केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

East Godavari, West Godavari and Krishna Districts, Andhra Pradesh

दक्षिणी क्षेत्र, हैदराबाद

Southern Region, Hyderabad

भारत सरकार
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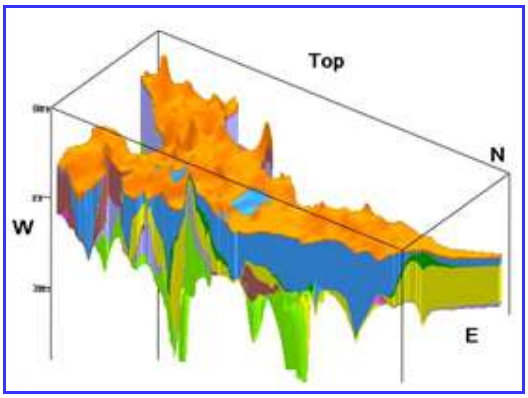
GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES,
RIVER DEVELOPMENT AND GANGA REJUVENATION
CENTRAL GROUND WATER BOARD

REPORT ON

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES
Sandstone Area of
East Godavari, West Godavari and Krishna Districts, Andhra Pradesh



SOUTHERN REGION
HYDERABAD
2016-17

REPORT ON

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Sandstone Area of

East Godavari, West Godavari and Krishna Districts, Andhra Pradesh

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REPORT ON

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Sandstone Area of

East Godavari, West Godavari and Krishna Districts, Andhra Pradesh

At a Glance

1	Districts Area Location	:	Parts of East Godavari, West Godavari and Krishna 4860 Km^2 16º 39' to 17º 20' N 80º 48' to 82º 32' E
2	Mandals Villages	:	47 (Full:11, Part:36) 486
3	State	:	West Godavari, Andhra Pradesh
4	Normal Rainfall (mm)	:	840 – 1283 mm Monsoon : ~ 70% Non-Monsoon : ~ 30%
5	Major Drainage	:	Godavari
6	Gross area sown	:	409940 ha Major crop : Paddy Irrigation is mainly based on groundwater (> 70%)
7	Ground water levels (2015)		Shallow Aquifer: 02-10 m Deeper Aquifer : 20 – 30 m (Piezometric head)
8	Aquifer - characteristics	:	Chintalapudi, Gollapalli, Thirupati and Rajahmundry sandstone General depth range of wells = 70 – 120 m Yield = 200 – 800 lpm
9	Ground water Resources (MCM)	:	Dynamic Resouces : • Net GW availability : 940 • Gross GW draft : 545 • Stage of GW Development : 58% • Category : Safe Static Resources : 12110 Lateral GW Flow : 367
9	Chemical quality of ground water	:	• EC in majority of the area : < 1500 µS/cm • Quality of ground water is potable
10	Major Ground Water Issue	:	• Water level depletion

REPORT ON

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES
Sandstone Area of
East Godavari, West Godavari and Krishna Districts, Andhra Pradesh

INTRODUCTION:

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers. In recent past, there has been a paradigm shift from “groundwater development” to “groundwater management”. As large parts of India particularly have become water stressed due to rapid growth in demand for water due to population growth, irrigation, urbanization and changing life style. Therefore, in order to have an accurate and comprehensive micro-level picture of groundwater in India, aquifer mapping in different hydrogeological settings at the appropriate scale is devised and implemented, to enable robust groundwater management plans. This will help in achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural and many parts of urban India. The aquifer mapping program is important for planning suitable adaptation strategies to meet climate change also. Thus the crux of National Aquifer Mapping (NAQUIM) is not merely mapping, but reaching the goal-that of ground water management through community participation.

In view of the above challenges, an integrated hydrogeological study was taken up in the Sandstone area covering parts of East Godavari, West Godavari and Krishna districts of Andhra Pradesh as per AAP 2016-17 of CGWB, SR, Hyderabad. The main objective of the study is to prepare aquifer maps and to suggest ground water management plans of Sandstone Aquifers of the area.

Study Area :

Administratively the area is with 486 habitations covering fully 11 and partially 36 mandals of East Godavari, West Godavari and Krishna districts of Andhra Pradesh (Fig.1). The area is located between North latitude 16°39’ to 17°20’ and East longitude 80°48’ to

82°32’ covering an area of 4860 km^2 falling in parts of Survey of India Toposheets 65 C/16, D/13 & 14, G/3, 4, 8, 12 & 16, H/1, 5, 9 & 13, K/4, 8, 11 & 12 and L/1.

Fig. 1 Location and Administrative Divisions of the Study Area

Climate and Rainfall :

Climatologically the area experiences dry, sub-humid with oppressive summer and good seasonal rainfall. The normal annual rainfall in the area by considering the data recorded at mandal head quarters is varying from 840 to 1283 mm (Fig. 2). Most of the rainfall (70%) occurs during the south west monsoon season.

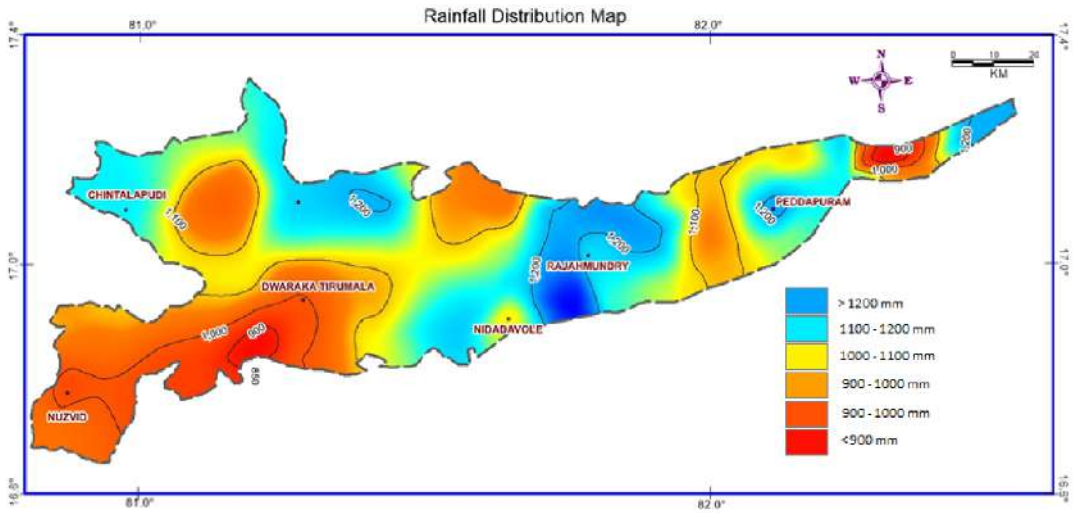

Fig. 2 Normal Rainfall Map of the Study Area

Drainage:

The area is mainly drained by Godavari river in the centre of the area and flows N to S direction (Fig. 3). The other major streams flowing in the area are Yerrakaluva, Tammileru and Yeleru. The general flow direction is NNW to SE. The area is characterized by sub-dendritic to dendritic nature of drainage pattern. In general the drainage density is decreases from north to south.

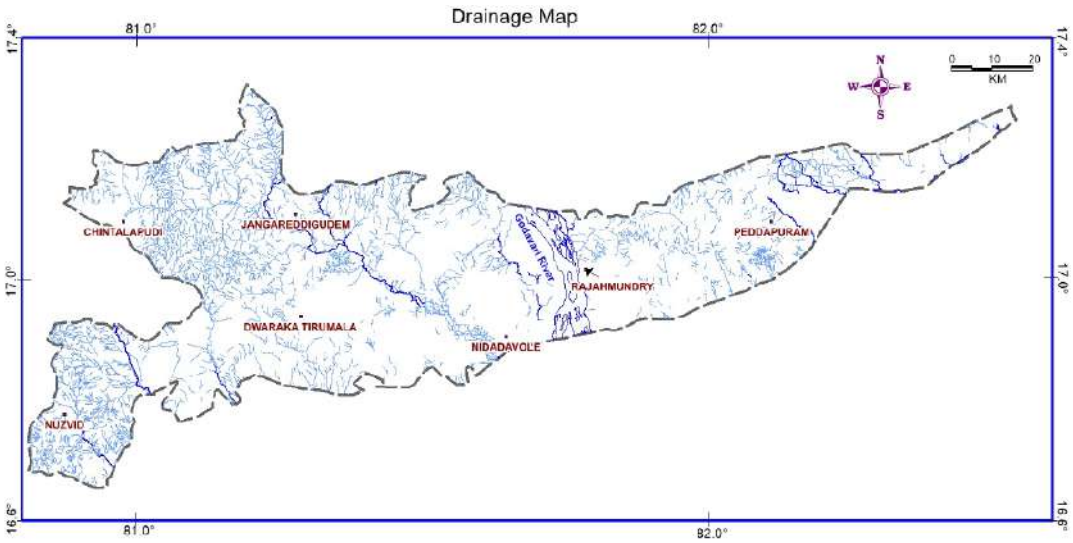

Fig. 3 Drainage Map of the Study Area

Geomorphology :

Geomorphologically major part of the area is occupied by pediplains, in the western part of the area isolated relict and residual hills occur (Fig. 4). Other landforms in the area are flood plains, palaeochannels and deltaic plains. The area is having a moderately undulating topography and the elevation is varying from 10 to 190 m amsl (Fig. 5).

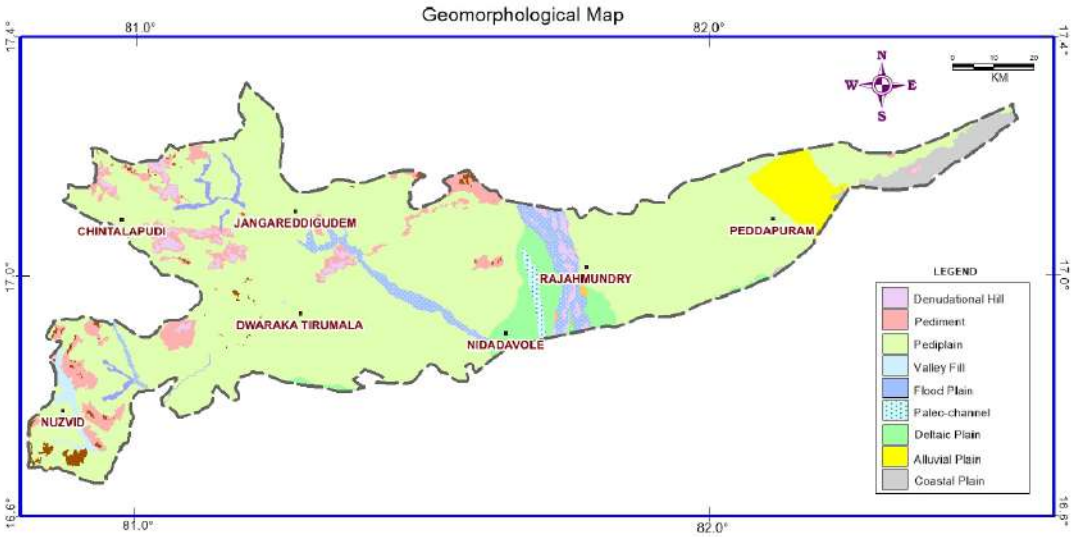

Fig. 4 Geomorphological Map of the Study Area

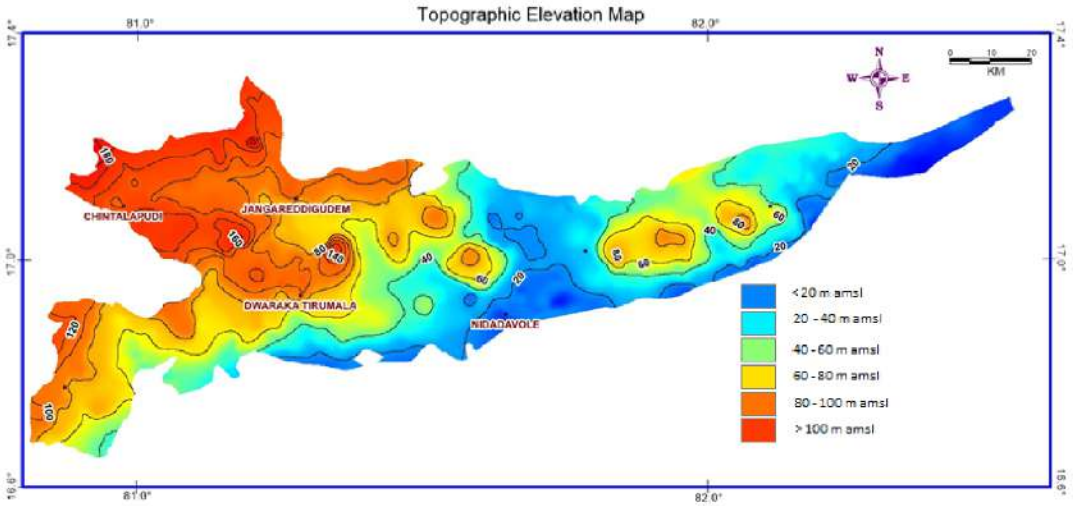

Fig. 5 Topographic Elevation of the Area

Soils :

The predominant soils in the area are sandy soils. The red soils comprise red sandy soils, red loamy soils with clay base and red earths with loamy sub soils. They are permeable and well drained to moderately well drained. Deltaic alluvial soils occur mainly along river Godavari and are highly fertile.

Land Use, Irrigation & Cropping Pattern:

The land use pattern in the study area indicates that the area is mostly agrarian. The irrigation in the area is mainly by groundwater and to the some extent surface water is being used from the Jalleru, Tammileru and Yerrakalava projects. Polavaram multi purpose project is the scheme contemplated under major irrigation project proposed on the river Godavari. It envisages providing irrigation facilities in the southern half of the study area. The project is in progress. The crops grown in the area are paddy and other cereals, coconut, banana, sugarcane, pulses, chillies, fruits and vegetables. Paddy is the main crop in the area followed by maize. Ground water is the main source of irrigation (>70 %). The land use pattern and the area irrigated by different sources in the area are presented as Fig. 6 a & b.

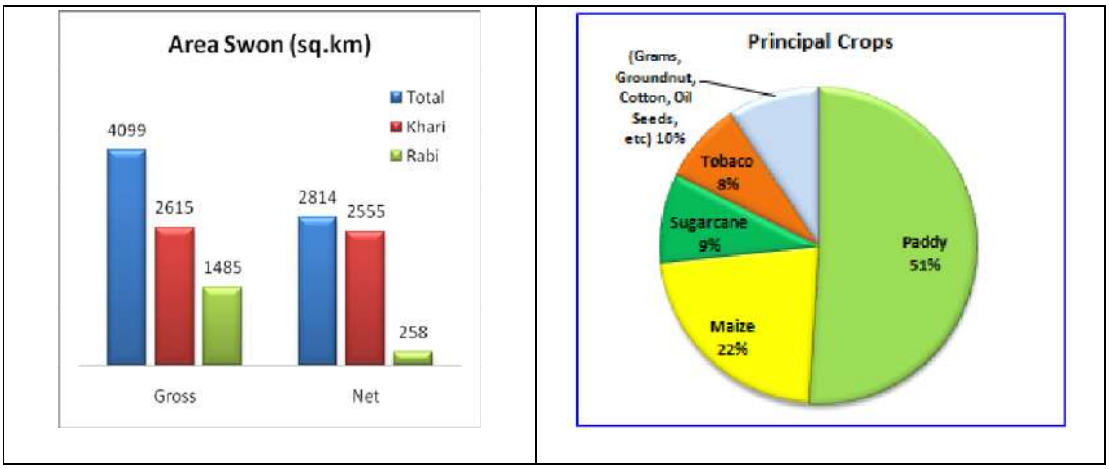

Fig. 6 a Land Use Pattern and Principal Crops

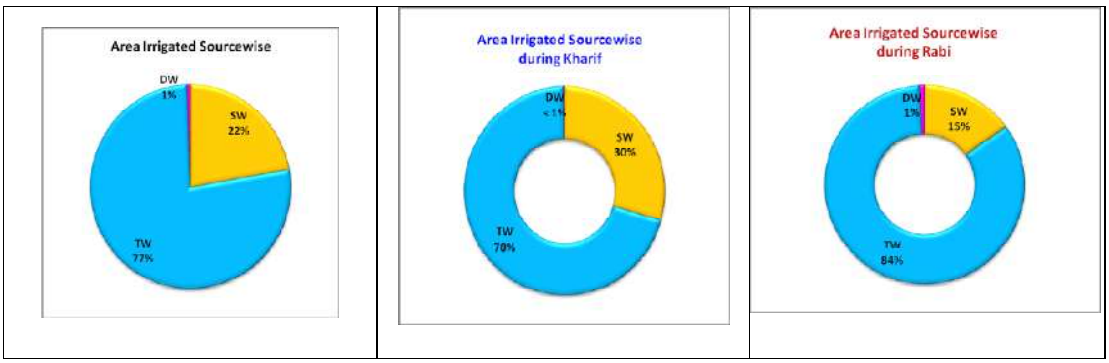

Fig. 6 b Area irrigated by Different Sources

Previous Work:

Several Organizations like Geological Survey of India, Central Ground Water Board at the National Level and Andhra Pradesh State Ground Water Department, Andhra Pradesh State Irrigation Development Corporation and Rural Water Supply and Sanitation Department at State level have carried out geological and hydrogeological surveys in this area.

DATA COLLECTION, INTERPRETATION, INTEGRATION and AQUIFER MAPPING

Collection, Compilation and processing of data for aquifer mapping studies is carried out in conformity with EFC document of XII plan of CGWB encompassing various activities.

Geology:

Geologically the area is mainly underlain by sandstone of Gondwana and Rajahmundry formations. The general geological succession of the area is shown in Table 1. The geological map of the area is given as Fig. 7**.**

Table – 1 : General Geological Succession of the Study Area

Age	System	Formation	*Lithology*
Recent to Sub-Recent		Alluvium	Gravel, sand , silt, clay and laterite
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, Charnockites and Gneisses

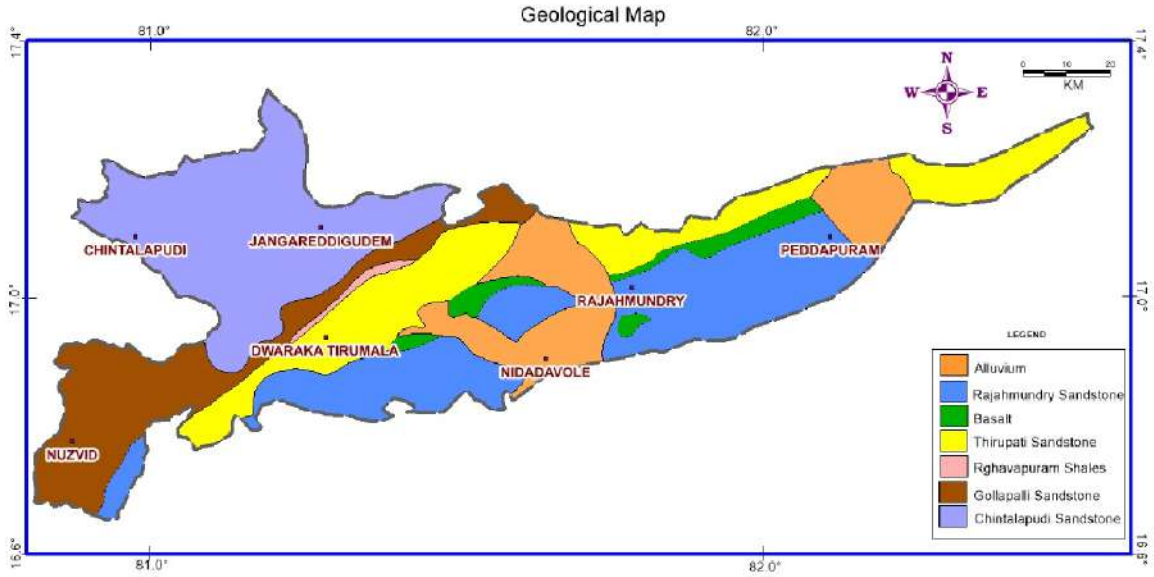

Fig. 7 Geological Map of the Study Area

The Archaean crystallines form the basement for the younger formations i.e., sandstone formation in the area. These are represented by khondalites, charnockites and gneisses. The Gondwana formations represented by Chintalapudi, Gollapalli, Raghavapuram and Thirupathis are occupy in the western part of the study area where as in eastern part of the area Thirupathi and Rajahmundry are major formations.

The Chintalpudi formation overlies unconformbly over the Archaeans It is represented by fine to medium grade sandstone interbedded with shale clays and pebbly sandstone. The Golapalli formation of the upper Gondwana directly overlis the archeans in the western part of the area and directly underlies the Tirupati sandstone and overlies Chintalapudi sandstone. These formations are represented by sandstone, shale and conglomerate of yellowish brown to buff colour and are sometimes purple in nature. Raghavapuram formation is occupied limited area and consist of white shale, medium to fine grained sandstone and ferruginous clay stones. The Tirupati formation is the youngest formation of the Gondwana super group in the district and conformably overlies the Raghvapuram formation in eastern portion of the study area and directly rests on Archaean basement at other places. These are overlain by Deccan Traps of Eocene age in central part. All the above formations are trending in NE-SW with 5 to 10^{o} dip toward southeast. Deccan

traps are well exposed in central part of the area. The basaltic flows are overlain mostly by Rajahmundry sandstones.

The Rajahmundry formation of Tertiary age overlies the traps in the eastern part and Gondwanas in the western part. Three different beds are recognized in the district. The oldest bed is characterized by conglomerates and ferruginous sandstones, which overlie traps. The second bed is Rajahmundry sandstone, which is brick red and occasionally yellowish in colour. The third and topmost bed is a set of variegated clays of different thickness. The sandstones are nearly horizontal with southerly low dips. In the central part of the area alluvium occurs, the thickness of this formation is less.

Based on the available subsurface data (both hydrogeological and geophysical) geological model, hydrogeological cross sections and fence diagrams are prepared and presented as Fig. 8, 9 & 10. Details of the data sets compiled for different studies are given below:

Organisation	Water Level		Water Quality		Aquifer Geometry		Geophysical
	DW	PZ	DW	PZ	EW/PZ	Depth Range(m)	VES
CGWB	15	9	12	2	80	45 - 750	65
State GW Dept.	39	52	38	39	117	42 - 186	
Total	54	61	50	41	197		65

Disposition of all geological formations, viz., Chintlapudi sandstone, Gollapalli sandstone, Tirupati sandstone, Basalt and Rajahmundry sandstone are clearly noticed in the section prepared across the entire along the direction of SW – NE between Vegavaram-Veldurthi. Tirupati sandstone and Rajahmundry sandstone forms the main formations in the area. Cross sections drawn along different directions of the area are presented as Fig. 8 b to d. The sections reveal that Chintalapudi, Gollapalli, Raghavapuram and Thirupathi formations occupy in the western part of the study area where as in eastern part of the area Thirupathi and Rajahmundry are major formations.

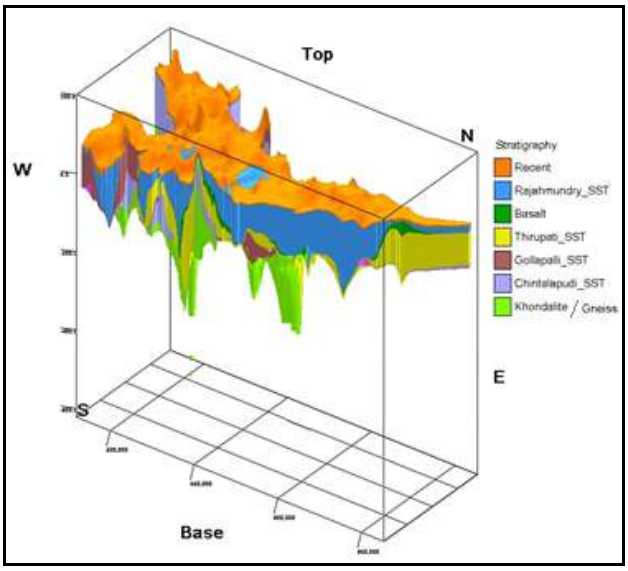

Fig. 8 a 3D Model

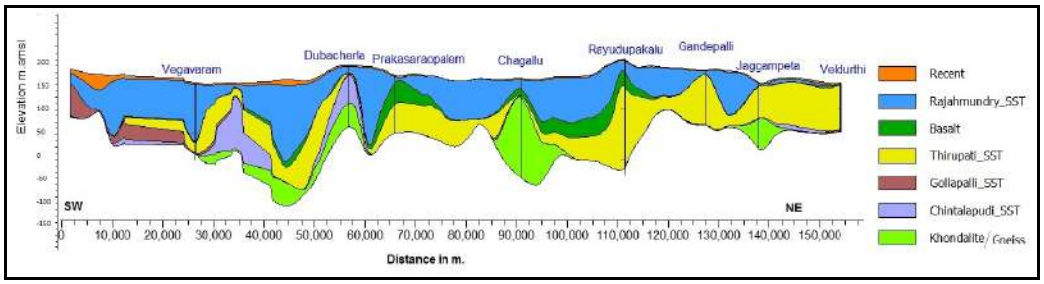

Fig. 8 b Geological Cross Section (NE-SW)

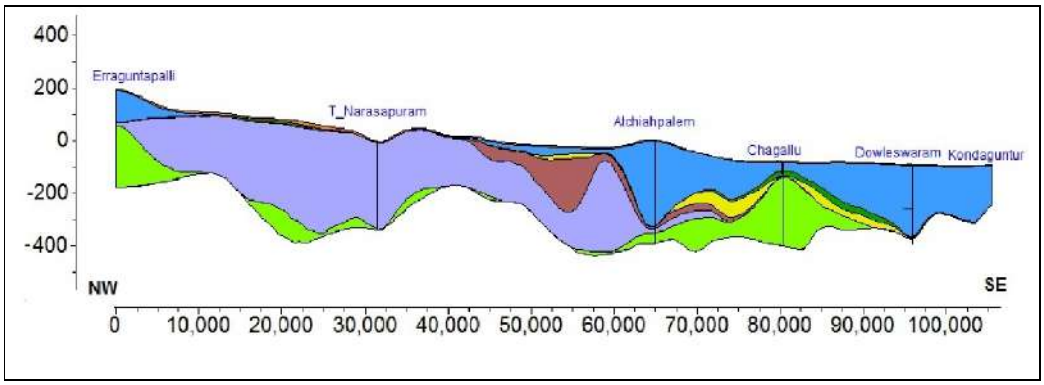

Fig. 8 c Geological Cross Section (NW-SE)

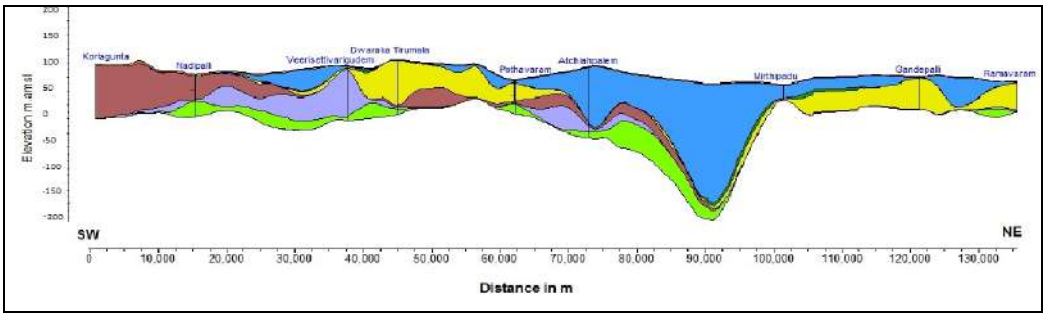

Fig. 8 d Geological Cross Section (NE'-SW')

Hydrogeology :

The area is underlain by multilayered and productive Gondwana and Rajahmundry Sandstones. Gondwana comprising Chintalapudi Sandstones, Gollapalli and Tirupati sandstones form important aquifer systems. These are continous and extensive aquifers but for intervening clays. The maximum thickness of Gondwana formations encountered in the area is upto 600 m.

Hydrogeological cross sections (Fig. 9 a) along NE – SW direction reveals 2 to 6 aquifer presence between Pragadavaram – Kesavaram area. Faults are noticed in between Mudicherla - Vempadu, Vempadu – Tirumalapalem, Tirumalapalem - pulla. Two aquifers are identified at Medicherla, Vempadu. At Tirumalapalem, 3 aquifers are demarcated. At Pulla 6 aquifer are deciphered- one in alluvium and 3 in Rajahmundry formation, and 2 in Tirupati formation.

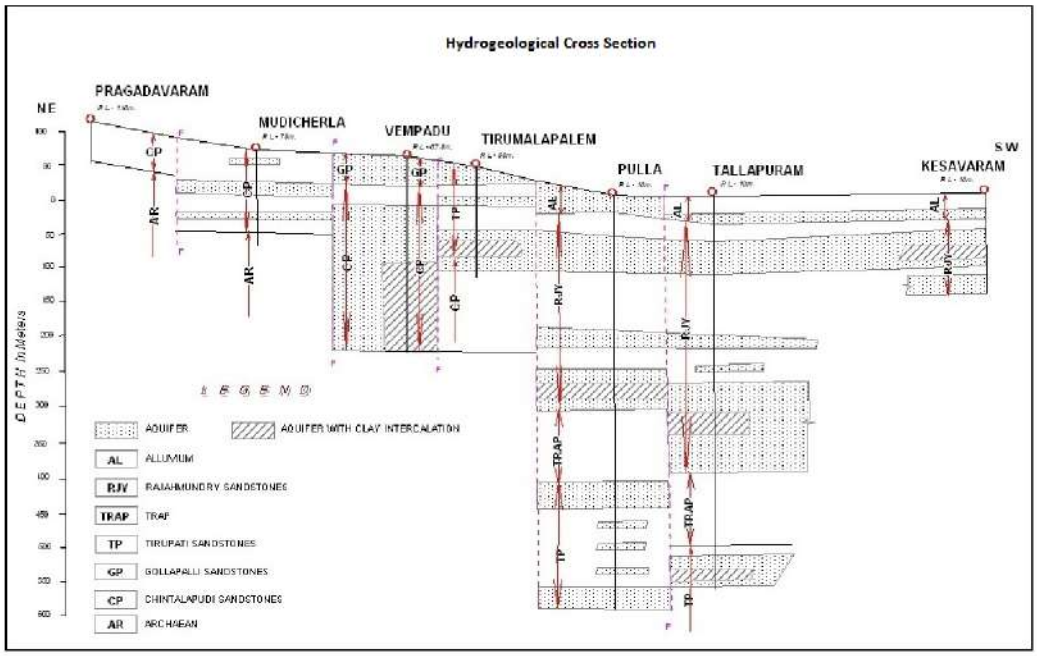

Fig. 9 a Hydrogeological Cross Section (NE – SW)

As many as 6 aquifers were demarcated between Bhimadolu-Gopalapuram section which along SW – NE direction in the central portion of the area (9 b). Archaean crystalline basement encountered at a depth of 170 m at Gopalapuram and the same is absent at Yadavolu suggest the faulting. At Bhimadolu 5 aquifers were identified, at Chinayegnapuram 6 aquifer, at Dubacherla and Nallajerla and only 2 aquifers occurred. The presence of trap at a depth of 132 m at Bhimadolu and at a depth of 21 m at Chinnayagnapuram also suggest faulting. Disposition of various geological formations are also shown in the form of panel diagrams (Fig. 10 a & b).

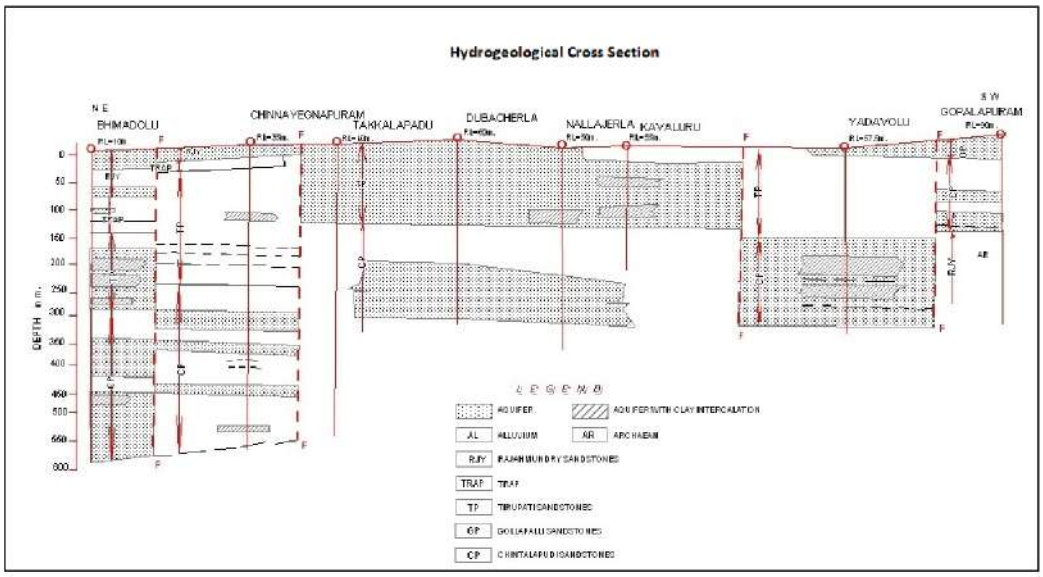

Fig. 9 b Hydrogeological Cross Section (NE' – SW')

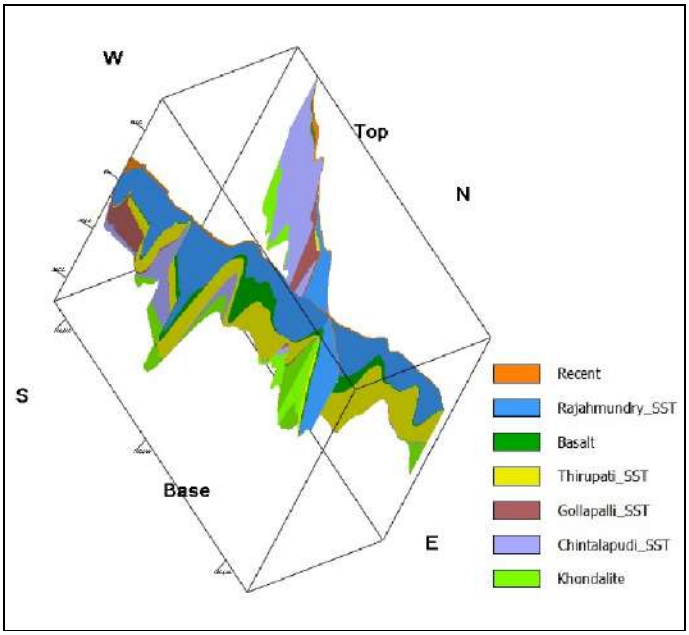

Fig. 10 a Open Fence Diagram

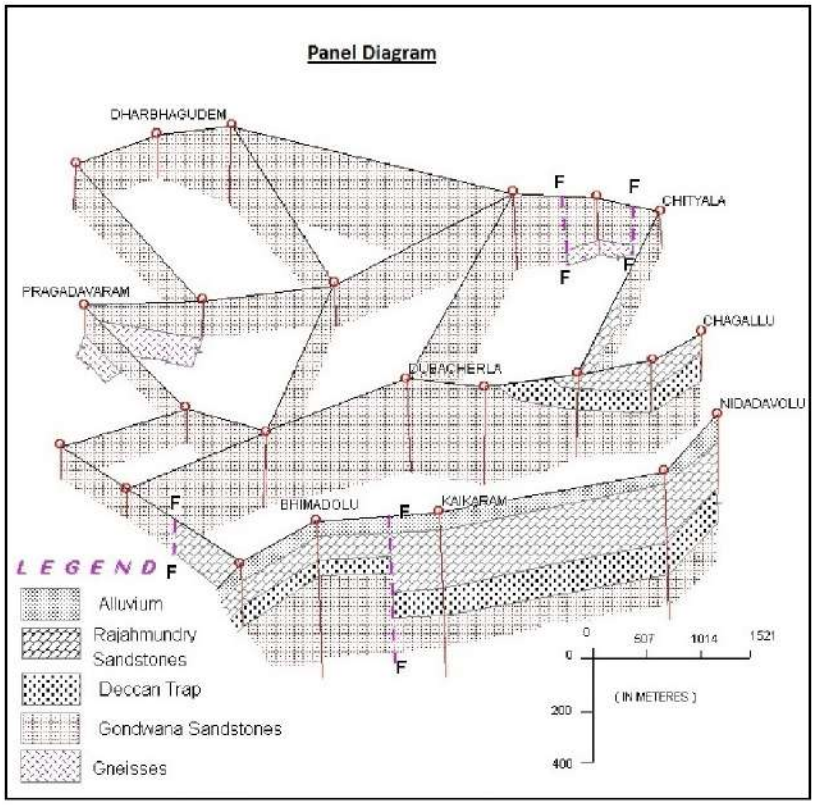

Fig. 10 b Panel Diagram

Aquifer Characteristics :

The Chintalapudi formations are the oldest sedimentary rocks in the area. Ground water occurs in this formation under water table, semi confined to confined conditions. The depth of the wells constructed in this formation range between 60 and 120 m bgl. The yields of the wells vary from 604 to 419 m^3/day for drawdown of < 1 to 23 m. The specific capacity of the wells varies from 20.95 to 530.6 lpm/mdd and the transmissivity of wells varies from 50 to 1465 m^2/day.

In Gollapalli formations ground water occurs under unconfined, semi-confined to confined conditions. The depth of the wells ranges between 84 and 169 bgl with a maximum discharge of 2419 m^3/day. However, tube wells in the depth range of 75 -120m bgl are common in this formation. The yields vary between 691 and 1382 m^3/day. The specific capacity of the wells is of the order of 20 to 389 lpm/m/dd and the transmissivity of this formation ranges between 247 and 1055 m^2/day. The associated Raghavapuram shales are poor aquifers.

In Thirupati formations ground water occurs under water table to confined conditions. However in southern part, these formations occur beneath Deccan trap formation where the ground water occurs under confined conditions and free flow conditions also occur. The depth of the wells constructed in this formation range between 99 and 300 m bgl. The yields of the wells vary from 155 to 345 m^3/day with a maximum yield of 3888 m^3/day. The specific capacity of the wells varies from 35 to 328 lpm/m/dd and transmissivity of formation varies between 76 and 846 m^2/day.

Deccan traps are restricted to small area in the central part of the study area. They are generally massive and the yield from this formation is low.

Rajahmundry formations occupy major portion in the eastern part of the study area. The thickness of this formation in the area recorded upto 390 m bellow which Deccan traps occur. The number of main aquifers varies from one to three. Ground water occurs under unconfined to confined conditions. The discharge of the wells constructed in these formations generally varies from 1200 to 3000 m3/day transmissivity varies between 395 and 3168 m^2/day. The summarized details of parameters formationwise are given in table – 2.

The interpretation of the available hydrogeological data indicates that there are multi aquifers (2 to 3 aquifers) in the sandstone formations of the area with intervening clay/shale beds. The first aquifer is unconfined where as the other aquifers are semi-confined/confined.

Table – 2 Formationwise Aquifer Parameters

Formation	Max. Thickness	Q (lps)	T (m2/day)
Rajahmundry Sandstone	692	15 - 35	395 - 3168
Thirupati Sandstone	224	4 - 18	76 - 846
Gollapalli Sandstone	71	8 - 16	247 - 1055
Chintalapudi Sandstone	107	7 - 28	50 - 1465

Ground Water Levels

The water levels behaviour was studied in the ground water regime of the area based on the pre-monsoon and post-monsoon water level data of observation wells maintained by CGWB and State Ground Water Department and the fluctuation of depth to water level for the pre-monsoon and post- monsoon is determined. The data set was used for preparing maps of pre-monsoon depth to water level, post monsoon depth to water level and fluctuation.

Depth to Water Level:

The depth to water level in the shallow aquifer during pre-monsoon (2015) is ranges from < 1 m bgl to a maximum of 12 m bgl. The average water level of the area is 4.50 m bgl. Pre-monsoon depth to water level map reveals that mostly the water levels in the western part of the area ranges inbetween 5 and 10 m bgl, whereas in the central and eastern part of the area it ranges inbetween 2 and 5 mbgl (Fig. 11). The depth to water level during post-monsoon (2015) ranges from <1 m bgl to a maximum of 9 m bgl. The average water level of the area is 3.00 m bgl. Post-monsoon depth to water level map reveals that mostly the water levels in the eastern part of the area is about 3 m bgl, whereas in the western part of the area is in the range of 3 to 5 m bgl except in Jangareddygudem and Nuzvidu areas, where it ranges inbetween 5 and 10 m bgl (Fig. 12).

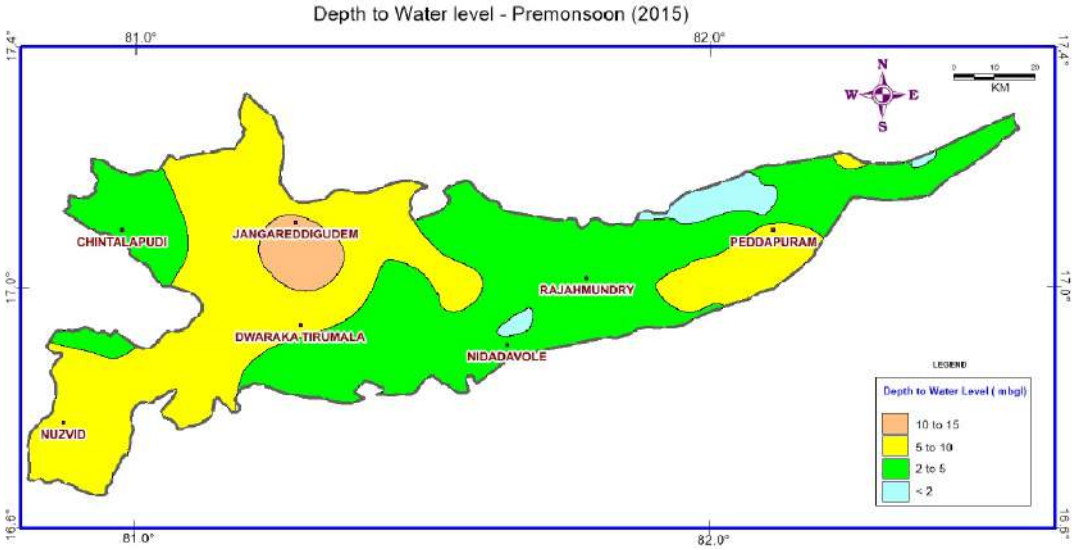

Fig. 11 : Depth to Water Level - Pre-Monsoon (2015)

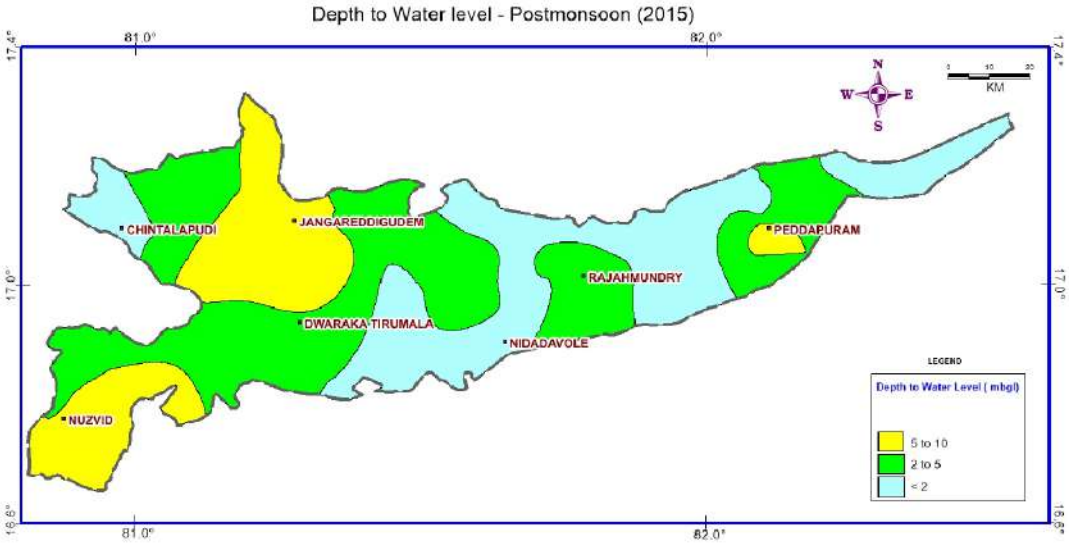

Fig. 12 : Depth to Water Level - Post-Monsoon (2015)

The water table elevation ranges between < 20 m amsl in central & southern part of the area and >120 m amsl in the north western and western part of the area. The general ground water flow direction is towards southeast (Fig. 12).

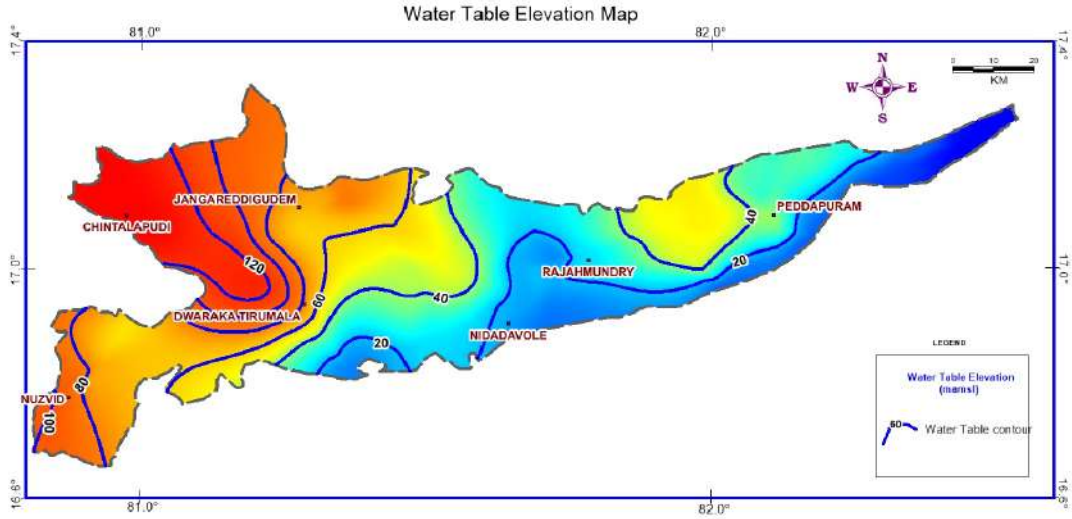

Fig. 13 Water Table Elevation Map

The piezometric head in the deeper aquifers during pre-monsoon (2015) is ranges from 4 m bgl to a maximum of 74 m bgl. In Majority of the area piezometric head is > 20 m. The average piezometric head of the area is 29 m bgl. Pre-monsoon piezometric head map

reveals that mostly heads are more than 20 m bgl except in south eastern, central, north western and south western parts of the area. Maximum piezometric heads (> 50 m bgl) recorded at NE of Rajahmundry, in eastern part of the study area at Dwaraka Tirumala and NE of Nuzivedu area. (Fig. 14). Similar magnitude is observed during post monsoon period (Fig. 15).

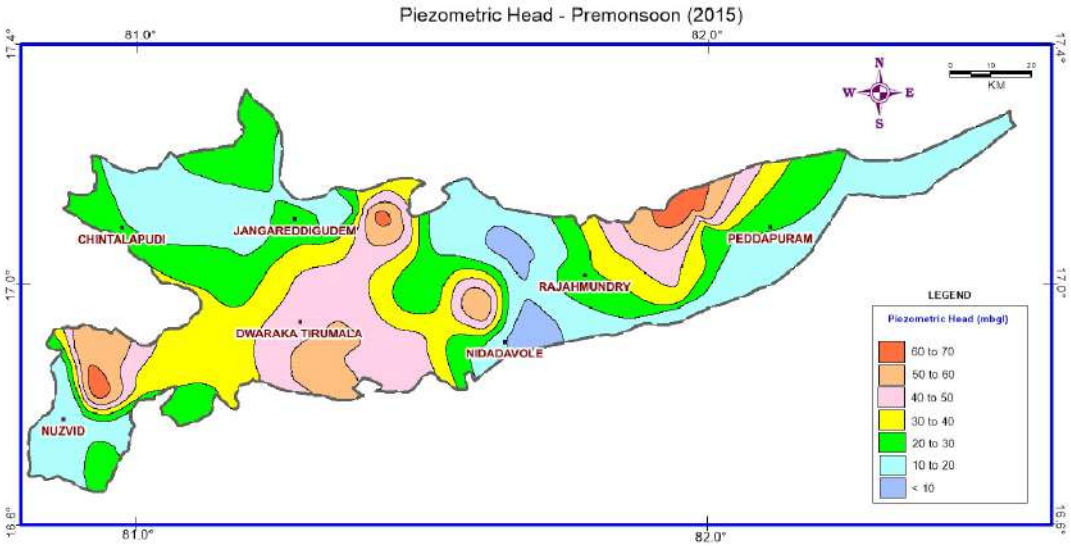

Fig. 14 : Pre Monsoon – Piezometric Head (2015)

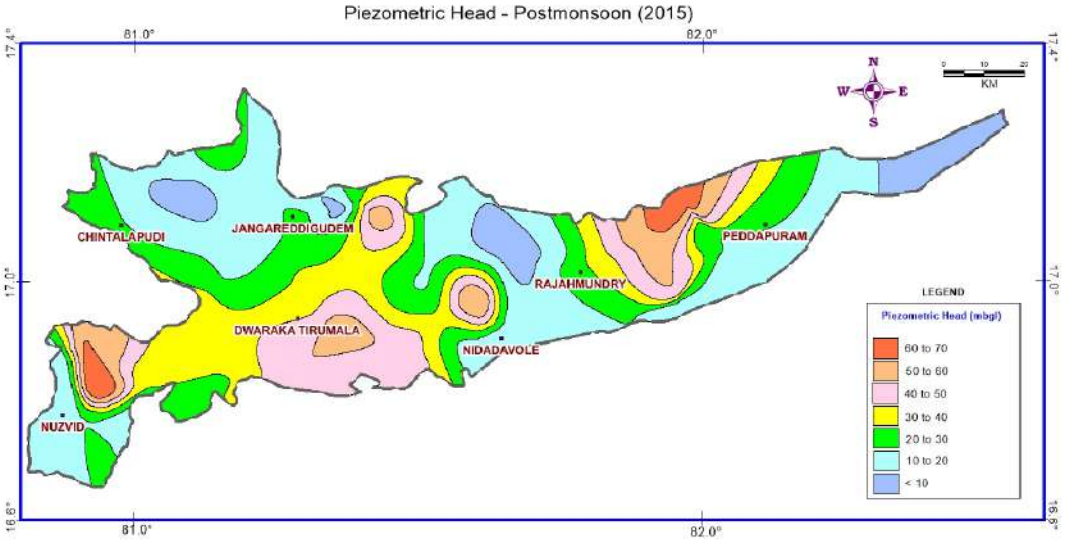

Fig. 15 : Post Monsoon – Piezometric Head (2015)

Water Level Fluctuation

The water level fluctuation in shallow aquifers between pre-monsoon and post-monsoon water levels i.e., May and December, 2015 ranges in between < 1 and 4 m. The fluctuation map reveals that the entire area shows rise of about 2 m in water level (Fig. 16).

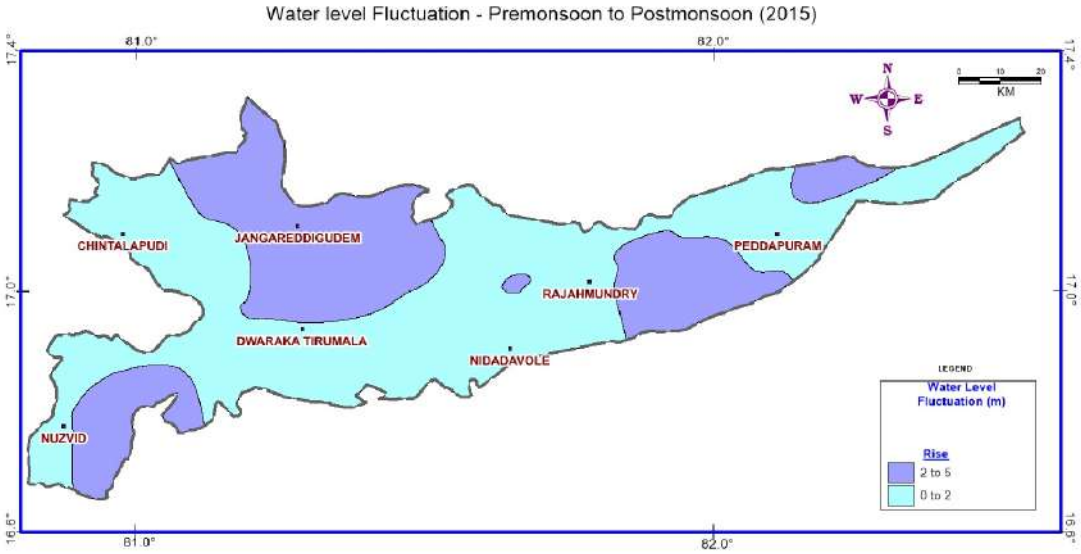

Fig. 16 Shallow Aquifer - Water Level Fluctuation (Pre monsoon to Post monsoon, 2015)

The piezometric head fluctuation in deeper aquifers between pre-monsoon and post-monsoon ranges in between -9 m and 9 m. The fluctuation map reveals that the major portion of the area shows rise in the range of 2 to 10 m, except as patches in between Dwaraka Thirumala and Peddapuram, and at Nuzivedu area where decline in the range of 2 to 5 m exist (Fig. 17).

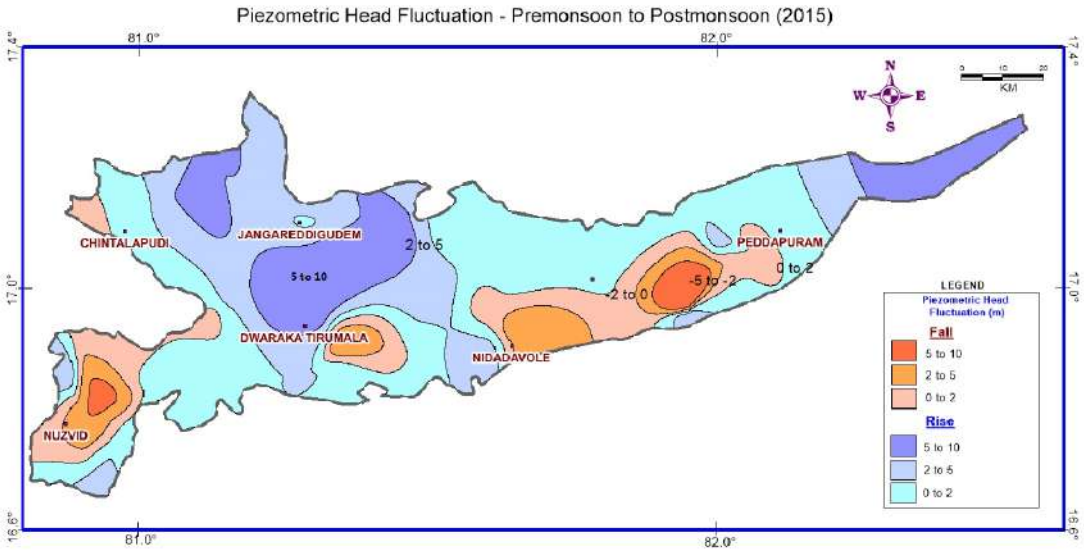

Fig. 17 Deeper Aquifer - Piezometric Head Fluctuation (Pre monsoon to Post monsoon, 2015)

The analysis of long term water level data indicates that the water levels in general stable except in Bapulapadu, Lingapalem and Nuzividu areas where decline trends are observed, where as declining trend is prominent in piezometric heads.

Ground Water Quality:

In order to understand the quality of ground water in the area the chemical data of the ground water samples collected during pre monsoon period from monitoring stations of both shallow and deeper aquifers is studied.

Classification of Ground Water:

The analytical data of water samples were plotted on Piper's Trilinear diagram and on modified piper diagram for Geochemical classification of waters. From the figures it is evident that the ground water is Na K – Cl HCO_3 (Fig. 18). It is observed from the data that not much variation observed chemically in between shallow and deeper aquifers.

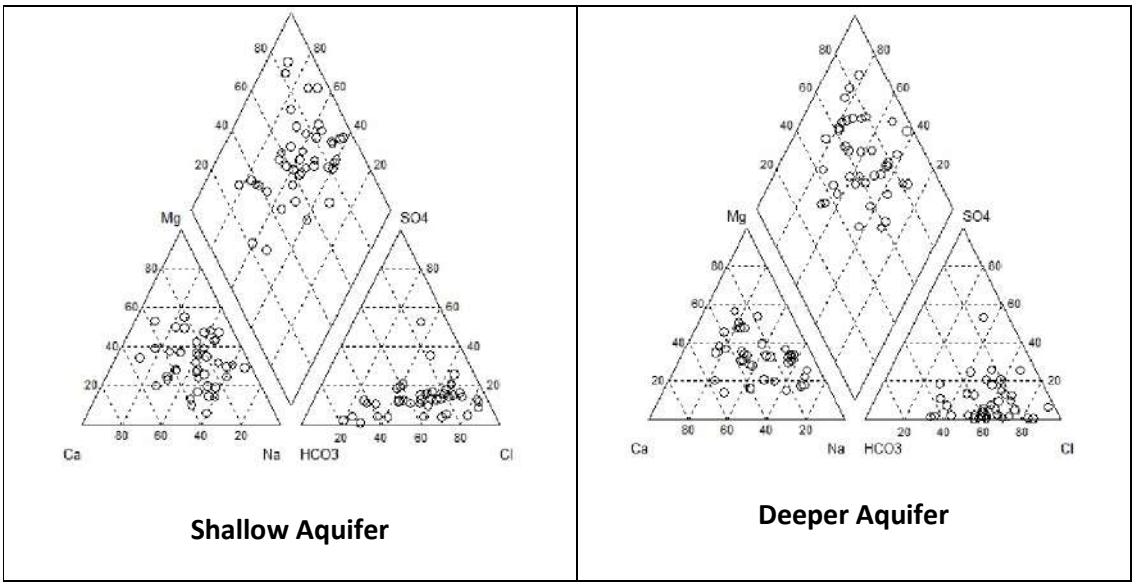

Fig. 18 Classification of Water - Piper's diagram

Suitability of Ground Water :

It is observed from the data that not much variation observed chemically in between shallow and deeper aquifers. However, comparatively water from deeper aquifers is slightly superior than shallow aquifers. The pH values of ground water in the study area are ranging in general between 7.41 and 8.99 indicating that water is alkaline. Electrical Conductivity distribution map for pre-monsoon period was prepared for the study area and presented as Fig. 19 & 20. The EC distribution map reveals that in major portion of the area EC is < 1500 micro siemens/cm at 25°C. The Chloride distribution map for pre-monsoon period was prepared and presented as Fig. 21 & 22. The chloride map reveals that in major portion of the study area Cl is less than 250 ppm. No other problem pertains to quality of ground water in the area is recorded.

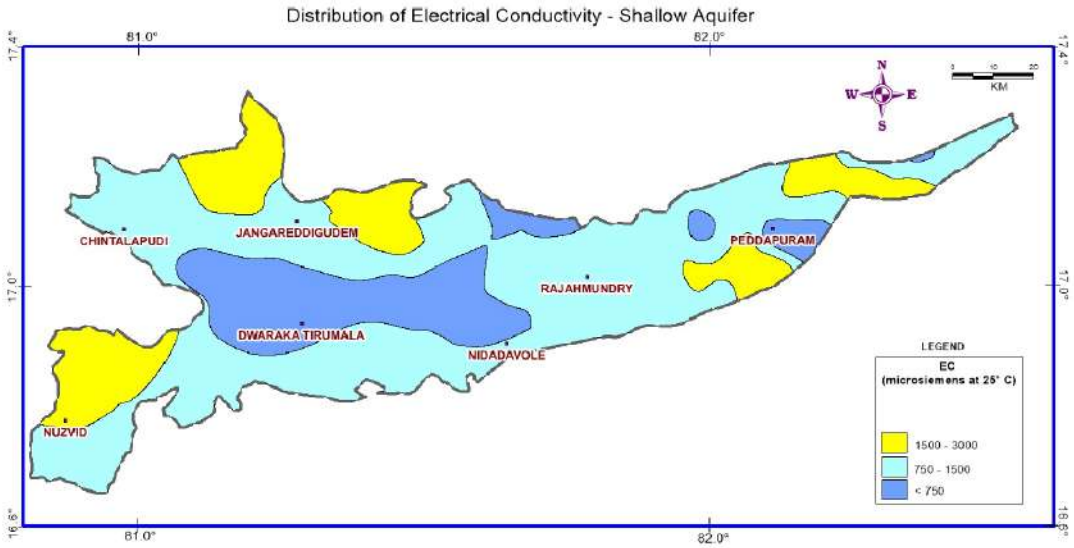

Fig. 19 Distribution of Electrical Conductivity in Shallow Aquifers

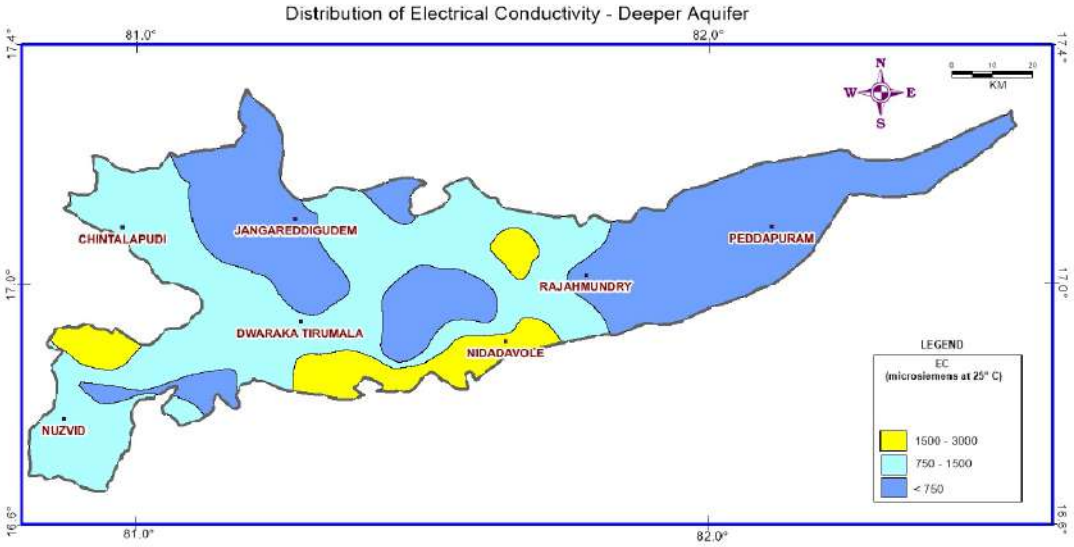

Fig. 20 Distribution of Electrical Conductivity in Deeper Aquifers

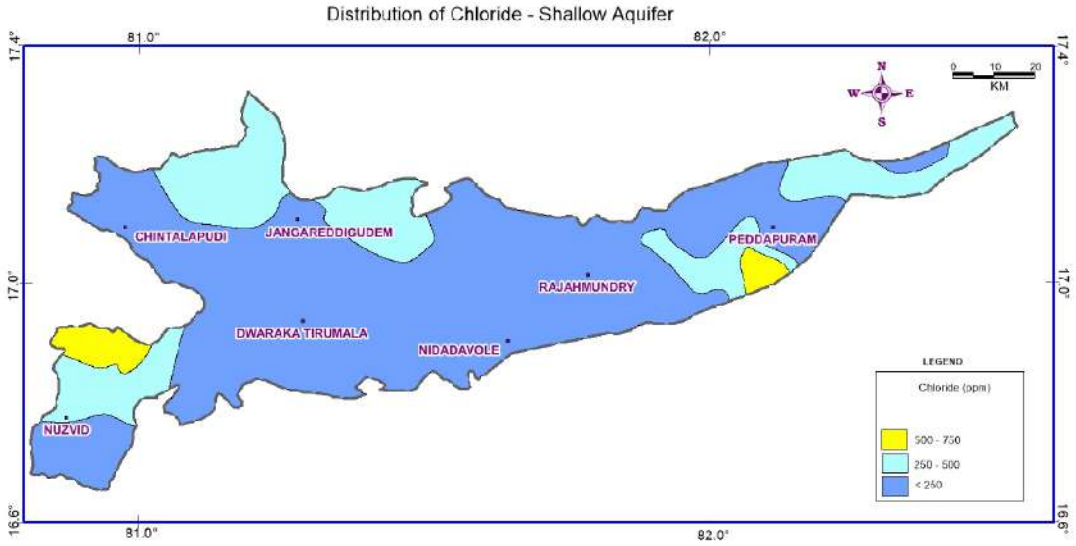

Fig. 21 Distribution of Chloride in Shallow Aquifers

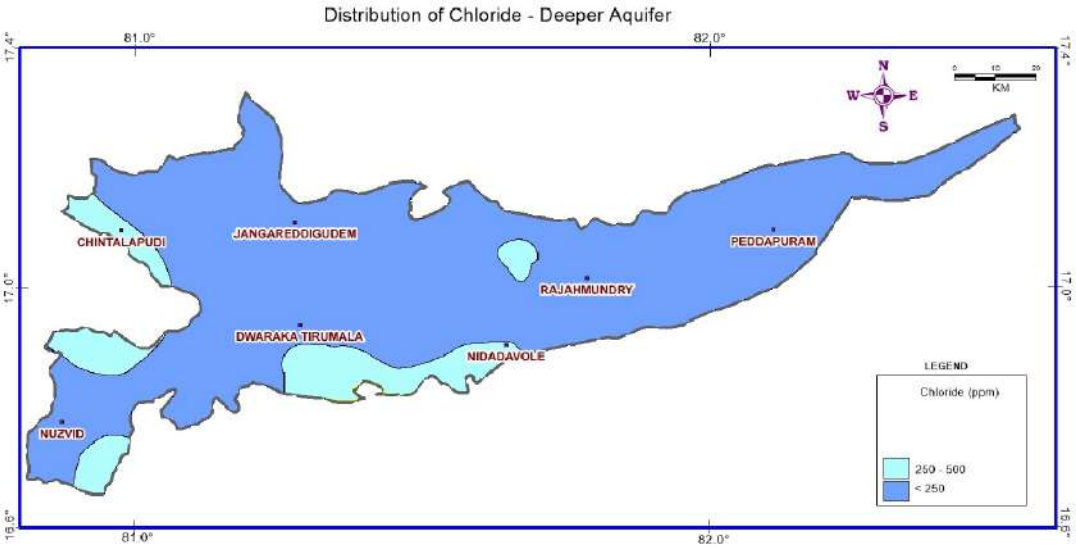

Fig. 22 Distribution of Chloride in Deeper Aquifers

Suitability for domestic Purpose :

Suitability of ground water from shallow and deeper aquifers of the study area for domestic purpose is examined on the basis of norms of Indian Standards for drinking water. The average concentration and variation of different chemical constituents present in ground water of study area along with the specifications of drinking water are presented in Table 3. The suitability of ground water for drinking purpose is examined based on the

quality standards recommended by WHO/ BSI. In general, the quality of ground in the area is potable.

Table – 3 : Ranges of Different Chemical Constituents and Drinking Suitability

Constituent	Shallow Aquifer			Deeper Aquifer			BSI Standards	
	Min	Max	Avg.	Min	Max	Avg.	Desirable Limit	Max. Permissible Limit
pH	7.41	8.78	8.25	7.78	8.82	8.29	6.5	8.5
EC	325	2750	1198	269	2730	925	750	3000
TH	120	720	319	70	680	255	300	600
Ca	8	176	57	16	104	42	75	200
Mg	5	107	43	5	112	36	30	100
Na	16	337	108	18	396	95		
K	1	424	65	1	157	22		
CO_3	< 1	160	20	< 1	60	16		
HCO_3	20	370	166	40	380	130		
Cl	29	764	214	30	880	162	250	1000
SO_4	1	236	72	1	256	43	200	400
NO_3 #	5	95					45	100
F #	0.9	1.3					1	1.5

 # Data is sparse

Suitability for Irrigation Purpose

In the study area majority of the water samples are varying from medium salinity - low Sodium hazard (C2S1) to high Salinity - low Sodium hazard (C3S1). High Salinity and low sodium hazard water may be used for irrigating salt tolerant crops with adequate drainage system and with special amendments like applying gypsum and organic matter.

GROUND WATER RESOURCES :

The ground water recharge worthy area is 4674 km^2. The Net annual ground water availability in the area is 940 MCM. The gross ground water draft for all uses in the area is 545 MCM. Net ground water availability for future irrigation use is 361 MCM. The stage of ground water development in the area is 58%, it varies from <20% to 140% (Musunuru mandal of Krishna district). The details of the ground water resources (dynamic) of the area are given in table – 4. The entire area is categorised as safe except the areas of Musunuru (OE) & Nuzividu (SC) of Krishna district, Lingapalem (SC) of West Godavari district and Gandepalli (SC) of East Godavari district (Fig. 23 & Table-5).

In-storage ground water resources down to the depth of 200m in the area are estimated to be 12,110 MCM, formationwise details are given in table – 4. The first approximation reveals that the lateral ground water flow from the aquifers is 367 MCM (Table-6).

Table – 4 Summarised Ground Water Resources of the Study Area

Recharge (MCM) : Monsoon recharge from rainfall = 457 Non-monsoon recharge from other sources = 219 Non-Monsoon recharge from rainfall = 197 Non-monsoon recharge from other sources = 156	
Net annual ground water availability (MCM)	940
Existing gross ground water draft for all uses (MCM)	545
Provision for domestic and industrial requirement supply to 2025 (MCM)	64
Net ground water availability for future irrigation development (MCM)	361
Stage of groundwater development (%)	58
Category	Safe
Unit Recharge (m)	0.20

In-storage ground water resources (MCM) Rajahmundry Formation = ~ 5692 Tirupati Formation = ~ 3875 Gollapalli Formation = ~ 727 Chintalapudi Formation = ~ 1817 Total	12,110
Lateral ground water flow (MCM)	367

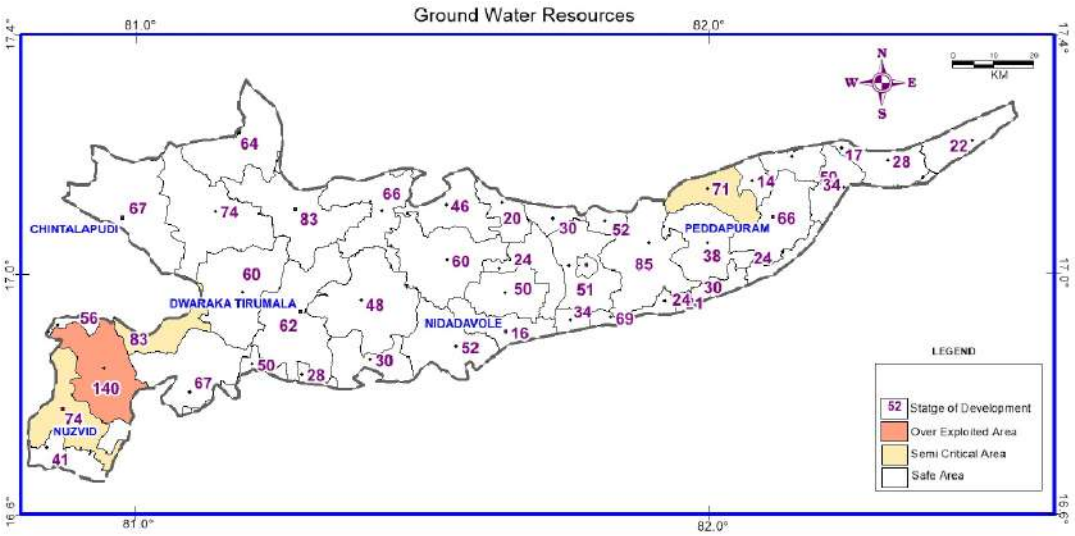

Fig. 23 Ground Water Resources of the Study Area

Table – 5 Ground Water Resources (Dynamic)

District	Mandal/ Block	GW Recharge Worthy Area (sq.km)	Net annual ground water availa-bility (MCM)	Existing gross ground water draft for all uses (MCM)	Provision for domestic and industrial requirement supply to 2025	Net ground water availability for future irrigation develop-ment(MCM)	Stage of groundwater develop-ment (%)	Category	Unit Recharge (m)
Krishna	Agiripalli	31.37	5.68	2.35	0.21	3.52	41	Safe	0.18
Krishna	Chatrai	16.71	2.62	1.46	0.20	1.16	56	Safe	0.16
Krishna	Musunuru	186.28	28.87	40.46	2.21	0.00	140	**O.E**	0.15
Krishna	Nuzvid	143.09	24.87	18.29	2.76	5.75	74	**S.C**	0.17
Krishna	Vissannapeta	4.03	0.70	0.35	0.07	0.34	51	Safe	0.17
East Godavari	Anaparthi	10.29	3.87	0.80	0.22	3.02	21	Safe	0.38
East Godavari	Biccavole	35.02	12.89	3.85	0.70	9.03	30	Safe	0.37
East Godavari	Gandepalli	99.90	19.45	13.83	1.10	5.01	71	**SC**	0.19
East Godavari	Gollaprolu	79.29	16.39	4.63	1.85	10.42	28	Safe	0.21
East Godavari	Jaggampet	35.62	6.18	0.85	0.55	4.92	14	Safe	0.17
East Godavari	Kadiam	14.86	5.49	3.77	0.36	1.45	69	Safe	0.37
East Godavari	Kirlampudi	55.07	11.07	5.51	1.60	4.44	50	Safe	0.20

East Godavari	Korukonda	30.22	5.89	3.04	0.42	2.66	52	Safe	0.19
East Godavari	Mandapet	19.78	8.13	1.98	0.57	5.73	24	Safe	0.41
East Godavari	Peddapuram	146.36	29.03	19.06	4.26	6.85	66	Safe	0.20
East Godavari	Pithapuram	75.25	14.85	5.10	2.58	7.75	34	Safe	0.20
East Godavari	Prathipadu	5.46	1.10	0.19	0.09	0.86	17	Safe	0.20
East Godavari	Rajahmundry	102.51	19.85	10.13	12.14	-0.87	51	Safe	0.19
East Godavari	Rajanagaram	213.82	44.48	37.81	2.30	5.56	85	Safe	0.21
East Godavari	Rangampet	145.75	31.04	11.80	1.46	18.91	38	Safe	0.21
East Godavari	Samalkota	35.61	6.97	1.66	1.28	4.30	24	Safe	0.20
East Godavari	Sithanagaram	35.98	7.56	2.25	0.59	4.94	30	Safe	0.21
East Godavari	Thondangi	86.89	15.79	3.47	1.55	11.07	22	Safe	0.18
East Godavari	U.Kothapalli	4.47	0.91	0.02	0.11	0.78	3	Safe	0.20
East Godavari	Atreyapuram	24.37	10.87	3.67	0.46	7.10	34	Safe	0.45
West godavari	Chintalapudi	238.01	46.14	31.09	0.85	14.32	67	Safe	0.19
West godavari	Bhimadole	21.65	3.92	1.10	0.14	2.76	28	Safe	0.18
West godavari	Buttayagudem	8.02	1.34	0.38	0.02	0.95	28	Safe	0.17
West godavari	Chagallu	109.29	30.68	15.33	1.17	14.44	50	Safe	0.28
West godavari	Devarapalli	210.31	42.95	25.71	0.82	16.63	60	Safe	0.20
West godavari	Denduluru	24.20	4.15	2.07	0.12	2.00	50	Safe	0.17
West godavari	Dwarakatirumala	265.50	49.95	31.12	5.99	13.03	62	Safe	0.19
West godavari	Gopalapuram	116.04	17.66	8.12	1.26	8.28	46	Safe	0.15
West godavari	Jangareddigudem	204.68	42.95	35.71	0.36	6.88	83	Safe	0.21
West godavari	Jeelugumilli	149.28	27.10	17.46	0.64	9.06	64	Safe	0.18
West godavari	Kamavarapukota	203.66	35.67	21.39	0.56	13.90	60	Safe	0.18
West godavari	Kovvuru	105.89	37.30	8.81	0.28	28.24	24	Safe	0.35
West godavari	Koyyalagudem	148.68	25.91	17.13	1.33	7.91	66	Safe	0.17
West godavari	Lingapalem	74.76	16.97	14.07	0.41	2.54	83	**SC**	0.23
West godavari	Nallajerla	245.70	48.61	23.12	5.54	20.11	48	Safe	0.20
West godavari	Nidadavole	82.44	18.14	2.98	0.35	15.08	16	Safe	0.22
West godavari	Pedavegi	181.62	33.01	22.20	1.37	9.58	67	Safe	0.18
West godavari	T. Narasapuram	353.86	63.25	47.03	0.89	15.95	74	Safe	0.18
West godavari	Tadepalligudem	143.87	29.45	15.40	1.52	12.66	52	Safe	0.20
West godavari	Tallapudi	53.63	9.33	1.85	0.15	7.34	20	Safe	0.17
West godavari	Unguturu	95.40	20.68	6.16	0.40	14.26	30	Safe	0.22
	Total	**4674.49**	**939.71**	**544.55**	**63.81**	**360.61**	**58**	**Safe**	**0.20**

Table – 6 Lateral Ground Water Flow from the Aquifers

S. No.	Section	Transmissivity (m2/ day)	Piezometric Contour value in up gradient point (mamsl)	Piezometric Contour value in down gradient point (mamsl)	dh (Col. 4 - Col. 5) (m)	dl (Average distance bet' 2 contours) (m)	I=dh/dl (Hydraulic grdient) (Col. 6 / Col. 7)	Average length of Aquifer along equipotential line (m) 'L'	Quantum of ground water discharged from the area (Col. 3 * Col. 8 * Col. 9) (CUM/day)
1	2	3	4	5	6	7	8	9	10
	Premonsoon								
1	Section - 1	1000	100	0	100	30700	0.00326	160000	521600
2	Section - 2	1000	60	0	60	9900	0.00606	78000	472680
	Total								994280
	Postmonsoon								
3	Section- I	1000	120	0	120	38940	0.00308	160000	492800
4	Section-2	1000	60	0	60	8700	0.0069	78000	538200
	Total								1031000

Say 367 MCM / yr

GROUND WATER RELATED ISSUES :

The major considerable ground water issue in the area is water level depletion. Due to increased ground water development in the area, there is depletion of piezometric heads and to some extent water table. An analysis of hydrographs of the ground water monitoring wells indicated falling trends of piezometric heads and deepest piezometric head in the area is 74 m. Hydrograph of Gandepalli station is presented as Fig. 24 a, where both shallow and deeper aquifers having different heads. The hydrographs of other selected stations are presented as Fig. 24 b to e. The depletion of piezometric heads is also reflected by the fact that free flow of wells has virtually stopped in wells due to excessive ground water draft from the deeper aquifers of the area. The reason for depletion of piezometric head is may be due to increase in cultivation water consuming crops by ground water mainly by tube well irrigation even during Rabi season (Fig. 24a & b). In addition to the above reduction in well yields in last few years are reported in the NW part of the area.

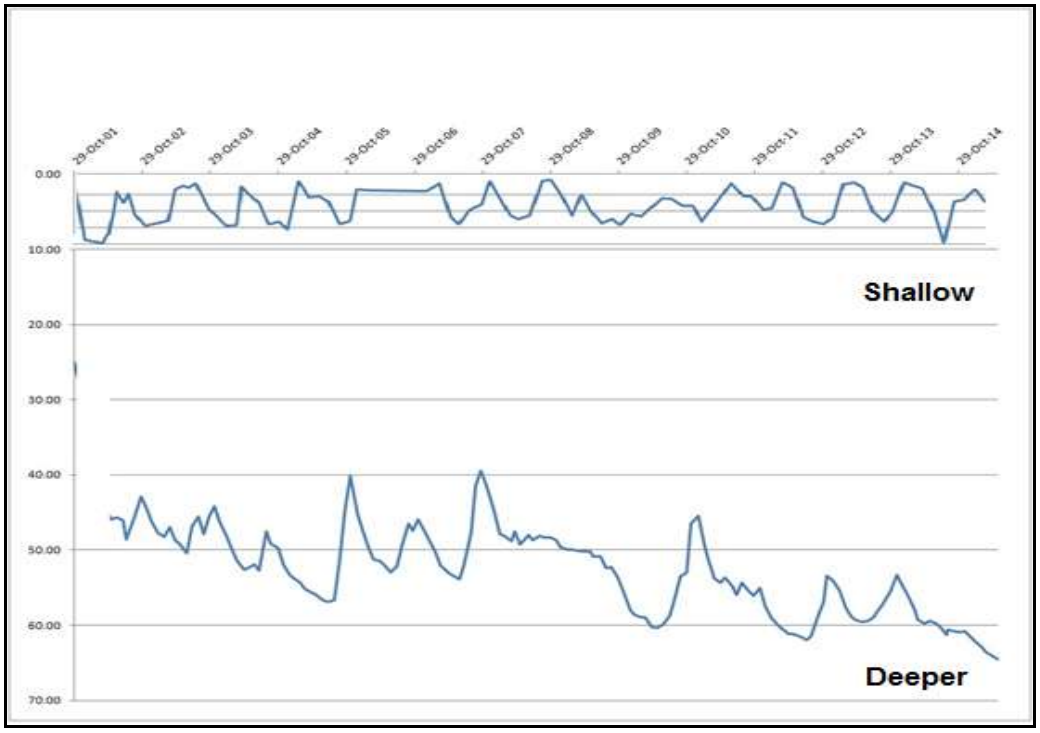

Fig. 24 a Hydrographs of Ground Water Monitoring Stations at Gandepalli
(Shallow Aquifer & Deeper Aquifer)

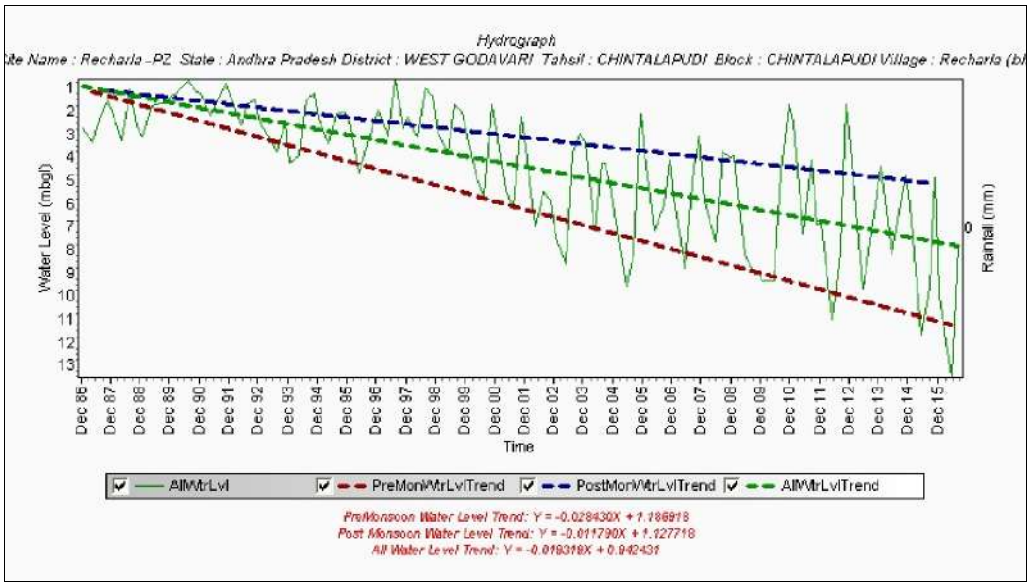

Fig. 24 b Hydrograph of Ground Water Monitoring Station (PZ) at Recharla
(Deeper Aquifer)

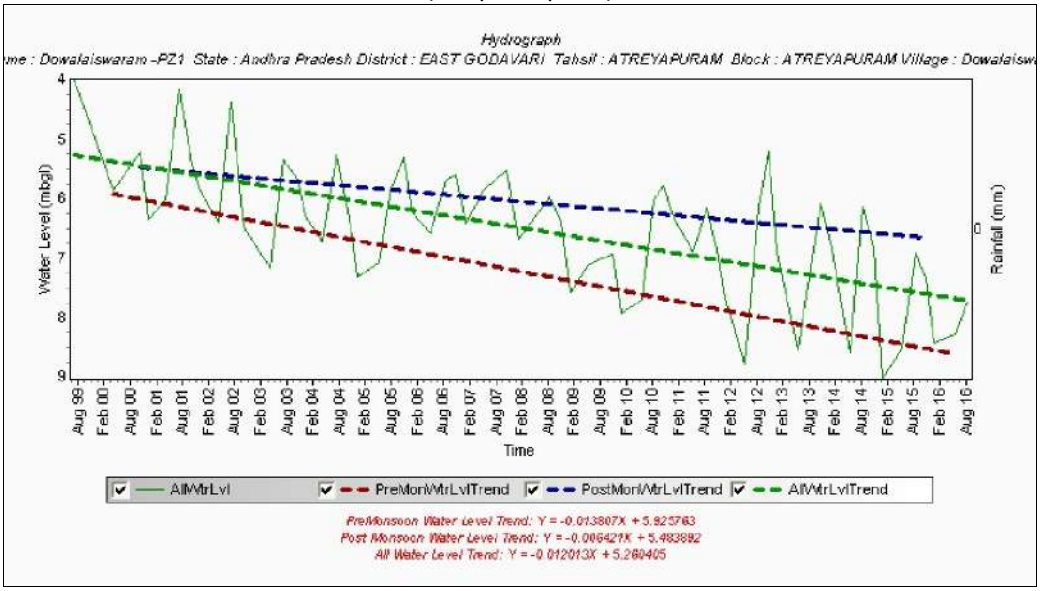

Fig. 24 c Hydrograph of Ground Water Monitoring Station (PZ) at Dawaleswaram
(Deeper Aquifer)

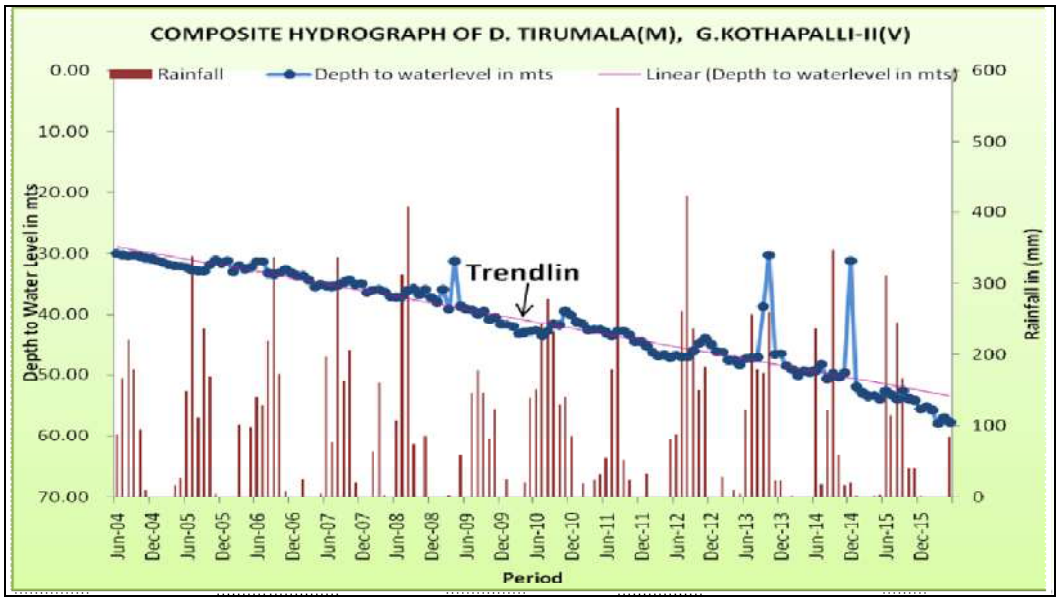

Fig. 24 d Hydrograph of Ground Water Monitoring Station (PZ) at G.Kothapalli

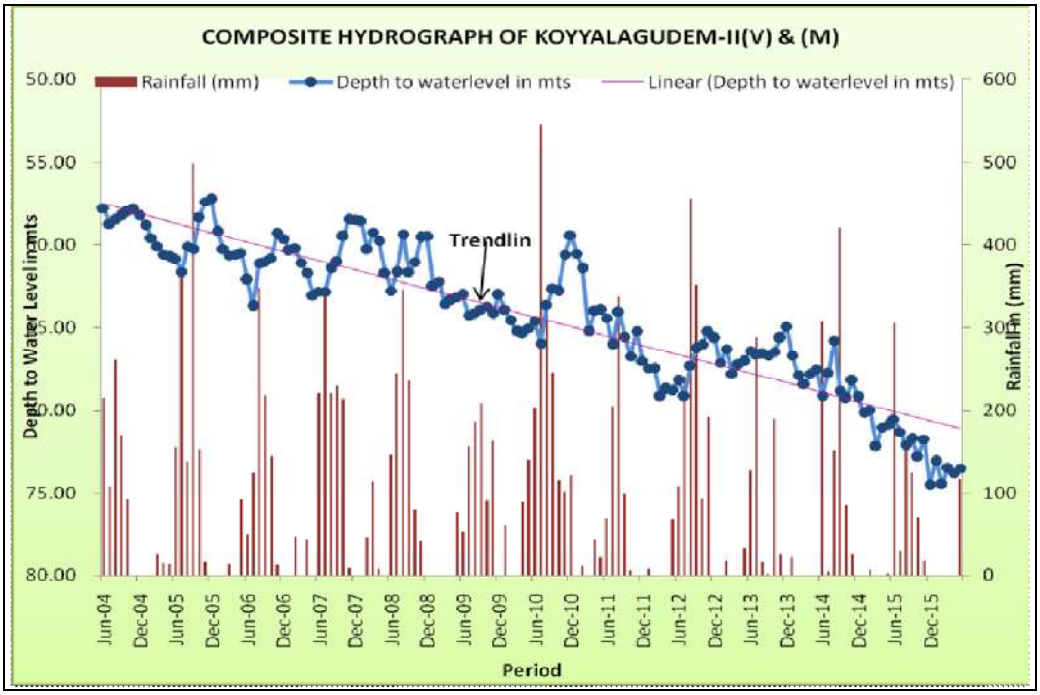

Fig. 24 e Hydrograph of Ground Water Monitoring Station (PZ) at Koyyalagudem

Fig. 25 a Variation in Paddy Cultivation

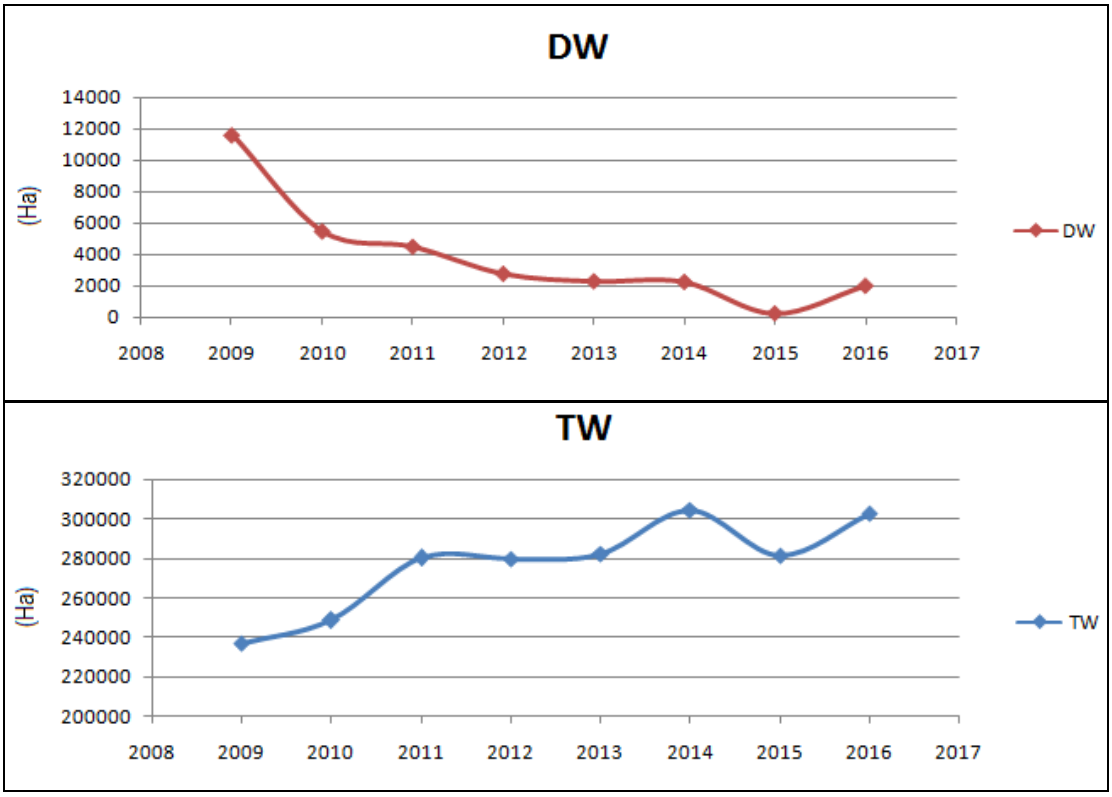

Fig. 25 b Variation in Irrigation by DW and TW

MANAGEMENT STRATEGIES

Aquifer Management Strategy:

Ground water is the main source of both for drinking and irrigation requirements. The main source of recharge in the area is precipitation. Therefore, it is essential that every drop of water fallen on the ground is to be properly utilized for better management. With this view a number of recharge structures proposed in the study area where water levels are deep and depleting.

The areas where intense ground water development, reduction in yields, DTW and piezometric heads considered in identifying the area for artificial recharge. An area of 4,040 km^2 and 1,860 km^2 is considered for ground water management by way of recharging shallow and deeper aquifers respectively (Fig. 26 & 27).

In shallow and deeper aquifers available sub-surface space volume is 325 MCM and 978 MCM respectively. Mandal wise available volume of sub-surface space is given in table - 7.

Table - 7 Volume of Sub-surface Storage Space Available for Artificial Recharge

S.No	District	Mandal	Sub-surface Space (MCM)		
			Shallow Aquifer	Deeper Aquifer	Total
1	East Godavari	Anaparthi	0.00	0.00	0.00
2	East Godavari	Atreyapuram	1.22	0.00	1.22
3	East Godavari	Biccavole	0.00	0.00	0.00
4	East Godavari	Gandepalli	0.00	73.43	73.43
5	East Godavari	Gollaprolu	0.00	0.00	0.00
6	East Godavari	Jaggampet	1.78	10.69	12.47
7	East Godavari	Kadiam	0.00	0.00	0.00
8	East Godavari	Kirlampudi	2.75	8.26	11.01
9	East Godavari	Korukonda	0.00	6.80	6.80
10	East Godavari	Mandapet	0.00	0.00	0.00
11	East Godavari	Peddapuram	25.61	6.59	32.20
12	East Godavari	Pithapuram	3.76	0.00	3.76
13	East Godavari	Prathipadu	0.27	0.00	0.27
14	East Godavari	Rajahmundry	5.13	21.53	26.65
15	East Godavari	Rajanagaram	10.69	48.11	58.80
16	East Godavari	Rangampet	0.00	19.68	19.68
17	East Godavari	Samalkota	2.67	0.00	2.67
18	East Godavari	Sithanagaram	0.00	0.00	0.00
19	East Godavari	Thondangi	0.00	0.00	0.00
20	East Godavari	U.Kothapalli	0.00	0.00	0.00
21	Krishna	Agiripalli	5.49	0.00	5.49
22	Krishna	Chatrai	2.92	5.01	7.94

23	Krishna	Musunuru	32.60	89.42	122.01
24	Krishna	Nuzvid	25.04	4.29	29.33
25	Krishna	Vissannapeta	0.20	0.60	0.81
26	West godavari	Bhimadole	1.08	8.12	9.20
27	West godavari	Buttayagudem	0.80	0.00	0.80
28	West godavari	Chagallu	5.46	73.77	79.24
29	West godavari	Chintalapudi	0.00	28.56	28.56
30	West godavari	Denduluru	1.21	7.26	8.47
31	West godavari	Devarapalli	10.52	12.62	23.13
32	West godavari	Dwarakatirumala	19.91	131.42	151.34
33	West godavari	Gopalapuram	2.90	0.00	2.90
34	West godavari	Jangareddigudem	35.82	6.14	41.96
35	West godavari	Jeelugumilli	14.93	15.67	30.60
36	West godavari	Kamavarapukota	35.64	30.55	66.19
37	West godavari	Kovvuru	0.00	0.00	0.00
38	West godavari	Koyyalagudem	7.43	89.21	96.64
39	West godavari	Lingapalem	3.74	16.82	20.56
40	West godavari	Nallajerla	6.14	147.42	153.56
41	West godavari	Nidadavole	0.00	0.00	0.00
42	West godavari	Pedavegi	9.08	43.59	52.67
43	West godavari	T. Narasapuram	45.42	0.00	45.42
44	West godavari	Tadepalligudem	0.00	36.69	36.69
45	West godavari	Tallapudi	0.00	0.00	0.00
46	West godavari	Unguturu	4.77	35.78	40.55
		Total	**325**	**978**	**1303**

To overcome the shallow aquifers problem the following management strategy may be adopted. Almost all the villages in the study area have one or two village tanks. With time, these tanks get silted & hardly any water percolates downward. Also, any excess water coming into the pond goes away as a run off due to limited storage capacity.

It is proposed to take the activity of desilting of existing tanks for effective recharging the shallow aquifers. A total number of 2815 tanks are identified for this activity. It is expected 168 MCM of ground water likely to be recharged with an estimated cost of Rs. 168 Crores (Table-8).

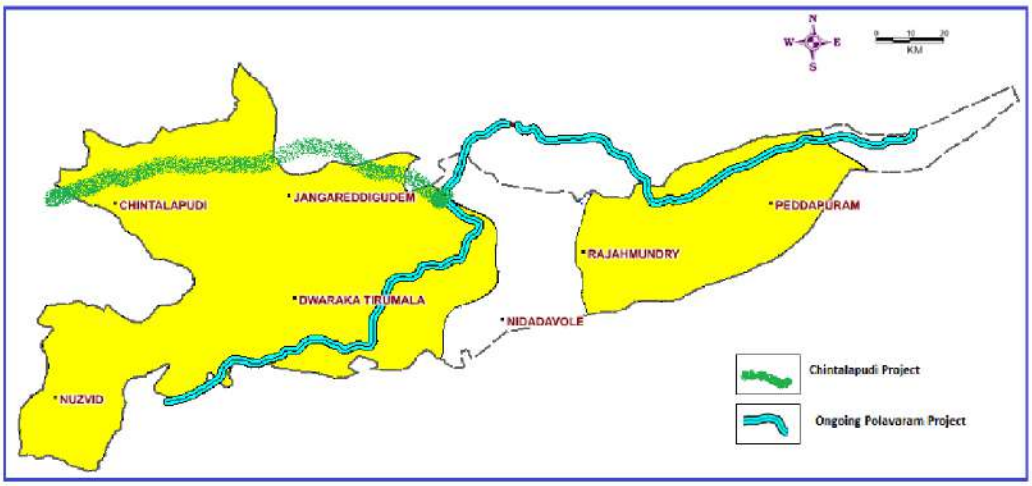

Fig. 26 Area Considered for Artificial Recharge to Shallow Aquifers

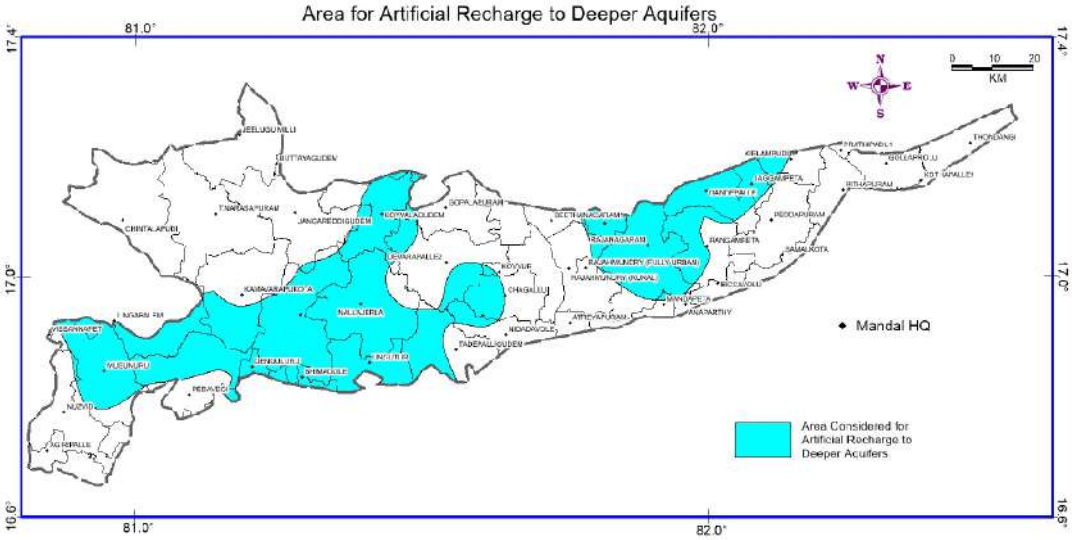

Fig. 27 Area Considered for Artificial Recharge to Deeper Aquifers

After completion of the ongoing Polavaram project the shallow aquifers naturally likely to be charged due to canal network and irrigation activities, hence the present concentration may be given to recharging of deeper aquifers. The recent Pattiseema project activity i.e., lifting of water from river Godavari and transferring to river Krishna through Polavaram right canal, which is at places unlined resulted in rising of water table in aquifers and increase in the yields of wells in the near vicinity of the canal are reported. This may be due to seepage/recharge from the unlined portion of the canal to the ground water.

The most effective ground water structure considered to recharge the deeper aquifers by isolating shallow aquifer is Recharge Shaft/ Recharge well constructed within or in the vicinity of the existing tank.

It is proposed to construct 'Recharge Shafts' for recharging the deeper aquifers where piezometric heads are more than 20 to 30 m bgl. The recharge well has to be designed in a manner that maximum surplus water would likely to be utilized for recharge as well as sufficient water is retained in the pond for local use. The major features of the recharge shaft are:

- The well should have sufficient diameter for recharge 10 to 12 inch diameter well with top and bottom screen, top opening.
- The well should have screen/ opening at the top, which should be at least 1.5m above the bed level of the pond.
- The upper opening should be surrounded with filter pack comprising graded filter media of medium, coarse sand & gravel, so that the Recharge well does not get silted.

The opening for inflow to the well has been proposed at 1.5m above Bed level of tank. This is necessary to ensure that the tank retains sufficient water for use by local consumers. A Single well as discussed above would be suitable for a pond upto an area of about 1.5 ha. Therefore, more number of such Recharge wells are envisaged for larger tanks. It is proposed one recharge shaft for tank area between 1.5 and 5 ha, 2 shafts for 3 to 7 ha and 4 for > 8 ha. Location and design of recharge shaft may be finalised scientifically based on the geological and geophysical investigations. Periodically these structures should be maintained for effective recharge. If recharge shaft is not feasible to construct within the tank bed, it may be constructed in the vicinity of the tank so that the source water can be supplied through trench or siphon system from the optimal level.

Table – 8 Proposed Recharge Plan

	Shallow Aquifer	**Deeper Aquifer**	**Total**
Volume of Unsaturated Zone (MCM)	13000	65200	78200
Volume of Sub-surface space (MCM)	325	978	1303
Available surplus surface Water for AR (MCM)			144
Type of AR structure	Desilting of Existing Tanks	Recharge Shaft (in/ in the vicinity of Existing Tank)	
Volume of water - that can be recharged per structure (MCM)	#	0.05	
No. of structures Existing	2815	0	
No. of structures Proposed	--	1475	

Volume of Water Required for the proposed structures (MCM)	336	73.75	410
Expected Recharge (MCM)	168	66	234
Cost per structure (Rs - lakhs)/ de-silting cost	#	3	
Total Cost (Rs - Lakhs)	16800	4425	21225

 # variable

The source water requirement for the recharge plan can be met from the right and left canals of ongoing Polavaram project and the proposed Chintalapudi Lift Irrigation Scheme during lean period in addition to surplus surface water (147 MCM).

Regulatory measures

Change in cropping pattern from water intensive paddy to irrigated dry other crops like pulses and oil seeds are recommended, particularly in water stress/Over-exploited/Critical areas. If necessary, some regulatory rules may be framed and implemented.

As a mandatory measure, every groundwater user should recharge rainwater through artificial recharge structures in proportionate to the extraction.

Institutional measures

A participatory groundwater management (PGWM) approach in sharing of groundwater and monitoring resources on a constant basis along with effective implementation of the existing Andhra Pradesh 'Water, Land and Trees Act' of 2002 (APWALTA 2002) are the other measures suggested. Subsidy/incentives on cost involved in sharing of groundwater may be given to the farmers involved.

Expected Out Come

With the above recharge plan costing Rs 212.25 Cr., the expected recharge is 234 MCM of ground water. With this there will be arrest in declining ground water levels/ piezometric heads, increase in well sustainability and reduction in power consumption in addition to creation of irrigation potential of 38,670 ha through Irrigated Dry crops or Stage of GW Development may come down by 12% (from present 58% to 46%). Mandalwise ground water resources' management plans are given in Annexure.

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