# Rainwater Harvesting at N.I.T. Rourkela

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BY

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UNDER THE GUIDANCE OF

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DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

2010

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

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# CERTIFICATE

This is to certify that the Project Report entitled "**RAINWATER HARVESTING AT NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA**" submitted by **Mr. Ranjit Kumar Sharma** in partial fulfillment of the requirements for the award of Bachelor Of Technology Degree in **Civil Engineering** at National Institute Of Technology, Rourkela (Deemed University) is an authentic work carried out by them under our supervision and guidance.

To the best of our knowledge, the matter embodied in this Project Report has not been submitted to any other University/Institute for the award of any Degree or Diploma.

DATE :-

Prof. K.C.Patra | Prof. Ramakar Jha

National Institute of Technology, Rourkela | National Institute of Technology, Rourkela

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My heart pulsates with the thrill for tendering gratitude to those persons who helped me in completion of the project.

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**RANJIT KUMAR SHARMA**
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# ABSTRACT

At the rate in which India population is increasing, it is said that India will surely replace China from its number 1 position of most densely populated country of the world after 20-30. These will lead to high rate of consumption of most valuable natural resource 'Water' resulting in augmentation of pressures on the permitted freshwater resources. Ancient method of damming river and transporting water to urban area has its own issues of eternal troubles of social and political. In order to conserve and meet our daily demand of water requirement, we need to think for alternative cost effective and relatively easier technological methods of conserving water. Rain water harvesting is one of the best methods fulfilling those requirements. The technical aspects of this paper are rainwater harvesting collected from rooftop which is considered to be catchment areas from all hostels and Institutes departmental building at N.I.T. Rourkela Campus. First of all, required data are collected i.e. catchment areas & hydrological rainfall data. Water harvesting potential for the hostels and faculty apartments was calculated, and the tank capacity with suitable design is being considered. Volume of tank has been calculated with most appropriate method of estimation. Optimum location of tank on the basis of hydrological analysis and GIS analysis was done in the campus. Finally, Gutter design, its analysis, first flush and filtration mechanism are also dealt with in detail.

**Keyword**: Rainwater harvesting, first flush mechanism, Roof water system, Gutter for conveyance, Underground RCC tank, Methods of distribution of harvested rainwater.

# CHAPTER 1

# INTRODUCTION

## 1.1. RAINWATER HARVESTING SYSTEMS AND ITS FEATURES

Rainwater Harvesting is a simple technique of catching and holding rainwater where its falls. Either, we can store it in tanks or we can use it to recharge groundwater depending upon the situation.

1.1.1. Features of Rainwater Harvesting are:

- Reduces urban flooding.
- Ease in constructing system in less time.
- Economically cheaper in construction compared to other sources, i.e. dams, diversion, etc.
- Rainwater harvesting is the ideal situation for those areas where there is inadequate groundwater supply or surface resources.
- Helps in utilizing the primary source of water and prevent the runoff from going into sewer or storm drains, thereby reducing the load on treatment plants.
- Recharging water into the aquifers which help in improving the quality of existing groundwater through dilution.

## 1.2. COMPONENTS OF RAINWATER HARVESTING SYSTEM

A rainwater harvesting system comprises of components for - transporting rainwater through pipes or drains, filtration, and tanks for storage of harvested water. The common components of a rainwater harvesting system are:-

1. **Catchments:** The surface which directly receives the rainfall and provides water to the system is called catchment area. It can be a paved area like a terrace or courtyard of a building, or an unpaved area like a lawn or open ground. A roof made of reinforced cement concrete (RCC), galvanized iron or corrugated sheets can also be used for water harvesting.

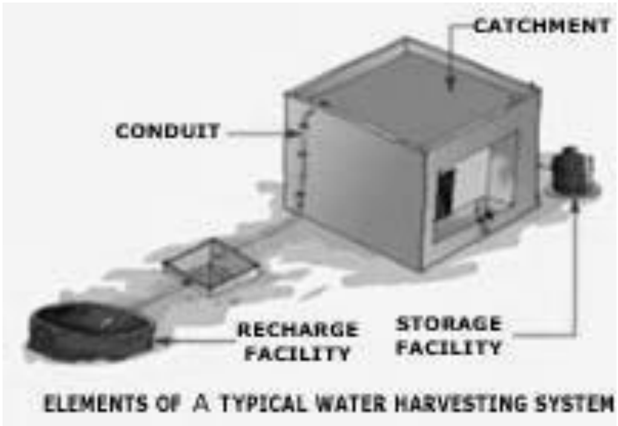


Figure 3: Components of Rainwater Harvesting system

2. **Coarse Mesh**: It prevents the passage of debris, provided in the roof.
3. **Gutters**: Channels which surrounds edge of a sloping roof to collect and transport rainwater to the storage tank. Gutters can be semi-circular or rectangular and mostly made locally from plain galvanized iron sheet. Gutters need to be supported so they do not sag or fall off when

loaded with water. The way in which gutters are fixed mainly depends on the construction of the house, mostly iron or timber brackets are fixed into the walls. The detail of the designing part of the Gutter is done in 7.3.

4. **Conduits:** Conduits are pipelines or drains that carry rainwater from the catchment or rooftop area to the harvesting system. Commonly available conduits are made up of material like polyvinyl chloride (PVC) or galvanized iron (GI).
5. **First-flushing**: A first flush device is a valve which ensures flushing out of first spell of rain away from the storage tank that carries a relatively larger amount of pollutants from the air and catchment surface. The detail designing of first flushing is dealt in section 7.4.
6. **Filters**: The filter is used to remove suspended pollutants from rainwater collected from rooftop water. The Various types of filters generally used for commercial purpose are Charcoal water filter, Sand filters, Horizontal roughing filter and slow sand filter.

7. **Storage facility**: There are various options available for the construction of these tanks with respect to the shape, size, material of construction and the position of tank and they are:-
   **Shape**: Cylindrical, square and rectangular.
   **Material of construction**: Reinforced cement concrete(RCC), masonry, Ferrocement etc.
   **Position of tank**: Depending on land space availability these tanks could be constructed above ground, partly underground or fully underground. Some maintenance measures like disinfection and cleaning are required to ensure the quality of water stored in the container.

If harvested water is decided to recharge the underground aquifer/reservoir, then some of the structures mentioned below are used.

8. **Recharge structures**: Rainwater Harvested can also be used for charging the groundwater aquifers through suitable structures like dugwells, borewells, recharge trenches and recharge pits. Various recharge structures are possible - some which promote the percolation of water through soil strata at shallower depth (e.g., recharge trenches, permeable pavements) whereas others conduct water to greater depths from where it joins the groundwater (e.g. recharge wells). At many locations, existing structures like wells, pits and tanks can be modified as recharge structures, eliminating the need to construct any fresh structures. Some of the few commonly used recharging methods are recharging of dug wells and abandoned tube wells, Settlement tank, Recharging of service tube wells, Recharge pits, Soak ways /Percolation pit , Recharge troughs, Recharge trenches, Modified injection well.

## 1.3. STUDIES CARRIED OUT GLOBALLY

Today due to rising population & economical growth rate, demands for the surface water is increasing exponentially. Rainwater harvesting is seems to be a perfect replacement for surface & ground water as later is concerned with the rising cost as well as ecological problems. Thus, rainwater harvesting is a cost effective and relatively lesser complex way of managing our limited resources ensuring sustained long-term supply of water to the community. In order to fight with the water scarcity, many countries started harvesting rain. Major players are Germany (Biggest harvesting system in Germany is at Frankfurt Airport, collecting water from roofs of the new terminal which has an large catchment area of 26,800 $m^2$), Singapore (as average annual rainfall of Singapore is 2400 mm, which is very high and best suited for rainwater harvesting application), Tokyo (as RWH system reserves water which can be utilized for emergency water demands for seismic disaster), etc.

## 1.4. STUDIES CARRIED OUT IN INDIA

Today, only 2.5 per cent of the entire world’s water is fresh, which is fit for human consumption, agriculture and industry. In several parts of the world, however, water is being used at a much faster rate than can be refilled by rainfall. In 2025, the per capita water availability in India will be reduced to 1500 cubic meters from 5000 in 1950. The United Nations warns that this shortage of freshwater could be the most serious obstacle to producing enough food for a growing world population, reducing poverty and protecting the environment. Hence the water scarcity is going to be a critical problem if it is not treated now in its peanut stage. Contrasting figures of water scarcity in world between two timeline (1999 & 2025) are shown in the fig. 2 & fig 3. Some of the major city where rainwater harvesting has already implemented is Delhi (Centre for Science and Environment's (CSE) designs sixteen model projects in Delhi to setup rainwater harvesting structures in different colonies and institutions), Bangalore (Rainwater harvesting at Escorts-Mahle-Goetze, Designed by S Vishwanath, Rainwater club, http://www.rainwaterharvesting.org/People/innovators-urban.htm#svis ), Indore (Indore Municipal Corporation (IMC) has announced a rebate of 6 per cent on property tax for those who have implemented the rainwater harvesting work in their house/bungalow/building). Source : The above photographs was the result shown in the website: http://www.rainwaterharvesting.org/crisis/Crisis_Scarcity.htm


Figure 2: About 450 million people in 31 countries (shaded) face a serious water shortage


Figure 3:About 2.8 billion people in 48 countries (shaded), including India, are expected to face water shortages

# CHAPTER - 2

# LITERATURE REVIEW

This chapter reviews the literature relevant to the objective of the study, i.e., Rainwater harvesting system in the campus of Engineering Institute, N.I.T. Rourkela as well as the information on development of its components. A brief review on complete analysis & designing of the different component of this system has also been included. A discussion on the purpose of rainwater harvesting i.e. storing harvested water in tank after different available way of filtration and different component & ways of recharging underground aquifer for increasing the water table level and increasing soil moisture condition for good agriculture purpose has also been incorporated. Again, on recharging underground aquifer, underground water can be fetched out by pumping .
Rainwater harvesting is an yearlong ancient technique studied by many scientist for different purposes e.g. for storing the harvested water in some storage tank, impact of rainwater harvesting on social and economic aspects and for recharging underground aquifer for increasing soil moisture condition. A few of them has been listed. Rural Rainwater Harvesting: Concept, Techniques, and Social & Economical Impacts by Dr. Osman Mohammed Naggar. This person has really dedicated his work in finding out all the factors which affects the surface runoff and rainwater harvesting impacts on environment.

Again a very decant work is being done by P.Sai Rukesh Reddy and A.K.Rastogi in their paper entitled, ‘Rainwater Harvesting in hostel 12 and hostel 13 of IIT Bombay’, The Indians society for Hydraulics and Journal of Hydraulic Engineering(2008). In this paper, rainwater is being conserved/harvested only for two hostel areas. And they used two methods of distribution of harvested rainwater (Rapid depletion method & Rationing method). Finally, the cost for construction of tank was calculated.

Apart from it, two books entitled 1. Estimation and costing in civil engineering, by :- Dutta, B. N. 2. R.C.C. Designs, By:- Punmia B.C., Jain Ashok, & Jain Arun Kumar , was referred. These books has carried out complete costing and estimation of sump and complete structural analysis of underground sump. So these two paper was being referred while doing complete structural analysis and calculating the complete cost of construction of tank.

Last but not the least, I would also like to mention Indian government body in various states of our country in the field of water resources for creating awareness programme for conserving rainwater using harvesting system. So almost every state hydrology governments (i.e. Maharashtra, Orissa, Madhya Pradesh, many other) are coming up with rainwater harvesting system and distributing the information through proper internet channels.

# CHAPTER - 3

# OBJECTIVE OF RAINWATAR HARVESTING AT N.I.T. ROURKELA CAMPUS

The campus of this institute is situated at the eastern end of Rourkela steel city, over an area of 2.62 $km^2$ (648 acres) of land provided by the Government of Orissa. The institute area is at the center of the campus and surrounded by the residential areas. Residential accommodation is provided to all faculty, staff and students. There are nineteen departments and eight halls of residence for the students. Hence, total strength of campus including students and staffs people will be more than 3,000. And its still under the expansion project adding more number of students and faculty person and increasing facilities by building new hall of residence with a capacity of 1,000 bedded room, lots of new departmental building and infrastructures.

Thus, with this present strength and also with the expansion programmes, campus should also increase its facilities and maintenance requirements. Thus water is the most natural resource which is being always in high demands by human being and is indispensable part of the life. If this demand is not met, then its will lead to water scarcity. Now on days, water scarcity has become the most common problem in every parts of India. And, this problem is also being profoundly seen in the residences halls inside the campus. And, if its has not been dealt earlier with proper care then this problem will become a major hurdle in the development phase of campus and the standard of living of will declining.

Hence, keeping in view all the above problems and status of campus, NIT Rourkela administrative body should focus more on the water scarcity problem. Therefore, in this situation, Rainwater harvesting system can be considered as a best solution for fighting against scarcity of water inside campus. Moreover, owing to its simple technique, ease of construction & installation and low cost of investment, this technique again suites for implementation inside NIT Rourkela campus. Rainwater harvesting can meet potable and non-potable water demands and also control flooding. Again, this non-potable harvested rainwater can be best utilized for purpose of constructing new infrastructure building, gardening, etc. which reduces the investment to be made for filtration purpose. And in this way, campus can easily meet the potable water demand and also able to save money which is being spends for procuring potable-water. In this way potable water can be conserve and harvested rainwater plays major part in conserving it. Rainwater harvesting also helps in increasing the soil moisture condition and fertility factor of soil for plantation. Hence, this simple technique tends to increase the greenery surrounding the campus, increasing aesthetic factor for a proper residential institute to live in. Thus in that similar way, rainwater harvesting systems has endless advantages without any harmful disadvantages or if there are any, then it must be negligible.

Hence for water scarcity, Rainwater harvesting is seems to be a perfect replacement for surface & ground water as later is concerned with the rising cost as well as with ecological problems. Therefore, Rainwater harvesting is highly recommended for campus of N.I.T. Rourkela.

# CHAPTER - 4

# STUDY AREAS
# &
# DATA COLLECTION

## 4.0. STUDY AREAS AND DATA COLLECTION

### 4.1. STUDY AREAS

As discussed earlier in the section of introduction – importance of rainwater harvesting at NIT Rourkela, we clearly came to know the all the advantages which we can draw out by implementing this small but highly efficient technique in the campus. Thus to increase the potential, benefits of this system and draw maximum advantages from it, we need to have large rooftop areas which will be going to act as catchment areas. More the catchment areas more will be the surface runoff and thus more will be the amount of harvested water.

Therefore as much as possible, we have included and considered all the major buildings having large rooftop areas. Hence, study areas includes all the eight halls of residence (SSB, MVV, GDB, DBA, MSS, HBH & CVR), all the departmental building (Computer science, Electronic, Mechanical, Chemical, Ceramic & Mining), Guest house, Audio-video (AV) hall, main institution building including (including Civil, Electrical, Metallurgical and many others departments, central library, computer center, and various laboratory).   Given below a satellite picture, fig no.4, showing majority of the buildings considered for rainwater harvesting system at NIT Rourkela.


Figure 4: N.I.T. ROURKELA CAMPUS [Google Earth, Date: 9th Dec, 2006}

## 4.2. DATA COLLECTION
### 4.2.1. RAINFALL DATA COLLECTION

Rourkela is located at 84.54E longitude and 22.12N latitude in Sundergarh district of Orissa at an elevation of about 219 meters above mean sea level. Rourkela has a tropical climate and receives high rainfall during Southwest monsoon (June-September) and retreating Northeast monsoon (December-January). Average annual rainfall ranges between120-160 cm.

The average monthly rainfall data are being taken from the Orissa premier Science and Technology organization, National Informatics Centre (*NIC*), Bhubaneswar. Again its followed that, 'Sundergarh' is a small city and thus has a uniform average rainfall through out the city in all location. Thus monthly rainfall data of the Sundergarh city is given below in the table no.1 which is assumed to be same for the station of NIT Rourkela campus.

**TABLE NO.1: MONTHLY RAINFALL DATA OF ROURKELA STATION**

| **Month** | **Rainfall (mm)** |
|---|---|
| January | 15.1 |
| February | 24.9 |
| March | 16 |
| April | 16 |
| May | 40.6 |
| June | 237.4 |
| July | 386.4 |
| August | 393.9 |
| September | 211.5 |
| October | 67.7 |
| November | 8.7 |
| December | 4.2 |
| TOTAL | 1422.40 |

### 4.2.2. DETERMINATION OF CATCHMENT AREA

The rooftop surface area is nothing but the catchment area which receives rainfall. Catchment areas of the different hostels and Institutional departments are measured. This measurement was done manually with the help of 'reinforced fiber tape' which is the simplest technique known as 'tape survey'. Before using the tape, tape was checked for any zero error and also length of the tape was also carefully checked for its accuracy. Those places which area not accessible to land on, are measured by using the ruler from tool box of 'Google Earth'. Given below the table no. 2 for calculated the rooftop areas of all the buildings suited inside the campus:-

**TABLE NO. 2: CALULATION OF ROOFTOP AREA OF ALL BUILDING**

| Serial no. | Building Name | Rooftop area ($m^2$) |
|---|---|---|
| 1. | S.S.B. HALL | 2285.52 |
| 2. | M.V.V. HALL | 2604.63 |
| 3. | G.D.B HALL | 2252.953 |
| 4. | D.B.A. HALL | 1997.65 |
| 5. | M.S.S. HALL | 2609 |
| 6. | C.V. Raman | 1520.81 |
| 7. | HBH Hall | 2169.76 |
| 8. | Main Institute Building | 5,008 |
| 9. | AV Hall | 1000 |
| 10. | Library | 354.76 |
| 11. | Mining Department | 723.56 |
| 12. | Ceramic Department | 1133.30 |
| 13. | Chemical Department | 1737.44 |
| 14. | Mechanical Department | 5364.06 |
| 15. | Computer SC. Department | 1220.04 |
| 16. | Electronics Department | 254 |
| 17. | Student Activity Centre | 256 |
| 18. | Guest house(North Block) | 837.1 |
| 19. | K.M.S Hall | 3154.8 |

# CHAPTER - 5

# METHODOLOGY

## 5.1. HYDROLOGICAL ANALYSIS

On the basis of experimental evidence, Mr. H. Darcy, a French scientist enunciated in 1865, a law governing the rate of flow (i.e. the discharge) through the soils. According to him, this discharge was directly proportional to head loss (H) and the area of cross-section (A) of the soil, and inversely proportional to the length of the soil sample (L). In other words,

$$Q \;\alpha\; \frac{H}{L} \,.\, A$$

Q = Runoff

Here, H/L represents the head loss or hydraulic gradient (I), K is the co-efficient of permeability

Hence, finally,

$$Q = K.\, I.\, A.$$

Similarly, based on the above principle, water harvesting potential of the catchment area was calculated.

The total amount of water that is received from rainfall over an area is called the rainwater legacy of that area. And the amount that can be effectively harvested is called the water harvesting potential. The formula for calculation for harvesting potential or volume of water received or runoff produced or harvesting capacity is given as:-

**Harvesting potential or Volume of water Received ($m^3$)**

**= Area of Catchment ($m^2$) X Amount of rainfall (mm) X Runoff coefficient**

Runoff coefficient for any catchment is the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface. Runoff coefficient accounts for losses due to spillage, leakage, infiltration, catchment surface wetting and evaporation, which will all contribute to reducing the amount of runoff. Runoff coefficient varies from 0.5 to 1.0. In present problem statement, runoff coefficient is equal to 1 as the rooftop area is totally impervious. Eco-Climatic condition (i.e. Rainfall quantity & Rainfall pattern) and the catchment characteristics are considered to be most important factors affecting rainwater Potential. Given below the table showing the value of runoff coefficient with respect to types of surface areas:-

TABLE NO.3: VALUE OF RUNOFF COEFFICIENT (K)

| Sl no. | Types of area | Value of K | | |
|---|---|---|---|---|
| | | Flat land 0-5 % slope | Rolling land 5%-10% slope | Hilly land 10%-30% slope |
| 1. | Urban areas | 0.55 | 0.65 | - |
| 2. | Single family residence | 0.3 | | |
| 3. | Cultivated Areas | 0.5 | 0.6 | 0.72 |
| 4. | Pastures | 0.30 | 0.36 | 0.42 |
| 5. | Wooden land or forested areas | 0.3 | 0.35 | 0.50 |

Source : Table 7.31, Chaper Hydrology and runoff computation, Irrigation Engineering & Hydraulic Structure, by Garg, S.K.

## 5.2. METHODS FOR STORAGE OF HARVESTED RAINWATER IN TANK

Finally, we need to store the water which is obtained from the rooftop areas of the different buildings. The volume of tank which stores the harvested water will be directly proportional to the total volume of water harvested.

Technically, there are two types of methods for distributing the harvested rainwater:-

- RATIONING METHOD (RM)
- RAPID DEPLETION METHOD (RDM)

To explain these both methods, let us first apply it on any hall say **M.S.S. hall**. The detail calculation is carried out to get the valuable steps. Later on, these crucial steps are again applied to all other building and number of days for consumption of stored water is calculated by using both of these methods.

### 5.2.1. RATIONING METHOD (RM):

The Rationing method (RM) distributes stored rainwater to target public in such a way that the rainwater tank is able to service water requirement to maximum period of time. This can be done by limiting the amount of use of water demand per person.

Suppose in this method, the amount of water supplied to student is limited which is equal to say, 100 lt/day per capita water demand

Again, Number of students at M.S.S. HALL = 300

Then, Total amount of water consumption per day = 300x0.1 = 30 $m^3$/day

Total no. of days we can utilize preserved water = stored water/water demand
For M.S.S. Hall (Sample hall), volume of water stored in tank was taken approx. = 3600 $m^3$
Hence finally, no of days = 3600/30 = 120 days (or 4 months)
For long term storage of preserved water in good condition, preserving chemical should be added.

## 5.2.2. RAPID DEPLETION METHOD (RDM):

In Rapid Depletion method, there is no restriction on the use of harvested rainwater by consumer. Consumer is allowed to use the preserved rain water up to their maximum requirement, resulting in less number of days of utilization of preserved water. The rainwater tank in this method is considered to be only source of water for the consumer, and alternate source of water has to be used till next rains, if it runs dries.

For example if we assume per capita water demand = 150 lt/day = 0.15 $m^3$/day

Total amount of water consumption per day = 300 x 0.15= 45$m^3$/day

Total no. of days, preserved water can be utilize = stored water/water demand
= 3600/45
= 80 days (2.67 months)

Hence, finally it is observed that, if the amount of water stored is equal to 3600 $m^3$, then applying

1. RDM, consumer can only utilize the preserved stored water for about 80 days (2.67 months),
2. Where as in RM, preserved stored water can be utilized for a period of 120 days (4 months).

## 5.3. GIS ANALYSIS

A geographic information system (GIS) is computer software that allows our young students, researchers and investigators to manage and manipulate interactions between data and geographic locations. GIS technology has the sophistication to go beyond mapping as simply a data management tool. GIS can integrate georeferenced imagery as data layers or themes and link them to other data sets to produce geospatial representations of data. These geographical pictures not only depict geographic boundaries but also offer special insight to students and researchers across disciplines such as health, economics, agriculture, and transportation.

Thus, in the present case, ILWIS 3.0 is being chosen as the software for carrying out the GIS analysis. Our aim is to convert the scanned map of the NIT Rourkela campus into a digital elevation model map, which gives detail distinct information on the variation in the elevation of different regions of surface giving clear idea on the surface topology. The high contour lines on the digital elevation model denotes surfaces of high altitudes i.e. Mountainous region and low lining contour lines denotes the surfaces with low altitudes such as valley region.

Hence below the steps for generating the digital elevation model map:

Step1: Importing the scan map to the ILWIS Software (Fig. 4)

Step2: Processing the scan map and generation of contour line map (Fig. 5).

Step3: Final digital elevation model map is generated (Fig. 6).

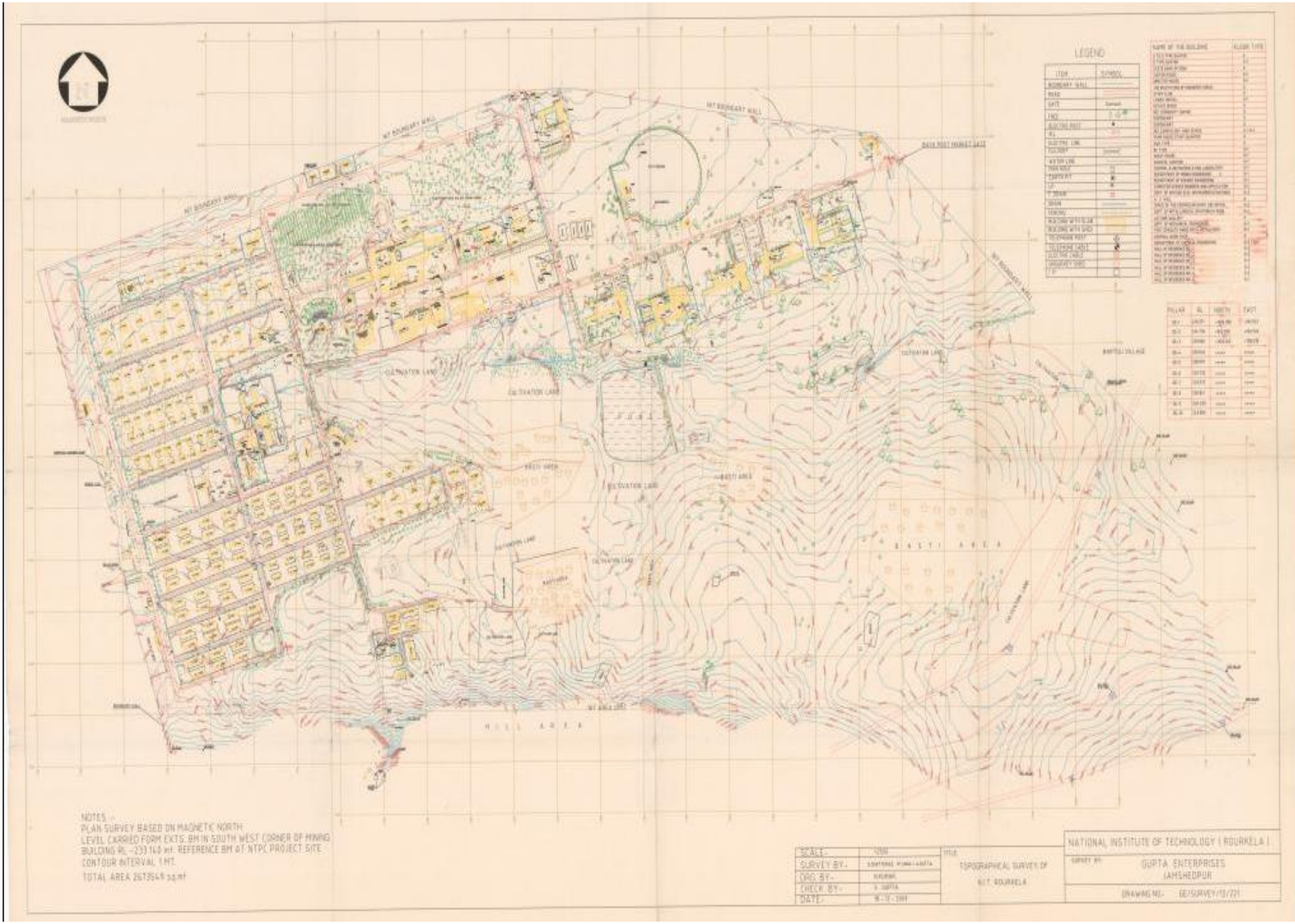


Figure 5: Scanned contour map of NIT Rourkela campus

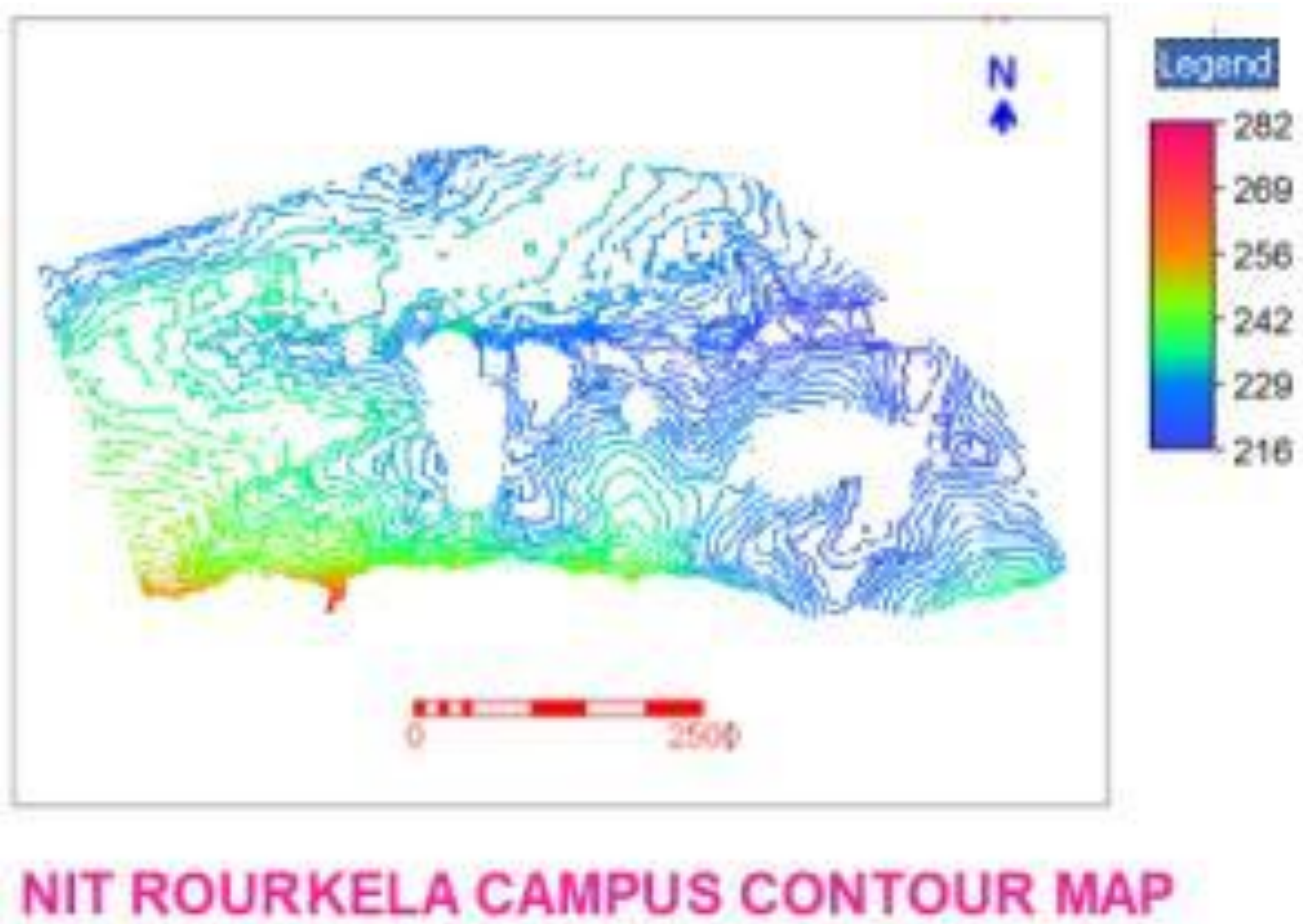


**Figure 6: N.I.T. Rourkela Campus contour map**

The above contour map is obtained on processing & conversion of the contour line map in ILWIS Software. Contour lines map are assigned with different colour to make easy distinction between high elevation line and low elevation line. Given below the final Digital elevation model map of NIT Rourkela campus. The different colour, denotes the different elevation level by the legends placed along side of the map.

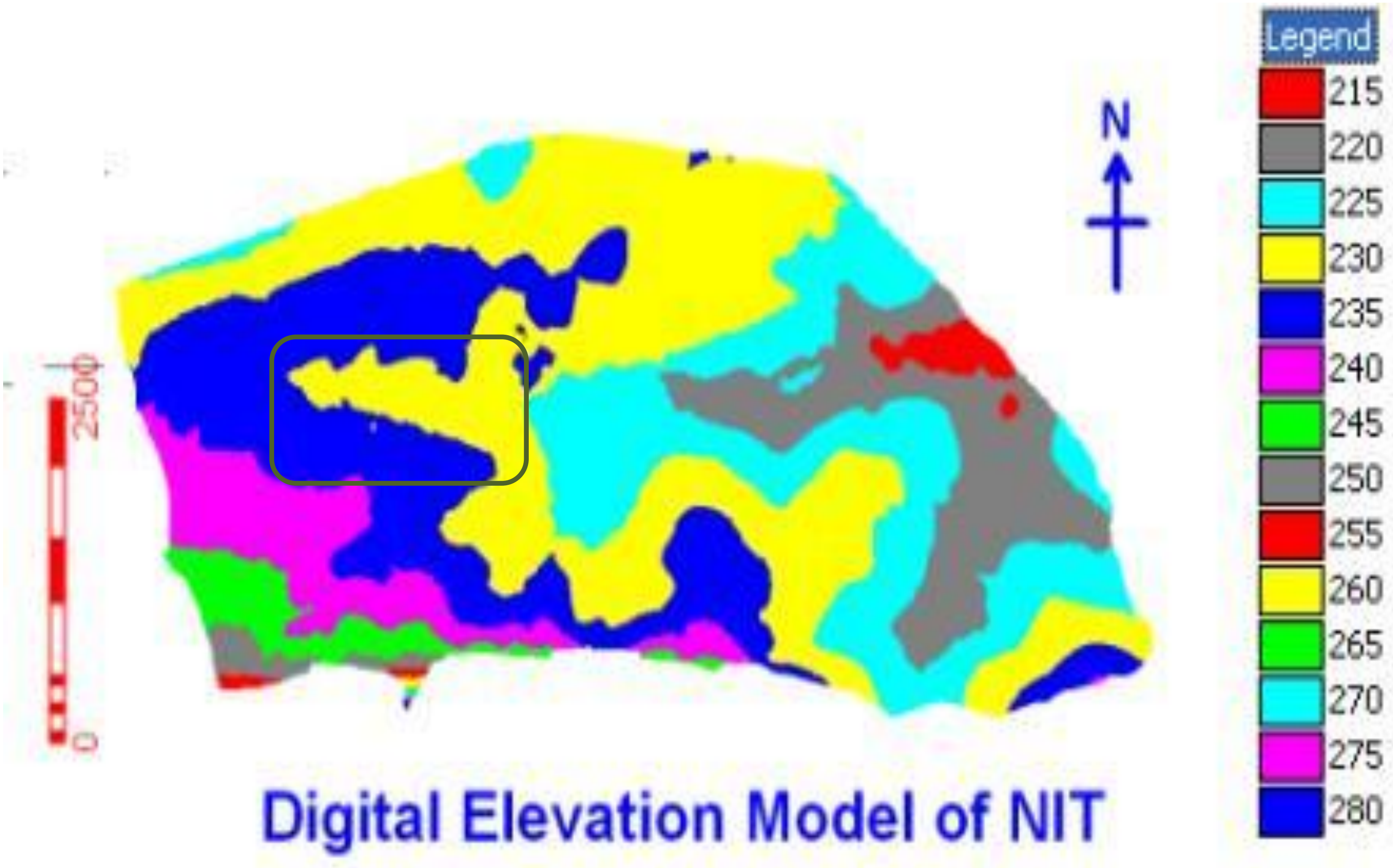


**Figure 7: Digital Elevation Model of NIT Rourkela Campus**

Hence, Digital elevation model was created from the contour line map.

Ultimately, the digital elevation model map was prepared. In this map, dark blue shaded region are the highest elevated patch of land (i.e. mountain) showing R.L. of 280 and the yellow shaded region is comparatively low land valley areas having R.L. of 230. Thus after GIS Analysis, clear difference in elevation between the surfaces are obtained. So, finally it is observed that there is a huge R.L. Level difference between these two regions, which shows that these areas are best suited for recharging underground reservoir or made available for human consumption purpose by storing the harvested rainwater in the tank. So, after a detail studies, finally a conclusion was drawn that there should be some fencing in the lowland areas in (in the yellow patched region, marked with a rectangle) which will obstruct the extra surge water from being drain off and go wasted. Rather, if on building fences water will get accumulate for longer period of duration and slowly & steadily underground reservoir will get recharge. Alternatively by constructing tank, water will be stored in it for emergency period and after a proper treatment, it can be used for day-to-day basic need of water requirement of human being.

Hence by GIS Analysis, we get an overview of potential rainwater harvesting and suitable location for groundwater recharge or tank inside the campus location.

# CHAPTER - 6

# OPTIMISTIC DETERMINATION OF SIZE & TYPES OF TANK

## 6.1. GENERAL

Just to start with, now let us consider only one hall M.S.S. Hall and proceed with calculation in details. And all the calculation in the later part of this project will be adopted for rest of the building. M.S. Swaminathan Hall of Residence is the present study area. This hall presently has capacity of 300 students including staffs. This hall is made up of 3 building (Block A, B, C) and it has continuous paved mess roof as shown in Fig 7.

The total rooftop area of the M.S.S. Hall available for the rainwater harvesting is 2,609$m^2$. The cumulative runoff that can be captured from the paved area is calculated using Orissa Meteorological Department. The cumulative rainfall runoff at the end of the year is calculated to be 3600$m^3$. The tank capacity can be estimated to be a lower value accounting for the continuous consumption going on during period of rainfall.

## 6.2. COMPUTATION OF VOLUME OF RUNOFF PER YEAR:

As we know the formula for runoff discharge from section 5.1. is

**Volume of water Received ($m^3$) = Area of Catchment X Amount of Rainfall**

Total roof area of M.S.S. Hall was calculated = 2,609$m^2$

Average annual rainfall at Rourkela=1400mm/year = 1.4$m^3$/year
Total volume of surface runoff water suppose to be collected=2,609 x 1.4 = 3600$m^3$/year

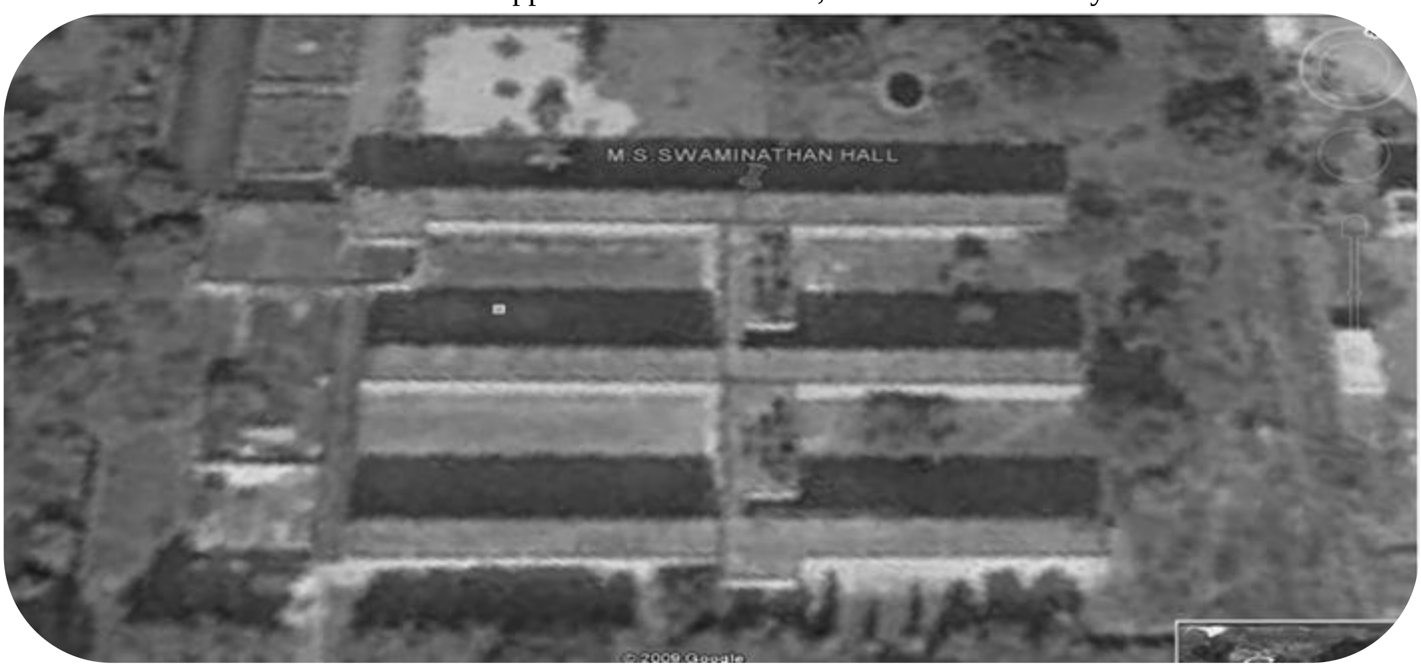


Figure 8: Satellite View of M.S.Swaminathan Hall

Given below fig. 8 the complete AutoCAD drawing of the M.S.S. giving clear view and dimension of the three blocks (A, B, C) and also dimensions of mess attached to these block in the left hand side.

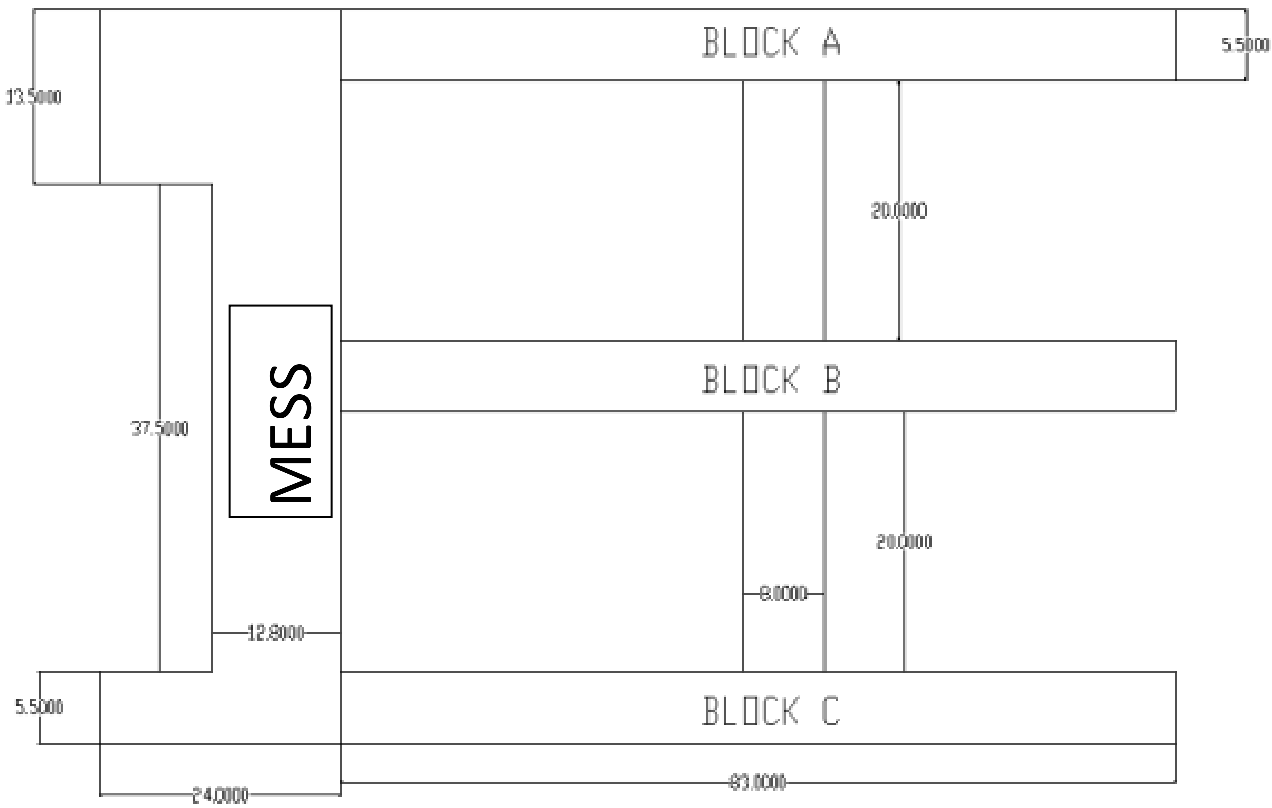


Fig. 9: Complete Dimensions of Roof Top of M.S.S. Hall

Given below the table no 4 which gives the monthly rainfall and discharge runoff obtained from the rooftop area of M.S.S. Hall and corresponding graph are also plotted in the fig.9 and fig.10.

**Table No.4: Showing Rainfall & Discharge of MSS Hall monthly at NIT RKL Campus**

| Sl. No | Month | Rainfall(mm) | Discharge($m^3$) |
|---|---|---|---|
| 1 | January | 15.1 | 39.396 |
| 2 | February | 24.9 | 64.96 |
| 3 | March | 16 | 41.74 |
| 4 | April | 16 | 41.74 |
| 5 | May | 40.6 | 105.9 |
| 6 | June | 237.4 | 619.38 |
| 7 | July | 386.4 | 1008.12 |
| 8 | August | 393.9 | 1027.69 |
| 9 | September | 211.5 | 551.8 |
| 10 | October | 67.7 | 169.63 |
| 11 | November | 8.7 | 22.7 |
| 12 | December | 7.2 | 10.96 |
| | TOTAL | 1422.40 | 3694 |

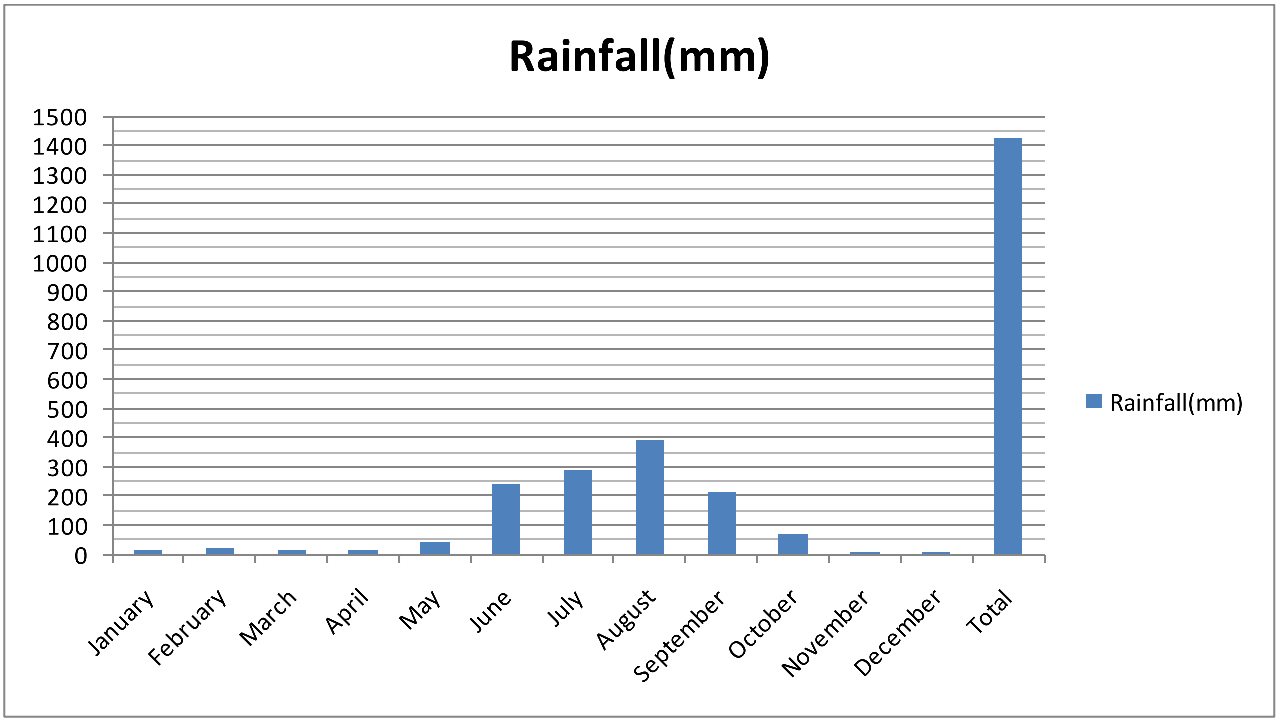


Fig.10: Showing Amount of Rainfall collected in throughout the year

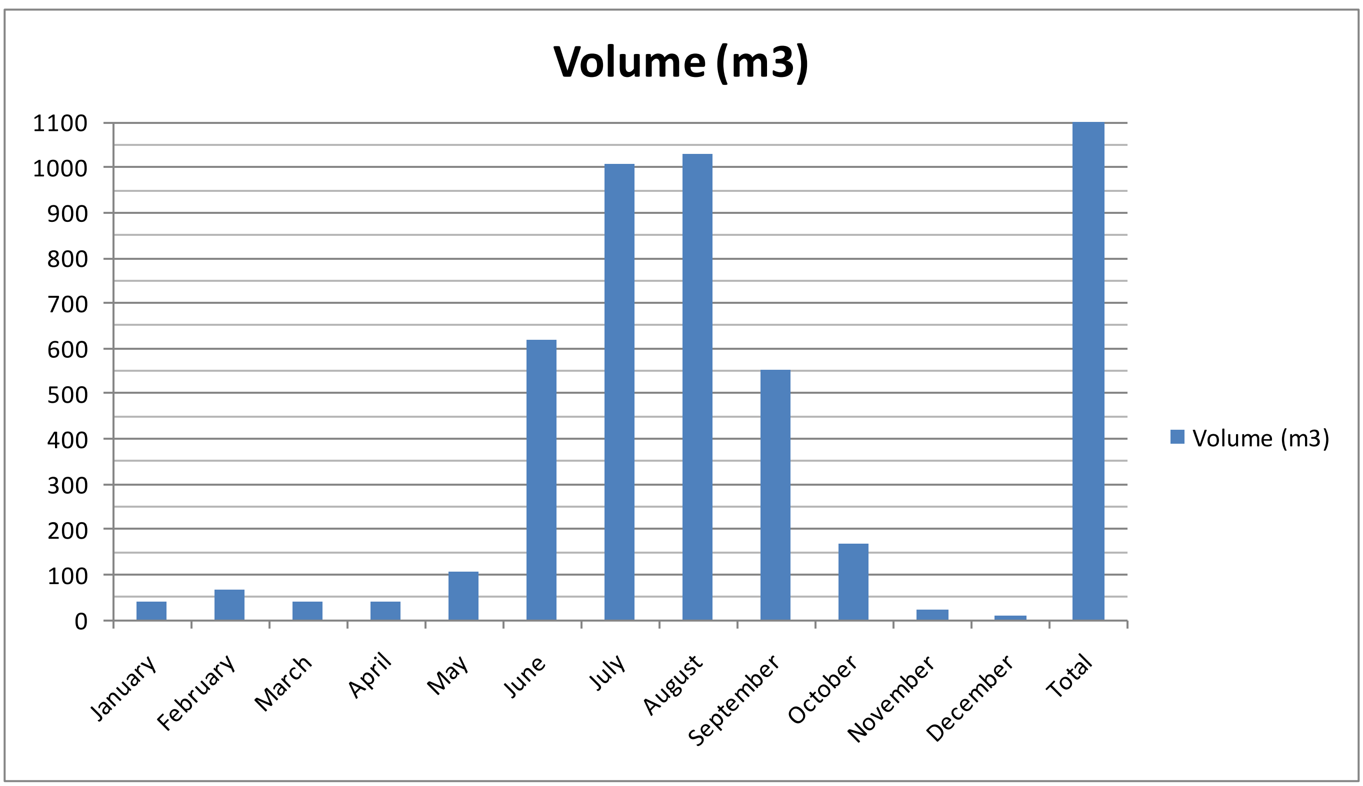


Fig.11: Showing Volume of water Collected from Rainfall throughout the year

## 6.3. OPTIMUM DIMENSION OF THE TANK

- For M.S.S. Hall, total amount of water collected in one year = size of the tank = 3600$m^3$
- Taking height of tank = 4m
- Area of the base = 3600/4 = 900$m^2$
- We can take square base each of side = 30m or rectangular base as per land availability.
- So our tank will be of dimensions 4x30x30 m (taking square tank) which is not economical.
- As water is stored on monthly basis, Size of the tank will be equal to the excess amount of water left over after consumption. Hence, mostly excess amount of water assumed to be collected during the period of maximum rainfall – June, July and August.
- Assuming amount of water consumed per month = 300 x 0.1x 30 = 900 $m^3$
- For M.S.S. Hall, Amount of water collected during July and August = 1008.12 + 1027.69 = 2035.81 $m^3$

  And, amount of water consumed during this two month = 2 X 900 = 1800 $m^3$.
- Hence, total amount of water to be stored = Size of tank = (2035.81-1800) $m^3$ = 235.81$m^3$
- Fixing the height of tank to be 4m
- Area of the base = 235.81/4 = 60$m^2$
- So, as per suitability base can be taken as square of size 7.8x7.8 m or rectangular.

Hence, now tank will be of dimension 4x7.8x7.8 m which is economical and feasible. Thus this is the optimum dimension of the tank. Similarly, the above procedure repeated to other all building inside the campus and rainwater harvesting capacities calculated.

## 6.4. TYPES OF TANK:

Two type of tank can be used for storing of rainwater discharged from the roof

- LINED STORAGE TANK
- UNLINED NATURAL STORAGE TANK

In lined storage tank, earth work excavation is done and under ground RCC water storage tank is constructed which is completely covered from the top. The land above the tank can be used for serving as playground or parking slot, etc. In unlined natural storage tank, earth excavation is done and all the water being allowed to fall directly in that pit and store it. In this method, we get two advantages.

Firstly, our natural water gets recharged leads to augmentation of water level and ground condition, increasing prospects for better future cultivation and plantation. Secondly, underground water can be extracted any where within some limited areas from that pit and can be used to satisfy daily water demand.

# CHAPTER - 7

# DETAIL ANALYSIS

# &

# DESIGNING OF RAINWATER HARVESTING SYSTEM COMPONENT

[ON ONE SAMPLE HALL]

In this section, all the component of rainwater harvesting system is to be designed for all the buildings located inside the campus of NIT Rourkela.

Hence to start of, a sample calculation was done on a sample hall say M.S.S. hall, which will draw the steps which has to be followed by all other building for designing its system components.

**Hence given below the complete design of all the components of rainwater harvesting of M.S.S. HALL whose dimensions are mentioned in the figures 7 and tank size is 4 X 5 X 12.**

## 7.1 ANALYSIS & DESIGN OF UNDERGROUND SUMP

Problem Statement :

Height of tank= 4m

Area of base = $60m^2$

Taking subsoil consists of sand, angle of repose = 30®

Saturated unit weight of soil = 17 $K/m^3$

Water table likely to rise up to ground level

M20 concrete, HYSD bar

Unit weight of water = 9.81 $KN/m^3$

Solution:

There are four components of design:-

i) Design of long wall

ii)Design of short wall

iii)Design of roof slab

iv)Design of base slab

### 1. GERNERAL

Design of wall be done under two condition:-

a) Tank full with water, with no earth fill outside
b) Tank empty with water, with full earth pressure due to saturated earth fill.

The base slab will be design for uplift pressure and the whole tank is to be tested against floatation.

Taking size of the base of tank =12X5m

As length (L)=12m

Breadth(B)=5m

L/B=12/5=2.3{>2} , Hence long wall be designed as a cantilever.

Bottom H/4 =4/4 = 1m of short wall be designed as cantilever , while

Top portion will be design as slab supported by long walls.

2. **DESIGN CONSTANT**

For M20 concrete, $б_{cbc}$=7N/mm$^2$ , m=13

Since face of wall will be in contact with water for each condition,

$Б_{st}$=15N/mm$^2$ for HYSD bar.

Permissible compressive stress is steel under direct compression = $Б_{sc}$ = 175 N/mm$^2$

For $Б_{cbc}$ = 7 N/mm$^2$ , $Б_{st}$ = 150 N/mm$^2$ , m= 13 ,

We have, K $=\frac{13X7}{13X7+150}$ = 0.378

J= 1-(0.378/3) = 0.874

R = 1/2 X 7 X 0.874 X0.378 = 1156

3. **DESIGN OF LONG WALL**

a) Tank Empty with pressure of saturated soil from outside

Pa = $Ka\gamma H+\gamma_w H$

$\gamma = \frac{1-\sin 30}{1+\sin 30}$ = 1/3

γ'=17-981=7.19 Kn/m3 = 7190 n/m3

$\gamma_W$ = 9.81 Kn/m$^3$

Pa = (1/3)X7190X4 + 9810X4 = 48,426.67 N/m$^2$

Maxm. B.M. @ base of wall = 48,426.67 X (4/2)X (4/3) = 130,204.44 nm

D=$\frac{\sqrt{130,204.44X103}}{1.156 X 1000}$ = 335.6mm

Provide total depth D= 380 mm

D = 380 -35 = 345 mm

Ast = $\frac{130204.44 X 1000}{1150 X 0.874X345}$ = 2,878.75 mm2

Using 30mm Φ bar, spacing $=\frac{1000X314}{2878.75}$=109.13mm

Hence, provide 20mm Φ bar @ 100mm c/c on the outside face @ bottom of long wall.

## CURTAILMENT OF REINFORCEMENT

Since the B.M. is proportional to $h^3$

Asth/Ast = $(h/H)^3$ from which, h= H(Asth/Ast) ^(1/3)

If Asth = 1/2XAst (I.e. half of bar being curtailed)

h= H(1/2)^(1/3) = 4(1/2)^(1/3)=3.17 m

Height from base = 4-3.17 = 820 mm

Height as per code, IS 456, bar should contain further for a distance of 12Φ or d (which ever more)

12 XΦ = 12X 12 = 240

D=345mm,

So bar curtailed @ distance from the base = 820+345 = 1.17m

Min % of reinforcement = $0.3 - 0.1\frac{340-100}{450-100}$ = 0.23 %

Min Ast = 0.23X380X1000/100=879.43$mm^2$

So, curtailment @ 1.17m from the base = 0.5XAst = 0.5 X 28787 =1439.35 > 879.43 (O.K)

## DISTRIBUTION REINFORCEMENT

Ast = 879.43 $mm^2$

Area to be provided on each face = 879.43/2 = 439.72 $mm^2$

Hence proving 10mm Φ @ spacing$\frac{1000X78.4}{439.72}$ = 170mm

Taking spacing = 160mm on both face of long wall

## DIRECT COMPRESSION IN LONG WALL

The earth pressure acting on short wall will cause compression in long wall, because top portion of short wall act as slab support on long walls.

At h=1m(>H/4) above the base of short wall

$Pa=Ka\gamma'(H-h)+\gamma_w(H-h)$

=(1/3)X7190(4-1)+9810(4-1) = 33,620N/$m^2$

This direct compression developed on long wall is given by

Plc=Pa.B/2=33620X5/2 = 91,550 N {This will be taken by distribution steel & wall section.}

**B>TANK FULL WIT H WATER & NO EARTH FILL OUTSIDE**

$P=\gamma_w h=9810x4$

$=39240\ N/M^2$

$M=P.H^2/6 = 39{,}240\ X4^2/6 = 104640\ Nm$

Ast $=\frac{1000X104640}{150X0.874X345} = 2{,}313.53\ mm^2$

Using 20mm Φ @ spacing $=\frac{1000X314}{1313.53} = 135.7$

Taking 20mm Φ @ spacing 130mm c/c @ inside face.

**CURTAILMENT OF REINFORCEMENT**

Asth/Ast = $(h/H)^3$ from which, h= H(Asth/Ast) ^(1/3)

If Asth = 1/2XAst (I.e. half of bar being curtailed)

h= H(1/2)^(1/3) = 4(1/2)^(1/3)=3.17 m

Height from base = 4-3.17 = 820 mm

Height as per code, IS 456, bar should contain further for a distance of 12Φ or d (which ever more)

12 XΦ = 12X 12 = 240

D=345mm,

So bar curtailed @ distance from the base = 820+345 = 1.17m

So, at the base, 20 mm Φ @ 130mm c/c

At top from 1.17m from base, 20mm Φ @ 260mm c/c

**DIRECT TENSION ON LONG WALL:-**

Since the top portion of short wall act as slab supported on long wall, the water pressure acting on short wall will cause tension in long wall:-

Pl=P.B/2 = 9810 X 3X 5/2 = 73, 575 N

As req. = 73,575/150 = 490.5mm2

Area of distribution steel (=879.43 $mm^2$) will take direct tension.

**4.DESGIN OF SHORT WALLS**

**A) TANK EMPTY WITH EARTH PRESSURE FRON OUTSIDE**

**I) TOP PORTION**

The bottom 1m (H/4) act as cantilever while the remaining above 3m act as slab on long wall

At, =1m, above base of short wall,

$Pa- = Ka\gamma'(H-h)+\gamma_w (H-h)$

=(1/3)X 7190X3 + 9810 X 3 = 36,620 N/$m^2$

Mf@ support = PaL^2/12 = 36,620 X 5^2 / 12 = 76,291.67 Nm

This causes tension outside.

Mf @ centre = $PaL^2/8$ – Mf = 36,620 X $5^2$ (1/8- 1/12) = 38,145.83 Nm

d= 380 –(25+20+10) = 325 mm

At support, Ast = $\frac{1000X76,261.67}{150X0.874X325}$ = 1790.57$mm^2$

Using 16mm Φ bar Ast =$\frac{1000X201}{1790.57}$ = 116.7mm

So providing 16mm Φ bar@ spacing 110mm c/c @ outer face.

At mid span, Ast = (0.5X1790.57 = 895.285 $mm^2$

Providing 16mm Φ @ spacing$\frac{1000X201}{895.285}$ = 223.3 .i.e. providing 220mm c/c at inner face.

## II)BOTTOM PORTION

The bottom 1m will bend as cantilever.

Intensity of earth pressure @ bottom = 48,826.67 N/$m^2$ (from step 3)

M = 0.5X 48,826.67X1X (1/3) = 8137.78 Nm

Ast =$\frac{1000X8137.78}{150X0.874X345}$ = 179.92 $mm^2$

Minm. Steel @ 0.23% = 879.43 $mm^2$

So, Ast = Ast minm.

Spacing of 12mm Φ =$\frac{1000X113}{879.43}$ = 128.5 .i.e. 120 mm c/c

Hence providing 12mm Φ bar @ spacing 120mm c/c at the outside face in vertical direction for bottom 1m height.

## DIRECT COMPRESSION IN SHORT WALL

Only one meter of long pushes the short wall due to earth pressure, Pbc = PaX1 =36,620n

This compression is being taken up by distribution reinforcement.

## B)TANK FULL WITH WATER AND NO EARTH FILL OUTSIDE

## i)TOP PORTION

P=W(H-h) = 9810 X3 = 29,430 N/$m^2$

Mf @ support = $PB^2/12$ = 29430 X 5^2 / 12 = 61,312.25 Nm causing tension at the inside.

Mc @ centre = $PB^2/24$ = 0.5 X 61,312.5 = 30,656.25 Nm causing tension at the outside.

Direct tension on short wall due to water pressure on the end 1meter of long wall

P b =W(H-h) X 1

=29,430 X1 = 29430 N

Effective depth d, for horizontal steel= 325mm @ distance x = d-D/2 = 325 – 380/2

= 135 mm

Ast1 = M-Pbx/Бstjd

Ast2 = Pb/бs

**AT INSIDE FACE (END OF SHORT WALL)**

Ast1 = $\frac{1000X61,312.5-29430X135}{150X0.874X325}$ = 1345.8$mm^2$

Ast2 = 29430 / 150 = 196.2 mm

Total = 196.2+1345.8 = 1542 $mm^2$

Using 12mm Φ bar, spacing = 1000X113/1542 = 75 mm c/c.

**AT OUTSIDE FACE (MIDDLE OF SHORT WALL)**

Ast1 = $\frac{1000X20,656.25-29430X135}{150X0.874X325}$ = 636.26$mm^2$

Ast2 = 29430 / 150 = 196.2 mm

Total = 196.2+636.26= 822.46 $mm^2$

Using 12mm Φ bar, spacing = 1000X113/822.46 = 120 mm c/c @ outside face.

**i)BOTTOM FACE**

P (from step 3b)= 39240 $N/m^2$

Mf 0.5X(1/3)X 39240 = 6540 Nm causing tension at the inside.

Mc @ centre = PB2/24 = 0.5 X 61,312.5 = 30,656.25 Nm causing tension at the outside.

Ast = $\frac{1000X6540}{150X0.874X345}$ = 144.6 $mm^2$

But min. Steel req. = 879 $mm^2$

So providing 12mm Φ bar @ spacing 120mm c/c.

**SUMMARY OF REINFORCEMENT IN SHORT WALL**

Taking of maxm out of both case 4A and 4B

I) Horizontal reinforcement @ inner face = 16mm Φ @ 75mm c/c

I) Horizontal reinforcement @ outer face = 16mm Φ @ 110mm c/c

III) Vertical reinforcement @ inner face & outer face = 12mm Φ @ 120mm c/c

**5.DESIGN OF TOP SLAB**

L/B = (12/5 ) = 2.4 (> 2) i.e. one way slab

Let live load on top slab = 2000 N/$m^2$

Assuming thickness of 200mm including finishing ,etc.

Self weight = 0.2 X 1X1X 25,000 = 5000 N/m $^2$

Total weight = 2000+5000 = 70000 N/$m^2$

M = WB^2 / 8 = 7000(5+0.38) $^2$ / 8 = 25,326.35 Nm

$D=\frac{\sqrt{255326.35X1000}}{1.156 X 1000}$ = 140mm

Providing a total thickness (D) = 180mm

d = 180-25-6 = 149 mm

Ast =$\frac{1000X25326.35}{150X0.874X149}$ = 1302.5 $mm^2$

Spacing of 16mm Φ = 1000X201/1302.5 = 150 mm c/c @ outside face.

**DISTRIBUTION REINFORCEMENT**

Pt % = 0.3 – 0.1 X$\frac{180-100}{450-100}$ = 0.277%

Spacing of 10mm Φ bar = 1000 X 78.54 / 415.7 = 180 mm c/c

**6.DESIGN OF BOTTOM SLAB**

Magnitude of uplift pressure, Pu = WH1= 9810 X 4.3 = 42,183 N/$m^2$

**A) CHECK FOR FLOATION**

Check is done when tank is empty.

Total upward floatation force = P = Pu X B X L = 42183X5X12 = 2530980 N

Total Downward force = weight of wall + (weight of roof slab + finishes) + weight of base slab

= [0.38(5+5+12+12) X4.3X25000] + [ 0.2X 5X12X25000] + [ 5X12X0.3X25000]

= 2138900N

Weight of roof so downward force is less than buoyant force, we need to provide extension of 0.5 m on both side.

Extra weight req. = 2530980-2138900 = 392080N

By extending 0.5 on both side, extra weight of tank

= [(0.5 x 5 X 2) + (0.5 X 12 X 2) + (0.5 X 0.5 X 4)] X 25000 X 0.3= 135000 N

Weight of soil = [(0.5 x 5 X 2) + (0.5 X 12 X 2) + (0.5 X 0.5 X 4)] X 17000 X 4= 1224000 N

Total = 1359000N (safe)

**B)DESIGN OF BASE SLAB**

Considering 1m length of slab, upward water pressure = 42183N/$m^2$

Self weight of slab = 1 X 1 X 0.3 X 25000 = 7500 N/$m^2$

Net upward pressure, P = 34683 N/$m^2$

Weight of roof slab per meter run = 0.2 (2+0.38)X1X25000 = 11900 N

Weight of wall / meter run = 0.38X4X1X25000 = 38000 N

Weight of earth projection = 1700 X 4 X 1 X 0.5 = 34000 N/m

Net unbalance force / meter run = 34683 (6.286 X 1) – 2 (38000 +11900 + 34000) = 50217.3N

Reaction on each wall = 50217.3/2 = 25108.67 N

Pa = Kaб'H + wH = 48826.67 N/$m^2$

Pa =48826.67 X(4/2) X 1 = 97653.34 Nm acting @ (4/3)+0.3 = 1.66 m from the bottom of base slab

B.M. @ edge of cantilever portion = (34683 X $0.5^2$ / 2 )+ 25108.67 X1.66- (1700X4X$0.5^2$/2)

= 45165.76Nm causing tension @ bottom face.

B.M @ centre of span = ((34683/2)X $(6.286)^2$/4) + 97653.34X1.66 – (38000+11900+25108.67)X4.38/2 -1700X4X0.5(6.38/2-0.25) = 234044.7 Nm

$d = \frac{\sqrt{234044.7X1000}}{1.156 X 1000}$ = 450 mm, so keeping D = 500 mm , d = 450 mm

$Ast = \frac{234044.7 X 1000}{150X0.874X250}$ = 7140.1 $mm^2$

Providing 24mm Φ bar spacing = 1000X 452.4 / 7140 = 65 mm c/c

Distribution reinforcement in longitudinal direction = 0.3 – 0.1[$\frac{300-100}{450-100}$]= 0.243 %

Area o n steel = 0.243 X 1000X300/100 = 729 $mm^2$

Area on steel on each face = 729 /2 = 364.5 $mm^2$

Spacing of 8mm Φ bar = 1000X 50.3 / 364.5 = 138 mm

Provide 8 mm Φ bar @ 130 mm c/c on each face.

## 7.2. **DETAIL COST ESTIMATION OF SUMP (UNDERGROUND TANK)**

Finally cost of entire project play a crucial role in any type of project. Before implementing the project, it is highly necessary for the engineers to check project, whether it is economical or not. Hence, the detail cost estimation should be done.

Tank shall be of first class brickwork in 1:4 cement mortar foundations and floor shall be of 1:3:6 cement concrete. Inside of septic tank shall be finished with 12mm cement plaster and floor shall be finished with 20mm cement plaster with 1:3 mortar mixed with standard water proofing compound. Upper and lower portion of soak-pit shall be of second class brickwork in 1:6 cement mortars and middle portion shall be of dry brickwork. Wall thickness is about 30cm. Roof covering slabs shall be precast R.C.C. The length of the connecting pipe from latrine seat may be taken as 3 meters. And suitable rates are assumed.

Given below the detail cost estimation of constructing an underground sump of dimensions (4 x 5 x 12) at hostel site:

**Table No. 5: DETAIL ESTIMATION OF SUMP**

| Sl. No. | Particular | No. | Length(m) | Breadth(m) | Height/depth(m) | Quantity($m^3$) |
|---|---|---|---|---|---|---|
| 1 | **earth work in excavation** | 1 | 12.80 | 5.80 | 4.3 | 319.232 |
| 2 | **Cement concrete 1:3:6 in foundation** | 1 | 12.80 | 5.80 | 0.3 | 22.27 |
| 3 | **I class brick work in 1:4 cement mortar** | | | | | |
| | **i. Long wall** | 2 | 12.60 | 0.30 | 4 | 30.24 |
| | **II.short wall** | 2 | 5.0 | 0.30 | 4 | 12 |
| | | | | | **Total** | 42.24 |
| 4 | **R.C.C work for slab cover** | 1 | 12.60 | 5.60 | 0.20 | 14.112 |
| 5 | **12mm plastering inside with 1:2 cement mortar** | | | | | |
| | **i.long wall** | 2 | 12 | - | 4 | 96 |
| | **ii.short wall** | 2 | 5 | - | 4 | 40 |
| | | | | | **Total (Rs)** | **136** |

**Table No. 6: ABSTRACT OF ESTIMATION COST**

| Sl no | Particular | Quantity | Rate | Cost(Rs) |
|---|---|---|---|---|
| 1 | **Earthwork in excavation** | 319.232 $m^3$ | 100 Rs/$m^3$ | 31923.2 |
| 2 | **Cement concrete 1:3:6 in foundation with brick ballast** | 22.27 $m^3$ | 2700 Rs/$m^3$ | 60129 |
| 3 | **I class brickwork 1:3 cement mortar** | 42.24 $m^3$ | 3000 Rs/$m^3$ | 126720 |
| 4 | **R.C.C work for slab cover** | 14.112 $m^3$ | 2700 Rs/$m^3$ | 38102.4 |
| 5 | **12mm plastering with 1:2 cement mortar** | 136 $m^3$ | 2700 Rs/$m^3$ | 367200 |
| | | | **Total** | 624074.6 |
| 6 | **Contingency + work charges establishment** | (3% + 2 % = 5 %) | -- | 31203.73 |
| 7 | **Engineering profit** | 10% | -- | 62407.46 |
| | | | **Grand Total** | **717685.80** |

Hence, after studying the present market value of material required for constructing the entire tank and using it while calculating during costing and estimation of tank. After all several steps, the total cost of tank was came out to be Rs. 7,17,685.80. This steps was applied to all other building for determining the final cost price of the tank.

## 7.3. GUTTER DESIGN

A channel which surrounds edge of a sloping roof to collect and transport rainwater to the storage tank is called gutter. Gutters can be semi-circular or rectangular and generally of PVC or galvanized iron sheet type of material.

The efficiency of gutter is highly influenced by its choice of optimal size, width and position relative to the roof edge and its slope. Hence, this parameter is cautiously chosen. So, in order to collect maximum water, it is highly required to build the gutter with large dimensions. However, it is economical to make large gutter with reasonable dimension because the value of water collected from it is much higher than the cost of constructing the gutter. Considering the throw wind and pulsating effects, gutter width was frozen on the basis of the roof size and the ideal positioning was found out. Keeping the present case in mind, results of various studies were extensively analyzed, and a suitable gutter design was proposed.

The final design recommendation is as follows. Design is made for trapezoidal shaped gutter whose angle was 30$^o$, and its sides are the same length as its base. The gutter has a slope of 0.5% in the first 2.3$^{rd}$ portion of its length, and 1.0% slope in the last 1.3$^{rd}$. The gutter width is designed to be 160mm, of which 120mm is extending out from the roof edge and 40mm extending towards the inner side.

## 7.4. FIRST FLUSH MECHANISMS

First flush mechanism is shown in the fig. 11. Due to long dry period, the catchment area generally gets dirty. Hence in order to prevent entry of excess dirt from the catchment area from entry into tank and polluting the water, first flush mechanism is designed. And the order of this mechanism becomes highly important when water preserved is utilized for drinking purpose. Turbidity factor was also considered while design first flush mechanism. After studying our requirement and prevailing condition, the design value of this mechanism was fixed to be 8litres/10m$^2$. And finally Ball-Valve design was chosen. Ball-Valve design has a unique mechanism for controlling the flow of water into and outside of the tank. Ball-Valve design is shown in the figure. This system consists of ball inside the specially designed pipe which opens and closes the opening of outlet to the storage tank and diversion chamber according the level of water. When the water fills up to the brim, the water is diverted to the main tank from the side outlet. And when the water needs to be rejected is sent to the small diversion chamber where it fills the inlet pipe. Hence total volume of

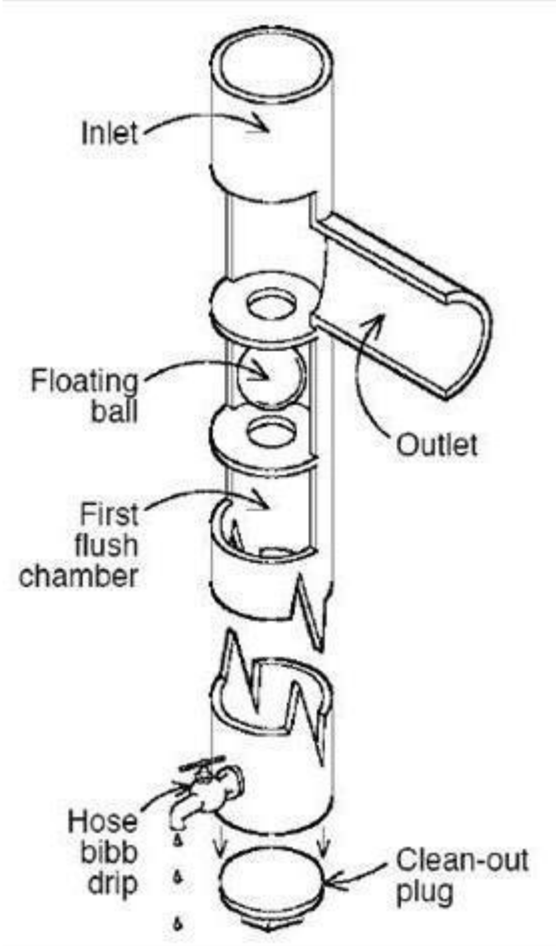


Fig. 12: Ball Valve Type First-Flush Mechanism

the diversion chamber and the pipe up to the Ball-Valve are carefully designed to match the diversion volume that is calculated. The connection between the terrace water and storage tank rebuilds when water reaches the level of the ball making the ball to float and block the connection between the terrace water and diversion chamber, thus sending the water back again to main storage tank. In this way, Small diversion chambers are designed for the downpipes from each terrace. The diversion tank can have a tap which may be operated.

## 7.5. FILTRATION

Filtration is highly required for the rainwater which is harvested from the rooftop area. When water is use for drinking purpose then this process become even more important. But, basic filtration is preferable required to avoid excessive dirt entering the system. A very simple, cost-effective mechanism has been chosen preferred over elaborate commercial systems. Leaf and twig screen, for basic which is a 5mm thick mesh with wire frame running along the gutters was selected. With most of the commercial fine filtration systems, there is a general difficulty of handling high flow rates, thus, a practical filtration method was selected running the flow through a fine cloth/mosquito net mesh. The flow rate would not be impeded much; it's very cost effective and can be easily maintained and replaced. Again, two cloth filters for hydraulic and cleaning efficiency using a graded sand load can be chosen whose results are highly comparable to commercial filters. Based on their results, the muslin type of cloth filter with conical shape was selected for usage in the proposed rainwater harvesting system. The proposed cloth filter design arrangement is shown in the Figure no 12.

Fig. 13: Simple cloth filter

# CHAPTER - 8

# RESULTS

## 8.1. OPTIMUM LOCATION OF TANK / UNDERGROUND RESERVOIR RECHARGING POINT

In this section, we need to find out the optimum or best location for underground tank or recharging point if harvested water decided to recharge the underground reservoir. Earlier we have already analyzed the entire campus on the platform of hydrology and GIS. And a very careful study was done on the output results from these analysis steps.

From the figure no 6, the final digital elevation model map, it was found that the surface with high elevation was situated in the extreme left hand side of the campus (areas nearer to Institute main building) with dark blue shaded region. The surface very next to it on right hand side (yellow shaded region) has a very low elevation and the elevation of the surface next to yellow shaded region is higher than preceding one. Thus the yellow patch of land is just sandwiched between two regions of higher elevation. And during the rainy season, all the surface runoff will naturally roll down to this yellow patched region due to its slope variation and gravitation force. Thus yellow patched region considered to be the best location for placing the artificial tank for storage or the artificial recharging point recharging the underground reservoir. The methods for recharging the underground reservoir have already been in dealt in detail in section 1.2.8 of Introduction part.

The hostels areas lies on the top north portion in the digital elevation model picture of NIT Rourkela, fig. no. 6. This portion more or less has equal elevation (yellow, light blue and black shaded region). Thus digital elevation model map tell us that land near the hostel side are almost flat with minimal degree of inclination of slope. So, from this it is concluded that runoff rainwater will persist in these areas naturally for a longer period of time as the land is flat and avoid water to get drain off easily. Hence, the best location of tank or may be artificial recharging point will the barren land in between the two hostels collecting discharge water from both hostels. Similarly, for the main institutional building, optimum location is situated behind collecting water from more than one department. And the tank should be an underground one, so that the land can be best used by building any useful structure above it, may cycle stand or tennis court, etc.

Hence based on the above detail studies, the 10 best possible locations for underground tank or recharge point are recommended (R1 to R10) and shown in the figure no. 13 on the map of NIT Rourkela Campus. Here, R1 to R10 is the combined reservoir point location or tank location of different building shown in fig. 13 and table no.7.

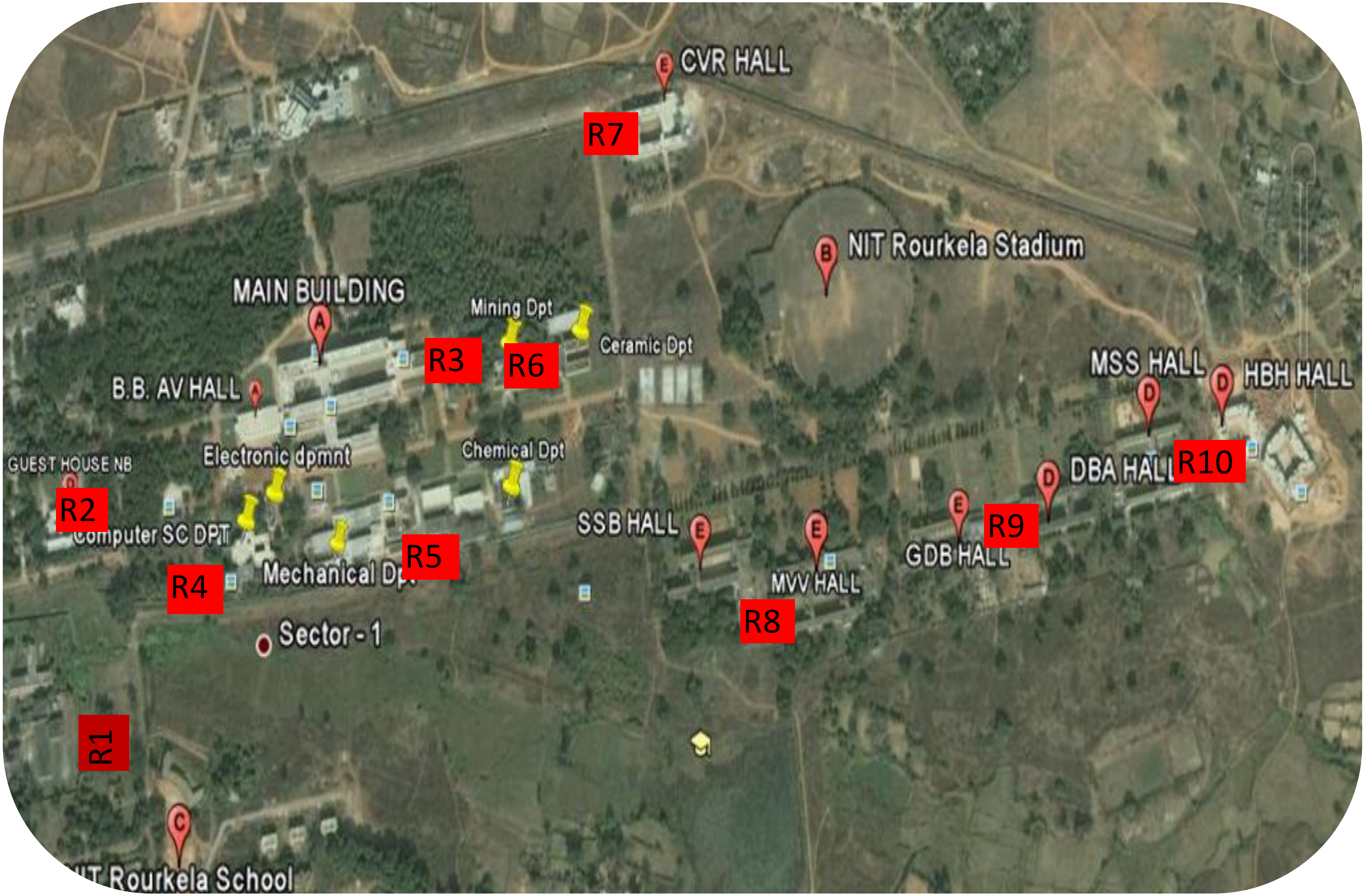


**Fig.14: Optimum location of storage tank or recharge point of underground Reservoir**

**TABLE NO. 7: COMBINED RESERVOIR LOCATION FOR DIFFERENT BUILDINGS**

| R | 1 | 2 | 3 | | | 4 | | | 5 | | 6 | | 7 | 8 | | 9 | | 10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hall name | K.M.S Hall-GH | Guest house-NB | Main Building | AV Hall | Library | CSE Dpt | Electronics Dpt | SAC | Mechanical Dpt | Chemical Dpt | Mining Dpt | Ceramic Dpt | C.V. R. Hall - 6 | S.S.B HALL-1 | M.V.V HALL-2 | G.D.B HALL-3 | D.B.A. HALL-4 | M.S.S. HALL-5 | H.B.H. Hall-7 |

## 8.2. RAINWATER HARVESTING POTENTIAL OF DIFFERENT BUILDING AT N.I.T. ROURKELA CAMPUS

Earlier in the context, rainwater harvesting potential has been explained and dealt in brief in the section 5.1., hydrological analysis. Hence, now the rainwater harvesting capacity of different building was found out with respect to same rainfall data.

As the rooftop surface area of different building including hall of residence and different departmental building varies greatly with each other, thus amount of discharge produced or rainwater runoff produced will be different. With the small ideas of rainwater harvesting potential of different building, one can best take the advantage by of rainwater harvesting by building the system in the more potential building.

Given below in the table no. 8, the detail rainwater harvesting capacity of the entire campus buildings:

**TABLE NO. 8: CALULATION OF ROOFTOP AREA & RUNOFF OF ALL BUILDING**

| Serial no. | Hall Name | Rooftop area($m^2$) | Runoff($m^3$) (rooftop area x1.4m) |
|---|---|---|---|
| 1. | S.S.B. HALL | 2285.52 | 3199.728 |
| 2. | M.V.V. HALL | 2604.63 | 3646.48 |
| 3. | G.D.B HALL | 2252.953 | 3154.1 |
| 4. | D.B.A. HALL | 1997.65 | 2796.71 |
| 5. | M.S.S. HALL | 2609 | 3652.6 |
| 6. | C.V. Raman | 1520.81 | 2129.134 |
| 7. | HBH Hall | 2169.76 | 3037.66 |
| 8. | Main Institute Building | 5008 | 7011.2 |
| 9. | AV Hall | 1000 | 1400 |
| 10. | Library | 354.76 | 496.66 |
| 11. | Mining Department | 723.56 | 1012.98 |
| 12. | Ceramic Department | 1133.30 | 1586.62 |
| 13. | Chemical Department | 1737.44 | 2432.42 |
| 14. | Mechanical Department | 5364.06 | 7509.68 |
| 15. | Computer SC. Department | 1220.04 | 1708.1 |
| 16. | Electronics Department | 254 | 355.6 |
| 17. | Student Activity Centre | 256 | 358.4 |
| 18. | Guest house(North Block) | 837.1 | 1171.94 |
| 19. | K.M.S Hall | 3154.8 | 4416.02 |

**8.3. DETAIL MONTHLY HYDROLOGICAL ANALYSIS OF ALL BUILDING**

**Given below the table no.9 which gives the details monthly analysis of surface runoff produced from the catchment areas of various building .Where the serial no. denotes the building name as given in the table no. 2.**

## TABLE NO.9: DETAIL MONTHLY HYDROLOGICAL ANALYSIS OF ALL BUILDING

| *sl no.* | Area-$m^2$ | Harvesting capacity (Monthly Runoff) | | | | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | J | F | M | AL | MY | JN | JY | AT | S | O | N | D | |
| 1. | 2286 | 34.51 | 56.9 | 36.5 | 36.5 | 92.7 | 542.5 | 883.1 | 900.3 | 483.4 | 154.7 | 19.88 | 16.45 | **3258** |
| 2. | 2605 | 39.32 | 64.85 | 41.67 | 41.67 | 105.7 | 618.3 | 1006 | 1026 | 550.8 | 176.3 | 22.66 | 18.75 | **3713** |
| 3. | 225 | 34.02 | 56.10 | 36.04 | 36.04 | 91.46 | 534.8 | 870.5 | 887.4 | 476.4 | 152.5 | 19.60 | 16.22 | **3211** |
| 4. | 1998 | 30.16 | 49.74 | 31.96 | 31.96 | 81.11 | 474.2 | 771.9 | 786.9 | 422.5 | 135.2 | 17.38 | 14.38 | **2847** |
| 5. | 2609 | 39.40 | 64.96 | 41.74 | 41.74 | 106 | 619.4 | 1008 | 1028 | 551.8 | 176.6 | 22.70 | 18.78 | **3719** |
| 6. | 1520 | 22.96 | 37.87 | 24.33 | 24.33 | 61.75 | 361.0 | 587.6 | 599.1 | 321.7 | 103 | 13.23 | 10.94 | **2168** |
| 7. | 2170 | 32.76 | 54.02 | 34.71 | 34.71 | 88.09 | 515.1 | 838.3 | 854.6 | 458.9 | 146.8 | 18.87 | 15.62 | **3093** |
| 8. | 5008 | 75.62 | 124.7 | 80.12 | 80.12 | 203.3 | 1189 | 1935. | 1972. | 1059. | 339.0 | 43.56 | 36.05 | **7138** |
| 9. | 1000 | 15.1 | 24.9 | 16 | 16 | 40.6 | 237.4 | 386.4 | 393.9 | 211.5 | 67.7 | 8.7 | 7.2 | **1425** |
| 10. | 354.7 | 5.356 | 8.833 | 5.676 | 5.676 | 14.40 | 84.22 | 137.0 | 139.7 | 75.03 | 24.01 | 3.086 | 2.55 | **505.6** |
| 11. | 723.5 | 10.92 | 18.01 | 11.57 | 11.57 | 29.37 | 171.7 | 279.5 | 285.0 | 153.0 | 48.98 | 6.294 | 5.20 | **1031** |
| 12. | 1133 | 17.11 | 28.21 | 18.13 | 18.13 | 46.01 | 269.0 | 437.9 | 446.4 | 239.6 | 76.72 | 9.85 | 8.15 | **1615** |
| 13. | 1737 | 26.23 | 43.26 | 27.79 | 15.11 | 70.54 | 412.4 | 671. | 684.3 | 367.4 | 117.6 | 15.11 | 12.50 | **2477** |
| 14. | 5364. | 80.99 | 133.5 | 85.82 | 85.82 | 217.7 | 1273 | 2072 | 2112 | 1135 | 363.1 | 46.66 | 38.62 | 38.62 |
| 15. | 1220 | 18.42 | 30.37 | 19.52 | 19.52 | 49.53 | 289.7 | 471.4 | 480.6 | 258.0 | 82.59 | 10.61 | 8.78 | 26204 |
| 16. | 254 | 3.83 | 6.32 | 4.06 | 4.06 | 10.31 | 60.29 | 98.14 | 100.0 | 53.72 | 17.19 | 2.20 | 1.82 | 5456 |
| 17. | 256 | 3.86 | 6.37 | 4.09 | 4.09 | 10.39 | 60.77 | 98.91 | 100.8 | 54.14 | 17.33 | 2.22 | 1.84 | 5498 |
| 18. | 837.1 | 12.64 | 20.84 | 13.39 | 13.39 | 33.98 | 198.7 | 323.4 | 329.7 | 177.0 | 56.67 | 7.282 | 6.02 | 1193 |
| 19. | 3155 | 47.63 | 78.55 | 50 | 50.47 | 128 | 748 | 1219 | 1243 | 667.3 | 213.0 | 27.44 | 22.71 | 4497 |

## 8.4. DIMENSIONS OF TANK & COST OF CONSTRUCTION

Depending upon the hydrological analysis of runoff per month for different building, the size of the underground tank was designed. As the design of the Sample tank i.e. M.S.S. Hall was carried out in the section 6 in detail. Hence, the same procedure is being followed for all other buildings in a similar manner to calculate the optimum dimension of tanks. Given below the results of optimum dimension of underground tank (incase if it is build over the option of artificial recharge of underground aquifer) in a tabular form in the table no. 10. Again, the optimum location of this tank is carried out through GIS analysis which has already been discussed in the section 7.1. As we know there are all together **ten optimum** locations (R1-R10) for artificial recharge of underground tank or for underground storage tank for the study areas buildings which we have considered here.

The dimension of the tank was so chosen that depth of the tank should not be too deep, which will create trouble like high cost of excavation, high cost of construction of retaining wall as pressure increases at the rate of square of the height and finally there will be great difficulty in maintenance. Hence the depth of the tank at max, was fixed to 5-6 m below the ground level. Again, underground tank was chosen for best possible utilization of land by building some playground or cycle stand above the tank.

Complete estimation and costing of sample hall (M.S.S Hall) was done in the section 7.2 in the table 5 & 6. The same procedure was just repeated neglecting any variation in thinness(30cm) of the tank for different tank size for ease of calculation and comparisons between them.

For designing purpose, following data were assumed to be constant. These value cab be change later on depending upon different situation.

Hence, No. of person consuming water from any one hall of residence was assumed to be 300.

Annual average rainfall was assumed to be 1400 mm.

The rate of consumption, here was fixed to be 100liter/day.

Hence all other parameter and steps where same as previous and results of complete analysis of tanks was tabulated in the table given below in table no. 10.

**TABLE NO. 10: DIMENSION OF TANK & ITS COST OF CONSTRUCTION FOR VARIOUS BUILDINGS INSIDE THE CAMPUS OF NIT ROUKELA**

| Sl no. | Hall Name | Rooftop area($m^2$) | Runoff ($m^3$) (rooftop area x1.4m) | Reservoir Capacity | Reservoir Location | Dimensions of Assume Tank | Cost of construction |
|---|---|---|---|---|---|---|---|
| 1 | K.M.S Hall-GH | 3154.8 | 4416.02 | 4416.02 | R1 | 5.5x10x12 | 1312628.4 |
| 2 | Guest house-NB | 837.1 | 1171.94 | 1171.94 | R2 | 5x6x13 | 993158.4 |
| 3 | Main Building | 5008 | 7011.2 | 8907.86 | R3 | 6x10x18 | 1857163 |
| 4 | AV Hall | 1000 | 1400 | | | | |
| 5 | Library | 354.76 | 496.66 | | | | |
| 6 | CSE Dpt | 1220.04 | 1708.1 | 2422.1 | R4 | 5x6x13 | 993158.4 |
| 7 | Electronics Dpt | 254 | 355.6 | | | | |
| 8 | SAC | 256 | 358.4 | | | | |
| 9 | Mechanical Dpt | 5364.06 | 7509.68 | 9942.1 | R5 | 6x10x19 | 1931310 |
| 10 | Chemical Dpt | 1737.44 | 2432.42 | | | | |
| 11 | Mining Dpt | 723.56 | 1012.98 | 2599.6 | R6 | 5x6x13 | 993158.4 |
| 12 | Ceramic Dpt | 1133.30 | 1586.62 | | | | |
| 13 | C.V. R. Hall-6 | 1520.81 | 2129.134 | 2129.13 | R7 | 5x6x13 | 993158.4 |
| 14 | S.S.B HALL-1 | 2285.52 | 3199.728 | 3199.73 | R8 | 6x10x14 | 1560573 |
| 15 | M.V.V HALL-2 | 2604.63 | 3646.48 | | | | |
| 16 | G.D.B HALL-3 | 2252.953 | 3154.10 | 5950.81 | R9 | 5x6x13 | 993158.4 |
| 17 | D.B.A. HALL-4 | 1997.65 | 2796.71 | | | | |
| 18 | M.S.S. HALL-5 | 2609 | 3652.6 | 6690.26 | R10 | 6x8x15 | 1463655.6 |
| 19 | H.B.H. Hall-7 | 2169.76 | 3037.66 | | | | |
| Total Cost of Construction of Underground Tank | | | | | Rs.1,30,91,122 | | |

## 8.5. CALCULATION OF NUMBER OF DAYS SUPPORTED BY STORED HARVESTED WATER IN TANK TO CONSUMER.

The two methods to distribute the stored harvested rainwater were already discussed in the section 5.2 in detail. Here we need to calculate the no of days of lasting of stored rainwater from different building inside the campus consumer. The number of consumer inside one building was assumed to be fixed 300. Both the two methods of distribution of the stored rainwater (Rapid depletion method(RDM) & Rational Method(RM)) were analyzed and results shown in table below

**TABLE 11: Analysis of distribution of stored harvested water by two methods:**

| Sl no. | Hall Name | Rooftop area($m^2$) | Reservoir Capacity (R) | RM = R/30 (days) | RDM= R/45 (days) |
|---|---|---|---|---|---|
| 1 | K.M.S Hall-GH | 3154.8 | 4416.02(R1) | 147.20 | 98.13 |
| 2 | Guest house-NB | 837.1 | 1171.94(R2) | 39.06 | 26.04 |
| 3 | Main Building | 5008 | 8907.86(R3) | 296.92 | 197.95 |
| 4 | AV Hall | 1000 | | | |
| 5 | Library | 354.76 | | | |
| 6 | CSE Dpt | 1220.04 | 2422.1(R4) | 80.73 | 53.82 |
| 7 | Electronics Dpt | 254 | | | |
| 8 | SAC | 256 | | | |
| 9 | Mechanical Dpt | 5364.06 | 9942.1(R5) | 331.40 | 220.93 |
| 10 | Chemical Dpt | 1737.44 | | | |
| 11 | Mining Dpt | 723.56 | 2599.6(R6) | 86.65 | 57.76 |
| 12 | Ceramic Dpt | 1133.3 | | | |
| 13 | C.V. R. Hall-6 | 1520.81 | 212.91(R7) | 70.97 | 47.31 |
| 14 | S.S.B HALL-1 | 2285.52 | 3199.73(R8) | 106.65 | 71.10 |
| 15 | M.V.V HALL-2 | 2604.63 | | | |
| 16 | G.D.B HALL-3 | 2252.953 | 5950.81(R9) | 198.36 | 132.24 |
| 17 | D.B.A. HALL-4 | 1997.65 | | | |
| 18 | M.S.S. HALL-5 | 2609 | 6690.26(R10) | 223.01 | 148.67 |
| 19 | H.B.H. Hall-7 | 2169.76 | | | |

# CHAPTER - 8

# CONCLUSION

This paper dealt with all aspect of improving the water scarcity problem in the NIT Rourkela campus by implementing ancient old technique of rainwater Harvesting. Two alternatives have been suggested for tank design, which takes separate approaches towards the consumption of harvested rainwater. These results are given clearly in the table no. 11. Hence from this table, we can draw out a conclusion that a huge amount of water got collected from the rooftop surfaces of all the entire buildings. And if, this project is being done seriously and implemented to the campus then R5 (behind Mechanical + Chemical department) has a huge harvesting potential. This reservoir should have to build for the storage of 9942.1 $m^3$ of water. Hence this tank has huge capacity of getting rainwater and on proper storage, this tank can supply almost through out the year for about 300 consumers having a consuming rate of 100liter/day as calculated by rational depletion method. The water has almost the potential amount of tank

| Reservoir capacity ($m^3$) | No. of days of potential by Rational Methods | No. of days of potential by Rapid depletion method |
|---|---|---|
| 9942.1(R5) | 331.40 | 220.93 |

It is concluded that RCC tank which is to be constructed should be an underground one, so that upper surface of the tank can be utilized economically for any land purpose such as playground or cycle stands or any such small structure.

Cost analysis has been done for all the tanks. And it was concluded that cost of construction was not so high, if it is compared with problems which are faced by the students and staffs inside the campus due to huge water scarcity. The other component of the harvesting systems such as Guttering, First-Flush, and Filtration mechanism have also been reviewed and designed for the hostels and all other building in details.

Hence it was finally concluded that implementation of RAINWATER HARVESTING PROJECT to the campus of N.I.T. Rourkela will be the best approach to fight with present scenario of water scarcity in all aspects, whether it is from financial point of view or from optimum utilization of land surface. Therefore, water is highly a precious natural resource which is always in high demand in the campus of N.I.T. Rourkela and thus, RAINWATER HARVESTING AT N.I.T. Rourkela campus is highly recommended.

# CHAPTER - 9

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