DESIGN OF TOTAL WATER MANAGEMENT SOLUTIONS TO JSSATE CAMPUS

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ABSTRACT

Our project deals with providing alternative water source for JSSATE campus through Rainwater Harvesting (RWH) and storm water management modelling (SWMM) using PCSWMM software and water auditing. Rainwater Harvesting and storm water management are low cost methods that help to recharge the aquifers, improve ground water quality by dilution and provide an alternative water source. Water auditing provides detailed water consumption of the campus and it helps in avoiding unnecessary water consumption by bringing awareness among people. A detailed simulation of rainfall-runoff analysis was done using PCSWMM for individual blocks inside the campus. We suggested a groundwater recharge pit near the bore well so that the water table level is maintained. By using the simulations generated from PCSWMM, we estimated that 30% of the water usage from the bore wells can be avoided and 30% of the energy consumption for pumping can be saved.

Keyword: *PCSWMM, Recharge pit, RWH, SWMM, Water Auditing*

1. INTRODUCTION

Managing scarce water resources in an efficient, effective and sustainable manner is an essential public service challenge for cities. Cities are particularly vulnerable for water scarcity as a special mismatch of available freshwater resources and population concentration, rather than an overall lack of water resources – can lead to supply challenges. Population growth, increasing urbanization, climate change induced droughts and rising temperatures exacerbate the situation leading to the risk of depleting reservoirs and reduced ground water recharge. Worlds urban population is expected to raise from current 54%.By 2030 the number of megacities namely cities with more than 10 million inhabitants, will grow over 40 million. This will boost residential water demand, which nowadays covers a large portion of the public drinking water supply worldwide. Most developing nations are struggling to provide water and energy, two resources that are greatly connected, hence the name energy water nexus. To fulfill these water demands one of the most common alternative is the rainwater for use in buildings, in particular residential buildings. The centuries old practice has been reviewed and world has seen a greater attention in the past decade to harvest rainwater to lessen the pressure on main water supplies and to provide water for living in many regions. For example, installation of rainwater tanks in residential houses has become popular in many Australian cities as a result of greater environmental awareness and employment of mandatory water restrictions. Rainwater is used as either the principal or a supplementary source of water to the main water supply system in a residential building, which is generated from rainwater harvesting (RWH) system.

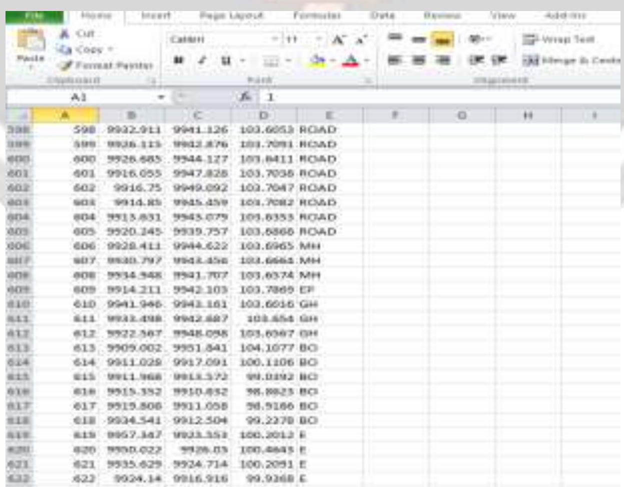
In the past few decades there has been growing awareness of the value of storm water as a resource to be factored into urban development. This has been driven by various trends including rising populations, increased water demand, increasing environmental awareness, risk of storm water damage exacerbated by climate change and growth in urban areas and related impervious surfaces. There has been a parallel emergence in many countries of more sustainable paradigms for urban storm water management including Water-Sensitive Urban Design (WSUD) in Australia, sustainable urban drainage system (SUDS) in Britain and Low Impact Development (LID) in North America. AS opposed to conventional drainage approaches, which treat storm water as nuisance to be removed from urban area as quickly as possible, the sustainable storm water management sees it as a multifunctional resource with many potential benefits for the society and environment if managed wisely.

In this study we selected JSSATE college campus, Bangalore located in Karnataka state, India as the experimental platform and provided total water management solutions through water auditing and by installing Rainwater Harvesting (RWH) and Storm Water Management Modelling (SWMM). The total area of the campus is spread across 85,793.43 sqmt with total population of 3100. The quantity of water required for the campus is 2,10,000 litres/day. The source of water is 2 bore wells connected to 2 pumps pumping 10 hrs/day. One reserved pump is present in case of overheating of any of the operating pumps. The issues faced in the campus are excess of energy consumption, excess water usage, water loss and depletion of water table leading to water crisis because of longtime bore well usage. In current status the rainwater which falls on surface runs down as storm water, part of it is infiltrated to ground and remaining is collected in the pond present inside the campus through adjacent roadside drains. The rainwater falling on roofs of the buildings is drained in to pond through pipelines and roadside drains, while the pond water is used only for landscape uses and it can be sometimes polluted because of mixing with improper treated water, which also released to the pond from Sewage Treatment Plant (STP) present inside the campus. PCSWMM software is used for development of model and simulation of real-life parameters to arrive at results. PCSWMM is an advanced and more sophisticated version of US EPA SWMM5 software. It is a dynamic rainfall-runoff and subsidence runoff simulation model that can be used for both single event as well as long term continuous simulation of surface-subsurface hydrology/hydraulic quantity and quality modelling primarily from urban and suburban areas.

2. MATERIALS AND METHODOLOGY

2.1 Contour Survey and Drainage pattern

Total Station was used for surveying entire campus. The imaginary line joining the points of equal elevation is known as contour. The water stream system achieves a particular drainage pattern to its network of stream channels and tributaries as determined by local geological factors. Our study areas drainage pattern was found to be dendritic pattern. Below image shows the data of contour survey conducted,



A	B	C	D	E
598	9932.911	9941.126	103.6053	ROAD
599	9926.115	9942.876	103.7091	ROAD
600	9926.685	9944.127	103.6411	ROAD
601	9916.055	9947.828	103.7036	ROAD
602	9916.75	9949.092	103.7047	ROAD
603	9914.85	9945.459	103.7082	ROAD
604	9913.631	9943.079	103.6353	ROAD
605	9920.245	9939.757	103.6866	ROAD
606	9928.411	9944.622	103.6965	MH
607	9930.797	9943.456	103.6664	MH
608	9934.948	9941.707	103.6374	MH
609	9914.211	9942.103	103.7869	EP
610	9941.946	9943.161	103.6016	GH
611	9933.498	9942.687	103.654	GH
612	9922.567	9948.098	103.6967	GH
613	9909.002	9951.841	104.1077	BO
614	9911.029	9917.091	100.1106	BO
615	9911.968	9913.572	99.0392	BO
616	9915.352	9910.852	98.8823	BO
617	9919.808	9911.058	98.9166	BO
618	9934.541	9912.504	99.2278	BO
619	9957.347	9923.353	100.2012	E
620	9950.022	9926.03	100.4643	E
621	9935.629	9924.714	100.2091	E
622	9924.14	9916.916	99.9368	E

Fig -1: Contour survey data

2.2 Data Collected

2.2.1 Evaporation data: Evaporation is the process by which water changes from liquid to gaseous or vapor state. It is one of the primary losses of hydrological cycle. According to government of Karnataka the average evaporation loss of Bangalore is

Table -1: Evaporation Data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1999	5.96	6.73	7.43	7.65	6.91	5.91	5.25	5.5	5.87	5.46	5.5	5.21
2000	5.94	6.46	7.52	7.61	7.24	5.58	5.35	5.44	5.79	5.4	5.45	5.32
2001	5.65	6.81	7.47	7.51	7.26	5.61	5.34	5.38	5.72	5.39	5.33	5.15
2002	5.78	6.64	7.42	7.71	7.05	5.37	5.5	5.5	5.99	5.47	5.41	5.35

2.2.2 Rainfall Data: Rainfall data covering 2010 – 2018 of nearest rain gauge is collected from Karnataka State Natural Disaster Monitoring center. Below image shows the rainfall data

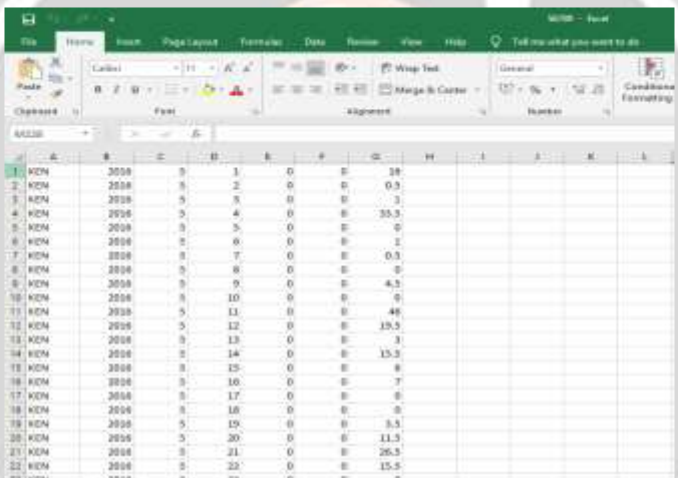


Fig -2: Rainfall data

2.2.3 Secondary Data:

Table -2: Rooftop area of Buildings

Name of the Blocks	Area of Rooftop (m^2)
Block A	4232
Block B (B1+B2)	2790
Block C	778
Canteen	263

Area of road/concrete surface is about 13540 sqmt, building area is about 12000 sqmt. Total impervious area makes up to 27.23% of total area. The pervious area is up to 72% of the total area of campus.

2.3 Hydrological studies and Model building

2.3.1 Generation of Digital Elevation Model (DEM)

A Digital Elevation Model is a specialized raster database that presents the relief of a surface between points of known elevation. BY interpreting known elevation data from available sources, a continuous raster surface was created using GIS platform

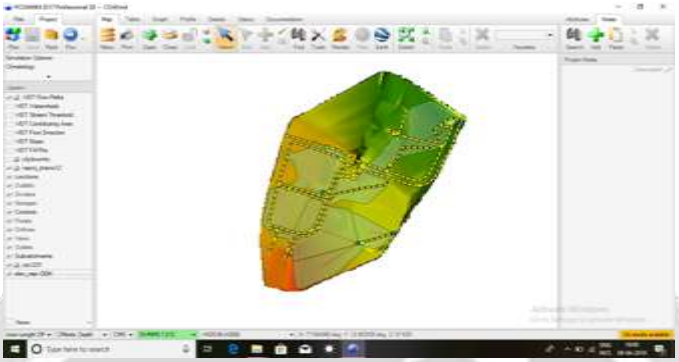


Fig -3: Generation of digital elevation model

2.3.2 Micro Catchment Generation

Watersheds, also known as basins or catchments are physically delineated by the area upstream from a specified outlet point which is the point of where the drainage leaves the plot site has been. The below figure shows the catchment area generated for JSSATE campus

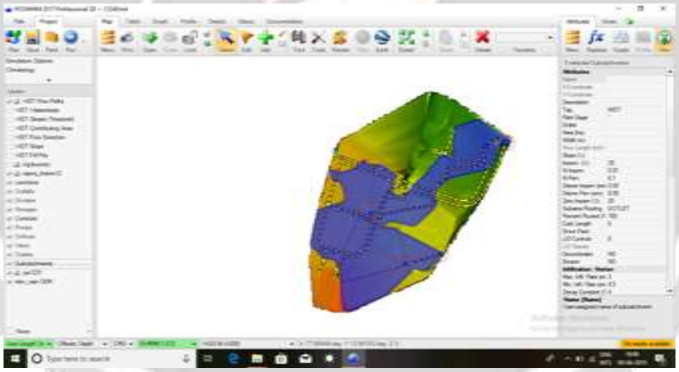


Fig -4: Micro catchments

2.3.3 Infiltration Model

PCSWMM has been used to model infiltration in the previous areas of the catchment using Green-Ampt method. This is because, Green-Ampt infiltration parameters are suitable for design of storm events where soil data is not available. Average capillary action, saturated hydraulic conductivity and initial moisture deficit are the parameters for which the infiltration has been modelled. JSSATE campus catchment soil was found to be mostly loamy sand type, for this type of soil the parameters used in the model are mentioned below

Suction head: 61.3mm
Conductivity: 59.8mm/hr
Initial deficit: 0.382

2.3.4 Model Simulation and Analysis

Dynamic wave flow routing computations have been chosen for simulation of the Hydrological-Hydraulic model in PCSWMM. The following criteria have been considered:

Both water surface slope and Froude number were selected as the basis to determine when supercritical flow occurs in a conduit. A 1minute wet weather time step was used for hydrological simulation whereas 5 second time step was chosen for performing hydraulic simulation.

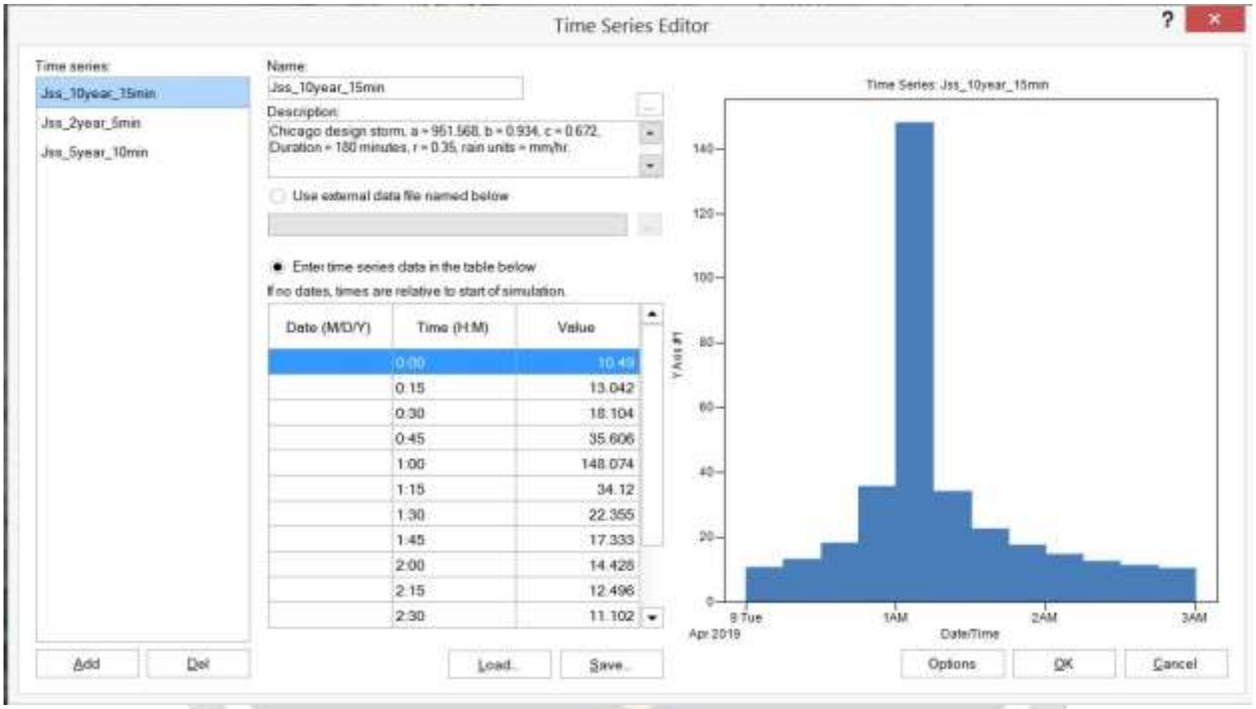


Fig -5: Model Simulation

Based on the above criterion, the model simulation was carried out for a design storm of 2-year return period rainfall for the entire catchments.

3. RESULTS AND DISCUSSION

After doing all the analysis and tests required, we fed all the required values for PCSWMM software and the model ran for about 28 minutes. The simulation period considered was from Nov 23. 2009 to Jun 7. 2019 (3482 days). The rainfall-runoff simulation w.r.t time was done for each blocks separately along with the rainfall-runoff simulation for each blocks separately along with the rainfall-runoff simulation for determining the depth of the recharge pit required. We observed that the total rainfall occurred in the campus was about 9179mm. The maximum rainfall observed was 167 mm/hr and the minimum rainfall observed was 0 mm/hr and the mean rainfall was 0.128 mm/hr. Rainfall visibility analysis estimated that the majority of rainfall happens in southwest monsoon season starting from middle of June to September.

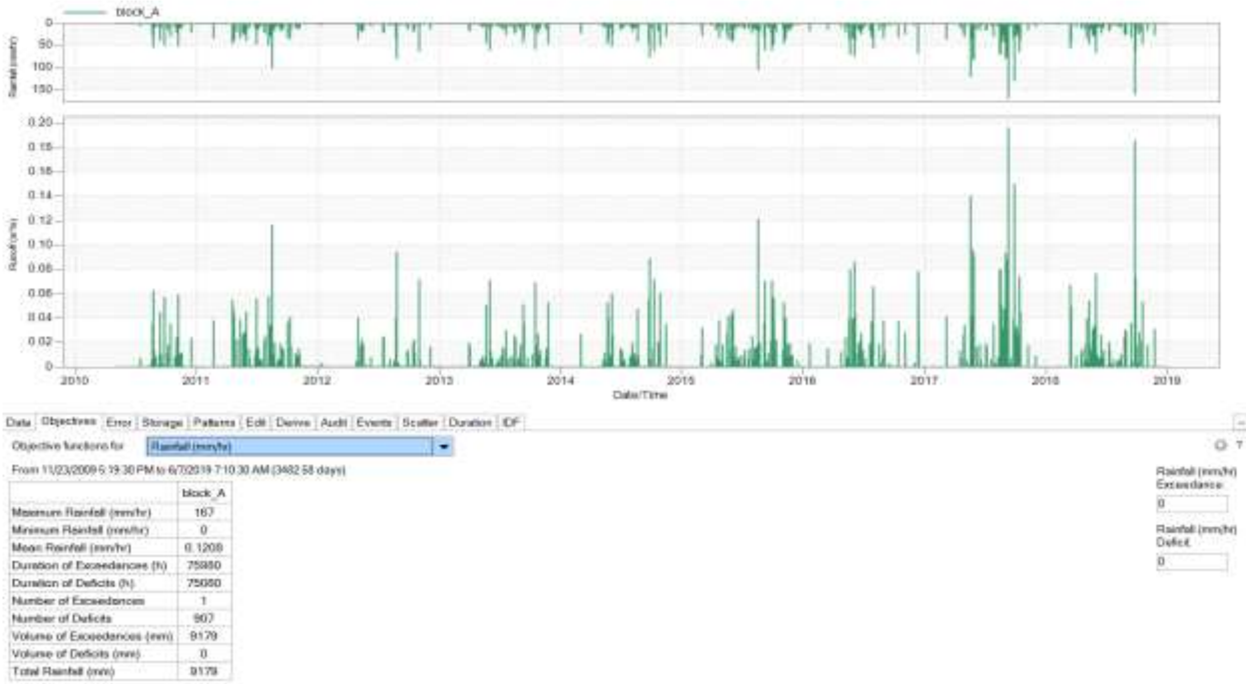


Fig -6: Rainfall-runoff simulation for Block-A

The maximum runoff volume for Block-A was 0.196 m^3/s and the mean runoff volume was 0.0001269 m^3/s, the total runoff volume observed for Block-A was 34710 m^3. Block-B consists of two adjacent structures (B1 and B2) connected to each other. The total discharge observed for Block-B1 was 11240 m^3 and for Block-B2 it was about 11140 m^3 as shown in Fig 8. Maximum runoff of 0.06305 m^3/s and 0.06249 m#/s were observed for block B1 and B2 respectively. In the rainfall-runoff simulation for canteen, the total runoff observed was 1709 m^3 and the mean runoff was very less.

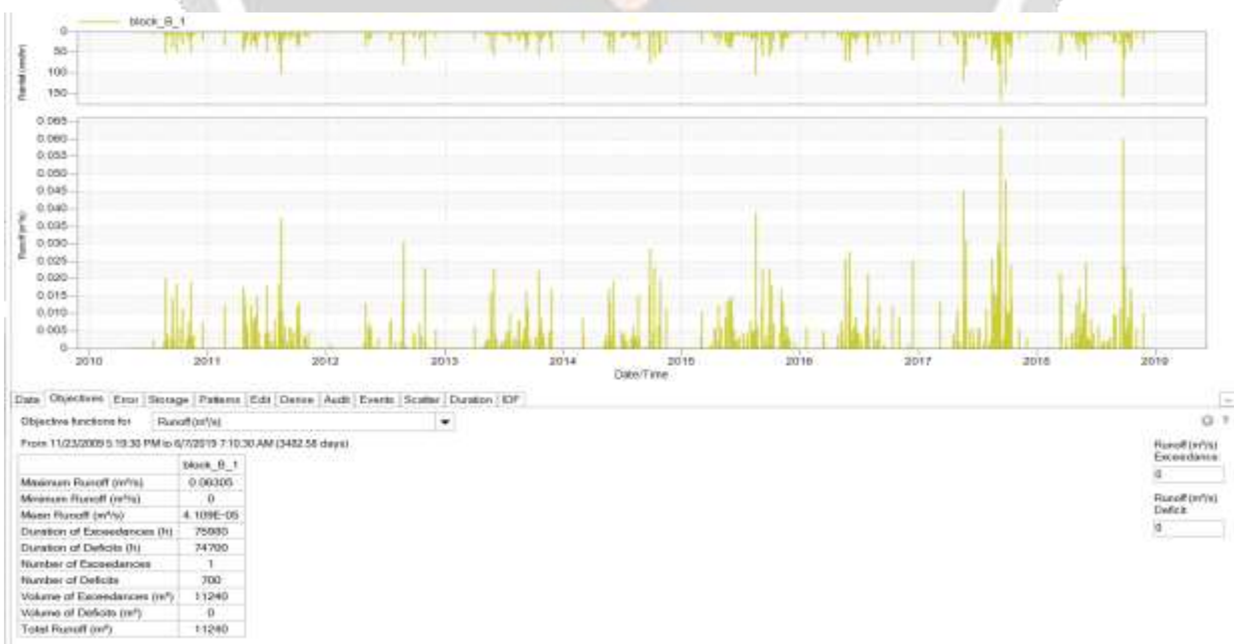


Fig -7: Rainfall-runoff simulation for Block-B1

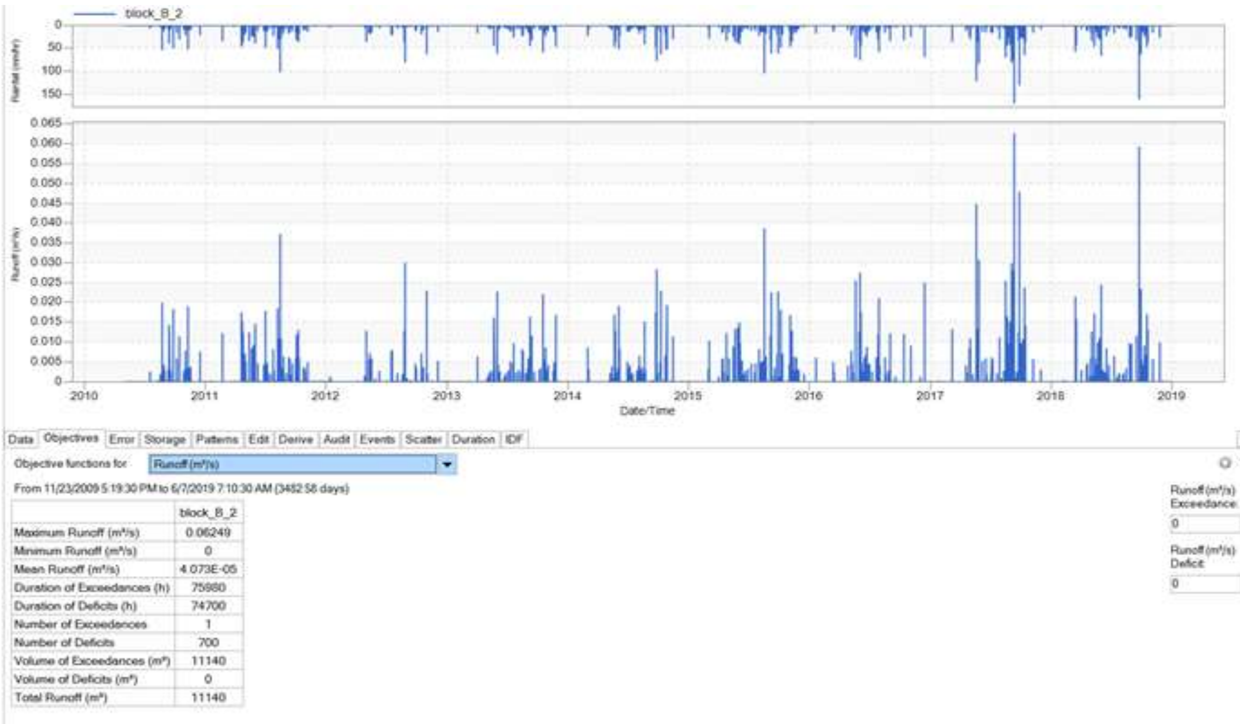


Fig -8: Rainfall-runoff simulation for Block-B2

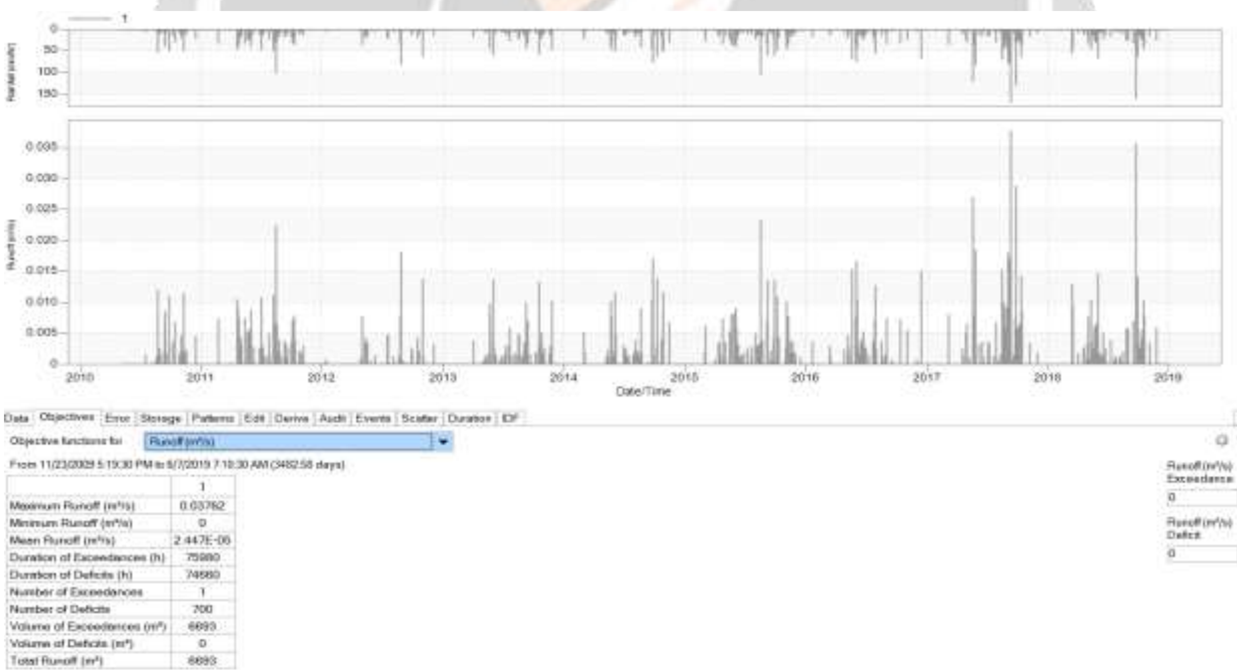


Fig -9: Rainfall-runoff simulation for Block-C

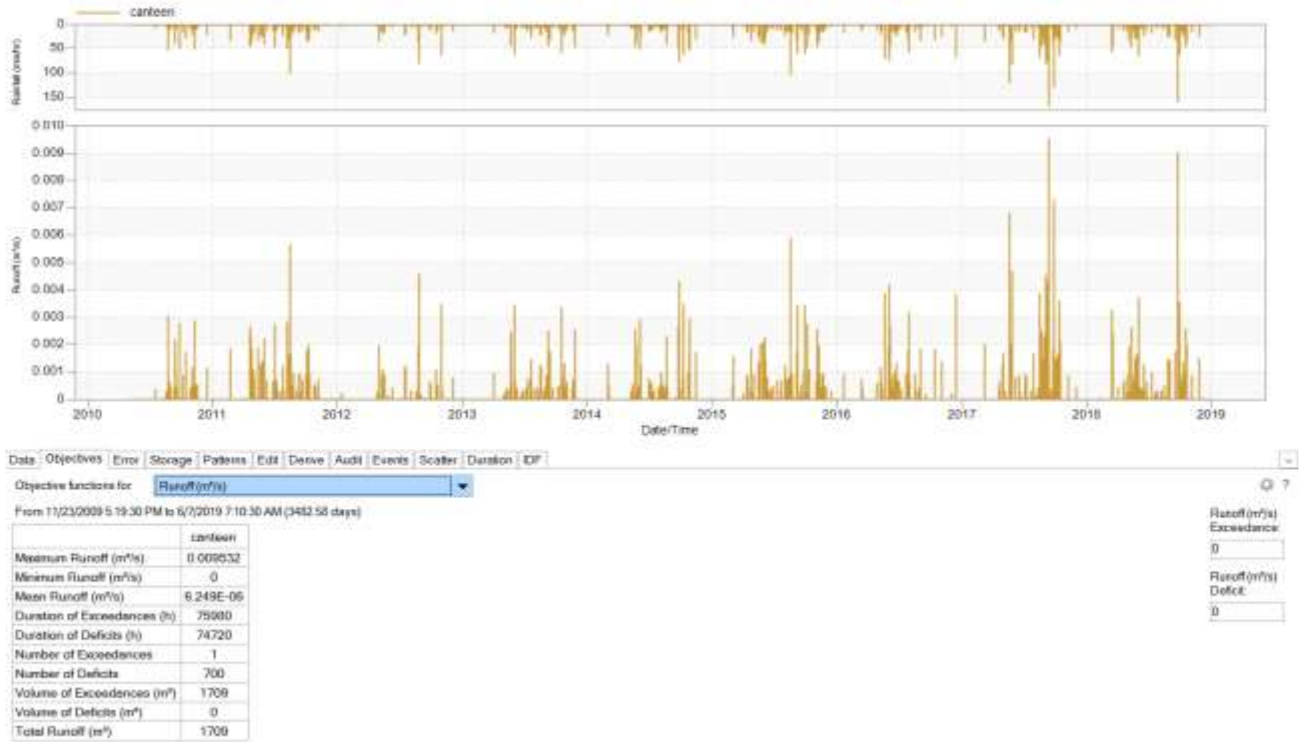


Fig -10: Rainfall-runoff simulation for Canteen

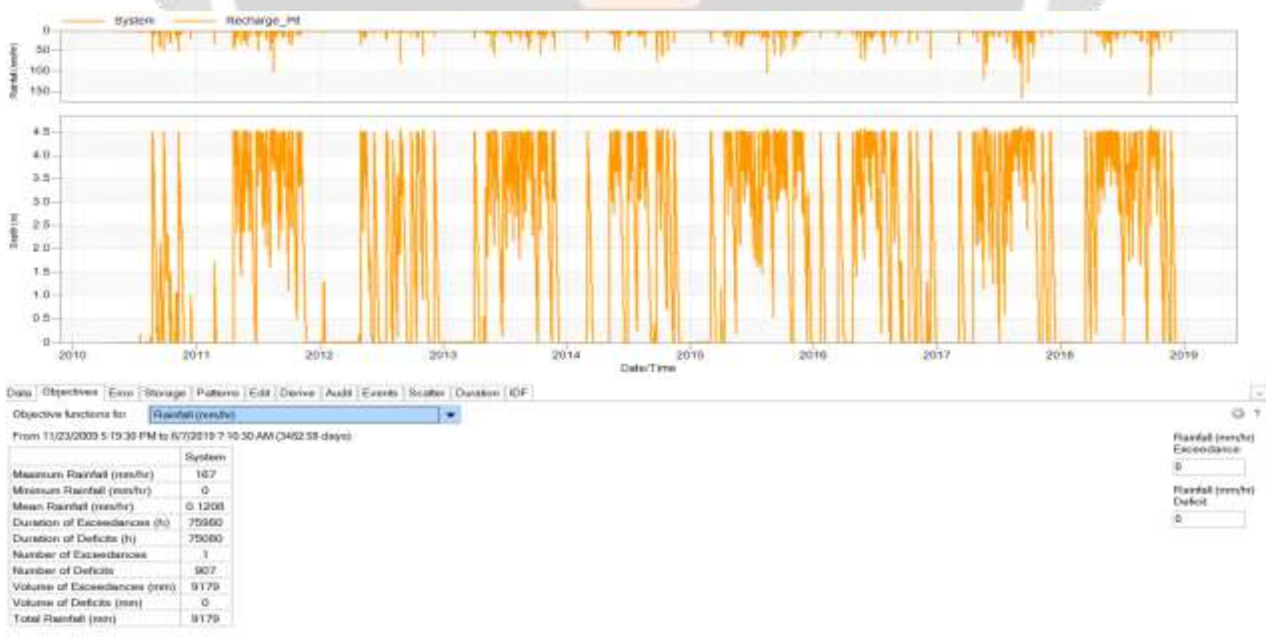


Fig -11: Rainfall-runoff simulation for recharge pit

From the simulation of recharge pit (Fig.12) w.r.t rainfall occurred in the campus and the depth required for recharge pit we designed a recharge pit of size 4*20 ft. for ground water recharging. The simulation time period for recharge pit is same as that of rainfall-runoff simulation period for individual blocks. We recommended FL – 300 filter type for Block-A and FL – 200 filter type was suggested for remaining blocks (refer Table-3)

Table -3: Type and cost of filters

Sl No	Name of the Blocks	Filter type	No. of filters	Cost of filters (Rs.)
1.	Block-A	FL-300	1	16750
2.	Block-B (B1+B2)	FL-200	2	24500
3.	Block-C	FL-200	1	12250
			Total	53500

Table -4: Cost estimation for recharge pit

Particulars	Quantity
Total Pipe length (m)	19.5
Labours	3
Height of recharge pit (ft.)	20
Volume of recharge Pit (L)	22263
Cost of pipes (Rs.)	9750
Cost of Labour (Rs.)	12000
Cost of Concrete rings (Rs)	3900
Cost of Concrete Slab (Rs.)	2600
Cost of Gravel (Rs.)	23550
Transportation Cost (Rs.)	2500
Total Cost (Rs.)	54300

Precast concrete rings of 5 ft. diameter and 9.5 inches height were selected, hence 14 rings are required.40mm crushed gravel stones and perforated concrete slab of height 0.6 feet was suggested, remaining specifications can be seen from Table 4. From this study we estimated that about 30% of the bore well water usage can be avoided and about 30% of the energy consumption for pumping operations can be saved. At present there are Bore wells and sufficient energy for operating them is available, but in the future there might be a depletion of ground water level in the bore wells and may become ineffective in fulfilling the water demands, during that time our study helps in adopting alternative sources of water for college campus and provide all the data and specifications required.

4. CONCLUSIONS

The following conclusions were drawn from the result of this study,

- PCSWMM gives an excellent rainfall-runoff analysis and it shows that adopting Rainwater Harvesting and Storm Water management is very easy done using this software.
- The water audit conducted gives a detailed information about the water usage of the campus and one can observe the differences in water usage in different blocks and can bring awareness among people if excess usage of water is noted.
- The storm water can be channeled and diverted to the proposed recharge pit near the bore wells to increase the ground water level of bore wells.

- Since there is considerably good rainfall in the region the rainwater can be collected, filtered and used as portable water, by this 30% of the bore well water usage can be avoided.

- Implementation of Rainwater Harvesting system (RWH), and installment of recharge pit for Storm Water Management can be easily done with low cost and about 30% of the energy consumption can be saved.

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