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Developing a Sustainable Ground Water Management Plan for Part of Ghaziabad District, Uttar Pradesh

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ABSTRACT
The availability of water resources is becoming a major constraint to the fast developing NCR extension covering Loni and Razapur Blocks,Ghaziabad District. Besides domestic and commercial infrastructure, there are 15000 small and 145 medium industries. All of them depend on groundwater resources, development of which has exceeded 76% and beyond this development will lead to saline ingress , ground water pollution and desaturation of aquifers. It thus becomes imperative to utilize 174 MCM run off potential in two blocks for recharge. The paper discusses various options towards attaining sustainability of the water resources to meet the growing demand.

Keywords: Groundwater Development, Sustainable, Aquifer Systems. Artificial Recharge, Pollution

INTRODUCTION
The new infrastructure development and residential complexes entirely depend upon the groundwater resources but for want of adequate information on aquifer system most of the tubewell have become defunct. The Loni and Razapur blocks which are located on the eastern end of NCR region and depend upon the groundwater resources for domestic and industrial water supply. Before becoming hub for infrastructure development, the irrigation was by tubewells and to some extend by surface irrigation system. The upper Ganga canal and its tributaries irrigate western part of the Ghaziabad District and Anup Shalon branch of upper Ganga canal irrigates eastern part of the district but Harpur and Loni block are practically devoid of surface irrigation. As such there is no surplus surface water which can be supplied to the emerging infrastructure, residential complexes, therefore for water supply they are entirely depending upon the groundwater resources. It is therefore imperative to explore the new aquifer zones upto the basement rock which can be exploited for water supply. The scarcity of water resources is leading to conflicts and very near to the water terrorism. The present study have identified the aquifer system upto the basement rock and have also worked on the lateral and vertical extension of the aquifer zones and also the water quality of each of the aquifer zones. In order to overcome the water scarcity, there is a need to regulate the groundwater development making rainwater harvesting and recycling of treated waste water as mandatory.

Geology & Hydrogeology
Regionally the eastern half of the district forms part of Ganga alluvial plain where as its western part in close proximity of Hindon and Yamuna rivers represents marginal alluvial plain. Tectonically the alluvial plain of Ganga basin represents a structural trough (Fore deep) or down wrap of earth crust. The origin of which is correlated to plate tectonic and Himalayan uplift. The area is underlain by quaternary sediments, their thickness increase from west to east and also towards north east. As per available subsurface, alluvium in the district varies from 115 m to 450 m. In Hindon Yamuna doab, the thickness of quaternary sediments including alluvial deposit varies from 300 m the north to 115 m in the central part of the Western side of Hindon river. The lithological variation in Loni Block is given in Table 1

Table 1: Sub-surface lithology of Loni Block

Lithology	Depth Range	Thickness
Surface soil, sandy wilt, grey coloured	GL – 3.00	3.00
Sand, medium to coarse, grey coloured	3.00 – 9.30	6.30
Sand, medium, grey coloured with micaceous and ferromagnesian minerals	9.30 – 21.85	12.55
Kankar with 10% clay and silt	21.85 – 28.10	6.25
Clay predominant with minor amount of kankar	28.10 – 31.35	3.25
Sand, fine, pale yellow coloured with 10% kankar, angular to sub rounded	31.35 – 34.55	3.20
Silt with clay and small amount of kankar grayish colour	34.55 – 43.85	9.30
Sand, fine, grey coloured	43.85 – 46.85	3.00
Sand, medium t coarse, grey coloured with micaceous minerals	46.85 – 50.10	3.25
Clay, sticky, pale yellow coloured with kankar	50.10 – 59.35	9.25
Clay with kankar in equal proportion, grey coloured	59.35 – 65.63	6.28
Clay with kankar, pale yellow gold, sticky (typical) 5% kankar of small size	65.63 – 71.91	6.28
Clay with small size of kankar, grayish (40% kankar)	71.91 – 74.93	3.02
Clay, sticky, pale yellow with bigger size of kankar	74.93 – 85.99	11.06

Depth to Water Table

The groundwater occurs under unconfined condition in shallow aquifers whereas it is under unconfined condition in the deeper aquifers more than 60m depths. In the post-monsoon period, depth to water level ranges between 1.70 m to 24.6 m bgl, in general the depth to water table varies between 10 and 15m bgl (Figure 1).

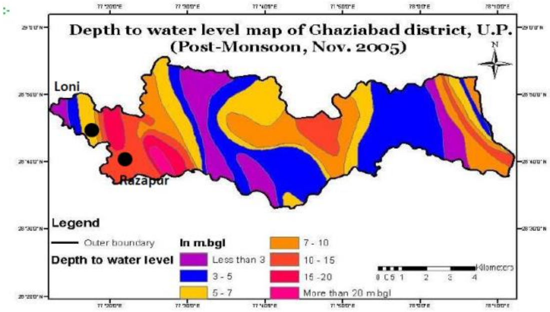


Figure 1: Depth to water level Map of Ghaziabad District, U.P (Post- Monsoon, Nov. 2005)

Water Level Fluctuation

Water level fluctuation data was analyzed for 10years and it was observed that on an average the water level fluctuation during monsoon is 0.2125 m per year and during post monsoon it was 0.3016m per year (Figure 2). The continuous decline will result in water quality problems as the area is surrounded by saline groundwater.

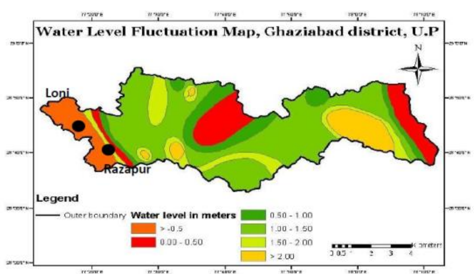


Figure 2: Water level Fluctuation Map of Ghaziabad district, U.P

Status of Groundwater exploration

In view of the water requirement to meet the domestic and industrial water requirement, CGWB carried out deep exploratory drilling, the data of which is presented in Table 2. It is evident from the results of the exploratory drilling that the bed rock is undulating and is observed at shallow depth of 104m in Ramprastha whereas in theRadha Kunj it is observed at the depth of more than 200 meter. Additional exploratory drilling is required to comprehend the rapid changes in lithology and chemical quality.

Sl. No.	Location	Type of Wells	Depth drilled (mbgl)	Depth of wells (mbgl)	Zones trapped/fracture (mbgl)	Static water level (mbgl)	Discharge (lpm)	Drawdown (m)	Transmissivity	Storativity	Aquifer	Remarks
1.	Babugarh	EW	453	145	71-83 101-119 133-139	13.18	2842	3.37	3053	5.29×10^{-4}	Alluvium	
2.	Loni	EW	118	67	36-42 47-62	3.84	1025	4.47	1435	1.31×10^{-5}	do	Basement encountered 117.9 (Delhi Quartzite)
3.	Radha kunj	EW	202.2	35	21-30	9.37	1018	-	1435	1.31×10^{-5}	do	Basement encountered 202.2 (Delhi Quartzite)
4.	Ramprastha	EW	106.53	35	20.5-32.5	6.18	1003	4.13	282	-	do	Basement encountered 103.53 (Delhi Quartzite)
5.	Sanjay Nagar	EW	449.6	215	100-103 106-112 134-137 148-154 200-212	16.37	11307.64	-	-	-	do	
6.	Surya Nagar	EW	85.99	38	22-26 30-35	4.95	1014	3.38	291	5.56×10^{-4}		

Groundwater Development Status

The groundwater development in the area being a continuous process, it was essential to know the status of groundwater development vis-a-viz the total recharge. CGWB, 2009 computed the groundwater recharge-discharge relationship and the stage of groundwater development for the unconfined aquifers, the following Table 3 gives the stage of groundwater development in Loni and Razapur block and also of the adjoining blocks of Muradnagar and Bhojpur.

Table 3: Block wise Groundwater Resources

S.No	Blocks	Annual Groundwater Recharge (in ham)	Net Ground Water Availability (in ham)	Existing Gross Groundwater Draft For All Uses (in ham)	Net Groundwater Availability for Future Irrigation Development (in ham)	Stage of Ground Water Development (in %)
1.	**Loni**	8185.45	7366.90	5548.47	1425.95	75.32
2.	**Rajapur**	11146.68	10032.02	5935.95	3925.35	59.17
3.	**Muradnagar**	12510.86	11259.77	7355.34	3747.72	65.32
4.	**Bhojpur**	11964.53	11336.30	8453.72	2759.71	74.38

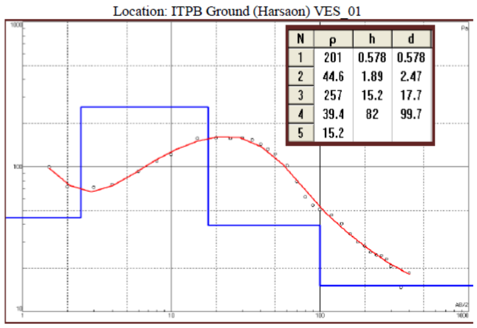
(Source: After CGWB, 2009)

The above dynamic resources are for the fresh water aquifers but it is equally important to estimate the potential of saline water aquifers for their conjunctive use with fresh water.

Geophysical Survey (Resistivity) for categorization of Aquifers

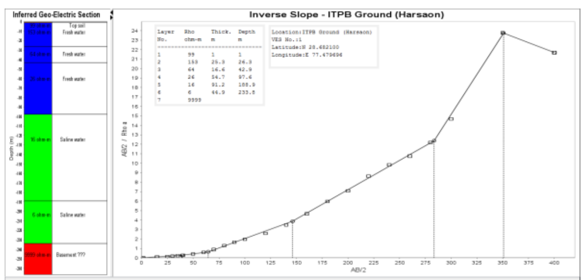
The resistivity survey is prelude to any exploration or construction of tube wells as it gives the information on the different aquifer zone and also water quality. Six deep resistivity survey was carried out to explore the depth upto 300 meter to comprehend the saline fresh interface and the different aquifer zone within the fresh water aquifer system. The data was interpreted using curve matching method and also inverse slope method.

The representative graph of both the methods is given in Figure 3.



A) Curve Matching- ITPB Ground (Harsaon)

The curve was showing KQ Type ($\rho_1 < \rho_2 > \rho_3 > \rho_4$) (Clay, Fresh Water Sand, Silty sand and Clay/sand with saline water)



The interpreted result show that the resistivity of the layer top soil ranges from 26.4-201 ohm-m and thickness is between 0.58-1.67 m. In the second layer, clay and sand was inferred with high resistivity values ranging from 9.14-257 ohm-m, this layer acts as the shallow aquifer in these places because this layer consists of fracture or weathered zone which constitutes an aquifer of very good quality of groundwater. The 3rd layer is the showing that saline water aquifers zone in the area of Ghaziabad.

Based on the interpretation of the resistivity survey data, resistivity pseudo section has been prepared (Figure 4) and the results are tabulated in Table 4.

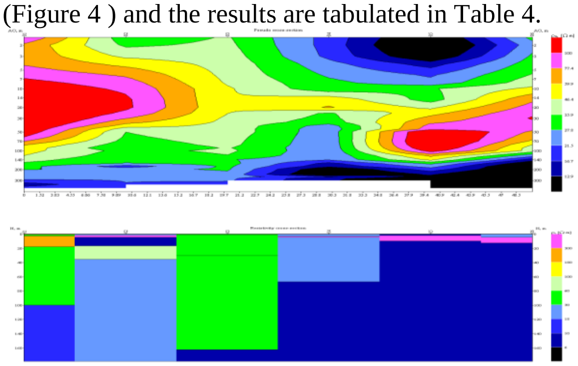


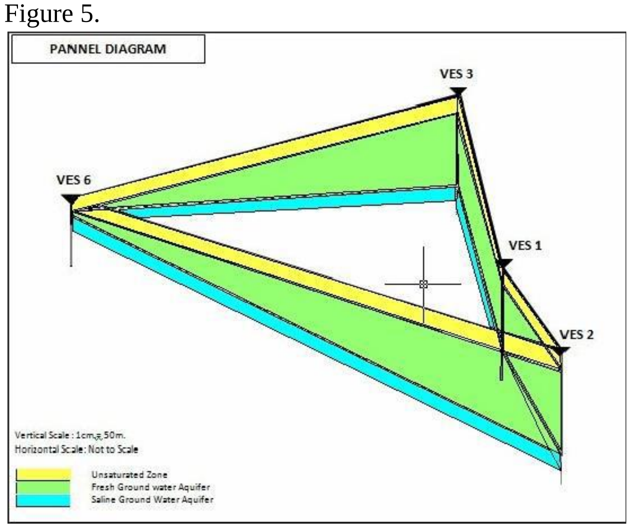
Figure4

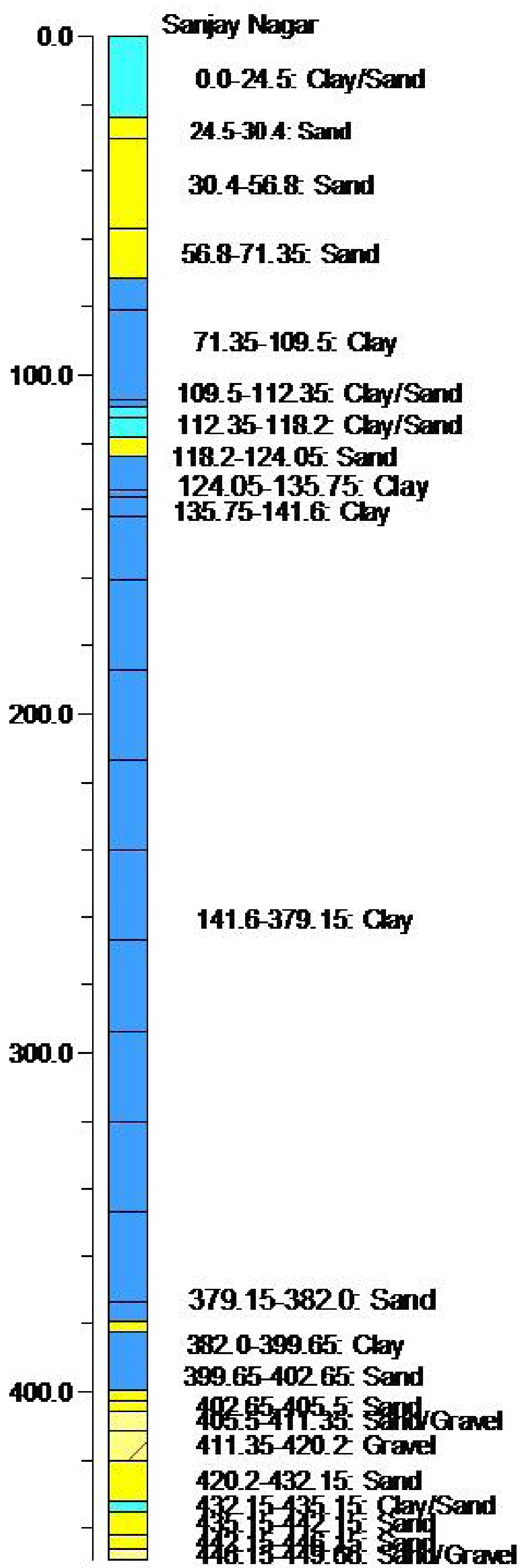
Table 4: Vertical Electrical Sounding Details of Ghaziabad Dist.

	No.	Latitude	Longitude				water quality
1	01	N 28.682100°	E 77.479696°	**P1 = 201 Ohm m.**	GL-0.5	Top soil	**Not applicable**
				P2 = 44.6 Ohm m.	0.5-2.4	Sands	**Not applicable**
				P3 = 257 Ohm m.	2.4-17	Sand with Kankar clays	**Fresh Water**
				P4 = 39.4 Ohm m.	17- 100	Fine to medium Sands inter-layered with clay bands	**Fresh water**
				P5 = 15 Ohm m.	100- indeterminate depth	Clayey Sands	**Saline water**
2	02	N 28.656848°	E 77.491458°	**P1 =26.4 Ohm m.**	GL- 1.6	Top soil	**Not applicable**
				P2 = 652 Ohm m.	1.6 - 4.2	Sand with kankar	**Not applicable**
				P3 = 9.1 Ohm m.	4.2- 16.4	Fine to medium sand with clay bands	**Fresh water**
				P4 = 90.5 Ohm m.	16.4 - 35.2	Fine sands interspersed with clays	**Fresh water**
				P5 = 18.5 Ohm m.	35.2 - downwards	Clayey sands	**Saline water**
3	03	N 28.736048°	E 77.475780°	**P1 = 35.6 Ohm m.**	GL- 1.2	Top soil	**Not applicable**
				P2 = 47.6 Ohm m.	1.2 – 28.4	Sands	**Fresh water**
				P3 = 32.4 Ohm m.	28.4 - 162	Fine to medium Sands inter-layered with clay bands	**Fresh water**
				P4 = 8.8 Ohm m.	162- indeterminate depth	Clayey sands	**Saline water**
4	04	N 28.693557°	E 77.487614°	**P1 = 18.4 Ohm m.**	GL- 3.1	Top soil	**Not applicable**
				P2 = 332 Ohm m.	3.1 – 4.2	Sand with kankar	**Not applicable**
				P3 = 26.4 Ohm m.	4.2- 67	Fine to medium sands interlayered with clay	**Fresh water**
				P4 = 9.1 Ohm m.	67 - interdeterminate depth	Clayey sands	**Saline water**
5				**P1 = 6.9 Ohm m.**	GL- 1.9	Top soil	**Not applicable**
	05	N 28.700031°	E 77.342004°	**P2 = 790 Ohm m.**	1.9 – 9.4	Sand with clay	**Fresh water**
				P3 = 8.5 Ohm m.	9.4- interdeterminate depth	Clayey sands	**Saline water**
6	06	N 28.706774°	E 77.335571°	**P1 = 26.9 Ohm m.**	GL- 4.3	Top soil	**Not applicable**
				P2 = 412 Ohm m.	4.3 – 12.5	Medium to coarse sands	**Fresh water**
				P3 = 6.51 Ohm m.	12.5 - interdeterminate depth	Clayey sands	**Saline water**

Panel Diagram

A panel digram showing the distribution of lithological units with groundwater quality is given in Figure 5.





It is thus concluded that in the heterogeneous aquifer system variation in lithology and water quality can be ascertain by the application of resistivity survey.

It is an important component to decide the potability of groundwater there being rapid changes in water quality both in the phreatic and semi confined aquifers, a number of samples were analyzed to study the variation in chemical quality. Based on the electrical conductivity values and Isoconductivity map has been prepared showing the areas under fresh and saline groundwater of the unconfined aquifers (Figure 6).

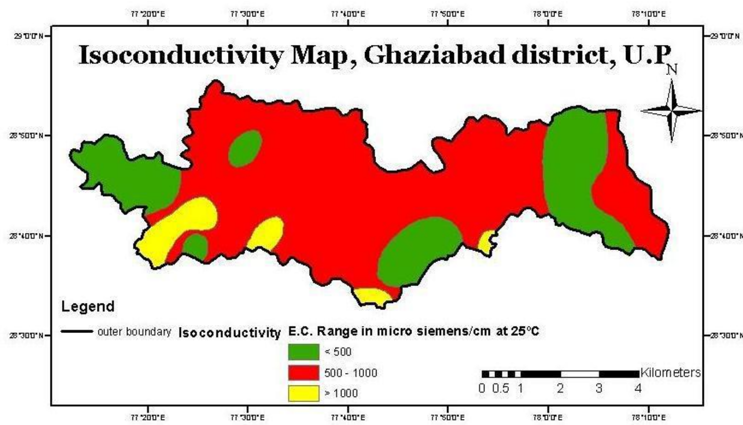


Figure 6: Isoconductivity Map of Ghaziabad

Recently, 14 water samples were collected from tubewell under operation to study the variation in chemical quality and their suitability for drinking and commercial purposes. The analysis are presented in table 5.

Table 5: Water Samples Analysis report of samples collected on 18-6-2013, Loni and Rajapur, Ghaziabad

S. no	Name of the Villages	(Type of Structure)	**Unit (mg/l)**	Ca	Mg	Na	K	CO 3	HCo3	Cl	No3	So4	F
1	Rajpur	Tube well		104	21.9	90	4.3	nil	196	112	11.8	72	0.78
2	Badarpur	Tube well		40	14.6	58	3.9	nil	120	18	10.5	34	0.56
3	Ristal	Tube well		100	26.7	98	4.8	nil	310	92	11.2	78	0.62
4	Dharipur	Tube well		80	46.2	102	4.4	nil	390	176	12.8	28.6	0.72
5	Nistoli	Tube well		104	43.7	80	4	nil	370	112	11.4	41.5	0.48
6	Farukhnagar	Tube well		76	24.3	102	4.2	nil	350	118	12.2	82.6	0.54
7	pachaura	Tube well		36	14.6	38	2.2	nil	160	22	9.8	42	0.48
8	Meerpur	Tube well		20	12.2	94	3.6	nil	210	108	10.6	118	0.72
9	Noraspur	Tube well		36	14.6	46	2.3	nil	110	18	9.2	32	0.68
10	Alipur	Tube well		72	31.6	82	4.8	nil	230	48	11.6	96.8	0.74
11	Iliachipur	Tube well		80	21.9	102	5.2	nil	320	22	12.5	52.6	0.86
12	Siti	Tubewell		60	24.3	72	3.5	nil	260	20	10.6	22.2	0.56
13	Bhupkhedi	Tubewell		64	7.3	98	4.2	nil	390	134	11.8	58	0.74
14	Sikheda	Tubewell		44	21.8	102	3.9	nil	410	196	12.5	146	0.86

In the classification of groundwater quality, Chadha (1999) has been used. In this diagram the differences in millie equivalent percentage between alkaline earths (Ca+Mg)and alkali metals (Na +K),expressed as percentage reacting valued , are plotted on the X-axis , and the differences in millie equivalent percentage between weak acidic anions (CO3 +HCO3) and strong acidic anions (Cl+SO4) are plotted on the Y-axis .The mill equivalent percentage difference between alkaline earth and alkali metals and between weak acidic anions and strong acidic anions , would be plotted in one of the four possible subfields of the rectangular diagram. The rectangular field describes the overall character of the water. In order to define primary character of the water , the rectangular field is divided into eight subfields , each of which represents a water type . Results of the chemical analysis are plotted on in the diagram below in figure 7.

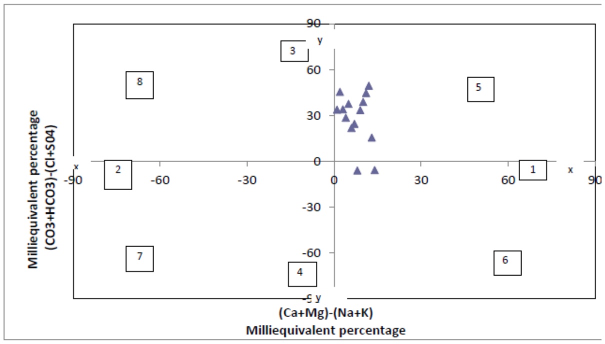


Figure 7: Results of the chemical analysis are plotted on in the diagram

Geochemical classification and hydrochemical parameters of groundwater (after Chadha 1999).

1. Alkaline earths exceed alkali metals;
2. alkali metals exceeds alkaline earths;
3. weak acidic anions exceed strong acidic anions;
4. strong acidic anions exceed weak acidic anions;
5. Ca2+--Mg2+--HCO3- water type with temporary hardness ;
6. Ca2+--Mg2+--Cl- water type with permanent hardness;
7. Na+--Cl- water type with salinity problems both in irrigation and domestic uses ;
8. Na+--HCO3- water type causes foaming problems in domestic use.

Therefore, the groundwater quality can be categorized as belonging to Ca2+--Mg2+--HCO3- water type with temporary hardness.

The cumulative values of Cations and Anions of 14 samples have been plotted in Figure 8. This cumulative value signifies the comparative assessment of the water quality.

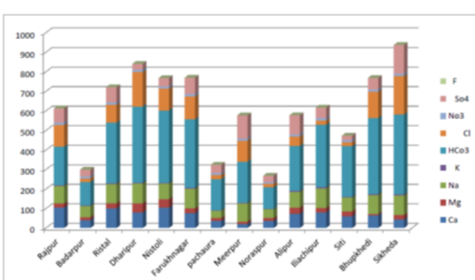


Figure 8: Groundwater pollution model

Potential for Groundwater Recharge

The runoff potential has been computed by using the following formula.

Average run off potential= Area X Coefficient of Run off X Average Annual Rainfall

It is thud computed that the runoff potential of Loni Block and the Razapur block and the corresponding potential for ground water recharge is given below:

1.Potential of Artificial Recharge Structure of LONI BLOCK

Water available from roof top = Annual rainfall (in mm) X Area of roof (in sq.m) X Coefficient of runoff for the roof

Run off Potential= 275876400*0.905*0.25= 62417035.5m3 = 62.41 MCM

Recharge potential= 70% of 62417035.5m3

= 43691924.85m3 = 43. 69 MCM

2. Potential of Artificial Recharge Structure of ROZAPUR BLOCK

1832750*0.905*0.25= 41465968.75 m3 = 41.46 MCM

Recharge potential= 70% of 41465968m3

=29026178.12m3 = 29.02 MCM

Pilot Project for rainwater harvesting

In order to showcase the low cost recharge to groundwater technology, a pilot project was implemented in the campus of RKGIT, Ghaziabad. The groundwater recharge structure has been designed to take care of the suspended load in the run off water by installing inverted filters. The length of the recharge well is 2m below the water table and the slotted assembly is placed against the potential aquifer zones consisting of fine to coarse sand. From the roof top of two of the building is 1501 m3.

Potential of Artificial Recharge Structure at RKGIT College

= 568.20 mm X 3774.69 sq.m X 0.7
= 1501.345 m3 or 15, 01, 345.201 litres

The diagram of the pilot recharge structure is given in Figure 9. The injection techniques are used as an alternative to surface spreading operations usually where a zone with low permeability, within the unsaturated zone, impedes the recharge to a designated aquifer. A cased recharge well or bore is generally used to penetrate a zone with low permeability. The open or perforated section at the base of the well allows infiltration into either the aquifer or vadose zone.

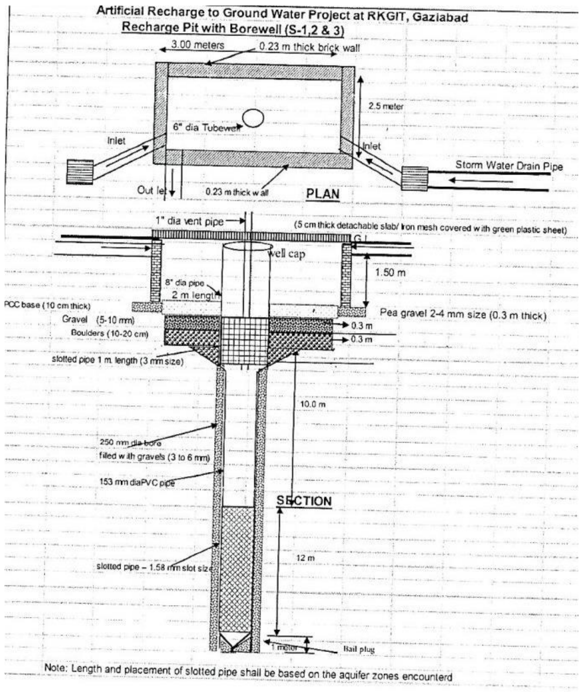


Figure 9: Artificial Recharge to ground water project at RKGIT, Gaziabad

In order to ensure the sustainable water supply from groundwater it is essential to have a detailed aquifer management plan. Aquifer management plan pertains to possibility of future development of

- Identification and development of deep aquifer fresh water zone wherever required.
- Rainwater harvesting as 71MCM of non committed monsoon water is available for water conservation and recharge.
- Utilization of surface water from canal system during monsoon when demand for surface water is substantially reduced.
- Conjunctive use: It is one of the best options to be exercised as there is quality variation and use of both the fresh groundwater and saline groundwater in reasonable proportion can be used and this will add to the availability of water resources.
- Utilization of saline groundwater: Although this potential is not assessed but the recent study indicate substantial potential is available which can be used by treating it with appropriate technology insitu or treating with the RO system. This will ensure water supply to the scattered habitation in the villages.
- In the urban scenario the domestic waste water will need to be treated for its secondary use and it should be made mandatory for any new infrastructure.

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