

## **Characteristic Rain Events – A tool to enhance amenity values in SUDS-design**

*Événements de pluies caractéristiques - Outil pour améliorer la conception esthétique de techniques alternatives*

Jonas Smit Andersen<sup>1,\*</sup>, Sara Maria Lerer<sup>2</sup>, Hjalte Jomo Danielsen Sørup<sup>2,3</sup>, Antje Backhaus<sup>1</sup>, Marina Bergen Jensen<sup>1</sup>

<sup>1</sup>University of Copenhagen, Department of Geosciences and Natural Resource Management

<sup>2</sup>Technical University of Denmark, Department of Environmental Engineering

<sup>3</sup>Technical University of Denmark, Global Decision Support Initiative

\*Corresponding author: [josa@ign.ku.dk](mailto:josa@ign.ku.dk)

### **RÉSUMÉ**

La conception de techniques alternatives doit prendre en compte à la fois les événements pluvieux extrêmes mais aussi des événements fréquents de plus faible intensité afin de ne pas donner l'impression d'être vide et surdimensionné. La nouvelle approche Characteristic Rain Events (CRE) est développée pour répondre à ce défi. Le concept du CRE est basé sur les réponses hydrauliques des techniques alternatives pour différents domaines de fonctionnement afin de fournir aux paysagistes une gamme de situations tangibles pour la conception. Des événements pluvieux historiques sont sélectionnés pour représenter les 3 domaines définis par « l'approche en trois points » (3PA) : (i) Le domaine journalier, (ii) Le domaine de conception fonctionnelle et (iii) le domaine des événements extrêmes. Cet article explore la réponse hydraulique d'un jardin pluvial fictif pour quatre CRE : (a) une pluie commune de courte durée (b) une pluie commune de longue durée, (c) un événement pluvieux plus intense, moins fréquent et (d) un événement pluvieux extrême. Les résultats sont comparés par rapport à la durée d'utilisation (présence d'eau), la profondeur d'eau, le volume de rétention, le volume de débordement, etc. L'approche CRE démontre un potentiel pour améliorer la conception esthétique des techniques alternatives.

### **ABSTRACT**

To overcome the challenge of designing good-looking open detention/retention areas in the urban landscape that can manage stormwater runoff from both the large, rare events and the frequent smaller events without looking empty and oversized a new approach referred to as Characteristic Rain Events (CRE) is proposed. The idea of the CRE is to demonstrate the water dynamics of a detention/retention area in a number of characteristic situations, in this way allowing the designer to work in a more tangible way with the design. Based on historical rain series single events are selected, representing the day-to-day domain, the design domain and the extreme domain as defined in the Three Point Approach (3PA). In this paper the ability of CRE to unfold the water dynamics of a detention/retention area is investigated by applying four CRE to a fictive rain garden including frequent, short event, a frequent long event, a seldom heavy event and a rare extreme event, and comparing resulting numbers for time with standing water, water depth, retention volume, overflow volume etc. The CRE approach is concluded to hold potential for improving the design process and thus the final design of detention-retention areas.

### **KEYWORDS**

Amenity value, Design tool, Landscape design, Three Points Approach, Transdisciplinarity

## 1 INTRODUCTION

When employing open detention-retention areas for urban stormwater management amenity values may be enhanced by informed decisions on water levels, e.g. for staging the water, in the design. An approach on how to do this is provided in the North American Best Practice (Echols and Pennypacker 2008) where a number of well-described goals, objectives and design techniques are described. However, to achieve this enhanced amenity value it is crucial to cope with stormwater dynamics in the design process. Backhaus and Fryd (2013) show examples of less successful designs like detention ponds appearing oversized and concrete gutters receiving no water due to upstream infiltration in raingardens. The explanation of this disproportion is that measures are carefully designed by engineers to manage seldom large events while the architects were lacking tools for designing for the small frequent events (Backhaus, Dam, and Jensen 2012). The above studies point to stormwater management having a large potential in adding amenity values to landscape design, but only if due attention is paid to the huge variability in the precipitation patterns.

The Three Points Approach (3PA) is a qualitative model, developed to help distinguish between different types of precipitation. This is done through the definition of three precipitation domains: the Day-to-day domain, the Design domain and the Extreme domain. The 3PA has successfully been used for inter- and transdisciplinary communication in SUDS-projects (Fratini et al., 2012). The 3PA has been further developed to quantify the domains based upon a statistical analysis of long historical time series. This quantification can result in simplified synthetic block rains, which makes the model suitable in engineering design practice (Sørup et al., in prep.) However, these synthetic block rains do not reveal variations in the rainfall pattern which are important for the aesthetic design of SUDS. Historical events in contrast can provide a tactile image of rain. In this study, the quantified 3PA domains have been used as the basis for distinguishing between precipitation types when selecting historical rains to characterise the precipitation pattern.

The architectural design process can be understood as a series of explorative experiments, staged in a solution-oriented approach (Schön 1983). The design-solution is evaluated by actively situating the design ideas in different scenario settings to gain information on their suitability to cope with the specific conditions. Characteristic Rain Scenarios is intended to support such an approach in SUDS-design, by provide a number of selected historical rain events to form relevant design-scenarios and thereby test the designs amenity value under different conditions.

## 2 METHOD

The value of the Characteristic Rain Scenarios-approach is illustrated by applying it to a fictive case in form of a rain garden.

The historical rain events to represent CRS must be selected to cover all three domains in the 3PA. In addition, they should result in varying performance of the raingarden. Based on these considerations the following four CRS are defined: A) Frequent short events, B) Frequent long events, C) Seldom heavy event and D) Rare extreme events. Considered jointly these four situations are assumed to cover the most relevant performance aspects of the raingarden.

The corresponding CRS are selected from a 35 year long time series. The individual events are separated by at least 24 hours of dry weather.

The raingarden is designed to manage the runoff from a 500 m<sup>2</sup> catchment during a 10 year event. The raingarden has an infiltration surface of 50 m<sup>2</sup> and the infiltration capacity is 5\*10<sup>-6</sup> m/s. The depth needed to provide the adequate detention volume of the raingarden is determined using the Danish standard design tool for this purpose, LAR-regneark. (IDA, 2011).

## 3 RESULTS

The characteristics of the four CRS and the resulting performance of the raingarden are listed in Table 1 along with the characteristics for the 10-year design event.

The four CRS result in four very different types of performance for the raingarden. Most notable is the varying utilisation of the storage volume: in scenario A and B there is only little water in the raingarden (7% storage over 1.5 hours and 0.6% storage over 6 hours, respectively). Scenario A and B are in the day-to-day domain, where rainfall commonly result in none or temporary small amounts of standing

water. In scenario C (62% storage over 20 hours) the raingarden is partly filled. This illustrates that the water level in the raingarden will only seldom rise to the gardens full capacity. In scenario D storage is filled completely and water will be standing over 40 hours. Scenario D is the most extreme event measured in Copenhagen, Denmark. This scenario results in massive overflow, yet approximately 50% of the stormwater is managed in the rain garden. Figure 1 illustrates the visualization of this last scenario. It shows that overflow happens for a relatively short period where the rainfall is most intense and the raingarden capacity is quickly exceeded.

Table 1 Results of testing a raingarden with the classical design rain and the defined scenarios.

	Classical design event	Scenarios with real rainfall events			
	Synthetic design event (T = 10y)	Scenario A: Frequent short event	Scenario B: Frequent long event	Scenario C: Seldom heavy event	Scenario D: Rare extreme event
3PA domain	Design	Day-to-day	Day-to-day	Design	Extreme
<b>Rainfall characteristics</b>					
Depth [mm]	44.1	4.3	11.2	30.6	151.8
Duration [min]	420	155	1910	240	2335
Intensity [ $\mu\text{m/s}$ ]	1.75	0.47	0.1	2.13	1.08
Approximate return period [y]	10	~0.1	~0.1	~5	>100
<b>Raingarden performance to stormwater flow characteristics</b>					
$Q_{in,max}$ [l/s]	0.96	4.3	0.58	8.43	21.27
$Q_{infiltrate,max}$ [l/s]	0.25	0.25	0.25	0.25	0.25
$Q_{overflow,max}$ [l/s]	0.00	0.00	0.00	0.00	21.02
Used volume [%]	83	7	0,6	62	100
Standing water [min]	1615	95	345	1120	2865
$V_{in,total}$ [ $\text{m}^3$ ]	24.2	2.4	5.3	16.8	83.5
$V_{infiltrate,total}$ [ $\text{m}^3$ ]	24.2	2.4	5.3	16.8	41.9
$V_{overflow,total}$ [ $\text{m}^3$ ]	0.0	0.0	0.0	0.0	41.6

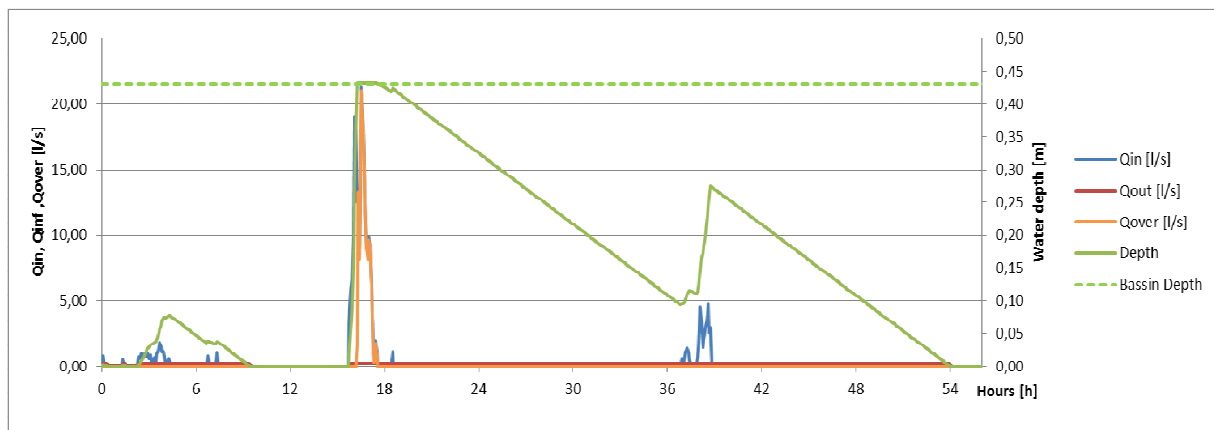


Figure 1 Example of the visualization of the scenario D event applied to the raingarden.

Figure 1 visualizes stormwater dynamics of the raingarden under scenario D (rare extreme event). The water level in the raingarden will under this scenario considerable overflow, by exceeding the raingardens storage volume at approximately 18 hours, but otherwise exploit the raingardens volume suitably. This chart-based way to present results of CRS, is embedded on top of the standard design tool, thus the visualization of CRS is automatically generated while a raingarden design is conducted.

When the characteristic and performance of the synthetic design-event are compared with the four historical events (CRS) it becomes apparent that CRS provide tactile images of different rainfall events

in contrast to the simplistic block rain.

## 4 DISCUSSION

The study has uncovered four significantly different performances of the fictive raingarden. This shows that just four carefully selected historical events (CRS) can exemplify the variety in stormwater dynamics of a SUDS-element. The different kinds of performances can raise questions in the design-process such as “How much water can usually be expected?”, “How will the design perform during an extreme event?” and “Which plant species will be suitable to the humidity conditions in the raingarden?”. However it is important to emphasise that CRS cannot stand alone in the process of designing SUDS, a tool based on statistics is still required for sizing to a certain return period.

It is possible to achieve similar results by using long-term time series for design evaluation. However such a dataset will often not be manageable by architects and the large output will be cumbersome to analyse. With the CRS approach a shortcut to the evaluation process is provided. The data is rapidly reduced to a few but essential outputs and thus easy to understand and use by non-hydrologists, such as architects and designers.

The charts displaying the stormwater dynamics allows a visual way to distinguishing between the different scenarios and the resulting performance. These pictures may be obvious for engineers familiar with statistic, but to other disciplines the visual result a crucial basis for understanding, discussing and solving a design problem.

Additionally, in international SUDS-project CRS can potentially be used to clarify the design objectives to practitioners coming from different climatic zones. The CRS may be an approach to answer the complex question: “What is rainfall like in this region?”. Adapting CRS to other climate zones will, however, require thorough statistical analysis of long term rainfall measurements, as has been done for Denmark prior to this study.

However, the selected CRS have not yet been proved to represent the entire rainfall time series fairly. A more thorough analysis of the precipitation patterns will be made to confirm the reliability of the method. We also plan to let architects test the method in order to study and document its benefits in the design process, following the concept of staging explorative experiment.

## 5 CONCLUSION

This study presents the idea of using Characteristic Rain Scenarios to embed knowledge on stormwater dynamic into the design process of SUDS. Applying the idea to a fictive raingarden using only four historical rains representing different precipitation domains returns promising results in that the differences in water dynamics are clearly illustrated. To standardise the approach more statistical analysis of the sensitivity of the result to the selection of historical events are needed.

## LIST OF REFERENCES

- Backhaus, A., and Fryd, O. (2013) The Aesthetic Performance of Urban Landscape-Based Stormwater Management Systems: A Review of Twenty Projects in Northern Europe. *Journal of Landscape Architecture* 8 (2): 52–63. doi:10.1080/18626033.2013.864130.
- Backhaus, A., Dam, T., and Jensen, M.B. (2012) Stormwater Management Challenges as Revealed through a Design Experiment with Professional Landscape Architects. *Urban Water Journal* 9 (1): 29–43. doi:10.1080/1573062X.2011.633613.
- Echols, S., and Pennypacker E. (2008) From Stormwater Management to Artful Rainwater Design. *Landscape Journal* 27 (2): 268–90.
- Fratini, C.F., Geldof, G.D., Kluck, J and Mikkelsen, P.S. (2012) Three Points Approach (3PA) for urban flood risk management: A tool to support climate change adaptation through transdisciplinarity and multifunctionality. *Urban Water Journal*, 9(5) pp. 317. doi: 10.1080/1573062X.2012.668913.
- IDA, 2011. IDA Spildevandskomiteen – LAR-regneark (in English: The Water Pollution Committee of the Danish Society of Engineers – Dimensioning local stormwater management systems – spreadsheet). [http://ida.dk/netvaerk/fagtekniskenetvaerk/energimiljooguland/spildevandskomiteen/Documents/SVK\\_LAR\\_Dimensionering\\_v1\\_0.xls](http://ida.dk/netvaerk/fagtekniskenetvaerk/energimiljooguland/spildevandskomiteen/Documents/SVK_LAR_Dimensionering_v1_0.xls) (accessed 27.11.15) (in Danish)
- Schön, D. (1983) *The Reflective Practitioner – How Professionals Think in Action*. Basic Books, USA.
- Sørup, H.J.D., Lerer, S.M., Arnbjerg-Nielsen, K., Mikkelsen, P.S. and Rygaard, M. (in prep.) Efficiency of stormwater control measures under varying rain conditions: Quantifying the Three Points Approach (3PA).