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Influencing Factors and Strategies for Sustainable Urban Drainage System

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Abstract

Well-designed urban drainage systems are necessary to discharge wastewater and storm water. In rapid urbanizing areas, there is an increasing need to improve drainage capacity to reduce flooding, pollution, and risks to health, while the traditional and simply expansion and upgrade of existing urban drainage systems are not sufficient. This paper reviews the types of urban water drainage systems and the influencing factors from urban development, and summarizes the strategies and techniques of the Sustainable Urban Drainage System (Su DS). It is recommended combining Su DS techniques with a wider range of co-operations among public and private entities for better and holistic operations.

Keywords: Drainage system; Pavement; Urban water system

Urban Drainage System Overview

Hurricane Harvey is the costliest and wettest tropical cyclone on record in the United States, which made a landfall at Rockport of Texas in August 26, 2017 as a Category 4 hurricane, and subsequently led to a financial lose of about $200 billions. The major damages were due to the induced extensive flooding that was far beyond the capacity of the urban drainage systems in the greater Houston area [1]. While attempts were made to control water release from Addicks and Barker Reservoirs in the Buffalo Bayou watershed, the flood levels in the immediate area were still very high. The Addicks Reservoir in western Houston area reached its capacity in the morning of August 29, 2017 and began spilling out [2], which flooded many residential houses in its nearby areas. It is estimated that a total of twenty-five to thirty percent of land in Harris County (about 444 squared miles or 1,150 squared kilometers) was submerged [3]. This is one of the typical events illustrating how the urban drainage systems draw public attention and significantly affect human properties and even lives.

The urban drainage system is a major part of city infrastructure, which is imperative and necessary for the needs of interactions between human's civil activities and the water cyclation within and even beyond an urban area. The urban drainage system can drain surface runoff from urban infrastructures such as paved streets, parking lots, sidewalks, and building roofs during storm events.

There are two basic types of water to be drainage din an urban area:

I. wastewater; and

II. Storm water.

In order to maintain the needs of living standard and industry, water would be extracted from natural cycle, which should then be drainaged after use so as to avoid the pollution and risks to public health, and form the wastewater. The waste water could be formed from water closets, washing, industry, and many other sources, possibly containing dissolved materials, fine solids, and sometimes even large solids.

Another type of water drainage is the rainwater from any forms of perciputation on a built-up urban area. The storm water could cause inconvenience of lives, damage to infrastructures and properties, flooding (like the aforementioned one caused by Hurricane Heavy in Houston), and health risks. In urban areas, the covered land with impermeable surfaces would divert rainwater away from the local natural system of drainage, and avoid or at least reduce the damage of storm water [4].

Factors in Urban Development that Influence Water Drainage

The efficiency of an urban drainage system could be affected by many factors, such as climate, topography, geology, scientific knowledge, engineering and construction capabilities, societal values, religious beliefs, and others [5]. Urban development modified the living environment and affect water drainage in a number of ways. The increase in impermeable surfaces such as highway systems, parking lots, and conversion of woodland to high-density residential and commercial uses greatly reduce water infiltration into underground.

On the other hand, climate change induced increasing storm rainfall intensity has direct impacts on surface runoff [6-10]. The combined effects lead to more surface runoff, faster runoff concentration, and higher peak flow rate, and would reduce groundwater recharge. Thus, there is an increasing need to improve drainage capacity to reduce flooding in rapidly urbanizing areas.

Traditionally, the improvement of drainage capacity relies on expanding and upgrading the existing storm drainage system. However, this has been increasingly proven to be unsustainable, costly and even impractical, particularly in densely urbanized areas [11].

Strategies for Sustainable Urban Drainage System

Sustainable urban drainage systems (SuDS) have been highly promoted as an alternative and/or a complement to the traditional approach to address long-term sustainability in the design of the system. Unlike conventional drainage focusing on the "end-of-pipe" or "at the point of the problem" solutions [12], with small and decentralized techniques, sustainable drainage systems can largely alleviate the adverse impacts of non-point source pollution to urban water bodies [13-15]. Today's drainage solutions highlight the need to embrace multi-disciplinary approach in urban water management, such as runoff quality, visual amenity, recreational value, ecological protection and multiple water uses [16].

Practitioners in UK environment agency [17] developed the "surface water management train" concept to implement SuDS by the following three broad groups:

o Develop source control techniques, which includes green roofs, permeable pavements, rainwater harvesting, infiltration trenches, infiltration basins, etc. to reduce the quantity of runoff from the site. Source control and prevention techniques are designed to counter increased discharge from developed sites, as close to the source as possible and to minimize the volume of water discharged from the site. This offers the benefits of reduced flood risk and improved water quality. It helps to restore underground water resources and maintain flows in surface water courses during dry weather.

o Implement permeable conveyance systems, so as to slow the velocity of runoff to allow settlement filtering and infiltration. The main types of permeable conveyance systems are underground systems such as filter drains (or French drains), surface water swales.

o Provide Passive treatment systems, to collected surface water before discharge into groundwater or to a water body. Small scale systems such as filter strips, can be designed into landscaped areas and are sited upstream of other SuDS. Larger, 'end of pipe' systems usually involve storage of water in constructed ponds where natural purification processes can be encouraged. Constructed wetlands and ponds also provide the opportunity to improve wildlife habitat in urban areas. Additionally, ponds can be made into amenity features for the local community.

These are a flexible set of options that allow engineers to choose the most suitable combination of techniques to the circumstances of a particular site. Ghaniet al. [18] investigated several projects in Malaysia that apply components of SuDS, namely ecological swales, biofiltration storage, and Ecological ponds (Wetpond, Detention Pond, Constructed Wetland, Wading River and Recreational Pond) not only greatly helped solving flash flood problems but also water quality degradation at urbanized catchments.

In addition, many comprehensive urban drainage simulation models can be utilized to identify deficiencies, assessing alternatives to avoid sewer overflows, reduce risks to public health and to protect the environment from water pollution. Multi-objective optimization provides more rational and practical solutions compared to single-objective optimization problems [19]. With the particular design and right combination of SUDS techniques, and support and cooperation from a wide range of public and private organizations involved in urban development, the SuDS systems will operate holistically.

Conclusion

There are two types of urban drainage systems: wastewater and storm water. The wastewater drainage is to discharge the after-use water to avoid pollution and risks to health, while the storm water drainage is to bypass the rainwater on a built-up urban area. Urban development would affect water drainage and the environment in various ways, including the impermeable surface and climate change. The SuDS is an alternative and/or a complement to the traditional approach to address long-term sustainability with multi-disciplinary approach, such as runoff quality, visual amenity, recreational value, ecological protection, and multiple water uses. Typical sustainable techniques include: source control, permeable conveyance, and passive treatments. Comprehensive urban drainage simulation models have been developed to better assess the effectiveness of the SuDS. It is recommended combining SuDS techniques with the co-operations from a wide range of entities for better and holistic operations.

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