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1. Management summary

The SUDPLAN project is built up in an iterative fashion. The project has three iteration cycles which consist of specification, design, implementation, test and validation. This document, the *Pilot Definition Plan V3* (D6.1.3), defines the objectives (plans and expected outcomes) of the Wuppertal Pilot in the course of the 3rd year of the project.

For every software development process it is crucial to understand the user requirements and their background in order to be able to build a system which meets the user needs as good as possible. The document includes a detailed description of the actual users and explains the relevant decision and planning processes. In the user description particular attention is laid on the different types of users and their characteristics. For better understanding of the user domain the tasks which are necessary to fulfil the pilot objectives will be analysed systematically and structured in a formal way [Diaper, 2003]. Therefore each task is broken down into its sub tasks until the necessary tasks are identified.

Another important part of the document is the design and specification of use cases [Cockburn, 2000], which describe the expected behaviour and functionality from the users' point of view. Based on these use cases we are then able to extract system requirements and to specify them in more general and technical oriented terms in the *Requirements Specification* (D3.1.i). These requirements define the boundaries of the future system and are the base for the technical specification and design.

2. Pilot Definition

This chapter describes the main pilot objectives and how the pilot takes the relevant effects of future climate changes into account. Particular emphasis will be laid on the usage of the *Scenario Management System SMS* (WP3) and how the SMS will support the city of Wuppertal in its efforts. A connection to the technical challenges proposed in the call of the framework program will be established and pilot considerations will show how these will be addressed in this pilot site.

An overview of the technical infrastructure in Wuppertal will be given which includes web services, data stores and models of potential interest for the SMS development and the integration in the Wuppertal pilot site. Current efforts, considerations and constraints regarding the establishment of a water surface run-off model for the region of Wuppertal are explained. The expectations and plans of relevant *Common Services* which have been implemented in the scope of the SUDPLAN project will be described. The chapter concludes with an explanation of the activities Wuppertal has to perform and a detailed view of the decisions in which users or responsible persons in Wuppertal have to be supported by the scenario management system.

2.1. Main Pilot Objectives

The city of Wuppertal, a town with approximately 350,000 residents, is the biggest town in Germany that is situated in hill country (from 98 to 353 m above mean sea level). It is located in the steep, narrow, and long valley of the Wupper river. There are several creeks on both sides of this valley that open into the storm water sewage system before they finally end in the Wupper. During a heavy rainfall event the city's storm water sewage system is quickly blocked by those swollen creeks causing the precipitation to runoff on the surface. The storm water run-off may thereby affect valuable public infrastructure and private property. This is a major concern to the city managers. Due to the complex geography it is completely unpredictable where a heavy rainfall event might occur and therefore unknown whether there will be flooding and where it will runoff.

Up to now the mid- and long-term planning of the storm water sewage system has been accomplished with iterative model runs of a hydrological model (for the creeks) and a hydrodynamical model (for the sewage system). This planning process is called 'Generalentwässerungsplanung' (GEP), what could be translated as 'General Drainage Strategy'. Wuppertal's first main objective is to **expand the GEP**: the modelling of surface run-off after heavy rainfall events should be integrated into the process. To achieve this goal, a hydrodynamical model should be used to **detect the critical spots** (high risk of flooding plus valuable and vulnerable facilities). This is the second main objective.

Wuppertal's third main objective is to **mitigate the risk of flooding** for the detected critical spots. The traditional strategies to achieve this are either the enlargement of the profiles of the sewage system or the construction of retention basins. Given these two options the potential needs for investments would be immense, considering that the city copes with water run-off from 350 kilometres of creeks (over 800 creek sections) and 650 kilometres of sewage channel system. An alternative and much more cost-efficient strategy is to look for localised planning options which are likely to prevent damage. Examples for such structural measures are the alteration of street profiles by means of higher road kerbs or the installation of stationary (or mobile) walls. So Wuppertal's fourth main objective is to **find the most cost-efficient measures for the flood risk mitigation** for each critical spot. These measures shall give a higher probability to prevent damage and should yet be practical to implement, including being capable to cope with the ever growing financial constraints of the city. Please see (Arun, 2009) and (Schanze, 2006) for more information on Flood risk management.

The fifth main objective is to provide the responsible planners and hydrological modellers in Wuppertal with a tool that enables them to simulate a multitude of modelling experiments with the model component for the surface run-off, both to detect the critical spots and to simulate the effects of different structural measures at the critical spots. The tool should be able to store the parameters and results of such a model run and to visualise the results. The SUDPLAN project should provide such a tool – the **Scenario Management System (SMS)**.

2.2. Relevance with respect to Climate Change Issues

Climate change is considered to have an increasing impact on the frequency and intensity of heavy storm water events in Wuppertal. This makes it necessary to include climate change effects both in the long-term planning of the storm water sewage system and in the simulations of surface run-off. To put it in a nutshell: The intensity and duration of a rainfall event of a given probability (e.g. one time in 30 years) is a crucial parameter in every single modelling experiment. If climate change is ignored in these simulations, the suggested structural measures would possibly not be effective in the long run.

To include the climate change effects in the modelling experiments the software that is used for the definition of the parameters of such an experiment needs to be able to process information concerning climate change. This means in the SUDPLAN project that the Scenario Management System must be able to communicate with the Common Services responsible for the allocation of future precipitation data.

Climate Change Issues	Pilot Consideration
Heavy storm water events are considered to happen **more often** in the future due to climate change.	(1) It is necessary to include climate change effects in the long term planning processes (in particular the GEP).
	(2) The Scenario Management System must be able to communicate with the Common Services to get the predicted precipitation data (with consideration of climate change).

2.3. Relevance with respect to ICT objectives of the proposal

Objective ICT-2009.6.4 ICT for Environmental Services and Climate Change Adaptation
Target Outcomes
a) **ICT for a better adaptation to climate change**
Easy-to-use, web-based systems for better preparedness, decision support and mitigation of climate change impact on population, utilities and infrastructures. Special emphasis is on scenario-based prediction, damage assessment, planning and training, 3D/4D modelling, simulation and visualisation, as well as sensor networks. Integrated solutions shall be validated in the urban context including for natural disasters, taking full advantage of recent advances in miniaturisation of sensors, wireless communications and increased computation power and data storage capacity.

The outcome of the Wuppertal pilot is expected to be an easy-to-use, web-based system using many environmental web services. It will be used to run multiple scenario-based simulations and to visualise the results in 2D-, 3D- and 4D-representations. The system will use a hydrodynamic modelling component that simulates the whole spatiotemporal progression of a heavy storm water event and the corresponding run-off in the sewage system and on the surface.

The system will help the responsible planners to assess damages that may be caused by flooding generated by heavy storm water events, that are likely to happen more often in the future due to climate change. It will also enable them to assess the effectiveness of different planning options to mitigate the impact of such events on population, infrastructure and utilities. In this way the system will provide decision support to the planners and will help them to discover the most cost-efficient planning options.

It is intended to run the system on mobile computers for on-site visualisations, thus taking advantage of the recent advances in wireless communication. This enables the planners to discuss different scenarios and planning options with the concerned property owners on-site.

ICT Objective	Pilot Consideration
ICT for a better adaptation to climate change	(1) The Wuppertal pilot will be an easy-to-use, web-based system for running scenario-based simulations including 2D-, 3D- and 4D-visualisations of their results.
	(2) The system will help planners to assess damages caused by climate change driven heavy storm water events and to find both effective and cost-efficient measures to mitigate the flood risk.
	(3) The system will be available on mobile computers for on-site visualisations.

2.4. Local models and data sources used

The Wuppertal pilot is a very good example for the need of a distributed yet integrated single information space for the environment. The required data and services span over different autonomous organizations. For water planning and management purposes the three main organizations for the given problem are

- The **City of Wuppertal** (http://www.wuppertal.de), in particular the '**Koordinierungs-stelle Stadtentwässerung**' (**KST**). The KST has to care for a cost-efficient maintenance and development of the storm water and the waste water sewage system (policy-maker).
- The **Wuppertaler Stadtwerke** (**WSW**) (http://www.wsw-online.de). This public utility company operates the sewage systems for the City of Wuppertal based on a contract between the two organizations.
- The **Wupperverband** (**WV**) (http://www.wupperverband.de) is a water body management organization. It manages the open rivers and creeks of the Wupper catchment of 813 km² on behalf of its members. Amongst them there are cities, counties, public utility companies and public real estate and utility owners (e.g. traffic utilities) affected by the Wupper catchment. The WV also operates twelve dams and eleven wastewater treatment plants in the Wupper catchment.

If the scope is extended towards the reaction to actual flood events, the above list of involved organizations has to be extended with institutions such as police, fire brigades, public works and so forth.

The currently existing data sources are spread between these different organizations, in the area of water management mainly between the City of Wuppertal, WSW and WV. The most important data sources are described in the following list.

- WV is operating a **database for the stream network** that covers its whole area of responsibility. The City of Wuppertal has its own database that is more detailed but will not be updated any longer (data has already been handed over to WV). The geometrical representation of the streams and creeks is their respective centre line that has been digitised from maps in the scale of 1:5000 thus it is 2D data. The streams are sub-divided into segments with homogeneous properties such as development condition (e.g. open, piped) and adjacent land use (e.g. forest, grassland). The both databases contain an assessment of the ecomorphological quality (German: 'Strukturgütekartierung') and the locations of transverse structures (German: 'Querbauwerke'). Both databases are used and updated with Geographic Information Systems (ArcGIS applications).
- A **database of the drainage system** is maintained by WSW. The geometrical representation of the pipes is their respective centre line. The manholes are represented by their outline and the position of the cover. The coordinates come from terrestrial surveys so they are quite accurate and best viewed together with the large scale cadastral map. Heights are available as attributes for the floor level of the foundation of each manhole and for the respective cover. At the time SUDPLAN started this database was used and updated with the GIS application KANDIS based on the GIS software

SICAD/open. In November 2010 the KANDIS data was migrated towards a new system called novaKANDIS which is based on ArcGIS.

- The City of Wuppertal has established a high quality spatial data infrastructure (SDI), consisting of Web Map Services (WMS) and Web Feature Services (WFS). It offers multidisciplinary data covering the topics land survey register, orthoimagery, topography, urban planning, environmental protection, traffic, utilities etc. A substantial part of this SDI service is publicly available as WMS at

  http://geoportal.wuppertal.de:8083/deegree/wms?REQUEST=GetCapabilities&SERVICE=WMS&

- The City of Wuppertal runs an integrated information management platform called Wuppertal Navigation and Data Management System (WuNDa) which is a service oriented platform linking the SDI with city databases, sensors, web cams and other diverse data sources; this platform is based on the cids platform of SUDPLAN partner cismet GmbH.

- The WV has its own SDI that is also publicly available at

  http://fluggs.wupperverband.de/wmsconnector/com.esri.wms.Esrimap/WV_WMS?VERSION=1.1.1&SERVICE=WMS&REQUEST=GetCapabilities&

The WSW is using the software products FLUT and DYNA by the German consortium tandler.com GmbH/Pecher Software GmbH. These are components for ++SYSTEMS, a GIS with subject-specific modules for all aspects of the sewerage domain. FLUT implements a hydrological model and is used for the dimensioning of new sewage systems parts. DYNA implements a hydrodynamic model and is used for the weak-point analysis of the sewage systems.

In the course of the SUDPLAN project (Q3 2010) the WSW procured GeoCPM, another module for ++SYSTEMS. GeoCPM is a model component for the hydrodynamic simulation of surface run-off. It is possible to perform combined model runs with DYNA and GeoCPM to consider the interaction between the surface run-off and the run-off in the sewers. The City of Wuppertal has access to FLUT, DYNA and GeoCPM and is able to run own simulations, to rerun the WSW simulations and to check the results. Therefore GeoCPM is used as the local model for the surface run-off in the Wuppertal pilot.

The WV uses the software NASIM, manufactured by Hydrotec GmbH, to perform rainfall run-off simulations.

There is a close cooperation between WV and WSW in matters pertaining to modelling because the most creeks in Wuppertal end up in the storm water sewage system. This means that the WSW modellers need results of WV's rainfall run-off simulations – hydrographs for each point where the piped segments begin– as input to their own model runs. These hydrographs can be seen as additional sources of water that are not included in WSW's models. On the other hand the WV modellers have to include the piped segments of the creeks into their own model runs. That is why they need the inflows into the piped creeks that come from other parts of the storm water sewage system. WSW and WV run their models with the same precipitation patterns and exchange the results in an iterative process until the model outputs converge.

With the availability of GeoCPM the WSW introduced the modelling of surface run-off as a regular yet optional part of the GEP process (cf. 2.10).

A crucial parameter for the modelling of surface run-off is an optimised digital elevation model (DEM) represented in the form of a triangulated irregular network (TIN), the so-called ‘calculation model’. To achieve the required accuracy of this TIN it is necessary to generate it from high resolution airborne laser scan data (see 2.7). This data is available for the whole area of Wuppertal with the following characteristics:

- produced by: GEObasis.nrw with co-financing from City of Wuppertal (for higher resolution)
- measurement date: December 2008 and January 2009
- spatial resolution: 4 points per square meter
- datasets (text format):
    - Digital Surface Model generated from first pulse registration of the laser scanner
    - Digital Terrain Model generated from last pulse registration of the laser scanner: man-made objects (buildings, cars) are removed from this dataset and the resulting gaps are filled with interpolated 3D-points

To enhance the calculation model it is helpful to introduce additional high accuracy data; in particular for the artificial breaklines like the exterior walls of buildings and the road kerbs. This information can be extracted from the municipality’s ‘Digitale Liegenschafts-karte / Stadtgrundkarte Wuppertal’ (DSGK-W), a 2D cadastral map that contains additional topographic objects:

- The boundaries of the buildings are labelled with a specific code. Hence they can easily be exported from the DSGK-W in well-established geographic data formats like ESRI shape-files or DXF.
- The road kerbs are labelled as ‘topographic boundaries’ with a more generic code. It will take some work to separate them from other topographic boundaries and to export them from the DSGK-W.

Wuppertal is involved in the project ‘Kritische Infrastruktur, Bevölkerung und Bevölkerungsschutz im Kontext klimabeeinflusster Extremwetterereignisse’[1] (KIBEX) that is managed by the United Nations University – Institute for Environment and Human Security (UNU-EHS). An important research partner organization in this project is the ‘Deutsches Zentrum für Luft- und Raumfahrttechnik’ (DLR). One of the main goals of the KIBEX project is to identify the classes of facilities that are most vulnerable to storm water flooding, focussing on drinking water supply and the power supply system. The DLR will analyse the above mentioned laser scan data and other remote sensing data to discover depressed areas. In a second step they will use GIS filter techniques to identify the depressed areas where vulnerable facilities are located. The expected outcome for Wuppertal is a dataset of depressed areas together with a first

[1] Critical Infrastructure, Population and Civil Protection in the context of Climate Change Induced Extreme Weather Events

assessment of the damage that could be caused by urban flooding. Wuppertal intends to use this data as input for the prioritization of the catchment areas in the GEP process.

2.5. Main deficiencies

At the start of the project the main deficiency was the lack of any systematic knowledge about the critical spots with regard to flooding after heavy storm water events. Unfortunately, the existing experiential knowledge was not sufficient for the planning processes. Wuppertal intends to gain the required knowledge in the forthcoming years particularly by its participation in the KIBEX and the SUDPLAN project.

In addition, there is a general deficiency in understanding the dynamic processes of floods triggered by heavy storm water events. Wuppertal expects to get a deeper understanding of this by running a multitude of modelling experiments with the combined model component for the sewer system and the surface run-off, both for different catchment areas and with different precipitation patterns.

Through the project results (availability of model- and application-infrastructure) that enable ‘what-if’ scenarios Wuppertal will be able to gain the necessary knowledge for a sound planning process.

2.6. Common Services Used

The Wuppertal pilot will use both flavours of precipitation Common Services (CS) that will be established by SMHI to simulate intense short-term rainfall under the predicted future climatic conditions:

- Intense rainfall: Urban downscaling both with IDF-curves and time series as input
- Intense rainfall: Design storm generator

In Figure 1 the detailed concept for the integration of the CS ‘Intense rainfall: Urban downscaling’ is depicted for the variation where the CS takes long time rain series as input.

As mentioned in chapter **Fel! Hittar inte referenskälla.** it is crucial for the modelling of surface run-off to consider the effects of climate change on precipitation patterns. To use the urban downscaling service it is necessary to provide historical high resolution precipitation data. This data is available for two gauging stations in Wuppertal

- Wastewater treatment plant Buchenhofen in the western part of Wuppertal, keeping records since January 1st 1960, operated by Wupperverband
- Wastewater treatment plant Schwelm close to the eastern boundary of Wuppertal, keeping records since November 2nd 1970, operated by Wupperverband

There are various other gauging stations in Wuppertal, but they were put into operation much later. Therefore the two stations with long-term records are considered to be the most valuable input for the urban downscaling service.

If the urban downscaling service is used with IDF-curves there are two ways to provide the required input data. The first is to use a published catalogue of IDF-curves, created by statistical analysis of historical precipitation data. For Germany the most prominent data source of this kind is the KOSTRA[2] Atlas (KOSTRA-DWD-2000). The second way is to compute local IDF-curves from local long time rainfall series (extreme value statistics).

Even though the current version of the local model GeoCPM is only used with static (spatially constant) rain events as input it is foreseen for the 3rd year to experiment with the design storm generator (Stormwater Generator). This service will deliver a grid of time variation curves for the precipitation describing the spatiotemporal progression of a synthetic storm water event for present or future climate conditions. It will be used to generate precipitation data for different runs of the surface run-off model and to study the influence of the direction a storm water event takes. The combined model runs (DYNA and GeoCPM) can be carried out with spatially variable rain events in the future (after the project).

The following 2 charts visualise the overall data flow to include Common Service results in the local model.

[2] Koordinierte Starkniederschlags-Regionalisierungs-Auswertungen, produced by Deutscher Wetterdienst

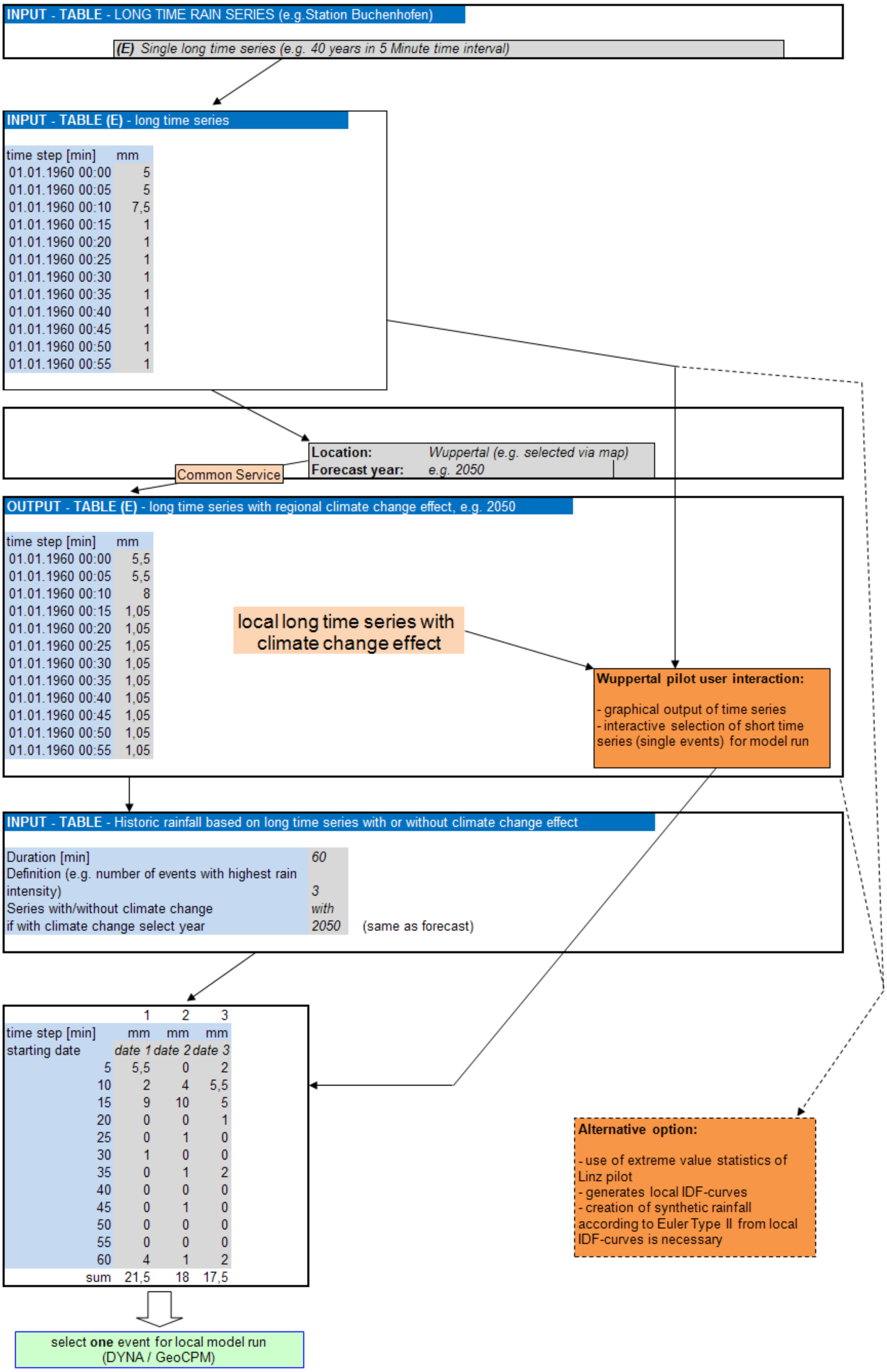

Fig. 1: Integration concept for CS 'Intense rainfall: Urban downscaling' (input: time series)

INPUT - TABLE - Definition of Storm Type

(A) Single Storm Event or (C) StormWaterGenerator or local IDF-Curves (with (D) /without (B) climate change effect)

INPUT - TABLE (A) - single storm water event (manual)

time step	mm
5	5
10	5
15	7,5
20	1
25	1
30	1
35	1
40	1
45	1
50	1
55	1
60	1
Sum	26,5

⇒ DYNA/GeoCPM

INPUT - TABLE (B) - User specfic local IDF-table in mm

data source: local extrem value statistics or in Germany KOSTRA-DWD

Rain-Duration Return Period in years

in minutes	1	2	3	5	10	20	30	50	100
D = 5 min	5,9	7,3	8,2	9,2	**10,6**	12,1	12,9	14,0	15,4
D = 10 min	8,3	10,2	11,4	12,8	**14,7**	16,6	17,7	19,1	21,0
D = 15 min	9,8	12,0	13,2	14,9	**17,1**	19,2	20,5	22,2	24,3
D = 20 min	10,8	13,2	14,6	16,3	**18,7**	21,1	22,5	24,3	26,7
D = 30 min	12,2	14,9	16,4	18,4	**21,1**	23,8	25,3	27,3	30,0
D = 45 min	13,6	16,6	18,3	20,5	**23,5**	26,4	28,2	30,3	33,3
D = 60 min	14,6	17,8	19,6	22,0	25,1	28,3	30,2	32,5	35,7
D = 90 min	17,3	20,6	22,5	24,9	28,2	31,5	33,4	35,8	39,1
D = 120 min	19,2	22,6	24,5	27,0	30,4	33,7	35,7	38,2	41,5
D = 180 min	21,9	25,4	27,4	30,0	33,4	36,9	38,9	41,5	44,9
D = 240 min	23,8	27,4	29,4	32,1	35,6	39,1	41,2	43,8	47,4
D = 360 min	26,5	30,2	32,3	35,0	38,7	42,3	44,5	47,2	50,8
D = 480 min	28,4	32,2	34,3	37,1	40,8	44,6	46,8	49,5	53,2

INPUT - TABLE - StormWater Generator and "Climate Change effect"

common services — **Location** *Wuppertal, coordinates, map?* / **Forecast year:** *2050* — common services

OUTPUT - TABLE (C) - StormWater Generator e.g for Wuppertal, 2050

Rain-Duration Return Period in years

in minutes	1	2	3	5	10	20	30	50	100
D = 5 min	7,4	9,2	10,2	11,5	13,3	15,1	16,1	17,5	19,2
D = 10 min	10,4	12,8	14,2	16,0	18,4	20,8	22,1	23,9	26,3
D = 15 min	12,2	14,9	16,5	18,6	21,3	24,1	25,7	27,7	30,4
D = 20 min	13,5	16,5	18,2	20,4	23,4	26,4	28,2	30,4	33,4
D = 30 min	15,2	18,6	20,5	23,0	26,4	29,7	31,7	34,2	37,5
D = 45 min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41,6
D = 60 min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	44,6
D = 90 min	21,6	25,7	28,1	31,1	35,2	39,3	41,7	44,8	48,9
D = 120 min	24,0	28,2	30,7	33,8	38,0	42,2	44,6	47,7	51,9
D = 180 min	27,4	31,7	34,3	37,5	41,8	46,1	48,7	51,9	56,2
D = 240 min	29,8	34,2	36,8	40,1	44,5	48,9	51,5	54,8	59,2
D = 360 min	33,1	37,7	40,4	43,8	48,3	52,9	55,6	58,9	63,5
D = 480 min	35,5	40,2	42,9	46,4	51,0	55,7	58,4	61,9	66,6

STORM WATER GENERATOR

OUTPUT - TABLE (D) - IDF-Curves with regional climate change effect e.g. 2050

Rain-Duration Return Period in years

in minutes	1	2	3	5	10	20	30	50	100
D = 5 min	7,6	9,4	10,5	11,8	13,6	15,5	16,5	17,9	19,7
D = 10 min	10,7	13,1	14,6	16,4	18,8	21,3	22,7	24,5	27,0
D = 15 min	12,5	15,3	17,0	19,0	21,8	24,7	26,3	28,4	31,2
D = 20 min	13,8	16,9	18,7	20,9	24,0	27,1	28,9	31,1	34,2
D = 30 min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38,4
D = 45 min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42,7
D = 60 min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45,7
D = 90 min	22,2	26,4	28,8	31,9	36,1	40,3	42,8	45,9	50,1
D = 120 min	24,6	28,9	31,4	34,6	38,9	43,2	45,7	48,9	53,2
D = 180 min	28,1	32,5	35,1	38,4	42,8	47,3	49,9	53,1	57,6
D = 240 min	30,5	35,1	37,7	41,1	45,6	50,2	52,8	56,2	60,7
D = 360 min	34,0	38,7	41,4	44,9	49,5	54,2	57,0	60,4	65,1
D = 480 min	36,4	41,2	44,0	47,5	52,3	57,1	59,9	63,4	68,2

local IDF-Table with climate change effect

INPUT - TABLE - Definition of Design Storm on Basis of Table (B) or (C) or (D)

Duration (min)		*45*
Return Period (Years)		*10*
Year (same as Forecast Year)		2050
TYPE:	*CONSTANT*	*EULER-TYPE II*

CONSTANT time step (min)	mm	EULER-TYPE II time	mm
5	2,61	5	2,4
10	2,61	10	4,0
15	2,61	15	10,6
20	2,61	20	1,7
25	2,61	25	1,2
30	2,61	30	1,2
35	2,61	35	0,8
40	2,61	40	0,8
45	2,61	45	0,8
50		50	
55		55	
60		60	
Sum	23,5	Sum	23,5

⇓ DYNA/GeoCPM or ⇓ DYNA/GeoCPM

Cell-description

- User Input or Input via StormWaterGenerator
- legend
- data from Common Services e.g. StormWaterGenerator

Fig. 2 Integration concept for CS 'Stormwater Generator & IDF Curves: Urban downscaling' (input: rain event, IDF table)

2.7. Planned Pilot Activities for the 1st year

An important activity of Wuppertal besides the activities that are already scheduled in the Description of Work (DoW) is the procurement of a software product that implements a hydro dynamic surface run-off model. Currently there are two products under discussion:

- **GeoCPM**, manufactured by the German consortium tandler.com GmbH/Pecher AG. This is a component for ++SYSTEMS, a GIS with subject-specific modules for all aspects of the sewerage domain.

- **HYDRO_AS-2D**, manufactured by 'Ingenieurbüro Nujic' and distributed by Hydrotec GmbH.

The City of Wuppertal favours GeoCPM, mainly because the ++SYSTEMS software is already in use with the modules FLUT and DYNA. Both of them are in use in the municipality of Wuppertal and at WSW (see 2.4). However, it is possible that both products will be procured since HYDRO_AS-2D has some features that are in line with requirements of the WV. To avoid a severe delay of the pilot implementation the software procurement has to be completed until the end of the 3rd quarter 2010. HYDRO_AS-2D is not able to carry out combined calculation of the sewer system <u>and</u> the surface as it is necessary in most areas in the city Wuppertal.

The most complex parameter for the modelling of surface run-off is an optimised DEM, the so-called 'calculation model'. Both GeoCPM and HYDRO_AS-2D expect this in the form of a TIN. It is important that the calculation model contains accurate information about man-made break lines. The most significant classes of such break lines are the exterior walls of buildings ('building break lines') and road kerbs or similar vertical structures ('road kerb break lines'). The properties of the terrain that have an influence on the surface run-off have to be included in the calculation model as well, usually as attributes of each single triangle of the TIN. Examples for such attributes are the run-off coefficient, the velocity of evaporation and the potential volume of infiltration.

A calculation model for Wuppertal can be generated from the existing high resolution aerial laser scan data (see 2.4). But this cannot be accomplished in a fully automatic manner. In fact the process is a stepwise refinement of a first rough model that is automatically calculated from the laser scan data. The refinement demands decisions of an expert like

- introducing additional high accuracy data, e.g. from 3D terrestrial topographical surveys or existing maps to enhance the model (this is particularly useful for the break lines)

- reducing the number of 3D-points in the laser scan data to get larger triangles in the TIN (this accelerates the computation of the later modelling experiments for the surface run-off)

- adding additional interpolated 3D-points in the laser scan data to get more evenly sized and shaped triangles in the TIN (this accelerates the computation of the later modelling experiments for the surface run-off as well)

Hence it would be an extremely time-consuming task to establish a calculation model for the whole area of Wuppertal in a single run. To allow a rapid progress of the SUDPLAN project Wuppertal intends to provide a separate calculation model for each catchment area. It is necessary to design and implement a new business process for this work that will continue over the whole duration of the SUDPLAN project. Nevertheless Wuppertal expects to establish a first calculation model for the creek 'Lüntenbeck' in the 3rd quarter 2010 that could be used as a representative in the software development process for the Wuppertal pilot.

With regard to the practical use of the SMS the Wuppertal pilot will largely focus on the integration aspects of this tool in a **multi-model**, **multi-data source**, **multi-SDI** environment. The main activities to make this happen are

- basic set up of the service infrastructure; this activity will start from a high level as the WuNDa system and two SDI's are already in place (see 2.4)
- analysis of software structure and interfaces of the procured products (see above, in the following referred to as 'model components') and wrapping of the model components into services which comply with open interfaces; this includes the definition of schema for data exchange and model runs. It may also require some software redesign on part of the model components
- integration of the model components into the service infrastructure
- definition of the business processes to be used in the pilot; definition of visualisation and interaction metaphors. Implementation of these business processes and metaphors using the SUDPLAN product
- definition and implementation of the different scenarios to be studied in the different pilot phases; set-up and implementation of the associated workflows using the SUDPLAN product
- validation with end users

2.8. Planned Pilot Activities for the 2nd year

In the first year of the project the main focus of the Wuppertal pilot work was the selection of an appropriate local model configuration and the provision of an initial calculation model. The focus of second year's work is on integration. The overall aim is to integrate the whole chain of components involved in the Wuppertal pilot scenario.

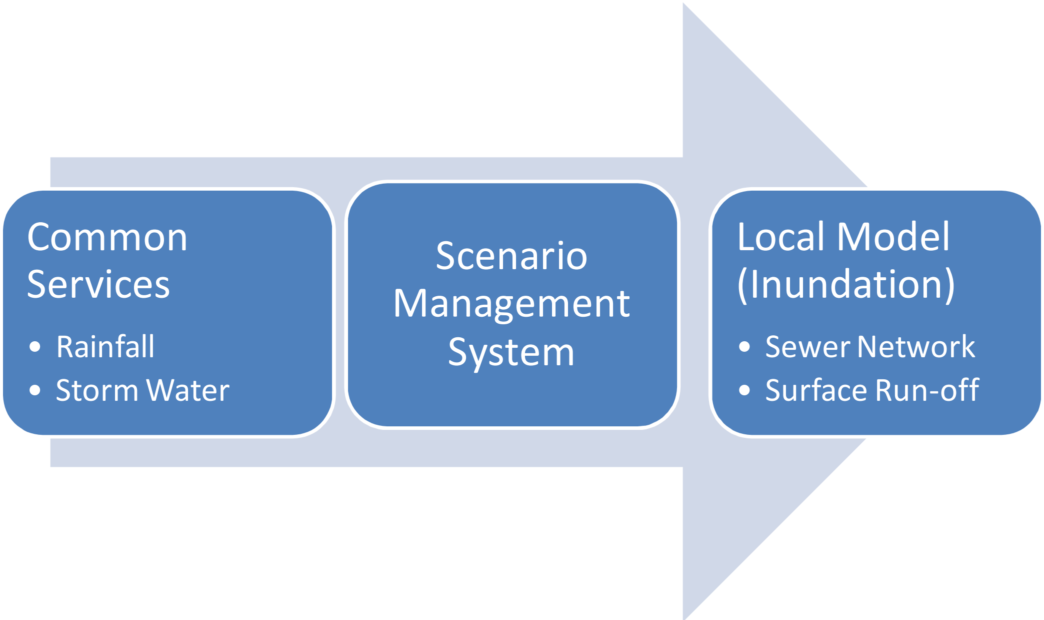

Fig. 3: Wuppertal application component chain

In addition advanced parameterization functionalities for the local model have to be designed and developed. The most complex parameter for the modelling of surface run-off is an optimised DEM, the so-called 'calculation model'. It is important that the calculation model contains accurate information about man-made breaklines. The most significant classes of such breaklines are the exterior walls of buildings ('building breaklines') and road kerbs or similar vertical structures ('road kerb breaklines'). The properties of the terrain that have an influence on the surface run-off have to be included in the calculation model as well, usually as attributes of each single triangle of the TIN.

The work plan to meet the objectives of the 2^{nd} year includes the following activities:

- A concrete concept for the communication with Common Services (cf. 2.6) and the local models needs to be established and implemented. This includes
  - the wrapping of the local model components (Service Wrapping)
  - a customization of the local models with regard to the pilot requirements (e.g. modification of the topographic model)
- A specialized instance of the SMS has to be deployed that
  - integrates the local models DYNA and GeoCPM
  - enables users to change the model parameterization (e.g. raise road kerbs)
  - provides a workflow support for the planning process
  - enables users to include climate change information through the integration of Common Services
  - supports appropriate visualization methods

After the 2^{nd} year activities the resulting Wuppertal application will be a working prototype and the basis for 2^{nd} year validation. Advanced visualization (flooding 4D), enhanced workflow support, integration of design storm functionality will be part of the work to be performed in the 3rd year.

2.9. Planned Pilot Activities for the 3rd year

The first year of the project consisted of preparatory activities regarding the local model and the underlying data requirements. In the second year of the project the focus was mainly on the integration of common services and local model as well as basic support of the identified use cases and workflows on basis of the SMS. Our planning of the 3rd year is not restricted to what can be done with available resources considering the remaining project time but we want to outline the pilot vision to drive the development process as far as possible.

More data

Part of the 3rd years work will be the integration and visualisation of the sewer network in the context of the pilot application. The additional information will help to support the planning process and provide the necessary overall context.

The combined model (DYNA+GeoCPM) for the test-catchment “Lüntenbeck” will be adjusted to new designed interfaces (e.g. artificial breaking edges) and final test model runs will be carried out. A “test version” is available for all further developments (e.g. WP3).

The modellers provided a test 3D-visualisation during the 2nd year (Fig. 4) that can serve as basis for a more sophisticated 3D/4D-visualisation within SUDPLAN.

Enhanced Use Case Support

A larger number of use cases will be supported by the Pilot Application. This will involve easier handling of local models (parameterisation, visualisation, coupling) as well as the integration of upcoming Common Service functionality (WP4).

Enhanced Visualisation

Another focus of the 3rd year will be the development and deployment of advanced features regarding visualisation and parameterisation of local models (based on WP3 results).

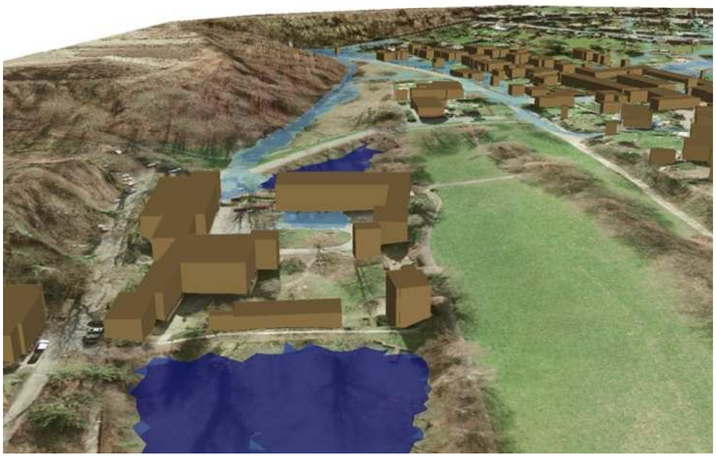

Fig. 4 ArcGis Based Flood Visualisation of a Wuppertal Site

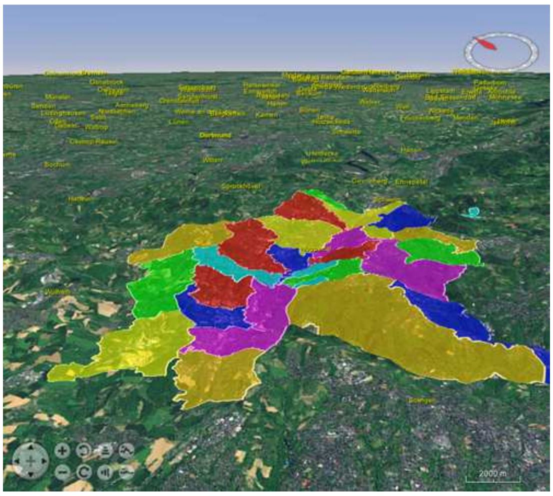

Fig. 5 GEP Catchment Areas (2D Shape)

Regarding the visualisation of local model results this includes:

- Dynamic (over time) 2D result visualisation on the map
- Predefined 3D visualisation trajectories
- fully interactive visualisation (3D scene navigation) is desirable but not mandatory for the fulfilment of the pilot requirements

Enhanced Model Parameterization,

The implementation plan for the second year included the possibility to modify the TIN predefined breaklines only. Based on the existing development we aim e.g. at the possibility to change height of street levels and to add new breaklines.

Mobile Application Support

In addition the vision contains support of mobile apps to support visits to property owners on sight, as a first step on sight GPS coordinates can be used to determine possible water levels more advanced visualisation features e.g. 4D animations in a likely scenario can be used to convince proprietors of necessary measures.

Fig. 6 SUDPLAN IPad Teaser

Augmented reality functionality may be of help here as well but this is clearly out of the focus and scope of the project objectives.

2.10. Decisions/Analyses to be supported by the DSS

The Wuppertal pilot will allow an analyst to predict areas of urban flooding within the City of Wuppertal for two purposes.

The first is to be able to inform property owners about possible risks threatening their low-lying assets ('Flood Risk Assessment'). For example, the owner of a commercial building that contains telecommunications equipment in the cellar might be informed that in the future his assets might be under increasing risk of inundation and destruction. This will give him an opportunity to undertake changes to protect this equipment from such risks.

The second purpose is to consider possible alterations that might reduce the risk of damage due to flooding ('Flood Risk Mitigation'). In this case there might be infrastructure changes which could be planned to prevent damage anticipated by the first analysis. For example, road kerbs might be raised, barrier walls could be erected, or storm water drainage basins might be constructed. Obviously this implies the involvement of more than one department of the urban administration, e.g. the town planning service, the public works service or the parks and gardens department.

These two purposes correspond to two optional steps in the overall planning process of the GEP that is shown in Fig. 7. They are only carried out for critical spots, where the previous mandatory steps have indicated a high risk of inundation of valuable private or public property. These mandatory steps comprise the sewer simulation, a simple flow path analysis by means of the D8-method[3] and an on-site inspection for risk assessment.

Both the Flood Risk Assessment and the Flood Risk Mitigation are relevant for the protection of private and public property from damage due to urban flooding during storm events. The tasks will be described in more detail in chapter 4. While the primary concern regarding flood events is short-term (e.g. 5 years in the future), there is also interest in the long-term effects of climate change to be able to take sustainable measures.

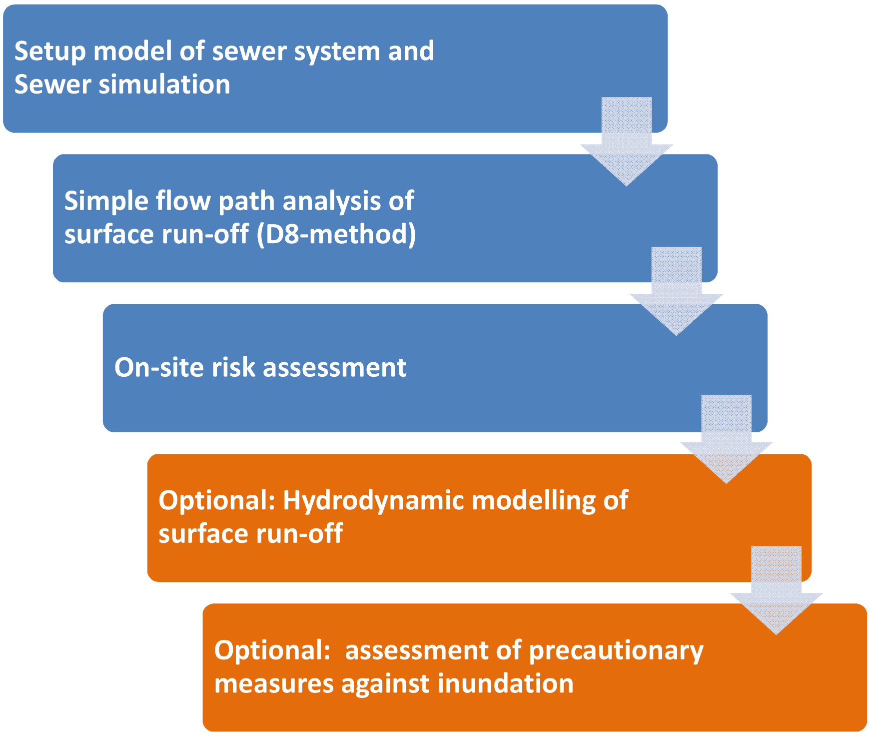

Fig. 7: Overall planning process of GEP (general wastewater management planning)

2.11. Expected Added Value

The following added values are expected for the City of Wuppertal:

- An operational DSS for the storm water management will be available for both (1) planners at WSW and WV and (2) in the municipality. This will support the co-operation of the three organizations and will help them to identify the most cost-efficient planning options for flood risk mitigation in Wuppertal. The DSS will make use of the recently established high resolution 3D data for Wuppertal. It will enable the user to explore what-if scenarios with modified topographic structures (road kerbs, walls etc.).
- The SMS will enable the City of Wuppertal to develop applications similar to the Wuppertal pilot in a quick and cost-efficient way. Such applications may or may not use the SUDPLAN Common Services.

[3] The well-known D8 algorithm is the most commonly used method for approximating flow directions on a topographic surface

- SUDPLAN will provide new generic components for Wuppertal's SDI and the WuNDa platform. These components will comprise services (e. g. services for access control and security) and application components (e. g. for 3D visualisation). The new components will offer further application options for Wuppertal's SDI and WuNDa and thus will intensify the use of the existing spatial data.

3. Users

The following chapter describes the different user types of the Wuppertal pilot application.

The users are categorized as follows:

1. Primary User – is working directly with the system
2. Secondary User – might use the system with the help of a primary user
3. Tertiary User – will not directly work with the system, but will use results produced by the system

Every user type is characterised with a short explanation which focuses on the intended usage of the Wuppertal pilot application. Particular emphasis is laid on the technical background of the different user types to be able to consider the human factor in the design and development process. For instance, a modelling expert with a strong background in information technology who is comfortable with complex modelling programs would certainly expect other functionality and complexity of the system than a clerk whose background is mostly in standard applications like office and reporting tools.

3.1. Primary Users

There are two types of users who will make regular and direct use of the Wuppertal Pilot system: Storm Water Managers and System Administrators.

3.1.1 Storm Water Manager

Wuppertal's storm water managers are hydrological modellers employed by the City of Wuppertal, the Wuppertaler Stadtwerke (WSW) and the Wupperverband (WV). These individuals are very comfortable with computers. As modellers they will want to interact with the local models used in the pilot and they may have some familiarity with precipitation models. However, they will likely have little to no experience with climate models. They may or may not have sophisticated GIS experience. The following table gives an overview on the expected number of storm water managers who will use the Wuppertal pilot application:

Organization	Scope of Business	Number of Storm Water Managers
City of Wuppertal	'Koordinierungsstelle Stadtentwässerung': responsible for cost-efficient maintenance and development of sewage system (policy-maker)	2
Wuppertaler Stadtwerke (WSW)	GEP (general wastewater management planning) cf. Fig. 7 for process description	3
Wupperverband (WV)	Flood protection and prevention for the not-piped sections of Wuppertal's streams	3

The approach these users take to the analysis tasks envisioned involves distributed collaborative analysis. While the City of Wuppertal is generally the lead agency there is close interaction with the other two organizations. For most of these users the German language is required.

3.1.2 System Administrator

The System Administrator for the Wuppertal pilot will be a City of Wuppertal staff member who is very comfortable with computers, computer networks, and software installation. He is a sophisticated GIS user who is comfortable installing and configuring both spatial and non-spatial databases. In general he has no expert knowledge regarding climate, precipitation or urban run-off modelling.

3.2. Secondary Users

There are two types of secondary users envisioned for the Wuppertal pilot, namely the property owners whose assets might be endangered by flooding and urban planners from other departments of the municipality.

3.2.1 Property Owners

Property owners in Wuppertal will be shown results by the modellers and may interact with the system together to engage in “what if” scenario sessions. They may or may not have technical backgrounds and likely have none. In general, the German language will be required. The operators of endangered facilities have the same profile as the property owners, hence they are subsumed under this type.

3.2.2 Urban Planners

Urban planners of other departments of the urban administration appear as users when the details (technical feasibility, restrictions, costs) of the planning options that have been simulated with the Wuppertal pilot application have to be discussed. They may come from a large variety of neighbouring disciplines as shown in the following table. Actually, there are more planners involved working for cooperating organizations in the field of urban drainage.

Department	Organizational Unit in Wuppertal Municipality	Approx. Number of Involved Persons
Town Planning Service	101 Stadtentwicklung und Städtebau	12
Land Registry Office	102 Vermessung, Katasteramt und geodaten	2
Parks and Gardens Department	103 Grünflächen und Forsten	6

Department	Organizational Unit in Wuppertal Municipality	Approx. Number of Involved Persons
Public Works Service (road construction)	104.2 Straßenbau	14
Building Regulatory Agency (urban land use planning)	105.1 Bauleitplanung	10
Office for the Environment (landscape planning)	106.11 Landschaftsplanung und -pflege, Untere Landschaftsbehörde	8
Office for the Environment (water authority)	106.29 Wasser, Gewässer, Untere Wasserbehörde	5
Fire Brigade / Emergency Management	304 Feuerwehr	4
	Total:	61
Cooperating Organizations		
Public utilities	Wuppertaler Stadtwerke (WSW)	9
Water Board	Wupperverband	5
Water Board	Bergisch-Rheinischer Wasserverband	2
	Total:	15

Members of these departments and cooperating organizations are supposed to take part in round tables discussions about the proposed planning options where ad hoc visualisations of the simulation results will be useful.

It is possible that some of these users will evolve into primary users in the course of time since they are familiar with GIS-systems and may want to work with the Wuppertal pilot visualisations independent from the storm water managers.

3.3. Tertiary Users

There are two types of tertiary users of the Wuppertal pilot: city politicians/managers and the general public. Both of these will interact with the system only in the sense that they will be shown results or reports whose content was produced by the system.

3.3.1 City Politician/Manager

The politician/manager will be the recipient of reports generated by primary users of the pilot system. While the content of these reports will in part come from the system, other content and formatting will generally be the product of other tools. The politician/manager is generally assumed to have little to no technical training or knowledge, but will be familiar with the general issues of urban flooding and property protection. In general, the German language will be required.

3.3.2 General Citizen

The general citizen of Wuppertal may be provided with information resulting from sessions conducted with the Wuppertal pilot, perhaps through publication on the city's web site. While the content of these publications will in part come from the system, other content and formatting will generally be the product of other tools. The general citizen is assumed to have no technical training or knowledge, and they may be only slightly familiar with the general issues of urban flooding and property protection. In general, the German language will be required.

3.4. Other Stakeholders

For the Wuppertal Pilot Application no other stakeholders have been identified.

4. Tasks and Task Analysis

This chapter is dedicated to the tasks which evolve from the Wuppertal objectives. Specific tasks of the Wuppertal application users are described in the structured form of the identified workflows. Each task is broken down into its sub tasks until the necessary granularity of task description is obtained. The results of the task analysis will enable the technical partners to swiftly understand the domain context of the pilot and to take the implicated requirements for the design of the scenario management system into account. For more information on task analysis please refer to (Diaper, 2003) and (Redish, 1998).

4.1. Flood Risk Assessment

The Flood Risk Assessment (FRA) task identifies the location of likely flooding so that property owners can be warned. This will be achieved by running **simulations of heavy rainfall events** for each catchment area. The limitation of model-runs to single catchment areas is necessary because it is not achievable to provide a sophisticated calculation model of Wuppertal's complete surface in a moderate time. Therefore a previous subtask appears, namely the determination of an optimal order that the catchment areas are analysed and processed in. This **catchment area prioritisation** will be done with a purely geometrical analysis of the lower areas in each catchment area and an assessment of vulnerable facilities inside of these areas. After the simulations for a single catchment area have been computed and validated it is possible to **analyse the run-off behaviour** in the course of urban flooding and to precisely **indentify the potential flood risk areas** and the endangered property and facilities. As some significant structures of buildings (stairways, funnels etc.) are not included in the calculation models, the **on-site inspection of a flood risk area** or endangered infrastructure is always necessary to finalise the assessment. The on-site inspection is typically done together with the property owner and / or the operator of the affected infrastructure. This allows the planners to get access to the interior of the building and to discuss different planning options with the concerned people.

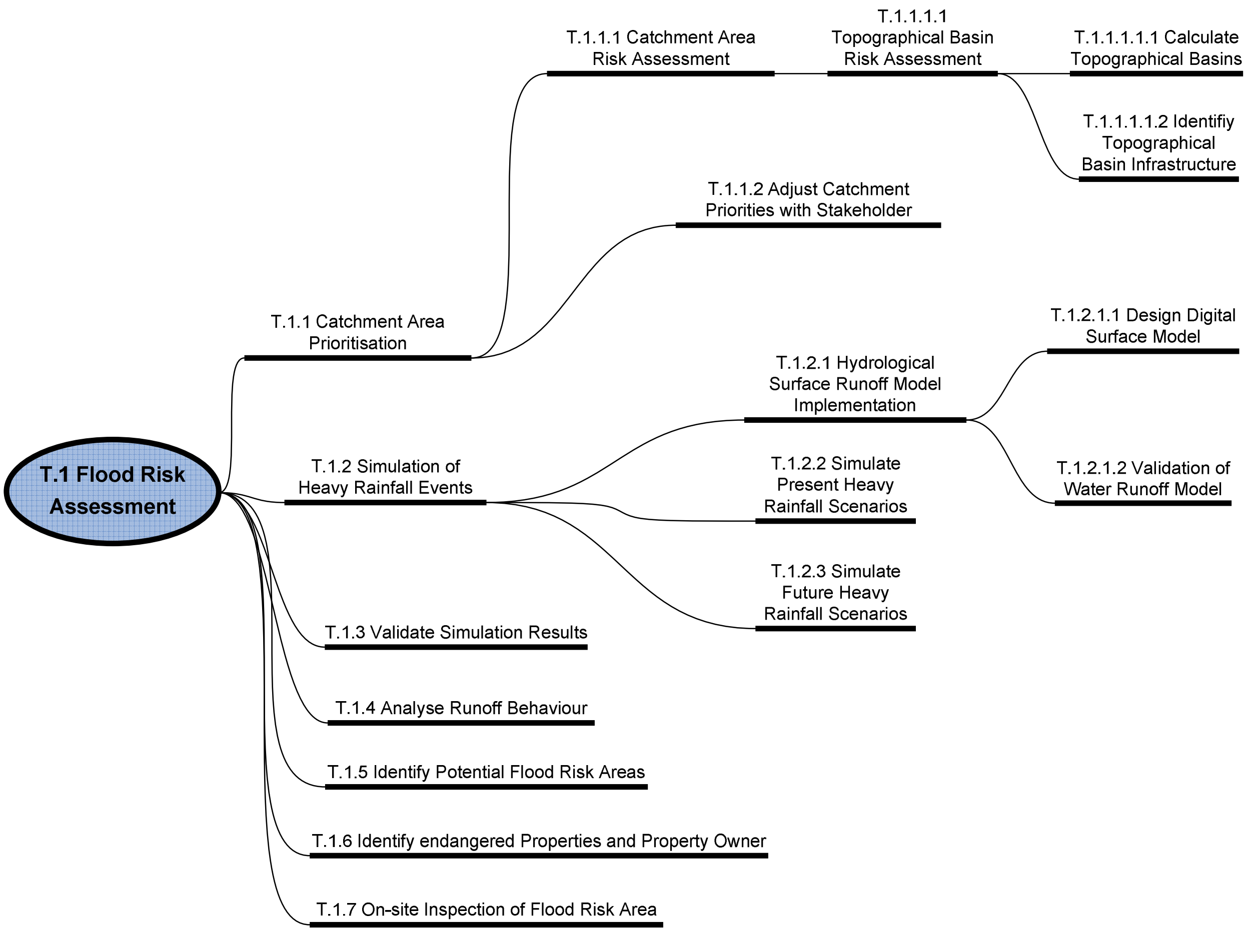

Fig. 8 Flood Risk Assessment Task Overview

Task	**1.1 Catchment Area Prioritisation**
Description	The flood risk assessment for the area of Wuppertal is an enormous task and requires substantial amount of work to achieve. In order to assure that the most critical areas regarding the probable impact of storm water flooding are assessed prior to less risky areas, an ordering of the single catchment areas is indispensable. The catchment areas will be evaluated by the risk of the containing basins and the critical infrastructures lying therein. The prioritisation allows the flood risk assessment of the catchment areas one by one and therefore assures that the most critical areas will be addressed first in the flood risk assessment process and first results will be achieved early.
Actor	Storm Water Manager
Goal	Establish prioritisation after which the catchment area flood risk assessment will be processed.
Input	Catchment area risk assessment
Output	Refined list of catchment areas sorted descending according to their priority
Components	N/A

Constraints	N/A

Task	**1.1.1 Catchment Area Risk Assessment**
Description	In this task the risk level of the single catchment areas will be determined. In order to be able to do this the single basin risk levels have to be assessed. Based on the risk level of the containing basins the overall risk level for the catchment area can be calculated.
Actor	Storm water Manager
Goal	Determine the risk level of the catchment areas of Wuppertal
Input	Basin Risk Assessment
Output	Catchment area risk assessment
Components	N/A
Constraints	N/A

Task	**1.1.1.1 Topographical Basin Risk Assessment**
Description	In order to be able to judge the importance of the catchment areas the topographical basins of Wuppertal have to be calculated and evaluated regarding the critical infrastructure and possible impacts on the surroundings in case of a storm water flooding of the basins. The calculated basins will be analysed regarding the infrastructure like hospitals, power lines, telephone network etc. they contain and the possible impact to the population in case of a storm flood. Basins which do not posses such properties will be sorted out in this process.
Actor	UNU, DLR
Goal	Assess the implications of heavy rainfall events for every depressed area containing critical infrastructure and evaluation of possible effects resulting from such events.
Input	Identified basins and containing infrastructure
Output	Basin Risk Assessment
Components	N/A
Constraints	The risk assessment will be done by the UNU and the DLR in the KIBEX project. The Wuppertal municipality plans to use the results for the catchment area prioritisation. If the assessment information of the depressed areas prove to be insufficient for the prioritisation of the catchment areas the municipality plans to further refine the assessment.

Task	1.1.1.1.1 Calculate Topographical Basins
Description	Identify and calculate topological depressed areas (basins) in the catchment area where the water will potentially collect during heavy rainfall events. A basin is a landform sunken or depressed below the surrounding area. The depression will be calculated with the aid of a digital elevation model (DEM). This process is a onetime task; after the depressed areas are identified they will hardly change.
Actor	Storm Water Manager, DLR
Goal	Identify all topological depressed areas in the Wuppertal region
Input	DEM
Output	The exact location and dimensions of the different basins
Components	N/A
Constraints	The calculation of the basins will be done by the DLR in the KIBEX project

Task	1.1.1.1.2 Identify Topographical Basin Infrastructure
Description	The calculated basins can be used to identify critical infrastructures which could be subject to severe damage during the event of a storm flood. Critical infrastructure, such as hospitals, power networks, telephone networks, transportation or security services etc., will be identified for later detailed risk assessment.
Actor	Storm Water Manager, DLR, UNU
Goal	Identification of critical infrastructures
Input	Calculated topographical basins, infrastructure information and location (cadastral map etc.)
Output	Geospatial mapped infrastructure location and information for the single basin
Components	Sudplan Scenario Management System
Constraints	One of the main goals of the KIBEX project is to identify the classes of facilities that are most vulnerable to storm water flooding, focussing on drinking water supply and the power supply system. The city of Wuppertal will be concerned primarily with infrastructures of these classes in this task.

Task	1.1.2 Adjust Catchment Priorities with Stakeholder
Description	The risk level priorities of the single catchment areas will be discussed with stakeholders which are directly influenced by the order the catchment areas will be processed. This process gives the stakeholders the possibility to propose changes to the ordering based on circumstances and facts which were

	not considered during the catchment area risk assessment. The result of this adjustment is a refined prioritisation of the catchment areas which not only mirrors the direct flooding risks but also concerns from other directly affected parties of the Wuppertal municipality.
Actor	Storm Water Manager
Goal	Refine the priorities of the catchment area
Input	List of catchment areas sorted descending according to their flood risk level
Output	Refined list of catchment area priorities
Components	N/A
Constraints	N/A

Task	**1.2 Simulation of Heavy Rainfall Events**
Description	The surface water runoff will be simulated with the help of a comprehensive and state of the art hydrological surface run-off model. A multitude of different rain scenarios will be run through the model in order to identify endangered public and private property. The goal of the calculation is to simulate the flow of water and maximum water levels reached in case of heavy rainfall events and flooding. The simulation will not only examine past rain patterns but also analyse possible future rain scenarios based on established climate models.
Actor	Storm Water Manager
Goal	Simulation of heavy rainfall events and the water runoff in a catchment area
Input	Measured rain time series, simulated rain time series for future climate scenarios, digital surface model
Output	Simulated water run-off and water levels for every point in the digital surface model
Components	SUDPLAN Scenario Management System, Hydrological Water Runoff model service, Common Services Precipitation
Constraints	N/A

Task	**1.2.1 Hydrological Surface Runoff Model Implementation**
Description	For the simulation of water run-off the city of Wuppertal must set up a hydrological surface run-off model ('calculation model') in the form of a TIN. Due to the fact that this is no trivial task the usual way to achieve an optimal result is to use an iterative approach of design (computation of the TIN from given 3D points, compare subtask 1.2.1.1) and validation (subtask 1.2.1.2). This means that at the end of each cycle the digital surface model has to be

	improved based on an evaluation report coming from subtask 1.2.1.2. The improvement may include the introduction of additional high accuracy data (e.g. from terrestrial surveys), the elimination of redundant 3D-points in the laser scan data and the addition of interpolated 3D-points in the laser scan data to get an evenly structured TIN. The iteration converges towards a model that is morphological correct and optimized with respect to the calculation time needed for a run of the hydrodynamical surface run-off model.
Actor	Storm Water Manager, Modelling Experts
Goal	Set up a functional surface runoff model
Input	Digital Surface Model, Rainfall Data
Output	Surface Runoff Model for the Region of Wuppertal
Components	N/A
Constraints	N/A

Task	**1.2.1.1 Design Digital Surface Model**
Description	In order to use a hydrological surface runoff model a digital surface model of the region of Wuppertal has to be created. The municipality possesses a digital laser scan of the Wuppertal region in form of a laser point cloud where every point has an elevation and classification value. Based on this point cloud an elevation model will be derived. Therefore breaklines of objects such as street kerbs have to be identified with the aid of additional information e.g. streets, paved surfaces, impervious surface etc. The breaklines further refine the elevation model because the additional lines will make the elevation model more exact and necessary to calculate the water run-off. In a second step the not scannable areas like underground crossings, pedestrian underpass etc. need to be incorporated. The method of laser scanning itself has its limitations which manifest in measurement errors, for example the capturing of non surface objects like trees, lamp poles etc. These objects must be removed to avoid distortion of the digital surface model. The resulting digital surface model will be optimised regarding the removal of redundant point information with the goal to reduce the later calculation time of the surface runoff model. This task represents a joint venture between storm water managers, surveyors and model experts and has to be performed in close collaboration.
Actor	Storm Water Manager, Surveyors, Modeller
Goal	Design and Implementation of a specialised surface model as the base for hydrological surface run-off simulation.
Input	Laser point cloud, Sealed Surface Information, Context Information (Buildings etc.)
Output	Digital Surface Model

Components	Water Surface Run-off Simulation Service (SRSS)
Constraints	This step cannot be performed automatically and efforts a lot of manual intervention and expert knowledge. This could have implications on structural changes to the surface model in the 4.2 Flood Risk Mitigation task.

Task	**1.2.1.2 Validation of Water Runoff Model**
Description	The accuracy of the surface runoff model results have to be compared to actual available damage records of areas where flooding already occurred. Because a 100 % validation will not be possible and additionally there are no historic data available which cover large areas, individual cases and experiences from the past will be taken into account to judge the quality of the model predictions. Furthermore the model results will be analysed with contextual information such as cadastral maps in order to discover errors in the simulation caused by wrong input parameters such as falsely detected breaklines, distortion in the surface model etc. which cannot be discovered automatically.
Actor	Storm Water Manager, Modeller
Goal	Validate the quality of the simulation predictions.
Input	Surface Runoff Model, Context/Background Information of the area, Visualisation of model results
Output	Validation Report – A List of unexpected or wrong behaviour of the model results and description of possible problem origin(s)
Components	Water Surface Run-off Simulation Service
Constraints	No area covering measurements to compare the model results.

Task	**1.2.2 Simulate Present Heavy Rainfall Scenarios**
Description	Simulations of heavy rainfall over the area of Wuppertal based on historical precipitation data. The surface runoff model is used to predict how the water will distribute over the surfaces. The Storm Water Manager wants the possibility to play through different kind of rain scenarios which imitate possible natural rainfalls or to use real data from past storm events to evaluate the water run-off. The simulation enables the Storm Water Manager to see different attributes, e.g. water run-off velocity, run-off direction, water levels etc., of the precipitation water for specified time steps. Not only can the single steps of the rainfall event be analysed but also an animation how the water will distribute throughout the city over time.
Actor	Storm Water Manager
Goal	Simulation of heavy rainfall events over Wuppertal and the water run-off ways on the surface.

Input	Historic precipitation data
Output	Simulation of the surface water run-off
Components	Scenario Manager, Visualisation Component, Precipitation Selector, Water Surface Run-off Model
Constraints	N/A

Task	**1.2.3 Simulate Future Heavy Rainfall Scenarios**
Description	Similar to task 1.2.2 Simulate Present Heavy Rainfall Scenarios. Instead of historic precipitation data calculated precipitation data of future climate scenarios will be used. This approach should enable the storm water manager to simulate how the water will run off the surface in different climate scenarios with increased occurrence or intensity of storm water events. The so gained insights will hopefully help to find suitable solutions for the flooding problems in a long term view.
Actor	Storm Water Manager
Goal	Simulate how future climate scenarios (precipitation) will influence the water run-off
Input	Calculated future precipitation data
Output	Simulation of the surface water runoff
Components	Scenario Manager, Visualisation Component, Precipitation Selector, Water Surface Run-off Model, Common Service Interface
Constraints	N/A

Task	**1.3 Validate Simulation Results**
Description	This task validates the results from Task 1.2.2 and Task 1.2.3 regarding the certainty of the model results. Due to the nature of models it is not possible to verify the simulation results completely or to assume a perfect representation of the real world. Instead the confidence of storm water managers in the model results shall be increased with single spot checks. Single flooding predictions of the model will be compared to present and past experiences. Examples are: • Experience of storm water manager • Input from public institutions (fire fighter, etc.) • Enquiry by property owner With the help of these facts the quality of the model predictions can be validated to a certain level.
Actor	Storm Water Manager
Goal	Validate the prediction of simulation results

Input	Information on direct and indirect flooding damage, simulation results
Output	No tangible results, but a better impression about the quality of simulation results for storm water managers.
Components	Scenario Manager, Visualisation Component, Precipitation Selector, Water Surface Run-off Model, Common Service Interface
Constraints	N/A

Task	**1.4 Analyse Runoff Behaviour**
Description	In this task water run-off behaviour of various rainfall scenarios will be analysed in order to understand the flow of water. A graphical representation of surface run-off shall help to comprehend the complex processes of water run-off such as water gathering points and the main ways the water will run-off. Further it will help the storm water manager to understand the cause or origin of such phenomena for example where the water comes from. This will lead to a new level of expertise which will help the storm water manager to not only cope with the end points of such causality chains, such as flooded areas, but to understand why these areas are flooded and how to prevent this at a much earlier position in the causality chain.
Actor	Storm Water Manager
Goal	Build a general understanding of water flow directions and the reason for water gathering points.
Input	Simulation results
Output	N/A
Components	Scenario Management Tool, Visualisation Component
Constraints	N/A

Task	**1.5 Identify Potential Flood Risk Areas**
Description	The simulation results gathered from Task 1.2.2 and 1.2.3 will be used to identify potential flood risk areas where water levels will exceed a certain threshold. For the identification of these areas the simulation results will be compared to background information like building locations and cadastral information of the affected area. The identified areas represent a potential endangered area and need further investigation about the probability of flood damage to single properties.
Actor	Storm Water Managers
Goal	Identify potential flood risk areas

Input	Simulation results, infrastructure background information
Output	Flood risk areas
Components	Visualisation component
Constraints	N/A

Task	**1.6 Identify endangered Properties and Property Owner**
Description	Based on the flood risk areas from task 1.5 the affected properties and the corresponding owners will be identified. The resulting list will later be used to contact the property owner and to inform them about potential risks and how these risks can be prevented, for example with structural measures.
Actor	Storm Water Manager
Goal	Identify flood risk endangered properties and their owner
Input	Flood risk areas
Output	List of properties and property owner
Components	N/A
Constraints	N/A

Task	**1.7 On-site Inspection of Flood Risk Area**
Description	In order to come to a final conclusion about the certainty by which a property will be endangered by flooding events the site has to be inspected by a storm water manager personally. During this inspection the storm water manager decides whether storm water damage will be likely or not based on the local circumstances. This on-site decision cannot be replaced by virtual modelling, because the simulation of the water surface run-off is only a model of the reality for a special purpose, not all information from reality can be captured and represented to make such a decision possible.
Actor	Storm Water Manager
Goal	Assess the endangered object on-site and in person regarding their storm water risk.
Input	List of endangered properties, simulations which indicates flood risk
Output	Expert opinion on the flood risk
Components	N/A
Constraints	Model results must be available to the storm water manager in the field in form of a mobile device such as a notebook

4.2. Flood Risk Mitigation

The Flood Risk Mitigation (FRM) task is intended to protect property by predicting the effect of various possible structural measures on the impact of urban flooding and identifying the most suitable and cost-efficient planning option. The three most important classes of local structural measures that are effective for flood risk mitigation are

- the raising of road kerbs
- the installation of barrier walls
- the construction of drainage basins

In order to accomplish the FRM task, the analyst must complete subtasks 2, 3, and 4 of the FRA task, but for running the simulations a new subtask appears, the modification **of the digital surface model that is underlying the surface run-off model**. This is by far the most complex interaction between the SUDPLAN SMS and the surface run-off model.

The other FRM subtasks include the **evaluation of the effectiveness** of a certain structural measure for flood risk mitigation on the concerned site as well as an **evaluation of** its **economic efficiency**. The final step is the **discussion of possible measures with the property owner**.

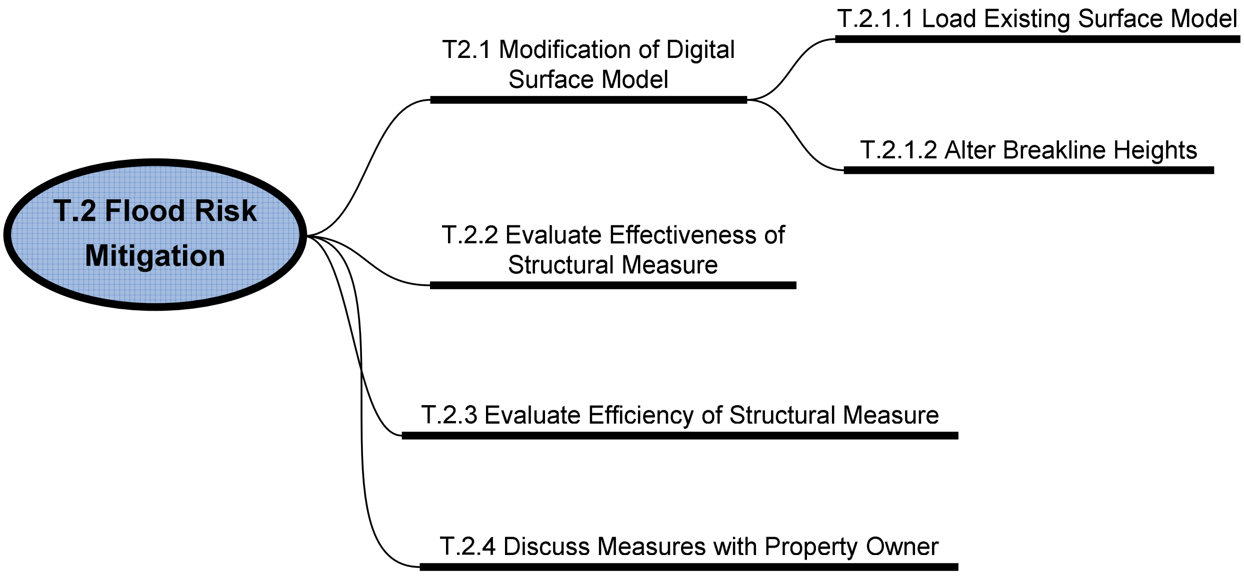

Fig. 9 Flood Risk Mitigation Task Overview

Task	**2.1 Modification of Digital Surface Model**
Description	To simulate the effect of a certain structural measure on the surface run-off it is necessary to introduce it into the digital surface model that is input for the surface run-off model. This task relies on the existence of a digital surface model that describes the initial situation (cf. T.1.2.1.1). The modification can only be carried out by the alteration of existing breaklines that have to be defined in the initial digital surface model.

Actor	Storm Water Manager
Goal	Set up an alternative of the initial digital surface model that represents a certain structural measure for the physical protection of buildings or other facilities.
Input	Digital Surface Model for initial situation
Output	Modified Digital Surface Model
Components	Scenario manager, Visualisation component
Constraints	Digital Surface Model for initial situation must be set up. Modification can be carried out only by alteration of the height of predefined breaklines.

Task	**2.1.1 Load Existing Surface Model**
Description	The first step in T.2.1 is to load an existing digital surface model from the repository of the Scenario Management System (SMS) or from a GeoCPM input parameter file.
Actor	Storm Water Manager
Goal	Meeting the prerequisites for the modification of the digital surface model via the Scenario Management System.
Input	Digital Surface Model for initial situation
Output	N/A
Components	Scenario manager
Constraints	Digital Surface Model for initial situation must be set up. It has to be stored in the repository of the SMS or has to be available in the format of the GeoCPM input parameter file.

Task	**2.1.2 Alter Breakline Heights**
Description	The interactive modification of the initial digital surface model can only be carried out by the alteration of existing breaklines that have to be defined in the initial digital surface model. Part of this task is to save the new alternative in the repository of the SMS.
Actor	Storm Water Manager
Goal	Instantiate an alternative of the initial digital surface model that represents a certain structural measure for the physical protection of buildings or other facilities.
Input	N/A

Output	Modified Digital Surface Model
Components	Scenario manager
Constraints	Digital Surface Model for initial situation must be loaded.

Task	**2.2 Evaluate Effectiveness of Structural Measure**
Description	After a model run (T.1.2.2 or T.1.2.3) with an alternative of the initial digital surface model T.2.1.2) the user needs to check the effectiveness of the simulated structural measure on the flood risk migration. To do this he needs to load the corresponding local model results from the SMS. Furthermore he needs to visualise the model results in different manners (2D, 3D and 4D). Finally he will annotate the model results with his findings.
Actor	Storm Water Manager
Goal	Evaluate the effectiveness of a certain structural measure on flood risk mitigation.
Input	Local model results for a model run with modified Digital Surface Model
Output	Expert opinion on the effectiveness of a certain structural measure, annotated local model results
Components	Scenario manager, Visualisation component
Constraints	Local model results for a model run with modified Digital Surface Model must be available in the repository of the SMS.

Task	**2.3 Evaluate Efficiency of Structural Measure**
Description	After he has proven the effectiveness of a certain structural measure on flood risk mitigation the user needs to assess its efficiency. To do this he needs to gather information about costs and technical restrictions from various experts working for other departments of the urban administration. It is likely that this will be done in the form of a round table discussion.
Actor	Storm Water Manager
Goal	Evaluate the efficiency of a certain structural measure with respect to flood risk mitigation.
Input	Annotated local model results for a model run with modified Digital Surface Model
Output	Expert opinion on the efficiency of a certain structural measure, prioritized list of feasible structural measures for flood risk mitigation on a given site, annotated local model results

Components	Scenario manager, Visualisation component
Constraints	Annotated local model results for a model run with modified Digital Surface Model must be available in the repository of the SMS.

Task	**2.4 Discuss Measures with Property Owner**
Description	The final step of the FRM task is the discussion with the property owner and/or the operator of threatened infrastructure about structural protection measures for flood risk mitigation, including measures that have to be carried out by the property owner himself as self protection.
Actor	Storm Water Manager
Goal	Increase risk awareness of property owner, raise his motivation to take measures for the physical protection of his facilities by himself, common understanding of the appropriate measures that will be carried out by the City of Wuppertal and the WSW
Input	Annotated local model results for different model runs with modified Digital Surface Model
Output	Results of discussion
Components	Scenario manager, Visualisation component
Constraints	Annotated local model results for different model runs with modified Digital Surface Model must be available in the repository of the SMS.

5. Use-cases

This chapter describes the use cases of the scenario management system from the Wuppertal pilot point of view. The interaction between user and the system will be explained in detail.

The use case analysis is used to facilitate the formal specification of the system behaviour without burdening the user with the technical implementation of the wished functionality. Instead the expected functionality is expressed in natural language to make the information transfer between the technical partner and pilots as easy and efficient as possible. The single steps of the use cases describe the expected functionality for the second version of the Wuppertal pilot application. In the following an overview of all use cases will be given:

- UC-611 Show Basin Information
- UC-612 Show Catchment Information
- UC-613 Visualise Objects in Map
- UC-614 Assess Basin Risk Level
- UC-615 Search Catchment/Basin
- UC-616 Prioritise Catchment Areas
- UC-617 Trace Prioritisation Changes
- UC-618 Print Information
- UC-619 Browse 3D Map
- UC-6110 Show Historic Precipitation
- UC-6111 Show Simulated Precipitation
- UC-6112 Generate Rainfall Pattern
- UC-6113 Compare Precipitation data
- UC-6114 Model Sewer and Surface Run-Off
- UC-6115 Validate Simulation Results
- UC-6116 Visualise Simulated Runoff Over Time
- UC-6117 Visualise Maximum Values of Simulated Runoff
- UC-621 Modify Digital Surface Model
- UC-622 Annotate Local Model Result
- UC-623 Compare Simulation Results

The single use cases follow a use case template to assure a consistent description throughout the different cases. The use case analysis will be extended in each of the Scenario Management System iterations. At the beginning of each iteration the expected functionality will be specified. After that the IT partners will translate them into a technical representation before the system is implemented and validated. In the final iteration all expected functionality from the user point of view should be described through the compiled use cases.

5.1. UC-611 Show Basin Information

Acronym	
	UC-611
Related tasks	
	T.1.1.1.1
Description	
	The user wants to access risk information and risk assessment to a particular basin. The risk information will be provided in a form of a risk evaluation report for the single basin. The single risk levels for different criteria chosen by the storm water manger will be displayed.
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal
Goal	
	Access detailed information for a topological basin.
Input	
	The basin of interest.
Output	
	Basin information: • *Risk Evaluation Report* • *Risk Level Assessment*
Components	
	Description *Object Catalogue consisting of :* • *Catchments* • *Containing Basins* *2D Map* *3D Map* *Map Layer*
Preconditions	
	Existing basins must be available
Main success scenario	
1	*The user selects the desired basin from a hierarchical list of object of interest.*
2	*The user opens the description page.*
Extensions	
1a	*The user selects the desired basin in the map*

5.2. UC-612 Show Catchment Information

Acronym	
	UC-612
Related tasks	
	T.1.1.1
Description	
	The user wants to access detailed information to a particular catchment area. Information about the containing basins, foremost their risk level, will be presented to the user. Based on this information a risk level for the catchment area is calculated and presented to the user. A prioritisation history shows changes made to the selected catchment area.
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal
Goal	
	Access detailed information for a catchment area.
Input	
	The catchment area of interest
Output	
	Catchment Area Information: • *Containing basins* • *Basin Risk Levels* • *Catchment Area Risk Level* • *Prioritisation History*
Components	
	Description *Object Catalogue* *2D Map* *3D Map* *Map Layer*
Preconditions	
	Existing catchment areas must be available
Main success scenario	
1	*The user selects the desired catchment area from a hierarchical list of objects.*
2	*The user opens the description page.*
Extensions	
1a	*The user selects the desired catchment area in the map*

5.3. UC-613 Visualise Objects in Map

Acronym	
	UC-613
Related tasks	
	T.1, T.2
Description	
	The user wants to visualise objects with a corresponding geometry or a spatial location on the 2D/3D maps. Possible objects are catchment areas and topological basins. The user should have controls to manipulate and remove the added objects. The objects in the map should be selectable and detailed information should be presented to the user when the object is selected. *Object information in the map should be contextualised:* • *Basin – The risk level of the basin* • *Catchment area – the risk level of the catchment area*
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal
Goal	
	Display an object of interested in a map
Input	
	The object which should be visualised
Output	
	The visualisation of the object in an geospatial context
Components	
	2D Map *3D Map* *Map Layer* *Object Catalogue* *Description Page*
Preconditions	
	Objects for visualisation must be available and must have a geospatial reference
Main success scenario	
1	*Select the desired objects from the catalogue (Basin, Catchment, etc.)*
2	*Add the desired objects to the map*
3	*Visualise objects in the map*
Extensions	
1a	*The user performsm a geo-spatial search (see UC-615) for the desired object in the map*

5.4. UC-614 Assess Basin Risk Level

Acronym	
	UC-614
Related tasks	
	T.1.1.1.1
Description	
	The user wants to rate the risk of a basin according to certain criteria. He should have the possibility to choose the different criteria from a list to enable later inclusion of new criteria. For every criterion the user should be able to choose a value from a well defined selection.
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal
Goal	
	Assess the basin risk level with the help of criteria.
Input	
	Basin information: • *Evaluation Report* • *Risk Criteria* • *Geospatial Extend*
Output	
	Assessed basin risk criteria
Components	
	Description Page *Editor Page*
Preconditions	
	Existing basin must be available
Main success scenario	
1	*Select the desired basin to assess*
2	*Open the description information of the basin*
3	*Open the basin for editing.*
4	*Choose the level for a criterion*
Extensions	
4a	*If the user needs more information to choose a value for a criterion it should be possible to consult the basin evaluation report to come to a decision.*
4b	*If no criteria are available for the current basin the user has the possibility to add criteria.*
4c	*The user repeats step 3 until all necessary criteria and their levels are chosen for the basin*

5.5. UC-615 Geospatial Search

Acronym	
	UC-615
Related Tasks	
	T.1, T.2
Description	
	This use case provides the possibility to use the map to search geospatially for objects with spatial context, such as basins and catchment areas. The user wants to browse the map and search within particular regions for objects of interest. A result list with all found basins and catchment areas should be presented to the user. The user will be able to display objects from this result list in the map.
Primary actor	
	Storm Water Manager
Stakeholder	
	N/A
Goal	
	Find basins and catchment areas based on their geospatial extent.
Input	
	Geospatial extent for the search
Output	
	Resulting list of found basins and catchment areas
Components	
	2D Map *3D Map* *Object Catalogue* *Search Results*
Preconditions	
	N/A
Main success scenario	
1	*Browse to the location in the map, where the search should be performed*
2	*Choose the region for the geospatial search (bounding box)*
3	*Search for intersecting basins and catchment areas*
4	*Display the search results*
Extensions	
4a	*Visualise found objects in the map (see UC-613)*

5.6. UC-616 Prioritise Catchment Areas

Acronym	
	UC-616
Related tasks	
	T.1.1
Description	
	The use case describes the functionality of the system to calculate an ordered list of catchment areas. In this list the catchment areas are ordered descending according to their risk levels. The risk levels for the single catchment areas will be calculated based on the containing basins and their particular risk levels. Catchment areas with no assigned risk level, for example due to not yet assessed basins, will be treated with the lowest priority. The user should have the possibility to change the prioritisation of single catchment areas manually regardless of their calculated values. A reason for the priority change should be provided and the system should keep track of the changes in order to make the manual prioritisation changes traceable.
Primary actor	
	Strom Water Manger
Stakeholder	
	City of Wuppertal
Goal	
	Create sorted priority list of catchment areas ordered according to their risk level
Input	
	N/A
Output	
	List of catchment areas prioritised according to their risk level
Components	
	Prioritisation List *Catchment Area Description*
Preconditions	
	In order to create a meaningful prioritisation each catchment area should possess a risk level.
Main success scenario	
1	*Open the Prioritisation List*
2	*Calculate the priority of the single catchment areas*
3	*Display the resulting list*
Extensions	
3a	*Access the description of the single catchment areas.*
3b1	*Change the priority of a catchment area manually. Move the priority up or down until the desired position is reached.*
3b2	*Enter a reason for the change of priority.*

3b3	*Display priority change information in the priority list as well as in the catchment area description page.*

5.7. UC-617 Trace Prioritisation Changes

Acronym	
	UC-617
Related tasks	
	T.1.1.2
Description	
	Traceability for manually changed priorities of catchment areas must be given. The user wants to trace the changes made to catchment area priorities; this includes the date when the modification was done, the user who performed the change and most importantly the reason for the change. This functionality enables the user to trace changes done in the past and to understand them in the present. In addition to the tracing information from the prioritisation list the changes should also be visualised in the single catchment area description pages.
Primary actor	
	Storm Water manager
Stakeholder	
	City of Wuppertal
Goal	
	Trace back changes made to the automatically calculated priority list.
Input	
	Catchment area prioritisation and history information
Output	
	N/A
Components	
	Prioritisation List *Catchment Area Description.*
Preconditions	
	Changes to the catchment area prioritisation exist.
Main success scenario	
1	*Open the prioritisation list*
2	*View the history of prioritisation changes.*
3	*Access additional information to a prioritisation change. (User, date, reason etc.)*
Extensions	
1a	*Open a catchment area description to view the specific changes for the single catchment.*
2a	*Open a list which contains only the changes made to the priority ordered ascending by the time of the change.*

5.8. UC-618 Print Information

Acronym	
	UC-618
Related Tasks	
	T.1, T.2
Description	
	This use case describes the general requirement of the user to print the presented information of the Scenario Management System. This includes: • *Description pages of basins and catchment areas as well as maps with their geospatial representation.* • *2D/3D maps* • *Prioritisation lists and priority change information*
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal
Goal	
	Print information of Scenario Management System
Input	
	The object which should be printed
Output	
	Printout of the selected information
Components	
	Description Pages *Prioritisation List* *2D Map* *3D Map* *Print Dialog*
Preconditions	
	N/A
Main success scenario	
1	*Open the desired information*
2	*Open the print dialog*
3	*Configure the print options (orientation, resolution etc.)*
4	*Print the document*
Extensions	
	N/A

5.9. UC-619 Browse 3D Map

Acronym	
	UC-619
Related tasks	
	T.1, T.2
Description	
	A digital elevation model of the Wuppertal region should be rendered and presented to the user. The user should have the possibility to browse the landscape and to add additional information like overlay maps of cadastral context information and 3D objects like building geometries. This use case creates the base for the later surface run-off modelling. The modelling results (flow direction of water, maximum water heights) will be displayed in the 3D environment.
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal
Goal	
	Spatial representation of the Wuppertal region as a base for representing content in the third dimension.
Input	
	User controls and content selection
Output	
	3D representation
Components	
	3D Map *Map Layer* *Object Catalogue*
Preconditions	
	N/A
Main success scenario	
1	*Open 3D Map*
2	*Choose version of the digital landscape (DEM)*
3	*Choose layer of interest (cadastre, building etc.)*
4	*Browse to the region of interest*
Extensions	
4a	*Jump to a specific region based on the geospatial coordinates of a certain object (basin, catchment, model result etc.)*
4b	*Jump to a specific region based on geospatial coordinates.*

5.10. UC-6110 Show Historic Precipitation

Acronym	
	UC-6110
Related Tasks	
	T.1.2.2
Description	
	The user would like to display measured precipitation values for the region of Wuppertal in form of precipitation maps (static) and animations of the event over time (dynamic). Also the functionality to display the precipitation data in alternative representations for example as time trend diagrams should be provided. The shown visualisation should allow querying the values at each point in time. This functionality enables the user to click in the map and to receive the exact precipitation amount or temperature value.
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal
Goal	
	Visualise measured precipitation levels for a specific region of Wuppertal
Input	
	Precipitation data source, time interval (boundaries), region of interest (geospatial boundaries)
Output	
	Precipitation values of the chosen time and spatial extend
Components	
	2D Map *3D Map* *Precipitation Selector*
Preconditions	
	N/A
Main success scenario	
1	*Choose precipitation data source*
2	*Select time interval for the rain event (precipitation data)*
3	*Select region of interest in the map (optional)*
4	*Visualise precipitation data in the map*
5	*Choose the point in time within the selected interval (slide rain event time)*
6	*Save the current select rain event for later use (optional)*
Extensions	
4a	*Visualise precipitation data as diagram (maximum precipitation level, time trends etc.)*
4b	*Query precipitation values for certain points in the map*
4c	*Visualise background information like map legend*
5a	*View the selected rain event as an animation*

5.11. UC-6111 Show Simulated Precipitation

Acronym	
	UC-6111
Related Tasks	
	T.1.2.3
Description	
	This use case provides similar functionality as the use case UC-6110 but instead of visualising historic precipitation data the user wants to generate and visualise future rain patterns. The simulated rain patterns will be generated based on an assumed climate scenario and historic precipitation data. The result is predicted precipitation in the future.
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal
Goal	
	Show precipitation prediction visualisation for climate scenarios based on historic data
Input	
	Precipitation data source, time interval of local precipitation data (boundaries), region of interest (geospatial boundaries), climate scenario, time interval of simulated precipitation data
Output	
	Simulated precipitation values of the chosen time and spatial extend
Components	
	2D Map *3D Map* *Precipitation Selector* *Common Service Control*
Preconditions	
	N/A
Main success scenario	
1	*Choose precipitation data source*
2	*Select time interval for the rain event (precipitation data)*
3	*Select spatial extend*
4	*Choose climate scenario as base for the calculation*
5	*Select time interval for simulated data (default is same length as the input data)*
6	*Request precipitation data*
7	*Notify user upon successful completion of the calculation*
8	*Visualisation of resulting precipitation data*
9	*Choose the point in time within the selected interval (slide rain event time)*
10	*Save calculated results permanently (optional)*
Extensions	
7a	*Notify user about errors, and their reasons, occurred during the calculation request. Inform him about contact persons to solve the issue*

8a	*Visualise precipitation data as diagram (maximal precipitation level, time trends etc.)*
8b	*Query precipitation values for certain points in the map*
8c	*Visualise background information like map legend*
9a	*View the selected rain event as an animation*

5.12. UC-6112 Generate Rainfall Pattern

Acronym	
	UC-6112
Related Tasks	
	T.1.2.2, T.1.2.3
Description	
	The storm generator gives the user the possibility to generate a rain event based on measured maximum precipitation levels and the desired direction of the storm. This use case enables the user to create rain patterns to use with the surface run-off model to simulate different rain events and to study the water run-off. The generated storm patterns can be saved by the user for later usage. This functionality also enables the user to create a grid of "virtual" pluviographs because the storm generator can generate time series for specific geospatial points. The resulting virtual measurements could be used for further surface run-off simulation.
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal
Goal	
	Generate custom storm patterns to use them with the surface run-off modelling
Input	
	Spatial region of interest, points where measurement data should be generated (optional), rain density, storm direction, climate scenario
Output	
	Generated storm
Components	
	2D Map *3D Map* *Object catalogue* *Precipitation Selector* *Common Service Control* • *Storm Generator*
Preconditions	
	N/A
Main success scenario	
1	*Choose spatial region for storm generation*
2	*Choose points where precipitation data should be generated (optional)*
3	*Choose maximum rain intensity*
4	*Determine the direction of the storm*
5	*Choose climate scenario (optional)*
6	*Generate storm event*
7	*Notify user upon successful completion of the calculation*
8	*Visualise storm event in map(optional)*

9	*Save generated storm event permanently (optional)*
Extensions	
2a	*Display available locations (pluviograph, points of landscape model etc.) to support the user to choose the points*
3a	*The maximum rain intensity will be taken from present precipitation measurements.*
7a	*Notify user about errors, and their reasons, occurred during the calculation request. Inform him about contact persons to solve the issue*

5.13. UC-6113 Compare Precipitation data

Acronym	
	UC-6113
Related Tasks	
	T1.3
Description	
	This use case gives the user the possibility to compare different rain events and IDF-Curves (historic [UC-6110], predicted [UC-6111], and generated [UC-6112]). This feature will be used to increase the confidence in predicted and generated rain events by comparing them with real world measurements. This use case also enables the user to study possibilities how the present/historic rain events will change in future climate scenarios.
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal
Goal	
	Compare different historic, predicted, and generated rain events + IDF.
Input	
	N/A
Output	
	N/A
Components	
	2D Map *3D Map* *Object catalogue* *Precipitation Selector* *Common Service Control*
Preconditions	
	N/A
Main success scenario	
1	*Choose rain pattern*
2	*Visualise different rainfall pattern*
3	*Compare rainfall pattern*
Extensions	
1a	*If the desired rain pattern is not available, the user can generate or simulate one as described in UC-6112 and UC-6111*
1b	*The first step is repeated until all desired rain patterns are selected*

5.14. UC-6114 Model Surface Run-Off

Acronym	
	UC-6114
Related Tasks	
	T.1.2
Description	
	The use case provides the possibility to configure and perform combined sewer and surface run-off modelling with precipitation data (historic, predicted, and generated) for a particular catchment area. The user has the possibility to choose the different input parameters for the model such as the digital surface model, precipitation data, etc. The execution of the model should be performed in the background so that the user still can work with the system. Upon completion of the surface run-off modelling the user will be notified and will be able to visualise the model results in the map.
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal, WSW, WV
Goal	
	Model different water run-off scenarios for a given catchment area and precipitation data
Input	
	Precipitation data, Digital Sewer and Surface Surface Model, model parameter
Output	
	Water surface run-off simulation
Components	
	2D Map *3D Map* *Object catalogue* *Precipitation Selector* *Common Service Control* *Model Control (Orchestrator)* *Model Execution (Executor)*
Preconditions	
Main success scenario	
1	*Open Model Execution Controls*
2	*Select model and model version*
3	*Select digital landscape (DEM)*
4	*Select precipitation data*
5	*Configure model parameter*
6	*Schedule model execution*
7	*Notify user upon successful completion of the calculation*
Extensions	

7a	*Notify user about errors, and their reasons, occurred during the calculation request. Inform him about contact persons to solve the issue.*

5.15. UC-6115 Validate Simulation Results

Acronym	
	UC-6115
Related Tasks	
	T.1.2.1.2, T.1.3
Description	
	The user wants to validate the results of a simulation by comparing them to historic flooding event. The user has the possibility to choose from already simulated model results and to choose from historic measurements taken from actual flooding events. He is then provided with a view of both data on the map so that he can compare the values in the desired hotspots. In case of discrepancies the user can then try to optimise the model (see UC-621).
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal, WSW, WV
Goal	
	Ensure that the model for a specific area provides adequate results
Input	
	Simulation results, historic measurements
Output	
	Comparison of simulated and historic data
Components	
	2D Map *3D Map* *Object catalogue*
Preconditions	
	Historic flooding events must be available
Main success scenario	
1	*Select simulation result*
2	*Select historic flooding event*
3	*Compare data on the map*
Extensions	
1a	*The user searches for simulation results in the map (see UC-615)*
2a	*The user selects multiple historic flooding events to compare all of them at once*

5.16. UC-6116 Visualise Simulated Runoff over Time

Acronym	
	UC-6116
Related Tasks	
	T.1.4
Description	
	The user wants to view the development of the runoff over the time of a simulation. He selects a simulation result and views the peak stages of the simulation on the map (see UC-6117). Additionally he is provided with a means to select the point in time for which the water level shall be shown. Moreover, he is provided with an animated visualisation of the runoff development in the selected area for a desired timespan.
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal, WSW, WV
Goal	
	Analyse the runoff behaviour
Input	
	Simulation model results
Output	
	Visualisation water levels on certain points in time
Components	
	2D Map *3D Map* *Object catalogue*
Preconditions	
	A simulation must have been performed successfully (see UC-6114)
Main success scenario	
1	*Select simulation result*
2	*View peak stages on the map*
3	*Select point in time*
4	*View water levels on the map*
5	*Select runoff development animation start time*
6	*Select runoff development animation end time*
7	*View runoff development animation*
Extensions	
1a	*The user searches for simulation results in the map (see UC-615)*

5.17. UC-6117 Visualise Maximum Values of Simulated Runoff

Acronym	
	UC-6117
Related Tasks	

	T.1.5, T.1.6
Description	
	The user wants to view the peak stages of a simulation in a geo-spatial context. He selects a simulation result and is presented with the peak stages of the selected simulation on the map.
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal, WSW, WV
Goal	
	Identify areas with potential flood risk
Input	
	Simulation model results
Output	
	Visualisation of peak stages
Components	
	2D Map *3D Map* *Object catalogue*
Preconditions	
	A simulation must have been performed successfully (see UC-6114)
Main success scenario	
1	*Select simulation result*
2	*View peak stages on the map*
Extensions	
1a	*The user searches for simulation results in the map (see UC-615)*

5.18. UC-621 Modify Digital Surface Model

Acronym	
	UC-621
Related Tasks	
	T2.1
Description	
	This use case describes the creation of an alternative Digital Surface Model starting with an initial Digital Surface Model that was set up by means of the local model DYNA+GeoCPM outside of the Wuppertal pilot application. The modification of the initial Digital Surface Model is restricted to the alteration of a set of existing breaklines that have to be defined in the initial Digital Surface Model (no recalculation of the TIN that defines the Digital Surface Model).The modified model represents certain structural measures for the physical protection of buildings or other facilities. It is possible input to UC-6114.
Primary actor	
	Storm Water Manager

Stakeholder	
	City of Wuppertal, WSW, WV
Goal	
	Set up an alternative of the initial Digital Surface Model representing a certain structural measure for the physical protection of buildings or other facilities.
Input	
	Initial Digital Surface Model
Output	
	Modified Digital Surface Model
Components	
	2D Map *3D Map* *Object Catalogue* *Surface Model Editor*
Preconditions	
	Initial Digital Surface Model must be set up and selectable via Object Catalogue
Main success scenario	
1	*Select initial Digital Surface Model (TIN) from Object Catalogue*
2	*Visualise alterable breaklines in 2D Map and (optional) in 3D Map*
3	*Select an alterable breakline(s) in 2D Map*
4	*Alter heights of the breaklines' nodes by one*
5	*Visualise modified Digital Surface Model in 3D Map for verification*
6	*Annotate modified Digital Surface Model with descriptive metadata*
7	*Store modified Digital Surface Model*
Extensions	
4a	*Alter heights of the nodes of all breaklines with constant value*

5.19. UC-622 Annotate Local Model Results

Acronym	
	UC-622
Related Tasks	
	T.1, T.2
Description	
	This use case describes the annotation of Local Model results that are stored in the SMS repository. These results have been generated via UC-6114. Supported by a visual interpretation of the Local Model results (cf. UC-619) the user will assess the effectiveness and efficiency of the simulated structural measures for the physical protection of buildings or other facilities. (Note: this is done by means of expert knowledge outside the scope of the Wuppertal pilot application!) In the end of this use case the user will annotate the Local model results with his findings to keep hold of them.
Primary actor	
	Storm Water Manager, possibly together with Urban planners

Stakeholder	
	City of Wuppertal, WSW, WV
Goal	
	Keeping hold of the findings concerning the effectiveness and efficiency of the simulated structural measures that follow from a visual interpretation of the Local Model results.
Input	
	Results of Local Model run
Output	
	Annotated results of Local Model run
Components	
	2D Map *3D Map* *Map Layer* *Object Catalogue* *Local Model Results Editor*
Preconditions	
	The results of a Local Model run (generally carried out with an alternative of the Digital Surface Model generated by UC-621) are stored in the SMS repository and are selectable via the Object Catalogue
Main success scenario	
1	*Select Local Model results from Object Catalogue*
2	*Visualise results in 2D, 3D and 4D (cf. UC-619)*
3	*Assess effectiveness and/or efficiency of simulated structural measures (activity outside the scope of the Wuppertal pilot application!)*
4	*Annotate Local Model results*
5	*Store modified Local Model results*
Extensions	

5.20. UC-623 Compare Simulation Results

Acronym	
	UC-623
Related Tasks	
	T.2.3
Description	
	In order to be able to evaluate the effectiveness of structural measures the user wants to compare various simulation results of an investigation area. The selects two simulation results and is presented with the peak values on the map so that he can evaluate the changes that were caused by the alteration of the surface modification (see UC-621)
Primary actor	
	Storm Water Manager
Stakeholder	
	City of Wuppertal, WSW, WV
Goal	

	Evaluate the efficiency of a surface modification
Input	
	Simulation results
Output	
	Comparison of simulations
Components	
	2D Map *3D Map* *Object catalogue*
Preconditions	
	Two simulation results must be available for a specific investigation area
Main success scenario	
1	*Select simulation result*
2	*Compare data on the map*
Extensions	
1a	*The user searches for simulation results in the map (see UC-615)*
1b	*The user selects multiple simulation results to compare all of them at once*

6. Conclusion

During the first year of the project the main focus of the Wuppertal pilot work was on the selection of an appropriate local model configuration and the provision of some initial calculation model. The focus of second year was on integration of the whole chain of components involved in the Wuppertal pilot scenario. For the 3rd Period (2012) we have planned to add more data to the Pilot Application, to support and implement a larger number of the defined use cases and to enhance model parameterization and visualization capabilities of the software. The vision of our Pilot Application includes a mobile application to support on sight discussions with owners of affected infrastructure.

The primary objective of this document is to define and specify the plan for the Wuppertal pilot site in the SUDPLAN project. All versions of this document describe the background and goals of the pilot in detail. Relations between the Wuppertal pilot and climate change issues are explained as well as the relevance regarding the ICT objectives of the proposal. The usage of the Common Services is examined and the potential decisions supported by the SMS are analysed. The main pilot activities are derived from the insights won through the single steps of the pilot definition process.

The methodology developed by WP2 was followed throughout the creation of this document. In the scope of this methodology a user analysis was performed to define the single user groups of the later system. In this process skills and properties of the single user groups were identified. Independent from the later system, tasks necessary to fulfil the pilot objectives were analysed and described in detail. This step has been undertaken to give all partners the possibility to understand the background and motives of the pilot. This would be rather difficult to understand only by the description of the system functionality without all the non system tasks. Particular emphasis was laid on the use case analysis and description in the document. The use cases define the boundary of the system and the interface to the user. As a whole, the use cases draft the behaviour of the system and are essential for the design and implementation of the Scenario Management System (WP3) because the use cases represent the system functionality expected by the user.

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8. Glossary

Breakline	A line that represents a distinct interruption in the slope of a surface commonly created by human hand.
Catchment Area	A extent or area of land where water from rain and melting snow or ice drains downhill into a body of water, such as a river, lake, reservoir, estuary, wetland, sea or ocean
Depressed Area	➔ Topological Basin.
Downscaling	In general the reduction of the scale. Here the transformation of lower scale climate data such as precipitation into higher resolution data sets.
Hydrodynamic Model	A tool able to describe or represent the motion of water in some way.
Hydrological Model	A simplified, conceptual representations of movement, distribution, and quality of water throughout the Earth
KIBEX	United Nations project with the focus on vulnerability assessment of population and critical infrastructure towards climate change related extreme event
Modelling Experiment	Multiple executions of a software model with different parameters
Storm Water Manager	Hydrological modellers employed by the City of Wuppertal, the Wuppertal Stadtwerke, and the Wupperverband.
Topological Basin	A large, bowl-shaped depression in the surface of the land or ocean floor
Use Case	A methodology used to describe the interaction between user and the resulting system.
Web Service	A software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a machine-processable format (specifically Web Services Description Language WSDL). Other systems interact with the web service in a manner prescribed by its description using SOAP messages, typically conveyed using HTTP with an XML serialization in conjunction with other web-related standards. For more information please refer to (Haas, 2004)
Wuppertaler Stadtwerke	Public utility company of Wuppertal
Wupperverband	Wuppertal’s water body management organization. It manages the open rivers and creeks of the Wupper catchment

9. Acronyms and Abbreviations

CS	Common Service
DEM	Digital Elevation Model
DLR	Deutsches Zentrum für Luft und Raumfahrt (German Aerospace Center)
DoW	Description of Work
DSGK-W	Digitale Liegenschaftskarte/Stadtgrundkarte Wuppertal
DWD	Deutscher Wetterdienst
FRA	Flood Risk Assessment
FRM	Flood Risk Mitigation
GEP	Generalentwässerungsplanung (general wastewater management plan planning)
GIS	Geographical Information System
ICT	Information and Communication Technologies
KIBEX	Kritische Infrastruktur, Bevölkerung und Bevölkerungsschutz im Kontext klimabeeinflusster Extremwetterereignisse
KOSTRA	Koordinierte Starkniederschlags-Regionalisierungs-Auswertungen
KST	Koordinierungsstelle Stadtentwässerung
SMS	Scenario Management System
SDI	Spatial Data Infrastructure
TIN	Triangulated Irregular Network
UC	Use Case
UNU	United Nations University
UNU-EHS	United Nations University – Institute for Environment and Human Security
WFS	Web Feature Service
WMS	Web Map Service

WP	Work Package
WSRSS	Water Surface Runoff Simulation Service (SRSS)
WSW	Wuppertaler Stadtwerke
WV	Wupperverband