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Rain Water Harvesting Plan and Design for Mangalayatan University Campus, Aligarh" Uttar Pradesh, India"

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ABSTRACT
The technical aspect of this paper is rooftop rainwater harvesting which is considered to be catchment areas of Mangalayatan University Campus, Aligarh. The campus is situated at the distance of 39 km from Aligarh city in a large area of about 72 acres with strength of about 2700 students and more than 250 staff. Water is the natural resource which is being always in high demands by students and staff. If this demand is not met, then it will lead to water scarcity. Therefore, Rain water harvesting system can be considered as a best solution for fighting against scarcity of water. Moreover, owing to its simple techniques ease of construction and installation and low cost of investment, this technique again suites for implementation inside. The campus can meet potable and non potable water demands. The simple technique tends to increase the greenery in land and around the campus, increasing aesthetic factor for a proper residential institute to live in. Required data such as catchment areas, rainfall data, runoff groundwater condition etc. are collected and calculated. Then a recharge pit of suitable capacity and design is constructed. Optimum location of recharge pit was done using the hydrological analysis from the available data. The cost of the project is also calculated. In order to conserve the groundwater, this paper was found cost effective and very useful for recharging the groundwater. It is observed that this paper will also be a useful and valuable resource to other organizations which are planning to promote rainwater harvesting to supplement existing water systems. This paper will also raise awareness of the importance of rainwater harvesting for recharging ground water.
The rain water harvesting in Mangalayatan University campus comprises numerous water collection and percolating pits at different locations. Therefore, keeping in mind all these positive aspects, Rain water Harvesting is highly recommended for Campus.
Key Words: Catchment Area, Conserve, Groundwater, Rainwater Harvesting, Rainfall Data, Recharge, Runoff.

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I. INTRODUCTION:

Aligarh district is situated on the western part of Uttar Pradesh occupying a small part of Ganga – Yamuna doab. It lies between latitude 27°35´ and 28°10´N and longitudes 77°29´00´´ and 78°36´00´´E falling in survey of India top sheet nos. 53H, L & 54E. The northern boundary of the district is contiguous with that of Bulandshar district. Ganga River forms the natural boundary between Aligarh and Badaun in the north eastern corner of the district whereas the Yamuna in the northwest forms the state boundary between Uttar Pradesh and Haryana shown in Figure No: 01.

The Mangalayatan University Campus is strategically located on the Aligarh Mathura High way having close proximities to the Yamuna Expressway in Uttar Pradesh, shown in Figure No-02.The need of Rain Water Harvesting (RWH) from roof catchments of buildings in Campus. The amount of water to be stored during rainy seasons and the methods it at the ground for various uses are discussed in this study. The few ground water recharge techniques using rainwater in the Campus.

II. RAINFALL AND CLIMATE:

The normal annual rainfall is 708.7 mm. The Standard Derivation is 58.4 and Coefficient of Variance works out to be 8.20%. The maximum rainfall occurs during monsoon period is June to September. July is the wettest month.

Aligarh experiences the tropical monsoon type of climate. The summer and winters are severe. Maximum temperature shoots upto 45°C during May and minimum temperature remains around 18°C. Average maximum temperature remains around 42°C during May. In the winter seasons the temperature rests around 21°C and minimum temperature remains around 10°C. Rainy season commences in the middle of June & continues till September. The average relative humidity in the morning is 62.25% and in the evening it is 44.2%. The wind velocity ranges between 4.6 and 9.3Kms/hr.

III. GEOMORPHOLOGY:

Physiographically the district forms a part of Yamuna-Ganga Doab. The upper Ganga canal which flows roughly over the water divide from NW to SE direction divides the district into two unequal parts shown in Figure no.3 Topographically, the area is almost open plain, sloping gently from north to south in the western side and north west to west in the eastern side. The highest elevation of the district is 195.072 M.S.L. and the lowest is 173.76 M.S.L. The average gradient of land surface is 2cm/km.geomorphologically the district can be grouped into three geomorphic units as detailed below:

	Geomorphic Units		Lithology
1.	Recent flood plain of stream	-	yellow coloured clay, silt and sand of various grades.
2.	Terrace Zone	-	yellow and grey coloured silt, sand and kankar beds.
3.	Older Alluvial Plains	-	yellow grey coloured silt, sand and kankar beds.

IV. DRAINAGE:

Aligarh district occupies interfluvial area of the rivers Ganga and Yamuna in the Central Ganga Plain. The drainage of the area is controlled by river Ganga and Yamuna and their tributaries. Karwan Sirsa and Sengar are the important tributaries of river Yamuna whereas Rind, Isan, Nin and Kali Nadi forms the principal tributaries of river Ganga are shown in Figure No.4.

V. GEOLOGY:

Aligarh district falling in Central Ganga Plain lies in the interfluvial tract of Ganga and Yamuna. Hydro geological data indicates that the area is underlain by moderately thick pile of quaternary sediments, which comprises of sand of various grades clays & kankar. Alluvial sediments overlies Vindhyan group of rocks in an unconformable way. The thickness of deposits varies from 287 to 380 meters. The stratigraphic sequence is as follows:

Older alluvium occupies the upland of the district while the newer alluvium occupies low land area along the courses of Ganga Yamuna & their tributaries and paleochannels of Ganga and Kali rivers.

VI. NEED ANALYSIS OF RAIN WATER HARVESTING:

1) To overcome the inadequacy of surface water to meet our demands.
2) To arrest decline in ground water levels.
3) To enhance availability of groundwater at specific place and time and utilize rainwater for sustainable development.
4) To increase infiltration of rainwater in the subsoil this has decreased drastically in urban areas due to paving of open areas.
5) To improve groundwater quality by dilution.
6) To increase agriculture production.
7) To improve ecology of the area by increasing in vegetation cover etc.

OBJECTIVE: This paper is carried out to cater the need of the Mangalayatan University campus and will not only be helpful the need of water supply to our University, but also to provide water to facility residing in the university. Keeping in mind the following aspects:-

1) Quality of water supply
2) Increasing water demand
3) Variations in water availability
4) Advantage of collecting and storage of rainwater near the place of use etc.

It was planned to design the RWH system for the Mangalayatan University Campus (Figure-05) The increased need for water may result in lowering the groundwater table and depleted reservoir ores. Hence the use of rainwater will be useful alternative to provide continuous water supply for our students, hostels and

Laboratories in Campus. The water stored from the rainwater will also be of good quality that is free from impurities which might be there in groundwater of Aligarh as it is having large no of Lock industries and e-waste.

The main object of this paper is to overcome from the crisis of water. The water that is going waste from roof tops after rains can be collected and reused for many purposes. For Campus, this paper set an example in front of the people who do not care for water conservation and water is wasted and run into channels and mix with pollutants and could not be reused. In future time there will exist no water for drinking and for other purposes if we do not conserve water. Rain water can be harvested and should be reused.

RAIN WATER HARVESTING PLANT DESIGN IN MANGALAYATAN UNIVERSITY CAMPUS:

The site plan we find the space available for RWH structures. This will determine the size and location of the structures. Note the numbers and location of existing rain water pipes, outlets/spouts. Find out if there are any defunct or existing bore wells , swimming pool , water storage tanks that can be used for storing the harvested water. Determine the natural drainage, slope and location of storm water drains. This will help to lay out the conveyance pipe along the natural drainage patterns. This is particularly important while planning for a large complex or colony. Mark the location of plumbing (water and sewage) and electrical lines in the site. Care must be taken to avoid plumbing and electrical lines while constructing the water harvesting structures. In case of project in public places this becomes even more important that underground sewer, water supply and other such as cables and lines are not inadvertently destroyed. Other information such as the existence and location of generator room, compost pit, waste dump etc. also need to be taken into account (Figure 6 and 7)

1. To make a study about the analysis and design of water tanks.

2. To make a study about the guidelines for the design of liquid retaining structure according to IS Code.

3. To know about the design philosophy for the safe and economical design of water tank.

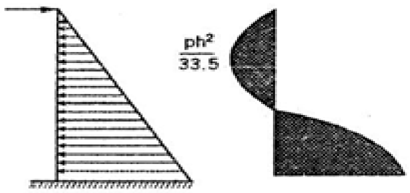
4. To develop programs for the design of water tank of flexible base and rigid base and the underground tank to avoid the tedious calculations.

5. In the end, the programs are validated with the results of manual calculation given in .Concrete Structure.

Design of underground rain water harvesting tank with specifications:-

Internal dimensions 5m×3m×3m.
Height 3m includes free board of 0.4m (2.6m + 0.4m = 3.00m)
The soil surrounding the tank always remains dry.
The tank shall be provided with a roof slab.
The soil weighs 1600 kg/meter^2 having an angle of repose of 30°.
Weight of R.C.C. = 2400 Kg/m^3.
Unless otherwise mentioned it will be taken that the soil surrounding the tank is not liable to be removed at any stage.

The tank will therefore be designed for following critical cases:
Case 1. When the tank is full.



Case 2. When the tank is empty.
All walls will be designed as propped cantilevers.

Case 1. Analysis: When the tank is full.
Maximum soil pressure =

$$1600 \times 3 \times \frac{1-\sin 30^\circ}{1+\sin 30^\circ} \text{Kg/m}^2 = 1600\text{Kg/m}^2$$

Maximum water pressure = 100×3=3000 Kg/m^2
Net pressure = p =3000-1600 =1400 Kg/m^2
∴ Max. B.M. producing tension away from the water side

$$\frac{ph^2}{33.5} = \frac{1400 \times 3^2}{33.5} Kgm = 376.1 Kgm$$
$$= 37610\ Kgm$$

Maximum bending moment producing tension near the water face

$$\frac{ph^2}{15} = \frac{1400 \times 3^3}{15} \text{Kgm} = 84000 \text{ Kgm}$$

Case 2. Analysis: When the tank is empty
Maximum soil pressure = 1600 Kg/m^2
Maximum bending moment producing tension near the water face

$$\frac{ph^2}{33.5} = \frac{1600 \times 3^2}{33.5} \text{ Kgm} = 429.8 \text{ Kgm} = 42980$$
Kgcm

Maximum bending moment producing tension away from the water side

$$\frac{ph^2}{15} = \frac{1600\times3^3}{15} Kg = 960\,\frac{Kg}{m} = 96000\,\frac{Kg}{cm}$$

The result obtained for the above two cases are tabulated below:

Case	B.M. producing	B.M. producing Tension away from water face (kg
Case 1	84000	37610
Case 2	42980	96000

The outer wall of an underground tank must also be designed from cracking stress consideration. Cracking stress means the actual tensile stress in concrete due to bending moment. This stress must be limited to 16 kg/cm^2. To satisfy this condition the walls must be sufficiently thick. The overall thickness D may be determined by assuming the moment of resistance as 2.67 bD^2.

$$\frac{1}{6} fbD^2 = \frac{1}{6} = 16\, bD^2 = 267\, bD^2$$

In our case equating the moment of resistance to the maximum bending moment, we have

2.67×100 D^2 = 96000, D = 19 cm
Let us provide a thickness of 20 cm.
Providing an effective cover of 4cm.
Effective depth = 20 – 4 = 16 cm
Steel for a bending moment of 96000 kg cm =

$$\frac{96000}{1250\times0.86\times15}\, cm^2 = 5.6\, cm^2$$

Provide 12 mm dia. Bars @ 20 cm centers (5.65 cm^2)
Steel for a bending moment of 84000 kg cm =

$$\frac{84000}{1000\times0.86\times16}\, cm^2$$

Provide 12 mm dia. Bars at 18 cm centers (6.28 cm^2)

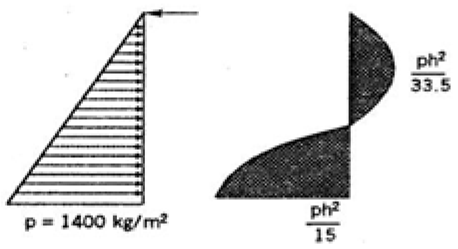
Crack of Cracking Stresses

Position of actual neutral axis. Taking moments about the neutral axis

$$100\frac{n^2}{2}(13-1)6.38(n-4) = 100\frac{(20-n)^2}{2} + (13-1)\, 5.65\, (20-n-4)$$

Solving, we get n = 8.84 cm

Moment of resistance determined from the tension zone may be taken as
Total tension × 0.82 d



Cracking stress due to a B.M. of 96000 Kg cm.

This B.M. produces tension away from the water side.
Let the maximum tensile stress be C1.

Total tension= $100\times11.16\frac{c_t}{2}\ (13-1)\, 5.65\times\frac{7.16}{11.16} C_t = 601.5\, C_t\ Kg$

Equating the M.R. to B.M.
$601.5\, C_t\times0.82\times16 = 96000$, ∴ C_t= 12.16 kg/cm^2 (less than 16 Kg/cm^2)

Cracking stress due to a B.M. of 84000 Kg cm

This bending moment produces tension near water face.
Let the tensile stress in concrete be C1
Total tension =

$$100\times8.84\,\frac{C_t}{2} + (13-1)\times6.28\times\frac{4.84}{8.84} C_t\ Kg = 483.3\, C_t$$

Equating the M.R. to the B.M. 483.3 C_t×0.82×16 = 84000 C_t =13.25 Kg/cm^2= less than 16 Kg/m^2 Provide also distribution steel of 8 mm diameter bars at 16cm centre near each face.

Design of roof slab

Loads. Dead load (15cm) = 360 Kg/m^2
Live load = 150 Kg/m^2
Total = 510 Kg/m^2
Consider a one meter wide strip of the slab

Maximum bending moment

$$\frac{510\times2.7^2}{8}\, kgm = 464.7\, Kgm$$
$$= 46470\, Kgcm$$

If the concrete mix. (M 150) be the used for the roof slab.
8.7 × 100 d^2= 46470, d = 7.30 cm.

Providing a cover of 4 cm effective depth available = 15 - 4 = 11 cm

$$A_{st} = \frac{46470}{1400 \times 0.87 \times 11} cm^2$$

Spacing of 10 mm diameter bars $= \frac{0.79 \times 100}{3.46} cm = 22.8 cm^2$

Distribution steel = $\frac{0.3}{100} \times 15 \times 100 \, cm^2 = 4.5 \, cm^2$

Spacing of 8 mm diameter bars = $\frac{0.5 \times 100}{4.5} cm = 11 \, cm$

Design of the base slab.

Case 1. When the tank is full.
Consider one meter run of the tank.
Weight of Roof Slab= 3.4×0.15×2400 = 1224 Kg/m
Walls: = 2×0.2×3×2400 = 2880 Kg/m
Total = 4104 Kg/m
Note: - Water pressure on the base slab and the weight of base slab will be directly Counteracted by ground pressure and will, therefore, not be included in the B.M. calculations.
Net upward reaction = $\frac{4104}{5} = 820.8 \, Kg/m^2$
B.M. at the centre due to the above loading
= 2052 (1.6 × 1.25) Kgm 718.2 Kgm
= 71820 Kgcm
Producing tension on the water side.
Water pressure and soil pressure action on the wall will produce a moment of 84000 Kg cm of the same type.
∴ Total bending moment at the centre = 71820 + 84000 kg cm = 155820 kg cm
Producing tension on the water side.
B.M. at the end. Hogging bending moment = 84000 kg cm
Sagging bending moment =
$820.8 \times \frac{0.9^2}{2} \times 100 = 33240 \; Kgcm$
∴ Net B.M. = 84000 - 33210 = 50760 kg cm
producing tension on the water side.

<u>Case 2.</u> When the tank is empty.
For this condition B.M. at centre due to vertical = 71820 kg cm
producing tension on the water side.
B.M. due to soil pressure on the vertical walls = 96000 kg cm
Producing tension away from water side.
∴ Net B.M. at the centre = 96000 - 71820 = 24180 kg cm
Producing tension away from the water side.
The result obtained for the above two cases are tabulated below:

Case	B.M. at End section	B.M. at Mild span (I-span)	B.M. produces Tension
Case 1	50760	155820	On water side
Case 2	129240	24180	Away from water side

Showing B.M. Produces Tension in Two case 1 and case 2.

Let the thick of the base slab he D cm.
From cracking stress consideration, equating the moment of resistance to maximum to B.M.,
We have,
$2.67 \, bD^2 = 2.60 \times 100 \, D^2 = 155820$, D=24cm,
Let us provide an overall depth of 25 cm.

Let the effective cover be 6cm.
∴ Effective depth =25-6= 19 cm
Steel for a bending moment of 155820 Kgcm = $\frac{155820}{1000 \times 0.84 \times 0.19} = 9.76 cm2$

Spacing of 12 mm diameter bars=
$$\frac{1.13 \times 100}{9.76} cm = 11.58 \, cm$$

Provide 12 mm diameter bars at 11 cm centers (10.27 cm')

Steel for a bending moment of 129240 kg/cm. =
$$\frac{129240}{1250 \times 0.86 \times 19} cm = 6.33 \, cm^2$$

Spacing of 12 mm diameter bars = $\frac{1.13 \times 100}{6.33}$ cm = 17.85 cm

Provide 12 mm diameter bars at 17 cm centers ($6.65 \, cm^2$)
Check for cracking stress

Position of actual neutral axis:
Taking moments above the neutral axis, we have,
$$100\frac{n^2}{2} + (13-1) \times 10.27 \, (n-6) =$$
$$100 \, \frac{(25-n)^2}{2} + (13-1) \, 6.65 \, (25-n-6)$$

n = 12.3 cm

Cracking stress due to a bending moment of 155820 kg cm.
This bending moment produces tension on the water face.

Let the tensile stress in concrete be C_t
Total tension

100 ×12.3 $\times\left(\frac{C_t}{2}+\right)(13-1)10.27\times\frac{8.3}{12.3}C_t$ kg = 708.8 C_t Kg

Equating the moment of resistance to the bending moment

708.8 C_t× 0.82×19 = 155820

C_t= 12.76 Kg/cm^2 (less than 16 Kg/cm^2)

Cracking stress due to a bending moment of 129240 kg cm

This bending moment produces tension away from the water side.

Let the tensile stress in concrete be C_t

Total tension = ×100 × 127 × $\frac{C_t}{2}+(13-1)\times$ 6.65 × $\frac{8.7}{127}C_t$ kg =687 C_t kg

Equating the moment of resistance to the bending moment,

6.87 C_t×0.82×19 = 129240

C_t = 10.92 Kg/cm^2 (less than 16 Kg/cm^2).

VII. CONCLUSION

In the most water, scarce region of India, RWH offers limited potential. In many other regions, which have medium rainfall but 'experience medium to high' evaporation, the poor ground water potential of hard rock which underlies these regions poses constraints for recharge. Economic evaluation of water harvesting systems poses several complex cities due to the problems in qualifying the hydrological impacts and the various benefits. The economics of water harvesting cannot be worked out for structures on the basis of individual benefits but rather on the basis of incremental benefits.

Storage of water in the form of tanks for drinking and washing purposes, swimming pools for exercise and enjoyment, and sewage sedimentation tanks are gaining increasing importance in the present day life. For small capacities, we go for rectangular water tanks while for bigger capacities we provide circular water tanks. Design of water tank is a very tedious method. Without power also we can consume water by gravitational force.

There is an optimum level of water harvesting which a basin can undergo to help optimize the crux value product of water economic, social, and environmental output basin wide. For research point of view of action the following steps seem to be important to make water harvesting more efficacious:-

1) Developing a better understanding of catchment hydrology.

2) Developing basin water accounting and balancing.

3) Focusing on wet water caving.

4) Enhancing the productivity of green water in the basin.

Now, if we concern about Mangalayatan University Campus the following specific conclusions have been drowning based on the above story:-

1) Since the ground water table of Mangalayatan University Campus and nearby area is continuously falling down, it is necessary to plan, design and construct the rain water harvesting system in the campus to capture rain water from roof surface and paved surface (Road Surface) catchment.

2) It will be better and more convenient to provide underground reservoir (Tanks) to store rainwater rather than providing storage tank without disturbing landscape of the area.

3) For recharging rainwater into the ground there are many steps of recharging system may be recommended depending upon the maximum rainfall in Aligarh.

On the basis of water requirement of the Mangalayatan University Campus, ground water conditions of the area and rain water data; it is proposed to develop rain water harvesting system for catering the need for the Mangalayatan University Campus. It will not only maintain the water level of the ground water of the region but also save our water resources and power consumption for future uses.

Based on calculation and result It is concluded that:-

1) The average rainfall in the season is around 55mm / Year.

2) After calculating the catchment area and the water harvested, the pit of size 5mm x 3mm x 3mm was suggested to construct.

3) By the use of this pit we can harvest a huge amount of water i.e. 10397025 L / Year.

4) The maintenance cost of this type of system is negligible i.e. economical.

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TABLES:

RAIN FALL DATA: (May 2011 October 2016)

Year	Average Rainfall
2011	609.64 ml
2012	467.10 ml
2013	542.02 ml
2014	257.46 ml
2015	369.32ml
2016	512.56 ml

Table no. 1: Average annual rainfall of Aligarh city (Year 2011 to 2016)
(Source: Central Meteorological Department, New Delhi)

Group	Age	Formation	Lithology
Quaternary	Recent to Upper Pleistocene	Newer / Younger Alluvium	Fine sand silt, clay admixed with gravels
	Upper Pleistocene	Older Alluvium	Clay with kankar and sand of different grades
-------------------------Unconformity-------------------------			
Paleozoic	Cambrian	Upper Vindhyans (Bhawder Series)	Red sandstone & shales

Table No.02: Geological Succession of Aligarh District, Uttar Pradesh

Construction cost for a typical RWH Tank (Size = 5 m x 3 m x 3 m)								
Detail of Measurements								
S. No.	Item	No	L (M)	W (M)	H (M)	Qty.	Unit	
1	E/W in Excavation	1	7.4	5.4	3.4	135.864	M^3	
2	Levelling & Dressing	1	7.4	5.4	-	39.96	M^2	
3	PCC in 1:4:8	1	7	5	0.25	8.75	M^3	
4	Making of Form work	1	5	0.25		1.25	M^2	
		2	7	0.25		3.5	M^2	
		2	3.4	3.15		21.42	M^2	
		2	5.4	3.15		34.02	M^2	
		2	3	3.15		18.9	M^2	
		2	5	3.15		31.5	M^2	
	Total Frame Work	110.59					M^2	
5	Fixing and Removing of Form Work	1	Same as column 4					
6	R.C.C in 1:2:4	5.4	5	0.25		6.75	M^3	Base wall
		5.4	3	0.2		6.48	M^3	Walls
		3	3	0.2		3.6	M^3	
		5.4	3.4	0.15		2.754	M^3	Roof Slab
Total Steel Required = 1% of R.C.C= 19.58/100x7860 kg.= 1572kg./Tank= 1.572 MT/Tank								
7	Plastering	1	Same as column 4					
8	Fixing of Fixtures	1			3	No. of staires =14 at distance of 20 cm each		
				No. of PVC socket required=1 No.				

Table No.3: Construction cost for a typical RWH tank (Size **= 5 m x 3 m x 3 m**)

Case	B.M. at End section (kg cm)	B.M. at Mild span (kg cm)	B.M. produces Tension
Case 1 Case 2	50760 129240	155820 24180	On water side Away from water side

Table no: 04 Table showing B.M. produces tension in two case 1 and case 2.

Abstract of cost					
S.R. No.	Item	Quantity	Unit	Rate (Rs.)	Amount(Rs.)
1	Earthwork and Excavation for underground Tank	135.86	cu.m	500 / cu. m	67930
2	Levelling and Dressing	39.96	sq.m	40 / sq. m	1598.40
3	P.C.C in 1:4:8	12	m	3400 / m	40800
4	Making of Form Work	111.82	sq.m	300 / sq. m	33546
5	Fixing and Removing of Form Work	111.82	sq.m	100 / sq. m	11182
6	Reinforcement Concrete Works	19.58	cu.m	6000 / cu.m	117480
6a	Reinforcement	1.572	MT	60000/MT	94320
7	Plastering	111.82	sq.m	300 / sq. m	33546
8	Fixing of Fixtures	3	m	8000 / m	24000
		Total Amount = Rs. 424402.4			

Table no: 05 Table showing Abstract of cost of RWH Tanks.

Cost of underground RWH tank of capacity 45 cu.m = Rs. 424402.4
Cost of 1 cu.m= Rs. 94.31.16
Cost of 397 cu.m = Rs. = 3744170.52

Figure No. 01: Aligarh in Doab region between the Yamuna and Ganga rivers

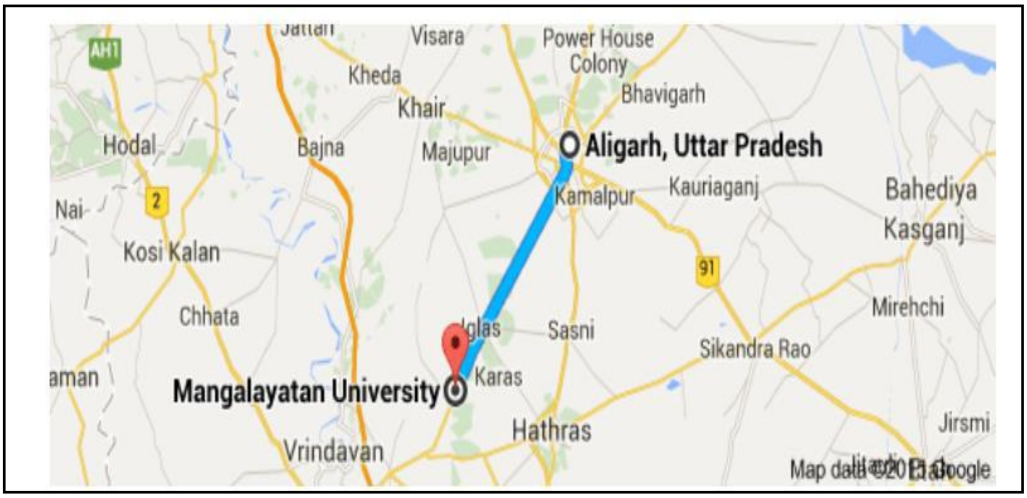

Figure No. 02: Location map of Aligarh to Mangalayatan University Campus.

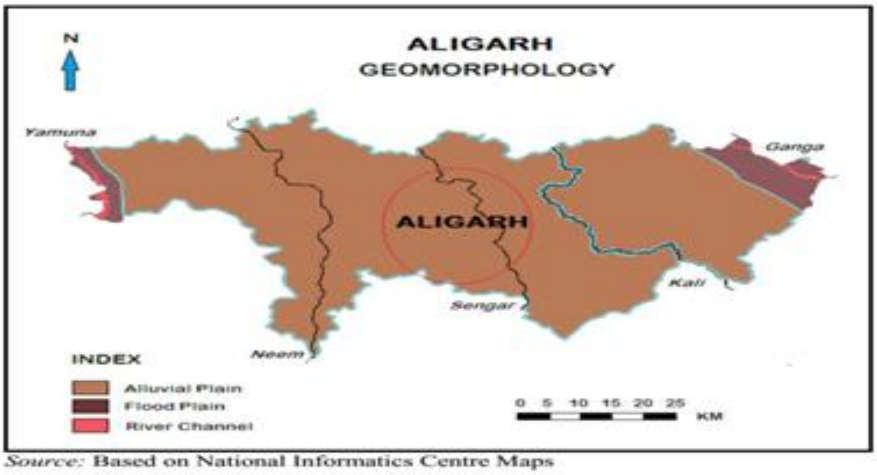

Figure No. 03: Map showing GeomorphicLands in Aligarh District.

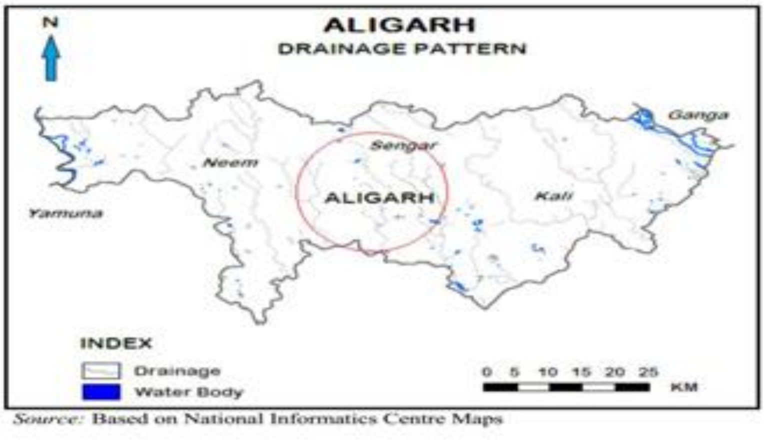

Figure No. 04: Map showing Drainage and Rivers in Aligarh District.

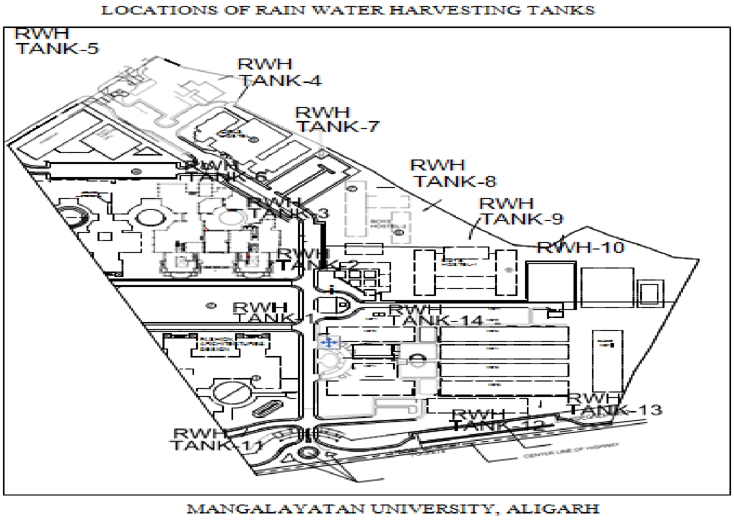

Figure No. 05: Locations of rain water harvesting tanks at M .U Campus.

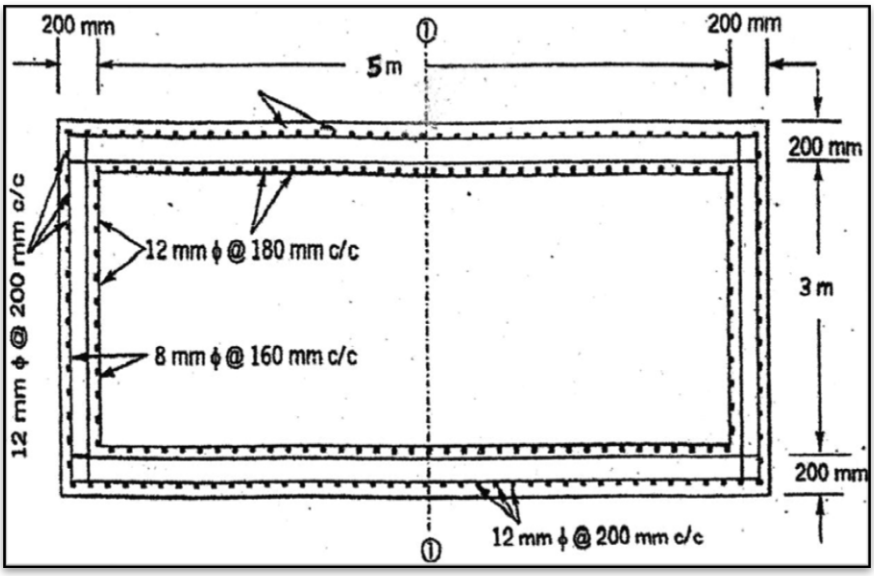

Figure No. 06: **Plan of underground rain water harvesting tank.**

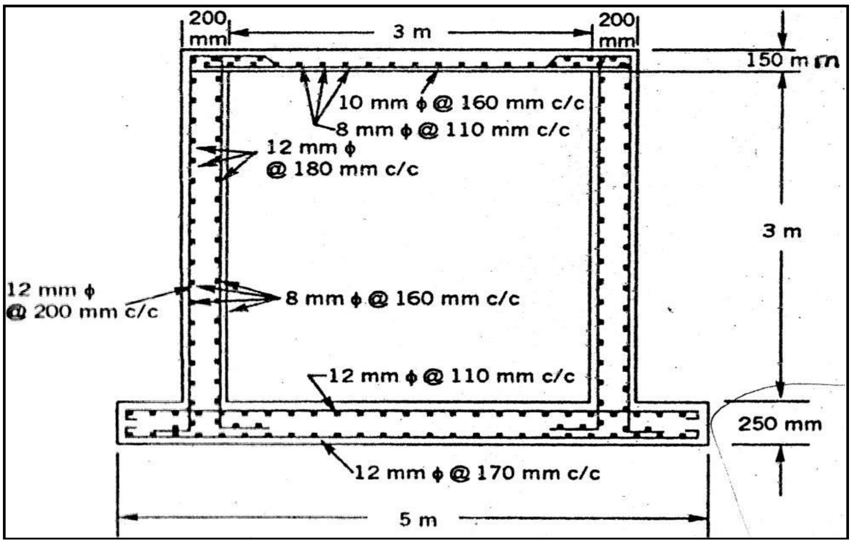

Figure No. 07: **Elevation of underground rain water harvesting tank.**

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