Groundwater Potential Zone Mapping using Geo-spatial Tools for Watersheds in Upper Bhima Basin, Pune, India

Shivaji Govind Patil, Ravindra Krishnarao Lad

Abstract: ***Water is one of the primary requirements of any region for sustainable economic development. There are number of limitations regarding availability of surface and subsurface water due to various reasons, hence exploration of groundwater becomes inevitable. Main objective of this study was to map groundwater potential zones for study area using geospatial tools; which comprises of watersheds in Upper Bhima Basin, Pune district. The primary groundwater controlling factors considered are geomorphology, soil, land use land cover, slope, drainage density and lineament density; for which respective maps were prepared using satellite image, toposheets and incidental data. Maps for various layers according to above said controlling factors were generated from different data collected. Finally these thematic layers were integrated using ArcGIS software to prepare groundwater potential zone map for the study area. Groundwater potential zones were marked as 'very poor', 'poor', 'moderate', 'good' and 'very good', based on knowledge based weightage factor. This, geo-spatial techniques based, result was validated using field data collected from the study area. It is concluded that using geospatial tool, identification and mapping for groundwater potential zones become comparatively easy task with saving lot of time and cost and with greater accuracy.***

Keywords**:** ***geomorphology, groundwater, remote sensing, spatial analysis.***

I. INTRODUCTION

In this information technology age, digital technology is used to integrate and analyse various data types to delineate groundwater prospect zones as well as to solve other problems related to the groundwater. This study is an attempt made in this direction by using geo-spatial tools to delineate groundwater prospect zones. Geo-spatial tool proves cost effective and effective to generate significant data on different groundwater controlling factors, which indicates groundwater prospect zones due to their characteristics relating to groundwater.

Manuscript published on November 30, 2019.
* Correspondence Author

Mr. Shivaji Govind Patil*, Research Scholar, Civil Engineering Department, JSPM's Rajarshi Shahu College of Engineering, Tathawade, Pune, Savitribai Phule Pune University, Pune, India.

Dr. Ravindra Krishnarao Lad, Research Guide, JSPM's Rajarshi Shahu College of Engineering, Tathawade, Pune, Director, JSPM Narhe Technical Campus, Savitribai Phule Pune University, Pune, India.

The groundwater maps show that the area where groundwater recharge is high, the degree of mismatch between the stimulated and surveyed drainage is high. Such mismatch between stimulated and surveyed drainage networks can be exploited to delineate the groundwater recharge zones [1]. Conclusion from the study is that the integrated approach provides an appropriate platform for convergent analysis of multi-disciplinary data for artificial recharge of groundwater [2]-[4]-[10]. The study reveals that integration of thematic maps for various influence factors provides data bank information to local authorities and planners for groundwater exploration and management. Weathered and fractured zones, granite, gneiss, schists and pegmatite are identified as major water bearing formations [3]. The method, based on logical conditions and reasoning, is applicable for other regions, which is also less expensive and more suitable; where adequate and good quality hydrogeologic data is lacking for groundwater evaluation [5]-[6]. The concept of integrated remote sensing and geographical information system has proved to be very useful in conducting studies of groundwater resources. The groundwater potential map is prepared considering various controlling factors, which influence the occurrence, movement, depth and yield of groundwater. It is significant, not only for groundwater potential zones but also for conserving groundwater [7]-[9]-[14]-[18]-[19]. The area which exhibits intersection of lineaments is considered as good area of potential for groundwater accumulation and recharge. It is very helpful for resolving problems relating to lack of details, which occurs during conducting GIS analysis, with proper interpretation [8]-[10]. The groundwater potential information obtained by using remote sensing and GIS helps to identify the reliable spots for exploitation of groundwater [11]. The remote sensing provides current spatial disposition of basic information of different factors related to groundwater with less time and with less cost when compared with traditional methods and also supplement for detail hydrogeological mapping for extraction of groundwater [12]-[13]-[15]-[16]-[17]-[20]. The connection of the geomorphological feature characteristics provides a view to understand the watershed and groundwater circulation model [21]. It becomes, therefore, necessary to adopt a systematic approach such as ground truthing, hydrogeological investigation, etc. for effective, fast and accurate mapping of groundwater potential zones.

Many researchers followed the comprehensive approach of remote sensing and geo-spatial techniques, mainly for identification of groundwater potential zones and for few studies included locating the artificial recharge sites too.Main objective of this study was to map groundwater potential zones using Geo-spatial tools for study area which comprises of two watersheds in Upper Bhima Basin, Pune district.

II. STUDY AREA

It is located in Purandar and Baramati taluka in Pune district of Maharashtra between 18^{o} 25' 0" N Latitude and 74^{o} 27'0" E Longitude and having spread over of two watersheds viz. BM 58 and BM 60, as designated by Groundwater Surveys and Development Agency, Govt. of Maharashtra. The study area comprises of total 57 villages, alongwith some part from urban area.

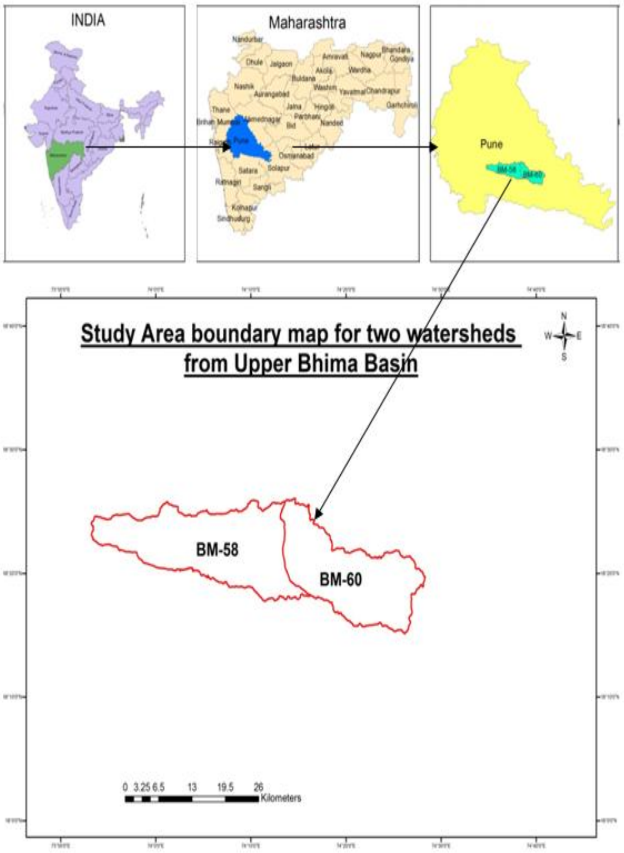

Fig. 1: Location Map of study area

III. DATA USED AND METHODOLOGY

A. *Data Used:*

For the research work primary and secondary data was required and out of total data, procured data are as below:

(a) Primary Data:

(i) Field observations for locations of observations wells
(ii) Field observations for water table depths for Pre-Monsoon and Post-Monsoon period

(b) Secondary Data:

(i) Watershed Maps: Source-Groundwater Surveys and Development Agency (GSDA), Govt. of Maharashtra
(ii) Toposheets: Source - Survey of India
(iii) DEM: Source - http://bhuvan.nrsc.gov.in
(iv) Satellite Imagery: http://nrsc.gov.in
(v) Groundwater Ancillary data - Source-Groundwater
(vi) Surveys and Development Agency (GSDA), Govt. of Maharashtra
(vii) Geological Map: Source- Geological Survey of India
(viii) Soil Map: Source - Agriculture Deptt., Govt. of Maharashtra

B. *Methodology*:

The general methodology used for study is as under:

(i) Collection of spatial and non-spatial data
(ii) Geo-processing of spatial data using GIS software
(iii) Extraction of various groundwater controlling features using GIS software and generation of thematic maps
(iv) Integration of spatial and non-spatial data and conducting GIS analysis to assess and identify the groundwater potential zone
(v) Preparation of groundwater potential zones map
(vi) Validation to be done using field observations comprised of well inventory and water table fluctuation investigations.

IV. GENERATION OF THEMATIC MAPS

Two watersheds from the maps, designated as BM-58 and BM-60 by GSDA, obtained from GSDA, are chosen for present study area, considering the characteristics of these watersheds. These two watersheds are designated as BM-58 and BM-60 by GSDA and are having spread over in the parts of Purandar and Baramati Taluka of Pune district in Maharashtra, having area of 326.18 sq. km. and 266.18 sq. km. respectively, i.e. study area is having total area of 592.36 sq. km. Study area falls under three toposheets viz. E43I3 (47J3), E43H15 (47F15), and E43I7 (47J7), and these toposheets were procured from Survey of India.

Satellite image (LISS III; dated Jan-2013) was downloaded from the website http://bhuvan.nrsc.gov.in, and clipped for the study area using shape file of boundary of study area i.e. for both the watersheds and DEM was downloaded from the website http://bhuvan.nrsc.gov.in, and clipped for study area. From the DEM, first map with elevation values is prepared, which shows the elevation values ranging from 575 m to 1101 m.

A. *Slope:*

The slope angle of a basin is a morphometric factor of hydrological relevance. The slope is important factor in the study of groundwater as infiltration is directly affected by this factor. As slope increases chances of infiltration gets dimmed and obviously groundwater potential reduces depending on the nature of the slope i.e. gentle, steep, etc. A slope (%) map was generated and it is observed that slope values are in the range of 0 ^{o} to 80.45^{o}. The slope (%) map is exhibited as below

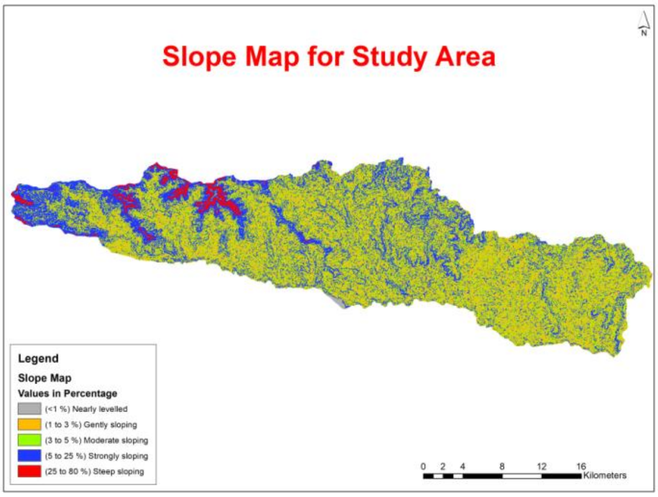

Fig. 2: Slope (%) map

B. *Geomorphology:*

It influences groundwater on large scale, due to its nature and scope in groundwater activities. In the study area different geomorphological forms are observed, which influences the groundwater occurrence and movement. The major geomorphological features in the study area observed were plateau slightly dissected (0.1 m weathering), followed by plateau weathered (1.2 m weathering). From the data procured from GSDA, geomorphology map was prepared, using Geo-spatial tools, indicating all the sub-classes of geomorphological features in the study area. The geomorphology map is exhibited as below

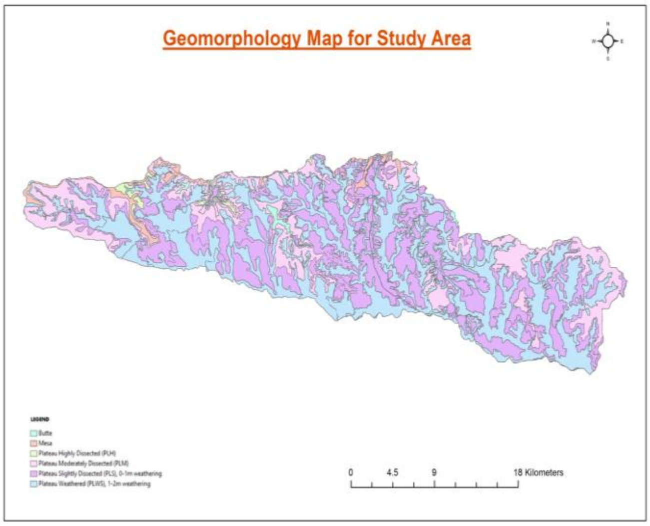

Fig. 3: Geomorphology map

C. *Drainage Density:*

It acts as important parameters for analysis of a drainage basin. Drainage density also has a bearing on the permeability of the rocks. From the toposheets and ancillary data, drainage map was prepared showing all the drainage streams occurring in the study area, using geo-spatial tolls. Then using grids, drainage density map for the study area was prepared. The drainage density map is exhibited as below

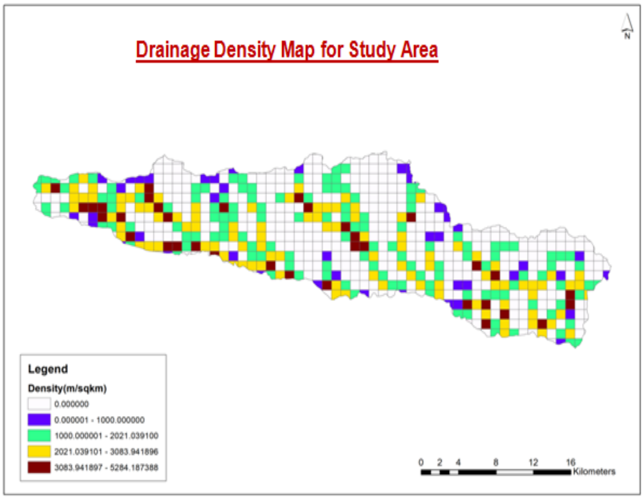

Fig. 4: Drainage Density map

D. *Geology:*

The porosity of the rock controls the storage capacity of the rock formations. Movement of groundwater in the rocks from recharge area to discharge area occurs, depending upon the hydraulic conductivity or permeability, under the influence of hydraulic gradients.

The complete study area of Pune district is occupied by Deccan basalts consisting of simple basaltic lava flows in 2 classes, 100-300 m and 50-350 m. The hydrogeological conditions in Deccan basalts helps to understand various factors that affects permeability and porosity for making proper groundwater storages.

Geological data for study area was obtained from Geological Survey of India and geology map was prepared showing all the geological classes occurring in the study area, using geo-spatial tools. The geology map is exhibited as below

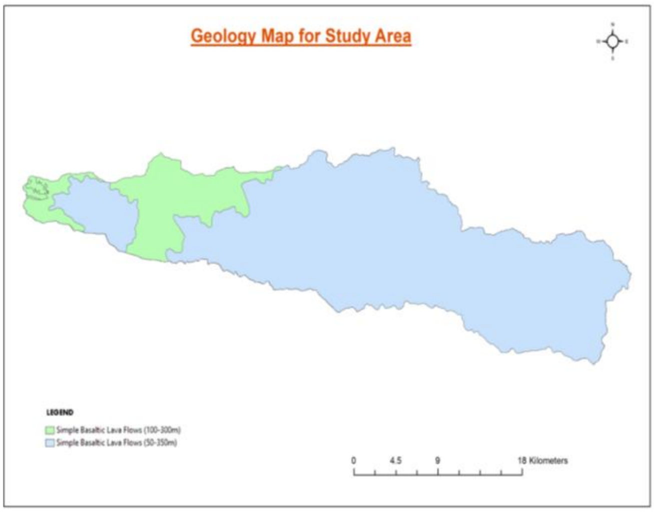

Fig. 5: Geology map

E. *Lineament Density:*

Lineaments are linear fractures commonly associated with dislocation and deformation. Lineaments provide the clues about the hydrogeology which causes groundwater movement and hence these are hydro-geologically significant. From the satellite image and data from GSDA, lineament map for study area was prepared, using geo-spatial tools. Then using grids, lineament density map was prepared, which is exhibited as below

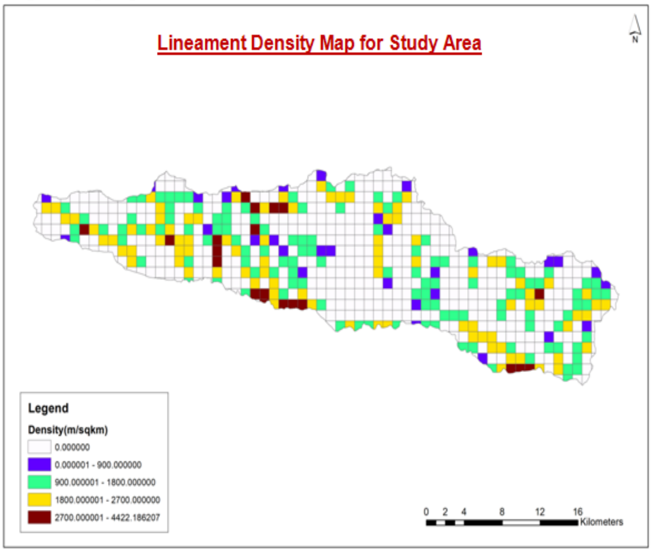

Fig. 6: Lineament Density map

F. *Soil:*

Soil texture is important soil characteristic because it helps to determine water intake rates. Water holding capacity is affected by soil texture and it increases with increasingly fine textured soil.Soil texture data for study area was obtained from Agricultural Department, Govt. of Maharashtra, Pune and a soil texture map was prepared showing all the classes of soil texture occurring in the study area, using geo-spatial tools. The soil texture map is exhibited as below

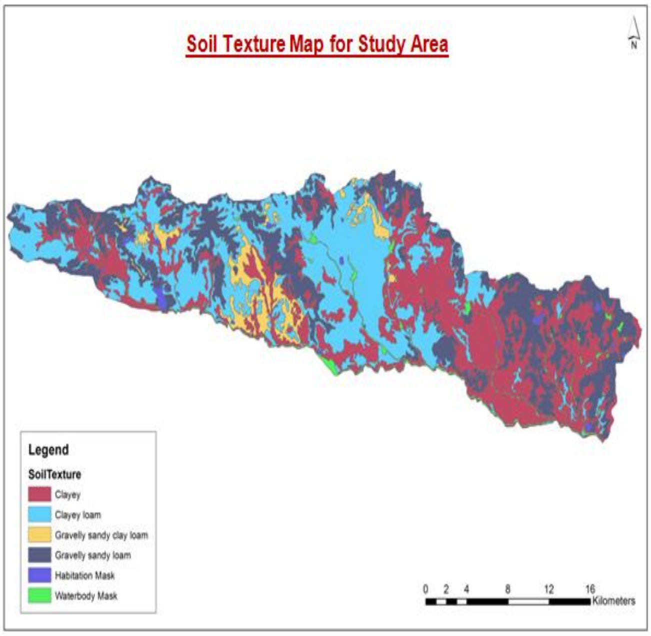

Fig. 7: Soil Texture map

G. *Land Use Land Cover:*

Physical, cultural, social, and economical factors have combined influence on the land use land cover pattern of study area. The land use land cover map is exhibited as below

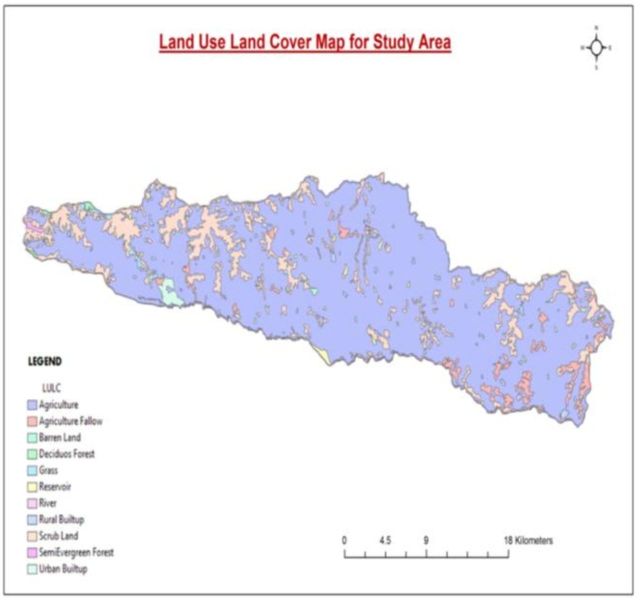

Fig. 8: Land Use Land Cover map

H. *Groundwater Table Fluctuation:*

Observation well inventory data in any region helps to understand the relationship between physiographic and movement of groundwater in that particular region. Observation well inventory of open dug wells in the study area was prepared to understand the groundwater status. Observation well inventory data also provides useful information about geology, characteristics of aquifers, depth of wells, groundwater table fluctuations, etc.

Using field data of locations of observation wells, within the study area, for all the 57 villages, a map showing locations of all the wells, village boundaries and study area boundary is prepared, which is as below:

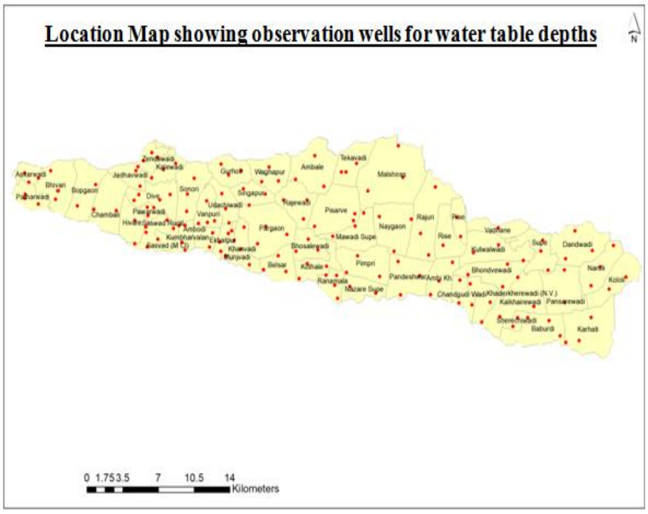

Fig. 9: Map showing observation wells

There are total 57 villages in study area out of which 37 villages are falling under watershed BM-58 and 20 villages are falling under watershed BM-60. Pre-monsoon water level depths were recorded for open dug wells for all these villages and thus pre-monsoon and post-monsoon water level depths for total 171 wells were recorded, considering the different stream for each well, wherever it exists.

Fig. 10: Observation wells in study area during Pre-Monsoon period

For each observation well in both the watersheds, field data regarding water level depths were collected, during pre-monsoon and post-monsoon period is exhibited in the table typically, as below:

Table 1: Water Level Depths in observation wells for BM-58 (Pre-Monsoon)

Table showing details of pre-monsson water table depths in BM - 58

Sr. No.	VillageName	Well Sr. No. in Village	Water Depth (In m)	Total Depth of well (In m)	Latitude	Longitude	Watershed No.
1	Askarwadi	1	0.90	15.00	18.39743	73.91111	BM-58
	Askarwadi	2	2.00	9.60	18.40135	73.89846	BM-58
	Askarwadi	3	3.20	11.00	18.39391	73.90223	BM-58
2	Amble	1	5.00	14.30	18.39195	74.17657	BM-58
	Amble	2	1.20	13.00	18.41698	74.16795	BM-58
	Amble	3	1.00	11.00	18.39762	74.15002	BM-58
3	Ambodi	1	1.80	7.00	18.34599	74.04475	BM-58
	Ambodi	2	0.20	17.10	18.35969	74.04201	BM-58
	Ambodi	3	2.60	15.50	18.35991	74.04768	BM-58
4	Bhivari	1	1.00	6.20	18.38023	73.92727	BM-58
	Bhivari	2	0.40	7.90	18.38725	73.92976	BM-58
	Bhivari	3	0.25	13.00	18.38719	73.92914	BM-58
5	Bopgaon	1	3.30	13.30	18.40358	73.92253	BM-58
	Bopgaon	2	0.90	25.25	18.39238	73.96431	BM-58
	Bopgaon	3	2.25	12.10	18.37498	73.94755	BM-58
6	Belsar	1	0.30	11.20	18.32417	74.12082	BM-58
	Belsar	2	1.50	6.90	18.35939	74.12272	BM-58
	Belsar	3	1.00	7.10	18.34535	74.11507	BM-58
7	Bhosalewadi	2	0.30	12.00	18.32271	74.14147	BM-58
	Bhosalewadi	1	2.80	6.70	18.35281	74.14237	BM-58
	Bhosalewadi	3	1.00	17.50	18.33545	74.13436	BM-58
8	Chambali	1	1.70	16.90	18.37219	73.96263	BM-58
	Chambali	2	0.70	9.90	18.37233	73.96285	BM-58
	Chambali	3	0.30	9.30	18.37138	73.98363	BM-58
9	Dive	1	2.80	8.70	18.38050	74.02407	BM-58
	Dive	2	1.00	9.70	18.38477	74.03353	BM-58
	Dive	3	0.60	12.30	18.38466	74.00460	BM-58
10	Ekhatpur	1	0.05	6.00	18.34458	74.00095	BM-58
	Ekhatpur	2	1.70	10.90	18.35568	74.09110	BM-58
	Ekhatpur	3	8.00	14.00	18.33532	74.08574	BM-58

Table 2: Water Level Depths in observation wells for BM-60 (Pre-Monsoon)

Table showing details of pre-monsson water table depths in BM - 60

Sr. No.	VillageName	Well Sr. No. in Village	Water Depth (In m)	Total Depth of well (In m)	Latitude	Longitude	Watershed No.
1	Ambi Khurd	1	1.20	12.10	18.30464	74.27606	BM-60
	Ambi Khurd	2	0.30	18.50	18.33088	74.29623	BM-60
	Ambi Khurd	3	1.20	11.30	18.31561	74.28368	BM-60
2	Baburdi	1	7.00	15.00	18.28389	74.38620	BM-60
	Baburdi	2	0.50	14.00	18.27160	74.39633	BM-60
	Baburdi	3	1.50	12.30	18.27128	74.06790	BM-60
3	Bhondavewadi	1	3.00	8.00	18.32086	74.31081	BM-60
	Bhondavewadi	2	4.10	11.00	18.32947	74.34725	BM-60
	Bhondavewadi	3	2.20	20.10	18.31126	74.34286	BM-60
4	Chandgudewadi	1	1.70	20.60	18.31650	74.30321	BM-60
	Chandgudewadi	2	2.00	16.00	18.29650	74.31433	BM-60
	Chandgudewadi	3	1.20	13.20	18.29791	74.30244	BM-60
5	Dandwadi	1	1.00	14.20	18.34070	74.09955	BM-60
	Dandwadi	2	2.30	9.20	18.34096	74.42606	BM-60
	Dandwadi	3	6.70	11.20	18.35687	74.40995	BM-60
6	Kalkhairewadi	1	2.30	12.00	18.31897	74.35694	BM-60
	Kalkhairewadi	2	5.50	13.00	18.29539	74.37206	BM-60
	Kalkhairewadi	3	3.50	16.50	18.28681	74.34037	BM-60
7	Karhati	1	4.00	13.00	18.28660	74.42506	BM-60
	Karhati	2	4.00	11.00	18.26631	74.40174	BM-60
	Karhati	3	1.00	8.00	18.26774	74.41400	BM-60
8	Khandukhairechiwad	1	1.10	12.90	18.31340	74.31274	BM-60
	Khandukhairechiwad	2	4.50	14.50	18.28267	74.32355	BM-60
	Khandukhairechiwad	3	5.00	14.00	18.29851	74.33144	BM-60
9	Kololi	1	8.00	10.00	18.33430	74.40126	BM-60
	Kololi	2	3.20	10.30	18.31936	74.45731	BM-60
	Kololi	3	3.00	6.00	18.30964	74.44190	BM-60
10	Kutwalwadi	1	5.30	15.60	18.33255	74.36194	BM-60
	Kutwalwadi	2	1.70	12.00	18.34516	74.33910	BM-60
	Kutwalwadi	3	0.60	20.00	18.33888	74.31565	BM-60

Fig. 11: Observation wells in study area during Post-Monsoon period

Typical photos of wells for both watersheds of study area, taken during pre-monsoon and post-monsoon period, are given to understand the water levels in the observation wells within study area.

Table 3: Water Level Depths in observation wells for BM-58 (Post-Monsoon)

Table showing details of post-monsson water table depths in BM - 58							
Sr. No.	*VillageName*	*Well Sr. No. in Village*	*Water Depth (In m)*	*Total Depth of well (In m)*	*Latitude*	*Longitude*	*Watershed No.*
1	Askarwadi	1	14.10	15.00	18.39743	73.91111	BM-58
	Askarwadi	2	2.00	9.60	18.40135	73.89846	BM-58
	Askarwadi	3	3.20	11.00	18.39391	73.90223	BM-58
2	Amble	1	5.00	14.30	18.39195	74.17657	BM-58
	Amble	2	1.20	13.00	18.41698	74.16795	BM-58
	Amble	3	1.00	11.00	18.39762	74.15002	BM-58
3	Ambodi	1	1.80	7.00	18.34599	74.04475	BM-58
	Ambodi	2	0.20	17.10	18.35969	74.04201	BM-58
	Ambodi	3	2.60	15.50	18.35991	74.04768	BM-58
4	Bhivari	1	1.00	6.20	18.38023	73.92727	BM-58
	Bhivari	2	0.40	7.90	18.38725	73.92976	BM-58
	Bhivari	3	0.25	13.00	18.38719	73.92914	BM-58
5	Bopgaon	1	3.30	13.30	18.40358	73.92253	BM-58
	Bopgaon	2	0.90	25.25	18.39238	73.96431	BM-58
	Bopgaon	3	2.25	12.10	18.37498	73.94755	BM-58
6	Belsar	1	0.30	11.20	18.32417	74.12082	BM-58
	Belsar	2	0.30	6.90	18.35939	74.12272	BM-58
	Belsar	3	1.00	7.10	18.34535	74.11507	BM-58
7	Bhosalewadi	2	6.70	12.00	18.32271	74.14147	BM-58
	Bhosalewadi	1	6.90	6.70	18.35281	74.14237	BM-58
	Bhosalewadi	3	7.10	17.50	18.33545	74.13436	BM-58
8	Chambali	1	1.70	16.90	18.37219	73.96263	BM-58
	Chambali	2	0.70	9.90	18.37233	73.96285	BM-58
	Chambali	3	0.30	9.30	18.37138	73.98363	BM-58
9	Dive	1	2.80	8.70	18.38050	74.02407	BM-58
	Dive	2	1.00	9.70	18.38477	74.03353	BM-58
	Dive	3	0.60	12.30	18.38466	74.00460	BM-58
10	Ekhatpur	1	0.05	6.00	18.34458	74.00095	BM-58
	Ekhatpur	2	1.70 MT	10.90	18.35568	74.09110	BM-58
	Ekhatpur	3	8.00	14.00	18.33532	74.08574	BM-58

Table 4: Water Level Depths in observation wells for BM-60 (Post-Monsoon)

Table showing details of post-monsson water table depths in BM - 60							
Sr. No.	*VillageName*	*Well Sr. No. in Village*	*Water Depth (In m)*	*Total Depth of well (In m)*	*Latitude*	*Longitude*	*Watershed No.*
1	Ambi Khurd	1	10.90	12.10	18.30464	74.27606	BM-60
	Ambi Khurd	2	18.20	18.50	18.33088	74.29623	BM-60
	Ambi Khurd	3	1.20	11.30	18.31561	74.28368	BM-60
2	Baburdi	1	7.00	15.00	18.28389	74.38620	BM-60
	Baburdi	2	0.50	14.00	18.27160	74.39633	BM-60
	Baburdi	3	1.50	12.30	18.27128	74.06790	BM-60
3	Bhondavewadi	1	3.00	8.00	18.32086	74.31081	BM-60
	Bhondavewadi	2	4.10	11.00	18.32947	74.34725	BM-60
	Bhondavewadi	3	2.20	20.10	18.31126	74.34286	BM-60
4	Chandgudewadi	1	1.70	20.60	18.31650	74.30321	BM-60
	Chandgudewadi	2	2.00	16.00	18.29650	74.31433	BM-60
	Chandgudewadi	3	1.20	13.20	18.29791	74.30244	BM-60
5	Dandwadi	1	14.20	14.20	18.34070	74.09955	BM-60
	Dandwadi	2	9.20	9.20	18.34096	74.42606	BM-60
	Dandwadi	3	11.20	11.20	18.35687	74.40995	BM-60
6	Kalkhairewadi	1	2.30	12.00	18.31897	74.35694	BM-60
	Kalkhairewadi	2	5.50	13.00	18.29539	74.37206	BM-60
	Kalkhairewadi	3	3.50	16.50	18.28681	74.34037	BM-60
7	Karhati	1	4.00	13.00	18.28660	74.42506	BM-60
	Karhati	2	4.00	11.00	18.26631	74.40174	BM-60
	Karhati	3	1.00	8.00	18.26774	74.41400	BM-60
8	Khandukhairechi	1	2.30	12.90	18.31340	74.31274	BM-60
	Khandukhairechi	2	5.50	14.50	18.28267	74.32355	BM-60
	Khandukhairechi	3	3.50	14.00	18.29851	74.33144	BM-60
9	Kololi	1	8.00	10.00	18.33430	74.40126	BM-60
	Kololi	2	3.20	10.30	18.31936	74.45731	BM-60
	Kololi	3	3.00	6.00	18.30964	74.44190	BM-60
10	Kutwalwadi	1	5.30	15.60	18.33255	74.36194	BM-60
	Kutwalwadi	2	1.70	12.00	18.34516	74.33910	BM-60
	Kutwalwadi	3	0.60	20.00	18.33888	74.31565	BM-60

From the field data collected for pre-monsoon and post-monsoon water table levels from observation wells in study area, water table difference map was prepared for the study area, using geo-spatial tools and is exhibited as below.

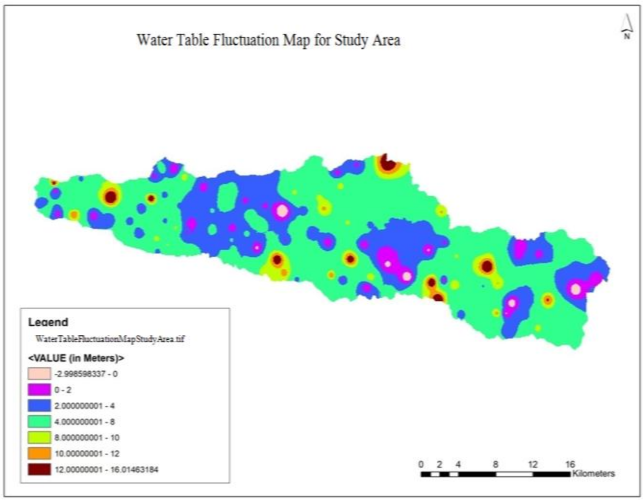

Fig. 12: Map showing water table fluctuation for Pre-monsoon and Post-monsoon Period

V. RESULTS AND DISCUSSION

For delineating the groundwater potential zones, weighted overlay analysis was carried out in GIS environment. As it is now well established fact that GIS has emerged as multi-faceted technology; which provide wide range of tools and techniques to conduct raster calculation along any spatial geographic areas.

Table 5: Different factors and their respective rank with weightage used in GIS analysis.

Sr. No.	Groundwater controlling factor	Class	Rank	Weightage (%)
(1)	Geomorphology	Plateau Slightly Dissected(PLS) 0.1 m Weathering	2	30
		Plateau Moderately Dissected(PLM)	3	
		Plateau Weathered (PLWS) 1.2 m Weathering	2	
		Messa (M)	5	
		Butte (B)	4	
		Plateau Highly Dissected(PLH)	1	
(2)	Soil	Clayey	5	15
		Clayey Loam	4	
		Gravelly Sandy Clay Loam	3	
		Gravelly Sandy Loam	2	
		Habitation Mask	5	
		Waterbody Mask	1	
(3)	Slope	Nearly Levelled (< 1%)	1	10
		Gently Sloping (1% to 3%)	2	
		Moderate Sloping (3% to 5%)	3	
		Strongly Sloping (5% to 25%)	4	
		Steep Sloping (25% to 89%)	5	
(4)	Land use land cover	Agricultural	2	10
		Agricultural Fallow	2	
		Barren Land	4	
		Deciduous Forest	1	
		Grass	3	
		Reservoir	1	
		Waterbody	1	
		Rural built up	4	
		Scrub Land	5	
		Semi Evergreen Forest	4	
		Urban built up	6	
(5)	Drainage density	Very Low (0 to 0.01)	5	10
		Low (0.01 to 1000)	4	
		Moderate (1000.01 to 2021)	3	
		High (2021.01 to 3083.94)	2	
		Very high (3083.95 to 5284.18)	1	
(6)	Lineament density	Very Low (0 to 0.01)	5	15
		Low (0.01 to 900)	4	
		Moderate (900.01 to 1800)	3	
		High (1800.01 to 2700)	2	
		Very high (2700.01 to 4422.18)	1	
(7)	Geology	Single Basaltic Lava Flows (100-300 m)	2	10
		Single Basaltic Lava Flows (50-350 m)	1	

The main objective of the study was to map groundwater potential zones for the study area based on various thematic maps by considering their relevance to groundwater occurrence, movement and recharge. All the maps were rasterized, reclassified and given appropriate rankings and weightages in order to integrate them for Multi Criteria Analysis (MCA) for generation of groundwater prospect zones map. In the present study thematic layers related groundwater potential zone are separately generated using Geo-spatial tools and then those layers were used for weighted overlay analysis.

In order to produce the groundwater prospect zones map, detailed overlay weighted analysis of thematic maps was conducted in GIS environment and finally groundwater potential zone map was generated using geo-spatial tools.

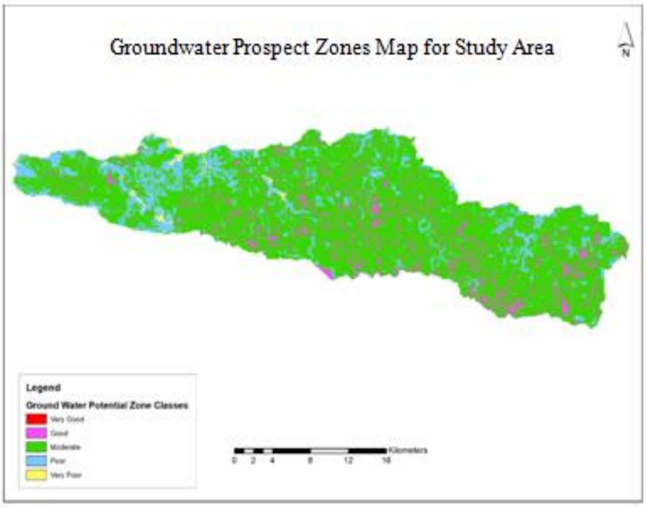

Fig. 13: Map showing groundwater potential zones

Table 6: Groundwater potential zone areas in accordance with their classes are as below

Groundwater Prospect Class	Area under Groundwater Prospect Class (in Sq. Km)	% of Total Area
Very Good	1.89	0.32
Good	177.92	30.04
Moderate	377.65	63.75
Poor	33.98	5.74
Very Poor	0.92	0.15

In the present study, the spatial distribution of groundwater potential zones can be observed from the Fig. 14, which shows that most of the area falls under *moderate* class of groundwater prospect zone, followed by *good* class and thus nearly more than 93 % of total area falls under these two categories; which indicates that the various influential factors for groundwater prospect are affecting the groundwater prospect in the study area.Landforms are playing major role in groundwater occurrence and potential of the groundwater. There is wide scope to study the landforms and other groundwater related parameters geographically. In the present study it is found that the watershed facing the problem of water scarcity during summer season because of hard rock topography. Study area watersheds are having very limited groundwater potential and most of the area comes under moderate and good groundwater potential zone. Some places have no groundwater zone areas along the study region.Lineaments have been observed during field work in the study area, in the south-eastern and northern part. These lineaments had given an advantage of groundwater convergence from western and eastern part of the study area. The lineament observed as the manifestation of straight stream course in the region. Along this lineament, high moisture zone and dense vegetation is noted during field check.

VI. CONCLUSION

The occurrence of groundwater in the watershed is dependent on slope, geomorphology (landforms), geology (rock type), drainage, lineament, land use land cover, and soil as revealed from the GIS analysis and the same is validated by the field investigations. Geo-spatial tools proved to be useful efficient for delineating groundwater potential zones and mapping the same for development and conserving on a scientific basis. The concluding results of the study reveal that the use of Geo-spatial tools proved to be dominant tools for study of groundwater resources of the region and make appropriate groundwater exploration plan.

VII. FUTURE SCOPE

This study can be used further to assess and identify the locations for the artificial recharge structures for the enhancement of groundwater recharge in the study area, alongwith the type of recharge structures, considering various factors influencing the groundwater recharge.

REFERENCES

1. A. K. Saraf et al., “GIS based surface hydrological modelling in identification of groundwater recharge zones,” Int. J. Remote Sensing, vol. 25, No. 24, 20 December 2004, pp. 5759-5770.
2. A. K. Jasrotia, R. Kumar, and A. K. Saraf, “Delineation of groundwater recharge sites using integrated remote sensing and GIS in Jammu district, India,” Int. J. Remote Sensing, vol. 28, No. 22, 20 November 2007, pp. 5019-5036.
3. Basavarajappa H. T., Jeevan L., and Manjunatha M. C., “Delineation of groundwater potential zones in Precambrian hard rock terrain of Tumakuru district, Karnataka, India using Geomatics application ,” Int. J. Civil Engg. and Tech., vol. 5, No. 12, December 2014, pp. 305-315.
4. B. S. Manjare, “Identification of groundwater prospecting zones using remote sensing and GIS techniques in upper Vena river watersheds Nagpur district, Maharashtra, India,” 15th ESRI India User Conference 2014, pp. 1-14.
5. Deepesh Machiwal, Madan K. Jha and Bimal C. Mal, “Assessment of groundwater potential in a semi-Arid region of India using remote sensing, GIS and MCDM techniques,” Water Resour Manage Springer, 25:1359-1386.
6. Jayanta Karmakar and Hari Natarajan, “Groundwater potential zone mapping using Geospatial approach: A case study of Ambar watershed Sehore district Madhya Pradesh,” Int. J. Advance Research, vol. 3, Issue 5, May 2015, pp. 549-555.
7. Jainendra Vishwakarma, Manish Kumar Sinha, M. K. Verma and Ishtiyaq Ahmad, “Application of remote sensing and GIS in groundwater prospects mapping,” Int. J. Engg. Research & Tech., vol. 3, Issue 10, October 2014, pp. 5759-5770.
8. Khadri S. F. R. And Kanak Moharir., “Identification of artificial recharge zones of the selected watershed using remote sensing and GIS,” Int. J. Research, vol. 2, Issue 10, October 2014, pp. 582-590.
9. M. A. Dar, K. Sankar and I. A. Dar, “Groundwater prospects evaluation based on Hydrogeo-morphological mapping: A case study in Kancheepuram district, Tamilnadu,” J. Indian Soc. Remote Sens. Springer, 19 February 2010, pp. 309-319.

10. M. C. Sashikkumar, S. Selvam, V. Lenin Kalyanasundaram and J. Colins Johnny, "GIS based groundwater modelling study to assess the effect of artificial recharge: A case study from Kodaganar River basin, Dindigul district, Tamil Nadu," J. Geo. Soc. India, vol. 89, January 2017, pp. 57-64.
11. M. L. Waikar and Aditya P. Nilawar, "Identification of groundwater potential zone using remote sensing and GIS technique," Int. J. Innov. Research in Sc., Engg. and Tech., vol. 3, Issue 5, May 2014, pp. 12163-12174.
12. M. Sedhuraman, S. S. Revathy and S. Suresh Babu, "Integration of geology and geomorphology for groundwater assessment using remote sensing and GIS techniques," Int. J. Innov. Research in Sc. Engg. and Tech., vol. 3, Issue 3, March 2014, pp. 10203-10211.
13. Pampiya Chowdhury and S. K. Nag, "Delineating groundwater potential zones in Khatra block, Bankura district, West Bengal using MCE, RS and GIS techniques," J. App. Geol. & Geophy., vol. 5, Issue 4 Ver. II, Jul.-Aug. 2017, pp. 45-60.
14. Ramamoorthy P., Arjun A. Gobinath K., Senthil Kumar V., and Sudhakar D., "Geo Spatial analysis of groundwater potential zones using remote sensing and GIS techniques in Varahanadhi sub basin, Tamilnadu," Int. J. Sc., Engg. and Tech., vol. 2, Issue 4, April-May 2014, pp. 273-285.
15. Raviraj A., Nimmi Kuruppath and Balaji Kannan, "Identification of potential sites for groundwater recharge GIS based decision support system in Jazan Region –Saudi Arabia," J. Remote Sensing & GIS, vol. 6, Issue 4, 27 October 2017, pp. 1-10.
16. R. K. Jaiswal, S. Mukherjee, J. Krishnamurthy and R. Saxenas, "Role of remote sensing and GIS techniques for generation of groundwater prospect zones towards rural development-an approach," Int. J. Remote Sensing, vol. 24, No. 5, 26 November 2001, pp. 993-1008.
17. Shereif H. Mahmoud, A. A. Alazba and Amin M. T., "Identification of potential groundwater recharge zones using remote sensing and Geographical Information System in Amaravathy basin," Water Resour Manage Springer, 1 June 2014, 28:3319-3340.
18. Shilpa A. Shiwarkar, "Delineation of groundwater potential in north-eastern parts of Nagpur district by GIS techniques," 11th ESRI India User Conference 2010, pp. 1-10.
19. S. K. Nag and Anindita Kundu, "Delineation of groundwater potential zones in hard rock terrain in Kashipur block, Purulia district, West Bengal, using Geospatial techniques," Int. J. Waste Resou., vol. 6, Issue 1, 14 March 2016, pp. 1-7.
20. S. Sukumar and V. Nagaraja, "Delineation of groundwater potential zones in parts of Vaigai River basin-Tamilnadu, India using remote sensing and GIS technique," Glob. J. Research Anal., vol. 6, Issue 4, June 2017, pp. 257-260.
21. T. Anuradha, M. Kamraju and M. Vani, "Geotechnical study for groundwater management a case study of Peddavagu mini watershed in Telangana state," Int. J. Innov. Research in Sc., Engg. and Tech., vol. 6, Issue 6, June 2017, pp. 11780-11793.

AUTHORS PROFILE

Mr. Shivaji Govind Patil, M. Tech. (Civil), Deputy Engineer, MIDC, Pune. Research Scholar, JSPM's Rajarshi Shahu College of Engineering, Tathawade, Pune, Maharashtra, India. Savitribai Phule Pune University, Pune. Membership: IE(India), ISRS. 3 Publications,
shivajigpatil@gmail.com

Dr. Ravindra Krishnarao Lad, Ph. D. (Civil Engg,), Director, JSPM Narhe Technical Campus, Narhe, Pune. Research Guide, Rajarshi Shahu College of Engineering, Tathawade, Pune, Maharashtra, India
Savitribai Phule Pune University, Pune
Professional Membership: ISTE, IEI
30 Publications.
ravindraklad5@gmail.com