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Hydrological problems of Mudasarlova Reservoir, one of the water supply surface sources to Visakhapatnam city - A case study

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ABSTRACT

Hydrological study of reservoir is essential for proper planning of the reservoir storage capacity and spillway capacity. In the present study Mudasaralova Reservoir in Visakhapatnam city is considered. The runoff and yield of the reservoir is computed using rain fall data of nearby two rain guage stations Pendurthi and Visakhapatnam. The peak flood flow into the reservoir is also computed. The catchment area map, contour map, drainage map, slope map, and Land use/ land cover maps are prepared using GIS software. The runoff is computed using SCS-CN and Stranges curves and the suggestions for improvement of the reservoir are given.

INTRODUCTION

The prediction of runoff including its time distribution generated by individual storm bursts is essential for efficient estimation of reservoir capacity, spillway capacity for proper forecasting and operation of hydraulic projects. Estimation of monthly, seasonal or annual runoff may be required for operational purposes for evaluating reservoir storage requirements.

Mudasarlova reservoir basin is lying between the longitudes 83º15'50"E and 83º18'30"E and latitudes between 17º45'50"N and 17º48'05"N.situated in the Visakhapatnam city. The catchment is located between Kailasa Konda, Kambala Konda and Simhachalam hills.

The main dam is constructed near Sri Krishnapuram village and it is formed connecting the kambala konda and kailasa hills The main dam is earthen dam provided with a spillway.

Earlier studies on hydrology of reservoirs

Bhaskar. N.R., James. W.P. and Devulapalli. R.S.[1] studied on Hydrologic parameters estimation using Geographic Information System (GIS) observed that the conventional hydrologic data are inadequate for the purpose of design and operation of water resources systems. In such cases GIS are of great use for the estimation of relevant hydrologic data.

GIS can be used for the determination of catchment characteristics, such as land use/ land cover, geomorphology, slope, drainage etc.

Schumann. A. H.[2] studied on the development of conceptual semi-distributed hydrological models and estimation of their parameters with the aid of GIS

Viswanadh. G. K. and Giridhar. M. V. S. S.[3] studied on Semi distributed Runoff Model for a Semi Arid Area of Andhra Pradesh – A Geomatic Approach.

Yu (1998) derived a model of the form of the SCS-CN method on the basis of assumptions as the spatial variability of infiltration capacities and the temporal variability in rainfall intensities. Under these assumptions, runoff will be produced anywhere on a catchment where

the time varying rainfall rate exceeds the spatially variable but time constant infiltration capacity making no allowances for any run on process. For an exponential distribution of infiltration capacity in space, and an exponential distribution of rainfall intensity in time, Yu computed that the runoff can be generated using SCS-CN equation.

Determination of catchment area and preparation of maps

The basin area obtained from survey of India maps was scanned and digitized in AUTO CAD. The digitized maps are further geo referenced and the areas and the final maps are processed using ARCINFO, ARCVIEW and DEM (Digital Elevation Model). The final layout maps of the reservoir are prepared in ERADAS software.

Using the above softwares the reservoir catchment map, drainage map, flow direction map, land use and land cover maps, contour map, shaded relief map and DEM are prepared.

Drainage map

The drainage pattern of the mudasarlova reservoir was prepared and shown in figure 1. The total tributories of mudasarlva basin catchment are 14 Nos (kambalakonda hill slopes-6 Nos and kailashagiri hills slopes- 8 Nos) situated in upstream side of of the reservoir. As per the present situation most of the catchment area of mudasarlova basin is occupied by residential buildings and lot of developmental activities are going on. Due to this the sewage effluents from the residential areas will be mixed with the surface water and the reservoir water quality will be degraded. Recently the central jail of visakhapatnam is also constructed in Mudasarlova catchment area. Unless the effluents from jail are treated and released the quality of mudasarlova reservoir will be spoiled.

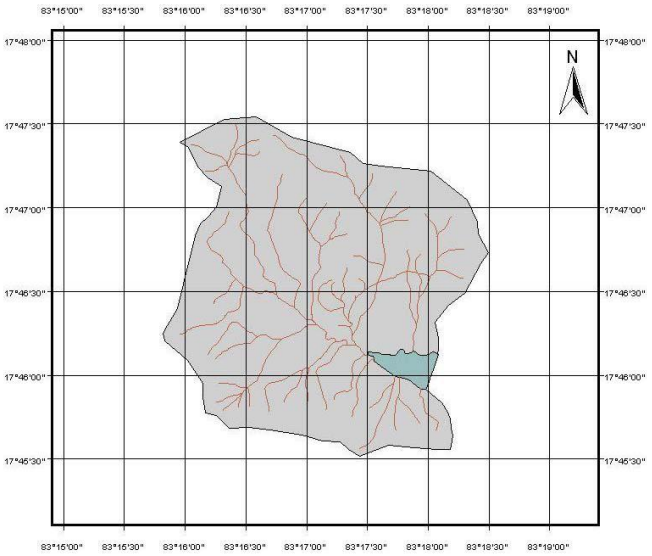

Figure 1 : Drainage map

Contour map

The contour map of the mudasarlova basin is prepared and presented in figure 2. From the contour map it is noted, the side slopes of kailasa hill and kambala konda hill are very steep. Due to this the velocity of rainfall / runoff will be high.

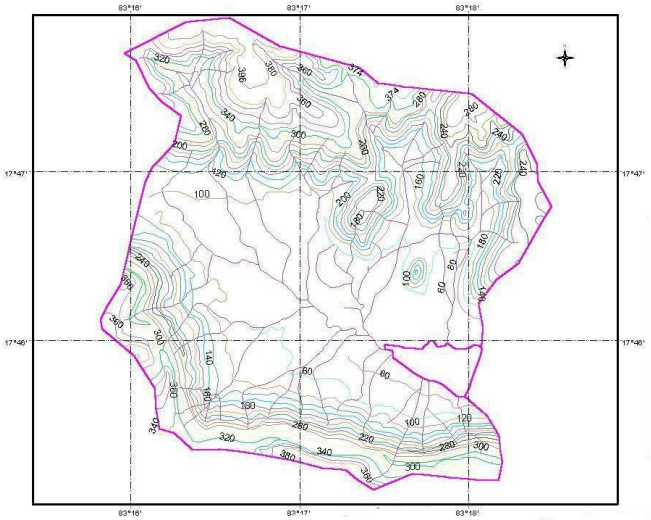

Figure 2 : Contour map

Average rainfall estimation

In the computation of average rainfall, three rain guage stations namely Pendurthi, Visakhapatnam and Bheemunipatnam were considered and thesian polygon was drawn. From the polygon it is observed that the rainfall of Pendurthi and Visakhapatnam rain guage stations are effective. Hence, the rainguage station of Visakhapatnam and Pendurthi were considered for computation of average annual rainfall of mudasarlova basin. The average annual rainfall computed for mudasarlova catchment are shown in TABLE 1

a) The average annual rainfall is 1023.18mm.
b) The maximum Annual rainfall is 1351.164mm.
c) The average monsoon rainfall is 905.094mm.
d) The maximum monsoon rainfall is 1289.69mm.

ANNUAL YIELD AND MONSOON YIELD

Annual yield

The average annual yield of muadasarlova basin is 4.265 x 10´m³. Which is computed by considering stranges runoff curves and annual rainfall.

Monsoon yield

a) The catchment area of Mudasarlova reservoir is 17.06 sq.km.
b) The average monsoon rain fall is 905.094 mm.
c) The Stranges runoff coefficient is 24.849.
d) The runoff depth is 224.907 mm.
e) The average monsoon yield of mudasarlova basin is 3.837 x 10 m³.

The 75% dependable yield is calculated by considering past 54 years yield occurred for rainfall of 792 mm which occurs in 1981. The runoff coefficient of strange table is 21.09. The 75% dependable yield is 2.850 x 10 m³.

Computation of runoff

Several empirical and analytical methods are available for estimation of runoff. Among them the USDA soil conservation service curve number method (SCS-CN) is the most popular and widely used method. In this method the soil classification Land Use and Land Cover Thematic Maps figure 3, Antecedent moisture condition are considered for evaluating the curve number and runoff. The weighted CN values are shown in TABLE 1. The maximum runoff was estimated using rational method and it is 106.634 m³. and the runoff volume of different intensities of rain fall in different years were computed and presented in TABLE 2. The land use / land cover maps shown in figure 3, Shaded Relief map and slope/flow direction map in figure 4. The following are the Land Use and Land Cover areas.

a) The Bare soils - 1.38 Sq. Km.
b) Built up lands - 0.78 Sq. Km.
c) Crop lands - 3.47 Sq. Km.
d) Fallow lands - 1.64 Sq. Km.
e) Forest lands - 4.85 Sq. Km.
f) Plantations - 2.98 Sq. Km.

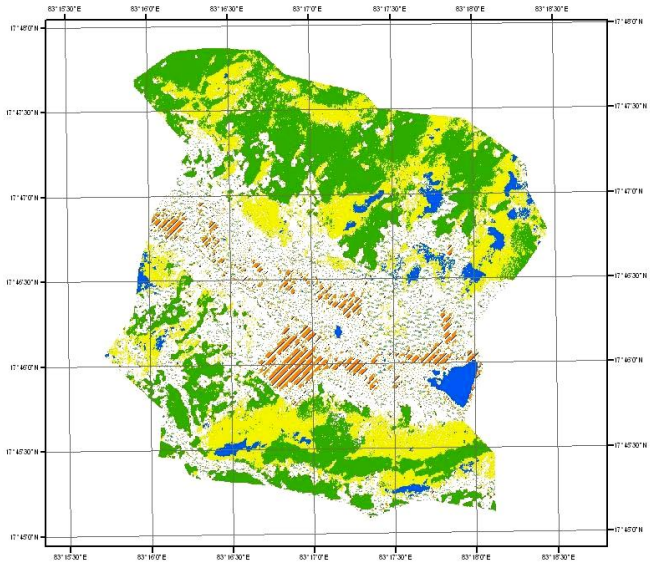

Figure 3 : Land use / Land cover map

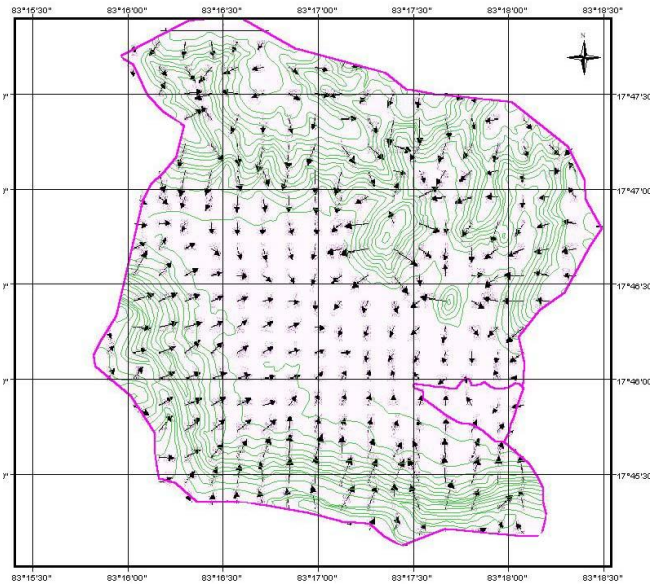

Figure 4 : Flow direction map

TABLE 1 : Showing average annual rainfall of Mudsarlova catchment

Sr. No	Rain gauge station	Average annual rainfall (1)	Average annual monsoon rainfall (2)	Influencing area In acres (3)	(1) x (3)	(2) x (3)
1	Visakhapatnam	1071.23	955.83	3089.225	3309279.764	2952773.93
2	Pendurthi	891.5	766.06	1127.293	1004981.709	863574.076
			Total	4216.518	4314261.473	3816348.006
	Average annual/monsoon rainfall = Total/4216.518 (mm)				1023.181	905.094

TABLE 2 : Calculation of weighted CN

Sr. No	Classification from land use/ land cover classification	CN	Areas in Sq.m	Area Total area	CnxA1/A
1.	Bare soils	82	1377187.8904	0.081	6.642
2.	Built up lands	84	785041.7366	0.046	3.864
3.	Crop lands	78	3471481.2949	0.203	15.834
4.	Fallow lands	86	1637938.5415	0.096	8.256
5.	Forest lands	55	4851169.3562	0.284	15.620
6.	Plantations	58	2976553.1565	0.174	10.092
7.	Scrubs	60	1357085.3707	0.080	4.8
8.	Water bodies	0	607181.3221	0.036	0
	Total		17063638.66	1.000	65.108

TABLE 3 : Calculation of runoff depth and volume

Sr. No	Date	Rainfall in mm	Runoff Depth in mm	Runoff volume in m^3
1.	9-10-95	65	3.643	62162.840
2.	12-10-95	62	2.848	48597.243
3.	14-7-96	89	12.588	214797.033
4.	15-7-96	74	6.497	110862.460
5.	31-10.98	109	22.744	388095.398
6.	9-10.99	96	15.908	271448.364
7.	10-10-99	47	0.267	4555.992
8.	14-10-99	62.9	3.077	52504.816
9.	31-8-02	45.09	0.129	2200.7400
10.	7-10-03	90.57	13.307	227017.42
11	22-10-03	83.83	10.320	176059.200
12	23-10-03	102.49	19.219	327876.14
13	24-10-03	93.95	14.907	254313.42
14	27-11-03	41.17	0.001	17.06
15	23-4-04	55.68	1.460	24907.6
16	10-6-04	44.33	0.087	1484.22
17	13-6-04	49.26	0.491	8376.46
18	14-7-04	45.32	0.143	2439.58
19	19-9-2005	112.2	24.545	418827.011
20	20-9-2005	161.2	56.484	963822.566
21	3-8-06	99.49	17.66	301279.6
22	4-8-06	124.91	32.103	547677.18
23	25-9-06	62.40	2.948	50292.88
24	29-9-06	49.39	0.534	9110.04
25	30-10-06	46.85	0.254	4333.24
26	9-11-06	49.13	0.476	8120.560
27	23-6-07	52.80	0.967	16497.02
28	24-6-07	58.20	1.964	33505.84

g) Scrubs - 1.36 Sq. Km.
h) Water bodies - 0.60 Sq. Km.
Total = 17.06 Sq. Km.

Maximum daily runoff

The maximum daily runoff calculated from the available data SCS-CN method. The maximum rain fall is occurred on 20-9-2005 with a rain fall of 161.20 mm. From this the following calculations are made. The daily run off volume and maximum daily yield are shown in TABLE 3.

a) The weighted CN for the basin … 65.108.
b) The recharge capacity of the basin … 136.121 mm.
c) The maximum daily runoff depth … 56.484 mm.
d) The maximum daily runoff volume … 963.822 x 10^6 m^3
e) The maximum daily yield … 0.965 x 10^6 m^3

Peak flood discharge

The peak flood discharge in to the reservoir is computed using the Ryves formula Dickens formula, Inglish Formula and Rational method. The computation is

TABLE 4 : Estimation of maximum rate of runoff using various formulae

Sr. No	Method	Formula	Coefficient	Run off in cumecs
1.	Dickens formula	$Q=CA^{3/4}$	25	209.857
2.	Ryves formula	$Q=CA^{2/3}$	30.34	201.064
3.	Inglis formula		-	403.692
4.	Rational method	Q=2.778CAI	0.45	106.634

TABLE 5 : Table showing the results

Sr. No	Parameter	Data calculated
1.	Average annual rainfall	1023.181mm (Obtained from previous 11 years data)
2.	Maximum annual rainfall	1351.164 mm
3.	Average annual monsoon rainfall	905.094mm
4.	Maximum annual monsoon Rainfall	1289.690mm
5.	Catchment area	17.06 Sq.km
6.	Annual yield	$4.265x10^6$ m^3
7.	Monsoon yield	$3.837x10^6$ m3
8.	75% dependable monsoon yield	$2.850x10^6$ m^3(from 50 years data)
9.	Maximum runoff rate	106.634 cumecs (from rational formula)
10.	Maximum annual yield	$5.459x10^6m^3$

shown in TABLE 4. All the above results are summarized in TABLE 5.

CONCLUSIONS

The catchment area of the Mudasarlova Reservoir is calculated using GIS software. Knowing the catchment area and maximum daily runoff is computed using SCS-CN method. Annual yield, Monsoon yield and 75% dependable yield is calculated from strange's curves, maximum rate of runoff is calculated using Four methods.

The average rainfall is computed from the average annual rainfall of Visakhapatnam and Pendurthi Rain gauge stations by Thiessen Polygon Method. Thiessen polygon network is constructed for three rain gauge stations of Visakhapatnam, Pendurthi and Bheemunipatnam. It was found that Bheemunipatnam rain gauge station has no influence on the Mudsarlova basin. The following conclusions are made

1. a) The average annual rainfall is 1023.181mm
   b) The average annual monsoon rainfall is 905.094mm
   c) The maximum annual rainfall is 1351.164mm
   d) The maximum annual monsoon rainfall is 1289.690mm
2. The average annual yield and maximum annual yield was computed using strange's curves.
   a) The average annual yield is $4.265 \times 10^6 m^3$
   b) The maximum annual yield is $5.459 \times 10^6 m^3$
3. The average annual monsoon yield and maximum annual monsoon yield is calculated using strange's tables
   a) The average annual monsoon yield is $3.837 \times 10^6 m^3$
   b) The maximum annual monsoon yield is $8.147 \times 10^6 m^3$
4. 75% dependable yield calculated from previous 54 years data (1951-2004) using strange's tables is $2.850 \times 10^6 m^3$
5. The Maximum daily runoff is calculated from the available data using SCS-CN method. The maximum rainfall occurred on 20-9-2005 with a rainfall of about 161.2mm. The following conclusions are made
   a) The weighted CN for the basin is 65.108
   b) The recharge capacity of the basin is 136.121mm
   c) Maximum daily runoff depth is 56.484mm
   d) Maximum daily runoff volume is 963, 822.566 m^3
   e) Maximum daily yield is $0.965 \times 10^6 mm^3$
6. The maximum runoff rate or flood discharge in Mudsarlova Basin is arrived considering Ryves formula which is mostly used for South Indian catchments. As per this the Peak flood discharge is 44.73 cumecs.

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