Government of India
Ministry of Jal Shakti
Department of Water Resources, River Development and Ganga Rejuvenation
Central Ground Water Board

AQUIFER MAPPING FOR SUSTAINALE MANAGEMENTOF GROUND WATER RESOURCES OF PALNADU DISTRICT, ANDHRA PRADESH STATE

Sourthern Region,
Hyderabad
May 2024

GOVERNMENT OF INDIA

MINISTRY OF JAL SHAKTI

DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

REPORT ON AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES OF PALNADU DISTRICT, ANDHRA PRADESH STATE (AAP-2023-24)

CENTRAL GROUND WATER BOARD

SOUTHERN REGION, HYDERABAD

MAY, 2024

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(AAP-2023 - 24)

CONTRIBUTORS' PAGE

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REPORT ON AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES OF PALNADU DISTRICT, ANDHRA PRADESH STATE (AAP-2023-24)

At a Glance

S.No.	Item		Particulars
1	District	:	Palnadu
2	Revenue Divisions/ Mandals	:	28
3	Villages	:	366
4	Municipalities	:	8
5	Mappable area	:	7281 km^2
6	Population (2011 Census)	:	20.42 lakhs
7	Density of population (2011 Census)	:	280 persons/km^2
8	Locations	:	North latitude 16°03´-16°37´ East longitude 79°22´-80°21’
9	Rainfall (Normal)	:	The annual normal rainfall of the area varies from 282mm (Machevaram mandal) to 826 mm (Chilakuripet mandal) with normal average of 775.37 mm.
10	Geomorphology	:	Pediplain (58% of the area). Structural hills (18 % of the area), Pediment (11% of the area), Structural Valley (5% of the area), and fluvial landforms (4% of the area).
11	Major River	:	Krishna, Gundlakamma and Vogeru vagu
12	Land Utilization	:	Agricultural land occupies nearly 44% of the area, forest occupies nearly 2 0 % of the area, 12% of the area is put to non agricultural uses and 12% of the area is fallow land. Remaining area is occupied by plantation, builtup, water bodies and barren land etc.
12	Soils	:	Based on the soil texture, the area is mainly occupied by Clayey skeletal mixed and clayey mixed (32%), Fine soil mixed (27%), fine montmorillonitic (23%), loamy skeletal (13%) and fine loamy mixed (4%).
13	Cropping Pattern (2019-20) (Ha)	:	The total gross cropped area during the year 2019-20 is 3,47,114 ha and net sown area is 3,15,650 ha. The gross area cropped during Khariff season is 2,98,740 ha and the major crops grown during khariff season is Paddy (18%), cotton (48%), chillies (18%) and total pulses (5%) and 11% remaining other crops. The gross area cropped during Rabi season is 3,47,114 ha and the major crops grown during the period are Paddy (40%), Pulses (33%), Maize (11%),Tobacco (3%) and remaining 13% by other crops.

14	Irrigation	:	The Gross area irrigated is 1,98,118 ha and the area irrigated more than once is 21,047 ha. In which, 69% (1,36,572 ha) of the irrigation is through surface irrigation and 319% (61,510 ha) of the area is irrigated through ground water irrigation.
16	Prevailing Water Conservation/ Recharge Practices	:	183 percolation tanks, 5906 Check dams and 11959 Farm ponds. Also 5 9 8 6 6 other water conservation structures
17	Geology	:	The Archean Granitic Gneiss and granites covers 30% of the area and charnockites covers 8%. The Precambrian metasedimentary formation of Kurnool and Cuddapah system covers 58% of the area.
18	**Hydrogeological data points**		
	Exploratory drilling data points	:	CGWB Exploration: 134
	Water Level data points	:	8 8 wells (CGWB:67, SGWD:21)
	Hydrochemical Points	:	Total 7 6 (CGWB: 55, SGWD: 21)
	Geophysical	:	VES: 49 and TEM: 21
	DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING		
20	**Ground water Level Scenario**		
	Water Levels Depth to water level (m bgl)	:	• Depth to water level varies from <1 m to 17 m bgl with an average of 4.73 mbgl during pre monsoon.In Majority of the areas in pre monsoon water level is 2 -5 m (62% of the wells), followed by 5 – 10 m bgl in 19% of the wells , 10 to 20 m bgl in 4% of the wells and > 20 m bgl reflected by about 9% of the wells monitored. • During post-monsoon season water level , <1 m - 24 m bgl with an average of 4.24 m bgl. and majority of the water level are in range of <5 m by 73% of the wells, followed by 5 - 1 0 m bgl by 23% of the wells. Deeper water levels in the range of > 20 m bgl represents about 4% of the monitored wells
	Water Level Fluctuations (May vs.November)	:	Most of the wells in the state records water level rise. The seasonal water level fluctuations varyfrom <1 to 6.3 m.
	Long term water leveltrends (2013-22)	:	• During pre-monsoon season 5 9 % o f w e l l s show a falling trend. • During post-monsoon season only 31% of monitoring wells show a falling trend.
21	**Ground Water Quality**		
	Electrical Conductivity (µ Siemens/cm)	:	• Pre: 680 - 5350 µ Siemens/cm (avg: 2145) Majority of the area EC is within 3000 µ Siemens/cm.
	Nitrate mg/l	:	• Pre: 1-560 mg/L and found 56% of samples are unfit for human consumption
	Fluoride mg/l	:	• Pre: 0 – 2.9 mg/L, 18% of sample are beyondpermissible limit of 1.5 mg/L.

22	**Aquifer Mapping**					
	Era		Pre-Cambrian		Archean Crystallines	
	Prominent Lithology		Meta sedimentary Formation		Granite Gneiss/ Charnockite (Basement)	
	Aquifer types		Aquifer-1 (Weathered Zone)	Aquifer-2 (Fracture Zone)	Aquifer-1 (Weathered Zone)	Aquifer-2 (Fracture Zone)
	Thickness range		1 - 35 m	up to 200m	1 - 35 m	up to 200m
	Depth of range of occurrence of fractures		-	42% fracture encountered within 100 m	-	42% fracture encountered within 100 m
	Range of yield potential		<1 to 6	Avg: 5 lps	<1 to 6	Avg: 5 lps
23	**Ground water Resources (2023) MCM**					
	Net Dynamic groundwater availability	:	953 MCM			
	Gross GW Draft	:	286 MCM			
	Provision for Domestic &Industrial (2025)	:	45 MCM			
	Average Stage of Ground water development (%)		30%			
	Net GW Availability for future irrigation	:	738 MCM			
	Categorization of mandals	:	Stage of ground water development varies from 9% (Pedakurapadu mandal) to 138% (Veldurthi mandal). Out of 28 mandals in the distrct, 2 mandals 1 mandal (Veldurthi mandal) is over exploited, Bollapalle mandal is Critical and remaining 26 mandals are safe.			
24	**Major Ground Water Issues Identified**	:	• The Over all stage of ground water development in the study area is 34%, except 2 mandals, Viz., , Bollapalle and Veldurthy mandals. The parts of district are known for its rich lime stone deposits and the industrial as well as mine dewatering may be the one of the reasons for high stage of ground water development. • Low yield (<1 lps) occurs in most of the area of both in eastern as well as western parts of the study area. • High nitrate (> 45 mg/L) due to anthropogenic activities is observed in 56% during pre-monsoon			
25	**ManagementStrategies**	:	Supply side measures To be taken up (Artificial Recharge Structures in the Study Area)			

			246 artificial recharge structures (152 CD's and 94 mini PT'in 85 villages)Water Conservation measures (WCM) Farm Ponds The size of form ponds can be 10 x 10 x 3 m. Total 1352 farm ponds already exist in study area should be desilted and maintained so that it will greatly helpin ground water augmentation. Demand side measure Micro irrigation: 30000 ha of land 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 with traditional irrigation methods). Other Recommendations • To avoid the interference of cone of depression between the productive wells, intermittent pumping of bore wells is recommended through regulatory mechanism. • The western part of the study area is known for its rich lime stone deposits. As mandated by Central Ground Water Authority, the mine dewatered seepage can effectively be utilized by filling the tanks and supply to agriculture fields. • As a mandatory measure, every groundwater user should recharge rainwater through artificial recharge structures in proportionate to the extraction • Declaration of Minimum Support Price in advance (before start of season) and improved facilities at procurement centres. • Capacity building in power supply regulation (4 hour each in morning and evening) will increase the sustainability of wells • A participatory groundwater management (PGWM) approach in sharing of groundwater and monitoring resources on a constant basis along with effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002). • Laser levelling of irrigated land. Subsidy/incentives on cost involved in sharing of groundwater may be given to the concerned farmers.
26	**Expected Results andOut come**	:	With the above interventions, the likely benefit would be the net saving of 63 MCM of ground water can besaved 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**
$_M3$	**:**	**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**

I. EXECUTIVE SUMMARY

The Palnadu district has a geographical area of 7,281 sq.kms, of which 2766 sq.kms is underlain by hard rock aquifer system, lies between north latitude 16°03′-16°37′and east longitude 79°22′- 80°21'. Administratively, the study area is governed by 28 mandals and 366 villages having a population of 20.42 lakhs (2011 census, population density of 280).

The district is underlain by various geological formation from Archean to Recent. The Archean granitic gneiss and granites covers 30% of the area and charnockites covers 8% overlain by precambrian metasedimentary formation of Kurnool and Cuddapah system covering 58% of the area. Pediplains are the major landforms followed by structural hills and pediment. The major rivers draining the study area are Krishna, Gundlakamma and Vogeru vagu. Agricultural land occupies nearly 44% of the area, 20% of the area is forest 12% 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 3,47,114 ha and net sown area is 3,15,650 ha. The gross area irrigated is 1,98,118 ha. In which, 69% (61,510 ha) of the irrigation is through surface irrigation and 31% (61,510 ha) of the area is irrigated through ground water irrigation.

Water level is monitored through 88 wells during pre and post-monsoon seasons. During pre-monsoon, depth to water level varies from <1 m to 17 m bgl with an average of 4.73 mbgl a n d during post-monsoon and <1 m - 24 m bgl with an average of 4.24 m bgl. In majority of the areas in pre monsoon water level is 2-5 m (62% of the wells), followed by 5-10 m bgl in 19% of the area, 10 to 20 m bgl in 4% of the wells and > 20 m bgl is reflected in about 9% of the monitoring wells but while during post monsoon season majority of the water level are in range of <5 m covering 73% of the wells followed by 5 to 10 m bgl in 23% of the wells and deeper water level of > 20 mbgl is represented by about 4%of the monitoring wells. Most of the wells in the state records water level rise. The seasonal water level fluctuations vary from <1 to 6.3 m.

Trend analysis for the last 10 years (2013-2022) is studied from hydrograph stations of CGWB and SGWD. It is observed that during pre- monsoon season 59% of wells shows falling trend while during post- monsoon season 31% of wells

show falling trend.

Total 60 ground water samples (CGWB:27 and SGWD:33) were analysed for assessing the suitability of ground water for drinking purposes. In majority of the sample EC is in the range of < 3000 µ Siemens/cm during pre-monsoon season. Nitrate concentration in 56% of samplesis beyond permissible limits of 45 mg/L.F luoride concentration varies from 0 – 2.9 with 18% of samples are beyond the permissible limits of BIS and rest is within the permissible limit.

On the basis of occurrence and movement of ground water, hard rock units of the district area are classified into two categories; Archean crystalline and Metasedimentary formations. Weathered and fractured Archean crystalline rocks (Charnockites and Granite Gneisses) form the Archean aquifer system. Metasedimentary aquifer system overlies Archean crystalline rocks aquifer system. Aquifers are conceptualized into two viz., weathered zone (~30 m) and fractured zone (~200: 30 -192 m). 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. Ground water yield varies from <1 to 6 lps and <1 to 9 lps respectively in the weathered portion of weathered and metasedimentary formation. Transmissivity varies from 1 to >100 sq.m/day. The depth of fracturing varies from 30 m to 192 m.

As per 2020 GEC report, the net dynamic replenishable groundwater availability is 953 MCM, gross ground water extraction for all uses 286 MCM, provision for drinking and industrial use for the year 2025 is 45 MCM and net annual ground water potential available for future irrigation needs is 278 MCM. Stage of ground water development varies from 9% (Pedakurapadu mandal) to 138% (Veldurthi mandal). Out of 28 mandals in the district, 2 mandals - Veldurthi is over - exploited and Bollapalle mandals is categorized as critical while the remaining 2 6 mandals are safe.

Major issues identified are critical and over-exploited mandals such, Bollapalle and Veldurthy are located in meta sedimentary formations comprising of Lime stones, Quartzites and Shales where the industrial as well as mine dewatering may be the one of the reasons for high stage of ground water development and in ground water quality, higher concentration of Nitrate is observed in 56% of samples.

NUMBER OF DATA POINTS USED FOR PREPARATION OF VARIOUS MAPS/FIGURES

PALNADU DISTRICT HARD ROCKS

S. No.	Data	Aquifer	Total data Points	Source
1	Panel Diagram	Combine	185	CGWB, GW & WAD
2	Hydrogeological Sections	2nos	185	CGWB, GW & WAD
4	Depth of Weathering	1no	138	CGWB ,GW & WAD
5	Depth of Fractures	1no	110	CGWB, GW & WAD
6	GW Yield	Combine	119	CGWB , GW & WAD
7	Transmissivity	Combine	80	CGWB , GW & WAD
8	Depth to Water Level Maps	Combine	137	CGWB , GW & WAD
9	VES	Combine	55	CGWB
10	TEM	Combine	36	CGWB
11	Water Level Trend (Long Term)	Combine	137	CGWB , GW & WAD
12	Water Quality	Combine	60	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 ground water in aquifers. In the recent past, there has been a paradigm shift from "**ground water development**" to "**ground water 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 ground water in India, aquifer mapping in different hydrogeological settings at the appropriate scale is devised and implemented, to enable robust ground water management plans. This will help in achieving drinking water security, improved irrigation facility, and sustainability in water resources development in large parts of rural and many parts of urban India. The aquifer mapping program is important for planning suitable adaptation strategies to meet climate change also. Thus, the crux of National Aquifer Mapping (NAQUIM) is not merely mapping, but reaching the goal-that of ground water management through recommendation of appropriate management strategies.

The Southern Peninsular Shield of India comprises mostly of crystalline rocks and consolidated sedimentary rocks. The occurrence and movement of ground water in these formations are restricted to weathered residuum and interconnected fractures at deeper levels and have limited ground water 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, ground water quality also represents a major challenge, which is threatened by both geogenic and anthropogenic pollution. In some places, the aquifers have high level of geogeniccontaminants, such as fluoride, rendering them unsuitable for drinking purpose. High utilization of fertilizers for agricultural productions and improper development of sewage system in rural/urban areas lead to point source pollution viz., nitrate and chloride.

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

1.2 Scope of the study: The main scope of the study is summarized below.

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

2. Periodic long-term monitoring of ground water regime (for water levels and water quality) for creation of time series database and ground water resource estimation.
3. Quantification of ground water 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 ground water development and management through information, education, and communication (IEC) activities, information dissemination, awareness, and training.
6. Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable ground water management.

1.3 Area Details:

The Palnadu district has a geographical area of 7,281 sq.kms, lies between north latitude 16°03´-16°37´and east longitude 79°22´- 80°21' (**Fig.1.1**), which is taken up in the NAQUIM in the AAP 2021-22. The district has been carved out from erstwhile Guntur district. The district is bounded on the North by Telangana State and Krishna district, on the West by Mahabubnagar district, on the Southwest by Prakasam district, Southeast by Bapatla and east by Guntur districts. Administratively, the district is governed by three revenue divisions – Narasaraopet, Satenapalli and Gurazala covering 28 mandals and 366 villages having a population of 20.42 lakhs (2011 census, population densityof 280).

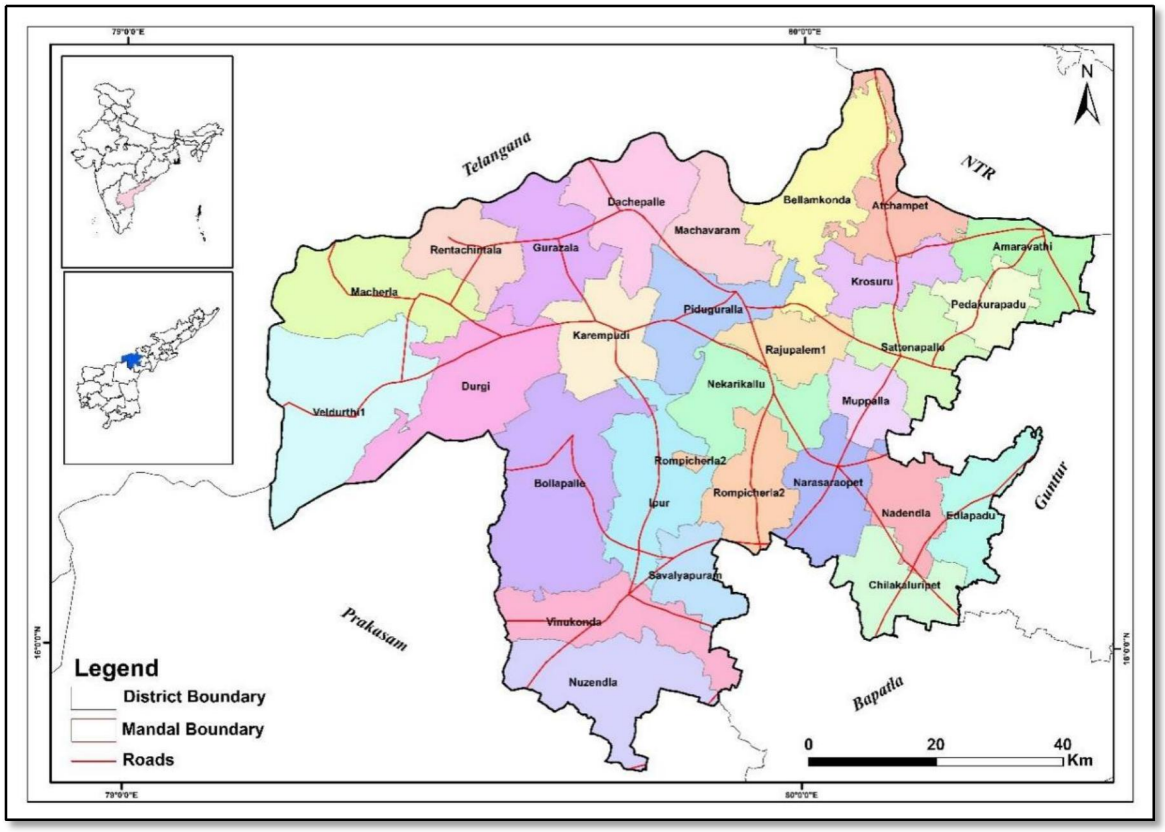


Fig.1.1: Administrative map of Palnadu District

1.4 Climate and Rainfall:

The district experiences tropical climate. Southwest monsoon enters into the district in June and lasts until the end of September and Northeast monsoon commences from October and extends upto December along with occasional cyclonic storms. Summer starts in the month of 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.

The annual normal rainfall of the area varies from 282 mm (Machavaram mandal) to 826 mm (Chilakaluripet mandal) with normal of 775.3 mm as per the data collected from IMD. Southwest monsoon normal rainfall (Avg: 486 mm) varies from 378 mm in Nuzendla to 662 mm in Amaravati and during Northeast monsoon normal rainfall varies from 149 mm in Dachepalle to 283 mm in Vinukonda by (Avg:198 mm) and rest during winter period. Isohyetal map prepared using annual normal rainfall of mandals in the district collected from DES, Andhra Pradesh is shown in **Fig.1.2**.

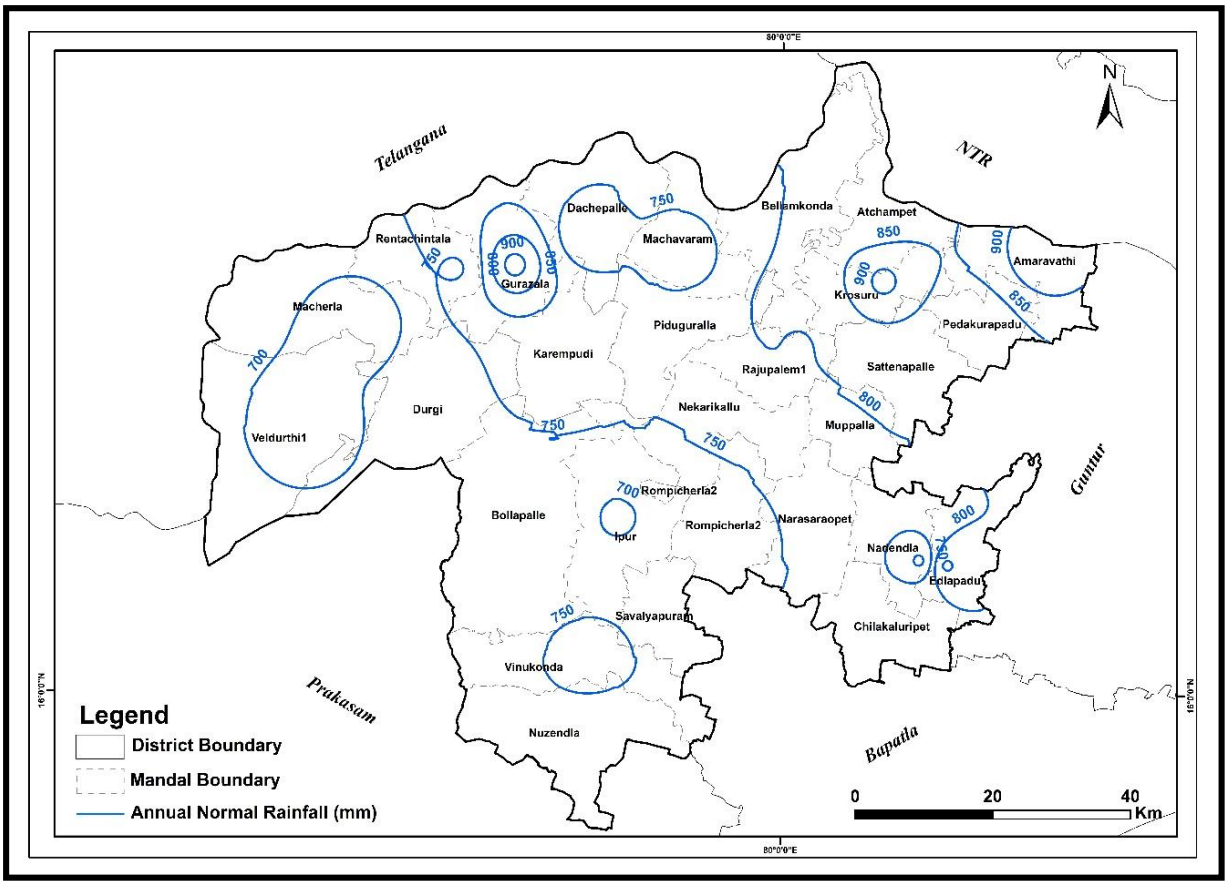


Fig.1.2: Isohyets of Palnadu District

1.5 Geomorphological Set up:

The district predominantly consists of pediplain (58% of the area), structural landforms (18 % of the area), pediment (11% of the area), structural valley (5% of the area), and fluvial landforms (7 % of the area), & remaining 5% of the area constitute other landforms. (**Fig. 1.3**). The ground water prospects are promising along valleys and foothills in the weathered and fractured zone.

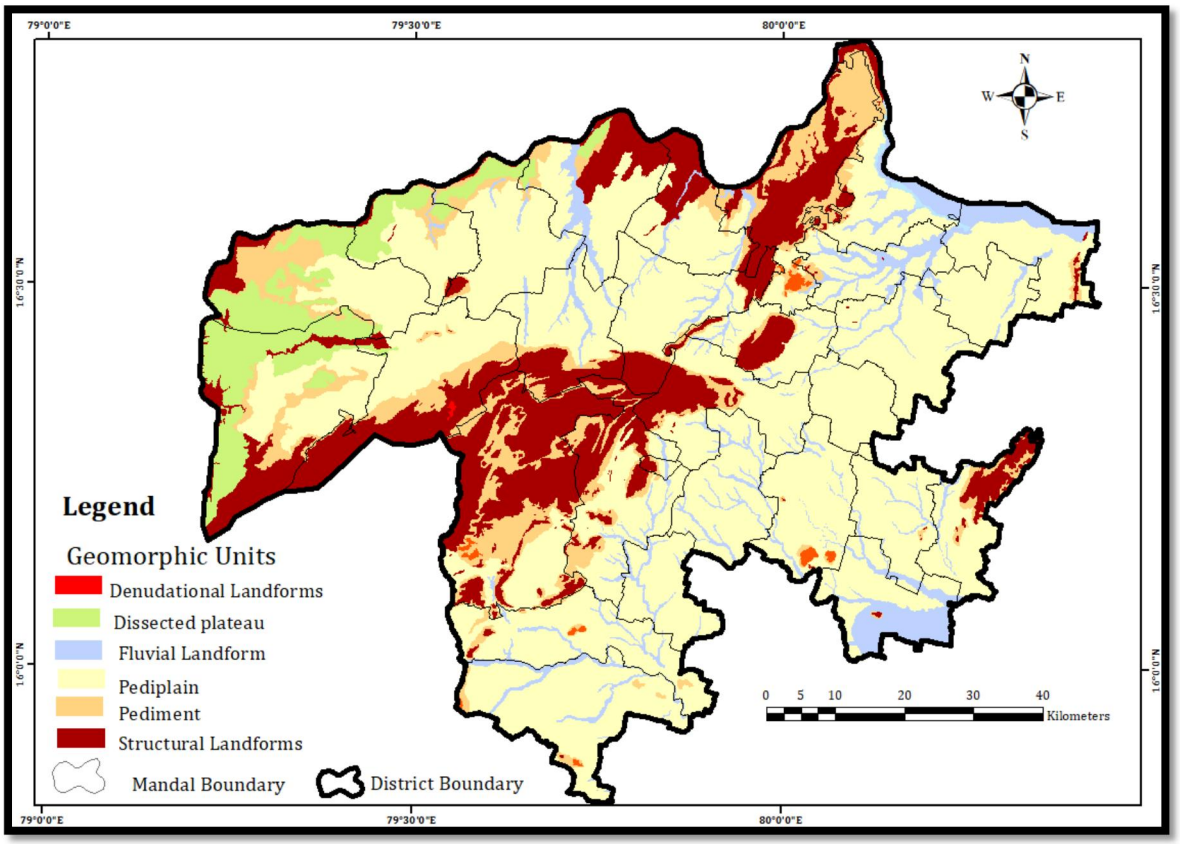


Fig 1.3: Geomorphologic units of Palnadu District

The shallow and moderately buried pediments constitutes the pediment unit in the area. They have gradational contact with pediplain and the thickness of the weathered residuum varies up to 30 m.The material comprises soil, gravel, clay, sand and silt. This unit is developed on crystalline rocks and metasedimentary formations (Koikuntla limestones, Paniam quartzites, Narji Limestones of Kurnool Group and Cumbum shales and phyllites of Cuddapah Super Group). The pediment area accelerates surface runoff with moderate to low infiltration along the jointed and weathered zone. The buried pediplains are suitable for construction of good yielding dug wells, dug cum bore well and shallow to deep bore wells.

1.6 Drainage

The major rivers draining the district are Krishna, Gundlakamma and Vogeru vagu. Other minor streams and rivulets flow into Gundlakamma and Krishna River. (**Fig.1.4**). The Krishna River forms the northern boundary of the district and flows to south between Palnadu and NTR district. Vogeru vagu flows from westto east. The general drainage pattern is sub parallel to sub-dendritic. The sub-parallel drainage in the area appears to be controlled by fractures and structures possibly of tectonic origin and the dendritic pattern in largely controlled by erosional nature of terrain.

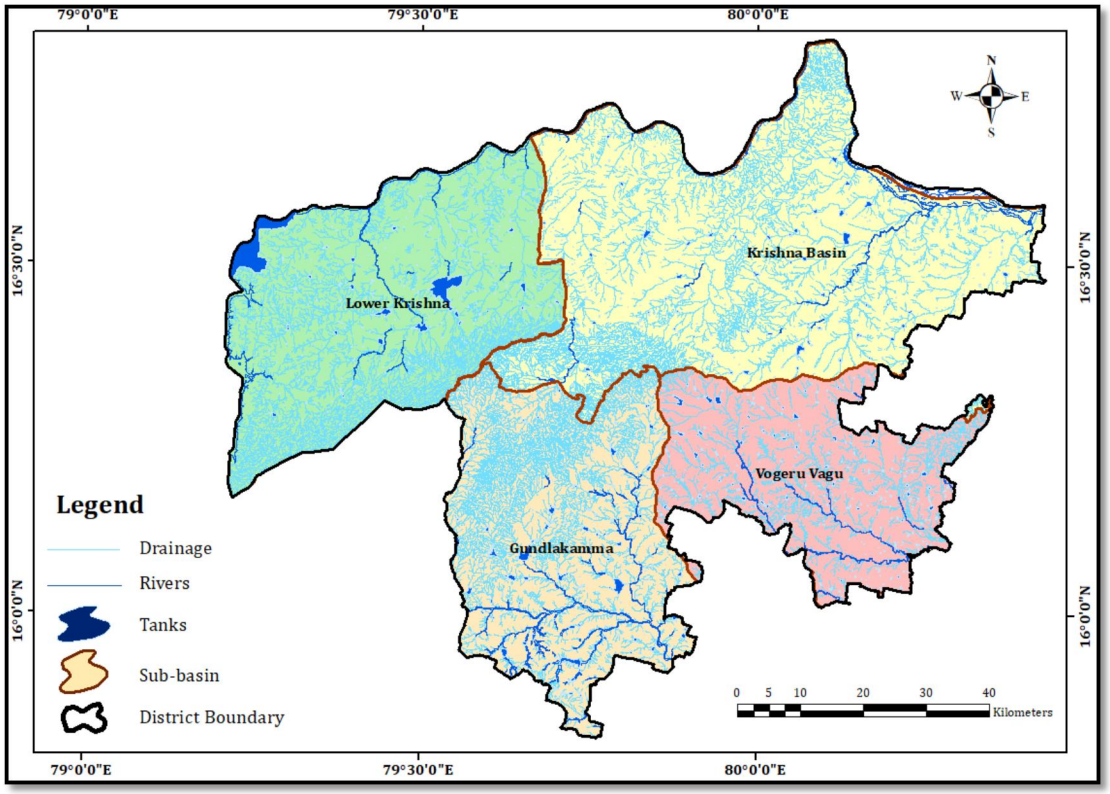


Fig 1.4: Drainage of Palnadu district

1.7 Soils:

Based on the soil texture, the area is mainly occupied by Clayey skeletal mixed and clayey mixed (32%), fine soil mixed (27%), fine montmorillonitic (23%), loamy skeletal (13%) and fine loamy mixed (4%) (**Fig.1.5**). Fine loamy mixed soils are seen in Vinukonda, Savalyapalem, Ipur mandals, Achampeta and Krosur mandals. Black soils are found in Narasaraopeta areas. Red loamy and red gravelly soils are seen mostly in the upper reaches of hills, hillocks and also along hill slopes.

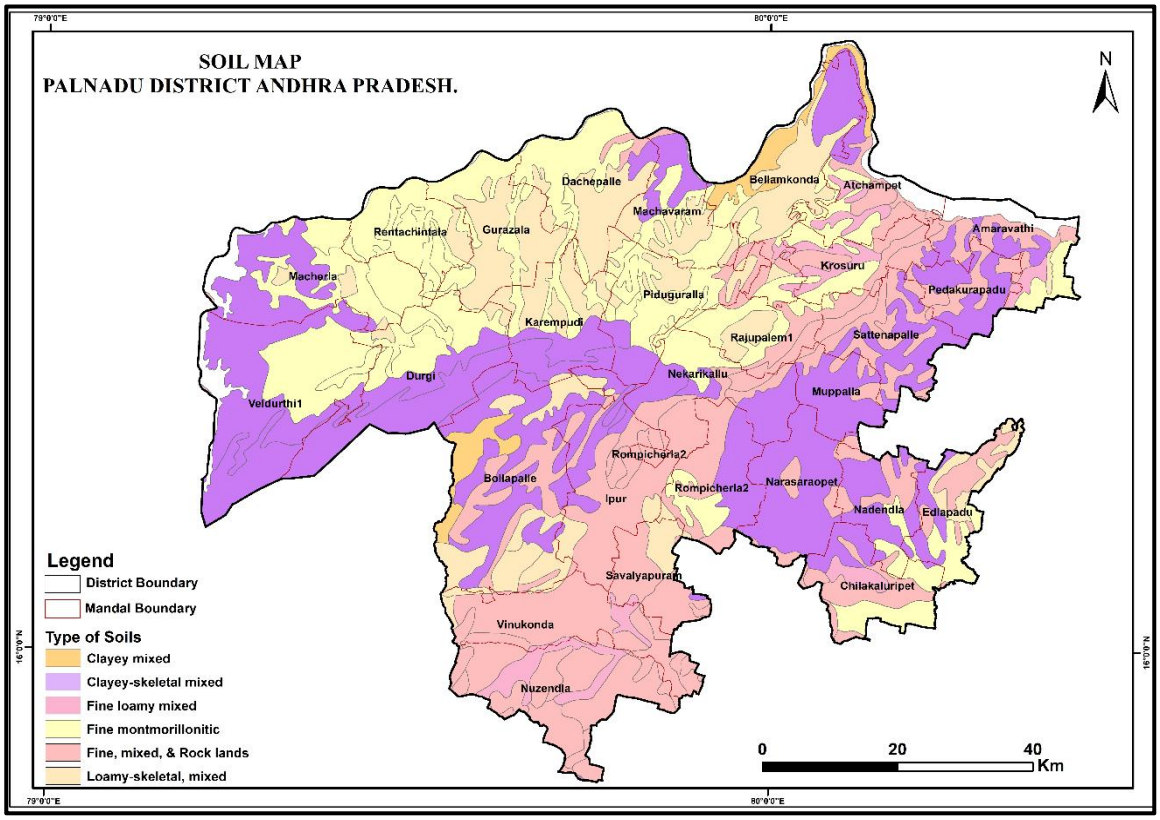


Fig.1.5: Soils of Palnadu district

1.8 Land use and cropping pattern 2019-20):

Major part of the district is occupied by agricultural area (44%). In the district, forest occupies nearly 20% of the area, 12% 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 (**Fig.1.6**). The total gross cropped area during the year 2021-220 is 3,47,114 ha and net sown area is 3,15,650 ha. The gross area cropped during Khariff season is 2,98,740 ha and the major crops grown during khariff season is Paddy (18%), cotton (48%), chillies (18%) and total pulses (5%) and 11% remaining other crops. The gross area cropped during Rabi season is 3,47,114 ha and the major crops grown during the period are Paddy (40%), Pulses (33%), Maize (11%), Tobacco (3%) and remaining 13% by other crops. Season wise cropping pattern is given in **Fig.1.6 a and Fig.1.6 b.**

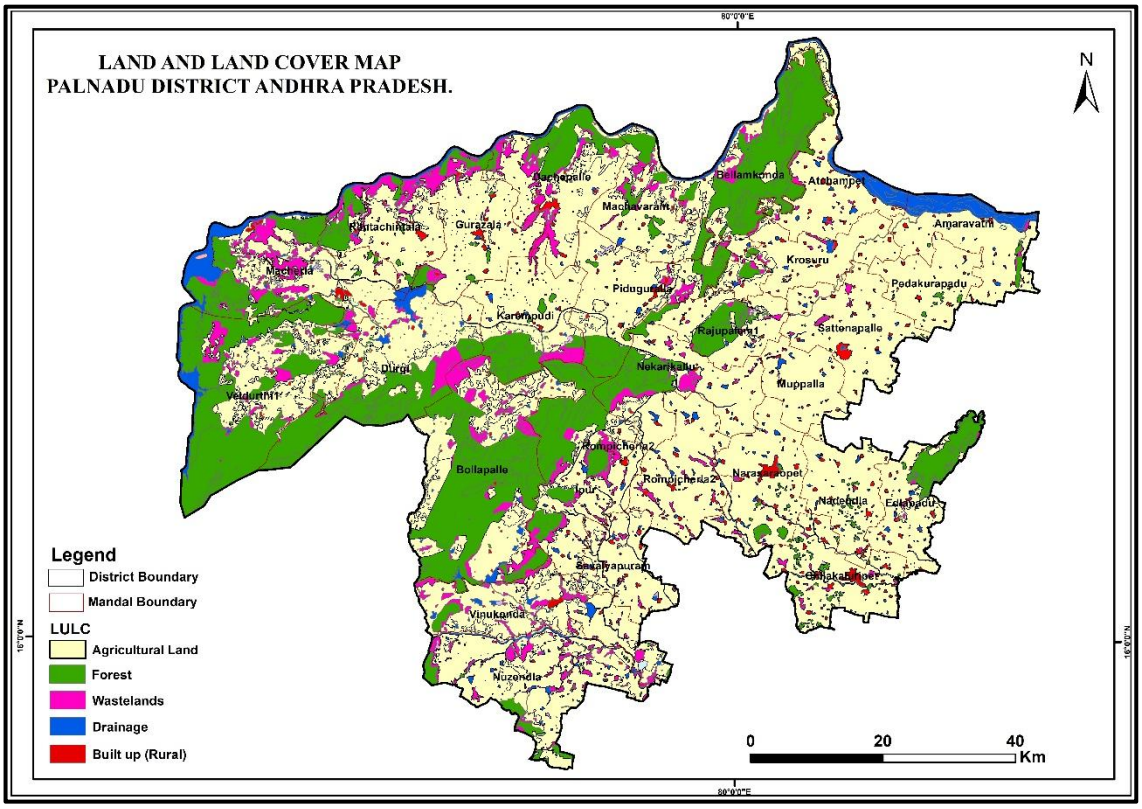


Fig-1.6: Land U se and Land Cover pattern of Palnadu district

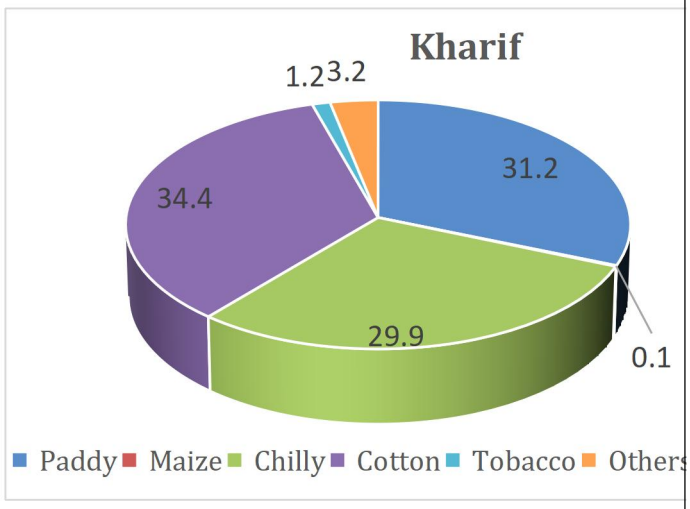


Fig .1.6 a: Kharif Major Crops

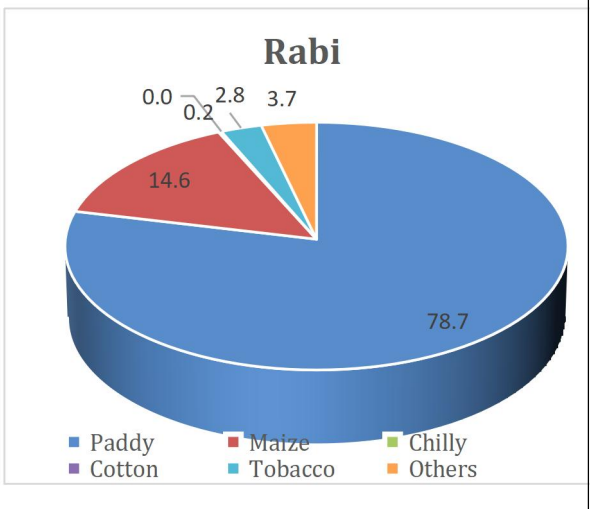


Fig .1.6 b: Rabi Major Crops

1.9 Irrigation Projects:

The Nagarjuna Sagar multipurpose project was constructed on the river Krishna is located near the then Nandigonda (Village now Hill colony) in Nalgonda District is the pride of Independent India. The districts benefited under NSP are Guntur, Palnadu, Prakasam, Krishna, Nalgonda, Khammam and West Godavari **(Fig 1.7).** The localised ayacut of Nagarjuna Sagar Right (Jawahar) Canal in the district is 466700ha.

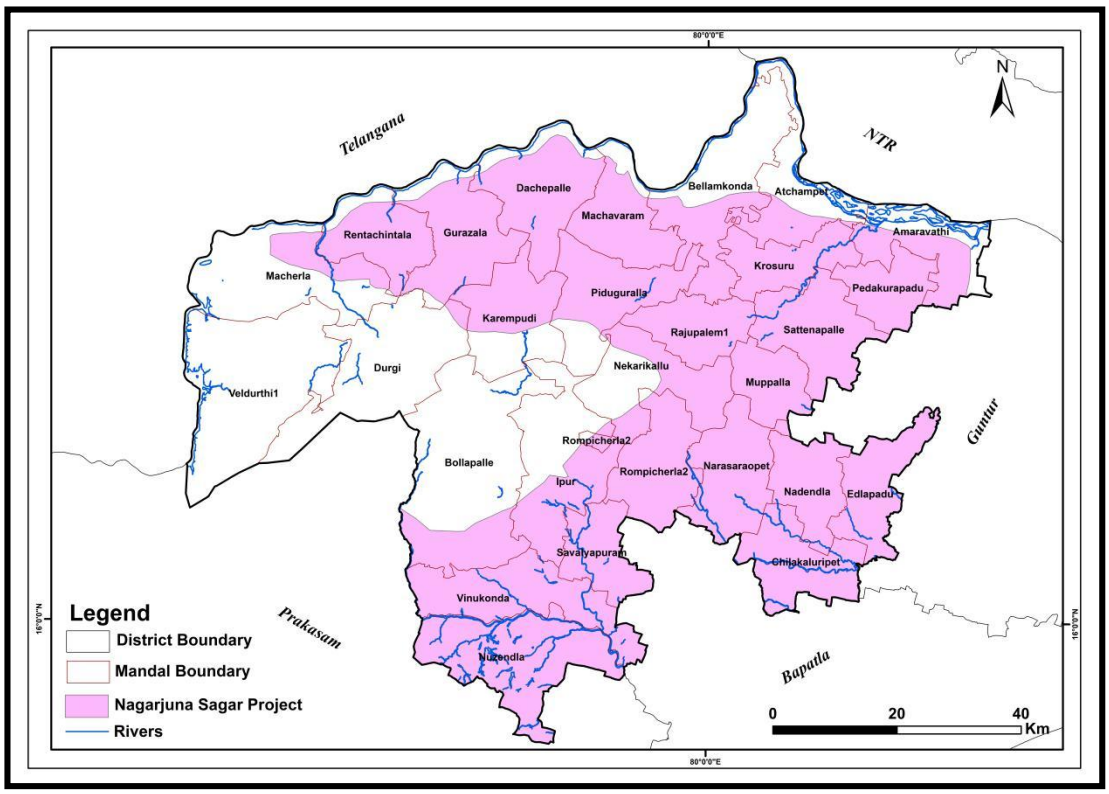


Fig 1.7 Irrigation Projects in Palnadu district

Table 1.1: Area Irrigated

District	No. of Mandals	Gross Area Irrigated (ha)	Area Irrigated More Than Once (ha)	Net Area Irrigated (ha)
Palnadu	28	1,98,118	21,047	1,77,071

Table 1.2: Salient Features of Irrigation in Palnadu District.

Source		Numbers	Gross Area irrigated (ha)
Ground Water Irrigation			
Tube wells	**Shallow**	1760	56555
	Medium	3504	
	Deep	9817	
Dug wells		7037	4955
Total		22118	61510
Surface Water Irrigation			
Canals		405	128386
Tanks		-	2110
Lift Irrigation		1584	5858
Other Sources		-	218
Total		1732	136572

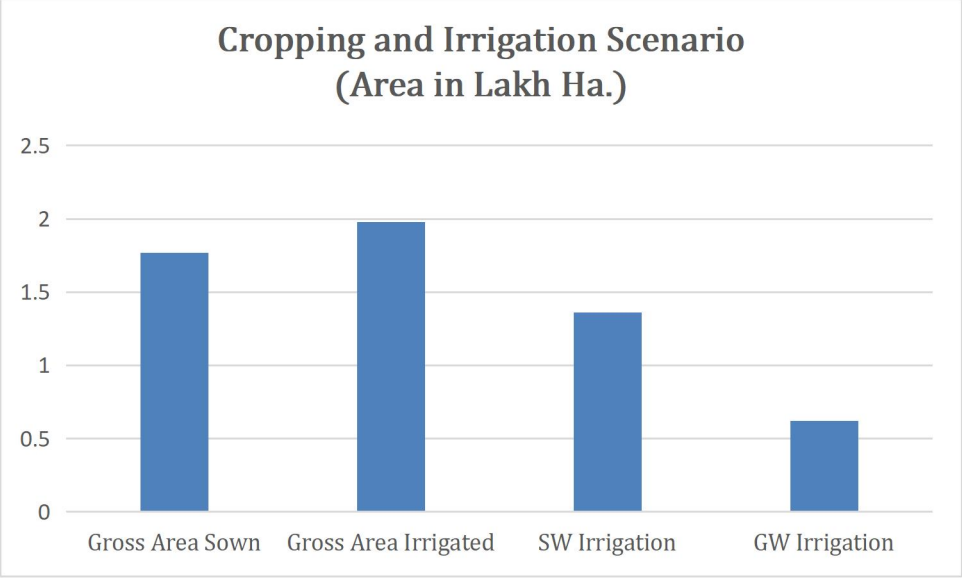


Fig.1.8: Cropping and Irrigation Scenario

Out of the total Gross area sown of 3,47,114 ha, 51% of the cropped area is under irrigation (**Fig.1.8**) & (**Table 1.1**). In which, 69% of the irrigation is through surface irrigation and 31% of the area is irrigated through ground water irrigation (**Table 1.2**).

1.10 Geology:

The district is underlain by various geological formation from Archean to Recent. (**Table: 1.3**). The Archean basement complex comprising the granite gneisses, migmatites, schists and is overlain by Cuddapah Super Group of rocks and Kurnool Group of rocks. The Archean Granitic Gneiss and granites covers 30% of the area and charnockites covers 8%. The Precambrian metasedimentary formation of Kurnool and Cuddapah system covers 58% of the area (**Fig1.9**).

Table 1.3: Stratigraphy of Palnadu District

Era	Period	Formation
Quaternary	Sub-Recent to Recent	Alluvium
Pre-Cambrian	Kurnool System	Narji Limestone & Owk shales
	Cuddapah System	Quartzites & Phyllites, Cumbum shales
.....Unconformity.....		
Archean	Dharwar (Basement Complex)	Veins of Pegmatite, dolerite dykes, Granite Gneisses, Charnockites khondalites

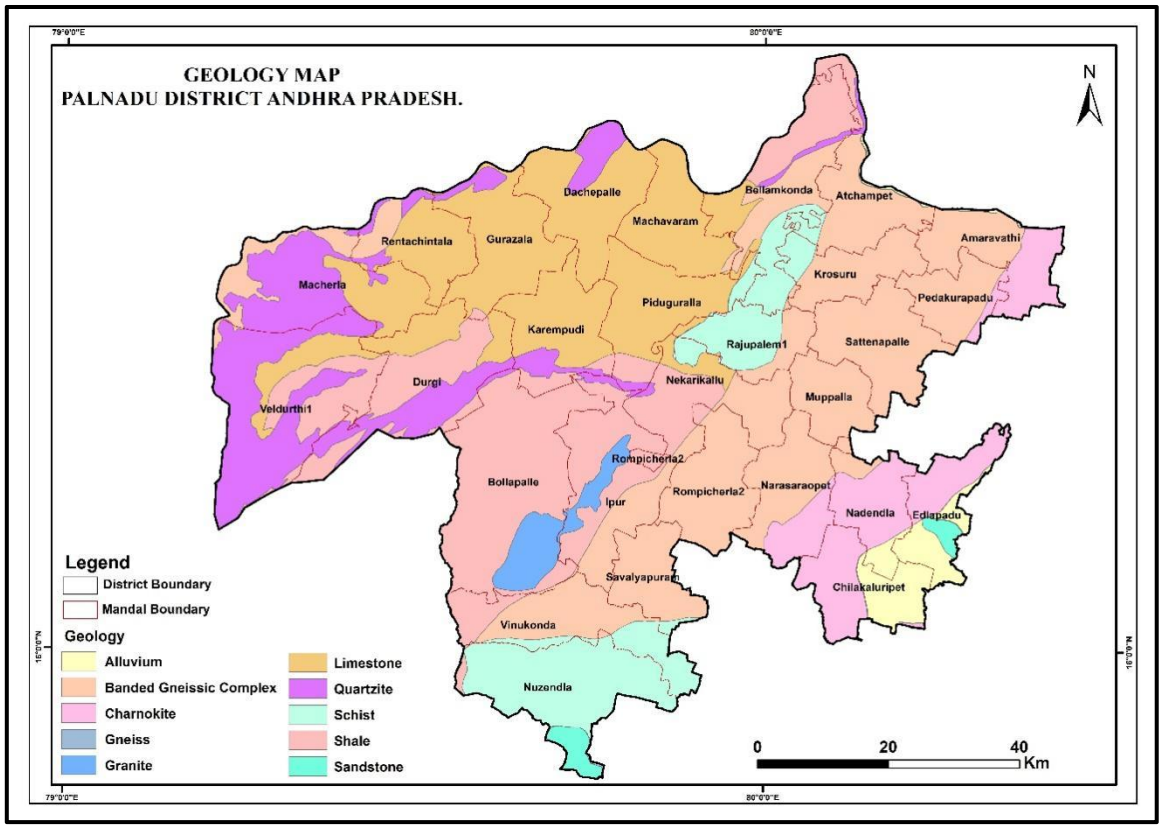


Fig.1.9: Map showing Geolog and Principal Aquifers of Palnadu District

Archean Rocks:

The Archean rocks comprising of Charnockites, Granites and Granite Gneisses that are intruded by basic rocks. Outcrops of Archeans are also seen as "Inliers" within the Cuddapah formations. The Granite Gneisses exhibit gneissosity trending NNE-SSW to ESE-WSW. They are light grey in colour and coarse grained with porphyritic texture at places. They are hard, compact and massive to jointed. The crystalline formation has developed secondary porosity with weathering, jointing and fracturing, which enable these rocks to become water bearing and water yielding.

Cuddapah Super Group of Rocks:

The Cuddapah Super Groups of rocks consist of phyllites and slates belonging to Cumbum formation. The quartzites generally form the relief areas and phyllites occupy valleys and plains. Phyllites generally grades into slate and at places into shale. The bedding plane of phyllites generally strike N10 E-S 19 W with easterly dip. Cumbum shales forming the core of the synclical folds. A typical feature in this is the domal upwards as seen near Nakrekallu and Achampeta areas.

Kurnool Group of Rocks:

Kurnool Group is also referred as Palnadu series. The formations of this group occurring in the stratigraphic succession are Banganapalli Conglomerate/Quartzite, Narji limestone and owk shales. The important formation is the Narji limestone, which are seen in and around Piduguralla, Dachepalli, Gurzala, Rentachinthala, and Macharla mandals. The Narji Limestone are good quality white, grey or buff coloured, compact limestones with conchoidal fractures whereas Banganapalli quartzites are hard, pebbly and white to black in colour.

2. DATA COLLECTION AND GENERATION

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 (**Fig 2.1**). 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)**.

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-	Verti cal Electri cal Soundi ng (VES),bore -

		surface geo-electrical and gravity data generation	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. 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 103 exploratory wells in the district constructed between 1997 to 2023. Out of these, 86 wells were drilled before 2012 and 17 wells in 2021-22 based on the data gap analysis carried out in the study area as part of NAQUIM.

A total of 124 exploratory borewell data of CGWB (103) and SGWD (21) were used for the hydrogeological analysis. Out of these exploration, 52 exploratory wells are located in eastern parts of the study area mainly comprising of Charnockites and Granite gneisses, the remaining 72 exploration wells in meta sedimentary formations comprising of limestone, quartzites and shales.

As on 31/12/2022, CGWB drilled 103 bore wells (Table-2.2) (exploratory, observation and piezometers) in the district. Data analyzed from CGWB wells indicates, 118 wells are of shallow depth (30 m), 42 nos are of 30-60 m, 21 nos are of 60-100 m, 15 nos are of 100-150 m and 78 nos are of 150-200 m. Depth of exploratory wells in metasedimentaries

varies from 17-208 m and discharge upto 12 lps encountered but 66% of wells yield less than 3 lps. In Charnockite, the depth of bore wells ranges from 18 - 200 m and discharge upto 92 lps encountered but 87% of wells yield less than 3 lps. The deepest fracture is encountered at 191 and 173 m bgl in metasedimentaries and charnockites respectively.

Table:2.2: Details of Exploratory Wells Drilled in Palnadu District

	Charnockites	Metasedimentaries
No. of exploratory wells	52	72
No. of observation wells		
No. of piezometer/water table wells		
Depth range (m bgl)	18-200	17-200
Depth of potential zone (m bgl)	25-85	20-40
General yield range (lps)	0.4 to 9	0.2 to 12
Transmissivity (m^2/day)	0.17 to 165	0.63 to 1685
Storativity	1x 10-6 to 0.001	1x 10-6 to 0.007
Specific Capacity (lpm/m.dd)	3-48	6 – 371

2.2 Water Level:

Water level monitoring wells of CGWB and SGWD is utilized for the Aquifer Mapping studies. CGWB monitors 67 NHS stations in the distrkct out of which 42 are dug wells and 25 Piezometers and State Ground water department monitors 21 piezometers in the district. 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 88 ground water monitoring wells were used in order to understand the annual as well as decadal spatio-temporal behaviour of the ground water regime.

2.3 Hydrochemical Studies:

Water quality data of CGWB and SGWD is utilized for understanding the spatial variation of quality in the district. A total of 76 Pre monsoon (CGWB: 55, SGWD: 21) 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 in the district. For the interpretation of the aquifer geometry, geophysical data in conjunction with the available ground water exploration data has been utilised. A total of 49 VES studies and 21 TEM studies have been carried out in the district.

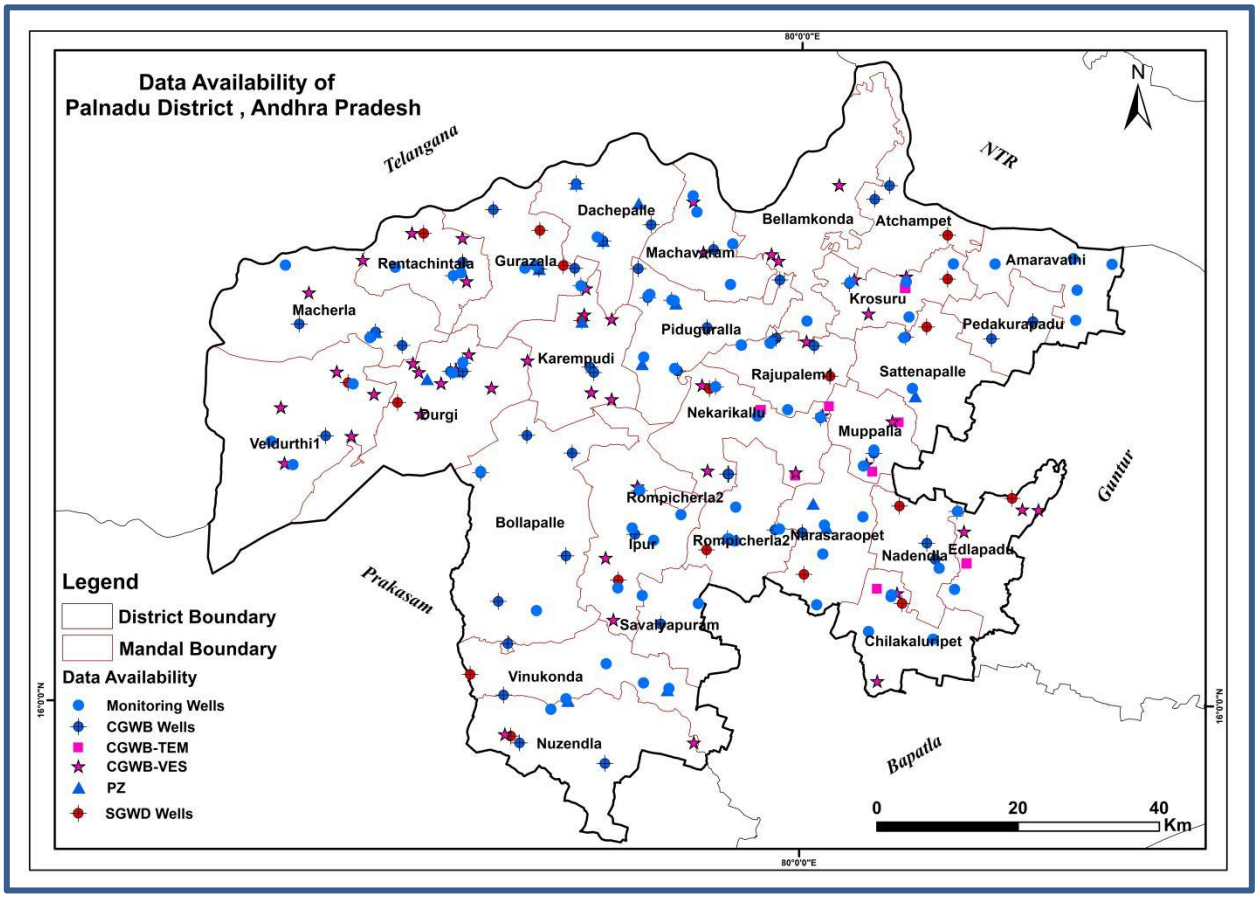


Fig. 2.1: Data availability of Palnadu District

3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1. Ground Water Level Scenario

3.1.1 Decadal Average Depth to Ground Water Levels (2014-23)

Analysis of the pre-monsoon and post-monsoon water level data from 88 (CGWB:67, SGWD: 21 PZ) ground water monitoring wells shows that depth to water level varies from <1 m to 17 m bgl with an average of 4.73 mbgl during pre monsoon and <1 m - 24 m bgl during post-monsoon season withan average of 4.24 m bgl.

Pre-monsoon season: The decadal average water level in majority of the areas, during pre-monsoon (May) season is in the range of 2-5 m represented by 62% of the wells, followed by 5 - 10 m bgl 19% of the wells and 10 to 20 m bgl by 4 % of the wells. Deeper water levels in the range of > 20 m bgl occupy about 9% of the area falling in parts of Veldurthi, Macherla and Durgi mandals and as isolated patches in Dachepalle and Bellamkonda mandals(**Fig.3.1**).

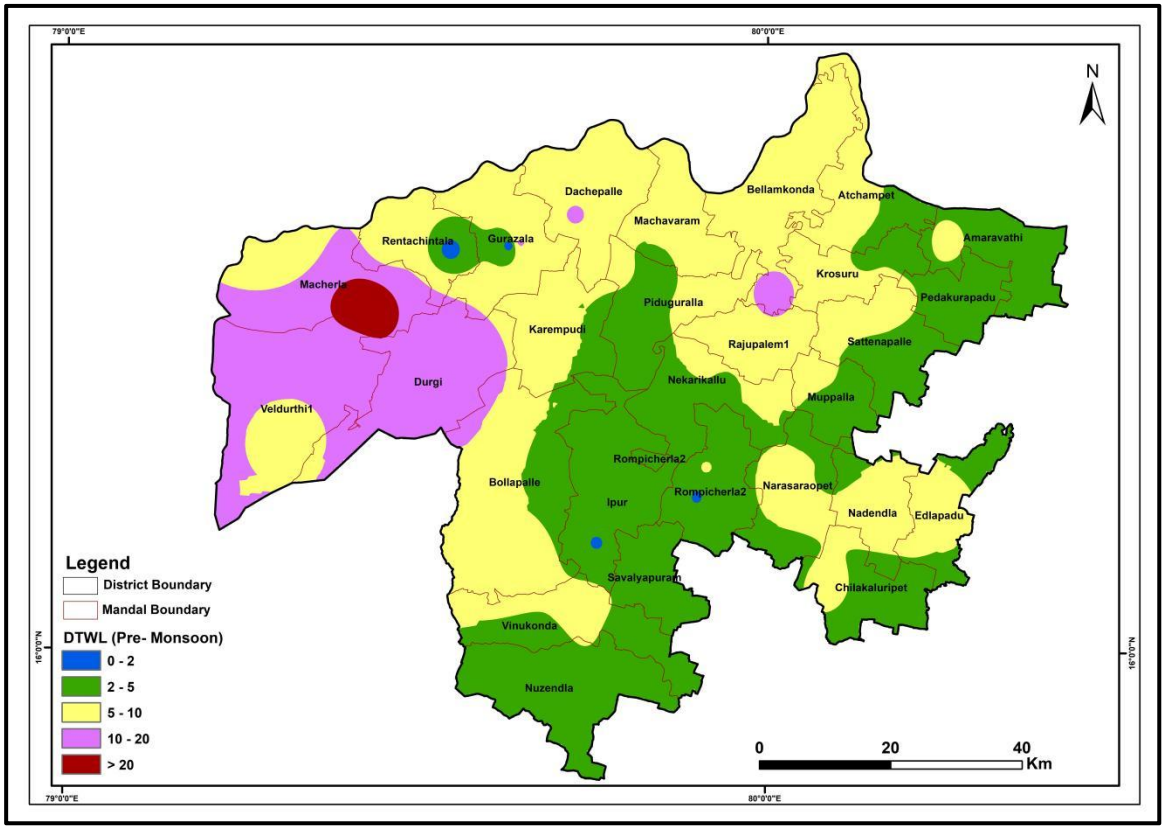


Fig.3.1: Decadal Average Depth to water level, Pre-monsoon(2014-23)

Post-monsoon season: The decadal average water level in majority of the areas, during post-monsoon (November) season is in the range of 0-5 m represented by 73% of the wells, followed by 5 - 10 m bgl 23% of the wells. Deeper water levels in the range of > 20 m bgl represented by about 4% of the monitoring wells and mainly in in parts of Veldurthi, Macherla and Durgi mandals. Shallow water level in eastern parts of Amaravathi, Pedakurapadu mandals and occurs as pockets in Atchampet, Rentachintala, Nekarikallu and Ipur mandals (**Fig.3.2**).

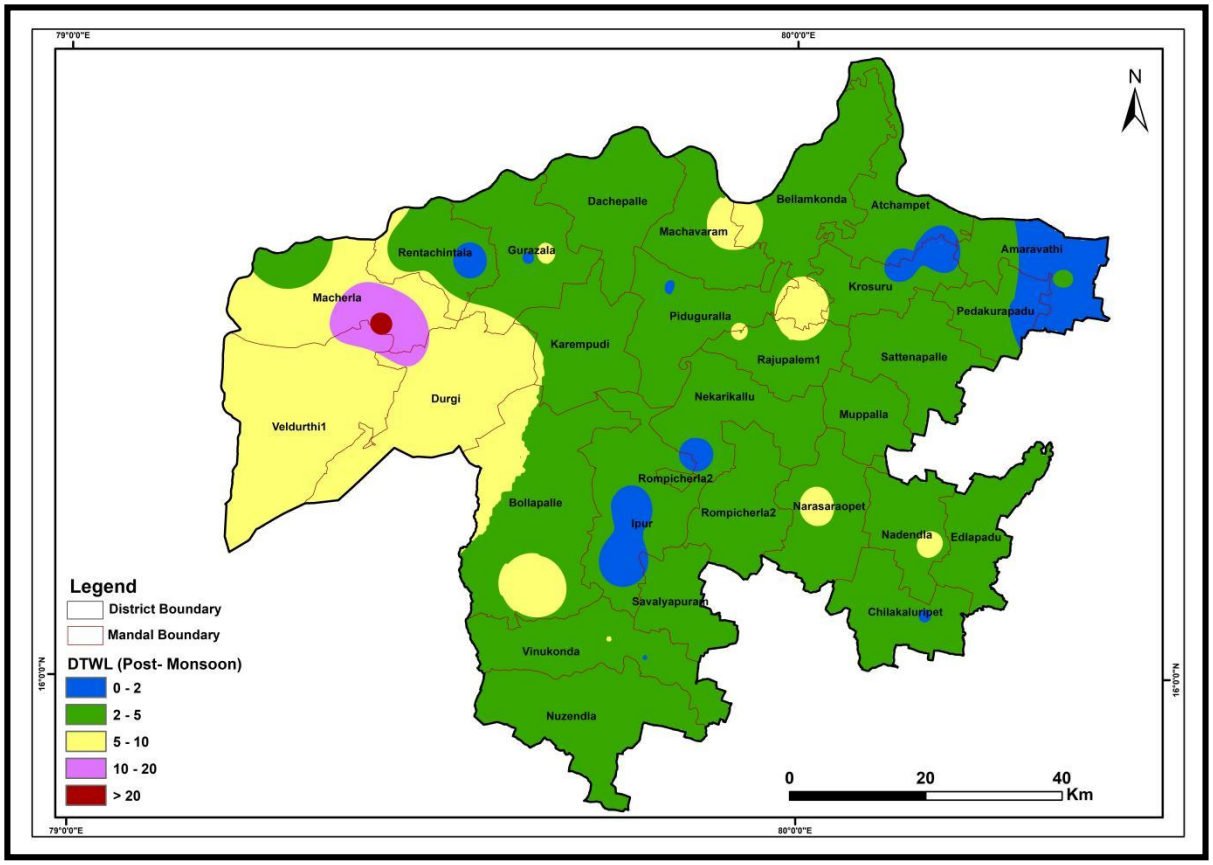


Fig.3.2: Decadal Average Depth to water level, post-monsoon (2014-23)

3.1.2 Seasonal Water Level Fluctuations (May vs. November): Out of 53 monitoring wells, seasonal water level fluctuation data is available only for 24 wells, which is shown in **Fig.3.3**. 92% of the wells show rise in water level and fall in water level is noticed as an isolated pocket in Vinukonda and Nuzendla mandals. The seasonal water level fluctuations vary from <1 to 6.3 m

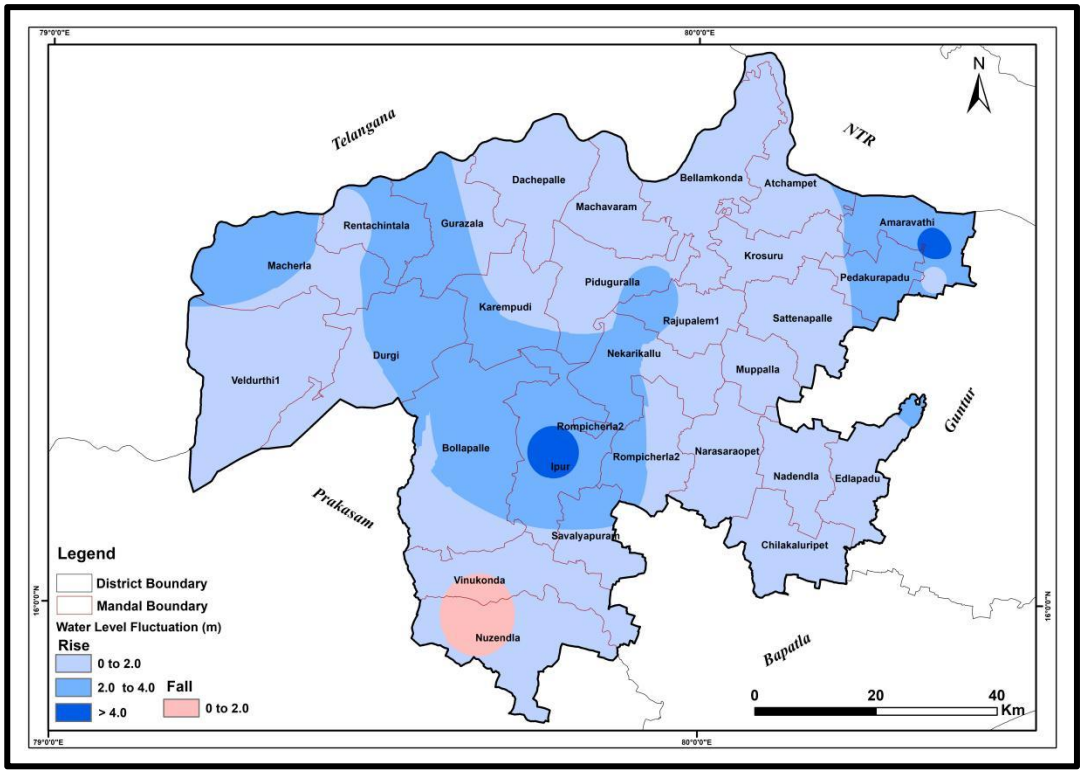


Fig.3.3: Seasonal Water Level Fluctuation (m) (Nov with respect to May)

3.1.3 Long term water level trends: Trend analysis for the last 10 years (2013-2022) is studied from hydrograph stations of CGWB and SGWD. It is observed that during pre-monsoon season, 59% of wells show a falling trend (**Fig. 3.4a)** while during post-monsoon, only 31% of monitoring wells show a falling trend (**Fig. 3.4b)**.

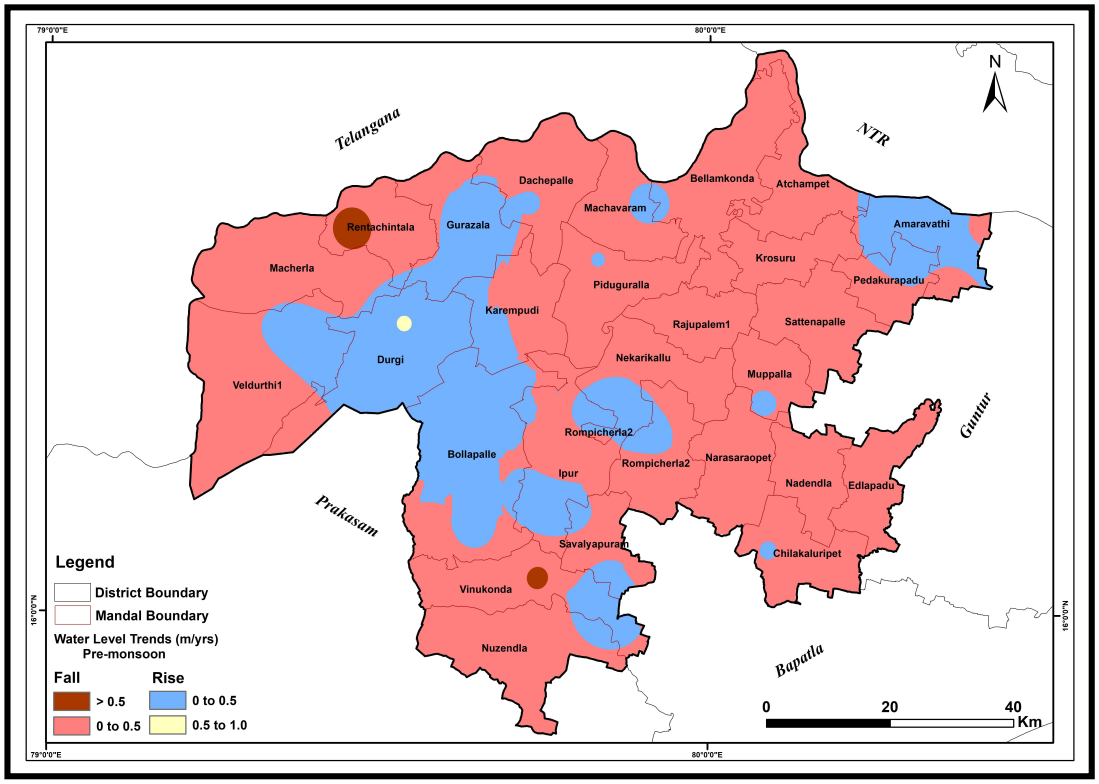


Fig.3.4a Long term water level trends : Premonsoon, 2013-22

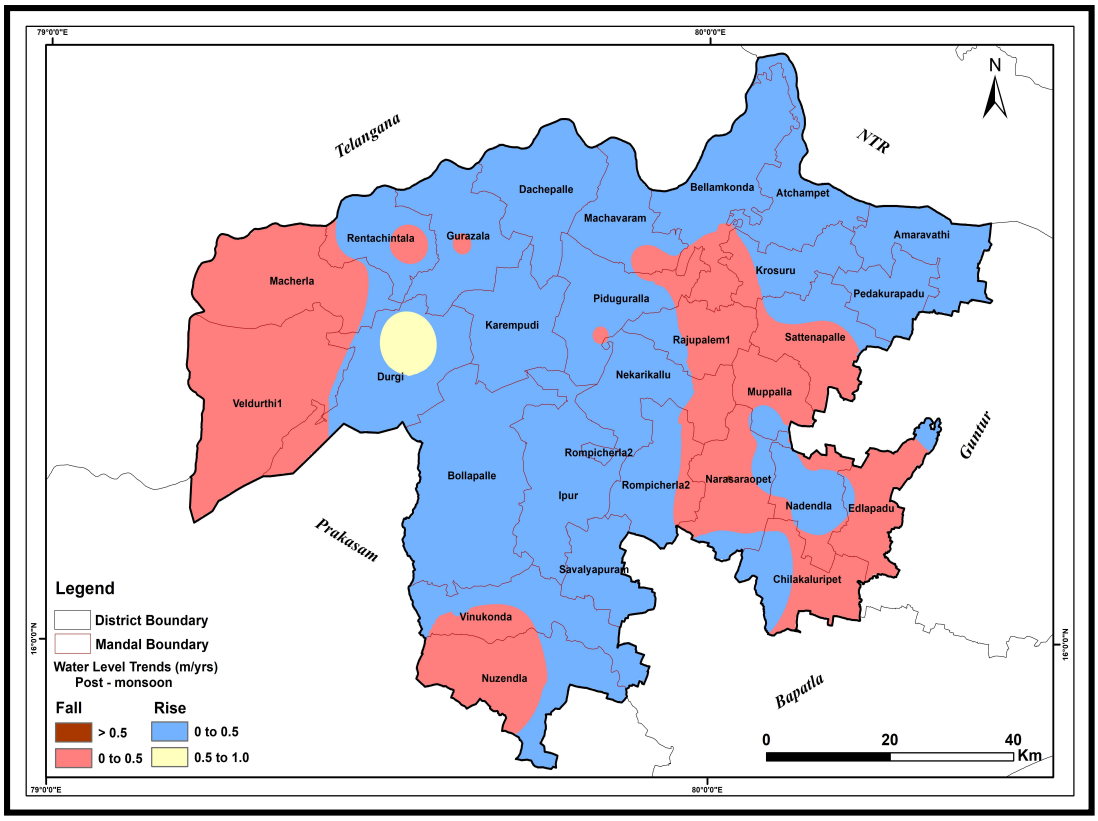


Fig.3.4b. Long term water level trends, Postmonsoon, 2013-22

3.2 Ground Water Quality

The ground water quality in the area is generally good. In all the locations pH is within the acceptable limit and shows mildly alkaline nature.

Pre-monsoon: Ground water is mildly alkaline with pH in the range of 6.90 - 8.3 (Avg: 7.6). Electrical conductivity varies from 680 - 5350 µ Siemens/cm (avg: 2145). In majority of the area, EC is within the permissible limit. (**Fig.3.6**). High EC value of more than 3000 µ Siemens/cm occur as patches in Veldurthi and Rompicherla mandals and an extended area in Atchampet, Krosuru and Sattenapalle. Average concentration of EC is 2145 µ Siemens/cm in the district. The NO_3 ranges from 1-560 mg/L. Nitrate concentration in 56% of samples is beyond permissible limits of 45 mg/L (**Fig.3.7**). Fluoride concentration varies from 0 - 2.9 (**Fig 3.8**) with 18% of samples is beyond the permissible limits of BIS and rest is within the permissible limits.

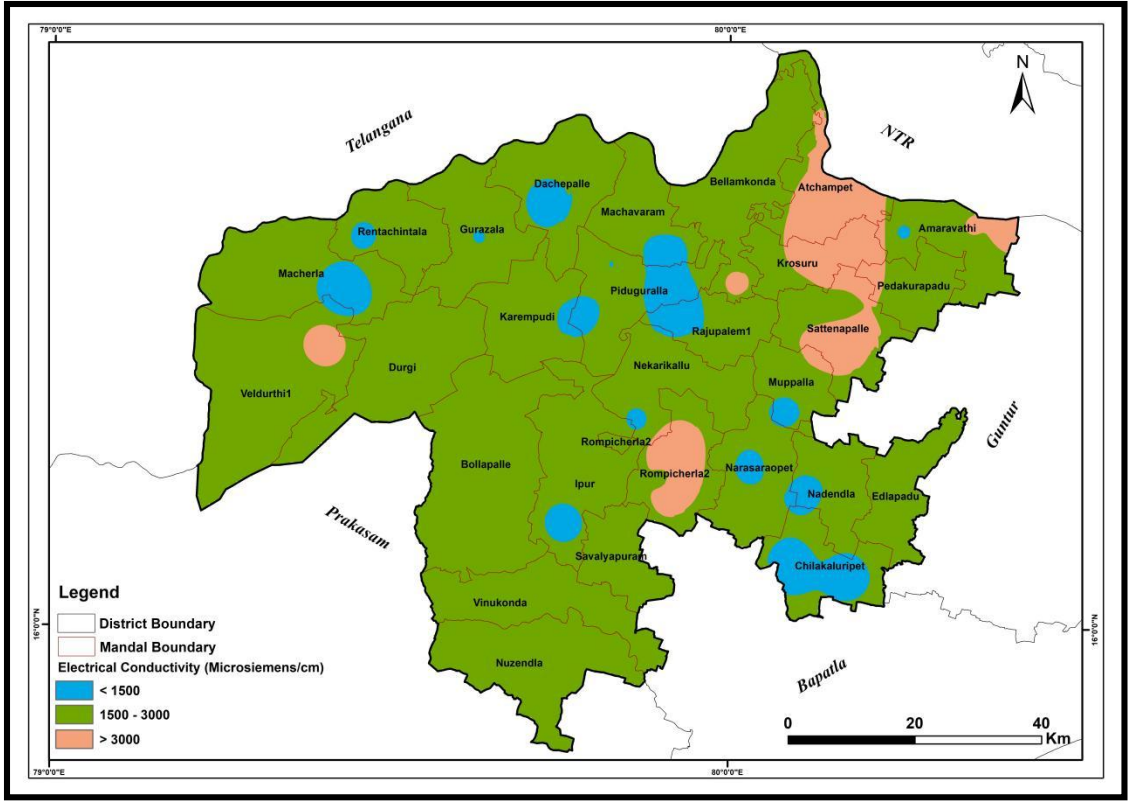


Fig.3.6: Distribution of EC during pre-monsoon

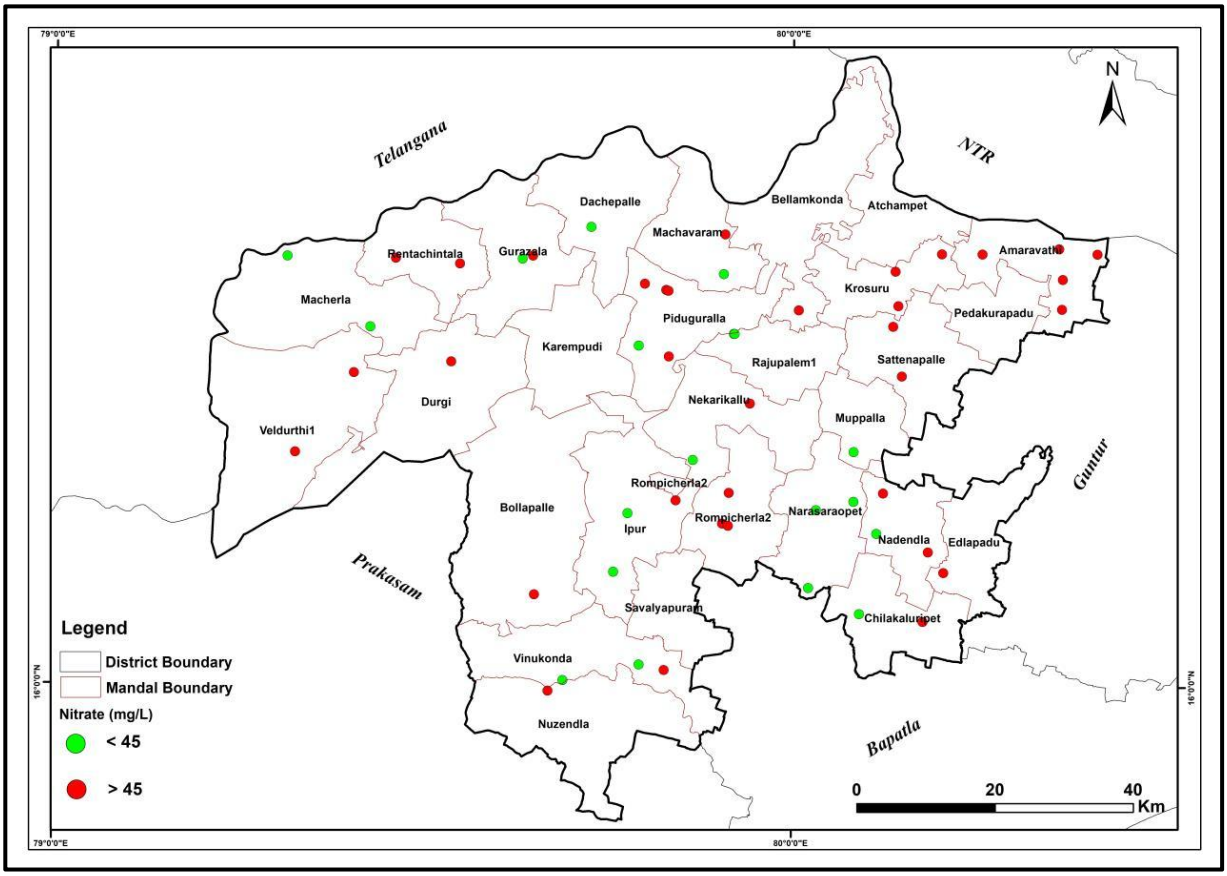


Fig.3.7: Distribution of Nitrate during pre-monsoon

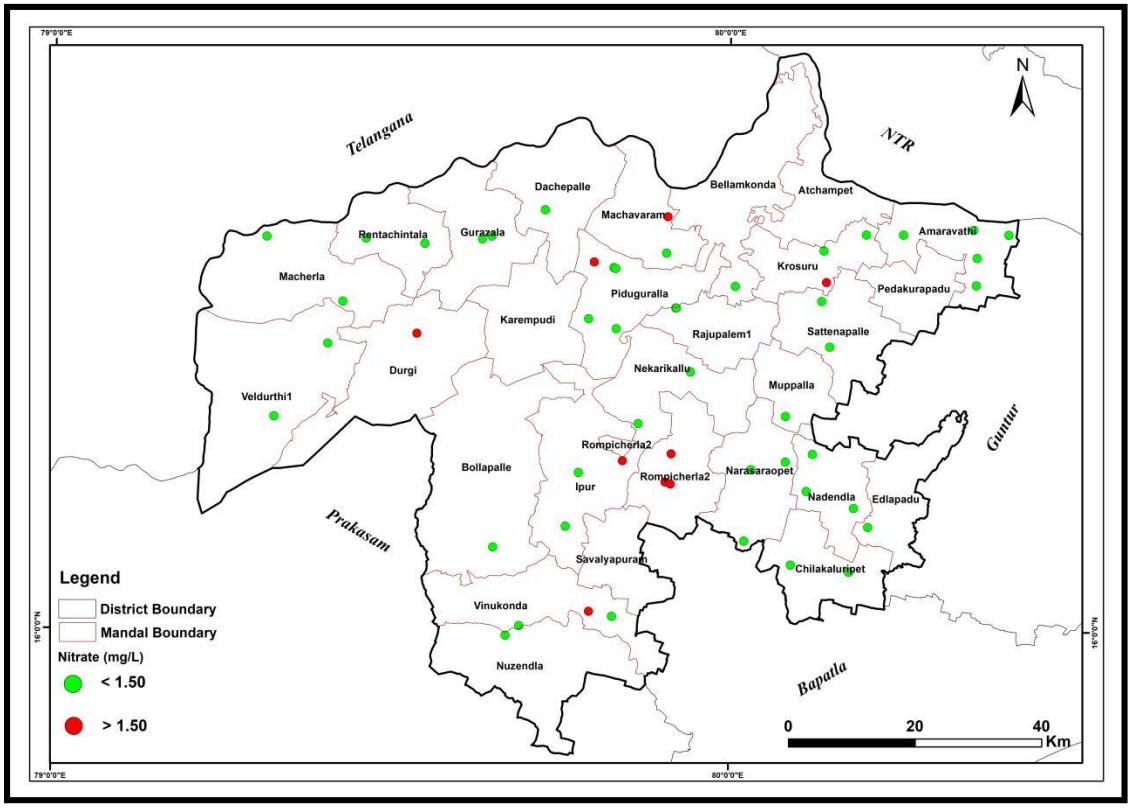


Fig.3.8: Distribution of Fluoride during pre-monsoon

3.3 AQUIFER MAPPING

The aquifer geometry for shallow and deeper aquifer has been established through hydrogeological 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**.

3.3.1 Aquifer System

Aquifer Characterization: On the basis of occurrence and movement of ground water, hard rock units of the study area are classified into two categories; Archean crystalline and Meta sedimentary formations. Two aquifer systems (Aquifer I & Aquifer II) have been conceptualized in crystalline and meta sedimentary formations. The aquifer units identified includes **- Shallow Aquifer and Deeper Aquifer.** Aquifer I comprises of weathered and semi-weathered crystalline and meta-sedimentary rocks and the thickness is varying between 10 to 20 m with isolated patches upto 40m. Aquifer II consists of discrete anisotropic fracture system varying from 30 - 200 m, with varying occurrence of fractures between the depth range of 30 - 60m, 60 - 90m , 90 -120m. Fractures beyond 120m are generally rare in occurrence but potential in nature.

Weathered zone:

Thickness of weathered zone in the range of 10 to 20 m in most part of area while shallow weathering of <10 m occurs in isolated patches. Similarly, weathered thickness of more than 20m also occurs in isolated pockets (**Fig.3.9**).

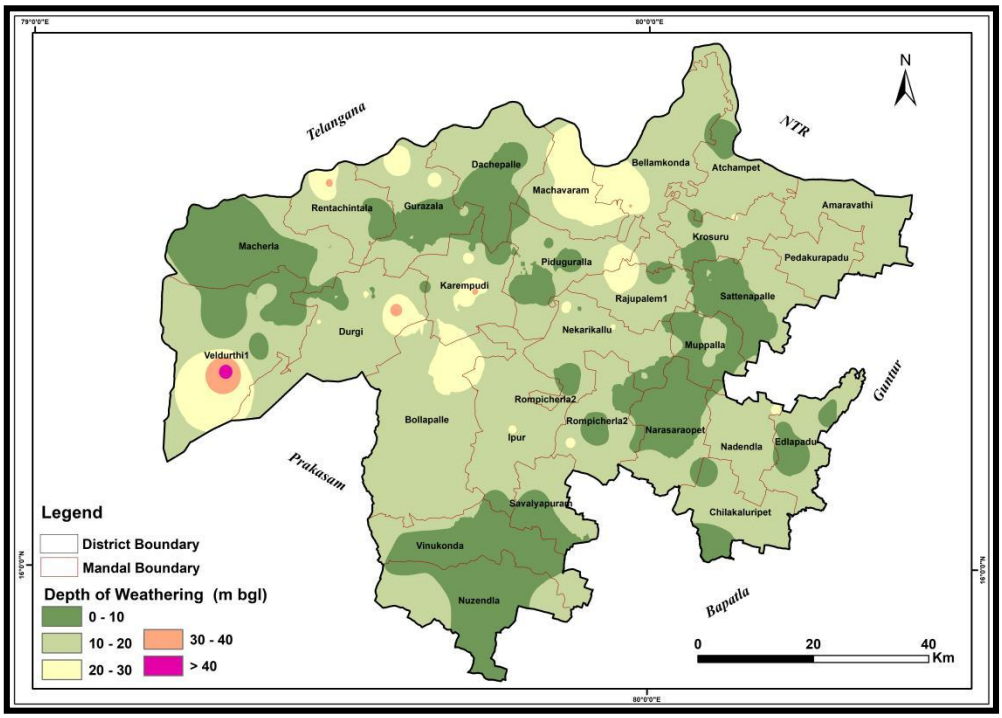


Fig.3.9: Map of Weathered zone thickness, Palnadu district

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 as hand pump. 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 <1 lps (avg: 1.0 lps) in weathered gneiss aquifer to 1 to 10 lps (avg: 5 lps) in metasedimentary aquifers.

Fractured Zone: Based on CGWB & SGWD data, it is inferred that majority of fractures (~81 %) occur within 100 m depth. In this, the wells drilled in the meta-sedimentaries are high yielding (upto 11 lps) when compared to charnockites. Deep fractures in the range of >150 m occur in Krosuru, Vinukonda and Savalyapuram mandals. The deepest fracture encountered is 192 m in Dodleru and Anupalem villages in Krosuru and Piduguralla mandals respectively. The spatial variation in the depth of fractures is given in **Fig. 3.10.**

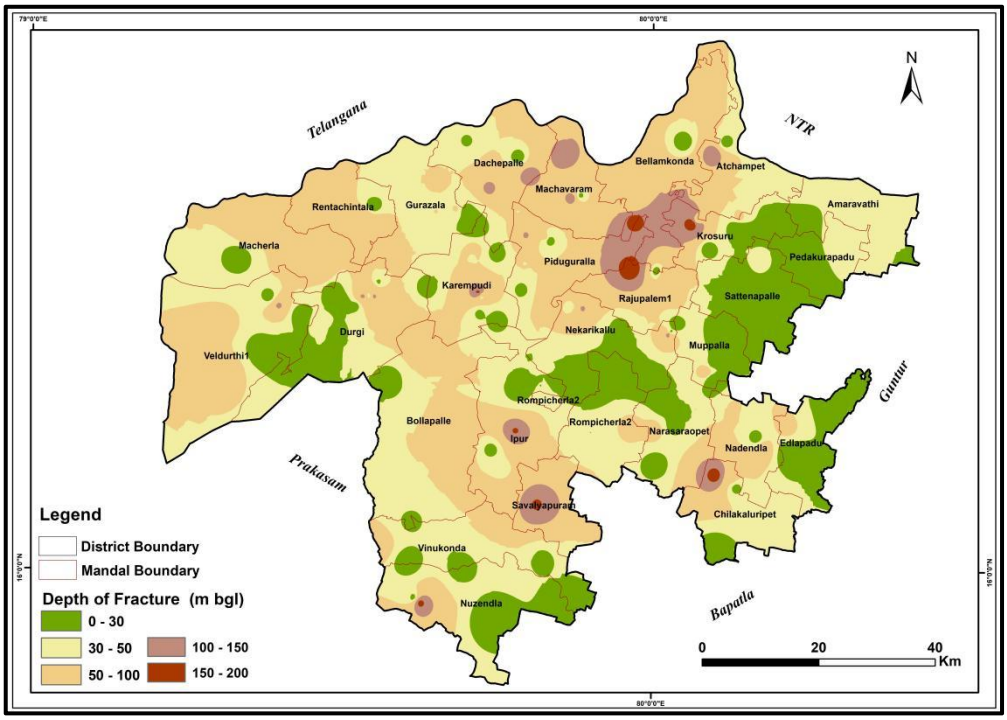


Fig.3.10: Map of fracture zone thickness, Palnadu district

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 192 m bgl (deepest fracture encountered). The deepest fracture encountered is 192 m in Dodleru(charnockite) and Anupalem(limestone) villages in Krosuru and Piduguralla mandals respectively. The detailed analysis of deeper fractures of more than 150 m bgl, reveals that the yield is more in meatsedimentaries upto 5 lps but in the case of charnockites majority are less than 1 lps.

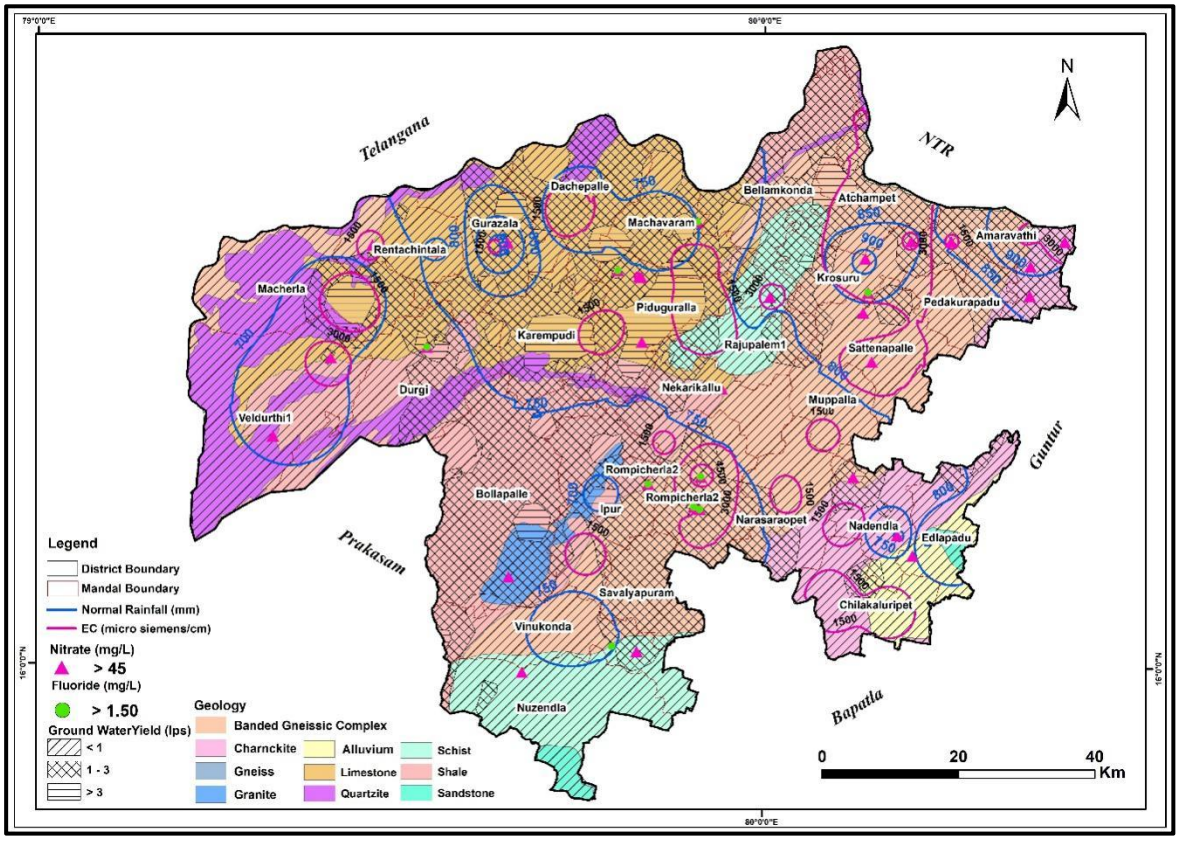


Fig 3.11: Hydrogeology map of Palnadu district

Table 3.1: Hydrogeological Characteristics

Era	Pre-Cambrian		Archean Crystallines	
Prominent Lithology	Meta sedimentary Formation		Granite Gneiss/Charnockite (Basement)	
Aquifer types	Aquifer-1 (Weathered Zone)	Aquifer-2 (Fracture Zone)	Aquifer-1 (Weathered Zone)	Aquifer-2 (Fracture Zone)
Thickness range	1 - 35 m	up to 200m	1 - 22 m	up to 200m
Depth of range of occurrence of fractures	-	42% fracture encountered within 100 m	-	57% fracture encountered between 30 – 100 m
Range of yield potential	<1 to 6	Avg: 5 lps	<1 to 9	Avg: 3 lps
Storativity				0.001 to 1 x 10^{-5}
Transmissivity (m^2/day)	More than 1 to >100 sq.m/day			

3.3.2 Aquifer Disposition 3D and 2D

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 194 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& 3.14)** along with panel diagram and (**Fig. 3.13 & 3.15**) hydrogeological sections.

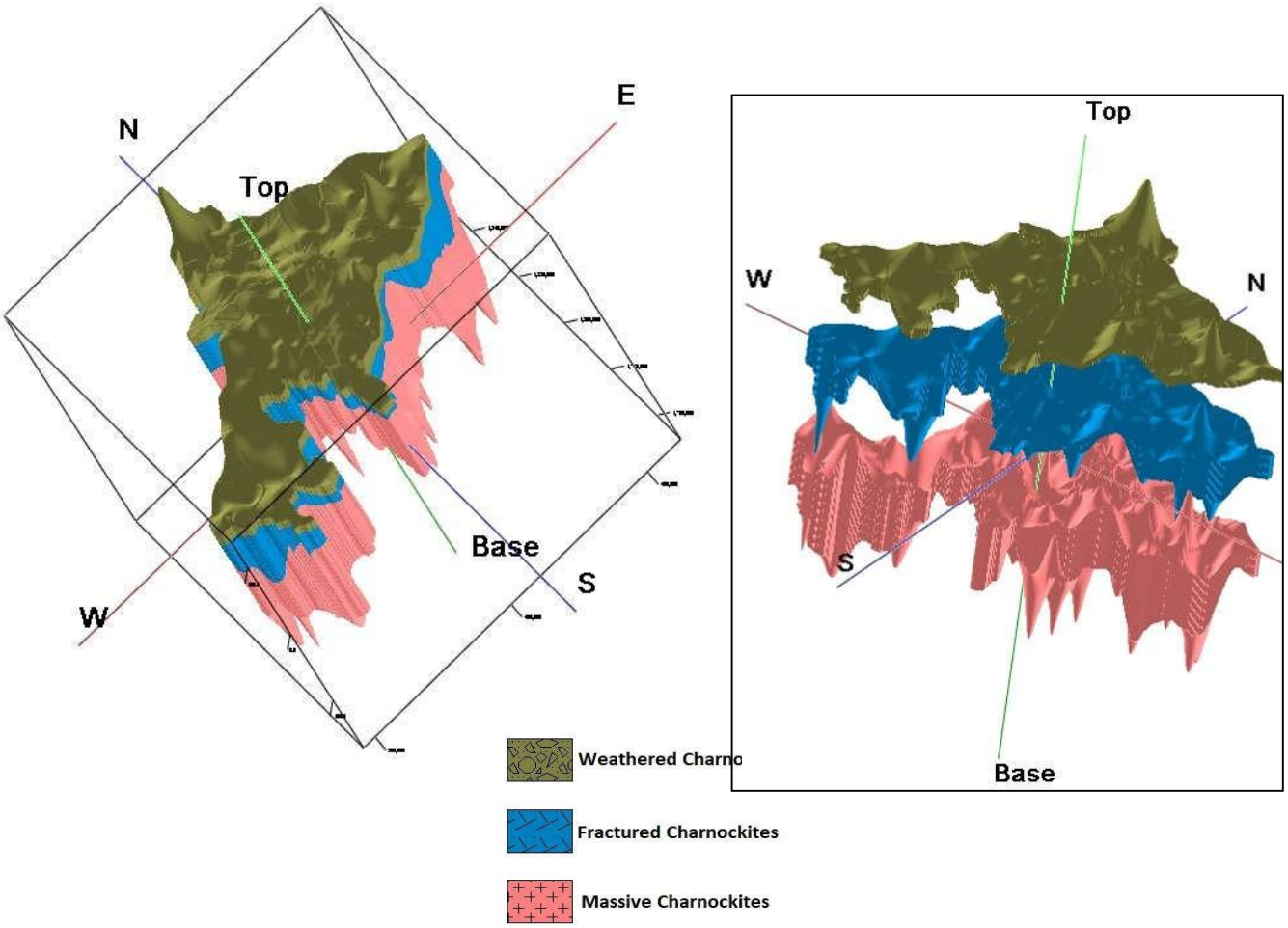
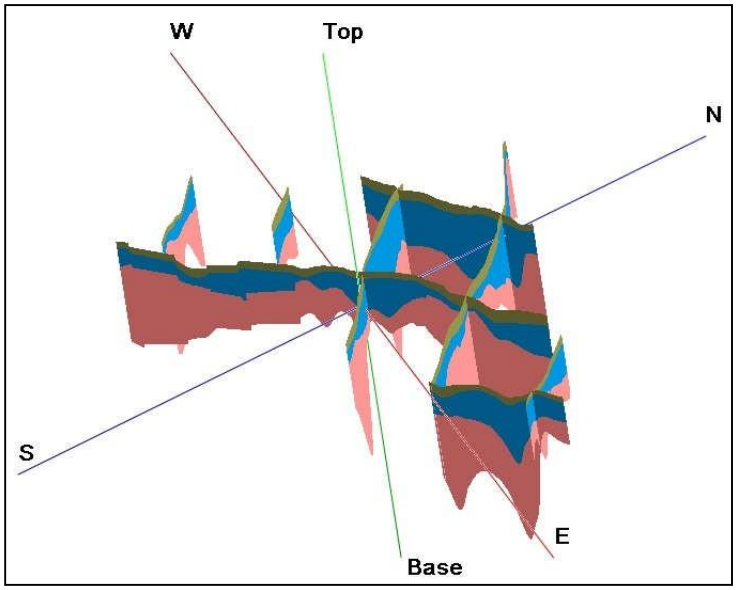
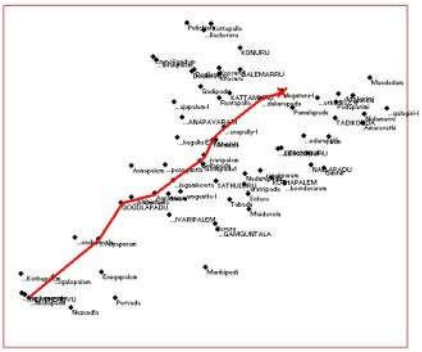


Fig 3.12: Aquifer Disposition of Charnockite Area

Panel Diagram and 2D Section of Charnockite Area





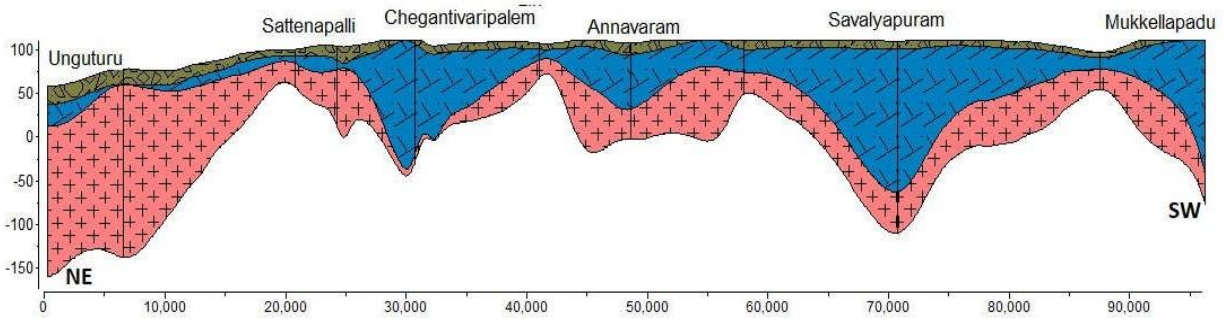


Fig 3.13 a. Section: NE-SW Section

Aquifer Disposition in Meta Sedimantary Formation:

Aquifer Disposition 2D

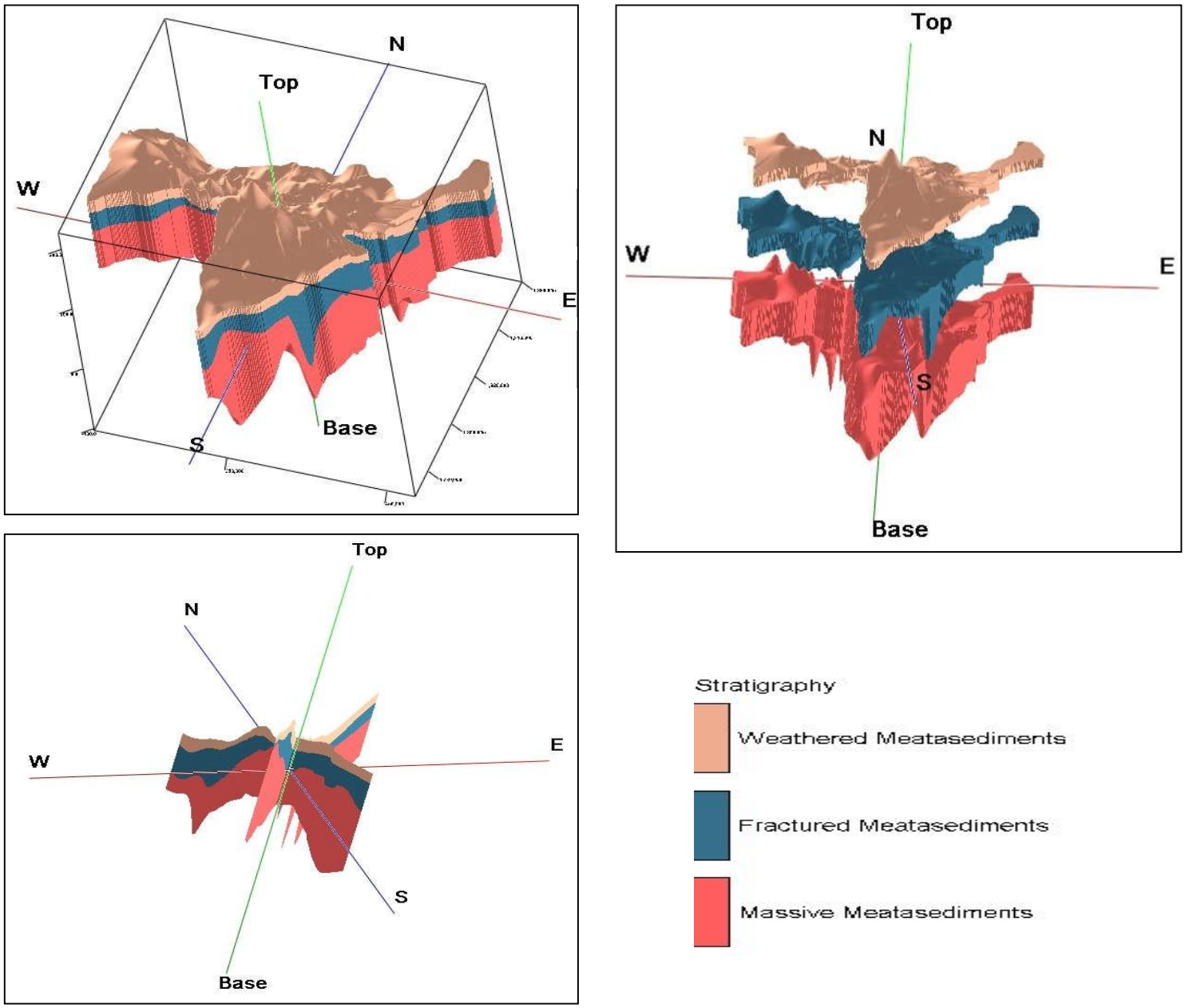
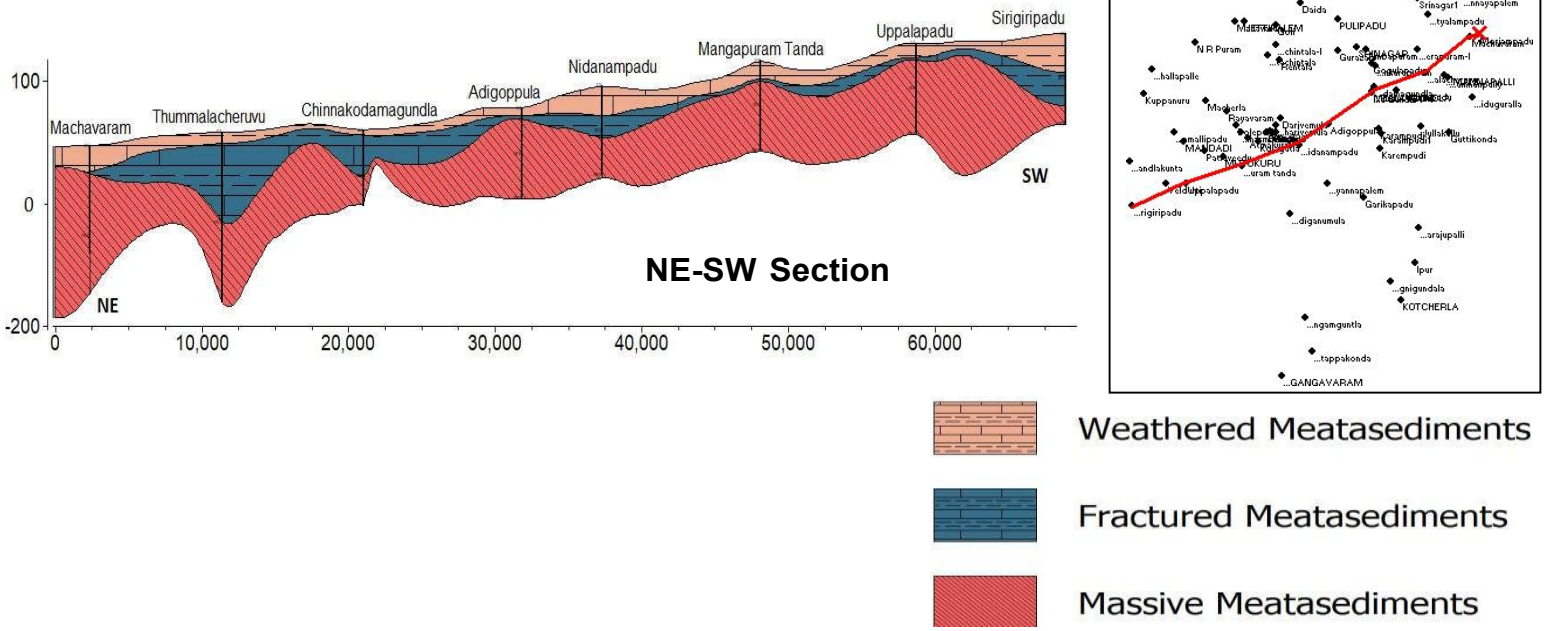
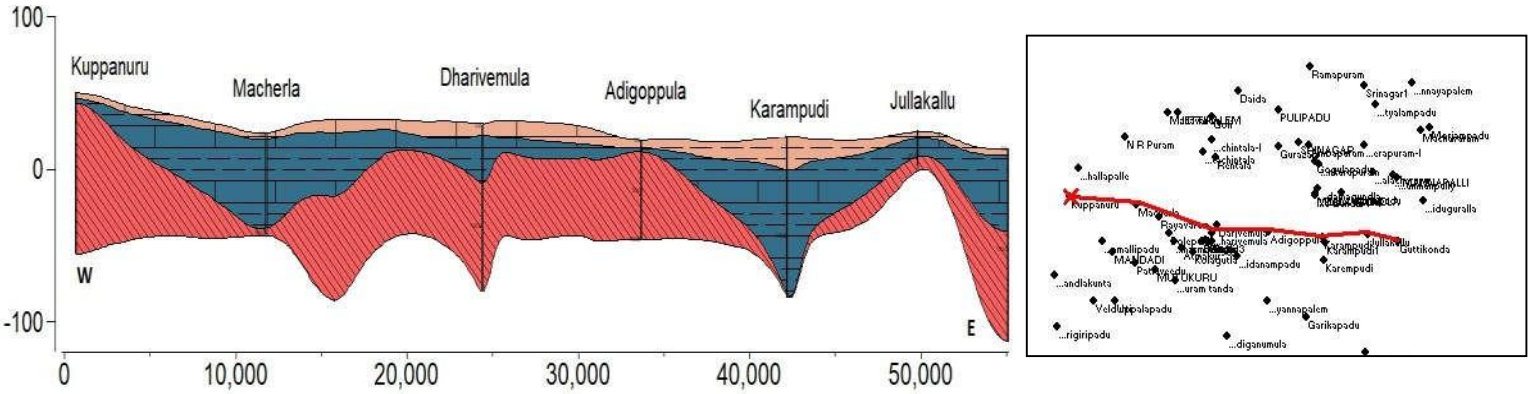


Fig 3.14: Aquifer Disposition of Metasedimentary Area





West -East Section

Fig 3.15: Hydrogeological profile of Metasedimentary Area

4.0 GROUND WATER RESOURCES (2023)

In hard rocks, for practical purpose it is very difficult to compute zone wise (aquifer wise) ground water resources, because the weathered zone and fractured zone are inter-connected with fractures/joints and fractured zone gets recharged through weathered zone. Therefore, it is very difficult to demarcate the boundary between two aquifers; hence the resources are estimated considering entire area as a single aquifer system. Village wise dynamic and in-storage ground water resources are computed as per the guidelines laid down in GEC methodology. The mandal wise Dynamic Ground Water Resources of Palnadu District, Andhra Pradesh (2023) are given in **Annexure No 3.** As per 2023 Ground Water Resources Assessment, the net dynamic replenishable ground water availability is 953 MCM, gross ground water extraction for all uses is 285 MCM, provision for drinking and industrial use for the year 2025 is 104 MCM and net annual ground water potential available for future use is 687 MCM. Stage of ground water extraction varies from 9% (Pedakurapadu mandal) to 138% (Veldurthi mandal). Out of 28 mandals in the study area, 1 mandal (Veldurthi mandal) is over exploited, Bollapalle mandal is Critical and remaining 26 mandals are safe (**Fig 4.1**). The summarized dynamic ground water resources of the Palnadu District, Andhra Pradesh (2023) given in **Table-4.1**

Table-4.1: Computed Dynamic Ground Water Resource

Parameters	Total (MCM)
Dynamic (Net GWR Availability)	952.86
• Monsoon recharge from rainfall	173.44
• Monsoon recharge from other sources	546.09
• Non-monsoon recharge from rainfall	94.27
• Non-monsoon recharge from other sources	189.22
• Total Natural Discharge	50.15
Gross GW Extraction	285.69
✓ Irrigation	242.19
✓ Domestic and Industrial use	43.50
Allocation of Ground Water Resource for Domestic Utilisation for projected year 2025	42.13
Net GW availability for future use	686.62
Stage of GW Extraction (%)	29.98

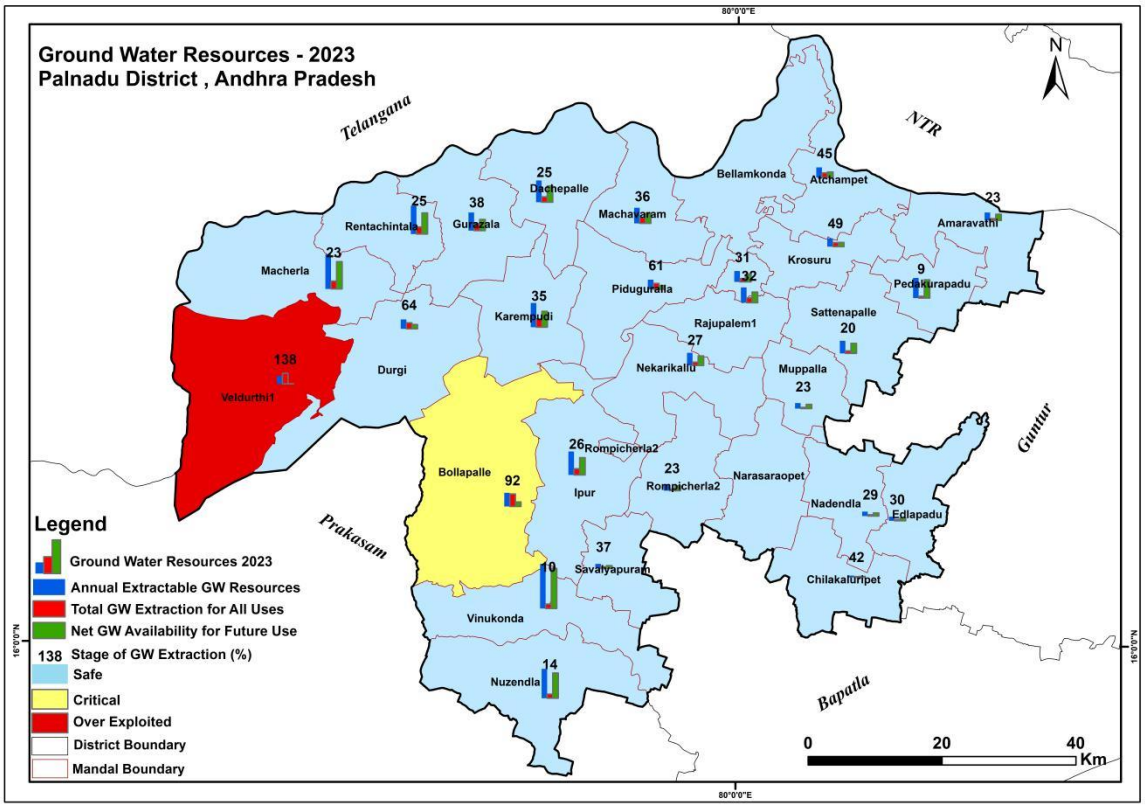


Fig.4.1 Mandal-wise stage of ground water development

4.1 Ground Water Recharge

The Annual Ground Water Recharge varies from 4.13 MCM (Chilakaluripet Mandal) to 105.82 MCM (Vidavaluru Mandal). The Gross Annual Ground Water Recharge in the district is 1075.84 MCM. The net available recharge after leaving natural discharge from monsoon period varies from 3.92 MCM (Bollapalle Mandal) to 100.52 MCM (Vidavaluru Mandal). The net available recharge in the district is 1022.05 MCM.

4.2 Ground Water Extraction

The ground water extraction from irrigation and Domestic /Industrial sources is presented in **Table:4.1.** The Existing Gross Ground Water extraction for all uses varies from 1.65 MCM (Chilakaluripet mandal) to 28.16 MCM (Bollapalle mandal). The Gross Ground Water Extraction for All uses in the district is 285.69 MCM.

5.0 GROUND WATER RELATED ISSUES

5.1 Issues

Stage Of Groundwater Extraction:

Albeit the Over all stage of ground water extraction of the district is 30%, 2 mandals, Viz., Bollapalle and Veldurthy mandals are categorized under Critical and Over-exploited category respectively. These 2 mandals are located in meta sedimentary formations comprising of Lime stones, Quartzites and Shales. The district is known for its rich lime stone deposits and the industrial as well as mine dewatering may be the one of the reasons for high stage of ground water development.

Sustainability

Low yield (<1 lps) occurs in most of the area of both in eastern as well as western parts of the study area. The western parts of the study area are mainly comprising of Charnockites and as per ground water exploration data, the general yield of the charnockites is between 1 to 2 lps. The meta sedimentary parts of the western parts of the study area are also low in sustainability, owing to the massive nature of lime stone in the area.

Ground Water Quality & Contamination/Pollution

Anthropogenic pollution: Higher concentration of Nitrate is observed in 56% of samples. This is due to unscientific sewage disposal of treated and untreated effluents in urban and rural areas. Use of NPK fertilizers and nitrogen fixation by leguminous crops. High EC value of more than 3000 µ Siemens/cm occur as patches in Veldurthi and Rompicherla mandals and an extended area in Atchampet, Krosuru and Sattenapalle.

Geogenic Contamination: Fluoride concentration varies from 0 - 2.9 with 18% of samples is beyond the permissible limits of BIS and rest is within the permissible limit. The high values are seen in areas underlain by banded gneiss complex, which points to the source as country rock.

6.0 MANAGEMENT STRATEGIES

The lacking of assured irrigation facilities in the entire area of Palnadu district exacerbated the dependency on ground water, which is increasing day by day. The ground water extraction in hard rock aquifer system may led 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 within 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. More over repair renovation and restoration of existing tanks will also help in ground water recharge.

The area suitable for ground water augmentation through artificial recharge has been demarcated based on the analysis of average post-monsoon depth to water level data of the observation wells for the period of 2013-2022 and the existing data on artificial recharge structures constructed under various schemes of Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) and Integrated Watershed Management Programs (IWMP) by Rural Development department.

Government of Andhra Pradesh had already created a total 773 recharge structure (590 Check dams and 183 percolation tanks: source: APWRIMS) though MGNREGS and IWMP scheme **(Fig 6.1**). Apart from this 11, 959 farm ponds and 59,866 other structures like cattle pond, minor drain, mini percolation tank, roof top rain water harvesting, feeder channels and field channel structures has been constructed in the district.

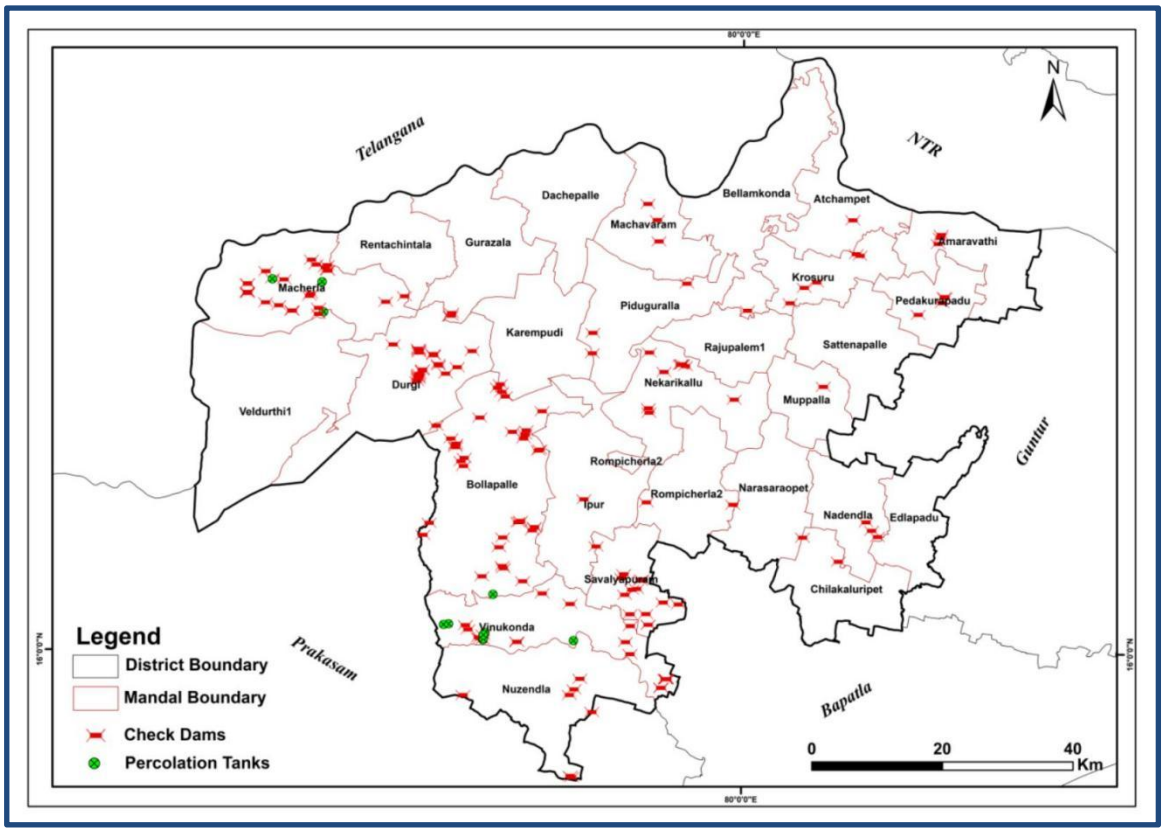


Fig 6.1: **Existing Artificial Recharge Structures in the district**

Considering the available run-off and recharge potential, there is a scope for construction of artificial recharge structures, which can be taken up as per requirement in the district. The availability of sub-surface storage volume of aquifers in each district 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 offavailable 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 artificial recharge 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 artificial recharge structures. Recharge and Runoff available in the

study area is given in **Table 6.1**.

Table 6.1: Recharge and Runofff available in Palnadu district

Total geographical area of district (Sq.km)	7281
Area feasible for recharge (Sq.km)	1546
Unsaturated Volume (MCM)	126
Recharge Potential (MCM)	2.52
Runoff available (MCM)	164
Surplus runoff available for recharge (MCM) (20% of runoff)	22

6.1.1.1 Artificial Recharge Structures in study area:

The area feasible for artificial recharge is 1546 sq.kms. The recharge potential by considering 2% of unsaturated volume and the total run off as 112 MCM. The surplus run off 22 MCM calculated as 20% of the total run off available in the district. The details in this regard are provided in the **Table 6.2**.

Table 6.2: Palnadu district Details

Area (Sq. Km)	7281
Recharge worthy area (Sq. Km)	1546
Average of Post Water Level (m bgl)	8
Run-off Village wise (MCM)	112
Uncommitted Runoff (20%)	22.45
Existing Check Dams	590
Existing Percolation Tanks	183
Runoff required for existing ARS(MCM)	5.47
Runoff considered for New ARS (MCM) (50% Of left Runoff)	8.5

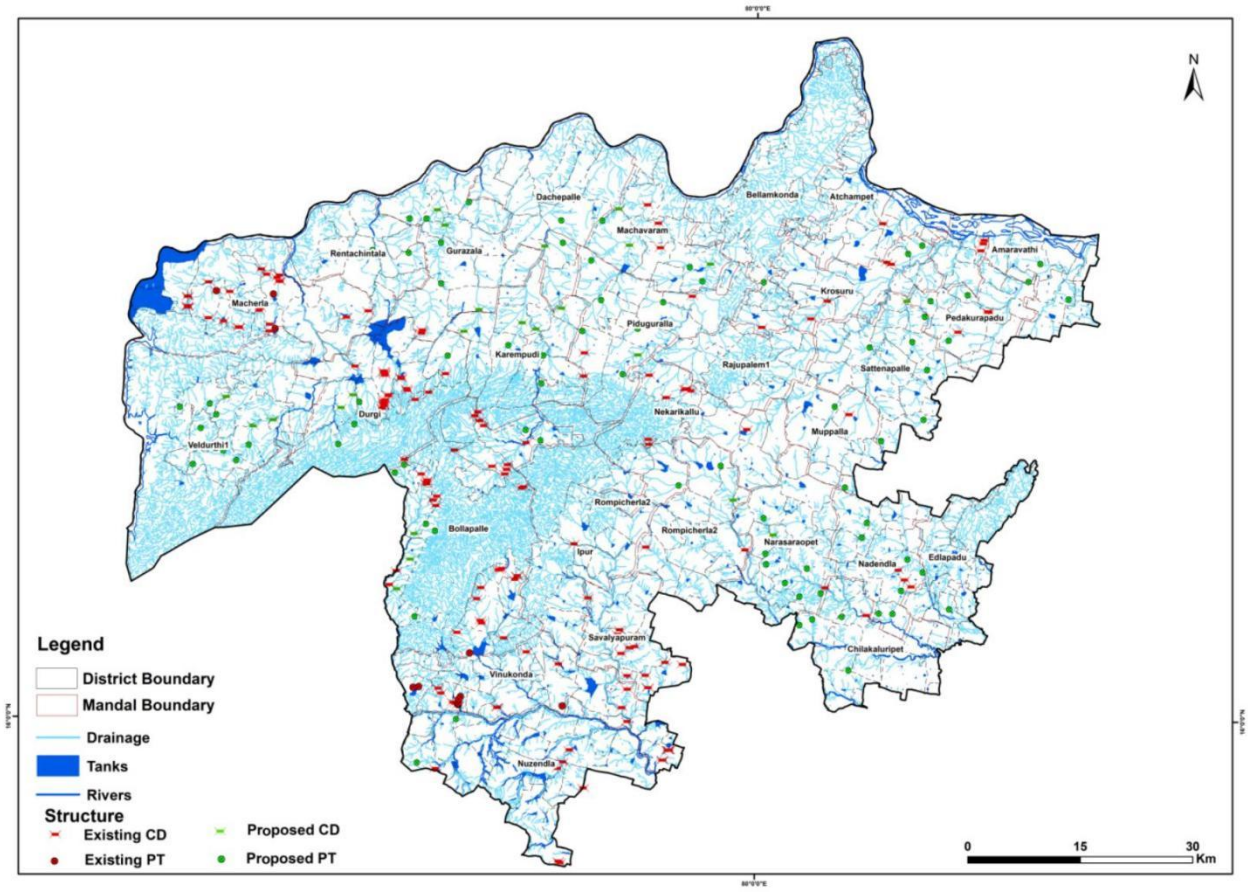


Fig 6.2: Existing and Proposed Artificial Recharge Structures

In the district, 82 percolation tanks and 24 check dams has been proposed considering the existing structures.

6.1.1.2 Other supply side measures:

Existing Artificial Recharge Structues 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). This will also help in sustainable management of groundwater resources.

6.1.1.3 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 10x 10 x 3 m. In the district, a total 11959 farm ponds exist which may save 4.1 MCM. In mandals, where stage of ground water extraction >50%, the existing farm ponds should be desilted and maintained so that it will greatly help in ground water augmentation.

6.1.2 Other measures

- To avoid the interference of cone of depression between the productive wells, intermittent pumping of bore wells is recommended through regulatory mechanism.

- The western part of the study area is known for its rich lime stone deposits. As mandated by Central Ground Water Authority, the mine dewatered seepage can effectively be utilized by filling the tanks and supply to agriculture fields.
- Power supply should be regulated by giving power in 4-hour spells two times a day in the morning and evening by the concerned department so that pumping of the bore well is carried out in phased manner to allow recuperations of the aquifer and increase sustainability of the bore wells.
- 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.

6.2 Expected Results and Out come

With the above interventions, the likely benefit would be the net saving of 10 MCM of ground water either through water conservation measures like adoption of drip and artificial recharge to ground water.

Acknowledgment

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