केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

Report

on

AQUIFER MAPPING AND GROUND WATER MANAGEMENT

Parts of Nalgonda District (Phase-III), Telangana

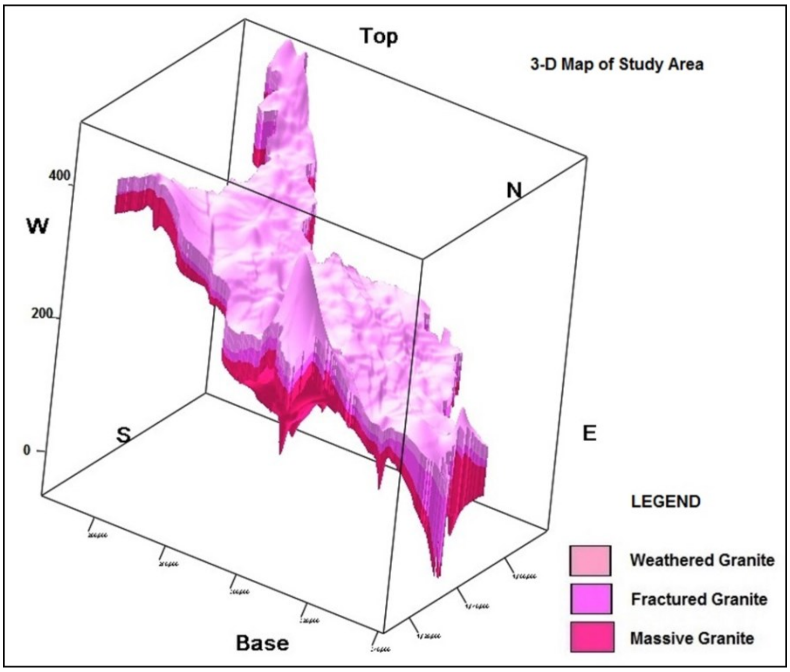
दक्षिणी क्षेत्र, हैदराबाद

Southern Region, Hyderabad

भारत सरकार
जल संसाधन नदी विकास एवम् गंगा संरक्षण मंत्रालय
केंद्रीय भूमिजलबोर्ड

GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES RIVER DEVELOPMENT AND GANGA REJUVENATION

REPORT ON AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN PARTS OF NALGONDA DISTRICT TELANGANA STATE (Phase-III)



CENTRAL GROUND WATER BOARD
SOUTHERN REGION
HYDERABAD
AUGUST-2016

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN PARTS OF NALGONDA DISTRICT TELANGANA STATE (PHASE-III)

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REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN PARTS OF NALGONDA DISTRICT TELANGANA STATE (PHASE-III)

EXECUTIVE SUMMARY

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REPORT ON AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCE SIN PARTS OF NALGONDA DISTRICT TELANGANA STATE (PHASE-III)

AT A GLANCE

S.No.	Item		Particulars
1	Districts	:	Nalgonda
2	Mandals	:	8 (Anumula, Chandam Pet, ChinthaPalle, Devarakonda, GundlaPalle, Gurrampode, PeddaAdiserlaPalle and Peddavoora)
3	Revenue villages	:	191
4	Geographical area	:	3061 Km^2
5	Population	:	~4.66 lakhs
6	Locations	:	North Latitude 16°21´12.88"-16°58´34.15" and East Longitude 78°36´41"-79°30´46.53"
7	Major Rivers	:	The Krishna
8	Other Rivers	:	The Dindi, The Peddavagu
9	Minor Irrigation tanks	:	724 tanks with 12640 ha ayacut.
10	Climate and rainfall (mm)	:	Tropical climate
11	Rainfall (Normal) Rainfall (2015)	:	Normal rainfall 538-736 (avg:626) Varies from 435-696 mm (avg:532 mm) -14% less than normal rainfall.
12	Geomorphology	:	Pedi plains (51 %), pediments (15%), Denudational hills (7%) etc.
13	Major crops (Khariff season)	:	Paddy (15%), Cotton, Jowar, maize etc.
14	Major crops (rabi season)	:	Paddy (74%)
15	Soils	:	Well drained gravelly loamy soils (31%), calcareous soils (21%) and clay soils (15%).
16	Geology	:	Granites and Gneisses (90%) with intrusive rocks (dolerite,andGabbro's) and quartzite's (10%)
17	Prevailing water conservation/recharge practices	:	PTs:540, CD's:200 and Farm ponds & other structures:75
18	Depth to water Table Elevations (m amsl)-2015	:	96.3-416.5 (pre) and 96.6-414.6 (post).

19	Depth to water levels (2015) (m bgl)	:	Pre-monsoon:0.6-21.1 (avg:8.6) Post-monsoon:1.7-23.4 (avg:8.7)		
20	Majority of water levels	:	Pre-monsoon:5-10 m bgl (57 % of area) Post-monsoon:5-10 m bgl (53 % of area).		
21	Water Level Fluctuations (m)	:	58% of area shows rise in water levels (< 2 to >5 m) and in rest of the area shows fall in water levels.		
22	Long-term water level trends (2006-15) m/yr	:	Pre-monsoon: Falling @0.1 to 0.7 and rising 0 .15 Post-monsoon: Rising @ 0.07 to 0.2 and falling 0.34		
23	Ground water yield (lps)	:	0.1 to 7		
24	Number of bore wells CGWB Exploratory/Observation wells Agricultural wells	:	 20 33631		
25	**Groundwater Quality 2015**				
25.1	EC (Ω Siemen's/cm)	:	Pre-monsoon: 420-3940, Post-monsoon: 254-6180		
25.2	Nitrate (mg/L)		Pre-monsoon: 3-465, Post-monsoon: 1-531		
25.3	Fluoride (mg/L)		Pre-monsoon: 0.3-3.9, Post-monsoon:0.1-4.8		
26	Conceptualization		**Weathered zone**	**Fractured zone**	
26.1	Depth (m bgl)	:	Up to 20	20-134	
27	Transmissivity (m^2/day)	:	8-633		
28	Specific yield (%)	:	2	-	
29	Storativity	:	-	0.0001 to 0.01	
30	Dynamic GW Resources-2013 **(MCM)**	:	Command	Non-Command	Total
30.1	Net dynamic groundwater availability	:	**167.12**	**111.82**	**278.94**
30.2	Gross GW Draft	:	**82.86**	**78.25**	**161.11**
30.3	Provision for Domestic &Industrial (2025)	:	7.41	8.19	15.60
30.4	Stage of Ground water development (%)		49.6	70	Avg:57.8
31	In storage GW Resources	:	73.5 MCM		
32	Ground water related issues	:	High fluoride, high nitrate, over-exploitation, deep water levels, low sustainability, water marketing,		

33	Sustainable Groundwater management Plan	:	**Supply side measures** 874 ARS with ~65.55crores. Water Conservation measures (WCM) Farm Ponds.3820 nos with total cost of 9.55 crores. **Mission Kakatiya** Repair Renovation and Restoration of 273 tanks with ~90 crores cost and created additional 4.16 MCM of storage capacity. The net ground water recharge will be 1.25 MCM. Remaining ~451 tanks are recommended for desilting under mission Kakatiya. **Mission Bhagiratha** Additional ~17 MCM of surface water into the basins which will save ~10.21 MCM of ground water from the area and can be effectively utilized to bring additional 1700 ha of land under ID crops. Construction of 1700 additional bore wells of 100 m depth with 34 crores cost in command area. **Demand side measure** Adaptation of micro-irrigations practices in 26000 ha area saved ~ 50 MCM of ground water from the basin. Additional 2658 MI are recommended with 15.9 crores cost. Change in cropping pattern from paddy to other ID crops during khariff season and complete ban on paddy during rabi season in non-command areas. Compulsory rain water harvesting in proportionate to withdrawal. Intermittent pumping of adjoining bore wells. Restricted power supply in two spells (@ interval of 4 hrs each). **Other measures** A participatory groundwater management (PGWM) approach. Going for salt tolerant plants like cheek pea, mustard etc. where water levels are deep and in shallow water table areas (Category-1 and 5), rice varieties like CSR-27, CSR-23, CSR-13 and CSR-10 are recommended in Category-2 and 6. Other measures include providing Ca, P and multivitamins to the children below the ages of 14 years along with mid-day meals in fluorosis endemic areas.
34	Expected Results and Out come	:	Stage of GW Development will come down by 6 % with one time investment of rupees ~91crores (excluding the cost of Mission Kakatiya and Mission Bhagiratha).

ABBREVATION:

2D	:	2 Dimensional
3D	:	3 Dimensional
ARS	:	Artificial Recharge Structures
Avg	:	Average
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 commite
GW	:	Ground Water
Ha	:	Hector
Ha.m	:	Hector meter
Km2	:	square kilometer
LPS	:	Liter per second
M	:	meter
M^3	:	Cubic meter
max	:	Maximum
M bgl	:	Miters below ground leval
MCM	:	Milian cubic meter
Mg/L	:	Milligram per liter
min	:	Minimun
MPT	:	Mini perculation tank
NL	:	North Lattitude
NO_3	:	Nitrate
OE	:	Over Exploited
PGWM	:	Particapated ground water management
WCM	:	Water conservation measures

EXECUTIVE SUMMARY

An integrated study including hydrometeorology, geophysics, hydrogeology and hydrochemistry was taken up to develop comprehensive aquifer maps (2-D & 3-D) and to suggest suitable groundwater management plans for 8 mandals.Area experiences semi-arid tropical climate with 626 mm annual normal rainfall. It is part of 15 watersheds consisting of 191 revenue villages with ~4.66 lakh population and~3061 km^2areain Nalgonda district, Telangana State.

Pediplains are major geomorphic features followed by pediments and hills. The major rivers that drain the area are river Krishna, river Dindi and river Peddavagu.The drainage is controlled by lineaments controlled by E-W directions. The area is underlain by granites and gneisses with basic intrusive rocks at places and quartzites.

Main aquifers constitute, weathered zone (~20 m) at the top followed by a discrete anisotropic fractured/fissured zone at the bottom (~20-134 m). Groundwater occurs under unconfined and semi-confined conditions and flows downward from the weathered zone into the fracture zone. In general ground water yield varies from 0.1-7.0lps and majority of fractures (98 %) occur within 100 m depth.

The DTW varies from 0.6 to 21.1 meter below ground level (m bgl) (average: 8.6 m) and 1.7-23.4 m bgl (average: 8.7) during pre and post-monsoon season respectively and majority of the area (58% area) there is rise of <2 to > 5 m during the year 2015. Long-term water level trends (2006-15) shows falling @0.1 to 0.7 and rising 0 .15 m/yr during pre-monsoon season and rising trends @ 0.07 to 0.2 and falling 0.34m/y during post-monsoon season.

Geophysical data reveals resistivity < 100 ohm (Ω) for weathered zone, 60-350 ohm (Ω) for fractured zone and > 350 ohm (Ω) for massive granite.

High incidence of fluorosis (maximum F up to 3.9 mg/L and 4.8 mg/L) during pre and post-monsoon season of 2015 respectively,is due to geogenic contamination while high concentrations of nitrate is due to anthropogenic contamination (as high as 531 mg/L). About 36 % and 60% of the samples are unfit for human consumption during pre and post-monsoon season of 2015.

Aquifer systems from the area are conceptualized in to 2 namely weathered zone down to ~20 m and fractured zone from 20-134 m bgl. Moderate weathering (10-20 m) is observed in 56 % of the area and majority of fractures (98%) occur within 100 m depth. Transmissivity (T) varies from 8 to 633 m^2/day and storativity of 0.0001 to 0.01.

As per 2013 GEC, net annual ground water availability is 278.9 MCM and the gross ground water draft is 161.1 MCM and net available balance for future irrigation use is 124.45 MCM with stage of ground water development varies from 40-72% %. The in-storage ground water resources which can be utilized in draught period are 73.5 MCM.

Major issues identified are pollution (both geo-genic (F) and anthropogenic (NO_3), over-exploitation in 154 km2 area covering 26 villages, deep water levels (20 m) in 3 % of the area during post-monsoon seasonand well sustainability.

The management strategies include supply side, demand side, regulatory and institutional measures. The supply side measures includes construction of 874 ARS with ~65.55 crores, 3820water conservation measures (WCM) (farm ponds) with 9.55 crores cost, Repair Renovation and Restoration of all tanks under Mission Kakatiya, providing drinking water needs under Mission Bhagiratha. Construction of additional 1700 bore wells of 100 m depth are with a cost of 34 cr in command area.

Demand side measure includesbringing 2658 ha of additional land under micro-irrigation with 15.9 crores. Regulatory measuresincludes **c**hange in cropping pattern from paddy to other ID crops during kharif season in non-command areas, ccompulsory rain water harvesting in proportionate to withdrawal, intermittent pumping of adjoining bore well, restricted power supply in two spells, complete ban on paddy crop cultivation during rabi season. Institutional measures includes participatory groundwater management (PGWM) approach and other measures include providing calcium and phosphorous rich food to the children below the ages of 14 years in fluorosis endemic areas. With above measures the stage of GW Development will come reduce by 6 % with one time investment of ~91crores.

NUMBER OF DATA POINTS USED FOR PREPARATION OF VARIOUS MAPS/FIGS-8 Mandal's of NALGONDA DISTRICT, TELANGANA STATE.

S. No.	Data	Aquifer	Total Data Points	Source		
				CGWB	SGWD	
1	Panel Diagram (3-D)	Combine	129	EW 20: Pz/DW 10, VES:24	38	37 (Irrigation wells)
2	Hydrogeological Sections	4 no's	129	EW 20: Pz/DW 10, VES:24	38	37 (Irrigation wells)
3	Fence/panel Diagrams	2 no's	129	EW 20: Pz/DW 10, VES:24	38	37 (Irrigation wells)
4	Depth of weathering	1 no's	129	EW 20: Pz/DW 10, VES:24	38	37 (Irrigation wells)
5	Depth of fracturing	1 no's	129	EW 20: Pz/DW 10, VES:24	38	37 (Irrigation wells)
6	Groundwater Yield	Weathered zone	129	EW 20: Pz/DW 10, VES:24	38	37 (Irrigation wells)
		Fractured zone	129	EW 20: Pz/DW 10, VES:24	38	37 (Irrigation wells)
7	Transmissivity (m^2/day)	Weathered zone	6	6		
		Fractured zone	6	6		
8	Depth to Water Level Maps (2015)	Combine	47	5	42	
9	Water Level Fluctuations	Combine	47	5	42	
10	Water quality (2015) (EC, F and NO_3)	Combine	64	6	58	

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 lifestyle. 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 NAQUIM is not merely mapping, but reaching the goal-that of ground water management through community participation.

Hard rocks (Granites/Gneisses) lack primary porosity, and groundwater occurrence is limited to secondary porosity developed by weathering and fracturing. Weathered zone is the potential recharge zone for deeper fractures and excessive withdrawal from this zone lead to drying up in places and reducing the sustainability of structures. 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 the study: The main scopeof study is summarised below.

1. Compilation of esisting data (exploration, geophysical, water level and water quality with georeferncing)
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 covering 3061 km^2, lies between north latitude 16°21´12.88"-16°58´34.15" and east longitude 78°36´41"-79°30´46.53" covering 8 mandals with 191 revenue villages in Nalgonda district, Telangana State with ~4.66 lakhs population of (2011 census) (**Fig.1.1**). In the area there are 2 major irrigation projects i.e., Nagarjunsagar and Dindi on the river Krishna and the river Dindi respectively. There are ~724 minor irrigation tanks with 12640 ha ayacurt.

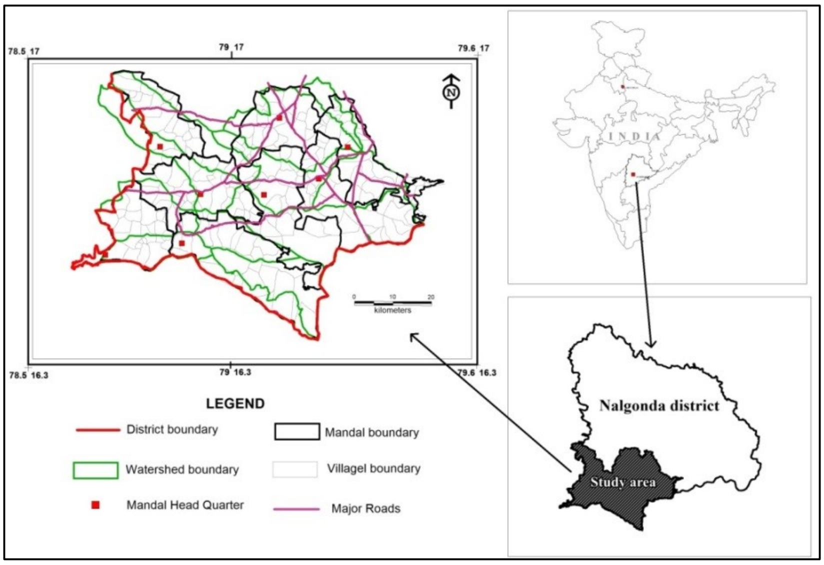

Fig.1.1: Location of study area.

1.4 Climate and Rainfall: The area experiences semi-arid and tropical climate with annual precipitation varying from 538-736 mm (average: 626) of which 73 % is contributed by SW monsoon and rest by non-monsoon months. During the year 2015, out of 8 mandals, 6 mandals have recived less rainfall (-39% to -14%) thann normal rainfall and 2 mandals (Devarkonda and Gurrampod) received excess rainfall (5 to 26%) than normal rainfall. Overall, area received -14% less rainfall.

1.5Geomorphological Set up: Pediplain is the major landform covering about 1575 km2 (51%) area, the other landforms observed are pediment (15%), plateau (10%),denudation hill (7%), structural valley (5%) and channel fill (4%), etc. (**Fig.1.2**).

1.6 Drainage and Structures: The drainage is controlled by lineaments trending E-W direction and mainly drained by river Krishna and its tributary river Dindi and river Peddavagu having dendritic, sub-dendritic to parallel drainage pattern (**Fig.1.3**). The area is part of 15 watersheds.

1.7Land use and cropping pattern: In the area, the land use can be grouped into 26 classes and main areais under kharif cultivations (paddy, cotton, pulses,spices & vegetables) and during rabiseason paddy, ground nut horse gram, etc. Forests cover 18% of the area.During Khariff season rainfed crops like cotton and pulses are grown in 85 % of area and paddy is grown in 15% of area. During rabi season paddy is grown in 74% of area and other crops in rest of the area.

1.8 Soils: The area is mainly occupied by moderately deep well drained gravelly loamy soils (31%), very deep moderately well drained calcareous soils (21%) and moderately shallow well drained clayey soils (15%) etc. (**Fig.1.4**).

1.9Prevailing water conservation/recharge practices: In the area there are 540 percolation tanks, 200 check dams and 75 farm ponds/other structures are present.

1.10Geology: Geologically the area is covered with crystalline rocks granites and gneisses (Banded Gneissic complex-BGC) with basic intrusive rock (Dolerites) at places (90 %) and quartzite rocks (10%) (**Fig.1.5**).

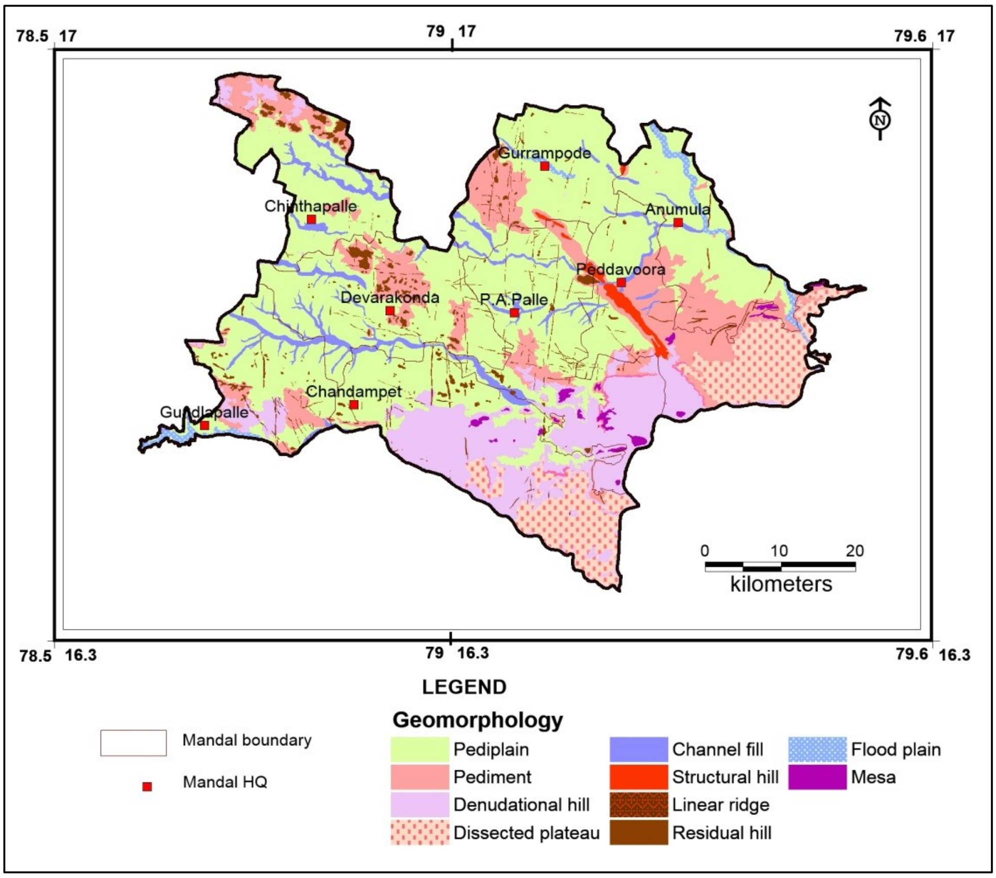

Fig.1.2: Geomorphology of Study area.

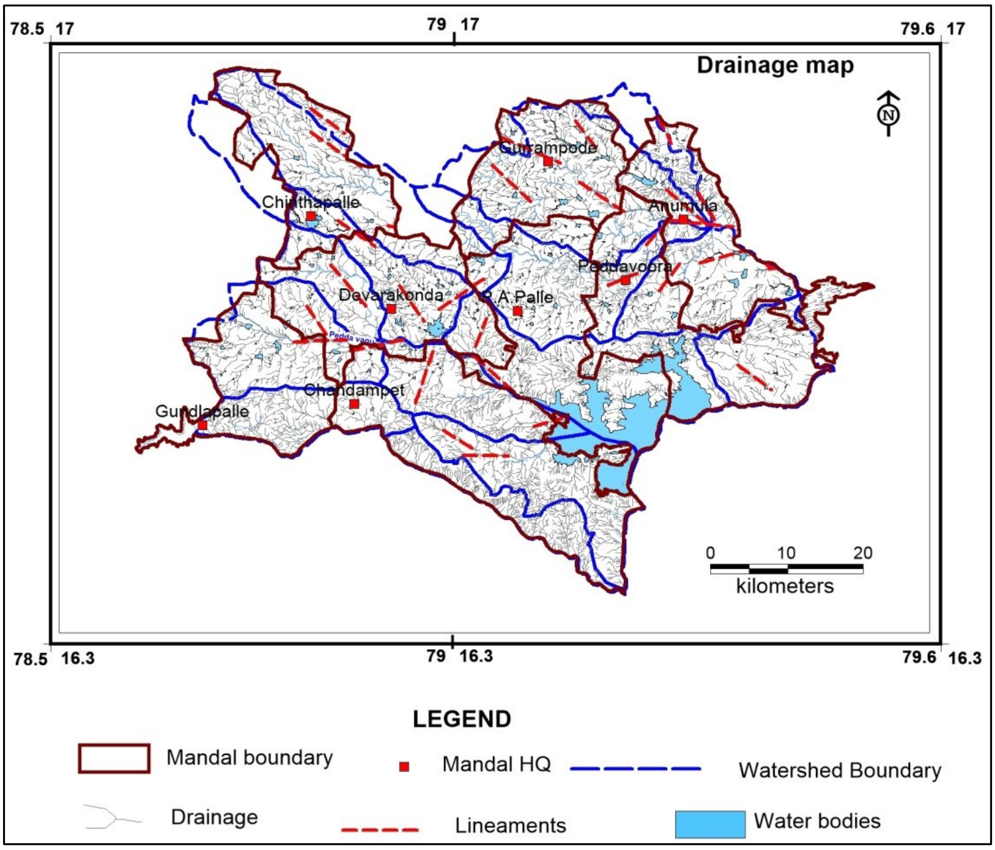

Fig.1.3: Drainage with watershed and Mandal boundaries.

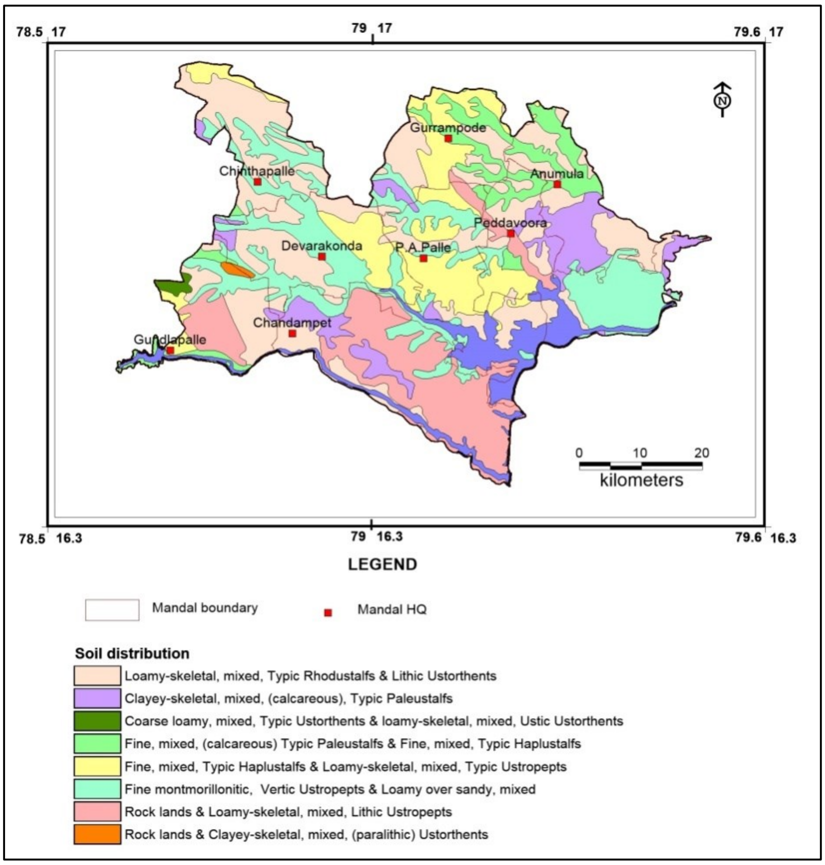

Fig.1.4: Soils of Study area.

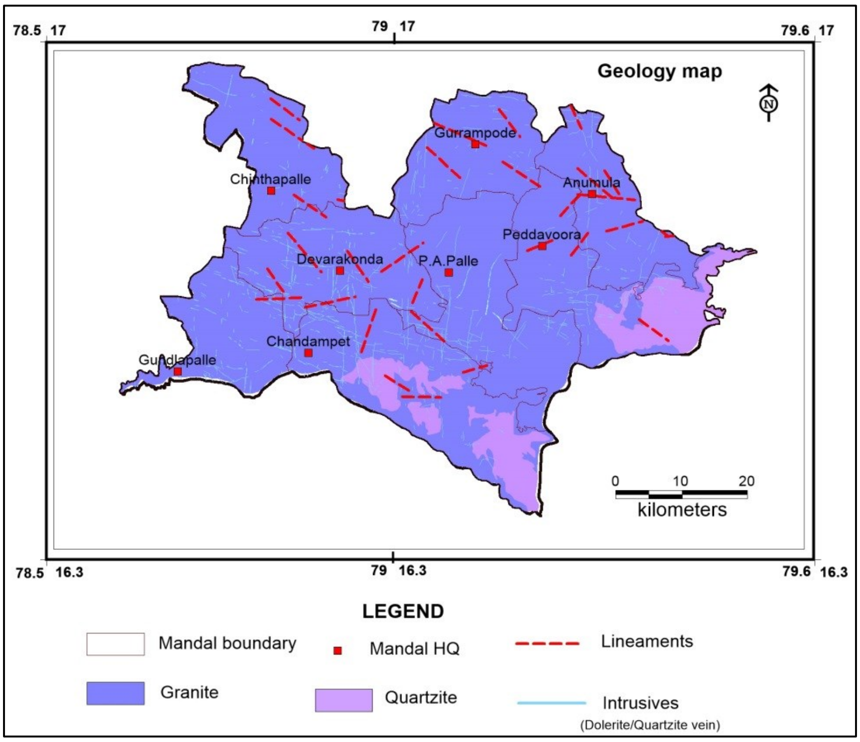

Fig.1.5: Geology of Study area.

2. DATA COLLECTION and GENERATION

Collection, compilation and integration for aquifer mapping studies is carried out in conformity with EFC document of XII plan of CGWB encompassing various 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 Hydrogeology

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of 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 aquifer in the area is granites and gneisses and the occurrence and movement of ground water in these rocks is controlled by the degree of interconnection of secondary pores/voids developed by fracturing and weathering. Based on 129data availability, hydrogeology map of area is prepared and presented in **Fig.2.1**.

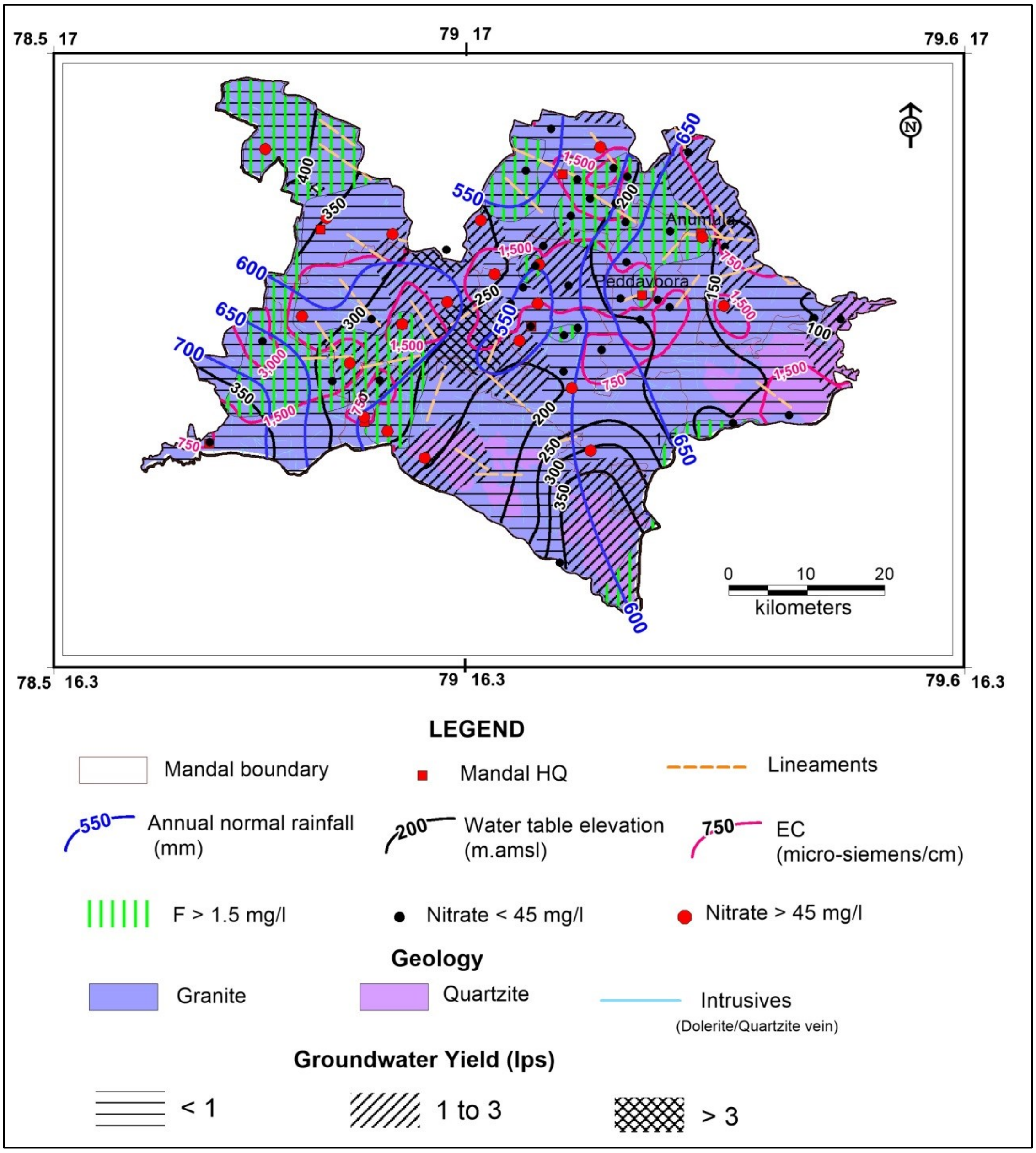

Fig.2.1: Hydrogeological map of study area.

2.1.1 Ground water Occurrences and Movement: Ground water occurs under unconfined and semi-confined conditions and flows downward from the weathered zone (saprolite and sap rock) into the fracture zone. 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. The storage in granite rocks is primarily confined to the weathered zone and its overexploitation, mainly for irrigation purposes, has resulted in desaturation of weathered zone at many places. At present, extraction is mainly through boreholes of 60-90 m depth, with yield between <0.1 and 7 litres/second (lps)(Mynampalli-Devarkonda mandal) (**Fig.2.1**). ~98% of fractures occur within 100 m depth and deepest fracture is encountered at the depth of 134 m depth (Chitriyal).

2.1.2 Exploratory Drilling: In the area 20 exploratory wells are drilled (EW and OW) in the depth range of 20-200 m for determination of hydraulic properties of the aquifers and discussed detailed in **Chapter -3**. In the area there are 33631 agricultural wells (mostly bore wells).

2.1.3 Ground water Yield: In general the ground water yield varies from <0.1 to 7 lps (avg: 0.6 lps). Wells located in the command area have higher yield and sustains for 4-6 hrs of pumping as compared to non-command area where yields are relatively low with sustainability of 2-3 hrs(**Fig.2.1).**In mojority of the area (72%) low yields (<1lps) are observed. 2-3 lps yields are observed in 26% and high yields (>3lps) in 2 % of area.

2.2 Water Levels (2015): Water levels from 47 wells (dug wells and bore wells) were monitored during pre and post-monsoon season of 2015.

2.2.1 Water Table Elevations: During pre and post-monsoon season (May and November) of 2015, the water-table elevation ranges from 96.3-416.5 and 96.6-414.6 meter above mean sea level (m amsl) respectively and in general, groundwater flow is in NW-SE part and follows the surface topography (**Fig.2.2**).

2.2.2 Depth to Water Levels (DTW): The DTW varies from 0.6 to 21.1 meter below ground level (m bgl) (average: 8.6 m) and 1.7 to 23.4 m bgl (average: 8.7) during pre and post-monsoon season respectively.

Pre-monsoon season: Majority of the water levels during this season are in the range of 5-10 m (57 % area) followed by 10-20 m bgl (37 %) and 2-5 mbgl (5 %), deep water levels (>20 mbgl) are noticed in Chadampet mandal(**Fig.2.3**).

Post-monsoon season: Majority of the water levels during this season are in the range of 5-10 m (53 % area) followed by 10-20 m bgl (34 %) and 2-5 mbgl (10 %), deep water levels (>20 mbgl) are noticed in Chadampet and Peddavura mandal (**Fig.2.4**).

2.2.3 Water Level Fluctuations: The water level fluctuations vary from -12.6 to 7.9 m with average fall of -0.1 m (**Fig.2.5**).In majority of the area (58%), water level shows a rise of 0-2 m occupying ~43% of area, 2-5 m (14 % area) and > 5 m (2% area) mostly covering command area. The fall in water levels (due to less rainfall than normal) is mostly observed in Chinthapalle, Chandampet, Anumula and eastern part of Peddavuramandals. Maximum negative WLF of 0-2 m is observed in 26 % of the area followed by 2-5 m (12%), 5-10 m (2 %) and >10 m in 2% of the area.

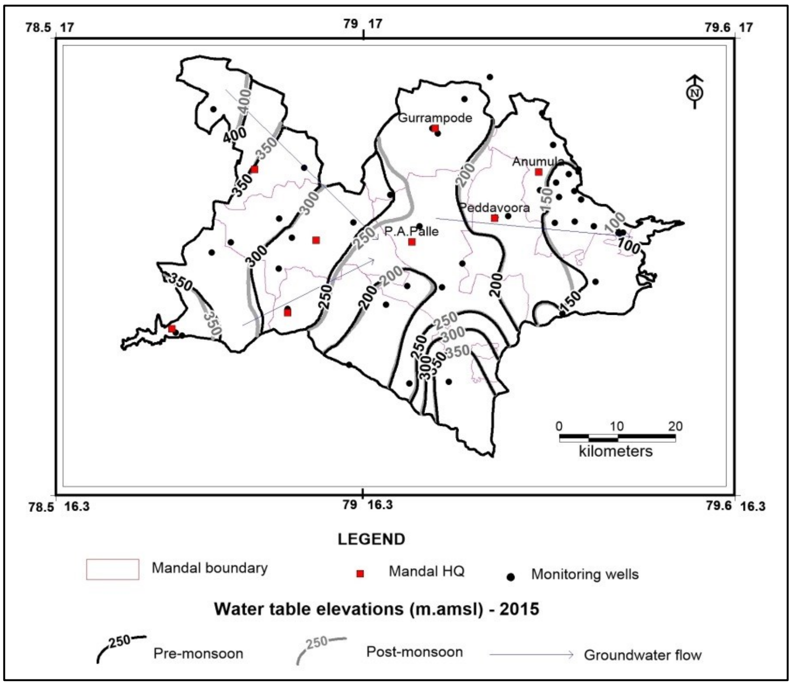

Fig.2.2: Water table elevations (Pre and Post-monsoon-2015).

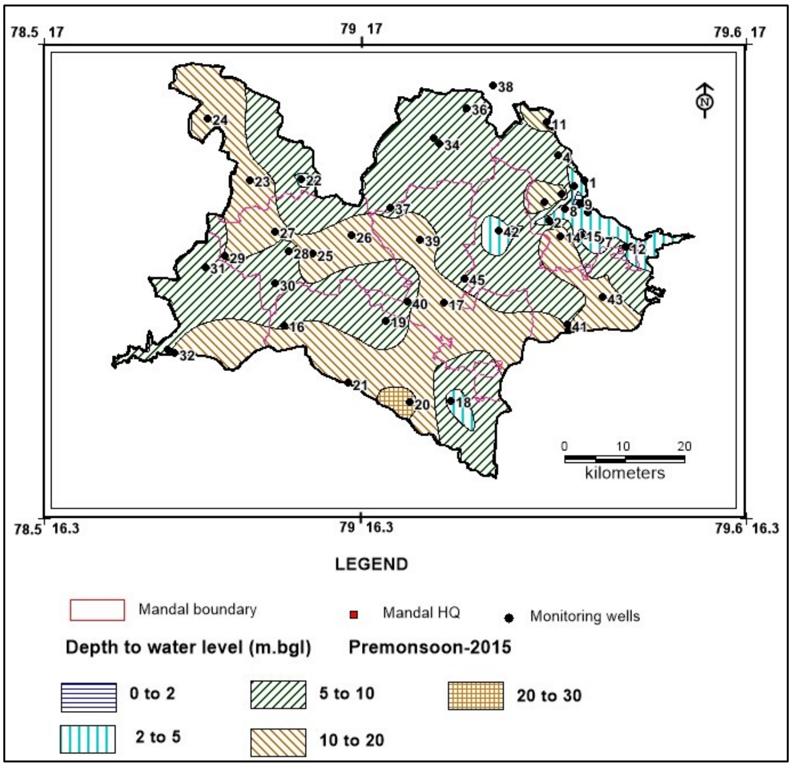

Fig.2.3: Depth to water levels Pre-monsoon (May-2015).

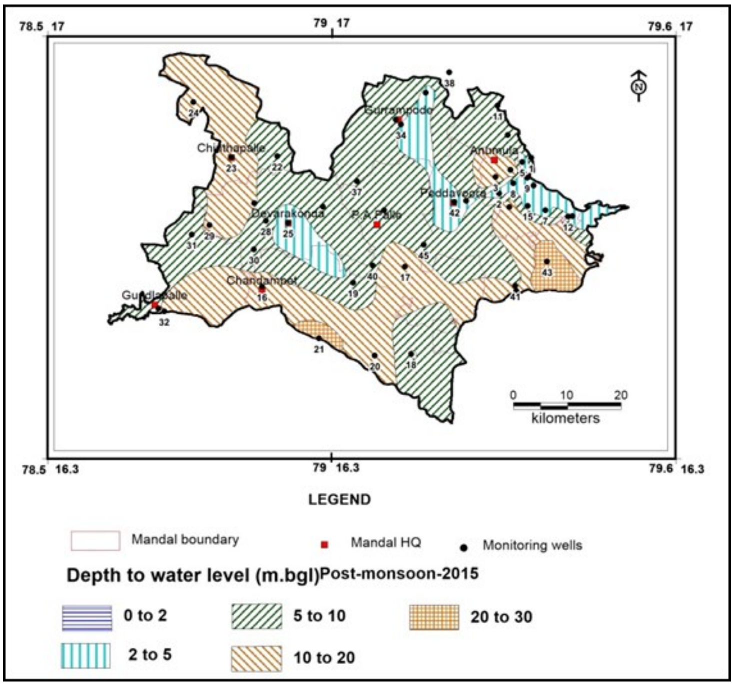

Fig.2.4: Depth to water levels Post-monsoon (November-2015).

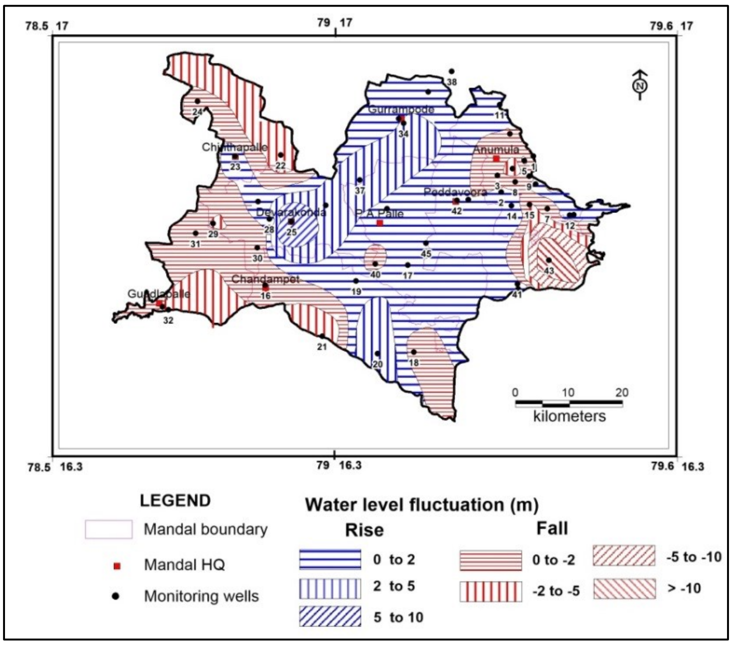

Fig.2.5: Water Level Fluctuations (m) (Nov with respect to May-2015).

2.3 Long-term water level trends (2006-15): Trend analysis for the last 10 years (2006-2015) is studied from 5 hydrograph stations of CGWB (**Table. 2.2 and Fig. 2.6**). 2 wells shows fall in water levels @ 0.3to 0.7 m/yr and rise of 0.07 to 0.1 m/yr during pre and post-monsoon seasons respectively. 1 wells shows rising trends of 0.15 m/yr and 0.2 m/ yr during pre and post-monsoon seasons respectively. 2 well shows falling water levels in both seasons.

Table-2.2: Long term Water Level Trends (2006-2015), (CGWB-GWMS).

S. No	Location	Pre-monsoon		Post-monsoon	
		Rise	Fall	Rise	Fall
		m/yr		m/yr	
1	Devarakonda-DW		0.7	0.1	
2	Devarakonda-Pz		0.3	0.07	
3	Dindi		0.11		0.34
4	Gurrampod	0.15		0.22	
5	Chintaplly		0.034		0.70

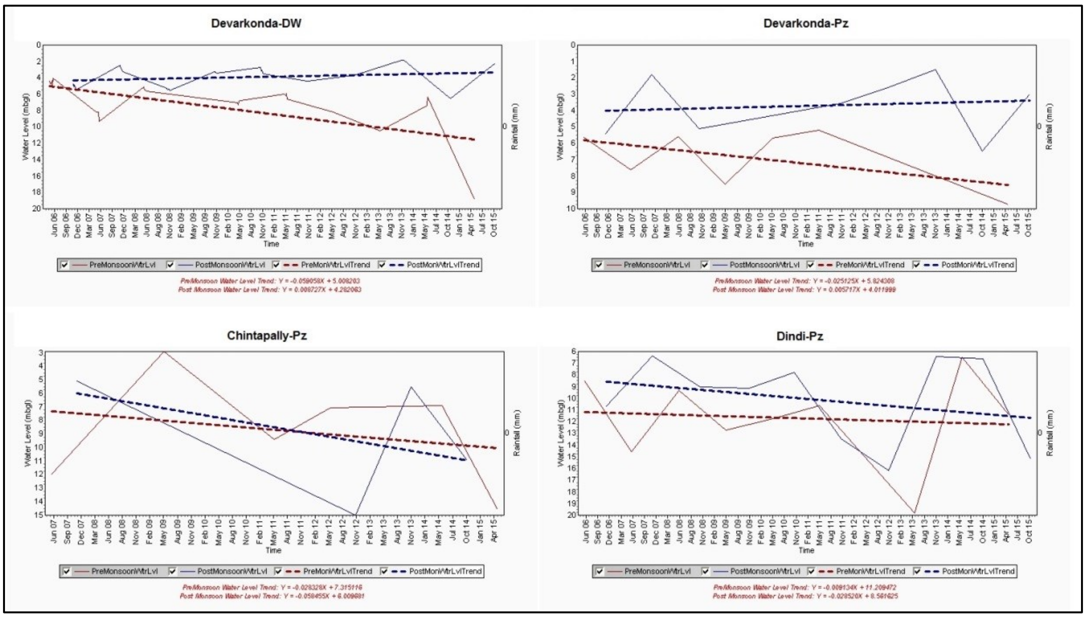

Fig.2.6: Long term water level trends from study area.

2.4 Geophysical: Total 24 VES are carried out and the analysed data reveals resistivity < 100 ohm (Ω) m for the weathered granite (1-20 m), 60-350 Ω m for underlying fractured granite with maximum thickness of 120 m and > 350 Ω for massive granite.

2.5Hydro chemical:

To understand chemical nature of groundwater water quality data from monitoring wells(114 samples) is utilized from ground water monitoring wells of CGWB and SGWD wells (mostly tapping combined aquifers) during the pre (64 nos) and post-monsoon season (50 nos) of 2015. 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.

Groundwater in the area is mildly alkaline to alkaline in nature in both seasons (pre-monsoon average pH 7.7 and post-monsoon average pH 7.9). The EC (µ Siemens/cm) varies from 420-3940 (avg:1502) and 254-6180(avg:1715) during pre and post-monsoon season respectively (**Fig.2.7 and Fig.2.8**).More than 3000 EC is detected in 1 % and4 % of the area during pre and post-monsoon season. Average concentration of TDS and TH is 965 & 1715 and 395 & 343mg/L during pre and post-monsoon season respectively. The concentration of NO_3 ranges from 3-465 and 1-531 mg/L during pre and post monsoon season respectively (**Fig.2.9 and Fig.2.10**). Fluoride concentration varies from 0.3-3.9 and 0.1-4.8 mg/L during pre and post monsoon respectively (**Fig.2.11 and Fig.2.12**). It is found that about 36 % and 60 % of the samples during pre and post-monsoon season are unfit for human consumption (BIS, 2012).

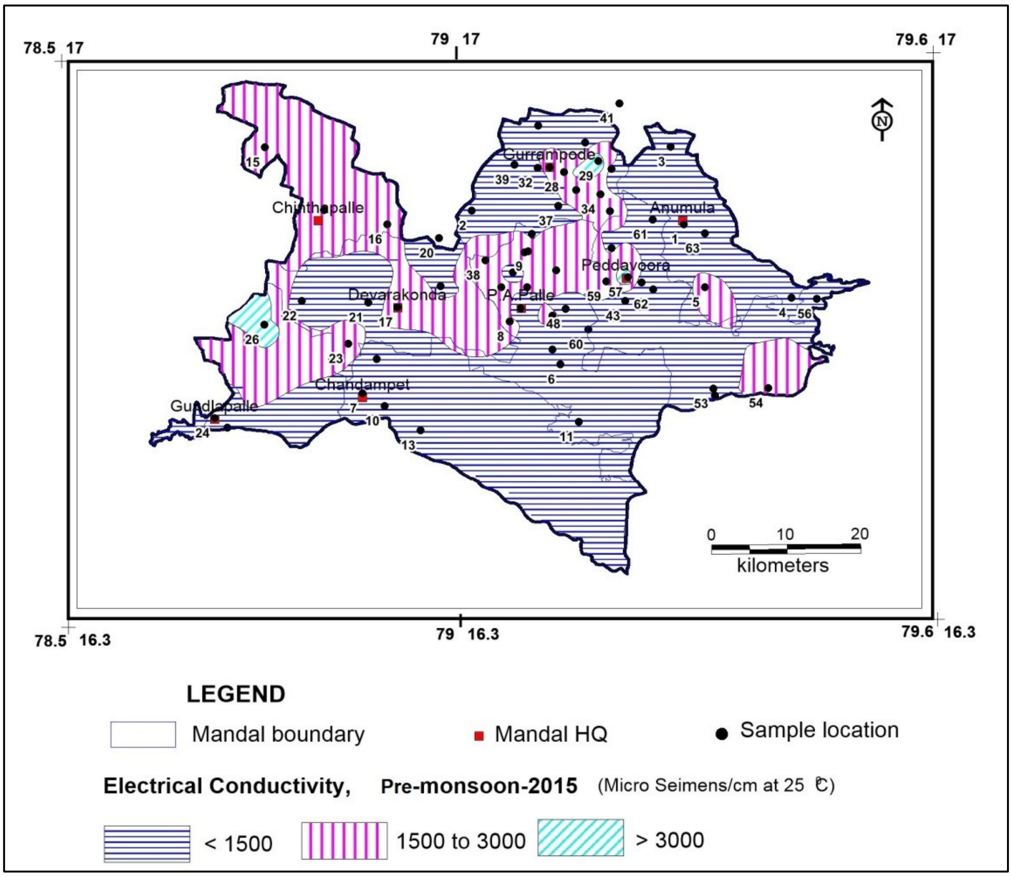

Fig.2.7: Distribution of Electrical conductivity (Pre-monsoon-2015).

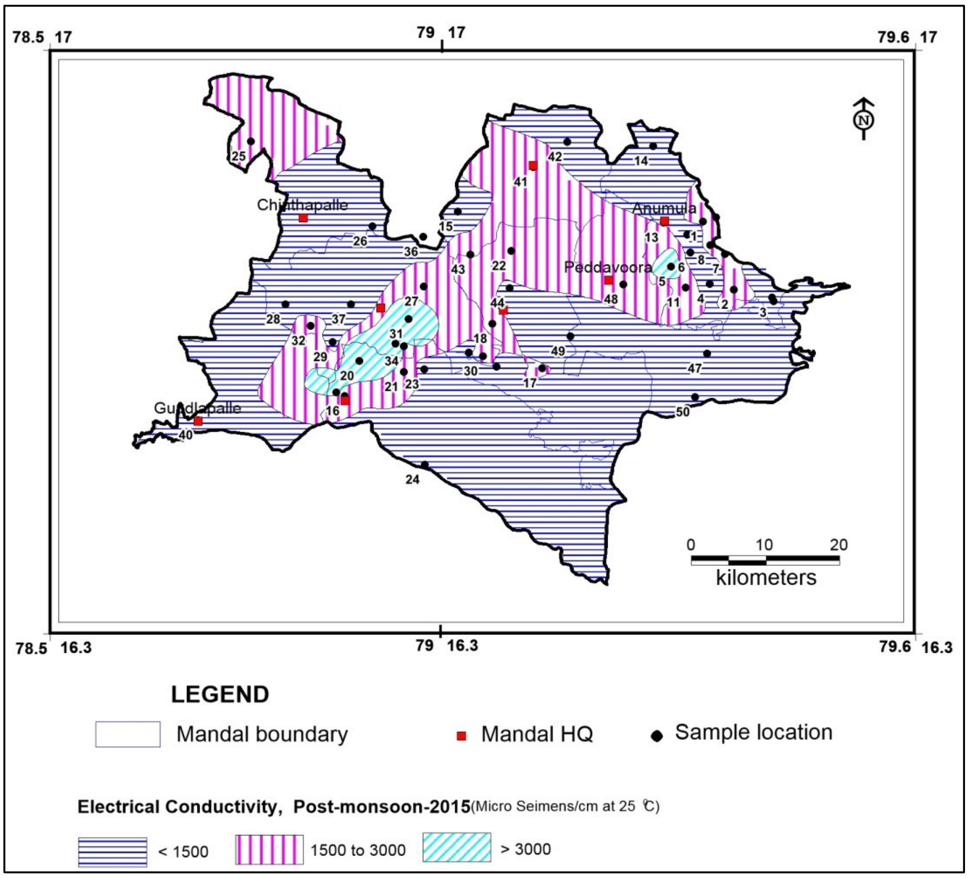

Fig.2.8: Distribution of Electrical conductivity (Post-monsoon-2015).

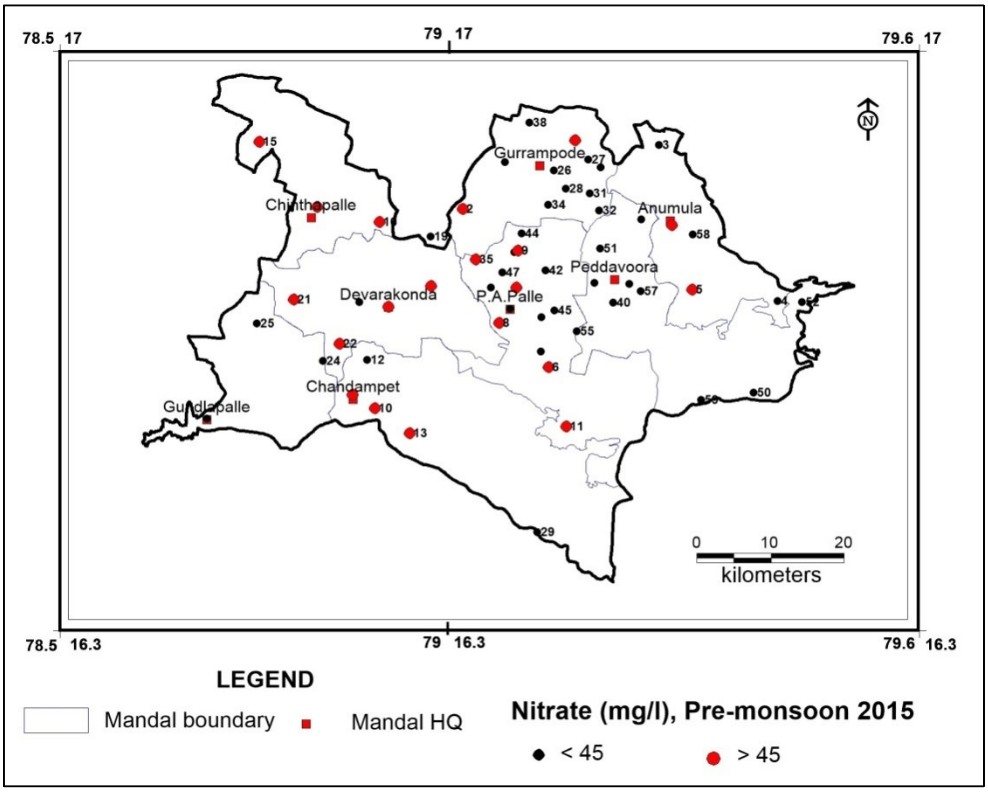

Fig.2.9: Distribution of Nitrate (Pre-monsoon-2015).

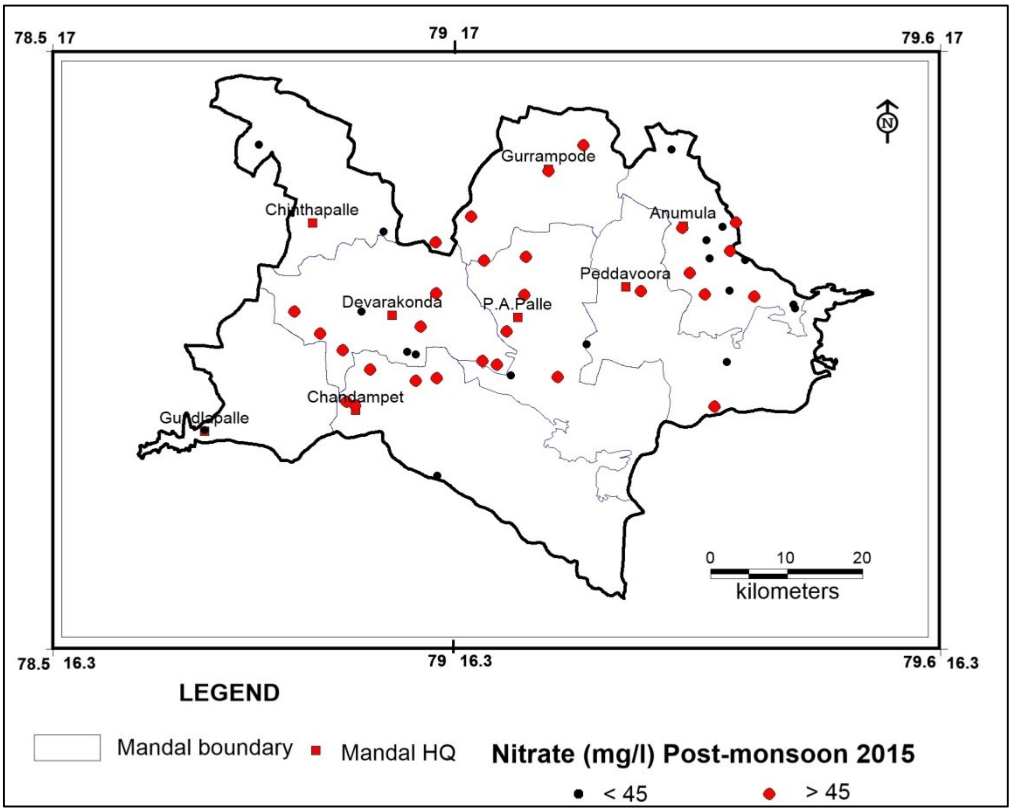

Fig.2.10: Distribution of Nitrate (Post-monsoon-2015).

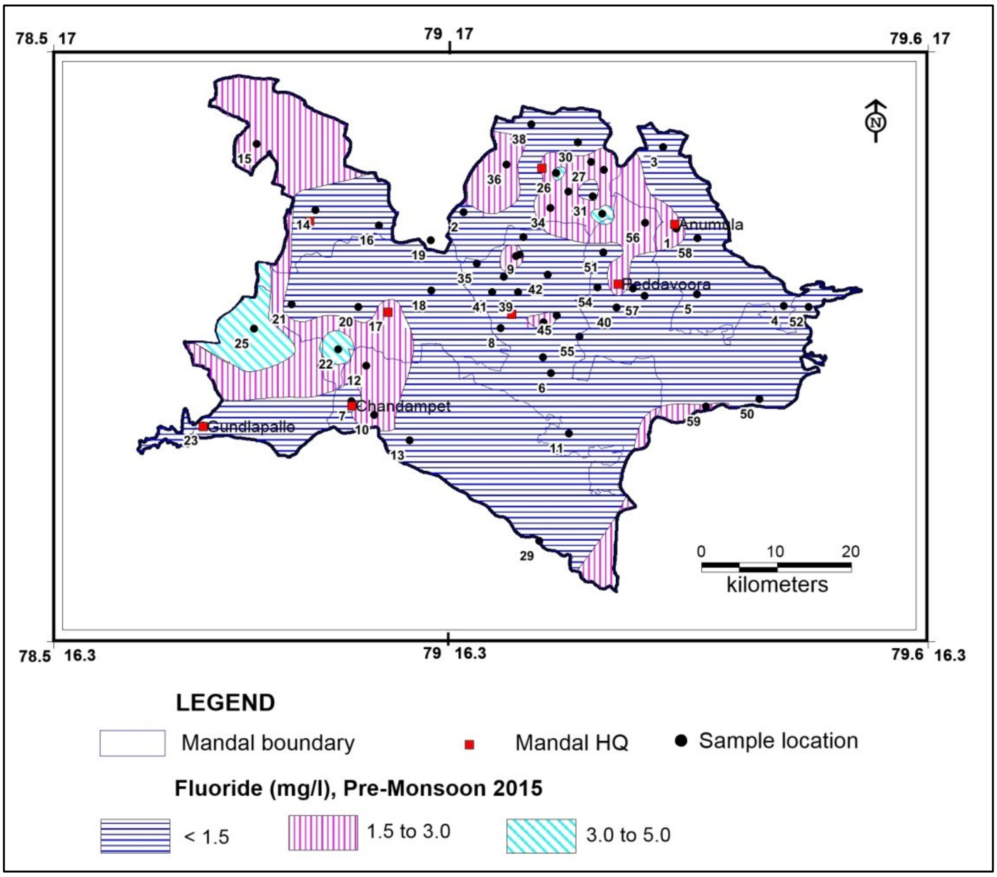

Fig.2.11: Distribution of Fluoride (Pre-monsoon-2015).

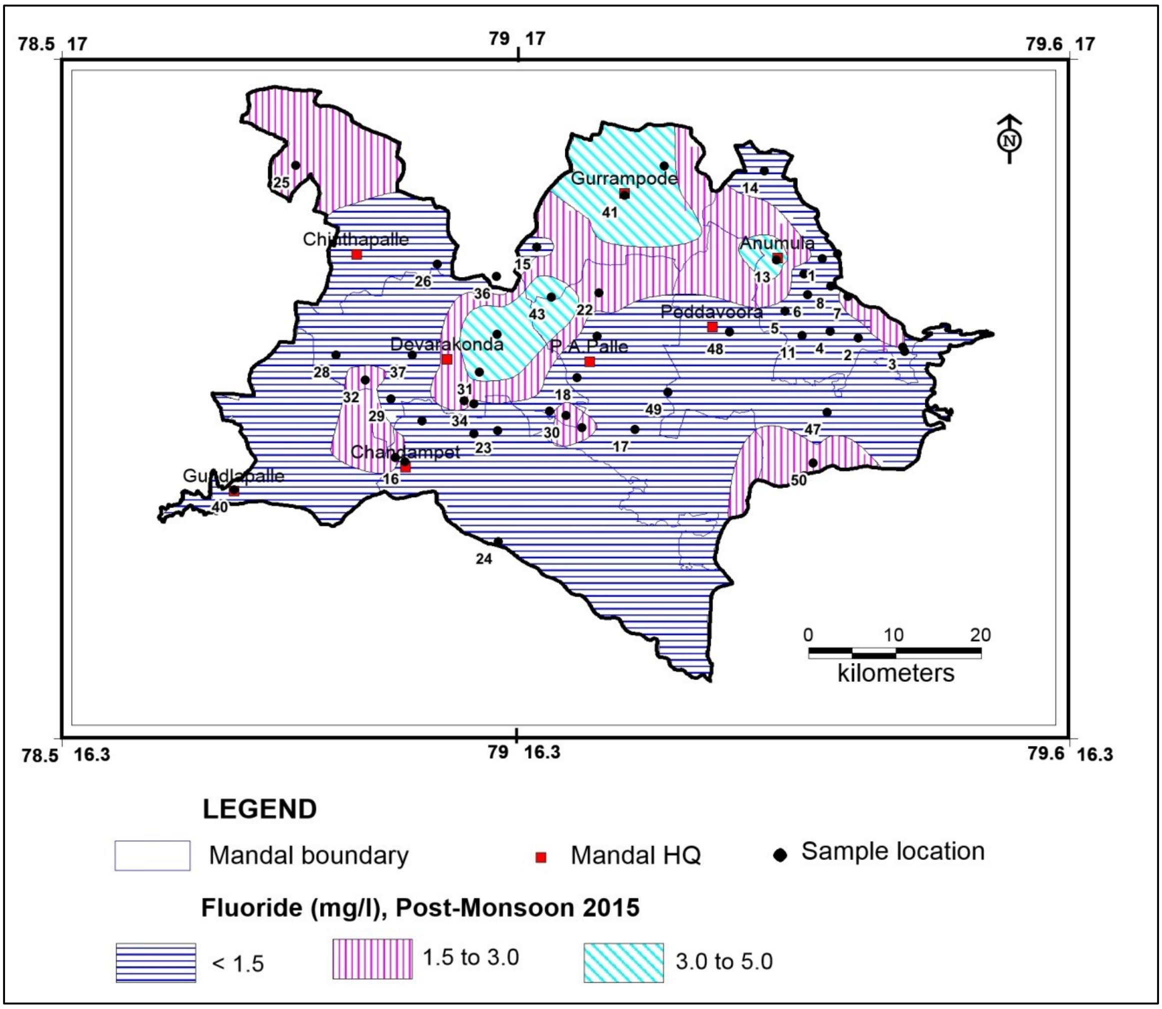

Fig.2.12: Distribution of Fluoride (Post-monsoon-2015).

3. DATA INTERPRETATION, INTEGRATION and AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 131 data points (both hydrogeological and geophysical down to 200 m) for preparation of 3-D map, panel diagram and hydrogeological sections. The data is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data (**Fig.3.1**). The lithological information was generated by using the RockWorks-16 software and generated 3-D maps for the area (**Fig.3.2)** along with fence diagram (**Fig. 3.3**)and hydrogeological sections (**Fig.3.4).**

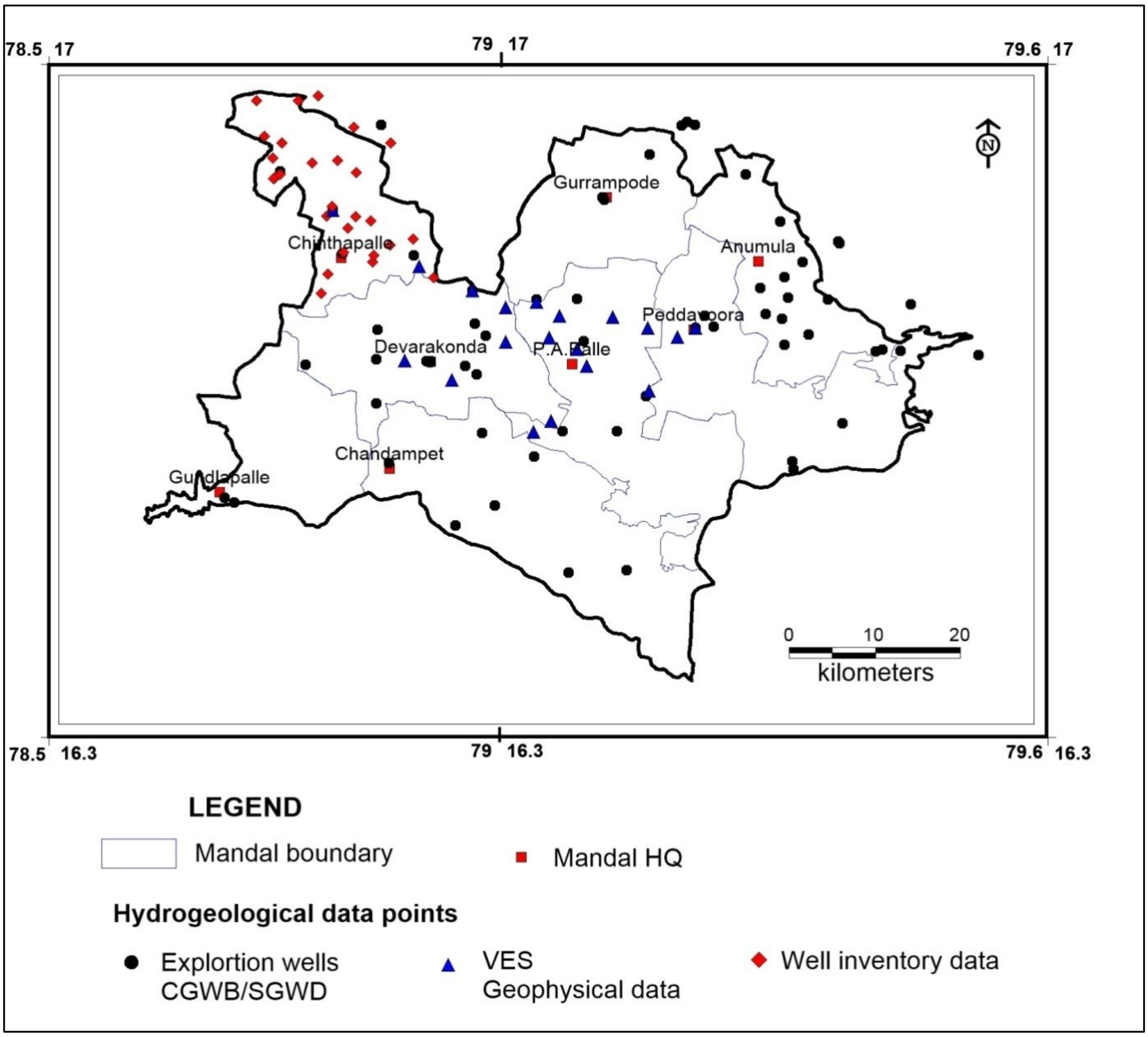

Fig.-3.1: Location map of hydrogeological/geophysicaldata points.

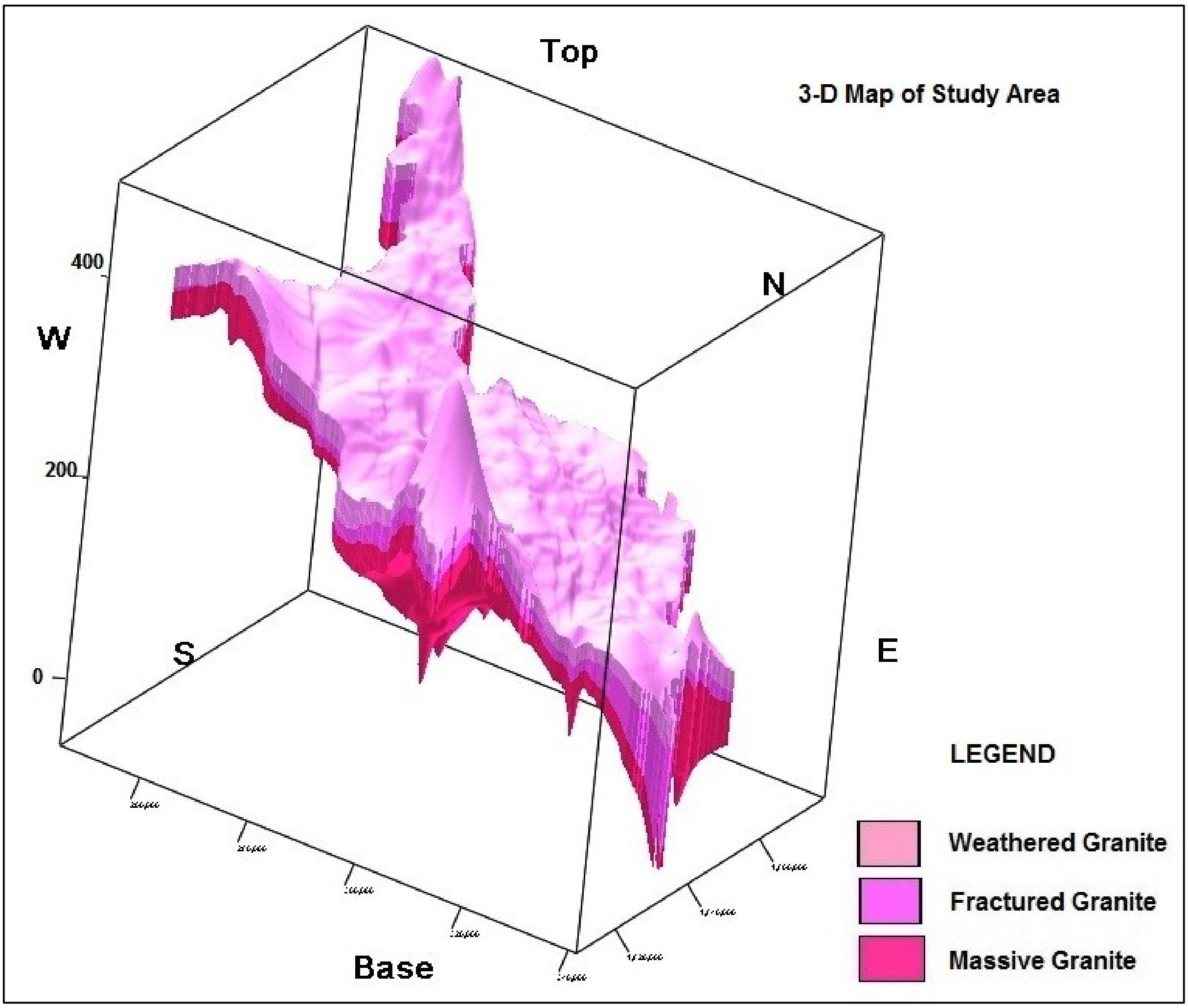

Fig.-3.2:3-D Model for study area.

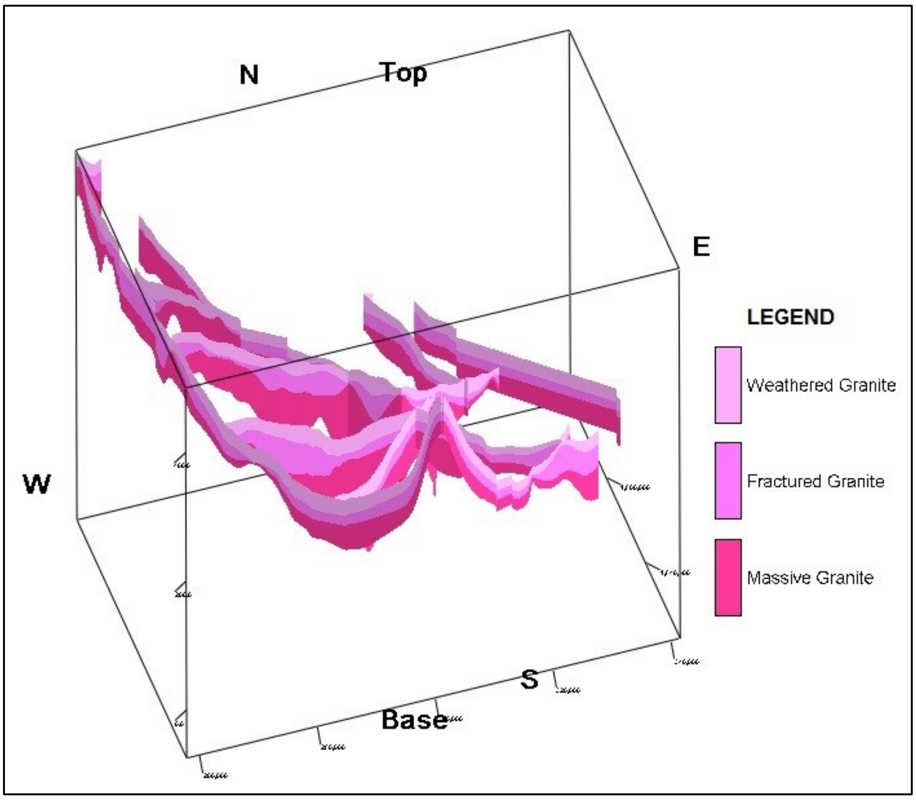

Fig.-3.3: Panel Diagram of study area.

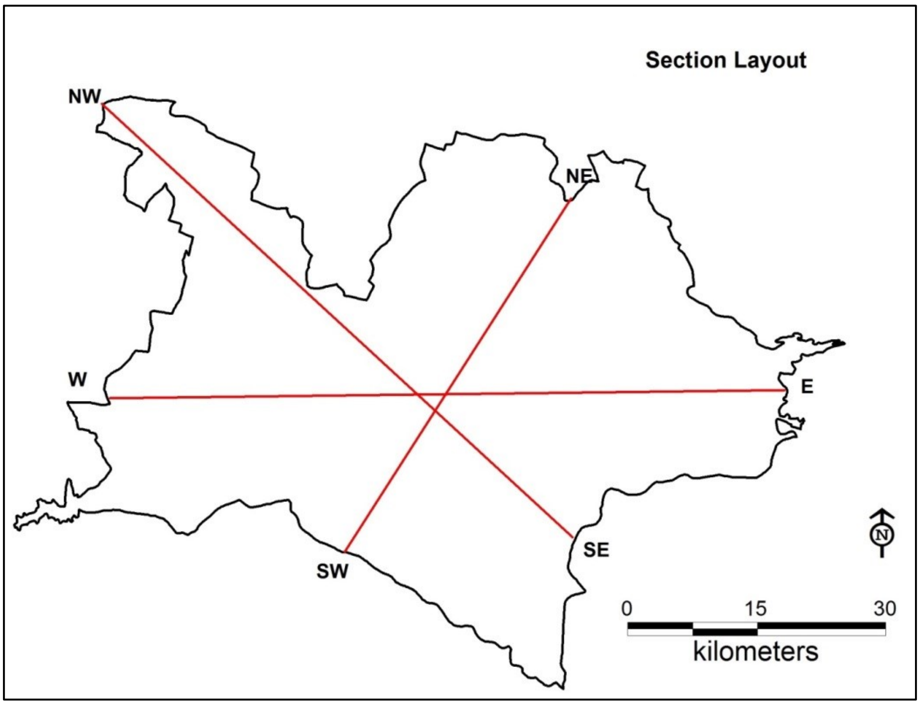

Fig.-3.4: Map showing orientation of various sections.

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. Weathered zone is considered up to the maximum depth of weathering and 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 below weathered zone (~20-134 m) (**Fig. 3.5**).

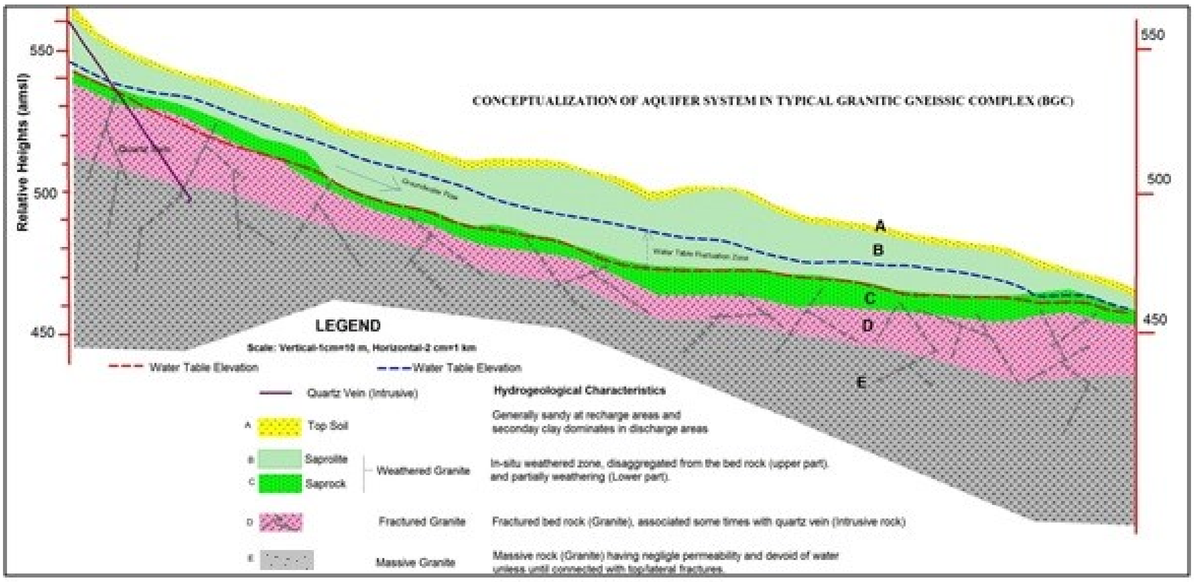

Fig.3.5: Conceptualization of Aquifer systems in typical Granite-Gneissic Complex (BGC).

3.2 Hydrogeological Sections

Section-NE-SW: The section drawn along the NE-SW direction, covering a distance of ~60 kms depicts uniform weathered zone thickness all along the section. The fracture thickness is more in SW parts in comparison to NE (**Fig.3.6**).

Section NW-SE: Section drawn along NW-SE directions, covering a distance of ~70 kms, depicts almost uniform weathered zone thickness in most part (**Fig.3.7**). The thickness of fractured zone is more in central part of section while it is negligible from the distance of 10 kms to 25 kms from NW towards SE directions.

SectionE-W: The section drawn along E-Wdirection covering a distance of ~70 kms depicts uniform weathered zone thickness except in central parts where thicknes is more as compared to other parts. Deep fractures are encountered in central part of the section ~20 kms from eastern part towards western part (**Fig.3.8**).

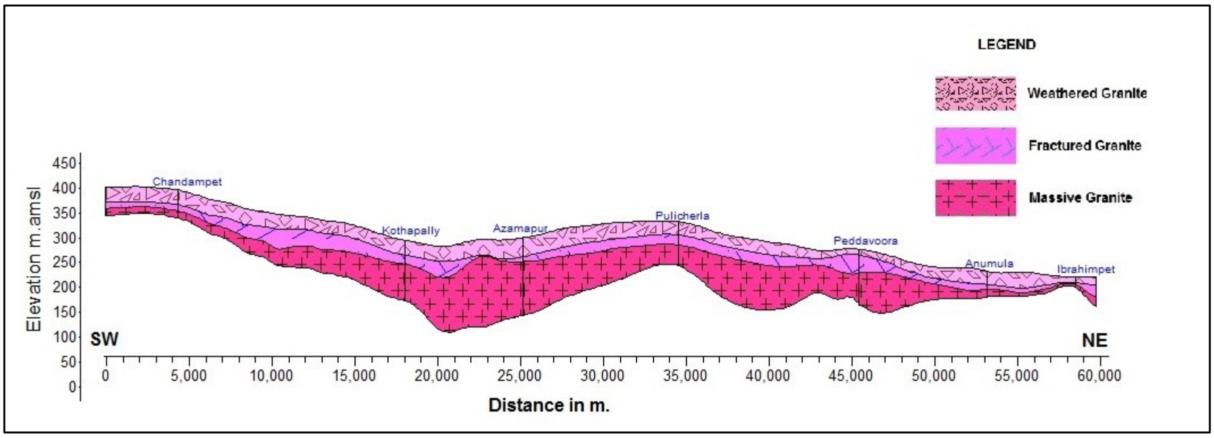

Fig-3.6: Hydrogeological section in NE-SW direction.

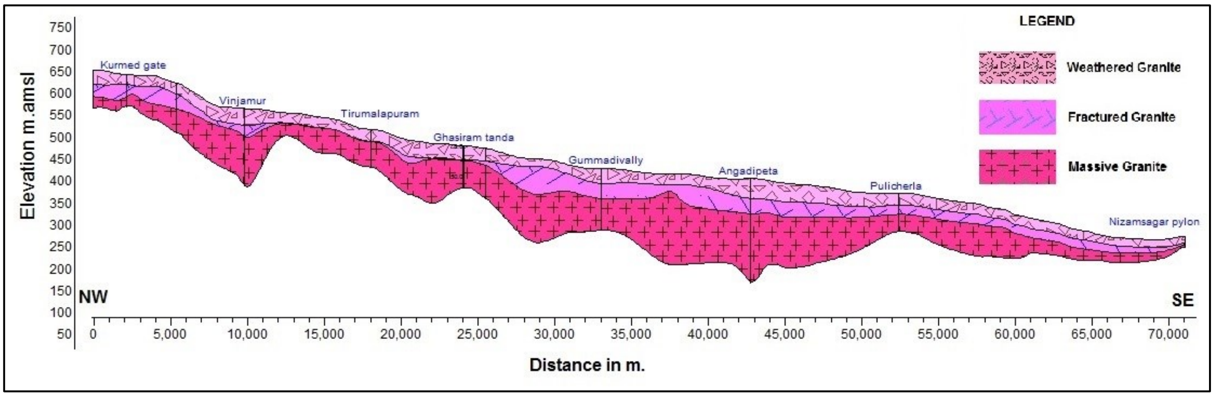

Fig-3.7: Hydrogeological section in NW-SE direction.

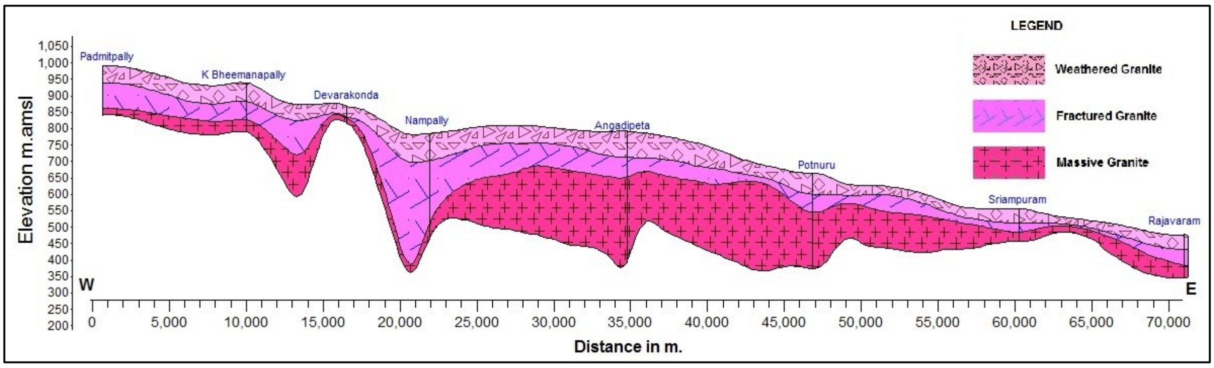

Fig-3.8: Hydrogeological section E-W direction.

3.3 Aquifer Characterization

3.3.1 Weathered zone: Thickness of weathered zone is shallow (< 10 m) in central, eastern and in parts of southern parts of Chandampetmandals covering ~42% of area and moderate weathering (10-20 m) is observed in 56 % of the area covering western, southern and south-eastern part and deep weathering (>20 m) is observed in 2% of the area covering north-western part of Chintapalle mandal(**Fig.3.9**). Average depth of weathering in the area is ~20 m.

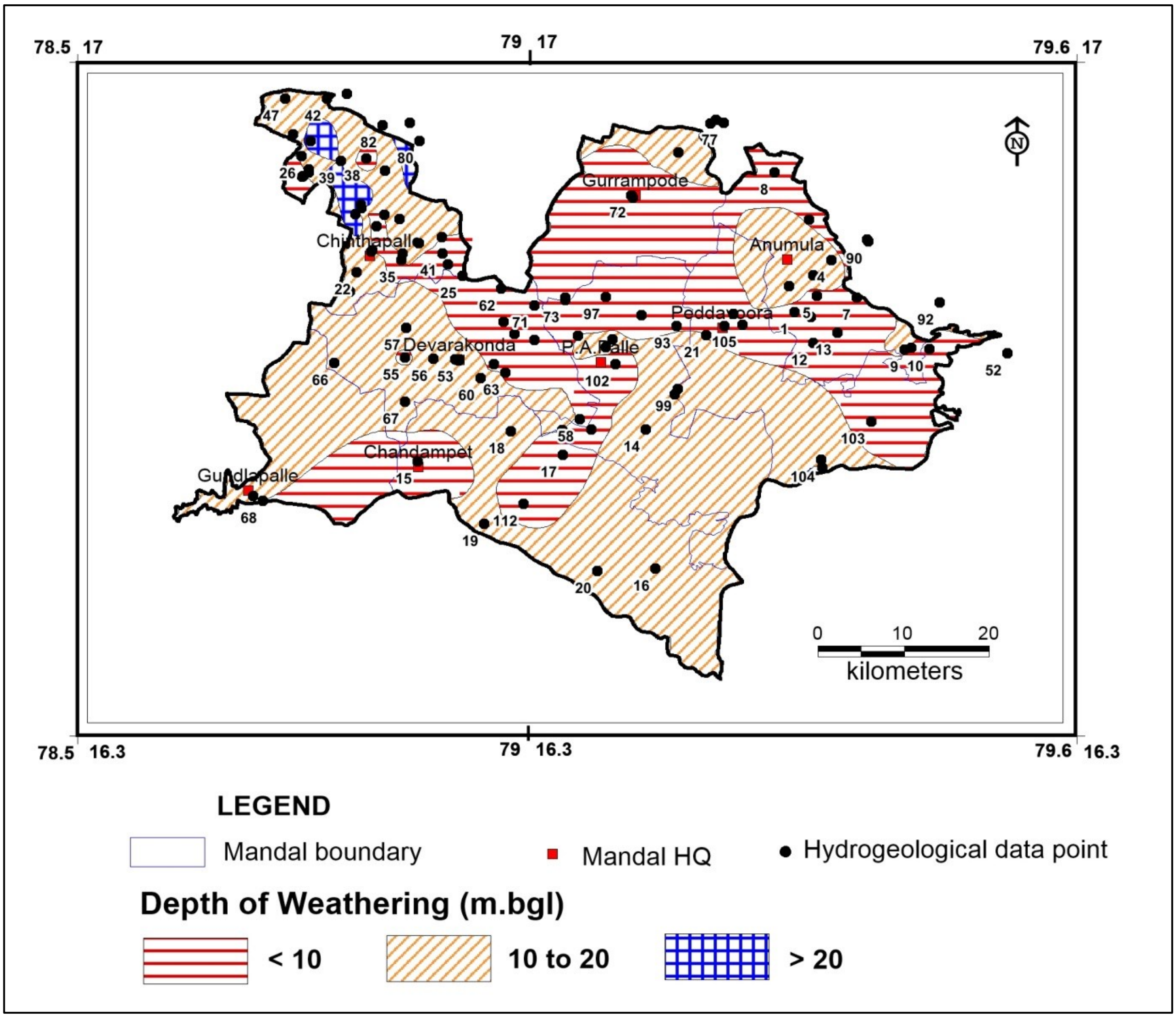

Fig.3.9: Thickness of Weathered zone.

3.3.2 Fractured zone: Ground water is extracted mainly through bore wells of 30 to 100 m depth from fractured zone (~20 to 133 m). Fractures in the range of 30-60 m depth are more predominant covering 82 % of the area followed by 60-100 m depth deep fractures (15% of the area) and shallow and deep fractures occur in negligible part (**Fig.3.10**). Analysis of occurrences of fracture from bore wells (111) reveal that majority of fractures (~98 %) occur within 100 m depth (**Fig. 3.11**). Transmissivity (T) varies from 8 to 633 m^2/day and storativity of 0.0001 to 0.01.

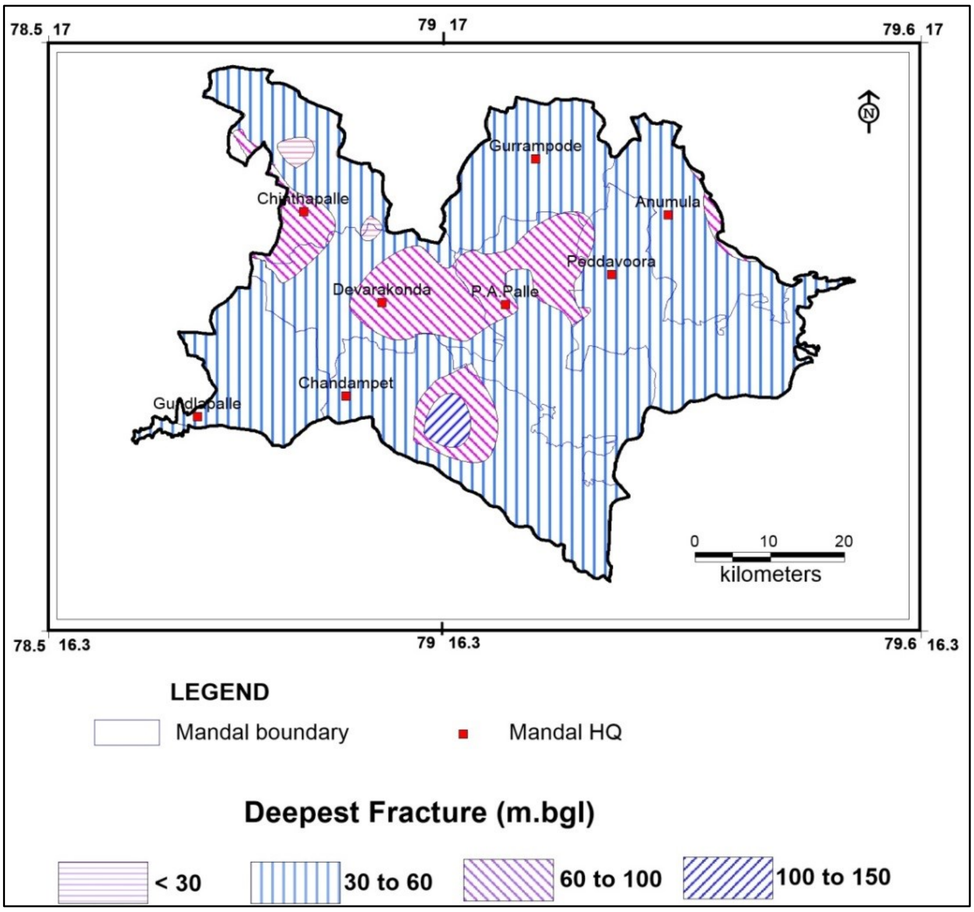

Fig.-3.10: Depth of Fractured zone (Maximum depth) (mbgl).

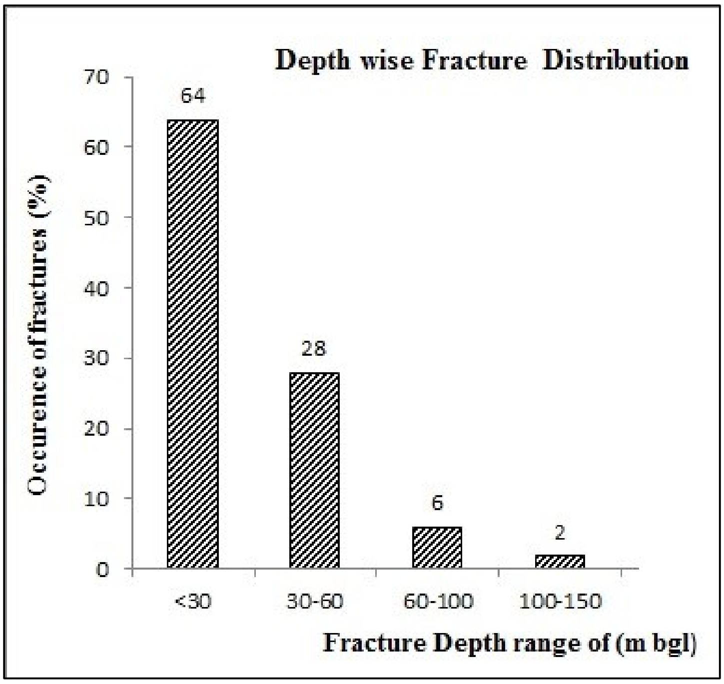

Fig.-3.11: Depth wise distribution of fractures.

4. GROUNDWATER RESOURCES

In hard rocks, for practical purpose it is very difficult to compute zone wise (aquifer wise) groundwater resources, because the weathered zone (WZ) and fractured zone (FZ) are inter-connected with fractures/joints and fractured zone gets recharged through weathered zone. Therefore it is very difficult to demarcate the boundary between two aquifers; hence the resources are estimated considering entire area as a single aquifer system. Village wise dynamic and in-storage groundwater resources are computed as per the guidelines laid down in GEC methodology.

While computing the in-storage resources, the general depth of deepest fractures in the area, pre-monsoon water levels and 2 % of granular zone (depth below pre-monsoon water level and down to deepest fracture depth in the village) is considered. Summarized command/ non-command area and mandal wise resources are given in **Table-4.1 and Annexure-1**respectively.

As per 2013 GEC report, the dynamic replenishable groundwater availability is **278.9** MCM, gross ground water draft for all uses **161.1** MCM, provision for drinking and industrial use is 15.6 MCM and net annual ground water potential available for future irrigation needs is 124.45 MCM. Overall 2 mandals (Chintapalle and Gurrampod) falls in Semi-critical category and others in safe category and overall stage of ground water development varies from 40 % to 72 %. Based on 2013 resources, village wise utilizable ground water resource map is prepared and presented in **Fig. 4.1.**The in-storage ground water resources which can be utilized in draught period are 73.5 MCM.

Table-4.1: Computed Dynamic, In-storage ground water resources from 8 mandals (MCM).

Parameters	Command	Non-command	**Total**
As per GEC 2013	MCM	MCM	MCM
Dynamic (Net GWR Availability)	**167.12**	**111.82**	**278.94**
• Monsoon recharge from rainfall	71.67	99.04	17.071
• Non-monsoon recharge from other sources	60.02	8.16	68.18
• Non-Monsoon recharge from rainfall	0	0	0
• Non-monsoon recharge from other sources	52.78	17.03	69.81
Gross GW Draft	**82.86**	**78.25**	**161.11**
• Irrigation	75.87	72.24	148.11
• Domestic and Industrial use	6.99	6.01	13.00
Provision for Drinking and Industrial use for the year 2025	7.41	8.19	15.60
Net GW availability for future irrigation	84.94	39.51	124.45
Stage of GW development (%)	49.6	70	Avg:57.8
	Mandal wise it varies from 40% (Anumula) to 72 % (Gurrampod)		
In-storage GW Resources (down to the maximum depth of fractures)	73.5 MCM		

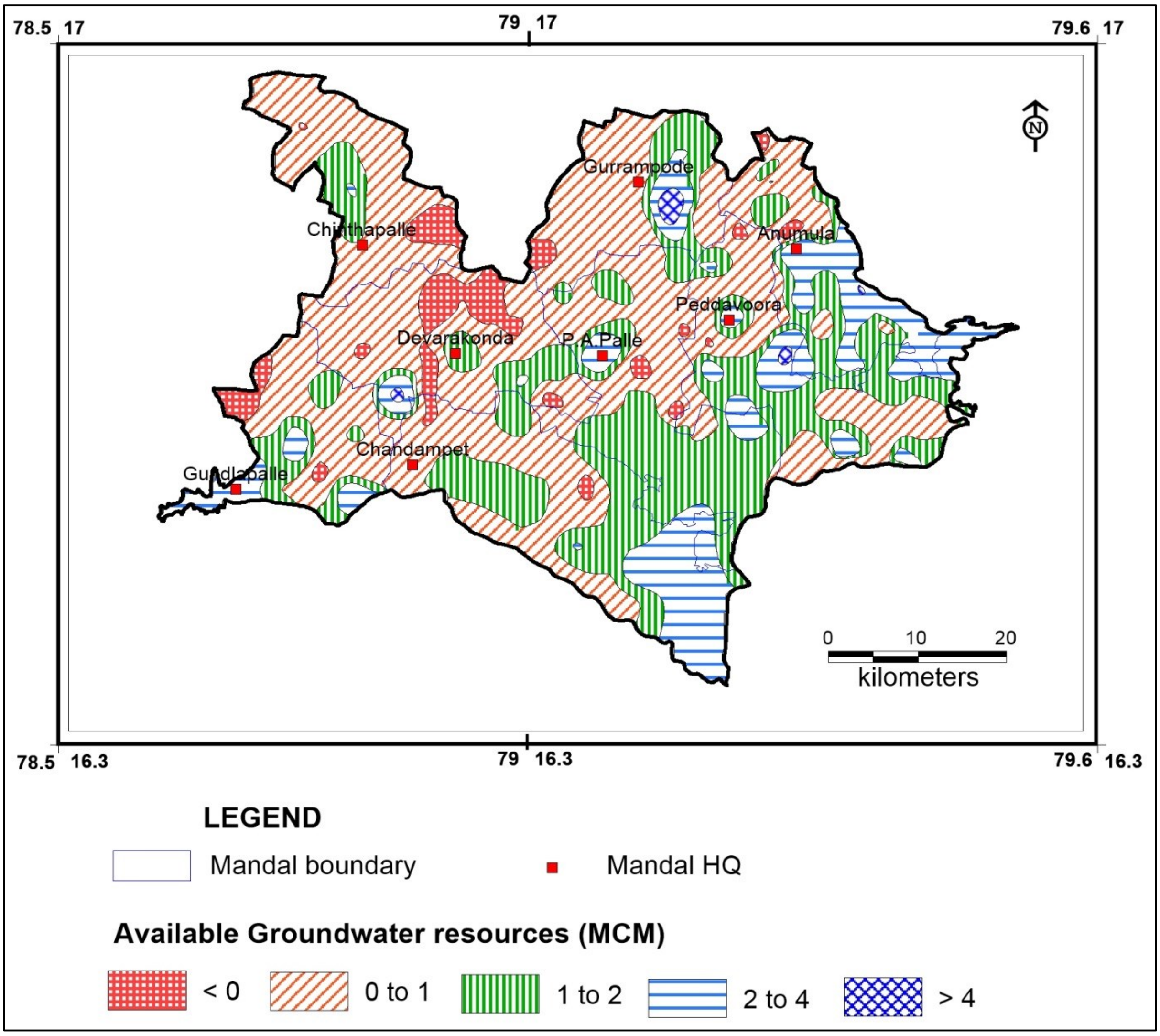

Fig.4.1: Utilizable ground water resources (2013).

5. GROUND WATER RELATED ISSUES and REASONS FOR ISSUES

5.1 Issues

Pollution (Geogenic and Anthropogenic)

1. Fluoride as high as 3.9 mg/L during pre and 4.8 mg/L during post-monsoon season is found in groundwaters from the area. The higher concentration of fluoride (>1.5 mg/L) occur in36% and 34 % of the area during pre and post-monsoon season of 2015.
2. High nitrate (> 45 mg/L) due to anthropogenic activitiesis observed in 36 % and 60 % of samples during pre and post-monsoon season of 2015.
3. High concentration of EC (> 3000 micro-seimens/cm) is observed in 1 % and 4 % of the area (mainly in Dindi Project canal command area).

Over-exploitation

4. ~ 154 Km^2 area (5%) covering 26 villages are categorized as over-exploited.

Deep water levels

5. Deep water levels (> 20 mbgl) are observed during pre and post-monsoon season in 1% and 3% of the area respectively.
6. Approximately in 42 % of the area, falling water levels are observed during post-monsoon season as compared to pre-monsoon season and this is due to deficient rainfall as compared normal rainfall.

Sustainability

7. Low yield (<1 lps) occurs in ~70 % of area and yields of bore wells have reduced over a period of time and some bore wells which used to yield sufficient quantity of water have gone dry and due to this rich farmers are acquiring water from nearby places (if available) or transporting water from far off places (1-2 km) and saving the commercial crops thereby incurring lot of financial expenses.

Other Issues

8. Based on ground water irrigation paddy is grown during rabi season in non command area also, thusleading to heavy withdrawal of ground water during non-monsoon period.

5.2 Reasons for Issues

Geo genic pollution (Fluoride)

1. Higher concentration of F in ground water is attributed due to source rock,which contains avg. 810 ppm of F (higher than surrounding Hyderabad granite rocks).
2. Rock water interaction where acid-soluble fluoride bearing minerals (fluorite, fluoro-apatite) gets dissolved under alkaline conditions.
3. Higher residence time of ground water in deeper aquifer.

Anthropogenic pollution (Nitrate)

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

Over-exploitation and Deep water levels

5. Over-extraction, paddy cultivation during rabi season, ground water mining, limited artificial measures etc. are the main causes for over-exploitation and deep water levels.

Sustainability

6. Absence of primary porosity, negligible development of secondary porosity, Low rainfall and desaturation of weathered zone.

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, raising questions on sustainability of existing groundwater structures, food and drinking water security. The studies revealed different behaviour of ground water in the weathered zone (~ 20 m) and fractured zone (20-134 m). The occurrence of fractures in fractured zone are very limited in extent, as the compression in the rock reduces the opening of fractures at depth and the majority of fractures occur within 100 m depth (98%) (**Fig.3.11**). Higher NO_3^- concentrations (> 45 mg/L) in weathered zone is due to sewage contamination and higher concentration of F^- (>1.5 mg/L) in weathered zone and fractured zone is due to local geology (granite rock), high weathering, longer residence time and alkaline nature of groundwater.

6.1 Management Plan

The uneven distribution of groundwater availability and its utilization indicates that a single management strategy cannot be adopted and it requires integrated hydrogeological aspects along with socio-economic conditions to develop an appropriate management strategy. The study suggests notable measures for sustainable groundwater management, which involves a combination of various measures given below. Mandal wise aquifer maps and management plans for fully covered and partly covered mandals are given in **Annexure-2**and **Annexure-3** respectively.

1. Supply side measures
2. Demand side measures

6.1.1 Supply side measures

6.1.1.1Artificial Recharge structures:

Construction of 874 artificial recharge structures (ARS) (14 villages: priority-1 and163 villages: priority-2 areas) are suggested by following standard methodology.

While formulating the village wise groundwater management plan, the unsaturated volume of aquifer is estimated by multiplying the area with specific yieldand unsaturated thickness (post-monsoon water levels below 3 m). Initially villagewise dynamic groundwater resources of 2011 are considered (**Fig.4.1**). Potential surface run off is estimated by following standard procedures. On conservative side 20 % runoff yield is considered as non-committed yield for recommending artificial recharge structures. The pre-monsoon groundwater quality is considered for categorising contaminated area (F >1.5 mg/l &EC >3000). Nitrate is not considered here because it is point source pollution and localized. Based on above criteria, the area can be prioritized into **priority-1** which needs immediate intervention and **priority-2**. Based on hydrogeological characteristics, the area is further sub-divided into following 8 categories (**Table-6.1 and Fig.6.1**).

Table-6.1: Hydrogeological characteristics of area.

Category	Hydrogeological 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 additionalscope 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.

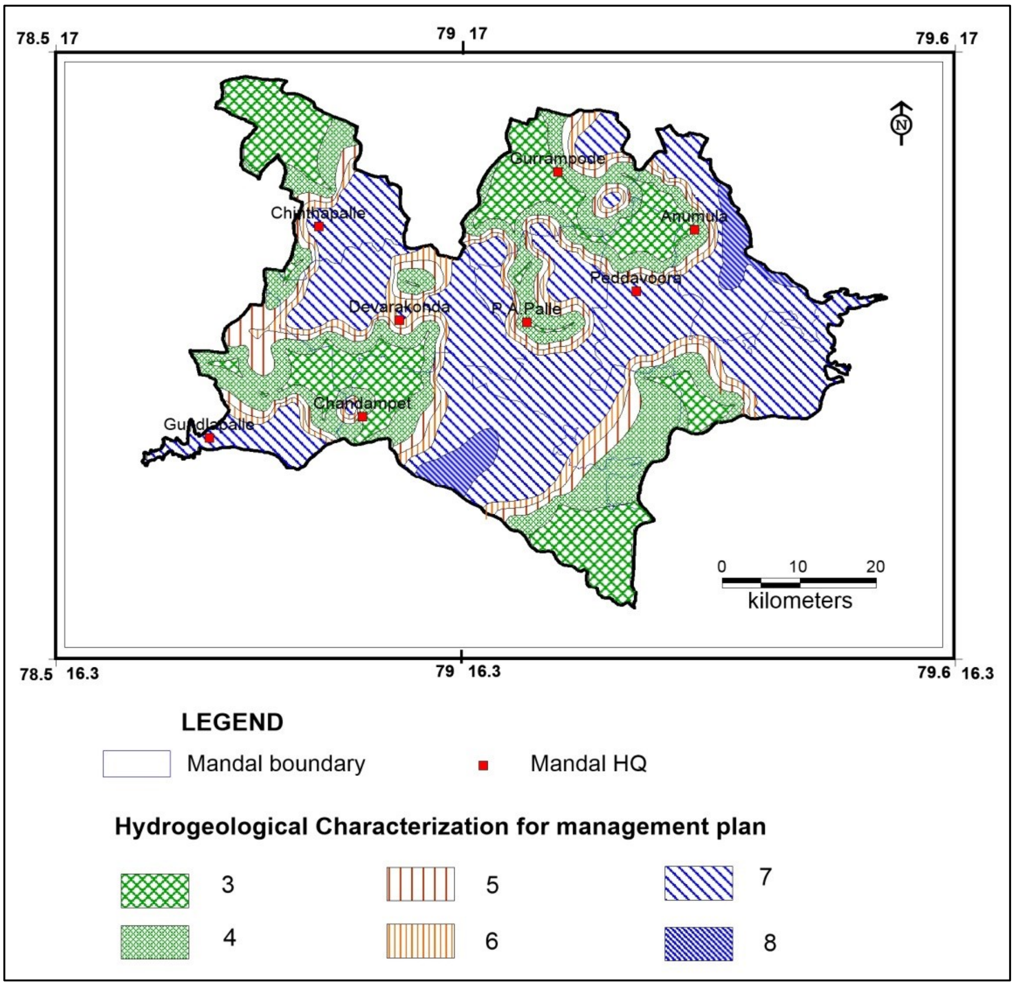

Fig.6.1: Hydrogeological characterization of area for management plan.

a) **Priority-1 (14 Villages, Rechargeable area: ~135Km^2) (Area where groundwater development is > 100 %)**

Area consisting of 14 villages (in other 12 villages there is no surplus runoff for additional ARS) having rechargeable area of ~135 Km2 (**Annexure-2**) are considered as Priority-1 where immediate intervention is required because, here, the stage of groundwater development is > 100%. The area is again sub-divided into 8 categories based on hydrogeological conditions as mentioned above. For sustainable development and management of the groundwater resources the following recommendations are made.

- 46 artificial recharge structures (23 CD's with 6 filling and 23 mini PT's with 1.5 fillings) with a total cost of 3.45 crores can be taken up.

b) **Priority-2 (163 Villages, 2553 Km^2) (areas where ground water development < 100 %)**

Area consisting of 163 villages covering ~2553 Km2 (**Annexure-3**) is considered as Priority-2, where there is scope for further groundwater development. The area is again further divided into 8 categories based on hydrogeological characteristics as mentioned above. For sustainable development and management of the groundwater resources the recommendations are made.

- 828 artificial recharge structures (ARS) (414 CD's with 6 fillings and 414 mini PT's with 1.5 fillings) can be taken up with a cost estimate of 62.1 crores.

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 ideal size of form ponds is 10 x 10 x3 m. In the area total 3820 farm ponds are recommended (20 in each village) with total cost of 9.55 crores.

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

- De-silting of existing minor tanks (273 no's) was taken under state Govt. sponsored Mission Kaktiya-Phase-1 and Phase-2 to remove ~4.16 MCM of silt, costing ~90 crores and this has created additional surface storage. The net recharge to ground water will be 1.25 MCM (considering 30% recharge) and with this ~200 ha additional land can be brought under irrigated dry (ID) crops in tank ayacut. There is need to take remaining tanks (~451nos) in next phases for de-silting, this will greatly help in stabilisation of tank ayacut and groundwater augmentation.

6.1.1.4 Mission Bhagiratha (Drinking water supply to every house hold):

- Under Telangana Drinking Water Supply Project (TDWSP) also known as Mission Bhagiratha, all the villages are proposed to be covered (the schemes are at various stages of completion). The scheme is to enhance the existing drinking water scheme and provide 100 lpd/persons and 135 lpd/person in rural and urban areas respectively. Thus all habitations (including fluoride affected) will be covered with the implementation of this project.
- Imported water to the tune of ~17 MCM from surface sources into the basins will reduce stress on groundwater. Considering 60lpcd as present utilization there will be net saving of 10.21 MCM of ground water, which can be effectively utilized to irrigate ~17000 ha of additional land under ID crops.

6.1.1.5 Construction of additional bore wells in command area

- In order to utilize 17 MCM of available resources in command area, construction of additional 1700 bore wells of 100 m depth are recommended with a cost of 34 cr.

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

- Conjunctive use of ground water and surface water in the command area is recommended where water levels are in the range of 0-5 m.bgl.
- Demand side measures include adaptation of micro irrigation practices which saves ~25 % water as compared to traditional flooding irrigation. In the area till date 22354 no's of drip and sprinklers are sanctioned which has irrigated ~25998 ha under ID crops.
- ~2658 additional MI are recommended in 4 mandals (Chandampet, Chintapalle, Devarkonda and Gundlapalle) costing 15.9 crores (considering 1 unit/ha @0.6 lakh/ha).
- Change in cropping pattern from water intensive paddy to other irrigated dry and drought resistant crops that have a short growing season is recommended, particularly in semic- critical mandals. If necessary some regulatory rules may be framed and implemented.
- To avoid the interference of cone of depression between two productive wells, intermittent pumping of borewells is recommended through regulatory mechanism.
- Complete ban on paddy cultivation during rabi season under ground water irrigation in non-command areas and semi-critical mandals.
- Power supply should be regulated by giving power in 4 hour spells (two times a day, in the morning and evening)to increase the sustainability of structures.
- As mandatory measures power connection may be given to only those farmers who are adopting micro irrigation for all new bore well to be constructed.
- Compulsory rain water harvesting in proportionate to withdrawal.

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 Andhra Pradesh 'Water, Land and Trees Act' of 2002 (APWALTA 2002) are the other measures suggested.
- Subsidy/incentives on cost involved in sharing of groundwater may be given to the farmers involved.
- In the existing ground water areas sharing of ground water amongst the users is to be encouraged to increase the sustainability of wells by reducing well interference and to promote this the bore well owner should be suitably compensated for the cost of well by funding to farmers for adopting micro irrigation practices in the entire well command area to be born by the Govt.
- The other measures includes, supplementary calcium and phosphorous rich food should be provided to children in fluoride contaminated areas (Category-3 and 4), creating awareness about safe drinking water habits, side effects of high fluoride and nitrate rich groundwater, improving oral hygiene conditions are recommended. In urban and rural areas the sewerage line should be constructed to arrest leaching of nitrate. Going for salt tolerant plants like cheak pea, mustard etc where water levels are deep and in shallow water table areas (Category-1 and 5), where EC is high, the

rice varieties like CSR-27, CSR-23, CSR-13 and CSR-10 are recommended in Category-2 and 6.

6.2 EXPECTED RESULTS AND OUT COME

With the above interventions costing Rs 91 crores (excluding the cost involved in Mission Kaktiya, Mission Bhagiratha and construction of new bore wells), the likely benefit would be the net saving of ~27MCM of ground water. This will bring down the stage of ground water development by 6 % (from 58 % to 52 %).

Acknowledgment

The authors thank Shri K.B. Biswas, Chairman, and Sri. D. Saha, Member (SAM), Sri. K.C.Naik, Member (ED & MM), of the Central Ground Water Board, Govt. of India and S/Shri A.D.Rao, Regional Director, and Dr.P.N.Rao and GRC Reddy of CGWB, for encouragement. The authors acknowledge State Ground Water Department and Rural Water Supply department, Govt of Telangana for making available of field data. Authors also thank the Executive Engineer and his drilling crew of CGWB, for carrying out the exploration activity.