Hydrogeology of the Vidrupa River basin, Akola District, Maharashtra, India with reference to water level fluctuation

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Abstract: Water is one of the main resources essential for the overall socio-economic development of any region and it requires careful planning and appropriate exploration. The study area (Vidrupa River basin) is characterized by the presence of 380 m thick pile of horizontal lava flows of Deccan Traps with the presence of Purna alluvial deposits. The topography is characterized by the presence of flat terraces of lava plateau, lava hill, mesa, butte, escarpment and linear ridges, which have been resulted from lateral erosion. The heterogeneous nature of the basaltic lava flows exposed in the study area is clearly evident from the wide variation in the hydro-geological parameters of these basalts; mainly their permeability and porosity resulted from the nature and degree of weathering, fracture pattern and jointing. Geomorphological studies have demonstrated the presence of five distinct landforms namely shallow dissected plateau, moderately dissected plateau, highly dissected plateau, undulations and valley fills. The shallow dissected plateau is characterized by the presence of thick weathered mantle ranging from 6 to 10m with less dissection, and intersecting lineaments indicating a potential storage zone. The depth to water level ranges from 15- 25 m bgl. The safe yield in the open dug wells various from 40-85m/d with sustained discharge of over 4 hours indicating phreatic and confined to semi confined aquifer conditions. The moderately dissected plateau occurs along the fringes of steep scarps indicating moderate thickness of the weathered horizons showing 2-6m. The bed rock is shallow and depth to water level various from 4-9m bgl with moderate water bearing horizons depending upon the placement of interflow zone suggesting the recharge nature and higher hydraulic potential. The highly dissected plateau is characterized by the presence of compact and massive lava flows showing intricate network of dissection. The availability of groundwater is scare due to negligible weathered mantle except where the top portion is either altered or due to the presence of vesicular horizon, which may retain some groundwater. The undulating plains represent potential groundwater horizons due to the availability of aquifer zones where the depth to water levels various from 10-14 m. bgl.In this study an attempt has been made to understand the hydrogeological parameters of the study area with special reference to groundwater level fluctuations to delineate the potential aquifers in the basaltic terrain. A comparison of water levels for the last four years brings out a clear picture of water level declines in major parts of the territory. The water levels and fluctuations during these periods indicate an urgent need for adopting the recharge techniques with suitable water resource management plan for the sustainable development of the region. In this study an attempt has been made to understand the environmental management of the region with emphasis on water resource management.

Key Words: *Hydrogeology, Aquifer zones, Vidrupa River, Water level fluctuations, Safe yield*

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I. INTRODUCTION

In this study area of the data gathered from GPS surveys and from environmental remote sensing systems can be fused within a GIS for a successful characterization and assessment of watershed functions and conditions. When faced with challenges involving water quality and quantity due to natural as well as human-induced hazards (e.g., droughts, hazard material spills, floods, and urbanization), planning becomes extremely important so as to mitigate their impacts and ensure optimal utilization of resources. Information obtained from characterization and assessment studies, primarily in the form of charts and maps can be combined with other data sets to improve understanding of the complex relationships between natural and human systems as they relate to land and resource use within watersheds. GIS provides a common framework – spatial location – for watershed management data obtained from a variety of sources. Thedatabase is created using various techniques for the watershed management and morphometric analysis the drainage map is digitized from Survey of India toposheets and open source satellite image using Arc Map software. The land use /land cover map created using supervised and unsupervised classification method in ERDAS Imagine software and Arc GIS 10 versions. Other thematic layers like soil, geomorphology, DEM, slope, land use land cover, and drainage density are also generated using Arc Map software using the available reference data. The Morphometric analysis is mathematical calculation of the parameter likes stream order, bifurcation ratio, and drainage density and so on. For the Morphometric analysis Geographic information system techniques has been used and Strahler (1964) stream order method used for stream ordering.

The crisis about water resources development and management thus arises because most of the water is not available for use and secondly it is characterized by its highly uneven spatial distribution (Wani, et al. 2002). Physical development will improve the economic situation significantly and lay a foundation for the support of improvement in living standards of the beneficiaries by the added income.

STUDY AREA

The study area is located at Telhara and Akot Taluka of Akola district of Maharashtra covering Survey of India toposheet no 55C/16 and D/13. The study area is covered by Purna Alluvium and is located at about 145 km from Amravati and about 75 km from Akola between. 20° 54' 30” to 21° 14' 35" N latitudes and between 76° 48' to and 77^0 03’E longitudes (Fig.1)

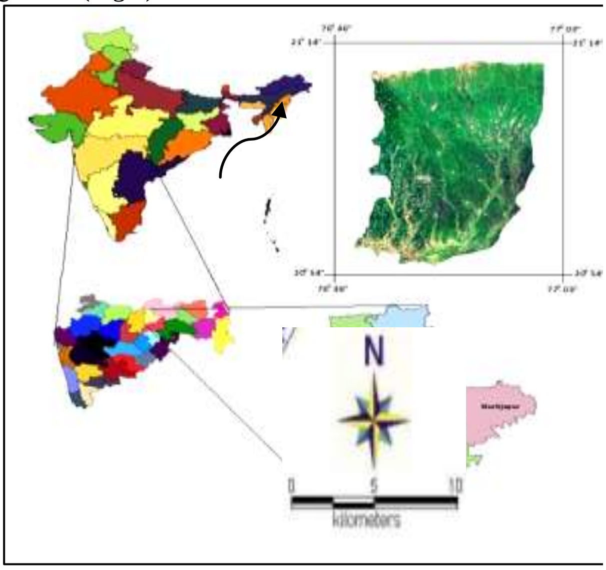

Figure1. Location map of the study area

II. MORPHOMETRY ANALYSIS

Morphometric analysis is giving very important in evaluating drainage pattern and watershed management programs of the watershed area. The study area is dominated by erosional land forms like lava plateau, lava plains, linear ridges, conical hills, mesa, butte and escarpments, and depositional landforms such as alluvial cones, alluvial fans, and Bajada deposits.Remote Sensing (RS) and Geographical Information System (GIS) techniques has in delineation of drainage pattern and it provides effective solutions to overcome most of the problems of land and water resources planning and management arising due to usage of conventional methods of data collection. Morphometric is the measurement and mathematical analysis of configuration of the earth surface and the shape and dimensions of its landforms (Thornbury, 1969). Horton, who made the first modern quantities studies of drainage basins provided theoretical base for the hydro geomorphic approach by suggesting that there were certain unvarying or intransient drainage basin characteristics that correlate to the hydrologic response of a basin. His laws of drainage composition were later modified by Strahler, 1952. The detailed Morphometric analysis of Vidrupa river basin reveals the predominance of dendritic, trellis and parallel drainage patterns with the presence of 5th order stream. On the basis of projection of the stream channel system to the horizontal plain, various morphometric parameters such as length. Area and arrangement etc. were computed.The linear aspects were studied using the methods of Horton (1945), Strahler (1957), Chorley (1967), the areal aspects using those ofSchumm (1956), (Table 1, 2 and Fig. 2).

Table I. Dimensions of Drainage Basin Exposed In The Study Area.

Name of River	Vidrupa					
Order of Streams	5					
	1	2	3	4	5	Total Length
Number of Streams	635	143	31	7	1	
Length of Streams(Km)	596.36	295.24	142.18	107.37	32.24	1173.3840
Bifurcation Ratio Rb= lower order/higher order	4.4406	4.6129	4.4286	7		
Area of Basin	653.8064 Sq. Km.					

Table II. Morphometric Analysis Results Of Drainage Basin Exposed In Study Area

Parameter	Formula	Vidrupa Basin
Area of the Basin	Ab	653.8064 Sq. Km
Perimeter	P	127.01 Km
Total number of Streams	Sum of 1st to 5th order streams	817
Total Stream Length	Sum of all orders stream	1173.3840 Km
Drainage density (D)	∑Li/ Ab	1.7947
Drainage Frequency (Sf)	N/Ab	1.2496
Length of Overland Flow	1/2D	0.2785
Basin Shape (Rf)	Ab/(L)2	0.7180
Relief (H)	Highest Elev. In the basin – Elevation at the basin mouth	664m
Ruggedness Number (R)	DH	1.1917
Relief Ratio(Rh)	H/L	0.0220

III. LAND USE LAND COVER

Land Cover, defined as the assemblage of biotic and a biotic components on the earth’s surface is one of the most crucial properties of the earth system.Land use and land cover is an important component in understanding the interactions of the human activity with the environment and thus it is necessary to be able to simulate changes. Land use refers to man’s activities and the varied uses which are carried on over land and land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and others noticed on the land.The land use/ land cover is derived from the LISS-III Open Source satellite image using image classification techniques such as supervised and unsupervised. The most of the land is under agricultural crop land in the present study area and other area is covered by forest, built up, waste land, and Water body. Land use describes how a parcel of land is used such as for agriculture, settlements or industry, whereas land cover refers to the material such as vegetation, rocks or water bodies that are present on the earth surface. The water bodies include river, canal, tank, pond and reservoir

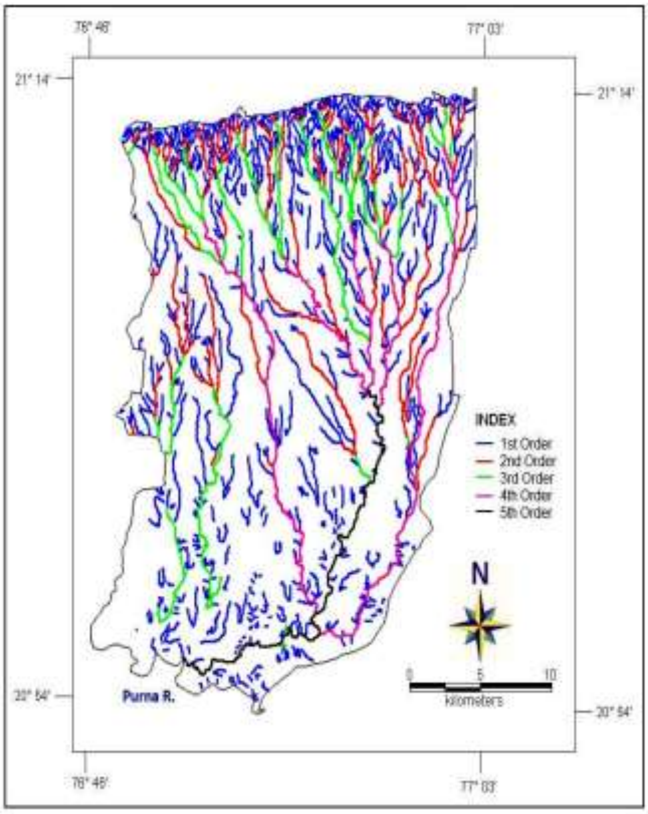

Figure 2. Drainage Map of the Study Area

Figure 3. Land Use Pattern Map of The Study Area.

VI. GROUND WATER PROPERTIES OF THE VIDRUPA RIVER BASIN

The Vidrupa river basin is characterized by the presence of thick alluvium, fractured, jointed basalt and compact, massive basaltic horizons showing variable groundwater content. The main groundwater bearing properties of the formation are described as follows.

A. Deccan Traps

The Deccan trap has three different water bearing horizons viz. massive basalt (Jointed, fractured), vesicular basalt and weathered basalt. In Deccan traps, the permeable zone includes the flows, themselves. The basic properties such as ability to receive recharge, hold water in storage and transmit it by gravity are different for different litho logical units of the trappean flows. In basalt groundwater occurs generally in unconfined condition. In general, the physical characters of basalts control the groundwater potential, its degree of weathering and weathered products.

B. Massive Basalt

The some part of study area is consisting Deccan trap which is composed of massive basalt. It is the main water bearing formation of the area. Massive basalt as such doesn't have primary porosity and permeability except some fractures and joints. The joints, which are later, enhanced by weathering along the joint plains, are the major conduits for water storage and transmission. Occasionally, the closely spaced interconnecting joints present in between the massive horizons may contribute towards the formational porosity and can form productive zones. The size and number of vesicles, degree of weathering and jointing pattern mainly control the water productivity and yielding strength of aquifer in basaltic terrain. Moderate discharge is observed in dug wells at Bhilli, Chippi, Dhondakhar and Shahapur villages in the basin.

C. Vesicular Basalt

The vesicular basalt occurs at some places in area followed by massive basalt; this unit of flow, unlike the massive part possesses primary porosity and permeability. Even at depth the weathering character is conspicuous, as there exists a time lag between the successive lava flows. Very often the vesicles in it are interconnected thereby making it highly permeable. Many times the vesicles found in portions of the unit immediately above the massive part are not interconnected and their characteristics are same as that of massive unit. Hence gradation from such compact and sparsely connected vesicular part to highly porous vesicular part above is very common. The vesicles of upper surface are filled by secondary calcareous material.

D. Weathered Basalt

It is upper part of flow weathered part either of massive basalt or/and vesicular basalt. This part is found at most of the places where the slope of the ground is less. The thickness of this part is about 2 to 3 meters and below that it grades into massive basalt or hard vesicular basalt. It becomes productive when it is located in geomorphologically lower parts of the area. Large diameter shallow dug-wells are common groundwater extraction

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structures in these aquifers. The type of aquifer is found in PWS dug well at village Chippigayran near the nala cutting.

VII. GEOMORPHOLOGICAL CONTROL FOR GROUNDWATER POTENTIAL

The geomorphology plays major role for occurrence and movement of groundwater. On the basis of field traverses and remote sensing interpretation, the important factors, which play a major role in the occurrence of groundwater, are as given below.

A. Topography

The area of investigation is traversed by the Vidrupa river basin experiencing subtropical to tropical monsoon climate. Undulating relief marked the study area with the presence 700 m to 500 m and 350 m thick lava files. The general slope of study area from North to South and the area is characterized by typical Deccan trap topography to alluvial tract. The area is demarcated by the presence of diversified heterogeneity within rock formation, which in turn affects ground water potential. The wells located at topographic low have better yield than those on topographic high. The topographic low forms water table convergence and hydraulic trough. Water in water table conditions moves down gradient to areas of topographical low. Thus most of high to moderate yielding dug wells are located in topographic lows. In case of tube wells, even though they can penetrate multiple aquifer system of alluvial terrain, percolation of water at higher altitudes to deeper aquifer is less.

1. Sand / clay ratio in case of alluvium.
2. Type of aquifer (Lithology)
3. Nature and extent of weathering.
4. Thickness of vesicular unit.
5. Nature of vesicles, their density, distribution and interconnection.

All the above motioned factors show considerable amount of lateral and vertical variations, but together they decide the potentiality of groundwater structures in the area (Fig. 4 and 5).

VIII. GROUNDWATER LEVEL FLUCTUATIONS

Groundwater level fluctuation is mainly dependent on the difference in water levels of pre monsoon and post monsoon periods, which can be directly linked, lo recharge and discharge of groundwater. The pre and post monsoon water level fluctuations were calculated based on the data of 40 wells established in the area. The result indicates four distinct zones viz., low water level fluctuation zone (< 1.5 m.), moderate water level fluctuation (1.5 – 3.5 m.), moderately high water level fluctuation zone (8-15 m.) and high water level fluctuation zone (>6). A map has been prepared to mark the different zones of fluctuation (Table 5.1, 5.5). The seasonal fluctuation of ground water level between the pre-monsoon and post-monsoon period for both the years varies between 0.50 to 9-m bgl Most of the study area is characterized by moderate to moderately high water level fluctuation. The low water level fluctuation is more prominent in the region, which is controlled by recharge of groundwater by surface irrigation. Whereas high level mining of groundwater during non-monsoon seasons for irrigation purpose causes fluctuation (Fig. 6 a & b, Table 4 and 5).

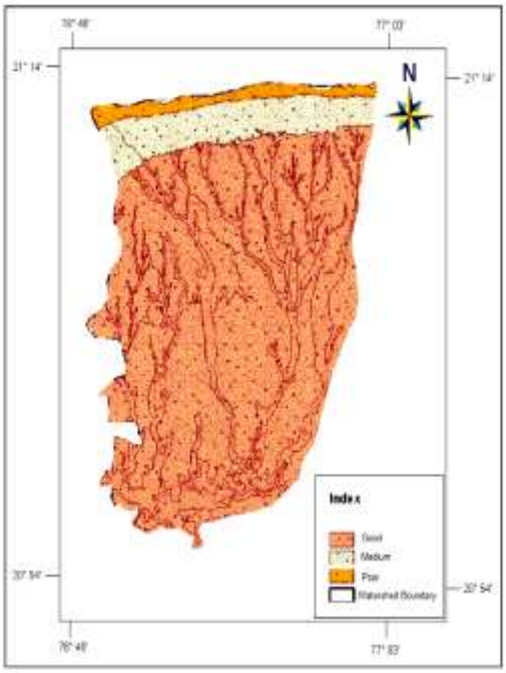

Figure 4. Hydro geomorphological Map of The Study Area

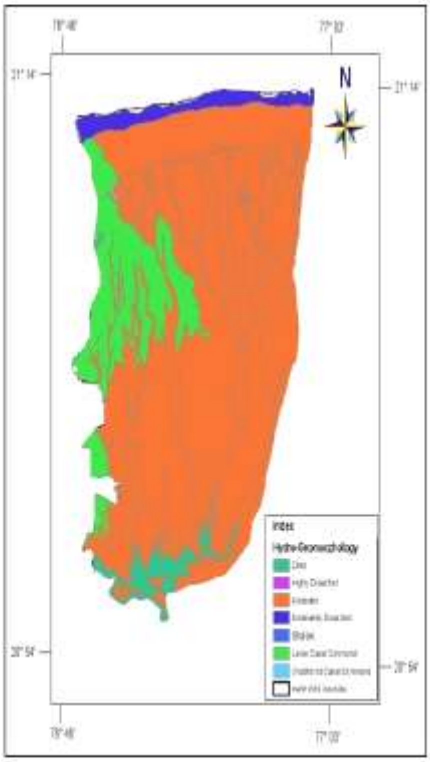

Figure5. Hydrogeological Map of the Study Area

Table III. Details of dug wells representing hydrological parameter of study area (Pre Monsoon SWL for Year 2010)

S N	Taluka	Village	Aquifer type	Well diameter (mtr)	Well depth (mtr)	Pre Monsoon Static water level(mtr)
1	Telhara	Pathardi	Alluvium	1.85	16	13.20
2	Akot	Pimpalkhuta	Alluvium	2.55	38.80	34.80
3	Telhara	Wadner	Alluvium	3.85	19.10	18.00
4	Telhara	Tudgaon	Alluvium	4.50	21.00	20.00
5	Akot	Nevrikh	Alluvium	3.15	37.85	35.30
6	Akot	Lohari	Alluvium	1.90	27.40	24.70
7	Akot	Mundgaon	Alluvium	4.10	21.65	20.00
8	Akot	Sirsoli	Alluvium	2.60	24.50	17.30
9	Telhara	Warud bk	Alluvium	2.80	20.10	18.00
10	Akot	Kari prrupa	Alluvium	3.60	36.00	29.00
11	Telhara	Khairkhed	Alluvium	4.30	41.30	27.30
12	Telhara	Dhondakhar	W.V.B.	3.40	12.70	9.60
13	Telhara	Chippi	W.V.B.	3.00	5.20	3.00
14	Telhara	Bhilli	W.V.B.	6.10	13.60	9.50
15	Telhara	Kalegaon	Alluvium	3.00	23.60	16.70
16	Telhara	Dapura	Alluvium	1.80	14.30	13.00
17	Telhara	Khakta	Alluvium	3.90	12.80	10.60
18	Akot	Sadarpur	Alluvium	2.40	27.00	27.00
19	Telhara	AkoliRupra	Alluvium	1.50	21.60	18.30
20	Telhara	Talegaon	Alluvium	4.90	19.60	15.40
21	Telhara	Dawala	Alluvium	4.50	17.40	17.00
22	Telhara	Pathardi	Alluvium	1.85	16.00	13.20
23	Telhara	Talegaonkh	Alluvium	3.80	26.60	21.20
24	Telhara	Babulgaon	Alluvium	2.90	21.50	20.00
25	Telhara	Malthanabk	Alluvium	5.25	21.90	20.90
26	Telhara	Adgaonbk	Alluvium	3.20	22.55	20.50
27	Telhara	Hiwarkhed	Alluvium	2.60	34.80	33.00
28	Telhara	Manabda	Alluvium	3.50	13.90	12.00
29	Telhara	Bambarda	Alluvium	3.00	14.80	12.70
30	Telhara	Manatri bk.	Alluvium	3.00	15.50	13.40
31	Telhara	Wadgaon	Alluvium	4.10	16.30	14.00
32	Telhara	Jastagaon	Alluvium	2.60	20.80	15.40
33	Telhara	Adampur	Alluvium	2.20	25.40	24.00
34	Telhara	Dahigaon	Alluvium	3.70	25.80	23.10
35	Telhara	Umra	Alluvium	2.80	33.50	33.20
36	Akot	Chorwad	Alluvium	3.10	23.10	23.10
37	Akot	Mundgaon	Alluvium	2.55	38.80	34.80
38	Akot	Pimpalkhuta	Alluvium	1.35	36.50	34.80
39	Akot	PimprIKh	Alluvium	2.10	41.00	41.00
40	Akot	JainpurPimpri	Alluvium	3.35	29.20	29.00

W – Weathered V - Vesicular B – Basalt, AL- Alluvium

Table V. Details of dug wells representing hydrological parameter of study area (Post Monsoon SWL For Year 2010)

S.N	aluka	Village	Aquifer type	Well dia (mtr)	Well depth (mtr)	tatic water evel(mtr)
1	elhara	Pathardi	Alluvium	1.85	16.00	9.70
2	kot	Pimpalkhuta	Alluvium	2.55	38.80	33.00
3	elhara	Wadner	Alluvium	3.85	19.10	17.00
4	elhara	Tudgaon	Alluvium	4.50	21.00	20.00
5	kot	Nevrikh	Alluvium	3.15	37.85	27.00
6	kot	Lohari	Alluvium	1.90	27.40	23.00
7	kot	Mundgaon	Alluvium	4.10	21.65	1.00
8	kot	Sirsoli	Alluvium	2.60	24.50	13.90
9	elhara	Warud bk	Alluvium	2.80	20.10	17.00
10	kot	Kari prrupa	Alluvium	3.60	36.00	21.25
11	elhara	Khairkhed	Alluvium	4.30	41.30	18.90
12	elhara	Dhondakhar	W.V.B.	3.40	12.70	1.00
13	elhara	Chippi	W.V.B.	3.00	5.20	0.20
14	elhara	Bhilli	W.V.B.	6.10	13.60	2.80
15	elhara	Kalegaon	Alluvium	3.00	23.60	15.50
16	elhara	Dapura	Alluvium	1.80	14.30	12.00
17	elhara	Khakta	Alluvium	3.90	12.80	8.80
18	kot	Sadarpur	Alluvium	2.40	27.00	27.00
19	elhara	AkoliRupra	Alluvium	1.50	21.60	16.00
20	elhara	Talegaon	Alluvium	4.90	19.60	14.00
21	elhara	Dawala	Alluvium	4.50	17.40	16.20
22	elhara	Pathardi	Alluvium	1.85	16.00	14.30
23	elhara	Talegaonkh	Alluvium	3.80	26.60	16.00
24	elhara	Babulgaon	Alluvium	2.90	21.50	19.00
25	elhara	Malthanabk	Alluvium	5.25	21.90	19.00
26	elhara	Adgaonbk	Alluvium	3.20	22.55	19.20
27	elhara	Hiwarkhed	Alluvium	2.60	34.80	27.00
28	elhara	Manabda	Alluvium	3.50	13.90	12.00
29	elhara	Bambarda	Alluvium	3.00	14.80	11.00
30	elhara	Manatri bk.	Alluvium	3.00	15.50	12.10
31	elhara	WadgaonRothe	Alluvium	4.10	16.30	14.00
32	elhara	Jastagaon	Alluvium	2.60	20.80	15.00
33	elhara	Adampur	Alluvium	2.20	25.40	23.00
34	elhara	Dahigaon	Alluvium	3.70	25.80	21.20
35	elhara	Umra	Alluvium	2.80	33.50	33.20
36	kot	Chorwad	Alluvium	3.10	23.10	23.10
37	kot	Mundgaon	Alluvium	2.55	38.80	1.20
38	kot	Pimpalkhuta	Alluvium	2.55	38.80	30.50
39	kot	PimprIKh	Alluvium	2.10	41.00	41.00
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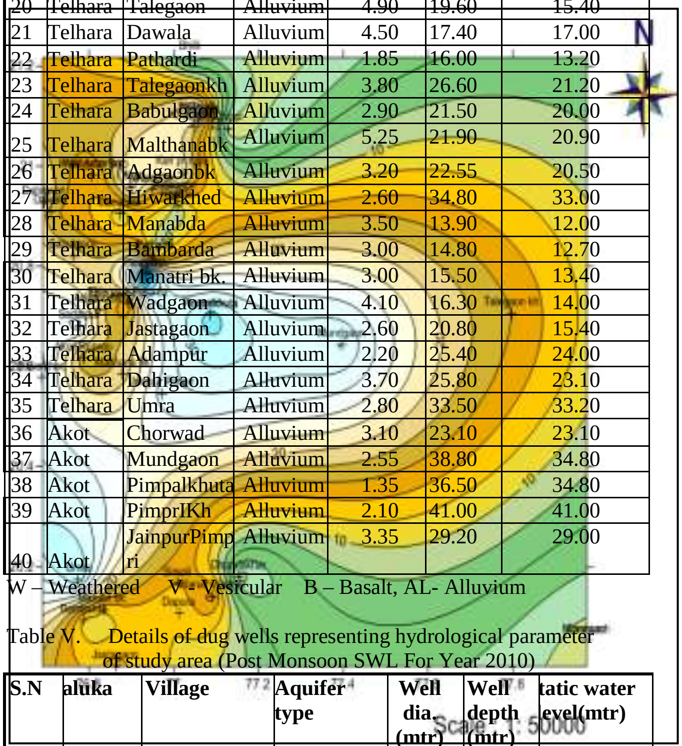

Figure 6. Water Table Contour Map of The Study Area (Summer 2010)

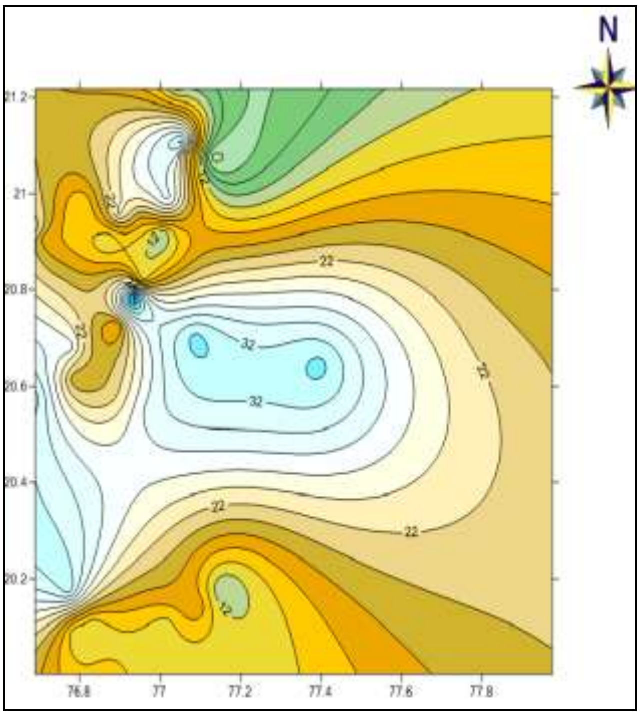

Figure 7. Water Table Contour Map of the Study Area (Winter 2010)

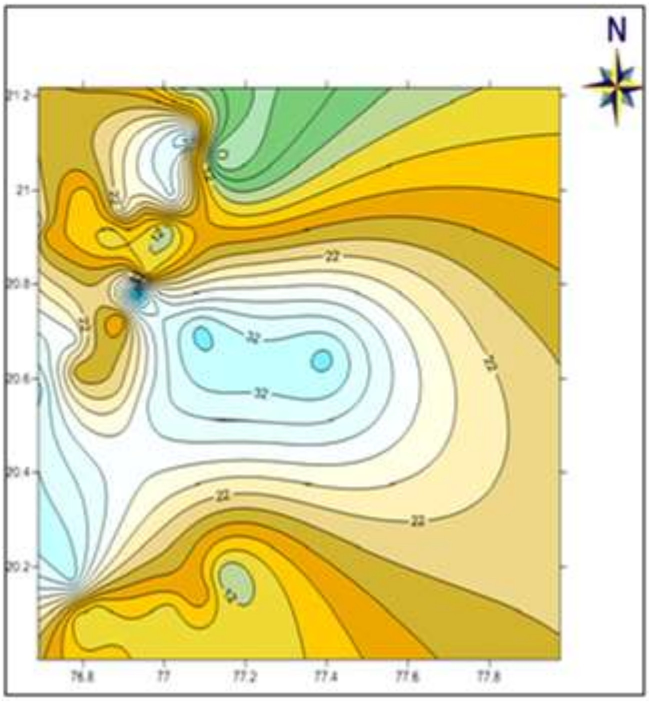

Figure 8. Water Table Contour Map of the Study Area (Winter 2009)

IX. CONCLUSION

In this study an attempt has been made to understand the hydrogeological investigations of Vidrupa River basin, Akola District, Maharashtra with reference to water resource management by utilizing remote sensing and GIS techniques. The modeling and visualization capabilities of modern GIS, coupled with the explosive growth of the Internet and the World Wide Web, offer fundamentally new tools to understand the processes and dynamics that shape the physical, biological and chemical environment of watersheds. The linkage between GIS, the Internet, and environmental databases is especially helpful in planning studies where information exchange and feedback on a timely basis is very crucial and more so when there are several different agencies and stakeholders involved. Remote sensing and GIS techniques have been utilized to not only to understand the morphometric parameters of the Vidrupa River basin, but also various other parameters like land use land cover, hydro geomorphological parameters, landforms along with the digital elevation model to quantify the groundwater potential zones in the region. This study has demonstrated the presence of potential groundwater zones by demarcating the potential aquifers which will be useful in developing the groundwater regime of the region.

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