BIOECODS MODELLING USING SWMM

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ABSTRACT

The Bio-Ecological Drainage System (BIOECODS) is a pilot project that meets the requirement of Storm Water Management Manual (MSMA), which is designed for water quantity and quality controls. BIOECODS has been constructed at Engineering Campus, University Sains Malaysia, Nibong Tebal, and Pulau Pinang. BIOECODS forms an alternative to storm water management practice and built in environmentally friendly manner.

The Bio-Ecological Drainage System (BIOECODS) is designed to characterize the element of storage, flow retarding and infiltration engineering. The Storm Water Management Model (XP-SWMM) is used to model and simulate the hydrologic and Hydraulic of BIOECODS. Storm Water Management Model (SWMM) is capable of simulating all aspects of the urban hydrologic processes with emphasis on quantity and quality of surface runoff; its transport through the drainage network, the storage and treatment applied to it and impact to the receiving water.

The characteristics of the catchments and components of BIOECODS, which include bio-ecological swale, dry pond and ecological pond, have been modeled in the XP-SWMM using the link-node concept. The calibration of SWMM is performed using various rainfall storm event and flow data obtained at the BIOECODS site. Initial losses, depression storages, infiltration parameters are among the hydraulic and hydrologic parameters used for the calibration process to evaluate the performance of SWMM in modeling the BIOECODS. The study has shown that a good agreement was found in term of runoff volume and peak between the simulation and observed data. The modeling and simulation indicate that the feature and characteristic of BIOECODS have been satisfactorily represented in XP-SWMM Model.

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1. INTRODUCTION

The rapid urbanization and industrialization in major Malaysian river basin involve a large portions of agricultural and ex-mining land are being converted for urban use. Growing demand to spur the economy is transforming the landscape into residential, commercial, industrial and institutional use. As a result of the extensive development, river basins are being subjected to over-bank floods, flash floods due to clogged drainage systems and river environment degradation. This prompted the authority to adopt a new concept in the planning and management of urban storm water runoff. An alternative concept, which is newly introduced nationally, is based on control at source approach. The water quantity control is derived from multiple combinations of drainage system components that include elements of infiltration engineering, storage and flow retarding facilities.

The planning of storm water system needs to be undertaken in a safe and ecologically sustainable manner. Many of our rivers, lakes and coastal waters are currently degraded by urban storm water, due to excessive flows, poor water quality, and removal of riparian vegetation and destruction of aquatic habitats. The new approach is to broaden the storm water management to minimize the impact of urban storm water towards degradation of receiving water body. In order to meet the water quality control criterion, the storm water runoff is treated at source and the treatment facility is optimized according to the train of treatment concept inherent in Best Management Practices (BMPs).

2. STUDY SITE

The site is enclosed in an area of 320 acres in Seberang Perai Selatan; located 1.5 km north-east of Parit Buntar Town; 2.0 km south-east of Town Nibong Tebal; and 1.5 km north-west of Bandar Baru Town. The main river in the area is the Kerian River that drains into the South Strait. The site is located near the bank of Kerian River. Typical feature for the rivers in Seberang Perai is that they are subjected to tidal influence, which seriously affects the area near the river mouth. The low-lying area couple with tidal influence has impaired the discharge of storm water into the river. This has resulted of water logged in the drainage system within the area and deteriorated quality of water permanently present in the drain. Therefore, it is desirable to explore the alternative environmentally friendly drainage system to address the inherent problems in the area.

In its pre-development state, the Engineering Campus site is covered with palm oil plantation estate. The site is characterized by flat topography at average ground level of +0.7m. A network of earth drain is used for the irrigation in the plantation area with water level in the drain is normally near the ground surface. This denotes the ground water surface is at an average level of +0.7m. The high ground water level in the area is typical pre-requisite for palm oil plantation. The imported fill is used to raise the construction platform level of the site to +2.44m. Preserving the existing condition in some area of the site minimizes the environmental impact due to development. The clearing of the palm oil tree and earth filling is undertaken at designated area where roads and buildings to be constructed.

3. CONCEPTS OF BIOECODS

The BIOECODS is a drainage system that exhibits the concept of control at source. The system component is designed to incorporate the concept of infiltration engineering, storage at source and flow retardation. BIOECODS is functioned to provide optimal flood protection by controlling storm water quantity and improved storm water quality. The system component of BIOECODS includes swale for floodwater conveyance, dry pond for on-site detention to manage storm water at source and ecological pond system. Perimeter swale is a smaller capacity conveyance that takes storm water from roof of the building. The storm water flowing in the perimeter swale is conveyed into bio-ecological swale, which is designed for a higher flow. The swale built for BIOECODS is a double layer of surface swale and a sub-surface drainage module overlaid with a layer of sand. The surface swale is a soft lined channel with gentle slope, a form of flow retarding facility. The sub-surface drainage module is enclosed with a permeable hydro-net and a layer of sand. The storm water from the surface swale infiltrates into the sub-surface drainage module through a layer of topsoil and river sand. This is a pre-treatment device that removes pollutant mainly particulate material by filtration and sorption to filter material.

Dry pond is a detention device design to store excess storm water in the development area. This is a multi-functional facilities blended with the landscape for optimum land use. Dry pond facility is an area with shallow depression that can retain water up to maximum depth 150mm. Sub-surface storage module is placed underneath the dry pond and connected to the sub-surface module of the swale. The storm water in the dry pond recedes by infiltrate through the layer of topsoil and river sand to the storage module underneath and then flows downstream along the sub-surface module of the swale.

The ecological pond system is a community facilities which include the detention pond as a facility to control the storm water quantity, constructed wetland for water treatment device, wading river which connects wetland and recreational pond where the treated water flow into. The ecological pond system is strategically placed at the downstream end of the BIOECODS to optimize and effectively attenuate and treat storm water runoff generated from the Engineering Campus development area.

4. BIOECODS MODELLING

The Storm Water Management Model (XP-SWMM) is used to model the hydrologic catchment processes and simulate the hydraulics of BIOECODS. The link-node model of XP-SWMM is used to represent the characteristic of the catchment and drainage system of BIOECODS. A link represents a hydraulic element of flow in the system where the model offers many different types of conduits for simulation. A node represents the junction of hydraulic elements (links) and can be assigned with a particular contribution area (watershed) associated with the drainage system. The storm water runoff hydrograph generated from sub-area enters the drainage system through the node. The node can also represent a storage device such as pond or lake, or a point junction to represent a point of change in channel or conduit geometry, or a boundary condition in the model.

BIOECODS modeling simulation is implemented with BIOECODS catchments divided into three sub-catchments i.e engineering sub-catchments, hostel sub-catchment and ecological pond development sub-catchment. The main component of BIOECODS is conveyance component, dry pond, wet pond components, detention pond and wetland. Figure 1 represents schematic nodes of BIOECODS sub-catchments in the SWMM model while Figure 2 represents a schematic link to represent the conveyance in the SWMM model.

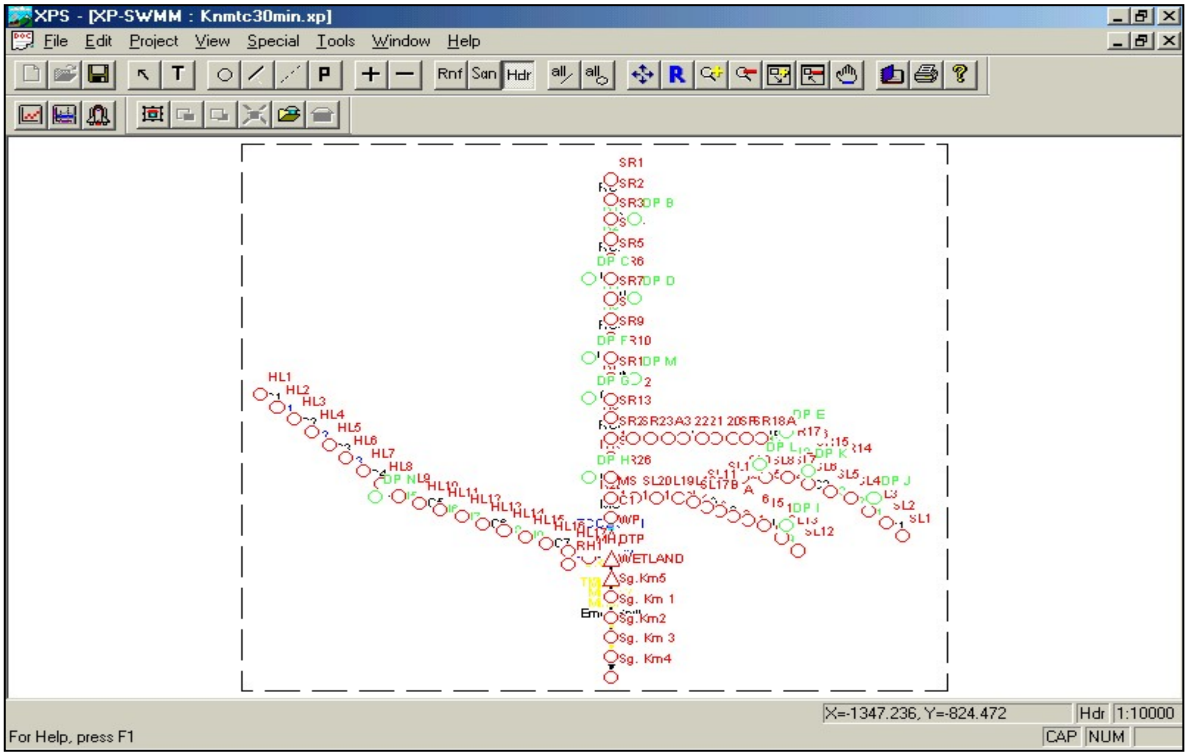
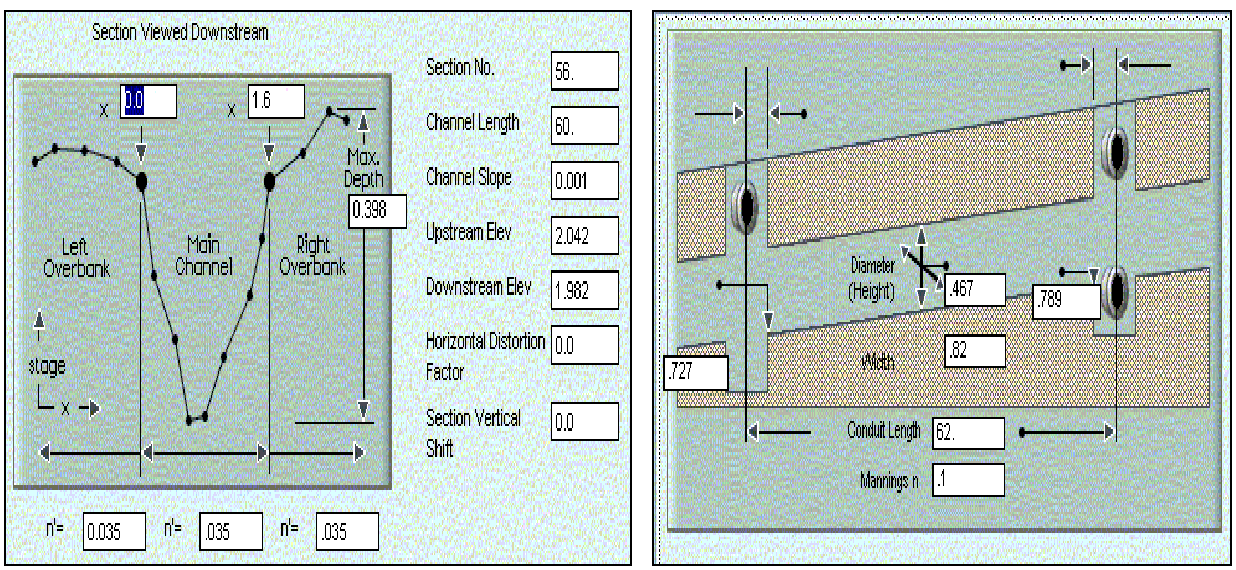


Figure 1 Representation of Schematic Node in XP-SWMM



a) Surface b) Sub-Surface

Figure 2 Representation of Ecological Swale in XP-SWMM

The catchment processes and hydrologic component models such as infiltration, evaporation, depression storage and transformation of effective rainfall to runoff are executed in the runoff layer. The hydrologic losses are the amount of losses through depression storage and infiltration is used to compute the effective rainfall. The hydrologic losses are the volume of storm water detain in the catchment and is characterized by the land use, topography and geology of the catchment. Table 1 shows the parameters of Horton's infiltration curve used for simulation of BIOECODS based on existing site condition.

Table 1 Horton's Infiltration Capacity Curve

Parameter	Rate
Initial Capacity (f_o)	25.4 (mm/hr)
Minimum Capacity (f_c)	2.54 (mm/hr)
Rate of Decay (k)	0.00115 (1/sec)
Depression Storage	25.00 (mm)

The non-linear reservoir method is used for the transformation of effective rainfall to runoff hydrograph. The overland flow hydrograph is generated by non-linear reservoir routing using Manning's equation and lumped continuity equation with depression storage and pervious and impervious area parameters. Table 2 shows the parameters depression storage and Manning "n" for impervious and pervious used for hydrologic losses simulation.

Table 2 Parameter of Depression Storage and Manning "n"

Parameter	Impervious	Pervious
Depression Storage (mm)	0.77	30
Manning "n"	0.013	0.06

The stormwater runoff hydrograph drains into the system through the node and is routed through the bio-ecological swale in the transport layer. The manning coefficients for surface swale and sub-surface module are shown in Table 3. The bio-ecological swale is designed in two layers consists of surface swale and sub-surface module. In actual condition the storm water infiltrates from the surface swale into the sub-surface module through a layer of river sand. The bio-ecological swale in XP-SWMM is modeled with two layers or double links to represent the surface swale and sub-surface module. These links are connected to the node that represents a manhole in transport layer. The storm water drain into the sub-surface module through the node and when its capacity is reached, the water level will rise into the surface swale. This modeling simplification is applied fro a simulation with 10-year ARI or major flood events. This enables the evaluation of the system components of BIOECODS is assessed particularly for the quantity control.

Table 3 Manning Coefficients

Parameter	Manning (n)
Surface Swale	0.035
Sub-Surface Module	0.100

The storm water is drained out from dry pond through the sub-surface storage module connected to the adjacent sub-surface module of the swale. However, in the XP-SWMM simulation, the storm water is drained from dry pond through orifice connected to the adjacent sub-surface module of the swale. The discharge rate of the orifice is based on the rate of infiltration of sand layer sandwich between topsoil and the module storages that drains out the water from dry pond.

5. SIMULATION RESULT

The simulation and calibration of SWMM is based on the flow measurements obtained at the downstream of School Engineering sub-catchment. *Site 3 left (*Figure 3) refers to the flow from the left hand side of the sub-catchment and *Site 3 Right* (Figure 3) refers to the flow from the right hand side sub-catchment. The simulation and calibration is limited to the surface swale. Figure 6 to Figure 8 show the simulation results for different rainfall events. Table 4 and Table 5 show the result of simulated and observed data and the relative error. The relative error for observation and simulation data for both volumes and peak flows range between 1.3 % and 30 %.

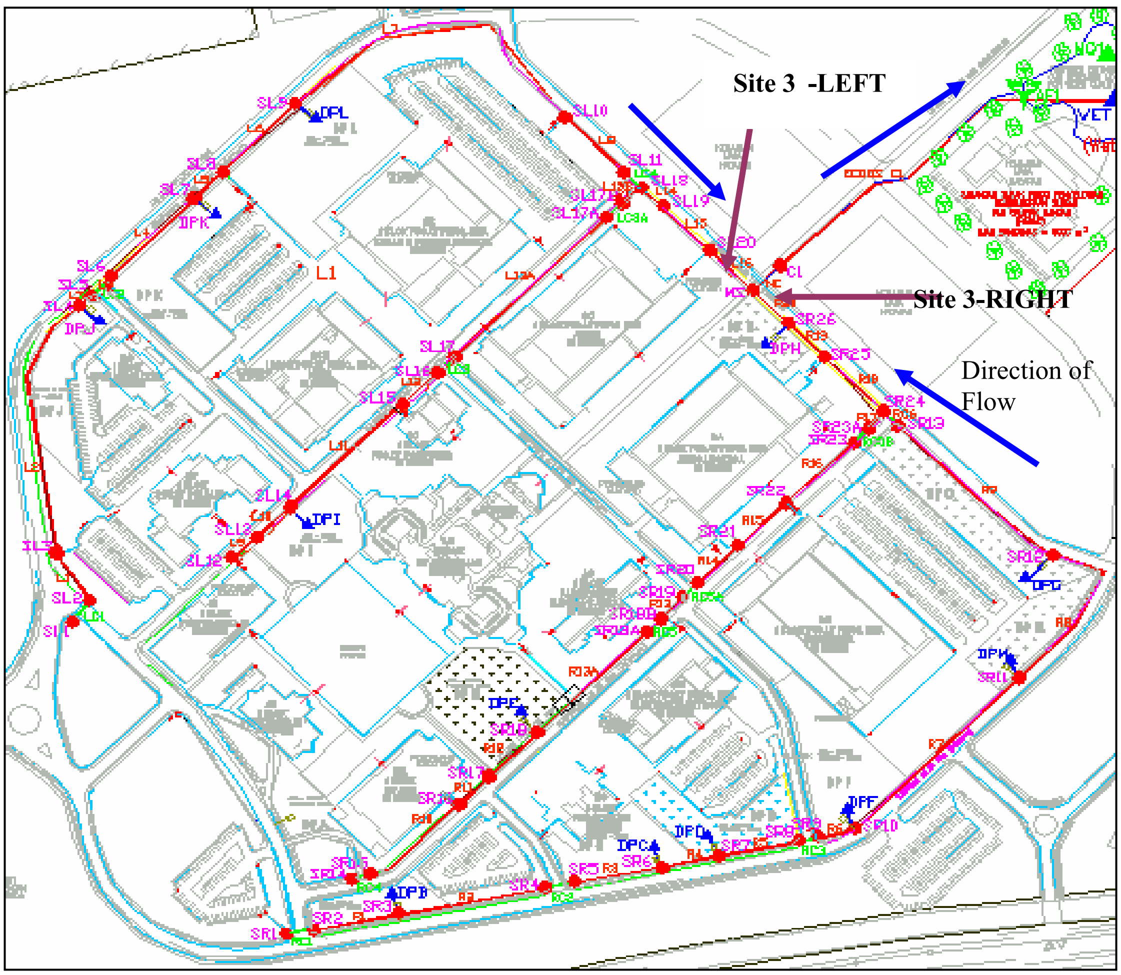


Figure 3 Locations of Velocity Area Module for Flow Measurement

Figure 4 Velocity-Area Module for Site 3-Left

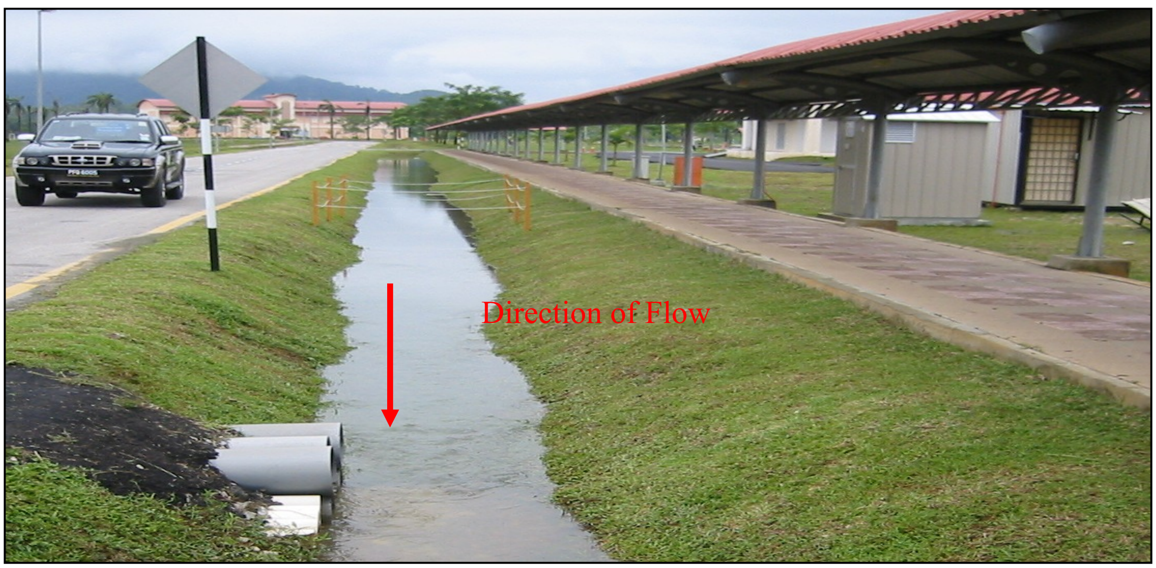
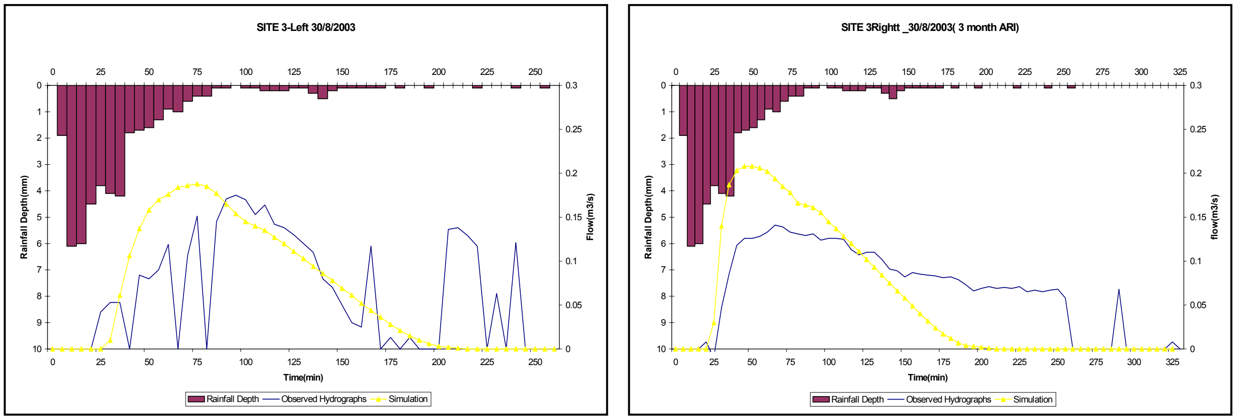
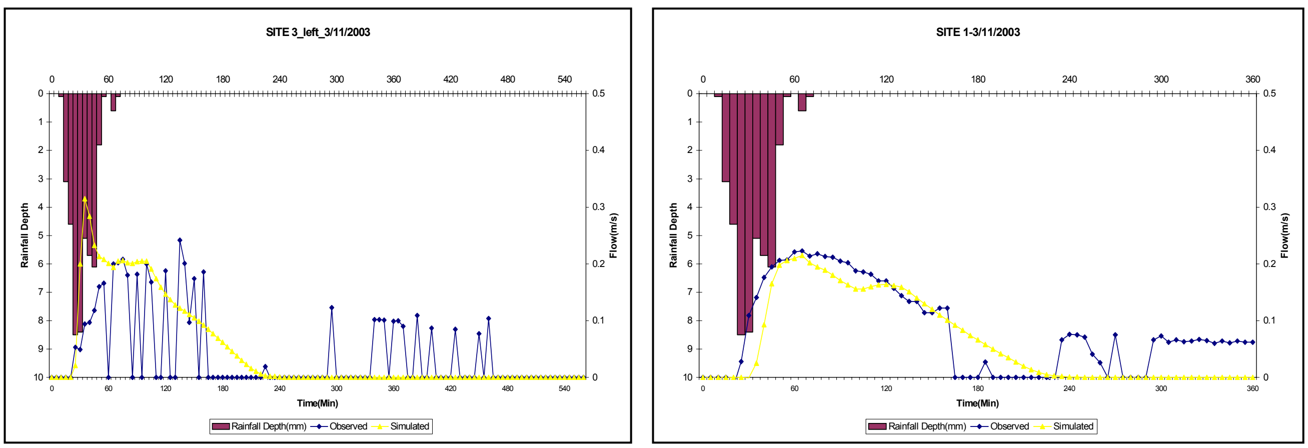


Figure 5 Velocity-Area Module for Site 3-Right



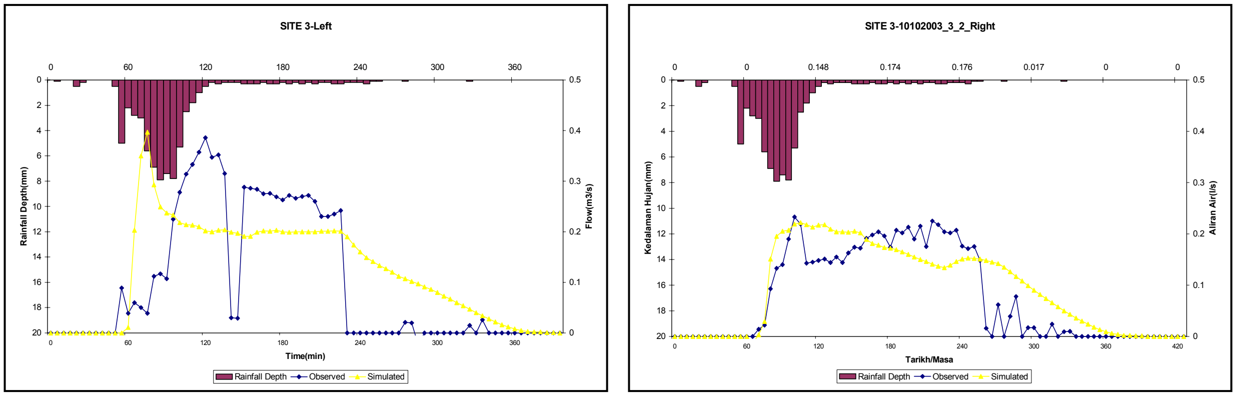
a) Left b) Right

Figure 6 Simulated and Observed Hydrographs on 30th August 2003 (3 month ARI)



a) Left b) Right

Figure 7 Simulated and Observed Hydrographs on 3 November 2003 (1 year ARI)



a) Left

b) Right

Figure 8 Simulated and Observed Hydrographs on 10th October 2003 (2 Year ARI)

Table 4 The Results of Simulation and Observation Site for 3_LEFT

Rainfall Event	Peak Flow (m^3/s)		Relative Error (%)	Volume (m^3)		Relative Error (%)
	Observation	Simulation		Observation	Simulation	
30th August 2003	0.179	0.2084	16.42	1063.2	1049	1.3
10th October 2003	0.386	0.397	2.85	2321.4	2870.4	23.64
3rd November 2003	0.242	0.315	30.16	1308.2	1621.2	23.9

Table 5 The Results of Simulation and Observation for Site 3_Right

Rainfall Event	Peak Flow (m^3/s)		Relative Error (%)	Volume (m^3)		Relative Error (%)
	Observation	Simulation		Observation	Simulation	
30th August 2003	0.141	0.1880	-33.3	1342.5	1169.1	12.92
10th October 2003	0.225	0.222	1.3	2023.8	2582.8	27.62
3rd November 2003	0.223	0.215	-3.58	1960.5	1399.5	28.61

6. CONCLUSIONS

The urban management model such as XP-SWMM is an invaluable tool in simulating the behavior of the BIOECODS. The relative error for observed and simulated for both volumes and peak flows between 1.3 % and 30 % was obtained for the assessment of the BIOECODS.

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