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Flood model Bergen Norway and the need for (sub-)surface INnovations for eXtreme Climatic EventS (INXCES)

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Abstract

Urban flooding has become a key issue for many cities around the world. The project 'INnovations for eXtreme Climatic EventS' (INXCES) developed new innovative technological methods for risk assessment and mitigation of extreme hydroclimatic events and optimization of urban water-dependent ecosystem services at the catchment level. DEMs (digital elevation maps) have been used for more than a decade now as quick scan models to indicate locations that are vulnerable to urban flooding. In the last years the datasets are getting bigger and multidisciplinary stakeholders are becoming more demanding and require faster and more visual results. In this paper, the development and practical use of DEMs is exemplified by the case study of Bergen (Norway), where flood modelling using DEM is carried out in 2017 and in 2009. We can observe that the technology behind tools using DEMs is becoming more common and improved, both with a higher accuracy and a higher resolution. Visualization tools are developed to raise awareness and understanding among different stakeholders in Bergen and around the world. We can conclude that the evolution of DEMS is successful in handling bigger datasets and better (3D) visualization of results with a higher accuracy and a higher resolution. With flood maps the flow patterns of stormwater are analysed and locations are selected to implement (sub-)surface measures as SuDS (Sustainable Urban Drainage systems) that store and infiltrate stormwater. In the casestudy Bergen the following (sub-)surface SuDS have been recently implemented with the insights of DEMS: settlement storage tank, rainwater garden, swales, permeable pavement and I/T-drainage. The research results from the case study Bergen will be shared by tools to stimulate international knowledge exchange. New improved DEMs and connected (visualization) tools will continue to play an important role in (sub-)surface flood management and climate resilient urban planning strategies around the world.

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1. Introduction

Urban flooding has become a key issue for many cities around the world. With the continuing effects of climate change the impacts of floods with social, economic, and environmental consequences will become more acute and will add to the serious problems already experienced in dense urban areas. Therefore tools that can assess the vulnerability to floods are of great importance as acknowledged in the project 'INXCES' (2015 - 2018). The project 'INnovations for eXtreme Climatic EventS' developed new innovative technological methods for risk assessment and mitigation of extreme hydroclimatic events and optimization of urban water-dependent ecosystem services at the catchment level. The mapping of floods is of great importance to raise awareness and deliver quick assessments of possible climate adaptation measures as SuDS (Sustainable urban Drainage Systems). Years ago scientists started to use DEMs (digital elevation maps) as quick scans to indicate locations that are vulnerable to urban flooding. Now the datasets are getting bigger and multidisciplinary stakeholders (urban planners, decision makers, water managers, engineers) are becoming more demanding and require faster and more visual results. This can be exemplified by the case study of Bergen (Norway), where flood modelling using DEM is carried out in 2017 within the INXCES project and in 2009 within the project 'Skills Integration and new technologies' or SKINT (2009-2012). In the case study Bergen the development and practical use of DEMs is demonstrated for (sub) surface stormwater management.

2. Case Bergen, Norway

Bergen (60° North, 5° East) is the second largest city in Norway located at the West coast of Norway. The average annual rainfall in Bergen is 2,250 mm/y. Bergen was founded in 1030, has about 260,000 inhabitants. The Bryggen area forms the core of the historic centre of Bergen. The Bryggen area has burned down several times, and the new city has been built on top of the former remains of the city; cultural deposits with high archaeological value. One of the challenges is dewatering due to increased use of impervious surfaces in the catchment area and to the drainage of groundwater. The highly organic archaeological deposits are prone to degradation by these human activities and by prolonged dry periods as a consequence of climate change [1]. Infiltration of local stormwater in order to restore the natural water balance will re-introduce a sustainable stormwater-management policy for the site.

3. Method

For the flood map analysis in Bergen in Norway, the GIS-tool Calamity Levels of Urban Drainage Systems (CLOUDS) was used [2]. This is a 'quick-scan' method to simulate storm water floods. CLOUDS is based on the assumption that for a cloud burst (> 60 mm/h) most of the stormwater will flow and stay above ground [2,3]. CLOUDS visualizes the streamlines and the depth of stormwater in depressions where water will accumulate. The quick-scan is based on only readily available data. The most important is an accurate DEM. For the floodmodelling in 2017 the FKB-Laser10 [4] DTM10 is used with for Bergen with 5 points per m2 (updated 6 june 2017) [5] in contrast to the dataset of 2009 when only 1 point per m2 was available.

By combining the elevation model, the dataset with buildings and aerial photographs, a 3D model of the city is constructed (figure 2) to increase the involvement and engagement of stakeholders by 'flying' to their favorite places and discuss the flooding issues and possible solutions. The model can be shown in the 3D virtual reality theater on a cylindrical screen using 6 HD projectors to project an image with a resolution of roughly 5000x1800. To display this model on a big screen a special 3D viewer was used based on the open source OpenSceneGraph 3D toolkit. The software was running simultaneously on 7 PC's, one master PC for the control of the model and 6 slave PC's to drive the projectors [6].

4. Results

Figure 1 and 2 show the visualization of the end result of flood modeling using DEMs for the case Bergen in Norway in 2009 and 2017.

The DEM from 2009 (figure 1) is used to study the flow patterns of stormwater and locating suitable (sub-) surface locations to store and infiltrate groundwater by Sustainable Urban Drainage systems (SUDS) in the Bryggen area. The improved DEM model of 2017 (figure 2) shows the new situation after implementing swales and rainwatergardens.

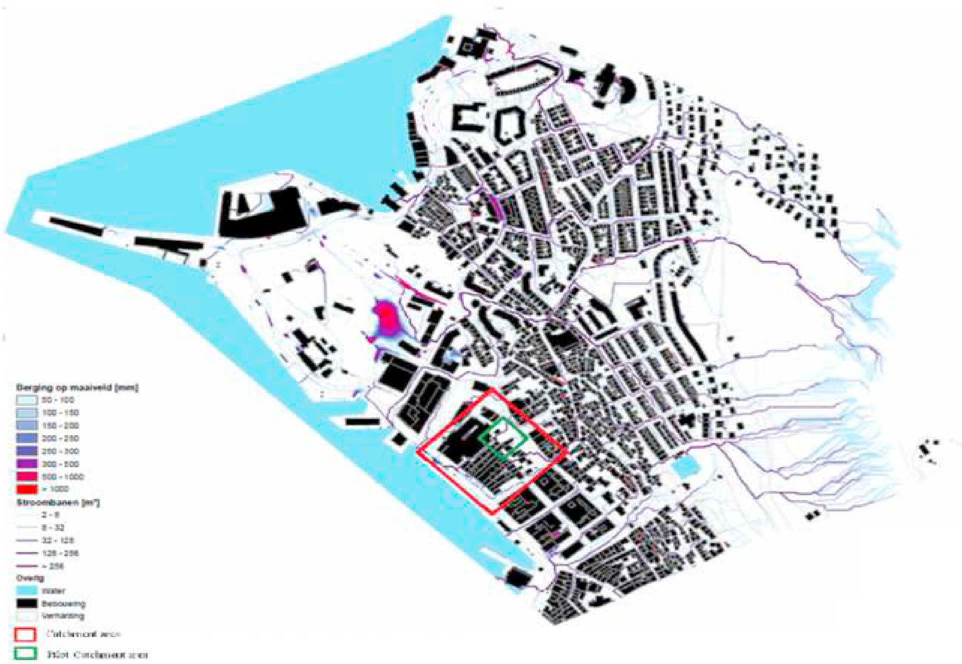

Fig. 1 Floodmap Bergen, 2009 [2]

In the case of historic Bryggen, the main goal is to increase groundwater recharge to the subsurface to reduce degradation of archaeological remains and subsidence to terrain and buildings.

Groundwater recharge can be improved by storing stormwater and infiltrating it into the ground. Infiltration-type SuDS, such as swales and rainwater gardens, can be used to achieve this. These SuDS have additional multiple benefits such as: flood reduction, pollutant retention, improve air quality, improve ecological values and reduce urban heat island effects [1].

The DEM from 2009 and visual inspections during rain showed that water would flow over the street Øvregaten just above the Bryggen area (figure 1). A plan was made to collect the water from Øvregaten by an inlet to a settlement storage tank. From the tank the water will flow into a rainwater garden with an overflow to swales. Permeable pavement and **I/T**-drainage (porous pipes that **I**nfiltrate and **T**ransport stormwater) are also used around the area for additional infiltration [1]. Detailed info (pictures, videos, papers) can be found on the the web-portal www.climatescan.nl 'Climatescan' [8] (figure 3).

Fig. 2 3D visualisation of floodmodelling Bergen 2016 (right) [5]

Fig. 3 Location and detailed information on the case study Bergen, Norway. (www.climatescan.nl/projects/16/detail)

5. Conclusions

With the continuing effects of climate change, several international stakeholders are in the need of tools that can assess and visualize the vulnerability to floods at exact locations in the urban area. DEMs (digital elevation maps) have been used for more than a decade now as quick scan models to indicate locations that are vulnerable to urban flooding. DEMs and connected (visualization) tools generate a better climate resilient urban planning and (sub-) surface flood management, exemplified by the Bryggen case. The evolution of DEMS is successful in handling bigger datasets and better (3D) visualization of results with a higher accuracy and a higher resolution. With flood maps the flow patterns of stormwater are analysed and locations are selected to implement (sub-)surface measures as SuDS (Sustainable Urban Drainage systems) that store and infiltrate stormwater. In Bergen the following (sub-)surface SuDS have been recently implemented with the insights of DEMS: settlement storage tank, rainwater garden, swales, permeable pavement and I/T-drainage.

The efficiency of SUDS to protect and preserve subsurface organic archaeological deposits in a historical urban area like Bryggen in Bergen, will be monitored in the next years. The research results will be shared by tools as the web-portal 'climatescan' to stimulate international knowledge exchange. More examples of products and good practices that can serve as inspiration for climate resilient urban planning can be found at the Sub-Urban toolbox [9].

6. Recommendations

Challenges and further developments associated with floods and other climate related issues in dense urban areas are continuously growing. DEMs could be further improved and used by urban planners and other stakeholders to assess the resilience and well-being of cities. A combined analysis of such maps with other challenges related to climate change (such as heatstress, waterquality issues, air pollution etc) has a strong potential to be used by decision makers to implement cost effective measures to mitigate the effects of climate change.

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