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# Implementation of infiltration in surface runoff models during short heavy rainfall events

*Jannis Valldorf* [1, *], *Svenja Kemper*[1] https://orcid.org/0000-0002-5079-9215
*& Andreas Schlenkhoff*[1] https://orcid.org/0000-0002-5142-508X

[1] *University of Wuppertal, Hydraulic Engineering Section, Wuppertal, Germany*
**Corresponding author email: valldorf@uni-wuppertal.de*

## Abstract

In a sub-catchment area of the river Wupper in the urban area of Wuppertal, Germany, a hydrodynamic 1D/2D dual drainage model is set up and calibrated by means of the infiltration during a heavy rain event on May 29, 2018. It turns out that even during a heavy rain event in an urban area, a significant proportion of the precipitation infiltrates. In order to estimate infiltration processes during short heavy rain events, established field tests are first examined and evaluated with regard to their applicability to the context of heavy rain events. A physical model is set up in laboratory to verify infiltration processes during heavy rain events by varying individual parameters. The overall goal of the presented study is to develop an easy-to-carry field test that provides information about the infiltration processes depending on site-specific parameters during heavy rain events. Based on the results an infiltration approach will be developed to be used either in 2D urban flood modelling or 1D/2D dual drainage models.

## Highlights

- A 1D/2D dual drainage model is calibrated to a heavy rainfall event by means of infiltration.
- Infiltration has a significant impact on the water balance of the heavy rain event.
- Established field tests have clear weaknesses in the context of heavy rainfall events

## Introduction

Infiltration during short rain events is particularly difficult in small catchment areas, by which infiltration processes are often neglected in urban flood simulations (MULNV, 2018). In addition, established software usually offers limited infiltration approaches, e.g. ++ Systems (Tandler.com GmbH), where important boundary conditions such as flow depths weren't considered. The aim of the present study is to investigate the importance of infiltration in urban areas during heavy rainfall events and how it can be included in urban flood modelling.

## Methodology

A 1D/2D dual drainage model of an urban area of the 1.7 km² sub-catchment area of the river Wupper in Wuppertal, Germany is built up using the ++Systems software GeoCPM v.13.0 (Tandler.com GmbH), see Figure 1. The 2D surface model is irrigated with a past heavy rain event on May 29, 2018 which is recreated using hydrographs from raingauges and radar data. The average intensity is 88 mm of precipitation in 94 minutes. The capacity of the sewer network is estimated with general assumptions. The 2D model is calibrated by means of infiltration. Calibration points are located at hot spots detected using video and photo recordings with a temporal classification of the heavy rain event (Figure 1, right).

Water depths derived from the photos and video recordings are used to determine the water levels at defined times and places. With this information, the infiltration processes during the pluvial flood event in an urban area can be estimated.

**Figure 1.** overview of the 2D model (left), video records of the heavy rain event (right).

The analysis of the numerical simulation shows that around 18% of the precipitation is infiltrated in the presented case, which is a significant proportion and cannot be neglected in urban flood modelling in general.

## Laboratory Model Setup

It is being investigated whether established field tests achieve meaningful results in the context of short heavy rain events and whether infiltration parameters for 2D surface runoff models can be derived from these. In order to estimate the infiltration processes during short heavy rain events even without calibration data from passed events, it is investigated if the easy-to-carry out field test of the double-ring-infiltrometer can be applied in the context of short heavy rain events. For this purpose, a laboratory model is set up which reflects the boundary conditions of the double-ring-infiltrometer test (see Figure 2).

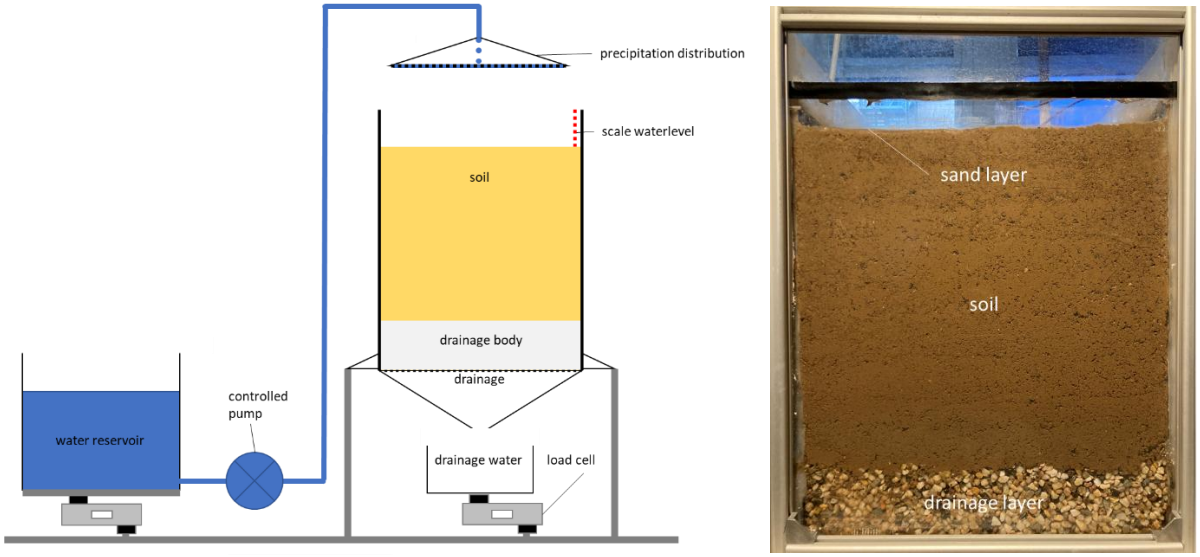


**Figure 2:** laboratory model based on the double-ring-infiltrometer-test

## Results and discussion

While comparing the drainage and the water depth it turns out that the infiltration rate corresponds directly to the affected water depth (Figure 2 – see "scale waterlevel" und see Figure 3). A water column is not considered as an applicable boundary condition in the context of short heavy rain events, since water depths of between 5 and 10 cm are usually not achieved over a wide area and long time in case of urban pluvial flooding with short and intense rainfall.

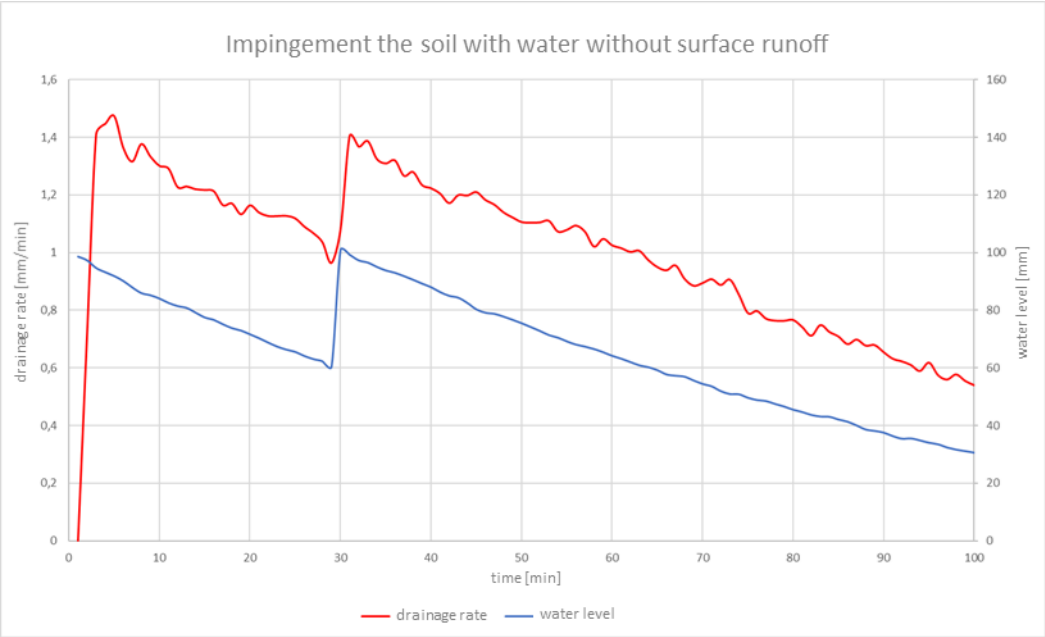


**Figure 3:** Comparison of water depth and drainage rate using the laboratory test based on the double-ring-infiltrometer-test

Therefore, another laboratory model test must be developed with which it is possible to determine infiltration parameters even without an existing water column. In case of initial orientation tests, a 2 m² soil sample is taken from the project site as undisturbed as possible (see Figure 4, left) and is installed in a laboratory lysimeter (see Figure 4, right). Varying boundary conditions of the model are the soil moisture, the slope of the soil sample and the intensity of precipitation. The soil moisture will be measured in different layers. Additionally, infiltration parameters such as inclination will be measured during the model test runs.

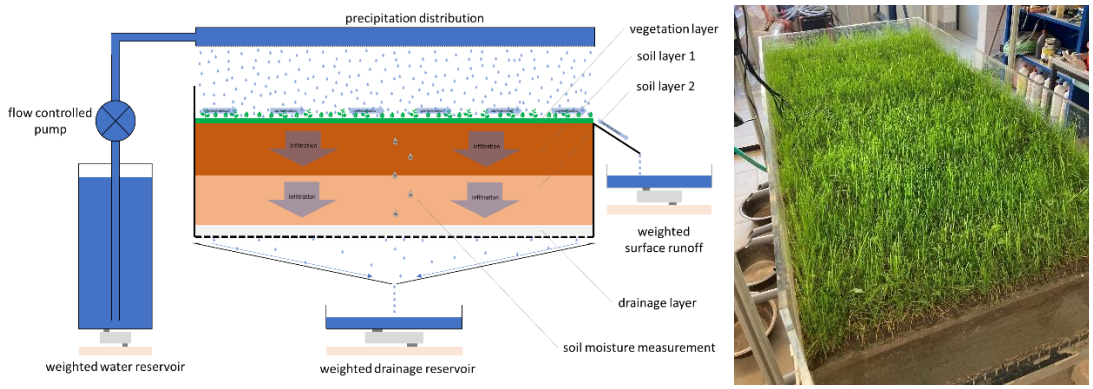


**Figure 4:** schematic setup of laboratory experiment (left), laboratory experiment with soil sample (right)

## Conclusions and future work

The analysis of a 2D surface runoff simulation of an urban area with pluvial flooding has shown that infiltration is a non-negligible component of the water balance during heavy rain events in urban areas and therefore adequate field tests are necessary to build up realistic urban flood models, e.g. to simulate and quantify the effectiveness of nature-based solutions in order to reduce urban flooding (Neumann et al., 2024). Laboratory studies under the boundary condition of the double-ring-infiltrometer have shown that the water column present in the double-ring-infiltrometer test has a significant influence on the derived infiltration parameters. Therefore, laboratory tests adjusted to the short heavy rain event boundary condition will be developed to investigate the influence of key parameters on infiltration. Based on the laboratory model an easy-to-carry field test will be developed with which specific infiltration parameters of a project area can be gained to be implemented in a 2D urban flood model setup.

## References

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