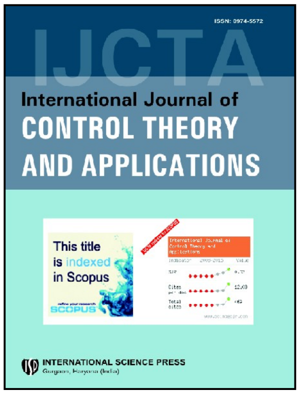

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Modelling of Sustainable Urban Drainage System by Using SWMM Software

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Abstract: Due to urbanization, management of urban water is very difficult. Traditional drainage has many disadvantages like disturbance of water balance, increase of runoff and flooding downstream, loss of groundwater recharge and base flow, increases heat island effects due to loss of evapo-transpiration and pollute receiving water bodies by oils, organic substances and heavy metals etc. The following paper focused on the integrated approach to sustainable urban drainage system (SUDS) by Using Storm Water Management Model (SWMM 5.1). SUDs are designed to planning and management strategies to control quality and quantity of storm water or surface runoff intend to overcome the problems of traditional drainage system. Sustainable drainage network is used to be modeled and analysis by Storm Water Management Model SWMM 5.1. It is a continuous simulation model used for dynamic rainfall-runoff calculations for shorter and longer time span to calculate the runoff quality and quantity of urban region.

Keywords: Sustainable urban drainage system (SUDS), integrated approach, storm water, surface runoff, SWMM software

INTRODUCTION

From the last few centuries, the developing and developed countries both have the witnessed rapid urbanization. Due to this various complex problems are arising which is related to the management of surface runoff and storm-water in the cities. Along with the increased impervious flooring of the urban region the water percolation to soil, infiltration, transpiration, depression storage and underground water table are absent and this results surface runoff and flooding in the cities roads and its surrounding. The discharge through point and non-point sources which adversely affects the water quality parameters of storm-water and runoff. If this drainage water is not managed properly, it may lead to economic losses, spread of diseases, deterioration of water quality in rivers and receiving waters due to the continual flooding of urban areas. Sustainable Urban System (SUDs) is a systematic approach to design the surface drain and storm water in a manner that will reduce the possible impact of new growth and development with respect to the discharges.

EFFECTS OF URBANISTAION TO URBAN DRAINAGE SYSTEM

The increase in population density and building density exert the most obvious influence on hydrological processes in an urban area. Modification of the land surface during urbanization alters the storm-water runoff characteristics. The major modification which alters the runoff process is the impervious surfaces of the catchment such as roofs, sidewalks, roadways and parking lots, which were previously pervious. Another factor is the natural channels, which were in existence before urbanization, are often straightened, deepened and lined to make them hydraulically smoother. Gutters, drains and storm drainage pipes are laid in the urbanized area to convey runoff rapidly to stream channels. These increase flow velocities, which directly affect the timing of the runoff hydrographs. The combined effect of all these changes is to reduce the lag time of runoff. Since a larger volume of runoff (due to urbanization) is discharged within a shorter time interval, the peak discharge inevitably increases.

The amount of waterborne waste increases in response to the growth in population and building density. The quality of storm-water runoff deteriorates as contaminants are washed from streets, roofs and paved areas. The disposal of both solid and waterborne wastes may also have an adverse effect on surface and groundwater quality. The degradation of the quality of flows in both the drainage networks serving the urban area and the underlying aquifers, gives rise to major hydrological problems.

Urbanization also considerably affects the climate of the area. It has been found that precipitation, evaporation and local temperature increase due to urbanization (Hall, 1984). The urban atmosphere is characterized by a marked abundance of dust particles along with Sulphur dioxide and other gases. These contaminants not only reduce the clarity of the atmosphere, thereby decreasing the amount of incoming radiation and sunshine, but also provide an excess of condensation nuclei that may change the nature of city fogs and affect the characteristics of precipitation. Increase of population density and impervious area leads to higher absorption of incoming radiation. Due to urbanization the evaporation may reduce as transpiration (lack of vegetation) and soil moisture (loss of pervious areas) reduces. Reduction of evaporation increases the sensible heat result in temperature increase.

URBAN DRAINAGE SYSTEM

Urban Drainage Systems physically involve the collection, storage, conveyance and treat runoff and drainage water in urban regions. This system required in the urban developing cities because of the interface of urban water hydrology and human activities. These interfaces includes the different phases of the waste water such as recycling of the waste water from the urban water cycle after fulfilling the needs of the human and distracting the rainfall from the impervious surface to the receiving water bodies. These services either completely artificial or combination of man-made structure and natural sites. It includes detention and retention ponds, streets, inlets and outlets and special arrangements such as energy dissipaters, manholes and others energy dissipaters structure (ASCE and WEF, 1992).

STORM WATER MANAGEMENT MODEL (SWMM)

SWMM model is continuous modelling software can be performed for hydrology and hydraulics process such as rainfall- runoff calculations (infiltration and evaporation losses), groundwater and its interactions with surface water, snowmelt and accumulation of snow, water quality buildup and wash-off, scour and deposition of pollutants in conduits, pollutants removal in treatment device, and fully dynamic routing of flows and pollutants .It involves typical application of continuous simulation i.e. design and analysis of Low impact development (LID), simulation of the effectiveness of detention / retention facilities , simulation of rain derived infiltration and inflow (RDII), simulation of wetlands, establishing water quality loads to receiving waters, long term changes in stream morphology , hydro-modification, duration and number of exceedances meeting water quality objectives.

It is conceptualized model used in drainage system as a series of water and stuff flow between different compartments of the environment. These environment components includes

1. The Atmosphere compartment: In this compartment, rainfall falls from the atmosphere and deposited on the land surface compartment and rain-gages are used input in the SWMM.
2. The Land surface compartment: It represented the one or more than subcatchment of the region which receives water and transferred to the groundwater compartment and some water flow as surface runoff.
3. The Groundwater compartment: This compartment receives the outflow of the land surface compartment and conveys some part into the transport compartment. It modeled using aquifer objects.

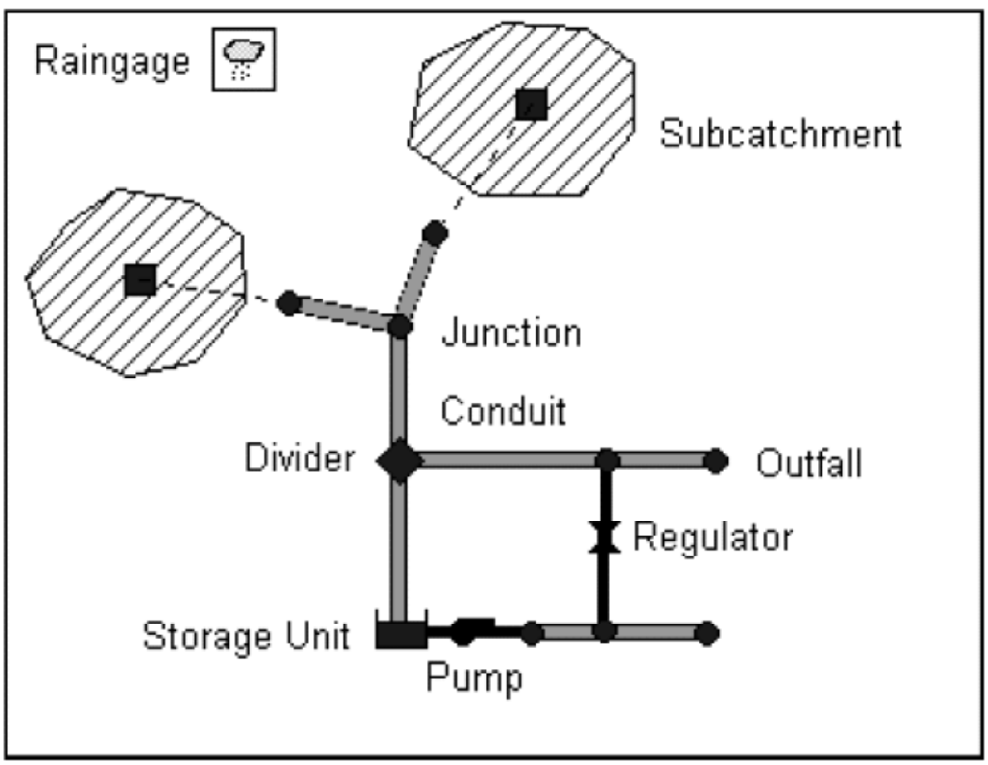

Figure 1: SWMM conceptualized model for typical urban drainage system(8)

The Transport compartment: It includes the conveyance elements (channels, pipes, regulators, pumps) and storage/ treatment plants that bring water to outfall or to treatments plants. Inflow for this compartment involves surface water runoff, groundwater flow, sewage water. In SWMM, they are modeled as Node and link objects.

There two objects in the SWMM either its visual or non- visual objects. Following objects might be arrange together to represent a storm water drainage system.

1. Rain-gages: This provides the rainfall data type, recording time interval, source of rainfall data, and name of rainfall data sources.
2. Sub-catchments: It usually divides into previous and impervious sub-regions. The following infiltration models such as Horton Infiltration, Green Ampt Infiltration and SCS-curve number Infiltration are described for the analysis of the pervious zone. in SWMM sub-catchment include assigned rain-gage, outlet node or sub-catchment, assigned land uses, tributary surface area, imperviousness, slope, characteristic width of overland flow, Manning's n for overland flow on both pervious and impervious area, depression storage in both pervious and impervious areas, percent of impervious area with no depression storage.
3. Junction nodes: it represents the convergence of natural surface channel, manholes in a series system or pipe fittings. The primary input parameters for a junction are invert elevation, height to ground surface, ponded surface area when flooded, and external inflow data.
4. Outfall Nodes: These are terminal nodes define the final downstream boundaries under dynamic wave flow routing. It behaves as junction for other flow routing. The input parameters for outfall nodes include invert elevation, boundary condition type and stage description and presence of a flap gate to prevent backflow through the outfall.
5. Flow divider Nodes: It only active under Kinematic wave routing. The important inputs for flow divider nodes are junction parameters, name of the link receiving the diverted flow and method used for computing the amount of diverted flow.
6. Storage units: It represents physically storage facilities. The primary inputs of storage units are invert elevation, maximum depth, depth-surface area data, evaporation potential, ponded surface area when flooded, and external inflow data.
7. Conduits: They are pipe or channels move water from one node to another node. The common shape of conduits define in SWMM are rectangular, trapezoidal, or user-defined irregular cross-section shape.

The Manning's equation used to express the relationship between discharge (Q), cross-sectional area (A), hydraulics radius (R), and slope (*S*) for all conduits. For standard U.S. units,

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

Where n = Manning roughness coefficient.

8. Pumps: They are links in the SWMM used to carry water at higher elevations. It describes the relationship between discharge and conditions at inlet and outlets. The input parameters involve

names of its inlet and outlet nodes, name of its pump curve, initial on/off status startup and shutoff depths.

9. Flow regulators: These are structures or devices used to control and direct flows within a conveyance system. SWMM can model the following type of flow regulators such as orifices, weirs and outlets.

The Non- visual objects involve class of non-visual data objects to describe additional characteristics and process within study area.

1. Climatology: It involves climatology factor such as temperature(user defined time series and climate file containing daily maximum or minimum value, evaporation, wind speed, snowmelt, areal depletion (tendency of accumulated snow).
2. Snow packs: It requires the following information in SWMM are minimum and maximum snow melt coefficients, minimum air temperature for snow melt to occur snow depth above which 100% areal coverage occur initial snow depth initial and maximum free water content in the pack.
3. Aquifers: Two zones are represented by aquifers i.e an un-saturated zone and a saturated zone. There performance are characterized by following parameters such a soil porosity, hydraulic conductivity, evapo-transpiration depth, elevation, and loss rate to groundwater. It also includes initial water table and moisture content of the unsaturated zones.
4. Unit Hydrographs: It estimates rainfall-dependent infiltration and inflow (RDII) into sewer system. UH defined by following parameters such as R: the fraction of rainfall volume goes into the sewer system, T: the time from the beginning of rainfall to the peak of the UH in hours and K: the ratio of time to recession of the UH to the time to peak.
5. Transects: It refers to the geometric data that involve bottom elevation varies with horizontal distance over the cross-section of a natural channel or irregular shape channel.
6. External Inflows: Along with runoff and groundwater, drainage system receives other external inflows i.e. direct inflows, dry weather inflows and rainfall-dependent infiltration/inflow (RDII).
7. Pollutants: It also simulates the pollutants generation, inflow and used defined pollutants. It required following information for each pollutants such as pollutant name, concentration units , concentration in rainfall, concentration in groundwater, concentration in direct infiltration/inflow, first-order decay coefficient.
8. Land-uses: It involves activities are residential, commercial, industrial and undeveloped regions. It characteristics might be include lawns, roof areas, paved roads, soils, rooftops etc. Land-use usually reports the variation in pollutants buildup and wash off rates from the catchment.
9. Treatment: SWMM also assigned for the modeled of the treatment of runoff water with the pollutants. It involves mathematical functions or expression to define the modelling.
10. Curves: The curves are used to define a functional relationship between two different quantities.

11. Time Series: It describe temperature data, evaporation data, rainfall data, and water stage at outfall nodes, external inflow hydrographs at drainage system nodes, external inflow pollute-graphs at drainage system nodes, control settings for pumps and flow regulators..
12. Time Patterns: It allows external dry weather flow (DWF) in periodic trends. There are different types of time patterns include such as monthly (one multiplier for each month of the year), daily (one multiplier for each day of the week), hourly (one multiplier for each hour from 12 AM to 11 PM), and weekend (hourly multipliers for weekend days).

It is discrete-time simulation model employees on the principles of conservation of mass, energy and momentum. The computational methods are surface runoff, infiltration, groundwater, snowmelt, flow routing, water quality routing, surface ponding used in SWMM to model runoff quality and quantity The hydrological processes depicted in this diagram include:

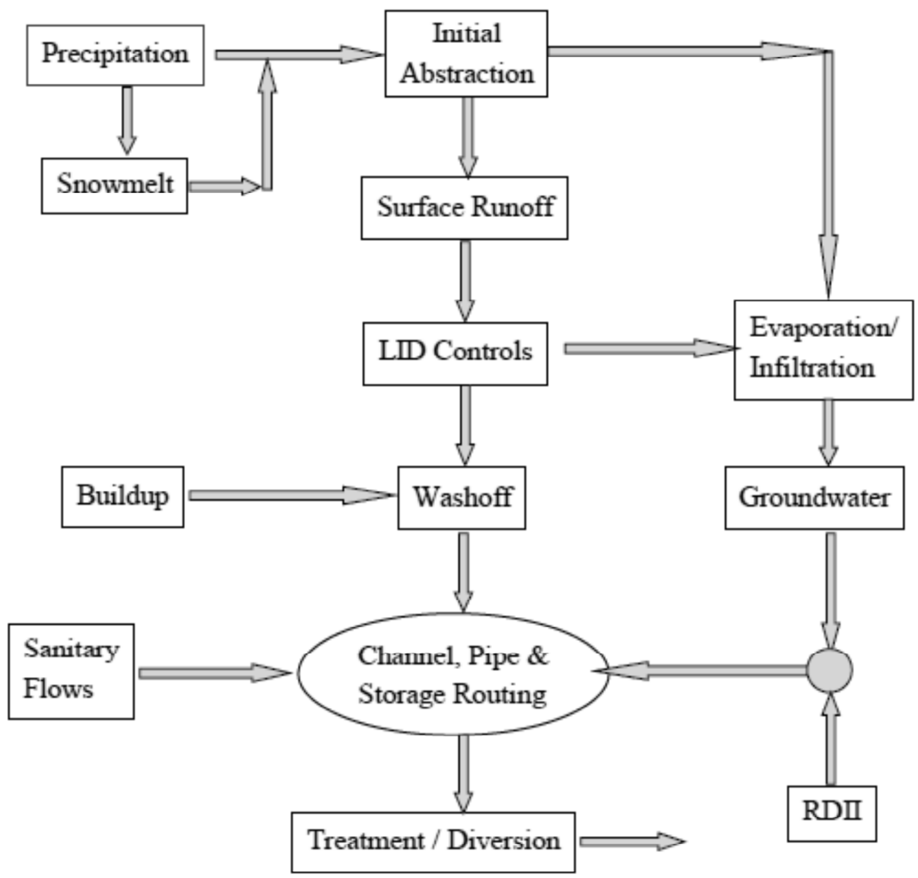

Figure 2: SWMM Model [8]

MODEL RESULTS AND CONCLUSION

The status report of SWWM 5.1 includes the input summary and simulation results. The report indicates the quality of the simulation is good or bad with mass balance continuity errors for both runoff and routing. The Summary Report contains tables listing summary results for each subcatchment, node and link in the drainage system. Total rainfall, total runoff, and peak surplus for all subcatchment, peak depth and hours flooded for each node, and peak flow, velocity, and depth for each conduit are just some of the outcomes included in the summary report. From the result of SWMM the total runoff generated from the storm event is to be found. The excess rainfall can be stored at a suitable location so that it may prevent flooding provide groundwater recharge and when treated can also act as source to fulfill the domestic needs. The surplus stormwater may then be diverted to nearby river.

This type of stormwater management will be sustainable as:

1. Network of stormwater drains of adequate capacity will provide effective drainage and prevent flooding of the area.
2. The storage of stormwater in small and big ponds will recuperate the existing ponds in the city as well as create new ponds. This will provide potential ground water recharge and additional water sources.
3. Ponds connected in series may act as sequential treatment units, improving the water quality that may be used for suitable purposes.
4. Revival of existing ponds and creation of new ponds will provide climate moderating effect for the city's climate conditions.
5. The stormwater which was creating nuisance can be converted to a valuable source.

Following conclusions can be drawn from the study:

(i) The rainfall and catchment characteristics have strong influence on urban stormwater. Accurate assessments of stormwater will result in the effective design of urban stormwater management systems.

(ii) Lack of availability of relevant data and difficulties in finding the relevant hydrological data such as water flow in natural and manmade drains can be overcome by the designers/ engineers by using modeling calibration processes, such as the use of inundation marks.

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