Water Budget Estimation in Water Resources Management in Drought Prone Areas in Rayalaseema Region, South India

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Abstract. Water is a valuable natural resource, fresh water is vital for health and to the economy, and reliable access to it is becoming increasingly important as the India’s population rises. Yet its availability is limited, per capita accessibility of useable water is depleting, but with increasing living standard of people, all around fast industrial development and expansion, necessity of fresh water is raising high continuously. Water audit is a successful tool for minimizing losses, working on different utilizations and in this way empowering water conservation in irrigation, domestic, power and industrial as well. Water audit controls the measure of water lost from a distribution system because of spillage and different reasons like burglary, unapproved withdrawals from the organizations and the cost of such misfortunes to the utility. Water budget is a bookkeeping of all the water that streams into and out of an undertaking region of project area. Water budget gives the financial aspects on the distribution of quantity of water in Rayalaseema region. The study area this paper to calculate the water budget in the study area of 51 Mandal of Rayalaseema region and based on the water quantity analysis to prepare water, soil conservation structures in study area, for effective water management.

Index Terms—Water data, Resources, Drought, South India.

1. Introduction

However fresh water is vital for health and to the economy, and reliable access to it is becoming increasingly important as the India’s population rises. Yet its availability is limited, per capita accessibility of useable water is depleting, but with increasing living standard of people, all around fast industrial development and expansion, necessity of fresh water is raising high endlessly. Majority of the study area mainly depends on groundwater as its primary source of drinking and irrigation water. Several water resource studies concerning to improve the standard of regional water resources in precise, and offer better description of the water cycle, available water level, the flow system and water demand, and factors affecting sustainability. The rain fall is usually measured in inches or mm or centimeters. The rain falls averages based on the daily rain fall measurements. The daily rain fall defined as 24 hour accumulated amount of rain on a day. The rain fall is highly variable from day to day.

Real assessment of excess is the essential and primary information need for the plan of recharge structures of optimal capacity. Unrealistic excess assessments of catchments yield frequently prompts to construction of larger than usual or small structures, which, regardless should be kept away from.
Excess is characterized as the portion of rainfall that advances towards streams or seas as surface or subsurface flow. After the occurrence of access and different losses from the rainfall, the excess precipitation streams out through the little normal channels on the land surface to the seepage channels. Such sorts of stream are called surface flow. A portion of the infiltrated water moves parallel to the land surface as subsurface flow, and returns on a superficial level at certain different points. Such streams are called interflows. One more part of infiltrated water permeates downwards to groundwater and moves along the side to arise in wretchedness and waterways and joins the surface flow.

This sort of flow is known as the subsurface flow or ground water flow. The measurement of the groundwater level in a well is regularly conducted in conjunction with ground water sampling to determine the “free” water surface. This potentiometric surface measurement can be used to establish ground water direction and gradients. Based on groundwater development, the mandals in YSR Kadapa district are divided into four categories: very high groundwater usage with more than 70% draft, high groundwater usage with draft between 50% to 70%, moderate groundwater usage with draft between 30% to 50%, and low groundwater usage with draft less than 30%.

Water data audit is an effective management tool for lessening losses, optimizing various uses and thus enabling water conservation in irrigation, domestic, power and industrial as well. Water review decides the measure of water lost from a distribution system because of spillage and different reasons like burglary, unapproved or unlawful withdrawals from the distribution system and the expense of such misfortunes to the utility. Components of water audit incorporate a record of the measure of water produced, water delivered to metered users, water delivered to unmetered users, water loss and suggested measures to address water loss.

Water budget gives the financial aspects, and an accounting of all the water that flows into and out of a project area in Kadapa district. A water budget is calculated from available data for a specific period of time. Permanent projects may be estimated using daily or monthly data, with the resulting net surplus of deficit is expressed as a seasonal or annual value. In this paper to study the existing water source management projects in Kadapa district and by using rainfall data, catchment area to determine the runoff and to propose which type of structures are required to conserve the water and also to study the cost of each structure and design procedure, and also study the water quality in pre-monsoon period and post monsoon period for applicability of water to the agriculture sector.

**Objectives of the Work**

Following are the specific objectives of the study:
- To calculate the average rainfall
- To estimate the runoff
- To calculate the water budgeting in Kadapa district of different mandals.
- To propose water conservation structures and soil conservation structures
- To study the different techniques in order to improve the water resources.

**2. Study Area**

Total terrestrial area of the district is 15,370 sq.m., with 3 Revenue divisions, 51 mandals, 790 Grama Panchayats, 972 Revenue villages and 4,954 Habitations. The Kadapa district was formed in the year 1808 with its head quarters in Kadapa town. There are 51 mandals in the district. As per 2011 census, the district population is 28,84,524. The district is bounded by Kurnool and Prakasam district in North, Chittoor district in South, Nellore district in East, Ananthapuramu district in West. The district is famous for its huge mineral wealth. Berates, Lead, lime stone, mica, talc sone, uranium, shale asbestos are the main minerals available in the study area.

As per the 2011 census the population of the district is 28,84,524 of which the Rural Population is 19,03,337 and the Urban population is 9,79,132. The density of population in the district is 188 per sq.km., the scheduled caste population is 465794 and scheduled tribe population is 75,886 in the district.

The total terrestrial area of Y.S.R. District is 15,35,900 hectares which has an extent of forest is 5,00,961 hectares. Barren & uncultivable land is 2,22,099 hectares, Land put to Non-agricultural uses is 1,81,090 hectares, cultivable waste is 45,921 hectares, permanent pastures and other grazing lands is
9,409 hectares, land under miscellaneous tree crops & groves not included in net area sown is 6,831 hectares, current fallows is 1,31,767 hectares, other fallow land is 81,815 hectares, total cropped area is 4,25,113 hectares and net area sown is 3,56,007 hectares and area sown more than once is 69,106 hectares during the year 2012-13.

Figure 1: Profile of Kadapa district

The district occupies an area of about 37.95 m acres, in which 1.560 m acres is suitable for cultivation. Irrigation facilities have been created for extent of 5 M acres. Kurnool-Cuddapah canal is the main age old irrigation project in the district. Subsequently many projects like Telugu Ganga, Mylavaram dam, Chitravathi balancing reservoir, Galeru-Nagari Sujala Sraavanthi (GNSS) etc., projects came into existence.

3. Methodology

3.1 Estimation of Average Rainfall Over a Basin
The Number of rain gauge stations located in basin or catchment region registers the mean rainfall. The density of rain gauge relies on the utilizations for which the rainfall information is planned. An organization ought to be so arranged as to have an agent image of the areal dispersion of rainfall. There ought to be no grouping of checks in weighty rainfall regions at the expense of dry regions. In the event that a basin contains more than one rain gauge station, the computation of mean or average rainfall can be done by following techniques: Arithmetic normal strategy, Thiessen polygon technique, Isohyetal technique, Grid point strategy.

3.2 Estimation of Runoff
The rain water should be estimated from the total area and average rainfall. Some amount of total rain water should be loss in percentages of ground water, soil moisture and evapotranspiration. The remaining percentage of water is known as runoff or flood. After falling the rainfall on earth surface some quantity of rain water should be in the form of ground water (9%), soil moisture (10%), Evapotranspiration (41%), and remaining is runoff (40%).

The runoff can be estimated for all mandals in Kadapa district by various methods., Rational method \( Q = CIA \), Dickens formulae \( Q = CA^{3/4} \), Ryve’s formulae \( Q = CA^{2/3} \)

3.3 Measurement of the Ground water levels
Based on groundwater development, the mandals YSR Kadapa district are divided into four categories: very high groundwater usage with more than 70% draft, High groundwater usage with draft between 50% to 70%, Moderate groundwater usage with draft between 30% to 50%, and low groundwater usage with draft less than 30%.

A Piezometre is either a gadget used to gauge liquid pressure factor in a system by estimating the height of which a section of the fluid ascents against gravity, or a gadget which estimates the pressure
factor of groundwater at a particular point. A piezometre is intended to quantify static pressures and consequently contrasts from a pitot tube by not being pointed into the fluid flow stream. Piezometres in durable casings can be covered or driven into the ground to gauge the groundwater pressure at the place of establishment. The pressure gauge can be vibrating-wire, pneumatic, or strain-gauge in operation, changing over pressure into an electrical signals. These piezometres are cabled to the surface where they can be perused by data loggers or portable readout units, permitting quicker or more regular reading than is conceivable with open standpipe piezometres. In Kadapa district is having 101 members of piezometres.

3.4 Water budget of different mandals in Kadapa district

Water budget is an accounting of all the water that flows into and out of a project area. Water budget gives the financial aspects on the distribution of quantity of water in kadapa district. A water budget is calculated for a specified period of time. Permanent projects may be evaluated using daily or monthly data, with the resulting net surplus or deficit is expressed as a seasonal or annual value. In this paper is to study the existing water source management projects in kadapa district and by using rainfall data, catchment area to determine the runoff and to propose which type of structures are required to conserve the water and also to study the cost of each structure and design procedure, and also study the water quality in pre monsoon period and post monsoon period for applicability of water to the agriculture sector.

For the last ten years monthly rainfall data the average rainfall can be calculated. From this rainfall and the catchment area can gives total rain water for a different mandals of kadapa district from the total rain water, 9% soil moisture, 10% ground water, 41% evapotranspiration and remaining 40% considered is runoff.

Domestic water budge procedure

- Calculating the average rainfall in kadapa district of different mandals.
- From the total rain water, we can consider 20% as runoff
- Usage of water for domestic can be 135lpcd
- Multiplying the population of every mandal with 135lpcd

4. Results & Discussion

4.1 Average rainfall of all Mandals in Kadapa District

In Kadapa district by using Arithmetic average method, we calculating the average rainfall from 2006-2015. This rainfall can be measured by Symon’s rain gauge. In this we observed that High rainfall mandals are Kodur (0.88 mts), Obulavaripalle (0.78 mts), Chitvel (0.76 mts) and Low rainfall mandals are Thondur (0.42 mts), Galiveedu (0.44 mts), Lingala (0.44 mts), Muddanur (0.45 mts)

4.2 Assessment of Runoff

Total rain water on earth surface some quantity of rain water should be loss in the form of ground water (9%), soil moisture (10%), Evapotranspiration (41%) and remaining is runoff (40%). The below table 1 represents the assessment of runoff

| S. No. | Mandal    | Area (Sq.m) | Average rainfall (m) | Total Rain water (cum) | Ground water (9%) (TMC) | Evapo-transpiration (41%) (TMC) | Soil Moisture (10%) (TMC) | Runoff (40%) |
|--------|-----------|-------------|----------------------|------------------------|-------------------------|----------------------------------|---------------------------|--------------|
| 1      | Atkur     | 216550000   | 0.63                 | 136426500              | 0.43                    | 1.97                             | 0.48                      | 1.92         |
| 2      | B. Kodur  | 220040000   | 0.54                 | 118821600              | 0.38                    | 1.72                             | 0.42                      | 1.68         |
| 3      | Badvel    | 367260000   | 0.53                 | 194647800              | 0.62                    | 2.82                             | 0.69                      | 2.75         |
| 4      | B. Mattam | 441860000   | 0.65                 | 287209000              | 0.91                    | 4.16                             | 1.01                      | 4.05         |
| 5      | Chakrayapat| 282820000   | 0.59                 | 166863800              | 0.53                    | 2.41                             | 0.59                      | 2.35         |
6 Chappad 127060000 0.49 62259400 0.19 0.91 0.21 0.87
7 Chennur 140890000 0.61 85942900 0.27 1.24 0.30 1.21
8 Chinnasamudram 208300000 0.65 135395000 0.43 1.95 0.47 1.91
9 C.K. Dinne 571610000 0.65 371546500 0.11 0.54 0.13 0.53
10 Chitvel 305720000 0.76 232347200 0.73 3.36 0.82 3.28
11 Duvvur 253300000 0.51 129183000 0.41 1.86 0.45 1.82
12 Galiveedu 356010000 0.44 156644400 0.49 2.26 0.55 2.21
13 Gopavaram 343280000 0.60 205968000 0.65 2.98 0.72 2.90
14 Jammalamadugu 344940000 0.53 182818200 0.58 2.64 0.64 2.58
15 Kadapa 950000000 0.65 62075000 0.19 0.89 0.21 0.87
16 Kalasapadu 573210000 0.59 338193900 1.07 4.89 1.19 4.77
17 Kamalapuram 186350000 0.54 100629000 0.31 1.45 0.35 1.42
18 Khajipet 287650000 0.60 172590000 0.54 2.49 0.60 2.43
19 Kodur 238420000 0.88 209809600 0.66 3.03 0.74 2.96
20 Kondapuram 393930000 0.45 177268500 0.56 2.56 0.62 2.50
21 L.R. Palli, 237720000 0.55 130746000 0.41 1.89 0.46 1.84
22 Lingala 301670000 0.44 132734800 0.42 1.92 0.46 1.87
23 Muddanuru 245110000 0.45 110299500 0.35 1.59 0.38 1.55
24 Mydikur 687860000 0.59 405837400 1.28 5.87 1.43 5.73
25 Mylavaram 390390000 0.48 187387200 0.59 2.71 0.66 2.64
26 Nandalur 239620000 0.71 170130200 0.54 2.46 0.60 2.40
27 Obulavaripalle 242170000 0.78 188853600 0.59 2.73 0.66 2.66
28 Peddamudium 300720000 0.54 162388800 0.51 2.35 0.57 2.29
29 Penagalur 313860000 0.63 197731800 0.62 2.86 0.69 2.79
30 Pendlimarri 652210000 0.46 300016600 0.95 4.34 1.05 4.23
31 Porumamilla 516680000 0.62 320341600 1.01 4.63 1.13 4.52
32 Proddatur 181070000 0.57 103209900 0.32 1.49 0.36 1.45
33 Pulivendula 171060000 0.51 87240600 0.27 1.26 0.30 1.23
34 Pullampet 259620000 0.68 176541600 0.56 2.55 0.62 2.49
35 Rajampet 312270000 0.71 221711700 0.70 3.20 0.78 3.13
36 Rajupalem 197650000 0.53 104754500 0.33 1.51 0.36 1.47
37 Ramapuram 201110000 0.50 100555000 0.31 1.45 0.35 1.41
38 Rayachoti 245110000 0.60 147066000 0.46 2.12 0.51 2.07
39 S.A. Kasinayana 414000000 0.47 194580000 0.61 2.81 0.68 2.74
40 Sambeppalle 245140000 0.61 149535400 0.47 2.16 0.52 2.11
41 Sidhout 215310000 0.64 137798400 0.43 1.99 0.48 1.94
42 Simhadripuram 325360000 0.46 149665600 0.47 2.16 0.52 2.11
43 Thondur 256860000 0.42 107881200 0.34 1.56 0.38 1.52
44 T Sundupalle 345560000 0.59 203880400 0.64 2.95 0.71 2.87
45 V.N. Palli 293730000 0.56 164488800 0.52 2.38 0.58 2.32
46 Vattur 144800000 0.51 73684800 0.23 1.06 0.26 1.04
47 Veeraballi 380820000 0.54 205642800 0.65 2.97 0.72 2.90
48 Vempalle 176050000 0.55 96827500 0.30 1.40 0.34 1.36
49 Venkata 231350000 0.50 115675000 0.36 1.67 0.40 1.63
50 Vontimitta 289980000 0.61 176887800 0.56 2.56 0.62 2.49
51 Yerragumilla 249950000 0.55 137472500 0.43 1.98 0.48 1.94

4.3 Ground Water Levels of All Mandals in Kadapa District

Ground water table is the availability of water in meter below ground level. The depth of ground water table should be estimated by using piezometers. The below table 2 shows the ground water levels in Kadapa district.
| S. No | Village          | Mandal    | Average Ground water Levels (M BGL) |
|-------|------------------|-----------|-------------------------------------|
| 1     | Kondur (S)       | Atlur     | 35.55                               |
| 2     | Amagampalle      | B. Kodur  | 4.378                               |
| 3     | Payalakuntla     | B. Kodur  | 9.361                               |
| 4     | B. Mattam        | B. Mattam | 7.578                               |
| 5     | Badvel           | Badvel    | 18.67                               |
| 6     | C.K. Dinne       | C.K. Dinne| 13.97                               |
| 7     | Maddimadugu      | C.K. Dinne| 4.467                               |
| 8     | Chakrayapet      | Chakrayapet| 8.737                              |
| 9     | Chennur          | Chennur   | 5.665                               |
| 10    | Thimmaiahgaripalle (S) | Chitvel | 31.64                              |
| 11    | Venkataraipurpalle | Chitvel | 25.14                              |
| 12    | Cuddapah         | Cuddapah  | 8.151                               |
| 13    | Kanagudur        | Duvvur    | 13.73                               |
| 14    | Nooliveedu       | Galiveedu | 18.32                              |
| 15    | Rachayapeta      | Gopavaram | 7.418                              |
| 16    | Jammalamadugu    | Jammalamadugu | 10.65                      |
| 17    | Chemareddyapalle | Kallasaadupadu | 40.7                       |
| 18    | Kamalapuram      | Kamalapuram | 15.68                      |
| 19    | Lavanur          | Kondapuram| 9.769                               |
| 20    | Lakkireddyapalle | Lakkireddyapalle | 7.897                      |
| 21    | Chinnakudala (S) | Lingala   | 47.37                               |
| 22    | Uppalur          | Muddanur  | 19.64                               |
| 23    | Yamavaram        | Muddanur  | 21.77                               |
| 24    | Nandyalampet     | Mydukur   | 7.385                               |
| 25    | Vanipeta (S)     | Mydukur   | 5.695                               |
| 26    | Talamanchipatnam | Mylavaram | 3.372                              |
| 27    | Nandalur         | Nandalur  | 4.341                               |
| 28    | Yerraguntlakota  | Obulavarpalle | 19.95               |
| 29    | Peddamudum       | Peddamudum| 4.42                                |
| 30    | Guralachinthalaapalle | Pendlimarri | 38.27                     |
| 31    | Porumamilla      | Porumamilla | 10.54                   |
| 32    | Proddatur        | Proddatur | 8.94                                |
| 33    | Pulivendula      | Pulivendula | 15.64                |
| 34    | Puttanivaripalle | Pullampet | 19.67                               |
| 35    | Rajampet         | Rajampet  | 3.201                               |
| 36    | Ramapuram        | Ramapuram | 8.032                               |
| 37    | Rayachoty        | Rayachoty | 3.794                               |
| 38    | Sambepalle       | Sambepalle | 13.69                     |
| 39    | Bhakrapet        | Siddavatam| 8.558                               |
| 40    | Balapanur        | Simhadripuram | 20.12           |
| 41    | Thondur          | Thondur   | 7.232                               |
| 42    | T. Sundupalle    | T. Sundupalle | 10.99            |
| 43    | Payasampalle (S) | V.N. Palle | 14.66                               |
| 44    | Vempalle         | Vempalle  | 13.6                                |
| 45    | Vemula           | Vemula    | 14.02                               |
| 46    | c. Kothapalle    | Vontimitta| 13.84                               |
In Kadapa district calculated the ground water level from 2006-2015, 46 wells in different mandals. The average ground water levels can be displayed on above table. In these we observed that Ground water available at lowest depth from below ground surface is Rajampeta (3.201 m bgl), Mylavaram (3.37 m bgl), Rayachoti (3.79 m bgl), Ground water available at highest depth from below ground surface is Lingala (43.37 m bgl), Kalasapadu (40.7 m bgl), pendlimarri (38.26 m bgl)

4.4 Water Budget of all Mandals in Kadapa District
Water budget is an accounting of all the water that flows into and out of a project area. Water budget gives the distribution of quantity of water in kadapa district. From the population and availability of runoff we estimated the domestic water requirement as shown in table 3.

| SL.NO | Mandal    | Population | Availability of Runoff (TMC) | Domestic Usage (TMC) | Surplus water (TMC) |
|-------|-----------|------------|-------------------------------|----------------------|---------------------|
| 1     | Atlur     | 24339      | 1.92                          | 0.042                | 1.878               |
| 2     | B. Kodur  | 20471      | 1.68                          | 0.035                | 1.645               |
| 3     | Badvel    | 50136      | 2.75                          | 0.087                | 2.663               |
| 4     | B. Mattam | 37278      | 4.05                          | 0.064                | 3.986               |
| 5     | Chakrayapet | 31258   | 2.35                          | 0.054                | 2.296               |
| 6     | Chapad    | 41379      | 0.87                          | 0.071                | 0.799               |
| 7     | Chennur   | 36987      | 1.21                          | 0.064                | 1.146               |
| 8     | Chinnamandem | 34515   | 1.91                          | 0.060                | 1.850               |
| 9     | C.K. Dinne | 54788   | 0.53                          | 0.099                | 0.430               |
| 10    | Chitrav    | 42104      | 3.28                          | 0.073                | 3.207               |
| 11    | Duvvur    | 51872      | 1.82                          | 0.090                | 1.730               |
| 12    | Galiveedu  | 50833      | 2.21                          | 0.088                | 2.122               |
| 13    | Gopavaram  | 59468      | 2.90                          | 0.106                | 2.794               |
| 14    | Jammalamadugu | 78326   | 2.58                          | 0.136                | 2.444               |
| 15    | Kadapa    | 318916     | 0.87                          | 0.550                | 0.320               |
| 16    | Kalasapadu | 31296   | 4.77                          | 0.054                | 4.716               |
| 17    | Kamalapuram | 52168  | 1.42                          | 0.090                | 1.330               |
| 18    | Khamipur   | 50320      | 2.43                          | 0.087                | 2.343               |
| 19    | Kodur     | 90814      | 2.96                          | 0.160                | 2.800               |
| 20    | Kondapuram | 42093   | 2.50                          | 0.073                | 2.427               |
| 21    | L.R. Palli, | 35246   | 1.84                          | 0.061                | 1.779               |
| 22    | Lingala   | 29945      | 1.87                          | 0.052                | 1.818               |
| 23    | Muddanur  | 34366      | 1.55                          | 0.059                | 1.491               |
| 24    | Mydunkur  | 81019      | 5.73                          | 0.140                | 5.590               |
| 25    | Mylavaram  | 41925      | 2.64                          | 0.072                | 2.568               |
| 26    | Nandalur  | 39902      | 2.40                          | 0.069                | 2.331               |
| 27    | Obulavaram | 53275   | 2.66                          | 0.090                | 2.570               |
| 28    | Peddamudium | 32541   | 2.29                          | 0.056                | 2.234               |
| 29    | Penagallur | 42360   | 2.79                          | 0.073                | 2.717               |
| 30    | Pendlimarri | 44008  | 4.23                          | 0.076                | 4.154               |
| 31    | Porumamilla | 57937   | 4.52                          | 0.100                | 4.420               |
| 32    | Proddatur  | 258879     | 1.45                          | 0.450                | 1.000               |
| 32    | Pulivendula | 78884  | 1.23                          | 0.137                | 1.093               |
| 34    | Pullampet  | 39434      | 2.49                          | 0.068                | 2.422               |
| 35    | Rajampet  | 103871     | 3.13                          | 0.180                | 2.950               |
| 36    | Rajupalem  | 32829      | 1.47                          | 0.057                | 1.413               |
| 37    | Ramapuram  | 35220      | 1.41                          | 0.061                | 1.349               |
In the calculation of domestic water budget the high amount of available runoff and surplus water mandals are given below table 4.

- Mydukur available runoff 5.73 tmc and it having surplus water 5.59 tmc
- Kalasapadu available runoff 4.77 tmc and it having surplus water 4.71 tmc
- Pendlimarri available runoff 4.23 tmc and it having surplus water 4.15 tmc
- Porumamilla available runoff 4.52 tmc and it having surplus water 4.42 tmc

Less amount runoff and surplus water mandals are given below

- Kadapa available runoff 0.87 tmc and it having surplus water 0.32 tmc
- Vallur available runoff 1.04 tmc and it having surplus water 0.99 tmc
- Proddatur available runoff 1.45 tmc and it having surplus water 1.00 tmc
- Pulivendula available runoff 1.23 tmc and it having surplus water 1.09 tmc

Table 4: Water Budget for Agricultural demand

| SL.No. | Mandal       | Availability of Runoff (TMC) | Required water (TMC) | Deficit (TMC) | Surplus water (TMC) |
|--------|--------------|------------------------------|----------------------|---------------|---------------------|
| 1      | Atlur        | 1.92                         | 1.45                 | 0.47          |                     |
| 2      | B. Kodur     | 1.68                         | 2.70                 | 1.02          |                     |
| 3      | Badvel       | 2.75                         | 4.6                  | 1.85          |                     |
| 4      | B. Mattam    | 4.05                         | 3.80                 | 0.25          |                     |
| 5      | Chakrayapet  | 2.35                         | 3.20                 | 0.85          |                     |
| 6      | Chapad       | 0.87                         | 2.80                 | 1.93          |                     |
| 7      | Chennur      | 1.21                         | 1.40                 | 0.19          |                     |
| 8      | Chinnamandem | 1.91                         | 1.90                 | 0.01          |                     |
| 9      | C.K. Dinne   | 0.53                         | 1.90                 | 1.37          |                     |
| 10     | Chitvel      | 3.28                         | 1.20                 | 2.08          |                     |
| 11     | Duvvar       | 1.82                         | 3.20                 | 1.38          |                     |
| 12     | Galiveedu    | 2.21                         | 4.10                 | 1.89          |                     |
| 13     | Gopavaram    | 2.90                         | 3.70                 | 0.80          |                     |
| 14     | Jammalamadugu | 2.58                 | 2.60                 | 0.02          |                     |
| 15     | Kadapa       | 0.87                         | 1.60                 | 0.73          |                     |
| 16     | Kalasapadu   | 4.77                         | 4.30                 | 0.47          |                     |
| 17     | Kamalapuram  | 1.42                         | 2.90                 | 1.48          |                     |
| 18     | Khajipet     | 2.43                         | 3.00                 | 0.57          |                     |
| 19     | Kodur        | 2.96                         | 2.40                 | 0.56          |                     |
| 20     | Kondapuram   | 2.50                         | 4.80                 | 2.30          |                     |
| 21     | L.R. Palli,  | 1.84                         | 3.20                 | 1.36          |                     |
5. Conclusions

- By using arithmetic average method it is observed that high amount of rainfall recorded in Kodur and lowest in Thondur.
- From the estimation of total rainwater by using the methods the highest runoff and lowest runoff recorded in Mydukur and C.K. Dinne.
- Types of soils in Kadapa district high percentage of clay soil mandals are vontimitta (100), Kodur (98.81), Peddamudium (90.28), and Chapad (88.57) and high percentage of Sandy clay loams are Chakrayapet (87.95), Ramapuram (84.57), thiondur (64.55).
- By using Piezeometre lowest depth of ground water level in Rajampeta and the highest depth of ground water table observed in Lingala.
- In the calculation of domestic water budget the amount of available runoff and surplus water noticed in Mydukur and lowest amount of runoff and surplus water recorded in Kadapa.
- Demonstrative artificial recharge project taken up in Lingala, Pulivendula, Vemula and Vempalli mandals of the district proved that has good impact on improvement of ground water levels, increased the sustainability of pumping in addition to increase in productivity of Farm products.
- Rainwater harvesting structures like contour bunding, check dams, percolation tanks, and farm ponds are already in vogue. The construction of the artificial recharge structures should be taken up scientifically for 50% of non-committed runoff so as to not to deprive the downstream watersheds.
technical team consisting of Scientists, Engineers and Bureaucrats should be constituted for monitoring the structures on regular basis.

➢ In ‘Safe’ mandals, the artificial recharge to ground water should go hand-in-hand with ground water development further development of ground water should be restricted upto a depth of 150m to avoid failures of bore wells.

Since the district is water scarce, land use system should place emphasis on cultivation of high value and low water requiring crops such as pulses, oilseeds.

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