Quantifying the effectiveness of LID approaches for stormwater flows and water quality control

Estimation de l'efficacité d'une approche de type assainissement durable pour le contrôle quantitatif et qualitatif du ruissellement

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RÉSUMÉ

La conception des réseaux de drainage pluvial à base de conduites continue souvent de suivre les méthodes traditionnelles mises en place il y a plus de 30 ans. Mais l'utilisation croissante des approches de type assainissement durable a rendu plus complexe la conception des systèmes d'assainissement pluvial. Les techniques et méthodes utilisées pour la conception et le dimensionnement ont besoin d'être actualisées et de nouveaux outils sont requis. Les ingénieurs ont besoin de comparer les débits et concentrations de polluants avant et après développement d'un site. Pour faciliter cette tâche, un flux de travail est présenté. La situation initiale est d'abord considérée en calculant les débits et concentrations de polluants avant le développement. Ensuite la topographie locale est analysée pour identifier le positionnement idéal des ouvrages (i.e. techniques alternatives) et les volumes de stockage pour le contrôle des débits et de la pollution sont estimés. Une fois positionnées, les techniques alternatives sont connectées pour mettre en place une chaine de traitement et sont analysées en utilisant des pluies appropriées. Cette analyse permet ensuite la comparaison avec les conditions avant développement pour démontrer quantitativement l'efficacité d'une chaine de traitement pour le contrôle des débits et de la pollution. Cette approche facilite une implémentation efficace de l'assainissement pluvial durable.

ABSTRACT

The design of stormwater drainage networks with pipes and manholes continues to follow traditional methods, some over 30 years old. But with the rise of sustainable drainage initiatives, drainage design has become a lot more complex. We need to re-assess the analysis techniques we are using for design and equip ourselves with a new set of tools. Practitioners ultimately have to compare pre- and post-development flows and water quality for various SuDS practices. In order to do this a succinct workflow is presented. First the pre-development stormwater runoff and pollutant wash-off must be calculated to characterize the existing conditions. Then the site topography is analysed to identify the best placement of Sustainable Drainage Systems and the approximate volumes needed for flow control and pollutant management are estimated. Once suitable stormwater controls have been located on the site, they are connected together to make a treatment train and are analysed using appropriate local rainfall. This analysis allows to compare the pre-development site with post-development conditions in order to demonstrate, in a quantifiable way, an effective treatment train approach to flow and pollution control. This approach facilitates the effective implementation of SuDS and contributes to the mitigation of urban flooding and the protection of the water quality.

KEYWORDS

LID, stormwater management, SuDS, sustainable drainage, WSUD

1 INTRODUCTION

The design of stormwater drainage networks with pipes and manholes continues to follow traditional methods. The rational method is still in widespread use, together with one dimensional (1D) hydraulic modelling in some parts of the world. But with the rise of sustainable drainage initiatives under BMP (Best Management Practices), LID (Low Impact Development), WSUD (Water Sensitive Urban Design) and SuDS (Sustainable Drainage Systems), drainage design has become a lot more complex (WEF, 2014; Water by Design, 2014). We need to re-assess the analysis techniques we are using for design and equip ourselves with a new set of tools.

2 STORMWATER DESIGN TECHNIQUES

Stormwater has often been an afterthought in the development process, fitting unattractive ponds in a hidden away corner of land or burying storage tanks underground. Mismanagement of stormwater has increasingly led to issues with quantity (flash floods) and quality (increased levels of pollution in our streams, rivers and oceans). However, a change has been occurring worldwide, to take a more sustainable approach to stormwater management that recognizes multiple benefits (Woods Ballard et. al., 2015) as demonstrated in Figure 1. Here are a few arguments in favour of an updated approach to stormwater design:

- Moving from traditional drainage design methods towards Sustainable Drainage Systems (SuDS)
- The Rational Method is not always suitable and more complex methods are often required
- The physical representation of stormwater controls needs to be included
- The analysis of stormwater quantity and quality is necessary

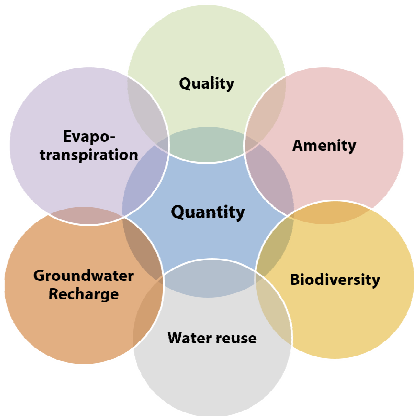

Figure 1 – The facets of stormwater control.

3 DESIGN WORKFLOW

Ultimately the design approach must be practical to build and operate the structure, and must demonstrate compliance with local requirements. Typically this may be to meet pre-development or existing conditions for water quantity (flows and volumes) and for water quality (pollution concentrations or percentage reduction goals). Whilst a number of spreadsheet tools exist to demonstrate part of the process, this tends to lead to a situation where stormwater controls are often designed individually, rather than building a complete treatment train approach that works better in practice. This can lead to confusion and increased costs.

A new tool, XPDRAINAGE, has been produced with an intuitive workflow (Figure 2) to guide the engineer or designer through the design process with visualization. This workflow is illustrated with some outputs from a 63 ha masterplan's case study in Houston, Texas. After importing surface data, and CAD or GIS data, a quick runoff analysis can be undertaken to assess where rainwater flows on the undeveloped site (Figure 3 left). The next step is to build a treatment train (Figure 3 right), as runoff areas drain into stormwater controls with pollutant concentrations tracked through each structure. A variety of hydrological methods are available, including SCS, to calculate the runoff. The tool can account for flows slowed through vegetation and filter media using a Muskingum-Cunge routing method and can limit flows based on one or more outlet controls such as weirs, orifices and gates.

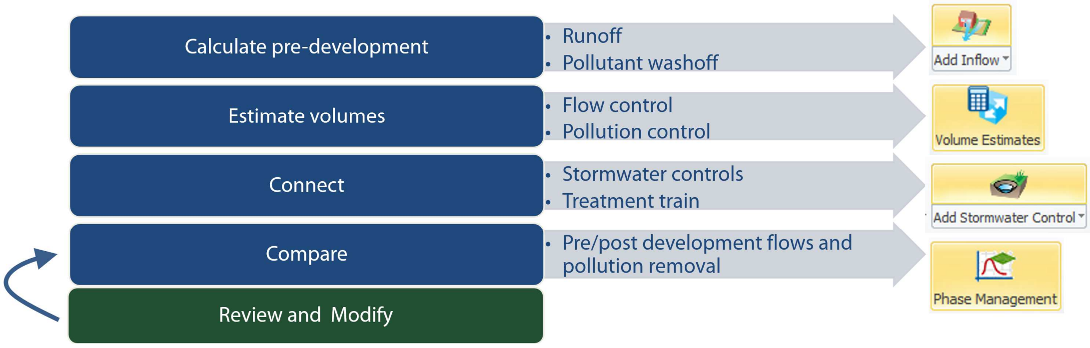

Figure 2 – Sustainable stormwater design workflow.

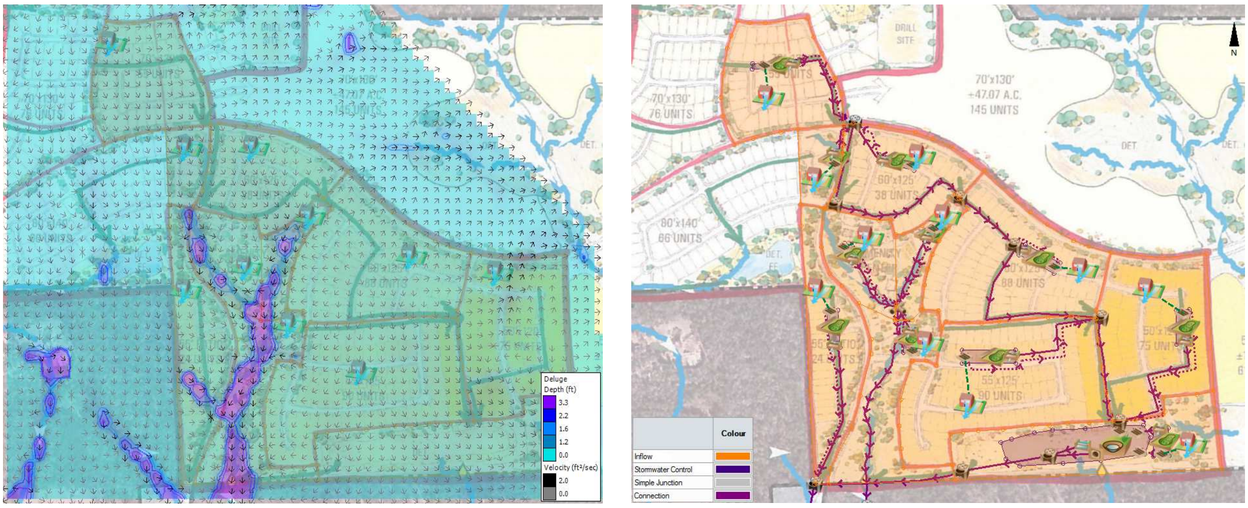

Figure 3 – Left, analysis of runoff flows and accumulation zones; Right, building the treatment train (Montgomery County, Houston, TX)

Most importantly the designer can see if the specified invert / soffit levels and calculated water levels are appropriate or adjust them in the Long-section Profile View, as shown in Figure 4. Finally, comparing the graphical results pre-and post-development allows to demonstrate the effectiveness of the design for mitigating increased flows and pollution concentrations (Figure 5). A more detailed case study can be found in a related Novatech 2016 paper (Jefferys et al., 2016).

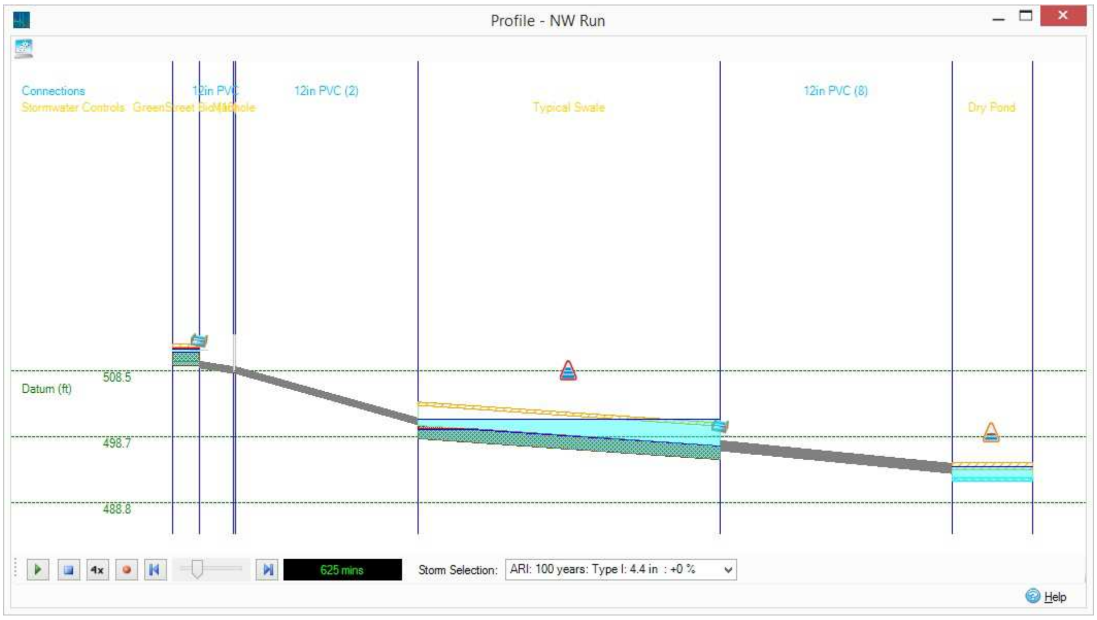

Figure 4 – Long-section Profile View.

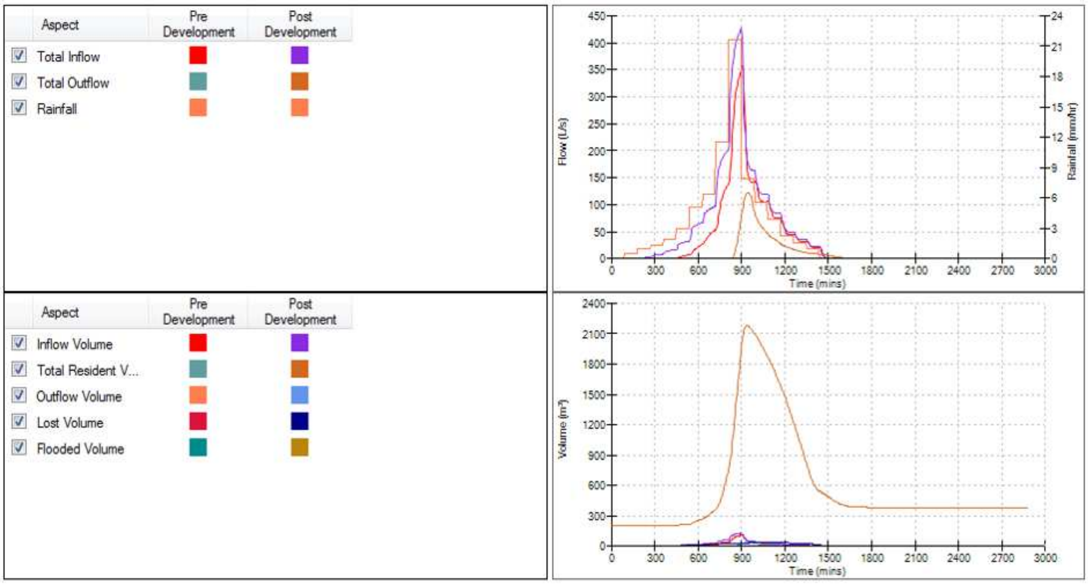

Figure 5 – Visualisation of the results.

4 CONCLUSIONS

Using a tool that allows visualization of the SuDS approach and dynamically analyses the hydrology and hydraulics gives more confidence in the effectiveness of the designs. Using XPDRAINAGE, this analysis allows the engineer or designer to compare the pre-development conditions with the post-development conditions in order to demonstrate, in a quantifiable way, an effective treatment train approach to flow and pollution control. This approach facilitates the effective implementation of SuDS and contributes to improving the mitigation of urban flooding and the protection of the water quality of receiving waters in a way that is affordable now and in the future.

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