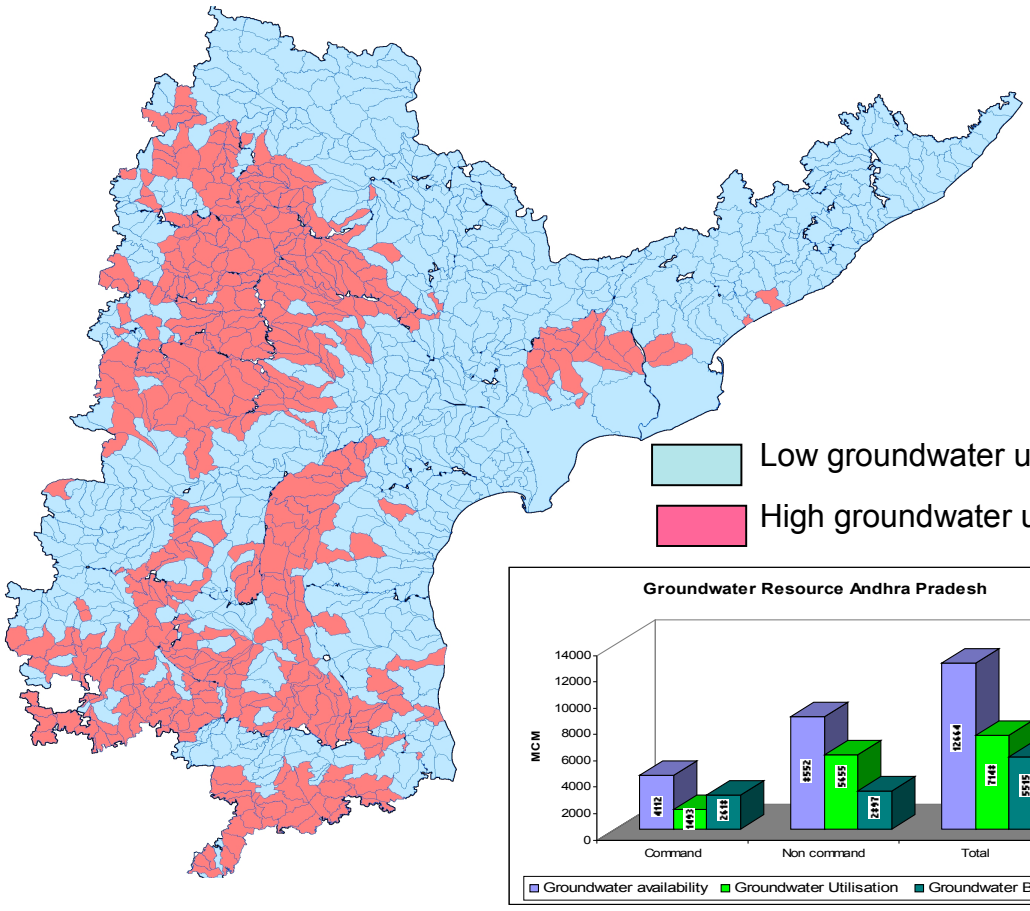
VOLUME - I

GOVERNMENT OF ANDHRA PRADESH
GROUND WATER DEPARTMENT

GROUNDWATER RESOURCE 2004-05
ANDHRA PRADESH
(Ministry of Water Resource Formats)



P.Sreenivas Prasad
Director

June, 2006
Hyderabad

Dr. Y.S.RAJASEKHARA REDDY
CHIEF MINISTER
ANDHRA PRADESH

HYDERABAD
26.7.2005

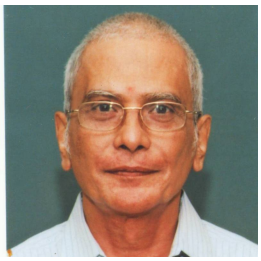
MESSAGE

It is heartening to note that our Andhra Pradesh stands first and foremost in the country to complete the process of Ground Water Resource estimation on a watershed approach right from the micro level of villages, and that the Ground Water Dept. has come out with the Report in this regard.

The stress on the groundwater utilization has been increasing. It is high time we think about future requirements, and formulate an effective strategy for water conservation. In order to combat frequent recurrence of drought, we are implementing Integrated watershed development, Rain shadow area development and Drought prone area development programmes, apart from enforcing the AP WALTA Act, by taking up soil and moisture conservation, water harvesting structures, afforestation and horticulture with micro-irrigation.

I hope that the resource data of the Report would be very much useful in planning and management of the user departments, and ultimately contribute to public in general and farmers in particular in a big way.

(Y. S. RAJASEKHARA REDDY)



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Dr. Mohan Kanda, I.A.S

CHIEF SECRETARY

Message

It gives me a great pleasure to compliment Ground Water Department for bringing out the report on State's groundwater resources for 2004-2005, on a watershed approach, bringing out the resource up to the village level. I understand that this report will be integrated with those of the other States by Ministry of Water Resources, Government of India, to bring out the Country's resources.

Water has sustained civilization since pre-historic times and as the need for civilization, especially after industrialization, has increased the man started to turn to groundwater more and more. It is an unseen natural reservoir below our ground, but is finite in extent like all reservoirs. This report gives in volumetric terms, the groundwater resource as well as its use. I feel confident that it will go a long way in assisting the formulation of management strategies down to the village level and in helping the common villager to know his resource and involve himself in the process of planning.

(Mohan Kanda)

MULINTI MAREPPA
MINISTER FOR LIFT IRRIGATION, APSIDC,
GROUND WATER DEVELOPMENT AND
RAIN SHADOW AREA DEVELOPMENT

HYDERABAD
DATE 28-07-2005

MESSAGE

It gives me immense pleasure to note that the A.P.Ground Water Department has completed the ground water estimation of the state on scientific line. I congratulate the Director and his Officers for this effort.

Sustainable Development and Management of Ground Water Resource requires quantitative assessment. I hope that the present assessment will help to achieve the goal. Apart from agriculture, large number of villages are dependent on ground water to meet their drinking and domestic water requirements

I am confident that this data would help the state administration to plan for judicious development of the available resource and a cautious approach in utilizing it in already over exploited villages.

The periodic assessment done by the Ground Water Department is in tune with National Water Policy and will help in implementation of WALTA and also other Governmental Programmes. This task would definitely fulfill the commitment of the government towards the farmers in general and Rain Shadow Area Development Areas in particular.

(MULINTI MAREPPA)

28/7/2005

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Dr. C.V.S.K.Sarma I.A.S
Principal Secretary to Government

IRRIGATION & C.A.D DEPARTMENT

MESSAGE

Andhra Pradesh is essentially an agrarian state. It is bestowed with good rainfall and water resources with per capita availability of more than 1700 cubic metres per annum. Although paradoxically, it also has near **desert-like** environs in some of its parts, so it has been always a challenge to manage the water resources. Management of groundwater is a greater challenge as it is an unseen reserve and its availability at a given place and time depends not just on rainfall but on complex set of parameters controlled by physiographic and geologic conditions, and by the history of usage. Besides, groundwater stored in rocks far exceeds the annual recharge which makes it difficult to realise when the resource is over-exploited as bore-wells or tube-wells continue to give water even when the resource is over-exploited. It is therefore necessary to know the annual replenishment and usage for planning the utilisation and for implementing management measures. This report, I am sure would go a long way in helping achieve these goals.

Date : 30-07-2005

(Dr.C.V.S.K.Sarma)

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FORE WORD

Water resources are linked very subtle to a Nation's economy. The resource now a days is not only perceived in terms of availability but also on the ability to preserve the quality of resource and keep the environmental values intact; ability to use the resource and the percentage of population of a nation that has access to the resource, which is driven by economic health of the country.

Water for use is drawn from the surface water that is captured as it flows or is halted in dams and reservoirs before being put to use. Groundwater can always be captured without recourse to stopping it as it sluggishly flows through the sub-terranean milieu of rocks. The stock of groundwater in the rocks is usually many times over that which is annually replenished. In the state this is especially true in sandstone aquifers along the River Godavari and alluvial aquifers of flood plains of major rivers and streams as well as the deltaic and coastal plains. Until man started his exploitation of nature all this water was in delicate balance. Giving out as streams in lean periods and soaking up enough in rainy season to feed the streams in next lean season. It was as life sustaining as ever. With active abstraction first in the form of dug wells, then in the form of bore wells, this delicate balance was lost. As a consequence, year by year the rocks are holding lesser and lesser water in many parts of the state. The aim of this report is to quantify the present annual recharge to the stock and usage from this stock. It brings out areas where the change in storage is negative i.e. areas where groundwater usage exceeds annual recharge and lists such points and areas

Andhra Pradesh has revised the assessment completely using the current year's (2004-05) data. The report is the final outcome of the assessment and contains the details of watershed wise (basin wise) annual availability of groundwater, current draft (utilisation), allocation for domestic and industrial needs, availability for future use (or the balance) and categorisation based on stage of development and rigorous statistical treatment of water levels. It also gives mandal wise resources which are apportioned and derived from the watershed assessment. The apportioning of resource at mandal level or at village level dilutes the guiding

principal of the resource assessment with watershed as units, but is unavoidable and is done for administrative convenience. This is the only state in the entire country, to have extended the assessment up to the village level. A supplement of this report also lists out the over exploited villages and poor groundwater quality areas. The district and basin reports up to village level are also generated for use at micro level for development and management of groundwater resources including water conservation, recharge and implementation of Land Water and Trees Act.

Some of the suggestions made during last meeting of this Committee for strengthening the database, especially those involving the University students and Research Organisations in pilot studies are being implemented. At present NIH, NGRI, JNTU, Osmania University, Andhra University and Tirupathi University are actively collaborating with the department in many of their research projects centred on groundwater themes.

This report is the culmination of the efforts of the officers of the Groundwater Department. It is to the credit of Dr. B.N.Prasad, Director, Ground Water Department that during his short tenure of 3 years and 3 months the assessment was carried out twice. I would like to express my appreciation to the Officers of the Ground Water Department involved in assessing the groundwater resource of the state and preparation of this report. It is hoped that the results of assessment would be of great help in formulating the resource augmentation and regulatory measures for sustainability of groundwater resource in the State.

S.P.Tucker IAS
CHAIRMAN, GROUNDWATER ESTIMATION COMMITTEE
AND PRINCIPAL SECRETARY TO GOVERNMENT,
Irrigation and Command Area Development Dept.
Andhra Pradesh.

PREFACE

Groundwater since historical times formed an important source of water. In fact even today in large number of villages it is the only source of drinking and domestic water. Small earthen dams form a supplemental source of irrigation while groundwater remains the main source for irrigation in many of the areas, which are not served by canal system in the state. Groundwater in such areas is again the only source of water for irrigation in summer months. And when the monsoon fails groundwater comes in handy for many of these parched lands.

Sustainable development and management of groundwater resource requires quantitative assessment of the resource. Systematic groundwater assessment for erstwhile taluks in the State was first attempted in 1984-85. Subsequent assessment for the State was done with mandal as a unit, using 1992-1993 data, based on Groundwater Estimation Committee, 1984 Methodology. The procedures were revised again in 1997 by a 'High Power Committee' constituted by the Ministry of Water Resources, Government of India. 'Groundwater Estimation Methodology-1997' was the outcome of the recommendations of the Committee which was released in the later part of 1998. In July 2002, the revised estimates for the state were released again. Prior to this release, the Government of Andhra Pradesh constituted a State level Groundwater Estimation Committee with the Principal Secretary, Irrigation and Command Area Development Department as Chairman and 21 members from different organisations in the state. The Director, State Groundwater Department is the Convenor of the Committee and the Department was vested with the responsibility of completing this task. A Technical Sub-Committee was formed with members from State Groundwater Department, Central Groundwater Board, NABARD, Directorate of Economics and Statistics for the purpose of framing the guide lines for data collection, validation and computing the groundwater potential in the State.

Detailed guidelines were formulated through discussions and deliberations in the three State Level Groundwater Estimation Committee and eight Technical Sub-Committee meetings held during 1999-2000 and communicated to the Deputy Directors of the district offices for collection of data. The data collection was made at village level and tentative steps were taken to report the results at village level. After the release of State Level Report in July 2002, resource estimation for each village was released in both English and in Telugu in 2003.

Groundwater is dynamic resource and a continuous re-assessment is necessary as new data is obtained and groundwater usage and cropping pattern changes. The National Water Policy enunciates periodic assessment of groundwater potential on scientific basis. Periodic re-assessment is also called for by a legislation of the State entitled, "WALTA", the Water Land and Tree Act. Central Ground Water Board has decided to bring Country's resources in a consolidated report this water year. It is with particular pride I state that the State of Andhra Pradesh has siezed this opportunity to once again embark on total revision of the resources. A videoconference was called in second week of December and all the District Offices were geared up for collection of the data. The data at village level for 26, 500 odd villages comprising more than a million data points of the state was collected in a record time of 2 to 4 weeks. The groundwater re-assessment is based entirely on these data inputs with limited field check and on the last 3 decades of inventory and hydrogeologic parameter estimation carried out by this department. It was started in January 2005 and took about 4 months to complete and compile the results. About 40 officers from the districts have participated in the process of data collection and computation. The assessment duly follows all the earlier recommendations of different committees and the procedures that were standardised during last assessment of 2002. As the standardised procedures were in place, a need for the meeting of Technical Committee was not felt. However, continuous interaction with other agencies was maintained informally during the process of assessment. Active cooperation from APTransco, sister Irrigation Departments, IMD, Revenue Offices at mandal level, etc. in providing needed data for this assessment is gratefully acknowledged.

The report has two volumes. Volume 1 of the report gives watershed wise assessment while volume 2 gives mandal wise resource.

The data and results at the Directorate were evaluated by Mr. Raoof Hashmi, Deputy Director (Hg); Dr.Pradeep Raj, Assistant Director (Hg) has done statistical analysis of the results using SPSS, MINITAB & Ms Excel and prepared the text of the report. The assessment was carried out using Ms Excel spreadsheet program for assessment of the groundwater resource (broadly following GEC 1997) developed by him. Useful inputs and support was provided by Sri B.R. Kishen, Deputy Director A/C (Hg), Sri M.Satyanarayana Deputy Director (Hg), Sri Harish Kache Assistant Director (Stat), Sri Suhas Raje Assistant Hydrogeologist, Sri G. Shashi Kumar Assistant Hydrogeologist and E.Sunil Kumar Assistant Hydrogeologist.

Sri C.Rakesh Chander, Assistant Director (H), Dr.P.Mohan Rao, Assistant Hydrogeologist; Sri T.Hansraj, Assistant Hydrogeologist and Sri K. Padma Prasad Assistant Hydrologist have put in untiring efforts to complete data verification, and have made necessary cross checks. They have thoroughly explored and probed the data and validated the results to bring the assessment to an acceptable form. Sri M. Sridhar Assistant Hydrogeologist and Sri Anjaneyulu Assistant Geophysicist have prepared GIS maps for the project. Ms K.Revati Assistant Engineer has helped in page formatting of output tables. Printed tables were scrutinised by various officers at different levels.

July 2005
Hyderabad.

[Dr.B.N.PRASAD]
DIRECTOR,
Ground Water Department,
Andhra Pradesh

Message

Dr C.V.S.K Sarma IAS
Principal Secretary to Government
Irrigation and Command Area Development Department

Andhra Pradesh is essentially an agrarian state. It is bestowed with good rainfall and water resources with per capita availability of more than 1700 cubic metres per annum. Although paradoxically, it also has near *desert-like* environs in some of its parts, so it has been always a challenge to manage the water resources. Management of groundwater is a greater challenge as it is an unseen reserve and its availability at a given place and time depends not just on rainfall but on complex set of parameters controlled by physiographic and geologic conditions, and by the history of usage. Besides, groundwater stored in rocks far exceeds the annual recharge which makes it difficult to realise when the resource is over-exploited as bore-wells or tube-wells continue to give water even when the resource is over-exploited. It is therefore necessary to know the annual replenishment and usage for planning the utilisation and for implementing management measures. This report, I am sure would go a long way in helping achieve these goals.

Dr C.V.S.K Sarma

GROUND WATER RESOURCE
ANDHRA PRADESH

EXECUTIVE SUMMARY

Andhra Pradesh, the third largest state of the country, is located between North and South India. The area of the state is 275,068 Sq Km. with a forest Cover of 23 %. Table 1 gives the Administrative set up of the state. The state shares her boundaries with Orissa, Tamil Nadu, Chattishgarh, Maharastra and Karnataka, and on the eastern side of the State is Bay of Bengal.

Table –1

ADMINISTRATIVE SET UP	1981	1991	1998
Districts	23	23	23
Revenue Divisions	69	74	79
Taluks / Mandals	195	1106	1123
Inhabited Villages	27379	26586	26586
Uninhabited Villages	1902	1414	1414
Towns	252	264	264

Rainfall

The normal annual rainfall is 940 mm. The rainfall record also shows that droughts are fairly recurrent in the state. The analysis of state rainfall during 1974-2004 indicates deficit rainfall in all the 30 years in one or the other parts of the State. The State receives about 66% of rainfall from south-west monsoon (June-September) and about 25% from north-east monsoon (October-December). The remaining 9% is received during winter and summer months.

Rivers of the state vis-à-vis watersheds

The state has 3 major rivers the Godavari, the Krishna and the Pennar, besides a number of small but splendid rivers of eastern-ghats. The River Godavari with its tributaries Pranahita, Manjeera, Maneru, Indravati, Kinnerasani, Pamuleru and Sileru drains through the northern parts of the State into Bay of Bengal. The river flows through Adilabad, Karimnagar, Nizamabad, Medak, Ranga Reddy, Warangal, Khammam, Krishna, East & West Godavari and Visakhapatnam districts. The River Krishna with its tributaries Tungabhadra, Vedhavati, Hundri, Musi, Paleru and Munneru flows through the

central parts of the State. It drains Anantapur, Kurnool, Mahabubnagar, Ranga Reddy, Nalgonda, Guntur and Krishna districts in to Bay of Bengal.

The River Pennar, the third biggest river, with its tributaries Chitravati, Papaghni, Cheyyeru and Pincha drains Rayalaseema region and Nellore district.

National codes for major river basins of the state

The Godavari river basin is designated as **E,** the Krishna river basin is designated as **D**. The Pennar river basin is a part of a catchment designated as **C**. The area between the Godavari river basin and the Mahanadhi river basin encompassing the eastern-ghats is defined as basin **F**. It lies in Srikakulam, Vizianagram, Visakhapatnam and East Godavari districts. The area between the Godavari and the Krishna basins is grouped as basin **I**. It lies in Krishna, Khammam and West Godavari districts. Similarly the area on the south of the Krishna catchment and including . It covers Chittoor, Anantapur, Cuddapah, Kurnool, Prakasam and Nellore districts.

There are in all 40 rivers that drain directly into the sea, and 81 sub basins are recognised as accounting units for the water. However, these sub basins which range in size from 90.65 km^2 to 15699 km^2 are generally too big for estimation of dynamic groundwater resources. The ideal recommended size of groundwater estimation unit i.e. the catchment is 300 km^2. Hence, in 2002, for the purpose of groundwater estimation these accounting units were further sub-divided into 1193 drainage basins that are called watersheds in consonance with the decision of the Groundwater Estimation Committee. However, these divisions are now modified and number 1229 in the state.

Soils and agro-climatic zones

The soils are broadly red, black, alluvial, lateritic and coastal sandy types. They support large variety of natural vegetation and in general good for agriculture and horticulture. The climate, rainfall and soil divide the state in 7 climatic zones, which are based as much on the water availability as on the type of agriculture that the area can support. Hence, these are properly referred as agro-climatic zones.

Geological and Hydrogeological characteristics

The state is covered by

1. The Archaean rocks essentially unclassified crystalline rocks mainly the granitic rocks but in eastern ghats comprising granulite suites locally called as khondalites and kodurites,
2. The Middle–Upper Proterozoic the Cuddapahs and its equivalents;
3. The Mesozoic the coal bearing Gondwana strata
4. Eocene lava flows (the deccan traps) and
5. The semi-consolidated or unconsolidated tertiary and recent rocks

Hard Rocks

Archaeans, Pre-Cambrians, Cuddapahs, Kurnools and Deccan traps are categorised as *Hard Rocks* from *groundwater* point of view. These rocks have negligible primary porosity. The development and management of aquifers in these diverse formations requires similar techniques. These rocks cover nearly 85% of the State that is about 2.332 lakh km^2. l . History of the wells shows that till 1970s there were mostly dug wells. Some of them could irrigate up to 10 or 15 acres (4 to 6 ha) of paddy in good monsoon years, especially if the area was served by small irrigation tanks. Wells that could sustain up to 5 acres (2 ha) were quite common. In 1980s the technique of drilling wells was well entrenched and initially some of the dug wells were converted to dug – cum – bore wells along and progressive farmers took up drilling of bore wells. Still it was quite common to find wells (now bore wells) irrigate 5 acres. The mean yield of the bore wells during this period was 2.47 ha.m and that of the dug wells with pumping facility was 0.91 ha.m. But with state's support through financial institutes for well sinking programme in 1990s, the number of bore wells started proliferating. And simultaneously, during this decade the mean well yields started showing a decline. Now (mid 2000s), it is common to see bore wells irrigate less than an acre of land. **An implication of this change is tragic wastage of energy**. Dug wells that pumped accumulated water from storage required just an hour of pumping to irrigate 2 acres of crop like groundnut. Present day bore well takes 6 to 8 hours of excruciatingly slow pumping to irrigate the same field.

Soft and unconsolidated Rocks

About 15% of area state that is 41,160 km2. is underlain by soft rocks Gondwanas, Rajahmundry formations, Recent Alluvium, etc. Well yields as high as 1500 l/m are recorded in these rocks. However, present day mean well yields are around 0.75 ha.m per annum and they are skewed towards lower side.

Gondwana rocks form extensive aquifers and sustain well yields quite beyond their annual replenishment. Tube wells constructed in these rocks have yielded 200 to 2000 l/m for drawdowns ranging from 12 to 38 m. The open wells tapping these formations yield from 20 to 30 m^3/day.

The Kamthi Sandstones beyond the depth of 250 m bgl are intercalated with shales and clays. Tube-wells constructed within the 200 m depth range in yield from 250 l/m to 3000 l/m for drawdowns of 9 to 30 m. Transmissivity of the aquifer varies between 28 and 950 m^3/day. The yield of tube wells in the Chinthalapudi Sandstones constructed down to 50 and 150 m bgl vary from 450 to 1000 l/m and the transmissivity of the aquifer varies between 150 and 303 m^2/day.

These aquifers are confined and in some cases potentiometric surface lies above the ground surface giving rise to flowing wells / springs.

Rajahmundry sandstones are also good aquifers; the yields of tube-wells tapping these tertiary aquifers down to depths of 300 m vary from 600 to 7500 l/m for drawdowns of 6 to 15 m and transmissivity of the aquifer varies from 90 to 2500 m^2/day indicating that these are the finest aquifers in the state.

The alluvial aquifers have high porosity and permeability. Filter points are most common in this formation. Filter points drilled down to 1.5 to 20 m bgl yield between 150 to 1500 l/m.

In Krishna-Godavari delta the alluvium attains a thickness of more than a few hundreds of metres. However, the deeper aquifers are found to contain highly saline water. The static water level in these formations is general shallow. Groundwater in the coastal alluvium occurs both under water table and confined conditions and is generally developed by means of dug-wells, filter points and shallow tube wells. The depth to water table in dug wells varies from near surface to about 5 m bgl. Usually the quality

of water is the main problem in coastal alluvium. Fresh water bodies occur as pockets and lenses in the top 20 m bgl. Deeper wells can lead to up-conning of salt water and fresh water interface, which can damage the groundwater irretrievably. Hence, the depth of the wells must be restricted to 4 or 5 m bgl. In Delta region of Krishna, it is found that the sediments have connate water, which is not completely flushed out, and as a result the water quality is poor in deeper aquifers – mostly beyond 60 metres bgl

Table 3 Monitoring network the Observation Wells and Piezometers

1	Observation wells in non-command areas	1582
2	Observation wells in command areas	1404
3	Total Piezometers	1017
4	i.Piezometers with AWLRs	888
	ii. Piezometers with manual measurement	129

The CGWB is also monitoring the changes in groundwater through their own network of 1000 observation wells and 200 piezometer wells and the data is also being integrated and utilised with the State Ground Water Department's data.

Groundwater estimates 1993

The net groundwater availability per annum for the entire State was estimated to be 35.3 BCM, which is 14.4% of the total quantity of water received through the normal precipitation. From this 15%, i.e., 5.3 BCM was earmarked for drinking and other committed uses leaving a balance of 30 BCM for irrigation. The net annual groundwater draft for irrigation was 7.092 BCM. The range of groundwater development for different districts was between 7% and 43% and for the State as a whole it was 25%. However, in 5 full mandals and 60 part mandals, the stage of development was more than 85% and such areas were declared as 'Dark'.

Groundwater estimates 2001-02

The State of Andhra Pradesh is divided into 1193 assessment units, which include basins with defined hydrological boundaries in hard rock areas of extent ranging between 50 and 450 km^2 and mandals (administrative blocks) in alluvial areas including 36 Saline mandals. Computations of net groundwater availability, its utilisation and availability for future use in all the assessment units for command, non command and poor

groundwater quality areas have been made separately. The estimates show groundwater availability is 30 BCM, usage is 13 BCM and the balance is 17 BCM per annum (Table 4)

TABLE 4

GROUND WATER ESTIMATES OF JULY 2002

S.No	Description	Com-mand	Non-com-mand	Poor ground water quality area	Total
1	Area considered for recharge in Sq.Kms.	34978	192760	4754	232492
2	Net annual groundwater availability in MCM (TMC)	11232 (397)	19173 (677)	1655 (58)	32060 (1132)
3	Current gross annual groundwater draft for all uses in MCM (TMC)	1744 (62)	11223 (396)	29 (1)	12996 (459)
4	Current gross annual groundwater draft for irrigation in MCM (TMC)	1506 (53)	10392 (367)	12 (0.42)	11910 (420)
5	Demand for domestic and industrial needs at year 2025 in MCM (TMC)	513 (18)	2105 (74)	0	2618 (92)
6	Allocation for domestic and industrial needs in MCM (TMC)	510 (18)	1643 (58)	0	2153 (76)
7	Net annual groundwater availability for future irrigation in MCM (TMC)	9220 (326)	7237 (256)	0	16457 (582)
8	Stage of development (%)	16	56		43

Groundwater estimates 2004-05

Net annual groundwater availability, its usage (groundwater draft under all uses) and balance or what is referred to as *availability for future use* in all the assessment units has been made using a spreadsheet developed for this purpose, adhering to GEC, 1997 norms. The computations are made separately for command, non-command and poor groundwater quality areas. The watershed boundaries are revised and now they number 1229. The estimates show groundwater availability is 32.8 BCM, usage is 14.9 BCM and the balance is 17.9 BCM per annum. This resource includes 1.3 BCM of net annual groundwater availability in poor quality and saline areas. The usage in saline areas is about 0.21 BCM. These results are summarised in Table 5. The district wise details are presented in the statements that follow this text. Figure 1 gives a summary of these results separated into command, non-command and total resource.

District wise **comparison** of the results with those obtained in 2002 shows definite increase (by about 13%) in groundwater usage under all sectors, this is corroborated by steep decline in mean water levels almost everywhere in the state. In many areas water level stands in fractured formation, rather than in weathered formation, as shown by the network of existing piezometers and drying up of traditional OB Wells.

TABLE -5

GROUNDWATER ESTIMATES FOR THE STATE 2005

Sl. No	Description	Com-mand	Non-com-mand	Poor ground water quality area	Total
1	Area considered for recharge in Sq.Kms.	56,018	1,92,092	(4114)	2,48,110
2	Net annual groundwater availability in MCM	14,964	17,794	(1307)	32,758
3	Current gross annual groundwater draft for all uses in MCM	3,330	11,525	(20.8)	14,855
4	Current gross annual groundwater draft for irrigation in MCM	3,026	10,716	-	13,742
5	Allocation for domestic and industrial needs in MCM	630	1,927	-	2,557
6	Net annual groundwater availability for future use in MCM	11,634	6,269	-	17,903
7	Stage of development (%)	22	65	-	45

Mean hydrograph (Figure 2) of the state records a fall of 1.95 metres in last 7 years. But three coastal districts Srikakulam, Vizianagaram and Guntur show a decrease in usage of groundwater. One district in Rayalaseema the Chittoor district also reports a decrease in use of groundwater.

The estimates of 2002 were made mainly using 2000 database and in some cases, data for 1993 was used along with a projected growth of wells. So effectively this assessment done using current year (2004-05) data reflects a change that has taken place in last 5 years.

The assessment shows that the districts can broadly be grouped into four groups (Figure 3).

a. The *very high usage* (over all stage of development >70%) districts comprising RangaReddy (& Hyd), Medak, Nizamabad, Anantapur, Kadapa and Chittoor

b. The high usage districts (over all stage of development >50% & <70%) Warangal, Mahabubnagar, Prakasam, Karimnagar and Nalgonda

c. The *moderate usage* (over all stage of development >30% & <50%) districts West Godavari, Nellore, Kurnool, Visakhapatam, Adilabad and East Godavari.

d. The *low usage* (over all stage of development <30%) districts Vizianagaram, Krishna, Khammam, Guntur and Srikakulam

Categorisation of basins/watersheds: Based on the rate (Percentage) of groundwater exploitation, the water sheds /villages/mandals are categorised into four categories. Where the groundwater usage (exploitation) is more than 100% of recharge possibilities;, the area (ie. Watershed or mandal or village) is called over exploited "(Over Exploited)"where the groundwater usage is 90% -<100% of recharge possibilities, the area is called "Critical" . Where the groundwater usage is from) 75 – 90% of recharge possibilities the area is called semi-critical and where the groundwater usage <70% of recharge possibilities, the areas are called "safe".

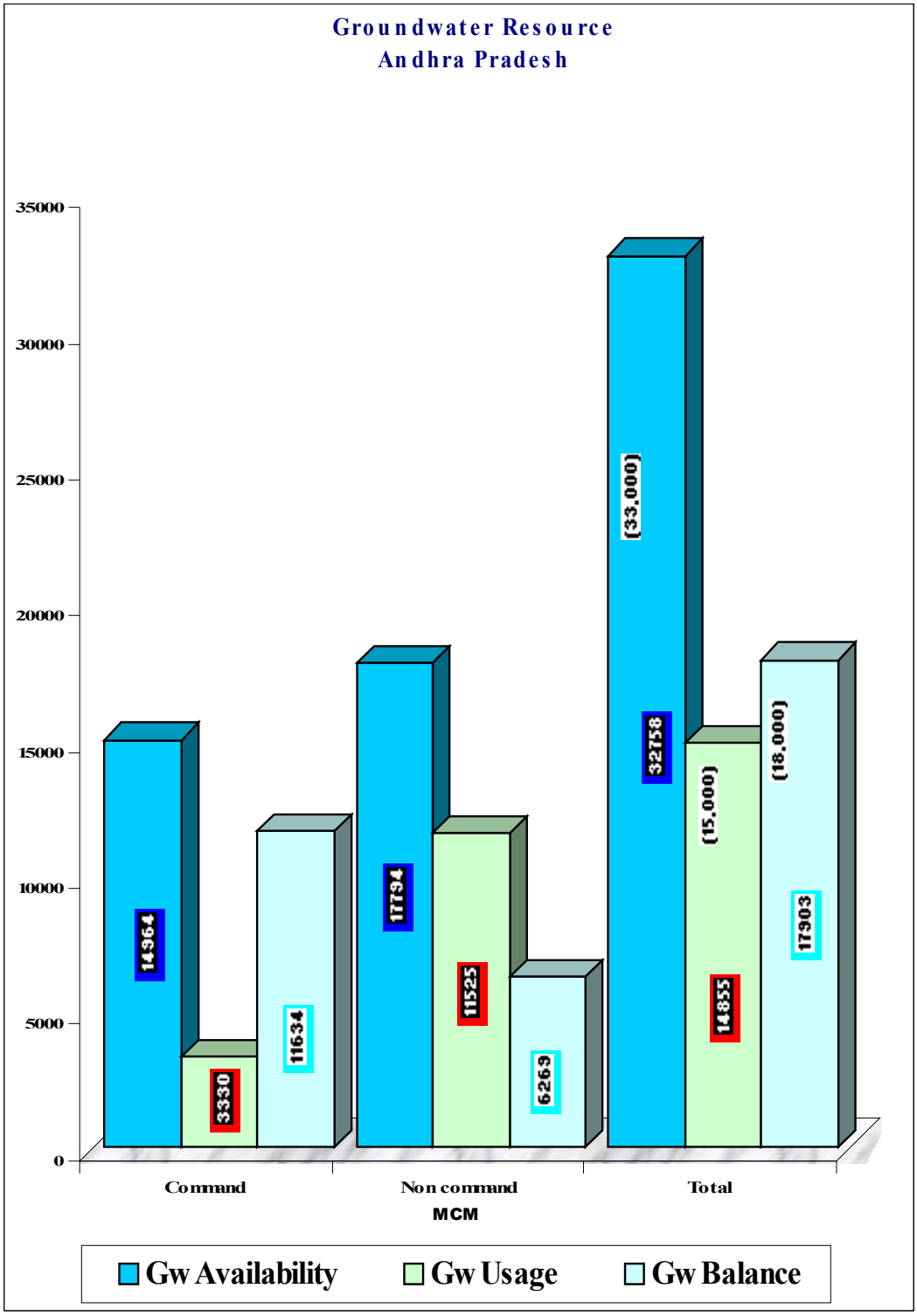
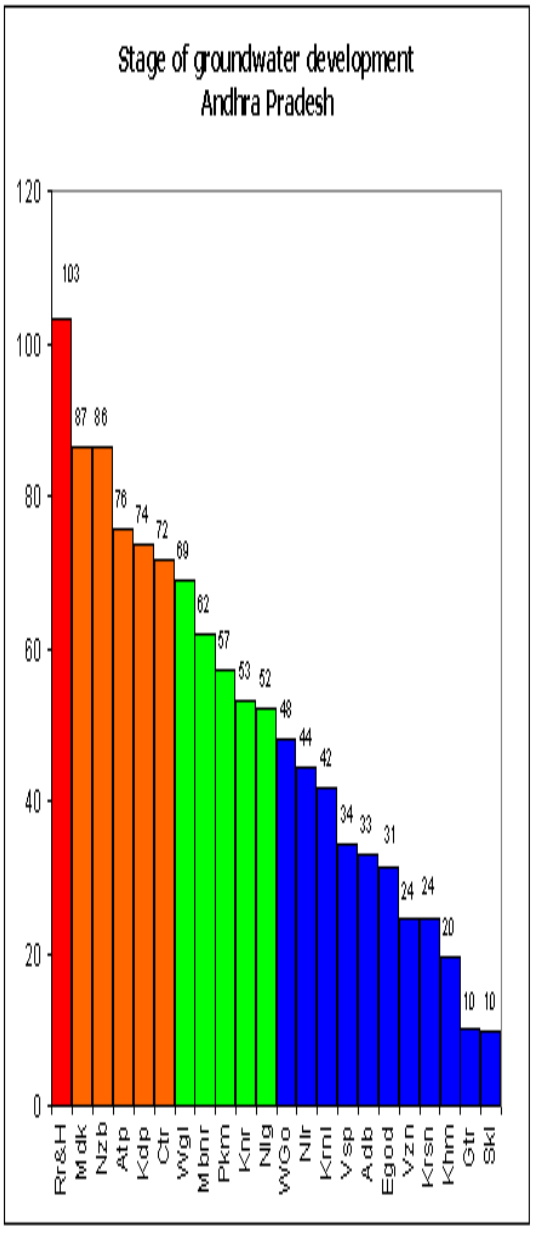
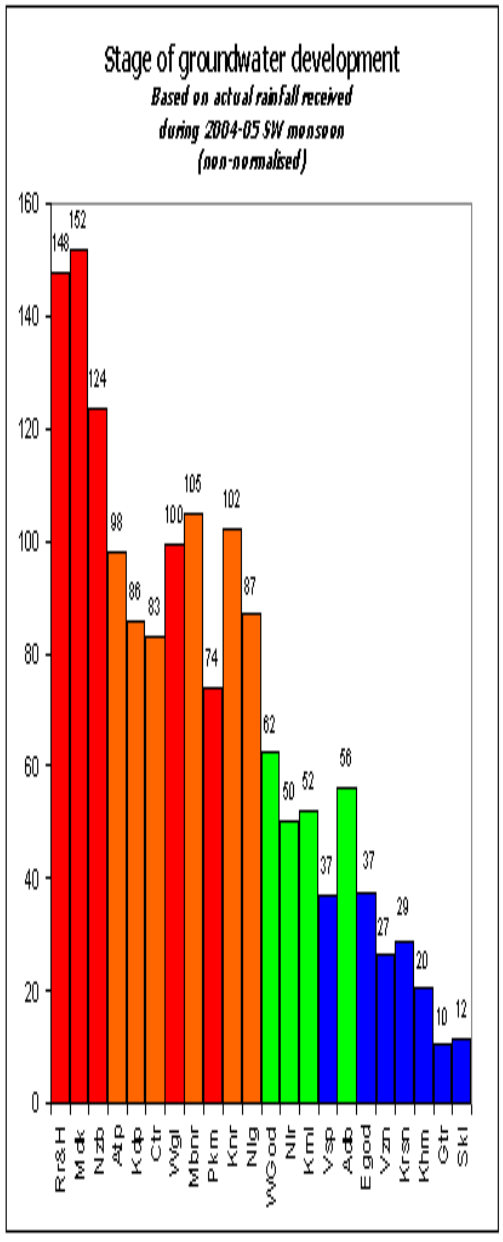


Figure 1 Groundwater resource of Andhra Pradesh


Stage of groundwater development
Andhra Pradesh
120
100
80
60
40
20
0
103
87
86
76
74
72
69
62
57
53
52
48
44
42
34
33
31
24
24
20
10
10
Rr&H
Mdk
Nzb
Atp
Kdp
Ctr
Wgl
Mbnr
Pkm
Knr
Nlg
WGo
Nlr
Krnl
Vsp
Adb
Egod
Vzn
Krsn
Khm
Gtr
Skl


Stage of groundwater development
Based on actual rainfall received
during 2004-05 SW monsoon
(non-normalised)
160
140
120
100
80
60
40
20
0
148
152
124
98
86
83
100
105
74
102
87
62
50
52
37
56
37
27
29
20
10
12
Rr&H
Mdk
Nzb
Atp
Kdp
Ctr
Wgl
Mbnr
Pkm
Knr
Nlg
WGod
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Krnl
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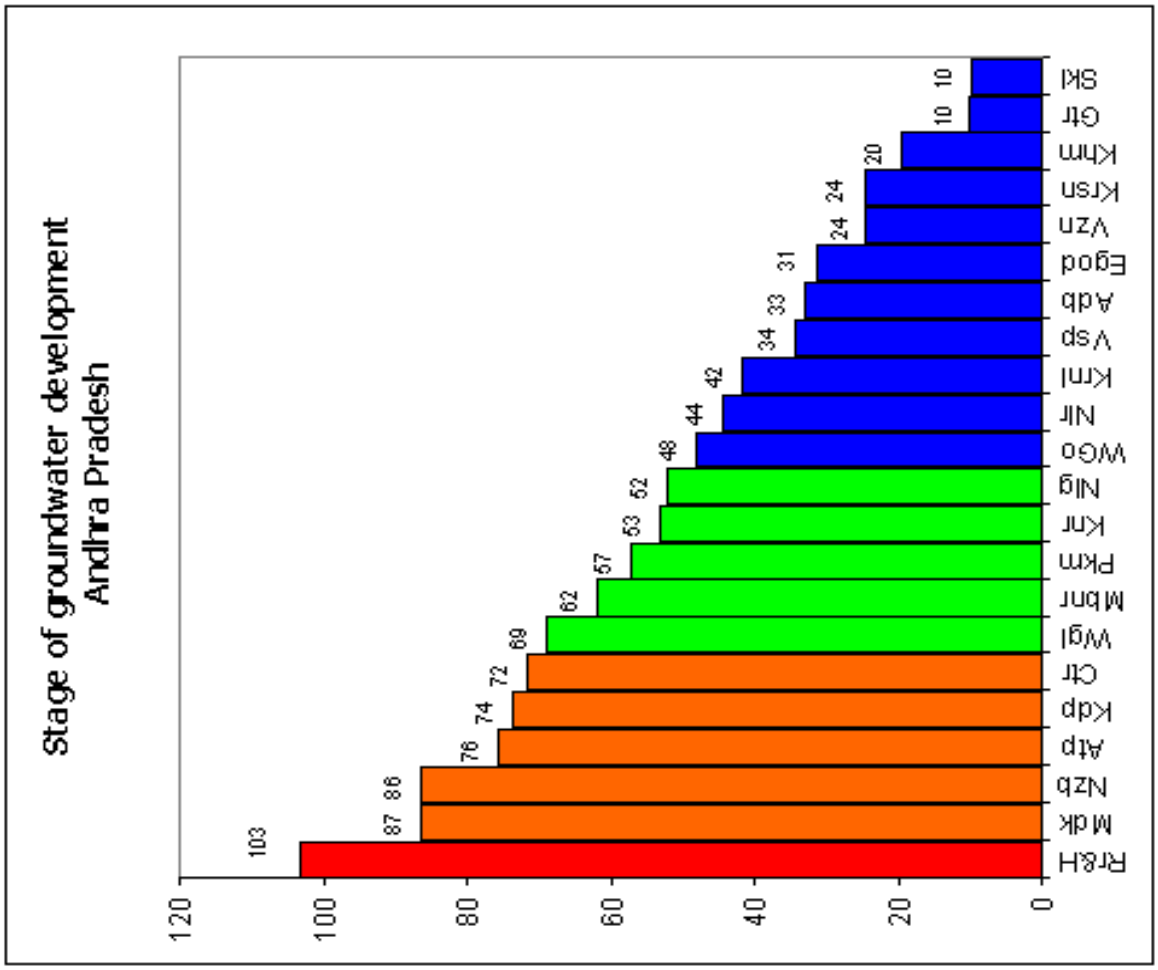


Figure 3 Stage of groundwater development in different districts of state and four categories of district

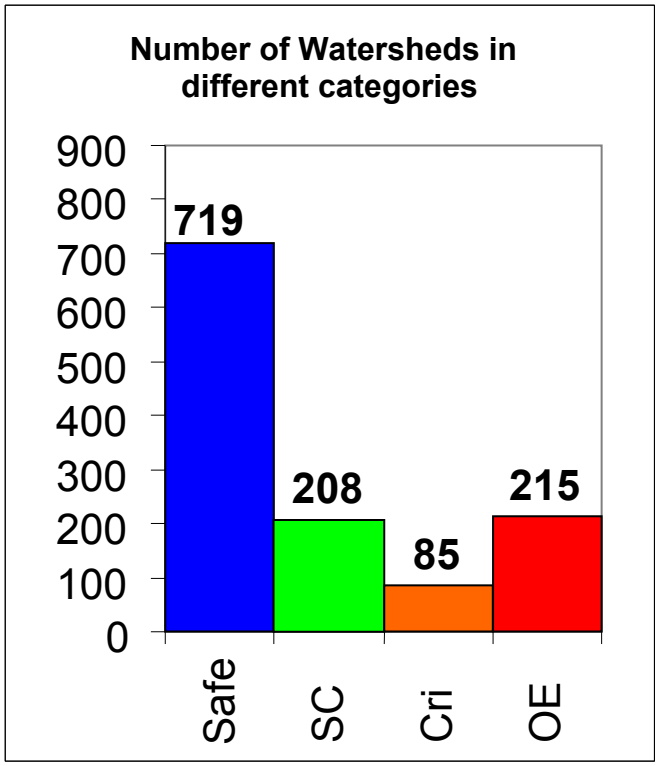


Figure 4 Different categories of assessment units in state

Stage of development has gone up and the state has 215 units under *over exploited* category, 85 units under *critical* category, 208 units under *semi-critical* category and 719 under *safe* category (Figure 4).

Groundwater resources have reached a very critical stage and thoughtful use, conservation and management is required. All the areas of the state that are not served by canal command including the areas in districts like West Godavari to districts like Mahabubnagar are showing almost 100% usage of the available groundwater it is reflected in the stage of development which consistently exceeds 70% which is perceived as the limit to which the aquifers can be safely exploited. Although, the choice would be 40 to 50% if the environmental considerations are applied too.

The District-wise ground water resource position is given in table – 6. watershed (unit)-wise groundwater resource details(formation, recharge from various components, existing draft, categorisation etc) for all the districts are given in Table – I,II,III, IVA, IVB tables. The districts of very high usage (over all stage of development >70%) and high usage (over all stage of development 50 – 70%) needs immediate attention of the Government to stop further Over Exploited and reverse to normal position. Other districts also require measures to prevent Over Exploited in future. Therefore certain recommendations are made based on the groundwater assessment of 2005, may be taken to include for the follow up action by various relevant departments.

- There are 22 lakh wells in the state and 26 lakh hectares is irrigated under ground water.
- Groundwater's share in the total water resources used in the state matches surface water.
- The stock of groundwater in the rocks is usually many times over that which is annually replenished. A third of the wells depend on this reserve stock at one point or the other during the year.
- Groundwater is the main source for irrigation in areas, which are not served by canal system.
- When the monsoon fails groundwater remains the sole source.

- Social problems related to groundwater exploitation are mild as compared to what generally happens in the case of surface water projects. There is no displacement of land holders, submergence of productive lands and forest lands, etc.

- Environmental issues associated with groundwater development are imperceptible and hardly evoke intense reactions at least in its initial stages.

- Since groundwater development follows a slow sluggish and imperceptible growth as well as fall, there is often time to adapt to changes, except in coastal aquifers where well water salinization is relatively a fast process and could take place over a few months or at the most few years. Salinization is almost an irretrievable process.

- Other problems such as groundwater-dependent wetland desiccation, loss of seepages and base flows, loss of vegetation and shift of species are not often seen as serious problems and none seem to complain about it. But these are serious concerns and need to be addressed.

- Groundwater is developed by individuals with minimal support of the government, but energy to pump with is now totally free of under agricultural sector.
- In many areas limit to groundwater is set by the rainfall and the recharge, but it can be due to poor geological conditions as observed in NE regions (Srikakulam, Vizianagram and Visakhapatnam) of the state which has good potential recharge but have rocks that are very poor aquifers.

- Water quality aspects need immediate attention and may become dominant in the future. The problem of fluoride and arsenic as natural contaminants in groundwater has already reached endemic proportions. Farm chemicals form another set of offenders.

- Comparatively lesser groundwater use is for following reasons

    a) Productive aquifers are few,

    b) Availability of alternate sources like big tanks or canal system and

    c) Socio-economic reasons

- Irrigation dependent solely on groundwater can sustain not more than 15% to 20% of the total land area. Any excess indicates groundwater mining.

- During rainy season, rainfall effectively contributes to about 300 to 400 mm of the water need in many areas. Supplemental irrigation during rainy season can support up to 30 or 40% of the total land area, provided rain is well spread out and is trapped in small dams, check dams, percolation tanks, etc.

- Recharge in command areas is very high and in some cases equals annual rainfall.

- There is need for more exploitation of groundwater in command areas.

- At the planning stage simultaneous plan for extraction of groundwater from closely spaced open dug wells must be envisaged in all command areas.

- Government support in form of heavy subsidy for using groundwater and making surface water costlier and supplying it alternate seasons or years.

- Social organisations should educate farmers in command area and encourage use of groundwater.

- Using groundwater in command areas prevents water loggings, retains soil fertility and makes water available in tail ends or in other needy areas.

Trends

- The analysis of rainfall during 1974-2001 indicates deficit rainfall in all the 18 years in one or the other parts of the State.

- Region wise analysis of rainfall pattern further suggests that every year at least 3 districts in the state are likely to have deficit rainfall.

- Mean hydrograph of the state records a fall of 1.95 metres in last 7 years (1998-2004). There is likely to be an improvement by about a metre (May 1998 to May 2006 trend) due to good monsoon

- In some districts like East and West Godavari, delta areas and coastal plains (sedimentary and alluvial areas) the groundwater use exceeds annual replenishment by 2 to 4 times, but the aquifers are so thick that wells continue to give copious water.

- In areas where aquifers are poor and estimated groundwater balance is available and if the water table is shallower than 6 to 8 metres, closely spaced dug wells can be tried parts of the safe areas may not be potential, because of the shallow basement and other hydrogeological conditions. Hence, even ins Safe villages/w.s/mandals also failures will occur after site specific local investigations. Another way is to make low yielding bore-wells and fit them with hand-pumps instead of electric driven pumps.

- Parts of the safe areas may not be potential, because of the shallow basement and other hydrogeological conditions. Hence, even ins Safe villages/w.s/mandals also failures will occur

- Recharge is small component of total rainfall and averages about 100 mm for the state.

It is not pumping per se that depletes ground water storage, but only that component of pumped water that evapo-transpires. Average annual precipitation has remained almost same the evapo-transpiration has greatly increased, from 400 mm/year when farmers grew only one rain-fed crop, to an average of 600 mm/year under the current, irrigated

two-crop-per-year system. Before irrigation development and during the early years of small-scale irrigation, precipitation exceeded evapo-transpiration. Excess water recharged the underlying aquifer and at times even filled the aquifer completely.

Management

- The National Water Policy enunciates periodic assessment of groundwater potential, the state follows the guidelines and periodic assessment and monitoring is taken up.

- Closer monitoring is needed to bring out heterogeneities in development. It is a fact that automated monitoring systems give unbiased and precise data at close intervals.

- Close interval data is useful in pointing out exact cause of a change in water level.

- It allows a better decision support and better planning for corrective actions.

- Sustainable development and management of groundwater resource requires quantitative and continuous assessment of the resource.

- To arrest water-table declines in ground water-irrigated areas, sustainability begins not with reducing irrigation pumping per acre, but with reducing the total pumpage and making efforts to increase recharge.

- Small earthen dams form a supplemental source of irrigation which also effectively recharges groundwater water. It is estimated that 30% of the recharge to groundwater is through these tanks and commands under the tanks.

- Narrow valleys where active groundwater irrigation is seen are sustained because of recharge from the minor irrigation tanks. It will become unsustainable in absence of these tanks.

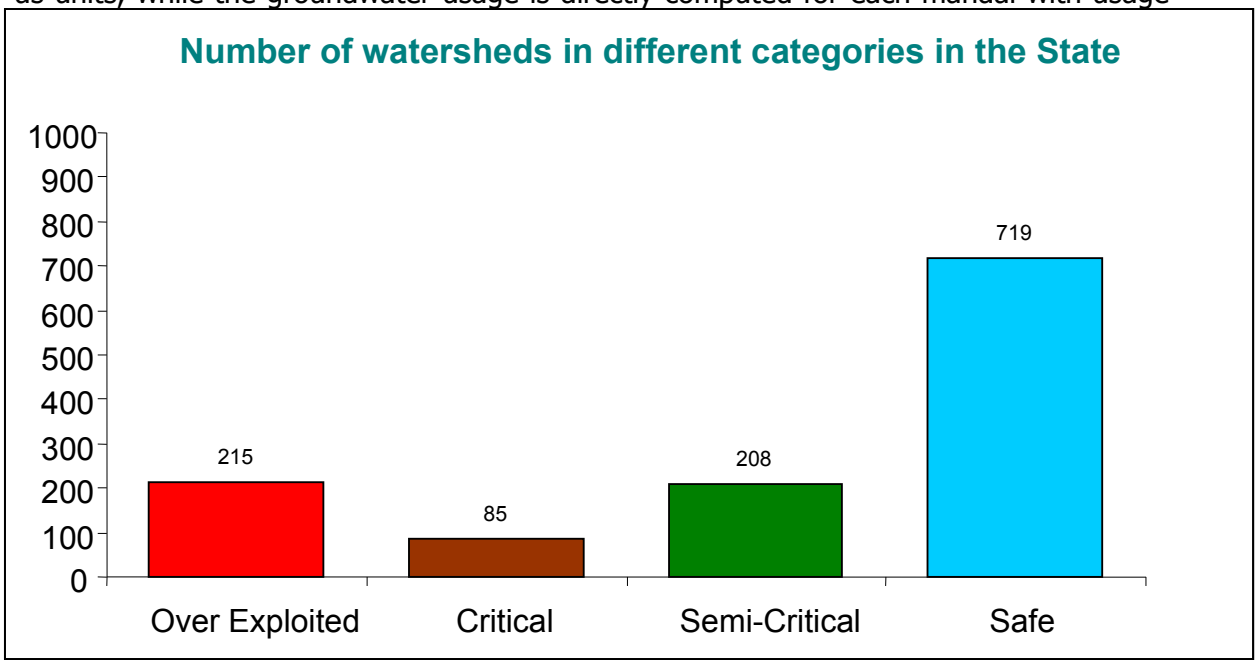
- Groundwater, in hard rock areas is a local resource and influence of cluster of wells (which are about 30 or 40 metres deep) will be marginal beyond a radius of 2 or 3 km and hence the influence of recharge will also be quite local. Only a series of tanks can bring noticeable improvement in groundwater and surface water availability. Hence, urgent need to study optimum tank storage and tank density to increase water.

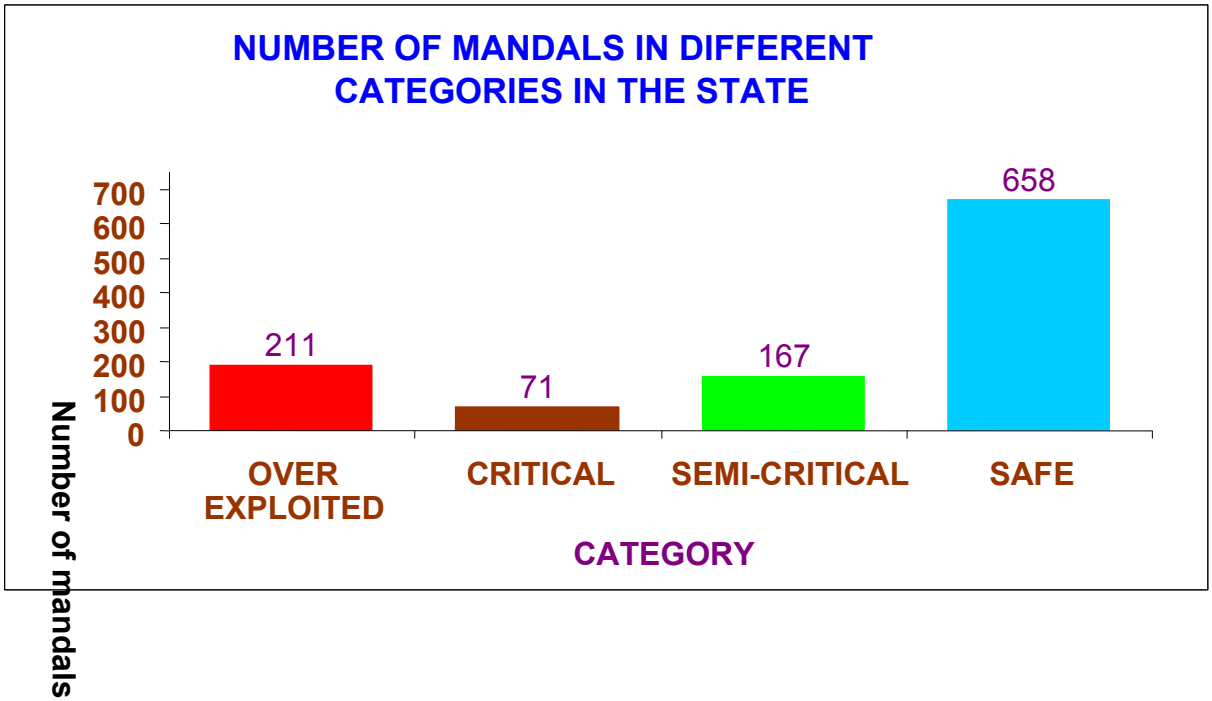
- As a first step groundwater resource is assessed with watersheds as units.

- Andhra Pradesh is the only State to attempt to bring out micro level segregation of areas.

This volume also gives the mandal wise groundwater resource. The groundwater availability is apportioned from the assessment carried out with watersheds (sub-basin)

as units, while the groundwater usage is directly computed for each mandal with usage





RECOMMENDATIONS FOR THE MANAGEMENT OF GROUND WATER RESOURCE BASED ON THE FINDINGS OF GROUND WATER ASSESSMENT 2005

Sl. No.	Recommendations	Departments to be Participated for implementation of recommendations
1.	**Paddy should be banned** under groundwater in Rabi season in all the over-exploited basins, which can be slowly extended to all semi-arid (in Telangana and Rayalaseema districts) and hard rock areas of the state. **Srivari** variety of paddy cultivation to be encouraged if farmers choice is only the paddy, to sustain ground water regime. However, it can be permitted in tank commands. Paddy cultivation under tank commands recharges groundwater to an extent of 40 to 60% of the applied water. It also traps about 20 to 40% of rainfall creating additional recharge to groundwater. As per NGRI Model studies 5% reduction in paddy cultivation can stretch the ground water availability by another decade. Agriculture Department to demonstrate alternate cropping pattern in farmers fields itself.	Agriculture Department, Irrigation Department and Panchayat Raj Department Revenue Department & Irrigation /Panchayat Raj Department Agriculture Department
2.	All farmers should be **persuaded to recharge through their wells** except in canal commands or where water level is shallower than 5 metres in post monsoon. Liberal loaning and subsidies for this programme to be made available. NGO's and WUA to help in implementation of the programme on a time bound and massive scale.	Rural Development Department , Non Government Organizations & Water Users Associations.
3.	In villages that have drinking water problem, reasons to be identified by a technical committee and appropriate solutions worked out. Cause to be immediately identified.	Ground Water Department and Rural Water Supply Wing of Panchayat Raj Department
4.	**Identifying an area of 20 to 30 hectares** -with good hydrogeological characteristics- as drinking water sanctuary in every village. Only drinking water wells to	Rural Water Supply Wing of Panchayat Raj Department & Ground

	be allowed in these areas, during emergencies.	Water Department.

5.	**Excess fluoride** in groundwater in areas of high groundwater exploitation brought to light by *groundwater resource estimation* as in Anantapur and Nalgonda districts. High fluoride in high groundwater exploitation areas is due to presence of fluoride bearing minerals in the rock. In these areas wells with permissible fluoride will have to be identified immediately.	Ground Water Department and Rural Water Supply Wing of Panchayat Raj Department
6.	In areas of low groundwater utilisation are in north coastal districts, Khammam and Adilabad districts; ground water development plans may be permitted.	All Welfare Departments dealing with Irrigation / Agriculture Banks, SC Corp., DRDA., Rural Development etc.
7.	Loaning and subsidy Priority for micro irrigation schemes should be given in areas of high groundwater utilisation(over exploitation) as brought out by the groundwater resource estimation.	All Welfare Departments dealing with Irrigation / Agriculture Banks, SC Corp., DRDA., Rural Development etc
8.	In all housing colonies common wells only be allowed to supplement Municipal water and individual wells to be dispensed.	Municipalities
9.	Recycling of water for some uses, especially in urban areas and Industrial Areas.	Municipalities , Industries Department, & Pollution Control Board.
10.	In **command areas exploitation of groundwater should always be encouraged and subsidised**. Surface water would cost more than the groundwater in all command area, but for the subsidy given for surface water(annexure-1)	Irrigation Departments & All Welfare Departments dealing with Irrigation / Agriculture, Banks, SC Corp., DRDA., Rural Development etc
11.	Groundwater exploitation must be encouraged in all areas where the water table stands shallower than 5 or 6 metres in post monsoon	All Welfare Departments dealing with Irrigation / Agriculture Department like Banks, SC Corp., DRDA., Rural Development etc
12.	Ground Water Infrastructure should be preserved in upcoming command areas. Eg., Jurala canal command which is in its infancy and has very good groundwater infrastructure with well density around 15 wells per square kilometre. Efforts must be made to keep this system of groundwater exploitation in place.	Irrigation Department

Groundwater Resource
Andhra Pradesh

Executive Summary

Andhra Pradesh, the third largest state of the country, is located between North and South India. The area of the state is 275,068 Sq Km. with a forest Cover of 23 %. Table 1 gives the Administrative set up of the state. The state shares her boundaries with Orissa, Tamil Nadu, Chattishgarh, Maharastra and Karnataka, and on the eastern side of the State is Bay of Bengal.

Rainfall

Table –1

ADMINISTRATIVE SET UP	1981	1991	1998
Districts	23	23	23
Revenue Divisions	69	74	79
Taluks / Mandals	195	1106	1123
Inhabited Villages	27379	26586	26586
Uninhabited Villages	1902	1414	1414
Towns	252	264	264

The normal annual rainfall is 940 mm. The rainfall record also shows that droughts are fairly recurrent in the state. The analysis of state rainfall during 1974-2004 indicates deficit rainfall in all the 30 years in one or the other parts of the State. The State receives about 66% of rainfall from south-west monsoon (June-September) and about 25% from north-east monsoon (October-December). The remaining 9% is received during winter and summer months.

Rivers of the state vis-à-vis watersheds

The state has 3 major rivers the Godavari, the Krishna and the Pennar, besides a number of small but splendid rivers of eastern-ghats. The River Godavari with its tributaries Pranahita, Manjeera, Maneru, Indravati, Kinnerasani, Pamuleru and Sileru drains through the northern parts of the State into Bay of Bengal. The river flows through Adilabad, Karimnagar, Nizamabad, Medak, Ranga Reddy, Warangal, Khammam, Krishna, East & West Godavari and Visakhapatnam districts. The River Krishna with its tributaries Tungabhadra, Vedhavati, Hundri, Musi, Paleru and Munneru flows through the central parts of the State. It drains Anantapur, Kurnool, Mahabubnagar, Ranga Reddy, Nalgonda, Guntur and Krishna districts in to Bay of Bengal.

The River Pennar, the third biggest river, with its tributaries Chitravati, Papaghni, Cheyyeru and Pincha drains Rayalaseema region and Nellore district.

National codes for major river basins of the state

The Godavari river basin is designated as **E,** the Krishna river basin is designated as **D**. The Pennar river basin is a part of a catchment designated as **C**. The area between the Godavari river basin and the Mahanadhi river basin encompassing the eastern-ghats is defined as basin **F**. It lies in Srikakulam, Vizianagram, Visakhapatnam and East Godavari districts. The area between the Godavari and the Krishna basins is grouped as basin **I**. It lies in Krishna, Khammam and West Godavari districts. Similarly the area on the south of the Krishna catchment and including . It covers Chittoor, Anantapur, Cuddapah, Kurnool, Prakasam and Nellore districts.

There are in all 40 rivers that drain directly into the sea, and 81 sub basins are recognised as accounting units for the water. However, these sub basins which range in size from 90.65 km^2 to 15699 km^2 are generally too big for estimation of dynamic groundwater resources. The ideal recommended size of groundwater estimation unit i.e. the catchment is 300 km^2. Hence, in 2002, for the purpose of groundwater estimation these accounting units were further sub-divided into 1193 drainage basins that are called watersheds in consonance with the decision of the Groundwater Estimation Committee. However, these divisions are now modified and number 1229 in the state.

Soils and agro-climatic zones

The soils are broadly red, black, alluvial, lateritic and coastal sandy types. They support large variety of natural vegetation and in general good for agriculture and horticulture. The climate, rainfall and soil divide the state in 7 climatic zones, which are based as much on the water availability as on the type of agriculture that the area can support. Hence, these are properly referred as agro-climatic zones.

Geological and Hydrogeological characteristics

The state is covered by

1. The Archaean rocks essentially unclassified crystalline rocks mainly the granitic rocks but in eastern ghats comprising granulite suites locally called as khondalites and kodurites,
2. The Middle–Upper Proterozoic the Cuddapahs and its equivalents;
3. The Mesozoic the coal bearing Gondwana strata
4. Eocene lava flows (the deccan traps) and
5. The semi-consolidated or unconsolidated tertiary and recent rocks

Hard Rocks

Archaeans, Pre-Cambrians, Cuddapahs, Kurnools and Deccan traps are categorised as *Hard Rocks* from *groundwater* point of view. These rocks have negligible primary porosity. The development and management of aquifers in these diverse formations requires similar techniques. These rocks cover nearly 85% of the State that is about 2.332 lakh km^2. l . History of the wells shows that till 1970s there were mostly dug wells. Some of them could irrigate up to 10 or 15 acres (4 to 6 ha) of paddy in good monsoon years, especially if the area was served by small irrigation tanks. Wells that could sustain up to 5 acres (2 ha) were quite common. In 1980s the technique of drilling wells was well entrenched and initially some of the dug wells were converted to dug – cum – bore wells along and progressive farmers took up drilling of bore wells. Still it was quite common to find wells (now bore wells) irrigate 5 acres. The mean yield of the bore wells during this period was 2.47 ha.m and that of the dug wells with pumping facility was 0.91 ha.m. But with state's support through financial institutes for well sinking programme in 1990s, the number of bore wells started proliferating. And simultaneously, during this decade the mean well yields started showing a decline. Now (mid 2000s), it is common to see bore wells irrigate less than an acre of land. **An implication of this change is tragic wastage of energy**. Dug wells that pumped accumulated water from storage required just an hour of pumping to irrigate 2 acres of crop like groundnut. Present day bore well takes 6 to 8 hours of excruciatingly slow pumping to irrigate the same field.

Soft and unconsolidated Rocks

About 15% of area state that is 41,160 km2. is underlain by soft rocks Gondwanas, Rajahmundry formations, Recent Alluvium, etc. Well yields as high as 1500 l/m are recorded in these rocks. However, present day mean well yields are around 0.75 ha.m per annum and they are skewed towards lower side.

Gondwana rocks form extensive aquifers and sustain well yields quite beyond their annual replenishment. Tube wells constructed in these rocks have yielded 200 to 2000 l/m for drawdowns ranging from 12 to 38 m. The open wells tapping these formations yield from 20 to 30 m^3/day.

The Kamthi Sandstones beyond the depth of 250 m bgl are intercalated with shales and clays. Tube-wells constructed within the 200 m depth range in yield from 250 l/m to 3000 l/m for drawdowns of 9 to 30 m. Transmissivity of the aquifer varies between 28 and 950 m^3/day. The yield of tube wells in the Chinthalapudi Sandstones constructed down to 50 and 150 m bgl vary from 450 to 1000 l/m and the transmissivity of the aquifer varies between 150 and 303 m^2/day.

These aquifers are confined and in some cases potentiometric surface lies above the ground surface giving rise to flowing wells / springs.

Rajahmundry sandstones are also good aquifers; the yields of tube-wells tapping these tertiary aquifers down to depths of 300 m vary from 600 to 7500 l/m for drawdowns of 6 to 15 m and transmissivity of the aquifer varies from 90 to 2500 m^2/day indicating that these are the finest aquifers in the state.

The alluvial aquifers have high porosity and permeability. Filter points are most common in this formation. Filter points drilled down to 1.5 to 20 m bgl yield between 150 to 1500 l/m.

In Krishna-Godavari delta the alluvium attains a thickness of more than a few hundreds of metres. However, the deeper aquifers are found to contain highly saline water. The static water level in these formations is general shallow. Groundwater in the coastal alluvium occurs both under water table and confined conditions and is generally developed by means of dug-wells, filter points and shallow tube wells. The depth to water table in dug wells varies from near surface to about 5 m bgl. Usually the quality of water is the main problem in coastal alluvium. Fresh water bodies occur as pockets and lenses in the top 20 m bgl. Deeper wells can lead to up-conning of salt water and fresh water interface, which can damage the groundwater irretrievably. Hence, the depth of the wells must be restricted to 4 or 5 m bgl. In Delta region of Krishna, it is found that the sediments have connate water, which is not completely flushed out, and as a result the water quality is poor in deeper aquifers – mostly beyond 60 metres bgl

Chemical quality

The **chemical quality** of groundwater exhibits considerable variations from place to place. The geological environment, climate and drainage have profound influence on its quality. Of late pollution by number of sources including the farm chemicals, etc is doing lot of harm and damage to groundwater system. The groundwater in Archaean crystalline rocks is in general neutral to alkaline and the chloride content ranges from 30 to 525 ppm. The quality of groundwater in Cuddapah and Kurnool formations is generally poor and TDS in some of these places exceeds 1000 ppm. The quality of groundwater from Gondwana formations is generally good except in some local patches. The groundwater from Gondwanas in parts of Karimnagar and Warangal is generally alkaline and in places excessively hard. The TDS of groundwater from trap rocks ranges from 200 to 300 ppm in upland areas and from 400 to 700 ppm in valley portions. Groundwater is often brackish to saline in black cotton soils associated with traps.

In Krishna and Godavari delta the quality of groundwater varies widely. The quality in the shallow zone is generally within potable limits, but deteriorates rapidly with depth.

Totally, 30 Mandals (East Godavari 10, Guntur 7 and Krishna 13) are categorized as poor quality areas and estimated separately. The groundwater quality in general is found to be not suitable for irrigation practices in these areas. However, some localized poor groundwater quality areas, identified in Anantapur, Kadapa, Kurnool, Nellore, Guntur and Vishakapatnam are not included in poor groundwater quality areas as groundwater is in use for irrigation. The groundwater quality may vary from place to place and hence there may be pockets of better and usable groundwater in these otherwise poor quality groundwater areas.

Groundwater Estimation Methodology

Groundwater assessment in India is made using computation techniques evolved mainly by the Central Ground Water Board, which actively co-ordinates with all the primer research institutes in the country and the NABARD. Besides, it also involves many state government agencies, and calls for individual opinions from across the country. In 1997 a detailed methodology along with guidebook giving all the computations needed for assessment was published by a high power committee of the MOWR, the Groundwater Estimation Committee. This is often referred as the **GEC 1997** methodology.

The State level committee for estimation of groundwater

Government of Andhra Pradesh constituted a State level Groundwater Estimation Committee with 21 members, drawn from different Organisations dealing with groundwater and Universities, with the Principal Secretary, Irrigation and Command Area Development Department as Chairman and Director, Groundwater Department, as the Convenor vide G.O.Ms.No.321, dated 20th September, 1998 and G.O.Ms.No.156, dated 5th August 1999. The responsibility of Assessment of groundwater resource for the State was vested with the Ground Water Department.

The members of the Committee constituted at the State level for estimation of groundwater resources are given in Table 2

Considering the requirement of enormous data and the constraints in obtaining the reliable data from various sources, a small 'Technical Group' was constituted with NABARD, Department of Economic and Statistics, CGWB and APSGWD to deliberate and evolve procedures for collecting the required data, validating the data, and for estimating the resource using the available data. In addition to the three State level meetings, the technical group met 8 times during 1999-2001 and the following decisions were taken based on the recommendations of both groups:

- Unit draft can be based on field inventory in 5 to 10 sample villages in each district.

Table 2 The members of the Committee constituted at the State level for estimation of groundwater resource

1	Principal Secretary, Irrigation and Command Area Development Department, Government of A.P.	Chairman
2	Vice-chairman and Managing Director, AP State Irrigation Development Corporation Ltd., Hyderabad.	Member
3	Director, Agricultural Department, Govt. of A.P., Hyderabad.	Member
4	Joint Secretary (Inter State) Irrigation and Command Area Development Department, Government of A.P.,	Member
5	Chief Engineer (RWS), Panchayat Raj Department, Hyderabad.	Member
6	General Manager [Irrigation] National Bank for Agriculture and Rural Development, Hyderabad.	Member
7	Commissioner, Command Area Development Authority, Govt. of A.P.,	Member
8	Chief Engineer, Minor Irrigation, Govt. of A.P.	Member
9	Director, National Geophysical Research Institute, Govt. of India, Hyderabad.	Member
10	Director, National Remote Sensing Agency, Govt. of India, Hyderabad.	Member
11	Professor and Head, Department of Agronomy, Achayra N.G.Ranga Agricultural University, Hyderabad.	Member
12	Professor and Head, Department of Geology, Andhra University, Waltair.	Member
13	Professor and Head, Department of Geology, Osmania University, Hyderabad.	Member
14	Professor and Head, Department of Geology, Sri Venkateswara University, Tirupathi.	Member
15	Regional Director, Central Groundwater Board, Govt. of India, Hyderabad.	Member
16	Director, Directorate of Economics and Statistics, Hyerabad.	Member
17	Chief Engineer[REC], Andhra Pradesh State Electricity Board, Vidhyut Soudha, Hyderabad	Member
18	Managing Director, Andhra Pradesh Scheduled Castes Cooperative Finance Corporation Ltd., Hyderabad	Member
19	Managing Director, Andhra Pradesh State Cooperative Rural Irrigation Corporation Ltd., Hyderabad	Member
20	Chief Project Manager, Rural Electrification Corporation, Vidhyut Soudha, Hyderbad.	Member
21	Director, Groundwater Department, Hyderabad	Convenor
	Special invitees Commissioner WCM and Special Commissioner WALAMTARI	

- Number of wells to be taken from the Chief Planning Offices, Mandal Revenue Offices and the records maintained by the Department of Economics and Statistics and A.P.Transco figures for comparison.

- Minor Irrigation Census data of 1993 can be adopted, wherever latest figures are not available and to apply growth rate as applicable. Growth rate shall be based on growth of power connections under irrigation sector as given by APTransco.
- Wherever, available APTransco's data giving number of electrical connections under the irrigation section can be used straight away as equal to the number of wells.
- To use area irrigated under surface water sources, wherever, data on canal releases is not available.
- To use a spreadsheet programme developed by the department, tested and the approved by the technical committee.

Data collection and data base constraints

The computations of groundwater draft and recharge are dependant on village level statistical information collected from various sources which include irrigation and drinking water well population and energisation information collected from Mandal Revenue Officer, A.P.Transco, Chief Planning Officer, Panchayat Raj Department; Rainfall data collected from Mandal Revenue Officer, India Meteorological Department and Chief Planning Officer. Surface water canal and distributaries details which includes length, type of canal, days of canal operation, wetted area etc., collected from Irrigation Department, groundwater and surface water irrigated area with cropping pattern collected from Irrigation Department, Mandal Revenue Officer and Agriculture Department; Number of Tanks and ponds with details of water spread area, days of water available etc., collected from Irrigation and Command Area Development Department, Panchayat Raj Department and derived from Toposheets, details of recharge structures which include storage volume, number of fillings etc., collected from Irrigation, Panchayat Raj Department Rural Development, Forest and other departments. The inaccuracies in the database available, particularly in the well census data is validated to some extent through field checks, comparing with APTransco and adopting APTransco figures in many cases, and comparing draft with the groundwater irrigated area etc.

The water level record

The spatial and temporal changes in groundwater levels are monitored through a network of observation wells, spread over the State. The water levels and the fluctuations noticed seasonally, annually and over long term are related to factors such as rainfall, drought and extraction of groundwater in the area and reports compiled on monthly and annual basis.

The monitoring network of the state's observation wells and Piezometers is shown in the Table 3

Table 3 Monitoring network the Observation Wells and Piezometers

1	Observation wells in non-command areas	1582
2	Observation wells in command areas	1404
3	Total Piezometers	1017
4	i.Piezometers with AWLRs	888
	ii. Piezometers with manual measurement	129

The CGWB is also monitoring the changes in groundwater through their own network of 1000 observation wells and 200 piezometer wells and the data is also being integrated and utilised with the State Ground Water Department's data.

Groundwater estimates 1993

The net groundwater availability per annum for the entire State was estimated to be 35.3 BCM, which is 14.4% of the total quantity of water received through the normal precipitation. From this 15%, i.e., 5.3 BCM was earmarked for drinking and other committed uses leaving a balance of 30 BCM for irrigation. The net annual groundwater draft for irrigation was 7.092 BCM. The range of groundwater development for different districts was between 7% and 43% and for the State as a whole it was 25%. However, in 5 full mandals and 60 part mandals, the stage of development was more than 85% and such areas were declared as 'Dark'.

Groundwater estimates 2001-02

The State of Andhra Pradesh is divided into 1193 assessment units, which include basins with defined hydrological boundaries in hard rock areas of extent ranging between 50 and 450 km^2 and mandals (administrative blocks) in alluvial areas including 36 Saline mandals. Computations of net groundwater availability, its utilisation and availability for future use in all the assessment units for command, non command and poor groundwater quality areas have been made separately. The estimates show groundwater availability is 30 BCM, usage is 13 BCM and the balance is 17 BCM per annum (Table 4)

Table 4 Ground water estimates of July 2002

S.No	Description	Com-mand	Non-com-mand	Poor ground water quality area	Total
1	Area considered for recharge in Sq.Kms.	34978	192760	4754	232492
2	Net annual groundwater availability in MCM (TMC)	11232 (397)	19173 (677)	1655 (58)	32060 (1132)
3	Current gross annual groundwater draft for all uses in MCM (TMC)	1744 (62)	11223 (396)	29 (1)	12996 (459)
4	Current gross annual groundwater draft for irrigation in MCM (TMC)	1506 (53)	10392 (367)	12 (0.42)	11910 (420)
5	Demand for domestic and industrial needs at year 2025 in MCM (TMC)	513 (18)	2105 (74)	0	2618 (92)
6	Allocation for domestic and industrial needs in MCM (TMC)	510 (18)	1643 (58)	0	2153 (76)
7	Net annual groundwater availability for future irrigation in MCM (TMC)	9220 (326)	7237 (256)	0	16457 (582)
8	Stage of development (%)	16	56		43

Groundwater estimates 2004-05

Net annual groundwater availability, its usage (groundwater draft under all uses) and balance or what is referred to as *availability for future use* in all the assessment units has been made using a spreadsheet developed for this purpose, adhering to GEC, 1997 norms. The computations are made separately for command, non-command and poor groundwater quality areas. The watershed boundaries are revised and now they number 1229. The estimates show groundwater availability is 32.8 BCM, usage is 14.9 BCM and the balance is 17.9 BCM per annum. This resource includes 1.3 BCM of net annual groundwater availability in poor quality and saline areas. The usage in saline areas is about 0.21 BCM. These results are summarised in Table 5. The district wise details are presented in the statements that follow this text. Figure 1 gives a summary of these results separated into command, non-command and total resource.

District wise **comparison** of the results with those obtained in 2002 shows definite increase (by about 13%) in groundwater usage under all sectors, this is corroborated by steep decline in mean water levels almost everywhere in the state. In many areas water level stands in fractured formation, rather than in weathered formation, as shown by the network of existing piezometers and drying up of traditional OB Wells.

Table 5 Groundwater estimates for the state 2005

Sl.No	Description	Com-mand	Non-com-mand	Poor ground water quality area	Total
1	Area considered for recharge in Sq.Kms.	56,018	1,92,092	(4114)	2,48,110
2	Net annual groundwater availability in MCM	14,964	17,794	(1307)	32,758
3	Current gross annual groundwater draft for all uses in MCM	3,330	11,525	(20.8)	14,855
4	Current gross annual groundwater draft for irrigation in MCM	3,026	10,716	-	13,742
5	Allocation for domestic and industrial needs in MCM	630	1,927	-	2,557
6	Net annual groundwater availability for future use in MCM	11,634	6,269	-	17,903
7	Stage of development (%)	22	65	-	45

Mean hydrograph (Figure 2) of the state records a fall of 1.95 metres in last 7 years. But three coastal districts Srikakulam, Vizianagaram and Guntur show a decrease in usage of groundwater. One district in Rayalaseema the Chittoor district also reports a decrease in use of groundwater.

The estimates of 2002 were made mainly using 2000 database and in some cases, data for 1993 was used along with a projected growth of wells. So effectively this assessment done using current year (2004-05) data reflects a change that has taken place in last 5 years.

The assessment shows that the districts can broadly be grouped into four groups (Figure 3).

a. The *very high usage* (over all stage of development >70%) districts comprising RangaReddy (& Hyd), Medak, Nizamabad, Anantapur, Kadapa and Chittoor
b. The high usage districts (over all stage of development >50% & <70%) Warangal, Mahabubnagar, Prakasam, Karimnagar and Nalgonda
c. The *moderate usage* (over all stage of development >30% & <50%) districts West Godavari, Nellore, Kurnool, Visakhapatam, Adilabad and East Godavari.
d. The *low usage* (over all stage of development <30%) districts Vizianagaram, Krishna, Khammam, Guntur and Srikakulam

Categorisation of basins/watersheds: Based on the rate (Percentage) of groundwater exploitation, the water sheds /villages/mandals are categorised into four categories. Where the groundwater usage (exploitation) is more than 100% of recharge possibilities;, the area (ie. Watershed or mandal or village) is called over exploited "(Over Exploited)"where the groundwater usage is 90% -<100% of recharge possibilities, the area is called "Critical" . Where the groundwater usage is from) 75 –

90% of recharge possibilities the area is called semi-critical and where the groundwater usage <70% of recharge possibilities, the areas are called "safe".

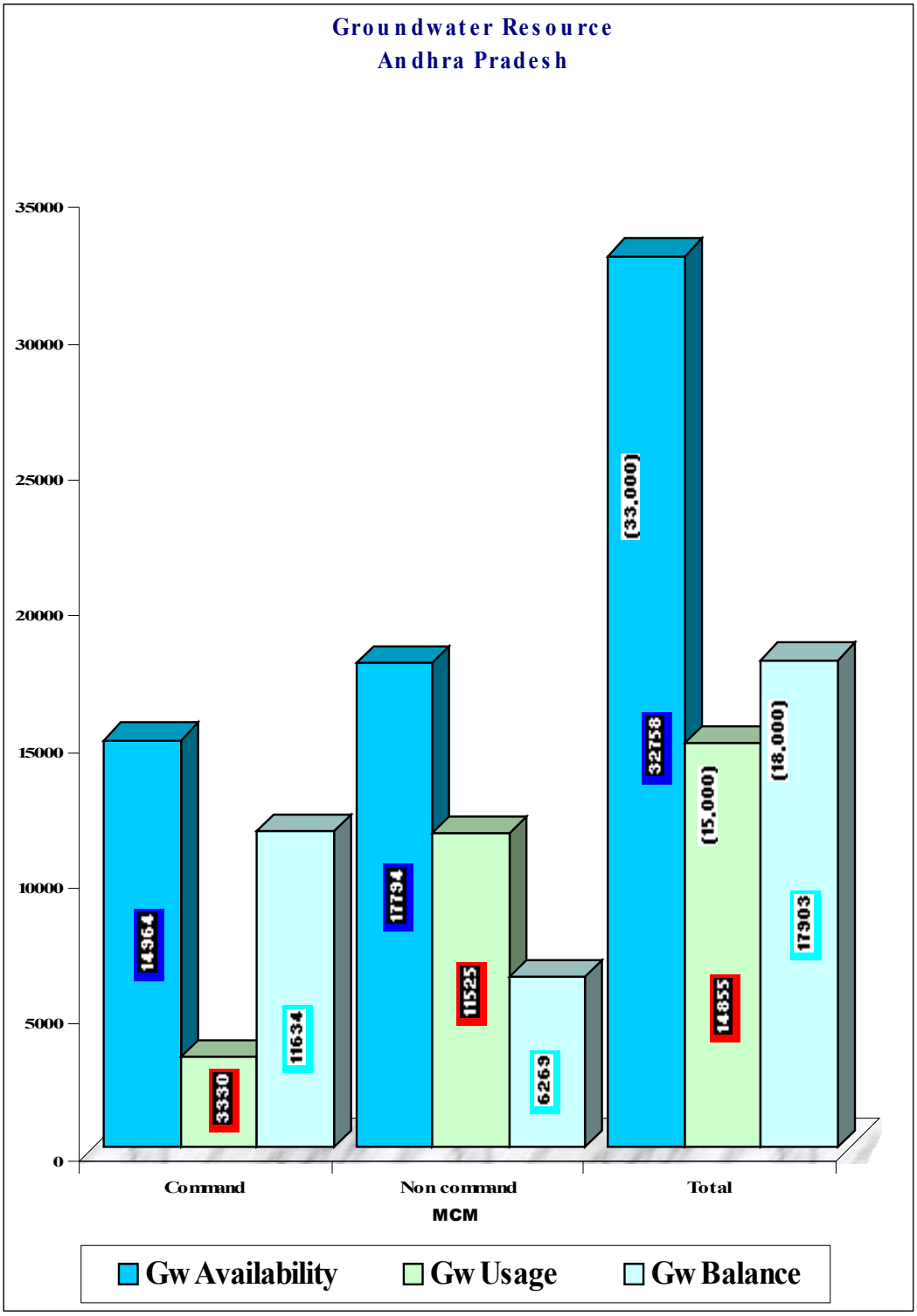


Figure 1 Groundwater resource of Andhra Pradesh

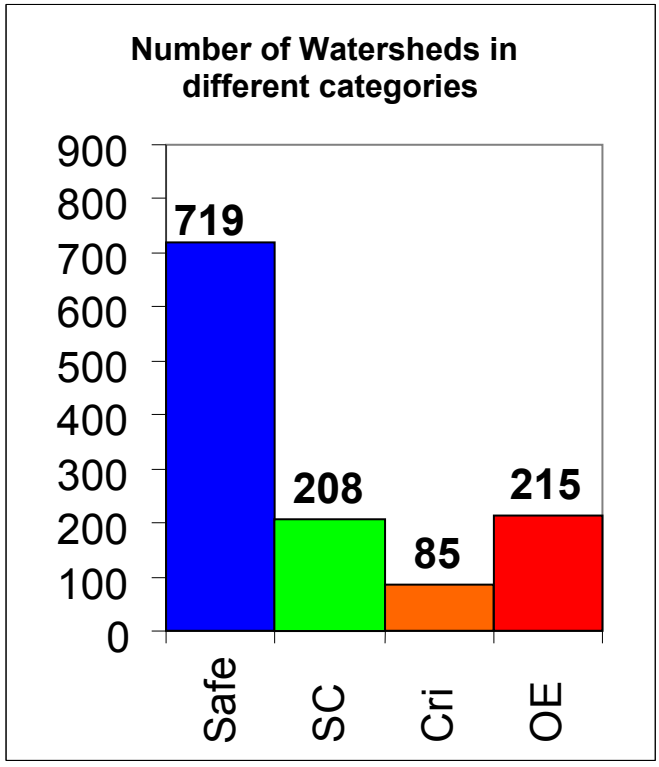
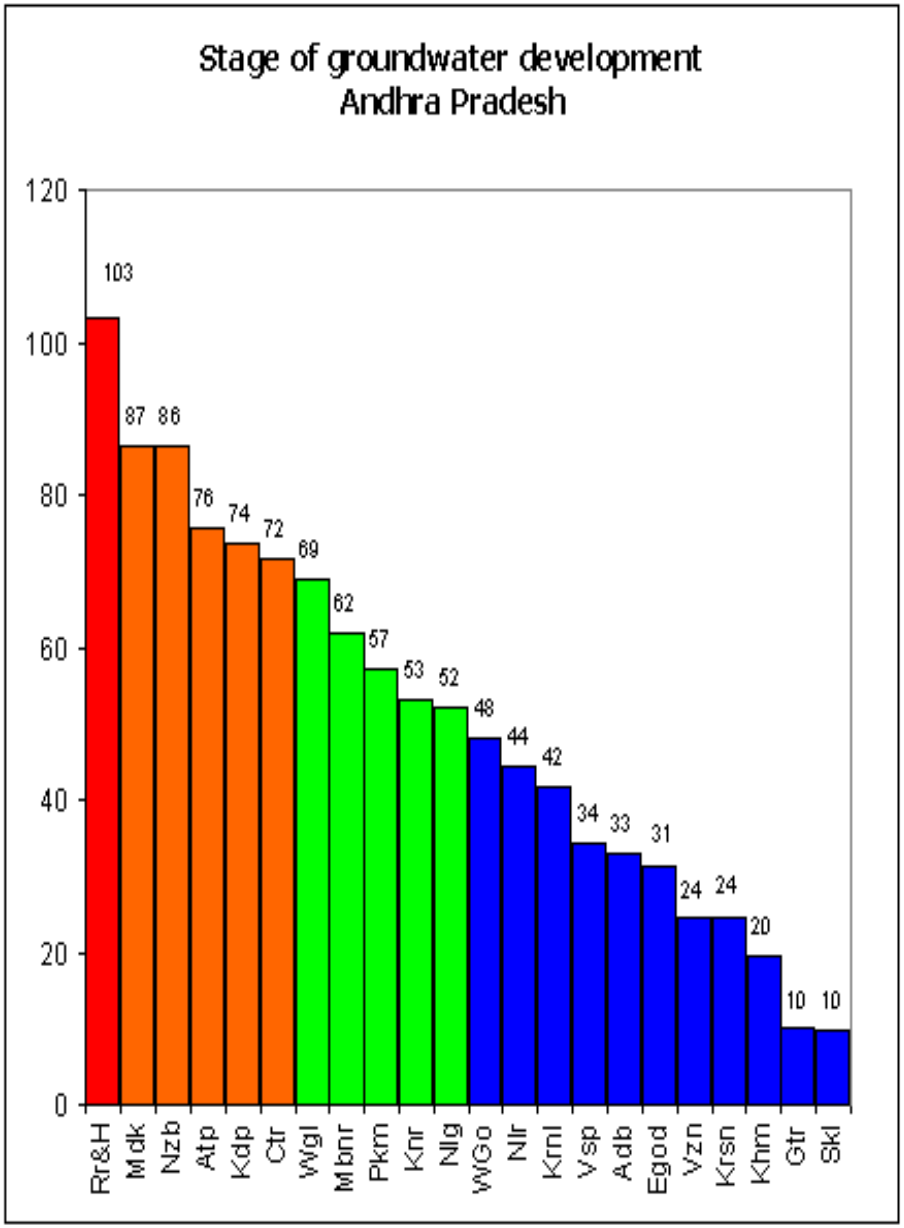


Figure 4 Different categories of assessment units in state


Stage of groundwater development
Andhra Pradesh
120
100
80
60
40
20
0
103
87
86
76
74
72
69
62
57
53
52
48
44
42
34
33
31
24
24
20
10
10
Rr&H
Mdk
Nzb
Atp
Kdp
Ctr
Wgl
Mbnr
Pkm
Knr
Nlg
WGo
Nlr
Krnl
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Adb
Egod
Vzn
Krsn
Khm
Gtr
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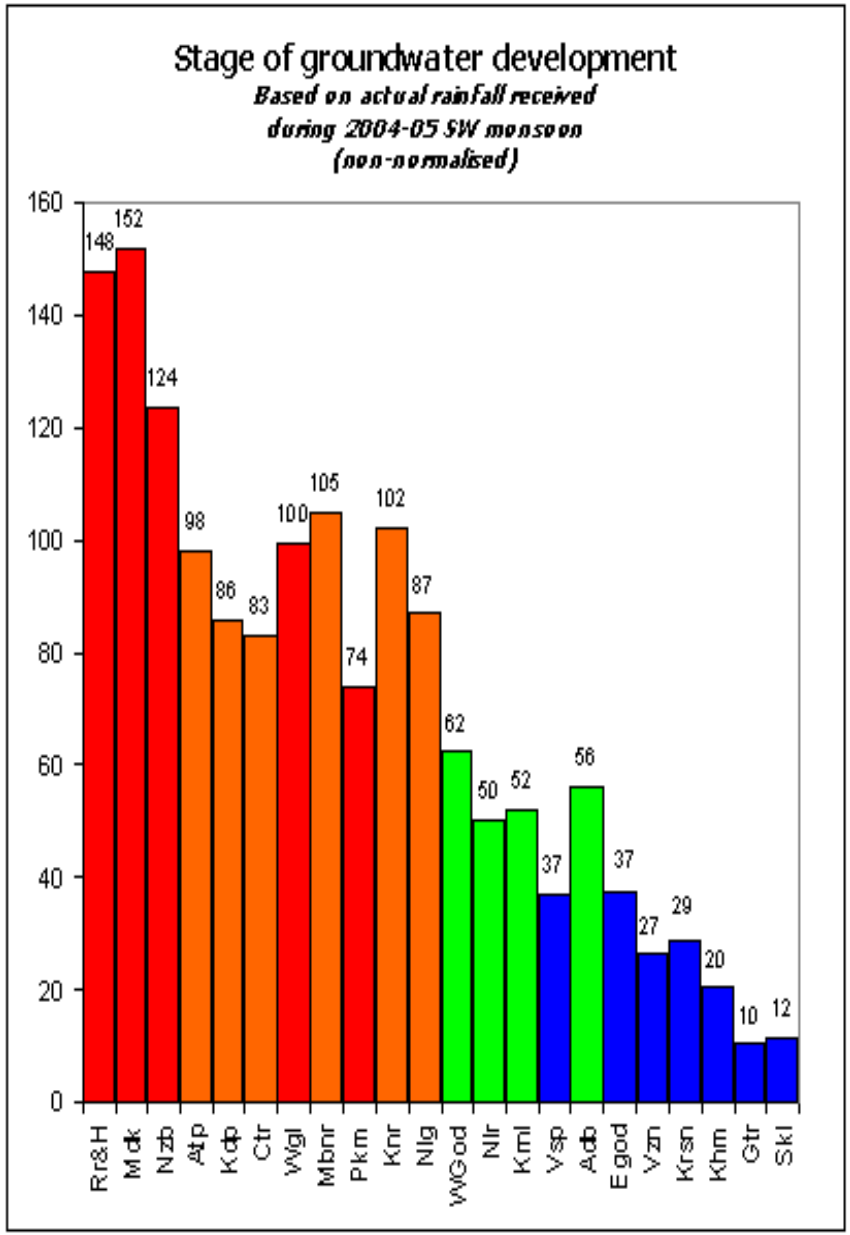
Stage of groundwater development
Based on actual rainfall received
during 2004-05 SW monsoon
(non-normalised)
160
140
120
100
80
60
40
20
0
148
152
124
98
86
83
100
105
74
102
87
62
50
52
37
56
37
27
29
20
10
12
Rr&H
Mdk
Nzb
Atp
Kdp
Ctr
Wgl
Mbnr
Pkm
Knr
Nlg
WGod
Nlr
Krnl
Vsp
Adb
Egod
Vzn
Krsn
Khm
Gtr
Skl

Stage of development has gone up and the state has 215 units under *over exploited* category, 85 units under *critical* category, 208 units under *semi-critical* category and 719 under *safe* category (Figure 4).

Groundwater resources have reached a very critical stage and thoughtful use, conservation and management is required. All the areas of the state that are not served by canal command including the areas in districts like West Godavari to districts like Mahabubnagar are showing almost 100% usage of the available groundwater it is reflected in the stage of development which consistently exceeds 70% which is perceived as the limit to which the aquifers can be safely exploited. Although, the choice would be 40 to 50% if the environmental considerations are applied too.

The District-wise ground water resource position is given in table – 6. watershed(unit)-wise groundwater resource details(formation,reacharge from various components,existing draft,categorition ete) for all the districts are given in Table – I,II,III, IVA, IVB tables. The districts of very high usage (over all stage of development >70%) and high usage (over all stage of development 50 – 70%) needs immediate attention of the Government to stop further Over Exploited and reverse to normal position. Other districts also require measures to prevent Over Exploited in future. Therefore certain recommendations are made based on the groundwater assessment of 2005, may be taken to include for the follow up action by various relevant departments.

Recommendations of the Technical Group on findings of groundwater assessment 2004-05

As per the directive of the Chairman of State level Technical Committee for Groundwater Resource Estimation & the Principal Secretary to Government of AP I &CAD, a small technical group was constituted to give recommendations that can be converted to decision support system for the implementation of the management measures.

The Group comprises

1. **Dr.B.N.Prasad**, Director Ground Water Department, Hyderabad – **Convener**
2. Dr.P.R. Reddy, Scientist, NRSA
3. Dr.A.Surya Rao, Scientist 'C' Regional Director, CGWB.
4. Deepthy Sunil, Assistant Manager, NABARD
5. Dr K. Subramanyam, Scientist, NGRI
6. Sri T.Narender CE, APTransco

The group met immediately after the State Level Technical Committee's Meeting on 13th July 2005 and deliberated for 3 hours and has given the following recommendations.

1. **Paddy should be banned** under groundwater in Rabi season in all the over-exploited basins, which can be slowly extended to all semi-arid (in Telangana and Rayalaseema districts) and hard rock areas of the state. However, it can be permitted in tank commands to an extent the tanks can meet the requirement. Paddy cultivation under tank commands recharges groundwater to an extent of 40 to 60% of the applied water. It also traps about 20 to 40% of rainfall creating additional recharge to groundwater.
2. All farmers should be **persuaded to go for recharge structures for each of their wells** except in canal commands or where water level is shallower than 5 metres in post monsoon. Liberal loaning and subsidies for this programme to be made available. NGO's WUA to help in implementation of the programme on a time bound and massive scale.
3. In villages that have drinking water problem, reasons to be identified by a technical committee and appropriate solutions worked out. Preliminary cause to be immediately identified.
4. **Protecting drinking water sources by making an area of 20 to 30 hectares** -with good hydrogeological characteristics- as drinking water sanctuary in every village. Only drinking water wells to be allowed in these areas.
5. Analysis of **groundwater assessment** along with NRSA maps in Karimnagar district indicated that 30% of the villages with drinking water shortage are in Over-exploited category and the poor groundwater prospects.

6. **Excess fluoride** in groundwater is in areas of high groundwater exploitation brought to light by *groundwater resource estimation* as in Anantapur and Nalgonda districts and in canal command areas, which is *also indicated in the resource report of Ground Water Department*. High fluoride in canal command is due to high input of farm chemicals, which invariably have fluoride and high fluoride in high groundwater exploitation areas is due presence of fluoride bearing minerals in the rock. In these areas "water sanctuaries" have to be implemented immediately.
7. Areas of low groundwater utilisation are in north coastal districts, in Khammam and Adilabad districts;
8. NGRI has stressed that their software may be used to forecast the water table position in future. They have claimed that this model shows that 5% reduction in paddy can stretch the groundwater availability by another decade.
9. Agriculture Department to demonstrate alternate cropping pattern in farmers fields itself.
10. Loaning and subsidies for micro-irrigation to be hassle free, farmer friendly and to have all the government support. Quality of the product should be high and farmers to be trained in maintenance of the system. Priority will be in areas of high groundwater utilisation areas as brought out by the groundwater resource estimation by the Ground Water Department.
11. In all housing colonies common wells to supplement Municipal water be only allowed and individual wells to be dispensed.
12. Recycling of water for some uses, etc especially in urban areas.
13. Burden of proving should be on respondent and not on petitioner in cases under WALTA.
14. Cropped area is a useful cross check on groundwater irrigation in rabi season when measured using satellite imagery with some field checks. In some pilot areas it can be worked out for a decade or so and compared with still older imagery.
15. In **command areas exploitation of groundwater should be always encouraged and subsidised**. Surface water would cost more than the groundwater in all command area, but for the subsidy given for surface water. Cost of groundwater irrigation vis-à-vis surface water irrigation (in shallow water table areas) is worked out and appended herewith Annexure -1.

    Groundwater irrigation in shallow water table areas and in command areas if taken up by Dug well irrigation is one-third of surface water.
16. Groundwater exploitation must be encouraged in all areas where the water table stands shallower than 5 or 6 metres in post monsoon
17. A case in point is Jurala canal command which is in its infancy and the area already has very good groundwater infrastructure in place with well density around 15 wells per square kilometre. Efforts must be made to keep this system of groundwater exploitation in place.

18. **Maintenance and upkeep of records and recording equipment deserves utmost priority of groundwater agencies**, as they are our only record to confirm or disprove the present judgement based partly on the data from the piezometers itself and partly from the field conditions.

Cost of providing paddy irrigation per year

Through groundwater	in non command areas soft rocks	Rs 5,500
	in non command areas Hard rocks	Rs 13,000
	in command areas soft rocks	Rs 2,500
	in command areas Hard rocks	Rs 2,500

Trough Surface water Rs 4,500 to 7,000

Note: A village wise list of over-exploited areas, groundwater availability, saline areas, shallow water table areas and areas for conjunctive use, will be prepared and will be communicated to the concerned district administration for making use in preparation of action plans.

Annexure -1
Cost of water per acre under surface and groundwater irrigation

For **surface water farmer pays** per acre

Paddy cultivation:	Rs 200
Sugercane	Rs 300
Aquaculture	Rs 500

Actual expenditure incurred on each acre (Source SE Irrigation Vijaywada Circle) Rs 4500 to 7000

For **Groundwater farmer incurs** per acre
Paddy cultivation in **non-command areas**

Cost of well construction (Capital Costs)	Rs 50, 000
Interest on capital	Rs 4, 000
Life of the structure 10 years	
Capital per year	Rs 5, 400
Energy charges per acre per crop	Rs 6, 000
Maintenance per annum	Rs 1, 500
Total Cost per acre	Rs 12, 900

For **Groundwater farmer incurs** per acre
Paddy cultivation in **command areas**

Cost of well construction (Capital Costs)	Rs 50, 000
Interest on capital	Rs 4, 000
Life of the structure 10 years	
Capital per year	Rs 5400
Energy charges per crop **5 acres**	Rs 6000
Maintenance per annum	Rs 1000
Total Cost per acre	Rs 12,400/5 = **2,480 say 2500**

Groundwater irrigation in shallow water table areas and in command areas if taken up by Dug well irrigation is about a third of surface water.

For **Groundwater farmer incurs** per acre
Paddy cultivation in **sedimentary areas (tubewell)**

Cost of well construction (Capital Costs)	Rs 2,00, 000
Interest on capital	Rs 4, 000
Life of the structure 10 years	
Capital per year	Rs 21,600
Energy charges per crop **5 acres**	Rs 24,000
Maintenance per annum	Rs 6000
Total Cost per acre	Rs 51,600/5 = **5,160 say 5,500**

MEAN HYDROGRAPH OF STATE

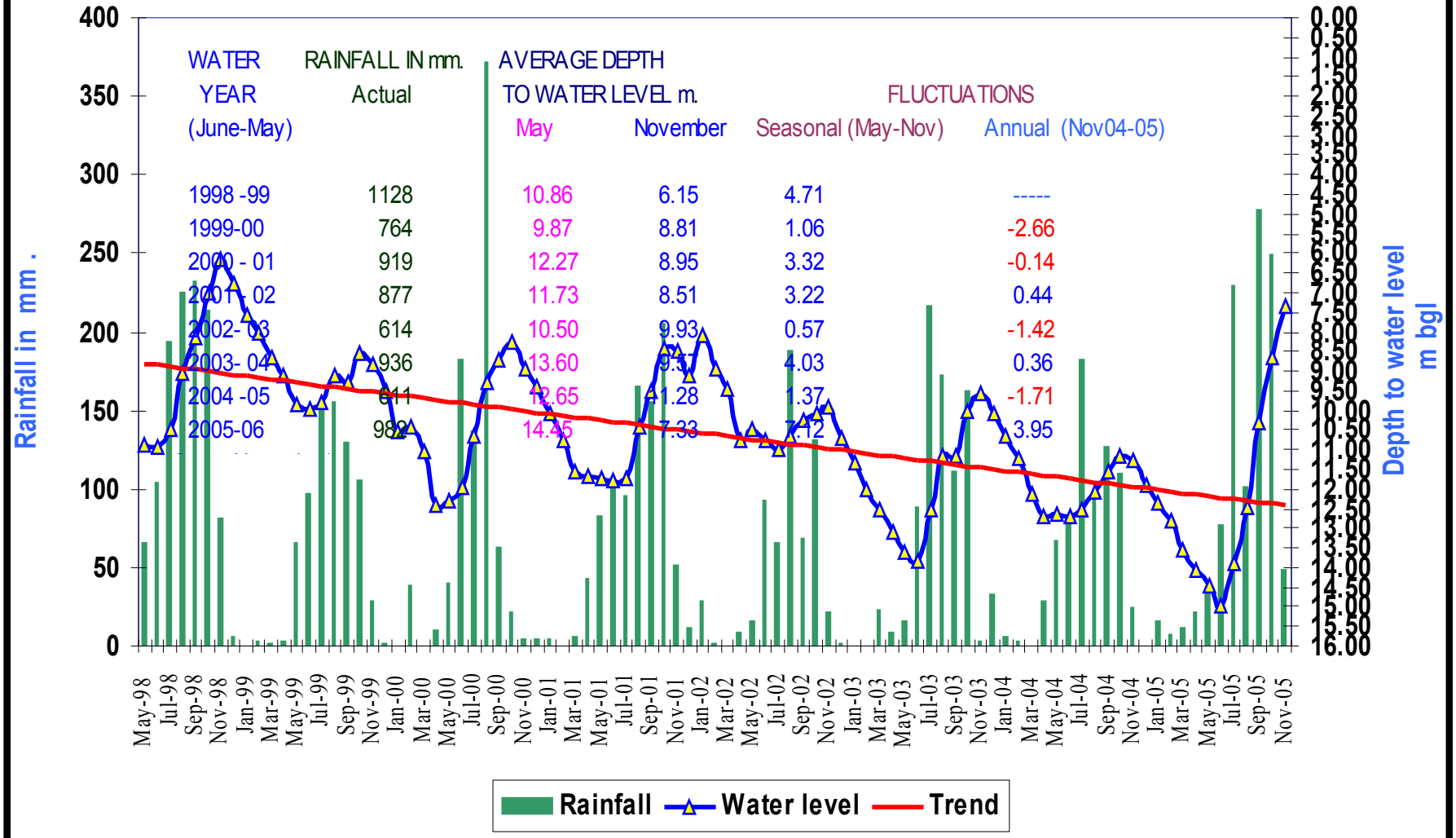

Fig: 2, Mean Hydrograph of the State