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Water Budget of Bhad River Watershed, Panzara River Basin, Dhule District of Maharashtra State

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Abstract*— The problems in this area appear even more serious than originally assessed and solutions are almost certainly more difficult. In simple terms a water budget for the "Bhad River" watershed area can be looked at as water inputs, outputs and changes in storage of this "over-exploited" area. The inputs into the area are precipitation, surface water inflows and capacity of different type of storage like dams, bandhara and yield must be comparable to the output that is various demands like Irrigation demand, public demand like domestic, industrial etc. These are comparatively expressed in this budget.

***Index Terms*— Runoff, Over-exploited.**

I. INTRODUCTION

The watershed of Bhad river for the this study is located in the north side of Maharashtra State, The Toposheet no. of map is T.E.65 and it is spread between Survey of India toposheets 46/K/12, 46/K/16, 46/L/9, and 46/L/13; bounded by longitudes between 74^0 40' E to 74^0 52' E and latitudes between 20^0 57' N to 21^0 6' N. It falls in Taluka and District Dhule of Maharashtra state. Bhad River is a tributary of Panzara River. There are two tributaries of Bhad River, namely Gul nadi and Majhar nadi. The climate of the area is hot and dry. The south-west monsoon is from June to September. The maximum temperature is 45^0 C and minimum is 6^0 C. The average annual rainfall is 571 mm. [1]

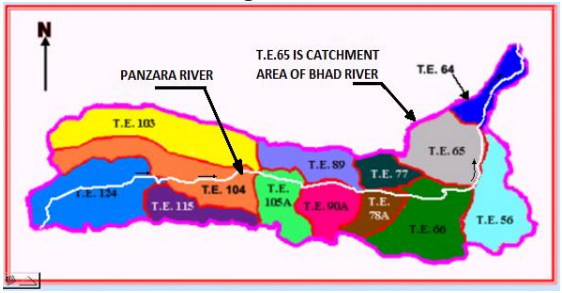

Fig 1 Catchment of Panzara River and 13 sub catchment of Panzara River

II. OBJECTIVE OF STUDY

The main purpose of this project is to work out the complete water budget of the watershed through the study hydrology and water resources of the area. This watershed has been selected because it has been classified as "over-exploited" as per the Fifth Ground Water Valuation by GSDA (Groundwater Survey Development Agency), Dist Dhule, and State of Maharashtra. Examples of what can change the storage include both natural and human impacts. During drought, precipitation decreases, this results in less input into the water budget for a particular basin. With less precipitation, it's probable that ground-water levels will decline. The ground-water level decline results in a change in water storage for the basin because less water is now held in the aquifers. Likewise, if climatic conditions changed and above-normal precipitation occurred for a few years, then more recharge to the aquifers would result, which would be an increase in basin water storage. [2]

III. METHOD OF COMPUTING OF WATER BUDGET

The most difficult part for computing the water budget at mentioned watershed area is collecting data that allows to accurately estimating the net surplus or deficit. The project depends primarily on surface runoff and ground water it can identify years with normal, below normal, and above normal rainfall and use that information to determine the surface runoff under present climate conditions. Rainfall data are readily available from the Agricultural department and other agencies like irrigation department.

For the project work following data will be collected / generated:-

1. Prepare map of project work site and mark the catchment area line on map.
2. Collect watershed map of GSDA Dhule.
3. Meteorological data such as rainfall, type of watershed like good, average or bad.
4. Collect population data of villages which comes under the watershed area.
5. Finding out yield of catchment area by Departmental method and other method.
6. Evapotranspiration details in the watershed.
7. Details such as storage capacity, catchment area etc of all the water storage/retaining structures; to be obtained from Minor Irrigation Department, and Zilla Parishad.
8. Collect information about land use pattern and total area in the form of Gross command area, Culturable command area and Non Culturable command area.
9. Crop pattern or types of crop which are sown in catchment area and water requirement of each type of crop.
10. The data collected / generated as above will be analyzed, synthesized to calculate total annual requirement of water for irrigation, drinking, institutional and commercial purposes etc. Further total annual available water will be estimated from the study of rainfall, evapotranspiration,

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infiltration and runoff. Recharge potential of the area will be evaluated. [2]

The data collected / generated as above will be analyzed, synthesized to calculate total annual requirement of water for irrigation, drinking, institutional and commercial purposes etc. Further total annual available water will be estimated from the study of rainfall, evapotranspiration, infiltration and runoff. Recharge potential of the area will be evaluated. The watershed of Bhad river for the project study is located in the north side of Maharashtra State, spread between Survey of India toposheets 46/K/12, 46/K/16, 46/L/9, and 46/L/13; bounded by longitudes between 74^0 40' E to 74^0 52' E and latitudes between 20^0 57' N to 21^0 6' N. It falls in Taluka and District Dhule of Maharashtra state. The toposheets mentioned above are purchased from survey of India department, Pune and the map of the watershed no TE-65 is obtained from office of senior Geologist, GSDA, Dhule.

IV. DETAILED INVESTIGATION

The detailed investigation is carried out in following steps:-

A. Preparing the map of the watershed from toposheets.

The watershed area of Bhad River is distributed in the four toposheets which are shown in figure no. 1 to 4. The dark dotted line shown on these toposheets is line of catchment area of site and the map showing the details of river, reservoirs locations and village locations. After plotting these lines on 4 toposheets and joining them, a single map is prepared. [8]

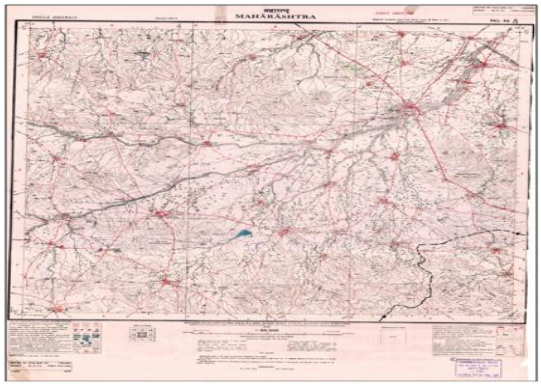

Fig 2 Toposheet No. 46/K/12

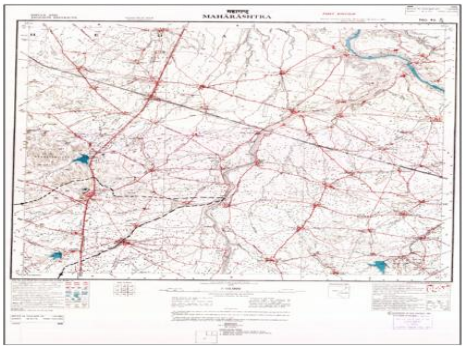

Fig 3 Toposheet No. 46/K/12

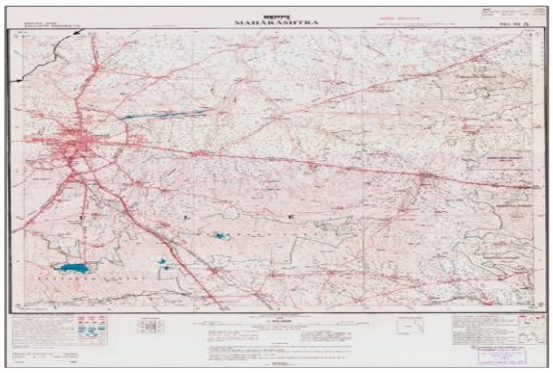

Fig 4 Toposheet No. 46/L/13

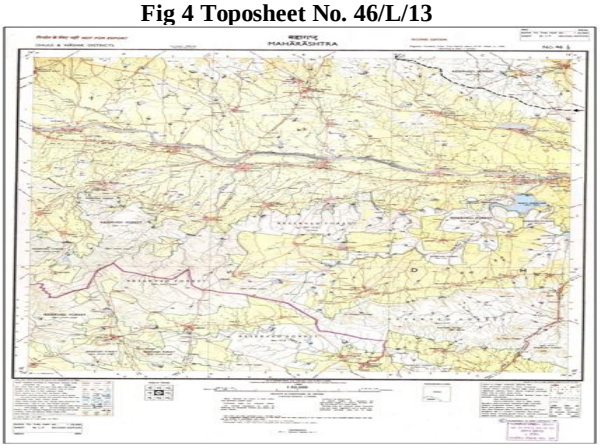

Fig 5 Toposheet No. 46/L/13

A. Prepared map of the watershed from these toposheets.

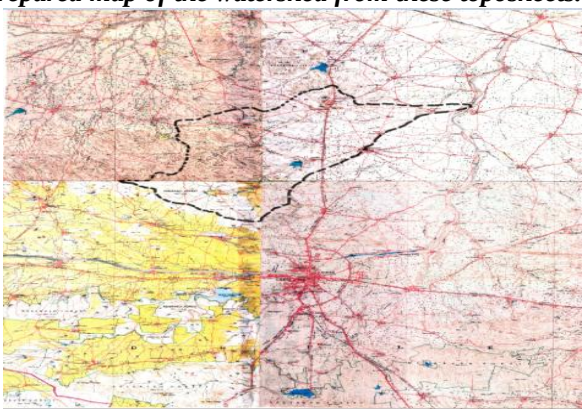

Fig 6 Final prepared map from Toposheet fig no 2, 3,4 and 5

B. Rainfall data

The rainfall data is collected from web site of Dhule Agricultural department and is as given below [9]

Table I: Rainfall Data Week wise Rainfall (In mm - average of 50 years 1963-2013) in Taluka & District Dhule (starting from week 21 [May] to week 44[October])

Date	Week	Rainfall (mm)
21 May To 27 May	W21	4.5
28 May To 03 June	W22	8.3
04 June To 10 June	W23	20.4
11 June To 17 June	W24	25.7

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18 June To 24 June	W25	39.5
25 June To 01 July	W26	46.6
02 July To 08 July	W27	38.8
09 July To 15 July	W28	31.6
16 July To 22 July	W29	32.1
23 July To 29 July	W30	32.6
30 July To 05 Aug	W31	37.4
06 Aug To 12 Aug	W32	20.3
13 Aug To 19 Aug	W33	18.6
20 Aug To 26 Aug	W34	25
27 Aug To 02 Sep	W35	29.4
03 Sep To 09 Sep	W36	26.9
10 Sep To 16 Sep	W37	31.3
17 Sep To 23 Sep	W38	37.2
24 Sep To 30 Sep	W39	29.6
01 Oct To 07 Oct	W40	17
08 Oct To 14 Oct	W41	5.5
15 Oct To 21 Oct	W42	6.4
22 Oct To 28 Oct	W43	3
29 Oct To 04 Nov	W44	4
	Average Rain	**571.7**

C. Population Data

The population data collected for last three decades are collected from census book of government of Maharashtra and website of district Dhule. [12]

Table II: Population villages which are comes to under watershed area of Bhad River

Name of villages	Population 2011	Population 2001	Population 1991
Songir	12115	11509	10835
Dapura	823	782	702
Vadel	380	361	383
Nandane	3281	3117	2550
Sayane	2093	1988	1441
Sarvad	1688	1604	1276
Tisgaon/ Dhandhane	871	827	695
Dongargaon	920	874	843
Deobhane	2357	2239	2127
Kapadne	11694	11109	10664
Dhanur	1985	1886	1964
Lonkute	113	107	116
Total population per Decade	**38320**	**36404**	**33596**

D. Area details of the watershed

The Gross command area, Culturable command area of all the villages in the watershed are detailed obtained from Talathi and Gramsevak of concerned villages and are as given below [10]

Table III: Area of Bhad river watershed

Name of villages	Gross command area (Hectare)	Culturable command area (Hectare)	Non Culturable command area (Ha)
Songir	421	294.7	126.3
Dapura	147	91.14	55.86
Vadel	125	78.75	46.25
Nandane	1520	1094.4	425.6
Sayane	1885	1365	520
Sarvad	888	256	632
Tisgaon/ Dhandhane	400	170	230
Dongargaon	569	260	309
Deobhane	1821.3	482.63	1338.67
Kapadne	2271.61	1050	1221.61
Dhanur	863.84	475	388.84
Lonkute	296.19	205	91.19
Area in Hectare	**11207.94**	**5822.62**	**5385.32**
Area in Acre	**27694.82**	**14387.69**	**13307.13**

E. Details of storage works in watershed

Table IV: live storage of tank in bhad river watershed

Sr no	Name of tank	Live storage in Mcft
1	Village tank at Vadel no.1 (local Nalla)	1.5
2	Village tank at Kapadne (Dhamane Nalla)	2.35
3	Percolation tank at Dongargaon (Nirgudi Nalla)	2.52
4	Percolation tank at Dongargaon (Bhavani Nalla)	5
5	Percolation tank at Dongargaon (Aasar Nalla)	1.98
6	Storage Bandhara at Deobhane	0.64
7	Percolation tank at Nandane (Hagrya Nalla)	4.600
8	Percolation tank at Nandane (Chetak Nalla)	2.617
9	Percolation tank at Nandane	6.173
10	Percolation tank at Dongargaon No 3	0.335
11	Percolation tank at Vadel	5.009
12	Percolation tank at Dongargaon (Mehandi Nalla)	2.293
13	Percolation tank at Tisgaon No 1	2.293
14	Percolation tank at Tisgaon (wakdya Nalla)	2.095
15	Percolation tank at Songir No 1	2.005
16	Percolation tank at Songir No 2	0.705
17	Percolation tank at Songir No 3	3.624
18	Village tank at Vadel (Khomrya Nalla)	1.121

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19	Village tank at Vadel (Upkari Nalla)	0.953
23	Village tank at Nandane (wadi Nalla)	0.411
24	Village tank at Nandane (Gaon Nalla)	0.356
25	Village tank at Nandane	0.274
20	Village tank at Nandane (Pari Nalla)	0.705
21	Village tank at Tisgaon	0.303
22	Village tank at Songir	0.649
23	Storage Bandhara at Songir	0.564
	Total available water	**51.08**

F. Yield calculation

For water budget of Bhad river watershed, it is decided to calculate total annual demand and total annual available water. For calculating total available water following methods are used. These methods are applicable to area in Maharashtra and used by Government department. [9]

1. Yield by Strange's method

Nature of catchment is assumed as Good Dependability of rainfall 50%. Stranges table Coefficient Value from Page No 153 of Minor Irrigation Book, Dhule District, and Government of Maharashtra.

Average rainfall is 571.7 mm so that is 22.51 inch

Table V Interpolation for 22.51 inch rainfall

Total Monsoon Rainfall In Inch	Yield of Run-off from Catchment per square mile in Mcft
22	8.842
22.51	**9.347**
23	9.832

Yield at site from catchment

Yield = catchment area x Yield in Mcft/sq mile

Yield = 43.40 x 9.347

Yield = 405.66 Mcft

Yield = 11488.29 Tcm

Yield = 11488291.2 m^3 **that is 11.488 Mm^3**

The maximum yield obtained from the above two methods is 11.488 Mm^3 and the same yield used in further analysis

Further total annual volume of rainfall required on the watershed is

= Gross command area of watershed in 'm²' X average annual rainfall in 'm'

= 112.0794 x 10^6 x 0.5717

= 64.06 x 10^6 m^3

= 64.076 Mm^3

2. Inglis Formula and DeSouza formula.

Data Available of Catchment

1. Catchment area on map 112.5 km2 i.e. 43.40 sq miles
2. No of years for which average rainfall is measured 1963 to 2013
3. Average rainfall measured 571.7 mm i.e. 22.51 inch

Runoff in inch = (P-7) x P ÷100

= (22.51-7) x 22.5 ÷100

= 3.49 inch

Yield = 2.3232 x Runoff in inch x catchment Area

Yield = 2.3232 x 3.49 x 43.40

Yield = 351.89 Mcft

Yield = 2.3232 x 3.49 x 43.40

Yield = 9965.5 Tcm

Yield = 9965524.8 m^3 **that is 9.965 Mm^3**

Irrigation water requirement

Irrigation water requirement is the main demand. It is obtained from data of Culturable command area and water requirement of crops as given area in following table

Culturable command area in watershed 5822.62 Hectare

58.2262 Km^2

14387.69 Acre

Table VI Crop Pattern and Water Requirement for Irrigation

Name of Crop		Area in %	Delta (m)	Actual Area in Hectare	Volume water in Hectare-m
Kharif Crop					
1	Bajara	55	0.300	3202.44	960.73
2	Ground nut	11	0.450	640.49	288.22
3	Deshi Cotton	22	0.450	1280.98	576.44
4	Vegetable	12	0.900	698.71	628.84
Rabi Crop					
5	Wheat	65	0.375	3784.70	1419.26
6	Jowar	15	0.30	873.39	262.02
7	gram	10	0.30	582.26	174.68
8	Vegetable	10	0.30	582.26	174.68
Total Area in Hectare Meter =					**4484.87**

Irrigation Water requirement is 44848730.55 cubic meter that is 44.849 Mm^3. In above calculation it is assumed that the entire Culturable command area will be irrigated; that is intensity is 100%. If intensity of irrigation is assumed as 20%, then Irrigation water demand = 44.849 x 0.20 = 8.790 Mm^3

So maximum population can be obtained by Geometric increase method and it considered in further analysis.

G. Population forecasting

Table VII Comparison of population forecasting by three methods

Population Year	Method 1 Arithmetic Increase Method	Method 2 Geometric Increase Method	Method 3 Incremental Increase Method.
P_{2021}	40682	40861	39790
P_{2031}	43044	43569	40368
P_{2041}	45406	46458	40054

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For calculating total annual demand of the area following demands have been considered;

1. Irrigation water demand = 44.849 Mm3
2. Domestic water demand = 135 l/h/d
3. Industrial water demand is neglected because the village area is not Industrialized
4. Institutional and commercial water demand = 20 l/h/d
5. Public uses = 10 l/h/d

Thus total water demand including domestic demand, Institutional and commercial demand and public uses demand is = 135+20+10=165 l/h/d that is 0.165 m^3/head/day
So, Total daily demand (for year 2011) = (38320 x 0.165)

= 6322.8 m^3 and

Total annual demand (for year 2011) = (6322.8 x 365) $\div 10^6$

= 2.308 Mm^3

Similarly total annual public water demands for year 2021, 2031, and 2041 are as given below

For year 2021= (40861x0.165x365) $\div 10^6$ = 2.461Mm^3

For year 2031= (43469x0.165x365) $\div 10^6$ = 2.624Mm^3

For year 2041= (46458x0.165x365) $\div 10^6$ = 2.798Mm^3

V. RESULTS AND DISCUSSION

The water budget of any watershed consists of two main parameters, that is

1. Total annual inflow that is annually runoff and
2. Total annual demand of water.

The total annual water received in the form of precipitation, total annual runoff and actually available in storage works are given below

Table VIII Surface Available Water on watershed

Particulars	Cubic meter (Mm3)	Mcft
Maximum yield water on watershed area	11.488	405.66
Available water in all existing reservoirs	1.448	51.08

The above table shows that the annual runoff is about 18% of total rainfall received. Remaining 82% of the rainfall is evaporation and ground water. The table also shows that there is much more scope for construction of storage works that is bandharas, dams etc; because total available water in all existing storage works is about 13% of annual runoff. The total annual water demand can be divided in to two main parts, that is

1. Annual irrigation demand, which is nearly 95% of the total annual demand. This demand is assumed to be constant and
2. Public demand consisting of domestic, institutional and commercial, and public use demands. These demands increased, depending on population.

All these demands along with annual runoff are shown in following table

Table IX Comparison of annual available water and future demands

Year	2011	2021	2031	2041
Annual runoff (Mm^3)	11.488	11.488	11.488	11.488
Irrigation demand (Mm^3)	44.849	44.849	44.849	44.849
Public Demand (Mm^3)	2.308	2.461	2.624	2.798
Total annual demand (Mm^3)	47.157	47.310	47.473	47.647
Irrigation demand assume intensity of irrigation as 20% (Mm^3)	8.970	8.970	8.970	8.970
Irrigation demand assume intensity of irrigation as 20% (Mm^3)	11.278	11.431	11.594	11.768

From the above table it is clear that the annual runoff is nearly 25% of the annual irrigation demand if it is calculated by assuming intensity of irrigation as 100% that is the entire Culturable command area will be irrigated. Ground water is not considered in above calculations. Generally intensity of irrigation is very less. In Maharashtra state intensity of irrigation is 20%. If 20% is the intensity of irrigation then the annual runoff is nearly sufficient to satisfy all the demands, (refer column 6 and 7 of table no 22). Generally more than 50% irrigation is carried out using well water that is ground water. So even if 20% of CCA is given assumed supply from storage works, it will be sufficient. But it is possible only if all runoff is stored in storage works such as bandharas, dams etc.

VI. CONCLUSION AND FUTURE SCOPE

1. The watershed of Bhad river, a tributary of Panzara river, has been studied with report to water budget. Study of water budget gives better understanding of supply and demand and steps to be taken to arrangement the supply. The gross area of the watershed is 112 km2 but the population is only 38320. The area is hilly having some Aadivasi population. The runoff water is not sufficient to satisfy the irrigation demand if entire CCA is to be irrigated completely. Ground water has not been considered in calculating input or supply.
2. Future scope of this project is to study ground water yield by carrying pumping tests and recuperation tests on wells. There are hundreds of wells in all the 12 villages of the watershed. Representative Wells may be selected and ground water yield can be calculated.
3. Also future scope is to suggest various methods of recharging the rain water into ground, so that more and more water will be stored in ground water and runoff

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will be less and hence losses will be less. Also to harness all the runoff water, it is necessary to suggest the construction of dams/bandharas at suitable locations.

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