APPLICATION OF STORM WATER MANAGEMENT MODEL OF JNTUK CAMPUS KAKINADA, ANDHRA PRADESH, INDIA

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ABSTRACT

Urban flooding and poor stormwater management are becoming increasingly prominent issues in fast-developing areas like Kakinada City. In this study, we will use the Storm Water Management Model (SWMM 5.0) to help design and simulate a successful and sustainable urban drainage system for Jawaharlal Nehru Technological University, Kakinada (JNTUK), which is about 110 acres. An integrated geospatial and hydrologic modeling approach was taken using Remote Sensing (RS), Geographic Information Systems (GIS), and hydrologic simulation systems to design and simulate the system. The satellite images and other topographic data were downloaded from Earth Explorer, ArcGIS (Map Viewer). The satellite imagery was analyzed to extract important surface parameters including land use/land cover, slope, and impervious surfaces. This data was then used to delineate the drainage sub catchments and determine the runoff coefficients to define the hydrologic input parameters for SWMM. The EPA SWMM 5.0 model was used to simulate rainfall-runoff processes and hydraulic behavior of the drainage network. During the analysis of proposed drainage systems, design storms with various intensities were used to assess system performance. Simulations indicated areas with potential water accumulation and flooding within the campus. The analysis provided input to optimize the drainage system with effective inlets, conduits, and outlet configuration to convey water with minimal pooling on the surface. This opportunistic study offers a tangible solution to existing drainage problems on the JNTUK Kakinada campus and illustrates the potential of geospatial technologies to enhance hydrologic modelling tools. The deliverables provide a scalable method to design urban drainage networks that are hydrologically resilient, as well as a planning guide for campus development and sustainably manage the stormwater within urban environments in the future.

Key words*:* EPA SWMM, runoff modeling, storm drainage, urban flooding, GIS hydrology, drainage optimization.

INTRODUCTION

Urban flooding has become an increasingly critical issue in rapidly expanding educational and institutional campuses, particularly in regions like Kakinada, which are susceptible to intense monsoon rainfall. The Jawaharlal Nehru Technological University Kakinada (JNTUK) campus, spanning over 110 acres, faces frequent waterlogging during the rainy season due to inadequate stormwater drainage infrastructure. With the rise in built-up areas and a corresponding decrease in natural infiltration zones, the existing open drainage systems fail to manage the increasing surface runoff. This not only affects the day-to-day functioning of the campus but also poses risks to infrastructure, mobility, and hygiene. The lack of a scientific and data-driven approach to drainage planning has led to inefficient layouts, undersized conduits, and poorly positioned inlets and outlets. To address these challenges, the present study integrates hydrologic simulation using the Storm Water Management Model (EPA SWMM 5.0) with geospatial data derived from Remote Sensing (RS) and Geographic Information Systems (GIS). This approach enables the modeling of rainfall-runoff behavior with spatial accuracy and allows for performance evaluation under different storm scenarios.

The study begins with the acquisition of high-resolution Digital Elevation Models (DEMs), slope maps, and land use data to delineate drainage sub-catchments and evaluate their hydraulic behavior. Rainfall data from the Indian Meteorological Department (IMD) is processed to develop intensity-duration-frequency (IDF) curves, which are then input into SWMM simulations to assess flow depth, velocity, and capacity of the drainage system. Simulation results reveal the critical segments of the network that are prone to flooding, especially near hostels, internal roads, and academic buildings.

By analyzing the limitations of the existing system and simulating proposed modifications, the research aims to develop an optimized stormwater drainage design tailored for the JNTUK campus. The methodology not only addresses current drainage inefficiencies but also builds resilience against future extreme weather events. Ultimately, this study contributes a replicable and scalable framework for other urban campuses facing similar hydrological and infrastructural challenges.

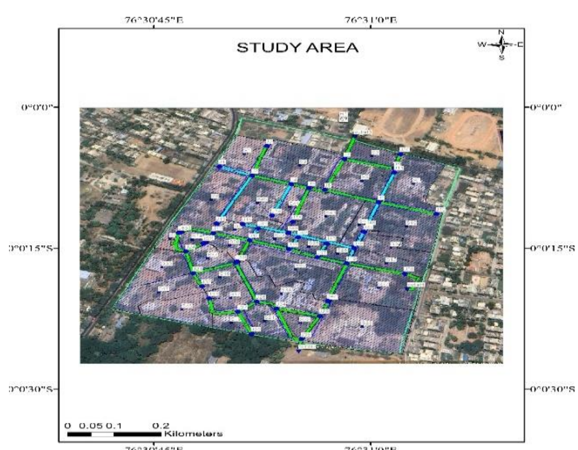

Figure 1. Study area of JNTUK Kakinada campus.

1.1 Objectives

1. Evaluation of stormwater drainage network of JNTUK Kakinada campus.

2. Simulation of rainfall-runoff behavior using EPA SWMM to identify flood-prone areas and drainage inefficiencies**.**

1.2 Scope

The following are the scope of the study:

1. To reduce flooding problems on the JNTUK campus.
2. To design a better drainage system using GIS and SWMM.
3. To create a model that can help in similar areas.

1.3 Software Used

ArcGIS10.3

ArcGIS 10.3 is a powerful geographic information system used to perform spatial analysis, data visualization, and terrain modeling. It was primarily employed to process satellite imagery and Digital Elevation Models (DEMs) for the JNTUK campus. Tools within ArcGIS, such as Flow Direction, Flow Accumulation, and Watershed, were used to delineate catchment and sub-catchment areas. Additionally, slope analysis and land-use mapping provided essential input parameters, such as the percent impervious area and average slope for each sub-catchment, which were later imported into SWMM.

Storm Water Management Model

EPA SWMM 5.0 (Storm Water Management Model) is a widely used hydraulic and hydrologic modeling software developed by the U.S. Environmental Protection Agency. It simulates the quantity and quality of stormwater runoff in urban areas. In this study, SWMM was used to configure a network of drainage elements including junctions, conduits, and outfalls. By inputting rainfall data and catchment characteristics, SWMM helped simulate flow depths, velocities, and flooding risks under various storm scenarios, making it an essential tool for stormwater infrastructure planning.

METHODOLOGY

The methodology for this study involved a combination of geospatial analysis, hydrologic modeling, and runoff estimation using the Curve Number (CN) method to evaluate and enhance the stormwater drainage network of the JNTUK campus. Hourly rainfall data for October 2024 were obtained from the National Institute of Hydrology (NIH) and used to define design storm events and input time series.

Topographic data, including Digital Elevation Models (DEMs), were processed using ArcGIS 10.3 to delineate the study area into hydrological sub catchments. Key tools such as Flow Direction, Flow Accumulation, Watershed Delineation, and Slope Analysis enabled the extraction of terrain parameters essential for hydrologic modeling.

Runoff from each sub catchment was estimated using the SCS Curve Number method, which incorporates land use, soil type, and hydrologic conditions. Parameters such as slope, width, impervious area, and CN values were computed and assigned to each sub catchment.

These parameters were then imported into EPA SWMM 5.0, where a detailed stormwater network comprising junctions, conduits, outfalls, and a rain gauge was modeled. Google Earth Pro was used to validate conduit lengths and spatial layouts—simulations employed dynamic wave routing and Curve Number infiltration to assess drainage performance and identify critical flood-prone areas.

DATA ANALYSIS

Arc GIS data analysis

The geospatial analysis for this study was conducted using ArcGIS 10.3 to delineate the drainage catchments and generate key hydrologic parameters. The study area's Digital Elevation Model (DEM) was obtained and clipped to the campus boundary. Hydrology tools such as Fill, Flow Direction, Flow Accumulation, Stream Definition, and Watershed Delineation were applied to extract flow paths and subcatchment boundaries.

The DEM was processed to compute slope variations using the Slope tool under the Spatial Analyst toolbox. These slope values were tabulated for each subcatchment using Zonal Statistics, providing input for the stormwater model. Subcatchment widths were derived by dividing the area by the maximum flow length, which was measured from the stream network polyline. The catchment layout, elevation data, and flow direction were exported to metafile formats to serve as a spatial backdrop in EPA SWMM.

The resulting subcatchment polygons included critical attributes such as area, perimeter, average slope, and overland flow length. This ArcGIS-derived data ensured spatial accuracy and consistency when configuring the stormwater model.

Stormwater management data analysis

The simulation of the stormwater drainage system for the JNTUK campus was carried out using the Storm Water Management Model (EPA SWMM 5.0), a comprehensive software tool developed by the United States Environmental Protection Agency. This software is widely used for hydrologic and hydraulic modeling of stormwater runoff and drainage networks in urban environments.

In this study, SWMM was utilized to replicate the behavior of surface runoff within the 110-acre campus area during heavy rainfall events. The primary objective was to identify potential flooding zones and propose an efficient drainage layout based on simulation outputs. The hydrologic modeling was based on the SCS Curve Number (CN) method, which was used to estimate direct runoff from rainfall data. This method considers land use, soil type, and antecedent moisture condition (AMC) to assign CN values to each sub catchment.

To begin with, the study area was delineated into subcatchments using ArcGIS 10.3. Each subcatchment represented a distinct hydrologic unit contributing runoff to the stormwater network. From the Digital Elevation Model (DEM), topographic features were extracted and slope values computed. These terrain attributes, along with land use data, were used to derive hydrological parameters like catchment area, slope, width, and percent imperviousness.

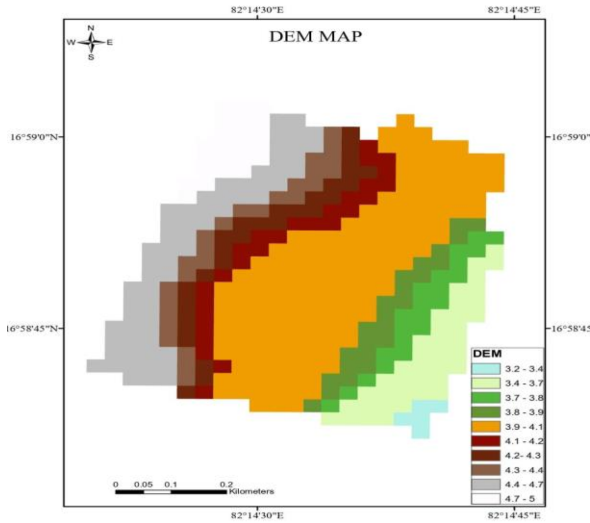

Figure 2. Digital elevation model of the study area

The Digital Elevation Model (DEM) provides a detailed representation of the topography of the JNTUK campus. It highlights variations in ground elevation, enabling the identification of natural depressions, ridges, and flow accumulation zones. These elevation values are essential for watershed and subcatchment delineation, as they determine the direction and concentration of surface runoff. The DEM was used as the base layer in ArcGIS for generating hydrologic inputs such as flow direction, flow accumulation, and watershed boundaries, which were later incorporated into the SWMM model to simulate realistic drainage behavior.

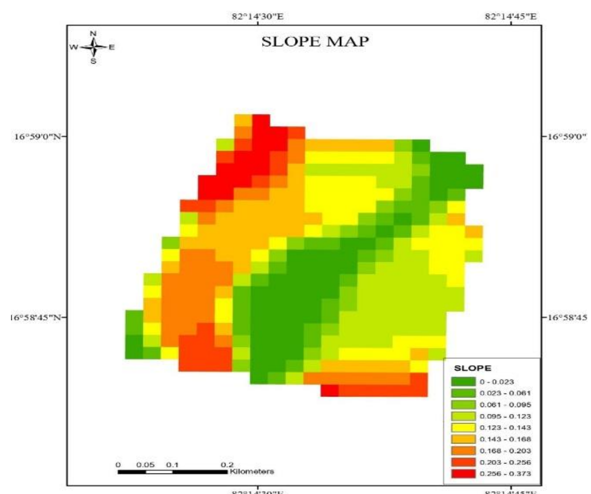

Figure 3. Percentage slope map of the study area.

The slope map depicts the spatial distribution of terrain gradients across the campus, derived from the DEM using GIS analysis tools. Areas with higher slopes indicate rapid surface runoff, while flatter zones are more prone to water stagnation and localized flooding. Understanding the slope distribution is crucial for assigning accurate hydraulic parameters to each subcatchment in the stormwater model. These values influence runoff velocity, infiltration rates, and overall drainage efficiency. The slope data also assisted in identifying zones requiring design interventions such as improved grading or additional inlet structures.

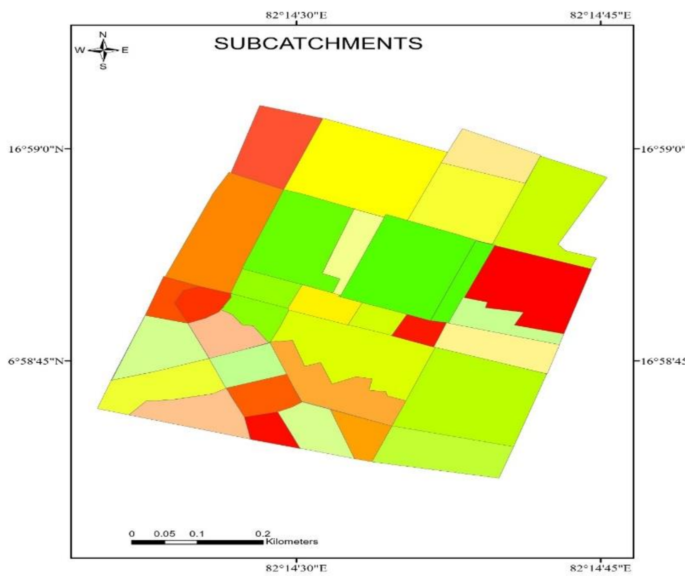

Figure 4. Sub catchment division.

Once the subcatchments were defined, CN values were assigned according to land cover classification. Impervious areas such as roads and rooftops were assigned higher CN values (ranging between 90–98), while vegetated or pervious zones had lower CN values (between 60–75). This approach ensured that the runoff estimation accurately reflected the campus's mixed land use.

Hourly rainfall data for two significant storm events—October 17 and 18, 2024—was obtained from the National Institute of Hydrology (NIH). The data was input into SWMM as a time series linked to a single rain gauge located within the model environment. This rainfall input served as the driving force behind the simulation, allowing for the estimation of runoff volumes from each subcatchment.

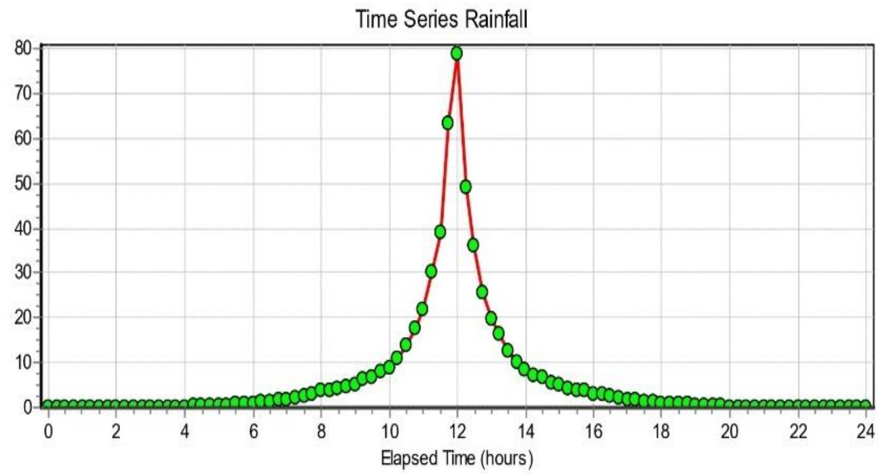

Figure 4. Rainfall Variation During the Storm Event on 17th October 2024.

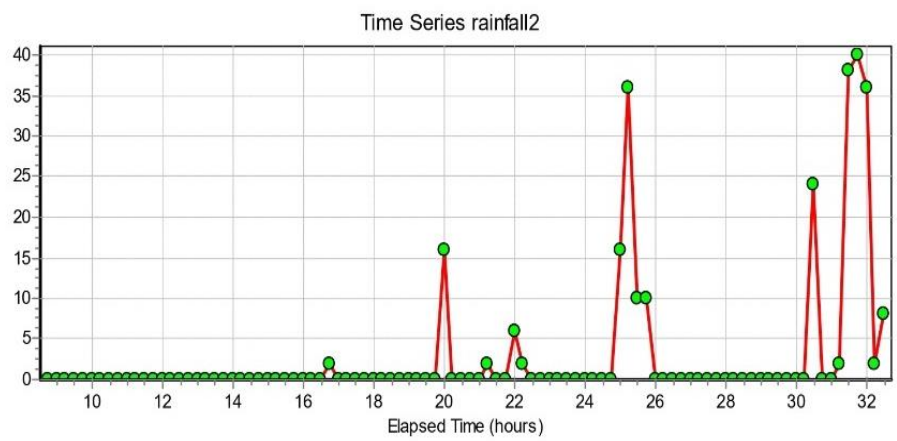

Figure 5. Rainfall Variation During the Storm Event on 18th October 2024

The drainage network was modeled in SWMM by plotting **junction nodes**, **outfall nodes**, and **conduits**. Junctions were placed at low points and intersections of subcatchments where water naturally accumulates. Outfalls were located at terminal points of the drainage system to represent discharge outlets. **Conduits** were defined between nodes to simulate open or closed channels through which stormwater flows. Each conduit was assigned attributes such as length, cross-sectional shape, slope, and Manning's roughness coefficient. The lengths were measured using **Google Earth Pro** to ensure spatial accuracy, while slopes were derived from elevation differences and DEM analysis.

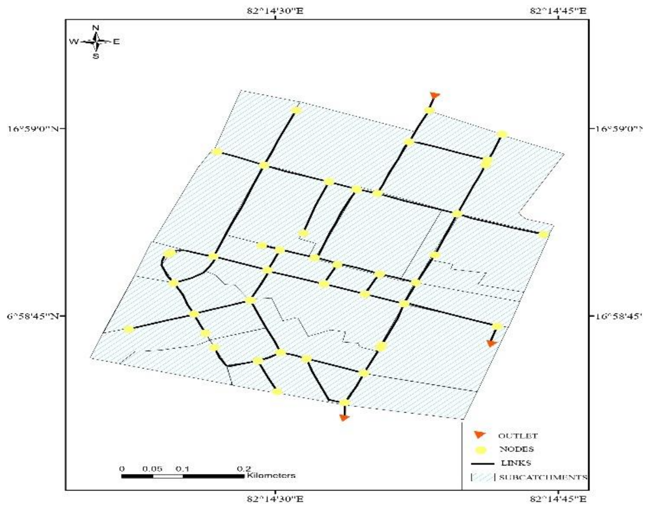

Figure 6. Network Layout.

All conduits in the model were configured as **rectangular sections** with a maximum depth of **1 meter** and a bottom width of 1 meter, consistent with existing field conditions. The **Manning's n** value was set at 0.013 to reflect concrete-lined channels. The network included 196 junctions, 242 conduits, and 9 outfall nodes.

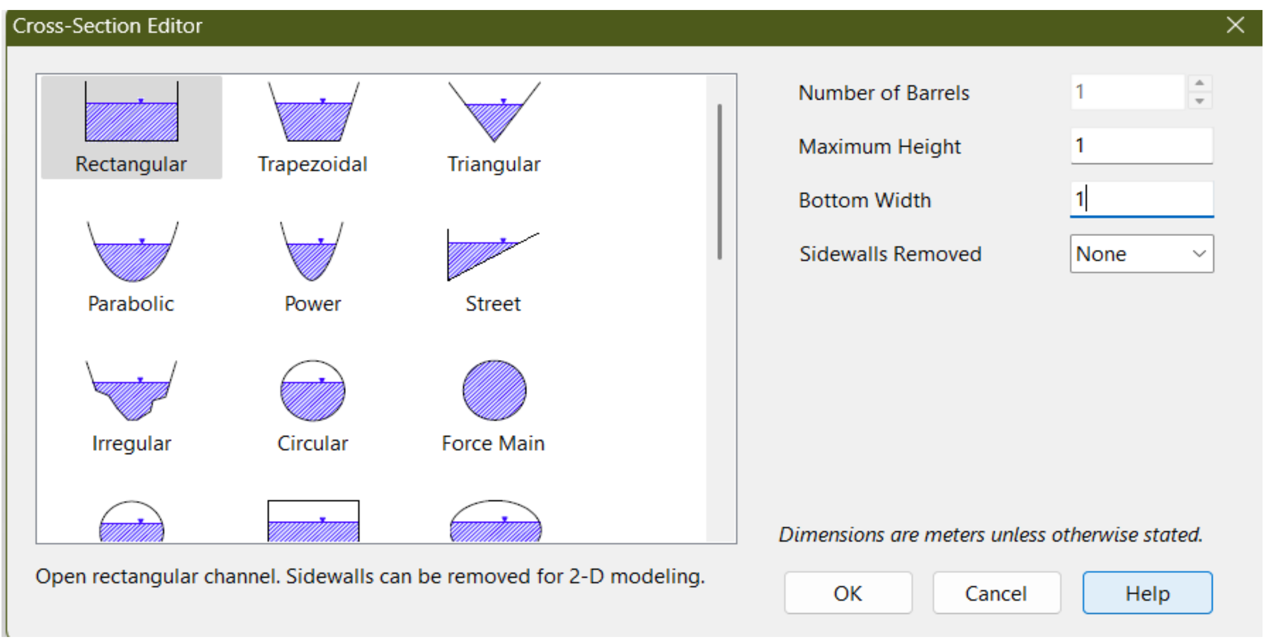

Figure 7. Layouts of the Conduits (software uploaded)

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Day of Maximum Depth	Hour of Maximum Depth	Maximum Reported Depth Meters
J1	JUNCTION	0.06	0.66	5.66	0	12:15	0.65
J2	JUNCTION	0.15	1.20	5.60	0	12:14	1.20
J3	JUNCTION	0.09	1.03	5.73	0	12:15	1.02
J4	JUNCTION	0.15	1.10	5.40	0	12:16	1.10
J5	JUNCTION	0.43	1.42	5.27	0	12:15	1.42
J6	JUNCTION	0.30	1.40	5.10	0	11:52	1.40
J7	JUNCTION	0.25	1.18	4.63	0	12:16	1.18
J8	JUNCTION	0.09	0.70	4.65	0	12:15	0.70
J9	JUNCTION	0.19	1.11	5.16	0	12:15	1.11
J10	JUNCTION	0.13	1.02	5.19	0	12:15	1.02
J11	JUNCTION	0.12	0.82	5.22	0	12:15	0.82
J12	JUNCTION	0.05	0.68	4.88	0	12:07	0.66
J13	JUNCTION	0.03	0.60	5.60	0	12:15	0.60
J14	JUNCTION	0.15	0.60	5.50	0	11:37	0.60
J15	JUNCTION	0.05	0.65	4.83	0	12:04	0.62
J16	JUNCTION	0.10	0.81	4.86	0	12:08	0.80
J17	JUNCTION	0.22	1.28	4.83	0	12:08	1.27
J18	JUNCTION	0.19	1.17	5.37	0	12:15	1.17
J19	JUNCTION	0.25	1.30	4.80	0	12:04	1.30
J20	JUNCTION	0.16	1.07	5.17	0	12:16	1.06
J21	JUNCTION	0.20	1.09	5.29	0	12:15	1.09
J23	JUNCTION	0.03	0.45	4.89	0	12:07	0.42
J24	JUNCTION	0.12	0.97	5.41	0	12:00	0.96
J26	JUNCTION	0.17	1.19	5.04	0	12:16	1.19
J27	JUNCTION	0.10	1.02	5.05	0	12:16	1.02
J28	JUNCTION	0.11	1.01	5.06	0	12:16	1.00

Figure 8. Junction Details (software uploaded)

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Imperv Runoff mm	Perv Runoff mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
S1	144.53	0.00	0.00	33.59	55.91	55.10	111.00	1.61	0.25	0.768
S2	144.53	0.00	0.00	30.67	51.45	62.40	113.85	3.60	0.55	0.788
S3	144.53	0.00	0.00	2.17	20.24	121.86	142.10	1.35	0.19	0.983
S4	144.53	0.00	0.00	54.33	34.43	55.86	90.28	1.64	0.26	0.625
S5	144.53	0.00	0.00	21.33	23.14	99.12	122.26	2.58	0.32	0.846
S6	144.53	0.00	0.00	19.36	18.34	106.91	125.25	2.99	0.48	0.867
S8	144.53	0.00	0.00	37.63	67.48	39.49	106.97	0.54	0.08	0.740
S13	144.53	0.00	0.00	16.56	27.33	100.73	128.06	1.31	0.21	0.886
S14	144.53	0.00	0.00	32.58	77.07	34.95	112.02	0.49	0.08	0.775
S16	144.53	0.00	0.00	15.99	72.29	56.33	128.62	0.86	0.14	0.890
S17	144.53	0.00	0.00	4.23	102.43	37.95	140.38	0.91	0.14	0.971
S19	144.53	0.00	0.00	2.40	120.54	21.70	142.24	0.54	0.08	0.984
S21	144.53	0.00	0.00	13.55	92.03	39.01	131.04	1.00	0.15	0.907
S22	144.53	0.00	0.00	3.89	0.00	140.56	140.56	0.68	0.10	0.973
S24	144.53	0.00	0.00	16.65	67.50	60.46	127.95	0.69	0.11	0.885
S25	144.53	0.00	0.00	2.62	0.00	141.62	141.62	0.54	0.07	0.980
S26	144.53	0.00	0.00	2.62	0.00	141.98	141.98	0.49	0.07	0.982
S27	144.53	0.00	0.00	13.61	54.53	76.42	130.95	4.06	0.62	0.906
S28	144.53	0.00	0.00	58.57	34.40	51.59	85.98	1.24	0.19	0.595
S32	144.53	0.00	0.00	15.27	0.00	129.38	129.38	0.48	0.08	0.895
S33	144.53	0.00	0.00	21.13	25.13	98.33	123.46	1.37	0.22	0.854
S34	144.53	0.00	0.00	11.46	36.15	96.87	133.02	1.81	0.27	0.920
S35	144.53	0.00	0.00	16.41	36.16	90.95	127.10	3.01	0.37	0.879
S37	144.53	0.00	0.00	15.55	36.14	92.92	129.06	0.89	0.14	0.893
S38	144.53	0.00	0.00	12.84	36.14	95.63	131.77	0.68	0.11	0.912
S39	144.53	0.00	0.00	17.21	36.14	91.22	127.36	0.86	0.14	0.881

Figure 9. Sub Catchment Details (software uploaded)

Outfall Node	Flow Frequency %	Avgerage Flow CMS	Maximum Flow CMS	Total Volume 10^6 ltr
outlet1	76.76	0.185	1.198	11.993
outlet2	78.92	0.182	1.583	12.170
outlet3	75.20	0.312	1.626	19.853

Figure 10. Outfall details (software uploaded)

Following the configuration, the model was run using Dynamic wave routing, consistent with the SCS CN approach which focuses primarily on overland flow. The simulation results provided detailed insights into flow depths, velocities, and runoff volumes throughout the drainage system.

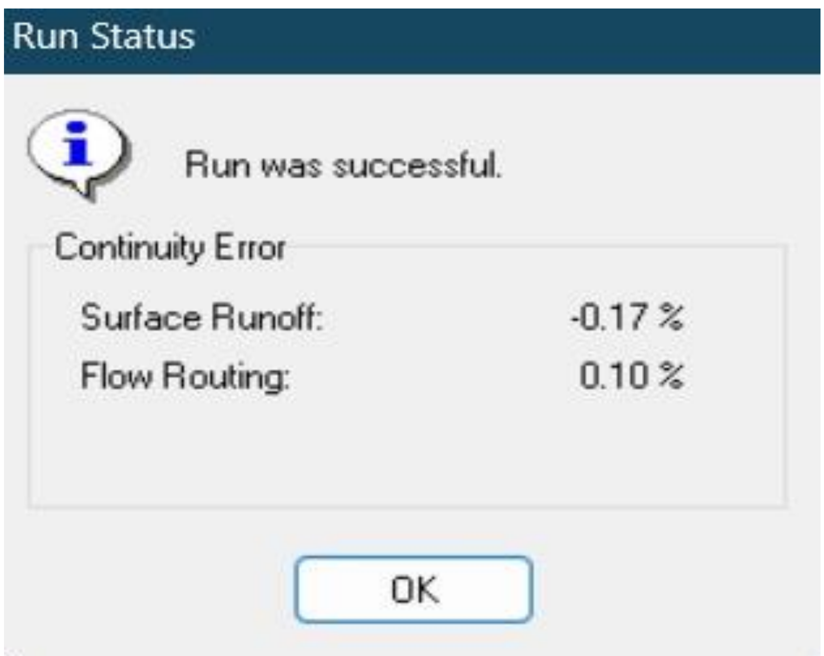

Figure 11. SWMM simulation run status showing Continuity error.

The output analysis revealed that flow depths in all conduits remained below the design limit of 1 meter, indicating no overflow occurred during the simulated storm events. A color-coded flow classification map was generated to visualize flow depths, where green and yellow colors indicated safe levels, and red would denote potential flooding. Notably, no conduit was flagged red, confirming sufficient conveyance capacity across the entire network.

Hydrographs plotted for selected subcatchments showed a rapid rise and gradual recession typical of semi-urban catchments. The runoff peaked shortly after rainfall intensity increased, demonstrating the sensitivity of impervious surfaces to storm events. These hydrographs allowed for the assessment of peak discharge timing and magnitude, both of which are critical for system design.

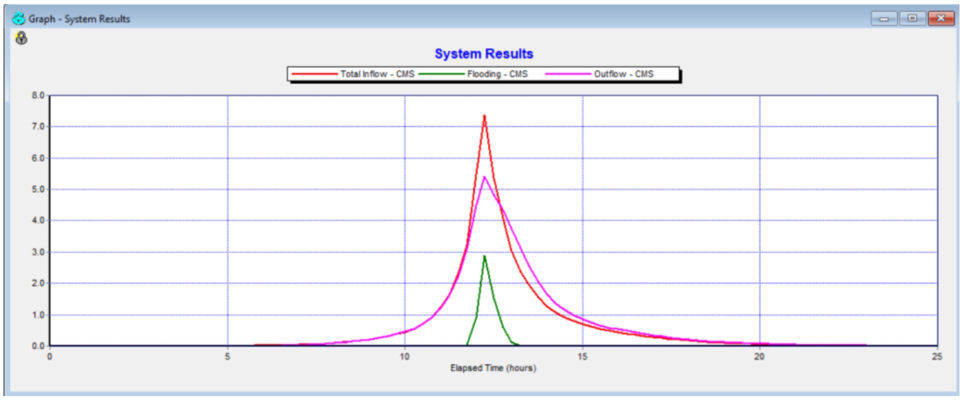

Figure 12. Graph showing runoff with duration for event 1

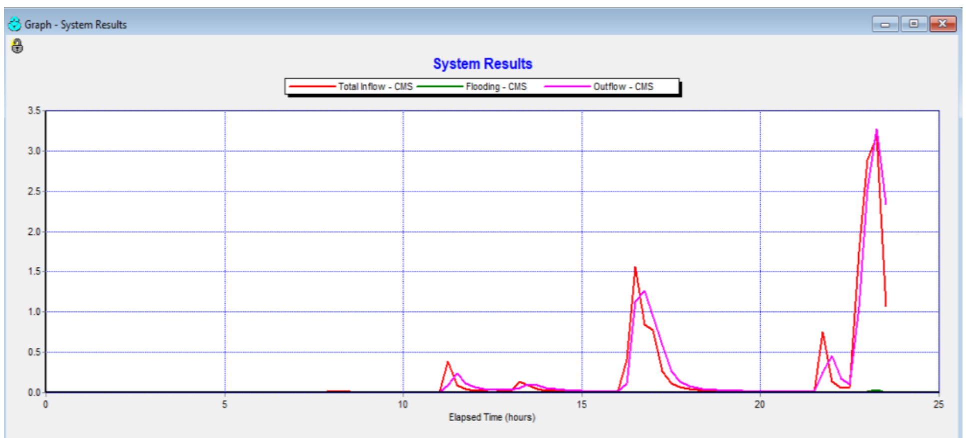

Figure 13. Graph showing runoff with duration for event 2

In addition to hydrographs, profile plots were generated between key nodes to examine water surface elevations throughout conduits. These plots confirmed that the hydraulic grade line remained below the crown of each conduit, validating the adequacy of conduit sizing under simulated storm conditions. The absence of surcharging or backflow indicates the robustness of the network layout.

In addition to hydrographs, profile plots were generated between key nodes to examine water surface elevations throughout conduits. These plots confirmed that the hydraulic grade line remained below the crown of each conduit, validating the adequacy of conduit sizing under simulated storm conditions. The absence of surcharging or backflow indicates the robustness of the network layout.

No ponding was observed at any junction node, as all nodes were able to drain effectively during the peak of the storm. This reflects the model's success in accurately predicting water levels and verifying outlet connectivity. Furthermore, **continuity error** in the simulation was minimal—less than ±0.2%—which confirms numerical stability and reliable hydrologic performance of the configured model.

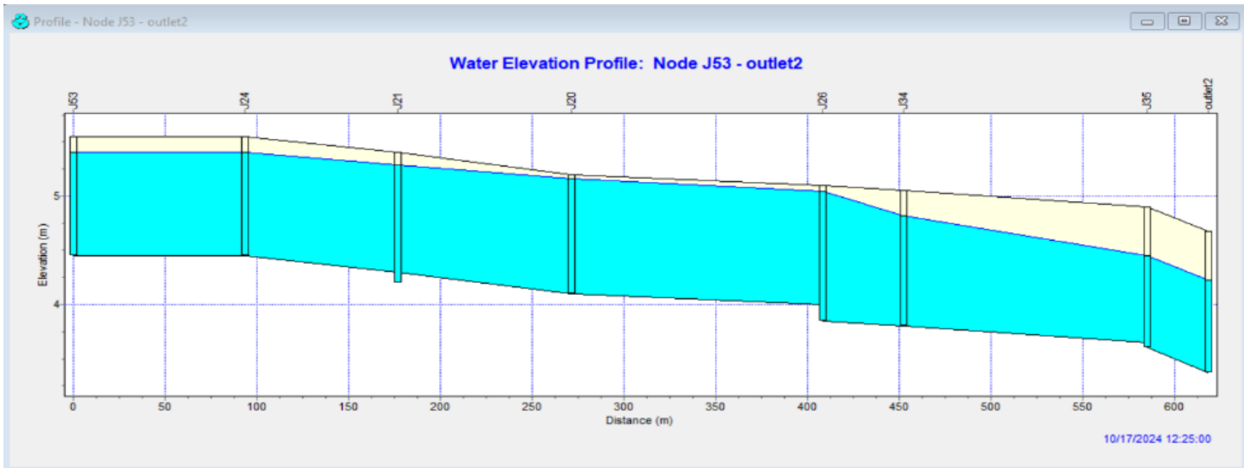

Figure 14. Water Elevation profile plot1

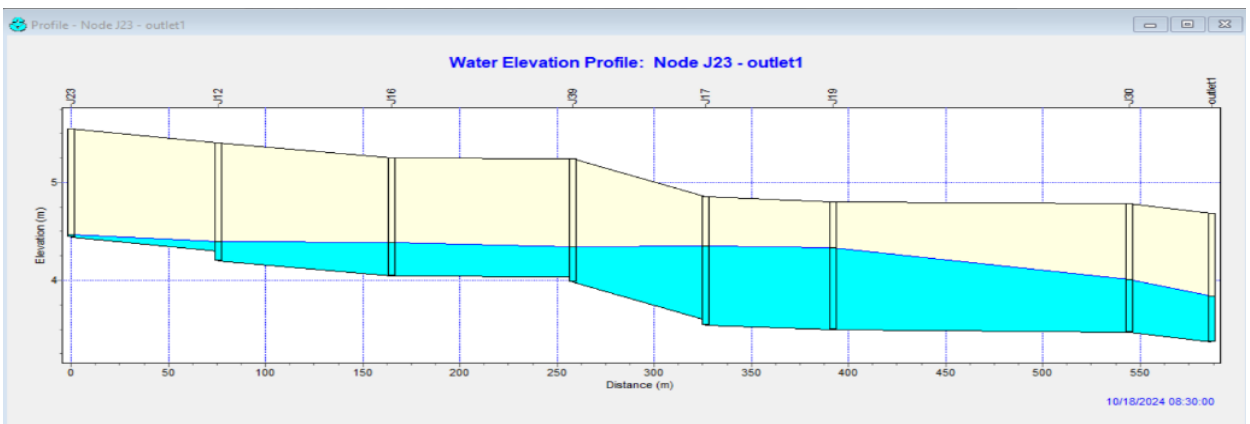

Figure 15. Water Elevation profile plot2

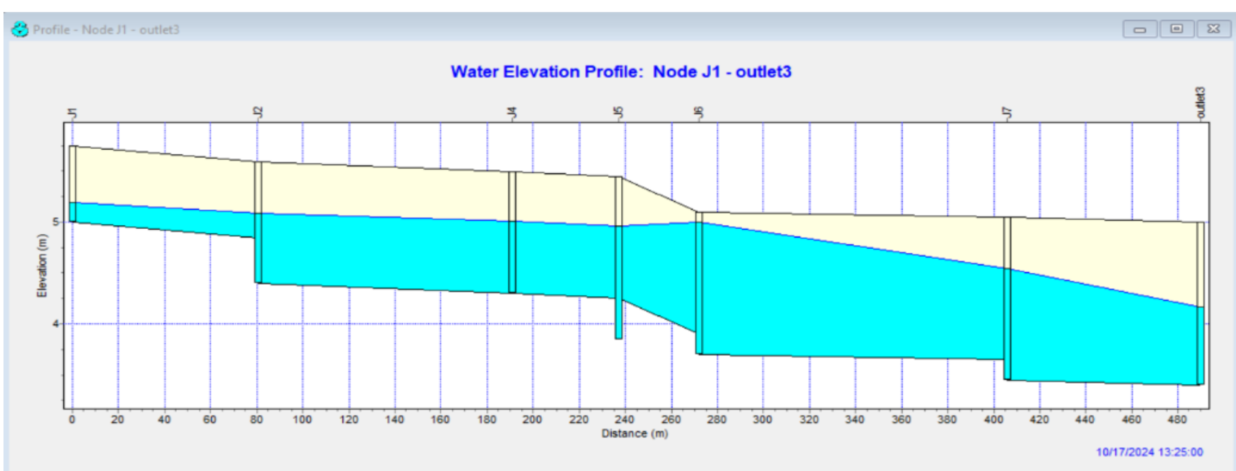

Figure 16. Water Elevation profile plot3

Although the overall drainage system was effective, simulation results pointed out **minor** inefficiencies in flat areas near residential and administrative blocks. These locations experienced delayed runoff routing due to reduced slope and extended overland flow lengths. Recommendations include the addition of secondary inlets, slight grading improvements, and localized widening of conduits to further improve flow conveyance.

CONCLUSION:

The stormwater drainage system for the JNTUK campus was analyzed using the EPA SWMM model. The simulation was performed for rainfall events on October 17 and 18, 2024, using observed data to evaluate runoff behavior across the campus. Hydrologic parameters were derived from GIS-based analysis using DEM, slope, and land-use data. The Curve Number method was used to estimate runoff, and the results were incorporated into the SWMM model to configure the campus drainage network.

The simulation showed that the existing drainage system handles average rainfall efficiently, with no conduit surcharging. However, areas with flat terrain and high imperviousness experienced delayed runoff, suggesting a need for local upgrades. Profile plots and hydrographs confirmed that flow depths remained within design limits, and no junction nodes experienced ponding. The model showed good continuity and minimal error, validating its reliability for stormwater planning. To enhance system performance, it is recommended to provide additional inlets in low-lying zones and to consider grading adjustments to improve flow direction. Regular maintenance and removal of debris are also essential to avoid clogging and ensure smooth flow. The study demonstrates the effectiveness of integrated GIS and SWMM modeling for sustainable campus-scale stormwater management.

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