केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Vizianagaram District
Andhra Pradesh

दक्षिणी क्षेत्र, हैदराबाद

Sourthern Region, Hyderabad

भारत सरकार

जल शक्ति मंत्रालय

जल संसाधन नदी विकास एवम् गंगा संरक्षण विभाग

केंद्रीय भूमिजल बोर्ड

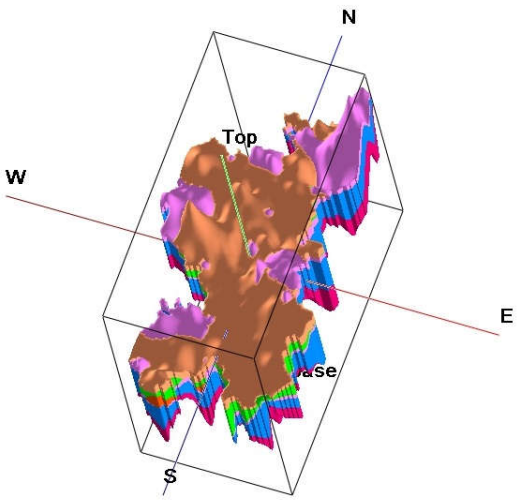
GOVERNMENT OF INDIA

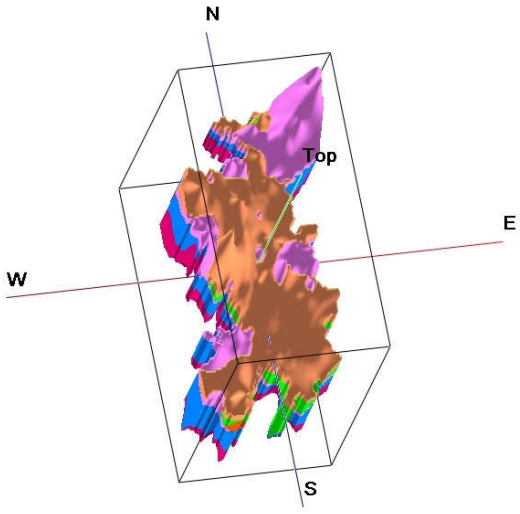
MINISTRY OF JAL SHAKTI

DEPARTMENT OF WATER RESOURCES, RD & GR

REPORT ON

AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN VIZIANAGARAM DISTRICT, ANDHRA PRADESH STATE





CENTRAL GROUND WATER BOARD

AP State Unit Office, Visakhapatnam

JUNE - 2022

REPORT ON

AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN HARD ROCK AREAS OF VIZIANAGARAM DISTRICT, ANDHRA PRADESH STATE

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REPORT ON

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AT A GLANCE

S. No.	Item		Particulars
1	Districts	:	Vizianagaram
2	Revenue Mandals	:	34
3	Villages	:	1551 Nos
4	Geographical area	:	6539 km^2
5	Mappable area	:	6133 km^2
5	Population (2011 Census)	:	23.44 lakh
6	Density of population (2011 Census)	:	361 persons/km^2.
7	Location	:	North latitude 17°15′ to 19°15′ East longitude 83°00′ to 83°45′
8	Rainfall (Normal)	:	1131 mm (SW: 71 % & NE: 11 %)
9	Geomorphology	:	Structural hills, Pediplain and Alluvium.
10	Major Rivers	:	Nagavali, Gosthani and Champavathi
11	Watersheds	:	10 minor basins 96 sub-basins 522 cascades
12	Land Utilization (Ha) (2019)	:	Total cropped area (~53%), area sown more than once (~12%), Forest (~18%), Barren and uncultivable land (11%), land put to non-agricultural uses (13%) and Cultivable waste (0.7%)
13	Soils	:	Clayey to gravelly clayey moderately deep Dark brown soils (24%), Loamy to clayey skeletal deep Reddish-brown soils (23%), Loamy to gravelly clay deep Dark reddish-

			brown soils (19%), Gravelly clayey moderately deep grass land soils (10%), Moderately deep calcareous black soils (9%), Gravelly loamy moderately deep grass land soils (7%), Fine loamy gravelly clayey shallow Reddish-brown soils (6%)
14	Cropping Pattern (2019)	:	**Kharif season:** Rice (82 %), Sugarcane (7 %), Dry fruits (5 %), Oil seeds (4 %) and Vegetable (2 %) **Rabi season:** Maize (36 %), Sugarcane (17 %), Dry fruits (12 %), Oil seeds (11 %), Seasmum (8 %), Rice (7 %), Vegetable (5 %)
15	Irrigation	:	**Ongoing major and medium irrigation projects**: o Thotapalli Barrage: 25113 ha (part ayacut) o Gajapathinaharam Branch Canal: 6070 ha o VKMN Janjhavathi: 9972 ha o Tarakarama Thirtha Sagaram: 10000 ha o Vengalarayasagar Project extension canal: 2023 ha o Andra HLC: 1659 ha **Proposed irrigation projects** o U.S.S: 160259 ha. **MI Tanks:** o 9226 no's (completed): 117176 ha o 428 no's (ongoing): 74000 ha
16	Prevailing Water Conservation/Recharge Practices	:	298 percolation tanks, 4285 Check dams, 51715 Farm ponds, 16677 others structures

			with combine capacity and storage of 64 and 22 MCM respectively. (Source: APWRIMS)
17	Geology	:	Khondalite (44%), Granite gneiss (39%), Charnockite (15%), Quartzite (1%) and Laterite (1%)
18	Hydrogeological data points	:	Hydrological Data: 346 Water Level: 68 (CGWB-24 & SGWD-44) Water Quality:108 (SGWD) Aquifer Geometry: 84 (CGWB: EW & OW), 52 (CGWB: VES), 34 (SGWD: VES) Geophysical: 52 (CGWB: VES)
19	Number of ground water structures	:	Irrigation: 22,180 no's of open wells, 16,207 no's of Bore wells and 3,105 no's Filter point wells.
20	Ground water yield (lps)	:	Granitic gneisses/Charnockite: < 0.1 to 5.2 lps (avg. < 1 lps) Khondalite: < 0.1 to 3.3 lps (avg. 1.5 lps). Yield <1 lps: ~20 % of area, 1 to 2 lps: 58 % and 2 to 3 lps: ~19 % of area Deepest Fracture: 199 m at Bobbili.
21	Water Levels (2020) Depth to water levels (m bgl)	: :	68 wells (CGWB:24, SGWD:44) DTWL: Avg. DTWL varies from 1.52 to 16.82 (m bgl) (avg. 6.25 m bgl) and 0.37 to 13.98 m bgl (average: 3.51 m bgl) during pre-monsoon and post-monsoon seasons respectively. WTE: Pre and post-monsoon season (May and November,2020), the water-table elevation ranges from 2.71 to 467.48 and 7.09

			to 468.91 meter above mean sea level (m amsl) respectively Pre-monsoon season: 5.0 to 10 m bgl in 68%, 2.0 to 5.0 m bgl in 26% and >10 m bgl in 5% of area. Post-monsoon: 2.0 to 5.0 m bgl in 73%, 5.0 to 10 m bgl in 15%, < 2.0 m bgl in 11% of area.
22	Water Level Fluctuations (May vs. November 2020)	:	Fluctuation ranges: 0.15 to 6.90 m. bgl. Fluctuation ranges: 2 to 5 m bgl in 89 %, 0 to 2 m bgl in 10% of area.
23	Long term water level trends (2011-20)	:	**Pre-monsoon:** o Falling trends: 54 wells (0.02 to 0.79 m/yrs.) o Rising trends: 14 wells show 0.01 to 0.22 m/yrs. **Post-monsoon:** Falling trends: 57 wells (0.01 to 1.24 m/yr) Rising trends: 11 wells show 0.01 to 0.89 m/yr.
24	Geophysical data (down to 200 m)	:	52 VES (CGWB) o Weathered khondalite (5.0 to 125 Ω m), Fractured khondalite (18 to 93 Ω m) Massive khondalite (53 to 940 Ω m). o Weathered charnockite (< 40 Ω m), Fracture charnockite (38 to 225 Ω m), Massive charnockite (> 3275 Ω m).
25	Hydrochemistry (2020)	:	Total 108 data Pre-monsoon (SGWD:104) Post-monsoon (SGWD:108)

25.1	Electrical Conductivity (µ Siemens/cm)	:	Pre-monsoon: 93 to 3950 µ Siemens/cm (avg. 1130), EC >3000 µ Siemens/cm covering < 1% area. Post-monsoon: 120 to 4362 µ Siemens/cm (avg. 1104), EC >3000 µ Siemens/cm covering < 1% area.	
25.2	Fluoride (mg/l)	:	Pre-monsoon: Fluoride concentration varies from 0.02 to 1.47 mg/L and is within permissible limits of 1.5 mg/L, except in Kothavalasa (1.72 mg/L) and Darmapuri (2.31 mg/L). Post-monsoon: Fluoride concentration varies from 0.03 to 1.31 mg/L and is within permissible limits (1.5 mg/L) except in Kothavalasa (2.34 mg/L)	
25.3	Nitrate (mg/l)	:	Pre-monsoon: Nitrate concentration varies between 0.28 to 40.19 mg/L and is with in permissible limits (45 mg/L), except in Jiyyammavalasa (46.96 mg/L) and Jannivalasa (51.54 mg/L) Post-monsoon: Nitrate concentration in all samples is below permissible limits of 45 mg/L, varies between 0.08 to 43.93 mg/L, except in Bhogapuram (66.87 mg/L) and Jannivalasa (58.14 mg/L)	
26	Conceptualization		Weathered zone (Aquifer-I): 6 to 57 m bgl	Fractured zone (Aquifer-II): 10 to 199 m bgl
27	Aquifer Characterization	:	Thickness of weathered zone: 20 to 40 m covering in	The fracture zones are more predominant in 90 to 100 m depth (34

			~67 % of area, 10 to 20 m occurs in ~31 % of the area Khondalite: 6 to 48 m bgl Granitic gneiss and Charnockite: meagre to 57 m bgl	% of the area), 60 to 90 m fractures occur in 29 % area; 120 to 150 m and 30 to 60 m fractures occur in 16 % and 13 % of area respectively. The deep fractures **>** 150 m occur in 8 % of area. Deepest fracture at 199 m at Bobbili.	
27.1	Aquifer wise Ground water yield	:	Yield of the wells in weathered zone vary from 0.03 to 3.0 lps	Yield in granitic gneisses aquifers varies from < 0.1 to 5.2 lps (avg. < 1 lps) and khondalite aquifers varies from < 0.1 to 3.3 lps (avg. 1.5 lps).	
27.2	Transmissivity (m^2/day)	:	-	0.144 to115 m^2/day	
27.3	Specific Yield	:	-	-	
27.4	Storativity	:	-	4.8 x 10^{-5} to 1.2 x 10^{-3}	
28	Ground water Resources (2020) MCM	:	**Command**	**Non-Command**	**Total**
28.1	Net Dynamic groundwater availability	:	1084.75	1171.60	2256.35
28.2	Gross GW Draft	:	103.41	323.80	427.21
28.3	Provision for Domestic utilization (2025)	:	15.00	39.39	54.40
28.4	Average Stage of Ground water development (%)		10.03	29.09	19.93

28.5	Net GW Availability for future use	:	921.21	782.13	1703.35
28.6	Categorization of mandals		All 34 mandals are categorized as Safe. The SOD varies from 2.8 % (Gummalakshmipuram) to 53.4% (Pusapatirega)		
29	Major Ground Water Issues Identified	:	Over all ground water scenario of the district is good except few issues related to sustainability and quality. **Groundwater Yield: L**ow yield (<1 lps) occurs in ~75 % of the district (<1 lps, 1 to 2 lps) **Deep water levels:** Deep water levels (**>** 10 m bgl) are observed during pre as well as post-monsoon seasons in 5 % and 2 % of the area respectively. Falling trend in the last 10 years is observed (0.02 to 0.79 m/yrs) during pre-monsoon and 0.01 to 1.24 m/yrs) during post monsoon. **Water Logging:** During post monsoon period, the water levels are < 2.0 m bgl (11% of area) in places around S.Kota, Gantyada, Vizianagaram, Nellimerla, Pusapatirega, Bobbili, Bandangi, Ballijipeta, Makkuva and Parvatipuram. **Pollution (Geogenic and Anthropogenic):** Nitrate more than **>**45 mg/l is observed in Jiyyammavalasa (46.96 mg/L) and Jannivalasa (51.54 mg/L) during pre-monsoon and Bhogapuram (66.87 mg/L) and		

			Jannivalasa (58.14 mg/L) during post-monsoon period. Fluoride more than >1.5 mg/l is observed in Kothavalasa (1.72 mg/L) and Darmapuri (2.31 mg/L) during pre-monsoon and at Kothavalasa (2.34 mg/L) during post-monsoon period. The high concentration of EC (>3000 µ Siemens/cm) in < 1 % of the area is observed during pre and post-monsoon period (along the coast line)
30	Ground Water Development and Management Strategies	:	Additional scope for ground water development by construction of bore wells for irrigation through PMKSY-HKKP (GW) / YSR Jalakala. Desiltation of existing CD's and PT's under MNREGS Adoption of micro irrigation In urban and rural area, the sewerage line should be constructed to arrest leaching of sewage.

ABBREVATIONS

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

EXECUTIVE SUMMARY

Vizianagaram district is one of the nine coastal districts of Andhra Pradesh with an aerial extent of 6,539 km^2 lies between north latitude of 17° 49' and 19° 10' and east longitudes of 83° 01' and 83° 49'. The district is divided into two revenue divisions viz., Vizianagaram and Parvathipuram and 34 revenue mandals. There are 14 towns, 1551 villages in the district. As per the 2011 census the population of the district is ~ 23.44 lakhs. The decennial growth rate from 2001 to 2011 is 4.22 percent. The density of population of the district is 361 persons per sq. km.

The district is physiographically comprises Eastern Ghats hilly region in the west and north. Plains with scattered hills in the central, southern and eastern parts. The topographic elevation of the hilly area varies from 300 to 950 m amsl, whereas the elevation of plains varies from 10 to 150 m amsl. The major rivers that drains the district are Nagavali, Gosthani and Champavathi and their tributaries viz. Suvarnamukhi and Vegavathi. They originate in the Eastern Ghats and after flowing through the district, joins Bay of Bengal. The drainage exhibits sub-dendritic to dendritic pattern, medium to coarse texture and drainage density is worked out to be 0.6 to 1 km/sq.km.

The normal annual rainfall of the district is 1131 mm of which SW monsoon 71 % and north-east monsoon contributes 11 %. During the year 2015, 2016, 2017, 2018 and 2019 the district received rainfall of 1014 mm (-10 % less), 1059 mm (-6% less), 994 mm (-12 less), 1071 mm (-5 less) and 841 mm (26 % less) rainfall respectively.

The area is underlain mainly by khondalites, granite gneiss, charnockites, quartzites and laterites. Geomorphologically, the district can be broadly divided into 4 distinct units viz.; structural hills, pediplains, alluvial plains and coastal plains. Total cropped area is ~53%, area sown more than once is ~12%, forest occupies ~18%, barren and uncultivable land is 11%, land put to non-agricultural uses is 13% etc. of the total geographical area. During Kharif season, main crops grown are rice, sugarcane, dry fruits, oil seeds and vegetable etc. During Rabi season, main crops grown are maize, sugarcane, dry fruits, oil seeds, seasum, rice, vegetable etc. The soils are clayey to gravelly clayey (24%), loamy to clayey skeletal (23%), loamy to gravelly clay (19%), gravelly clayey (10%), moderately

deep calcareous black soils (9%), gravelly loamy moderately deep grass land soils (7%), fine loamy gravelly clayey (6%) etc.

The ongoing major irrigation projects are Thotapalli Barrage, Gajapathinaharam Branch Canal with total 31183 hectares ayacut. The ongoing medium irrigation projects are VKMN Janjhavathi Reservoir Project, Tarakarama Thirtha Sagaram Reservoir Project, Vengalarayasagar Project extension canal and Andra HLC (Champavathi River) with total 23653 hectares ayacut. Besides these, a total of 9226 no's completed and 428 no's ongoing minor irrigation tanks exist in the district with an ayacut of 117173 hectares and 73998 hectares respectively. There are 298 percolation tanks, 4285 Check dams, 51715 Farm ponds and 16677 other artificial recharge structures (ARS) and water conservation structures (WCS) with combine capacity and storage is 64 and 22 MCM respectively.

CGWB drilled 84 no's bore wells (70 no's exploratory and 14 no's observation wells), 65 wells were drilled in granite gneiss area and 19 wells were drilled in khondalitic area. Ground water yield of granitic gneisses aquifers varies vary from <0.1 to 5.2 lps (avg. < 1 lps) and khondalite aquifers varies from <0.1 to 3.3 lps (avg. 1.5 lps). Majority of fractures occur within 90 to 100 m depth and deepest fracture is encountered at 199 m bgl at Bobbili.

Geophysical data from 52 VES data (CGWB) reveals resistivity 5.0-125 Ω m for the weathered khondalite (5-46 m), 18-93 Ω m for underlying fractured khondalite with depth ranges between 24-95 m and 53-940 Ω m for massive khondalite. The resistivity < 40 ohm (Ω) m for the weathered charnockite (7-25 m), 38-225 Ω m for underlying fractured charnockite (30-107 m) and > 3275 Ω m for massive charnockite rocks. A major lineament (A-A') was traced in the central part of the investigated district with a trend of NW-SE for a length of 95 kms and river Champavathi is observed to be following this lineament.

Water levels are being monitored through 68 Piezometers (CGWB: 24 & SGWD: 44) during pre and post-monsoon season. The DTW varies from 1.52 to 16.82 m bgl (avg. 6.25 m bgl) and 0.37 to 13.98 m bgl (avg. 3.51) during pre and post-monsoon season respectively. During pre-monsoon season, 5.0 to 10 m water level covering 68% of the area, followed by 2.0 to 5.0 m bgl (26%) and >10 m bgl (5%). During post-monsoon season, 2.0 to 5.0 m water level covering 73% of the area, followed by 5.0 to 10 m bgl (15%), < 2.0 m bgl (11%). Water

level fluctuation (Nov'2020 Vs. May'2020) data indicates that water levels rise is observed throughout the district. Water level fluctuations vary from 0.15 to 6.90 m with average rise of 2.74 m. Long-term water level trends during pre-monsoon, 54 wells show falling trends ranging 0.02 to 0.79 m/yrs and 14 wells shows a rising trend in the range of 0.01 to 0.22 m/yrs. During post-monsoon season, 57 wells show falling trends in the range of 0.01 to 1.24 m/yrs and 11 wells show rising trends in the range of 0.01 to 0.89 m/yrs.

During Pre and post-monsoon season, EC is in the range of 1000 to 2000 µ Siemens/cm covering 56% and 57 % of area respectively. During pre-monsoon season, Nitrate concentration varies between 0.28 to 40.19 mg/L and is within permissible limits of 45 mg/L except in Jiyyammavalasa (46.96 mg/L) and Jannivalasa (51.54 mg/L). Fluoride concentration varies from 0.02 to 1.47 mg/L and is within permissible limits of 1.5 mg/L, except in Kothavalasa (1.72 mg/L) and Darmapuri (2.31 mg/L). In post-monsoon, Nitrate concentration varies between 0.08 to 43.93 mg/L and is within permissible limits of 45 mg/L, except in Bhogapuram (66.87 mg/L) and Jannivalasa (58.14 mg/L). Fluoride concentration varies from 0.03 to1.31 mg/L and is with in permissible limit of 1.5 mg/L and except in Kothavalasa (2.34 mg/L).

The aquifers of the district can be conceptualized in to **Aquifer-1** (weathered zone and contiguous semi weathered and fractured zones) up to the depth of 30-35 m and **Aquifer-2** (discrete fracture zone occurring in between 35 to 200 m depth). However, the weathered thickness varies from 6 to 57 m and occurrence of fractures varies from 10 to 199 m. The weathered thickness in the range of 20 - 40 m occurs in ~67 % of area, 10 to 20 m occurs in ~31 % of the area and shallow (<10 m) and deeper (>40 m) weathering occurs in rest of the area. Ground water yield of this zone varies from 0.03 to 3.0 lps. The occurrence of fractures in the depth range of 90 to 100 m is more predominant (34 % area) followed by occurrence with in the depth ranges of 60 to 90 m (29 % area). The fracture occurs between 120 to 150 m and 30 to 60 m depth in 16 % and 13 % of area respectively. The deep fractures (>150 m) occur in 8 % area. The discharge in the exploratory wells vary from meagre to as high as 5.2 lps with general range of 0.1 to 2.0 lps. The specific capacity of the bore wells varies from 1.05 to 72.7 lpm /m.d whereas the Transmissivity ranges from 0.144 to115 m^2/day. The storage co-efficient of bore wells vary from 4.8 x 10^{-5} to 1.2 x 10^{-3}.

Net dynamic replenishable ground water availability as on 2020 is 2256 MCM, gross ground water draft is 427 MCM, provision for drinking and industrial use for the year 2025 is 54 MCM and net available balance for future use is 1703 MCM. The stage of ground water development varies from 2% to 53% (avg. 19 %). In Vizianagaram district, the present stage of ground water development is low (19%). The total utilization of ground water is 427 MCM against the total ground water potential of 1703 MCM available for future use. Ground water irrigation in the district is accounts only for 38 % of the net irrigation of the district. There is an additional scope for ground water development in the district. Under PMKSY-HKKP-GWI/YSR Jala Kala, the Govt. of Andhra Pradesh proposed to bring 16385 hectares through ground water irrigation by construction of 15849 ground water extraction structures in 1219 villages with an estimated cost 745.34 crores.

The overall ground water scenario of the district is good except few issues related to sustainability and quality. Low yield (<1 lps) occurs in ~20 % of the district and 1 to 2 lps yield occurs in ~58 % of the district. Deep-water levels (>10 m bgl) are observed in 5 % and 2 % of the area during pre and post-monsoon periods respectively. The long-term water level trends (10 years) indicate falling trend in the range of 0.02 to 0.79 m/yrs during pre-monsoon and 0.01 to 1.24 m/yrs during post monsoon periods. The coastal parts of the district, in Bhogapuram and Pusapatirega, the EC of groundwater is higher than other parts of the district. Nitrate and fluoride beyond permissible limits occur in isolated patches of the district.

A total 4940 recharge structures (4045 check dams, 493 check walls, 269 PT's and 133 mini-PT's) were already constructed through MGNREGS and IWMP schemes in the district with a density of one artificial recharge structure per square km area. Considering the existing no. of AR structures in the district, it is recommended for desiltation and maintenance of all existing CD's and PT's. In future, artificial recharge structure can be taken up in specific areas, where vulnerabilities for groundwater resources increase.

As the yield of bore wells is low, adoption of micro irrigation through drip and sprinkler with suitable cropping pattern wherever feasible may be practiced as a measure for groundwater conservation, protection and management.

In areas S. Kota, Gantyada, Vizianagaram, Nellimerla, Pusapatirega, Bobbili, Bandangi, Ballijipeta, Makkuva and Parvatipuram, which are prone to water logging, It is recommended for conjunctive use of surface and ground water. In urban and rural area, the sewerage line should be constructed to arrest leaching of sewage.

Upon completion of the ongoing Thotapalli Barrage Project and Uttarandhra Sujala Sravanthi (USS), the irrigation facilities through surface water will be assured in the district. The existing ayacut can be stabilized and new ayacut will be created. The stress on ground water will be further reduced and additional ground water recharge will take place due to infiltration form tank storage, canal seepage and return irrigation.

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

S. No.	Data	Aquifer	Total Data Points	Source	
				CGWB	SGWD
1	Panel Diagram (3-D)	Combine	170	Expl:84 VES:52	34
2	Hydrogeological Sections	6 no	170	Expl:84 VES:52	34
3	Fence/panel Diagrams	1 no	170	Expl:84 VES:52	34
4	Depth of weathering	1 no	170	Expl:84 VES:52	34
5	Depth of fracturing	1 no	170	Expl:84 VES:52	34
6	Groundwater Yield	Combine	63	63	-
7	Transmissivity (m^2/day)	Combine	48	48	-
8	Depth to Water Level Maps (2020)	Combine	68	24	44
9	Water Level Fluctuation	Combine	68	24	44
10	Long term water level trends	Combine	68	24	44
11	Water quality Pre-2020 Post-2020	Combine	212 Pre:104 Post:108	- -	SGWD:104 SGWD:108

1. INTRODUCTION

Aquifer mapping is a process wherein a combination of geological, geophysical, hydrological and chemical analyses is applied to characterized 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 rock 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 for sustainable development and management of ground water resources of the country. As a part of NAQUIM in Andhra Pradesh, the Vizianagaram district has been selected and completed during AAP 2021-2022.

Hard rock (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 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 comprehensive aquifer map and to suggest suitable groundwater management plan on 1: 50,000 scale in Vizianagaram district, Andhra Pradesh.

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, 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 Vizianagaram district, Andhra Pradesh having geographical area of 6,539 km^2, lies between north latitude 17°15′ to 19°15′ and east longitude 83°00′ to 83°45′(**Fig.1.1**). Administratively the district is governed by 34 revenue mandals and 1551 revenue villages with a population of ~23.44 lakhs (2011 census) (urban: 21 %, rural: 79 %). The density of population is 361 persons/ km^2 and there is an increase in 4.22 % growth rate over last 10 years. (2011 census)

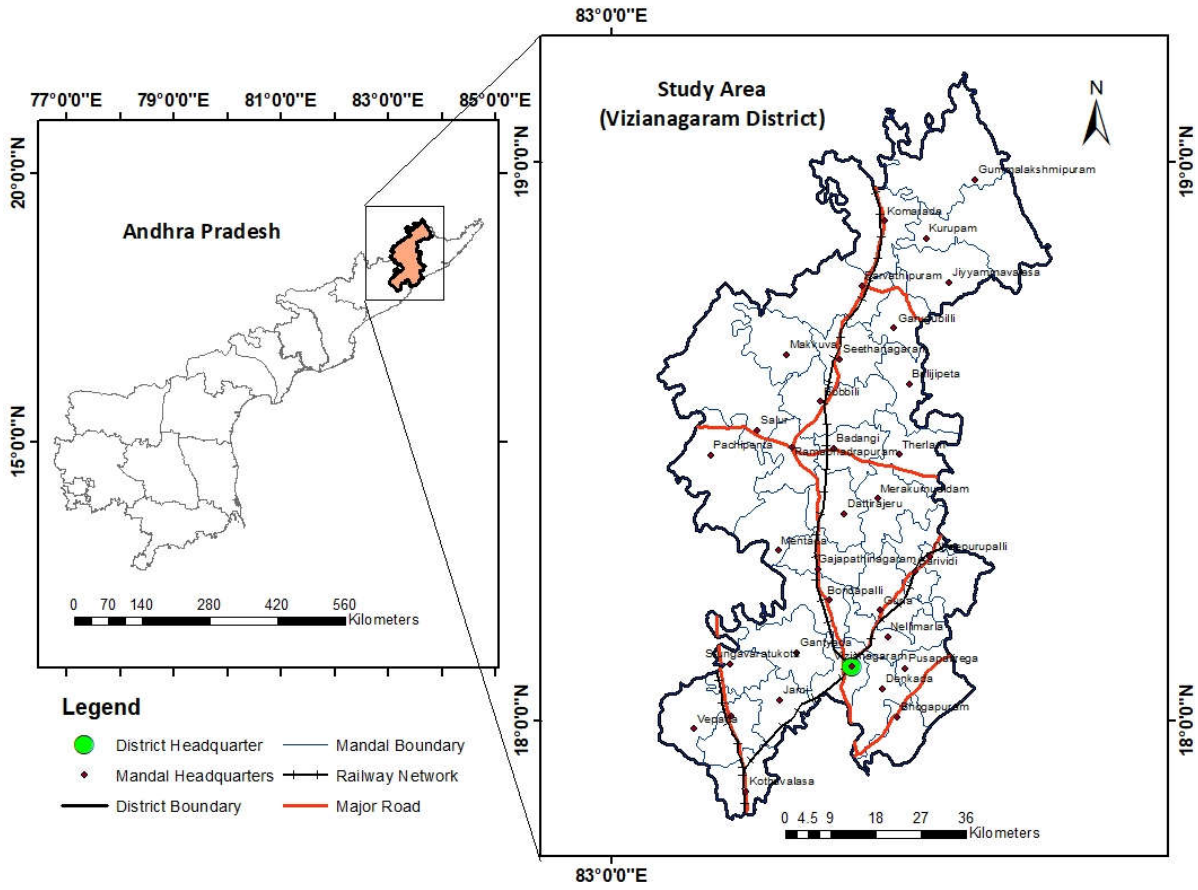

Fig.1.1: Location map of Vizianagaram district.

1.4 Climate and Rainfall: The climate of the district is moderate and characterized by high humidity all through the year and good seasonal rainfall. The mean daily maximum temperature in the district is about 35°C and the mean daily minimum temperature is about 27°C. The mean monthly relative humidity is 79%. The relative humidity increases after the onset of monsoon.

The normal annual rainfall of the district is 1131 mm (Indian Meteorological Department). This varies between 685 mm (Bhogapuram) to 1140 mm (Kurupam) (**Fig.1.2**). The South west monsoon (June to September) contributes ~71 %, North east monsoon (October to December) contributes ~11%, and remaining by winter and summer season. During the year 2015, 2016, 2017, 2018 and 2019 the district received rainfall of 1014 mm (-10 % less), 1059 mm (-6% less), 994 mm (-12 less), 1071 mm (-5 less) and 841 mm (26 %

less) rainfall respectively. The annual rainfall and trend of annual rainfall are depicted in **Fig.1.3**

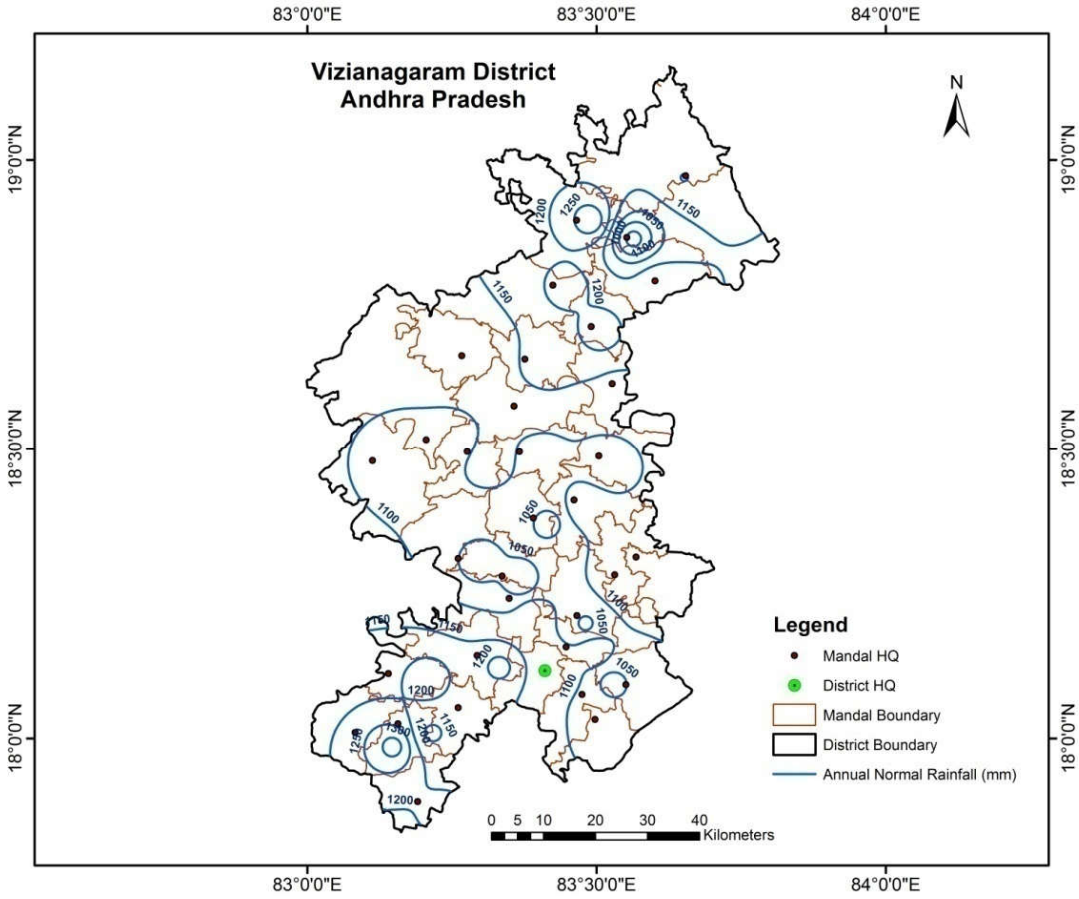

Fig.1.2: Isohyetal map of Vizianagaram district.

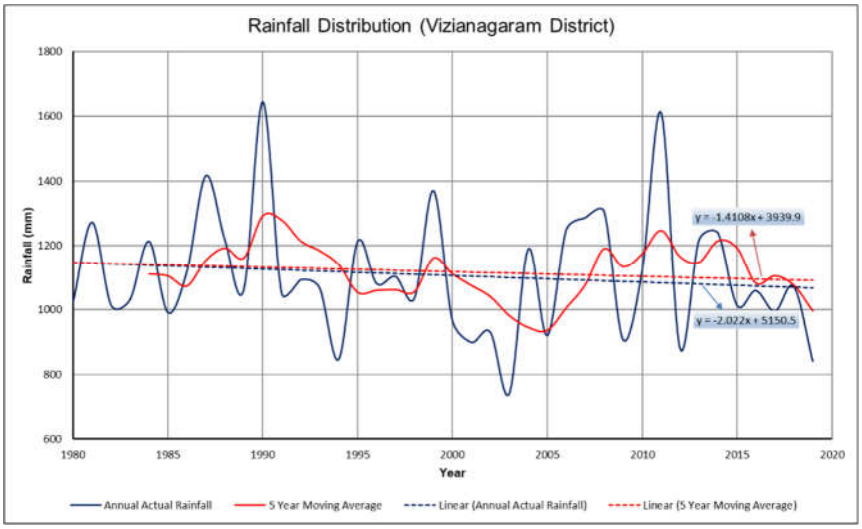

Fig.1.3: Annual rainfall and trend of annual rainfall of Vizianagaram district.

1.5 Geomorphological Set up: Geomorphologically, the district can be broadly divided into 4 distinct units viz.; structural hills, pediplains, alluvial plains and coastal plains. The western and northern parts of Vizianagaram district are occupied by structural hills and also, they occur in isolated patches. They occur as linear to arcuate hills showing definite trend lines and all are composed of charnockites and Khondalites. The pediplains occupy larger parts of the district, comprising shallow buried pediplain, deeply buried pediplain, pediment, residual hills and inselbergs of granites and gneisses. Generally, they form poor aquifers except along the major fractures. The pediment is a broad and generally sloping rocky surface with low relief and thin veneer of detritus.

The alluvial plains are developed along major river courses, valleys and at the feet of structural hills in the district. The alluvial plains along major river courses are known as flood plains and consist of unconsolidated gravels, sands, silts and clays and are generally capable of giving very high yields. The occurrence of alluvial plains in the district is seen partly in the northwest, northeast and in the central mid plains and also in the southeast and south western parts. The coastal plain occurs parallel and nearer to the sea and is of marine origin consisting of generally saline aquifers except on beach ridges where moderate to fresh water aquifers occur. The beach ridges are suitable for construction of very shallow dug wells of 2 to 3 m in depth and infiltration galleries. **(Fig.1.4.)**

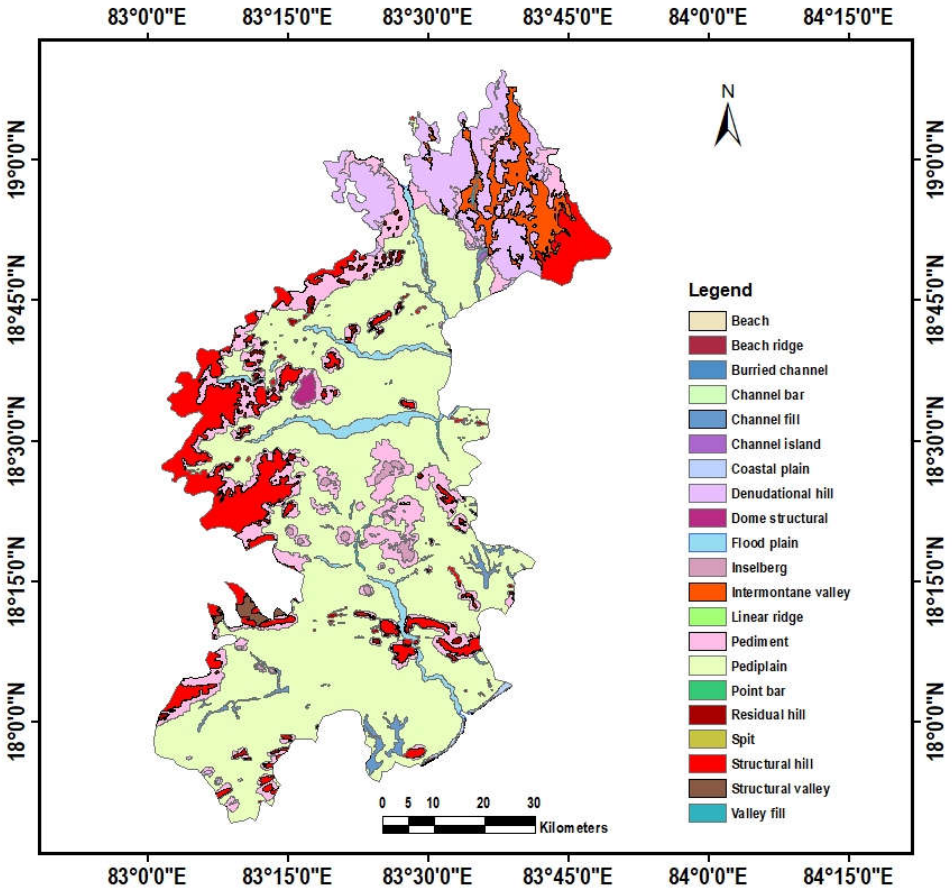

Fig.1.4: Geomorphological map of Vizianagaram district.

1.6 Drainage and Structures: Six rivers draining the district, viz. Nagavali, Gosthani, Suvarnamukhi, Champavathi, Vegavathi, and Gomukhi. They originate in the Eastern Ghats and after flowing through the district, finally join Bay of Bengal. The Nagavali also known as the Langulya in the lower reaches, is the main river in the district. Its total length is 200 km and flows for about 112 km in Vizianagaram district. The total catchment area of this river is 8,964 sq. km. The annual flow of water in this river is about 1.21 million hectares. The main tributries of this river are Vegavathi, Suvarnamukhi, Janjhavathi and Vottigedda.

The Nagavali, Champavathi and Gosthani basin covering major portion of the district; Vamsadara basin occupy in northern part; Peddagedda and Kandivalasagedda basin occur in SE part and Sarada basin in SW part of the

district. The drainage exhibits sub-dendritic to dendritic pattern, medium to coarse texture and drainage density is worked out to be 0.6 to 1 km/sq.km.

The district has consolidated formations which include crystalline (khondalites, charnockites and granitic gneisses) and meta sediments (dolomites, shales, phyllites and quartzites) of Archaean and Pre-cambrian ages respectively. The khondalite group of rocks are seen as prominent hill ranges (strike ridges). The rocks of khondalite, charnockite groups and the layered complex show foliation trending dominantly N-S with local swerves to NE-SW and NW-SE (Map depicting drainage, river and basin is presented in **Fig.1.5**.)

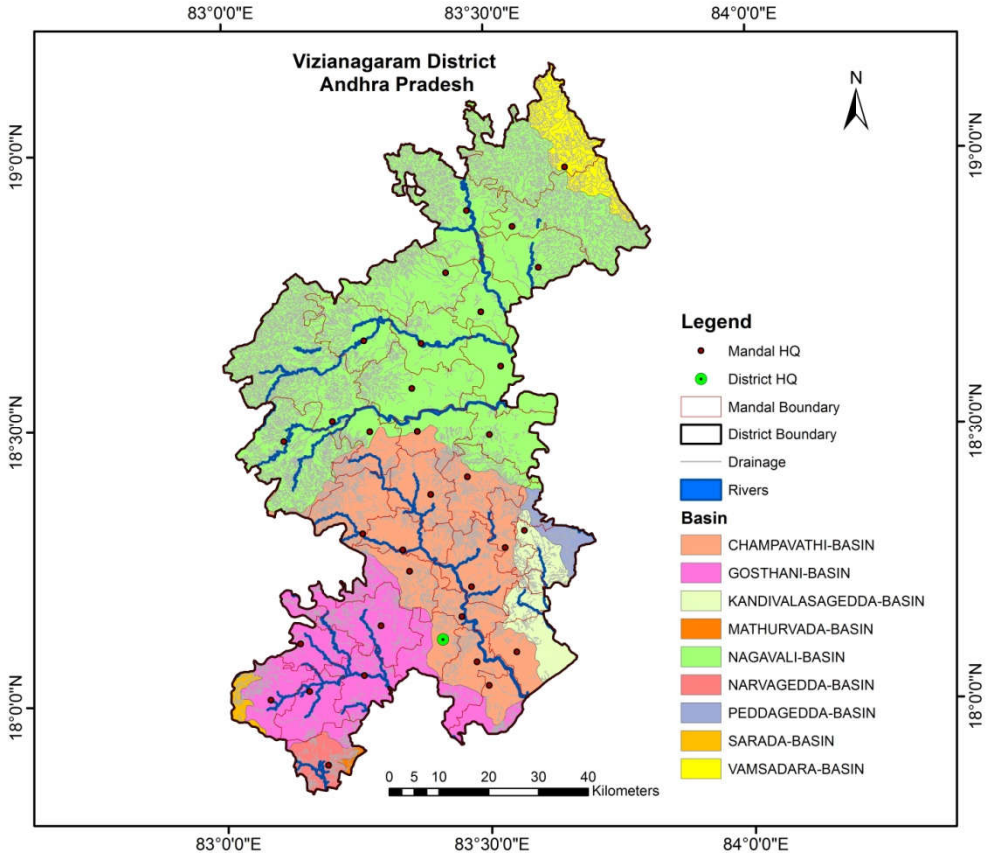

Fig.1.5: Drainage and Basin map of Vizianagaram.

1.7 Land use and cropping pattern: Total cropped area is 345860 ha (~53%), area sown more than once is 74479 ha (~12%), forest occupies 119303 ha (~18%), barren and uncultivable land is 72981 ha (11%), land put to non-

agricultural uses is 81629 ha (13%), cultivable waste is 4221 ha (0.7%) etc. of the total geographical area.

During Kharif season, main crops grown are rice (82 %), sugarcane (7 %), dry fruits (5 %), oil seeds (4 %) and vegetables (2 %) etc. During Rabi season, main crops grown are Maize (36 %), Sugarcane (17 %), dry fruits (12 %), oil seeds (11 %), seasmum (8 %), rice (7 %), vegetable (5 %) and cotton etc. The other crops are onion, sunflower, chillies etc. Land use and land cover map of the district is depicted in **Fig. 1.6.** The season wise irrigated area **(Fig.1.6a)** and season wise cropping pattern is given in **Fig.1.6b** and **Fig.1.6c.** In the district there are 405100 marginal farmers (< 2.47 acres of land), 59765 small farmers (2.47 to 4.93 acres), 23689 semi-medium (4.94 to 9.87 acres), 7769 medium (9.88 to 24.7 acres) and 738 large farmers (> 24.71 acres)

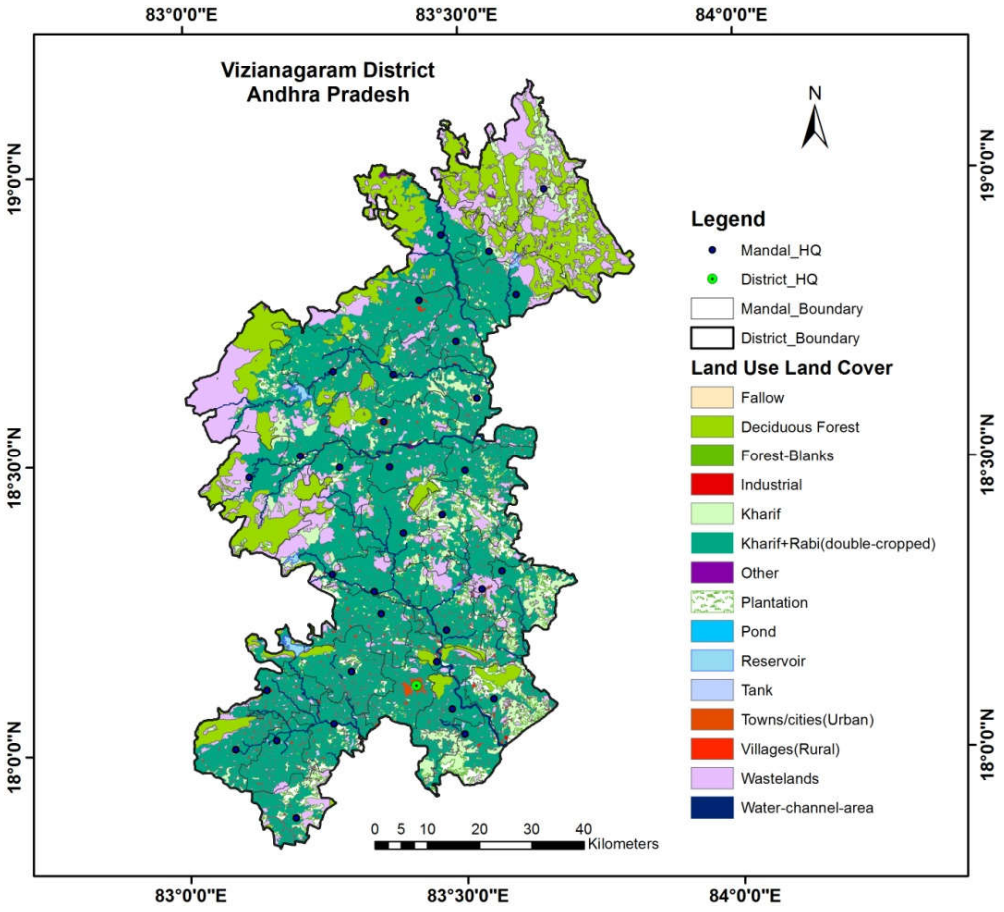

Fig.1.6: Land use and land cover map of Vizianagaram district.

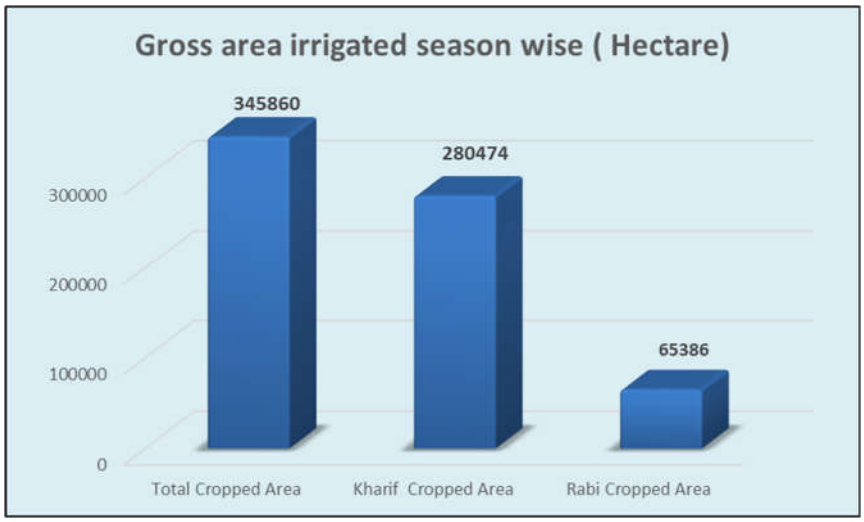

Fig.1.6a: Irrigated area season wise.

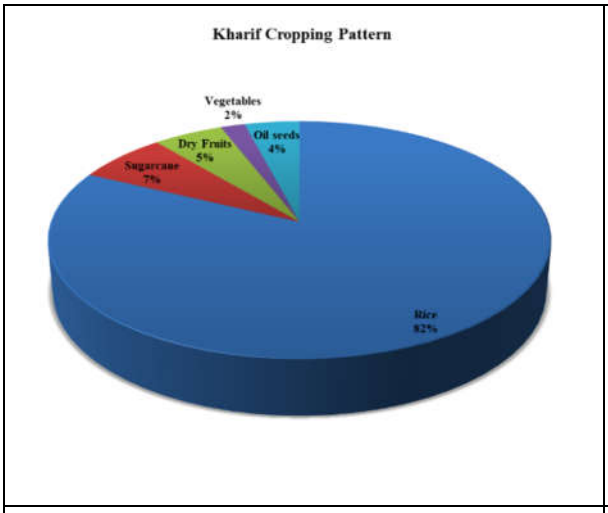

Fig.1.6 b:Cropping pattern in Kharif

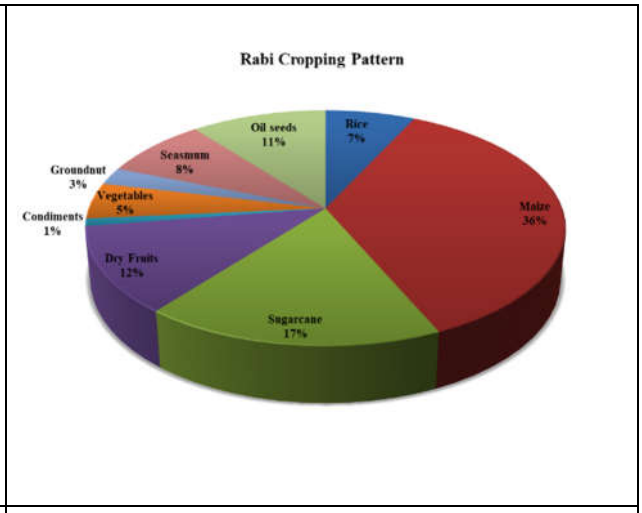

Fig.1.6 c:Cropping pattern in Rabi

1.8 Soils: The area is mainly occupied by Clayey to gravelly clayey moderately deep dark brown soils (24%), Loamy to clayey skeletal deep reddish brown soils (23%), Loamy to gravelly clay deep dark reddish brown soils (19%), gravelly clayey moderately deep grass land soils (10%), moderately deep calcareous black soils (9%), Gravelly loamy moderately deep grass land soils (7%), Fine loamy gravelly clayey shallow reddish brown soils (6%) etc. of the total geographical area. (**Fig.1.7**)

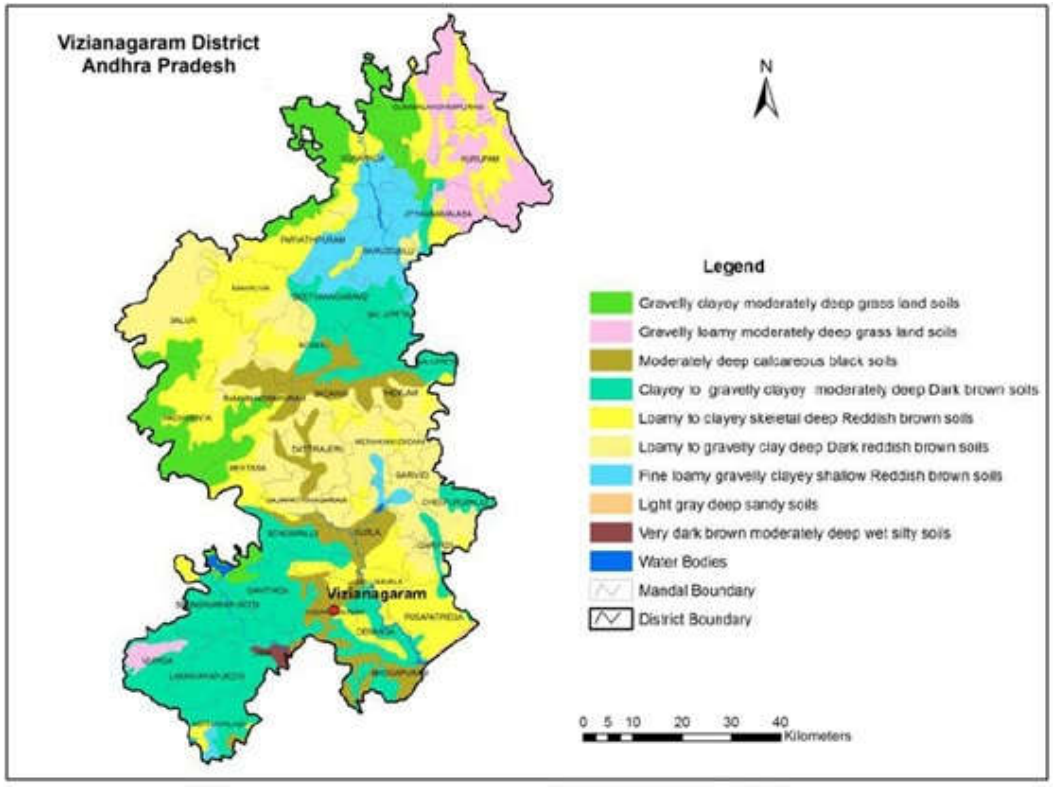

Fig.1.7: Soil map of Vizianagaram district (Source: District survey report-2018)

1.9 Irrigation:

The major river basin of the district are Nagavali, Champavathi, Gosthani and Kandivalusagedda and tributaries of Nagavali are Vottigedda,Jhanjhavathi, Gomukhi, Suvarnamukhi and Vegavathi.

The major irrigation projects completed in Vizianagaram district are Thotapalli Regulator (Nagavali River) with 3527 hectares (part ayacut). The ongoing major irrigation projects are Thotapalli Barrage Project (Nagavali River) with 25113 hectares (part ayacut) and Gajapathinaharam Branch Canal (taking-off from Thotapalli RMC) with 6070 hectares ayacut. The total ayacut under ongoing major irrigation project is 31184 ha.

The medium irrigation projects completed in the district are Vengala Raya Sagaram Project with an ayacut of 9996 ha, Vottigedda Reservoir

with an ayacut of 6740 ha, Peddankalam Anicut with 3113 ha, Paradhi Anicut with 3314 ha, Thatipudi Resrvoir with 6184 ha, Andhra Reservoir Project with 3814 ha, Denkada Anicut with 2106 ha, Pedda Gedda Reservoir Project with 4856 ha of ayacuts. The total completed medium irrigation project is 40138 ha ayacut. The ongoing medium irrigation projects are VKMN Janjhavathi Reservoir Project (Janjhavathi - Nagavali River) with an ayacut of 9972 ha, Tarakarama Thirtha Sagaram Reservoir Project (Champavathi River) with 10000 hectares ayacut, Vengalarayasagar Project extension canal (Suvarnamukhi - Nagavali River) with 2023 hectares ayacut and Andra HLC (Champavathi River) with 1659 hectares ayacut. The total ongoing medium irrigation project is 23654 hectares ayacut. **(Fig.1.8)**

A total of 9226 no's completed and 428 no's ongoing minor irrigation tanks exist in the district with an ayacut of 117176 hectares and 74000 hectares ayacut respectively.

There are about 22,180 no's of open wells, 16,207 no's of Bore wells and 3,105 no's Filter point wells in the District. Under Open wells 26439 hectares and under Bore wells & Filter points 30421 hectares is being cultivated in the district. The area irrigated under different sources is depicted in **Fig.1.8a**.

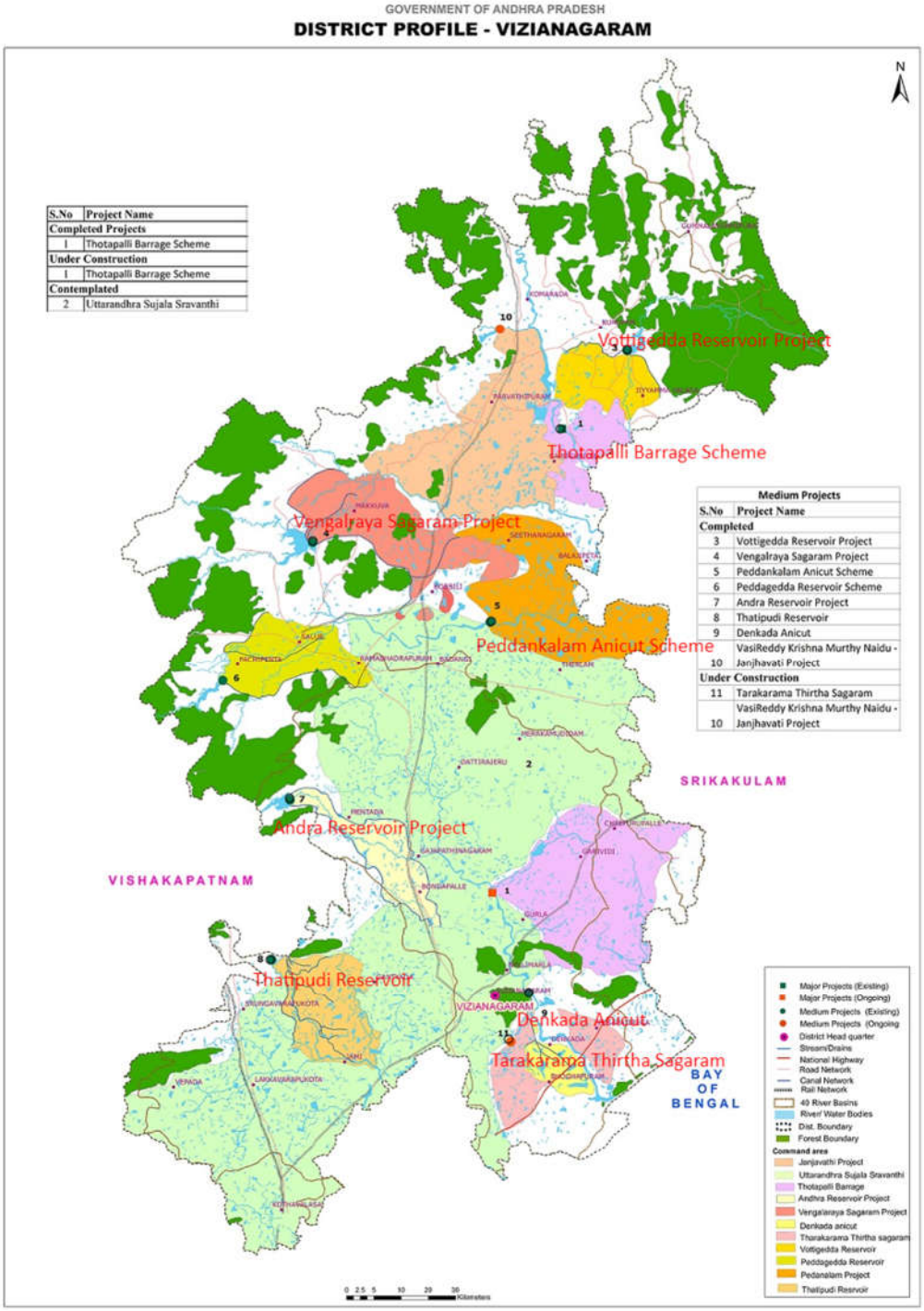

Fig. 1.8: Major and Medium Irrigation Projects of Vizianagaram District (Source: Water Resource Department)

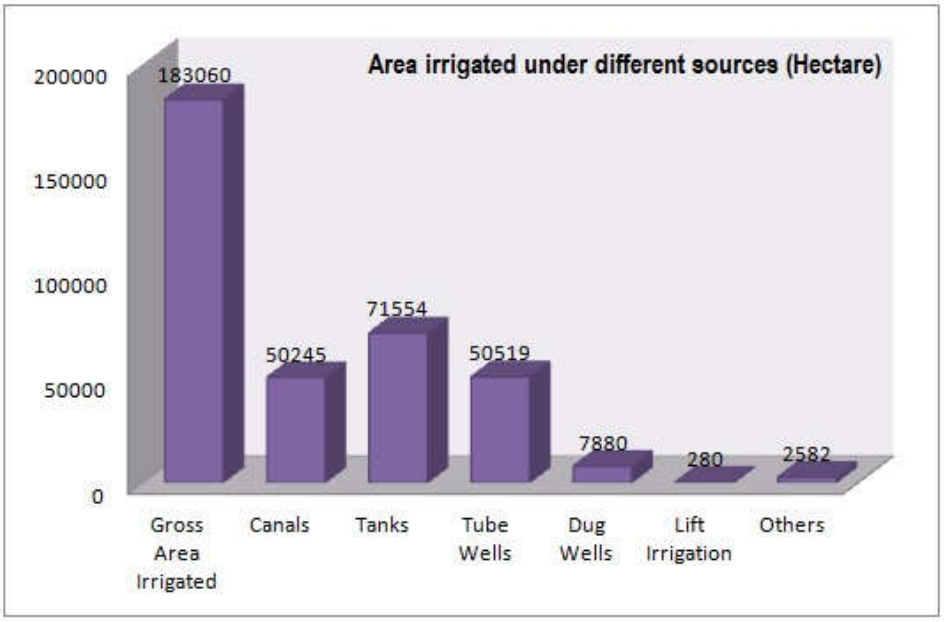

Fig. 1.8a: Area irrigated under different sources.

1.10 Prevailing water conservation/Recharge practices: In the district there are 298 percolation tanks, 4285 Check dams, 51715 Farm ponds and 16677 other artificial recharge structures (ARS) and water conservation structures (WCS) with combine capacity and storage is 64 and 22 MCM respectively. (Source: APWRIMS)

1.11 Geology: The Vizianagaram district is underlain by various geological formations, namely Khondalite (44%), Granite gneiss (39%), Charnockites (15%), Quartzite (1%) and Laterite (1%). The Khondalite group include quartzite, talc-granulite, talc-silicate, garnetiferrous quartzo-feldspathic gneisses with sillimanite and graphite. The Charnockite group include pyroxene granulite (basic charnockite) and charnockite (acid/intermediate). The Migmatite group include porphyroblastic hypersthene-biotite gneiss, hypersthene-quartz-feldspar augen gneiss, cordierite-hypesthene gneisses with biotite and granitoid gneiss. The Upper Gondwanas and Tertiaries are represented by sandstones and shales, but these formations are not exposed in the study area as laterite occur as capping on the Khondalite. The alluvium occurs along the river

courses consisting of sandy clay, sands and gravel. The general geological succession of the area is given in **Table 1.1** & **Fig.1.9.**

Table 1.1: Geological Succession of the Study Area

Age	Super Group	Group	Formation	Lithology
Quaternary			Soils/Alluvium	Soil, sand, silt and clay.
Cenozoic			Laterite	Laterite
Cretaceous to Jurassic		Upper Gondwana	-	Sandstones and clays
Archaean	Eastern Ghat Super Group	Migmatite Group	Younger Intrusive	Pegmatites and quartz veins Porphyroblastic charnockites Porphyroblastic gneissic granites
			Migmatites	Biotite gneisses Charnockites Migmatised quartzite Cordiorite bearing gneisses Migmatised sillimanite gneisses
			Old Intrusive	Quartzo feldspathic gneisses
		Charnockite Group	Basic Charnockite	Pyroxene granulites
		Khondalite Group	Khondalite Suite (Meta sediments)	Calc-sillicate rocks Quartzites Granites sillimanite gneisses

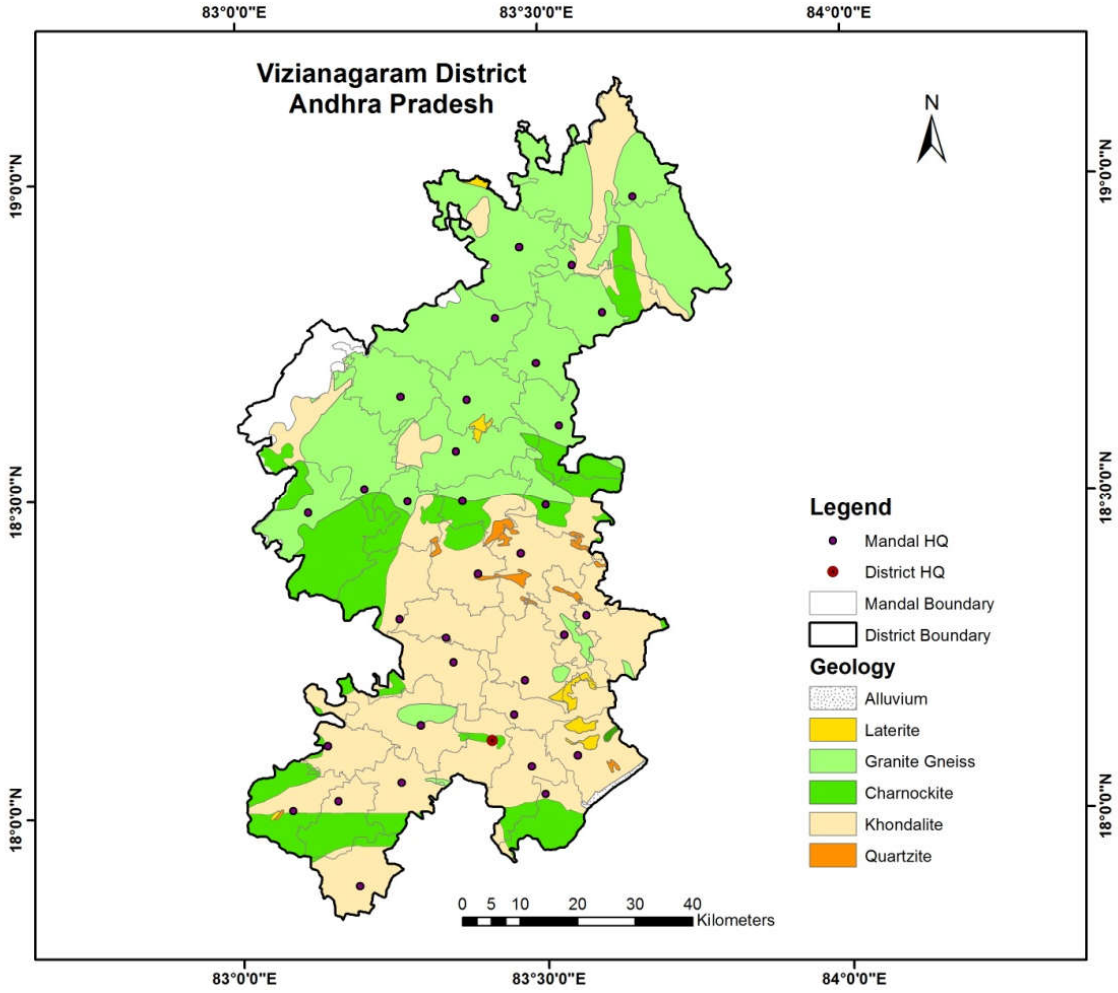

Fig.1.9: Geological map of Vizianagaram district.

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 granites gneisses, Charnockites, khondalites, migmatites, quartzites and intrusives. 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 346 hydrogeological data points, hydrogeological map is prepared. (**Fig.2.1)** The details of data availability is given bellow-

Organisation	Water Level	Water Quality	Aquifer Geometry			Geophysical
			EW	OW	VES	VES
CGWB	24	-	70	14	52	52
State GW Dept.	44	108	-	-	34	-
Total	68	108	70	14	86	52

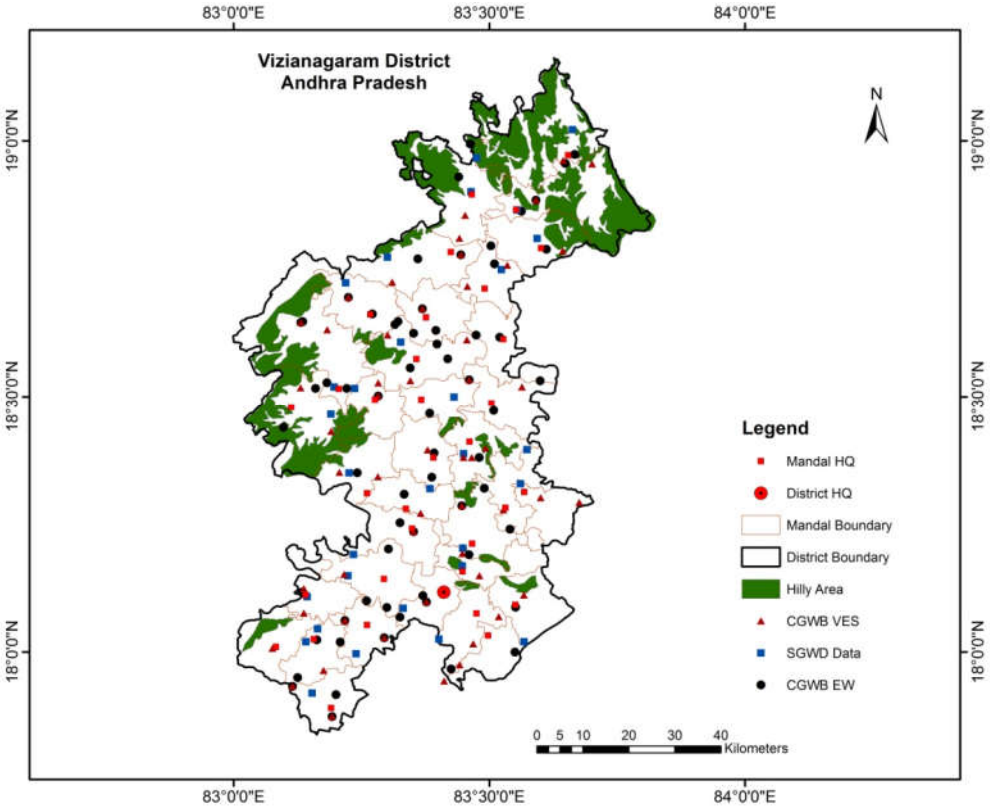

Fig. 2.1: Hydrogeological data availability.

2.1.1 Ground water occurrences and movement: Ground water occurs under unconfined and semi-confined/confined conditions 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 200 m depth. The potential fracture zones were encountered within the depth range of 30 to 100 m only. At some location like Madhupada, Budtangagalli, Savaravelli, Kondrajupalem, the potential fractures were encountered between 100 to 150 m bgl. The discharge in the exploratory wells vary from meagre to as high as 5.2 lps with general range of 0.1 to 2.0 lps. The specific capacity of the bore wells varies from 1.05 to 72.7 lpm /m/d whereas the Transmissivity ranges from 0.144 to115 m^2/day. The storage co-efficient of bore wells vary from 4.8 x 10^{-5} to 1.2 x 10^{-3}. The hydrogeological map of the area is presented in **Fig. 2.2.**

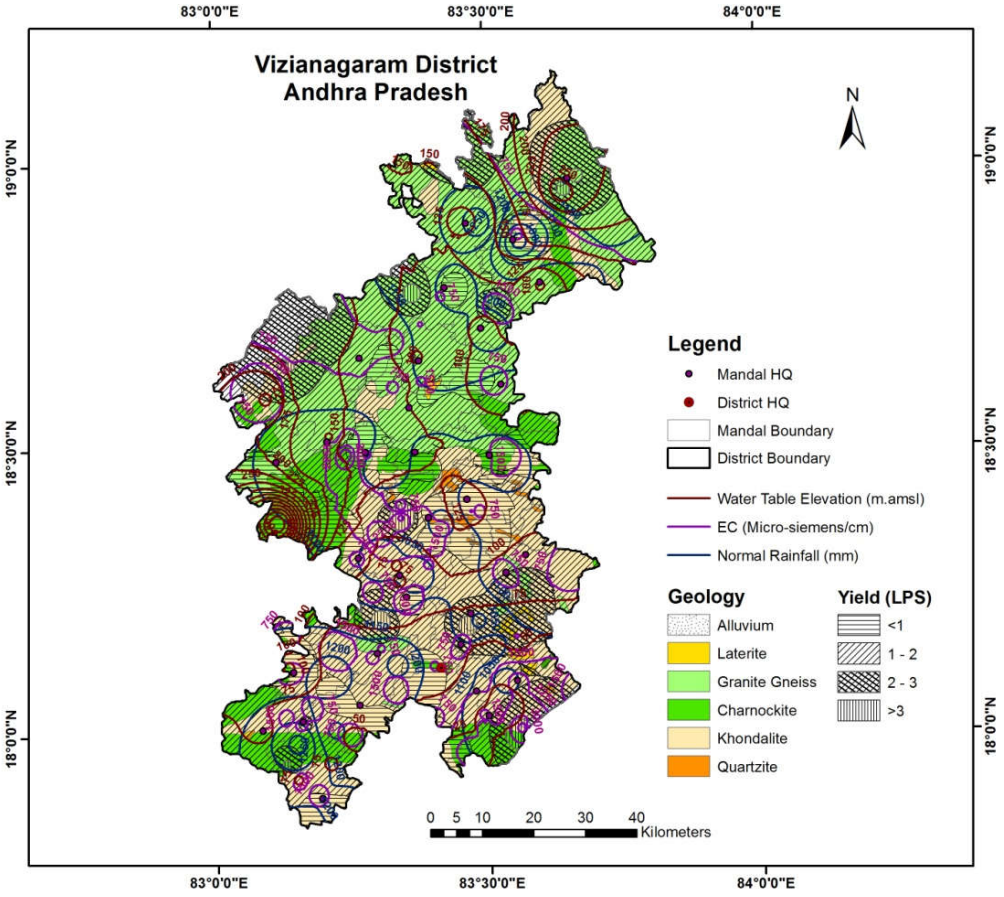

Fig.2.2: Hydrogeological map of Vizianagaram district.

2.1.2 Exploratory Drilling: CGWB drilled 84 no's bore wells (70 no's exploratory and 14 no's observation), out of which, 65 wells were drilled in granite gneissic area and 19 wells were drilled in khondalitic area. Data analysed from CGWB wells indicates, 11 no's well of depth ranges 24-100 m, 15 no's (100-150 m), 58 no's (150-200 m) depth. The deepest fracture was encountered at 197 m. bgl at Bobbili.

2.1.3 Ground water Yield: Ground water yield of granitic gneisses aquifers varies varies from <0.1 to 5.2 lps (avg: < 1 lps) and khondalite aquifers varies from <0.1 to 3.3 lps (avg: 1.5 lps). The low yield (<1 lps) occurs in ~20 % of area, 1 to 2 lps yield occurs in ~58 % and 2 to 3 lps yield occurs in ~19 % of area covering district. (**Fig.2.3)**

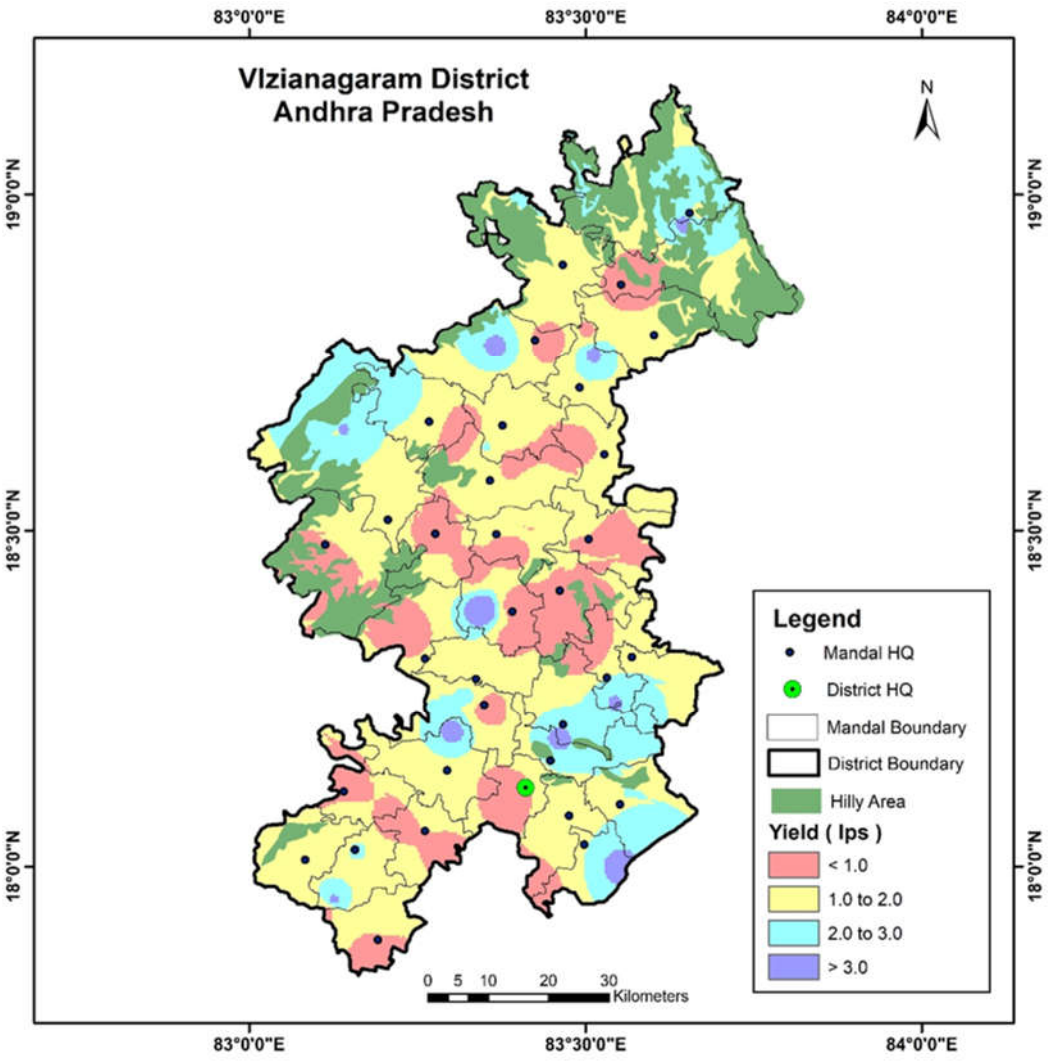

Fig.2.3: Ground water yield potential map of Vizianagaram district.

2.2 Water Levels: Ground water levels from 68 piezometers (CGWB: 24 and SGWD: 44 were monitored for pre-monsoon and post-monsoon season (2020).

2.2.1 Water Table Elevations: During pre and post-monsoon seasons (May and November), the water-table elevation ranges from 2.71 to 467.48 and 7.09 to 469 meter above mean sea level (m amsl) respectively and general ground flow is towards Nagavali river in north and central parts and towards Champavati and Gosthani river in southern parts i.e., towards SW in the northern parts, East and NE in the central parts of the district and SE direction in the southern parts of the district. (**Fig.2.4**)

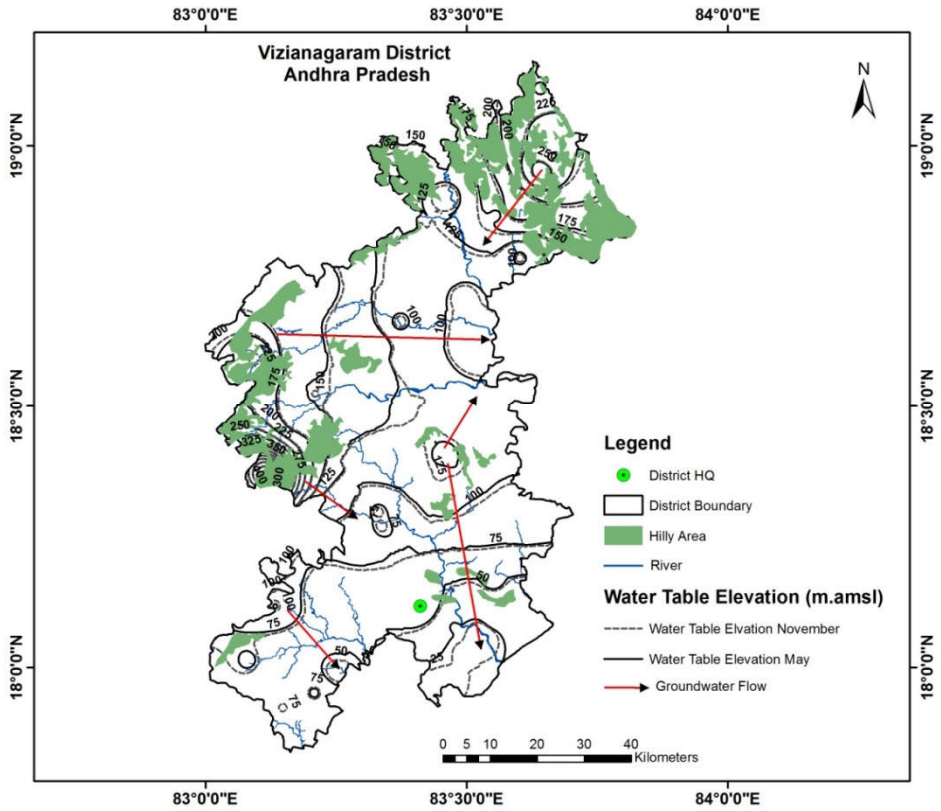

Fig.2.4: Water table elevation map (m amsl) during pre and post-monsoon

2.2.2 Depth to Water Levels (DTWL): The average DTWL of 10 years (2011 to 2020) for pre-monsoon and post-monsoon were analysed, the avg. DTWL varies from 1.52 to 16.82 m bgl (average: 6.25 m bgl) and 0.37 to 13.98 m bgl (average: 3.51 m bgl) during pre-monsoon and post-monsoon seasons respectively.

Pre-monsoon season: Majority of the water levels during this season are in the range of 5.0 to 10 m covering 68% of the area, followed by 2.0 to 5.0 m bgl (26%) and >10 m bgl (5%). The water levels > 10 m bgl occupy in parts of Salur, Pachipenta, Bhogapuram and Kothavalasa mandals. (**Fig.2.5**)

Post-monsoon season: Majority of the water levels during this season are in the range of 2.0 to 5.0 m covering 73% of the area, followed by 5.0 to 10 m bgl (15%), < 2.0 m bgl (11%). The water levels > 10 m bgl occupy about 2 % of the area falling in parts of Salur and Kothavalasa mandal. The shallow water level < 2.0 m bgl occupy in parts of S.Kota, Gantyada, Vizianagaram,

Nellimerla, Pusapatirega, Bobbili, Bandangi, Ballijipeta, Makkuva and Parvatipuram mandals. (**Fig.2.6**)

2.2.3 Water Level Fluctuations (May vs. November): The water level fluctuations vary from 0.15 to 6.90 m with average rise of 2.74 m (**Fig.2.7**). The water levels rise is observed throughout the district and no fall in water level is recorded. Rise in water level range of 2 to 5 m covers majority of the area with 89 % followed by 0 to 2 m rise in 10% of the area. The rise of water levels > 5 m is observed only in 1% of area in parts of Kurupam mandal.

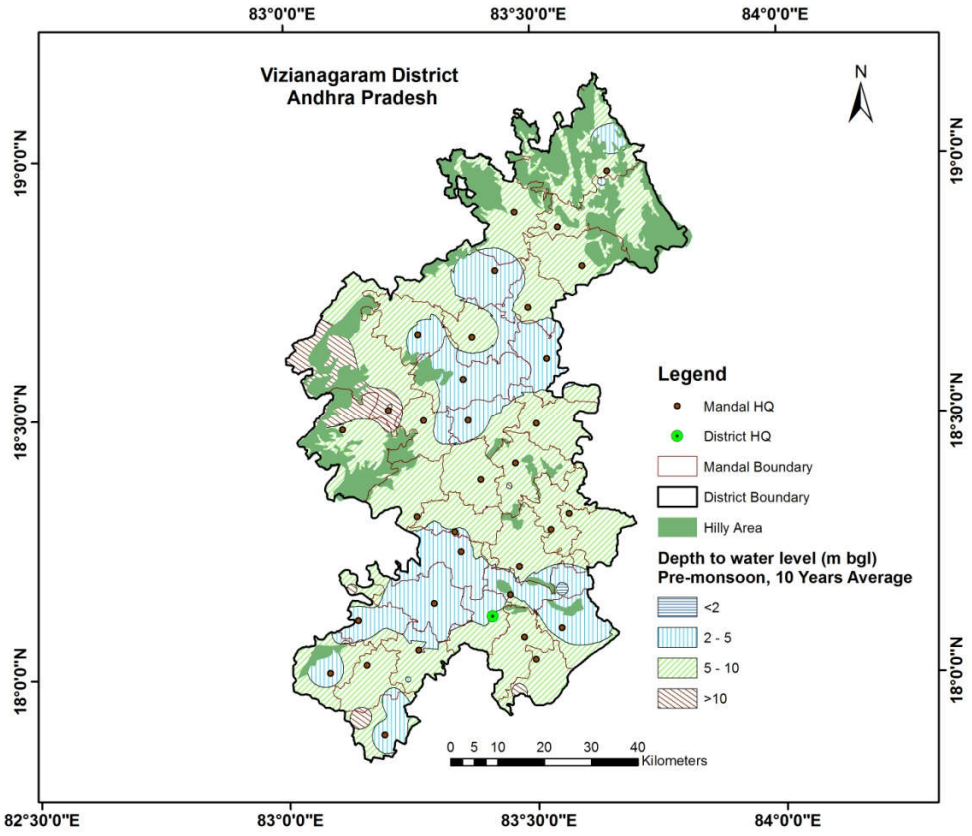

Fig.2.5: Depth to water levels Pre-monsoon (Average).

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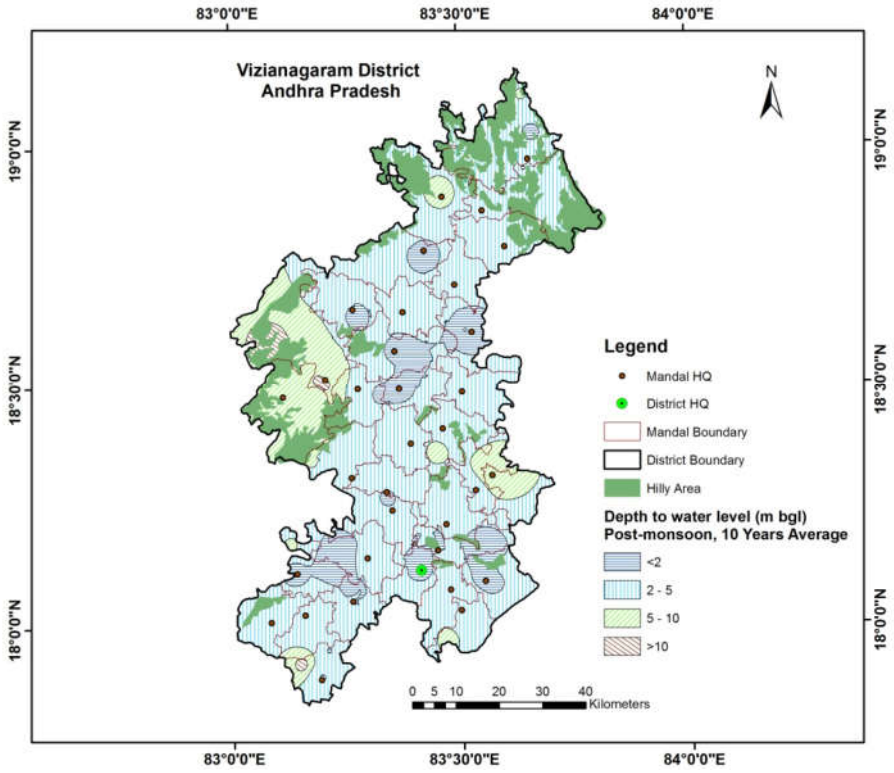


Fig.2.6: Depth to water levels Post-monsoon (Average).

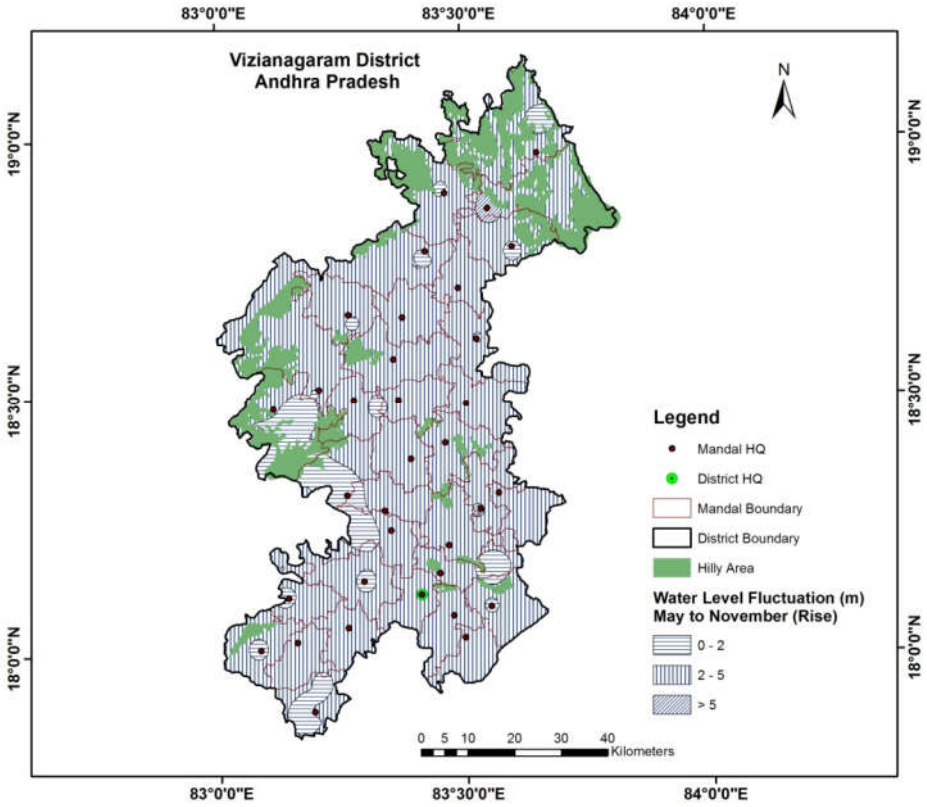


Fig.2.7: Water Level Fluctuations (m) (Nov with respect to May).

2.2.4 Long term water level trends: Trend analysis for the last 10 years (2011-2020) is studied from 68 hydrograph stations of CGWB and SGWD. It is observed that during pre-monsoon season 14 wells shows rising trend ranging 0.01 to 0.22 m/yrs and 54 wells shows falling trends ranging 0.02 to 0.79 m/yrs. During post-monsoon season 11 wells shows raising trend ranging 0.01 to 0.89 m/yrs and 57 wells shows falling trends ranging 0.01 to 1.24 m/yrs. The magnitude of trend values indicates that significant change is not occurred in the ground water scenario except at few places. The Long-term water level trends of Pre-monsoon and Post-monsoon map is shown in **Fig.2.8 & Fig.2.9** respectively and representative hydrograph are shown in **Fig.2.10.**

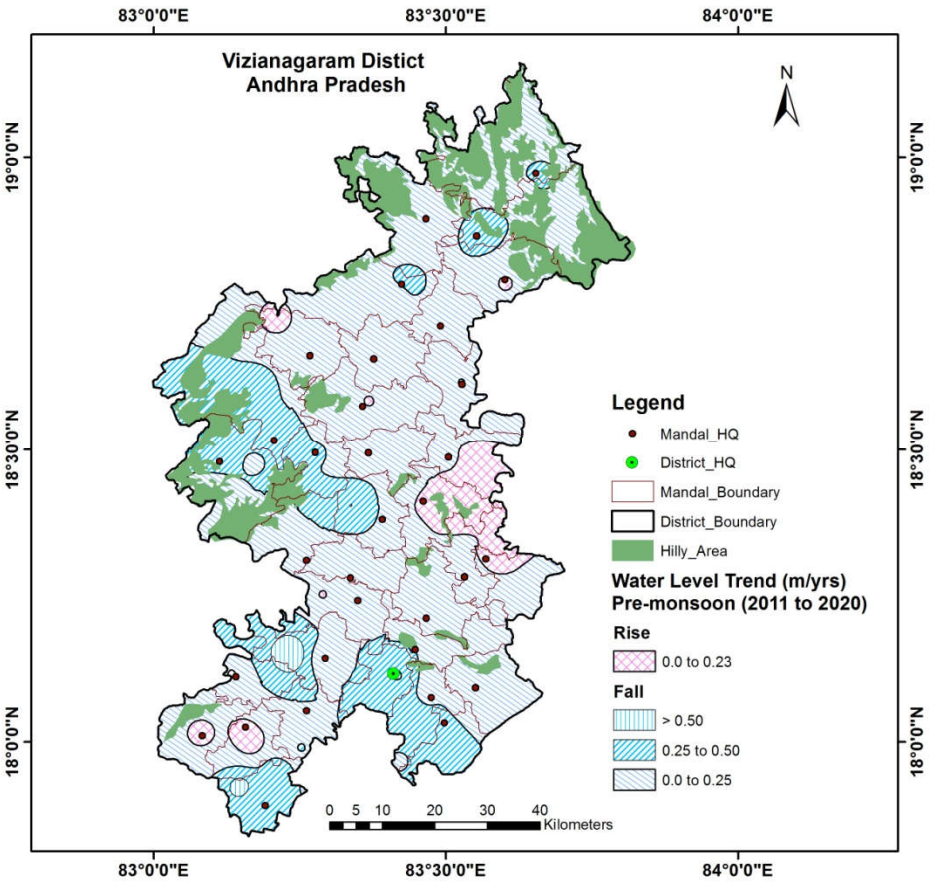


Fig. 2.8: Long-term water level trends of Pre-monsoon (2011-2020).

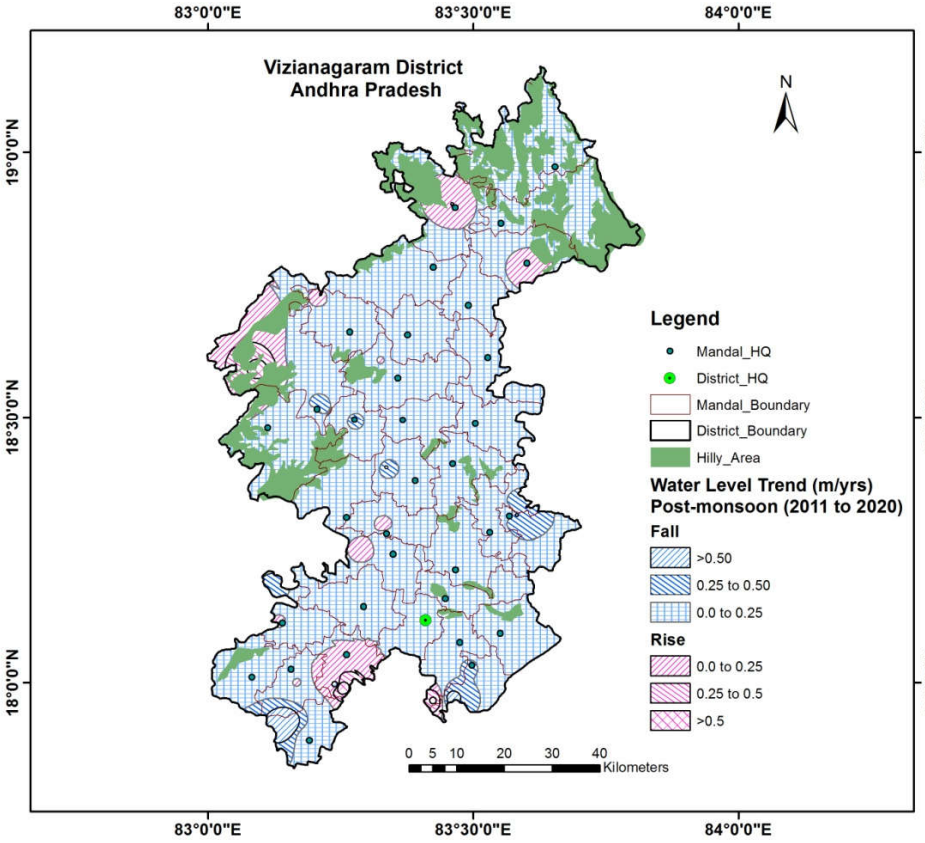


Fig. 2.9: Long-term water level trends of Post-monsoon (2011-2020).

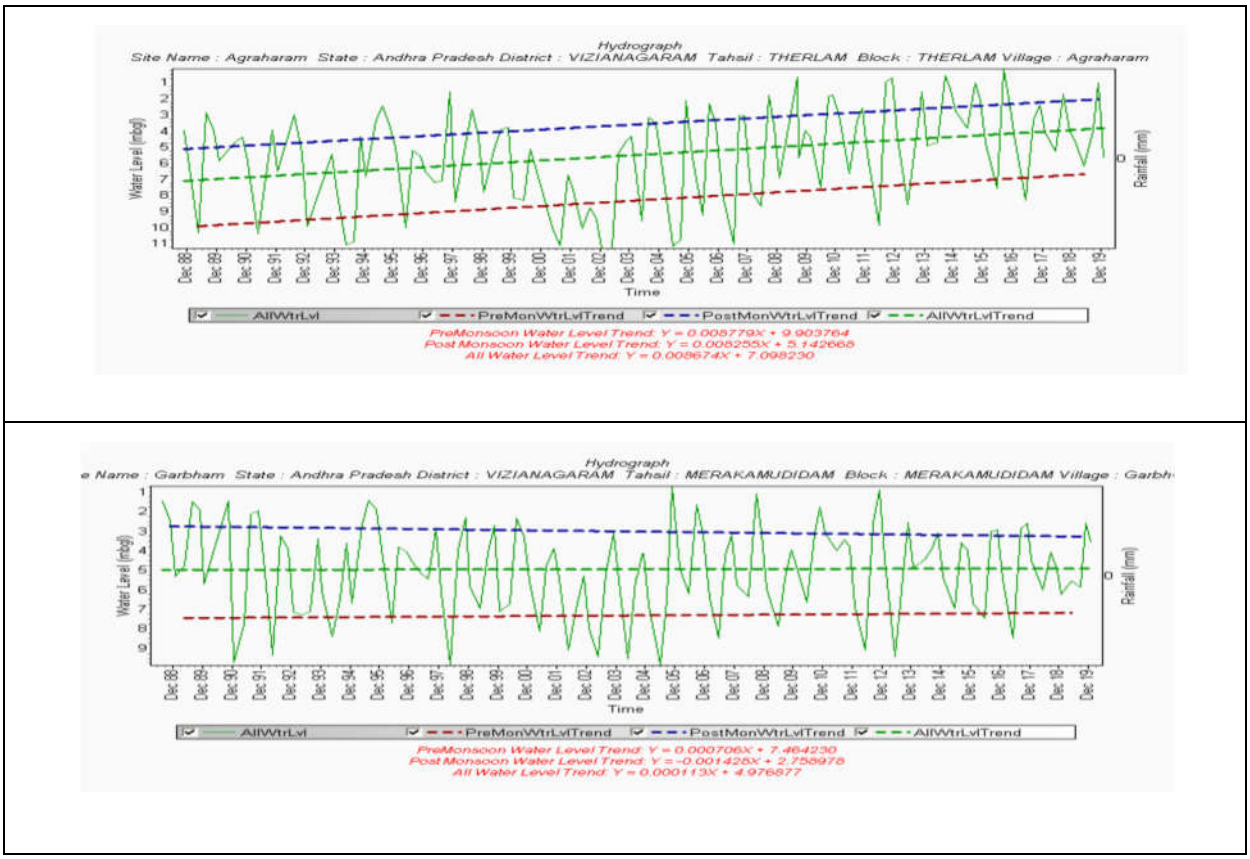


Fig.2.10: Representative Hydrographs of Vizianagaram district.

2.3 Geophysical Studies:

Vertical Electrical Sounding (VES) were carried out in 52 locations across the district and able to demarcate semi-weathered, weathered, fracture zone and basement of khondalites and charnockites. Attempt on factor analysis of VES data at each location marked probable occurrence of fractured aquifer in compact rocks. An analysis of VES curve matches more or less with the occurrence of aquifers and lithology of exploratory drilling.

A total of 52 VES data is interpreted, which reveals resistivity 5.0 to 125 ohm (Ω) m for weathered khondalite (5-46 m), 18-93 Ω m for underlying fractured khondalite with depth ranges between 24 to 95 m and 53-940 Ω m for massive khondalite. Resistivity < 40 ohm (Ω) m for weathered charnockite (7-25 m), 38-225 Ω m for underlying fractured charnockite (30-107 m) and **>** 3275 Ω m for massive charnockite rocks.

Though three major lineament trends have been identified, only the Lineament A-A' covers number of VES sites and few exploratory borehole sites. An attempt has been made to draw geo-electrical section along with probable fracture zone occurrences delineated by Factor analysis. It is expected that these depth fractures might be controlled by these regional lineaments. The VES locations and demarcated lineament is presented in **Fig. 2.11.** A major lineament was traced in the central part of the district with a trend of NW- for a length of 95 km and river Champavathi is observed to be following this lineament for a maximum length till it meets the Bay of Bengal. The Section A-A' drawn (**Fig.2.12)**. The weathered part forms the shallow aquifer extending to a depth of 20 m in north western part (structural hill) to 10 m over central parts (pediplains) and further east its thickness slightly increases to more than 10 m. Weathered zone is followed by semi-weathered and fractured formations till to a depth around 90 m with number of fracture at different depth levels. Prolific aquifer zones are found to be associated with semi-

weathered, fractured formation and matched with the findings of exploratory wells drilled by CGWB. The compact formation with discrete fracture zones was envisaged below semi-weathered formation beyond 100 m till to the investigated spread of AB/2=300 m.

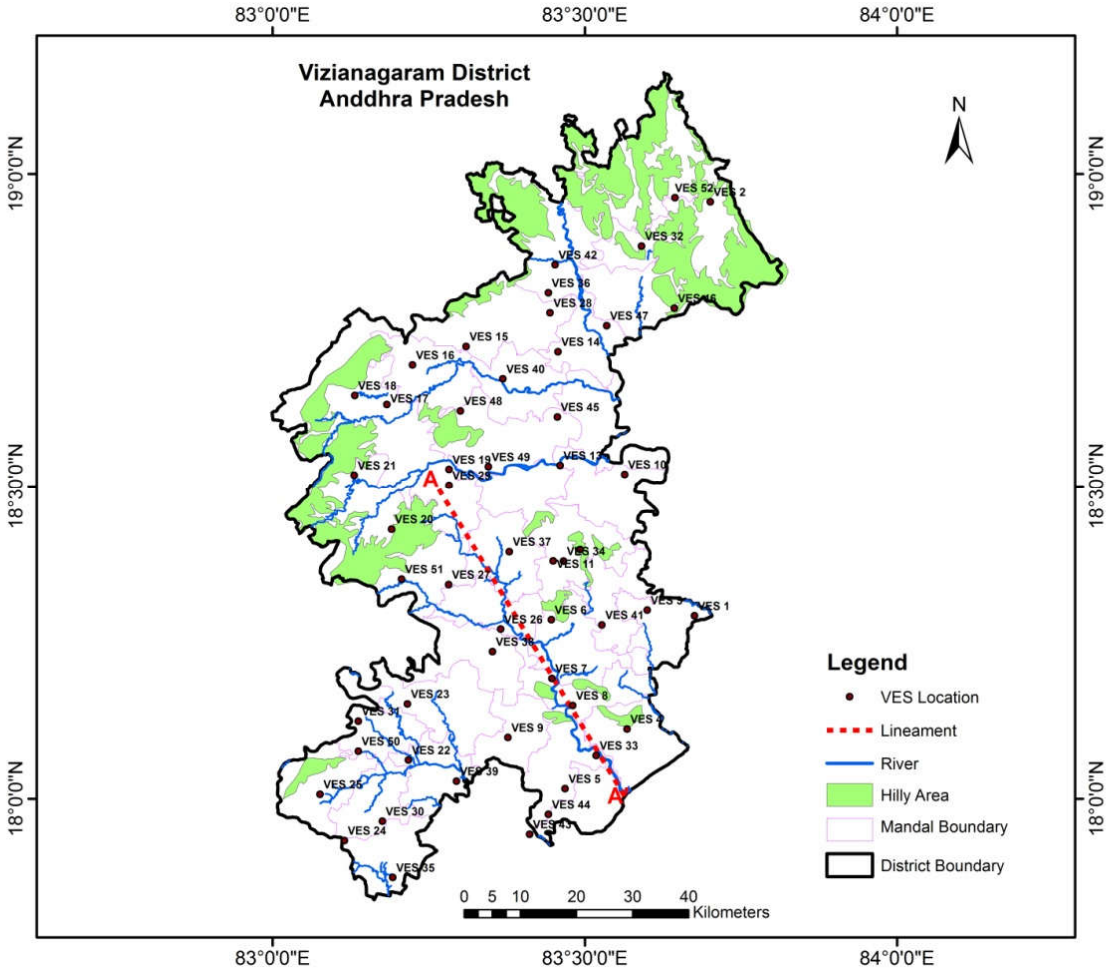


Fig-2.11: VES locations and demarcated lineament.

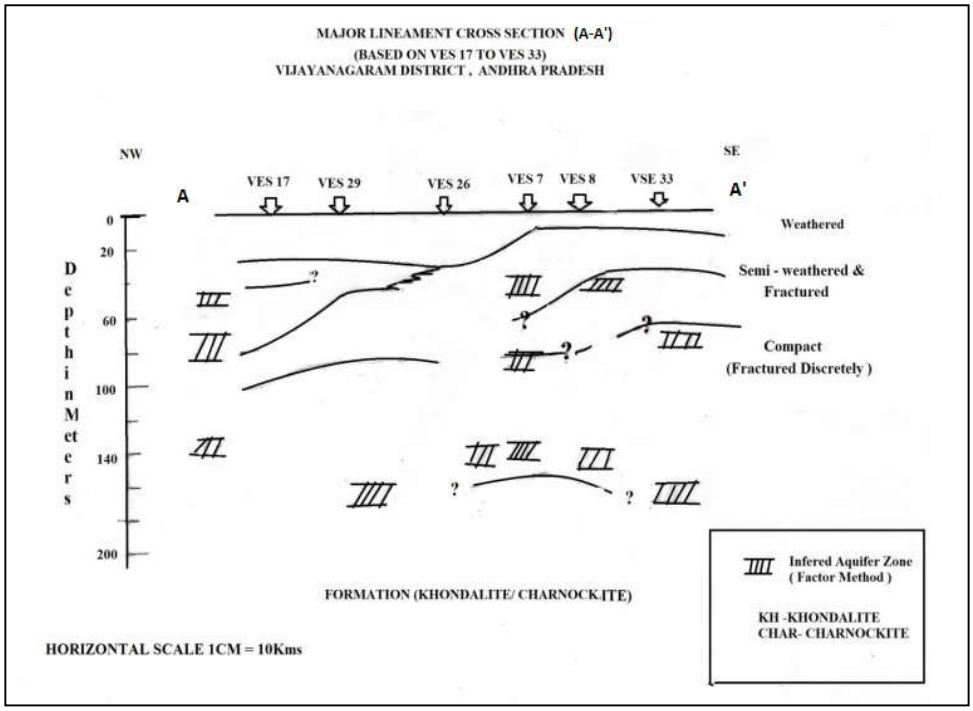


Fig.2.12: Geo-electrical section along A-A'

2.4 Hydro chemical Studies:

To understand chemical nature of groundwater, 212 water sample data is utilized from ground water monitoring wells of SGWD wells (Pre-monsoon:104 and post-monsoon:108) (mostly tapping combined aquifers Aq-I and Aq-II) during the pre-monsoon season of 2020 and post-monsoon season of 2020. The 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 analysed.

2.4.1 Pre-monsoon:

Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 6.56 to 8.78 (Avg: 7.89). Electrical conductivity varies from 93 to 3950 (avg: 1130) µ Siemens/cm. In 56 % of area EC is within 1000 to 2000 µ Siemens/cm; in 32 % area, it is 500 to 1000 µ Siemens/cm; in 7 % area it is < 500 µ Siemens/cm; in 4 % area, EC is within 2000 to 3000 µ Siemens/cm, occur in coastal and portion of central western part of the district and EC above >3000 µ Siemens/cm covering < 1% area. (**Fig.2.13).** Nitrate

concentration in all samples is below BIS permissible limits of 45 mg/L, varies between 0.28 to 40.19 mg/L, except in Jiyyammavalasa (46.96 mg/L) and Jannivalasa (51.54 mg/L) (**Fig.2.14**). Fluoride concentration varies from 0.02 to 1.47 mg/L and all samples falling under permissible limits of 1.5 mg/L, except in Kothavalasa (1.72 mg/L) and Darmapuri (2.31 mg/L) (**Fig 2.15**)

2.4.2 Post-monsoon:

The groundwater is mildly alkaline to alkaline in nature with pH in the range of 6.26 to 8.77 (avg. 7.65). Electrical conductivity varies from 120 to 4362 µ Siemens/cm (avg. 1104 µ Siemens/cm). In 57 % of area, EC is within 1000 to 2000 µ Siemens/cm; in 33 % area, it is 500 to 1000 µ Siemens/cm; in 6 % area it is < 500 µ Siemens/cm; in 4 % area, EC is within 2000 to 3000 µ Siemens/cm, occur in coastal and portion of central western part of the district and EC above 3000 µ Siemens/cm covering < 1% area.(**Fig.2.16)** Nitrate concentration in all samples is below permissible limits of 45 mg/L, varies between 0.08 to 43.93 mg/L, except in Bhogapuram (66.87 mg/L) and Jannivalasa (58.14 mg/L) (**Fig.2.17)** Fluoride concentration all samples is below BIS permissible limits of 1.5 mg/L and varies from 0.03 -1.31 mg/L, except in Kothavalasa (2.34 mg/L) (**Fig 2.18**)

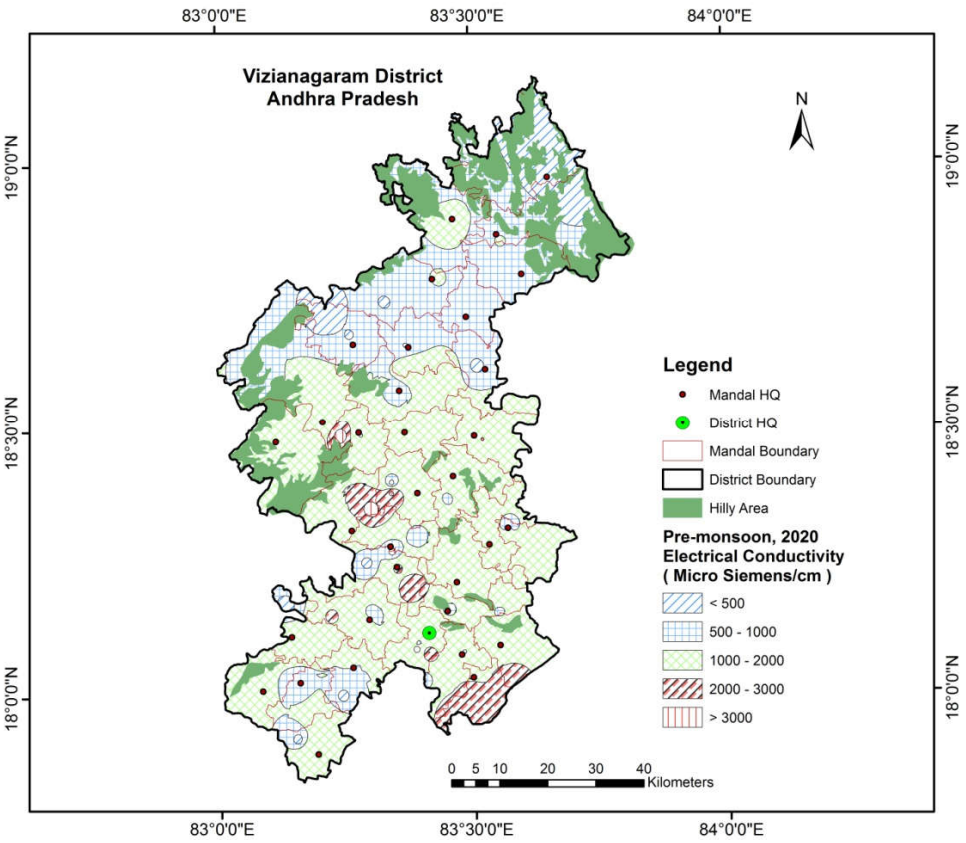


Fig.2.13: Distribution of Electrical conductivity (Pre-monsoon).

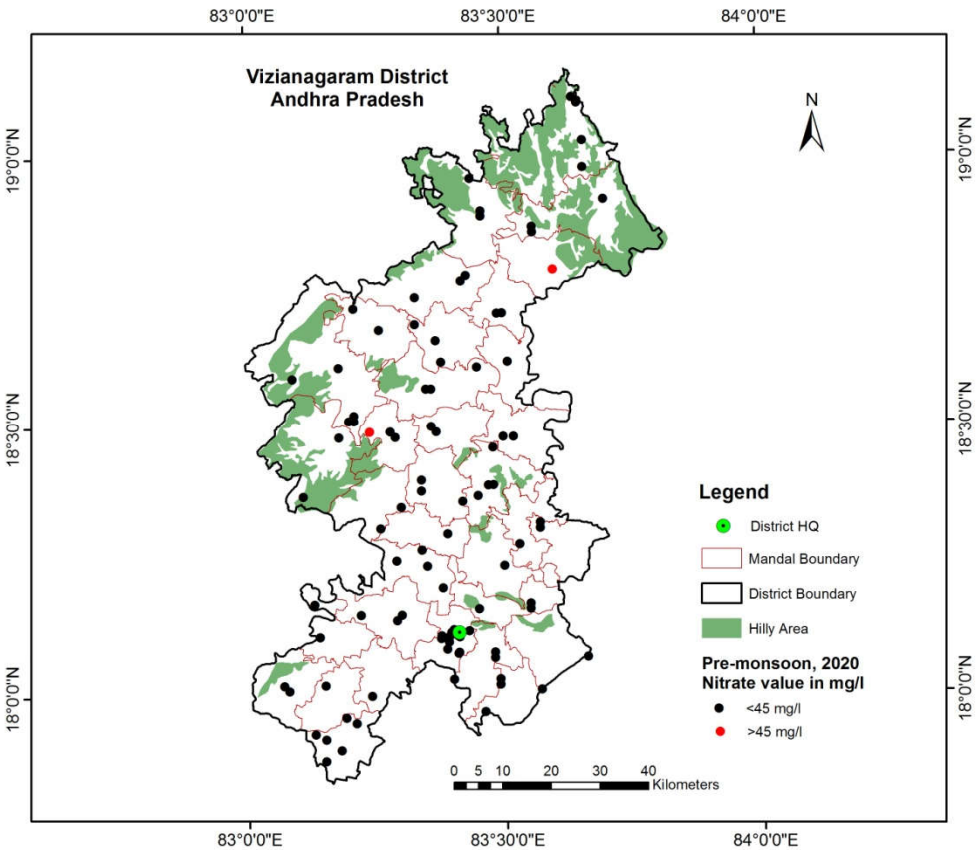


Fig.2.14: Distribution of Nitrate (Pre-monsoon).

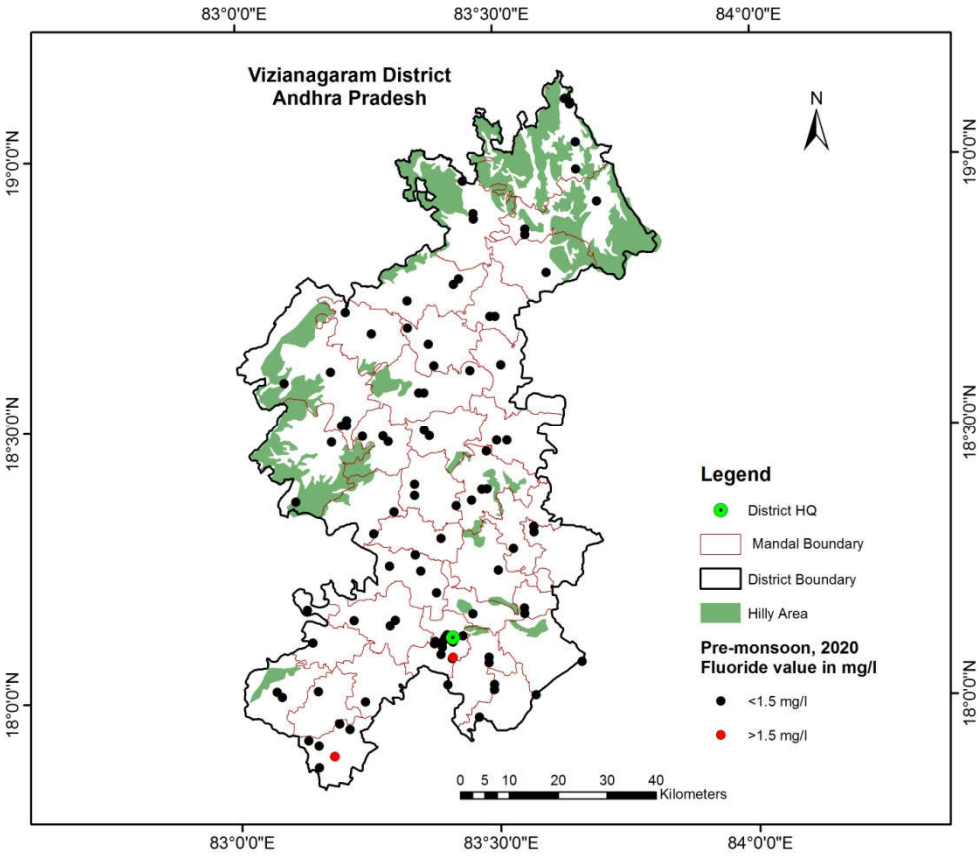


Fig.2.15: Distribution of Fluoride (Pre-monsoon).

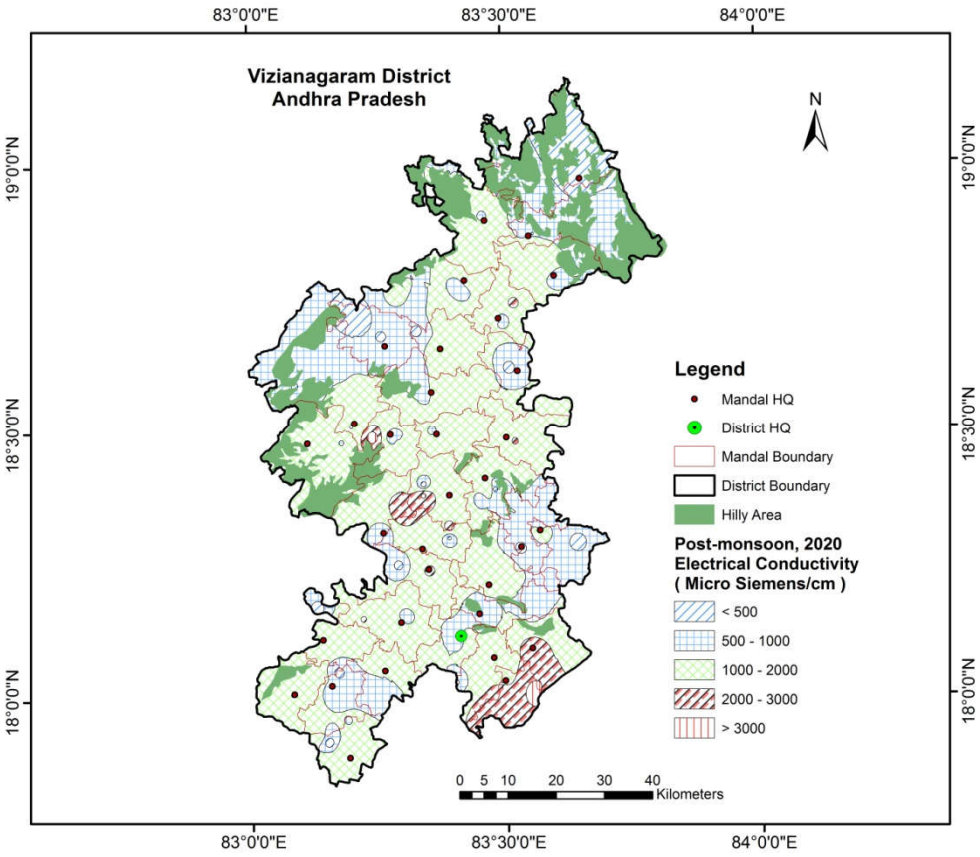


Fig.2.16: Distribution of Electrical conductivity (post-monsoon).

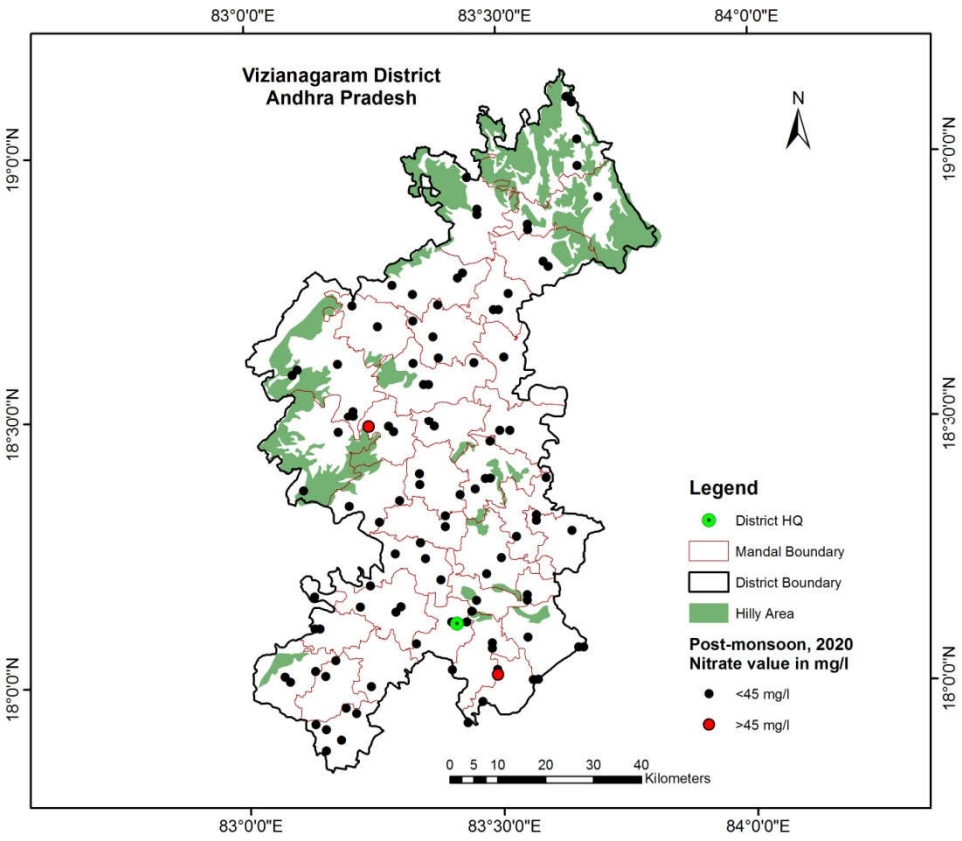


Fig.2.17: Distribution of Nitrate (Post-monsoon).

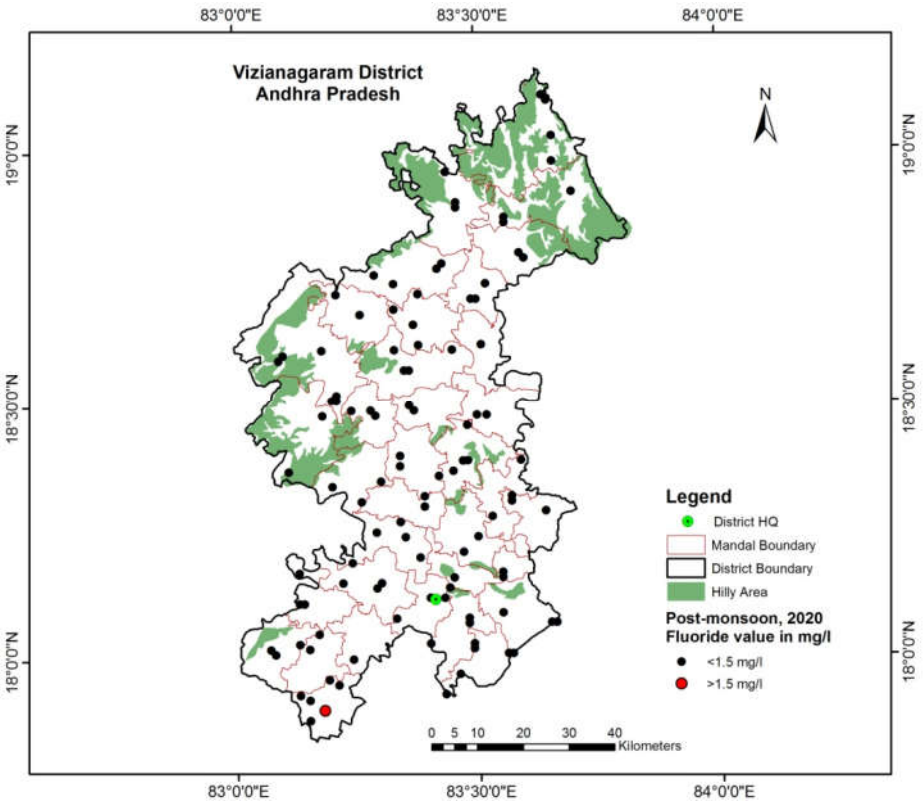
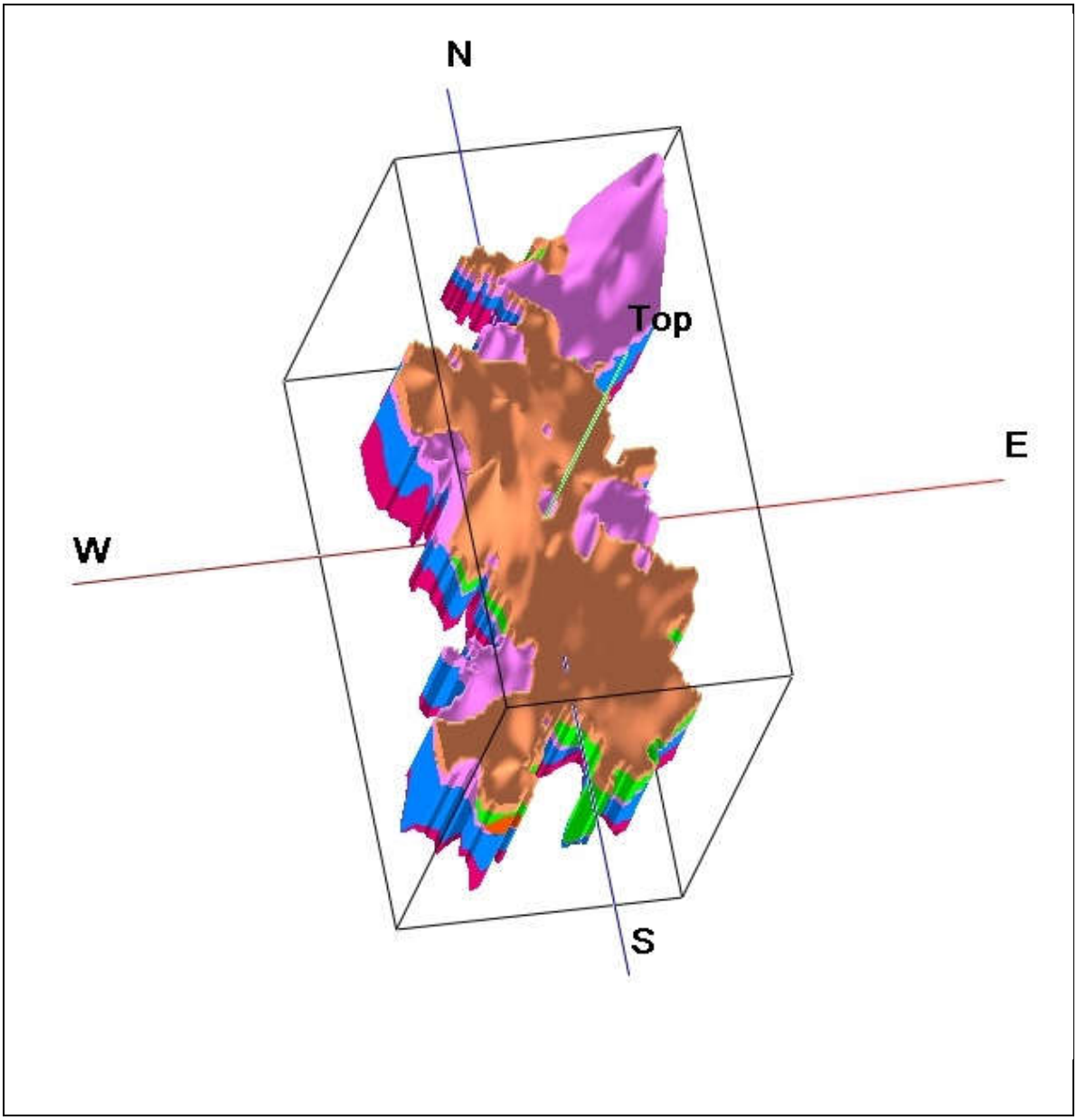
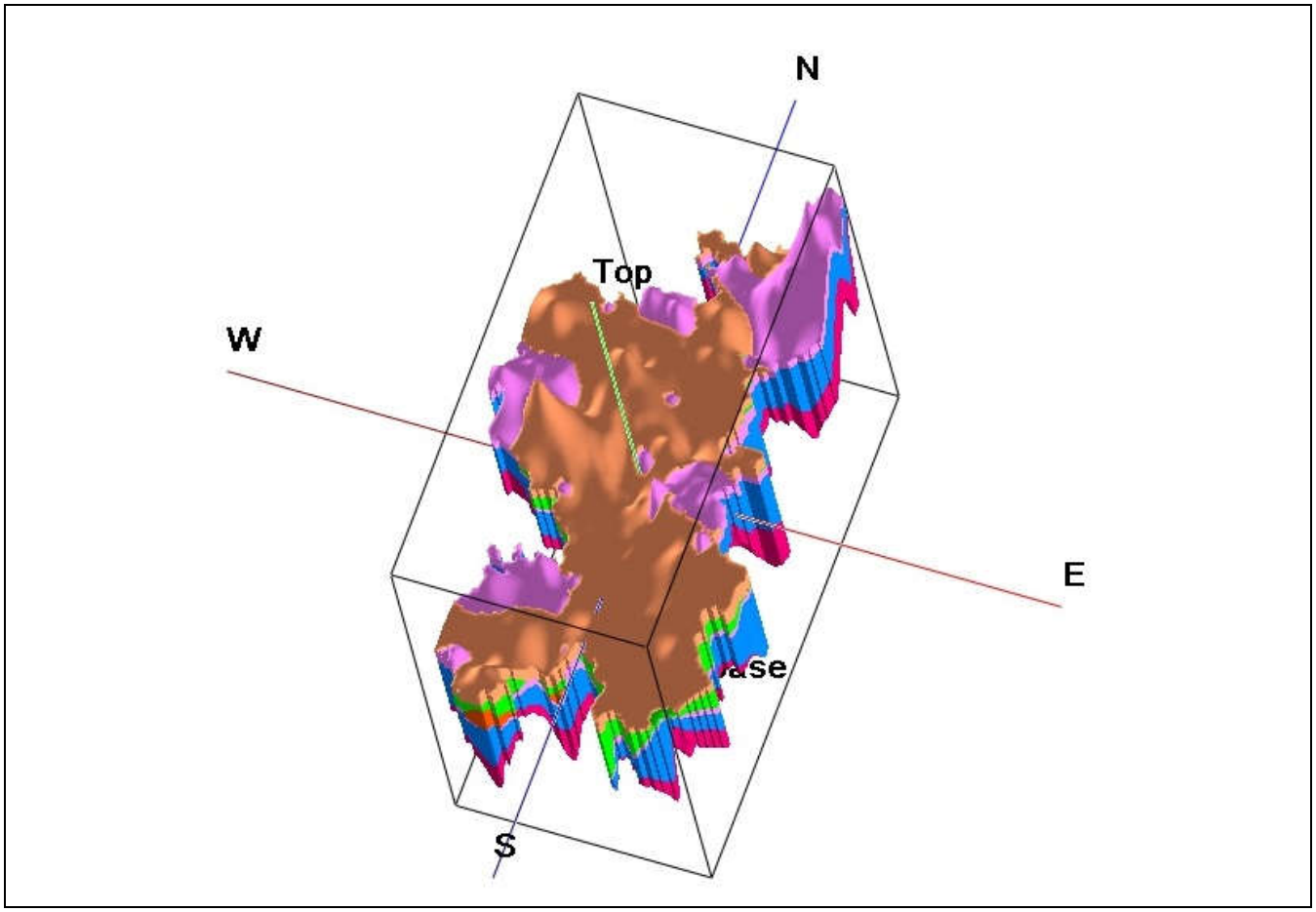


Fig.2.18: Distribution of Fluoride (Post-monsoon).

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 118 data points (both hydrogeological and geophysical down to 200 m) for preparation of 3-D map, panel diagram and hydrogeological sections. The data (**Fig.2.1**) is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data. The lithological information was generated by using the Rock Works-17 software and generated 3-D map for Vizianagaram district (**Fig.3.1)** and hydrogeological sections. **(Fig.3.3a-e)**




N
Top
W
E
S

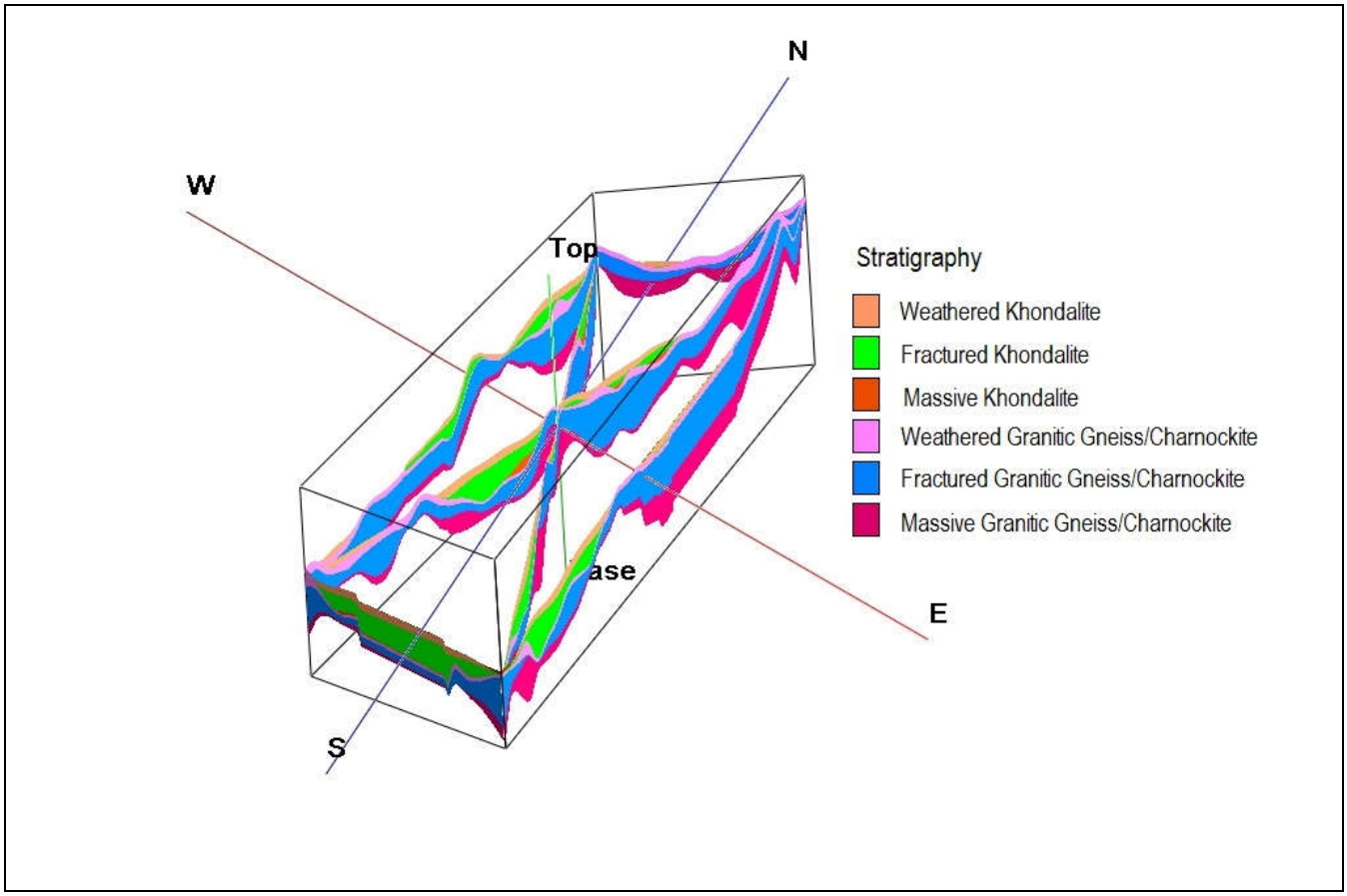


Fig.-3.1:3D Model for study area.

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 ~21 m depth and the fractured zone (fractured granite) is considered up to the depth of deepest fracture below weathered zone (~21 to 200 m).

3.2 Hydrogeological Sections:

Hydrogeological sections are prepared in A-A', B-B', C-C', D-D' and E-E' direction. (**Fig.3.2**).

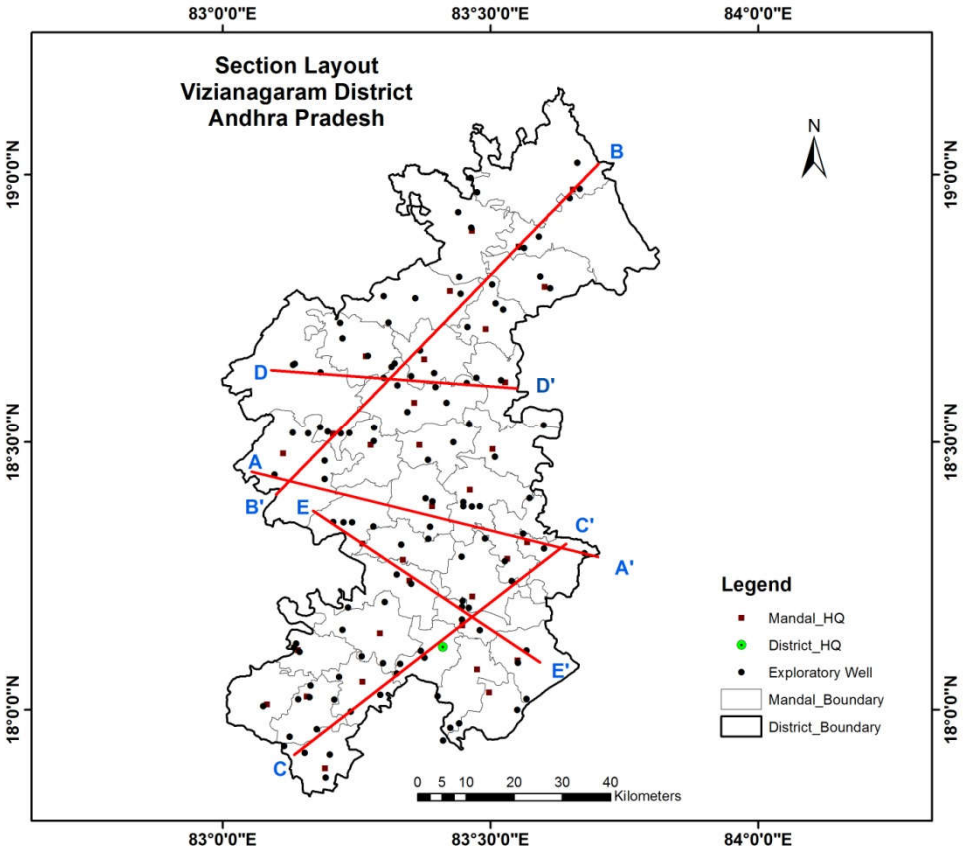


Fig.-3.2: Map showing orientation of hydrogeological sections

3.2.1 Hydrogeological Cross Section (A-A'): The section drawn along the NW-SW direction in central part of district covering distance of ~68 km (**Fig.3.3a**). It depicts khondalites are overlying Granitic gneisses in entire section but at Jammunarayanapuram weathered granitic gneisses followed by fractured and massive granitic gneisses observed. The deepest fracture in khondalites are seen at Garividi, Alagangi and Madhupada and in granitic gneiss at Sivarampuram, Chinakada area.

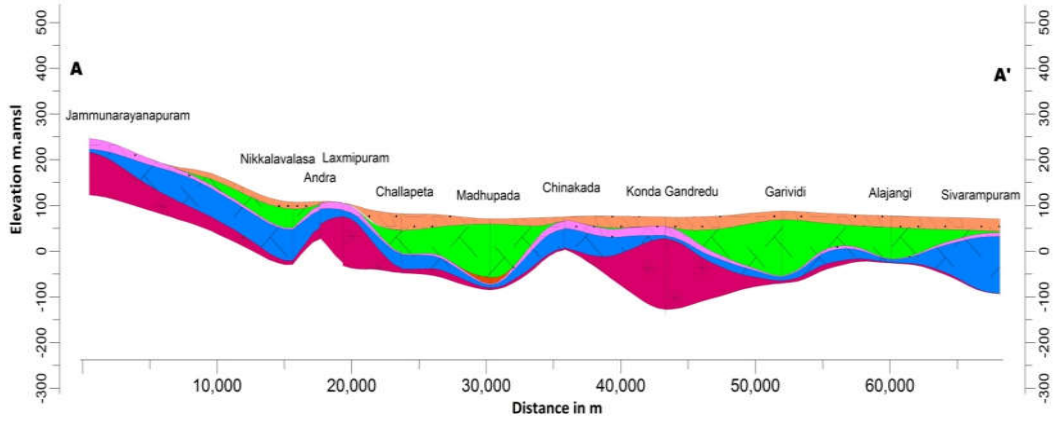
3.2.2 Hydrogeological Cross Section (B-B'): The section drawn along the NE-SW direction in northern parts of the district covering distance of ~97 km (**Fig.3.3b**). It depicts weathered and fractured khondalite occur only at

Chinagudaba and Seetharampuram. The deeper fractures in granitic gneisses observed in Bobbili, Rangampeta, Santoshpuram and Komatipalli area.

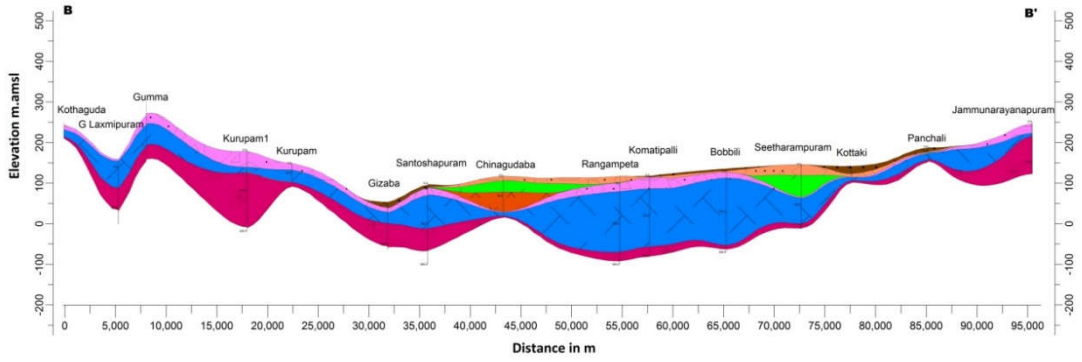
3.2.3 Hydrogeological Cross Section (C-C'): The section drawn horizontally along the SW-NE direction in southern part of the district covering distance of ~74 km (**Fig.3.3c**). It depicts thick fractured khondalite overlain by weathered khondalite and occur in Alajangi, Neelamrajupeta, Duppada area (NE parts of section). In SW and central part of section, fractured granitic gneisses form potential aquifer.

3.2.4 Hydrogeological Cross Section (D-D'): The section drawn horizontally along the W-E direction in central part of the district covering distance of ~44 km (**Fig.3.3d**). It depicts fractured granitic gneisses form potential aquifer throughout the cross section. At Velagavalasa, fractured khondalite is overlaying on fractured granitic gneisses.

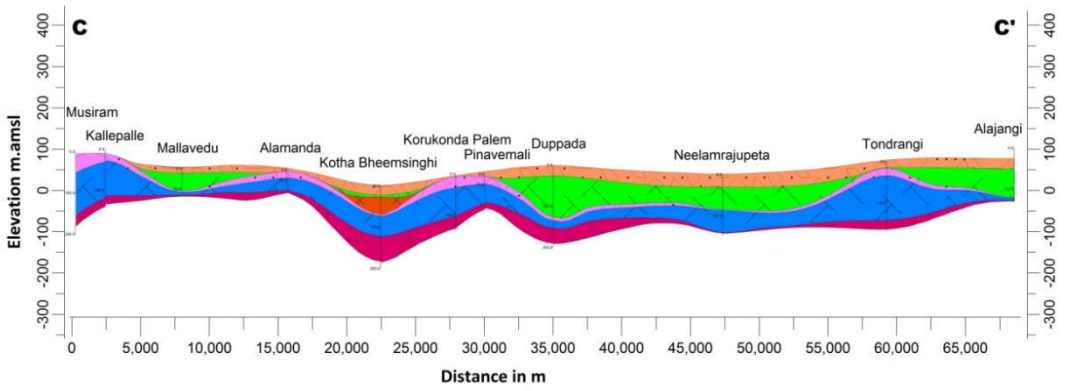
3.2.5 Hydrogeological Cross Section (E-E'): The section drawn horizontally along the NW-SE direction in southern part of the district covering distance of ~72 km (**Fig.3.3e**). It depicts fractured khondalite overlain by weathered khondalite and form potential aquifer throughout the cross section whereas at Nanda fractured granitic gneisses form potential aquifer.



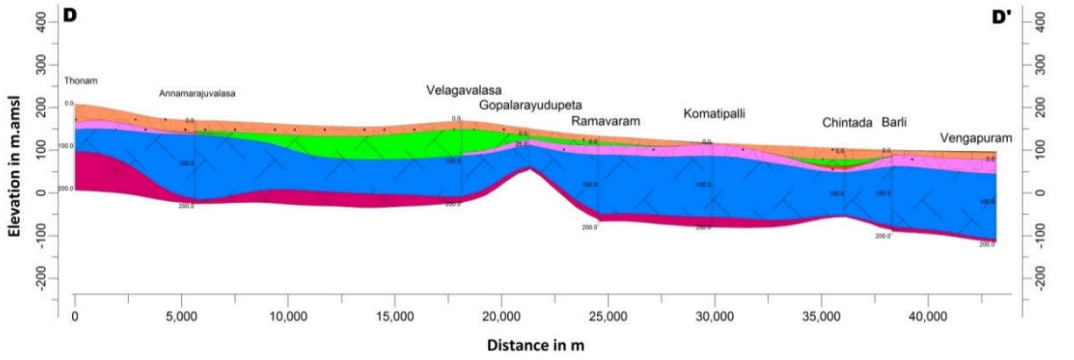
(a)


B
B'
Elevation m.amsl
Kothaguda
G Laxmipuram
Gumma
Kurupam1
Kurupam
Gizaba
Santoshapuram
Chinagudaba
Rangampeta
Komatipalli
Bobbili
Seetharampuram
Kottaki
Panchali
Jammunarayanapuram
Distance in m

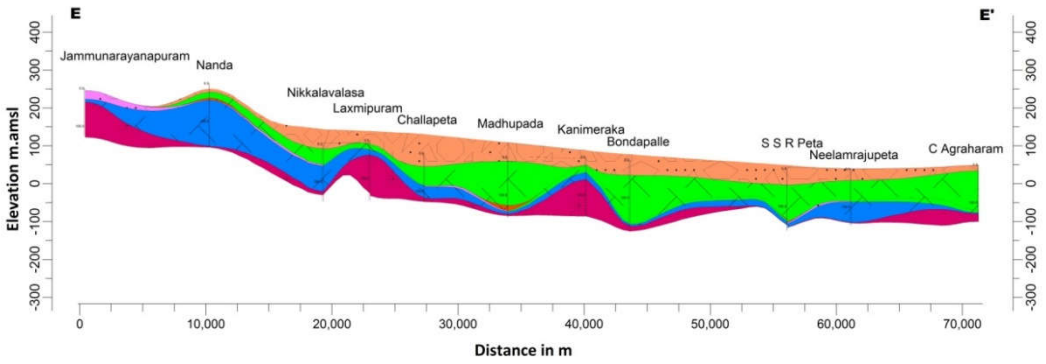
(b)


C
C'
Elevation m.amsl
Musiram
Kallepalle
Mallavedu
Alamanda
Kotha Bheemsinghi
Korukonda Palem
Pinavemali
Duppada
Neelamrajupeta
Tondrangi
Alajangi
Distance in m

(c)


D
D'
Elevation in m.amsl
Thonam
Annamarajuvalasa
Velagavalasa
Gopalarayudupeta
Ramavaram
Komatipalli
Chintada
Barli
Vengapuram
Distance in m

(d)



(e)

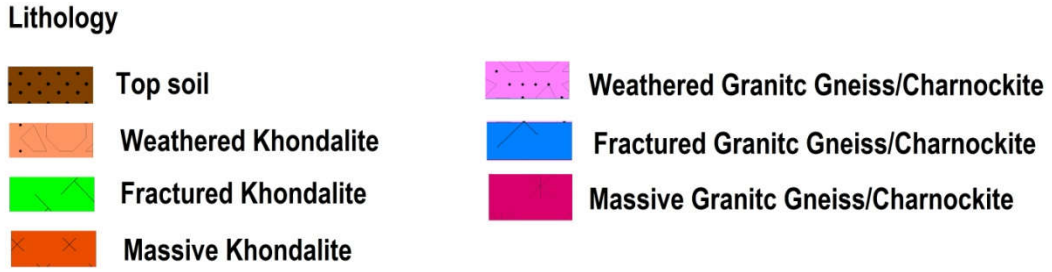


Fig.3.3 (a-d): Hydrogeological Cross Section in different directions in Vizianagaram district.

3.3 Aquifer Characterization:

3.3.1 Weathered zone: The weathered zone (avg. ~21 m) varies from 6 to 48 m bgl in khondalitic formation and meagre to 57 m bgl in granitic gneiss formation. The spatial distribution of weathering depth zone map is given in **Fig.3.4**. The weathered zone is in the range of 20 to 40 m in most part of area covering ~67 % of area; 10 to 20 m occurs in ~31 % of the area; shallow (<10 m) and deeper (>40 m) weathering occurs in rest of the area (**Fig.3.5**) The yield of the wells piercing the weathered zone vary from 0.03 to 3 lps depending on the location.

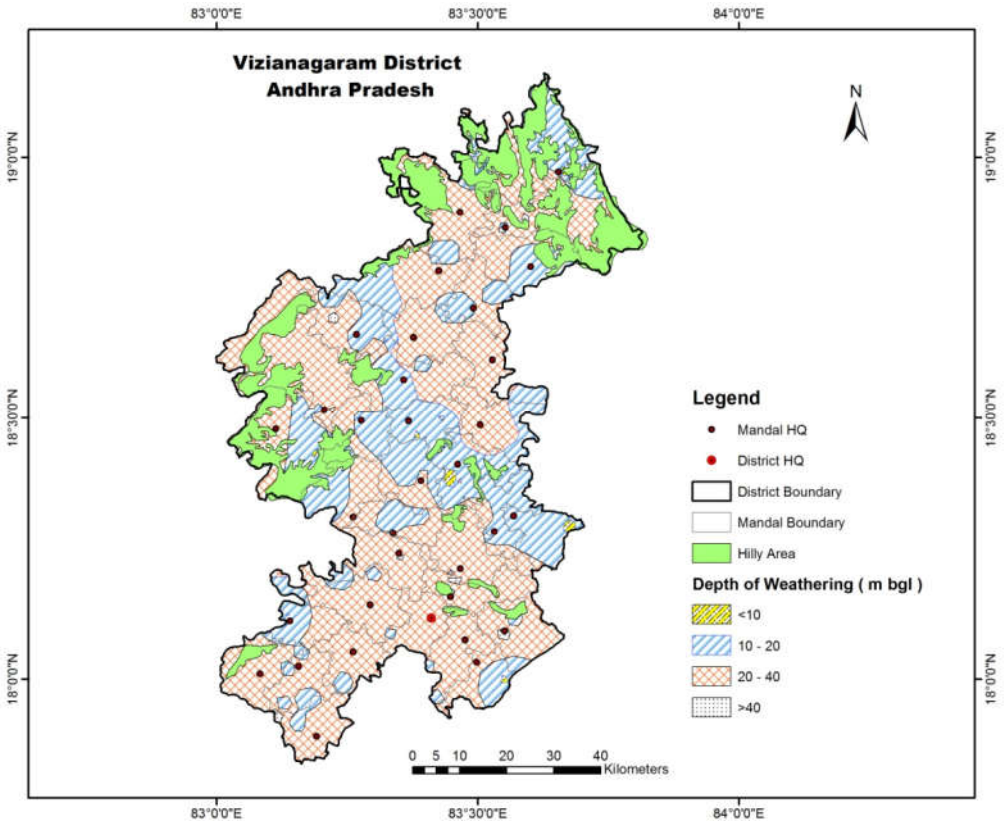


Fig.3.4: Depth to weathered zone, Vizianagaram district

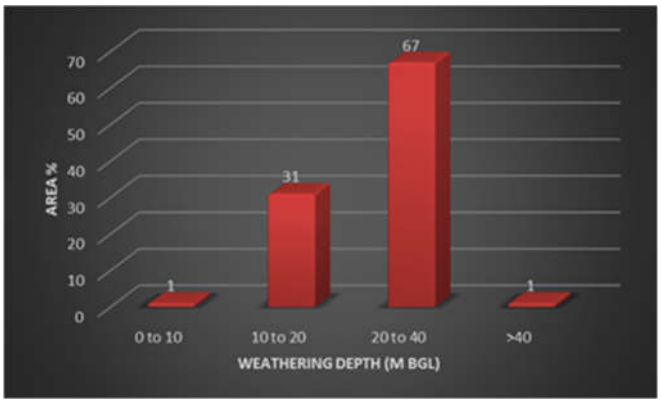


Fig.3.5: Depth wise weathered zone distribution

3.3.2 Fractured zone: The groundwater is extracted mainly through bore wells of 30 to 200 m depth from fractured zone (~10 to 199 m). Based on CGWB and SGWD data, it is inferred that, fractures in the range of 90 to 100 m depth are more predominant (34 % of the area), 60 to 90 m fractures occur in 29 % area; 120 to 150 m and 30 to 60 m fractures occur in 16 % and 13 % of area respectively. The deep fractures > 150m occur in 8 % area, in

parts of Bobbili, Balijipeta, Salur and Seethanagaram mandals. The shallow fracture (<30 m) occurs in ~ 1% area (**Fig.3.6**). The depth ranges of bore wells are between 30 to 200 m bgl with yields varying from 0.5 to 5 lps. The depth wise distribution of fractures, Vizianagaram District shown in (**Fig. 3.7)**

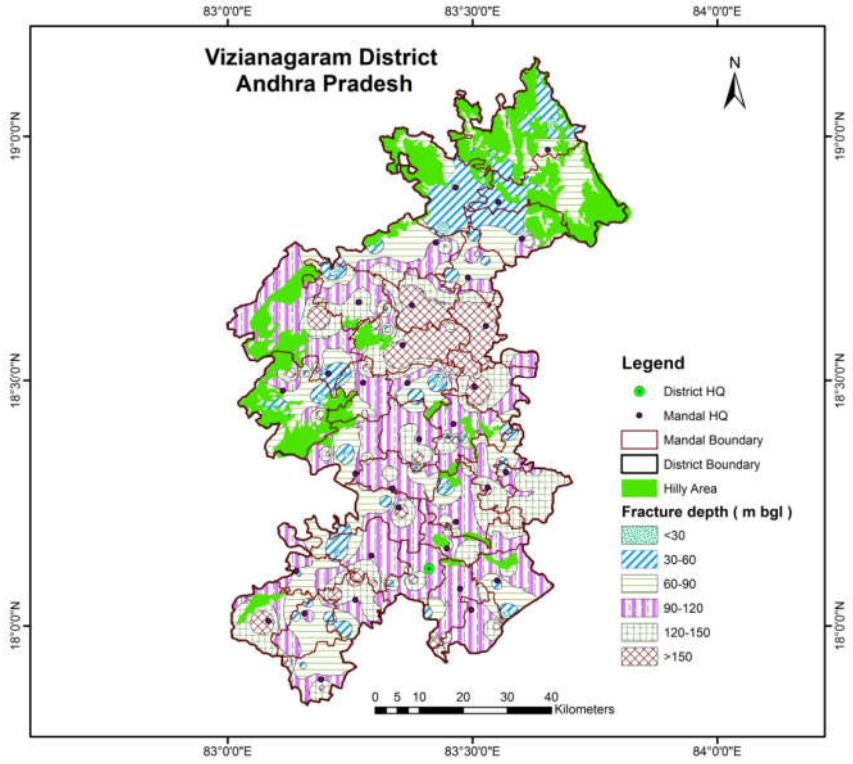


Fig.-3.6: Depth of Fractured zone, Vizianagaram District.

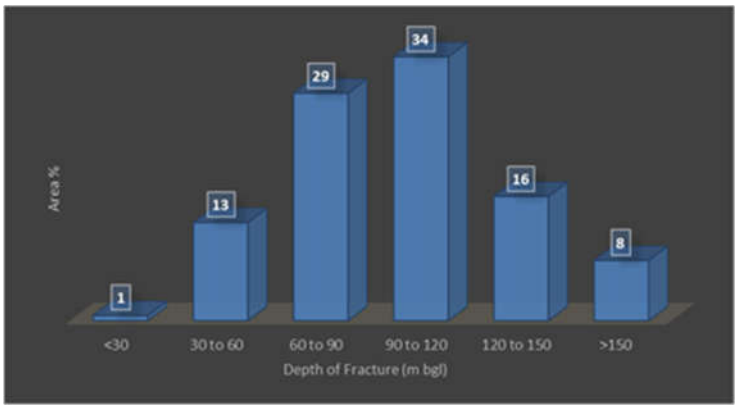


Fig.-3.7: Depth wise distribution of fractures, Vizianagaram District.

4.0 GROUND WATER RESOURCES (2020)

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. The 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 and 2 % of granular zone (depth below pre-monsoon water level and down to deepest fracture depth in the village) is considered. Computed Dynamic ground water resources and assessment of mandal wise Dynamic Ground Water Resources of the Vizianagaram District, Andhra Pradesh (2020) are given in **Table-4.1 and Annexure-I, II & II**.

Table-4.1: Computed Dynamic ground water resources, Vizianagaram district.

Parameters	Command	Non-command	**Total**
As per GEC 2020	MCM	MCM	MCM
Dynamic (Net GWR Availability)	**1084.75**	**1171.60**	**2256.35**
• Recharge from rainfall	133.18	469.82	603.00
• Recharge from canal	17.86	-	17.86
• Recharge from surface water irrigation	142.72	235.46	378.19

• Recharge from ground water irrigation	24.43	77.90	102.34
• Recharge from tank and ponds	729.41	216.61	946.02
• Recharge from water conservation structure	37.12	171.80	208.92
Gross GW Draft	**103.41**	**323.80**	**427.21**
• Irrigation	98.89	308.86	407.75
• Domestic and Industrial use	4.51	14.94	19.46
Allocation of Ground Water Resource for Domestic Utilisation for projected year 2025	15.00	39.39	54.40
Net GW availability for future use	921.21	782.13	1703.35
Stage of GW development (%)	10.03	29.09	19.93
	Mandal wise it varies from 2.8 % (Gummalakshmipuram) to 53.4% (Pusapatirega)		

As per 2020 GEC report, the net dynamic replenishable groundwater availability is 2256.35 MCM, gross ground water draft for all uses 427.21 MCM, provision for domestic utilisation for the year 2025 is 54.4 MCM and net annual ground water potential available for future needs is 1703.35 MCM. Stage of ground water development varies from 2.8 % in Gummalakshmipuram mandal to 53.4 % in Pusapatirega mandal (avg. 19.93 %). Based on present stage of ground water development, 34 mandals are falling under safe category **(Fig-4.1)**

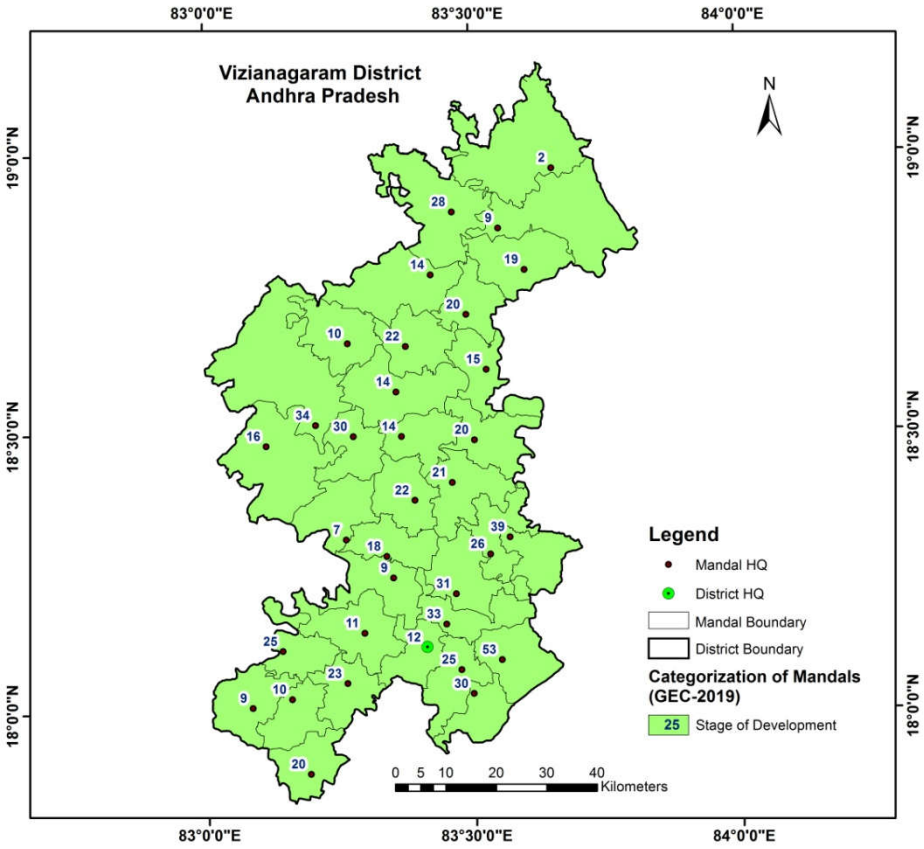


Fig-4.1: Categorization of Mandals (GEC 2020)

5. GROUND WATER RELATED ISSUES AND REASONS

Groundwater Yield:

- The low yield (<1 lps) occurs in ~20 % of area and 1 to 2 lps yield occurs in ~58 % area of the district.
- The low yield is due to crystalline terrain and absence of primary and secondary porosity, poor interconnection of fractures and less recharge during rainy season. Among the crystalline formations granite gneiss/charnockite have developed moderate to highly fractured zones compared to khondalite formation. In khondalite formation, fractures after saturation gets highly weathered and form clay due to chemical decomposition and filled fracture zones. Hence, yielding very low or as dry fractures.

Deep water levels:

- Deep water levels (> 10 m bgl) are observed during pre as well as post-monsoon season in 5 % and 2 % of the area respectively.
- Out of 68 wells analysed, 54 wells during pre-monsoon and 57 wells during post-monsoon shown falling trend in the last 10 years (0.02 to 0.79 m/yrs and 0.01 to 1.24 m/yrs) respectively.

Water Logging:

- In Vizianagaram district, at present there is no water logging. However during post monsoon period in places around S.Kota, Gantyada, Vizianagaram, Nellimerla, Pusapatirega, Bobbili, Bandangi, Ballijipeta, Makkuva and Parvatipuram area, the water levels are < 2.0 m bgl (11% of area) indicating that these areas are prone to water logging. The water logging conditions may be due to surface water irrigation and can be overcome by conjunctive utilization of both surface and groundwater.

Pollution (Geogenic and Anthropogenic):

- In Vizianagaram, Fluoride concentration is within permissible limit except in Kothavalasa (1.72 mg/L) and Darmapuri (2.31 mg/L) during pre-monsoon and at Kothavalasa (2.34 mg/L) during post-monsoon period. The high concentration of fluoride is due to rock water interaction where fluoride bearing minerals (fluorite, fluoro-apatite) gets dissolved under alkaline condition and higher residence time of ground water in deeper aquifer.
- Nitrate concentration in the entire district is within the permissible limits except in Jiyyammavalasa (46.96 mg/L) and Jannivalasa (51.54 mg/L) during pre-monsoon and Bhogapuram (66.87 mg/L) and Jannivalasa (58.14 mg/L) during post-monsoon period which may be of local anthropogenic activity.
- The high concentration of EC (> 3000 µ Siemens/cm) occurring <1 % of the area is observed during pre and post-monsoon period along the coast line where fresh water is limited.

Ground water Development:

- The present stage, ground water development in the district varies from 3.0 to 54 percent and as a whole comes under safe category. The level of development is maximum in Pusapatirega (54%), Cheepurupalle (40%), Salur (35%) and while it is least in the mandals viz; Gummalakshmipuram (3%), Mentada (8%), Vepada (9%) and Kurupam (10%).

6. GROUND WATER DEVELOPMENT AND MANAGEMENT STRATEGIES

6.1. Groundwater Development:

At present the ground water abstraction in the district is quiet low as the overall ground water development is only 19% and there is a vast scope for further ground water development by construction of additional wells for irrigation. The total utilization of ground water is 427 MCM against the total ground water potential of 1703 MCM available for future use. The ground water irrigation in the district is accounts for 38 % of the net irrigation of the district. There are about 22,180 no's of open wells, 16,207 no's of Bore wells and 3,105 no's Filter point wells in the District.

Government of Andhra Pradesh proposed to bring 16385 hectares area under irrigation through ground water by construction of 15849 bore wells with an estimated cost 745.34 crores in 1219 villages through PMKSY-HKKP-GWI/YSR Jala Kala **(Annexure-IV)**. By extracting more ground water through bore-wells / Tube wells, this will be generating more ayacut in irrigation sector and more subsurface ground water recharge through applied irrigation.

While taking up the developmental schemes in the district, priority may be given to those mandals where level of groundwater development is less than 20 percent and there are 17 such mandals. Next priority may be given to those mandals where level of ground water development is 20 to 35 percent and there are 15 such mandals in the district. There is one mandal, Pusapatirega where the groundwater development is 53 %.

The developmental activities of the district may be reviewed critically, once the level of groundwater development crosses 50 % in any mandal and this will enable to understand how the groundwater regime is getting adjusted both in space and time to the new stress conditions and also wherever the

surface water irrigation conditions prevailing, the conjunctive use of surface and groundwater may be adopted.

The coastal parts of the district, in Bhogapuram and Pusapatirega electrical conductivity of groundwater is higher than other parts of the district. So, ground water development in these two mandals has to be taken up very judiciously to avoid any possibility of sea water ingress/intrusion. The groundwater development activities if planned properly without disturbing ecological balance may bring the overall prosperity of this agrarian based district.

6.2. Groundwater Management Strategies:

6.2.1. Supply Side Measures:

6.2.1a. Artificial Recharge:

Government of Andhra Pradesh had already constructed a total 4940 recharge structure (4045 check dams, 493 check walls, 269 PT's and 133 mini PT's) through MGNREGS and IWMP scheme (source: Department of Rural Development and Panchayat Raj). At present, @1 artificial recharge structure existed @per square km area in the district. Considering the no. of ARS, it is recommended that the existing CD's and PT's shall be desilted and maintained prior to planning for any new artificial recharge structure. In future, artificial recharge structure can be taken up in specific areas considering any vulnerability and requirement.

6.2.2. Demand Side Measures:

6.2.2a. Micro-irrigation: The sustainability of bore well is low because of hard/crystalline rock. The yield of bore well is <1.0 lps identified in 20 % of area, and 1.0 to 2.0 lps in 58% of the area. This may be due to low interconnection among fractures or fracture becomes closed by clay due to chemical dissolution action of weathered portion in khondalite formation. Under

Andhra Pradesh Micro Irrigation Project, a total 1457 and 537 ha irrigated so far through sprinklers and drip irrigation method respectively. As sustainability of bore well is low, the sprinkler and drip irrigation system with suitable cropping pattern wherever feasible may be practiced as a measure for groundwater conservation, protection and management.

6.2.3. Other Measures:

- Even though there is no immediate threat to the soil or crop due to water logging condition. It is recommended measures like conjunctive use of surface and ground water in the feasible areas as the number of surface water irrigation projects are coming up in the district.
- In urban and rural area, the sewerage line should be constructed to arrest leaching of nitrate.

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Mandal wise recharge worthy and hilly area of the district **ANNEXURE-I**

S.No.	Mandal	Recharge Worthy Area (ha)				Hilly Area	Total Geographical area (ha)
		Com	N.Com	PQ	Total		
1	2	3	4	5	6	7	8
1	BADANGI	172	11791	0	11963	40	12003
2	BALAJIPETA	10688	5188	0	15876	227	16103
3	BHOGHAPURAM	3483	6841	0	10324	32	10356
4	BOBBILI	12323	8103	0	20426	279	20705
5	BONDAPALLE	5668	11003	0	16670	596	17266
6	CHEEPURUPALLE	0	11954	0	11954	270	12225
7	DATTIRAJERU	656	20476	0	21132	333	21465
8	DENKADA	4254	6760	0	11014	90	11104
9	GAJAPATHINAGARAM	7812	7195	0	15007	317	15324
10	GANTYADA	6911	9895	0	16807	317	17123
11	GARIVIDI	0	13680	0	13680	298	13977
12	GARUGUBILLI	1476	12594	0	14070	200	14270
13	GUMMALAKSHMIPURAM	2642	32187	0	34829	5589	40418
14	GURLA	3093	13533	0	16625	917	17542
15	JAMI	7483	6712	0	14195	84	14279
16	JIYYAMMA VALASA	10520	5259	0	15779	821	16600
17	KOMARADA	0	26916	0	26916	2131	29047
18	KOTHAVALASA	0	13442	0	13442	1448	14889
19	KURUPAM	199	35484	0	35683	6160	41843
20	LAKKAVARAPUKOTA	0	12429	0	12429	129	12558
21	MAKKUVA	16263	1082	0	17345	797	18142
22	MENTADA	9347	16697	0	26044	1556	27600
23	MERAKAMUDIDAM	4674	11935	0	16609	897	17506
24	NELLIMARLA	1333	14365	0	15698	420	16118
25	PACHIPENTA	7040	29234	0	36274	2183	38457
26	PARVATHIPURAM	0	27530	0	27530	2874	30404
27	PUSAPATIREGA	11422	782	0	12204	1177	13381
28	RAMABHADRAPURAM	637	13849	0	14486	293	14779
29	SALUR	2006	25202	0	27208	5805	33013
30	SEETHANAGARAM (VIZIANAGARAM)	6188	8579	0	14767	533	15299
31	SRUNGAVARAPUKOTA	2566	11724	0	14289	551	14840
32	THERLAM	0	14903	0	14903	171	15074
33	VEPADA	0	15027	0	15027	371	15398
34	VIZIANAGARAM MANDAL	588	11548	0	12136	301	12437

Mandal wise rainfall recharge and recharge due to different structures ANNEXURE-II

S.No.	Mandal	Rainfall Recharge (ha.m)	Recharge due to Canals (ha.m)	Recharge due to Surface Water Irrigation (ha.m)	Recharge due to Ground Water Irrigation (ha.m)	Recharge due to Tanks and Ponds (ha.m)	Recharge due to Water Conservation Structures (ha.m)	Total Ground water recharge (ha.m)
1	2	3	4	5	6	7	8	9
1	BADANGI	970	0	1732	296	5181	350	8528
2	BALAJIPETA	1921	684	2475	421	3760	111	9371
3	BHOGHAPURAM	1249	43	226	180	671	319	2689
4	BOBBILI	2083	0	2111	446	3141	564	8346
5	BONDAPALLE	1320	0	1201	78	4024	1025	7648
6	CHEEPURUPALLE	1261	104	755	521	1420	1307	5369
7	DATTIRAJERU	2097	0	720	443	3916	934	8110
8	DENKADA	1189	0	1492	231	1703	726	5340
9	GAJAPATHINAGARAM	1317	0	1682	289	2714	872	6874
10	GANTYADA	1497	0	1812	153	3579	753	7794
11	GARIVIDI	1512	0	918	404	2873	1268	6974
12	GARUGUBILLI	1389	0	1741	298	2215	188	5831
13	GUMMALAKSHMIPURAM	4299	0	477	5	563	621	5966
14	GURLA	1885	89	671	540	3114	969	7267
15	JAMI	1449	0	1450	282	2083	392	5655
16	JIYYAMMA VALASA	1387	0	2172	221	561	350	4692
17	KOMARADA	2531	0	1091	441	1853	412	6328
18	KOTHAVALASA	1161	0	385	220	2773	998	5538
19	KURUPAM	3603	0	1004	176	1374	385	6542
20	LAKKAVARAPUKOTA	1125	0	1529	135	3734	753	7275
21	MAKKUVA	1837	0	2365	116	2398	289	7006
22	MENTADA	1890	0	1107	152	5225	469	8844
23	MERAKAMUDIDAM	1789	0	677	399	3884	1044	7793
24	NELLIMARLA	1340	52	744	434	2995	727	6293
25	PACHIPENTA	3793	0	442	272	948	787	6242
26	PARVATHIPURAM	2854	0	1644	275	5030	509	10312
27	PUSAPATIREGA	1167	377	228	777	3468	338	6355
28	RAMABHADRAPURAM	1493	0	415	379	2240	646	5173
29	SALUR	3172	0	30	555	1273	600	5630
30	SEETHANAGARAM (VIZIANAGARAM)	1346	0	1570	424	2709	397	6447
31	SRUNGAVARAPUKOTA	1188	0	489	246	3036	296	5255
32	THERLAM	1005	438	746	175	2774	657	5795
33	VEPADA	1156	0	1152	150	4382	617	7457
34	VIZIANAGARAM	1024	0	565	102	2987	218	4896

Mandal wise GW Extraction and ground water categorization **ANNEXURE-III**

S.No.	Mandal	Annual Ground water Recharge (ham)	Environmental Flows (ham)	Annual Extractable Ground water Resource (ham)	Ground Water Extraction for domestic purpose	Ground Water Extraction for Industrial purpose	Ground Water Extraction for Irrigation purpose	Ground Water Extraction for all uses	Net Annual Ground Water Availability for Future Use (ham)	Stage of Ground Water Extraction (%)	Ground Water categorisation
1	2	3	4	5	6	7	8	9	10	11	12
1	BADANGI	8528	426	8102	39	9	1107	1154	6948	14	safe
2	BALAJIPETA	9371	469	8903	35	0	1359	1393	7545	16	safe
3	BHOGHAPURAM	2689	134	2554	57	24	687	769	1684	30	safe
4	BOBBILI	8346	417	7929	25	1	1116	1142	6682	14	safe
5	BONDAPALLE	7648	382	7265	35	1	626	662	6466	9	safe
6	CHEEPURUPALLE	5369	268	5100	36	0	1985	2021	2919	40	safe
7	DATTIRAJERU	8110	405	7705	10	1	1715	1727	5994	22	safe
8	DENKADA	5340	267	5073	34	1	1242	1277	3677	25	safe
9	GAJAPATHINAGARAM	6874	344	6530	36	4	1190	1230	5194	19	safe
10	GANTYADA	7794	390	7405	46	1	835	883	6347	12	safe
11	GARIVIDI	6974	349	6626	51	12	1694	1756	4721	26	safe
12	GARUGUBILLI	5831	292	5540	41	0	1117	1157	4293	21	safe
13	GUMMALAKSHMIPURAM	5966	299	5667	92	0	68	160	5394	3	safe
14	GURLA	7267	363	6904	48	13	2127	2187	4583	32	safe
15	JAMI	5655	283	5372	54	1	1217	1273	4030	24	safe
16	JIYYAMMA VALASA	4692	235	4457	38	0	833	871	3607	20	safe
17	KOMARADA	6328	317	6012	80	1	1661	1742	4375	29	safe

18	KOTHAVALASA	5538	277	5261	79	4	991	1075	4055	20	safe
19	KURUPAM	6542	327	6215	76	0	535	611	5515	10	safe
20	LAKKAVARAPUKOTA	7275	364	6911	50	16	649	716	6195	10	safe
21	MAKKUVA	7006	350	6655	46	1	655	702	5821	11	safe
22	MENTADA	8844	442	8402	30	1	596	628	7715	7	safe
23	MERAKAMUDIDAM	7793	390	7403	31	7	1541	1579	5743	21	safe
24	NELLIMARLA	6293	315	5978	42	0	1977	2019	3913	34	safe
25	PACHIPENTA	6242	312	5930	74	0	916	990	4941	17	safe
26	PARVATHIPURAM	10312	516	9796	76	9	1297	1382	8275	14	safe
27	PUSAPATIREGA	6355	318	6037	69	92	3062	3223	3111	53	safe
28	RAMABHADRAPURAM	5173	259	4914	43	0	1447	1490	3518	30	safe
29	SALUR	5630	281	5349	80	0	1767	1847	3758	35	safe
30	SEETHANAGARAM (VIZIANAGARAM)	6447	322	6124	42	1	1356	1400	4697	23	safe
31	SRUNGAVARAPUKOTA	5255	263	4993	72	12	1167	1250	3864	25	safe
32	THERLAM	5795	290	5505	56	0	1089	1145	4557	21	safe
33	VEPADA	7457	373	7085	59	0	633	692	6267	10	safe
34	VIZIANAGARAM MANDAL	4896	245	4651	42	4	521	568	3930	12	safe
total		225636	11283	214353	1726	220	40776	42722	170335	20	safe

Mandal wise tentative estimation for drilling of GW extraction structures under PMKSY-HKKP (GW) **ANNEXURE-IV**

S.No	District	Mandal Name	No. of Villages	No. of Bore Wells	No. of Shallow Tube Wells	No. of Deep Tube Wells	Total No. of Structures	No. of Feasible Structures	Area Proposed to be irrigated (Ha)	Total Cost of Drilling Component	Cost of Energization including Electric and Solar Structure (24 to 26)	Total cost (Lakhs)
1	2	3	4	5	6	7	8	9	10	11	12	13
1	Vizianagaram	BADANGI	21	178	8	0	186	186	194	171	630	874
2	Vizianagaram	BALAJIPETA	32	345	125	0	470	470	597	443	1595	2222
3	Vizianagaram	BHOGHAPURAM	19	374	0	0	374	374	373	342	1270	1759
4	Vizianagaram	BOBBILI	40	505	117	0	622	622	738	581	2112	2937
5	Vizianagaram	BONDAPALLE	30	782	0	0	782	782	780	716	2656	3678
6	Vizianagaram	CHEEPURUPALLE	25	272	0	0	272	272	272	249	924	1280
7	Vizianagaram	DATTIRAJERU	32	386	0	0	386	386	388	353	1311	1815
8	Vizianagaram	DENKADA	26	530	0	0	530	530	528	485	1799	2492
9	Vizianagaram	GAJAPATHINAGARAM	34	845	0	0	845	845	846	773	2871	3975
10	Vizianagaram	GANTYADA	37	197	0	0	197	197	199	180	664	922
11	Vizianagaram	GARIVIDI	28	358	0	0	358	358	360	328	1216	1684
12	Vizianagaram	GARUGUBILLI	26	168	0	0	168	168	167	154	569	789
13	Vizianagaram	GUMMALAKSHMIPURAM	84	758	0	0	758	758	753	694	2569	3559
14	Vizianagaram	GURLA	38	723	161	0	884	884	1047	825	3005	4176
15	Vizianagaram	JAMI	26	382	0	0	382	382	384	350	1297	1796
16	Vizianagaram	JIYYAMMA VALASA	47	377	0	0	377	377	376	345	1276	1769
17	Vizianagaram	KOMARADA	94	955	0	0	955	955	955	874	3237	4485
18	Vizianagaram	KOTHAVALASA	16	206	0	0	206	206	207	189	700	969
19	Vizianagaram	KURUPAM	79	364	0	0	364	364	363	333	1227	1703
20	Vizianagaram	LAKKAVARAPUKOTA	30	486	0	0	486	486	486	445	1648	2283
21	Vizianagaram	MAKKUVA	45	306	0	0	306	306	301	280	1037	1437

22	Vizianagaram	MENTADA	23	584	0	0	584	584	581	534	1985	2748
23	Vizianagaram	MERAKAMUDIDAM	33	586	0	0	586	586	586	536	1989	2755
24	Vizianagaram	NELLIMARLA	29	499	0	0	499	499	497	457	1694	2346
25	Vizianagaram	PACHIPENTA	43	1089	6	0	1095	1095	1099	1003	3721	5152
26	Vizianagaram	PARVATHIPURAM	37	171	0	0	171	171	168	156	578	801
27	Vizianagaram	PUSAPATIREGA	33	1160	86	0	1246	1246	1333	1149	4233	5870
28	Vizianagaram	RAMABHADRAPURAM	19	182	0	0	182	182	182	167	617	854
29	Vizianagaram	SALUR	68	374	42	0	416	416	458	385	1406	1954
30	Vizianagaram	SEETHANAGARAM (VIZIANAGARAM)	36	300	11	0	311	311	319	286	1055	1462
31	Vizianagaram	SRUNGAVARAPUKOTA	22	149	0	0	149	149	151	136	505	699
32	Vizianagaram	THERLAM	20	47	0	0	47	47	45	43	158	220
33	Vizianagaram	VEPADA	30	474	0	0	474	474	473	434	1609	2228
34	Vizianagaram	VIZIANAGARAM MANDAL	17	181	0	0	181	181	180	166	614	851
Grand Total			1219	15293	556	0	15849	15849	16385	14558	53778	74543

Exploratory well details of deep wells (200m.) in Vizianagaram district **ANNEXURE-V**

S.No.	Location	Mandal	Well Type	Total Depth (m)	Weathered Depth (m bgl)	Deepest Fracture Depth (m)	Yield (lps)	Geology	Year
1	Badangi	Badangi	EW	200	12.5	20	0.8	Gneiss	2001
2	Pedavemali	Gantyada	EW	200	33.0	158	2	Gneiss	2001
3	S.Gurjuvalasa	Dattirajeru	EW	200	16.5	31.5	0.45	Gneiss	2003
4	Tadivada	Denkada	EW	200	15.0	142	1.57	Gneiss	2003
5	Savaravelli	Bhogapuram	EW	200	16.5	180	2.97	Gneiss	2003
6	Kondarajupalem	Bhogapuram	EW	200	11.5	158	3.82	Gneiss	2003
7	Kondarajupalem	Bhogapuram	OW	200	11.5	159.6	3.35	Gneiss	2003
8	Piridi	Bobbili	EW	200	17.7	64	1.41	Gneiss	2003
9	Komatipalli	Bobbili	EW	200	17.7	29	0.22	Gneiss	2003
10	Barli	Balijapeta	EW	200	16.8	188	0.7	Gneiss	2003
11	Rangampeta	Sitanagaram	EW	200	5.6	49.8	1.21	Gneiss	2003
12	Ramavaram	Sitanagaram	EW	200	15.0	25	3.5	Gneiss	2003
13	Ramavaram	Sitanagaram	OW	200	15.0	67	2.15	Gneiss	2003
14	Vengapuram	Balijipeta	EW	200	17.8	41	1.8	Gneiss	2003
15	Galavvelli	Balijipeta	EW	200	11.9	14.2	1.1	Gneiss	2003
16	Manchakavalasa	Pachipenta	EW	200	7.6	13	Meager	Gneiss	2004
17	Jeegiram	Salur	EW	200	21.0	31	1.2	Gneiss	2004
18	Makkuva	Makkuva	EW	200	8.5	63	1.21	Gneiss	2004
19	Kanchendavalasa	Makkuva	EW	200	5.6	32	0.21	Gneiss	2004
20	Vasanta	Gantyada	EW	200	25.3	120	1.71	Gneiss	2004
21	Bobbili	Bobbili	EW	200	11.6	164	1.37	Gneiss	2004
22	Santoshapuram	Garugubilli	OW	200	17.6	128	1.49	Gneiss	2004
23	Jiyyammavalasa	Jiyyamavalasa	EW	200	4.9	13	1.29	Gneiss	2004

S.No.	Location	Mandal	Well Type	Total Depth (m)	Weathered Depth (m bgl)	Deepest Fracture Depth (m)	Yield (lps)	Geology	Year
24	Ulipiri	Komarada	EW	200	30.8	56	1.29	Gneiss	2005
25	Appayapet	Seethanagaram	EW	200	24.0	191	1.2	Granite	2020-21
26	Bondapalle	Bondapalle	EW	200	42.0	181	0.03	Khondalite	2020-21
27	Duppada	Vizianagaram	EW	200	25.0	181	0.07	Khondalite	2020-21
28	Guchimi	Dattirajeru	EW	200	25.0	102	0.3	Khondalite	2020-21
29	Jagaram	Jami	EW	200	30.0	181	0.07	Khondalite	2020-21
30	Konda Gandredu	Nellimarla	EW	200	22.0	22	Meager	Granite	2020-21
31	Kotha Bheemsinghi	Jami	EW	200	25.0	132	0.31	Khondalite	2020-21
32	Kotha Valasa	Kothavalasa	EW	200	21.0	153	0.21	Khondalite	2020-21
33	Kurupam1	Kurupam	EW	200	42.0	52	0.31	Granite	2020-21
34	M Mamidipalle	Salur	EW	200	35.0	90	4.3	Granite	2020-21
35	Markondaputti-EW	Makkuva	EW	200	48.0	95	3	Khondalite	2020-21
36	Musiram	Kothavalasa	EW	200	57.0	171	0.44	Granite	2020-21
37	Parvatipuram	Parvatipuram	EW	200	30.0	151	0.31	Khondalite	2020-21
38	Pedda Bantupalli	Gurla	EW	200	31.0	129	0.07	Khondalite	2020-21
39	Pinapenki	Badangi	EW	200	30.0	197	1.29	Khondalite	2020-21
40	Pusapatirega	Pusapatirega	EW	200	48.0	48	Meager	Granite	2020-21
41	Rajapulova	Bhogapuram	EW	200	18.0	186	0.44	Khondalite	2020-21
42	Ramabhadrapuram	Ramabhadrapuram	EW	200	12.0	116	0.76	Granite	2020-21
43	S S R Peta	Gurla	EW	200	47.0	143	3.3	Khondalite	2020-21
44	Srungavarapukota	Srungavarapukota	EW	200	18.0	131	0.07	Granite	2020-21
45	Thonam	Sallur	EW	200	30.0	121	1.01	Khondalite	2020-21