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

MULUGU DISTRICT, TELANGANA

दक्षिणी क्षेत्र, हैदराबाद

Southern Region, Hyderabad

भारत सरकार
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MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION
CENTRAL GROUND WATER BOARD

REPORT ON
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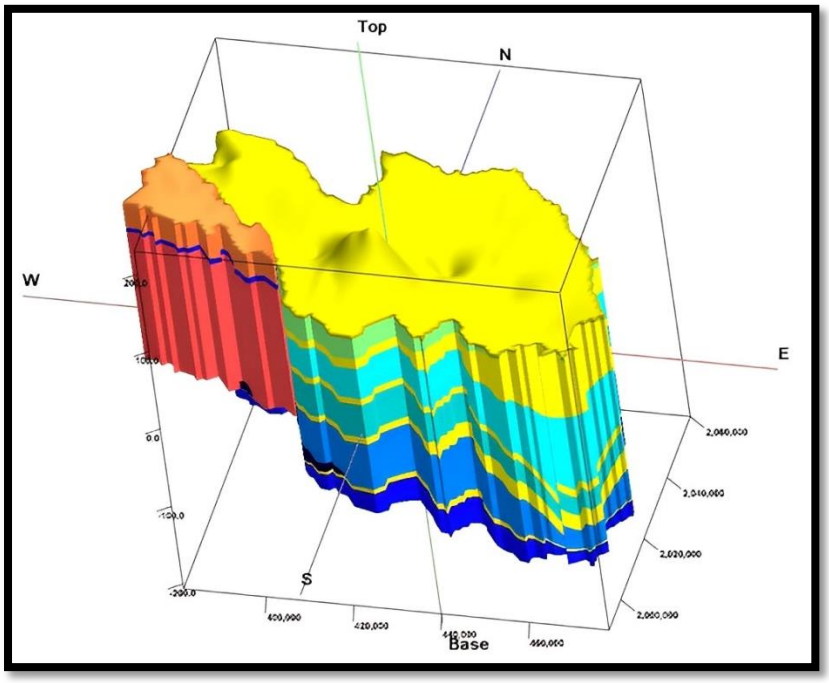

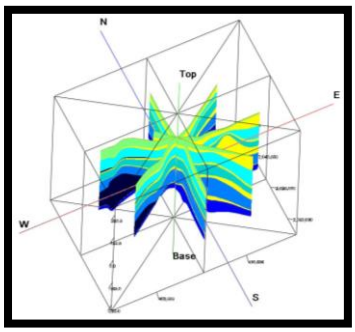

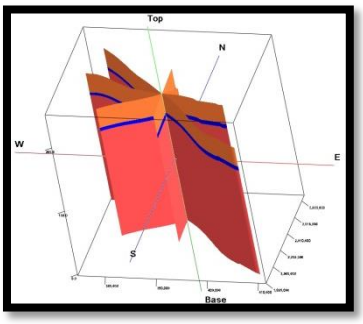

CENTRAL GROUND WATER BOARD
SOUTHERN REGION
HYDERABAD
JANUARY, 2023

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN MULUGU DISTRICT, TELANGANA STATE

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AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN MULUGU DISTRICT, TELANGANA STATE

Executive summary

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ABBREVATIONS

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

EXECUTIVE SUMMARY

The Mulugu district is situated in the eastern part of Telangana State and covers a total area of 4126.83 km^2, spanning from north latitudes 18°05'36.42"N to 18°14'41"N and east longitudes 80°18'52.99"E to 80°29'9.14"E. The district comprises of 9 revenue mandals and 336 villages, with a population of approximately 2.94 lakhs as per the 2011 census. The district's population density stands at 71 individuals per square kilometer.

The area is underlain by various geological formation from the oldest Archaean rocks comprising granite/gneisses, Sullavai, Purana, Gondwana to the recent alluvium. The Gondwana succession rest unconformabely over Lower Palaeozoic and Archeans. About 91% of the area is underlain by Gondwana formation, 9% by Metasedimentary and Sullavai formation.

The study area, which encompasses a portion of the Godavari river basin and a small region in the southwest that forms part of the Krishna river basin, comprises several distinct landforms. The most prominent are structural hills, which cover roughly 34% of the area. Other landforms include pediplains (22%), pediments (19%), dissected plateaus (9%), flood plains (7%), and various others. The eastern boundary of the study area is defined by the meandering Godavari River, while the central region is traversed by the Laknavaram River, a tributary of the Godavari that flows from south to north.

Agriculture and forest are the primary land use features, covering 71% and 14% of the total geographical area of 4126.83 km^2, respectively. The net sown area is 573.21 km^2, while the gross cropped area is 758.51 km^2. The major crop grown in the district is paddy, which accounts for 91% of the total cropped area.

The district has several major and medium irrigation projects that facilitate agriculture in the region. The PV Narasimha Rao and J. Chokka Rao Lift Irrigation Scheme (LIS) built across the Godavari River in the Eturnagaram mandal provide irrigation potential of 7,50,000 acres and 6,21,000 acres, respectively. Additionally, the Maluruvagu, Gundlavagu, Modikuntavagu, and Palemvagu projects built across the tributaries of the Godavari River create significant irrigation potential in the district. In total, the district has 727 minor irrigation tanks with an ayacut of 58,303.50 acres. Moreover, there are 10,975 irrigation wells, including 739 dug wells and 10,236 tube wells.

Groundwater levels are monitored using 45 groundwater monitoring stations during both the pre and post-monsoon seasons. During the pre-monsoon season, the depth to water levels varied from 2.72 m bgl in Laxmidevipet to 22.37 m bgl in Jakkaram. In the post-monsoon season, the depth to water levels ranged from 1.32 m bgl in Laxmidevipet to 16.85 m bgl in Tadvai. The water table elevation during the pre-monsoon period ranged from 69 to 308 m amsl, while during the post-monsoon period it ranged from 72

to 312 m amsl. The direction of groundwater flow is mainly towards the eastern and northeastern regions.

Water level trend analysis for the last 10 years (2011-2020) is studied from 37 hydrograph station (CGWB: 21, SGWD:16). The decadal pre-monsoon water level trend analysis indicates that 24 wells show falling and 13 wells show rising trend. During post-monsoon season 10 wells show falling trend and 27 wells shows rising.

Multiple aquifer systems (1 to 5 aquifers) are found in semi-consolidated/ unconsoidated sandstone formations with intervening clay beds. The first aquifer is unconfined whereas the deeper aquifers are in semi-confined/ confined condition. Depth of aquifers are decided based on the depth of bottom clay layers. The thickness of Aquifer-I or unconfined zone varies from 13-54 m. The unconfined zone extend from bottom of the soil layer to top of the first clay layer. Unlike Aquifer-I, ground water occurs under confined to semi-confined condition in Aquifer-II to V. The ground water yields vary from 1 to 8 lps in Sullavai Sandstone. In Lower Gondwana formations the yield varies form < 1 to 45 lps, where as in upper gondwana it varies from 1 to 23 lps. In Talchir boulder beds yield varies from 1 to 10 lps. In Barakar sandstone yield varies between <1 and 20 lps where as Kota and Kamthi formations show maximum yields varying between 10 and 45 lps.

The metasediments like Shales and Limestones of Pakhal supergroup and Sulavai Sandsones represents the consolidated formation. They are devoid of primary porosity. However, subsequent weathering, fracturing and fissuring developed secondary porosity. The main aquifers constitute the weathered zone at the top, followed by a discrete anisotropic fractured/fissured zone at the bottom, generally extending down to 200 m depth.

A total of 88 groundwater samples were collected and analyzed from the Mulugu district, with 49 samples taken during the pre-monsoon season and 39 during the post-monsoon season. The majority of the area had an electrical conductivity (EC) of less than 3000 μ Siemens/cm during both seasons. During the pre-monsoon season, nitrate concentration ranges from 1-608 mg/L, with 32% of the samples exceeding the maximum permissible limit of 45 mg/L set by the Bureau of Indian Standards (BIS). Fluoride (F) concentration ranges from 0.01-2.20 mg/L, with 6% of the samples exceeding the maximum permissible limit of 1.5 mg/L set by the BIS. During the post-monsoon season, nitrate concentration ranges from 1.0-257.68 mg/L, with 36% of the samples exceeding the maximum permissible limit of 45 mg/L set by the BIS. Fluoride concentration ranged from 0.07-2.32 mg/L, with 13% of the samples exceeding the maximum permissible limit set by the BIS.

The net dynamic replenishable ground water availability in the Mulugu district is 392.91 million cubic meters (MCM), while the gross ground water draft is 150.40 MCM. There is a provision for 9.42 MCM for drinking and industrial use for the year 2025. The

net available balance for future irrigation use is 235.52 MCM. The stages of ground water development in the district is 38.27%.

Major issues identified are high fluoride concentration (>1.5 mg/L) occur in 6 % and 13 % of the samples during pre and post-monsoon season, high EC concentration (> 3000 micro-seimens/cm) in parts of Eturnagaram, Mulugu and Venkatapuram mandal during pre-monsoon and post-monsoon seasons respectively, High nitrate (> 45 mg/L) occur in 32 % and 36 % of the samples during pre-monsoon and post-monsoon season respectively.

The management strategies mainly include supply side and demand side management. The supply side measure includes ongoing work under Mission Kakatiya where de-silting of existing minor tanks (543 no.) was taken under state Govt. sponsored Mission Kaktiya (Phase-1 to 4) to remove silt and this has created additional surface storage and enhance groundwater recharge. Under Mission Bhagiratha, there is plan to import ~11.65 MCM of water for drinking purposes which will save the present ~6.99 MCM of water for drinking and domestic purposes and with this additional ~1165 ha of land can be brought under ID crops.

As the stage of ground water development in the district is 38.27 % and 1 out of 9 mandals are falling in semi-critical category as per the GEC 2020 estimation, the artificial recharge structures are not proposed for entire district. To control further increase in stage of ground water development, artificial recharge structures are recommended for 1 semi-critical mandal (i.e. Mangapet) only which includes construction of 20 artificial recharge structures (9 CD's and 11 PT's). In demand side management 653 ha of additional land that can be brought under micro-irrigation (@1000 ha/mandal including existing area in 1 semi-critical mandals (i.e., Mangapet mandal) costing about 3.91 crores (considering 1 unit/ha @0.6 lakh/ha). With this 0.97 MCM of ground water can be conserved over the traditional irrigation practices.

In addition to this roof top rainwater harvesting structures should be made mandatory to all Government buildings.

Other measure includes strict implementation of WALTA and participatory groundwater management (PGWM). the likely benefit would be net saving of 1.45 MCM of ground. This will bring down the stage of groundwater development by 2.43 % (from 71% to 68.56%) in Mangapet mandal.

1. INTRODUCTION

National Aquifer Mapping (NAQUIM) had been taken up by CGWB to create robust database of hydrogeological information at 1:50,000 scale for sustainable ground water management. Aquifer mapping is a multidisciplinary and a holistic scientific approach wherein a combination of geological, geophysical, hydrological and chemical analysis is applied to characterize the quantity, quality and sustainability of ground water in aquifers. It had been taken up by CGWB to carry out detailed hydrogeological investigation on toposheet scale of 1:50,000. The vagaries of rainfall, inherent heterogeneity and unsustainable nature of hard rock aquifers, over exploitation of aquifers, insufficient regulation mechanism has a detrimental effect on ground water scenario of the country in last decade or so. Thus, prompting the paradigm shift from "**traditional ground water development concept**" to "**modern ground water management concept**".

Varied and diverse hydrogeological settings demand precise and comprehensive mapping of aquifers down to the optimum possible depth at appropriate scale to arrive at the robust and implementable ground water management plan. The proposed management plans will provide necessary inputs and recommendations for ensuring sustainable management of ground water resources of district. The aquifer maps and management plans will be shared with the Administration of Mulugu district, Telangana State for its effective implementation.

1.1 Objective and Scope

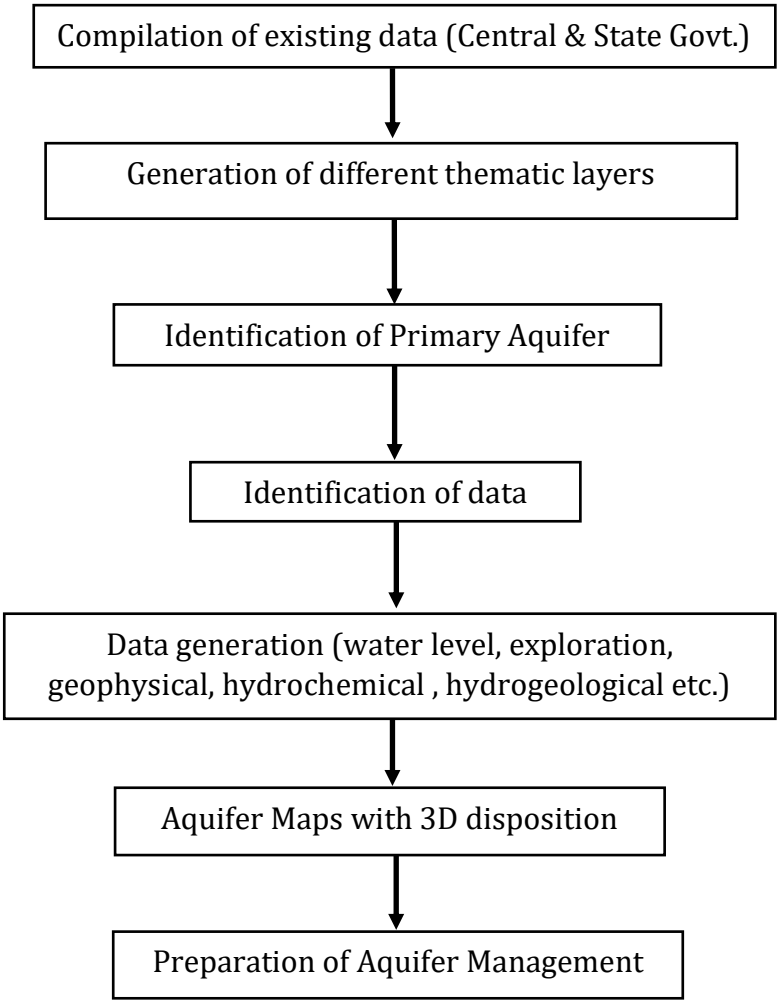
An integrated hydrogeological study was taken up to develop a reliable and comprehensive aquifer map and to suggest suitable ground water management plan on 1: 50,000 scale. The activities under NAQUIM are aimed at:

- Identifying the aquifer geometry
- Aquifer characteristics and their yield potential
- Ground water quality
- Aquifer wise assessment of ground water resources
- Preparation of aquifer maps in 3D and 2D
- Formulate ground water management plan

1.2 Approach and Methodology

The ongoing activities of NAQUIM include toposheet wise micro-level hydrogeological data acquisition supported by geophysical and hydro-chemical investigations supplemented with ground water exploration down to the depths of 200- 300 meters.

Considering the objectives of the NAQUIM, the data on various components was segregated, collected and brought on GIS platform by geo-referencing the available information for its utilization for preparation of various thematic maps. The approach and methodology followed for Aquifer mapping is as given below:



1.3 Study area

The Mulugu district having geographical area of 4126.83 km^2, lies between north latitudes from 18°05'36.42"N to 18°14'41"N and east longitudes from 80°18'52.99"E to 80°29'9.14"E located in the east of Telangana State. The location map of the study area is presented in **Fig.1.1**. The district shares boundaries with Bhadradri Kothagudem, Mahabubabad and Warangal district in southern side, Jayashankar Bhupalapally in northwestern side and Chhattisgarh state in the northeastern and eastern side. The district headquarters is located at Mulugu Town and Godavari river flows in the eastern part of the district. Administratively the district is governed by 9 revenue mandals and 336 villages with a population of ~**2.94** lakhs (2011 census). The density of population in the district is 71 per Sq.km.

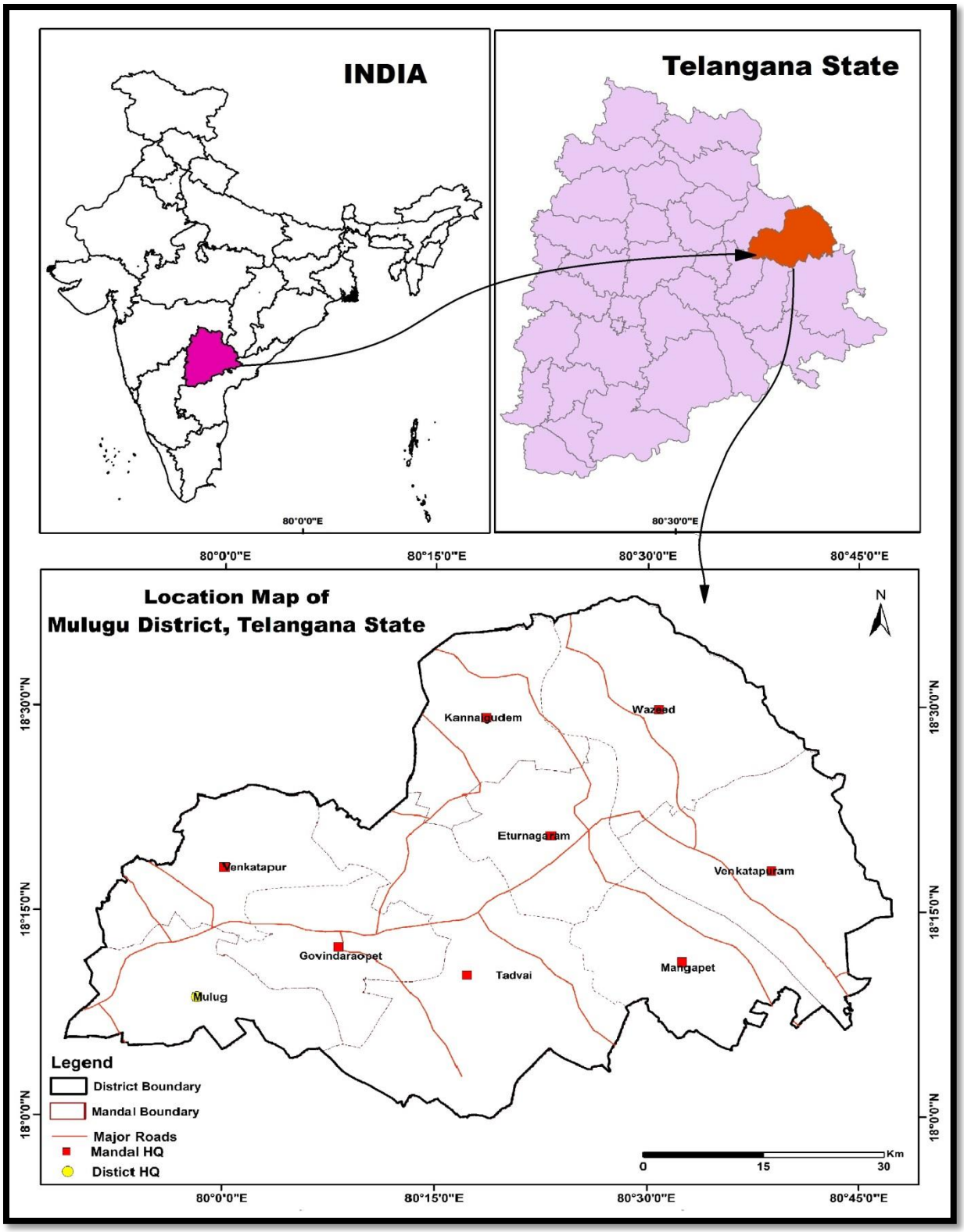


Fig.1.1: Location map of Mulugu district.

1.4 Climate and Rainfall

The climate of the district is characterised by hot summer and cool winters with a fairly good amount of seasonal rainfall. The minimum and maximum temperature recorded is 5.7°C in winter and 48.7 °C in summer. The annual normal rainfall of Mulugu district is 1292.7 mm, which ranges from 826 mm at Mulugu mandal to 1592 mm at Venkatapuram mandal. The area receives more than 85 % of the annual rainfall by

southwest monsoon between June and September and the rest during the northeast monsoon from October to November. As per Telangana State Development Planning Society (TSDPS) for the year 2021-22, it received average annual rainfall of 1338.5 mm (3.5% more rainfall than normal rainfall). The Isohyetal map of the study area is presented in **Fig.1.2a.**

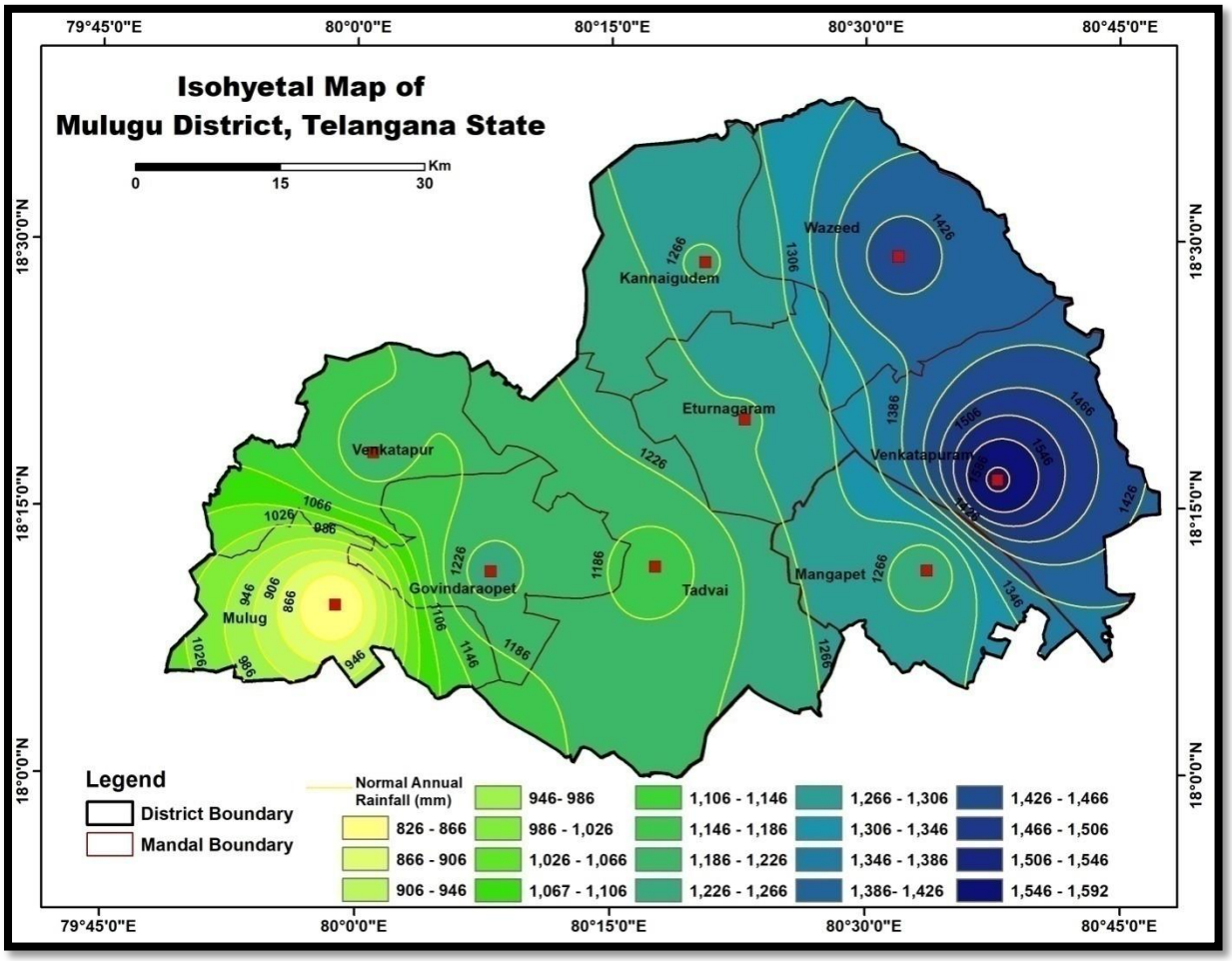


Fig.1.2a: Isohyetal map of Mulugu district.

Analysis of long term rainfall data of 17 years from 2005 to 2021 shows increasing trend in annual rainfall by 22.76 mm/year. District received large excess rainfall (+60% and above normal) in 2020-21, excess rainfall (+20 to +59% from normal) in 2010-11, 2013-14, 2019-20, normal rainfall (+19% to -19% from normal) in 2005-06, 2006-07, 2007-08, 2008-09, 2014-15, 2015-16,2016-17, 2017-18, 2018-19, 2021-22, deficient rainfall (-20% to –59% from normal) in remaining years (**Fig.1.2b)**.

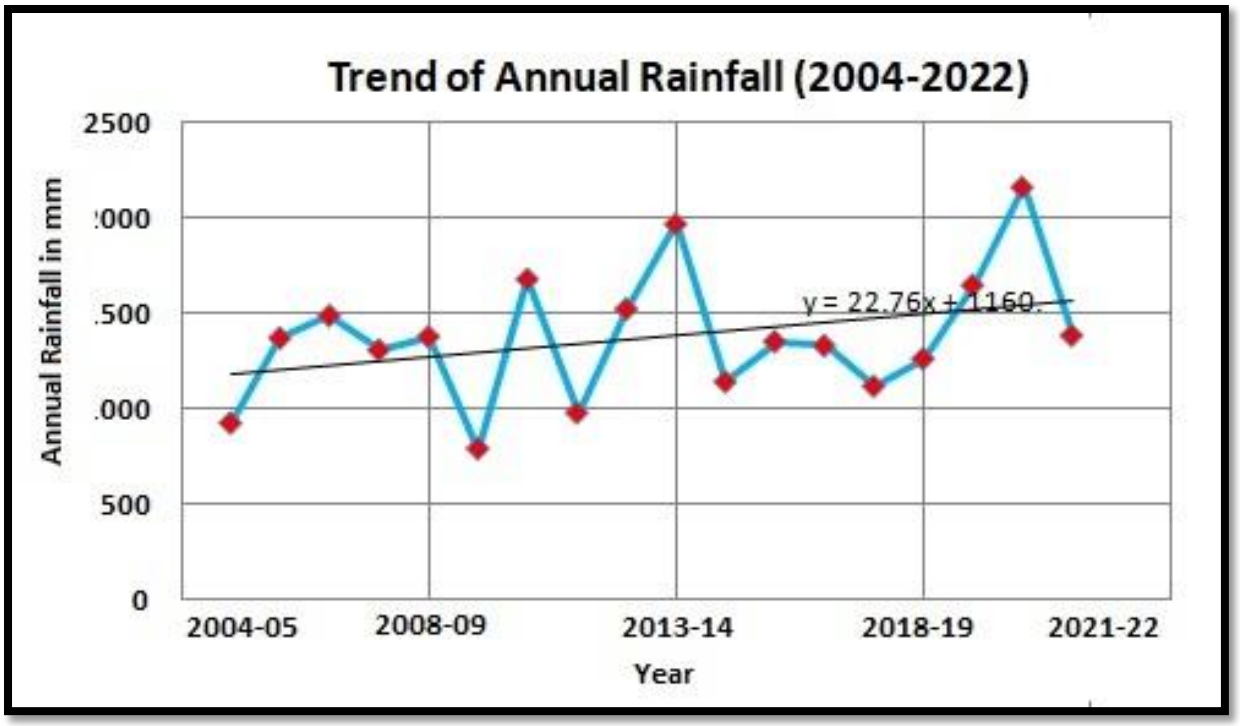


Fig.1.2b: Annual rainfall trend (2004-2022)

1.5 Geomorphological Set up

Mulugu district is characterised by undulating topography with pedeplain, pediment, structural hills, flood plain and piedmont zone. Structural hills are the major landform covering about 34% of the area. The other landforms observed are pedeplain (22%), pediment (19%), dissected plateau (9%), flood plain (7%) and others. The geomorphology map of the study area is presented in **Fig.1.3**.

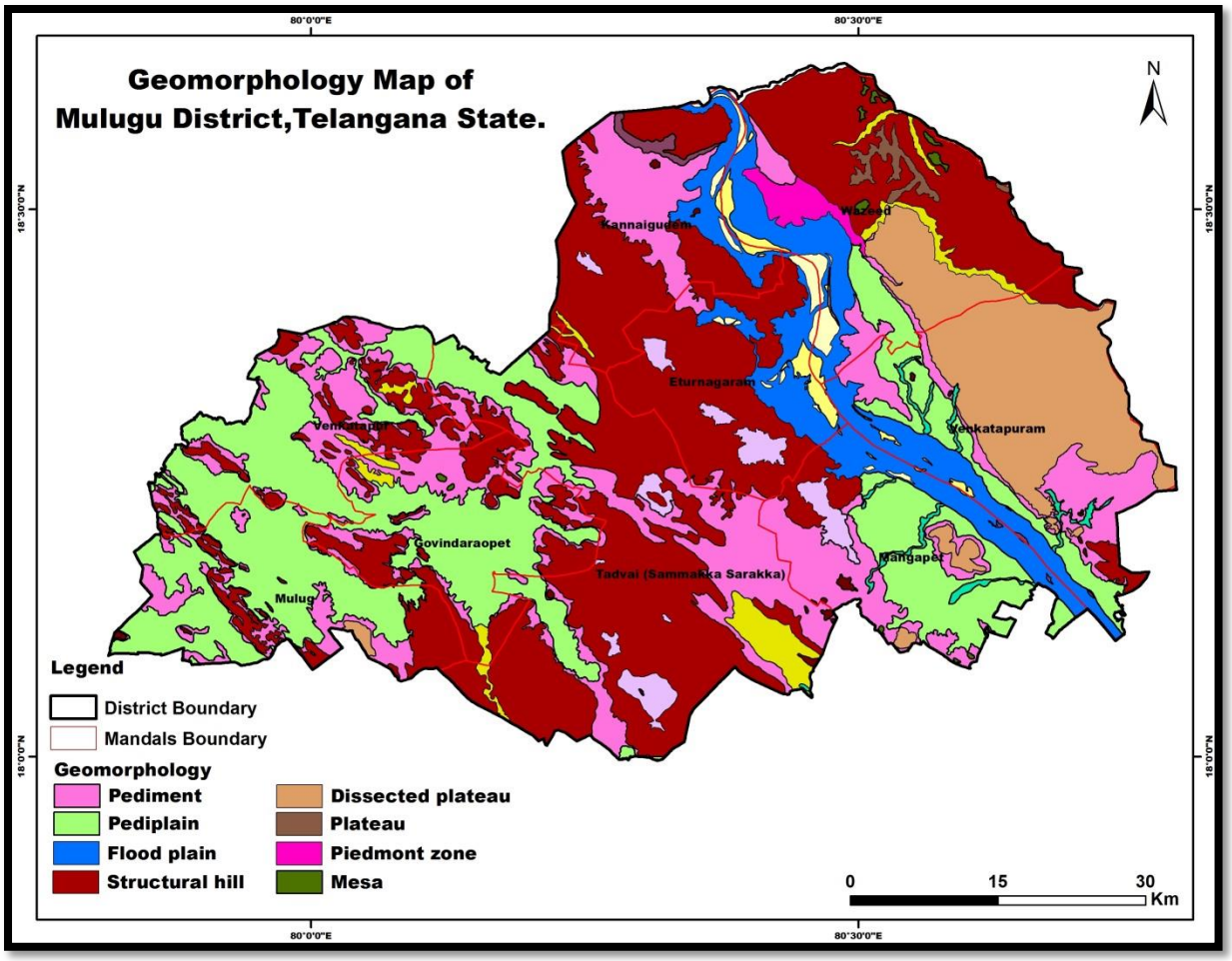


Fig.1.3: Geomorphology map of Mulugu district.

1.6 Drainage and Structures

The major parts of study area forms a part of Godavari river basin and small part in the south-western part forms part of Krishna river basin. Eastern part of the area is bordered by meandering Godavari River, whereas Laknavaram River a tributary to river Godavari flow through the central part from south to north. The Malleruvagu, Palemvagu, Vativagu and Modikuntavagu are the other minor streams which drains the area. The drainage pattern in the area is dendritic to sub-dendritic in nature. Map depicting drainage, water bodies, and river is presented in **Fig.1.4.**

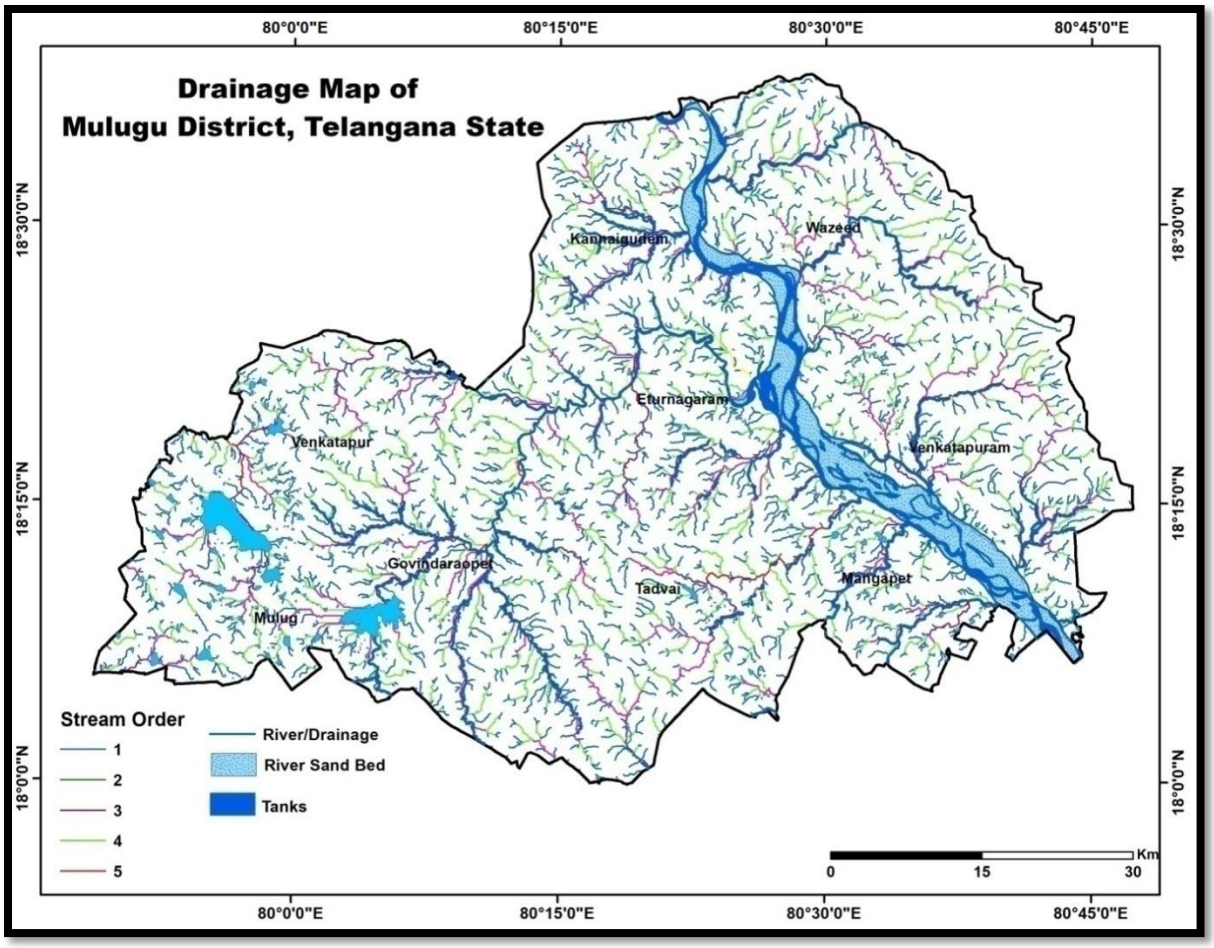


Fig.1.4: Drainage map of Mulugu district

1.7 Land use and cropping pattern

Out of the total geographical area of 4126.83 km^2, forest and agriculture are the prominent land use aspects in Mulugu district and forms 71 % and 14 % of total area respectively. The spatial distribution of land use is presented in **Fig. 1.5.** The land utilization of Mulugu district is given in Table 1.1 and crop distribution is given in table 1.2.

Table: 1.1 Land utilisation in Mulugu District

LULC	Land Use Land Cover (in %)
Forest	71.22
Barren & Uncultivable	5
Non Agricultural Use	4.99
Culturable Waste	0.83
Permanent Pasture	0.78
Miscellaneous	2.02
Current Fallows	0.76
Other fallows	0.72
Net Area Sown	13.89
Area sown more than Once	4.5
Grossed crop Area	18.38

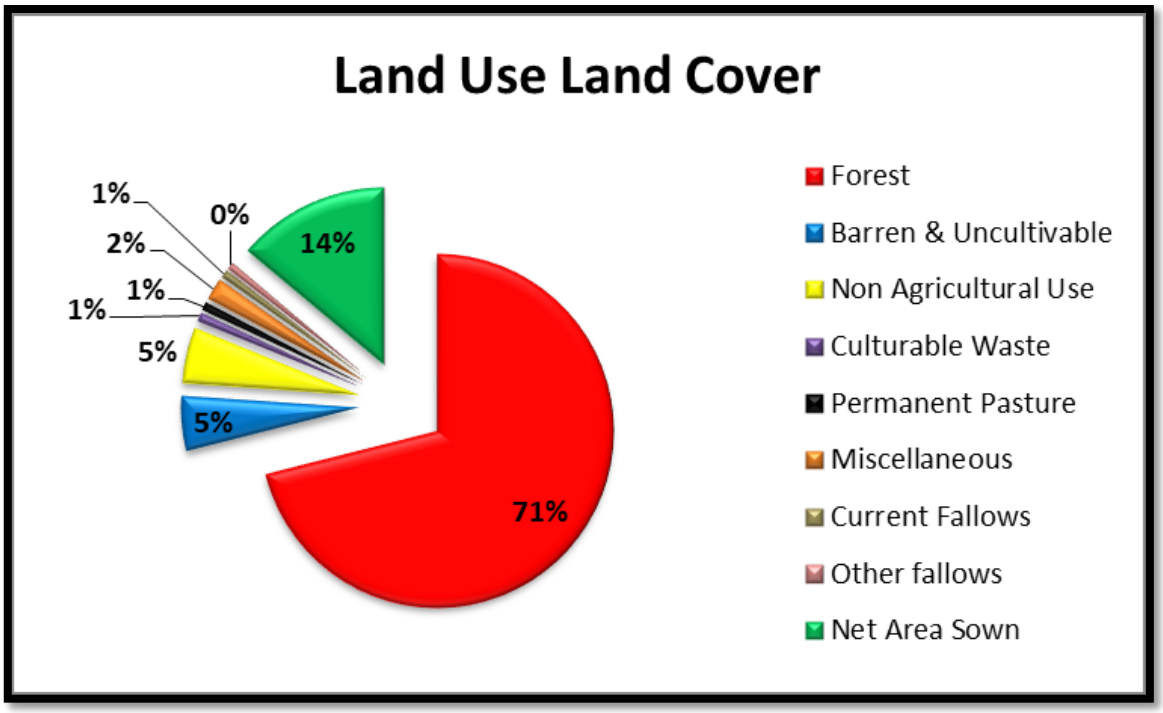


Fig.1.5: LULC of Mulugu district

The net sown area is 573.21 km^2 while the gross cropped area is 758.51 km^2. There are wide varieties of crops grown in the district. Paddy (91%) is the major crop grown in the district during Kharif season followed by cotton (8%), coarse grains (1.55%), pulses (0.10%) and oil seeds (0.015%). In Rabi season, Paddy (46%) is the major crop grown followed by cotton (26%), coarse grain (13%), pulses (10%) and oil seeds (5%).

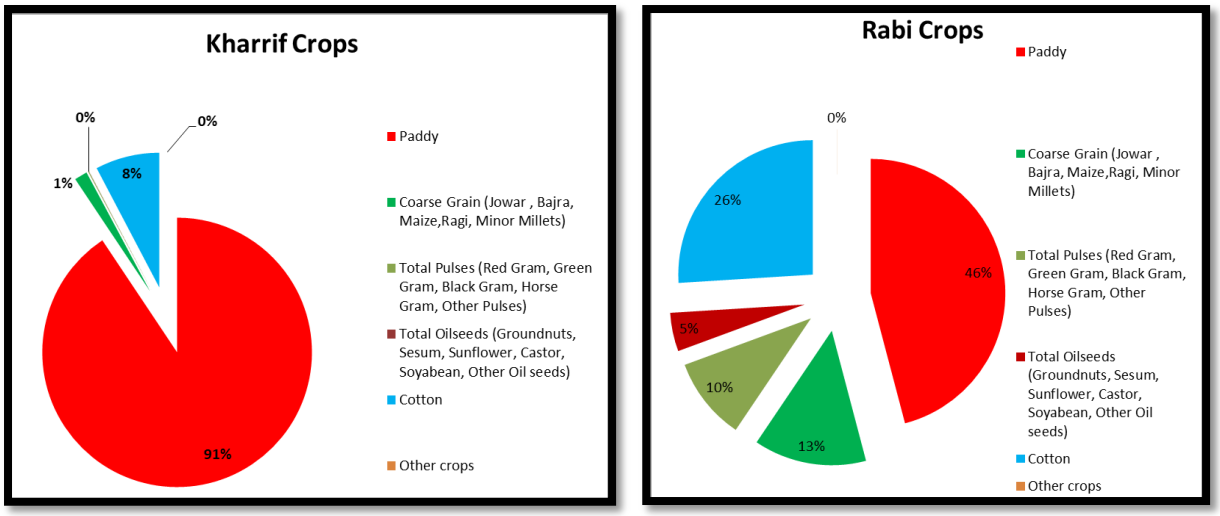


Fig.1.6 & 1.7: Khariff and Rabi crop distribution of Mulugu district

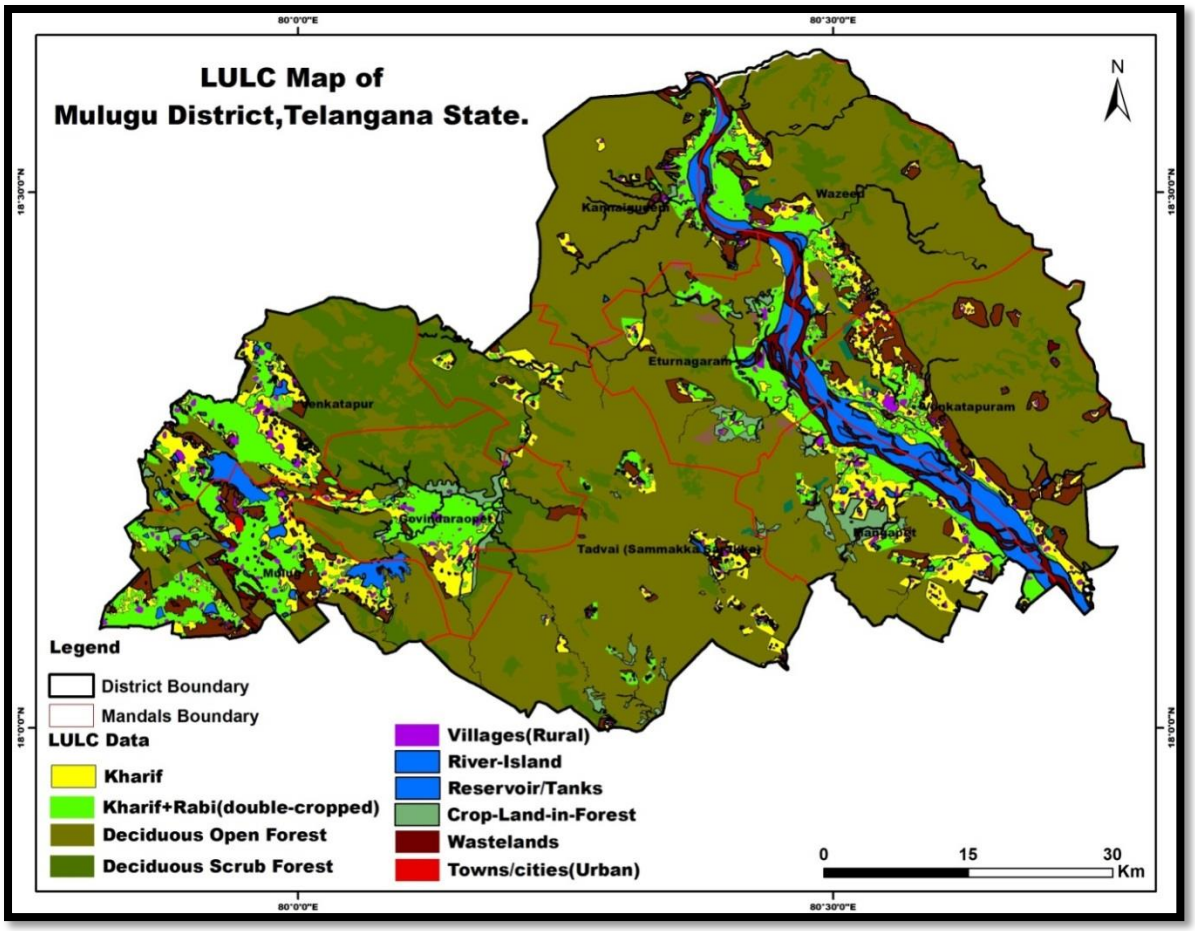


Fig.1.8: Land use and land cover map of Mulugu district.

1.8 Soils

Mulugu district is endowed with a wide variety of soils ranging from loamy to fine mixed, montmorillonite, clayey and alluvial soil. The fine mixed soil occupy 48% of the area, loamy soils occupy 37% of the area, montmorilonitic soil occupy 13% of the area and the remaining 2% occupied by rocky soil and alluvial. The loamy soils mostly occur in Sullavais, Barakars and Kamthi formations (**Fig.1.7**).

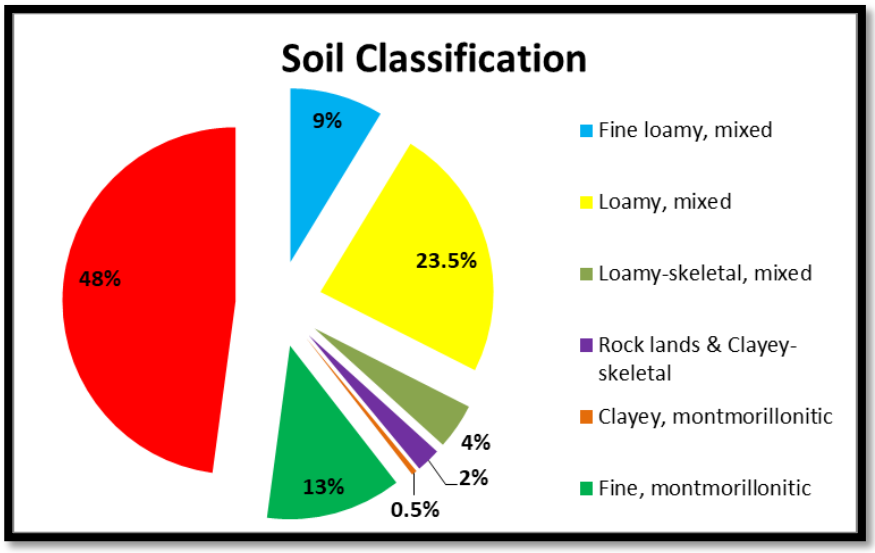


Fig.1.9: Soil classification of Mulugu district

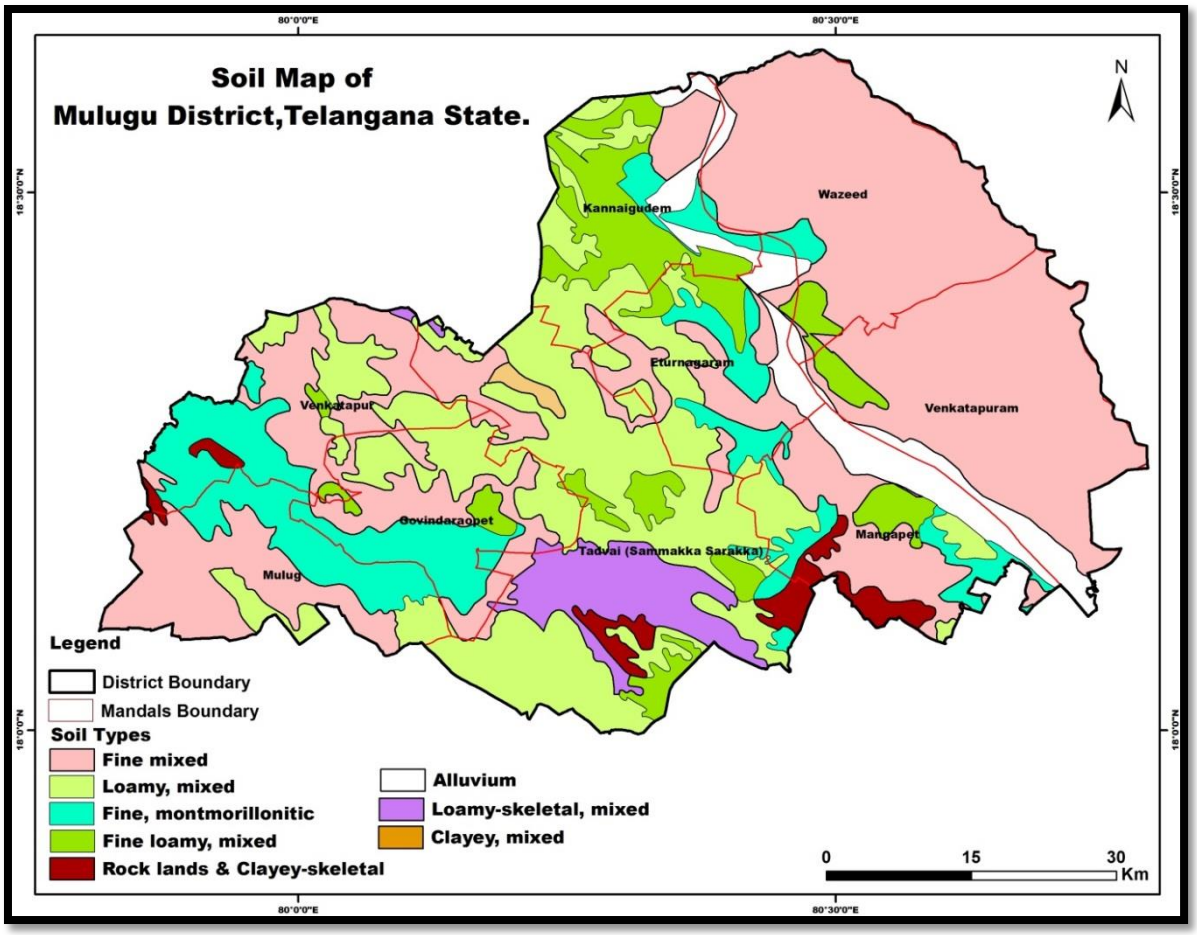


Fig.1.10: Soil map of Mulugu district

1.9 Irrigation

Major Irrigation Projects:

PV Narasimha Rao Kanthanapally Sujala Sravanthi Project is proposed on Godavari River near Kanthanapally (V), Eturnagaram (M), Mulugu district. A total of 50 TMC of water is proposed to be diverted annually by lifting from the river for stabilization of 7,50,000 acres command under SRSP Stage-I & Stage-II in erstwhile Warangal, Nalgonda and Khammam districts, as SRSP is not in a position to provide irrigation to the command as envisaged during its planning.

J. Chokka Rao Devadula Lift Irrigation Scheme envisaged with lifting of water from Godavari River near Gangaram (V), Eturunagaram (M), Mulugu District to irrigate 6.21 Lakh Acres in upland drought prone areas of Karimnagar, Warangal (U), Warangal (R), Jayashankar Bhupalpally, Siddipet, Yadadri, Jangaon and Suryapet districts from an Elevation +71 m to +540 m.

Table: 1.2 Major Irrigation Project

Name of the Project (Ongoing)	IP Irrigation Project) (in Acres)
PV Narasimha Rao (Kanthanapally)	7,50,000

JCR Godavari LIS	6,21,000
Total	**1,37,1000**

Medium Irrigation Projects:

Malluruvagu Project is a Medium irrigation project constructed across malluruvagu in Narsimhasagar village of Mangapet mandal in present Mulugu district in the year 1986. The project provides irrigation to 17 villages of Mangapet mandal.

Gundlavagu Project is an irrigation Project proposed across Gundlavagu, a minor Left flank tributary of river Godavari near Pragallapally village in Wazeedu (M) of Khammam District, Telangana. The project is intended to provide irrigation facilities to an extent of 2580 Acres under right and left bank canals benefiting five tribal villages of Wazeedu Mandal, Mulugu District.

The Modikunta vagu medium irrigation project located in Wazeedu mandal of Mulugu district. The scope of the project is to create a command area of 13,591 acres (5500 Ha).

This project is a medium Irrigation Project across Palemvagu stream, a major tributary of river Godavari. It is located near Mallapuram village, Venkatapuram mandal, of Mulugu district. It provides irrigation facilities to 4100 Ha. (10132 Acres). Kharif wet and 1250 Ha (3089 Acres) ID Rabi ayacut and drinking water supply **(Fig 1.8).**

Minor Irrigation Tanks:

A total of 727 minor irrigation tanks exist in the district with an ayacut of 58,303.50 acres. In the district there are 10,975 irrigation wells (739 dugwells and 10,236 tubewells). (Source: Telangana state statistical abstract-2021)

1.10 Prevailing Water Conservation/Recharge Practices

In the district there exist 541 percolation tanks and 271 check dams. Under Mission Kakatiya (Phase 1 to 4), 543 tanks have been undertaken for desiltations.

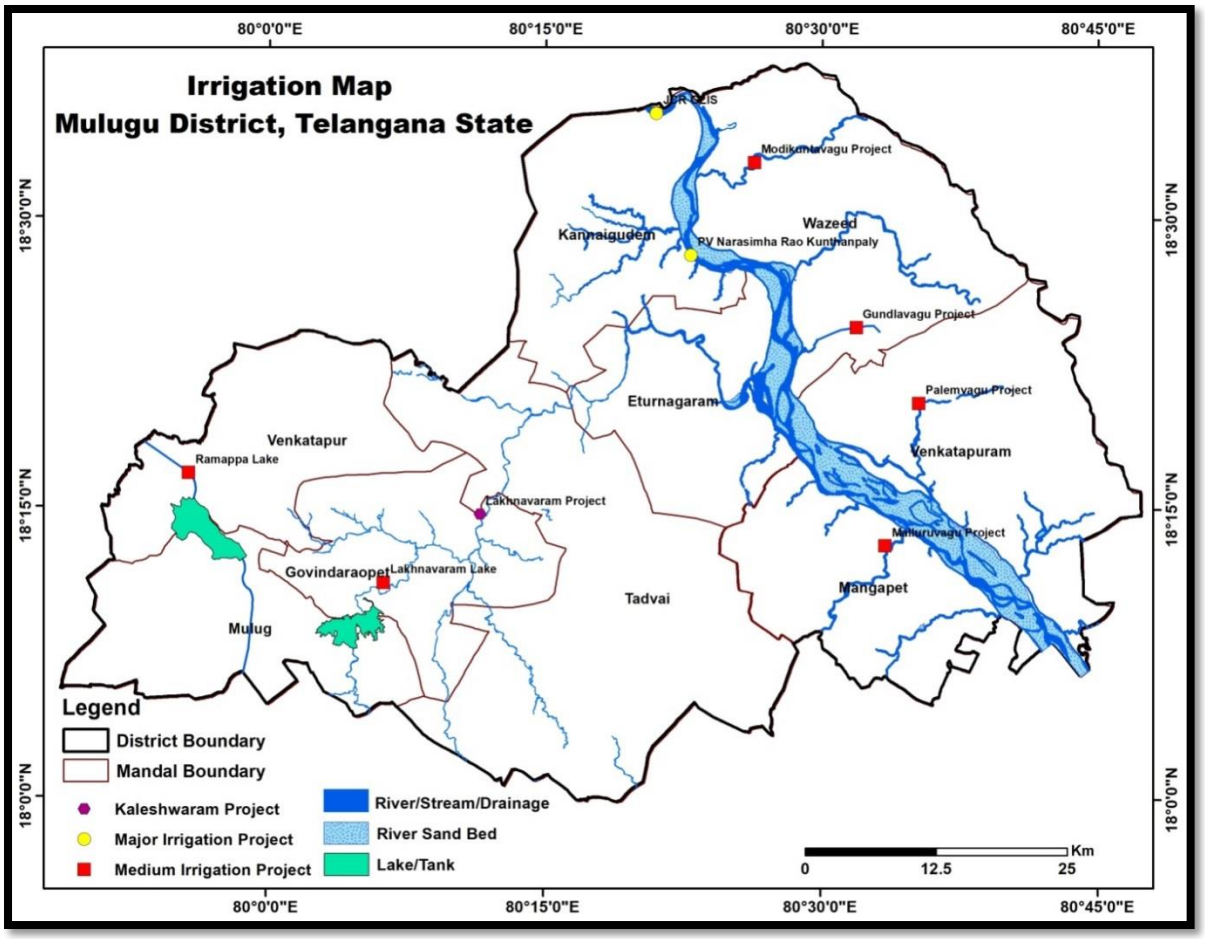


Fig. 1.11 Irrigation project in Mulugu district
(Source:https://irrigation.telangana.gov.in/icad/projects)

1.11 Geology

Major part of the study area is underlain by Gondwana formation. Recent to Upper Pre-Cambrian age formations can be seen in the area. The geology map of the study area is given in **Fig-1.8** and the Stratigraphy is given in **Fig-1.9**.

The Pakhals form Purana group of sediments and are equivalent to Cuddapahs. Pakhals overlie Archaean's either by an unconformity, disconformity or through a fault contact. The Pakhals are divisible into Mallampalli group and Mulugu group representing two distinct episodes of sedimentation with an intervening depositional interludes not accompanied by structural deformation. These two groups consist of conglomerates, quartzites, dolomites, sandstones and shales. The older dolomite is confined to plains while the younger Jakaram dolomites occupy the hillocks. Dolomites are medium to fine grained pale gray to pale pink in colour with secondary veins of calcite. At places the dolomites are massive and stromatolitic. Sandstones are arkosic, glauconitic sandstones and feldspathic wackes and arenites, they are coarse to medium grained and fairly compact with siliceous matrix. The shales are micaceous, carbonaceous and pyritiferous. They grade into slates, slaty phyllites and phyllites. The shales contain numerous interbeds of quartzites and sandstones. The general strike of these Pakhal formations is NW-SE changing at places to NNW-SSE with dips ranging between 5^0 and 20^0 towards NE and NNE Numbers of faults running NW-SE, NNW-SSE

and NE-SW directions criss-cross the area. The formations are also folded to form anticlines and synclines of southerly and northerly plunging fold having varying plunge values. The direction of plunge also varies considerably.

The Sullavai group of sedimentary formations are equivalent of Kurnools, occupy parts of Mulugu. They are brown to brick red coloured, medium to coarse grained, occasionally pebbly and quartzitic to feldspathic. They are blotchy and mottled around the type area Chelvai. The massive sandstones form huge hillocks. The general strike of these formations varies from NW-SE to WNW-ESE direction dipping 10^0 to 30^0 due NE and ENE. Thinly bedded quartzitic sandstones are sheared at places.

The Gondwana formation overlies unconformably over the Pakhal super Group of sediments. They occupy area between Chelvai and Eturnagaram covering an area of 1200 sq.km. An outlier of older Gondwanas are divisible into Lower Gondwana group and upper Gondwana group of sediments. Talchirs, Barakars and Kamthi constitute the Lower Gondwana group while, Maleri, Kota and Chikialas form the Upper Gondwana group. The general trend of the Gondwana formation is NW-SE with dip ranging between 8^0 and 12^0 in NE. The dip amount of Kamthi formation, at depth is about 9^0 calculated from the bed elevation data. The major fault directions are NW-SE and NE-SW. The NW-SE trending gravity faults may be responsible for the steep scarp and vast areal extent of the Kamthi formations.

Talchirs: Talchirs are the oldest group of Gondwana super group, conformably overlying Sullavai sandstones and shales. They consist of boulder bed, green splintery shale and white to buff coloured, fine to medium grained sandstone. The boulders composed of granite, quartzite, dolomite, limestone and shales of varying sizes are cemented together by clay. The white to buff coloured, fine to medium grained sandstone occur as inter-tongued deposits with in the tillite. The thickness of these formations as estimated from the borehole data is about 80m.

Barakars : Barakars are essentially composed of feldspathic, grayish white, coarse to gritty sandstones inter bedded with gray clays and coal seams. Barakars occur as narrow bands covered by sandy soils. The estimated thickness of Barakars is about 220m.

Kamthis : Kamthi formations occupy an area of about 1300 sq. km covering parts of Mulugu. Kamthis are divisible into four distinct lithological units namely (i) coarse grained sandstones and clays (ii) ferruginous sandstones and clays (iii) haematitic red clays and siltstones (iv) gritty to pebbly sandstones and haematitic red clays. The purple to reddish brown, medium to coarse grained, ferruginous sandstones form massive cliffs and are easily distinguishable from other units of this series. The haematitic red clays and siltstones overlie the hard resistant ferruginous sandstones. The siltstones at places grade in to fine to medium grained sandstone and are difficult to distinguish from each other. The gritty to pebbly sand stone with haematitic red clay generally occupying the plains and gentle slopes is the uppermost unit and is highly friable and loosely cemented.

Maleris : Maleri formations unconformably overlie the Kamthis. They comprise brick red to dark brown clays and poorly sorted coarse to gritty sandstones consisting of white and transparent quartz. They occur as narrow thin bands in the northeastern part of the district.

Kotas : Kotas consists of shales and clays intercalated with calcareous, fine to medium grained, white sand stones. The base of the formations is composed of coarse, poorly sorted gritty and pebbly sandstone. The sandstone alters through finer grades upward to white fine grained sandstone, red clays, nodular limestone, red mudstone and siltstone. They occupy approximately and area of 50 sq.km in the northwestern part of Mulug.

Chikialas : Chikialas are the youngest formations of Gondwana Super Group .They comprise light brown, buff, ferruginous sandstones and conglomerates. The rocks are associated with clays and shale bands in the northeastern corner of the district .They occupy about 20 sq.km and mostly covered by forest.

Laterite and Alluvium: Laterite deposits are found over the dolomitic limestones near Mallampalli. The maximum thickness is around 15 m. alluvial sands and clays ranging in thickness from 6 to 8 m occur along the stream courses of Laknavaram. Coarse to fine sands and clays ranging in thickness from 8 to 20 m are found between Eturnagaram and Mangapet along the banks of the Godavari river. The general geological succession of the area is presented as **Table-1.2**.

Table- 1.3: General Geological Succession

Age	Group/System	Series	Lithology
Recent to Pleistocene			Soils, alluvium and laterites
Lower Cretaceous to Middle Triassic	Upper Gondwanas	Chikialas	Conglomerates sandstones and clays.
		Kotas	Clays, sandstones and limestones
Lower Triassic to Upper Carboniferous	Lower Gondwanas	Kamthis	Ferruginous sandstones, clay and shales
		Barakars	Feldspathic sandstones, Clays and coal seams
		Talchirs	Shales and sandstones, Boulder beds and tillites
----------Unconformity----------			
Upper Pre-Cambrain to Lower Palaeozoic	Kurnool Group	Sullavais	Conglomerates sandstones and shales
Upper Pre-Cambrian	Pakhal Super Group	Mulugu group	Cherts, Conglomerates Quartzites, dolomites and shales
		Mallampalli group	Basal conglomerates, Dolomites, Arkosic Glauconitic Sandstones and Shales

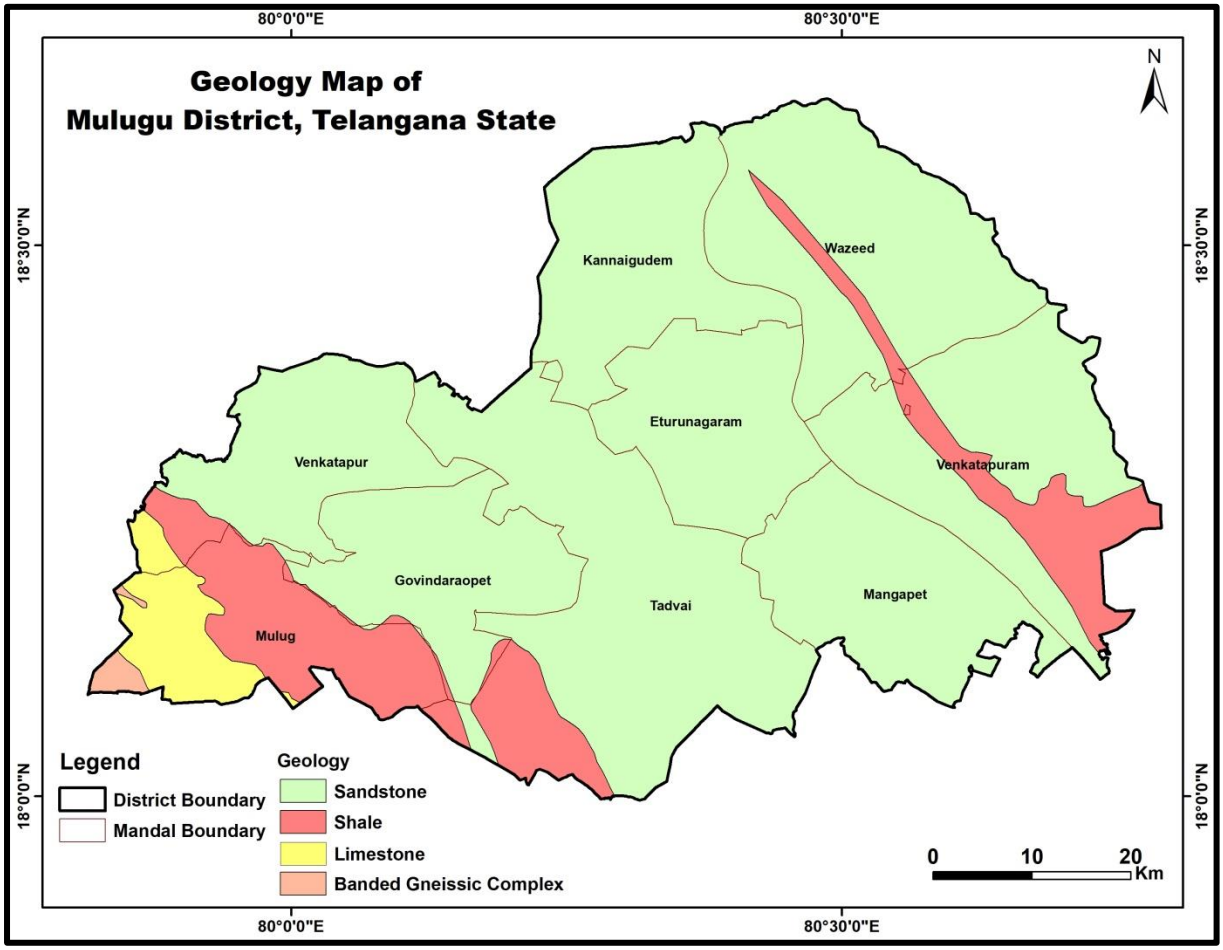


Fig.1.12: Geology map of Mulugu district.

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 and Geo-chemical. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data.
		Identification of Data Gap	Data gap in 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.
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 data generation	Vertical Electrical Sounding (VES), bore-hole logging, 2-D imaging.
		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 and dissemination through training to administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain.

The aquifer geometry for shallow and deeper aquifer has been established by utilising the data generated through various hydrogeological, exploration, surface and subsurface geophysical studies in the district. The data used for the integration and interpretations are explained in the following sections:

2.1 Ground Water Exploration

CGWB has constructed 13 borewells and SGWD has constructed 12 borewells at different depths in the Mulugu district (Table 2.2). 05 representative wells data of SCCL also utilized. Out of these, 28 borewells were drilled in Sandstone formation and 2 were drilled in Limestone formation. Data analysed from CGWB/SGWD wells indicates that 1 well of shallow depth (<30 m), 17 nos in the range of 30 to 100 m, 2 nos in the range of 100-200 m, and 8 nos in the range of 200-300 m depth. The locations of exploratory wells are shown in **Fig. 2.1**.

Table-2.2: Ground Water Exploration wells

Source	Borewells (EW/OW/Pz)
CGWB	13
SGWD	12
SCCL	05

2.2 Ground Water Monitoring Wells

Ground water level data of 45 (CGWB: 21, SGWD: 25) monitoring wells were utilized for the Aquifer mapping studies. In order to understand the groundwater level trend, current and historical water levels along with water level trend data for pre-monsoon and post-monsoon season of 37 borewells (CGWB: 21, SGWD: 16) has been used**.** 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.The data is given in **Table-2.3** and locations of monitoring wells are shown in **Fig. 2.1.**

Table-2.3: Ground Monitoring wells

Source	**No. of wells**
CGWB	21
SGWD	24
Total	**45**

2.3 Ground Water Quality

To understand chemical nature of ground water, 49 (CGWB: 10, SGWD: 39) water quality data for pre-monsoon season and post-monsoon season were utilized in the analysis (**Table 2.4**.). Parameters namely pH, EC (in µS/cm at 25° C), TH, Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, NO_3 and F were analyzed and locations of sampling wells are shown in **Fig. 2.1.**

Table-2.4: Ground Water Sampling wells

Source	Pre-monsoon	Post-monsoon
CGWB	10	-
SGWD	39	39

2.4 Geophysical Studies

Geophysical data on VES and profiling are used to extract information on the weathered thickness, fracture depth and thickness of fractures in hard rock area. For the interpretation of the aquifer geometry, geophysical data in conjunction with the available ground water exploration data is utilised. The data from 5 Vertical Electrical Soundings (VES) employing the Schlumberger electrode configuration with the maximum electrode separation (AB) of 400 meters is used for the aquifer mapping studies **(Fig. 2.1)**. The data was processed and interpreted by IPI2Win software enveloped by Moscow State University, after marginally modifying the manually interpreted results in corroboration with geology and hydrogeology.

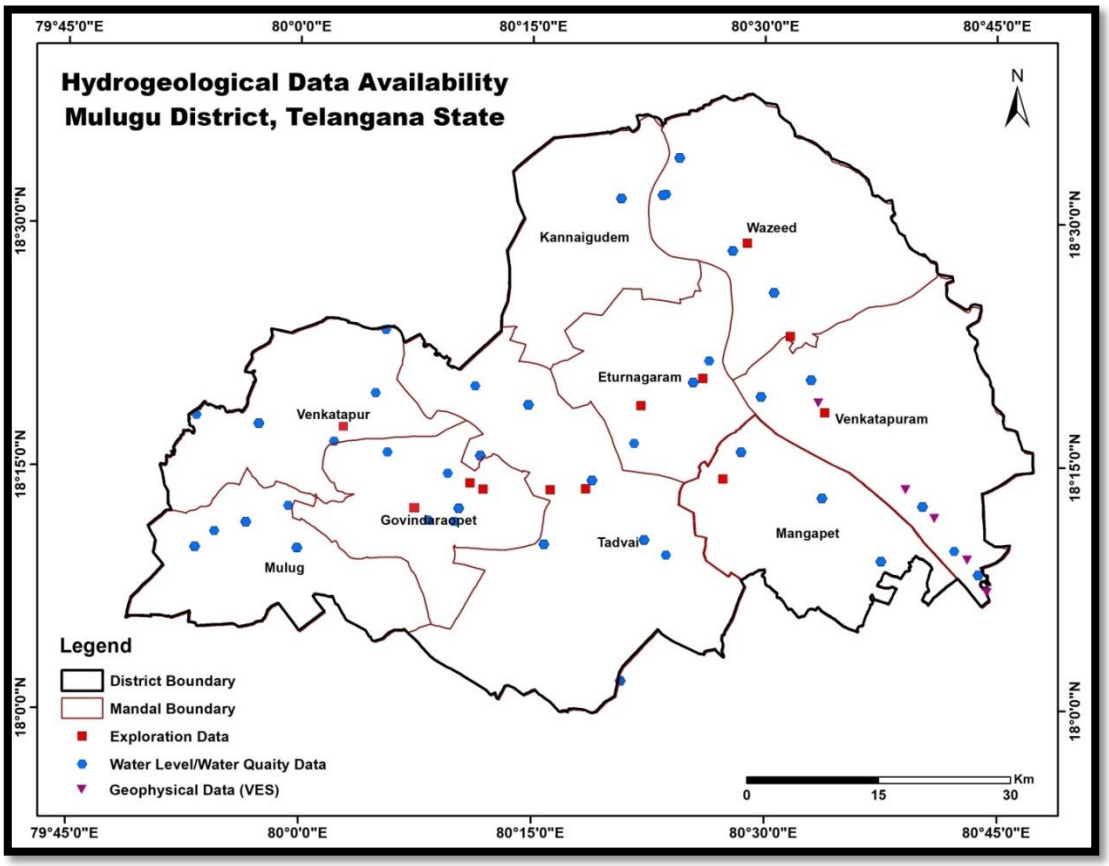


Fig.2.1: Hydrogeological Data availability

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The data collected and generated on various parameters viz., water levels, water quality, exploration, aquifer parameters, geophysical, hydrology, hydrometeorology, irrigation was interpreted and integrated. Based on this, various thematic layers such as hydrogeology, water level scenario of both current and long term scenarios, aquifer wise ground water quality, 2-D and 3-D sub surface disposition of aquifers by drawing fence and lithological sections, yield potential, groundwater resources were generated and are discussed in detail in following sections .

3.1 Water Level Scenario

The present depth to water level scenario for pre-monsoon and post-monsoon season was generated by utilizing water level data of 45 monitoring wells. The pre-monsoon depth to water levels ranged between 2.72m bgl (Laxmidevipet) and 22.37mbgl (Jakkaram (S)). The shallow water level in range of 2-5 m bgl are observed as isolated patches in parts of Venkatapuram, Govindaraopet and Tadvaimandal(2% of area).The water level in the range of 5-10 m bgl is observed mainly in Govindaraopet, Venkatapur, Tadvai, Mulugu, Kanaigudem mandals(43 % of area).The deeper water levels of >10 m bgl are observed mainly in Tadvai, Wazeed, Eturnagaram, Mangapet, Tadvai and Mulugumandal (55% of area). The pre-monsoon depth to water level map is given in **Fig.3.1.**

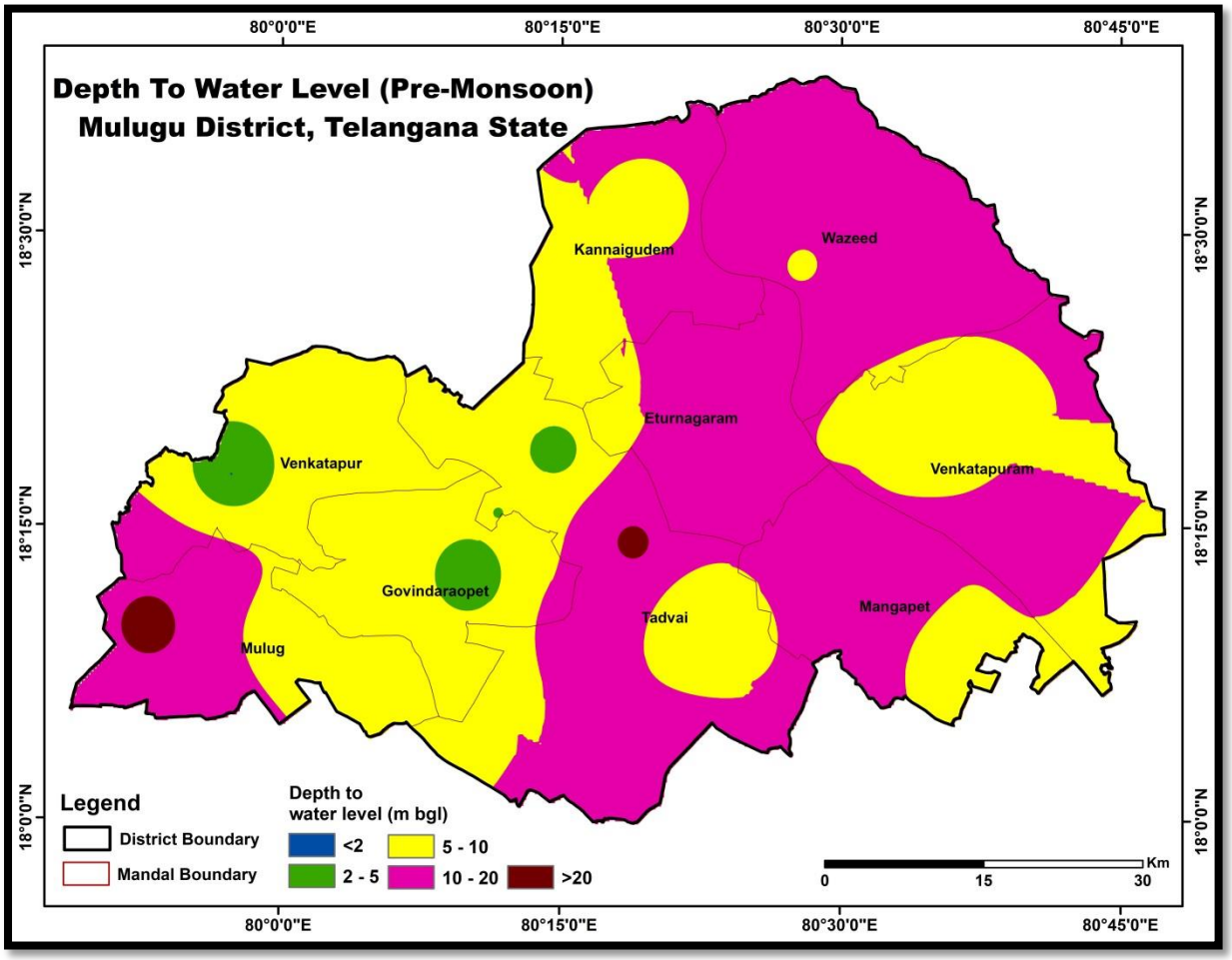


Fig.3.1: Depth to water level map of pre-monsoon season (Average: 2011-2020)

The post-monsoon depth to water level ranges between 1.32 m bgl (Laxmidevipet) and 16.85mbgl (Tadvai). The shallow water levels of <2 mbgl are observed as isolated patches in Venkatapur mandal and 2-5 m bgl are observed in Venkatapuram, Govindraopet, Mulugu, Mangapet mandal of the district (28% of area).The water levels between 5-10 m bgl are observed in majority parts of the district (70% of area). The deeper water levels of >10 mbgl are observed as isolated patch in Tadvai mandal (2% of area). The post-monsoon depth to water level map is given in **Fig.3.2.**

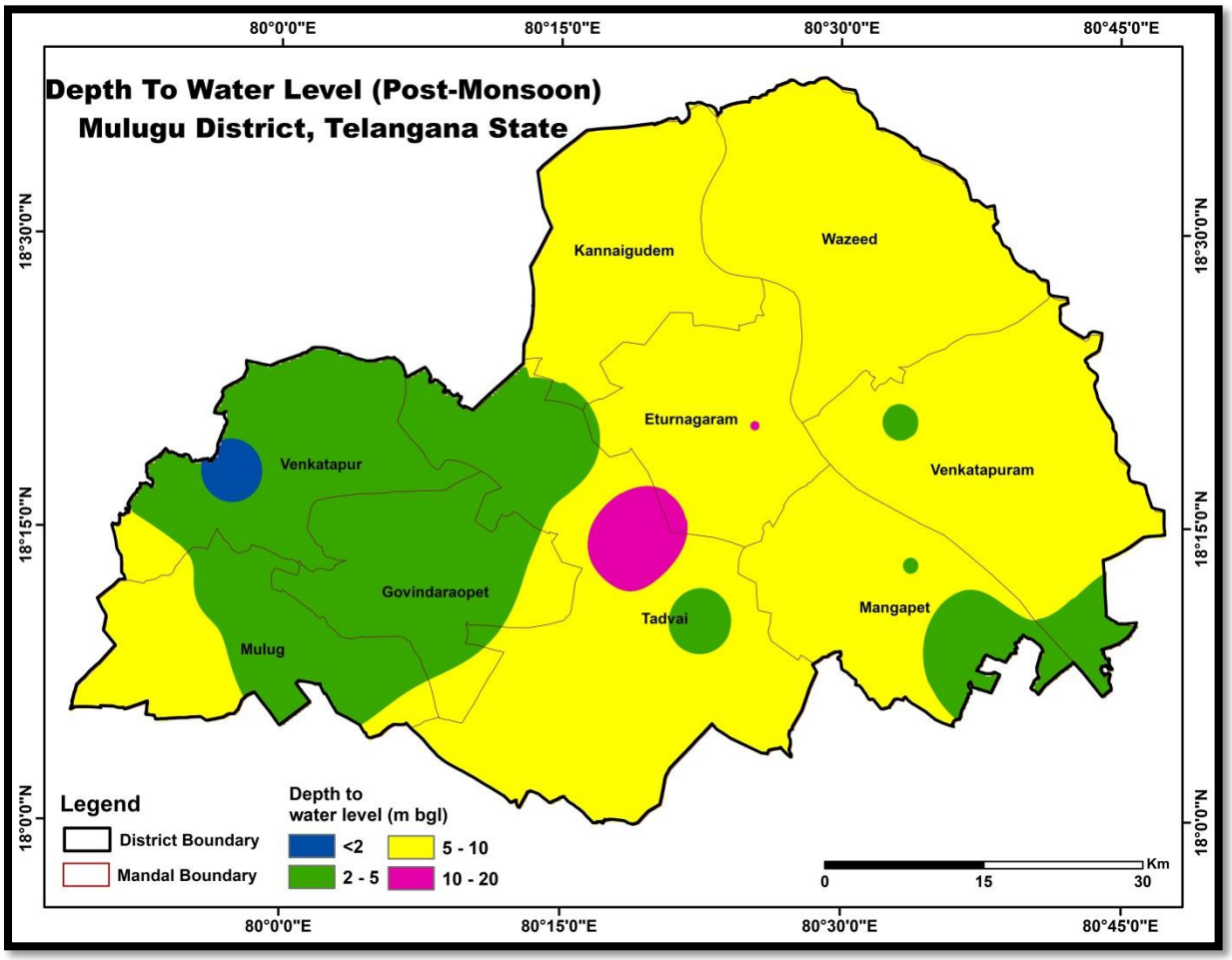


Fig.3.2: Depth to water level map of post-monsoon season (Average: 2011-2020)

3.1.1 Water Level Fluctuation

The water level measured during pre and post monsoon period was used to compute the seasonal fluctuation. 100% (24no's) of the wells show rise in water level and no wells show fall in water level. The analysis of water level fluctuation data indicates that minimum water level fluctuation was observed at Pasra (0.29m) while maximum water level fluctuation was observed at Jakkaram (12.43m). The water level fluctuations were grouped under three categories i.e., less, moderate and high and the % of wells in each category was analysed (**Table-3.1**).

Table-3.1: Analysis of Water Level Fluctuation

S. No.	Category	Fluctuation Range	% of area
1.	Less water level fluctuation	0 to 5m	93%
2.	Moderate water level fluctuation	5to 10m	5%
3.	High water level fluctuation	>10m	2%

The analysis indicates that majority of the area (93%) are falling in less fluctuation range indicating good aquifer storage, whereas moderate water level fluctuations are observed in 5 % area and high water level fluctuation of more than 10m were observed in the 2% of area. The seasonal fluctuation map is presented as **Fig.3.3**, the perusal of map indicates that fluctuation of upto 5 m is observed in major part of the district, whereas moderate fluctuation of more than 5 m is observed in parts of Mulugu, Venkatapur and Mangapet mandal.

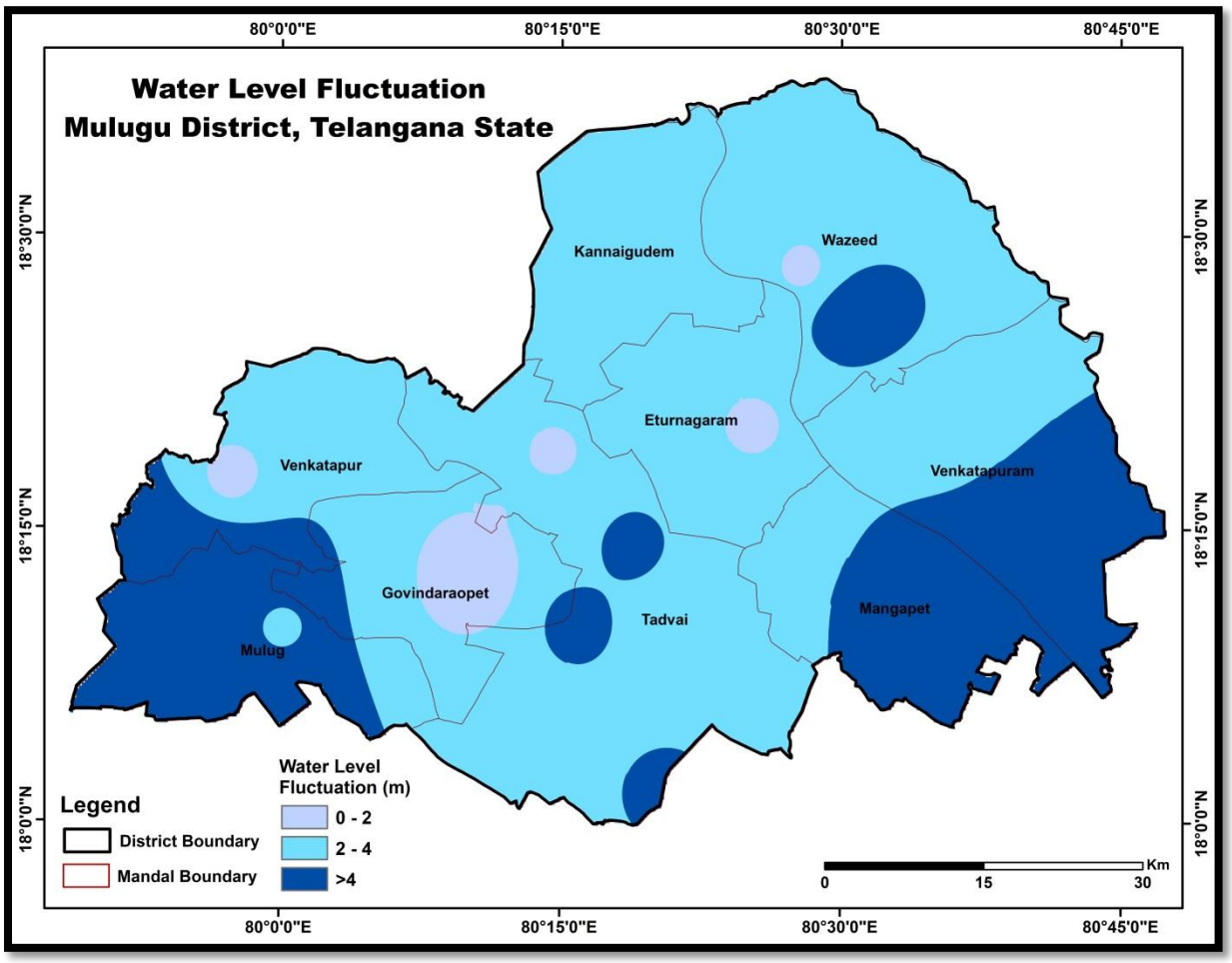


Fig.3.3: Seasonal Water Level Fluctuations (m) (post-monsoon with respect to pre-monsoon (Average: 2011-2020))

3.1.2 Water Table Elevation

The water table elevation map for pre-monsoon and post-monsoon period was also prepared (**Fig.3.4 (a) & 3.4(b)**) to understand the ground water flow directions. The

water table elevation ranges from 68 to 308m amsl during pre-monsoon period and 72 to 312m amsl during post-monsoon period. The groundwater flow is mainly towards Eastern and Northeastern direction.

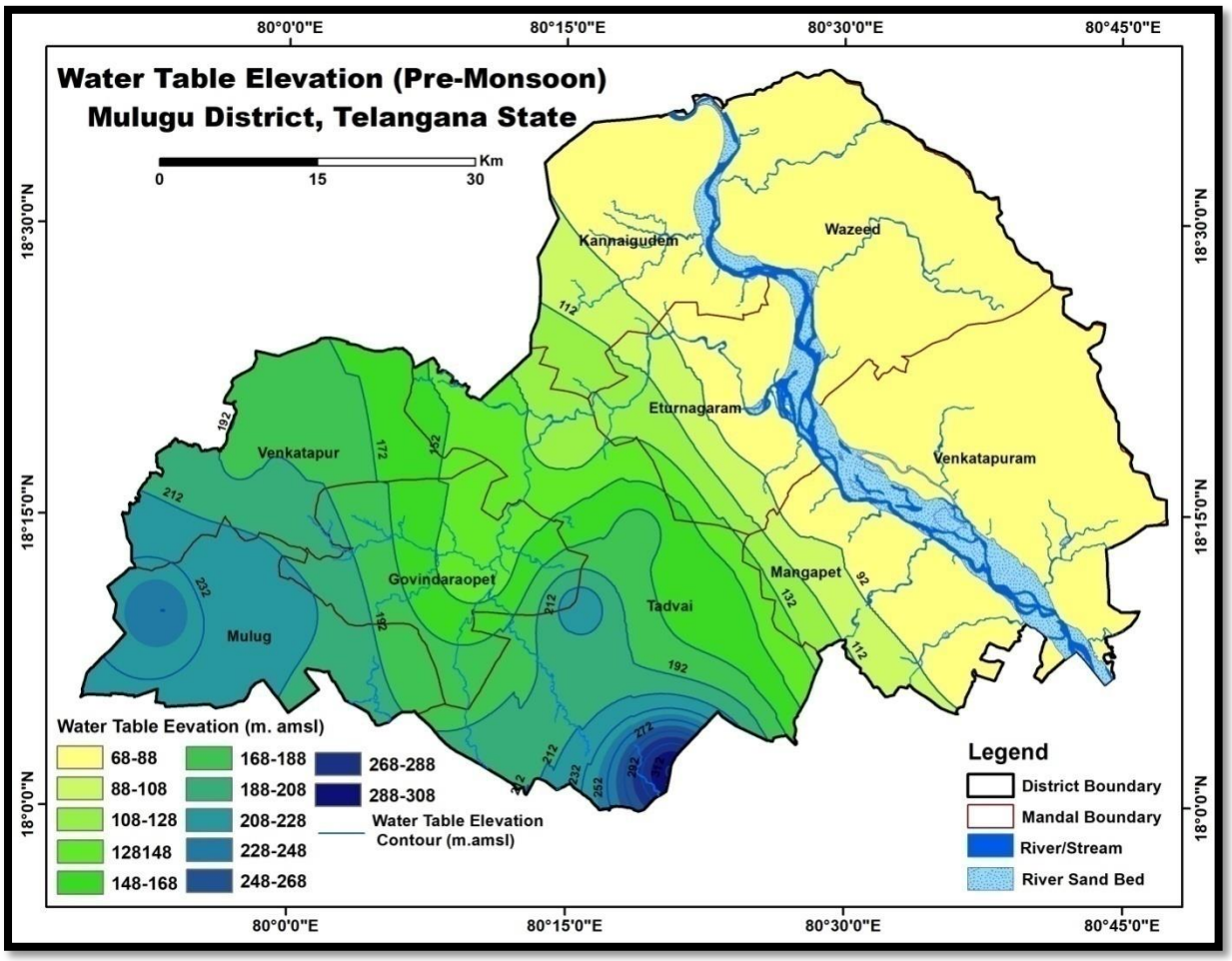


Fig.3.4 (a): Water table elevations (m amsl) during pre-monsoon season (Average: 2011-2020)

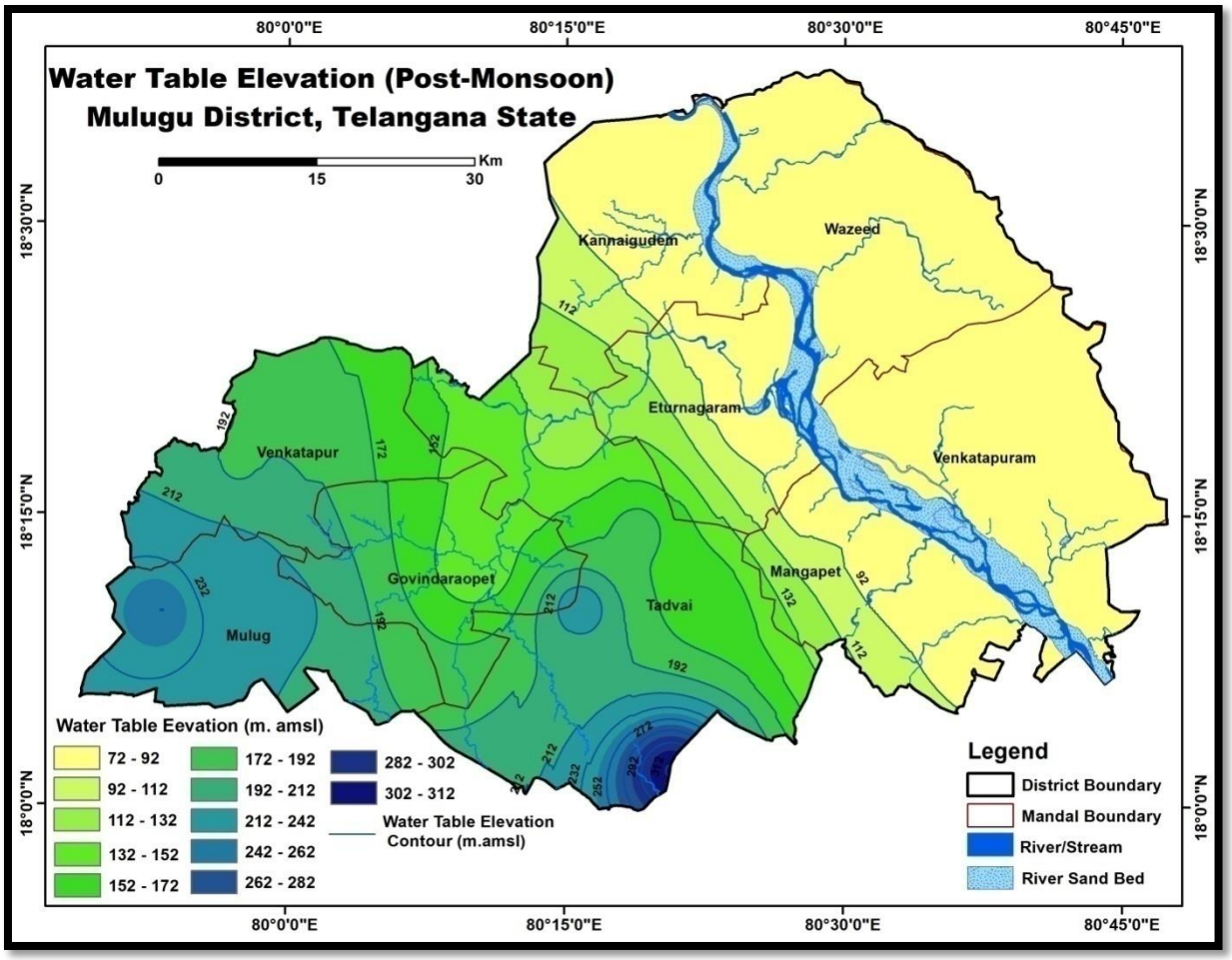


Fig. 3.4(b): Water table elevations (m amsl) during post-monsoon season (Average: 2011-2020)

3.1.3 Long Water Level Trend (2011-20)

In order to study long term behavior of the water levels and also the effect of various developmental activities with time, the data from 37 hydrograph station (CGWB:21, SGWD:16) for the period 2011-20 have been computed and analyzed. The decadal pre-monsoon water level trend analysis indicates that 24 wells show falling trend (>1.0m:1, 1.0-0.5 m: 6, 0-0.5m: 17wells) (max fall: 1.06 m/yr) and 13 wells show rising trend (0-0.5: 9, 1.0-0.5: 3, >2: 1 well) (max rise: 2.09 m/yr). During post-monsoon season 10 wells show falling trend ((>0.5 m: 1, 0-0.5m:9) (maximum fall: 0.55 m/Yr) and 27 wells shows rising trends (0-0.5m: 21, 0.5-1.0m: 5, >1.0 m: 1 wells) (max rise: 3.7 m/yr). The graphical representation of fall and rise is shown in **Fig.3.5** and spatial distribution map is shown in **Fig.3.6** and **3.7.**

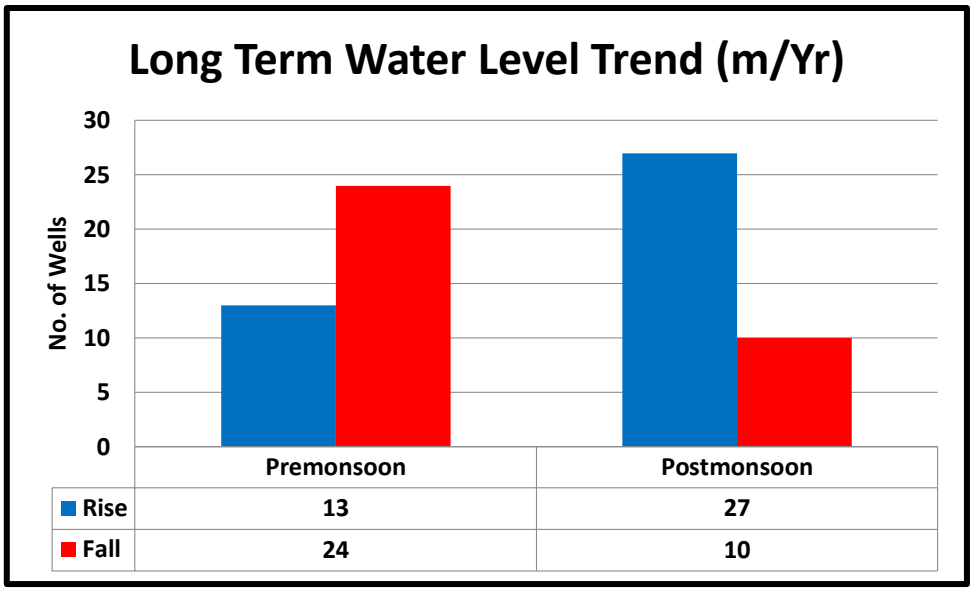


Fig. 3.5: Graphical representation of water level trends (2011-2020)

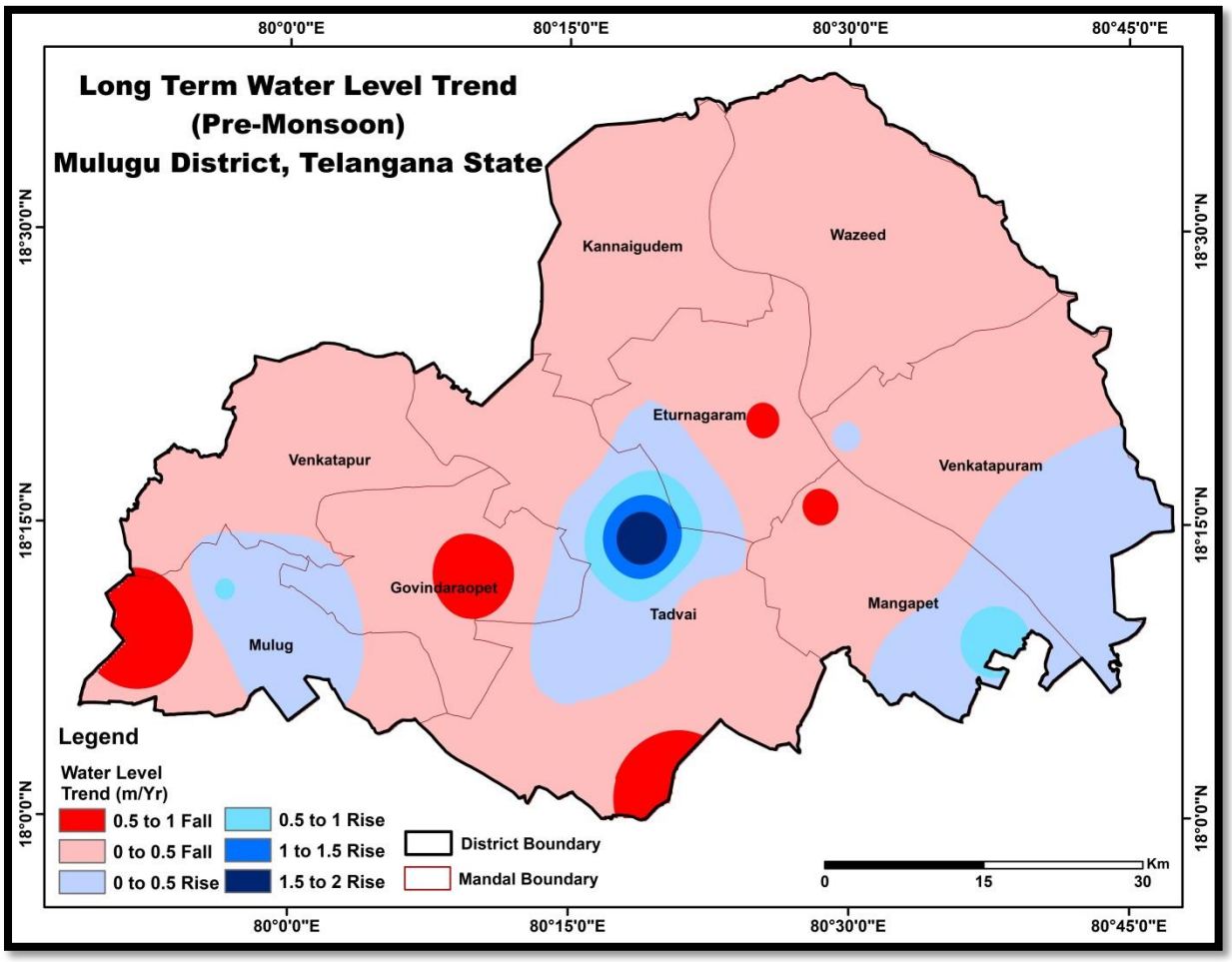


Fig. 3.6: Long-term water level trend, Pre-monsoon (2011-2020)

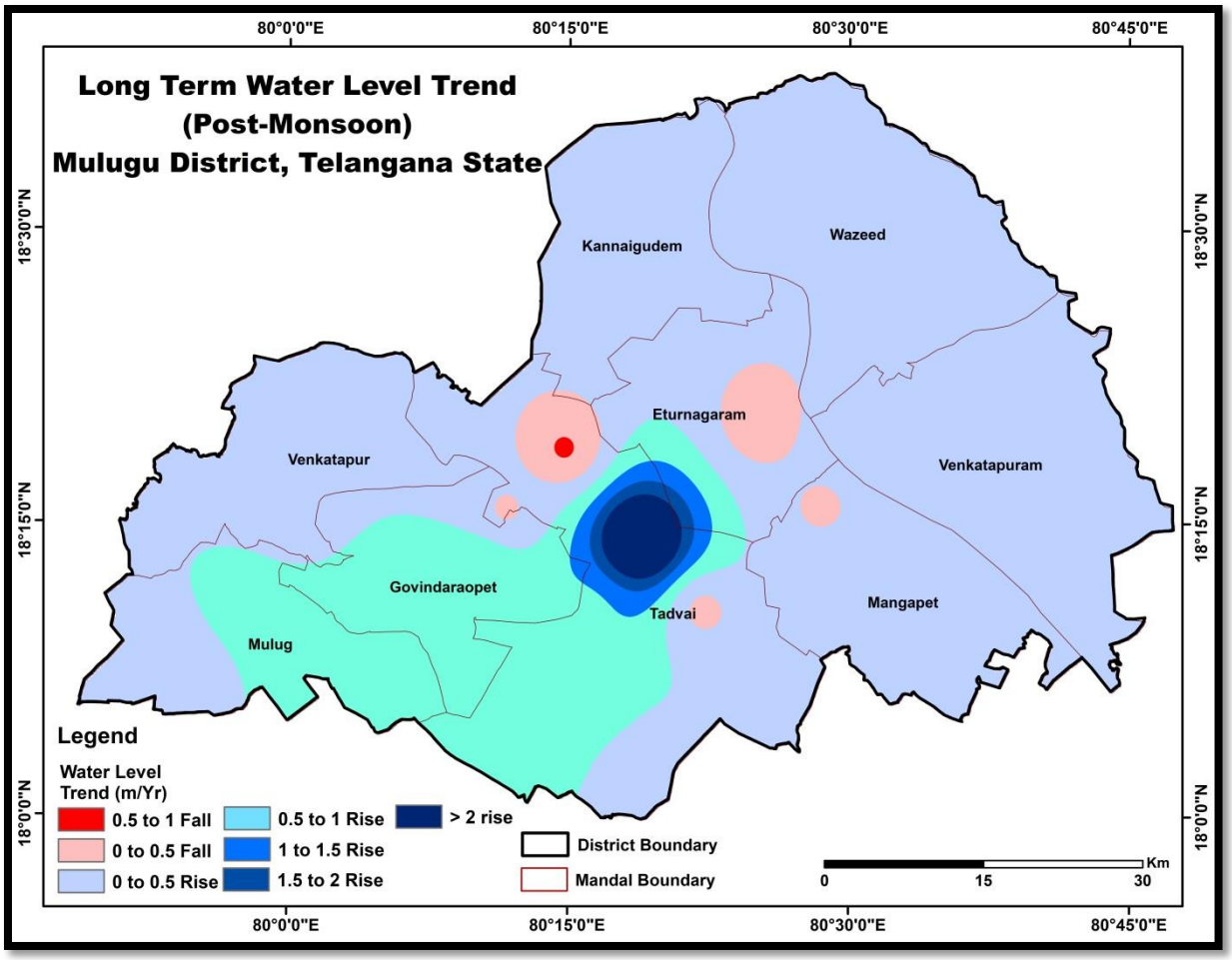


Fig. 3.7: Long-term water level trend, Post-monsoon (2011-2020)

3.2 Ground Water Quality

The suitability of groundwater for drinking/irrigation/industrial purposes is determined keeping in view the effects of various chemical constituents present in water on the growth of human being, animals, various plants and also on industrial requirement. Though many ions are very essential for the growth of plants and human body but when present in excess, have an adverse effect on health and growth. For assessment of ground water quality, 88 samples (Pre-monsoon: 49 and post-monsoon: 39) were utilised from monitoring wells. The ground water samples were analysed for major chemical constituents. Parameters namely pH, EC (in µS/cm at 25° C), TH, Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, NO_3 and F were analysed.

3.2.1 Pre-Monsoon

A total of 49 samples were analyzed. Ground water is mildly alkaline to alkaline in nature with pH in the range of 7.21-8.65 (Avg: 8.13). Electrical conductivity varies from 54-5130(avg: 1064) µ Siemens/cm. In 0.5% of area EC is more than 3000 µ Siemens/cm in patches in Eturnagaram, Venkatapuram and Mulugu mandals (**Fig.3.8**). Nitrate concentration varies from 1-608 mg/L and 32% of the samples it is beyond permissible limits of BIS Standard (>45 mg/L) (**Fig.3.9**). High Nitrate concentration is observed in parts of Govindraopet, Tadvai, Wazeed, Venkatapuram, Mulugu and

Mangapet mandal. Fluoride concentration varies from 0.01to 2.20 mg/L (**Fig 3.10**) and in 6% of the samples it is beyond permissible limits of BIS Standard (>1.5 mg/L). High Fluoride concentration is observed in parts of Govindraopet and Venkatapur mandal.

3.2.2 Post-Monsoon

A total of 39 samples were analyzed. Ground water from the area is mildly alkaline to alkaline in nature with pH in the range of 7.19-8.40 (Avg: 7.86). Electrical conductivity varies from 262-2699 (avg: 996) µ Siemens/cm. In 100 % of area EC is within 3000 µ Siemens/cm (**Fig.3.11**). Nitrate concentration varies from 1.0-257.68 mg/L and in 36% of the samples it is beyond permissible limits of BIS Standard (>45 mg/L) (**Fig.3.12**). High Nitrate concentration is observed in majority parts of the district except Kannaigudem and Mulugu mandals. Fluoride concentration varies from 0.07-2.32 mg/L **(Fig 3.13**) and in 13 % of samples it is beyond permissible limits of BIS standard (>1.5 mg/L). High fluoride concentration is observed in Tadvai, Govindraopet, Eturnagaram and Venkatapur mandal.

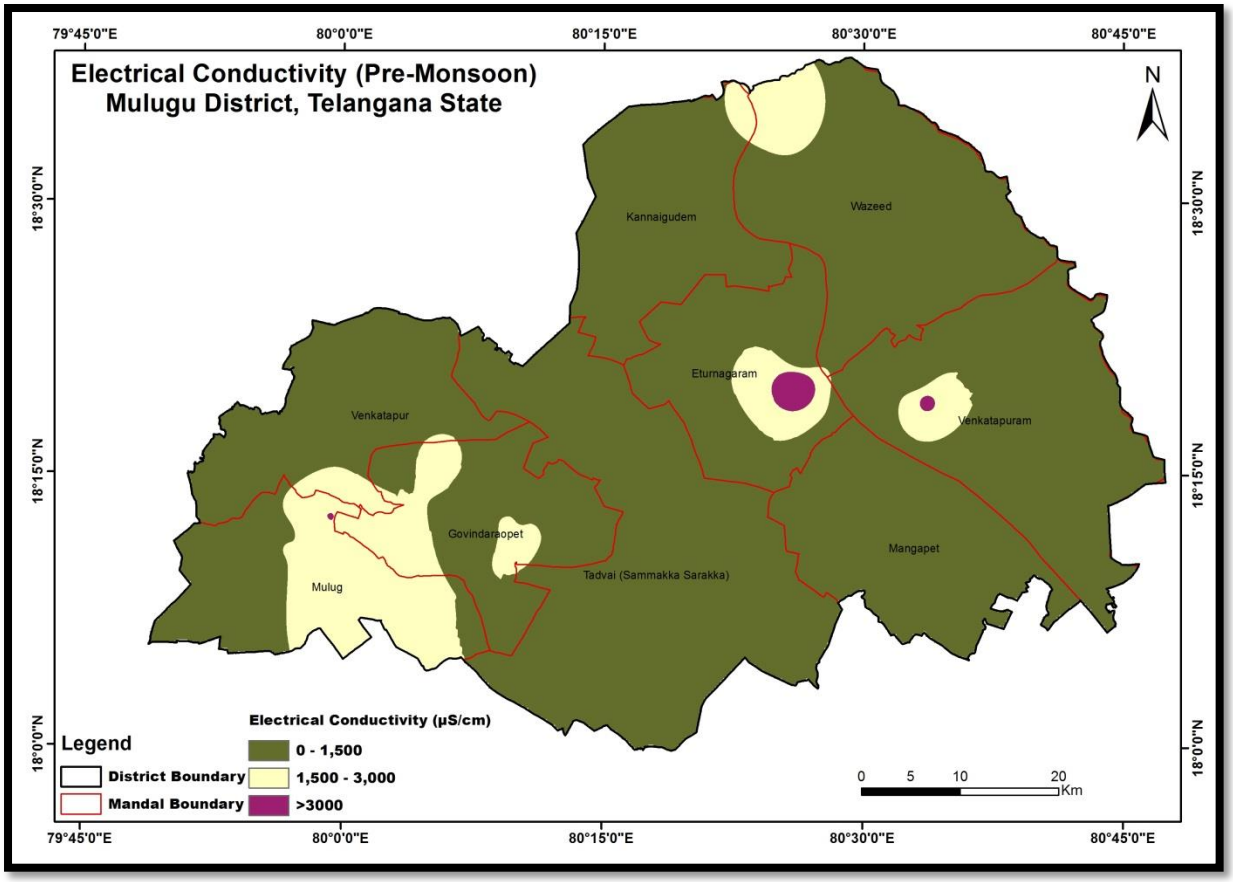


Fig.3.8: Distribution of Electrical conductivity (Pre-monsoon).

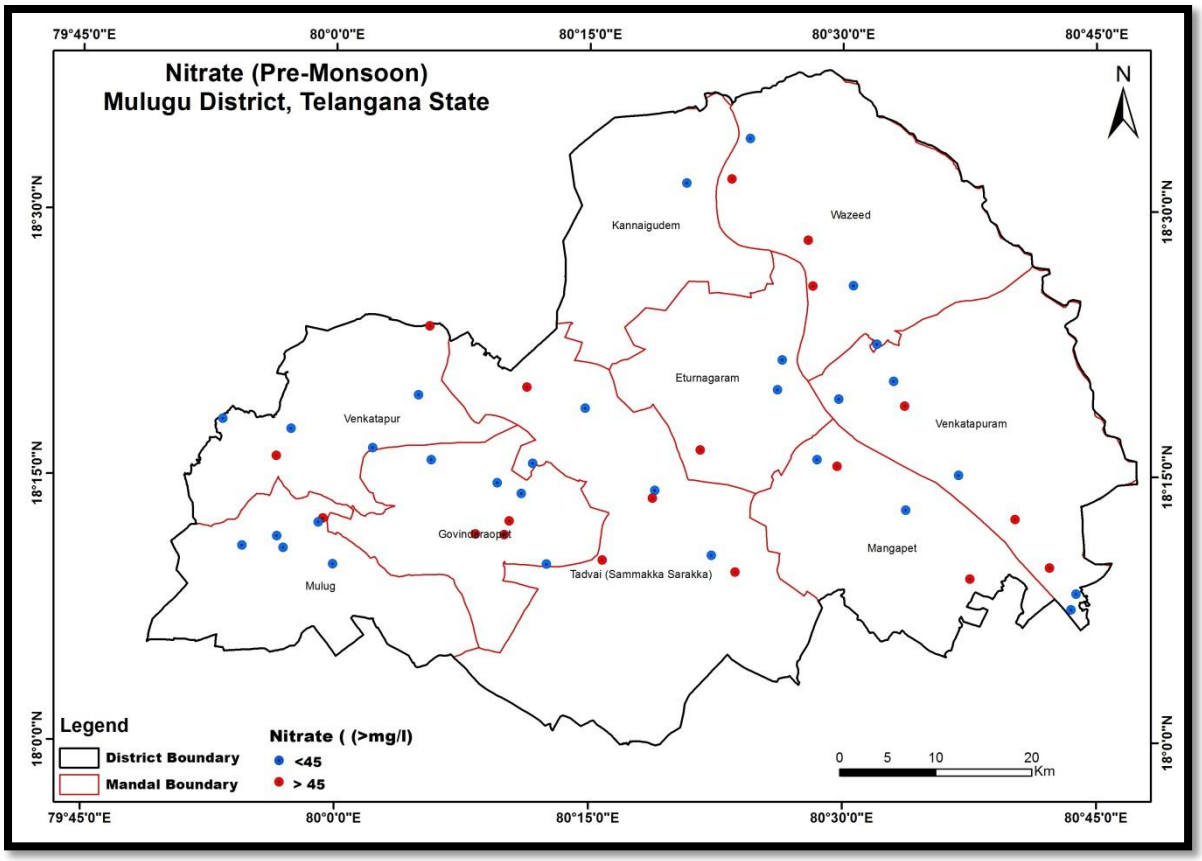


Fig.3.9: Distribution of Nitrate (Pre-monsoon)

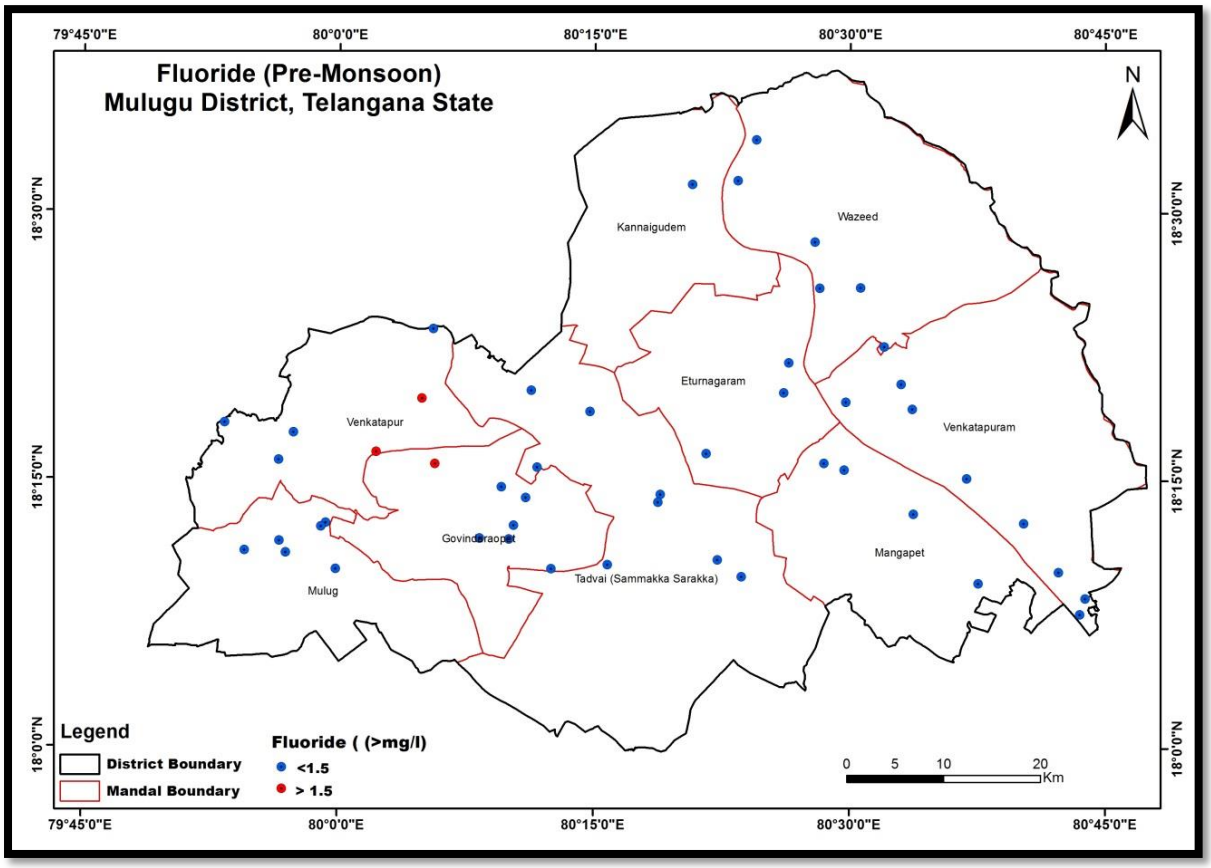


Fig.3.10: Distribution of Fluoride (Pre-monsoon)

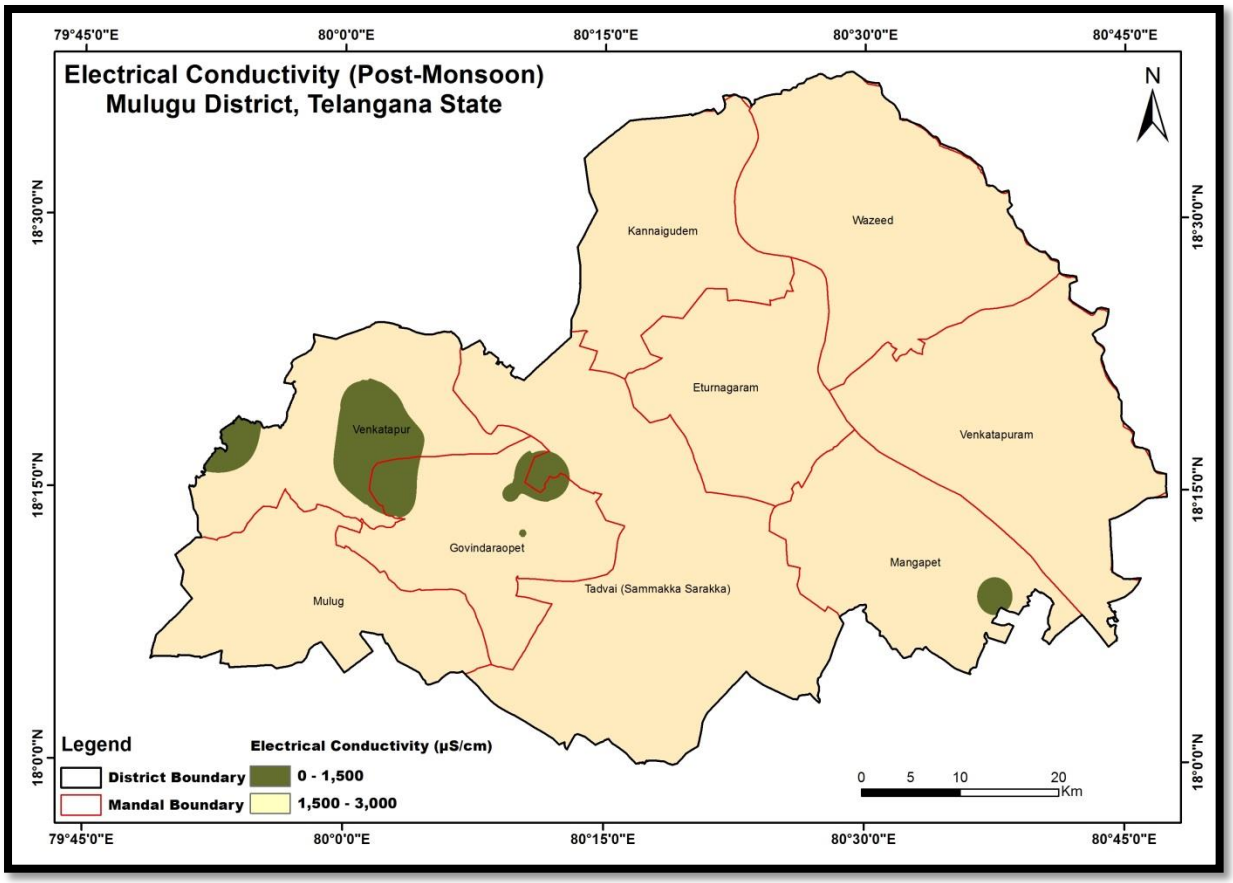


Fig.3.11: Distribution of Electrical conductivity (Post-monsoon)

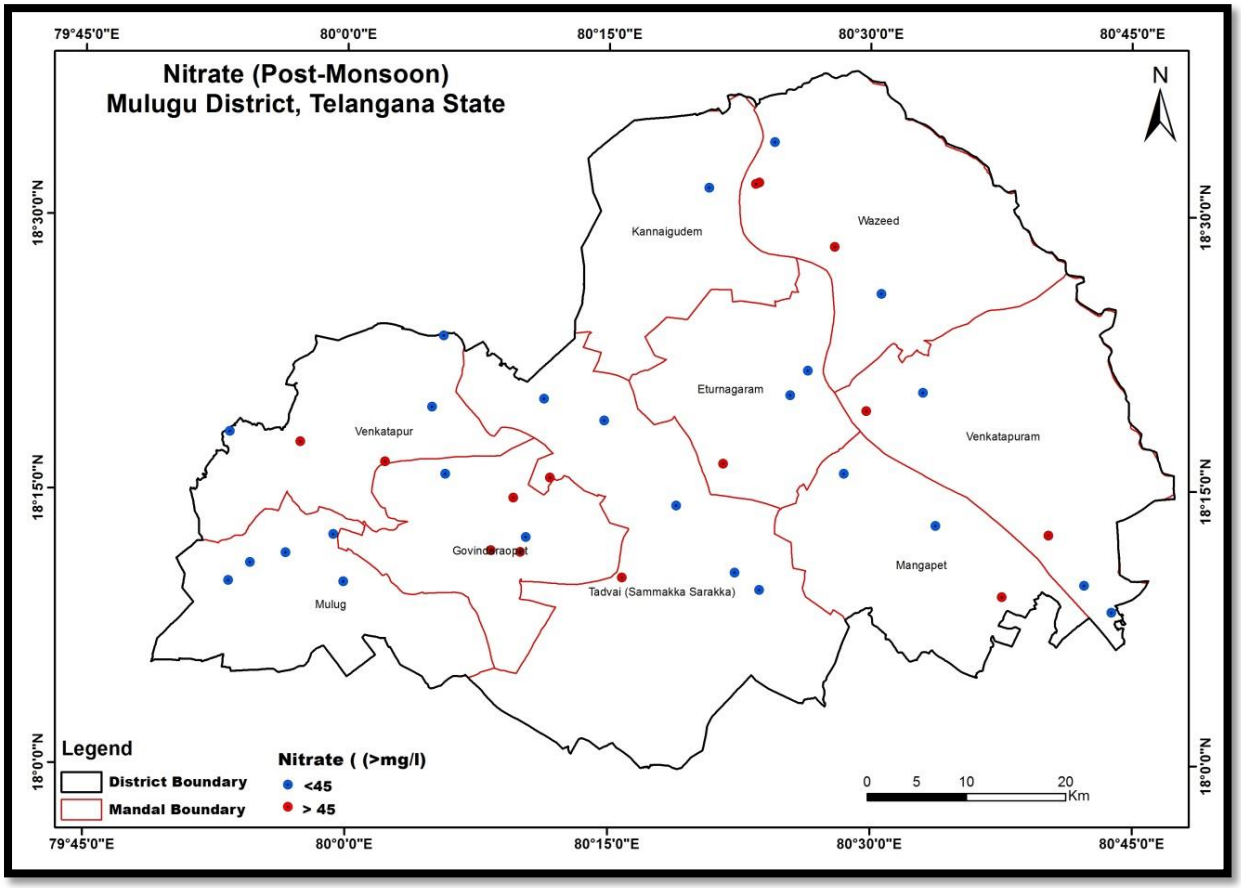


Fig.3.12: Distribution of Nitrate (Post-monsoon)

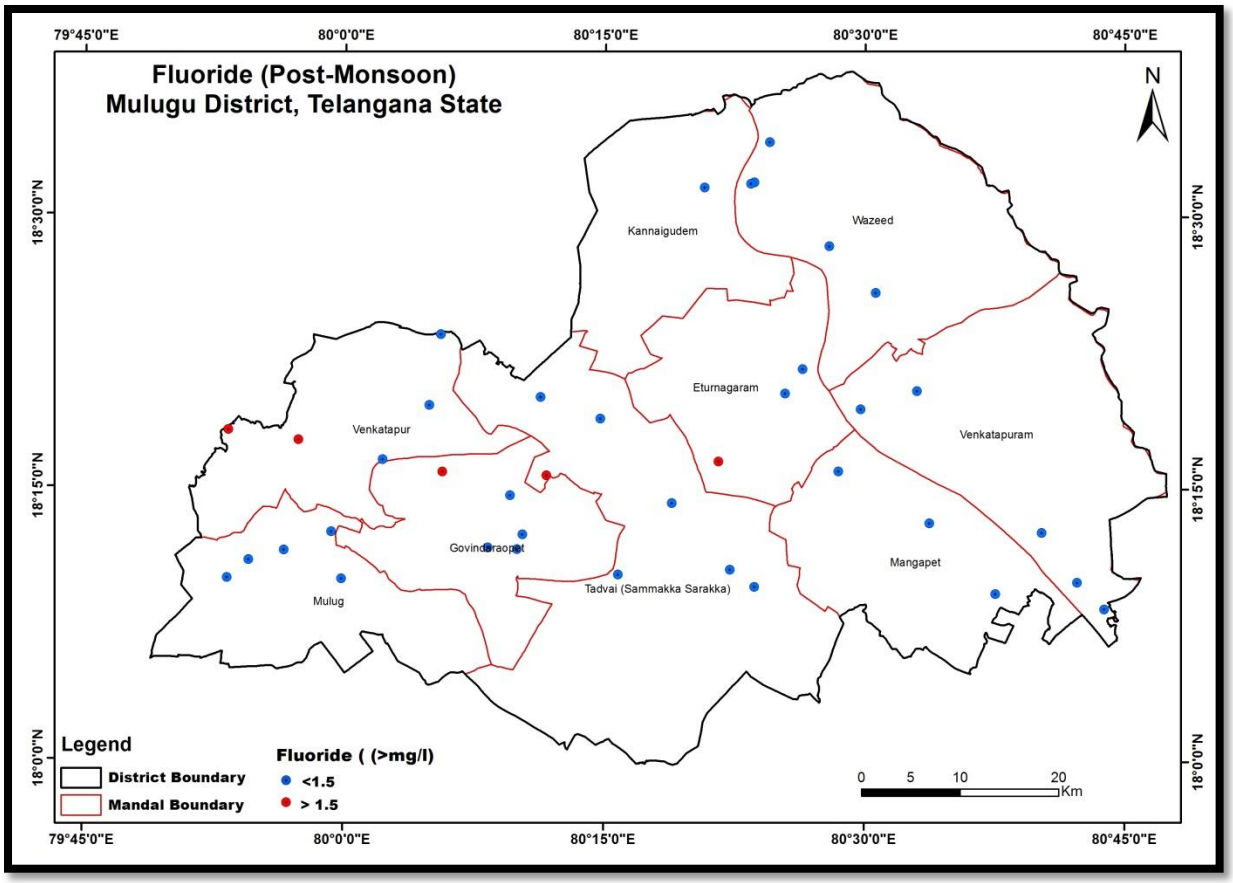


Fig.3.13: Distribution of Fluoride (Post-monsoon)

3.3 Aquifer Mapping

The aquifer geometry for shallow and deeper aquifer has been established through analyzing data generated through various hydrogeological, exploration, surface and subsurface geophysical studies in the district. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks. It depends on rock types, depth of weathering and extension of weak zones like fractures, joints etc, in hard rocks, while in sedimentary rocks it depends on porosity, granularity, cementing matrix, permeability, bedding plains and faults, etc. Based on 103 hydrogeological data points hydrogeological map is prepared and is presented in **Fig 3.14**.

On the basis of occurrence and movement of ground water, rock units of the Mulugu district can be broadly classified into two categories: semi-consolidated to unconsolidated formation (Gondwana formation) which occupies 91 % of the area and consolidated formation (Sullavai and Pakhal formation) which occupies 9% of the area.

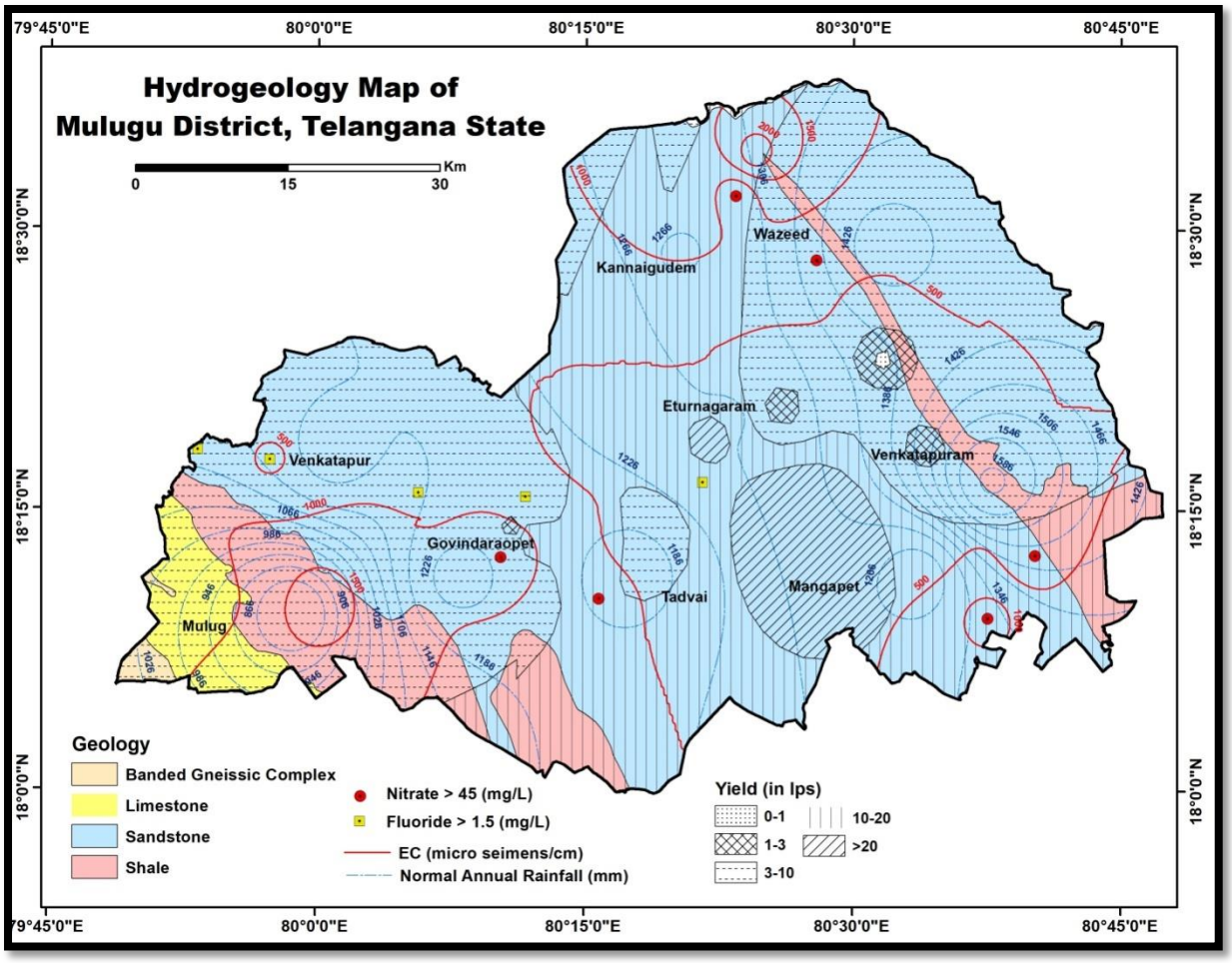


Fig.3.14: Hydrogeological map of Mulugu district

Gondwana formations represent the semi-consolidated rocks, which consists of sandstone, shale and clay that makes a thick sequence of sediments. They are generally bedded deposits with well-defined lithologic units and had undergone structural disturbances. Hence the area shows lateral and vertical variation within short distances, due to which the hydrogeological properties of the formation vary widely. The sandstones are generally medium to coarse, friable and loose due to weathering. The sandstones form the principal aquifers except in areas where thin intercalations of clays exist. The ferruginous kankary material formed on the surface due to weathering augments the infiltration and saturates the underlying sandstones. The ground water in the Gondwana formations occurs under both water table and confined conditions.

Multiple aquifer systems (1 to 5 aquifers) are found in the sandstone formations with intervening clay beds. The first aquifer is unconfined whereas the deeper aquifers are in semi-confined/ confined condition. Depth of aquifers are decided based on the depth of bottom clay layers.

The Sullavai Sandstone and Shale, Limestone of Pakhal supergroup represents the consolidated formation. They are devoid of primary porosity. However, subsequent weathering, fracturing and fissuring developed secondary porosity. The main aquifers constitute the weathered zone at the top, followed by a discrete anisotropic fractured/fissured zone at the bottom, generally extending down to 200 m depth.

3.3.1 Aquifer Characterization

3.3.1.1 Unconfined aquifer

The unconfined aquifer thickness in unconsilodated formation range from 13 to 54 m. The Sullavai Sandstones, Limestones are associated with interbedding of clays and shales towards the top. The formations are hard and compact and have lost their primary porosity. During post-depositional tectonic activity, the formations were subjected to shearing and fracturing and together with subsequent weathering these formations turned out to be good aquifers locally. The thickness of weathered zone is 8 m in shales, 30 m in dolomitic limestones, 10 m in quartzites and 20 m in Sullavai sandstones. The depths of wells in Sullavai sandstones vary from 3 to 9.5 m bgl.

Gondwanas are the youngest sedimentary rocks, the medium and coarse grained, weathered sandstone occurring near the surface form unconfined aquifers.The unconfined zone extends from bottom of the soil layer to top of the first clay layer.

Ground water yield of unconfined aquifer of Sullavai sand stone varies from <1 to 8 lps and Gondwana formation aquifers varies from <1 to 6 lps with transmissivity of 20 to 72 m^2/day.

3.3.1.2 Confined/Semi-confined aquifer (Aquifer-II to Aquifer-V)

The confined aquifers extend below unconfined aquifer occurring underneath semi-pervious and impervious clayey strata. Based on the extention of clay strata, the confined aquifers area demarcated into 4 aquifer units, viz. Aquifer-II, Aquifer-III, Aquifer-IV and Aquifer-V.

Unlike Aquifer-I, ground water occurs under confined to semi-confined condition in these aquifers. The occurrence of ground water depends on porosity, granularity, cementing matrix, permeability, bedding plains and faults etc. The deeper aquifers identified upto a depth of 300 m and are mainly composed of fine to coarse grained sandstone.

Type of Aquifer	Depth range (m.bgl)
Unconfined Aquifer (Aquifer-I)	13 to 54
Confined Aquifer (Aquifer-II)	32 to 122
Confined Aquifer (Aquifer-III)	62 to 197
Confined Aquifer (Aquifer-IV)	110 to 256
Confined Aquifer (Aquifer-V)	200 to 300

The exploratory drilling data in Talchir boulder beds revealed the occurance of fractured shales between the depths 35 and 75 m bgl with ground water yield range of 5 to 10 lps. The specific capacity of successful wells ranged from 10 to 55 lpm / mdd. In Barakar sandstones, the sandstone horizons of 50 to 80 m thickness shown poor discharge of 0.64 to 0.83 lps with specific capacity of 27 to 330 lpm/mdd and the aquifer transmissivity range between 128 and 396 m^2/day.

The lower group of Kamthi sandstone, comprising coarse to gritty ferruginous sandstones having low to moderate yields of 3.75 to 12 lps and transmissivity ranging from 70 to 135 m^2/day and storage coefficient value of $3.7*10^{-4}$. The middle group consisting of coarse to medium grained sandstones with intercalations of clays having moderate yield of 13.68 lps at draw down of 24.6 m with transmissivity value of 70 m^2/day and storage coefficient value of $1.6*10^{-4}$.The upper Kamthi sandstones comprising coarse to gritty sandstones having very high yields ranging from 22 to 45 m^3/day, transmissivity ranging from 225 to 740 m^2/day and storage coeffient varying from 2.6 *10-4 to 8.4 *10-5.

Kota sandstones are interbedded with soft to hard thick clay units. At depths these sandstones are very clear and devoid of cementing material. The aquifers occurring at depths between 60 to 220 m are under confined conditions with yield range of 11.57 to 23 lps. The transmissivity ranges upto 126 m^2/day with storage coefficient upto 7.98×10^{-4}.

Formation	**Drilled Depth range (m.bgl)**	**Sp.capacity range (lpm/mdd)**	**Transmissivity (m2/day)**	**Storage coefficient**
Talchir boulder bed	42 to 91	10 to 55	_	-
Barakar sandstones	Up to300	27 to 330	128 to 396	-
Kamthi sandstones	27 to 330	47 to 80	70 to 740	1.6 ×10-4 to 8.4 × 10-5
Upper Gondwana (Kota Sand stone)	Up to 220	-	126	7.98 × 10-4

3.4 3D and 2D Aquifer Disposition

The data generated from ground water monitoring wells, hydrogeological inventories, exploratory wells and geophysical studies as well as various thematic layers were utilized to decipher the aquifer disposition of the area. This particularly includes the information on 3D geometry of aquifers, panel diagram and hydrogeological information of these aquifers. RockWorks-16 software was used for this purpose. The data is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data. The 3-D representation of Aquifer disposition is presented in **Fig. 3.15**

The detailed analysis of the data reveals that sandstone is the principal aquifer system. Ground water occurs in unconfined, semi-confined and confined conditions in the district depending on the availability of impervious beds. Aquifers are classified into 5 Aquifer units, viz. Unconfined Aquifer (Aquifer-I), Confined Aquifers i.e., Aquifer-II, Aquifer-III, Aquifer-IV and Aquifer-V. Based on the available hydrogeological data a fence diagram and a panel diagram showing the aquifer disposition were prepared and presented in **Fig.3.16 & 3.17 .**

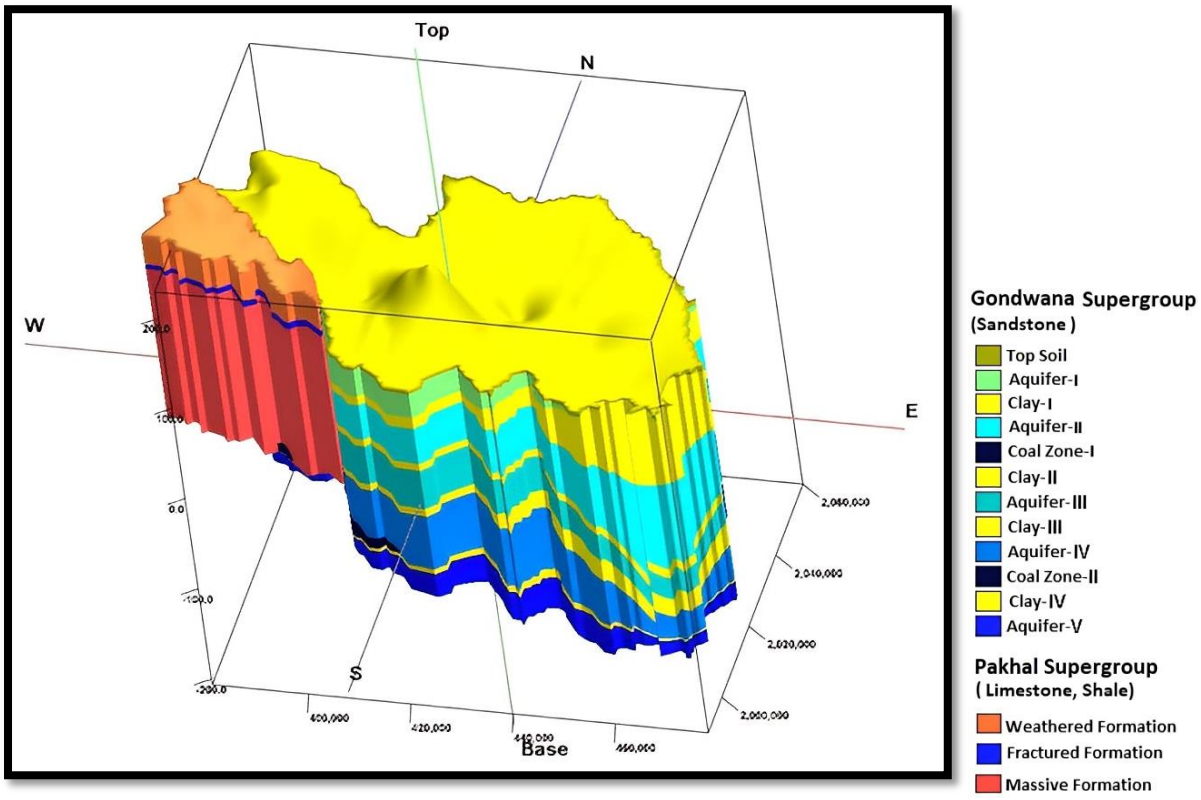


Fig.-3.15: 3-D disposition of Aquifers

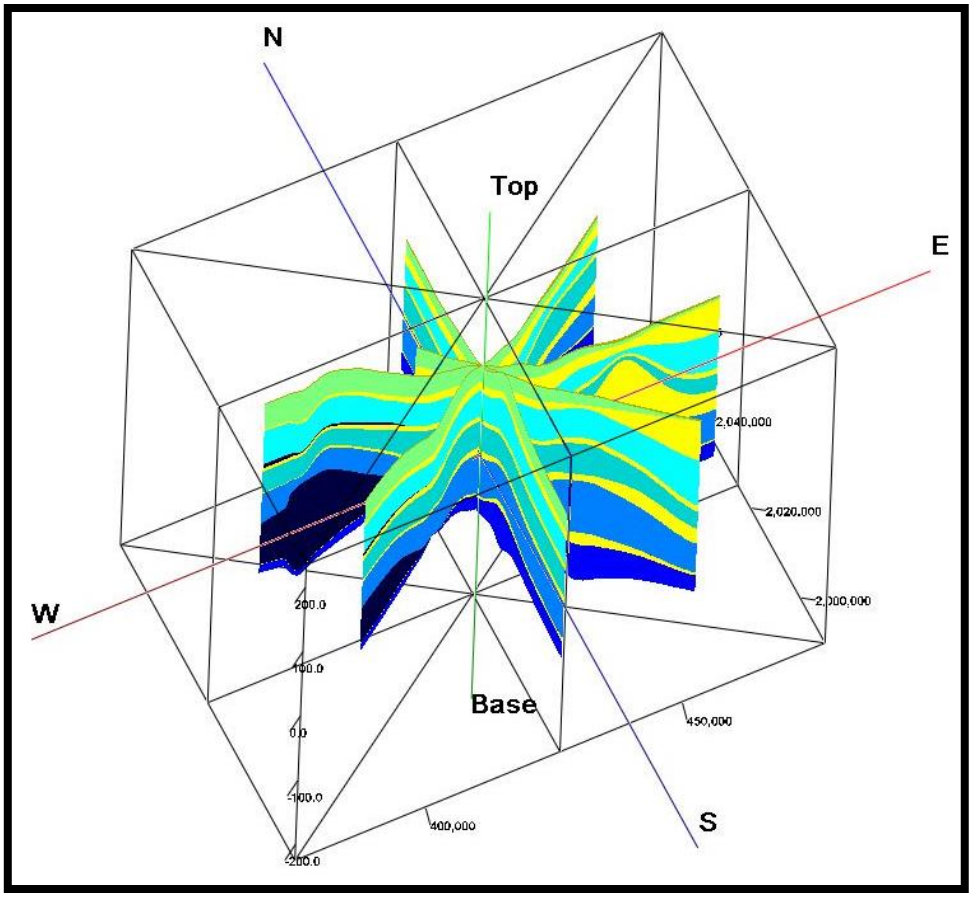


Fig.-3.16: Fence diagram of Unconsolidated/Semiconsolidated Formation

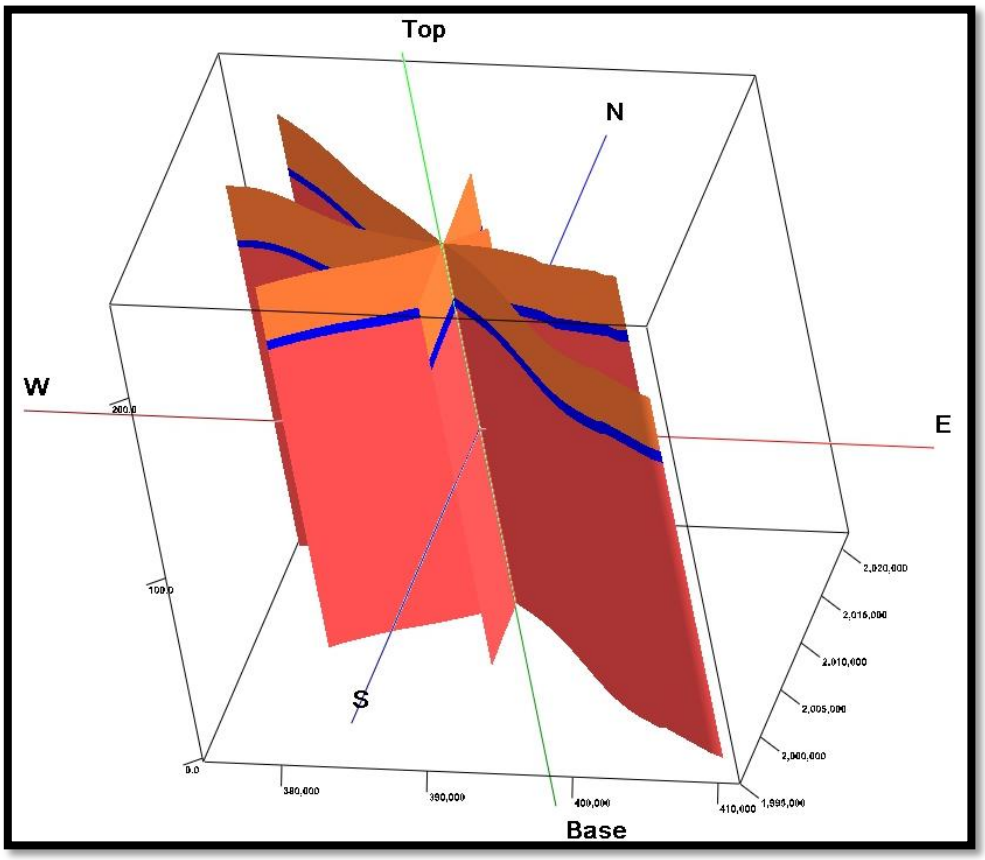


Fig.-3.17: Fence diagram of Consolidated Formation

3.4.1 Hydrogeological Cross Sections

The perusal of the data indicates that there are multi aquifers in the area with intervening thick clay beds. These sandstone bed which act as main aquifers in the area consists of five distinct beds, which behave as regional aquifers. Thin beds and pinched beds are neglected in making out the regional aquifer system. Hydrogeological cross sections drawn along different directions of the area are presented as **Fig. 3.19 to 3.21**. The study of the different sections indicates that the clay thickness is increasing from west to east and there are five aquifers exist upto a depth of 300m in Mulugu district. The shallow aquifer thickness is varying from place to place. The first aquifer which is present upto a maximum of 90 m below MSL is unconfined whereas the other aquifers are confined.

To study the aquifer disposition in detail, various hydrogeological cross sections indicating aquifer geometry has been prepared viz. NE-SW and NW-SE directions (**Fig. 3.18**).

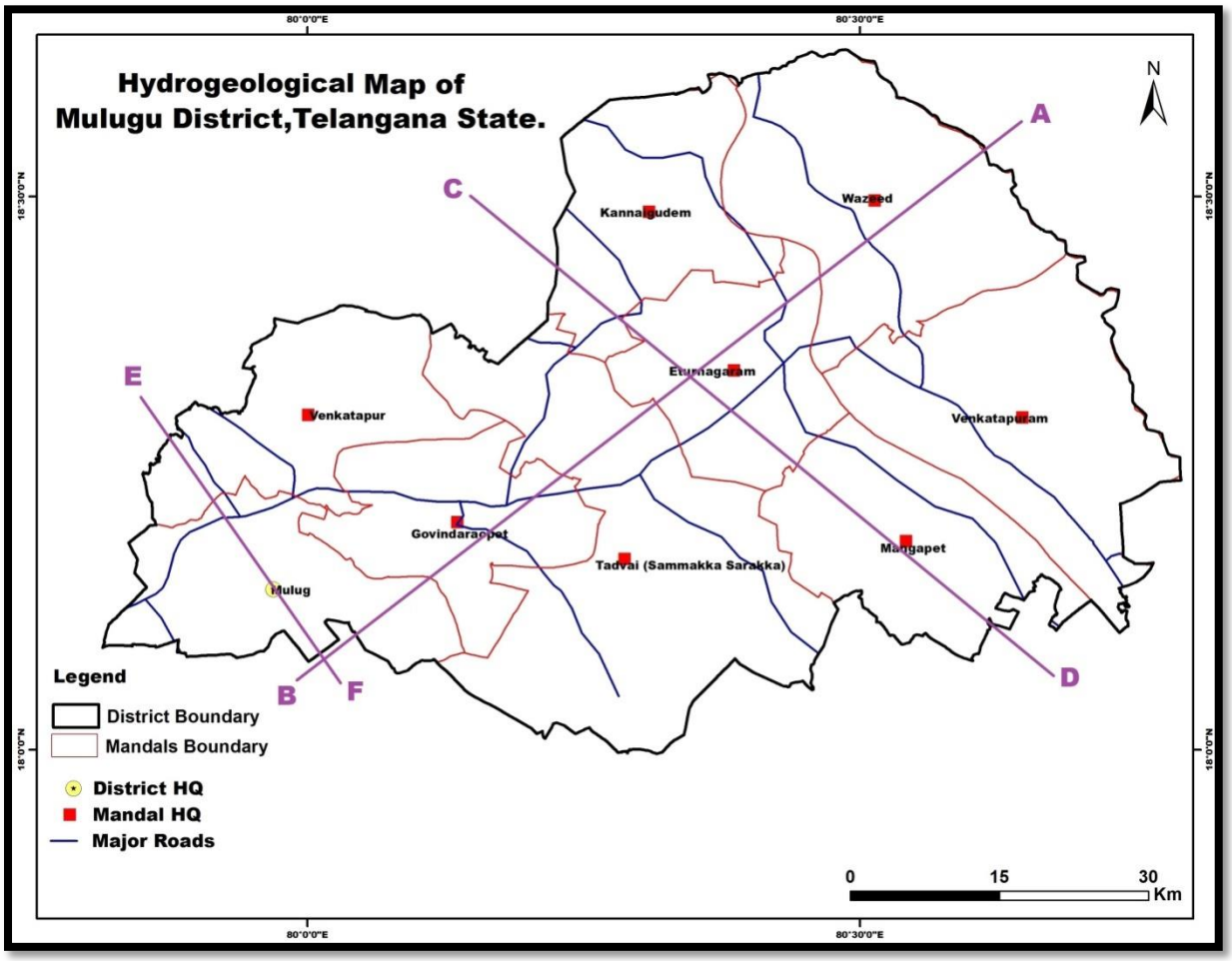


Fig. 3.18: Map showing orientation of hydrogeological sections

3.4.1.1 Hydrogeological Cross Section A-B

Hydrogeological cross section A-B (**Fig.3.19**) represents northeast- southwest direction covering a distance of ~73 kms. It can be clearly seen from the section that as we move from northeast to southwest direction i.e. from Wazeed to Mulugu the elevation increases. As many as 4 aquifers are demarcated in the sandstone formation of

Eturnagaram, separated by 3 intervening clay layers. At Tadvai, 5 aquifers are identified, separated by 4 intervening clay layers. The thickness of unconfined zone varies from 13 m at Eturnagaram to 33 m at Tadvai.

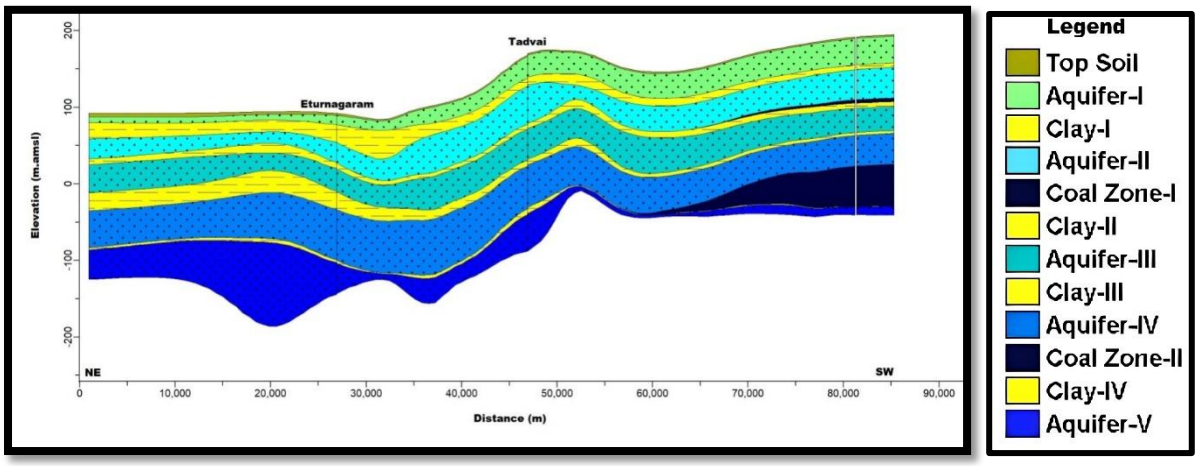


Fig.3.19: Hydrogeological cross section A-B

3.4.1.2 Hydrogeological Cross Section C-D

Hydrogeological cross section C-D (**Fig.3.20**) represents northwest–southeast direction covering a distance of ~54 kms. As many as 4 aquifers are demarcated in the sandstone formation of Shapally, separated by 3 intervening clay layers. At Chinnapally and Ramannagudem, 5 aquifers found with 4 intervening clay layers. The thickness of unconfined zone varies from 17 m at Ramannagudem to 22 m at Shapally and 26 m at Chinnapally.

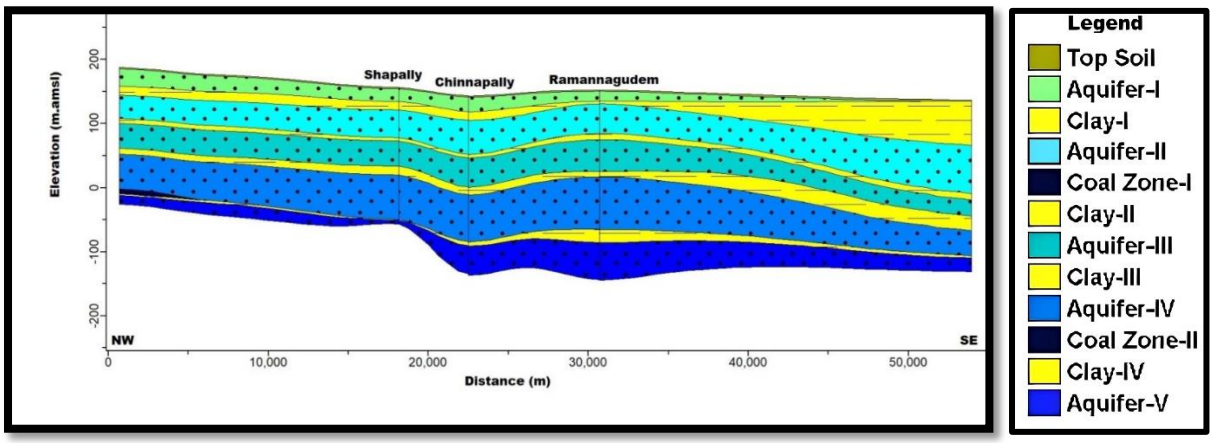


Fig.3.20: Hydrogeological cross section C-D

3.4.1.3 Hydrogeological Cross Section E-F

Hydrogeological cross section E-F (**Fig.3.21**) represents northwest–southeast direction in Meta Sediments of Pakhal supergroup covering a distance of ~21 kms. It depicts massive zone overlaid by thin fractured zone and thick weathered zone in Meta Sediments. The maximum depth of weathering observed is 30 m bgl at Mulugu.

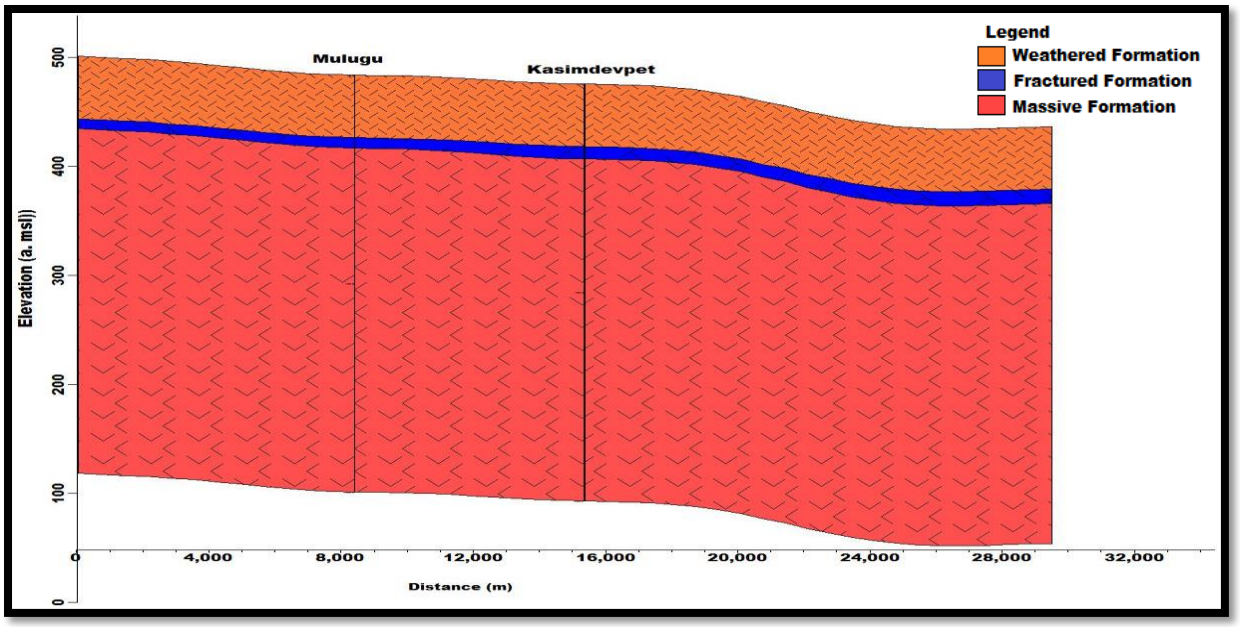


Fig.3.21: Hydrogeological cross section E-F

4. GROUND WATER RESOURCES

Dynamic ground water resources are computed as per the guidelines laid down in GEC-15 methodology. As per 2020 GEC report, the net dynamic replenishable groundwater resources availability is 392.91 MCM, gross ground water draft for all uses 150.40 MCM and net annual ground water potential available for future irrigation needs is 235.52 MCM. Stage of ground water development varies from 22% to 71 % with average of 38.27 %. Out of 9 mandals, 1 mandal fall in Semi-critical category (i.e., Mangapet). 98.38 % (MCM) of gross ground water draft is utilized for irrigation purpose only. Computed Dynamic ground water resources of the study area are given in Table-4.1.

Table-4.1: Computed Dynamic ground water resources.

As per GEC 2020	MCM
Dynamic (Net GWR Availability)	**392.91**
• Monsoon recharge from rainfall	268.42
• Monsoon recharge from other sources	61.68
• Non-Monsoon recharge from rainfall	0
• Non-monsoon recharge from other sources	83.48
• Natural Discharge	20.68
Gross GW Draft	**150.40**
• Irrigation	147.97
• Domestic and Industrial use	2.43
Provision for Drinking and Industrial use for the year 2025	9.42
Net GW availability for future irrigation	235.52
Stage of GW development (%)	**38.27%**

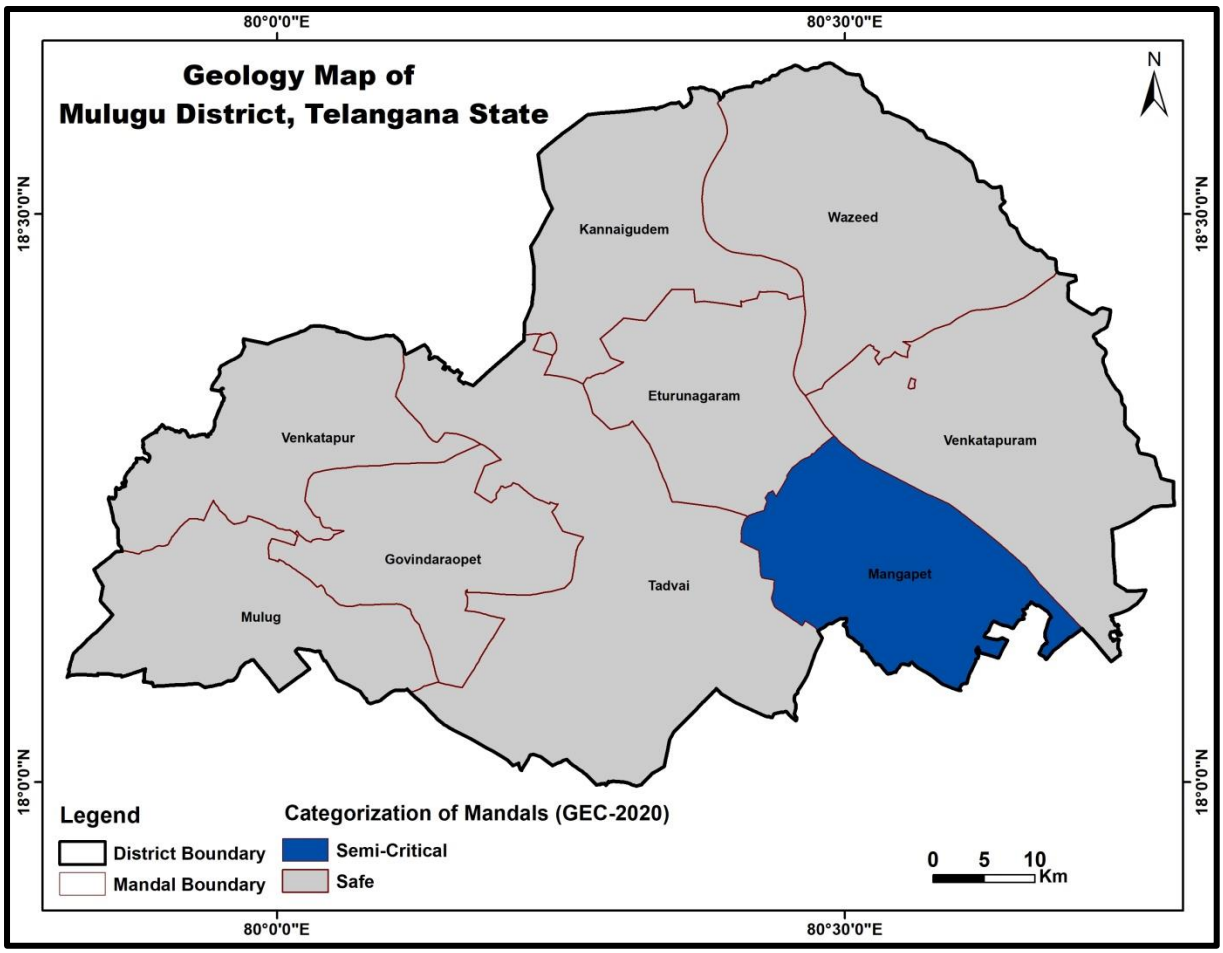


Fig.4.1: Categorization of mandals (GEC-2020)

5. GROUND WATER RELATED ISSUES

5.1 Deeper water Level

Deeper water level of >10 m in observed in parts of Wazeed, Mangapet, Eturnagaram, Tadvai and Mulugu mandal during pre-monsoon season. This may be due to urbanization, over extraction of ground water and limited artificial recharge measures. However, during post-monsoon season water level is within 10 m bgl in majority of area.

5.2 Inferior groundwater quality

- Some mandals (i.e., Govindraopet, Eturnagaram and Tadvai) are fluorosis endemic where fluoride (geogenic) is as high as 2.20 mg/L during pre-monsoon and 2.32 mg/L during post-monsoon season. The high fluoride concentration (>1.5 mg/L) occur in 6 % and 13 % of the samples during pre-monsoon and post-monsoon season.

  Higher concentration of fluoride in ground water is attributed due to source 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.

- High nitrate (> 45 mg/L) due to anthropogenic activities are observed in few mandals (i.e., Govindraopet, Tadvai, Venkatapur, Mangapet, Venkatapuram & Wazeed) as high as 608 mg/L during pre-monsoon and 257.68 mg/L during post-monsoon season. The high nitrate concentration (>45 mg/L) occur in 32% and 36 % of the samples during pre-monsoon and post-monsoon season respectively.

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

- The high concentration of EC (> 3000 micro-seimens/cm) is observed in parts of Eturnagaram, Mulugu and Venkatapuram mandal during pre-monsoon season.

5.3 Higher Groundwater Development

Mangapet mandal is categorized as semi-critical as per GEC-2020 estimations, where stage of ground water development is 71%.

6. MANAGEMENT STRATEGY

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

6.1 Supply side management

The supply-side management of ground water resources can be done through the artificial recharge by computing surplus runoff available within river sub-basins and also by repairing, renovation and restoration of existing tanks.

6.1.1 Artificial Recharge Structures (To be taken up)

The areas feasible for construction of recharge structures has been demarcated based on the analysis of average post-monsoon depth to water level data and existing data on artificial recharge structures constructed under various schemes of MGNREGA and IWMP by Rural Development department, Govt. of Telangana. The availability of unsaturated volume of aquifer was computed by multiplying the area feasible for recharge and unsaturated depth below 5 mbgl. The recharge potential of aquifer is calculated by multiplying the unsaturated volume with specific yield of the aquifers (0.03 for soft rock).

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, only 20% is considered 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 run-off is considered for the recommendation of artificial recharge structures, as the remaining 50 % is recommended for implementing water conservation measures in recharge areas through MGNREGS. The **Table 6.1** gives the area feasible and volume available for the recharge.

As the stage of ground water development in the district is 38.27 % and 1 out of 9 mandals are falling in semi-critical category as per the GEC 2020 estimation, the artificial recharge structures are not proposed for entire district. To control further increase in stage of ground water development, artificial recharge structures are recommended for 1 semi-critical mandal (i.e. Mangapet) only.

Table 6.1: Area feasible and volume available for artificial recharge

Total geographical area of district (Sq.km)	4126.83
Area feasible for recharge (Sq.km) (in Mangapet mandal)	485.41
Unsaturated Volume (MCM)	44.01
Recharge Potential (MCM)	1.32
Surplus run-off available for recharge (MCM)	17.68
PROPOSED ARTIFICIAL RECHARGE STRUCTURES	
Percolation Tanks	11
Check Dams	9

The total unsaturated volume (below the depth of 5 m) available for artificial recharge is 44.01MCM, having 1.32 MCM of recharge potential (3%). The available surplus run-off can be utilized for artificial recharge through construction of percolation tanks, check dams with recharge shafts at suitable sites. The number of percolation tanks, and check dams are decided based on the number of suitable streams available in the district.

Thus, after taking into consideration all the factors, only 17.68 MCM of surplus water can be utilised for recharge, which is given in **Table 6.1**. This surplus water can be utilized for constructing 9 check dams and 11 percolation tanks at suitable sites. The amount of recharge from these artificial recharge structures was calculated by considering 0.0105 MCM per percolation tanks and 0.042 MCM per check dam. This intervention would lead to recharge of about 0.488 MCM/year (**Fig. 6.1 & 6.2**). The details are given in **Annexure-1.**

In addition to this roof top rainwater harvesting structures should be made mandatory to all Government buildings.

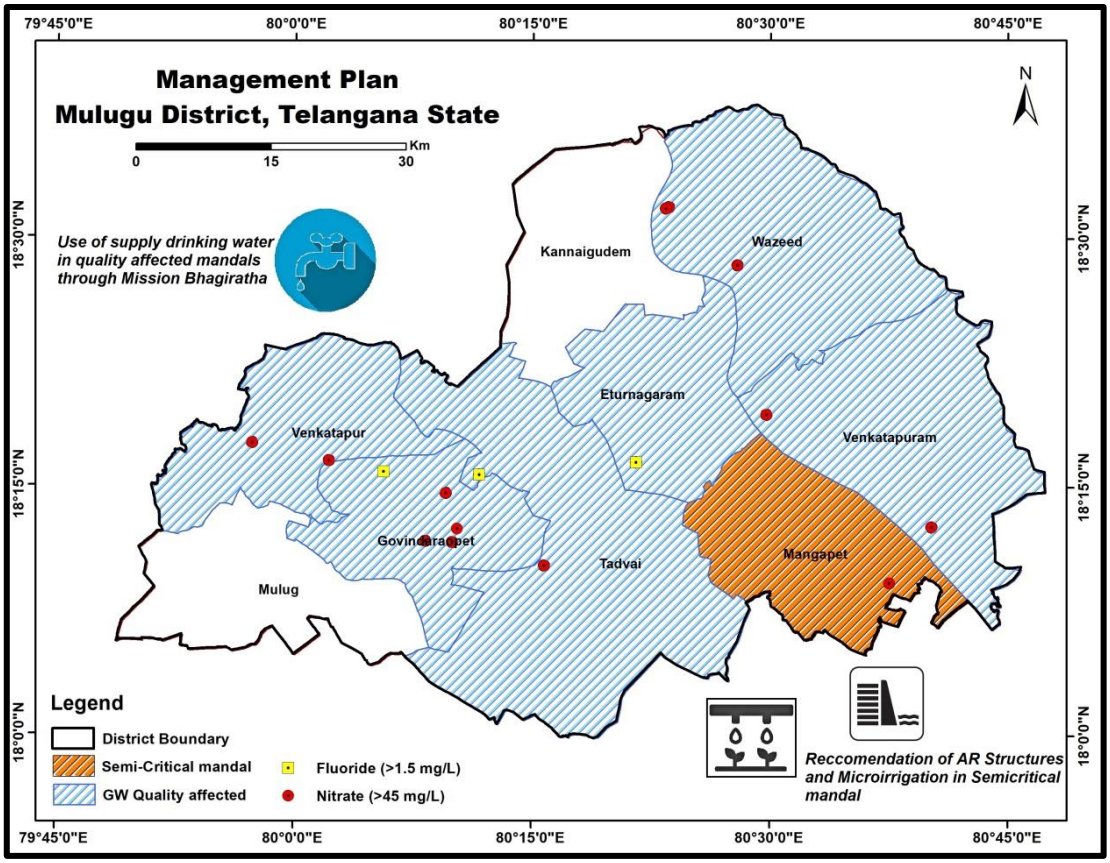


Fig.6.1: Management Plan of Mulugu district

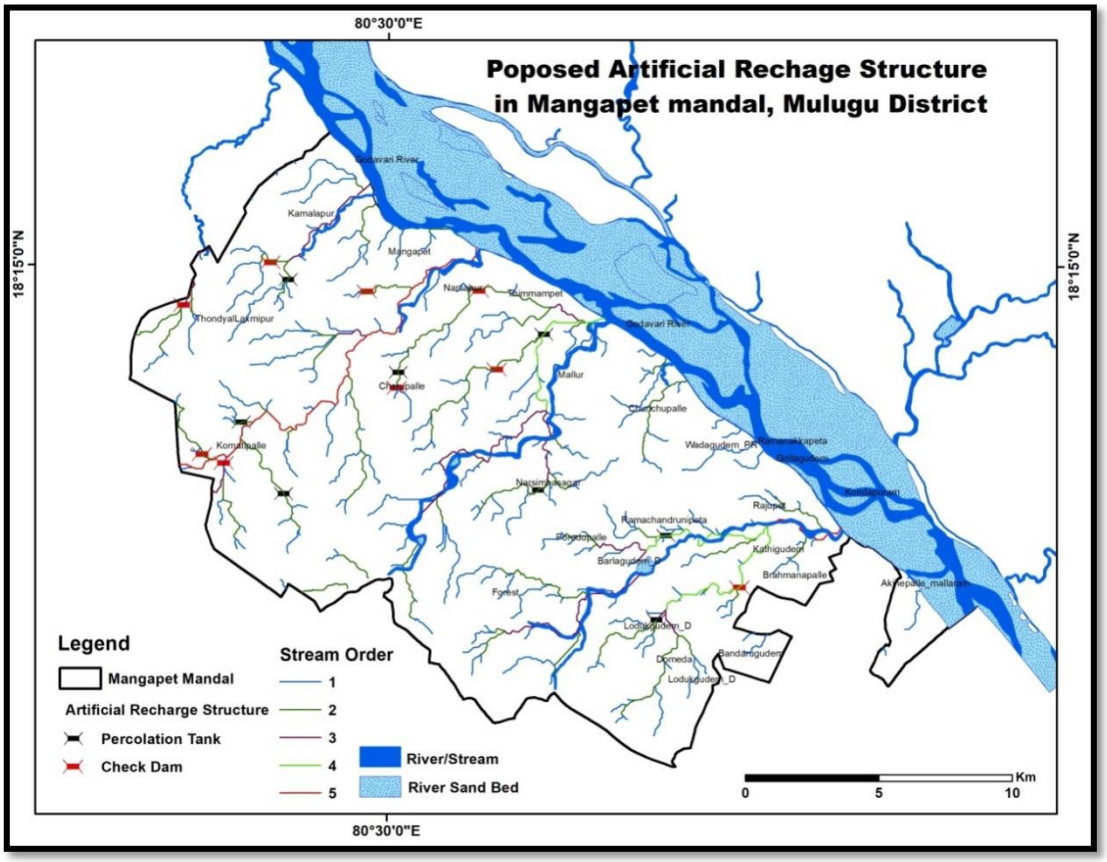


Fig. 6.2: Proposed Artificial Recharge Structure in Mangapet mandal

6.1.2 State Government Projects

- **Mission Kakatiya:**

  De-silting of existing minor tanks (543 no.) was taken under state Govt. sponsored Mission Kakatiya (Phase-1 to 4) to remove silt and this has created additional surface storage and enhance ground water recharge.

- **Mission Bhagiratha**:

  Under Telangana Drinking Water Supply Project (TDWSP), also known as Mission Bhagiratha, all the villages and towns are proposed to be covered from the three water grids with intake from Ramappa lake in 4 segments (i.e., Godavari-Pusuru, Godavari-Mangapet, Manthani-Bhupalapally and Palair-Warangal) to provide protected water from surface reservoirs. The scheme is to enhance the existing drinking water scheme and to provide safe drinking water to 82935 no. of households.

  The total water requirement as per 2020 census is 11.65 MCM and this imported water from surface sources will reduce the present utilized ~6.99 MCM of ground water (considering 60 lpcd). This can be effectively utilized to irrigate ~1165 ha of additional land under ID crops.

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

6.2 Demand side management

In order to manage the available resources more effectively the following measures are recommended.

- In the district, till date 2473 no's drip and sprinklers are sanctioned which has irrigated ~2514 ha under ID crops saving ~3.77 MCM (considering 25% saving of 0.006 MCM/ha) of groundwater from the basin. Considering the current scenario of groundwater development, existing number of structures and shallow water levels, demand side intervention such as change in cropping pattern and micro irrigation has been proposed.
- ~653 ha of additional land that can be brought under micro-irrigation (@1000 ha/mandal including existing area in 1 semi-critical mandals (i.e., Mangapet mandal) costing about 3.91 crores (considering 1 unit/ha @0.6 lakh/ha). With this 0.97 MCM of ground water can be conserved over the traditional irrigation practices.
- Change in cropping pattern from water intensive paddy to irrigated dry crops like pulses and millets are recommended particularly in 1 mandal viz, Mangapet where paddy cultivated area is ~ 80% of the Gross cropped area.

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

6.3 Other Recommendations

- In villages/mandals where concentration of Fluoride and Nitrate is beyond the permissible limit, supply drinking water through Mission Bhagiratha and installation of water treatment plant is recommended.
- 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.
- In urban and rural areas, the sewerage line should be constructed to arrest leaching of nitrate.

6.4 Expected results and outcomes

With the above interventions (excluding the cost involved in Mission Kakatiya and Mission Bhagiratha), the likely benefit would be net saving of 1.45 MCM of ground. This will bring down the stage of groundwater development by 2.43 % (from 71% to 68.56%) in Mangapet mandal.

Annexure-1

Proposed supply side interventions for ARS

Mandal	Village	Proposed CDs	Proposed PTs
Mangapet	Lodukgudem (D)	0	1
Mangapet	Mangapet	1	0
Mangapet	Narsapur	1	0
Mangapet	Thondyala Laxmipur	2	1
Mangapet	Kathigudem	1	0
Mangapet	Ramachandrunipeta	0	1
Mangapet	Thimmampet	1	0
Mangapet	Komatipalle	2	2
Mangapet	Narsimhasagar	0	1
Mangapet	Mallur	0	2
Mangapet	Cherupalle	1	1
Mangapet	Kamalapur	0	1
Mangapet	Poredupalle	0	1