

# Synergistic benefits between stormwater management measures and a new pricing system for stormwater in the City of Hamburg

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## ABSTRACT

Hamburg is a growing metropolitan city. The increase in sealed surfaces of about 0.36% per year and the subsequent increased runoff impacts on the city's wastewater infrastructure. Further potential risks to the drainage infrastructure arise also from effects of climate change, e.g. increased intensity and frequency of heavy rainfalls. These challenges were addressed in the Rain Infrastructure Adaption (RISA) project conducted 2009–2015 by HAMBURG WASSER and the State Ministry for Environment and Energy, supported by several municipal stakeholders. RISA addressed intensifying conflicts in the context of urban development and stormwater management at that time. Major results of the project are improvements and recommendations for adequate consideration of stormwater management issues during urban planning as well as new funding mechanisms for stormwater management measures. The latter topic resulted in the introduction of a separated stormwater charge based on the amount of sealed area connected to the sewer system of each property. For both undertakings – the RISA project and the introduction of the separated stormwater charge – a novel, comprehensive, digital database was built. Today, these geographical information system (GIS)-based data offer various scale-independent analysis and information opportunities, which facilitate the day-to-day business of HAMBURG WASSER and stormwater management practice in Hamburg.

**Key words** | attributed surface partial area, geographical information system (GIS), rain infrastructure adaption (RISA), separated stormwater charge, stormwater management, surface sealing

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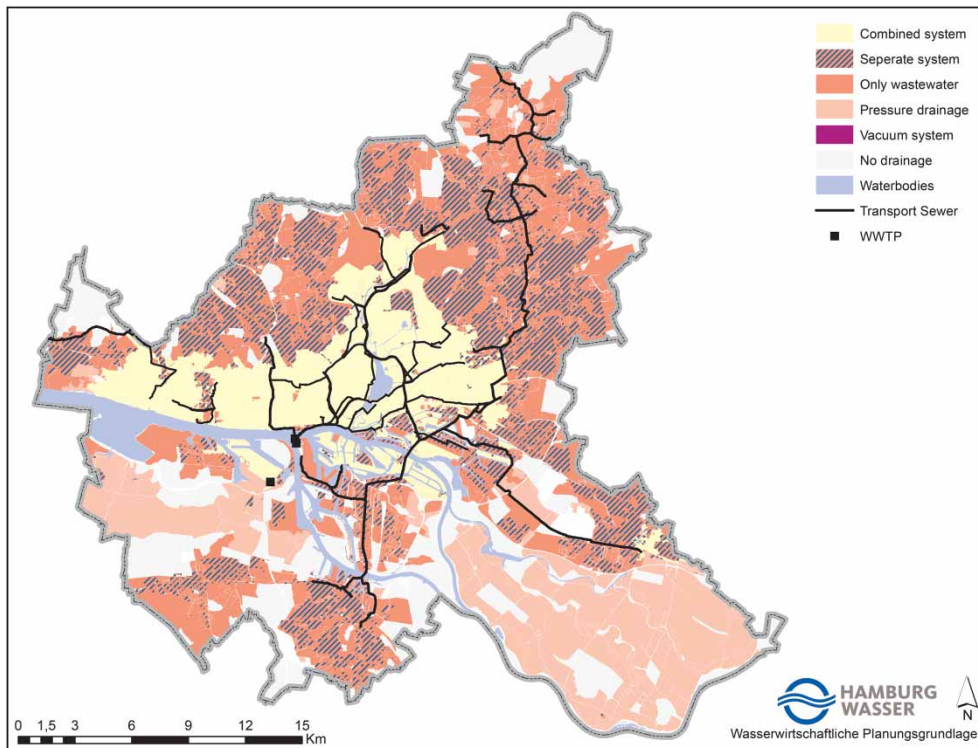
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## INTRODUCTION

Urban development in the growing metropolitan city of Hamburg challenges the city's wastewater management practices: with the building of up to 10,000 new homes per year and further redensification of residential and industrial areas comes an increase in surface sealing of 0.36% per year. These areas produce runoff that is an increased burden on the city's drainage systems (sewer networks, water bodies and trenches). In the inner city area there is a predominantly combined system (approximately 1,200 km), whereas in the outskirts there is primarily a separate system (approximately 2,300 km for wastewater and approximately 1,700 km for stormwater). An overview of the drainage methods in Hamburg is shown in Figure 1. The sewer network encompasses

an area of approximately 360 km<sup>2</sup>, of which approximately 175 km<sup>2</sup> (i.e. 49%) can be classified as paved areas by three-dimensional (3-D) photogrammetric evaluation. Approximately 105 km<sup>2</sup> of the paved areas are connected to the public sewer network. HAMBURG WASSER, as the drinking water and wastewater management utility for 2 million population in Hamburg, invests about €60 million per year in the renewal of the sewer network. Today, the frequency of combined sewer overflows into inland waters in Hamburg happens at a mean rate of once per year – which is exemplary across Germany and a result of high investments in the city's sewer system and its storage capacities. Yet the majority of water bodies in Hamburg are defined as artificial or as



**Figure 1** | The spatial distribution of drainage methods in Hamburg.

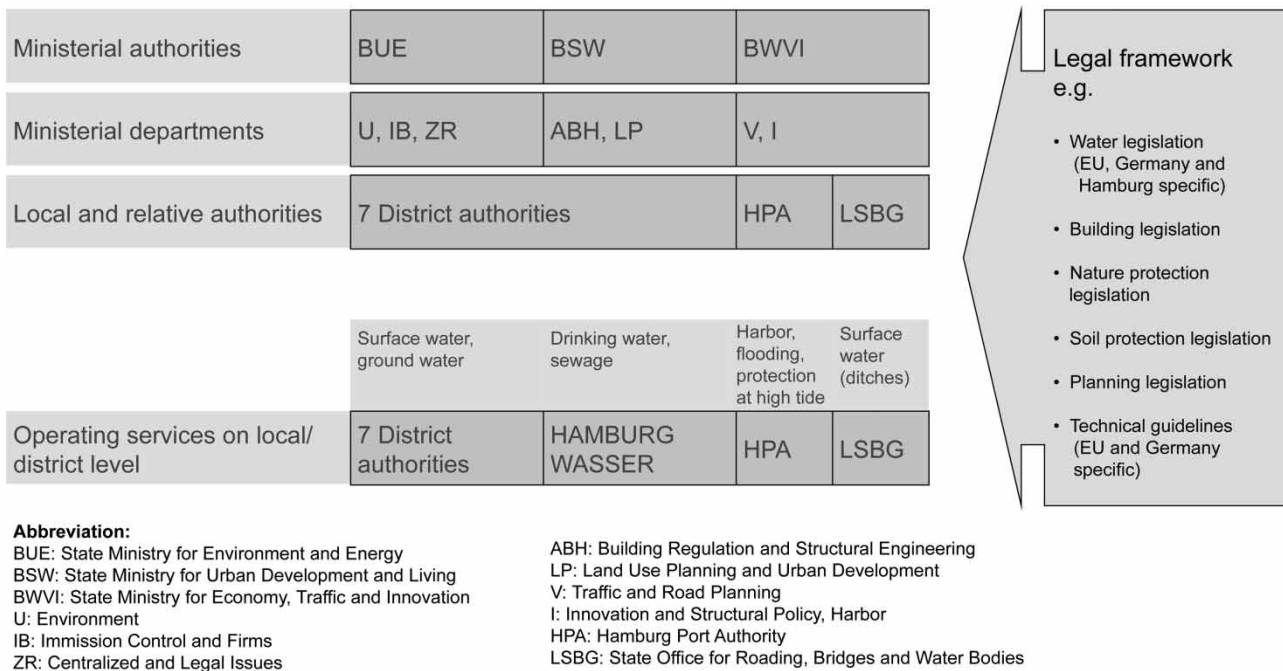
having considerable changes to them (FHH 2005). Currently only five water bodies can be classified as natural (FHH 2005).

Besides the continuous increase in sealed surfaces, there is a potential risk to the drainage infrastructure and water bodies arising from an increased intensity and frequency of heavy rainfall due to climate change. Studies on the hydrological consequences of climate change for the combined system in Hamburg have shown that until the end of the century a significant increase in combined sewer overflows has to be expected. These studies are based on simulated precipitation data from the so-called climate model REMO and were conducted using the A1B scenario from the IPCC (International Panel for Climate Change) (Kuchenbecker *et al.* 2010). Based on the same A1B scenario Hüffmeyer (2011) has also shown for the Wandse catchment area in Hamburg that until the end of the century the potential hydraulic effects from climate change on the sewer network will be seen in the form of increased occurrence of flooding.

#### Administrative framework and pricing system for wastewater management

The responsibility of the water management administration in Hamburg has historically developed in the

past and reaches a high grade of complexity today: the supreme technical authority, the so-called State Ministry for Environment and Energy (BUE), has the ministerial task of managing water resources. BUE has several associated authorities taking care of superior operating tasks. Whereas on the local level the districts, which are the lower water authorities, are responsible for the operative tasks as well as planning and approval decisions. Another important stakeholder is the State Ministry of Economy, Transport and Innovation (BWVI), which is for instance responsible for the major roads. Measures are carried out through the State Office for Roads, Bridges and Water Bodies (LSBG). In the sphere of drinking water supply for about 2 million people, as well as wastewater drainage and treatment, all operating tasks, including construction and maintenance of infrastructure, are the duty of the state-owned utility HAMBURG WASSER. For their services regarding wastewater management, HAMBURG WASSER appoints a cost-covering wastewater charge in consent with its board of governors and other involved municipal boards. A simplified overview of the different stakeholders and their respective responsibilities for water management in Hamburg is given in Figure 2.



**Figure 2** | Simplified illustration of water management responsibilities in Hamburg.

The management of stormwater in Hamburg has been for a long time to a great extent fragmented amongst these different stakeholders and fragmentally regulated by their respective legal frameworks. Building, planning and traffic legislation include key references to stormwater management. The legal frameworks are supplemented through technical guidelines for building drainage, property drainage, public drainage systems, road drainage and waterway construction. This situation did not allow either HAMBURG WASSER or the other stakeholders to pursue a comprehensive and integrated approach to stormwater management in the city.

### A new approach for stormwater management and its funding – the RISA project and the introduction of a separated stormwater charge in Hamburg

In 2009, HAMBURG WASSER and the State Ministry for Environment and Energy initiated the so-called ‘Rain Infrastructure Adaption’ (RISA) project. RISA was set up in order to adequately react to intensifying conflicts in the context of the urban development and to deficiencies in the framework of wastewater management at that time, such as:

- a permanent increase in sealed and paved areas due to a growing city,
- an increasing demand for open and green spaces in residential areas,

- the predicted challenges for the urban drainage system and the urban water bodies caused by the effects of climate change,
- increasing living standards, e.g. bigger flats or living areas next to urban water bodies,
- current infrastructure requirements e.g. limitation of wastewater retention volume,
- a highly fragmented administrative and legal framework impeding a holistic stormwater management approach,
- an insufficient planning basis and insufficient information system data impeding an adequate consideration of decentral stormwater management interests in urban planning activities,
- a so far long-term unsustainable pricing system for stormwater management measures.

The RISA project was meant to produce a comprehensive and new information basis concerning various topics, aiming at improvements for the stormwater management in Hamburg. These topics comprised a vision of integrated stormwater management in Hamburg, the public perception and communication of stormwater management, the adequate consideration of stormwater management during urban planning activities under their respective administrative and legal frameworks as well as new and sustainable funding mechanisms for stormwater management measures. In the case of Hamburg, the latter topic climaxed in the

introduction of a new pricing system for HAMBURG WASSER in May 2012, working with a separated stormwater management charge based on the amount of sealed area connected to the sewer system of each property. The whole complex of stormwater management became highly valorized in Hamburg by setting up the RISA project and by the introduction of the new pricing system. Both undertakings unfolded various synergistic benefits to each other and created a favorable environment for successful change and organizational improvement. These synergies and interactions will be presented in more detail in the following section on methods and in the results and discussion section.

### The Hamburg case seen from a national and international perspective

Setting up the RISA project in 2009 and introducing a separated stormwater management charge in 2012 reflects a development towards an integrated, holistic approach in wastewater and especially in stormwater management in Hamburg. However, the Hanseatic City is by far not the only city moving in that direction. Sustainable wastewater management instead of sole wastewater disposal has been an emerging topic in Germany and abroad since the 1980s and 1990s. The paradigm shifted during these decades more and more towards a natural, local water balance and the conservation of water resources. In Germany another big player in the water sector – the so-called Emschergerossenschaft as water management association in the Emscher region – conducted between 1990 and the target year 2020 more than 300 projects for the conversion of their previous wastewater disposal system towards modern wastewater and stormwater management. The development towards the above-mentioned integrated, holistic approach was renewed and even strengthened by the declaration from 2005 of the Emschergerossenschaft and its local partners in the water sector that unpolluted stormwater shall be of benefit for the natural, local water balance and a decoupling of 15% shall be achieved by 2020 (Emschergerossenschaft 2005). Recently, the Emschergerossenschaft has engaged within a joint German research project named SAMUWA (BMBF 2014) aiming at further steps towards an adaptable management of the urban water balance.

The European environmental policy flanks the above-mentioned trend by setting ambitious goals for the European water sector in the Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council) dated October 2000. In turn, this directive promotes

development towards an integrated, holistic approach in stormwater management in many German cities. Next to Hamburg, Berlin and its so-called KURAS project as well as Bremen and its so-called KLAS project could be mentioned here: both cities and their utilities are exemplary exchange partners for HAMBURG WASSER, seeking mutual professional exchange regarding adequate approaches to holistic urban stormwater management. The KURAS and the KLAS projects focus like the RISA project on interdisciplinary work with the municipal stakeholders involved to develop stormwater management further (Freie Hansestadt Bremen 2017; Kompetenzzentrum Wasser Berlin 2017). However, there is a certain unique feature of the RISA project in comparison to the other German examples: besides the interdisciplinary project approach, the RISA project focuses on sophisticated data collection in order to form a new kind of scale independent data basis for geographical information system (GIS)-supported local analysis, simulations and concept development. This kind of Hamburg-wide data basis today offers outstanding accuracy and can be analyzed down to a unit area of 1 m<sup>2</sup>. As a result of the RISA project, HAMBURG WASSER can act today in a very independent way with regard to, for example, calculation of the revenues from the stormwater charge or the evaluation and development of decentralised decoupling possibilities.

A valuable reference city for Hamburg's RISA project is also the exemplary City of Copenhagen with its remarkable achievements in the field of holistic wastewater and stormwater management (City of Copenhagen 2012). Hamburg shares with Copenhagen the same challenges to sustainable water management, such as the challenges caused by climate change. However, due to the very different historic developments, the current frameworks for wastewater management differ a lot to the one signifying Hamburg.

Outside Europe, especially Australia's paradigm shift towards the so-called Water Sensitive Cities concept has to be mentioned in this context: the Water Sensitive Cities concept was adopted in 2004 by the Australian Government. Since then research, practitioners, political communities, as well as the general public in Australia have adopted a system-thinking approach to define a way towards a sustainable water future (Rijke et al. 2012; International Water Center 2017). This system-thinking approach resembles the interdisciplinary approach in Germany.

Coming back to the Hamburg case, the RISA project may be one example out of many outstanding cities' initiatives tackling holistic, sustainable development in the water sector. However, the methodology, structure and aims of

the RISA project in association with the parallel undertaking to introduce a sustainable funding mechanism for stormwater measures unlocked remarkable synergies in Hamburg. This effect may be somewhat special within the above-mentioned national and international water landscape.

## METHODS

The RISA project was set up with three key aims for future stormwater management in Hamburg. These refer to the achievement of:

1. a near-natural local water balance,
2. extensive water pollution abatement, and
3. flood protection and inland flood control.

The project was organized in four work groups (WG) covering the areas of urban drainage, urban and spatial planning, traffic planning and river basin management. These WG worked next to their designated topic also in the context of four interdisciplinary topics, namely technical planning basics, costs and funding, institutional and legal framework as well as communication and public perception. [Figure 3](#) shows the project structure graphically. In the end, more than 70 persons were involved in the RISA WG during the project's duration from 2009 to 2015. It was seen as important that a reasonable composition of experts, stakeholders and institutions concerning stormwater management (please compare [Figure 2](#)) was represented in the working groups to get well-balanced, comprehensive results and to establish a common ground for future change and improvement.

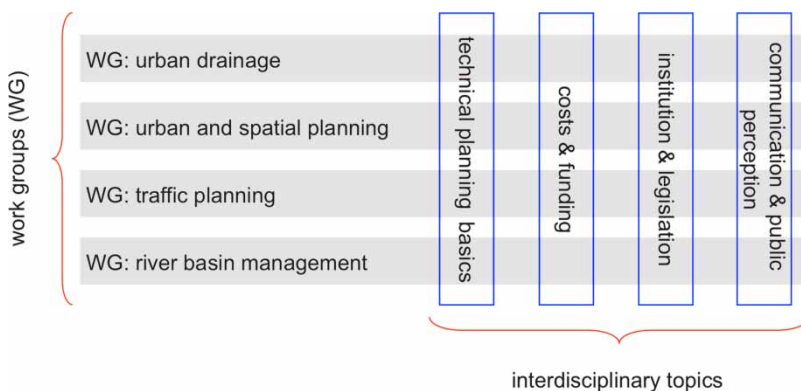
The WG used classical project management for organizing the workload. The work schedules of the WG were set

by the RISA participants and included several milestones for the reports of preliminary results, input and analysis by external experts as well as diverse workshop formats such as the World Café or Fishbowl for broad exchange. Event and problem related participants in the WG gathered to work on the four interdisciplinary topics in a WG-spanning way. The content of the WG and the interdisciplinary topics will be presented as follows.

Each of the four WG evaluated within RISA the status quo concerning their designated topic. Conflicting issues in the course of the current urban development and challenges to wastewater management, for example, due to climate change effects, were subsequently anticipated and discussed within the respective topic. At the end the participants assessed the room for improvement, which resulted in numerous recommendations for the current planning practice. These results were combined and published as a final report ([HSE/BUE 2015](#)).

The urban drainage WG was managed by HAMBURG WASSER and evaluated the current situation of the drainage infrastructure at that time. In association to that, drainage and treatment of stormwater and local stormwater management measures were also analyzed. Another focus was on the evaluation and prognosis of precipitation and evaporation within the city as well as the hydrogeological situation. The situation of water bodies was included in this WG as well as in the river basin management WG. Principal supporter of this WG was the Technical University Kaiserslautern.

Urban and spatial planning: This WG was managed by the Ministerial Department for Land Use Planning and Urban Development. The work schedule included, for example, evaluation of the urban structure, the biotopes and open spaces, the land use and sealed areas. The WG assessed also the open city spaces, which could be safely



**Figure 3** | Project structure of the RISA project.

used as retention areas in case of rainfall or flooding. Principal supporter of this WG was the Hafencity University Hamburg.

**Traffic planning:** This WG was managed by the Ministerial Department for Traffic and Road Planning. The WG identified the current situation of the traffic infrastructure in regard to their effects to wastewater management and water pollution at that time. This WG developed improved and new ways of road drainage, which integrate stormwater management measures such as retention and treatment [FHH \(2015\)](#). Principal supporter of this WG was the RWTH Aachen University.

The river basin management WG was managed by the Ministerial Department for Environment and evaluated the status quo of the urban water bodies and their pollution due to shortfalls in wastewater and stormwater management. The WG prioritized those water bodies suffering most from pollution due to emissions from stormwater/wastewater and road runoff. An assessment of which water bodies could be restored in a cost effective way was included. Principal supporter of this WG was the engineering bureau Prof. Sieker mbh.

**Technical planning basics:** Within this interdisciplinary topic, mainly comprehensive planning basics were developed. This included, for example, the development of digital mapping data for spatial and topographical analysis. The methodology for this topic will be presented in detail in the next section.

**Costs and funding:** This interdisciplinary topic included the analysis of current costs of stormwater management in Hamburg at that time as well as the origin of the funding. Subsequently a prognosis of the future cost development was performed. In this context, different ways of future sustainable funding mechanisms were evaluated.

**Institutional and legal framework:** Within this interdisciplinary topic the existing institutional and legal framework for stormwater management was analyzed in regard to room for improvement. This was done for different legal frameworks (please compare [Figure 2](#)) covering different parts of stormwater management in Hamburg. Based on this legal and institutional analysis, recommendations for adequate adaptations in that field were formulated. These recommendations aim at a stronger consideration of stormwater management issues in planning and administration practice.

The communication and public perception topic deals with the development of a corporate strategy for the involved stakeholders in order to increase positive public perception of stormwater management issues in Hamburg. This topic also comprises an improvement to the

reconciliation processes of that time regarding communication work of different institutions towards citizens as well as towards experts and professionals in the water sector.

In the following, we focus on the methodology used to work on the two interdisciplinary topics of technical planning basics and costs and funding and the special approach to combine both topics in such a way that synergistic benefits were generated.

### Tools and methods for the development of technical planning basics

Essential for a future integrated and holistic approach in stormwater management is a consistent and precise up-to-date database, which is accessible and analyzable with modern information system technologies. The RISA project developed in this context a Hamburg-wide GIS, which was lacking at that time. A huge stock of information was collected and combined for that purpose ([Waldhoff \*et al.\* 2012](#)), such as the following:

- Digital base map, so-called DSGK ([LGV 2009](#))
- Information on property owner and property usage, so-called HALB ([LGV 2009](#)) and ALKIS<sup>®</sup> ([LGV n.d.](#))
- Topographical information, so-called ATKIS<sup>®</sup> ([LGV n.d.](#))
- Digital terrain model ([LGV n.d.](#))
- Three-dimensional digital City model (Level of Detail 1) ([LGV 2014](#))
- Digital tree register ([LGV 2014](#))
- Stereo aerophotos and digital orthophotos ([LGV n.d.](#))
- Biotope type ([BSU 2006](#))
- Water book ([BSU 2011](#))
- Groundwater levels, information on water bodies, hydrology, protection zones ([BSU n.d.](#))
- Drilling database and geological information such as stratification ([GLA n.d.](#))
- Engineering geology ([GLA n.d.](#))
- Sewer register ([HAMBURG WASSER n.d.](#))
- Register of sealed space ([HAMBURG WASSER n.d.](#))
- Information on the drainage situation of every property in Hamburg ([HAMBURG WASSER n.d.](#)).

Some information was publicly available. Most of the collected public information had to be processed, edited or combined in a certain way in order to be part of the GIS database. Soil type and groundwater levels were, for example, combined into information on the area's potential for stormwater infiltration. The collection and processing of original essential information was commissioned as in the

case of digital orthophotos and stereopair aerial photos of Hamburg.

Once collected, the data were used to build up a GIS, which is today useful for all stakeholders involved in stormwater management: the smallest unit in this GIS analysis is the so-called surface partial area. Surface partial areas can reach 1 m<sup>2</sup> as their smallest size. Several surface partial areas combine together to a parcel of land. The sum of all parcels of land combines to the territory of the City of Hamburg. The GIS database today comprises more than 1.2 million entries of surface partial areas. Every surface partial area is comprehensively attributed in regard to its characteristics based on the collected information (see list above, e.g. sealed surface, location, slope, etc.). In that way, scale-independent analyses on micro or on macro-scale become possible because the data are superposed in the GIS to form several kinds of data layers.

#### Tools and methods for the development of costs and funding mechanisms

Tools and methods used in the RISA project for the development of suitable funding mechanisms for stormwater management in Hamburg were classical cost analysis, cost evaluation and future cost prognosis. The cost allocation, which is presented below, was done with the help of a separated sewer model for all Hamburg.

However the special approach to develop this topic further – going beyond the analysis, evaluation and

prognosis efforts, which were performed as part of the RISA project – towards the actual pricing system adaption in 2012 was a new way of organizational integration at HAMBURG WASSER. This by nature to a great extent economic and legal topic was merged at HAMBURG WASSER with the department for stormwater management – a by nature rather technical department in charge of the RISA project. The background to this decision was the ambition to generate an advantageous environment for both topics. For the undertaking of pricing system adaption as well as for the RISA project it was necessary to create an accurate data basis regarding every property in Hamburg and to make this information electronically accessible. It was achieved that a common understanding of the nature of the information needed by the RISA project and the pricing system adaption was built prior to data and information collection. One example is the mutually performed areal stereopair photography of all areas of Hamburg and the subsequent 3-D visualization of buildings and sealed areas. This analysis of stereopair files produces information on the surface drainage situation of each property in Hamburg. For verification and consent, the generated data set was supplemented by a comprehensive data survey: every property owner had the chance to check the outcome of the areal photography results regarding his or her property by answering an individual, posted data entry form. An example of the accuracy and specificity of the data entry forms is shown in Figure 4. It can be seen that the property contains several surface partial areas with different



Figure 4 | Detail of an exemplary data entry form for verification of surface drainage situation at property level.

attributes. To define the type of area, the property owner could choose between the following items:

- Area:
  - Completely sealed
  - Partly sealed
- Roof:
  - Conventional roof
  - Green roof
- Drainage:
  - Direct connection to sewer
  - Indirect connection to sewer: cistern/ infiltration facility with overflow
  - No connection to sewer: cistern/ infiltration facility without overflow/ water body/trench or other.

Data capture and data processing were handled by use of the GIS techniques presented in the previous section. The huge amount of data could subsequently also be used by the RISA project. The mutually developed comprehensive GIS, based on originally collected and processed data, is one example of mutual results, which will be presented in more detail in the results section.

## RESULTS AND DISCUSSION

All results and recommendations of the RISA project are summarized in the so-called RISA Structure Plan Stormwater 2030 (HSE/BUE 2015). This compilation can serve as a framework for the integrated stormwater management in

Hamburg. The Structure Plan Stormwater 2030 presents an inventory of the current status of stormwater management and provides recommendations for the future handling of stormwater based on the results achieved in the work groups of the RISA project: technical solutions, the legal foundation, new planning foundations, new planning instruments and procedures as well as novel communication paths were prepared, agreed on amongst the project stakeholders, and published. The content also includes costs and cost prognoses, current funding and discussion of new funding options for the integrated stormwater management in Hamburg. Of all the results, the achievements regarding new technical planning basis and suitable funding mechanisms will be presented more detailed.

### Information system for integrated stormwater management based on new technical planning basics

To plan and implement appropriate stormwater management measures in terms of ecological and economical aspects, a comprehensive GIS-based analysis, planning and information system for stormwater management at the property level was developed for Hamburg. This information system comprises several data layers with essential data. The analysis of these data layers can be used during the planning process. The layer structure is exemplarily shown in Figure 5. The cartography and background data used for this digital information system for stormwater management in Hamburg are presented in the methods section and comprises, for example, ALKIS<sup>®</sup>, ATKIS<sup>®</sup>, digital terrain model, tree registry, types of biotope, water book,

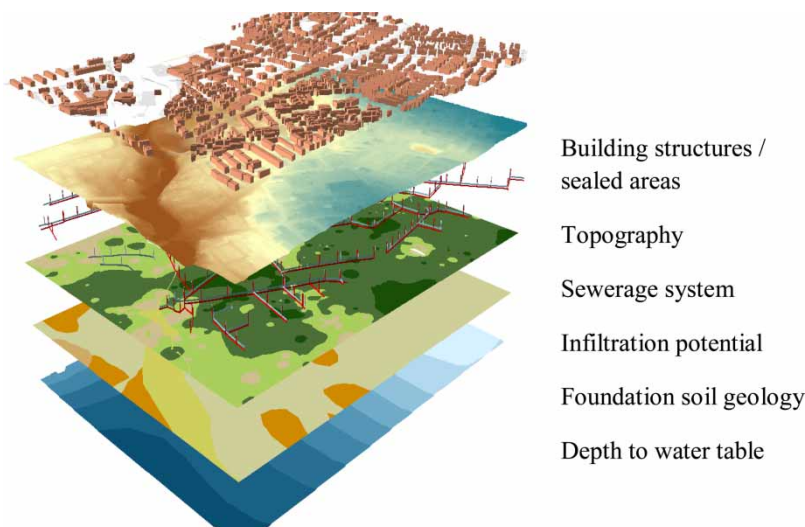


Figure 5 | Exemplary representation of data layers with fundamental data building the novel information and planning system for integrated stormwater management in Hamburg.



groundwater levels, geological stratification, engineering geology, sewer registry, sealing land register and property drainage data.

An essential result in the sphere of the RISA key aim of a near-natural local water balance is the so-called infiltration potential map. The infiltration potential map is based on hydrological, geological and topographical data that were validated, extended and updated in the RISA project. Furthermore, knowledge about potential areas is essential for stormwater management measures: therefore another result is the so-called potential area map. Paved areas, the availability of areas, area use, building structures and the drainage situation are the information basis for the potential area map. The infiltration potential map and the potential area map are together building another map, which is the so-called decoupling potential map. Furthermore, water resource balances are used to build a water resource potential map. These maps provide concrete planning fundamentals and potential analysis at various levels of detail for integrated stormwater management in Hamburg.

With regard to the RISA key objective, inland flood protection hazard and damage maps were created. The hazard and damage maps were created to estimate the flood risk to infrastructure objects. This information shall contribute towards the cooperation between administration, planners and, more importantly, property owners in providing enhanced flood precautions. In addition to this, it is possible due to the improved analysis of large-scale hazard potentials to compare the use of flood precaution measures and the associated costs, hence providing a base for political/economic decisions.

With regard to the RISA key objective of extensive water pollution abatement, a so-called emission potential map was developed. This is based upon the yearly mean load pollutant emission rates (calculated as suspended solids) from paved areas. It provides improved detection of the main pollution areas in settled regions.

The series of maps were used, for instance, as the basis for the compilation of stormwater treatment concepts for Hamburg in which the necessity, the extent, the expense and emission orientated uses of the stormwater treatment measures are represented.

Besides the tools (maps) based on spatial analysis, a novel tool for HAMBURG WASSER's day-to-day business is based on topographical analysis: the above mentioned GIS functions of the information system for stormwater management offer, in connection with modern computer processing power, detailed, small-scale information regarding the rather flat topography in Hamburg. This

information can be used to determine topographical depressions, to identify the catchment area of every depression and also to identify the overland flow paths for stormwater runoff towards the depressions. Using this digital information it is possible for HAMBURG WASSER to, for example, predict revenues from the separated stormwater charge in a more precise way. Furthermore, the collection of these revenues is today resulting in invoicing charges based on this digital information instead of the error-prone declaration by customers.

### Suitable funding for stormwater management

The RISA project was conducted parallel to the development of the separated stormwater charge by HAMBURG WASSER. To ensure a high transparency of costs, a fair arrangement of the charge and to get, at the same time, the targeted ecological guiding effects, HAMBURG WASSER prepared the pricing system adaptation for about three years. During that time, a large collection of data was performed – often correlating with essential data for the RISA project: this included, for instance, data records concerning the accurate area relevant for the stormwater charge for each property in Hamburg – in this case, analysed by areal pictures and supplemented by a data survey amongst all property owners in Hamburg.

As the basis for the stormwater charge calculation, a comprehensive cost analysis regarding the actual costs of HAMBURG WASSER for the stormwater drainage and management was performed: the so far known overall costs for wastewater management as a whole were split up into capital costs and operational costs separately for sole sewerage drainage and treatment and for sole stormwater management. In 2012, the overall costs for wastewater management summed up to about 263 million Euros. The cost analysis resulted in the following cost allocation formula for the year 2012:

- 29.3% of the overall costs is allocated to stormwater management, equalling €77 million
- 70.7% of the overall costs is allocated to sewerage drainage and treatment, equalling €186 million.

Based on this separate cost calculation, in May 2012 the separated stormwater charge was finally implemented next to the wastewater charge. At that time the wastewater charge amounted to €2.09/m<sup>3</sup>. Its calculation is based on the measured consumption of drinking water, since almost 100% of the citizens are completely connected to the wastewater sewer in Hamburg: therefore, the overall annual costs

can be set in correlation with the individually, flat-wise/house-wise measured consumption of drinking water (in 2012, about 89,000 million m<sup>3</sup>), which relates to the produced wastewater. Since January 2017 the wastewater charge amounts to €2.11/m<sup>3</sup>.

On the contrary, the separated stormwater charge is calculated by the overall annual costs for stormwater in correlation to the total sealed area in Hamburg connected to the public sewer system for stormwater (in 2012, about 105 km<sup>2</sup>). It currently amounts to €0.73/m<sup>2</sup> sealed area per year and has to be paid for every sewer-connected property.

In Germany, this kind of pricing system with a separate stormwater charge is widely established. In Table 1, a comparison of the separated stormwater charge of several large cities in Germany is presented. However, the way of implementation in Hamburg in association with the RISA project gave the whole topic of integrated stormwater management a new awareness and broad support within the city.

## CONCLUSIONS AND OUTLOOK

During 2009 and 2015, several stakeholders concerned with stormwater management performed the RISA project in Hamburg. At the same time, HAMBURG WASSER as the water and wastewater utility prepared and implemented a novel pricing system, accounting a separated stormwater charge in spite of the established overall wastewater charge. Both projects were benefiting from a new and comprehensive database at property level, which was collected throughout the projects. The data set today consists of more than 1.2 million comprehensively attributed surface partial areas, of which the smallest unit reaches 1 m<sup>2</sup>. Based on this data set, a GIS for integrated stormwater management was built for Hamburg. It is now the basis of the day-to-day business of the stormwater management at HAMBURG WASSER and enables the utility to work on area and proprietors' management in a scale-

independent way. The GIS can produce various maps, combining and superposing the spatial data in the form of layers. Today HAMBURG WASSER and the other stakeholders involved in stormwater management in Hamburg can use a series of informative maps in their administrative and planning practice. The infiltration potential map, the potential area map and the decoupling potential map are particularly useful for the development of local stormwater management measures. The hazard and damage maps are used for the development of flood protection measures and the emission potential map for river basin management measures.

HAMBURG WASSER plans to produce further maps in the future dealing with associated topics. One aim is to combine the data set in the GIS to gain a water balance map. This water balance map will support the urban planning practice and offer compact information as a decision basis in regard to local water balance issues such as infiltration potential, evaporation potential or drainage limitations.

RISA has produced numerous conclusions and recommendations towards the adaption and potential improvements of stormwater management in Hamburg. The developed planning foundations and the further formulation of new planning instruments were important work steps. Today, the involved stakeholders keep the direction of change towards the long-term RISA key objectives even after formal completion of the RISA project. Currently, there is a senate document in progress for this purpose based on the results summarized in the RISA Structure Plan Stormwater 2030 (HSE/BUE 2015). This includes the following tasks:

- Creation of a legal and management framework that plans the drainage of additional stormwater into the sewer network only in exceptional situations
- Further development and introduction of the RISA planning instruments into planning practice
- Further development and introduction of the principles of flood precautions under the framework of integral risk management for Hamburg
- Introduction of uniform guidelines towards the prioritization and implementation of stormwater treatment concepts for Hamburg
- Development and introduction of a sustainable financial and administrative concept for surface water drainage facilities in Hamburg
- Incorporation of water pollution abatement and flood protection into the road construction policies of Hamburg
- The establishment of long-term communication and training concepts for integrated stormwater management in Hamburg.

**Table 1** | Stormwater charges of big cities in Germany, data from 2014 (Oelmann et al. 2014)

City	Inhabitants	Stormwater charge [€/m <sup>2</sup> /a]
Berlin	3,502,000	1.825
Hamburg	1,799,000	0.73
Munich	1,378,000	1.30
Cologne	1,017,000	1.30
Stuttgart	613,000	0.66
Düsseldorf	592,000	0.98

The issue of stormwater management became highly valorized and visible in Hamburg by conducting the RISA project parallel to the introduction of a new pricing system for wastewater and stormwater. Both undertakings unfolded various synergistic benefits to each other and created a favorable environment for successful change and organizational improvement. The mutual data collection at property level in regard to surface sealing may be mentioned as one exemplary result. It could only be achieved with the combined workforce of both undertakings because the requirements in regard to accuracy at small-scale level for the whole of Hamburg were immense. Putting scale-independent spatial data in the center for further development towards integrated stormwater management makes the RISA project special. RISA's unique result is a comprehensive data set of attributed surface partial areas, which can be processed and analyzed using powerful GIS techniques. This data set was also the key towards sustainable funding of stormwater management measures in Hamburg because it is the basis for the calculation of the separated stormwater charge. With this digital information, HAMBURG WASSER's prediction and achievement of revenues becomes independent from the declaration by customers.

Looking back on the RISA project, it becomes clear that even though the technical results are outstanding, the integration of the RISA project results into local political decision, and political action did not happen sufficiently. The above-mentioned senate document, which could confirm the RISA results for stormwater management in Hamburg, progresses very slowly. One reason for the lacking political follow-up action may be that the stakeholders focused very much on technical results and missed the active support and collaboration with policy-makers during the project's duration. Apart from that, one can conclude that HAMBURG WASSER and other municipal stakeholders implemented the technical results and products of the RISA project very successfully and with that developed stormwater management in Hamburg further: decision making and planning activities on a daily basis benefit to a great extent from the comprehensive information basis generated by RISA.

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