केंद्रीय 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

NIRMAL DISTRICT, TELANGANA

दक्षिणी क्षेत्र, हैदराबाद

Southern Region, Hyderabad

भारत सरकार

GOVERNMENT OF INDIA

जल शक्ति मंत्रालय

MINISTRY OF JAL SHAKTI

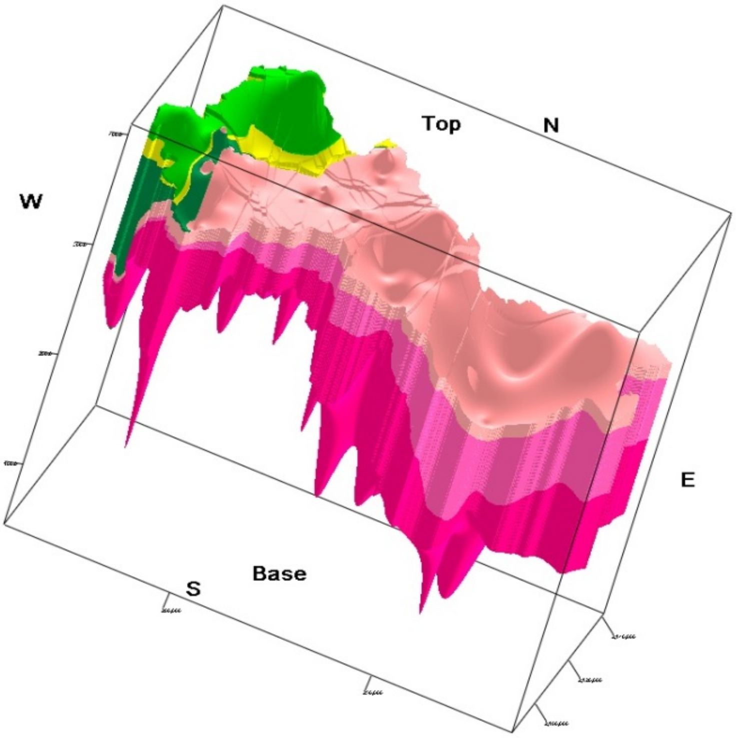
जल संसाधन नदी विकास एवम् गंगा संरक्षण विभाग

DEPARTMENT OF WATER RESOURCES, RD & GR

केंद्रीय भूमि जल बोर्ड

CENTRAL GROUND WATER BOARD

REPORT ON
AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES IN NIRMAL DISTRICT, TELANGANA STATE
(AAP-2020-21)



SOUTHERN REGION, HYDERABAD
MARCH, 2022

REPORT ON

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES IN NIRMAL DISTRICT, TELANGANA STATE

(AAP-2020-21)

CONTRIBUTORS' PAGE

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Pre-monsoon season: Majority in the range of 5-10 m (39 %), followed by 10-20 m bgl (35%). Deep water level > 20 m bgl occupy about 10% of the area covering western parts. Shallow water level (0-5 m bgl) occupies about 15 % of area in eastern and southern part of district.
Post-monsoon: Majority of the water levels are in the range of 2-5 m bgl (57%) followed by 5 to 10 m bgl (24%). Water levels in the range of 10-20 m. bgl</td></tr>
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			occupy 6 % of the area in parts of Narsapapur and aKuntala mandals. **Water table elevations** During pre-monsoon season, water-table elevation ranges from 212 to 400 and during post monsoon season water table elevation ranges from 213 to 402 meter above mean sea level (m amsl). The regional ground water flow is towards the river Godavari from northwest to southeast direction
20	Water Level Fluctuations (May vs. November) (Decadal mean)	:	All the wells in the district shows rise in water levels in the range of 1.23 to 23.23 m bgl (average: 5.03 m). 20 % of the area shows water level rise in the range of 0 to 2 m bgl. 33 % of the area has shown water level rise in the range of 2-5 m, and >5 m rise is observed in 47% of area falling in western parts of the district.
21	Long term water level trends (10yrs)	:	During pre-monsoon season, 7 wells show falling trends -0.02 m/yr to -1.43 m/yr and 25 wells shows a rising trend in the range of 0.01 to 2.81 m/yr in the southern region. During post-monsoon season, 15 wells show falling trends in the range of -0.001 m/yr to -1.7 m/yr and 17 wells shows rising trends in the range of 0.05 to 2.4m/yr.
22	Hydrochemistry	:	Pre-monsoon (70 samples - CGWB: 8, SGWD: 20, RWS:63), post-monsoon (107 samples- SGWD: 20, RWS: 97)
22.1	Electrical Conductivity (µ Siemens/cm)	:	Pre-monsoon (2019): Electrical conductivity varies from 121-1783 µ Siemens/cm (avg: 1011). Post-monsoon (2019): Electrical conductivity varies from 85-2160 µ Siemens/cm (avg: 908).
22.2	Fluoride mg/l	:	**Pre-monsoon (2019):** Fluoride concentration varies from 0.06-4.36 mg/L. Only 4 samples (5 %) are beyond permissible limits (>1.5 mg/l). **Post-monsoon (2019):** Fluoride concentration varies from 0.06 - 2.04 mg/L and found that 2 samples (2 %) are unfit for human consumption (>1.5 mg/l).
22.3	Nitrate mg/l	:	**Pre-monsoon (2019):** NO_3 concentration ranges from 3 to 191 mg/l. In 14 % of samples (10 nos) are beyond permissible limits (> 45 mg/l). **Post-monsoon (2019):** NO_3 concentration ranges from 1.31 to 159 mg/l and in 4 % of samples (5 nos) the No3 is beyond permissible limits (> 45 mg/l).

23	Conceptualization of Aquifers		**Aquifer-I (~30 m).**	**Aquifer-II (~30-195 m).**
24	Aquifer Characterization	:	The depth of weathering varies from 10-20 m (49 %), < 10 m weathering occurs in 41 % of the area. Deeper weathering (> 20 m) occurs in isolated parts falling in Kuntala, Tanoor Pembi and Narsapur	The fracture occurrence varies between 30-60 m, 60-100 m, 100-150 m and 150-200 m depth. Deepest fracture was encountered at 190.6 m. bgl at Rajura in Kubeer mandal in granitic formation
24.1	Specific Yield	:	< 1.5% to 2%	-
24.2	Storativity	:	-	0.01 to 5.0 x 10^{-6}
25	Ground water Resources (2020) MCM	:		
25.1	Annual Extractable Ground Water Resources	:	**504.67**	
25.2	Annual Extraction for all uses	:	**187.12**	
25.3	Provision for Domestic & Industrial (2025)	:	22.73	
25.4	Average Stage of Ground water development (%)		37%	
25.5	Net GW Availability for future irrigation	:	315.24	
25.6	Categorization of mandals		9 % in Pembi mandal and 73% in Dilawarpur mandal (SC:2 and Safe:17)	
26	Major Ground Water Issues Identified	:	Low sustainability of aquifers. An about ~ 147 Km^2 area (8 % of area) covering 37 villages are categorized as over-exploited where ground water balance for future irrigation is nil. The high fluoride concentration (>1.5 mg/l) occur in 5 % and 2 % of samples respectively during pre- and post-monsoon seasons. High nitrate (> 45 mg/l) due to anthropogenic activities is observed in 14% and 4 % of samples during pre and post-monsoon season respectively.	
27	Management Strategies	:	A total of 304 artificial recharge structures (161 CD's and 143 mini-PTs in 96 villages) and 7420 farm ponds are recommended. De siltation of all exiting CDS and PTs. Other recommendations include participatory groundwater management (PGWM) along with effective implementation of the existing	

			'Water, Land and Trees Act' of 2002 (WALTA-2002).
28.	Expected Results and Out come	:	With the above interventions costing Rs 189 crores (excluding the cost involved in Mission Kakatiya and Mission Bhagiratha), the likely benefit would be the net saving of 38.2 MCM of ground water. This will bring down the stage of ground water development by 3 % (from 37% to 34 %).

NUMBER OF DATA POINTS USED FOR PREPARATION OF VARIOUS MAPS
NIRMAL DISTRICT, TELANGANA STATE

S. No	Data	Aquifer	Total Data Points	Source	
				CGWB	SGWD
1	Panel Diagram (3-D)	Combine	79	Expl: 40 VES: 25	14
2	Hydrogeological Sections	Combine	79	Expl: 40 VES: 25	14
3	Fence/panel Diagrams	Combine	79	Expl: 40 VES: 25	14
4	Depth of weathering		79	Expl: 40 VES: 25	14
5	Depth of fracturing		79	Expl: 40 VES: 25	14
6	Depth to Water Level Maps (2019)	Combine	86	24	62
	Pre-monsoon 2019		86	24	62
	Post-monsoon 2019		86	24	62
7	Water Level Fluctuation	Combine	86	24	62
8	Long term water level trends	Combine	38	10	28
9	Water quality	Combine	177		
	Pre-monsoon 2019		Pre: 70	8	SGWD:20 RWS: 63
	Post-monsoon 2019		Post: 107	0	SGWD:20 RWS: 97

Executive Summary

The National Aquifer Mapping & Management is an important step in planning of suitable adaptation of strategies for sustainable ground water development and management in the Country. As a part of NAQUIM, Nirmal District in Telangana State has been taken up during AAP 2020-21 of Central Ground Water Board, Southern Region, Hyderabad with an over objective of mapping the aquifers and recommendation of suitable management stratagies for Nirmal District.

The Nirmal district covering ~3845 km^2 lies between north latitude 18°50´41"-19°20´20"-and east longitude 77°45´37"--78°57´03" and is bounded by Adilabad in the north, Komaram Bheem in the northeast, Mancherial in the east, Jagityal and Nizamabad (along with the Godavari) in the south and Nanded District of Maharashtra in the west. As per old district set up, it is part of Erstwhile Adialabd district. Administratively the district is governed by 19 mandals covering 428 revenue villages and 3 Municipalities with a population of ~7.10 lakhs (2011 census) (urban: ~21.4 %, rural: ~78.6 %) with average density of 185 persons/km^2.

The district experiences tropical climate and is geographically located in a semi-arid area with predominantly hot and dry climate. The annual normal rainfall of the district varies from 976 mm (Tanur mandal) to 1129 mm (Pembi mandal) with district normal of 1051 mm. Average number of rainy days for a year is around 63 days. The River Godavari flows along southern boundary of the district running in W-E direction. Pediplains are the major landforms occupying 52% of the area, followed by pediment in 22% area, dissected plateaus in 12% of the area and denudational hills in 8% of the area. The drainage is mainly dendritic to semi-dendritic. The district falls in the Godavari basin. The Swarna and Siddha, tributaries of the Godavari River traverse through the Nirmal district. The district consists of 13 watersheds ~84 % non-command area and ~16 % command area. Red loamy soils are the major soil type in the district, which are derived from country rocks. The other soils are black cotton soils mainly derived from basalt rock.

The Forest occupies about 33 % of the total geographical area, and the Net area sown in 41% and area sown more than once in 14% of the area. The net area sown is 1774.96 Sq.Km. The gross cropped area is 2865 Sq.Km. The district is benefitted by two major irrigation projects namely Sriram Sagar across the river Godavari at Pochampad (Nizamabd district) and Kadam on river Kadem. Gaddenvagu Vagu (Suddavagu) and Swarna Projects are Medium Irrigation Projects constructed across Godavari River in Bhainsa village and across Swarna river located in Jowli (Jewly) village of Sarangapur mandal respectively. The total no. of ground water abstraction structures in the district is 35,127 irrigating approximately around 52,690 ha. The total no. of minor irrigation tanks is 773 with an ayacut of 23,612 ha.

The district is underlainby Hard rocks comprising of Granites and Granite gnieeses and Basalats, which forms the principal aquifer systems. The hard rock aquifers lack primary porosity, and groundwater occurrence is limited to secondary porosity, developed by weathering and fracturing. 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 aquifer geometry for shallow and deeper aquifer has been established through hydro geological studies, exploration, surface and subsurface geophysical studies in the district. Based on the analysis of data, two aquifer systems were identified viz, weathered zone (Aquifer-1) and the fracture zone (Aquifer-2).

The Aquifer-1, consists of weathered residuum. The shallow aquifer is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~30 m depth. In most of the area the depth of weathering varies from 10-20 m (49 %), <10 m weathering occurs in 41 % of the area. Deeper weathering (> 20 m) occurs in isolated parts falling in Kuntala, Tanoor Pembi and Narsapur. These are unconfined aquifers. The average yield of these dug wells range between 20 and 50 m^3/day. Specific yield of 0.2 to 4 % is observed with average of 1.1 %. The storage coefficient (S) varies from 0.005 to 0.02 and specific capacity ranges from 0.17 to 0.165 litres/meter/drawdown (lpm/m/dd).

The Aquifer II, consists of fractured zone upto the maximum depth of 195 m bgl (deepest fracture at Rajura in Kubeer mandal). Fractures less than 100 m occupies 61% of the area. < 30 m in 9%, 30 to 60 m in 24% and 60-100 m in28% of the area. Deep fractures 100-150 and > 150 m are observed in 27 % and 12% area. Ground water is extracted mainly through bore wells of 60 to 200 m depth in the district. Ground water in the second aquifer occurs under semi-confined to confined condition. The depth of fracturing varies from 25 m to 195 m with yield of < 1-5 lps. The transmissivity (T) between 7.8 and 286 sq.m/day and the storage co-efficient ranges 0.01 to 5.0 x 10^{-6} respectively. The specific capacity ranges from 15 to 30 lpm/m/d

The depth to water level varies from 3.56 to 28.32 meter below ground level (m bgl) during pre-monsoon (May) and 1.2 to 13.2 m bgl during post-monsoon (November) season. During Pre-Monsoon, majority of the water level are in the range of 5-10 m covering 39 % of the area mostly in eastern and northern parts, followed by 10-20 m bgl (35% of the area) in western parts. Deep water level > 20 m bgl occupy about 10% of the area covering western parts. Shallow water level (0-5 m bgl) occupies about 15 % of area in eastern and southern part of district. During Post-monsoon Season, majority of the water levels are in the range of 2-5 m bgl, covering 57% of the area, in western and eastern parts. Water levels in the ranges of 5 to 10 m bgl occupy 24 % of the district area in parts of Narsapur, Kuntala, Lokeshwaram and Mudhole mandals. Water levels in the range of 10-20 m.bgl occupy 6 % of the area in parts of Narsapapur and aKuntala mandals. All the wells in the district shows rise in water levels in the range of 1.23 to 23.23 m bgl (average: 5.03 m). The Long-term water level trend (2010-2019) analysis reveled rising trends except few locations, which is insignificant.

INTRODUCTION

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic, hydrogeological and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers. In recent past, there has been a paradigm shift from "**groundwater development**" to "**groundwater management**". As large parts of India particularly hard 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 groundwater in India, aquifer mapping in different hydrogeological settings at the appropriate scale is devised and implemented, to enable robust groundwater management plans. This will help in achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural and many parts of urban India. The aquifer mapping program is important for planning suitable adaptation strategies to meet climate change also. Thus the crux of National Aquifer Mapping (NAQUIM) is not merely mapping, but reaching the goal-that of ground water management through community participation.

Hard rock's (Granites/Gneisses and shale/limestone) lack primary porosity, and groundwater occurrence is limited to secondary porosity, developed by weathering and fracturing. Weathered zone is the potential recharge zone for deeper fractures and excessive withdrawal from this zone lead to drying up at 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 purposes. High utilization of fertilizers for agricultural productions and improper development of sewage system in rural/urban areas lead to point source pollution viz., nitrate and chloride.

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

1.2 Scope of study: The main scope of study is summarised below.

1. Compilation of existing data (exploration, geophysical, groundwater level and groundwater quality with geo-referencing information and identification of principal aquifer units.
2. Periodic long-term monitoring of ground water regime (for water levels and water quality) 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 its characterization.
5. Capacity building in all aspects of ground water development and management through information, education and communication (IEC) activities, information.

6. Dissemination, education, awareness and training.
7. Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable ground water management.

1.3 Area Details: The Nirmal district covering ~3845 km^2 lies between north latitude 18°50′41" to 19°20′20" and east longitude 77°45′37" to 78°57′03" (**Fig.1.1**) and named after king Nimma Rayudu. The district is bounded by Adilabad in the north, Komaram Bheem in the northeast, Mancherial in the east, Jagityal and Nizamabad (along with the Godavari) in the south and Nanded District of Maharashtra in the west. As per old district set up, it is part of Erstwhile Adialabd district. Administratively the district is governed by 19 mandals covering 428 revenue villages and 3 Municipalities with a population of ~7.10 lakhs (2011 census) (urban: ~21.4 %, rural: ~78.6 %) with average density of 185 persons/km^2.

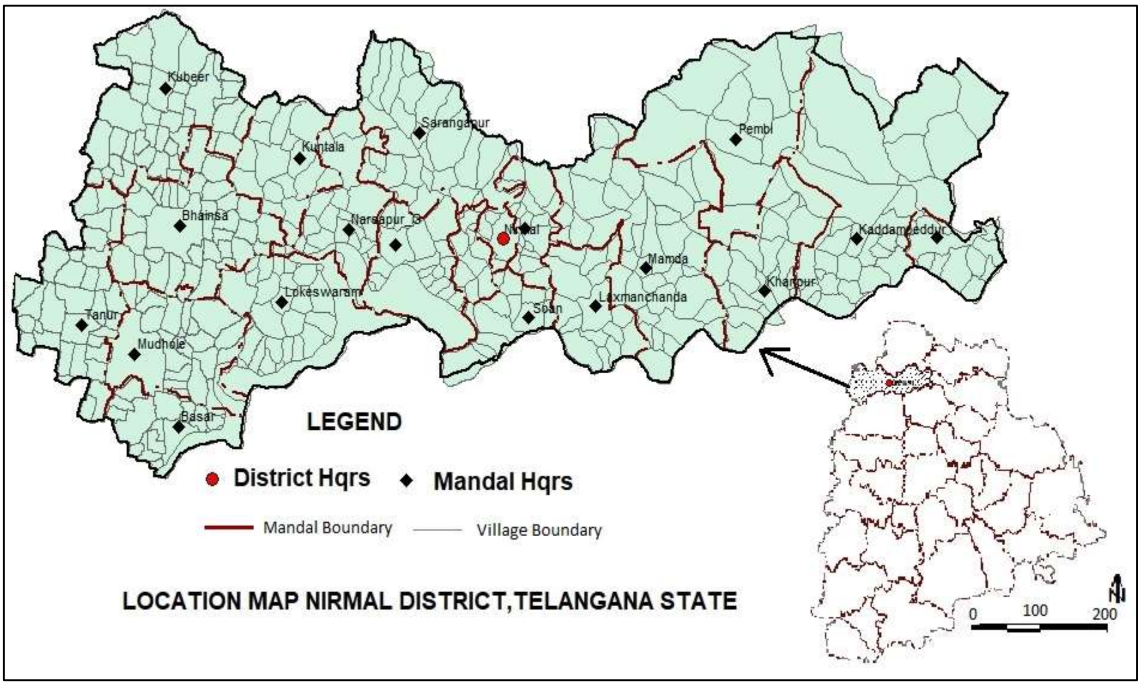

Fig.1.1: Location Map of Nirmal district.

1.4 Climate and Rainfall: The district experiences tropical climate and is geographically located in a semi-arid area with predominantly hot and dry climate. The district falls under Northern Telangana agro-climatic zone. The Southwest monsoon enters into the district in June and lasts until September and Northeast monsoon from October to December. Summer starts in March, and reaches peak in May with average maximum temperatures of 42.2°C. A dry, mild winter starts in late November and lasts until early February with lowest average minimum temperature of 13.8°C in January. The annual normal rainfall of the district varies from 976 mm (Tanur mandal) to 1129 mm (Pembi mandal) with district normal of 1051 mm. Average number of rainy days in a year is around 63 days. Southwest monsoon contributes 86% (901 mm), Northeast monsoon by 9 % (96 mm) and rest 5 % by

January to May months of normal annual rainfall. Monthly rainfall varies from 292 mm in July to 4.9 mm in December. Isohyetal map prepared using annual normal rainfall of mandals shows increase in rainfall from central to east direction in the district **(Fig.1.2).** The district received annual rainfall of 953 mm (9% below normal rainfall) during the year 2020 (Jan- Dec) and 1068 mm in 2019 (2% above normal).

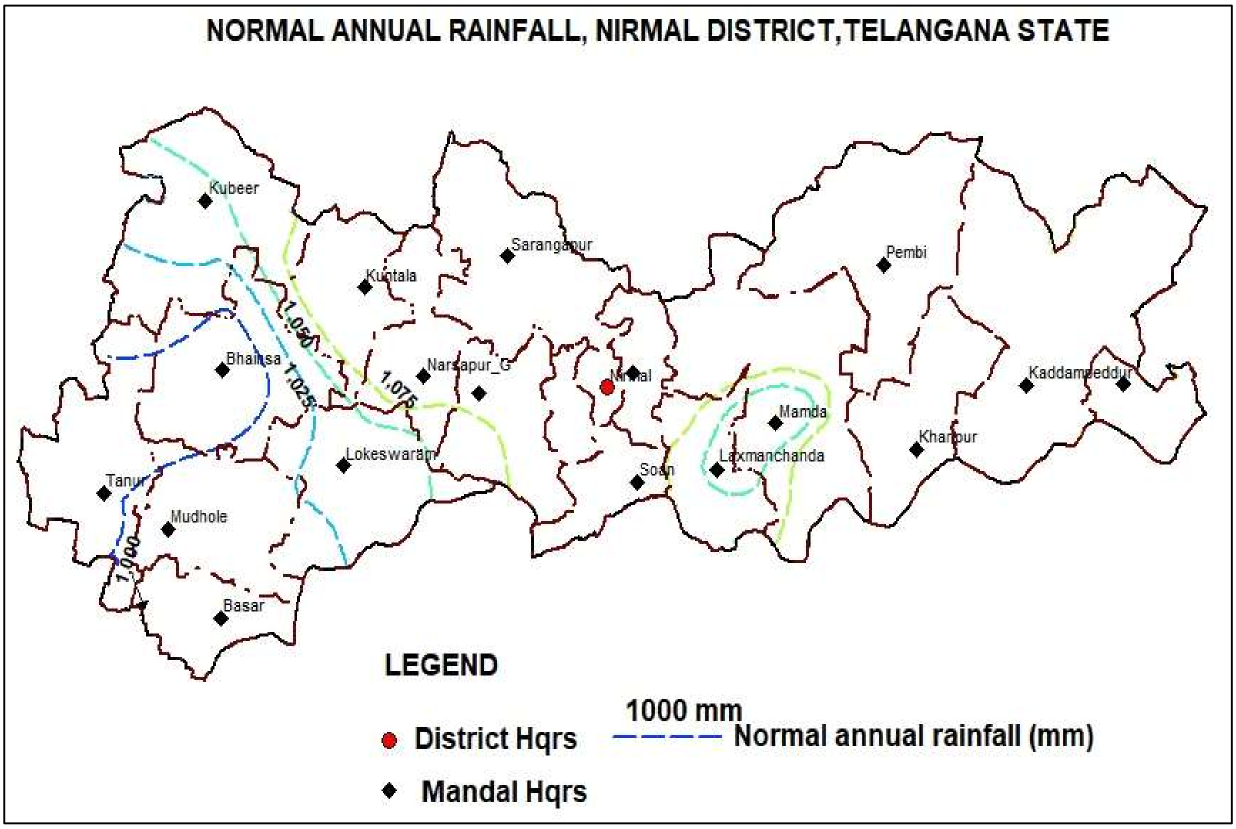

Fig.1.2: Isohyetal map of Nirmal district.

Analysis of long-term annual rainfall (Jan-Dec) data of 16 years from 2005 to 2020 shows slight decrease in annual rainfall by -2.3 mm/year. The monthly rainfall time series trend analysis for 16 years from 2005 to 2020 shows increase in rainfall trend of 5.7 mm/year in June and decrease in trend for July and September (-4.7 & -4.2 mm/year respectively) (**Fig.1.3 a & 1.3 b**).

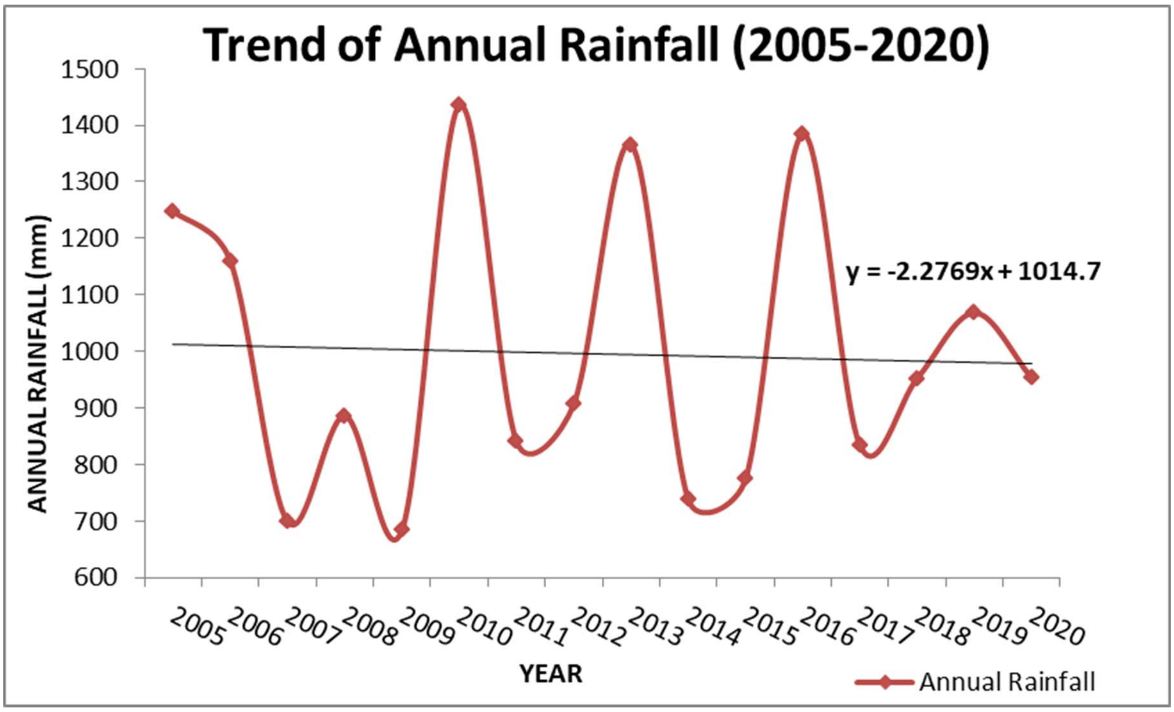

Fig.1.3a Trend of Annual Rainfall

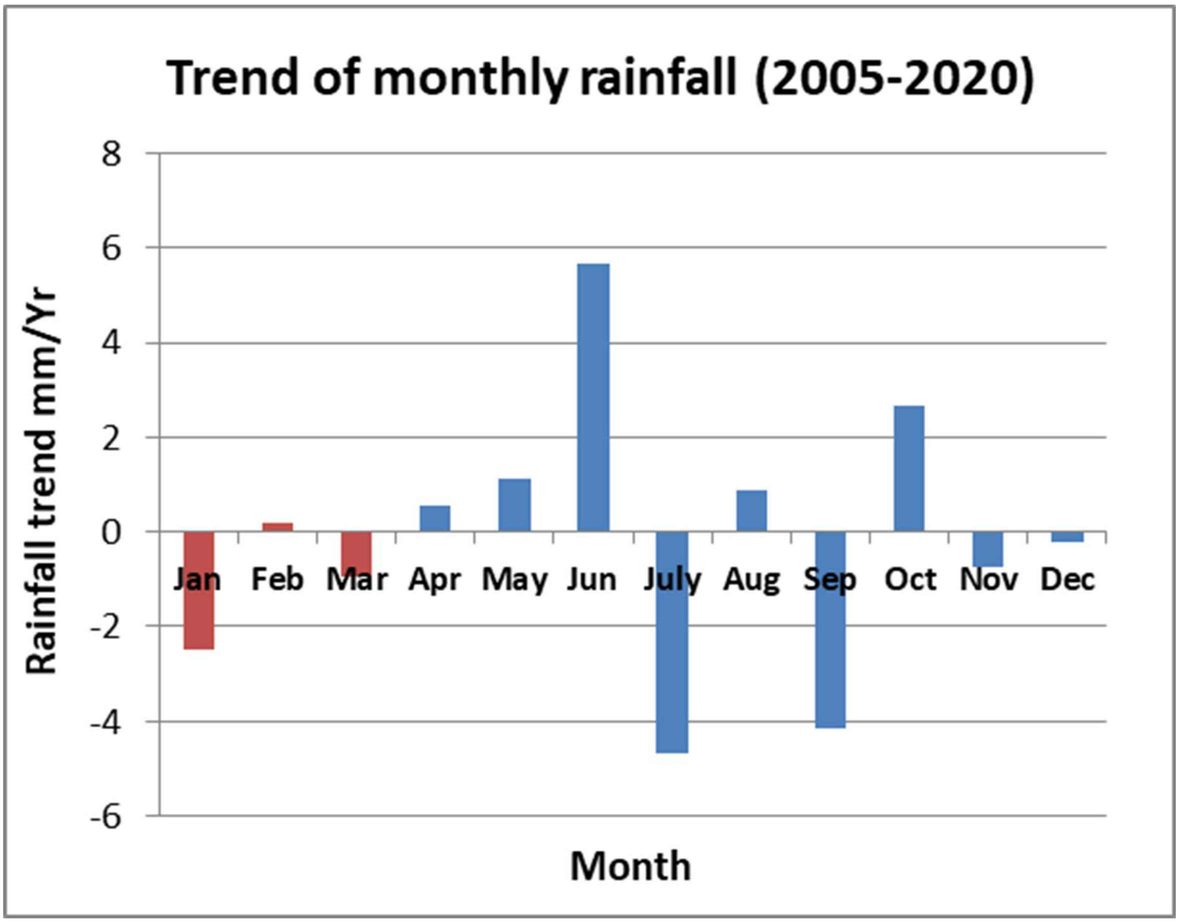

Fig 1.3b Trend of Monthly rainfall

1.5 Geomorphological Set up: The district is situated on Deccan Plateau and characterised by erosional topography with general slope from north to south. The River Godavari flows along southern boundary of the district running in W-E direction. Pediplains are the major landforms occupying 52% of the area, followed by pediment in 22% area, dissected plateaus in 12% of the area and denudational hills in 8% of the area etc (**Fig.1.3**).

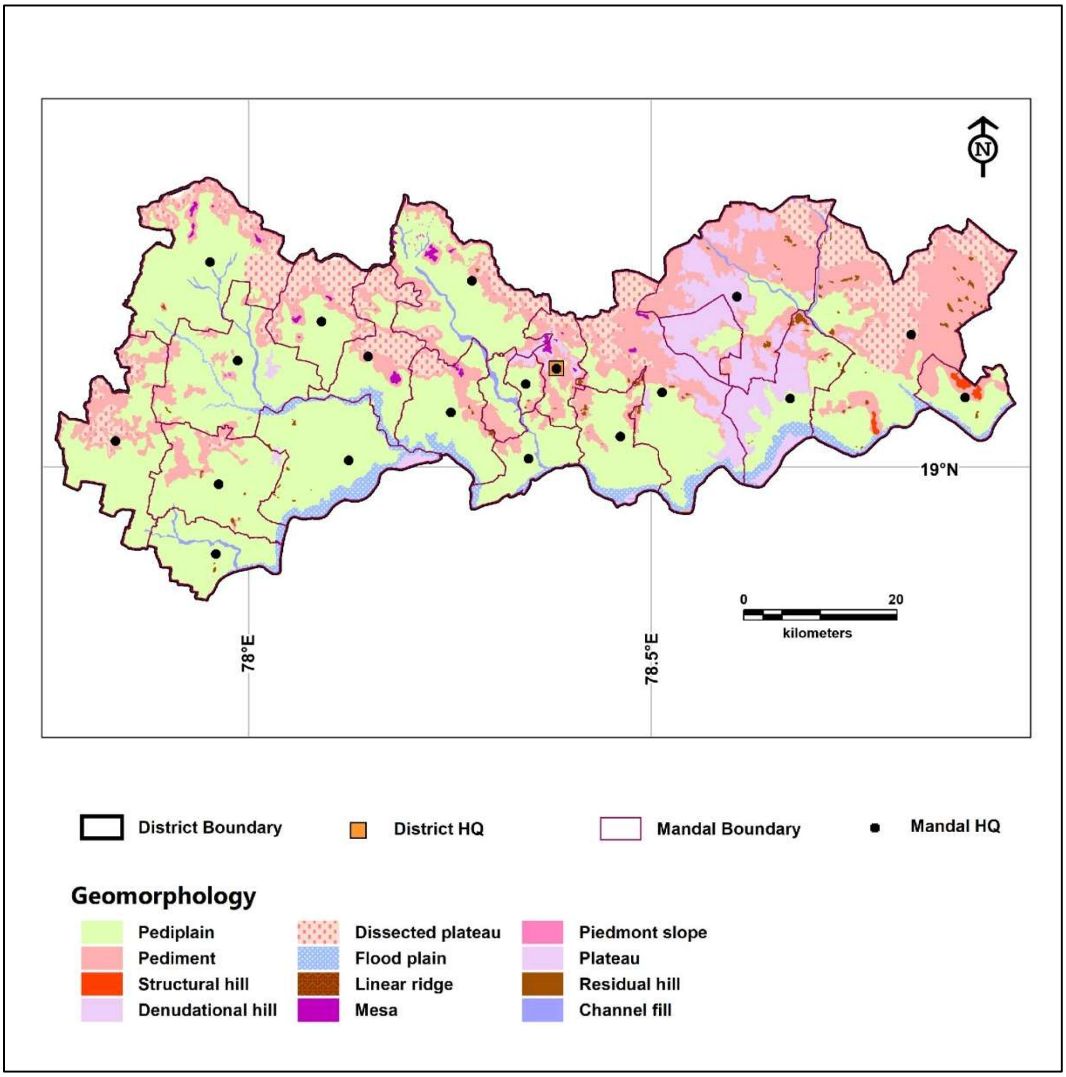

Fig.1.4: Geomorphology map.

1.6 Drainage and Structures:

The drainage is mainly dendritic to semi-dendritic. The district falls in the Godavari basin. The Swarna and Siddha, tributaries of the Godavari River traverse through the Nirmal district. The district consists of 13 watersheds ~84 % non-command area and ~16 % command area. Map depicting drainage, hills, and water bodies are given in **Fig.1.4**. The River Godavari flows along the southern border of the district.

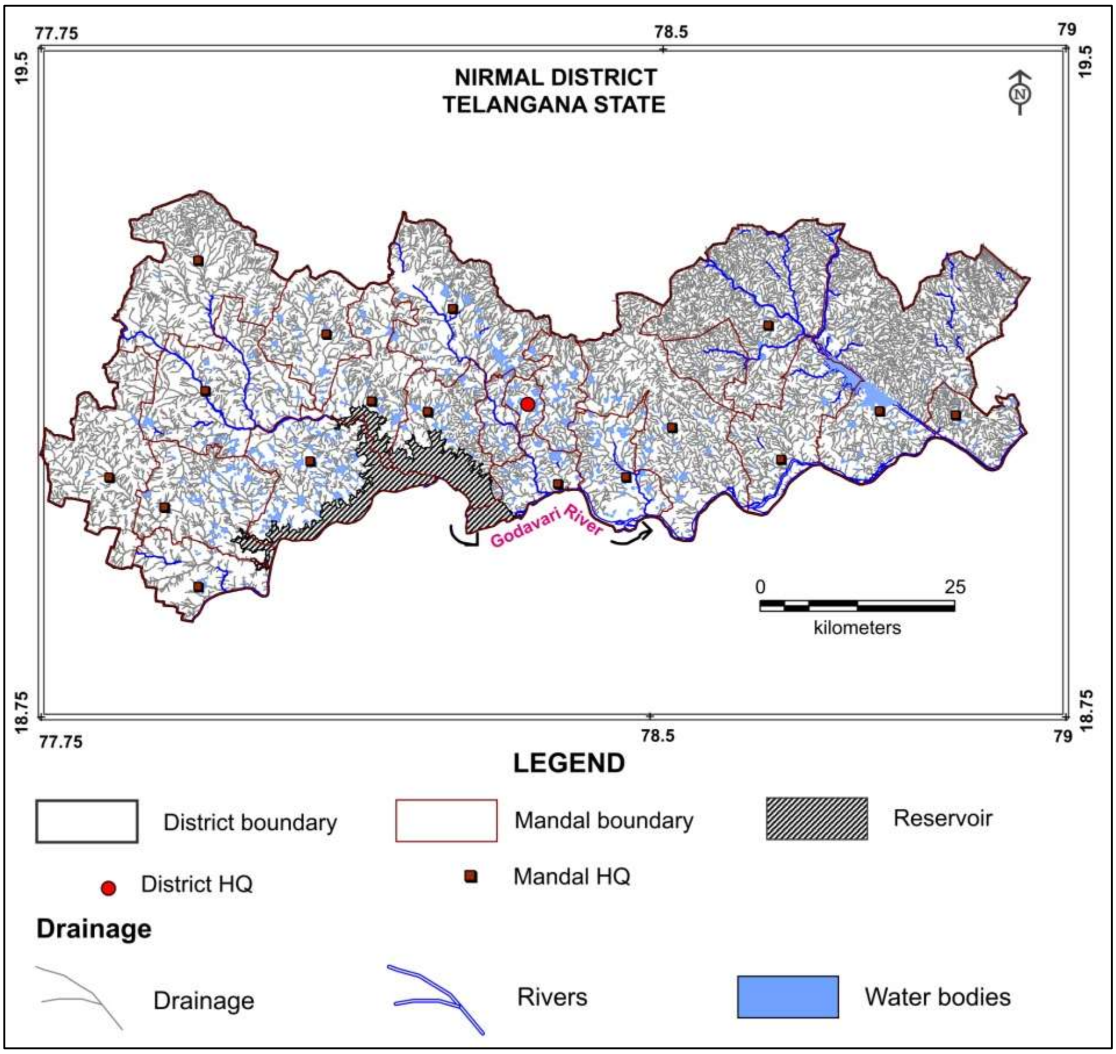

Fig.1.5: Drainage and water bodies Map, Nirmal district.

1.7 Soils: Red loamy soils are the major soil type in the district, which are derived from country rocks. The other soils are black cotton soils mainly derived from basalt rock. Clayey montmorlitic type soil is more predominant in the district, which occupies 40% of the area. Clayey skeletal occupies 23% of the area. Fine montmorillonitic type of soil occupies 23 % of the area. Fine, mixed type of soil occupies 18% of the area **(Fig.1.6).**

1.8 Land use, land cover and land holdings (2018-19):

Forest occupies ~32.60 % of the total geographical area, barren and uncultivable land occupy ~2.8% of area, land put to non-agricultural use is 5.16 %, cultivable waste land is ~3.4 %, Permanent pastures in 3.78 % of the area, Current fallows in 8.34 % of the area, other fallows in 2.12 % of the area, Net area sown in 40.47 % of the area, Area swon more than twice in 14 % of the area.

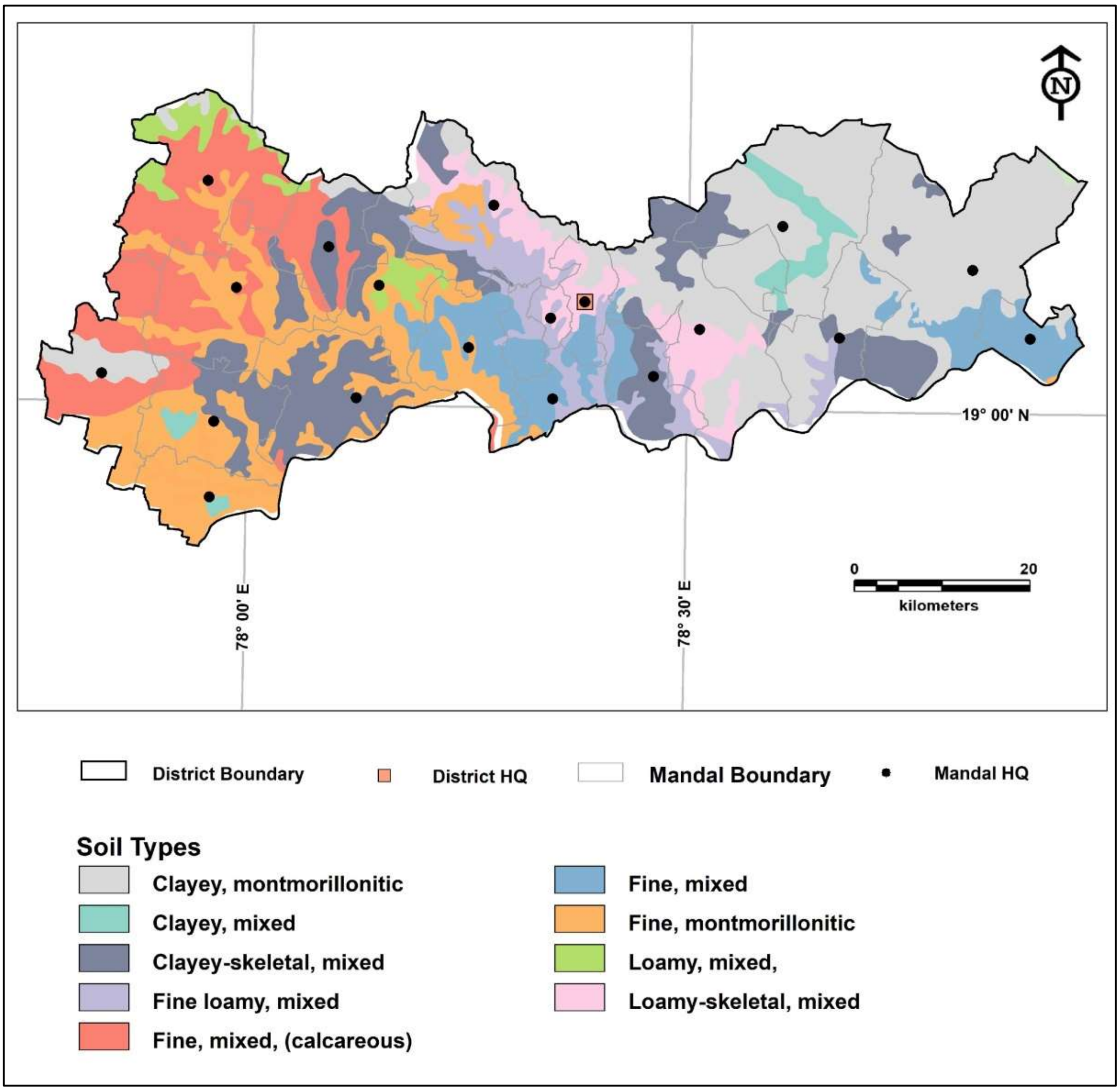

Fig.1.6: Soil map of Nirmal district.

1.9 Cropping Pattern (2019-20):

The net area sown is 1774.96 Sq.Km. The gross cropped area is 2865 Sq.Km. In Khariff Season 2291 Sq. Km is utilized for the crop cultivation, in which Cottan is cultivated in 22 % of the area, Cerals in 23% of the area, Oil seeds in 19% of the area, Paddy in 17 % of the area and remaining area with pulses, millets, fruits and vegetables etc. In Rabi Season 1859 Sq. Km area is utilized for the cultivation in which major crops grown includes Cerala in 42% of the area, millets in 19% of the area, Paddy in 22% of the area and the remaining area with pulses and Oil seeds **(Fig-1.7 a and b).**

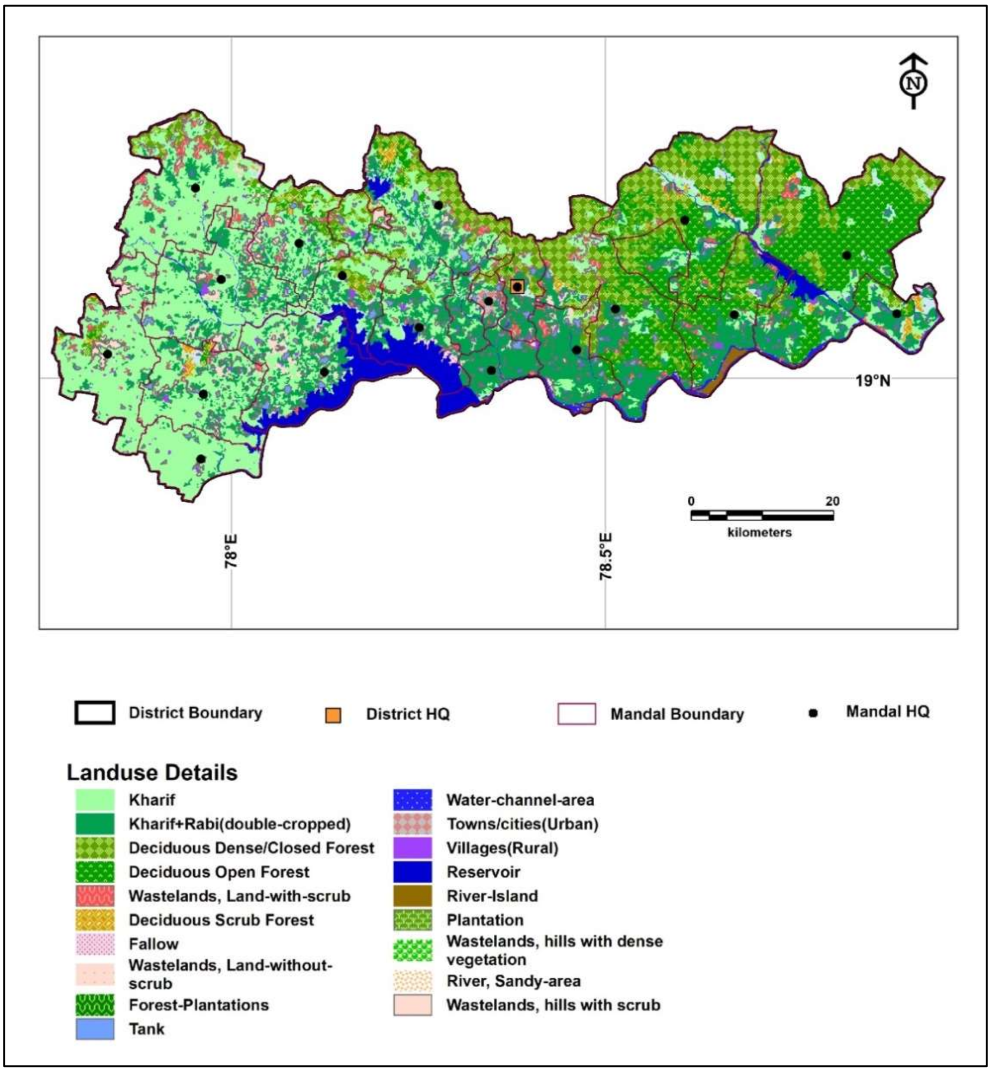

Fig.1.7: Land use map of Nirmal district.

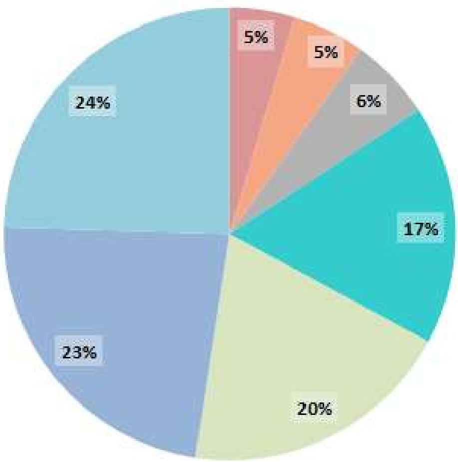

Fig 7a. Kharrif Cropped Area

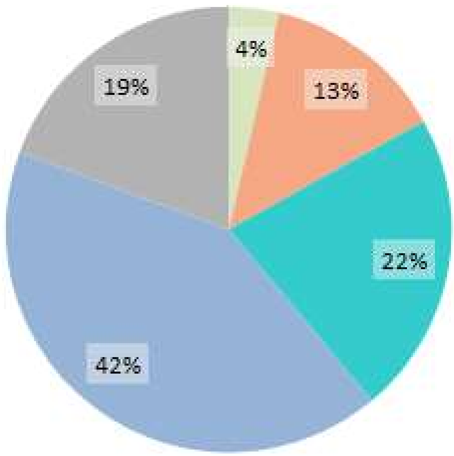

Fig 7b Rabi Cropped Area

Condiments & Spices
Pulses
Paddy
Oil Seeds
Millets
Cerels & Millets

1.10 Irrigation (2018-19)

Major Irrigation Project:

The district is benefitted by two major irrigation projects namely Sriram Sagar across the river Godavari at Pochampad (Nizamabd district) and Kadam on river Kadem.

Medium Irrigation Project

Gaddenvagu Vagu (Suddavagu) Project is a Medium Irrigation Project constructed across Godavari River in Bhainsa village in Nirmal district. This Project is having the ayacut of of 14000 acres.

Swarna Project is a medium irrigation project constructed across Swarna river located in Jowli (Jewly) village of Sarangapur mandal of Nirmal district. This Project is having the ayacut of 8,945 acres.

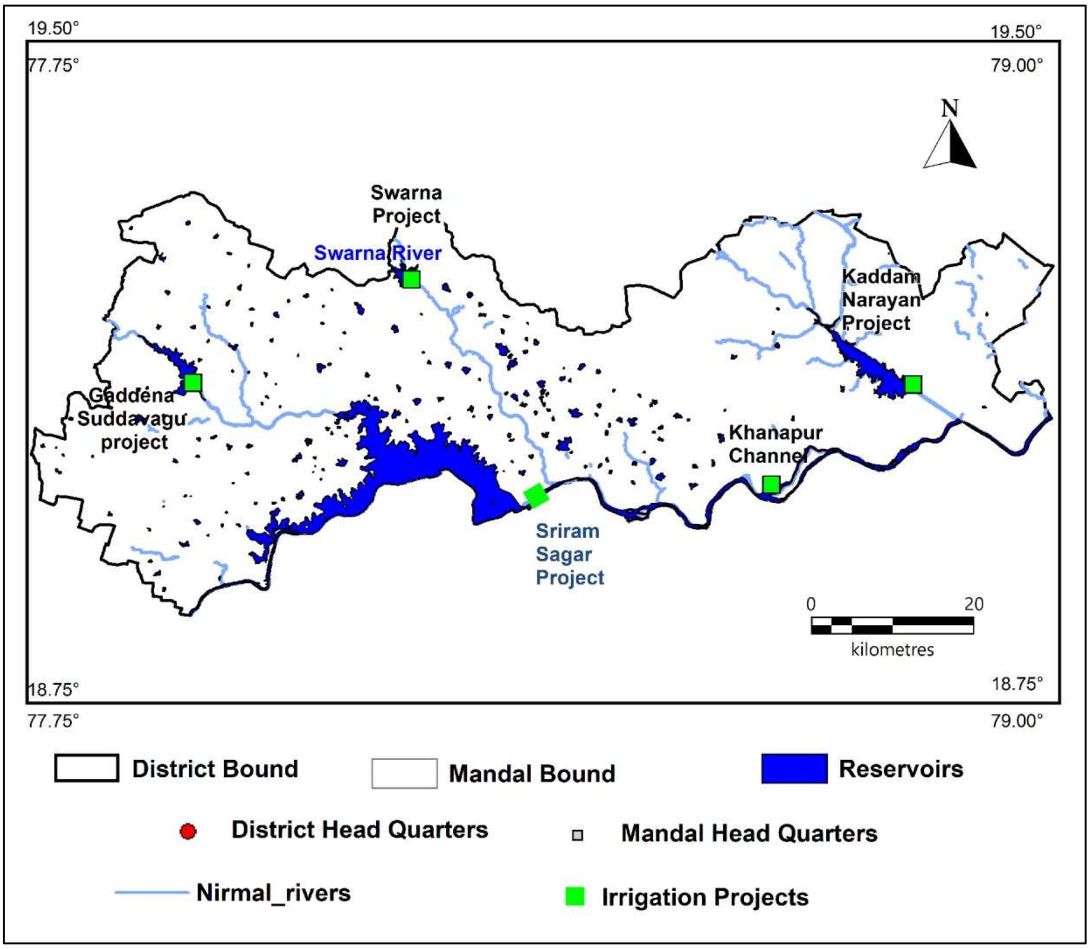

Fig.1.8: Irrigation map of Nirmal district.

Lift Irrigation scheme commisioned

Ditrict	No. of Schemes	Irrigation Potential created in acres
Nirmal	42	45,022

Ground Water Schemes (Source: 6th Minor Irrigation Census, 2017-18 (Provisional)

	Number
Villages Covered	431
Dugwell	8509
Shallow Tubewell	2759
Medium Tubewell	19533
Deep Tubewell	4326
Total	35127

Minor irrigation tanks

State	No. of Tanks	Ayacut in acres
Nirmal	**773**	**59977**

1.11 Geology: The Nirmal district is underlain by various geological formations from oldest archeans to the Teritiary basaltic formations. The crystalline rocks of Archean age comprise of granites and gneisses. Dolerite dyke intruding the granites rocks are common in the area. The Deccan trap constitutes a number of lava flows of basaltic compostion and overlies the Archean in the North West of Nirmal district. The mega lineament trending NW-SE and NNW-SSE correlate with joint pattern occurring in the district. The other sets of lineaments trend in NE-SW, ENE-WSW directions.

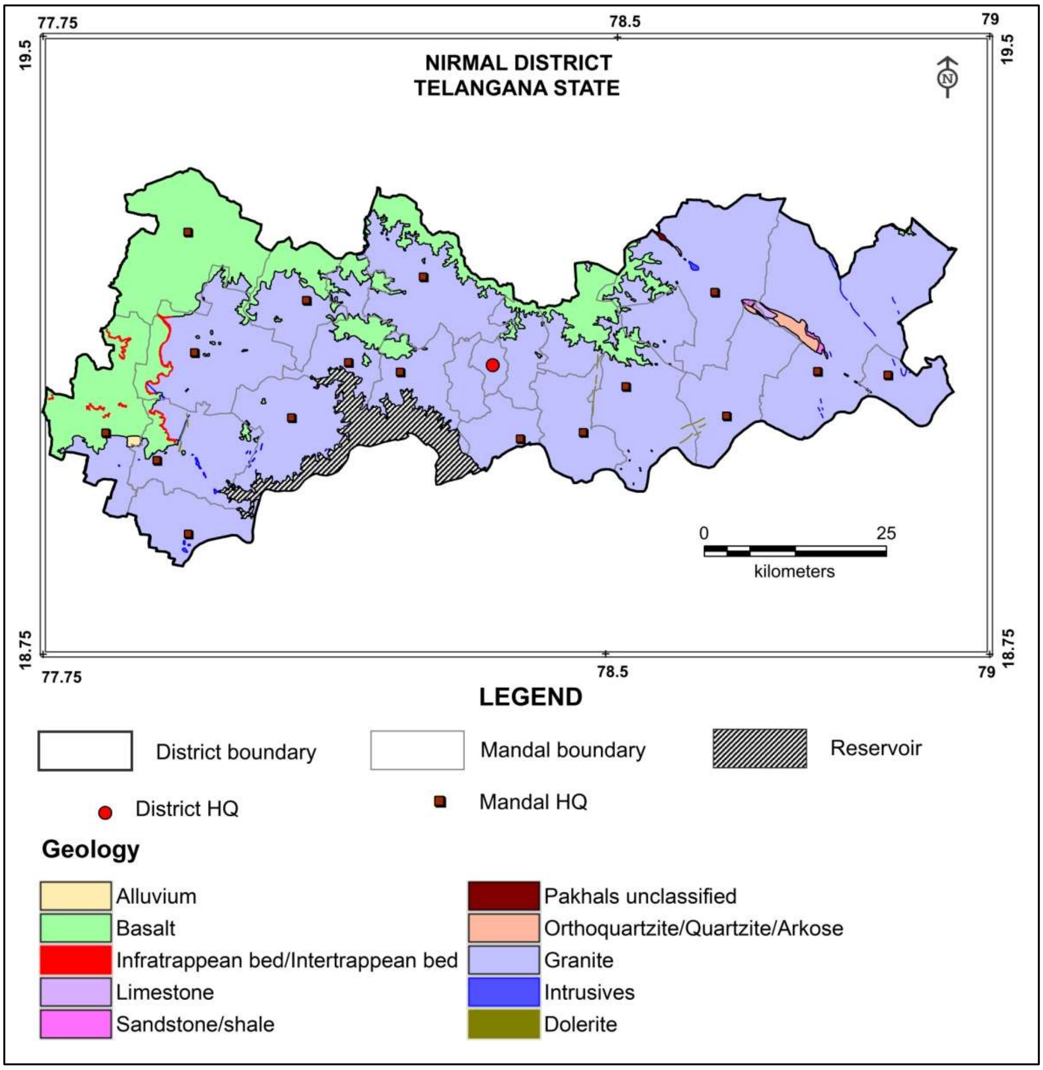

Fig.1.9: Geology map Nirmal district.

2. DATA COLLECTION AND GENERATION

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

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

S. No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
	Generation of Data	Generation of geological layers (1:50,000)	Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern.
		Surface and sub-surface geo-electrical and gravity data generation	Vertical Electrical Sounding (VES), bore-hole logging, 2-D imaging etc.
		Hydrological Parameters on groundwater recharge	Soil infiltration studies, rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of sub-surface hydrogeological sections.

		Generation of additional water quality parameters	Analysis of groundwater for general parameters including fluoride.
3.	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.
4.	Aquifer Manageme nt 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.

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 aquifer geometry for shallow and deeper aquifer has been established through hydro geological studies, exploration, surface geophysical studies in the district. The data used for the integration and interpretation includes:

2.1 Exploratory drilling

Information on aquifer geometry, Groundwater potential of fracture systems and their characterization are primarily inferred from exploratory drilling data. CGWB is having a total of 40 wells in the district. Out of these, 17 wells were newly drilled in 2019-20 based on the data gap analysis carried out in the study area. A total of 54 exploratory borewell data of CGWB (40) and SGWD (14) were used for the hydrogeological studies and aquifer maps. Based on data gap analysis Out of these, 50 wells are from granitic area and 4 from basaltic area.

2.2 Geophysical Studies

Geophysical data on VES and profiling are used to extract information on the weathered thickness, fracture depth, thickness of fracture etc of hard rock area. For the interpretation of the aquifer geometry geophysical data in conjunction with the available groundwater exploration data is utilised. The data from 25 Vertical Electrical Soundings (VES) data of CGWB employing the Schlumberger electrode configuration with the maximum electrode separation (AB) of 400 meters is used for the aquifer mapping studies. The data was processed and interpreted by IPI2Win software eveloped by MoscowState University, after marginally modifying the manually interpreted results in corroboration with geology and hydrogeology.

2.3 Water Levels

Water level monitoring wells of CGWB and SGWD is utilized for the Aquifer Mapping studies. 19 dug wells and 5 Piezometers are presently being monitored by CGWB and 62 piezometers by SGWD. CGWB wells are being monitored four times (January, April, August and November) in a year whereas the monitoring wells of State Ground Water Department (SGWD) are being monitored every month. These groundwater monitoring wells were used in order to understand the spatio-temporal behaviour of the groundwater regime.

2.4 Hydro chemical Studies

Water quality data of CGWB, SGWD and RWS is utilized for understanding the spatial variation of quality in the district. A total 320 data from CGWB (Pre-monsoon 2017: 08 nos) and SGWD (Post-monsoon 2016: 150 & Post: 162). Five parameters namely pH, EC, TDS, NO_3 and F were analyzed and suitability for drinking purposes is assessed as per BIS standards (2012) and irrigation suitability as per electrical conductivity.

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1. Hydrogeological Data Interpretation

3.1.1 Ground Water level scenario

Analysis of the pre- and postmonsoon water level data shows that the depth to water level varies from 3.56 to 28.32 meter below ground level (m bgl) during pre-monsoon (May) and 1.2 to 13.2 m bgl during post-monsoon (November) season.

Pre-monsoon Season: Majority of the water levels during this season are in the range of 5-10 m covering 39 % of the area mostly in eastern and northern parts, followed by 10-20 m bgl (35% of the area) in western parts. Deep water level > 20 m bgl occupy about 10% of the area covering western parts (**Fig. 3.1**). Shallow water level (0-5 m bgl) occupies about 15 % of area in eastern and southern part of district.

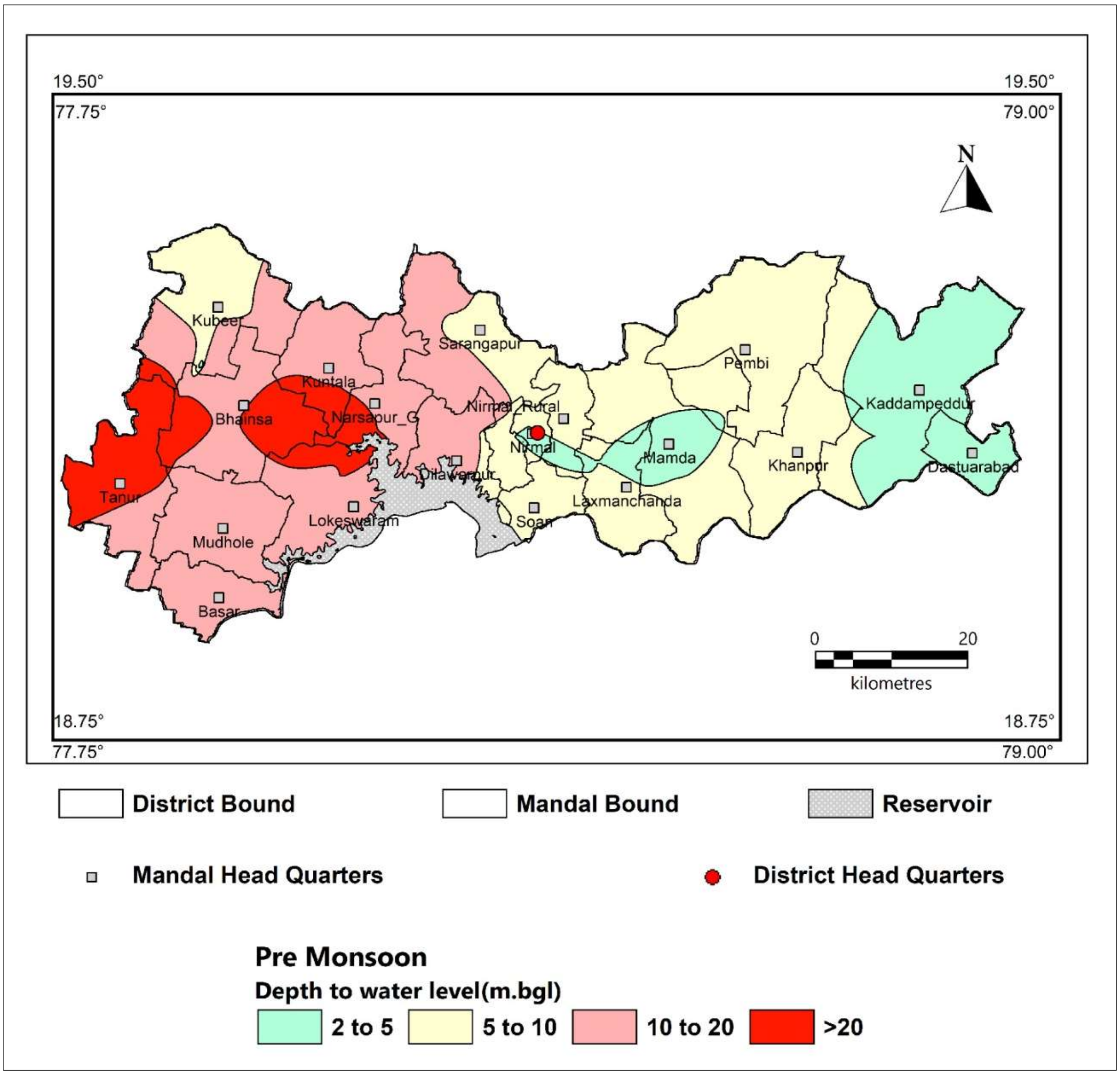

Fig. 3.1: Depth to water levels Pre-monsoon

Post-monsoon Season: Majority of the water levels during this season are in the range of 2-5 m bgl, covering 57% of the area, in western and eastern parts. Water levels in the ranges of 5 to 10 m bgl occupy 24 % of the district in parts of Narsapur, Kuntala, Lokeshwaram and Mudhole mandals. Water levels in the range of 10-20 m bgl occupy 6 % of the area in parts of Narsapapur and Kuntala mandals (**Fig-3.2**).

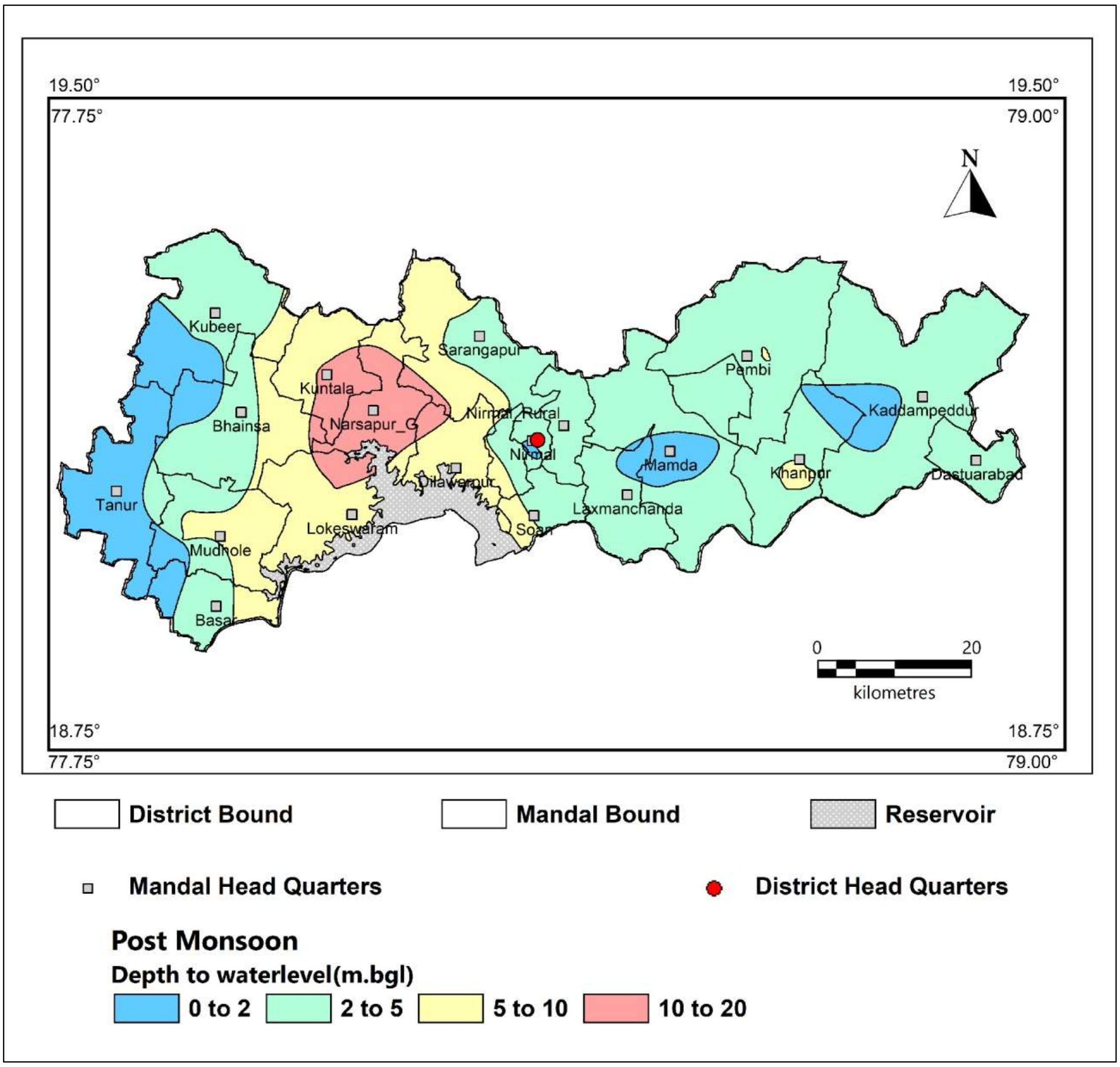

Fig.3.2: Depth to water levels post-monsoon season

3.1.2 Water Table Elevations (m amsl): During pre monsoon season, water-table elevation ranges from 212 to 400 m amsl and during post monsoon season water table elevation ranges from 213 to 402.3 m amsl. The regional ground water flow is towards the river Godavari from northwest to southeast direction (**Fig. 3.3).**

3.1.3 Seasonal Water Level Fluctuation (November vs May): All the wells in the district shows rise in water levels in the range of 1.23 to 23.23 m bgl (average: 5.03 m) (**Fig- 3.4**). 20 % of the area shows water level rise in the range of 0 to 2 m bgl. 33 % of the area has shows water level rise in the range of 2-5 m, and >5 m rise is observed in 47% of area falling in western parts of the district

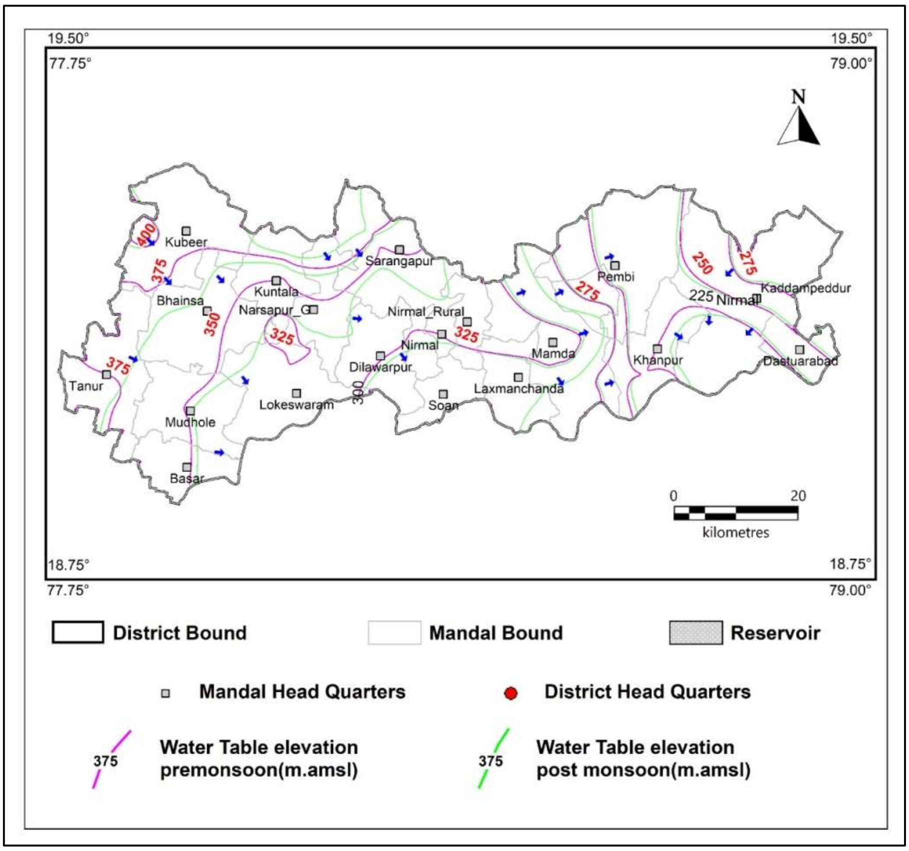

Fig.3.3: Water Table Elevation Map, Nirmal District

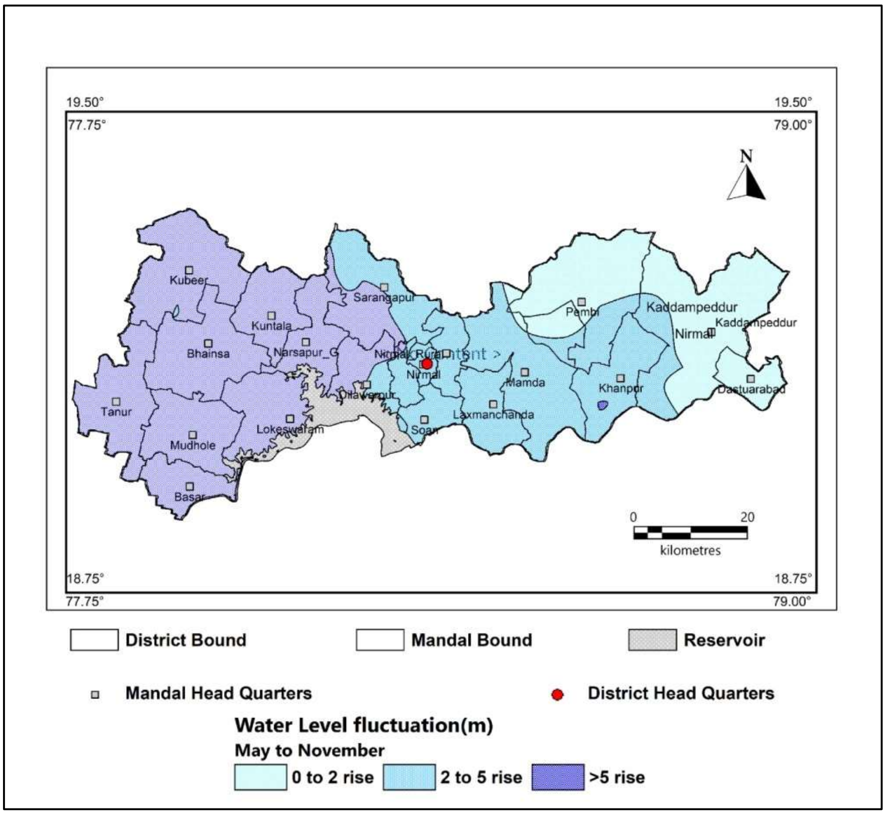

Fig.3.4: Water Level Fluctuations (m) (Nov vs. May-2019)

3.1.4 Long term water level trends (2010-2019): Trend analysis for the last 10 years (2010-2019) is studied from 38 hydrograph stations of CGWB (10 nos) and SGWD (28 nos). During pre-monsoon season, 7 wells show falling trends -0.02 m/yr to -1.43 m/yr (0 to 1 m: 5 wells and 1-2 m: 2 wells) and 25 wells shows a rising trend in the range of 0.01 to 2.81 m/yr (**Fig. 3.5**) in the southern region. During post-monsoon season, 15 wells show falling trends in the range of -0.001 m/yr to -1.7 m/yr (0 to 1 m: 13 wells and 1-2 m: 1 well) and 17 wells shows rising trends in the range of 0.05 to 2.4m/yr (**Fig. 2.9**).

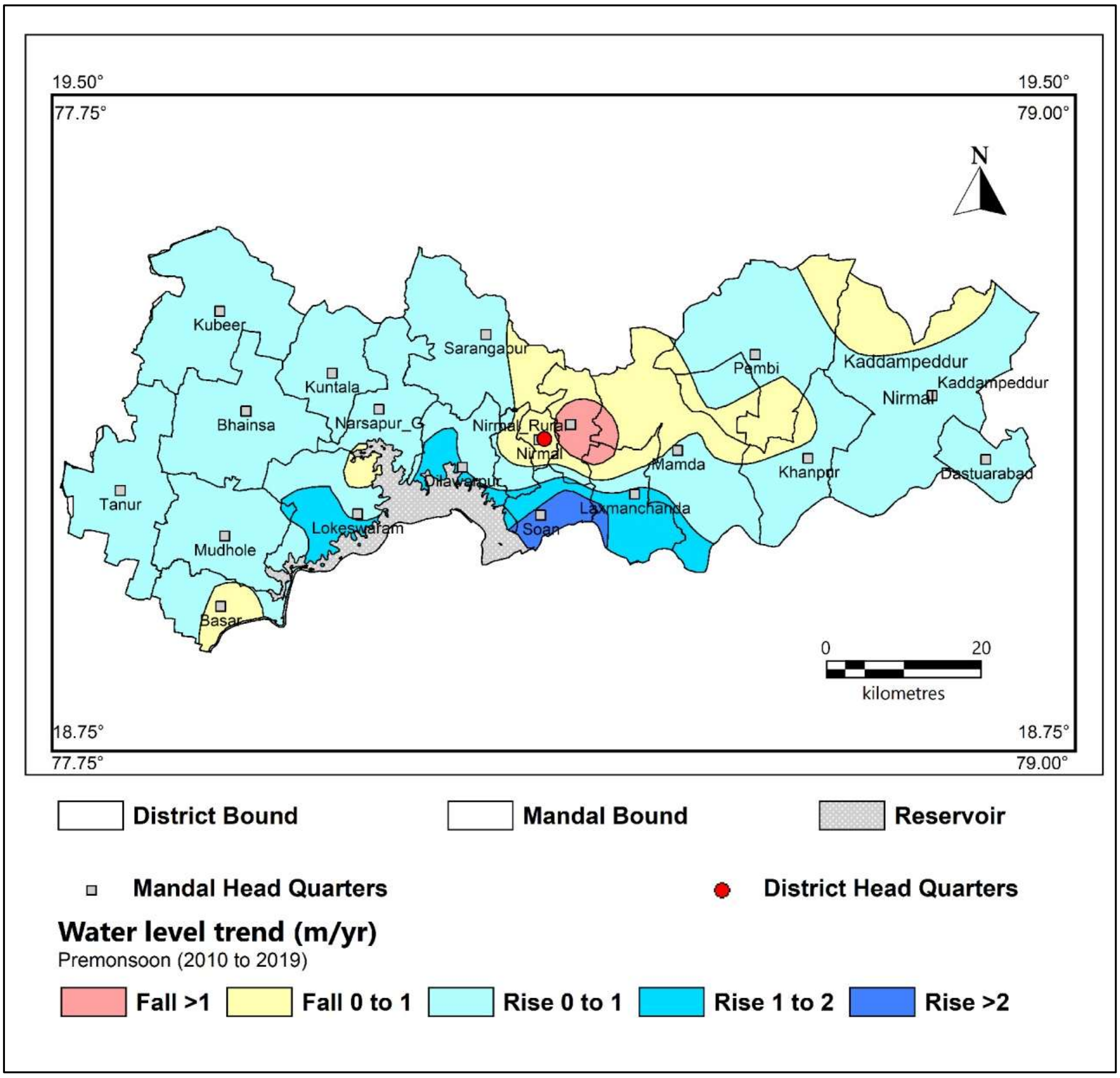

Fig. 3.5: Long-term water level trends (Pre-monsoon-2010-19)

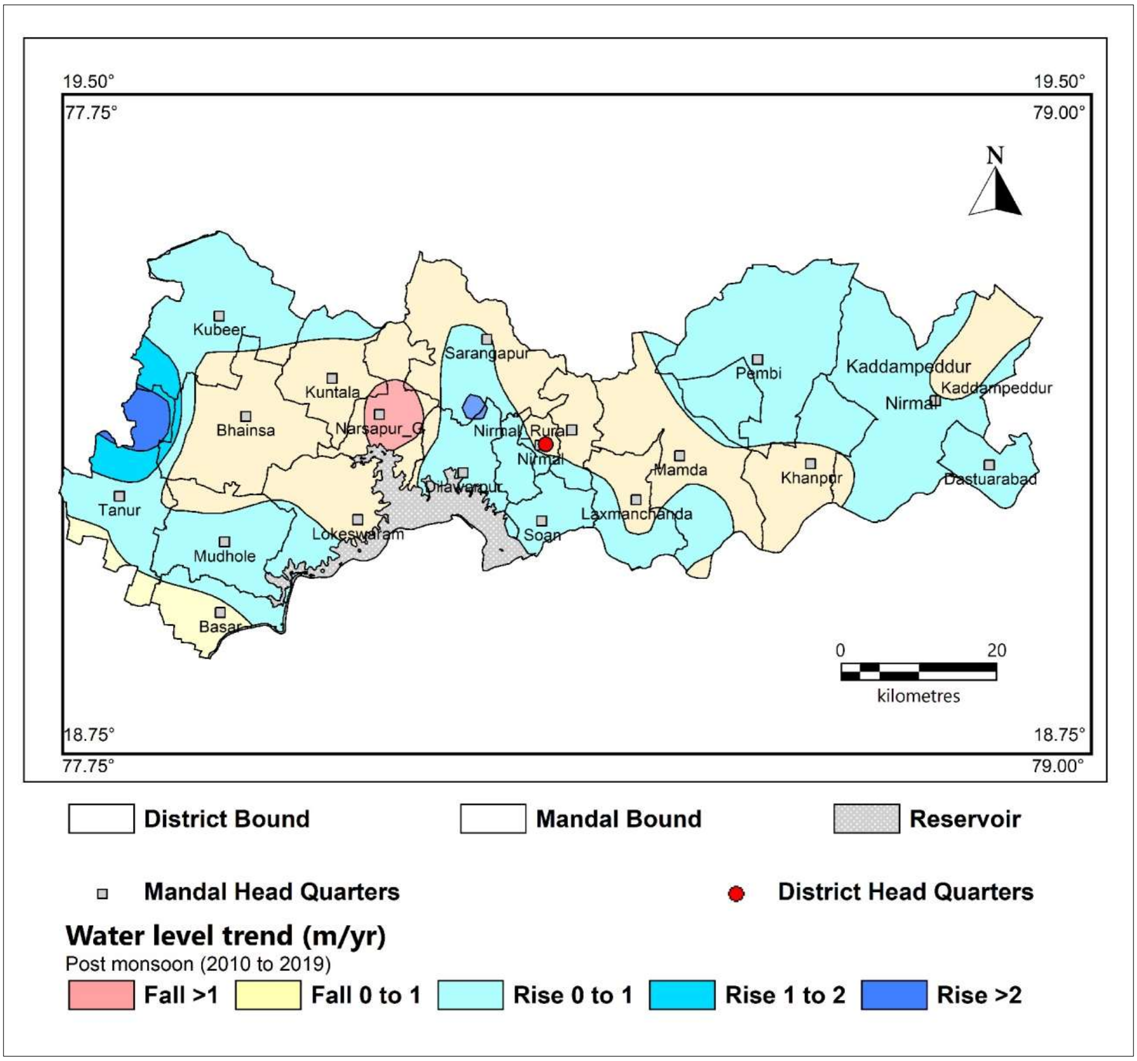

Fig. 3.6: Long-term water level trends (Post-monsoon-2010-19)

3.2 Ground Water Quality

Pre-monsoon (70 samples-CGWB: 8, SGWD: 20, RWS:63)

Groundwater is mildly alkaline in nature with pH in the range of 7.02-8.52 (Avg: 7.9). Electrical conductivity varies from 121-1783 µ Siemens/cm (avg: 1011). In the district, EC is within the permissible limit of 3000 µ Siemens/cm (**Fig.3.7).** The Fluoride concentration varies from 0.06-4.36 mg/L (**Fig 3.9**) and found that 4 samples (5 %) are unfit for human consumption (>1.5 mg/l). NO_3 concentration ranges from 3 to 191.45 mg/l and found 14 % of samples (10 nos) are unfit for human consumption (> 45 mg/l) (**Fig.3.11**). High fluoride concentration (>1.5 mg/l) is observed in Kubeer, Narsapur, Sarangapur, and Kaddempeddur mandals.

Post-monsoon (107 samples- SGWD: 20, RWS: 97)

The pH is in the range of 7.9 - 8.39 (Avg: 8.2). Electrical conductivity varies from 85-2160 µ Siemens/cm (avg: 908). In 62 % of samples (66 nos) covering EC is within 1500 µ Siemens/cm and in 2% of samples (41 Nos) Ec is in the range of 1500-3000 µ Siemens/cm.

(**Fig.3.8).** Fluoride concentration varies from 0.06- 2.04 mg/L (**Fig 3.10**) and found that 2 samples (2 %) are unfit for human consumption (>1.5 mg/l). NO_3 concentration ranges from 1.31 to 159.4 mg/l and found 4 % of samples (5 nos) are unfit for human consumption (> 45 mg/l) (**Fig.3.12**).

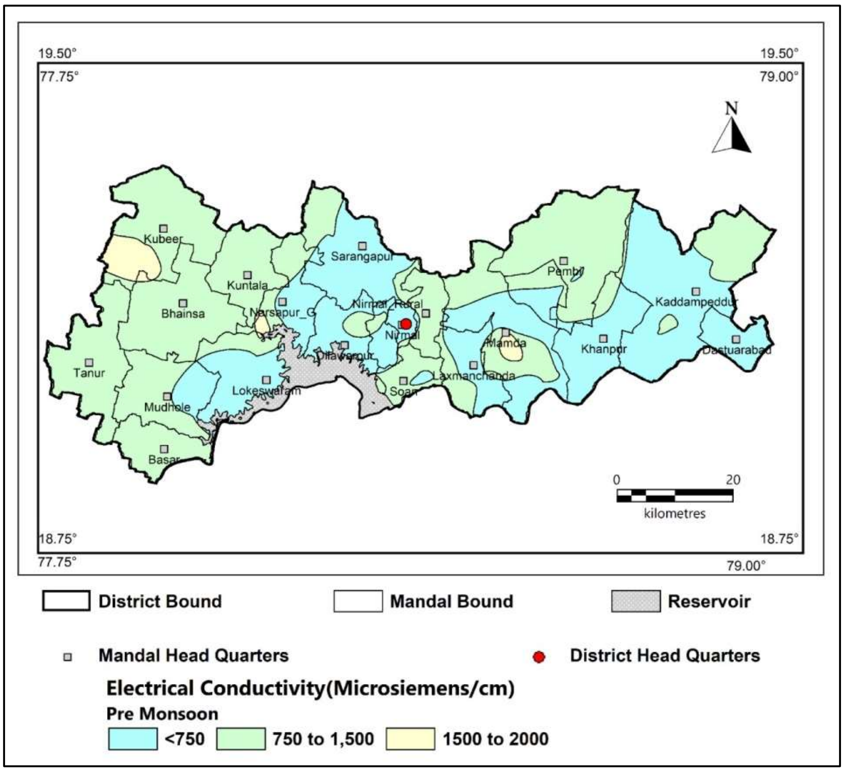

Fig.3.7: Distribution of Electrical conductivity (Pre-monsoon)

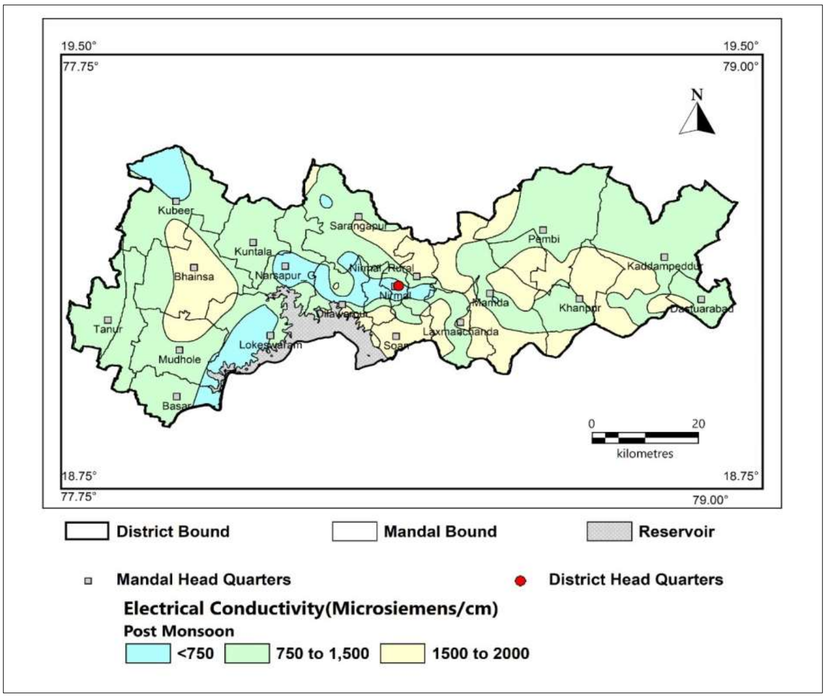

Fig.3.8: Distribution of Electrical conductivity (post-monsoon)

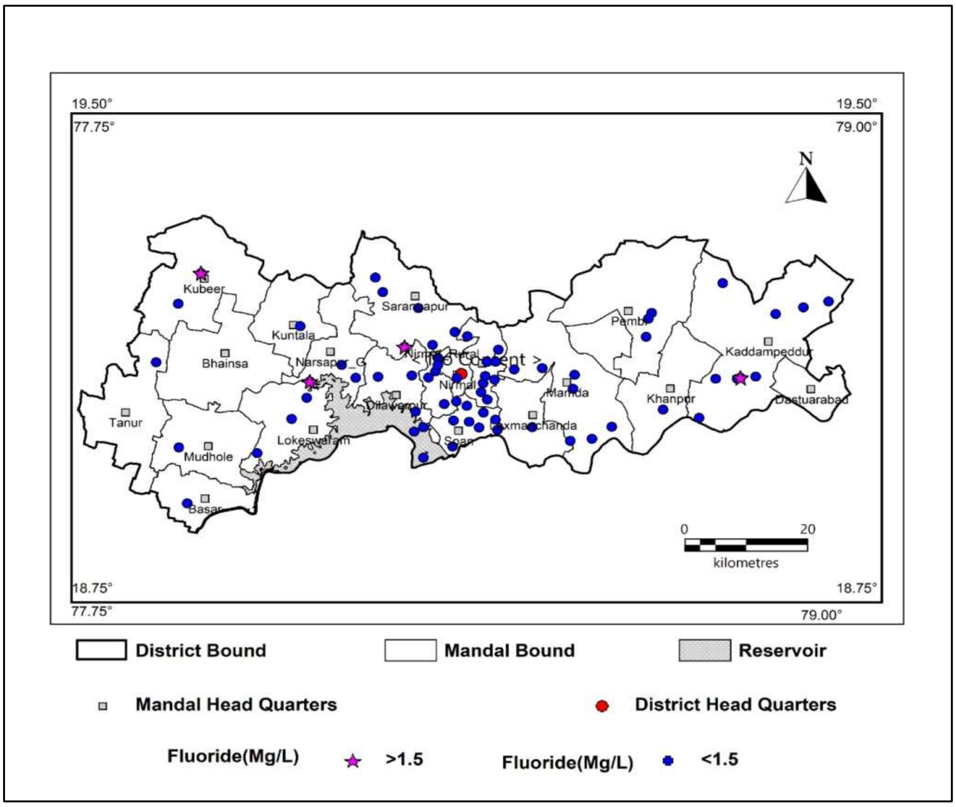

Fig.3.9: Distribution of Fluoride (Pre-monsoon)

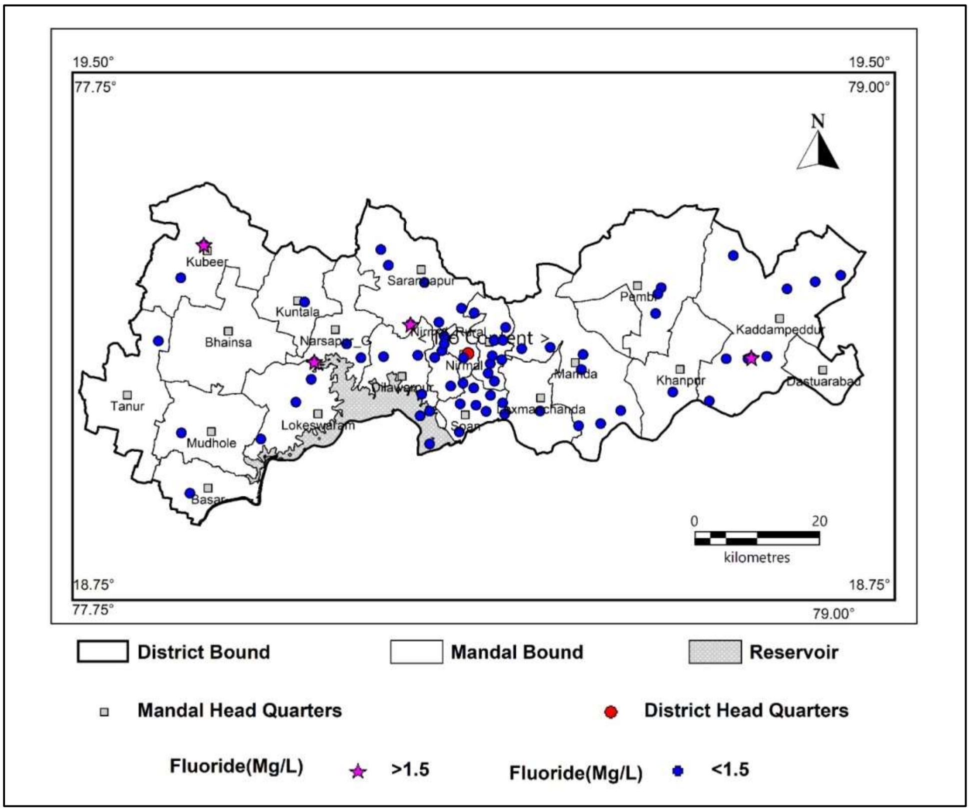

Fig.3.10: Distribution of Fluoride (Post-monsoon)

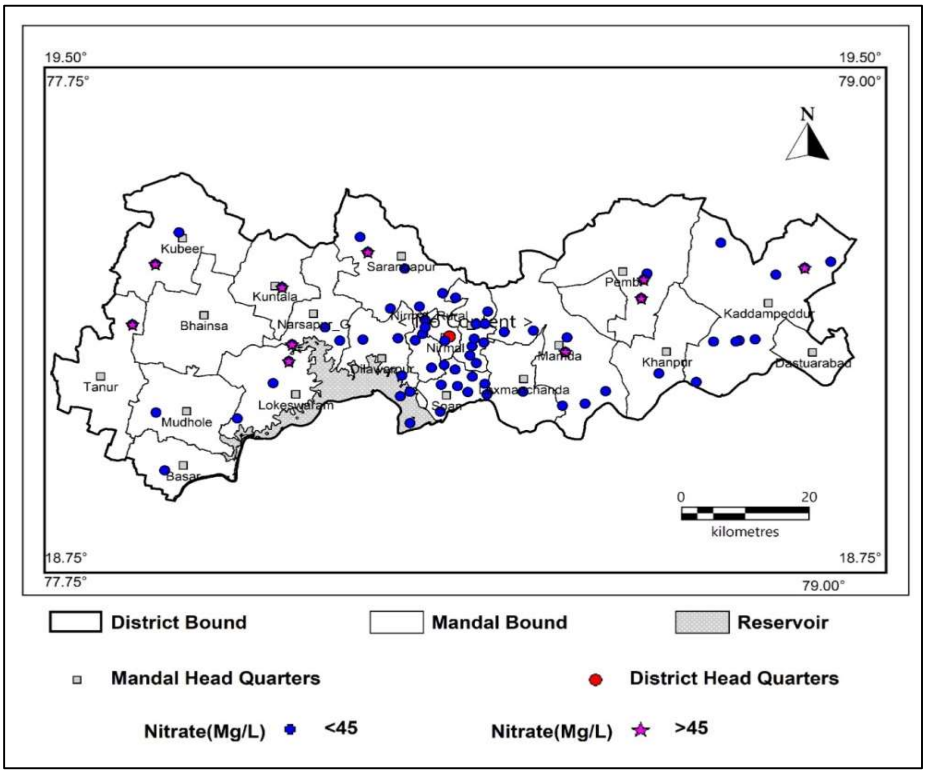

Fig.3.11: Distribution of Nitrate (Pre-monsoon)

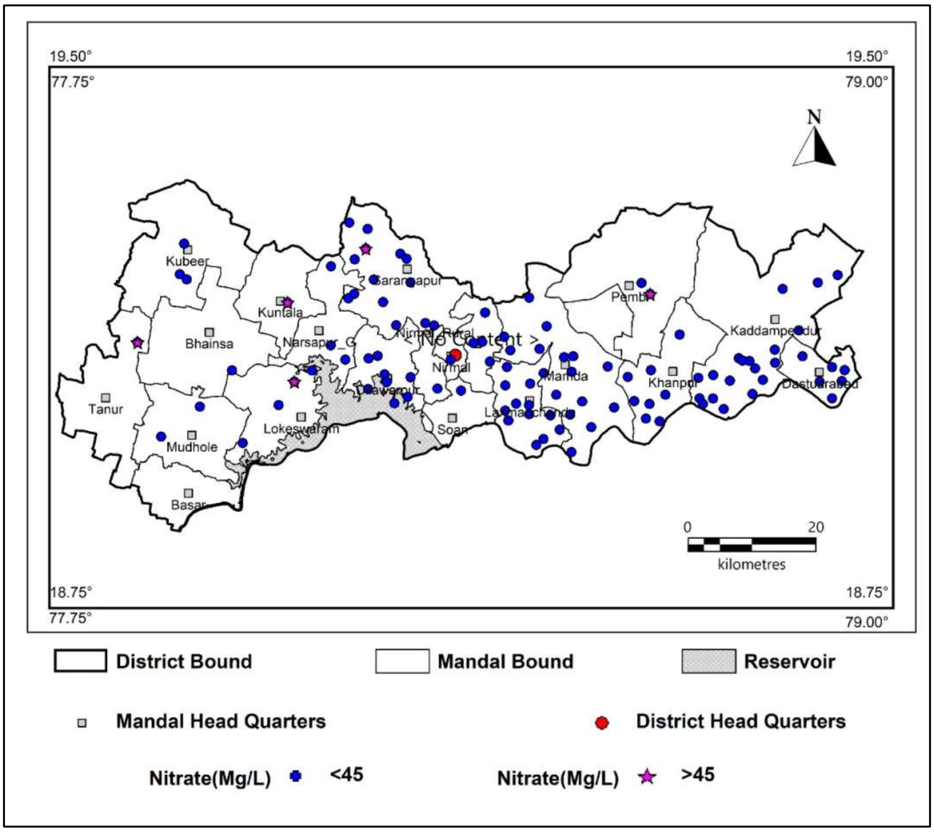

Fig.3.12: Distribution of Nitrate (Post-monsoon)

3.3 AQUIFER MAPPING

Information on aquifer geometry, Groundwater potential of fracture systems and their characterization are primarily inferred from exploratory drilling data. The principal aquifer in the area is granites and gneisses 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. (**Fig – 3.13).**

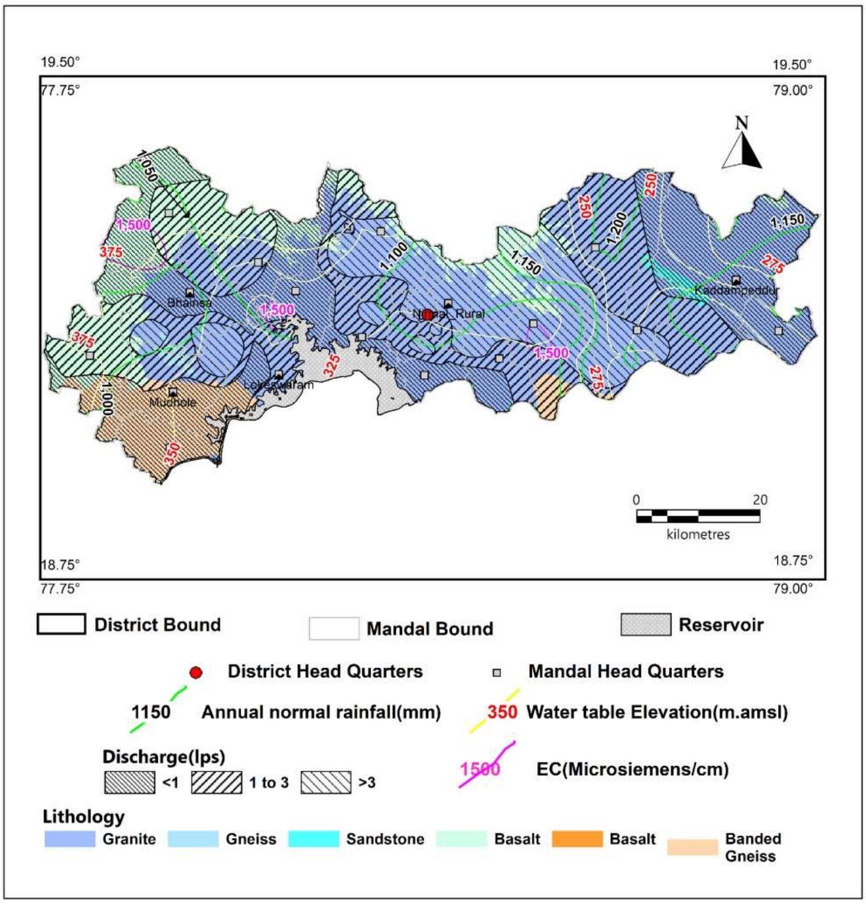

Fig. 3.13: Hydrogeology map of Nirmal district

3.3.1 Weathered Aquifers: The ground water exploratory drilling data and geophysical VES data have been used to elucidate the lateral and vertical changes in weathered zone. In most of the area the depth of weathering varies from 10-20 m (49 %), < 10 m weathering occurs in 41 % of the area. Deeper weathering (> 20 m) occurs in isolated parts falling in Kuntala, Tanoor Pembi and Narsapur (**Fig – 3.14 & 3.15**).

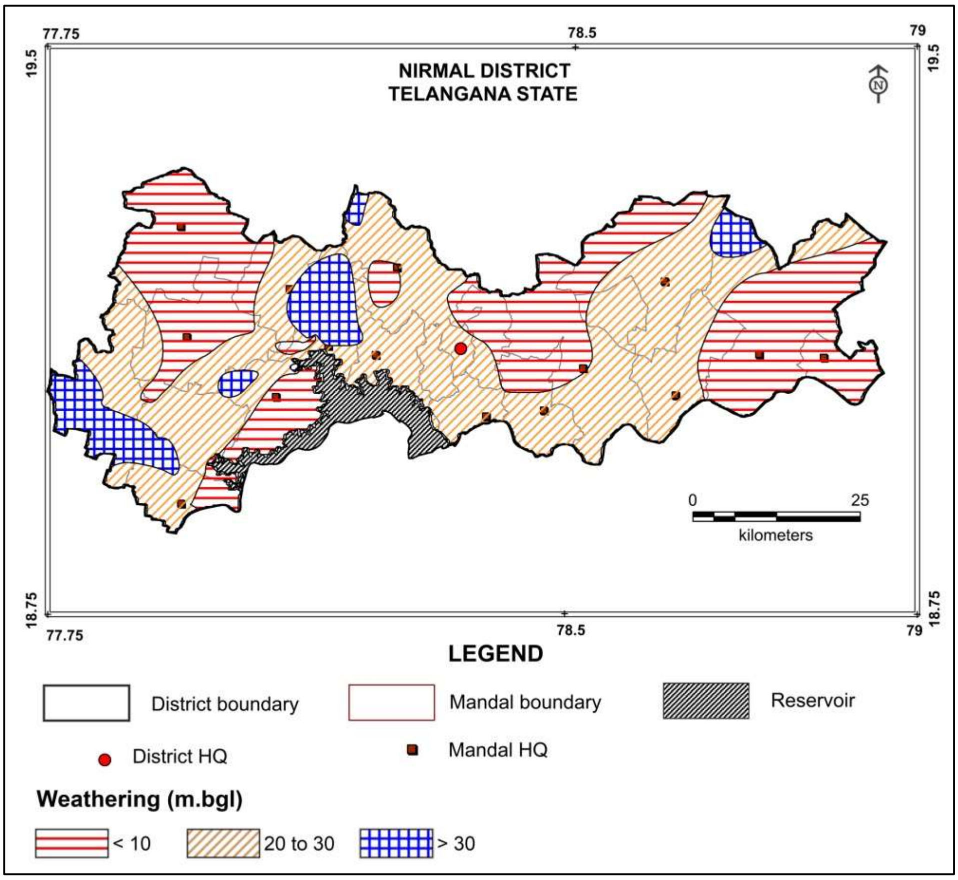

Fig.3.14: Thickness of Weathered zone, Nirmal district

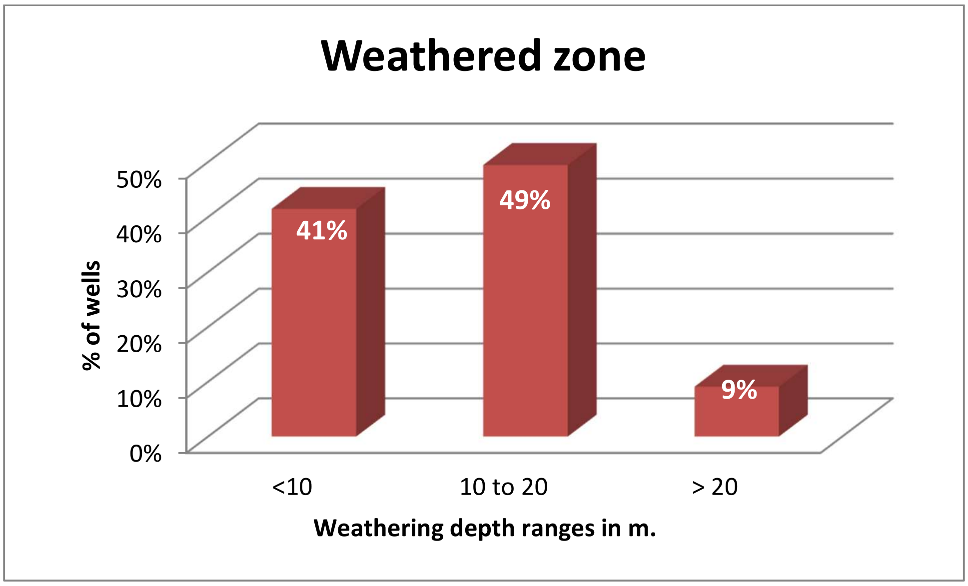

Fig.-3.15: Depth wise distribution of weathering zone, Nirmal district.

3.3.2 Fractured Aquifers:

Data analysed from CGWB wells indicates, 04 wells of shallow depth (30 m), 12 wells of 30-60 m depth, 01 well of 60-100 m. 02 wells of 100-150 m depth and 31 wells of 150-200 m depth. Deepest fracture was encountered at 190.6 m.bgl at Rajura in Kubeer mandal in granitic formation.

Ground water is extracted mainly through bore wells of 60 to 200 m depth from fractured zone (~30 to 190.5 m) (deepest fracture at Rajura in Kubeer mandal). Based on CGWB data, it is inferred that fractures less than 100 m occupies 61% of the area. < 30 m in 9%, 30 to 60 m in 24% and 60-100 m in 28% of the area. Deep fractures 100 - 150 m and > 150 m are observed in 27 % and 12% area (**Fig.3.16 and Fig.3.17**).

From the exploratory drilling data and VES data two aquifer zones were identified viz: the weathered zone (Aquifer-1) and the fracture zone (Aquifer-2) below it. Many of dug wells in the area have less than one meter water column during most of the years and about 50% of wells get dry during summers. The principal aquifer in the area is granites and gneisses 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.

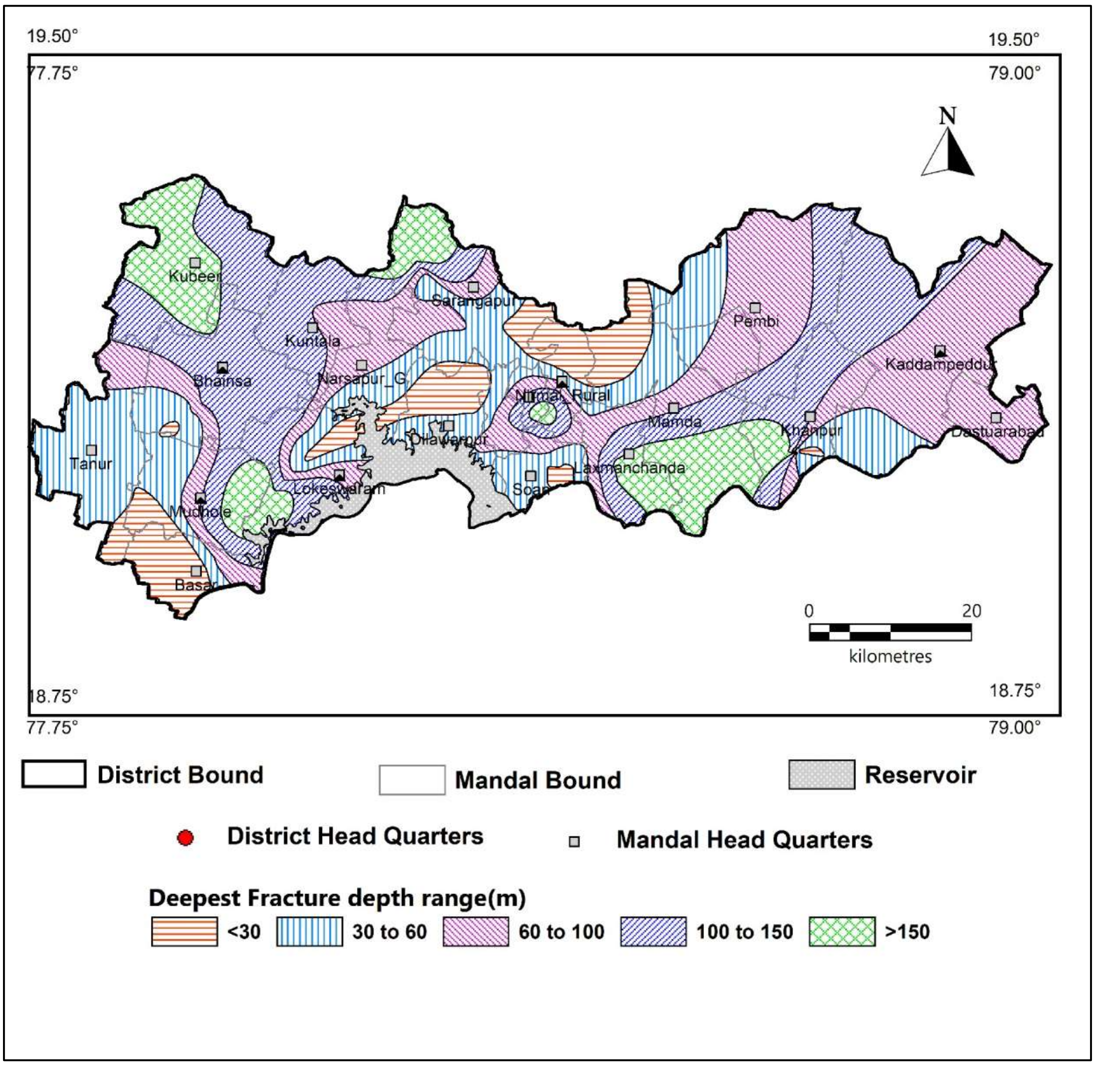

Fig.-3.16: Depth of Fractured zone, Hard rock areas, Nirmal district.

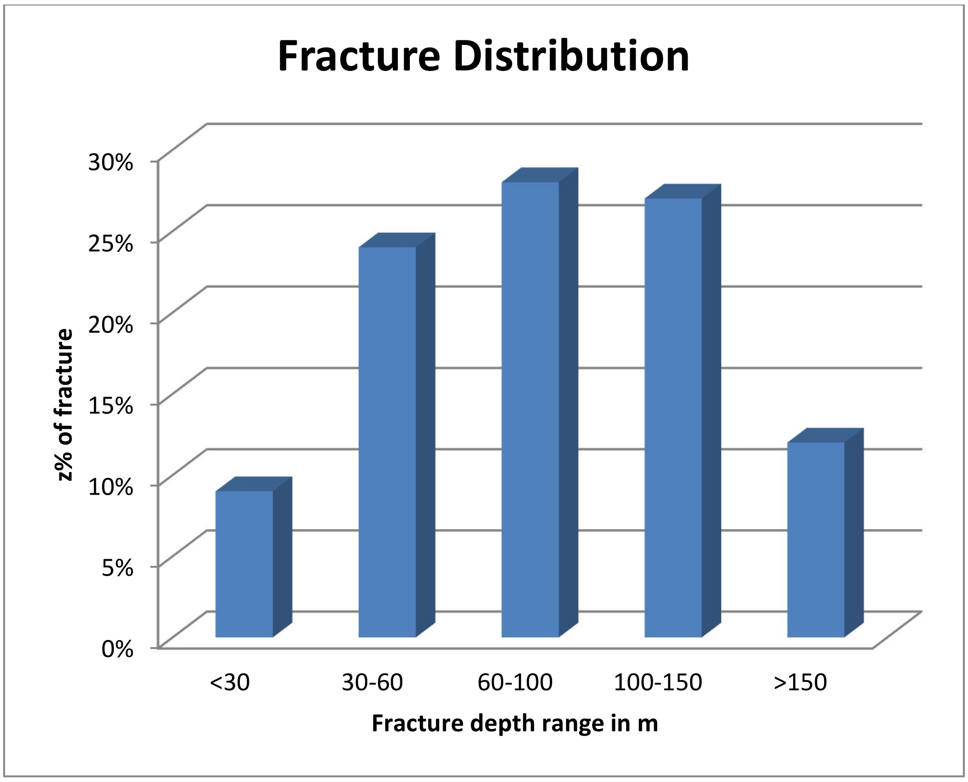

Fig.-3.17: Depth wise distribution of fractures, Hard rock areas, Nirmal district.

Aquifer-I: consists of weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells or shallow bore wells. The shallow aquifer is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~30 m depth. They are unconfined aquifers. The average yield of these dug wells range between 20 and 50 m^3/day. Specific yield of 0.2 to 4 % is observed with average of 1.1 %. The storage coefficient (S) varies from 0.005 to 0.02 and specific capacity ranges from 0.17 to 0.165 litres/meter/drawdown (lpm/m/dd).

Aquifer-II: The second aquifer is the deeper aquifer which tapped the fractured zone. Ground water in the second aquifer occurs under semi-confined to confined condition in the fractures upto the maximum depth of 195 m bgl (deepest fracture at Rajura in Kubeer mandal). The depth of fracturing varies from 25 m to 195 m with yield of <1-5 lps. The transmissivity (T) between 7.8 and 286 sq.m/day and the storage co-efficient ranges 0.01 to 5.0 x 10^{-6} respectively. The specific capacity ranges from 15 to 30 lpm/m/d

3.3.3 Conceptualization of aquifer system in 3D

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative both hydrogeological and geophysical data down to 200 m for preparation of 3-D map, panel diagram and hydrogeological sections. The lithological information was generated by using the RockWorks-16 software and generated 3-D map for Nirmal district (**Fig.3.18)** along with panel diagram and hydrogeological sections **(Fig – 3.19)**.

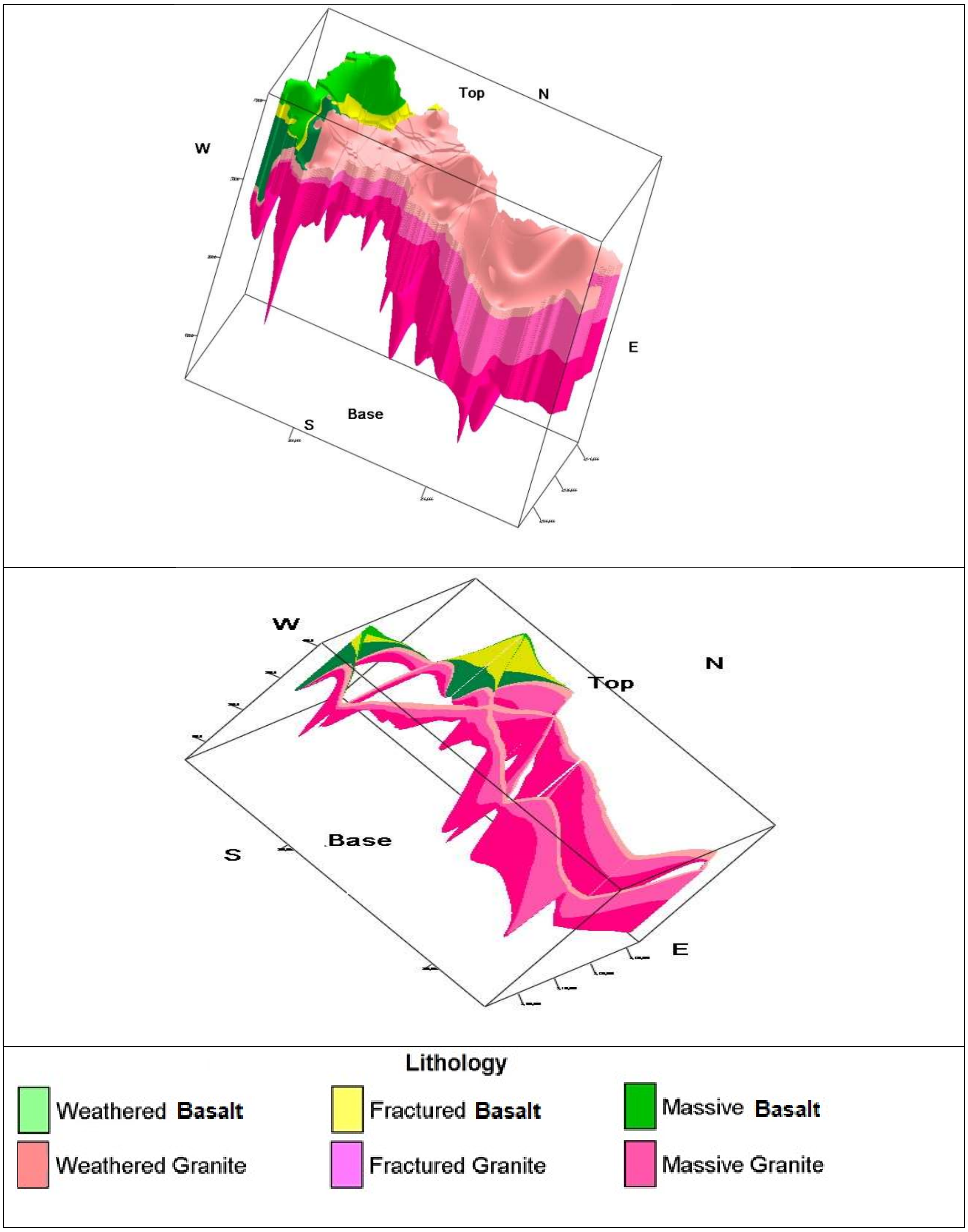

Fig-3.18: 3D Aquifer Disposition, Nirmal District

3.3.4 Hydrogeological Sections

Four hydrogeological sections are prepared in NW-SE (a), W-E (b) and SW-NE-1 (c), and SW-NE-2 (d) (**Fig. 3.19)**.

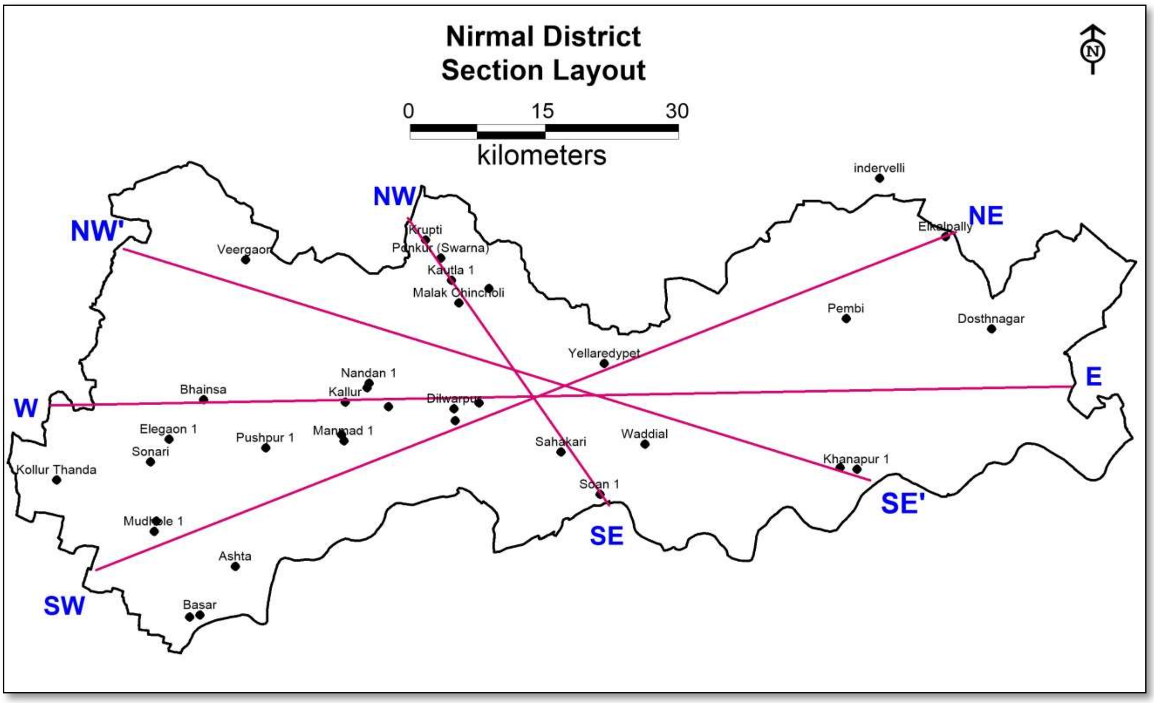

Fig.-3.19: Layout of hydrogeological Sections.

NW-SE Section (a): The section drawn along the NW-SE direction covering distance of ~75 kms (**Fig.3.20 a**). The basalstic formation is noticed upto 15 km from north west. The section depicts almost uniform weathered zone throughout the length of section. Thick fractured zone occurs from a distance of 0 to 20 kms and 40 to 75 km from NW to SE direction.

W-E Section (b): The section drawn along the W-E direction covering distance of ~97 kms (**Fig.3.20 b**). The thickness of fracture zone is more in the eastern part in comparison to western part.

SW-NE Section (c): The section drawn along the SW-NE direction covering distance of ~95 kms (**Fig.3.20c**). It shows thick weatherd and fractured zone in the north eastern part.

NNW-SSE Section (d): The section drawn along the NNW-SSE direction covering distance of ~35 kms (**Fig.3.20 d**). Thick weathered zone is noticed in the central and northwestern parts in granitic terrain. Thick fracture zone is seen in North West and South of the section.

Fig.3.20 a: NW'-SE' Section (a)

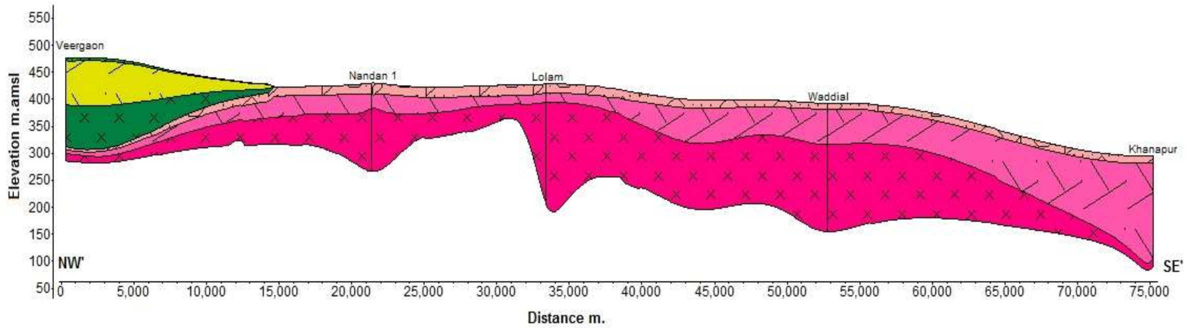

Fig.3.20 b: W-E Section (b)

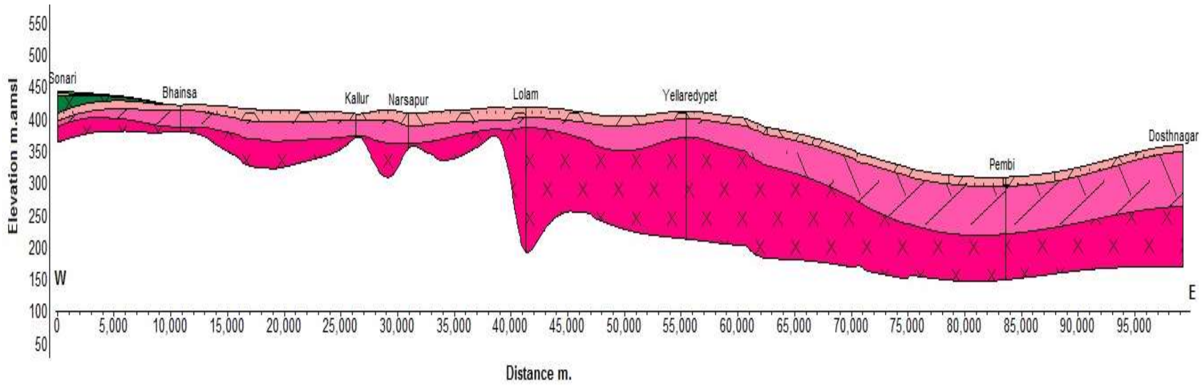

Fig.3.20 c: SW-NE Section (c)

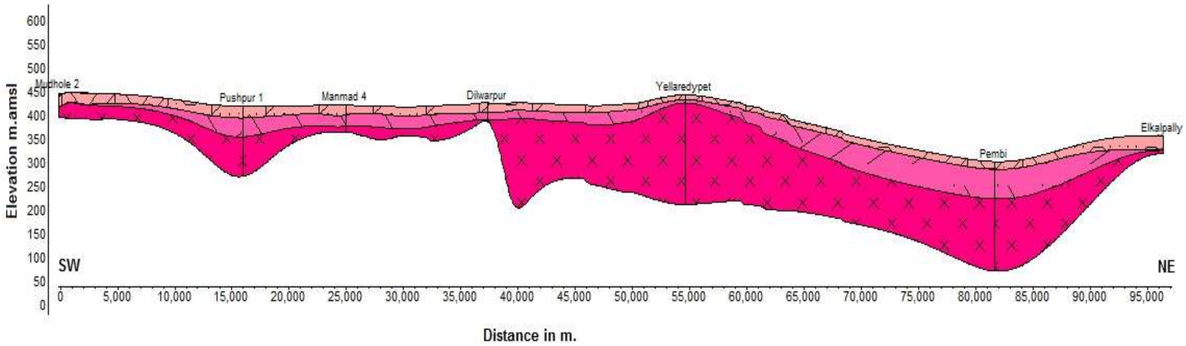

Fig.3.20 d: NNW-SSE Section (d)

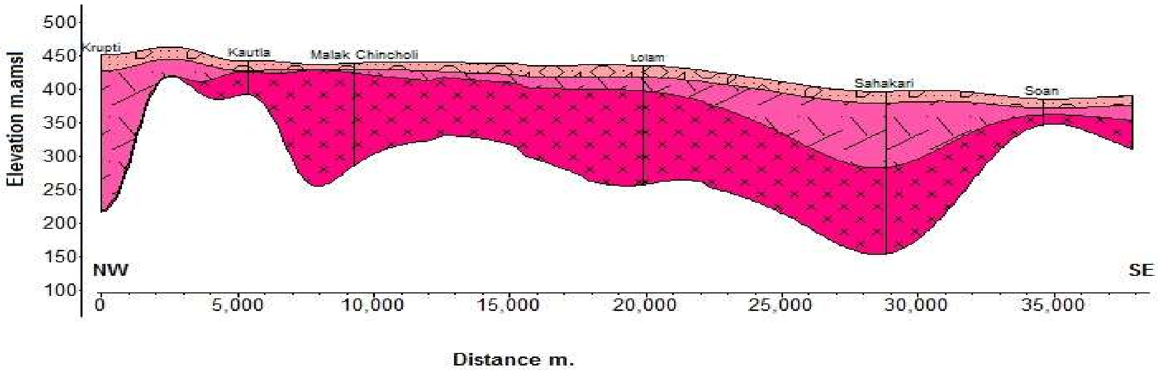

Fig.3.20 (a-d): Hydrogeological sections in different directions,
Hard rock areas, Nirmal district.

4. GROUND WATER RESOURCES (2017)

In hard rocks, for practical purpose it is very difficult to compute zone wise (aquifer wise) ground water resources, because the weathered zone (WZ) and fractured zone (FZ) 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. As per 2017 GEC report, the net dynamic replenishable groundwater availability is 504.67 MCM, gross ground water draft for all uses 187.18 MCM, provision for drinking and industrial use for the year 2025 is 22.73 MCM and net annual ground water potential available for future irrigation needs is 315.24 MCM. The stage of ground water development varies from 9 % in Pembi mandal and 73% in Dilawarpur mandal with average of 37 %. Out of 19 mandals, 2 mandals falls in semicritical category and remaining 17 mandals are in safe category.

Table-4.1: Computed Dynamic, In-storage ground water resources, Nirmal district.

Parameters	Command	Non-command	**Total**
As per GEC 2017	MCM	MCM	MCM
Dynamic (Net GWR Availability)	**135.29**	**369.38**	**504.67**
○ Monsoon recharge from rainfall	50.53	281.44	331.97
○ Monsoon recharge from other sources	40.56	31.13	71.69
○ Non-Monsoon recharge from rainfall	11.32	46.67131	57.99131
○ Non-monsoon recharge from other sources	47.65	47.5	95.15
○ Natural Discharge	14.78	37.37	52.15
Gross Recharge			
Gross GW Draft	**50.50**	**136.62**	**187.12**
○ Irrigation	45.90	120.80	166.7
○ Domestic and Industrial use	4.66	15.82	20.48
Provision for Drinking and Industrial use for the year 2025	5.75	16.98	22.73
Net GW availability for future irrigation	83.64	231.60	315.24
Average Stage of GW development (%)	37	37	37
Categorization of mandals	9 % in Pembi mandal and 73% in Dilawarpur mandal (SC:2 and Safe:17)		

5. GROUND WATER RELATED ISSUES AND REASONS FOR ISSUES

5.1 Issues

Over-exploitation

- ~ 147 Km^2 area (8 % of area) covering 37 villages are categorized as over-exploited where ground water balance for future irrigation is nil.

Pollution (Geogenic and Anthropogenic)

- Few ground water samples found high concentration of fluoride during pre (5%) and post monsoon (2%). High nitrate (> 45 mg/l) due to anthropogenic activities is observed in 14% and 4% of samples during pre and post-monsoon seasons respectively.

Sustainability

- Low yield (<1 lps) occurs in ~39% of area and yields covering eastern and western part.

5.2 Reasons for Issues

Geo-genic pollution (Fluoride)

- Higher concentration of fluoride in ground water is attributed due to source rock (i.e., granite), rock water interaction where acid-soluble fluoride bearing minerals (fluorite, fluoro-apatite) gets dissolved under alkaline conditions.
- Higher residence time of ground water in deeper aquifer.

Anthropogenic pollution (Nitrate)

- Higher concentration is due to sewage disposal of domestic effluents in urban and rural areas. Use of NPK fertilizers and nitrogen fixation by leguminous crops.

6. MANAGEMENT STRATEGIES

High dependence on groundwater coupled with absence of augmentation measures has led to a steady fall in water levels and desaturation of weathered zone in some parts, raising questions on sustainability of existing groundwater structures, food and drinking water security. The occurrence of fractures in fractured zone are very limited in extent, as the compression in the rock reduces the opening of fractures at depth and the majority of fractures occur within 100 m depth. 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.

6.1 Management plan

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. The study suggests notable measures for sustainable groundwater management, which involves a combination of 1) Supply side measures and 2) Demand side measures.

6.1.1 Supply side measures:

In the district, 1047 MCM of unsaturated volume (below the depth of 5 m) is available during post-monsoon season with a recharge potential (2%) of 20.94 MCM. This can be utilized for implementing management strategy.

Ongoing Projects

6.1.1.1 Mission Kakatiya (Repair Renovation and Restoration of existing tanks):

- De-silting of existing 359 tanks was taken under state Govt. sponsored Mission Kaktiya (Phase-1 to 4) programm and removed nearly 3.96 MCM of silt and this has created additional surface storage. This can contribute nearly ~1 MCM of groundwater recharge. With this additional ~167 ha land can be brought under irrigated dry (ID) crops in tank ayacut.

- There is need to take remaining tanks (~445 MI and other small tanks) for de-silting, this will greatly help in stabilisation of tank ayacut and ground water augmentation.

6.1.1.2 Mission Bhagiratha:

- Under Mission Bhagiratha, Telangana Drinking Water Supply Project (TDWSP), All villages in Nirmal district are covered under protected drinking water source from Kadam Reservoir and SRSP. During 2020, the imported water from Kadem-Khanapur and SRSP-Adilabad segment is 35.39 MCM. This imported water from surface sources will reduce the present utilized ~15.4 MCM of ground water (considering 60 lpcd). This can be effectively utilized to 2567 ha of additional land under ID crops

To be taken up

6.1.1.3 Artificial Recharge Structures:

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 2011-2020 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, Govt. of Telangana. The availability of sub-surface storage volume of aquifers in each district is computed as the product of area, thickness of aquifer zone between 5 m. bgl and the average post-monsoon water level. The recharge potential/sub surface space of the aquifers is calculated by multiplying the sub surface storage volume with 2% specific yield.

- The source water availability is estimated from the rain fall and run off correlations. The runoff was calculated by taking into account of normal monsoon rainfall of the mandal and corresponding runoff yield from Strangers Table for average catchment type. Out of the total run 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.
- 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.

Area Identified for artificial recharge structures

Area Identified for AR (Sq.Km.)	Available Subsurface Space for AR (MCM)	Available Surplus runoff (MCM)	50% of Available Surplus runoff (MCM)	Proposed Numbers of structures		Total volume of water expected to be recharged @50% efficiency	
				CD	PT	CD	PT
757	44	15.2	7.6	161	143	5.6	2

The 757 Km^2 area in 96 villages is having recharge potential of 44 MCM and availability of 12.8 MCM Uncommitted Surplus runoff (MCM).

- 304 artificial recharge structures (161 CD's and 143 mini PT'in 96 villages) with a total cost of **37.55** rores can be taken up. (Considering CDS with recharge shafts with 5 fillings with a unit cost of Rs 10 lakhs each and mini-PTs with 2 fillings with a unit cost of Rs 15 lakhs each)
    - After effective utilization of this yield, there will be 3.4 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).

6.1.1.4 Water Conservation Measures (WCM) (Farm Ponds):

The farm ponds are the ideal water conservation structures, which are constructed in the low-lying areas of the farm. The size of form ponds can be 10 x 10 x 3 m. Total 7420 farm ponds are recommended (20 in each village in 371 villages) at Rs 25,000/- each with total cost of **1.85** crores, this can create an additional storage of 2.2 MCM.

Other Supply Side Measures:

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

6.1.2 Demand Side Measures: In order to manage the available resources more effectively the following measures are recommended.

6.1.2.1 Ongoing Micro-irrigation

- In the area till date a total ~6329 ha area is brought under micro-irrigation (Sprinklers: 1269 and drip: 5050) saving ~12 MCM of groundwater (considering 25 %

of saving to traditional practices). New areas can be taken up for implementation of micro irrigation under PMKSY to increase more cop per drop. This can greately reduce the ground water withdrawal in the district.

6.1.3 Other Recommendations

- As a mandatory measure, every groundwater user should recharge rainwater through artificial recharge structures in proportionate to the extraction.
- Roof top rainwater harvesting structures should be made mandatory to all Government/industrial buildings (new and existing).
- A participatory groundwater management (PGWM) approach in sharing of groundwater and monitoring resources.
- Effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002).
- Subsidy/incentives on cost involved in sharing of groundwater may be given to the concerned farmers
- Proper treatment and disposle of urban and rural sewerage to arrest leaching of nitrate.

6.2 Expected results and out come

With the above interventions costing Rs 189 crores (excluding the cost involved in Mission Kakatiya and Mission Bhagiratha), the likely benefit would be the net saving of 38.2 MCM of ground water. This will bring down the stage of ground water development by 3 % (from 37% to 34 %).

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