Integrated Forecast Storage Management and Flood Warning System in urban catchments and small watersheds

Système intégré de gestion des stockages et d'alerte de crues dans les bassins versants urbains et les petits bassins versants

Harald Sommer*, Frauke Jakobs, Zhengyue Jin, Heiko Sieker

Ingenieurgesellschaft Prof. Dr. Sieker mbH, Hoppegarten, Germany
*h.sommer@sieker.de

RÉSUMÉ

Les évènements pluvieux intenses sont une cause majeure de problèmes d'inondation dans les zones urbaines et non urbaines. Ces problèmes résultent de l'augmentation du bouchage des zones causé par les hauts volumes de ruissellement. Dans les zones urbaines et les petits bassins versants, l'intervalle entre l'évènement pluvieux et le pic d'écoulement peut être très court.

Cet article décrit le système de modélisation intégré hydraulique des ruissellements de précipitation STORM.Control qui utilise les données de précipitations prédites pour gérer les systèmes d'eau urbains et/ou des bassins versants entiers. Ce système permet d'intégrer un système d'alerte pour que la protection civile puisse réagir rapidement et protéger les bâtiments.

En couplant les données virtuelles et les données mesurées, il est possible de piloter les stockages pour réduire les pics de flux dans les systèmes d'assainissement et dans les cours d'eau.

Le système utilise la norme SOS ouverte pour la collecte et la distribution des données. Un système de visualisation HydroWebView sur internet permet une visualisation en temps réel des données sur le système d'assainissement et les cours d'eau.

MOTS CLÉS

Gestion du stockage, gestion de bassin versant, prévision de précipitations, SUDS, contrôle des flux, STORM, internet, service SOS

ABSTRACT

Intense rainfall events are a major cause of flooding problems in urban and non urban areas. Due to increased sealing of areas high runoff volumes are the result. Especially in urban areas and small catchments the time interval between rainfall event and flood peak can be very short.

This paper describes the integrated hydraulic precipitation runoff modelling system STORM.Control using predicted rainfall data to manage urban water systems and/or whole water sheds in non urban areas. It gives the opportunity to integrate an alarm system for civil protection forces to react in short time period and prevent relevant constructions from damages or flooding.

Coupling virtual and measured data enables steering of storages in order to lower peak flows in sewers and water courses. The system is using the open GIS SOS standard for data collection and delivering. A web based Viewer HydroWebView is enabling “real time viewing” of the data in the sewer and river system.

Further measurements in the sample catchments will be done in order to validate and improve the approach.

KEYWORDS

Storage management, Watershed management, rainfall forecast, SUDS, Flood control, STORM, Internet, SOS Service

1 INTRODUCTION

The big flood events in Germany with severe damages which occurred in the last 10-15 years are still in mind. Due to strong medial reflection the sensitivity was raised esp. after the floods at the rivers Elbe in 2002, Oder in 1997 and Rhein in 1993 and 1995.

Flood events don't occur only in big rivers but also in small streams and creeks and can cause severe local damages. Sewer systems are affected too. Reasons are heavy rainfall events, which cannot be handled by the drainage system (Sewers, rivers, streams). Conventional measures like retention basins and higher runoff capacity or other measures like infiltration and area management are in most cases only a partial solution of the flooding problem.

Therefore, a warning is necessary because the time period between rainfall event and runoff can be very short in small catchment areas in contrary to large river basins. A possible solution is the simulation of runoff based on predicted rainfall data.

2 MODELLING

2.1 Rainfall forecast

There are several ways to integrate rainfall into modelling. First method is to have online rainfall gauges delivering actual data a modelling station which then can produce immediate outputs which can be visualized. The disadvantage of this system is that the reaction time is only very limited.

The enhanced method is to use predicted rainfall data. So called "Virtual rain gauges" delivering predicted rainfall data are of offered as a service via Internet based on rainfall data of weather service Meteomedia. [HST, 2007]. The data can be viewed via web browser interface or directly downloaded via ftp. The data is processed from radar data and calibrated with a dense net of terrestrial rain gauges. This data can be provided for the whole area of Germany in high resolution for past and future forecast for 72 h in 1h time steps and for 2 hours in advance in 5 min time steps.

2.2 Runoff simulation

Based on the predicted rainfall data the runoff can be simulated with the simulation model STORM. (IPS, 2009) STORM is a hydrological model with the ability to simulate rainfall-runoff-processes for urban areas as well as for natural and rural areas (Soil water balance model). Pollution load can be modelled too.

These models have to be established and calibrated in advance with past rainfall events of different heights and reoccurrence. Even rainfall events leading to flood events have to be considered for calibration.

The connection to the „virtual rain gauges“ is realised by the STORM-module STORM-Control. This module reads the rainfall data from the ftp-server and runs the simulations with specified time intervals. With new available predicted data the simulation is started too. For larger catchments multiple rain gauges can be used for catchment wide rainfall. The runoff will be calculated within minutes and available as a "virtual runoff gauges" or "virtual water gauges".

3 VISUALISATION

3.1 Data Management

To realise a data retrieval independent from software and hardware the predicted and simulated data will be stored in a SQL data base (PostgreSQL) located on the internet.

Via freely available web browsers (i.e. Firefox, Internet Explorer etc.) the actual and the predicted runoff data can be visualised and viewed from any point with internet connection within offices or out in the field. The graphical view includes a map with the position of the location of existing or virtual gauges. A diagram with graphs of the actual and predicted data can viewed too. If a predefined water level or runoff limit at any existing gauges is exceeded a warning can be send via email and/or SMS. Data integration and transfer is realised via open standards as Web Map Service (WMS) and Sensor

Observation Service (SOS) defined by the OGC Consortium. (OGC, 2009). By using open standard interfaces integration in other systems can be realised very easily.

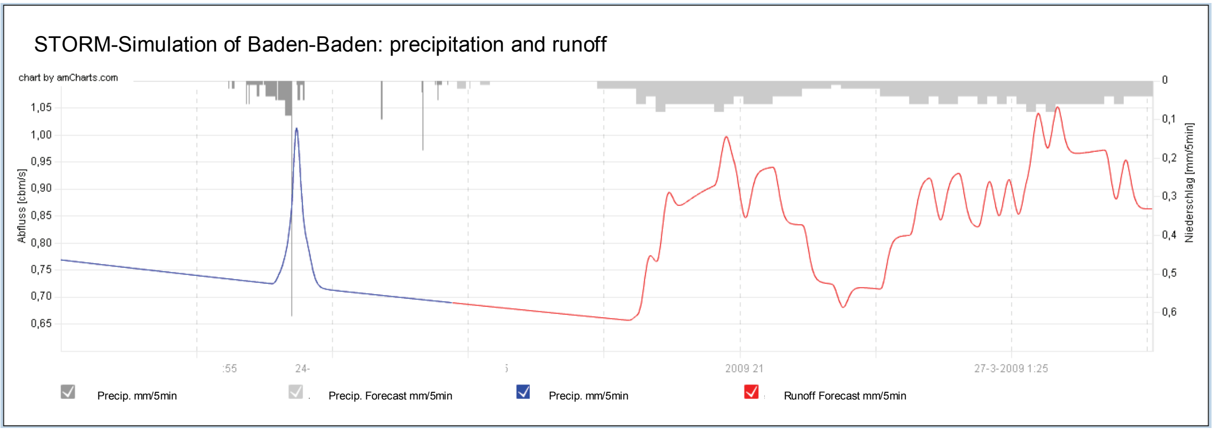

Fig.1: First Graphical view of predicted or simulated time series via Web browser.

3.2 Visual Calibration

Like other precipitation runoff models the models have to be calibrated. Via SOS-interface existing water gauges can be compared with „virtual runoff gauges“. This enables a validation of the precipitation-runoff-model. Additionally runoff simulations for different forecast periods can be compared. This enables an evaluation of the runoff forecast.

3.3 Integrated System

The developed integrated system consists of several parts:

- Virtual rain gauges (others gauges can be used too)
- STORM.Control as the modelling heart of the system which allows also delivering steering commands
- Database collecting the virtual, modelled and real data
- Steered measures
- Sensors, delivering data
- Web based Viewer HydroWebView, can be viewed with standard browsers

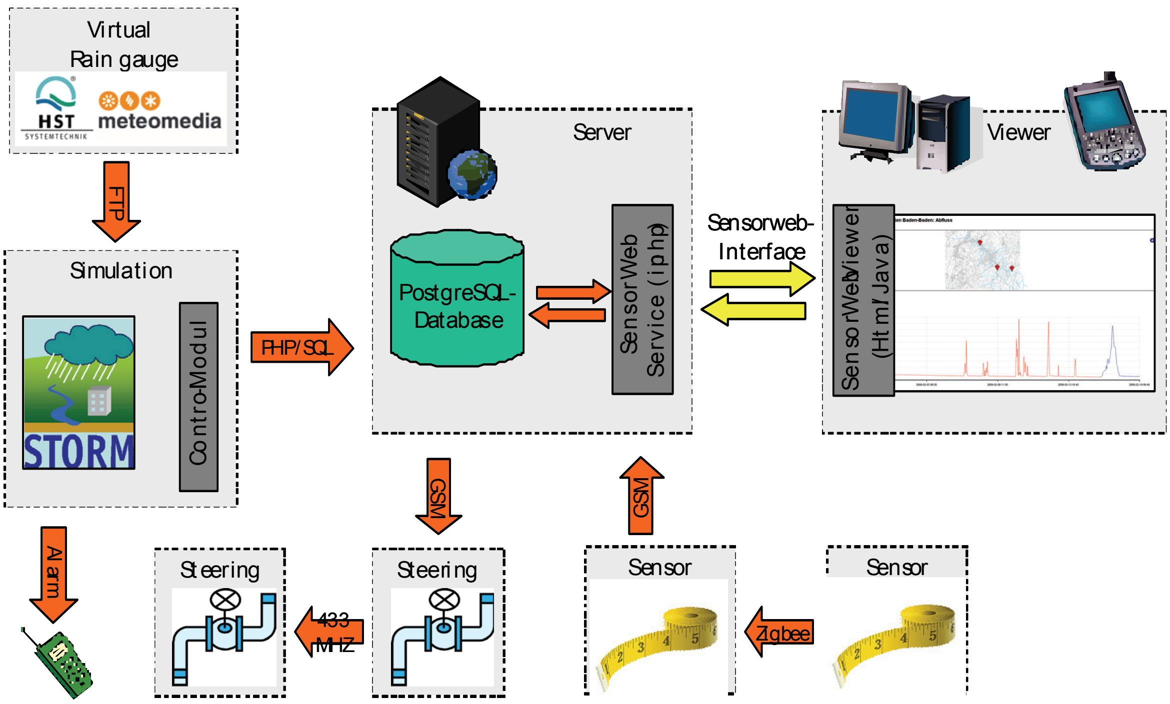

Fig.2: Rainfall forecast based runoff modelling, steering and visualisation

The figure describes the system. The predicted rain data is fetched by the simulation model. The model will calculate runoff volumes and water levels and store them in a predefined data base. Steering commands for valves etc. can be integrated too. Independent sensors are delivering measured data via GSM/GPRS. The visualization is realized with a web based viewer (HydroWebView). (Steering of small storages, 2006),(HydroSensorWeb, 2007)

4 EXAMPLES

The system was applied to 3 catchment areas.

4.1 Baden-Baden

The first one is the catchment of the rivers Oos and Grobbach. In the lower catchment area the city of Baden-Baden is located. This catchment has a total size of 80.9 km². The overall average sealing rate is 7.9%. The catchment starts in the Black Forest Mountains at 800 m above sea level. In this area the land use is mainly forest (Wald). Typically the city of Baden-Baden itself is located in the valley at app. 200 m above sea level. For the settled area is located closely aside the river banks this area is affected by flooding.

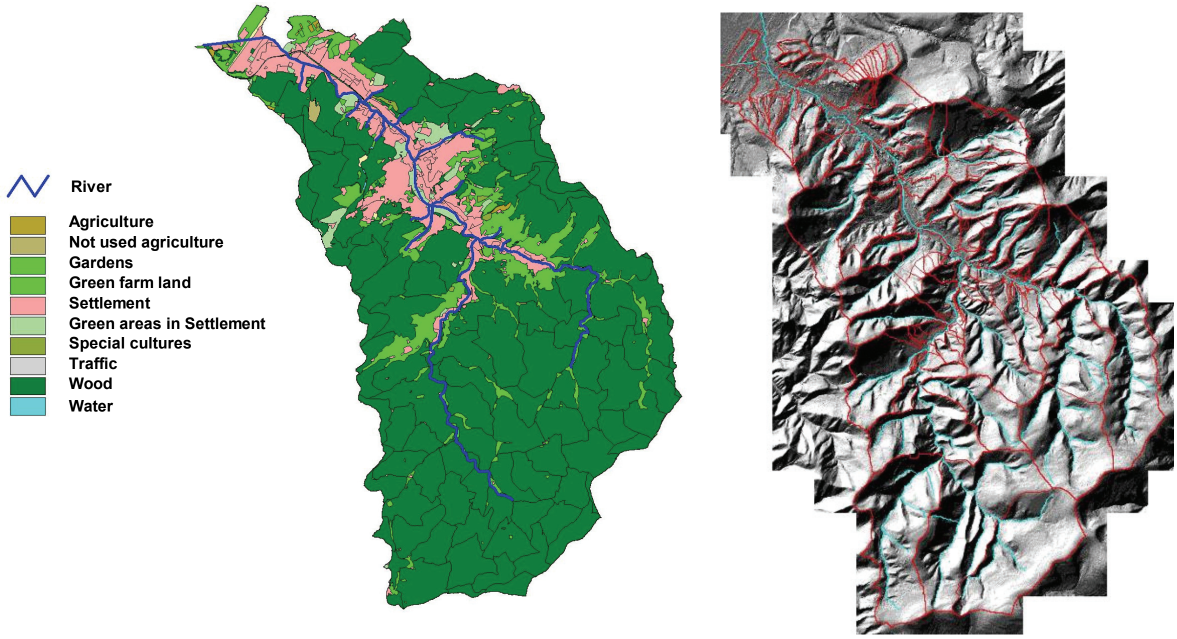

Fig.3: Land use and elevation model in catchment of rivers Os and Grobbach in Baden-Baden

For this catchment a precipitation runoff model was established and calibrated. The calibration was realised with several rainfall events. One major calibration event was causing extreme flooding on Jan 13th 2004. The time from rainfall resulting in a flood event in the urban area is 0.5-1 h.

To enlarge the reaction time for fire brigades and other civil protection forces the aim was to establish an alarm system. This can be done using the already established and calibrated model for the catchment and integrating rainfall and temperature forecast for better forecast of runoff.

A flood level forecast is made with STORM.Control using 8 “virtual rain gauges”. Additionally 2 temperature gauges, one in the upper mountain area and one in the lower part of the city) are integrated into the forecast.

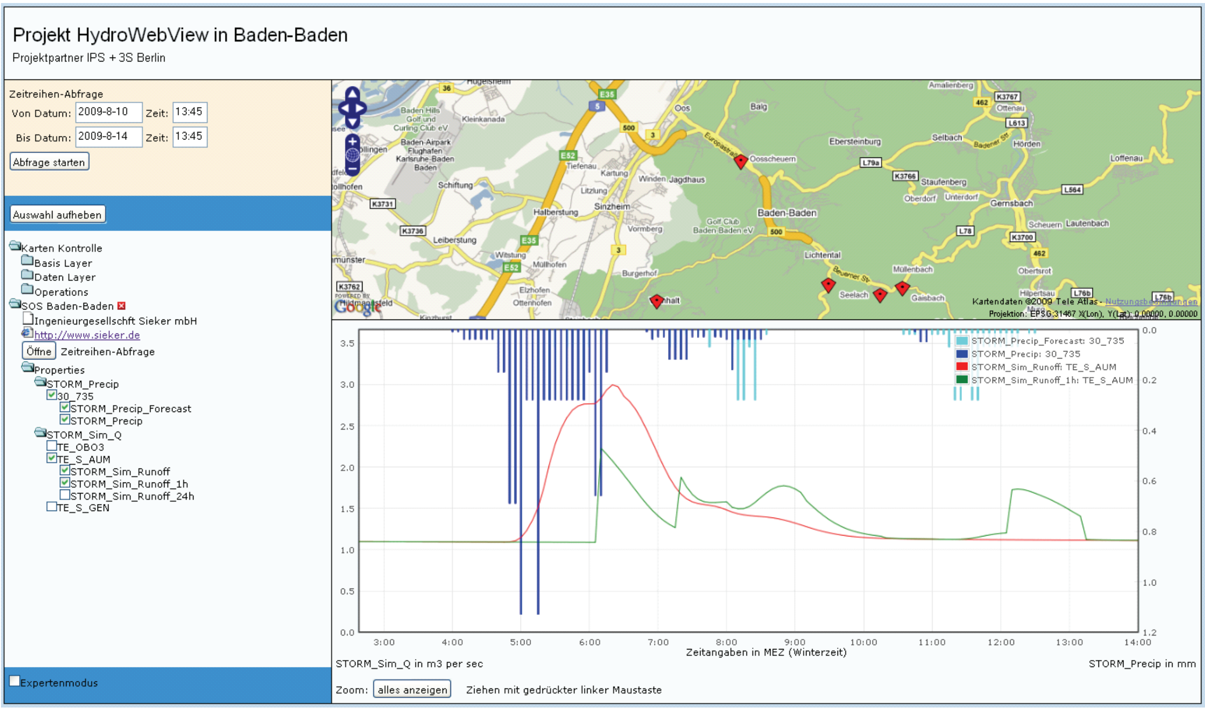

Fig.4: HydroWebView showing the available precipitation and runoff data in the catchment of the river Oos in Baden-Baden

With the Script based Internet software HydroWebView it is possible to visualise the measured and the predicted precipitation and runoff “on the fly”. This enables the relevant people in the city to react in a sufficient time frame.

If a simulated water gauge is reaching a certain determined level, the alarm system sends an SMS with a warning that a certain water level will be reached.

The figure shows the web based viewer HydroWebView. In the map several points of measurement are shown. From these points available data is presented and can be downloaded from the SOS sensor or from an SOS compatible database. After selecting the time period the graph present the data. On the top the measured (dark column) and predicted (light columns) are visible. The lines represent the simulated data with measured and predicted rainfall data.

Within the catchment of the river Oos in Baden-Baden further investigations and validating of the simulated data is done. Therefore measurements in the river are taken and compared with the simulated data.

4.2 Prenzlau

The separate sewer system in the city of Prenzlau is overloaded in rainfall events. In the past it was not possible to get online information of the runoff status in the sewer system especially in manhole in streets without power supply.

A new type of measuring system was used to establish a measurement in manholes which would be usually due to manual service. A data logging system is integrated sending the data at defined intervals via GSM from the inside of the manhole to the internet based server. So with STROM.Control overload of sewer systems can be measured online. A forecast of the overload is possible too if the water level forecast is coupled with a hydrodynamic model driven by predicted rainfall.

The following figure shows the separate sewer network of Prenzlau. 2 measurement points are installed in separate sewer manholes. From inside these manholes runoff data is provided via GSM/GPRS wireless network to the database (pictures). HydroWebView visualises the runoff data of both points of measurement.

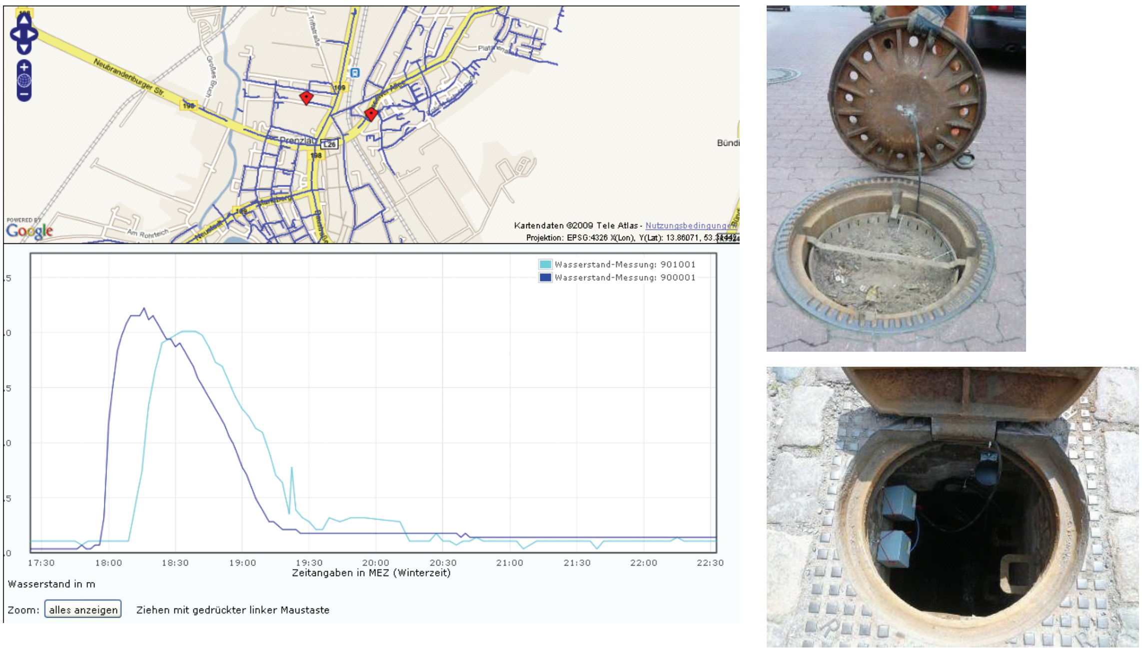

Fig.5: HydroWebView showing the available runoff data in the catchment of Prenzlau

4.3 Berlin Rummelsburg Bay

The area of Rummelsburg Bay in Berlin is a new urban development area developed in the 90th of the last century, shortly after the reunion of Germany and Berlin. A new storm water management was implemented in this area. This storm water management is based on infiltration measures in nearly every part of the area. The measures are applied for private properties and for public streets.

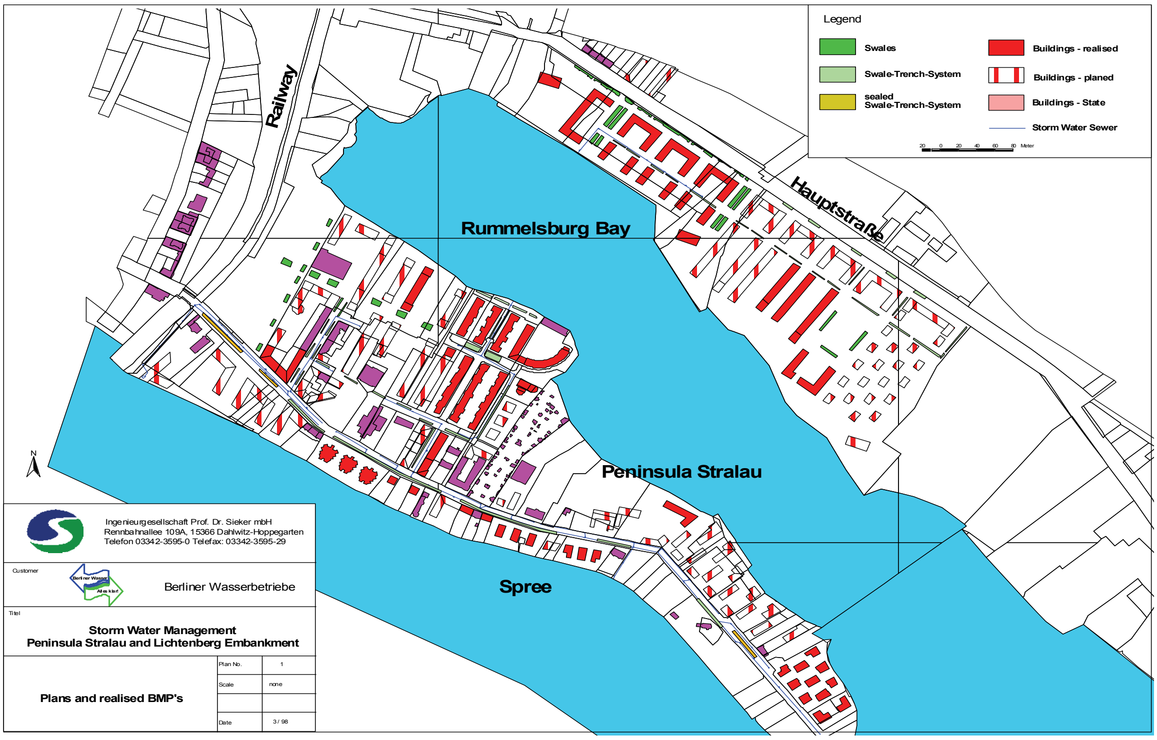

Fig.6: Map of the area of Rummelsburg Bay in Berlin with infiltration SUDS as storm water management measures

SUDS as Swale-trench-system can be connected to the sewer system by a throttled outlet to ensure that the trench is empty in case of following rain falls. Normally this is done by a static throttle. To enable the system to keep water in dry seasons on site or to discharge the not needed in advance of predicted heavy rain storms steered throttles can achieve the regulation of small storages.

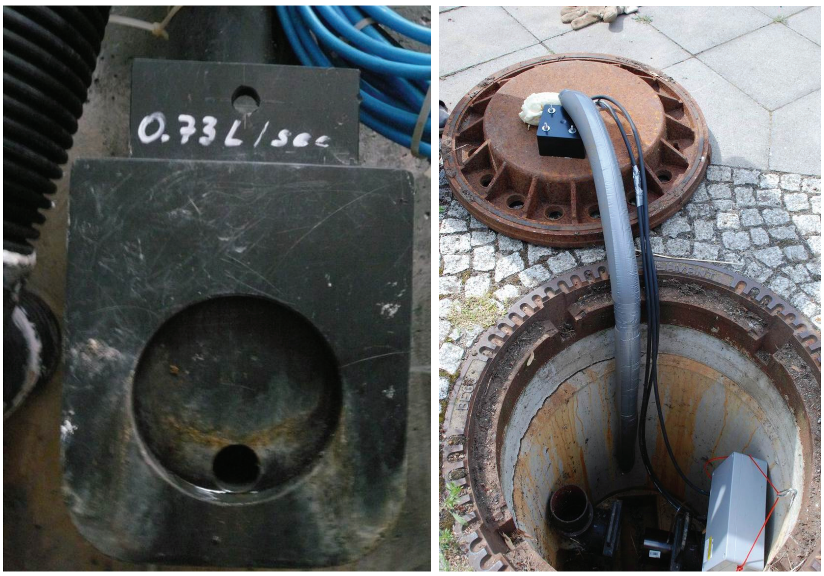

Fig.7: Conventional static and managed throttle

The communication of the throttles is done by communication via GSM/GPRS. The software STORM.Control manages the throttles in respect of opening or closing the throttle. The visualisation is also done by HydroWebView like in the examples before.

5 CONCLUSIONS

Flood control and management in urban areas is one of the major challenges in urban and rural storm water management. With conventional storm water management systems the reaction time in heavy rainfall events is too short for effective warning and protection of people and buildings.

This inspired the development of a management system driven by rainfall forecast. With STORM. Control it is possible to manage and steer large storages like flood retention basins or storage tanks as well as small scale storage measures, i.e. swale trench elements, or rural drainages. Viewing and managing of urban and non urban water systems will be available.

With a web based server application HydroWebView based on the OGC SOS standard different measured data can be visualised. The data can be seen wherever an internet connection is available. This enables the user to react in time. Further on, relevant persons will be warned based on the OGC SMS Service. This will happen in case of future flood events occurring.

To validate the system further investigations and evaluations in comparison with measured data is done. The outcomes will be used in order to improve the reliability. One outcome is that the quality of predicted rainfall data especially in mountain areas shall be improved.

6 POSSIBLE FUTURE APPLICATIONS

There are various applications where these forecast methods will be useful and suitable:

- Flood warning systems for urban and non urban areas
- Alarm system for civil protection forces
- Online visualisation of sewers status and open water courses
- Automated management of sewer system by steering of storages

7 ACKKNOWLEDGEMENT

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