

SPATIAL DISTRIBUTION OF GROUND WATER QUALITY AFTER RAIN WATER RECHARGE IN JNTUH CAMPUS

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Abstract

Globally, water scarcity is being witnessed at every corner of world irrespective of resource availability. The fresh water sources either surface or ground water resources are in constant peril owing to pollution, degradation and over exploitation. Judicious use and sustainable water conservation practices are the need of the hour. In an effort towards sustainability, an initiation has been taken up in Jawaharlal Nehru Technological University Hyderabad campus to recharge rainwater artificially into the aquifers. In the study area, five rainwater recharge structures with 9 injection wells at different locations were constructed for harvesting the rain water and recharging into the confined and unconfined aquifers. Apart from these, three Piezometers were drilled in the campus to study the groundwater level fluctuations due to artificial recharge. An attempt is made to monitor these injection wells. Physico-Chemical water quality parameters like pH, TDS, EC, Total Hardness, Chlorine, Fluorine, Nitrate, Sulphate, Calcium, Magnesium, Carbonates, Bicarbonates, Sodium and Potassium parameters were tested for samples collected from these injection wells. Spatial analysis has been developed in GIS environment from the results of physico- Chemical parameters and is compared with BIS: 105000, 1991 standards.

Keywords: Sustainability, Rainwater recharge, Recharge structures, Injection wells, Water quality, Spatial analysis.

1. INTRODUCTION

The chief merit of ground water is its availability in some quantity almost in every human settlement. Even in areas where there is abundant surface water supply ground water is playing an increasingly crucial role in supplementing surface water. In urban conglomerations where surface water bodies are rapidly shrinking, ground water has become essential to supplement drinking water demands of rising population. However this precious and limited resource has been subjected overexploitation and leading to deterioration in ground water quality and quantity more so in congested urban spaces those are devoid of natural recharge spaces.

Rainwater harvesting (RWH) has been found to be the most sustainable solution to be included in the urban water management system to could mitigate the water crisis problem. It has proved effective to reduce the burden on traditional water sources, alleviate nonpoint source pollutant loads, control water logging problems, prevent flood and contributes to effective storm water management, and so forth (Zhu 2004). United Nations Environment Programme (Mati et al. 2006) study conducted to determine if RWH technologies can be mapped at continental and country scales utilized a number of GIS data sets including rainfall, land use, land slope, and population density to identify 4 commonly adaptable RWH technologies: roof top RWH, surface runoff collection from open surfaces into ponds, flood flow storages and sub-surface dams and in-situ RWH. Sivanappan (2006) has highlighted Rain Water Harvesting, Conservation and Management Strategies for Urban and Rural Sectors and emphasized community participation.

Giridhar et al (2014) have studied Rooftop Rainwater Harvesting for Groundwater Sustainability with a case study from JNTU Hyderabad where 12 different models for aquifer recharge for rainwater harvesting were demonstrated. Measurement of rainfall and corresponding improvement in ground water levels have been carried out for Piezometers in campus in 2014. John Sansalone et al (1998) studied urban storm water runoff from paved surfaces that transport a wide gradation of solids ranging in size from smaller than 1 μ m to greater than 10,000 μ m. This study measured physical characteristics of solids transported in lateral pavement sheet flow from a heavily travelled roadway in Cincinnati, Ohio, USA.

The GIS could be in forefront for groundwater modeling simulation devised to fully capture the contaminant and distribution patterns. Areas that have been over pumped of groundwater can subside, and may also lead to flooding when near to sea. Groundwater quality mapping can help the planners to take suitable action to improve the groundwater quality in contaminated regions. The spatial variation in chemical and physiochemical parameters of groundwater were used to identify suitable zone for pumping for irrigation and domestic purposes (Srinivasarao, 2007). GIS was effectively used for the evaluation of groundwater quality by several researchers (Shahid and Nath, 2000; Phukon et al., 2004). The spatial groundwater quality index and the procedure of weighing is widely used to identify the spatial characteristics of the aquifer by many researchers (Horton, 1965; Prati et al., 1971; Provencher and Lamontagne, 1979; 1987; Sinha and Shrivastava, 1994; Pradhan et al., 2001; Connell and Van den Daele, 2003; Chachadi and Lobo-Ferreira, 2005; Ckakraorthy et al.,

2007; Mamadou et al., 2010). Many approaches have been developed to extract aquifer vulnerability such as process based method, statistical methods and overlay methods (Zhang et al., 1996; Tesoriero et al., 1998). Ramakrishnaiah et al. (2008) used the spatial groundwater quality index for ranking, which reflected the influence of different parameters. The results obtained by such techniques was used to point out the quality groundwater of a particular region (Rajankar et al., 2009). Giridhar et al.(2014) have formulated spatial decision support system for ground water quality management at village level using geomatics for borewells in Nandyal mandal of Kurnool district of Andhra Pradesh and identified bore wells unsuitable for drinking purposes and identified villages with deteriorated ground water quality. The prime objective of the study is to observe the quality of the water by the rain water harvesting technique in the injection zones in Jawaharlal Nehru Technological University Hyderabad, Kukatpally campus in the year 2015.

2. STUDY AREA

Hyderabad city is situated in the Krishna basin and the river Musi, a tributary of river Krishna, passes through the city and bifurcates it into Northern and Southern Hyderabad. The Study region covers an area of 179 km² and is situated between 78°22'30" & 78°32'30" East Longitude & between 17°18'30" & 17°28'30" North latitude. The Spatial representation of the study area is shown in the **Figure 1**. In the study area, five rainwater recharge structures with 9

injection wells at different locations were constructed for harvesting the rain water and recharging into the confined and unconfined aquifers. These structures are located near Library, Girls Hostel, New IST, and Old Quarters along with an open pond adjoining Mechanical Engineering department. Three piezometers are constructed each at EEE department (17°29'42.9"N & 78°23'35.2"E), Girls hostel (17°29'39.6"N & 78°23'37.1"E) and New IST building (17°29'38.9"N & 78°23'30.4"E) adjacent to injection wells. The elevation is varying from 487 meters to 610 meters above mean sea level. The region of interest for site selection includes all area, which falls within the buffer distance of 50km from the center of Hyderabad city. It is covered by toposheet No.56K on 1:2,50,000 scale. The study area stands on gray and pink granites as foundation materials, which is suitable for building construction.

3. RAINWATER STRUCTURES CONSTRUCTED

With the above objectives and based on the available roof top area the following rain water harvesting structures were constructed in JNTUH campus. The location of building and location of the rainwater harvesting structures in the campus is shown is **Figure1**. The description of the structure, locations and nomenclatures of recharge shafts and their Latitude and Longitudes are listed in Table 1

Table 1: Details of bore wells and their location with ID number

Sl. No	Well ID	Details of the structure	Location	Type of Shaft	Longitude	Latitude
1	A	Recharge structures along with two bore wells in the tank for percolation .	Behind EEE Department, College of Engineering, JNTUH	Piezometer	17°29'42.9"N	78°23'35.2"E
2	B			Recharge Shaft I	17°29'43.7"N	78°23'27.9"E
3	C			Recharge ShaftII	17°29'43.7"N	78°23'27.8"E
4	D	Recharge structures along with two bore wells in the tank for percolation..	Between Girls hostel compound and incubator building new	Piezometer	17°29'39.6"N	78°23'37.1"E
5	E			Recharge Shaft I	17°29'39.6"N	78°23'37.1"E
6	F			Recharge shaft II	17°29'40.3"N	78°23'36.4"E
7	G	Recharge structures along with two bore wells in the tank for percolation.	Behind new JNTUHIST Building, JNTUH	Piezometer	17°29'38.9"N	78°23'30.4"E
8	H			Recharge Shaft I	17°29'34.5"N	78°23'31.6"E
9	I			Recharge shaftI I	17°29'34.4"N	78°23'31.4"E
10	J	Roof top rainwater harvesting structures	Behind old quarters	Recharge shaft	17°29'28.4"N	78°23'33.6"E
11	L	Open pond recharge structures.	Besides Mechanical building	Recharge shaft I	17°29'38.9"N	78°23'29.7"E
12	M			Recharge shaft II	17°29'38.7"N	78°23'30.3"E

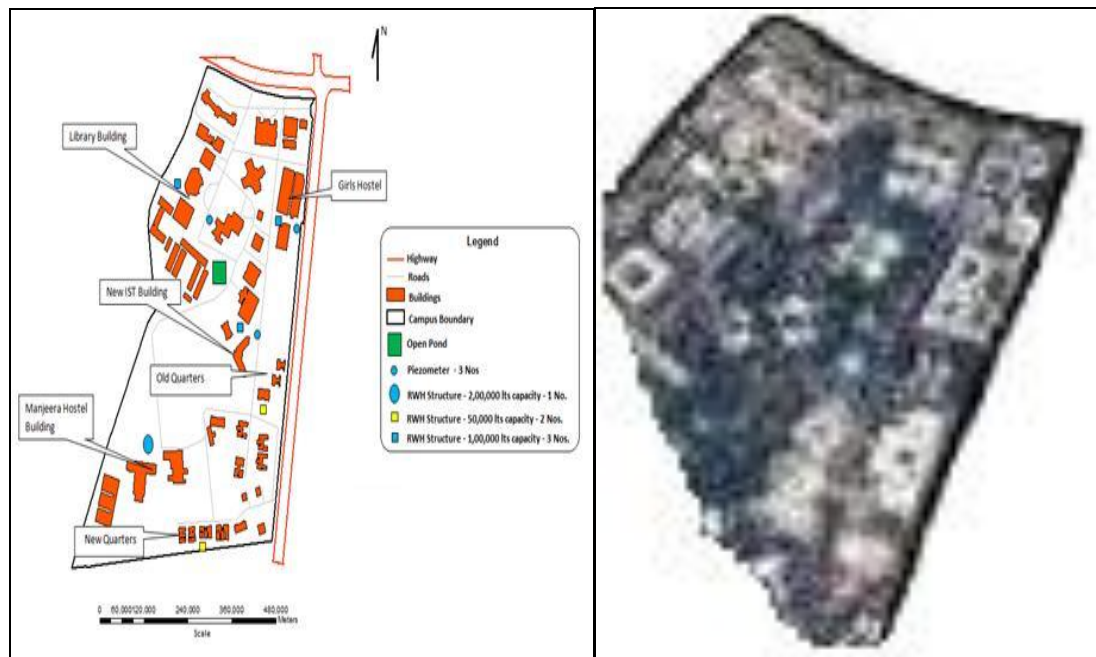


Fig 1: Location of Rainwater harvesting structures in the JNTUH campus and Google earth view of study area.

4. METHODOLOGY

Study area has been delineated from Bhuvan website in GIS environment using Arc GIS 9.2. The water samples are collected from 12 observation wells and analyzed for various physico-chemical parameters. Data pertaining to Post monsoon (10th January, 2015) Ground water quality parameters such as pH, Total Dissolved Solids, Electrical Conductivity, Chlorides, Sulphates, Nitrates Potassium, Sodium, Magnesium, Calcium, and Total hardness were tested in college laboratory as per standard analytical procedures of government of India and listed in **Table 1**. In this paper an attempt has been made to prepare maps representing spatial distribution of the groundwater parameters in GIS environment. Water quality data thus obtained forms the attribute database. The geographic positions in terms of latitude and longitude of the observation wells were obtained using Global Positioning System (GPS) which are listed in **Table 1**. The spatial and the attribute database formed are integrated for the generation of spatial distribution maps of the water quality parameters. Using Surface analysis tool from spatial analyst extension contour maps for various groundwater parameters were prepared and presented in figures.

5. RESULTS AND DISCUSSIONS

Entire campus was surveyed and three watershed boundaries were delineated using geomatic techniques for Piezometer construction in each watershed along with injection shafts in recharge sites using remote sensing, global positioning and GIS techniques. Rain water is being harvested from 9 injection wells in the years 2012, 2013, 2014, 2015 in the JNTUH campus. Though rainwater is being harvested since 2012, quality of water harvested and recharged at each structure is tested for 13 parameters in 2015 for first time. The quality of water harvested and recharged at each

structure is explained below for different physico-chemical parameters like pH, Total Dissolved Solids, Electric Conductivity, Calcium, Magnesium, Carbonates, Bicarbonates, Sodium, Potassium, Chlorides, Sulphates, Nitrates and Fluorides and corresponding spatial distribution of water quality parameters are presented in **Table 2** and **Table 3**. It was observed that the quality of water had lot of fluctuations from structure to structure and different trends are seen for the same parameter in different structures. For the clarification of these fluctuations the research is being continued on the quality of the samples.

6. ELECTRICAL CONDUCTIVITY

Soluble salts present in water as ions are the carriers of electricity, electrical conductivity of water sample may be related to the presence of soluble salts. EC concentration showed variation for each well ranging from as low as 288 for borewell I to as high as 1406 and represented spatially in **Fig.2**. Highest EC is observed in open pond injection wells L and M.

7. TOTAL DISSOLVED SOLIDS

Total solids may be considered as that matter which is left as a residue on evaporation, drying at 105°C. The spatial distribution of TDS concentration as shown in **Fig.2**. The higher TDS indicates high amount of organic matter in water samples. The TDS values are expected to be between 500-2000 as per BIS standards. All the wells had TDS values below the standards with least TDS observed in well I with TDS 140ppm and well G has highest TDS of 835ppm.

Table 2: The observed values of water quality Vs. Bureau of Indian Standards for 12 wells

SNo	WELL	TDS mg/l	EC μ S	TH mg/l	Ca mg/l	Mg mg/l	Km g/l	Na mg/l
		500-2000	<2250	200-600	75- 200	30-100	NG	NG
1	A	569	1375	680	272	63.2	7	147
2	B	294	550	210	168	34	8	58
3	C	294	559	220	92	34	8	58
4	D	500	1247	520	208	9.9	6	165
5	E	424	1049	552	240	34	7	109
6	F	492	982	513	152	20	6	98
7	G	835	2071	1048	416	175	7	158
8	H	546	1274	671	304	72.9	16	115
9	I	140	288	151	56	24	9	28
10	J	217	454	285	112	10	8	54
11	L	614	1406	360	128	43.7	26	130
12	M	614	1406	360	136	43.7	26	130

Table 3: The observed values of water quality Vs. Bureau of Indian Standards for 12 wells

SNo	WELL	No3 mg/l	CL mg/l	SO4 mg/l	Co3 mg/l	F mg/l	HCO3 mg/l	Ph
		10-16	250-1000	200-400	200-600	0.6-1.5	200-600	6.50 to 8.50
1	A	0.89	193.6	17.4	0	0.94	350	6.8
2	B	2.85	54.6	7	0	0.49	60	6.9
3	C	3.31	54.6	7	0	0.74	70	7
4	D	1.15	208.5	5	0	1.1	345	7.5
5	E	2.28	134	11.6	0	0.71	310	7.08
6	F	8.7	188.6	4.2	0	0.82	287	7.6
7	G	1.2	312.7	18.6	0	1.29	240	6.8
8	H	2.68	422	14.6	0	0.30	160	7.1
9	I	10	44.6	2.8	0	0.40	30	6.89
10	J	1.78	49.7	5	0	0.57	50	6.85
11	L	63	263	11	0	0.97	120	7.1
12	M	49.5	263	11	0	0.61	122	7.2

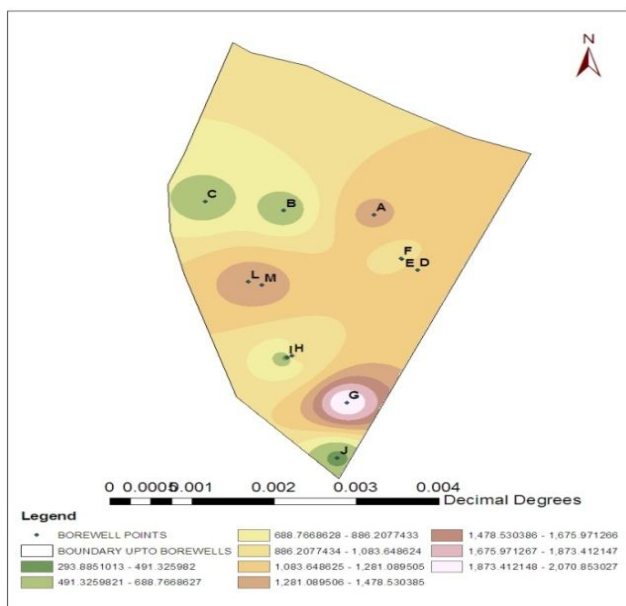


Fig.2. Spatial distribution of Electrical Conductivity

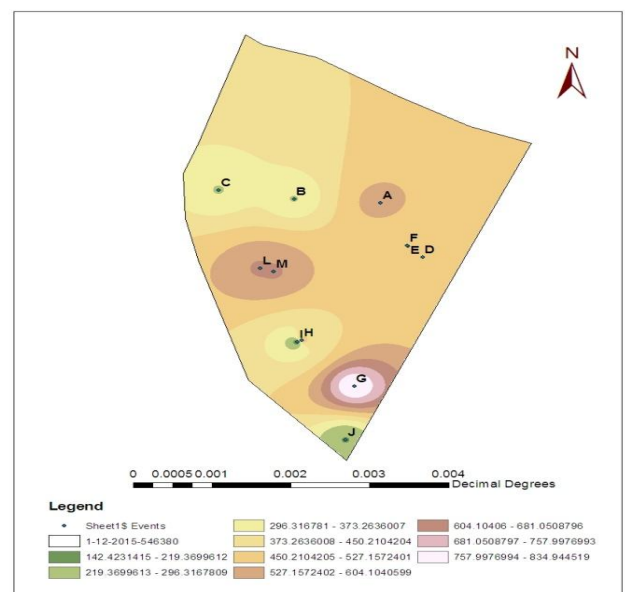


Fig.3. Spatial distribution of Total Dissolved Solids

7.1 Total Hardness

Total hardness is the hardness of the mineral content of water that is irreversible by boiling. Hard water is not seriously harmful to human health. The ISI standard for the total hardness of water is 300-600 ppm. The spatial distribution is presented in Fig.4. These varied from 150ppm for well I to 1048ppm for peizometer G. Wells A, G and H exceeded the drinking water standards.

7.2 Calcium

Calcium and magnesium are abundant in rocks and soil, particularly limestone and dolomites. They are relatively soluble. Concentration of these chemicals in an aquifer is a function of geology, aquifer sensitivity and ground water residence time. As residence time increases, concentrations of these chemicals increase. The drinking water standard for calcium is 75-200 ppm. Calcium content varied from 56-416 ppm.

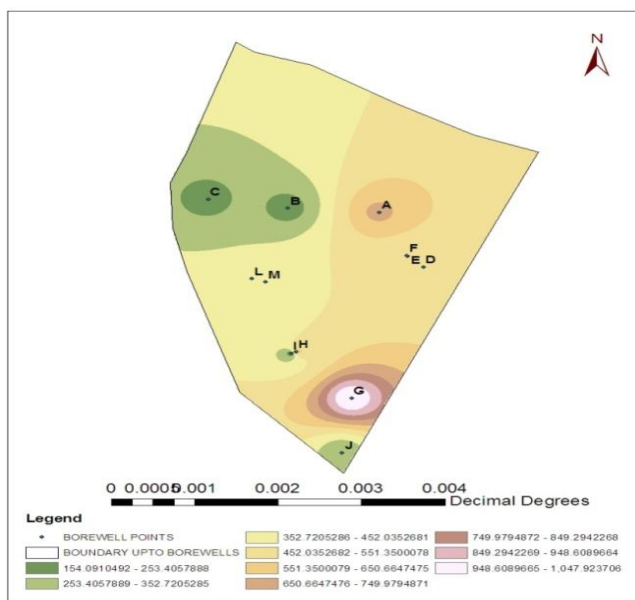


Fig.4 Spatial distribution of Total Hardness

Wells A, E, G, H showed high calcium concentration above standards while well I showed least Calcium concentration. These spatial distribution patterns in Fig.5 are in similarity with total hardness and TDS as per spatial distribution.

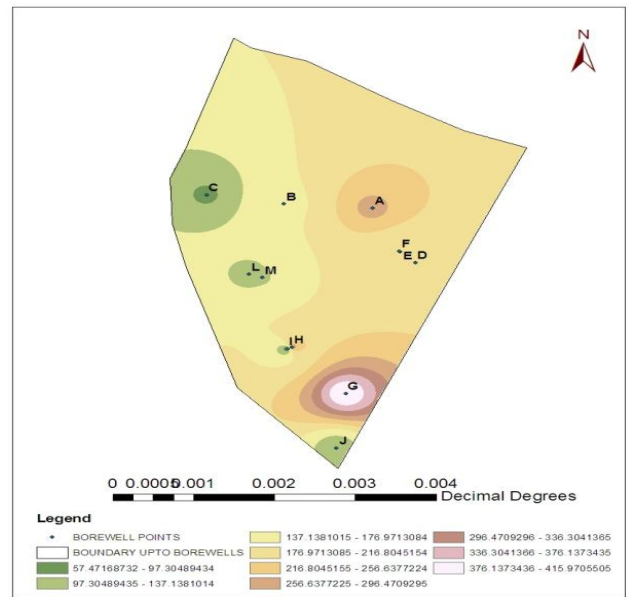


Fig.5 Spatial distribution of Calcium

7.3 Magnesium

Magnesium content in water contributes to hardness. Magnesium standards for drinking water are 30-100ppm. Least Mg content is found in wells D, F, I, J that exhibited values below standards and peizometer G that has high TDS, TH and EC also has high Mg of 175ppm. The spatial distribution pattern of magnesium is presented in Fig.6.

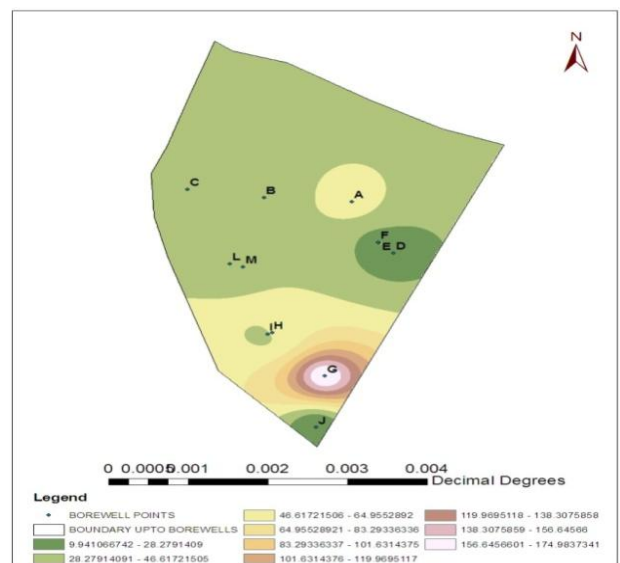


Fig.6 Spatial distribution of Magnesium

7.4 Sodium

Sodium concentrations contribute to salt content in water. Figure 8 represents the spatial distribution of Sodium concentration. However no guidelines were given for sodium concentrations in ground water. The sodium content in samples distributed spatially in Fig.7 varied from 28-165 ppm with least sodium in well I and highest Sodium in all peizometers A, D and G.

7.5 Potassium

Large amounts (500 ppm or more) of potassium in combination with chloride give a salty taste. Indian standards don't have any guidelines for potassium content. Almost all samples had potassium content of 6-8 ppm except for wells H, L, M. The spatial distribution for potassium is observed in Fig.8

7.6 Bicarbonates

Generated by the action of carbon dioxide in water on carbonate rocks such as limestone and dolomite, bicarbonate (HCO₃⁻) and carbonate (CO₃⁻²) produce an alkaline environment. The standards for bicarbonates range between 200-600 ppm. All samples had bicarbonates below the permissible limits. However peizometers exhibited comparatively higher bicarbonates than their injection wells while well I has least bicarbonates as observed in distribution in Fig.9.

7.7 Carbonates

Carbon concentration in water depends on dissolved carbon dioxide, temperature, pH, cations and other dissolved salts. Calcium carbonate found in rocks is almost insoluble in water, but it dissolves readily as bicarbonate in carbonic acid[10]. All the wells showed zero carbonate concentrations.

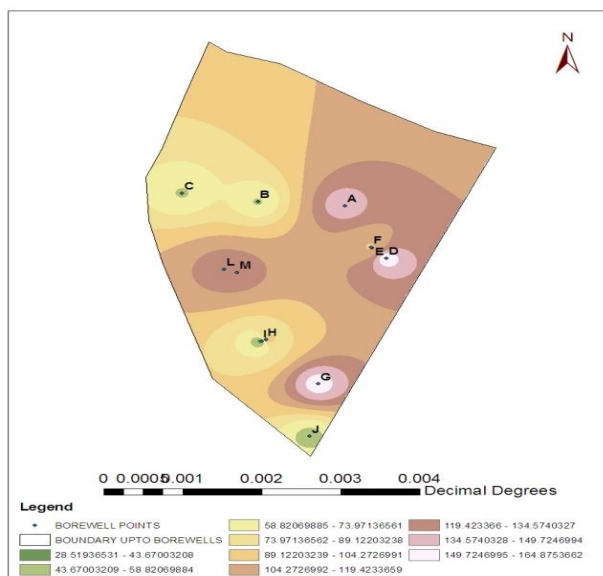


Fig.7 Spatial distribution of Sodium

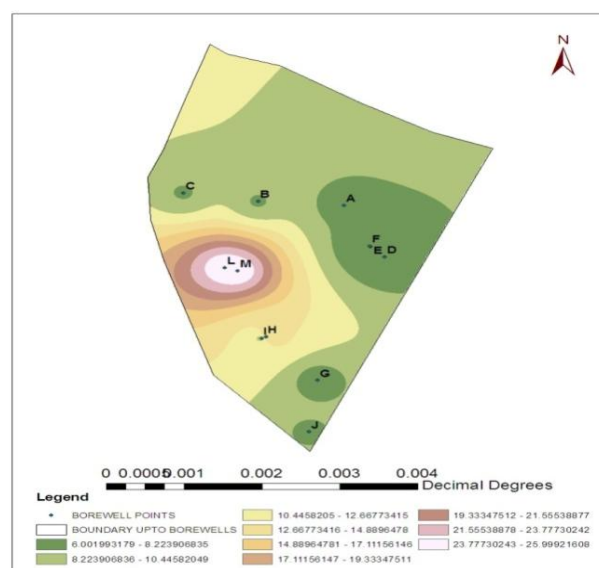


Fig.8 Spatial distribution of Potassium

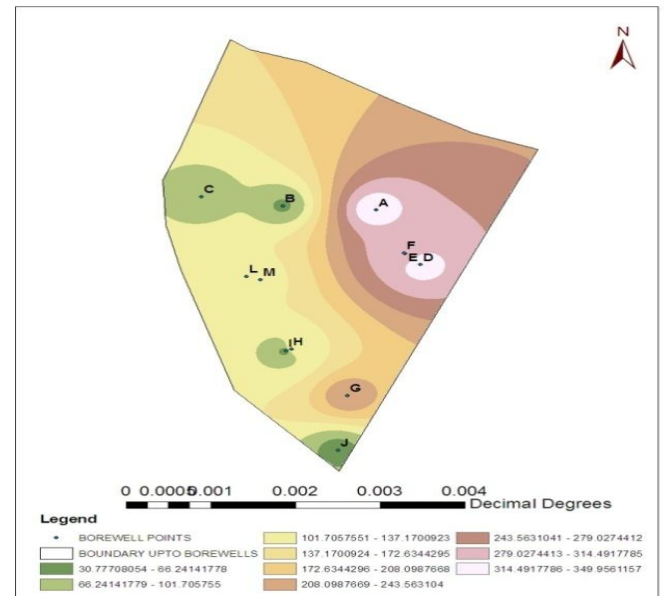


Fig.9 Spatial distribution of Bicarbonates

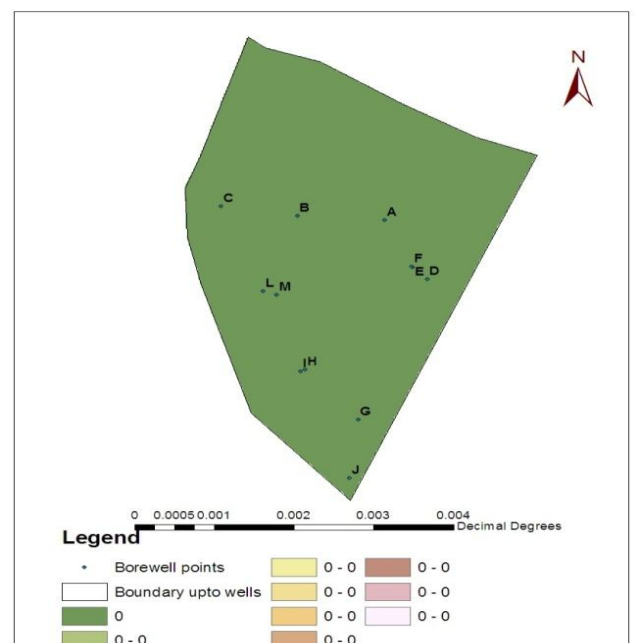


Fig.10 Spatial distribution of Carbonates

7.8 Chlorides

Chlorides (Cl⁻) are present in sewage and found mostly in sea water, and industrial brines. Large quantities of chlorides increase the corrosiveness of water and, in combination with sodium, give a "salty" taste [10]. All the samples have chlorides within permissible level of 250-1000

ppm. The spatial distribution in **Fig.6** shows least chlorides for wells **B, C, I, J**. Peizometers have higher chlorides compared to their injection wells. Also open pond wells had higher chlorides that might be due to higher salts from runoff.

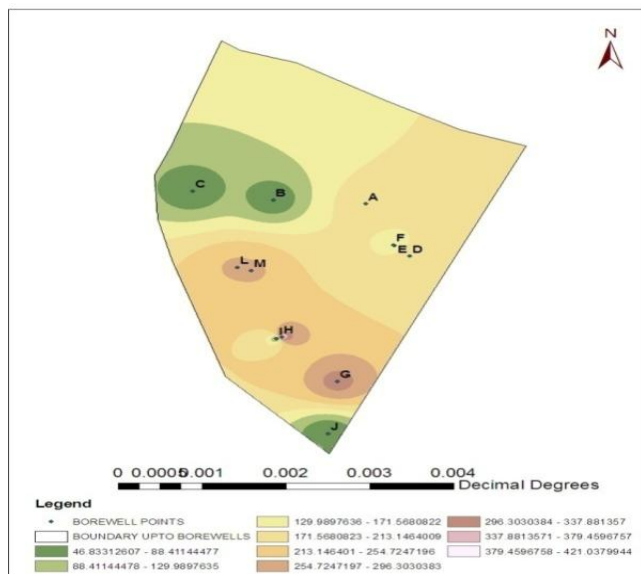


Fig.11 Spatial distribution of Chlorides

7.8 Fluorides

Fluorides are dissolved from most rocks and soils such as fluorspar and cryolite. Drinking water standards for fluorides are 0.6-1.5 ppm. All the samples have fluorides below 1.5ppm. From the spatial analysis in **Fig.12** wells **B, H, I** have very less fluorides below 0.6 ppm and are cause of concern.

7.9 Nitrates

Decaying organic matter, legume plants, sewage, nitrate fertilizers, and nitrates in soil contributes to nitrates. Nitrate in water may indicate sewage or other organic matter. In amounts less than 5 ppm, nitrate has no effect on the value of water for ordinary uses [10]. The standards for nitrate concentrations vary above 45ppm. The spatial map in **Fig.13** demonstrates nitrate concentration below standards except for wells in open pond **L** and **M**. Higher nitrates particularly in open pond can be attributed to higher decayed organic matter from runoff.

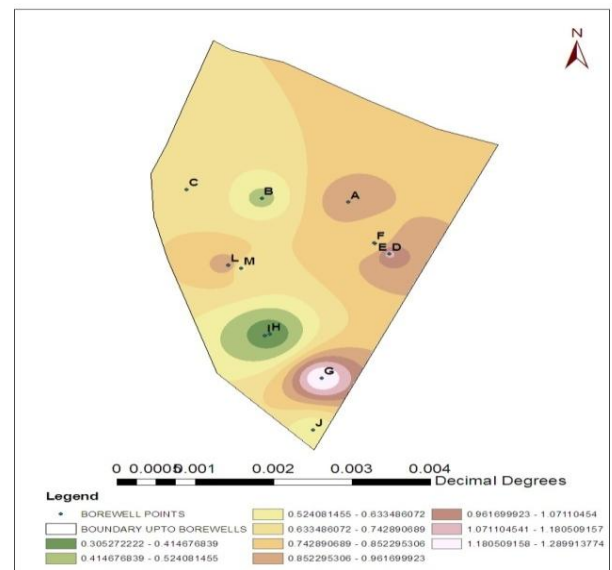


Fig.12 Spatial distribution of Fluorides

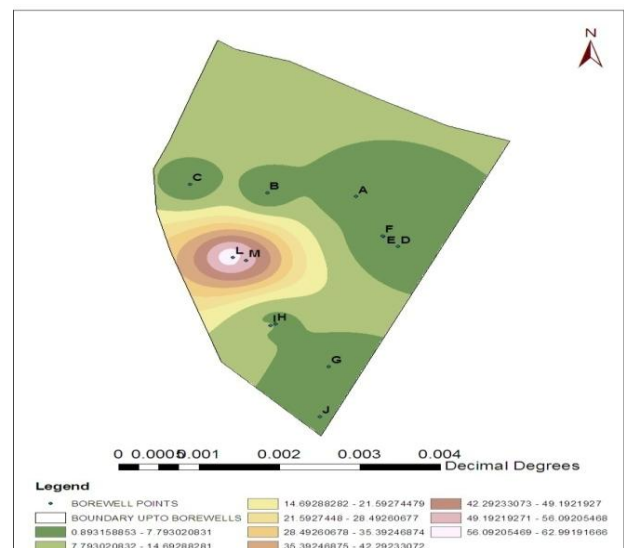


Fig.13 Spatial distribution of Nitrates

7.10 Sulphates

Sulfates (SO_4^{2-}) are dissolved from rocks containing gypsum, iron, sulfides, and other sulfur compounds. A higher Sulphate concentration has a laxative effect and, in combination with other ions, gives a **bitter taste**. Sulfate in water containing calcium forms a hard scale in steam boilers [10]. The drinking water standards specify sulphate concentrations vary between 150-400 ppm. All the wells exhibited less sulphate concentrations below the standards. **Fig.14** gives spatial distribution.

7.11 pH

pH is a measure of the acidity or alkalinity of an aqueous solution. The spatial distribution of pH values are shown in **Fig.15**. The pH values for samples range in 6.8-7.5. However all the values are in desirable range as per IS: 10500 Indian drinking water standards. Rainwater reaching the water courses as a runoff from bogs, dense forest litter, and similar substrata tends to have a low pH because of the

hydrogen ions produced by disassociation of carbonic acid and the loss of cations by base exchange with the organic matter.

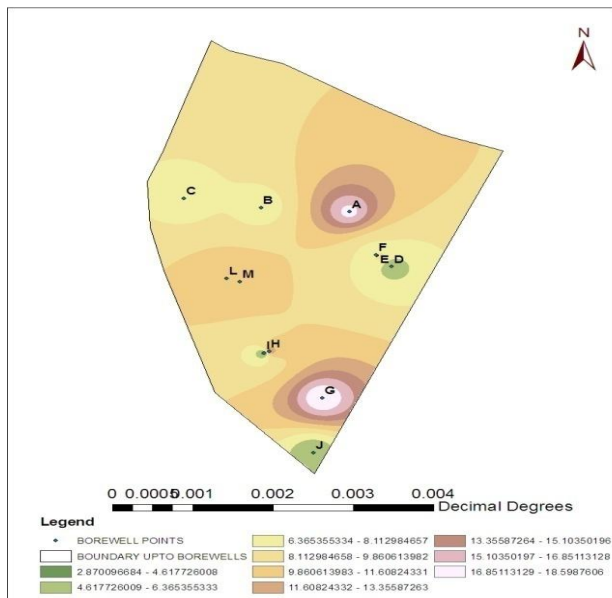


Fig.14.Spatial distribution of Sulphates

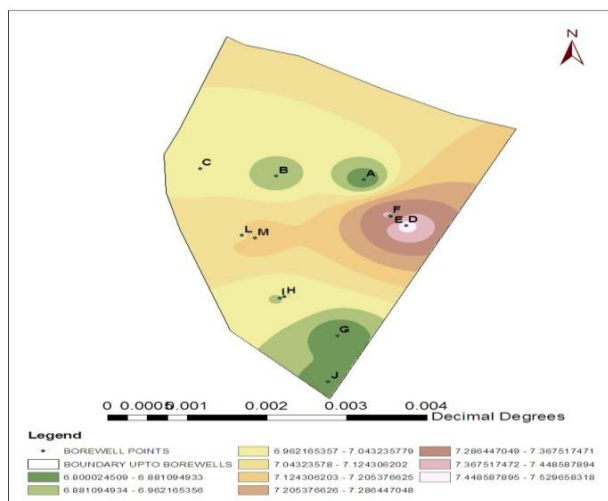


Fig.15. Spatial distribution of pH

8. CONCLUSION

The study demonstrated the application and effectiveness of GIS in studying the spatial distribution of groundwater quality parameters in the study area. The groundwater quality of the study area reflected large spatial and temporal variations. However spatial distribution of calcium, total hardness and TDS exhibited similar patterns with higher concentrations near peizometers compared to corresponding injection shafts. Also spatial distribution of nitrates and potassium concentrations are high in concentrations at open pond wells L and M. The well I exhibited least concentrations for all parameters. Hardness both calcium and magnesium were found to be relatively more in observation wells near to new IST building. The wells in the open pond has higher nitrates and potassium salts.

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