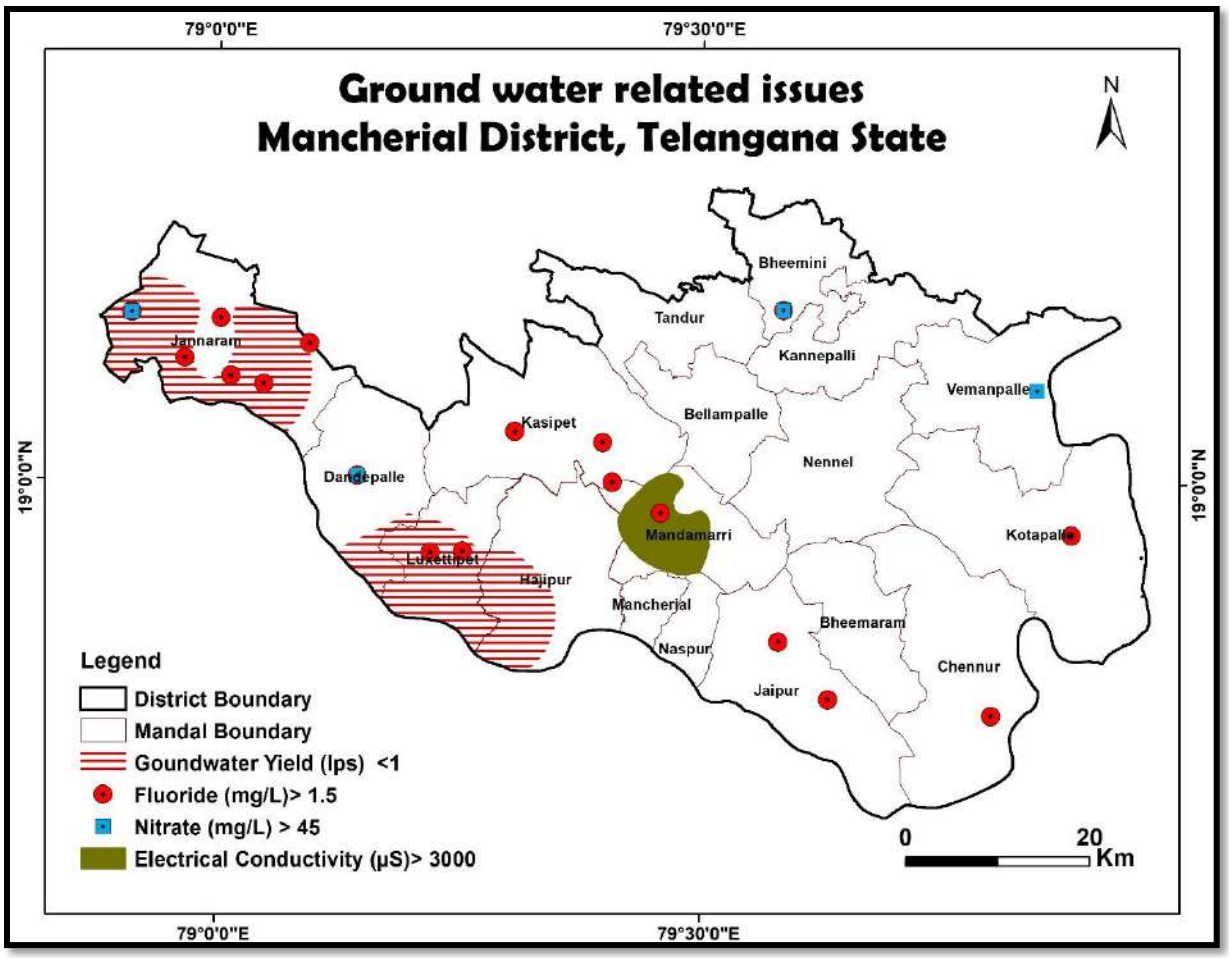


Fig. 5.1: Groundwater related issues in Mancherial district

6 MANAGEMENT STRATEGY

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.The management plan comprises two components namely supply side management and demand side management. The supply side management is proposed based on surplus surface water availability and the unsaturated thickness of aquifer whereas the demand side management is proposed by use of micro irrigation techniques.

6.1 Supply side management

The supply side management of ground water resources can be done through the artificial recharge of surplus runoff available within river sub basins and repairing, renovation & restoration of existing tanks.

6.1.1 Artificial Recharge Structures (To be taken up)

The areas feasible for construction of recharge structures has been demarcated based on the analysis of post-monsoon depth to water level data and existing data on artificial recharge structures constructed under various schemes of MGNREGA and IWMP by Rural Development department, Govt. of Telangana. The availability of unsaturated volume of aquifer was computed by multiplying the area feasible for recharge and unsaturated depth below 5 mbgl. The recharge potential of aquifer is calculated by multiplying the unsaturated volume with specific yield of the aquifers (0.02 for hard rock and 0.03 for soft rock).

The source water availability is estimated from the rainfall and run off correlations. The runoff was calculated by taking into account of normal monsoon rainfall of the mandal and corresponding runoff yield from Strangers table for average catchment type. Out of the total run off available in the mandal, only 20% is considered for recommending artificial recharge structures in intermittent areas.

The storage required for existing artificial recharge structures by State Govt. departments under different IWMP and MNREGS schemes is deducted to find the available surplus run off for recommending the additional feasible artificial recharge structures.

50% of the available surplus runoff is considered for the recommendation of artificial recharge structures, as the remaining 50 % is recommended for implementing water conservation measures in recharge areas through MGNREGS. The **Table 6.1** gives the area feasible and volume available for the recharge.

As the stage of ground water development in the area is 32% 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, 2 mandals i.e., Bellampalli and Tandur showing the stage of ground water development of above 50% (with average water level >5 mbgl). To control further increase in stage of ground water development, artificial recharge structures are recommended in these two mandals only.

Table 6.1: Area feasible and volume available for artificial recharge

Total geographical area of district (Sq.km)	4016.33
Area feasible for recharge (Sq.km)	236.16
Unsaturated Volume (MCM)	475.45
Recharge Potential (MCM)	14.26
Surplus runoff available for recharge (MCM)	9.08
PROPOSED ARTIFICIAL RECHARGE STRUCTURES	
Percolation Tanks (@ Rs.20 lakh, Av. Gross Capacity=0.007 MCM*1.5 fillings = 0.0105 MCM) Volume of Water expected to be conserved / recharged (in MCM) Estimated Expenditure (in Crores)	56 0.58 11.20
Check Dams (@ Rs.30 lakh, Av. Gross Capacity=0.007 MCM* 5 fillings = 0.035 MCM) Volume of Water expected to be conserved / recharged (in MCM) Estimated Expenditure (in Crores)	90 3.15 13.50
Total volume of water expected to be recharged (in MCM)	3.73
Total Estimated Expenditure for Artificial Recharge (Rs. in Cr.)	**24.70**

The total unsaturated volume (below the depth of 5 m) available for artificial recharge is 475.45 MCM, having 14.26 MCM of recharge potential (3%).The available surplus runoff can be utilized for artificial recharge through construction of percolation tanks, check dams with recharge shafts at suitable sites. The number of percolation tanks, and check dams are decided based on the number of suitable streams available in the district.

Thus, after taking into consideration all the factors, only 9.08 MCM of surplus water can be utilised for recharge, which is given in **Table 6.1**. This surplus water can be utilized for constructing 90 check dams with estimated expenditure of Rs.13.50 crores and 56 percolation tanks with estimated expenditure of Rs.11.20 crores at suitable sites. The amount of recharge from these artificial recharge structures was calculated by considering 0.0105 MCM per percolation tanks and 0.035 MCM per check dam. This intervention should lead to recharge of about 3.73 MCM/year. The details are given in **Annexure-1.**

In addition to this roof top rainwater harvesting structures should be made mandatory to all Government buildings.

The area is again further divided into 5 categories based on hydrogeological characteristics as mentioned in the **Table-6.2**. 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.

Table-6.2: Hydrogeological characteristics of area

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

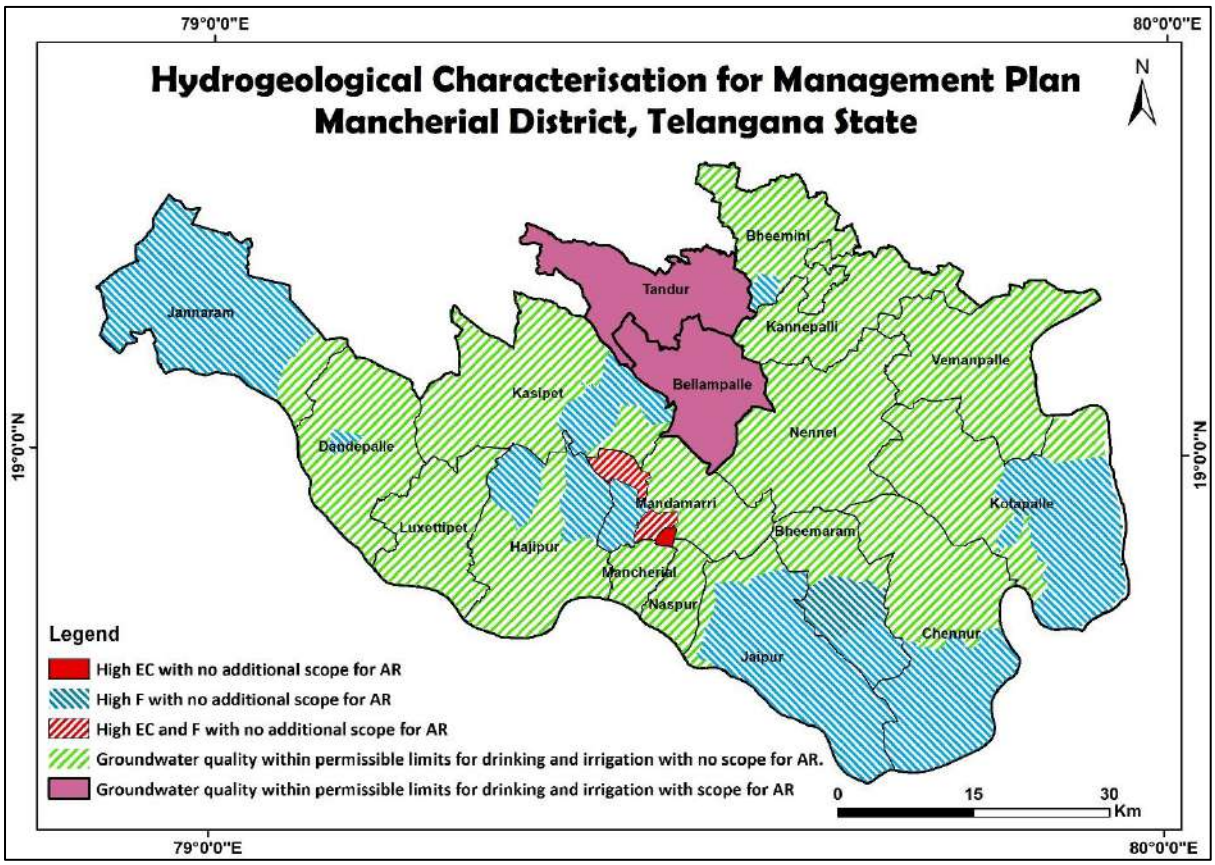


Fig.6.1: Hydrogeological characterization for management plan

6.1.2 State Government Project

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

  De-silting of existing minor tanks (405 no) was taken under state Govt. sponsored Mission Kaktiya (Phase-1 to 4) to remove 2.04 MCM of silt and this has created an additional surface storage. This will contribute ~ 0.51 MCM to groundwater (considering 25 % of recharge) and with this additional ~85 ha land can be brought under irrigated dry (ID) crops in the tank ayacut.

  There is need to take remaining tanks (~505 MI tanks) in next phases 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 three water grids with intake from 1)Kadem Reservoir (Segment-Kadem-Khanapur) covering 1 mandal 2)Godavari River (Segment- Komoram Bheem Asifabad) covering 7 mandals 3)Yellampally Reservoir (Segment- Yellampally-Mancherial) covering 9 mandals to provide protected water from surface reservoirs. 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 40.78 MCM and this imported water from surface sources will reduce the present utilized ~22 MCM of ground water (considering 60 lpcd). This can be effectively utilized to irrigate ~3666 ha of additional land under ID crops.

- 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.

6.2 Demand side management

In the area till date a total number of 1624 no's drip and sprinklers are sanctioned which has irrigated ~1826.82 ha under ID crops saving ~3.28 MCM (considering 30% saving of 0.006 MCM/ha) of groundwater from the basin. Considering the current scenario of groundwater development, existing number of structures and shallow water levels, demand side intervention such as change in cropping pattern and micro irrigation has not been proposed.

6.3 Other Recommendations

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

6.4 Expected results and outcomes

With the above interventions costing Rs 24.70 crores (excluding the cost involved in Mission Kakatiya and Mission Bhagiratha), the likely benefit would be net saving of 29.52 MCM of ground. This will bring down the stage of groundwater development by 1% (from 32% to 31%)

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Proposed supply side interventions for ARS **Annexure-I**

Mandal	Village	Existing PTs	Existing CDs	Proposed CDs	Proposed Pts	Cost for CDs@15 lakh	Cost for PTs@ 20 lakh
Bellampally	Ankusam	0	0	4	0	60	0
Bellampally	Batwanpalle	12	0	2	0	30	0
Bellampally	Budha Kalan (Rural)	14	0	7	0	105	0
Bellampally	Budha Khurd (Rural)	22	0	1	0	15	0
Bellampally	Chakepalle	0	0	4	0	60	0
Bellampally	Chandravelli	1	0	11	11	165	220
Bellampally	Dugnepalle	0	0	1	1	15	20
Bellampally	Gurjal (Rural) @ Talla Gurjal	32	0	5	0	75	0
Bellampally	Kannal (Rural)	16	0	6	0	90	0
Bellampally	Perkapalle	2	0	2	0	30	0
Bellampally	Rangapet	0	0	3	3	45	60
Tandur	Akenipalle	0	0	2	2	30	40
Tandur	Boyapalle	0	0	1	2	15	40
Tandur	Chandrapalle	0	0	3	3	45	60
Tandur	Choutpalle	2	0	2	0	30	0
Tandur	Gopalnagar	0	0	1	1	15	20
Tandur	Kasipet	0	0	1	1	15	20
Tandur	Katherla	0	0	1	1	15	20
Tandur	Kistampet	4	0	1	0	15	0
Tandur	Kothapalle	1	0	3	2	45	40
Tandur	Madaram (CT)	0	0	4	4	60	80
Tandur	Madnapur	0	0	1	1	15	20
Tandur	Pegadapalle	0	0	4	5	60	100
Tandur	Rampur	0	0	1	1	15	20
Tandur	Rechini	6	0	2	0	30	0
Tandur	Repallewada	0	0	1	1	15	20
Tandur	Tandur	1	0	15	16	225	320
Tandur	Venkaipalle	0	0	1	1	15	20