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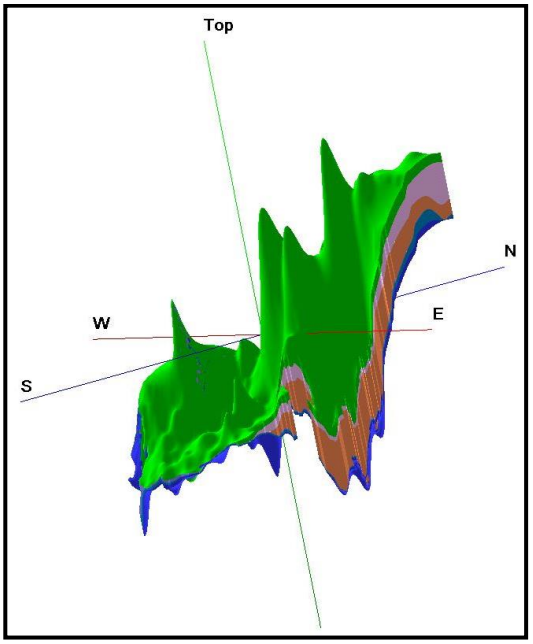
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RD & GR
CENTRAL GROUND WATER BOARD

REPORT ON
AQUIFER MAPPING AND MANAGEMENT OF
ALLURI SITARAMARAJU DISTRICT ANDHRA PRADESH STATE
(AAP-2023-24)



CENTRAL GROUND WATER BOARD
SOUTHERN REGION
HYDERABAD
February 2025

REPORT ON
AQUIFER MAPPING AND MANAGEMENT OF ALLURI SITARAMARAJU DISTRICT, ANDHRA PRADESH STATE
(AAP-2023-24)

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AQUIFER MAPPING AND MANAGEMENT OF ALLURI SITARAMARAJU DISTRICT ANDHRA PRADESH STATE

Executive summary

Contents

ABBREVATIONS

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

EXECUTIVE SUMMARY

The Alluri Sitarama Raju district, Andhra Pradesh having geographical area of 12253.42 km2, and lies between 17º 17’ and 18º 21’ of the Northern Latitude and 80º 53’ to 82º 50’ of the Eastern Longitude Administratively, the district is governed by 02 Revenue Divisions viz., Paderu and Rampachodavaram with 22 Revenue Mandals and 3326 villages. The total populationof the district as per 2011 population census is ~9.54 lakhs. The normal rainfall of the district is 1286 mm. The main River that drains the Alluri Sitarama Raju district is Godavari River.

Geomorphologically the district can be broadly divided into 2 distinct units, viz., hills & plains. 72% of state area is covered by structural hills and followed by pediment, pediplain etc Physiographically, the district is mostly covered by Eastern Ghats with an altitude of about 900 meters dotted by several peaks exceeding 1200 meters. Predominantly, high elevations are concentrated in the North-eastern part of the district, while the south-western sectors feature lower elevations. All these individual ranges form part of the Eastern Ghats. The rivers flowing through the district create a drainage pattern that ranges from dendritic to sub-dendritic.

The district's predominant soils include red soils, sandy loams, and sandy clay, covering 96% of the area and characterized by medium fertility. Of the total geographical area of 12,250 km², forests occupy approximately 63% (7,760 km²), net sown area is 12% (1,440 km²), barren and uncultivable land constitutes 9% (1,080 km²), land for non-agricultural uses covers 4% (460 km²), and fallow land accounts for 9% (1,140 km²).

The geology of Alluri Sita Ramaraju district is primarily composed of rocks from the Eastern Ghat Mobile Belt, including the Khondalite Group, Charnockite Group, and Migmatite complex, with sediments of Cenozoic laterite and Quaternary deposits overlying these formations. The district's lithology features Khondalite, Charnockite, Gneiss, and Banded Gneissic Complex as the major units, along with smaller occurrences of Granite and Alluvium. The geological framework influences the occurrence and movement of groundwater, with groundwater primarily present in secondary porosities formed by weathering and fracturing of these rocks

The Central Ground Water Board has conducted significant groundwater research in the district, drilling 23 bore wells, performing 20 Vertical Electrical Soundings (VES), and carrying out 21 Transient Electromagnetic (TEM) surveys. Groundwater monitoring is facilitated through 59 groundwater level monitoring (GWM) stations, while groundwater quality is assessed using data from 42 quality monitoring stations.

Data density is established at one data point per 40 square kilometers for analyzing the lateral and vertical distribution of aquifers, one point per 99 square kilometers for assessing spatial and temporal variations in groundwater levels, and one point per 42 square kilometers for evaluating groundwater quality changes over time.

The Depth to Water Levels (DTWL) in Alluri Sita Ramaraju district was analyzed for a 10-year period (2014 to 2023). During the pre-monsoon season, the DTWL ranged from 0.92 to 18.32 meters below ground level (m bgl), with an average of 6.58 m bgl. In the post-monsoon season, it ranged from 0.59 to 14.78 m bgl, with an average of 4.41 m bgl. Most pre-monsoon water levels were found between 5 to 10 m (43% of the area) and less than 5 m bgl (43%), with a minor occurrence of levels beyond 15 m. Post-monsoon water levels were predominantly under 5 m bgl (69%), followed by 5 to 10 m bgl (25%).

The long-term trend analysis from 41 hydrograph stations showed a mix of falling and rising water level trends. During the pre-monsoon season, 18 wells exhibited a declining trend (0.00765 to 0.37452 m/year, average 0.075 m/year), while 22 wells showed an increasing trend (0.00285 to 0.34510 m/year, average 0.129 m/year). In the post-monsoon season, 14 wells had a falling trend (0.122806 to 0.280238 m/year, average 0.119 m/year), while 22 wells demonstrated a rising trend (-0.052 to 0.68 m/year, average 0.260 m/year).

To understand chemical nature of groundwater, total 42 data points is utilized from ground water monitoring wells to assess spatial and temporal variations. The groundwater is mildly alkaline to alkaline, with a pH range of 6 to 8.8 (average 7.54). Electrical conductivity (EC) varies from 22 to 2051 µSiemens/cm, with 66% of the area having EC below 750 µSiemens/cm, 33% between 750 and 1500 µSiemens/cm, and 1% exceeding 1500 µSiemens/cm. Nitrate concentrations range from 0.01 to 154 mg/l, with 78% of samples below the permissible limit of 45 mg/l, while 22% exceed this limit. Fluoride levels range from 0.01 to 4.39 mg/l, with 88% of samples within safe limits (<1.5 mg/l) and 12% above the permissible range.

According to the 2023 Ground Water Resource Assessment report, the Alluri Sita Ramaraju district has net annual extractable groundwater resources of 888 million cubic meters (MCM). The total gross groundwater draft for all uses is 22 MCM, with a provision of 18 MCM for domestic use projected for 2025. The net groundwater availability for future use stands at 866 MCM. The stage of groundwater extraction ranges from 1% in Y Ramavaram to 9% in Paderu, with an overall stage of extraction (SoE) of 2.49%. Based on this assessment, all mandals in the district are classified as safe concerning groundwater development.

The aquifers in the district have a recharge potential of 2,095 million cubic meters (MCM), with an additional 98 MCM available as surplus runoff, accounting for 20% of the monsoon runoff. To enhance groundwater recharge, the District Water Management Agency (DWMA) of the Rural Development Department, Government of Andhra Pradesh, has constructed 284 artificial recharge structures. These include 46 percolation tanks, 6 mini percolation tanks, 208 check dams, and 24 check walls, implemented under the IWMP and MGNREGS programs.

REPORT ON

AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN ALLURI SITARAMA RAJU DISTRICT, ANDHRA PRADESH

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 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 Alluri Sitarama Raju district has been selected and completed during AAP 2023-2024.

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 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.

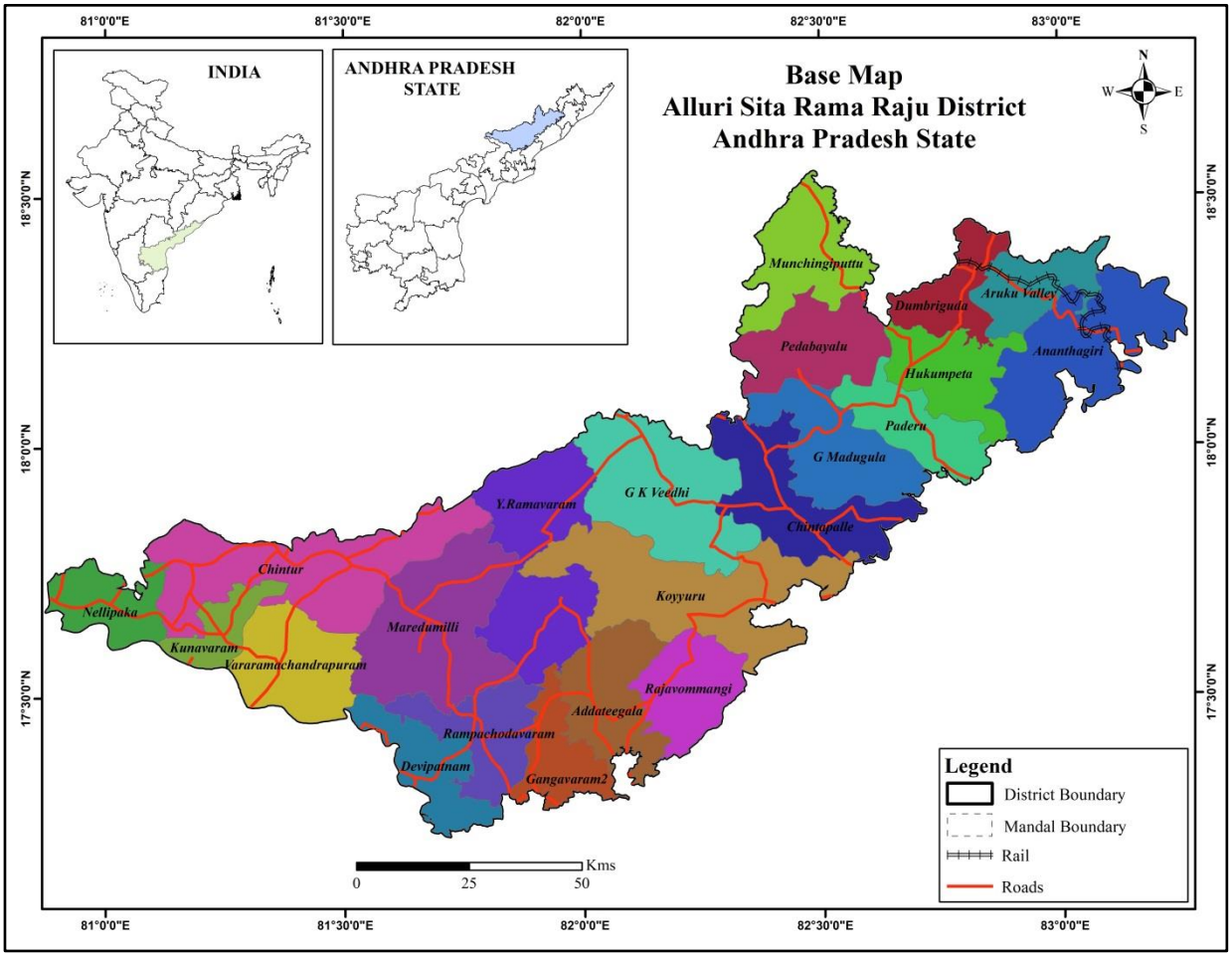
1. Compilation of existing data (exploration, geophysical, groundwater level and groundwater quality with geo-referencing information and identification of principal aquifer units.
2. Periodic long-term monitoring of ground water regime (for water levels and water quality) or creation of time series 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: Alluri Sitharama Raju District is one of the North Eastern district of Andhra Pradesh having a geographical area of 12253.42 km^2, and lies between 17^0 17′ and 18^0 21′ of the Northern Latitude and 80^0 53′ to 82^0 50′ of the Eastern Longitude. It is bounded on the North partly by the Odisha State Partly by Chattisgarh State and partly by Telangana State on the South by Anakapalli, Kakinada and East Godavari Districts on the West covered by Godavari River and East by Vijayanagaram (**Fig.1.1**). For administrative convenience, the district is divided into 2 Revenue Divisions, Paderu and Rampachodavaram with 22 Revenue Mandals.

S.No	Paderu Division	Rampachodavaram Division
1	Ananthagiri	Addateegala
2	Araku Valley	Chintur
3	Chintapalle	Devipatnam
4	Dumbriguda	Gangavaram
5	G.Madugula	Kunavaram
6	Gudem Kotha Veedhi	Maredumilli
7	Hukumpeta	Nellipaka
8	Koyyuru	Rajavommangi
9	Munchingi Puttu	Rampachodavaram
10	Paderu	Vararamachandrapuram
11	Peda Bayalu	Y.Ramavaram

There are 3326 villages with a population of ~9.54 lakhs (2011 census). G. Madugula mandal is having maximum number of villages (361) and Devipatnam mandal having minimum number of villages (47). Out of 22 mandals of the district, the maximum area (1038.77 Sq.km) is occupied by Chintur mandal and minimum area in Kunavaram mandal (218.70 Sq.km). The mandals covered in each Revenue division are shown in Table-1 and its spatial distribution is shown in the Figure-1.1. The density of population is 78 persons/ km^2 in the State. The total forest area in the district accounts for 7760 km^2occupying 63% of the total geographical area. The basic details of the district are provided in Table-1.

Fig.1.1: Location map of Alluri Sitarama Raju district.



1.4 Climate and Rainfall: The climate of the district is characterised by hot summer and generally dry weather except during S-W monsoon season. The minimum and maximum temperatures recorded in the district are 13.3°C in January and 43.3°C in May respectively. The average normal annual rainfall of the district is 1286 mm. This varies between 1100 mm (Gangavaram) to 1614 mm (Munchingiputtu) (Fig. 1.2). The South west monsoon contributes

64% of the rainfall and northeast monsoon contributes 17% of the rainfall in the district. The season wise normal and actual rainfall is provided in Table-1.2.

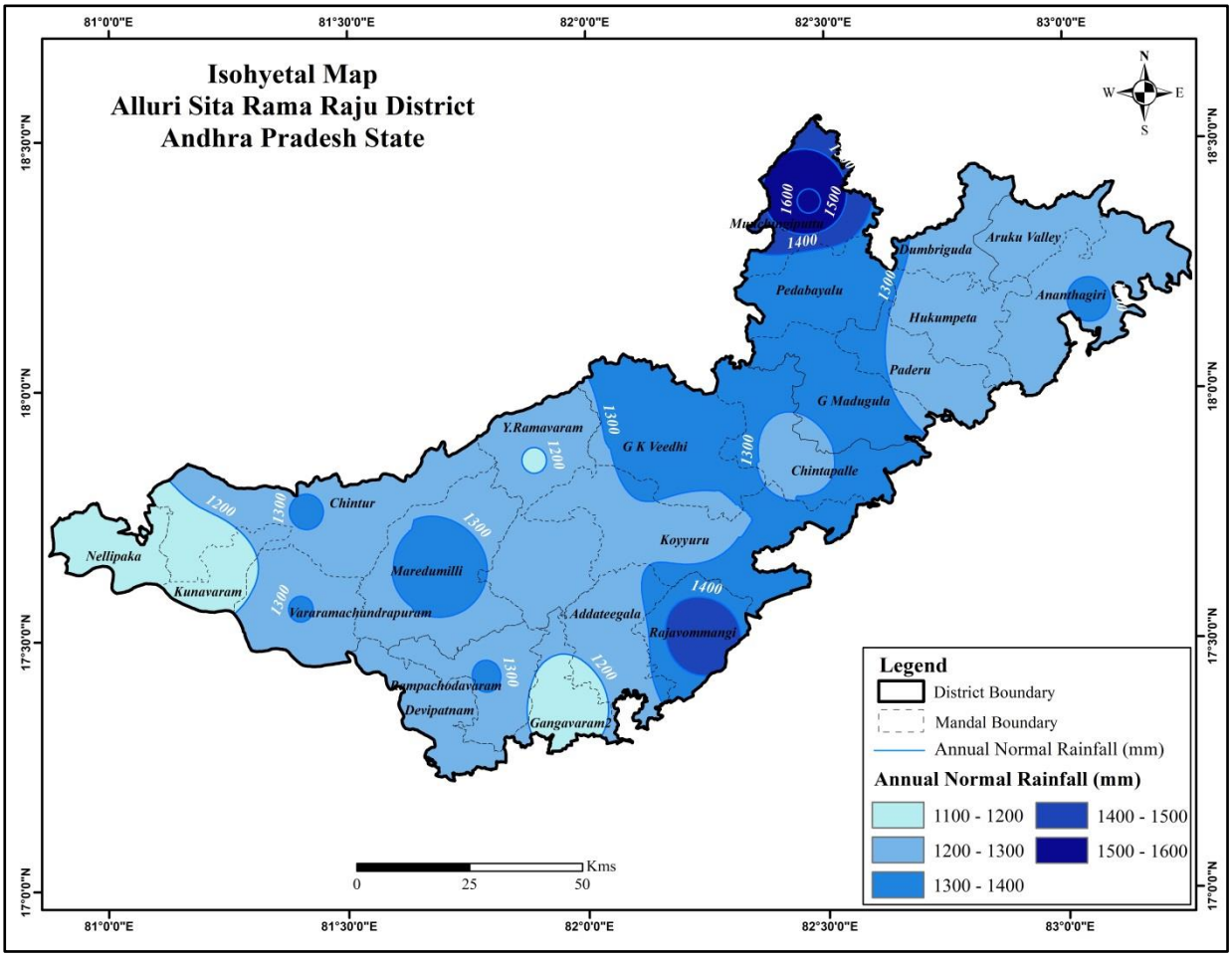


Fig.1.2: Isohyetal map of Alluri Sita Rama Raju district

Table: 1.2 Season wise in the Alluri Sita Rama Raju District, AP

S.No.	MANDAL	SW Monsoon		NE Monsoon		Winter		Summer		Total	
		Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual
1	Addateegala	801	643	235	237	16	0	161	247	1214	1127
2	Ananthagiri	736	727	312	187	16	2	224	232	1288	1147
3	Araku Valley	755	746	214	188	12	1	225	278	1207	1213
4	Chintapalle	786	726	211	256	21	1	241	227	1258	1210
5	Chintur	1128	1255	100	170	10	0	71	188	1308	1614
6	Devipatnam	854	792	208	220	19	0	137	197	1219	1210
7	Dumbriguda	775	769	217	200	16	1	243	293	1252	1264
8	Gangaraju Madugula	965	707	220	241	27	2	173	238	1385	1188
9	Gangavaram (East Godavari)	711	636	215	228	16	0	152	242	1094	1106
10	Gudem Kothaveedhi	890	782	238	218	21	0	216	228	1364	1228
11	Hukumpeta	745	740	205	215	19	4	257	258	1225	1216
12	Koyyuru	830	766	223	231	26	1	183	228	1261	1226

13	Kunavaram	964	1255	101	210	9	0	69	170	1144	1635
14	Maredumilli	901	900	256	198	21	0	157	207	1334	1305
15	Munchingiputtu	1256	1017	198	188	10	2	144	289	1609	1496
16	Nellipaka	938	1175	111	218	21	0	82	218	1152	1611
17	Paderu	779	737	201	221	17	5	261	247	1258	1210
18	Pedabayalu	914	741	186	217	13	1	182	263	1294	1222
19	Rajavommangi	1025	641	263	258	28	0	172	236	1489	1136
20	Rampachodavaram	879	713	268	222	24	0	133	217	1305	1153
21	Vararamachandrapur	1071	1148	112	209	13	0	109	163	1306	1520
22	Y Ramavaram	798	807	236	195	14	0	141	239	1189	1242

**Rainfall in mm*

1.5 Geomorphology: Pediplains, Structural hills, Denudational hills and pediments are the major geographic units in the district. The details and percentage of geomorphological features of the district is given in the table 1.3 and depicted in **Fig.1.3.**

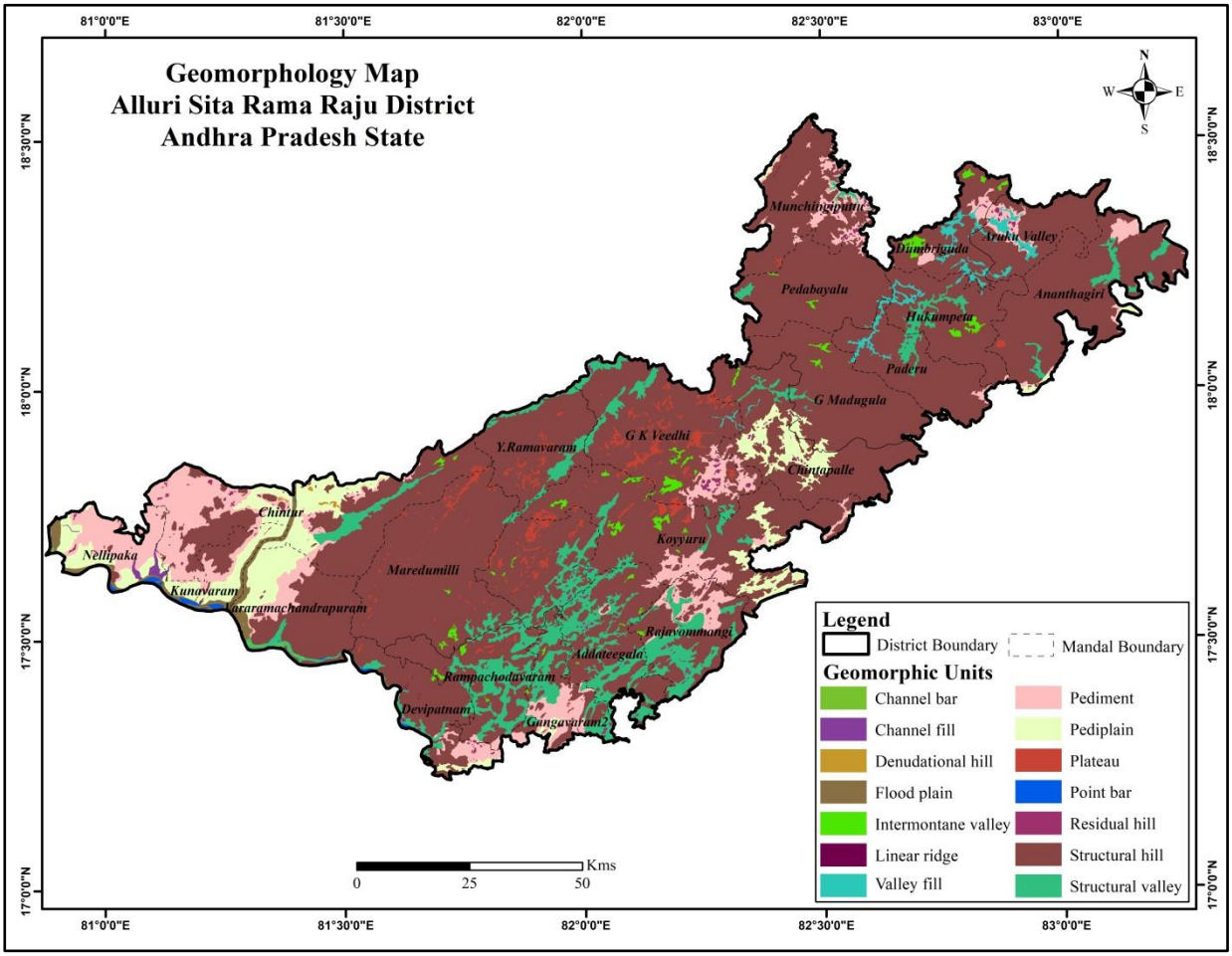


Fig.1.3: Geomorphology of Alluri Sitarama Raju district.

Table-1.3: Geomorphology of Alluri Sitarama Raju District

S.No.	Code	Geomorphology	Area (Sq kms)	Percentage (%)
1	Sh	Structural hill	9101.10	72.03
2	Pd	Pediment	1119.94	8.86
3	Sv	Structural valley	1067.06	8.45
4	Pp	Pediplain	742.87	5.88
5	P	Plateau	171.14	1.35
6	Fp	Flood plain	110.14	0.87
7	Vf	Valley fill	106.88	0.85
8	Iv	Intermontane valley	96.89	0.77
9	Rh	Residual hill	68.80	0.54
10	Pb	Point bar	22.63	0.18
11	Cf	Channel fill	14.96	0.12
12	Cb	Channel bar	5.16	0.04
13	Dh	Denudational hill	4.90	0.04
14	Lr	Linear ridge	2.20	0.02
Total			**12634.68**	**100**

1.6 Physiography:

The District presents a distinct geographic division. It consists of the hilly regions covered by the Eastern Ghats with an altitude of about 900 meters dotted by several peaks exceeding 1200 meters. Forest block topping with 1615 meters embraces the Mandals of Paderu, G.Madugula, Munchingput, Araku Valley, Ananthagiri, Chinthapalli. The Koyyuru, G.K.Veedhi and Chinthapalli mandals are clubbed with Rampachodavaram Division of East Godavari District. Galikonda hill rising to a height of 5,000 feet (1,500 m) is amongst the highest peaks. Elevations range from 15 meters above mean sea level (m.amsl) to 1677 meters above mean sea level (m.amsl). Predominantly, high elevations are concentrated in the North-eastern part of the district, while the south-western sectors feature lower elevations. All these individual ranges form part of the Eastern Ghats. These ranges with their detached hills show a distinct North-East-South-West trend. The elevation map of the district is provided in **Fig-1.4**

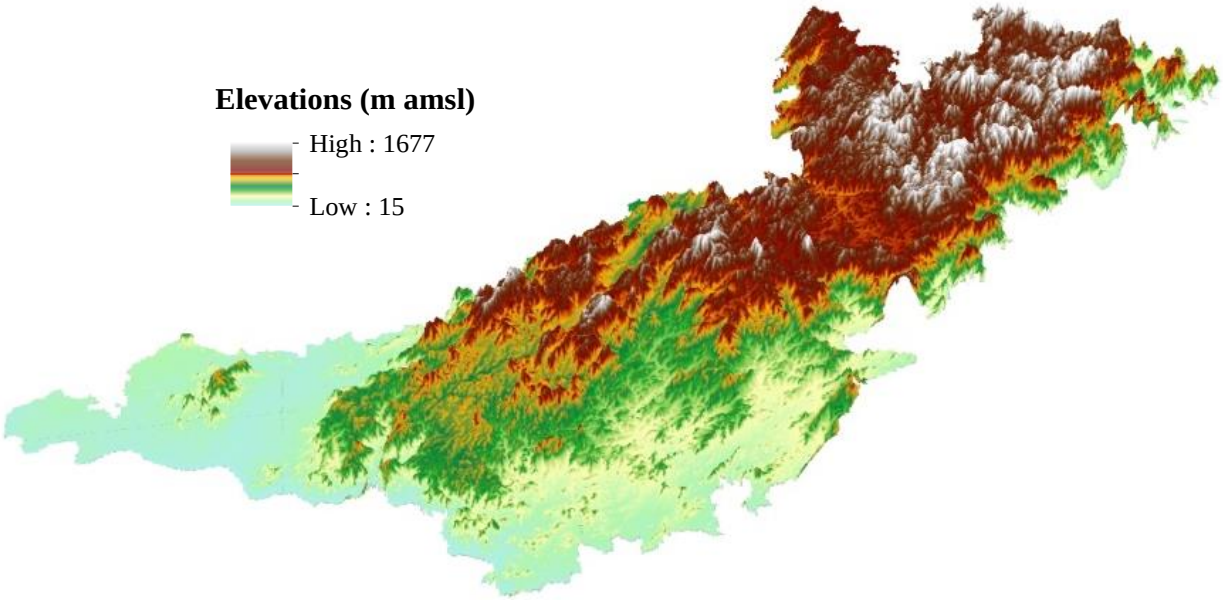


Fig-1.4: Physiography of the Alluri Sitarama Raju District, Andhra Pradesh

1.7 Drainage: The principal rivers flowing in the district are Godavari, Yeleru, Thandava, Sarada, Gosthani rivers and partially covered with Suddagedda, Pampa, Varaha, Champavathi, Nagavali rivers. The district consists of the hilly regions covered by the Eastern Ghats with an altitude of about 1,500m. The Sabari, Pamuleru, Sethapallivagu, Burdakalva, Yeleru, Suddagedda, Pampa, Varaha, Thandava, Sarada, Gosthani and Champavathi rivers are rises in the Eastern Ghats of Alluri Sitharama Raju district**.** The drainage system of the district primarily relies on natural river systems and man-made canals. These rivers play a crucial role in the drainage of the district, carrying water away from the land and ultimately draining into the Bay of Bengal. Additionally, the district has an extensive network of canals, both natural and artificial, which aid in irrigation and drainage. The canals are often interconnected with the river systems, facilitating the flow of water across different parts of the district. The general drainage pattern is dendritic to sub-dendritic. The map depicting river, drainage and water bodies is presented in **Fig.1.5.**

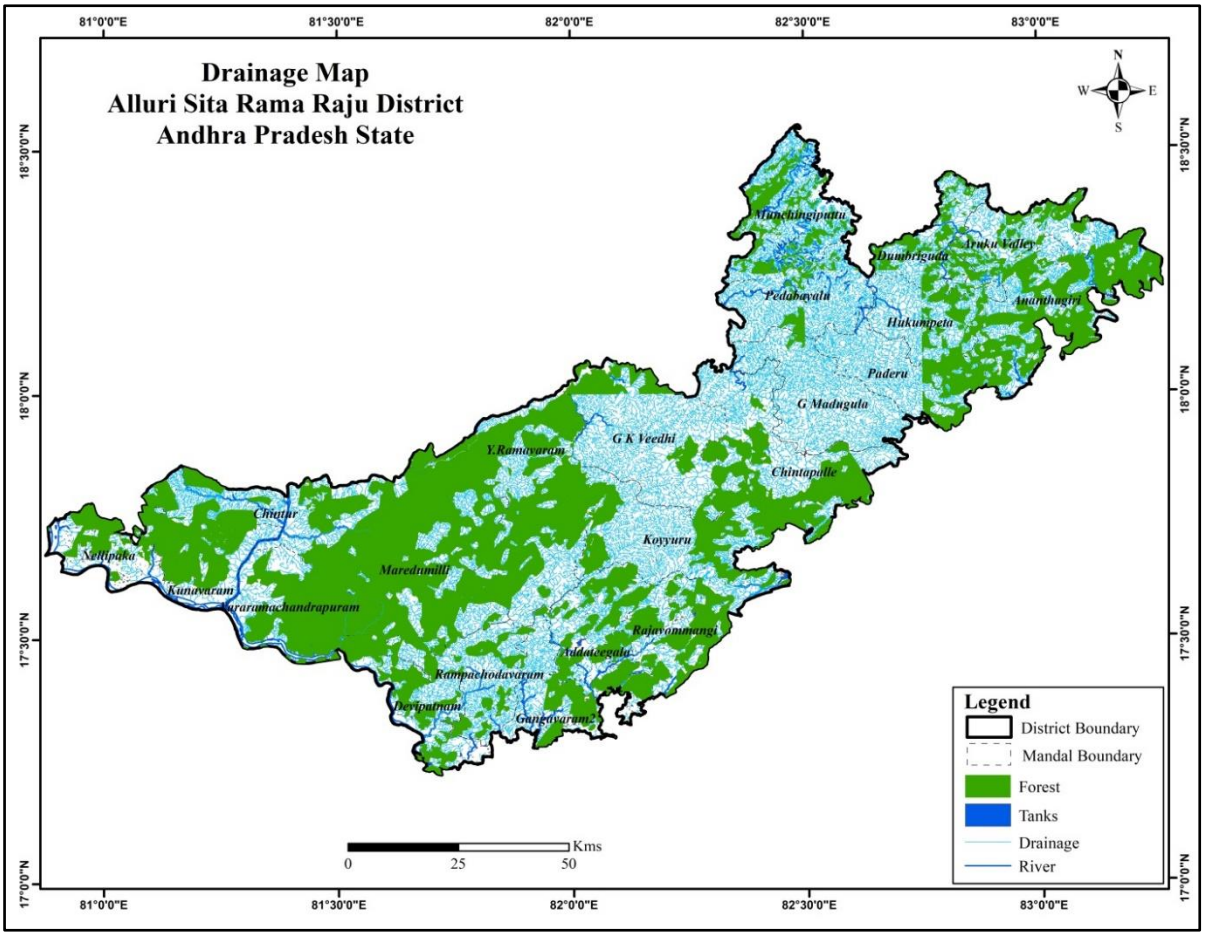


Fig.1.5: Drainage map of Alluri Sitarama Raju District, Andhra Pradesh.

1.8 Land Use: Out of total geographical area of 12250 km^2, forest occupies 7760 sq. kms (~63%), the net area sown is 1440 sq kms (12%), barren and uncultivable land is 1080 sq kms (9%), land put to non-agricultural uses is 460 sq. kms (4%), the fallow is 1140 sq kms (9%) etc. The details of land use pattern in the district are provided in Table-1.4. The maps depicting Land use and land cover of the district is provided in Fig. 1.5 and 1.6.

S. No	CATEGORY	AREA (ha)	Area (Sq. kms)	Percentage
1	Total Geographical area	1225000	12250	100
2	Forests	776000	7760	63
3	Net Area Sown	144000	1440	12
4	Barren & Uncultivable Land	108000	1080	9
5	Fallows	114000	1140	9
6	Land put to Non Agri & Others	46000	460	4
7	Water Bodies	16900	169	1
8	Villages and Town	81000	810	1
9	Cultivable Waste	12000	120	1

Table-1.4: Land use and land cover of Alluri Sita Rama Raju district

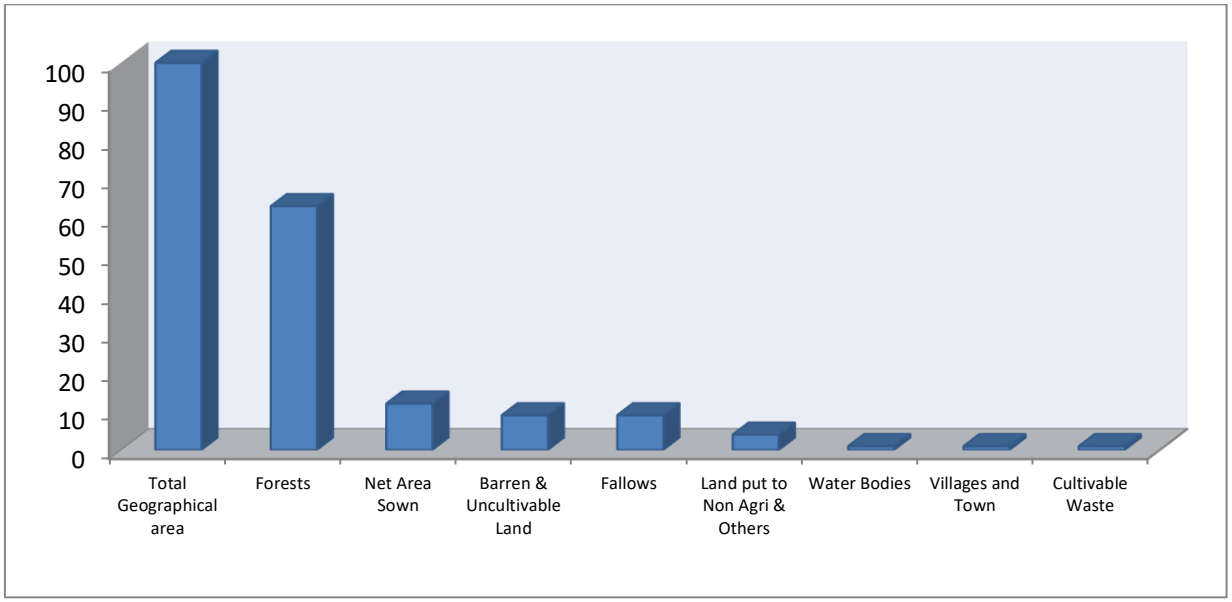


Fig- 1.6 Graphical presentation of Land Use in Alluri Sitarama Raju District, AP

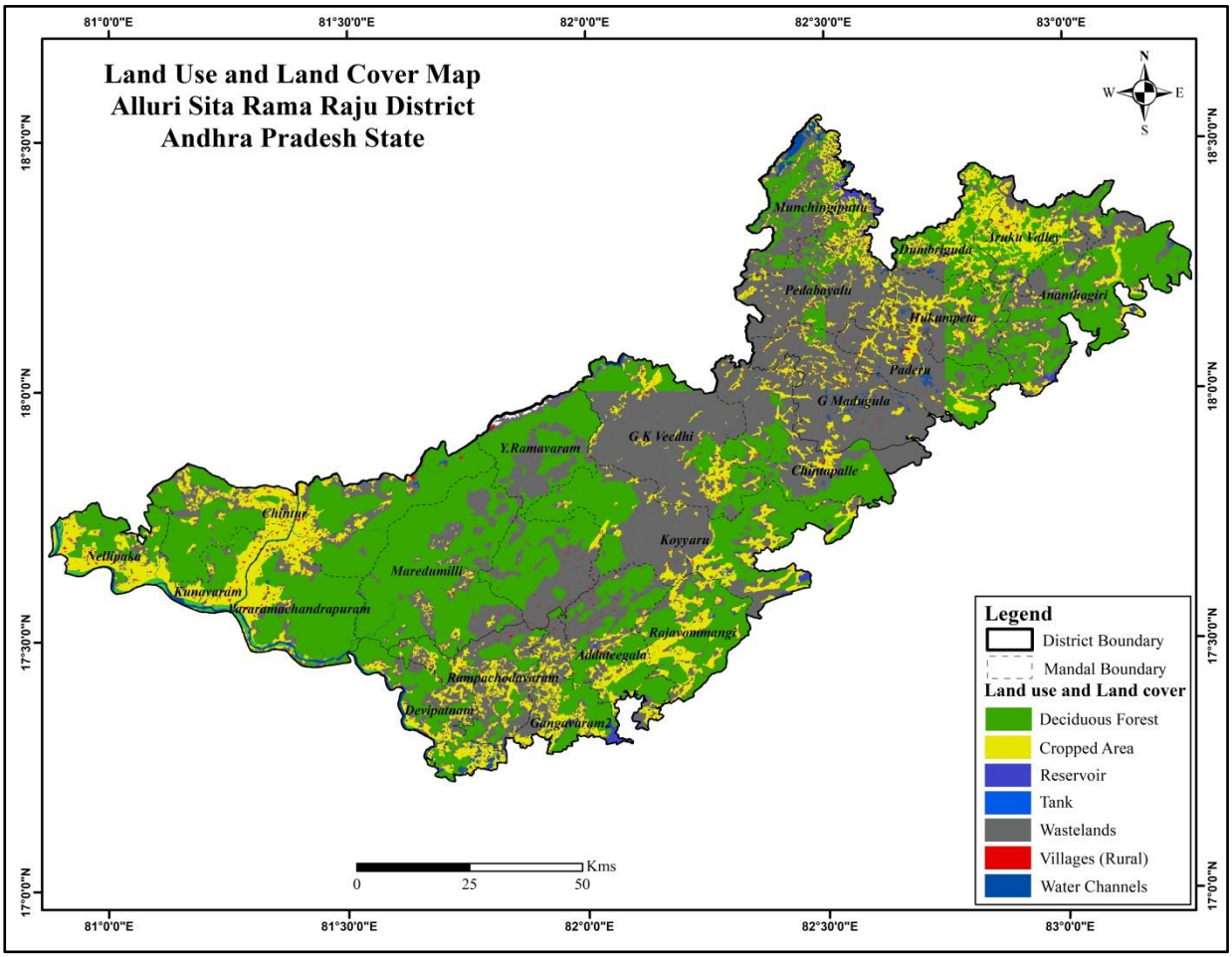


Fig-1.7: Land Use in Alluri Sitarama Raju District, AP

1.9 Soils: The main soils in the district are red soils, sandy loams and sandy clay and they constitute 96% of the total area. The soils in the district are predominantly loamy with medium fertility. The soils at some places are as thick as 4 Metres in alluvial tracts and valleys. The map depicting the soils are provided in fig-1.7

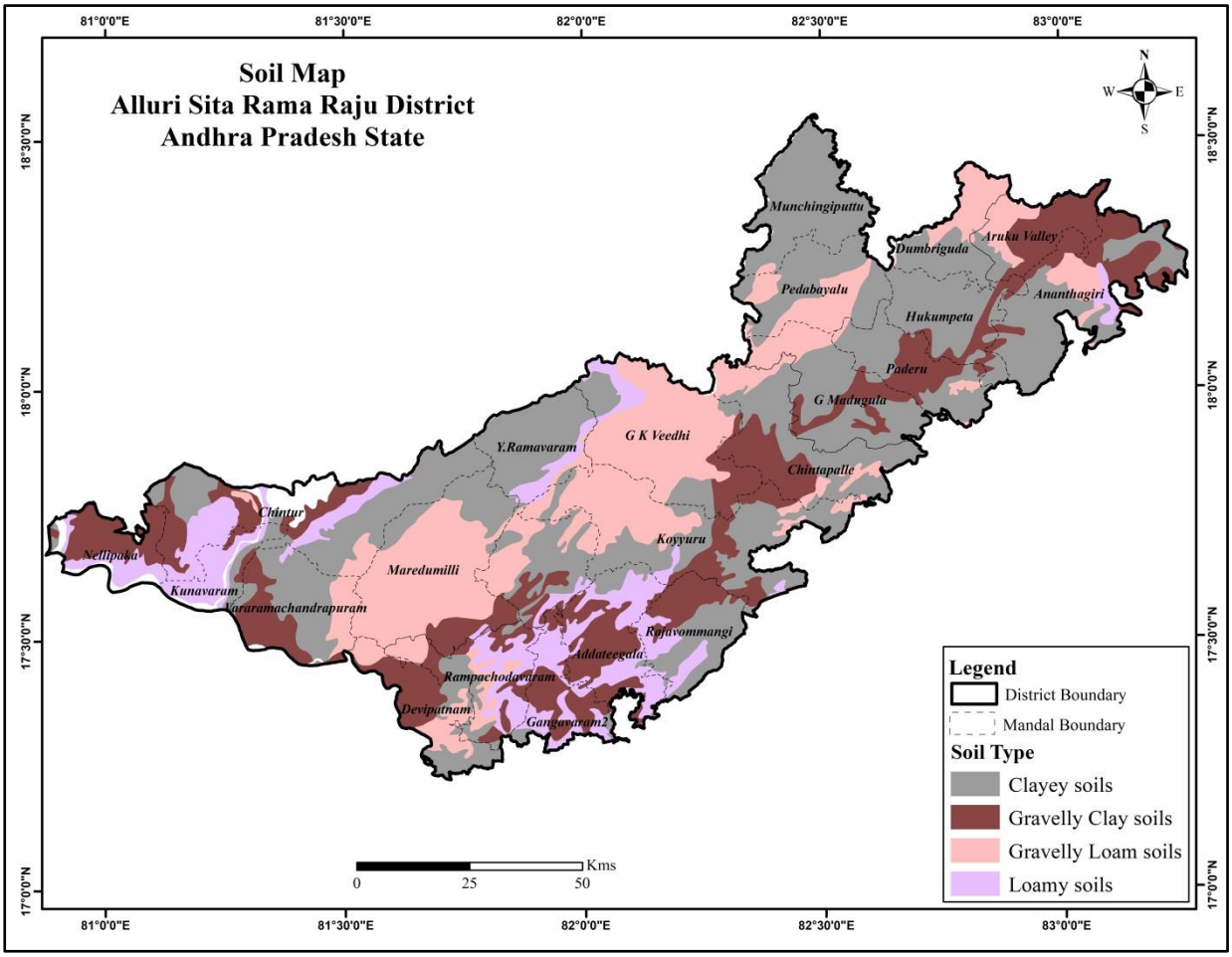


Fig-1.8: Soils of Alluri Sitarama Raju District, AP

1.10 Prevailing water conservation/Recharge practices: In the district, a total of 283 artificial recharge structures (45 Percolation Tanks, 6 Mini Percolation Tanks, 208 Check Dams and 24 Check Walls) are constructed under IWMP and MGNREGS. The mandal wise distribution of the ARS is provided in Table-1.9 and f**ig.1.9.4.**

Table-1.9: Mandalwise details of Existing ARS in ASR District, AP

S.No.	Mandal	No. of Existing ARS
1	Peddabayalu	18
2	Paderu	2
3	Gk Veedhi	1

4	Devipatnam	55
5	Y. Ramavaram	45
6	Addateegala	64
7	Gangavaram	28
8	Maredumilli	30
9	Rajavommangi	39
10	Chintur	1
	Grand Total	283

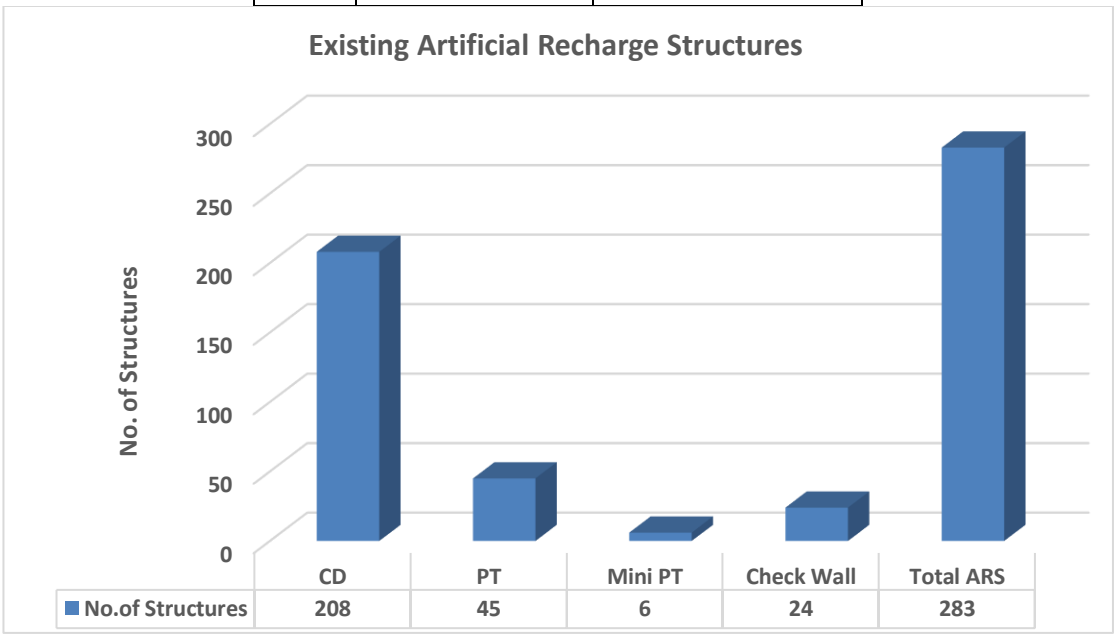


Fig. 1.9.4: Existing AR Structures in ASR District

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.

The aquifer mapping and management plan of Alluri Sita Rama Raju district is broadly carried out in following steps:

2.1 Data gap analysis, generation and Data Compilation: The identification of data gap was done after the detailed analysis, examination, synthesis and interpretation from available sources. The conversion of analog data in the form of digital data that could be processed readily on GIS platform. The data from erstwhile Vishakapatnam district and East Godavari district, basic data reports of exploratory wells/observation wells/ piezometers drilled by CGWB, details of wells drilled by State Departments, geophysical data of CGWB are compiled and integrated for aquifer mapping.

The Central Ground Water Board had drilled 23 no's bore wells, carried out 20 Vertical Electrical Soundings (VES) and 21 TEM in the district so far. The ground water regime is being monitored from 59 GWM stations and ground water quality data from 42 GW quality monitoring stations. The spatial distribution of data points are provided in Fig-2.1 and the no. of data points utilized for NAQUIM is provided in Table-2.1. The density of the data calculated as 1 data point for 40 sqkms for deciphering the lateral and vertical disposition of aquifers, 1 data points per 99 sqkms for understanding the spatial and temporal variation in ground water regime and 1 data point per 42 sq.kms for understanding the spatial and temporal variation in ground water quality. The data is utilized for NAQUIM in the district.

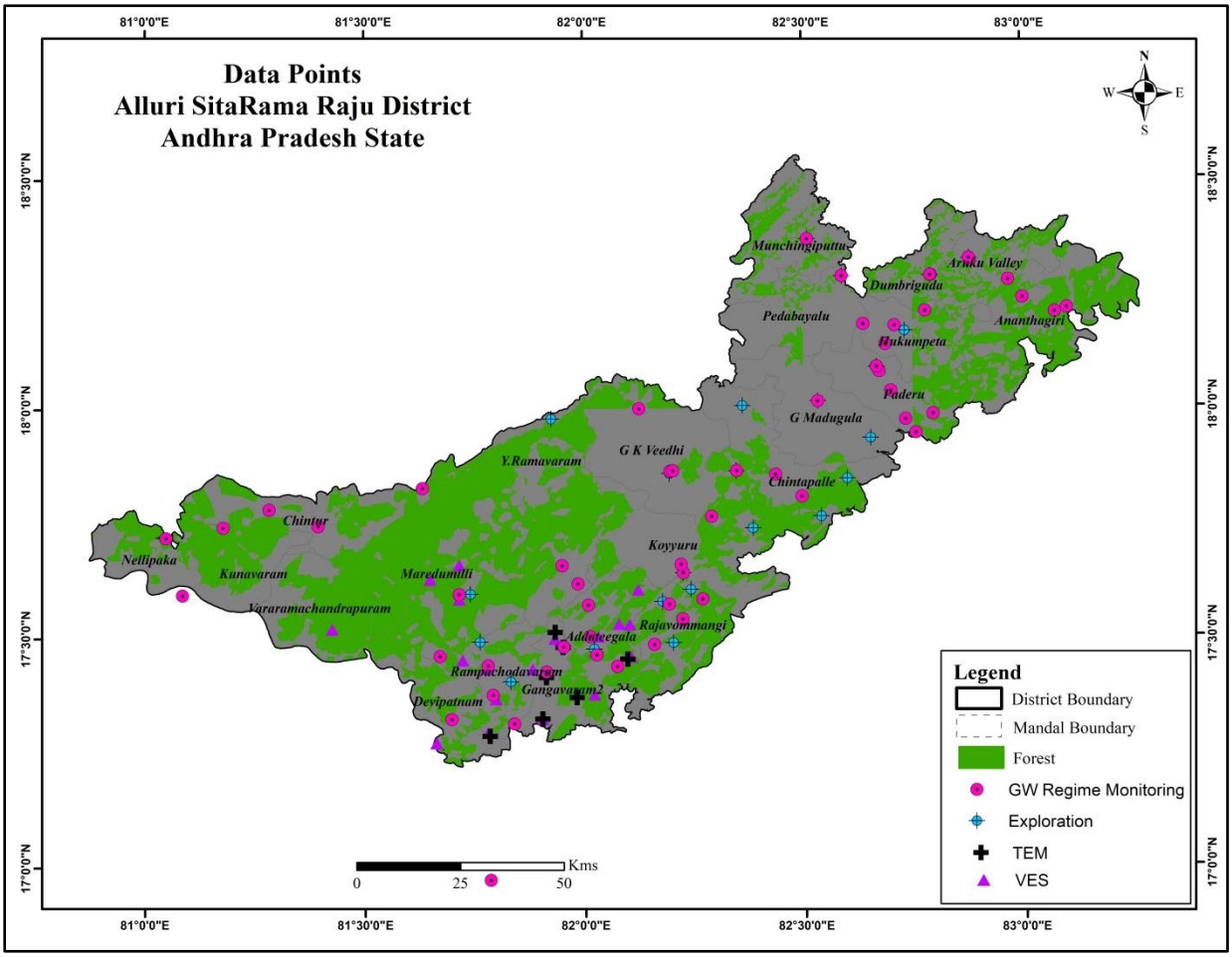


Fig. 2.1: Hydro geological data availability.

Table 2.2: Status of Data Integration		
S. No.	Activity	No. of data Points
1	Exploration	23
2	Geophysical	41
3	GW Quality Monitoring Stations	42
4	Ground water level Monitoring Stations	59

3. Geology, Hydrogeology and Aquifer Characterization

The district is underlain by Eastern Ghat Mobile Belt of Archaean age. It includes rocks of Khondalite Group, Charnockite Group and Migmatite complex. Sediments of Cenozoic laterite and Quaternary deposits overlie the Archeans. The lithological units of Khondalite Group include quartzite, talc- granulite and talc-silicate rock. The Charnockite Group include pyroxene granulite (basic Charnockite) and charnockite (acid/intermediate). The Migmatite complex includes hypersthene-biotite gneiss, hypersthene-quartz-feldspar augen gneiss, granitoid gneiss. Gneissosity in the granite gneiss is more pronounced in the vicinity of Khondalite. Quaternary sediments, including brown, residual soil of fluvial origin occur along the river courses. Thick mantle of flood plain deposits comprising clay and silt occurs in the Gostani, Champavati, Kandivalasa, Vegavati, Suvarnamukhi and Nagavali river valleys. Nagavali River is marked by a major NNW-SSE trending lineament. The geological map and percentage distribution of geological formations in the district is shown in Fig-3.1 and 3.2 respectively. The distribution of lithological units is shown in Table- 3.1.

Table- 3.1: Distribution of Aquifer/Formation, ASR District, AP

Aquifer/Formation	Area (Sq.Kms)	Percentage (%)
Khondalite	4287	34.04
Charnockite	3887	30.86
Gneiss	3041	24.14
Banded Gneissic Complex	1344	10.67
Granite	20	0.16
Alluvium	17	0.13
Total	**12596**	**100**

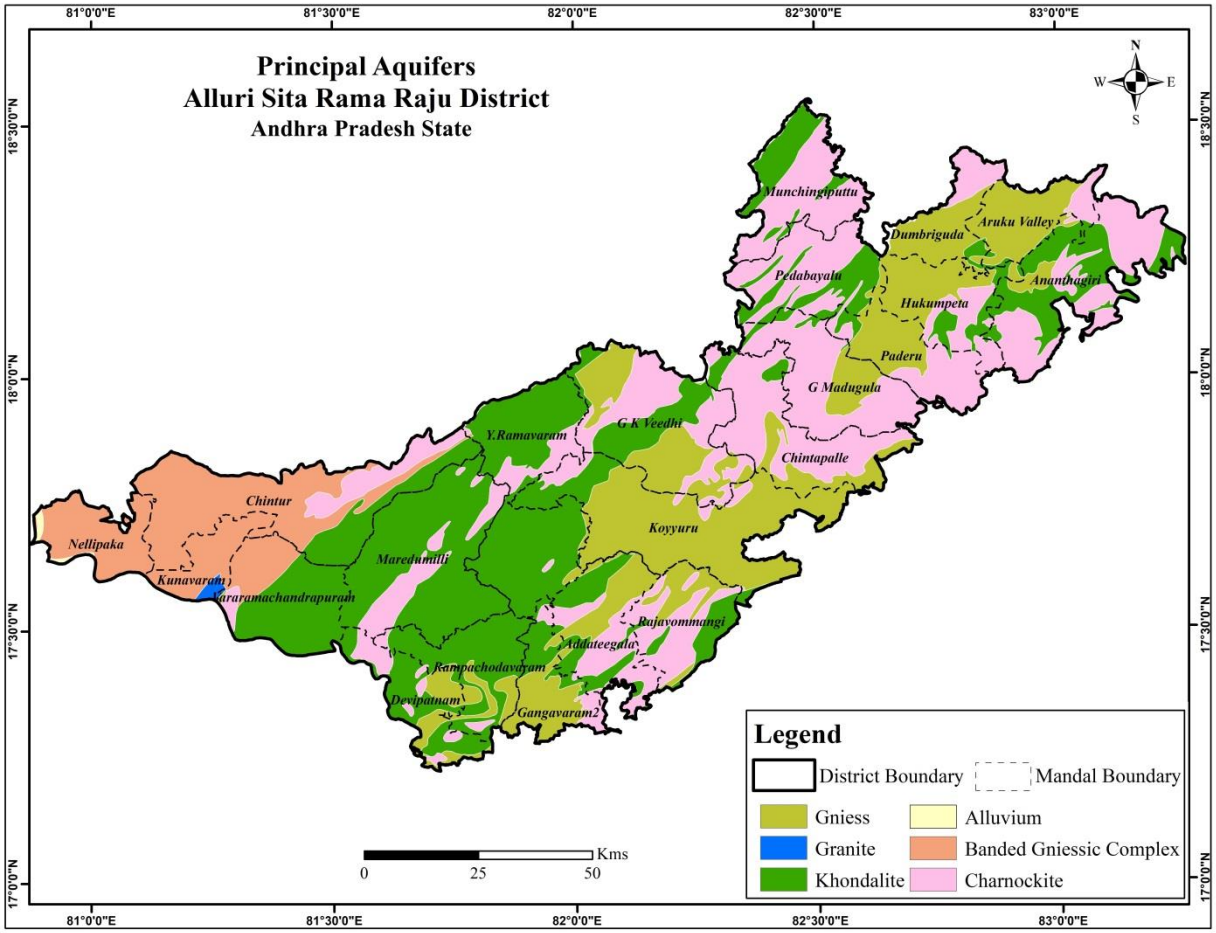
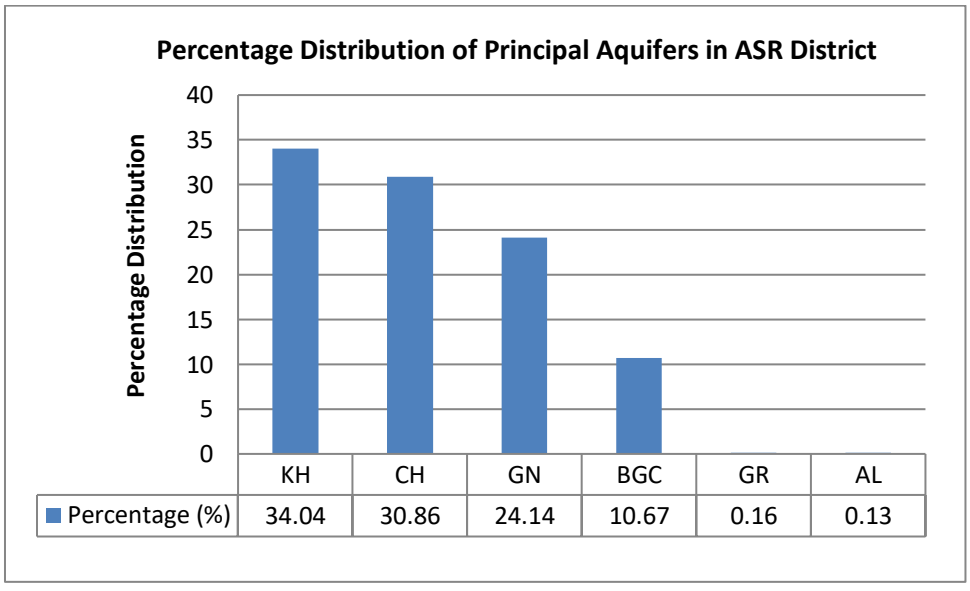


Fig.3.1: Geology of Alluri Sitarama Raju district.



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 Archean eastern ghat mobile belt mainly comprising of Khondalites, Charnockites, Migmatites and Granite Gneisses etc overlain by Recent Alluvium. 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 of hard and crystalline formation and presence of sand and clay layers in alluvium formation.

4. Hydrogeology and Aquifer Characterization

Data analysed from CGWB exploration and VES studies indicates that the weathering ranges from 5 m to 63 m with an average weathering thickness of 21 m. The fracture occurs in range of 10 to 155 m bgl depth

4.1 Weathered zone: The Thickness of weathered zone varies from <5 m to 63 m with an average thickness of ~21 m. The average thickness of weathering is 19 m in Khondalites, 20 m in Granites and Granite gneisses, 25 m in Charnockites. The spatial distribution of weathering thickness is shown in Fig.3.4 & Fig.3.5 respectively. Thickness of weathering < 10 m occurs in ~16 % of the area, 21-30 m occurs in 31 % of area, 31-40 m occurs in 12 % of area and >40 m occurs in 4% of area. High thickness of weathering (10-20 m) occurs in 37% of the district in isolated parts of Addateegala, Rampachodavaram, Rajavommangi, Kunarvaram mandals.

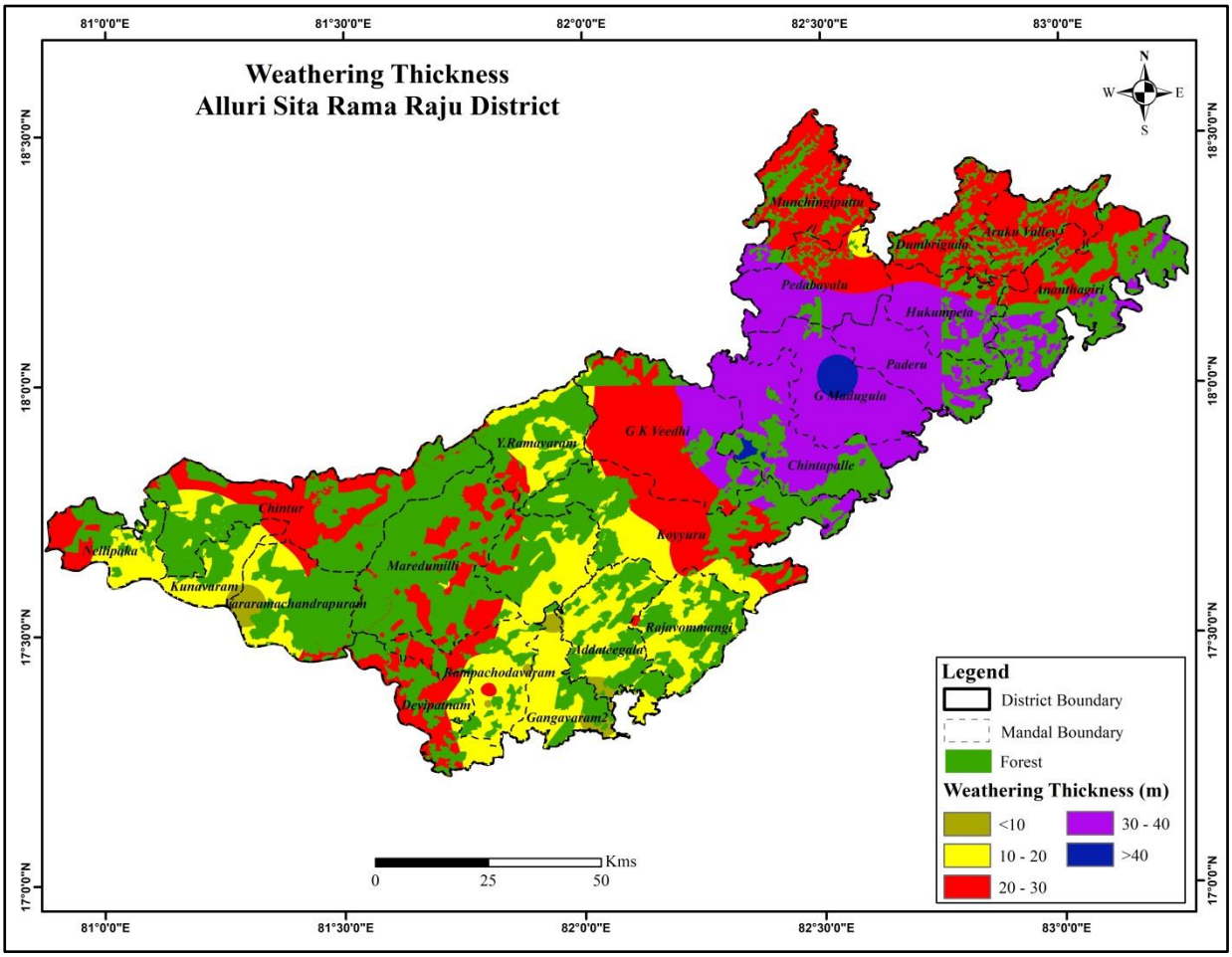


Fig.4.1: Depth to weathered zone, Alluri Sita Rama Rajudistrict.

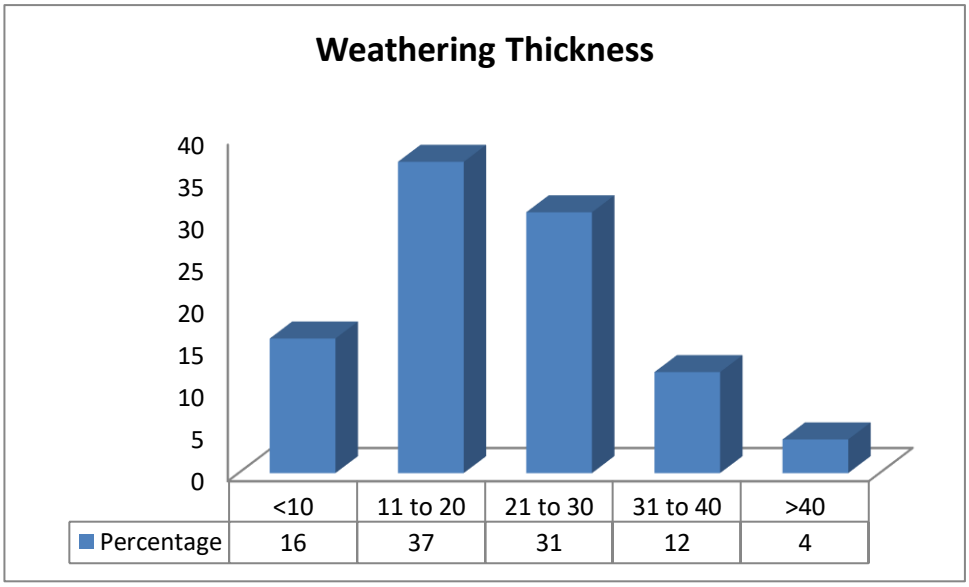


Fig: 4.2 Depth wise distribution of weathering, Alluri Sita Rama Raju District.

4.2 Fractured zone: The depth of fracturing varies from 8-155 m and deepest fracture encountered in exploratory drilling is 155 m at Aruku Valley mandal. The yield of the deepest fracture encountered is 1.2 lps. From the data, it is inferred that fractures in the range of 0 to 30m depth and 31 to 60 m are more predominant (37 % and 35% of the area), 60 to 90 m occur in 16 % area. The Depth wise distribution of fractures is shown in Fig.3.6 and 3.7

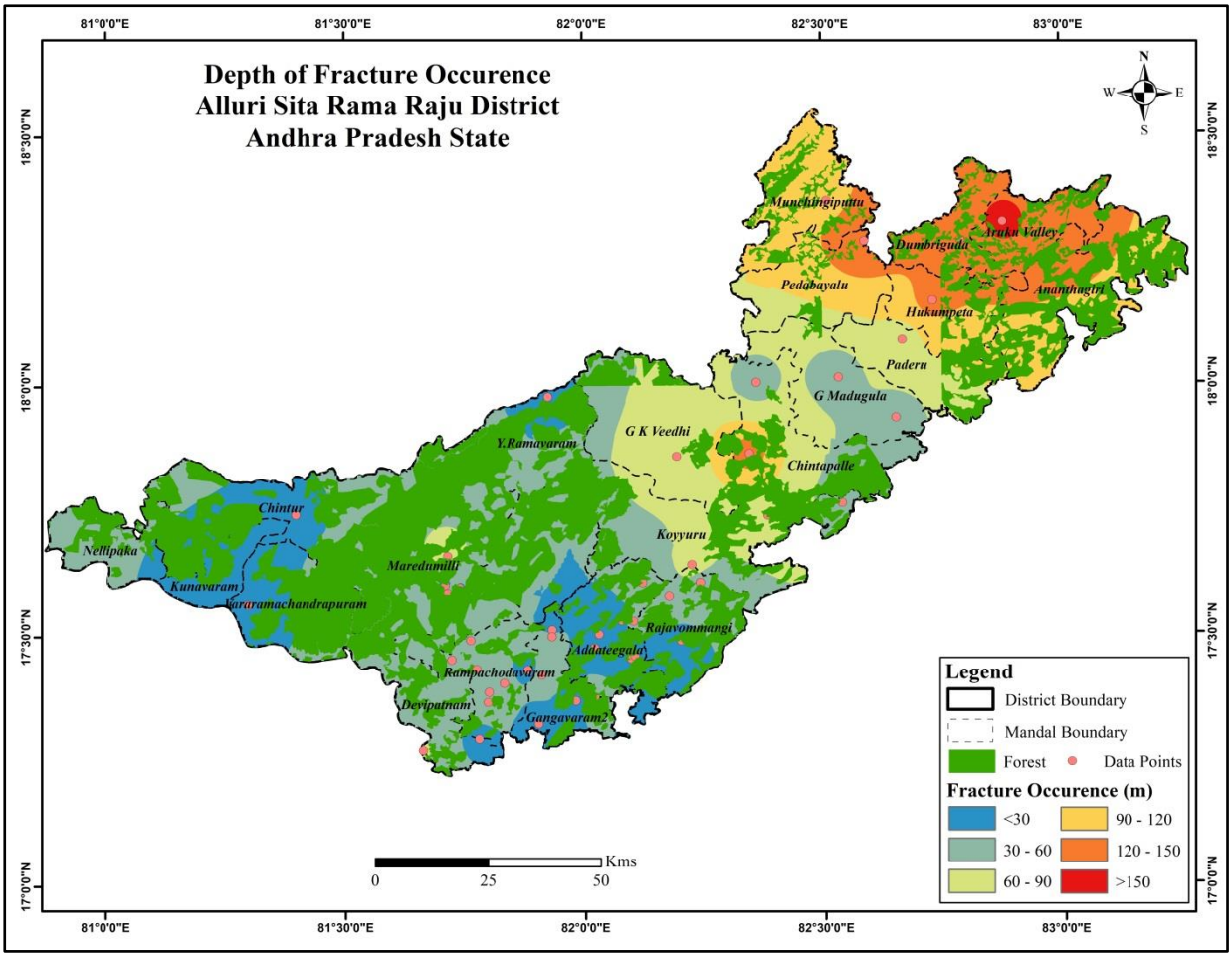


Fig.4.3: Depth of Fractured zone, Alluri Sita Rama Raju District.

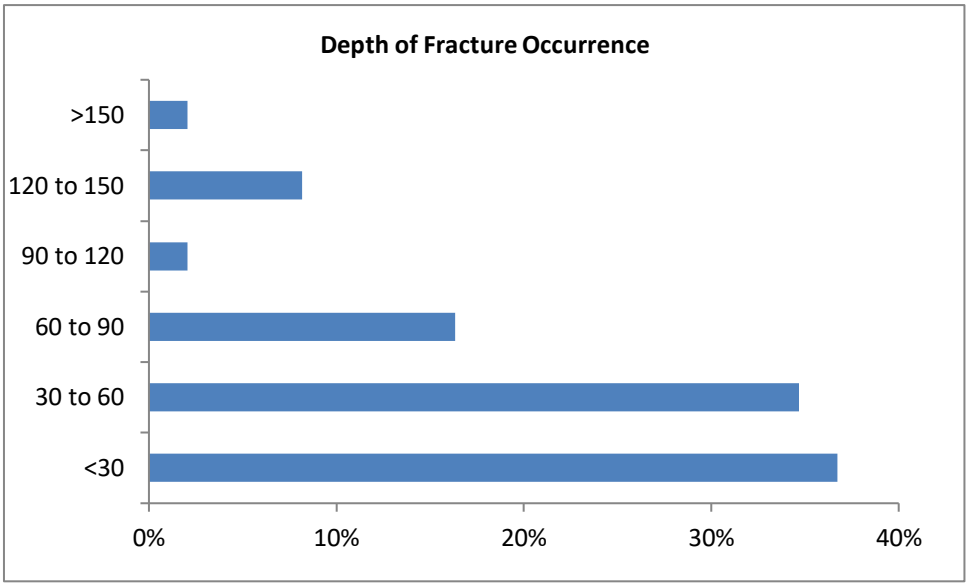


Fig: 4.4 Depth wise distribution of fractures, Alluri Sitarama Raju District

4.3 Depth to Water Levels: Ground Water Levels are continuously being monitored by Central Ground Water Board and State Ground Water Department in the district. The data of Ground water level monitoring from 36 monitoring stations (CGWB: 16 and SGWD: 20) of both pre and post-monsoon seasons (2014 to 2023) was utilized for understanding the ground water regime of the district.

4.4 Water Table Elevations: During pre and post-monsoon season (May and November), the water-table elevation ranges from 26.87 to 1149 m amsl and 31 to 1041.11 m amsl respectively. **(Fig.4.5)**

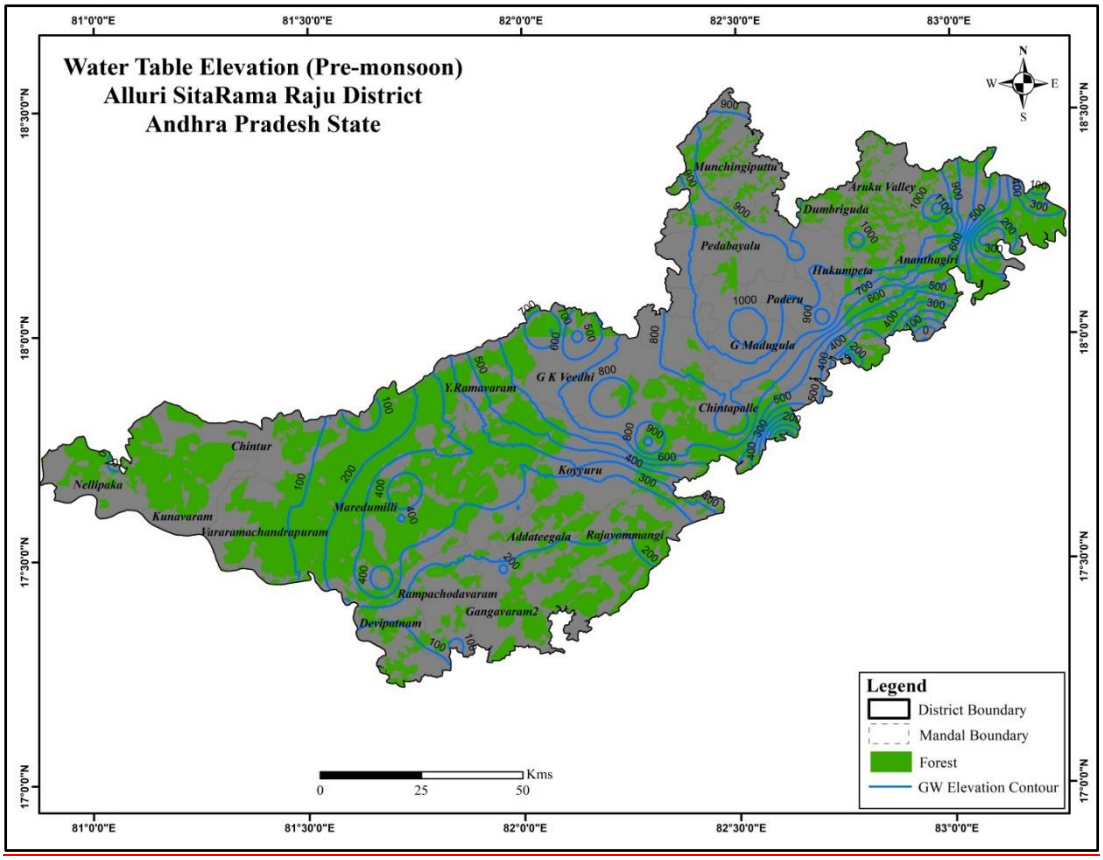


Fig 4.5 Ground Water Elevation Pre monsoon

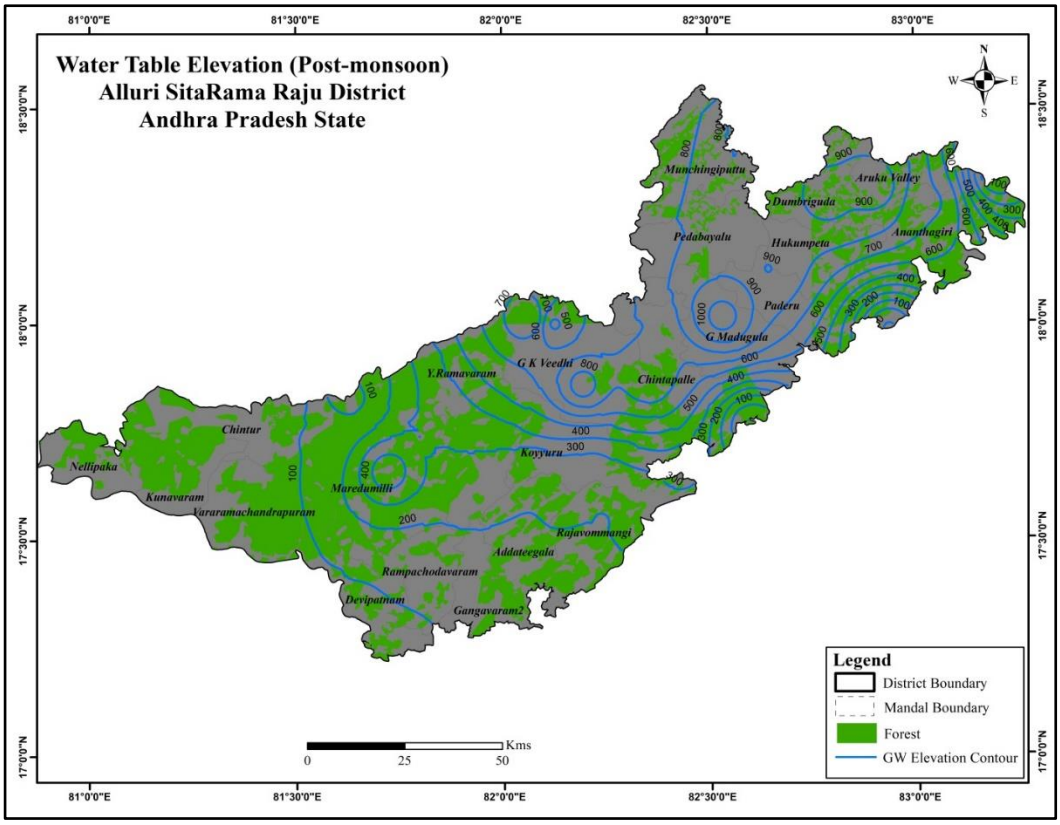


Fig 4.6 Ground Water Elevation Post monsoon

4.5 Depth to Water Levels (DTWL): The average DTWL of 10 years (2014 to 2023) for pre-monsoon and post-monsoon were analysed, the avg. DTWL varies from 0.92 to 18.32 meter below ground level (m bgl) (average: 6.58 m bgl) and 0.59 to 14.78 m bgl (average: 4.41 m bgl) during pre-monsoon and post-monsoon seasons respectively.

4.5.1 Pre-monsoon season: Majority of the water levels during this season are in the range of 5 to 10 m covering 43% of the area and < 5 m bgl (43%) and 10 to 15 m (13%). DTWL more than 15 m is observed very sporadically, which is insignificant (**Fig.4.7**)

4.5.2 Post-monsoon season: Majority of the water levels during this season are in the range of <5 m (69%) of the area, followed by 5 to 10m bgl (25 %) and > 10 m (5%) of area. (**Fig.4.8**)

4.6 Long term water level trends: Trend analysis for the last 10 years (2014-2023) is studied from 41 hydrograph stations of CGWB for pre-monsoon and post-monsoon season respectively. It is observed that during pre-monsoon season 18 wells shows falling trend ranging from 0.37452 m to 0.00765 m/year (Avg: 0.075 m/yr) and 22 wells shows rising trends ranging 0.00285 to 0.34510 m/yr (Avg: 0.129 m/yrs).

During post-monsoon season 14 wells shows falling trend ranging 0.280238 to to 0.122806 m/yr(Avg: 0.119 m/yr) and 22 wells shows rising trend ranging -0.052 to 0.68 m/yrs (Avg: 0.260 m/yrs).

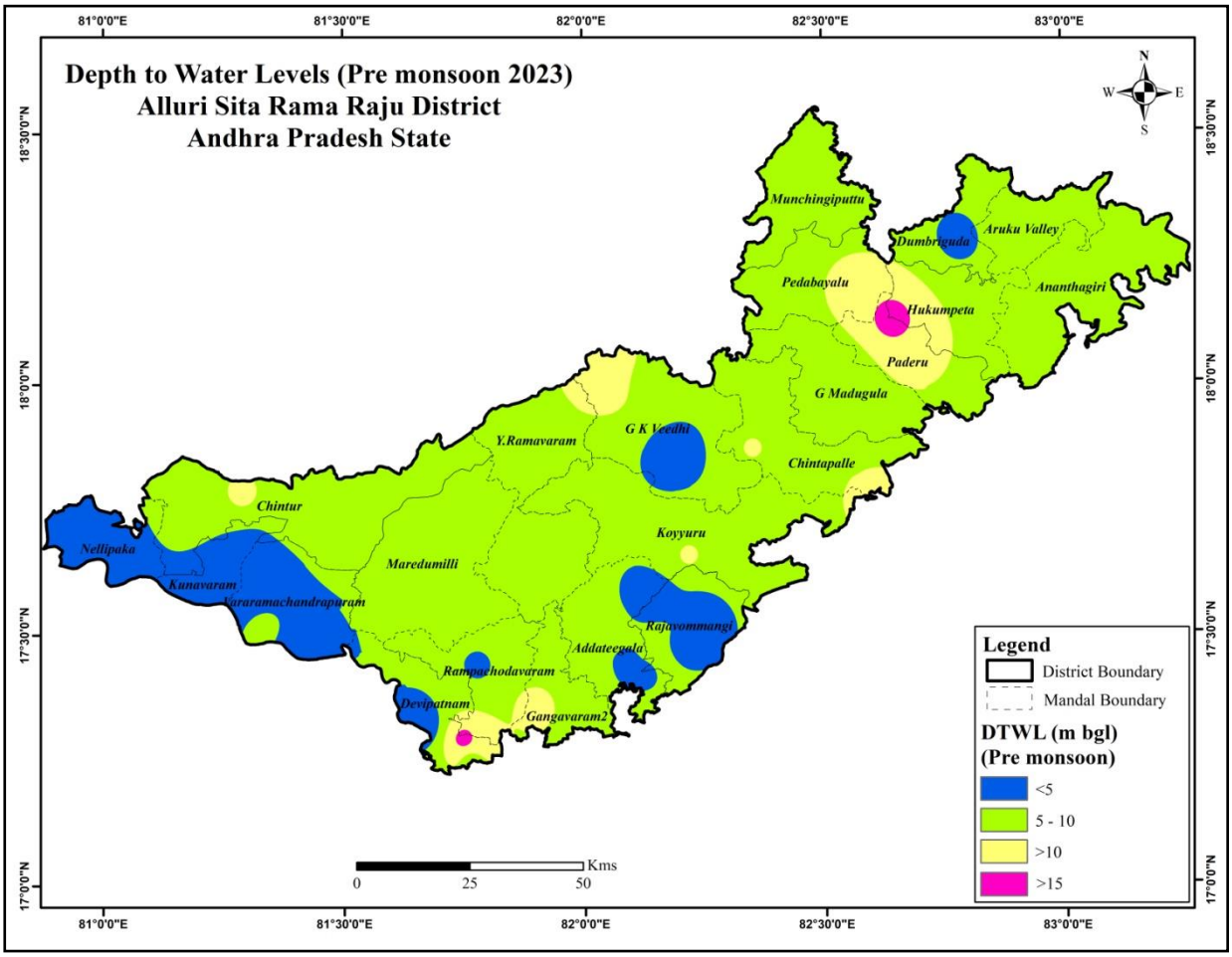


Fig.4.7: Depth to water levels Pre-monsoon, 2023

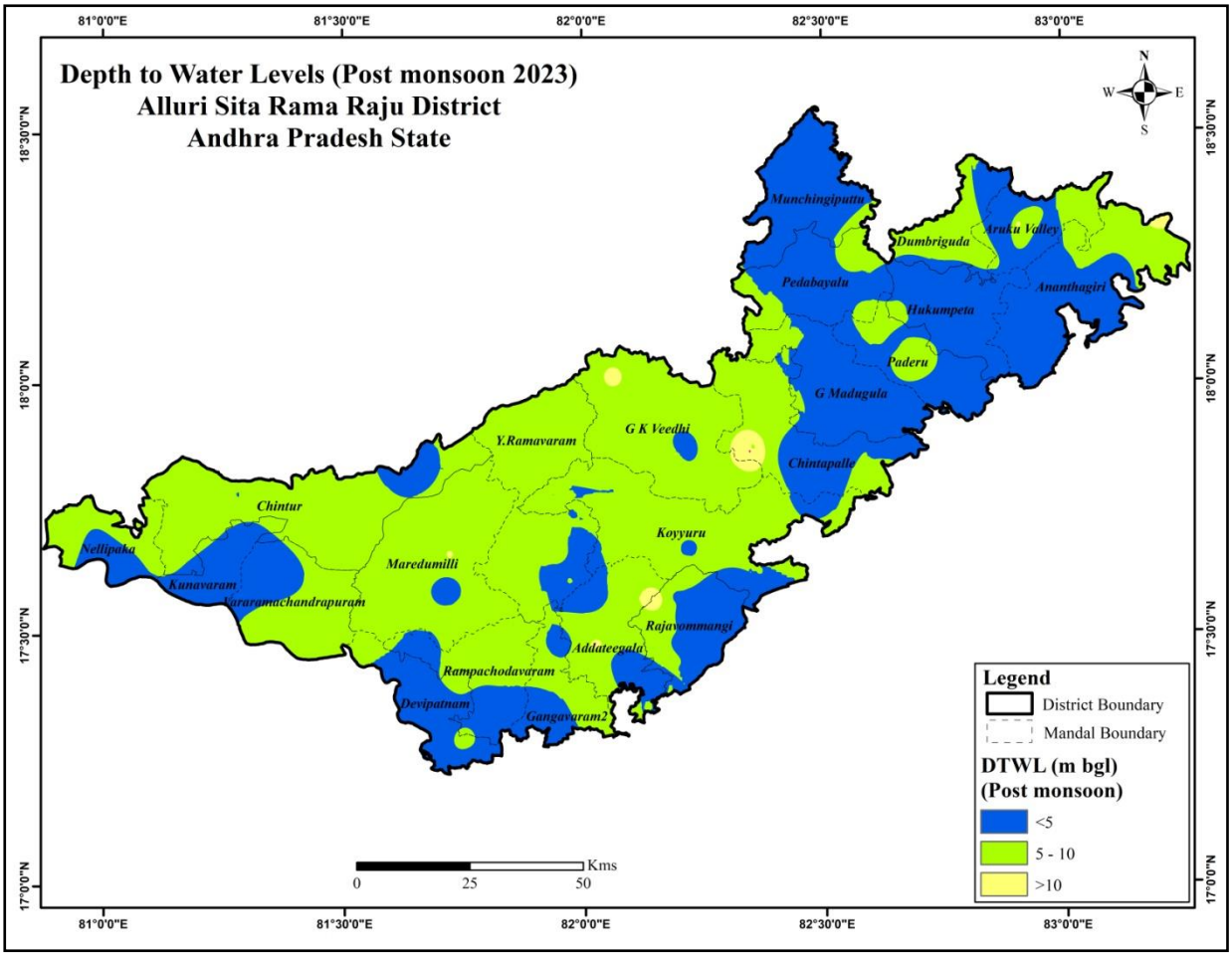


Fig.4.8: Depth to water levels Post-monsoon, 2023

4.7. Hydro chemical Studies: For groundwater quality analysis 42 NHS monitoring wells are being used for spatial and temporal variation of ground water quality.

Ground Water from the area is mildly alkaline to alkaline in nature with pH in the range of 6 to 8.8 (avg: 7.54). Electrical conductivity varies from 22 to 2051 (avg: 624) µ Siemens/cm. In majority of area 8382 sq.km (66 %) EC is within 750 Siemens/cm; in 4200 sq. kms (33 %) area, it is 750 to 1500 µ Siemens/cm and in 77 sq. kms (1 %) area, it is 1500 to 2250 µ Siemens/cm. **(Fig.4.9 ,4.9a).** The Concentration of NO3 ranges from 0.01-154 mg/l with an average 29.59 mg/l. Nitrate concentration <45 mg/l is observed in 33(78 %) sample out of 42 sample and above permissible limit of >45 mg/l is observed 9(22%) samples**(Fig.4.10).** The concentration of Fluoride ranges from 0.01-4.39 mg/l with an average of 0.53 mg/l. In 37samples (88%), F concentration is observed less than the permissible limits (<1.5 mg/l) and in 05 (12%) samples F is more than the permissible range (>1.5 mg/l) **(Fig.4.11)**

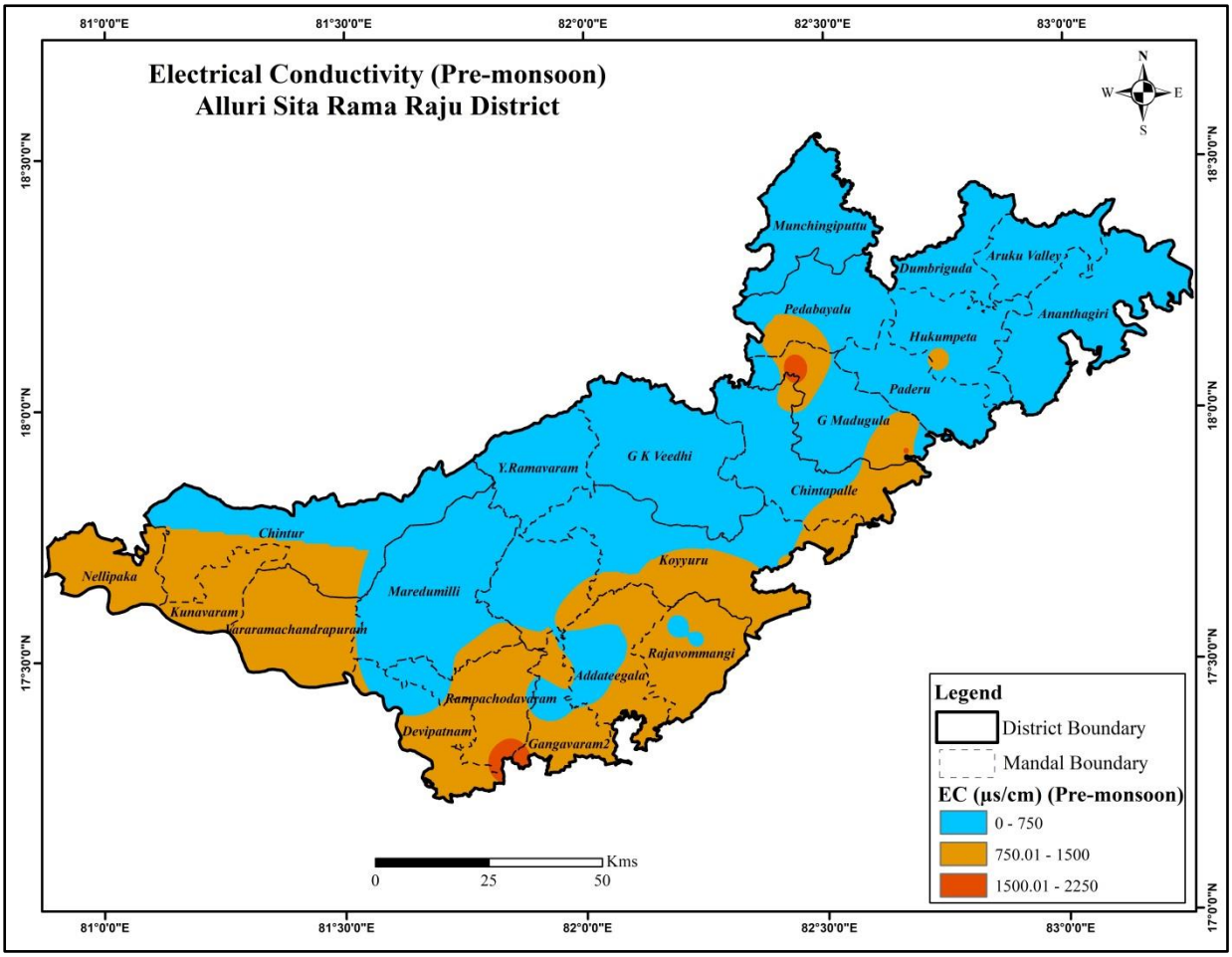


Fig.4.9. Distribution of Electrical Conductivity in Pre monsoon.

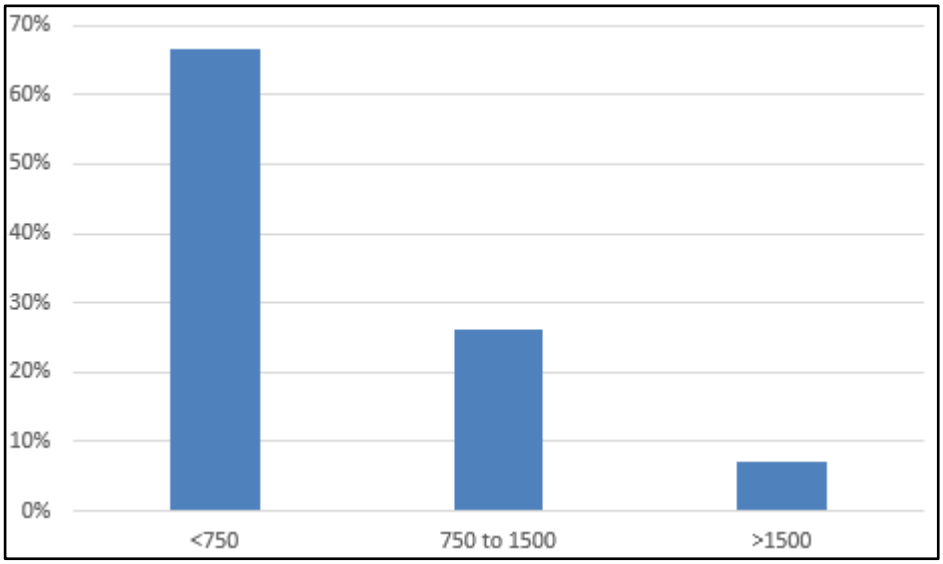


Fig.4.9a: Percentage of area (EC).

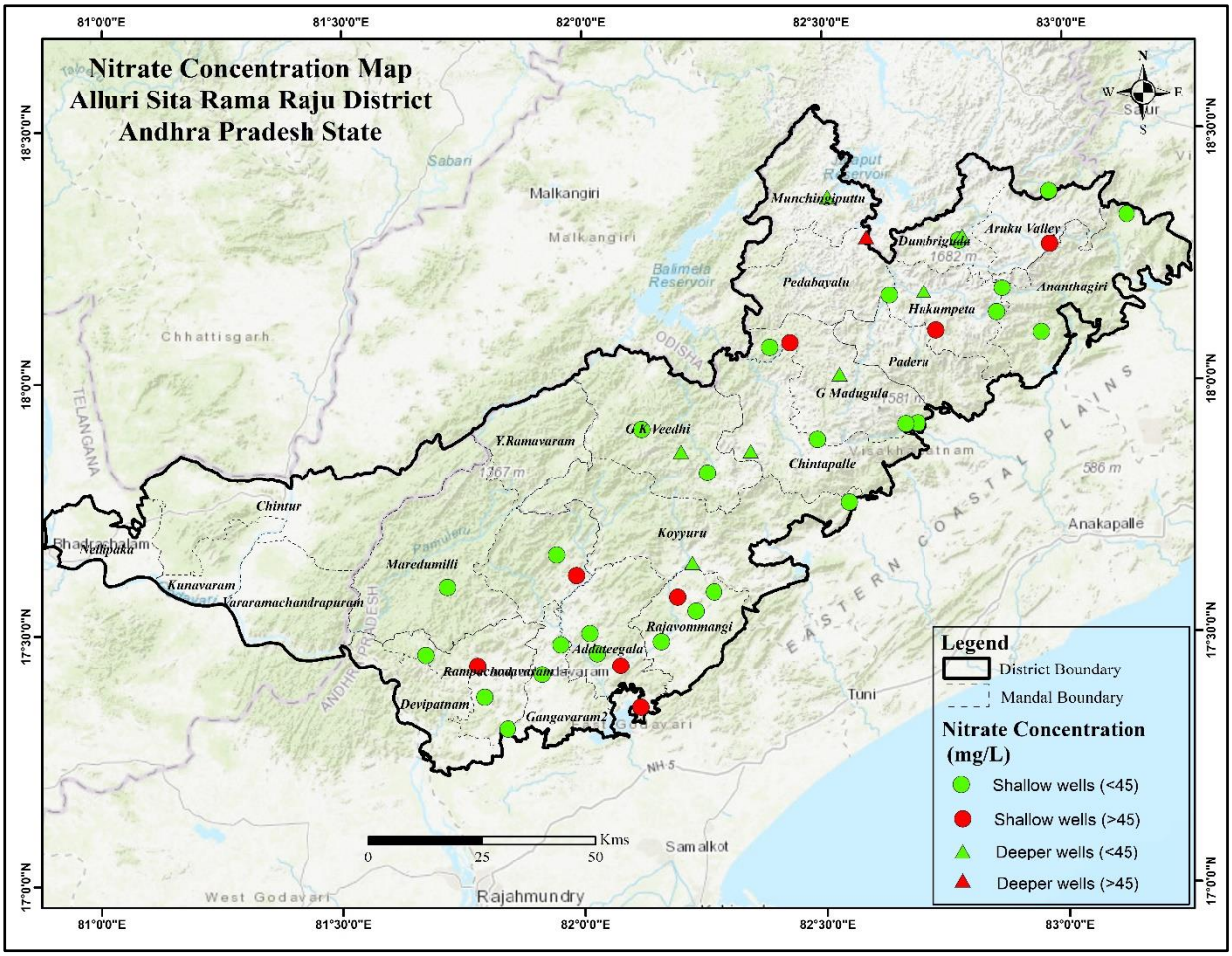


Fig.4.10. Nitrate Concentration Map.

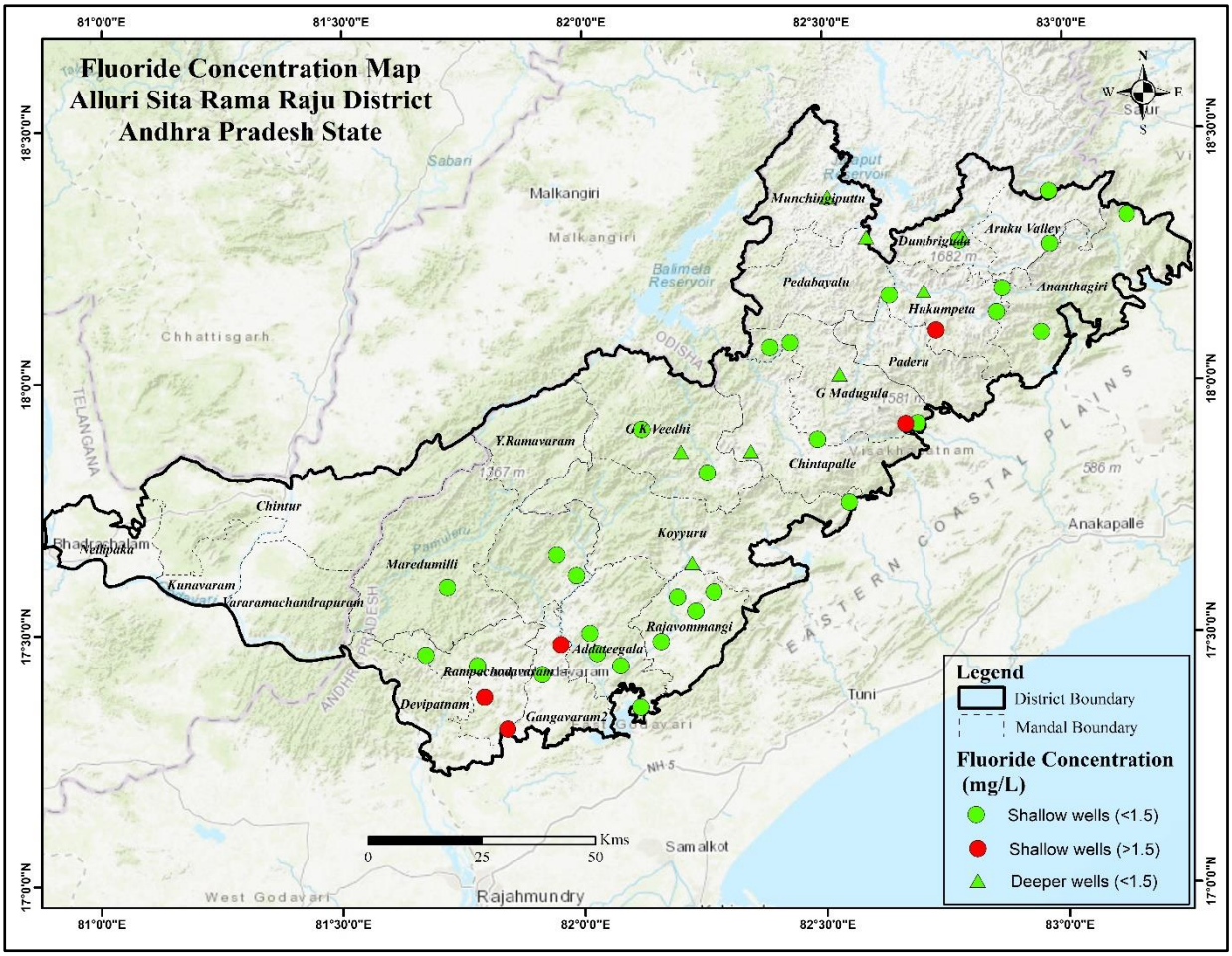


Fig.4.11. Fluoride Concentration Map.

5. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was done by interpreting and integrating representative 49 data points (26 exploration and 23 VES). The data 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, panel diagram of aquifers and hydro geological sections for Alluri Sitarama Raju district **(Fig.5.1).** The 2-D hydro geological sections are shown in **(Fig.5.2&Fig.5.3).**

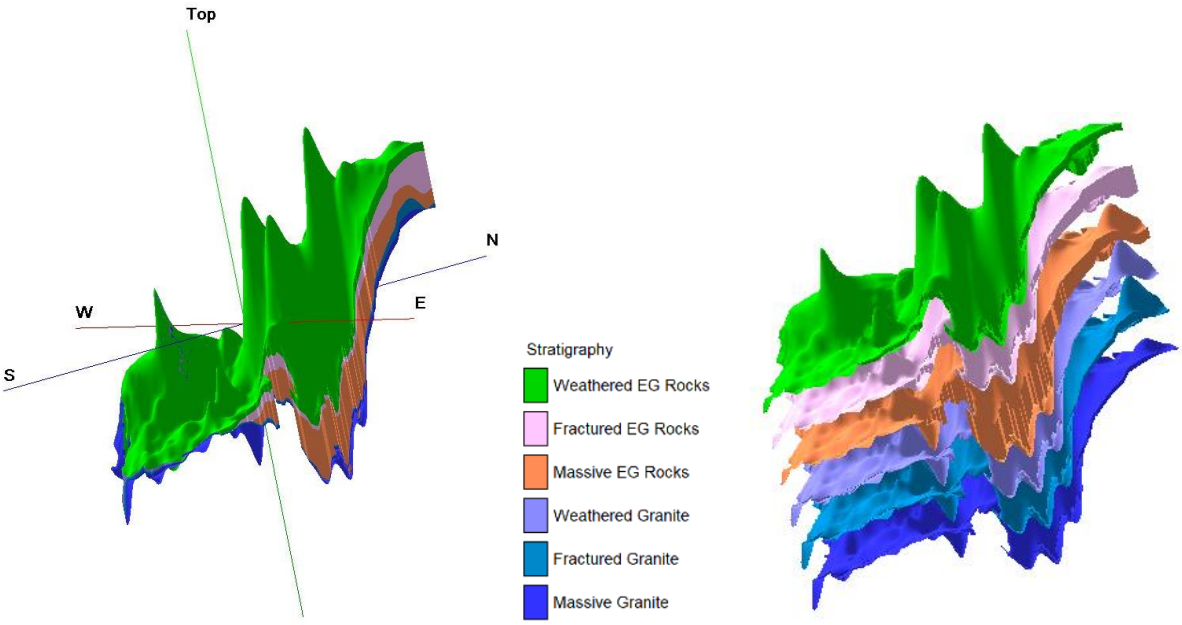


Fig.5.1: Aquifer disposition in 3D, Alluri Sitarama Raju district, Andhra Pradesh.

5.1 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 ~43 m depth and the fractured zone (fractured granite) is considered up to the depth of deepest fracture below weathered zone (~43 to 155 m).

5.1.2 Hydrogeological Sections:

Hydro geological sections are prepared in NE-SW & SW-NE direction. (**Fig.5.2 & Fig.5.3**).

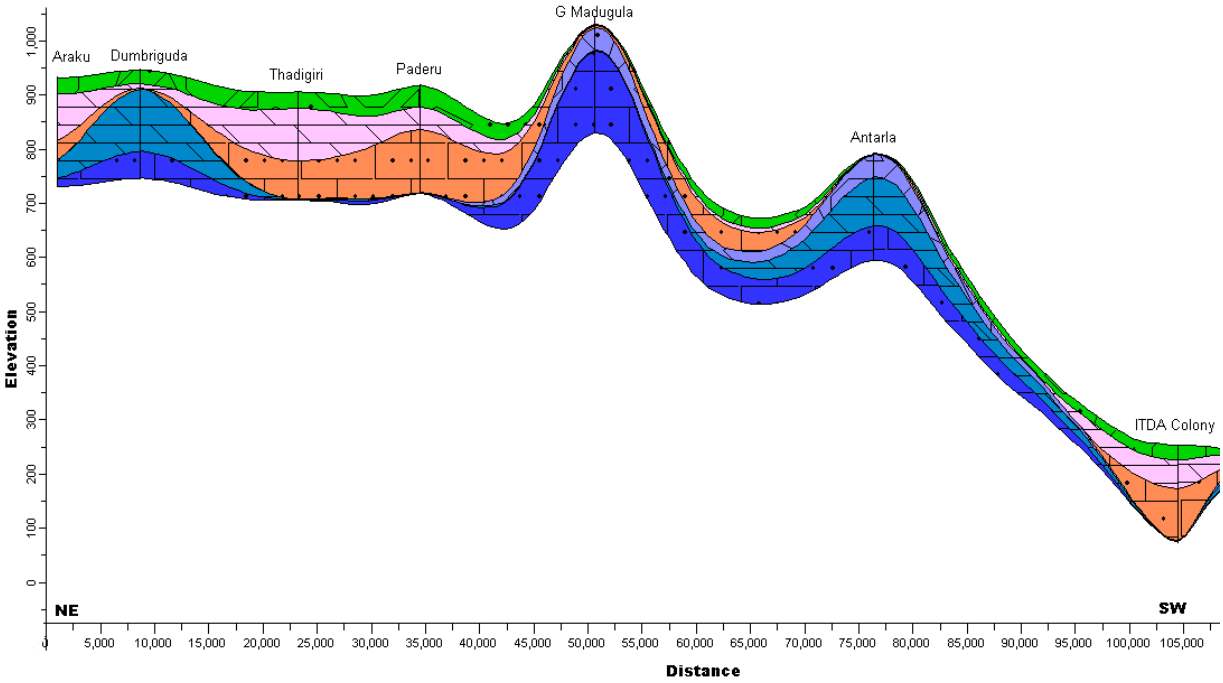


Fig.5.2: Hydrogeological Cross Section (NE-SW Direction).

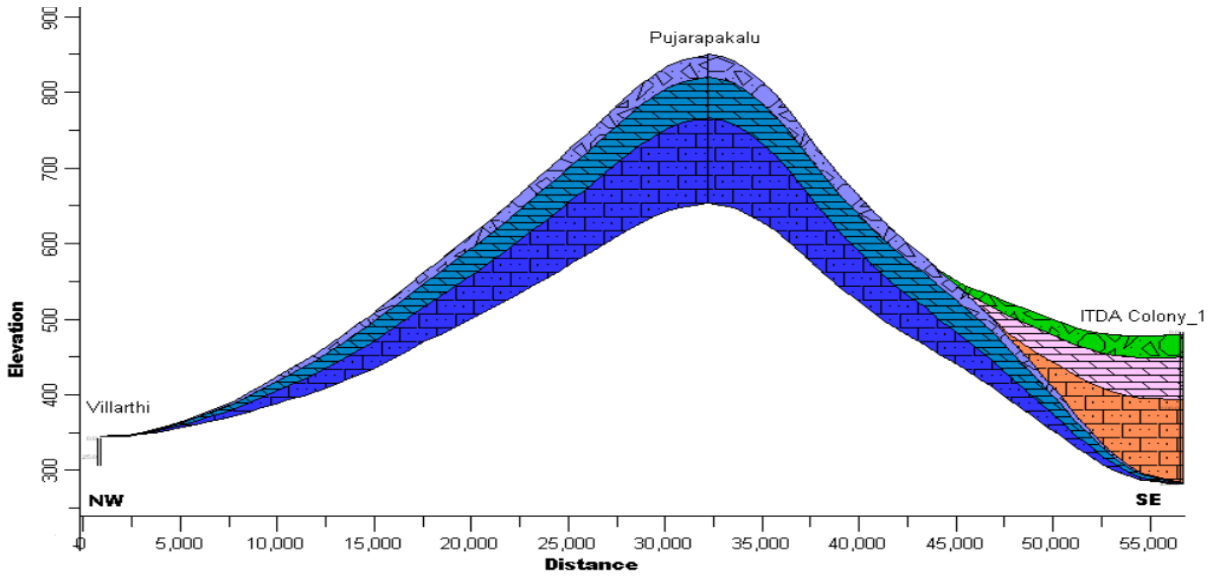


Fig 5.3: Hydro geological Cross Section NW to SE direction

6.0 GROUND WATER RESOURCES (2023)

In hard rocks, 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. Village wise dynamic ground water resources are computed as per the guidelines laid down in GEC methodology. The mandal wise dynamic ground water resources of the Alluri Sitarama Raju District, Andhra Pradesh (2023) are given in **Table-6.1 and Annexure**

Ground Water Resources - 2023		
Total area of the district	Sqkms	12253
Recharge worthy area	Sqkms	6392
Recharge from Rainfall - Monsoon	MCM	397
Recharge from Other Sources - Monsoon	MCM	451
Recharge from Rainfall - Non-Monsoon	MCM	36
Recharge from Other Sources-Non-Monsoon	MCM	50
Total Annual Ground Water Recharge	MCM	935
Total Natural Discharges	MCM	46
Annual Extractable Ground Water Resource	MCM	888
Irrigation Use	MCM	6
Industrial Use	MCM	0
Domestic Use	MCM	16
Total Extraction	MCM	22
Annual GW Allocation for Domestic Use as on 2025	MCM	18
Net Ground Water Availability for future use	MCM	866
Stage of Ground Water Extraction	(%)	2.49
Categorization	(OE/C/SC/Safe)	Safe

As per 2023 Ground Water Resource Assessment report, the net annual extractable groundwater resources in the district are 888 MCM, gross ground water draft for all uses 22 MCM, provision for domestic utilisation for the year 2025 is 18 MCM and Net Ground Water Availability for future use is 866 MCM. The stage of ground water extraction varies from 1 % in Y Ramavaramto 9% in Paderu with an overall SoE of 2.49%. Based on the stage of ground water development,all mandals in the district are categorized as Safe.

7.0 Ground Water Issues, Development and Management

7.1 Low Groundwater Yield

Low yield (<3 lps) occurs in ~more than 90% of the district. This is due to hard rock aquifer system in the district. The hard rock aquifers lack primary porosity and ground water yield depends on secondary porosity developed due to weathering or fracturing. The Poor interconnection and discrete nature of fractures and less recharge aquifers of hard rocks are resulting in low yield.

7.2 Ground Water Contamination: High nitrate (> 45 mg/L) due to anthropogenic activities is observed in about 09 samples (22%). This is due to unscientific sewage disposal of sewage and use of NPK fertilizers.

7.3 Ground Water Development:

The Ground Water Assessment – 2023 indicates that the annual extractable groundwater resources in the district amount to 888 million cubic meters (MCM), while total groundwater extraction for all purposes is 22 MCM, resulting in a stage of groundwater extraction of 2.49%. This suggests potential for further groundwater development. However, considering the criteria of depth to water levels (less than 15 m), rainfall (greater than 750 mm), stage of groundwater extraction (below 60%), and net annual groundwater availability for future use, the opportunities for recommending additional artificial recharge structures are limited.

7.4 Ground Water Management:

The supply side management include artificial recharge of available surplus runoff through construction of check dams and percolation tanks in rural areas and roof top rainwater harvesting in urban areas. More over repair renovation & restoration of existing tanks in rural and urban areas will also help in ground water recharge.

The recharge potential of the aquifers in the district is 2095 MCM and the availability of surplus run off (20% of the monsoon run off) is 98 MCM. The District Water Management Agency (DWMA), Rural Development Department, Govt. of Andhra Pradesh had constructed 284 artificial recharge structures (46 Percolation Tanks, 6 Mini Percolation Tanks, 208 Check Dams and 24 Check Walls) are constructed under IWMP and MGNREGS (Table 6.2- and Fig - 3.24).

Table- 7.1 Existing Artificial Recharge Structures in the Alluri Sitarama Raju District

S.No	Mandal	Check Dam	Check Wall	Mini PT	PT	Grand Total
1	Addateegala	37	3		24	64
2	Chintur				1	1
3	Devipatnam	47	7		1	55
4	Gangavaram	15		2	11	28
5	Gudem Kothaveedhi	1				1
6	Maredumilli	24		2	5	31
7	Paderu	2				2
8	Pedabayalu	14	3		1	18
9	Rajavommangi	32	3	1	3	39
10	Y Ramavaram	36	8	1		45
	Grand Total	208	24	6	46	284

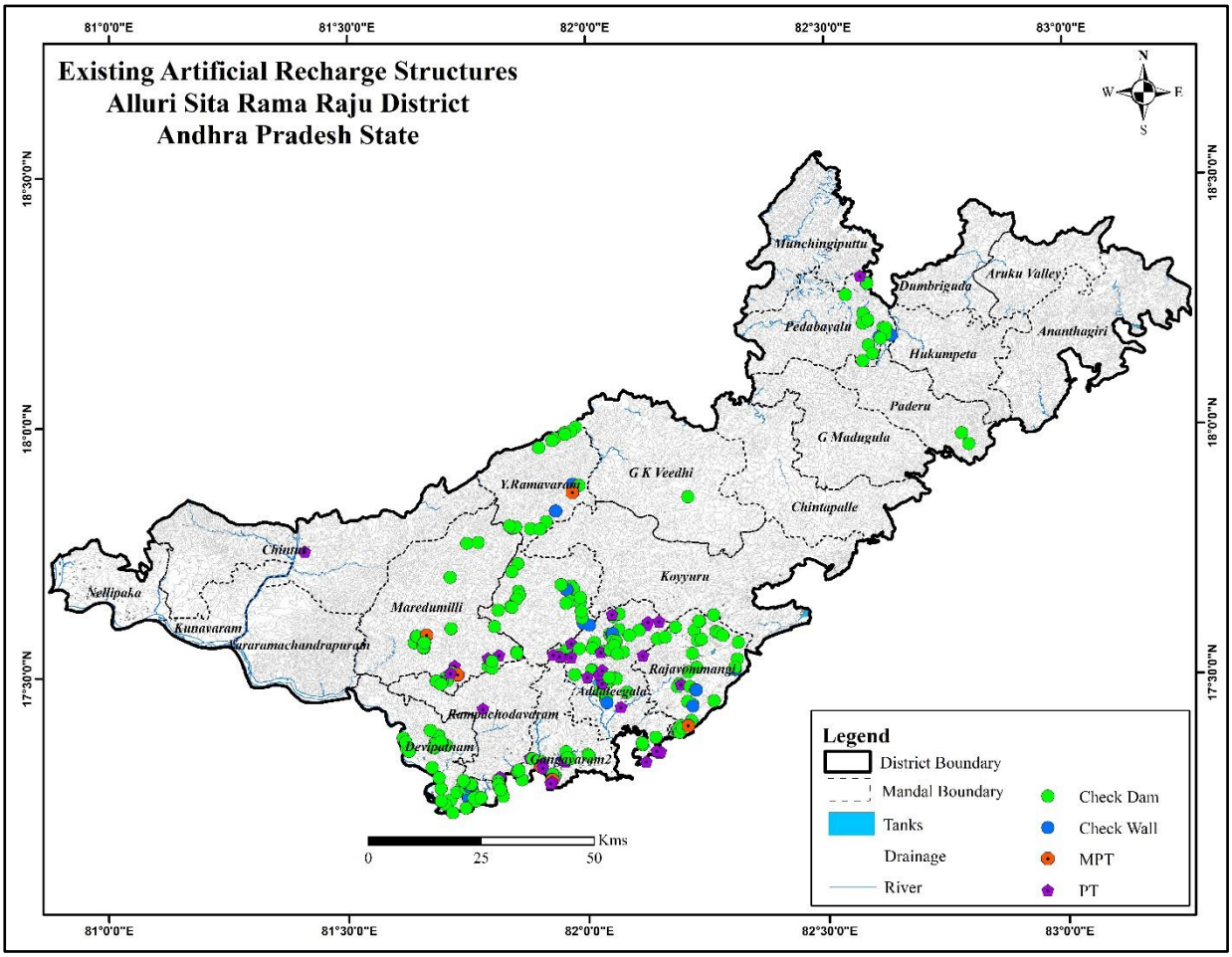


Fig-7.1 Existing Artificial Recharge Structures in ASR District

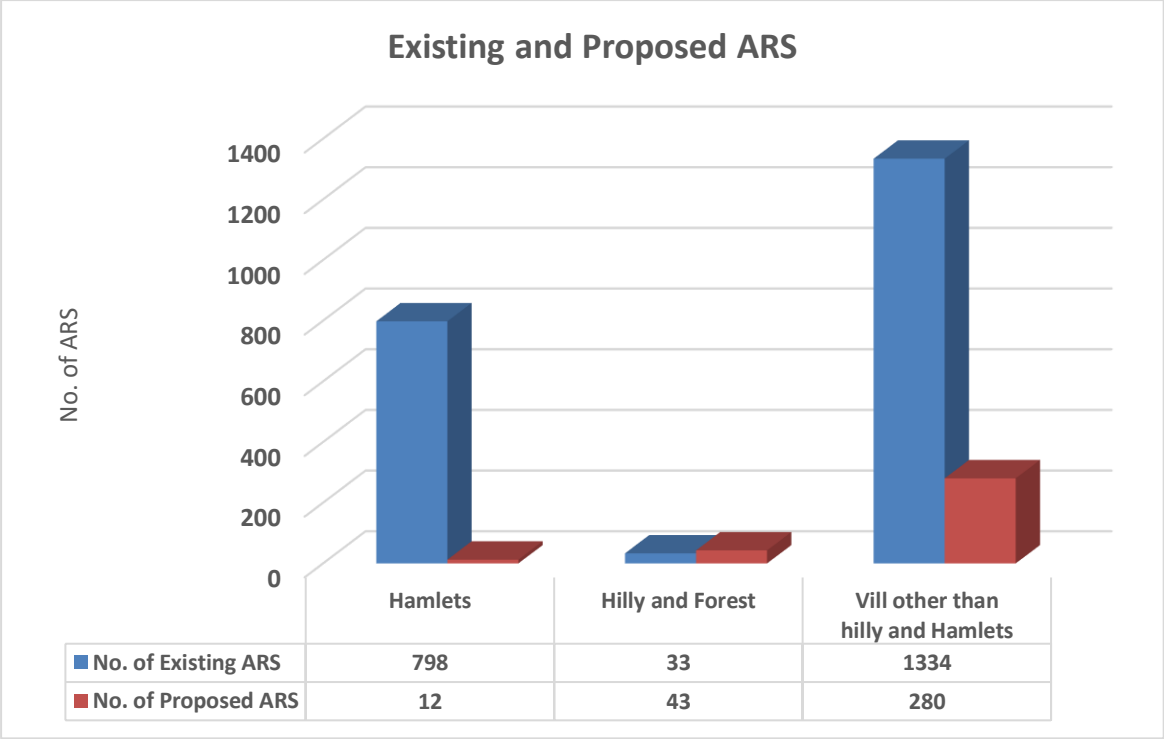


Fig-7.2: Graphical representation of existing and Proposed ARS

As demand side measurement, Micro Irrigation is recommended 17325 ha @25 ha per village in 693 villages. Roof top rainwater harvesting in Government buildings, proper waste water management, participatory groundwater management (PGWM), lining of sewerage to arrest leaching of nitrate and effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002) are other recommended measures in the district.

Acknowledgment

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References:

1. Handbook of Statistics, Alluri Sitarama Raju district, Government of Andhra Pradesh. Published by Chief Planning Officer, Alluri Sitarama Raju district.
2. District Survey Report (2021), Vishakapatnam District, Department of Mines and Geology, Government of Andhra Pradesh.
3. District Survey Report (2021), East Godavari District, Department of Mines and Geology, Government of Andhra Pradesh
4. Report on Aquifer Mapping for Sustainable Management of Ground Water Resources in Vishakapatnam District, CGWB, Govt. of India (2021)
5. Report on Aquifer Mapping for Sustainable Management of Ground Water Resources in East Godavari District CGWB, Govt. of India (2023).
6. Dynamic Ground Water Resources of India, 2022, Central Ground Water Board, Government of India.
7. Dynamic Groundwater Resources of Andhra Pradesh. (2023)
8. Ground Water Year Book, Andhra Pradesh, 2022.
9. Irrigation Report of Vishakapatnam District, Water Resources Department, Government of Andhra Pradesh.
10. Irrigation Report of East Godavari District, Water Resources Department, Government of Andhra Pradesh.
11. Exploration Report of Andhra Pradesh (2018), CGWB, Govt. of India.
12. Existing Water Harvesting Structure Survey Report, Department of Rural Development and Panchayat Raj, Government of Andhra Pradesh (e Muster/AP MIS Reports).
13. Existing Water Harvesting Structure Survey Report-IWMP, Department of Rural Development and Panchayat Raj, Government of Andhra Pradesh (e Muster/AP MIS Reports).
14. BIS (2012) Drinking water-specification IS: 10500; 1991. Bureau of Indian Standards, New Delhi.