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GOVERNMENT OF INDIA
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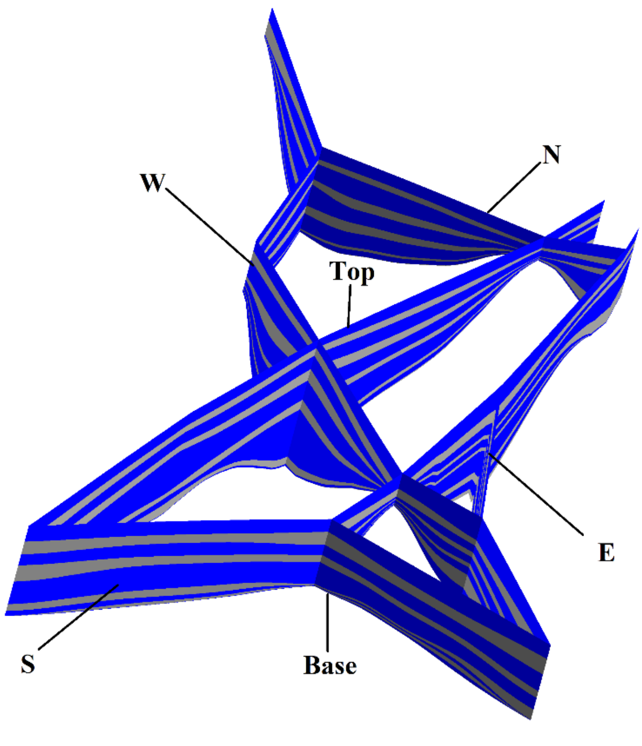
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION

REPORT ON AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN DR. B.R. AMBEDKAR KONASEEMA DISTRICT, ANDHRA PRADESH STATE



CENTRAL GROUND WATER BOARD
AP STATE UNIT OFFICE
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REPORT ON

AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN DR. B.R. AMBEDKAR KONASEEMA DISTRICT, ANDHRA PRADESH STATE

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REPORT ON

AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN DR. B.R. AMBEDKAR KONASEEMA, ANDHRA PRADESH STATE

Co n t e n t s

Chapter No.	Content			Page No.
1	**INTRODUCTION**			
	1.1	Objectives		1
	1.2	Scope of study		1-2
	1.3	Area details		2
	1.4	Climate and Rainfall		3
	1.5	Geomorphological set up		4
	1.6	Drainage and Structures		6
	1.7	Land use and cropping pattern		6-7
	1.8	Soils		8
	1.9	Irrigation		9-10
	1.10	Prevailing water conservation/recharge practices		11
	1.11	Geology		11-12
2	**DATA COLLECTION AND GENERATION**			
	2.1	Hydrogeological Studies		14
		2.1.1	Ground water Occurrences and Movement	15
		2.1.2	Exploratory Drilling	15
		2.1.3	Ground water yield	16
	2.2	Water Levels		
		2.2.1	Water Table Elevations (m amsl)	17
		2.2.2	Depth to Water Levels (DTW)	17
		2.2.3	Water level fluctuations (November vs. May)	17
		2.2.4	Long term water level trends	17
	2.3	Geophysical studies		20
	2.4	Hydro-chemical studies		20
		2.4.1	Pre-monsoon	20
		2.4.2	Post-monsoon	21
3	**DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING**			
	3.1	Conceptualization of aquifer system in 3D		24
	3.2	Hydro-geological sections		25
		3.2.1	Hydrogeological Cross Section (NW-SE)	26
		3.2.2	Hydrogeological Cross Section (SW-NE)	26
		3.2.3	Hydrogeological Cross Section (SW'-NE')	26

4	**GROUNDWATER RESOURCES (2020)**	28-29
5	**GROUND WATER RELATED ISSUES and REASONS**	30-35
6	**GROUND WATER DEVELOPMENT AND MANAGEMENT STRATEGIES**	36-38
ACKNOWLEDGMENT		40
REFERENCES		40

Figures

Figure-1.1	Location map	2
Figure-1.2	Isohyetal map	3
Figure-1.3	Geomorphological landform distribution	4
Figure-1.4	Geomorphology map	5
Figure-1.5	Shoreline Development in Godavari Delta	5
Figure-1.6	Drainage and basin map	6
Figure-1.7	Land use and land cover map	7
Figure-1.8	Cropped Area	7
Figure-1.9	Distribution of LULC	8
Figure-1.10	Pie diagram of Soil	8
Figure-1.11	Soil map.	9
Figure-1.12	Major irrigation projects	10
Figure-1.13	Area irrigated under different sources	11
Figure-1.14	Geology map	12
Figure-2.1	Hydrogeological data availability map	14
Figure-2.2	Hydrogeology map, Konaseema district	16
Figure-2.3	Water Table Elevations (m amsl)	18
Figure-2.4	Depth to water levels Pre-monsoon	18
Figure-2.5	Depth to water levels Post-monsoon	19
Figure-2.6	Water Level Fluctuation (m) (Nov vs. May)	19
Figure-2.7	Distribution of Electrical conductivity (Pre-monsoon-2022)	22
Figure-2.16	Distribution of Electrical conductivity (Post-monsoon-2022)	22
Figure-3.1	3-D Model for study area	23

Figure-3.2	Fence diagram	24
Figure-3.3	Layout of hydro geological Sections	25
Figure-3.4a-c	Hydro-geological sections in different direction	26-27
Figure-4.1	Categorization of mandals (GEC 2022)	29
Figure-5.1a-b	Location of the Toe of Fresh Water – Saline Water Interface During Pre-monsoon	33
Figure-5.2a-b	Location of the Toe of Fresh Water – Saline Water Interface During Pre-monsoon	33-34
Figure-5.3.	Ground Water Issues in Konaseema District.	35
Figure-5.3.	Area identified for artificial recharge.	39

Table

Table-1.1	Geological succession of the study area	11
Table-2.1	Brief activities showing data compilation and generations	13
Table-4.1	Computed Dynamic ground water resources, Konaseema district	28

Annexure-I: Mandal wise recharge worthy area of the district (Page No. 41)

Annexure-II: Mandal wise rainfall recharge and recharge due to different structures (Page No. 42)

Annexure-III: Mandal wise GW Extraction and ground water categorization (Page No. 43-44)

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN DR. B.R. AMBEDKAR KONASEEMA DISTRICT, ANDHRA PRADESH STATE

AT A GLANCE

S. No.	Item		Particulars
1	Districts	:	Dr. B.R. Ambedkar Konaseema
2	Revenue Mandals	:	22
3	Villages	:	314 Nos
4	Geographical area	:	2081 km^2
5	Mappable area	:	2081 km^2
5	Population (2011 Census)	:	17.19 lakh
6	Density of population (2011 Census)	:	826 persons/km^2.
7	Location	:	North latitude 16°15´ to 17°00´ East longitude 81°35´ to 82°25´
8	Rainfall (Normal)	:	1295 mm (SW: 61 % & NE: 32 %)
9	Geomorphology	:	Deltaic Plain, Coastal Plain and Flood Pain.
10	Major Rivers	:	Godavari River
11	Watersheds	:	Godavari Basin
12	Land Utilization (Ha)	:	Net area sown (~65%), Forest (~1%), Barren and uncultivable land (4%), land put to non-agricultural uses (19%), Current/Other Fallows (5%), Fish & Prawn Culture (5%) and Cultivable waste (1%)
13	Soils	:	Very deep, imperfectly drained, cracking clay soils (90%); Deep, imperfectly drained, clayey soils (4%); Very deep, well drained, clayey soils (3%); Deep, imperfectly drained, silty soils (2%) & Deep, well drained, gravelly clay soils (1%)
14	Cropping Pattern	:	Principal crops are paddy, sugarcane and banana. Paddy is the main crop in the area both in Kharif and Rabi seasons. The other crops are coconut, cashew, mango, tobacco, turmeric, pulses chillies, and vegetables
15	Irrigation	:	Command Area of Central Godavari Delta is 145571 ha, Eastern Godavari Delta (50948 ha) and Chagaland LIS irrigation project (1205 ha).
16	Prevailing Water Conservation/Recharge Practices	:	2026 Farm ponds and 55213 others structures with combine capacity and storage is 31.22 and 29.15 mcft respectively. (Source: APWRIMS)

17	Geology	:	Alluvium (99%)and Rajahmundry Sandstone (1%)
18	Hydrogeological data points	:	Hydrological Data: 185 Water Level: 44 (CGWB-16 & SGWD-28) Water Quality:58 (CGWB) Aquifer Geometry: 83 (EW-27, OW-11 & VES-45) Geophysical: 45
19	Number of ground water structures	:	As on date, CGWB drilled 38 bore wells (EW-27, OW-06 & PZ-05)
20	Ground water yield (lps)	:	Unconfined Top Aquifer: 5.0 to 16 lps (Upto 34 m) Confined Aquifer-I (Aq-I): 5.0 to 8.0 lps (22 to 60 m) Confined Aquifer-III (Aq-III): 2.0 to 6.0 lps (68 to106 m)
21	Water Levels Depth to water levels (m bgl)	: :	44 wells (CGWB:16, SGWD:28) DTWL: Avg. DTWL varies from 0.98 to 10.71 (m bgl) (avg. 4.13 m bgl) and 00.32 to 11.21 m bgl (average: 3.90 m bgl) during pre-monsoon and post-monsoon seasons respectively. WTE: Pre and post-monsoon season (May and November), the water-table elevation ranges from 1.85 to 15.66 and -1.90 to 14.29 meter above mean sea level (m amsl) respectively Pre-monsoon season: 2.0 to 3.0 m bgl (36%); 3.0 to 5.0 m bgl (28%); 5.0 to 10 m bgl (25%) & <2.0 m bgl (11%) of the area. Post-monsoon: 2.0 to 3.0 m bgl (22%); 3.0 to 5.0 m bgl (39%); 5.0 to 10 m bgl (18%) & <2.0 m bgl (20%) of the area.
22	Water Level Fluctuations (May vs. November 2020)	:	Fluctuation ranges: -2.11 to 5.0m. Rise: 0.0 to 2.5 m (70%) & 2.5 to 5.0 m rest of area Fall: 0.0 to 2.11 covering 26% of area.
23	Long term water level trends (2011-20)	:	**Pre-monsoon:** Falling trends: 33 wells (0.13 to 0.26 m/yrs.) Rising trends: 11 wells shows 0.078 to 0.32 m/yrs. **Post-monsoon:** Falling trends: 15 wells (0.03 to 0.35 m/yrs) Rising trends: 29 wells shows 0.003 to 0.80 m/yrs.
24	Geophysical data (down to 200 m)	:	45 VES (CGWB) VES indicate a three to four layered geoelectric model. Top soil - 4 to 22 Ω m (<1 to 3.0 m) Second layer - 07 to 52 Ω m (upto 25 m and fresh in quality) Third layer - 30 to 60 m (beyond 25 m and saline in nature)
25	Hydrochemistry (2022)	:	Total 58 data Pre-monsoon-29 Post-monsoon-29
25.1	Electrical Conductivity (µ Siemens/cm)	:	Pre-monsoon: For shallow aquifer, 395 to 3930 Siemens/cm (avg. 1316). EC >2250 µ Siemens/cm covering 3% of area. Post-monsoon: For shallow aquifer, 360 to 3670 Siemens/cm (avg. 1326). EC >2250 µ Siemens/cm covering 3% of area.

25.2	Fluoride (mg/l)	:	Pre-monsoon: Fluoride concentration varies from 0.02 to 1.47 mg/L and all samples falling within permissible limits of 1.5 mg/L. Post-monsoon: Fluoride concentration all samples is below BIS permissible limits of 1.5 mg/L and varies from 0.03 to 2.29 mg/L, except in Muramalla (2.29 mg/L).	
25.3	Nitrate (mg/l)	:	Pre-monsoon: Nitrate concentration in all samples is below BIS permissible limits of 45 mg/L, varies between 0 to 60 mg/L, except in Amalapuram (60 mg/L) and Vegayammapeta (56 mg/L). Post-monsoon: Nitrate concentration in all samples is below permissible limits of 45 mg/L, varies between 0 to 115 mg/L, except in Tallapolam (57 mg/L), Rally (83 mg/L), Dwarapudi (55 mg/L) and Mukteshwaram (115 mg/L).	
26	Conceptualization		Top most shallow unconfined aquifer (up to 35 m bgl) 4 nos confined aquifer (22 to 300 m bgl)	
27	Aquifer Characterization	:	Unconfined Aquifer- upto 34 m (Fresh in nature) Confined Aquifer I- 22 to 60 m (Brakish to Saline) Confined Aquifer II-68 to 106 m (Saline) Confined Aquifer III-124 to 203 m (Saline) Confined Aquifer IV-212 to 305 m (Saline)	
27.1	Aquifer wise Ground water yield	:	Unconfined Aquifer-5.0 to16 lps Confined Aquifer I-5.0 to 8.0 lps Confined Aquifer II-2.0 to 6.0 lps	
27.2	Transmissivity (m^2/day)	:	Unconfined Aquifer-290 to 600 Confined Aquifer I-350 to 800 Confined Aquifer II-150 to 300	
27.3	Specific Yield	:	Unconfined Aquifer-25 and 90 m3/hrs	
27.4	Storativity	:	Unconfined Aquifer- $3.14\times10^{-}3$ to $5.5\times10^{-}4$	
28	Ground water Resources (2020) MCM	:	**2020**	**2022**
28.1	Net Dynamic groundwater availability	:	964	1032
28.2	Gross GW Draft	:	186	171
28.3	Provision for Domestic utilization (2025)	:	7	13
28.4	Average Stage of Ground water development (%)		22	18
28.5	Net GW Availability for future use	:	787	861
28.6	In storage GW Resources	:	-	-
28.7	Categorization of mandals		Safe-17 & Saline-5	Safe-15 & Saline-7
29	Major Ground Water Issues Identified	:	The major considerable ground water issues are • **Water Logging** Pre-monsoon- 248 sq.km (11%) of area (Water logged condition) and 842 sq.km (36%) of area (Prone to Water Logging)	

			Post-monsoon- 478 sq.km (20%) of area (Water logged condition) and 523 sq.km (22%) of area (Prone to Water Logging) • **Ground Water Salinity:** AQ-I to AQ-IV (35 m to 300 m)- Brackish to Saline nature of groundwater. (Salinity due to palaeo salinity, leakage from bottom aquifer or salt water intrusion.) • **Saline Water Intrusion:** Displacement of freshwater by Salt water as a result of excess pumping in coastal areas. • **Aquaculture:** 122 sq.km (5%). This includes prawn culture and pisciculture. Brackish water from ponds, creeks is generally used in prawn cultivation causing degradation of shallow top fresh water aquifer. Conversion of paddy fields into tanks in the coastal area for aqua culture. construction shallow filter point bore well and fracturing of saline confined aquifer and mixing with top fresh aquifer. • **Saline Mandal:** 760 sq.km (32%)- Allavaram, I. Polavaram, Katrenikona, Malikipuram, Mamidikuduru, Sakhinetipalle and Uppalaguptam.
30	Ground Water Development and Management Strategies	:	• Strict Implementation of Ban on Pumping in the areas which are less than 2 kms from the sea to thwart any Saline Water Intrusion • Strict Implementation of Ban on Pumping from the first two aquifers for the purpose of Aquaculture. • Artificial Recharges Measures should be practised in upper reaches such that the ground water head is always 2m above MSL which in turn maintain the natural hydraulic gradient towards sea. • The CDs and PTs are calculated by taking 5 fillings for Check dams and 2 fillings for Percolation Tanks and a total 83 number of AR structures (43 number of PTs, 40 number of CDs) are feasible in the district. • Aqua Culture should not be encouraged beyond 2 kms from the coast. • Strict Implementation of Ban on Pumping from the first two aquifers for the purpose of Aquaculture. • Restriction of uncontrolled pumping through filter points during periods of less surface water availability. • For the water logged areas, ground water extraction should be encouraged through conjunctive use.

			• Demarcate the dynamic boundary of saline and fresh water interface and Monitoring of the saline water - fresh water interface by establishing purpose built piezometers. • Navigable coastal/tidal regulators may be installed on the creeks to check the quality deterioration where the direct recharge of saline water is taking place due to back waters. • Existing regulations must be adhered strictly to avoid ecological imbalances and environmental problems arise due to aquaculture.

ABBREVATIONS

2D	:	2 Dimensional
3D	:	3 Dimensional
ARS	:	Artificial Recharge Structures
Avg	:	Average
BDL	:	Below Detection Level
BW	:	Bore Well
CD	:	Check dam
CGWB	:	Central Ground Water Board
Cr	:	Crore
DTW	:	Depth to water
DW	:	Dug well
EC	:	Electrical conductivity
EL	:	East Longitude
F	:	Fluoride
FP	:	Farm Pond
GEC	:	Ground Water Estimation committee
GW	:	Ground Water
Ha	:	Hectare
Ha.m	:	Hectare meter
ID	:	Irrigated dry
IMD	:	India 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

Dr. B. R. Ambedkar Konaseema district is one of the twelve coastal districts of Andhra Pradesh with an aerial extent of 2,081 km^2. The district lies between north latitude of 16°15´ to 17°00´ and east longitudes of 81°35´ to 82°25´. The district headquarters is located at Amalapuram town. Administratively the district is governed by 22 revenue mandals and 314 villages with a population of ~17.19 lakhs (2011 census) (urban: 10 % & rural: 90 %). The density of population is 826 persons/ km2. (2011 census)

The climate of the district is comparatively equitable, dry, sub-humid, mega thermal climate with oppressive summer. The normal annual rainfall of the district is 1295 mm varies from 1105 mm (Pamarru) to 1738 mm (Amalapuram). The actual rainfall is 1011.7 mm and -21.9% of deviation over normal rainfall of which SW monsoon 61 % and north-east monsoon contributes 32 %.

The district is physiographically comprises deltaic and coastal plains. Plains with scattered hills in the central, southern and eastern parts. The topographic elevation of the district varies from 10 to 12 m amsl. The major rivers that drains the district is Godavari.The Godavari River bifurcates into two distributaries, the Vruddha Gautami (Gautami Godavari) and the Vasishta Godavari, which then further splits into the Gautami and the Nilarevu. Similarly, the Vasishta splits into two branches, the Vasishta and the Vainateya. These branches form a delta 170 km long along the coast of the Bay of Bengal. The drainage density in the area is sparse due to high permeability of alluvial soils.

The area is underlain mainly by the recent to sub-recent alluvium comprising Sand, Gravel, Clay and Silt. The alluvium is underlined by sandstones. The predominant landforms in the region are fluvial in nature, resulting from the actions of rivers and streams, and there are also landforms shaped by marine and aeolian processes. Fluvial landforms can arise from either erosional or depositional activities. Notable depositional landforms in this area include channel bars, Channel Islands, cut-off meanders, deltaic plains, natural levees, oxbow lakes, paleo channels, and mangrove ecosystems. Total cropped area is 2.34 Lakh ha, area sown more than once is 1 Lakh ha, forest occupies 0.75 %, barren and uncultivable land is 4%, land put to non-agricultural uses is 19% etc. of the total geographical area. In deltaic alluvium two to three crops are harvested every year. Paddy, sugarcane and Coconut, Banana plantations are extensively raised on these lands. The important soil groups in the area are deltaic alluvial soils and coastal sands.

The region is under the control of the Godavari Canal System, which operates for 11 months a year, with a one-month closure in April-May. The Sir Arthur Cotton Barrage at Dowlaiswaram has been serving the irrigation needs of the deltaic area since 1852 for both Kharif and Rabi seasons, ensuring sufficient or excess water flow during Kharif. The three major canal systems, Eastern Delta Canal System, Central Delta Canal System, and Western Canal System, collectively cover a total command area of 4,08,331 hectares. There are 2026 Farm ponds and 55213 other artificial recharge structures (ARS) and water conservation structures (WCS) with combine capacity and storage is 64 and 22 MCM respectively.

CGWB drilled 38 no's bore wells (27 no's exploratory,6 no's observation and 5 no's piezometer well), 31 wells were drilled in alluvium area and 07 wells were drilled in sandstone area. The depth of well ranges from <30 meter to up to 300 meter below ground level and identified 5 aquifers including shallow unconfined aquifer which is extended up to 34 meter below ground level. Groundwater yield of unconfined aquifers varies from 5.0 to 16 lps, 5.0 to 8.0 lps for first confined aquifer (AQ-I) and 2.0 to 6.0 lps for second confined aquifer (AQ-II).

The VES data suggests a geoelectric model consisting of three to four distinct layers. The uppermost layer, representing the topsoil, exhibits resistivity values ranging from 4 to 22 ohm.m, with a thickness that varies from less than 1 meter to 3 meters. The second layer, characterized by resistivity values of 7 to 52 ohm.m, is of fresh water quality. However, it is noteworthy that beyond a depth of 25 meters below ground level (bgl), the majority of the area contains saline water, except for localized patches where resistivity values range from 30 to 60 ohm.m and have a thickness of 10 to 25 meters. This data indicates a general trend of deteriorating groundwater quality with increasing depth in the region.

The DTWL 0.98 to 10.71 meter below ground level (m bgl) (average: 4.13 m bgl) and 0.32 to 11.21 m bgl (average: 3.90 m bgl) during pre-monsoon and post-monsoon seasons respectively. During pre-monsoon season, 2.0 to 3.0 m covering 36% of the area, followed by 3.0 to 5.0 m bgl (28%), 5.0 to 10 m bgl (25%) and shallow water level <2.0 m bgl (11%) in parts of Sakhinetipalle, Malikipuram, Razole and Katrenikona mandal. During post-monsoon season, of 3.0 to 5.0 m covering 39% of the area, followed by 2.0 to 3.0 m bgl (22%), < 2.0 m bgl (20%) found in Sakhinetipalle, Malikipuram, Uppalaguptam, Katrenikona, I. Polavaram and Mamidivaram mandal and 5.0 to 10 m covering in 18 % of the district mostly in northern part. The water level fluctuations vary from -2.11 to 5.0 m. The Rise in water level range of 0 to 2.5 m covers majority of the area with 70 % followed by 2.5 to 5.0 m rise in rest of the area. The fall in water level range of 0 to 2.11 covering 26% of the area. Long-term water level trends during pre-monsoon, 11 wells show rising trend ranging 0.078 to 0.32 m/yrs and 33 wells shows falling trends ranging 0.13 to 0.26 m/yrs. During post-monsoon season 29 wells shows raising trend ranging 0.003 to 0.80 m/yrs and 15 wells shows falling trends ranging 0.03 to 0.35 m/yrs.

In unconfined aquifer, during Pre and post-monsoon season, EC is in the range of 395 to 3930 (avg. 1316) µ Siemens/cm and 360 to 3670 µ Siemens/cm (avg. 1326 µ Siemens/cm) respectively. During pre-monsoon season, 0 to 60 mg/L, except in Amalapuram (60 mg/L) and Vegayammapeta (56 mg/L). Fluoride concentration varies from 0.02 to 1.47 mg/L and all samples falling under permissible limits of 1.5 mg/L. In post-monsoon, Nitrate concentration in all samples is below permissible limits of 45 mg/L, varies between 0 to 115 mg/L, except in Tallapolam (57 mg/L), Rally (83 mg/L), Dwarapudi (55 mg/L) and Mukteshwaram (115 mg/L). Fluoride concentration all samples is below BIS permissible limits of 1.5 mg/L and varies from 0.03 - 2.29 mg/L, except in Muramalla (2.29 mg/L).

Based on 185 hydrogeological data points, aquifers from the area can be conceptualized in to two principal aquifers namely, Alluvium and Sandstone. The data indicates that there are multi aquifers in the area with intervening thick clay beds. These sand beds which act as aquifers in the area and there are five distinct beds which behave as regional aquifer. The study of the different sections indicate that the alluvium thickness is increasing from north to south and there are five aquifers exist up to a depth of 300 m in the study area. The shallow aquifer thickness is varying from place to place. The first aquifer which is present up to a maximum of 34m below MSL is unconfined whereas the other aquifers are confined. The depth of the wells generally ranges from 3 to 12 m bgl. In the areas near coast wells are restricted 3 to 4 m. The yield of the wells varies in between 25 and 90 m3/hr. T and S are varying from 250 to 6200 m2/day and 3.14x10-3 to 5.5x10-4 respectively.

Net dynamic replenishable ground water availability as on 2022 is 1086 MCM, gross ground water draft is 171 MCM, provision for drinking and industrial use for the year 2025 is 13 MCM and net available balance for future use is 861 MCM. The stage of ground water development is 18%.

The study reveals that waterlogging is a common issue in the region. Approximately 11% of the area experiences waterlogging during the pre-monsoon period, which increases to

20% during the post-monsoon period. Factors contributing to waterlogging include surface water irrigation, minimal groundwater withdrawal, flat terrain, high rainfall, poor drainage, and soil characteristics. The groundwater in shallow aquifers is generally fresh except in areas near the coast and isolated patches inland. Deeper aquifers consistently contain saline water. The origin of this salinity is due to Palaeo Salinity, Leakage from Bottom Aquifer and Sea Water. The coastal region has witnessed significant growth in aquaculture, including prawn and fish farming. Brackish water from tidal creeks and groundwater sources is used for aquaculture. The release of brackish water and organic feed used in aquaculture is causing pollution of shallow aquifers. Despite these challenges, the study suggests that there hasn't been a significant reduction in crop yields, and the area's aquifer quality hasn't deteriorated significantly. This could be due to historical agricultural practices and the natural flushing of inferior water after rainfall and canal water releases.

The effective management of water resources in areas facing various challenges requires a combination of awareness campaigns, regulatory measures, and sustainable practices.

Promoting Groundwater Utilization: Encouraging the judicious use of fresh groundwater resources is essential, especially when surface water is available. Awareness campaigns and education on aquifer disposition are crucial to ensure that farmers and communities can access and utilize this valuable resource efficiently.

Conjunctive Use of Water Resources: To reduce the pressure on groundwater, conjunctive use of surface and groundwater resources should be promoted. This involves limiting surface water for tail end areas and encouraging groundwater use in upper and middle reaches, ultimately leading to a more sustainable water balance.

Addressing Sea Water Intrusion: To combat quality deterioration due to sea water intrusion, supplying surface water to tail end areas should be a top priority. Strict bans on pumping near the sea and aquifer restrictions for aquaculture can help mitigate the problem, while artificial recharge measures can maintain a healthy groundwater head.

Controlling Quality Deterioration from Aquaculture: Regulating the distance of aquaculture activities from the coast and enforcing bans on pumping from the first two aquifers for aquaculture purposes can protect groundwater quality.

Preventing Direct Recharge of Saline Water: Strategies such as arresting backwater flows beyond 2 km from the coast and installing navigable coastal regulators can help prevent the direct recharge of saline water, particularly in areas used for navigation and aquaculture.

Managing Uncontrolled Pumping during Water Scarcity: In areas where uncontrolled pumping becomes a problem during periods of water scarcity, prioritizing surface water supply for tail end areas and promoting artificial recharge measures can alleviate the pressure on groundwater resources.

Addressing Waterlogging: Waterlogged areas can benefit from groundwater extraction through a network of filter points and the distribution of water to canals for irrigation. Implementing a ban on surface water supply in such areas can help mitigate waterlogging issues.

Artificial Recharge: The Check dams and Percolation Tanks are calculated by taking 5 fillings for Check dams and 2 fillings for Percolation Tanks and a total 83 number of AR structures (43 number of PTs,40 number of CDs) are feasible in the district. In future, artificial recharge structure shall be recommended in specific areas, where vulnerabilities for groundwater resources increase.

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

S. No.	**Data**	**Aquifer**	**Total Data Points**	CGWB/ SGWD
1	Panel Diagram (3-D)	Combine	83	Expl:38 VES:45
2	Hydrogeological Sections	3 no	83	Expl:38 VES:45
3	Fence/panel Diagrams	1 no	83	Expl:38 VES:45
6	Groundwater Yield	Combine	38	38
7	Transmissivity (m^2/day)	Combine	38	38
8	Depth to Water Level Maps	Combine	44	44
9	Water Level Fluctuation	Combine	44	44
10	Long term water level trends	Combine	44	44
11	Water quality Pre-2022 Post-2022	Combine	58 Pre:29 Post:29	58

1. INTRODUCTION

Aquifer mapping is a process wherein a combination of geological, geophysical, hydrological and chemical analyses is applied to characterized 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 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 for sustainable development and management of ground water resources of the country. As a part of NAQUIM in Andhra Pradesh, the Dr. B.R. Ambedkar Konaseema district has been selected and completed during AAP 2023-2024.

Hard rock (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 leads to drying up in places and reducing the sustainability of structures. Besides these quantitative aspects, groundwater quality also represents a major challenge which is threatened by both geogenic and anthropogenic pollution. In some places, the aquifers have high level of geogenic contaminants, such as fluoride, rendering them unsuitable for drinking purpose. High utilization of fertilizers for agricultural productions and improper development of sewage system in rural/urban areas lead to point source pollution viz., nitrate and chloride.

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

1.2 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 their characterization on 1:50,000 scale.
5. Capacity building in all aspects of ground water development and management through information, education and communication (IEC) activities, information dissemination, education, awareness and training.
6. Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable ground water management.

1.3 Area details: The Dr. B.R. Ambedkar Konaseema district, Andhra Pradesh having geographical area of 2081 km^2, lies between north latitude 16°15´ to 17°00´ and east longitude 81°35´ to 82°25´(**Fig.1.1**). Administratively the district is governed by Amalapuram and Ramachandrapuram revenue divisions with 22 revenue mandals and 314 villages with a population of ~17.19 lakhs (2011 census) (urban: 10 % & rural: 90 %). There are 3 Municipalities Ramachandrapuram, Mandapeta and Amalapuram, one Nagar Panchayat i.e, Mummidivaram. The density of population is 826 persons/ km^2. (2011 census)

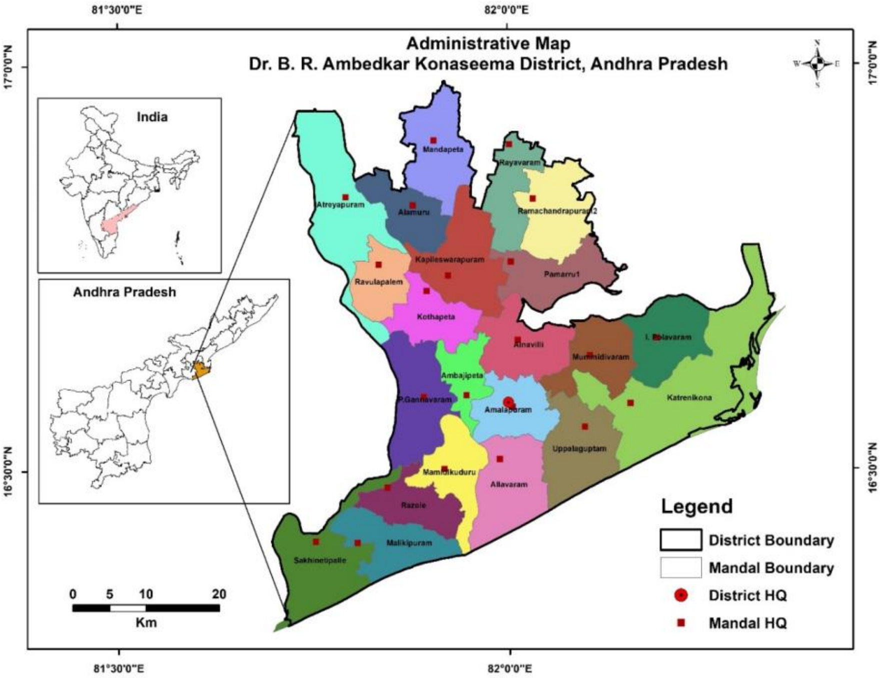


Fig.1.1: Location map of Konaseema district.

1.4 Climate and Rainfall: The climate of the district is comparatively equitable, dry, sub-humid, mega thermal climate with oppressive summer and although it is very warm during May month and good seasonal rainfall. The mean daily maximum temperature in the district is about 38.9°C and the mean daily minimum temperature is about 20°C. Relative humidity in this area is generally high throughout the year. During Pre-monsoon season heavy rains and storms occur due to depressions in Bay of Bengal.

The normal annual rainfall of the district is 1295 mm varies from 1105 mm (Pamarru) to 1738 mm (Amalapuram) (Indian Meteorological Department), actual rainfall is 1011.7 mm and -21.9% of deviation over normal rainfall. (**Fig.1.2**) The south west monsoon sets in the second week of June and lasts till September end. October and November receives rainfall from north east monsoon. The winter starts from December and lasts till mid-February followed by summer season upto early June. The South west monsoon contributes ~61 %, North east monsoon contributes ~32%, and remaining by winter and summer season.

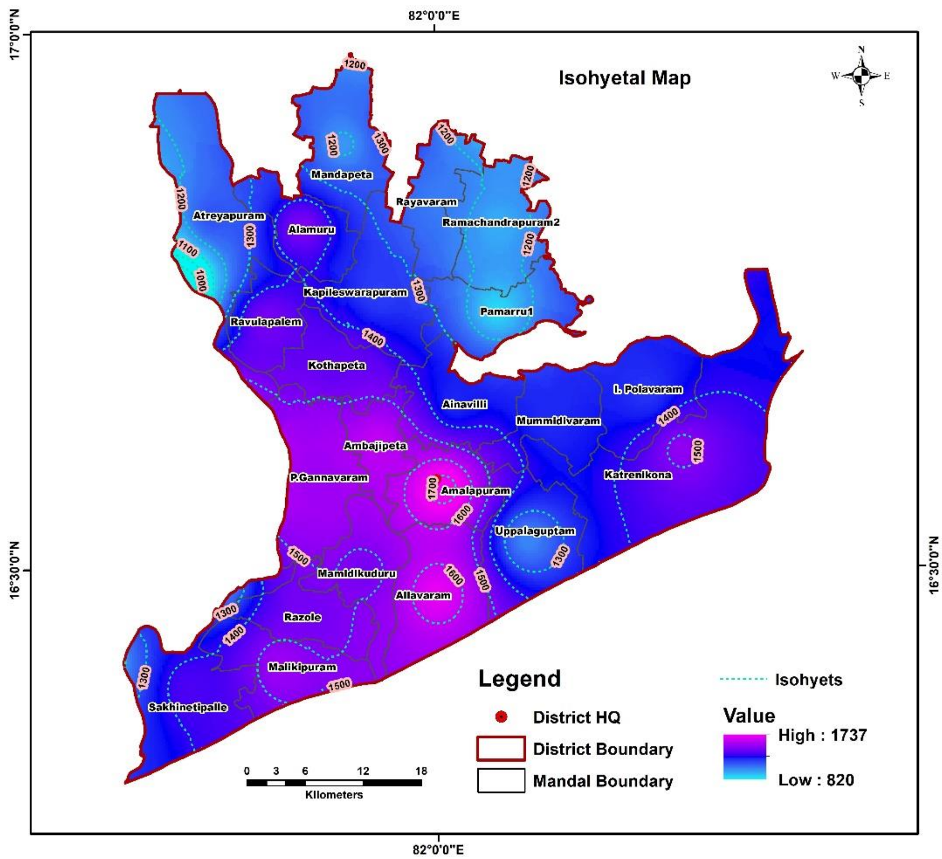


Fig.1.2: Isohyetal map of Konaseema district.

1.5 Geomorphological Set up: The area is basically occupied by deltaic and coastal plains. The landforms present in the area are mainly fluvial land forms and other forms are of marine and aeolian. Various landforms occurring in the area are presented in **Fig.1.4.** Land forms derived from the streams are known as fluvial land forms. These land forms can be due to erosional or depositional processes. The study area has some of the important depositional land forms viz. Channel bars, Channel-islands, Cut off meanders, Deltaic plains, Natural levees, Oxbow lakes, Palaeo channels and Mangrove. The altitude varies from 1 m near coast to 12 m above MSL in the upper reaches of the area.

Shoreline Development- Present is the key to the past. The geomorphic features present in the coast indicate the possible shoreline in the past if similar structures are present on land. In Godavari delta the presence of beach ridge complexes on land indicate the existence of four strand lines or palaeo shore lines, which were delineated using the remote sensing studies. The strand lines and the present day coast were depicted in (**Fig.1.5)**. Changes in the present day shoreline are also observed near Kakinada, where the Kakinada spit is becoming cuspate and growing towards the coast and the enclosed Coringa bay is becoming shallower. Where, as on the other hand, the coast near Uppada, North of Kakinada is moving landwards by assimilating the land by erosion.

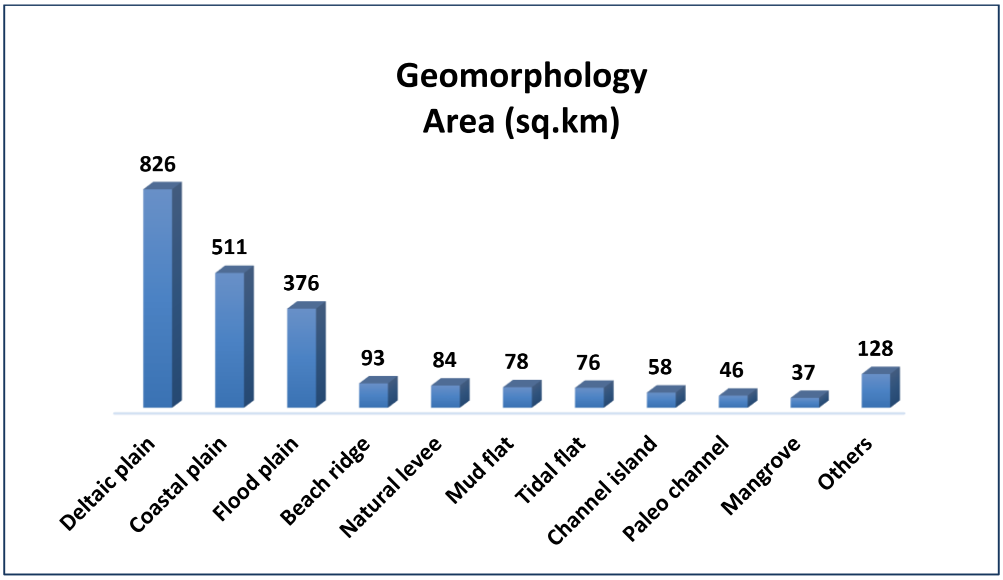


Fig.1.3: Geomorphological landform distribution of Konaseema district.

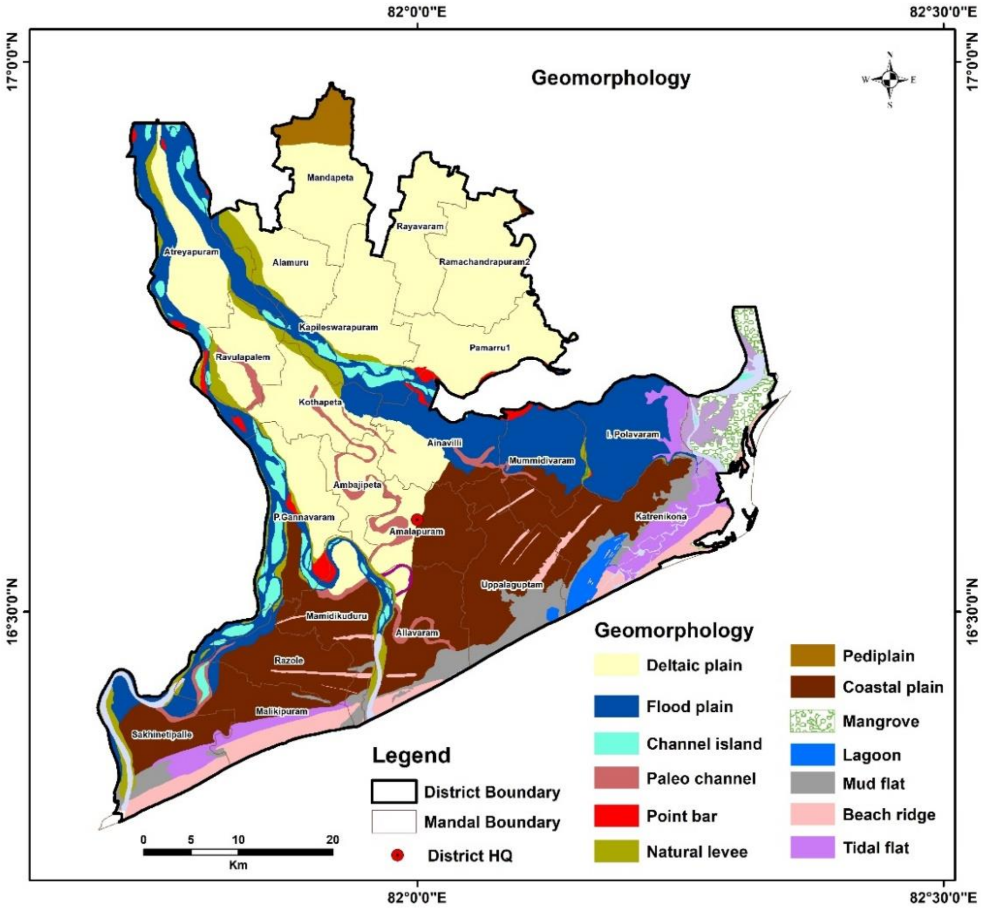


Fig.1.4: Geomorphological map of Konaseema district.

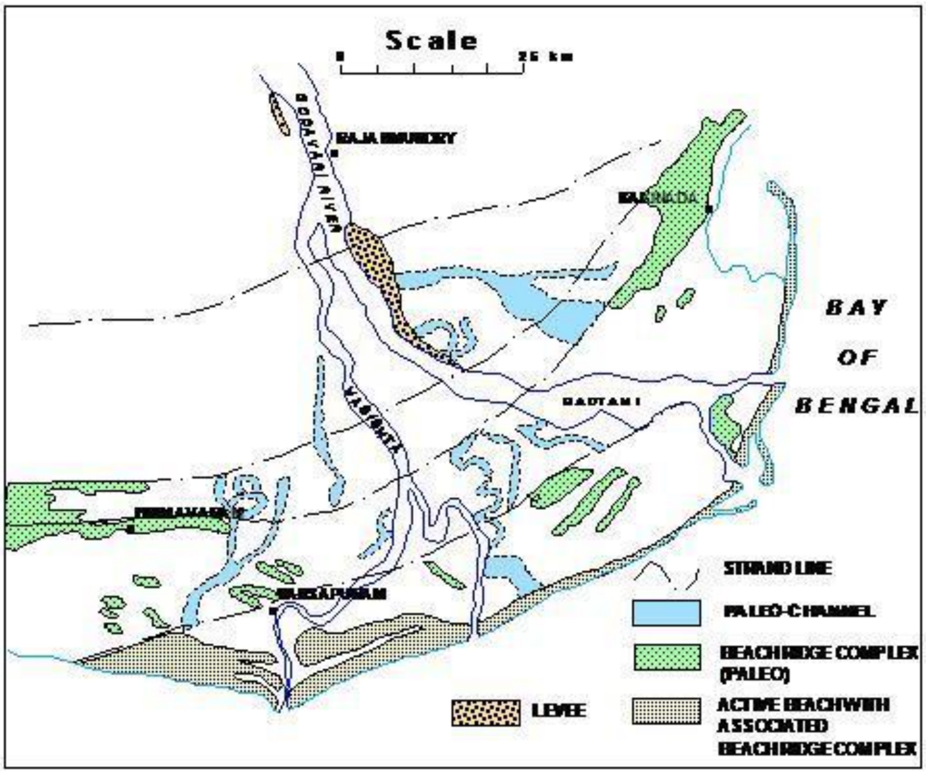


Fig. 1.5: Shoreline Development in Godavari Delta**.**

1.6 Drainage and Structures: The area is drained by Godavari River and flows N to S direction. (**Fig.1.6**.) The Godavari delta is formed by the tributaries of Vruddha Godavari, Vasishta Godavari, Gautami and Nilarevu. After crossing the city of Rajahmundry, the Godavari River bifurcates into two distributaries, the Vruddha Gautami (Gautami Godavari) and the Vasishta Godavari, which then further splits into the Gautami and the Nilarevu. Similarly, the Vasishta splits into two branches, the Vasishta and the Vainateya. These branches form a delta 170 km long along the coast of the Bay of Bengal. This delta makes up the Konaseema region. The area is served by Godavari canal system and numerous other drains. The drainage density in the area is sparse due to high permeability of alluvial soils.

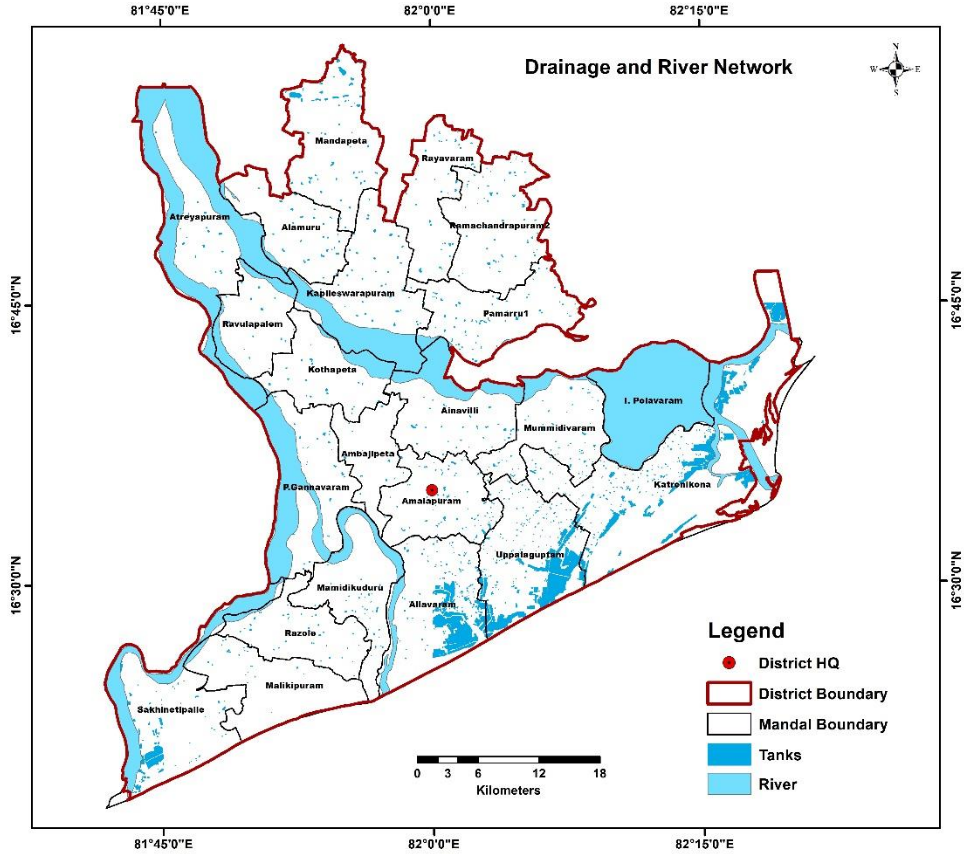


Fig.1.6: Drainage and Basin map of Konaseema.

1.7 Land use and cropping pattern: The land use pattern in the study area indicates that the area is mostly agrarian. The total geographical area of the district is 2.081 Lakh ha. During 2019-20 the area covered by Forest is 0.015 Lakh ha., which forms 0.75 % to the total geographical area. The rest is distributed among Barren and uncultivable land about 4 % and Land put to Non-agricultural uses about 19 %. The Net area sown is 1.34 Lakh ha, forming 64

% to the total geographical area. The total cropped area in the district is 2.34 Lakh ha. The area sown more than once is 1.00 Lakh ha. **(Fig.1.7.)** The principal crops are paddy, sugarcane and banana. The other crops are coconut, cashew, mango, tobacco, turmeric, pulses chillies, and vegetables. Paddy is the main crop in the area both in Kharif and Rabi seasons. In the second ranking crops coconut occupies large part in the coastal plain. Surface water is the main source of irrigation (>90 %).

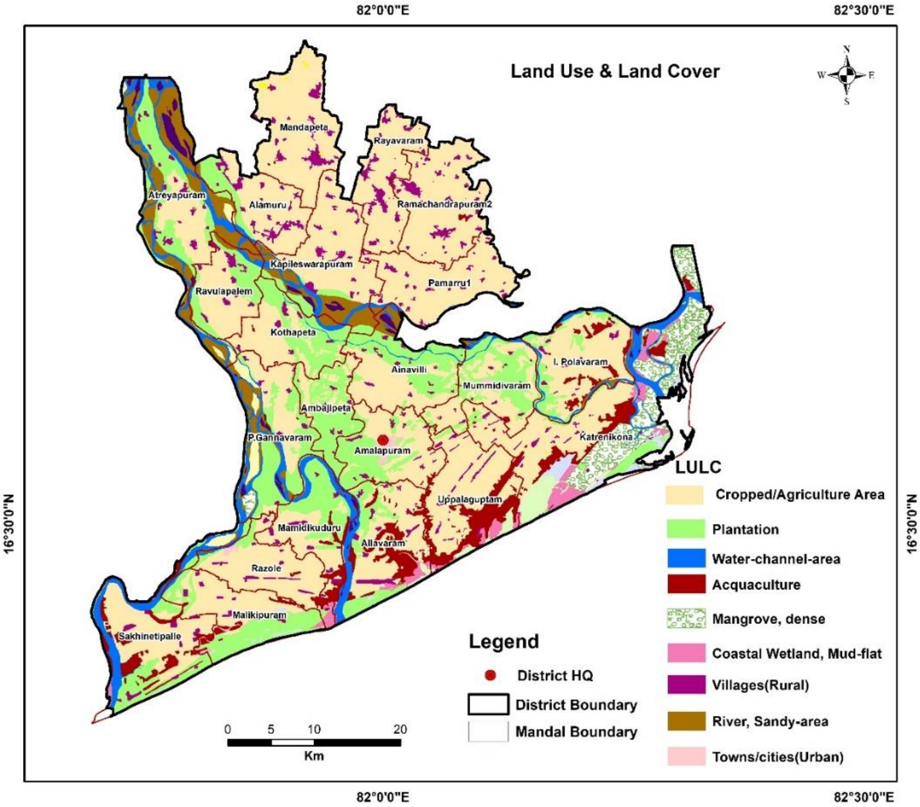


Fig.1.7: Land use and land cover map of Konaseema district.

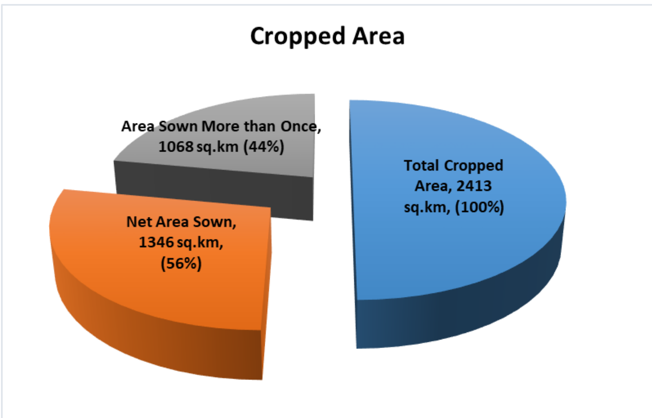


Fig.1.8: Cropped Area

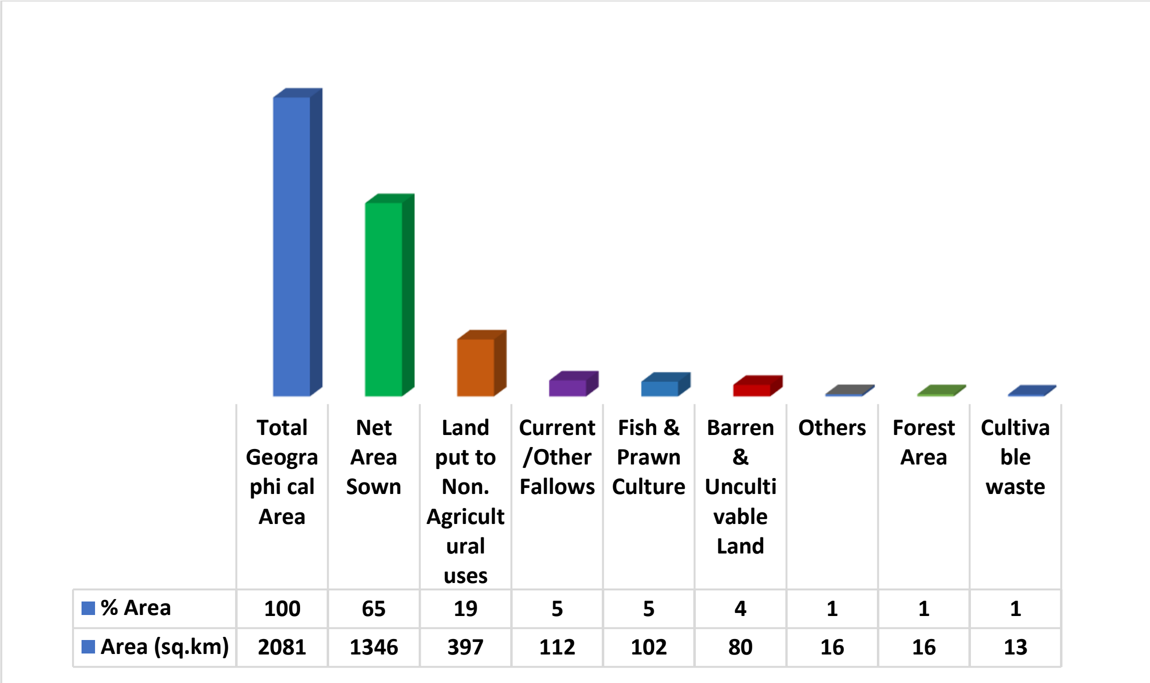


Fig.1.9: LULC

1.8 Soils: The area is mainly occupied by delta soils are considered to be the most fertile. The important soil groups in the area are deltaic alluvial soils and coastal sands. The deltaic soils have high clay content and are less permeable and poorly drained and are highly fertile in nature and have high cation exchange capacity. In deltaic alluvium two to three crops are harvested every year. Paddy, sugarcane and Coconut, Banana plantations are extensively raised on these lands. The Coastal sands on the other hand are highly porous and lack binding material. The taxonomic classification is depicted in the **Fig. 1.10** and distribution of soil is shown in **Fig. 1.11.**

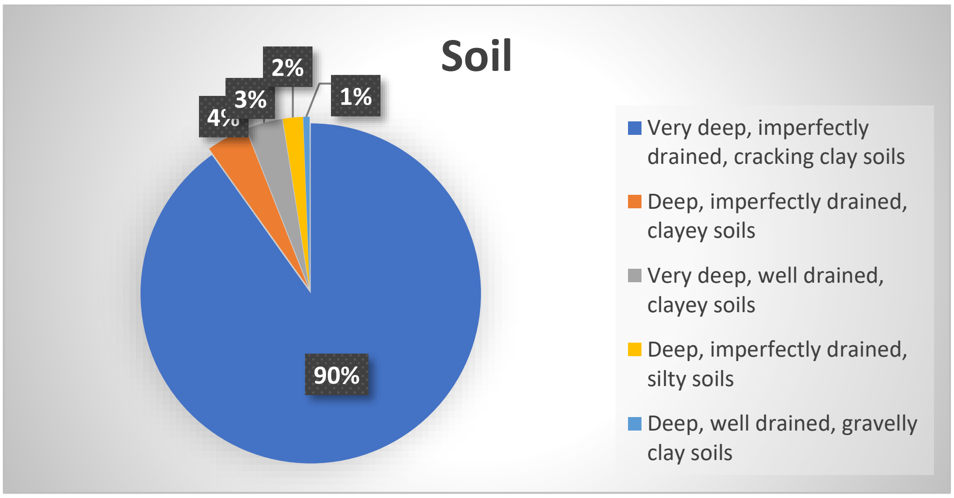


Fig.1.10: Pie diagram of Soil.

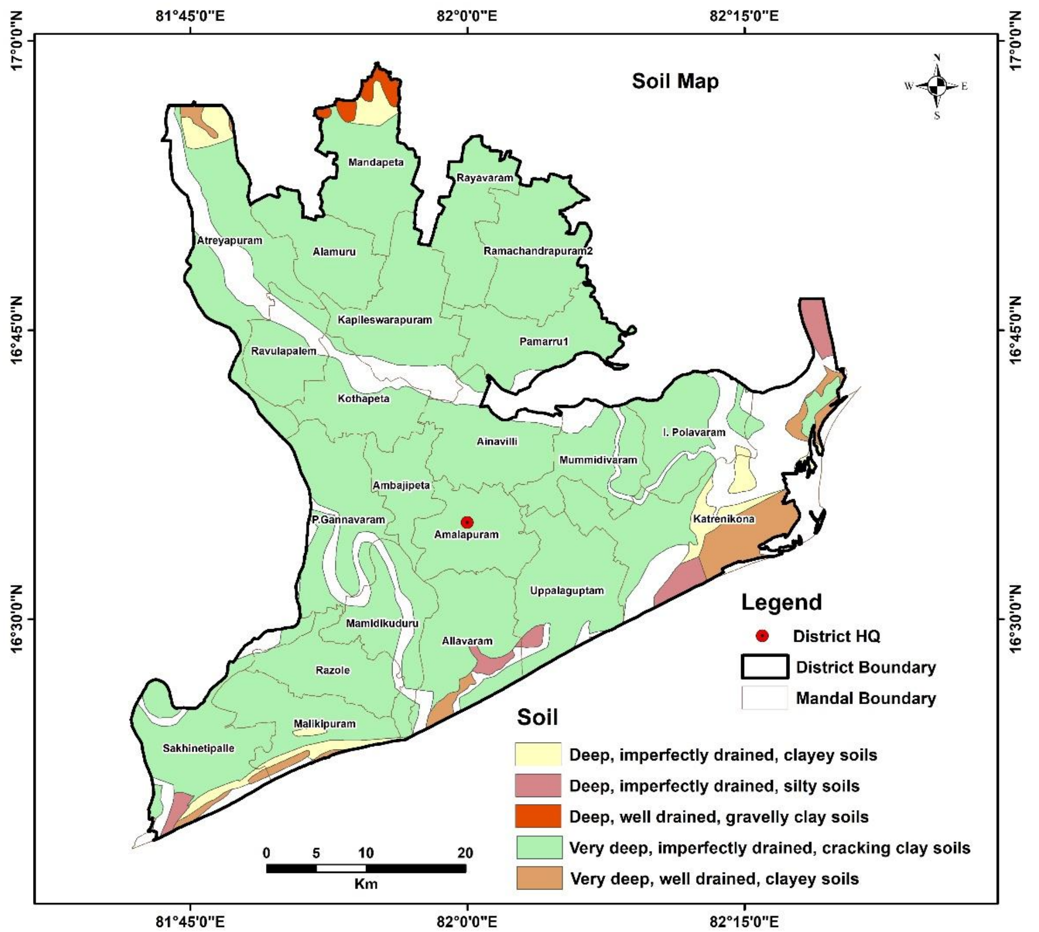


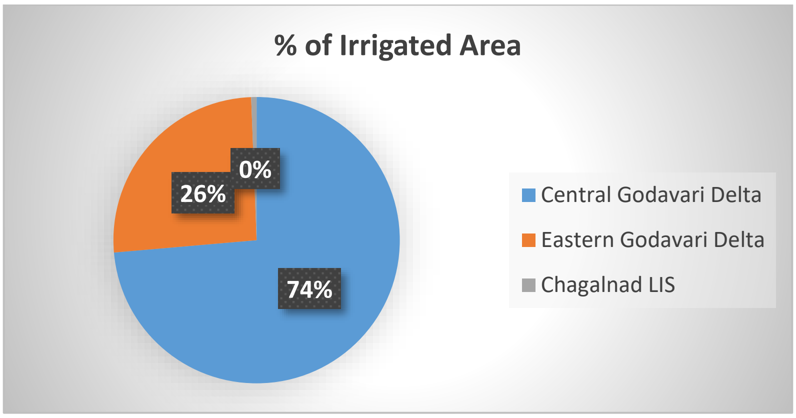
Fig.1.11: Soil map of Konaseema district.

1.9 Irrigation:

The area has the distributary network of the river Godavari. The area is crisscrossed by the canal netwok of Godavari Delta Irrigation System. The Godavari Delta Irrigation Project is catering the irrigation needs of the area both in Kharif and Rabi seasons. The village tanks, ponds and percolation tanks present in the area are very limited. The majority of the ponds are being converted to pisciculture.

The area is under the command of Godavari Canal System. The canal system remains operational for 11 months with a one-month closure period during April-May. The Sir Arthur Cotton Barrage at Dowlaiswaram serving the irrigation needs of the deltaic area since 1852, for both Kharif and Rabi seasons. During Kharif time sufficient or excess flow are available in the river. In general, there will not be any problem of shortfall of water for irrigation during Kharif period. The Godavari Eastern, Central and Western Deltas area served by mainly 3 major canal systems. They are the Eastern Delta Canal System, Central Delta Canal System and Western canal system. The total command area of the Delta is 4,08,331 ha. When the irrigation system was first established in 1852, the drainage system was also formulated with the branches of Godavari and the available rivulets. Since then, these natural valleys are called as drains and being utlised for irrigation system. The area irrigated under different sources is depicted in **Fig.1.12.**

Irrigation Project	Area (Ha)
Central Godavari Delta	145572
Eastern Godavari Delta	50948
Chagalnad LIS	1205



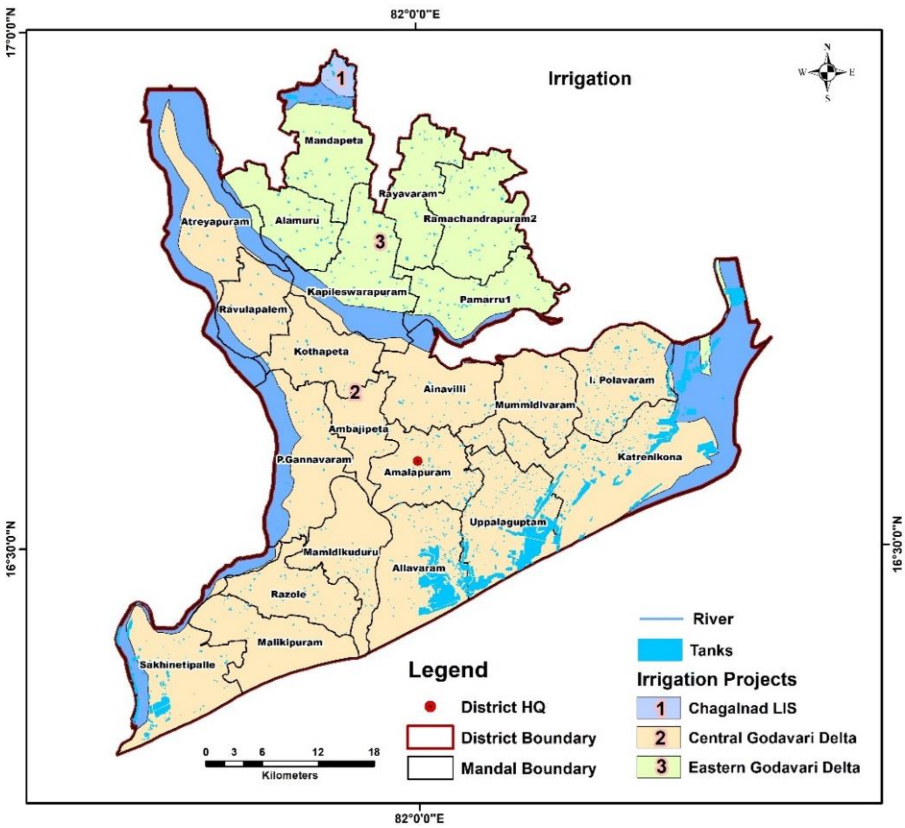


Fig.1.12: Irrigation Projects of Konaseema District.

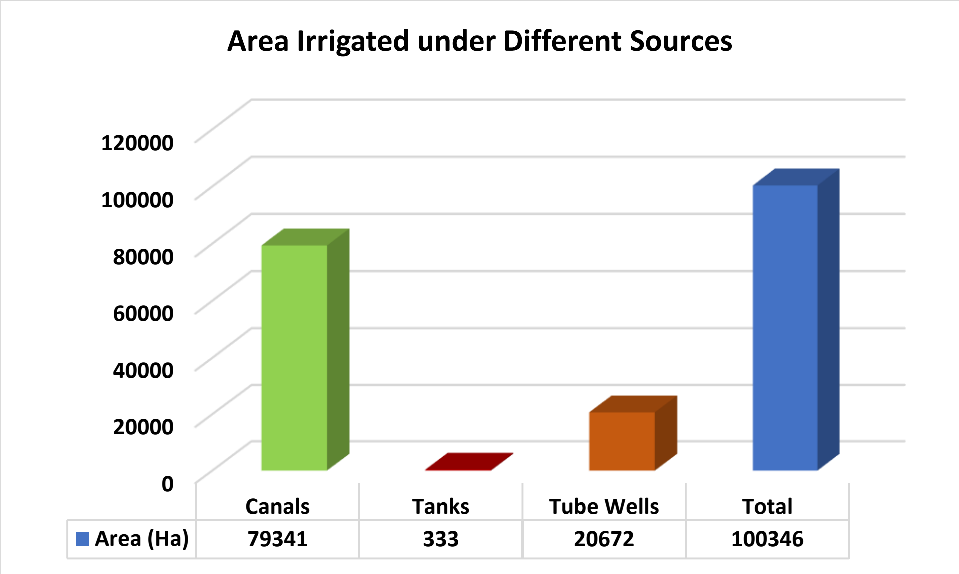


Fig. 1.13: Area irrigated under different sources.

1.10 Prevailing water conservation/Recharge practices: In the district there are 2026 Farm ponds and 55213 other artificial recharge structures (ARS) and water conservation structures (WCS) with combine capacity and storage is 31.22 and 29.15 mcft respectively. (Source: APWRIMS)

1.11 Geology: Geologically the area is underlain by the recent to sub-recent alluvium comprising Sand, Gravel, Clay and Silt. The alluvium is underlined by sandstones. The sandstones formations are encountered at different depth in the boreholes drilled by CGWB in the northern part of the area at shallow depths, and towards coast the sandstone could not encounter even depths beyond 250m. The general geological succession of the area is given in **Table 1.1** & **Fig.1.14.**

Table-1.1 : General Geological Succession of the Study Area

Age	System	Formation	Lithology
Recent to Sub-Recent		Alluvium	Gravel, sand , silt, and clay
Mio-Pliocene		Rajahmundry	Sandstone and shale/ clay
Upper Cretaceous to Lower Eocene		Deccan Traps	Basalt
Lower Cretaceous to Lower Triassic	Upper Gondwana	Tirupathi	Sandstone and shale/ clay
		Raghavapuram	Sandstone and shale/ clay
		Gollapalli	Sandstone and shale/ clay
	Lower Gondwana	Chintalapudi	Sandstone and shale/ clay
------------------------------ Unconformity ------------------------------			
Archaean			Khondalites and Gneisses

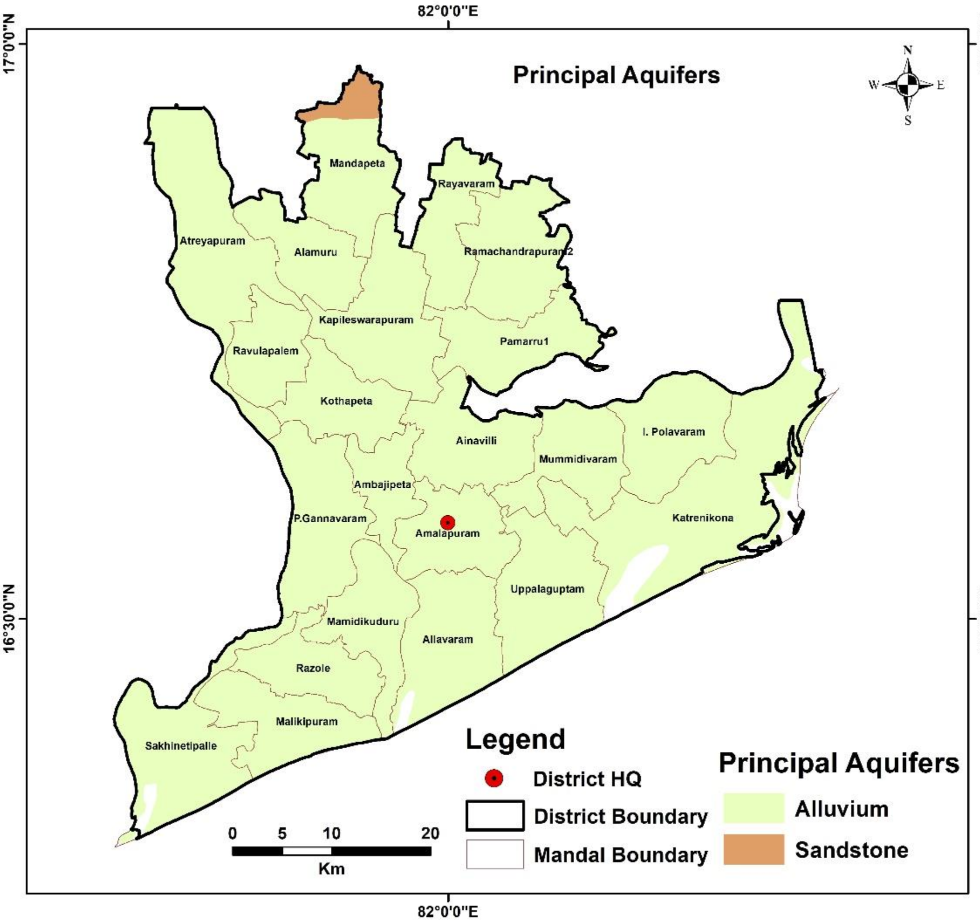


Fig.1.14: Geological map of Konaseema district.

There is a major ENE-WSW lineament in the southern part of the Godavari delta. All the three major distributaries of the river Godavari viz. Gauthami Godavari, Vasishta Godavari and Vainateya Godavari cross this lineament and the obliterated trend of their drainage indicate a continuous movement along this lineament.

2. DATA COLLECTION AND GENERATION

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

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

S. No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc.
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
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.

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 (Multi-aquifer) in the area is Alluvium and Sandstone. The occurrence and movement of ground water in these rocks is controlled by the degree of interconnection of primary pores/voids. Based on 185 hydrogeological data points, hydrogeological map is prepared. The details of data availability (**Fig.2.1)** is given bellow-

Organisation	Water Level	Water Quality	Aquifer Geometry			Geophysical
			EW	OW	VES	VES
CGWB/SGWD	44	58	27	11	45	45
Total	44	58	27	11	45	45

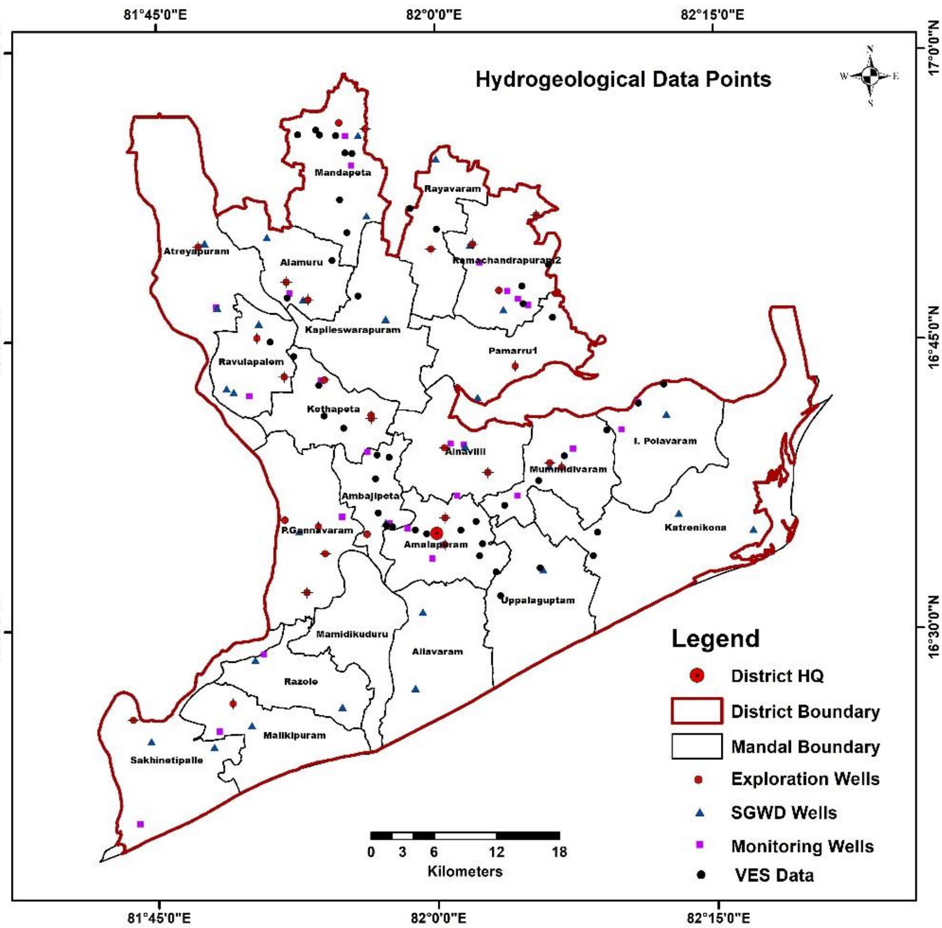


Fig. 2.1: Hydrogeological data availability.

2.1.1 Ground water occurrences and movement: The area is underlain by deltaic and coastal alluvium consisting of fine to medium sand, silt and gravel with intercalations of clay of recent age followed by sandstones of Mio Pliocene age. The sandstone formations are not exposed in the deltaic area but encountered at shallow to greater depths. Hydrogeological map of the area is presented as **Fig.2.2.** Ground water in alluvium occurs under unconfined conditions in shallow aquifers, whereas semiconfined to confined conditions in the deeper aquifers. Buried/Paleo channels existing in central delta are promising potential zones. Overall the ground water development is insignificant in the area except in few mandals. Shallow aquifer is being tapped by dug wells and by filter points/ shallow tube wells in the area as and when need arises because of the insufficient availability of surface water, for raising seedbeds during canal closures and to some extent in the high level patches to where canal water cannot reach apart from domestic and drinking purposes. The depth of the wells generally ranges from 3 to 12 m bgl. In the areas near coast wells are restricted 3 to 4 m. The yield of the wells varies in between 25 and 90 m3/hr. T and S are varying from 250 to 6200 m2/day and 3.14x10-3 to 5.5x10-4 respectively. Rainfall, canal system and the river Godavari are the main source of recharge. The fresh ground water is limited to shallow aquifer. The depth of these fresh water shallow aquifers varies considerably from place to place. The exploratory data reveals that the thickness of this aquifer is restricted to a maximum depth of 34 m. The deeper aquifers are not being tapped as the quality of the water is saline. In the Godavari delta the deeper alluvial aquifers explored down to 300 m depth contains saline water, whereas sandstone aquifers encountered below alluvium yielded fresh water.

2.1.2 Exploratory Drilling: As on date, CGWB drilled 38 no's bore wells (27 no's exploratory,6 no's observation and 5 no's piezometer well), 31 wells were drilled in alluvium area and 07 wells were drilled in sandstone area.

Formation	**EW**	**OW**	**PZ**	**Total**
Alluvium	22	5	4	31
RJY SST	5	1	1	7
Total	**27**	**6**	**5**	**38**

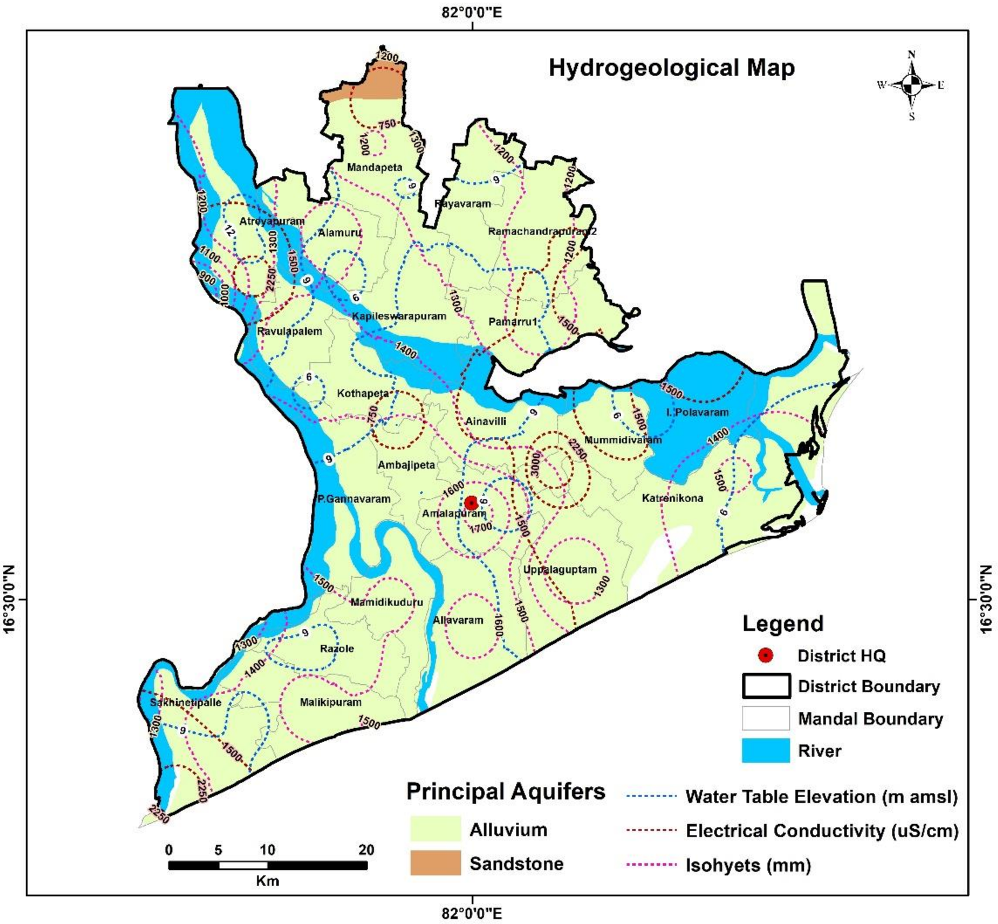


Fig.2.2: Hydrogeological map of Konaseema district.

2.1.3 Ground Water Yield: Ground water yield of unconfined aquifers varies varies from 5.0 to 16 lps, 5.0 to 8.0 lps for first confined aquifer (AQ-I) and 2.0 to 6.0 lps for second confined aquifer (AQ-II). Aquifer wise hydrogeological attributes is given bellow-

Aquifer System					
Hydrogeological Attributes/ Aquifers	**Alluvium Formation**				
	Unconfined	C1	C2	C3	C4
Depth Range (m)	Upto 34 m	22-60	68-106	124-203	212-305
EC Range (uS/cm)	395 - 3930	3000 - 5650	10600 - > 20000	-	-
Quality	Fresh	Brackish to Saline	Saline	Saline	Saline
Discharge/Yield (lps)	5.0-16	5.0-8.0	2.0-6.0	-	-
Transmissivity Range (m2/day)	290-600	350-800	150-300	-	-

2.2 Water Levels: Ground water levels from 44 piezometers were monitored for pre-monsoon and post-monsoon season.

2.2.1 Water Table Elevations: During pre and post-monsoon season (May and November), the water-table elevation ranges from 1.85 to 15.66 and -1.90 to 14.29 meter above mean sea level (m amsl) respectively and general ground flow is towards south and SE direction. (**Fig.2.3**)

2.2.2 Depth to Water Levels (DTWL): The average DTWL of 10 years (2011 to 2020) for pre-monsoon and post-monsoon were analysed, the avg. DTWL varies from 0.98 to 10.71 meter below ground level (m bgl) (average: 4.13 m bgl) and 0.32 to 11.21 m bgl (average: 3.90 m bgl) during pre-monsoon and post-monsoon seasons respectively.

Pre-monsoon season: Majority of the water levels during this season are in the range of 2.0 to 3.0 m covering 36% of the area in parts of Razole, Malikipuram, Mamidikuduru, Allavaram, Uppalaguptam, Katrenikona, I. Polavaram, Mamidivaram, Pamurru and Ramachandrapuram mandal, followed by 3.0 to 5.0 m bgl (28%), 5.0 to 10 m bgl (25%) found in norther part of the district and shallow water level <2.0 m bgl (11%) in parts of Sakhinetipalle, Malikipuram, Razole and Katrenikona mandal. (**Fig.2.4**)

Post-monsoon season: Majority of the water levels during this season are in the range of 3.0 to 5.0 m covering 39% of the area, followed by 2.0 to 3.0 m bgl (22%) covering in part of Sakhinetipalle, Malikipuram, Razole, Mamidikuduru, Allavaram, Uppalaguptam, I. Polavaram Mamidivaram and Pamurru mandal and < 2.0 m bgl (20%) found in Sakhinetipalle, Malikipuram, Uppalaguptam, Katrenikona, I. Polavaram and Mamidivaram mandal and 5.0 to 10 m covering in 18 % of the district mostly in northern part. (**Fig.2.5**)

2.2.3 Water Level Fluctuations (May vs. November): The water level fluctuations vary from -2.11 to 5.0 m (**Fig.2.6**). The Rise in water level range of 0 to 2.5 m covers majority of the area with 70 % followed by 2.5 to 5.0 m rise in rest of the area. The fall in water level range of 0 to 2.11 covering 26% of the area.

2.2.4 Long term water level trends: Trend analysis for the last 10 years (2011-2020) is studied from 44 hydrograph stations of CGWB and SGWD. It is observed that during pre-monsoon season 11 wells shows rising trend ranging 0.078 to 0.32 m/yrs and 33 wells shows falling trends ranging 0.13 to 0.26 m/yrs. During post-monsoon season 29 wells shows raising trend ranging 0.003 to 0.80 m/yrs and 15 wells shows falling trends ranging 0.03 to 0.35 m/yrs. The magnitude of trend values indicates that significant change is not occurred in the ground water scenario except at few places.

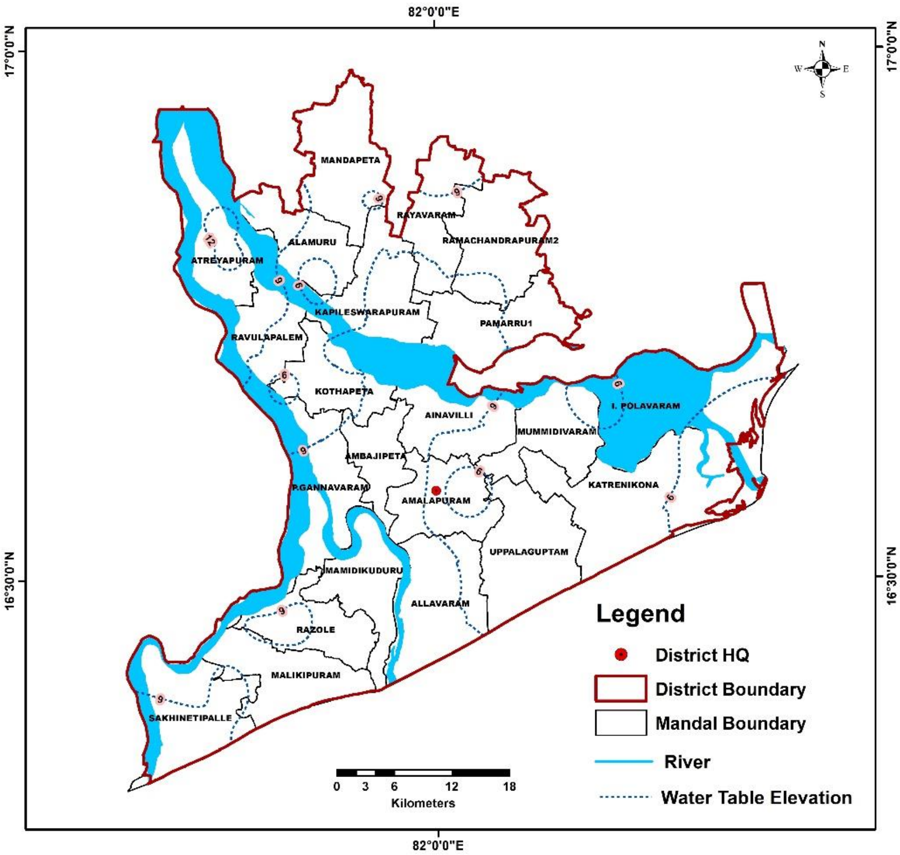


Fig.2.3: Water table elevation map (m amsl)

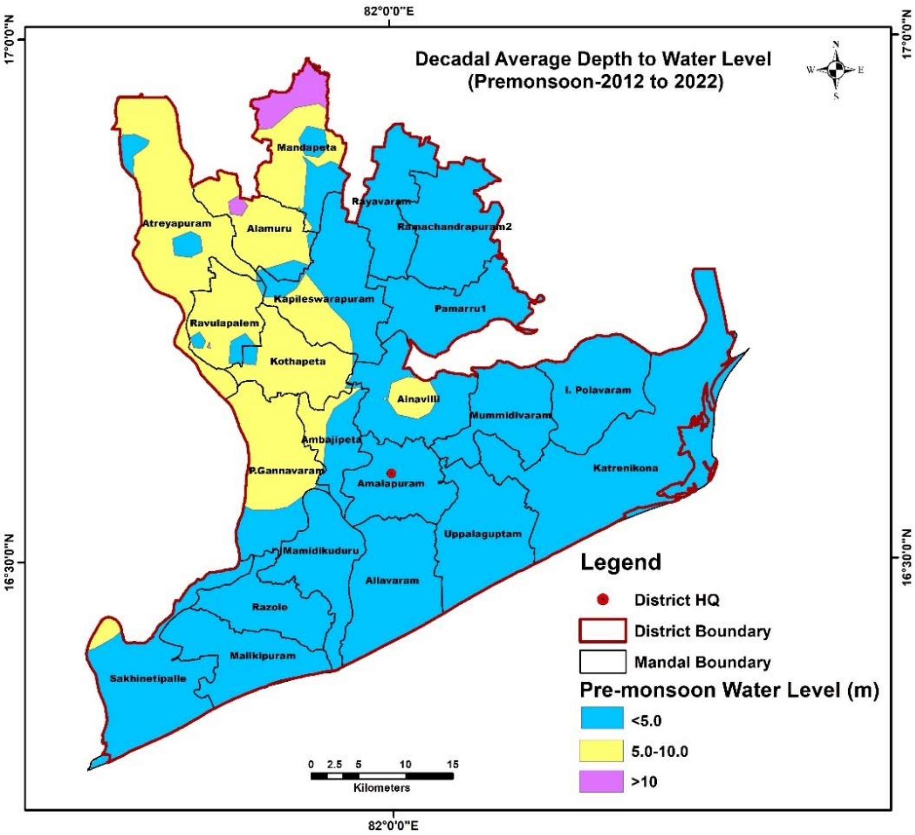


Fig.2.4: Depth to water levels Pre-monsoon (Average).

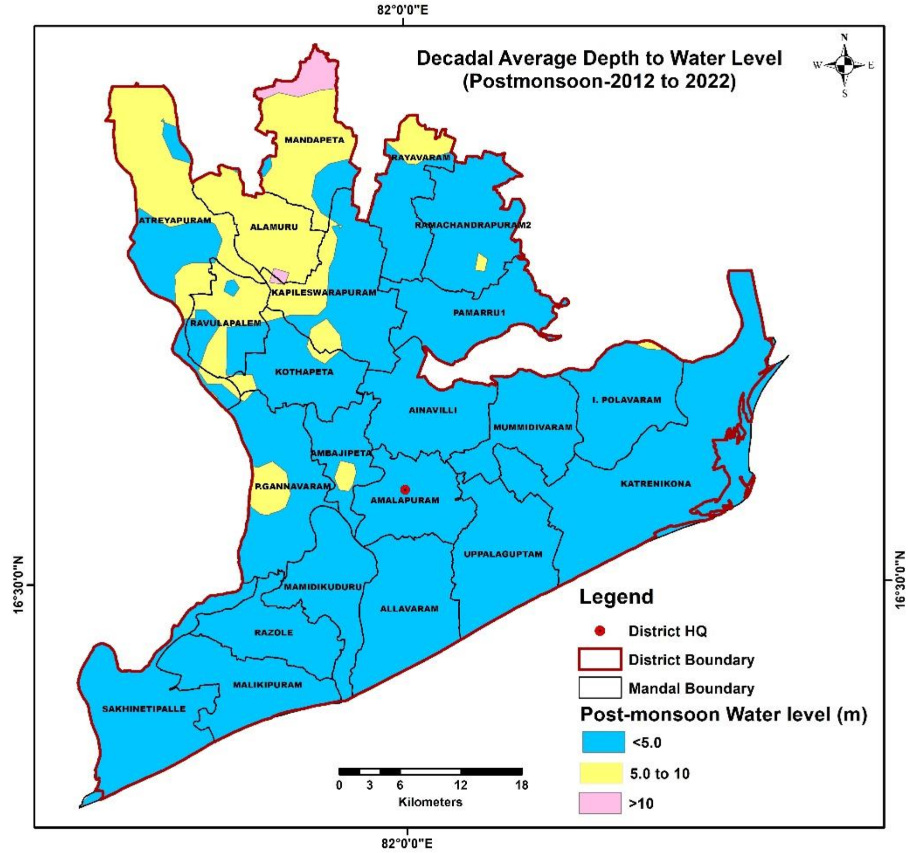


Fig.2.5: Depth to water levels Post-monsoon (Average).

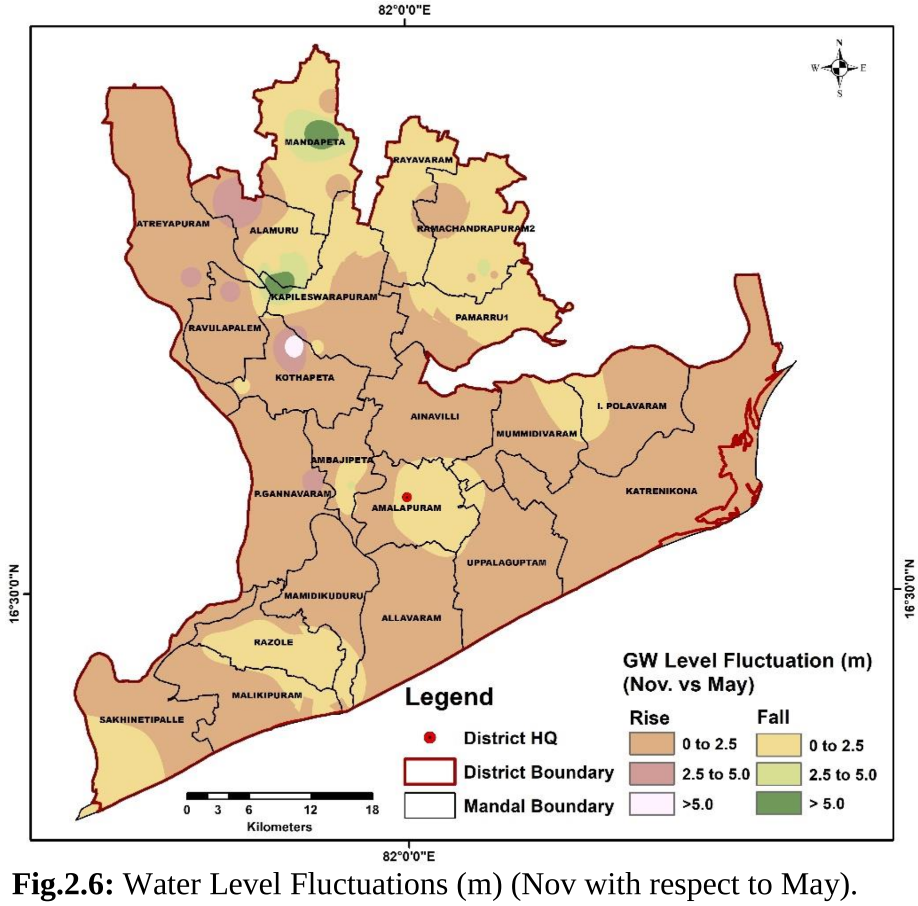


Fig.2.6: Water Level Fluctuations (m) (Nov with respect to May).

2.3 Geophysical Studies:

The geophysical studies i.e., VES indicate a three to four layered geoelectric model. The top soil is characterised by the resistivity from 4 to 22 ohm.m and the thickness varies from <1 to 3m. The second layer is characterised with a resistivity of 7 to 52 ohm.m and is of fresh in quality. The data reveals that most of the area beyond 25 m bgl is of saline except in some localized patches, where the resistivity values are varying from 30 to 60 ohm.m with a thickness of 10 to 25 m. The data reveals that in general the quality of ground water deteriorates with depth.

2.4 Hydro chemical Studies:

To understand chemical nature of groundwater, 57 water sample data is utilized from ground water monitoring wells of CGWB wells (Pre-monsoon:29 and post-monsoon:28) (mostly tapping unconfined aquifers) during the pre-monsoon season of 2022 and post-monsoon season of 2022. The parameters namely pH, EC (in µS/cm at 25° C), TH, Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, NO_3 and F were analysed.

2.4.1 Pre-monsoon:

Groundwater from shallow topmost aquifer of the area is alkaline in nature with pH in the range of 7.07 to 8.07 (Avg. 7.67). Electrical conductivity varies from 395 to 3930 (avg. 1316) µ Siemens/cm**.** In 65 % of area EC is within 750 to 1500 µ Siemens/cm; in 30 % area, it is 1500 to 2250 µ Siemens/cm; in 2 % area it is < 750 µ Siemens/cm; in 3 % area, EC is >2250 µ Siemens/cm. Higher salinity occur in coastal part of the district. (**Fig.2.7).** Nitrate concentration in all samples is below BIS permissible limits of 45 mg/L, varies between 0 to 60 mg/L, except in Amalapuram (60 mg/L) and Vegayammapeta (56 mg/L). Fluoride concentration varies from 0.02 to 1.47 mg/L and all samples falling under permissible limits of 1.5 mg/L. The groundwater quality of shallow aquifer during pre-monsoon season is given below table-

Constituent	Min.	Max.	Avg.	BSI Standards	
				Desirable Limit	Max. Permissible Limit
pH	**7.07**	**8.07**	**7.67**	6.5	8.5
EC	**395**	**3930**	**1316**	750	3000
TH	**130**	**930**	**310**	300	600
Ca	**34**	**229**	**66**	75	200
Mg	**9**	**81**	**35.5**	30	100
Na	**19**	**699**	**136**		
K	**1.6**	**219**	**25**		

CO3	0	0	0		
HCO3	158	805	429		
Cl	11	878	172	250	1000
SO4	0	107	42.5	200	400
NO3	0	60	12	45	100
F	0	0.67	0.15	1	1.5

2.4.2 Post-monsoon:

The groundwater is alkaline in nature with pH in the range of 7.07 to 7.97 (avg. 7.50). Electrical conductivity varies from 360 to 3670 µ Siemens/cm (avg. 1326 µ Siemens/cm). In 71 % of area EC is within 750 to 1500 µ Siemens/cm; in 23 % area, it is 1500 to 2250 µ Siemens/cm; in 2 % area it is < 750 µ Siemens/cm; in 3 % area, EC is >2250 µ Siemens/cm. **(Fig.2.8.)** Nitrate concentration in all samples is below permissible limits of 45 mg/L, varies between 0 to 115 mg/L, except in Tallapolam (57 mg/L), Rally (83 mg/L), Dwarapudi (55 mg/L) and Mukteshwaram (115 mg/L). Fluoride concentration all samples is below BIS permissible limits of 1.5 mg/L and varies from 0.03 - 2.29 mg/L, except in Muramalla (2.29 mg/L). The groundwater quality of shallow aquifer during post-monsoon season is given below table-

Constituent	Min.	Max.	Avg.	BSI Standards	
				Desirable Limit	Max. Permissible Limit
pH	7.07	7.97	7.50	6.5	8.5
EC	360	3670	1326	750	3000
TH	102	693	327	300	600
Ca	18	157	76.42	75	200
Mg	5	94	33.53	30	100
Na	12	778	124.75		
K	1.9	77.2	25.33		
CO3	0	0	0		
HCO3	146	1123	443		
Cl	6	776	165	250	1000
SO4	5	143	48.3	200	400
NO3	0	115	18.92	45	100
F	0.03	2.29	0.25	1	1.5

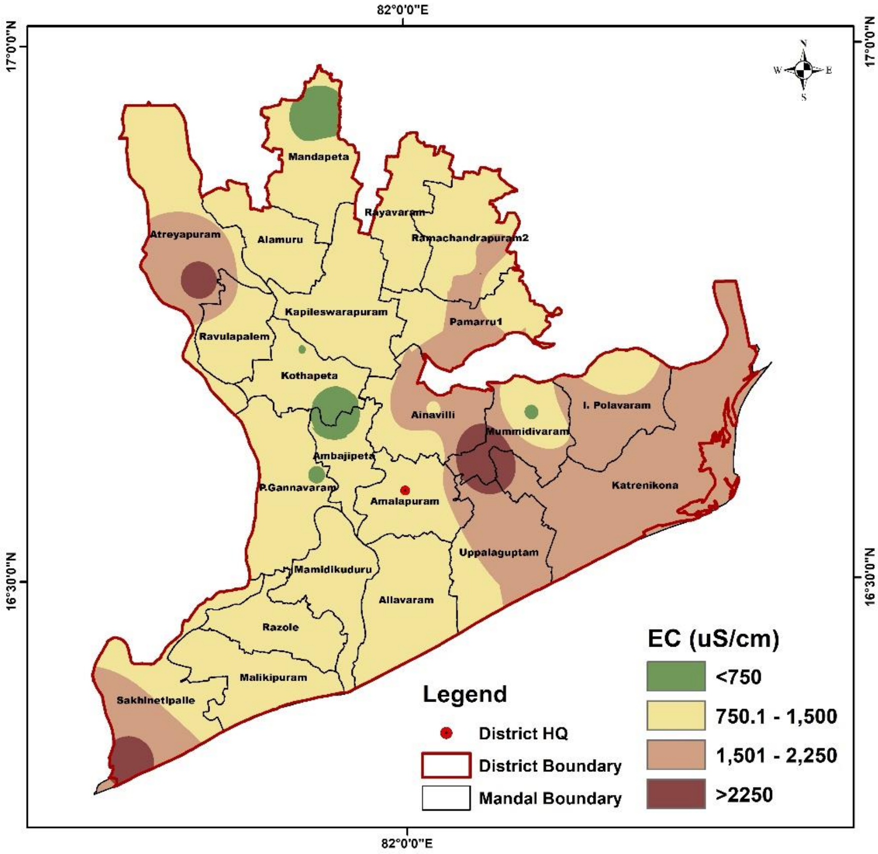


Fig.2.7: Distribution of Electrical conductivity (Pre-monsoon).

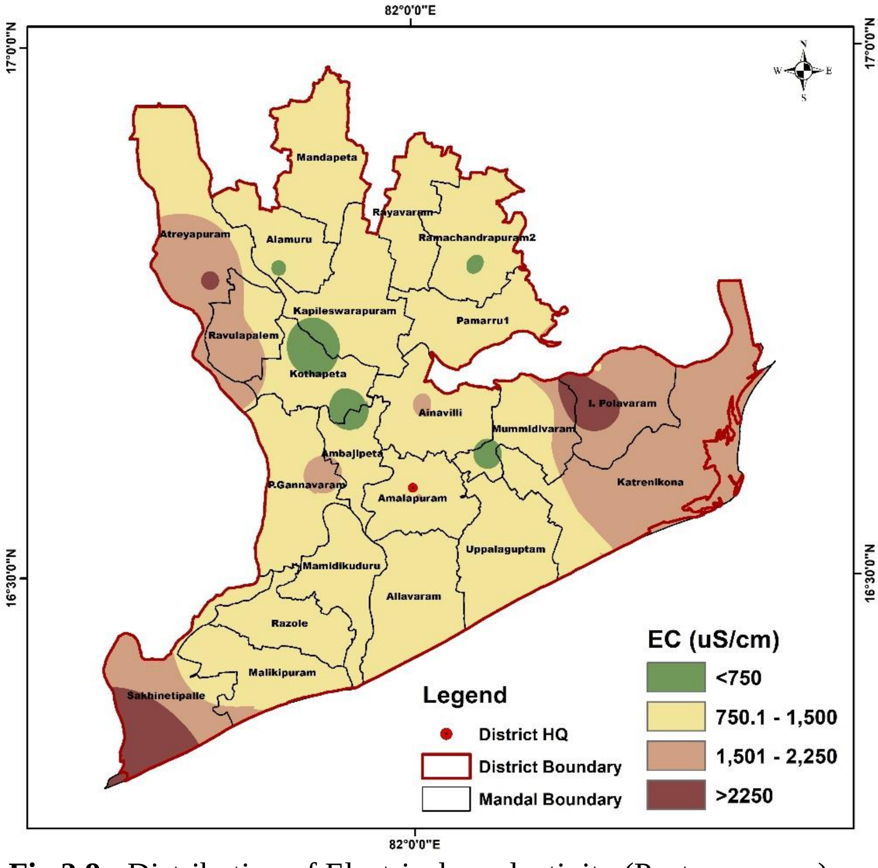


Fig.2.8.: Distribution of Electrical conductivity (Post-monsoon)

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 83 data points (both hydrogeological and geophysical down to 300 m) for preparation of 3-D map, fence diagram and hydrogeological sections. The lithological information was generated by using the Rock Works-17 software and generated 3-D map for Konaseema district and hydrogeological sections.

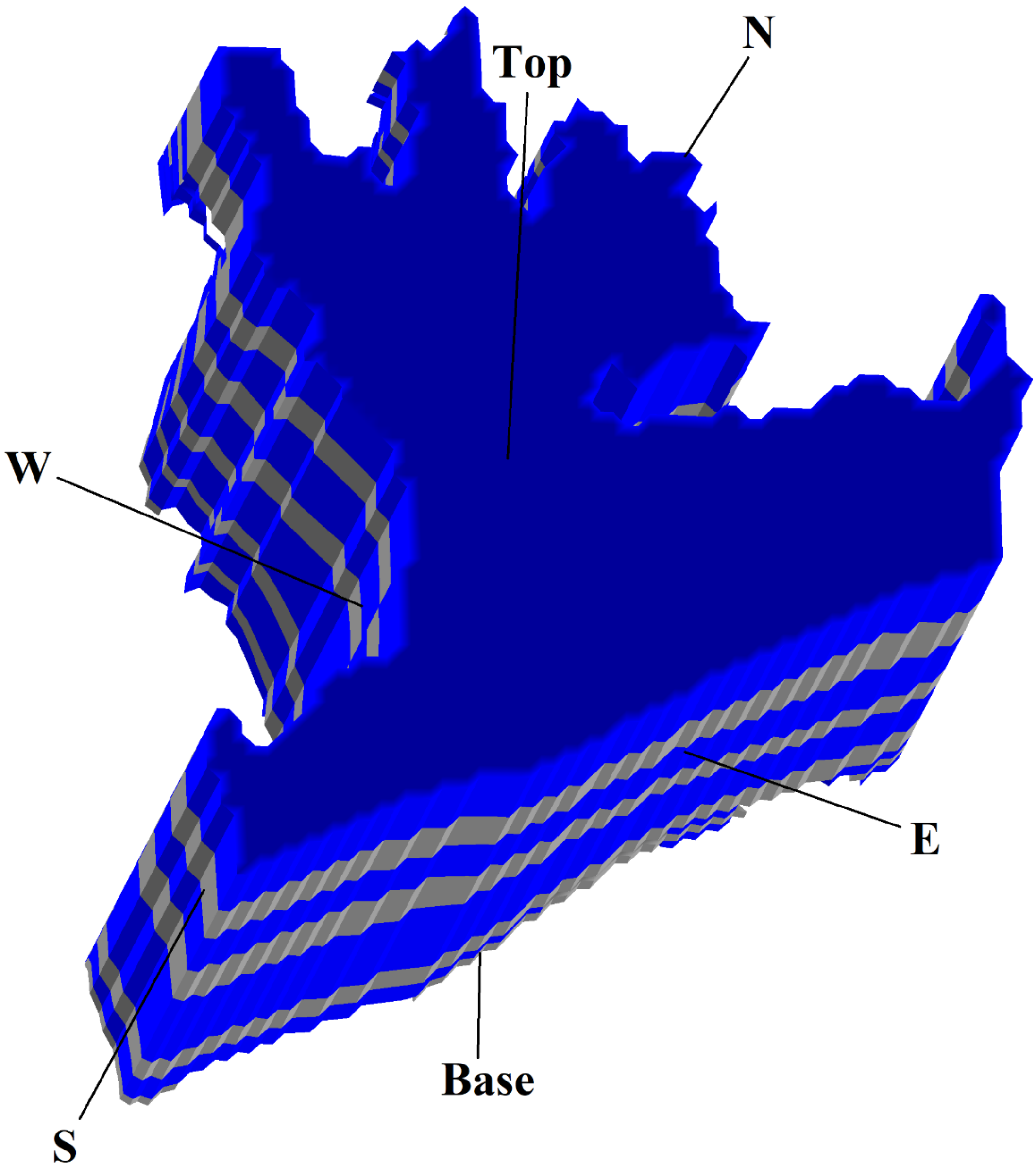


Fig.3.1:3-D Model of Konaseema district.

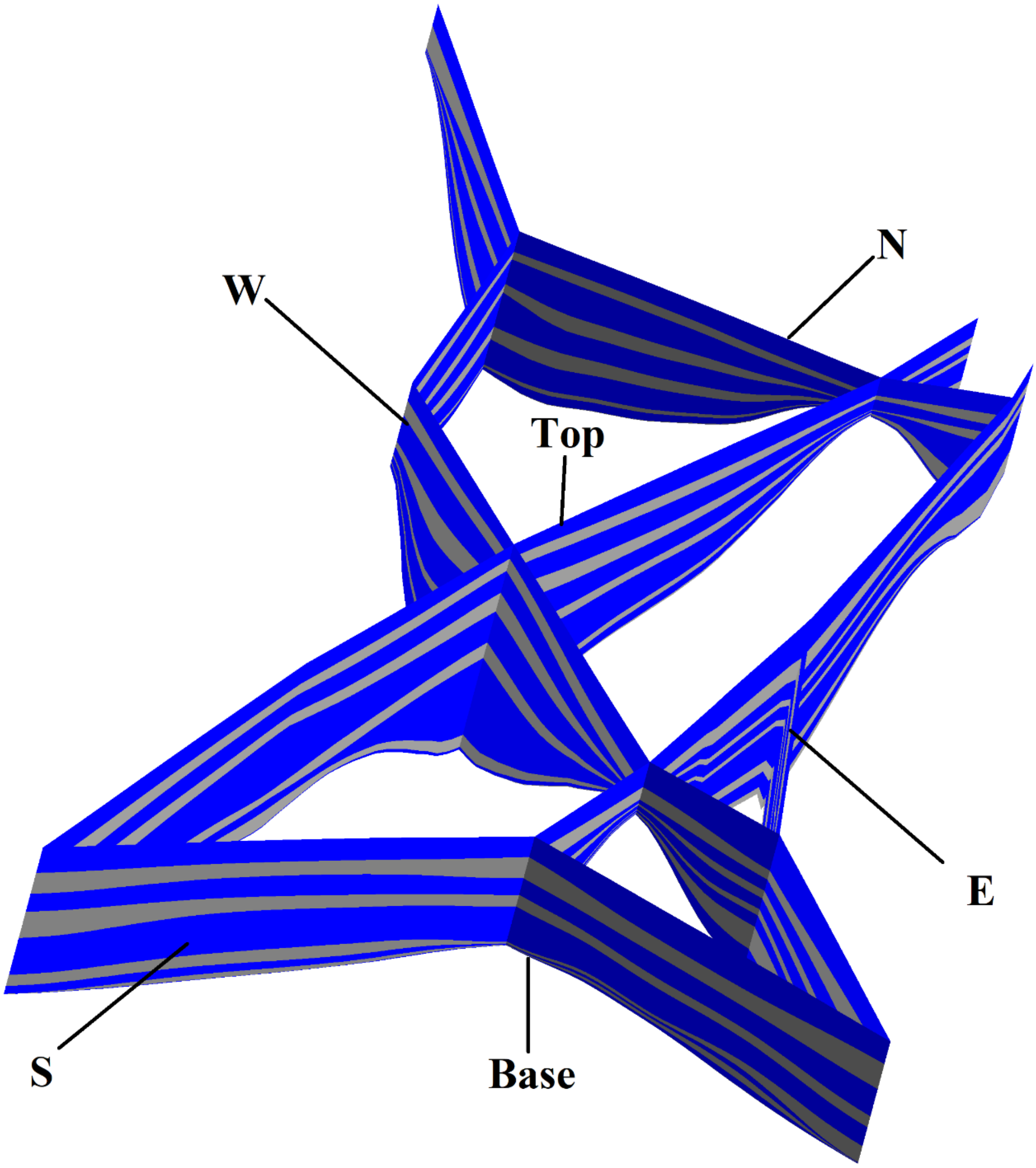


Fig.3.2.: Fence diagram

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. The detailed analysis of the data reveals that the alluvium is the principal aquifer system. 3-Dimensional model of the area is presented as **Fig. 3.1.** Ground water occurs in unconfined, semi-confined and confined conditions in the study area depending on the availability of impervious beds. Based on the available hydrogeological data a fence diagram showing the aquifer disposition were prepared and presented as **Fig.3.2.**

3.2 Hydrogeological Sections:

Hydrogeological sections are prepared in NW-SE, NE-SW and NE’-SW’ direction. (**Fig.3.3.**). The data indicates that there are multi aquifers in the area with intervening thick clay beds. These sand beds which act as aquifers in the area and there are five distinct beds which behave as regional aquifer. The study of the different sections indicate that the alluvium thickness is increasing from north to south and there are five aquifers exist up to a depth of 300 m in the study area. The shallow aquifer thickness is varying from place to place. The first aquifer which is present up to a maximum of 34m below MSL is unconfined whereas the other aquifers are confined.

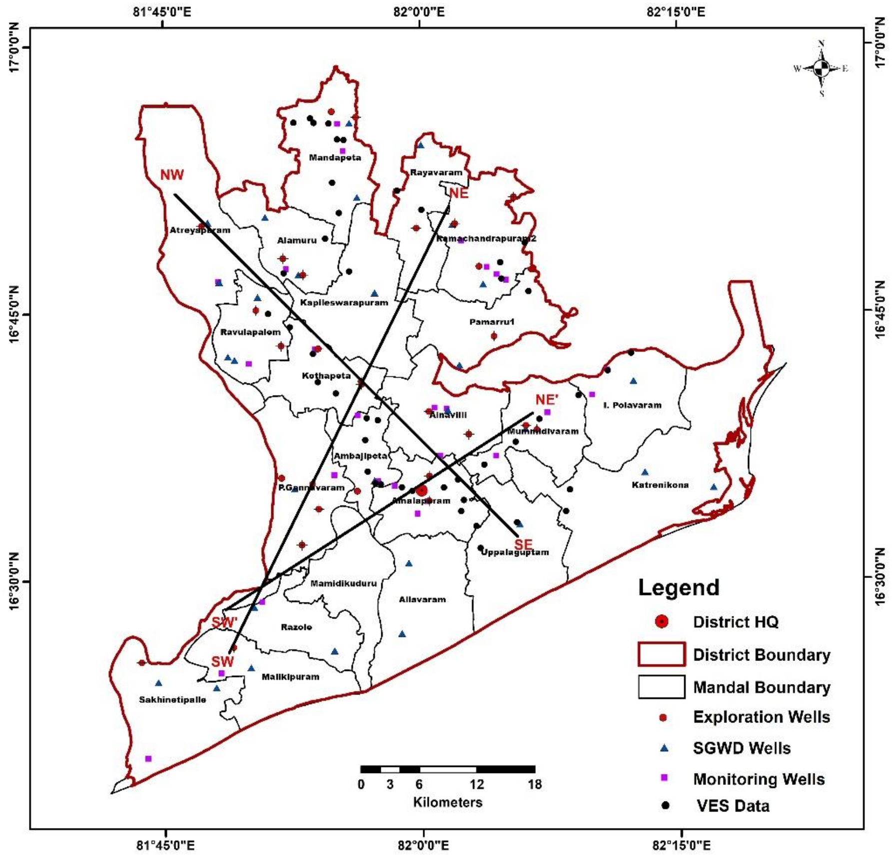


Fig.3.3: Map showing orientation of hydrogeological sections

Shallow aquifer is in unconfined condition and having the fresh ground water with EC ranges from 540 to 1700 micro siemens/cm at 25°C. The second aquifer is confined in nature and quality of the ground water is brackish to saline, where the EC ranges from 3000 to 5650 micro siemens/cm at 25°C. The deeper aquifers are saline with EC ranges from 10600 to >

20000 micro siemens/cm at 25°C and confine in conditions. Sandstone aquifers encountered below the alluvium are yielding fresh quality of ground water. The disposition of aquifers in the area is as given below

Depth range	Type of Aquifer	Quality of water
Upto 34 m	Unconfined Aquifer	Fresh
22 m - 60m	Confined Aquifer I	Brackish to Saline
68 m – 106 m	Confined Aquifer II	Saline
124 m – 203 m	Confined Aquifer III	Saline
212 m – 305 m	Confined Aquifer IV	Saline

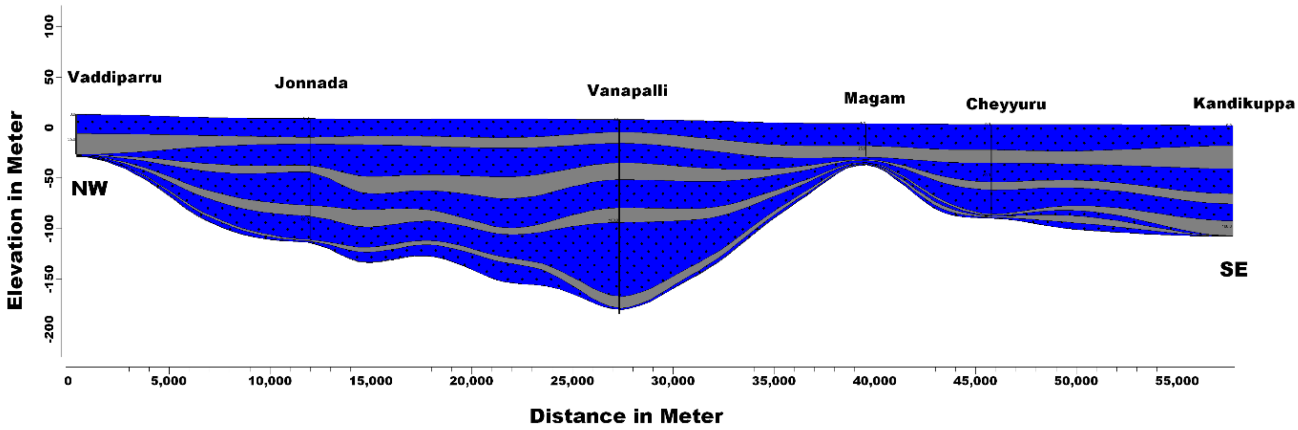


Fig.3.4a: Hydrogeological Cross Section (NW-SE)

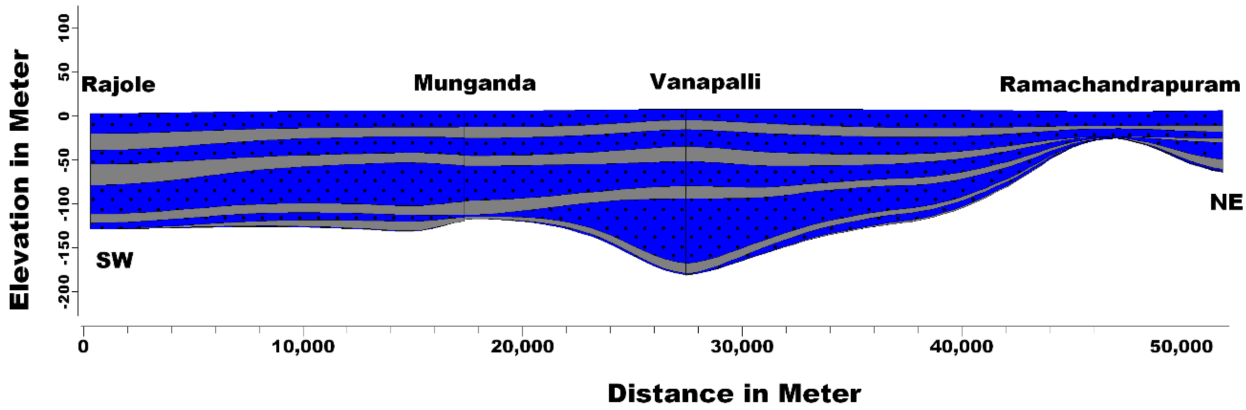


Fig.3.4a: Hydrogeological Cross Section (SW-NE)

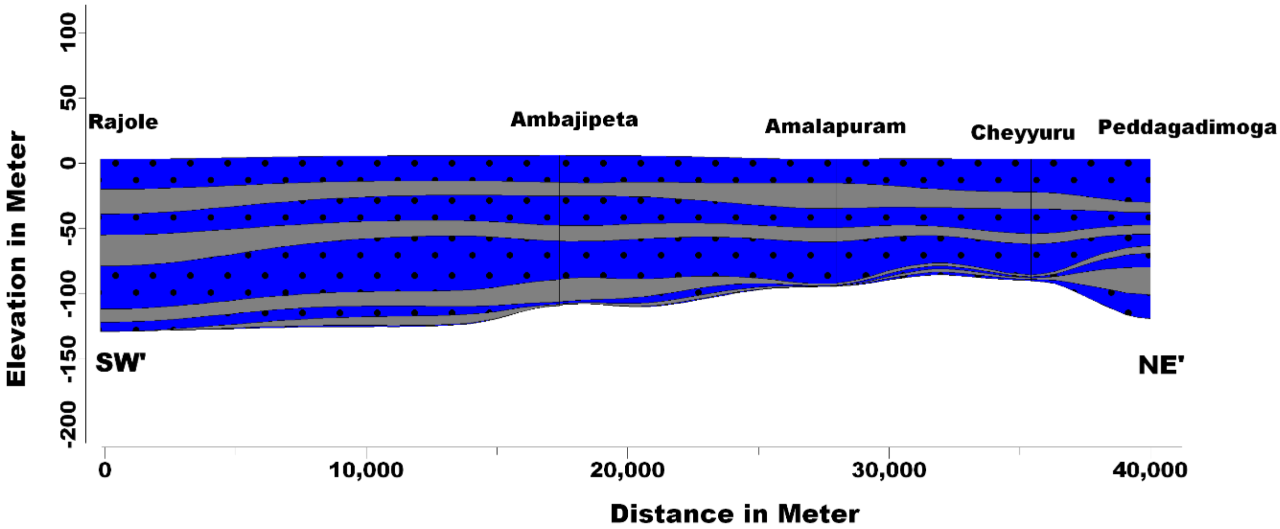


Fig.3.4c: Hydrogeological Cross Section (SW'-NE')

4.0 GROUND WATER RESOURCES (2022)

The study area is being the part of command of Godavari Irrigation system, the requirement of ground water for irrigation is limited and when required is met through dug wells and filter point. In the area during monsoon season recharge from rainfall and other sources is 120 MCM and 450 MCM respectively. During non-monsoon season recharge from rainfall and other sources is 78 MCM and 439 MCM respectively. The Net annual ground water availability in the area is 1086 MCM. The gross ground water draft for all uses in the area is 171 MCM. Net ground water availability for future irrigation use is 861 MCM. The stage of ground water development in the area is 18%. Computed Dynamic ground water resources and assessment of mandal wise Dynamic Ground Water Resources of the Konaseema District, Andhra Pradesh (2022) are given in **Table-4.1 and Annexure-I, II & III**.

Table-4.1: Computed Dynamic ground water resources, Konaseema district

Ground Water Resource Assessment		
Year	**2020**	**2022**
Total Area (Sq.km)	2081	2081
Recharge worthy Area (Sq.km)	2080	2080
Resource	**MCM**	**MCM**
Recharge from Rainfall (Monsoon)	158	120
Recharge from Other Sources (Monsoon)	533	450
Recharge from Rainfall (Non-monsoon)	3	78
Recharge from Other Sources (Non-monsoon)	320	439
Total Annual Ground Water Recharge	**1015**	**1086**
Total Natural Discharges	51	54
Annual Extractable Ground Water Resource	964	1032
Irrigation Use	156	129
Industrial Use	25	29
Domestic Use	6	13
Total Extraction	**186**	**171**
Annual GW Allocation for for Domestic Use as on 2025	7	13
Net Ground Water Availability for future use	**787**	**861**
Stage of Ground Water Extraction (%)	**22**	**18**
Categorization (OE/Critical/Semicritical/Saline/Safe)	**Safe-17; Saline-5**	**Safe-15; Saline-7**

Stage of ground water development varies from 10 % in Mummidivaram to 28 % in Ambajipeta mandal. Based on present stage of ground water development, 15 mandals are falling under safe category and 7 mandal are saline. **(Fig-4.1)**

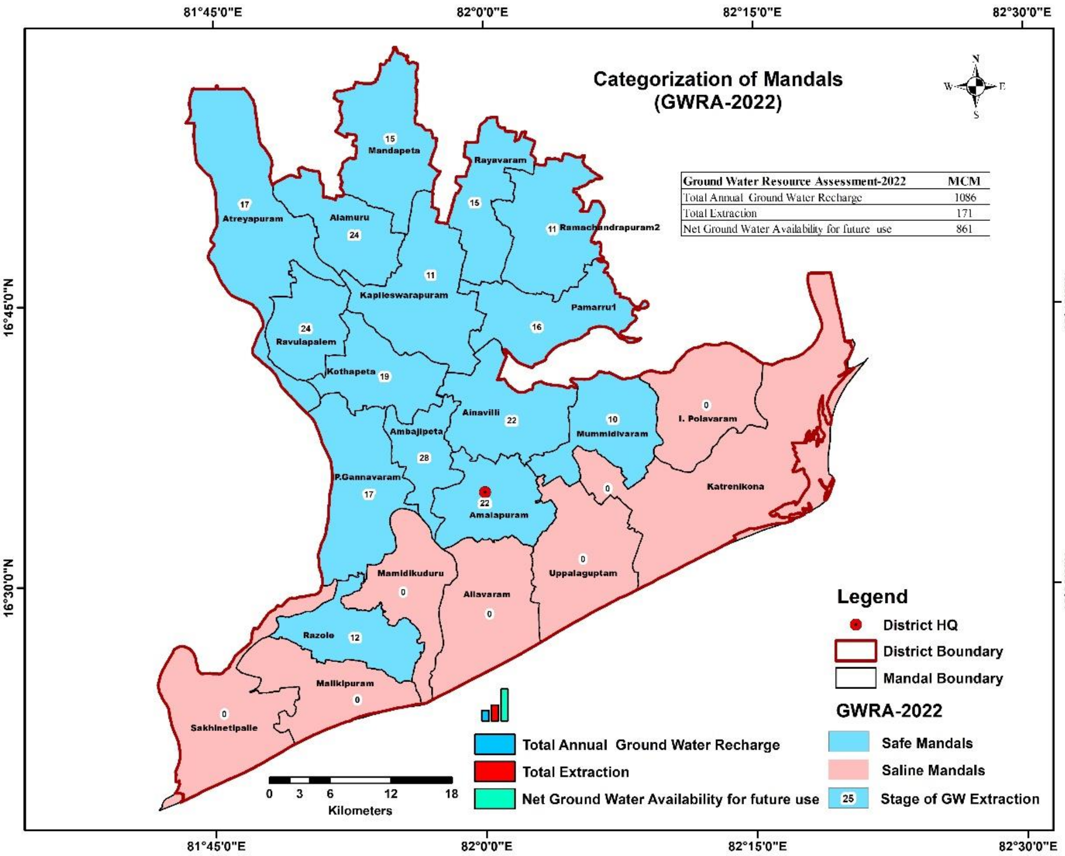


Fig-4.1: Categorization of Mandals (GWRA-2022)

5. GROUND WATER RELATED ISSUES AND REASONS

The study area has emerged due to the depositional cycles of the River Godavari, debouching the inland sediments into the Bay of Bengal. Along the coastal area the action of the saline water is predominant. Since the area is just few meters above mean sea level with very low gradient and large quantum of water from the river Godavari and canal system are applied from landward side on one hand and on the other hand it is bounded by the large saline water body in the form of Bay of Bengal, naturally problems like water logging, saline water intrusion etc., are of great concern. During the last two decades with the advent of prawn culture some of the paddy fields have been converted into tanks for growing the prawns and fish. This took place mostly in the areas along the coast where water is available with the required degree of salinity from the drains/creeks or groundwater by means of filter point/shallow tube wells.

- **Water Logging:**

Water logging is a common feature in irrigation commands of surface water projects. The DTW maps (< 2 m) reveal that an area of 248 km^2 (11%) is under water logged condition during pre-monsoon period, whereas during post-monsoon period it is extended to 478 km^2 (20%). The area prone to water logging (DTW- 2.0 to 3.0 m) during pre-monsoon and post-monsoon periods is 842 km^2 (36 %) and 523 km^2 (22 %) respectively. Irrigation by surface water, minimal withdrawal of ground water, flat topography, high rainfall, poor drainage and nature of soils are responsible for the water logging conditions in the area.

- **Deeper Groundwater level:**

In Konaseema district deeper water level means groundwater level in ranges 5 m to 10 m bgl. Its varying 25 % (520 sq.km) area to 18 % (375 sq.km) during pre-monsoon and post-monsoon season respectively although it is not significant, occurs mostly in northern part of the district in 7 mandals namely Mandapeta, Alamuru, Atreyapuram, Ravulapalem, Kothapeta, Kapileswaram and P Gangavaram.

- **Ground Water Salinity:**

The ground water in shallow aquifers is fresh except in the area near the coast and as isolated patches in inland, whereas in the deeper aquifers ground water is invariably saline.

The origin of the salinity in any area can be due to the following three reasons viz., palaeo salinity, due to leakage from the bottom aquifer, due to sea water intrusion caused by human activity. Based on the studies carried out by CGWB, the origin of salinity in the unconfined aquifer is discussed in the following paragraphs.

1) **Palaeo Salinity:** By palaeo salinity, it is indicated that the ground water being extracted from the aquifer today is the entrapped water in the geologic formation at the time of deposition. By studying the strand lines in the Godavari delta, it can be understood that most of the delta is under sea in the geological past. If the ground water is palaeo water, the salinity of the ground water in the past, due to marine regression and land upliftment, should be highest and year by year as it is being recharged by the rainfall and canal water, the salinity should follow a declining trend. In the first instance most of the saline water would have drained because of the rejuvenated hydraulic gradient. But the study reveals that the salinity in the area is not uniformly decreasing day by day. Instead it is varying depending on the ground water being abstracted in the area. This may be leading to change in hydraulic gradient and inducing flow either from the bottom aquifer or from the sea. The salinity was also observed to have a relationship with the proximity to sea. Hence it can be safely concluded that the salinity in the unconfined aquifer in study area is not of palaeo salinity.

2) **Leakage from Bottom Aquifer:** There is five aquifers upto a depth of 300 m bgl and the top one is upto maximum of 34 m bgl and is unconfined in nature and has fresh water. The other four aquifers are saline in nature. The second aquifer which exists in between 22 m and 60 m bgl is in confined condition and is saline. Normally, in multi-aquifer systems, it is possible that the second aquifer may not be fully confined and there exists a flow or leakage between the top unconfined and the bottom (semi) confined aquifer. But long duration pumping tests conducted on well fields by CGWB in the delta indicate that the second aquifer in this area is fully confined and the intervening clay bed is an aquiclude. Even pumping one aquifer does not show any reflection in the other aquifer. In this situation, it can be safely concluded that the salinity in the unconfined aquifer cannot be due to the vertical flow of the saline water from the bottom aquifer.

3) **Sea Water Intrusion:** The first and foremost indicator of sea water intrusion is reversal of hydraulic gradient and hence there should not be any fresh ground water discharges into the sea. In normal course, the ground water from the aquifer will have a positive hydraulic gradient which is towards the sea and discharges directly onto sea bed. Hence as long as

there are fresh water discharges into sea, it can be stated that there is a fresh water lense floating over the bottom saline water in the area and full encroachment by sea water is not present in the area. Because of the human activity, e.g. ground water withdrawal, when the fresh water head falls below mean sea level and reversal of gradient takes place, then the saline sea water flows into the coastal aquifer by contaminating the aquifer permanently and there will not be any fresh water discharges into the sea. The tip of the interface also starts moving towards the land. This type of situation is not present in study area as there are huge ground water discharges into the sea at present. But even though there are fresh ground water discharges in to the sea, there is a possibility that the diffusion zone of the saline-fresh water interface interferes with the pumping water level in turn deteriorating the quality of ground water.

Status of Sea Water Ingress in the Unconfined Aquifer: Ground water in the coastal aquifers exists in hydraulic connectivity with the sea water. Hence the situation is very delicate and requires a precise management strategy to obstruct the sea water intrusion or upconing which will either permanently or temporarily deteriorate the ground water quality in the aquifer or in the well. The unconfined aquifer in the delta is maximum to a depth of 34 m bmsl and the ground water in this aquifer is fresh excepting small pockets. The field EC measured during the time of monthly monitoring of water levels indicate the increase in the vicinity of Dinda, N.Kothapalli, Kandikuppa, S.Yanam and Narsapur during the water stress months indicates the rise of transition zone of fresh water – saline water interface due to abstraction of ground water in this area for the purpose of Irrigation.

For estimating the status of sea water ingress Ghyben-Hertzberg surface was prepared for both the pre and post monsoon seasons at different places. The perusal of the Ghyben-Hertzberg surface during pre-monsoon season indicates that the saline water occurs at a depth of 40 - 480 m during post monsoon season saline water occurs at deeper level compare to pre-monsoon season. The aquifer has an extension up to 34m below MSL hence normally in the interior areas there will not be any effect of this current day intrusion. To identify the extent of damage, different sections were studies, and the distance from the coast Vs Depth to Ghyben-Hertzberg surface was made. The study indicates that in general the toe of the interface is effective up to 750m from the coast during pre-monsoon season and 500m from the coast during post monsoon season. One of the sections (in the eastern most part of the delta) is presented as Fig. 5.1. Whereas in the vicinity of Upputeru area (Mallvaki Lanka to Kodurupadu) the figure 5.2. indicates that at most the toe of the interface is effective up to

24 Km from the coast during pre-monsoon season and 4 km from the coast during post monsoon season.

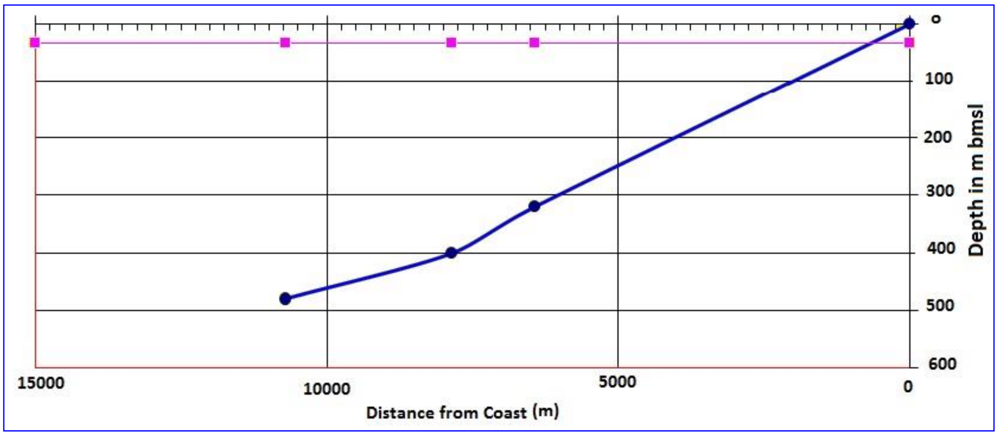


Fig.5.1a. Location of the Toe of Fresh Water – Saline Water Interface During Pre-monsoon

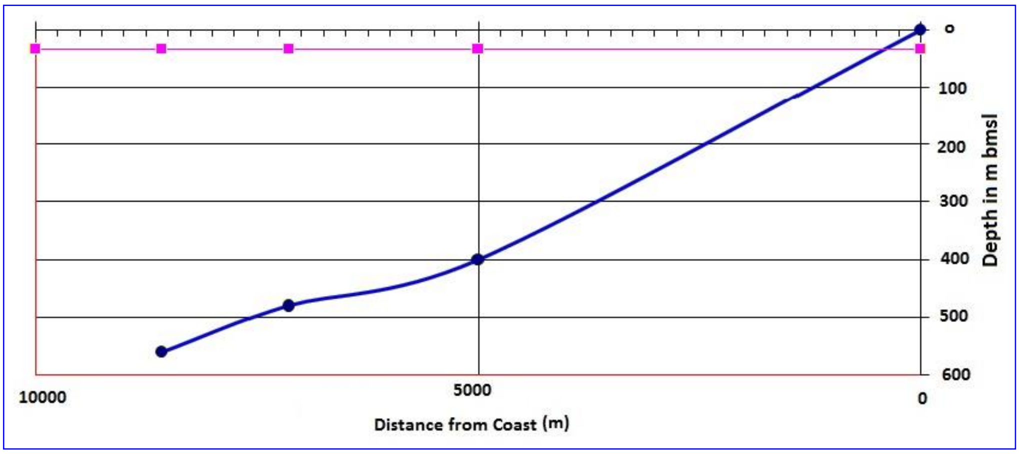


Fig.5.1b. Location of the Toe of Fresh Water – Saline Water Interface During Post-monsoon

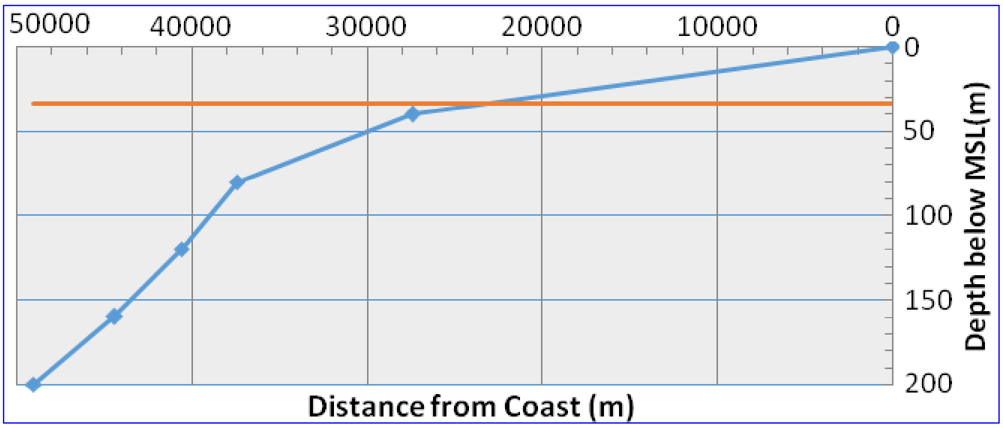


Fig.5.2a. Location of the Toe of Fresh Water – Saline Water Interface During Pre-monsoon

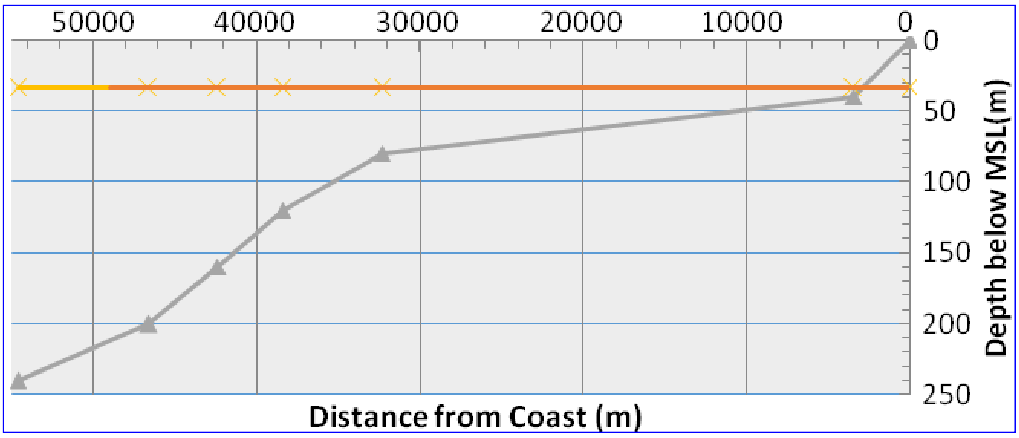


Fig.5.2b. Location of the Toe of Fresh Water – Saline Water Interface During Post-monsoon

The area covered by poor quality ground water in the Godavari delta is estimated to be 930 km^2 during premonsoon period in the area along coast and some patches in inland, whereas during postmonsoon period it is limited to 475 km^2. It is evident from this that as soon as water released into canals for irrigation and after rainfall the temporarly accumulated inferior water is flushed out or being diluted and the area is getting reclaimed naturally to some extent.

In this scenario the problem of salinity if at all exists in the areas near to coast, it is not a serious issue as the present cropping pattern being of semi-tolerant type i.e., Paddy, Coconut, Banana etc. Inland salinity in certain patches in western part of the delta mainly due to the direct recharge of saline water through Upputeru and some contribution may be from the aquaculture activities.

It is reported that there is no reduction in crop yields and other problems due to water logging and salinity in the area. As the command area is in operation since 1852, if there is any problem of significant increase of salinity/water logging in the area, by now the quality of the shallow aquifer should have been deteriorated.

- **Aqua Culture:**

In coastal tracts, there has been enormous growth of aqua culture farming 122 sq.km (5%) during the last two decades. This includes prawn culture and pisciculture. Brackish water from ponds, creeks is generally used in prawn cultivation. The availability of brackish water through tidal creeks as well from the ground water sources in this area facilitates aquaculture growth. Realizing this, palaeo mudflats zones, which are traditionally under paddy crop, are also being converted in to aquaculture in the recent years Lot of brackish water is pumped from tidal creeks and after use it is released on land surface. In aquaculture, lot of organic feed is applied, this causing the pollution of shallow aquifers.

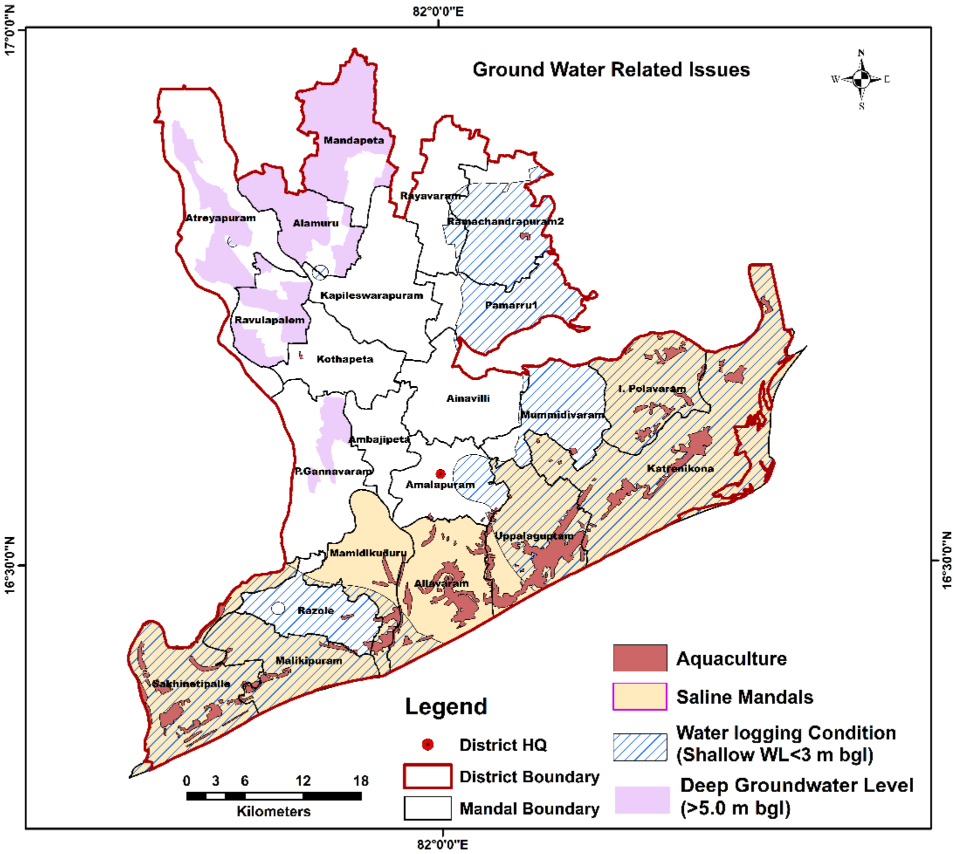


Fig.5.3. Ground Water Issues in Konaseema District.

6. GROUND WATER MANAGEMENT STRATEGIES

The Problems can be summarised as below:

- Limited utilization of fresh ground water resources.
- Quality deterioration due to sea water intrusion.
- Quality deterioration due to aqua culture.
- Quality deterioration due to direct recharge of saline water.
- Uncontrolled pumping through filter points during periods of less surface water availability.
- Water Logging.
- Deeper groundwater level.

Management Plan for the areas where limited utilization of fresh ground water resources:

When surface water is available plenty, normally people will not extract ground water for any purpose. But it should be encouraged so that the available surface water can be utilised in the tail end areas. Unless and until people understand the aquifer disposition and availability of fresh ground water in the aquifers, people may fail in tapping the available fresh ground water. Hence for encouraging farmers for utilising the fresh ground water resources, Awareness campaigns are to be organized to educate the farmers about the aquifer disposition and the bottom of first aquifer in the area which is containing fresh water so that the depth of the filter points should be limited to the bottom of fresh unconfined aquifer in the area,

The available fresh ground water may be encouraged to extract through conjunctive use. One option can be limiting surface water for the tail end areas and encouraging GW usage in upper and middle reaches. It can also be attempted that the Government can extract ground water through a network of filter points preferably in the shallow water table areas and supply the water through the canal system for irrigating the lower command. The surplus surface water will lead to enhanced command / gross irrigated area. This can lead to less extraction of ground water near the sea because of availability of surface water in tail end areas i.e., near the sea.

Management Plan for the areas where quality deterioration due to sea water intrusion is taking place:

In the area where already sea water intrusion is taking place and is observed by quality deterioration, top priority should be given for supplying surface water for the gross irrigated area in the tail end areas of the command so that the ground water extraction is reduced and in turn sea water intrusion and quality deterioration. There should be strict Implementation of Ban on Pumping in the areas which are less than 2kms from the sea and also pumping from the first two aquifers for the purpose of Aquaculture.

Artificial Recharges Measures should be practised in upper reaches such that the ground water head is always 2m above MSL which in turn maintain the natural hydraulic gradient towards sea.

Management Plan for the areas where quality deterioration due to aqua culture is taking place:

For controlling quality deterioration due to Aquaculture, Aqua Culture activities should not be encouraged beyond 2kms from the coast and also strict Implementation of Ban on Pumping from the first two aquifers for the purpose of Aquaculture.

Management Plan for the areas where quality deterioration due to direct recharge of saline water is taking place:

Direct recharge from sea water is possible where the back waters are reaching areas beyond 2 kms from the coast and the same water is used for spreading in the ponds for aqua culture and pisciculture. The back waters available in the creeks should be arrested beyond 2kms from the coast by maintaining the flows in the creek either from direct river water or drain water from the irrigation canals. Aqua Culture Should not be encouraged beyond 2kms from the coast.

This problem can be solved to some extent by installing coastal/tidal regulators on the creeks to arrest the back waters. As the creeks in most of the area are used for navigation by the fishing industry, it is required to install navigable coastal regulators i.e., regulators with gates, which can stop the flow of back waters and at the same time it will not disturb the navigation through the channel when required.

Management Plan for the areas where uncontrolled pumping through filter points during periods of less surface water availability:

As this problem exists only in case where surface water is not available in the area, top priority should be given for providing surface water for the gross irrigated area in the tail end areas of the command. Based on the availability of surface water, ground water in the upper reaches should be pumped into the canal network such that it should not arise a need for pumping in the tail end areas especially areas less than 2kms from the coast. Strict Implementation of Ban on Pumping in the areas which are less than 2kms from the sea.

Artificial Recharges Measures should be encouraged to be practised in upper reaches such that the ground water head is always 2m above MSL.

Management Plan for the areas which are water logged or prone to water logging:

For the water logged areas, ground water extraction should be encouraged through conjunctive use. Pumping the ground water through a network of filter points and pump the water in the canals for catering the irrigation needs of the lower reaches of the command. There should be strict Implementation of Ban on Surface Water Supply for Irrigation and Industrial purpose.

Management Plan for the areas where groundwater level more than 5 m bgl:

In Konaseema district, 18 % of the area mostly in NW and Northern parts in seven mandals where water level more than 5 m bgl is recorded. The area suitable for artificial recharge has been determined based on the analysis of average post-monsoon depth to water level data of the observation wells for the period 2013-2022. Accordingly, an area of 186 sq. kms is identified which is spread over in 40 villages in 7 mandals (part) of the district. (Fig.6.1) The remaining area of 3138 sq. kms comprises of 274 villages in 22 mandals have water level less than 5 m bgl are not suitable for groundwater artificial recharge.

The availability of unsaturated sub surface volume of aquifers is computed as the product of area, thickness of aquifer zone between 5 m bgl and the average post-monsoon water level and specific yield of the aquifers. The unsaturated volume of the aquifers is calculated as 7 MCM. Out of the total run off available, only 20% is considered for recommendation of artificial recharge structures considering the riparian rights and other practical considerations for recommending the artificial recharge structures. The Check dams and Percolation Tanks are calculated by taking 5 fillings for Check dams and 2 fillings for Percolation Tanks. After considering the existing AR Structures and data gap, a total 83 number of AR structures (43 number of PTs, 40 number of CDs) are feasible in the district.

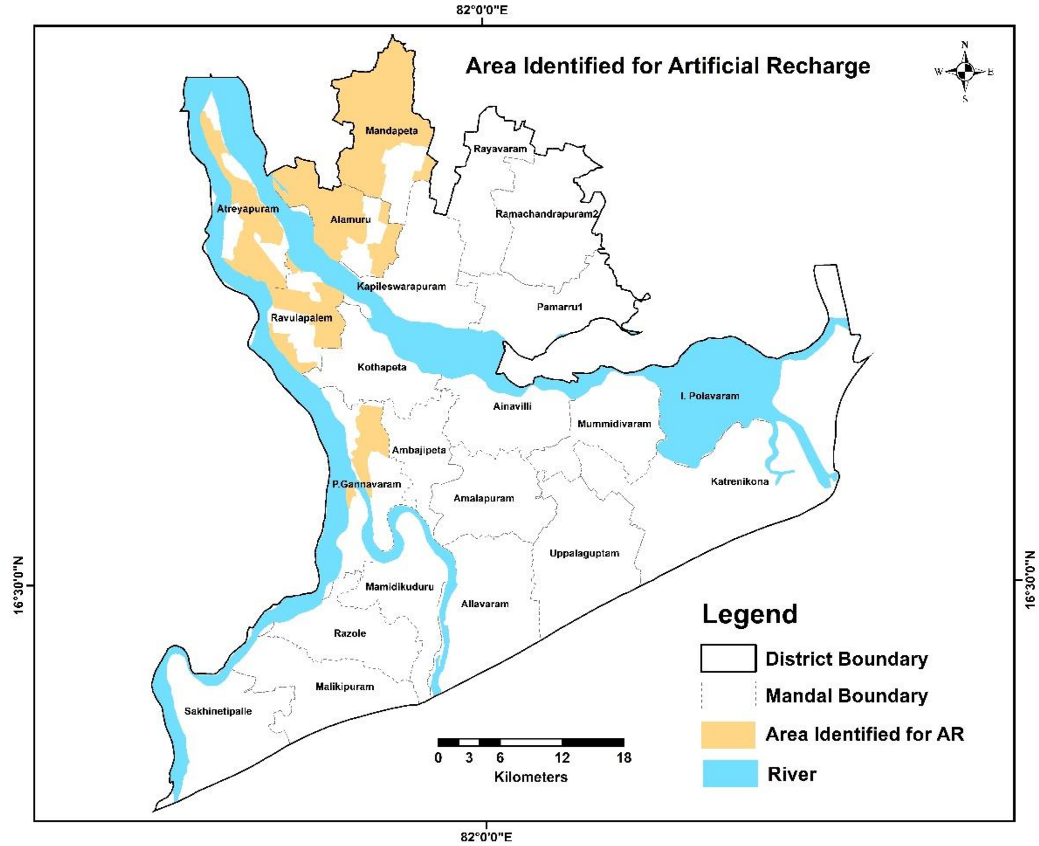


Fig.6.1. Area identified for Artificial Recharge Structures.

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Mandal wise recharge worthy area of the district **ANNEXURE-I**

Sl.No.	Mandal	Total area of assesment unit (Ha)	Recharge worthy area (Ha)
1	AINAVILLI	9348	9342
2	ALAMURU	7841	7838
3	ALLAVARAM	10492	10492
4	AMALAPURAM	8060	8057
5	AMBAJIPETA	5402	5395
6	ATREYAPURAM	8611	8597
7	I. POLAVARAM	12942	12942
8	KAPILESWARAPURAM	10660	10657
9	KATRENIKONA	13816	13816
10	KOTHAPETA	7957	7956
11	MALIKIPURAM	8955	8942
12	MAMIDIKUDURU	7995	7970
13	MANDAPETA	10994	10994
14	MUMMIDIVARAM	9571	9571
15	P.GANNAVARAM	8381	8354
16	PAMARRU1	11705	11705
17	RAMACHANDRAPURAM2	10669	10669
18	RAVULAPALEM	7254	7254
19	RAYAVARAM	7904	7904
20	RAZOLE	7714	7714
21	SAKHINETIPALLE	10071	10071
22	UPPALAGUPTAM	11755	11755
Total		208096	207995

Mandal wise rainfall recharge and recharge due to different structures **ANNEXURE-II**

Sl.No.	Mandal	Recharge from Rainfall-MON	Recharge from Other Sources-MON	Recharge from Rainfall-NM	Recharge from Other Sources-NM	Total Annual Ground Water (Ham) Recharge
1	AINAVILLI	855	2684	621	2462	6621
2	ALAMURU	845	3152	402	3024	7423
3	ALLAVARAM	0	0	0	0	0
4	AMALAPURAM	637	2399	537	2222	5795
5	AMBAJIPETA	544	1202	346	1170	3262
6	ATREYAPURAM	876	4905	399	4138	10318
7	I. POLAVARAM	0	0	0	0	0
8	KAPILESWARAPURAM	873	4285	578	4035	9770
9	KATRENIKONA	0	0	0	0	0
10	KOTHAPETA	644	2486	372	2217	5720
11	MALIKIPURAM	0	0	0	0	0
12	MAMIDIKUDURU	0	0	0	0	0
13	MANDAPETA	1184	4057	857	3654	9752
14	MUMMIDIVARAM	827	2654	647	2358	6486
15	P.GANNAVARAM	726	2554	514	2402	6195
16	PAMARRU1	979	3018	669	3049	7715
17	RAMACHANDRAPURAM2	920	4003	531	6262	11716
18	RAVULAPALEM	726	2392	334	2086	5537
19	RAYAVARAM	711	2884	451	2740	6787
20	RAZOLE	648	2297	545	2054	5544
21	SAKHINETIPALLE	0	0	0	0	0
22	UPPALAGUPTAM	0	0	0	0	0
Total		11995	44971	7802	43872	108640

Mandal wise GW Extraction and ground water categorization **ANNEXURE-III**

Sl.No.	Mandal	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)	Irrigation Use (Ham)	Industrial Use (Ham)	Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (OE/Critical/Semicritical /Safe)
1	AINAVILLI	331	6290	906	433	68	1408	73	4878	22	safe
2	ALAMURU	371	7052	1296	288	73	1657	78	5434	24	safe
3	ALLAVARAM	0	0	0	0	0	0	0	0		salinity
4	AMALAPURAM	290	5505	662	414	139	1215	148	4299	22	safe
5	AMBAJIPETA	163	3099	807	0	75	882	80	2212	28	safe
6	ATREYAPURAM	516	9802	1339	236	57	1632	60	8166	17	safe
7	I. POLAVARAM	0	0	0	0	0	0	0	0		salinity
8	KAPILESWARAPURAM	489	9282	842	69	68	978	72	8299	11	safe
9	KATRENIKONA	0	0	0	0	0	0	0	0		salinity
10	KOTHAPETA	286	5434	906	74	78	1058	83	4371	19	safe
11	MALIKIPURAM	0	0	0	0	0	0	0	0		salinity
12	MAMIDIKUDURU	0	0	0	0	0	0	0	0		salinity
13	MANDAPETA	488	9264	1121	144	130	1396	139	7861	15	safe
14	MUMMIDIVARAM	324	6162	472	100	68	641	72	5517	10	safe
15	P.GANNAVARAM	310	5885	731	188	76	994	80	4887	17	safe
16	PAMARRU1	386	7329	780	292	67	1139	71	6186	16	safe
17	RAMACHANDRAPURAM2	586	11130	906	239	118	1263	125	9860	11	safe
18	RAVULAPALEM	277	5260	1007	168	79	1253	83	4039	24	safe
19	RAYAVARAM	339	6447	772	149	68	989	72	5454	15	safe

20	RAZOLE	277	5267	396	148	86	630	92	4632	12	safe
21	SAKHINETIPALLE	0	0	0	0	0	0	0	0		salinity
22	UPPALAGUPTAM	0	0	0	0	0	0	0	0		salinity
Total		5432	103208	12943	2943	1250	17135	1328	86094	18	