Executive summary

Poor or lacking urban drainage systems increase the risk of urban floods, especially in cities where the population is growing fast. Ghana's capital Accra, as many other African cities, is periodically subject to strong flooding that claim victims, cause health risks through contaminated overflows, and undermine economic activities. Dense and paved urban landscape reduces the infiltration capacity of the soil, inadequate drainage infrastructure limits the retention of flood water, and the lack of institutional coordination leads to weak management of the services. In addition, the accumulation of solid waste in the drains poses a risk for people's health and reduces the capacity of the drainage system.

All these factors, within a scenario of increasing climate variability and more intense rainfall, are considered in the present study to (a) analyze the flood risk and assess the causes of urban flooding in a pilot area in Accra, using an innovate and integrated approach; and to (b) develop a methodology for urban flood risk assessment that can be applied in other African cities facing similar issues. This research is carried out by students from Delft University and Kwame Nkruma University of Science and Technology (KNUST) and is supported by a cooperation of consultants and funding organisations. The research consists of collecting and organizing relevant technical and social information, in a typical data-scarce context, to answer two research questions: (1) what are the causes of floods in Accra; and (2) what are useful elements in developing a methodology for flood assessment in African cities.

The flood assessment is executed through different activities, from institutional, technical and social angles. Those activities include: *stakeholder consultation; technical and social fieldwork* in a neighborhood scale pilot area - the districts of Alajo and New Town in Accra - to collect technical data and other information; *flood assessment modelling,* by developing a hydrodynamic model based on collected field data; *awareness creation* to bring topics of flood and waste management under attention by engaging with the community and participating in local initiatives; and s*ocial media experiments,* to test the feasibility of gathering georeferenced data from citizens through social media as WhatsApp and Facebook.

To carry out the activities, preparatory steps, background analysis and preliminary studies are completed in advance of organizing the fieldwork. Data on the functioning of the drainage system is collected through smart surveys by the use of the smartphone app AkvoFLOW. The open source geographic information system QGIS is used to process the fieldwork results and draw the drainage network. The software SOBEK is used for building a hydrodynamic model, in which network characteristics and available land height data are combined with hydrological data to carry out 1D and 2D flood simulations. Five different scenarios, based on percentage of the drains clogging with waste and the level of the downstream seawater, are evaluated to simulate flood events and to indicate possible bottlenecks and vulnerable areas. Modeling results are then compared with information of historical floods level, collected through social surveys during fieldwork, to validate the model.

The answers to the research questions (1) and (2) are supported by the findings from fieldwork activities and the modeling results. Floods in the pilot area of Alajo and New Town are caused by a combination of factors: a) the drainage network is not properly designed and maintained; b) high heterogeneity in drain types creates hindrances and makes it difficult to predict the water behavior; c) at specific bottlenecks such as culverts and erosion paths, the capacity of the system is insufficient; d) waste disposal and accumulation in the drains causes blockages in the drainage network as it decreases the capacity especially in low-lying areas, therefore raising awareness on the negative effects of waste disposal should be addressed in upstream areas since the waste is flushed downstream; e) siltation occurs along the entire drainage network, especially in the major drains and flat areas; and f) lack of spatial planning and weak

cooperation between the responsible institutions for urban drainage management results in a lack of drain maintenance which leads to higher flood risks. Based on the hydrodynamic model, no clear conclusions could be drawn on the effects of waste and silt accumulation, given the misrepresentations of the storage capacity of the water system. However, the model suggests that the main influence on flooding comes from imposed downstream water levels and not from the rainfall in the pilot area itself.

The tools applied to analyze the flood risk in the pilot area in Accra are evaluated for the purpose of a flood assessment methodology in African cities. *Social surveys and stakeholder consultation* are useful methods to quickly understand and map relevant problems in the area. They also provide useful data to calibrate or validate model results. With an organized fieldwork strategy using smartphone based collection and a handheld GPS device, a large amount of technical information on the drainage system can be orderly mapped in QGIS in few days. Choosing boundaries for the sub-catchment and deciding to what level of detail the network should be mapped depends on the size of the flood levels that have relevant impact in a neighborhood.

The flood assessment model developed in this research is based on field measurements in the pilot area and elevation data derived from satellites, which introduces uncertainty due to its coarse resolution. The hydrodynamic model gives an impression of the flood prone areas in the neighborhood and helps to assess the effects of varying downstream water levels. Model scenarios of waste and silt clogging are constructed to get insight into the sensitivity of the system. Due to the current stage of development of the model, the accuracy is limited for now. For future research the model could be used to get insight into the effectiveness of measures to reduce the flood risk.

Crowd sourced flood risk mapping is a promising tool to collect data for flood risk assessment given the amount of received reactions after the launched social media experiment. The number of valuable responses could be increased by more clear and simple communication of the message. It is in any way an effective means to raise awareness about the analyzed problematic and to engage citizens in the discussion.

Another good tool to *raise awareness* about waste accumulation causing blockages in the drains is taking part in local initiatives such as a 'garbage removal mission'. Such an initiative creates engagement and mobilizes more community members to join the cleaning activities. Furthermore, developing communication strategies to engage stakeholders, partners and inhabitants in the project is important to create trust, enthusiasm and participation.

In this case study lots of information was collected about the current status of drainage system, the underlying causes of flood risk and the related issues on drainage and waste management. The structural measures proposed could be evaluated using the urban drainage model. The accuracy of the model could be improved by using more detailed height data and by extending the model with more information on the primary drainage system outside the pilot area. Other areas of continued research are: investigating the dynamics of waste flow in the drainage network and assessing the causes of malfunctioning of the waste management services.

The report is written with an emphasis on lessons learned and recommendations for improving results. Although validation of this methodology is still required, it can serve as a starting point for continued research into the urban flood risk in Accra as well as in other African cities.