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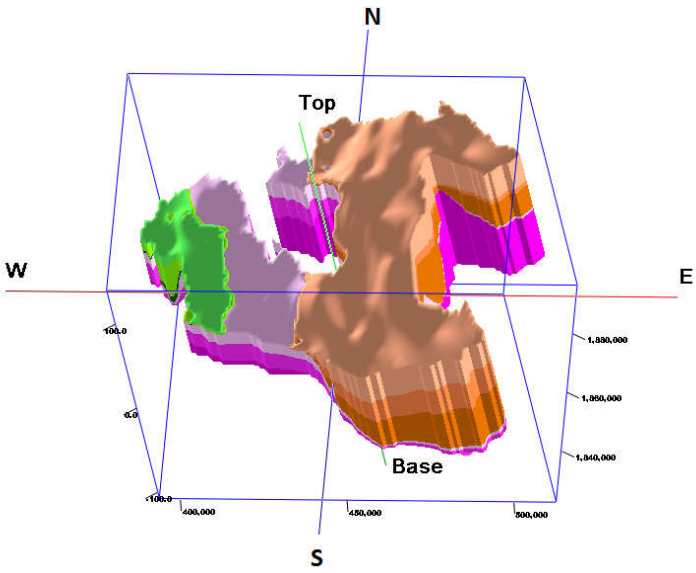
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RD & GR

REPORT ON
AQUIFER MAPPING AND MANAGEMENT OF KRISHNA DISTRICT (PARTS), ANDHRA PRADESH STATE (AAP-2021-22)



CENTRAL GROUND WATER BOARD
SOUTHERN REGION, HYDERABAD
JUNE, 2022

REPORT ON
AQUIFER MAPPING AND MANAGEMENT OF
KRISHNA DISTRICT (PARTS), ANDHRA PRADESH STATE
(AAP-2021-22)

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AQUIFER MAPPING AND MANAGEMENT OF KRISHNA DISTRICT (PARTS), ANDHRA PRADESH STATE

Executive summary

Contents

Figures

Tables

Annexure-1: Proposed Supply side interventions attached.

REPORT ON
AQUIFER MAPPING AND MANAGEMENT OF KRISHNA DISTRICT (PARTS), ANDHRA PRADESH STATE (AAP-2021-22)

At a Glance

S.No.	Item		Particulars
1	Districts	:	Krishna District (Parts) & 2 Mandals of West Godavari
2	Revenue Divisions/ Mandals	:	23 Mandals of Krishna District and 2 Mandals of West Godavari district
3	Villages	:	470 villages
4	Mappable area	:	4493 km^2
5	Population (2011 Census)	:	26.9 lakhs
6	Density of population (2011 Census)	:	305 persons/km^2
7	Locations	:	North latitude 17°19´10.4”-16°28´58” and East longitude 80°0´4.87”- 81°7’
8	Rainfall (Normal)	:	The annual normal rainfall of the area varies from 886 mm (Ungututru mandal) to 1148 mm (Tiruvuru mandal) with normal of 1025 mm
9	Geomorphology	:	Pediplain (70% of the area). Structural hills (11% of the area), channel fill and Valley fill (10% of the area), Deltaic plain (5% of the area) and Flood plain (4% of the area).
10	Major River	:	Krishna, Muniyeru, Tamileru and Budameru.
11	Land Utilization	:	Agricultural land occupies nearly 54% of the area, forest occupies nearly 11% of the area, 14% of the area is put to non-agricultural uses and 12% of the area is fallow land. Remaining area is occupied by Plantation, built up, water bodies and barren land etc.
12	Soils	:	Based on the soil texture, the area is mainly occupied by fine loamy soil (38%), loamy skeletal (31%), Clayey skeletal (17%) and Fine Clayey soil (14%)
13	Cropping Pattern (2019-20) (Ha)	:	The total gross cropped area during the year 2019-20 is 316629 ha. The area cropped during Khariff season is

			243792 ha during Rabi season is 72837 ha.
14	Irrigation	:	Out of the total Gross area sown of 316629 ha, 167785 ha (53%) of the cropped area is under surface and ground water irrigation ground water irrigation. Area Irrigated under surface water irrigation is 89041ha and area irrigated under ground water is 78744ha.
16	Prevailing Water Conservation/Recharge Practices	:	~ 690 Check dams,2790 Farm ponds and 51251 other water conservation structures.
17	Geology	:	The Archean Charnockite (19% of the area) and Khondalite (30% of the area) overlies the Archean Granitic Gneiss (41% of the area). The Precambrian metasedimentary formation covers of Kurnool and Cuddapah system covers 4% of the area and remaining 6% is alluvium sediments along the river channels
19	Hydrogeological data points		
	Exploratory drilling data points	:	73 Wells (CGWB:44, SGWD: 29)
	Water Level data points		86 wells (CGWB:23, SGWD:63)
	Hadrochemical Points		Total 85 (CGWB: 54, SGWD: 31)
20	**DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING**		
20.1	**Ground water Level Scenario**		
	Water Levels Depth to water level (m bgl)	: :	• Depth to water level varies from <1 to 25.2 m bgl during pre-monsoon and 0.4-17.9 m bgl during post-monsoon season. • In Majority of the areas, water level during pre-monsoon is in the range of 5-10m (57% of the area), followed by 10 to 20 m bgl (26%). • Majority of the water level during post-monsoon are in the range of 5 to 10 m covering 45% of the area, 3 to 5 m bgl in 38 % of the area.
	Long term water level trends (2010-2020) 60 wells	:	It is observed that during pre-monsoon season 54 wells shows falling trend in the range of 0.01 m/yr to 1.8 m/yr and 6 wells shows rising trend 0.01-0.4 m/yr. During post-monsoon season 56 wells show falling trend 0.01 to 1.6 m/yr and 4 wells shows rising trends 0.1-1.5 m/yr.

20.2	**Ground Water Quality**			
	Electrical Conductivity (µ Siemens/cm)	:	Pre: 313-7800 (avg: 2443) micro-Siemens/cm. 95% of area EC is within 3000 µ Siemens/cm.	
	Nitrate mg/l	:	Pre: 1-183 mg/L and found in 28% of samples are unfit for human consumption	
28	Fluoride mg/l	:	Pre: 0.12-2.1 mg/L.	
20.3	Aquifer Mapping			
	Era		Archean Crystallines	
	Prominent Lithology		Granite Gneiss/Charnockite (Basement)/Khondalite	
	Aquifer types		Aquifer-1 (Weathered Zone)	Aquifer-2 (Fracture Zone)
	Thickness range		1 - 35 m	up to 200m
	Depth of range of occurrence of fractures		-	80% fracture encountered within 100m
	Range of yield potential		<3	<1 to >10 lps
	Transmissivity (m2/day)		More than 1 to 200 sqm/day	
21	**Ground water Resources (2020) MCM**			
	Net Dynamic groundwater availability	:	1238 MCM	
	Gross GW Draft	:	388 MCM	
	Provision for Domestic &Industrial (2025)	:	65 MCM	
	Average Stage of Ground water development (%)		31%	
	Net GW Availability for future irrigation	:	859 MCM	
	Categorization of mandals		Stage of ground water development varies from 11% (Vijayawada Rural, Krishna) to 64% (Chintalapudi mandal, West Godavari). All Mandals are safe.	
22	Major Ground Water Issues Identified	:	• The over all stage of ground water development in the study area is 31%, except Nuzvid, Agiripalle,	

			Chintalapudi and Lingapalem mandals which have SOD> 50%, where vulnerability of groundwater resource in future is identified. • High nitrate (> 45 mg/L) due to anthropogenic activities is observed in 28% during pre-monsoon
23	Management Strategies	:	Desilting and maintenance of existing CD's and PTs. Further, it is recommended 116 artificial recharge structures (63 CD's and 53 mini PT's) in 56 villages in mandals where the SOD is >50%. Rooftop Rain water Harvesting structures for building with above 200 sq.m as per APWALTA. Desiltation of 12790 existing farm ponds in 435 villages. Adoption of micro irrigation in 30000 ha @100 ha/village in 300 villages.
24	Expected Results and Out come	:	With the above interventions, the likely benefit would be the net saving of 57 MCM of ground water can be saved either through water conservation measures like adoption of drip and artificial recharge to ground water.

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 study area is hard rock area of Krishna district and parts of West Godavari district with a mappable area of 4493 sq.km. The study area lies between north latitude 17°19´10.4"-16°28´58" and east longitude 80°0´4.87"- 81°7'. Administratively the area is governed by two revenue divisions – Vijayawada and Nuzvid covering 23 mandals of Krishna district, 2 mandals of west Godavari district and 470 villages having a population of 26.9 lakhs (2011 census, population density of 305).

The study area is underlain by various geological formation from Archaean to Tertiary age, with some isolated pockets of Recent to Sub-recent alluvium. The Archean Charnockite (19% of the area) and Khondalite (30% of the area) overlies the Archean Granitic Gneiss (41% of the area). The Precambrian metasedimentary formation covers of Kurnool and Cuddapah system covers 4% of the area and remaining 6% is alluvium sediments along the river channels. Pediplains are the major landforms covering 70% of the study area. The district is drained by Krishna, Muniyeru, Tamileru and Budameru. rivers. Agricultural land occupies nearly 54% of the area, 11% of the area is forest,14% of the area is put to non-agricultural uses and 12% of the area is fallow land. The total gross cropped area during the year 2019-20 is 316629 ha. The area cropped during Khariff season is 243792 ha and during Rabi season is 72837 ha. Out of the total Gross area sown of 316629 ha, 167785 ha (53%) of the cropped area is under surface and ground water irrigation

Water level is monitored through 86 wells during pre and post-monsoon seasons. During Pre-Monsoon, water-table elevation ranges from 4-120 meter above mean sea level and in post-monsoon season 7-150 meter above mean sea level (m amsl). Depth to water level varies from <1 to 25.2 m bgl during pre-monsoon and 0.4-17.9 m bgl during post-monsoon season In Majority of the areas, water level during pre-monsoon is in the range of 5-10m (57% of the area), followed by 10 to 20 m bgl (26%) and during post monsoon season, majority of the water level are in range of 5 to 10 m covering 45% of the area, 3 to 5 m bgl in 38 % of the area. Most of the wells in the state records water level rise. The seasonal water level fluctuations vary from 0.10 to 13 m.

Trend analysis for the last 10 years (2011-2020) shows falling trends in 54 wells in the range of 0.01 m/yr to 1.8 m/yr and 6 wells shows rising trend 0.01-0.4 m/yr. During post-monsoon season 56 wells show falling trend 0.01 to 1.6 m/yr and 4 wells shows rising trends 0.1-1.5 m/yr.

In 69% of area, EC is between 1500-3000 µ Siemens/cm, in 26 % area it is within 1500 µ Siemens and in 5% of area, it is beyond permissible limit**.** Average concentration of TDS is 1529 mg/L and NO_3 ranges from 0.5-183 mg/L. Nitrate concentration in 28% of samples is beyond permissible limits of 45 mg/L.

On the basis of occurrence and movement of ground water, rock units of the Krishna district (Parts) is classified into two categories; hard rocks (Archean crystalline and Metasedimentary formations). Weathered and fractured Archean crystalline rocks form the major aquifer system. Metasedimentary aquifer system overlies Archean crystalline rocks (Khondalites, Charnockites/Granite Gneisses) aquifer system. The main aquifers constitute the weathered zone at the top (~30 m), followed by a discrete anisotropic fractured zone at the bottom (~200). The aquifer units identified includes - Shallow Aquifer and Deeper Aquifer. The shallow aquifer is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~30 m depth with ground water yield <3 lps. The depth of fracturing varies from 25 m to 180 m with yield of <1 to more than 10 lps and transmissivity varies from 1 to 200 sq.m/day**.** The storativity varies from 4.84 $*10^{-6}$ to 1.06$*10^{-4}$.

As per Ground Water Resources Assessment (2020), the net dynamic replenishable groundwater availability is 1238 MCM, gross ground water draft for all uses is 388 MCM, provision for drinking and industrial use for the year 2025 is 65 MCM and net annual ground water potential available for future use is 859 MCM. The Stage of ground water development varies from 11% (Vijayawada Rural, Krishna) to 64% (Chintalapudi mandal, West Godavari). All Mandals are safe.

Overall, the stage of ground water development in the study area is 31%, except Nuzvid, Agiripalle, Chintalapudi and Lingapalem mandals which have SOD is > 50%, where vulnerability of groundwater resource in future is expected. Higher concentration of Nitrate is observed in 28% of samples. This is due to unscientific sewage disposal of treated and untreated effluents in urban and rural areas.

The management strategies mainly include both supply side and demand side. The supply side management of ground water resources include artificial recharge of available surplus runoff in check dams and percolation tanks in rural areas and roof top and open space rain water harvesting in urban areas. In the study area, a total of 698 artificial recharge structures (690 CDs and 8 PTs) are already in existence. Considering the stage of Ground water development (SOD), it is recommended that instead of planning for new artificial recharge structures for the entire study area, it is more viable to propose structures only in areas having SOD >50% to control further increase in stage of groundwater Development. The AR structures are suggested only in Nuzvid, Agiripalle, Chintalapudi and Lingapalem Mandals in the Study area considering 50% Of left Runoff (3MCM), 116 artificial recharge structures (63 CD's and 53 mini-PT' in 56 villages) are recommended.

Demand side measure includes micro irrigation in ~30000 ha of additional land that can be brought under micro-irrigation (@100 ha/village in 300 villages) considering 1 unit/ha @0.6 lakh/ha. With this 54 MCM of ground water can be conserved over the traditional irrigation practices (considering 0.006 MCM/ha for ID crops against 0.008 MCM/ha).

Other measure includes capacity building in power supply regulation, providing proper sewerage system, intermittent pumping of bore wells through regulatory mechanism, mandatory rainwater harvesting and participatory groundwater management (PGWM).

With the above interventions, the likely benefit would be the net saving of 57 MCM of ground water either through water conservation measures like adoption of drip and artificial recharge to ground water.

NUMBER OF DATA POINTS USED FOR PREPARATION OF VARIOUS MAPS/FIGURES-KRISHNA DISTRICT HARD ROCK (Parts)

S. No.	Data	Aquifer	Total data Points	Source
1	Panel Diagram	Combine	76	CGWB ,GW & WAD
2	Hydrogeological Sections	2nos	76	CGWB , GW & WAD
4	Depth of Weathering	1no	73	CGWB ,GW & WAD
5	Depth of Fractures	1no	73	CGWB ,GW & WAD
6	GW Yield	Combine	47	CGWB , GW & WAD
7	Transmissivity	Combine	30	CGWB , GW & WAD
8	Depth to Water Level Maps	Combine	86	CGWB , GW & WAD
9	VES	Combine	10	CGWB
11	Water Level Trend (Long Term)	Combine	60	CGWB , GW & WAD
12	Water Quality	Combine	85	CGWB , GW & WAD

1. INTRODUCTION

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

The Peninsular Shield consists mostly of consolidated sedimentary rocks and crystalline rocks. The occurrence and movement of groundwater in these formations are restricted to weathered residuum and interconnected fractures at deeper levels and have limited groundwater potential. The 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.

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 a suitable groundwater management plan on a 1: 50,000 scale.

1.2 Scope of the study: The main scope of the 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 groundwater regime (for water levels and water quality) for creation of time series database and groundwater resource estimation.
3. Quantification of groundwater availability and assessing its quality.
4. To delineate aquifer in 3-D along with their characterization on a 1:50,000 scale.
5. Capacity building in all aspects of groundwater 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 groundwater management.

1.3 Area Details: The study area is hard rock area of Krishna district and parts of West Godavari district with a mappable area of 4493 sq.km, covering 23 revenue mandals of Krishna district which includes parts of Agiripalle, Bapulapadu, Chatrai, Nuzvid and Ungutur mandals and also small parts of Chintalapudi and Lingapalem mandals of West Godavari district. The study area lies between north latitude 17°19′10.4"-16°28′58" and east longitude 80°0′4.87" - 81°7' (**Fig.1.1**). Administratively, the study area is governed by two revenue divisions – Vijayawada and Nuzvid with 470 villages having a population of 26.9 lakhs (2011 census, population density of 305 per sq.km and in urban area 8553). Chintalapudi and Lingapalem mandals of West Godavari have a population of 1.4 lakhs with a density of 275 persons per sq.km.

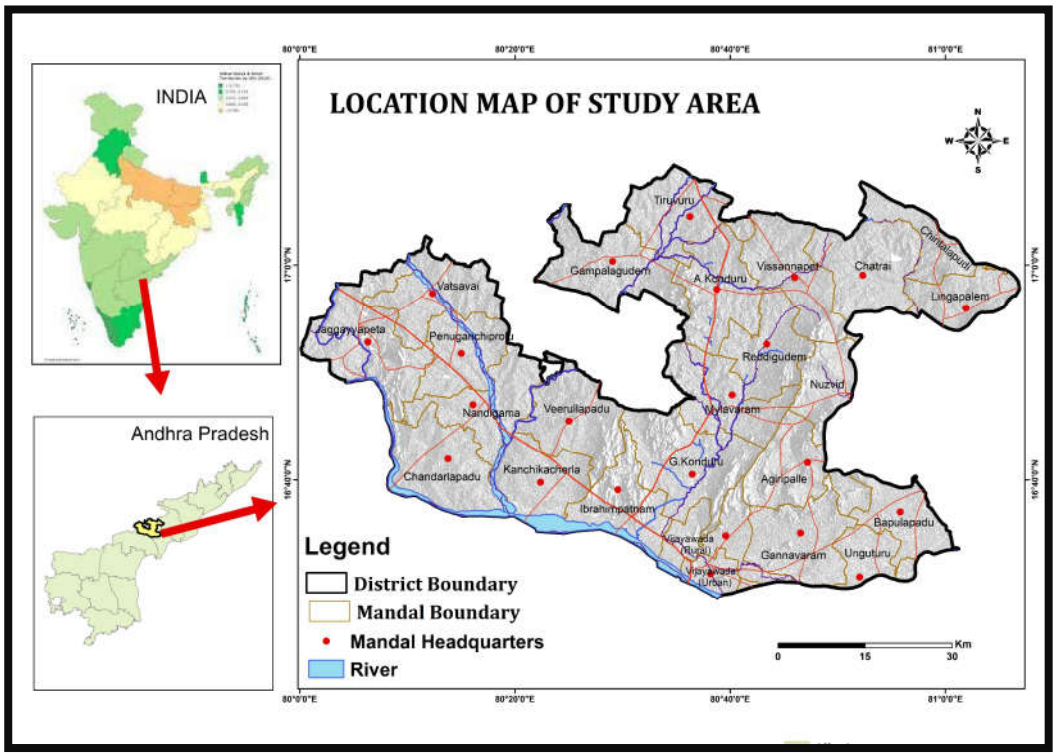


Fig.1.1: Location map of Study Area (Krishna District and West Godavari district Parts)

1.4 Climate and Rainfall: The area experiences sub humid and tropical climate with oppressive summer and good seasonal rainfall. The area falls under Krishna Agro-climatic zone based on the geographical characteristics such as rainfall (700-1100 mm), temperature, nature of soils etc. Southwest monsoon enters into the district in June and lasts until the end of September and Northeast monsoon from October to December along with occasional cyclonic storms. Summer starts in March, and reaches peak in May with average highest temperature of 40°C and winter season starts in late November and lasts until early February with average lowest temperature of 18.6°C in January at Gannavaram Airport IMD station. The area consists 23 mandals of Krishna district. The annual normal rainfall of the area varies from 886 mm (Unguturu mandal) to 1148 mm (Tiruvuru mandal) with normal of 1025 mm as per the data collected from DES, Andhra Pradesh. Average number of annual rainy days is around 55 days. Southwest monsoon contributes 71 % (733 mm), Northeast monsoon by 19 % (194 mm) and rest 10 % by January to May months of normal annual rainfall. Mean monthly rainfall varies from 233 mm in August to 4.8 mm in February. Isohyetal map prepared using annual normal rainfall of mandals in the district collected from DES, Andrapradesh is shown in **Fig.1.2**. Gannavaram A P IMD station received large excess rainfall of 1659 mm (70% above normal) rainfall during the year 2021.

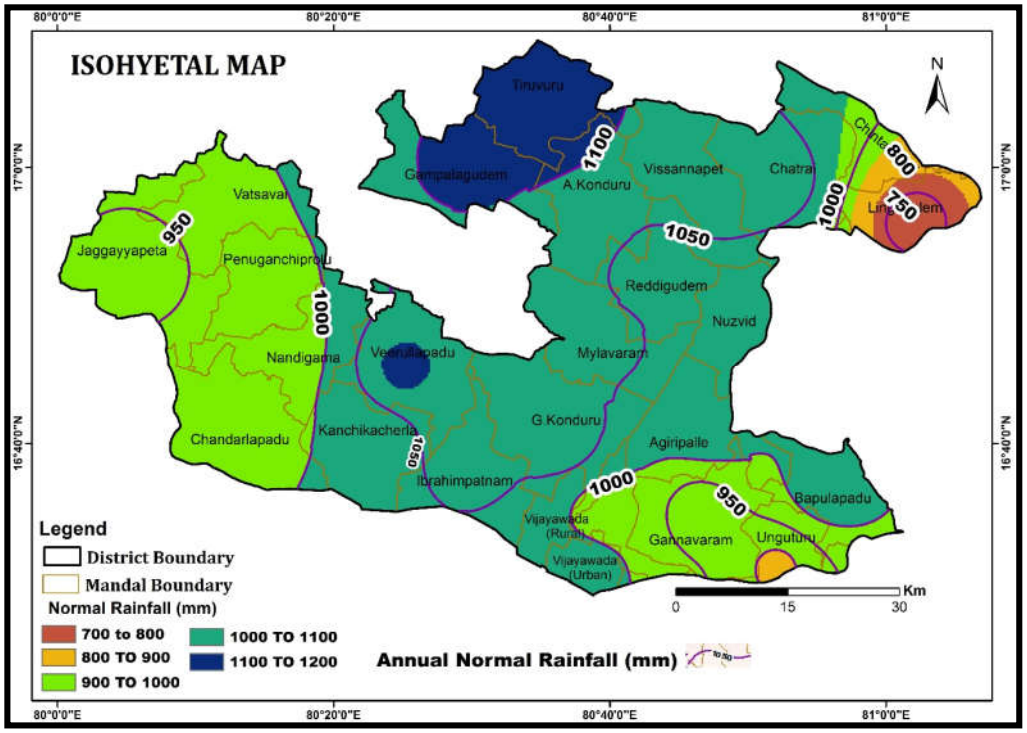
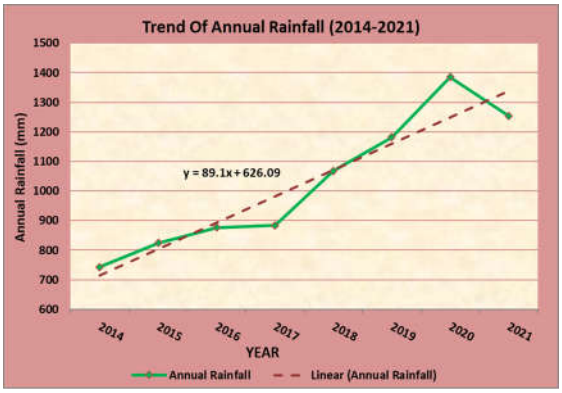


Fig.1.2: Isohyetal map of Study Area



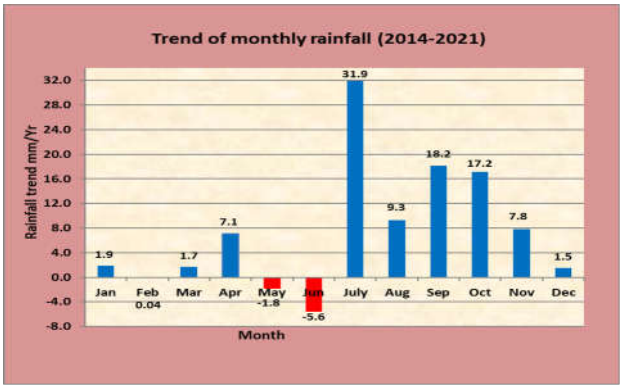


Fig:1.3 a and **Fig.**1.3 b

Analysis of time series annual rainfall data of the region for 8 years (2014-2021) considering data of Gannavaram Airport and Nandigama IMD stations shows increasing trend in annual rainfall of around 89 mm/yr (**Fig.1.3a**). The region received excess rainfall (+20% to +59% departure from normal) in 2020 & 2021, deficient rainfall (-20% & below normal) in 2014 & 2015 and normal rainfall (-19% to +19%) in the remaining 4 years. The monthly rainfall trend graph for 8 years shows increasing trend in rainfall significantly for July (32 mm/yr), September (18 mm/yr), October (17 mm/yr) and August (9mm/yr) months and decreasing trend for June (6 mm/yr) (**Fig.1.3b**).

1.5 Geomorphological Set up: Geomorphologically the study area predominantly consists of Pediplain (70% of the area) which is observed in north western, eastern and north eastern parts of Jaggayapeta, Nandigama, Tiruvur, Vijayawada and Nuzvid Mandals. Channel fills & Valley fills (10% of the area), and Structural hills, Resuidal hill & Denudation hills constitute 11% of the area, Deltaic plain (5% of the area) and Flood plain (4% of the area). The denudational hills and residual hills mainly consist of charnockites, which appear to have smoothened ridges due to wind erosion (**Fig:1.4**).

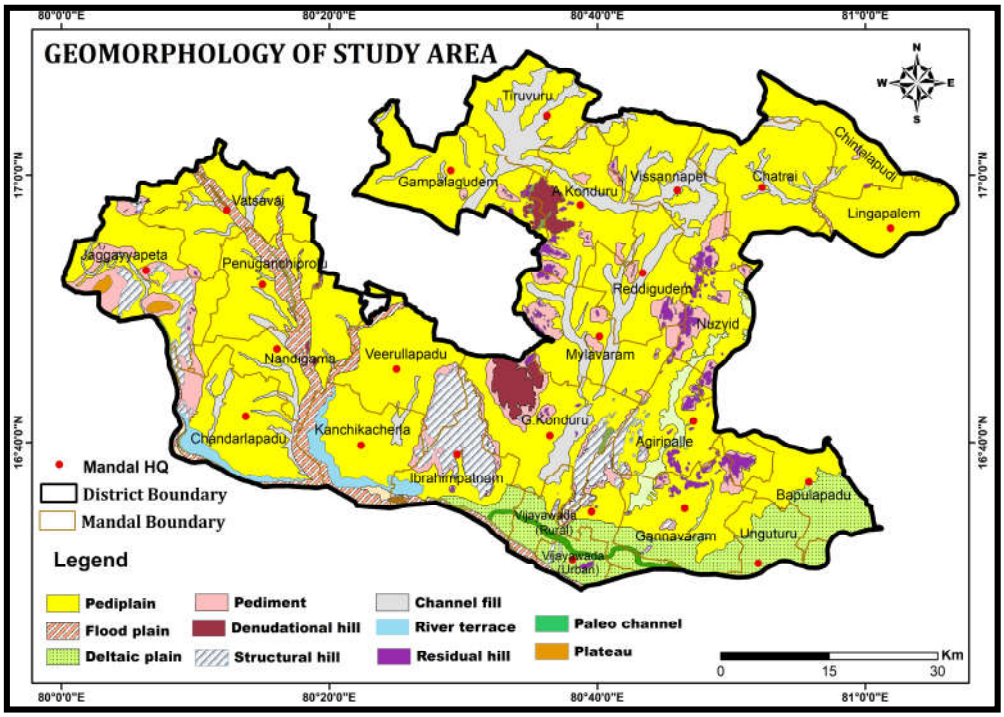


Fig 1.4: Geomorphology Map

Pediment ls well developed around the khondalites outcrop area while it is not so extensive in charnockite area. The topographical lows are occupied by valley fills and alkaline soils. The area between the charnockites and khondalites is underlain by granite gneisses and this area is characterised by bed rock surface with practically no out crops.

The development of of flat alluvial plains is attributed to both degradation and aggradation process of the running nature of the river Krishna over considerable length of time. It is to be noted that not only the river Krishna but also its tributaries have contributed to the formation of this alluvial plain. This geomorphic unit show palaeo- channels (old river courses of Krishna). There is practically no development of

surface drainage in these alluvial plains, probably due to the higher permeable character of the sediments comprising the alluvium. The alluvial plains developed by the alluvial process extend inland beyond Vijayawada upto the confluence point of Muneru and Krishna rivers.

1.6 Drainage: The main rivers of the study area are Krishna, Muniyeru, Tammileru and Budameru. The general drainage pattern is dendritic to sub-dendritic. The drainage density is high in consolidated formations, low in semi-consolidated formations, whereas in alluvial areas the density is merged. The krishna river originates in Western Ghats, and passes through Maharashtra and Karnataka states and enters plains of the Coromandal coast after passing through a narrow gorge in the Nallamalai hills flowing with a slight inclination to the south, it touches Vljayawada where it attains a width of l, 188 meters. It flows to the east and then to the south between Krishna and Guntur districts (**Fig.1.5**). Reaching the chain of the Eastern Ghats and turning sharply to the sough-east and flowing for about 160 km, it debouches into the Bay of Bengal at Hamsala Devi and Nachugunta in the district.

The river Muniyeru (Muneru) is the chief tributary of the Krishna River in this district. It flows from the north to the south across Jaggayyapet and Nandigama mandals. The Tamileru is another minor river, which flows along the eastern boundary of the Tiruvuru and Nuzvid mandals and enters the West Godavari district separating along the Krishna district boarder. The river Budameru, another small river, is also a hill stream and flows through Vijayawada, Gannavaram, Gudivada and Kaikalur and finally falls in to the Kolleru lake. Besides these rivers, the district has also small hill streams viz., Jayanti, Kattaleru, Ippalavagu, Upputeru, Telleru, Ballaleru, Nidimiyeru, Vaira river etc.

Drainage Analysis: River Krishna is a consequent stream. Some of its tributaries might be subsequent and adjusting themselves to structural features or roughly follows the already existing lineaments. The overall drainage of river Krishna is dendritic which is the most common drainage pattern in hard and resistant terrains like granites and gneisses. This implies lack of structural control. In Jaggayyapeta and Nandigama mandals in the west, the drainage density is coarse. Here the tributary stream takes almost 90° turn in the course indicate joint or fracture/fault control. East of Jaggayyapeta, river Paleru follows a 'meander loop' course and then becomes a

straight segment in the west, evidently adjusting itself to a structural trend. North of Nandigama town and in the eastern pan of Jaggayyapeta mandal, the drainage of Munneru stream shows a typical 'Yazoo' pattern.

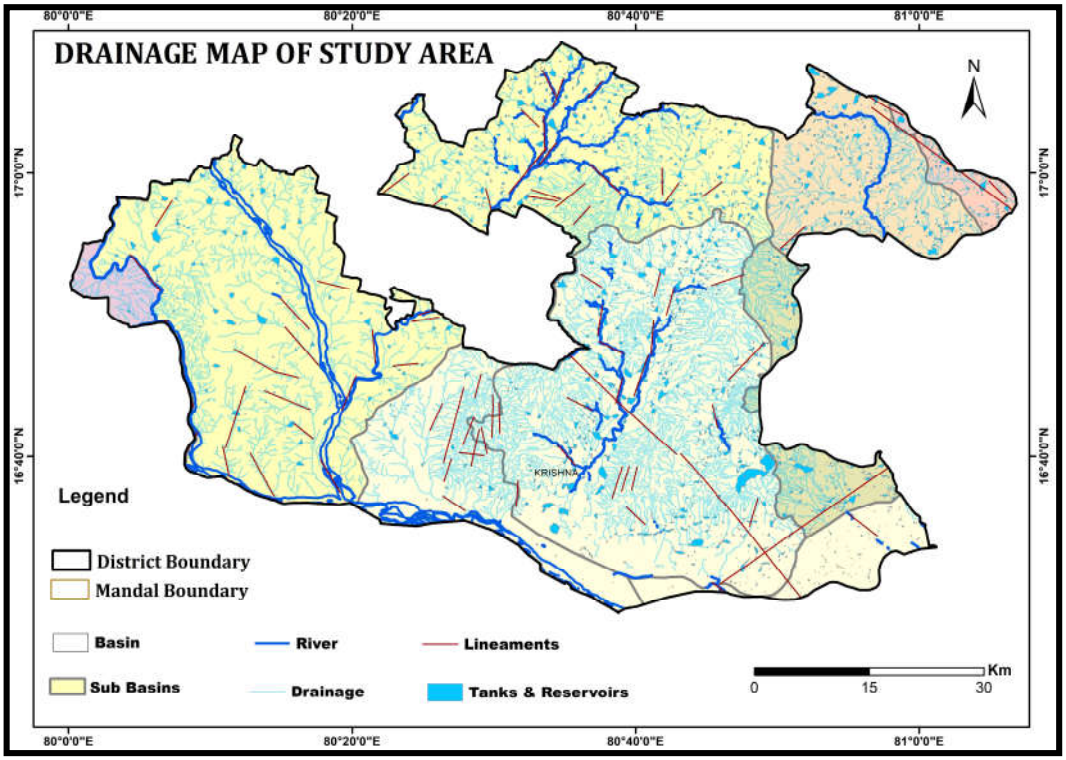


Fig 1.5: Drainage Map

Lineament Analysis: The N-S extending hill ranges of charnockites have two sets of lineaments (major fractures and joints) trending in N10°W - S10°E and N30°E - S30°W are observed. The area to the north and east of charnockite range is underlain by granite gneisses. Predominant exposures of khondalites are seen on the eastern side of granite gneisses. The contact between khondalites and granite gneisses appears to be faulted in a curvilinear fashion. Khondalites show sharp ridges and linear trend in NE-SW direction. However, one major lineament probably a fault, trending in N l8°W-S18°E direcion passes on the eastern side of Nuzvid. Another lineament interpreted as a fault or a major fracture zone trending in the N23°W- S23°E direction passes through khondalite inliers and controls the course of Tamileru river.

1.7 Soils: Based on the soil texture, the area is mainly occupied by fine loamy soil (38%), loamy skeletal (31%), clayey skeletal (17%) and fine clayey soil (14%) in **Fig1.6.**

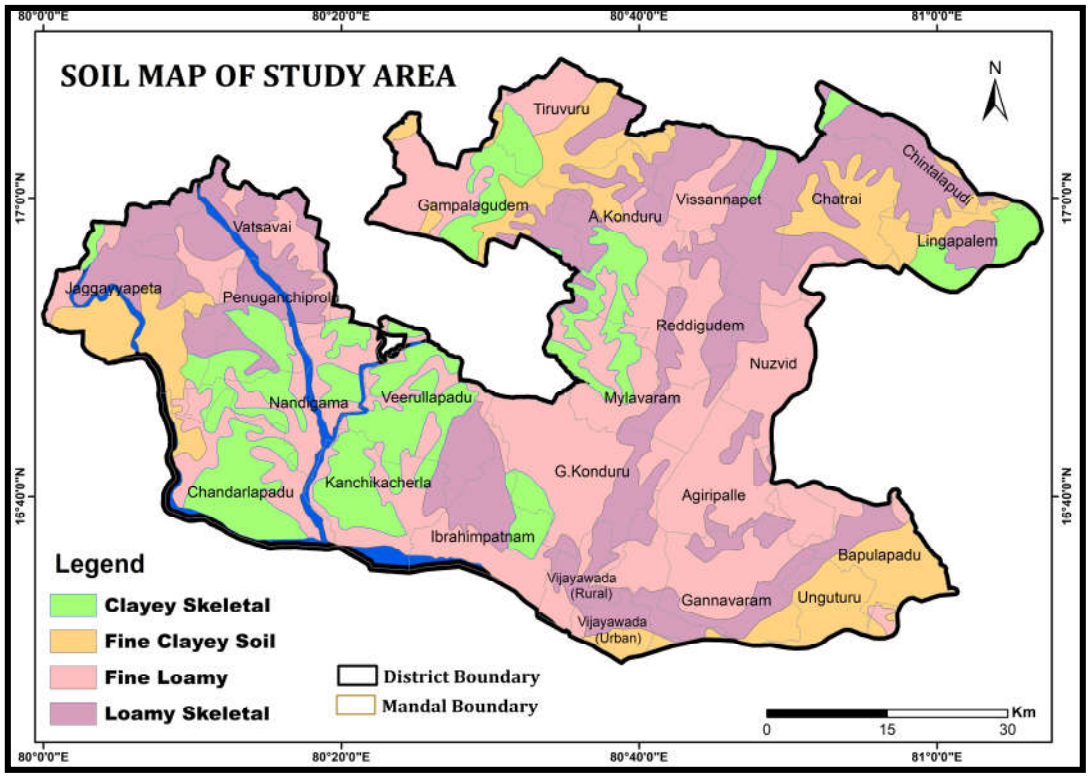


Fig.1.6: Soil map

1.8 Land use and cropping pattern (2019-20): Major part of the district is occupied by agricultural area (54%). In the district, forest occupies nearly 11% of the area and 14% of the area is put to non agricultural uses. Remaining area is occupied by Plantation, builtup, water bodies and fallow land etc (**Fig.1.7**). The total gross cropped area during the year 2019-20 is 316629 ha. The area cropped during Khariff season is 243792 ha and the major crops grown during khariff season is Paddy (32%), Cotton (20%) and remaining by other crops. The gross area cropped during Rabi season is 72837 ha and the major crops grown during the period include Paddy (48%), Pulses (26%), Maize (18%) and remaining by other crops. Season wise croppingpattern is given in **Fig.1.7a** and **Fig.1.7b.**

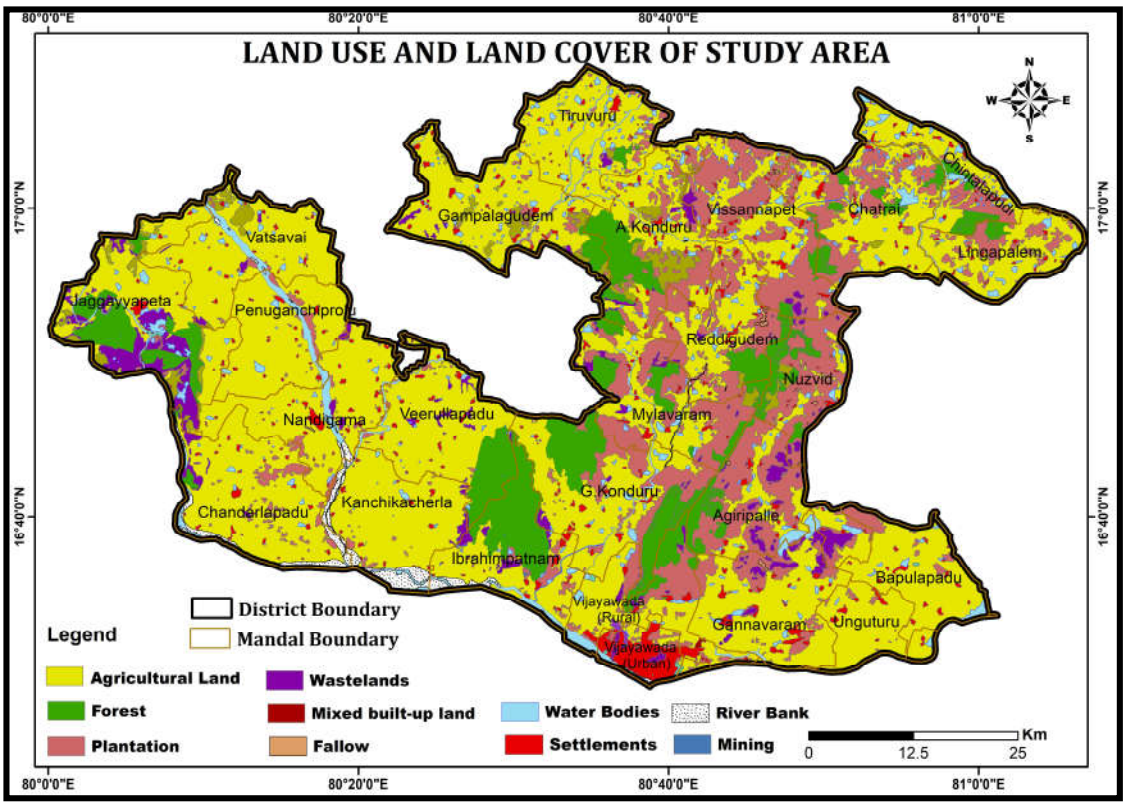


Fig.1.7: Land use and land cover

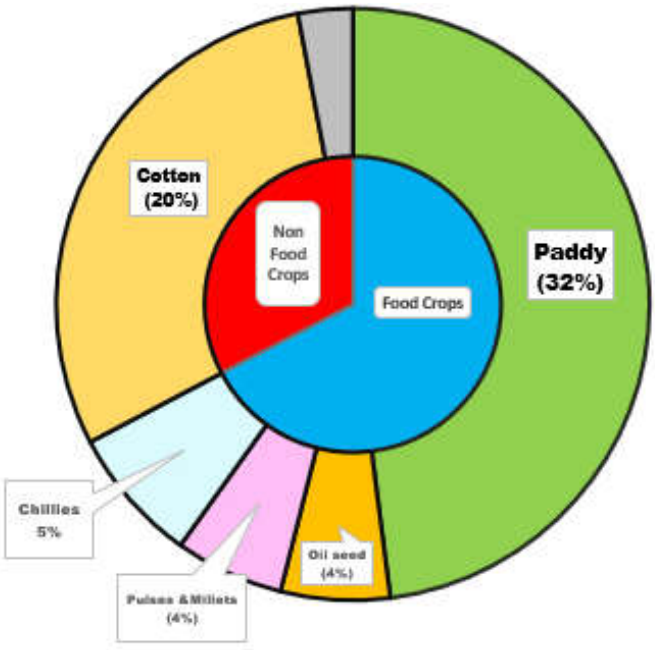


Fig .1.7a: Kharif Major Crops

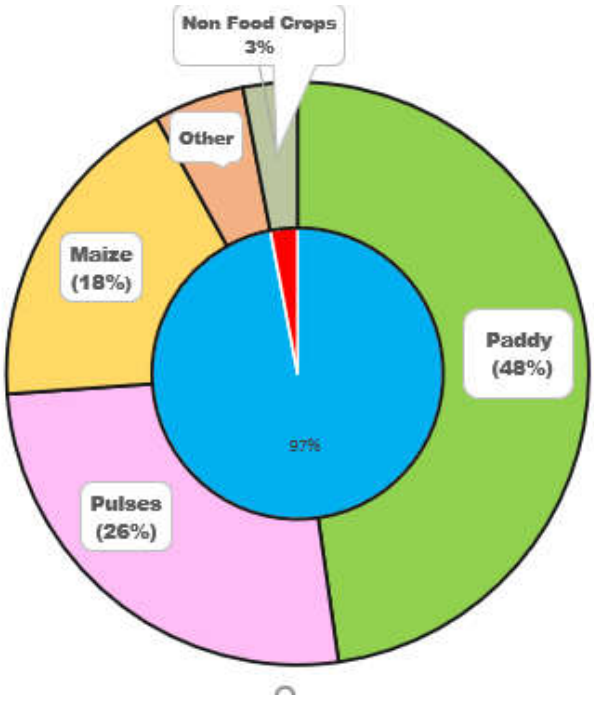


Fig .1.7b: Rabi Major Crops

1.9 Irrigation:

Major Irrigation & Medium Irrigation Projects:

The major irrigation project covering the Krishna District are Prakasam Barrage and Nagarjuna Sagar Project. The major ongoing project is the Indira Sagar Project Canal, under this, 25495 ha are covered in Gangavaram, Mylavaram, Nuzvid and Vijayawada mandals. The Tarakarama lift Irrigation scheme is intially proposed to rrigation facilities to 8 upland mandals by utilizing return water from Vijayawada thermal power station in Budameru diversion channel. Total extent under TRLIS was restricted to 5592 ha as construction of Polavaram Irrigation Project Right Main Canal is taken up and the balance ayacut can be covered under Polavaram Irrigation Project Right Main Canal. Muniyeru Project and Tammileru Project are the other projects in the study area. The segments covered are Jaggiahpeta, Nandigama and Nuzvid**. (Fig 1.8)**

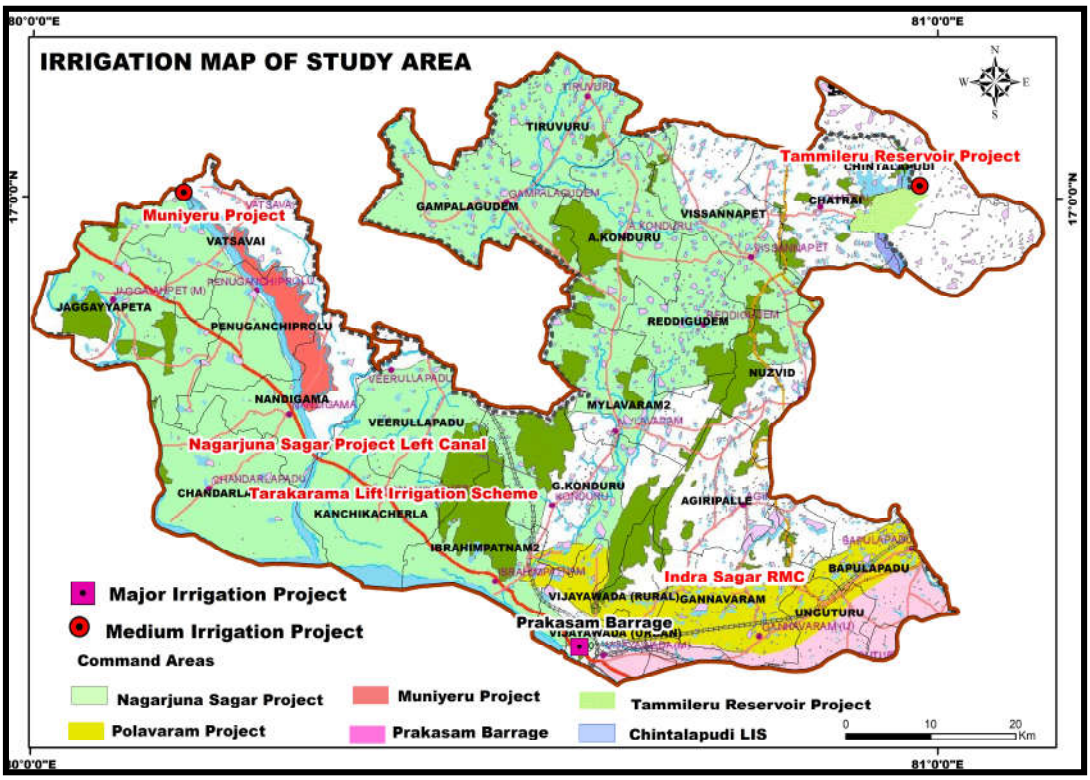


Fig 1.8 Irrigation Projects Krishna District (Parts)

Table 1.1: Minor irrigation Details

State	Minor Irrigation Sources	Actual Area Irrigated Hectares
Krishna (Parts)	839	27160

Table 1.2: Salient Features of Irrigation in Krishna District (Parts)

Source		Numbers	Area irrigated (ha)
Ground Water Irrigation			
Tube wells	**Shallow**	7147	74455
	Medium	10658	
	Deep	13284	
Dug wells		5784	4289
Total		**36873**	**78744**
Surface Irrigation			
Canals			49313
MI Tanks		839	27160
Lift Irrigation		191	12568
Total			**89041**

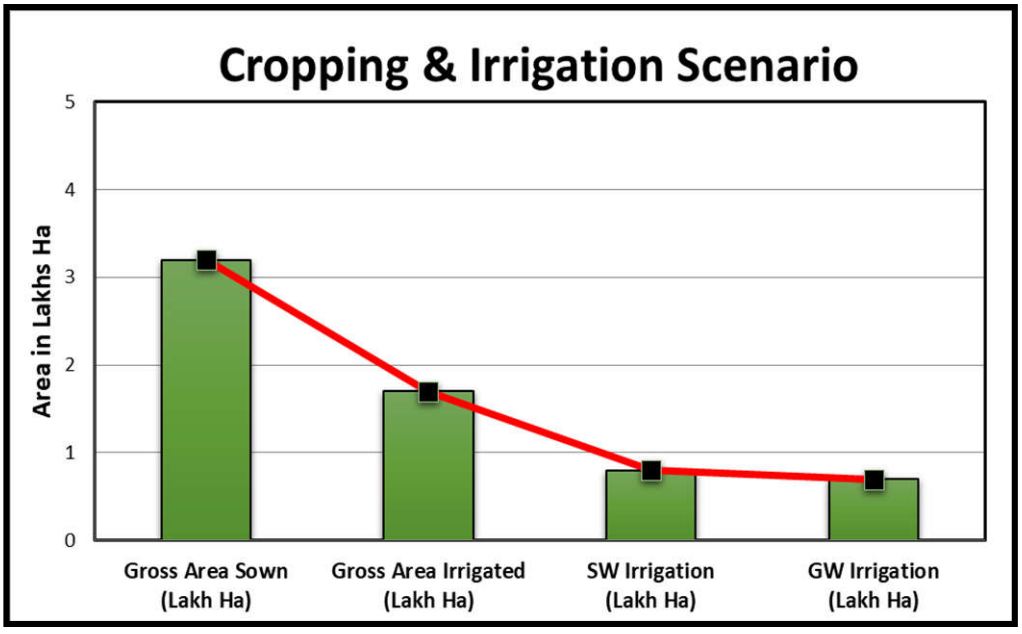


Fig.1.9: Cropping and Irrigation Scenario

Out of the total Gross area sown of 316629 ha, 167785 ha (53%) of the cropped area is under surface and ground water irrigation (**Fig.1.9**) & (**Table1.1 & 1.2**).

1.10 Geology:

The study area is underlain by various geological formations from Archaean to Teritary age, with some isolated pockets of Recent to Sub-recent alluvium. Archean to proterozoic Banded Gneiss occupies 41% of the area (Table:1.3). The Archean Charnockite (19% of the area) and Khondalite (30% of the area) overlies the Archean Granitic Gneiss (41% of the area). The Precambrian metasedimentary formation covers of Kurnool and Cuddapah system covers 4% of the area and remaining 6% is alluvium sediments along the river channels (Fig1.10).

Table 1.3: Stratigraphy of Krishna District (Parts)

Era	Period	Formation	Location
Quaternary	Sub-Recent to Recent	Alluvium	Along the river banks
Tertiary	Upper Gondawana	Sandstone	Nuzvid and Gannavaram
Pre-Cambrian	Kurnool System	Krishna district (Parts)Narji Limestone & shales,	Jaggayyapeta
	Cuddapah System	Cumbum Quartzites & Phyllites	
……Unconformity……			
Archean	Dharwar	Veins of Pegmatite, dolerite dykes, Granite Gneisses, Charnockites khondalltes	Nandigama, Vijayawada, Vissannapet, Tiruvur mandals and Kondalli hills

Pre-Cambrian Crystallines: The Pre-cambrian crystallines consist of Khondalite suite of rocks, charnockites and gneissic-granites. The general trend of foliation of the gneisses are NE-EW direction with easterly dips. The older metamorphic occur mostly as enclaves within the gneissic complex having predominance of amphiboles and biotite minerals. These granites are medium to coarse grained and occur mostly as sheet like or gentle dome like hills wherever exposed in the district. Dolerite, meta-dolerite rocks, veins of pegmatite, aplites, quartz etc., occur as intrusive units into the

older litho units of the Peninsular Gneissic Complex. Dykes of dolerite traverse the terrain covered by the granites and their dimensions are highly variable.

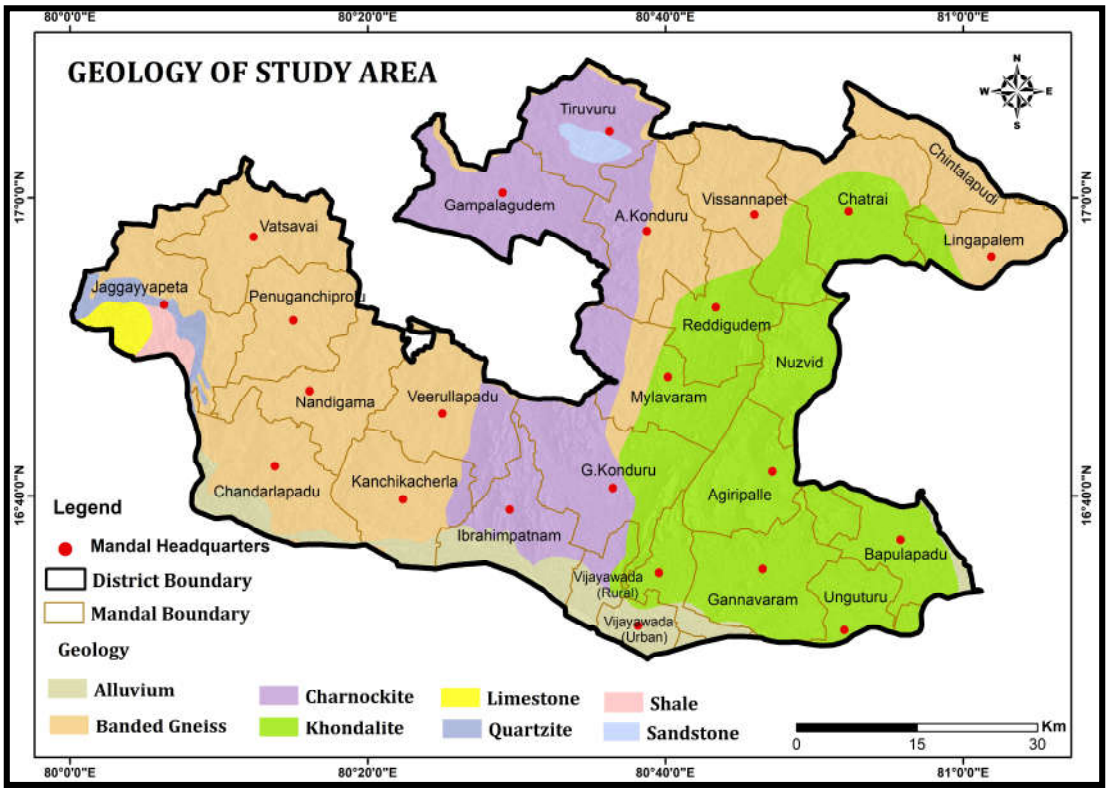


Fig.1.10: Principal Aquifers of Krishna District (Parts)

Khondalites: Khondalites are consisting essentially of garnet, with varying amounts of sillimanite, quartz, graphite and fairly large amount of potash feldspars. Quartzites occur as bands within these khondalites. Feldspars and garnets in these formations alter to kaolin and ferruginous mass respectively. The hill ranges extending from Vijayawada to Vissannapet are made up of khondalites.

Charnockites: The charnockites occur as intrusions into the khondalite suite and are exposed on the Kondapalli range of hills and to their east. The rocks are of acidic to intemediate to basic to ultra basic varieties. Mineral hypersthene is characteristic of these rocks, the acid and intermediate varieties consist of waxy, blue quartz, potash feldspar, plagioclase and garnet, serpentine and chromite are associated with the ultra baslc varieties.

Pre-Cambrian Meta-Sediments: The pre-cambrian meta-sediments are represented by Cuddapah and Kurnool system of rocks and occur unconformably overlying the pre-cambrian crystallines. These formations occupy an area of about 150 sq.km south of Jaggayyapet. The Cuddapah system is represented by brownish quarzites and phyllites

referable to the Cumbum stage. The Kurnool include gritty quartzites belonging to Banaganapalle stage and limestones and shales belonging to Narji stage. The limestones are occasionally flaggy and vary in colour from white to light grey and dark grey, where as shales are green in colour. The rocks of the Cuddapah system mentioned above are traversed by numerous veins of secondary quartz.

Sub-Recent to Recent: Sub-Recent to Recent and Holocene deposits including laterite and kankar formed due to the weathering of khondalitic rocks and gravel, and alluvium deposited by the river Krishna along its banks area.

2. DATA COLLECTION AND GENERATION

Collection and compilation of data for aquifer mapping studies are carried out in conformity with the Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various data generation activities **(Table-2.1)**. The historically available data of Geology, Geophysics, Hydrogeology, and Hydrochemistry generated under various studies by the CGWB through systematic hydrogeological studies, Reappraisal hydrogeological studies, Groundwater Management studies, Exploratory drilling and special studies have been utilized for data gap analysis, along with the data collected from various State and Central government departments.

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

S. No	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc.
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
2.	Generation of Data	Generation of geological layers (1:50,000)	Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern.
		Surface and sub-surface geo-electrical 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 geometry for shallow and deeper aquifer has been established through hydro geological studies, exploration, surface and subsurface geophysical studies in the district (**Fig 2.1**). The data used for the integration and interpretation includes:

2.1 Exploratory Drilling: Information on aquifer geometry, groundwater potential of various formations, fracture systems, their characterization is primarily inferred from the exploratory drilling data. CGWB has a total of 44 wells in the study area. Out of these, 34 wells were drilled before 2012 and 10 wells in 2021-22 based on the data gap analysis carried out in the study area as part of NAQUIM. A total of 73 exploratory borewell data of CGWB (44) and SGWD (29) were used for the hydrogeological studies. 5 wells are located in Semi consolidated formation and 68 wells in consolidated rock areas.

2.2 Water Level: Water level monitoring wells of CGWB and SGWD is utilized for the Aquifer Mapping studies. 20 dug wells and 3 Piezometers are presently monitored by CGWB and 63 piezometers by SGWD. CGWB wells are being monitored four times (January, April, August and November) in a year whereas the monitoring wells of State Ground Water Department (SGWD) are being monitored every month. These groundwater monitoring wells were used in order to understand the spatio-temporal behaviour of the groundwater regime.

2.3 Hydro chemical Studies: Water quality data of CGWB and SGWD is utilized for understanding the spatial variation of quality in the district. A total of 85 Pre monsoon (CGWB: 54, SGWD: 31) ground water monitoring well data of Central Ground Water Board and Andhra Pradesh State Ground Water Department (mostly tapping combined aquifers Aq-1 and aq-2) is utilized to understand the chemical characteristics of groundwater. Parameters namely pH, EC (in µS/cm at 25 ° C), TH, Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, NO_3 and F were analyzed.

2.4 Geophysical Studies: Geophysical data on VES and profiling are used to extract information on the weathered thickness, fracture depth, thickness of fracture etc of hard rock area. For the interpretation of the aquifer geometry, geophysical data in conjunction with the available groundwater exploration data is utilised. The VES data from Tiruvuru, A Konduru, Vissanapeta, Nuzivedu and Mylavaram areas were analysed for NAQUIM. The measurements were taken at the central part of the profile leaving 200m on either side of the profile. The VES positions were all along the seismic profile at most of the shot points to a maximum electrode separation of 400m (AB).

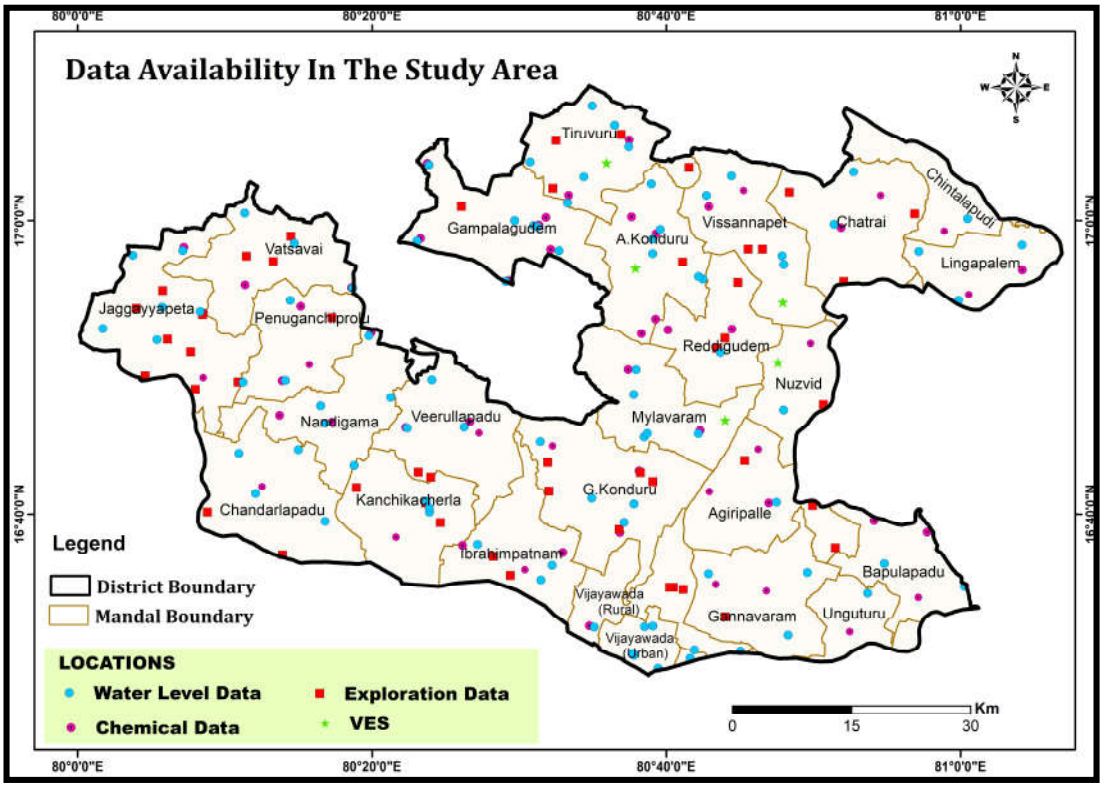


Fig. 2.1: Data availability

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1. Ground water Level Scenario

3.1.1 Depth to ground water level

Analysis of the pre and post monsoon water level data from 86 (CGWB:23, SGWD: 63 PZ) groundwater monitoring wells shows that depth to water level varies from <1 to 25.2 m bgl during pre monsoon and 0.4-17.9 m bgl during post-monsoon season.

Pre-monsoon season: In Majority of the areas, water level during this season is in the range of 5-10 m (57% of the area), followed by 10 to 20 m bgl (26%). Deeper water levels in the range of > 20 m bgl occupy only about 1 % of the area falling in parts of Chatrai, Vissannapet and Chintalapudi mandals (**Fig.3.1**). Shallow water level <5 m bgl occupy about 16% of the area.

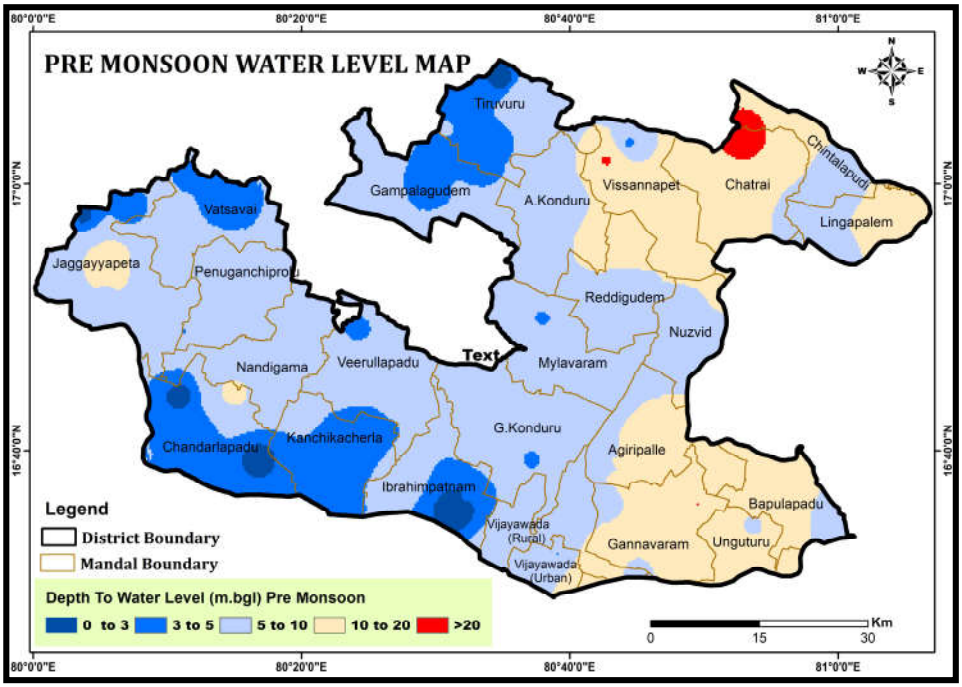


Fig.3.1: Depth to water levels Pre-monsoon

Post-monsoon season: Majority of the water level during this season are in the range of 5 to 10 m covering 45% of the area, 3 to 5 m bgl in 38 % of the area. (**Fig.3.2**). Shallow water level < 3 mbgl occupy about 10% of the area in parts mainly in parts of Chandarlapadu, Vatsavai, Ibrahimpatnam and Tiruvuru mandals. Water level in the range of 10 to 20 m bgl occupies about 7 % of the area falling in parts of Chatrai, Vissanapeta, Ganavaram and Vijayawada mandals.

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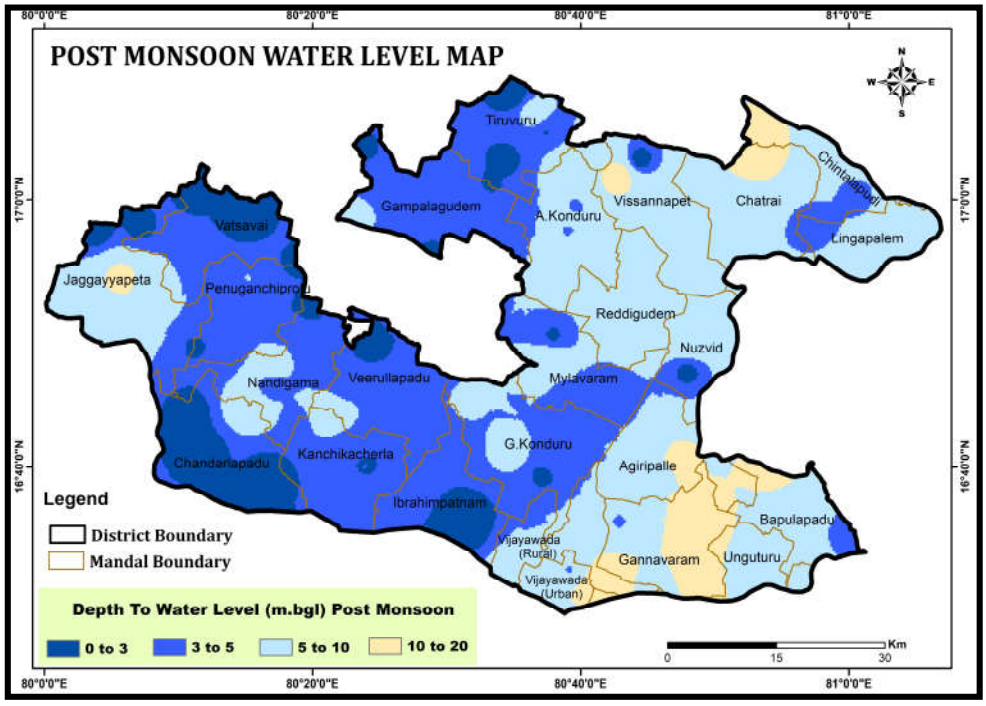


Fig.3.2: Depth to water levels post-monsoon

3.1.2 Seasonal Water Level Fluctuations (May vs. November): Out of 80 wells, 76 wells in the state records water level rise. The water level rise varies from 0.10 to 13 m in all the wells (**Fig.3.3**). 49% of the area have 0 to 3 m rise in water level and 27% of the area have 3 to 5 m rise. Rise of >5 m is observed in 24% of area. Water level fall is recorded in four wells. The seasonal water level fluctuations vary from 0.10 to 13 m.

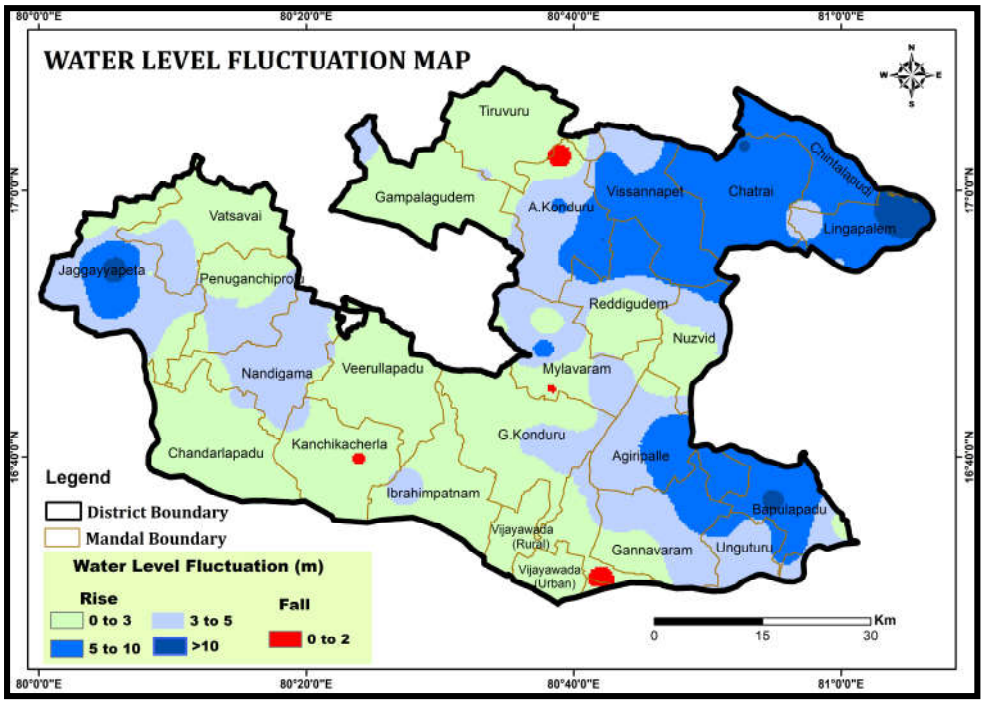


Fig.3.3: Water Level Fluctuation (m) (Nov with respect to May)

3.1.3 Long term water level trends: Trend analysis for the last 10 years (2011-2020) is studied from 60 hydrograph stations of CGWB and SGWD. It is observed that during pre-monsoon season 54 wells shows falling trend in the range of 0.01 m/yr to 1.8 m/yr and 6 wells shows rising trend 0.01-0.4 m/yr. During post-monsoon season 56 wells show falling trend 0.01 to 1.6 m/yr and 4 wells shows rising trends 0.1-1.5 m/yr (**Fig. 3.4 a-b)**.

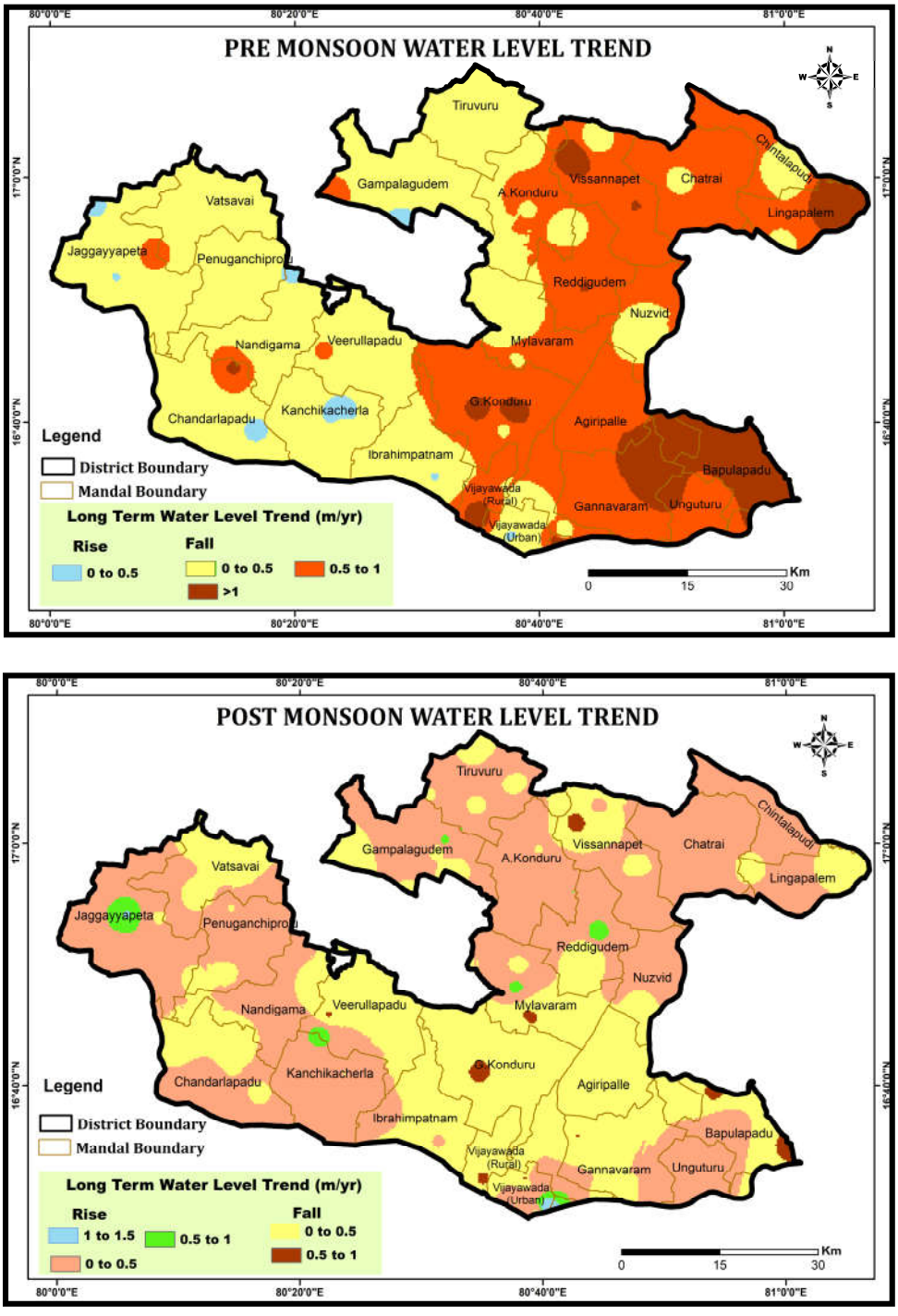


Fig. 3.4a-b: Long-term water level trends (10 yrs)

3.1.4 Water Table Elevation: During Pre-Monsoon, water-table elevation ranges from 4 to 120 m amsl and in post-monsoon season 7-150 m amsl. The ground water flow also has the same drainage flow direction. (**Fig.3.5**).

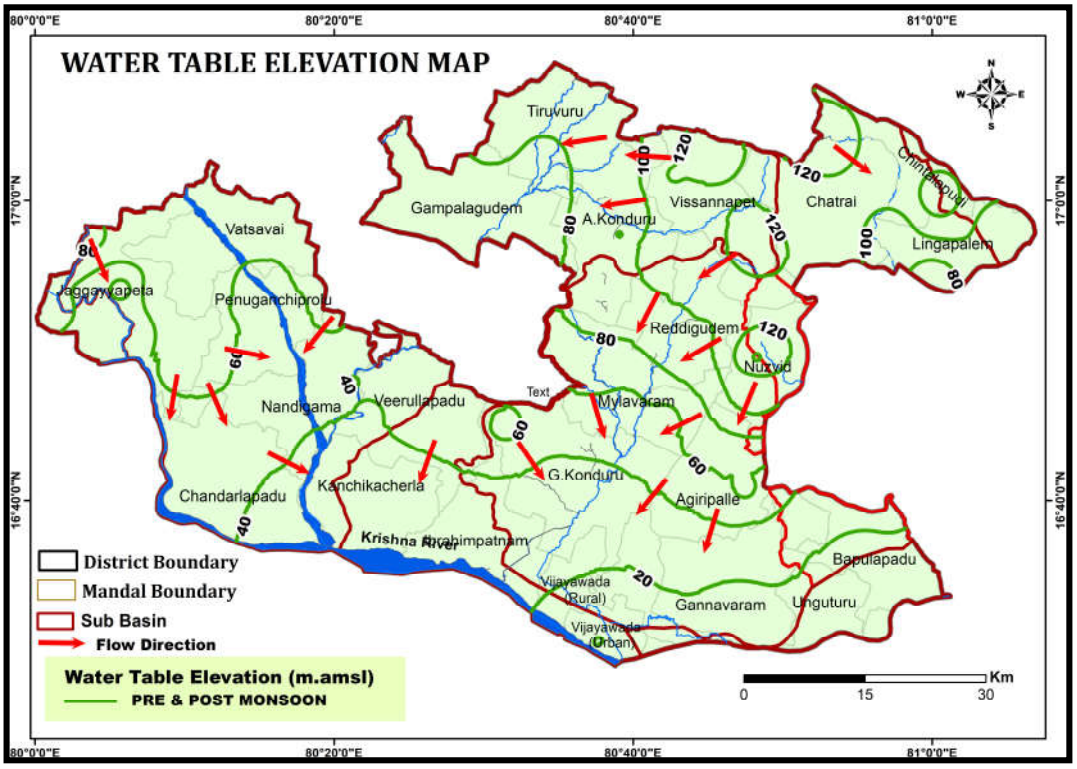


Fig.3.5: Water table elevations (m amsl) during Pre- and Post-monsoon season

3.2 Ground Water Quality

The groundwater quality in the area is generally good for all purposes. In all the locations PH is within the acceptable limit and shows mildly alkaline nature.

Pre-monsoon:

Groundwater from the area is mildly alkaline with pH in the range of 6.52 - 9.0 (Avg: 7.9). Electrical conductivity varies from 313-7800 (avg: 2443) µ Siemens/cm**.** In 69% of area, EC is in between 1500-3000 µ Siemens/cm, in 26 % area, it is within 1500 µ Siemens and in 5% of area it is beyond permissible limit. (**Fig.3.6).** Average concentration of TDS is 1529 mg/L and NO_3 ranges from 0.5-183 mg/L. Nitrate concentration in 28% of samples is beyond permissible limits of 45 mg/L (**Fig.3.7**). Fluoride concentration varies from 0.12-2.1 (**Fig 3.8**) and 96% of samples is within the permissible limits of BIS and rest is beyond the permissible limit.

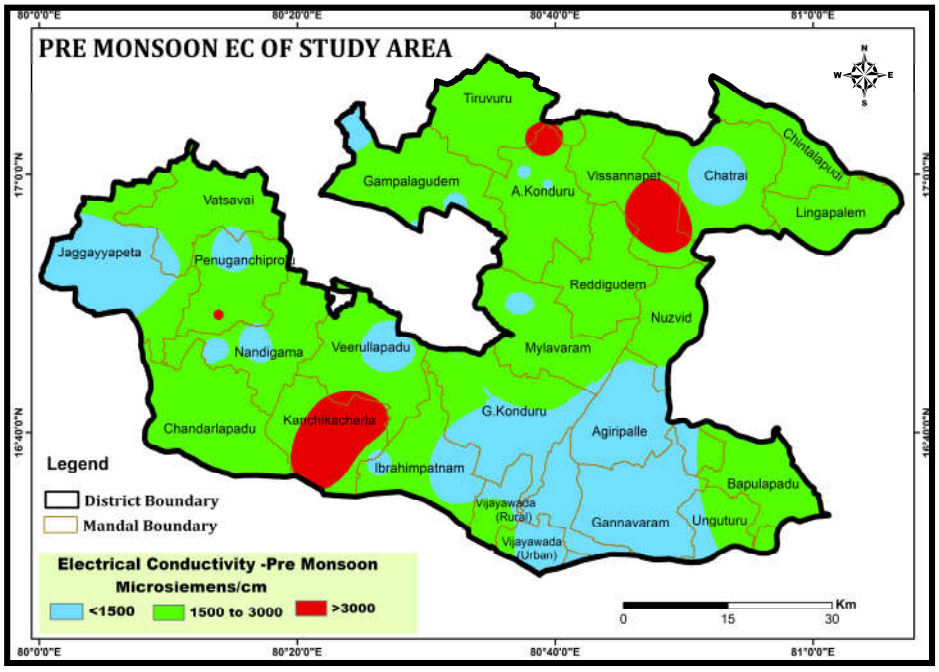


Fig.3.6: Pre monsoon EC distribution

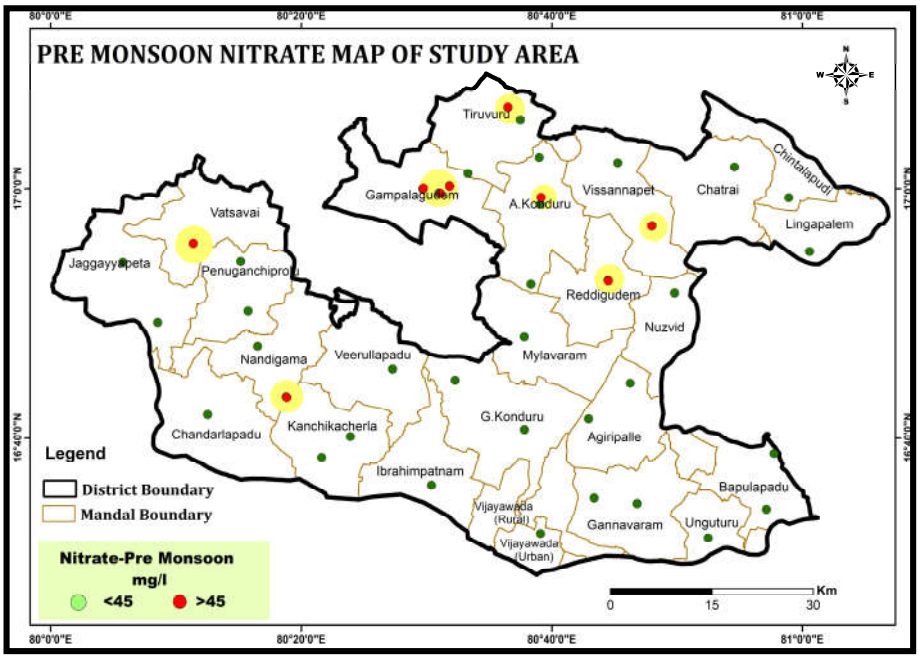


Fig.3.7: Pre monsoon Nitrate distribution

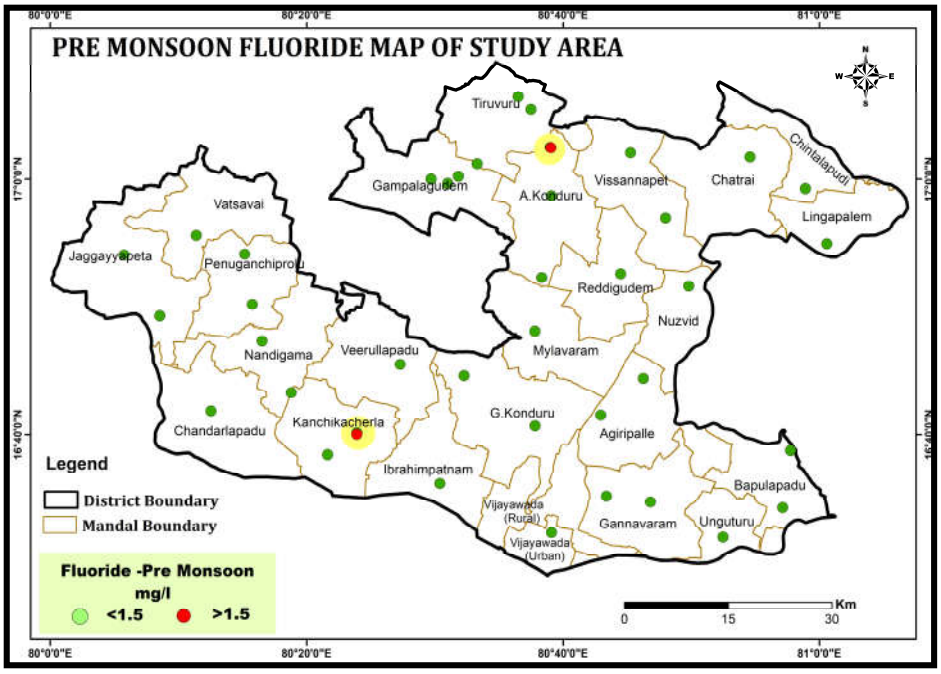


Fig.3.8: Premonsoon Fluoride distribution

3.3 AQUIFER MAPPING

The aquifer geometry for shallow and deeper aquifer has been established through hydro geological studies, exploration, surface and subsurface geophysical studies in the district. Aquifers were characterized in terms of potential and quality. The aquifer wise characteristics have been delineated and are shown in **Table 3.1.** Hydrogeology map in the **Fig. 3.11**.

Aquifer Characterization: On the basis of occurrence and movement of ground water, mainly rock units of the Krishna district (Parts) is classified into two categories; hard rocks (Archean crystalline and Metasedimentary formations). Weathered and fractured Archean crystalline rocks form the major aquifer system. Metasedimentary aquifer system overlies archean crystalline rocks (Khondalites, Charnockites/Granite Gneisses) aquifer system. The main aquifers constitute the weathered zone at the top, followed by a discrete anisotropic fractured zone at the bottom. Ground water occurs under unconfined and semi-confined conditions and flows downward from the weathered zone (saprolite and sap rock) into the fracture zone. The aquifer units identified includes**- Shallow Aquifer and Deeper Aquifer.**

Weathered zone:

Thickness of weathered zone in the range of 20-35 m in most part of area covering ~85 % of area, shallow weathering 10 -20 m occurs in 14% of the area and deep weathering (> 40 m) occurs in rest of the area (**Fig.3.9**).

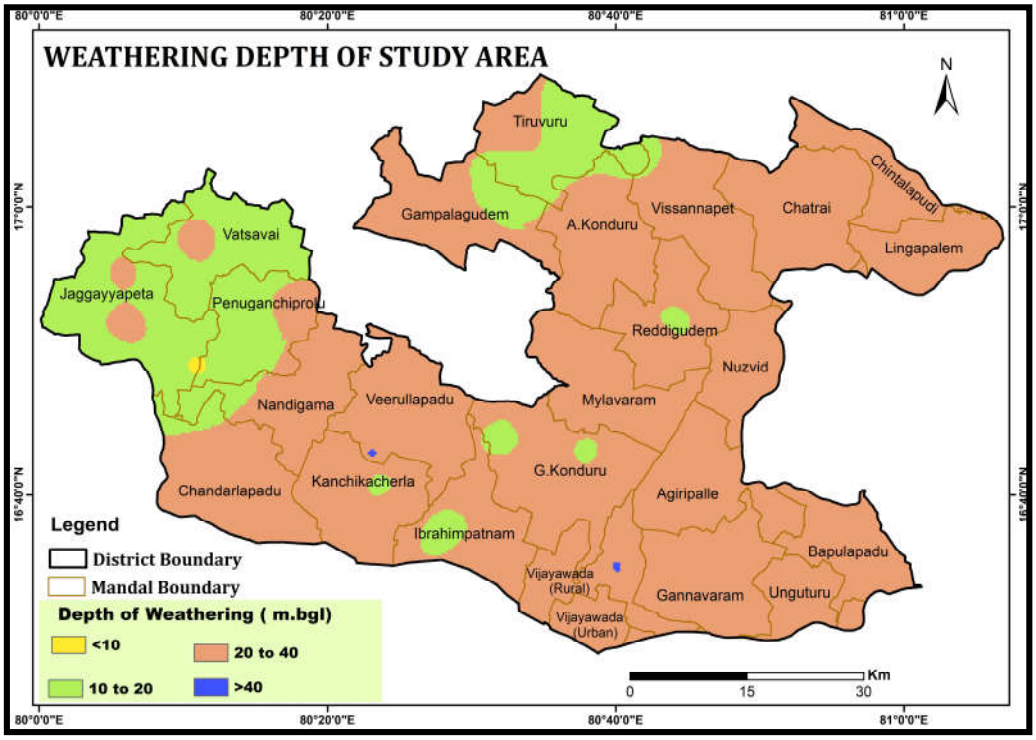


Fig.3.9: Weathered zone

Aquifer Characterization of Shallow Aquifer: (Aquifer-1): It consists of weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells or shallow bore wells. The shallow aquifer is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~30 m depth. They are unconfined aquifers. Ground water yield varies from <0.1 to 2 lps (avg: 1.0 lps in weathered granite/gneiss aquifer, 0.4 to 6.9 lps (avg: 3.6 lps) in weathered Khondalites and 1 to 12 lps (avg: 4 lps) in metasedimentary aquifers. The transmissivity varies from <1 to 70m^2/day in weathered archean crystalline aquifers and varies from <100 m^2/day in metasedimentary aquifers.

Fractured Zone: Based on CGWB & SGWD data, it is inferred that fractures in the range of 30 to 60 m depth are more predominant (64 % of the area), 60-120 and 120 to 150 fractures occur in 31% and 3% of area respectively and deep fractures in the range of 120-150 m. Analysis of occurence of fractures reveal that majority of fractures (~80 %) occur within 100 m depth (**Fig. 3.10)**

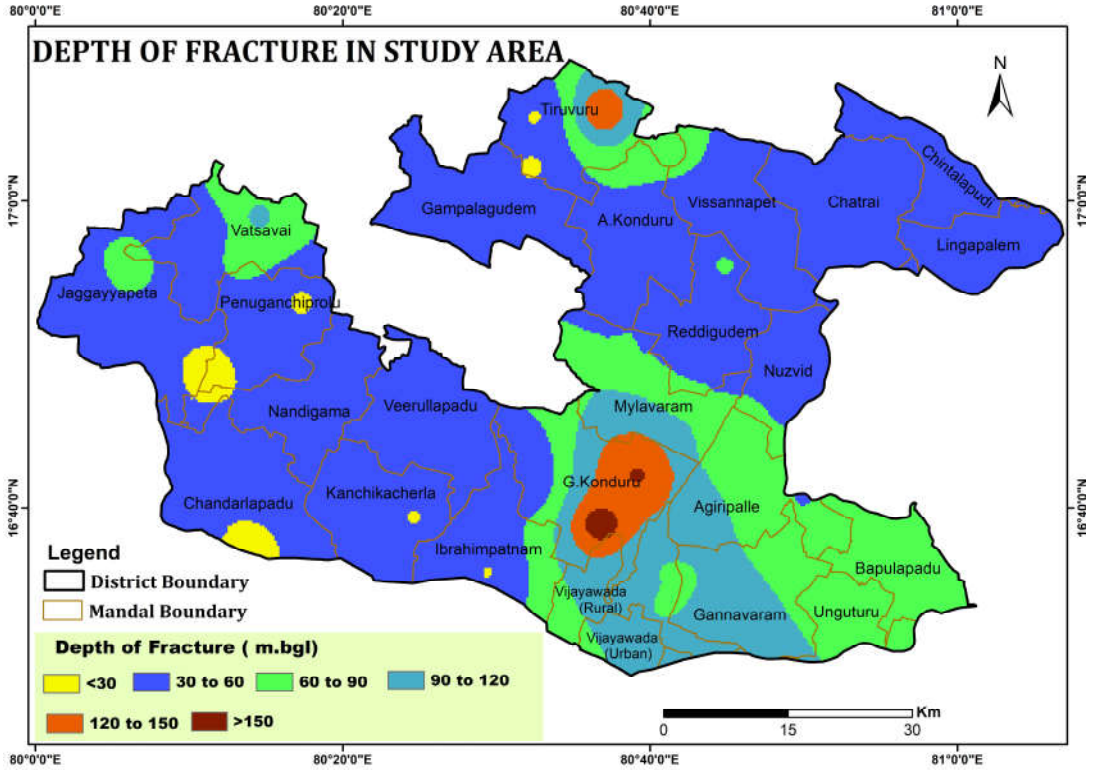


Fig.3.10: Depth of occurrence of fracture zone

Aquifer Characterization of Deeper Aquifer (Aquifer II): The aquifer-II is the deeper aquifer which tapped the fractured zone. Ground water in the second aquifer occurs under semi-confined to confined condition in the fractures upto the maximum depth of 180 m bgl (Deepest fracture encountered). The deth of fracturing varies from 25 m to 180 m with yield of <1 to more than 10 lps. The specific capacity of the consolidated formation ranges between 5 and 700 lpm/mdd and transmissivity of consolidated formation varies from <1 to more than 100 sq.m/day. The storativity varies from $4.84 *10^{-6}$ to $1.06*10^{-4}$.

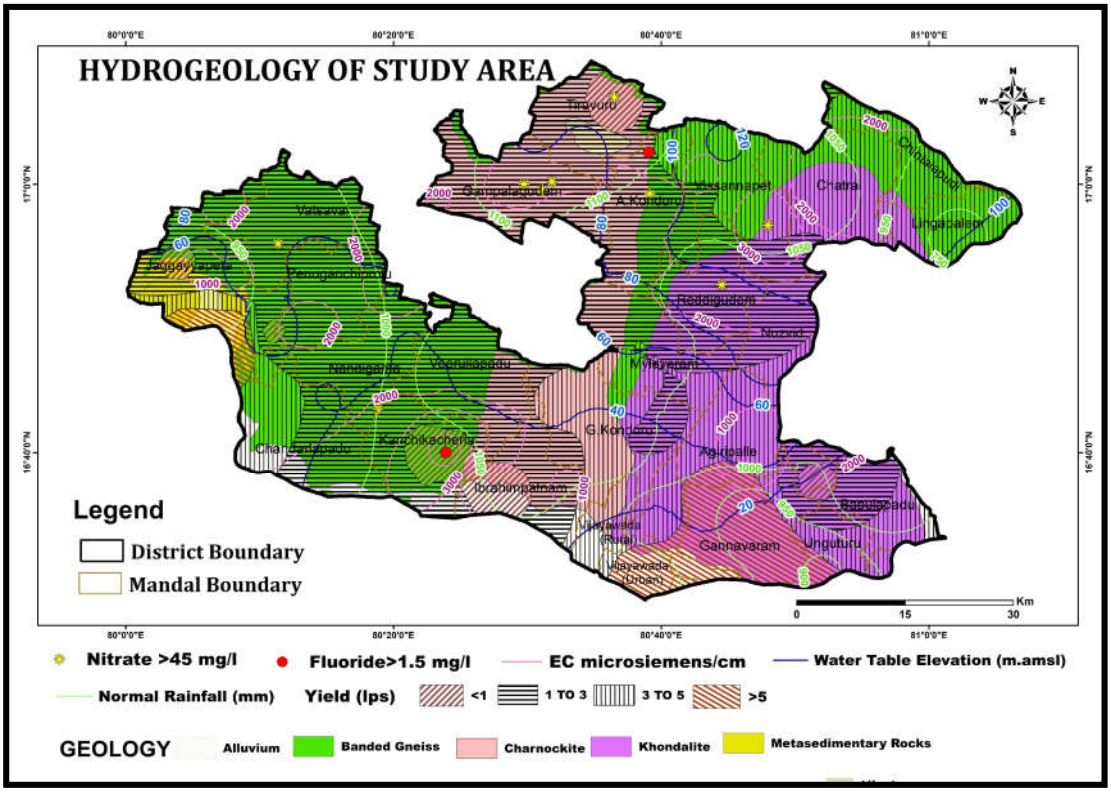


Fig3.11: Hydrogeology Map

Out of the total study area of 4,493 sq.km approximately 91 % of the area is underlain by the Arechean group of rocks consisting khondalites, granites, gneisses and Charnockites and 4% is covered with schists, phyllite and limestone etc., exposed in Jaggayyapet, Tiruvur, Nandigama, Vijayawada and parts of Nuzvid and Gannavaram mandals. These rocks are devoid of primary porosity due to compaction and consolidation. These formations tend to become ground water repositories with the development of secondary porosity and permeability with weathering and fracturing. Groundwater in these rocks occurs under water table conditions restricted to weathered, fractured and jointed horizons.

The thickness of the weathered mantle of the crystalline rocks varies widely from 0 to 10 m near the hill slopes and out crops to as much as 40 m in valleys and topographic lows. This weathered formation has been extenslvely developed by open dug wells and shallow bore wells. Water from these rocks is extracted by dug wells of depth ranging from 6 to 20 m bgl. Domestic wells are mostly circular with about 1m

diameter or rectangular with dimensions of 4 m X 6 m to 10 m X l5 m. In the areas underlain by shales and limestones between Jaggayyapet and Vedadri, the open wells are used for domestic and irrigation purposes and the depth to water level in these wells varies from 3 to 15 m bgl. Available data indicates that these wells sustain 2 to 3 hours of continuous pumpage in a day.

In parts of Tiruvur mandal especially in Vissannapet area, weathering of khondalites has been observed down to the depth of l5 m bgl. The dug wells tapping this aquifer have depths ranging from 5 to 14 m and the depth to water level varies from 1.5 to 7.5 m bgl. The yield of the wells, computed from the reported recuperation, vary from 50 to 250m^3/day. In contrast to khondalites, granites are less susceptible to weathering and as such the thickness of the weathered zone is very much limited, usually 6 to 12 m thick. Dug wells tapping this zone vary in depth from 5 to l l m bgl. The yields of these wells range from 20 to 100 m^3/day.

In Jaggayyapet mandal, ground water occurs in granite gneisses intruded by dykes of dolerite and quartz reefs, shales, limestones etc., In the granite gneisses open wells pierce through weathered and jointed granitic rocks, whose depth range is between 2 and 12 m bgl. The depth to water level in these rocks varies from 1.2 to 9.0 m bgl. Analysis of pumping test data has indicated that the average rate of inflow of water into the wells vary from 275 to 534 lph/sq.m. In the quartzites of Cuddapah group, ground water occurs in joints, fissures and fractures. The dug wells in these formations range in depth up to 15 m bgl and depth to water from 1.5 to 7 m bgl. In the limestones ground water is reported to occur in solution channels, joints, fractures and other types of large openings. The depth of wells in the limestones ranges from 3 to 14 m bgl and depth to water level from 1.5 to 13 m bgl. The depth of wells located in shales ranges from 5 to 10 m bgl. Very limited yields are obtained from wells located in shales. In Tiruvur area, ground water occurs in the weathered crystalline rocks and in associated pegmatites. Dug wells and dug-cum-bore wells are the ground water abstraction structures in the area.

In Kanumuru and Koduru areas, where weathered mantle is thick, wells dug down to 13 m bgl wlth 12 m diameter are expected to yield 250m^3/day. In the Nandigama and Kanchikacherla areas, wells located in biotite-gneiss, schist and phyllites vary in depth from 10.4 to 17.5 m bgl. In charnockites the weathered mantle is upto a maximum

depth of 25 m bgl. Wells in charnockites range in depth from 5 to 10 m bgl with depth to water from 3 to 6 m bgl. There are abundant bore wells in this fomation with water levels ranging from 10 to 18 m bgl and having yields of 1-3 lps. In the area west of Munneru River, in the gneissic granites, the ground water conditions are comparatively better than those in the east. In this area, the yield of the wells is controlled by the degree of weathering, thickness of the weathered zone and presence of fractures, joints etc. The dug wells in this granitic area range in depth from 4 to 12 m bgl and depth to water vary from 2 to 10 m bgl. Groundwater in this formation occurs mostly under water table conditions and rarely under semi-confined to confined conditions. In some of the dug wells, in order to improve the yield, bore of 100 mm diameter has been drilled from the bottom of the wells to depths of 5 to 15m. Water is lined from these dug-cum-bore wells by centrifugal pumps and is used for irrigation. These wells sustain 4 to 6 hours continuous pumping at an average discharge of l0m^3/hr.

Table 3.1. Salient features of Aquifer system in Krishna District (Parts)

Era	Archean Crystallines	
Prominent Lithology	Granite Gneiss/Charnockite (Basement)/Khondalite	
Aquifer types	Aquifer-1 (Weathered Zone)	Aquifer-2 (Fracture Zone)
Thickness range	1 - 35 m	up to 200m
Depth range of fractures	-	80% fracture encountered within 100m
Range of yield potential	<3	<1 to >10 lps
Transmissivity (m2/day)	More than 1 to 200 sqm/day	
Storativity	$4.84 *10^{-6}$ to $1.06*10^{-4}$	
Quality (Suitability of Irrigation)	Yes	Yes

3.3.2 Aquifer Disposition 3D and 2D

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 76 data points (both hydrogeological and geophysical down to 200 m) for preparation of 3-D map, panel diagram and hydrogeological sections. The lithological information was generated by using the RockWorks-16 software and generated 3-D map of study area (**Fig.3.12)** along with panel diagram (**Fig. 3.13a-b**) and hydrogeological sections.

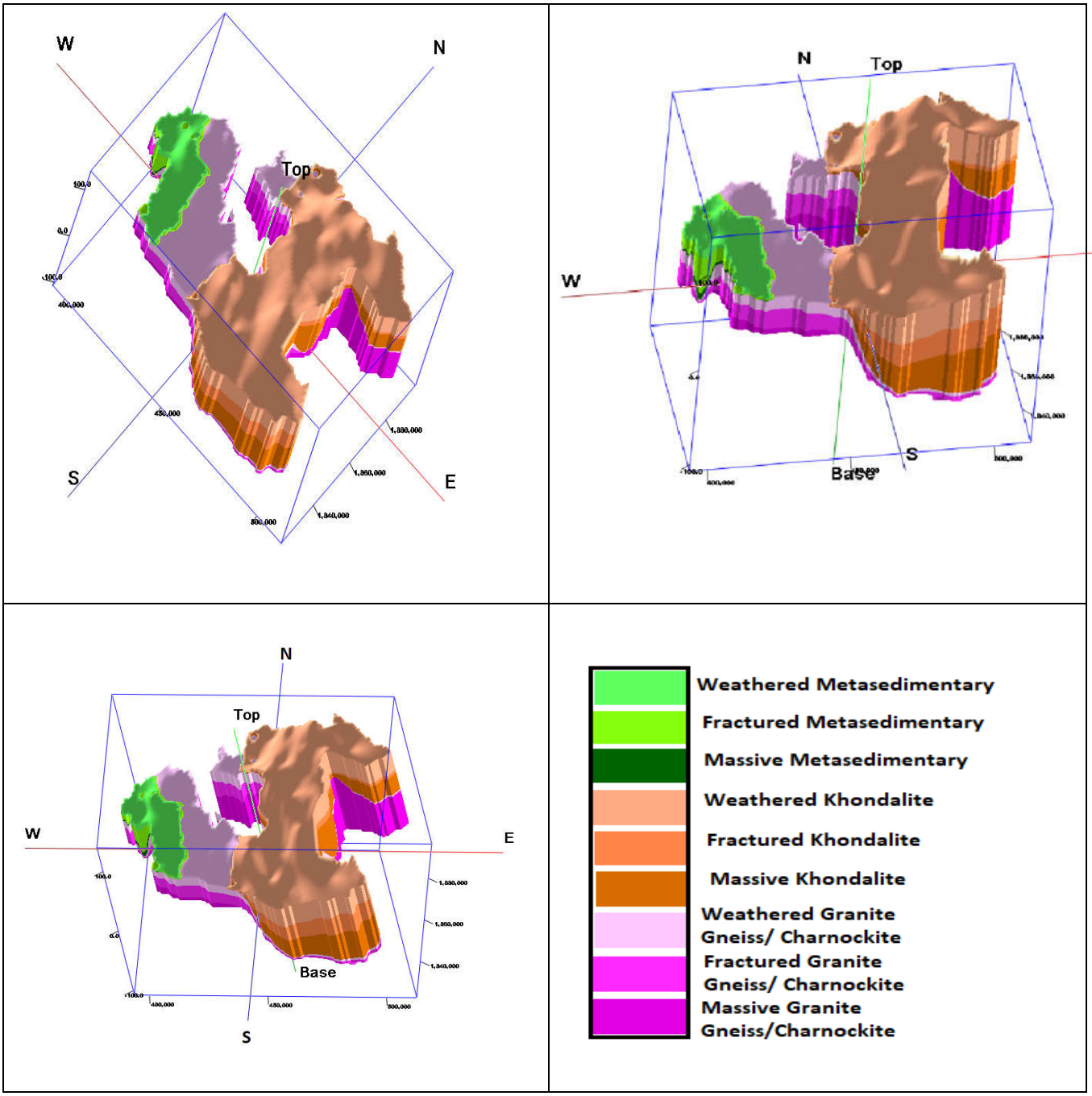


Fig.-3.12: 3-D Model for study area

Aquifer Disposition 2D

Two hydrogeological sections are prepared in SW-NE and SSW-NNE directions.

South West and North East Section: The section drawn along the SW-NE direction covering distance of 69 kms (**Fig.3.13a**). A thin stretch of metasedimentary formation extends upto 10 km into the Jaggayapeta mandal from NW boundary and the metasedimentary rocks tappers out as moved in east direction. The thickness of fractured granitic zone increases in the central part of the study area.

SSW and NNE Section: The section covers a distance of ~90 kms (**Fig.3.13b**). It depicts thick Khondalite zone overlying the Charnockite/Granite gneiss base in the north east direction and reduces in the central part.

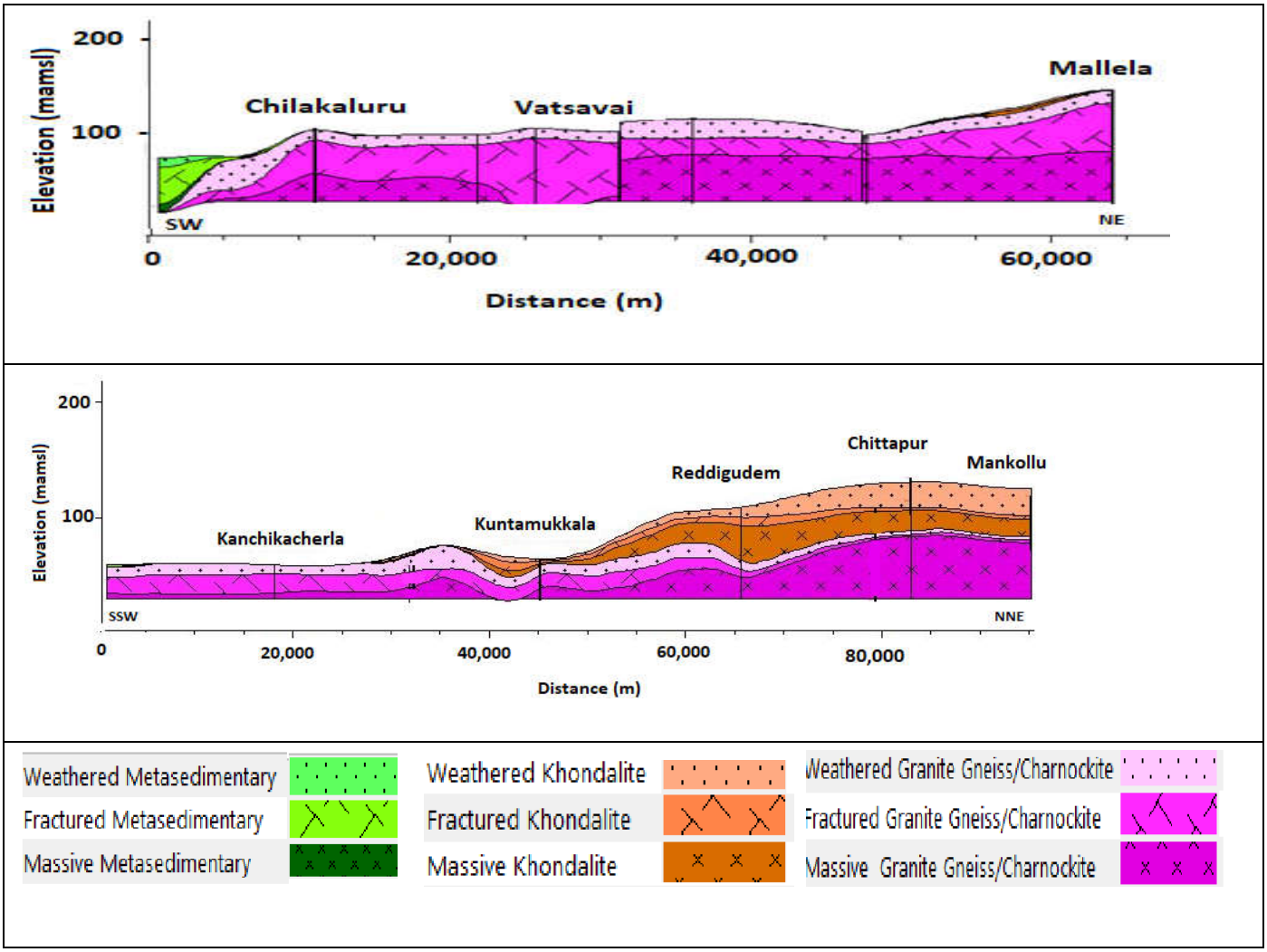


Fig.3.13 (a-b): Hydrogeological profile in different directions in Krishna District (Parts)

4. GROUND WATER RESOURCES (2020)

As per Ground Water Resources Assessment (2020), the net dynamic replenishable groundwater resources is 1238 MCM, gross ground water draft for all uses is 388 MCM, provision for drinking and industrial use for the year 2025 is 65 MCM and net annual ground water potential available for future use is 859 MCM. Stage of ground water development varies from 11% (Vijayawada Rural, Krishna) to 64% (Chintalapudi mandal, West Godavari). All Mandals are in the study area are categorized as Safe.

Table-4.1: Computed Dynamic ground water resources

Parameters	Total
As per GEC 2020	MCM
Dynamic (Net GWR Availability)	**1238**
• Monsoon recharge from rainfall	306
• Monsoon recharge from other sources	583
• Non-Monsoon recharge from rainfall	81
• Non-monsoon recharge from other sources	333
• Total Natural Discharges (Ham)	65
Gross GW Draft	**388**
• Irrigation	307
• Domestic and Industrial use	81
Provision for Drinking and Industrial use for the year 2025	65
Net GW availability for future use	859
Stage of GW development (%)	31%

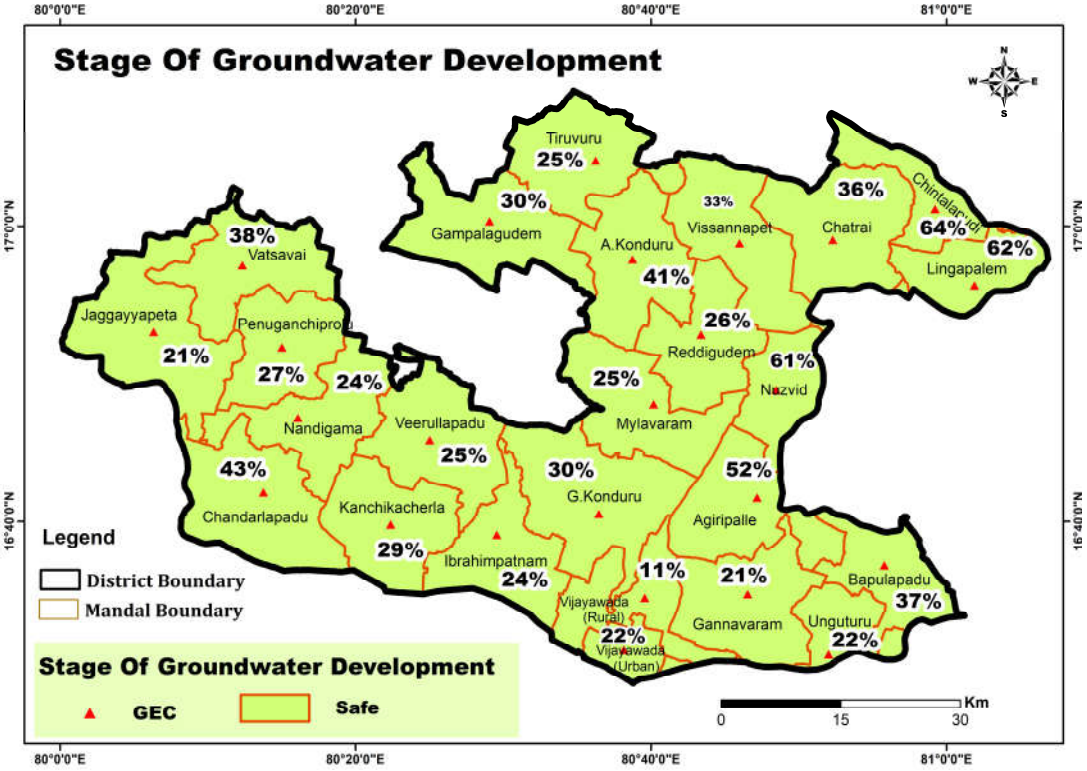


Fig.4.1 Mandal wise stage of ground water development

5. GROUND WATER RELATED ISSUES AND REASONS FOR ISSUES

The over all ground water scenario of the study area is good except a few localized issues.

5.1 Issues

Stage Of Groundwater Development:

The over all stage of ground water development in the study area is 31%, except Nuzvid, Agiripalle, Chintalapudi and Lingapalem mandals which have SOD >50%, where vulnerability of groundwater resource in future is expected.

Sustainability

Low yield (<1 lps) is found in many places as the study area is mainly comprises hard rocks such as Charnockites, Khondalites and granite gneiss as per ground water exploration data

Ground Water Quality: Higher concentration of Nitrate is observed in 28% of samples.

5.2 Reasons for Issues

Lack of primary pososity and variable thickness of weathering and discrete occurrence of fracture sytem in hard rock aquifers are the reasons behind low sustainability of wells. The unscientific sewage disposal of treated and untreated effluents in urban, rural areas, use of NPK fertilizers and nitrogen fixation by leguminous crops are the reasons for high nitrate concentration in ground water in the study area.

6. MANAGEMENT STRATEGIES

The ground water development in hard rock aquifer system leding to a steady fall in water levels, pose sustainability issues which may pose challenges to food and drinking water security in future. The occurrence of fractures in hard rock aquifers are very limited in extent, as the compression in the rock reduces the opening of fractures at depth and the majority of fractures occur with in 35 to 100 m depth. Though the general ground water scenario of the district is good, the uneven groundwater availability and its utilization indicates for requirement of integrated water resource management and sustainable practices for maintaining sustainable ground water scenario in the district.

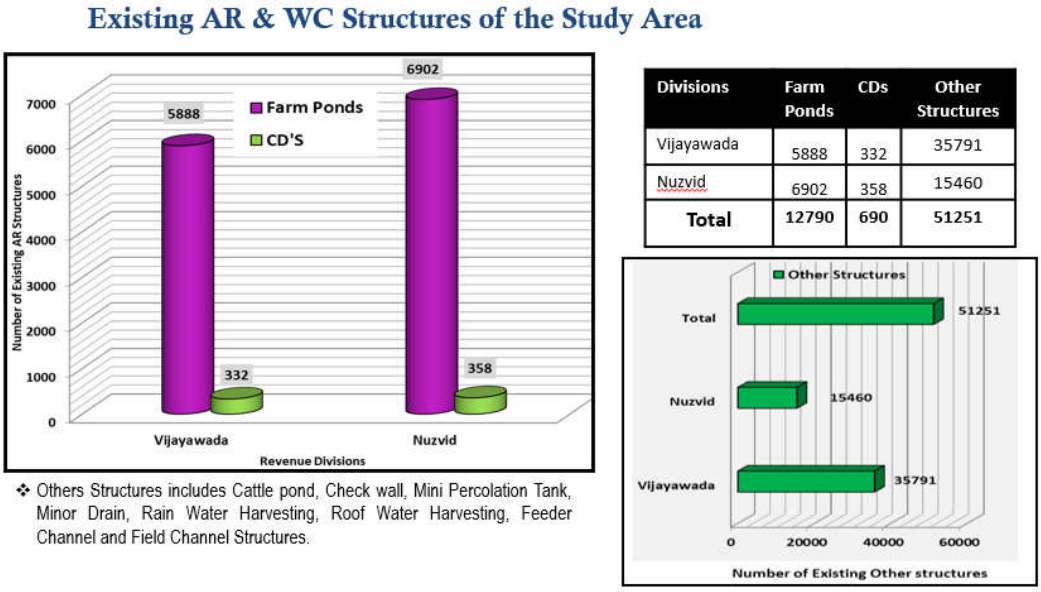
6.1 Management plan

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

6.1.1 Supply side management

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

The area suitable for ground water augmentation through artificial recharge (AR) has been demarcated based on the analysis of average post-monsoon depth to water level data of the observation wells for the period of 2012-2021 and the existing data on artificial recharge structures constructed under various schemes of Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGS) and Integrated Watershed Management Programs (IWMP) by Rural Development department. Government of Andhra Pradesh had already created a total 698 recharge structure (690 Check dams and 8 percolations tank) though MGNREGS and IWMP scheme source: APWRIMS) though MGNREGS and IWMP scheme **(Fig 6.1**).



Divisions	Farm Ponds	CDs	Other Structures
Vijayawada	5888	332	35791
Nuzvid	6902	358	15460
Total	**12790**	**690**	**51251**

❖ Others Structures includes Cattle pond, Check wall, Mini Percolation Tank, Minor Drain, Rain Water Harvesting, Roof Water Harvesting, Feeder Channel and Field Channel Structures.

Fig 6.1: Existing Artifical Recharge Structures in the study Area

Desilting and maintanence of existing CD's and PTs shall be taken up on priority basis in the entire study area. Further, it is recommended for construction of new artificial recharge structures in mandals where the SOD is >50% where vulnerability of groundwater resource in future is expected.

- While recommending the artificial recharge measures, the availability of sub-surface storage volume of aquifers is computed as the product of area, thickness of aquifer zone between 5 m. bgl and the average post-monsoon water level. The recharge potential/sub surface space of the aquifers is calculated by multiplying the sub surface storage volume with 2% specific yield.

- The source water availability is estimated from the rain fall and run off correlations. The runoff was calculated by taking into account of normal monsoon rainfall of the mandal and corresponding runoff yield from Strangers Table for average catchment type. Out of the total run off available in the mandal, 20 % run off yield is considered as un-committed yield and for recommending artificial recharge structures in intermittent areas.
- The storage required for existing AR structures by State Govt. departments under different IWMP and MNREGS schemes is deducted to find the available surplus run off for recommending the additional feasible AR structures.The recharge and runoff available in the district is given in **Table 6.1** and **Fig 6.2**

Table 6.1: Recharge and Runofff available in the Entire Study Area

Area feasible for recharge (Sq.km)	4132
Unsaturated Volume (MCM)	5268
Recharge Potential (MCM)	105
Runoff available (MCM)	577
Surplus runoff available for recharge (MCM)(20% of runoff)	115

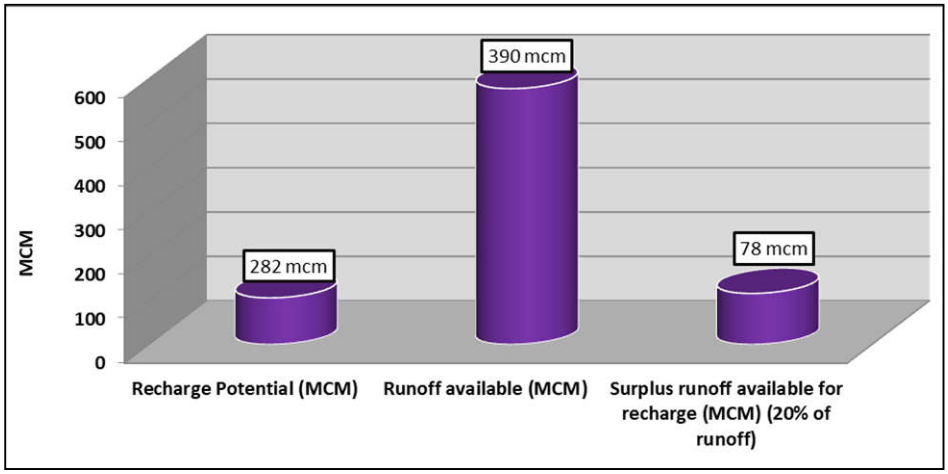


Fig 6.2: Recharge and Runofff

6.1.1.1 Artificial Recharge (AR) Structures in areas >50% SOD

The AR structures are suggested only in Nuzvid, Agiripalle, Chintalapudi and Lingapalem Mandals in the Study area. The surplus run off 9.5 MCM calculated as 20% of the total run off available in the study area. The study area details in this regard are provided in the **Table 6.2**.

Table 6.2: Details of Management Plan of 4 Mandals SOD>50%	
Average of Post Water Level (m bgl)	7.2
Runoff Village wise (MCM)	47
Uncommitted Runoff (20%)	9.5
Existing Check Dams	62
Existing Percolation Tanks	0

Runoff required for existing ARS(MCM)	2.17
Runoff considered for New ARS (MCM)(50% Of left Runoff)	3
Number of CDs Feasible	63
Number of PT feasible	53

116 artificial recharge structures (63 CD's and 53 mini PT'in 56 villages) with a total cost of 13 crores can be taken up. Considering CDS with recharge shafts with 5 fillings with a unit cost of Rs 10 lakhs each and mini-PT's with 2 fillings with a unit cost of Rs 15 lakhs each (**Table 6.3**)

- After effective utilization of this yield, there will be 3 MCM of ground water recharge.
- Roof top rainwater harvesting structures should be made mandatory to all Government buildings (new and existing).

For sustainable development and management of the groundwater resources the above recommendations are made and summarised in **Annexure-1**.

Table 6.3 Proposed artificial recharge structures in 4 Mandals

Percolation Tanks (@ Rs.15 lakh Capacity of the tank: 0.007 MCM, Av. Gross storage in a year =0.007 MCM*2 fillings = 0.014 MCM Volume of Water expected to be recharged (in MCM) Estimated Expenditure (in Crores)	53 1 7
Check Dams (@ Rs.10 lakh, Av. Gross storage in a year =0.007 MCM* 5 fillings = 0.035 MCM Volume of Water expected to be recharged (in MCM) Estimated Expenditure (in Crores)	63 2 6
Total volume of water expected to be recharged (in MCM)	3
Total Estimated Expenditure for Artificial Recharge (Rs. in Cr.)	13

6.1.1.2 Roof top and open space rain water harvesting for artificial Recharge in Vijayawada Mandal.

Government of Andhra Pradesh is supplying surface water from Krishna River through Prakasam Barrage to Vijayawada city, which will reduce the dependency on Ground water. Moreover, the city is having a stage of groundwater of 21% only. Therefore, for maintaining this ground water scenario as the population density is high is to construct, rooftop Rain water Harvesting structure for building with above 200 sq.m as per APWALTA.

6.1.1.3 Other supply side measures:

Existing ARS like percolation tanks and check dams and dried dug wells can be de-silted involving people's participation through the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) (NREGA 2005). This will also help in sustainable management of groundwater resources.

6.1.1.4 Water Conservation Measures (WCM) (Farm Ponds)

The farm ponds are the ideal water conservation structures, which are constructed in the low-lying areas of the farm. The size of farm ponds is 10 x 10 x 3 m. In the district total 12790 farm ponds exist in 435 villages and these existing farm ponds can be desilted and maintained so that it will greatly help in ground water augmentation.

6.1.2 Demand Side Measures:

6.1.2.1. Micro-irrigation:

Under Andhra Pradesh Micro Irrigation Project irrigated through sprinklers and drip irrigation method. 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.

Proposed Work

- 30000 ha of additional land that can be brought under micro-irrigation (@100 ha/village in 300 villages). With this 54 MCM of ground water can be conserved over the traditional irrigation practices (considering 0.006 MCM/ha for ID crops against 0.008 MCM/ha).

6.1.3 Other measures

- To avoid the interference of cone of depression between the productive wells, intermittent pumping of bore wells is recommended.
- Power supply should be regulated by giving power in 4-hour spells two times a day so that pumping of the bore well is carried out in phased manner to allow recuperations of the aquifer and increase sustainability of the bore wells.
- As a mandatory measure, every groundwater user should recharge rainwater through artificial recharge structures in proportionate to the extraction.
- A participatory groundwater management (PGWM) approach in sharing of groundwater and monitoring resources on a constant basis along with effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002) are the other measures suggested. Subsidy/incentives on cost involved in sharing of groundwater may be given to the farmers involved.
- In urban and rural areas, the sewerage line should be constructed to arrest leaching of nitrate.

6.2 Expected Results and Out come

With the above interventions, the likely benefit would be the net saving of 57 MCM of ground water either through water conservation measures like adoption of drip and artificial recharge to ground water.

Acknowledgment

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Annexure I: Proposed Supply Side Interventions

District	Mandal	Village	Number of CDs feasible	Number of PTs feasible
Krishna	Agiripalle	Adivinekkalam	3	3
Krishna	Agiripalle	Agiripalle	3	3
Krishna	Agiripalle	Boddanapalle	5	4
Krishna	Agiripalle	Chopparametla	1	1
Krishna	Agiripalle	Edara	5	4
Krishna	Agiripalle	Garikapativari Khandrika	0	0
Krishna	Agiripalle	Kalaturu	2	1
Krishna	Agiripalle	Kanasanapalle	0	0
Krishna	Agiripalle	Krishnavaram	2	1
Krishna	Agiripalle	Malleswaram	1	1
Krishna	Agiripalle	Malliboinapalle	1	1
Krishna	Agiripalle	Narasingapalem	2	2
Krishna	Agiripalle	Nugondapalle	1	1
Krishna	Agiripalle	Pinnamareddipalle	1	1
Krishna	Agiripalle	Pothavarappadu	2	2
Krishna	Agiripalle	Sagguru	1	1
Krishna	Agiripalle	Suravaram	6	5
Krishna	Agiripalle	Thotapalle	3	2
Krishna	Agiripalle	Vadlamanu	3	3
West Godavari	Chintalapudi	Amudalachalaka	0	0
West Godavari	Chintalapudi	Chintalapudi	2	2
West Godavari	Chintalapudi	Endapalle	1	1
West Godavari	Chintalapudi	Errampalle	0	0
West Godavari	Chintalapudi	Kanupade	0	0
West Godavari	Chintalapudi	Mallayagudem	0	0
West Godavari	Chintalapudi	Pothunuru	0	0
West Godavari	Chintalapudi	Talarlapalle	0	0
West Godavari	Chintalapudi	Thimmareddipalle	0	0
West Godavari	Chintalapudi	Venkammapalem	0	0
West Godavari	Chintalapudi	Venkatarayapuram	0	0
West Godavari	Lingapalem	Chandrannapalem	0	0
West Godavari	Lingapalem	Ganapavarigudem	0	0
West Godavari	Lingapalem	Juvvachalakarayudupalem	1	1
West Godavari	Lingapalem	Kalyanampadu	0	0
West Godavari	Lingapalem	Kothapalle	0	0
West Godavari	Lingapalem	Kothulagokavaram	0	0
West Godavari	Lingapalem	Lingapalem	0	0
West Godavari	Lingapalem	Malleswaram	0	0
West Godavari	Lingapalem	Mattamgudem	1	0
West Godavari	Lingapalem	Mulagalampadu	0	0

District	Mandal	Village	Number of CDs feasible	Number of PTs feasible
West Godavari	Lingapalem	Patchanagaram	1	1
West Godavari	Lingapalem	Pochavaram	0	0
West Godavari	Lingapalem	Puppalavarigudem	0	0
West Godavari	Lingapalem	Rangapuram	1	0
West Godavari	Lingapalem	Singagudem	1	1
West Godavari	Lingapalem	Yedavalli	0	0
Krishna	Nuzvid	Annavaram	1	1
Krishna	Nuzvid	Bathulavarigudem	0	0
Krishna	Nuzvid	Digavalli	4	3
Krishna	Nuzvid	Enamadala	0	0
Krishna	Nuzvid	Hanumanthunigudem	1	1
Krishna	Nuzvid	Narsupet	2	2
Krishna	Nuzvid	Nuzvid (M)	0	0
Krishna	Nuzvid	NUZVID (Rural)	3	3
Krishna	Nuzvid	Sunkollu	1	0
Krishna	Nuzvid	Venkatayapalem	1	1