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Procedia Engineering 21 (2011) 1110 – 1117

Procedia Engineering

www.elsevier.com/locate/procedia

2011 International Conference on Green Buildings and Sustainable Cities

Water management in local development plans: the case of the old Fruit and Vegetable Market in Bologna

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Abstract

This paper describes the hydraulic simulation of an urban drainage system with SWMM 5.0 in order to evaluate the behavior of different solutions for the management of urban runoff. In particular have been analyzed different solutions for the flow peak reduction in the receiving water: retention basin, green roofs and infiltration tanks. The reuse of rainfall for irrigation has been analyzed in order to evaluate the reduction in the volume that flow into the sewer system. The simulations were performed adopting a long time rainfall series of 15 years recorded in Bologna (Italy).

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Selection and/or peer-review under responsibility of APAAS

Keywords: urbanization; *hydraulic modelling;BMP; retention basin;SWMM.*

1. Introduction

The effect that urbanization has on a watershed has been well documented in the literature [1] in fact undeveloped land has very little surface runoff, most of the rainfall soaks the top soil and flows to the groundwater. But as a watershed develops and the land is covered over with impervious surfaces (roads, parking, roofs, etc.) most of the rainfall is transformed into surface runoff.

The hydrologic effect is that a rainfall now produces a significantly more runoff volume, than before, and flows peaks area increased by a factor of 2 or more than 10 [1]. In this way the flow peaks increase magnitude and frequency.

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doi:10.1016/j.proeng.2011.11.2118

The effects on the receiving water, typically a natural or artificial channel, are an increased flood frequency, downstream the urbanization, and a deterioration of the water quality. The pollution due to urban runoff is well described in the literature. The main constituents in urban runoff are total suspended solids, COD, heavy metals, and several research activities have been carried out from 1970s.

Many Local Agencies or Municipalities now have ordinances and regulations requiring that rainfall events be controlled so the postdevelopment peak flow, for a given return period, does not exceed the predevelopment peak flow for that same storm.

To obtain this result the most common practice is to use detention or retention basins so that basin outflow does not exceed predevelopment flow for the design storm. These facilities reduce downstream flooding, but they are not effective at reducing the volume runoff spilled into the receiving water.

The pollution could be controlled with tank usually called "first foul flush" tank that send the first part of the rainfall event to the Waste Water Treatment Plant (WWTP).

Instead of using detention or retention pond for runoff and pollution control in urbanized area BMPs (Best Management Practices) [6] could be adopted in order to infiltrate or accumulate rainfall and reduce the runoff over the catchment. But probably the best solution is adopting a combination between detention basins and BMPs [1]. In fact the BMPs can control small runoff volume and this means that for storms larger than the design storm, the BMP will capture the first flush, thereby attenuating the initial portion of the runoff hydrograph. But once that volume is exceeded, the remainder of the flow is unregulated until the outflow control for the drainage detention basin begins to take effect. In this way integrating the storage of the detention or retention basin and BMPs it is possible to better control wet weather discharges to receiving waters.

In this work we have analyzed the case of development plan of the old fruit and vegetable market in Bologna, where, through the hydraulic dynamic modeling with SWMM 5.0 [5] of a long time rainfall series, we have assessed the effectiveness of the adopted BMPs.

2. The old Fruit and Vegetable market redevelopment plan

The redevelopment plan involves an area of about 29 hectares which is situated near the city center of Bologna. Since the thirties, this area was dedicated to fruit and vegetable wholesale trade.

The redevelopment plan, which has been approved by the Local Authority in 2007, provides the storage of water from roofs and green areas to be reused as non drinkable water, collecting it into two cisterns, each measuring 650 m3. The remaining waters are laminated through a retention basin which has a total volume of 10’800 m3 and a lamination capacity of 7’200 m3. and it was designed with the criteria developed by the Local Authorities which impose a volume equal to 500 m3 per hectare, which correspond about a 30 years of Return Period; it is excavated in the ground and it has a concrete bottom and grass banks revetment, assuming also the function of a lake in the park in the northern area of the development zone.

Before that water flows into the basins, waters pass through a first flush rainwater tank measuring 930 m3 which is divided into two parts, one for managing the waters form the development zone (315 m3) and one for capturing the waters coming from the neighborhood (615 m3) that is not taken into account in the simulations.

The development zone sewerage system is divided into three networks, to allow a high environment protection and water reuse: sewage collectors (to transfer the wastewaters to the Waste Water Treatment Plant), drainage collectors for streets and parking lots rainwater (to be disposed after flood detention and first rainwater collection) and drainage collectors for rainwater from roofs and green areas (to be transferred to the cisterns and to be reused as non drinking water).

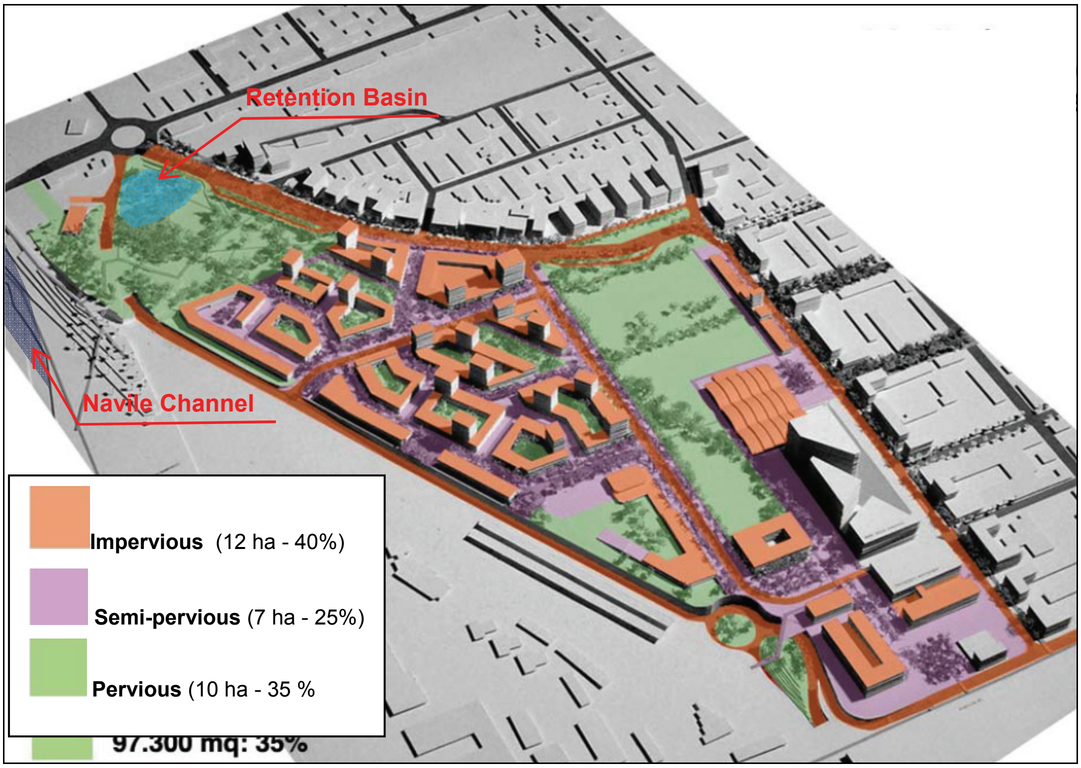

Fig. 1. Plan of the development area

3. Modeling of the urban drainage system

The simulation of the urban drainage system has been performed with the software EPA SWMM 5 [5]. It is an open source software developed by the U.S. EPA United States Environmental Protection Agency, which is widely used to plan, analyze and design sewage systems. Through the model, we have simulated the behaviour of the urban drainage system of the development area by using historical time series rainfall data.

With this purpose, the sewer system, completed with all the pipes, tanks and retention basin, was drawn in SWMM.

The adopted pipes roughness, basing on Manning's coefficient, was assumed equal to 0.0125 for PVC and 0.0143 for concrete pipes. Green roofs were modelled by means of ponds (storage unit), with an outlet which is a circular orifice equal to 50 mm [4].

Also the two rainwater cisterns for water reuse were included in the model by using the object storage units, whose defined characteristics are the absolute height of the cisterns bottom, the maximum storing height and the cisterns geometry. A pump which carries out drainage waters for irrigation has been associated to each cistern. The pump is regulated by a "control" which turns it off during winter months and on during the six warmer months, from April to September, according to the water demand for irrigation. The flow from the pump was assumed equal to 0.005 m^3/s.

The retention basin and the first foul flush tank have also been modelled as "storage unit" objects.

The parameters of the sub-catchments, which allow the transformation of rainfall into urban runoff, have been assumed equal to 0.01 the Manning's coefficient for impervious area and 0.1 for pervious area;

the average surface slope equal to 0.5%; the depth of depression storage equal to 2 mm on impervious area and 5 mm on pervious area. The infiltration on pervious area have been modelled with the Horton's equation with a maximum infiltration rate equal to 120 mm/h; the minimum infiltration rate equal to 10 mm/h; the decay constant equal to 4 1/hours.

In order to analyze the behaviour of the entire drainage system, 16 years rainfall time series, representing rain which has been registered in the city of Bologna from 1990 to 2005, recorded with time step of 15 minutes, were adopted. In order to simulate the evaporation effect for the green roof, temperature data, for the same period were included in the model.

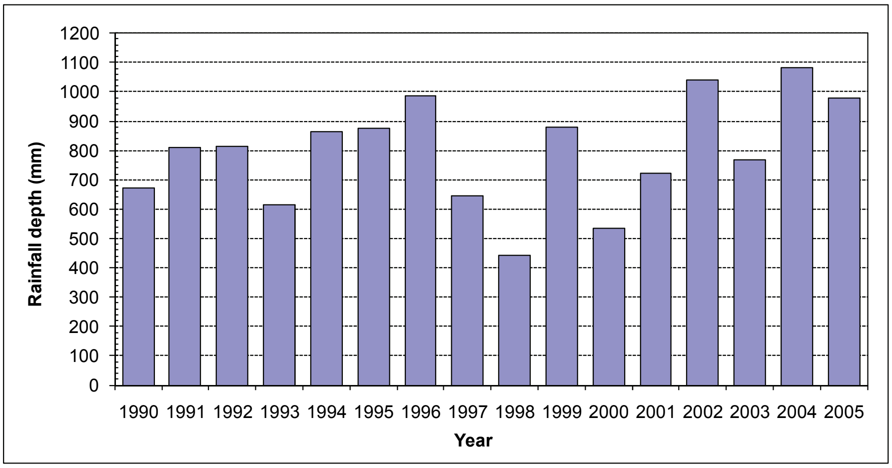

Fig. 2. Annual rainfall depth recorded in the city of Bologna for the 16 years adopted in the simulations

In addition, to control the irrigation pumps of the tanks collecting water from roofs and drains, a control that operates only six months a year, from April to September, was included to maintain a constant flow of 0.005 m^3/s.

Evaporation and transpiration (ET) are depending on temperature and water availability in the soil. The maximum value of ET that cannot be overcome is called potential evapotranspiration ET_P, and it is defined as "height of the water surface which evaporates or transpirates from a pool if the water available in the soil is always equal to the field capacity", where the field capacity is defined as the maximum amount of water that a well-drained soil can hold.

Through Thornthwaite’s formula [2] the monthly potential evapotranspiration has been calculated; the value has been assumed equivalent to the real evaporation registered during the months where the rains were likely to provide values greater or equal to the potential evapotranspiration.

In the months when rains are scarce, evapotranspiration has been calculated using the Turc’s formula [3] which allowed an assessment of evapotranspiration (mm/year) using the known monthly average temperatures and rainfall.

The simulations of the drainage system have been performed with the actual configuration and evaluating the behaviour of the system without green roofs and rainwater cisterns.

4. Long term simulation results

The long-term simulation of the drainage system in the actual configuration, with retention basin, first foul flush tank, green roofs and rainwater cistern, show that the maximum water level per year in the retention basin varying from 2 to 30 cm and it has been estimated that the basin laminates a water volume per year varying from 156 to 4'825 m^3. If we consider single rainfall event, the maximum discharge, in the 16 years simulated, which flows to the detention basin is equal to 0.5 m^3/s, and the maximum volume accumulated in the detention basin for a single event is equal to 630 m^3.

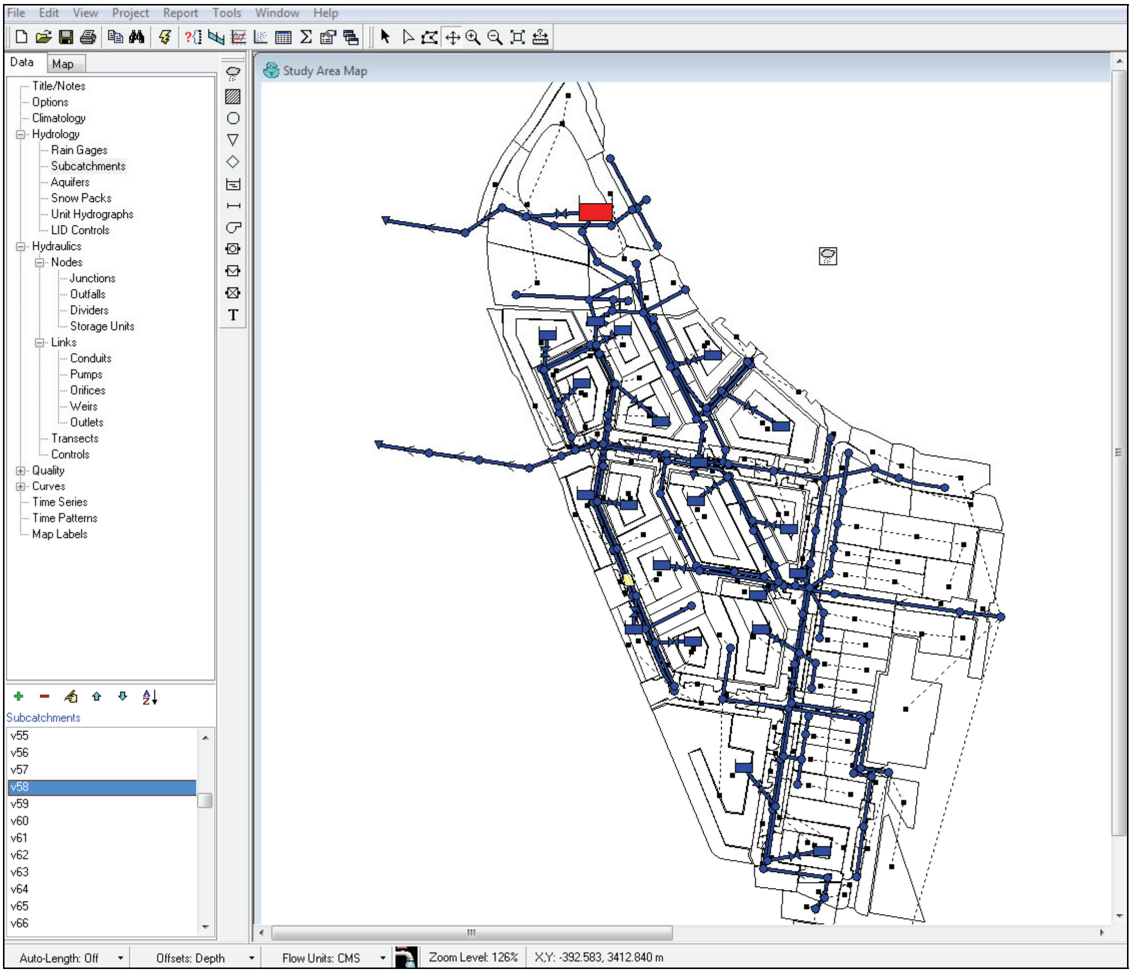

Fig. 3. Scheme of the sewer system simulated in SWMM

In order to analyze the effect of BMP like the green roofs or the rainwater cisterns, the simulations have been performed without these elements.

In case that green roofs are not realized, it is necessary to increase the pipeline diameter: the 315 mm PVC pipes have therefore been replaced in the model with 800 mm concrete pipes and the 400 mm and 500 mm PVC pipes have been replaced with 1000 mm concrete pipes. In this way we avoid flooding on the catchment and pressurised pipes.

The sewer system behaviour with data referring to the 16 years rainfall in Bologna has been simulated, analysing the variation of discharges and volume to the waste water treatment plant and to the Navile Channel.

In scenario without green roof the maximum discharge, in the 16 years simulated, to the detention basin is equal to 1.13 m^3/s, and without rainwater tank is equal to 0.757 m^3/s.

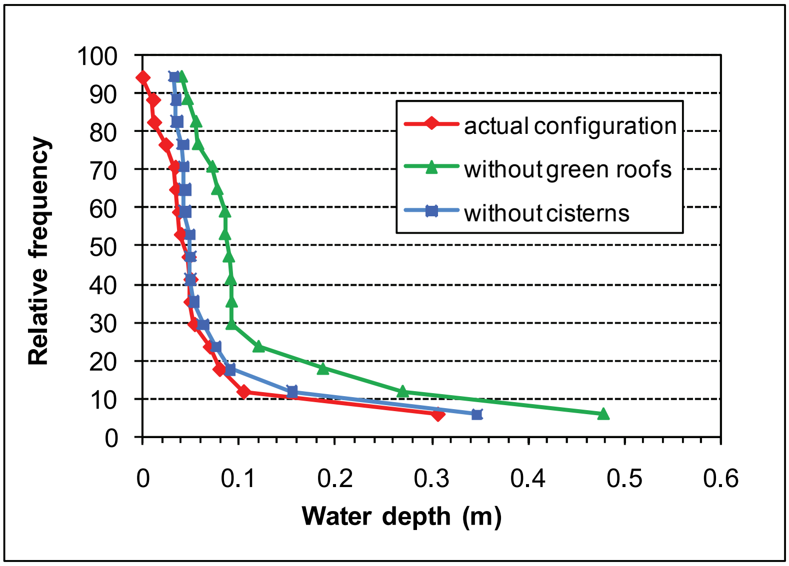

Fig. 4. Relative frequency of the water level in the retention basin

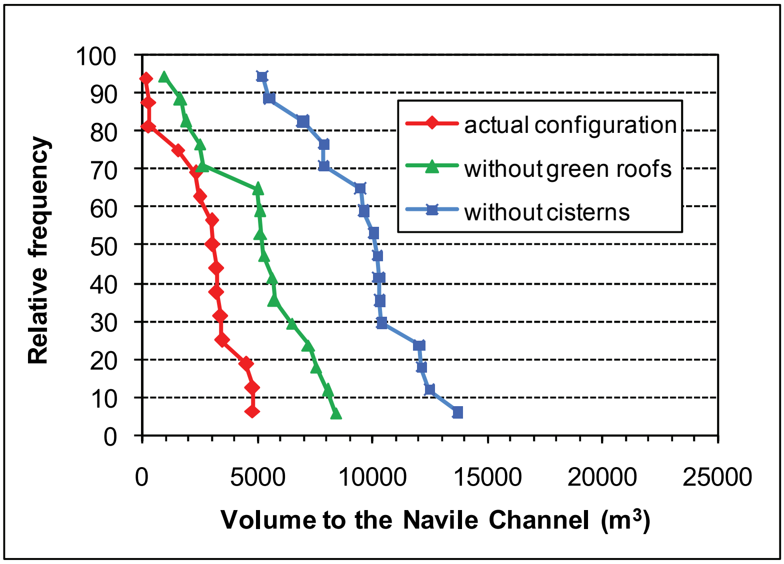

Fig. 5. Relative frequency o of annual volume sent to the channel Navile from the retention basin

In the scenario without green roof, the maximum rainfall levels reached in the retention basin doubles in the 50% of cases. If the system is deprived of cisterns for reuse, rainfall levels don't take significant gains.

The simulations showed that the water volume that the retention basin sends towards the Navile Channel increases suddenly (and it doubles in the 50% of cases) without the use of green roofs or rainwater cisterns for water reuse. In fact, if green roofs are absent, there is no water lamination and evapotranspiration, which extracts each year from 8.500 to 6.000 m^3 of water over 80.000 m^3 of rainfall per year.

Where cisterns are absent, the volumes sent to the Channel Navile quadruple in the 50% of cases, because all the rainfall of the area are being slowly flowed from the retention basin towards Navile channel, except for a small part that is retained by the first foul flush basin and sent to the waste water treatment plant.

If we remove rainwater cisterns or green roofs there are effects also on the first foul flush tank, in fact the overflows of the cisterns is connected with the sewer network which flows to the first foul flush tank.

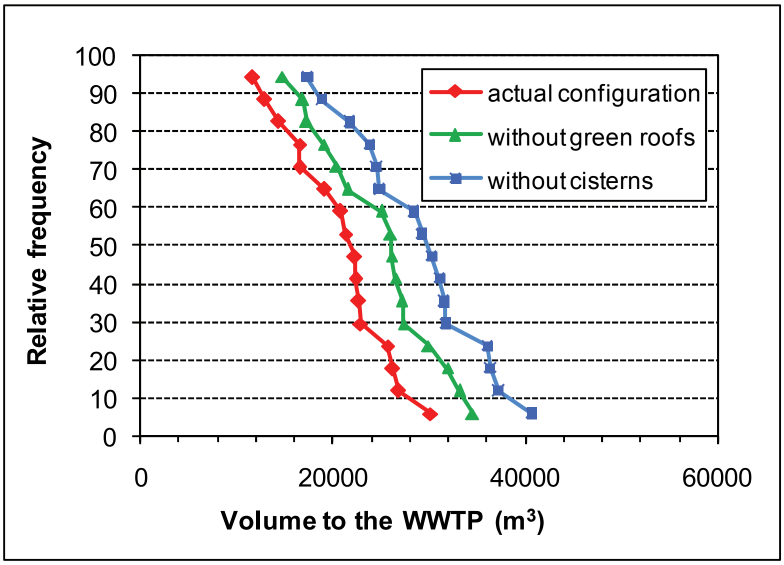

Fig. 6. Relative frequency of annual volume sent to WWTP from the first foul flush tank

By analyzing the behaviour of the first foul flush tank, it is possible to notice that the absence of green roofs or cisterns makes an excess of water volumes that are sent to the treatment plant, overloading it with storm water. The system without green roofs sends an average water excess of 4’100 m^3 to the waste water treatment plant, whereas the system without cisterns sends an average water excess of 8’240 m^3.

5. Conclusions

Applications of BMP technologies for rainwater reuse bring important benefits to the system, but it is necessary to verify these choices through a simulation model to predict their effectiveness and to identify their criticalities.

The results show that the system proposed for the ex vegetable and fruit market redevelopment area is fully functional. The adoption of green roofs permits to reduce the pipes diameter thanks to their flood control effect. Nevertheless, in case the green roofs were not properly functioning (for example, because of blockages, bad maintenance, or even for their being afterwards replaced by traditional flat roofs), the runoff system could reveal to be underestimated.

The careful assessment of their effect on the urban water system and the implementation of a system maintenance plan for guaranteeing their proper functioning make the BMPs a cheap and feasible solution aiming at ensuring that the postdevelopment peak flow does not exceed the predevelopment peak flow and water saving in local development plans.

Reference

[1] Roesner LA, Bledsoe BP, Brashear RW. Are Best-Management-Practice Criteria Really Environmentally Friendly?. *Journal of Water Resources Planning and Management* 2001; **127(3)**, May/June,

[2] Thornthwaite CW. *Instructions and tables for computing Potential Evapotranspiration and the water balance*. Publications in Climatology, John Hopking University, Volume 10, No.3; 1957.

[3] Turc L. *Le bilan d' eau des sols. Relations entre les precipitations, l' evaporation, et l' ecoulement.* Ann. Agr., 6, 5-131,1955.

[4] US EPA. *Green Roofs. Stormwater Menu of BMPs*; 2005. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/.

[5] US EPA. *Storm Water Management Model. User's Manual, Version 5.0*. Cincinnati (OH);2005.

[6] Wright Water Engineers Inc. and Geosyntec Consultants. *International Stormwater Best Management Practices (BMP) Database project websites;*2010. www.bmpdatabase.org.