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Amr Ghazal

Urban Flood Protection in Arid Regions

Stormwater Management has become a major challenge in urban areas. Urbanization considerably transforms the natural water cycle to an urban water cycle resulting in increasing the ratio between the impermeable to the permeable surfaces in the catchment.

Warum habe ich mich um den Nachwuchspreis beworben?

„Ich war beeindruckt von der Idee, meine Arbeit im wwt-Magazin zu präsentieren. Ich fand es eine gute Gelegenheit, meine Arbeit mehr Menschen vorzustellen, die sich für den Bereich Hochwasserschutz und Regenwassermanagement interessieren."

This transformation mostly leads to a significant decrease in infiltration and evaporation, a considerable increase in the surface runoff amounts and flows, and at the end may increase the possibility of flood occurrence. Not only humid regions are susceptible to urban flooding problems, but also arid and semi-arid regions might be exposed to flood risks. The main issue is that the arid regions are usually less ready to face such kind of occasional risks with respect to the absence of flood mitigation plans and the lack of proper maintenance for the existing systems. Thus, when the flood risks occur in an arid city, most of the time the consequences are devastating.

Pilot study King Fahd suburb in Dammam (Saudi Arabia)

Although Saudi Arabia is one of the most extreme arid regions, the kingdom has suffered from severe flooding events in the recent years. Urbanization and climate change have been the main triggers for these flooding hazards. Many studies have been carried out recently in Saudi Arabia to introduce flood adaptation solutions. Yet, most of these practices have focused on the traditional mitigation techniques such as conventional stormwater networks and flow diversions. After reviewing the previously published literature and practices pertaining to flood protection in arid regions, especially the ones related to locations in Saudi Arabia, this study was carried out. The main aim of the study was to fill the gap in the previous practices through evaluating the possibility of implementing Sustainable Urban Drainage Systems (SUDS) in arid regions with consideration of climatic and landscaping conditions of such dry areas.
Dammam city is the capital of the Eastern Province and one of the major cities in Saudi Arabia. The city has been prone to urban flooding in the recent years. King Fahd Suburb (Figure 1) is a neighborhood (35 km²) in Dammam for which the local authorities are seeking urban flood protection solutions. The neighborhood was chosen as a case study for this research. The scope of the study included:

- the evaluation of the hydrological status of the neighborhood,
- the investigation of the basic flooding conditions that may occur within the district with no consideration of any mitigation measures,
- the proposal of two flood mitigation strategies using SUDS and observing their hydrological impact, and
- the assessment of the combination of these decentralized systems with the conventional networks system.

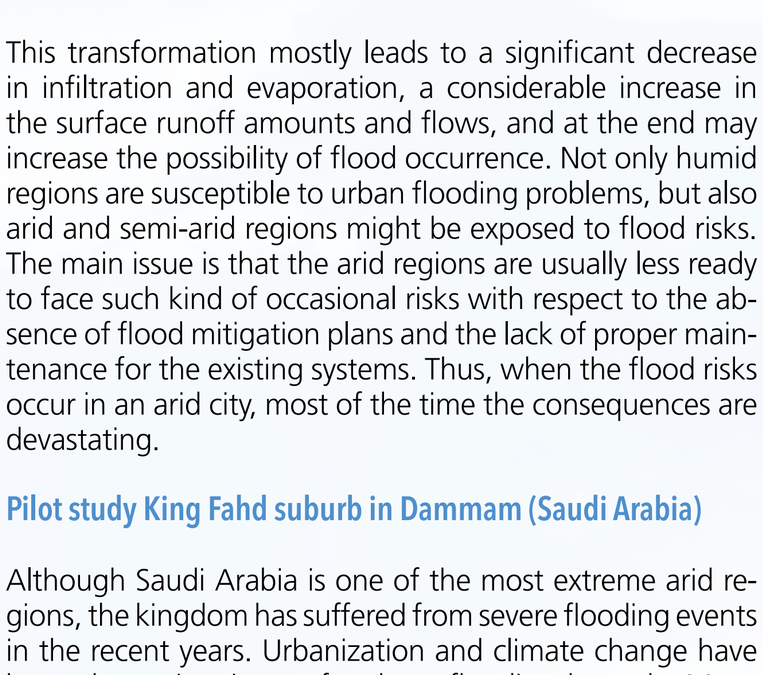

Figure 1 King Fahd Suburb and the neighbouring fluvial catchments (from ArcGIS)
Source: Ghazal

Structure of the models

The study area of this thesis is an urban district with a complex land use distribution, which consists of various impermeable surfaces such as streets, walkways and buildings. For such urban areas, the stormwater runoff is basically multi-directional with no dominant pathway. Therefore, the main method used during the thesis work was implementing a high-resolution 2D hydrodynamic model as a flood simulation method across the neighborhood using Infoworks ICM software. At first, the software was used to setup a hydrological model to calculate the runoff of the neighboring catchments flowing toward the suburb and deliver it in the 2D hydrodynamic model. The 2D simulation consisted of two stages. The first stage was to set up a model to simulate the surface runoff across the suburb to determine the basic flooding conditions by applying direct rainfall (pluvial flooding) and introducing the runoff from the neighboring catchments (fluvial flooding) to the model domain without implementing any mitigation measures. In the second stage, the software was used to model the proposed mitigation strategies and evaluate the effect of implementing these solutions on the model results.

Analysis and evaluation of adaptation measures

Two flood mitigation strategies using SUDS were tested. Strategy 1 comprised using rainwater harvesting from rooftops using cisterns, in addition to implementing of rock-lined swales along the medians of the main streets within the neighborhood to increase infiltration and surface storage. On the other hand, Strategy 2 included employing permeable pavements covering various surfaces within the neighborhood to increase infiltration as well.
The achieved flood mitigation levels after implementing each strategy were investigated through the results of the 2D simulations. Furthermore, a brief assessment of the two strategies was done with regard to impacts on the water quality, maintenance requirements and rough cost estimates. The outcomes of the simulations (Figure 2) showed that Strategy 1 could achieve intermediate flood mitigation and pollutants removal levels especially for rainfall events of short and intermediate return periods. On the other hand,

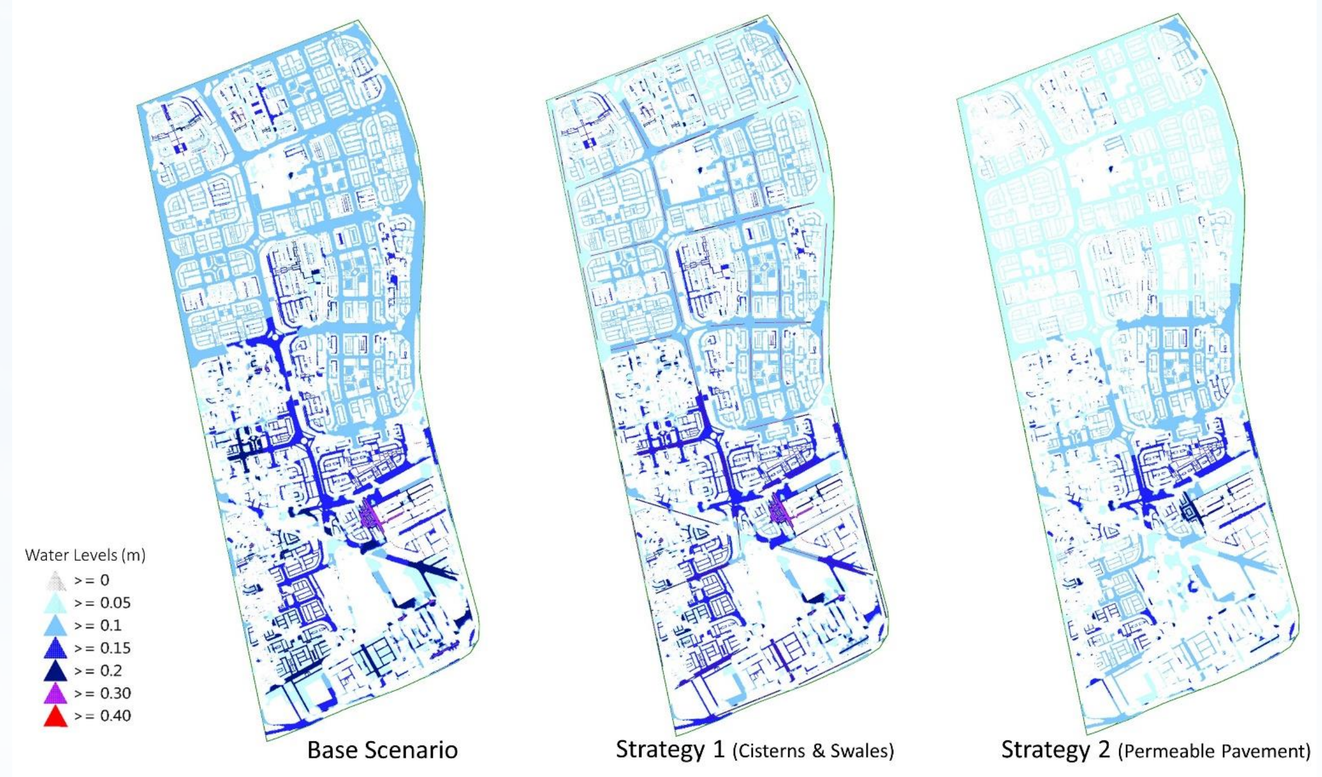

Figure 2 Results of different scenarios of the 2D hydrodynamic simulations for the 100-year event (from Infoworks ICM)
Source: Ghazal

Strategy 2 has proven to have high performance in terms of reduction of runoff volumes and pollutants against all return periods. Nevertheless, the cost analysis showed that implementing Strategy 2 might require much higher investments than Strategy 1. On the other hand, both strategies showed high potential of achieving sufficient mitigation levels against the intermediate and long return periods when combined (separately) with the conventional network systems as a flood adaptation strategy.

Outlook

At the end, the study gave a brief idea about the potential further practices (outlooks) addressing:

- performing coupled 1D & 2D models for better understanding of the combination between SUDs and the conventional drainage systems,
- the role of groundwater modeling when considering infiltration solutions, and
- the significance of evaluating the impact of the proposed flood mitigation strategies on the quality of the receiving surface and sub-surface water courses.

This research was a pioneering study combining hydrological and high-resolution 2D hydrodynamic model for detailed analysis of SUDs measures especially in arid environments. It can be also considered as a key study for further practices which can be carried out in similar approaches in other (semi-) arid regions. Furthermore, the study introduced a step by step catalogue to set up a 2D hydraulic model, in addition to technical capsules (through the literature review) related to important aspects in the field of stormwater management and flood protection such as: urban hydrology, the evolution of urban drainage systems, and the hydrodynamic modeling approaches and their functions.

■ *Amr Ghazal*
Ing.-gesellschaft Prof. Dr. Sieker mbH
amrsamir1990.eng@gmail.com

Supervisor of the master thesis

Prof. Dr.-Ing. Heiko Sieker
(Ing.-gesellschaft Prof. Dr. Sieker mbH)
Prof. Dr.-Ing. Reinhard Hinkelmann
(TU Berlin)