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ASSESSING THE BENEFITS OF NATURE-BASED SOLUTIONS IN A STORM DRAINAGE SYSTEM – A CASE STUDY

ABSTRACT

In most developing countries, stormwater drainage practice consists of a conventional storm drainage system designed to collect and convey excess runoff to the recipient as soon as possible, without any attenuation or peak flow decreasing effects. This paper aims to show the overall need for change in the urban drainage paradigm by showing the effects of reconstruction of the existing conventional stormwater drainage system into a new one by including green elements. Part of the existing system is replaced with vegetated swales, and two detention ponds are added in the common green areas (parks). Effects are analysed through a comparison of results from a mathematical rainfall-runoff model for the existing and reconstructed stormwater drainage system for both water quality and quantity at the sub-basin outlet point. The cost-effectiveness of the applied measures is quantified by comparing construction prices for the existing and the reconstructed system. The obtained results clearly show an urgent need for stormwater drainage practice improvement in countries where the conventional approach is still in use.

Keywords: *green infrastructure, rainfall-runoff model, water quality, stormwater drainage system*

ПРОЦЈЕНА ПРЕДНОСТИ ПРИРОДОМ ИНСПИРИСАНИХ РЈЕШЕЊА У СИСТЕМУ КИШНЕ КАНАЛИЗАЦИЈЕ – СТУДИЈА СЛУЧАЈА

Апстракт: У већини земаља у развоју пракса одвођења кишних вода у градовима се базира на конвенционалним системима који су пројектовани тако да вишак воде од падавина што брже сакупе и одведу до реципијента, без икаквог ефекта задржавања или ублажења отицаја. У овом чланку се указује на потребу за промјеном парадигме одвођења кишних вода у градовима кроз ефекте који се постижу реконструкцијом постојећег конвенционалног система каналисања кишних вода увођењем природом инспирисаних рјешења. Дио постојећег система је замијењен затрављеним каналима и два детенциона базена су додана у систем на мјесту заједничких зелених површина (паркови). Ефекти су анализирани поређењем резултата математичког модела падавине-отицај за постојеће и реконструисано стање система кишне канализације, по питању количине отицаја али и квалитета на излазној тачки са слива. Исплативост примијењених мјера је квантификована поређењем трошкова изградње постојећег и реконструисаног система. Добијени резултати јасно показују хитну потребу за побољшање постојећих система кишне канализације у градовима гдје је конвенционални систем каналисања још у употреби.

Кључне ријечи: *природом инспирисана рјешења, модел падавине - отицај, квалитет воде, систем кишне канализације*

1. INTRODUCTION

In most developing countries, the usual stormwater drainage practice assumes a conventional stormwater drainage system design by the inherent principle of removing excess water from the surface "as soon as possible". Hence, the stormwater drainage system aims to collect the storm runoff from the surface, which is usually done by connecting all impervious surfaces directly to the system. An adverse effect of this practice is that it does not allow groundwater recharge, and consequently, drains are over-designed to convey all excess stormwater irrespective of natural processes (i.e. percolation, seepage and groundwater recharge). In this instance, we mainly consider excess water from roofs, parking areas and other urban impervious surfaces that should be rather directed to nearby pervious areas such as parks and other green areas.

Conventional storm drainage systems are seen as ineffective in the event of torrential rains [1] and largely interrupt the natural hydrological cycle. With the goal of restoring natural hydrological cycles in urban areas, many new concepts offered novel drainage systempractices, i.e. Sustainable Urban Drainage System (SUDS) [2], [3], stormwater Best Management Practices (BMPs) [4], Water Sensitive Urban Design (WSUD) [5], Low Impact Development (LID) [6], [7], Blue Green Dream (BGD) [8] and many more. Many authors quantified the hydrological and pollution benefits of nature-based solutions (NBS) in order to prove their effectiveness in the meaning of water quantity or quality control. For example, Stovin et al. [9] found in their study that green roofs attenuated peaks during significant storms by over 60%, while Wang et al. [10] concluded that the reduction of total suspended solids (TSS) with these elements was around 63%. Studies in China [11] found that the highest stormwater volume reduction in bioretention systems was 68%, while peak flow was reduced by 86%. The same elements are found to reduce phosphates by 81% and nitrates by 69% [12]. Young et al. [13] found that vegetated swales reduced the runoff from the highway on average by 87%, while removal of TSS, chemical oxygen demand (COD), total nitrates (TN) and total phosphorus (TP) was by 90%, 57%, 32% and 20%, respectively. Some of the review and comparative analysis of different NBS elements can be found in [14]. The economic benefit of the NBS is usually evaluated in terms of economic and social benefits by investing in these solutions [15].

This paper aims to prove the effectiveness of a simple reconstruction of a conventional drainage system to decrease the water quantity entering the stormwater drainage system and improve the water quality. Economic aspects of cost-saving with this reconstruction are also highlighted as a very important decision-making tool in developing or low-income countries.

2. RESEARCH SETUP

In this paper, the complete analysis and conclusions rely upon model simulations of a few variants of a drainage system. Different drainage system models are developed as: (i) the existing one, (ii) the existing one with disconnection of impervious surfaces from the system and connection to pervious zones, and (iii) reconstructed system with the inclusion of green elements, more specifically, dry detention ponds and vegetated swales. The rainfall depth, sub-basin characteristics and pollution parameter inputs are the same for all models, so the results are easily comparable. Finally, the costs of the systems are compared to prove that the inclusion of green infrastructure not only gives a better technical solution and cleaner collected water, but it is also economically more favourable.

Different storm drainage systems are analysed using a rainfall-runoff modelling software called StormNET®® [16]. Simulations include both water quantity and water quality modelling in several different sewer system setups.

As a case study, the urban settlement of Veseli Brijeg in the city of Banja Luka, Bosnia and Herzegovina, has been chosen. Data for the existing drainage system at the site was collected, and the corresponding drainage system model was developed. This drainage system is referred to hereinafter as Conventional, and it represents the reference model to which others are compared by changing the drainage practice and changing/adding elements.

The second model keeps the same settings as the Conventional model but with one change: all impervious areas such as roofs and parking areas are connected to pervious zones instead directly to the drainage system. This is the conventional system with source control included as the first in the line of sustainable urban drainage practices. Hereinafter it is called Conventional + source control.

The third model is an alternative one constructed from the conventional model by replacing parts of the drainage pipes with vegetated swales and including two dry detention ponds in the catchment that need to be located appropriately. Hereinafter, this model is called Alternative.

Additionally, the basin has also been modelled as a natural one, i.e. without urbanisation, for additional comparison of outflow hydrographs before and after urbanisation and with conventional and NBS elements in the urbanised drainage system. This comparison highlights the NBS for mimicking natural site conditions. This model is called Pre-development.

3. RAINFALL-RUNOFF MODELLING

StormNET® is a physically-based model with dynamic hydrologic and hydraulic calculations. The concept for rainfall-runoff modelling is based on the interaction of several main factors of the environment [16]:

- atmosphere/precipitation, modelled with rain gauges;
- land surface, modelled with sub-basins;
- groundwater system which is modelled with the aquifer and
- network elements that accept and convey the computed runoff, modelled with nodes and links.

In addition to the above, there is a water quality modelling that can be defined together with a water quantity model generation.

This program offers several different computation methods for calculating components of the rainfall-runoff processes. In this analysis for the water quantity modelling, rainfall-runoff processes are calculated using the EPA SWMM [17] [18] (Environmental Protection Agency Stormwater Management Model) model that dynamically generates the runoff based on rainfall, evapotranspiration and potential infiltration data. The surface runoff is calculated by the non-linear reservoir method, while the Green and Ampt method based on continuity and mass conservation equations (known as Darcy's Law) is used for the calculation of infiltration. The pipe flow calculation uses St. Venant's equations, specifically the diffusion wave with inertial part omitted from the mass conservation equation. In addition, the software includes calculations for sustainable urban drainage elements, such as NBS, for both quantity and quality control.

For all three model setups, one rain gauge station is assigned. Various synthetic rainfall events were analysed in terms of catchment response to find out the most unfavourable runoff for the system element design. It was concluded that for the analysed watershed, the maximum peak runoff occurs for the rainfall duration of 15 minutes while the maximum runoff volume is generated with the 1-hour rainfall, which is an important factor for the attenuation element design.

The temporal variability of rainfall was also checked in order to find the maximum runoff peak appropriate for drainage element design. Four various temporally distributed synthetic rainfall events were considered, according to StormNET® rainfall designer options [19]:

- constant intensity over the duration (block storm),
- cumulative rainfall with decreasing intensity (advanced storm),
- cumulative rainfall with increasing intensity (delayed storm) and
- cumulative rainfall with almost uniform intensity (same as one but differently defined in StormNET® software).

After simulating runoff hydrographs for all temporal rainfall distributions, the cumulative rainfall with decreasing intensity was adopted for further analyses. Three different return periods of synthetic storms were considered:

- Synthetic storm of 2-year return period or 50% probability of exceedance, representing local design practice,
- Synthetic storm of 10-year return period or 10% probability of exceedance, corresponding to the design practice in most developed countries,
- Synthetic storm of 5-year return period or 20% probability of exceedance as a “middle of the road” solution between the previous ones.

In urban stormwater drainage systems, the main sources of contamination are pollution wash-off with runoff from the catchment surfaces and pollutants that have accumulated in the sewers during dry weather [20]. The pollution modelling available within StormNET® is a common two-stage process: a pollution build-up during dry periods and pollution wash-off during wet weather. This causes the simulation to be continuous with both dry and wet weather periods to capture pollution loads because normally, pollution loads increase with the increasing antecedent dry period.

According to an experimental study [21], after a rain event, the pollution wash-off builds up again relatively quickly to the previous amount on the surface. This implies that during the comparison of pollution resulting from different drainage model setups, the distribution of the specific pollution load during simulation time is not so relevant. Green drainage elements will reduce only a maximum of the pollution load during the analysed time since they do not affect the pollution build-up on the surface during dry weather. In this paper, detailed pollution modelling was not in focus, and it was only used for relative comparison purposes between different drainage systems. Input parameters, since there were no measured ones, were adopted as typical values given in StormNET® [18], [22], [23].

Urban stormwater pollution sources such as the atmospheric deposition, catchment surface attrition/elution or urban land use activities produce various amounts of pollution parameters, varying from site to site. It is recognized [24] that the most common parameters of urban non-point source pollution are: total suspended solids (TSS), total phosphorus (TP), total nitrogen (TN), biological oxygen demand (BOD), chemical oxygen demand (COD), Lead (Pb), Copper (Cu) and Zinc (Zn).

In this study, three pollution parameters are analysed: TSS, TP and BOD.

Sub-catchments characteristics are kept the same in all models as well as the conveyance system lengths. The pollution input data remain constant in all three models to ensure comparability of the simulation results.

4. DEVELOPMENT OF STORMWATER DRAINAGE MODELS: CASE STUDY

4.1. STUDY AREA AND DATA

As a case study, a catchment in the city of Banja Luka called Veseli Brijeg was chosen, with an area of 9.2 ha. The land use is typically residential, with mainly dense apartment blocks and some individual households. The drainage system is of a separate type, so the stormwater drainage network could be individually analysed without the influence of municipal wastewater.

The models are developed with 12 sub-catchments. The main input data is given in Table 1, while the study catchment is shown in Figure 1 [25].

Table 1. Sub-catchments input data

Sub-catchment ID	Area	Equivalent width	Average slope	Impervious areas Model I	Impervious areas (without roofs) Model II and III
	(ha)	(m)	(%)	(%)	(%)
1	0.27	70.89	4.3	30	20
2	0.47	87.43	6.1	30	20
3	1.04	148.52	4.3	35	25
4	0.91	225.86	6.1	38	28
5	0.65	114.34	4.3	30	20
6	1.05	118.77	4.3	40	30
7	0.72	168.44	4.0	25	15
8	0.52	106.93	1.3	35	25
9	0.56	114.73	3.2	30	20
10	0.53	57.08	4.0	40	30
11	0.37	44.58	3.2	40	30
12	0.33	139.66	4.3	40	30
Other input data for sub-catchments					
Pervious area depression depth					4 mm
Impervious area depression depth					1.5 mm
Soil conductivity					36 mm/h
Manning's roughness for pervious					0.35
Manning's roughness for impervious					0.018
Suction head (for the Green-Ampt method)					61 mm
Initial moisture deficit (porosity minus initial moisture content)					0.25

Sub-catchment areas and slopes are derived from the DEM (Digital Elevation Model), while impervious/pervious areas are estimated from digital ortho-photo maps. Other data (given in the lower part of Table 1) are estimated upon recommended values published in various global literature sources and embedded in the software [26][27][28][29].

Unfortunately, there was no data for the model calibration. Instead, the parameter variability and sensitivity analysis were performed to estimate the range of output results of varying parameters within the expected range.

Figure 1. Study area of Veseli Brijeg, Banja Luka

4.2. EXISTING STORMWATER DRAINAGE SYSTEM – CONVENTIONAL MODEL SETUP

The conventional drainage system layout is designed by standard procedures that are part of the state regulations and with standard elements. The system is very simple, and it is comprised of circular pipes, standard manholes with an inner diameter of 1000 mm and one outlet where the runoff hydrograph is computed and data tracked for further analysis and comparison.

The drainage network junctions and pipe data are taken from the existing network design, with all their physical properties (e.g. geographic coordinates, invert and ground/rim elevations and offsets, length and diameters for the existing system) as they are built on site.

4.3. CONVENTIONAL MODEL WITH SOURCE CONTROL SETUP

This model is the same as the previous one, except for the inclusion of simple source control. This is done by disconnecting the roof runoff from the drainage system and connecting it to pervious areas instead, such as lawns and gardens. The model is changed by assigning less impervious areas to each sub-basin by reducing the percentage of the overall roof area. This is considered to be accurate because the routing roof runoff to the pervious zones first, from where it will be conveyed to the drainage network, makes these areas act as pervious. The used impervious area percentage for each sub-basin is shown in Table 1 (last column).

4.4. RECONSTRUCTED MODEL WITH NBS ELEMENTS

This model presents the re-designed conventional model, with the source control measure from the previous model and two additional dry detention ponds within the site included. In addition, from three sub-basins, S1, S2 and S3 (Figure 1), the runoff is collected and conveyed with the grassed swales modelled along the roads. The swales are 1 m wide and 40 cm deep. The schematic representation of the conventional and alternative model setup is shown in Figure 2.

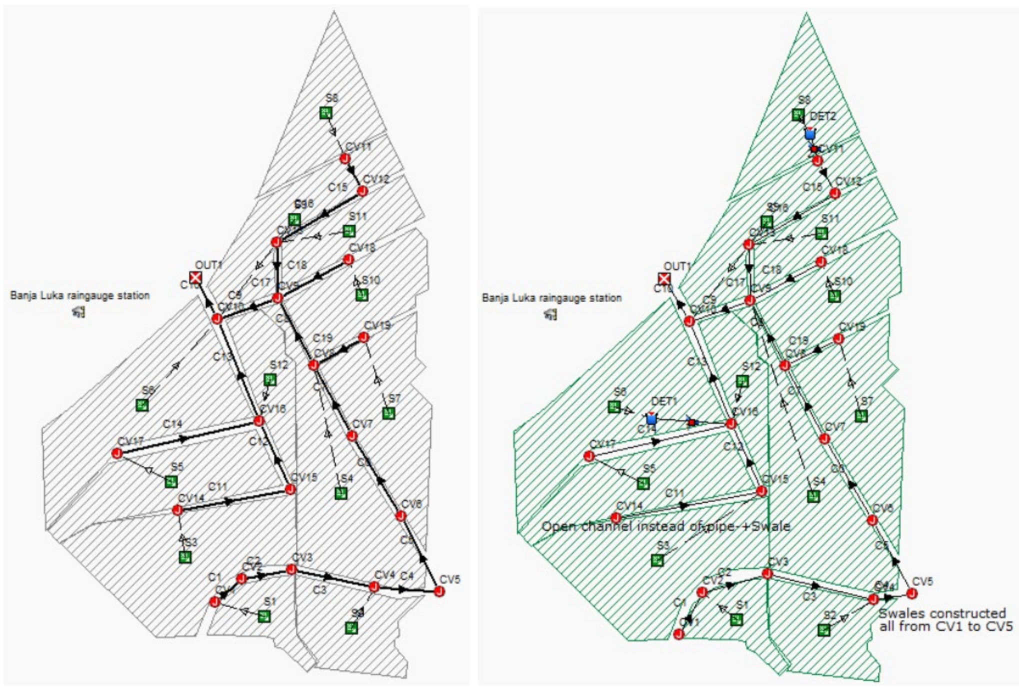

Figure 2. Schematic representation of storm drainage network models in the case study area: conventional (left) and alternative (right).

Detention ponds are sized according to the runoff volume from the conventional model results for that particular sub-basin. The first detention pond is placed on the sub-basin S6 with a volume of 131 m^3 and the second on the sub-basin S8 with a volume of 35 m^3. Both locations are chosen to be green areas between buildings, with a proper topographic configuration because the surrounding runoff gravitates towards them. Both ponds are designed to accept the sub-basin runoff volumes, and with the outlet control structure, they can slowly drain to the downstream part of the drainage network.

The control structure element called the “outlet” from the computer model is used as detention pond outlets. It is possible to completely control the flow rate by defining the head-outflow rating curve for this element.

Water in ponds can exfiltrate to the ground at all water levels, so it is assumed that there is no liner in the pond. The exfiltration method used is the Horton equation for all wet pond surfaces with the following parameters:

(1) maximum exfiltration rate is 8 mm/hr,

(2) minimum exfiltration rate is 1.6 mm/hr and

(3) decay constant is 4 h^1.

According to some research [30], the efficiency of green elements in the pollution removal varies from one element to another. It is found that for both dry detention ponds (using data collected from 8 studies) and for swales (using data collected from 20 studies), the range of percentages of typical pollution removals are:

- for TSS 30-65%,
- for TP 15-45% and
- for BOD-30%.

According to these findings, input data for the pollution removal in green elements included in the Alternative model were adopted to be: 20% for BOD, 30% for TSS and 50% for TSS. With such efficiencies, the model simply calculates the pollution concentration downstream of the element by decreasing pollution values in each time step by a defined percentage.

4.5. NATURAL CONDITION MODEL

In the reviewed literature, various methods for peak runoff estimation for a site with natural conditions are recommended and set within the state regulation [3]. Notwithstanding, it is possible to model natural site conditions and compare the results with the post-development conditions in order to assess differences in the runoff rate and hydrograph shape.

In this study, the pre-development system is modelled as a whole catchment with a very small percentage of the impervious area (5%). This model is made for the estimation of the difference in pre- and post-development runoff rates, as well as for sizing the storage facilities at the site.

4.6. MODEL PARAMETER VARIABILITY AND SENSITIVITY ANALYSIS

Since there was no data for model calibration, a sensitivity analysis was performed to determine how model results vary in response to changes in input parameters. In simple models, the sensitivity is readily apparent. However, in a sophisticated sewer model, the model response at one location relative to changes in flows or parameters at another location may not be that obvious. Combinations of parameters may have unpredictable interactive effects.

In this paper, data variability and sensitivity analysis were performed on the alternative system by making simulation runs while varying relevant input parameters. These parameters are varied for a range of expected values, and the effect on the output results was analysed.

Parameter variability and model sensitivity analysis is performed using the 15-minute rainfall of the 10-year return period. While varying one parameter, the rest are kept to the fixed model value (i.e. column two in Table 2). Consequently, values of varied parameters and the corresponding deviation of the model results are given in Table 2.

From these results, it can be concluded that for the developed simulation model, two parameters have the most uncertainty, namely: hydraulic conductivity and the initial moisture deficit, which are both soil characteristics, controlling infiltration and percolation processes.

Table 2. Overview of parameters variability and outflow sensitivity analysis.

Variable parameter	Exact model value	Uncertainty	Range of parameter		Deviation (max minus min obtained runoff) (l/s)
			min value	max value	
Hydraulic conductivity [mm/hr]	36	30	6	66	91.18
Impervious areas depression storage [mm]	1.5	1	0.5	2.5	2.59
Pervious areas depression storage [mm]	4	3	1	7	8.44
Manning coefficient for pervious n [m-1/3s]	0.35	0.05	0.3	0.4	0.61
Manning coefficient for impervious n [m-1/3s]	0.018	0.003	0.015	0.021	1.1
Initial moisture deficit [-]	0.25	0.20	0.05	0.4	15.07
Suction head [mm]	61	12	49	73	2.64

4.7. COST ANALYSIS

In addition to the technical aspects of improving the drainage system, it is useful to consider the difference in costs between the two models because this is the most important factor for the decision-makers in the developing countries (as well as in the developed countries). The simplified cost structure is developed and compared based on pipe lengths in the two models and with additional ponds and swales construction.

For the conventional pipe system, prices include all works from the construction site preparation, earthworks, manholes construction, laying of sand substratum, hydraulic test etc. In the Alternative model, the pipe length and number of manholes are reduced by substituting them with the swales-grassed shallow parabolic channels. The NBS elements used in this model include swales and detention ponds, which are among the cheapest in terms of construction and maintenance. This is intentionally adopted to reflect known problems encountered with the local community/municipality.

5. RESULTS AND DISCUSSION

The simulation of all model setups described previously show various catchment responses and the runoff at the catchment outlet. In Figure 3, runoff hydrographs for 15-minute 2-year return period storms are shown. It can be clearly seen how simple replacement of conventional elements (pipes) with the vegetated swales and inclusion of runoff attenuation elements (detention ponds) can affect the runoff from the catchment. Simple source control decreases the peak runoff by its third while the alternative model produces only a near-half of the conventional model runoff.

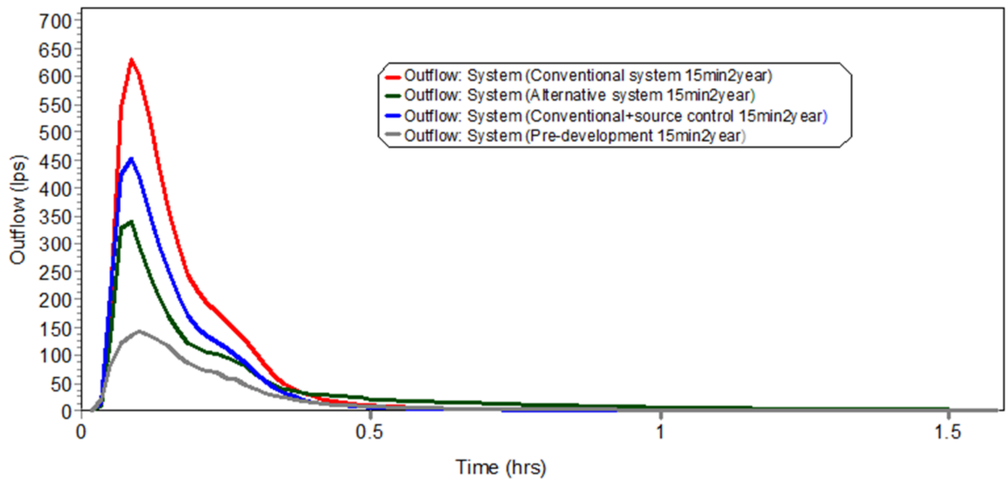

Figure 3. Comparison of runoff hydrographs for different storm drainage models (results for a 15-minute storm of a 2 years return period)

Figure 4 shows the resulting runoff at the system outlet as a function of the rainfall duration and return period. Different flow controlling measures can be seen to decrease the peak flow (i.e. through source control, detention ponds and swales). Figure 5 shows the percentage decrease of the peak flow for a 15-minute storm and runoff volume for a 1-hour storm for two models, namely the Conventional + source control and the Alternative one, compared to the conventional model.

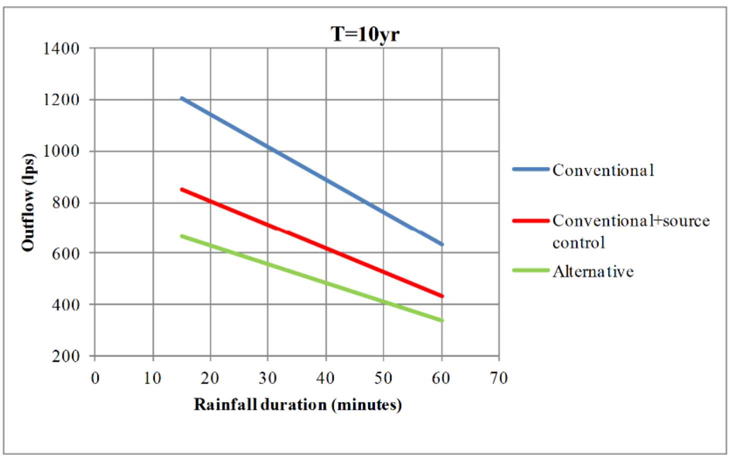

Figure 4. Runoff at the catchment outlet vs. rainfall duration for different storm drainage models and three different return periods

Directing the roof runoff towards pervious areas around buildings instead of into the storm drainage system leads to a decrease of the impervious areas by approximately 10% and it decreases the peak runoff by around 30%. With the inclusion of detention ponds and swales, this decrease is by up to 47%.

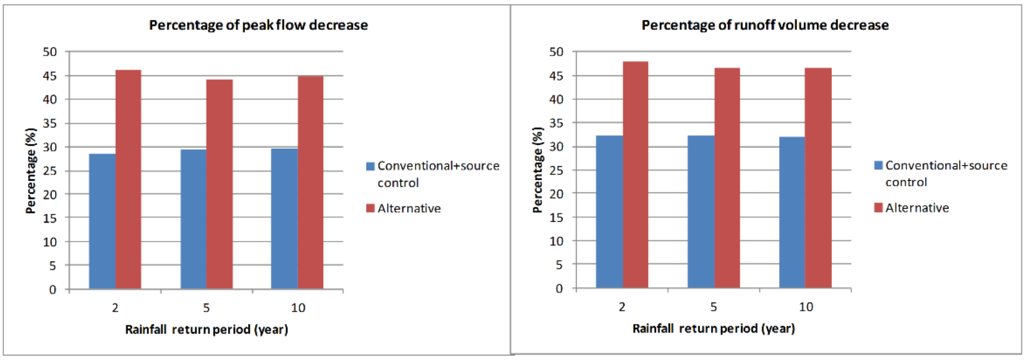

Figure 5. Percentages of decrease in peak flow and runoff volume for two models - Alternative and Conventional + source control in comparison to the conventional one.

To clarify what is happening with the flow, Figure 6 shows the flow through link C2, which is a pipe in the conventional system and a swale in the reconstructed one. The flow is substantially attenuated in the wide vegetated swale compared to the conventional system. This is because infiltration is allowed and even encouraged using vegetated swales with the especially porous underlying soil. Similar results in the pipe downstream of the detention ponds can also be expected, since ponds are designed to capture the local flood volume and release it slowly and uniformly downstream.

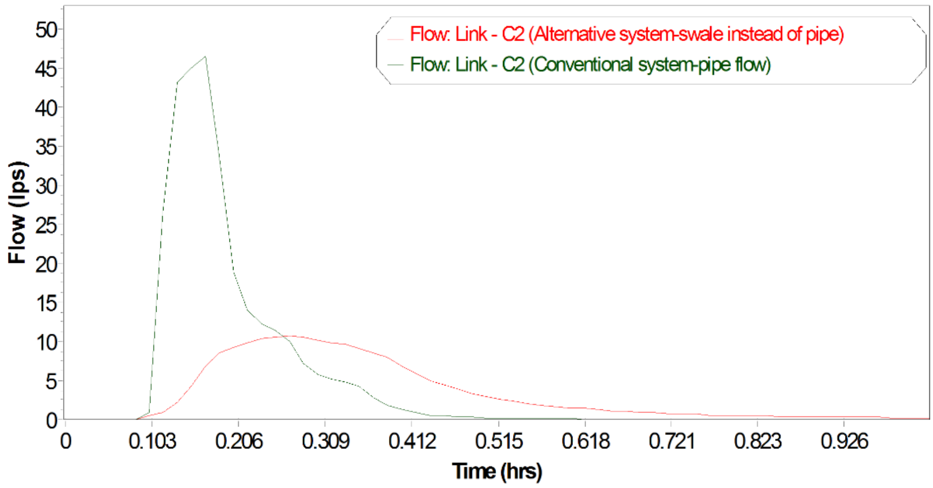

Figure 6. Flow hydrographs through link C2 – pipe vs. swale as an alternative

As mentioned previously, during the comparison of different drainage models, the setup, the pollution results, and the distribution of the specific pollution load during simulation time are not so relevant. Therefore, event mean pollution concentration is compared at the catchment outlet for conventional and alternative systems.

Figure 7 provides graphs of BOD, TP and TSS concentrations for 15-minute storms and different return periods. Pollution reduction in the model with source control only (conventional + source control model) is not so significant, since it mainly represents a reduction of pollution from the roofs, that does not enter the system but is discharged instead onto pervious areas such as grass. Conversely, with detention ponds and swales, the decrease in pollution is significant.

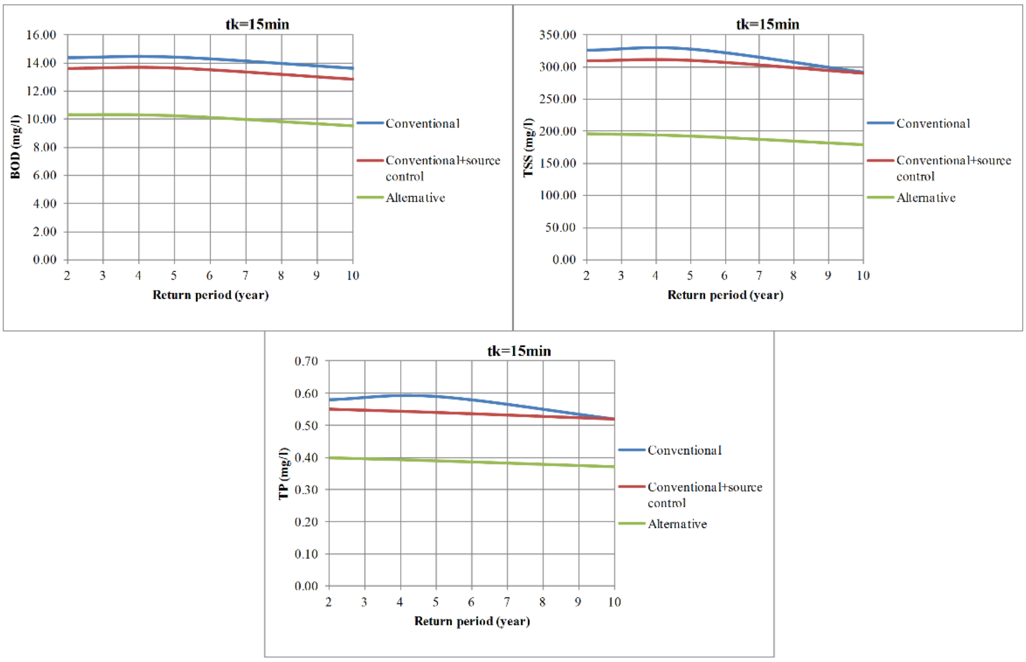

Figure 7. Mean change of BOD, TP and TSS vs. rainfall return period for different storm drainage models

Figure 8 shows the percentages of pollution reduction at the catchment outlet for BOD, TP and TSS. The best efficiency of sustainable drainage elements included in this reconstructed model is related to TSS removal, but TP and BOD concentrations decrease substantially.

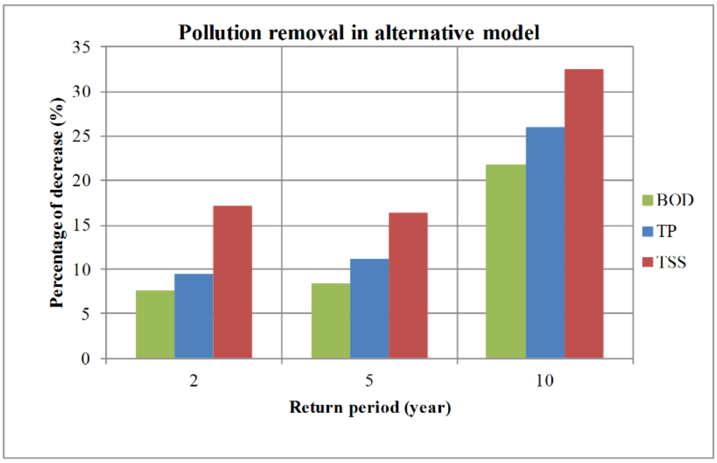

Figure 8. Percentage of decrease of pollution in the Alternative model in comparison to Conventional one

The cost analysis also provides very good results in favour of green infrastructure. If a multi-criteria analysis for technical, environmental, social and sanitary parameters was included, it is likely the results would likely be very satisfactory [31]. A simple comparison of construction costs of conventional and alternative drainage systems are given in Table 3 and Table 4, respectively. The given prices are taken as mean market values while NBS costs are taken from [2].

As can be seen, cost savings can be expected if we choose to build in a sustainable urban drainage way. In other words, 26% less capital cost is required for the construction of an alternative system using green infrastructure compared to those using the conventional design.

Table 3. Construction costs for conventional drainage system

Construction work	Cost [€]
Construction site preparation	13.112,00
Earthworks	65.149,00
Concrete works	10.129,00
Masonry	6.685,00
Pipe purchase and installation	39.362,00
Other (additional) works	26.276,00
Σ	160.713,00

Table 4. Construction costs for alternative/reconstructed drainage system

Construction work (conventional elements)			Cost [€]	
Construction site preparation			9.995,00	
Earthworks			52.830,00	
Concrete works			8.840,00	
Masonry			4.934,00	
Pipe purchase and installation			17.706,00	
Other (additional) works			20.040,00	
NBS element	Size	Unit	Cost [€/units]	Cost [€]
Detention pond (1+2)	166	m^3	12	1992
Swales	304	m^2	8	2432
Σ			118.769,00	

6. CONCLUSIONS

From the analysis presented above, the summary of conclusions can be listed as follows:

(1) the impact of urbanisation and the design of conventional drainage systems increase natural catchment runoff by a factor of almost five times,

(2) with simple source control (in this example, the roof runoff was discharged onto pervious areas instead of being drained directly to the drainage system), both peak runoff and runoff volume are decreased by around 30%,

(3) an alternative system that includes sustainable, green infrastructure elements (e.g. detention ponds and swales) decreases both runoff and runoff volume by around 45%,

(4) pollution is decreased by 8%-30% depending on the pollution parameter, which is significant and has important repercussions for the future design of wastewater treatment plants,
(5) cost savings in the construction of a system using green elements are 26% compared to the conventional system, mainly because natural conveyance systems are cheaper than pipes, while pipe diameters are generally smaller than in a conventional system (due to the decreased peak flow),
(6) reconstruction of a conventional system is quite simple with substantial positive effects; a new storm drainage design can also represent a cheaper option.

Notwithstanding, it is not clear how new storm drainage design will turn out in the long-term when maintenance is included, since it has been shown through various reports and studies [3], [32], [33]. The aspect of costs during the life cycle should be considered in future research.

Obtained results are comparable with other studies with the difference that the benefits of the NBS elements are usually quantified as a single element(s) in the system, while this paper explores multiple benefits of NBS coupled with the conventional system.

Generally speaking, reconstruction of conventional storm drainage systems is very feasible. Relatively small investments can make highly positive influences on both water quantity and quality at the outlet point of the system. The full value of NBS solutions can be perceived by assessing the other benefits such as environmental [34], spatial and social [1], built environment [35], etc. Therefore, it is highly recommended for countries that have not yet adopted this type of storm drainage practice to improve it and start using sustainable and environmentally friendly solutions.

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