CASE STUDY CS (AR) 162

SEASONAL GROUNDWATER BALANCE STUDY IN BANDAR CANAL COMMAND AREA, KRISHNA DELTA ANDHRA PRADESH (PART-II)

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PREFACE

The conjunctive use studies in Krishna Delta were started by Deltaic Regional Centre of NIH, with collaboration of A.P State Ground Water Department, Hyderabad. The study is mainly divided into three parts. The first part of the report is "Conjunctive use studies in Krishna Delta System - Status of Data Availability" which is prepared by Andhra Pradesh State Ground Water Department. The second part of the study is the present report titled " Seasonal Ground Water Balance Study in Bandar Canal Command Area" which deals with the methodologies adopted to estimate various components and to find important theoretical and practical hydrological problems in this area. However, the studies related to ground water are very limited in this area. Hence, the present study is very important for understanding the behavior of the Hydrological System and working out the strategies for development and management of water resources of a region or basin. Due to limited data the Seasonal Ground Water Balance for monsoon and non-monsoon seasons for five years i.e from 1985 to 1990 has been prepared and presented in this report.

This report has been prepared by **Sh Y. Ramji Satyaji Rao, Scientist 'B'** and the technical assistance during course of data analysis, and in preparation of the report provided by **Sh T. Thomas, SRA**. The overall guidance for conducting the study was provided by **Dr P.V. Seethapathi, Scientist 'F'**.

(S.M. SETH)
DIRECTOR

ABSTRACT

Water balance approach is a viable method of establishing the rainfall recharge coefficient and for evaluating the methods adopted for the quantification of recharge and discharge from different sources. The seasonal ground water balance study of Bandar canal command area in Krishna Delta has been carried out for a period of five years(1985-1990). The study brings out the assessment of different water balance components of upper Bandar canal command area, having 190 Sq.Kms in area. The recharge from rainfall during the monsoon season has been computed from the water balance equation. The recharge coefficient varies between 0.16 to 0.19 and the unaccounted water in monsoon season has been found to be less than 6 MCM. The estimated components of water balance equation could be useful in Conjunctive use of surface water and groundwater studies in Krishna Delta.

1.0 INTRODUCTION

Water is one of the most important natural resources of the country. But today we are wasting more water than we are actually using - whether it is in our irrigation, urban systems or any· where else. Agriculture which is a major part of the Indian economy and the backbone of our self-reliance is dependent primarily on water. Water which was considered to be in plenty has now come to be realised as a limited resource which is further acentuated by the failure of monsoons and recurrence of droughts. No water-resources management or development, whether it be for the purpose of water supply for the population, agriculture, industry or engery production, is possible without an assessment of the quantity and quality of the water available. Accurate information on the existing condition and trends of a country's water resources are required as a basis for economic and social development and for maintenance of environmental quality through a proper perception of the physical processes controlling the hydrological cycle in time and space.

To improve the management of water resources, greater knowledge about their quantity and quality is required. There is also a need for regular and systematic collection of hydrometeorological, hydrological and hydrogeological data, together with a system for processing the quantitative and qualitative information for the various types of water bodies. Moreover keeping an adequate inventory of water availability is one of the desirable pre-requisites for the quantification of water-user rights, for the formulation of water quality standards, for the adjustment of economic incentive systems and for the development of many other administrative measures. When multiple sources of water with different characteristics are available, it may be possible to develop an operating strategy that exploits the different sources. This exploitive strategy has become to be known as the conjunctive management of different sources of water or conjunctive use. Before preparing any development plans for groundwater development and conjunctive water use using mathematical models, it is necessary to carry out water balance study. The water balance study helps to evaluate quantitatively, individual contribution of sources of water in the system over different time periods, and to establish the degree of variation in water regime due to changes in components of the system. It is also useful in proper assessment of available potential, present use and additional exploitability of water resources at optimal level. The study of water balance is defined as the systematic presentation of data on the supply and use of water within a geographic region for a specific period. A basinwise approach yields the best results where the ground water basin can be characterised by prominent drainages.

Andhra Pradesh being predominantly an agricultural

State, the State Groundwater Department reflected the conjunctive use practice now in vogue in Krishna and Godavari Delta's. At present there is an unplanned use of ground water through construction of wells, private shallow wells and deep state tube wells. Therefore this practice may not be useful in increasing the command area and it may invite saltwater intrusion problems in delta's. To improve the present practices, a realistic assessment of the surface and groundwater resources and also a proper planning for their use would be required. This can be done in a conventional manner by water balance technique and also using the modern techniques of mathematical modelling with the help of computers.

In these circumstances, it is intended to take up a Seasonal Ground Water Balance study in the Bandar Canal Command area, using the available data for five years. This may provide a base for understanding the influence of various components and behaviour of the aquifer system under these dynamic changes. This study is also helpful in developing new conjunctive use practices in the canal command area.

This report brings out the assessment of different water balance components of Upper Bandar canal command area in Krishna delta, which is around 190 sq.kms in area with the main objective of estimating the seasonal ground water balance for monsoon (June - October) and non-monsoon (Nov - May) seasons from 1985-86 to

1989-90. The description of the study area, methodology adopted for the assessment of various components and the analysis and results etc., are discussed in subsequent chapters.

2.0 STATEMENT OF THE PROBLEM

Water resources can be defined as any aspect of water that has value or which is needed by some water user in order to produce it's beneficial product. The different water resources aspects of great interest are: the water quantity, the water quality, it's potential energy, it's flow depth, it's surface area, it's aesthetics value, it's waste assimilating capacity and it's biological productivity. In order to understand and estimate the extent to which the groundwater development should be practiced in a particular area or a basin, a water balance study is necessary. This study will also serve as a useful tool for modelling the area for attempting simulation of alternative policies for safe abstraction in the future. To increase the Bandar Canal command area and to supply canal water to tailend reaches, the upper portion of Bandar canal command area has been selected to estimate the quantity of available groundwater and it's utility in this area.

Conjunctive use of groundwater with surface water resources has been a subject receiving considerable attention in Andhra Pradesh since 1972 and has attained utmost importance during the recent years. The recent groundwater assessment carried out for the State, revealed that more than 50% of the ground water available in the State exists in the command areas of Surface Water Projects. (State Groundwater report 1993).

The existing canal net-work system in this region is not able to cope up with the water requirement of the entire command area, especially in the tailend reaches. Paddy is limited to kharrif season and some pockets in rabi season due to non-availability of water. Perennial crops like sugarcane are limited to smaller extents due to practical problems involved in ensuring regular canal water supplies throughout the year.

The main objective of the study is to find solutions for these problems and to augment canal supplies to the tailend reaches and increase the duration of irrigation supplies. In order to develop the criteria for utilisation of surface and groundwater resources, it is necessary to study the availability of groundwater resources and particularly the interaction between groundwater and surface water. Then the model can be used for studying and inferring suitable strategies in development of surface water systems in the short run and conjunctive utilisation of surface water and groundwater in the long term.

The study area which is bounded by East Bank canal and Ryves canal, has been restricted upto Vuyyuru because, beyond that the quality of groundwater is quite different from the quality of water in the study area. The study area is around 190 sq.kms, which is free fom saltwater intrusion problems. The continuous use of canal water alone in study area may cause problems like waterlogging, salinity etc., However very limited studies have been undertaken in the study area so far. No definite rainfall-recharge relationships are available. Therefore the seasonal groundwater balance study of Bandar canal command area in Krishna delta has been carried out to understand the influence of various components of water balance equation on the ground water regime and establishing rainfall- recharge relationships.

3.0 STUDY AREA

The general description of the study area is given in the Part-I of the study report. However, few details of the study area are briefly discussed here in this chapter. The Krishna river canal-network system forms the main source of irrigation in this delta. Krishna being a great and sacred river of South India like Godavari and Cauvery flows almost across the peninsula from West to East and finally joins the sea by two principal mouths. The development of irrigation in Krishna delta may be said to have started in 1855. The old Krishna anicut and the canals were constructed during 1852 to 1885 to irrigate an ayacut of 5.0 lakh acres. The crest level of the Anicut was increased to provide the irrigation potential of 8.5 lakh acres in 1895, by fixing automatic falling shutters of 1.8m in height.In 1957 the present Krishna Barrage was completed. The index map of study area is shown in Fig.1

Three major canals passing through this area are East Bank Canal, Bandar Canal and Ryves Canal. Among these canals, Bandar canal is having major and minor channel network in the proposed study area. The East Bank canal essentially feeds the lower reaches of the delta region. The Ryves canal contributes mostly to the Eastern part of the Delta region, and it's command area does not form a part of the proposed area of study. The study area has been fixed by the State Ground Water Deptt, on the

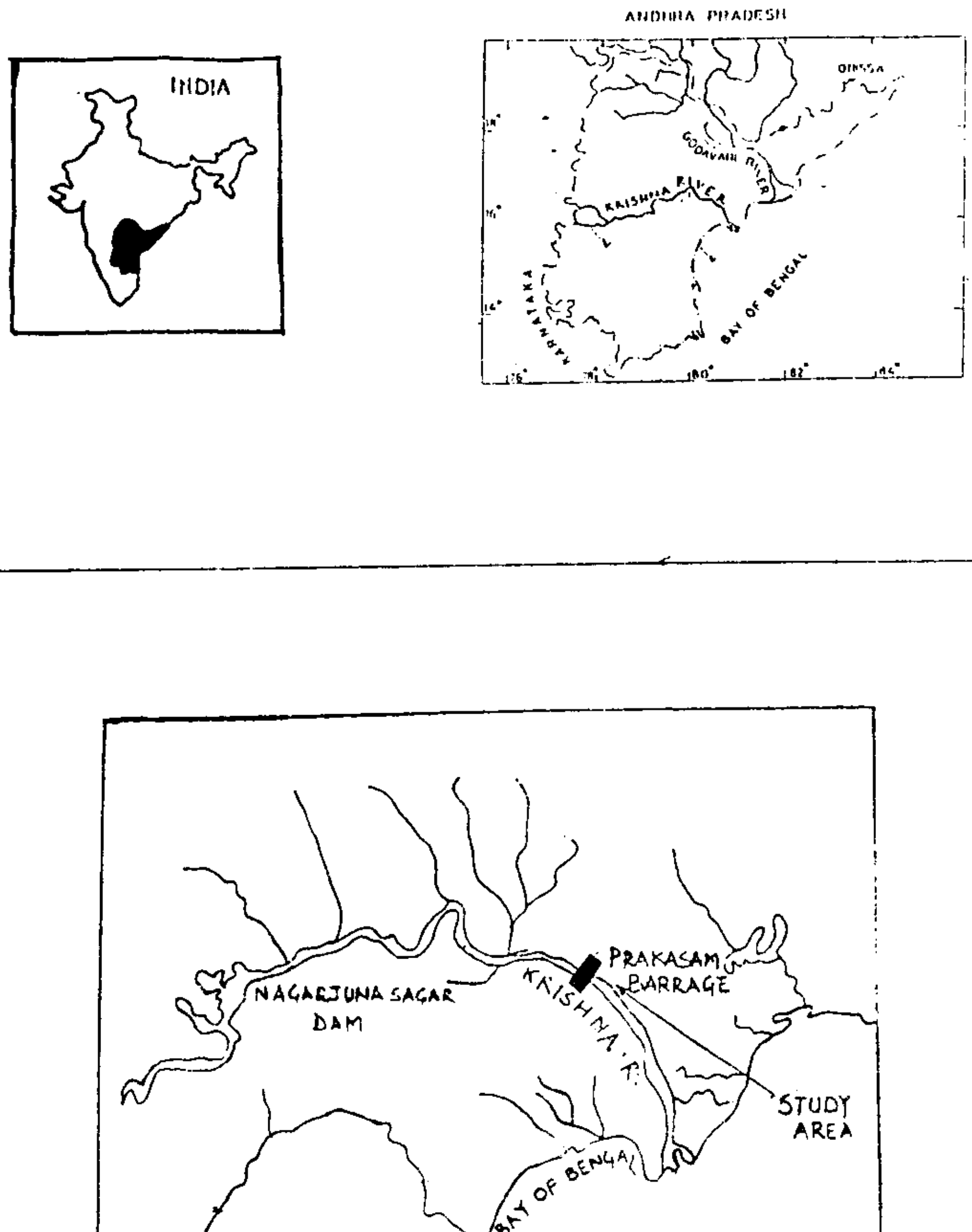

FIG 1 INDEX MAP

basis of salt water intrusion zone in Krishna delta.The study area lies between East longitudes 80°40'10"to 80°52'30" and North Latitudes 16°22'30" to 16°30'30"and falls in the toposheets no. 65 D/11, 65 D/15. The topographical map of study area is shown in Fig.2. The present study area is falling under four mandals namely Penamaluru, Kankipadu, Vuyyuru and Thotlavalluru. Among these four mandals, Penamaluru is completely covered and the other three mandals are partially covered. The data required for present study is computed on proportionate area basis from the mandals falling under the study area. The total geographical area of the study is computed as 190 sq.kms.

3.1 CLIMATE

The area is influenced by tropical climate. The minimum and maximum temperatures in this area are 16° C and 41.6° C respectively. The rainfall of this area is contributed through both South-West and North-East monsoons. The normal annual rainfall recorded in the raingauge station at Vijayawada is 959.4mm, out of which 854.2mm comes from South-West monsoon.

3.2 LANDUSE AND SOILS

The main crops that are grown in this area are paddy and sugar cane. The other crops generally cultivated are jowar, turmeric and vegetables. Paddy is grown in kharrif season and other crops are grown in both kharrif and rabi seasons. The area

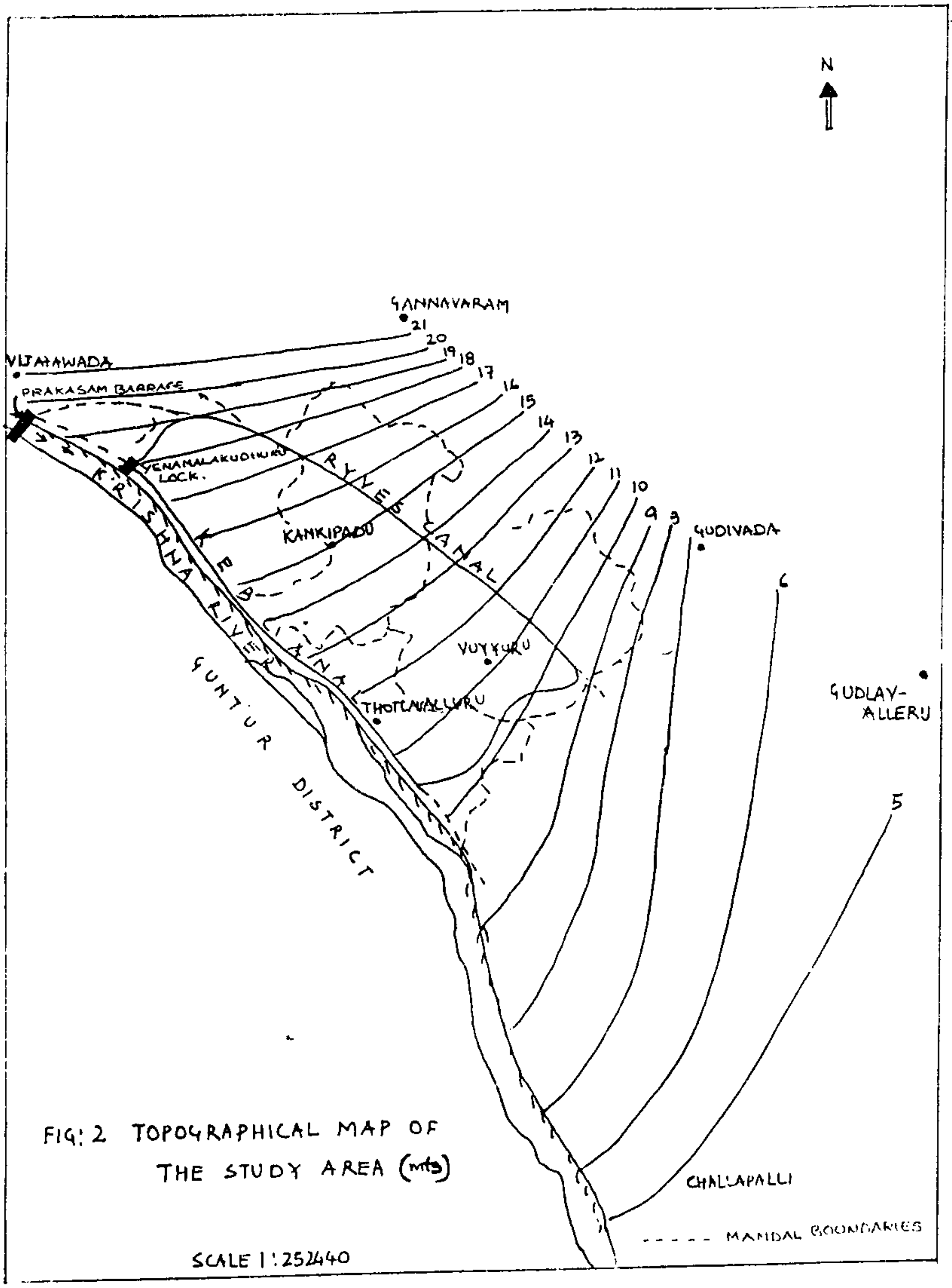

FIG: 2 TOPOGRAPHICAL MAP OF THE STUDY AREA (mts) is generally covered by black cotton soils with the percentage of clay ranging from 65% to 70% and these soils are classified as silt and clay type (A.P. State Groundwater Deptt., April,1993).

3.3 HYDROGEOLOGY

The Krishna delta area is underlain by recent alluvium of fluvial origin. The formation consists of sand, silt, gravel and clay. The ground water in this area occurs under watertable, semiconfined and confined conditions. The average water table fluctuations are limited and range from 1 to 2 mts.

4.0 DATA

4.1 GENERAL

The data collection and it's preliminary processing, analysis and a proper presentation is essential before being subjected to further detailed analysis. To carry out the present Groundwater Balance study, the related data of Bandar canal command area were collected from various field organisations like State Irrigation Deptt., State Ground Water Deptt., District Chief Planning Office, etc. The details of the data are given in the following paragraphs.

4.2 RAINFALL DATA

Monthly rainfall data for five stations within and around the study area have been collected from State Irrigation Department for a period of 10 years i.e. 1980-90 and is presented in Annexure-I. The map showing the locations of these raingauge stations is presented in Fig.3. The available normal annual rainfall of above stations are presented in Annexure-II. The Thiessen polygons have been prepared for the study area using the effective raingauge stations and shown in Fig.4. Due to the study area being small, only three raingauges are having their effect on the study area. The stations are Vijayawada, Kankipadu and Veeranki. Each of the polygon thus formed by these raingauge stations, is assumed to be controlled by the respective raingauge station. The area of each polygon was measured and given in

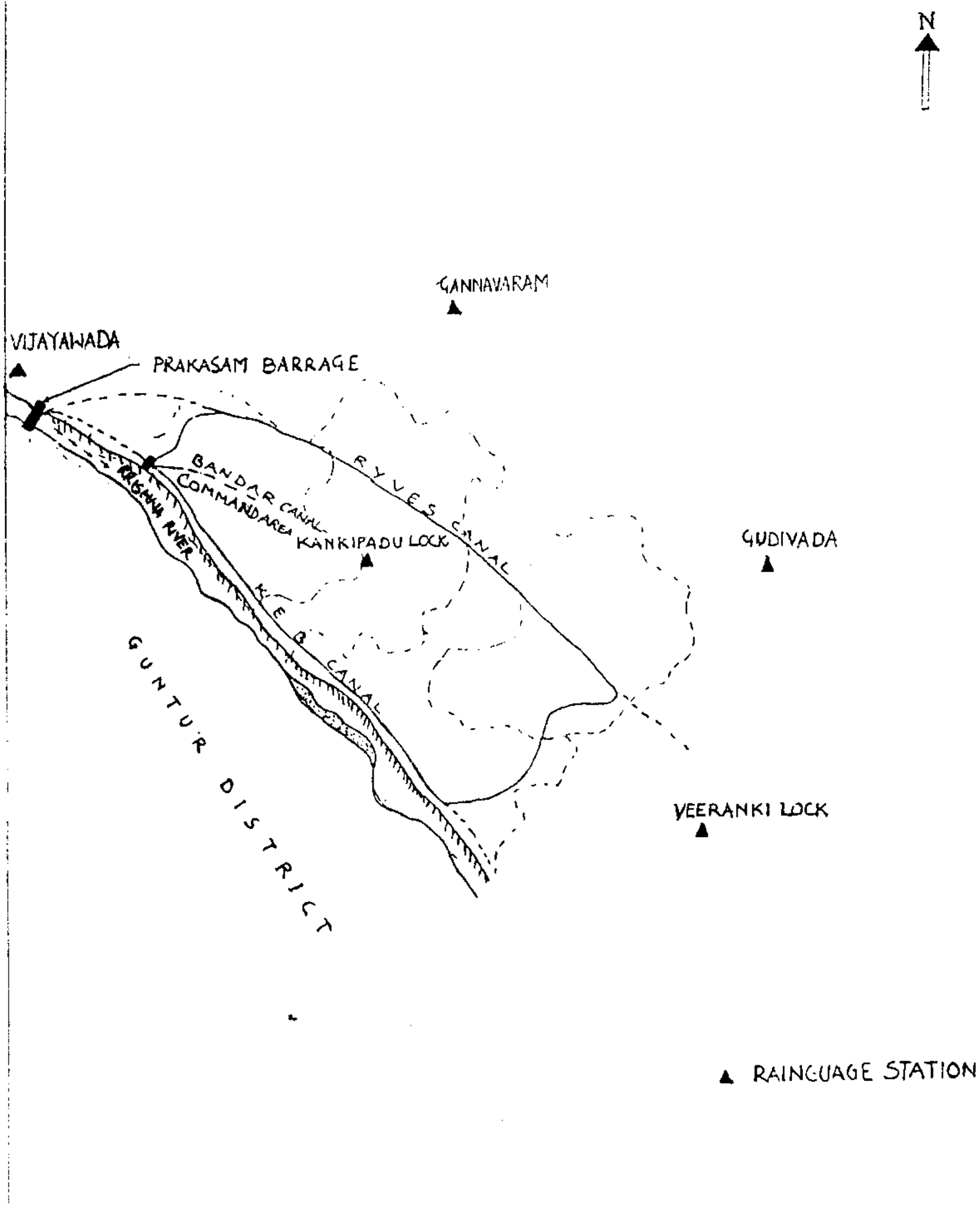

FIG. 3 MAP SHOWING RAINGUAGE STATIONS SCALE 1:252440

Table - 1. The weighted average monthly rainfall over study area have been calculated using the following equation :

$$\bar{P} = \frac{\sum Pi * Ai}{\sum Ai}$$

where,

Pi = Rainfall(mm)

Ai = Area of polygon(sq.kms)

$\bar{P}$ = Average Rainfall over study area(mm)

The average monthly rainfall over study area for a period of five years from 1985 to 1990 is presented in Table - 2.

4.3 STREAM FLOW AND CANAL DISCHARGES DATA

River gauge data (i.e. total monthly discharges), river cross-sections and stages at few locations are required to estimate the exchange of flow between the river and the aquifer. As the study area is bounded on both sides by two main canals, the effect of the river on the aquifer might be less predominant than the effect of canals. At present there is no gauging site down stream of Krishna river except at Prakasam Barrage. So the stage and discharge data of Krishna river on the down stream side are not available. However the monthly inflow/outflow of Krishna river at Prakasam Barrage have been collected and is presented in Annexure-III.

The monthly discharges at barrage and other control points on the main canal, branch canals, distibutaries and it's length and cross sections of all canals, wetted perimeter and number of

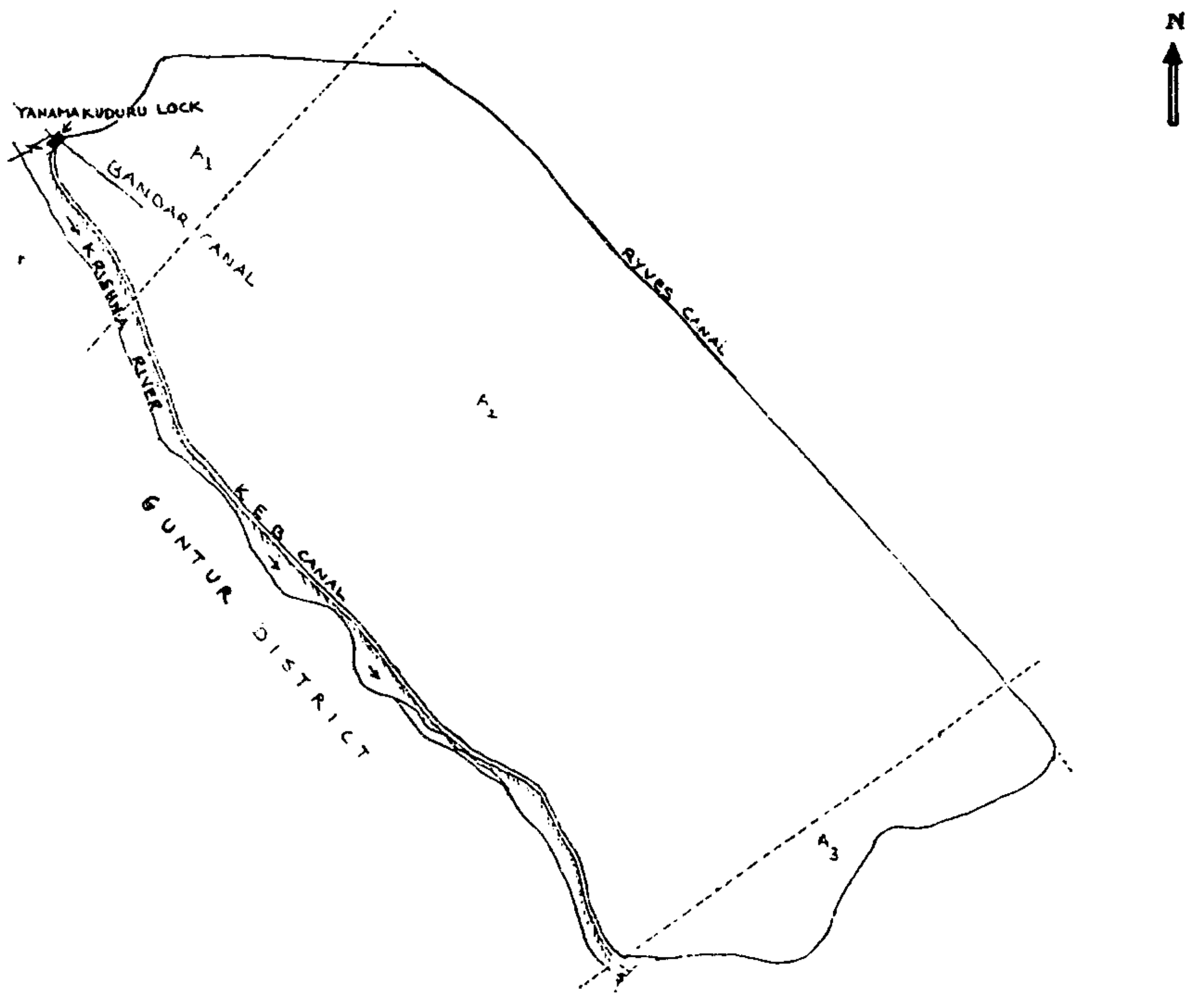

FIG 4 MAP SHOWING THIESSEN POLYGONS

TABLE-1

LIST OF EFFECTIVE RAINGUAGE STATIONS &
AREA OF POLYGONS

S.No	Rainguage Station	Area of Polygon (sq.kms)
1.	Vijayawada	13.48
2.	Kankipadu Lock	160.67
3.	Veeranki Lock	15.85
	Total :	190.00

TABLE-2

MONTHLY MEAN AREAL PRECIPITATION OVER THE STUDY AREA (mm)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1985	53.36	0.0	0.0	0.0	1.85	101.63	110.00	257.02	73.96	165.33	47.15	100.74
1986	29.83	12.99	0.0	10.34	7.55	93.71	96.90	291.81	49.52	45.03	71.64	2.28
1987	0.0	0.0	121.19	0.32	1.48	49.61	111.39	165.75	69.89	130.41	361.60	86.57
1988	0.0	1.07	0.29	10.27	15.26	63.93	485.60	280.72	270.91	25.16	0.0	45.35
1989	0.0	0.0	23.53	0.0	18.67	125.05	385.14	295.32	208.45	68.22	18.51	0.0
1990	1.98	20.62	72.25	30.50	347.60	167.71	148.67	178.22	217.28	297.60	40.50	0.50

running days are required to estimate the seepage losses from canal system. The canal network in the study area is shown in Fig.5. The total monthly discharges of main canals named as Krishna East Bank canal, Ryves canal, which are originating directly from the Prakasam Barrage have been collected. The monthly discharges of Bandar canal which starts from Yanamalakuduru Lock have been collected (Fig.5). The discharges at other controlling points on Bandar canal i.e Kankipadu Lock, Veeranki Lock and Pulleru Chanel have been collected and is presented in Annexure-III. The cross-section of canals, including its branches, length of canals, full supply-depth, wetted perimeter, seepage losses are given in the Table - 3.

4.4 GROUNDWATER DATA

A complete inventory of the groundwater structures, well log data, aquifer material, specific yield, and transmissibility data should be available to estimate the quantity of groundwater available in the study area. However, the monthly watertable levels for a large number of wells distributed within and outside the study area with their locations are also required to study the change in groundwater storage. The monthly groundwater levels of 11 years from 1980 to 1990 with some gaps which were collected from A.P.State Groundwater Department, Vijayawada, is presented in Annexure-IV. The map showing the location of observation wells is given in Fig.6. Based on these levels,the average

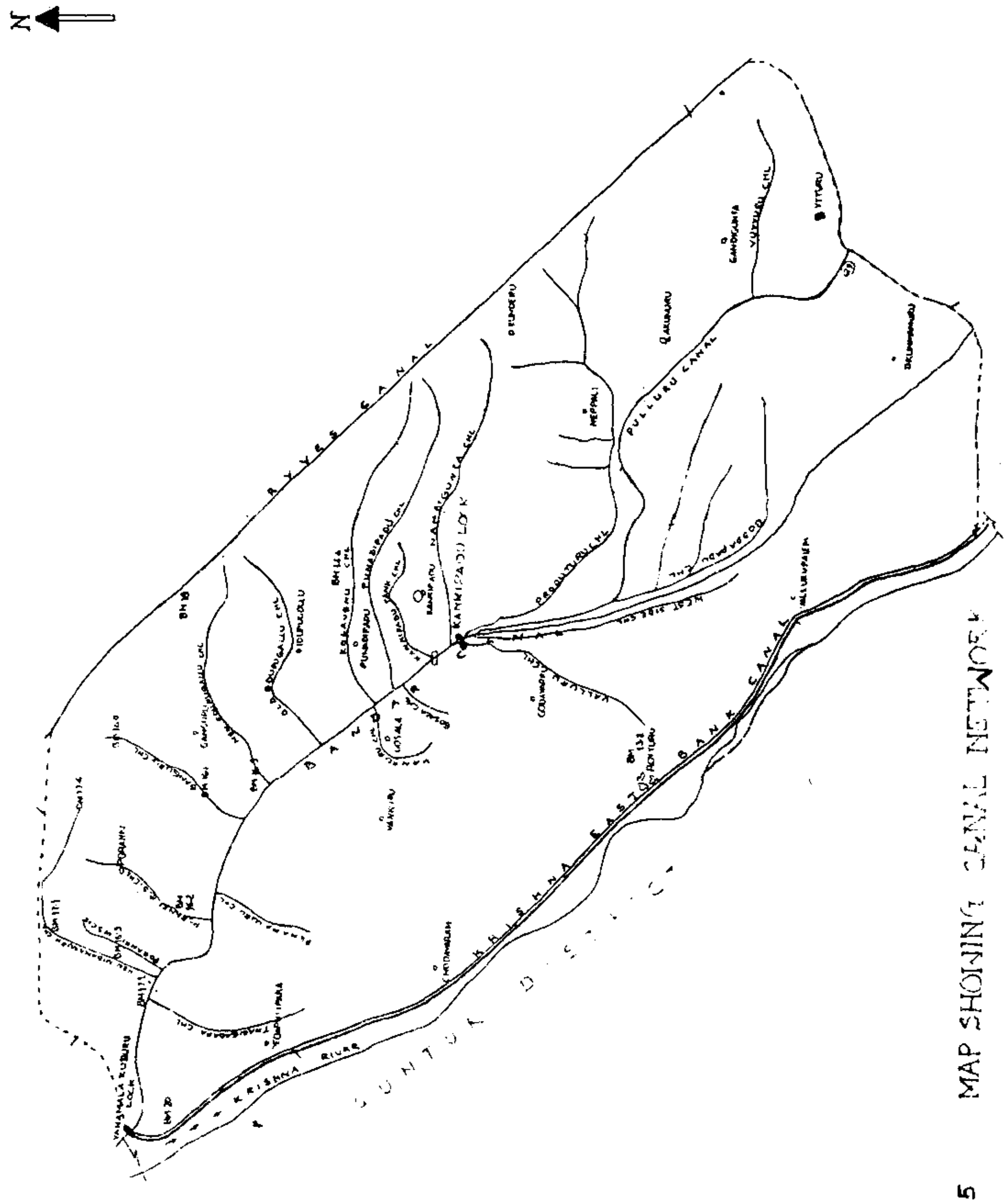

FIG: 5 MAP SHOWING CANAL NETWORK

TABLE-3

CANAL CROSS SECTION DETAILS IN STUDY AREA

SNO.	NAME OF CHANNEL	TOTAL LENGH (Kms)	REACH (Kms)	F S D (Mts)	BED WIDTH (Mts)	SIDE SLOPE IN CUTTING	SIDE SLOPE IN BANKING	WETTED PERIMETER (mt)	AREA OF WETTED PERI-METER (sq.mts)	MONSOON NO. OF RUNNING DAYS	MONSOON SEEPAGE LOSS (MCM)	NONMONSOON NO. OF RUNNING DAYS	NONMONSOON SEEPAGE LOSS (MCM)
1.	BANDAR CANAL	27.980	7.486 TO 20.378	2.70	25.90	0.5:1	1.5:1	33.782	435524	153	9.99	167	10.91
			20.378 TO 30.175	2.43	13.10	0.5:1	1.5:1	19.973	195676	153	4.49	167	4.90
			30.175 TO 35.466	2.50	11.58	0.5:1	1.5:1	18.650	98677	153	2.26	167	2.47
2.	NEW NIDAMANURU CHANNEL	6.282	0.000 TO 5.382	0.610	2.44	0.5:1	1.5:1	4.165	22420	153	0.51	167	0.56
			5.382 TO 6.282	0.564	1.67	0.5:1	1.5:1	3.271	2940	153	0.07	167	0.07
3.	OLD EDUPUGALLU CHANNEL	5.031	0.000 TO 1.416	0.92	2.057	0.5:1	1.5:1	4.659	6597	153	0.15	167	0.16
			1.416 TO 2.430	0.61	1.372	0.5:1	1.5:1	3.097	3140	153	0.07	167	0.08
			2.430 TO 3.825	0.46	0.91	0.5:1	1.5:1	2.211	3084	153	0.07	167	0.08
			3.825 TO 5.031	0.31	0.91	0.5:1	1.5:1	0.996	1204	153	0.03	167	0.03
4.	KOLAVENNU CHANNEL	7.274	0.000 TO 1.873	0.88	1.22	0.5:1	1.5:1	3.709	6947	153	0.16	167	0.17
			1.873 TO 4.024	0.64	1.067	0.5:1	1.5:1	2.877	6188	153	0.14	167	0.15
			4.024 TO 7.274	0.61	0.91	0.5:1	1.5:1	2.635	8564	153	0.20	167	0.21
5.	PUNADIPADU CHANNEL	4.789	0.000 TO 1.006	0.85	1.18	0.5:1	1.5:1	3.584	3606	153	0.08	167	0.09
			1.006 TO 2.618	0.80	0.91	0.5:1	1.5:1	3.173	5115	153	0.12	167	0.13
			2.618 TO 4.789	0.45	0.91	0.5:1	1.5:1	2.183	4737	153	0.11	167	0.12
6.	GOSALA CHANNEL	0.989	0.000 TO 0.989	0.66	2.36	0.5:1	1.5:1	4.227	4180	153	0.09	167	0.11
7.	KANKIPADU TANK CHANNEL	2.084	0.000 TO 0.788	0.61	2.75	0.5:1	1.5:1	4.52	3561	153	0.08	167	0.09
			0.788 TO 2.084	0.86	1.68	0.5:1	1.5:1	3.780	4898	153	0.11	167	0.12
8.	NAMBIGUNTA CHANNEL	5.837	0.000 TO 1.067	0.67	1.676	0.5:1	1.5:1	3.571	3810	153	0.09	167	0.09
			1.067 TO 5.837	0.53	1.6	0.5:1	1.5:1	3.099	14782	153	0.34	167	0.37

Contd..

9. VALLURU CHANNEL	2.215	0.060 TO 2.215	0.59	2.21	0.5:1	1.5:1	3.878	8590	153	0.20	167	0.21
10. PRODUTURU CHANNEL	9.213	0.00 TO 0.544	1.4	4.725	0.5:1	1.5:1	8.685	4725	153	0.11	167	0.12
		0.544 TO 5.655	1.0	3.500	0.5:1	1.5:1	6.328	32343	153	0.74	167	0.81
		5.655 TO 7.607	0.86	2.81	0.5:1	1.5:1	5.242	10232	153	0.23	167	0.25
		7.607 TO 9.213	0.79	1.82	0.5:1	1.5:1	4.056	6525	153	0.15	167	0.16
11. WEST SIDE CHANNEL	13.077	20.237 TO 23.737	0.91	3.88	0.5:1	1.5:1	6.454	22589	153	0.52	167	0.57
		23.737 TO 27.177	0.91	2.97	0.5:1	1.5:1	5.544	19071	153	0.44	167	0.48
		27.177 TO 28.183	1.06	2.39	0.5:1	1.5:1	5.888	5923	153	0.13	167	0.15
		28.183 TO 30.095	0.91	2.20	0.5:1	1.5:1	4.774	9126	153	0.21	167	0.23
		30.095 TO 33.314	0.91	1.82	0.5:1	1.5:1	4.394	14144	153	0.32	167	0.35
12. BODDAPADU CHANNEL	5.713	0.000 TO 1.213	0.99	3.65	0.5:1	1.5:1	6.450	7824	153	0.18	167	0.19
		1.213 TO 1.487	0.99	1.67	0.5:1	1.5:1	4.470	1225	153	0.03	167	0.03
		1.487 TO 1.526	0.99	1.52	0.5:1	1.5:1	4.320	168	153	0.01	167	0.01
		1.526 TO 2.490	0.66	1.21	0.5:1	1.5:1	3.133	3020	153	0.07	167	0.08
		2.490 TO 3.200	0.68	1.21	0.5:1	1.5:1	3.133	2224	153	0.05	167	0.06
		3.200 TO 4.339	0.68	1.37	0.5:1	1.5:1	3.293	3751	153	0.09	167	0.09
		4.339 TO 5.063	0.68	1.21	0.5:1	1.5:1	3.133	2268	153	0.05	167	0.06
		5.063 TO 5.298	0.68	1.21	0.5:1	1.5:1	3.133	736	153	0.02	167	0.02
		5.298 TO 5.713	0.68	1.21	0.5:1	1.5:1	3.133	1300	153	0.03	167	0.03
13. KEB CANAL	18.500	7.466 TO 25.986	2.52	25.60	1:1	1.5:1	33.7	320697	153	7.36	167	8.03
14. RYVES CANAL	25.100	1.610 TO 26.710	3.28	42.70	1:1	1.5:1	53.25	684096	153	15.70	167	17.14

watertable contours during pre-monsoon (June) and post monsoon (Nov) periods are drawn for a period of five years i.e. (1985 to 1990).

4.5 WATER QUALITY DATA

The ground water quality data of observation wells for pre- monsoon (May) and post monsoon (Nov) for a period of eight years(1982-1990) are given in Annexure- V. The ground water quality shows that below the Vuyyuru mandal the ground water may not be suitable for drinking and irrigation purposes. As per Indian Standards the TDS > 2100 ppm is not suitable for drinking and irrigation purposes. The TDS contours of May 90 and Nov. 90 are shown in Fig.7 and Fig.8 respectively. The postmonsoon(Nov.) TDS contours shows that near Vuyyuru mandal the TDS values are more than the limit for drinking and irrigation purposes. It has been observed that the TDS values near Vuyyuru are more in post-monsoon period than in pre-monsoon. The Na-Mg-HCO_3 -Cl facies of Vuyyuru observation well water indicate shallow water table conditions and the ground water has slightly higher concentration of dissolved solids due to evaporation with less concentration of Magnesium ions(A.P State Ground Water Deptt., April, 1993)

4.6 LANDUSE AND CROPPING PATTERN

Landuse data is required for estimating the evapotranspiration losses from the water table through forested

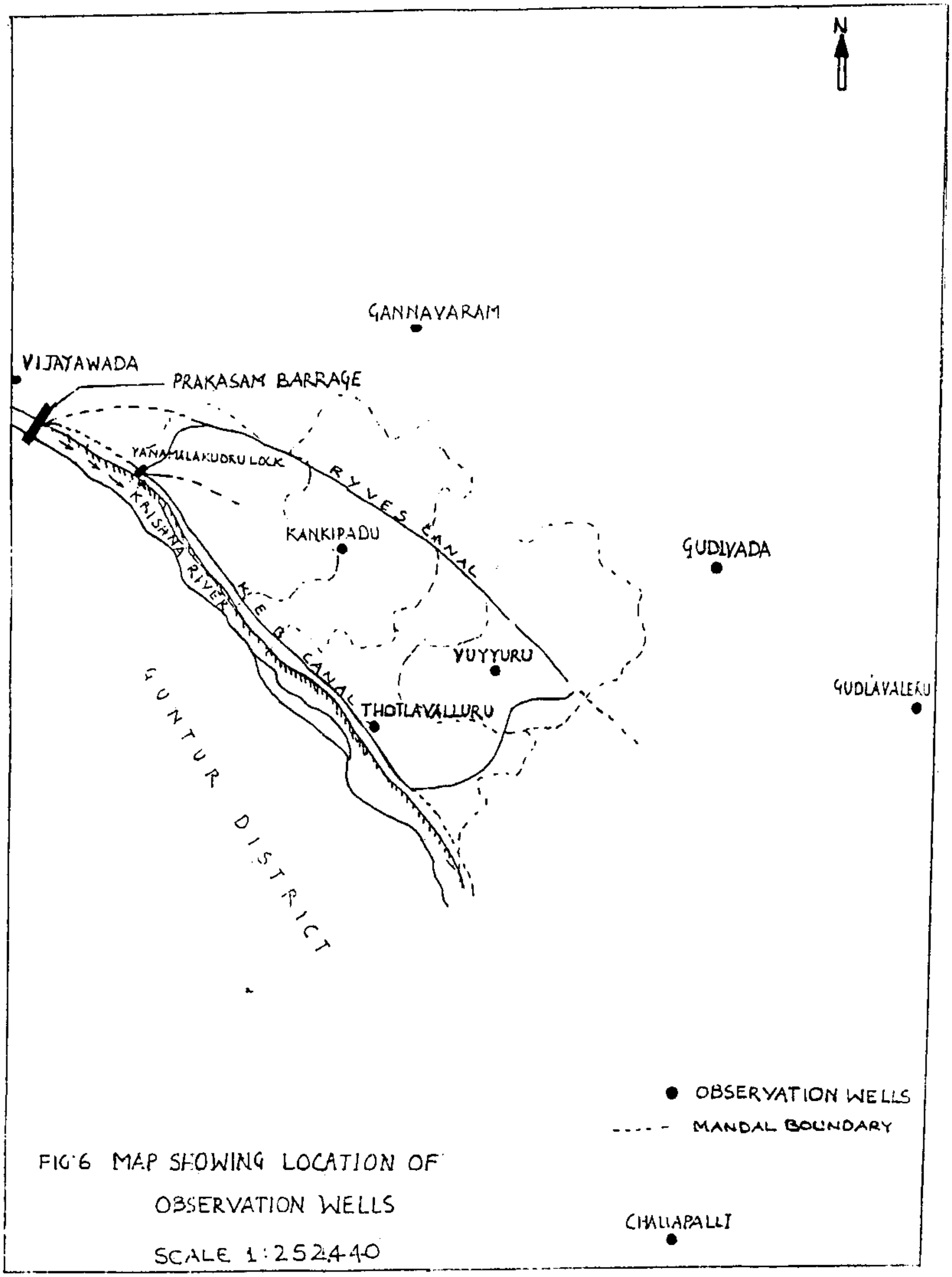

FIG 6 MAP SHOWING LOCATION OF OBSERVATION WELLS

SCALE 1:252440

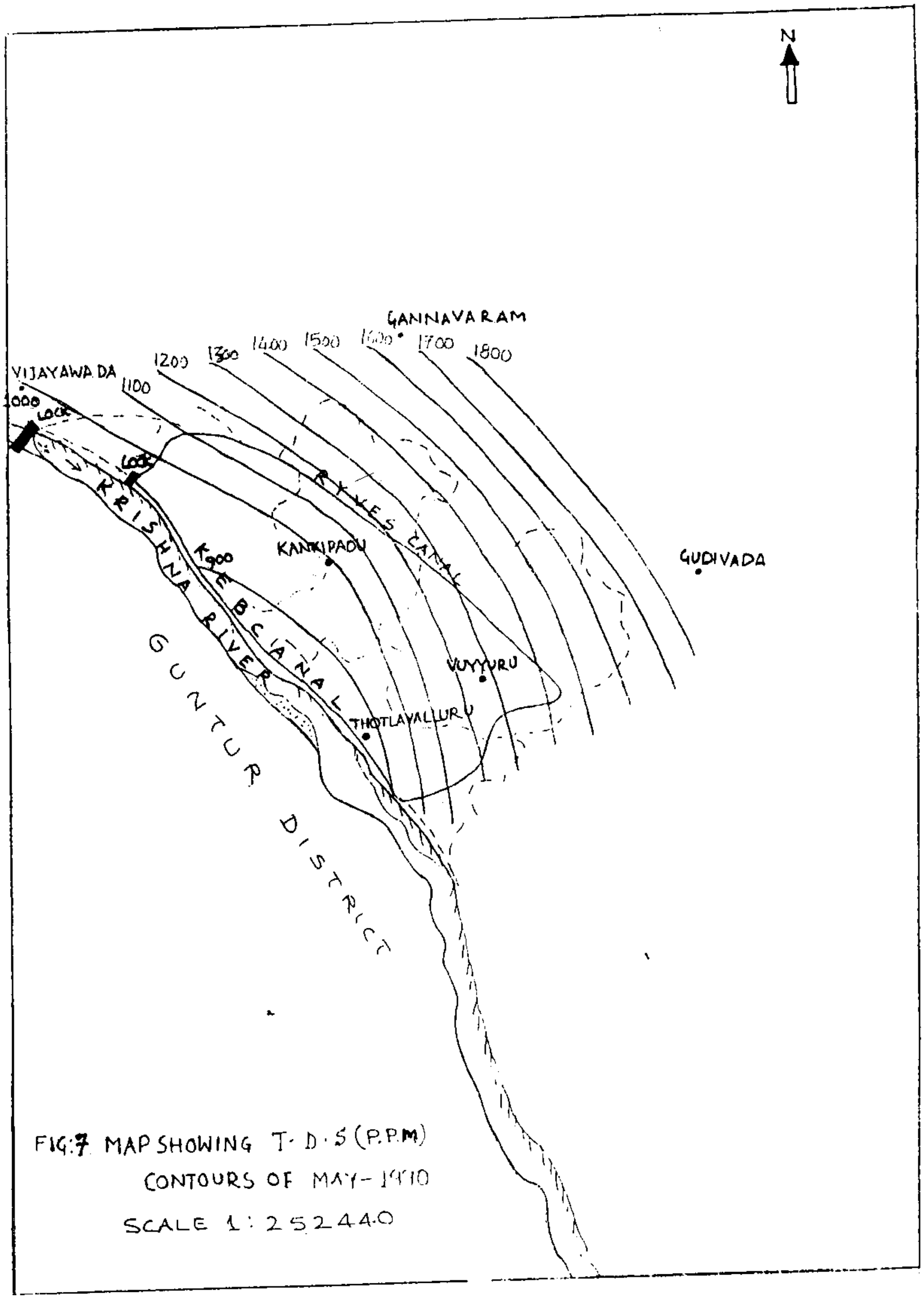

FIG:7 MAP SHOWING T.D.S (P.P.M)
CONTOURS OF MAY-1990
SCALE 1:252440

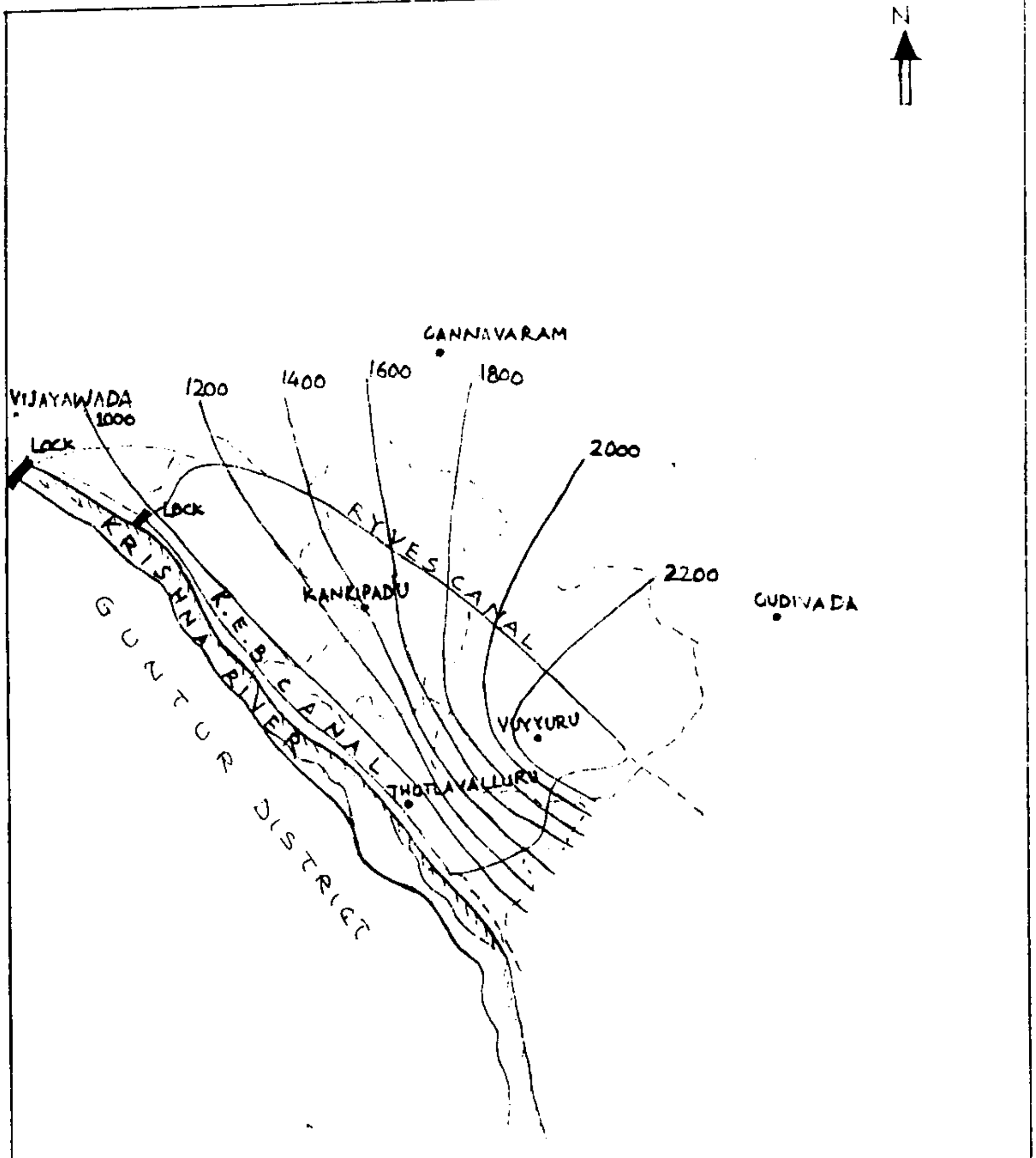

FIG: 8 MAP SHOWING T·D·S·(P.P.M)
CONTOURS OF NOV - 1990

SCALE 1:2,52,440

and deep rooted tree areas. Cropping pattern is also required in the estimation of the spatial and temporal distributions of the groundwater withdrawals and canal releases. The landuse and cropping pattern of study area as available for a few years from 1985-1990 were collected from Krishna District Statistical Hand Book, at Chief Planning Office, Machilipatnam. The details of landuse and cropping pattern for 190 sq.Kms under study area were worked on proportionate area basis and is presented in Table - 4 and Table - 5. Paddy and sugarcane are main crops in study area. The monthly potential evapotranspiration and pan evaporation rates for the study area are not available. The yearwise and source wise utilization of water in the study area have been calculated from district statistical year books . The details are shown in Table - 6.

4.7 AQUIFER DATA

The well log data, aquifer material, depth of aquifer, specific yield and transmissibility data at different places over the study area are required to study the change in groundwater storage. At present no pumping test has been conducted in the study area. But the well log data and pumping test details for some nearby place have been collected. However the detailed description of the data is given in the Part -I of the report titled "Conjunctive use studies in Krishna Delta System - status of data availability".

LAND USE PATTERN OF STUDY AREA TABLE-4

S NO.	LAND USE	AREA IN ACRES				
		1985 - 86	1986 - 87	1987 - 88	1988 - 89	1989 - 90
1.	TOTAL GEOGRAPHICAL AREA	46957	46957	46957	46957	46957
2.	FORESTS	--	--	--	--	--
3.	BARREN & UNCULTIVABLE LAND	3464	3464	3464	3464	3464
4.	L P NON-AGRICULTURAL USES	5102	5300	5403	5403	6539
5.	CULTIVABLE WASTE	90	90	90	90	90
6.	GRAZING LAND	448	448	459	459	459
7.	MISCELLANEOUS TREES & GROOVES	308	308	308	308	308
8.	CURRENT FALLOW	671	778	857	1710	173
9.	OTHER FALLOW	1589	1209	929	1804	2345
10.	NET AREA SOWN	35285	35360	35447	33719	33579
11.	TOTAL CROPPED AREA	53850	49000	54156	54262	54568
12.	AREA SOWN MORE THAN ONCE	18565	18640	18709	20543	20989

SOURCE : CHIEF PLANNING OFFICE, MACHLIPATNAM, KRISHNA DISTT.

TABLE-5

CROPPING PATTERN OF THE STUDY AREA
(AREA IN ACRES)

S.No CROP	1985 - 86 K	1985 - 86 R	1985 - 86 T	1986 - 87 K	1986 - 87 R	1986 - 87 T	1987 - 88 K	1987 - 88 R	1987 - 88 T	1988 - 89 K	1988 - 89 R	1988 - 89 T	1989 - 90 K	1989 - 90 R	1989 - 90 T
1. PADDY	22455	40	22495	21800	60	21860	21885	52	21937	21414	122	21536	21745	97	21842
2. MAIZE	256	16	272	90	110	200	117	13	130	101	126	227	52	62	114
3.CHILLIES	232	220	452	40	160	200	45	181	226	54	112	166	51	56	107
4.TURMERIC	1675	--	1675	1480	--	1480	1496	--	1496	1707	--	1707	1366	--	1366
5.SUGARCANE	7736	--	7736	9124	--	9124	9839	--	9839	7605	--	7605	7655	--	7655
6.PLANTAINS	209	--	206	125	--	125	47	--	47	396	--	396	542	--	542
7.[illegible]	432	--	432	200	--	200	167	--	167	530	--	530	610	--	610
8.TOTAL VEGE- TABLES	566	546	1112	800	200	1000	934	835	1769	1305	526	1831	926	384	1310
9.GROUNDNUT	--	20	20	--	28	28	--	31	31	--	22	22	2	4	6
10.SEASUM	28	78	106	4	--	4	--	--	--	5	6	11	-	1	1
11.FODDER CROP	769	2839	3608	1105	1404	2509	1147	2395	3542	703	899	1502	641	1371	2012
12.OTHER MISC. CROPS	6	--	6	--	--	--	--	--	--	--	--	--	192	37	229
13.NET IRRI- GATED AREA	34585	702	35287	35210	140	35350	35198	85	35283	33590	69	33659	33579	--	33579

K: KHARRIF R: RABI T: TOTAL

SOURCE : CHIEF PLANNING OFFICE, MACHLIPATNAM, KRISHNA DISTT.

TABLE-6

AREA IRRIGATED BY DIFFERENT SOURCES (AREA IN ACRES)

S NO.	SOURCE OF IRRIGATION	1985 - 86		1986 - 87		1987 - 88		1988 - 89		1989 - 90	
		K	R	K	R	K	R	K	R	K	R
1.	CANALS IRRIGATION	23962	121	24221	97	24013	120	23922	62	24987	83
2.	TANKS	--	--	--	--	--	--	--	--	--	--
3.	LIFT IRRIGATION	152	80	443	160	282	--	897	--	541	--
4.	IRRIGATION FROM PETTY SOURCES	302	52	309	40	316	--	--	--	--	--
5.	IRRIGATION FROM PUBLIC & PRIVATE TUBE WELLS	9062	761	9120	772	9856	1089	8023	856	7252	499
6.	DUGWELLS WITH PUMP	242	12	--	--	--	--	--	--	--	--
7.	TOTAL AREA IRRIGATED	30720	1026	34093	1069	34467	1209	32842	918	32780	582

K: KHARRIF R: RABI

SOURCE: CHIEF PLANNING OFFICE, MACHLIPATNAM, KRISHNA DISTT.

5.0 METHODOLOGY

5.1 GENERAL

The water balance study is carried out to evaluate the net available water resources and to assess the existing water utilization pattern to plan optimal and efficient management of water resources. The basic concept of water balance is

$$I - O = \Delta S$$

where,

I = input to the system
O = output from the System
ΔS = change in storage of the system

The detailed input and output components of the ground water system can be written as:

INPUT:

A) Natural Recharge

(i) Rainfall Recharge
(ii) Recharge from river
(iii) Inflow from other basins

B) Artificial Recharge

(i) Induced recharge from rivers
(ii) Irrigation channels and fields
(iii) Recharge by injection or spreading

OUTPUT:

A) NATURAL

(i) Evapotranspiration
(ii) Regeneration in rivers
(iii) Outflow to other basins.

B) ARTIFICIAL

Pumpage through open wells, pumping sets, shallow tube wells and deep tubewells.

Considering the above components, the groundwater balance equation can be rewritten as

$$Ig + Rc + Ri + Rr + Si = Et + Og + Se + Tp + \Delta S$$

Where,

Et = evapotranspiration
Ig = inflow from other basin
Og = Outflow to other basins
Rc = Recharge from Canal Seepage
Ri = Recharge from precipitation
Rr = Recharge from deep percolation
Se = Effluent seepage to rivers
Si = Influent seepage from rivers
ΔS = Change in ground water storage
and Tp = with drawal from Groundwater

This equation considers only one aquifer system and thus does not account for the interflows between the aquifers in a multi-aquifer system. However if sufficient data related to watertable and piezometric head fluctuations and conductivity of intervening layers are available, then the additional terms for these interflows can be included in the governing equation.

In practice, the computations of water balance components always involve errors, due to lack of data and shortcomings in the data used. The discrepancy of water balance (η) is given as a residual term of the water balance equation. A low value of(η) may indicate that it's component parts tend to balance out. However, the general ground water balance equation may be represented by the following equation :-

$$Ig + Rc + Ri + Rr + Si - Et - Og - Se - Tp - \Delta S - \eta = 0$$

It is to be noted that when the inflow part of the water balance equation exceeds the outflow part, the total water storage increases and an inflow less than the outflow results in decreased storage.

5.2 METHODOLOGY

The above general groundwater balance equation includes occurance of all sources of water but there may be situations in which it is possible to eliminate certain items from the equation because either they are negligible or they do not affect the solution.

So, initially in ground water balance study, all significant components for the study area need to be identified. In this regard the hydraualic boundaries of study area are to be studied thoroughly. The Bandar canal command area is bounded by two main canals namely East bank Canal and Ryves Canal. The East Bank Canal is aligned parallel to the Krishna River. The Bandar Main Canal is starting from Yenamalakuduru lock and it's command area is being considered for present study. A good network of canals in the study area is an important source of recharge and the study area is predominantly a paddy and sugarcane growing area in both the seasons and a certain depth of water is maintained in the fields. So, it may help in the recharge to the groundwater through irrigation fields. However, the major contribution to groundwater recharge is from rainfall with it's time and space variability. Due to dense canal network in this area, very few number of tube wells are available here. Since, the area irrigated by these wells is comparatively less, so the direct extraction of groundwater through pumping is also low. The indirect extraction of groundwater is mainly through shallow water table areas i.e through evaporation from soil and evapotranspiration. Both the river and the canal influence the shallow aquifer. A study of the behaviour of water table in terms of recharge and discharge was attempted and it was found that the Poranki village represents the area of recharge which is located outside the present study area(A.P State Ground Water Deptt., April 1993). The river Krishna continuously contributes to the recharge of the permeable substrata. The river has influent character. This is reflected by the water table contours which are bent towards the downstream side. The lower reaches of the Krishna delta i.e the far south of the study area forms the discharge area.

These physical and hydrological characteristics of the study area provide the necessary background information for identification and estimation of different components of groundwater balance. The study consists of identifying the various groundwater balance components and it's computation on seasonal basis i.e. monsoon [June - Oct] and non-monsoon [Nov-May].Keeping in view the availability of data, the study has been restricted to five years i.e. 1985-86 to 1989-90. The following groundwater balance equation is adopted for the present groundwater balance study in Bandar canal command area

$$Ri + Rc + Rr = Tp + Et + \Delta S + Ot$$

where

Ri = Recharge from rainfall

Rc = Recharge from canal seepage

Rr = Recharge from deep percolation

= Rrs + Rrg

Rrs = Recharge from surface water irrigation

Rrg = Recharge from groundwater irrigation

Tp = Withdrawal from ground water.

Et = Evapotranspiration losses

= Etf + Etw

Etf = Evapotranspiration losses from forested areas

Etw = Evapotranspiration losses from water logged areas.

Ot = Net outflow to other areas

= Og - Ig

Og = Outflow to other basins

Ig = Inflow from other basins

ΔS = change in groundwater storage.

There are so many methods to estimate the components of above equation, but in this report keeping in view the availability of data the following methodologies have been adopted to estimate the above parameters.

5.3.1 DRAFT FROM GROUND WATER (Tp)

Draft is the amount of water lifted from the aquifer by means of various groundwater structures and divies. The withdrawal can be made by means of public tubewells, private tube wells, pumping sets etc., The draft from these individual sources may vary widely depending upon the yield, type of well, well design, depth of water level, method of lift, crops grown land-holding of farmer, soil and water management practices adopted. Due to lack of well inventory and pumping test details of the study area, the groundwater draft in the present study has, therefore been calculated using the agricultural statistics.

In this regard, the seasonwise and cropwise area irrigated by tube wells were collected. The average irrigation requirement for these crops were also estimated. Thus, the draft from groundwater for irrigation purpose was arrived at by multiplying the irrigation requirement with the irrigated area. Similarly, the groundwater draft for drinking purpose was also estimated by multiplying the total population in the study area with the average per capita water consumption.

5.3.2 EVAPOTRANSPIRATION FROM GROUNDWATER RESERVOIR (Et)

Evapotranspiration is the amount of water lost by evaporation and transpiration through plants. When this evapotranspiration is from an area where the water table is close to the ground surface, the evapotranspiration from the soil and transpiration from the plant will be at the maximum rate i.e. at potential rate. Since the study area does not have any surface water structures fed by groundwater and forest area, so the evapotranspiration losses from groundwater have been estimated from shallow water table areas only.

5.3.3 SHALLOW WATER TABLE AREAS (Etw)

From the observed water level data, depth to water level contours were drawn and areas with depth to water table below ground level less than 2 meters identified. These surface areas have been considered as areas of discharge and the evapotranspiration from these areas have been considered at potential rate. The total amount of water extracted through evapotranspiration was estimated by multiplying the area with the average rate of potential evapotranspiration for the respective months.

5.3.4 RECHARGE FROM CANAL SEEPAGE (Rc)

Seepage refers to the process of water movement from a canal, through the bed and wall material. The process of seepage from a canal occurs as soon as water is conveyed through it.

In the beginning, the seepage rate undergoes rapid changes due to dispersion and swelling of soil particles after wetting and elimination of entrapped air by solution in the water. It may be noted that seepage rate from canal is not equal to the recharge rate to the watertable at all times. Therefore the recharge from canal seepage depends on the infiltration capacity of the canal bed and sides, sub-surface lithology, extent of wetted area, physical and chemical properties of water and relative position of bed with respect to the water table. There are so many methods to estimate the seepage losses from canals like inflow-outflow method, ponding method, seepage-meter methods etc.

The available cross sections, wetted perimeters and discharges of canals have been collected in Bandar canal command area. But the available data may not be suitable to adopt any of these above methods. The discharge measuring systems in command area are very old and existing canal cross sections are different from its original cross sections. In order to estimate the canal seepage the Groundwater Water Estimation Committee (GEC) has recommended the following norms. The seepage losses in the present study have been estimated using the GEC norms. (i) for unlined canals in normal type of soil with some clay content along with sand 15 to 20 ha.m/day/10^6 sq.meters of wetted area of canal or 6 to 8 cusee/10^6 sq.ft of wetted area of canal or 1.8 or 2.5 cumec/10^6 sq.m of wetted area.

(ii) for unlined canals in sandy soils 25 to 30 ha.m/day/10^6 sq.m of wetted area or 10 to 12 cusec/10^6 sq.ft of wetted area or 3 to 3.5 cumec/10^6 sq.mt of wetted area.

(iii) for lined canals, the seepage losses may be taken as 20% of the above values.

5.3.5 RECHARGE FROM FIELD IRRIGATION (Rr)

The irrigation water applied to the fields is partly lost by crops for meeting their consumptive use requirements and the balance infiltrates as recharge to the groundwater storage. The irrigation source may be canal water or ground water, hence the recharge is to be calculated separately for surface water and ground water. The recharge from field irrigation depends on various factors like cropping pattern, type of soil, type of irrigation practices etc., However, in the study area, paddy and sugarcane are the major crops in both the seasons & so there is a continuous submergence of land for long durations. The amount of recharge from applied irrigation water is derived both from groundwater and surface water sources. In the present study, as per the GEC norms the return flow from irrigation fields have been assumed as 40% and 30% of water delivered at the outlet for canal irrigation and groundwater irrigation respectively.

5.3.6 NET OUTFLOW TO OTHER BASINS (Ot)

For the estimation of sub-surface flows, the inflow from other basins (Ig) and outflow to other basin (Og) are to be calculated separately and from these values the net outflow (Ot) can be estimated. For this the contour maps of the phreatic surface should be drawn using water level data of wells located both within and outside the section limiting the basin outlet. The flow into the region or out of the region will be governed mainly by the hydraulic gradient and the transmissibility of the aquifer. Since the study area comprises of single aquifer, the length of the section across which groundwater inflow/outflow occurs is determined from contour maps, the length being measured parallel to the contour. Then the inflow/outflow can be determined by the following relationship :

$$Q = T * I * L$$

where,

T = Coefficient of transmissibility

I = Hydraulic gradient averaged over a length L

and L = Total length of the contour line.

5.3.7 CHANGE IN GROUNDWATER STORAGE (ΔS)

The change in storage refers to the effect of recharge and discharge on the ground water regime. These effects are measured by changes in water levels in the observation wells. The change in groundwater storage between the begining and end of the non-monsoon season is the total quantity of water withdrawn from groundwater storage and is represented by -ve sign, while the change between the beginning and end of monsoon season indicates the volume of water gone in to the reservoir and is represented by the +ve sign. For estimating the change in storage, a few observation wells in and around study area have been selected. Using the monthly water table observations ground water level contours have been prepared for pre-monsoon (June) and post-monsoon (Nov.) seasons. Then with the help of planimeter the areas between two successive contours were measured for the pre-monsoon and post-monsoon periods. The average position of water table in each period is calculated by the following equation.

$$W = \frac{A1(W1+W2) + A2(W2+W3) + \cdots An(W_{n-1} + Wn)}{2(A1+A2+A3+\cdots An)}$$

where,

W = Average position of water table.

W1, W2, W3 are the values of successive water table contours

A1, A2, A3 are the areas enclosed by two successive contours.

Once, the above equation is applied for all the years, the change in groundwater storage (ΔS) during monsoon and non-monsoon seasons were calculated as below.

Change in Groundwater Storage = Average Change in water table * Specific yield * Total study area.

The specific yield (Sy) is taken as 0.12 from near by area i.e. Vijayawada mandal in Krishna District. Since the study area is in delta, the average specific yield has been assumed as 12% for analysis purpose.

5.3.8 RECHARGE FROM RAINFALL (Ri)

Recharge from rainfall is the most important parameter, in a water balance equation. Direct groundwater recharge from rainfall depends on the intensity, duration of rainfall , the evaporative demand, soil moisture defficiency, the sorptivity, depth of unsaturated zone etc. Given all these parameters it is possible to predict the groundwater recharge at a site due to rainfall. The rainfall recharge would result in rise of water table and it is irregularly distributed in time and place. Various types of empirical relationships were established over the years between recharge and rainfall for different regions which can be used to estimate the recharge.

The Groundwater Estimation Committee has also recommended a range of recharge values for different types of geologic formations. However, in present study the groundwater balance approach has been adopted to calculate rainfall recharge of study area. This method may give fairly better results, provided a very extensive and accurate hydrological and meteorological data and all other components of water balance equation are estimated independently with suitable methodologies (Seethapathi, P V et al 1987 - 88). In this approach all components of water balance equation other than the rainfall recharge are estimated using the relevant hydrological and meteorological information. Since almost all the rainfall recharge takes place during monsoon season with little or no recharge in non-monsoon, the recharge has been calculated for monsoon season by substituting the estimates of other components in water balance equation. The mean values of precipitation over study area have been computed by using Thiessen Polygon method.

6.0 ANALYSIS

The analysis of hydrological and meteorological data of study area provides the necessary background information for identification and estimation of different components of water balance. After analysing the basic data the following groundwater balance components have been identified to carryout seasonal groundwater balance study of Bandar Canal Command area. The components are draft from groundwater, evapotranspiration from groundwater reservoir, seepage losses, recharge from field irrigation and change in groundwater storage. The methodology for estimation of these components, have been explained in Chapter five of this report. Finally the major component i.e. rainfall recharge was estimated using water balance approach to arrive the overall groundwater balance of the study area. The seasonal groundwater balance has been done for the period 1985-86 to 1989-90 for monsoon (June to Oct) and Non-monsoon (Nov-May) seasons.

6.1 DRAFT FROM GROUNDWATER (Tp)

In the present study the draft requirement is mainly for irrigated area through groundwater structures and for domestic drinking water purposes. The data on seasonwise and sourcewise irrigation were collected from Chief Planning Office, Machilipatnam and presented in Table - 6. From these details the irrigated area is mainly from canals and lesser area is from groundwater structures. The main crops irrigated from these sources are paddy and sugarcane. For the estimation of groundwater draft the average water requirement of crops which are supposed to be met from groundwater have been assumed as 0.45m and 0.6 m in kharif and rabi respectively. The seasonwise draft was calculated by multiplying the individual crop irrigated area with the average water requirement during that season. Similarly, the draft for drinking purpose has also been estimated at the rate of 40lit/capita/day for total population of study area. After adding these two sources of drafts, the seasonwise total estimated draft is given in the following table for different years.

S.NO.	YEAR	DRAFT (MCM)	
		MONSOON	NONMONSOON
1.	1985-86	17.57	30.20
2.	1986-87	17.23	22.59
3.	1987-88	18.58	29.55
4.	1988-89	15.24	32.08
5.	1989-90	13.84	32.62

6.2 EVAPOTRANSPIRATION FROM GROUNDWATER RESERVOIR (Etw)

According to available statistics there are no forests area in the study area. So the evapotranspiration is considered only from shallow water table areas. Generally at the end of monsoon period, the water table reaches it's highest levels and gradually recedes to it's lowest levels by the beginning of the next monsoon. From the observed water level data, depth to waterlevel contours were drawn and areas with depth to water table below the ground level less than 2 mts are identified.

The average potential evapotranspiration rates for the study area have been adopted for calculating the evapotranspiration losses from shallow water table areas. Due to non-availability of average potential evaporation rates for the study area, the values of evapotranspiration for Central Godavari delta have been adopted (Tyagi, 1993-94). The table shows the average Potential Evapotranspiration rates for the study area.

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
AVER-AGE P.E.T (mm/day)	3.18	4.18	5.05	5.97	6.51	5.39	5.13	4.86	3.85	3.38	2.88	2.78

Finally, the evapotranspiration losses from shallow water table areas is given in following table.

S.NO.	YEAR	EVAPOTRANSPIRATION LOSSES (MCM)	
		MONSOON	NONMONSOON
1.	1985-86	68.86	75.47
2.	1986-87	64.79	75.47
3.	1987-88	46.94	97.91
4.	1988-89	82.65	81.67
5.	1989-90	65.51	100.82

6.3 RECHARGE FROM CANAL SEEPAGE (Rc)

In the study area the seepage from the Bandar main canal is completely contributing to the recharge in study area, whereas the KEB and Ryves main canals are partially contributing its seepage as recharge to the groundwater storage, because these two canals act as boundaries of the study area. The canal cross sections, wetted perimeters, and monthly discharges of major and minor canals have been collected and shown in Annexure-III and Table - 3 respectively. Due to limited data the Groundwater Estimation Committee recommendations have been followed and the recharge due to seepage from unlined canals in clayey soil of the study area was taken as 15 ha.m/day/10^6 sq.m.of wetted area of canals. The estimated seasonal recharge due to canal seepage is presented in the following table.

S.NO.	YEAR	CANAL SEEPAGE LOSS (MCM)	
		MONSOON	NONMONSOON
1.	1985-86	45.82	50.00
2.	1986-87	45.82	50.00
3.	1987-88	45.82	50.00
4.	1988-89	45.82	50.00
5.	1989-90	45.82	50.00

6.4 RECHARGE FROM FIELD IRRIGATION (Rr)

The recharge from field irrigation is estimated separately for canal water and groundwater. In the study area paddy and sugarcane are the major crops irrigated by canal water and groundwater. According Groundwater Estimation Committee norms, the recharge due to return flow from canal irrigation was thus taken as 40% of the water applied in the fields and the recharge due to groundwater irrigation was taken as 30% of the groundwater draft used for irrigation purpose. The seasonal estimation of recharge due to canal irrigation and groundwater irrigation are given the following table.

S.NO.	YEAR	RECHARGE (MCM)			
		CANAL IRRIGATION		GROUNDWATER IRRIGATION	
		MONSOON	NONMONSOON	MONSOON	NONMONSOON
1.	1985-86	43.46	13.45	12.42	15.13
2.	1986-87	44.14	7.16	12.09	8.06
3.	1987-88	46.60	12.86	13.05	14.46
4.	1988-89	44.03	8.04	10.66	9.01
5.	1989-90	46.60	15.42	9.97	17.34

6.5 NET OUTFLOW TO OTHER BASIN (Ot)

Inflows to the study area (Ig) and outflow from the area (Og) are computed by dividing the whole boundary into small segments and the gradient of the water table calculated by using the ground water levels on both sides of the boundary of each segment. The net flows were calculated for each segment by using the relationship :

$$Q = T * I * \Delta L$$

where,

Q = discharge passing through a particular segment.

I = hydraulic gradient

ΔL = length of segment concerned

Thus to get the total discharge passing across the study boundaries, the discharge values for each segment were summed up. The study area has been divided into four segments bassed on the observation well at Vuyyuru. The segments are Challapalli, Vijayawada, Gannavaram, Gudivada respectively. The Segmentwise gradient and discharges for monsoon and nonmonsoon are given in the Table7 .

Thus,

$$Q = T * I * \Delta L$$

The following table presents the net out flow from the study area to other areas i.e (Og - Ig) and these are found to vary between 4.14 MCM to 14.36 MCM for the study period.

S.NO	YEAR	NET OUTFLOW TO OTHER AREAS (MCM)	
		MONSOON	NON-MONSOON
1.	1985-86	8.88	13.54
2.	1986-87	9.23	11.11
3.	1987-88	8.21	14.36
4.	1988-89	4.67	10.45
5.	1989-90	4.14	5.89

TABLE-7

SEGMENTWISE GRADIENT AND DISCHARGE

YEAR	SEGMENT 1				SEGMENT 2				SEGMENT 3				SEGMENT 4				NET OUTFLOW TO OTHER BASIN (Ot) (MCM)	
	M		NM		M		NM		M		NM		M		NM			
	G	Q (MCM)	G	Q (MCM)	G	Q (MCM)	G	Q (MCM)	G	Q (MCM)	G	Q (MCM)	G	Q (MCM)	G	Q (MCM)	M	NM
1985-86	$2.4X10^{-4}$	2.37	$2.54X10^{-4}$	3.46	$-2.77X10^{-5}$	-0.21	$-4.75X10^{-5}$	-0.48	$2.38X10^{-5}$	0.24	$2.18X10^{-4}$	2.96	$4.71X10^{-4}$	6.48	$3.96X10^{-4}$	7.60	8.88	13.54
1986-87	$2.6X10^{-4}$	2.54	$2.40X10^{-4}$	3.32	$-2.38X10^{-5}$	-0.17	$-8.71X10^{-5}$	-0.91	$1.07X10^{-4}$	1.04	$3.57X10^{-5}$	0.52	$4.24X10^{-4}$	5.82	$4.28X10^{-4}$	8.18	9.23	11.11
1987-88	$2.6X10^{-4}$	2.53	$2.26X10^{-4}$	3.14	$-1.19X10^{-5}$	-0.10	$-8.32X10^{-5}$	-0.88	$-1.58X10^{-4}$	-0.14	$1.23X10^{-4}$	1.67	$4.32X10^{-4}$	5.92	$5.47X10^{-4}$	10.43	8.21	14.36
1988-89	$2.4X10^{-4}$	2.34	$1.78X10^{-4}$	2.45	$-3.57X10^{-5}$	-0.26	$-1.03X10^{-4}$	-1.06	$-3.80X10^{-4}$	-3.66	$1.94X10^{-4}$	2.59	$4.12X10^{-4}$	5.65	$3.41X10^{-4}$	6.47	4.07	10.45
1989-90	$2.4X10^{-4}$	2.34	$2.19X10^{-4}$	2.98	$-3.57X10^{-5}$	-0.27	$-3.57X10^{-5}$	-0.37	$-3.21X10^{-45}$	-3.07	$-2.77X10^{-4}$	-3.72	$3.72X10^{-4}$	5.14	$3.64X10^{-4}$	7.00	4.14	5.89

M: MONSOON NM: NONMONSOON G: GRADIENT Q: DISCHARGE

6.6 CHANGE IN GROUNDWATER STORAGE (ΔS)

The change in groundwater storage is obtained by drawing water table contours for the study area for June (Premonsoon) and November (Postmonsoon) for each year with 1m contour interval. The watertable contour maps for pre and post monsoon period in the years of 1986 and 1988 are given in Fig.9 to Fig.12. The methodology of estimating the changes in groundwater storage is explained in Chapter 5 of this report. The seasonal change in groundwater storage during different years of study are given in following table:

S.No.	YEAR	CHANGE IN GROUND WATER (MCM)	
		MONSOON	NON-MONSOON
1.	1985-86	29.58	-37.39
2.	1986-87	31.92	-38.76
3.	1987-88	49.93	-47.16
4.	1988-89	33.06	-51.07
5.	1989-90	52.21	-38.52

6.7 RECHARGE FROM RAINFALL (Ri)

The monthly rainfall data for raingauge stations within and around the study area have been collected. Among these stations the effect of only three raingauge stations are falling

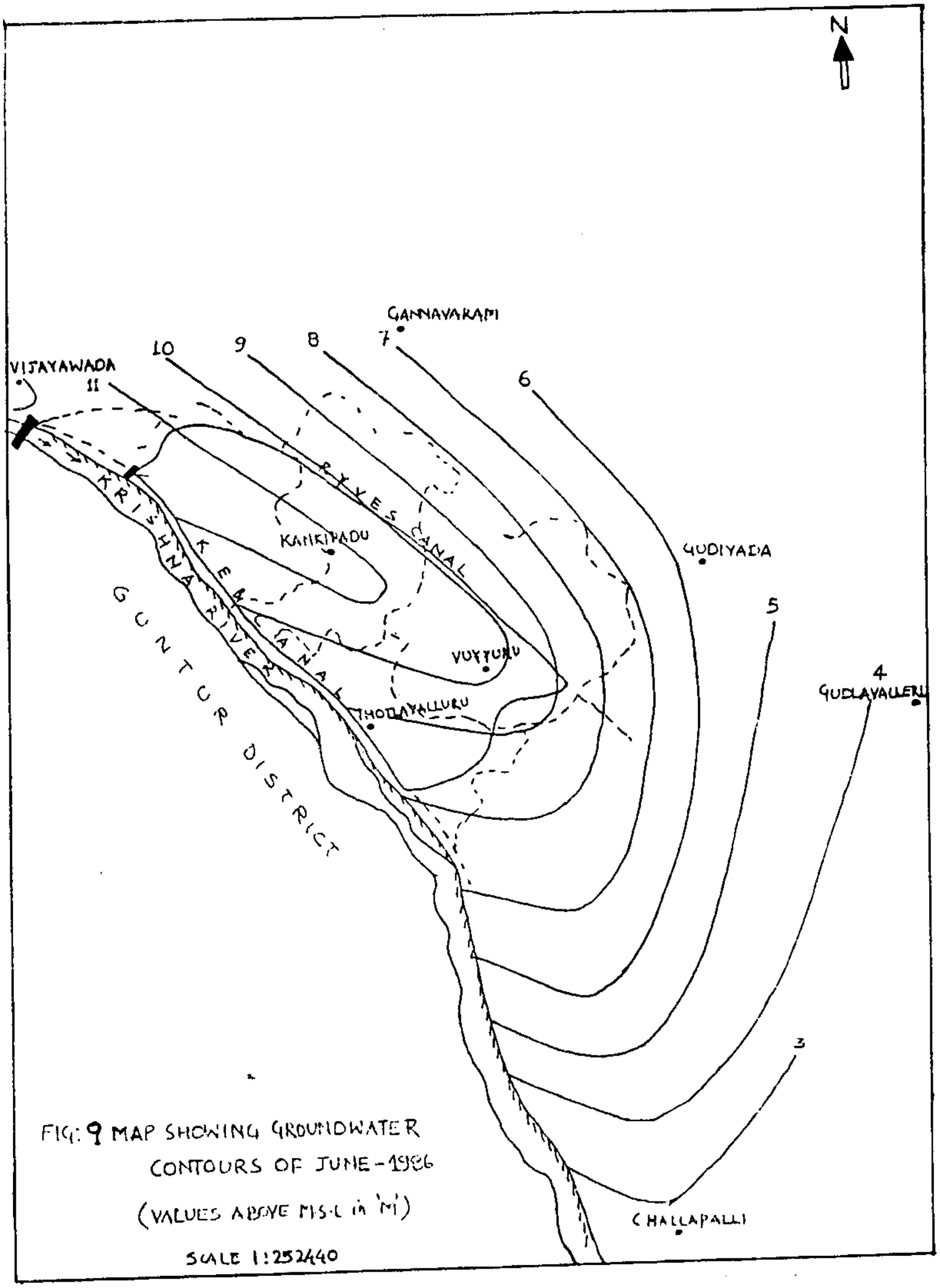

FIG: 9 MAP SHOWING GROUNDWATER CONTOURS OF JUNE-1986

(VALUES ABOVE M.S.L in 'M')

SCALE 1:252440

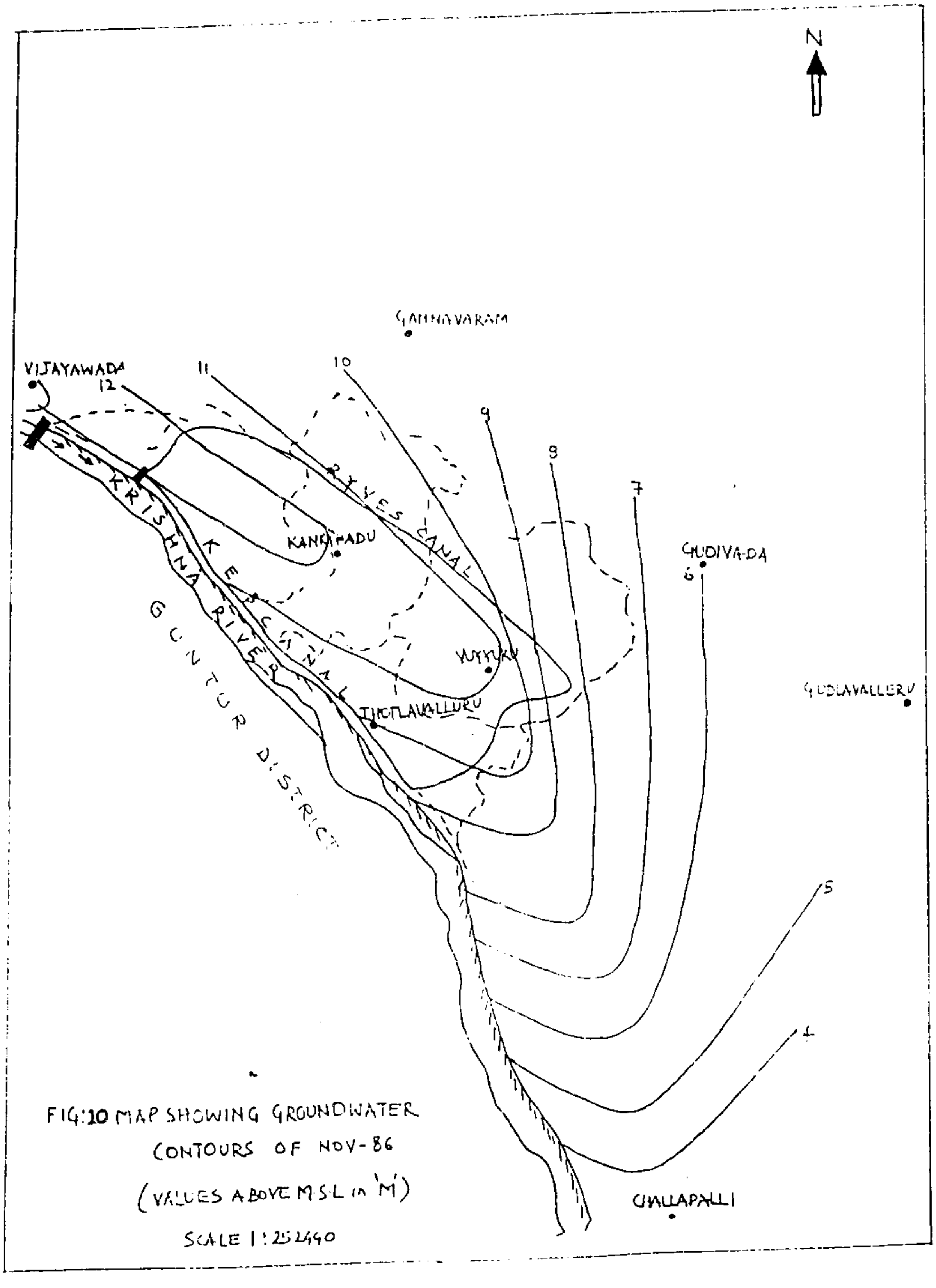

FIG:10 MAP SHOWING GROUNDWATER CONTOURS OF NOV-86
(VALUES ABOVE M.S.L in 'M')
SCALE 1:252440

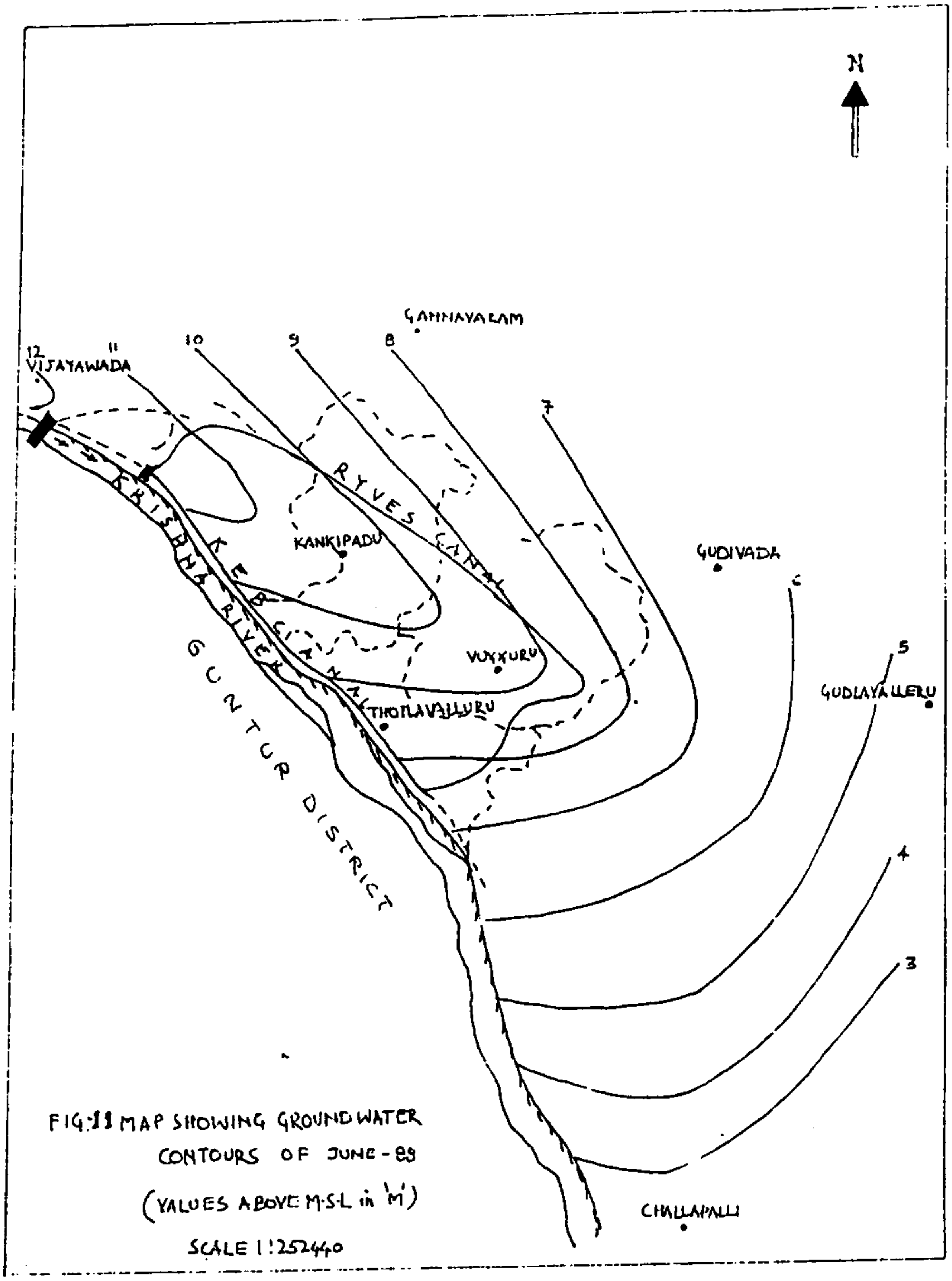

FIG: 11 MAP SHOWING GROUNDWATER CONTOURS OF JUNE - 89

(VALUES ABOVE M.S.L in 'M')

SCALE 1:252440

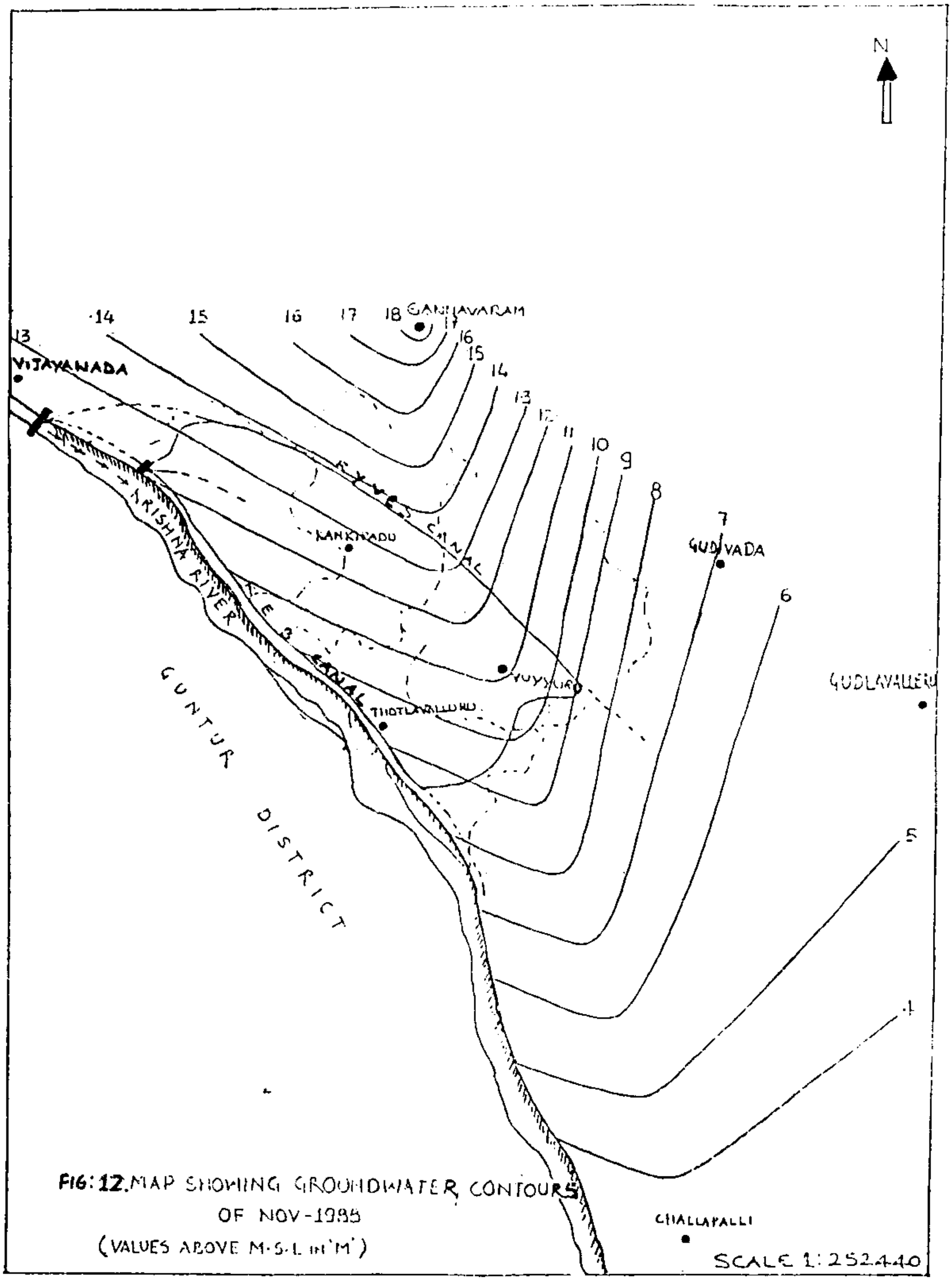

FIG: 12. MAP SHOWING GROUNDWATER CONTOURS OF NOV-1985 (VALUES ABOVE M.S.L. in 'M') on study area. Using Thiessen Polygon method, the average monthly precipitation over study area during 1985-86 to 1989-90 were calculated and is given in Table - 4 and Table - 5. The methodology for estimating recharge from rainfall is discussed in Chapter 5. However the total rainfall over the study area during monsoon and non-monsoon seasons were calculated and is presented in the following table.

S.No.	YEAR	RAINFALL (mm)	
		MONSOON	NON-MONSOON
1	1985-86	708	209
2.	1986-87	577	197
3.	1987-88	527	475
4.	1988-89	1126	87.5
5.	1989-90	1082	491

7.0 GROUND WATER BALANCE

The ground water balance study of Bandar Canal Command area has been carried out seasonwise for monsoon (June to Oct) and non-monsoon (Nov to May) from 1985 to 1990. The methodology for estimating various components of groundwater balance equation is explained in Chapter 5. The seasonwise components of ground water balance study is presented in Table - 8. Since the study area is having dense canal network system. The major recharge to groundwater storage from canal seepage and return flows. The major portion of rainfall recharge takes place during monsoon season. So, the rainfall recharge has been calculated using water balance approach. Based on the monsoon season rainfall,the recharge co-efficients were calculated and presented in Table - 7. The recharge co-efficients for the study area during 1985-86 to 1989-90 are found to vary from 0.16 to 0.19. A graph drawn between seasonal rainfall(monsoon) and the recharge due to rainfall is presented in Fig. 13. From the graph, it is observed that as the rainfall increases, the quantity of recharge also increases but the increase is not linearly proportional. For non-monsoon seasons, unaccounted water has been computed as (Inflow-outflow-change in groundwater storage), the discrepancy being less than 6 MCM in all cases. This amount of unaccounted water seems to be quite reasonable and within the limits. Therefore, overall water balance can be considered to be correct although individual components may have some errors.

TABLE-8

GROUND WATER BALANCE TABLE

S.NO.	COMPONENTS	1985-86 M	1985-86 NM	1986-87 M	1986-87 NM	1987-88 M	1987-88 NM	1988-89 M	1988-89 NM	1989-90 M	1989-90 NM
01	Draft from groundwater	17.57	30.20	17.23	22.59	18.58	29.55	15.24	32.08	13.84	32.62
02	Evapotranspiration losses from shallow water table areas	68.86	75.47	64.79	75.47	46.94	97.91	82.65	81.67	65.51	100.82
03	Net effluent seepage to other basins	8.88	13.54	9.23	11.11	8.21	14.36	4.07	10.45	4.14	5.89
04	Recharge from canal seepage	45.82	50.00	45.82	50.00	45.82	50.00	45.82	50.00	45.82	50.00
05	Return flow from:										
	a. Surface water irrigation	43.46	13.45	44.14	7.16	46.60	12.86	44.03	8.04	46.60	15.42
	b. Groundwater irrigation	12.42	15.13	12.09	8.06	13.05	14.46	10.66	9.01	9.97	17.34
06	Change in groundwater storage	29.58	-37.39	31.92	-38.76	49.93	-47.16	33.06	-51.07	52.21	-38.52
07	Recharge from rainfall	23.19	0.00	21.12	0.00	18.19	13.00	34.51	0.00	33.31	14.00
08	Rainfall	134.52	39.63	109.62	37.41	100.14	90.26	214.00	16.63	205.61	93.38
09	Recharge coefficient	0.17	---	0.19	---	0.18	---	0.16	---	0.16	---
10	Unaccounted water	---	-3.24	---	-5.19	---	-4.34	---	-6.08	---	-4.05

M: MONSOON NM: NON-MONSOON

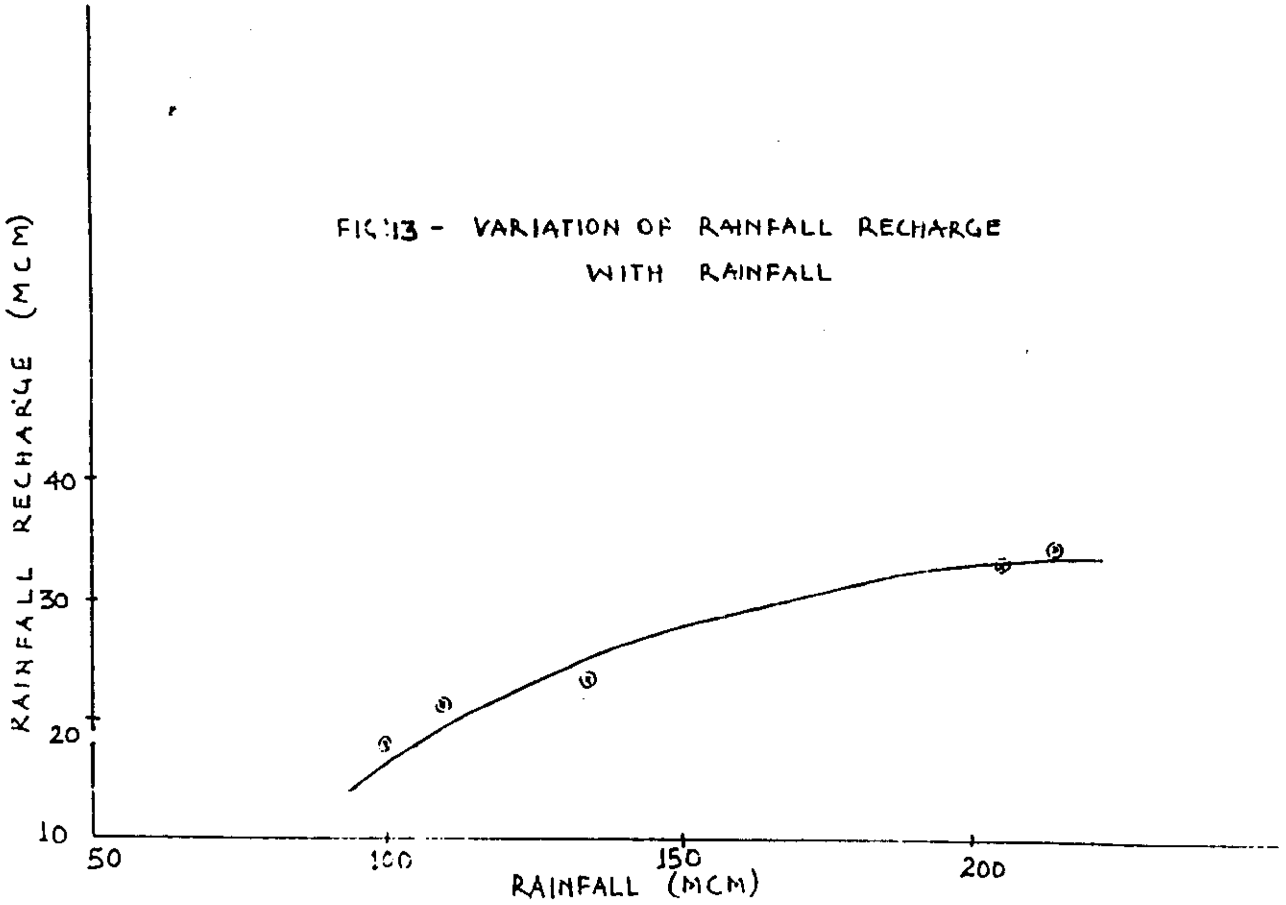

FIG. 13 - VARIATION OF RAINFALL RECHARGE WITH RAINFALL

8.0 CONCLUSIONS

Water balance approach is a viable method of establishing the rainfall recharge coefficient and for evaluating the methods adopted for the quantification of recharge and discharge from other sources.

The present study "Seasonal groundwater balance of Bandar Canal command area" has been carried out to understand the existing water utility in the system and this information can further be used in conjunctive use study of surface and groundwater for this area. In this study the water balance components are identified and each component is estimated independently except the rainfall recharge. The recharge from rainfall during the monsoon season has been computed from the water balance equation. The recharge co-efficients varies between 0.16 to 0.19 and the unaccounted water in non-monsoon season has been found to be less than 6 MCM. Keeping in view study area (i.e. 190 sq.km), these amounts or figures can be considered to be within reasonable limits and this further indicates a reasonable degree of accuracy in quantification of the various components.

The estimates of groundwater balance components in a seasonwise manner provides a general guideline for model calibration. The results of the water balance will be useful for mathematical modelling of the command area and to predict the response of groundwater system due to combined usage of groundwater and surface water in the study area.

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2. Shri V.V.Someswara Rao, D A O, K C Division.

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MONTHLY RAINFALL DATA OVER THE STUDY AREA (mm)

STATION:VIJAYAWADA

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.0	0.0	0.0	2.6	14.2	277.7	253.6	147.8	77.0	129.9	24.2	0.0
1981	8.3	0.0	4.8	32.0	21.6	112.4	256.2	118.5	241.9	137.4	21.2	0.0
1982	0.0	0.0	0.0	0.0	24.4	58.2	156.2	154.6	204.5	92.3	35.8	0.0
1983	0.0	3.5	0.0	0.0	30.8	137.0	164.9	210.4	271.1	179.6	6.4	5.6
1984	0.0	0.6	1.2	0.0	0.0	30.5	264.8	99.8	141.2	129.2	5.2	0.0
1985	50.6	0.0	0.0	0.0	26.2	116.7	150.3	195.0	48.8	233.1	22.6	87.0
1986	17.8	0.0	0.0	1.2	3.2	97.4	124.6	363.3	100.6	22.0	0.6	5.6
1987	0.0	0.0	92.4	4.5	8.4	32.0	85.8	67.0	79.2	154.8	170.6	13.5
1988	0.0	15.2	4.1	9.4	45.9	107.3	537.2	370.1	251.9	25.2	0.0	40.4
1989	0.0	0.0	33.6	0.0	15.2	96.6	526.0	258.7	319.7	44.8	7.4	0.0
1990	28.0	0.0	39.0	11.4	290.9	173.4	92.8	156.9	137.7	104.8	34.7	0.0

STATION:GANNAVARAM

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.0	0.0	0.0	0.0	62.1	261.8	229.4	141.3	32.4	119.6	41.2	0.0
1981	4.6	0.0	7.2	94.0	14.5	154.9	250.4	109.4	123.4	126.2	38.2	0.0
1982	0.0	0.0	0.0	0.0	27.7	96.8	124.1	161.2	137.0	136.2	68.8	0.0
1983	0.0	8.2	4.4	0.0	28.1	190.1	213.5	217.6	327.9	118.8	12.2	5.9
1984	0.0	4.1	19.4	0.0	0.0	26.7	256.4	53.7	83.8	184.7	0.0	0.0
1985	56.2	0.0	0.0	0.0	2.0	123.5	134.4	198.7	48.4	145.8	0.0	93.5
1986	22.4	11.1	0.0	39.3	0.0	77.1	93.1	294.4	41.1	56.5	22.5	13.1
1987	0.0	0.0	29.0	4.8	32.2	56.7	156.8	98.4	62.3	108.6	193.8	53.2
1988	0.0	9.6	1.7	71.2	16.0	138.4	619.4	237.9	173.0	20.8	0.0	34.2
1989	0.0	0.0	81.5	4.2	10.4	141.6	392.6	277.2	214.4	53.2	12.4	0.0
1990	5.0	22.8	121.8	50.6	328.8	N.A	N.A	N.A	N.A	N.A	N.A	N.A

STATION: GUDIVADA

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.0	0.0	0.0	0.0	85.1	188.0	157.0	71.9	58.1	137.7	45.4	2.4
1981	7.5	0.0	39.9	3.4	4.5	149.8	152.1	232.0	61.3	176.6	9.8	0.0
1982	0.0	0.0	0.0	65.3	26.7	73.6	168.3	126.9	58.3	208.8	47.3	0.0
1983	0.0	8.9	2.4	0.0	10.6	192.5	209.8	197.6	311.5	108.7	9.4	9.8
1984	0.0	0.6	0.0	8.2	4.2	33.9	294.7	118.2	307.4	172.9	29.7	1.0
1985	47.5	0.0	0.0	0.0	4.2	108.8	119.7	267.3	65.6	106.8	46.6	107.8
1986	32.8	31.2	0.0	60.0	90.2	110.6	116.0	367.0	47.2	24.4	156.7	0.0
1987	5.2	0.0	20.8	17.8	0.0	25.4	95.6	270.4	65.6	323.4	330.2	26.0
1988	0.0	0.0	0.0	16.6	46.4	122.4	484.2	211.2	279.6	20.8	0.0	45.8
1989	0.0	0.0	41.2	0.0	76.0	159.3	313.0	263.7	236.4	61.5	20.6	0.0
1990	0.0	74.0	54.8	6.6	399.6	N.A	N.A	N.A	N.A	N.A	N.A	N.A

STATION:VEERANKI LOCK

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.0	0.0	0.0	0.0	9.3	155.1	221.6	108.6	40.1	150.0	70.2	1.2
1981	0.0	0.0	1.8	0.0	48.8	112.4	177.4	170.6	176.6	133.4	55.6	0.0
1982	0.0	0.0	0.0	1.9	3.5	82.5	104.5	148.5	185.4	174.3	101.5	0.0
1983	0.0	0.0	0.0	0.0	9.0	76.8	172.0	146.2	332.6	97.2	11.7	5.2
1984	0.0	7.2	0.0	0.0	0.0	0.0	135.8	111.6	31.6	145.8	101.4	0.0
1985	18.9	0.0	0.0	0.0	0.0	60.8	90.0	170.2	89.9	146.6	46.3	79.4
1986	18.1	7.8	0.0	5.3	14.8	108.0	82.5	227.1	15.3	18.3	77.7	5.3
1987	0.0	0.0	26.0	0.0	10.6	28.8	0.0	55.0	50.6	136.1	212.6	50.7
1988	0.0	0.0	0.0	17.8	0.0	326.8	311.4	294.3	45.0	0.0	0.0	39.0
1989	0.0	0.0	26.5	0.0	0.0	44.4	465.5	248.7	193.5	49.8	37.2	0.0
1990	0.0	30.0	78.8	N.A	N.A	127.5	154.4	207.7	191.6	264.9	0.0	6.0

STATION:KANKIPADU LOCK

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.0	0.0	0.0	0.0	10.7	183.2	224.8	137.8	79.3	106.2	28.6	0.0
1981	0.0	0.0	21.0	0.0	14.7	116.5	149.8	79.8	37.7	61.4	3.4	0.0
1982	0.0	0.0	0.0	3.0	0.0	102.0	192.3	148.9	162.7	124.6	56.2	0.0
1983	0.0	2.4	0.0	0.0	7.0	52.9	260.9	170.2	227.1	102.4	4.8	4.8
1984	0.0	6.1	3.2	0.0	0.0	0.0	124.2	52.8	176.2	118.8	19.2	0.0
1985	57.0	0.0	0.0	0.0	0.0	104.4	108.6	270.8	74.5	161.5	49.3	104.0
1986	32.0	14.6	0.0	11.6	7.2	92.0	96.0	292.2	48.6	49.6	77.0	1.6
1987	0.0	0.0	133.0	0.0	0.0	12.8	0.0	76.8	17.6	69.5	144.2	52.5
1988	0.0	0.0	0.0	9.6	N.A	497.0	460.8	270.2	23.2	0.0	0.0	46.4
1989	0.0	0.0	22.4	0.0	20.8	135.2	365.4	303.0	200.6	72.0	17.6	0.0
1990	0.0	21.4	74.4	N.A	N.A	171.2	152.8	177.1	227.0	317.8	45.0	0.0

NORMAL ANNUAL RAINFALL FOR RAINGUAGE STATIONS IN & AROUND THE STUDY AREA (mm)

S.No	Name of Rainguage Station	Normal Rainfall (mm)
1.	Tiruvuru	1067.3
2.	Vijayawada	959.4
3.	Gannavaram	935.8
4.	Nuzvid	1005.9
5.	Jaggaiahpeta	796.8
6.	Bandar Town	1067.3
7.	Gudivada	970.6
8.	Kaikaluru	943.1
9.	Nandigama	826.4

SOURCE: CHIEF PLANNING OFFICE, MACHLIPATNAM, KRISHNA DISTT.

ANNEXURE-III

MONTHLY DISCHARGES OF CANALS IN THE STUDY AREA
(CUMEC-DAY)

YEAR: 1985

S.NO.	CHANNEL	JANUARY Q	D	FEBRUARY Q	D	MARCH Q	D	APRIL Q	D	MAY Q	D	JUNE Q	D	JULY Q	D	AUGUST Q	D	SEPTEMBER Q	D	OCTOBER Q	D	NOVEMBER Q	D	DECEMBER Q	D
01	INFLOW TO RIVER	7644.19	31	8861 25	28	12456.1	31	5496.54	15	CLOSED		3804.85	16	15452.95	31	31767.55	31	22799.83	30	19295.95	31	9091.13	30	3915.99	31
02	K.E.B. CANNEL	155.87	31	239.96	28	325.78	31	194.59	15	CLOSED		304.11	15	1300.62	31	1237.87	31	1388.69	30	1027.18	31	936.42	30	176.28	31
03	RYVES CANAL	1470.18	31	1845.86	28	15454.72	31	529.28	15	CLOSED		674.52	15	2977.58	31	2185.15	31	2702.49	30	1552.61	31	1301.50	30	1148.75	31
04	BANDAR DIRECT	831.24	31	865.08	28	1026.02	31	527.98	15	CLOSED		509.84	15	2105.24	31	1511.14	31	2080.56	30	1085.15	31	669.69	30	415.84	31
04-A	KANKIPADU LOCK	287.53	31	279.99	28	391.27	31	386.65	23	CLOSED		176.39	25	729.39	26	899.21	31	1078.71	30	732.57	31	525.93	30	198.55	31
04-B	PULLERU CHANNEL	549.38	31	555.87	28	569.13	31	224.91	18	CLOSED		159.50	17	671.63	26	346.57	31	750.00	30	358.53	31	234.07	30	245.21	31
04-C	VEERANKI LOCK	263.32	31	217.94	28	296.74	31	198.50	18	CLOSED		104.96	12	534.16	30	513.61	31	567.52	30	466.89	30	304.99	30	209.52	31
05	SURPLUS FROM BARRAGE	2794.78	22	4998.24	27	8246.91	31	3275.03	15	CLOSED		1356.29	10	1705.64	08	18713.86	26	7891.16	25	9736.54	15	45.80	08	343.11	02

Q: DISCHARGE N: NO. OF RUNNING DAYS

Contd..

YEAR: 1986

S.NO. CHANNEL	JANUARY Q	D	FEBRUARY Q	D	MARCH Q	D	APRIL Q	D	MAY Q	D	JUNE Q	D
01 INFLOW TO RIVER	3527.81	31	2843.45	4	3223.95	31	CLOSED		CLOSED		CLOSED	
02 K.E.B. CANAL	165.62	31	158.16	28	136.39	31	377.66	17	CLOSED		CLOSED	
03 RYVES CANAL	922.87	31	1217.57	28	1289.98	31	1155.30	17	CLOSED		CLOSED	
04 BANDAR DIRECT	666.81	31	602.64	28	723.16	31	582.43	17	CLOSED		CLOSED	
04-A KANKIPADU LOCK	290.14	31	300.28	28	190.42	24	CLOSED		CLOSED		CLOSED	
04-B PULLERU CHANNEL	296.88	31	243.08	28	134.75	24	CLOSED		CLOSED		CLOSED	
04-C VEERANKI LOCK	332.37	31	260.66	28	298.64	23	CLOSED		CLOSED		CLOSED	
05 SURPLUS FROM BARRAGE	218.82	5	CLOSED		434.10	6	CLOSED		CLOSED		CLOSED	

S.NO. CHANNEL	JULY Q	D	AUGUST Q	D	SEPTEMBER Q	D	OCTOBER Q	D	NOVEMBER Q	D	DECEMBER Q	D
01 INFLOW TO RIVER	13466.38	31	69984.49	31	19170.46	30	14864.94	31	8029.56	30	5928.12	31
02 K.E.B. CANAL	1228.77	31	1224.60	31	1510.77	30	1417.69	31	714.88	30	317.32	31
03 RYVES CANAL	2891.18	31	1351.62	31	3009.86	30	2781.75	31	539.28	22	2046.17	31
04 BANDAR DIRECT	1922.02	31	1404.59	31	2027.58	30	1746.71	31	499.32	30	423.04	31
04-A KANKIPADU LOCK	CLOSED		CLOSED		CLOSED		CLOSED		26.33	5	151.39	31
04-B PULLERU CHANNEL	CLOSED		CLOSED		CLOSED		CLOSED		35.86	5	322.28	31
04-C VEERANKI LOCK	CLOSED		CLOSED		CLOSED		CLOSED		5.95	5	191.98	31
05 SURPLUS FROM BARRAGE	164.39	1	27525.99	22	3472.93	16	1212.44	6	3851.19	12	164.12	3

Q: DISCHARGE N: NO. OF RUNNING DAYS

Contd..

YEAR: 1987

S.NO. CHANNEL	JANUARY Q	D	FEBRUARY Q	D	MARCH Q	D	APRIL Q	D	MAY Q	D	JUNE Q	D	JULY Q	D	AUGUST Q	D	SEPTEMBER Q	D	OCTOBER Q	D	NOVEMBER Q	D	DECEMBER Q	D
INFLOW TO RIVER	6449.88	31	5043.08	28	7576.19	31	1456.41	17	CLOSED		2592.66	20	18016.81	31	13998.78	31	10734.13	31	10502.66	31	10923.67	30	4019.13	31
02. K.E.B. CANAL	489.96	31	468.85	28	480.07	31	246.54	17	CLOSED		157.34	12	1312.41	31	1222.34	31	1026.61	30	856.09	31	446.00	30	366.41	31
03. RYVES CANAL	1941.75	31	2109.96	28	1354.54	31	365.76	17	CLOSED		986.62	17	2930.66	31	2088.09	31	2073.10	30	1526.79	31	147.34	6	1028.79	31
04. BANDAR DIRECT	743.76	31	791.69	28	948.10	31	225.88	17	CLOSED		555.84	20	2115.53	31	1298.36	31	1057.77	30	764.31	31	353.49	30	413.60	31
04-A. KANKIPADU LOCK	247.42	31	208.82	28	285.18	31	67.46	17	CLOSED		300.94	19	262.33	7	843.37	28	850.20	30	709.66	31	354.59	30	CLOSED	
04-B. PULLERU CHANNEL	376.19	31	546.12	28	460.49	31	100.68	17	CLOSED		287.70	19	194.55	7	564.29	26	532.96	30	323.02	31	221.00	30	CLOSED	
04-C. VEERANKI LOCK	244.02	31	68.76	6	CLOSED		18.28	5	CLOSED		160.99	19	173.72	7	341.38	24	326.98	26	305.16	28	120.52	30	CLOSED	
05. SURPLUS FROM BARRAGE	637.05	7	842.54	9	3517.66	23	61.65	1	CLOSED		CLOSED		4189.34	5	1397.39	6	102.75	1	2075.54	7	13679.76	21	308.25	4

Q: DISCHARGE   N: NO. OF RUNNING DAYS

Contd..

YEAR: 1988

S.NO.	CHANNEL	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
		Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D
01.	INFLOW TO RIVER	6932.82	31	4692.43	28	11249.43	31	8581.38	30	CLOSED		6815.36	30	30730.80	31	103712.7	31	216271.1	30	79321.57	31	11779.79	30	5986.73	31
02.	K.E.B. CANAL	794.84	31	777.75	28	948.55	31	172.25	30	CLOSED		255.16	20	1108.73	31	1075.99	[illegible]	939.63	30	1472.73	31	1073.90	30	390.31	31
03.	RYVES CANAL	1335.83	31	1276.50	28	[illegible]	31	444.59	23	CLOSED		705.69	20	1154.02	17	577.78	20	1081.55	24	2395.83	31	1357.11	30	1377.83	31
04.	BANDAR DIRECT	1038.63	31	1104.25	28	1278.63	31	754.34	30	CLOSED		530.84	20	1129.71	31	956.32	31	749.38	30	1836.20	31	997.95	30	608.25	31
04-A.	KANKIPADU LOCK	110.60	9	340.84	28	429.28	31	178.97	24	CLOSED		208.70	19	606.18	31	597.70	31	CLOSED		CLOSED		CLOSED		CLOSED	
04-B.	PULLERU CHANNEL	175.94	9	771.68	28	855.22	31	471.09	30	14.54	5	203.54	19	491.55	31	436.519	31	CLOSED		CLOSED		CLOSED		CLOSED	
04-C.	VEERANKI LOCK	196.97	9	291.84	28	334.81	31	50.17	9	CLOSED		46.23	5	278.26	31	441.16	31	CLOSED		CLOSED		CLOSED		CLOSED	
05.	SURPLUS FROM BARRAGE	CLOSED		CLOSED		6945.86	24	5363.52	22	CLOSED		3144.13	14	20400.37	15	86322.08	29	207791.1	30	63354.03	27	3211.88	18	1191.89	11

Q: DISCHARGE N: NO. OF RUNNING DAYS

Contd..

YEAR: 1989

S.NO.	CHANNEL	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
		Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D
01.	INFLOW TO RIVER	6086.08	31	6492.34	28	13315.96	31	12104.85	30	4175.19	31	5528.46	30	52749.52	31	43819.05	31	74118.42	30	75701.16	31	11970.35	30	11325.06	31
02.	K.E.B. CANAL	753.54	31	789.00	28	94[illegible].21	31	263.55	12	CLOSED		255.24	14	865.14	26	1325.57	31	1273.10	30	1376.89	31	1030.61	30	558.70	31
03.	RYVES CANAL	1384.47	31	1676.39	28	1099.55	31	82.43	5	CLOSED		1066.44	23	1542.60	22	1064.48	22	1439.54	30	2002.27	31	1220.46	30	1664.47	31
04.	BANDAR DIRECT	1004.45	31	976.39	28	1361.99	31	149.06	12	CLOSED		231.58	14	1318.90	26	1531.2[illegible]	31	1483.22	30	1765.87	31	1207.91	30	796.15	31
04-A.	KANKIPADU LOCK	305.84	22	371.94	28	587.05	31	121.23	10	CLOSED		96.97	7	792.99	31	964.60	31	971.51	30	1064.97	31	627.55	30	371.32	31
04-B.	PULLERU CHANNEL	491.58	22	546.15	28	664.09	31	54.45	10	CLOSED		76.16	7	685.52	31	782.96	31	732.79	30	816.72	31	498.87	30	716.18	31
04-C.	VEERANKI LOCK	270.63	22	119.05	10	371.98	31	CLOSED		CLOSED		27.24	2	431.75	31	490.05	31	481.06	30	503.94	31	410.26	30	44.02	6
05.	SURPLUS FROM BARRAGE	924.74	12	780.89	10	7213.01	31	10994.19	30	3765.18	24	3311.90	17	47006.52	16	16972.08	31	62679.71	30	10646.25	31	3678.43	20	5507.31	26

Q: DISCHARGE N: NO. OF RUNNING DAYS

Contd..

YEAR: 1990

S.NO.	CHANNEL	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
		Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D
01.	INFLOW TO RIVER	8695.00	31	9216.00	28	9749.00	31	7193.00	30	15380.2	31	9968.30	30	16066.64	31	149979.7	31	71915.40	30	62588.30	31	20745.01	30	12618.57	31
02.	K.E.B. CANAL	816.00	30	713.00	28	886.00	31	228.00	15	CLOSED		365.65	30	1066.18	31	1213.77	31	1324.29	30	1151.59	31	961.65	30	352.32	31
03.	RYVES CANAL	1629.00	31	1466.00	28	1062.00	31	426.00	15	CLOSED		679.34	30	2175.30	31	2113.21	31	2166.27	30	1480.61	31	1053.40	30	1117.73	31
04.	BANDAR DIRECT	984.00	31	750.00	28	974.00	31	204.00	15	CLOSED		483.90	30	1627.27	31	1725.65	31	1775.09	30	1091.38	31	87788.44	30	615.82	31
04-A.	KANKIPADU LOCK	444.73	31	335.40	28	539.73	31	104.48	15	40.28	15	203.66	30	900.09	31	977.91	31	1079.70	30	698.24	31	918.48	30	334.07	31
04-B.	PULLERU CHANNEL	841.18	31	781.21	28	810.77	31	68.62	15	5.39	4	247.42	30	720.58	31	722.05	31	330.13	30	675.91	31	595.46	30	530.89	31
04-C.	VEERANKI LOCK	361.05	31	185.54	28	350.71	31	CLOSED		10.15	2	60.86	20	454.79	31	527.66	31	236.25	30	423.87	31	525.37	30	191.81	31
05.	SURPLUS FROM BARRAGE	3082.00	25	4089.00	26	4829.00	28	6391.00	30	15960.1	29	7808.96	22	5625.28	21	137652.5	31	59392.70	30	65814.90	31	12238.50	25	7932.26	31

Q: DISCHARGE N: NO. OF RUNNING DAYS

SOURCE: A.P STATE IRRIGATION DEPARTMENT, VIJAYAWADA

ANNEXURE-IV

REDUCED GROUND WATER LEVELS (Mts.) OF OBSERVATION WELLS IN & AROUND THE STUDY AREA

VUYYURU (R.L OF GROUND 11.615 M)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	11.050	N.A	N.A	N.A	N.A	9.755	11.085	11.055	N.A	N.A	N.A	N.A
1981	N.A	9.935	9.975	10.905	10.225	8.975	11.205	11.195	11.325	11.375	11.505	11.175
1982	10.935	10.685	10.635	10.905	11.125	11.275	11.395	10.825	11.495	11.605	11.565	11.275
1983	11.215	11.235	11.145	11.095	11.005	10.905	11.095	11.335	11.435	11.455	11.535	11.435
1984	11.375	11.315	11.285	11.095	10.765	10.515	10.935	11.135	N.A	11.055	11.105	11.135
1985	11.085	10.955	N.A	N.A	N.A	10.865	11.185	11.335	11.375	11.385	11.585	11.285
1986	11.285	11.255	11.195	11.015	10.775	10.685	11.275	11.315	11.435	11.395	11.345	N.A
1987	11.295	11.325	11.235	11.155	10.835	9.645	11.055	11.095	11.135	11.085	11.835	11.135
1988	11.185	11.215	11.225	11.155	N.A	9.765	11.015	11.495	11.775	11.405	11.215	10.655
1989	11.045	11.115	11.025	11.045	9.625	8.975	10.635	11.575	11.455	11.535	11.265	11.265
1990	11.185	11.185	11.175	11.025	10.845	N.A	11.445	11.535	11.445	11.495	11.495	11.435

GANNAVARAM (REDUCED LEVEL OF GROUND 21.705 MTS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1982	N.A	N.A	N.A	N.A	N.A	N.A	6.105	5.505	6.485	9.105	11.955	12.045
1983	11.405	10.705	7.005	6.305	5.055	4.055	5.055	9.305	12.345	12.005	20.105	18.905
1984	18.506	17.505	14.305	12.205	9.005	7.205	N.A	11.405	9.205	11.805	13.305	9.405
1985	12.105	N.A	10.405	8.905	7.105	6.405	9.305	12.005	10.805	N.A	11.105	10.305
1986	11.105	7.405	9.405	8.405	7.805	6.505	8.105	7.905	6.905	6.105	9.305	7.305
1987	7.405	12.405	6.405	6.905	5.405	8.905	8.405	8.105	7.905	7.105	12.105	7.105
1988	7.325	7.305	7.105	6.405	7.105	7.405	9.405	14.505	18.905	19.005	18.405	15.405
1989	15.405	13.205	N.A	9.405	9.405	5.305	12.305	19.405	19.405	19.305	17.305	17.405
1990	15.705	14.405	N.A	13.405	17.405	16.105	15.405	16.405	17.405	16.105	15.405	17.405

VIJAYAWADA (R.L OF GROUND 20.825 MTS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	11.725	11.575	11.425	12.425	12.025	11.775	11.825	15.675	15.225	12.025	12.025	11.825
1981	11.475	11.375	11.325	11.325	11.375	11.475	11.675	15.225	14.425	15.325	12.725	12.075
1982	11.725	11.755	11.725	11.825	11.825	11.725	11.625	11.725	16.725	11.575	11.425	10.875
1983	10.875	11.625	N.A	11.725	11.775	11.725	11.275	12.375	12.775	17.175	13.175	12.175
1984	11.825	12.125	11.775	12.125	11.925	11.875	11.525	12.025	12.175	11.925	12.025	12.125
1985	12.125	12.025	12.225	12.225	12.125	N.A	N.A	N.A	12.525	12.225	12.425	11.725
1986	11.765	11.545	11.325	11.625	12.045	12.045	11.925	11.825	12.125	12.475	12.025	N.A
1987	11.685	11.795	12.475	11.745	11.375	11.145	11.185	11.765	11.665	11.395	12.215	11.745
1988	11.505	11.535	11.545	12.305	12.075	12.275	11.505	13.555	16.925	16.275	12.245	12.045
1989	11.825	11.925	11.845	12.305	12.205	11.985	11.685	12.965	13.295	17.125	12.305	12.345
1990	12.045	12.045	12.045	12.095	12.175	11.895	12.275	12.235	13.835	15.685	12.975	12.305

Contd..

GUDIVADA (R.L OF GROUND 6.765 MTS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	6.015	5.605	N.A	N.A	N.A	N.A	N.A	N.A	N.A	6.185	6.125	N.A
1981	6.135	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	6.125
1982	5.615	5.325	5.005	4.635	N.A	4.455	5.805	6.085	6.135	6.545	6.205	N.A
1983	5.695	5.405	5.285	5.045	4.775	4.545	5.325	6.805	7.005	7.105	6.815	6.085
1984	5.845	5.585	5.305	5.085	4.765	4.405	4.455	6.005	N.A	6.465	6.545	6.185
1985	6.355	5.655	5.305	5.085	4.785	4.405	4.575	5.955	6.705	6.405	5.635	6.055
1986	6.325	5.875	5.505	5.115	5.005	5.645	5.045	5.905	6.275	6.005	N.A	N.A
1987	5.655	5.355	4.905	4.785	4.615	4.225	4.205	4.955	5.905	5.845	6.395	N.A
1988	5.385	5.245	5.005	4.675	4.865	4.305	6.305	6.585	6.735	6.765	6.025	N.A
1989	5.735	5.505	N.A	5.215	N.A	4.865	N.A	N.A	6.465	N.A	6.545	5.945
1990	5.635	N.A	N.A	4.825	6.205	N.A	N.A	6.625	6.695	N.A	N.A	6.615

CHALLAPALLI (R.L OF GROUND 4.535 MTS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	3.035	2.235	1.935	2.035	1.735	1.735	2.935	3.635	3.635	3.335	3.535	3.335
1981	3.085	2.585	2.185	2.035	1.785	1.585	2.235	3.335	3.835	3.435	3.835	3.635
1982	3.235	2.635	2.135	1.785	1.685	1.485	1.845	1.735	3.535	3.135	3.235	2.535
1983	2.585	1.935	1.635	1.735	2.235	2.135	2.335	3.235	3.635	3.635	3.585	3.535
1984	3.135	2.685	2.835	2.235	2.035	N.A	N.A	N.A	N.A	N.A	2.295	N.A
1985	N.A	N.A	N.A	N.A	N.A	N.A	2.585	3.335	3.835	4.235	4.005	3.435
1986	3.455	3.335	3.135	2.795	2.745	2.715	2.755	3.235	3.435	3.235	N.A	3.125
1987	2.635	2.715	3.195	3.135	2.585	1.985	3.985	3.955	3.885	3.635	3.735	3.335
1988	3.935	3.435	N.A	3.285	N.A	2.535	2.535	3.985	3.965	4.115	3.735	3.485
1989	3.435	3.235	3.235	3.985	3.515	3.335	3.985	4.035	3.785	4.085	3.785	3.715
1990	3.585	3.785	3.735	4.085	3.785	3.985	3.965	3.685	3.735	3.935	3.785	3.785

GUDLAVALERU (R.L OF GROUND 5.26)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	N.A	N.A	N.A	N.A	N.A	3.460	4.720	5.320	4.860	4.810	4.490	4.910
1981	4.510	4.360	4.310	3.930	3.710	2.840	5.160	5.460	5.210	5.060	5.360	4.960
1982	N.A	N.A	N.A	N.A	N.A	N.A	N.A	5.260	N.A	N.A	N.A	5.150
1983	4.960	4.960	4.710	4.460	4.170	3.900	4.710	5.510	5.560	5.560	5.410	5.170
1984	5.150	5.060	4.960	4.760	4.360	4.310	4.310	5.560	5.060	5.460	5.460	5.130
1985	5.260	5.060	5.010	4.810	4.350	2.280	4.260	5.360	6.560	5.560	5.070	5.150
1986	5.340	5.170	5.120	4.800	3.970	5.310	5.210	5.380	5.260	5.030	5.460	N.A
1987	N.A	4.710	4.660	4.360	3.960	1.410	3.160	4.760	N.A	N.A	N.A	4.860
1988	N.A	N.A	N.A	4.760	4.360	3.960	4.860	5.560	5.060	5.460	5.360	N.A
1989	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
1990	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	5.360	N.A	6.360	5.460

CHEMICAL WATER QUALITY OF OPEN WELLS IN AND AROUND THE STUDY AREA

LEGEND:-

1	: Aquifer Depth Tapped (m)	10	: Na (ppm)
2	: PH at 28^0C	11	: K (ppm)
3	: Sp.c at 25^0c microseimans/cms	12	: Ca (ppm)
4	: TDS (ppm)	13	: Mg (ppm)
5	: CO_2(ppm)	14	: Total Hardness ($CaCO_3$)
6	: HCO_3 (ppm)	15	: Geology
7	: Cl_2 (ppm)	16	: SAR
8	: F (ppm)	17	: % of Na
9	: No_2 (ppm)	18	: RSC

1. VUYYURU

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
MAY-82	1.86	8.28	1177	753	--	338	114	--	--	155	35	32	49	280	ALLUVIUM	4.02	--	1.13
NOV-82	1.80	8.18	1240	794	--	299	120	--	--	144	50	48	29	240	--DO--	4.05	--	1.20
MAY-83	2.16	8.48	1127	721	38	259	110	--	--	146	40	24	29	180	--DO--	4.75	--	2.36
NOV-83	2.10	8.65	1843	1180	118	304	165	--	--	238	45	56	49	340	--DO--	5.80	--	1.61
MAY-84	3.85	8.54	1208	773	50	355	112	--	--	145	14	32	41	250	--DO--	4.00	--	3.13
NOV-84	3.28	7.69	2000	1280	--	550	230	--	--	250	88	72	58	420	--DO--	5.31	--	2.63
MAY-85	2.86	8.20	1208	773	--	276	247	--	--	158	22	16	53	260	--DO--	4.28	--	0.36
NOV-85	2.10	8.32	2300	1472	110	469	350	--	--	221	78	104	66	530	--DO--	4.17	--	0.95
MAY-86	3.90	7.32	5350	3424	--	602	1284	--	--	663	178	160	165	1080	--DO--	8.78	--	-9.53
NOV-86	6.70	7.33	2605	1667	--	446	415	--	--	292	111	64	78	480	--DO--	5.79	--	-0.69
MAY-87	3.20	7.30	2140	1370	--	326	470	0.1	--	246	350	16	58	280	--DO--	22.93	--	4.63
NOV-87	1.58	7.46	1385	886	--	196	312	0.2	--	206	38	32	53	300	--DO--	5.19	--	2.04
MAY-88	3.15	7.60	3960	2534	--	493	410	0.1	--	640	102	73	88	540	--DO--	11.95	--	-0.98
NOV-88	1.82	7.56	3360	2150	--	678	660	0.1	--	436	79	112	88	640	--DO--	7.48	--	0.72
MAY-89	4.35	7.92	3280	2099	--	285	749	0.2	--	410	21	56	112	600	--DO--	7.28	--	-6.31
NOV-89	1.15	7.60	4350	2784	--	787	959	0.1	--	667	77	128	92	700	--DO--	10.97	--	0.77

Contd..

MAY-90	0.69	8.13	2000	1280	--	252	324	0.1	--	300	50	72	19	260	--DO--	8.12	--	-0.12
NOV-90	1.00	8.01	3500	2240	--	627	490	0.1	--	581	69	64	58	400	--DO--	12.65	--	4.57
GANNAVARAM																		
MAY-82	17.58	7.79	1611	1031	--	150	288	--	--	188	7	48	68	400	RAJAHMU-NDRY SAND-STONE	4.09	--	-4.99
NOV-82	11.34	8.16	1650	1056	--	100	239	--	--	181	11	56	68	420	--DO--	3.84	--	-6.30
MAY-83	18.95	7.49	1785	1142	--	192	241	--	--	194	11	40	76	420	--DO--	4.11	--	-4.57
NOV-83	1.70	7.84	2680	1722	--	167	563	--	--	271	9	138	97	740	--DO--	4.33	--	-11.44
MAY-84	15.02	7.70	1657	1060	--	200	392	--	--	196	10	64	53	380	--DO--	4.38	--	-3.56
NOV-84	10.73	7.59	2000	1280	--	90	432	--	--	235	8	64	83	500	--DO--	4.56	--	-8.23
MAY-85	16.75	7.48	2180	1395	--	238	494	--	--	238	8	112	92	660	--DO--	4.03	--	-8.41
NOV-85	12.64	7.49	2350	1504	--	175	500	--	--	219	8	104	102	680	--DO--	3.65	--	-10.09
MAY-86	17.35	7.42	2140	1370	--	359	381	--	--	214	10	124	66	580	--DO--	3.86	--	-4.45
NOV-86	22.20	7.07	1930	1235	--	148	394	--	--	200	8	72	83	520	--DO--	3.81	--	-7.41
MAY-87	9.44	8.20	1488	952	--	114	350	0.9	--	171	8	136	19	420	--DO--	3.63	--	-6.08
NOV-87	13.76	7.39	1786	1143	--	265	364	1.0	--	207	7	80	68	500	--DO--	4.03	--	-4.69
MAY-88	17.40	8.00	1582	1012	--	149	300	0.4	--	180	6	40	63	360	--DO--	4.13	--	-4.20
NOV-88	4.58	7.83	2900	1856	--	282	720	0.4	--	368	9	136	68	620	--DO--	6.43	--	-6.75
MAY-89	16.23	7.89	1980	1267	--	378	298	1.0	--	176	8	144	68	640	--DO--	3.03	--	-5.23
NOV-89	2.84	7.66	4750	3040	--	273	1015	0.8	--	625	9	320	63	1080	--DO--	8.27	--	-16.13
MAY-90	5.69	7.82	2520	1613	--	273	498	0.5	--	307	9	120	68	580	--DO--	5.55	--	-6.13
NOV-90	3.59	7.62	2800	1792	--	76	554	0.5	--	354	8	120	68	580	--DO--	6.39	--	-10.07
VIJAYAWADA																		
MAY-82	10.20	8.14	1138	728	--	188	150	--	--	134	7	24	53	280	ALLUVIUM	3.50	--	-1.80
NOV-82	9.68	8.30	735	470	50	149	74	--	--	62	6	32	34	220	--DO--	1.82	--	-0.42
MAY-83	10.30	7.71	1208	773	--	365	117	--	--	120	12	56	44	320	--DO--	2.91	--	0.88
NOV-83	9.75	8.24	950	808	--	274	114	--	--	101	7	56	24	240	--DO--	2.84	--	0.71

Contd..

MAY-88	3.70	7.45	5080	3251	--	539	560	0.5	--	929	30	128	92	700	--DO--	15.28	--	-3.19
NOV-88	2.12	7.41	6160	3942	--	361	1280	0.1	--	857	13	216	122	1040	--DO--	11.55	--	-13.61
MAY-89	3.32	8.30	3340	2138	75	248	480	0.5	--	600	160	64	44	340	--DO--	14.13	--	-0.36
NOV-89	3.42	7.80	2800	1792	--	464	150	0.5	--	486	12	72	49	380	--DO--	10.82	--	1.65
MAY-90	1.27	8.52	2890	1850	63	294	350	0.5	--	538	10	56	53	360	--DO--	12.36	--	-0.02
NOV-90	2.88	8.11	3600	2304	--	285	450	0.5	--	696	16	40	58	340	--DO--	16.45	--	-1.07
TELAPROLU																		
MAY-82	2.93	8.24	913	584	--	179	88	--	--	131	5	16	34	180	ALLUVIUM	4.25	--	-0.02
NOV-82	1.38	7.93	7670	4909	60	220	1490	------------------- HIGHLY SALINE ------------------------										
MAY-83	3.00	7.73	4920	3149	--	202	307	--	--	600	240	56	165	820	--DO--	9.12	--	0.05
NOV-83	1.45	7.61	7981	5108	--	314	933	------------------- HIGHLY SALINE ------------------------										
MAY-84	3.70	8.37	5200	3328	40	150	1150	--	--	621	277	48	175	840	--DO--	9.32	--	-12.99
NOV-84	1.57	7.66	7820	5005	--	150	1927	--	--	1000	514	64	233	1120	--DO--	13.00	--	-19.36
MAY-85	3.50	7.80	4560	2198	--	171	1330	--	--	588	289	64	165	180	--DO--	0.88	--	-0.71
NOV-85	1.65	7.46	6590	4218	--	386	1700	--	--	717	356	160	224	1320	--DO--	8.58	--	-18.70
MAY-86	3.63	7.67	5080	3251	--	252	1340	--	--	575	289	96	170	940	--DO--	8.16	--	-13.74
NOV-86	4.85	7.11	7150	4576	--	230	1910	--	--	846	425	104	229	1200	--DO--	10.61	--	-19.43
MAY-87	3.55	8.20	4850	3104	--	132	1460	0.5	--	700	231	72	146	780	--DO--	10.89	--	-12.97
NOV-87	0.75	7.68	9970	6381	--	480	3015	0.1	--	1231	625	256	282	1800	--DO--	12.62	--	-26.39
MAY-88	2.70	7.60	6380	4083	--	326	1440	0.2	--	829	371	104	204	1100	--DO--	10.87	--	-15.46
NOV-88	1.16	8.13	6380	4083	--	590	1460	0.1	--	857	371	144	126	880	--DO--	12.57	--	-5.76
MAY-89	2.72	7.50	6450	4128	--	480	1536	0.1	--	724	300	192	204	1320	--DO--	8.67	--	-16.78
NOV-89	0.62	7.94	6600	4224	--	619	1354	0.1	--	919	375	96	165	920	--DO--	13.19	--	-5.99
MAY-90	1.12	8.13	6120	3917	--	515	1484	0.1	--	842	500	112	117	760	--DO--	13.27	--	-4.92
NOV-90	0.48	8.42	6280	4019	76	380	1156	0.1	--	883	375	104	117	740	--DO--	14.10	--	-5.70
MUNNA																		
MAY-82	4.10	8.55	2780	1779	60	430	369	--	--	176	500	16	73	340	KHONDAL-	4.15	--	3.00

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MAY-84	9.95	8.80	1238	792	60	250	190	--	--	166	27	8	58	260	--DO--	4.49	--	1.03
NOV-84	9.58	8.31	972	622	80	160	134	--	--	117	12	24	39	220	--DO--	3.43	--	0.39
MAY-85	10.10	8.15	1167	747	--	342	200	--	--	139	36	48	44	300	--DO--	3.48	--	0.82
NOV-85	10.30	8.36	1064	681	37	239	150	--	--	105	23	32	44	260	--DO--	2.83	--	0.30
MAY-86	10.10	7.30	1633	1045	--	601	149	--	--	167	40	120	46	490	--DO--	3.28	--	2.24
NOV-86	11.92	7.20	1346	861	--	405	154	--	--	132	35	64	63	420	--DO--	2.80	--	-0.37
MAY-87	10.95	7.20	1490	954	--	396	190	0.2	--	146	56	56	58	380	--DO--	3.26	--	0.35
NOV-87	10.32	7.59	1259	806	--	343	146	0.1	--	133	12	64	49	360	--DO--	3.04	--	-0.37
MAY-88	10.06	7.90	1803	1154	--	539	170	0.2	--	187	30	104	68	540	--DO--	3.50	--	-0.01
NOV-88	9.56	7.34	1173	751	--	396	120	0.2	--	92	10	48	68	400	--DO--	2.00	--	-0.07
MAY-89	11.15	8.37	425	272	15	113	48	0.4	--	39	3	40	5	120	--DO--	1.55	--	0.15
NOV-89	9.05	7.61	1292	827	--	437	132	0.5	--	136	12	80	49	400	--DO--	2.95	--	0.71
MAY-90	9.35	7.99	1425	912	--	410	138	0.1	--	127	10	88	58	460	--DO--	2.58	--	-0.97
NOV-90	9.20	7.88	1380	883	--	390	108	0.1	--	130	10	80	58	440	--DO--	2.70	--	-0.97
GUDIVADA																		
MAY-82	3.50	7.50	4475	2864	--	357	739	--	--	762	19	144	88	720	ALLUVIUM	12.33	--	-7.30
NOV-82	1.75	8.49	2710	1734	--	166	331	--	--	444	50	32	53	300	--DO--	11.18	--	-2.00
MAY-83	3.37	7.88	3830	2451	--	394	585	--	--	524	400	48	73	420	--DO--	11.12	--	-0.52
NOV-83	1.85	8.30	2930	1875	59	314	427	--	--	500	20	72	63	440	--DO--	10.38	--	-1.32
MAY-84	3.66	8.45	2610	1670	70	250	448	--	--	437	20	40	78	420	--DO--	9.27	--	-2.01
NOV-84	3.26	7.38	2550	1632	--	170	365	--	--	433	20	32	58	320	--DO--	10.55	--	-2.97
MAY-85	3.33	8.22	2150	1376	--	323	304	--	--	413	18	16	49	240	--DO--	11.56	--	1.63
NOV-85	2.00	8.25	2240	1434	--	276	240	--	--	353	12	16	63	300	--DO--	8.88	--	-0.46
MAY-86	3.01	7.42	1885	1206	--	310	242	--	--	312	16	32	39	240	--DO--	8.75	--	1.39
NOV-86	4.72	N A	1574	1007	--	230	192	--	--	264	10	40	44	280	--DO--	6.85	--	-1.02
MAY-87	3.78	7.02	2500	1600	--	299	370	0.9	--	426	21	32	53	300	--DO--	10.73	--	0.02
NOV-87	1.71	8.11	2580	1651	--	353	333	0.4	--	444	12	72	49	380	--DO--	9.88	--	-0.57

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NOV-82	2.37	8.09	3300	2112	--	548	377	--	--	234	666	16	58	280	--DO--	6.09	--	5.30
MAY-83	4.38	8.01	2900	1856	--	518	311	--	--	185	596	20	56	280	--DO--	4.80	--	4.75
NOV-83	1.75	8.33	3985	2550	118	500	598	--	--	337	732	40	49	300	--DO--	8.44	--	6.35
MAY-84	3.29	8.01	3050	1952	--	570	428	--	--	193	533	24	78	380	--DO--	4.30	--	3.79
NOV-84	2.25	8.52	3340	2138	60	500	490	--	--	316	660	8	49	220	--DO--	9.23	--	6.77
MAY-85	3.75	8.42	2670	1709	38	541	418	--	--	181	588	16	53	260	--DO--	4.90	--	6.42
NOV-85	2.28	8.55	3280	2099	110	460	490	--	--	286	600	24	73	360	--DO--	6.55	--	4.20
MAY-86	4.35	7.70	3000	1920	--	524	358	--	--	167	584	24	58	300	--DO--	4.20	--	4.51
NOV-86	7.55	7.13	2880	1843	--	540	364	--	--	246	471	24	53	280	--DO--	6.42	--	5.24
MAY-87	5.25	7.40	2470	1581	--	450	380	0.5	--	192	475	16	34	180	--DO--	6.22	--	5.56
NOV-87	3.95	7.99	2890	1850	--	637	354	0.4	--	186	500	40	97	500	--DO--	3.62	--	2.76
MAY-88	4.71	7.81	2680	1715	--	558	320	0.4	--	173	486	48	58	360	--DO--	3.97	--	3.99
NOV-88	2.05	7.63	3750	2400	--	660	480	0.1	--	225	714	88	63	480	--DO--	4.47	--	3.62
MAY-89	4.33	8.50	2790	1786	75	405	384	0.5	--	189	575	24	68	340	--DO--	4.46	--	2.81
NOV-89	1.24	7.90	3690	2362	--	746	235	0.5	--	243	675	80	73	500	--DO--	4.73	--	4.92
MAY-90	1.47	8.57	3420	2189	105	515	403	0.1	--	200	733	80	58	440	--DO--	4.15	--	3.63
NOV-90	2.04	8.39	3800	2432	57	637	549	0.1	--	325	650	64	73	460	--DO--	6.59	--	4.68

SOURCE: STATE GROUNDWATER DEPT., VIJAYAWADA

DR S M SETH	:	DIRECTOR

STUDY GROUP

DR P V SEETHAPATHI	:	SCIENTIST 'F'
SRI Y R SATYAJI RAO	:	SCIENTIST 'B'
SRI T THOMAS	:	S R A