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

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Chittoor District, Andhra Pradesh

दक्षिणी क्षेत्र, हैदराबाद

Southern Region, Hyderabad

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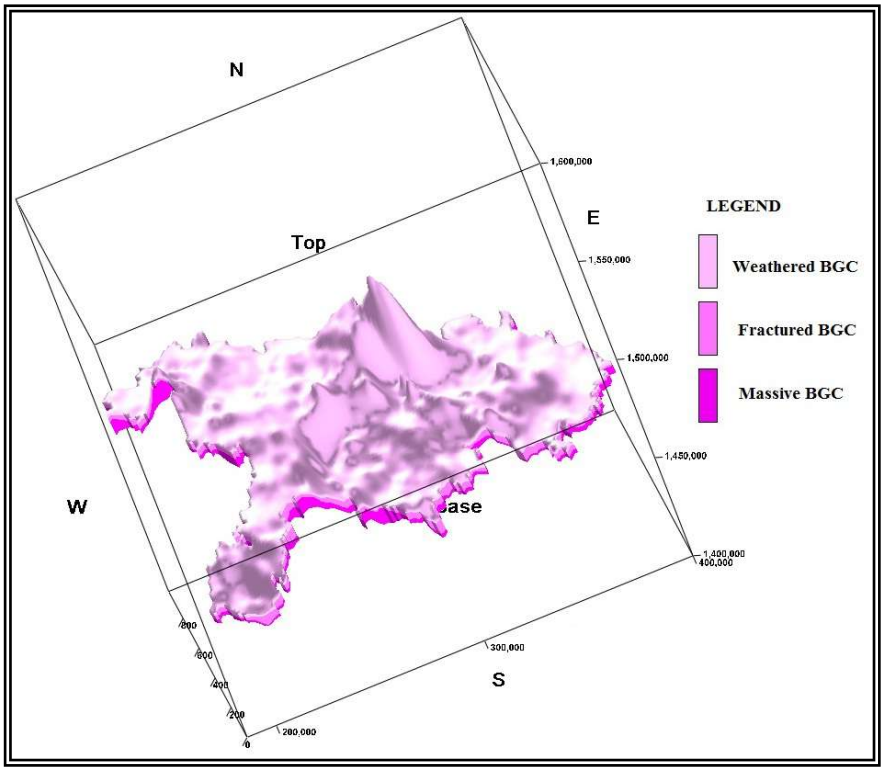
GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN CHITTOOR DISTRICT, ANDHRA PRADESH



CENTRAL GROUND WATER BOARD
SOUTHERN REGION
HYDERABAD
JANUARY-2017

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN CHITTOOR DISTRICT, ANDHRA PRADESH

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REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN CHITTOOR DISTRICT ANDHRA PRADESH

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REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN CHITTOOR DISTRICT ANDHRA PRADESH

AT A GLANCE

S.No.	Item		Particulars
1	Districts	:	Chittoor
2	Revenue Divisions/ Mandals	:	3/66
3	Villages	:	1540
4	Geographical area	:	15151 Km^2
5	Population (2011 Census)	:	41.57 lakhs (71% Rural and 29 % urban)
6	Density of population (2011 Census)	:	292 persons/Km^2
7	Growth rate	:	11.4 % over previous census
8	Locations	:	North Latitude 12°37´23"-13°59´27" East Longitude 78°04´12"-80°03´36"
9	Rainfall (Normal)	:	600-1294 mm (avg: 934) (SW: 48% & NE: 42%) (During 2015 it received 745.1 mm (-20% less than normal rainfall)
10	Geomorphology	:	It is part of Mysore plateau. Pediplain (45%), hills (32%), Pediments (14%), valley fills (5%) etc.
11	Major Rivers	:	Ponnai, Pincha, Bahuda, Swarnamukhi and Palar etc.
12	Watersheds	:	75
13	Land Utilization (Ha) (2013-14)	:	Net sown area: 417066 (28%); Area sown more than once: 45350 (3%), Land put to non-agricultural use: 157842 (10%), cultivable waste land: 152700 (10 %) . Forest :~30% (4520 Km^2)
14	The Gross cropped area (Ha) 2013-14	:	Groundnut (37%), paddy (12%), Sugarcane (5%), vegetable and pulses (5% each) etc.
15	Soils	:	Red soils 91% (loam: 57% and sandy: 34%) 9% black soils.
16	Irrigation	:	**Major (Contemplated):** 5 with registered ayacut of 442387 ha. **Medium:** 8 with registered ayacut of 15310 ha. **MI Tanks:** 8188 with ayacut 122918 ha during 2013-14 is 12610 ha only (10 %)

			Ground water contributes 90% and Surface water 10% (**2014-15**).		
17	Prevailing water conservation/Recharge practices	:	PT: 4619, CD's:4614 and mico-irrgation: 6934 units irrigating ~6065 ha (2013-14).		
18	Geology	:	Banded Gneissic complex (90%), quartzite (4%), Shale (1%), laterite 1% and alluvium 1 % etc.		
19	Exploratory Drilling (CGWB and SGWD)	:	CGWB: 114 wells and SGWD 176 nos		
20	Number of ground water structures	:	Agricultural bore wells:290627 nos		
21	Ground water yield	:	Basin	:	lps
21.1			Ponnai	:	0.4-13
21.2			Pincha	:	Meagre to 7
21.3			Bahuda	:	0.2-8.4
21.4			Swarnamukhi	:	0.04-14
21.5			Palar	:	0.4-17
22	Water Levels (2015) Depth to water levels (m bgl)	: :	223 Wells (CGWB:47 and SGWD:176) Pre-monsoon:0.1-96.2 (avg: 11.9) and majority is in the range of 5-10 m bgl (44% area followed by 10-20 m bgl (37% of area). Post-monsoon:0.1-118.2 (avg: 12.9) and majority is in the range of 10-20 m bgl (29% area followed by 5-10 m bgl (26% of area).		
23	Water Level Fluctuations (May vs. November 2015)	:	-95.7 to 41.5 (average fall of 1.3 m)		
24	Long term water level trends (2006-15) (84 wells)	:	**Pre-monsoon:** Falling :63 wells (0-1 m:43, 1-2 m:9 and > 2:11, Rising: 21 wells (0-1 m:20, 1-2:0 and > 2 m:1) **Post-monsoon:** Falling:57 wells (0-1m:42, 1-2m:7, > 2:8, Rising: 27 wells (0-1m:23,1-2:3 and >2:1)		
25	Water level during 2015 with average WL of last 10 years	:	**Pre-monsoon:** 73 wells shown fall and 10 shown rise and 1 shown neither rise nor fall. **Post-monsoon:** 30 wells shown fall and 54 shown rise.		
26	Geophysical data	:	104 no's (VES) weathered BGC: < 115 ohm (Ω) m, fractured BGC: 115-250 Ω m and Massive BGC: > 250 Ω m		
27	Hydrochemistry	:	1053 samples pre-monsoon:503 (2015), post-monsoon-550 (2014)		
27.1	Electrical Conductivity (µ Siemens/cm)	:	Pre: 530 to 2985 in majority it is <1500 (79% samples) and Post: 418 to 3619 in majority it is <1500 (75% samples)		
27.2	Nitrate mg/l	:	Pre: BDL to 199 (310 samples unfit for human consumptions) Post: BDL to 399 (340 samples unfit for human consumptions)		
27.3	Fluoride mg/l	:	Pre: 0.01to 2.1 (3 samples unfit for human consumptions. Post:0.01-2.0 (6 samples unfit for human consumptions)		

28	Ground water suitability for drinking	:	~62% samples are unfit for human consumptions in both seasons.		
28.1	Conceptualization		**Weathered zone**	**Fractured zone**	
28.2	Aquifer Characterization	:	~20 m (< 10 m: 35%, 10-20 m 56% > 20 m: 9%)	20-185 m but 99% fractures occur within 100 m depth.	
28.3	Ground water yield	:	Average:1.1 lps	0.1-13 lps	
28.4	Transmissivity (m^2/day)	:	2 to 489 m^2/day	1 to 489m^2/day	
28.5	Specific Yield	:	1 to 3 %	-	
28.6	Storativity	:	-	1.6 x 10^{-4} to 5.9 x 10^{-4}	
29	**Ground water Resources (2013) MCM**	:	Command	Non-Command	Total
29.1	Net dynamic groundwater availability	:	102.28	1546.53	1648.81
29.2	Gross GW Draft	:	31.74	1145.22	1176.96
29.3	Provision for Domestic &Industrial (2025)	:	3.36	184.81	188.17
29.4	Stage of Ground water development (%)		31	74	71
29.5	Net GW Availability for future irrigation	:	69.93	403.47	473.4
29.6	In storage GW Resources	:	**340.33**		
29.7	Categorization of mandals		Out of 66 mandals 12 mandals falls in OE, 7 in Critical, 18 in Semi-critical and remaining 29 in safe category.		
30	Major Ground Water Issues Identified	:	Over-exploitation in 12 Mandals covering 13 % of area. Deep water levels (>20 m) in 9 % and 11 % of area in pre and post-monsoon seasons respectively (2015). Most of hydrographs are showing falling trends in both seasons. 62 % ground water samples are unfit for human consumption (Nitrate is main anthropogenic contamination) and ~57 and 88 Km^2 area is contaminated with fluoride (geogenic) during pre and post-monsoon season. Low yields (< 1 lps) 10 % of total geographical area.		
31	Management Strategies	:	**Supply side measures** **Ongoing Projects (Mission NEERU CHETTU)** • De-silting of 22.82 MCM of silt from existing 3079 (minor irrigation tanks and Percolation tanks) are taken under state Govt. sponsored NEERU-CHETTU programme this has created additional surface storage and this will contribute ~6.84 MCM of GW and with this additional ~1140 ha of land can be brought under ID crops. **To be taken up** • De-silting of 9.98 MCM of silt from existing 2737 (minor irrigation tanks and Percolation tanks) is proposed to be taken under state Govt. sponsored NEERU-CHETTU programme. This will create additional surface storage and will contribute		

			~3 MCM of GW and with this additional ~500 ha of land can be brought under ID crops when completed. **Artificial Recharge Structure (ARS)** **Priority-1:Over-exploited villages: 227** • 1409 ARS (CD:1213 and PT:196) • Cost Rs ~80.25 Crores **Priority-2:Other remaining villages:776** • 7278 ARS (CD:6062 and PT:1216) • Cost Rs ~424.7 Crores **Contemplated Projects (HNSS) (**Cost: 1314.68 cr) to bring 9.8 TMC of water in to the district for irrigation and drinking purposes). ~10 lakhs population will be provided with safe drinking water from river Krishna. ~72840 ha will be irrigated **Water Conservation measures (WCM) Farm Ponds** Recommended 32020 nos farm ponds with total cost **80.05 crores** in ~1600 villages (@ 20/village). **Demand side measure** **Ongoing work** • Under NTR Jala Siri project 9090 ha of land brought under assured irrigation and micro-irrigation @ cost of Rs 31.65 crores benefitting 11108 farmers and created additional 9090 ha of land and saving ~18.2 MCM of ground water from traditional irrigation. • In the district till date a total number of 6934 no's drip and sprinklers are installed, irrigating ~6065 ha of land. **Proposed Work** **Scenario-1** • 1.63 lakh ha. Of existing groundwater irrigated area recommended for micro-irrigation • Cost **~980 crores** (@0.6 lakhs/ha) • Will save 326 MCM of GW to traditional Irrigation practices. **Scenario-2 (OE and Critical mandals)** • Change in cropping pattern from water intensive sugarcane and paddy crops to ID crops like groundnut is are recommended. • Minimum support price for Ground nut recommended is

			Rs 5300/quintal from present 4200/quintal to compensate the loss • Improved facilities at procurement centers. • To avoid the interface of cone of depression between the productive wells, intermittent pumping of bore wells is recommended through regulatory mechanism • Participatory groundwater management (PGWM) approach are recommended. • In urban and rural areas the sewerage line should be constructed to arrest leaching of nitrate.
32	Expected Results and Out come	:	With the above interventions costing Rs **1565** crores (excluding the cost involved in HNSS project), the likely benefit would be the net saving of 412 MCM of ground water or additional creation of ~36000 ha of irrigated land or the stage of ground water can be reduced by 11 % from present 71 % to 60 %.

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 committee
GW	:	Ground Water
Ha	:	Hector
Ha.m	:	Hector meter
ID	:	Irrigated dry
IMD	:	Indian Meteorological Department
Km2	:	square kilometre
LPS	:	Litres per second
M	:	meter
M^3	:	Cubic meter
max	:	Maximum
m bgl	:	Mitres below ground level
MCM	:	Million cubic meter
Mg/L	:	Milligram per litre
MI	:	Micro irrigation
min	:	Minimum
MPT	:	Mini percolation tank
NL	:	North Latitude
NO_3	:	Nitrate
OE	:	Over Exploited
PGWM	:	Participatory ground water management
PT	:	Percolation tank
SGWD	:	State Ground Water Department
S	:	Storativity
T	:	Transmissivity
WCM	:	Water conservation measures
MSP	:	Minimum Support price

EXECUTIVE SUMMARY

The Chittoor district covering 15151 Km^2 area, receives an average annual normal rainfall of 934 mm of which 48 % is contributed by SW monsoon and 42 % by north-east monsoon. During the year 2015, the district received -20 % (less) rainfall than normal rainfall. Administratively, the district is governed by 66 revenue mandals with 1595 villages. The population of the district is ~ 41.57 lakhs (2011 census) and shown an increase of 11.4% growth rate compare to previous census.

Pediplains are major geomorphic features (45% of area) followed by hills (32%), pediments (14%) and valley fills (5%) etc. The district is part of 5 river basins and divided into 75 watersheds. There are 8 medium projects with 15310 ha ayacut and 5 major contemplated projects with proposed ayacut of 442387 ha and 8188 MI tanks. The gross irrigated area during 2014-15 is 169451 ha. Groundwater contributes ~90 % of the net irrigated area and surface water contributes 10%. There are ~4619 percolation tanks, 4614 Check dams and ~ ~6065 ha area is brought under micro-irrigation practices (Drip and Sprinklers).

Gross cropped area of the district is 417066 ha (~28%) and forests occupy ~30 % of the area. Major crops grown are ground nut (37%), paddy (12%), sugarcane (5%), vegetables (5%) and pulses (5%). Among irrigated crops sugarcane is the major crops (28%) followed by paddy (24%), vegetables (11%) and ground nut (6%). It is observed that in the last 5 years irrigated crops like paddy, sugarcane, groundnut is decreased. The soils are mainly red soils (91%) and black soils (9%). ~90 % of the area is underlain by crystalline rocks (Banded Gneissic complex-BGC) followed by quartzite (4%), shale, laterite and alluvium (1 % each).

Exploratory results of CGWB (114 wells) suggests that yields are better in Palar and Swarnamukhi basin (0.4 to 17 lps) than other 3 basins and among them Pincha basin have less yield (meagre to 7 lps). Majority of fractures occur within 100 m depth and deepest fracture is encountered at the depth of 185 m depth (Gangasagaram). There are ~290627 agricultural bore wells in the district out of which free power is supplied to 286005 bore wells.

The T and S varies 1.39 to 143 m^2/day and 1.6 x 10^{-4} to 5.9 x 10^{-4} respectively in Ponnai basin, 1.58 to 166 m^2/day and1.37 x 10^{-4} to 1.58 x 10^{-3} respectively in Pincha basin, 2 to 489 m^2/day and 1.4 x 10^{-4} to 2.7 x 10^{-3} respectively in Bahuda basin, 11-231 m^2/day and

5.2 x 10^{-4} to 7.1 x 10^{-4} respectively in Palar basin and T in Swarnamukhi basin varies from 1-222 m^2/day.

Water levels are monitored through 223 wells during pre and post-monsoon season of 2015. The DTW varies from 0.1 to 96.2 meter below ground level (m bgl) (average: 11.9 m) and 0.1 to 118.2 m bgl (average: 12.9) during pre and post-monsoon season of 2015 respectively. During pre-monsoon season 5-10 m water levels is more predominant (44 % of area) followed by 10-20 m (37 % of area). During post-monsoon season 10-20 m water levels is more predominant (29 % of area) followed by 5-10 m (26 % of area).

During the year water level fluctuation (Nov WRT to May of 2015) varies from -95.7 to 41.5 m with average fall of 1.3 m. Long-term water levels trends from 84 wells shows a falling trend in 63 wells (0-1m:43, 1-2 m: 9 and > 2 m: 11 wells) (max fall: 4.42 m/yr) and 21 wells shows rising trend (0-1m:20, 1-2 m: 0 and >2 m: 1 well) (max rise: 2.87 m/yr). During post-monsoon season 57 shows falling trend (0-1 m: 42, 1-2 m: 7 and >2 m: 8 wells) (maximum fall: 3.49 m/Yr) and 27 wells shows rising trends (0-1 m: 23, 1-2 m: 3 and >2 m: 1wells) (max rise: 2.32 m/yr). Average water levels for the last 10 years (2006-15) were compared with 2015 data and it is found that during pre-monsoon season of 2015, 73 wells have shown fall, 10 shown rise and 1 well shown neither rise nor fall in water levels. During post monsoon season 30 wells shown fall and 54 shown rise in water levels.

Geophysical data 105 nos (VES)) reveals resistivity < 115 ohm (Ω) m for the weathered BGC, 115-250 Ω m for underlying fractured BGC and > 250 Ω m for massive BGC.

Total 1053 ground water samples (Pre-monsoon:503 and Post-monsoon:550) were analysed for knowing the suitability of ground water for drinking purposes. In 79 % and 75% of area EC is in the range of <100-1500 µ Siemens/cm during pre and post-monsoon season respectively. During pre-monsoon season, concentration of NO_3 ranges from BDL to 199 mg/l and found that in 310 samples (62 %) it is beyond maximum permissible limit of BIS (45 mg/L) and F concentration varies from 0.01 to 2.1 mg/l (Diguvapalem) and found that in 3 samples it is beyond maximum permissible limits of BIS (1.5 mg/l). During post-monsoon season concentration of NO_3 ranges from BDL to 399 mg/l and found that in 340 samples (62 %) it is beyond maximum permissible limit of BIS (45 mg/L) and F concentration varies from 0.01 to 2.0 mg/l (Siddamanaidu and Gnanamamba) and found that in 6 samples it is beyond maximum permissible limits of BIS.

Based on 966 hydrogeological data points, aquifers from the area can be conceptualized in to two nos namely, 1) weathered zone (~13 m) and 2) fractured zone (13-185m). Weathered zone in most of aquifers has gone dry in 12 mandals due to over-exploitation. Weathered zone in the range of 10-20 m occupy 56% of the area , followed by <10 m 35% and deep weathering (> 20 m) occurs in 9 % of area covering eastern, central and south-western part of the district. The average yield of this zone is 1.1 lps and T in the range of 2 to 489 m^2/day. Depth of fracturing varies from 20 to 185 m (Gangasagaram) and ~99 % of fractures occur within 100 m depth. Ground water yield from fractured zone varies from <0.1 to 13 lps. The hydraulic properties of weathered and fractured zone like specific capacity, transmissivity (T) and storativity (S) varies from 1.0 to 574 lpm/m/dd, 1 to 489 m^2/day and 1.6 x 10^{-4} to 5.9 x 10^{-4} respectively.

Net dynamic replenishable ground water availability is 1648.8 MCM, gross ground water draft is 1176.96 MCM, provision for drinking and industrial use for the year 2025 is 118.17 MCM and net available balance for future irrigation use is 473.4 MCM. The stage of ground water development varies from 26 to 166 % (avg: 71 %). The in-storage ground water resources down to the maximum fractured depth (185 m) are 340.33 MCM.

Major issues identified are over-exploitation (13% of area covering 12 mandals); deep water levels are > 20 m bgl in 9 % and 11% of the area during pre and post-monsoon season respectively. Ground water pollution (both anthropogenic (NO_3) and geo-genic (F), declining water levels in majority of hydrograph stations and low yields in 10 % of the area in BGC formation.

The management strategies mainly include both supply side and demand side. The supply side measure includes ongoing work under NEERU-CHETTU where 3079 tanks are taken up which will contribute ~6.84 MCM of ground water by recharge, with this additional ~1140 ha land can be brought under irrigated dry (ID) crops in tank ayacut. De-silting of 9.98 MCM of silt from existing 2737 (minor irrigation tanks and Percolation tanks) are proposed to be taken up under NEERU-CHETTU programme which will create additional surface storage and contribute ~3 MCM to groundwater and with this additional ~500 ha land can be brought under irrigated dry (ID) crops in tank ayacut.

Construction of 1409 ARS with ~80.25 crores in **priority-1** area (over-exploited) and construction of 7278 ARS with ~424.7 crores in **priority-2** area (other area) are recommended as supply side measures. Under **Handri Niva Sujala Sravanthi** (HNSS)

drinking water supply scheme, Govt is intended to supply drinking water needs to 10 lakhs population and to irrigate 72840 ha of land from surface water from river Krishna. Water conservation measures include construction of 32020 nos of farm ponds with 80.05 crores in all villages.

Demand side measure includes 2 scenarios. **Scenario-1** includes ~1.695 lakh ha micro-irrigation area (1.695 lakh structures (@50/village)) with total cost of 1017 crores. This will save ~340 MCM of ground water. **Scenario-2** includes change in cropping pattern in 19 mandals (OE: 12 and C: 7) from sugarcane and paddy to ground nut with increased support price of Rs 5300/quintal to compensate the loss of income. This will increase the area of crops from 17,746 ha to 54300 ha benefitting more farmers.

Other measure includes providing good quality seeds, improved procurement facilities, mandatory artificial recharge at every Govt and industrial units. Iintermittent pumping of adjoining bore wells, restricted power supply in two spells and participatory groundwater management (PGWM). With above measures the gross irrigated area will be increased from 1.695 lakhs ha to 2.26 lakhs ha or net saving of 340 MCM of ground water.

With the above interventions costing Rs **1633.65** crores (excluding the cost involved in HNSS project), the likely benefit would be increases in gross ground water irrigated area from 1.695 lakh ha to ~ 2.26 lakh ha or net saving of **~426** MCM of ground water (net reduction of 14% in stage of ground water). The other benefits will be more distribution of income among farmers. The onetime cost will be ~4 paise/liter (Rs 4/m^3 of water).

NUMBER OF DATA POINTS USED FOR PREPARATION OF VARIOUS MAPS/FIGS-CHITTOOR DISTRICT, ANDHRA PRADESH

S. No.	Data	Aquifer	Total Data Points	Source		
				CGWB	SGWD	Well Inventory
1	Panel Diagram (3-D)	Combine	965	EW 98: VES:104	711	52
2	Hydrogeological Sections	4 no	965	EW 98: VES:104	711	52
3	Fence/panel Diagrams	2 no	965	EW 98: VES:104	711	52
4	Depth of weathering	1 no	965	EW 98: VES:104	711	52
5	Depth of fracturing	1 no	965	EW 98: VES:104	711	52
6	Groundwater Yield	Weathered zone	188	98	38	52
		Fractured zone	188	98	38	52
7	Transmissivity (m^2/day)	Weathered zone	63	63	-	-
		Fractured zone	63	63	-	-
8	Depth to Water Level Maps (2015)	Combine	223	47	176	-
9	Water Level Fluctuation	Combine	223	47	176	-
10	Water quality Pre-2015 Post-2014	Combine	503 (Pre) 550 (Post) 1053 Total	17 -	486 550	-

1. INTRODUCTION

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

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 leads 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 purpose. High utilization of fertilizers for agricultural production and improper development of sewage system in rural/urban areas lead to point source pollution viz., nitrate and chloride.

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

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

1. Compilation of existing data (exploration, geophysical, groundwater level and groundwater quality with geo-referencing information and identification of principal aquifer units.

2. Periodic long term monitoring of ground water regime (for water levels and water quality) for creation of time series data base and ground water resource estimation.
3. Quantification of groundwater availability and assessing its quality.
4. To delineate aquifer in 3-D along with their characterization on 1:50, 000 scale.
5. Capacity building in all aspects of ground water development and management through information, education and communication (IEC) activities, through 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 Chittoor district, Andhra Pradesh having geographical area of 15151 km^2, lies between north latitude 12°37´23"-13°59´27" and east longitude 78°04´12"-80°03´36" (**Fig.1.1**).The mappable area is ~13610 Km^2 (90%) and rest is hilly area. Administratively the district is governed by 3 revenue divisions consisting 66 revenue mandals and 1540 revenue villages with a population of ~41.57 lakhs (2011 census) (urban: 29 %, rural: 71 %). The density of population is 292 persons/Km^2 and there is an increase in 11.4% growth rate over last 10 years.

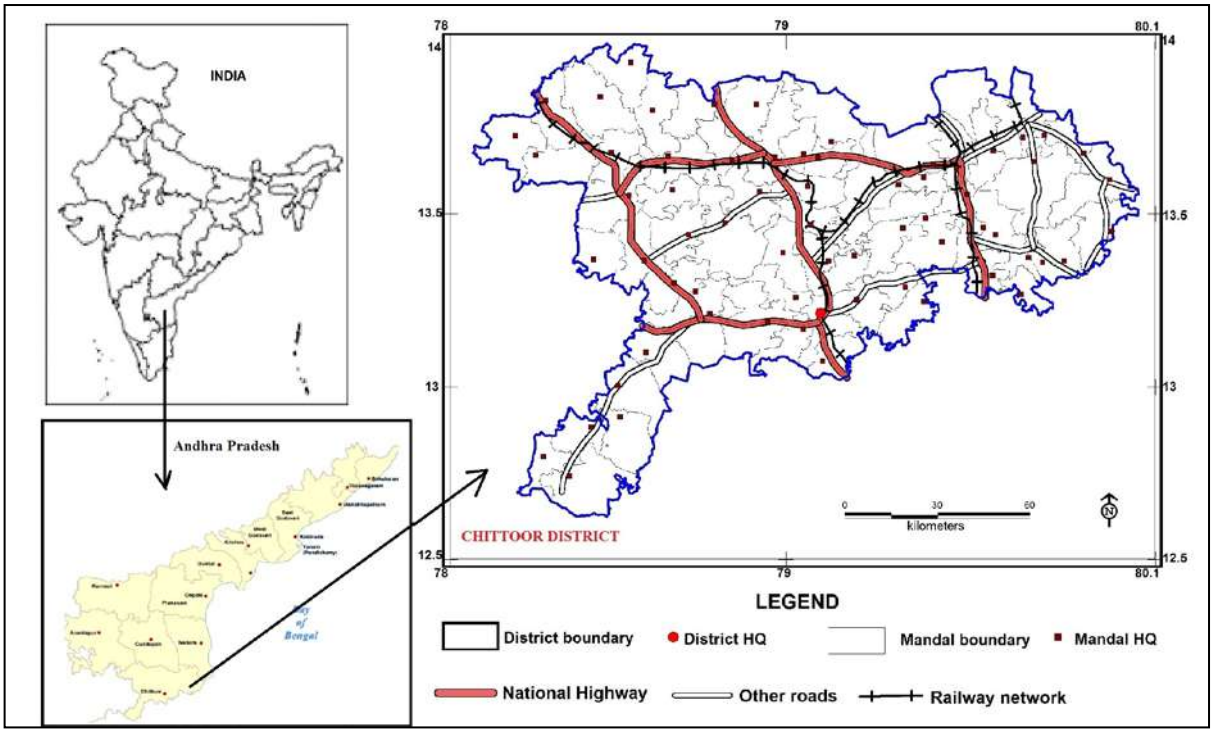

Fig.1.1: Location map of Chittoor district.

1.4 Climate and Rainfall: The climate of the district is characterised by dry. The upland mandals are comparatively cooler than eastern mandals except Chittoor where climate is moderate. The normal mean daily minimum and maximum temperature are 27.9 °C and 40.3 °C during May and 18.7 °C and 29.9 °C during January. The normal annual rainfall of the district is 934 mm (India Meteorological Department). This varies between 600 mm (Mulkalcheruvu) and 1294 mm (Satyavedu) (**Fig. 1.2**). The South west monsoon contributes ~48 %; North east monsoon contributes ~42%, and remaining by winter season. Rainfall increases from west to eastern part and low rainfall recorded in the central and north-western parts. During the year 2013-14 the district received rainfall of 745.1 mm (-20 % less) rainfall.

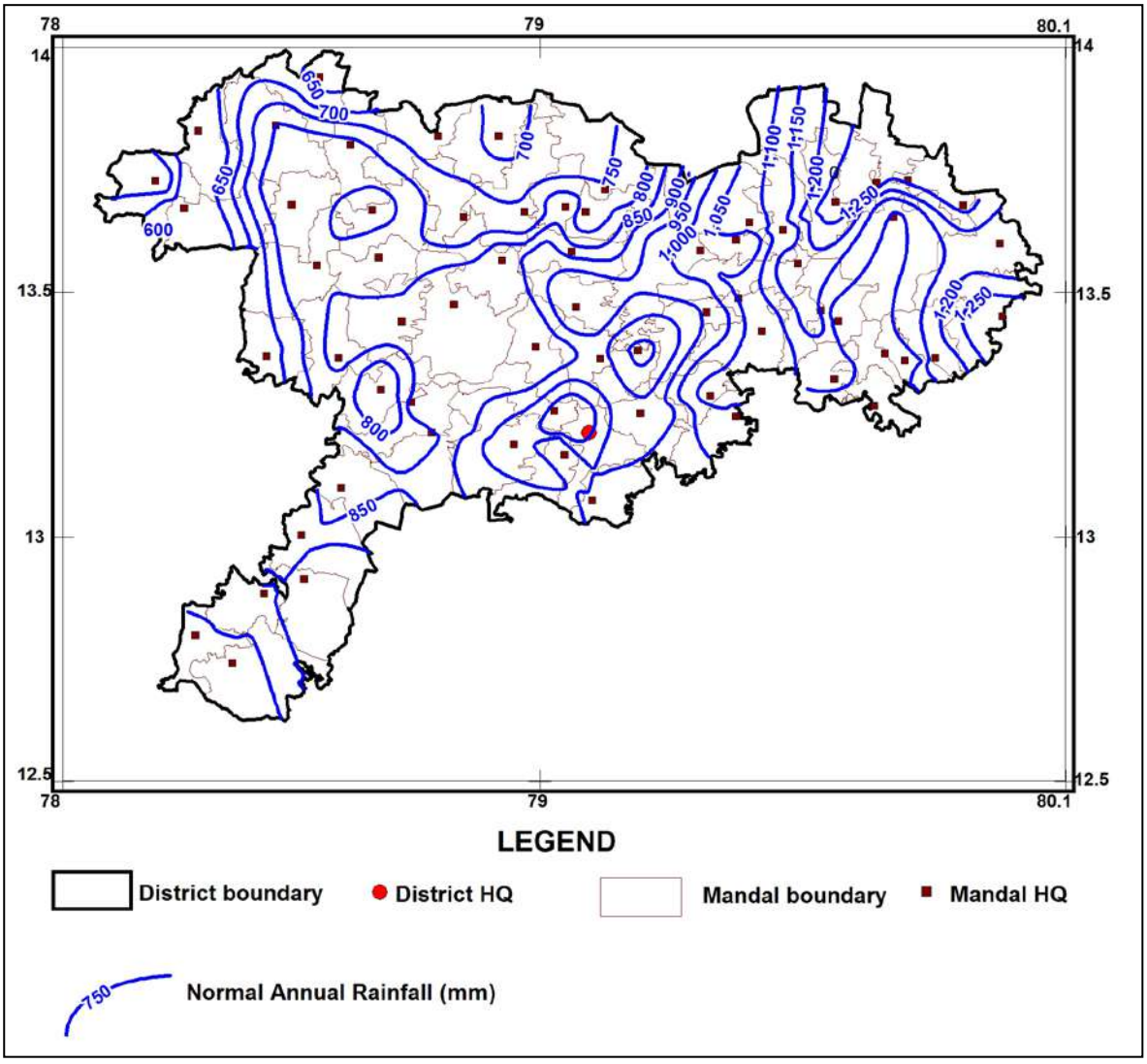

Fig.1.2: Isohyetal map of Chittoor district.

1.5 Geomorphological Set up: The district forms a part of the Mysore plateau and can be distinguished into 3 regions (i.e., area with 600-900 m above mean se level elevations, 300-600 m amsl and < 300 m amsl). The western and southwestern parts comprising Kuppam, Palamaneru, Punganur, Thamballapalle and Madanapalle areas have an altitude between 600 m and 900 m amsl. The altitude of central region comprising Bangarupalem, Chittoor, Piler, Vayalpad, Chandragiri areas has 300 m to 600 m amsl. The eastern/southern parts covering parts of Puttur, Karvetinagar, Satyavedu, Tottambedu and Srikalahasty areas have an altitude of less than 300 m amsl. Vertical scraps are developed at several places and notable one is Tirumala which shows a drop of 100 m from 500 to 400 m amsl.

Pediplain is the major landform covering about 6709 km^2 (45 %) area. The other landforms observed are hills (denudational, structural and residual) (32%), pediment (14%), valley fills (5%), flood plain (1%), plateau (1%) etc. (**Fig.1.3**).

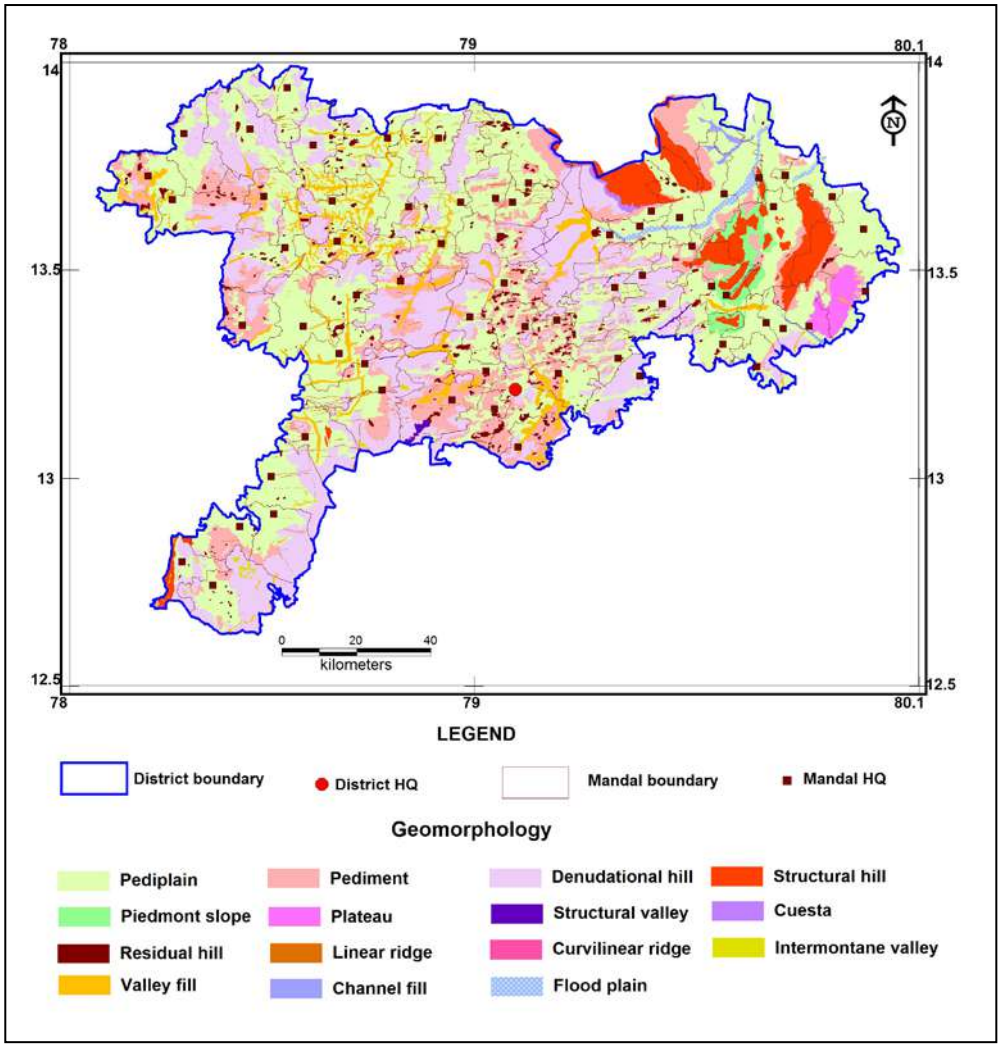

Fig.1.3: Geomorphology map of Chittoor district.

1.6 Drainage and Structures: The rivers flowing in the district are non-perennial in nature of which river Ponnai flows towards south-east along the prominent NW-SE fault and joins river Palar in Tamil nadu. Swarnamukhi is another important river originates in Eastern Ghats and flows in NE direction before flowing into Nellore district. Other important rivers are river Bahuda, river Pincha, river Kushastali, river Kalyani, river Bheema, river Araniyar and river Pedderu etc (**Fig1.4**). The drainage pattern is dendritic to sub-dendritic in nature and divided into 75 watersheds.

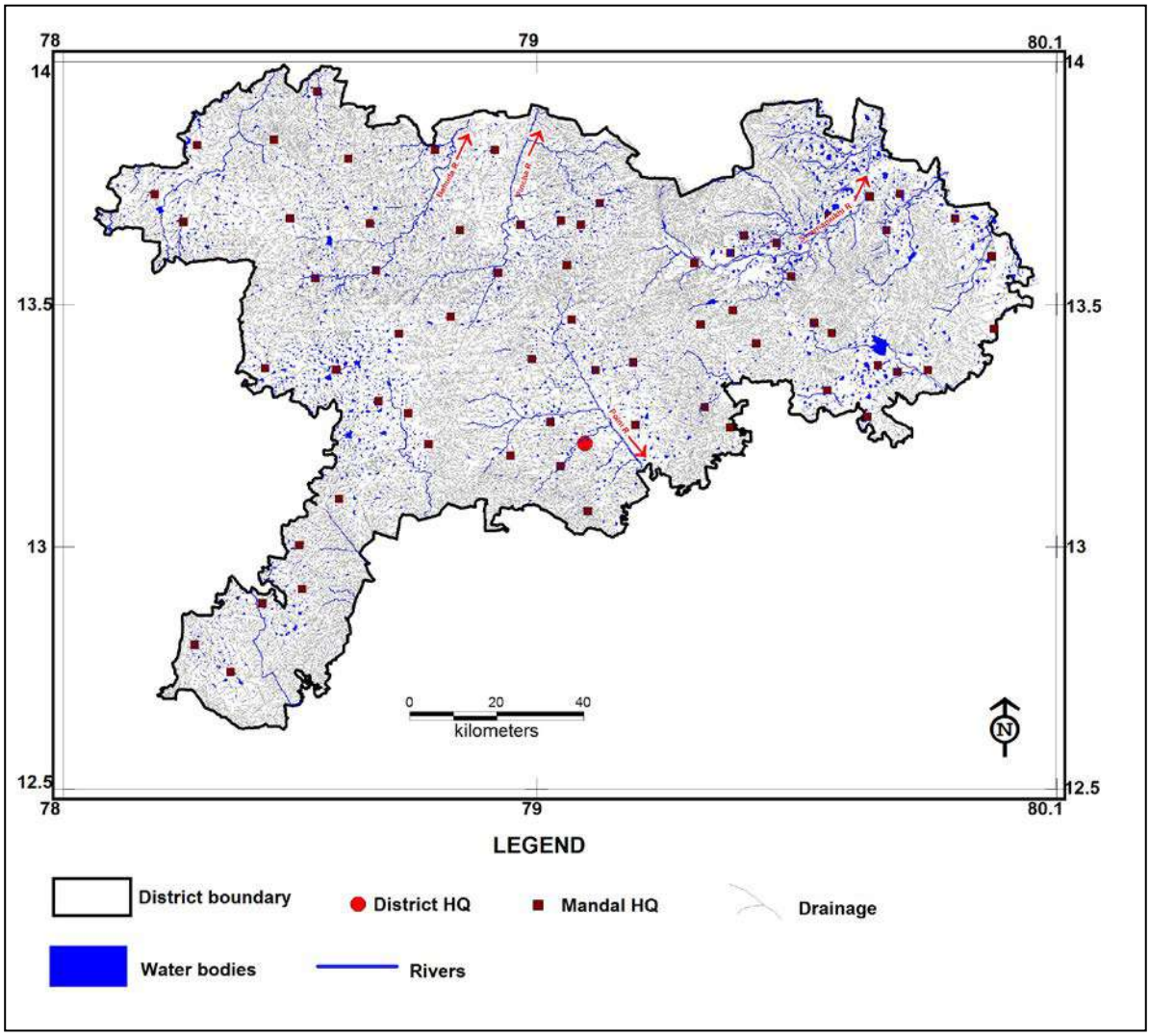

Fig.1.4: Drainage and water bodies map of Chittoor district.

1.7 Land use and cropping pattern (2013-14): Forests occupy 4520 km^2 (~30%) of the total geographical area.Total gross cropped area is 417066 ha (~28 %) (Khariff: 324712 and Rabi: 92354) and net area sown is 371717 ha (25%) (Khariff: 324118 and Rabi: 47600) and area sown more than once is 45350 ha (3%). Forests occupy ~30% of area, barren and un-cultivable land is 152700 ha (10%), land put to non-agricultural uses is 157842 ha (10%),

permanent pastures and other grazing lands 34246 (2%), tree crops 30722 (2%) etc. of the total geographical area. The major crops grown in the district are groundnut 155078 ha (37%) (Khariff: 143027 and Rabi: 12051), paddy 49860 ha (12%) (Kharif: 15206 and Rabi: 34654), sugarcane 28152 ha (5%), vegetables 21890 ha (5%) (mainly tomatoes, brinjal, beans etc), pulses 20352 ha (5 %) (Kharif: 16913 and Rabi: 3439) other crops grown are maize, ragi, bajra etc. (**Fig. 1.5).**

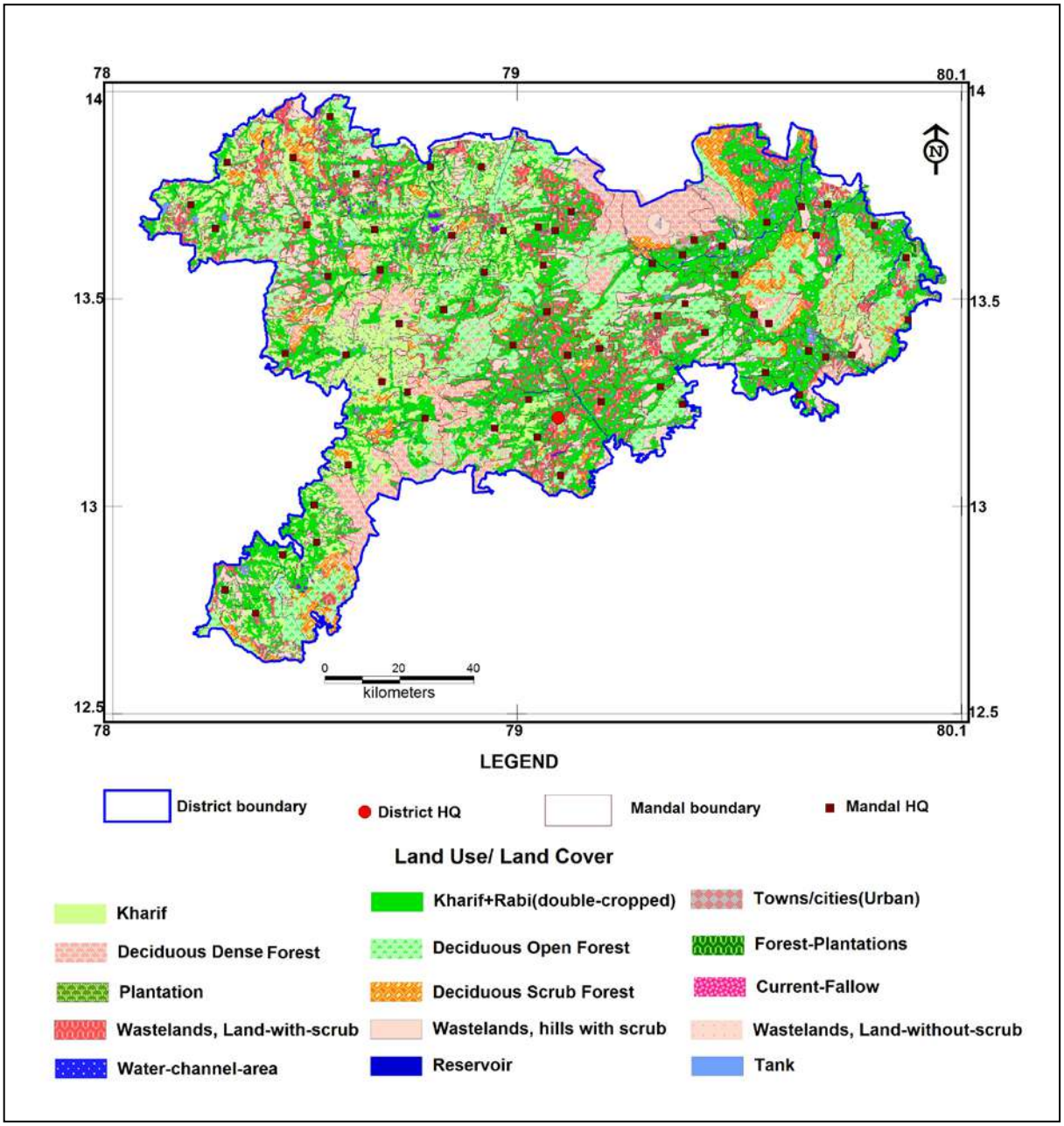

Fig.1.5: Land use and land cover of Chittoor district.

It is observed that gross area irrigated under principal crops during the last 5 years (2010-11 to 2014-15) namely paddy, sugarcane and groundnut cultivation decreased from 61132, 54927 and 20024 ha in 2010-11 to 40912, 46839 and 10966 ha in 2014-15 respectively and vegetable cultivation almost remained constant (**Fig. 1.6**).

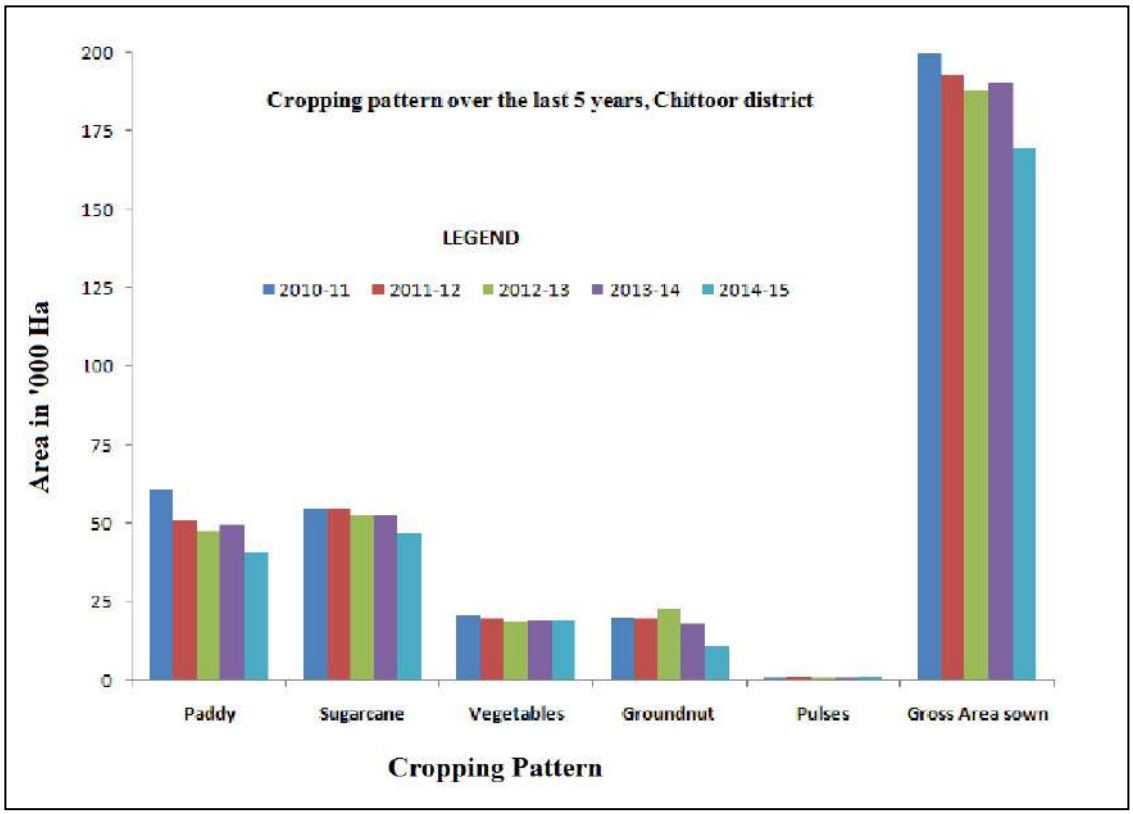

Fig.1.6: Cropping pattern over a period of time.

In the district there are 6, 67,182 farmers out of which 455190 are marginal farmers (<2.47 acres of land), 144431 are small farmers (2.47-4.93 acres), 54981 are semi-medium farmers (4.94-9.87 acres) and rest are medium to big farmers (9.88-24.7 acres and > 24.71 ha).

1.8 Soils: The district is covered mainly by red soils (91%) (Loamy: 57% and sandy: 34%) and remaining 9% is covered by black soils. As per All India Soil survey and Land Use Planning report, soils can be classified into 10 types of which fine mixed (calcareous) occupy 38% followed by rock lands-clayey skeletal soils (28%). The other types are clayey skeletal mixed (12.5%), loamy soils (6%) etc. (**Fig.1.7**).

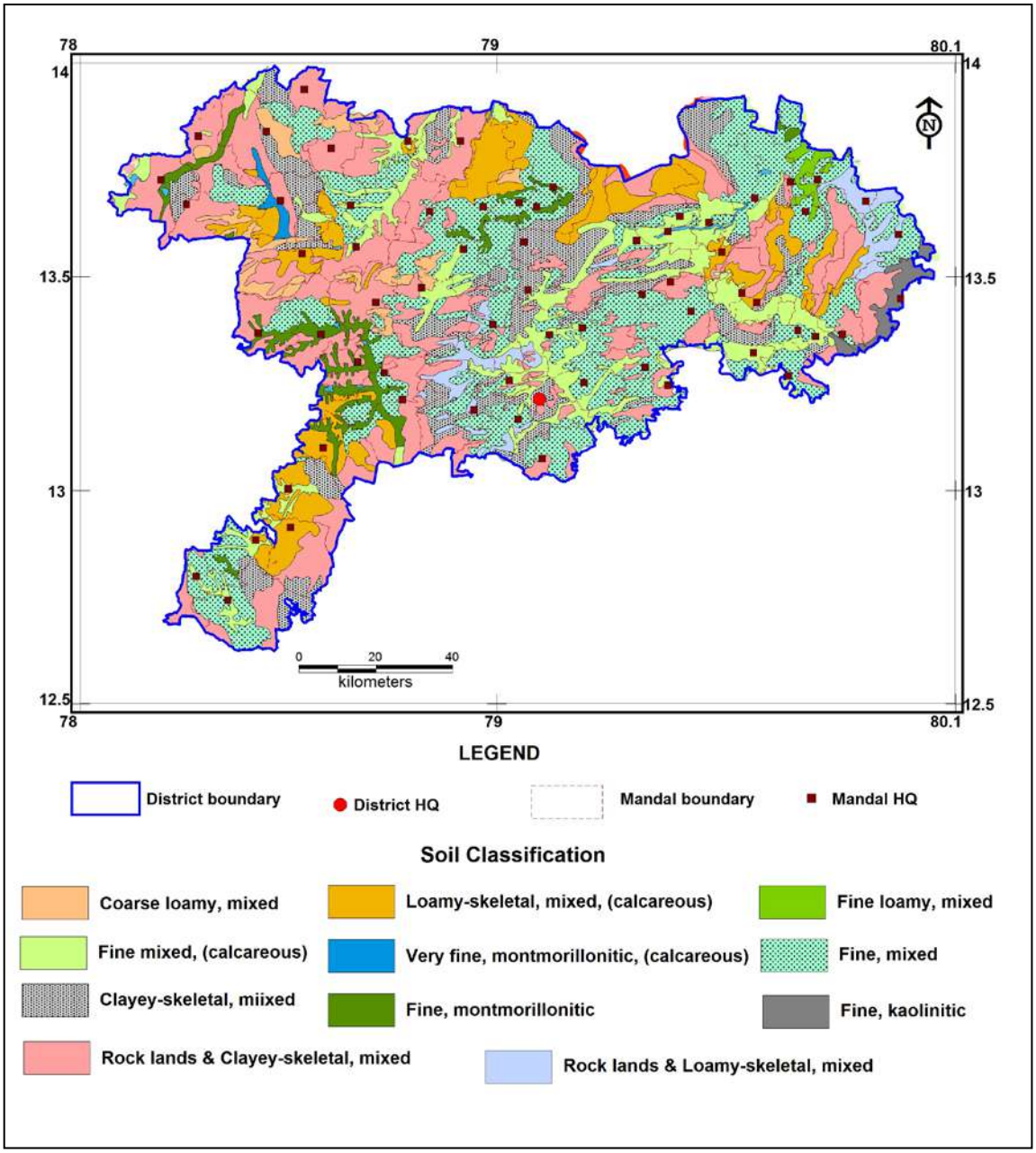

Fig.1.7: Soil map of Chittoor district.

1.9 Irrigation: In the district there are 8 medium irrigation projects with register ayacut of 15310 ha and upcoming 4 major irrigation projects with registered ayacut of 442387 ha. ~85% of the area is non-command, 5% command area. There are 668 minor irrigation tanks with > 100 acres ayacut and 7520 MI tanks with < 100 acres ayacut. The total registered ayacut is 122918 ha out of which only 12610 ha (10%) is irrigated during the year 2013-14. Area showing details of irrigation is given in **Fig. 1.8** and **Table-1.1.**

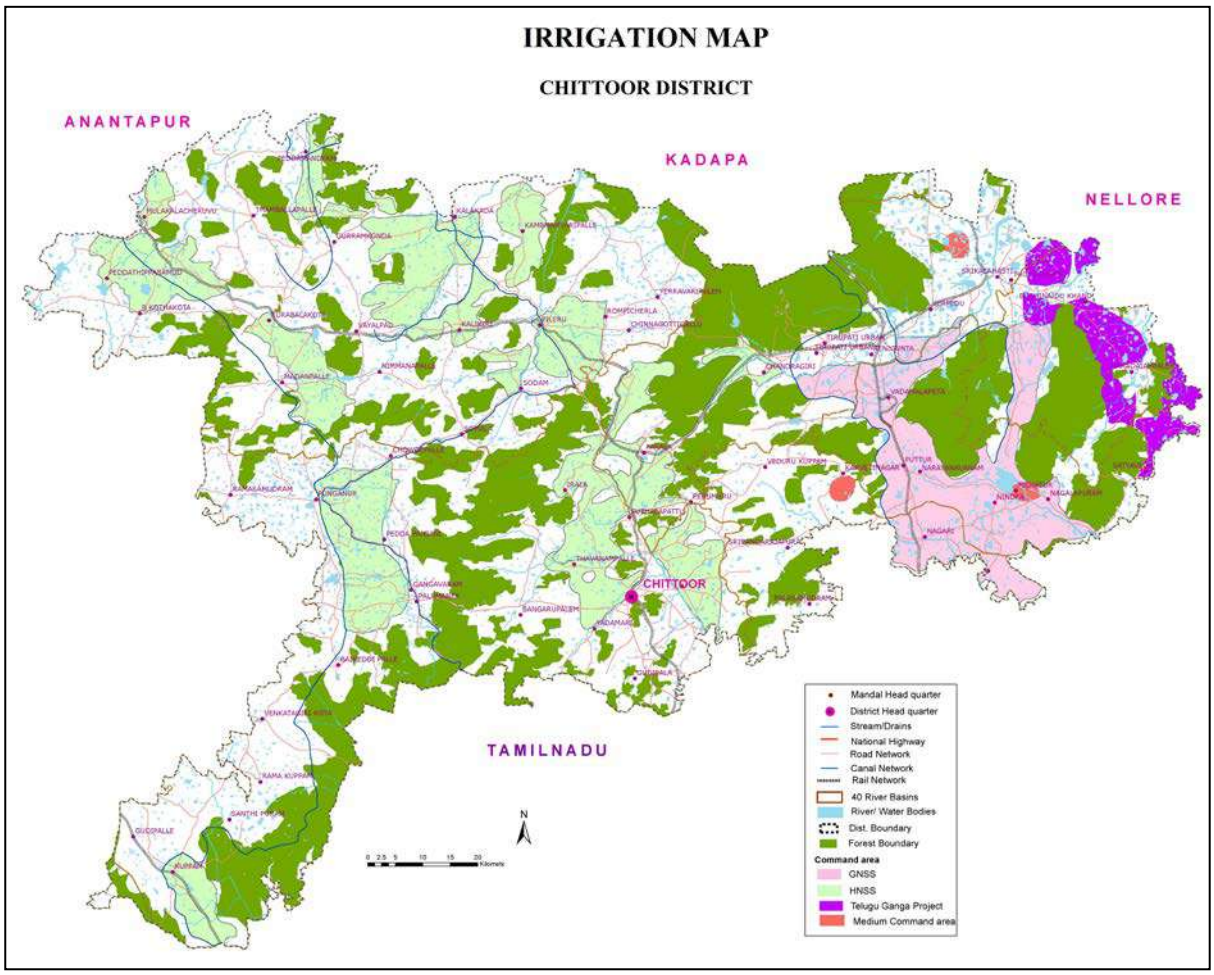

Fig.1.8: Details of irrigation projects, Chittoor district.

The gross and net area irrigated during 2013-14 is only 4535 ha and 4119 ha only under these projects.

During the year 2014-15, out of 169450 ha area is under irrigation and out of which 89 % is through ground water (Bw:78 % and DW:11%) and 10 % through surface water (canals:2 % and Tanks:8 %). The salient features of irrigation are given in **Table-1.1**. It is also observed that there is decrease in irrigation area during the last 5 years for all sources (including bore well irrigation) (**Fig. 1.9**).

Table-1.1: Salient Features of Irrigation during 2013-14 (Ha).

Source of Irrigation	Irrigation Structures	Total	Total (%)
Ground Water	Bore wells	149363	89
	Dug wells	20253	
Surface Water	Canals	4866	11
	Tanks	16011	
	Lift Irrigation	0	
Others	Others	97	
Gross irrigated area		190580	100
Area irrigated more than once		43893	
Net area irrigated		146687	

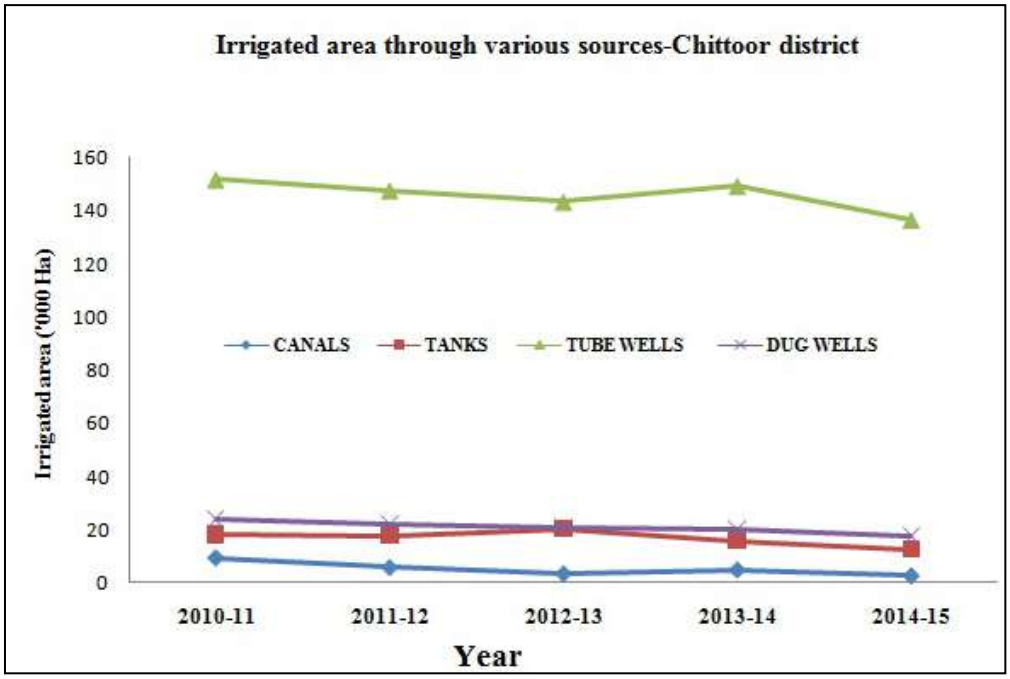

Fig.1.9: Irrigated area through different sources.

1.10 Prevailing water conservation/Recharge practices: In the district there are ~4619 percolation tanks, 4614 Check dams. In the district till 2013-14 only 6934 units (sprinklers: 612, Drips: 6322 irrigating ~6065 ha area under micro-irrigation (Drip and Sprinklers).

1.11 Geology: The district is underlain by rocks belonging to Archaean to recent age. The oldest rocks belong to Migmatite Complex, represented by migmatised quartzo-felspathic gneiss and are exposed in the north-eastern part of the district. Older metamorphic comprise amphibolites, hornblende-talc-mica-schist, fuchsite quartzite, calc-silicate rock, marble and banded ferruginous quartzite. These older metamorphic occur as enclaves within Peninsular

or Banded Gneissic Complex (PGC/BGC) and occupy ~90% of the area. They are represented by biotite-hornblende gneiss, biotite granite and migmatite rocks. The Dharwar Super group of rocks represented by quartz-mica schist, amphibolites schist, quartzo-flespathic mica schist (Champion gneiss, metabasalt, metadacite and banded ferruginous quartzite, belonging to various schist belts and occur as long linear N-S trending belts and overlie PGC non-conformably. Acid intrusives of Proterozoic Age comprises granite and quartz veins. The granite plutons are exposed as patches and linear bodies in south-western and north-western parts of the district respectively. Three sets of dolerite dykes trending E-W, N-S, and NW-SE occur. The rocks belonging to Cuddapah super Group occupy north-eastern part and are represented by shale (1%) and quartzite (4%) of Bairenkonda Formation and limestone of Cumbum Formation. The Gondwana Super group rock occurs non conformably over the PGC in south-eastern part of the district, represented by Satyavedu Formation. Laterite (1%) capping over Gondwana formations is observed. Alluvial formation (1%) of recent age occurs along the major streams (**Fig.1.10**).

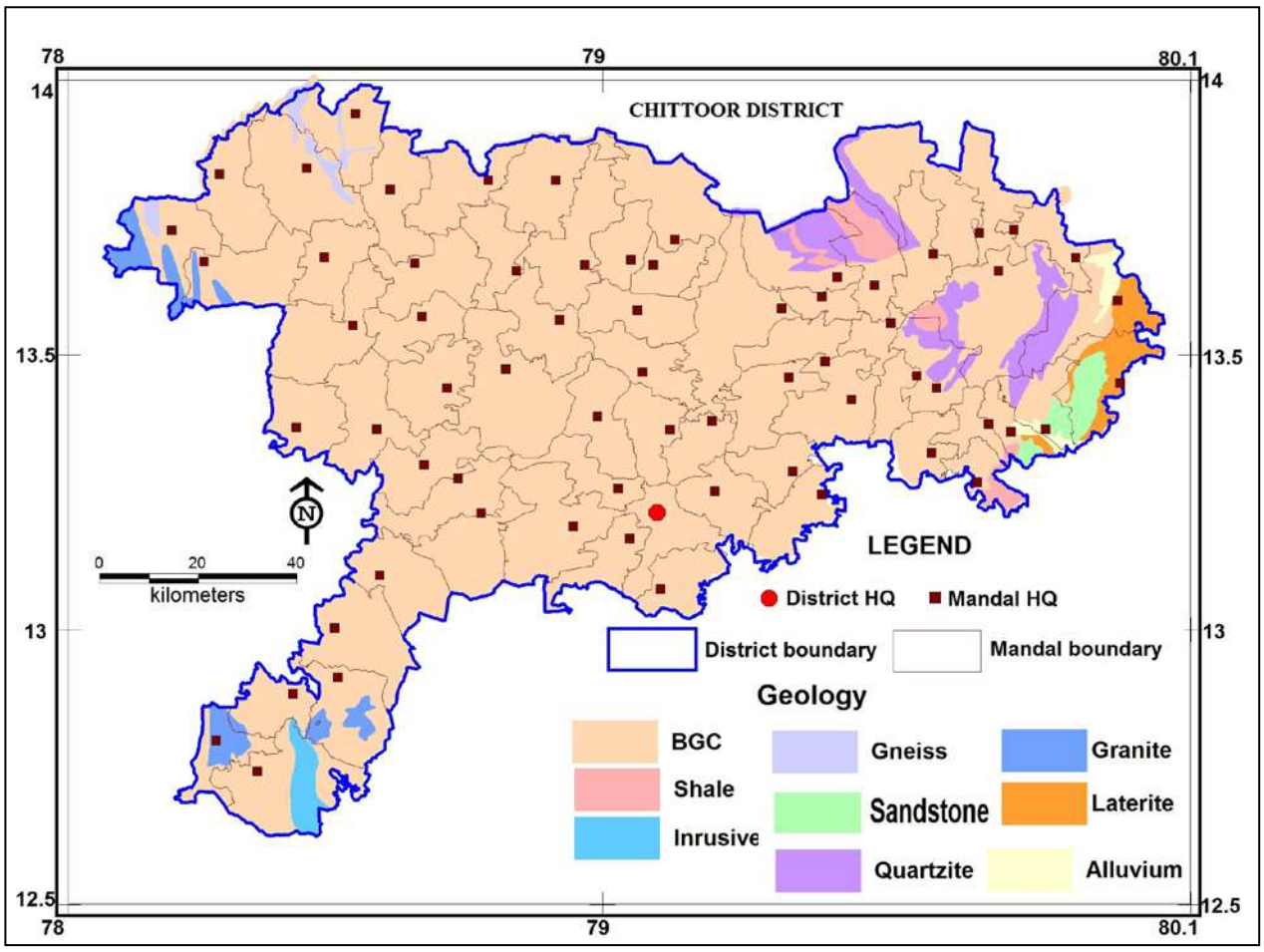

Fig.1.10: Geology of Chittoor district.

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)**.

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

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

2.1 Hydrogeological Studies

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of ground water occurring in the subsurface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. The principal aquifer in the area is Gneisses (BGC) 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 965 hydrogeological data points (Exploration: CGWB: 98 and SGWD: 711 Geophysical: 104 and well inventory: 52) hydrogeological data availability map is prepared (**Fig.2.1)**.

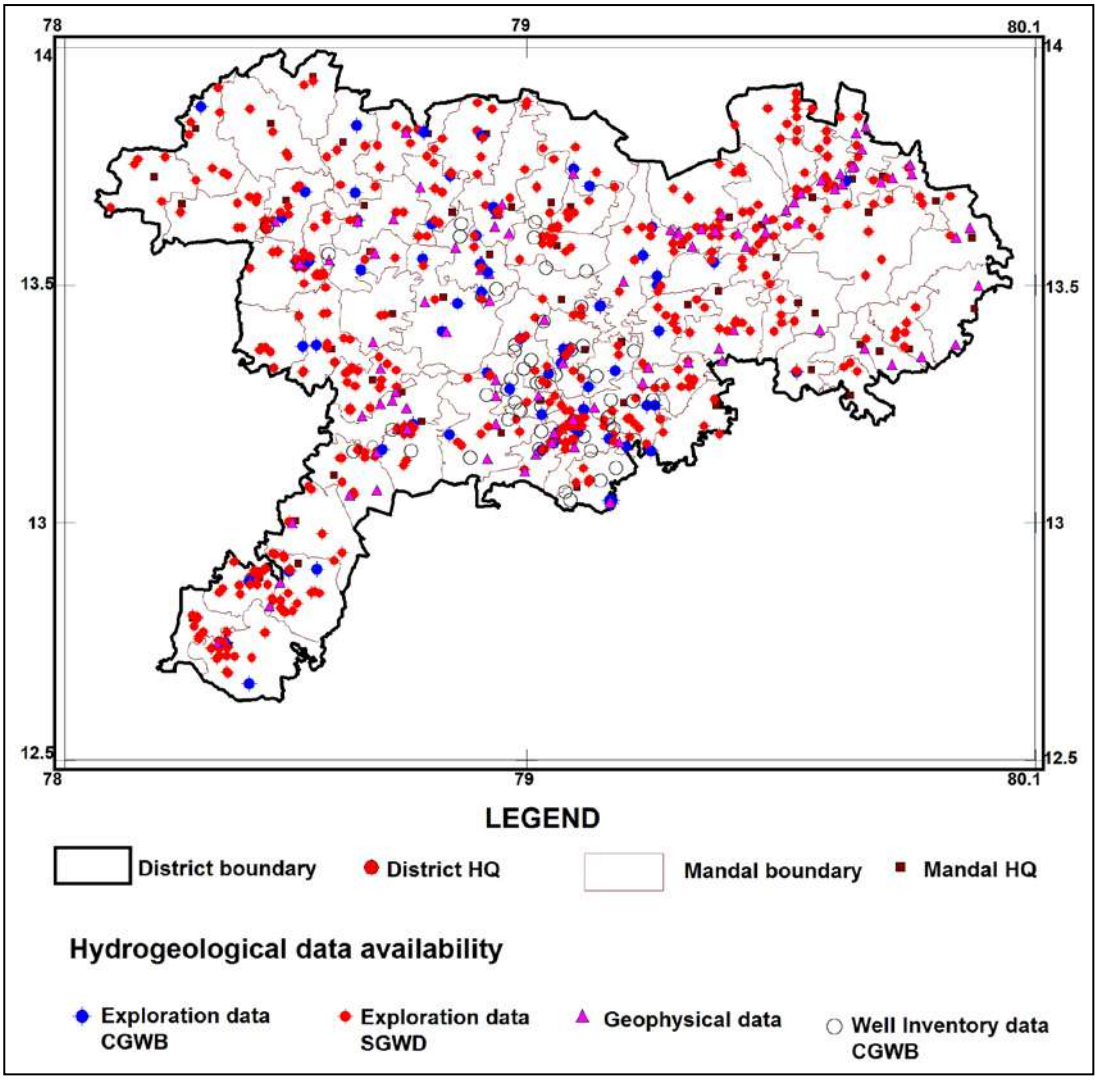

Fig.2.1: Hydrogeological data availability, Chittoor district.

2.1.1 Ground water occurrences and movement: Ground water occurs under unconfined conditions in weathered zone and semi-confined to confined conditions in fractured zone and flows downward from the weathered zone 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 100 m depth. The storage in these rocks is primarily confined to the weathered zone and its overexploitation, mainly for irrigation purpose, has resulted in desaturation of weathered zone at many places. At present, extraction is mainly through boreholes of 60-200 m depth, with yield between <0.1 and 17 litres/second (lps). Majority of fractures occur within 100 m depth and deepest fracture is encountered at the depth of 185 m depth (Gangasagaram). Quartzites occupy the uplands and hilly areas and are massive and compact and possess meagre ground water potential. Alluvium which is confined to major rivers are developed through filter points and shallow dug wells of 10 m having yield of 3-10 lps and sustains 6-8 hrs of pumping with 2-6 m drawdown. The hydrogeological map of the area is presented in **Fig. 2.2**.

2.1.2 Exploratory Drilling: CGWB carried out ground water exploration in 2 spells (1973 to 1977 and 1991 to 1997) and total 114 wells are drilled (exploratory:105, observation :9) and SGWD drilled 176 wells in the district. Data analysed from CGWB wells in five basins is summarized in **Table 2.1 (Fig.2.3)**. During the 1st phase exploration is carried out in Ponnai basin (1973-1976) and in 2nd phase in other 4 basins. There are ~290627 agricultural bore wells in the district out of which free power is supplied to 286005 bore wells.

Table-2.2: Basin wise summary of Ground water exploration in Chittoor district.

S. No.	Basin	No. of Wells	Depth (m)	Yield (lps)	Sp. Capacity (lpm/m/dd)	T (m^2/day)	Storativity
1	Ponnai	20	52-72	0.4-13	1.0-1.6	1.3-143	1.6×10^{-4} to 5.9×10^{-4}
2	Pincha	22	54.7-200	Meager-7.0	4.4-79	158-166	1.37×10^{-4} to 1.58×10^{-3}
3	Bahuda	29	60-200	0.2-8.41	7.0-45.0	0.2-489	1.4×10^{-4} to 2.7×10^{-4}
4	Swarnamukhi	17+9(OW)	13.5-200	0.04-14	6-10	0.6-222	--
5	Palar	17	104-200	0.4-17.0	10-184	11-231	5.2×10^{-4} to 7.1×10^{-4}
	Total	**105+9(OW)**					

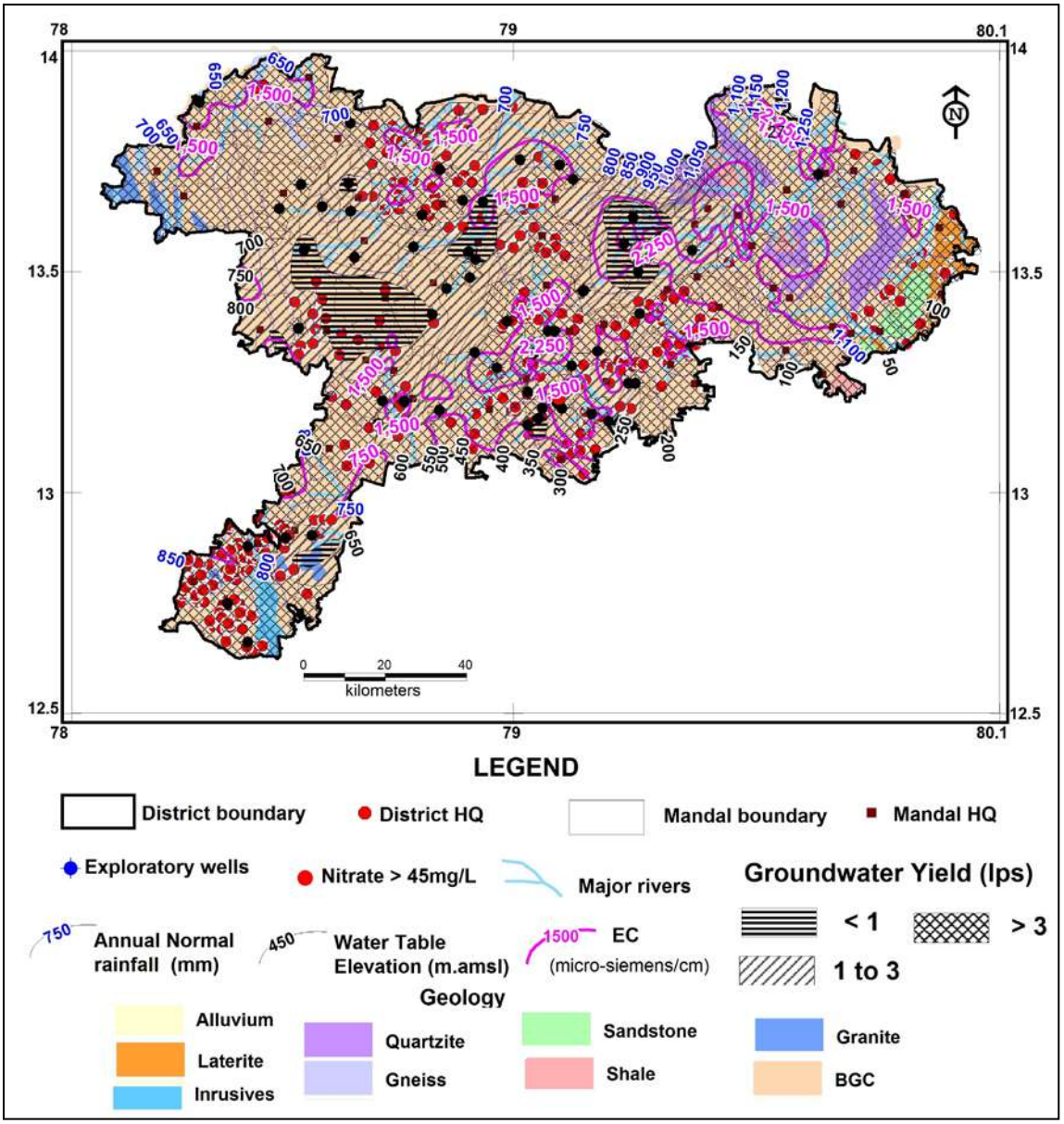

Fig.2.2: Hydrogeological map of Chittoor district.

2.1.2.1 Ground Water Exploration in Ponnai Basin:

During the years 1973 to 1977, 20 exploratory wells of 53-73 m depth were constructed in the basin. The yields ranged from 0.4-13 lps. The specific capacity varied from 1.0 to 16 lpm/m/dd. The transmissivity and storativity varies 1.39 to 143 m^2/day and 1.6 x 10^{-4} to 5.9 x 10^{-4} respectively. Out of 20 exploratory wells, 3 wells yielded <1 lps, 2 wells yielded 1 to 3 lps, 2 wells yielded 3 to 5 lps and 13 wells yielded >5 lps.

2.1.2.2 Ground Water Exploration in Pincha Basin:

During the years 1991-93, 22 exploratory wells were constructed in the basin down to a maximum depth of 200 m bgl. The yield of bore wells ranges from meagre to 7.0 lps. The specific capacity of the bore wells ranges from 4.47 to 71.0 lpm/m/dd. The transmissivity and storativity ranges from 1.58 to 166 m^2/day and1.37 x 10^{-4} to 1.58 x 10^{-3} respectively. Out of 22 exploratory wells, 7 wells yielded <1 lps, 5 yielded 1 to 3 lps, 5 wells yielded 3 to 5 lps and 4 wells more than 5 lps discharge.

2.1.2.3 Ground Water Exploration in Bahuda Basin:

During the years 1991 to 1997, 29 exploratory wells were constructed down to a maximum depth of 200 m with 0.44 to 8.4 lps yield. The specific capacity ranges from 7.0 to 45.5 lpm/m/dd. The transmissivity and storativity ranges from 2 to 489 m^2/day and 1.4 x 10^{-4} to 2.7 x 10^{-3} respectively.

2.1.2.4 Ground Water Exploration in Swarnamukhi Basin:

Total 26 exploratory wells (17+9) were constructed in the basin down to a maximum depth of 200 m with 0.4 to 14 lps yield. The specific capacity ranges from 6 to 10 lpm/m/dd. The transmissivity ranges from 1-222 m^2/day. Out of 17 exploratory wells, 5 wells yielded <1 lps, 9 wells yielded 1 to 3 lps, 3 wells yielded 3 to 5 lps.

2.1.2.5 Ground Water Exploration in Palar Basin:

During the years 1995-1997, 17 exploratory wells were constructed in the basin down to a maximum depth of 200 m with 0.4 to 17 lps yield. The specific capacity ranges from 10 to 484 lpm/m/dd. The transmissivity and storativity ranges from 11-231 m^2/day and 5.2 x 10^{-4} to 7.1 x 10^{-4} respectively. Out of 17 exploratory wells, 3 wells yielded <1 lps, 3 wells yielded 1 to 3 lps, 2 wells yielded 3 to 5 lps.

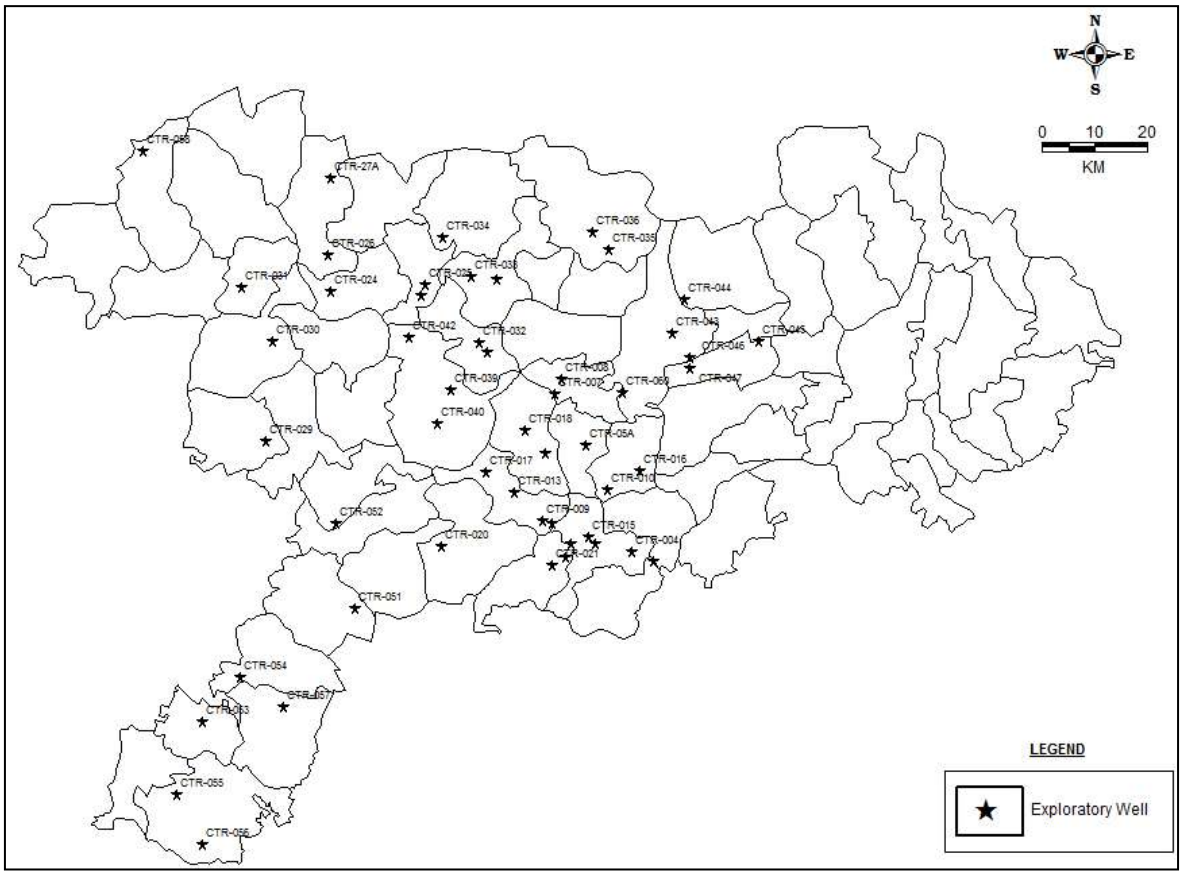

Fig.2.3: Location of Exploratory wells drilled by CGWB.

2.2 Water Levels (2015): Ground water levels from 223 wells (CGWB: 47 and SGWD: 176) consisting of dug wells and piezometers were monitored for pre-monsoon and post-monsoon seasons. Comparatively shallow water levels are observed in eastern part and deep in western part of the district.

2.2.1 Depth to Water Levels (DTW): The DTW varies from 0.1 to 96.2 meter below ground level (m bgl) (average: 11.9 m bgl) and 0.1-118.2 m bgl (average: 12.9) during pre and post-monsoon season of 2015 respectively.

2.2.1.1 Pre-monsoon season: Majority of the water levels during this season are in the range of 5-10 m.bgl cover in 44% of area, followed by 10-20 m bgl (37% of area). Deep water levels in the range of > 20 m bgl occupy ~9% of area mostly in north-western and south-western part of the district (**Fig.2.4**). Shallow water levels (2-5 m bgl) occur in eastern part of the district covering 9 % of area.

2.2.1.2 Post-monsoon season: Majority of the water levels during this season are in the range of 10-20 m.bgl covering ~29 % of area, followed by 5-10 m bgl (26 % of area), 20-40 m bgl (11%). Deep water levels in the range of > 40 m bgl occupy ~50 Km^2 of area (central part) of the district (**Fig.2.5**). Shallow water levels (0-2 and 2-5 m bgl) occupy ~16 and 18 % of area respectively and occur in eastern and central part of the district.

2.2.2 Water Level Fluctuations (May vs. November): The water level fluctuations vary from -95.7 to 41.5 m with average fall of 1.3 m (**Fig.2.6**). Out of 200 wells, in 127 wells (63 %) rise in water levels (0.1 to 41.5 m) is observed covering most of eastern and western part of district. Falling water levels in the range of -95.7 to -0.06 m is observed in 61 wells and 12 well shows neither rise nor fall in water levels. Fall in water levels is mostly observed in central and southern part of the district.

2.2.3 Long term water level trends: Trend analysis for the last 10 years (2006-2015) is studied from 84 hydrograph stations of CGWB and SGWD. It is observed that during pre-monsoon season 63 wells shows a falling trend (0-1 m: 43, 1-2 m: 9 and >2 m: 11 wells) (max fall: 4.42 m/yr) and 21wells shows rising trend (0-1 m: 20, 1-2 m: 0 and >2 m: 1 wells) (max rise: 2.87 m/yr) (**Fig. 2.7**). During post-monsoon season 57 shows falling trend (0-1 m: 42, 1-2 m: 7 and >2 m: 8 wells) (maximum fall: 3.49 m/yr) and 27 wells shows rising trends (0-1 m: 23, 1-2 m: 3 and >2 m: 1wells) (max rise: 2.32 m/yr) (**Fig. 2.8)**.

Average water levels for the last 10 years (2006-15) were compared with 2015 data and it is found that during pre-monsoon season of 2015, 73 wells have shown fall, 10 shown rise and 1 well shown neither rise nor fall in water levels. During post monsoon season 30 wells shown fall and 54 shown rise in water levels. The graphical representation of fall and rise is shown in **Fig 2.9**.

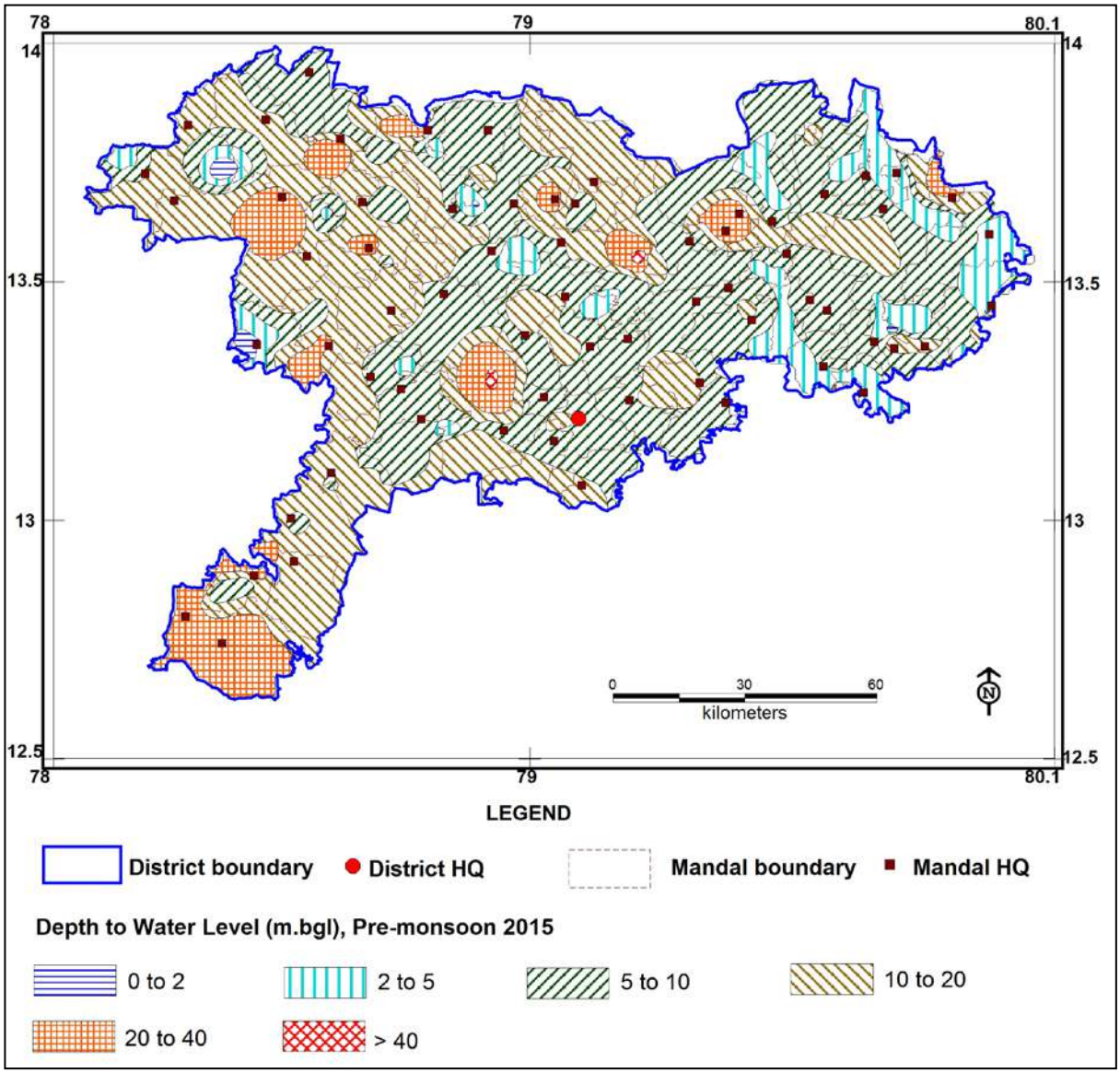

Fig.2.4: Depth to water levels Pre-monsoon (May-2015).

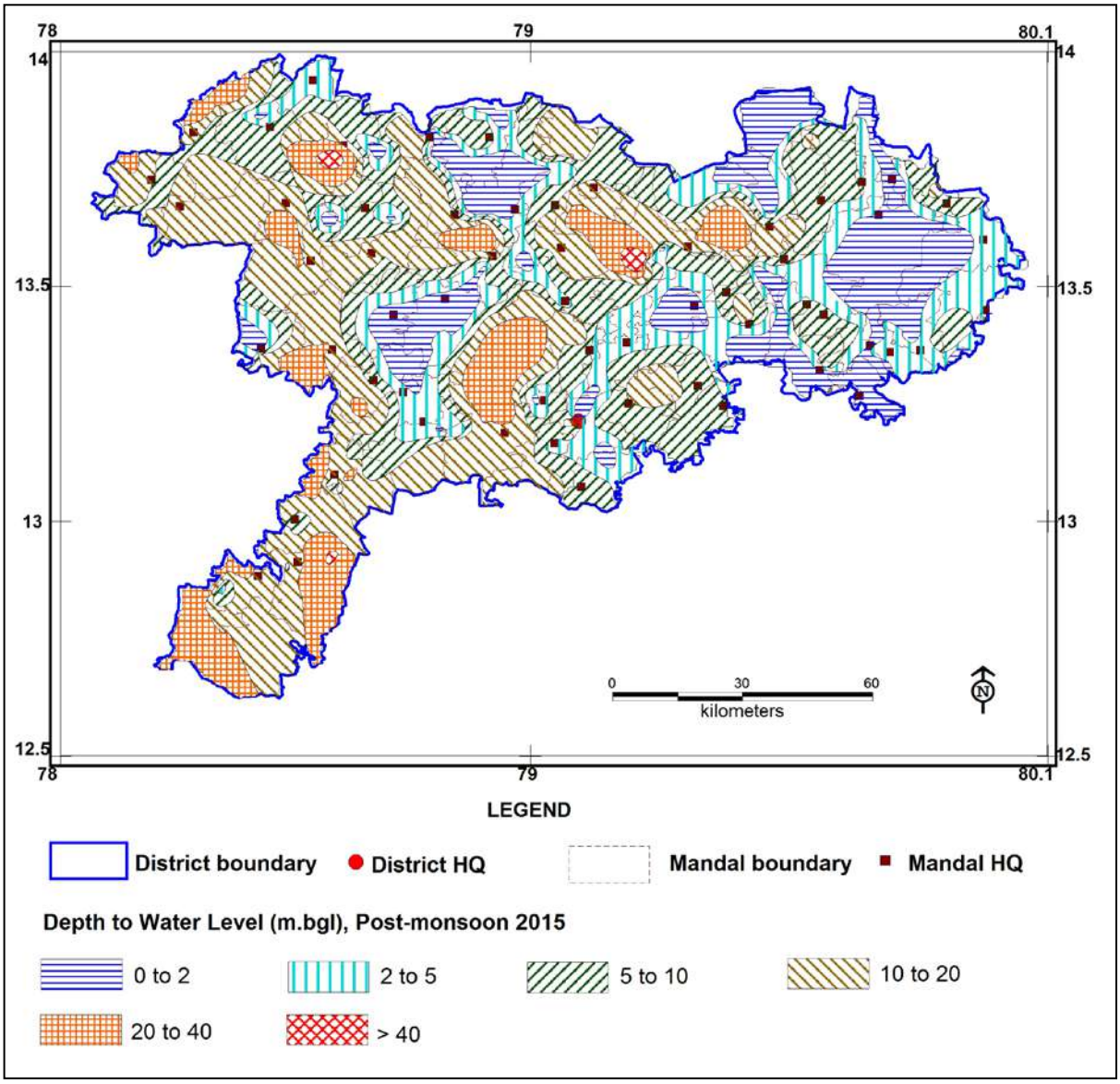

Fig.2.5: Depth to water levels Post-monsoon (November-2015).

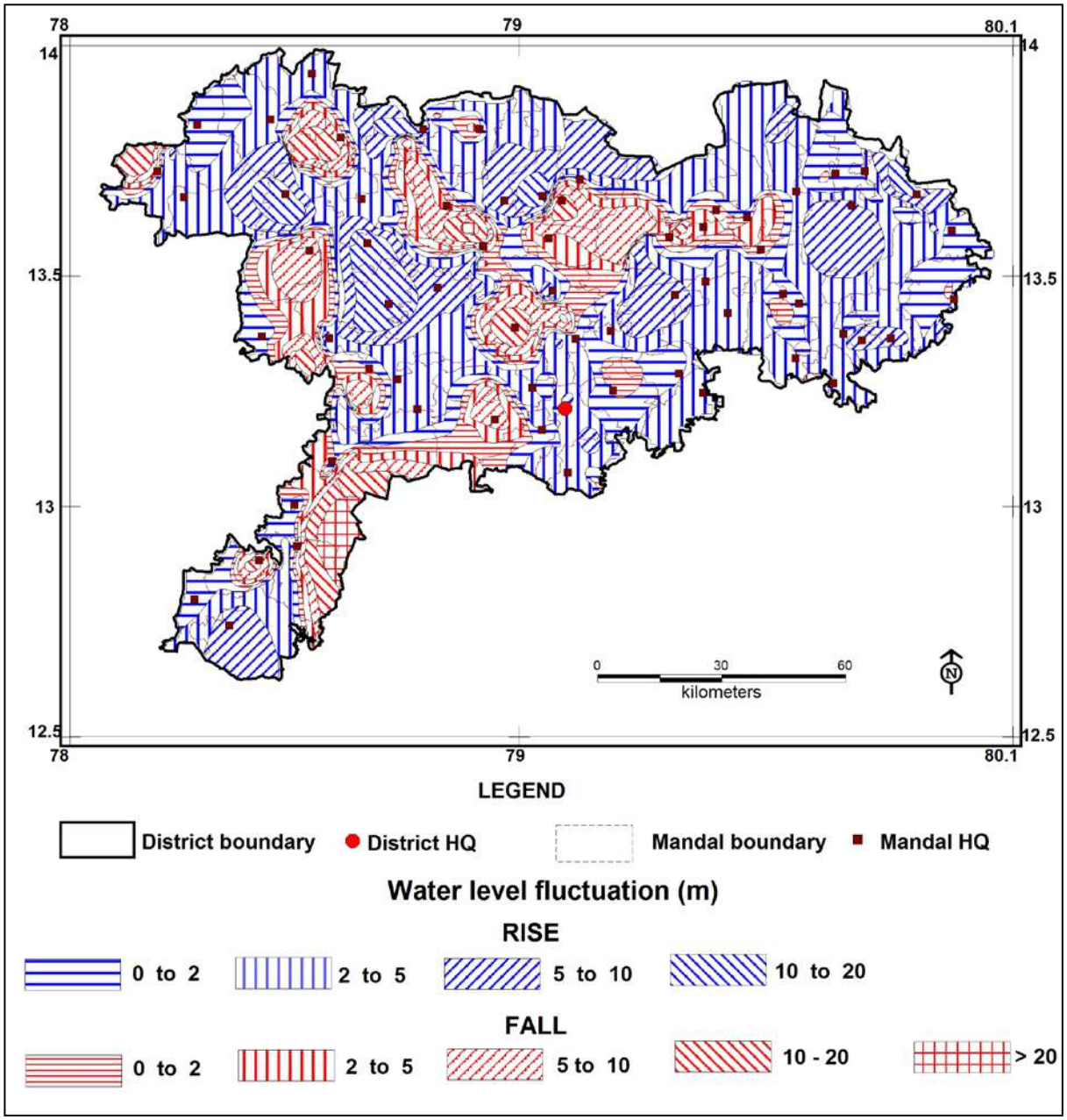

Fig.2.6: Water Level Fluctuations (m) (November-15 Vs May-2015).

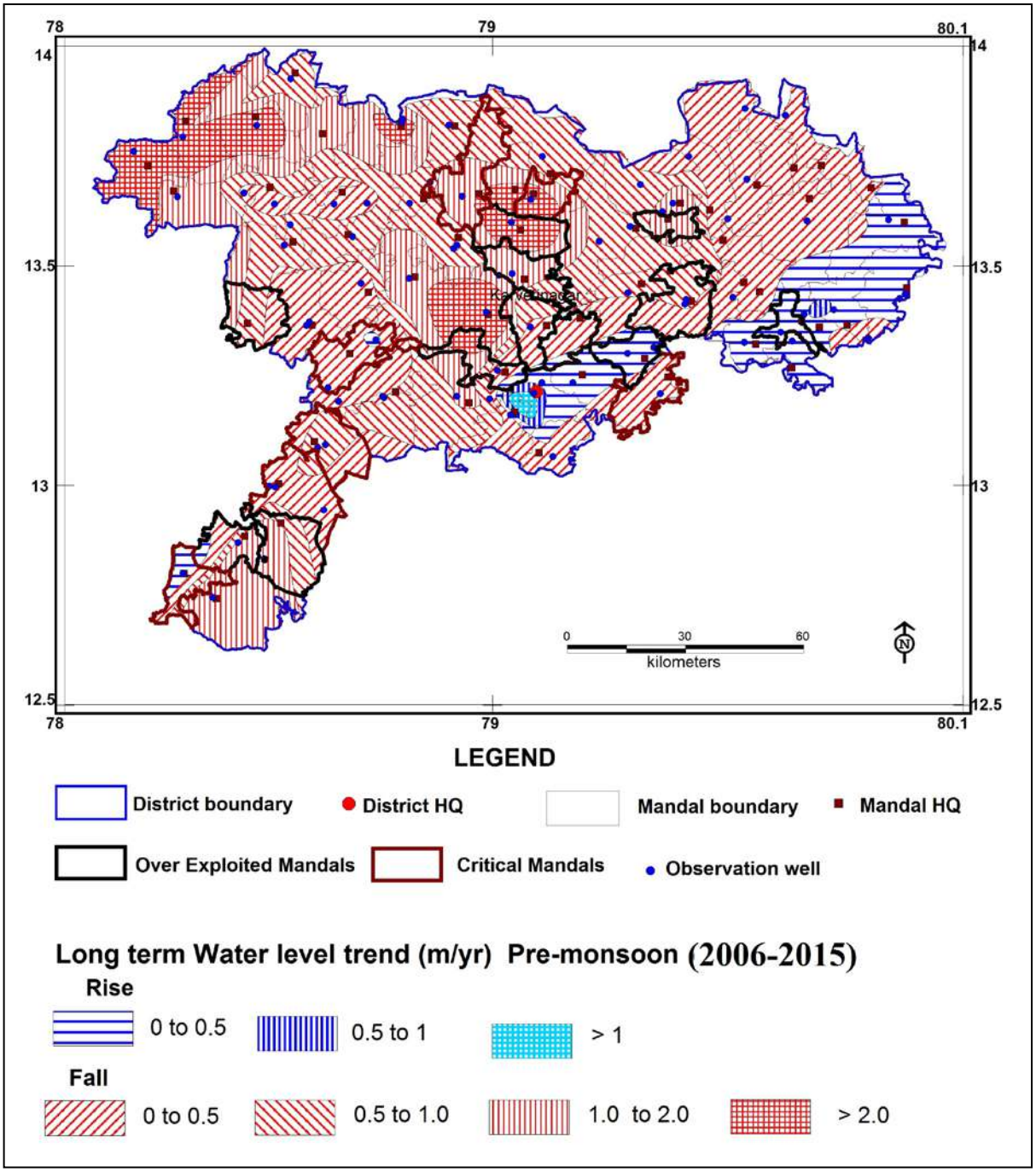

Fig.2.7: Long-term water level trends, Pre-monsoon (2006-2015).

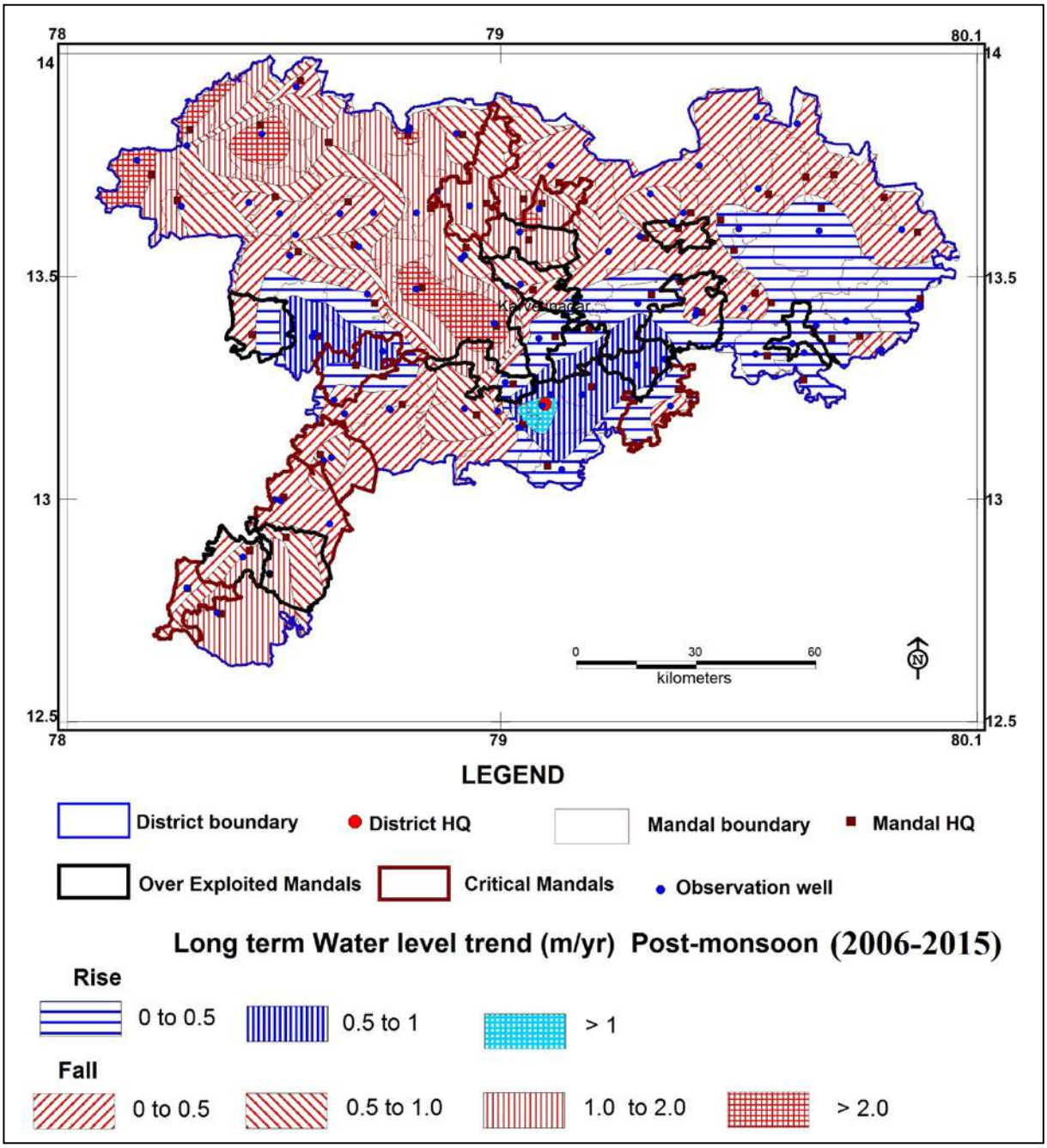

Fig.2.8: Long-term water level trends (Post-monsoon-2006-2015).

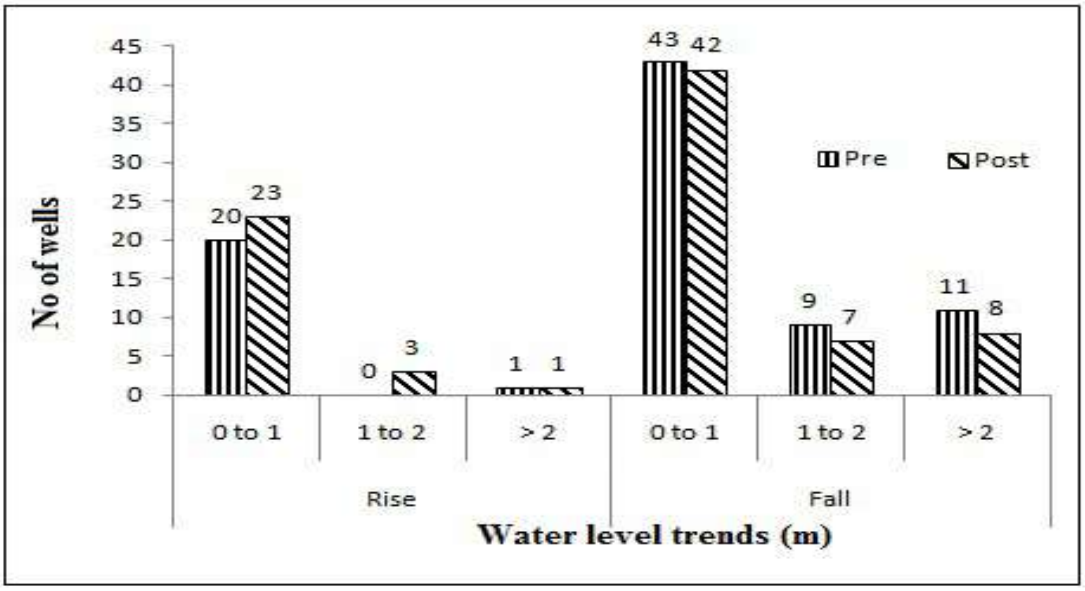

Fig. 2.9: Long-term water level trends (2006-2015).

2.3 Geophysical Studies

A representative 104 geophysical data (mostly VES) is interpreted (**Fig. 2.1**), which reveals resistivity < 115 ohm (Ω) m for the weathered BGC, 115-250 Ω m for underlying fractured BGC with maximum thickness of 100 m.and > 250 Ω m for massive BGC.

2.4 Hydro-chemical Studies

To understand chemical nature of groundwater, total 1053 data is utilized from ground water monitoring wells (Pre: 503 and Post: 550). During pre-monsoon season of 2015 (CGWB: 17 and SGWD: 486 wells (mostly tapping combined aquifers Aq-1 and aq-2) were analyzed. 550 samples (all SGWD) during post-monsoon season of 2014 are analyzed. Parameters namely pH, EC (in µS/cm at 25 ° C), TH, TDS, Ca, Mg, Cl, SO_4 NO_3, F and Iron were analyzed.

2.4.1 Pre-monsoon (May-2015)

Groundwater from the area is mildly acidic to alkaline in nature with pH in the range of 6.7 to 8.5 (Avg: 7.4). Electrical conductivity varies from 530-2985 (avg: 1100) µ Siemens/cm. In majority of area (79 %) EC is in the range of <100-1500 µ Siemens/cm, in rest of the area covering central eastern part, EC is between 1500 and 3000 µ Siemens/cm (**Fig.2.10**). The concentration of TDS varies from 316 to 2000 (avg: 877) and TH varies from 130-680 (avg: 349) mg/l. In 1 samples (Gudipala) TH is beyond maximum permissible limit of BIS (600 mg/l).

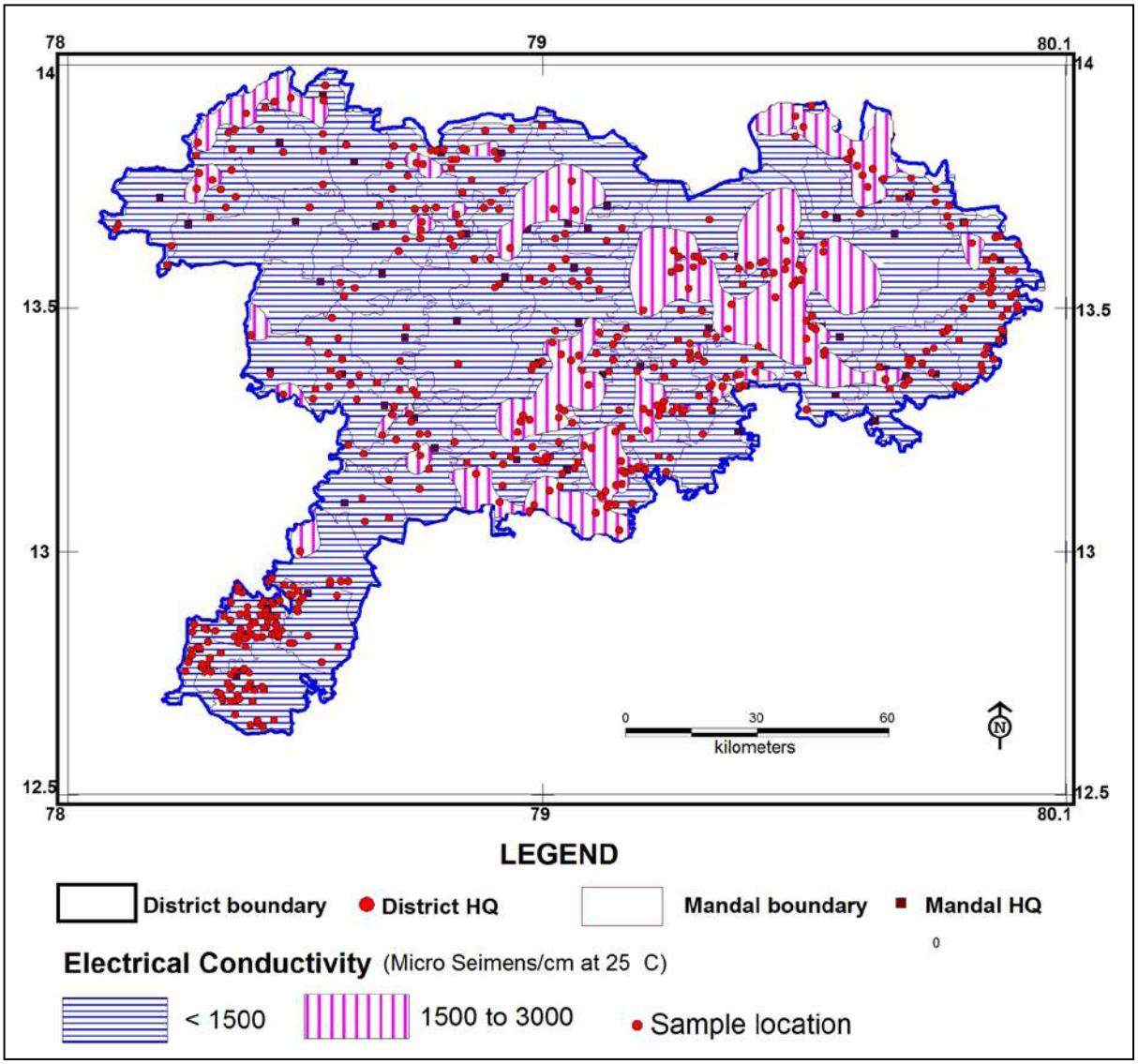

Fig.2.10: Distribution of Electrical conductivity (Pre-monsoon-2015).

The concentration of Ca^{2+} and Mg^{2+} ranges from 28-288 and 12-116 mg/l respectively and found that in 8 & 2 samples Ca and Mg are beyond the maximum permissible limit of BIS. The concentration of chloride (Cl) and sulphate (SO_4) varies from 48-659 mg/l (avg: 196) and 1-298 mg/l (avg: 74) respectively. Concentration of NO_3 ranges from BDL to 199 mg/l and found that in 310 samples (62 %) it is beyond maximum permissible limit of BIS (45 mg/l) (**Fig.2.11**). Fluoride concentration varies from 0.01 to 2.1 mg/l (Diguvapalem) and found that in 3 samples it is beyond maximum permissible limit of BIS (1.5 mg/l) (**Fig.2.12**). Iron concentration varies from BDL to 0.28 mg/l and is within maximum permissible limit of BIS.

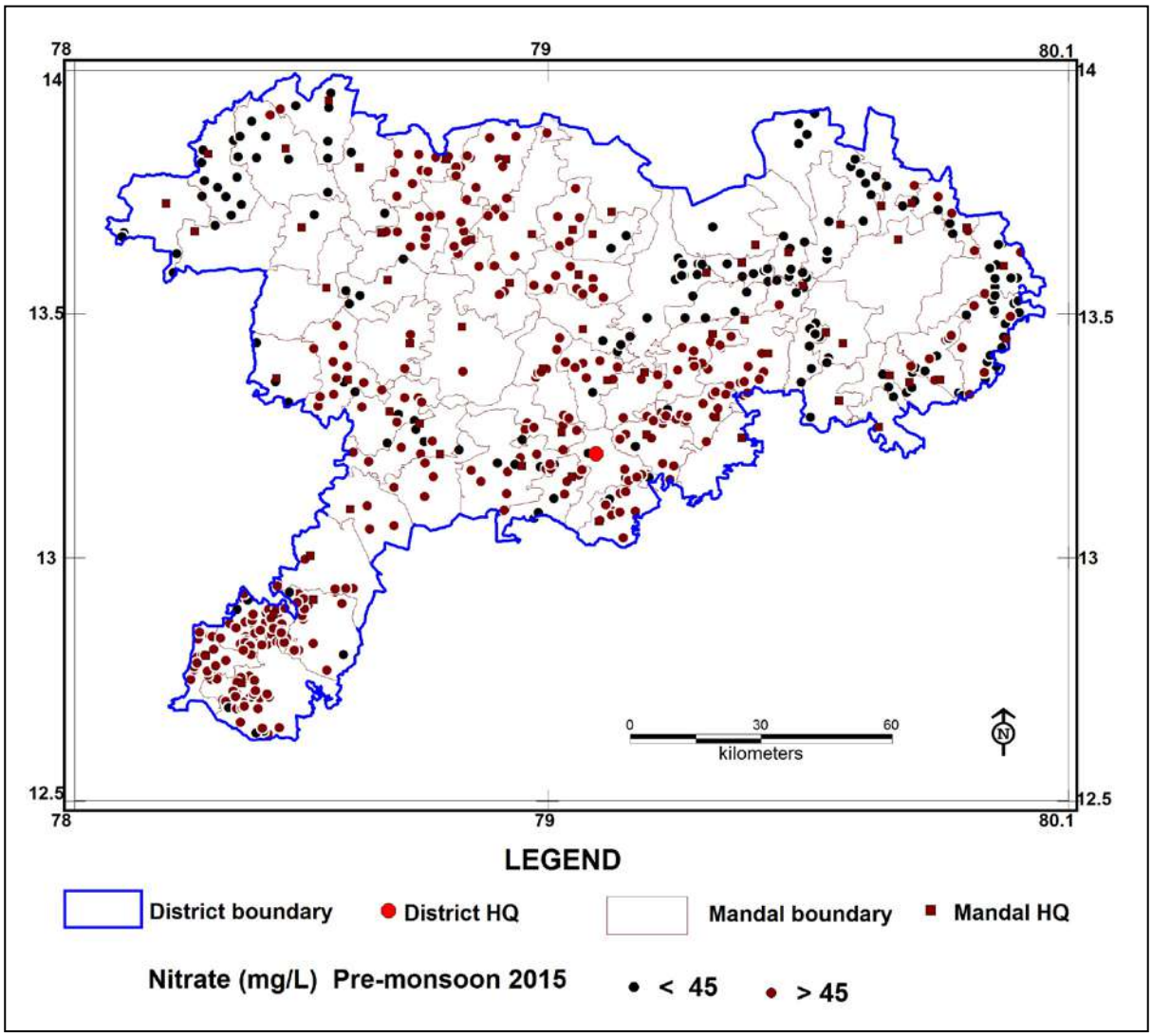

Fig.2.11: Distribution of Nitrate (Pre-monsoon-2015).

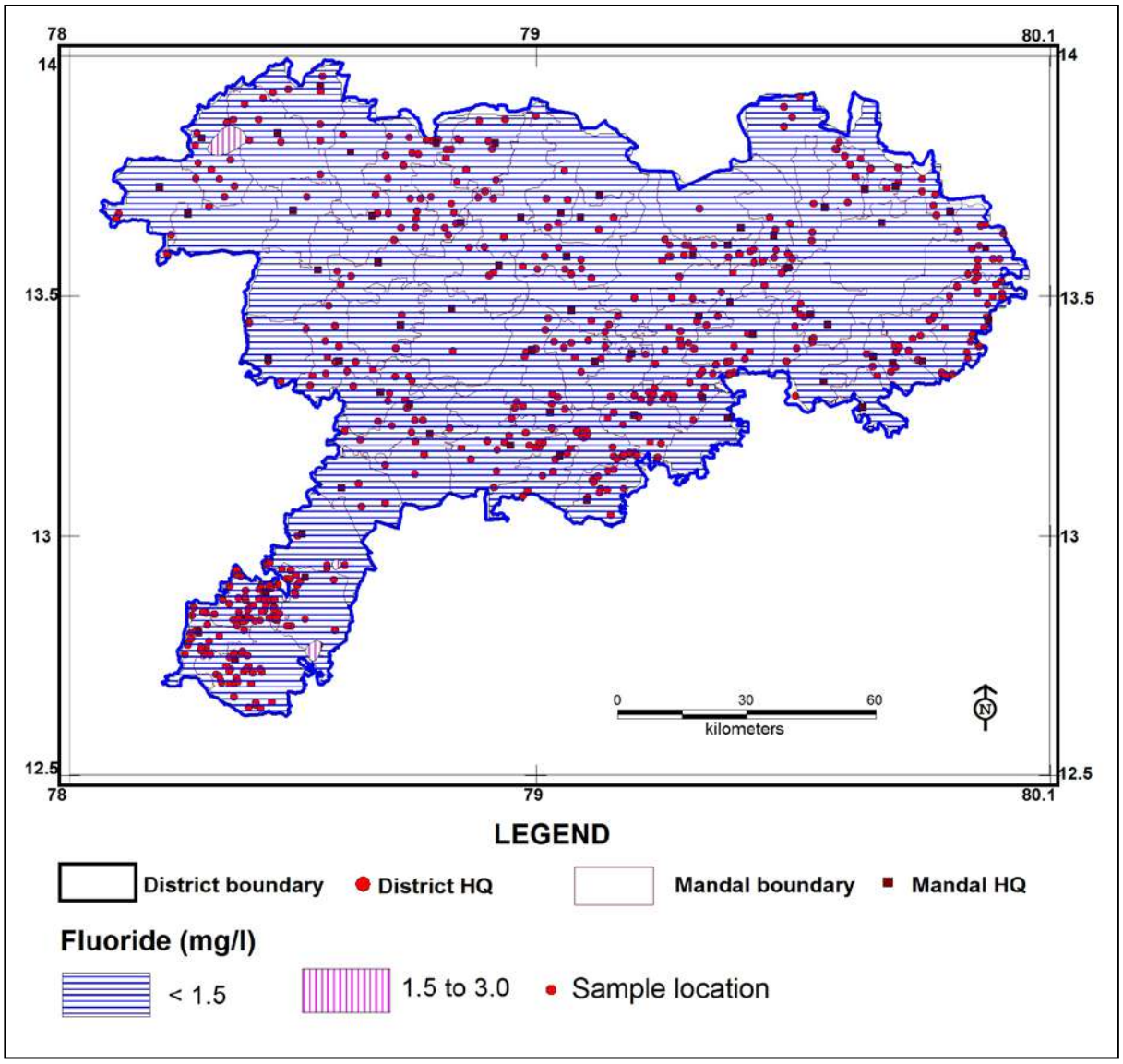

Fig.2.12: Distribution of fluoride (Pre-monsoon-2015).

2.4.2 Post-monsoon (November-2014)

Groundwater from the area is mildly acidic to alkaline in nature with pH in the range of 6.1 to 8.2 (Avg: 7.4). Electrical conductivity varies from 418-3619 (avg: 1369) µ Siemens/cm. In majority of area (75 %) EC is in the range of <100-1500 µ Siemens/cm, in rest of the area covering central eastern part, EC is between 1500 and 3000 µ Siemens/cm (**Fig.2.13**). The concentration of TDS varies from 280 to 2425 (avg: 917) and TH varies from 104-700 (avg: 342) mg/l. In 8 samples (Gudipala) TH is beyond maximum permissible limit of BIS (600 mg/l).

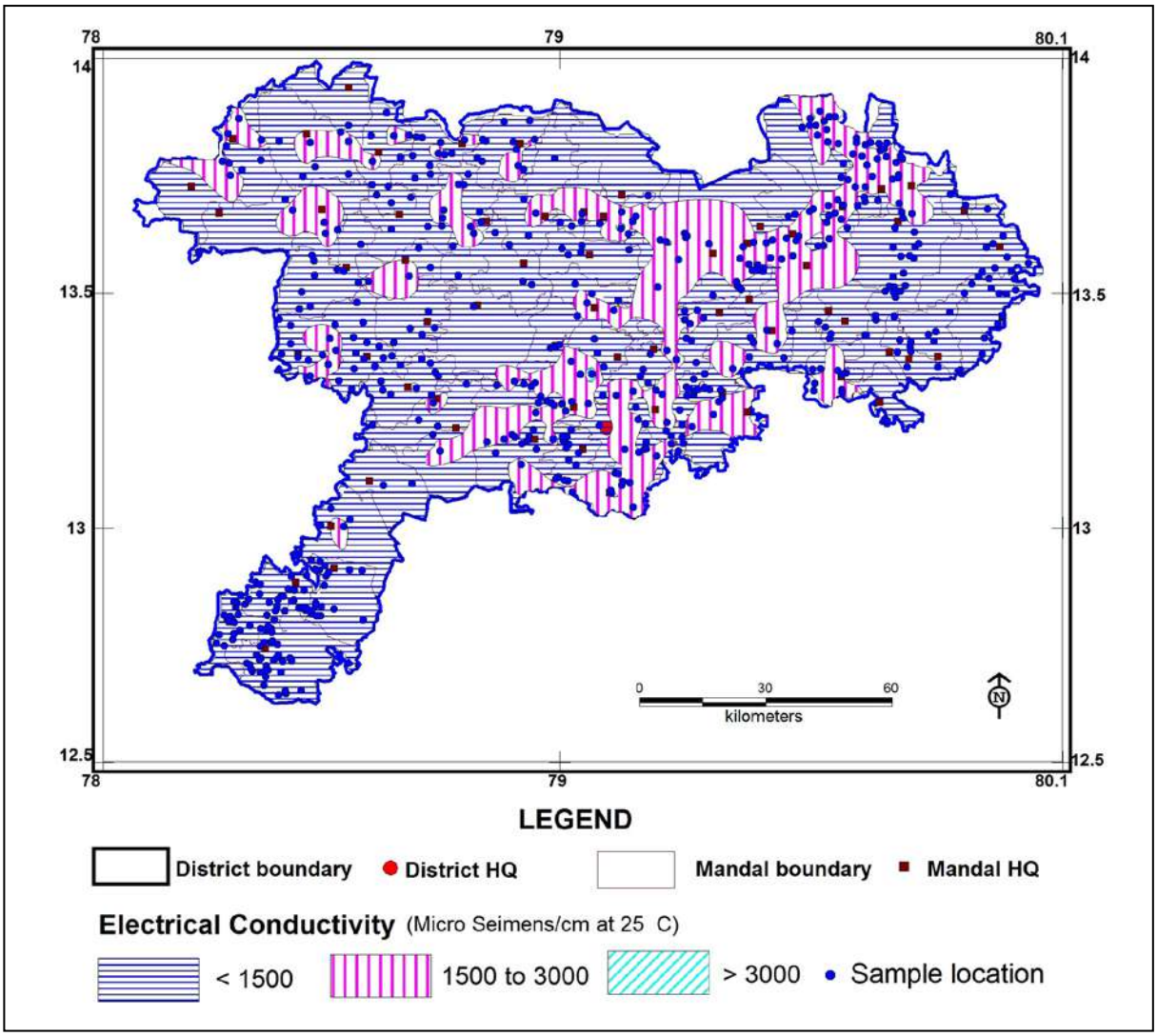

Fig.2.13: Distribution of EC (Post-monsoon 2014).

The concentration of Ca^{2+} and Mg^{2+} ranges from 5-368 and 6-108 mg/l respectively and found that in 16 & 2 samples Ca and Mg are beyond the maximum permissible limit of BIS. The concentration of chloride (Cl) and sulphate (SO_4) varies from 28-978 mg/l (avg: 203) and 5-368 mg/l (avg: 75) respectively. Concentration of NO_3 ranges from BDL to 399 mg/l and found that in 340 samples (62 %) it is beyond maximum permissible limit of BIS (45 mg/l) (**Fig.2.14**). Fluoride concentration varies from 0.01 to 2.0 mg/l (Siddamanaidu and Gnanamamba) and found that in 6 samples it is beyond maximum permissible limit of BIS (1.5 mg/l) (**Fig.2.15).**

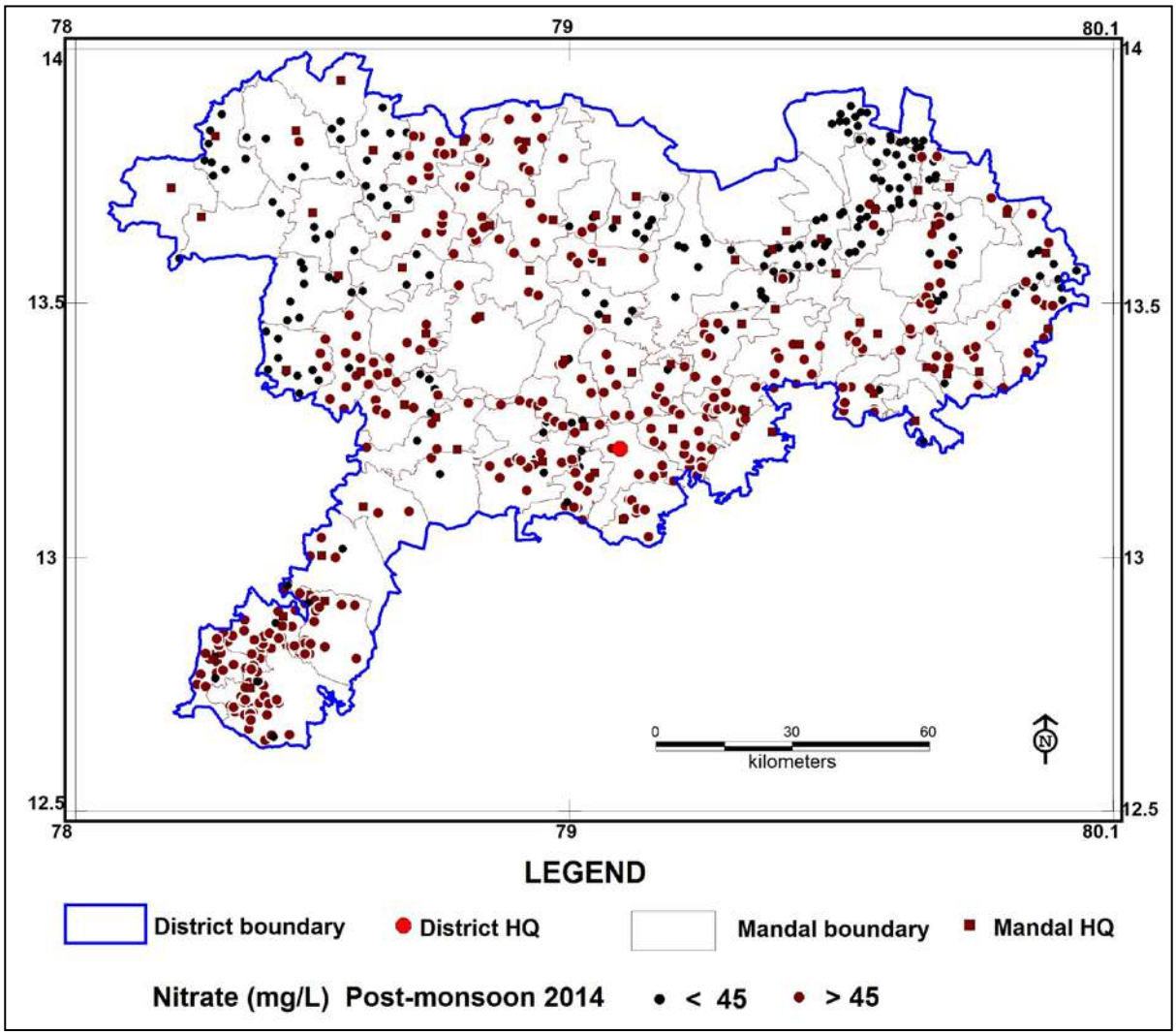

Fig.2.14: Distribution of Nitrate (Post-monsoon 2014).

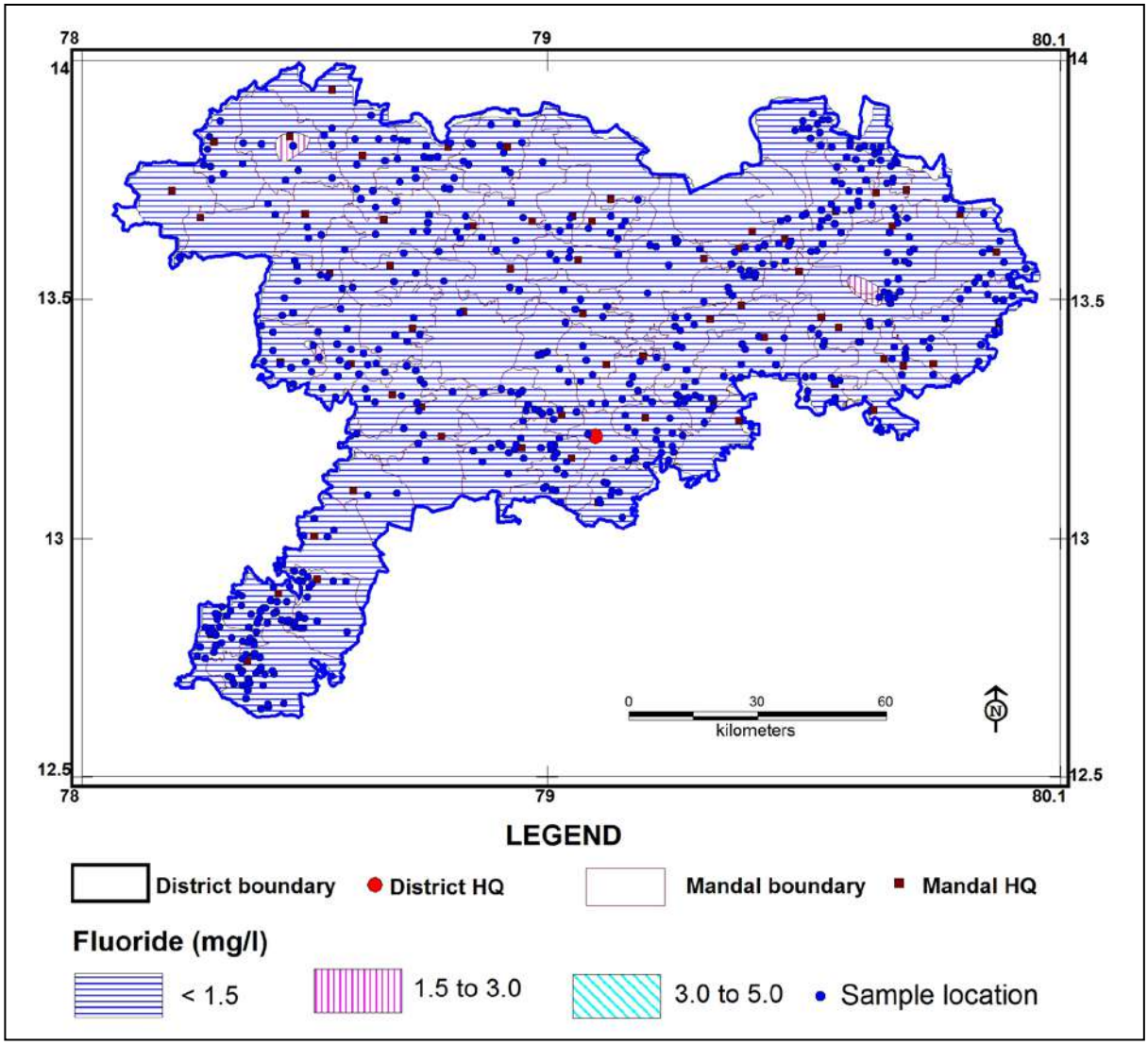

Fig.2.15: Distribution of Fluoride (Post-monsoon 2014).

3. DATA INTERPRETATION, INTEGRATION and AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 966 data points (Exploratory wells: CGWB: 98 and SGWD: 712, Geophysical: 105 well inventory: 52) down to 200 m is used for preparation of 3-D map, panel diagram and hydrogeological sections. 3-D map is generated for BGC area only as sufficient data is not available from other formations. The data is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data **Fig.2.1**). The lithological information was generated by using the RockWorks-16 software and generated 3-D map for Chittoor district (**Fig.3.1)** along with panel diagram (**Fig. 3.2**) and hydrogeological sections (**Fig-3.3 and 3.4a-f**).

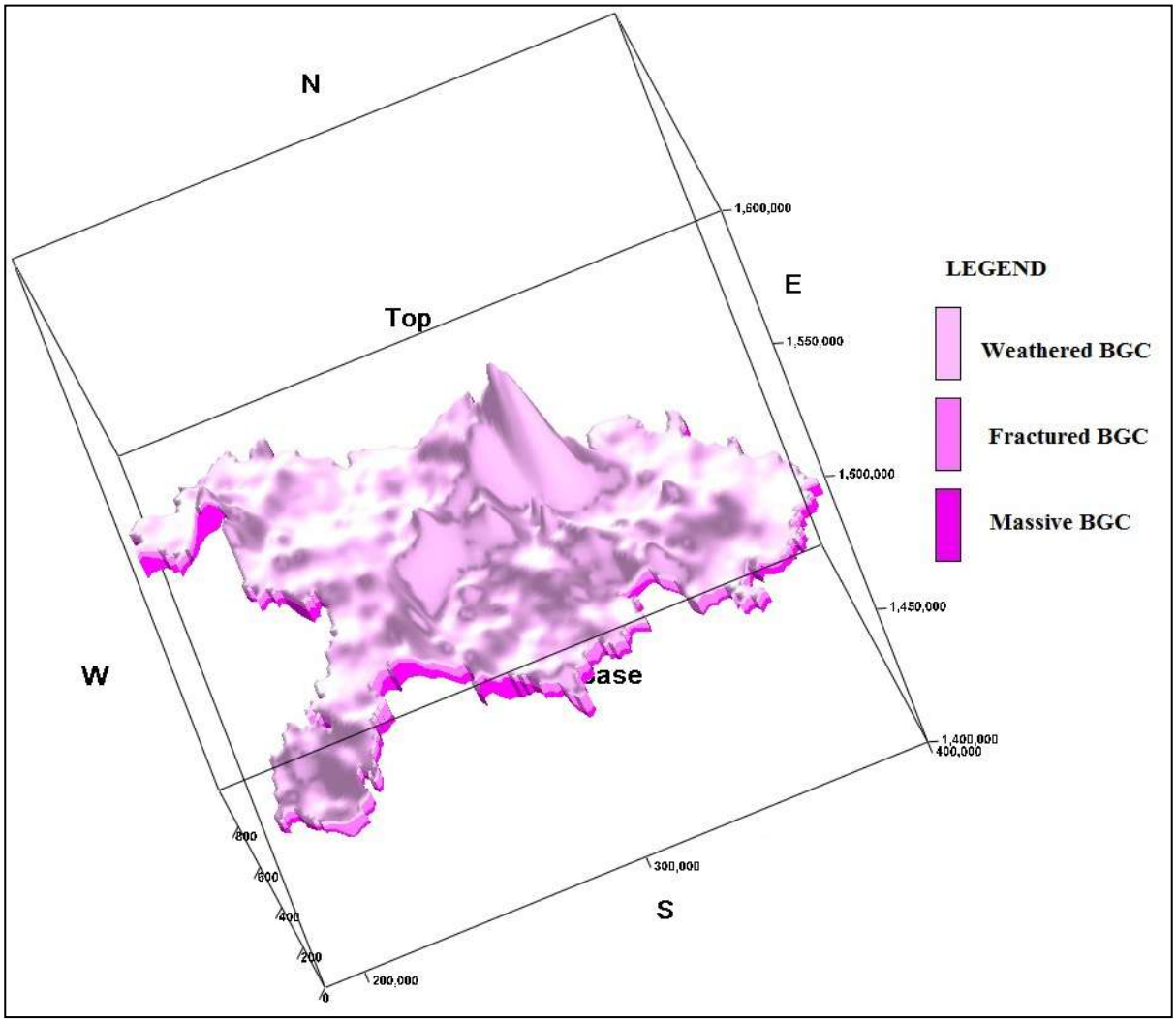

Fig.-3.1: Aquifer disposition in 3-D Model, Chittoor district.

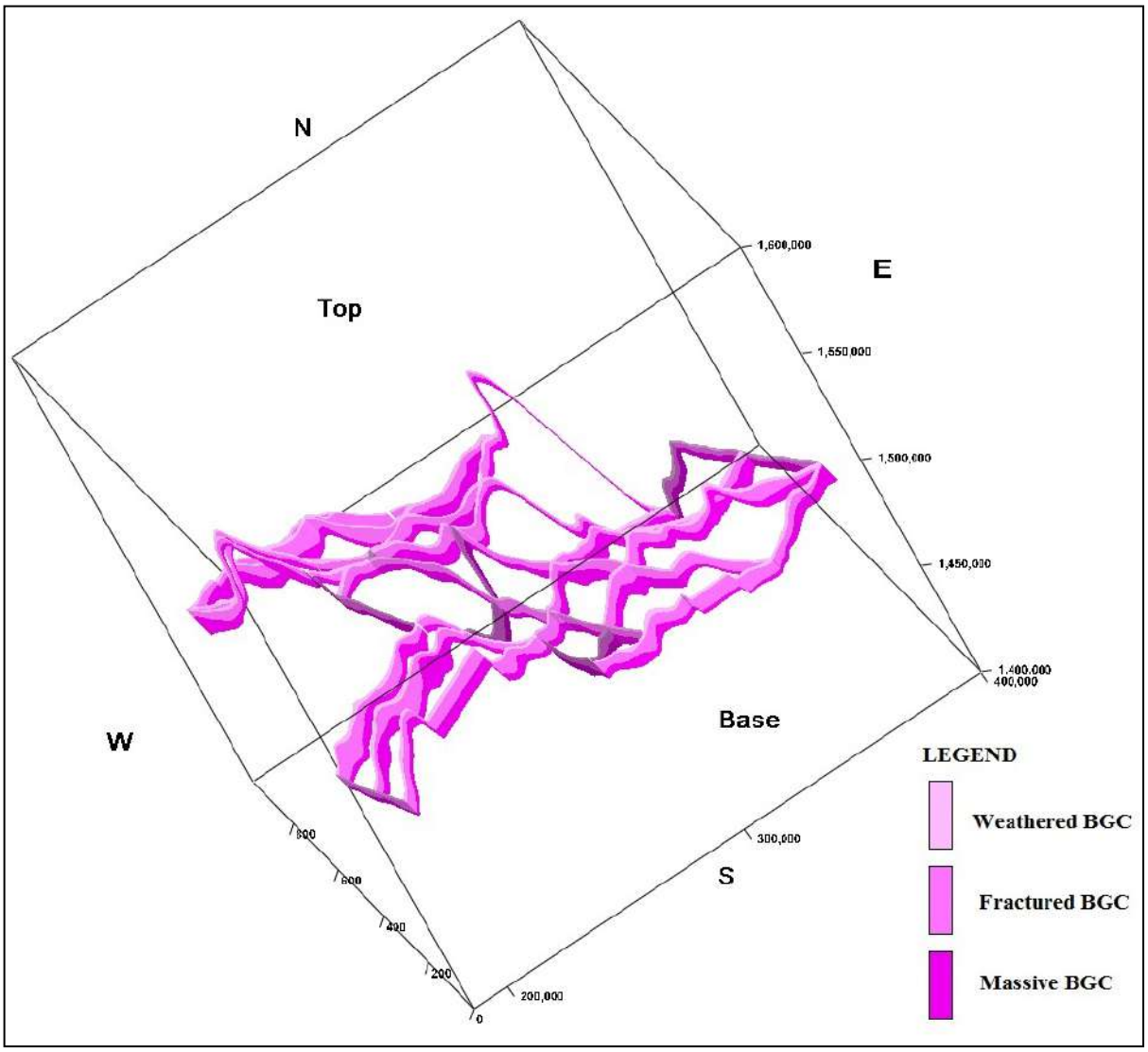

Fig.-3.2: Panel diagram, Chittoor district.

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 ~35 m depth (average ~13 m) and the fractured zone (fractured BGC) is considered up to the depth of deepest fracture below weathered zone and down to 185 m.

3.2 Hydrogeological Sections

10 hydrogeological sections are prepared (6 in NE-SW and 4 in W-E direction) covering entire district (**Fig. 3.3**).

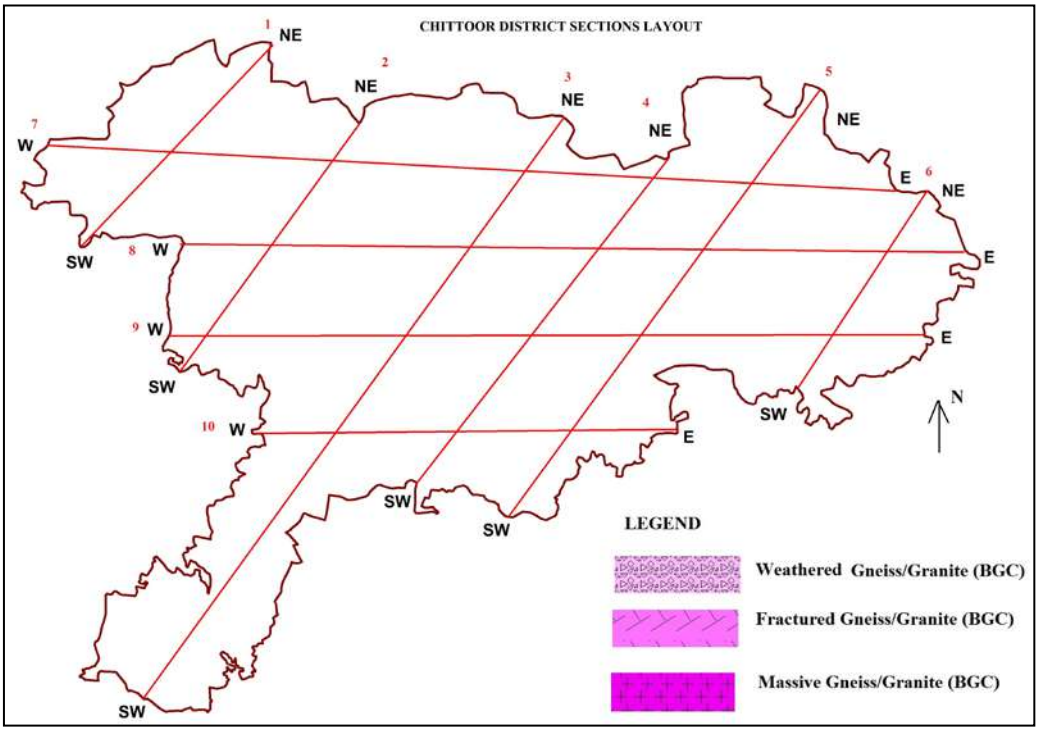

Fig.-3.3: Map showing orientation of various sections, Chittoor district.

3.2.1 Northeast-Southwest Section (1): The inclined section drawn along the NE-SW direction covering distance of ~51 kms (**Fig.3.4 (1)**). It depicts thick weathered zone in south-east corner as compared to other areas. In central part of section deep fractures and in SW corner shallow fractures are observed.

3.2.2 Northeast-Southwest Section (2): The inclined section drawn along the NE-SW direction covering distance of ~58 kms (**Fig.3.4 (2)**). It depicts uniform weathered zone in entire areas and deep fractures are encountered in NE and SW part and shallow fractures are observed in central part of the section.

3.2.3 Northeast-Southwest Section (3): The inclined section drawn along the NE-SW direction covering distance of ~150 kms (**Fig.3.4 (3)**). It depicts uniform weathered zone in entire areas and deep fractures are encountered between 100 to 120 kms distance from NE side and shallow fractures are observed from distance 0 to 15 kms and 80-90 kms and 130 to 150 kms from NE side.

3.2.4 Northeast-Southwest Section (4): The inclined section drawn along the NE-SW direction covering distance of ~90 kms (**Fig.3.4 (4)** including famous Tirumala Hills. It depicts uniform weathered zone in entire areas and shallow fractures from distance 0 to 60 kms and deep fractures between 60 to 80 kms and again shallow fractures beyond this distance from Northeast side.

3.2.5 Northeast-Southwest Section (5): The inclined section drawn along the NE-SW direction covering distance of ~115 kms (**Fig.3.4 (5)** including Tirupathi town. It depicts uniform weathered zone in entire areas and moderate fractures in entire section.

3.2.6 Northeast-Southwest Section (6): The inclined section drawn along the NE-SW direction covering distance of ~48 kms (**Fig.3.4 (6)**. It depicts thick weathered zone between 21 to 33 kms and in other area shallow weathering is observed. Deep fractures are encountered in central part of the section between 15 to 28 kms distance from NE side.

3.2.7 West-East Section (7): The horizontal section drawn along the W-E direction in upper part of the districts covers a distance of ~185 kms (**Fig.3.4 (7)**. It depicts shallow weathered zone in entire area and steep fall is observed in east of Tirumala Tirupathi town. Moderate deep fractures are encountered in western part up to 80 kms and no fractures are encountered east of Tirumala-Tirupathi up to 130 kms.

3.2.8 West-East Section (8): The horizontal section drawn along the W-E direction in central part of the districts covers a distance of ~185 kms (**Fig.3.4 (8)**. It depicts shallow weathered zone in entire area. Moderate fractures are encountered between 160-170 kms distance from west.

3.2.9 West-East Section (9): The horizontal section drawn along the W-E direction in central part of the districts covers a distance of ~160 kms (**Fig.3.4 (9)**. It depicts shallow weathered zone in entire area. Moderate fractures are encountered in entire area excluding the area beyond 130 to 160 kms.

3.2.10 West-East Section (10): The horizontal section drawn along the W-E direction in central part of the districts covers a distance of ~80 kms (**Fig.3.4 (10)**. It depicts shallow weathered zone in entire area. Moderate fractures are encountered between 15 to 50 kms and deep fractures are encountered between 65 to 75 kms.

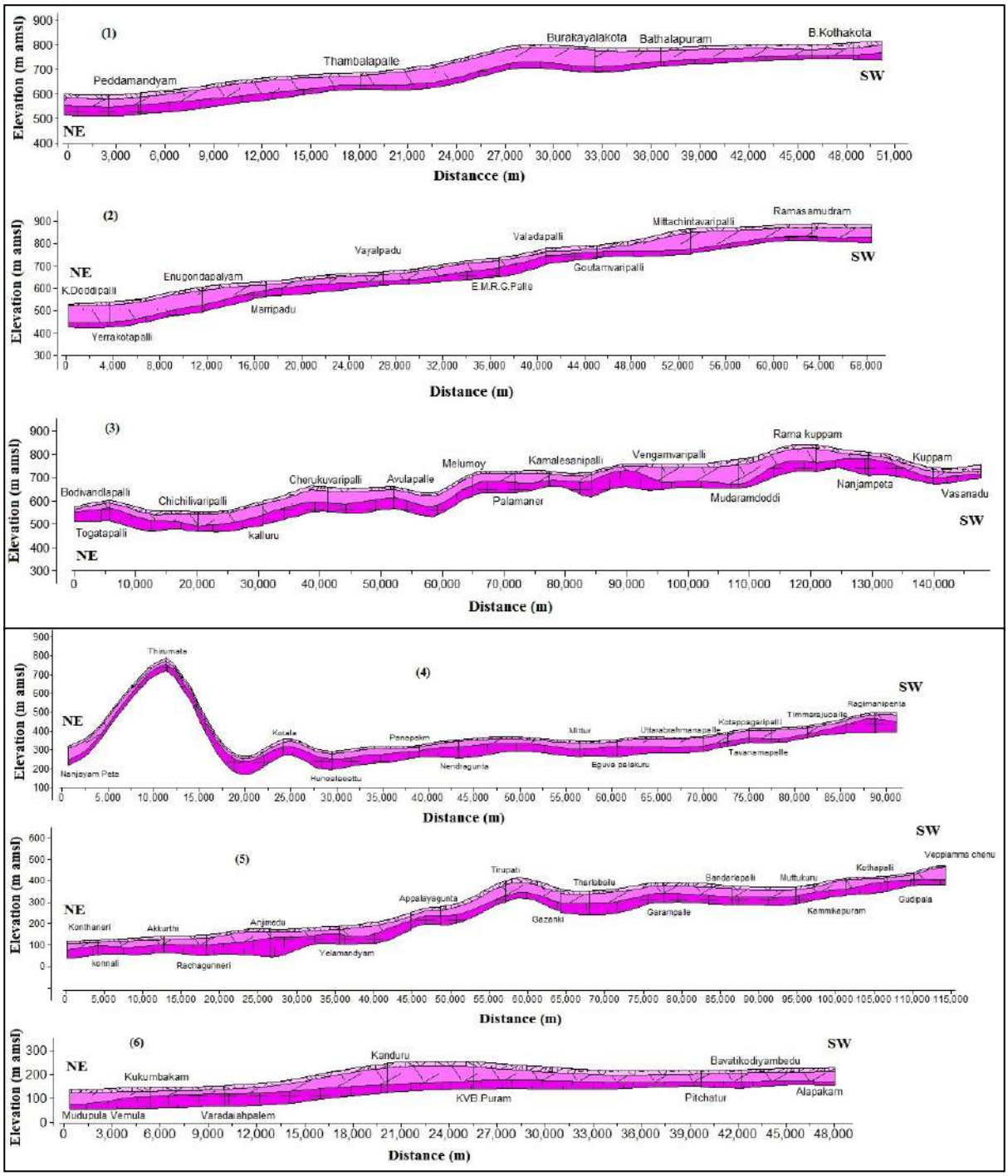

Fig-3.4 (1 to 6): Northeast-Southwest Sections, Chittoor district.

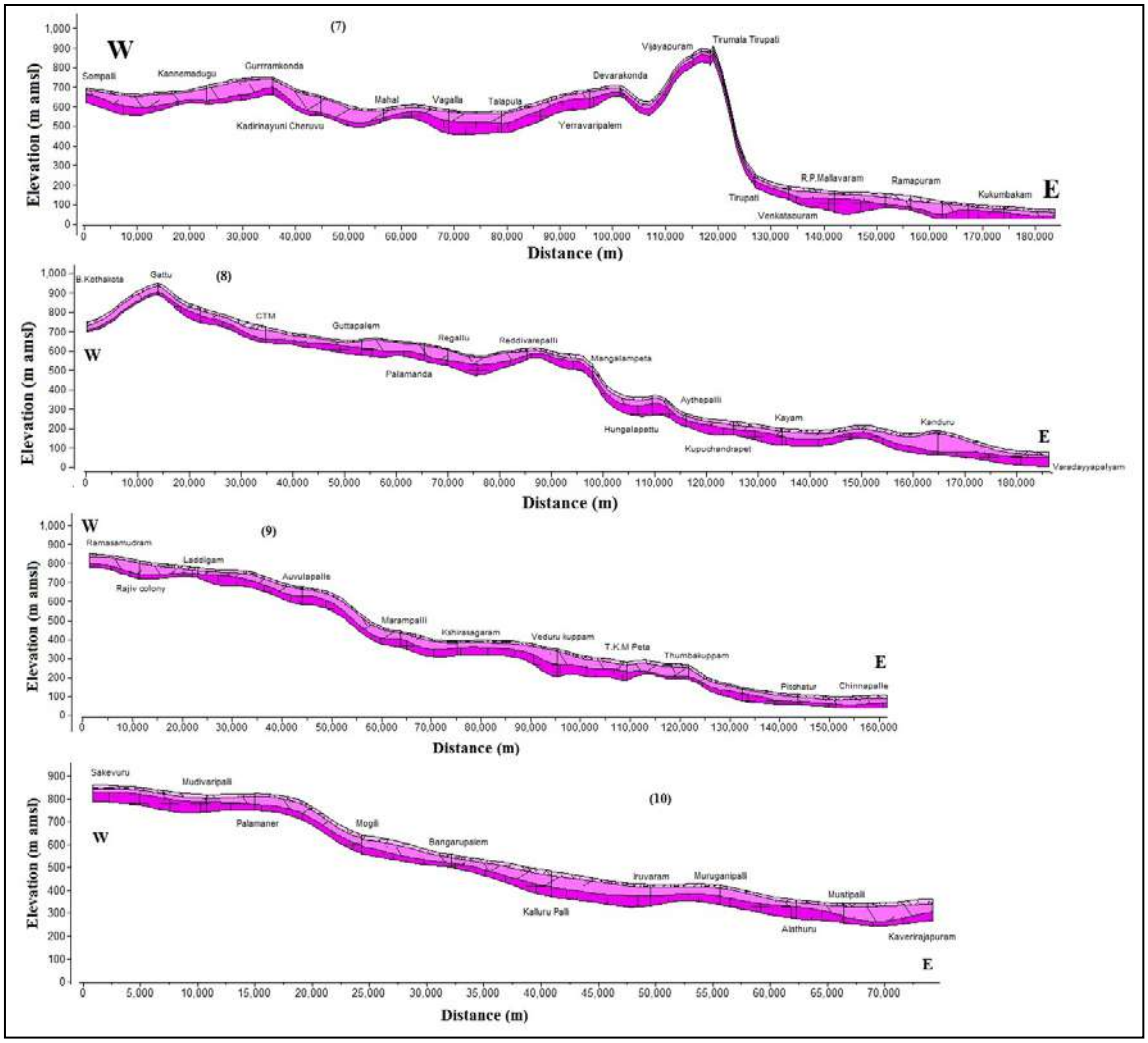

Fig-3.4 (7 to 10): West-east Sections, Chittoor district.

3.3 Aquifer Characterization

3.3.1 Weathered zone: Average depth of weathering in the district is ~13 m and it ranges from 7 to 34.6 m. In majority of area, thickness of weathered zone is in the range of 10-20 m (56%), followed by <10 m (35%). Deep weathering (> 20 m) occurs in 9 % of area in eastern, central and south-western part of the district (**Fig.3.5**). Yield varies from < 0.1 to 8 lps and transmissivity in the range of 2 to 489 m^2/day abd specific yield ranges from 0.1 to 0.3 % (only 2 wells data).

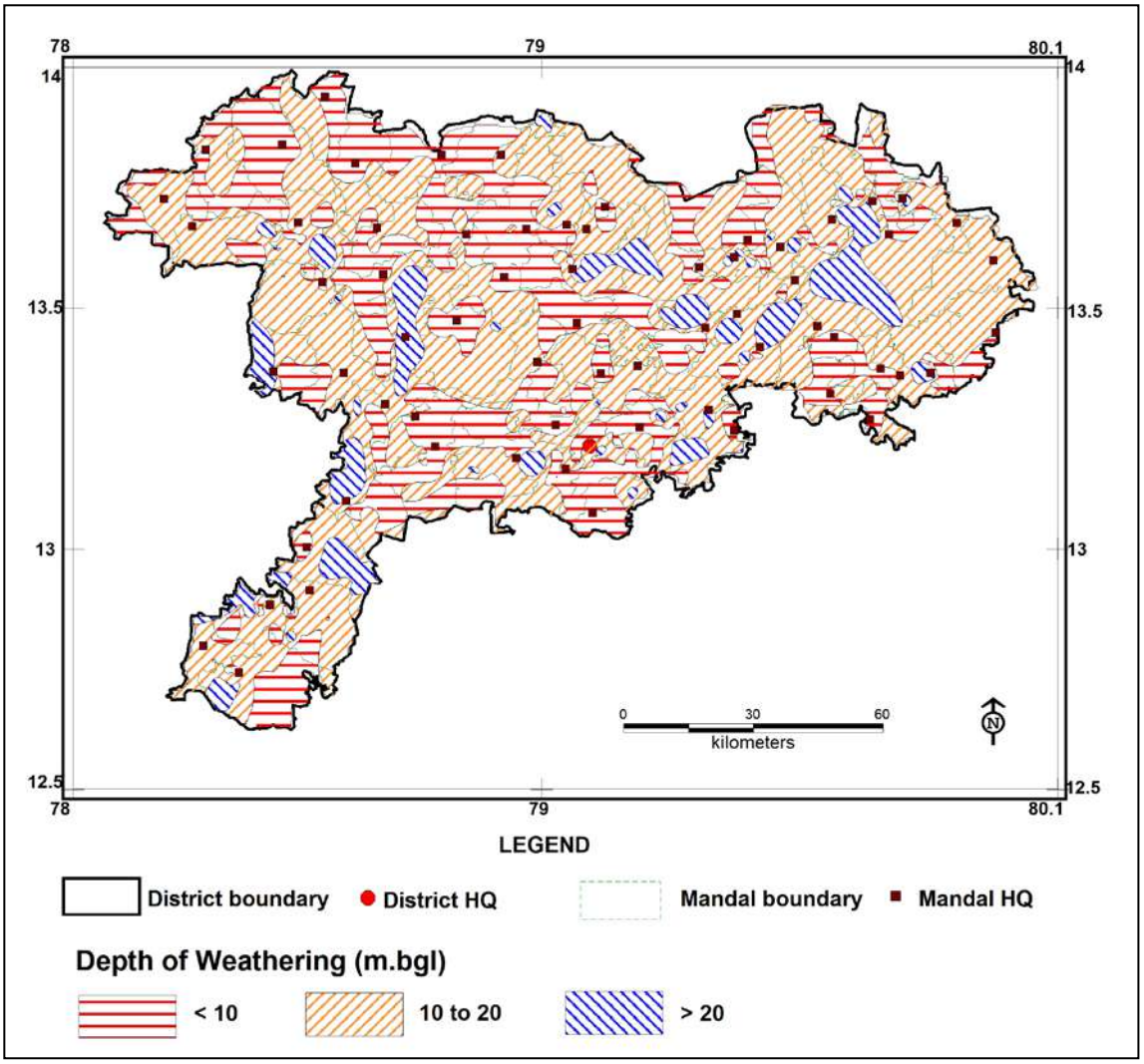

Fig.3.5: Thickness of weathered zone, Chittoor district.

3.3.2 Fractured zone: Depth of fracturing varies from 20 to 185 m (Gangasagaram). The depth of fracture map is presented in **Fig. 3.6.** ~99 % of fractures occur within 100 m depth and rest occur below this depth (**Fig.3.7**). Ground water yield from fractured zone varies from <0.1 to 13 lps. The hydraulic properties of weathered and fractured zone like specific capacity, transmissivity (T) and storativity (S) varies from 1.0 to 574 lpm/m/dd, 1 to 489 m^2/day and 1.6 x 10^{-4} to 5.9 x 10^{-4} respectively.

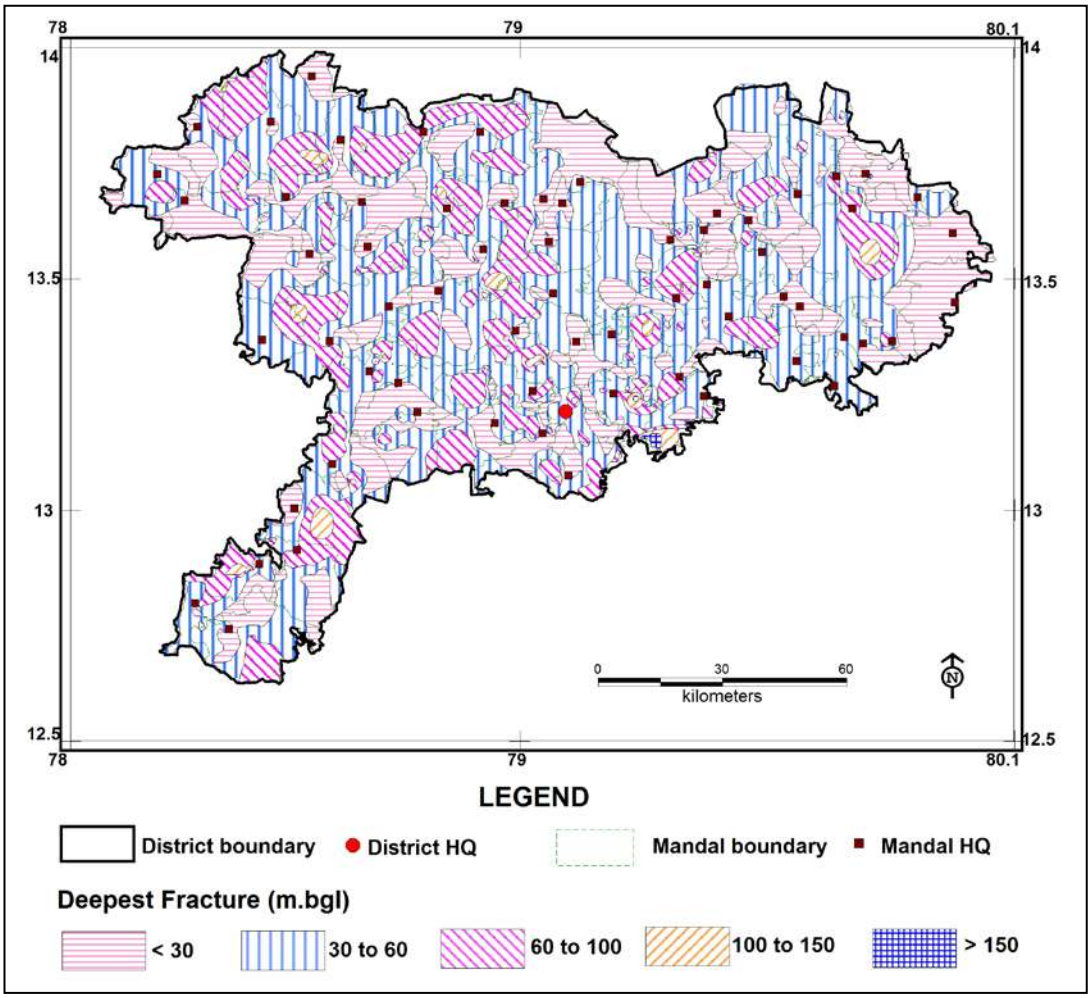

Fig.-3.6: Depth of fractured zone (Maximum depth) (m bgl), Chittoor district.

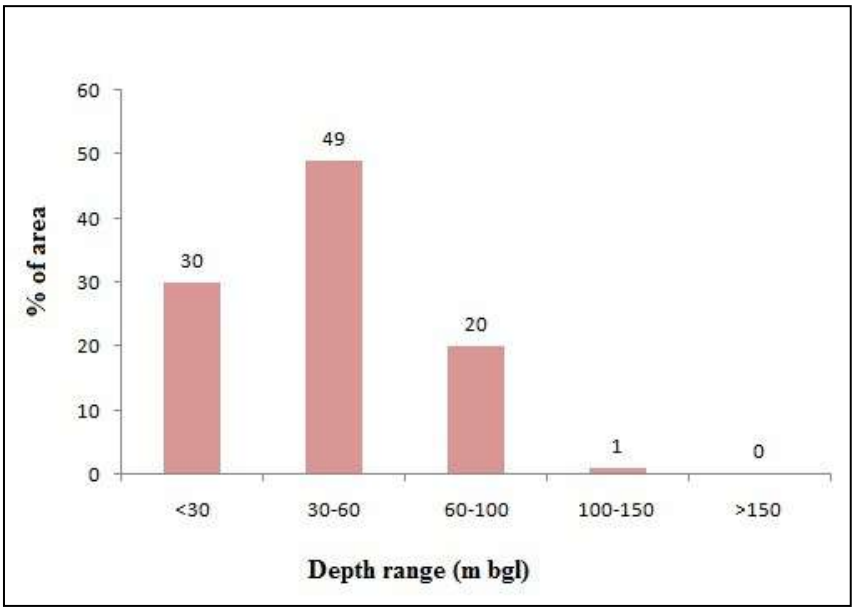

Fig.3.7: Depth wise distribution of fractures zones (%), Chittoor district.

4.0 GROUND WATER RESOURCES (2013)

In hard rocks, for practical purpose it is very difficult to compute zone wise (aquifer wise) ground water resources, because the weathered zone and fractured zone 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. In the district 85 % of the falls under non-command and 5% under command category and rest 10% is hilly area. Village wise dynamic and in-storage ground water 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, 2 % of granular zone (depth below pre-monsoon water level and down to deepest fracture depth in the village) and 3% of the specific yield is considered. Summarized command/ non-command area and mandal wise resources are given in **Table-4.1** and **Table-4.2** respectively.

As per 2013 GEC report, the net dynamic replenishable groundwater availability is 1648.8 MCM, gross ground water draft for all uses 1176.96 MCM, provision for drinking and industrial use for the year 2025 is 188.17 MCM and net annual ground water potential available for future irrigation needs is 473.4 MCM. Stage of ground water development varies from 26 % in Satyavedu mandal to 166 % in Ramasamudram mandal (avg: 71 %). Out of 66 mandals 12 mandals falls in over-exploited category, 7 in critical category, 18 in semi critical category and remaining 29 in safe category. Summarized mandal wise ground water resources are given in **Table-4.2**.The in-storage ground water resources down to the maximum fractured depth (185 m) are 340.33 MCM.

Table-4.1: Computed Dynamic, In-storage ground water resources, Chittoor district.

Parameters	Command	Non-command	**Total**
As per GEC 2013	MCM	MCM	MCM
Dynamic (Net GWR Availability)	**102.28**	**1546.53**	**1648.81**
• Monsoon recharge from rainfall	73.95	1267.52	1341.47
• Monsoon recharge from other sources	12.49	144.69	157.18
• Non-Monsoon recharge from rainfall	7.45	84.4	91.85
• Non-monsoon recharge from other sources	19.76	215.29	235.05
• Provisional for natural discharge	11.36	165.37	176.73
Gross GW Draft	**31.74**	**1145.22**	**1176.96**
• Irrigation	29.00	976.49	1005.49
• Domestic and Industrial use	2.74	168.73	171.47
Provision for Drinking and Industrial use for the year 2025	3.36	184.81	188.17
Net GW availability for future irrigation	69.93	403.47	473.4
Stage of GW development (%)	31	74	71
	Out of 66 mandals 12 mandals falls in OE, 7 in Critical, 18 in Semi-critical and remaining 29 in safe category.		
In-storage GW Resources (down to the maximum depth of fractures)	**340.33**		

Table-4.2: Summarized Mandal wise ground water resources, Chittoor district (2013)-(Ham).

S. No.	Mandal	Net Annual GW Availability	Gross GW Draft	Provision for the year 2025	Net GW for future Irrigation	Stage of ground water development %	Category
1	B N Kandriga	3223	1029	89	2159	32	S
2	B.Kothakota	2047	1589	215	394	78	SC
3	Baireddypalli	1854	1747	244	86	94	C
4	Bangarupalem	4804	2617	283	2196	54	S
5	CGGallu	1641	1499	153	240	91	C
6	Chandragiri	5848	2042	355	3756	35	S
7	Chittoor	2405	1746	585	535	73	SC
8	Chowdepalli	2884	2293	241	509	80	S
9	G.D.Nellore	2431	2096	428	300	86	SC
10	Gangavaram	2546	2260	248	275	89	SC
11	Gudipala	1990	1383	269	622	69	S
12	Gudupalli	1618	1502	167	139	93	C
13	Gurramkonda	2244	1720	240	470	77	SC
14	Irala	2356	1886	389	501	80	SC
15	Kalakada	2203	1269	187	940	58	S
16	Kalikiri	2059	1464	276	433	71	SC
17	Karvetinagaram	2776	1994	264	574	72	SC
18	Kuppam	4539	2184	790	2009	48	S
19	Kurabalakota	1520	1234	153	289	81	SC
20	KV Palli	2577	1845	294	755	72	SC
21	KVB Puram	5043	1752	145	3232	35	S
22	Madanapalli	2887	2287	685	111	79	SC
23	Molakalacheruvu	1561	1311	183	243	84	SC
24	Nagalapuram	2698	948	113	1700	35	S
25	Nagari	1583	1292	359	49	82	S
26	Narayanavanam	1787	1223	214	508	68	S
27	Nimmanapalli	1854	1135	119	590	61	S
28	Nindra	1286	1875	108	0	146	OE
29	Pakala	1542	1959	456	0	127	OE
30	Palamaneru	2637	2110	314	306	80	SC
31	Palasamudram	882	869	159	4	99	C
32	Pedda Thippa Samudram	2206	1878	210	201	85	SC
33	Peddamandyam	1880	876	143	900	47	S
34	Peddapanjani	3039	2744	260	29	90	C
35	Penumuru	1470	1727	280	0	117	OE
36	Piler	1570	1467	435	0	93	C
37	Pitchatur	2306	1275	118	822	55	S
38	Pulicherla	1697	1763	280	0	104	OE
39	Punganur	3597	3186	445	328	89	SC

40	Puthalapattu	1885	2489	352	0	132	OE
41	Puttur	2881	2422	232	464	84	S
42	R.C.Puram	1554	1849	200	0	119	OE
43	Ramakuppam	1646	1761	220	0	107	OE
44	Ramasamudram	1664	2755	267	0	166	OE
45	Renigunta	2478	1459	226	805	59	S
46	Rompicherla	3334	1396	181	1749	42	S
47	S.R.Puram	1518	2074	253	0	137	OE
48	Santhipuram	2034	2205	225	0	108	OE
49	Satyavedu	3762	989	160	2630	26	S
50	Sodam	2207	1768	198	464	80	SC
51	Somala	3499	1904	225	1481	54	S
52	Sri Kalahasti	5291	2616	608	2290	49	S
53	Tamballapalli	2029	1245	182	785	61	S
54	Thavanampalli	2010	2293	319	0	114	OE
55	Thottambedu	3983	1663	143	2306	42	S
56	Tirupathi(U)	2556	1408	1299	1050	55	S
57	Tirupathi®	1321	1900	412	0	144	OE
58	V.Kota	2481	2272	337	184	92	C
59	Vadamalapeta	2724	1858	172	898	68	S
60	Valmiki Puram	3099	1712	194	1073	55	S
61	Varadaiahpalem	3144	1011	122	2142	32	S
62	Vedurukuppam	2835	1698	266	1009	60	S
63	Vijayapuram	1363	1218	132	124	89	S
64	Y.V.Palem	2342	1805	339	525	77	SC
65	Yadamarri	1752	1520	200	308	87	SC
66	Yerpedu	4396	3333	458	849	76	S
	District Total	**164878**	**117699**	**18818**	**47341**	**71**	

5. GROUND WATER RELATED ISSUES and REASONS FOR ISSUES

5.1 Issues

Over-exploitation

1. ~ 2016 Km^2 area (13%) covering 12 mandals is categorized as over-exploited where ground water balance for future irrigation is zero or negative.

De-saturation of weathered zone and Deep water levels

2. ~3265 Km^2 of the area having ~1906 MCM of un-saturated volume is de-saturated where water levels are more than 15 m bgl.

3. Deep water levels (> 20 m bgl) during pre as well as post-monsoon season in 9 % and 11 % of the area respectively are observed.

4. Out of 84 wells analyzed, 63 wells and 57 wells shows falling trends in pre and post-monsoon season in the last 10 years (@-4.42 to -0.0076 and -3.49 to -0.003 m/yr) respectively.

Pollution (Geogenic and Anthropogenic)

5. Few mandals are fluorosis endemic where fluoride (geogenic) as high as 2 mg/l is found in groundwater. The fluoride concentration is >1.5 mg/l in 3 and 6 samples during pre and post-monsoon season respectively.

6. High nitrate (> 45 mg/l) due to anthropogenic activities is observed in ~62 % samples in both seasons.

Sustainability

7. Low yield (< 1 lps) occurs in ~1450 Km^2 area (10%).

5.2 Reasons for issues

Over-exploitation and Deep water levels

1. Over-extraction, high water consuming cash crop cultivation (Sugarcane and paddy), moderate rainfall and limited artificial measures etc.

Geo-genic pollution (Fluoride)

2. 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.
3. Higher residence time of ground water in deeper aquifer.

Anthropogenic pollution (Nitrate)

4. 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.

Sustainability

5. Absence of primary porosity, negligible development of secondary porosity, low rainfall, de-saturation of weathered zone and urbanization.

6. MANAGEMENT STRATEGIES

Low rainfall and high dependence on groundwater 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 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 (99 %) (**Fig.3.7**). 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/gneiss 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 requires integrated hydrogeological aspects along with socio-economic conditions to develop appropriate management strategy.

- In the district having 0.963 lakh MCM of unsaturated volume having 2890 MCM of recharge potential (below the depth of 3 m) is available during post-monsoon season of 2015 (considering 3 % specific yield) and this can be utilized for formulating implementing management plans.

- Total 119.4 MCM of surface runoff is available for taking additional artificial recharge structures.

The study suggests notable measures for sustainable groundwater management, which involves a combination of both supply side and demand side measures

6.1.1 Supply side measures:

Ongoing Projects

Repair, Renovation and Restoration of existing tanks (Competed):

- De-silting of 22.82 MCM of silt from existing 3079 (minor irrigation tanks and Percolation tanks) tanks are completed under state Govt. sponsored NEERU-CHETTU programme and created additional surface storage. This will contribute ~

6.84 MCM to groundwater (considering 30% of recharge) and with this additional ~1140 ha land can be brought under irrigated dry (ID) crops in tank ayacut.

To be taken up

Repair Renovation and Restoration of existing tanks (Proposed):

- De-silting of 9.98 MCM of silt from existing 2737 tanks (minor irrigation tanks and Percolation tanks) are proposed to be taken up under state Govt. sponsored NEERU-CHETTU programme which will create additional surface storage. This will contribute ~3 MCM to groundwater (considering 30% of recharge) and with this additional ~500 ha land can be brought under irrigated dry (ID) crops in tank ayacut.

Artificial Recharge structures:

Constructions of 8687 artificial recharge structures (ARS) with 119.4 MCM of non-committed surface runoff, costing ~**504.95** crore rupees are proposed in 1003 villages. This will recharge ~**36 MCM** to the ground water considering 30 % recharge to the ground water.

While formulating the village wise groundwater management plan, the unsaturated volume of aquifer is estimated by multiplying the area with specific yield and unsaturated thickness (post-monsoon water levels below 3 m). Initially village wise dynamic groundwater resources of 2013 are considered. Potential surface run off is estimated by following standard procedures. On conservative side 20 % run off yield is considered as non-committed yield for recommending artificial recharge structures.

The pre-monsoon groundwater quality is considered for categorising contaminated area (F >1.5 mg/l & EC >3000 µ S/cm). Nitrate is not considered here because it is point source pollution and localized. Based on the hydrogeological characteristics, the area is further sub-divided into following three categories (**Table-6.1**).

Table-6.1: Hydrogeological characteristics of area.

Category	Hydrogeological characterizations
1	Ground water problematic are with additional scope for artificial recharge.
2	Groundwater quality safe area, but no scope for artificial recharge.
3	Groundwater quality safe area, with scope for artificial recharge.

6.1.1.1 Priority-1 (Area where groundwater development > 100 %)

Area consisting 227 villages falling in 12 mandals (partly and fully) covering ~1500 Km^2 (**Fig.6.1**) is 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 3 categories based on hydrogeological conditions as mentioned above. For sustainable development and management of the groundwater resources total 1409 ARS (CD: 1213 and PT: 196) are recommended with total cost of 80.25 crores (**Annexure-1)**.

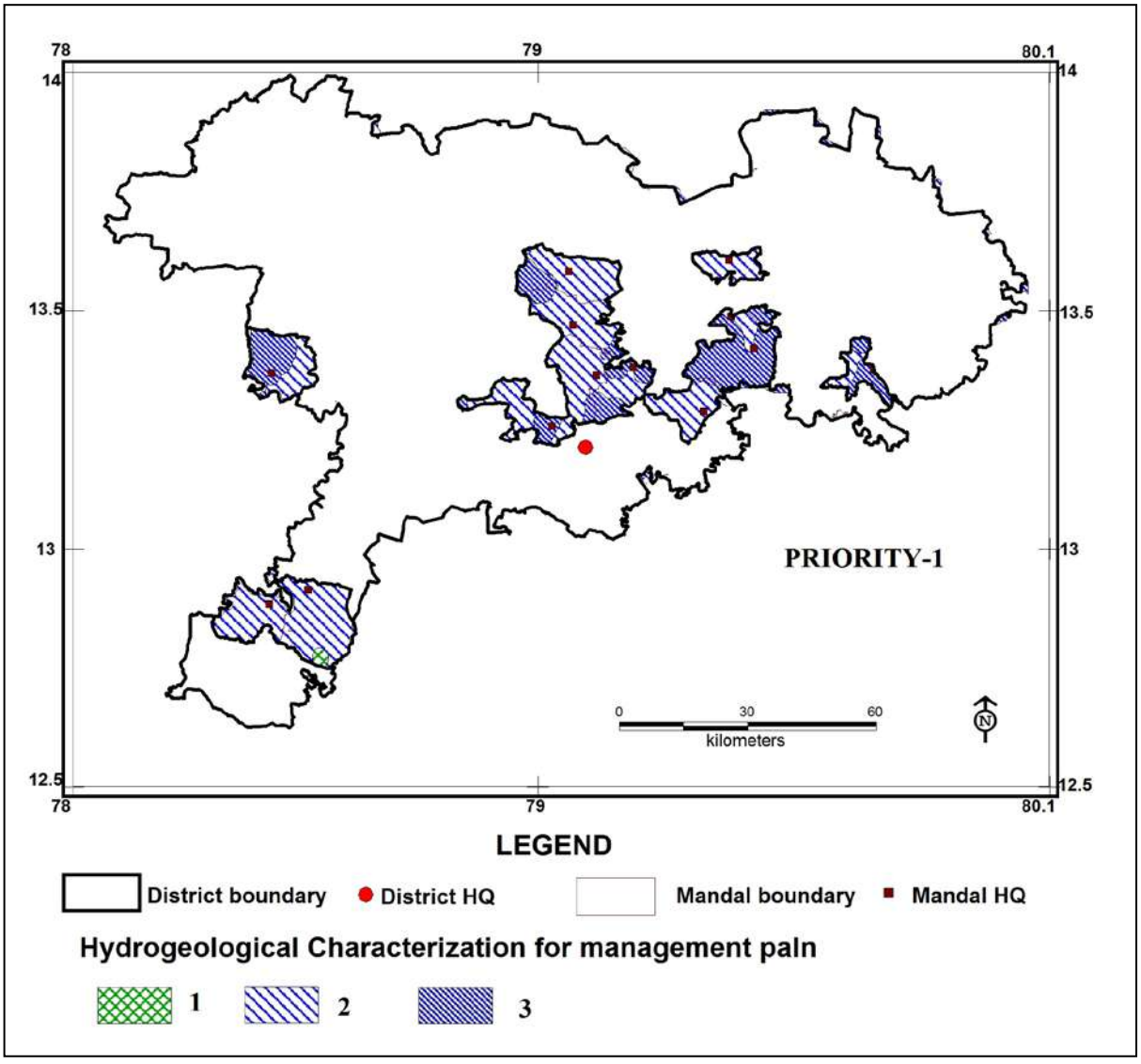

Fig.6.1: Management plan for Priority-1 area, Chittoor district.

6.1.1.2 Priority-2 (Area where groundwater development <100 %)

Area consisting 776 villages (partly and fully) covering ~8080 Km^2 (**Fig.6.2**) is considered as Priority-2. For sustainable development and management of the groundwater resources total 7278 ARS (CD: 6062 and PT: 1216) are recommended with total cost of 424.7 crores (**Annexure-2**).

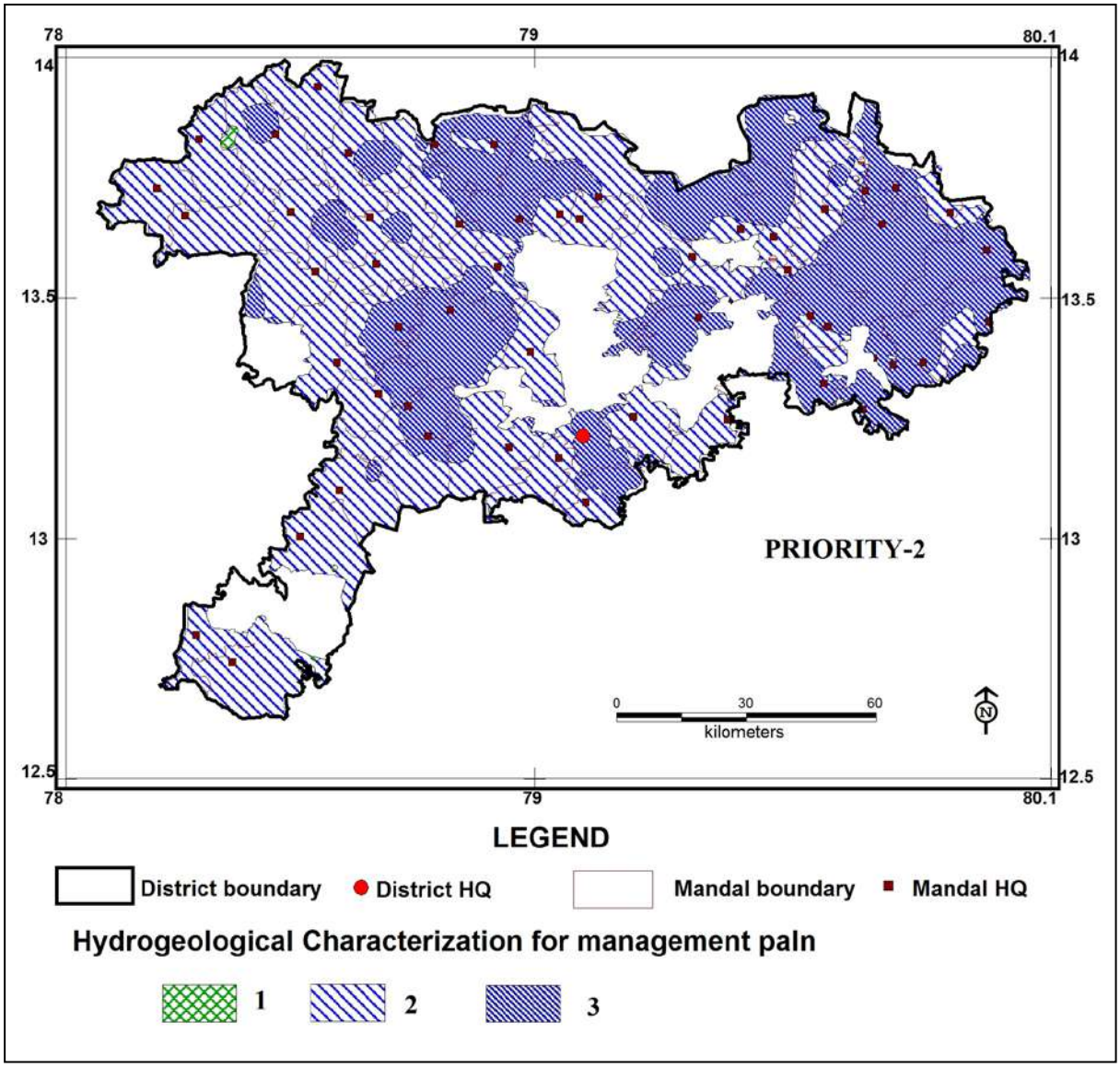

Fig.6.2: Management plan for Priority-2 area,Chittoor district.

Contemplated Projects:

Under Handri Niva Sujala Sravanthi (HNSS) drinking water supply scheme there is provision to supply drinking water needs of 10 lakh population and to create additional ~72840 hectare of irrigation potentential in Chittoor district at the cost of 1314.68 crores (up to March 2015). The scheme is to lift 40 TMC of surplus water from river Krishna at Malayala village in Kurnool district and out of 40 TMC, 9.8 TMC is allocated for Chittoor district.

As the scheme is to provide drinking water needs to 10 lakh population, there will be net saving of 21.9 MCM of ground water from the district.

Considering the 5827 MCM of water requirement for 72800 hectares (@0.08MCM/ha). If micro irrigation practices are implemented, than it will irrigate about 97000 hectares (additional 24200 hectares).

Water Conservation Measures (WCM) (Farm Ponds):

The farm ponds are the ideal water conservation structures, which are constructed in the low lying areas of the farm. The size of farm ponds can be 10 x 10 x 3 m. Total 32020 farm ponds are recommended (20 in each village in 1540 villages) with total cost of **80.05** crores.

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

6.1.2.1 Ongoing Work

NTR Jala Siri Scheme

- It is a flag ship programme of Govt of A.P. with assistance from NABARD and MGNREGS with objective to provide assured source of irrigation to the fallow and uncultivable land to poor SC/ST farmers of the state as a welfare measure with emphasis on micro-irrigation. Here ground water to be used as a community assest and beneficieries will share the access of ground water. So far in the district (till 6th March 2017) ~9090 ha of land benefitting ~11108 farmers (SC: 84%, ST: 15% and rest) costing ~31.65 crores is grounded. These measures might have saved ~18.2 MCM of ground water in the district so for.

- In the district till date a total number of 6065 ha of land is under micro-irrigation and thus saved ~12 MCM of groundwater from the district considering 25 % of net savings as compared to traditional practice of flood irrigation.

6.1.2.2 Proposed Work

Scenario-1:~Existing 1.634 lakh ha of land irrigated through groundwater (2013-14) can be brought under micro-irrigation costing about **980 crores** (considering 1 unit/ha @0.6 lakh/ha). With this **326 MCM** of ground water can be conserved over the traditional irrigation practices (considering 0.006 MCM/ha for pulses and other ID crops against 0.008 MCM/ha) or with same water 2.26 lakh ha land can be brought under irrigation.

Scenario-2 (on Priority): In 19 mandals (12 OE and 7 Critical), ~17,746 Ha of land is under sugarcane and paddy covering ~33% and 8% of the gross irrigated area. In the district sugarcane and paddy average yield per hector is 910 quintal/ha and 33.9 quintal/ha. Thus the total income of farmers from these 19 mandals is Rs **326.18 crores/year**.

Proposed Change in cropping pattern and support price (in OE and Critical mandals)

If change in cropping pattern is adapted from these water intensive crops to other ID crops like oil seeds (groundnut) ~54,300 ha of land can be brought under irrigation with same water. In the district groundnut average yield per hector is 11.31 quintal/ha and support price is Rs.4200/quintal. If the support price of groundnut is increased from present Rs.4200/quintal to Rs 5300/quintal than the total income of farmers will be **325.18** crores/year and this will compensate the farmers and the income will be equally distributed among more farmers (**Table-6.2**). If necessary more incentives and subsidy may be given to the farmers who are adopting the change in cropping pattern.

- As intended by the policy makers, good quality seeds should be provided to the farmers and MSP should be announced well in advance of the sowing season so as to enable the farmers to plan their cropping.

- Improved facilities at procurement centres, such as drying yards, weighing bridges, toilets, etc. should be provided to the farmers. More go downs should be set up and maintained properly for better storage and reduction of wastage.

Table-6.2: Present and Proposed status of water intensive and ID crops in Critical and OE mandals.

Crop (19 mandals) (Critical:7, OE:12)	**Total area (Ha)**	**Average Yield (Quintal/ha)***	**Total Yield (quintal)**	**Minimum support Price (Rs/Quintal)****	**Total Income (Rs in crores)**
Present Scenario					
Paddy	3642	33.9	123464	1470	18.15
Sugarcane	14104	910	12834640	240	308.03
Total	21306	-	12998332	-	**326.18**
Proposed Scenario					
Ground nut	54297	11.31	613556	5300***	**325.18**

(* CPO, 2015; **PIB, 2016; ***Proposed MSP).

- As a mandatory measure, every groundwater user should recharge rainwater through artificial recharge structures in proportionate to the extraction.

- Roof top rainwater harvesting structures should be made mandatory to all Government/industrial buildings (new and existing).

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

- 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 concerned farmers.

- In urban and rural areas the sewerage line should be constructed to arrest leaching of nitrate.

6.2 Expected results and out come

With the above interventions costing Rs **1565** crores (excluding the cost involved in HNSS project and NTR Jala Siri), the likely benefit would be increases in gross ground water irrigated area from 1.695 lakh ha to ~ 2.26 lakh ha or net saving of **~412** MCM of ground water (net reduction of 11% in stage of ground water). The other benefits will be more distribution of income among farmers. The onetime cost will be ~4 paise/liter (Rs 4/m^3 of water).

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