

GREEN STREETS AS A MODEL OF STORMWATER MANAGEMENT IN NOVI SAD

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Summary: *Streets are an important element of any settlement. In the physical sense, streets make the communication areas, which consist of various elements: driveway, bike paths, sidewalks, parking lots, views and green area (green belts and green islands). Greenery, as an element of streets, in addition to their basic function - insulation of pedestrian flows and peripheral buildings from motor vehicle traffic, the creation of favorable sanitary-hygienic and microclimate conditions, can also perform the function of absorbing and filtering stormwater, generated as a result of rain, the melting of snow etc. The term "green street" refers to the ecological spaces that offer different technical solutions for the accumulation of stormwater, such as: containers for collecting water, rain gardens, specially selected vegetation, permeable surface layer overlay, porous surfaces and others. Green streets can be designed, tailored to different types of streets and roads, or fit into the existing road network. The primary objective of the application of green streets is management of stormwater water in urban conditions, through the processes of absorption, filtration and water purification, which contributes to increasing the quality of the environment. Different innovation solutions for the implementation of green streets, allow conversion of conventional, existing streets into ecological oasis with multiple benefits, which is reflected in the improvement of the quality of water, air, reducing heat island, thereby highlighting all the important roles of greenery, which is no longer just a "decorative" element the urban landscape. This paper deals with the definition and identification of key characteristics of green streets, typology, and recommendations for improving the existing street system in Novi Sad, using green streets.*

Keywords: *green streets, stormwater management, Novi Sad*

1. INTRODUCTION

The existing, traditional systems for stormwater management in urban cities, are often hydrologically unfunctional. Intensive urbanization and increase of impermeable surfaces, leads to an overload of manholes and water runoff, that can not infiltrate into the soil. Since the infiltration rate of soil is high, water originating from rainfall is absorbed to its

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maximum volume. One part of water evaporates into the atmosphere, while the rest is retained in the soil, ie. in the deeper layers.

A higher ratio of soils infiltration means less runoff and vice versa. Natural vegetation cover infiltrate into the soil in the amount of 25% of the water that falls on the surface, but only 10% of water flows from the surface, while 40% is the result of the atmosphere through evapotranspiration. In urban conditions with dominant impermeable surfaces, which can be defined as a physical barrier to the passage of water, or lack of infiltration into the soil, only 5% of the water originating from precipitation infiltrates into the soil, while 65% is part of the water runoff [1].

"Green Systems" that are nowadays increasingly applied, through the integration of stormwater treatment techniques, use natural processes and landscaping by creating areas that mimic nature, such as wetlands and buffer zones. The implementation of green systems, as natural measures to absorb, filter or purify stormwater before it discharges into receiving waters, is part of a strategy of stormwater management or Green Stormwater Solutions (GSS) which aims to reduce the negative impacts of pollution from stormwater runoff [2].

2. CURRENT CONDITION OF STORMWATER MANAGEMENT IN NOVI SAD

Importance of drainage, as one of the direct impact on the stability of road construction as well as on safe traffic that monitors every road, is forgotten [3]. The amount of water that remains on the surface after a rainfall, represent runoff coefficient.

The speed and amount of runoff is influenced by many factors, such as soil type, the presence of impermeable surfaces, surface roughness, climatic factors (evaporation, transpiration), grass cover, transverse and longitudinal section of the street, etc. [4].

Streets are not designed for transferring large amounts of water and therefore, during the strong rainfall, landslides often occur in asphalt, curbs and even parts of buildings, which contributes to clogging drains, forming small obstacles on roads and runoff of rain water [5]. In the area of Novi Sad, a city sewage system is combined, with a common drain network for used water (household, industry) and stormwater.

Overload of sewage systems can leads to flooding of streets. Such acedental scenarios in Novi Sad could be observed in 2014. and 2015. year, when in one day fell from 30 to 60 liters of rain per square meter, which is generally the average rainfall for the whole month. Some examples of water retention on the streets of Novi Sad are given in figure 1.

Water that flows from paved surfaces in Novi Sad, is directed to the projected gutters or drains. From a small paved surfaces and narrow trails, water is most often focused on the surrounding lawns, folding curbs in the level of protection and gently leveling flat surfaces (min 0.50%, optimally 1% slope).

In addition to the gutters, an important element of interpretation of paths and roads are curbs. Their role is visual and physical separation of surface routes for pedestrians and vehicles, as well as bordering green areas.

The height of the curbs, and whether it will be a straight or lowered, depends on the method of directing storm water. Transverse and longitudinal profile of the street are the most important elements that affect the drainage paths.



Figure 1. Photos after heavy rains, May 2015; Kornelija Stankovića Street; Oslobođenja Boulevard; Partizanska street; Filipa Filipovića street.

Rainwater flowing out of the gutter with residential facilities, is directed to green areas and lawns. Manholes along the curbs are used to receive water that flows from the surface of roads and trails, but in some locations in Novi Sad there is a problem of water retention and flooding after rainfall of higher intensity.



Figure 2. Manholes along the road: Europe Boulevard; Janka Čmelika Street



Figure 3. Rigole: longitudinally along a residential street (Cankareva street); Stage center transverse (Janka Čmelika street); grid (right) -Olga Petrov Street

3. GREEN STREETS AND STORMWATER MANAGEMENT

Green Streets as part of the BMP (best management practice) represent a sub-category of higher principles and management system called "green infrastructure" [6]. Green infrastructure uses vegetation, land and natural processes for water management, thereby creating a healthier urban environment. At the level of the city or state, green infrastructure refers to natural areas that provide habitat, flood protection, cleaner air and cleaner water. At the neighborhood level, or specific locations, green infrastructure refers to stormwater systems for water management, that imitate natural absorption and storage of water. City of Portland, as one of the leaders in the application of green street green systems defines

green streets as landscaped streetside planters or swales that capture stormwater runoff and allow it to soak into the ground as soil and vegetation filter pollutants. Green street consider rain as a valuable resource, not as a waste and are mostly implemented to be visible components of the infrastructure. Instead of the term "green street", often in the literature and practice green streets are also defined as "complete streets" or "sustainable streets" [7].

Beginning at the late 1990s, the city of Portland has begun a study on the improvement of the city in the management stormwater, in order to find solutions to its infiltration into the ground before it reaches the sewer system. By 2008, thanks to the campaign "From gray to green", urban landscape of Portland, contained more than 20,000 square meters of vegetation whose role was to manage rain runoff [8]. Many other cities in America have begun to follow the example of Portland in the implementation of this system, and of some European countries, program of stormwater management is applied in the UK, France, Sweden, Denmark, Germany, the Netherlands and many others.

The European Water Framework Directive 2000/60/EC and the European Directive on flood risks 2007/60/EC have set high standards on both issues. Urban StormWater Management (USWM) is an important issue in Europe both for the improvement of water bodies' ecological status and for flood protection. The European Water Framework Directive 2000/60/EC and the European Directive on flood risks 2007/60/EC have set high standards on both issues [9].

The role of plants to purify the air, mitigate the effects of heat as well as reduce energy needs, has long been known. Its ability to absorb water in large quantities is underestimated and underused. Many studies have shown that use of green areas can help mitigate runoff in a very cost-effective way [10].

Especially in cities, trees can largely control surface water runoff caused by heavy rains, like mini reservoirs. Rain gardens, for example as part of the green street can infiltrate 30% more water than regular lawn [11]. Green streets can manage stormwater on public roads, residential areas, alleys or other parts of the city [12].

Elements of green street consists of containers for collecting water, rain gardens, specially selected vegetation, permeable surface layer, permeable soil, and others. Green streets as a system can be applied to public and private areas, at the level of the garden, street, block, city as well as the state.

4. ANATOMY OF GREEN STREETS: STREET DESIGN ELEMENTS FOR STORMWATER MENAGMENT

When it comes to green street design, the most innovative solutions are offered by the mentioned Portland city. The new Portland urban planning, indicates that the streets in the city center, despite the large urban demands can retrofit, not only for stormwater runoff, but also for the care and preservation of living space of a new pedestrian street plan, for which the city of Portland received national and international recognition [13]. This adaptable plan includes a variety of green spaces and alternative modes of transport. In conventional street design, stormwater runoff is directed into pipes. With green streets, runoff is directed into landscaped areas, captured and absorbed into the ground as plants and soil filter pollutants [14].

Green streets consists of many design elements. They may differ in shape and space requirements depending on their purpose, but all provide stormwater benefits. In order for successful planning, this systems must be well planned and designed. The positive side of green streets are that they are environmentally friendly, can be applied everywhere, they are economic and specify all the important roles of greenery, which is not only "decorative" element of the urban landscape. In addition to the characteristics of the buffer zone, green schemes have a role in increasing road safety, considering it to form a calm image of the landscape and direct the driver to concentrate on traffic [15].

4.1. FLOW-TROUGH-PLANTERS

Planters are narrow, flat-bottomed, often rectangular, landscape areas used to treat stormwater runoff [15,16]. They belong to bioretention systems, and their main characteristics vertical side walls. They can be set to or above ground level. Planter are filled with gravel, soil and vegetation, and usually do not infiltrate water. Their role is temporary storage of stormwater on top of the soil and filtering pollutants with gradual passage of water through the planter. Excess water is collected in a perforated pipe at the bottom of the planter and leads to transmission (sewage) systems. Planter may be different shapes and sizes and are made of stone, concrete, brick or wood. Narrow, residential streets and parking lots where space is often limited, are best places for their implementation because they can fit into existing utilities, trees, furniture, etc. They often have a curb opening that directs runoff from the street into the planter [16].

4.2. VEGETATED SWALES

Vegetated swales are usually narrow, shallow landscaped depressions with a slight longitudinal slope. Water that flows through a vegetated swale, it is slowed by the interaction with plants and soil, allowing sediments and associated pollutants to settle out [16]. Most frequently are applied along the streets and parking lots with a steeper conditions up to 5% longitudinal slope. The greater the surface depression is, the more quantitative and higher retention and filtration of water is. The vegetation that can be applied in these depressions are mostly ornamental grasses, rushes, shrubs and ground covers. In urban conditions the best places for implementation can along the streets with the broad cross-section (boulevards) or medians, and center lanes. If the soil has poor infiltration capacity, the design of vegetated swale can contain underground pipes.

4.3. STORMWATER CURB EXTENSION

The role of curbs as a supporting element of roads, is visual and physical separation of areas intended for motor vehicles of trails for pedestrians and cyclists. In a system of green streets, the role of curbs completely changes its character. Curbs extensions (ie. stormwater curbs) have a function as stormwater facility, while still providing traffic calming. They are enclosed by a curb on the street side, which has openings, called "curb cuts". Curb extensions can be implemented in a variety of land uses from low-density residential streets to highly urbanized commercial streetscapes [17,18]. Curb extensions can be fitted into the existing infrastructure with minimal investment.

Below: Rain gardens, cross-section and examples in urban areas.

Rain gardens are not wetlands, but they are designed to periodically be under water, therefore plants that thrive in such conditions like wetlands, would be unable to survive in rain gardens. When choosing plants for rain gardens, priority is given to native plants that are adapted to drought conditions and occasional rain as well as intense flooding. Surface of rain garden should absorb 70-85% of the water that enters through the rain to the ground, temporarily retained and filtered [20].

Rain gardens are taking shape in the form of mild depression, in order to accommodate a greater amount of water infiltrated into the soil. Except in private gardens, there is an increase use of these systems in urban conditions. Also, as a part of green streets, often applied elements, are permeable materials that allow rainwater to pass through their surface layer, and also accumulate harmful metals from the roads.

More often, permeable materials are use separately, as part of LID practices which describes approaches to planning and design of stormwater drainage with the practices of sustainable management of rain runoff.

5. IMPLEMENTATION OF GREEN STREETS ELEMENTS IN NOVI SAD - PROPOSALS FOR PLANNING AND RECONSTRUCTION OF EXISTING STREETS

In urban areas there is not enough space to set aside extensive green belts that will carry out the function of treating stormwater, as a "buffer" zone. Also, applied vegetation in these systems must be characterized by the ability to adapt quickly and develop in conditions which are often not the most encouraging. It follows, that finding space for the collection and stormwater management, may be a big challenge.

However, there are several options for the design of green streets elements, that Novi Sad can adopt even in the streets with little space. The key to creative thinking in finding a space that can be multipurpose, primarily requires an integrated approach, a detailed study of the natural and urban environmental conditions, as well as planners, designers and departments for water management cooperation, in order to find a balance between the stormwater management and street system design.

Residential areas (urban blocks) offer the greatest potential for the application of green streets, in the reconstruction of the street and initial planning. The application of green system is the easiest in areas where they are already present elements of the landscape (green bars, islands).

Elements of Green Street will find application in the newly designed streets, where the placement of underground installations facilities, is planned from the start. For streets with the existing utility of infrastructure, strategic analysis is required. Knowing that in Novi Sad there are areas where flooding occurs, the application of these systems could reduce the negative consequences of such rain events.

At the reconstruction of the existing streets, primarily is necessary to locate potential sites for "treatment" by identifying areas during heavy rainfall which are often flooded. Also, it is necessary to carry out street typology, based on the disposition, longitudinal and cross section, length, width, frequency, its importance, the functionality, presence of greenery, position, spatial design, presence of information etc. The next step would be analysis of groundwater, installation and infiltration capacity of the soil and finally, sizing system

with a catchment area (site acceptance of water), as well as indigenous plant materials, and indigenous plant materials, which will be applied in these systems. In the newly designed streets, the planning system to manage stormwater should be done at the same time with the street network planning, installations and construction of underground facilities. Solutions of green street design will be successful if their ultimate goal, which is to maintain the natural cycle of water circulation in the city, is achieved.



Figure 6. Some options for implementation of Green streets elements in Novi Sad: landscape median in residential streets and streets with high-density; along parking zones; in residential streets-sidewalks; between travel lanes and the side walk zone.

5. CONCLUSION

Implementation of Green Street elements on existing roads, acquired and planned urban core requirements, while meeting traffic and infrastructure demands, in an urban environment is a very complex task.

The practice of introducing sustainable, green system should be in addition to its primary role, the management of stormwater, and also to meet other functions of a street such as public transport, parking spaces, bicycle transport, pedestrians, access to buildings and other facilities. The solution method for the collection, treatment and disposal of stormwater in Novi Sad, while respecting the conditions for the release of waste water into the sewage system, it should be aimed at preventing the ordinary and accidental flooding and pollution of ground and surface waters. Stormwater from streets, terraces and other impervious surfaces should be clean-up to the level of quality that requires the recipient. Only such approach can provide and guarantee that pollution of ground and surface water will be mitigated.

The adoption of some solutions and practices from other countries, can improve the existing approach to solving the problem of drainage of rain water in Novi Sad in urban conditions. By making recommendations and draft legislation, adapted to local conditions and needs, modern systems for controlling the quantity and quality of runoff rain could be introduced as standard practice. Novi Sad can develop a sustainable program for the stormwater management, not only at local, but also urban and regional level, that would prevent periodic spills of sewage during heavy rains, and at the same time improve greenery in the city.

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ЗЕЛЕНЕ УЛИЦЕ КАО МОДЕЛ УПРАВЉАЊА АТМОСФЕРСКОМ ВОДОМ У НОВОМ САДУ

Резиме: Улица је основни градивни елемент сваког насеља. У физичком смислу, улице чине комуникационе површине које се састоје од: коловоза, бицикличких стаза, тротоара, паркинга, стајалишта и зелених површина (дрвореда, зелених трака, зеленог острва). Зеленило, као елемент улице, поред својих основних функција - изолација пешачких токова и ободних зграда од колског саобраћаја, стварање повољних санитарно-хигијенских и микроклиматских услова, може да врши и функцију апсорбовања и филтрирања атмосферске воде, настале као последица кише, топљења снега и сл. Појам „зелених улица” односи се на еколошке просторе, који нуде различита техничка решења за акумулацију атмосферских вода, као што су: контејнери за сакупљање воде, кишне баште, посебно одабрана вегетација, пропусни површински слој застора, пропусно земљиште и др. Зелене улице могу бити пројектоване, прилагођене различитим типовима улица и потребама саобраћајница или да се уклопе у већ постојећу уличну мрежу. Примарни циљ примене зелених улица јесте одрживо управљање атмосферском водом у урбаним условима, кроз процесе апсорбовања, филтрирања и пречишћавања воде, што доприноси повећању квалитета животне средине. Различита иновациона решења за имплементацију зелених улица, омогућавају претварање конвенционалних, постојећих, улица у еколошке оазе са вишеструким бенефитом, који се огледа у побољшању квалитета воде, ваздуха, смањењу топлотних острва, истичући све важне улоге зеленила, које више није само „украсни” елемент урбаног пејзажа. Овај рад бави се дефиницијом и идентификовањем кључних карактеристика зелених улица, типологијом, као и препорукама за побољшање постојећих уличних система у Новом Саду, применом зелених улица.

Кључне речи: зелене улице, атмосферске воде, одрживост, Нови Сад