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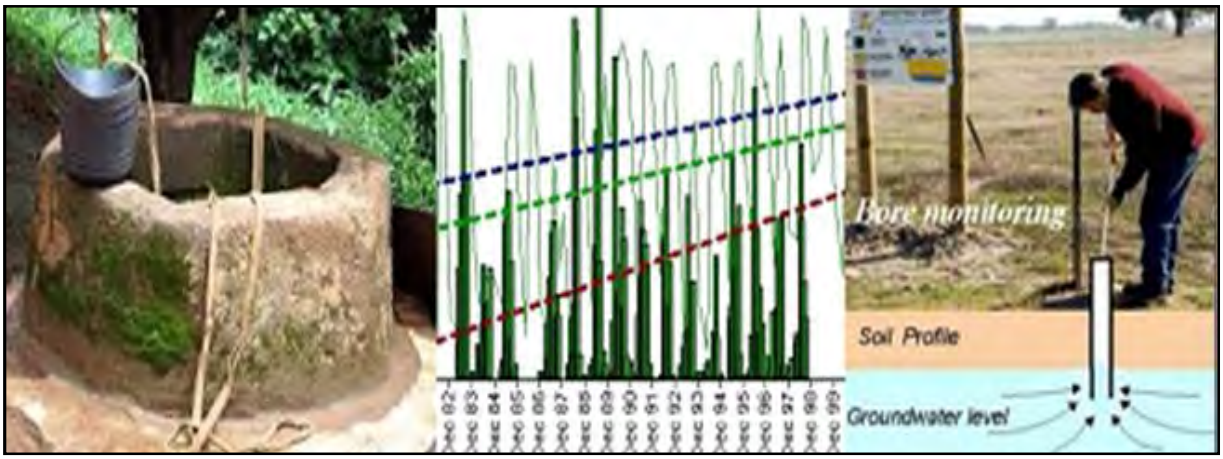
Central Ground Water Board

Ministry of Water Resources,
River Development & Ganga Rejuvenation
Government of India

GROUND WATER YEAR BOOK 2013-14 ANDHRA PRADESH



By

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Southern Region, Hyderabad
January, 2015

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GROUND WATER YEAR BOOK
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GROUND WATER YEAR BOOK
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ANDHRA PRADESH

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FOREWORD

The historical ground water monitoring data is useful in understanding changes in ground water regime in time and space for preparation of sustainable management plan for the country. Central Ground Water Board has been monitoring ground water regime since 1969. During the year 2013-2014, 328 new ground water monitoring wells (318 dug wells and 10 piezometers) were established forming a network of 879 National Ground Water Monitoring Wells including 756 dug wells 123 Piezometers as on 31-3-2014. These stations are being monitored four times a year during May, August, November and January to study the seasonal and long term changes. The water samples are also collected once in a year during May for chemical analysis. The ground water monitoring, during 2013-14, carried out by Central Ground Water Board, Southern Region, Hyderabad, outlines the water level behavior in the current year with reference to the corresponding periods of previous year and also with last decadal mean. It also elaborates the chemical quality of ground water.

The sincere efforts made by Sri. A. B. Kawade, Scientist-C, Sri.P.Sudhakar, Scientist-C (HM), Ms. Lubna Kauser, Asst.Hydrologist, Sri.Bhaskar Reddy, Scientist-B, Sri.K.Maruthi Prasad and Scientist-B and Sri. Y. Satya Kumar, Asstt. Chemist in preparation of the year book are commendable. The efforts of Sri. G.Y.Setty, Scientist-C and Sri M.K.Rafiuddin, Scientist-C, Report Processing Section, in scrutiny, processing and issuance of the report are also appreciated.

It is hoped that the Year Book will be quite useful as baseline information for planners, administrators and researchers involved in ground water development and management in the State of Andhra Pradesh.

Hyderabad
31.01.2015

(A.D.Rao)
REGIONAL DIRECTOR

EXECUTIVE SUMMARY

Central Ground Water Board, under Ministry of Water Resources, Government of India, is carrying out Ground water Regime monitoring all over the country for generating historical data base to study the changes in ground water regime which plays crucial role for estimation of ground water resource (both dynamic and static).

In Andhra Pradesh, a total of 879 (756 dug wells and 123 Piezometers) Ground Water Monitoring wells are present as on 31-03-2014. The Water levels were monitored four times during May, 2013, August, 2013 November, 2013 and January, 2014. This report pertains to ground water monitoring carried out during all the four monitoring periods except August 2013 during AAP 2013-14. It depicts the ground water level scenario in the State and describes the regional behaviour of water levels during the period.

During the year 2013, the State had received annual rainfall of 1018 mm, about 11% more than normal against the normal rainfall of 952mm. It is normal to deficit in all the districts of the state. The deficit rainfall was recorded in Rayalaseem region and it was excess in the remaining districts. Highest annual rainfall of 1166 mm was recorded in Srikakulam district and lowest of 501 mm was recorded in Anantpur district. Monthly rainfall ranges from 3 mm in December to 323 mm in October month. July to November are the rainiest months of the year.

In general, the water levels are deep in the month of May and shallow during November. Water level rise takes place during August, November and January depending on the monsoon rainfall and level of ground water development. During the year 2013-14, the water level vary between 0.69 m agl to 33.73 m bgl during pre-monsoon and -0.8 m bgl to 19.75 m bgl during post-monsoon. The depth to water level of 2-5 m and <2 m bgl are more prevalent in the State during pre and post-monsoon. Number of wells with depth to water level in the range of 0-2 m bgl has increased from 8.4% in May 2013 to 59% in November 2013. Deep water levels (20-40 m bgl) were observed in 4% of the wells during May, 2013 and reduced to 0 % during November, 2013.

Rise in water level was observed in 46.7% of the wells during May, 2013 in comparison with May 2012 and 45.9% of the wells shows fall. When compared with mean of pre-monsoon water levels of last decade (2003-2012), rise during pre-monsoon 2013 was observed in 48.35% of the wells and fall in 51.64% of the wells. Water level rise of more than 4 m was observed in 1.0% of the wells and fall of more than 4 m was observed in 4.0% of the wells.

Rise in water level was observed in Novemebr 2013 when compared to November, 2012 in 45.9 % of the wells and fall in 52.5% of wells. Maximum rise was observed in 0-2 m range in 34 % of wells, maximum fall was in 0-2 m range in 46 %of wells.

Water level fluctuation between May 2013 and November 2013 indicates that rise of water levels was observed in 94.3% of the wells. This can be attributed to the normal to excess rainfall recorded in the state. Water level fluctuation during November 2013 with reference to decadal mean of November (2003-2012) shows rise in water levels in 69.42% of the wells. Rise was also noticed in 89.28% of wells when compared the water levels of May, 2013 to January, 2014. Rise

in 53.6% and fall in 43.5% of the wells was observed from the fluctuation between Jan 2014 and Jan 2013.

The water table elevation follows the topography which ranges from <10 m in east to >900 m in south and west. The general gradient is from west to east.

The area under water logging (0-2m bgl) was 2,421sq.km, 0.88% of the state during pre-monsoon period. The area under prone to water logging (2-3 m bgl) in May 2013 is 11,079 sq.km 4.02% of the area of the state. During the post-monsoon Nov 2013, the area under water logging was 68790 sq.km. 25% of the state. It is an increase from 0.88% to 25% from May to November. Area under prone to water logging in November was 32,520 sq.km, about 11.82% of the state area. There was an increase from 4.02% to 11.82% from May to November. This can be attributed mainly to good monsoon during the year, about 8% more than normal.

During May, 2013 (pre-monsoon), 520 samples were collected from from shallow aquifers (GWMW) to assess the quality of ground water.

In general pH ranges from 7.03 to 9.23. Electrical Conductivity (EC) in ground water ranges from 76 to 13600 micromhos/cm at 25^{o}C. EC beyond 3000 micromhos/cm occurs in 57 samples (11%). In general it ranges from 750-3000 micromhos/cm at 25^{o}C. Chloride is in the range of 7.1 to 4041 mg/l. Only (24 samples) 4.6% of the samples have chloride concentration beyond BIS permissible limit (1000mg/l). Nitrate concentration is in the range of 0 to 2410 mg/l, which includes 199 samples (38.3%) exceeds the BIS limit of 40 mg/l. Fluoride is in the range of 0 to 5.3 mg/l, which includes 55 samples (10.6%) exceeds the BIS limit of 1.5 mg/l .

GROUND WATER YEAR BOOK
2013– 14
ANDHRA PRADESH

1.0 INTRODUCTION

Central Ground Water Board has taken up the task of all complex issues of ground water management, development, augmentation, protection and regime monitoring both in terms of quality and quantity. A network of national hydrograph Stations (NHS) are being monitored on long term basis since 1969 through a network of wells (Dug wells and Piezometers) in order to arrive at proper parametric indices of evaluation and judicious development of ground water resources and to study its long term behavior. A historical database on the ground water levels and water quality has been developed over a period of time since 1969.

The monitoring programme mainly comprises measurement of water levels and temperatures, four times in a year during May 2013, August 2013, November 2013 and January 2014 and collection of water samples for chemical analysis during May 2012. As on 01.04.2013, 583 monitoring wells were in operation. (467 dug wells and 116 piezometers).

During the year 2013-14, 29 Dug wells and 3 Piezometers are abandoned and 328 new monitoring wells (318 Dug wells and 10 Piezometers) are established forming a network of 879 wells including 756 Dug wells and 123 Piezometers (as on 31-3-2014). The dug wells tapping unconfined aquifers, located in the villages, are used for domestic purpose by local public. Some of these are community wells and the rest belong to private individuals. The piezometers tapping unconfined and confined aquifers are constructed under various projects and exploration programmes by the department. The location of ground water monitoring wells are shown in the Fig.1.1

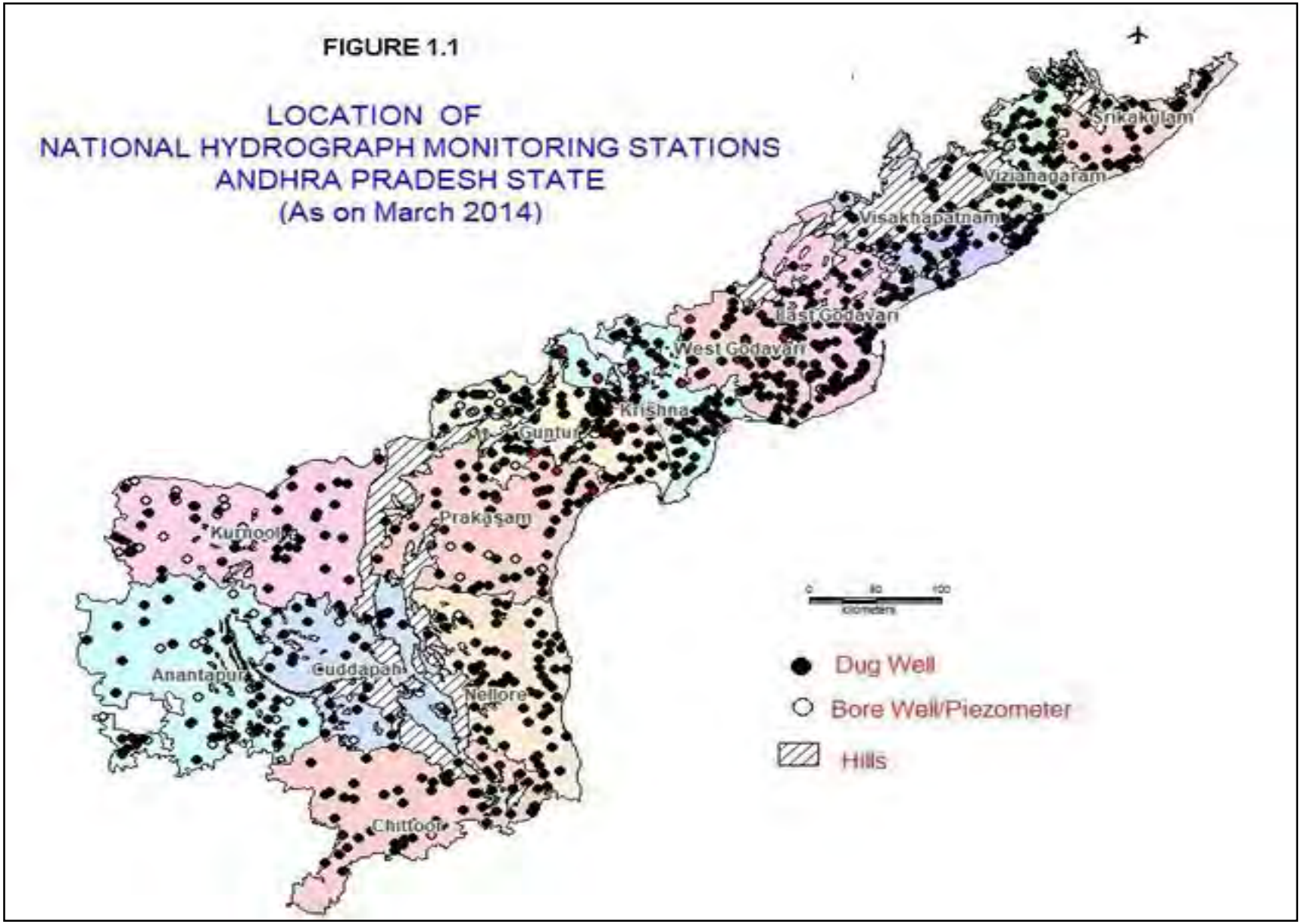
1.1 LOCATION AND EXTENT

Andhra Pradesh is the fourth largest State in India covering geographical area of 2,75, 068 sq.km. It lies between north latitudes 12° 14’ and 19° 54’ and, east longitudes 76° 50’ and 86° 50’. The State is bounded on the east by about 970 km long coastline of Bay of Bengal, on the south by Tamil Nadu and Karnataka States, on the west by Karnataka State and on the north by Telangana, Madhya Pradesh, Chhattisgarh and Orissa States. Administratively, the State is divided into 13 districts and 1128 mandals. Based on geographical position, the State is divided in to two regions viz., Coastal Andhra, and Rayalaseema. The Coastal Andhra region comprises nine districts namely Srikakulam, Vizianagaram, Visakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasam and Nellore districts. The Rayalaseema region is comprised of four districts viz., Kurnool, Kadapa, Anantapur and Chittoor districts.

The present ground water year book for the year 2013-14 depict the ground water level scenario in the State and describes the regional behaviour of water levels. The wells are distributed more or less uniformly over the State covering 17 major and minor river basins.

FIGURE 1.1

LOCATION OF
NATIONAL HYDROGRAPH MONITORING STATIONS
ANDHRA PRADESH STATE
(As on March 2014)



2. PHYSIOGRAPHY, DRAINAGE AND SOIL

2.1 PHYSIOGRAPHY

Physiographically, Andhra Pradesh State can be divided into three distinct zones, viz., Coastal Plains, Eastern Ghats and Western Pedeplains. The landforms, altitude and drainage pattern are different in each zone. The first two units stretch from Northeast to Southwest in a narrow strip while the western pedeplains occupy rest of the area.

2.1.1 COASTAL PLAINS

The coastal plains stretch from Kalingapatnam (Srikakulam district) in the north to Pulicot (Nellore district) in the south along a narrow strip, which broadens in the middle along Godavari - Krishna deltas (up to 80 sq.km). The altitude of coastal plains ranges from sea level at the coast to 150 - 200 m amsl on the west.

2.1.2 EASTERN GHATS

The Eastern Ghats follow the Coastal Plains stretching closely from one end to the other except in area between the Godavari and Krishna rivers. The hill ranges trend in NE - SW direction in the north and in N-S direction in the south and attain elevation of 600 to 1200 m amsl. The Nallamala, Erramala, Seshachalam, Velikonda and Palakonda hills falling in Rayalaseema region, cover southern section of Ghats**.**

2.1.3 WESTERN PEDEPLAINS

A major part of the State covering part of Rayalaseema region (Kurnool and Anantapur districts), fall in this category of physiographic unit. The pedeplains show rolling topography with flat to undulating tracts. This plateau in the interior of the State extends largely between elevation of 150 to 600 m amsl except at places where it is overlain by Basaltic Lava flows, the elevation of which ranges from 600 to 900 m amsl.

2.2 DRAINAGE

The State is drained by 40 major and minor rivers. The important rivers are Godavari, Krishna, Pennar, Palar, Vamsadhara, and Nagavalli. Godavari and Krishna rivers and their tributaries drain the northern and central part and Pennar river drains the southern part of the state before confluence in to Bay of Bengal. There are 3 major basins and 11 medium river basins in the state. The major river basins are Godavari, Krishna and Pennar and medium basins are Vamsadhara, Nagavalli, Sarada, Yeleru, Gundlakamma, Palleru, Kurieru, Swarnamukhi and inter stream areas between Krishna and Godavari basins. The drainage pattern is generally dendritic with wide valleys in western peneplain. The drainage in Eastern Ghat is coarse and dendritic with steep and narrow valleys. Youthful streams and valleys mark the eastern coastal tract intersected by innumerable feeder and distributory canal system. The mature river courses of Godavari, Krishna and Pennar meanders through the vast areas covered by delats as well as coastal plains. Most of the smaller streams feed innumerable tanks.

The Tungabhadra, Vedavati, Hindri, and Paleru rivers drain the northen part of the state. River Penna flows across the southern part of the state with its tributaries Chitravati, Ppaghni and Cheyyeru and drains major part of Rayalaseema region and Nellore district of coastal region. The drainage basins are charecterised by undulating topography comprising a series of ridges and valleys intersperse by hill ranges. The seltas of rivers are very extensive and charecterised by considerable thichness of alluvial material. Vamsadhara and Nagavalli rivers with their distributaries drain the northeastern part of the state in Srikakulam district. Visakhapatnam district is mostly drained by local rivulets like Sarada. River Eleru drains most of the East Godavari district while Yerrakalave, Tammileru drain West Godavari district. Nellore district is drained by Pennar, Swarnamukhi and Arani rivers.

2.3 SOIL

The State has a wide variety of soil viz., Red soil, Laterite, Black Cotton soil, Deltaic Alluvium soil, Coastal soil and Saline soil. Red clayey soil occur predominantly in Srikakulam, Visakhapatnam, East Godavari and West Godavari districts in coastal region. Black cotton soil commonly occur in Krishna and Guntur districts. Red earths with loamy sub-soil and red sandy loamy soil occur in Prakasam and Nellore districts. and Laterite soils in Nellore and Prakasam districts. Black cotton soil is predominant in parts of Kadapa, Kurnool and Anantapur district in Rayalaseema region, red loamy soil occur in parts of Chittoor and Kadapa districts. Red earths are predominant in Anantapur district.

3.0 HYDROMETEOROLOGY

3.1 Climate

The climate of the state is tropical in nature and is influenced by the topographical variations and maritime influence. The Deccan Plateau has more of a temperate climate than the coastal belt. The Eastern Ghats in Vishakhapatnam and its neighbourhood play a significant role, which acts as a barrier to easterly winds in association with depression from Bay of Bengal during the southwestern monsoon. The Agro-climatic classification (agricultural department) of the state is given in the Table-3.1.

Table-3.1
Agro-climatic classification (agricultural department)

Region	Classification
Rayalaseema Plateau	Scarce rainfall zone
	Southern zone
Coastal Andhra Pradesh	Krishna – Godavari Zone
	North Coastal zone
	South Coastal zone
	High Altitude
	Tribal Zone
	Scarce Rainfall Zone

3.2 Rainfall Analysis

3.2.1 Rainfall Analysis 2013

District-wise monthly, seasonal and annual rainfall of both normal and actual of the year 2013 and its departure from normal is presented in the Table-3.2. The district-wise normal annual rainfall and its departure from normal is depicted in Fig. 3.1. The salient features of the analysis are given below:

- The normal annual rainfall of the state is 952mm. Season-wise normal rainfall is 555 mm, 285 mm, 9.8 mm and 96.3mm in monsoon (June-Sept), post-monsoon (Oct-Dec), winter (Jan-Feb) and summer (March-May) respectively, contributing 58% of annual in SW monsoon, 30% of annual rainfall in north-east monsoon and 12% in non-monsoon season. Annual normal rainfall ranges from 574 mm in Anantapur district to 1166 mm in Srikakulam district(Fig 3.2).

- The mean annual rainfall in the year 2013 of the state is 1018 mm. Seasona-wise rainfall is 525 mm, 378 mm, 31.6 mm and 84.1 mm in monsoon (June-Sept), post-monsoon (Oct-Dec), winter (Jan-Feb) and summer (March-May) respectively contributing 52% of annual rainfall in SW monsoon, 37% of annual rainfall in north-east monsoon and 11% in non-monsoon season. Annual rainfall in 2013 ranges from 501 mm in Anantapur district to 1438 mm in Srikakulam district.

Table-3.2

District wise monthly Rainfall(2013) –Andhra Pradesh

S No	District	JAN		FEB		MAR		APR		MAY		JUNE		JULY	
		Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal
1	East godavari	5	5.9	16.1	9	0	10.5	52.6	25.4	25.7	75.3	93.1	131.9	163.4	206.4
2	Guntur	0.4	5.3	80.6	7.9	0.3	6.7	19.3	16.7	32.4	58.4	115.4	90.2	151.2	147.3
3	Krishna	0.6	4.6	76.7	6.2	0	7.8	53.6	18.5	27.5	46.8	148	120.9	249	216.6
4	Nellore	0	15.6	51.8	11.4	30.1	5.6	15.6	17.4	7.6	51.4	38	53.4	140.1	91.2
5	Prakasam	0	7.9	48.5	8.8	0	8.6	21.9	17.6	22.3	52.3	72.6	64.3	128.8	99.3
6	Srikakulam	0	7.4	1.2	18.3	1.8	15	71.2	29.4	21.6	63.9	184.9	145	178.6	190.2
7	Vishakhapatnam	4.2	8.3	5	11.2	0.6	14.6	51.4	50.5	20.2	96.6	93.9	132.6	101.6	178.2
8	Vizianagaram	0	8.2	1.8	14.7	0.3	14.7	57.4	37.3	32	90.7	172.4	140.7	160.4	181.5
9	West godavari	0.7	6	23.9	10.4	0	8.4	29.7	20.8	9.6	55.8	119.1	135.8	217.4	240.2
10	Anantapur	0	2.4	7.4	3.6	0.6	5.2	18.3	21	33	56.7	49.5	55.2	36.3	64.3
11	Chittoor	3	7.5	44.5	7.4	20.7	8.4	36.8	29.8	38.6	67.2	76.4	66.8	80.4	100.1
12	Cuddapah	0	1.9	26.5	2.3	5.2	4.2	7.7	19.2	32	47.6	82.7	69.8	90	101.1
13	Kurnool	0	1.1	12.6	1.9	217.9	4.9	29.7	19.9	48.7	51.7	57.4	80.5	129	115.8
	State average	1.1	6.3	30.5	8.7	21.3	8.8	35.8	24.9	27.0	62.6	100.3	99.0	140.5	148.6

S No	District	AUG		SEP		OCT		NOV		DEC		ANNUAL			
		Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Dep(%)	
1	EAST GODAVARI	71.8	188.4	143.9	177.2	495.8	199	49.5	69.8	2.8	7.8	1120	1107	1%	
2	GUNTUR	178.2	155.4	163.6	150.1	358.8	143.9	59.6	75.8	2.5	14.5	1162	872	33%	
3	KRISHNA	152.7	194.2	143.6	169.7	376.8	164.2	84.2	66.1	4.6	12.1	1317	1028	28%	
4	NELLORE	101.6	95	102.9	112.8	225.4	248.2	149.5	283.9	9.2	107.2	872	1093	-20%	
5	PRAKASAM	156.2	95.9	144.6	123	346.8	181.9	43.7	115	0.8	32.1	986	807	22%	
6	SRIKAKULAM	86.1	202.4	194.7	208.1	659.7	211.4	37.3	69.8	1	4.9	1438	1166	23%	
7	VISHAKHAPATNAM	223.8	178.2	138.7	185.4	445.5	204.3	72.6	59.2	7.3	4.3	1165	1123	4%	
8	VIZIANAGARAM	111.4	194.8	94	209.1	368.8	188.1	29.1	56.3	0	6.1	1028	1142	-10%	
9	WEST GODAVARI	268.6	227.8	123.6	180.1	345.6	197.8	36.4	66.7	9.4	11.7	1184	1162	2%	
10	ANANTAPUR	37.9	74.5	226.8	128.8	85.6	115	5.5	35.3	0.2	11.6	501	574	-13%	
11	CHITTOOR	120.2	110.2	174.2	140	181.5	167.2	73.9	137.3	5.4	58.4	856	900	-5%	
12	CUDDAPAH	97.7	108.6	134.1	124.6	190.1	137.3	21.7	77.2	1.1	24.4	689	718	-4%	
13	KURNOOL	115.7	124.3	183.5	139.6	121.2	105.6	1.6	28.4	0	6.6	917	680	35%	
	State Average	132.5	150.0	151.4	157.6	323.2	174.1	51.1	87.8	3.4	23.2	1018.0	951.7	7%	

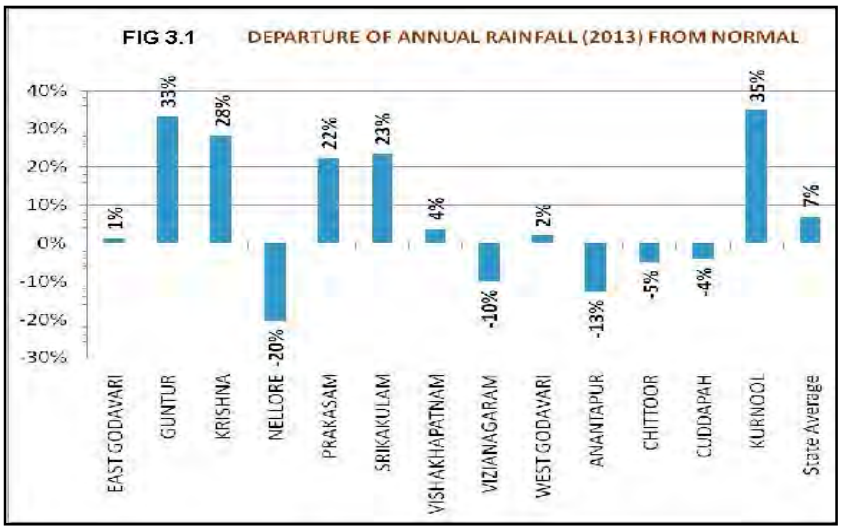
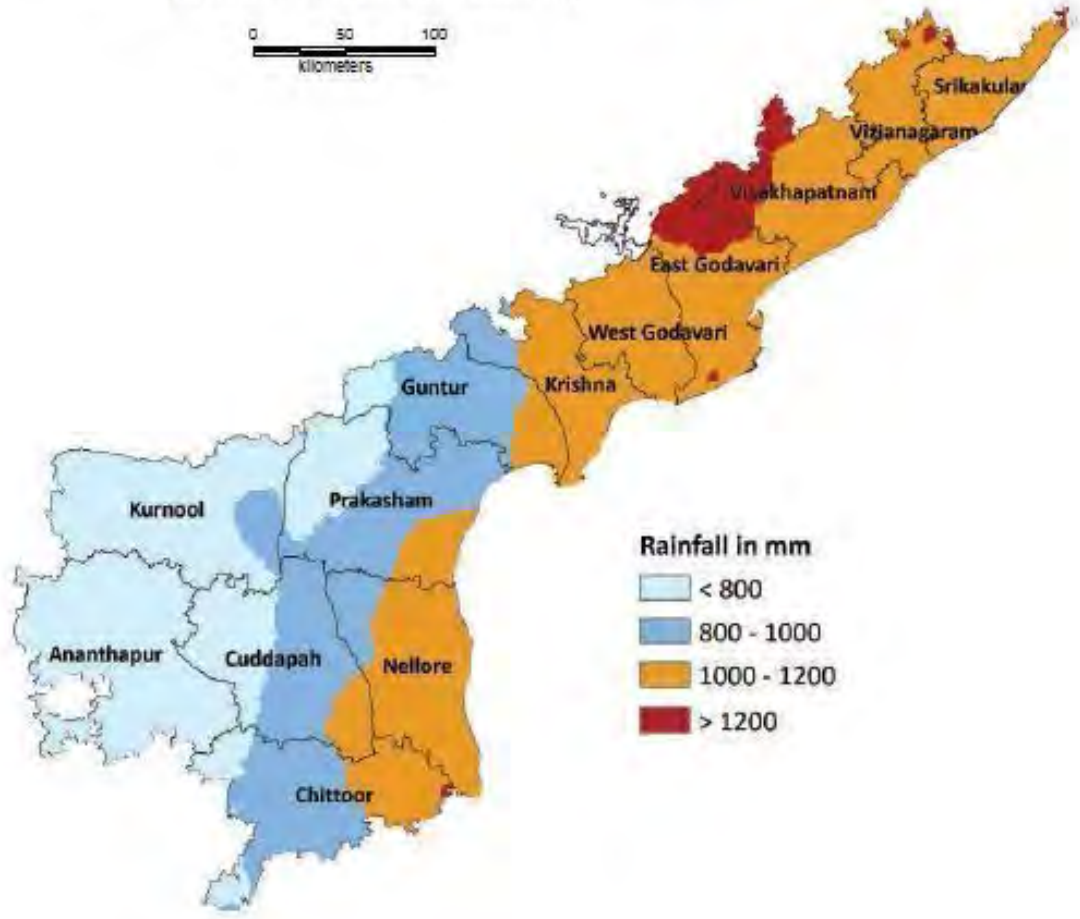


Figure 3.2

ISOHYETAL MAP OF ANDHRA PRADESH STATE

Normal Annual Rainfall(mm)



- During the year 2013, annual rainfall was excess by 7% in the state. No drought conditions were prevailed in the entire state.
- The annual (2013) rainfall ranges from 501 mm in Anantapur district (deficit by 13%) to 1438 mm (excess by 23%) in Srikakulam district.
- Monthly rainfall ranges from 1.1 mm in January to 323.2 mm in October.
- The analyses of rainfall (Jan 2003 to Dec 2013) is carried out based on the weekly weather reports of India Meteorological Department for correlating with water levels (May 2013 to Jan 2014).

3.2.2 Rainfall analysis - May 2013

The analysis of rainfall data (India Meteorological Department) has been carried out utilizing weekly weather reports during the period Jun 2003 to May 2013.

Departure of rainfall during June 2012-May 2013 from June 2011-May 2012 rainfall

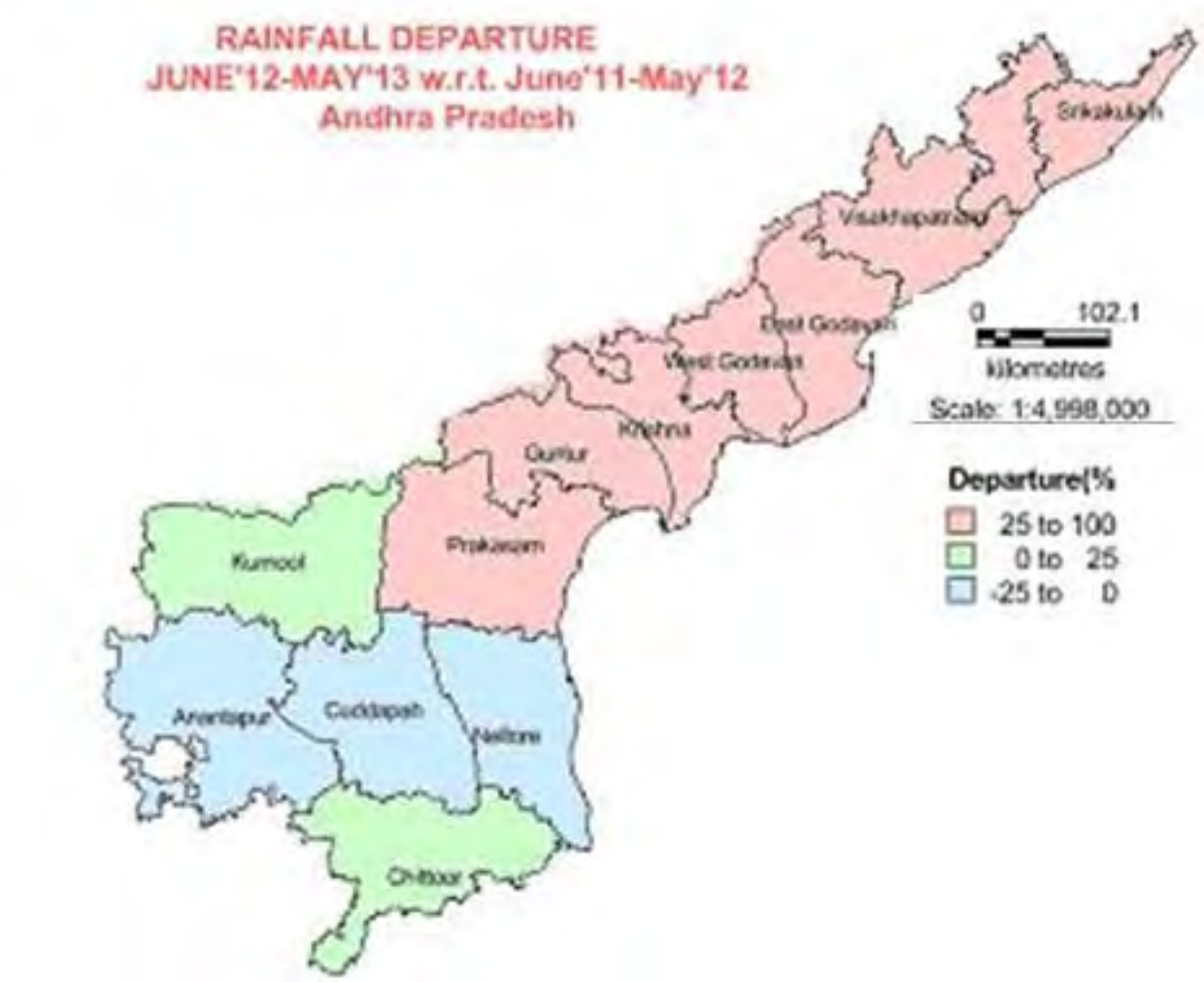
The district-wise rainfall data for the period Jun'12-May'13, Jun'11-May'12, decadal mean (Jun-May) of 2003-2012 and normals of Jun – May and the respective departures of rainfall during Jun'12-May'13 has been given in the Table-3.3. The thematic maps depicting departure from normal rainfall are shown in the Fig.3.3 to 3.6. Water level fluctuation between May 2013-May 2012 is correlated with departure of rainfall during the period. Table -3.3 reveals that the state has received 1070 mm of rainfall during the period June 2012 to May 2013 and 771 mm during the period June'11-May'12. The rainfall during the period May'12 - May'13- is 28% more than the rainfall recorded during the same period last year. The departure in percentage ranges from -18.6% in Cuddapah district to 48.8% in East Godavari district. Anantapur, Cuddapah and Nellore districts have received less rainfall than last year same period. All the other districts have recorded more rainfall than the last year same period.

TABLE - 3.3
RAINFALL AND ITS VARIABILITY IN ANDHRA PRADESH

S NO	DISTRICT	RAINFALL(mm)				Departure of rainfal (%)		
		June'12 - may'13	June'11 - may'12	Decadal mean	Normal	June'11 - may'12	Decadal mean	Normal
1	Anantapur	481	502	618	573	-4.4	-28.6	-19.1
2	Chittor	1002	935	979	898	6.7	2.3	10.3
3	Cuddapah	552	655	999	717	-18.6	-80.8	-29.8
4	East Godavari	1540	788	913	1106	48.8	40.7	28.2
5	Guntur	1040	673	846	872	35.3	18.7	16.2
6	Krishna	1512	898	1011	1027	40.6	33.1	32.1
7	Kurnool	627	512	725	680	18.3	-15.7	-8.4
8	Nellore	910	1024	1046	1092	-12.5	-15.0	-19.9
9	Prakasam	875	575	818	806	34.3	6.5	7.9
10	Srikakulam	1285	880	1105	1165	31.5	14.0	9.3
11	Vishakhapatnam	1195	797	1102	1121	33.3	7.8	6.2
12	Vizianagaram	1262	906	1145	1140	28.2	9.3	9.7
13	West Godavari	1627	872	1062	1160	46.4	34.7	28.7
	State Mean	1070	771	952	950	28.0	11.1	11.2

Source: India Meteorological Department, GOI

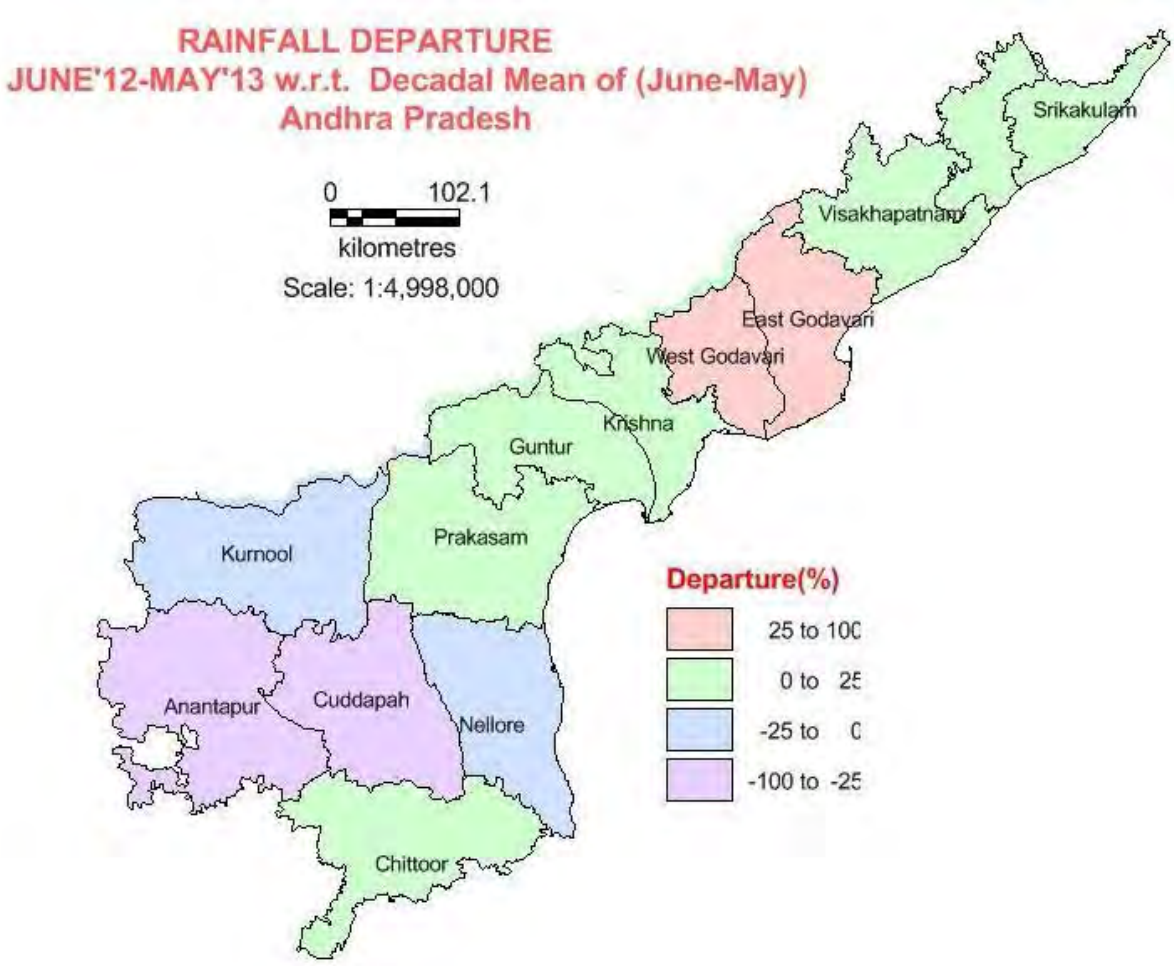
Fig.3.3



Departure of rainfall during June 2012-May 2013 from decadal mean rainfall 2003-2012 (Jun-May)

The departure of rainfall during June 2012-May 2013 from decadal mean rainfall 2003-2012 (Jun-May) is presented in the Fig.3.4. Water level fluctuation between May 2013 and decadal means (May) is correlated with departure of rainfall during the period. Table-3.3 reveals that the decadal mean rainfall (June-May) of the state is 952 mm. The state has received 20% less rainfall than the decadal mean rainfall. The state has received 11% more rainfall than the decadal mean rainfall.The departure in percentage ranges from -80.8% in Cuddapah to 40.7% in east Godavari district. Anantapur, Kurnool, Cuddapah, and Nellore districts received less rainfall than the decadal mean.

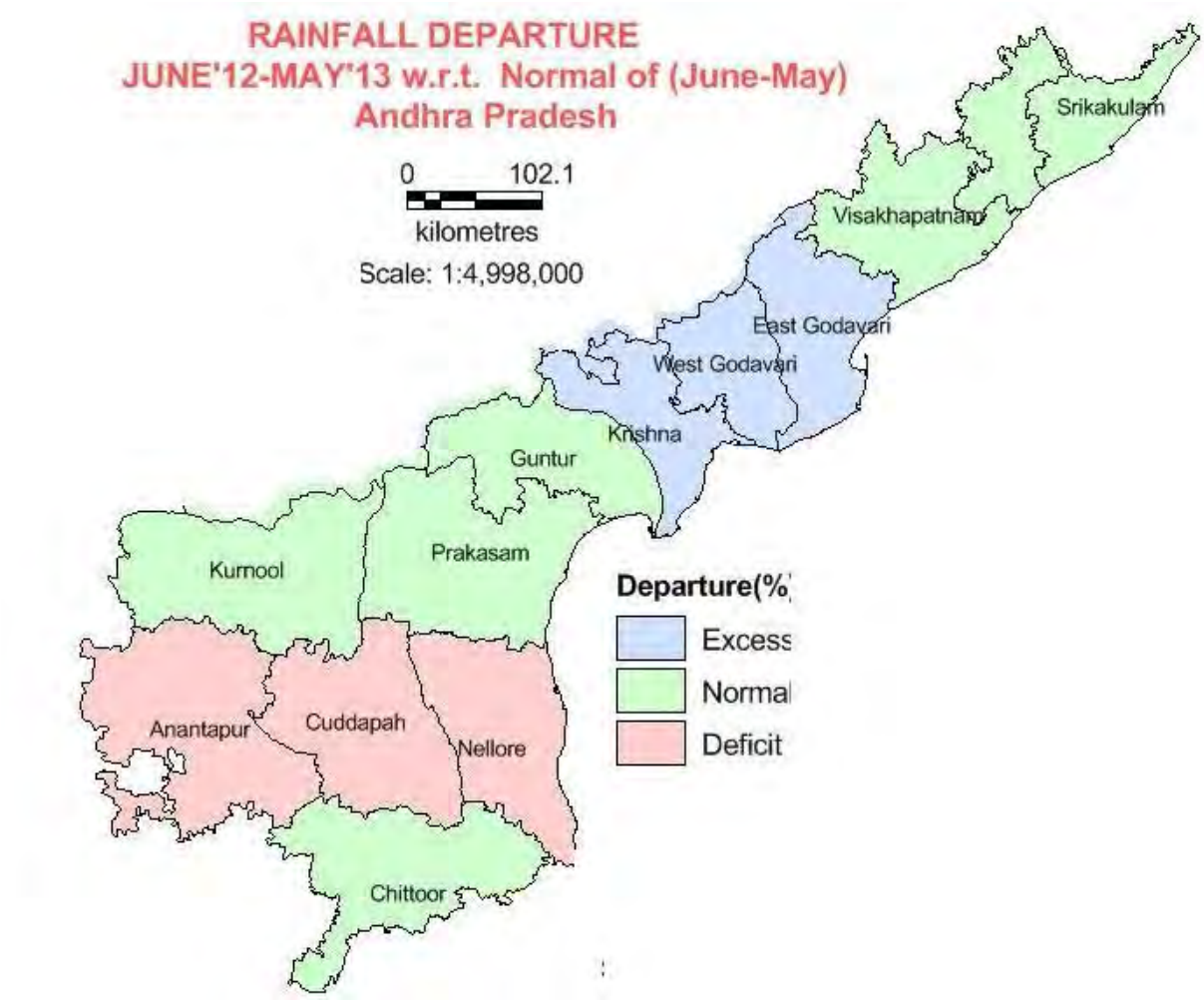
Fig.3.4



Departure of rainfall during June 2012-May 2013 from normal rainfall

The departure of rainfall during June 2012-May 2013 from normals of the same period is presented in the Fig.3.5. During the period June 2012-May 2013, the state has received 11.2% more rainfall than normal. It ranges from -29.8% (Cuddapah district) to 32.1 (Krishna district). The normal rainfall during the period June-May is 950 mm . Anantapur, Cuddapah and Nellore districts have received deficit (between 40 % to 80 % of normal) rainfall. East Godavari, Krishna, and West Godavari districts have recorded Excess (more than 120 % of normal) rainfall and rest of the state has received normal (between 80% to 120 % of normal) rainfall. The departures are depicted in **Fig. 3.5.**

Fig.3.5



3.2.3 Rainfall - August 2013

The district wise rainfall data for the period June 2012-August 2012, June 2012-August 2013, decadal mean of June to August and normal's (June-August) and its departures are furnished in the Table-3.4. The thematic maps depict departure of rainfall from normals shown in the Fig.3.6 - 3.8

Table - 3.4
Rainfall and its variability in Andhra Pradesh

S NO	District	Rainfall(mm)				departure of june'13-aug'13 rainfall from(%)		
		June'13-aug'13	**june'12-aug'12**	**decadal mean**	**normal**	**june'12-aug'12**	**decadal mean**	**normal**
1	East godavari	328	563	268	280	-72%	22%	17%
2	Guntur	445	413	541	527	7%	-	-16%
3	Krishna	550	682	556	532	-24%	-1%	3%
4	Nellore	280	220	245	240	21%	14%	17%
5	Prakasam	358	274	264	260	23%	36%	38%
6	Srikakulam	450	524	559	538	-17%	-	-16%
7	Vishakhapatnam	419	340	479	489	19%	-	-14%
8	Vizianagaram	444	442	550	517	0%	-	-14%
9	West godavari	605	702	591	604	-16%	2%	0.22%
10	Anantapur	124	209	235	194	-69%	-	-36%
11	Chittor	277	331	323	277	-19%	-	0%
12	Kadapa	270	245	499	478	9%	-	-44%
13	Kurnool	302	320	338	321	-6%	-	-6%
MEAN		373	405	419	404	-9%	-	-8%
Source: India Meteorological Department, GOI								

Departure of rainfall during June to August 2013 from June – August 2012

The departure of rainfall during June 2013 - August 2013 from June, 2011 – August 2012 is presented in the Fig.3.6. The state has received 373 mm of rainfall during the period June'13 to Aug'13, which is 9.3 % less than the rainfall during the same period last year, which was 405 mm. It ranges from 124 mm in Anantapur to 605 mm in West Godavari district. The departure ranges from -72% in East Godavari district to 23% in Prakasam district.

Departure of rainfall during June to August, 2013 from decadal mean

The departure of rainfall during June 2013 - August 2013 from decadal mean of the same period is presented in the Fig.3.7. The decadal mean rainfall for the period (June 2013 - August 2013) of the state is 419 mm. The state has received 11% less rainfall than the decadal mean. The decadal mean rainfall ranges from 235mm in Anantapur to 591mm West Godavari district. The departure in percentage ranges from -47 % in anantapur to 36 % Prakasam districts.

Fig.3.6

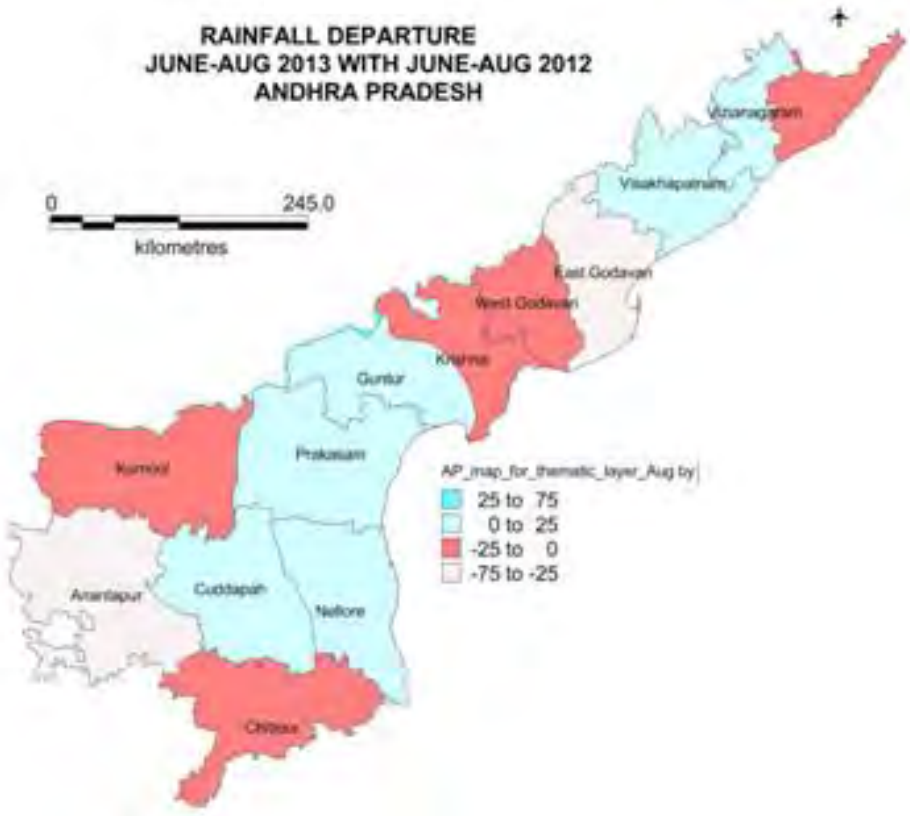
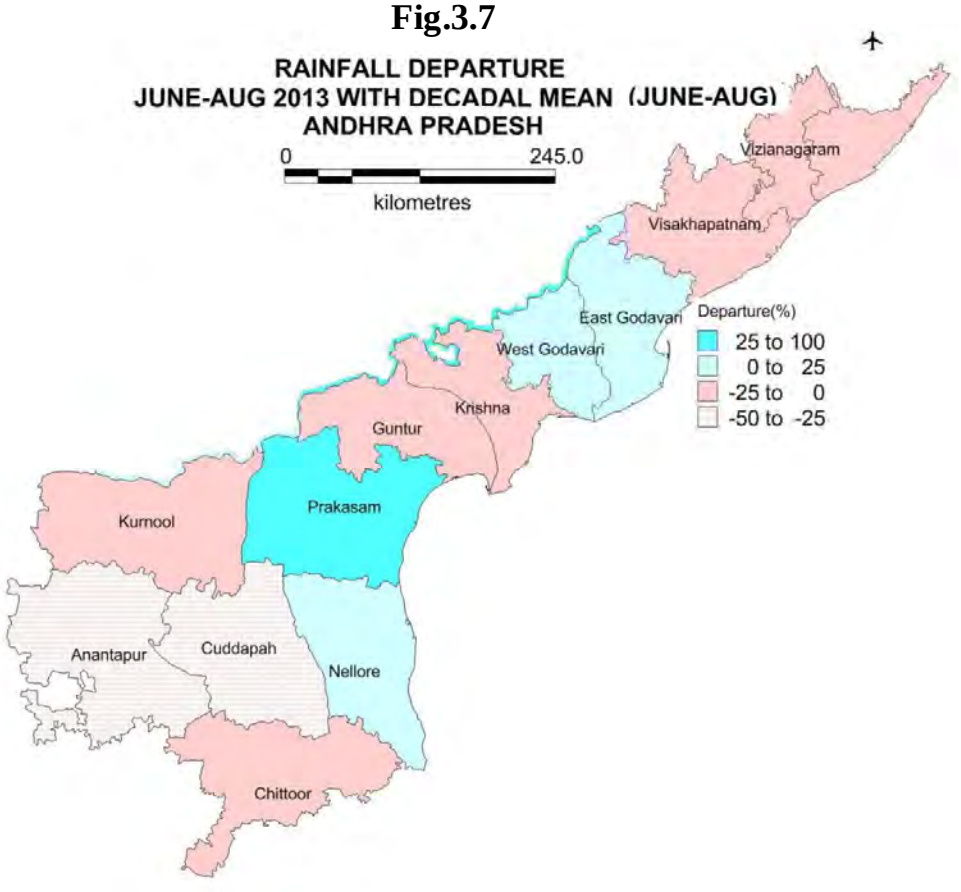

RAINFALL DEPARTURE
JUNE-AUG 2013 WITH JUNE-AUG 2012
ANDHRA PRADESH
0
245.0
kilometres
Vizianagaram
Visakhapatnam
East Godavari
West Godavari
Krishna
Guntur
Prakasam
Kurnool
Anantapur
Cuddapah
Nellore
Chittoor
AP_map_for_thematic_layer_Aug by
25 to 75
0 to 25
-25 to 0
-75 to -25

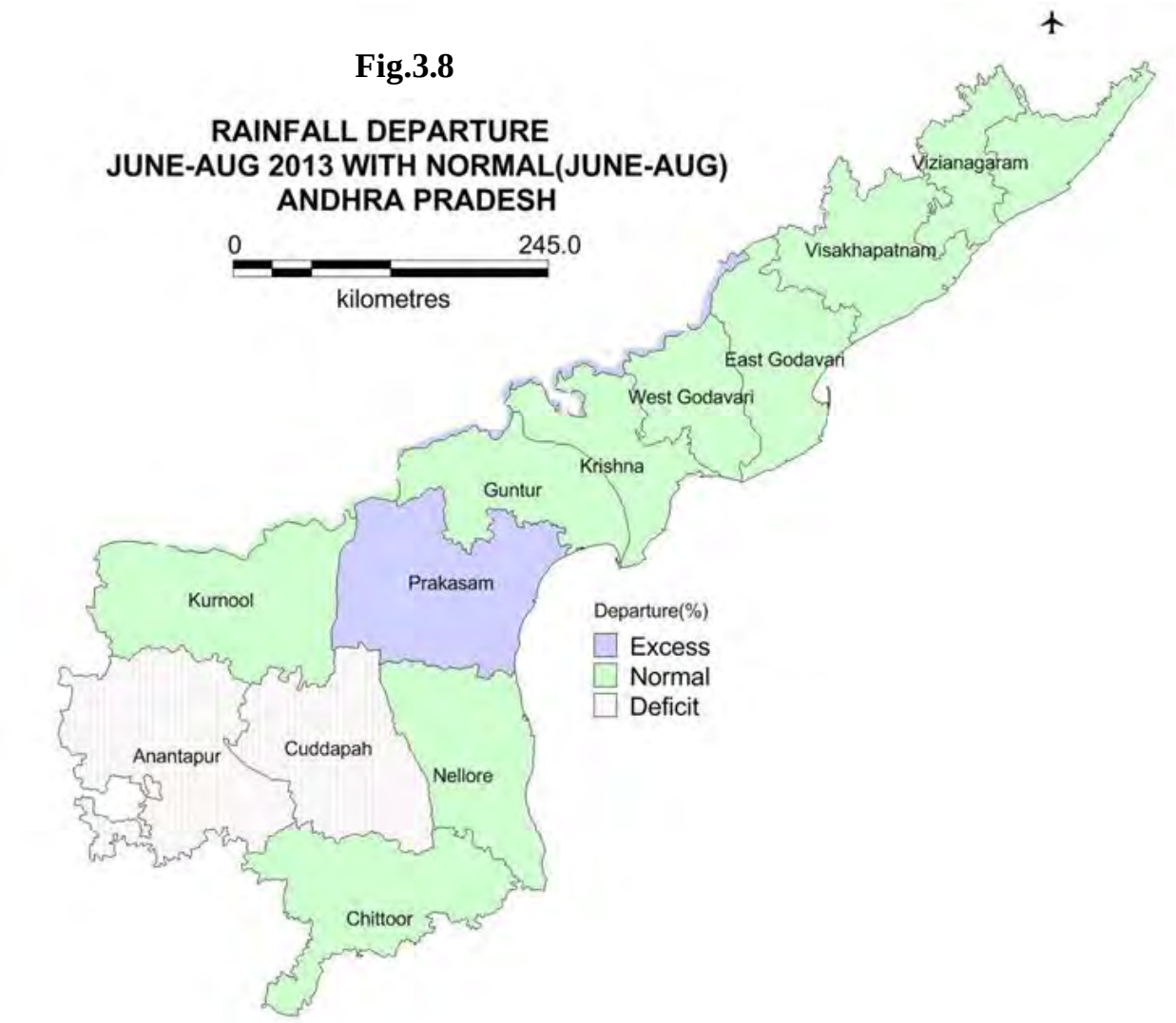
Fig.3.7


RAINFALL DEPARTURE
JUNE-AUG 2013 WITH DECADAL MEAN (JUNE-AUG)
ANDHRA PRADESH
0
245.0
kilometres
Vizianagaram
Visakhapatnam
East Godavari
West Godavari
Krishna
Guntur
Prakasam
Kurnool
Anantapur
Cuddapah
Nellore
Chittoor
Departure(%)
25 to 100
0 to 25
-25 to 0
-50 to -25

Departure of rainfall during June to August 2013 from normal rainfall

The departure of rainfall during June 2013 - August 2013 from normal rainfall is presented in the Fig.3.8. The normal rainfall received during the period June-Aug 2013 is 404 mm. It ranges from 194 mm in Anantapur to 604 mm in West Godavari district. The departure of June-Aug rainfall with normal ranges from -44 % in Kadapa district to 38% in Prakasam district. It is deficient (-19% to -59% of normal) in Anantapur and Kadapa districts, Excess (more than 20% of normal) in Prakasam district and normal (-19% to + 19% of normal) in the rest of the state.

Fig.3.8



3.2.4 Rainfall - November 2013

The district wise rainfall data for the period June'13 - Oct'13, June'12- Oct'12, normals of June - Oct and decadal mean of June-Oct and the departure of June'13 – Oct'13 and its departures are furnished in the Table-3.5. The thematic maps depict departure of rainfall from normals shown in the Fig.3.9 - 3.11.

Table- 3.5
District-wise rainfall variability and departure in
Andhra Pradesh

S No	District	Actual (June 2013-Oct 2013)	Actual (June 2012-Oct 2012)	Normal (June-Oct)	Decadal (2003-12) Mean (June-Oct)	Departure of Rainfall (June 2013-Oct 2013) with		
						(June 2012 -Oct 2012)	Normal (June - Oct)	Decadal (2003-12) Mean (June-Oct)
		(mm)	(mm)	(mm)	(mm)	(%)	(%)	(%)
1	Anantapur	436	365	438	458	19.5%	-0.4%	-4.8%
2	Chittor	633	622	584	632	1.7%	8.3%	0.1%
3	East Godavari	968	1080	903	509	-10.4%	7.2%	90.2%
4	Guntur	967	724	687	950	33.6%	40.8%	1.8%
5	Krishna	1070	1110	866	917	-3.6%	23.6%	16.7%
6	Kurnool	607	489	566	594	24.1%	7.2%	2.2%
7	Prakasam	849	598	564	576	42.0%	50.4%	47.4%
8	SPS Nellore	608	565	601	640	7.6%	1.2%	-5.1%
9	Srikakulam	1304	920	957	967	41.7%	36.2%	34.8%
10	Vishakhapatnam	1004	809	879	889	24.0%	14.2%	12.9%
11	Vizianagaram	907	879	914	931	3.2%	-0.8%	-2.6%
12	West Godavari	1074	1260	982	961	-14.7%	9.4%	11.8%
13	YSR Kadapa	595	364	541	744	63.4%	9.8%	-20.1%
	STATE MEAN	848	753	729	751	12.6%	16.2%	12.8%

Departure of rain fall during June to October, 2013 from June to October, 2012

The departure in percentage during June to October, 2013 from June to October, 2012 is depicted in the Fig.3.9. The state has received 848 mm of rainfall during the period June'13 - Oct'13, which is 12.6% more than the rainfall received during the same period last year which was 753 mm. The departure in percentage ranges from -14.7% in West Godavari district to 63.4% in Kadapa district. Only East Godavari and West Godavari districts have received significantly less rainfall during June'13 – Oct'13 compared with last year same period.

Fig.3.9

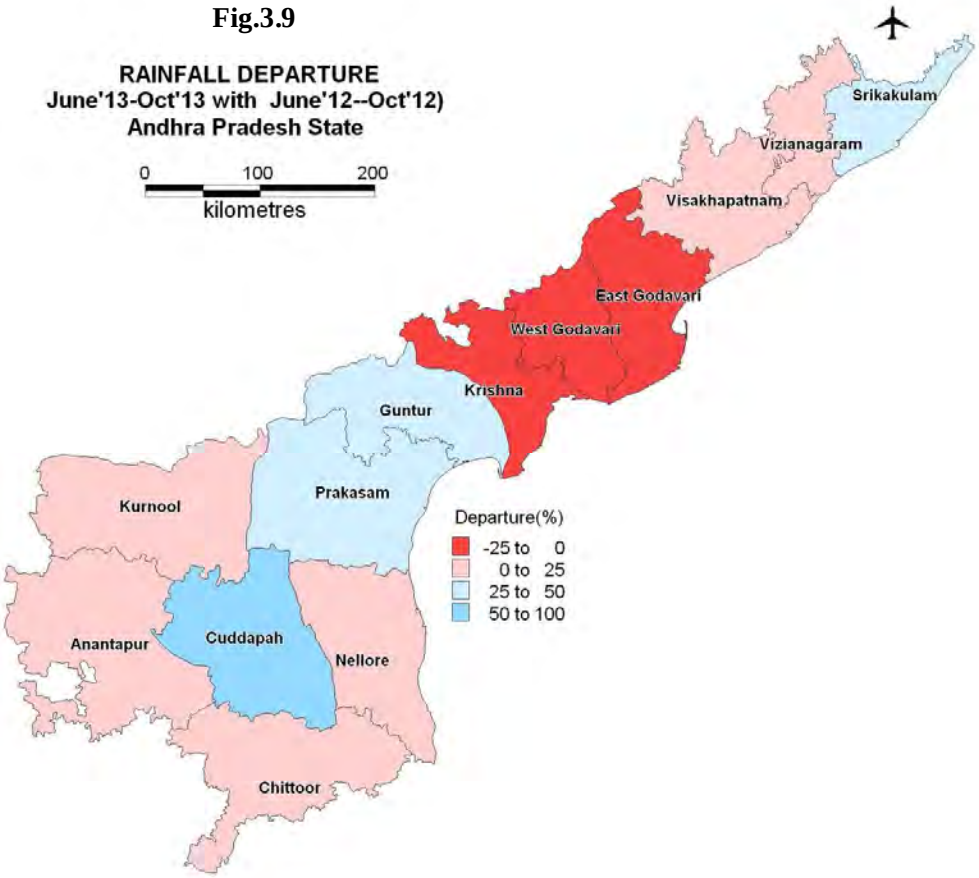
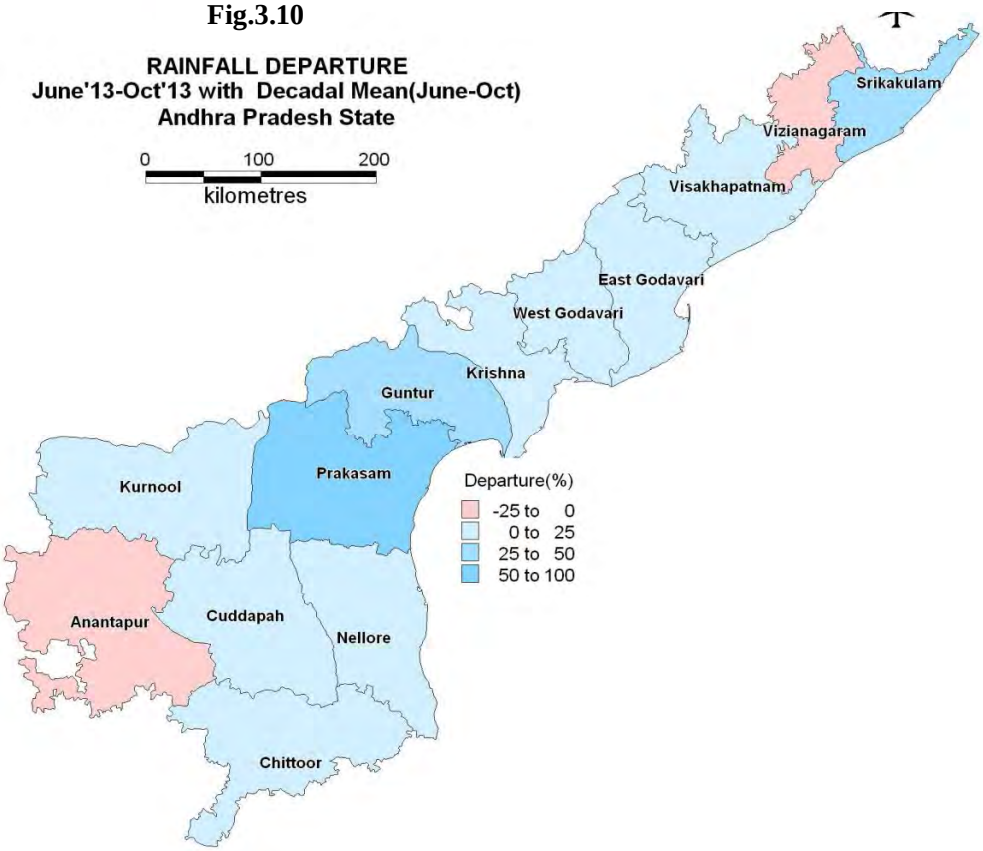


Fig.3.10



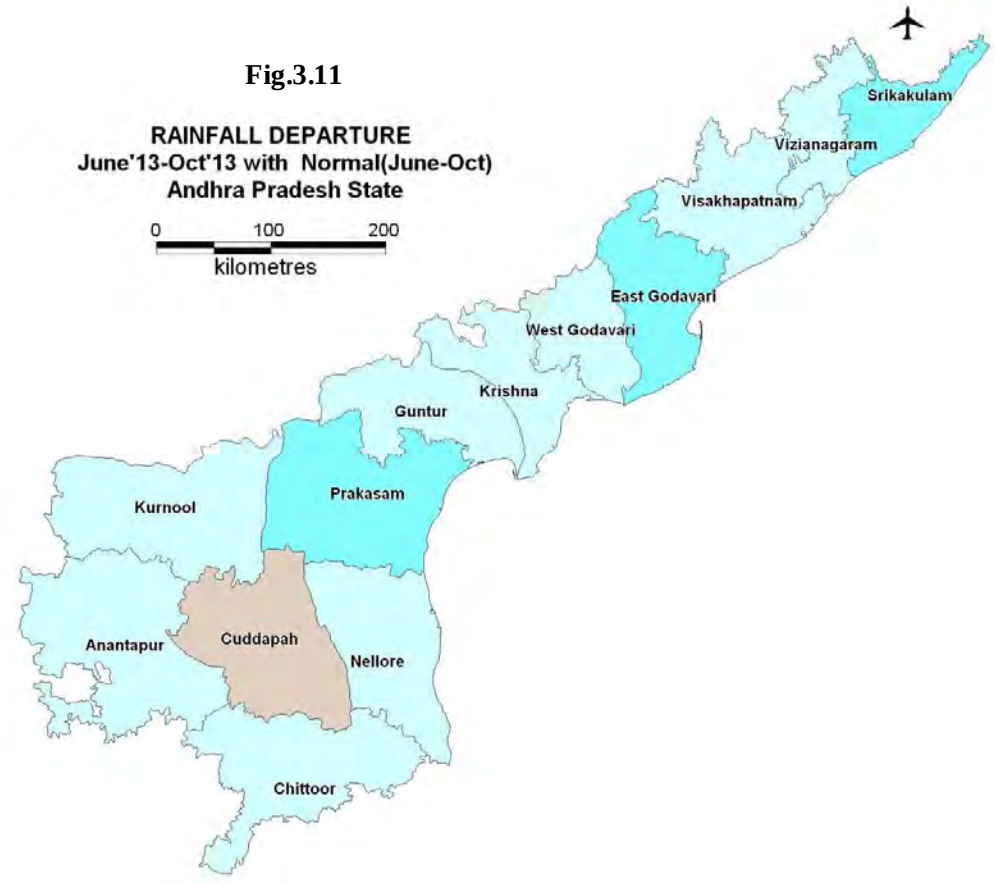
Departure of rainfall during June to October, 2013 from decadal mean - June to October - 2003-12

The departure of current period from decadal mean is depicted in the Fig 3.10.The decadal mean rainfall in the state during the period June - Oct (2003-12) is 751 mm. The mean rainfall during the period June'13 – Oct'13 was 12.8% more than the decadal mean. The departure ranges from -20.1% in YSR Kadapa district to 90.2% in East Godavari district.

Departure of rainfall during June to October, 2013 from normal (June to October)

The departure of rainfall during current period from mean normal rainfall is depicted in the Fig 3.11. The state has received 16.2% more rainfall than normal, during the period June'13 -Oct'13. The normal rainfall is 729 mm. Departure in percentage range from -0.8 % in vizianagaram district to 50.4 % in Prakasam district. The rainfall is normal to excess during the period June-Oct. Excess rainfall (more than 120% of normal rainfall)is received in Guntur, Krishna, Prakasham, and Srikakulam districts. The remaining districts namely Anantapur, Chittoor, East Godavari, Kurnool, SPS Nellore, Visakhapatnam, Vizainagaram, West Godavari and YSR Kadapa districts have received normal rainfall (81% to 119%).

Fig.3.11



3.2.4 Rainfall Analysis - January - 2014

District-wise rainfall data for the period Jan'13-Dec'13, Jan'12-Dec'13, decadal mean (Jan-Dec) of 2003-2012 and normals of Jan – Dec and the departure of Jan'13-Dec'13 rainfall from the respective periods are given in the Table-3.6. The thematic maps depicting rainfall departure from different periods are presented in the Fig. 3.12, 3.13 & 3.14.

Table-3.6
Rainfall distribution and its Variability in Andhra Pradesh

S No	District	Rainfall(Mm)				Depature(%) of Column (3)		
		Jan'13 - Dec'13	Jan'12-Dec'12	Decadal Mean (2003-12)	Normal Jan-Dec	From Last Year Same Period	From Decadal Mean	From Normals
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Anantapur	501	535	642	573	-6%	-	-13%
2	Chittor	856	976	989	898	-12%	-	-5%
3	East Godavari	1120	1497	1185	1106	-25%	-6%	1%
4	Guntur	1162	1013	951	872	15%	22%	33%
5	Krishna	1317	1510	1183	1027	-13%	11%	28%
6	Kurnool	917	615	748	680	49%	23%	35%
7	Prakasam	986	882	890	806	12%	11%	22%
8	S P S Nellore	872	889	1103	1092	-2%	-	-20%
9	Srikakulam	1438	1289	1208	1165	12%	19%	23%
10	Vishakhapatnam	1165	1218	1148	1121	-4%	1%	4%
11	Vizianagaram	1028	1298	1196	1140	-21%	-	-10%
12	West Godavari	1184	1612	1189	1160	-27%	0%	2%
13	Y S R Kadapa	689	550	698	717	25%	-1%	-4%
	State Mean	1018	1068	1010	950	-5%	1%	7%

Departure of rain fall during Jan to Dec 2013 from Jan-Dec 2012

Departure of rainfall during Jan'13-Dec'13 from Jan'12-Dec'12 rainfall is depicting in the Fig.3.12. The State has received 1018 mm of rainfall during the period Jan'13 to Dec'13 , which is 5% less than the rainfall received during the same period last year, 1% more than the decadal mean(2004-2013) and 7% more than the normal. During the same period last year it was 1068mm of rainfall. The departure in percentage ranges from -27% in West Godavari district to 49% in Kurnool district.

Fig.3.12

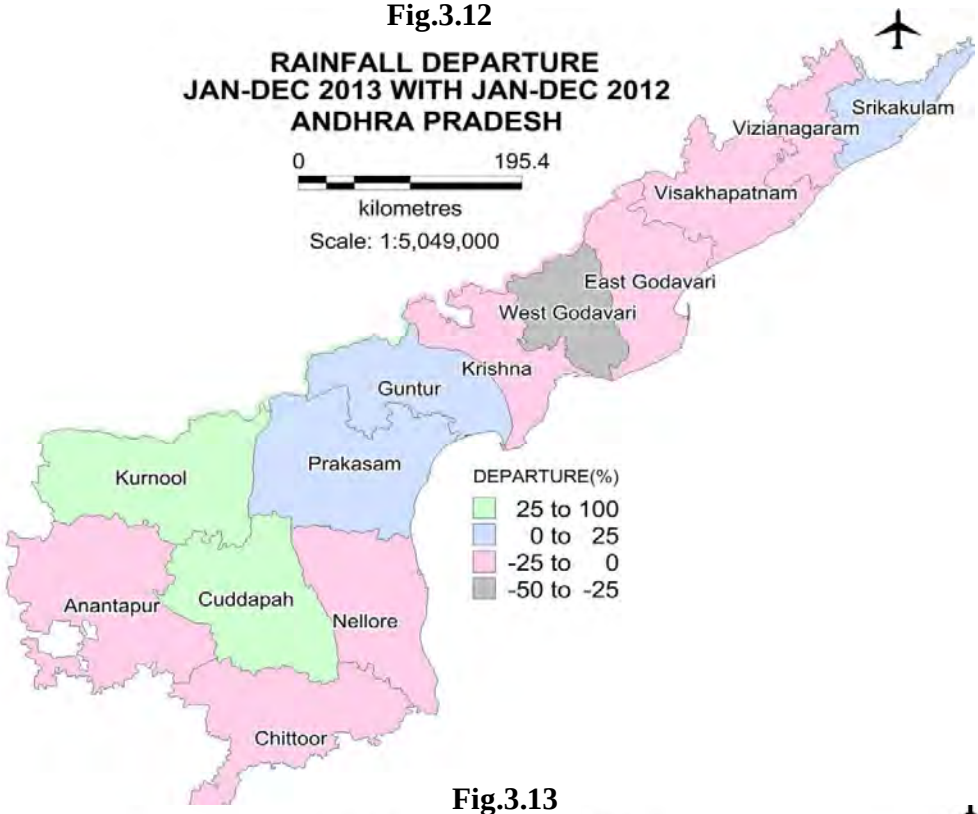
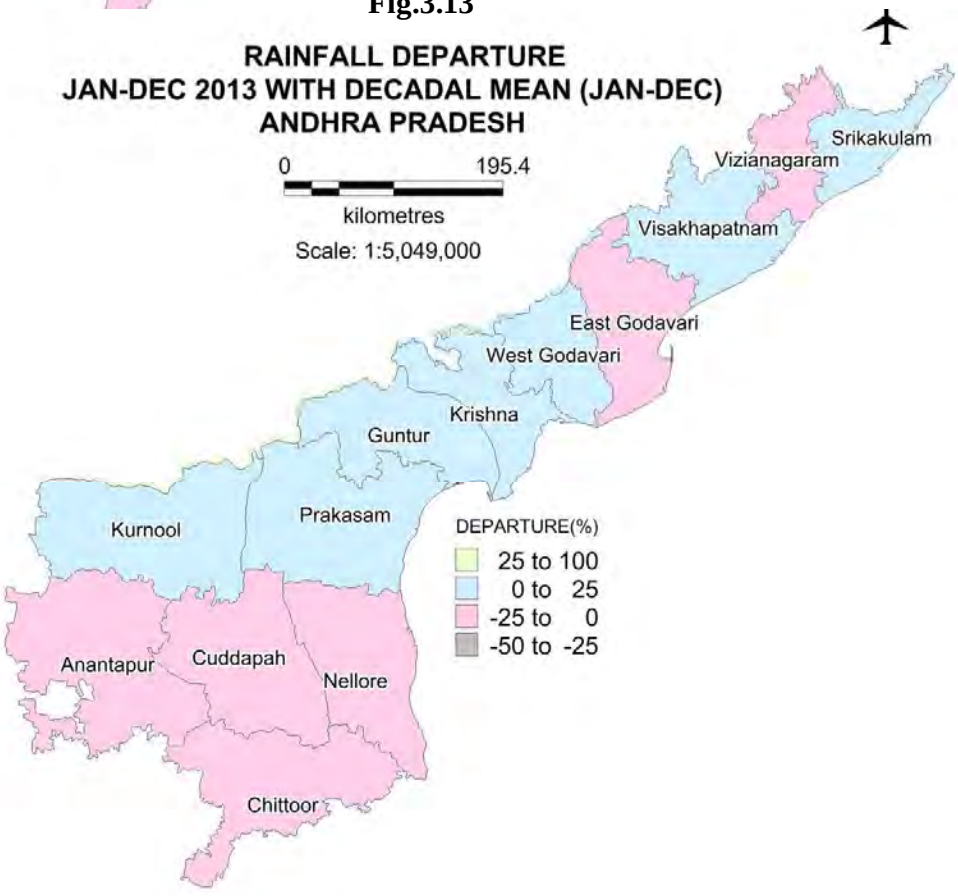


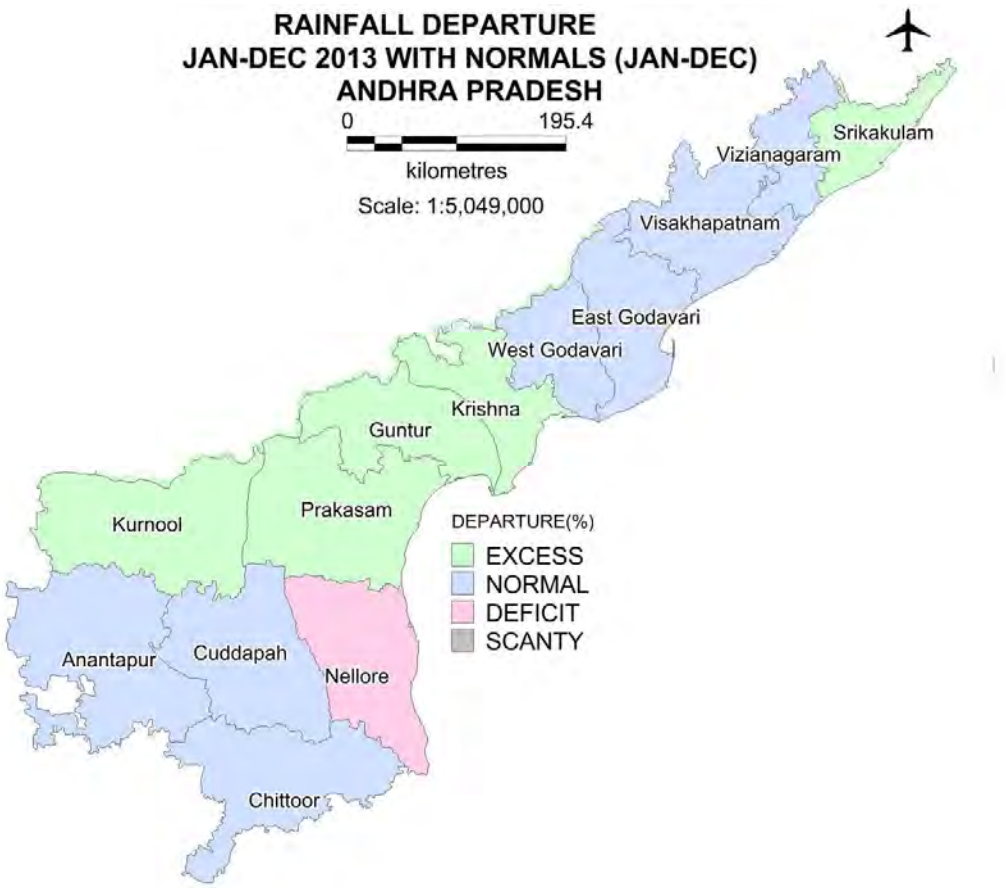
Fig.3.13



Departure of rain fall during Jan to Dec 2013 from decadal mean rainfall Jan-December

Departure of rainfall during Jan to Dec 2013 from decadal mean is depicted in the Fig.3.13 and correlated the data with water level fluctuation between January 2014 and decadal mean. Table-3.6 reveals that the decadal mean rainfall (January-December) of the state is 1010 mm**.** The state has received 5% less rainfall than the decadal mean rainfall of Jan-Dec during the period Jan'13-Dec'13. The departure (in percentage) ranges from -22% in Kadapa to 23% in Kurnool district.

Fig.3.14



Departure of rain fall during Jan to Dec 2013 from normals of the same period

Departure of rainfall during Jan to Dec 2013 from normals of the same period is depicted in the Fig.3.14 and correlated the data with water level fluctuation of January 2014 and normals of the same period. During the period Jan'13-Dec'13 the state has received 7% more rainfall than normal (Jan-Dec 2013) which is 950 mm. It ranges from -20% in SPS Nellore district to +35% in Kurnool district. Deficit rainfall is seen only in SPS Nellore district.

4.0 GEOLOGY

A wide variety of geological formations occur in Andhra Pradesh, ranging from the oldest Archaean crystalline rocks to Recent alluvium. The geological set up and principal aquifer systems are presented in the Fig.4.1 and 4.2 respectively. Major part of the State is underlain by gneissic complex with a structural fill of sedimentary rocks and basin-fill of meta-sedimentary rocks. The gneissic complex is overlain by basaltic lava flows in the northwestern part and is intruded by several younger rocks – granites, dolerites, pegmatites, etc.

4.1 Archaeans and Lower Pre-Cambrians

Peninsular gneiss, which is predominant rock type of Archaean, is dominant in Rayalaseema region. The Charnockites and Khondalites occur in an extensive belt in Srikakulam, Vizianagaram, and Visakhapatnam districts and in upland areas of East Godavari and West Godavari districts. The Charnockite bands also occur as narrow patches adjoining Coastal alluvium in Krishna, Guntur and Prakasam districts. Dharwars, comprising amphibolites, gneisses, schists, and quartzites occur as narrow isolated bands within granites in Chittoor, Anantapur, Kurnool, Kadapa, Nellore, and Prakasam districts.

4.2 Upper Pre-Cambrian to Early Pre-Cambrian

The group includes Cuddapahs, Pakhals, Pengangas, Kurnools and Sullavais comprising shales, limestones, dolomites, sandstones and conglomerates. The Cuddapah Super Group of rocks occur in parts of Krishna, Kurnool, Prakasam, Guntur, Nellore, Kadapa, Chittoor and Anantapur districts. These rocks, forming a crescent shaped Cuddapah basin, cover an area of 42,100 sq.km. Kurnools occur in Kundair valley and Palnad tract. Sullavais are exposed in Godavari valley. Gondwana Formations, comprising lower group of rocks, the Talchirs, Barakars and Kamthis and upper group of rocks, the Maleris, Kotas and Chikialas, occupy parts of West Godavari district. The Gondwana formations, of alluvial and lacustrine sediments, are exposed in lower reaches of Godavari valley. Gondwanas also occur as disconnected outcrops along the coast from Tuni in East Godavari district to Satyavedu in Chittoor district.

4.3 Deccan Trap and Associated Rocks.

Deccan traps, the horizontally disposed lava flows are confined to Minor outcrops near Rajahmundry on either banks of the river Godavari. The thickness of individual flow varies between few metres to as much as 30 m. Inter-trappean beds comprising limestones, cherts and sandstones occur between trap flows near Rajahmundry. Infra-trappean beds, comprising deposits of limestones and sandstones, underlie the trap flows. These are exposed in an area covering a stretch of 6 km from Pangidi in West Godavari district to Kateru in East Godavari district.

4.4 Tertiary Formations

The formation of this group is locally known as Rajahmundry formation. It constitutes mainly Sandstones occurring from Eluru to Rajahmundry as isolated out crops dipping gently towards the coast. Sandstones of equivalent age occur along the southern coast in Prakasam and Nellore districts.

4.5 Recent To Sub-Recent Formations

Alluvium, beach sands, Laterite soils etc. belong to this group. Beds of clay, sand, gravel and boulders stretch along the coast except near Visakhapatnam. This distribution is not only confined to deltas but also extends deep inland in narrow patches along river courses of Godavari, Krishna, Pennar and Vamsadhara. The alluvial deposits attain a thickness of more than 600 m in East and West Godavari districts sloping towards the coast. In Srikakulam and Visakhapatnam districts, the thickness varies between 60 m and 100 m.

Fig.4.1

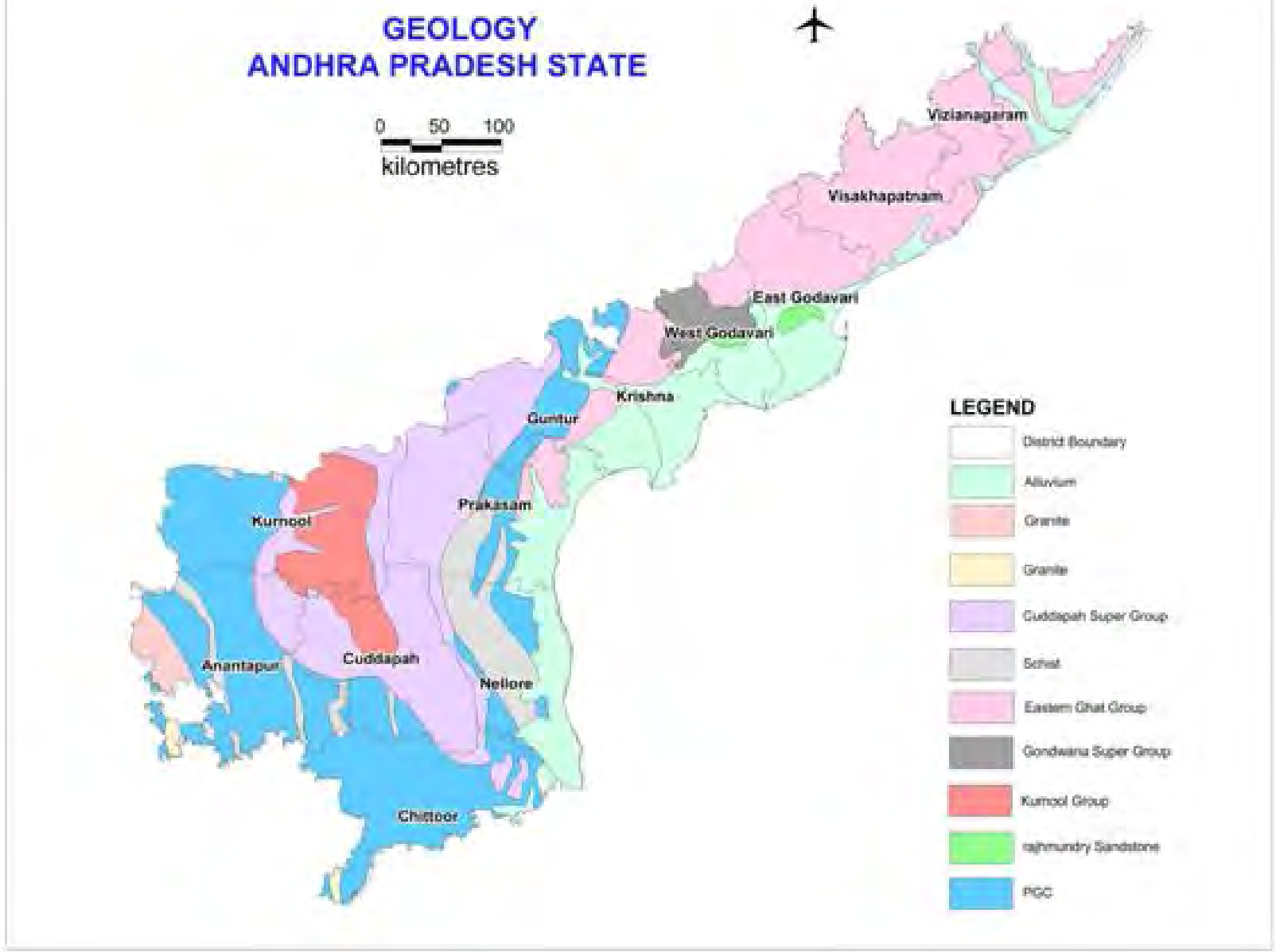
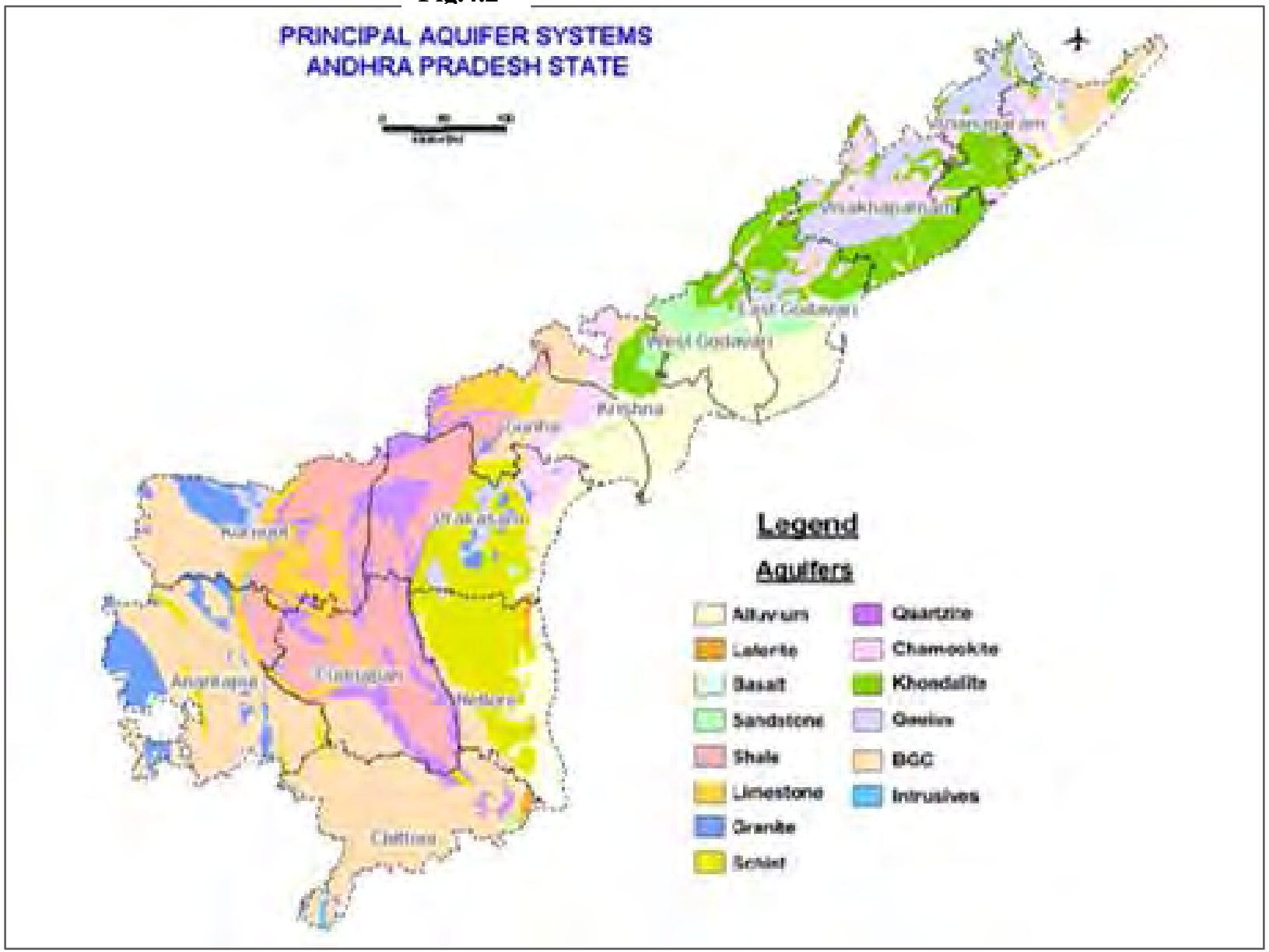

GEOLOGY
ANDHRA PRADESH STATE
0 50 100
kilometres
Vizianagaram
Visakhapatnam
East Godavari
West Godavari
Krishna
Guntur
Prakasam
Nellore
Cuddapah
Kurnool
Anantapur
Chittoor
LEGEND
District Boundary
Alluvium
Granite
Granite
Cuddapah Super Group
Schist
Eastern Ghat Group
Gondwana Super Group
Kurnool Group
rajhmundry Sandstone
PGC

Fig.4.2


PRINCIPAL AQUIFER SYSTEMS
ANDHRA PRADESH STATE
Legend
Aquifers
Alluvium
Laterite
Basalt
Sandstone
Shale
Limestone
Granite
Schist
Quartzite
Chamockite
Khondalite
Gneiss
BGC
Intrusives

5.0 GROUND WATER REGIME MONITORING

The lithounits, Hydrogeologically, are classified into three groups, namely

i) Consolidated
ii) Semi-consolidated and
iii) Unconsolidated.

i) The Consolidated formations occupy about 83% of geographical area of the State. They comprise rocks of Archaean age, limestones, quartzites and slates of pre-Cambrian age and massive Deccan Traps of Cretaceous to Eocene age. Weathered and fractured zones form the aquifer system. Vesicular zones, inter and infra-trappean contacts constitute aquifer system in Deccan Traps. Fractures and cavernous zones are the main aquifers in limestone formations. The aquifer system extends down to 100 mbgl in general 150 mbgl at places.

ii) Semi-consolidated formations comprise Gondwana sandstones & shales, inter and infra-trappean and Rajahmundry sandstones. Coarse grained sandstone down to 700 mbgl form the main aquifer.

iii) Unconsolidated formations consist of river and coastal alluvium of Sub-Recent to Recent age. Sand layers forms the main aquifer system in unconsolidated formations and are generally confined to shallow depth of 30 mbgl.

5.1 Monitoring Methodology

Ground water regime is monitored through a network of dug wells and piezometers. The dug wells, which are owned by government and non-government agencies and individual users, are located in the shallow aquifer system. Piezometers (basically bore wells/tube wells) constructed exclusively for ground water regime monitoring purpose by Central Ground Water Board, tapping shallow and deeper aquifer system independently. The network of ground water structures is monitored manually during the following periods, every year.

i) 1^{st} to 10^{th} January
ii) 20^{th} to 30^{th} May
iii) 20^{th} to 30^{th} August
iv) 1^{st} to 10^{th} November.

5.1.1 Participatory Ground water Monitoring

Under Participatory Ground water Monitoring Programme weekly water level measurements are initiated in phases involving local people as observers to observe the periodic and short term changes in ground water regime. A total of 190 observers are engaged since May 2005.

5.1.2 Ground Water Quality monitoring

Chemical Quality of Ground Water is monitored once in a year by collecting water samples from the monitoring wells (dug wells) in the month of May and analysing the samples in Chemical Laboratory. The effect of geogenic, anthropogenic factors on ground water in

different hydrogeological environments are being observed by quality monitoring over a period of time.

5.2 Database on Ground Water Monitoring Wells

The database on water levels and chemical quality is developed since 1969 and maintained in Oracle using GEMS (Ground water Estimation and Management System) software, which is adopted by all ground water agencies in the country.

5.3 Distribution of Ground Water Monitoring Wells

The district wise, basin wise, aquifer wise and canal command wise distribution and density of monitoring wells is presented in the following sections.

5.3.1 Distribution of Ground Water Monitoring Wells - District-Wise (as on 31st March, 2014)

The highest representation of dug wells is one well per 79 sq.km in Vishakhapatnam district, and the lowest representation is in Kurnool district, one dug well per 478 q.km. Similarly, in case of Piezometers, the highest representation is in Guntur district, one well per 600 sq.km and the lowest is in Chittoor distric, one well per 15224 sq.km. The highest density of wells combined together of PZ and DW is in Vishakhapatnam district, one well per 76 km and lowest is one well per 428 sq. km in YSR Kadapa district (Table-5.1).

Table-5.1
National Ground Water Regime Monitoring Stations in Andhra Pradesh
District-Wise Distribution (as on March, 2014)

S.No	District	Area (Sq.Km.)	No.of NGWRM Stations			Area represented by each GWMW (sq.km)		
			DW	PZ	Total	DW	PZ	TOTAL
1	Anantapur	19123	41	20	61	466	956	313
2	Chittoor	15224	52	1	53	293	15224	287
3	East Godavari	10800	87	15	102	124	720	105
4	Guntur	11400	89	19	108	129	600	106
5	Krishna	8700	64	7	71	136	1243	123
6	Kurnool	17700	37	24	61	478	737	290
7	SPS Nellore	13100	63	2	65	207	6550	271
8	Prakasam	17600	58	16	74	303	1100	237
9	Srikakulam	5800	42	0	42	138		138
10	Visakhapatnam	6500	82	4	86	79	1625	76
11	Vizianagaram	11200	46	0	46	243		243
12	West Godavari	7700	62	12	74	124	642	104
13	YSR Kadapa	15421	33	3	36	467	5140	428
	Total	160268	756	123	879	220	1169	185

5.3.2 Area represented by Ground Water Monitoring Wells (as on 01.04.2013)

As on 01.04.2013, the highest representation of dug wells are observed in Vishakhapatnam district, one well per 125sq.km and the lowest of one well per 643 sq.km in YSR Kadapa district It was one well per 274 sq.km for the State as a whole. As on 31.03.2014, the highest representation of one well per 79 sq.km was noticed in Vishakhapatnam district and lowest of one well per 478 sq.km in Kadapa district and for the State, it was one well per 182 sq.km(Table-5.2).

Table-5.2
District wise Distribution of National Ground Water Monitoring Stations in Andhra Pradesh during 2013 & 2014 (Area in sq.km) Comparison

Sl. No.	District	Area	As on 31.3.2013		As on 31.3.2014	
			Total GWMW	Area Represented	Total GWMW	Area Represented by each GWMW
1	Anantapur	19123	54	354	61	313
2	Chittoor	15224	39	390	53	287
3	East Godavari	10800	67	161	102	105
4	Guntur	11400	69	165	108	106
5	Krishna	8700	38	229	71	123
6	Kurnool	17700	42	421	61	290
S7	Prakasam	17600	56	314	74	238
8	SPS Nellore	13100	44	298	65	201
9	Srikakulam	5800	27	215	42	138
10	Visakhapatnam	6500	52	125	86	76
11	Vizianagaram	11200	28	400	46	243
12	West Godavari	7700	43	179	74	104
13	YSR Kadapa	15421	24	643	36	428
	Total	160268	583	274	879	182

5.3.3 Distribution of Ground Water Monitoring Wells - command areas wise

The major command areas in the State are

I. Krishna Delta,
II. East Godavari Delta,
III. Pennar Delta, West Godavari Delta and
IV. Tunga Bhadra Low Level Canal

The total number of National Ground Water Monitoring Stations in the command area is 365 (Table-5.3).

Table-5.3
Distribution of National Ground Water Monitoring Stations in Andhra Pradesh, Command Area Wise

Number of NGWM Wells			
District	Command	Non-command	Total
Anantapur	5	56	61
Chittoor	0	53	53
East Godavari	66	36	102
Guntur	82	26	108
Kadapa	9	27	36
Krishna	71	0	71
Kurnool	22	39	61
Nellore	19	46	65
Prakasam	25	49	74
Srikakulam	19	23	42
Visakhapatnam	3	83	86
Vizianagaram	0	46	46
West Godavari	44	30	74
	365	514	879

Table -5.4
Basin-Wise Disribution of Monitoring Wells, Andhra Pradesh State

DIST	Cauvery to krishna	Godavari	Godavari to mahanadi	Krishna	Grand total
Anantapur	48			13	61
Chittoor	53				53
East Godavari		62	40		102
Guntur	38			70	108
Kadapa	36				36
Krishna				71	71
Kurnool	20			41	61
Nellore	65				65
Prakasam	73			1	74
Srikakulam			42		42
Visakhapatnam		18	68		86
Vizianagaram			46		46
West Godavari	1	12		61	74
Grand Total	334	92	196	257	879
Area of the Basin	86450	11340	23640	35560	156990

5.3.4 Distribution of Ground Water Monitoring Wells - Basin-wise

The Godavari, Krishna, Mahanadi and Cauvery are the major river basins in the State. The state is divided in to 17 sub-basins. The number of network stations in the major basins are 92 in Godavari, 257 in Krishna, 334 in Cauvery and 196 in Mahanadi basins. The basin wise distribution of GWM is given in the Table-5.4.

5.3.5 Distribution of ground water monitoring wells - District-wise and aquifer-wise

Hydrogeologically, there are three distinct aquifer units in the State. The rocks of Archaean and Pre-Cambrian age and the massive Deccan Traps constitute the hard rock aquifers constituting about 87% of the total aquifers.

The semi-consolidated sedimentary formations comprising Gondwanas, Inter-trappeans, Infra-trappeans, Rajahmundry sandstones form soft rocks aquifers and the granular sandy litho units constitute the alluvial aquifers. Of the 583 Ground Water monitoring wells existing in the State as on 31.3.2013, 705 wells were located in hard rocks, 188 wells in soft rocks and the rest 89 wells were located in alluvial areas. As on 31.3.2014, of the total 879 wells, 345, 313, and 221 wells are in hard rock, Soft Rock and Alluvium areas respectively. The district-wise distribution of Ground Water Monitoring Wells in the three broad aquifer/litho units as on March, 2014 is presented in Table-5.5.

Table – 5.5
Principal Aquifer-wise Monitoring Wells in Andhra Pradesh State as on March 2014

District	Alluvallum	Banded Gnessic Complex	Charnockite	Gniess	Granite	Khondalite	Limestone	Laterite	Quartzite	Schict	Shale	Sandstone	Grand Total
Anantapur		43			15						3		61
Chittoor		47						4	2				53
East Godavari	61		4	8		18						11	102
Guntur	27	19	20		2		25		3	7	1	4	108
Kadapa		8					1		4	3	20		36
Krishna	39	13	7			10	1					1	71
Kurnool		21		2	10		13		4		11		61
Nellore	21	8						5		31			65
Prakasam	13	5	10	7	6			2	4	17	9	1	74
Srikakulam	8	16	9	6		3							42
Visakhapatnam	4		11	23		48							86
Vizianagaram			9	13		22		1	1				46
West Godavari	48	3				7		1				15	74
Grand Total	221	183	70	59	33	108	40	13	18	58	44	32	879

5.3.5.1 Hard rock aquifers

The granites, granite gneisses, Khondalites and Charnockites, constituting the Archaeans and Pre-Cambrian rocks cover major part of the State. Maximum number (345 wells as on 01.04.2014) of Ground Water Monitoring Wells are located in the hard rock formations . The depth of wells in granites, gneisses, vary between 3.8 m and 200 mbgl and depth to water level varied between 0.69 m and 33.73 m bgl with general variation of 5 to 12 mbgl during May, 2013 and between -0.8 and 19.75m bgl with a general variation of 2 m to10 m bgl during November 2013. Water level fluctuation between pre and post monsoon seasons of the year 2013 varied between -3.72 m to 23.87 m.

The depth of wells located in Cuddapah, Kurnool, Pakhal and Sullavai formations vary between 4.50 m and 200 m bgl. Depth to water level varied between 1.58 m and 17.35 m bgl with a general variation of 5 m to 10 m bgl during May 2013 and between 0.47 m and 22.29 m bgl with a general variation of up to 10 metres during November 2013. The water levels are shallow in canal command areas. The water level fluctuation between pre and post monsoon seasons, during the year 2013, varies between 0.3 and 8.54 metres with a general variation of up to 5 metres.

The total depth of wells located in basalts vary between 6.47 m and 200 mbgl. The depth to water level varied between 1.40 m and 28.99 m bgl with a general variation of 5 m to 10 m bgl during May, 2012 and between 0.54 m and 16.72 m bgl with a general variation of 0 to 10.0 m during November, 2012. The water level fluctuation between pre and post monsoon seasons, varied between -2.71 and 13.2 m with a general variation of 2 to >4 m, during the year 2012.

5.3.5.2 Soft rock aquifers

The semi-consolidated sedimentary formations, Gondwanas, infra-trappeans, inter-trappeans, Rajahmundry sandstones and laterites, constitute the soft rocks in the State. Central Ground Water Board has constructed shallow and deep piezometers to study the changes in piezometric heads in different aquifers in sedimentary rocks. As on 1.4.2014, 159 Ground Water Monitoring Wells exist in the soft rocks aquifers.

The depths of dug wells/phreatic zones in soft rocks vary between 3.92 m and 200 m bgl and depth to water level varied between 1.0 and 20.0 m bgl with a general variation of 2 m to 10 m bgl during May 2013 and between 0.39 to 13.80 m bgl with a general variation of about 2 to 5 m bgl, during November 2013. The water level fluctuation between pre and post monsoon seasons, during the year 2013 varied between -1.66 and 7.80 m.

5.3.5.3 Alluvium

As on 1.4.2014, 221 Ground Water Monitoring Wells exist in alluvial formations in the State. The depth of dug wells vary between 2.10 m and 13.92 m bgl and depth to water level varied between ground level and 8.0 m bgl with a general variation of 0 to 5 m bgl during May 2013 and between above ground level to 4.0 m bgl with a general variation of 0 to 2 m bgl during November 2013. The water level fluctuation between pre and post monsoon seasons during the year 2013, varied between 2-4 m with a general variation of up to 2 m.

6.0 GROUND WATER LEVEL SCENARIO

Ground Water Level Monitoring is a scientific surveillance system to observe the periodic and long-term changes in ground water regime. The water level data collected over a period of time provides information about changes in ground water levels with progressive ground water development or with input in to the ground water system brought in by natural and artificial recharge and surface water irrigation system.

The establishment of a network of Ground Water Monitoring Wells provides necessary information on ground water regime with a fair degree of accuracy. With the interpolation of data between various representative observation points, keeping in view of the hydrogeological environment in the area, the ground water level scenario in the State is studied periodically. The status of ground water monitoring wells as on March 2013 and number of NHS wells established, abandoned, and ground water monitoring wells as on March 2014 is given in the Table – 6.1.

Table -6.1
Status of National Ground Water Monitoring Wells in Andhra Pradesh

Sl. No	District	No. of NHS wells as on March-13			No. of NHS wells Established			No. of wells Abandoned during 2013-			No. of NHS wells as on March-14		
		DW	**PZ**	**Total**	**DW**	**PZ**	**Total**	**DW**	**PZ**	**Total**	**DW**	**PZ**	**Total**
1	Anantapur	34	20	54	8	0	8	1	0	1	41	2	61
2	Chittoor	38	1	39	19	0	19	5	0	5	52	1	53
3	Cuddapah	21	3	24	14	0	14	2	0	2	33	3	36
4	East	51	16	67	41	0	41	5	1	6	87	1	10
5	Guntur	50	19	69	43	0	43	4	0	4	89	1	10
6	Krishna	31	7	38	36	0	36	3	0	3	64	7	71
7	Kurnool	24	18	42	16	6	22	3	0	3	37	2	61
8	Nellore	41	3	44	23	0	23	1	1	2	63	2	65
9	Prakasam	40	16	56	19	0	19	1	0	1	58	1	74
10	Srikakulam	27	0	27	17	0	17	2	0	2	42	0	42
11	Vizianagara	28	0	28	18	0	18	0	0	0	46	0	46
12	Visakhapatn	52	0	52	32	4	36	2	0	2	82	4	86
13	West	30	13	43	32	0	32	0	1	1	62	1	74
Total		**467**	**116**	**583**	**318**	**10**	**329**	**29**	**3**	**32**	**756**	**123**	**879**

6.1 Depth to Water Level

The data on periodic monitoring of depth to water levels from Ground water monitoring Wells generally indicates deeper water levels during pre-monsoon period, in the month of May and shallow water levels during post-monsoon period, in the month of November of the same year. The water level measurements carried out during the month of August reveal the passing phase of southwest monsoon. Water level data recorded during November show the peak effects of both southwest and northeast monsoons. The depth to water level maps are prepared for May, August, November 2012 and January 2013 (unconfined aquifers) using GEMS (Ground Water Management System) software.

6.1.1 Depth to water level - MAY, 2013

Analysis of water levels during May, 2013 (Fig.6.1) reveals that the depth to water level of 0 to 10 mbgl is more prevalent in the State.

Shallow water levels of less than 2.0 mbgl are noticed as very small isolated parts in all districts except Vizianagaram in Coastal Region and in small areas in Kurnool district of Rayalaseema Region. Depth to water level ranging from 2 to 5 m bgl is observed mostly in major parts of all Coastal Region, and in small parts of all districts of Rayalaseema Region.

5 and 10 mbgl zones are observed in major parts of Nellore, Prakasham, Vishakapatnam, Srikakulam and as small areas in all other districts of Coastal Region and major parts in all districts of Rayalaseema Region.

Depth to water level varying between 10 and 20 m bgl is noticed mostly in small parts of all districts except Vizianagaram in Coastal Region and major part in Chittoor district and small parts of all other districts of Rayalaseema Region. 20 - 40 m bgl zone is noticed in small parts of Prakasham and Krishna districts in Coastal Region and in small parts of Ananthapur district in Rayalaseema Region.

Analysis of depth to water level data of 605 wells (Table-6.2) shows that water levels vary between 0.69 mbgl (Guntur district) and 33.73 mbgl (Prakasham district). Water level of less than 2.0 mbgl is recorded in 8.4% of wells, between 2-5 mbgl in 45% wells, between 5-10 m bgl in 35.7% wells, between 10-20 m bgl in 10.2% wells and in the rest of 0.7% of wells it is more than 20 mbgl. The percentage of wells in different ranges of depth to water table during May 2013 is presented in the Fig.6.2.

FIGURE 6.1

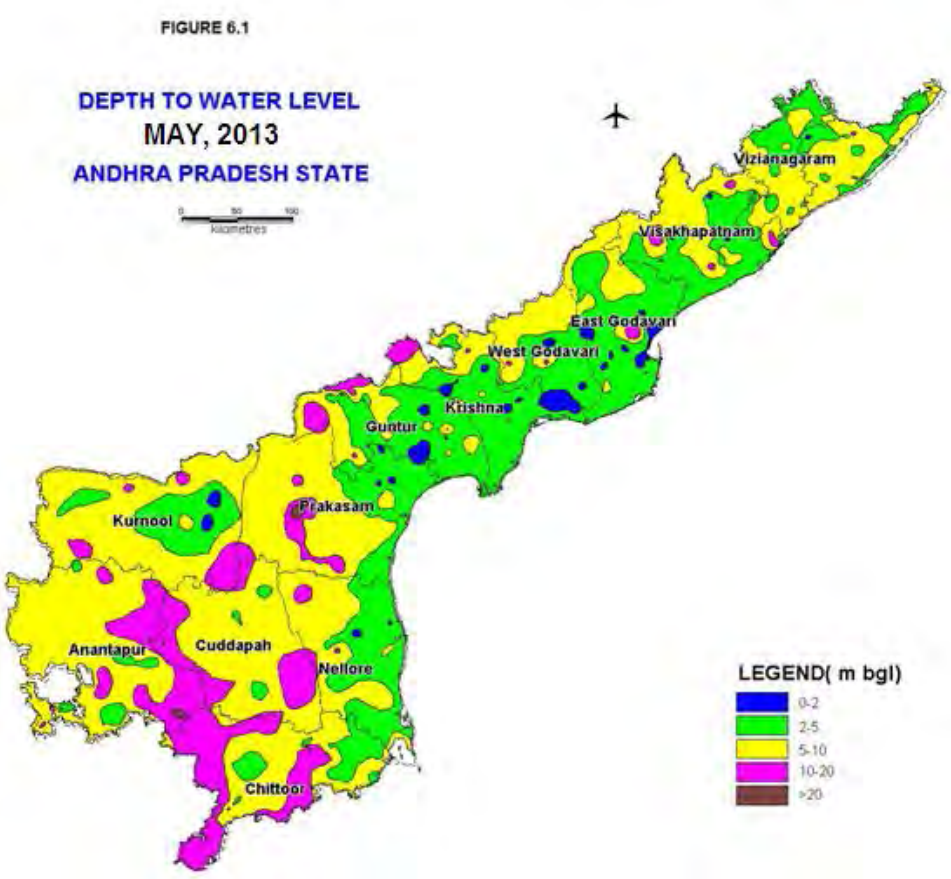
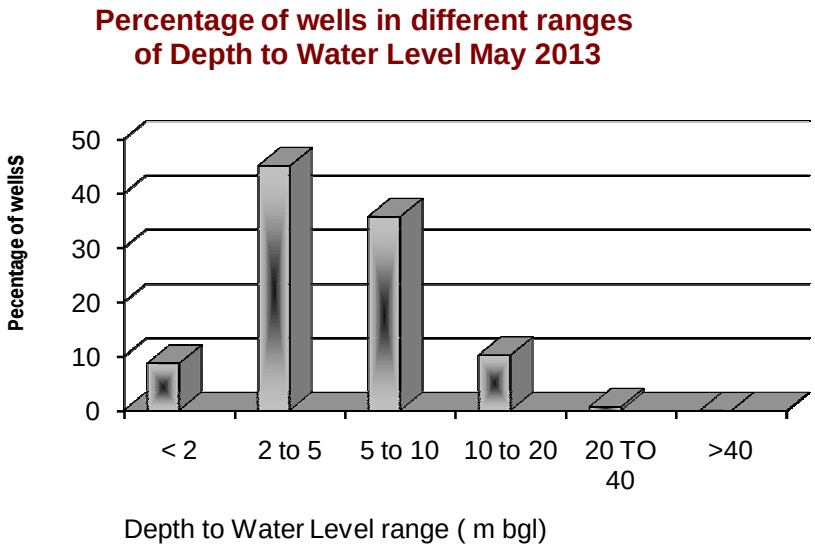


Table-6.2
Percentage of Wells in different Ranges of Depth to Water Table(m bgl)
May - 2013

Sl. No	District	No of Wells Analysed	Depth to Water Table (m bgl)		No and Percentage of Wells Showing Depth to Water Table (m bgl) in Ranga of											
					0.0 - 2.0		2.0 - 5.0		5.0- 10.0		10.0 - 20.0		20.0 - 40.0		> 40.0	
			Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
1	Anantapur	36	1.43	29.5	1	2.78	4	11.11	19	52.78	11	3.56	1	2.78	0	0
2	Chittoor	45	2.1	21.25	0	0	16	34.78	18	39.13	11	23.91	1	2.17	0	0
3	East Godavari	60	1.06	18.36	13	21.67	40	66.67	6	10.0	1	1.67	0	0	0	0
4	Guntur	82	0.69	16.89	9	10.98	45	54.88	21	25.61	7	8.54	0	0	0	0
5	Krishna	52	071	15.41	6	11.54	30	57.69	11	21.15	5	9.62	0	0	0	0
6	Kurnool	32	0.95	17.11	2	6.25	12	37.5	14	43.75	4	12.5	0	0	0	0
7	Nellore	45	1.5	12.63	2	4.44	23	51.11	18	40.0	2	4.44	0	0	0	0
8	Prakasham	53	1.46	33.73	4	7.55	20	37.74	23	43.40	5	9.43	1	1.89	0	0
9	Srikakulam	37	1.43	11.37	1	2.7	14	37.84	21	56.84	1	2.7	0	0	0	0
10	Visakhapatnam	61	0.9	17.30	6	9.84	21	47.54	29	34.43	5	8.20	0	0	0	0
11	Vizianagaram	38	2.74	9.45	0	0	17	44.74	21	56.26	0	0	0	0	0	0
12	West Godavari	36	0.69	11.35	7	19.44	17	47.22	10	27.78	2	5.56	0	0	0	0
13	YSR Kadapa	27	3.05	27.7	0	0	5	18.52	13	48.15	8	29.63	1	3.70	0	0
Total State		605	0.69	33.73	51	8.4	272	45.0	216	35.7	62	10.2	4	0.7	0	0

Fig.6.2



6.1.2 **Depth to water level - November, 2013**

Analysis of water levels during November, 2013 (Fig.6.3) reveals that the depth to water level of 0 to 10 mbgl is more prevalent in the State.

Shallow water levels of less than 2 m bgl are noticed in Prakasham, Nellore districts, major parts of all other districts in Coastal region and in small areas in Anantapur, Chittoor and Kurnool districts of Rayalaseema region. Depth to water level ranging from 2 to 5 m bgl is noticed mostly in parts of all Coastal districts, and major parts of Kurnool and small parts of Anantapur, Kadapa and Chittoor districts of Rayalaseema Region.

Depth to water levels varying between 5 and 10 m bgl are observed in major parts of Nellore, Prakasham and small parts of all other districts except West Godavari district of Coastal region and in major parts in all districts of Rayalaseema Region. 10 - 20 m bgl zone is noticed mostly in small parts of Prakasham district in Coastal region and major parts of Chittoor, small parts of Kurnool, Ananthapur and Kadapa districts of Rayalaseema Region.

Depth to water level varying between 20 and 40 m bgl is observed in small parts of Kurnool district of Rayalaseema Region.

An analysis of depth to water level data of 640 wells (Table-6.3) shows the water levels vary between -0.80 m.bgl (Chitoor district) and 19.75 m.bgl (Chitoor district). Water level of less than 2 mbgl is recorded in 59% of wells, between 2-5 m bgl in 23.7% of wells, between 5-10 m bgl in 14.5% of wells, between 10-20 m bgl in 2.6% of wells. The percentage of wells in different ranges of depth to water table during November, 2013 is presented in the Fig.6.4.

Fig.6.3

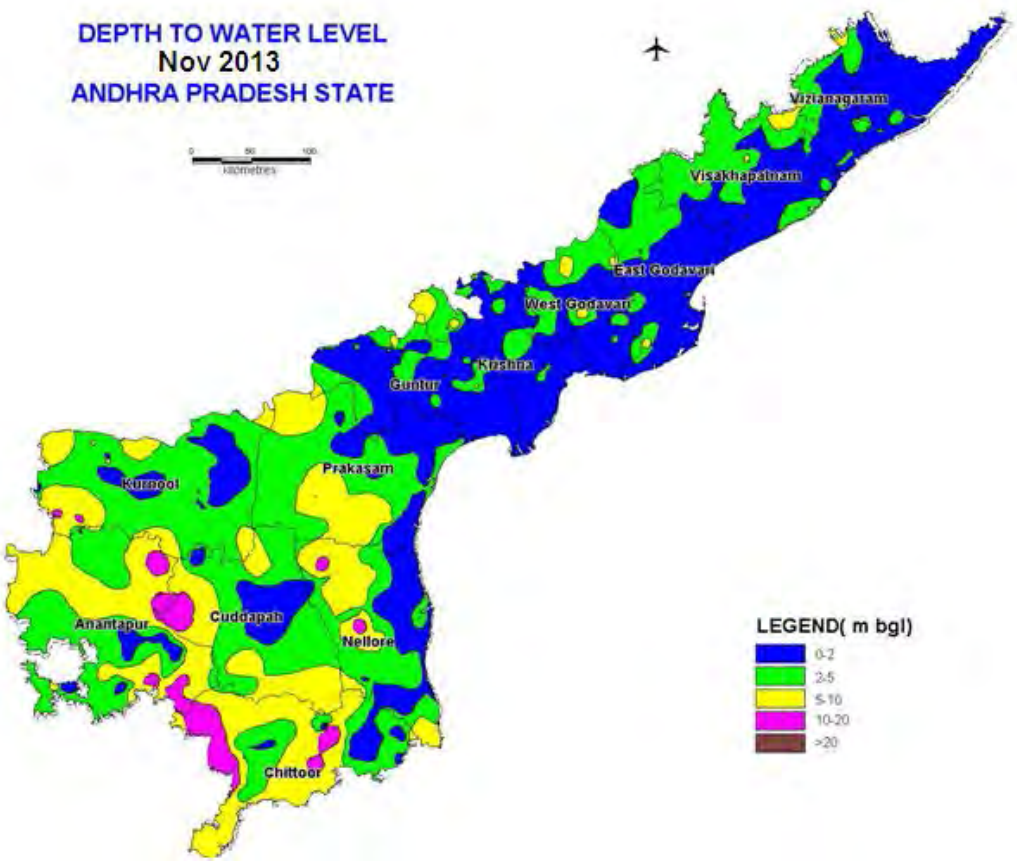


Fig.6.4

Percentage of wells in different ranges of Depth to Water Level November 2013

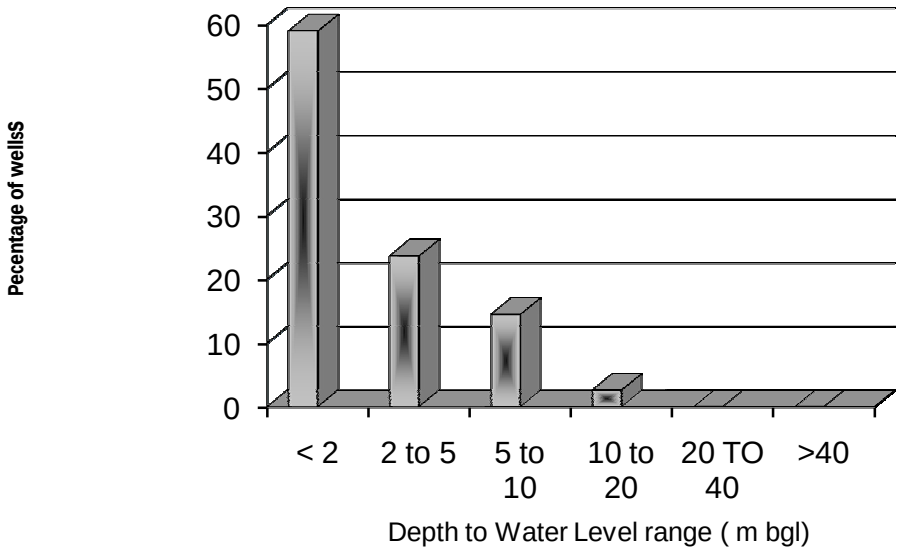


Table-6.3
Percentage of Wells in different Ranges of Depth to Water Table (m bgl)
November-2013

Sl. No	District	No of Wells Analysed	Depth to Water Table (m bgl)		Percentage of Wells Showing Depth to Water Table (m bgl) in Range of											
					0.0 - 2.0		2.0 - 5.0		5.0- 10.0		10.0 - 20.0		20.0 - 40.0		> 40.0	
			Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
1	Anantapur	38	0.47	13.2	9	23.68	13	34.21	12	31.58	4	10.53	0	0	0	0
2	Chittoor	45	-0.8	19.75	12	26.67	12	26.67	15	33.33	6	13.33	0	0	0	0
3	East Godavari	76	0.23	7.35	57	75.0	17	22.37	2	2.63	0	0	0	0	0	0
4	Guntur	79	-0.1	9.4	61	77.22	16	25.5	2	2.53	0	0	0	0	0	0
5	Krishna	51	-0.36	8.54	39	76.47	9	17.65	3	5.88	0	0	0	0	0	0
6	Kurnool	36	-0.03	10.9	12	33.33	10	27.78	12	33.33	2	5.56	0	0	0	0
7	Nellore	46	0.05	14.36	19	41.3	14	30.43	11	23.91	2	4.35	0	0	0	0
8	Prakasham	55	-0.5	10.08	23	41.82	18	32.73	13	23.64	1	1.82	0	0	0	0
9	Srikakulam	39	0.42	3.96	36	92.31	3	7.69	0	0	0	0	0	0	0	0
10	Visakhapatnam	60	0.23	7.5	38	63.33	17	28.33	5	8.33	0	0	0	0	0	0
11	Vizianagaram	43	0.26	6.65	34	79.07	6	13.95	3	6.98	0	0	0	0	0	0
12	West Godavari	45	0.3	7.5	32	71.11	8	17.78	5	11.11	0	0	0	0	0	0
13	YSR Kadapa	27	0.3	16.7	6	22.22	9	33.33	10	37.04	2	7.41	0	0	0	0
State Total		640	-0.8	19.75	378	59.0	152	23.7	93	14.5	17	2.6	0	0	0	0

6.1.3 Depth to Water Level January, 2014

Analysis of water levels during January, 2014 (Fig.6.5) reveals that the depth to water level of 0 to 10 mbgl is more prevalent in the State.

Shallow water levels of less than 2 m bgl are noticed in small patches in Srikakulam, Vizianagaram, Vishakapatnam, Prakasham, major parts of all other districts in Coastal region and as isolated parts in all districts of Rayalaseema region. 2 to 5 mbgl zone is noticed mostly in parts of all coastal districts, major parts of Kurnool, Kadapa and small parts of Anantapur and Chittoor districts of Rayalaseema Region.

5 and 10 mbgl zones are observed in major parts of Nellore, Prakasham and as small isolated parts in all other districts of coastal region, and in Rayalaseema Region.

Depth to water level varying between 10 and 20 m bgl is noticed mostly in small parts of Prakasham, Nellore, Guntur, Vishakapatnam districts in coastal region and major parts of Chittoor, small parts of Kurnool, Ananthapur and Kadapa districts of Rayalaseema Region. 20 and 40 mbgl zone is noticed as small patches in Chittoor district of Rayalseema Region.

An analysis of depth to water level data of 763 wells (Table-6.4) shows water levels vary between -0.53 m.bgl (Krishna district) and 20.04 mbgl (Chitoor district). Water level of less than 2 mbgl is recorded in 38% of wells, between 2-5 m bgl in 40.5% of wells, between 5-10 m bgl in 17.3% of wells, between 10-20 m bgl in 4.1% wells and in the rest 0.1% of wells, depth to water level was more than 20 m bgl. The percentage of wells in different ranges of depth to water table during January, 2014 is presented in the Fig.6.6.

Fig.6.5

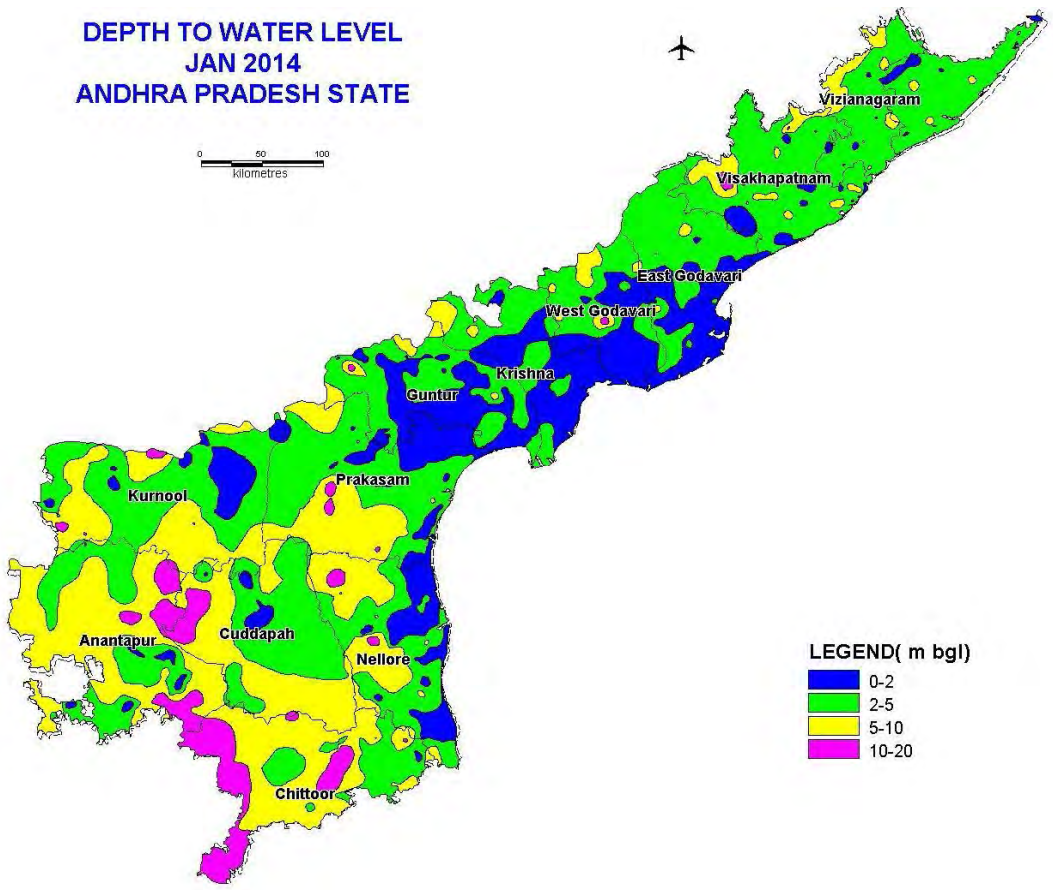
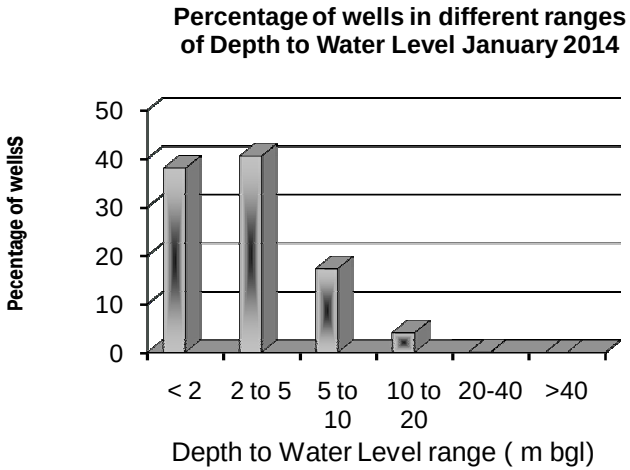


Table-6.4

Percentage of Wells in different Ranges of Depth to Water Table (m bgl), January-2014

Sl. No	District	No of Wells Analysed	Depth to Water Table (m bgl)		No and Percentage of Wells Showing Depth to Water Table (m bgl) in Ranga of											
					0.0 - 2.0		2.0 - 5.0		5.0- 10.0		10.0 - 20.0		20.0 - 40.0		> 40.0	
			Min	Max	No	%	No	%	No	%	No	%	No	%	No	%
1	Anantapur	42	0.47	13.65	9	21.43	10	23.81	18	42.86	5	11.9	0	0	0	0
2	Chittoor	51	0.72	20.04	3	5.88	16	31.37	22	43.14	9	17.65	1	1.96	0	0
3	East Godavari	92	0.45	6.75	51	55.43	38	41.3	3	3.26	0	0	0	0	0	0
4	Guntur	94	-0.5	12.65	54	57.45	34	36.17	5	5.32	1	1.06	0	0	0	0
5	Krishna	57	-0.53	9.73	35	61.4	20	35.09	2	3.51	0	0	0	0	0	0
6	Kurnool	41	-0.08	11.2	13	31.71	16	39.02	9	21.95	.	7.32	0	0	0	0
7	Nellore	64	-0.2	14.36	24	37.5	21	32.81	17	26.56	2	3.13	0	0	0	0
8	Prakasham	69	-0.35	12.78	28	40.58	23	33.33	15	21.74	3	4.34	0	0	0	0
9	Srikakulam	39	1.24	6.45	8	20.51	26	66.67	5	12.82	0	0	0	0	0	0
10	Visakhapatnam	84	0.6	14.66	19	22.62	50	59.52	13	15.48	2	2.38	0	0	0	0
11	Vizianagaram	43	1.18	8.45	8	18.6	29	67.44	6	13.95	0	0	0	0	0	0
12	West Godavari	53	0.38	12.8	33	62.26	14	26.42	5	9.43	1	1.89	0	0	0	0
13	YSR Kadapa	34	0.59	16.26	5	14.71	12	35.29	12	35.29	5	14.71	0	0	0	0
State Total		763	-0.53	20.04	290	38.0	309	40.5	132	17.3	31	4.1	1	0.1	0	0

Fig.6.6



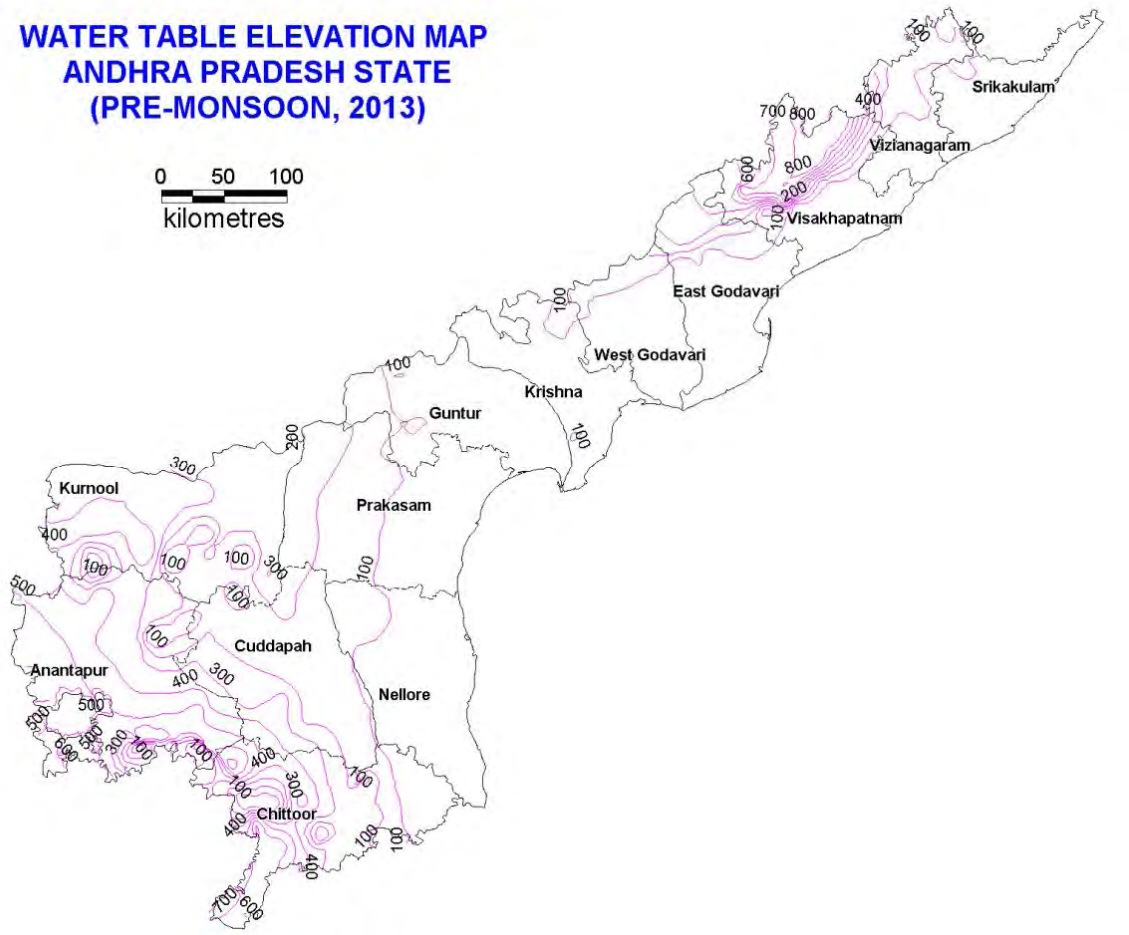
6.2 Frequency Distribution of Depth to Water Level

The categorization of depth to water levels (district-wise) with its percentages during May 2013, November 2013 and January 2014 are presented in the Table- 6.2 - 6.4. An analysis of water level data reveals the following observations (Table-6.5).

Table-6.5
Frequency Distribution of Depth to Water Level

Sl No	Range of Depth to water level (mbgl)	May, 2013	November, 2013	Remarks	
1	< 2	8.4 %	59%	% of wells in < 2mbgl range Increased	Impact of good monsoon from pre-monsoon to post-monsoon
2	2 - 5	45%	23.7%	% of wells in 2-5mbgl range reduced	Marginal decrease in percentage of wells in categories 2-5, 5-10 10-20 mbgl depth to water level.
3	5 to 10	35.7%	14.5%	% of wells in 5-10mbgl range reduced	
4	10 to 20	10.2%	2.6%	% of wells in 10-20mbgl range reduced	

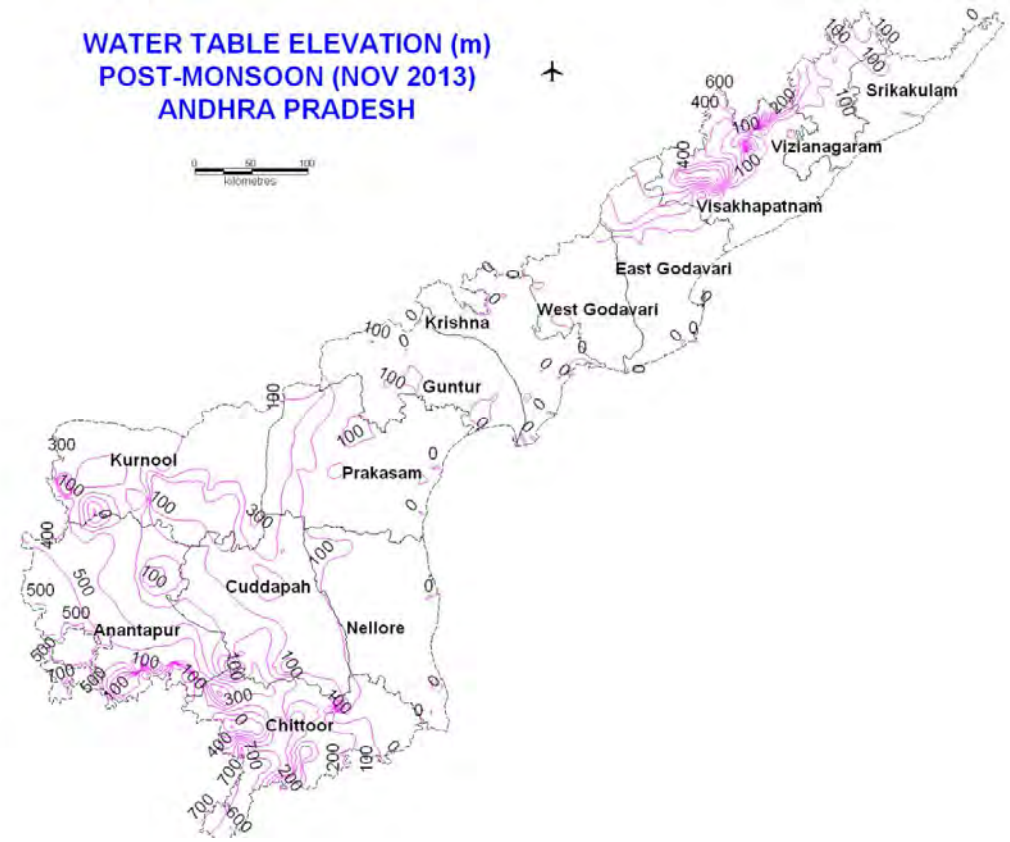
Fig.6.7



6.3 Water Table Elevation

Water table elevation maps during pre(May, 2013) and post (November, 2013) monsoon are presented in Fig.6.8 and 6.9. A perusal of the maps rveals that water table generally follows the topography. The elevation of water table in the State ranges from <10 (zero) mamsl on eastern side to >750 mamsl on southern side of the State. However, in Eastern Ghats area it varies from 500 -926 mamsl. The general gradient of water table is from west to east. Hydraulic gradient ranges from 8 m/1km in southwestern part of Chittoor district to as low as 0.5 m/1km in Godavari valley (Highly permeable area), with general gradient of 2 m/km. In Eastern Ghats the hydraulic gradient ranges from 20 m/1km to as much as 50 m/1km.

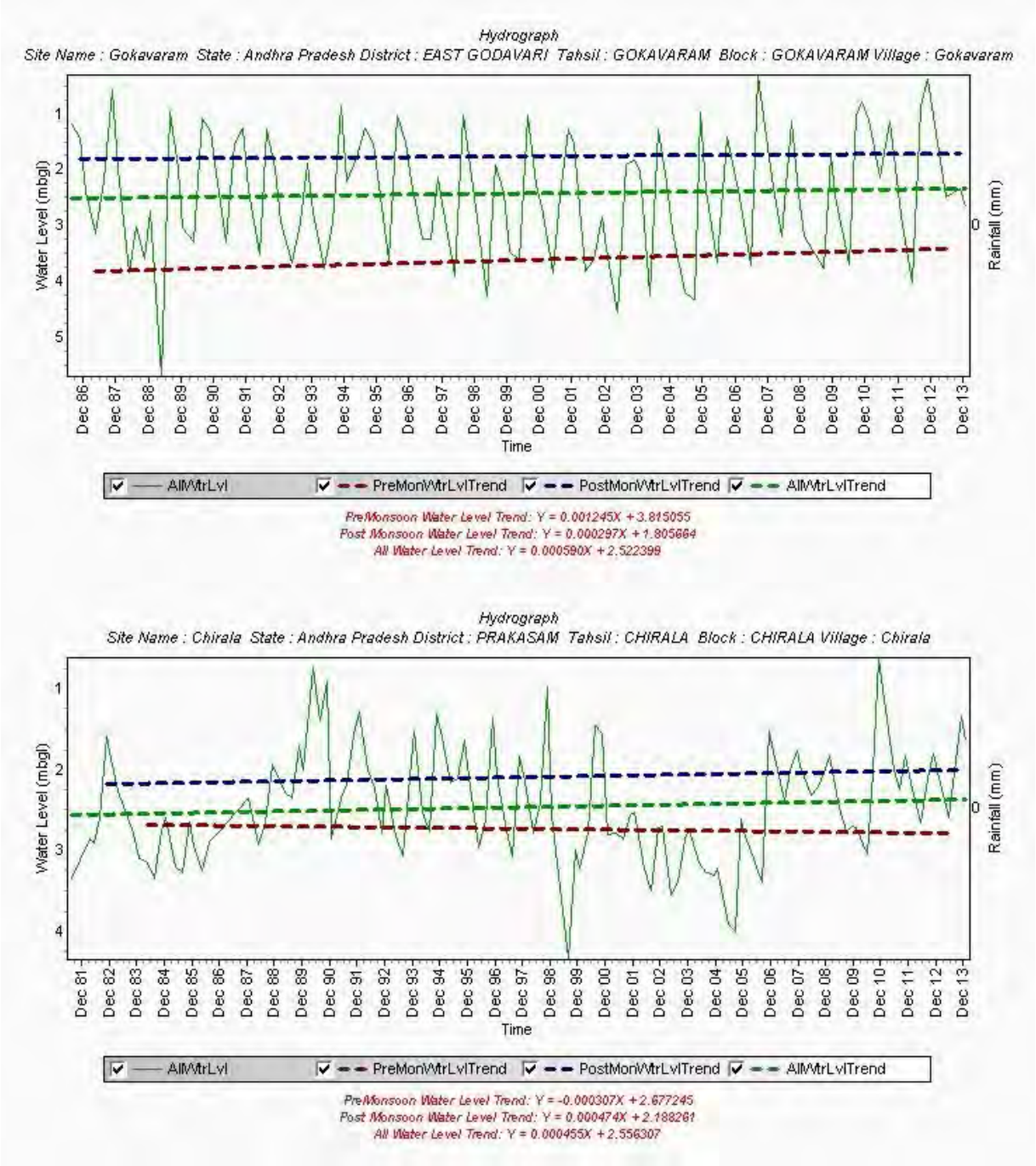
Fig.6.8

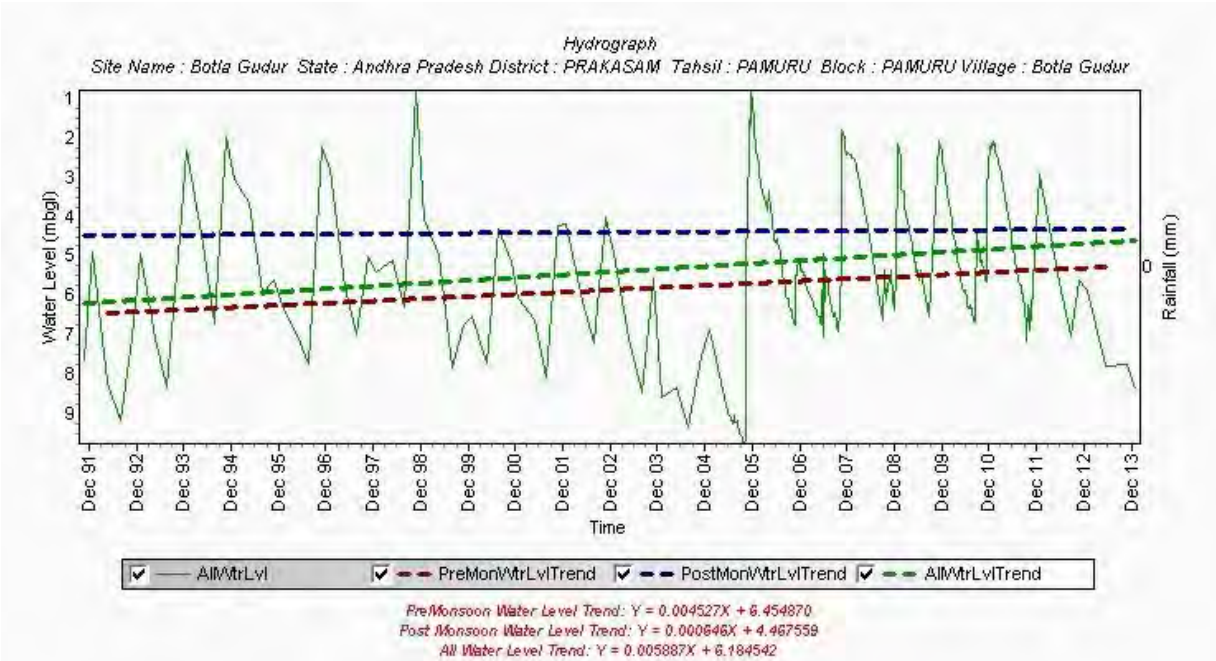


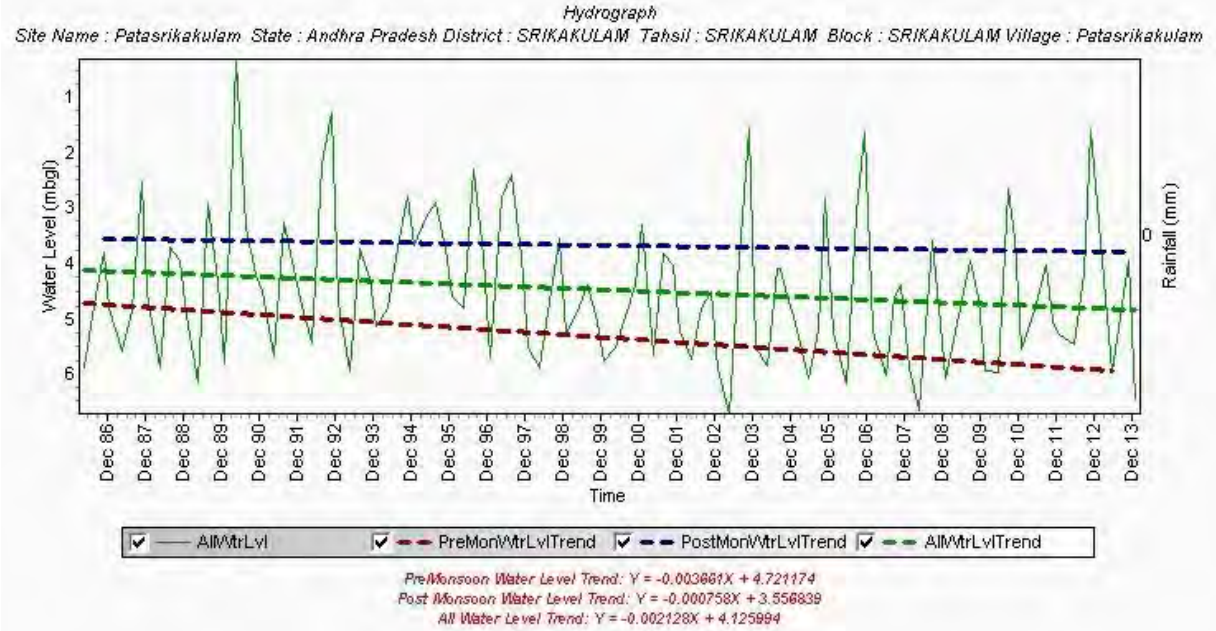
6.4. Hydrographs

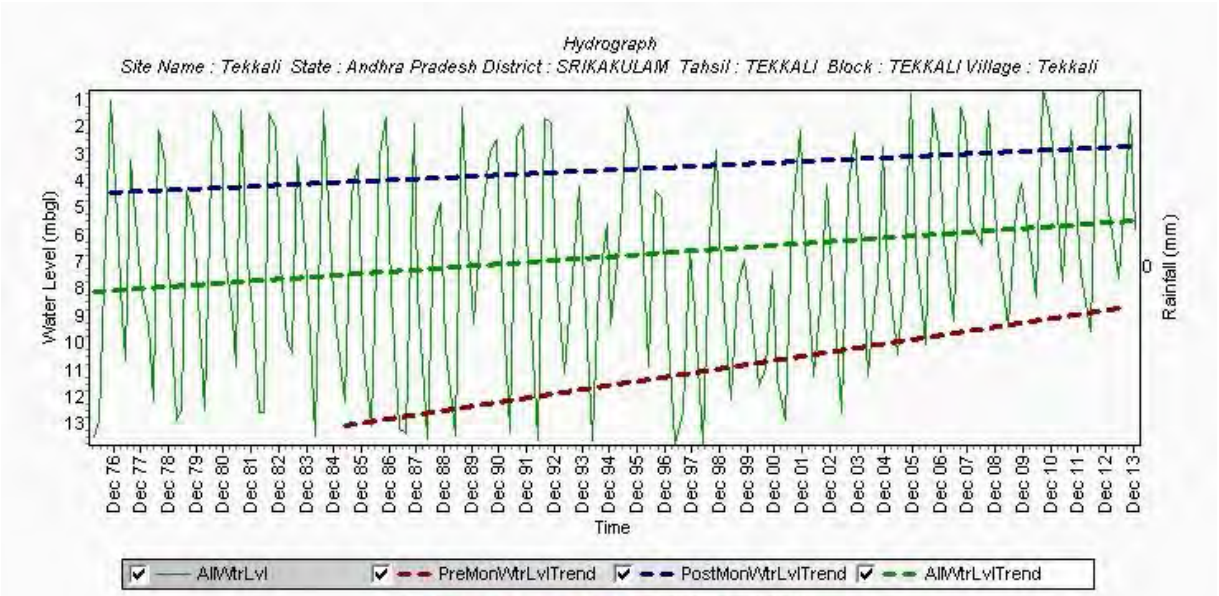
Variations in ground water level with time, due to recharge and discharge, is generally depicted in hydrographs. A study of long term water level trend for the last 15 to 25 years , indicate the annual and seasonal fluctuations. It depends on recharge factors such as rainfall, seepage from canals, irrigated areas, water storage bodies, etc. The fluctuations are observed to be high along drainage divides, upland areas and in chronically drought-affected areas. The fluctuations are minimum/low in low-lying, canal command and in coastal alluvial areas. The hydrographs of select wells have been depicted in the Fig.6.9. The water level trends during pre and post monsoon and for annual are presented in the Fig.6.10, 6.11 and 6.12.

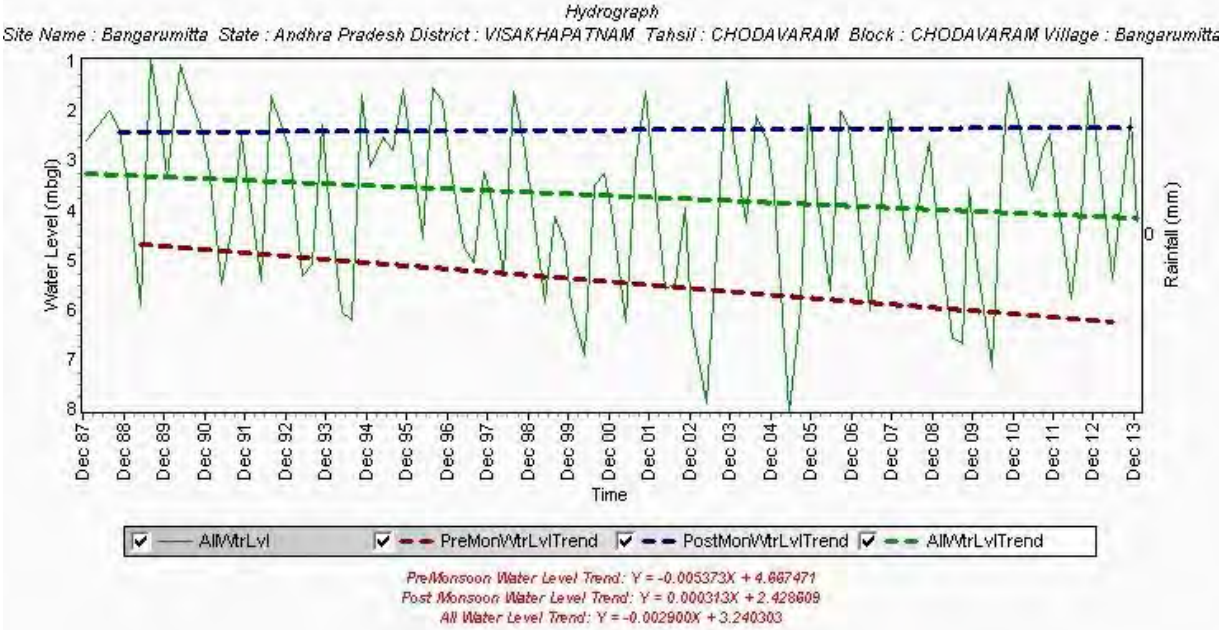
Fig.6.9
Hydrographs of select National Ground Water monitoring wells in Andhra Pradesh

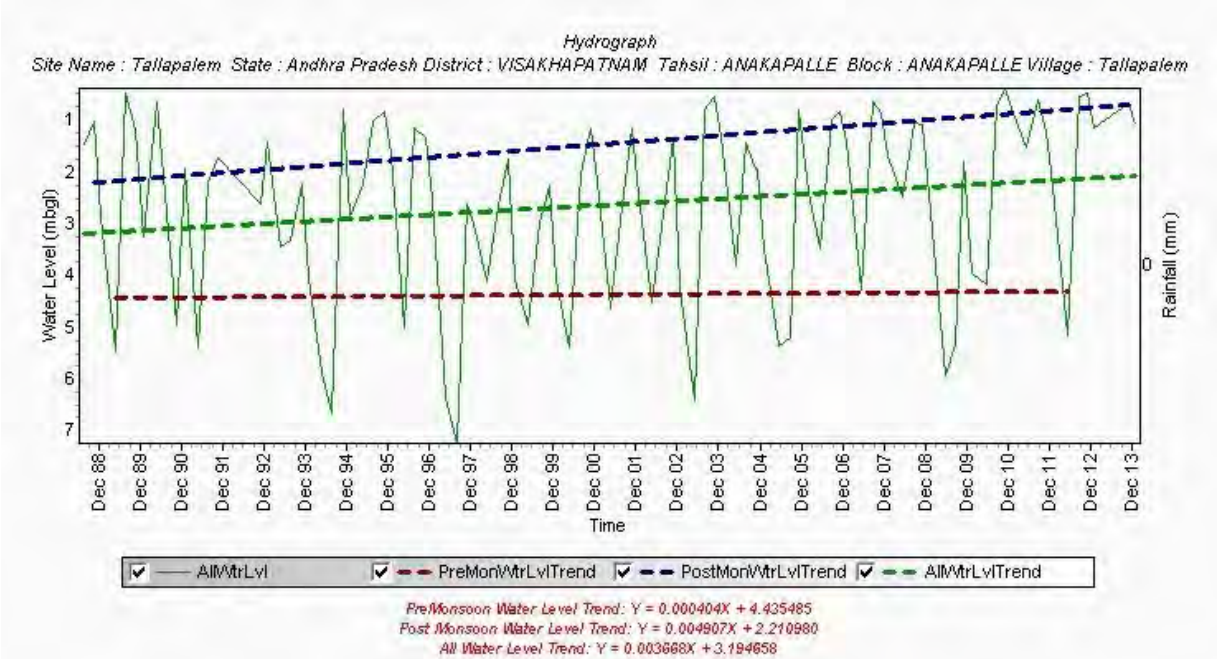


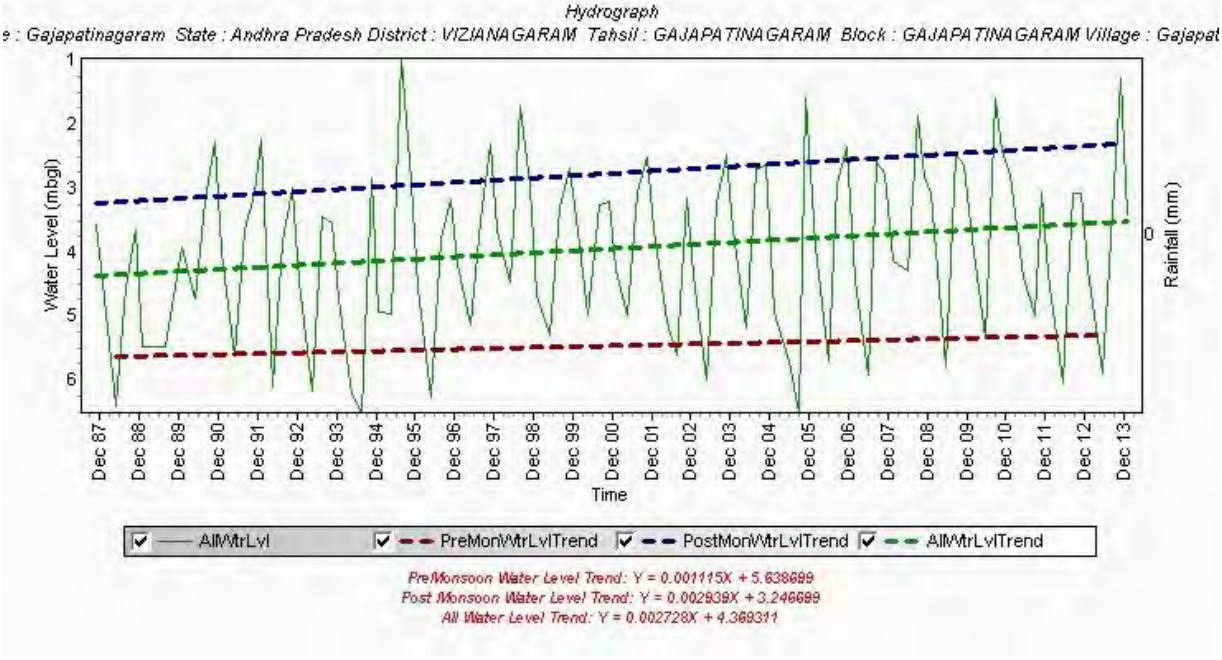

Hydrograph
Site Name : Botla Gudur State : Andhra Pradesh District : PRAKASAM Tahsil : PAMURU Block : PAMURU Village : Botla Gudur
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.004527X + 6.454870
Post Monsoon Water Level Trend: Y = 0.000646X + 4.467559
All Water Level Trend: Y = 0.005887X + 6.184542


Hydrograph
Site Name : Patasrikakulam State : Andhra Pradesh District : SRIKAKULAM Tahsil : SRIKAKULAM Block : SRIKAKULAM Village : Patasrikakulam
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.003661X + 4.721174
Post Monsoon Water Level Trend: Y = -0.000758X + 3.556839
All Water Level Trend: Y = -0.002128X + 4.125994


Hydrograph
Site Name : Tekkali State : Andhra Pradesh District : SRIKAKULAM Tahsil : TEKKALI Block : TEKKALI Village : Tekkali
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.012752X + 13.054380
Post Monsoon Water Level Trend: Y = 0.003813X + 4.459120
All Water Level Trend: Y = 0.005817X + 8.084830


Hydrograph
Site Name : Bangarumitta State : Andhra Pradesh District : VISAKHAPATNAM Tahsil : CHODAVARAM Block : CHODAVARAM Village : Bangarumitta
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.005373X + 4.667471
Post Monsoon Water Level Trend: Y = 0.000313X + 2.428609
All Water Level Trend: Y = -0.002900X + 3.240303


Hydrograph
Site Name : Tallapalem State : Andhra Pradesh District : VISAKHAPATNAM Tahsil : ANAKAPALLE Block : ANAKAPALLE Village : Tallapalem
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.000404X + 4.435485
Post Monsoon Water Level Trend: Y = 0.004907X + 2.210980
All Water Level Trend: Y = 0.003668X + 3.194658


Hydrograph
e : Gajapatinagaram State : Andhra Pradesh District : VIZIANAGARAM Tahsil : GAJAPATINAGARAM Block : GAJAPATINAGARAM Village : Gajapat
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.001115X + 5.638699
Post Monsoon Water Level Trend: Y = 0.002939X + 3.246699
All Water Level Trend: Y = 0.002728X + 4.369311

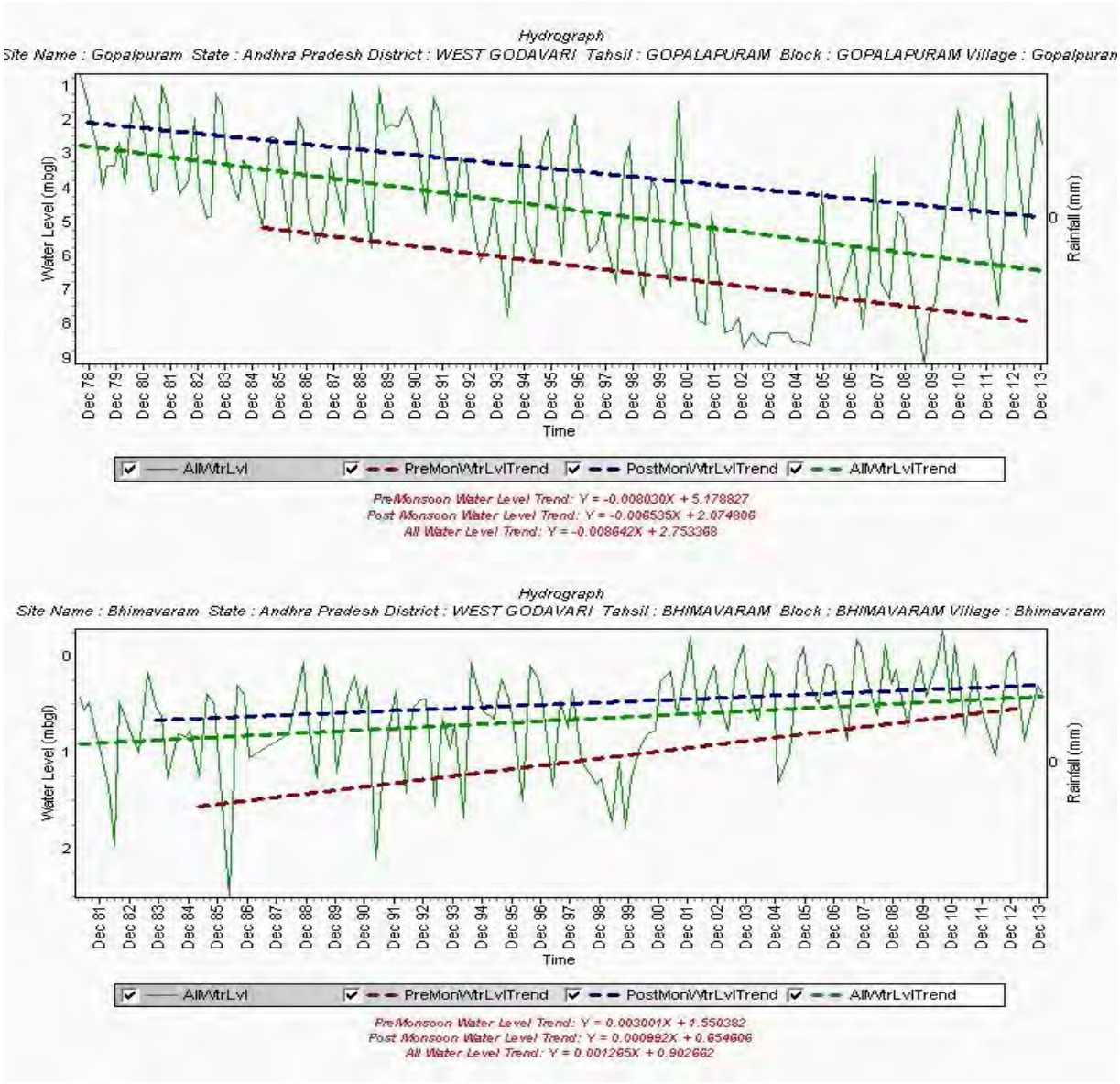

Hydrograph
Site Name : Gopalpuram State : Andhra Pradesh District : WEST GODAVARI Tahsil : GOPALAPURAM Block : GOPALAPURAM Village : Gopalpuram
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.008030X + 5.178827
Post Monsoon Water Level Trend: Y = -0.006535X + 2.074806
All Water Level Trend: Y = -0.008642X + 2.753368
Hydrograph
Site Name : Bhimavaram State : Andhra Pradesh District : WEST GODAVARI Tahsil : BHIMAVARAM Block : BHIMAVARAM Village : Bhimavaram
Water Level (mbgl)
Rainfall (mm)
Time
AllWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
AllWtrLvlTrend
PreMonsoon Water Level Trend: Y = 0.003001X + 1.550382
Post Monsoon Water Level Trend: Y = 0.000992X + 0.654606
All Water Level Trend: Y = 0.001265X + 0.902662

Fig.6.10

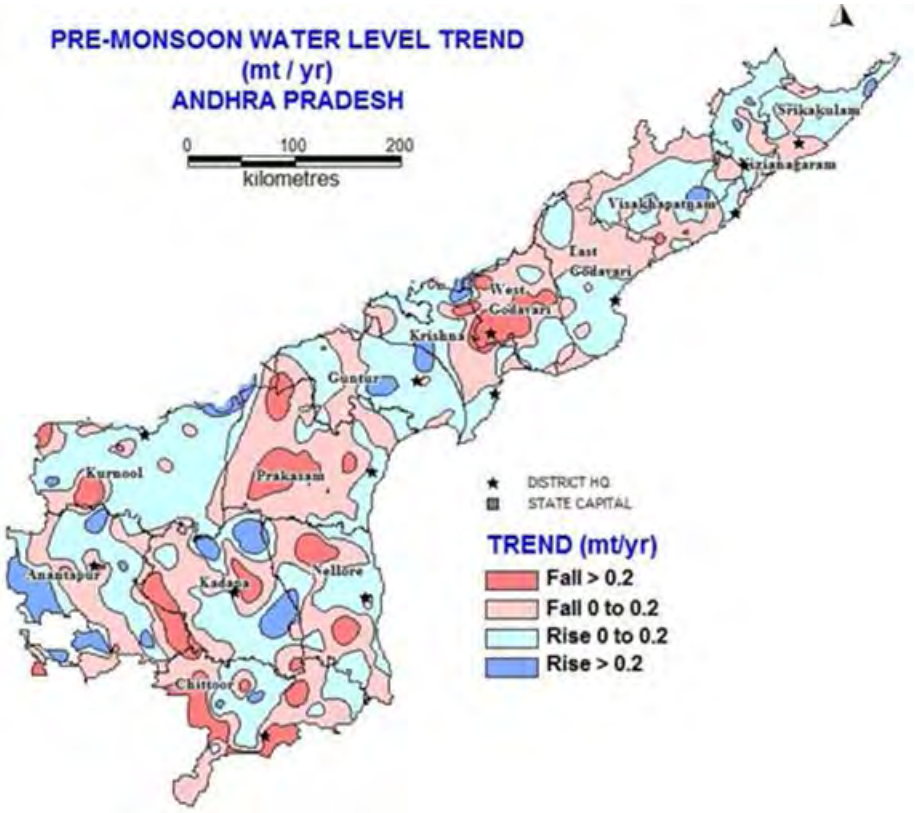


Fig.6.11

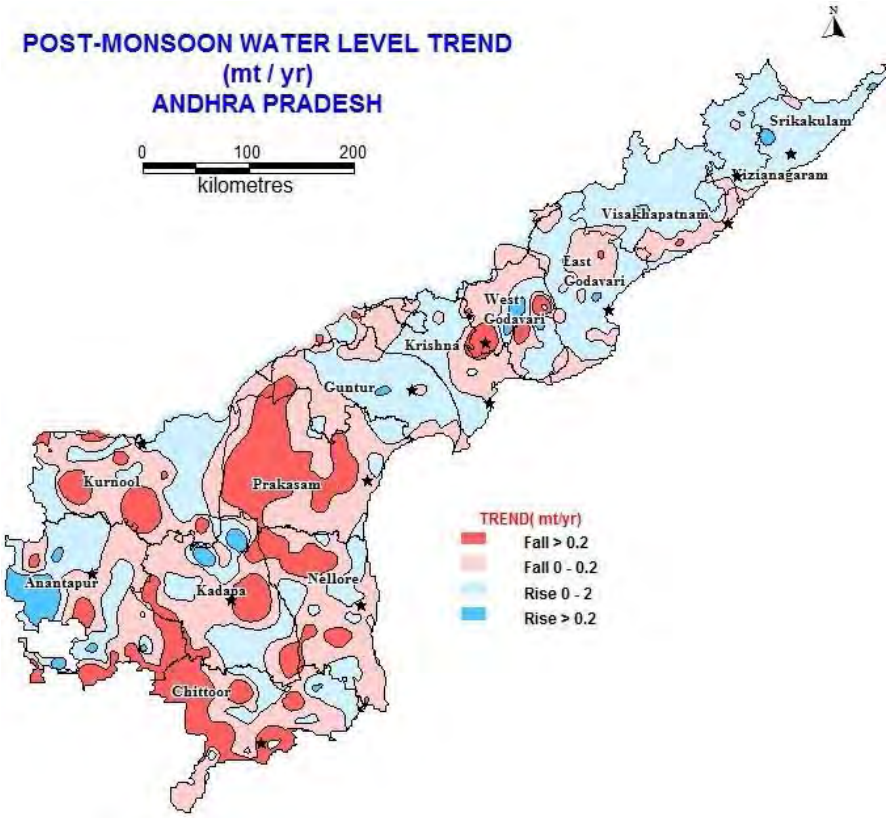
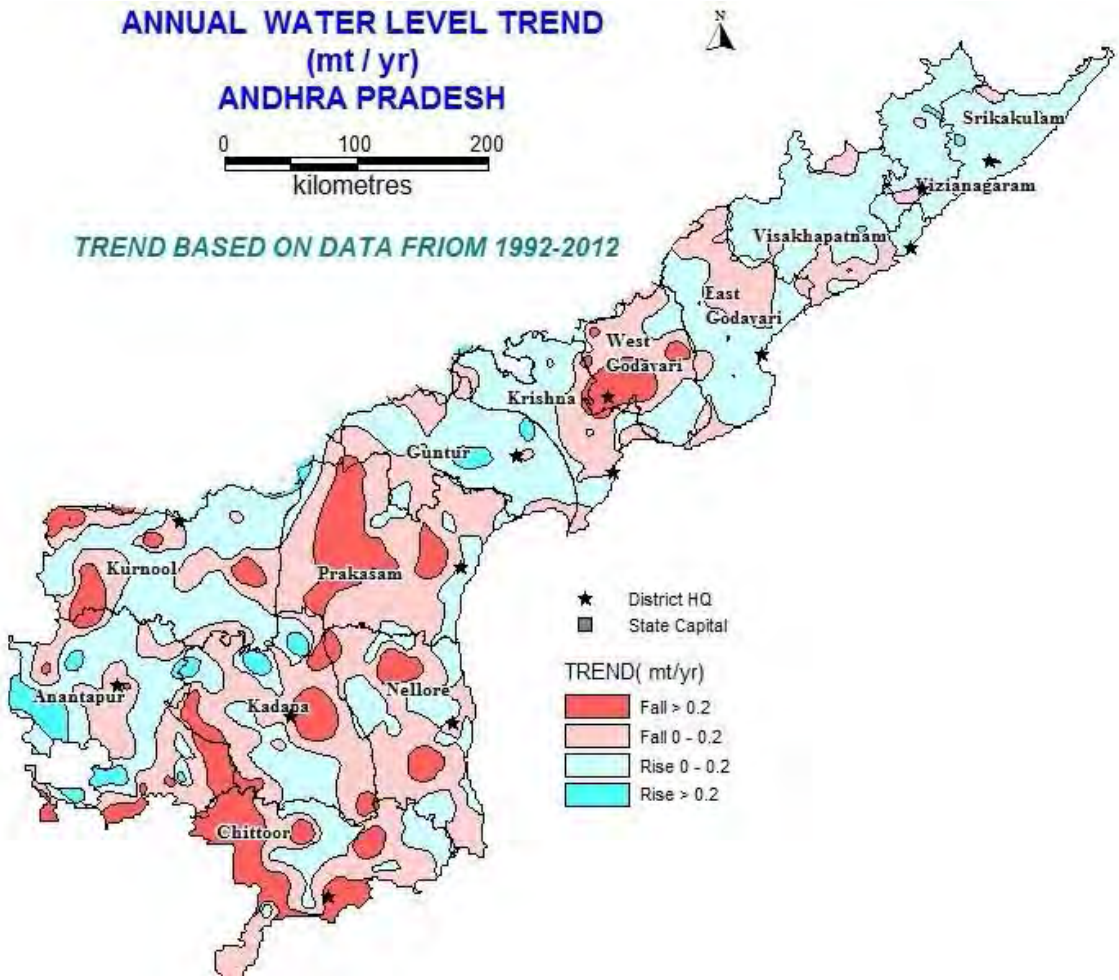


Fig.6.12



6.5 Water Level Fluctuation

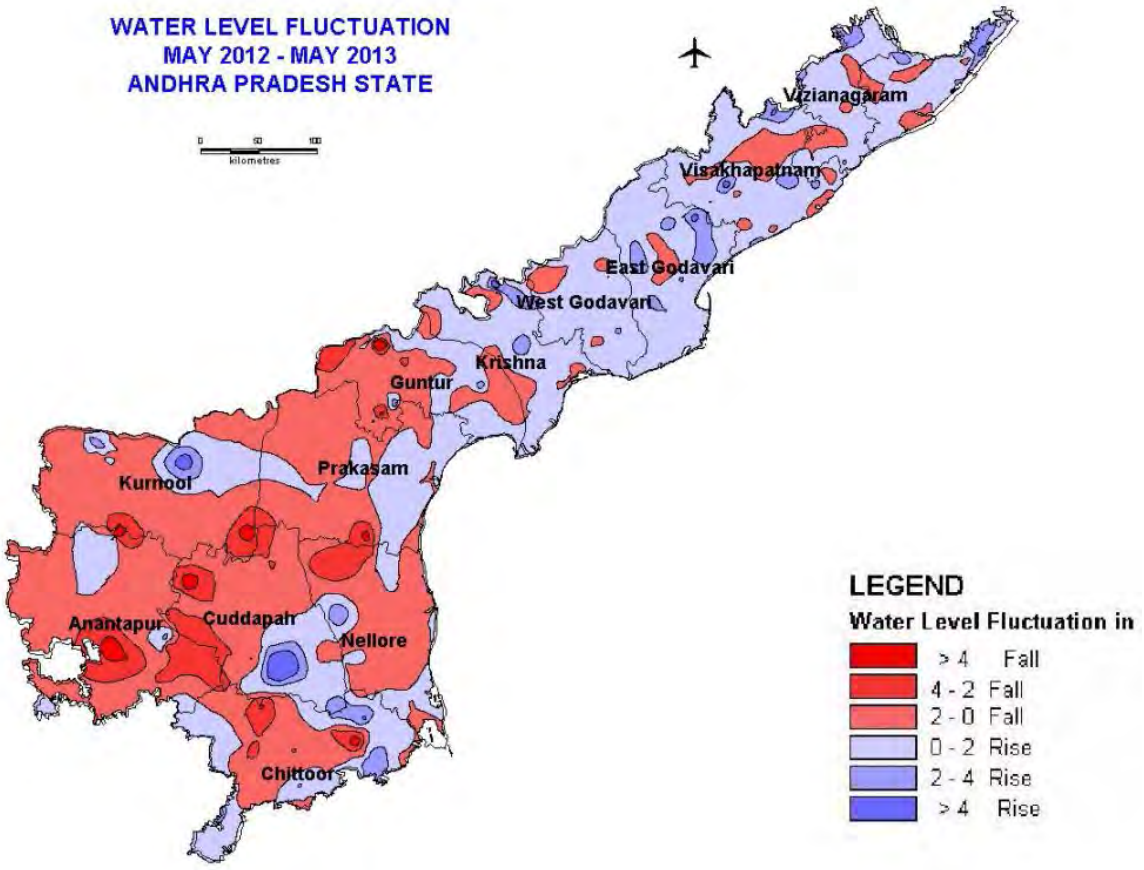
The periodic monitoring of Ground Water Monitoring Wells depicts long term seasonal and annual trend changes due to ground water withdrawal, canal seepage, and other input and output components.

6.5.1 Water Level Fluctuation - May 2013 vs May 2012

Fluctuation of water levels during May, 2013 with reference to May, 2012 is depicted in Fig.6.13. A perusal of the map (Fig.6.13) shows a predominant rise of water levels in the State.

Rise in water level of < 2 m is observed at few locations in Nellore, Prakasham, Guntur districts and in major parts of all other districts of Coastal Region. It is also observed in major parts of Chittoor and in few locations in other districts of Rayalaseema. Rise of 2-4 m is observed in small parts of coastal region except West Godavari and Prakasham.

Fig.6.13



More than 4m zone is observed in small areas of Kurnool, Kadapa, Chittoor district of Rayalaseema Region, and in Vishakapatnam, East Godavari, Krishna and Guntur districts in coastal region.

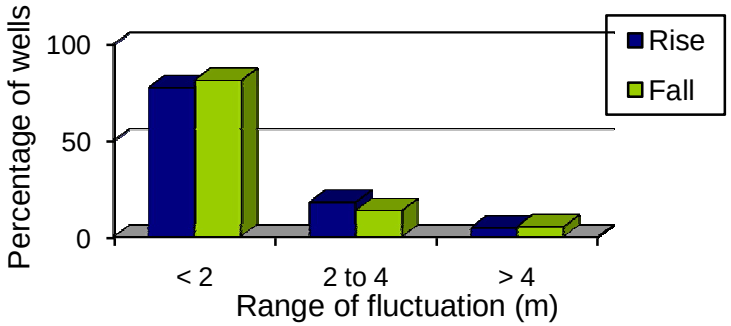
Fall in water levels of less than 2m is observed in considerable areas of Nellore, Prakasham, Guntur and in small parts of all other districts of Coastal Region, in major parts of all districts of Rayalaseema region. Fall of 2-4 m zone is noticed in small parts of all districts of Rayalaseema Region and as small isolated areas in Nellore, Prakasham, Guntur and Krishna districts of Coastal Region. More than 4 m water level fall is observed in small parts of all district of Rayalaseema Region and in small areas of Prakasham, Guntur and Krishna districts in Coastal Region.

Water level fluctuation data of between May 2013 and May 2012 is presented in the Table- 6.6**.** An analysis of data of 368 wells shows that water level rise is recorded in 50.95% wells (172), water level fall is recorded in 41.55% wells (169), while in the rest, 7.5 % wells (50) no fluctuation is recorded.

Table-6.6
Fluctuation and frequency distribution of different ranges May, 2013 and May, 2012

Sl. No	District	No of Wells Analysed	Range of Fluctuation (m)				No of Wells/ Percentage Showing Fluctuation													
			Rise		Fall		Rise						Fall						Total No. of Wells	
							0 to 2		2 to 4		> 4		0 to 2		2 to 4		> 4			
			Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%	Rise	Fall
1	Anantapur	28	0.39	2.45	0.23	5.41	3	10.71	2	7.14	0	0	8	28.57	8	28.57	2	7.14	5	18
2	Chittoor	33	0.24	4.28	0.3	5.0	8	24.24	3	9.09	1	3.03	10	30.30	3	9.09	2	6.06	12	15
3	East Godavari	30	0.01	4.78	0.11	1.73	17	56.67	7	23.33	1	3.33	3	10.0	0	0	0	0	25	3
4	Guntur	43	0.07	3.2	0.05	9.02	15	34.88	2	4.65	0	0	21	48.84	2	4.65	2	4.65	17	25
5	Krishna	24	0.09	5.73	0.06	2.17	12	50.0	2	8.33	1	4.17	7	29.17	1	4.17	0	0	15	8
6	Kurnool	23	0.35	5.14	0.05	4.75	4	17.39	1	4.35	1	4.35	14	60.87	0	0	1	4.35	6	15
7	Nellore	31	0.07	3.32	0.02	3.48	7	22.58	1	3.23	0	0	21	67.74	2	6.45	0	0	8	23
8	Prakasham	31	0.06	1.94	0.03	4.79	10	32.26	0	0	0	0	15	48.39	1	3.23	1	3.23	10	17
9	Srikakulam	24	0.08	5.24	0.08	1.19	10	41.67	3	12.5	1	4.17	9	37.5	0	0	0	0	14	9
10	Visakhapatnam	36	0.06	5.15	0.03	2.01	19	52.78	3	8.33	2	5.56	11	30.56	1	2.78	0	0	24	12
11	Vizianagaram	25	0.02	3.58	0.01	1.1	15	60.0	3	12.0	0	0	7	28.0	0	0	0	0	18	7
12	West Godavari	19	0.16	3.6	0.1	1.94	12	63.16	3	15.79	0	0	4	21.05	0	0	0	0	15	4
13	YSR Kadapa	21	0.92	8.48	0.29	5.5	1	4.76	1	4.76	1	4.76	7	33.33	5	23.81	1	4.76	3	13
Total State		368	0.01	8.48	0.01	9.02	133	36.1	31	8.4	8	2.2	137	37.2	23	6.3	9	2.4	172	169

Fig. 6.14
Categorisation of fluctuation of water levels (May 2013 - May 2012)



Water level rise of less than 2 m is recorded in 36.1% wells, in the range of 2-4 m in 8.4% wells and rise of more than 4 m is recorded in 2.2% wells. Fall of Water level, less than 2 m range is recorded in 37.2% wells, 2-4 m range in 6.3% and fall of more than 4 m is registered in 2.4% wells. Water level rise of more than 4 m is recorded maximum in Vishakhapatnam (5.56 % wells) while fall of more than 4 m is registered maximum in Anantpur district (7.14 % of wells).

Rise

Out of 172 wells that have registered rise in water levels, 77.3% wells are in the range of less than 2 m, 18% wells in the range of 2 to 4 m while the rest of 4.7% wells recorded rise of more than 4 m.

Fall

Of the 169 wells that have registered fall in water levels, 81.1% have recorded less than 2 m fall, 13.6% wells in the range of 2-4 m and the rest of 5.3% wells registered water level fall of more than 4 m.

6.5.2 November, 2013 Vs May, 2013

Fluctuation of water levels during November 2013 with reference to May 2013 is depicted in Fig.6.15 and categorization of water level fluctuation is shown in the Fig.6.15A. A perusal of the map shows that dominantly there is rise in water levels in the State. Rise in water level of less than 2 m is observed in major parts of Nellore, Prakasham, Guntur, in small areas in other districts of Coastal region, and in major parts of all districts of Rayalaseema region.

Water level rise of 2-4 m is observed in major parts of Prakasham, East Godavari, West Godavari, Krishna, Guntur districts, in small areas of all other districts in Coastal region and in few locations of all districts of Rayalaseema region. Rise of water level more than 4 m is observed in small areas of Kurnool, Ananthapur, Kadapa, Chittoor districts of Rayalaseema, In major parts of Srikakulam, Vizianagaram, Vishakapatnam, East Godavari, West Godavari, Krishna districts and in small parts of Guntur, Prakasham districts of coastal region.

Fall in water levels of less than 2 m is observed in major parts of Nellore, small parts of Prakasham districts in Coastal region, in small parts of all districts of Rayalaseema region. Water level fall of 2-4 m is noticed in small parts of Ananthapur, Kadapa and Kurnool districts of Rayalaseema, in small parts of Nellore district in Coastal region. Water Level Fall of more than 4 m observed in small parts of Ananthapur, Kadapa and Kurnool districts of Rayalaseema region.
Water level fluctuation data of May 2013-November 2013 is presented in the Table-6.7**.** An analysis of data of 560 wells shows that water level rise is recorded in 94.28% wells (528), water level fall is recorded in 6.79% wells (46), while in the rest, 5.72% wells (27) no fluctuation is recorded. Water level rise of less than 2 m is recorded in 38.4% wells in the range of 2-4 m in 31.1% wells and rise of more than 4 m is recorded in 24.8% wells. Water level fall of less than 2 m is recorded in 4.3% wells in the range of 2-4 m in 0.5%. Water level rise of more than 4 m is recorded maximum in Anantpur district (47.06% wells).

Fig.6.15

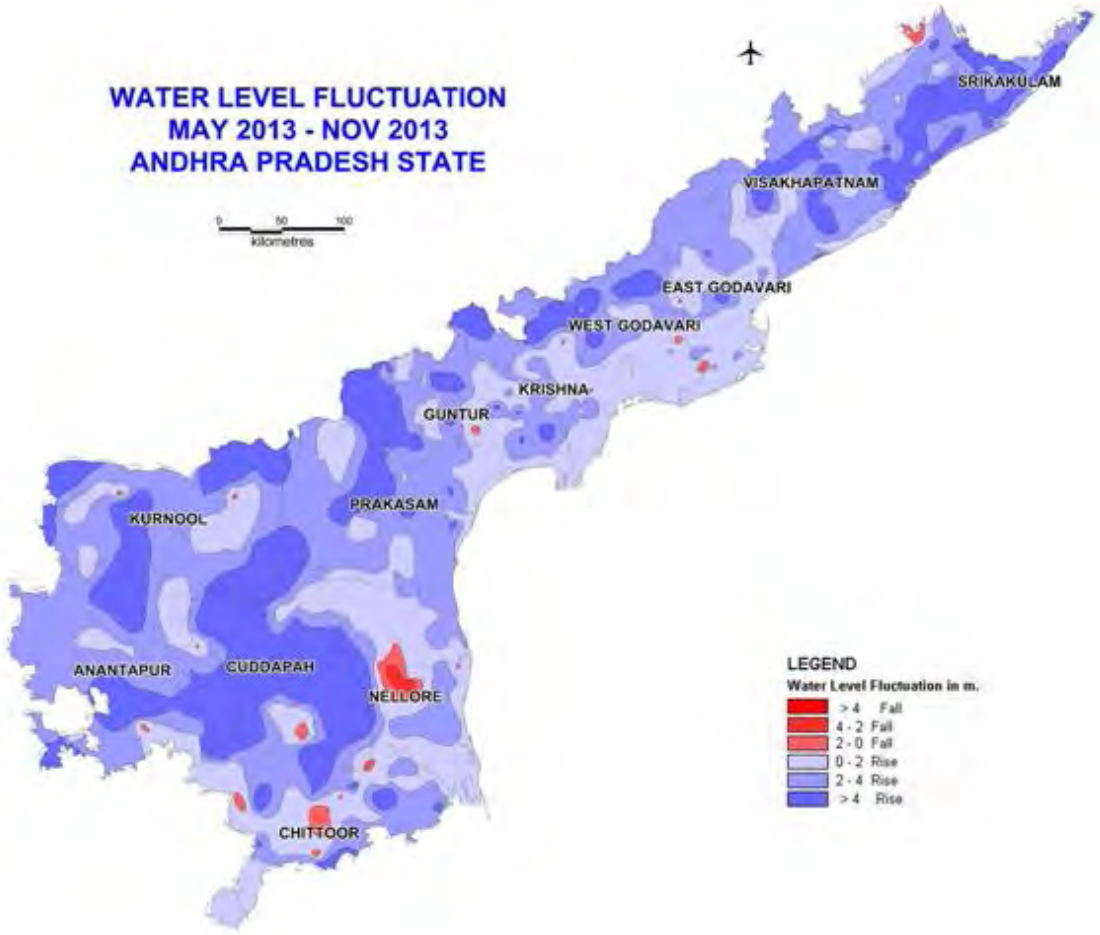


Fig.6.15A
Categorisation of fluctuation of
water levels (May 2013 - November 2013)

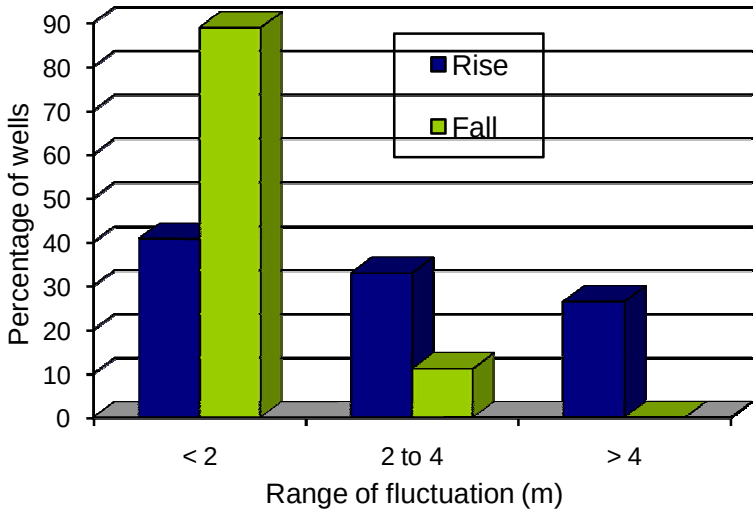


Table - 6.7
Fluctuation and frequency distribution of different ranges - November, 2013 and May, 2013

Sl. No	District	No of Wells Analysed	Range of Fluctuation (m)				No of Wells / Percentage Showing Fluctuation													
			Rise		Fall		Rise						Fall						Total No. of Wells	
							0 to 2		2 to 4		> 4		0 to 2		2 to 4		> 4			
			Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%	Rise	Fall
1	Anantapur	34	0.12	22.6	0.6	0.6	7	20.59	8	23.53	16	47.06	1	2.94	0	0	0	0	31	1
2	Chittoor	43	0.17	10.6	0.15	1.7	18	41.86	13	30.23	7	16.28	5	11.63	0	0	0	0	38	5
3	East Godavari	57	0.02	5.74	1.19	1.66	36	63.16	17	29.82	2	3.51	2	3.51	0	0	0	0	55	2
4	Guntur	72	0.15	12.39	0.48	0.48	33	45.83	20	27.78	18	25.0	1	1.39	0	0	0	0	71	1
5	Krishna	48	0.36	7.8	0.19	0.49	22	45.83	15	31.25	9	18.75	2	4.17	0	0	0	0	46	2
6	Kurnool	29	0.55	11.78	0.65	2.44	9	31.03	6	20.69	12	41.38	1	3.45	1	3.45	0	0	27	2
7	Nellore	42	0.56	4.09	0.17	3.72	21	50.0	12	28.57	1	2.38	5	11.9	2	4.76	0	0	34	7
8	Prakasham	49	0.04	23.87	0.13	0.13	16	32.65	22	44.9	8	16.33	1	2.04	0	0	0	0	46	1
9	Srikakulam	33	0.82	8.65	0	0	5	15.15	13	39.39	15	45.45	0	0	0	0	0	0	33	0
10	Visakhapatnam	58	0.1	11.98	0	0	22	37.93	18	31.03	18	31.03	0	0	0	0	0	0	58	0
11	Vizianagaram	35	1.32	7.18	1.01	1.01	4	11.43	15	42.86	15	42.86	1	2.86	0	0	0	0	34	1
12	West Godavari	35	0.27	7.21	0.25	0.63	17	48.57	9	25.71	7	25.0	2	5.71	0	0	0	0	33	2
13	YSR Kadapa	25	0.15	12.43	0.3	1.2	5	20.0	6	24.0	11	44.0	3	12.0	0	0	0	0	22	3
Total State		560	0.02	23.87	0	3.72	215	38.4	174	31.1	139	24.8	24	4.3	3	0.5	0	0	528	27

Rise

Out of the 528 wells that have registered a rise in water levels, 40.7% wells recorded water level rise of less than 2 m, 32.9% wells in the range of 2 to 4 m while the rest 26.4% wells recorded water level rise of more than 4 m.

Fall

Of the 27 wells that have registered fall in water levels, majority of them (88.9%) have recorded less than 2 m fall, in the range of 2-4 m in 11.1% wells while water level fall of more than 4 m is not recorded in any wells.

6.5.3 January 2014 Vs. May 2013

Fluctuation of water levels in January 2014 with reference to May 2013 is depicted in the Fig.6.16 and categorization of water level fluctuation is presented in the Fig.6.17. A perusal of the map shows that dominantly there is rise in water levels in the State.

Rise in water level of less than 2 m is observed in major parts of all districts in coastal region. It is also observed in major areas of Chittoor, Ananthpur, Kurnool and in small part of Kadapah district of Rayalaseema region. 2-4 m zone is observed in major areas of Prakasham, in small areas of all other districts of coastal region, in major part of Kurnool district and as small isolated areas in all other districts of Rayalaseema region. Rise of Water level more than 4 m is observed in major part of Kadapa district and small parts of all other districts of Rayalaseema, in small areas of all districts of coastal region.

Fall in water levels of less than 2 m is observed in small parts of East Godavari, Krishna, Prakasham, Visakhapatnam, Vizianagaram, Srikakulam districts of Coastal region and in small parts of all districts in Rayalaseema region. Water level fall of 2-4 m is noticed in areas of Chittoor, Kadapa districts of Rayalaseema and in few locations of Nellore, Visakhapatnam, Vizianagaram, Srikakulam districts in Coastal region. Fall of more than 4 m observed in few areas of Chittoor, district of Rayalaseema region.

Water level fluctuation data of January 2014 - May 2013 is presented in the Table-6.8. An analysis of data of 560 wells shows that water level rise is recorded in 89.28% wells (500), water level fall is recorded in 8.57% wells (48), while in the rest, 2.15% wells (12) no fluctuation is recorded.

Water level rise of less than 2 m is recorded in 51% wells in the range of 2-4 m in 24.4% wells and rise of more than 4 m is recorded in 13.75% wells. Water level fall of less than 2 m is recorded in 6.4% wells in the range of 2-4 m in 1.6% and water level fall of more than 4 m is registered in 0.5% wells. Water level rise of more than 4 m is recorded maximum in Anantapurdistrict (32.35% wells) while water level fall of more than 4 m is registered maximum in Chitoor district (7.69%) wells.

Rise

Out of the 500 wells that have registered a rise in water levels, 57.2% wells recorded rise of less than 2 m, 27.4% wells in the range of 2 to 4 m while 15.4% wells recorded rise of more than 4 m.

Fall

Of the 48 wells that have registered fall in water levels, majority of them (75%) have recorded less than 2 m fall, 18.8% wells in the range of 2-4 m and the 6.2% wells registered fall of more than 4 m.

Fig.6.16

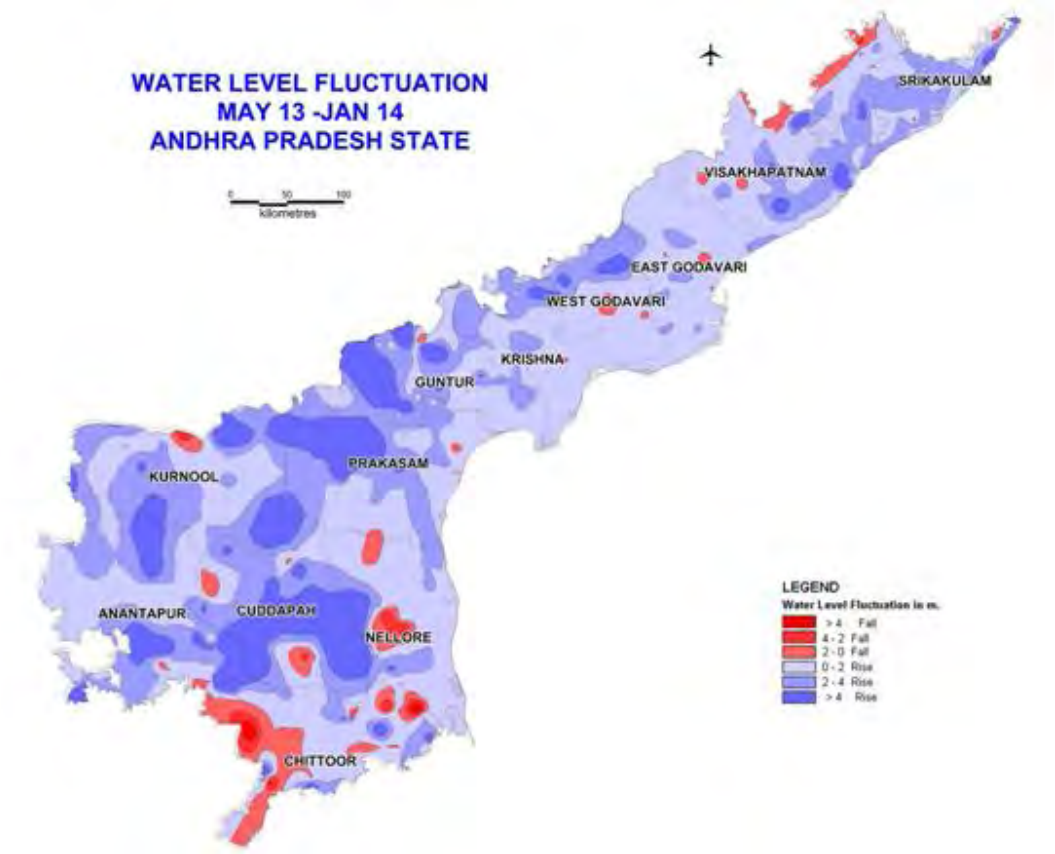


Fig.6.17
Categorisation of fluctuation of water levels (January, 2013 -May, 2014)

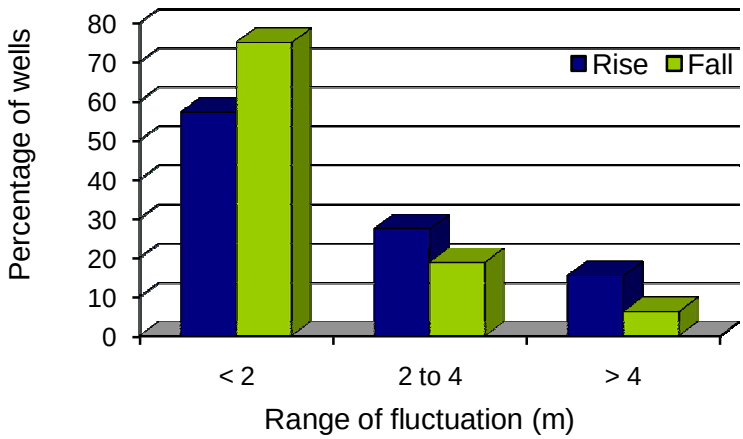


Table-6.8
District Wise Fluctuation & Frequency Distribution of Ranges
January, 2014 to May, 2013

Sl. No	District	No of Wells Analysed	Range of Fluctuation (m)				No of Wells / Percentage Showing Fluctuation													
			Rise		Fall		Rise						Fall						Total No. of Wells	
							0 to 2		2 to 4		> 4		0 to 2		2 to 4		> 4			
			Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%	Rise	Fall
1	Anantapur	34	0.28	21.2	0.8	0.8	14	41.18	5	14.71	11	32.35	1	29.94	0	0	0	0	30	1
2	Chittoor	39	0.03	6.12	0.08	6.43	12	30.77	4	10.26	6	15.38	8	20.51	2	5.13	3	7.69	22	13
3	East Godavari	57	0.16	3.58	0.16	1.45	45	78.95	9	15.79	0	0	3	5.26	0	0	0	0	54	3
4	Guntur	77	0.19	11.17	0	0	39	50.65	25	32.47	13	16.88	0	0	0	0	0	0	77	0
5	Krishna	42	0.03	5.09	0.55	0.55	29	69.05	11	26.19	1	2.38	1	2.38	0	0	0	0	41	1
6	Kurnool	31	0.21	10.23	0.13	0.13	12	38.71	9	29.03	9	29.03	1	3.23	0	0	0	0	30	1
7	Nellore	45	0.15	5.5	0.1	3.72	29	64.44	8	17.78	2	4.44	3	6.67	2	4.44	0	0	39	5
8	Prakasham	51	0.05	20.95	0.56	1.07	23	45.1	18	35.29	5	9.8	2	3.92	0	0	0	0	46	2
9	Srikakulam	32	0.02	5.4	0.01	2.13	10	31.25	13	40.63	5	15.63	3	9.38	1	3.13	0	0	28	4
10	Visakhapatnam	59	0.09	11.43	0.05	2.38	27	45.76	14	23.73	9	15.25	7	11.86	2	3.39	0	0	50	9
11	Vizianagaram	35	0.33	5.68	0.02	2.2	15	42.86	14	40.0	3	8.57	2	5.71	1	2.86	0	0	32	3
12	West Godavari	34	0.1	6.74	0.92	1.45	24	70.59	4	11.76	4	11.76	2	5.88	0	0	0	0	32	2
13	YSR Kadapa	24	0.29	12.09	0.51	2.62	7	29.17	3	12.5	9	37.5	3	12.5	1	4.17	0	0	19	4
Total State		560	0.02	21.2	0	6.43	286	51.0	137	24.4	77	13.75	36	6.4	9	1.6	3	0.5	500	48

6.5.3 Water Level Fluctuation – November, 2013 with November, 2012

Fluctuation of water levels in November 2013 with reference to November 2012 is depicted in Fig.6.18.The categorization of water level fluctuation is shown in the Fig.6.19. A perusal of the map shows rise in water levels in the State. Rise in water level of less than 2 m is observed in small areas of Nellore district, in major parts of all other districts in Coastal region, in major parts of Chittoor and small parts of all other districts of Rayalaseema region.

Rise of 2-4 m is observed in small areas in coastal region except Nellore district, few locations in Ananthapur, Kadapa and Chittoor districts of Rayalaseema region. More than 4 m rise is observed in small areas of Vishakapatnam, East Godavari and Guntur districts in Coastal region.

Fall in water levels of less than 2 m is observed in major parts of Nellore, Prakasham, few locations in Guntur, Krishna, East Godavari, Vishakapatnam districts of Coastal region, major parts of all districts in Rayalaseema region.

Water level fall of 2-4 m is noticed in small parts in Nellore, Prakasham, Guntur districts of Coastal region, Major parts of Kadapa and small parts all other districts of Rayalaseema Region.

Fall of Water level more than 4 m noticed in small parts of all districts of Rayalaseema region, Small parts Nellore district of Coastal region.

Water level fluctuation data of November 2013-November 2012 is presented in the Table-6.9**.** An analysis of data of 381 wells shows that water level rise is recorded in 45.93% wells (175), fall is recorded in 52.49% wells (200), fluctuation is nil in 1.58% wells (06).

Water level rise of less than 2 m is recorded in 34.8% wells, 2-4 m range in 6.1% wells and rise of more than 4 m is recorded in 5% wells. Fall of less than 2 m is recorded in 46.0% wells, 2-4 m range in 4.7% and fall of more than 4 m is registered in 1.8% wells. Water level rise of more than 4 m is recorded maximum in YSR Kadappa district (31.58% wells) while fall of more than 4 m is registered maximum in YSR Kadapa and West Godavari district (5.26% wells).

Rise

Out of the 175 wells, registered a rise in water levels, 74.3% wells recorded water level rise of less than 2 m, 14.8% wells in the range of 2 to 4, 10.9% wells recorded water level rise of more than 4 m.

Fall

Of the 200 wells, registered fall in water levels, majority of them (87.5%) have recorded less than 2 m fall, in the range of 2-4 m in 9% wells and 3.5% wells registered fall of more than 4 m.

Fig.6.18

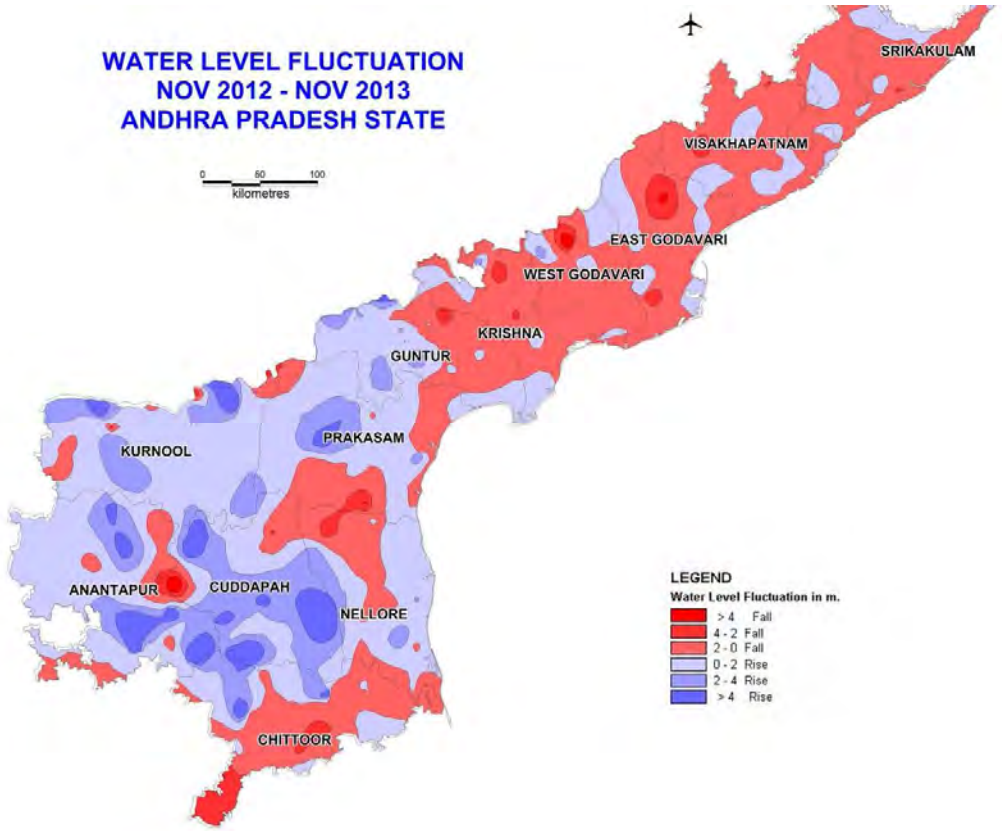


Fig.6.19
Categorisation of fluctuation of
water levels (November 2013 - November 2012)

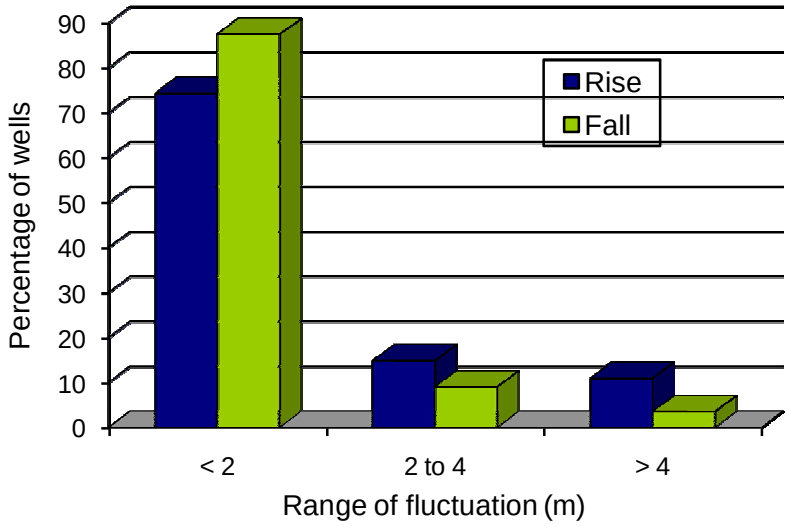


Table – 6.9
District wise fluctuation and frequency distribution of different water level ranges
November, 2013 to November, 2012

Sl. No	District	No of Wells Analysed	Range of Fluctuation (m)				No of Wells / Percentage Showing Fluctuation													
			Rise		Fall		Rise						Fall						Total No. of Wells	
							0 to 2		2 to 4		> 4		0 to 2		2 to 4		> 4			
			Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%	Rise	Fall
1	Anantapur	29	0.08	12	0.11	1.68	10	34.48	3	10.34	7	24.14	7	24.14	0	0	0	0	20	7
2	Chittoor	32	0.01	7.92	0.1	4.06	8	25.0	1	3.13	3	9.38	15	46.88	4	12.5	1	3.13	12	20
3	East Godavari	39	0.01	1.58	0.05	4.47	9	23.08	0	0	0	0	24	61.54	3	7.69	2	5.13	9	29
4	Guntur	37	0.03	3.77	0	2.86	13	35.14	8	21.62	0	0	15	40.54	1	2.7	0	0	21	16
5	Krishna	23	0.06	3.37	0.08	3.7	4.0	17.39	1	4.35	0	0	14	60.87	3	13.04	0	0	5	17
6	Kurnool	24	0.07	6.6	0.15	3.12	12	50.0	5	20.83	2	8.33	3	12.5	2	8.33	0	0	19	5
7	Nellore	29	0.05	3.19	0.04	2.29	15	51.72	3	10.34	0	0	10	34.48	1	3.45	0	0	18	11
8	Prakasham	35	0.02	4.94	0.14	4.17	16	45.71	2	5.71	1	2.86	14	40.0	1	2.86	1	2.86	19	16
9	Srikakulam	22	0.15	1.19	0.11	2.33	5	22.73	0	0	0	0	16	72.73	1	4.55	0	0	5	17
10	Visakhapatnam	48	0.01	2.73	0.03	4.63	20	41.67	1	2.08	0	0	23	47.92	1	2.08	1	2.08	21	25
11	Vizianagaram	25	0.03	1.8	0.02	1.92	7	28.0	0	0	0	0	18	72.0	0	0	0	0	7	18
12	West Godavari	19	0.01	3.25	0.1	6.66	4	21.05	1	5.26	0	0	13	68.42	0	0	1	5.26	5	14
13	YSR Kadapa	19	0.15	8.19	0.3	6.57	7	36.84	1	5.26	6	31.58	3	15.79	1	5.26	1	5.26	14	5
Total State		381	0.01	12	0	6.66	130	34.1	26	6.8	19	5.0	175	46	18	4.7	7	1.8	175	200

6.5.4 Water Level Flucuation – January 2014 Vs January 2013

Fluctuation of water levels in January 2014 with reference to January 2013 is depicted in the Fig-6.20. The categorization of water level fluctuation is shown in the Fig.6.21. A perusal of the map shows that there is rise in water levels in the State. Rise in water level of less than 2 m is observed in most of the areas except chittoor, Nellore and Visakhapatnam districts. Rise of 2-4 m and >4m zones are observed as isolated areas in south western parts of the State.

Fall in water levels of less than 2m, 2-4 m and >4m zones are observed in most of the areas in Vizianagaram, Vishakapatnam, Nellore, Prakasham districts.

Water level fluctuation data of January 2014-January 2013 is presented in the Table – 6.10. An analysis of data of 438 wells shows that rise is recorded in 53.65% wells (235), fall is observed in 43.6% wells (191) while fluctuation is nil in 2.7% wells (12).

Water level rise of less than 2 m is recorded in 43.3% wells in the range of 2-4 m in 6.4% wells and rise of more than 4 m is recorded in 3.9% wells. Fall of less than 2 m is recorded in 35.6% wells, 2-4 m range in 5.4% and fall of more than 4 m is registered in 2.5% wells. Water level rise of more than 4 m is recorded maximum in YSR Kadappa district (15% wells) while fall of more than 4 m is registered maximum in Chittoor district (16.67%) wells.

Rise

Out of the 235 wells, registered water levels rise, 80.8% wells recorded water level rise of less than 2 m, 11.9% wells in the range of 2 to 4 m while 7.3% wells recorded water level rise of more than 4 m.

Fall

Of the 191 wells that have registered fall in water levels, majority of them (81.7%) have recorded less than 2 m fall, in the range of 2-4 m in 12.6% wells and the rest 5.7% wells registered water level fall of more than 4 m.

Fig.6.20

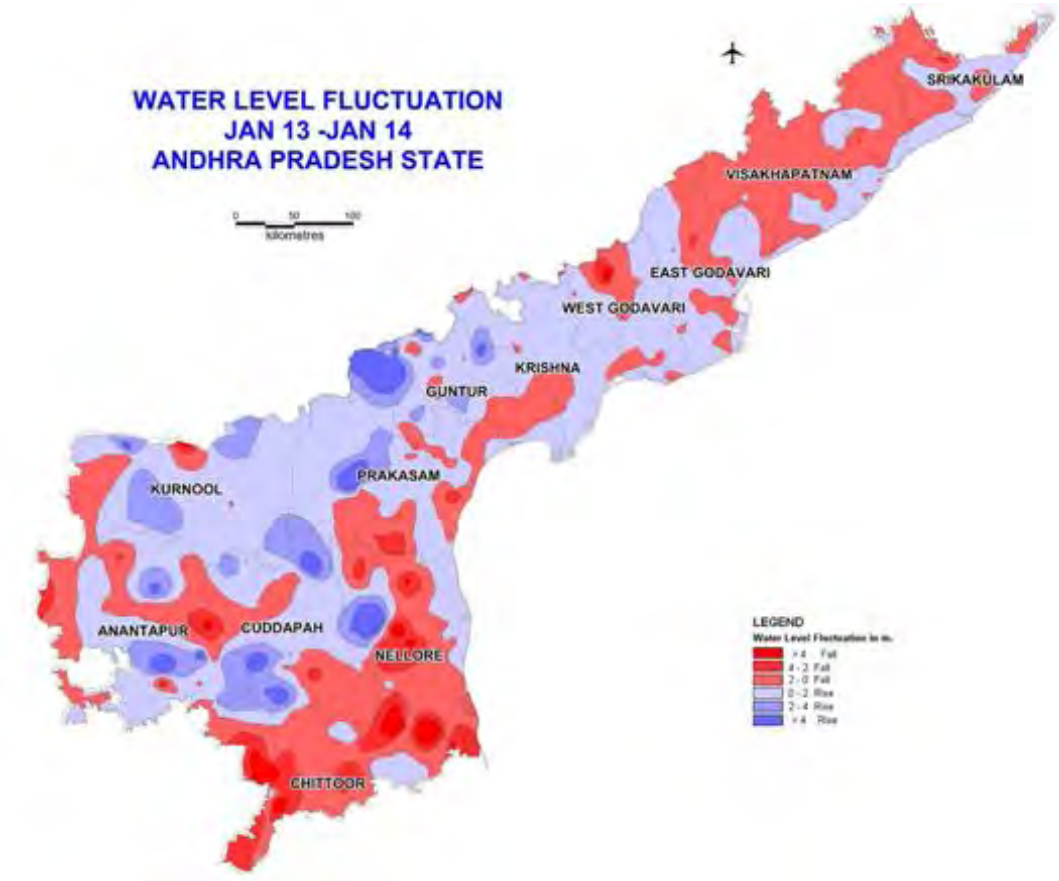


Fig.21
Categorisation of fluctuation of
water levels (January 2013 - January 2014)

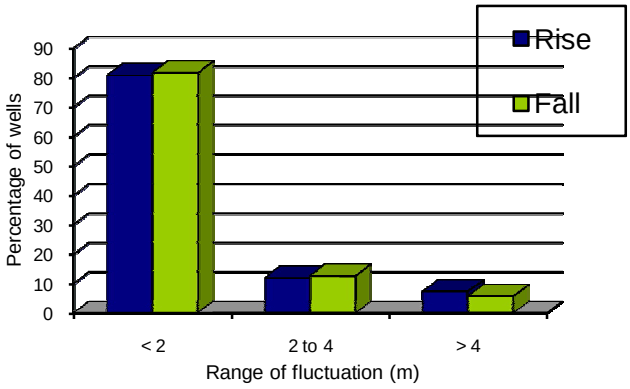


Table – 6.10
District wise fluctuation and frequency distribution of different water level ranges
Between January, 2014 and January, 2013

Sl. No	District	No of Wells Analysed	Range of Fluctuation (m)				No of Wells / Percentage Showing Fluctuation													
			Rise		Fall		Rise						Fall						Total No. of Wells	
							0 to 2		2 to 4		> 4		0 to 2		2 to 4		> 4			
			Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%	Rise	Fall
1	Anantapur	34	0.19	6.3	0.01	3.44	12	35.29	3	8.82	4	11.76	9	26.47	4	11.76	0	0	19	13
2	Chittoor	30	1.01	1.37	0.07	9.89	4	33.33	0	0	0	0	15	50.0	5	16.67	5	16.67	4	25
3	East Godavari	51	0.04	2.25	0.02	2.39	29	56.86	3	5.88	0	0	18	35.29	1	1.96	0	0	32	19
4	Guntur	49	0.04	26.85	0.12	1.76	24	48.98	6	12.24	7	14.29	12	24.49	0	0	0	0	37	12
5	Krishna	21	0.06	2.14	0.02	0.25	15	71.43	1	4.76	0	0	4	19.05	0	0	0	0	16	4
6	Kurnool	26	0.26	4.71	0.03	1.93	13	50.0	5	19.23	1	3.85	7	26.92	0	0	0	0	19	7
7	Nellore	40	0.08	8.82	0.02	5.96	12	30.0	0	0	1	2.5	17	42.5	6	15.0	4	10.0	13	27
8	Prakasham	47	0.05	10.94	0.06	3.57	24	51.06	4	8.51	1	2.13	11	23.4	5	10.64	0	0	29	16
9	Srikakulam	21	0.06	1.67	0.11	2.57	14	66.67	0	0	0	0	6	28.57	1	4.76	0	0	14	7
10	Visakhapatnam	49	0.03	3.39	0.03	1.87	20	40.82	2	4.08	0	0	25	51.02	0	0	0	0	22	25
11	Vizianagaram	24	0.02	0.82	0.05	2.13	6	25.0	0	0	0	0	17	70.83	1	4.17	0	0	6	18
12	West Godavari	26	0.02	1.61	0.06	6.22	14	53.85	0	0	0	0	9	34.62	0	0	1	3.85	14	10
13	YSR Kadapa	20	0.06	5.69	0.17	4.68	3	15.0	4	20.0	3	15.0	6	30.0	1	5.0	1	5.0	10	8
Total State		438	0.02	26.85	0.01	9.89	190	43.3	28	6.4	17	3.9	156	35.6	24	5.4	11	2.5	235	191

6.5.5 Water Level Fluctuation - Decadal Mean of May - 2003-2012, Vs May 2013

Water level fluctuation between May, 2013 and decadal mean of May-2003-2012 depicted in the Fig.6.22. The categorization of water fluctuation is shown in the Fig.6.23. The Perusal of the map shows a general fall in water levels in about 52.12% of wells analyzed in the State.

Rise of less than 2m is observed in most of the areas of Srikakulam, Vizianagaram, Vishakapatnam, East Godavari, West Godavari, Krishna, Kurnool, Chittoor disatricts. 2-4 m and >4m zones are observed all districts except Nellore and Krishna district of Coastal Region, and Rayalaseema Region except Kurnool district.

Fall of water level (less than 2 m, 2-4m and >4m) is noticed in most of the areas in south western part of the state.

Water level fluctuation of May, 2013 with reference to Decadal mean of May, 2003-2012 is presented in the Table-6.11**.** An analysis of data of 395 wells show that 48.35% wells (191) registered rise while 51.65% wells (204) recorded fall.

Rise of less than 2 m is recorded in 38.2% wells, 2-4 m range in 9.11% wells and rise of more than 4 m is recorded in 1% wells. Fall of less than 2 m zone is recorded in 39.4% wells, 2-4 m in 8.1% and fall of more than 4 m is registered in 4% wells. Water level rise of more than 4 m is recorded maximum in YSR Kadappa district (4.55% wells) while water level fall of more than 4 m is registered maximum in Anantapur district (16.67% wells).

Rise

Out of the 191 wells, registered rise, 79% wells recorded water level rise of less than 2 m, 19% wells in the range of 2 to 4 m while 2% wells recorded rise of more than 4 m.

Fall

Of the 381 wells, registered fall, most of them (76%) have recorded less than 2m fall, 2-4m range in 16% of wells and 8% wells registered water level fall of more than 4m.

Fig.6.22

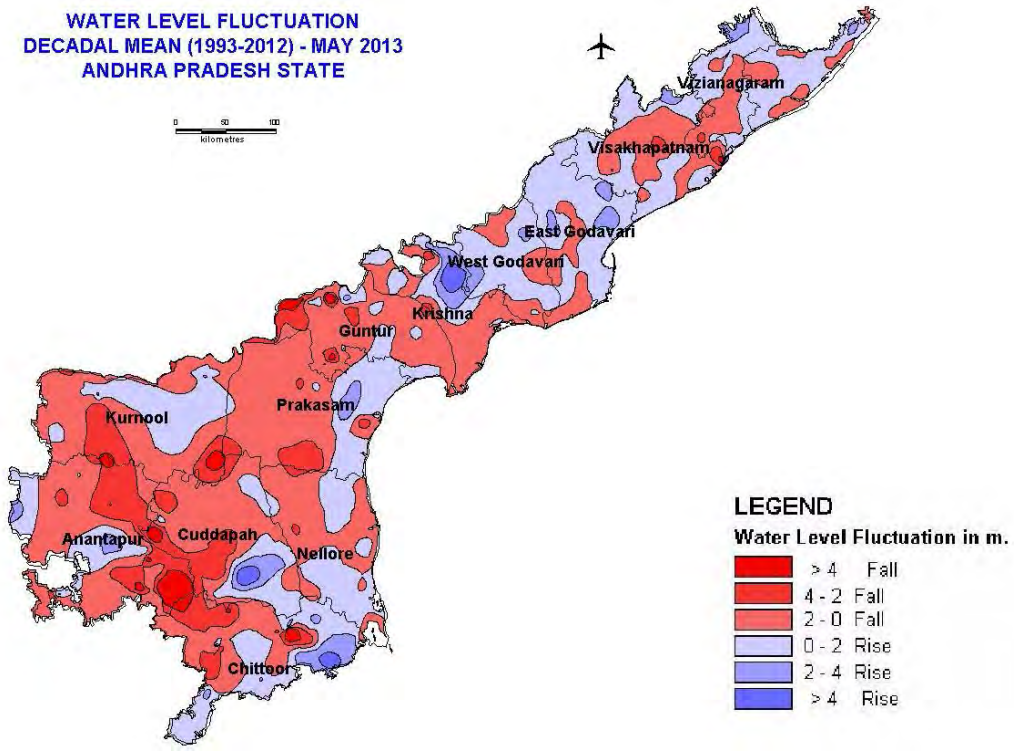


Fig.6.23
Categorisation of fluctuation of water levels
Decadal mean ofMay (2003-2012) with May 2013

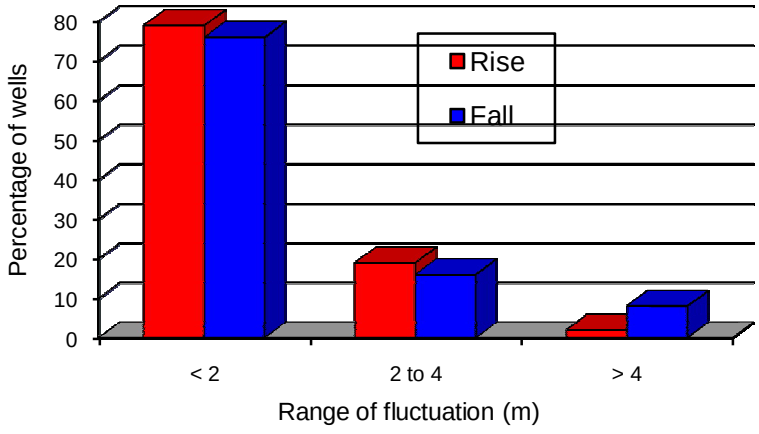


Table – 6.11
District wise fluctuation and frequency distribution of different water level ranges
May 2013 - Mean (2003-12)

Sl. No	District	No of Wells Analysed	Range of Fluctuation (m)				No of Wells /Percentage Showing Fluctuation													
			Rise		Fall		Rise						Fall						Total No.	
							0 to 2		2 to 4		> 4		0 to 2		2 to 4		> 4		Rise	Fall
			Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%		
1	Anantapur	30	0.06	3.32	0.2	15.59	4	13.33	3	10.0	0	0	13	43.33	5	16.67	5	16.67	7	23
2	Chittoor	35	0.04	4.4	0.03	8.42	10	28.57	9	25.71	1	2.86	7	20.0	6	17.14	2	5.71	20	15
3	East Godavari	33	0.08	3.46	0.01	1.15	17	51.52	5	15.15	0	0	11	33.33	0	0	0	0	22	11
4	Guntur	44	0.04	1.41	0.07	9.02	16	36.36	0	0	0	0	21	47.73	2	4.55	5	11.36	16	28
5	Krishna	25	0.03	7.28	0.14	3.53	7	28.0	3	12.0	1	4.0	12	48.0	2	8.0	0	0	11	14
6	Kurnool	25	0.06	2.22	0.08	4.66	10	40.0	2	8.0	0	0	9	36.0	3	12.0	1	4.0	12	13
7	Nellore	31	0.06	1.81	0.09	1.92	14	45.16	0	0	0	0	17	54.84	0	0	0	0	14	17
8	Prakasham	31	0.08	3.45	0.04	3.99	9	29.03	2	6.45	0	0	16	51.61	4	12.9	0	0	11	20
9	Srikakulam	24	0.01	3.34	0.01	1.66	14	58.33	1	4.17	0	0	9	37.5	0	0	0	0	15	9
10	Visakhapatnam	50	0.11	9.23	0.05	6.05	22	44.0	4	8.0	1	2.0	18	36.0	4	8.0	1	2.0	27	23
11	Vizianagaram	25	0	3.25	0.23	4.24	15	60.0	1	4.0	0	0	7	28.0	1	4.0	1	4.0	16	9
12	West Godavari	20	0.02	3.42	0.01	1.36	11	55.0	3	15.0	0	0	6	30.0	0	0	0	0	14	6
13	YSR Kadapa	22	0.52	6.34	0.07	6.19	2	9.09	3	13.64	1	4.55	10	45.45	5	22.73	1	4.55	6	60
Total State		395	0	9.23	0.01	15.59	151	38.2	36	9.11	4	1.0	156	39.4	32	8.10	16	4.0	191	204

6.5.7 Water Level Fluctuation: Decadal Mean of November-2003-2012 Vs November 2013

Water level fluctuation between decadal mean of November 2003-2012 and November 2013 is depicted in the Fig.6.24. The categorization of water level fluctuation is shown in the Fig.6.25. Perusal of the map (Fig.6.22) shows a general rise in water levels in about 65.47% of wells analyzed in the State.

Water level rise of less than 2 m is observed in all districts of Coastal Region and Rayalaseema Regions. Rise of 2-4 m is observed as small isolated areas in all the districts except Nellore and Chittoor districts. More than 4 m is observed in few locations as small isolated areas in Vishakapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasham districts of Coastal region and in Chittoor district of Rayalaseema Region.

Fall of less than 2 m is noticed in most of the areas in Nellore, Prakasham, Guntur, Krishna, East Godavari, Vizianagaram and in Rayalaseema region. Fall of 2-4 m is noticed in small areas in Nellore, Prakasham, Guntur districts of Coastal region and in Rayalaseema Region. Fall of more than 4 m is noticed and small isolated zones in Prakasham and Nellore districts of Coastal region and in small areas of all districts except Kadapa district of Rayalaseema Region.

Water level fluctuation of November, 2013 with reference to Decadal means of November, (2002-2011) is presented in the Table-6.12**.** An analysis of data of 399 wells show that 69.42% wells (277) registered rise in water levels while the rest 30.07% wells (120) recorded fall in water levels.

Water level rise of less than 2 m is recorded in 55.6% wells in the range of 2-4 m in 10% wells and rise of more than 4 m is recorded in 3.7% wells. Water level fall of less than 2 m is recorded in 22.5% wells in the range of 2-4 m in 5.7% and water level fall of more than 4 m is registered in 1.7% wells. Water level rise of more than 4 m is recorded maximum in Prakasham district (13.16% wells) while water level fall of more than 4 m is registered maximum in Kurnool district (7.41% wells).

Rise

Out of the 277 wells that have registered a rise in water levels, 80% wells recorded water level rise of less than 2 m, 14% wells in the range of 2 to 4 m while the rest 6% wells recorded water level rise of more than 4 m.

Fall

Of the 120 wells that have registered fall in water levels, majority of them (75%) have recorded less than 2m fall, in the range of 2-4m in 19% wells and the rest 6% wells registered water level fall of more than 4m.

Fig.6.24

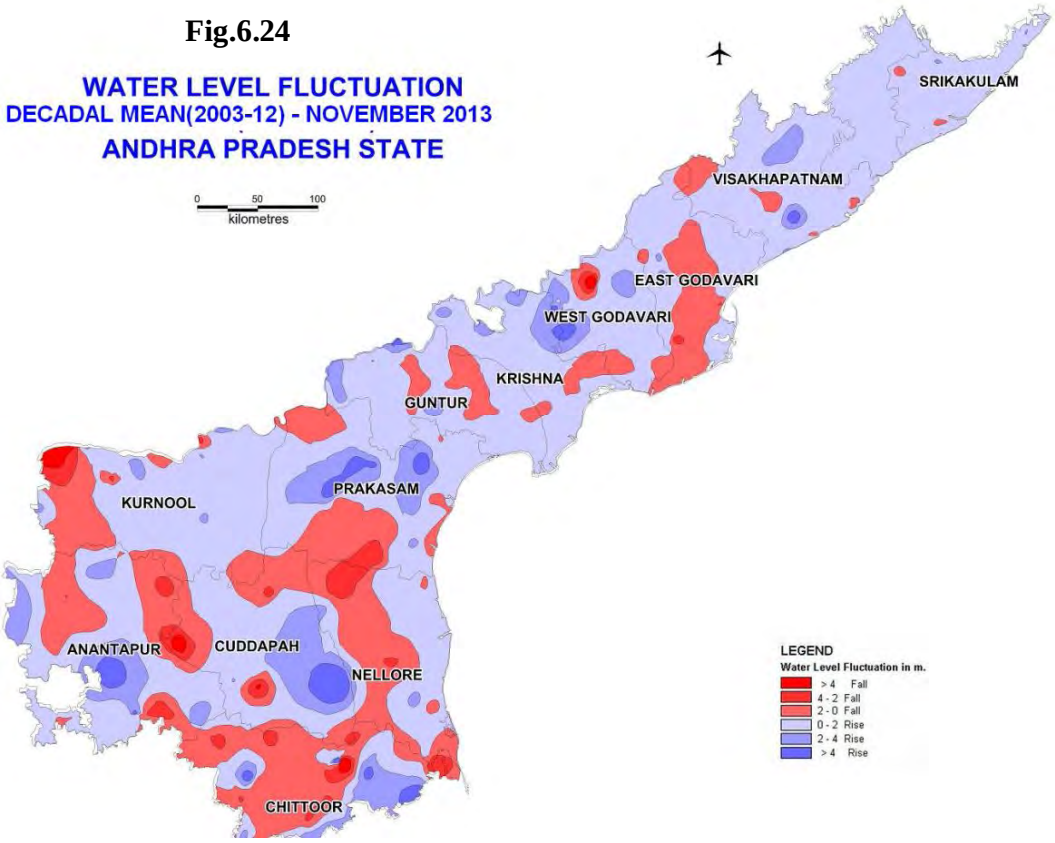


Fig.6.25
Categorisation of fluctuation of water levels
Decadal mean of November (2003-2012) with November 2013

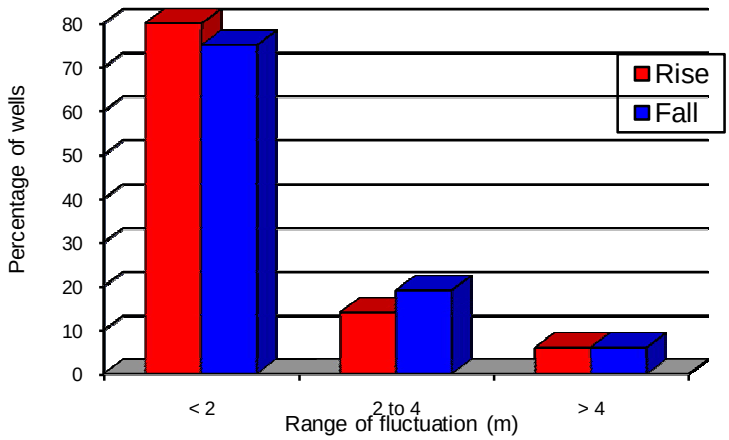


Table – 6.12

District wise fluctuation and frequency distribution of different water level ranges

Decadal Mean November (2003-2012) - Nov 2013

Sl. No	District	No of Wells Analysed	Range of Fluctuation (m)				No of Wells / Percentage Showing Fluctuation													
			Rise		Fall		Rise						Fall						Total No.	
							0 to 2		2 to 4		> 4		0 to 2		2 to 4		> 4		Rise	Fall
			Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%		
1	Anantapur	30	0.15	5.95	0.28	4.33	13	43.33	6	20.0	2	6.67	6	20.0	2	6.67	1	3.33	21	9
2	Chittoor	33	0.27	10.21	0.24	7.53	9	27.27	5	15.15	4	12.12	8	24.24	6	18.18	1	3.03	18	15
3	East Godavari	42	0.02	3.01	0.11	3.08	15	35.71	2	4.76	0	0	20	47.62	3	7.14	0	0	17	23
4	Guntur	38	0.1	3.7	0.01	2.49	21	55.26	5	13.16	0	0	11	28.95	1	2.63	0	0	26	12
5	Krishna	23	0.09	2.56	0.12	1.16	18	78.26	2	8.7	0	0	3	13.04	0	0	0	0	20	3
6	Kurnool	27	0.04	2.78	0	5.21	14	51.85	3	11.11	0	0	5	18.52	3	11.11	2	7.41	17	10
7	Nellore	30	0.04	2.58	0.05	3.85	16	53.33	2	6.67	0	0	8	26.67	4	13.33	0	0	18	12
8	Prakasham	38	0.16	4.94	0.11	4.05	18	47.37	2	5.26	5	13.16	11	28.95	1	2.63	1	2.63	25	13
9	Srikakulam	22	0.38	2.07	0.19	0.48	19	46.36	1	4.55	0	0	2	9.09	0	0	0	0	20	2
10	Visakhapatnam	50	0.01	5.39	0.03	0.92	34	68.0	6	12.0	1	2.0	9	18.0	0	0	0	0	41	9
11	Vizianagaram	25	0.03	1.82	0	0	25	100	0	0	0	0	0	0	0	0	0	0	25	0
12	West Godavari	21	0.01	5.38	0.12	6.66	12	57.14	4	19.05	2	9.52	2	9.52	0	0	1	4.76	18	3
13	YSR Kadapa	20	0.36	6.9	0.12	6.45	8	40	2	10	1	5	5	25	3	15	1	5	11	9
Total State		399	0.01	10.21	0	7.53	222	55.6	40	10.0	15	3.7	90	22.5	23	5.7	7	1.7	277	120

6.5.8 Water Level Fluctuation

Between decadal mean of January (2004-2013) Vs January 2014 water levels

Water level fluctuation between decadal mean of January 2004-2013 and January 2014 is depicted in the Fig.6.26. The categorization of water level fluctuation between decadal mean of January (2004-2013) vs January 2014 is shown graphically in the Fig.6.27. A Perusal of the map shows a general rise in water levels in about 69.60% of wells in the State.

Water level rise of less than 2 m is observed as small isolated areas in Nellore district and most of the areas in all other districts of Coastal region. It is also observed in parts of Rayalaseema Region. Water level rise of 2 - 4 m is observed in all districts of Coastal region except Nellore, Vizianagaram districts, and few locations in all districts of Rayalaseema Region. Water level rise of more than 4 m is observed in parts of Guntur, Krishna, Prakasham, West Godavari districts of Coastal region and parts of Ananthpur, Kadapa districts of Rayalaseema Region.

Fall of less than 2 m and 2-4 m zones are noticed in most of the areas in Nellore, Prakasham, Vishakapatnam, East Godavari districts of Coastal region and in all districts of Rayalaseema region. More than 4 m zone is noticed as small isolated areas in Nellore, Prakasham, West Godavari districts of Coastal region in all districts of Rayalaseema region except Kurnool district.

Water level fluctuation of January, 2014 with reference to decadal mean of January, 2004-2013 is presented in the Table-6.13**.** An analysis of data of 452 wells indicate that 61.5% of wells (278) have registered rise while 38.05% of wells (172) recorded fall.

Water level rise of less than 2 m is recorded in 52.6% of wells in the range of 2-4 m. Rise of more than 4 m is recorded in 1.8% wells. Fall of less than 2 m is recorded in 28.3% of wells, 2-4 m rise has registered in 4.8% of wells. More than 4 m rise is registered in 4.8% of wells. Water level rise of more than 4 m is recorded maximum in YSR Kadappa district (5% of wells) while water level fall of more than 4 m is registered maximum in Chittoor district (21.21% of wells).

Rise

Out of the 278 wells, registered rise, 86% wells recorded rise of less than 2 m, 11% of wells in the range of 2 to 4 m while 3% of wells recorded rise of more than 4 m.

Fall

Out of 172 wells that have registered fall in water levels, majority of them (74%) have recorded less than 2m fall, 13% of wells recorded fall of 2-4m, 13% of wells registered water level fall of more than 4m.

Fig.6.26

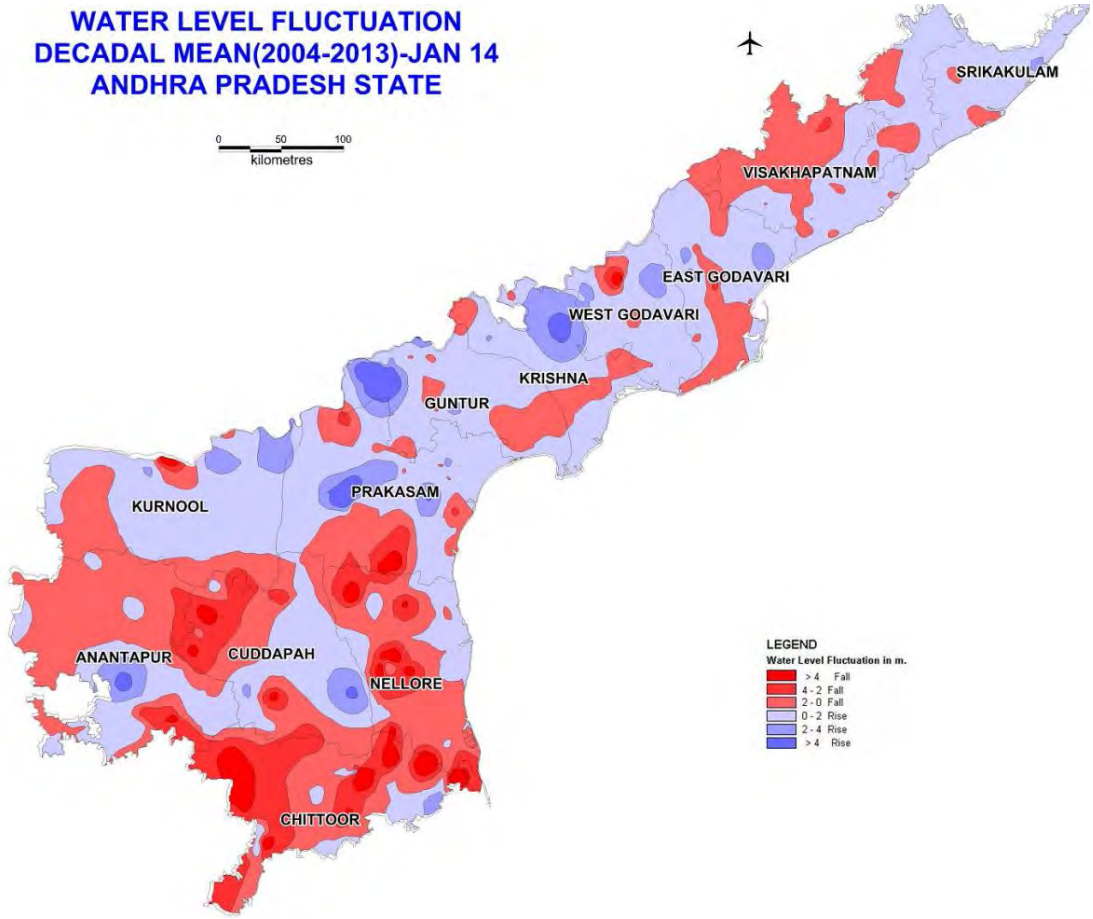


Fig.6.27
Categorisation of fluctuation of water levels
Decadal mean of January (2004-2013) with January 2014

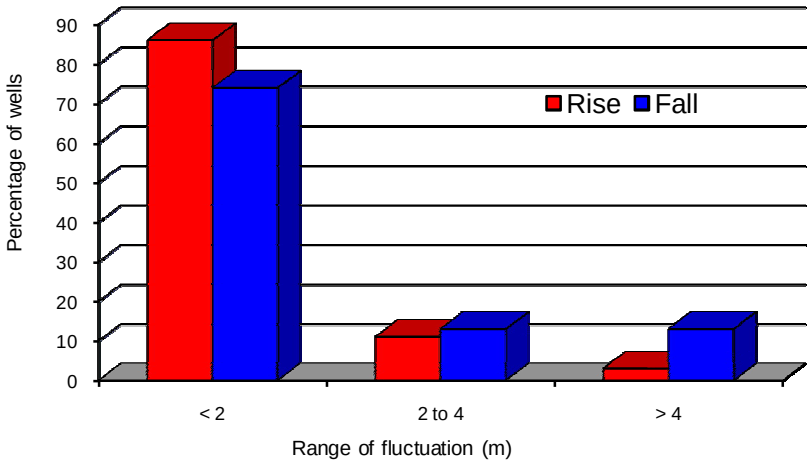


Table – 6.13
District wise fluctuation and frequency distribution of different water level ranges
Decadal mean of January (2004-2013) Vs January 2014

Sl. No	District	No of Wells Analysed	Range of Fluctuation (m)				No of Wells / Percentage Showing Fluctuation													
			Rise		Fall		Rise						Fall						Total No.	
							0 to 2		2 to 4		> 4		0 to 2		2 to 4		> 4		Rise	Fall
			Min	Max	Min	Max	No	%	No	%	No	%	No	%	No	%	No	%		
1	Anantapur	34	0.19	4.99	0.14	4.76	16	47.06	1	2.94	1	2.94	12	35.29	3	8.82	1	2.94	18	16
2	Chittoor	33	0.11	3.64	0	8.67	8	24.24	2	6.06	0	0	8	24.24	8	24.24	7	21.21	10	23
3	East Godavari	53	0.03	3.26	0	3.07	31	58.49	3	5.66	0	0	18	33.96	1	1.89	0	0	34	19
4	Guntur	49	0.01	26.85	0.05	1.51	29	59.18	5	10.2	2	4.08	13	26.53	0	0	0	0	36	13
5	Krishna	22	0.01	4.9	0	0.82	12	54.55	3	13.64	1	4.55	6	27.27	0	0	0	0	16	6
6	Kurnool	28	0.13	3.22	0.15	2.99	16	57.14	5	17.86	0	0	6	21.43	1	3.57	0	0	21	7
7	Nellore	41	0.04	1.27	0.04	5.96	18	43.9	0	0	0	0	13	31.71	2	4.88	8	19.51	18	23
8	Prakasham	48	0.05	10.94	0.02	5.7	22	45.83	4	8.33	2	4.17	14	29.17	4	8.33	2	4.17	28	20
9	Srikakulam	22	0.12	3.05	0.09	0.92	18	81.82	1	4.55	0	0	3	13.64	0	0	0	0	19	3
10	Visakhapatnam	51	0.11	3.58	0.03	2.72	26	50.98	4	7.84	0	0	18	35.29	1	1.96	0	0	30	19
11	Vizianagaram	25	0.01	1.34	0.07	1.26	18	72	0	0	0	0	7	28	0	0	0	0	18	7
12	West Godavari	26	0.25	4.29	0.02	6.22	17	65.38	3	11.54	1	3.85	4	15.38	0	0	1	3.85	21	5
13	YSR Kadapa	20	0.26	4.59	0.12	5.66	7	35	1	5	1	5	6	30	2	10	3	15	9	11
Total State		452	0.01	26.85	0	8.67	238	52.6	32	7.10	8	1.8	128	28.3	22	4.8	22	4.8	278	172

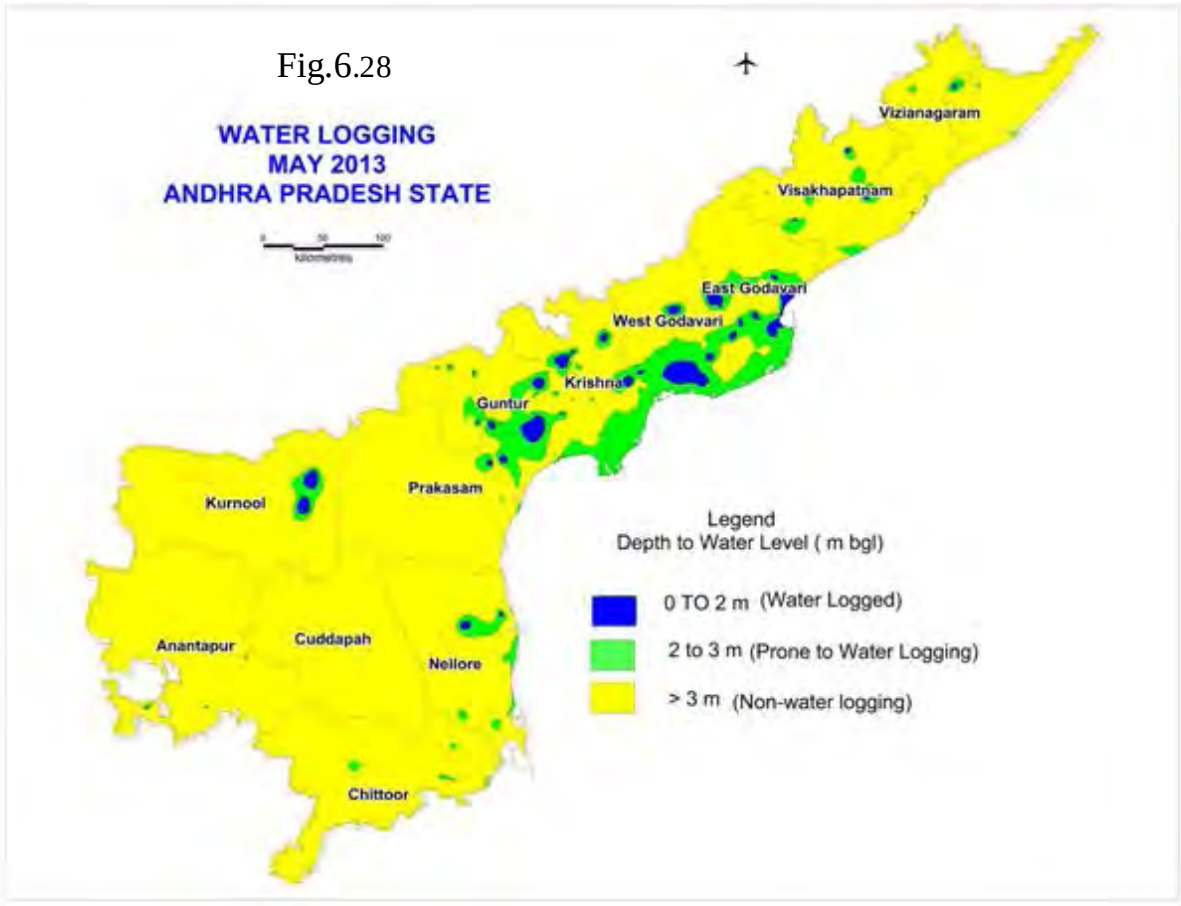
6.6 Water Logged Area and the Area Prone To Water Logging

6.6.1 Water Logged Area

Pre-monsoon Period - May 2013

Demarcation of water logged area and the area prone to water logging, for pre-monsoon, May 2013 is presented in the Fig.6.28. Water logged areas are observed in smaller extents mainly in parts of East Godavari, West Godavari, Krishna, Prkasam, Guntur districts of Coastal region; The total water logged area during the pre-monsoon period in the State is 17,180 sq.km. viz about 6.25% of the total area of the State.

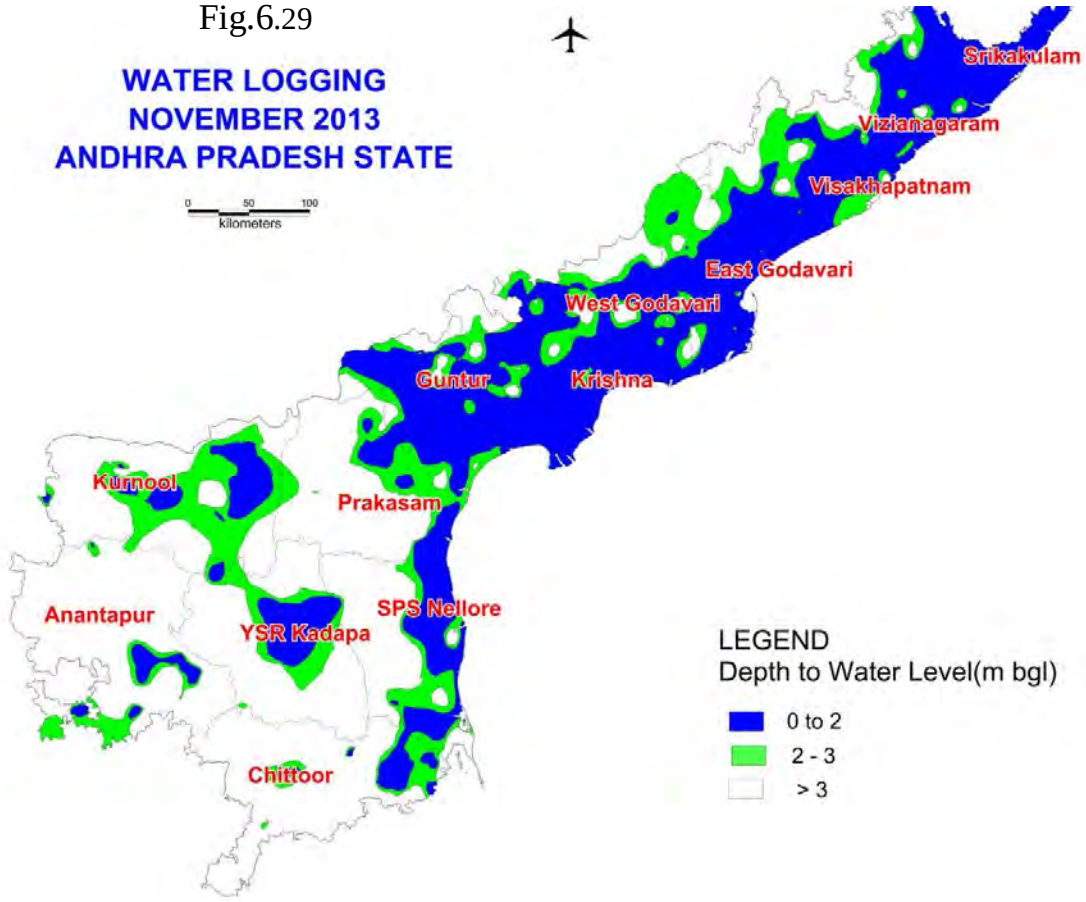
Fig.6.28



Post-monsoon Period - November, 2013

Water logged area and area prone to water logging during post-monsoon season (November 2013) is presented in **Fig.6.29**. A perusal of the map shows that water logged areas with less than 2 m depth to water levels are observed in all the coastal districts, southern Rayalaseema, and Kurnool districts. The total water logged area during the post-monsoon period in the State is 68,790 sq.km viz about 25% of the total area of the State. The waterlogged area has increased from 6% to 25% of the total area of the state, which is due to the excess rainfall recorded during the year 2012 in the entire state.

Fig.6.29



6.6.2 Area Prone to Water Logging

Pre-monsoon Period – May, 2013

A perusal of the Fig.6.1 shows that during pre-monsoon (May, 2013), the area prone to water logging with depth to water level 2 to 3 mbgl are mostly observed in parts of coastal districts, East Godavari, West Godavari, Krishna, Guntur, Prakasam and Nellore districts, in small Parts of Kurnool, Anantapur, Khammam, Srikakulam and Visakhapatnam districts. The total area prone to water logging during pre-monsoon in the State is 59,930 Sq. km viz about 22% of the total area of the State.

Post-monsoon Period - November 2013

A perusal of the map (Fig.6.2) reveals that the area prone to water logged with water level less between 2 to 3 m is observed as small patches in all the districts and as major portion in Vizainagaram, Khammam, Kurnool, Nellore, Easr Godavari, Kadapa districts. The total area under prone to water logging during post monsoon period is 33,878 sq.km constituting 12% of total geographical area of the State. The area prone to water logged has decreased from 22% to 12% of the total area of the state,

7.0 GROUND WATER QUALITY

Groundwater plays an important role in global drinking water supply and food security. It is estimated that two billion people, worldwide, depend on groundwater for drinking purpose. Its regional importance is demonstrated by its provision of 70% of drinking water in the EU, 80% of rural water supply in Sub-Saharan Africa, and 60% of agricultural irrigation in India (IAH, 2006). Groundwater depletion and contamination will result in spiralling costs for water access, claiming valuable economic resources with the poor suffering most. At the start of groundwater exploitation, fresh water was easy to find and available at limited cost because of the shallow depth and short transportation distances from the point of use. In the case of groundwater depletion, the water level in the aquifers drop and the quality of water deteriorates. Over time, the freshest and most easily accessible water is depleted, leaving behind marginal quality water at much greater depth. Deeper wells, larger capacity pumps and additional treatment facilities will be needed to make the water potable. The combination of deteriorating water quality, increasing depth and increasing distance from centre of use creates a 'perfect storm' of extreme water scarcity and spiralling cost. Because of its local availability and generally good quality, limiting treatment costs, groundwater is often cheap compared to alternative sources of supply.

The occurrence of ground water and availability is largely governed by the state of cementation and compaction of the formation, which control the pore volume. The geological formations encountered in the state are broadly divided into consolidated, semi-consolidated and unconsolidated. In Andhra Pradesh, sizeable proportion of population is dependent on ground water for drinking and other household utilities besides its use in irrigation at large. Due to limited cost effective treatment options for polluted ground water, the affected resource is generally lost for drinking and other utilities.

In many locations, over-abstraction has resulted in sharp declines in the groundwater table and, at times, even to exhaustion of the resource. In other areas, groundwater resources have been gradually rendered useless as a result of pollution. Major sources of groundwater pollution are infiltration of untreated waste water, pesticides and nitrates from agricultural activities, and effluents from industrial and mining activities. Probably even more dramatic is the loss of groundwater resources due to pollution from natural sources that is often aggravated as a result of poor aquifer management. Natural pollution sources include saline water intrusion in coastal aquifers and pollution by toxic elements present in aquifers or adjacent geological formations like arsenic, fluoride and radioactive isotopes. Notwithstanding the increasing number of examples of deteriorating groundwater conditions knowledge on the status of groundwater resources is scattered and there is a lack of solid data.

Ground water studies are incomplete unless the physical and chemical dynamics of the aquifer system is established. In groundwater studies, the physical characteristics of the ground water flow system describe the potential for ground water to move from one place to another. The geochemistry of ground water explains its chemical nature and changes takes place along the path. This area of research, known as hydro-geochemistry, allows researchers to determine the time and source of recharge, estimation of residence time in the aquifer, the degree of mixing between waters of various sources and evaluate type of chemical processes occurred during the journey through the system. This information provides a broad, more regionally extensive

understanding of groundwater system. Furthermore, this improved knowledge can be used to formulate more comprehensive management and conservation plans, and more equitable groundwater regulations.

With rapid growth of population, the development and use of ground water for domestic, irrigation and industrial purposes has increased too many fold. At the same time, this vital resource is polluted anthrophogenically in the process, to such an extent it is rendered unsuitable for various purposes, in certain areas. Once the pollution has entered the sub-surface environment, it may remain concealed for many years and dispersed over wide areas in the aquifer system. Because natural dilution is slow, artificial flushing is expensive and treatment is impractical, the effects of such pollution may continue for indefinite period. In this context the evaluation of ground water in terms of physical, chemical and bacteriological characteristics is important to determine its suitability for drinking, irrigation and industrial uses and to remedial measures to protect it from further deterioration. A data base is generated by monitoring the ground water monitoring wells.

7.1 Quality of Ground Water in Shallow Aquifers

Rainwater infiltrates into the soil and interacts with carbon dioxide to become acidic. The acidic water then comes in contact and dissolves minerals in the soil. Eventually the water becomes neutral to mildly alkaline. This process is even more enhanced when cation exchange (in the case of calcium for sodium) takes place. Groundwater interacts with the soils and other materials as it flows and becoming more mineralized over time, and distance. The earth material, such as glacial tills or marine shale, contain soluble minerals that dissolve relatively rapidly in groundwater and can cause deterioration in groundwater quality at a shallow depth. A network of national ground water monitoring wells has been periodically monitored for assessing quality and variability of chemical constituents of ground water in the state. During May 2013(pre-monsoon), 520 samples were collected for analysis. The Water used for drinking and domestic purposes should be safe chemically and free from undesirable physical properties such as temperature, colour, turbidity and unpleasant taste or odour. The potability of ground water is judged based on drinking water specifications of Bureau of Indian Standards (BIS)-IS-10500(2003): 2012.

pH

pH is the measure of acidity/alkalinity balance in a solution. It is also a measure of availability of hydrogen ions (H+) in solution, known as “protons”. pH is sometimes referred to as an indicator of “proton acidity” of a groundwater. In formal terms, pH is defined as the negative logarithm (to base 10) of the hydrogen ion activity (in moles/liter). Values are commonly in between 0 to 14, normally reported without units. The pH of ground water varies from 7.03 to 9.23 and it is beyond BIS limits at 34(6.5%) locations.

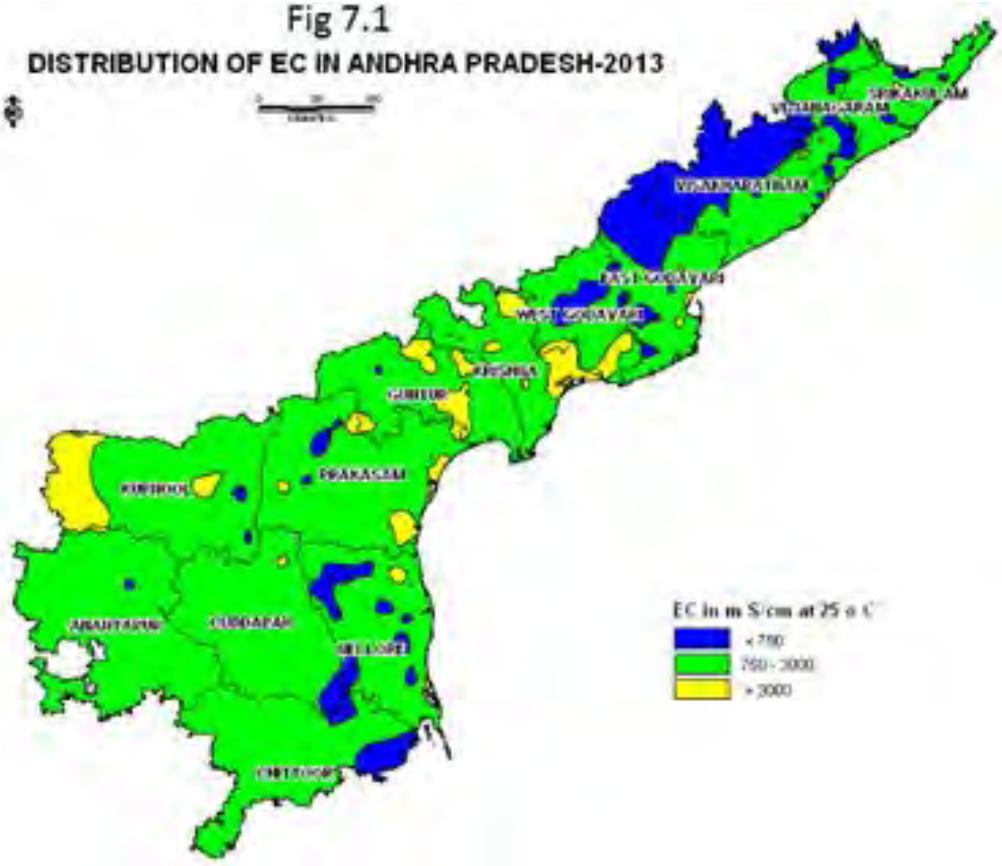
Electrical conductivity (EC)

Although strictly termed “specific electrical conductance” in practice the term “conductivity” is very widely used. The ability of given water to conduct electricity is directly proportional to the

amount of dissolved, charged species (ions) which it contains. Conductivity values are normally expressed in units of microsiemens per centimeter (µS/cm), or else for more saline waters, in millisiemens per centimeter (mS/cm). (1 mS/cm = 1000 µS/cm) at 25°C. Electrical conductivity varying from 76 to 13600 µS/cm at 25^{0}C. The distribution of electrical conductivity is presented in the Fig.7.1. Electrical conductivity in proportion to Total Dissolved Solids (TDS), exceeds BIS permissible limit of 3000 micromhos /cm in 11% of the samples in the state.

Fig 7.1

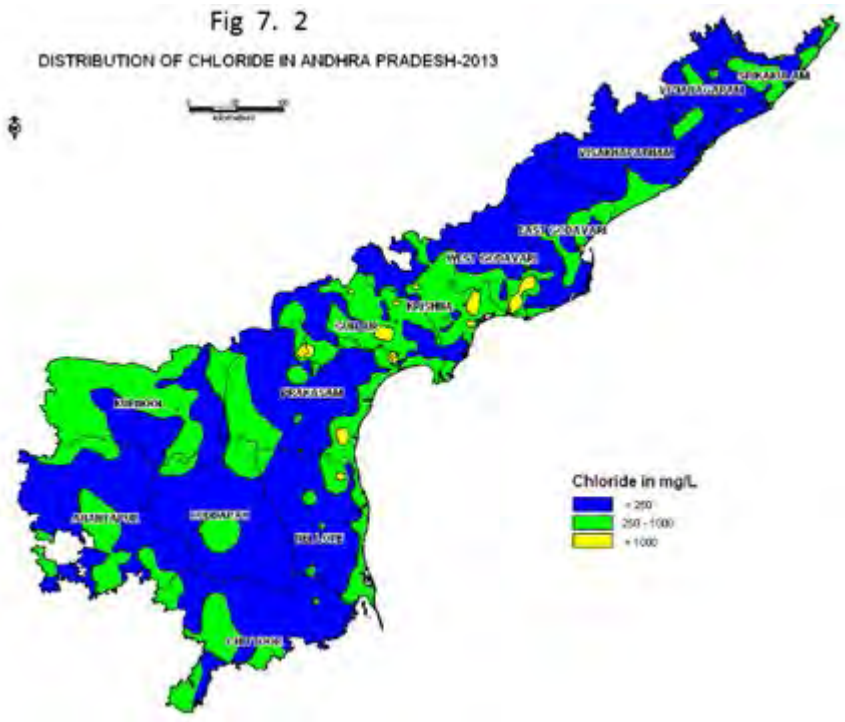
DISTRIBUTION OF EC IN ANDHRA PRADESH-2013



Chloride

Halite dissolution is the main natural source of Chloride in ground water. Small amount of chloride occur naturally in rainfall. Pollutant Cl^- is very common, and occurs in human, animal and industrial wastes. Chloride is very conservative chemically, and is therefore a good ground water tracer, unlike sulphate, for instance, which is retarded by reactions. Chloride occurs in all natural waters in varying concentrations. The chloride content increase as the soluble mineral content increases. Chloride in reasonable concentration is not harmful to human beings. At concentrations above 1000 mg/l, water acquires salty taste which is objectionable to many people. Only 4.6% of the samples in the state have chloride concentration beyond BIS permissible limit (Fig.7.2).

Fig 7. 2



Nitrate

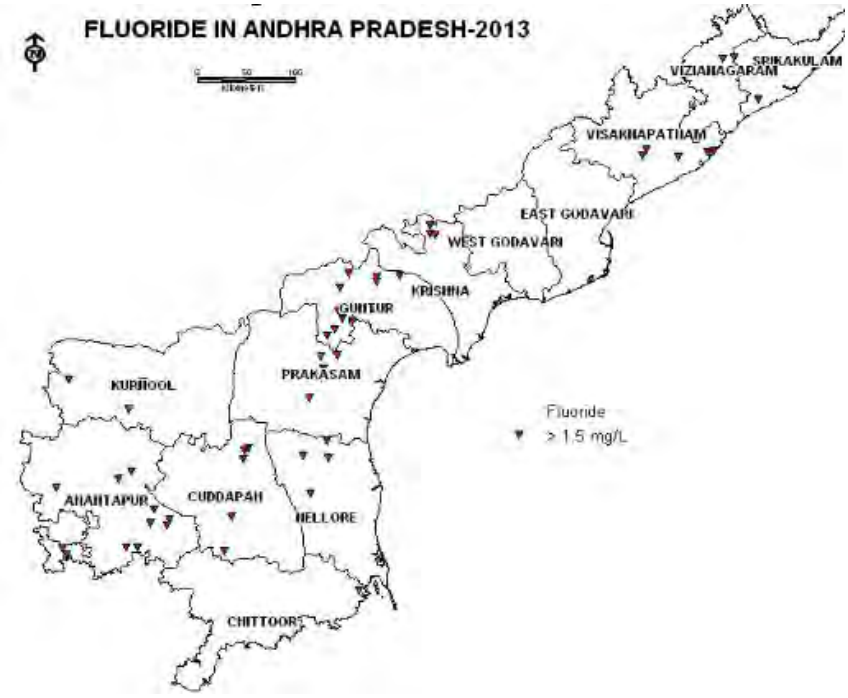
The presence of high nitrate concentration would normally indicate pollution of ground water at some state of its history. Since presence of excess nitrate ions is deleterious to human health, their occurrence in ground water is a matter of great concern. The leaching of nitrate from agriculture land has been a major research topic in recent years. Although commercial fertilizers are suspected to be a major source of nitrate in ground water, researchers have also identified natural organic nitrogen, livestock, septic tanks and atmospheric inputs as contributing factors. Nitrate exceeds the BIS permissible limit of 45 mg/L in 38.3% of the samples in the state. When we observe closely the average levels of Nitrate (66 ppm) is much higher than BIS recommended standards. Distribution of Nitrate in Andhra Pradesh is shown in the Fig.7.3.

Fig 7. 3

Fluoride

It is a minor constituent of natural water, but plays an important role in assessing the quality of water for domestic use. Deleterious effects of fluoride on human system are well known. Fluoride acts as two edged sword. It is beneficial when present in concentrations of 0.8-1.0mg/L for calcification of dental enamel especially for the children below 8 years of age. Below this limit it can cause dental carries. It can cause dental fluorosis if present in excess of 1.5mg/L and such water is consumed for long time. Fluoride exceeds the BIS permissible limit of 1.5 mg/L in 10.6% of the samples in the state. The distribution of Fluoride in Andhra Pradesh is shown in the Fig.7.4

Fig.7.4



7.2 Quality of ground water for drinking purpose

The hydrochemical data is compared with the drinking water quality standards set by Bureau of Indian Standards to assess the suitability of ground water from shallow aquifers for drinking purpose. The minimum, maximum and average concentrations of various chemical parameters in the state is presented in the Table-7.1 and ground water not suitable of drinking purpose with respect to chemical parameters is shown in the Table-7.2. In general, ground water from shallow aquifers in the state is alkaline in nature and average value of p^H is 7.9.

Electrical conductivity ground water in the state varies from 76 to 13600 µs/cm at 25^0C with an average value of 1702 µs/cm at 25^0C. Ground Water is suitable for drinking purpose with respect to electrical conductivity. The average value of EC is highest in Krishna district followed by Guntur and Prakasam in the state, in all 11% of samples are beyond permissible limit of BIS. It is also evident from the Fig.7.1 that the EC of ground water in the state varies from 750-3000µs/ cm.

Chloride concentration in ground water from shallow aquifers in the state varies from 7.1 to 4041 mg/L. 4.6% of samples in the state exceeds the BIS permissibility levels. The percent of samples having chloride concentration is very high in Krishna and West Godavari districts and ground water is not suitable for drinking purpose. Whereas, the chloride value is less than 250 mg/L in majority of samples (Fig.7.2).

Table-7.1
Minimum, Maximum and Average values of various Chemical Parameters Andhra Pradesh State.

District	Maxima Minima	pH	EC µs/cm at 25^0C	Cl	NO3	F
				mg/L		
ANDHRA PRADESH	Maxima	9.23	13600	4041	2410	5.3
	Minima	7.03	76	7.1	0.0	0.00
	Average	8.05	1702	297	66	0.66
Srikakulam	Maxima	8.65	4720	1333	169	3.0
	Minima	7.03	330	34	2	0.10
	Average	7.94	1346	260	49	0.52
Vizianagaram	Maxima	8.54	3490	908	146	2.1
	Minima	7.50	380	28	0.20	0.09
	Average	8.03	1152	204	38	0.69
Visakhapatnam	Maxima	8.87	7958	1843	260	3.9
	Minima	7.16	99	7.1	0.00	0.03
	Average	7.95	1242	207	50	0.59
East Godavari	Maxima	8.27	7918	2269	177	1.1
	Minima	7.61	76	7.1	0.00	0.02
	Average	8.05	1431	255	35	0.32
West Godavari	Maxima	8.94	13220	4041	179	2.4
	Minima	7.38	137	11	0.00	0.05
	Average	8.20	2000	431	41	0.31
Krishna	Maxima	9.23	13600	3687	170	2.2
	Minima	7.74	712	71	1.00	0.02
	Average	8.24	2484	489	38	0.45
Guntur	Maxima	8.56	8670	2099	2410	3
	Minima	7.34	522	57	0.00	0.02
	Average	8.00	2239	381	133	0.69
Prakasam	Maxima	8.92	13570	3368	1141	5.3
	Minima	7.75	430	11	7.3	0.04
	Average	8.22	2068	331	142	1.0
Nellore	Maxima	8.67	4710	1305	207	4
	Minima	7.52	333	7.1	0.45	0.03
	Average	8.01	1305	220	43	0.58
Chittoor	Maxima	8.36	2496	574	210	1.6
	Minima	7.62	185	25	0.23	0.07
	Average	7.95	1211	197	39	0.63
YSR Kadapa	Maxima	8.28	3322	737	351	2.0
	Minima	7.63	400	92	1.9	0.25
	Average	8.02	1529	226	49	1.0
Anathapur	Maxima	8.44	2654	503	226	5
	Minima	7.34	593	43	0.00	0.00
	Average	7.96	1571	209	84	1.4
Kurnool	Maxima	8.50	4960	1035	227	3.5
	Minima	7.41	540	35	0.64	0.11
	Average	7.97	2142	338	64	0.93

The average nitrate concentration in ground water in the state is 66 mg/L. 38.3% of samples are exceeding the BIS permissible limit, indicating anthropogenic contamination. The chemical analyses reveal that ground water is not suitable for drinking purpose in many parts of Prakasam, Guntur and Anathapur districts.

Fluoride content in the state varies from Traces to 5.3 mg/L, with an average value of 0.66 mg/L. 10.6% of samples in the state exceeds BIS permissible limit. Ground water is not suitable for drinking purpose, in terms of fluoride, in many parts of Kadapa Anathapur, Kurnool and Prakasam districts.

Table- 7.2
No. of samples not suitable for drinking purpose
with respect to different chemical constituents

District	Total Samples	% Samples not suitable with respect to chemical constituents			
		EC	Cl	NO3	F
Srikakulam	35	5.7	2.9	45.7	2.9
Vizianagaram	37	10.8	0.0	29.7	8.1
Visakhapatnam	58	8.8	3.5	29.8	10.5
East Godavari	57	7.0	1.8	22.8	0.0
West Godavari	39	15.4	8.8	21.1	1.8
Krishna	44	20.5	13.6	25.0	6.8
Guntur	71	18.3	7.0	49.3	15
Prakasam	43	14.0	4.7	65.1	14.0
Nellore	42	4.8	2.4	33.3	9.5
Chittore	26	0.0	0.0	34.6	3.8
Kadapa	12	8.3	0.0	25.0	41.7
Ananthapur	33	0.0	0.0	54.5	33.3
Kurnool	24	20.8	4.2	50.0	12.5
Andhra Pradesh	520	11.0	4.6	38.3	10.6

7.3 Quality of ground water for irrigation purpose

The most extensive use of ground water in the world is for irrigation consumption. The chemical quality of ground water is an important factor in evaluating its usefulness for irrigation. Poor quality ground water may adversely affect the crop production due to salinity, specific ion toxicity or infiltration problem in soil.

It is important to ascertain the nature of soil, crop and the prevailing climatic conditions in addition to the quality of water used for irrigation purpose. In arid regions, soil having heavy texture and high pH, usually develop alkalinity and salinity problems much more quickly than the light sandy soil. Besides texture; permeability, drainage, water table, calcium status and pH are other factors, which govern the effect of the water on properties of soil. Some crops are more tolerant to saline water than others. In areas of good rainfall even low quality of water can be used with advantage as number of irrigations would be small and high rainfall will have moderate effect by leaching salts. The constraints of water quality in irrigation can be examined using a number of empirical indices that have been established on the basis of field experience and experiments.

7.3.1 US salinity laboratory classification

The laboratory has constructed a diagram and described 16 classes with reference to (SAR) Sodium Absorption Ratio (index for sodium hazard) and electrical conductivity (index for salinity hazard). US salinity laboratory classification diagrams for the state of Andhra Pradesh is presented in the Fig.7.5 and for the individual districts are depicted in the Fig.7.7 - 7.18.

SAR is defined as

$$SAR = (Na^{+})/Sqrt\{(Ca^{+2}+Mg^{+2})/2\}$$

Where concentrations are expressed in meq/L.

The ground water (samples collected from the monitoring wells) in Andhra Pradesh classified as 9 classes (Fig.7.5) as described below.

C_1S_1 Class

Low salinity and low sodium waters are good for irrigation and can be used with most of the crops with no restriction on use on most of the soils.

$C2S_1$ Class

Medium salinity and low sodium waters are good for irrigation and can be used on all most all soils with a little danger of development of harmful levels of exchangeable sodium if moderate amount of leaching occurs. Crops can be grown without any special consideration for salinity control.

$C3S_1$ Class

The high salinity and low sodium waters require good drainage. Crops with good salt tolerance should be selected.

C3S2 Class

High salinity and medium sodium waters require good drainage and can be used on coarse textured or organic soils having good permeability.

C3S2 Class

These high salinity and high sodium waters require special soil management, good drainage, high leaching and organic matter additions. Gypsum amendments make feasible the use of these waters.

C4S$_1$ Class

Very high salinity and low sodium waters are not suitable for irrigation unless the soil must be permeable and drainage must be adequate. Irrigation waters must be applied in excess to provide considerable leaching. Salt tolerant crops must be selected.

C4S2 Class

Very high salinity and medium sodium waters are not suitable for irrigation on fine textured soils and low leaching conditions and can be used for irrigation on coarse textured or organic soils having good permeability.

C4S3 Class

Very high salinity and high sodium waters produce harmful levels of exchangeable sodium in most soils and will require special soil management, good drainage, high leaching and organic matter additions. Gypsum amendements makes feasible the use of these waters.

C4S$_4$ Class

Very high salinity and very high sodium waters are generally unsuitable for irrigation purpose. These are sodium chloride type of waters and can cause sodium hazard. Can be used on coarse textured soils with very good drainage for very high salt tolerant crops. Gypsum amendments make feasible, the use of these waters.

It is observed from the US salinity diagram(Fig.7.5) – for shallow aquifer of Andhra Pradesh that 36.7% of water samples are falling in C_2S_1 class. 28.3% of water samples are falling in C_3S_1 class. 20.4% of samples falling in C_3S_2 class. 4.3% and 3.1%, samples falling in C_3S_3, and C_1S_1, and remaining samples falls in C_4S_4, C_4S_3, C_4S_2 and C_2S_2 classes respectively. 0.96% of samples are beyond classification due to high electrical conductivity (i.e Electrical Conductivity greater than 10,000µs/cm) or SAR values.

Fig.7.5

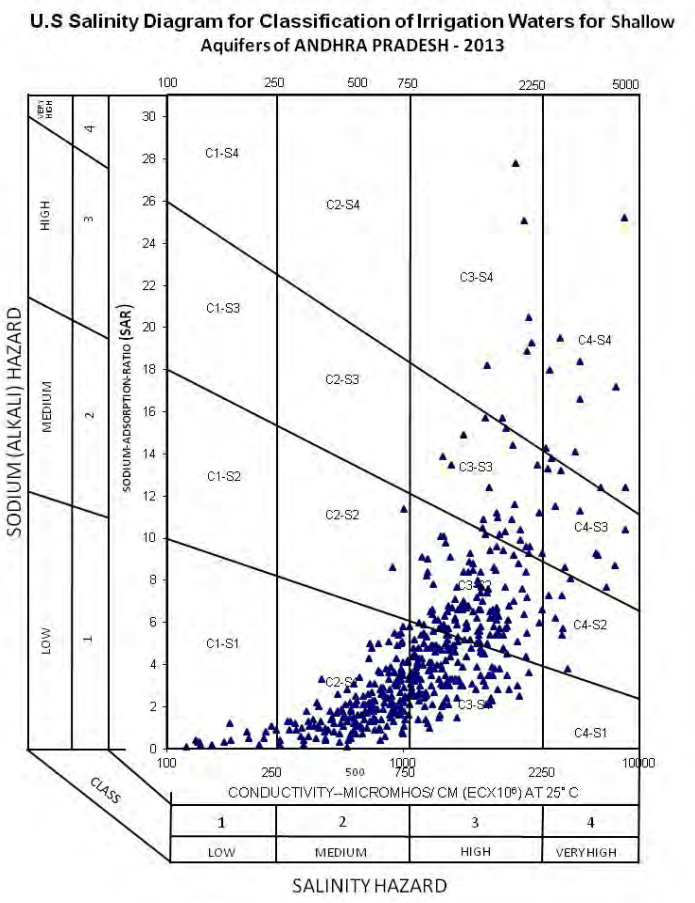
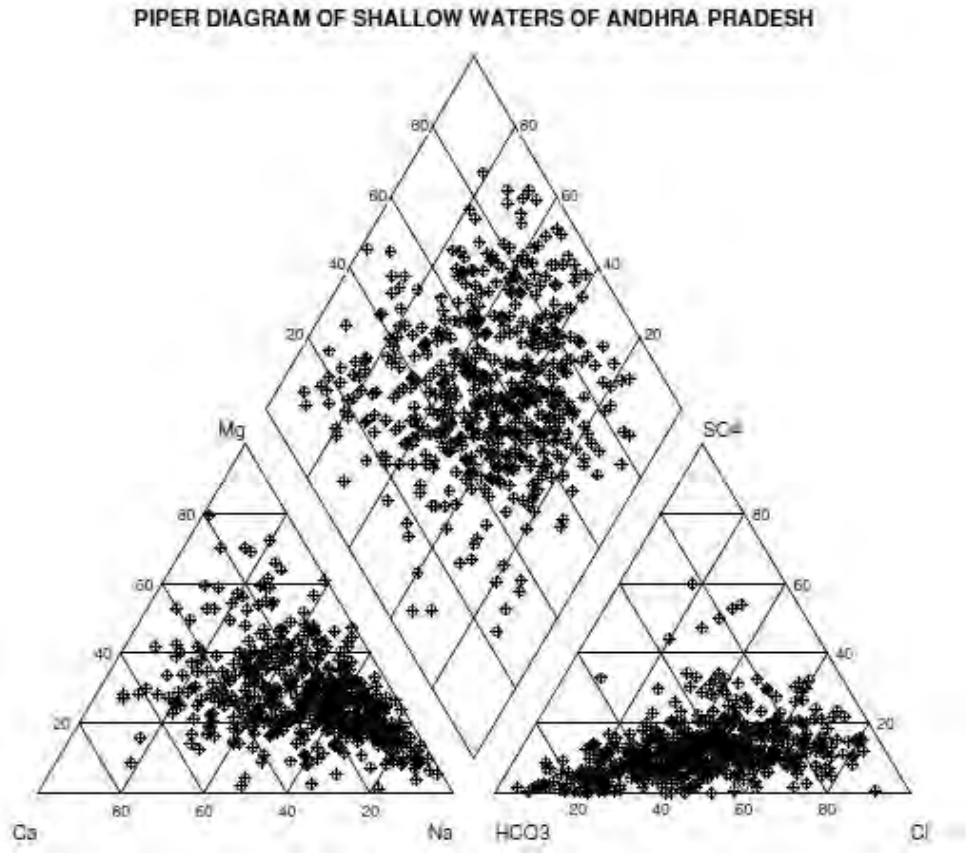


Fig.7.6



7.4 Piper Trilinear Diagram – Types of Water

The Piper Trilinear diagram for the state of Andhra Pradesh is presented in the Fig.7.6 and for the individual districts is depicted in the Fig. 7.19 – 7.31.

Dominant Water types recognized based on Piper Trilinear diagram in the state are Na-Cl, Na-HCO3, Na-Ca-Cl-HCO3 and Na-Mg-HCO3.

7.5 Water quality for live stock and poultry

Though there was no livestock standards regulated in India, based on FAO and other international organizations standards classified the water quality for Livestock and Poultry. One of the important parameter is Salinity/Electrical Conductivity, which moderately shows the suitability of most of the samples in usable. Magnesium and Nitrate are other important parameters to be considered for the usage of ground water for the livestock. Magnesium and Nitrate (except in one case) are within the range specified and suitable for live stock. Guide for use of saline water for livestock and poultry and number of samples in limits and suggested limits for magnesium in drinking water for livestock[1] are given in the Table-7.3 & 7.4 respectively. Guide for use of water containing nitrates for livestock is summarized in the Table-7.5.

Table- 7.3
Guidelines for use of saline water for livestock and poultry and no of samples in limits

Soluble salt content	Rating	No of samples in the range	Uses
< 1 000 mg/Litre (<1.5 dS/m)	Excellent	304	Excellent for all classes of livestock and poultry
1 000-3 000 mg/Litre (1.5-5 dS/m)	Very satisfactory	198	Satisfactory for all classes of livestock. May cause temporary mild diarrhoea in livestock not accustomed to them. Those waters approaching the upper limits may cause some watery droppings in poultry.
3 000-5 000 mg/Litre (5-8 dS/m)	Satisfactory for livestock Unfit for poultry	12	Satisfactory for livestock but may be refused by animals not accustomed to it. If sulphate salts predominate, animals may show temporary diarrhoea. Poor waters for poultry, often causing watery faeces, increased mortality and decreased growth especially in turkeys.
5 000-7 000 mg/Litre (8-11 dS/m)	Limited use for livestock Unfit for poultry	3	This water can be used for livestock except for those that are pregnant or lactating. It may have some laxative effect and may be refused by animals until they become accustomed to it. It is unsatisfactory for poultry
7 000-10 000 mg/Litre (11-16 dS/m)	Very limited use	3	Considerable risk for pregnant and lactating cows, horses, sheep and for the young of these species. It may be used for older ruminants or horses. Unfit for poultry and probably swine.
> 10 000 mg/Litre (> 16 dS/m)	Not recommended	0	This water is unsatisfactory for all classes of livestock and poultry.

Source: FAO, 1985b, and Guyer, 1996

Table – 7.4
Suggested limits for magnesium in drinking water for livestock[1]

Livestock	No of Samples within the range	Magnesium (mg/L)	Concentration (me/l)
Poultry[2]	513	<250	<21
Swine[2]	513	<250	<21
Horses	513	<250	<21
Cows (lactating)	513	<250	<21
Ewes with lambs	513	<250	<21
Beef cattle	518	<400	33
Adult sheep on dry feed	520	<500	41

[1] Adapted from Australian Water Resources Council (1969).
[2] The tolerance of swine and poultry for magnesium is unknown but could well be less than 250 mg/L .

Table – 7.5

Guidelines to use of waters containing nitrates for livestock

Nitrate content* as parts per million (ppm) of nitrate nitrogen (NO3-N)**	As Nitrate, NO3	No. of samples in the range	Comments
Less than 100	<440	514	Experimental evidence indicates this water should not harm livestock or poultry.
100 to 300	440 - 1320	5	This water by itself should not harm livestock or poultry. If hays or silages contain high levels of nitrate this water may contribute significantly to a nitrate problem in cattle, sheep, or horses.
More than 300	> 1320	1	This water could cause typical nitrate poisoning in cattle, sheep, or horses, and its use for these animals is not recommended. Because this level of nitrate contributes to the salts content in a significant amount, use of this water for swine or poultry should be avoided.

Source : Water Quality for Livestock and Poultry, FO-1864-GO. University of Minnesota Extension Division, 1990.

* The values shown include nitrate and nitrite nitrogen. In no case should the waters contain more than 50 ppm nitrite nitrogen (NO2N) because of the greater toxicity of the nitrite form.

**1 ppm of nitrate nitrogen is equivalent to 4.4 ppm of nitrate (NO3).

7.6 Over view of ground water quality

- Monitored 520 number of ground water monitoring wells throughout the state to assess the quality of ground water from shallow aquifers in Andhra Pradesh during May, 2013.
- In general pH is in the range of 7.03 to 9.23.
- Electrical conductivity beyond 3000 micromhos/cm occurs in 11.0% of the samples. It is in the range of 750-3000 micromhos/cm
- Alkalinity exceeds BIS limit of 600 mg/L in 43 samples in the state.
- Sodium is in the range of 2.0 - 2783 mg/L.
- Potassium is in the range of traces to 600 mg/L. In general it is in the range of 3 to 25 mg/L.
- Only 4.6% of the samples have chloride concentration beyond BIS permissible limit. In general it is in the range of 50 to 500 mg/L.
- Sulphate exceeds the BIS permissible limit of 400 mg/L in 3.1% of the samples. In general it is in the range of 5 to 50 mg/L.

- Fluoride exceeds the BIS permissible limit of 1.5 mg/L in 10.6% of the samples. It is in the range of 0.3 to 1.0 mg/L.
- Most of the samples are suitable for livestock and poultry consumption.
- Majority of the ground water water samples are falling in C_2S_1 class followed by C_3S_1 , C_3S_2 C_3S_3, C_1S_1, C_4S_4, C_4S_3, C_4S_2 and C_2S_2 classes.
- Dominant Water types are Na-Cl, Na-HCO3, Na-Ca-Cl-HCO3 and Na-Mg-HCO3 type.
- Most of the samples are suitable for livestock and poultry consumption.
- Electrical Conductivity >13000 µS/cm is found in ground water at Upparigudem, Krishna district, due to saline water intrusion.
- High values of Hardness (2102 mg/L) is found in ground water at Marteru, West Godavari district.
- Chloride concentration >4000 mg/L is observed at K.Bhetipudi, West Godavari district, indicative of Saline water intrusion.
- Sulphate concentration is very High (1013 mg/L) at Upparigudem, Krishna district.
- Highest concentration of Nitrate (2410 mg/L) is found in ground water at Utukuru, Guntur district.
- Highest Fluoride content is noticed (5.3 mg/L) at Podili, Prakasam district.

Fig.7.7

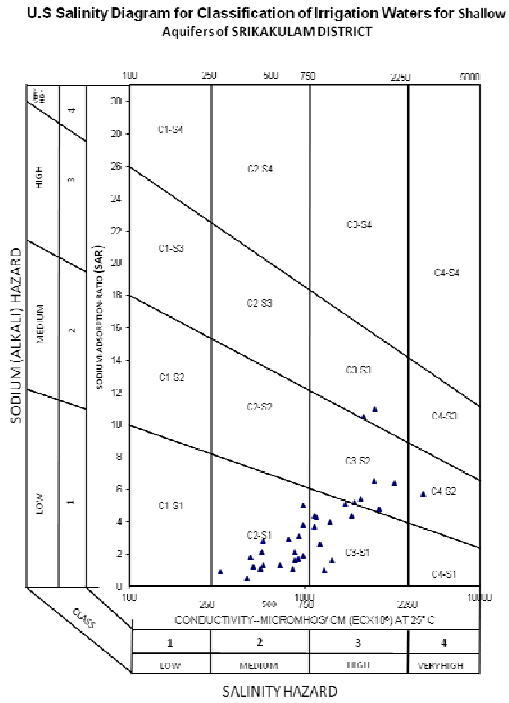


Fig.7.8

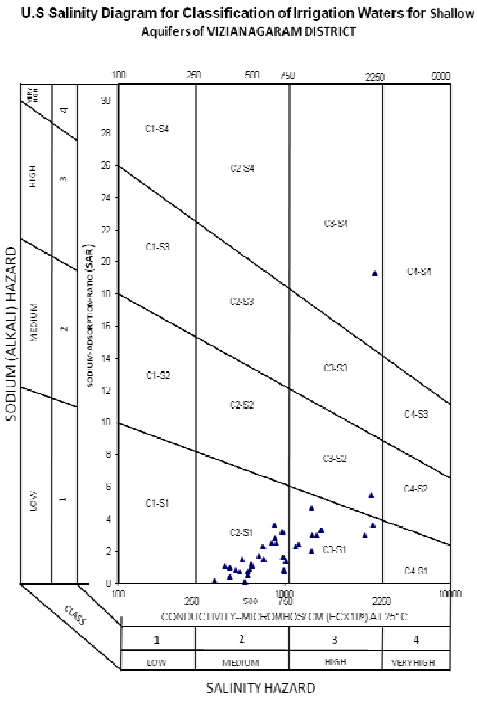
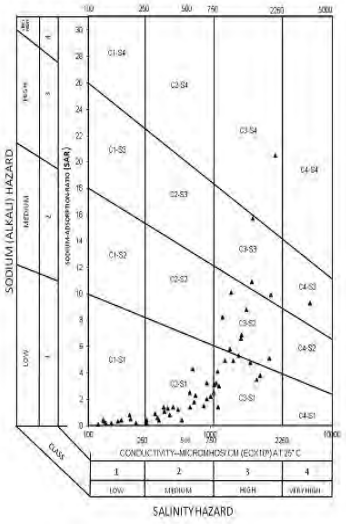
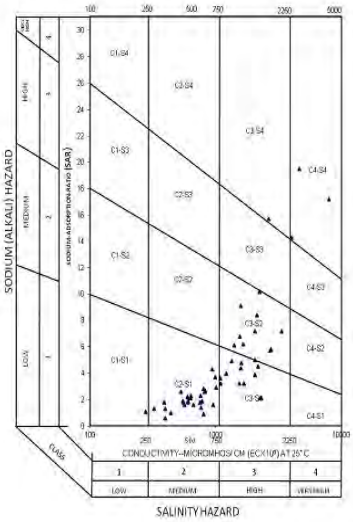


Fig.7.9-7.14

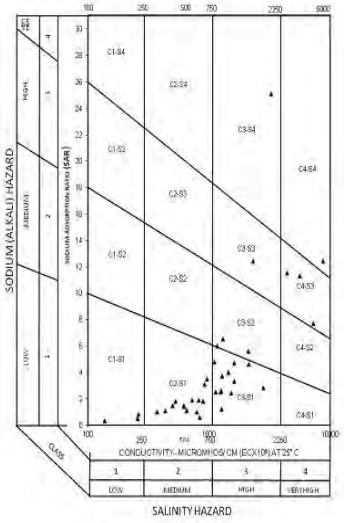
U.S Salinity Diagram for Classification of Irrigation Waters for Shallow Aquifers of VISAKHAPATNAM DISTRICT



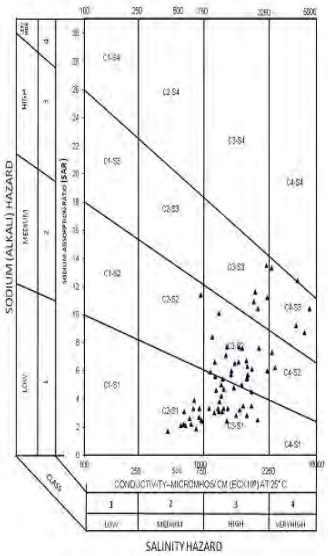
U.S Salinity Diagram for Classification of Irrigation Waters for Shallow Aquifers of EAST GODAVARI DISTRICT



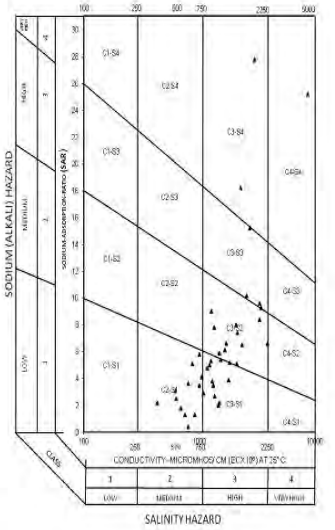
U.S Salinity Diagram for Classification of Irrigation Waters for Shallow Aquifers of WEST GODAVARI DISTRICT



U.S Salinity Diagram for Classification of Irrigation Waters for Shallow Aquifers of GUNTUR DISTRICT



U.S Salinity Diagram for Classification of Irrigation Waters for Shallow Aquifers of PRAKASAM DISTRICT



U.S Salinity Diagram for Classification of Irrigation Waters for Shallow Aquifers of YSR KADAPA DISTRICT

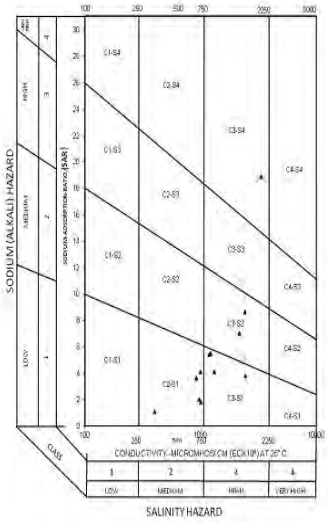
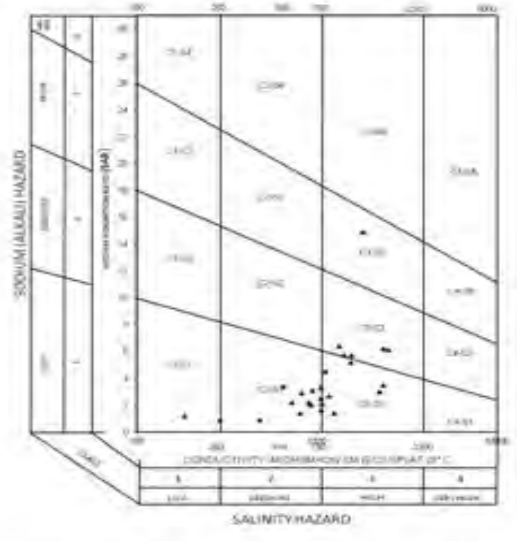
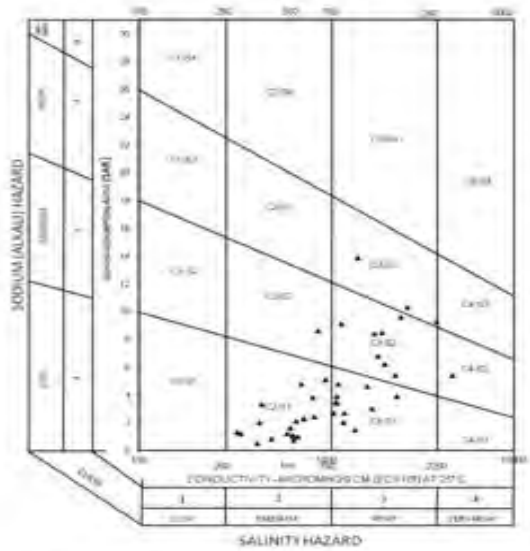


Fig 7.15 - 7.18

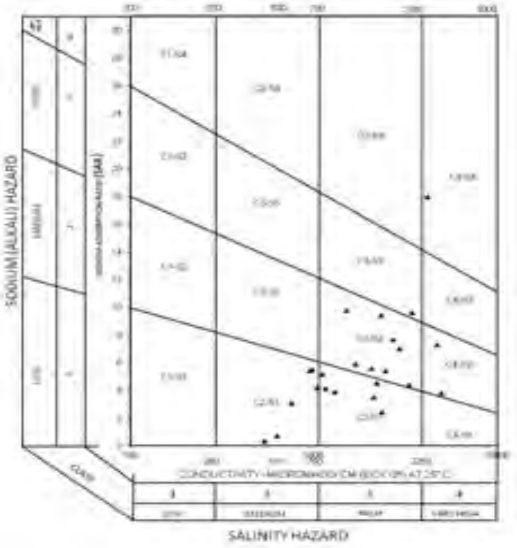
U.S Salinity Diagram for Classification of Irrigation Waters for Shallow Aquifers of CHITTUR DISTRICT



U.S Salinity Diagram for Classification of Irrigation Waters for Shallow Aquifers of NELLORE DISTRICT



U.S Salinity Diagram for Classification of Irrigation Waters for Shallow Aquifers of KURNOOL DISTRICT



U.S Salinity Diagram for Classification of Irrigation Waters for Shallow Aquifers of ANATHAPUR DISTRICT

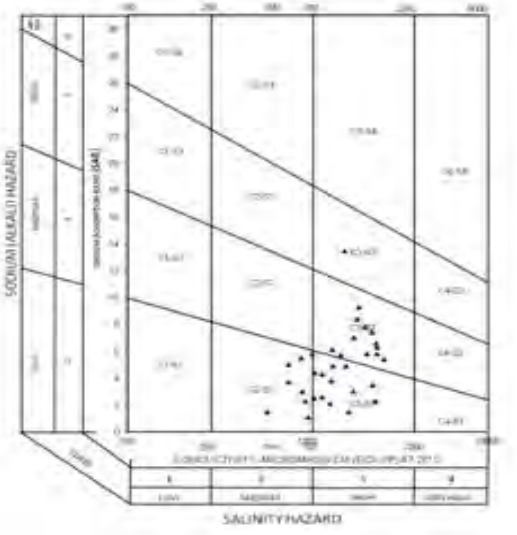
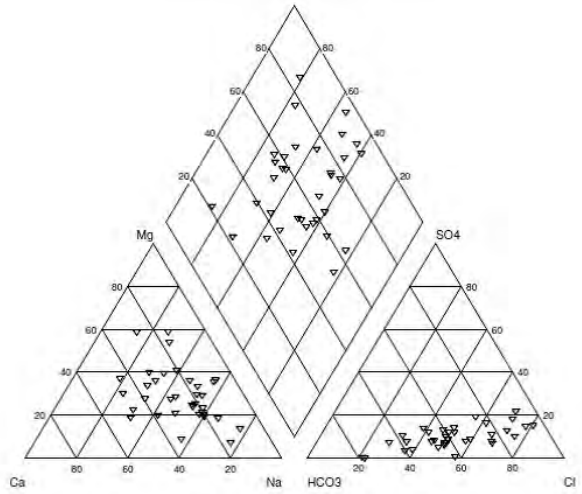
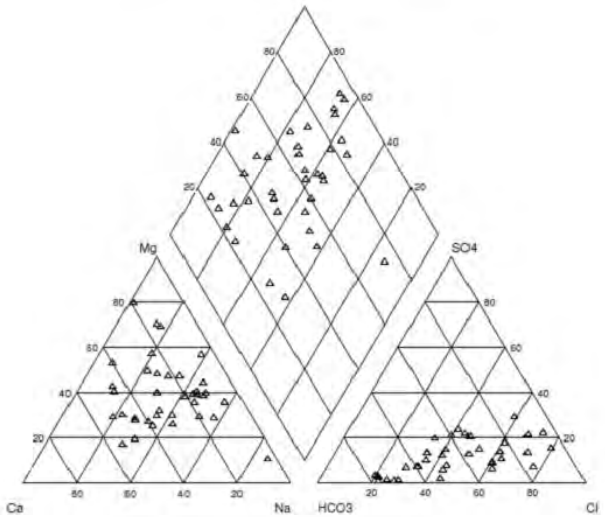


Fig.7.19-7.22

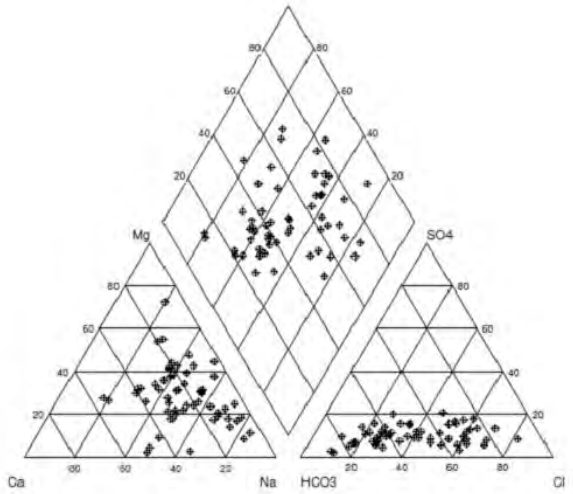
TRILINEAR DIAGRAM OF SRIKAKULAM DISTRICT



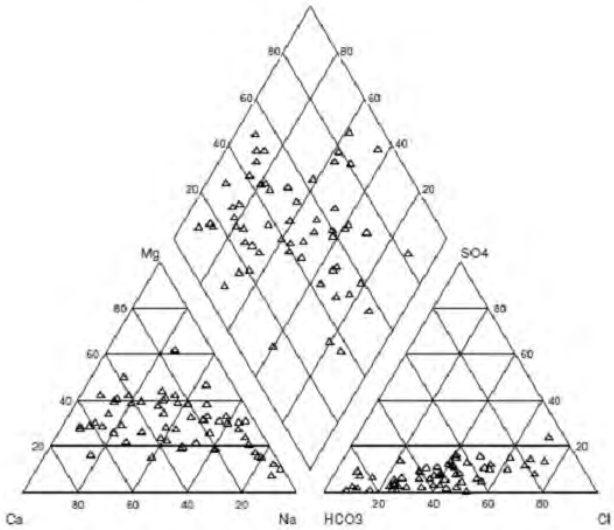
TRILINEAR DIAGRAM OF VIZIANAGARAM DISTRICT



TRILINEAR DIAGRAM OF EAST GODAVARI DISTRICT

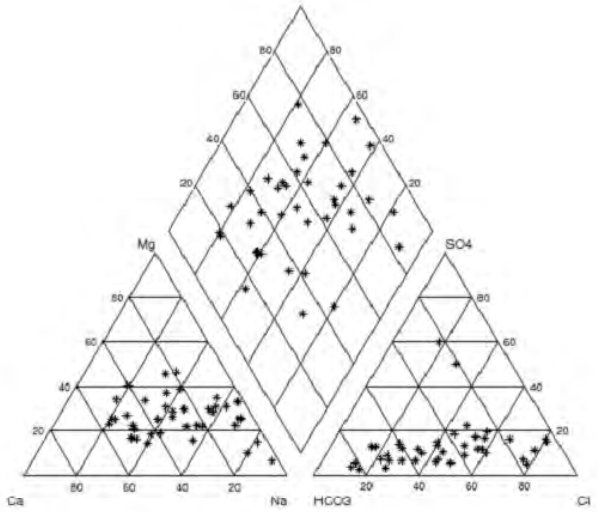


TRILINEAR DIAGRAM OF VISAKHAPATNAM

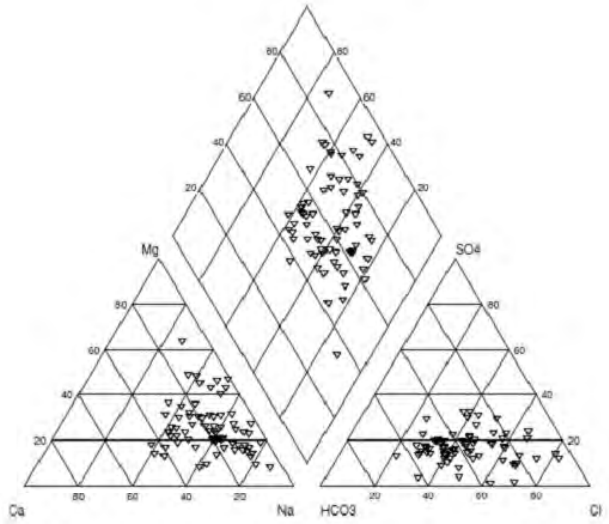


TRILINEAR DIAGRAM OF WEST GODAVARI DISTRICT

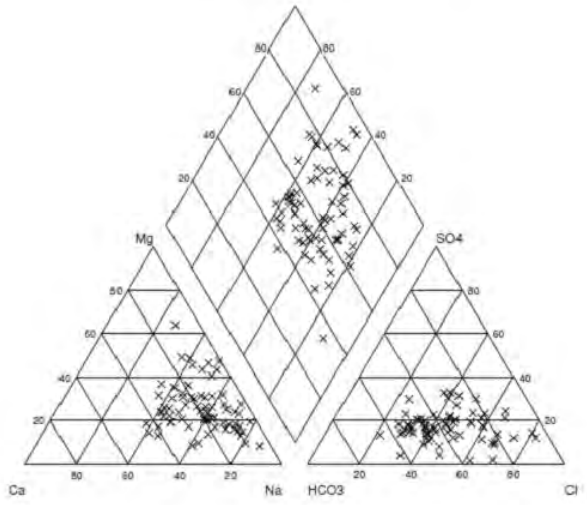
Fig.7.23-7.26



Trilinear Diagram of Krishna District



TRILINEAR DIAGRAM OF GUNTUR DISTRICT



TRILINEAR DIAGRAM OF PRAKASAM DISTRICT

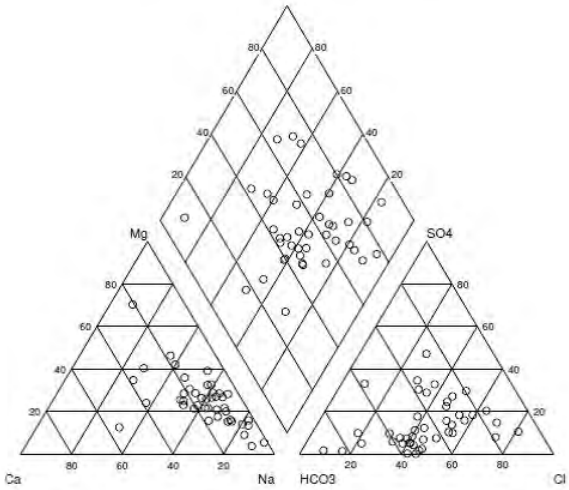
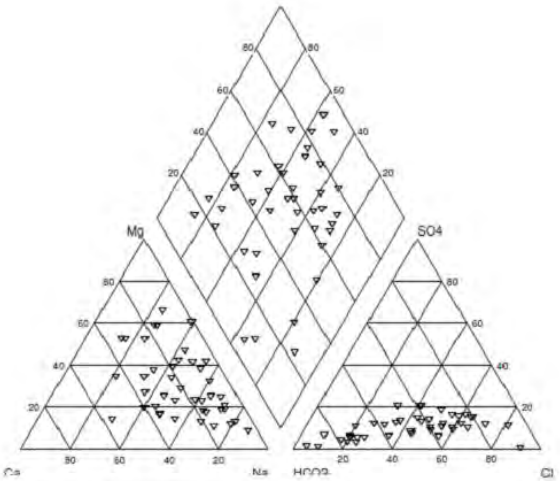
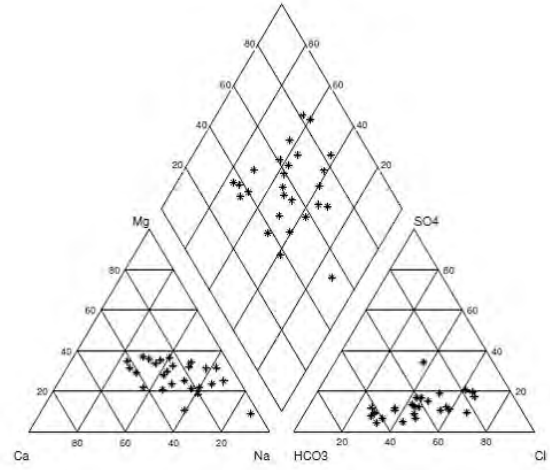


Fig.7.27- 7.31

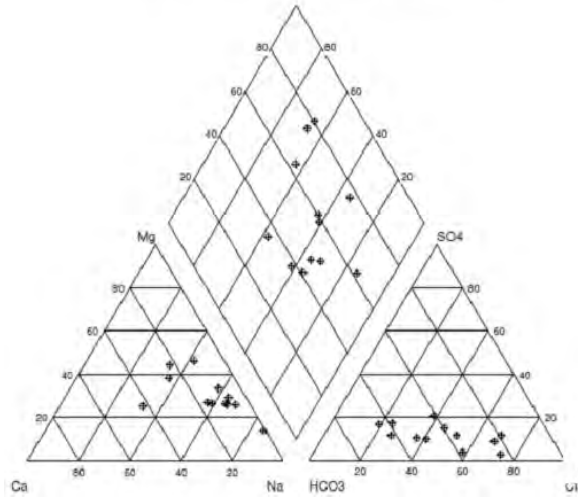
TRILINEAR DIAGRAM OF NELLORE DISTRICT



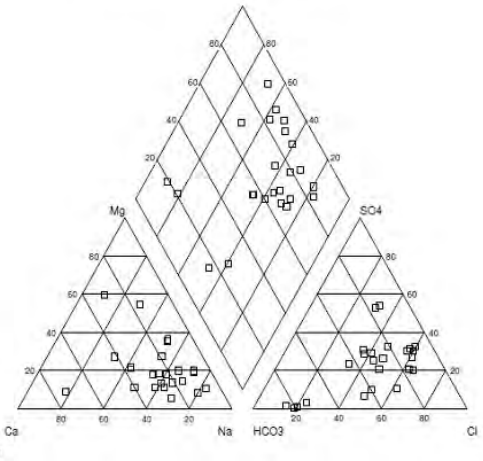
TRILINEAR DIAGRAM OF CHITTOR DISTRICT



TRILINEAR DIAGRAM OF YSR KADAPA DISTRICT



TRILINEAR DIAGRAM OF KURNOOL DISTRICT



TRILINEAR DIAGRAM OF ANATHAPUR DISTRICT