
**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

## KARIMNAGAR DISTRICT, TELANGANA

दक्षिणी क्षेत्र, हैदराबाद

Southern Region, Hyderabad

# REPORT ON
# AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN HARD ROCK AREAS OF KARIMNAGAR DISTRICT, TELANGANA STATE

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# REPORT ON
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# AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN HARD ROCK AREAS OF KARIMNAGAR DISTRICT, TELANGANA STATE

## AT A GLANCE

| S.No. | Item | | Particulars |
|---|---|---|---|
| 1 | Districts | : | Karimnagar (Hard Rock Area) |
| 2 | Revenue Divisions/ Mandals | : | 49 |
| 3 | Villages | : | 863 Nos |
| 4 | Geographical area | : | 9152 $km^2$ (77 % area of entire district) |
| 5 | Population (2011 Census) | : | 32.1 lakh (urban: ~21 %, rural: ~79 %) |
| 6 | Density of population (2011 Census) | : | 350 persons/$km^2$. |
| 7 | Locations | : | North latitude 17°58´-19°05´<br><br>East longitude 78°30-79°36" |
| 8 | Rainfall (Normal) | : | ~673-1157 mm (avg: 942 mm) (SW: 81 % & NE: 12 %) (During 2014-15 it received 704 mm (-25 % less than normal rainfall) |
| 9 | Geomorphology | : | Pediplain (71 %, pediment (13 %), Denudation hills (7 %), flood plains (3 %) and channel fill (2 %). |
| 10 | Major Rivers | : | The Godavari and The Mannair river |
| 11 | Watersheds | : | 43 nos (Command: 48% and Non-Command:52%) |
| 12 | Land Utilization (Ha) | : | Double cropped area occupies ~56% of the total geographical area, 15% of area is cultivated during kharif season.<br>Forest: ~11%, wastelands ~ 8%, water bodies (tanks) 4 % and cultivable waste land ~2%. |
| 13 | Soils | : | Loamy soils (52 %) and Clayey soils (48 %) |
| 14 | Cropping Pattern (2014-15)<br><br>(Gross Area:634139 Ha) | : | Khariff: 458327 Ha<br><br>Cotton (41%), paddy (34 %), Oil seeds (9%), maize (7 %), Spices (3%), pulses (1 %), chillies (3%) , groundnut (1 %), vegetables (1%) other non –food crops 2 % are grown<br><br>Rabi: 175812 Ha<br><br>paddy (51 %), maize (30 %), oil seeds (1%) and other non-food crops 2 % etc. |
| 15 | Irrigation | : | **Major project:** Sri Ram Sagar Project (Stage-1) (Registered ayacut:166397 ha)<br><br>**Medium Projects:** Mannair Project (ayacut: 5463 ha), Shanigaram Project (ayacut: 2065 ha), Boggalavagu Project (ayacut: 2085 ha)<br><br>**MI Tanks:** 3665 minor irrigation tanks |

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|---|---|---|---|
| | | | During 2014-15 ground water contributed **97 %** of irrigation needs<br>(Khariff: 96 % and Rabi: 99 %). |
| 16 | Prevailing Water Conservation/Recharge Practices | : | PT: 635 and CD: 409 and Farm ponds:140<br>Micro irrigation: 32264 Ha.<br>Under Mission Kakatiya (Phase 1 and 2) total ~4.3 MCM of silt is removed from 937 tanks. |
| 17 | Geology | : | Banded Gneissic complex (Gneisses: 59 %) Granites: 36 % and Charnokites: 2 and Sandstone/shale (1 %), and quartzite (1%) and ultramafic rocks. |
| 18 | Hydrogeological data points | : | 499 hydrogeological data points (Exploration: 128 (CGWB: 74 and SGWD: 54), VES: 195 and Well inventory: 176) |
| 19 | Number of ground water structures | : | As on 31/03/2017, CGWB drilled 74 bore wells<br>Irrigation Wells: 2.75 lakhs (DW:2.3 lakhs and BW: 0.35 lakhs Domestic Wells: 0.10 lakhs |
| 20 | Ground water yield (lps) | : | 0.1 to 10 lps<br>Low yield (<1 lps):25 % of area, Moderate yield (1-3 lps):51% of area and high yield (>3 lps): 24% of area.<br>Deepest Fracture : 167 m at Dharmaram in Jammikunta mandal |
| 21 | Water Levels (2016)<br>Depth to water levels (m bgl) | :<br>: | 271 wells (CGWB:60, SGWD:96 and Key Observation wells:115)<br>Water table elevations during pre-monsoon season varies from 148-439 m amsl and during post-monsoon season it varies from 154.3 to 452.5 m amsl.<br>Pre-monsoon season: 4.97 to 31 m bgl (average: 13.6 m bgl) and majority are in the range of 10-20 m bgl (67 % area) followed by 5-10 mbgl (25% area). Deep water levels (> 20 mbgl) occupy 8% of area.<br>Post-monsoon: 0.2 to 18.7 m bgl (average: 5.7) and majority are in the range of 2-5 m bgl (48 % area) followed by 5-10 mbgl (43 % area). |
| 22 | Water Level Fluctuations (May vs. November 2016) | : | 1.25 to 23.4 mbgl Out of 271 wells 270 wells shows rise in water levels and 1 well shows fall in water levels. |
| 23 | Long term water level trends (2007-16)<br>(95 wells) | : | **Pre-monsoon:** Falling trends: 84 wells (-0.03 to -2.33 m/yr) Rising trends: 11 wells shows 0.63 to 0.02 m/yr<br>**Post-monsoon:** Falling trends: 72 wells (-0.01 to -1.39 m/yr) Rising trends: 23 wells shows 0.6 to 0.01 m/yr. |
| 24 | Water level during **(2007-2016)** with average WL of last 10 years (2006-15) | : | **Pre-monsoon:** 79 wells show fall<br>**Post-monsoon:** 27 wells shows fall and 58 shows rise. |

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| 25 | Geophysical data (down to 200 m) | : | 195 VES<br><br>Weathered granite/Gneiss < 90 Ω m , Semi-weathered granite/Gneiss 90-180 Ω m, Fractured granite/Gneiss 180-350 Ω m and > 350 Ω m for massive gneiss/granite. | | |
| 26 | Hydrochemistry (2015) | : | Total 1263 data<br><br>Pre-monsoon (CGWB:12 nos, SGWD:405 and RWS:258)<br><br>Post-monsoon (SGWD:416 and RWS:172) | | |
| 26.1 | Electrical Conductivity (µ Siemens/cm) | : | Pre: 343-4681 µ Siemens/cm (avg:1282) in 70 % of samples covering 67 % of area EC is within 1500 µ Siemens/cm.<br><br>Post: 315-3830 µ Siemens/cm (avg:1285) in 71 % of samples covering 79 % of area EC is within 1500 µ Siemens/cm. | | |
| 26.2 | Nitrate mg/l | : | Pre: BDL to 592 mg/l and found 58 % of samples (391 nos) are unfit for human consumption<br><br>Post: BDL to 479 (402 samples (68%) are unfit for human consumptions). | | |
| 26.3 | Fluoride mg/l | : | Pre: 0.1-6.0 mg/L (167 samples (25 %) covering 21% of area are unfit for human consumptions.<br><br>Post: 0.1-5.0 mg/L (95 samples (16 %) covering 15 % of area are unfit for human consumptions. | | |
| 27 | Conceptualization | | Weathered zone (~30 m). | Fractured zone( 30 -167 ) m | |
| 27.1 | Aquifer Characterization | : | Saprolite (~10 m) and lower sap rock (10-30)<br><br>10-20 m weathering occurs in 68 % followed by < 10 m in 26% of area and deep weathering occurs in 6% of area. | Majority of fractures ~98% occurs within 100 m depth.<br><br>Deepest fracture at 167 m at Dharmaram in Jammikunta mandal. | |
| 27.2 | Aquifer wise Ground water yield | : | <0.1 to 10 lps. Lower yields (< 1 lps) occur in central part of study area and moderate yields (1-3 lps) occur in eastern part and higher yields (> 3 lps) occur in western, | 0.01 to 5.4 lps. | |
| 27.3 | Transmissivity ($m^2$/day) | : | 1-412 $m^2$/day and in majority of wells it is ~20 $m^2$/day, | 1 to 77 $m^2$/day (avg: 25 $m^2$/day) | |
| 27.4 | Specific Yield | : | < 1 to 2.3 %.( avg: 1 %). | - | |
| 27.5 | Storativity | : | - | 0.00001 to 0.0001 | |
| 28 | Ground water Resources (2013) MCM | : | Command | Non-Command | Total |
| 28.1 | Net Dynamic groundwater availability | : | **878.61** | **623.06** | **1501.67** |
| 28.2 | Gross GW Draft | : | 591.7 | 635.80 | 1227.50 |

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|---|---|---|---|---|---|
| 28.3 | Provision for Domestic &Industrial (2025) | : | 286.70 | 55.82 | 342.52 |
| 28.4 | Average Stage of Ground water development (%) | | 67 | 102 | 82 |
| 28.5 | Net GW Availability for future irrigation | : | 75.56 | 0 | 75.56 |
| 28.6 | In storage GW Resources | : | **90.48 MCM (May)**<br>**Net recharge during monsoon season is 47.96 MCM** | | |
| 28.7 | Categorization of mandals | | Mandal wise it varies from 33 % to 140 %<br>(OE:12, C:8, SC: 7and Safe:22) | | |
| 29 | Major Ground Water Issues Identified | : | • Over-exploitation: ~2666 $Km^2$ area (12 Mandals) covering 346 villages.<br>• Ground water Pollution (Geogenic: Fluoride ( 21 % samples are unfit for human consumptions).(Anthropogenic: Nitrate 58 % samples are unfit for human consumptions).<br>• Deep water levels (> 20 m bgl) are observed during pre - monsoon season in 8 % of area.<br>• Declining water levels: Out of 95 wells analyzed, 84 wells shown falling trend in pre-monsoon and 72 during post-monsoon season.<br>• Sustainability Low yield (<1 lps) occurs in ~25 % of area and reduction in yield over a period of time.<br>• Water marketing is present in almost all over the area.<br>• Change in land use from agricultural land to residential purposes and cropping pattern from traditional crops to cash crops (cotton and spices) is observed. | | |
| 30 | Management Strategies | : | **Supply side measures**<br>**Ongoing Projects**<br>**Mission Kakatiya: (**Phase-1 and -2): ~4.3 MCM of silt is removed contributing to ~ 2.15 MCM to groundwater and with this additional ~270 ha land can be brought under irrigated dry (ID) crops under tank ayacut.<br>**To be taken up**<br>~2200 remaining tanks in next phases for de-silting.<br>**Mission Bhagiratha:**~197.93 MCM of water will be imported from surface sources this will save ~192.6 MCM and from this ~24000 ha of additional land can be brought under ID crops.<br>**To be taken up (Artificial Recharge Structure)**<br>**Priority-1:Over-exploited villages: 263(~2212 $km^2$)** | | |

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| | | | • 1294 ARS (CD:671 and PT:623)<br>• Cost Rs ~95.86 Crores<br>**Priority-2:Other remaining villages:365 (~4440 km$^2$)**<br>• 2692 ARS (CD:1360 and PT:1332)<br>• Cost Rs ~201.2 Crores.<br>**Water Conservation measures (WCM) Farm Ponds**<br>• The size of form ponds can be 10 x 10 x 3 m. Total 17320 farm ponds are recommended (20 in each village in 866 villages) with total cost of **43.3** crores.<br>**Demand side measure**<br>**Ongoing work:** In the area till date a total ~43329 ha area is brought under micro-irrigation (Sprinklers: 11065 and drip: 32264) saving ~87 MCM of groundwater.<br>**Other Recommendations**<br>• ~17453 ha of additional land that can be brought under micro-irrigation (33 mandals) **Cost: 104.72** crores. With this ~35 MCM of ground water can be conserved over the traditional irrigation practices.<br>• Declaration of MSP in advance (before start of season) and improved facilities at procurement centres.<br>• As a mandatory measure, every groundwater user should recharge rainwater through artificial recharge structures in proportionate to the extraction<br>• Roof top rainwater harvesting structures should be made mandatory to all Government/industrial buildings (new and existing).<br>• Capacity building in power supply regulation (4 hour each in morning and evening) will increase the sustainability of wells<br>• A participatory groundwater management (PGWM) approach in sharing of groundwater and monitoring resources on a constant basis along with effective implementation of the |

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| | | | existing 'Water, Land and Trees Act' of 2002 (WALTA-2002).<br>• Laser levelling of irrigated land.<br>• Subsidy/incentives on cost involved in sharing of groundwater may be given to the concerned farmers.<br>• In urban and rural areas the sewerage line should be constructed to arrest leaching of nitrate |
| 31 | Expected Results and Out come | : | With the above interventions costing Rs **445.08** crores (**excluding the cost involved in Mission Kakatiya and Mission Bhagiratha**), the likely benefit would be increases in gross groundwater based irrigation from ~4.46 lakhs ha to 4.93 lakhs ha or net saving of **282.15** MCM of ground water or net reduction of 13 % in stage of ground water, i.e., from 82 % to 69 %<br>One time cost will be ~2 paisa/litre (Rs 20 /$m^3$ of ground water). |

**ABBREVATIONS**

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

## EXECUTIVE SUMMARY

The hard rock areas of Warangal district covering ~9152 $Km^2$ area (77 % of total district), receives an average annual normal rainfall of 942 mm of which 81 % is contributed by SW monsoon and 12 % by north-east monsoon. During the year 2014-15, the district received 704 mm (25 % less) rainfalls than normal annual rainfall. Administratively, the area is governed by 49 revenue mandals with 863 villages. The population of the district is ~ 32.1 lakhs (2011 census) with average density of 350 persons/$km^2$.

Area is underlain by gneisses (59%), granite (36%), Charnokites (2%), Sandstone/Shale (1%) and Quartzite (1%). Pediplains are major geomorphic features (71% of area) followed by pediment (13%), denudation hills (7 %), flood plain (3%) and channel fill and residual hills (2 % each). Most of the area is drained by rover Godavari and its tributary Mannair and are divided into 43 watersheds. The gross cropped area during 2014-15 is 634139 ha (Khariff: 458327 ha and Rabi:175812 ha). Forest occupies 11% of the total geographical area, cultivable waste occupies2 % and water bodies occupy 8 % of area. Cotton (41%), paddy (34 %), oil seeds (9%), maize (7%), spices (3%) are main crops during kharif season. During rabi season paddy (51%), maize (30%), oil seeds (1%), and non food crops are gown in 2 % of area. The soils are loamy (52%) and clayey soils (48 %).

The registered ayacut under Sri Ram Sagar major irrigation projects is 166397 ha and under medium irrigation project is 9613 ha. In the area there are 3665 minor irrigation tanks. During the year 2014-15 only 21358 ha area was irrigated from surface water. Ground water contributes 99 % of irrigation and surface water 1 %. In the area there are ~635 PT and 409 CD and ~32264 ha of land is brought under MI and ~4.3 MCM of silt is removed under Mission Kakatiya.

Exploratory results of CGWB (74 wells) suggest that 10 wells are drilled down to 200 m, 28 between 60-100 m, 33 nos (30-60 m) and 3 nos (< 30 m).There are ~2.75 agricultural bore wells (Irrigation BW: 0.35 lakhs, Irrigation DW: 2.3 lakhs and Domestic wells 0.10 lakhs). Ground water yield varies from <0.1 to 10 lps in granite/gneisses. Majority of fractures occur within 100 m depth and deepest fracture is encountered at 167 m depth (Dharmaram in Jammikunta mandal).

Water levels are monitored through 271 wells during pre and post-monsoon season of 2016. The DTW varies from 4.97 to 31 m bgl (average: 13.6) and 0.2 to 18.7 m bgl (average:

5.7) during pre and post-monsoon season of 2016 respectively. During pre-monsoon season 10-20 m water levels is more predominant (67 % of area) followed by 5-10 m (25 % of area). During post-monsoon season 2-5 m water levels is more predominant (48 % of area) followed by 5-10 m (43 % of area). Water level fluctuation (Nov Vs. May of 2016) all but one wells shows rise in water level 1.25-23.4 m and 1 well shows fall (-6.03 m). Long-term water levels trends from 95 wells shows a falling trend in 84 wells (0-1m: 77, 1-2 m: 6 and < 2 m: 1) (max fall: -2.33 m/yr) and 11 wells shows rising trend (max rise: 0.63 m/yr). During post-monsoon season 72 wells shows falling trend (maximum fall: -1.39 m/Yr) and 23 wells shows rising trends (max rise: 0.6 m/yr). Average water levels for the last 10 years (2006-15) were compared with 2016 data and it is found that during 2016 pre-monsoon season 79 wells have shown fall and 16 wells have no sufficient data and during post monsoon season 27 wells shown fall and 58 shown rise in water levels.

Geophysical data from 195 VES data (CGWB) reveals resistivity < 90 Ohm (Ω) m for the weathered granite, 90-180 Ω m for underlying semi weathered granite, between 180-350 Ω m fractured granite and > 350 Ω m for massive granite.

Total 1263 ground water samples (Pre-monsoon:675 and Post-monsoon:588) were analysed for knowing the suitability of ground water for drinking purposes. In 70 % and 79 % of area EC is in the range of < 1500 µ Siemens/cm during pre and post-monsoon season respectively. During pre-monsoon season, concentration of $NO_3$ ranges from BDL to 592 mg/l and found that in 58 % samples nitrate is beyond maximum permissible limit of BIS (45 mg/l) and F concentration varies from 0.1 to 6.0 mg/l and found that in 167 samples (25 %) it is beyond maximum permissible limits of BIS (1.5 mg/l). During post-monsoon season, concentration of $NO_3$ ranges from BDL to 479 mg/l and found that in 402 samples (68 %) it is beyond maximum permissible limit of BIS (45 mg/l). The F concentration varies from 0.1 to 5 mg/l and found that in 95 samples (16 %) it is beyond maximum permissible limit of BIS.

Based on 499 hydrogeological data points, aquifers from the area can be conceptualized in to two nos namely, 1) weathered zone (~30 m) and 2) fractured zone (30-167 m). Weathered zone has gone dry in ~75 % of area due to over-exploitation during pre-monsoon season. Weathered zone in the range of 10-20 m in 68 % of area, < 10 m occurs in 26 % of area and deep weathering (> 20 m) occurs in 6 % of area. Ground water yield of this zone varies from 0.1-10 lps, Transmissivity varies from 1 to 412 $m^2$/day, specific yield ranges

from 1-2.3 % (avg: 1%). Fracturing zone varies from 30 to 167 m (deepest fracture at Dharmaram in Jammikunta mandal). Majority of area (67%) fractures occur within < 30 m depth, 30-60 m and 60-86 fractures occur in 24 % and 7 % of area respectively and deep fractures (100-150 and > 150 m) are observed in < 2 % of wells. Ground water yield varies from 0.01 to 5.4 lps. Transmissivity (T) varies from 1 to 77 $m^2$/day (avg: 25 $m^2$/day) and storativity varies from 0.00001 to 0.0001.

Net dynamic replenishable ground water availability is 1501.7 MCM, gross ground water draft is 1227.5 MCM, provision for drinking and industrial use for the year 2025 is 342.5 MCM and net available balance for future irrigation use is 75.6 MCM. The stage of ground water development varies from 33 to 140 % (avg: 82 %). The in-storage ground water resources down to the maximum fractured depth (85 m) are 90.48 MCM and there is net recharge of 47.96 MCM during 2016 post-monsoon season.

Major issues identified are over-exploitation (2666 $km^2$ area covering 346 villages), ground water pollution (both anthropogenic ($NO_3$) and geo-genic (F), deep water levels are > 20 m bgl in 8 % of the area during pre-monsoon season and declining water levels in majority of hydrograph stations and sustainability in 25 % of the area. Other issues identified are water marketing, change in cropping pattern from agricultural to residential colonies etc.

The management strategies mainly include both supply side and demand side. The supply side measure includes ongoing work under Mission Kakatiya where ~4.3 MCM of silt has been removed from existing 40 % tanks. This will contribute ~2.15 MCM of ground water by recharge, with this additional ~270 ha land can be brought under irrigated dry (ID) crops in tank ayacut. There is immediate need to take remaining 60 % of tanks under Mission Kakatiya. Under Mission Bhagiratha, there is plan to import ~197.9 MCM of water for drinking purposes which will save the present ~192.6 MCM of water for drinking and domestic purposes and with this additional ~24000 ha of land can be brought under ID crops.

Construction of 1294 ARS with ~95.86 crores in **priority-1** area (over-exploited 263 villages having storage potential) and constructions of 2692 ARS with ~201.2 crores in **priority-2** area (other area) are recommended as supply side measures. Under Water conservation measures include, construction of 17320 nos of farm ponds with 43.3 crores in all villages.

Demand side measure includes bringing ~17453 ha of land (from 33 mandals where actual MI is < 1000 Ha) under micro-irrigation with total cost of **104.72** crores. With this 35 MCM of ground water will be saved in both seasons by utilizing same units.

Other measure includes providing good quality seeds, improved procurement facilities, mandatory artificial recharge at every Govt and industrial units. Capacity building in power supply regulation, application of laser levelling technology in irrigated land, providing proper sewerage system and participatory groundwater management (PGWM) are the other measures recommended.

With the above interventions costing Rs **445.08** crores (excluding the cost involved in Mission Kakatiya and Mission Bhagiratha), the likely benefit would be increases in gross ground water irrigated area from 4.46 lakh ha to 4.93 lakh Ha from ground water or net saving of **~282.15** MCM of ground water (net reduction of 13 % in stage of ground water development from 82 % to 69 %). The other benefits will be more distribution of income among farmers.

**NUMBER OF DATA POINTS USED FOR PREPARATION OF VARIOUS MAPS/FIGS- KARIMNAGAR DISTRICT, ANDHRA PRADESH**

| S. No. | Data | Aquifer | Total Data Points | Source | | |
|---|---|---|---|---|---|---|
| | | | | CGWB | SGWD | Well Inventory |
| 1 | Panel Diagram (3-D) | Combine | 499 | Expl:74 VES:195 | 54 | 176 |
| 2 | Hydrogeological Sections | 4 no | 499 | Expl:74 VES:195 | 54 | 176 |
| 3 | Fence/panel Diagrams | 1 no | 499 | Expl:74 VES:195 | 54 | 176 |
| 4 | Depth of weathering | 1 no | 499 | Expl:74 VES:195 | 54 | 176 |
| 5 | Depth of fracturing | 1 no | 499 | Expl:74 VES:195 | 54 | 176 |
| 6 | Groundwater Yield | Weathered zone | 290 | 74 | 40 | 176 |
| | | Fractured zone | 290 | 74 | 40 | 176 |
| 7 | Transmissivity ($m^2$/day) | Weathered zone | 36 | 36 | 0 | 0 |
| | | Fractured zone | 36 | 36 | 0 | 0 |
| 8 | Depth to Water Level Maps (2015) | Combine | 271 | 60 | 96 | 115 |
| 9 | Water Level Fluctuation | Combine | 271 | 60 | 96 | 115 |
| 10 | Long term water level trends | Combine | 95 | 49 | 46 | 0 |
| 11 | Water quality<br>Pre-2015<br>Post-2014 | Combine | 1263<br>Pre:675<br><br><br><br>Post:588 | <br>12<br><br><br><br>0 | <br>SGWD:405 and RWS : 258)<br><br><br>SGWD:416 and RWS : 172) | <br>0<br><br><br>0 |

# 1. 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 rock,s 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) 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 on 1:50, 000 scale.
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 Karimnagar hard rock area covering ~9152 km$^2$ (77 % area, Karimnagar district area: 11823 km$^2$), lies between north latitude 17°58′-19°05′ and east longitude 78°30-79°36"(**Fig.1.1**). As per present district set up, it is part of Jagityal, Peddapalli, Karimnagar, Rajanna Sircilla, Siddipet and Warangal (U) districts. Administratively the area is governed by 49 revenue mandals covering 863 villages with a population of ~32.1 lakhs (2011 census) (urban: ~21 %, rural: ~79 %) with average density of 350 persons/km$^2$.

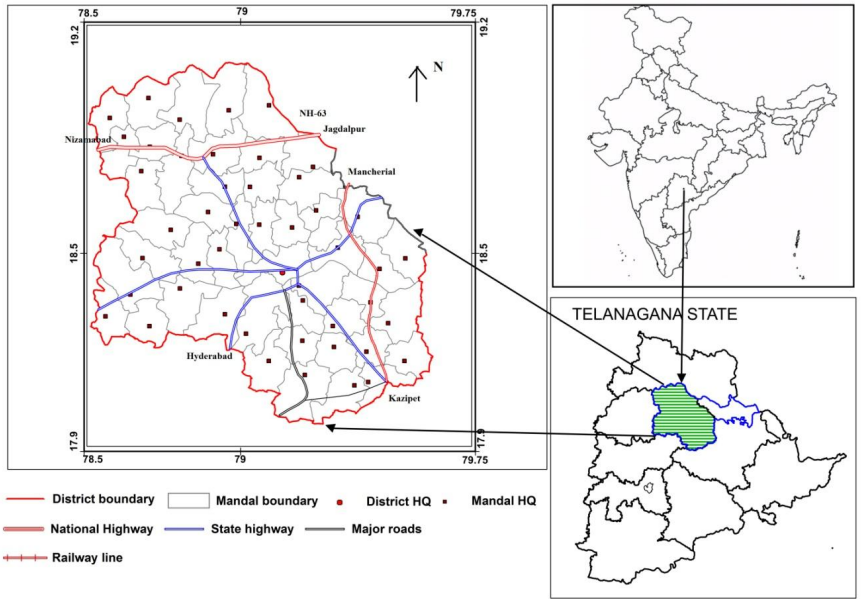



**Fig.1.1:** Location Map of Hard rock areas, Karimnagar district.

**1.4 Climate and Rainfall:** The area experiences dry inland climatic conditions with hot summers and cool winters. The normal mean daily minimum and maximum temperature of 28 °C and 42 °C during summer season (highest recorded ~44 °C during may month) and 15 °C and 30 °C during winter season (December month). The normal annual rainfall varies between 673 mm (Chigurmamidi) and- 1157 mm (Jagityal) with average of 942 mm ( **Fig. 1.2**). ~SW monsoon contributes 81 % and 12 % is contributed by retreating monsoon (NE) season and rest by winter and summer rainfall. Rainfall increases from south to north direction. The area received average annual rainfall of 704 mm (-25% less rainfall than normal rainfall) during the year 2014-2015.

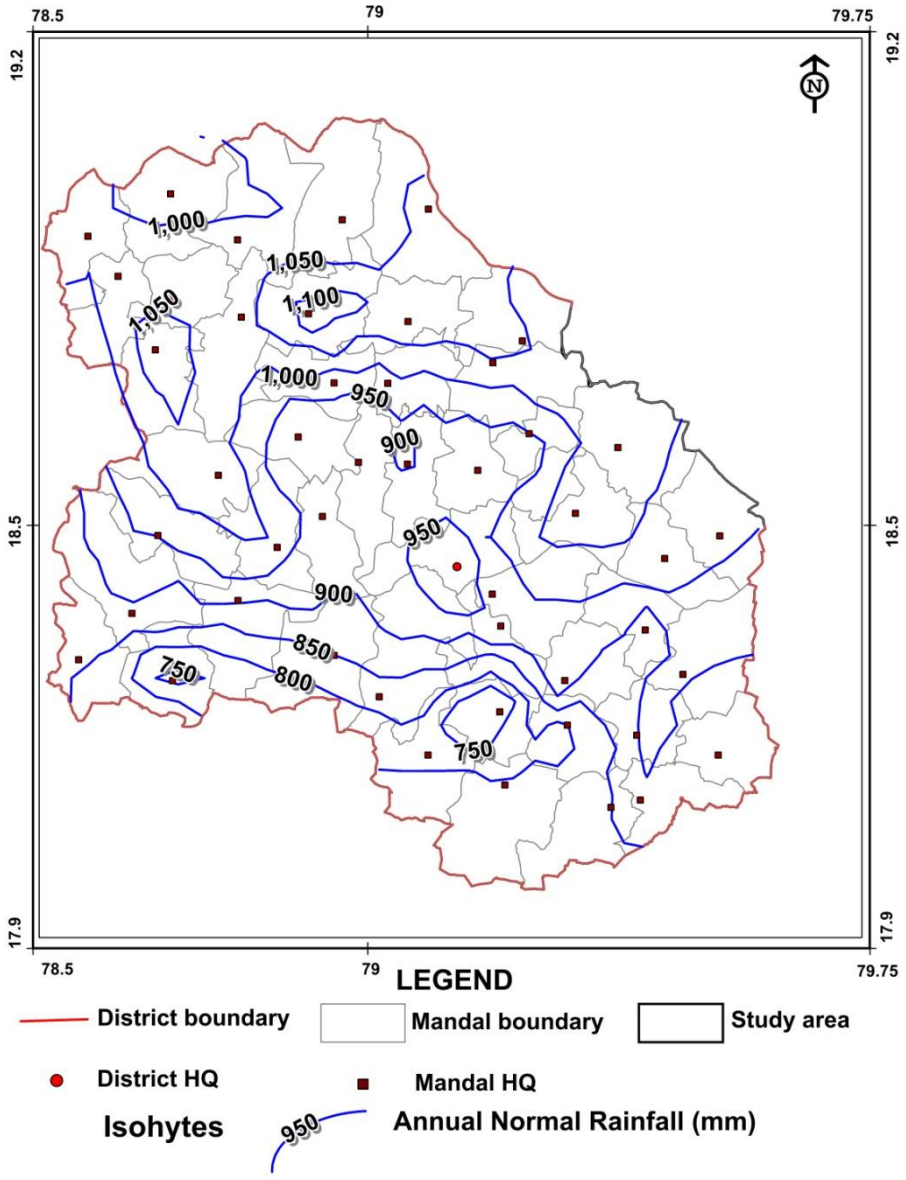



**Fig.1.2:** Isohyetal map Hard rock areas, Karimnagar district.

**1.5 Geomorphological Set up:** Pediplain is the major landform covering about 71 % area. The other landforms observed are pediment (13 %), Denudation hills (7 %), flood plain (3 %), Channel fill and residual hills (2 % each) etc (**Fig.1.3**).

**1.6 Drainage and Structures:** It is part of the River Godavari basin and river Mannair sub basin. The area is further divided in to 43 watersheds having ~52% non-command area and ~48 % command area. Map depicting drainage, hills and water bodies is presented in **Fig.1.4**.

**Fig.1.3:** Geomorphology map.

**Fig.1.4:** Drainage & water bodies map.

**1.7 Land use and land cover:** In the area, the land use can be grouped into 17 types (**Fig.1.5**). The double cropped area occupies ~56 % of the total geographical area, 15 % of area is cultivated during kharif season. Forest occupies ~11 % of the total geographical area, wasteland (with and without shrub) occupy ~ 8% of area; tanks occupy about 4 % of area and the cultivable waste land is ~2 %.

**1.8 Soils:** The soils from area can be broadly grouped into 2 classes and 8 sub classes. Broadly area is occupied by loamy soils (52 %) and clayey soils (48%) (**Fig.1.6**).

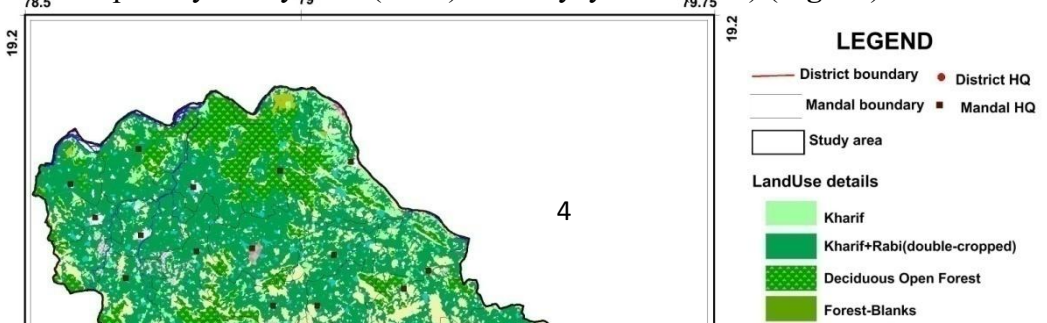


**Fig.1.5:** Land use and land cover map of Hard rock areas, Karimnagar district.

**1.9 Cropping Pattern (2014-15 in Ha):**The gross area sown (2014-15) during kharif season is 458327 ha and during rabi season is 175812 ha (Total: 634139 ha). During kharif season cotton (41%), paddy, (34 %), oil seeds (9 %) maize (7 %), spices (3%) pulses (1 %), groundnut 1 %, other non –food crops 2 % are grown. During rabi season paddy (51 %), maize (30 %), pulses (6%) oil seeds (1 %) and other non-food crops 2 % etc are grown.

**1.10 Irrigation:**

In the area, irrigation need is planned to be met from Sri Ram Sagar Project (Stage-1) located on River Godavari (at Pochampad in Nizamabad district) with (registered ayacut of 166397 ha). The other medium irrigation projects are Mannair Project (ayacut: 5463 ha), Shanigaram Project (ayacut: 2065 ha), Boggalavagu Project (ayacut: 2085 ha) and Minor irrigation schemes (ayacut: 317587 ha). Location map of Major, medium irrigation projects in study area is given in**Fig. 1.7**. In the area there are ~3665 minor irrigation tanks and during the year 2014-15 only 21358 ha area was irrigated from surface sources (including tanks). The salient features of irrigation during 2014-15 are given in **Table-1.1.** It is observed that during 2014-15 ground water contributed 99 % of irrigation needs (Kharif: 96% and Rabi: 99%).

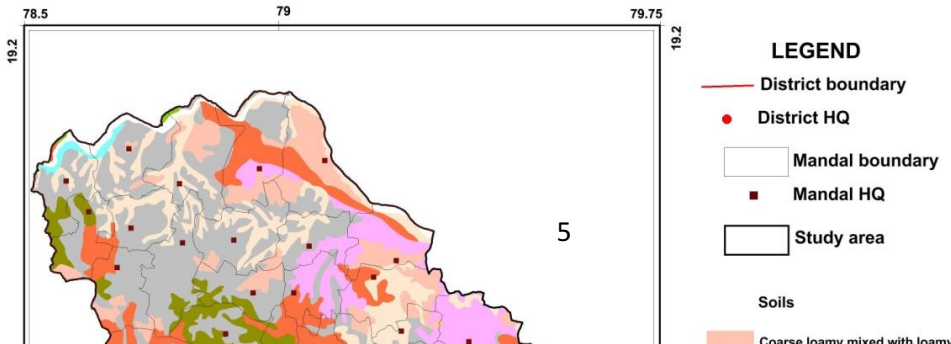


**Fig.1.6:** Soil map of hard rock areas, Karimnagar district.

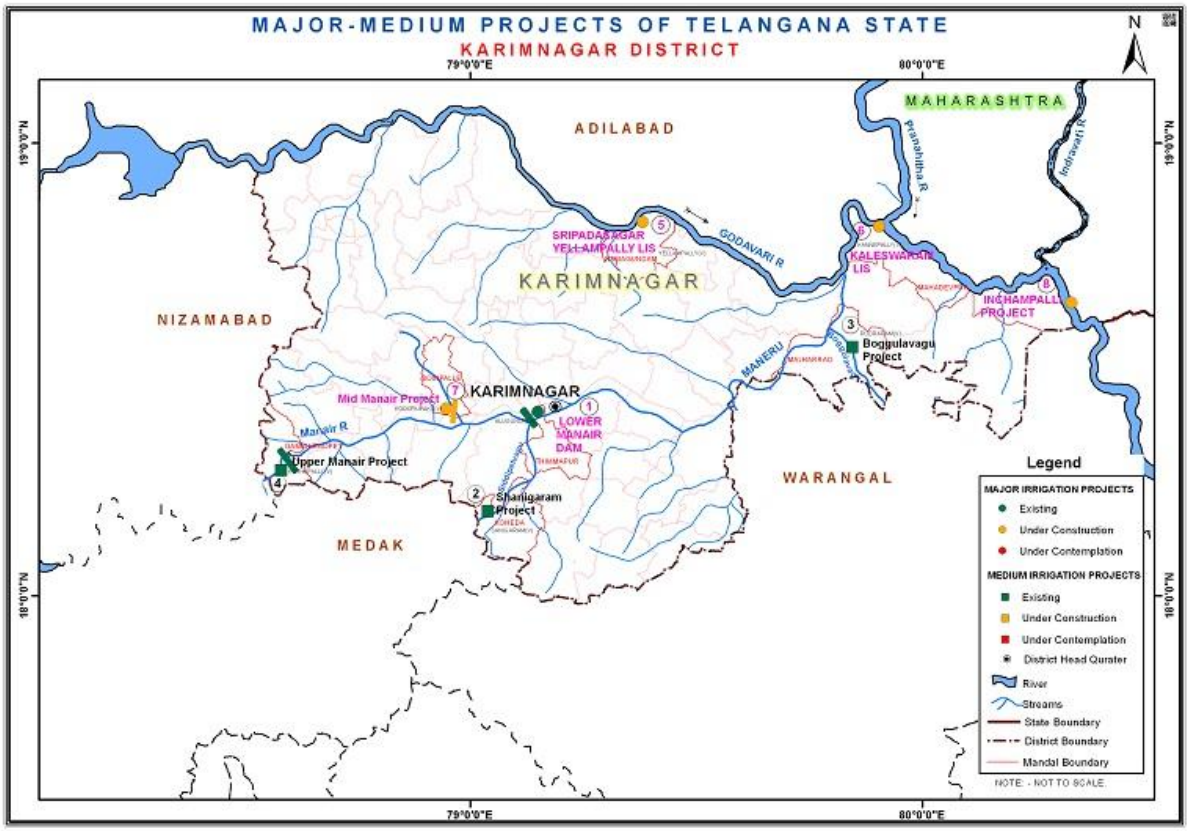



**Fig.1.7:** Irrigation map, Karimnagar district.

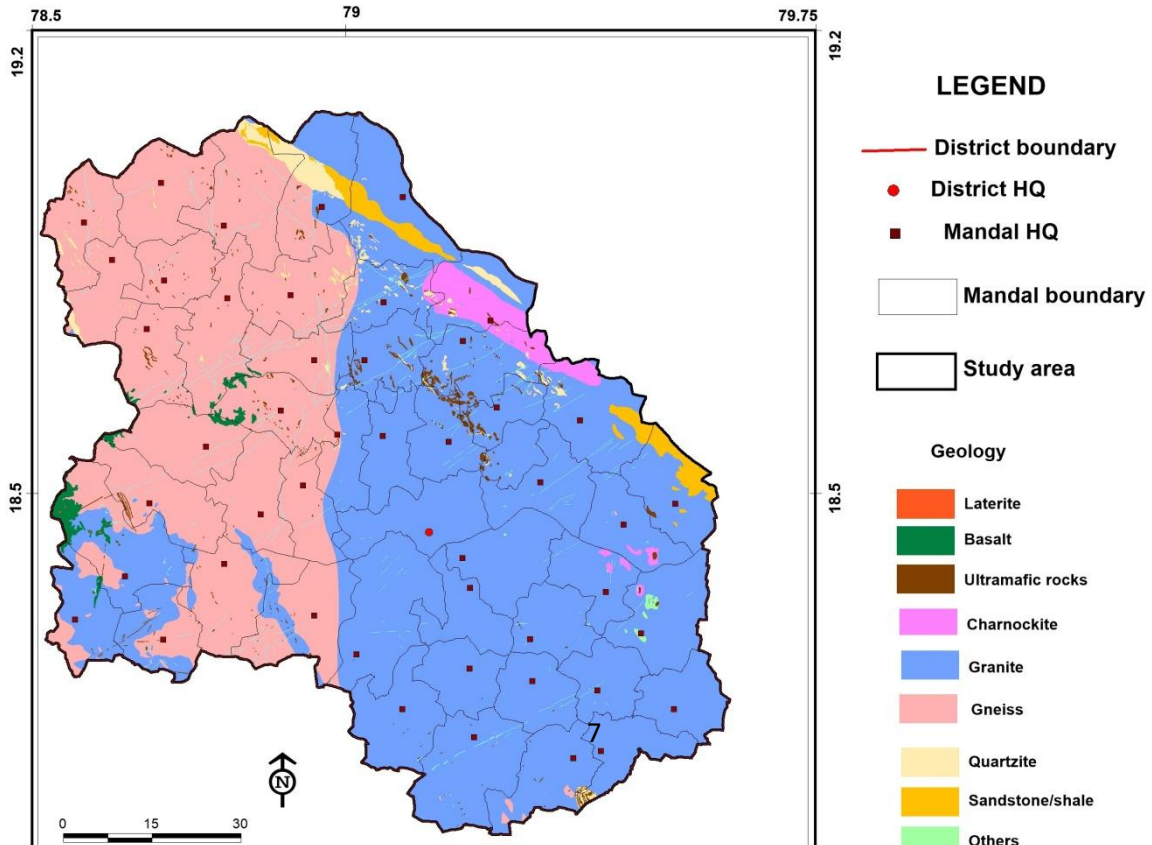
**Table-1.1: Salient features of Irrigation in hard rock areas of Karimnagar district (2014-15)**.

| Source of Irrigation | Kharif | % | Rabi | % | Total | % |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| **2014-15** | **( Ha)** | | **( Ha)** | | **( Ha)** | |
| • Bore wells | 69865 | | 21240 | | 91105 | |
| • Dug wells | 204203 | | 151143 | | 355346 | |
| **Total Ground water** | **274068** | **96** | **172383** | **99** | **446451** | 97 |
| • Canals | 258 | | 0 | | 258 | |
| • Tanks | 11707 | | 1,251 | | 12,958 | |
| • Lift | 0 | | 0 | | 0 | |
| **Total Surface water** | **11965** | **4** | **1251** | **1** | **13216** | **3** |
| **Gross Total Area** | **286033** | | **177674** | | **45667** | |

**1.11 Prevailing Water Conservation/Recharge Practices:** In the area there are ~ 1044 artificial recharge structures (PT: 635 and CD: 409) and ~140 farm ponds. In the district ~32264 ha of agricultural land is brought under micro irrigation from 66506 drip and sprinklers. Under Mission Kakatiya (Phase 1 and 2) total ~4.3 MCM of silt is removed from 937 tanks.

**1.12 Geology:** ~ 59% of the area is underlain by gneisses, 36 % by granite, and 2 % by Charnokite of Archaean to Proterozoic age. Other rocks namely Basalt (<1%), Sandstone/shale (1 %), quartzite (1%) and ultramafic rocks which occurs as patches in central northern part covering <0.1% of area **(Fig1.8).** Dolerite dykes mostly trending NE and SW also occurs in the area.



# 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/<br><br>Identification of Principal Aquifer Units and Data Gap | Compilation of Existing data on groundwater | Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc. |
| | | Identification of Data Gap | Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc. |
| 2. | Generation of Data | Generation of geological layers (1:50,000) | Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern. |
| | | Surface and sub-surface geo-electrical and gravity data generation | Vertical Electrical Sounding (VES), bore-hole logging, 2-D imaging etc. |

| | | | |
|---|---|---|---|
| | | Hydrological Parameters on groundwater recharge | Soil infiltration studies, rainfall data analysis, canal flow and recharge structures. |
| | | Preparation of Hydrogeological map<br><br>(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<br><br>(1:50,000 scale) | Analysis of data and preparation of GIS layers and preparation of aquifer maps | Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data. |
| 4. | Aquifer Management Plan | Preparation of aquifer management plan | Information on aquifer through training to administrators, NGO's progressive farmers and stakeholders etc. and putting in public domain. |

## 2.1 Hydrogeological Studies

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of ground water occurring in the subsurface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. The principal aquifer in the area is 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. Based on 499 hydrogeological data points (Exploration: 128 (CGWB: 74 and SGWD: 54), VES: 195 and Well inventory: 176) hydrogeological map is prepared (**Fig.2.1).**

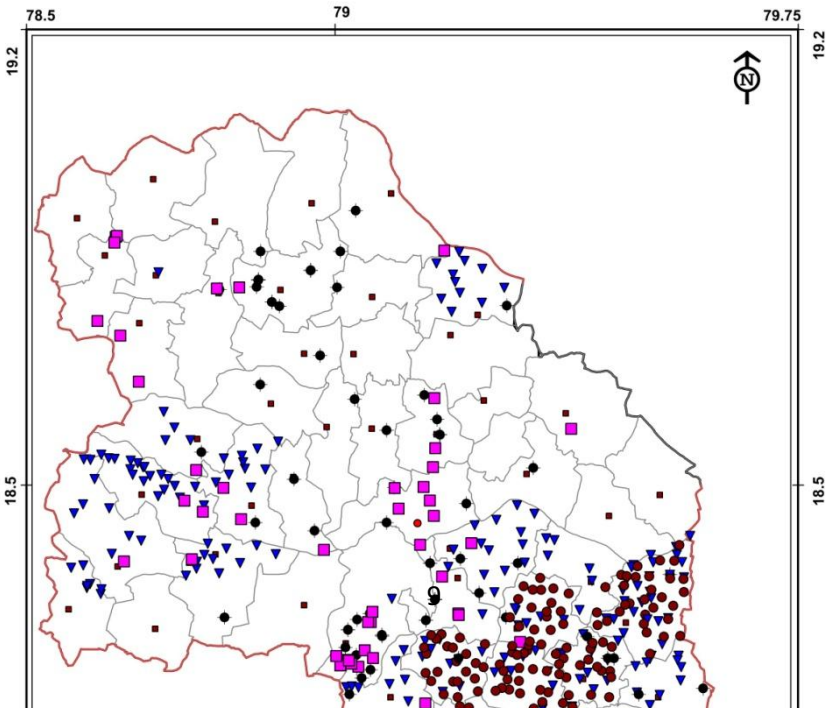


**Fig. 2.1:** Hydrogeological data availability, Hard rock areas, Karimnagar district.

**2.1.1 Ground water occurrences and movement** Ground water occurs under unconfined and semi-confined conditions and flows downward from the weathered zone into the fracture zone. 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 100 m depth. The storage in granite/gneiss rocks is primarily confined to the weathered zone and its over exploitation has resulted in desaturation at many places and at present, extraction is mainly through boreholes of 60-100 m depth.

**2.1.2 Exploratory Drilling:** As on 31/03/2017, CGWB drilled 74 bore wells (exploratory, observation and piezometers) and SGWD drilled 54 wells in the hard rock areas of the district. Data analysed from CGWB wells indicates 3 wells are of shallow depth (30 m), 33 nos (30-60 m), 28 nos (60-100 m) and 10 nos (200 m) depth**.**

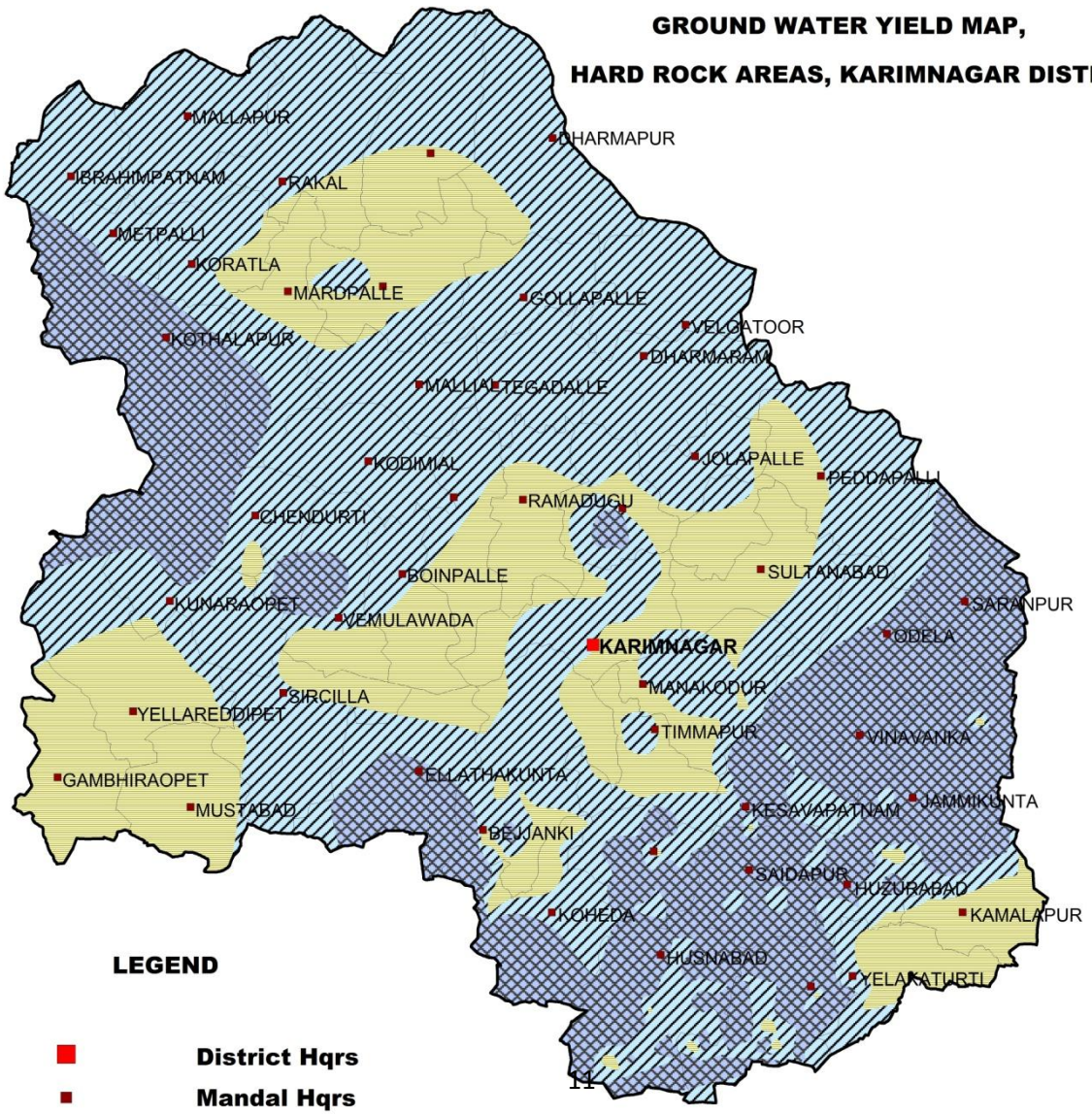
In the district, there are ~2.75 lakhs existing wells (Irrigation DW: 2.3 lakhs, Irrigation BW: 0.35 lakhs and rest domestic wells 0.10. Various hydraulic properties of the aquifers are discussed in C**hapter -3**.

**2.1.3 Ground water Yield:** Yields from granite/gneiss formation varies from < 0.1 and 10 litres/second (lps). Low yield (< 1 lps) occur in ~25 % of area covering Gambhiraopet, Yellareddypet, Mustabad, Mardpalle, Jagatyal, Sircilla, Vemulawada, Gandhara, Ramadugu, Karimnagar, Sultanabad, Timmapur, Kamalapur, Yelakatur etc. Moderate yield (1 to 3 lps)

occur in most of the area covering ~51 % of area and higher yield (>3 lps) occur in south-eastern and central western part of area (24% of area) (**Fig. 2.2)**. Studies from hydrogeological data reveal that all fractures occur within 100 m depth and deepest fracture is encountered at 167 m depth (Dharmaram in Jammikunta mandal). The hydrogeological map of the area is presented in **Fig.2.3**.

**2.2 Water Levels (DTW) (2016):** Water level data from 271 wells (CGWB: 60, SGWD: 96 and Key wells: 115 was utilised. The DTW varies from 4.97 to 31 meter below ground level (m bgl) (average: 13.6 m bgl) and 0.2 to 18.7 m bgl (average: 5.7) during pre-monsoon (May) and post-monsoon (November) season of 2016 respectively.

**2.2.1 Water Table Elevations (m amsl):** During pre and post-monsoon season, water-table elevation ranges from 148.0-439.0 and 154.3-452.5 meter above mean sea level (m amsl) respectively and general ground water flow is towards the river Mannair and the river Godavari from western to eastern and from western to northern part respectively (**Fig.2.4**).



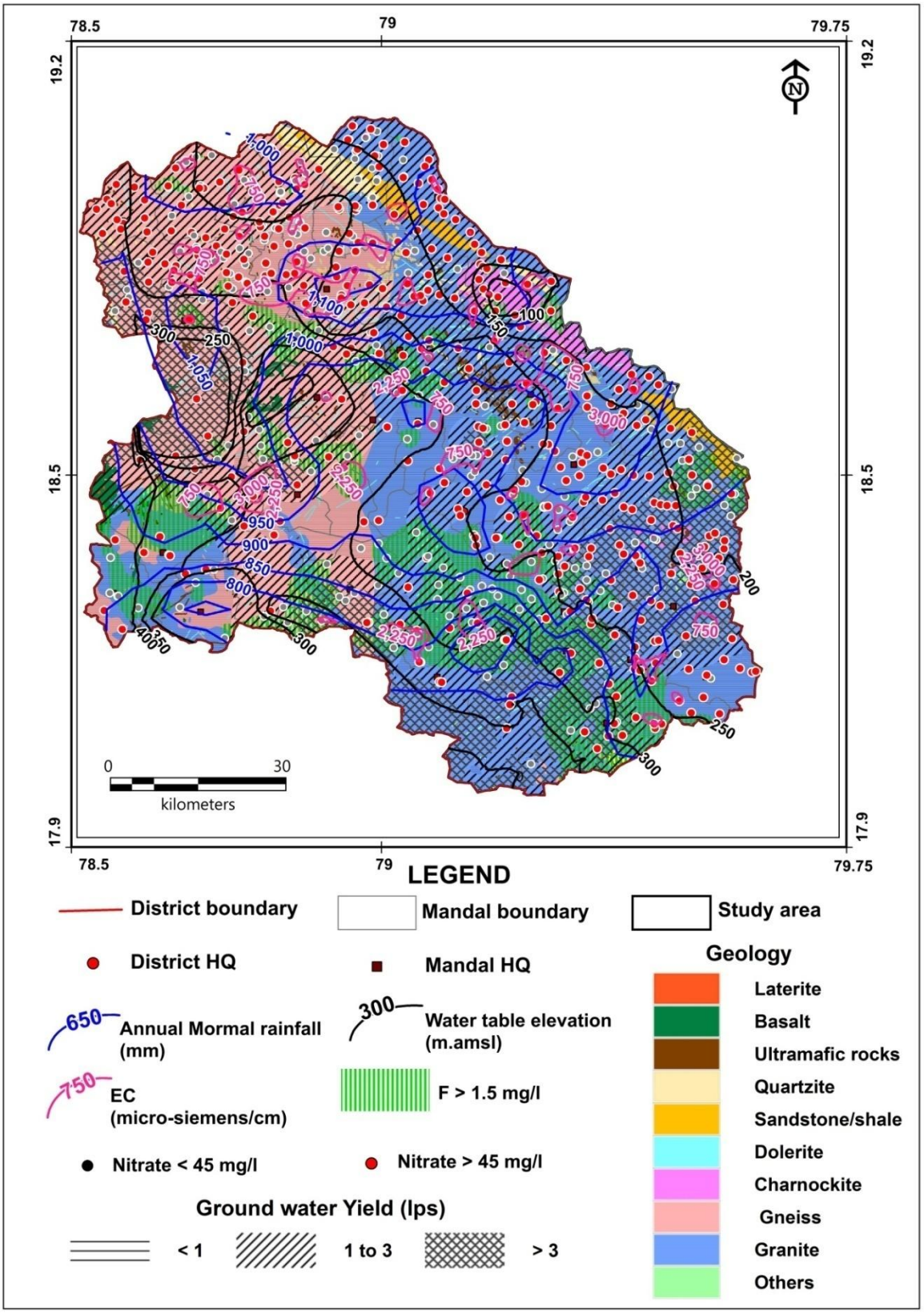





**Fig.2.3:** Hydrogeological map of Hard rock areas, Karimnagar District.

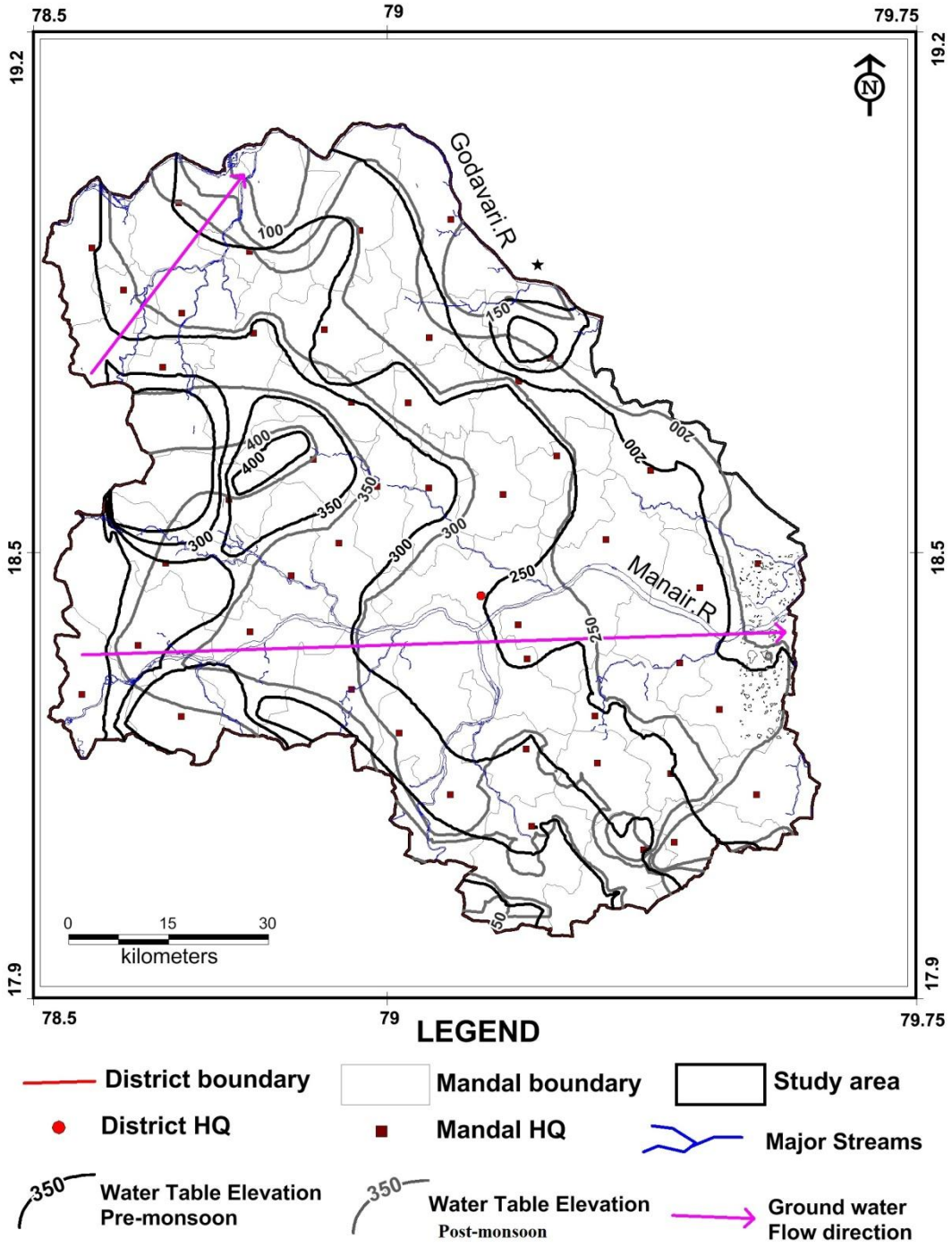



**Fig.2.4:** Water Table Elevation Map, Karimnagar District.

**2.2.2 Pre-monsoon Season:** Majority of the water levels during this season are in the range of 10-20 m covering 67 % of the area, followed by 5-10 m bgl (25 %). Deep water levels > 20 m bgl occupy about 8 % of the area covering Gambhirraopet, Yellareddypet, Vemulwada, Ellathakunta, Bejjanki and Gangadhara mandals ( **Fig.2.5**). Shallow water levels (2-5 m bgl) occupy about < 1 % of area in Kamalapur mandal.

**2.2.3 Post-monsoon Season:** Majority of the water levels during this season are in the range of 2-5 m bgl, covering 48 % of the area, covering northern and eastern part of the area. Water levels in the ranges of 5-10 m bgl water levels occupy 43 % of the area covering most of western part. Water levels in the range of 0-2 m bgl occupy ~4 % area and water levels in the range of 10-20 m bgl occupy ~5 % of the area covering Konaraopet, Sircilla, Vemulwada, Bejjanki and Koheda mandals etc (**Fig.2.6**).

**2.2.4 Water Level Fluctuations (November vs. May):** Out of 271 wells, 270 wells show a rise in water levels in the range of 1.25 to 23.4 m bgl (average:8 m) ( **Fig.2.7**). Only 1 well shows fall in water levels (-6.03 m) (Indurthi in Chigurumamidi mandal). ~64 % of the area has shown water level rise in the range of 5-10 m, 0-2 m rise is observed in < 1 % of area, 2-5 m in 13 %, 10-20 m in 22 % of area and > 20 m in 1% of an area covering Sircilla, Mustabad and Yellareddipet mandals.

**2.2.5 Long term water level trends (2007-2016):** Trend analysis for the last 10 years (2007-2016) is studied from 95 hydrograph stations of CGWB (49 nos) and SGWD (46 nos). During pre-monsoon season, 84 wells show falling trends -0.03 m/yr to -2.33 m/yr (0 to 1 m: 77 wells, 1-2 m: 6 wells and > 2: 1 well) and 11 wells shows a rising trend in the range of 0.02 to 0.63 m/yr ( **Fig. 2.8** ) in south-western, north western and eastern part as patches. During post-monsoon season, 72 wells shows falling trends in the range of -0.01 m/yr to -1.39 m/yr (0 to 1 m: 70 wells and 1-2 m: 2 wells) and 23 wells shows a rising trends in the range of 0.01 to 0.60 m/yr (all below 1 m) and (**Fig. 2.9**). Rise is mostly observed in southern, western and eastern part as patches.

Average water levels for the last 10 years (2006-15) were compared with 2016 data and it is found that during 2016 pre-monsoon season 79 wells have shown fall and 16 wells have no sufficient data and during post monsoon season 7 wells shown fall and 58 shown rise in water levels.

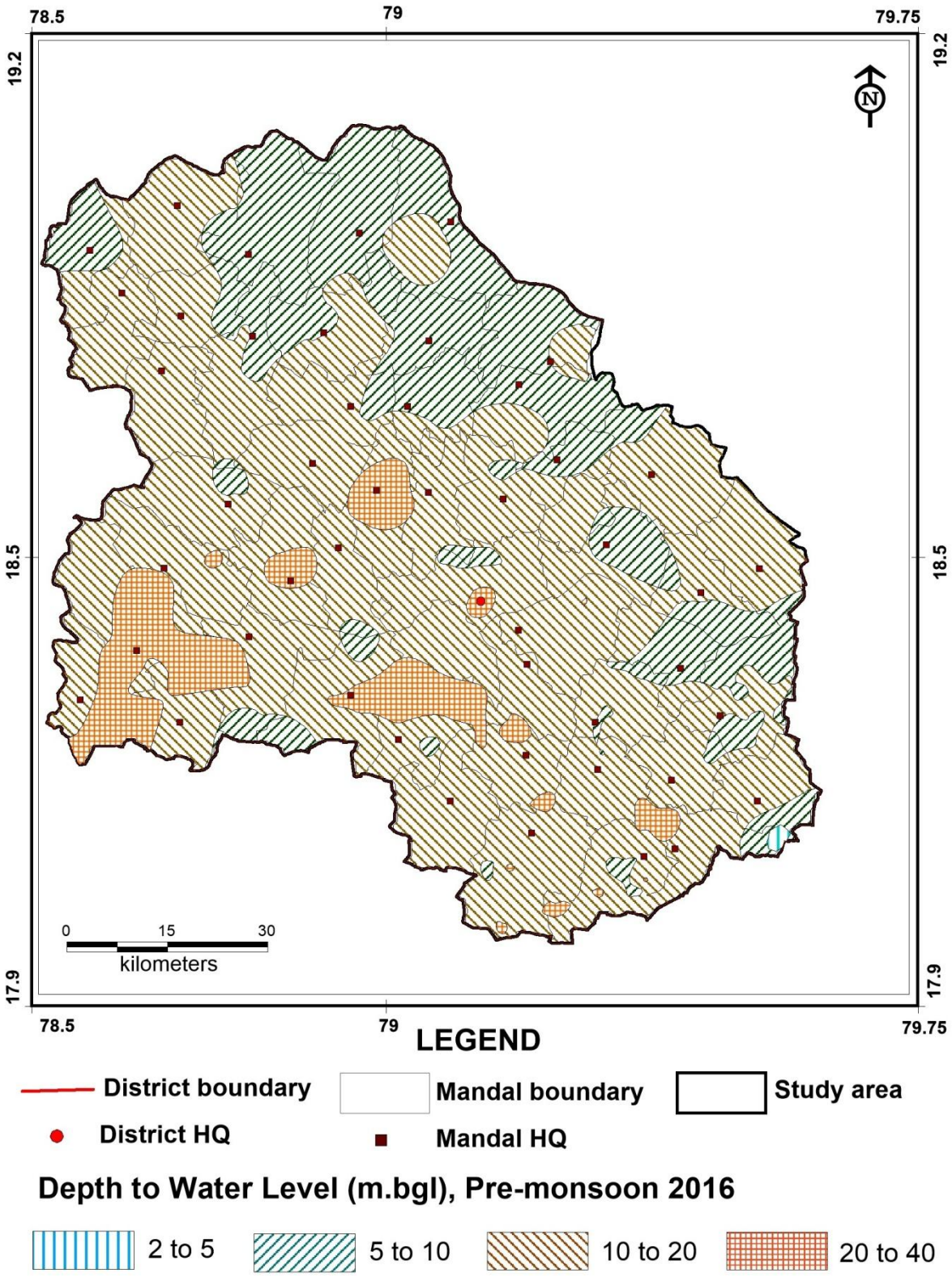



**Fig.2.5:** Depth to water levels Pre-monsoon (May-2016).

**Fig.2.6:** Depth to water levels Post-monsoon (Nov-2016).

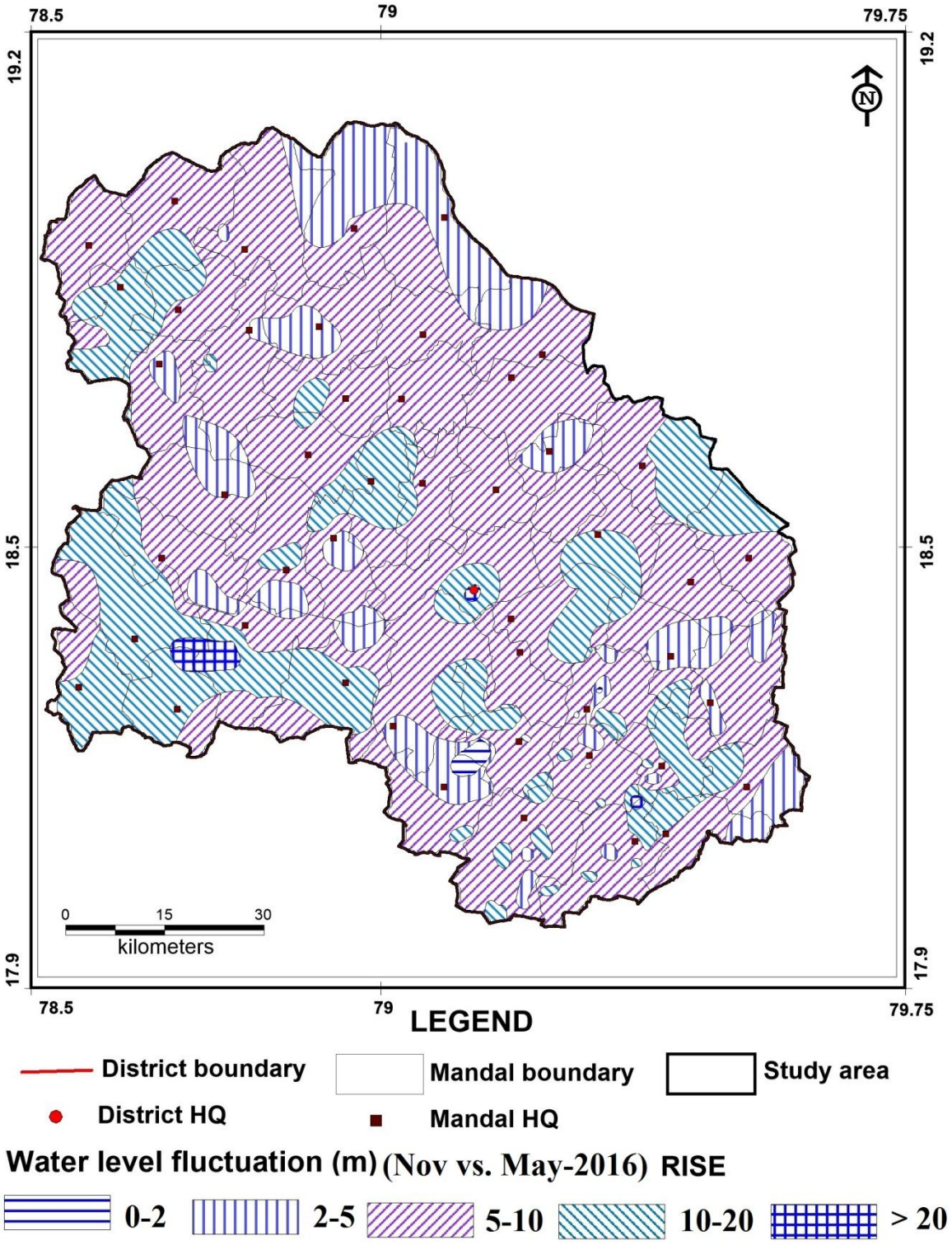



**Fig.2.7:** Water Level Fluctuations (m) (Nov vs. May-2016).

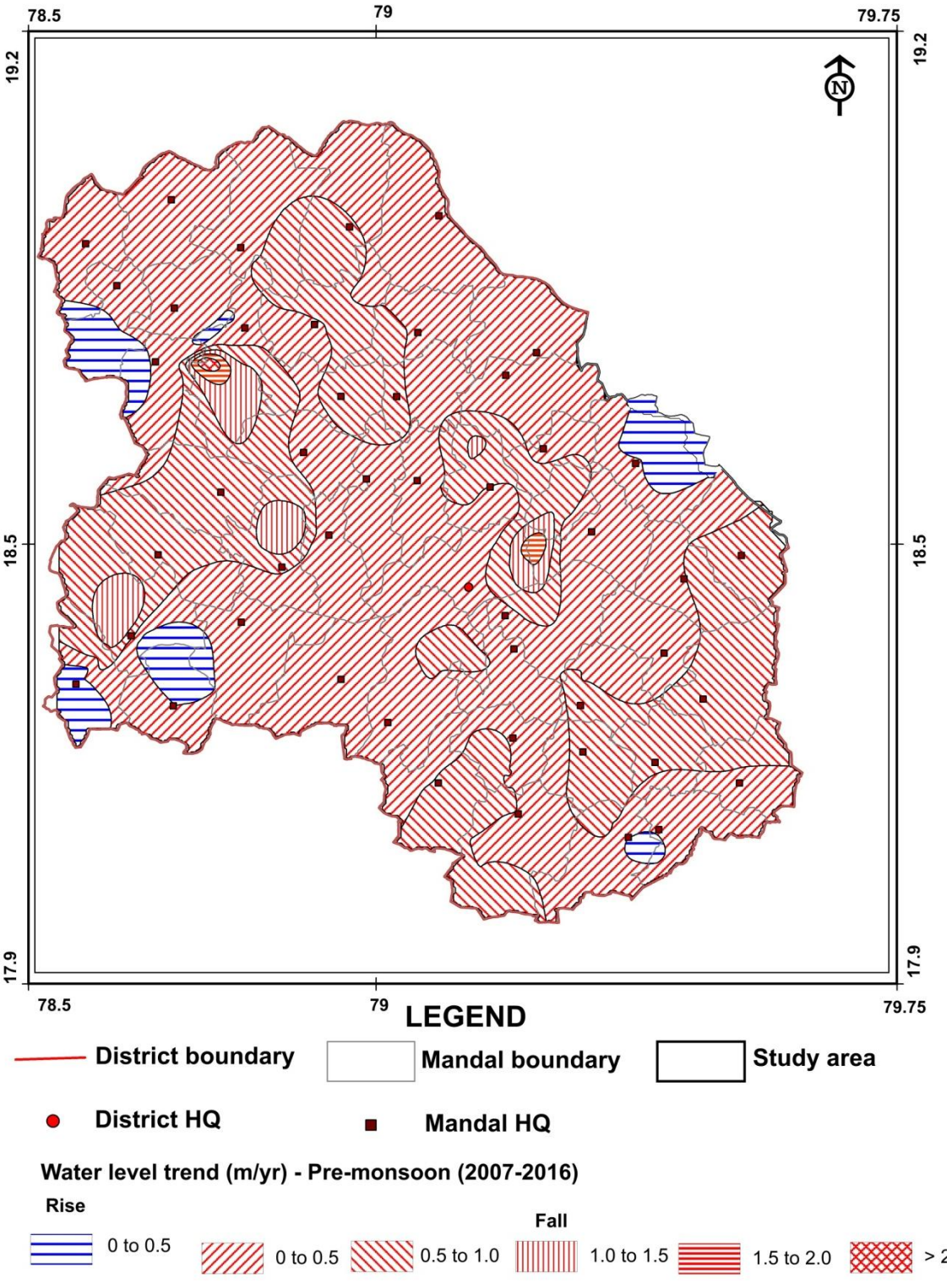



**Fig. 2.8:** Long-term water level trends (Pre-monsoon-2007-16).

**Fig. 2.9:** Long-term water level trends (Post-monsoon-2007-16).

## 2.3 Geophysical Studies

A total of 195 VES data of CGWB is interpreted, which reveals resistivity < 90 Ohm (Ω) m for the weathered granite, 90-180 Ω m for underlying semi weathered granite, between 180-350 Ω m fractured granite and > 350 Ω m for massive granite.

## 2.4 Hydrochemical Studies

To understand chemical nature of groundwater, total 1263 data is utilized from CGWB (Pre-monsoon:12 nos), SGWD (Pre: 405 & Post: 416) and RWS (pre: 258 & Post: 172) wells during 2015. 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.

### 2.4.1 Pre-monsoon (May-2015) (675 samples-CGWB: 12, SGWD: 405 & RWS: 258)

Groundwater from the area is mildly alkaline in nature with pH in the range of 7-9.3 (Avg: 8.0). Electrical conductivity varies from 343-4681 µ Siemens/cm (avg: 1282). In 70 % of samples (476 nos) covering 67 % of area, EC is within 1500 µ Siemens/cm and in 188 samples covering 32 % area in the range of 1500-3000 µ Siemens/cm. > 3000 EC is observed in 11 samples covering 1 % of area (falling in patches in Konaraopet, Bejjanki, Jammikunta and Peddapalli mandals) and is not suitable for irrigation ( **Fig.2.10).** Concentration of TDS varies from 230 to 3136 mg/L (avg: 859 mg/l) and found that 98 % of samples falls within maximum permissible limits of BIS (2000 mg/l). $NO_3$ concentration ranges from BDL to 592 mg/l and found 58 % of samples (391 nos) are unfit for human consumption (> 45 mg/l) ( **Fig.2.11**). Fluoride concentration varies from 0.1-6.0 mg/L **(Fig 2.11**) and found that 167 samples (25 %) covering 21 % area are unfit for human consumption (>1.5 mg/l). High fluoride concentration (>1.5 mg/l) is observed in mandals located in south-western, southern and central part ((Gambirraopet, Yellareddipet, Ellathakunta, Bejjanki, Chigurumamidi, Koheda, Saidapur, Yelakatur, Boinpally, Chendurthi, Tegadpalle, Mallal mandals) and eastern part mandals namely Odela and Saranpur etc.

### 2.4.2 Post-monsoon (November-2015) (Total 588 samples (SGWD: 416 & RWS: 172)

Groundwater from the area is mildly alkaline in nature with pH in the range of 6.9-9.3 (Avg: 8.1). Electrical conductivity varies from 315-3830 µ Siemens/cm (avg: 1285). In 71 % of samples (420 nos) covering 79 % of area, EC is within 1500 µ Siemens/cm and in 165 samples covering 21 % area in the range of 1500-3000 µ Siemens/cm. > 3000 EC is observed in 3 samples covering < negligible area of area (in Kamalpur mandal) and is not suitable for irrigation (**Fig.2.12).** TDS concentration varies from 211 to 2566 (avg: 861 mg/l) and found that 99.5 % of samples falls within maximum permissible limits of BIS (2000 mg/l) and only 3 falls beyond permissible limits of (BIS) (falling in Kamlapur and Keshavpatnam mandals). $NO_3$ concentration ranges from BDL to 479 mg/l and found 68 % of samples (402 nos) are unfit for human consumption (> 45 mg/l) ( **Fig.2.13**). Fluoride concentration varies from 0.1-5.0 mg/L (**Fig 2.13**) and found that 95 samples (16 %) covering 15 % area are unfit for human consumption (>1.5 mg/l). High fluoride concentration (>1.5 mg/l) is observed in mandals located in central, southern and eastern part of the area (Konaraopeta, Vemulwada, Ellathakunta, Boinpalle, Bejjanki, Saidapur Bheemadevarpalle, Gangadhara, Dharmaram etc. mandals).

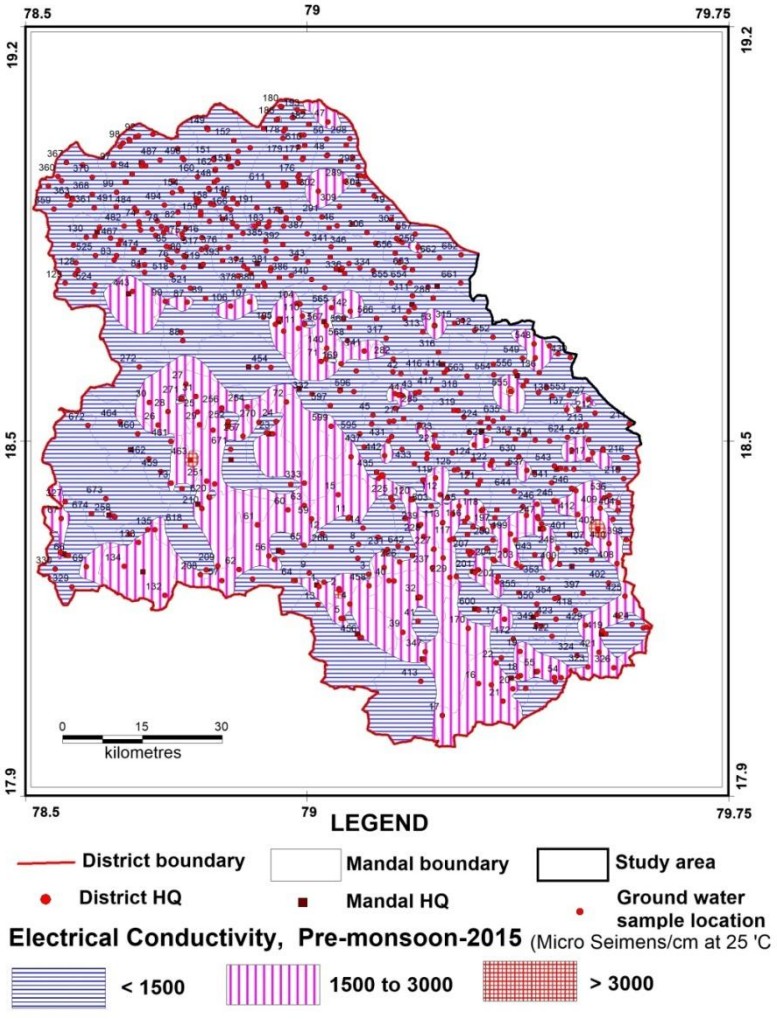


**Fig.2.10:** Distribution of Electrical conductivity (Pre-monsoon-2015).

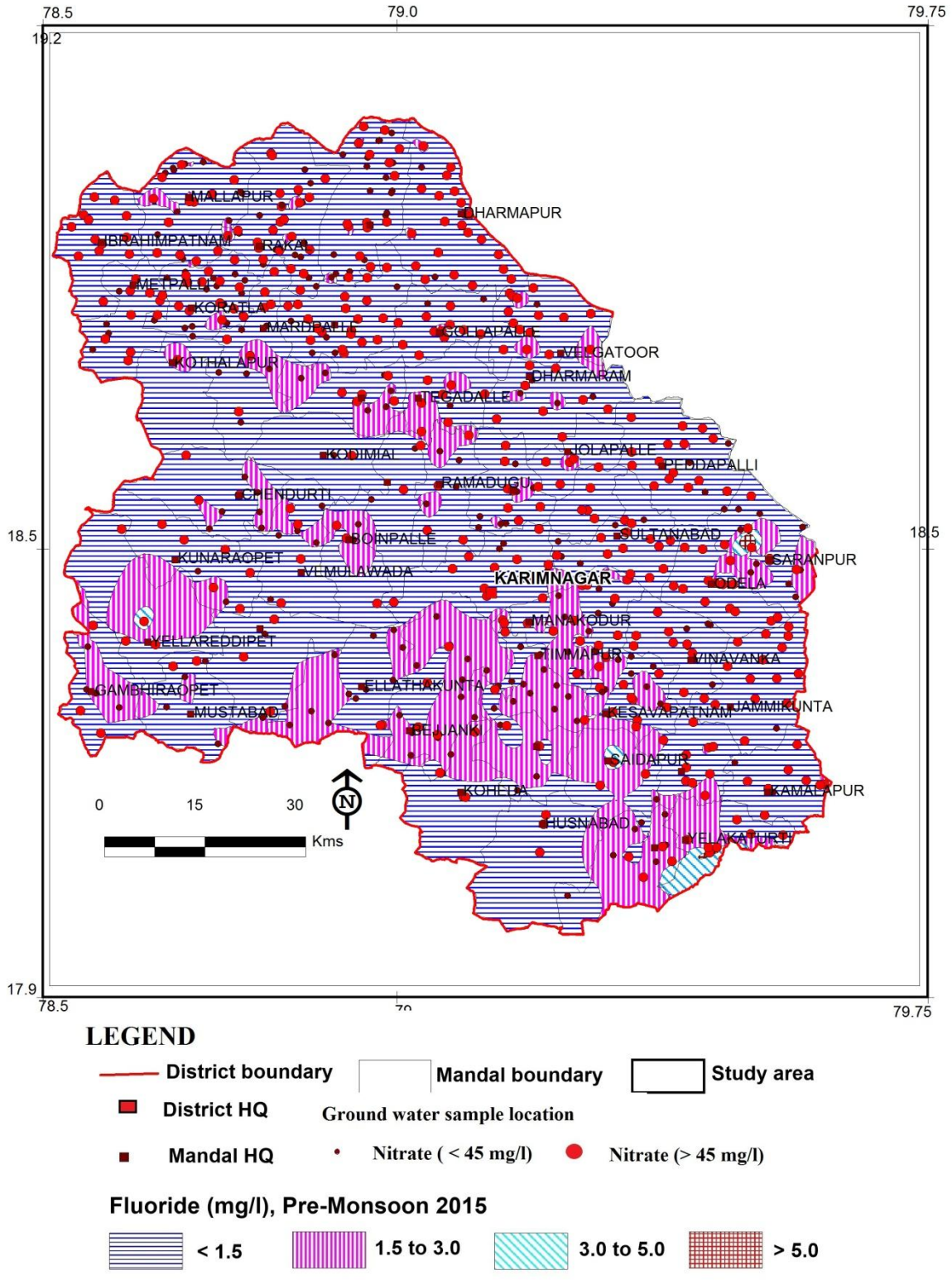



**Fig.2.11:** Distribution of Nitrate and Fluoride (Pre-monsoon-2015).

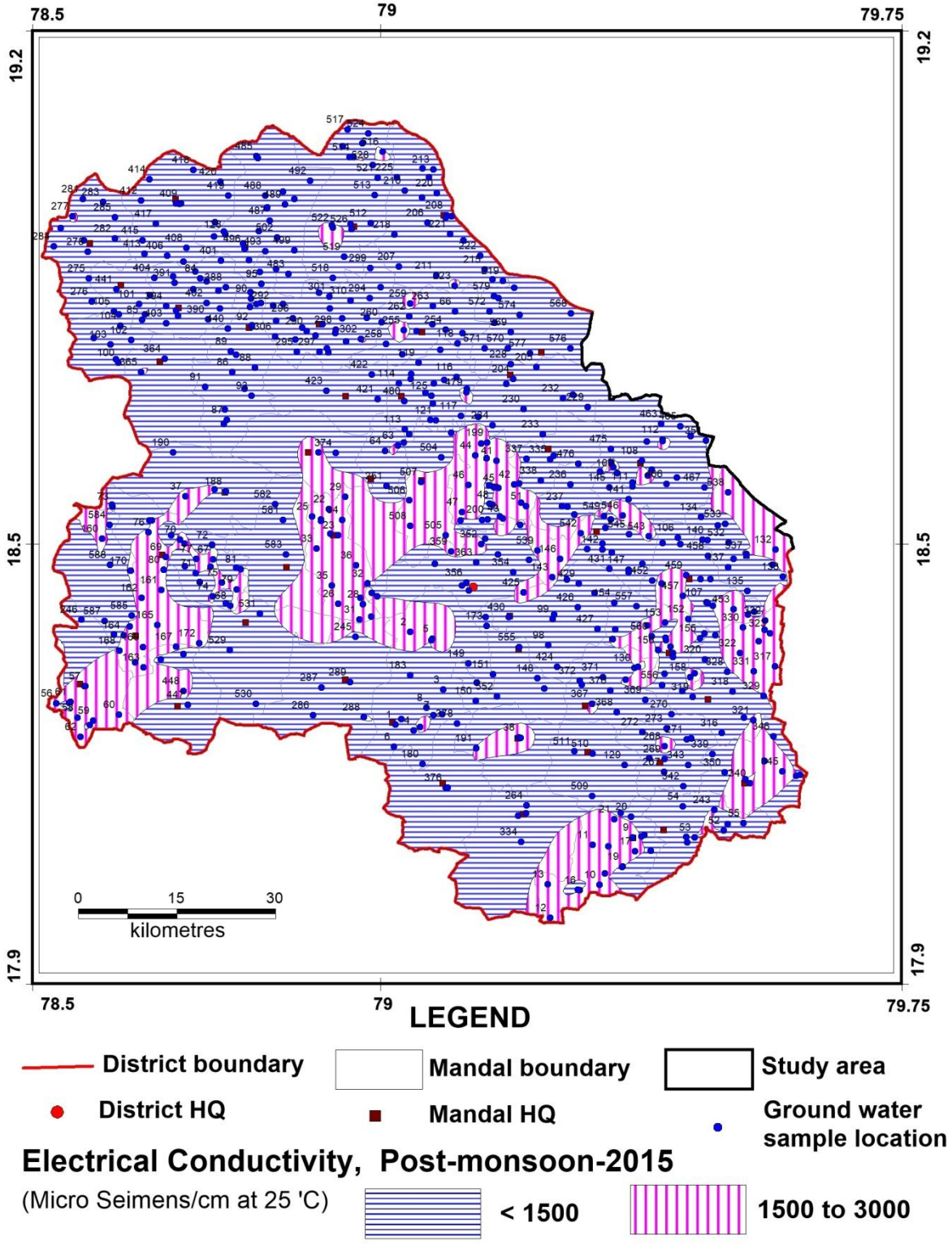



**Fig.2.12:** Distribution of Electrical conductivity (Post-monsoon-2015).



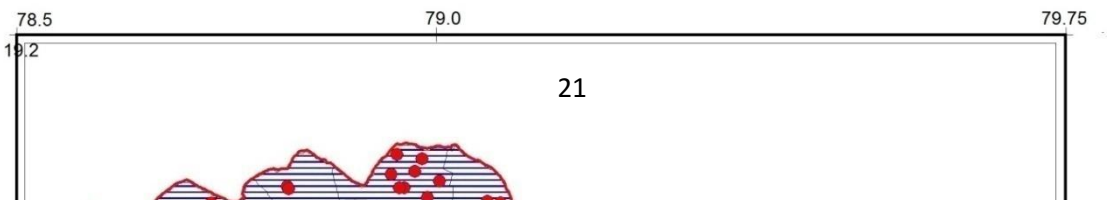


**Fig.2.13:** Distribution of Nitrate and Fluoride (Post-monsoon-2015).

## 3. DATA INTERPRETATION, INTEGRATION and AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 499 data points (Exploration: 128 (CGWB: 74 and SGWD: 54), VES (CGWB): 195 and Well inventory: 176) down to 200 m for preparation of 3-D map, panel diagram and hydrogeological sections. The data ( **Fig.2.1**) is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data. The lithological information was generated by using the RockWorks-16 software and generated 3-D map for hard rock areas of Karimnagar district ( **Fig.3.1)** along with panel diagram ( **Fig. 3.2** ) and hydrogeological sections.

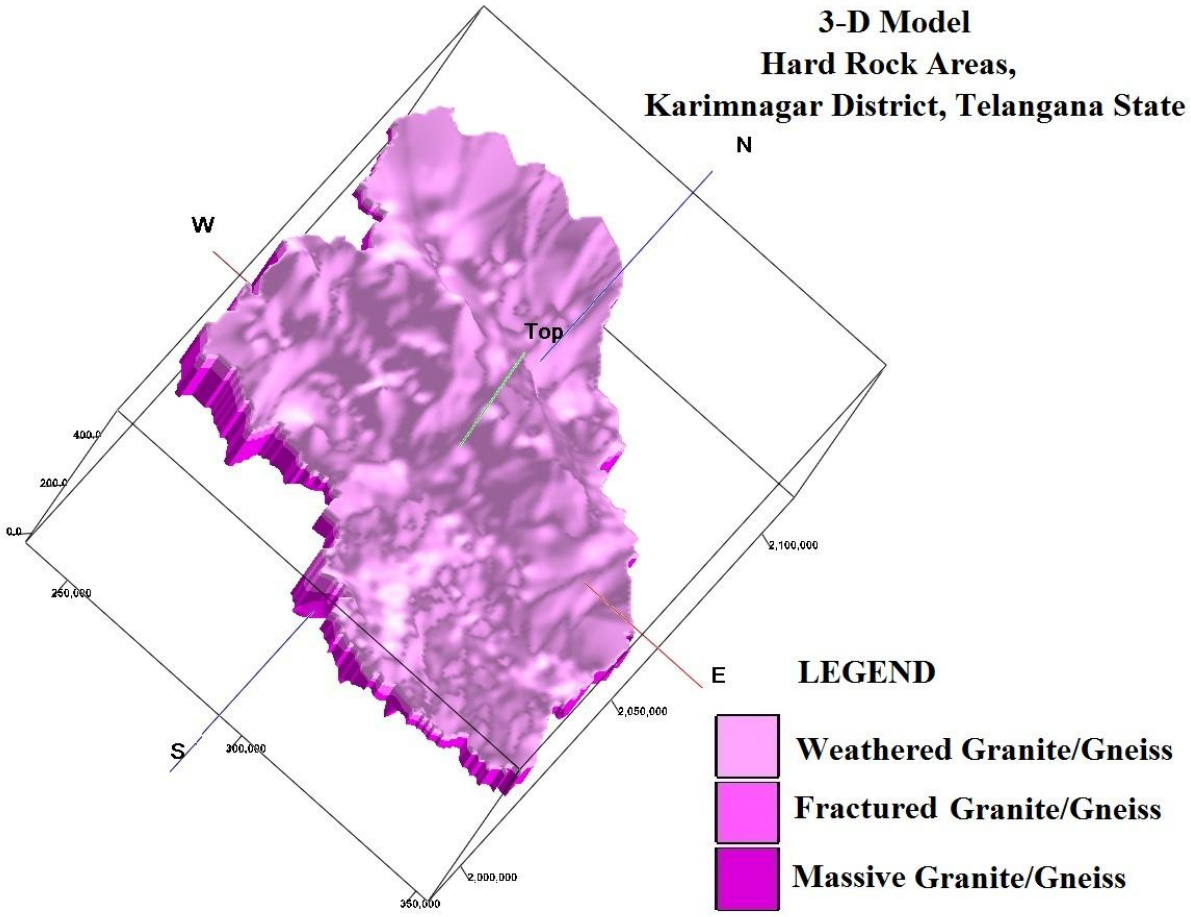



**Fig.-3.1:**3-D Model for study area.

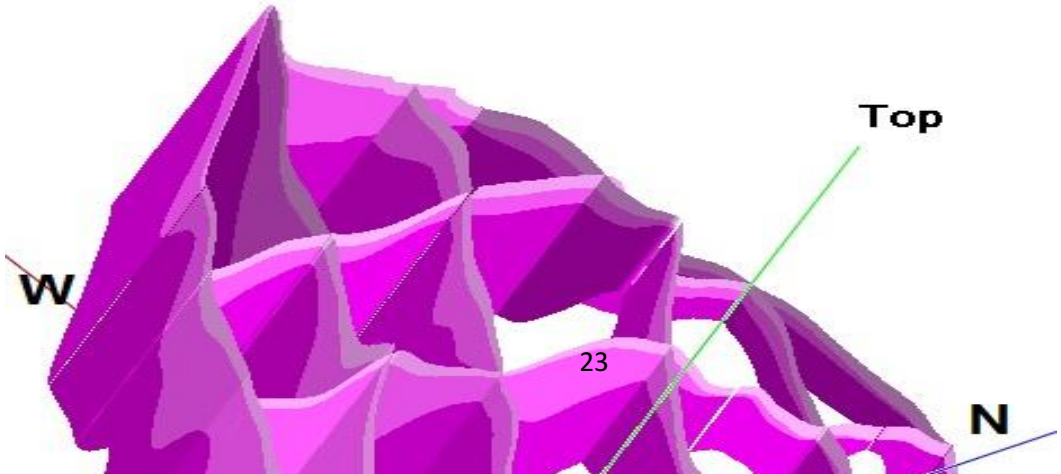


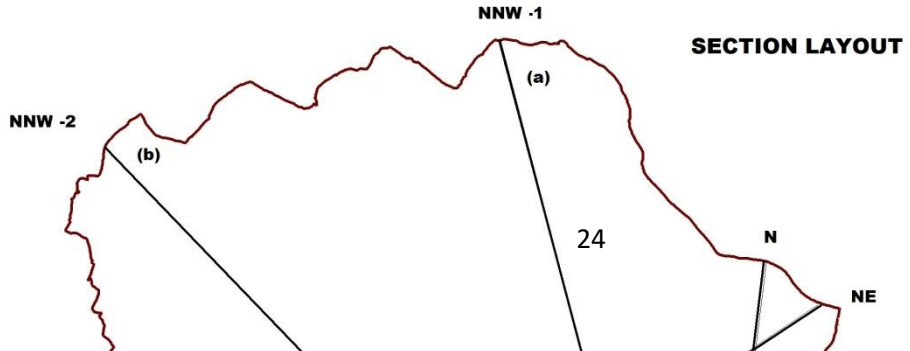
**Fig.-3.2:** Panel Diagram, Hard rock areas, Karimnagar district.

### 3.1 Conceptualization of aquifer system in 3D

Aquifers were characterized in terms of potential and quality based on integrated hydrogeological data and various thematic maps. Weathered zone is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~30 m depth (avg depth 13 m) and the fractured zone is considered up to the depth of deepest fracture below weathered zone (~30-167 m). Out of 499 data points ~30 % of data points (151 nos) have information down to 200 m depth and 10, 25, 105, 91 and 117 data points have information down to 150-192, 100-150, 60-100, 30-60 and < 30 m respectively.

### 3.2 Hydrogeological Sections

Five hydrogeological sections are prepared in NNW-SSE-1 (a), NNW-SSE-2 (b) and NW-SE (c), NE-SW (d) and N-S (e) directions (**Fig. 3.3)**.



**3.2.1 NNW-SSE-1 Section (a):** The section drawn along the NNW-SSE direction covering distance of ~110 kms ( **Fig.3.4a**). It depicts uniform weathered zone throughout the section. Thick fractured zone occurs from a distance of ~70 kms further SSE directions.

**3.2.2 NNW-SSE-2 Section (b):** The section drawn along the NNW-SSE direction covering distance of ~140 kms ( **Fig.3.4b**). It depicts thick weathered zone from NNW direction to 20 km distance and again between ~90-135 kms. Thick fractured zone occurs between ~55-65, ~85 and ~125 kms from NNW direction.

**3.2.3 NW-SE Section (c):** The section drawn along the NW-SE direction covering distance of ~115 kms (**Fig.3.4c**). It depicts uniform weathered zone in entire section. Thick fractured zone occurs in NW part up to ~40 km distance and in other part no major fractures are encountered.

**3.2.4 NE-SW Section (d):** The section drawn along the NE-SW direction covering distance of ~93 kms (**Fig.3.4d**). It depicts uniform weathered zone in entire section. Thick fractured zones are encountered at a distance of 3 to 20 kms, 43-60 Kms from NE directions.

**3.2.5 N-S Section (e):** The section drawn along the N-S direction covering distance of ~95 kms (**Fig.3.4e**). It depicts comparatively thick weathered zone in Southern part and thick fractured zones in Northern part and between 65-70 kms. In central part no major fractured zones are encountered.

### 3.3 Aquifer Characterization

**3.3.1 Weathered zone:** The weathered zone (~30 m) consisting of upper saprolite (~10 m) and lower sap rock (10-30) has gone dry in ~75 % of area due to over-exploitation during pre-monsoon season and dug wells, which were in operations earlier, have gone dry and become defunct. In most of the area 10-20 m (68 %) weathering is most common followed by < 10 m (26 %). Deep weathering (> 20 m) occurs in Mallapur, Peddapalli and southern mandals covering 6 % of area (**Fig.3.5**).

Ground water yield from weathered granite/gneiss aquifer varies from <0.1 to 10 lps. Lower yields (< 1 lps) occur in central part of study area and moderate yields (1-3 lps) occur in eastern part and higher yields (> 3 lps) occur in western, southern and eastern part of study area (**Fig. 2.2** ). The transmissivity varies from 1-412 $m^2$/day and in majority of wells it is ~20 $m^2$/day, specific yield (Sy) ranges from < 1 to 2.3 %.( avg: 1 %).

**Fig.3.4 (a-d):** Hydrogeological sections in different directions, Hard rock areas, Karimnagar district.

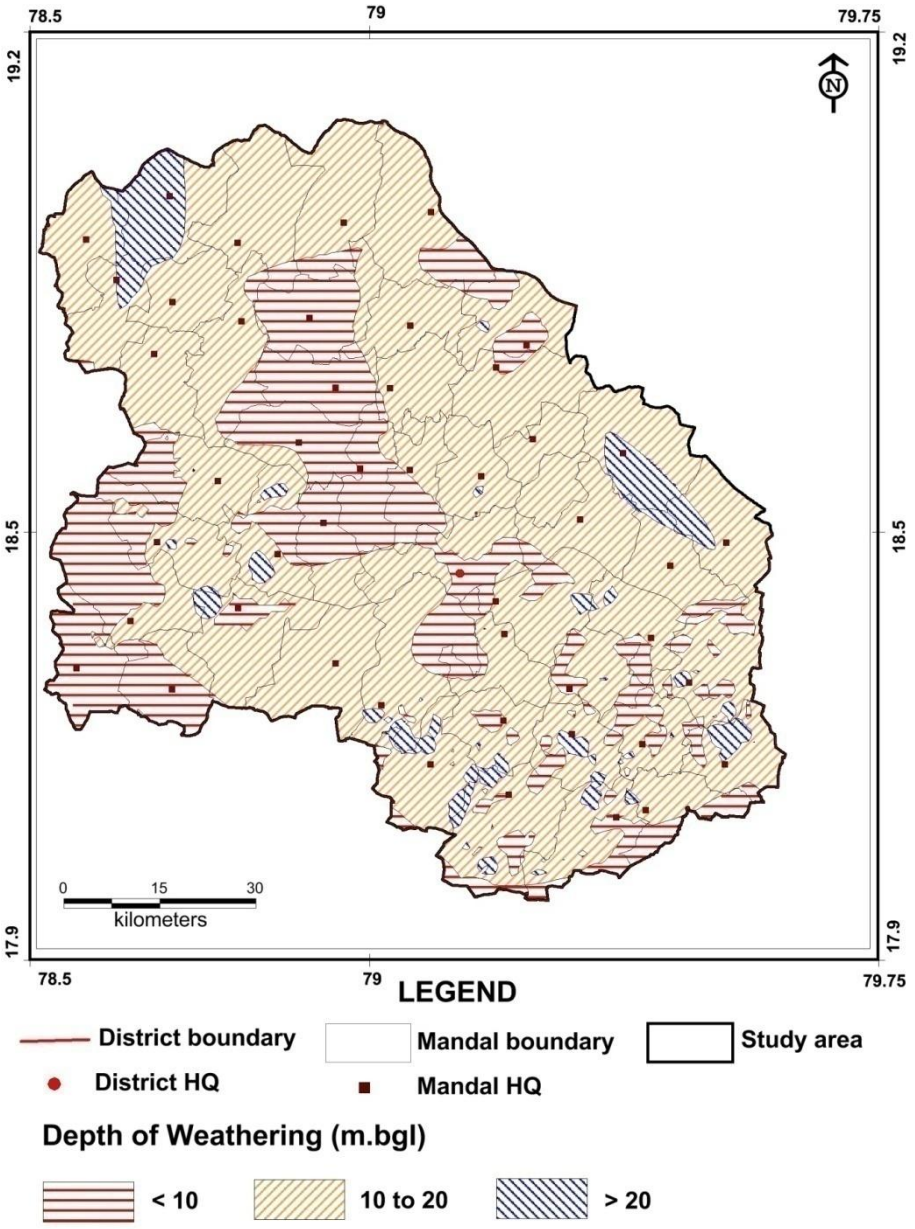



**Fig.3.5:** Thickness of Weathered zone, Hard rock areas, Karimnagar district.

**3.3.2 Fractured zone:** Ground water is extracted mainly through bore wells of 60 to 100 m depth from fractured zone (~30 to 167 m) (deepest fracture at Dharmaram in Jammikunta mandal). Based on CGWB data, it is inferred that fractures in the range of < 30 m depth are more predominant (covering 67 % of area); 30-60 m and 60-86 fractures occur in 24 % and 7 % of area respectively and deep fractures (100-150 and > 150 m) are observed in < 2 % of wells

(**Fig.3.6 and Fig.3.7** ). Ground water yield in this zone varies from 0.01 to 5.4 lps. The transmissivity (T) varies from 1 to 77 m $^2$/day (avg: 25 m $^2$/day) and storativity varies from 0.00001 to 0.0001.

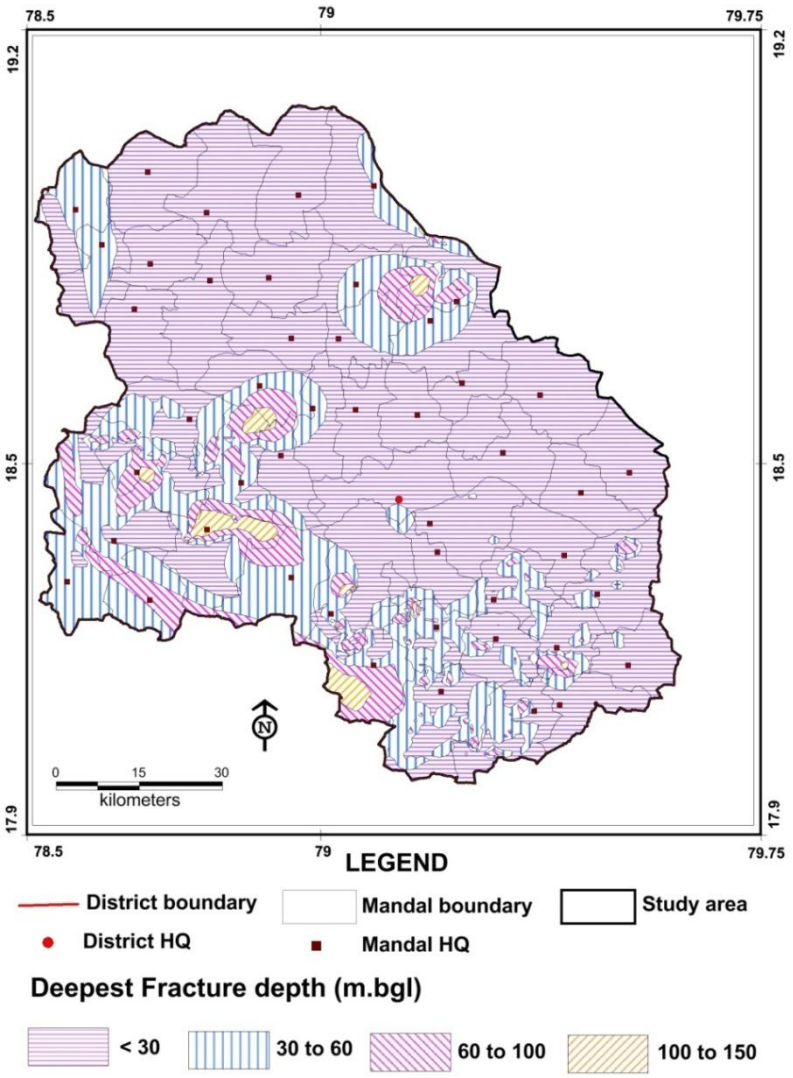



**Fig.-3.6:** Depth of Fractured zone, Hard rock areas, Karimnagar district.

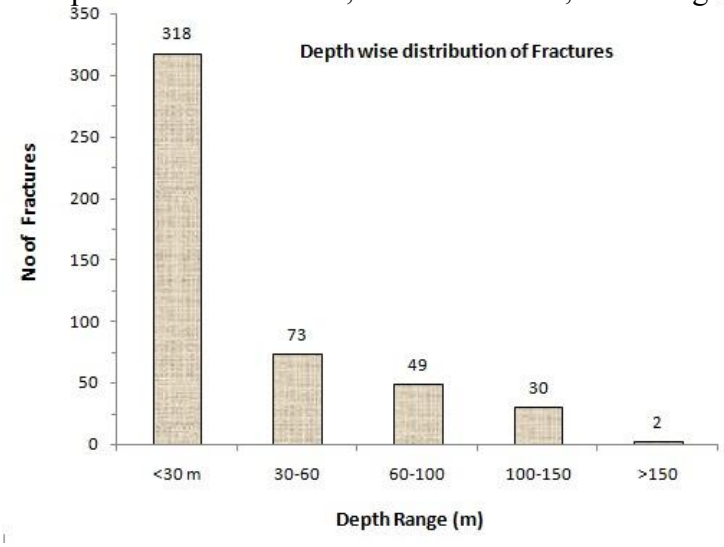


**Fig.-3.7:** Depth wise distribution of fractures, Hard rock areas, Karimnagar district.

# 4. GROUND WATER RESOURCES (2013)

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.

While computing the in-storage resources, the general depth of deepest fractures in the area, pre-monsoon water levels and 2 % of granular zone (depth below pre-monsoon water level and down to deepest fracture depth in the village) and 3 % as specific yield is considered. Summarized command/non-command area wise and mandal wise resources for 49 mandals are given in **Table-4.1 and Table-4.2** respectively.

As per 2013 GEC report, the net dynamic replenishable groundwater availability is 1501.7 MCM, gross ground water draft for all uses 1227.5 MCM, provision for drinking and industrial use for the year 2025 is 342.5 MCM and net annual ground water potential available for future irrigation needs is 75.6 MCM. The stage of ground water development varies from 67 % in command area and 102 % in non-command area with average of 82 %. 12 mandals falls in over-exploited category, 8 in critical category, 7 in semi critical category and 22 in safe category. Mandal wise stage of ground water development varies from 33 % (Julapalle mandal) to 140 % (Mallial mandal) ( **Avg: 82 %** ). Based on 2013 resources, village wise utilizable ground water resource map is prepared and presented in **Fig. 4.1.**

Computed total in-storage ground water resources from hard rock areas down to the maximum depth of fracture are estimated at 90.48 MCM. During the post monsoon season there is net recharge of 47.96 MCM.

**Table-4.1:** Computed Dynamic, In-storage ground water resources, Hard rock areas, Karimnagar district.

| **Parameters** | Command | Non-command | **Total** |
|---|---|---|---|
| **As per GEC 2013** | MCM | MCM | MCM |
| **Dynamic (Net GWR Availability)** | **878.61** | **623.06** | **1501.67** |
| • Monsoon recharge from rainfall | 290.78 | 368.81 | 659.59 |
| • Monsoon recharge from other sources | 203.84 | 86.67 | 290.51 |
| • Non-Monsoon recharge from rainfall | 71.61 | 80.36 | 151.97 |
| • Non-monsoon recharge from other sources | 397.94 | 154.64 | 552.59 |
| • Natural Discharge | 85.55 | 67.43 | 152.98 |
| **Gross GW Draft** | **591.7** | **635.80** | **1227.50** |
| • Irrigation | 516.36 | 587.12 | 1103.48 |
| • Domestic and Industrial use | 75.34 | 48.68 | 124.01 |
| Provision for Drinking and Industrial use for the year 2025 | 286.70 | 55.82 | 342.52 |
| Net GW availability for future irrigation | 75.56 | 0 | 75.56 |
| Average Stage of GW development (%) | 67 | 102 | 82 |
| Categorization of mandals | Mandal wise it varies from 33 % to 140 % (OE:12, C:8, SC: 7and Safe:22) | | |
| **In-storage GW Resources (down to the maximum depth of fractures)** | **90.48 MCM (May) Net recharge during monsoon season is 47.96 MCM** | | |

**Table-4.2: Administrative Unit Wise Assessment of Dynamic Groundwater Resources, Hard Rock Areas, Karimnagar District [2012-2013] [in ham.]**

| S. No. | Administrative unit/District | Net annual ground water availability | Gross ground water draft (Irr) | Gross ground water draft (Domestic and Industrial) | Total draft | Provision for domestic and industrial requirement (for the year 2025) | Net ground water availability for future irrigation | Stage of ground water development % | Category |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Bejjanki | 3037 | 2848 | 184 | 3033 | 0 | 189 | 100% | C |
| 2 | Bheemadevarpalle | 2470 | 3050 | 193 | 3243 | 0 | -580 | 131% | OE |
| 3 | Boinpalle | 1766 | 782 | 138 | 919 | 649 | 335 | 52% | S |
| 4 | Chandurthi | 2927 | 2280 | 149 | 2429 | 498 | 149 | 83% | SC |
| 5 | Chigurmamidi | 2142 | 2176 | 147 | 2324 | 0 | -34 | 108% | OE |
| 6 | Choppadandi | 2780 | 1763 | 223 | 1986 | 784 | 233 | 71% | S |
| 7 | Dharmapuri | 4457 | 2763 | 356 | 3119 | 1315 | 379 | 70% | S |
| 8 | Dharmaram | 3989 | 1345 | 204 | 1549 | 2651 | -6 | 39% | S |
| 9 | Eligadu | 1469 | 973 | 76 | 1049 | 411 | 85 | 71% | SC |
| 10 | Elkathurthi | 2036 | 1797 | 208 | 2005 | 178 | 61 | 98% | C |
| 11 | Ellanthakunta | 2894 | 2649 | 180 | 2829 | 65 | 180 | 98% | C |
| 12 | Gambhiraopet | 1880 | 792 | 161 | 953 | 927 | 161 | 51% | S |
| 13 | Gangadhara | 2094 | 2393 | 173 | 2566 | 0 | -299 | 123% | OE |
| 14 | Gollapalle | 2930 | 2672 | 155 | 2827 | 74 | 185 | 96% | C |
| 15 | Husnabad | 3300 | 3993 | 306 | 4299 | 0 | -693 | 130% | OE |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 16 | Huzurabad | 3398 | 1984 | 284 | 2268 | 1127 | 287 | 67% | S |
| 17 | Ibrahimpatnam | 2564 | 1545 | 257 | 1802 | 928 | 92 | 70% | S |
| 18 | Jagityal | 4374 | 2533 | 221 | 2754 | 1584 | 256 | 63% | S |
| 19 | Jammikunta | 5592 | 2967 | 389 | 3356 | 2213 | 412 | 60% | S |
| 20 | Julapalle | 1471 | 402 | 82 | 484 | 987 | 82 | 33% | S |
| 21 | Kamalapur | 3166 | 1837 | 210 | 2047 | 1109 | 219 | 65% | S |
| 22 | Karimnagar | 4489 | 2048 | 1885 | 3933 | 548 | 1893 | 88% | S |
| 23 | Kathlapur | 2983 | 3161 | 290 | 3452 | 40 | -218 | 116% | OE |
| 24 | Kodimial | 1614 | 1884 | 151 | 2035 | 0 | -270 | 126% | OE |
| 25 | Koheda | 2162 | 925 | 156 | 1081 | 181 | 1056 | 50% | S |
| 26 | Konaraopeta | 2448 | 2465 | 143 | 2608 | 0 | -18 | 107% | OE |
| 27 | Korutla | 4325 | 3041 | 405 | 3446 | 874 | 410 | 80% | SC |
| 28 | Mallapur | 3220 | 2876 | 224 | 3100 | 91 | 253 | 96% | C |
| 29 | Mallial | 2003 | 2572 | 233 | 2804 | 0 | -569 | 140% | OE |
| 30 | Manakondur | 4906 | 3683 | 246 | 3929 | 1184 | 39 | 80% | SC |
| 31 | Medipalle | 4190 | 5274 | 269 | 5543 | 154 | -1238 | 132% | OE |
| 32 | Metpalle | 3467 | 2283 | 348 | 2631 | 817 | 368 | 76% | S |
| 33 | Mustabad | 1979 | 2352 | 147 | 2499 | 0 | -373 | 126% | OE |
| 34 | Odela | 3296 | 1429 | 145 | 1574 | 1703 | 164 | 48% | S |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 35 | Peddapalle | 3911 | 1362 | 366 | 1727 | 2168 | 381 | 44% | S |
| 36 | Pegadapalle | 2742 | 1491 | 165 | 1656 | 1069 | 182 | 60% | S |
| 37 | Raikal | 4734 | 2306 | 255 | 2561 | 2112 | 316 | 54% | S |
| 38 | Ramadugu | 2001 | 2184 | 296 | 2480 | 0 | -183 | 124% | OE |
| 39 | Saidapur | 2995 | 1964 | 201 | 2165 | 801 | 230 | 72% | SC |
| 40 | Sarangapur | 4222 | 2327 | 168 | 2495 | 1683 | 212 | 59% | S |
| 41 | Shankarapatnam Keshavapatnam | 2371 | 3027 | 302 | 3329 | 0 | -656 | 140% | OE |
| 42 | Sircilla | 3239 | 2839 | 242 | 3081 | 162 | 238 | 95% | C |
| 43 | Srirampur | 2315 | 1043 | 140 | 1182 | 1132 | 140 | 51% | S |
| 44 | Sultanabad | 3499 | 1625 | 223 | 1849 | 1609 | 265 | 53% | S |
| 45 | Timmapur_Lmd Colony | 2528 | 1726 | 254 | 1980 | 116 | 686 | 78% | SC |
| 46 | Veenavanka | 3500 | 2575 | 178 | 2753 | 725 | 200 | 79% | SC |
| 47 | Velgatoor | 4065 | 3646 | 190 | 3836 | 534 | -115 | 94% | C |
| 48 | Vemulawada | 2827 | 2522 | 273 | 2795 | 32 | 273 | 99% | C |
| 49 | Yellareddipet | 3397 | 2175 | 207 | 2382 | 1016 | 206 | 70% | S |
| | **Total** | **150167** | **110348** | **12401** | **122749** | **34252** | **5568** | | |

**(Note:S-Safe,SC-Semi-critical,C-Critical,OE-Over-exploited).**

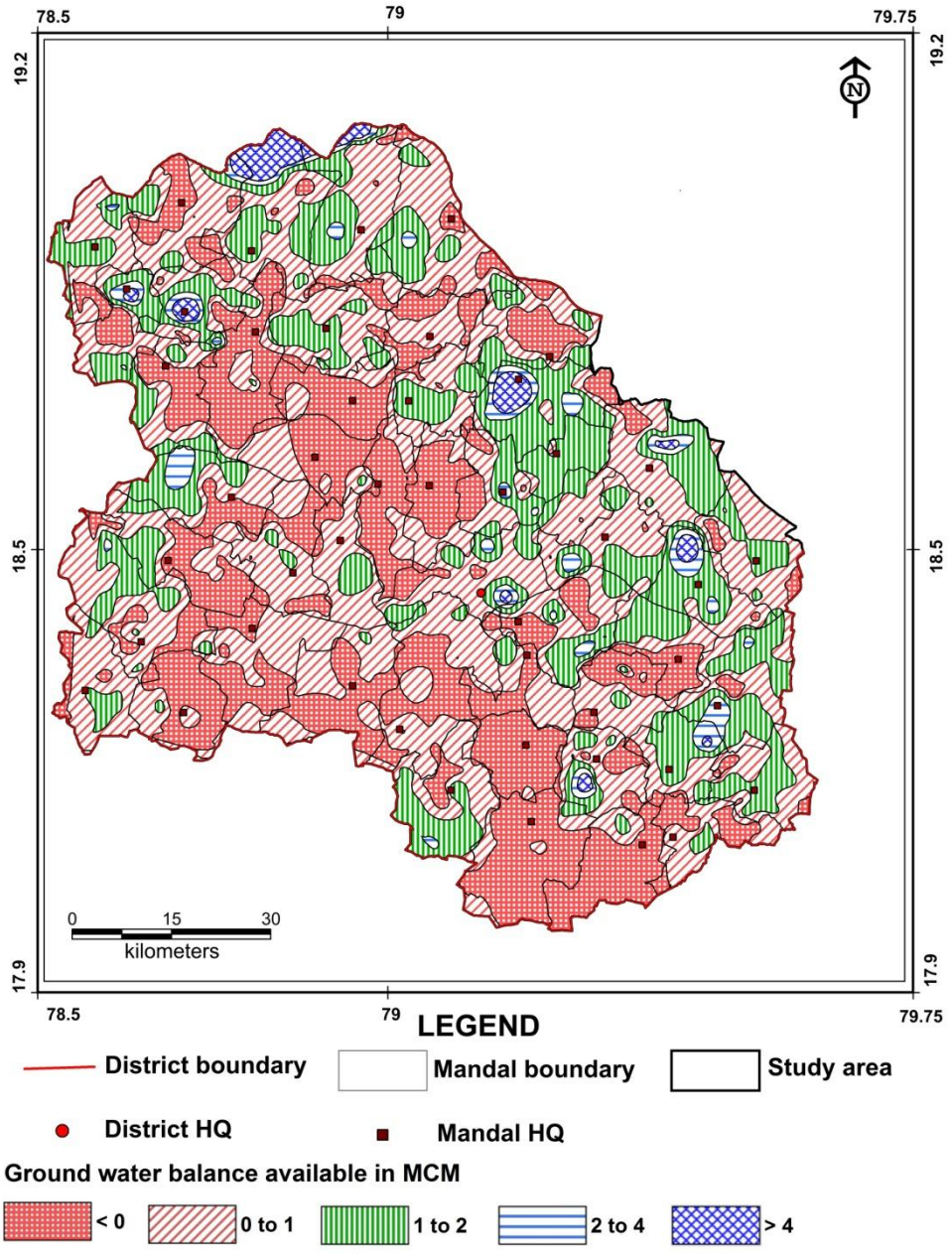



**Fig.4.1:** Utilizable ground water resources, Hard rock areas, Karimnagar district (2013).

## 5. GROUND WATER RELATED ISSUES and REASONS FOR ISSUES

### 5.1 Issues

**Over-exploitation**

- ~ 2666 Km $^2$ area (29 % of area) covering 346 villages are categorized as over-exploited where ground water balance for future irrigation is nil.

**Pollution (Geogenic and Anthropogenic)**

- Few mandals are fluorosis endemic where fluoride (geogenic) as high as 6.0 mg/l during pre-monsoon and 5.0 mg/l during post-monsoon season is found in groundwater. The high fluoride concentration (>1.5 mg/l) occur in 21 % (167 samples) and 16 % area (95 samples) respectively during pre and post-monsoon season of 2015.

- High nitrate (> 45 mg/l) due to anthropogenic activities is observed in 391 samples (58 %) and 402 samples (68 %) during pre and post-monsoon season respectively.

**Deep water levels**

- Deep water levels (> 20 m bgl) are observed during pre -monsoon season in 8 % of area.

**Declining water level trends**

- Out of 95 wells analyzed, 84 wells shown falling trend in pre-monsoon and 72 during post-monsoon season (@-0.03 to -0.2.33 and -0.01 to -1.39 m/yr) respectively.

- Water levels of 2016, compared to average of 2006-15 have shown fall in 79 and 27 wells (total wells: 95) during pre and post-monsoon season respectively.

**Sustainability**

- Low yield (<1 lps) occurs in ~25 % of area and yields covering south-western, central and north central part. The yield from bore wells have reduced over a period of time and some bore wells which used to yield sufficient quantity of water have gone dry due to more exploitation.

**Water Marketing and other Issues**

- Water marketing is present in almost all over the area and people are buying bottled water from the market for drinking purposes as there is no sufficient supply of potable water.
- Change in land use from agricultural land to residential purposes and cropping pattern from traditional crops to cash crops (cotton and spices) is observed.
- Paddy crop based on ground water is grown during rabi season in non-command area also leading to heavy withdrawal of ground water during non-monsoon period.

**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 unscientific sewage disposal of treated and untreated effluents in urban and rural areas. Use of NPK fertilizers and nitrogen fixation by leguminous crops.

**Over-exploitation and Deep water levels**

- Over-extraction, paddy cultivation during rabi season (51 % to total crops) more ground water extraction in proportion to recharge, limited artificial measures etc.

# 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 22790 MCM of unsaturated volume (below the depth of 3 m) is available during post-monsoon season of 2016, having 455.8 MCM of recharge potential (2 %) Out of this 455.8 MCM (50%) only is considered for implementing ARS structures and remaining 50% considered for implementing other waer conservation measures.

**Ongoing Projects**

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

- Under state Govt. sponsored Mission Kakatiya-Phase-1 and Phase-2, ~4.3 MCM of silt has removed from 40 % of excising tanks (from 35 mandals) and this has created additional surface storage. This will contribute ~ 1.07 MCM (25% as recharge) to groundwater and with this additional ~178 ha land can be brought under irrigated dry (ID) crops in tank ayacut.

- There is need to take remaining tanks in next phases for de-silting, this will greatly help in stabilisation of tank ayacut and ground water augmentation.

**6.1.1.2 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 Lower Mannair Dam, Mid Mannair Dam, BheemGhanapur, Yellampally reservoirs and SRSP.

- The total water import for the year 2018 will be 197.93 MCM (drinking and industrial needs) and this imported water from surface sources will reduce the present utilized ~192.6 MCM of ground water (considering 60 lpcd). This can be effectively utilized to irrigate ~ 24000 ha of additional land under ID crops.

**To be taken up**

**6.1.1.3 Artificial Recharge Structures:**

While formulating the village wise groundwater management plan, the unsaturated volume of aquifer is estimated by multiplying the area with specific yield and unsaturated thickness (post-monsoon water levels below 3 m). Initially village wise dynamic groundwater resources of 2013 are considered (**Fig.4.1**). Potential surface run off is estimated by following standard procedures. Initailly, 20 % run off yield is considered as non-committed yield and for recommending artificial recharge structures in intermittent areas 50 % of yield is considered and in remaining 50 % is recommended for implementing water conservation measures in recharge areas through MGNREGS.

The pre-monsoon groundwater quality is considered for categorising contaminated area (F >1.5 mg/l & EC >3000 μ S/cm). Nitrate is not considered here because it is point source pollution and localized. Based on above criteria, the area can be prioritized into **Priority-1(over-exploited)** which needs immediate intervention **and Priority-2** . Based on hydrogeological characteristics, the area is further sub-divided into following 8 categories (**Table-6.1**).

**Table-6.1:** Hydrogeological characteristics of area.

| Category | Hydrogeological characterizations |
|---|---|
| 1 | High EC with additional scope for artificial recharge. |
| 2 | High EC with no additional scope for artificial recharge. |
| 3 | High F with additional scope for artificial recharge. |
| 4 | High F with no additional scope for artificial recharge. |
| 5 | High EC and F with additional scope for artificial recharge. |
| 6 | High EC and F with no additional scope for artificial recharge. |
| 7 | Groundwater quality within permissible limits for drinking and irrigation with scope for artificial recharge |
| 8 | Groundwater quality within permissible limits for drinking and irrigation with no scope for artificial recharge. |

**Priority-1 (Area where groundwater development > 100 %)**

Area consisting of 241 villages covering ~2010 $Km^2$ (**Fig.6.1**) is considered as Priority-1 where 8484 unsaturated volume having 170 MCM recharge potential and ~31.3 MCM utilizable yield is available and immediate intervention is required because, here, the stage of groundwater development is > 100 % (**Annexure-1**).

- 1175 artificial recharge structures (614 CD's with 6 fillings with a unit cost of Rs 5 lakhs each and 561mini PT's with 1.5 fillings) with a unit cost of Rs 10 lakhs earn with a total cost of **86.8** crores can be taken up.
- After effective utilization of this yield, there will be 15.15 MCM of ground water recharge (50 % of ARS capacity).
- Roof top rainwater harvesting structures should be made mandatory to all Government buildings (new and existing).

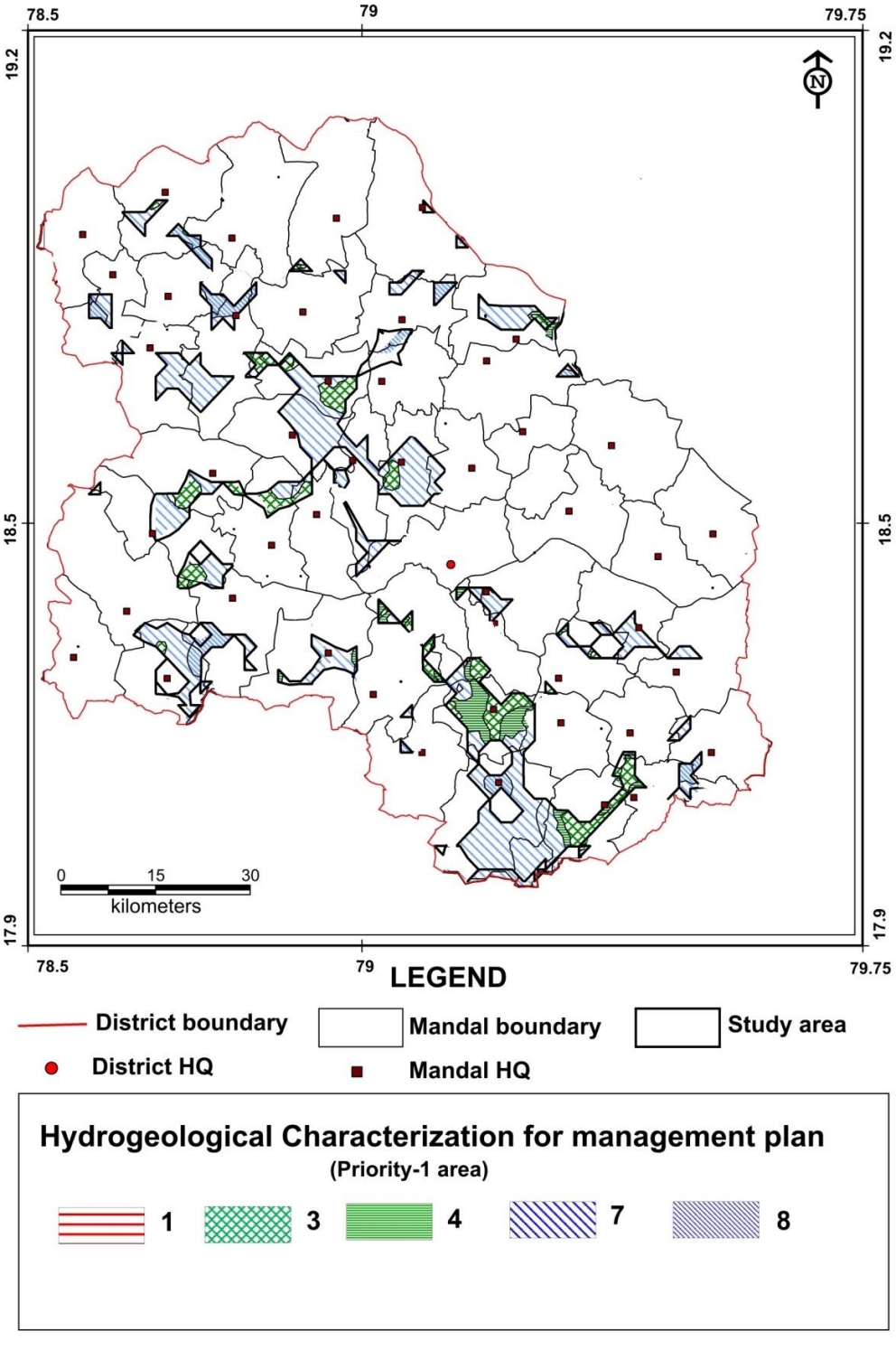



**Fig.6.1:** Priority-1 area, for sustainable management of ground water Resources, Hard rock areas, Karimnagar district.

**Priority-2** (A**rea where groundwater development <100 %)**

- Area consisting of 334 villages having ~4102 Km$^2$ chargeable area (**Fig.6.2**) is considered as Priority-2, where ~14305 MCM unsaturated volume 286 MCM recharge potential and ~66.44 MCM utilizable yield is considered for recharge (**Annexure-2**).
- Artificial recharge structures are recommended for 50% of the utilizable yield in the intermittent areas.
- 2442 Artificial recharge structures (ARS) (1229 CD's with 6 fillings with a unit cost of Rs5 lakhs each and 1213 mini PT s with 1.5 fillings) with a unit cost of Rs 10 lakhs each can be taken up with a cost estimate of **182.75** crores to augment 66.44 MCM. After effective utilization of this yield, there will be 33.2 MCM of ground water recharge (50 % of total utilizable yield).
- Roof top rainwater harvesting structures should be made mandatory to all Government buildings.

**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 17320 farm ponds are recommended (20 in each village in 866 villages) at Rs 25,000/-each with total cost of **43.3** crores.

**Other Supply Side Measures:**

- Existing ARS like percolation tanks, 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.

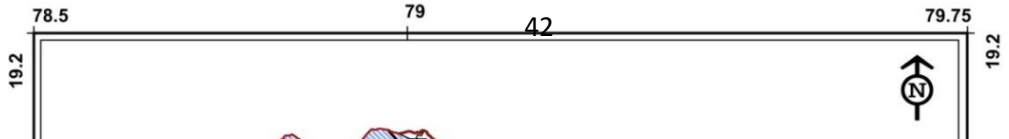


**Fig.6.2:** Priority-2 area, for sustainable management of ground water Resources, Hard rock areas, Karimnagar district.

**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 ~43,329 ha area is brought under micro-irrigation (Sprinklers: 11,065 and drip: 32,264) saving ~87 MCM of groundwater (considering 25 % of saving to traditional practices).

#### 6.1.2.2 Proposed Micro-irrigation

- ~17453 ha of additional land that can be brought under micro-irrigation (from 33 mandals where actual area irrigated though MI is Less than 1000 Ha) costing about **104.72** crores (considering 1 unit/ha @0.6 lakhs/ha). With this ~35 MCM of ground water can be conserved over the traditional irrigation practices (considering 25% of net saving forr ID crops).

### 6.1.3 Other Recommendations

- Declaration of MSP in advance (before start of season) and improved facilities at procurement centres.
- 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).
- Capacity building in power supply regulation (4 hour each in morning and evening) will increase the sustainability of wells.
- A participatory groundwater management (PGWM) approach in sharing of groundwater and monitoring resources on a constant basis along with effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002).
- Subsidy/incentives on cost involved in sharing of groundwater may be given to the concerned farmers
- Laser levelling of irrigated land.

- In urban and rural areas the sewerage line should be constructed to arrest leaching of nitrate.

### 6.2 Expected results and out come

With the above interventions costing Rs **417.57** crores (**excluding the cost involved in Mission Kakatiya, Mission Bhagiratha and MNREGA/PMKSY** ), the likely benefit would be increases in gross groundwater based irrigation from ~4.46 lakhs ha to 4.92 lakhs ha or net saving of **277.1** MCM of ground water or net reduction of 13 % in stage of ground water, i.e., from 82 % to 69 %. The other benefits will be more distribution of income among farmers. The onetime cost will be ~2 paisa/litre (Rs 20 /$m^3$ of ground water).

### Acknowledgment

The authors thank Shri K.B. Biswas, Chairman, and Sri. D. Saha, Member (SAM), Sri. K.C. Naik, Member (ED & MM), of the Central Ground Water Board, Govt. of India and Shri Subba Rao, Regional Director, and Dr. P. N. Rao, Supt HG Shri GRC Reddy of this office for encouragement and finalization of report. The authors acknowledge State Ground Water Department and Rural Water Supply department, Govt of Telangana for making available of field data. Authors also thank the Executive Engineer and his drilling crew of CGWB, for carrying out the exploration activity.