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

HYDERABAD DISTRICT, TELANGANA

दक्षिणी क्षेत्र, हैदराबाद

Southern Region, Hyderabad

भारत सरकार
जल शक्ति मंत्रालय
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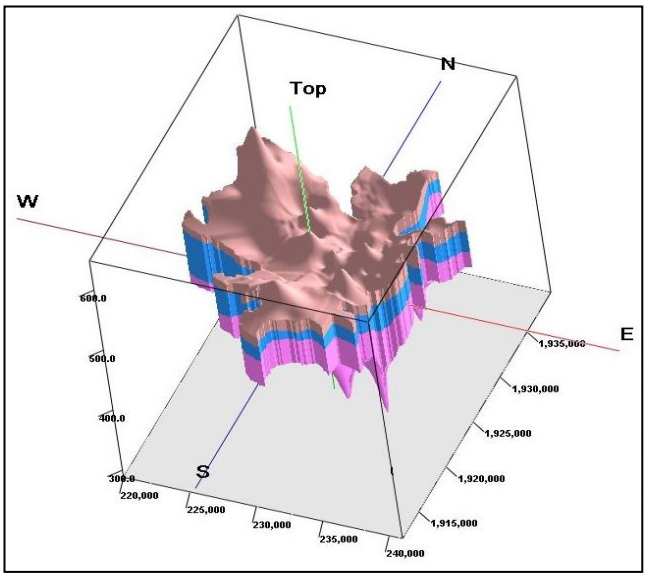
केंद्रीय भूमि जल बोर्ड

GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RD & GR

REPORT ON
AQUIFER MAPPING AND MANAGEMENT OF HYDERABAD DISTRICT, TELANGANA STATE (AAP-2021-22)



CENTRAL GROUND WATER BOARD
SOUTHERN REGION, HYDERABAD
JUNE, 2022

REPORT ON
AQUIFER MAPPING AND MANAGEMENT OF
HYDERABAD DISTRICT, TELANGANA STATE
(AAP-2021-22)

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AQUIFER MAPPING AND MANAGEMENT OF HYDERABAD DISTRICT, TELANGANA STATE

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AQUIFER MAPPING AND MANAGEMENT OF
HYDERABAD, TELANGANA STATE
(AAP-2021-22)
At a Glance

S.No.	Item		Particulars
1	District	:	Hyderabad , Hard Rock area
2	Revenue Divisions/ Mandals	:	36

3	Villages	:	448 villages
4	Mappable area	:	8125 km^2
5	Population (2011 Census)	:	27.5 lakhs
6	Density of population (2011 Census)	:	152 persons/km^2
7	Locations	:	North latitude 15°49´-16°49´and east longitude 79°12´- 80°40’
8	Rainfall (Normal)	:	The annual normal rainfall of the area varies from 659 mm (Macherla mandal) to 997 mm (Mangalagiri mandal) with normal average of 807 mm.
9	Geomorphology	:	Pediplain (60% of the area). Structural hills (11 % of the area), Pediment (10% of the area), Structural Valley (5% of the area), Dissected plateau (5% of the area) and channel fill (4% of the area).
10	Major River	:	Krishna and Gundlakamma
11	Land Utilization	:	Agricultural land occupies nearly 44% of the area, forest occupies nearly 18% of the area, 16% of the area is put to non agricultural uses and 12% of the area is fallow land. Remaining area is occupied by plantation, builtup, water bodies and barren land etc.
12	Soils	:	Based on the soil texture, the area is mainly occupied by Clayey skeletal mixed and clayey mixed (31%), Fine soil mixed (29%), fine montmorillonitic (23%), loamy skeletal (13%) and fine loamy mixed (4%)
13	Cropping Pattern (2019-20) (Ha)	:	The total gross cropped area during the year 2019-20 is 4,15,655 ha and net sown area is 3,76,212 ha. The gross area cropped during Khariff season is 3,55,438 ha and the major crops grown during khariff season is Paddy (18%), cotton (48%), chillies (18%) and total pulses (5%) and 11% remaining other crops. The gross area cropped during Rabi season is 60,217 ha and the major crops grown during the period are Paddy (40%), Pulses (33%), Maize (11%),Tobacco (3%) and remaining 13% by other crops
14	Irrigation	:	The Gross area irrigated is 235029 ha and the area irrigated more than once is 25291 ha. In which, 70% (166247 ha) of the irrigation is through surface irrigation and 29% (68782 ha) of the area is irrigated through ground water irrigation.
16	Prevailing Water Conservation/Recharge Practices	:	~1259 percolation tanks, 606 Check dams,185 Percolation Tanks and 13552 Farm ponds. Also 73934 other water conservation structures.
17	Geology	:	The Archean Granitic Gneiss and granites covers 29% of the area and charnockites covers 17%. The Precambrian metasedimentary formation of Kurnool and Cuddapah system covers 54% of the area
18	Hydrogeological data points		
	Exploratory drilling data points	:	CGWB Exploration: 138

	Water Level data points		137 wells (CGWB:53, SGWD:84)
	Hydrochemical Points		Total 60 • Pre-monsoon:60(CGWB: 27, SGWD: 33)
	Geophysical		VES: 55 (CGWB) and TEM (36)
19	DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING		
20	Ground water Level Scenario		
	Water Levels Depth to water level (m bgl)	:	• During Pre-Monsoon, water-table elevation ranges from 5-235 meter above mean sea level and in post-monsoon season 8-242 meter above mean sea level (m amsl). • Depth to water level varies from <1 m to 52 m bgl with an average of 7.25 mbgl during pre monsoon. In Majority of the areas in pre monsoon water level is 5-10 m (46% of the area), followed by shallow water leve (<5 m bgl) in 30% of the area, 10 to 20 m bgl in 15% of the area and > 20 m bgl occupy about 9% of the area • During post-monsoon season water level , <1 m - 35 m bgl with an average of 5.2 m bgl. and majority of the water level are in range of <5 m covering 46% of the area followed by 5 to 10 m bgl in 39% of the area 10 to 20 m bgl in 11 % of the area and < 20 mbgl occupy about 4% of the area.
	Water Level Fluctuations (May vs. November)	:	• Most of the wells in the state records water level rise. The seasonal water level fluctuations vary from <1 to 11.5m.
	Long term water level trends (2010-20) (137 wells)	:	During pre-monsoon season 117 wells shows falling trend in the range of 0.01 m/yr to 1.9 m/yr and 20 wells shows rising trend 0.02-0.5 m/yr. During post-monsoon season 57 wells show falling trend 0.01 to 1.5 m/yr and 80 wells shows rising trends 0.01-0.5 m/yr.
21	Ground Water Quality		
	Electrical Conductivity (µ Siemens/cm)	:	Pre: 622-7210 (avg: 2697) micro Siemens/cm 65% of area EC is within 3000 µ Siemens/cm.

	Nitrate mg/l	:	Pre: 1-560 mg/L and found 56% of samples are unfit for human consumption			
	Fluoride mg/l	:	Pre: 0.10-2.23 mg/L, 10% of sample are beyond permissible limit of 1.5 mg/L.			
22	Aquifer Mapping					
	Era		Pre-Cambrian		Archean Crystallines	
	Prominent Lithology		Meta sedimentary Formation		Granite Gneiss/Charnockite (Basement)	
	Aquifer types		Aquifer-1 (Weathered Zone)	Aquifer-2 (Fracture Zone)	Aquifer-1 (Weathered Zone)	Aquifer-2 (Fracture Zone)
	Thickness range		1 - 30 m	up to 200m	1 - 30 m	up to 200m
	Depth of range of occurrence of fractures		-	85% fracture encountered between Within 100 m	-	80% fracture encountered between 30 - 90m
	Range of yield potential		<1 to 3	Avg 5 lps	<1	Avg 3 lps
	Transmissivity (sqm/day)		More than 1 to >100 sq.m/day			
23	Ground water Resources (2020) MCM					
	Net Dynamic groundwater availability	:	1033 MCM			
	Gross GW Draft	:	354 MCM			
	Provision for Domestic &Industrial (2025)	:	104 MCM			
	Average Stage of Ground water development (%)		34%			
	Net GW Availability for future irrigation	:	707MCM			
	Categorization of mandals		Stage of ground water development varies from 11% (Tadikonda mandal) to 137% (Veldurthi mandal). Out of 36 mandals in the study area, 2 mandals (Veldurthi and Bollapalle mandals) are over exploited, Piduguralla mandal is Critical and remaining 33 mandals are safe.			
24	Major Ground Water Issues Identified	:	• The Over all stage of ground water development in the study area is 34%, except 3 mnadals, Viz., Piduguralla, Bollapalle and Veldurthy mandals. The Piduguralla mandal is known for its rich lime stone deposits and the industrial as well as mine dewatering may be the one of the reasons for high stage of ground water development. • Low yield (<1 lps) occurs in most of the area of both in eastern as well as western parts of the study area. • High nitrate (> 45 mg/L) due to anthropogenic activities is			

			observed in 56% during pre-monsoon
25	Management Strategies	:	Supply side measures To be taken up (Artificial Recharge Structures in the Study Area) 246 artificial recharge structures (152 CD's and 94 mini PT'in 85 villages) Water Conservation measures (WCM) Farm Ponds The size of form ponds can be 10 x 10 x 3 m. Total 1352 farm ponds already exist in study area should be desilted and maintained so that it will greatly help in ground water augmentation. Demand side measure Micro irrigation: 30000 ha of land can be brought under micro-irrigation (@100 ha/village in 300 villages, considering 1 unit/ha @0.6 lakh/ha). With this ~54 MCM of ground water can be conserved over the traditional irrigation practices, considering @ 0.006 MCM/ha for ID crops with traditional irrigation methods). Other Recommendations • To avoid the interference of cone of depression between the productive wells, intermittent pumping of bore wells is recommended through regulatory mechanism. • The western part of the study area is known for its rich lime stone deposits. As mandated by Central Ground Water Authority, the mine dewatered seepage can effectively be utilized by filling the tanks and supply to agriculture fields. • As a mandatory measure, every groundwater user should recharge rainwater through artificial recharge structures in proportionate to the extraction • Declaration of Minimum Support Price in advance (before start of season) and improved facilities at procurement centres. • Capacity building in power supply regulation (4 hour each in morning and evening) will increase the sustainability of wells • A participatory groundwater management (PGWM) approach in sharing of groundwater and monitoring resources on a constant basis along with effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002). • Laser levelling of irrigated land. Subsidy/incentives on cost involved in sharing of groundwater may be given to the concerned farmers.

26	Expected Results and Out come	:	With the above interventions, the likely benefit would be the net saving of 63 MCM of ground water can be saved either through water conservation measures like adoption of drip and artificial recharge to ground water.

ABBREVATIONS

2D	:	2 Dimensional
3D	:	3 Dimensional
ARS	:	Artificial Recharge Structures
Avg	:	Average
BDL	:	Below Detection Level
BW	:	Bore Well
CD	:	Check dam
CGWB	:	Central Ground Water Board
Cr	:	Crore
DTW	:	Depth to water
DW	:	Dug well
EC	:	Electrical conductivity
EL	:	East Longitude
F	:	Fluoride
FP	:	Farm Pond
GEC	:	Ground Water Estimation committee
GW	:	Ground Water
Ha	:	Hector
Ha.m	:	Hector meter
ID	:	Irrigated dry
IMD	:	Indian Meteorological Department
Km^2	:	square kilometre
LPS	:	Litres per second
M	:	meter
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 Guntur district has a geographical area of 11,391 sq.kms, of which 8125 sq.kms is underlain by hard rock aquifer system, lies between north latitude 15°49´-16°49´and east longitude 79°12´- 80°40'. Administratively, the study area is governed by three revenue divisions – Narasaraopet, Guntur and Gurazala covering 36 mandals and 448 villages having a population of 27.5 lakhs (2011 census, population density of 152).

The study area is underlain by various geological formation from Archean to Recent. The Archean granitic gneiss and granites covers 29% of the area and charnockites covers 17% overlain by precambrian metasedimentary formation of Kurnool and Cuddapah system covering 54% of the area. Pediplains are the major landforms followed by structural hills and pediment. The major rivers draining the study area are Krishna and Gundlakamma.. Agricultural land occupies nearly 44% of the area, 18% of the area is forest, 16% of the area is put to non-agricultural uses and 12% of the area is fallow land. The total gross cropped area during the year 2019-20 is 4,15,655 ha and net sown area is 3,76,212 ha. The Gross area irrigated is 235029 ha. In which, 70% (166247 ha) of the irrigation is through surface irrigation and 29% (68782 ha) of the area is irrigated through ground water irrigation.

Water level is monitored through 137 wells during pre and post-monsoon seasons. During Pre-Monsoon, water-table elevation ranges from 5-235 meter above mean sea level and in post-monsoon season 8-242 meter above mean sea level (m amsl). Depth to water level varies from <1 m to 52 m bgl with an average of 7.25 mbgl during pre-monsoon and <1 m - 35 m bgl during post-monsoon season with an average of 5.2 m bgl. In Majority of the areas in pre monsoon water level is 5-10 m (46% of the area), followed by shallow water level (<5 m bgl) in 30% of the area, 10 to 20 m bgl in 15% of the area and > 20 m bgl occupy about 9% of the area and during post monsoon season majority of the water level are in range of <5 m covering 46% of the area followed by 5 to 10 m bgl in 39% of the area 10 to 20 m bgl in 11 % of the area and < 20 mbgl occupy about 4% of the area. Most of the wells in the state records water level rise. The seasonal water level fluctuations vary from <1 to 11.5 m.

Trend analysis for the last 10 years (2011-2020) is studied from 137 hydrograph stations of CGWB and SGWD. It is observed that during pre-monsoon season 117 wells shows falling trend in the range of 0.01 m/yr to 1.9 m/yr and 20 wells shows rising trend 0.02 m/yr to 0.5 m/yr. During post-monsoon season 57 wells show falling trend 0.01 to 1.5 m/yr and 80 wells shows rising trends 0.01-0.5 m/yr

Total 60 ground water samples (CGWB:27 and SGWD:33) were analysed for knowing the suitability of ground water for drinking purposes. In 65 % of area EC is in the range of < 3000 µ Siemens/cm during pre-monsoon season. During pre-monsoon, average concentration of TDS is 1607 mg/L and NO_3 ranges from 1-560 mg/L. Nitrate concentration in 56% of samples is beyond permissible limits of 45 mg/L.Fluoride concentration varies from 0.10-

2.23 with 10% of samples is beyond the permissible limits of BIS and rest is within the permissible limit.

On the basis of occurrence and movement of ground water, hard rock units of the study area are classified into two categories; Archean crystalline and Metasedimentary formations. Weathered and fractured Archean crystalline rocks (Charnockites and Granite Gneisses) form the archean aquifer system. Metasedimentary aquifer system overlies archean crystalline rocks aquifer system. Aquifers are conceptualized in to two namely, weathered zone (~30 m) and fractured zone (~200: 30 -192 m). The shallow aquifer is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~30 m depth. Ground water yield varies from <1 to 3 lps in archean crystallines and <1 to 5 lps in metasedimentary formation. Transmissivity varies from 1 to >100 sq.m/day. The depth of fracturing varies from 30 m to 192 m

As per 2020 GEC report, the net dynamic replenishable groundwater availability is 1033 MCM, gross ground water draft for all uses 354 MCM, provision for drinking and industrial use for the year 2025 is 104 MCM and net annual ground water potential available for future irrigation needs is 278 MCM. Stage of ground water development varies from 11% (Tadikonda mandal) to 137% (Veldurthi mandal). Out of 36 mandals in the study area, 2 mandals (Veldurthi and Bollapalle mandals) are over exploited, Piduguralla mandal is Critical and remaining 33 mandals are safe.

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

The management strategies mainly include both supply side and demand side. The supply side management of ground water resources include artificial recharge of available surplus runoff in check dams and percolation tanks in rural areas and roof top and open space rain water harvesting in urban areas. In the study area, a total of 678 artificial recharge structures (534 CDs and 144 PTs) are already in existence. Considering 50% of the available left surplus runoff, a total of 246 AR structures (152 check dams and 94 percolation tanks) are recommended in the study area. After effective utilization of this yield, there will be 9.4 MCM of ground water recharge can be feasible. Under Water conservation measures include, desilting of already existing 13552 numbers of farm ponds in the entire study area. Roof top and open space rain water harvesting for artificial recharge in urban areas.

Government of Andhra Pradesh had proposed to bring about 12423 ha of additional land under ground water irrigation in the district through construction of 11241 no. of bore wells in 268 villages of 24 mandals of study area with an estimated cost of 524 crores.

Demand side measure includes micro irrigation in ~30000 ha of additional land that can be brought under micro-irrigation (@100 ha/village in 300 villages) considering 1 unit/ha @0.6 lakh/ha. With this 54 MCM of ground water can be conserved over the traditional irrigation

practices (considering 0.006 MCM/ha for ID crops against 0.008 MCM/ha). Other measure includes capacity building in power supply regulation, effective utilization of mine dewatered seepage for filling the tanks and supply for irrigation, application of laser levelling technology in irrigated land, providing proper sewerage system, intermittent pumping of bore wells is recommended through regulatory mechanism, every groundwater user should recharge rainwater through artificial recharge structures in proportionate to the extraction and participatory groundwater management (PGWM) are the other measures recommended.

With the above interventions, the likely benefit would be the net saving of 63 MCM either through water conservation measures like adoption of drip and artificial recharge to ground water.

NUMBER OF DATA POINTS USED FOR PREPARATION OF VARIOUS

S. No.	Data	Aquifer	Total data Points	Source
1	Panel Diagram	Combine	185	CGWB, GW & WAD
2	Hydrogeological Sections	2nos	185	CGWB, GW & WAD
4	Depth of Weathering	1no	138	CGWB ,GW & WAD
5	Depth of Fractures	1no	110	CGWB, GW & WAD
6	GW Yield	Combine	119	CGWB , GW & WAD
7	Transmissivity	Combine	80	CGWB , GW & WAD
8	Depth to Water Level Maps	Combine	137	CGWB , GW & WAD
9	VES	Combine	55	CGWB
10	TEM	Combine	36	CGWB
11	Water Level Trend (Long Term)	Combine	137	CGWB , GW & WAD
12	Water Quality	Combine	60	CGWB , GW & WAD

1.0 INTRODUCTION

Aquifer mapping is a multidisciplinary scientific approach wherein a combination of geologic, geophysical, hydrologic, and chemical analysis is applied to characterize the quantity, quality, and sustainability of groundwater in aquifers. In the recent past, there has been a paradigm shift from "**groundwater development**" to "**groundwater management**". As large part of India particularly hard rock aquifers has become water stressed due to rapid growth in demand for water in response to population growth, irrigation, urbanization, and changing lifestyle. 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 groundwater management through community participation.

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 plans. The proposed management plans will provide necessary inputs and recommendations for ensuring sustainable management of groundwater resources of district. The aquifer maps and management plans will be shared with the Administration of Hyderabad district, Telangana state for its effective implementation.

1.1 Objectives

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

1.2 Scope of the Study:

The main scope of the 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 groundwater regime (water levels and water quality) for creation of time series database and groundwater resource estimation.
3. Quantification of groundwater availability and assessing its quality.
4. To delineate aquifer in 2-D and 3-D along with their characterization on a 1:50,000 scale.
5. Capacity building in all aspects of groundwater development and management through information, education, and communication (IEC) activities, information dissemination, education, awareness, and training.
6. Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable groundwater management.

1.3 Area details:

Hyderabad centrally located on the top of the Deccan Plateau, is one of the fastest growing cities in India and has emerged as a strong industrial, commercial, technology centre and occupies prime position. It was founded by Sultan Mohammed Quli Qutub Shah, the 5th King of Qutub Shah dynasty in 1590 A.D. of Golconda Kingdom. Soon after India gained independence, Hyderabad State merged with the Union of India in the year 1948. Hyderabad (Urban) District had come into existence in August, 1978 covering an area of 217 Sq Km consists of 16 mandals including Municipal Corporation of Hyderabad (MCH), Secunderabad Cantonment and Osmania University (**Fig.1.1**). Hyderabad is situated at 17°17' to 17°28' N Latitude and 78°28' E to 78°32' E Longitude with an elevation of 525 m amsl.

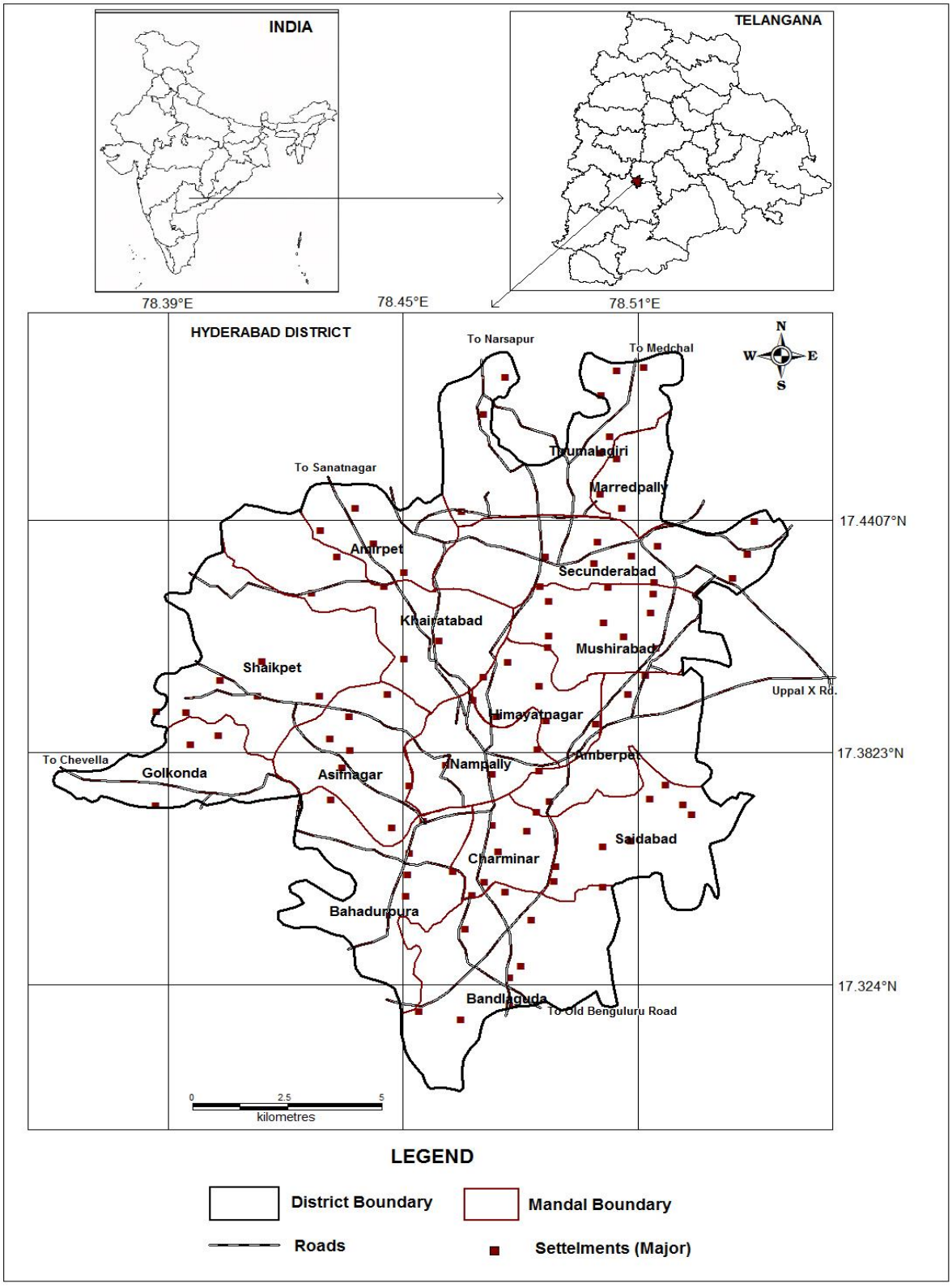


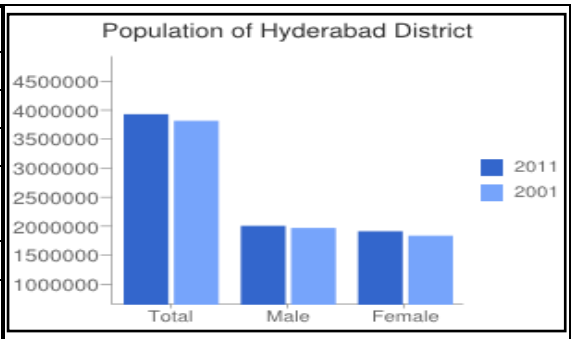
Fig-1.1: Location Map of Hyderabad District

According to the 2011 census, Hyderabad district has a population of 3,943,323 (39.43 lakhs) of which male and female were 20.0 lakhs and 19.2 lakhs respectively. There was 2.97 percent increase in population compared to population

as per 2001, which recorded increase of 21.74 percent to its population compared to 1991. The population density of Hyderabad district for 2011 is 18,172 people per sq. km.

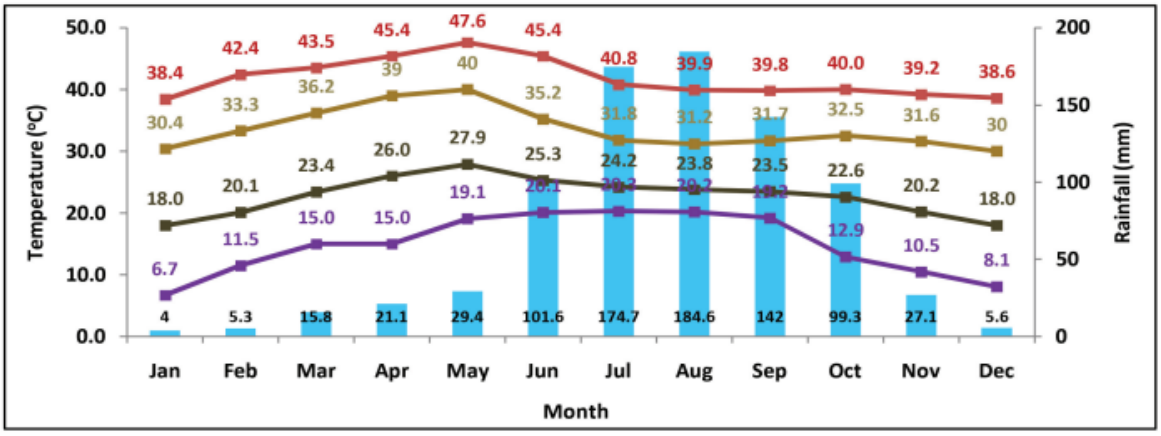
Table-1.1: Population Trends in Hyderabad District

Description	2011	2001
Actual Population	3,943,323	3,829,753
Male	2,018,575	1,981,173
Female	1,924,748	1,848,580
Population Growth	2.97%	21.74%
Density/km^2	18,172	17,649
Sex Ratio (Per 1000)	954	933



1.4 Climate and Rainfall:

Hyderabad experiences semi-arid tropical climatic conditions. The temperatures reach 47.6º C during the summer season and with the onset of monsoons during June the temperature drop and varies between 22.6º C to 40.2º C. T. The Average annual Rainfall is 779 mm. The rainfall ranges from 744.7mm in Charminar to 811 mm in Musheerabad. The south west monsoon contributes 72% of annual rainfall and north east monsoon contributes 19%. About 40% of the annual rainfall is



Month wise average Rainfall; Temperature - Extreme Maximum, Avg Max, Avg Min, Extreme Minimum

contributed by July and August months.

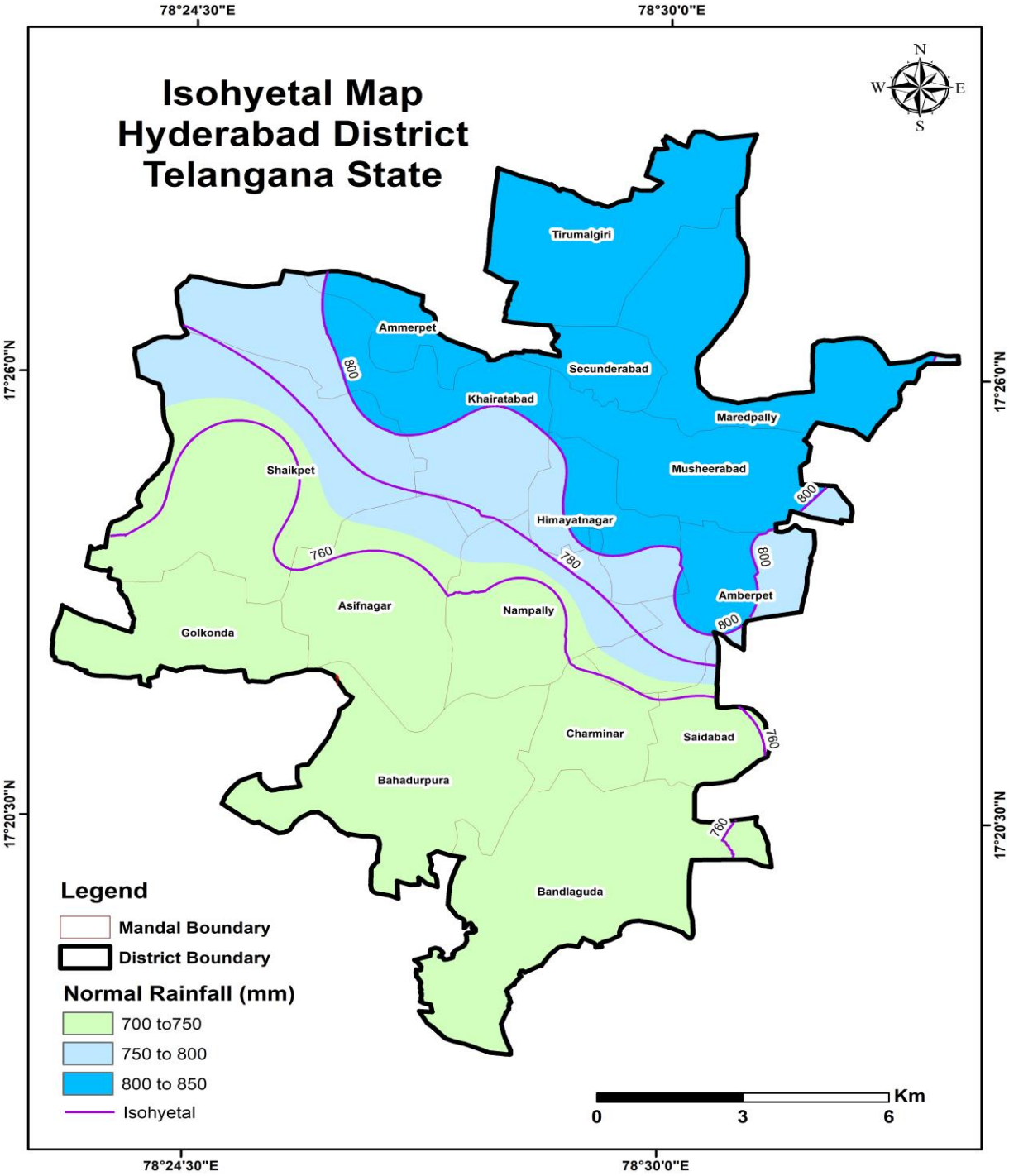
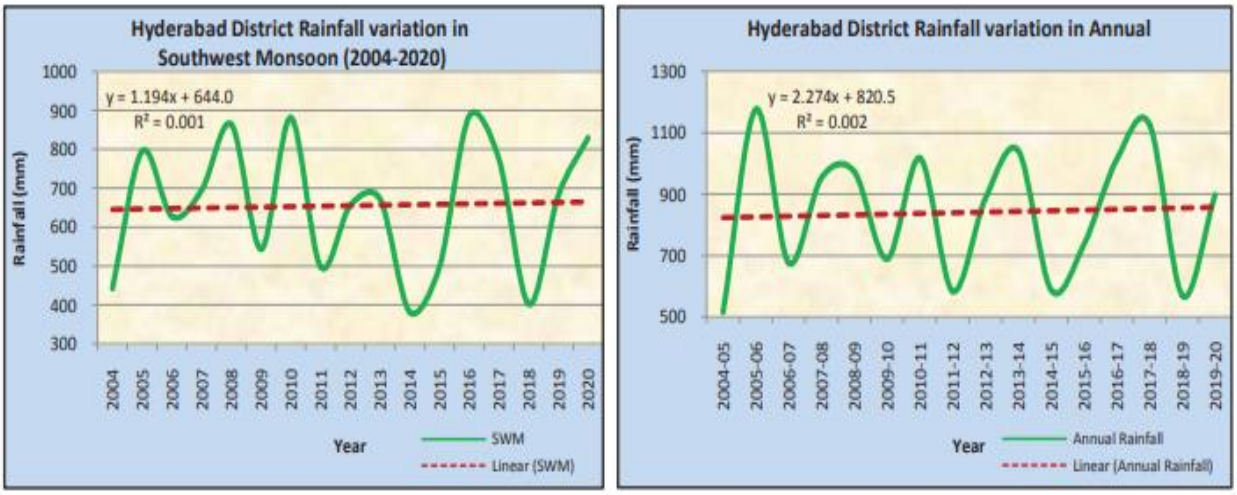


Fig-1.2: Isohyetal Map of Hyderabad District



Source: https://www.tsdps.telangana.gov.in/

Fig-1.3: Graphs showing rain fall variation in Hyderabad District

1.5 Drainage and Physiography

The district is drained by Musi River, a tributary of Krishna River. The River Musi originates from Anantagiri hills in Vikarabad area of Ranga Reddy district and flows through the centre of the district. Apart from the River Musi, Hyderabad was endowed with a number of natural and artificial lakes which includes Hussain Sagar. Hussain Sagar, an artificial lake was built across a tributary of the Musi River by Ibrahim Quli Qutub Shah in the year 1563. Hussain Sagar was originally constructed to supply drinking water to Hyderabad before Himayat Sagar and Osman Sagar were built on River Musi. The lake also protects the low-lying areas from floods. The Map depicting drainage and water bodies is presented in **Fig- 4.** The Hyderabad is an undulating topography with an elevation ranging between 478 - 637 m amsl (**Fig-5).**

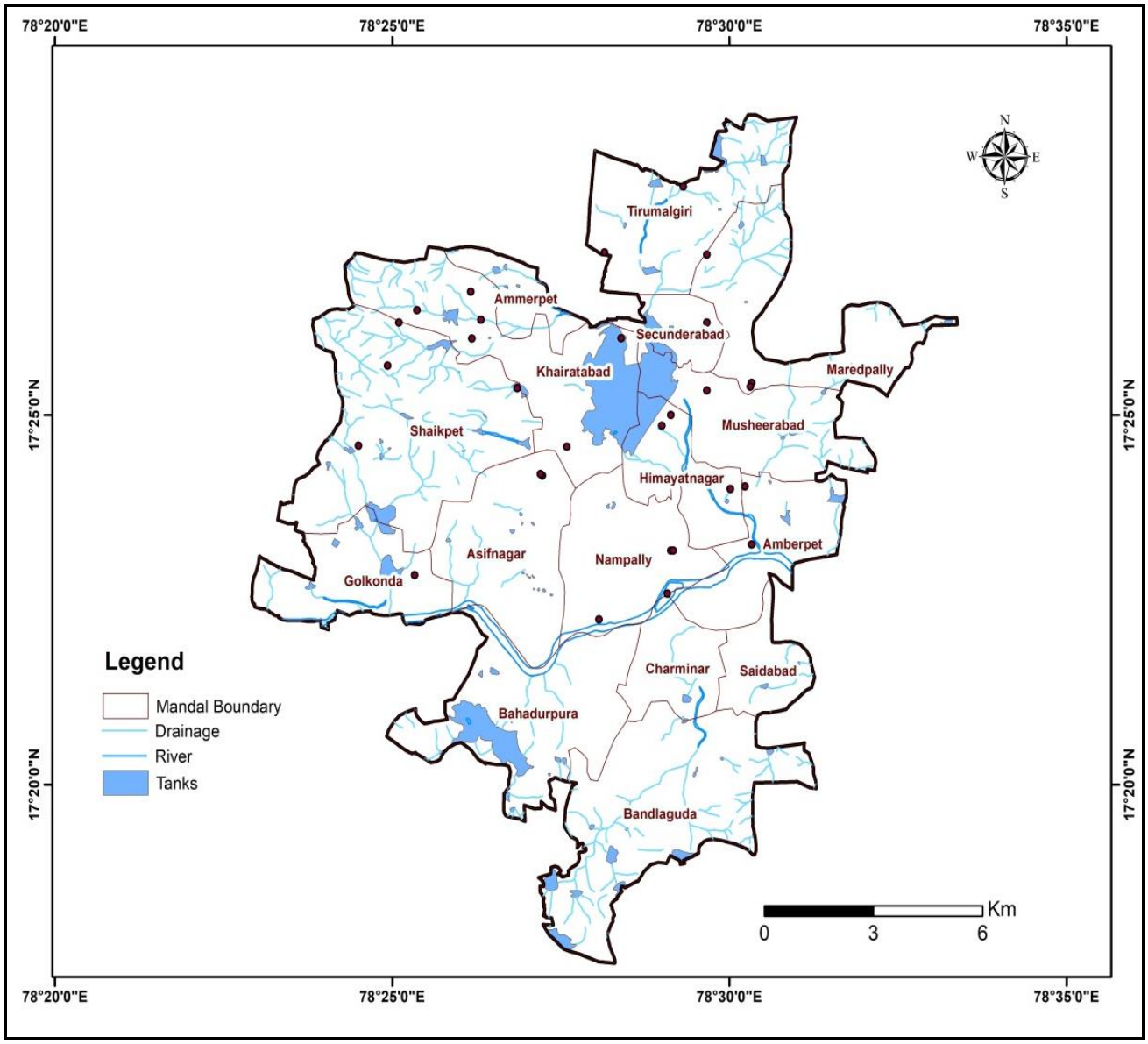


Fig-1.4: Drainage and water Bodies map of Hyderabad District

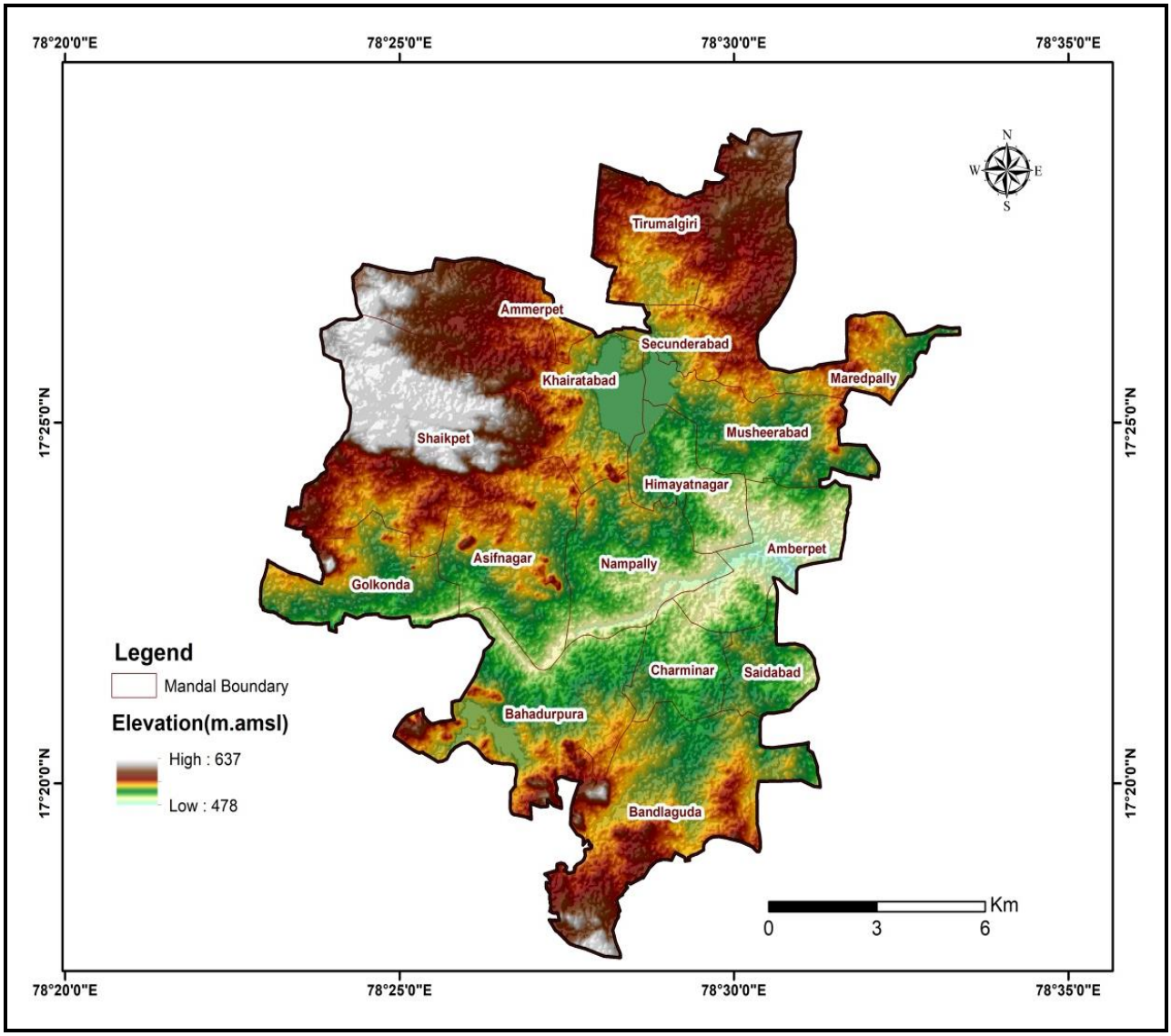


Fig-1.5: Elevation map of Hyderabad District

1.6 Geomorphology

The major geomorphic units are Piedmonts, Pediplains, Pediment Inselberg complex, Residual Hills and Plains. This undulating terrain is punctuated by granite hillocks and mounds. Many of these hills and ridges (for example in Banjara Hills, Shaikpet, Malkajgiri and Addagutta areas) are intervened by low-lying areas and drained by minor streams.

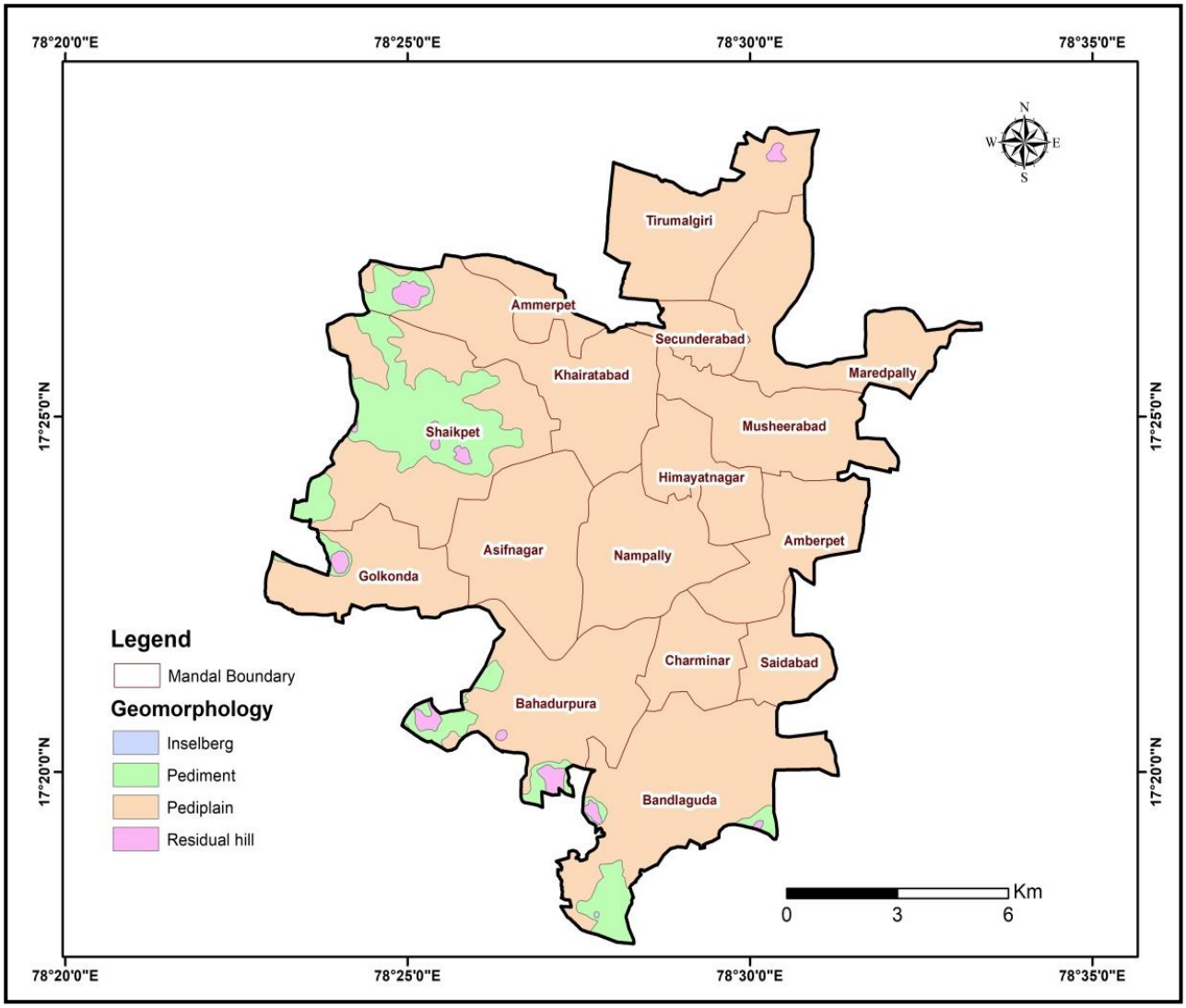


Fig-1.6: Geomorphology map of Hyderabad District

1.7 Soils

The major part of the district is covered by red soil and based on the texture, they are classified into Clayey Skeletal (5 % area), Fine mixed (13 %area) and Gravelly clay soil (82%).

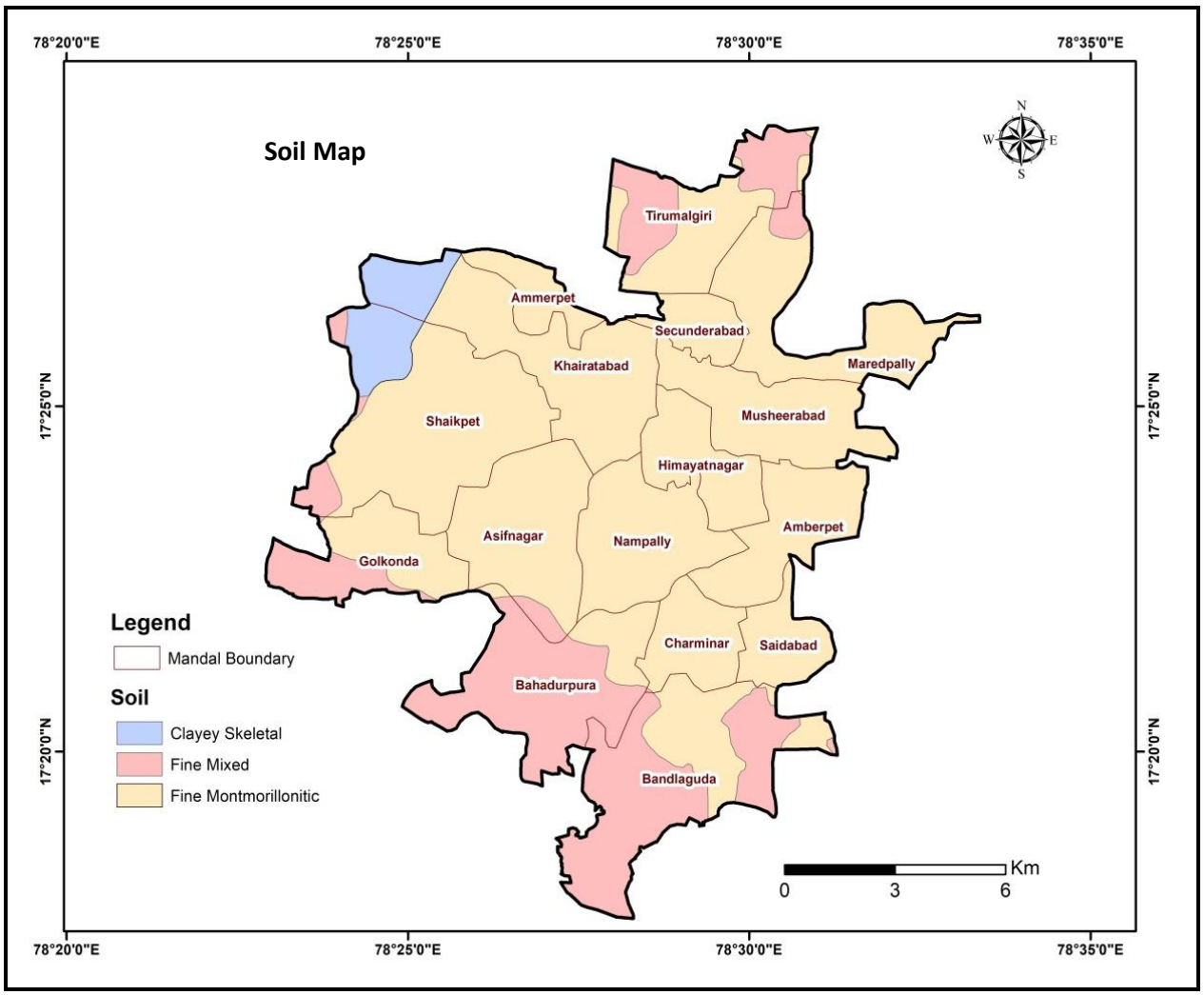


Fig-1.7: Soil Map of Hyderabad District

1.8 Land Use: The first land use survey was covering 172.60 sq, km of city area (MCH) and 21.52 sq km of peripheral area was prepared and notified by Municipal Corporation area of Hyderabad (MCH) in the year 1975. Later, the Land use pattern survey for the MCH area was done by HMDA in the year 2008. The land use pattern during 1975 and 2008 are shown in Table-3 (i) and (ii) respectively.

Table:1. 2 (i) Land use Pattern (Area in Sq. Kms)

S. No	Land Use	Area	%
1	Residential	26.94	13.88
2	Commercial	1.47	0.76
3	Industrial	3.06	1.57
4	Recreational	7.71	3.97
5	Public and Semi-public	10.16	5.23
6	Transport and Communications	12.95	6.67
7	Vacant	76.33	39.32
8	Agricultural	34.62	17.84
9	Other	20.89	10.76
	Total	194.11	100

(Source: Development Plan for Hyderabad, 1975)

Table-1.2 (ii) Land use Pattern -2008 (Area in Sq. Kms)

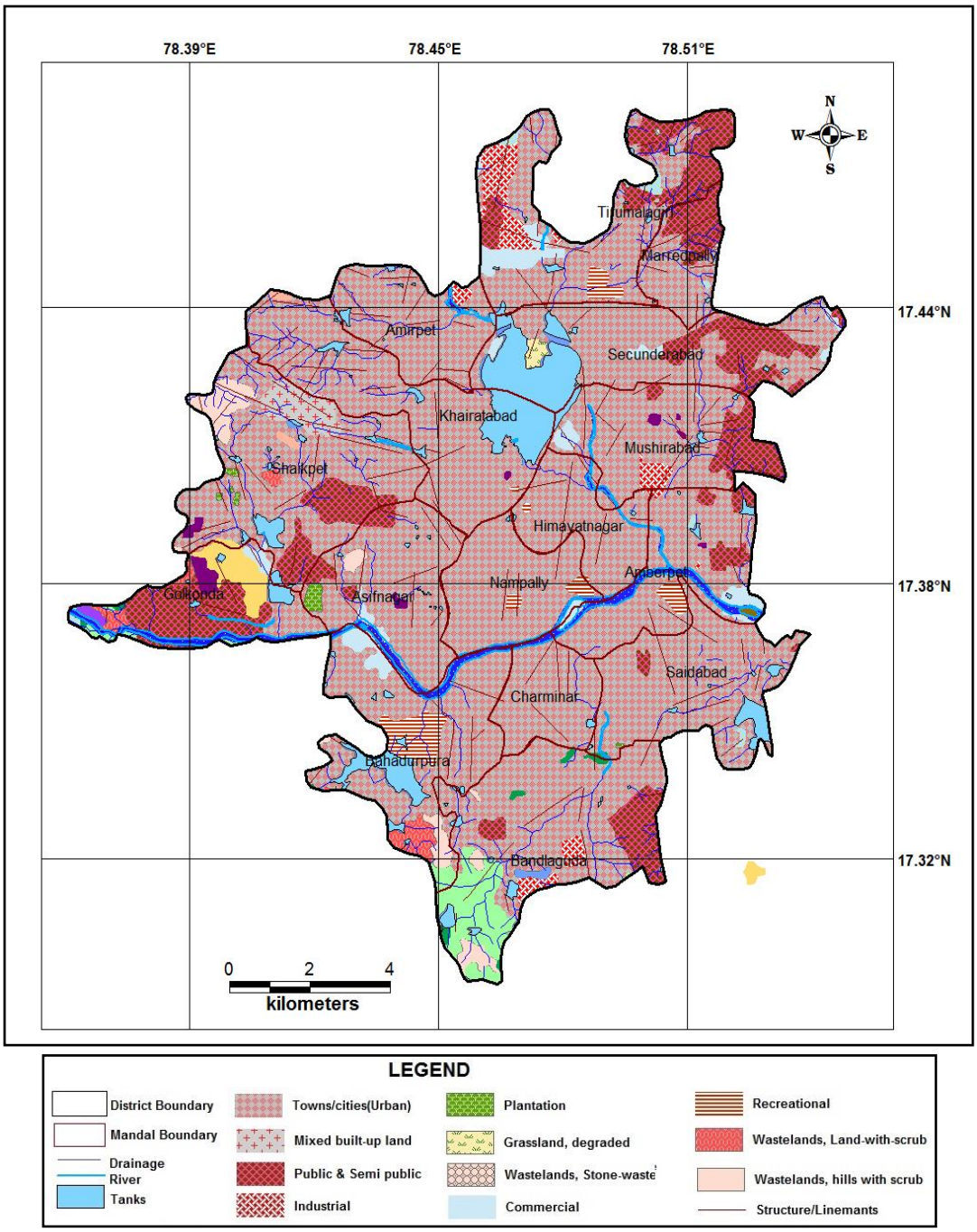
S. No	Land Use	Area	%
1	Residential	76.35	44.24
2	Commercial	12.70	7.36
3	Mixed	7.49	4.34
4	Industrial (Including manufacturing, small scale, household, garages etc)	4.25	2.46
5	Public Semi Public	15.55	9.01
6	Parks & Playgrounds	11.75	6.81
7	Vacant lands, open lands, Rocks & Hills	2.73	1.58
8	River, Lakes, Nalahs, Kuntas	10.75	6.23
9	Agriculture & Gardens etc	1.04	0.6
10	Transportation & Communication	18.64	10.8
11	Defence	8.34	4.83
12	Burial Grounds Crematoria etc	3.00	1.74
13	Total	172.59	100

(Source: Master Plan of HMDA (MCH Area))

The land use and land cover of the Hyderabad was studied by NRSC and the details are also tabulated in Table-3(iii) and are shown Fig -3.

Table-1.2 (iii): Land Use pattern of Hyderabad District

Land Use Pattern		Area (Sq. Kms)
Build up Area	:	174
Open Grass land	:	0.6
Waste Land	:	6.5
Water Bodies	:	9.5



Source: NRSC

Fig-1.8 Land Use map of Hyderabad District

1.9 Geology

Hyderabad forms part of the Pre-Cambrian peninsular shield and is underlain by the Archaean crystalline complex, comprising pink and grey granites and granite gneisses. The pink granites are very coarse grained and porphyritic in texture and are considered to be younger to grey granites. Numerous younger intrusive quartz veins, pegmatite and dolerite dykes intrude granites along mega fractures and joints. Several dykes intrude the granite, and some of these dykes form linear ridges. A thin veneer of alluvium lies along the Musi River.

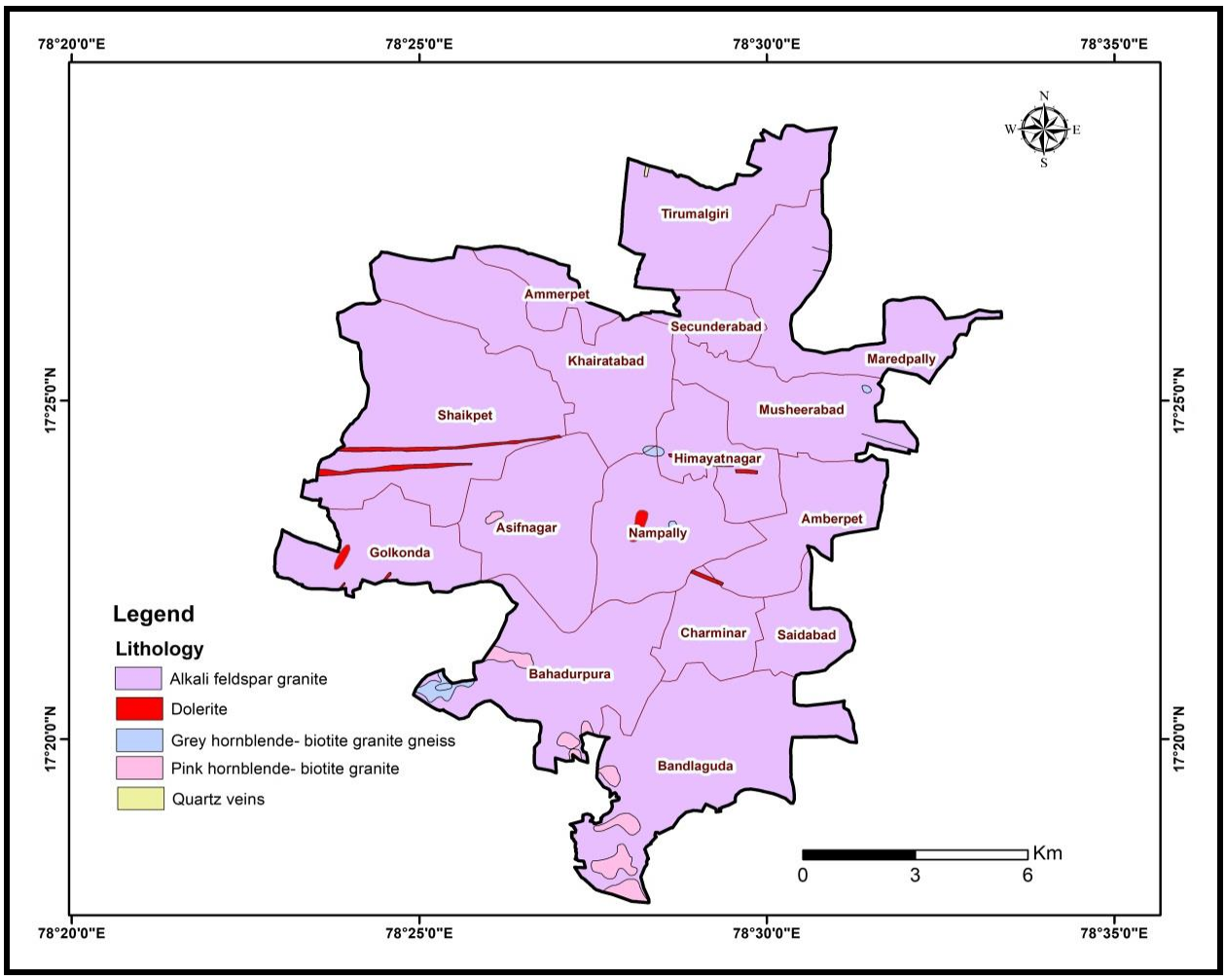


Fig-1.9: Geology map of Hyderabad District

The Granites exhibit structural features such as fractures, joints, faults and fissures. WNW - ESE and ENE-WSW, NE-SW trending structures are tensional in nature while NW-SW& NW-SE structures are shears in type. Innumerable dolerite dykes mostly in East-West, ESE-WNW & NE-SW directions occur in the area.

1.10 Hydrogeology

More than 97% of the area is underlain by the Archaean group of rocks consisting of mostly pink and grey granites and the remaining 3% of the area is underlain by the Alluvium. Accordingly, two aquifer systems exist in the area, i.e Aquifers of the granites and Aquifers of Alluvium, though alluvial aquifers are insignificant.

Ground water occurs under phreatic conditions in weathered zone and under semi-confined to confined conditions in the fractured zones. The piezometric elevations in northern part vary from 500 to 563 m amsl with steep gradient in NE direction. In southern part, the piezometric elevation is between 470 and 520 m amsl with gentle gradient towards Musi River. Ground water was exploited through shallow, large diameter dug wells until 1970 to meet domestic and irrigation requirements. Presently ground water is being exploited through shallow and deep bore wells with depth ranging from 100-300 m.

Central Ground Water Board (CGWB) had constructed 10 Exploratory wells in Hyderabad district (Table-5). The depth to water level ranges from 3.30 m (Manikeswarinagar) to 56.3 m in (Film nagar). The yield of wells varies from 0.21 to 6.9 lps with drawdown of 6 to 20.6 m. The specific capacities of the bore wells range between 10.0 lpm/m (New Boiguda) to 72 lpm/m (Borabanda) and the Transmissivity of the aquifers ranges between 0.48 and 202 sq.m/day.

The aquifers are of anisotropic and non-homogenous type resulting in different hydrogeological conditions within the shorter distances depending upon degree and intensity of fracture and recharge conditions. The thickness of the weathered zone varies from 5-25 m. and yield ranges from negligible to 5 lps. High density of shallow fractures is observed in the eastern, western and northern parts of the area while moderate to low density fractures are observed in central part in the main city area. In general, the shallow fractures are more productive than the deeper ones. But, in some locations in the western parts, the deeper fractures (127 m & 172 m) are more productive (6 lps at Film Nagar and 10 lps at Borabanda).

Table-1.3: Details of Ground Water Exploration, Hyderabad District

S.No	Location	Topography	Hydro-geological set-up		Other Information	S.W.L (m)	Q (lpm)	T (m^2/day)	Quality
			Weathered Depth	Fracture zones					
Potential deep fracture rock									
1	BJR (film) nagar	Topographic High	Nil	61-63, 127-128	Massive rock in recharge area	56.35	216	31	Not potable, high F
2	Borabanda	Topographic High	Nil	172-173	Near major E-W lineament and intersecting N-S block joints	25	574	202	Not potable, high F
Moderately potential weathered &fractured rock									
3	Manikeswari Nagar	Moderately sloping ground	18.8	24-25	Recharge area	3.30	357	63	Not potable
4	Krishna Nagar	Topographic low	13.7	50,51, 68-70, 77	Upstream	12.35	314	59	Potable
5	Lower Tank bund	Moderately sloping ground	14.7	34-35, 56-57, 71-72	Close to contaminated drainage course	13.4	225	9	
6	New Boiguda		7.1	9-10, 18-19, 25-26, 156-157	Recharge area	5.34	240	11	Potable
Massive rock with very poor yield									
7	Rehmat Nagar	Topograhic high	nil	nil	Massive rock in recharge area	14		0.87	Not Potable
8	Sanath Nagar	Moderately sloping ground	5.5	nil	Massive rock	19.3		0.666	Potable
Less potential rock with minor fractures									
9	Sultan Bazar	Moderately sloping ground	11	80-82	Low recharge area, massive rock	11	60	6	
10	Gowliguda	Topographic low	8.0	11-12, 130-132, 156-158	In Musi River Island	8.6	60	0.48	

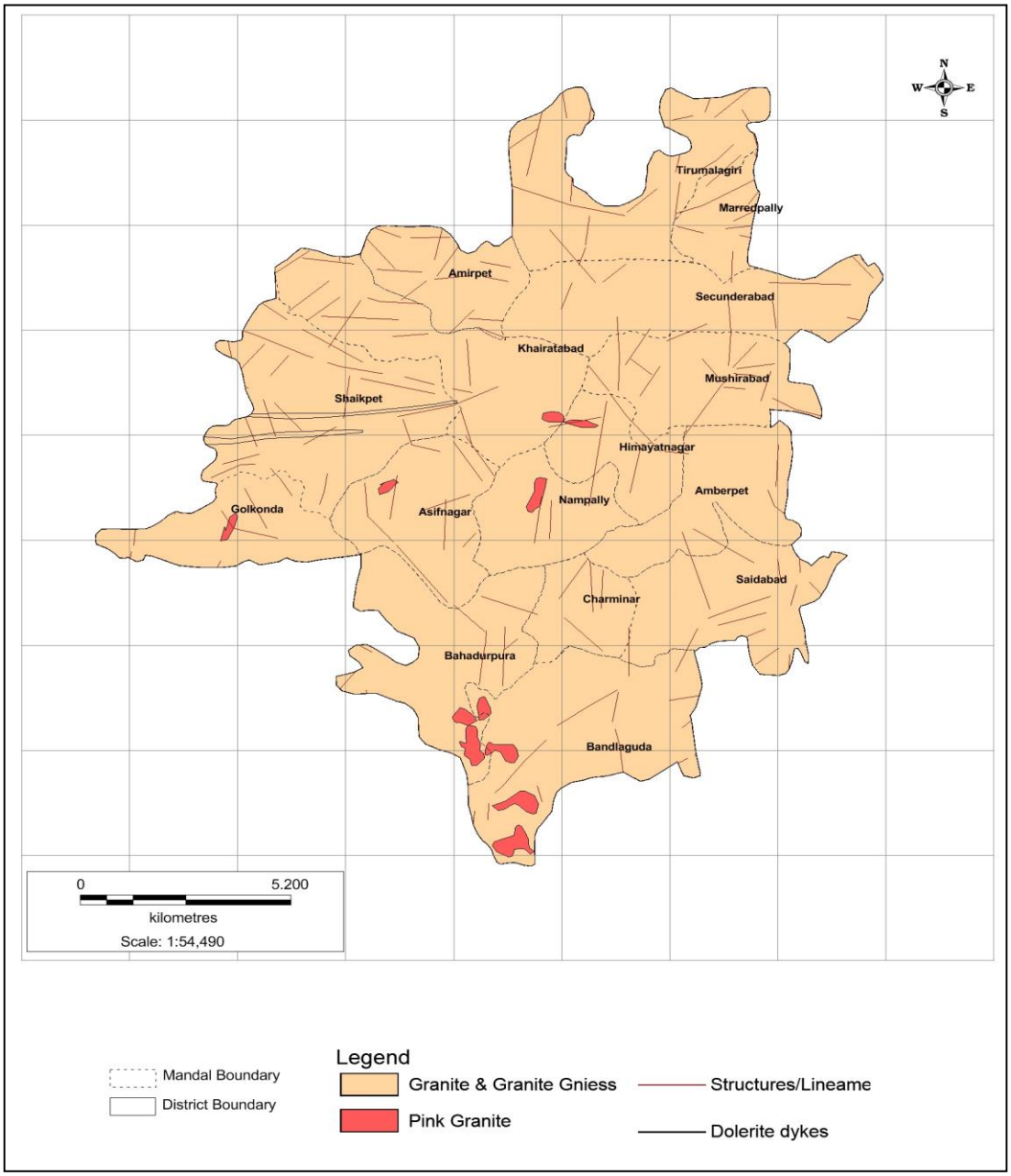


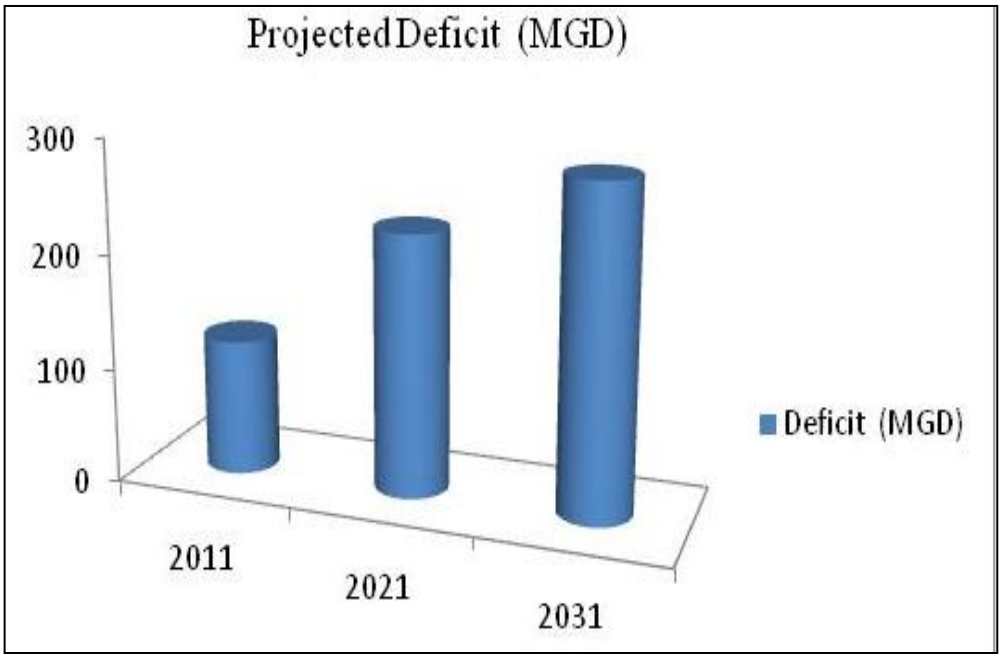
Fig-1.10: Principal Aquifers of Hyderabad district

1.11 Surface Water Supply:

Hyderabad Metropolitan Water Supply and Sewerage Board (HMWS&SB) is providing and maintaining water supply to Hyderabad. As per the data provided by HMWS & SB, the present water supply is 392 MGD/1.77 MCM per day (649 MCM/year) through Krishna and Godavari Rivers. The supply from River Krishna is 270 MGD/1.2 MCM per day through its Phase-I, II and III. The supply from Godavari River is 122 MGD/ 0.55 MCM per day.

Table-1.4: Indicators of water supply positions.

Indicators	**MCH/Hyderabad district**
Total Population	36.33 lakhs
Slum Population	14.1 lakhs
Network Coverage	90%
% Access to piped water supply	70%
Average Per capita Supply	162 lpcd
Duration of supply	2 hours alternate day



2.0 DATA COLLECTION AND GENERATION

Collection and compilation of data for aquifer mapping studies are carried out in conformity with the Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various data generation activities **(Table-2.1)**. The historically available data of Geology, Geophysics, Hydrogeology, and Hydrochemistry generated under various studies by the CGWB through Systematic Hydrogeological studies, Reappraisal Hydrogeological studies, Groundwater Management studies, Exploratory drilling, and special studies have been utilized for data gap analysis, along with the data collected from various State and Central government departments.

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

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

3.	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.
4.	Aquifer Management Plan	Preparation of aquifer management plan	Information on aquifer through training to administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain.

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

2.1 Exploratory drilling

Information on aquifer geometry, groundwater potential of various formations, fracture systems, their characterization is primarily inferred from the exploratory drilling data. CGWB has a total of 10 wells in the district.

2.2 Water Levels

The ground water level data of 20 CGWB wells and 20 SGWD wells are utilized for the Aquifer Mapping studies. 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 spatial-temporal behaviour of the groundwater regime.

2.3 Hydro chemical Studies

Water quality data of CGWB and SGWD is utilized for understanding the spatial variation of quality in the district. A total of 80 ground water monitoring well data (Central Ground Water Board:20, SGWD:60) Telangana State is utilized to understand the chemical characteristics of groundwater. Parameters namely pH, EC (in µS/cm at 25 ° C), NO_3 and F were analysed.

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1. Ground water Level Scenario

3.1.1 Depth to ground water level

Analysis of the pre and post monsoon water level data from 40 (CGWB: 20, SGWD: 20 PZ) groundwater monitoring wells shows that depth to water level varies from 3.2 to 35.9 m bgl during pre-monsoon and 0.96 to 20.13 m bgl during post-monsoon season.

Pre-monsoon season: In majority of the areas, water level during this season is in the range of 10-20 m (54% of the area), 5 to 10 m in 33% of the area, 2 to 5 m in 3% of the area. Deeper water level in the range of > 20 m bgl occupies about 8 % of the area falling in parts of Golkonda and Ameerpet mandals (**Fig.3.1**).

Post-monsoon season: Majority of the water level during this season are in the range of 5 to 10m covering 73% of the area, 2 to 5 m bgl in 18 % of the area, <2 m in 1% of the area and 10 to 20 m in 9% of the area. (**Fig.3.2**). Shallow water level < 5 mbgl) occupy about 19% of the area in parts mainly in parts of Charminar, Bahadurpura, Amberpet, Saidabad and Tirumalagiri mandals. Deep water level in the range of > 10 m bgl occupies about 8 % of the area falling in parts of Golkonda, Ameerpet, and Asif Nagar mandals.

3.1.2 Seasonal Water Level Fluctuations (May vs. November): Out of 40 wells, 39 wells in the state records rise in water level. The water level rise varies from 0.53 to 23.22 m (Fig.2.6). 64% of the area have >4 m rise in water level, 28% of the area have 2 to 5 m rise and 7% of the area have less than 2m rise.

3.1.3 Long term water level trends: Trend analysis for the last 10 years (2011-2020) is studied from 28 hydrograph stations of CGWB and SGWD. It is observed that during pre-monsoon season 25% of the area shows falling trend and 75% of the area shows rising trend. The falling trend in the range of -0.02 m/yr to -1.81 m/yr and rising trend 0.01-1.2 m/yr. During post-monsoon season 3 % of the area shows falling trend and falling trend -0.07- to -0.10 m/yr rising trend ranges from 0.075-2.73 m/yr (**Fig 3.4)**.

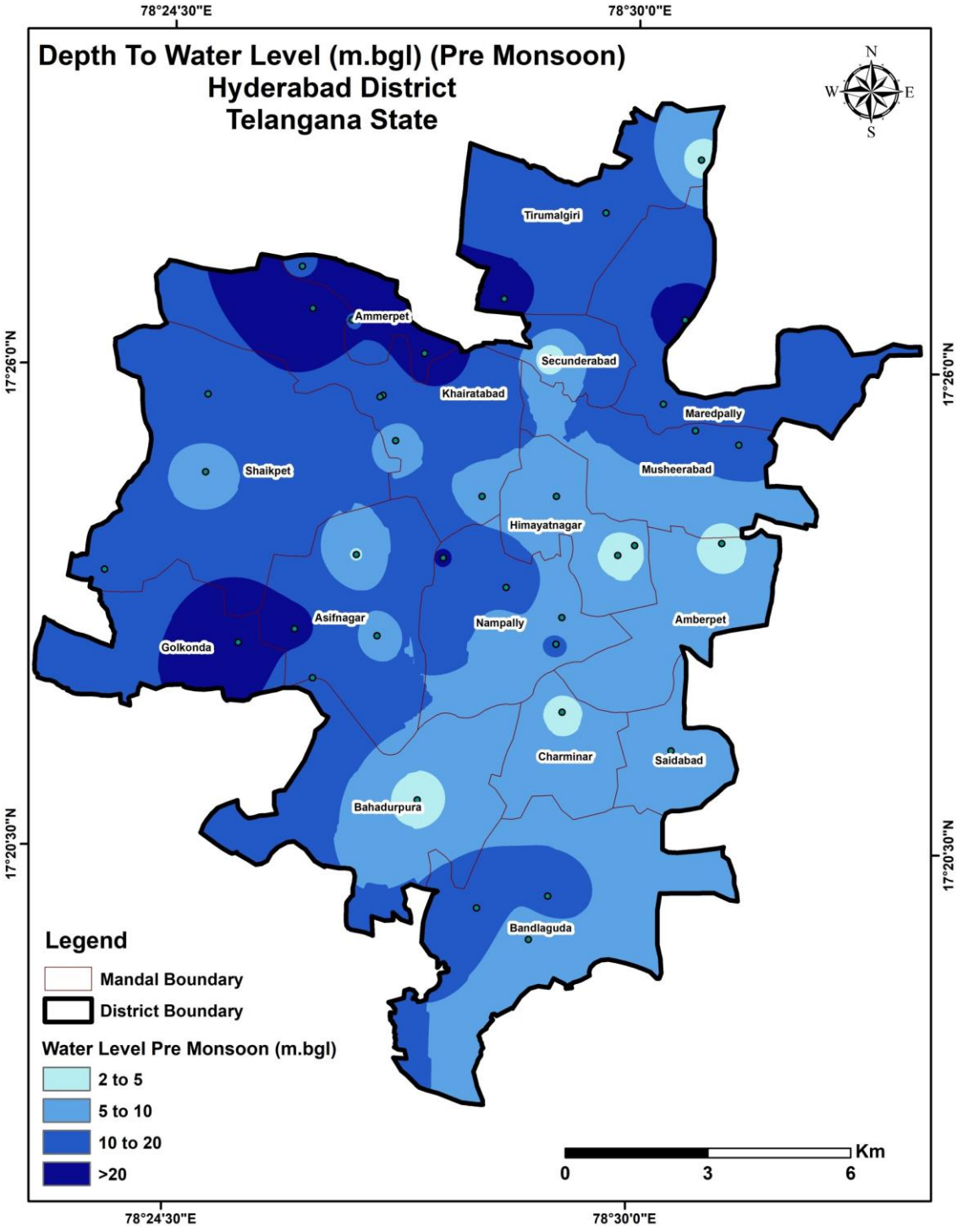


Fig.3.1: Depth to Water level (Pre-monsoon)

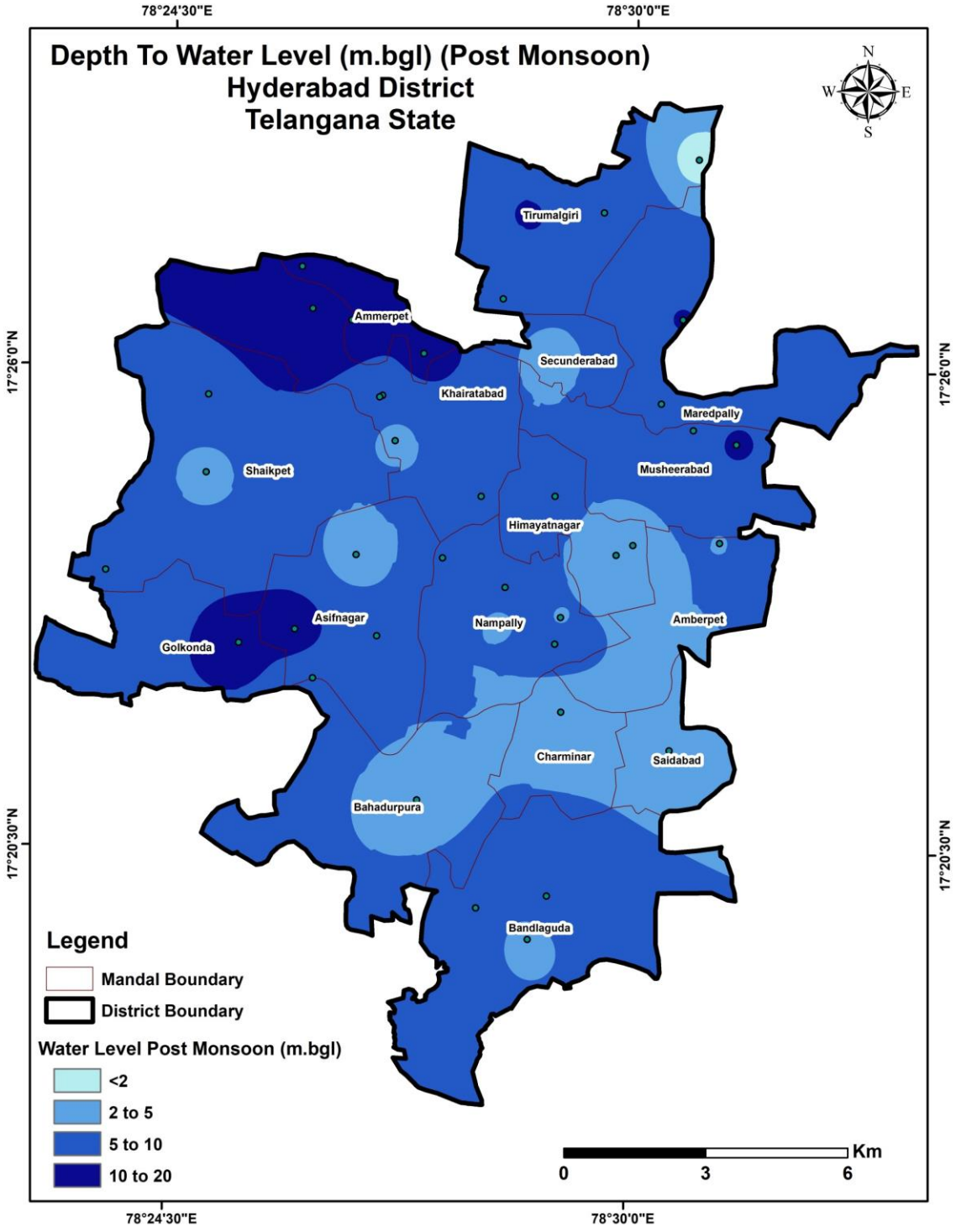


Fig.3.2: Depth to Water levels (post-monsoon)

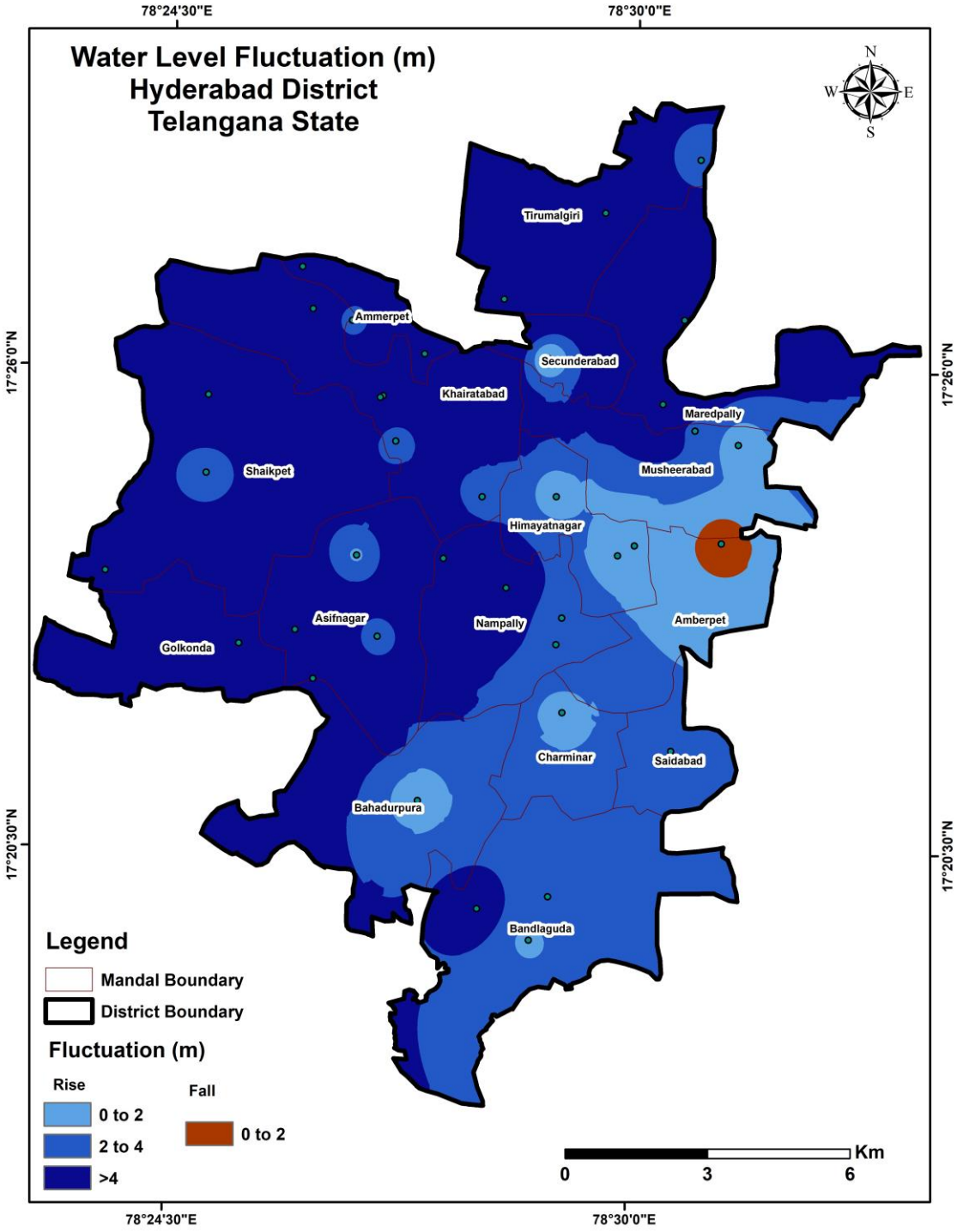


Fig.3.3: Water Level Fluctuation (m) (Nov with respect to May)

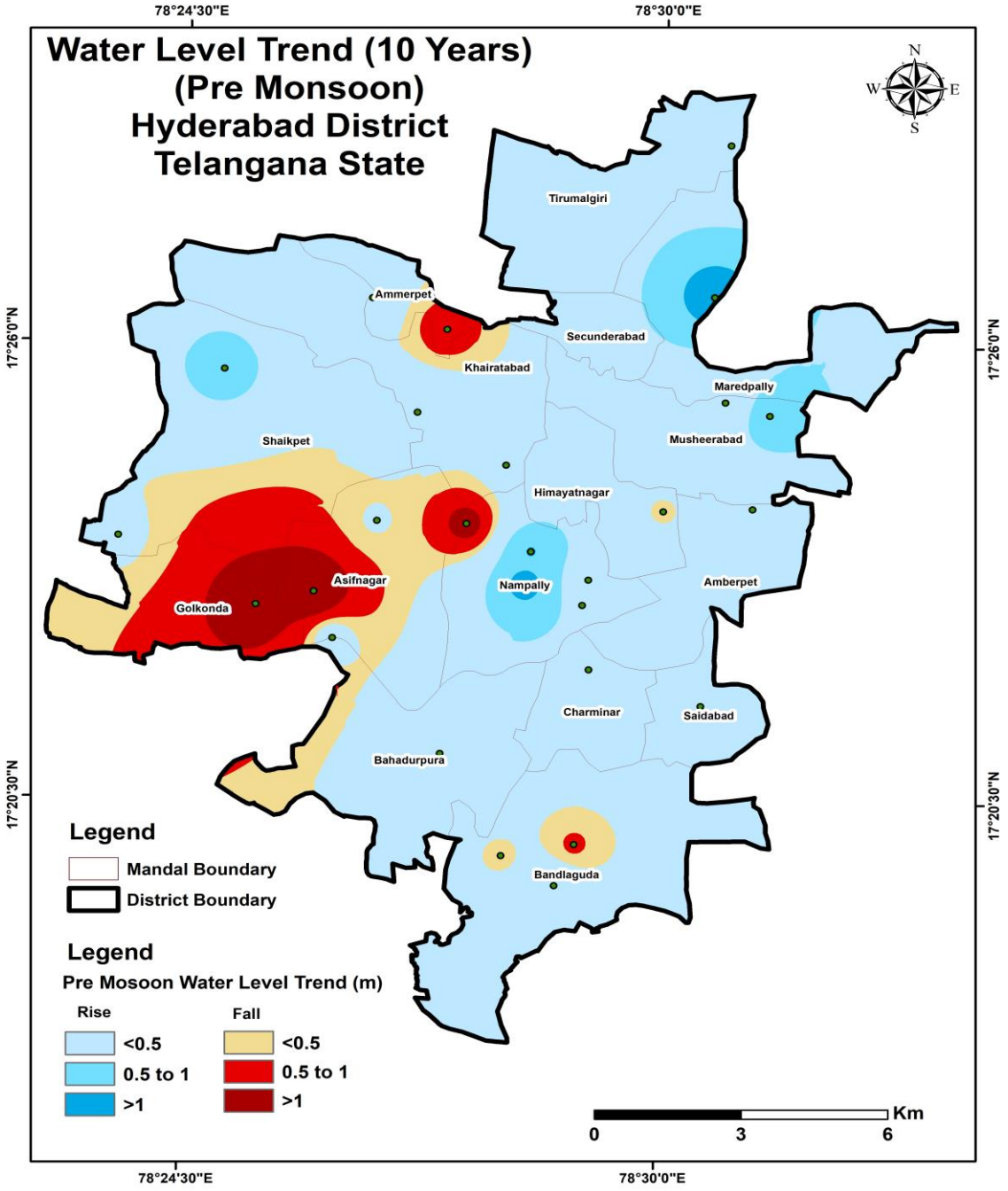


Fig. 3.4 a Long-term water level trends 10 years – Pre-Monsoon

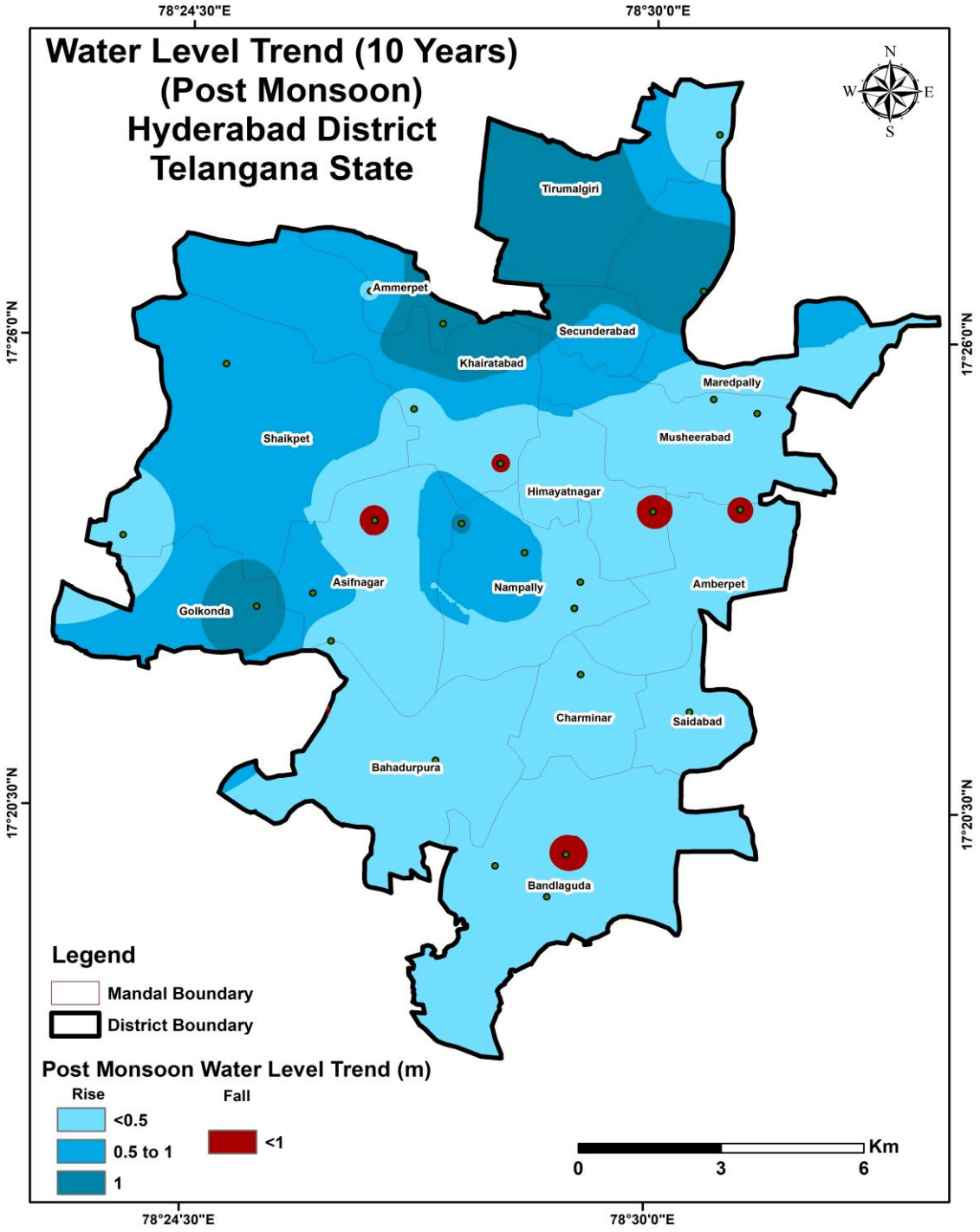


Fig. 3.4 b: Long-term water level trends 10 years – Post Monsoon

3.1.4 Water Table Elevation: During pre-monsoon water-table elevation ranges from 480 to 604 meter above mean sea level and post-monsoon season 484 to 606 meter above mean sea level (m amsl). The ground water flow follows the drainage flow direction. The ground water flow is towards south eastern direction in northern part and in case of southern part of the district, ground water flow is towards north eastern direction (**Fig.3.5).**

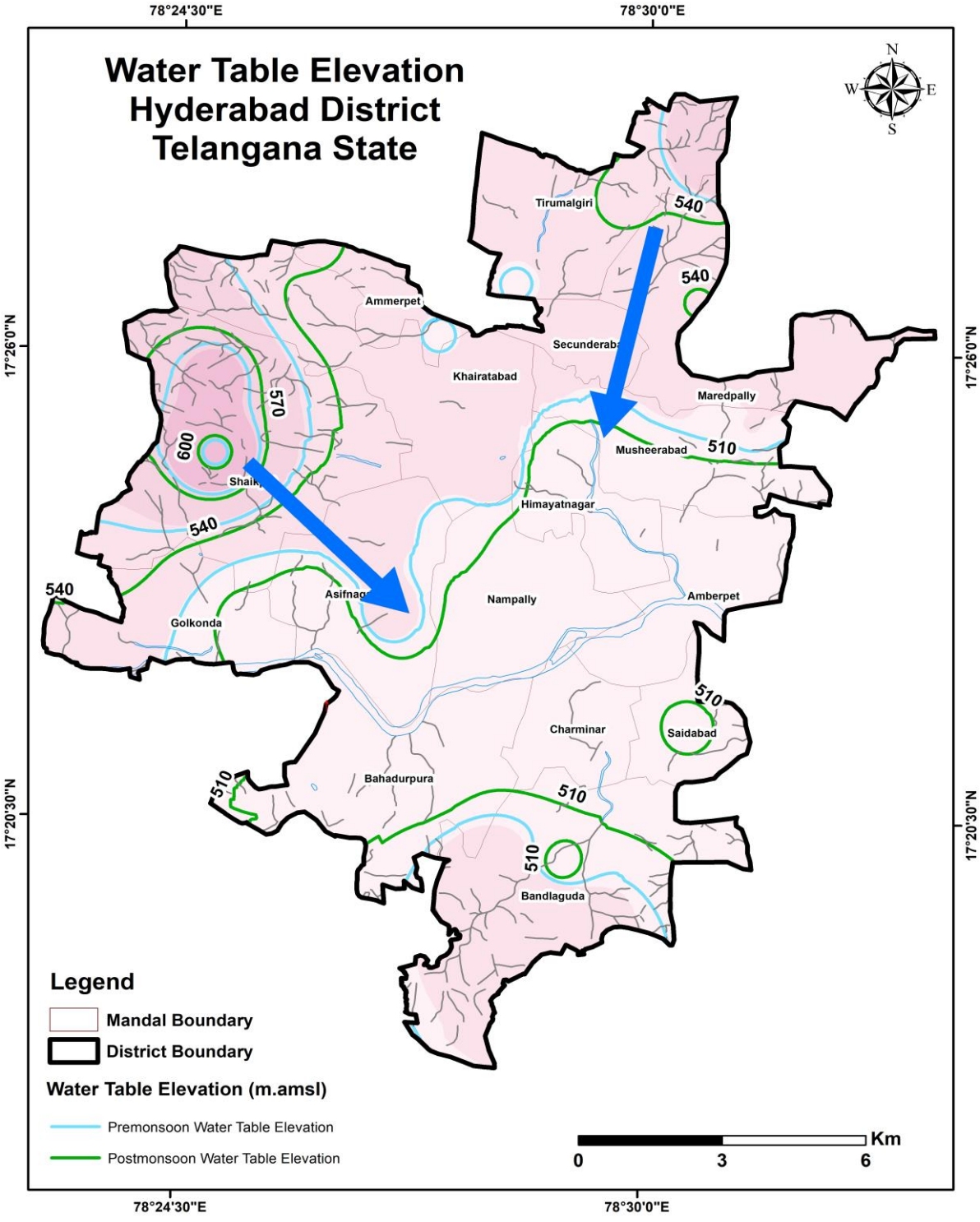


Fig-3.5: Water Table Elevations (m amsl)

3.2 Ground Water Quality

The groundwater quality in the area is generally good for all purposes. In all the locations PH is within the acceptable limit and shows mildly alkaline to alkaline.

3.2.1 Pre-monsoon:

Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 6.74-8.28 (Avg: 7.6). Electrical conductivity varies from 340-2885 (avg: 1032) µ Siemens/cm**.** In 96% of area EC is within 1500 µ Siemens/cm and 2 % area, it is more than 1500 µ Siemens. (**Fig.2.6).** NO_3 ranges from 1-204 mg/L. Nitate concentration in 84 % of samples is within the permissible limit of 45 mg/L (**Fig.2.7**). Fluoride concentration varies from 0.25-3.65(**Fig 2.10**) and 95% of samples is within the permissible limits of BIS and rest is beyond the permissible limit of 1.5 mg/L.

3.2.2 Post-monsoon

Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range 6.33 to 7.85 (Avg: 7.3) Electrical conductivity varies from 466 to 4071 (avg: 1160) µ Siemens/cm. In 99% of area EC is within 3000 µ Siemens/cm and in 2 percentage of the area EC>3000 µ Siemens/cm (Fig.2.11). NO_3 ranges from <0.35-259 mg/L. Nitrate concentration in 77% (20 Nos) of samples is within the permissible limits of 45 mg/L (Fig.2.12). Fluoride concentration varies from 0.24-3.33 (Fig 3.10) and 87% (32 Nos) of the samples is within permissible limits of BIS and rest is beyond permissible limits of 1.5 mg/L

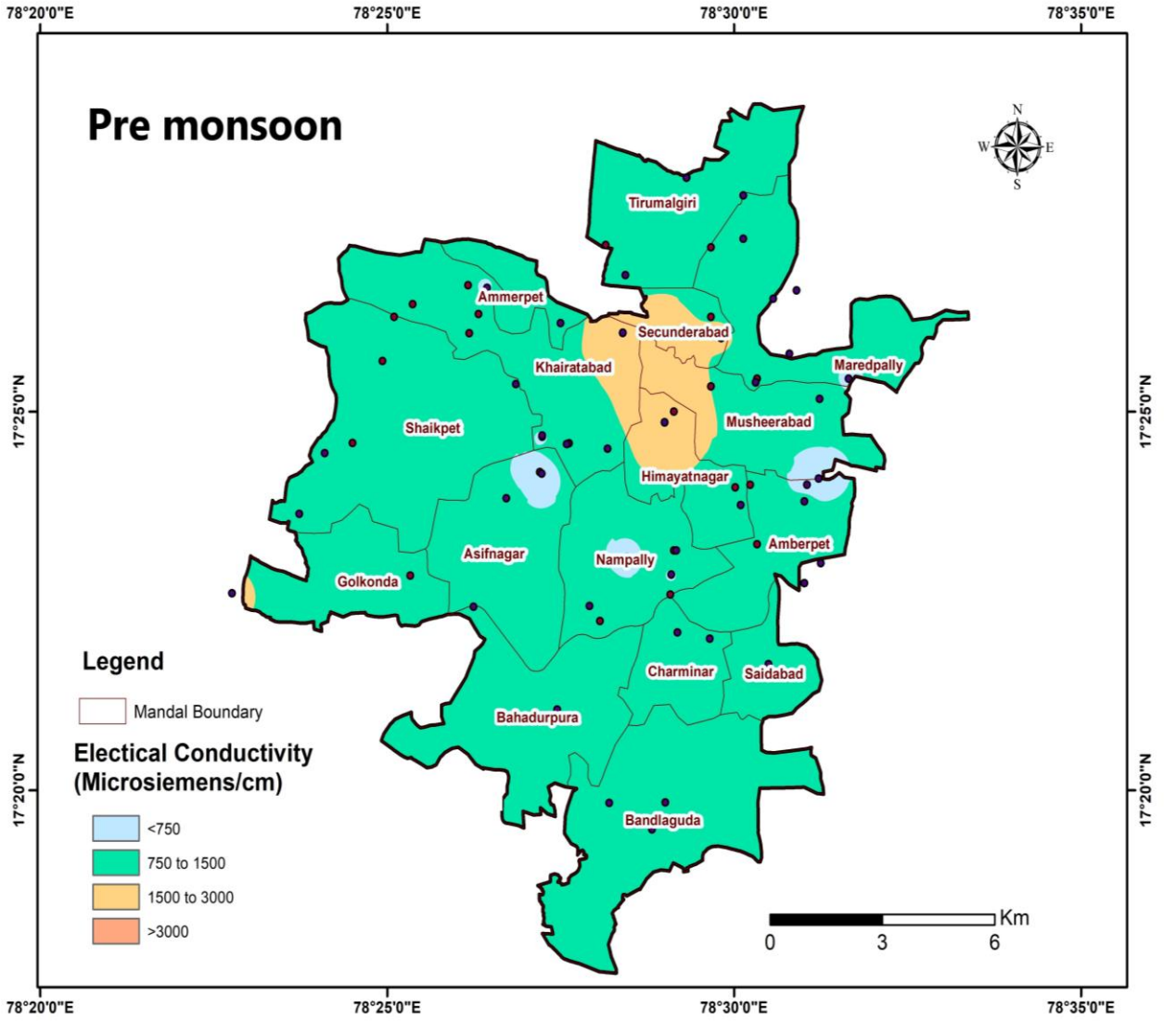


Fig-3.6: Pre monsoon EC distribution

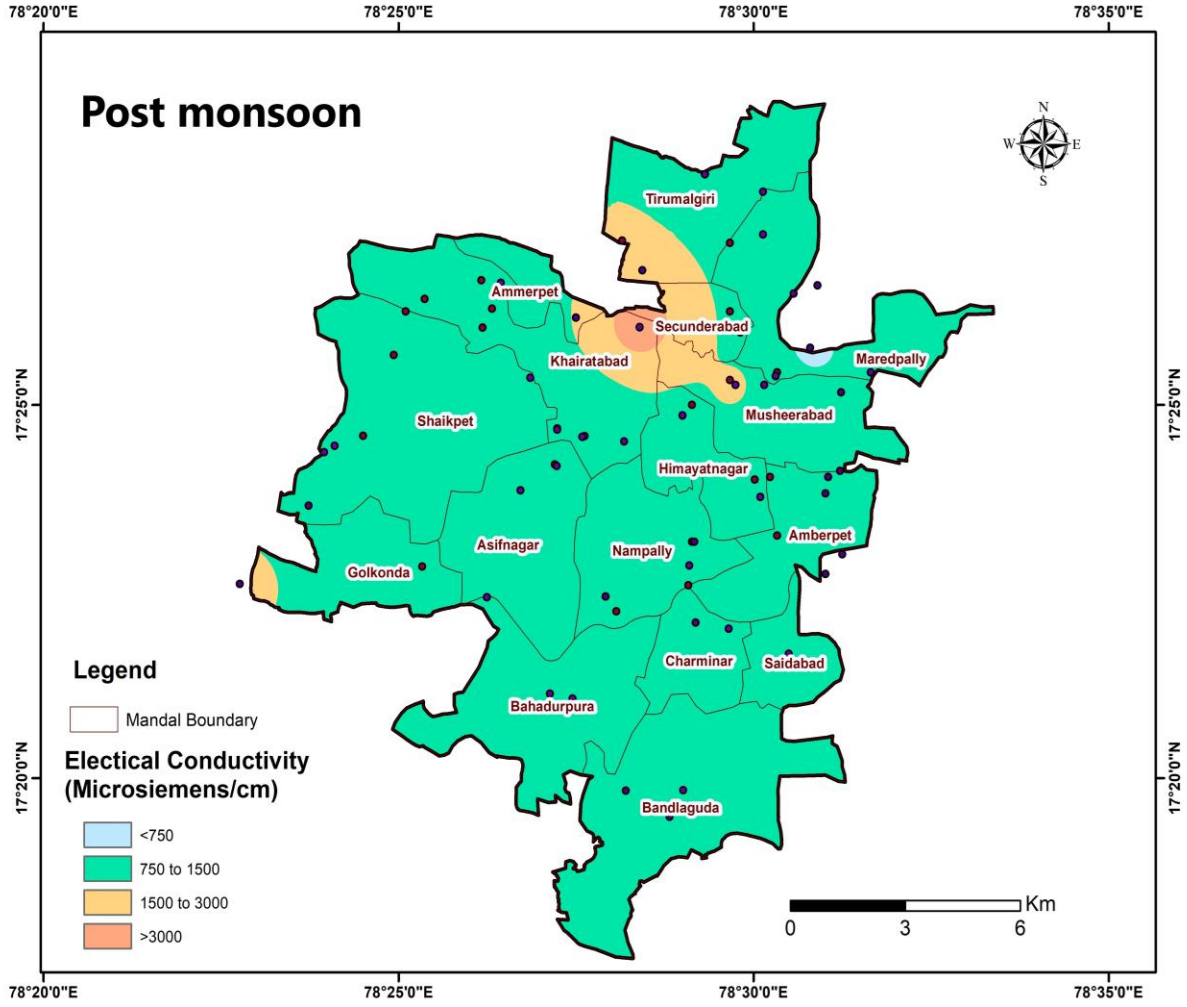


Fig-3.7 Post monsoon EC distribution

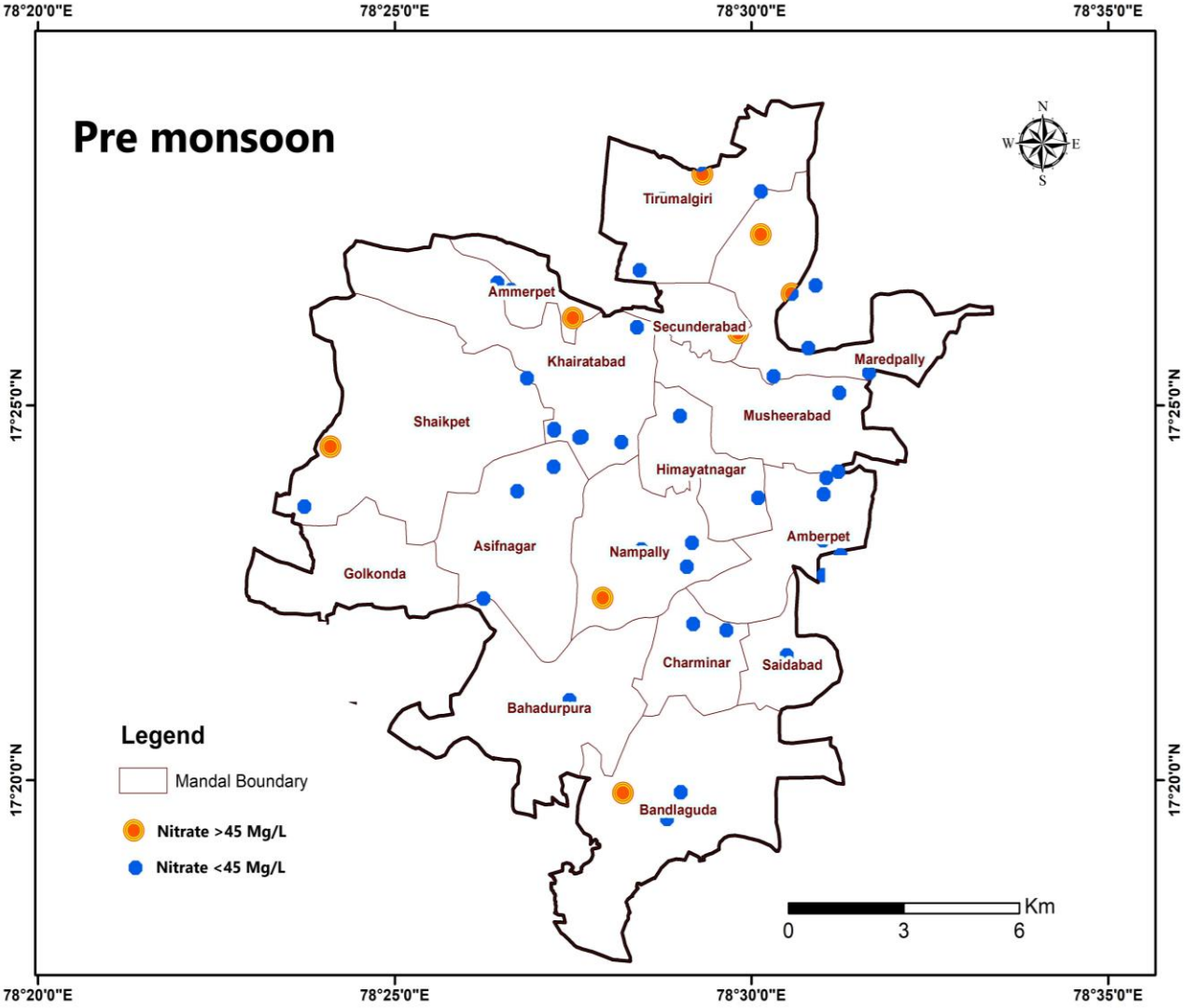


Fig.3.8: Pre monsoon Nitrate distribution

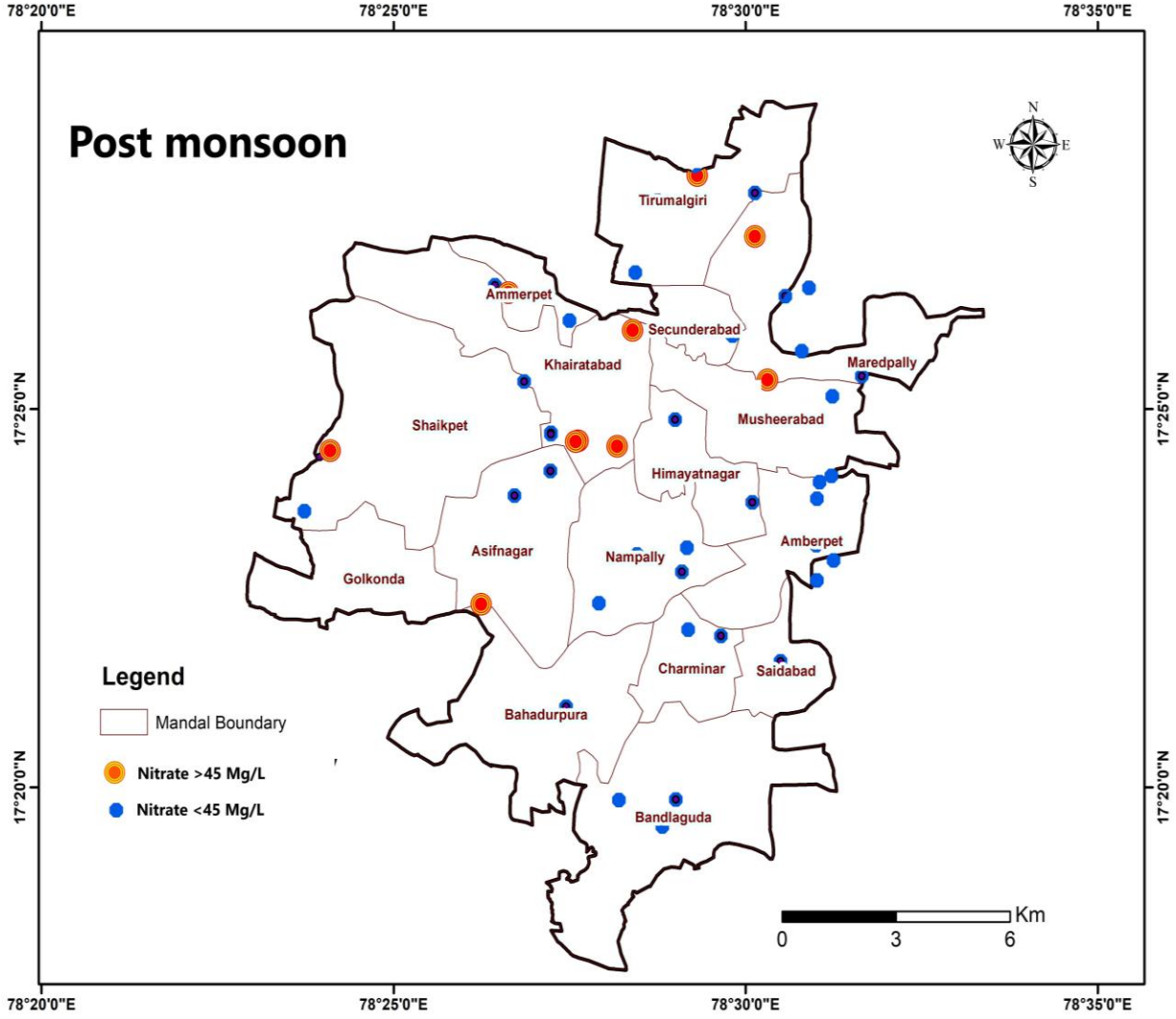


Fig.3.9: Post monsoon Nitrate distribution

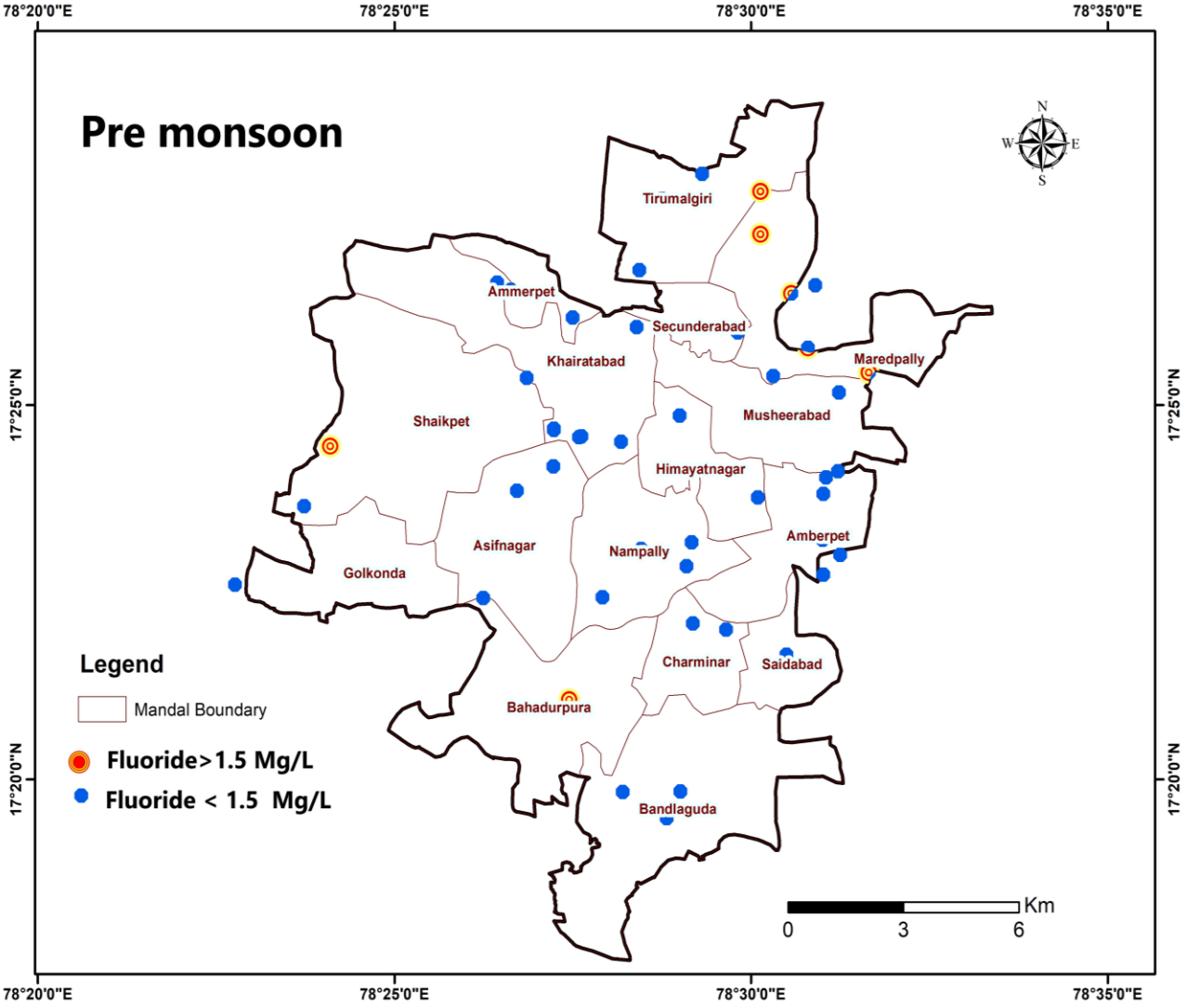


Fig – 3.10 Fluoride Distribution (Pre monsoon)

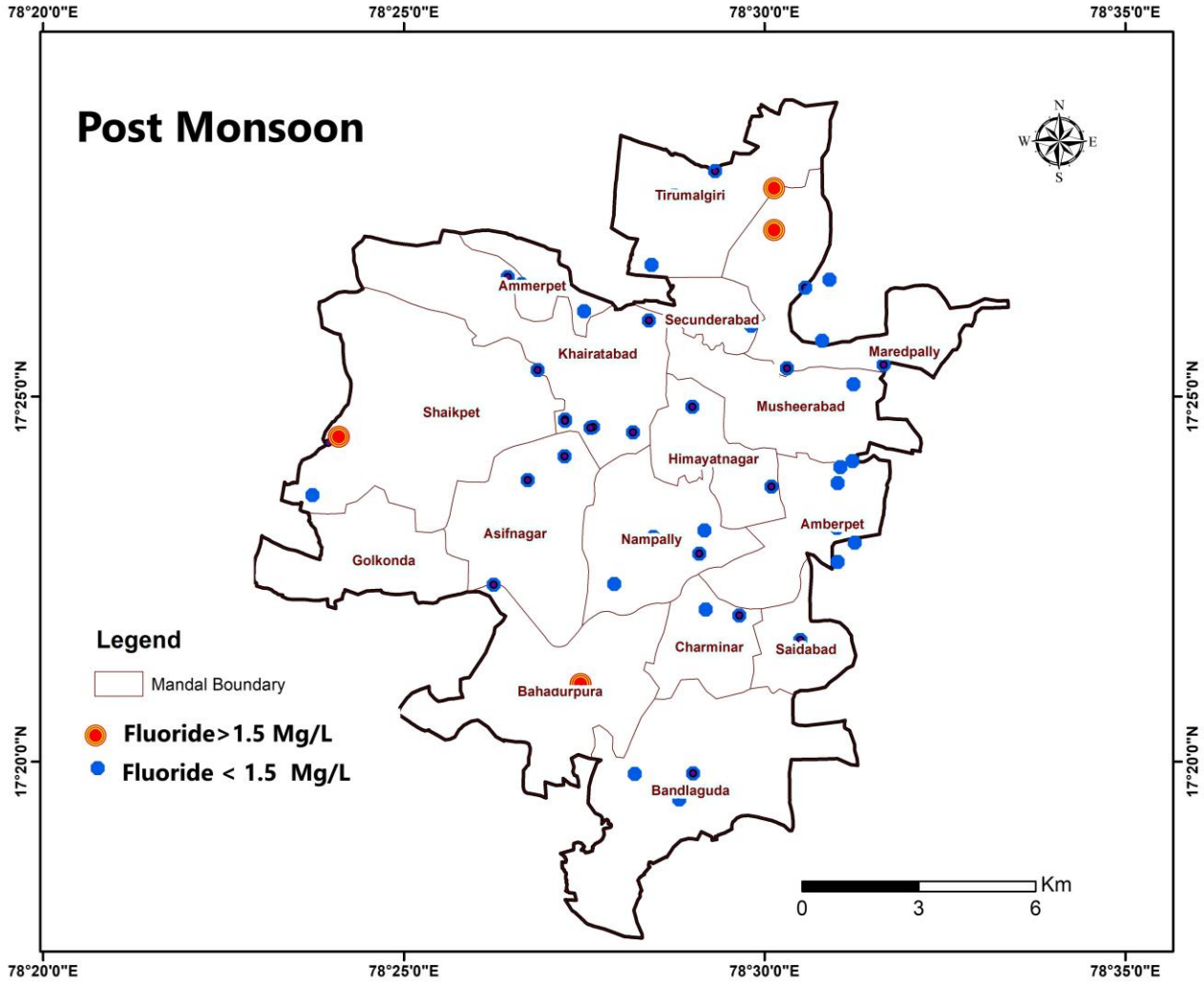


Fig-3.11: Fluoride distribution (Post monsoon)

3.3 Aquifer Systems of Hyderabad District

The aquifers are the weathered zone at the top, followed by a discrete anisotropic fractured zone at the bottom, generally extending down to 200 m depth. Weathered and fractured granites and gneisses form the major aquifer system. Ground water occurs under unconfined and semi-confined conditions and flows downward from the weathered zone (saprolite and sap rock) into the fracture zone. Ground water occurs under phreatic conditions in weathered zone (Aquifer-I) and under semi-confined to confined conditions in the fractured zones (Aquifer-II). Presently ground water is being extracted through shallow and deep bore wells with depth ranging from 100 - 300 m**.** The thickness of the weathered zone varies from 5-25 m and discharges generally vary from negligible to 5 lps. High density fractures are observed in the eastern, western and northern parts of the area while moderate to low density fractures are observed in central part.

Central Ground Water Board (CGWB), under its exploration programme constructed 10 exploratory bore wells with depths ranging from 132 to 203. Laterite Caps of 1-2 m thickness are noticed at Yerragadda and Sanath Nagar areas. Thickness of weathered mantle is meagre at Film Nagar, Yousufguda areas where as it extends up to 20 m at various locations. Fractures at 60 m, 100 m, 130 m and 165 m depth ranges are observed in bore holes drilled in Film Nagar, Borabanda, Sanath Nagar areas with local elevation variations. Shallow conjugate shear fractures up to 70 m depth in NW-SW & NW-SE directions are recorded in Lower Tank Bund, Koti, Ameerpet areas. Deep Fractures below 80 m are negligible in these areas.

The discharges of these wells vary from 0.21 to 10 lps with drawdown of 6 to 20 m. The specific capacities of the bore wells range from 10 lpm/m (New Boiguda) to 72 lpm/m (Borabanda) and the Transmissivity of the aquifers ranges between 0.48 and 202 sq.m/day.

Table 3.1: ■ .

	Achaean Crystalline	
Prominent Lithology	**Granite gneiss**	
Aquifers	**Aquifer-1 (Weathered Zone)**	**Aquifer-2 (Fracture Zone)**
Thickness range	**5 to 25 m**	**up to 199 m**
Depth of range of occurrence of fractures	**-**	**86% fracture encountered between 30 to 100m**
Range of yield potential	**<1 to 5**	**<1 to 10**
Transmissivity (m2/day)	**Upto 202**	
Specific Capacity (lpm/mdd)	**10 to 72**	
Specific yield/Storativity	**0.01 to $1x10^{-5}$**	

3.4 Aquifer Disposition 3D and 2D

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative data points (both hydrogeological and geophysical down to 200 m) for preparation of 3-D map, panel diagram and hydrogeological sections. The lithological information was generated by using the RockWorks-16 software and generated 3-D map for Hyderabad district (**Fig.3.12)** along with panel diagram (**Fig. 3.15a-b**).

subsurface aquifer disposition is deciphered from the exploratory boreholes drilled by CGWB and well Inventory data. Aquifer disposition in 3 dimensions and the vertical cross sections drawn along North-South, West-East and North West to South East are provided in Fig-2.1 to 2.2 (A, B and C). Uniform thickness is observed along the North-south and West and east sections. The weathering thickness is meager in North West.

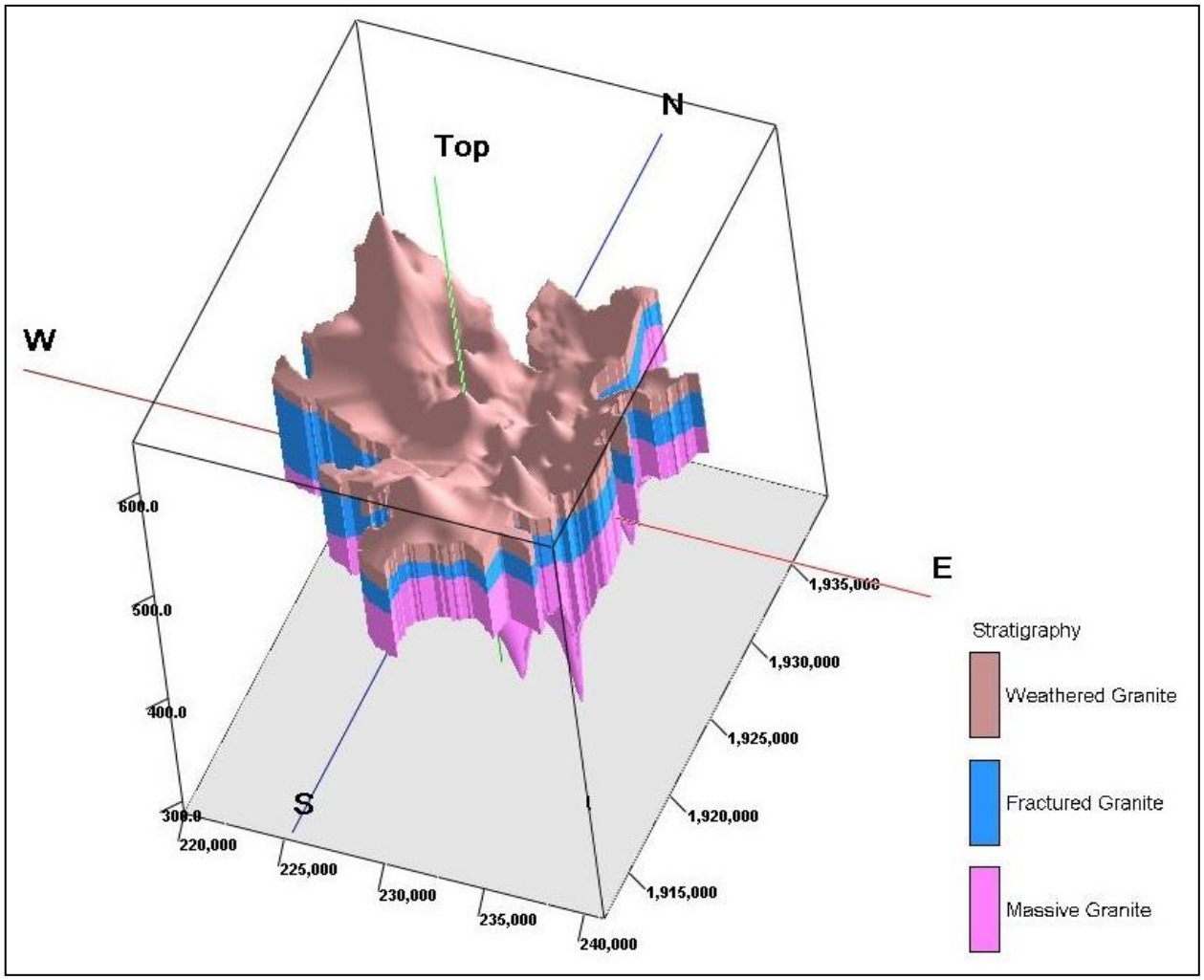


Fig-3.12: 3-Dimensional Aquifer Disposition of Hyderabad District

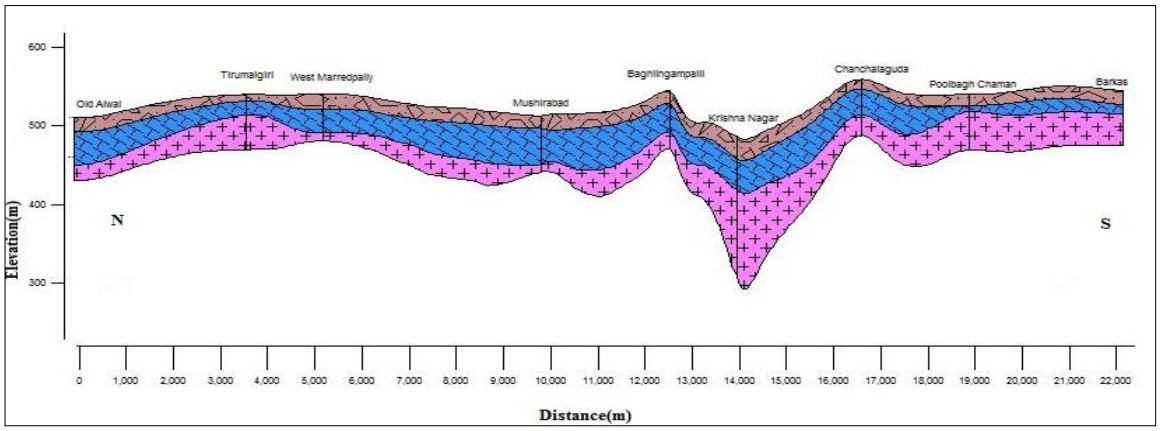


Fig-3.13 a: 2-Dimensional cross section (Nort-South direction)

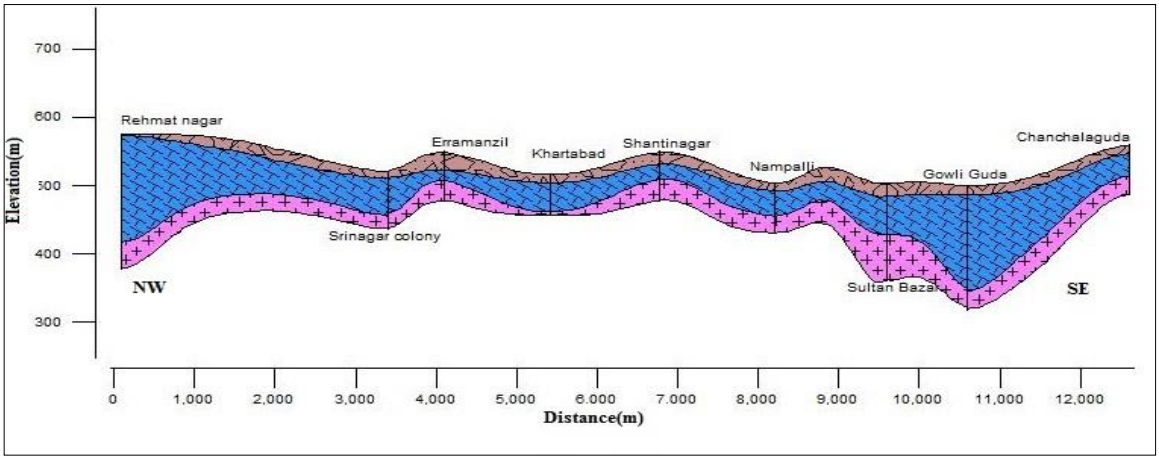


Fig.-3.13 b: 2-Dimensional Cross section (**North West - South East direction)**

4.GROUND WATER RESOURCES (2020)

As per 2020 GEC report, the net dynamic replenish able groundwater availability of Hyderabad district is 97.86 MCM, gross ground water draft for all uses 95.25 MCM. Stage of ground water development varies from 77% (Charminar mandal) to 113% (Ameerpet mandal). Out of 16 mandals, 8 mandals are categorized as over exploited, 5 mandals are categorized as Critical and 3 mandals are categorized as Semi Critical.

Table-4.1: Dynamic Ground Water resources, Hyderabad district.

Parameters	**Total**
As per GEC 2020	MCM
Dynamic (Net GWR Availability)	**97.86**
Monsoon recharge from rainfall	27.96
Recharge from other sources	80.5
• Recharge from pipelines losses	58.9
• Recharge from Sewage and flash floods	21.5
• Recharge from water conservation	0.1
Non-Monsoon recharge from rainfall	3.23
Non-monsoon recharge from other sources	41.69
Total Natural Discharges	10.49
Gross GW Draft	**95.25**
Domestic Ground Water Extraction	95.25
Stage of GW development (%)	97

5. GROUND WATER RELATED ISSUES AND REASONS

Hyderabad is one of the fastest emerging City in Peninsular India. The ground water is under severe stress owing to the fast phase of development of the city resulted in over exploitation of ground water resources, shrinking and encroachments of tanks, reduction in recharge to ground water and ground water pollution due to untreated sewerage into ground water system etc.

5.1 Over Exploitation of Ground Water Resources: The population growth, high density of population, rapid phase of city development resulted in over exploitation of ground water resources in the district. The overall stage of ground water development is 97% and out of 16 mandals, 8 mandals are categorized as over exploited, 5 mandals are categorized as Critical and 3 mandals are categorized as Semi Critical.

5.2 Extinct/shrinkage of tanks: Tanks/lakes contribute significant ground water recharge. With the progressive urbanization, many of the tanks were disappeared (Masab tank, Nallakunta etc) or their sizes got reduced.

Historical data on land use/land cover for Hyderabad reveals that the area under water bodies has come down from 2.51% of the geographical area in 1964 to 2.40 per cent in 1974 and to 1.57 per cent in 1990 (Mujtaba, 1994). Hussain Sagar Lake has shrunk from about 550 hectares to about 349 hectares (nearly 40%).

Population growth, rapid urbanization, unplanned land use development are the reasons behind the reduction in sizes of tanks as well as reduction in flows to the tanks.

5.3 Pollution of Water Bodies: Discharge of untreated industrial and domestic effluents has led to the total degradation of the water quality in many water bodies. About 15 MLD (Million Litres a Day) of industrial effluents, 55 MLD domestic sewage, are released into Kukatpally Nallah which flows into Hussain Sagar Lake.

Musi River near Indira Park/Domalaguda

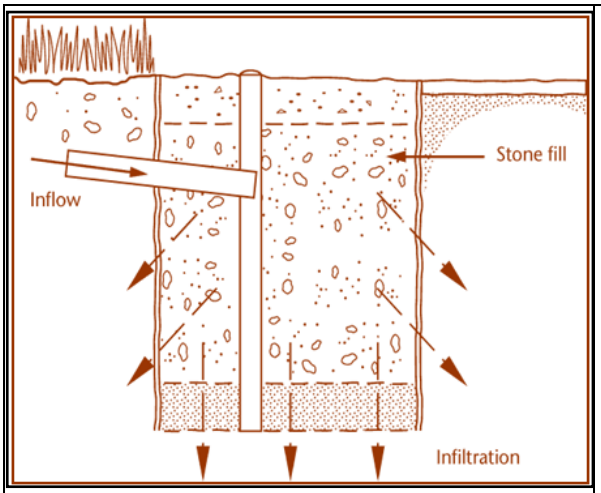
Musi River near Attapur

5.4 Reduction in GW Recharge: During the last 4 decades there was an increase of residential area (10-44 %) and reduction of vacant land (38 to 2 %) and open spaces. The change in land use reduced the scope of natural recharge and resulted in drying of shallow bore wells and dug wells in many parts of Hyderabad. Lack of specific infrastructure for storm water discharge, impervious surface, clogging of drains and the blockage of natural drains from improper waste management, lack of systems to recharge groundwater with runoff or to harvest rainwater and unplanned urban development resulting in frequent flooding in Hyderabad. The existing system is unable to carry the total precipitation to discharge points, as it is designed only for 12 mm/hour rainfall as against an average of 23 mm/hour of rainfall and a peak rainfall of 52 mm/hour to 75 mm/hour leading to frequent flooding of low-lying areas. Land use planning is not concomitant with natural drainage patterns.

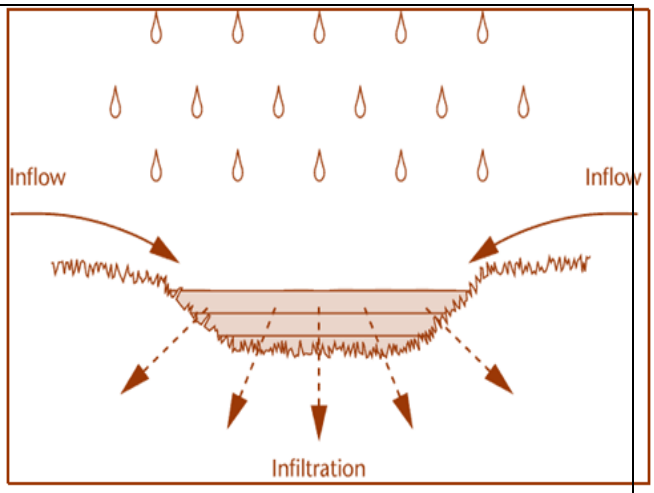
6. GROUND WATER MANAGEMENT STRATEGIES

Management Strategies in urban areas includes Storm water management, Roof top rain water harvesting and artificial recharge and sewage treatment and re-use.

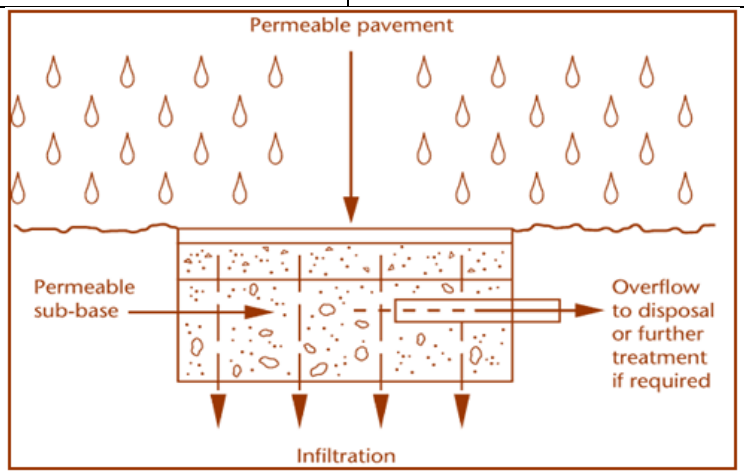
6.1 Storm Water Management: There is an immediate need for proper storm water management for effectively addressing the present crisis and also contain and manage runoff flow rates at the site-level itself. Localized storm water diversion to the nearby water bodies, lakes and tanks is one of the viable options for storm water management *through Source Control & Prevention Techniques like construction of Infiltration/Recharge Trenches and Infiltration Basins and Pervious Pavements and Filter drains etc*.



Infiltration Trench

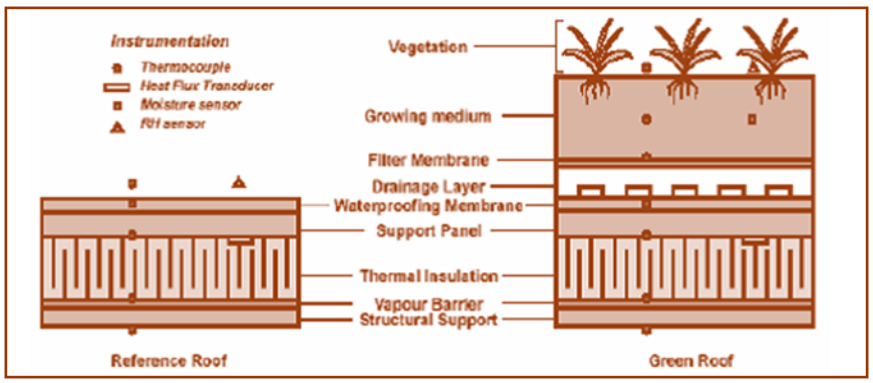


Infiltration Basin



(Figure adapted from www.ciria.org).

***6.2 Green Roofs**:* The system offers significant benefits in terms of reductions in the amount of water running off the roof, the rate of runoff and quality improvements. Many conventional flat roof systems used in industrial buildings could be converted to green roofs without exceeding design loadings and with the additional benefit of improving insulation and extending roof life. Green roofs built with the most appropriate base and vegetation has the potential to absorb 15 – 90% of roof run-off. The schematic diagram shows a green roof section with its typical components.



(Source: Karen Liu, PhD, from Proceedings of the Green Rooftops for Sustainable Communities Conference, Chicago, 2003, p.279)

6.3 **Rain Water Harvesting and Artificial Recharge*:*** In the district, out of total geographical area, more than 50 % of the land is being developed by residential, commercial & mixed purposes, 5% of the land is being utilized by Industries and Defence 8.34% together make 70% of the total land use pattern in Hyderabad City. The Road and transportation constitute about 18.64 sq. kms and agriculture & Garden makes 1.04%, Vacant & open land constitute 2.73% of the land.

Table: 6.1 Land Use Pattern and area considerations for Artificial Recharge

	Land Use	Area in sq. kms	Area Considered for RWH & AR (Area *0.75)	Area Considered for RWH & AR (Area *0.50)	Remarks
1	Residential	76.35	57.262	38.175	Completely/ Partially Built up area
2	Commercial	12.70	9.525	6.35	
3	Mixed	7.49	5.617	3.745	
4	Industrial	4.25	3.187	2.125	
5	Public & Semi Public	15.55	11.662	7.775	
6	Defense	8.34	6.255	4.17	
I	*Total*	*124.68*	*93.51*	*62.34*	
7	Parks & Playgrounds	11.75	8.8125	5.875	Vacant Area
8	Vacant lands, open lands, Rocks & Hills	2.73	2.0475	1.365	
II	*Total*	*14.48*	*10.86*	*7.24*	
9	Transportation & Communication	18.64	13.98	9.32	Road network
III	*Total*	*18.64*	*13.98*	*9.32*	
10	River, Lakes, Nalahs, Kuntas	10.75	8.0625	5.375	Not considered for planning
11	Agriculture & Gardens etc	1.04	0.78	0.52	
12	Burial Grounds Crematoria etc	3.00	2.25	1.5	
IV	*Total*	*14.79*	*11.0925*	*7.395*	
V	*Total*	*172.59*	*129.4425*	*86.295*	

The mean annual rainfall of Hyderabad is 884 mm recorded in 50 rainy days. The per capita consumption of water is 162 lpcd and the network coverage is 90% with the quantity of supplied water at 130 MGD (0.585 MCM). The thickness of weathering varies from 10-15 m and the depth of occurrence of shallow fractures ranges between 20-40 m.

Table 6.2: Run-Off Generation and Artificial Recharge in City Core Area (Total Area)						
S.No.	Type	Area (Sq.kms)	Rainfall Hrly(mtr)	Runoff Coeff	Runoff MCM/hr	Annual Runoff (MCM)
1	Built up area	124.68	0.025	0.8	2.494	88.174
2	Vacant Area	14.48	0.025	0.3	0.109	3.840
3	Roads & Pavements	18.64	0.025	0.6	0.280	9.887
4	Total Area	157.8		Total	2.882	101.900
	Required Design Capacity of the Trench					
		Width	Length	Depth	Total	No. of Pits
		3	3	4	2880000	80,000
Run-Off generation calculation in *City Core area (*Area *0.75)						
S.No.	Type	Area (Sq.kms)	Rainfall Hrly(mtr)	Runoff Coeff	Runoff MCM/hr	Annual Runoff (MCM)
1	Built up area	93.51	0.025	0.80	1.87	66.13
2	Vacant Area	10.86	0.025	0.30	0.08	2.88
3	Roads & Pavements	13.98	0.025	0.60	0.21	7.41
4	Total Area	118.35		Total	*2.16*	76.43
	Required Design Capacity of the Trench					
		Width	Length	Depth	Total	No. of Pits
		3	3	4	*2160000*	*60,000*
Run-Off generation calculation in *City Core area (*Area *0.75)						
S.No.	Type	Area (Sq.kms)	Rainfall Hrly(mtr)	Runoff Coeff	Runoff MCM/hr	Annual Runoff (MCM)
1	Built up area	62.34	0.03	0.80	1.25	44.09
2	Vacant Area	7.24	0.03	0.30	0.05	1.92
3	Roads & Pavements	9.32	0.03	0.60	0.14	4.94
4	Total Area	78.34			1.44	50.95
	Required Design Capacity of the Trench					
		Width	Length	Depth	Total	No. of Pits
		3	3	4	***1440000***	***40,000***

To harvest the Run-Off from Built-up area, vacant/open lands and from Road network, it is estimated to construct recharge pits with dimensions of 3.0*3.0*4.0 m as shown in table- respectively are required to be constructed to harvest the run-off

from the rainfall. The recharge bore wells of 5-15 m bgl is recommended to harvest the run-off wherever the sub-surface is underlain by the impermeable formation. These structures may be constructed at built-up areas, vacant lands and along or in the middle of road side. Filter drains along the roads are most viable option for harvesting the storm water generated on the road tops. A total of 76.43 /50.95 MCM Run-Off can be harvested, if 75%/50% of the area in Core City area of Hyderabad is taken for strict implementation of Rain Water Harvesting and Artificial Recharge.

6.4 SEWEGE TREATMENT & MANAGEMENT: Indian cities, in general, are characterized by an improper and inefficient sewerage system, and Hyderabad is no exception to this. The existing sewerage system for the twin cities of Hyderabad and Secunderabad was designed to serve an area of about 54 km^2 and a population of only about 4,68, 000. Currently, a very small percentage of the sewage generated by the cities is reaching the STPs (sewage treatment plants). Since the sewage treatment facilities at present are inadequate, a large quantity of untreated sewage is discharged into water bodies. Often, sewage drains also carry storm water along with sewage, thereby, getting flooded. The sewerage network coverage within the MCH area is about 70%, and in some surrounding ULBs/Municipalities it is between 20-50%, in the rest ULBs the coverage is only about 20%. At Present, HMWSSB having treatment plants of capacity 591 MLD. At present, only 23% of the collected sewerage is treated of which only 3% is recycled. However, part of treated water is being used for irrigation in the lower reaches of Musi River. Mccartney et.al (2008) estimated waste water for irrigation use for 10,000 ha of irrigated land in the lower reaches of Musi River in 2004 to be 193 M $m^{3.}$ They also estimated that the total annual salt load of water from the city is to tune of 497000 tonnes and the average annual salt content in waste water irrigation is approximately 256000 tonnes and also observed soil salinity in irrigated land. Considering the potential of waste water generation, it is suggested that the waste water be used for irrigation after proper treatment.

Various measures can be taken up to manage the problem of sewage generation and treatment. Adaptation of decentralized alternatives like introduction of dual plumbing system for separating & treating the grey and black water at the source of

generation itself and to increase its reuse potential enable efficient sewage management.

6.5 Water Auditing Measures: Water use audits are an important initiative toward understanding a building's water use and how it can be reduced. It examines all the major aspects in which a building uses water, including sanitation, maintenance, mechanical systems, building processes, and landscaping. All buildings/layout with water consumption >10 million litres per year should undertake water audit and show a water saving of at least 30%, when compared to water consumption identified in the audit or when compared to the NBC standards, whichever is lower. A water audit report must broadly contain the following aspects.

Advantages of water auditing

Water audit is the assessment of the quantity of water and involves calculating water use, identifying losses, and assessing methods for saving water. Conducting water audit leads to both tangible as well as non-tangible benefits, as listed below.

1. Improves the knowledge and documentation of the distribution system and also the problems and risks associated with it.
2. Provides a better understanding of what is happening to the water after it leaves the source point.
3. Gives a detailed profile of the distribution system and water users, thereby facilitating easier and effective management of resources, with improved reliability.
4. Helps in the realistic understanding and assessment of the present performance level and efficiency of the service.
5. Saves money by reducing water bills or sewer bills.
6. Helps reduce water usage by about 30% by implementing simple conservation measures.