केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Parts of Hard Rock areas of Parakasam District Andhra Pradesh

दक्षिणी क्षेत्र, हैदराबाद

Sourthern Region, Hyderabad

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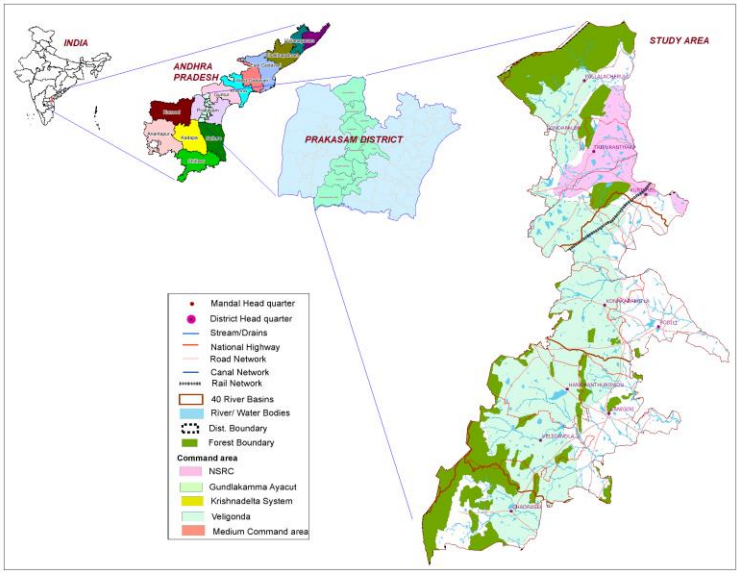
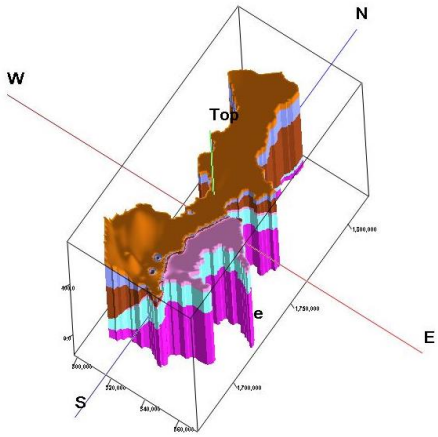
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN PARTS OF HARD ROCK AREAS OF PARAKASAM DISTRICT, ANDHRA PRADESH STATE





CENTRAL GROUND WATER BOARD
SOUTHERN REGION
HYDERABAD

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN PARTS OF HARD ROCK AREAS OF PARAKASAM DISTRICT, ANDHRA PRADESH STATE

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REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN PARTS OF HARD ROCK AREAS OF PARAKASAM DISTRICT, ANDHRA PRADESH STATE

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FOREWORD

India is the largest groundwater user in the world, with an annual groundwater withdrawal of 253 billion cubic meters (BCM). This represents about 25% of the world's groundwater withdrawals. India has about 112.3 BCM of water resources, of which 690 BCM is surface water and the remaining 433 BCM is groundwater. Out of the total available groundwater, 90% is used for irrigation purposes, mainly in agriculture. The remaining 10% is used for domestic and industrial purposes. According to the Composite Water Management Index (CWMI) report released by NITI Aayog in 2018, 21 major cities, including Delhi, Bengaluru, Chennai and Hyderabad, are at risk of running out of groundwater, affecting access for 100 million people. The CWMI report also states that the country's water demand is expected to be twice the available supply by 2030, which would mean serious water shortages for hundreds of millions of people and a 6% loss to the country's GDP.

In view of the above, it is necessary to scientifically plan groundwater development and its management in different hydrogeological environments, and develop effective management methods with the involvement of the community to better manage groundwater. The National Aquifer Mapping Project (NAQUIM) is being implemented by the Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India and is being undertaken by the Central Ground Water Board (CGWB). The NAQUIM provides the mapping of aquifers (water-bearing formations), their characterization, and the development of aquifer management plans to enable sustainable management of groundwater resources to delineate and describe aquifers and develop groundwater management plans for their sustainable development with stakeholder participation.

The report titled "Aquifer Mapping for Sustainable Ground Water Resources in parts of Hard Rock areas of Prakasam District, Andhra Pradesh State" prepared from hydrogeological, geophysical and hydro chemical data generated by CGWB over the years and integrated with the of data from various stake holder departments viz., ground water, irrigation, statistics, Rural Development and Micro irrigation etc. The data has been analysed and interpreted using various software tools, GIS and Rockworks for conceptualization of aquifers, their vertical and horizontal disposition and extent, assessment of ground water resources, quality of shallow and deeper aquifers and various aspects of ground water occurrence, distribution, and utilization in the district. The report identified specific groundwater related issues and recommended various supply and demand side management strategies for sustainable ground water development and management in the district.

This report has been prepared by Shri. B.J. Madhusudhan, Assistant Hydrogeologist and the efforts made by the officer in preparation of this report are greatly appreciated. Special Thanks to Smt Rani V.R, Scientist-C and Sh. Ravi Kumar Gumma, Scientist-C, for valuable suggestion/contributions in finalizing this document. Thanks to various organizations of the Government of Telangana for providing data required for compiling this report.

I hope this report will be helpful to District Administration and Stakeholder Departments for planning and sustainable management of groundwater resources in the district.

Sh. J. Siddhardha Kumar
Regional Director
CGWB, SR, Hyderabad

EXECUTIVE SUMMARY

The Study area is located in central part of Prakasam district, Andhra Pradesh covering an area of 4095 Km^2 and the area with 10 mandals and 283 revenue mandals and receives an annual rainfall of 763 mm.. The population of the district is ~ 5.25 lakh (2011 census). The area

Pediplain, Structural hills and pediments are the major geomorphic units in the study area, which is mainly drained by tributaries of River Krishna and Pennar. There is only one major project in the area (Veligondla Project) with **~1503** Check dams and ~**373** percolation tanks / mini percolation tanks with combine capacity of 6.36 MCM. Groundwater contributes ~67% of the net irrigated area and surface water contributes 33%. Till 2019-20 ~ 114888 ha area is brought under micro-irrigation practices (Drip and Sprinkler).

Total cropped area of the study area is 116347 ha (~28%) and forests occupy ~21 % of the area. The total gross cropped area during the year 2019-20 is 116347 ha and net sown area is 115198 ha, remaining agricultural land was kept fallow. The gross area cropped during Khariff season is 193177 ha and the major crops grown during Khariff season are Pulses (52%), Cotton (10%) and Paddy (11%). The soils are mainly clayey skeletal, mixed loamy and loamy types. The area is underlain by meta-sediments comprising of Shales, Quartzites (56%), Shales and slates (43%) and Schists (0.4%) of Cuddapah Super Group.

Datagap analysis carried out by integrating data collected from state govt. and CGWB data. Integration and interpretation of data done for ground water exploration, geophysical studies, ground water quality and water level. (Hydrogeological data from 9 (CGWB & 20 (SGWD), Geophysical: 15, water quality: 14 and well inventory: 30) used for datagap analysis. The study corroborates that the extraction is mainly through boreholes of 60-100 m depth, with yield between <1 to 11 litres/second (lps). Majority of fractures occur within 100 m depth and deepest fracture is encountered at the depth of 115 m depth. Ground water yield from weathered and fractured aquifer varies from <1 to 2 lps. To understand the ground water levels from 29 wells (9 wells of CGWB and 20 wells of SGWD) are utilized. The depth to water level varies from 3.7 to 49.5 meter below ground level (m bgl) during pre-monsoon period and (average: 14.39 m bgl) and 2.02 to 26.9 m bgl (average: 10.03) during post-monsoon season 2020.

Majority of the area shows water level between 10 and 20 m bgl during pre-monsoon and post monsoon except the western part of the study area. Deeper water levels of more than 20 m bgl is confined to the western part. During post monsoon the area of coverage increased for the water level in the range of 10 to 20 m bgl when compared to pre-monsoon period. Deeper water level of more than 20 m bgl is confined to isolated pockets in Pullalacheruvu and Veligondla mandals during post monsoon period.

Majority of the area shows rise in water level, when compared to pre-monsoon in the range of 0.06 to 37.38 m.

The chemical nature of groundwater in the study area shows that 79% of samples are not fit for drinking purpose. Electrical conductivity varies from 810-4010 (avg: 2439 µ /Siemens/cm) and concentration of NO_3 ranges from 36-430 mg/l. The concentration of Flouride ranges from 0.7 to 3.7 mg/l with an average of 2.2 mg/l.

Aquifers were characterized in terms of potential and quality based on integrated hydrogeological data and various thematic maps. Weathered zone is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~20 m depth and the fractured zone (fractured granite) is considered up to the depth of deepest fracture below weathered zone (~20-110 m).

As per 2020 GEC report, the net annual groundwater availability is 259 MCM, gross ground water draft for all uses 97 MCM, provision for drinking and industrial use for the year 2025 is 17 MCM and net annual ground water potential available for future irrigation needs is 169 MCM. Stage of ground water development varies from 15.7 % in Veligandla mandal to 161.7 % in Pullalacheruvu mandal (avg: 37.4 %). Out of 10 mandals, 9 mandals falls in safe category (63% of area) and one mandal in over-exploited category.

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. Supply side management has been prepared separately for urban and rural areas.

In Prakasam District there are 952 Minor Irrigation Tanks (363 M.I + 589 Panchayati Raj) having a registered ayacut of 135427 Acres. During 2013-14 an ayacut of 28706 Acres is irrigated. (5^{th} MI Census). In the study area, Chadrashekarpuram, Donakonda, Kanigiri,

Hanumanthunipadu, Konakanamitla, Podili, Pullalacheruvu, Tripuranthakam and Veligandla, mandals are also will be covered under the proposed Veligonda project, which is contemplated to create additional ~38075 hectare of irrigation potential. The crop water requirement for 38075 ha is 228 MCM for ID crops. After the implementation of the project, the area under rainfed irrigation (38075 ha) in the study area will be brought into the ambit of assured surface water irrigation. The conserved surface water can be effectively being utilized to supplement irrigation, which will reduce the stress on ground water.

Based on the availability of ground water resources and existing ground water conservation structures, 36 artificial recharge structures (25 CD's and 14 mini PT's in 25 villages) with a total cost of 4.6 crores are recommended to 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), with these interventions, the likely benefit would be the net saving of 4.6 MCM recharge of ground water.

1. INTRODUCTION

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

Hard rocks (Granites/Gneisses) lack primary porosity, and ground water occurrence is limited to secondary porosity developed by weathering and fracturing. Weathered zone is the potential recharge zone for deeper fractures and excessive withdrawal from this zone leads to drying up in places and reducing the sustainability of structures. Besides these quantitative aspects, groundwater quality also represents a major challenge which is threatened by both geogenic and anthropogenic pollution. In some places, the aquifers have high level of geogenic contaminants, such as fluoride, rendering them unsuitable for drinking purpose. High utilization of fertilizers for agricultural productions and improper development of sewage system in rural/urban areas lead to point source pollution viz., nitrate and chloride.

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

1.1 Scope of study: The main scope of study is summarised 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 data base and ground water resource estimation.
3. Quantification of groundwater availability and assessing its quality.
4. To delineate aquifer in 3-D along with their characterization on 1:50, 000 scale.
5. Capacity building in all aspects of ground water development and management through information, education and communication (IEC) activities through education, awareness and training.
6. Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable ground water management.

1.2 Area details: The Study area consists of 10 mandals with 283 revenue villages located in Central part of Prakasam district, Andhra Pradesh State covering a geographical area of 4095 km^2, lies between 15° 10' 49"- 16° 9' 28" N latitude and 79° 16' 56"- 79° 37' 2" East longitude (**Fig.1.1**). Out of total area, the hilly and forest area about is 862 km^2 (21%). The list of the mandal and its geographical areas are provided below

Sl.No	Mandal Name	Geographical Area (sq.km)	Forest Area (sq.km)	Normal Rainfall (mm)	Main Crops	Categorization (GEC-2020)
1	Chandrasekharapuram	532.8	216.3	777.1	Redgram,Chillies	Safe
2	Donakonda	390.7	11.7	728	Redgram, Chillie	Safe
3	Hanumanthunipadu	346.2	35.9	753.3	Chillies, Redgram	Safe
4	Kanigiri	513.3	61.6	795.2	Redgram,Chillies	Safe
5	Konakanamitla	492.5	67.3	770.5	Chillies, Redgram	Safe
6	Kurichedu	294.3	30.0	771.2	Chillies, Redgram	Safe
7	Podili	298.8	6.0	789.1	Redgram,Chillies	Safe
8	Pullalacheruvu	645.7	370.4	709.3	Chillies, Castor, Rice	OE
9	Tripuranthakam	263.9	7.5	728.8	Chillies, Redgram, Castor	Safe
10	Veligandla	317.1	55.5	808.8	Chillies, Redgram	Safe

The population of the study area is 5.25 lakhs (2011 census) and density is 137 persons/Km^2 (CPO, Prakasam).

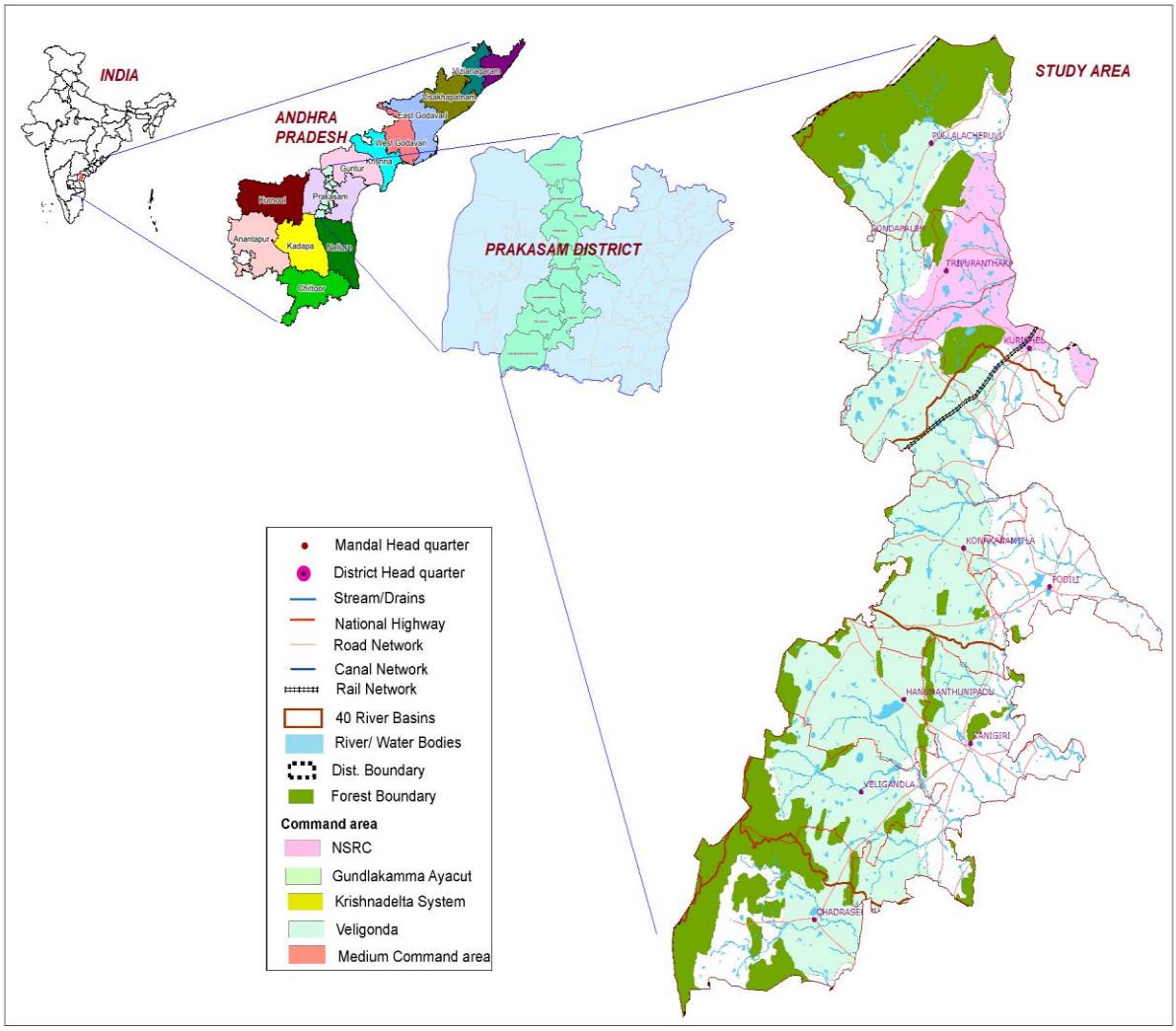

Fig-1.1 Location Map of the Study Area, Prakasam District (Parts), AP

1.4 Climate and Rainfall: The climate of the study area is characterised by hot summer and generally dry weather except during S-W monsoon season. The normal annual rainfall of the study area is 763 mm (Indian Meteorological Department) and annual rainfall between 709 mm (Pullalacheruvu) to 808 mm (Veliganda) (**Fig. 1.2**). The South west monsoon contributes ~50%, North east monsoon contributes ~40%, and remaining by winter season.

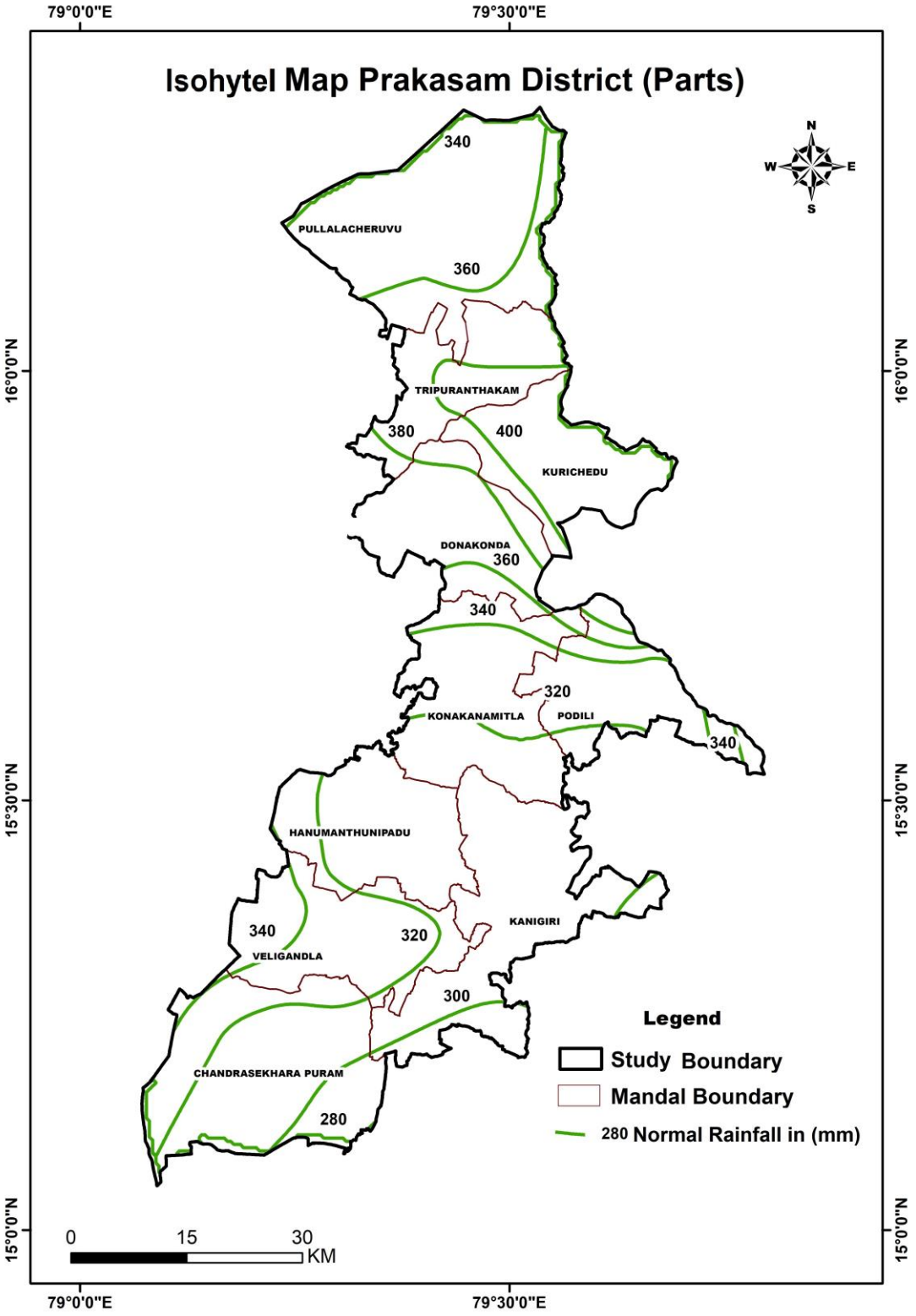

Fig-1.2 Isohytel map of the Study Area, Prakasam District (Parts), AP

1.5 Geomorphological Setup: Pediplain, Structural hills and pediments are the major geographic units in the study area. The details and percentage of geomorphological features of the area is given in the table and depicted in **Fig-1.3.**

Geomorphological Unit	Area (sq.km)	Percentage		Geomorphological Unit	Area (sq.km)	Percentage
Channel bar	0.3	0.01		Pediment	436.5	10.68
Channel fill	98.3	2.40		Pediplain	2573.9	62.97
Denudational hill	191.8	4.69		Piedmont slope	2.1	0.05
Flood plain	79.7	1.95		Piedmont zone	87.3	2.13
Inselberg	0.5	0.01		Point bar	0.2	0.00
Intermontane valley	22.6	0.55		Residual hill	32.5	0.79
Linear ridge	0.3	0.01		Structural hill	486.8	11.91
Paleo channel	12.5	0.30		Structural valley	62.7	1.53

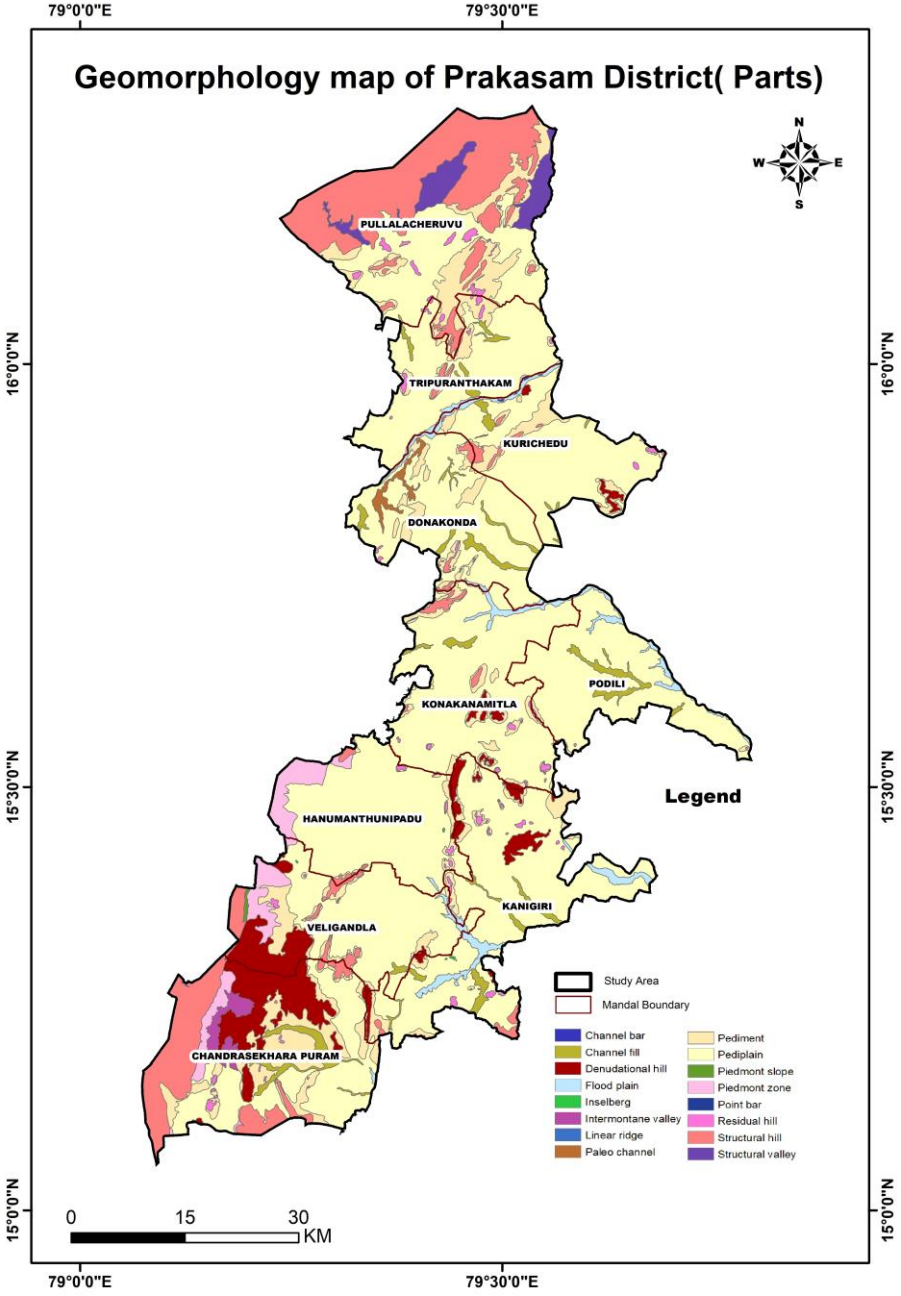

Fig-1.3 Geomorphology of the Study Area, Prakasam District (Parts), A.P

1.6 Drainage and Structures: The study area is mainly drained by tributaries of River Krishna and Pennar. The drainage is dendritic and parallel in nature. The map depicting drainage and water bodies is presented in **Fig.1.4**.

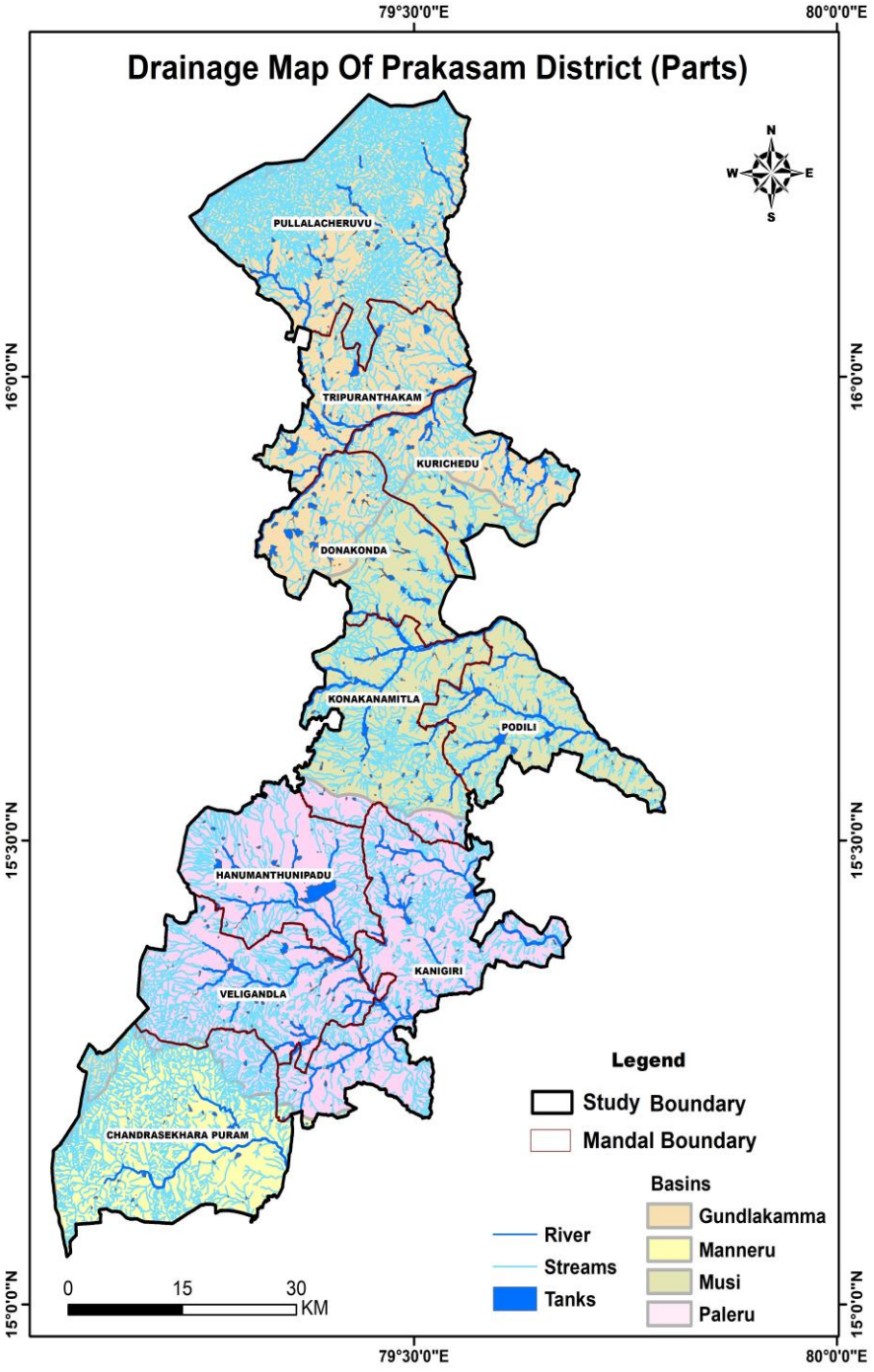

Fig-1.4 Drainage of the Study Area, Prakasam District (Parts), A.P

1.7 Land use and cropping pattern (2019-20): Out of the of the total geographical area of 4095 sq.kms, the total cropped area is 1163 sq.km (~28%) and area sown more than once is 11.50 sq.km (~1%), Forest occupies 862 sq.km (~21%), Barren and cultivable land is 531 sq.km (12.9%), land put to non-agricultural uses is 344 sq.km (8.4%), Cultivable waste is 205 sq.km (5%). During Khariff season, main crops grown are Paddy, Cotton and Chillies. During Rabi season, main crops grown are Paddy, maize, oil seeds. The other crops are turmeric, jowar. Land use and land cover map of the study area is depicted in **Fig. 1.5** and tabulated below.

Sl.No	Mandal Name	Geographical Area	Forest Area	Barren & Uncultivable Land	Land Put To Non Agri Uses	Culturable Waste	Permanent Pastures & Grazing Land
1	Pullalacheruvu	64565	37044	4443	2550	1976	1787
2	Tripuranthakam	26387	750	3650	2295	1604	548
3	Donakonda	39069	1174	8079	3864	4520	5780
4	Kurichedu	29427	3000	5034	1921	2001	3241
5	Konakanamitla	49249	6733	6012	4170	3660	4441
6	Podili	29883	600	757	4190	1686	2359
7	Hanumanthunipadu	34619	3587	5400	2215	1130	146
8	Veligandla	31712	5554	3688	3738	794	346
9	Kanigiri	51333	6162	10813	5629	1160	2519
10	Chandrasekhara Puram	53275	21627	5239	3864	2018	3424
	Total	**409519**	**86231**	**53115**	**34436**	**20549**	**24591**

Sl.No	Mandal Name	Land Under Misc. Tree Crops & Groves not included in NAS	Other Fallow Lands	Current Fallow Lands	Net Area Sown	Total Cropped Area	Area Sown More than Once
1	Pullalacheruvu	214	4324	1207	11020	11130	110
2	Tripuranthakam	5	2192	4575	10768	11479	711
3	Donakonda	0	1185	4698	9769	9793	24
4	Kurichedu	23	939	1316	11952	11952	0
5	Konakanamitla	0	3647	5398	15188	15454	266
6	Podili	42	5383	453	14413	14418	5
7	Hanumanthunipadu	0	7641	6019	8481	8481	0
8	Veligandla	0	3624	3935	10033	10033	0
9	Kanigiri	0	5400	3878	15772	15805	33
10	Chandrasekhara Puram	0	5005	4296	7802	7802	0
	Total	**284**	**39340**	**35775**	**115198**	**116347**	**1149**

Source: CHIEF PLANNING OFFICER, ONGOLE

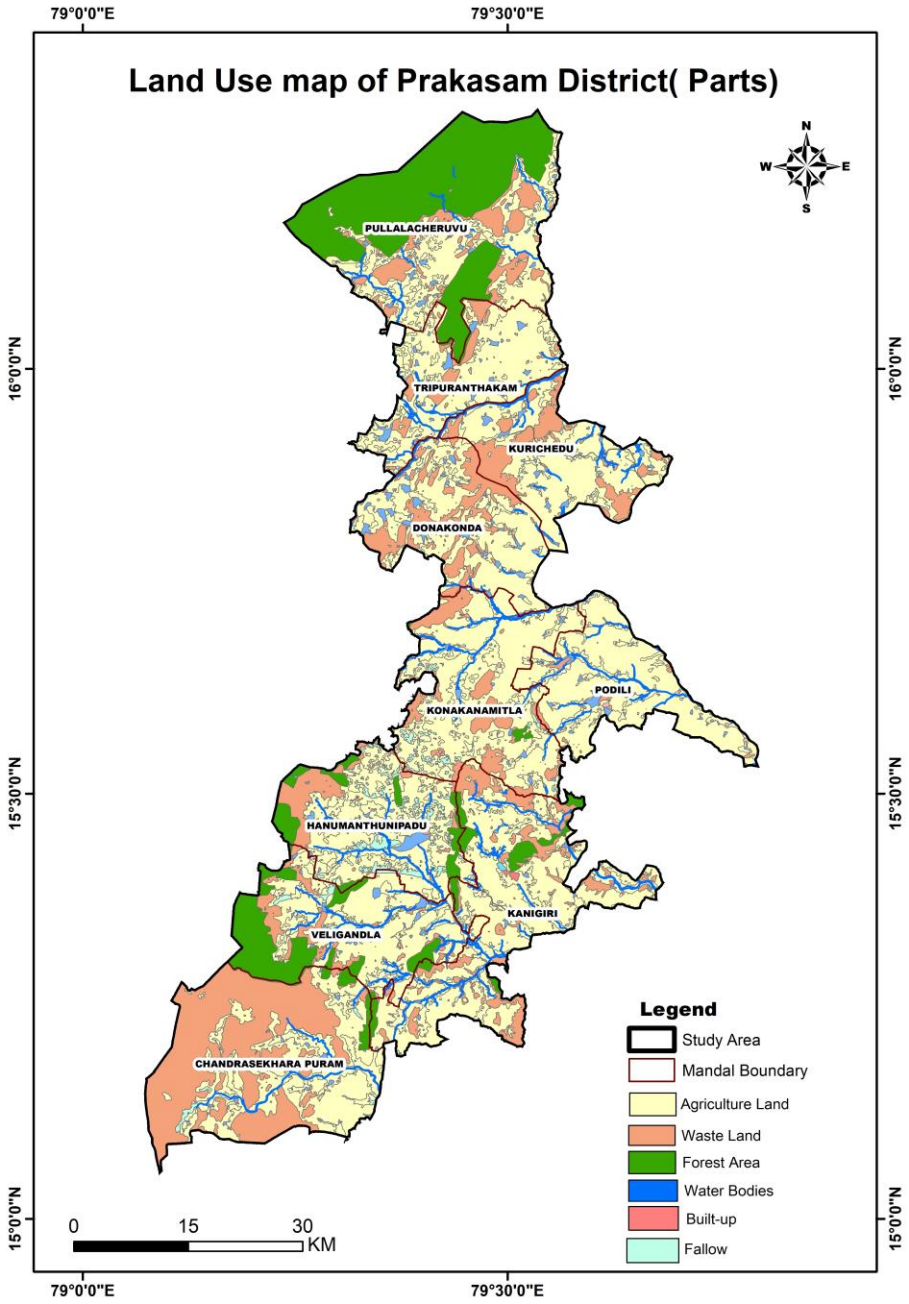

Fig-1.5 Land use map of the Study Area, Prakasam District (Parts), A.P

1.8 Agricuture:

Major part of the district is occupied by agricultural area (28%). In the district, forest occupies nearly 21% of the area and the remaining area is occupied by permanent pasturewaste land etc (**Fig.1.5**).The total gross cropped area during the year 2019-20 is 116347 ha and net sown area is 115198 ha, remaining agricultural land was kept fallow. The gross area cropped during Khariff season is 193177 ha and the major crops grown during khariff season are Pulses (52%), Cotton (10%) and Paddy (11%). The gross area cropped

during Rabi season is 29668 ha and the major crops grown during the period include Pulses (73%) and Paddy (19%).

1.9 Irrigation:

The study area is mainly irrigated by ground water. Out of total gross irrigated area of 29726 ha, ~ 19952 ha (~67%) is irrigating through tube wells. The remaining 33% (9774 ha) is through canal.

Veligonda Project is on going irrigation project which is located in the study area (Markapuram divison). By commissioning of this project irrigational facilities will be provided to 4,59,000 acres and drinking water to 1.5 million people in 29 Mandals of fluoride and drought affected areas in Prakasam district and adjacent Nellore and Kadapa district by diverting 43.5 TMC (1232 MCM) of floodwater of Krishna River from foreshore of Srisailam Reservoir near Kollamvagu and proposed to store in Nallamalasagar Reservoir. The water for the project is drawn through two 18.8 km long tunnels across Nallamala hills. The proposed Veligonda project and its canal network in the study area are shown in **Fig-1.6**.

1.10 Prevailing water conservation/Recharge practices: In the study area there are **~1503** Check dams and ~**373** percolation, mini percolation tanks with combine capacity of 6.36 MCM. Till 2019-20 ~ 114888 ha area is brought under micro-irrigation practices.

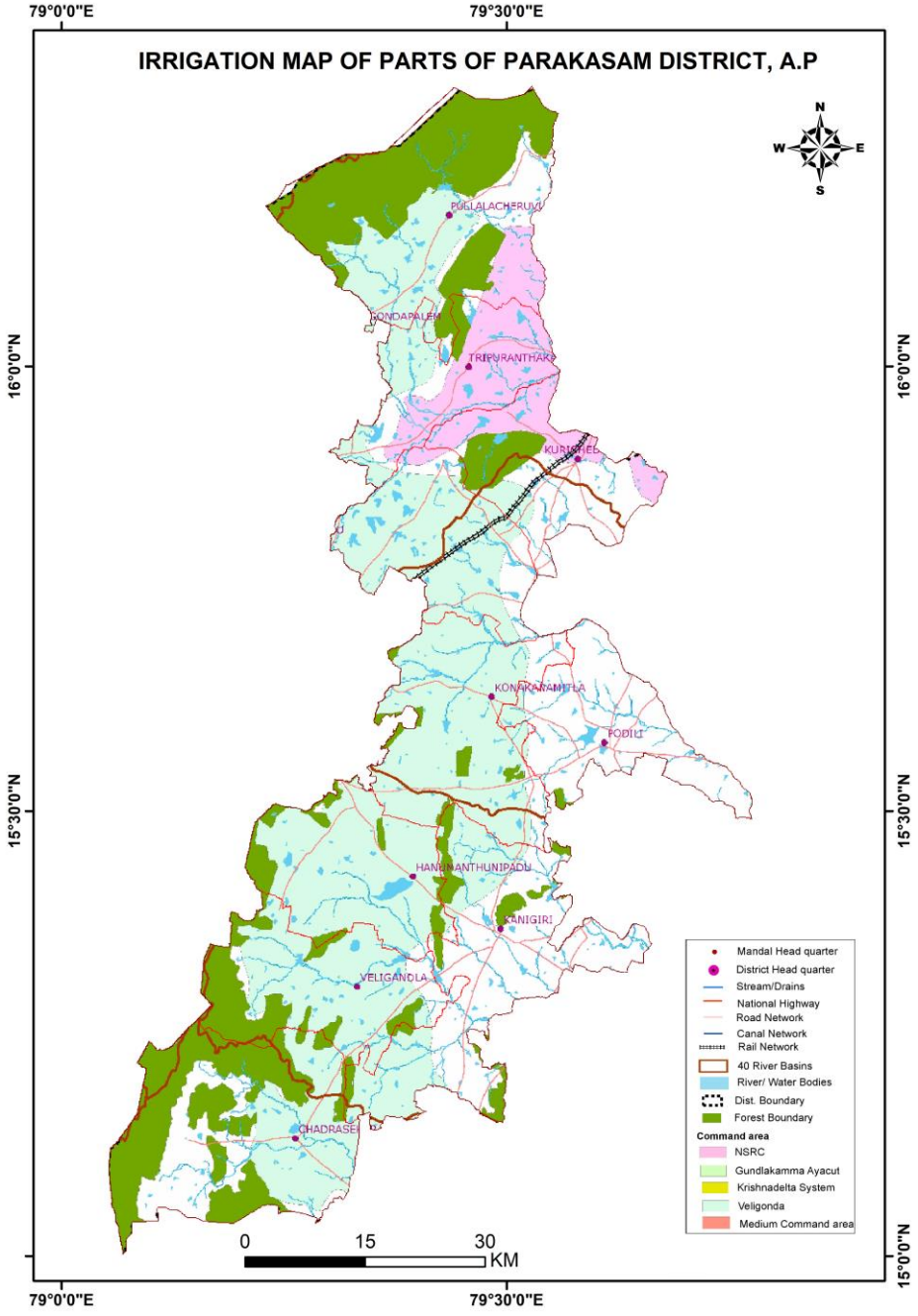

Fig- 1.6 Irrigation Map of the Study Area, Prakasam District (Parts), A.P

1.11 Geology: The area is mainly underlain by the Meta Sediments/ Rocks (Shales and Quartzites) belonging to Cuddapah Super Group of Proterozoic age and Gniesses of Archean age (Fig 1.7). The geological succession is shown below.

Table- Geological succession of the Study area

Age	Group	Lithology
Proterozoic	Cuddapah Super Group	Quartzites, Shales
Archaean	Dharwar Super Group	Schists, Quartzites, Gniesses, Khondalites

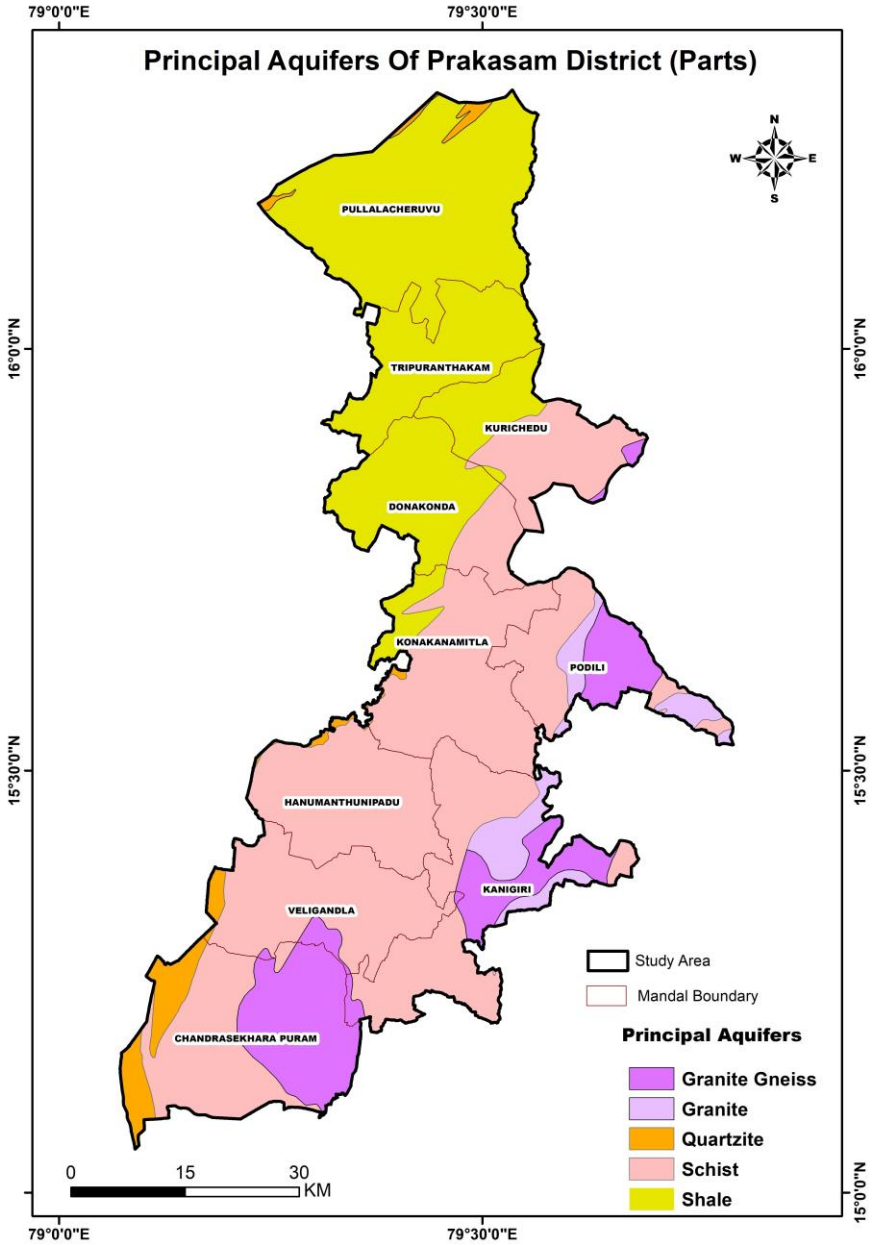

Fig-1.7 Geology Map of the Study Area, Prakasam District (Parts), AP

2. DATA COLLECTION AND GENERATION

Collection and compilation of data for aquifer mapping studies is carried out in conformity with Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various data generation activities **(Table-2.1)**.

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

S. No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, 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) etc.
		Hydrological Parameters on groundwater recharge	Soil infiltration studies, rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of sub-surface hydrogeological sections.
		Generation of additional water quality parameters	Analysis of groundwater for general parameters including fluoride.
3.	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.
4.	Aquifer Management Plan	Preparation of aquifer management plan	Information on aquifer through training to administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain.

2.1 Hydrogeological Studies

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of ground water occurring in the subsurface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. The principal aquifer in the area is

Meta sediments (Shales and quartzites) and the occurrence and movement of ground water in these rocks is controlled by the degree of interconnection of secondary pores/voids developed by fracturing and weathering. The 88 hydrogeological data points (Exploration: 9 (CGWB & 20 (SGWD), Geophysical: 15, water quality: 14 and well inventory: 30) used for datagap analysis is shown in **Fig.2.1**.

2.1.1 Groundwater occurrences and movement: Groundwater occurs under unconfined and semi-confined conditions below weathered zone. The main aquifers constitute the weathered zone at the top, followed by a discrete anisotropic fractured/fissured zone at the bottom which are interconnected and generally extending down to 115 m depth. The storage in granite rocks is primarily confined to the weathered zone and its overexploitation, mainly for irrigation purpose, has resulted in desaturation of weathered zone at many places. At present, extraction is mainly through boreholes of 60-100 m depth, with yield between <1 to 11 litres/second (lps). Majority of fractures occur within 100 m depth and deepest fracture is encountered at the depth of 115 m depth. The hydrogeological map of the area is presented in **Fig. 2.2**.

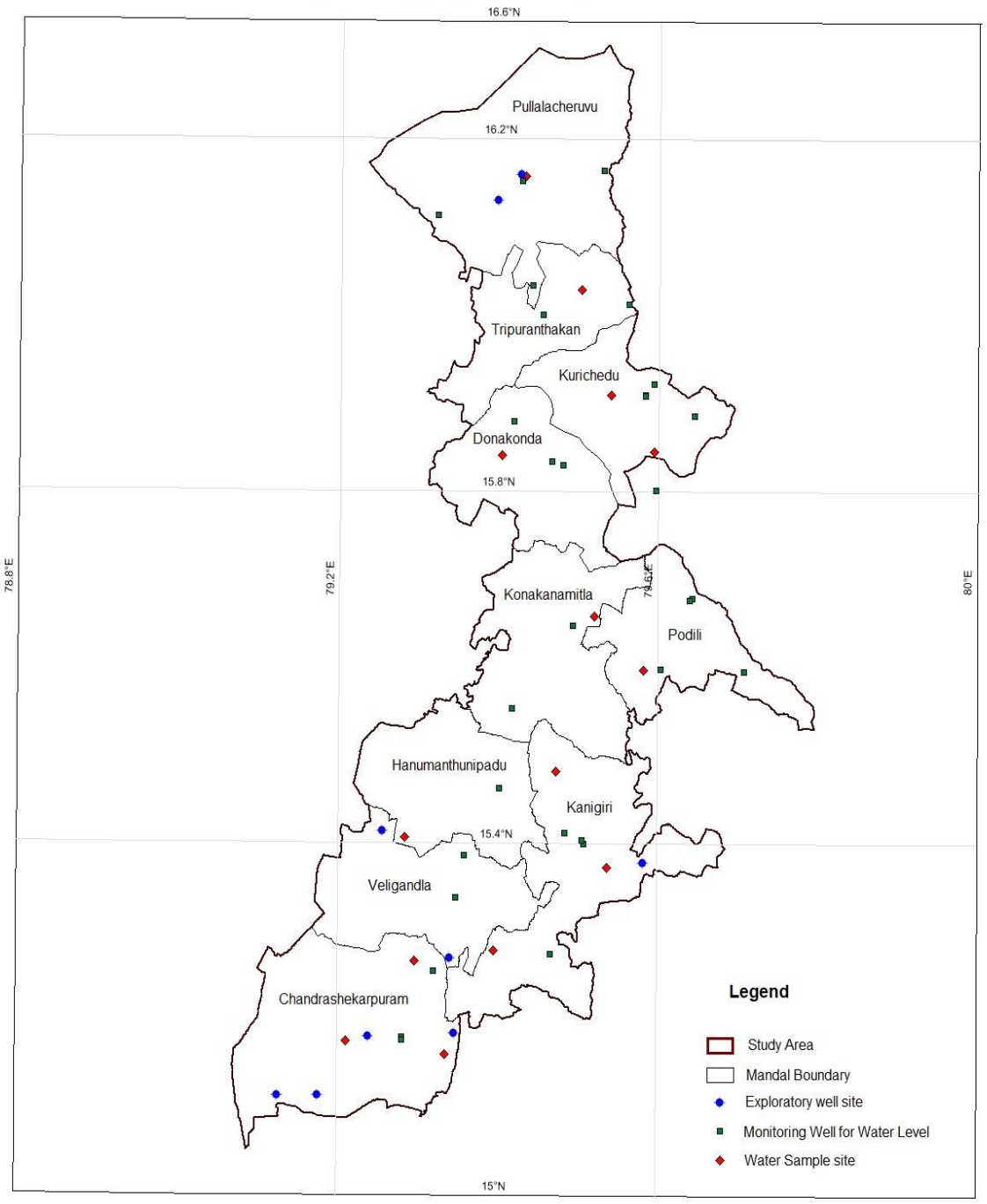

Fig- 2.1 Data used for Aquifer mapping in the Study Area, Prakasam District (Parts) A.P.

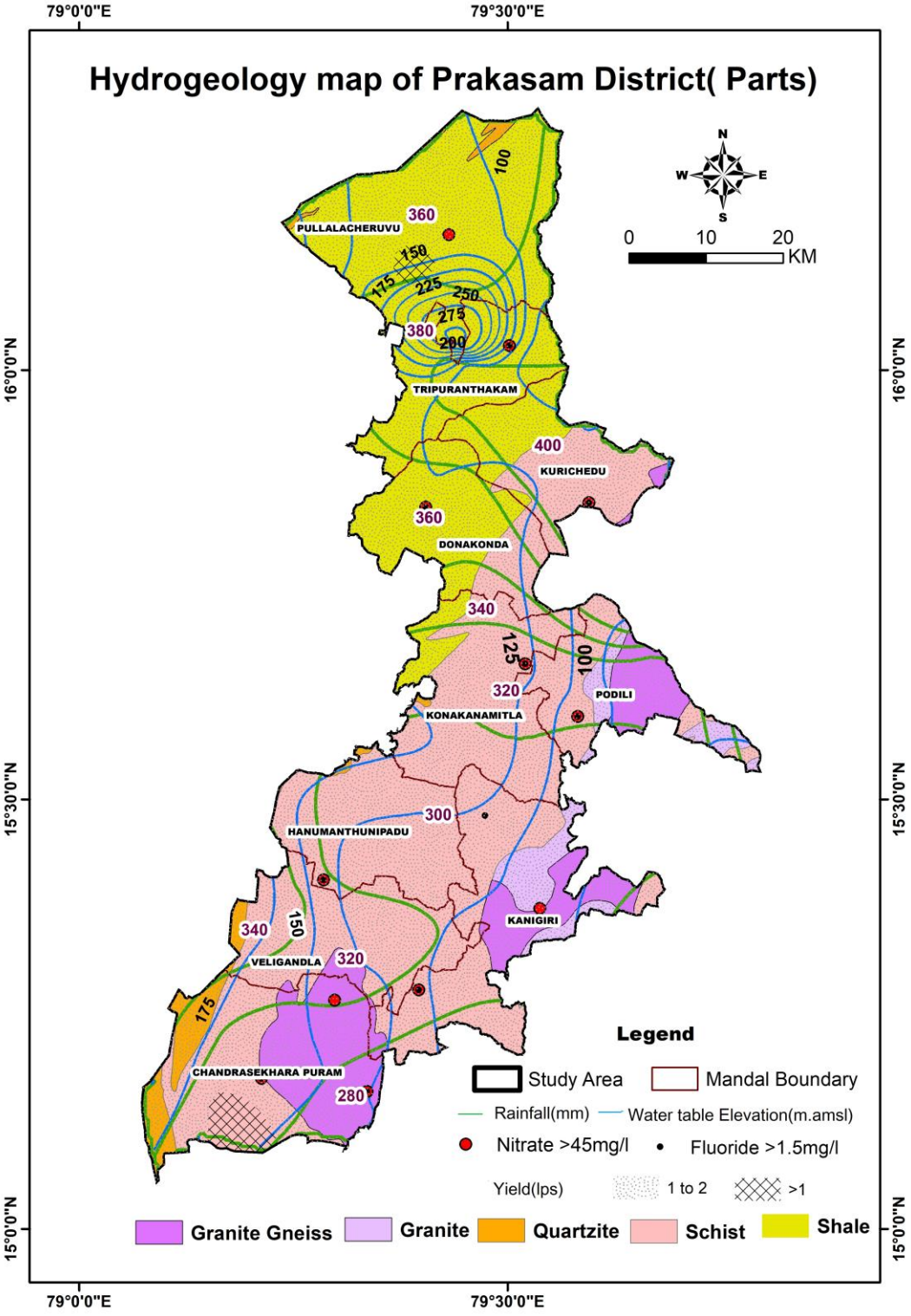

Fig-2.2 Hydrogeology of the Study Area, Prakasam District (Parts), A.P

2.1.2 Exploratory Drilling: As on 31/03/2019, SGWD drilled 20 wells in the study area. An analysis exploratory bore wells drilled by SGWD indicate that 2 bore wells are <30 m depth, 17 bore wells are of 30-60 m depth and remaining 03 wells are of 60-100 m depth range. The

depth to the deepest fracture occurred in these formation is 68 m at Podili and deepest fractured dechiphered through VES studies is 109 m in Chandrashekarpuram.

2.1.3 Ground water Yield: Ground water yield from weathered and fractured aquifer varies from <1 to 2 lps. Based on the combined data of CGWB and SGWD yield map is prepared and shown in **Fig.2.2**. In most of the area yield varies from 1 to 2 lps.

2.2 Water Levels (2020): Ground water levels from 27 wells (9 wells of CGWB and 18 wells of SGWD) are utilized for Water levels of pre-monsoon and post-monsoon season.

2.2.1 Water Table Elevations: During pre and post-monsoon season (May and November) of 2020, the water-table elevation ranges from 25 to 275 (m amsl) respectively and general ground flow is towards South East direction (**Fig.2.3**).

2.2.2 Depth to Water Levels (DTW): The DTW varies from 3.7 to 49.5 meter below ground level (m bgl) during Pre-monsoon period and (average: 14.39 m bgl) and 2.02 to 26.9 m bgl (average: 10.03) during post-monsoon season of 2020 respectively.

Majority of the area shows water level between 10 and 20 m bgl during pre-monsoon except the western part of the study area. Deeper water levels more than 20 m bgl is confined to the western part. Water levels are shallow in the study area mainly in the range of 10 to 20 m bgl (~65%). Premonsoon depth to water level map is depicted in **Fig.2.4**. During post-monsoon season, majority of the area shows water level in the range of 10-20 m bgl, but the area of coverage increased, when compared to pre-monsoon period. Deeper water level of more than 20 m bgl is confined to isolated packotes in Pullalacheruvu and Veligondla mandals. The post monsoon depth to water level map is depicted as **Fig-2.5**.

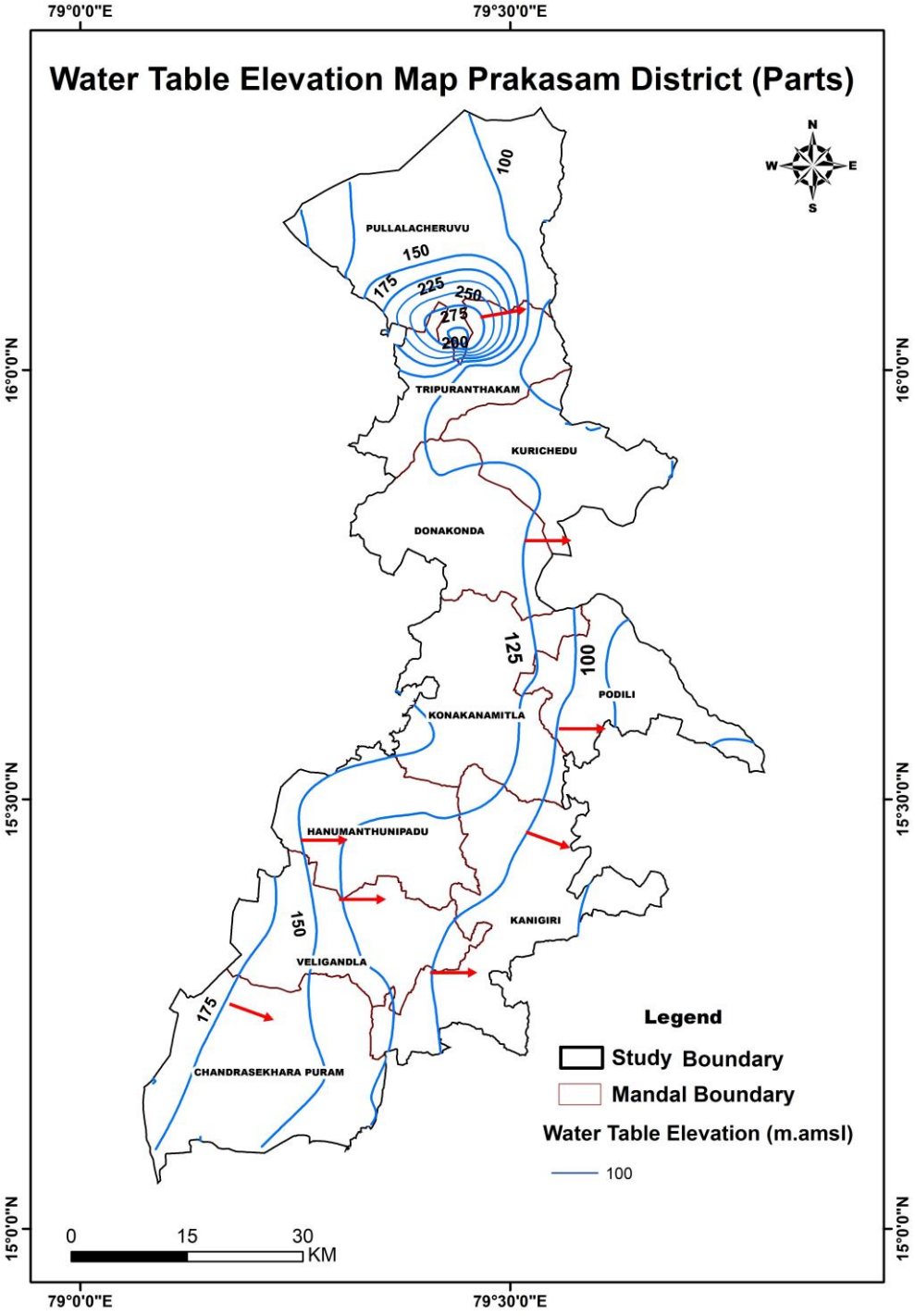

Fig- 2.3 Water Table Elevations

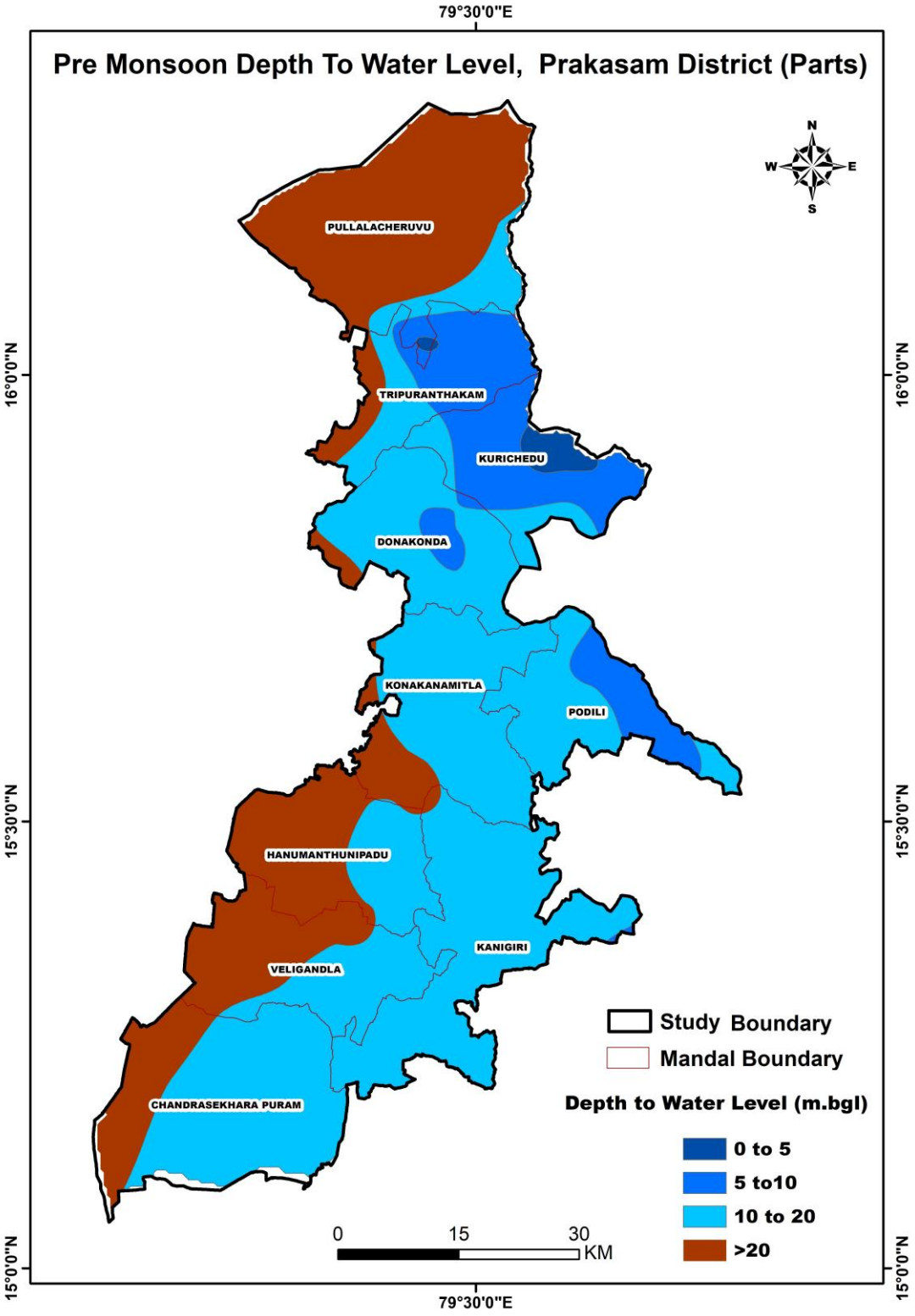

Fig- 2.4 Depth to Water Level (Pre Monsoon)

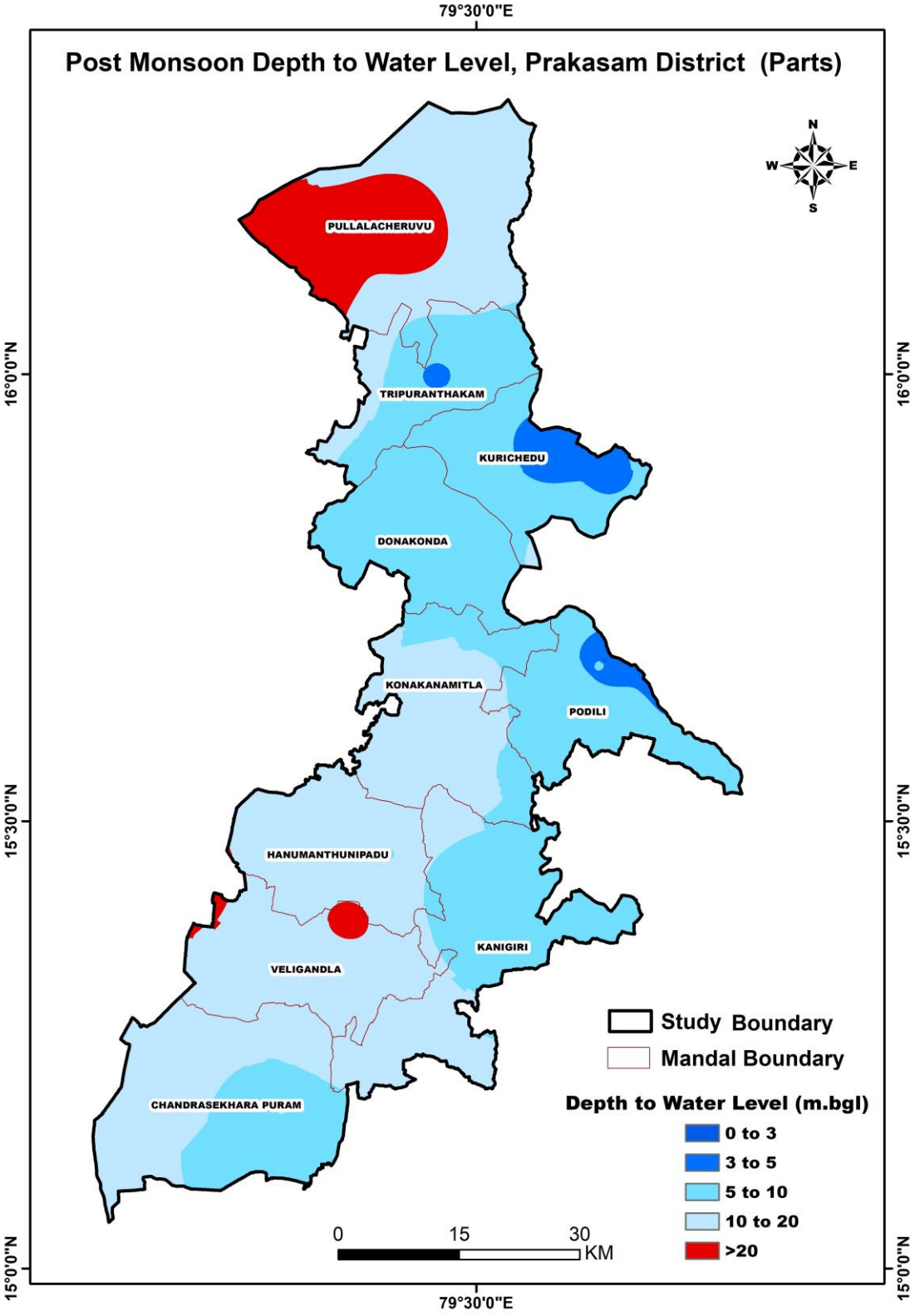

Fig- 2.5 Depth to water Levels (Post Monsoon)

2.2.3 Water Level Fluctuations (May vs. November): The water level fluctuations vary from -13.13 to 37.38 m with average fall of - 5.03 m and rise of 9.92 m (**Fig.2.6**). Out of 25

wells, in 12 wells (50%) shows fall in water levels (-0.03 to -13.13 m) and 10 wells show rise in water levels (0.06 to 37.38 m) and 3 wells show neither rising nor fall in water levels. In general, water level fluctuation shows rise in water level from pre to post monsoon seasons.

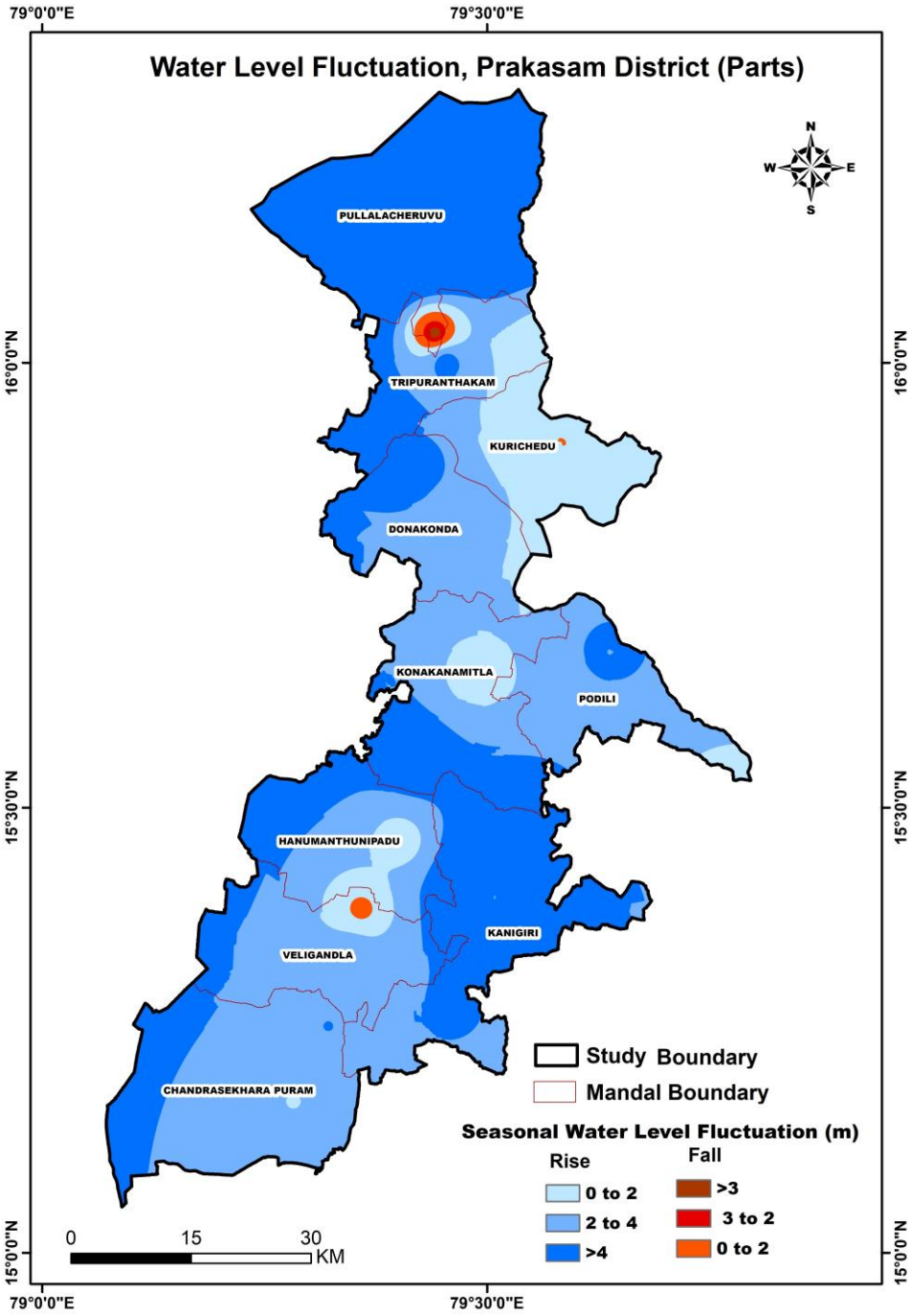

Fig.2.6: Water Level Fluctuations (m) (Post monsoon with respect to Pre-monsoon)

2.4 Hydro-chemical Studies

To understand chemical nature of groundwater in the area, water quality analysis data from 14 wells have been considered. Groundwater from the area is alkaline in nature with pH in the range of 7.05 to 7.82 (Avg: 7.49). Electrical conductivity varies from 810 to 4010 (avg: 2439) µ/Siemens/cm. In majority of area (80 %) covering northern, central and southern part, EC is in the range of 1500-3000 µ/Siemens/cm covering all the mandals excluding Pullalacheruvu mandal and 20 % of the area where EC is < 3000 µ/Siemens/cm **(Fig-2.7).** The Concentration of NO_3 ranges from 36-430 mg/l. Nitrate concentration upto 45 mg/l is observed in 1 sample and above permissible limit of >45 mg/l is observed in remaining samples (**Fig-2.8**). The concentration of Flouride ranges from 0.70 to 3.70 mg/l with an average of 2.2 mg/l. In 11 samples (78%), F concentration is observed more than the permissible limits (>1.5 mg/l) and in 3 (22%) samples F is with in the permissible range (<1.5 mg/l) **(Fig-2.9).**

2.4.1 Suitability of Groundwater for drinking purpose:

Suitability of ground water for different purposes is assessed based on the BIS (2012) standards. It is found that, 79 % samples (11 out of 14 analyzed) are not suitable for drinking purpose, where F is beyond the maximum permissible limit of BIS during post monsoon.

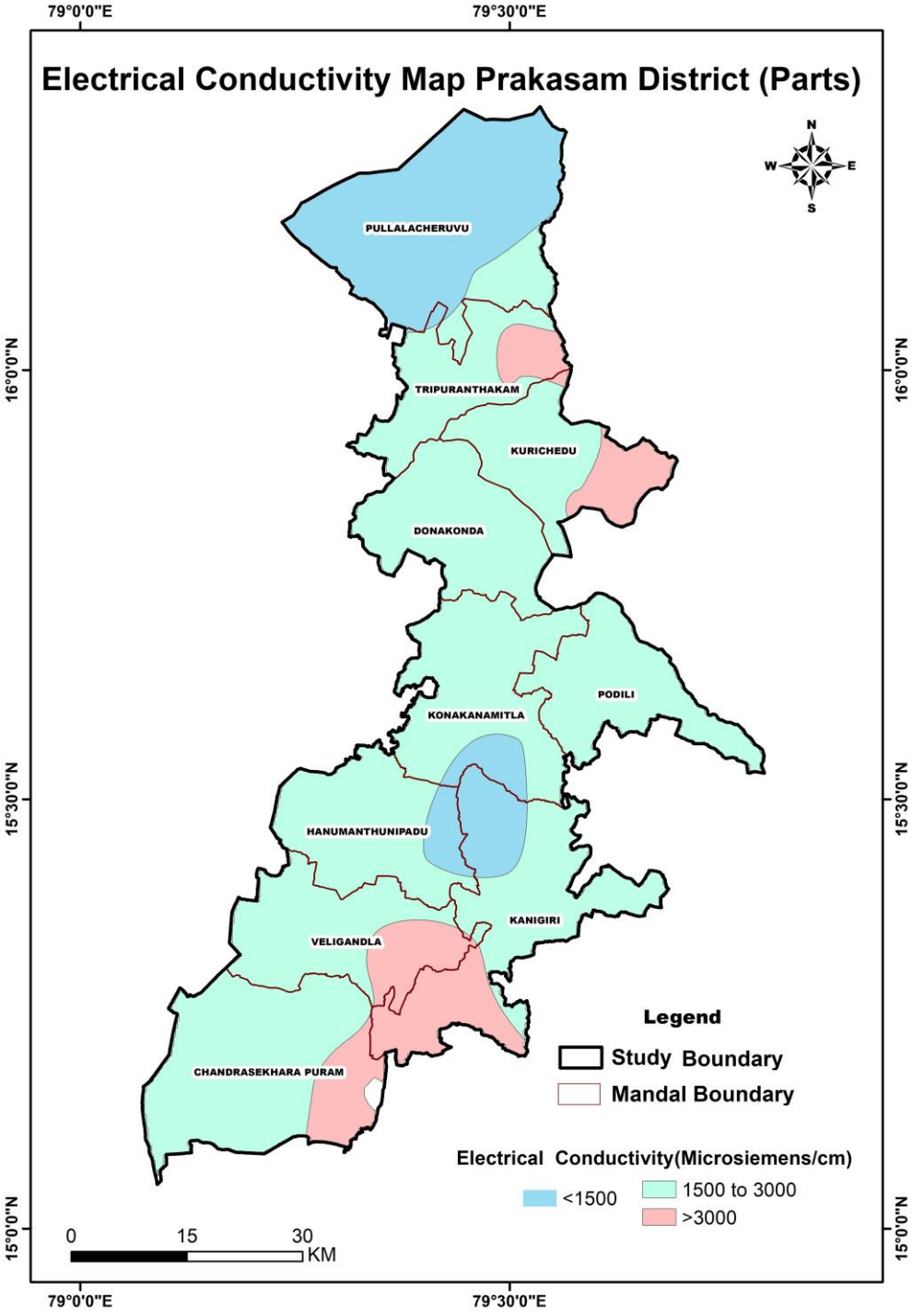

Fig.2.7: Distribution of Electrical conductivity

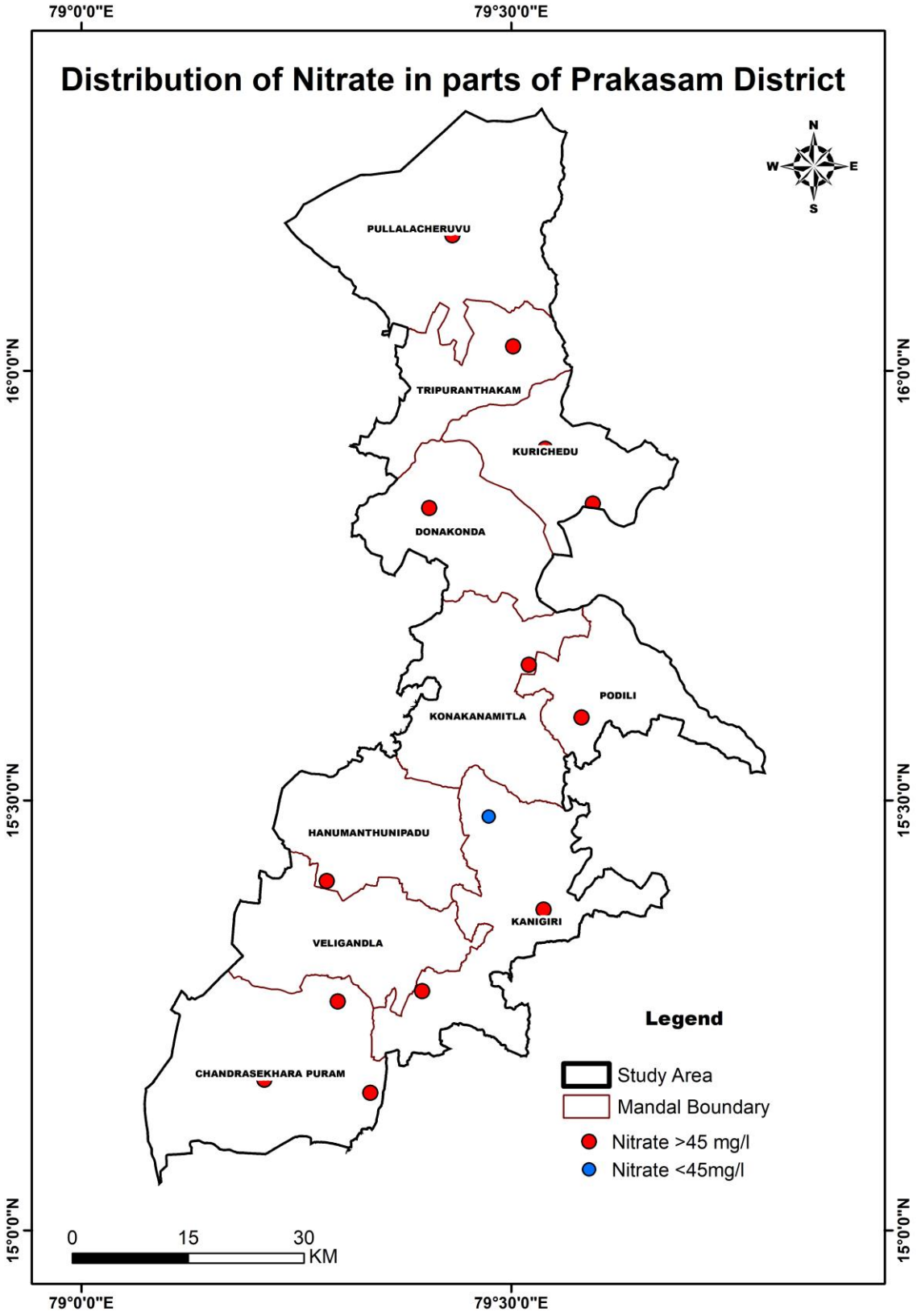

Fig.2.8: Distribution of Nitrate

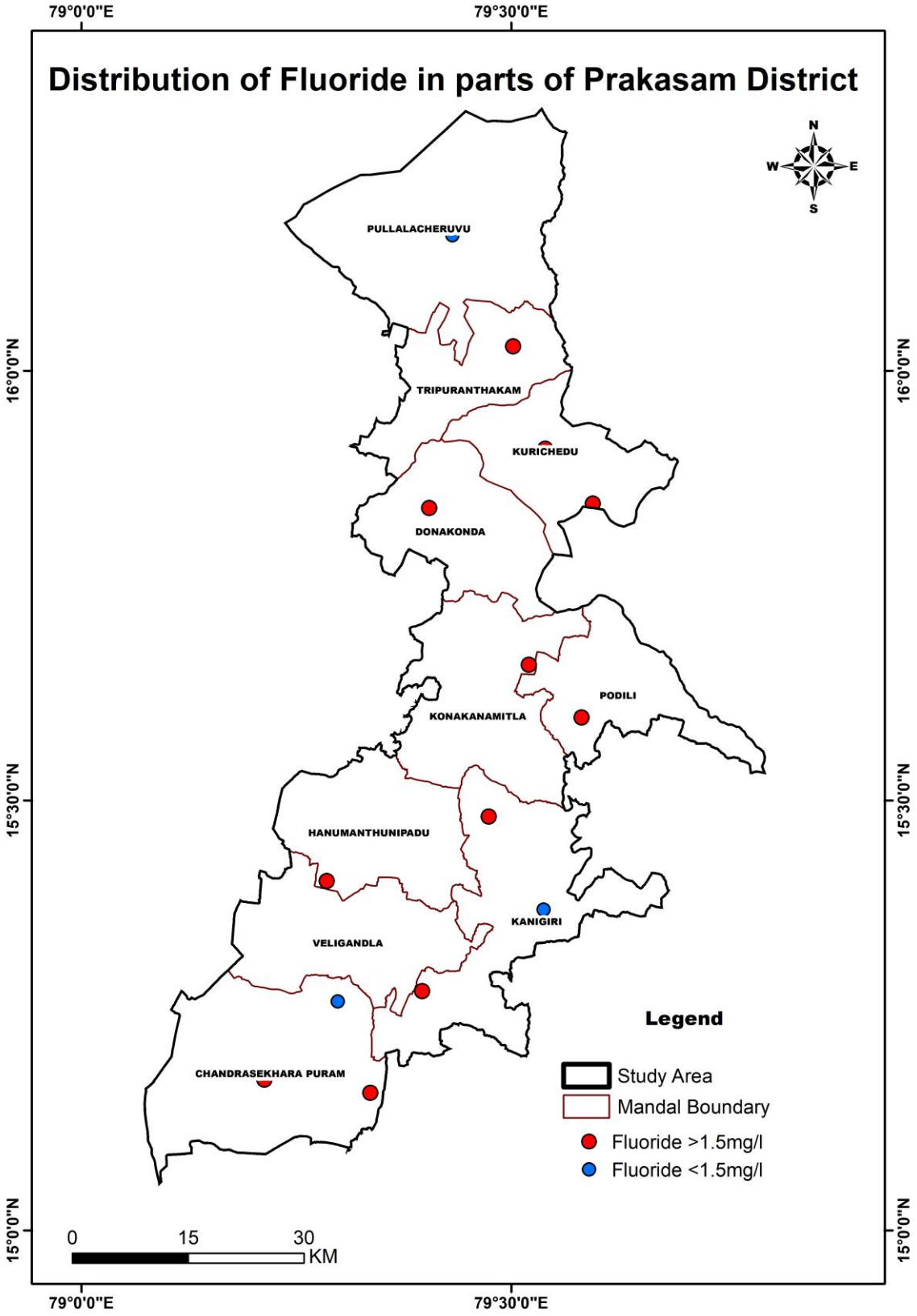

Fig-2.9 Distribution of Fluoride

3. DATA INTERPRETATION, INTEGRATION and AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 88 hydrogeological data points (Exploration: 9 (CGWB & 20 (SGWD), Geophysical: 15, water quality: 14 and well inventory: 30), down to 150 m is used for preparation of 3-D map, panel diagram and hydrogeological sections. The data is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data. The lithological information was generated by using the RockWorks-16 software and generated 3-D map for study area (**Fig.3.1 and 3.2**) along with panel diagram and hydrogeological sections (**Fig-3.3a & b**).

3.1 Conceptualization of aquifer system in 3D

Aquifers were characterized in terms of potential and quality based on integrated hydrogeological data and various thematic maps. Weathered zone is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~20 m depth and the fractured zone (fractured granite) is considered up to the depth of deepest fracture below weathered zone (~20-110 m).

3.2 Hydrogeological Sections

Hydrogeological sections (2 nos) are prepared in N-S and SW-NE directions (**Fig. 3.3**).

3.2.1 N-S Section: The section drawn along the **N-S** direction covering distance of ~125 kms (**Fig.3.4a**), depicts thick fractured zone in Northern parts compared to massive nature of Meta sediments in Southern parts. The weathering is showing undulating thickness in the section.

3.2.2 SW-NE Section: The section drawn along the SW-NE direction covering distance of ~86 kms (**Fig.3.4b**), depicts very thin weathering parts in central part and is hilly.

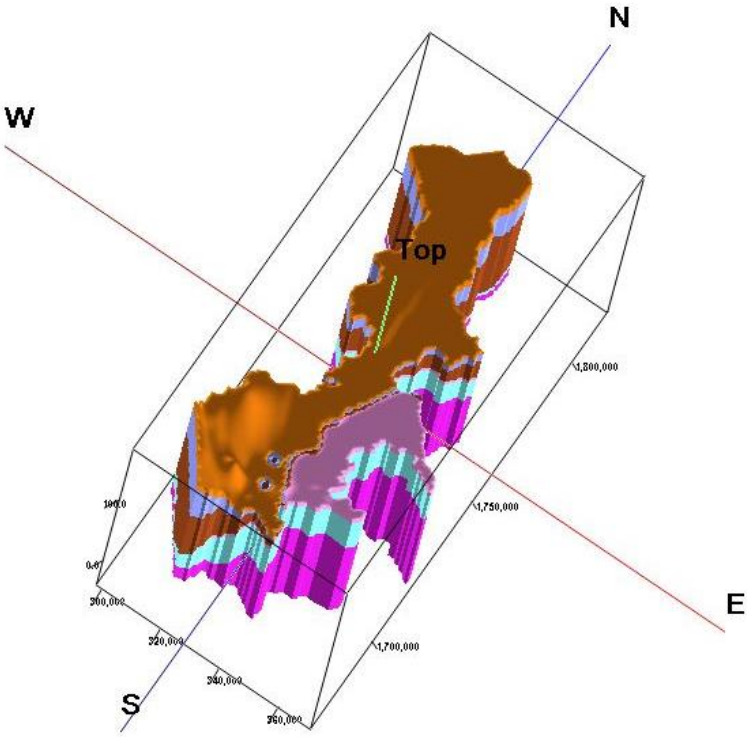

Fig.-3.1: -3D Model for study area.

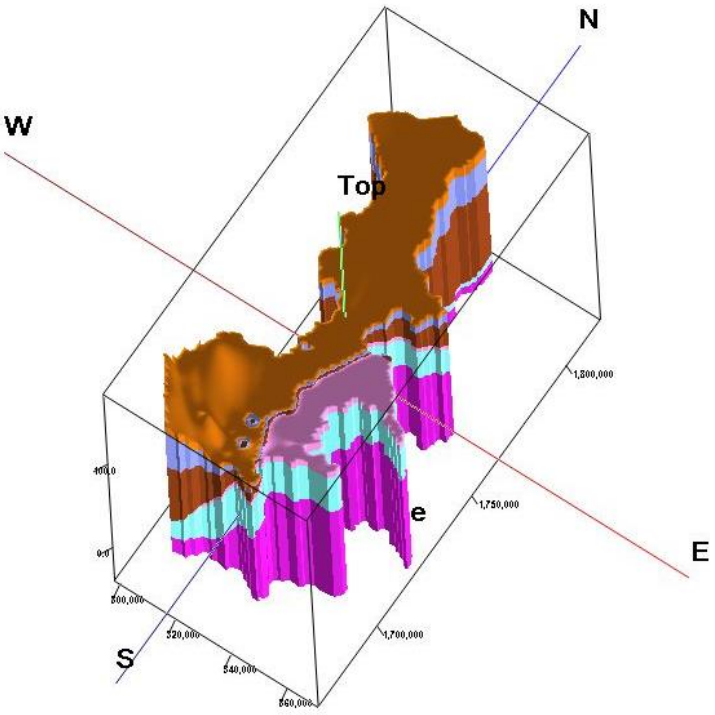

Fig.-3.2: 3D Model for study area.

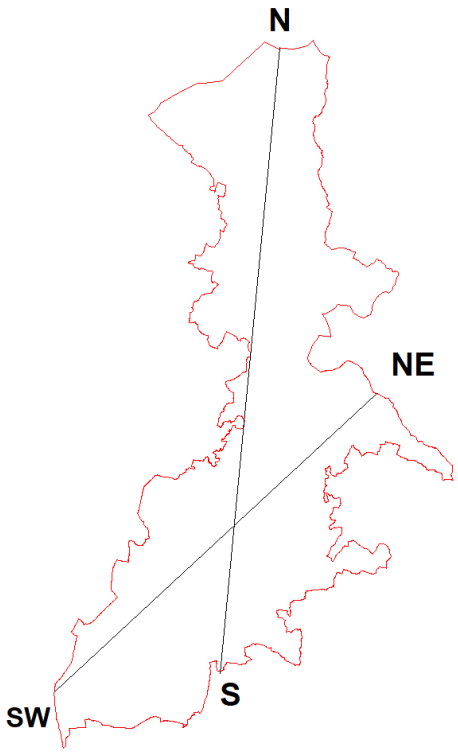

Fig.-3.3: Map showing orientation of various sections.

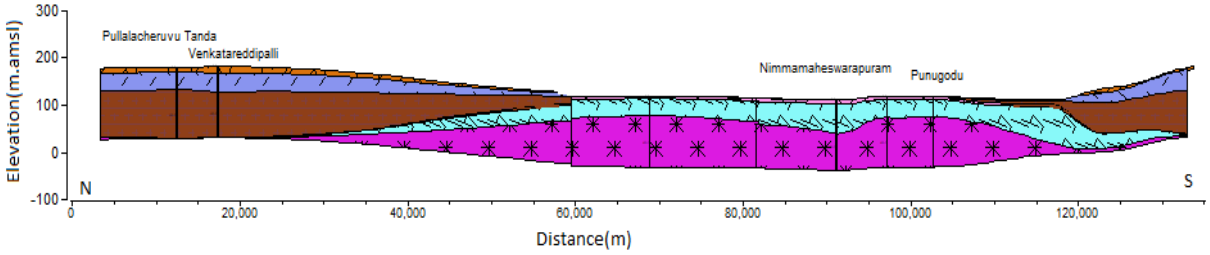

Fig-3.4 a: N-S Section

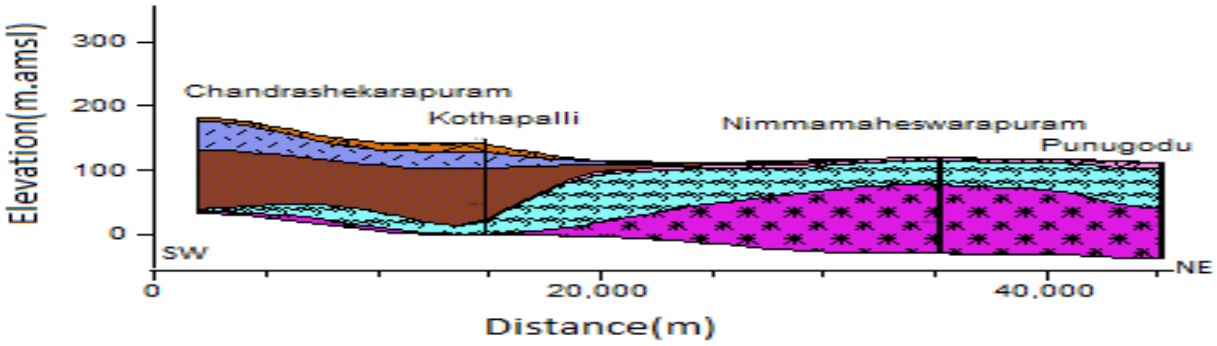

Fig-3.4 b: SW-NE Section

3.3 Aquifer Characterization

3.1 Weathered zone:

The Thickness of weathered zone varies from 5.5 m to 23.6 m. In most of the study area, the thickness of weathering is in between 10-20 m (90%) in most part of area followed by <10 m Deep weathering in Kanigiri mandal and > 20 m occurs in isolated parts of Chandrashekarpuram mandal of the study area. The weathered thickness map is presented in **Fig-3.5.**

3.2 Fractured zone:

The depth of fracturing varies from 25-133 m and deepest fracture is dechiphered at 133m at CS Puram. The yield of the deepest fracture encountered at CS Puram is ~2 lps indicating the potential nature of Second aquifer in the study area. The depth of fracture map is presented in **Fig. 3.6.** The depth of all the exploratory wells drilled so far are ~150 m and the potential fractures occur with in the depth range of 133 m (100%) The ground water yield varies from <0.22 to 2.33 lps.

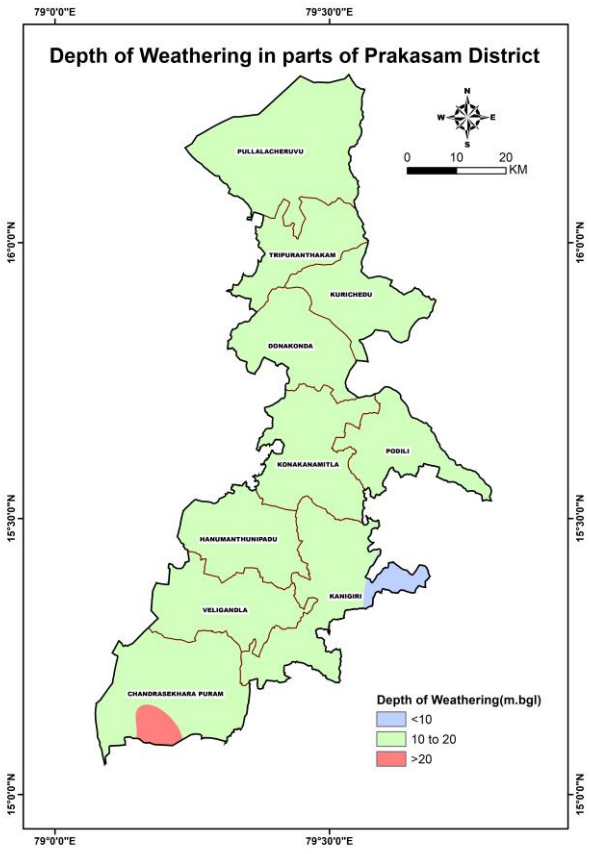

Fig.3.5: Thickness of weathered zone- Study area, Prakasam (Parts).

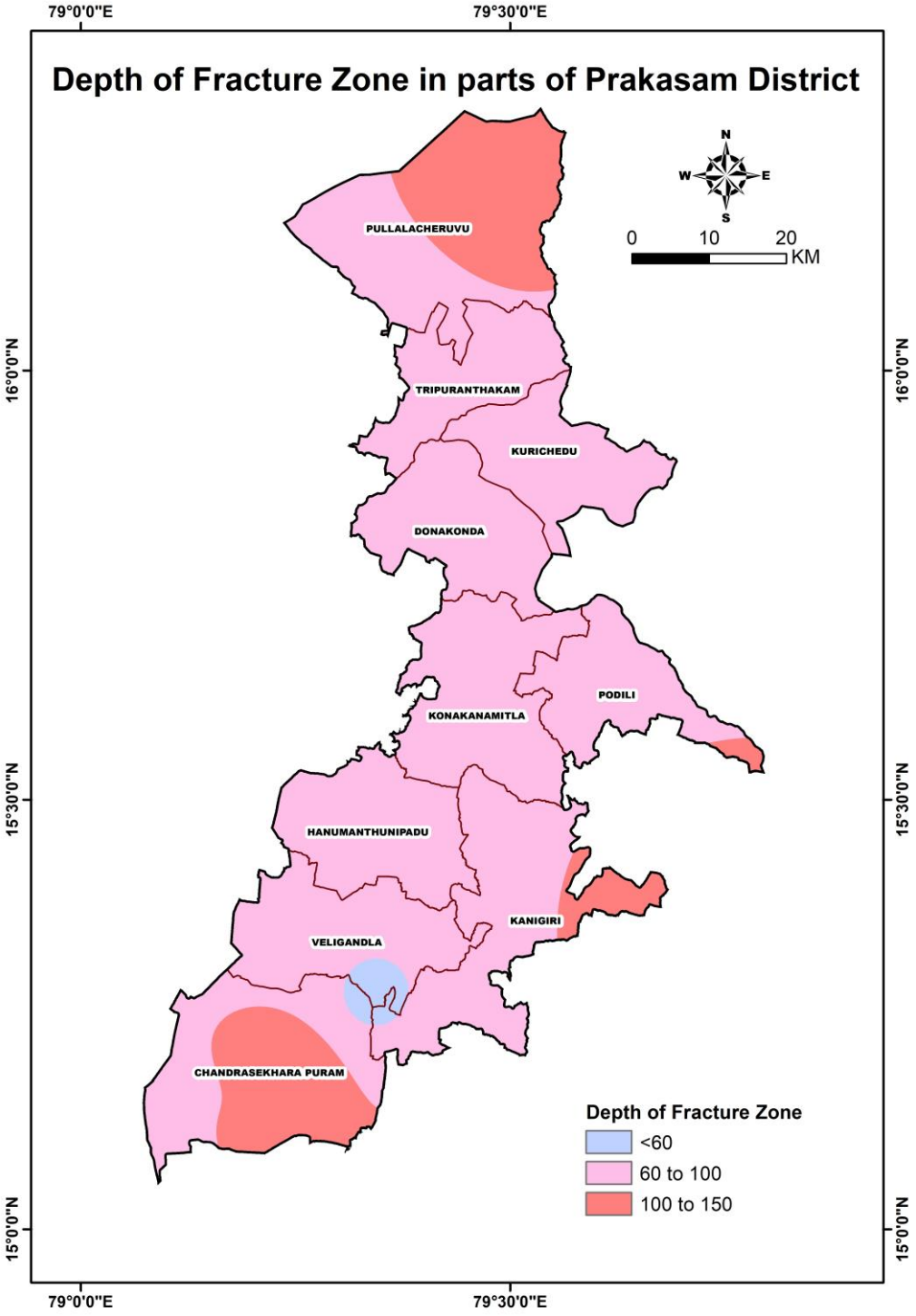

Fig.-3.6: Depth of fractured zone (Maximum depth) (m bgl).

4.0 GROUND WATER RESOURCES (2020)

In hard rocks, for practical purpose it is very difficult to compute zone wise (aquifer wise) ground water resources, because the weathered zone and fractured zone are inter-connected with fractures/joints and fractured zone gets recharged through weathered zone. Therefore it is very difficult to demarcate the boundary between two aquifers; hence the resources are estimated considering entire area as a single aquifer system. Village wise dynamic and in-storage ground water resources are computed as per the guidelines laid down in GEC methodology.

While computing the in-storage resources, the general depth of deepest fractures in the area, pre-monsoon water levels and 2 % of granular zone (depth below pre-monsoon water level and down to deepest fracture depth in the village) is considered. Summarized command/ non-command area and mandal wise resources are given in **Table-4.1 and** Village-wise in **Annexure-1** respectively.

As per 2020 GEC report, the net annual groundwater availability is 259 MCM, gross ground water draft for all uses **97** MCM, provision for drinking and industrial use for the year 2025 is 17 MCM and net annual ground water potential available for future irrigation needs is 169 MCM. Stage of ground water development varies from 15.7 % in Veligandla mandal to 161.7 % in Pullalacheruvu mandal (avg: 37.4 %). Out of 10 mandals 9 mandals falls in safe category (63% of area) and one mandal in over-exploited category.

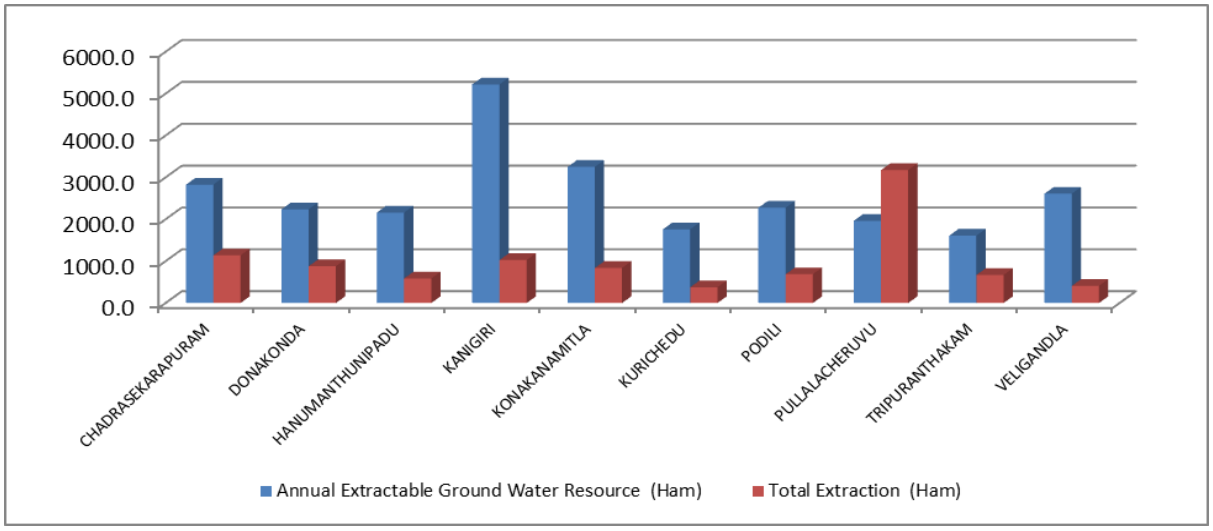

Fig-4.1: Ground Water Resources – 2020 Study area, Prakasam district (Parts).

Table-4.1: Ground Water Resources – 2020 Study area, Prakasam district (Parts).

Assessment Unit Name	Recharge from Rainfall-Monsoon Season	Recharge from Other Sources- Monsoon Season	Recharge from Rainfall-Non Monsoon Season	Recharge from Other Sources- Non Monsoon Season	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (Over-ExploitedE/Critical/Semicritical/Safe/Saline)
C.S. PURAM	1511.8	372.4	561.9	529.4	2975.5	148.8	2826.7	1074.4	0.0	61.7	1136.1	193.4	1558.9	40.2	Safe
DONAKONDA	1319.5	335.2	303.6	396.8	2355.0	117.8	2237.3	831.6	0.0	46.2	877.8	180.0	1259.2	39.2	Safe
H.M.PADU	1031.1	313.5	547.7	381.5	2273.8	113.7	2160.1	513.5	0.0	72.0	585.5	133.2	1513.4	27.1	Safe
KANIGIRI	3105.8	341.6	1545.3	502.3	5494.9	274.8	5220.1	867.8	0.0	157.8	1025.6	246.7	4105.6	19.6	Safe
KONAKANAMITLA	2163.3	392.9	421.4	442.4	3419.9	171.1	3248.9	805.3	0.0	30.9	836.2	208.3	2235.3	25.7	Safe
KURICHEDU	955.0	286.3	318.2	292.4	1852.0	92.6	1759.3	366.2	0.0	11.1	377.3	105.8	1287.3	21.4	Safe
PODILI	1017.1	388.7	503.7	484.5	2394.1	119.7	2274.4	612.9	0.0	73.9	686.8	222.6	1438.9	30.2	Safe
PULLALACHERUVU	1066.0	330.7	252.9	415.8	2065.3	103.3	1962.1	3150.4	0.0	22.7	3173.1	208.9	642.4	161.7	OE
TRIPURANTHAKAM	747.8	318.3	138.2	487.6	1691.9	84.6	1607.2	665.7	0.0	2.3	668.0	234.2	731.9	41.6	Safe
VELIGANDLA	1277.7	300.2	863.6	305.5	2747.0	137.4	2609.6	358.8	0.0	50.9	409.7	50.9	2199.9	15.7	Safe
Total	**14195.0**	**3379.8**	**5456.4**	**4238.1**	**27269.3**	**1363.7**	**25905.6**	**9246.6**	**0.0**	**529.4**	**9776.0**	**1784.0**	**16972.9**	**37.4**	

Computed Dynamic ground water resources as per GEC 2020.

Parameters	**Total** (MCM)
Dynamic (Net GWR Availability)	**259**
• Monsoon recharge from rainfall	142
• Monsoon recharge from other sources	34
• Non-Monsoon recharge from rainfall	54
• Non-monsoon recharge from other sources	42
• Total Natural Discharges (Ham)	13
Gross GW Draft	**97**
• Irrigation	92
• Domestic and Industrial use	5
Provision for Drinking and Industrial use for the year 2025	17
Net GW availability for future use	169
Stage of GW development (%)	37.4%

5.0 GROUND WATER RELATED ISSUES and REASONS FOR ISSUES

5.1 Issues and Resons

Over-exploitation

1. 1 mandals comprising an area of ~ 228 Km^2 area (16%) is categorized as over-exploited where ground water balance for future irrigation is zero or negative.
2. Out of the total irrigated area of 20433 ha, GW contributes 19839 ha (97%) resulted in desaturation of weathered zone and extraction of GW from deeper aquifers.

Pollution (Geogenic and Anthropogenic)

1. Majority mandals are fluorosis endemic where fluoride (geogenic) as high as 3.7 mg/L is found in groundwater. The high fluoride concentration (>1.5 mg/L) occur in 78 % of analyzed samples in the study area.
2. Higher concentration of fluoride in ground water is attributed due to source rock, rock water interaction where acid-soluble fluoride bearing minerals (fluorite, fluoro-apatite) gets dissolved under alkaline conditions and higher residence time of ground water in deeper aquifer.
3. High nitrate (> 45 mg/L) due to anthropogenic activities is observed in about 92 % samples. This is due to excessive use of NPK fertilizers.
4. EC is > 3000 µ Siemens/cm is observed in parts of Tripurankathakam, Kurichedu, Veligandla and Chandrashekarpuram mandals, which is mainly due to geogenic.

6. 0 MANAGEMENT STRATEGIES

Dependence on ground water coupled with absence of augmentation measures has led to a fall in water level and desaturation of weathered zone in some parts of the district. The sustainability of existing ground water structures, food and drinking water security are challenging tasks in the preparation of management plan. Higher NO_3^- concentrations (> 45 mg/L) in weathered zone is due to sewage contamination and higher concentration of F^- (>1.5 mg/L) in weathered zone and fractured zone is due to local geology (granite/gneiss rock), high weathering, longer residence time and alkaline nature of groundwater. The uneven

distribution of groundwater availability and its utilization indicates that a single management strategy cannot be adopted and requires integrated hydrogeological aspects along with socio-economic conditions to develop appropriate management strategy.

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. supply side management has been prepared separately for urban and rural areas.

6.2 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 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 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 687 recharge structure (679 Check dams and 8 percolations tank) though MGNREGS and IWMP scheme. Considering the SOE, it is recommended that instead of planning for new artificial recharge structure for the entire study area, it is more viable to propose structures only in areas having SOE >50% to control further increase in stage of ground water extraction, where vulnerability of ground water resource in future is identified and also to consider the desilting and maintanenceof existing CD’s and PT’s.

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 rainfall 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 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.

The recharge and runoff available in the district is given in **Table 6.1**

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

Total geographical area of district (Sq.km)	4095
Area feasible for recharge (Sq.km)	3360
Unsaturated Volume (MCM)	18376
Recharge Potential (MCM)	367
Runoff available (MCM)	67
Surplus runoff available for recharge (MCM)(20% of runoff)	13

6.2.1 Supply side measures:

6.2.1a Artificial Recharge Structures in Over exploited areas

The artificial recharge structures (ARS) are suggested in Kanigiri, Kurichedu, Donakonda and Hanumanthnipadu Mandal in the Study area. 50% of the available surplus runoff is considered for the recommendation of artificial recharge strutcures, as the remaining 50 % is recommended for implementing water conservation measures in recharge areas through MGNREGS. **(Table 6.2)**

Table 6.2 Proposed artificial recharge structures in Kanigiri, Kurichedu, Donakonda and Hanumanthnipadu Mandal	
Percolation Tanks (@ Rs.15 lakh Capacity of the tank: 0.007MCM, Av. Gross storage in an year = 0.007 MCM*2 fillings = 0.014 MCM Volume of Water expected to be recharged (in MCM) Estimated Expenditure (in Crores)	14 0.2 2.10
Check Dams (@ Rs.10 lakh, Av. Gross storage in an year = 0.007 MCM* 5 fillings = 0.035 MCM Volume of Water expected to be recharged(in MCM) Estimated Expenditure (in Crores)	25 1 2.5
Total volume of water expected to be recharged (in MCM)	1.2
Total Estimated Expenditure for Artificial Recharge (Rs. in Cr.)	4.6

36 artificial recharge structures (25 CD's and 14 mini PT'in 25 villages) with a total cost of 4.6 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)

- After effective utilization of this yield, there will be 1.2 MCM of ground water recharge (50 % of total utilizable yield).
- Roof top rainwater harvesting structures should be made mandatory to all Government buildings (new and existing).

For sustainable development and management of the ground water resources the above recommendations are made and summarised in **Annexure-2**.

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 ground water resources.

State Government Intiatives:

In Prakasam District there are 952 Minor Irrigation Tanks (363 M.I + 589 panchayataj Raj) having an Registered ayacut of 135427 Acres. During 2013-14 an ayacut of 28706 Acres is irrigated. (5^{th} MI Census). In the study area, Chadrashekarpuram, Donakonda, Kanigiri, Hanumanthunipadu, Konakanamitla, Podili, Pullalacheruvu, Tripuranthakam and Veligandla, mandals are also will be covered under the proposed Veligonda project **(Fig-1.6)** which is contemplated to create additional ~38075 hectare of irrigation potential. The proposed extention of ayacut under this project is as follows.

Sl.No.	Mandal	No.of sources	Regd. Ayacut
1	Chandrasekhara Puram	32	3488
2	Donakonda	50	2945
3	Hanumanthunipadu	8	1516
4	Kanigiri	30	8311
5	Konakanamitla	28	4371
6	Kurichedu	34	2118
7	Podili	23	3676
8	Pullalacheruvu	39	3931
9	Tripuranthakam	24	3735
10	Veligandla	22	3985
	Study area Total	**290**	**38075**
	District Total	**952**	**135427**
	Percentage %	**30.5**	**28.1**

The crop water requirement for 38075 ha is 228 MCM for ID crops. After the implementation of the project, the area under rainfed irrigation (38075 ha) in the study area will be brought into the ambit of assured surface water irrigation. The conserved surface water can be effectively being utilized to supplement irrigation, which will reduce the stress on ground water.

6.2.2 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 15658 farm ponds, exist in 283 villages and in the mandals where SOE >50% there are 865 farm ponds which can be desilted and maintained so that it will greatly help in ground water augmentation.

6.2.2a. Micro-irrigation:

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

- 1900ha of additional land in Pullalacheruvu that can be brought under micro-irrigation (@100 ha/village in 19 villages) costing about 16.8 crores (considering 1 unit/ha @0.6 lakh/ha). With this ~3.42 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) .

- 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 ground water user should recharge rainwater through artificial recharge structures in proportionate to the extraction.

6.2.3 Other measures

- A participatory ground water 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.

6.2.4 Expected Results and Out come

With the above interventions, the likely benefit would be the net saving of 4.6 MCM recharge of ground water.

Acknowledgment

The author expresses his sincere thanks to Shri Sunil Kumar, Chairman CGWB, Govt. of India and Shri J. Siddardha Kumar, Regional Director (I/C), CGWB, Shri Ravi Kumar Gumma, Scientist C for encouragement, guidance and support. The author also extends his thanks to Smt Caroline Louis, Sc-B (HG) and Smt. Resma S. Pillai, Sc-B (HG) for providing technical support for preparation of the report. Thank are due to State Ground Water Department, Rural Water Supply department, Directorate of Economics and Statistics, Minor Irrigation, Govt of Andhra Pradesh for providing the available field data.

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Annexure-1

Proposed Structures					
Village	Mandal	Existing		Proposed	
		PTs	Check dam	Number of cd feasible	Number of PT feasible
Kutagundla	HANUMANTHUNIPADU	0	0	1	0
Hazis Puram	KANIGIRI	0	0	1	0
Challagirigala	KANIGIRI	0	0	1	0
Aravallipadu	DONAKONDA	0	0	1	0
Pedaraju Palem	CHADRASEKARAPURAM	0	0	1	0
Vijaya Gopala Puram	KANIGIRI	0	0	1	0
Doddi Chintala	HANUMANTHUNIPADU	0	0	1	0
Vemula Padu	HANUMANTHUNIPADU	0	0	1	0
Ummana Palle	HANUMANTHUNIPADU	0	0	1	0
Pedagola Palle	HANUMANTHUNIPADU	0	0	1	0
Chirla Dinne	KANIGIRI	0	0	1	0
Sankavaram	KANIGIRI	0	0	1	1
Yadavalli	KANIGIRI	0	0	1	1
Punugodu	KANIGIRI	0	0	1	1
Mummayapalem	KONAKANAMITLA	0	0	1	1
Hazee Puram	HANUMANTHUNIPADU	0	0	1	1
Thimmareddi Palle	HANUMANTHUNIPADU	0	0	1	1
Bommireddi Palle	KANIGIRI	0	0	1	1
Guravajipeta-1	KANIGIRI	0	0	1	1
Kanigiri (U)	KANIGIRI	0	0	1	1
Nandanavanam	HANUMANTHUNIPADU	0	0	1	1
Chakirala	KANIGIRI	0	0	1	1
Mustla Gangavaram	KURICHEDU	0	0	1	1
Baduguleru	KANIGIRI	0	0	1	1
Balli Palle	KANIGIRI	0	0	1	1

FOREWORD

India is the largest groundwater user in the world, with an annual groundwater withdrawal of 253 billion cubic meters (BCM). This represents about 25% of the world's groundwater withdrawals. India has about 112.3 BCM of water resources, of which 690 BCM is surface water and the remaining 433 BCM is groundwater. Out of the total available groundwater, 90% is used for irrigation purposes, mainly in agriculture. The remaining 10% is used for domestic and industrial purposes. According to the Composite Water Management Index (CWMI) report released by NITI Aayog in 2018, 21 major cities, including Delhi, Bengaluru, Chennai and Hyderabad, are at risk of running out of groundwater, affecting access for 100 million people. The CWMI report also states that the country's water demand is expected to be twice the available supply by 2030, which would mean serious water shortages for hundreds of millions of people and a 6% loss to the country's GDP.

In view of the above, it is necessary to scientifically plan groundwater development and its management in different hydrogeological environments, and develop effective management methods with the involvement of the community to better manage groundwater. The National Aquifer Mapping Project (NAQUIM) is being implemented by the Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India and is being undertaken by the Central Ground Water Board (CGWB). The NAQUIM provides the mapping of aquifers (water-bearing formations), their characterization, and the development of aquifer management plans to enable sustainable management of groundwater resources to delineate and describe aquifers and develop groundwater management plans for their sustainable development with stakeholder participation.

The report titled "Aquifer Mapping for Sustainable Ground Water Resources in parts of Hard Rock areas of Prakasam District, Andhra Pradesh State" prepared from hydrogeological, geophysical and hydro chemical data generated by CGWB over the years and integrated with the of data from various stake holder departments viz., ground water, irrigation, statistics, Rural Development and Micro irrigation etc. The data has been analysed and interpreted using various software tools, GIS and Rockworks for conceptualization of aquifers, their vertical and horizontal disposition and extent, assessment of ground water resources, quality of shallow and deeper aquifers and various aspects of ground water occurrence, distribution, and utilization in the district. The report identified specific groundwater related issues and recommended various supply and demand side management strategies for sustainable ground water development and management in the district.

This report has been prepared by Shri. B.J. Madhusudhan, Assistant Hydrogeologist and the efforts made by the officer in preparation of this report are greatly appreciated. Special Thanks to Smt Rani V.R, Scientist-C and Sh. Ravi Kumar Gumma, Scientist-C, for valuable suggestion/contributions in finalizing this document. Thanks to various organizations of the Government of Telangana for providing data required for compiling this report.

I hope this report will be helpful to District Administration and Stakeholder Departments for planning and sustainable management of groundwater resources in the district.

Sh. J. Siddhardha Kumar
Regional Director
CGWB, SR, Hyderabad

EXECUTIVE SUMMARY

The Study area is located in central part of Prakasam district, Andhra Pradesh covering an area of 4095 Km^2 and the area with 10 mandals and 283 revenue mandals and receives an annual rainfall of 763 mm.. The population of the district is ~ 5.25 lakh (2011 census). The area

Pediplain, Structural hills and pediments are the major geomorphic units in the study area, which is mainly drained by tributaries of River Krishna and Pennar. There is only one major project in the area (Veligondla Project) with **~1503** Check dams and ~**373** percolation tanks / mini percolation tanks with combine capacity of 6.36 MCM. Groundwater contributes ~67% of the net irrigated area and surface water contributes 33%. Till 2019-20 ~ 114888 ha area is brought under micro-irrigation practices (Drip and Sprinkler).

Total cropped area of the study area is 116347 ha (~28%) and forests occupy ~21 % of the area. The total gross cropped area during the year 2019-20 is 116347 ha and net sown area is 115198 ha, remaining agricultural land was kept fallow. The gross area cropped during Khariff season is 193177 ha and the major crops grown during Khariff season are Pulses (52%), Cotton (10%) and Paddy (11%). The soils are mainly clayey skeletal, mixed loamy and loamy types. The area is underlain by meta-sediments comprising of Shales, Quartzites (56%), Shales and slates (43%) and Schists (0.4%) of Cuddapah Super Group.

Datagap analysis carried out by integrating data collected from state govt. and CGWB data. Integration and interpretation of data done for ground water exploration, geophysical studies, ground water quality and water level. (Hydrogeological data from 9 (CGWB & 20 (SGWD), Geophysical: 15, water quality: 14 and well inventory: 30) used for datagap analysis. The study corroborates that the extraction is mainly through boreholes of 60-100 m depth, with yield between <1 to 11 litres/second (lps). Majority of fractures occur within 100 m depth and deepest fracture is encountered at the depth of 115 m depth. Ground water yield from weathered and fractured aquifer varies from <1 to 2 lps. To understand the ground water levels from 29 wells (9 wells of CGWB and 20 wells of SGWD) are utilized. The depth to water level varies from 3.7 to 49.5 meter below ground level (m bgl) during pre-monsoon period and (average: 14.39 m bgl) and 2.02 to 26.9 m bgl (average: 10.03) during post-monsoon season 2020.

Majority of the area shows water level between 10 and 20 m bgl during pre-monsoon and post monsoon except the western part of the study area. Deeper water levels of more than 20 m bgl is confined to the western part. During post monsoon the area of coverage increased for the water level in the range of 10 to 20 m bgl when compared to pre-monsoon period. Deeper water level of more than 20 m bgl is confined to isolated pockets in Pullalacheruvu and Veligondla mandals during post monsoon period.

Majority of the area shows rise in water level, when compared to pre-monsoon in the range of 0.06 to 37.38 m.

The chemical nature of groundwater in the study area shows that 79% of samples are not fit for drinking purpose. Electrical conductivity varies from 810-4010 (avg: 2439 µ /Siemens/cm) and concentration of NO_3 ranges from 36-430 mg/l. The concentration of Flouride ranges from 0.7 to 3.7 mg/l with an average of 2.2 mg/l.

Aquifers were characterized in terms of potential and quality based on integrated hydrogeological data and various thematic maps. Weathered zone is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~20 m depth and the fractured zone (fractured granite) is considered up to the depth of deepest fracture below weathered zone (~20-110 m).

As per 2020 GEC report, the net annual groundwater availability is 259 MCM, gross ground water draft for all uses 97 MCM, provision for drinking and industrial use for the year 2025 is 17 MCM and net annual ground water potential available for future irrigation needs is 169 MCM. Stage of ground water development varies from 15.7 % in Veligandla mandal to 161.7 % in Pullalacheruvu mandal (avg: 37.4 %). Out of 10 mandals, 9 mandals falls in safe category (63% of area) and one mandal in over-exploited category.

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. Supply side management has been prepared separately for urban and rural areas.

In Prakasam District there are 952 Minor Irrigation Tanks (363 M.I + 589 Panchayati Raj) having a registered ayacut of 135427 Acres. During 2013-14 an ayacut of 28706 Acres is irrigated. (5^{th} MI Census). In the study area, Chadrashekarpuram, Donakonda, Kanigiri,

Hanumanthunipadu, Konakanamitla, Podili, Pullalacheruvu, Tripuranthakam and Veligandla, mandals are also will be covered under the proposed Veligonda project, which is contemplated to create additional ~38075 hectare of irrigation potential. The crop water requirement for 38075 ha is 228 MCM for ID crops. After the implementation of the project, the area under rainfed irrigation (38075 ha) in the study area will be brought into the ambit of assured surface water irrigation. The conserved surface water can be effectively being utilized to supplement irrigation, which will reduce the stress on ground water.

Based on the availability of ground water resources and existing ground water conservation structures, 36 artificial recharge structures (25 CD's and 14 mini PT's in 25 villages) with a total cost of 4.6 crores are recommended to 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), with these interventions, the likely benefit would be the net saving of 4.6 MCM recharge of ground water.

1. INTRODUCTION

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

Hard rocks (Granites/Gneisses) lack primary porosity, and ground water occurrence is limited to secondary porosity developed by weathering and fracturing. Weathered zone is the potential recharge zone for deeper fractures and excessive withdrawal from this zone leads to drying up in places and reducing the sustainability of structures. Besides these quantitative aspects, groundwater quality also represents a major challenge which is threatened by both geogenic and anthropogenic pollution. In some places, the aquifers have high level of geogenic contaminants, such as fluoride, rendering them unsuitable for drinking purpose. High utilization of fertilizers for agricultural productions and improper development of sewage system in rural/urban areas lead to point source pollution viz., nitrate and chloride.

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

1.1 Scope of study: The main scope of study is summarised 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 data base and ground water resource estimation.
3. Quantification of groundwater availability and assessing its quality.
4. To delineate aquifer in 3-D along with their characterization on 1:50, 000 scale.
5. Capacity building in all aspects of ground water development and management through information, education and communication (IEC) activities through education, awareness and training.
6. Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable ground water management.

1.2 Area details: The Study area consists of 10 mandals with 283 revenue villages located in Central part of Prakasam district, Andhra Pradesh State covering a geographical area of 4095 km^2, lies between 15° 10' 49"- 16° 9' 28" N latitude and 79° 16' 56"- 79° 37' 2" East longitude (**Fig.1.1**). Out of total area, the hilly and forest area about is 862 km^2 (21%). The list of the mandal and its geographical areas are provided below

Sl.No	Mandal Name	Geographical Area (sq.km)	Forest Area (sq.km)	Normal Rainfall (mm)	Main Crops	Categorization (GEC-2020)
1	Chandrasekharapuram	532.8	216.3	777.1	Redgram,Chillies	Safe
2	Donakonda	390.7	11.7	728	Redgram, Chillie	Safe
3	Hanumanthunipadu	346.2	35.9	753.3	Chillies, Redgram	Safe
4	Kanigiri	513.3	61.6	795.2	Redgram,Chillies	Safe
5	Konakanamitla	492.5	67.3	770.5	Chillies, Redgram	Safe
6	Kurichedu	294.3	30.0	771.2	Chillies, Redgram	Safe
7	Podili	298.8	6.0	789.1	Redgram,Chillies	Safe
8	Pullalacheruvu	645.7	370.4	709.3	Chillies, Castor, Rice	OE
9	Tripuranthakam	263.9	7.5	728.8	Chillies, Redgram, Castor	Safe
10	Veligandla	317.1	55.5	808.8	Chillies, Redgram	Safe

The population of the study area is 5.25 lakhs (2011 census) and density is 137 persons/Km^2 (CPO, Prakasam).

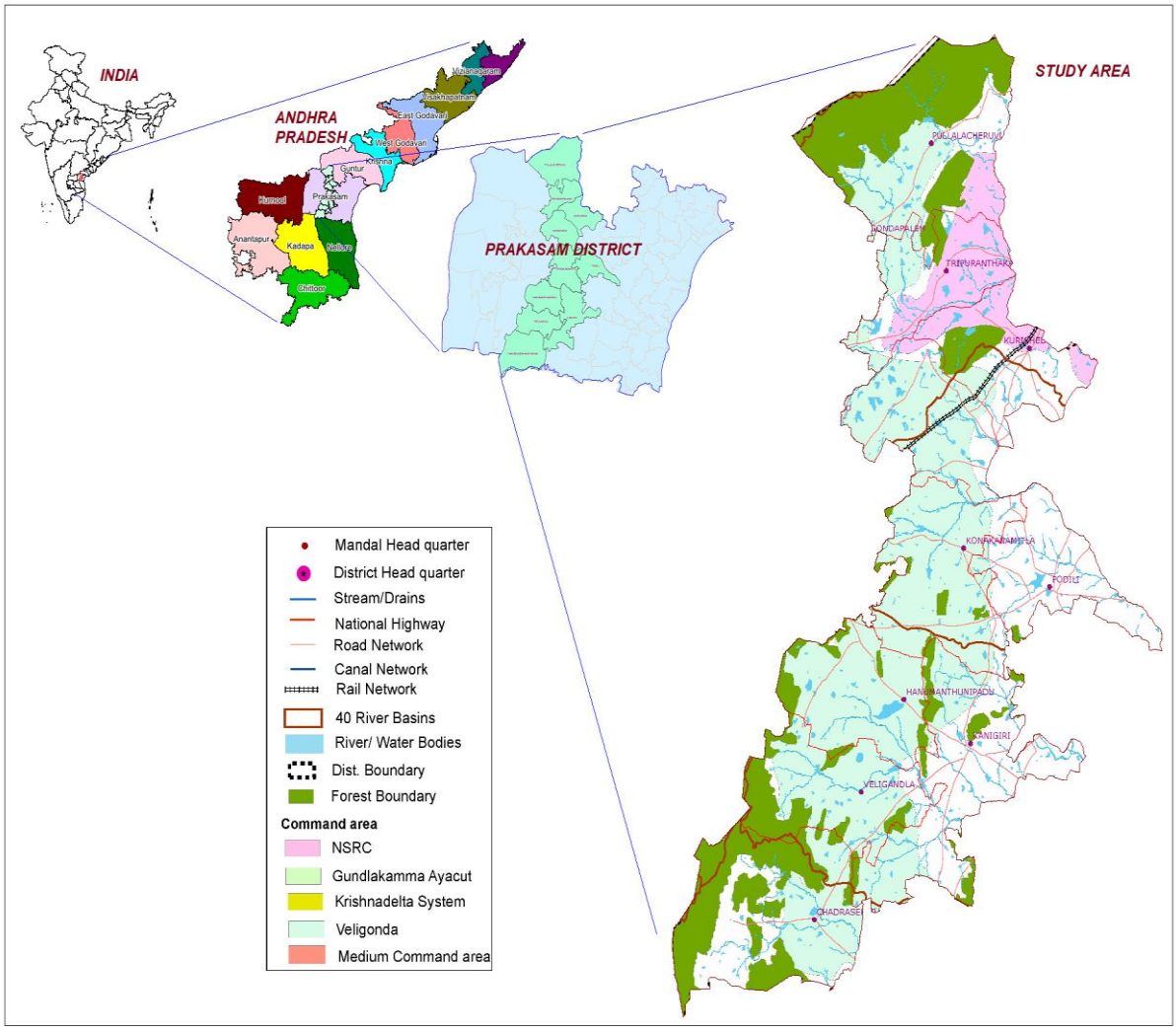

Fig-1.1 Location Map of the Study Area, Prakasam District (Parts), AP

1.4 Climate and Rainfall: The climate of the study area is characterised by hot summer and generally dry weather except during S-W monsoon season. The normal annual rainfall of the study area is 763 mm (Indian Meteorological Department) and annual rainfall between 709 mm (Pullalacheruvu) to 808 mm (Veliganda) (**Fig. 1.2**). The South west monsoon contributes ~50%, North east monsoon contributes ~40%, and remaining by winter season.

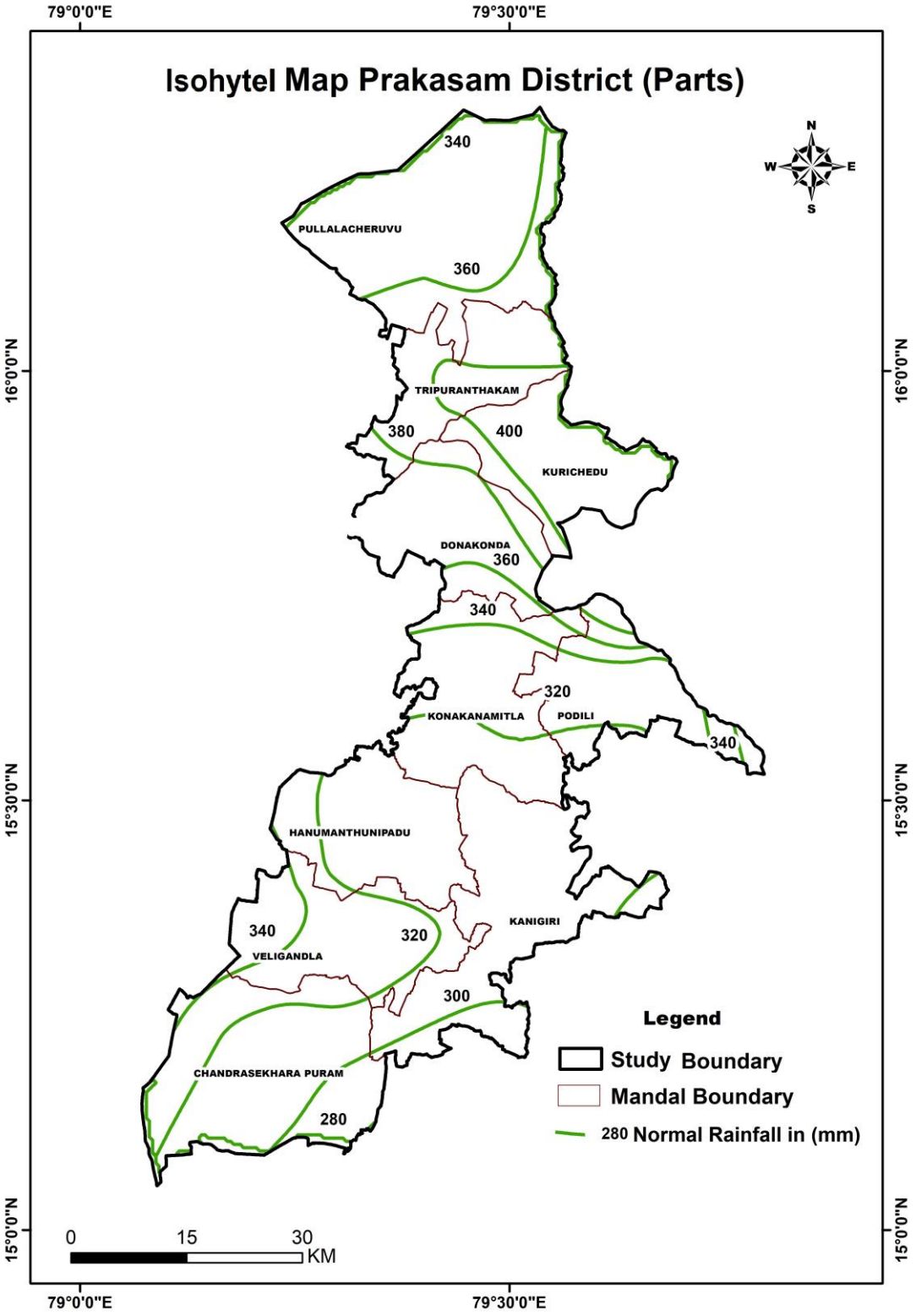

Fig-1.2 Isohytel map of the Study Area, Prakasam District (Parts), AP

1.5 Geomorphological Setup: Pediplain, Structural hills and pediments are the major geographic units in the study area. The details and percentage of geomorphological features of the area is given in the table and depicted in **Fig-1.3.**

Geomorphological Unit	Area (sq.km)	Percentage		Geomorphological Unit	Area (sq.km)	Percentage
Channel bar	0.3	0.01		Pediment	436.5	10.68
Channel fill	98.3	2.40		Pediplain	2573.9	62.97
Denudational hill	191.8	4.69		Piedmont slope	2.1	0.05
Flood plain	79.7	1.95		Piedmont zone	87.3	2.13
Inselberg	0.5	0.01		Point bar	0.2	0.00
Intermontane valley	22.6	0.55		Residual hill	32.5	0.79
Linear ridge	0.3	0.01		Structural hill	486.8	11.91
Paleo channel	12.5	0.30		Structural valley	62.7	1.53

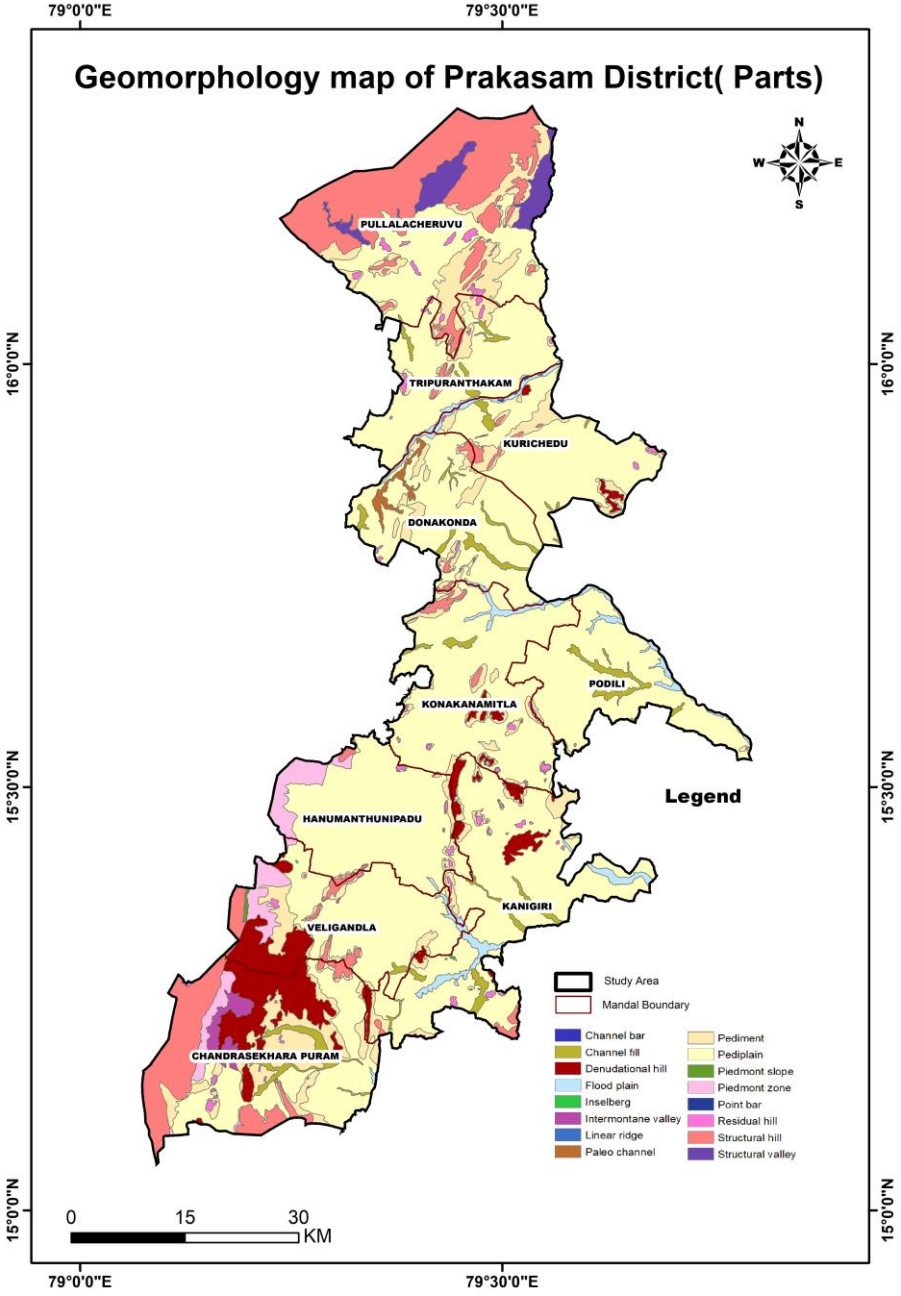

Fig-1.3 Geomorphology of the Study Area, Prakasam District (Parts), A.P

1.6 Drainage and Structures: The study area is mainly drained by tributaries of River Krishna and Pennar. The drainage is dendritic and parallel in nature. The map depicting drainage and water bodies is presented in **Fig.1.4**.

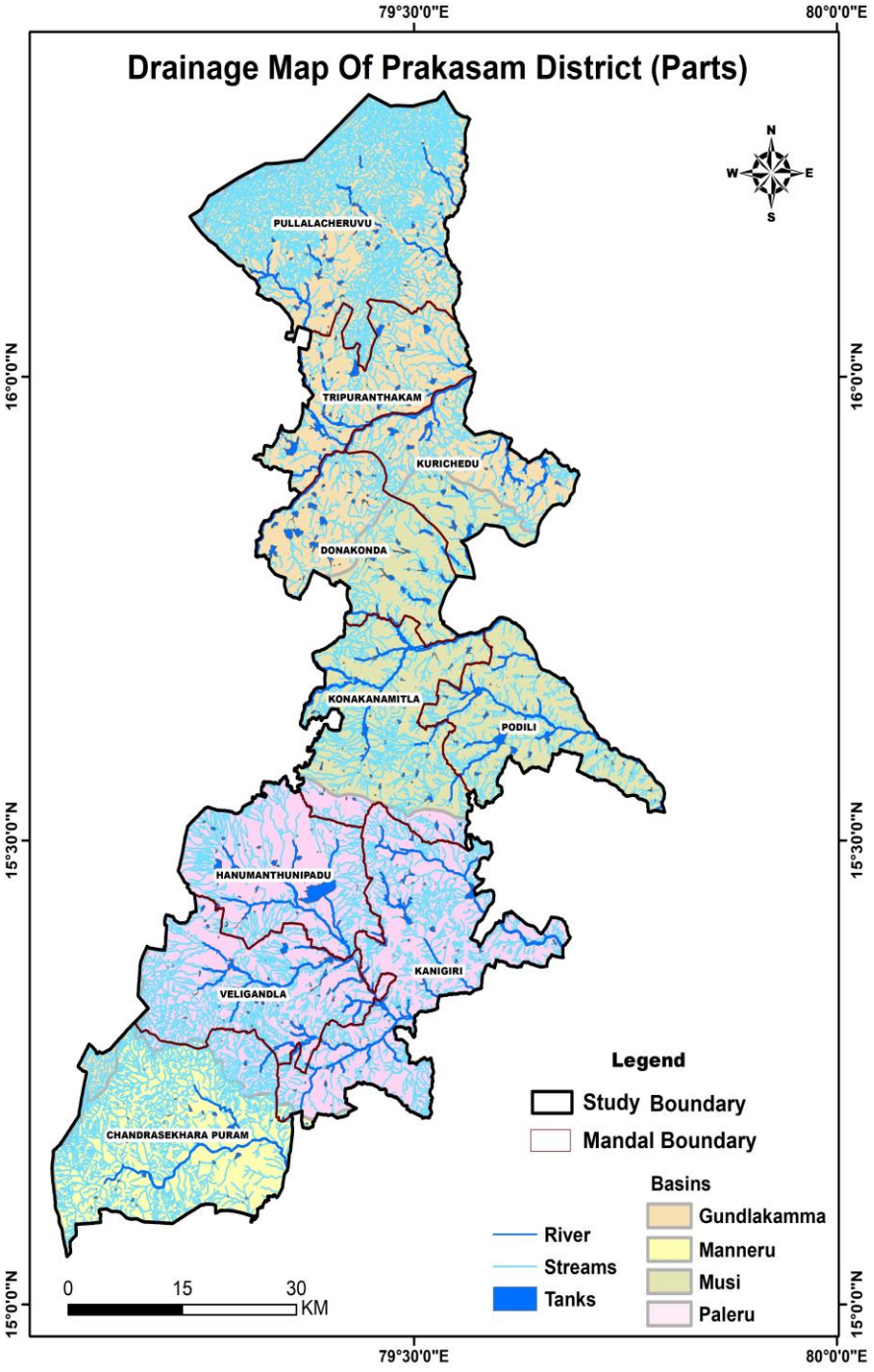

Fig-1.4 Drainage of the Study Area, Prakasam District (Parts), A.P

1.7 Land use and cropping pattern (2019-20): Out of the of the total geographical area of 4095 sq.kms, the total cropped area is 1163 sq.km (~28%) and area sown more than once is 11.50 sq.km (~1%), Forest occupies 862 sq.km (~21%), Barren and cultivable land is 531 sq.km (12.9%), land put to non-agricultural uses is 344 sq.km (8.4%), Cultivable waste is 205 sq.km (5%). During Khariff season, main crops grown are Paddy, Cotton and Chillies. During Rabi season, main crops grown are Paddy, maize, oil seeds. The other crops are turmeric, jowar. Land use and land cover map of the study area is depicted in **Fig. 1.5** and tabulated below.

Sl.No	Mandal Name	Geographical Area	Forest Area	Barren & Uncultivable Land	Land Put To Non Agri Uses	Culturable Waste	Permanent Pastures & Grazing Land
1	Pullalacheruvu	64565	37044	4443	2550	1976	1787
2	Tripuranthakam	26387	750	3650	2295	1604	548
3	Donakonda	39069	1174	8079	3864	4520	5780
4	Kurichedu	29427	3000	5034	1921	2001	3241
5	Konakanamitla	49249	6733	6012	4170	3660	4441
6	Podili	29883	600	757	4190	1686	2359
7	Hanumanthunipadu	34619	3587	5400	2215	1130	146
8	Veligandla	31712	5554	3688	3738	794	346
9	Kanigiri	51333	6162	10813	5629	1160	2519
10	Chandrasekhara Puram	53275	21627	5239	3864	2018	3424
	Total	**409519**	**86231**	**53115**	**34436**	**20549**	**24591**

Sl.No	Mandal Name	Land Under Misc. Tree Crops & Groves not included in NAS	Other Fallow Lands	Current Fallow Lands	Net Area Sown	Total Cropped Area	Area Sown More than Once
1	Pullalacheruvu	214	4324	1207	11020	11130	110
2	Tripuranthakam	5	2192	4575	10768	11479	711
3	Donakonda	0	1185	4698	9769	9793	24
4	Kurichedu	23	939	1316	11952	11952	0
5	Konakanamitla	0	3647	5398	15188	15454	266
6	Podili	42	5383	453	14413	14418	5
7	Hanumanthunipadu	0	7641	6019	8481	8481	0
8	Veligandla	0	3624	3935	10033	10033	0
9	Kanigiri	0	5400	3878	15772	15805	33
10	Chandrasekhara Puram	0	5005	4296	7802	7802	0
	Total	**284**	**39340**	**35775**	**115198**	**116347**	**1149**

Source: CHIEF PLANNING OFFICER, ONGOLE

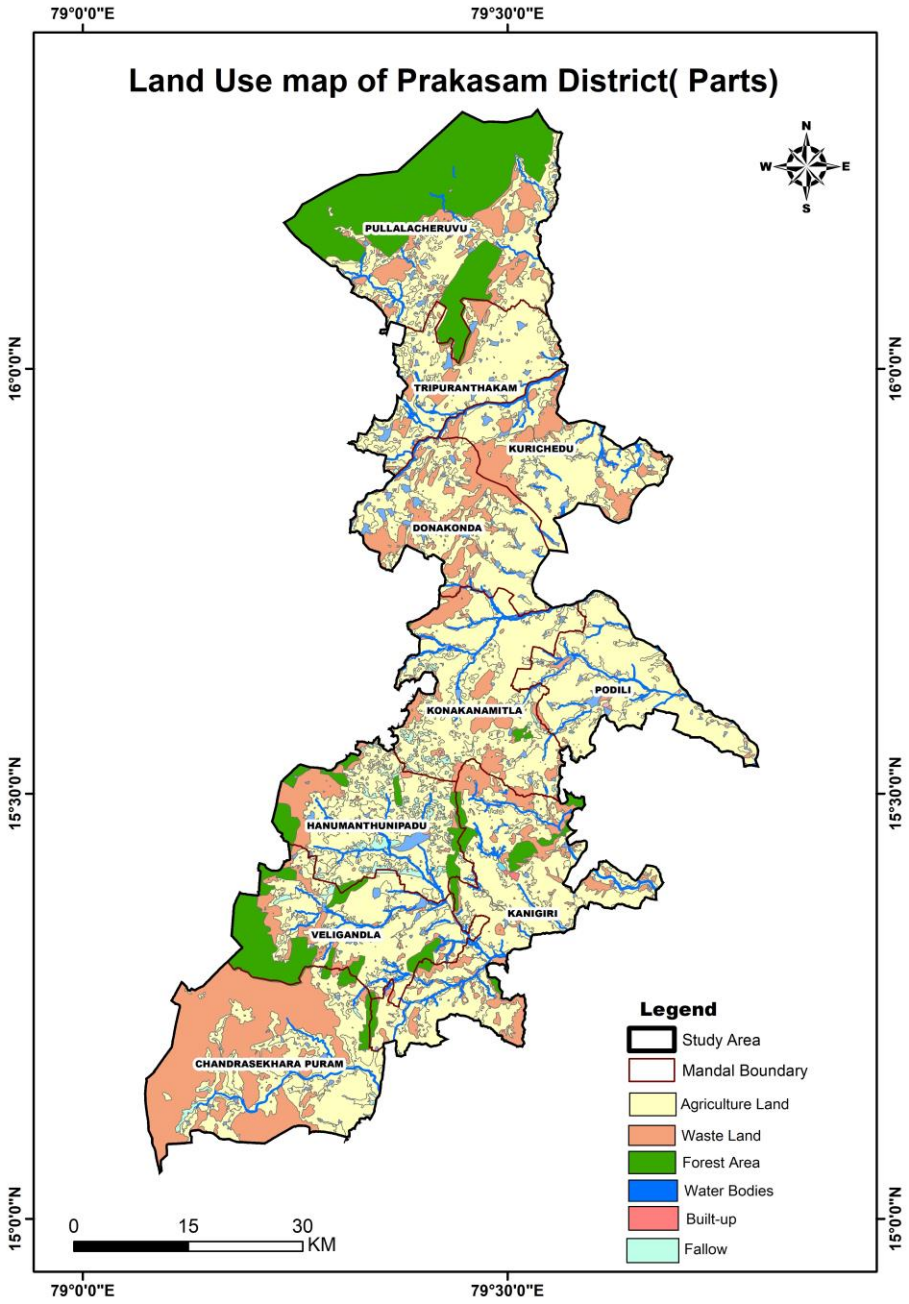

Fig-1.5 Land use map of the Study Area, Prakasam District (Parts), A.P

1.8 Agricuture:

Major part of the district is occupied by agricultural area (28%). In the district, forest occupies nearly 21% of the area and the remaining area is occupied by permanent pasturewaste land etc (**Fig.1.5**).The total gross cropped area during the year 2019-20 is 116347 ha and net sown area is 115198 ha, remaining agricultural land was kept fallow. The gross area cropped during Khariff season is 193177 ha and the major crops grown during khariff season are Pulses (52%), Cotton (10%) and Paddy (11%). The gross area cropped

during Rabi season is 29668 ha and the major crops grown during the period include Pulses (73%) and Paddy (19%).

1.9 Irrigation:

The study area is mainly irrigated by ground water. Out of total gross irrigated area of 29726 ha, ~ 19952 ha (~67%) is irrigating through tube wells. The remaining 33% (9774 ha) is through canal.

Veligonda Project is on going irrigation project which is located in the study area (Markapuram divison). By commissioning of this project irrigational facilities will be provided to 4,59,000 acres and drinking water to 1.5 million people in 29 Mandals of fluoride and drought affected areas in Prakasam district and adjacent Nellore and Kadapa district by diverting 43.5 TMC (1232 MCM) of floodwater of Krishna River from foreshore of Srisailam Reservoir near Kollamvagu and proposed to store in Nallamalasagar Reservoir. The water for the project is drawn through two 18.8 km long tunnels across Nallamala hills. The proposed Veligonda project and its canal network in the study area are shown in **Fig-1.6**.

1.10 Prevailing water conservation/Recharge practices: In the study area there are **~1503** Check dams and ~**373** percolation, mini percolation tanks with combine capacity of 6.36 MCM. Till 2019-20 ~ 114888 ha area is brought under micro-irrigation practices.

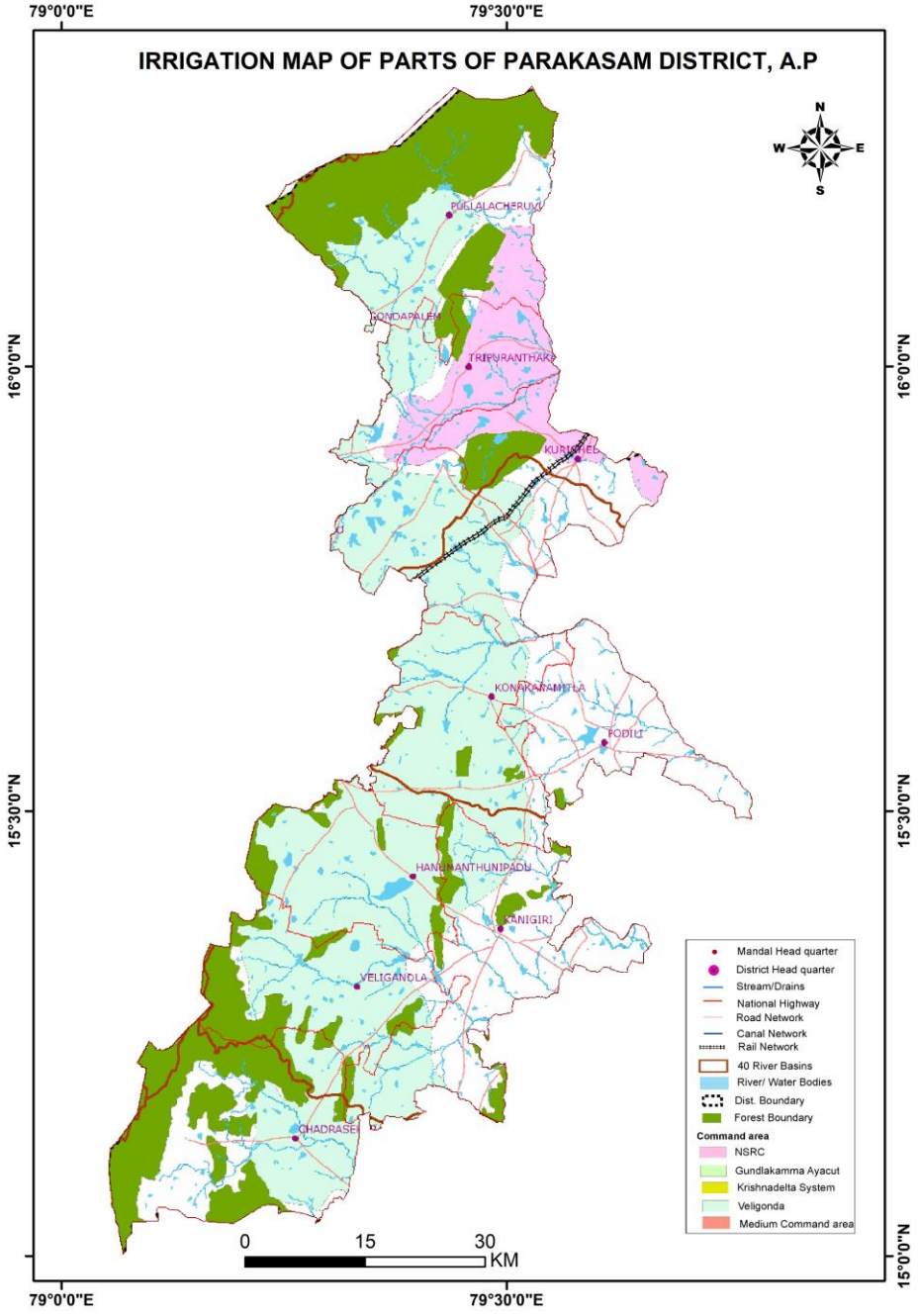

Fig- 1.6 Irrigation Map of the Study Area, Prakasam District (Parts), A.P

1.11 Geology: The area is mainly underlain by the Meta Sediments/ Rocks (Shales and Quartzites) belonging to Cuddapah Super Group of Proterozoic age and Gniesses of Archean age (Fig 1.7). The geological succession is shown below.

Table- Geological succession of the Study area

Age	Group	Lithology
Proterozoic	Cuddapah Super Group	Quartzites, Shales
Archaean	Dharwar Super Group	Schists, Quartzites, Gniesses, Khondalites

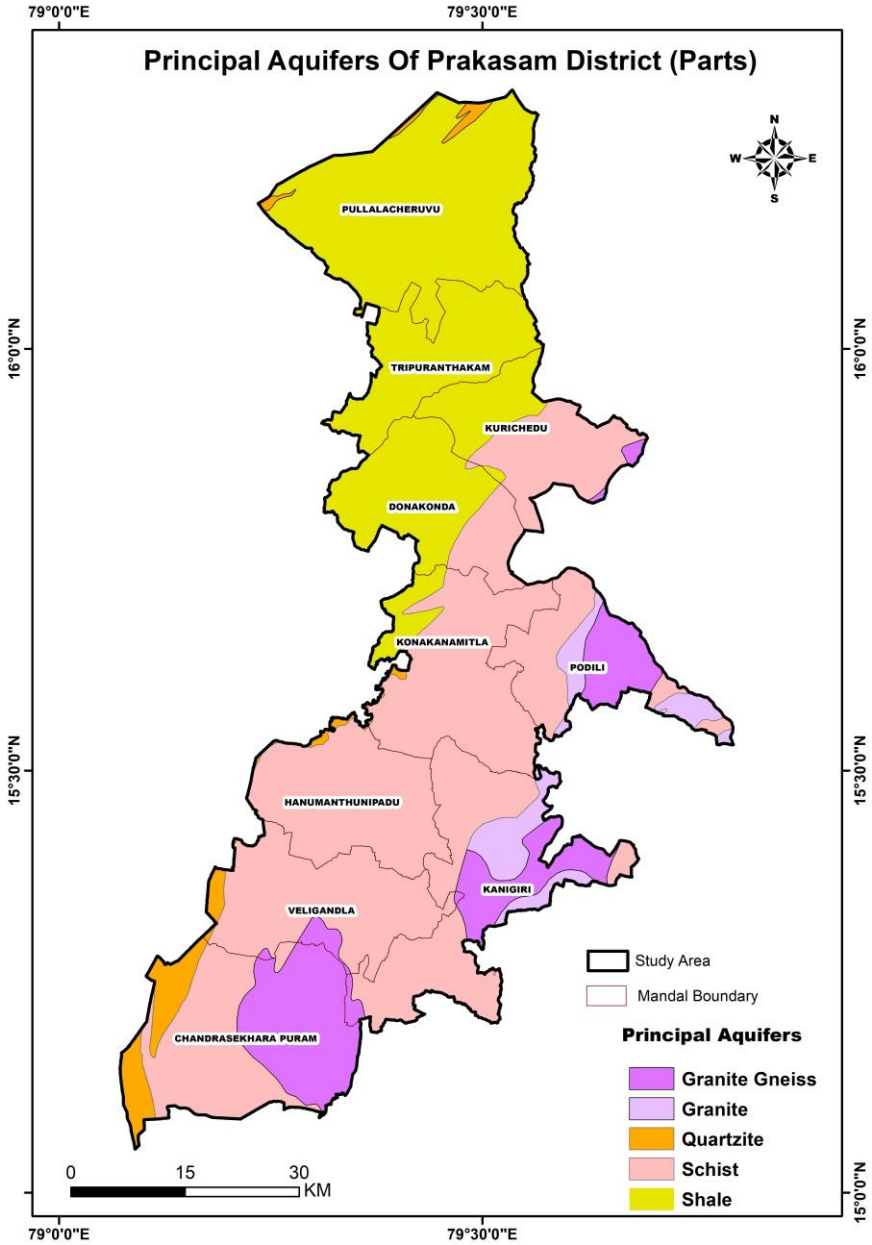

Fig-1.7 Geology Map of the Study Area, Prakasam District (Parts), AP

2. DATA COLLECTION AND GENERATION

Collection and compilation of data for aquifer mapping studies is carried out in conformity with Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various data generation activities **(Table-2.1)**.

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

S. No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, 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) etc.
		Hydrological Parameters on groundwater recharge	Soil infiltration studies, rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of sub-surface hydrogeological sections.
		Generation of additional water quality parameters	Analysis of groundwater for general parameters including fluoride.
3.	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.
4.	Aquifer Management Plan	Preparation of aquifer management plan	Information on aquifer through training to administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain.

2.1 Hydrogeological Studies

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of ground water occurring in the subsurface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. The principal aquifer in the area is

Meta sediments (Shales and quartzites) and the occurrence and movement of ground water in these rocks is controlled by the degree of interconnection of secondary pores/voids developed by fracturing and weathering. The 88 hydrogeological data points (Exploration: 9 (CGWB & 20 (SGWD), Geophysical: 15, water quality: 14 and well inventory: 30) used for datagap analysis is shown in **Fig.2.1**.

2.1.1 Groundwater occurrences and movement: Groundwater occurs under unconfined and semi-confined conditions below weathered zone. The main aquifers constitute the weathered zone at the top, followed by a discrete anisotropic fractured/fissured zone at the bottom which are interconnected and generally extending down to 115 m depth. The storage in granite rocks is primarily confined to the weathered zone and its overexploitation, mainly for irrigation purpose, has resulted in desaturation of weathered zone at many places. At present, extraction is mainly through boreholes of 60-100 m depth, with yield between <1 to 11 litres/second (lps). Majority of fractures occur within 100 m depth and deepest fracture is encountered at the depth of 115 m depth. The hydrogeological map of the area is presented in **Fig. 2.2**.

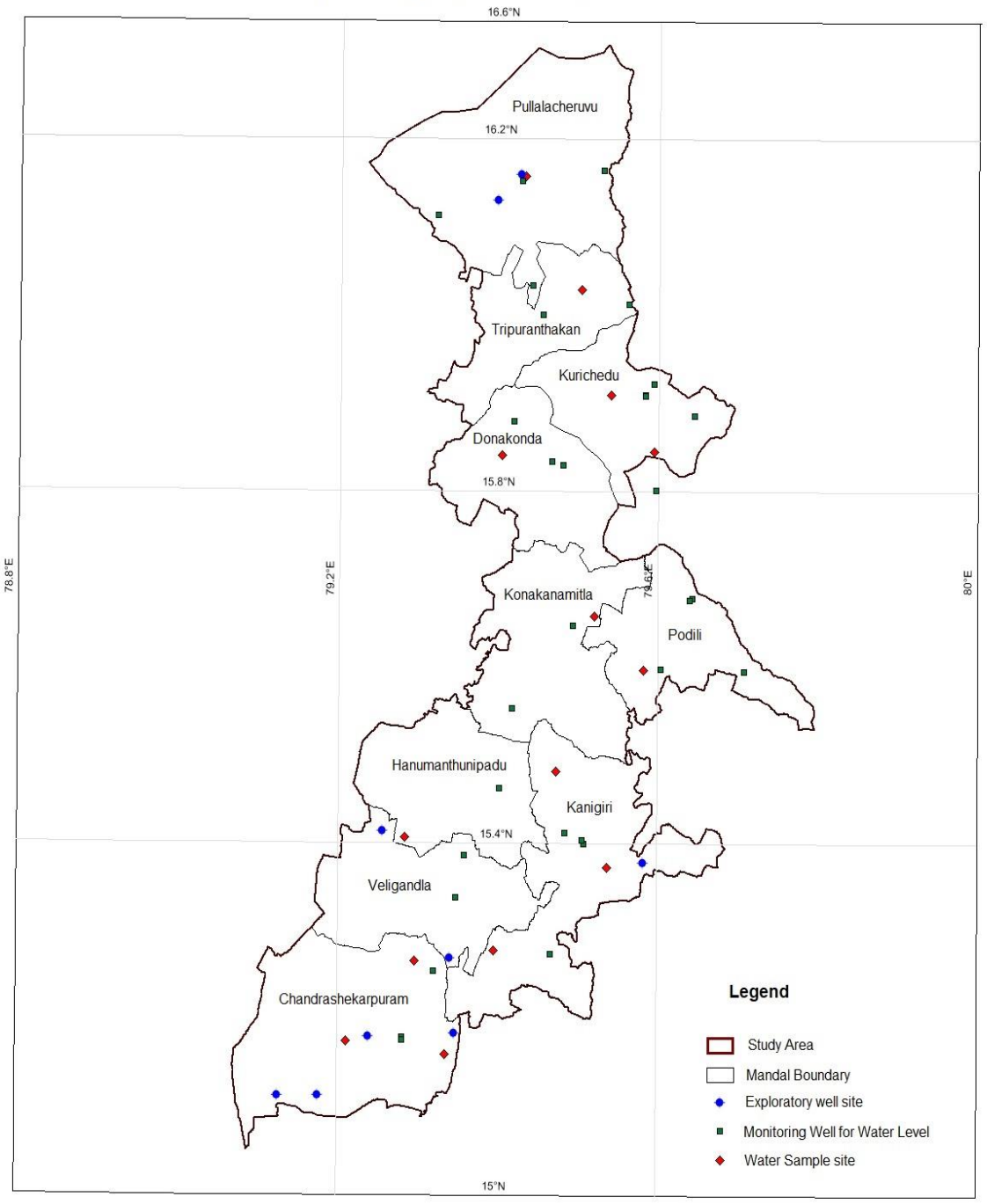

Fig- 2.1 Data used for Aquifer mapping in the Study Area, Prakasam District (Parts) A.P.

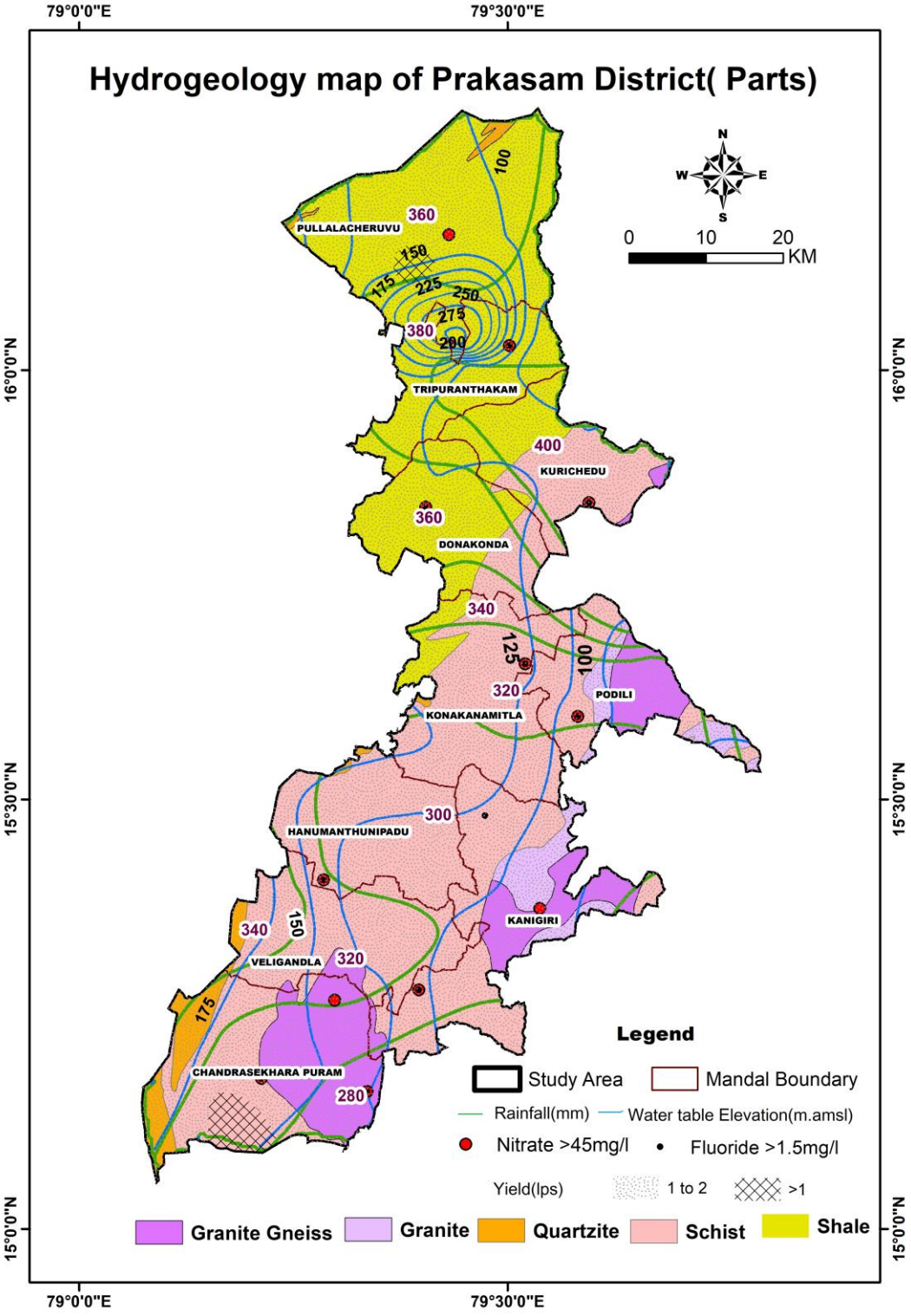

Fig-2.2 Hydrogeology of the Study Area, Prakasam District (Parts), A.P

2.1.2 Exploratory Drilling: As on 31/03/2019, SGWD drilled 20 wells in the study area. An analysis exploratory bore wells drilled by SGWD indicate that 2 bore wells are <30 m depth, 17 bore wells are of 30-60 m depth and remaining 03 wells are of 60-100 m depth range. The

depth to the deepest fracture occurred in these formation is 68 m at Podili and deepest fractured dechiphered through VES studies is 109 m in Chandrashekarpuram.

2.1.3 Ground water Yield: Ground water yield from weathered and fractured aquifer varies from <1 to 2 lps. Based on the combined data of CGWB and SGWD yield map is prepared and shown in **Fig.2.2**. In most of the area yield varies from 1 to 2 lps.

2.2 Water Levels (2020): Ground water levels from 27 wells (9 wells of CGWB and 18 wells of SGWD) are utilized for Water levels of pre-monsoon and post-monsoon season.

2.2.1 Water Table Elevations: During pre and post-monsoon season (May and November) of 2020, the water-table elevation ranges from 25 to 275 (m amsl) respectively and general ground flow is towards South East direction (**Fig.2.3**).

2.2.2 Depth to Water Levels (DTW): The DTW varies from 3.7 to 49.5 meter below ground level (m bgl) during Pre-monsoon period and (average: 14.39 m bgl) and 2.02 to 26.9 m bgl (average: 10.03) during post-monsoon season of 2020 respectively.

Majority of the area shows water level between 10 and 20 m bgl during pre-monsoon except the western part of the study area. Deeper water levels more than 20 m bgl is confined to the western part. Water levels are shallow in the study area mainly in the range of 10 to 20 m bgl (~65%). Premonsoon depth to water level map is depicted in **Fig.2.4**. During post-monsoon season, majority of the area shows water level in the range of 10-20 m bgl, but the area of coverage increased, when compared to pre-monsoon period. Deeper water level of more than 20 m bgl is confined to isolated packotes in Pullalacheruvu and Veligondla mandals. The post monsoon depth to water level map is depicted as **Fig-2.5**.

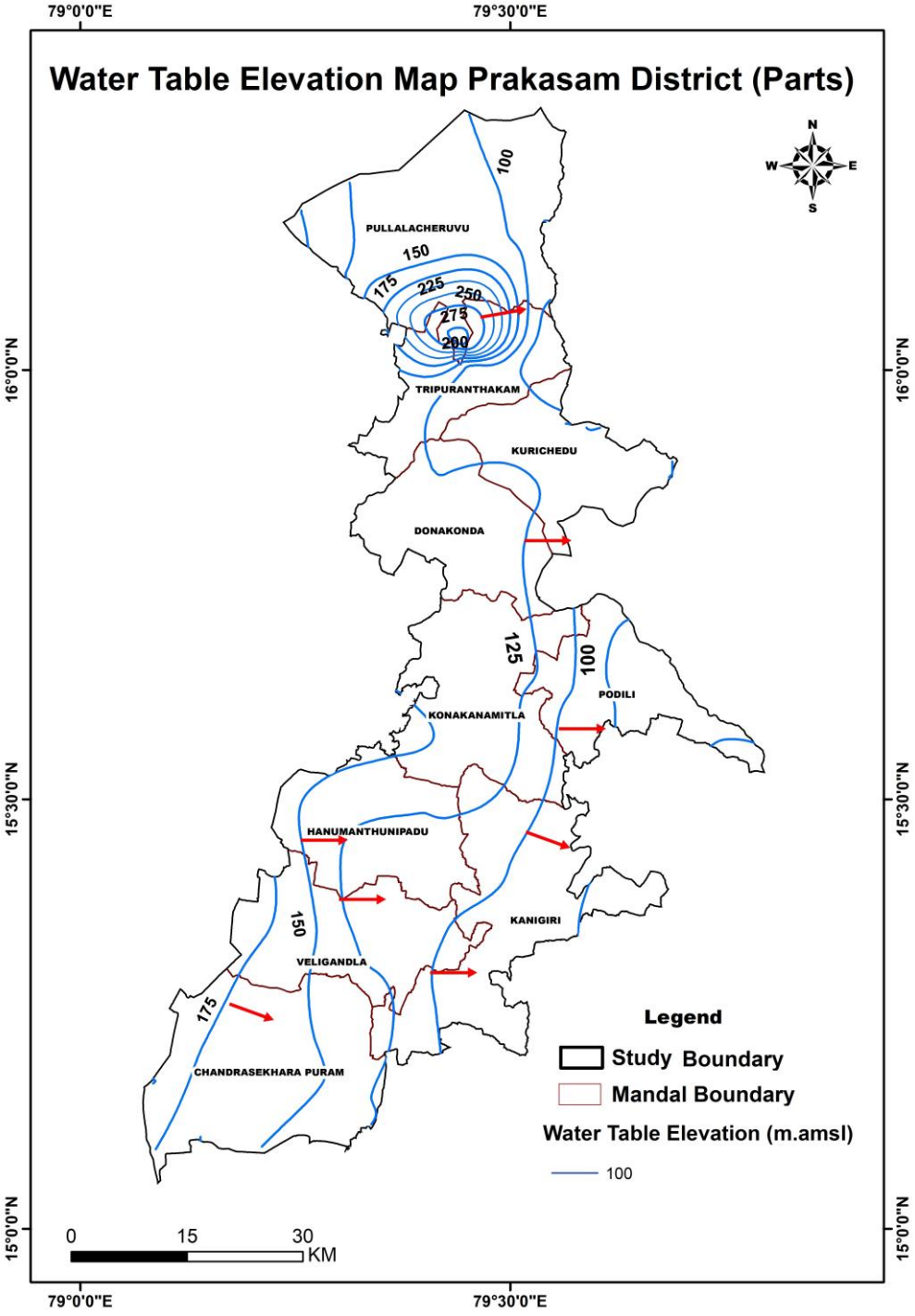

Fig- 2.3 Water Table Elevations

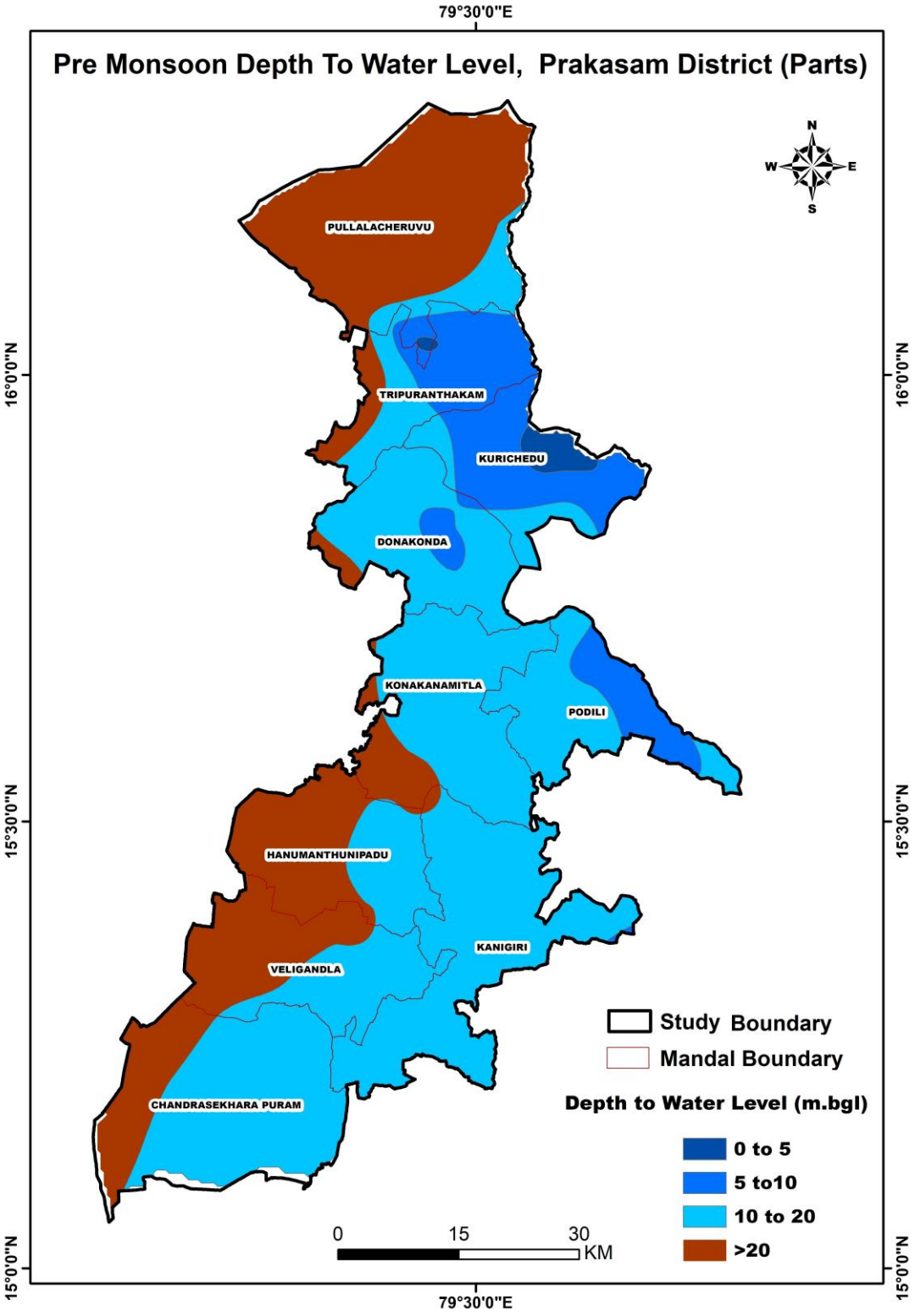

Fig- 2.4 Depth to Water Level (Pre Monsoon)

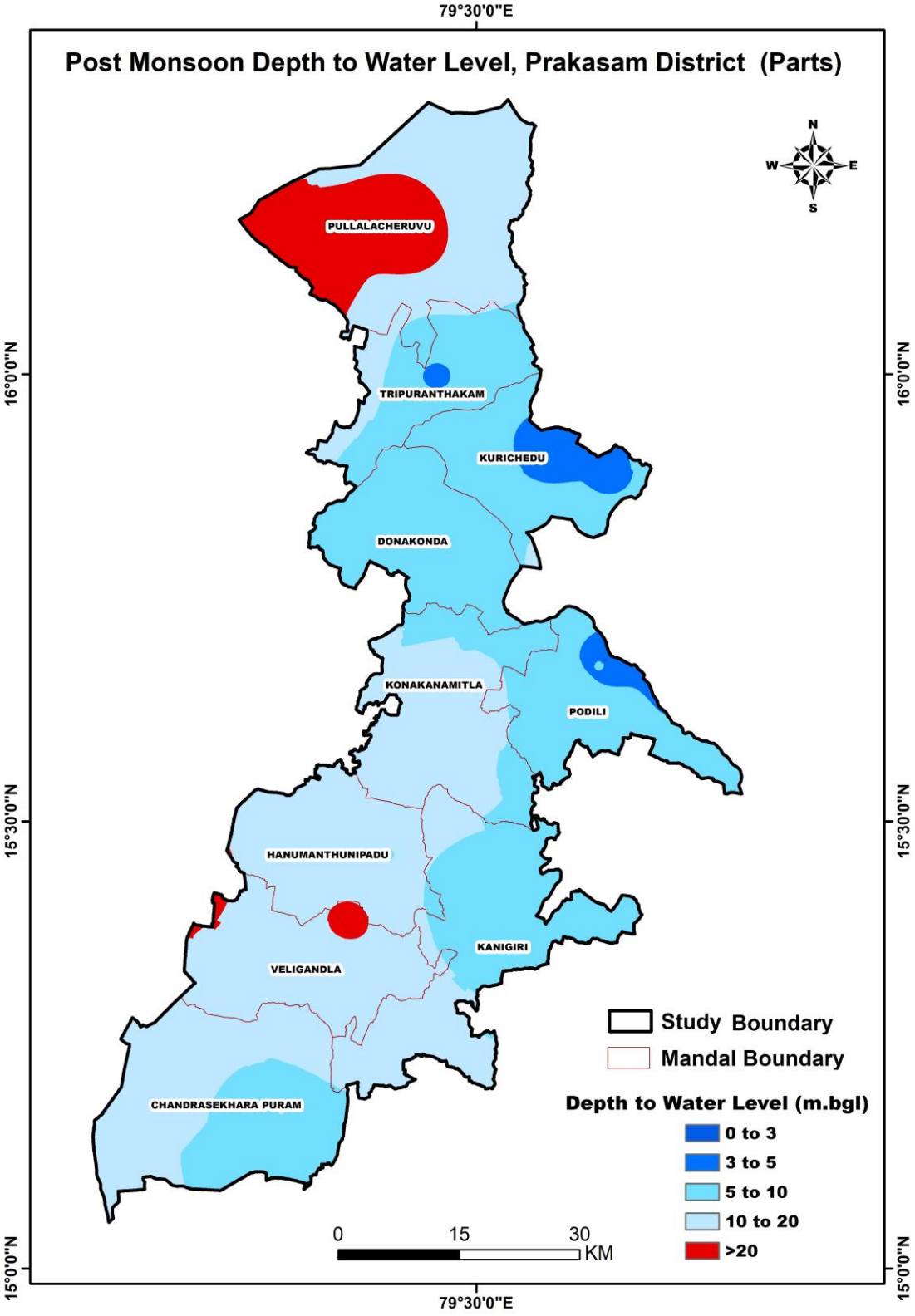

Fig- 2.5 Depth to water Levels (Post Monsoon)

2.2.3 Water Level Fluctuations (May vs. November): The water level fluctuations vary from -13.13 to 37.38 m with average fall of - 5.03 m and rise of 9.92 m (**Fig.2.6**). Out of 25

wells, in 12 wells (50%) shows fall in water levels (-0.03 to -13.13 m) and 10 wells show rise in water levels (0.06 to 37.38 m) and 3 wells show neither rising nor fall in water levels. In general, water level fluctuation shows rise in water level from pre to post monsoon seasons.

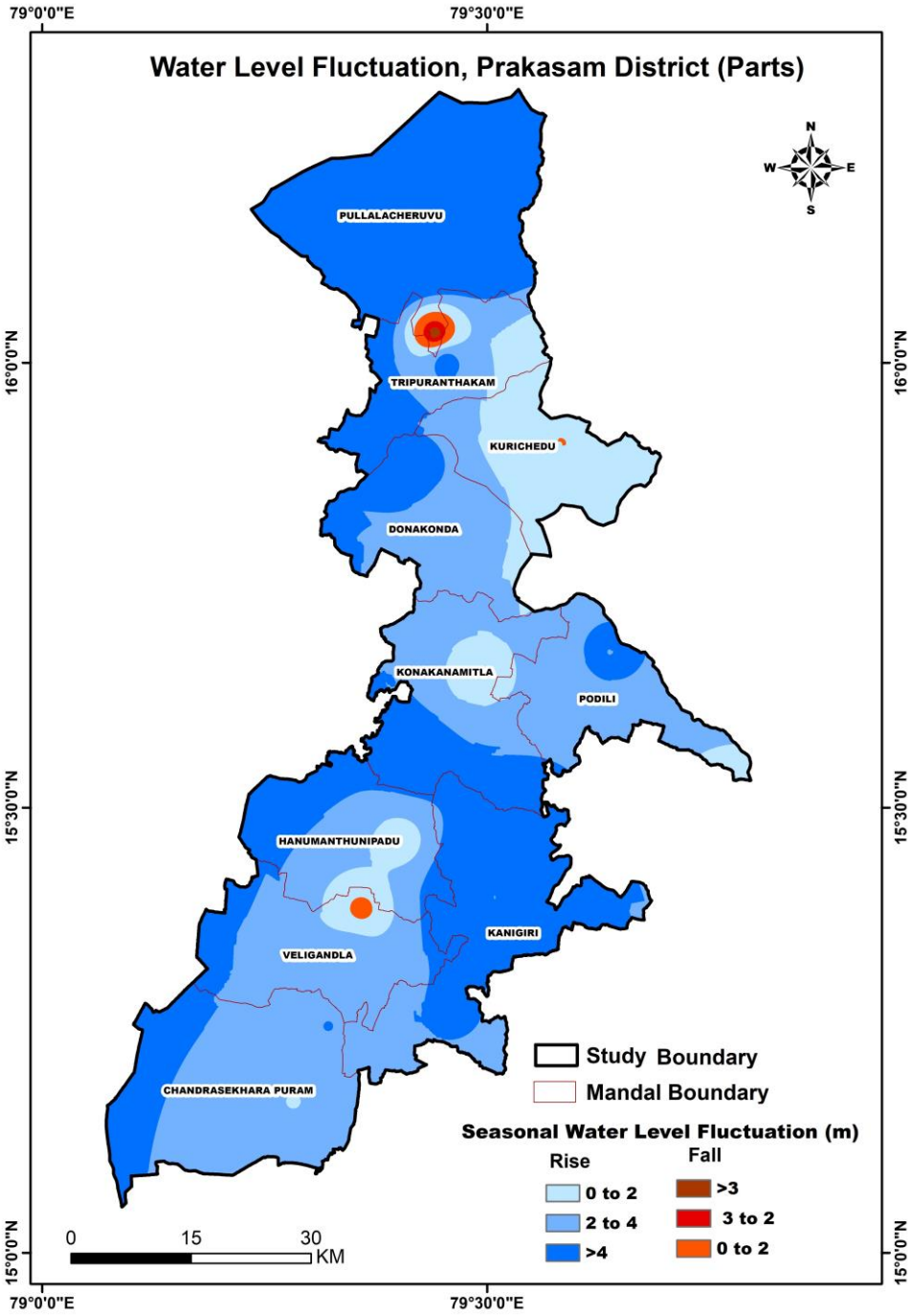

Fig.2.6: Water Level Fluctuations (m) (Post monsoon with respect to Pre-monsoon)

2.4 Hydro-chemical Studies

To understand chemical nature of groundwater in the area, water quality analysis data from 14 wells have been considered. Groundwater from the area is alkaline in nature with pH in the range of 7.05 to 7.82 (Avg: 7.49). Electrical conductivity varies from 810 to 4010 (avg: 2439) µ/Siemens/cm. In majority of area (80 %) covering northern, central and southern part, EC is in the range of 1500-3000 µ/Siemens/cm covering all the mandals excluding Pullalacheruvu mandal and 20 % of the area where EC is < 3000 µ/Siemens/cm **(Fig-2.7).** The Concentration of NO_3 ranges from 36-430 mg/l. Nitrate concentration upto 45 mg/l is observed in 1 sample and above permissible limit of >45 mg/l is observed in remaining samples (**Fig-2.8**). The concentration of Flouride ranges from 0.70 to 3.70 mg/l with an average of 2.2 mg/l. In 11 samples (78%), F concentration is observed more than the permissible limits (>1.5 mg/l) and in 3 (22%) samples F is with in the permissible range (<1.5 mg/l) **(Fig-2.9).**

2.4.1 Suitability of Groundwater for drinking purpose:

Suitability of ground water for different purposes is assessed based on the BIS (2012) standards. It is found that, 79 % samples (11 out of 14 analyzed) are not suitable for drinking purpose, where F is beyond the maximum permissible limit of BIS during post monsoon.

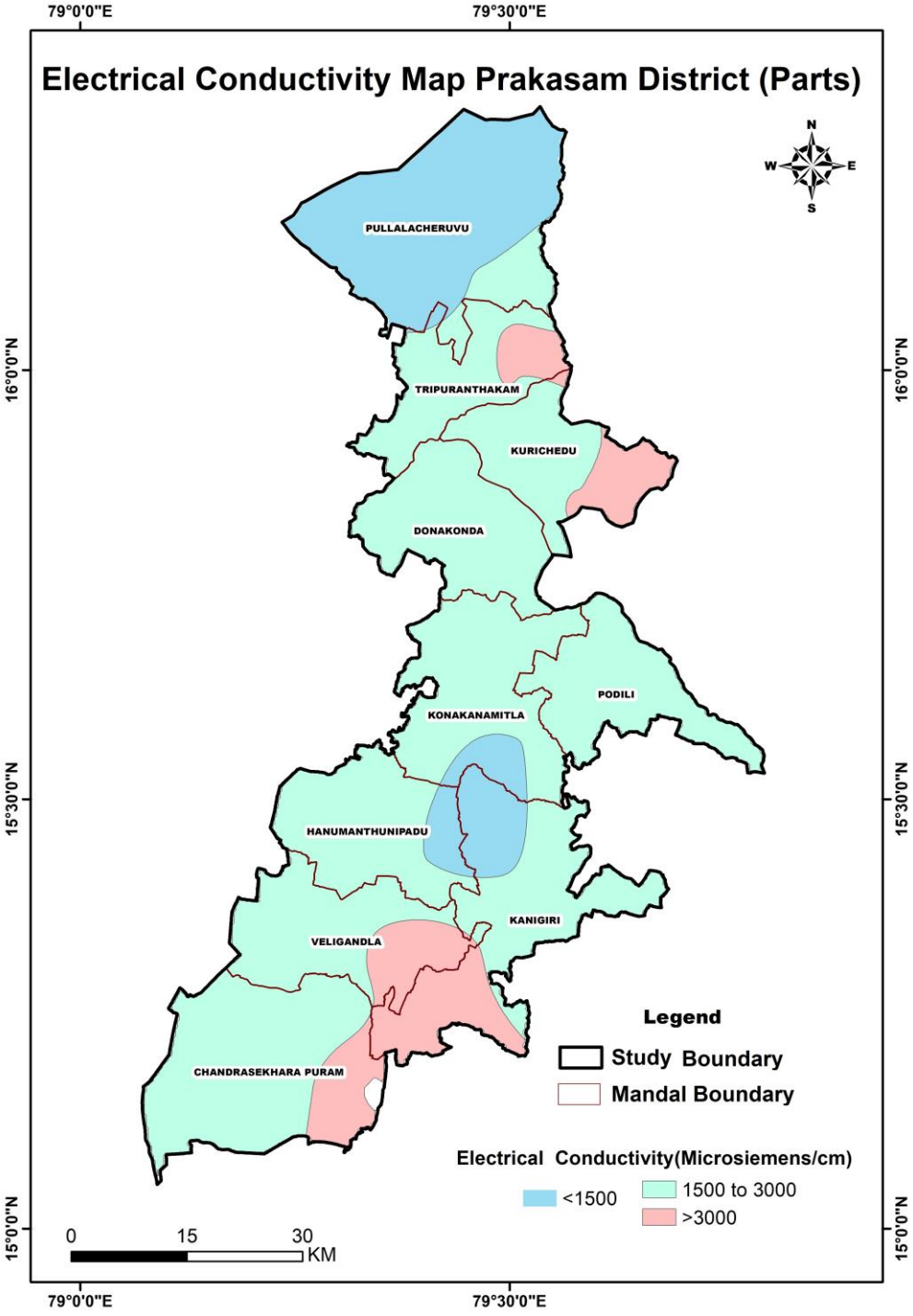

Fig.2.7: Distribution of Electrical conductivity

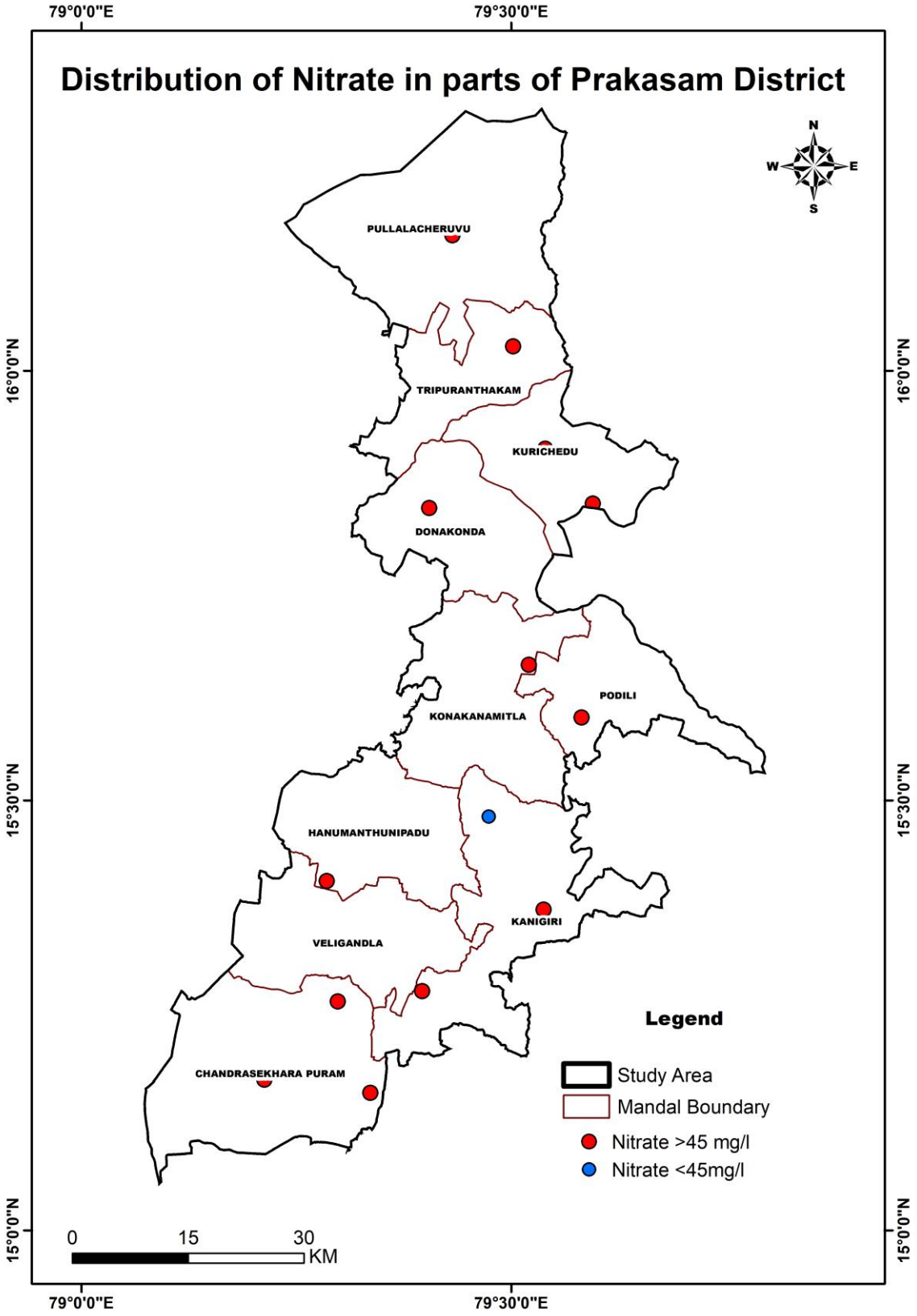

Fig.2.8: Distribution of Nitrate

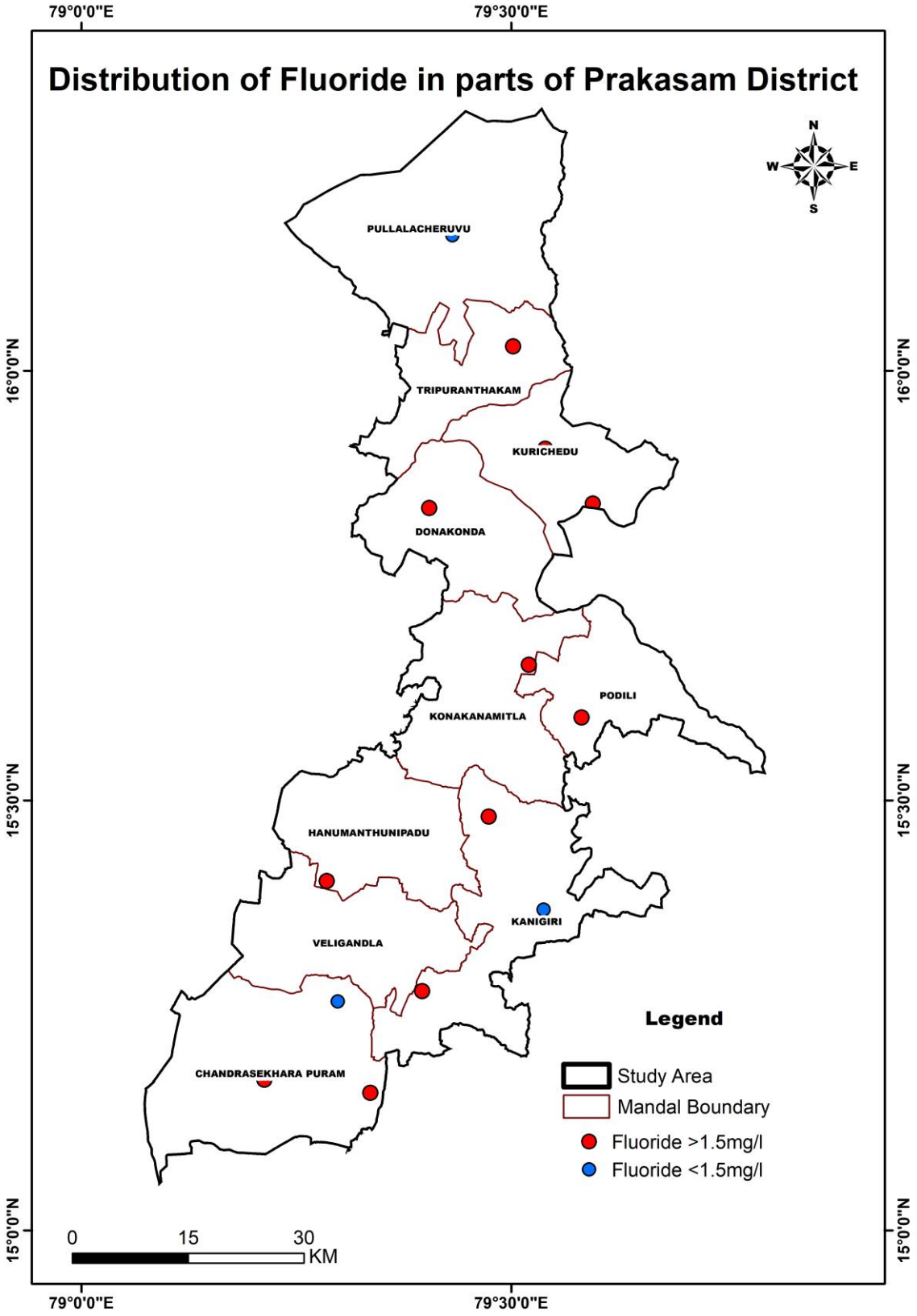

Fig-2.9 Distribution of Fluoride

3. DATA INTERPRETATION, INTEGRATION and AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 88 hydrogeological data points (Exploration: 9 (CGWB & 20 (SGWD), Geophysical: 15, water quality: 14 and well inventory: 30), down to 150 m is used for preparation of 3-D map, panel diagram and hydrogeological sections. The data is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data. The lithological information was generated by using the RockWorks-16 software and generated 3-D map for study area (**Fig.3.1 and 3.2**) along with panel diagram and hydrogeological sections (**Fig-3.3a & b**).

3.1 Conceptualization of aquifer system in 3D

Aquifers were characterized in terms of potential and quality based on integrated hydrogeological data and various thematic maps. Weathered zone is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~20 m depth and the fractured zone (fractured granite) is considered up to the depth of deepest fracture below weathered zone (~20-110 m).

3.2 Hydrogeological Sections

Hydrogeological sections (2 nos) are prepared in N-S and SW-NE directions (**Fig. 3.3**).

3.2.1 N-S Section: The section drawn along the **N-S** direction covering distance of ~125 kms (**Fig.3.4a**), depicts thick fractured zone in Northern parts compared to massive nature of Meta sediments in Southern parts. The weathering is showing undulating thickness in the section.

3.2.2 SW-NE Section: The section drawn along the SW-NE direction covering distance of ~86 kms (**Fig.3.4b**), depicts very thin weathering parts in central part and is hilly.

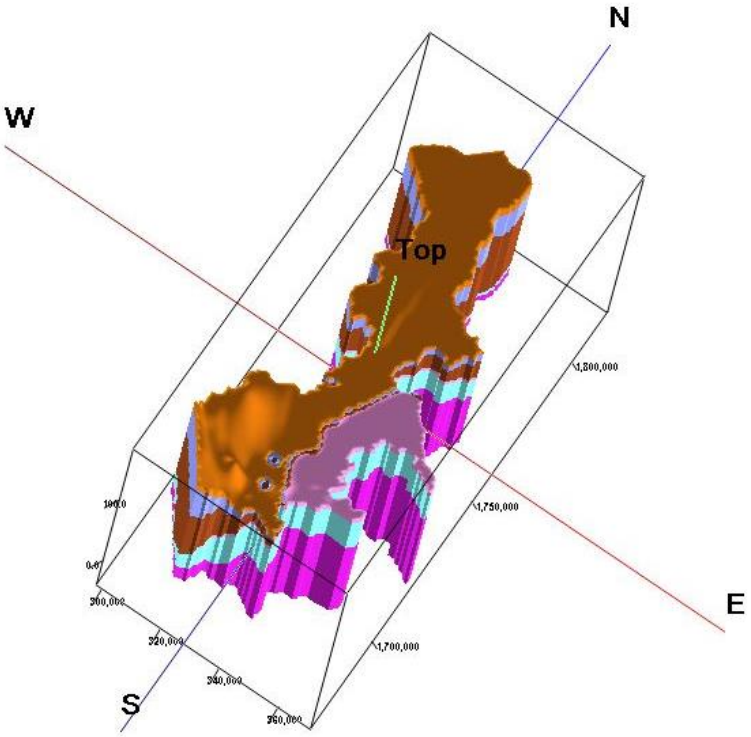

Fig.-3.1: -3D Model for study area.

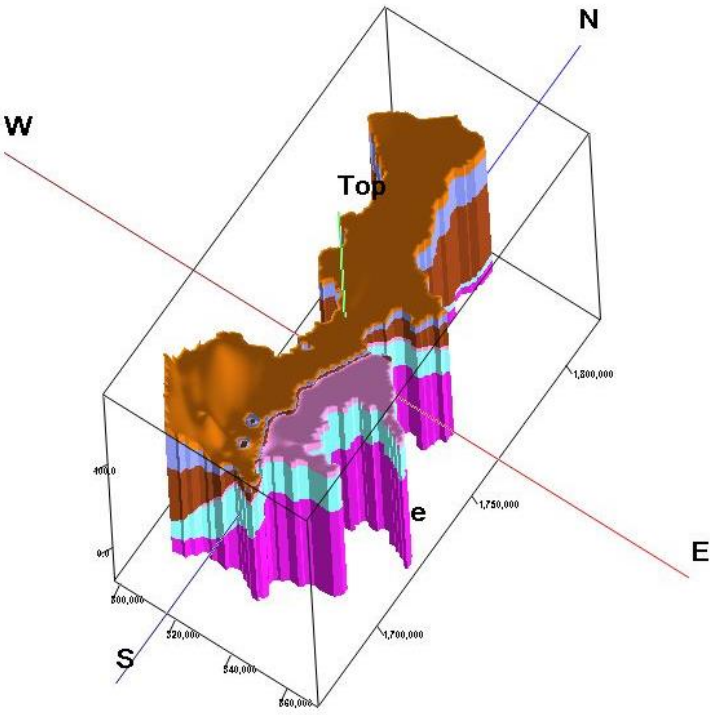

Fig.-3.2: 3D Model for study area.

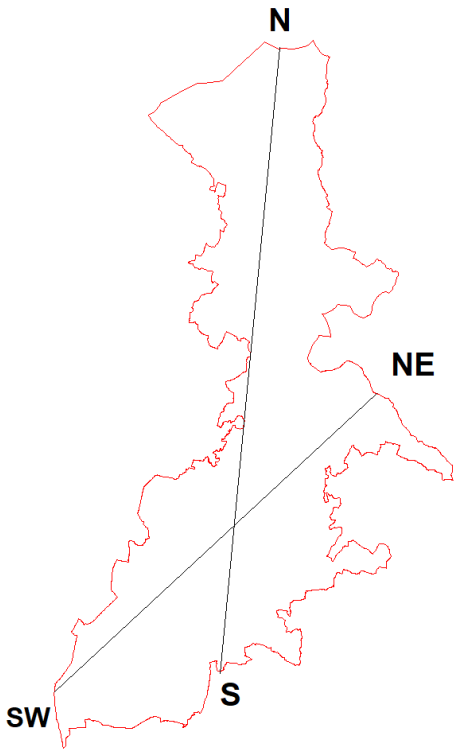

Fig.-3.3: Map showing orientation of various sections.

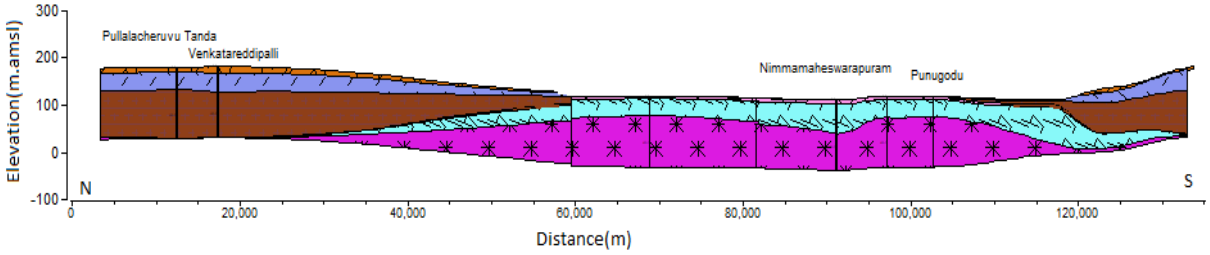

Fig-3.4 a: N-S Section

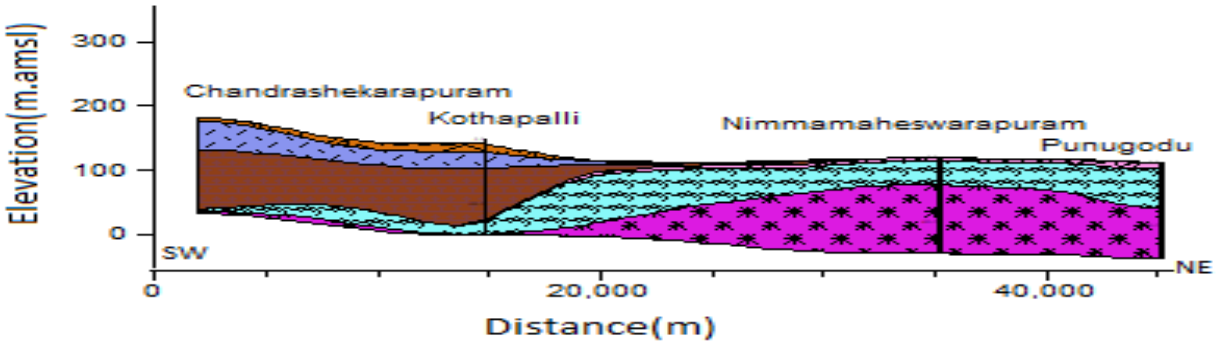

Fig-3.4 b: SW-NE Section

3.3 Aquifer Characterization

3.1 Weathered zone:

The Thickness of weathered zone varies from 5.5 m to 23.6 m. In most of the study area, the thickness of weathering is in between 10-20 m (90%) in most part of area followed by <10 m Deep weathering in Kanigiri mandal and > 20 m occurs in isolated parts of Chandrashekarpuram mandal of the study area. The weathered thickness map is presented in **Fig-3.5.**

3.2 Fractured zone:

The depth of fracturing varies from 25-133 m and deepest fracture is dechiphered at 133m at CS Puram. The yield of the deepest fracture encountered at CS Puram is ~2 lps indicating the potential nature of Second aquifer in the study area. The depth of fracture map is presented in **Fig. 3.6.** The depth of all the exploratory wells drilled so far are ~150 m and the potential fractures occur with in the depth range of 133 m (100%) The ground water yield varies from <0.22 to 2.33 lps.

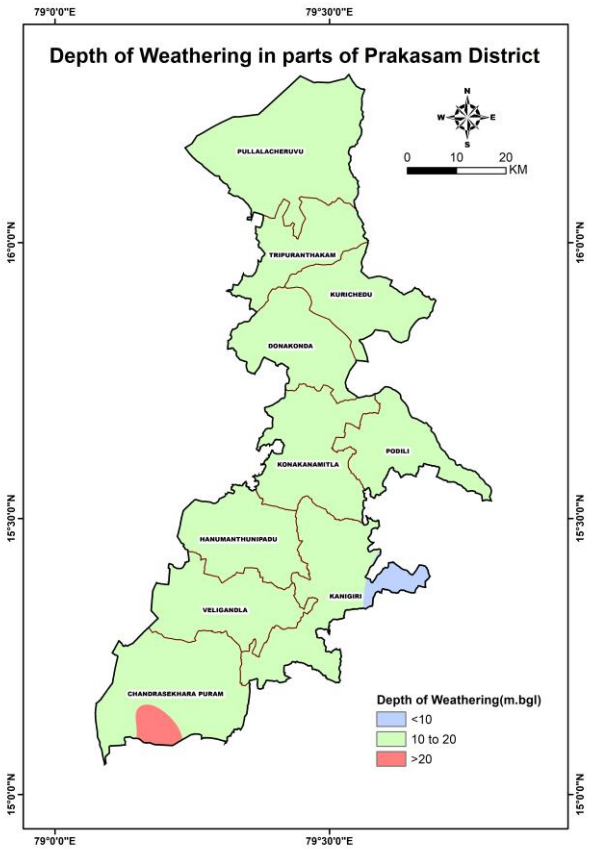

Fig.3.5: Thickness of weathered zone- Study area, Prakasam (Parts).

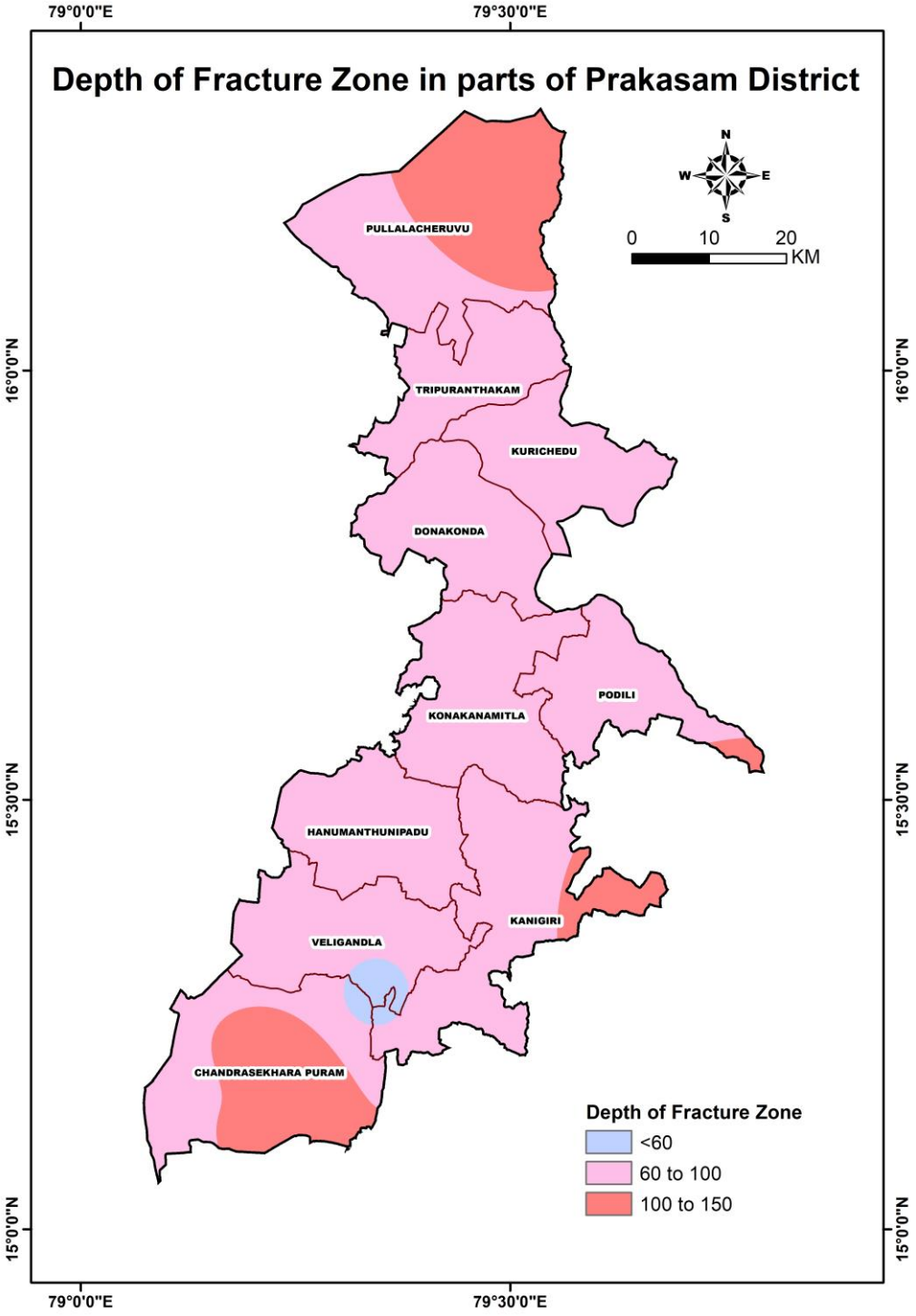

Fig.-3.6: Depth of fractured zone (Maximum depth) (m bgl).

4.0 GROUND WATER RESOURCES (2020)

In hard rocks, for practical purpose it is very difficult to compute zone wise (aquifer wise) ground water resources, because the weathered zone and fractured zone are inter-connected with fractures/joints and fractured zone gets recharged through weathered zone. Therefore it is very difficult to demarcate the boundary between two aquifers; hence the resources are estimated considering entire area as a single aquifer system. Village wise dynamic and in-storage ground water resources are computed as per the guidelines laid down in GEC methodology.

While computing the in-storage resources, the general depth of deepest fractures in the area, pre-monsoon water levels and 2 % of granular zone (depth below pre-monsoon water level and down to deepest fracture depth in the village) is considered. Summarized command/ non-command area and mandal wise resources are given in **Table-4.1 and** Village-wise in **Annexure-1** respectively.

As per 2020 GEC report, the net annual groundwater availability is 259 MCM, gross ground water draft for all uses **97** MCM, provision for drinking and industrial use for the year 2025 is 17 MCM and net annual ground water potential available for future irrigation needs is 169 MCM. Stage of ground water development varies from 15.7 % in Veligandla mandal to 161.7 % in Pullalacheruvu mandal (avg: 37.4 %). Out of 10 mandals 9 mandals falls in safe category (63% of area) and one mandal in over-exploited category.

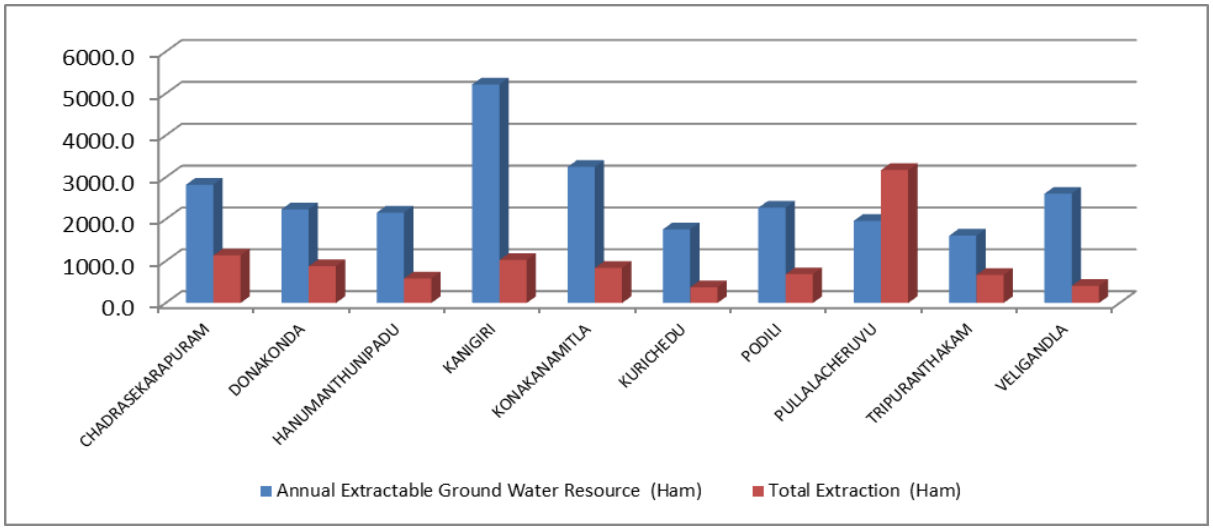

Fig-4.1: Ground Water Resources – 2020 Study area, Prakasam district (Parts).

Table-4.1: Ground Water Resources – 2020 Study area, Prakasam district (Parts).

Assessment Unit Name	Recharge from Rainfall-Monsoon Season	Recharge from Other Sources- Monsoon Season	Recharge from Rainfall-Non Monsoon Season	Recharge from Other Sources- Non Monsoon Season	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (Over-ExploitedE/Critical/Semicritical/Safe/Saline)
C.S. PURAM	1511.8	372.4	561.9	529.4	2975.5	148.8	2826.7	1074.4	0.0	61.7	1136.1	193.4	1558.9	40.2	Safe
DONAKONDA	1319.5	335.2	303.6	396.8	2355.0	117.8	2237.3	831.6	0.0	46.2	877.8	180.0	1259.2	39.2	Safe
H.M.PADU	1031.1	313.5	547.7	381.5	2273.8	113.7	2160.1	513.5	0.0	72.0	585.5	133.2	1513.4	27.1	Safe
KANIGIRI	3105.8	341.6	1545.3	502.3	5494.9	274.8	5220.1	867.8	0.0	157.8	1025.6	246.7	4105.6	19.6	Safe
KONAKANAMITLA	2163.3	392.9	421.4	442.4	3419.9	171.1	3248.9	805.3	0.0	30.9	836.2	208.3	2235.3	25.7	Safe
KURICHEDU	955.0	286.3	318.2	292.4	1852.0	92.6	1759.3	366.2	0.0	11.1	377.3	105.8	1287.3	21.4	Safe
PODILI	1017.1	388.7	503.7	484.5	2394.1	119.7	2274.4	612.9	0.0	73.9	686.8	222.6	1438.9	30.2	Safe
PULLALACHERUVU	1066.0	330.7	252.9	415.8	2065.3	103.3	1962.1	3150.4	0.0	22.7	3173.1	208.9	642.4	161.7	OE
TRIPURANTHAKAM	747.8	318.3	138.2	487.6	1691.9	84.6	1607.2	665.7	0.0	2.3	668.0	234.2	731.9	41.6	Safe
VELIGANDLA	1277.7	300.2	863.6	305.5	2747.0	137.4	2609.6	358.8	0.0	50.9	409.7	50.9	2199.9	15.7	Safe
Total	**14195.0**	**3379.8**	**5456.4**	**4238.1**	**27269.3**	**1363.7**	**25905.6**	**9246.6**	**0.0**	**529.4**	**9776.0**	**1784.0**	**16972.9**	**37.4**	

Computed Dynamic ground water resources as per GEC 2020.

Parameters	**Total** (MCM)
Dynamic (Net GWR Availability)	**259**
• Monsoon recharge from rainfall	142
• Monsoon recharge from other sources	34
• Non-Monsoon recharge from rainfall	54
• Non-monsoon recharge from other sources	42
• Total Natural Discharges (Ham)	13
Gross GW Draft	**97**
• Irrigation	92
• Domestic and Industrial use	5
Provision for Drinking and Industrial use for the year 2025	17
Net GW availability for future use	169
Stage of GW development (%)	37.4%

5.0 GROUND WATER RELATED ISSUES and REASONS FOR ISSUES

5.1 Issues and Resons

Over-exploitation

1. 1 mandals comprising an area of ~ 228 Km^2 area (16%) is categorized as over-exploited where ground water balance for future irrigation is zero or negative.
2. Out of the total irrigated area of 20433 ha, GW contributes 19839 ha (97%) resulted in desaturation of weathered zone and extraction of GW from deeper aquifers.

Pollution (Geogenic and Anthropogenic)

1. Majority mandals are fluorosis endemic where fluoride (geogenic) as high as 3.7 mg/L is found in groundwater. The high fluoride concentration (>1.5 mg/L) occur in 78 % of analyzed samples in the study area.
2. Higher concentration of fluoride in ground water is attributed due to source rock, rock water interaction where acid-soluble fluoride bearing minerals (fluorite, fluoro-apatite) gets dissolved under alkaline conditions and higher residence time of ground water in deeper aquifer.
3. High nitrate (> 45 mg/L) due to anthropogenic activities is observed in about 92 % samples. This is due to excessive use of NPK fertilizers.
4. EC is > 3000 µ Siemens/cm is observed in parts of Tripurankathakam, Kurichedu, Veligandla and Chandrashekarpuram mandals, which is mainly due to geogenic.

6. 0 MANAGEMENT STRATEGIES

Dependence on ground water coupled with absence of augmentation measures has led to a fall in water level and desaturation of weathered zone in some parts of the district. The sustainability of existing ground water structures, food and drinking water security are challenging tasks in the preparation of management plan. Higher NO_3^- concentrations (> 45 mg/L) in weathered zone is due to sewage contamination and higher concentration of F^- (>1.5 mg/L) in weathered zone and fractured zone is due to local geology (granite/gneiss rock), high weathering, longer residence time and alkaline nature of groundwater. The uneven

distribution of groundwater availability and its utilization indicates that a single management strategy cannot be adopted and requires integrated hydrogeological aspects along with socio-economic conditions to develop appropriate management strategy.

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. supply side management has been prepared separately for urban and rural areas.

6.2 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 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 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 687 recharge structure (679 Check dams and 8 percolations tank) though MGNREGS and IWMP scheme. Considering the SOE, it is recommended that instead of planning for new artificial recharge structure for the entire study area, it is more viable to propose structures only in areas having SOE >50% to control further increase in stage of ground water extraction, where vulnerability of ground water resource in future is identified and also to consider the desilting and maintanenceof existing CD’s and PT’s.

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 rainfall 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 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.

The recharge and runoff available in the district is given in **Table 6.1**

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

Total geographical area of district (Sq.km)	4095
Area feasible for recharge (Sq.km)	3360
Unsaturated Volume (MCM)	18376
Recharge Potential (MCM)	367
Runoff available (MCM)	67
Surplus runoff available for recharge (MCM)(20% of runoff)	13

6.2.1 Supply side measures:

6.2.1a Artificial Recharge Structures in Over exploited areas

The artificial recharge structures (ARS) are suggested in Kanigiri, Kurichedu, Donakonda and Hanumanthnipadu Mandal in the Study area. 50% of the available surplus runoff is considered for the recommendation of artificial recharge strutcures, as the remaining 50 % is recommended for implementing water conservation measures in recharge areas through MGNREGS. **(Table 6.2)**

Table 6.2 Proposed artificial recharge structures in Kanigiri, Kurichedu, Donakonda and Hanumanthnipadu Mandal	
Percolation Tanks (@ Rs.15 lakh Capacity of the tank: 0.007MCM, Av. Gross storage in an year = 0.007 MCM*2 fillings = 0.014 MCM Volume of Water expected to be recharged (in MCM) Estimated Expenditure (in Crores)	14 0.2 2.10
Check Dams (@ Rs.10 lakh, Av. Gross storage in an year = 0.007 MCM* 5 fillings = 0.035 MCM Volume of Water expected to be recharged(in MCM) Estimated Expenditure (in Crores)	25 1 2.5
Total volume of water expected to be recharged (in MCM)	1.2
Total Estimated Expenditure for Artificial Recharge (Rs. in Cr.)	4.6

36 artificial recharge structures (25 CD's and 14 mini PT'in 25 villages) with a total cost of 4.6 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)

- After effective utilization of this yield, there will be 1.2 MCM of ground water recharge (50 % of total utilizable yield).
- Roof top rainwater harvesting structures should be made mandatory to all Government buildings (new and existing).

For sustainable development and management of the ground water resources the above recommendations are made and summarised in **Annexure-2**.

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 ground water resources.

State Government Intiatives:

In Prakasam District there are 952 Minor Irrigation Tanks (363 M.I + 589 panchayataj Raj) having an Registered ayacut of 135427 Acres. During 2013-14 an ayacut of 28706 Acres is irrigated. (5^{th} MI Census). In the study area, Chadrashekarpuram, Donakonda, Kanigiri, Hanumanthunipadu, Konakanamitla, Podili, Pullalacheruvu, Tripuranthakam and Veligandla, mandals are also will be covered under the proposed Veligonda project **(Fig-1.6)** which is contemplated to create additional ~38075 hectare of irrigation potential. The proposed extention of ayacut under this project is as follows.

Sl.No.	Mandal	No.of sources	Regd. Ayacut
1	Chandrasekhara Puram	32	3488
2	Donakonda	50	2945
3	Hanumanthunipadu	8	1516
4	Kanigiri	30	8311
5	Konakanamitla	28	4371
6	Kurichedu	34	2118
7	Podili	23	3676
8	Pullalacheruvu	39	3931
9	Tripuranthakam	24	3735
10	Veligandla	22	3985
	Study area Total	**290**	**38075**
	District Total	**952**	**135427**
	Percentage %	**30.5**	**28.1**

The crop water requirement for 38075 ha is 228 MCM for ID crops. After the implementation of the project, the area under rainfed irrigation (38075 ha) in the study area will be brought into the ambit of assured surface water irrigation. The conserved surface water can be effectively being utilized to supplement irrigation, which will reduce the stress on ground water.

6.2.2 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 15658 farm ponds, exist in 283 villages and in the mandals where SOE >50% there are 865 farm ponds which can be desilted and maintained so that it will greatly help in ground water augmentation.

6.2.2a. Micro-irrigation:

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

- 1900ha of additional land in Pullalacheruvu that can be brought under micro-irrigation (@100 ha/village in 19 villages) costing about 16.8 crores (considering 1 unit/ha @0.6 lakh/ha). With this ~3.42 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) .

- 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 ground water user should recharge rainwater through artificial recharge structures in proportionate to the extraction.

6.2.3 Other measures

- A participatory ground water 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.

6.2.4 Expected Results and Out come

With the above interventions, the likely benefit would be the net saving of 4.6 MCM recharge of ground water.

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Annexure-1

Proposed Structures					
Village	Mandal	Existing		Proposed	
		PTs	Check dam	Number of cd feasible	Number of PT feasible
Kutagundla	HANUMANTHUNIPADU	0	0	1	0
Hazis Puram	KANIGIRI	0	0	1	0
Challagirigala	KANIGIRI	0	0	1	0
Aravallipadu	DONAKONDA	0	0	1	0
Pedaraju Palem	CHADRASEKARAPURAM	0	0	1	0
Vijaya Gopala Puram	KANIGIRI	0	0	1	0
Doddi Chintala	HANUMANTHUNIPADU	0	0	1	0
Vemula Padu	HANUMANTHUNIPADU	0	0	1	0
Ummana Palle	HANUMANTHUNIPADU	0	0	1	0
Pedagola Palle	HANUMANTHUNIPADU	0	0	1	0
Chirla Dinne	KANIGIRI	0	0	1	0
Sankavaram	KANIGIRI	0	0	1	1
Yadavalli	KANIGIRI	0	0	1	1
Punugodu	KANIGIRI	0	0	1	1
Mummayapalem	KONAKANAMITLA	0	0	1	1
Hazee Puram	HANUMANTHUNIPADU	0	0	1	1
Thimmareddi Palle	HANUMANTHUNIPADU	0	0	1	1
Bommireddi Palle	KANIGIRI	0	0	1	1
Guravajipeta-1	KANIGIRI	0	0	1	1
Kanigiri (U)	KANIGIRI	0	0	1	1
Nandanavanam	HANUMANTHUNIPADU	0	0	1	1
Chakirala	KANIGIRI	0	0	1	1
Mustla Gangavaram	KURICHEDU	0	0	1	1
Baduguleru	KANIGIRI	0	0	1	1
Balli Palle	KANIGIRI	0	0	1	1