MUFFIN

MUFFIN: Multi-scale Urban Flood Forecasting: From Local Tailored Systems to a Pan-European Service

End-user Requirement Specification Report / Final End-User Report (Appendix 4)

WP2, Deliverables D2.1 and D2.3

May 2018 with Appendix 4 update August 2019

Statens geotekniska institut
Olaus Magnus väg 35
581 93 Linköping
Tel. 013-20 18 00
www.swedgeo.se

2018-08-26

Date:	**May 2018 with update August 2019**
SMHI Project manager:	**Jonas Olsson**
SGI WP 2 leader	**Lisa Van Well**
SGI Diarienr:	**1..1-1605-0347**
SGI Project no.:	**16093**

INDEX

INTRODUCTION TO UPDATE

This updated report contains the entirety of the MUFFIN End-user Requirement Specification, finalised in May 2018, but with the added Appendix 4 update of the Final End-user Report, a short document profiling how and to what extent MUFFIN has been able to meet the needs of the end-users, as specified in the body of the report.

1 BACKGROUND AND AIM OF THE END-USER REQUIEMENT SPECIFICATION

Urban flooding, caused by extreme rainfall in combination with large areas of impervious surfaces and limited capacity of storm water sewer systems, is a major hazard today and is expected to increase in northern Europe as the climate changes. The development of early warning systems and urban flood forecasting systems are therefore crucial to the security and sustainability of cities.

The Swedish Meteorological and Hydrological Institute (SMHI) together with partners from the Technical University of Delft (TUD), Aalborg University (AAU), Aalto University (AALTO) and the Swedish Geotechnical Institute (SGI) are cooperating in a study on Multi-scale Urban Flood Forecasting: From local tailored systems to a pan-European service (MUFFIN).

The aim of MUFFIN is to bridge the gap between the urban and large-scale hydrological modelling communities and develop innovative tools for reducing the urban impacts of extreme precipitation, including sensor technology, systems for interpreting and communicating data, and monitoring networks that will contribute to improved integrated risk management solutions to urban floods.

WP2 on “End-user value” has as a goal to optimize the process and outputs of the project with respect to practical value for relevant end-user categories. This is to ensure that the flood forecasting meets the specific and concrete needs of the urban users and can be integrated into their existing organizational structures and current use of forecasting.

2 METHODS

2.1 Triangulation

To specify the end-user value, SGI prosed a three-prong or triangulation method to understand the needs and requirements of the MUFFIN end-users. Triangulation means using more than one method to approach a study object. It can consist of mixed qualitative and quantitative methods. They goal is that these methods complement one another and help to enrich the analysis and the interpretation of the results. In the MUFFIN case these three methods to ascertain end-user requirements consisted of 1) an international Workshop in February of 2017, 2) an End-user survey administered in December 2017 and in-depth telephone interviews with end-users in November 2017- February 2018.

Figure 1 Triangulation method used by the MUFFIN team for end-user requirements.

International Video Workshop
February 2017
Qualitative method/results

On-line survey
December 2017
Quantitative method/results

Telephone interviews
December 2017 – March 2018
Qualitative method/results

2.2 End-user identification and inventory

The first step in the determining the end-user requirements was to identify all potential stakeholders. Sometimes these terms stakeholders, users and end-users are used interchangeably. But we have made the following distinctions:

In general, a **stakeholder** is any person who has a "stake" or interest in a policy or knowledge question. This is a very broad category and includes both persons involved in making a decision or providing knowledge as well as those affected by it. This includes politicians, planners, administrators, home owners, knowledge providers, users and end-users of a service, and private interests, civil society, citizens of all ages that are affected by a decision.

A **user** is person or organization that uses an intermediate product or service in order to provide a final product or service. An **end-user** is person or organization that uses and gains the benefits of a final product or a service.

Thus we started out quite broad with an extensive and wide list of *stakeholders* who might be interest in the project and who could potentially contribute to the societal relevance of the project, such as national and regional authorities We then focused on those *users* who could potential use the MUFFIN results, such as academics and consultants and as well the *end-users*, who were mainly the partners and end-users specified in the case studies in Aalborg, Espoo and Rotterdam.

Stakeholder lists and contact details were drawn up at the beginning of the project by the Swedish, Dutch, Danish and Finnish partners. Each list included the following categories of end-users (where relevant in each case):

- Local authorities
- Regional authorities
- National authorities
- Local and Regional waterboards
- National waterboards
- Consultants and commercial users
- Academics

We then used these lists as a basis for invitations to the workshop, e-mail addresses for the on-line survey and for choosing the telephone interviews. The goal was to have contact with each relevant stakeholder group for each case

We also gained a great understanding of the needs of the end-users in our discussions with the MUFFIN Advisory Board members.

3 THE MUFFIN INTERNATIONAL VIDEO WORKSHOP

The MUFFIN End-user Workshop was the first of three methods used within the project to discern the specific needs and requirements of potential end-users. It was the first task in this Inventory and requirement specification (D. 2.1), together with a survey to a broader range of end-users and 4-5 telephone interviews performed later in the project.

On 28 February 2017 the project team welcomed specified end users to the workshop with the aim to:

- gain an understanding of how end-users currently use data on urban flooding,
- identify end-user needs and gaps in the use of urban flooding forecasts
- identify how the MUFFIN-project can help to fulfil end-user needs.

3.1 Workshop agenda and structure

The MUFFIN workshop was held on 28 February 2017 in Norrköping (at SMHI), Delft (at Technical University of Delft), Espoo (at Aalto University) and in Aalborg (at Aalborg University). Via video we connected all four locations for plenary sessions in English and then had break-out sessions/discussions in each country in national languages.

The workshop was held from 09.30-15.30 CET (10.30-16.30 EET). See Figure 2 Brief workshop agenda. For the extended workshop agenda see Appendix 1.

Figure 2: Brief workshop agenda

09.30-10.00 CET	Coffee and registration
10.00-10.45 CET	Plenary: Introductions, MUFFIN objectives and Work Package presentations *SMHI, TUD, Aalto, Aalborg, SGI*
	Block 1: Today's situation: End-user limitations and needs
10.45-11.10 CET	Locally discussions- Today's situation: • How do you currently use flood simulation and forecast data in your work? • Which type of data do you use today? • What limitations have you experienced in this work?
11.10-12.00 CET	Local brainstorming: • What are your current needs for data – before, during and after the flood?

12.00-13.00 CET	*Lunch*

	Block 2: "The perfect flood": What can MUFFIN contribute to the local cases?
13.00-13.40 CET	Plenary: Short wrap-up presentations from morning sessions from each city.
13.40-14.40 CET	Local Brainstorming: • Presentations of each site case study • How can MUFFIN contribute within each site? • Discussion
14.40-15.00 CET	Plenary: Reports from each group
15.00-15.30 CET	Plenary: General discussion, summing up and next steps and coffee.

3.2 Identifying the end-users

Early in the project the project partners were asked to make a gross list of all potential stakeholders of the MUFFIN results. The end-users were categorized as 1) local authorities, 2) regional authorities, 3) national authorities, 4) water organizations , 5) emergency services, 6) consultants and commercial users, and 7) academics. Invitations were sent by each partner to most of the end-users on their respective lists. See Appendix 2 for the full list of participants.

The total number of participants was 40, of which 15 were project partners and 25 were end-users. See Appendix 2 for a list of all participants, e-mails and user category.

MUFFIN Workshop participants								
	Local authorities	Regional authorities	National authorities	Water organisa-tions	Emergen-cy ser-vices	Consult-ants / Private	Academics (incl project partners)	**Total**
SMHI	1		3		2	4	5	*15*
Aal-borg	1			3			3	*7*
TUD	1		1				5	*7*
Aalto	1	2	2			2	4	*11*
Total	*4*	*2*	*6*	*3*	*2*	*6*	*17*	*40*

Table 1. Muffin Workshop participants

3.3 Running the workshop

The first video plenary began with the project leader welcoming all participants. Each participant briefly introduced themselves. SMHI then gave an introduction to the MUFFIN objectives and presented some multi-scale examples. TUD presented WP3 on Hydro-meteorological data, Aalborg presented WP4 on Urban flood forecasting, AALTO presented their case study on Storm water management and SGI presented WP2 on End-user value as well as the objectives of the workshop

After the first plenary, sessions broke-out locally with two-three chosen end-users in each city briefly presenting 1) how they currently use flood simulation and forecast data in your work, 2) which type of data that they use today, and 3) what limitations they have experienced in their work.

These presentations provided background to the first local brainstorming sessions where participants (in smaller groups) discussed their current data needs, before, during and after the storm, in terms of resolution, geographic coverage, lead time and accuracy/certainty.

After the lunch break, the participants met in plenary again for short wrap-up presentations from morning sessions from each city. The case studies were then presented in each local break-out session, which was followed by discussions on what the MUFFIN project could contribute to each site. In the final plenary the groups presented the discussions from the afternoon with a general discussion of how the cases could learn from each other and the next steps of the project.

4 WORKSHOP RESULTS

4.1 End-user current needs

4.1.1 Data needs before the flood

How could the data available to end-users on rainfall forecasts and/or urban flood forecasts (before the flood) better meet your needs with regard to:

Table 2: Data needs before the flood

	Resolution	Coverage	Lead Time	Accuracy	Other
SMHI	Resolution should be higher – need to know what might happen, ground water levels, hydrological boundaries Resolution linked to certainty	Cloudbursts very local and it is hard to get correct dimensions Updates needed on elevation data for models Need to include topography, land use and hotspots	1-2 hours is good to allow for action, physical and mental Time period is short for contingencies	Need for more accurate forecasts but the data must be correct Avoid warning too often Coordinate among authorities for classification of warnings Info on intensity and duration very important Better spatial accuracy needed	Lots of information available, but need help to interpret data Because of short time tween warning and downpour it is good to have clear maps on various scenarios and type of rain
TUD	Currently weather forecasting model is HARMONIE at 2.5 km with updates every 3 h at Western European scale	Exact location not relevant now HARMONIE sufficient	Exact timing not relevant now Forecasts interpreted qualitatively looking at possibility of heavy rain in coming day or hours Warnings 10-12 hours ahead useful but could be uncertain	HARMONIE Resolution and accuracy could be improved, especially for heavy and fast-developing rain events.	Pumping stations in Rotterdam based on local water level observations in pump chambers and not quantitative info on past or future rainfall Decisions on closures and evacuations based on field info, not rainfall info
AALTO	Model-specific data input resolution Sufficient resolution	Catchment scale Stormwater network data in not all FI Location and condition of culverts	According to requirements of emergency services response time At least a few hours for certainty	Models calibrated before flood so that there is no extra uncertainty during the flood	Updating the design rainfalls and uniform, e.g. Internet based search service (e.g. using constant or stochastic rainfall) Level-based preparedness Climate change impacts
AALBORG	Coarse resolution forecasts are usable to advise municipalities Coarse resolution forecasts would on catchment size would suffice	Local coverage, but potential for national Catchment size coverage	Extreme, flood producing events: few hours- <1 day 5-6 hours for urban areas, 1 week for catchment areas	Need for high accuracy or come with uncertainty. Limit false warnings	Not much potential for use in sewer drainage systems What can forecasts be used for? Warnings?

4.1.2 Data needs during the flood

How could the data available to end-users for real-time observations (during the flood) better meet your needs with regard to:

Table 3: Data needs during the flood

	Resolution	Coverage	Timing	Accuracy	Other
SMHI	Better resolution needed in time and space No need for forecasts while the flood is happening. But want to know "when will the rain stop?" (which requires a forecast)	More problems with flooding in small streams and on small roads Need to take soil moisture into account	Forecasts during floods influence measures. Observations can be linked to forecasts There are limitations in data for immediate evaluation of the event	Usually the pluvial flooding is what causes problems Hydrologic nowcasts (SMHI home page) are very good. Update the documentation	
TUD					Currently no rainfall data and/or forecasts are used during flood, but city managers and water boards are interested in making better use of available data
AALTO		Merging of radar and rain gauges (needed for online simulations- FMI) Real time observations from stormwater network and ditches	Real-time observation of stormwater flow network not sufficient Photo documentation of flood Delay between event and informing the public		Interest in using public observations and crowdsourcing data Documentation with photos and web-cams
AAL-BORG	High resolution for better management of waste water High resolution oxygen measurements have potential for real-time control of drainable from fields etc.	National and urban coverage Single observation station , more coverage for river systems on catchment size	Lots of real-time data already available with limited lag time More real-time data needed. Very few on-line measurements available. On-line observation of oxygen levels relevant	High accuracy and known levels of uncertainty are important Possibilities for real-time control limited	On-line analysis of observations rather than staff-monitoring

4.1.3 Data needs after the flood

How could the data available to end-users for event assessment (after the flood) better meet your needs with regard to:

Table 4: Data needs after the flood

	Resolution	Coverage	Timing	Accuracy	Other
SMHI	Lack of high resolution time and spatial rainfall measures make it difficult to reproduce events	Lack of distribution data for research purposes – where does the rain go? Big difference in data for urban and non-urban areas Need for more rainfall monitoring stations		Evaluate return time, intensity and duration . Evaluate how the forecasts matched what happened Need for valida-tion and sharing of info	Learn from others how events are managed, level of competency in municipalities is linked to resources- lots of variation Need for documenta-tion in terms of levels and damages of actual rainfall. Guidelines for requirements and legal responsibilities
TUD	High resolution rainfall data and time series at pumping stations can help better under-stand and operate the pumps Spatial resolution rainfall products need to be about 100m, and 1 min to accurately capture storm dynamics . Now at 1 km and 5 min	No info on spatial distribution of rainfall provided	No info on temporal distribution of rainfall provided		Reporting of rain accumulation done using single KNMI station at Rotterdam airport
AALTO	Information to media about return period of flood using interesting resolution	Data-producers: which locations need special atten-tion? Collection of flow rates and depths in as many locations as possible in storm-water network Qualitative info (drone photos) on areal extent of flooding	Desire easy-to-use visual-isation after event for area and time period	Currently rain-fall data is more accurate than the models/flow data used for event recon-struction Reliability of rainfall infor-mation, etc. who has responsibil-ity to assess how rare the event was? How to come to a common understanding of the magnitude of the event? What is normal?	Crowd-sourcing data Photos from Pronto system Aerial images Archiving and analys-ing old events
AAL-BORG	High spatial and temporal resolution important – basis for new solutions and adapt-ing to climate change High resolution for reanalysis and insurance	E- Radar and rain gauge available at urban scale – would like on national scale More data at catch-ment		High accuracy and known levels of uncer-tainty important	Historical conditions of river water. Easily processed data formats (e.g GIS) Ensure that knowledge is not forgotten Observations of stream water bed erosion

4.2 How can MUFFIN contribute to meeting end-user needs?

Table 5: What specifically would you like to see as an output of MUFFIN?

SMHI	Before the flood: **Coordinate forecasts** for pluvial and fluvial warnings, help municipalities using the data and documents available, what are the consequences of the rain? Different types of warnings to public authorities and general public. **Coordinate data for local purposes**, take soil moisture into account, help with interpreting the ensemble forecasts (which are most likely and which are worst-case), more information on the extent of the error on the geographical distribution Before/during the flood: Use more data on run-offs and depth of flooding, more rain gauges for more correct data, help for smaller municipalities to prepare for downpour (e.g GIS resources), focus also on small watercourses, document as much as possible during the events, levels, actual rainfall, photos). After the flood: Validation of models, data on infrastructure, visualisations after the flood. More clarity on responsibilities, before, during and after the flood; Information on low water levels; What can Sweden learn from the other MUFFIN case studies? More comparative aspects
TUD	Rotterdam: Better integrate rainfall data and forecasts into decision-making and emergency management services – before, during and after the flood The Netherlands uses the HARMONIE model but would like to have higher resolution and accuracy 12-14h lead times cannot be spatially detailed and come with large uncertainties. Radar-based forecasts more accurate, but only over short lead times. What types of actions and preventative measures can be taken on the different types of information? Better coupling of high-resolution rainfall observation forecasts with 3Di hydrology-sewer groundwater model Flood forecasting/early warning and assessment on coupling of rainfall and flow/water levels and or (3Di) model outputs. First evaluation for Rotterdam In the Netherlands, rainfall forecasts are looked at qualitatively to decide how to operate the pumping stations. But the city of Rotterdam is interested in developing a more quantitative approach based on past, current and future rainfall data.
AALTO	**Visualization** of rainfall depths (with different return periods for rain events, breaks in traffic routs / detours, location of valuable property. How? Map-based visualizations via internet, probabilistic ensemble based visualizations, same colour scheme as typically in flooding maps. **Improved preparedness**: warnings earlier enough, self-directed precautionary actions, informing rescue services early, clear division of responsibilities, prior planning of actions, informing local residents and operators; flow routes, detention basins and other structures, current knowledge often insufficient. **Assessment of consequences**: prior assessments , analysis and archiving of historical flood events, digital elevation and drainage network data used in identifying flood risk areas, location of historical floods. **Other**: Role of areas under intensive urban development, another operational FMI weather radar in capital area and denser gauge network, new knowledge about parameterization of SWMM model for Finnish conditions, gathering existing information about pluvial flooding risks.
AALBORG	General method developments rather than case-specific. Visualised web/SMS. Question is who is the end user.. readable data formats. GIS compatible formats. On-line monitoring of hydrological parameters, photo documentation during events, input to hydraulic models combining various elements. Integrated models including relevant aspects of the hydrological cycle: rivers, groundwater, drainage system,. Important to include all.

	Performance of forecasts: radar, NWP Multi scale approaches sounds interesting, but end-users are in principle unconcerned with the “road” to the flood warnings – they are only interested in the output.

4.3 FINAL PLENARY DISCUSSION

The final plenary discussion focused on a few questions:

To what extent can we compare and learn from one another?
End-users were interested in comparisons among the case studies and between countries in order to facilitate transnational learning. However end users realised it might be difficult to draw many specific conclusions across the cases, as they are quite different in how they play out in real life. What we can compare, however, are the processes and here we may be able to draw some general conclusions about how

Where is the most value added in the forecasting chain?

There are different values for different users. In the Rotterdam case, for instance, there may be added value in providing high-resolution rainfall forecasts, which usually do not enter the process. In Espoo better land use data would add value. In Aalborg the focus is on both modelling and rainfall issues and the challenge to combine and compare the two. In Denmark, a holistic mind-set and monitoring across different water disciplines, such as groundwater, river water and climate adaptation adds value. In Sweden there is a great opportunity to get data and studies about urban flooding. We don’t know how to compared different local scenarios but we can compare the experiences. More general knowledge about urban flooding is always good. As MUFFIN progresses we have a good basis for more concrete work.

4.4 Summary of data needs before the flood:

Sweden requests higher **resolution**, Finland would like model specific data input resolution, and in Denmark coarse resolution at catchment size would suffice. Netherlands uses HARMONIE model and this is sufficient.

Geographical coverage was also requested at catchment area and factors such as elevation data and topography (Sweden) and location and condition of culverts (Finland) were important. In Denmark there is a potential for national coverage.

Needs for **lead time** on rainfall forecasts and urban flood forecasts varied depending on how the warnings would be used. Shorter lead times (1-2 hours) are more certain and enough to allow for some action, both physical actions and mental preparedness. The requirements of emergency services should be taken into account. Longer lead times are useful for longer-term planning, but are less certain. In the Netherlands lead times of 12-14 hours are necessary for preventative work (ordering extra pumps, sewer maintenance) and shorter lead times (1-2 hours) are needed for pre-pumping to lower water levels, etc.

End-users required more **accuracy** in the forecasts, especially in terms of intensity and duration of the rainfall. There was also the need to avoid extra uncertainty and to limit the number of false alarms.

Other factors important before the flood included the need for municipalities to have help interpreting the data (Sweden), interest in the how the forecasts could be used for warnings (Denmark) and including climate change impacts (Finland). In the Netherlands rainfall forecasts are looked at qualitatively, but decisions for operating the pumping stations in Rotterdam are based on water level observations in the pump chambers rather than quantitative information about rainfall.

4.5 Summary of data needs during the flood

Higher **resolution** real-time forecasts would be useful for better management of waste water and drainage from fields etc. (Finland) but a pressing question (Sweden) is also "when will the rain stop?". The **coverage** of the observations during the flood should also include observations from the storm water network and ditches and the merging of radar and rain gauges (Finland) single observation stations and catchment areas (Denmark) and also smaller streams and roads (Sweden). More real-time observations with **limited time lag** were needed during the flood, but there are limitations in the data for immediate evaluation of the event. **Accuracy** was also important for the real time observations as well as the known levels of certainty.

In the Netherlands rainfall data and/or forecasts are not used during the flood, but city managers and water boards are interested in making better use of the available data. In Finland there is interest in using public observations and crowdsourcing data, as well as photo and web-cam documentation. In Denmark, on-line analysis of observations were relevant.

4.6 Summary of data needs after the flood

High resolution temporal and spatial forecasts are needed to reproduce events, for analysis and as a basis for new solutions. This information is largely available at urban scale in DK and SE, but would be useful at a national scale and for non-urban areas as well. There was a general need for more rainfall monitoring stations. Accuracy in the forecasts can validated by evaluating how well the forecasts matched what happened.

Documentation, analysis and archiving of the data, including aerial images, crowdsourcing data, historical conditions, flow/water level observations in some points in drainage system, water level measurements in rivers/streams etc. in easy processed formats and documentation on the damages of rainfall - are important to ensure that knowledge is not forgotten and that others can learn from how events progressed and were managed. In general there was some discussion about which information should be reserved for the authorities and which for the general public. In the Netherlands reporting is only done from registered complaints. The local authorities know little about probabilistic forecasts and need to learn to deal with forecasts uncertainties as well as how to communicate uncertainty.

4.7 What can MUFFIN do to meet end-user needs?

There was obviously some variation in end-user needs as the nature of the local case studies and the role of the participants in the workshop varied. Each case study area has received specific feedback from end-users on how MUFFIN might be able to meet their needs. It is more difficult to draw more general conclusions on how the MUFFIN project as a whole could better meet end-user requirements. Below are some brief recommendations ensuing from the results of the workshop that might be considered by the MUFFIN team. At the moment they are only suggestions for adding value for end-users of the MUFFIN project. How they can be implemented will be further explored in the questionnaire and in the interviews, and should be discussed within the project group. MUFFIN is not able to fulfil all end-user requirements and many of the suggestions from discussions in the workshop are outside of the scope of MUFFIN. However, MUFFIN can still be sensitive to how project results fit into the broader picture of end-user needs.

1) Local and regional actors were interested in accurate and high resolution forecast data at local level or catchment scale, while national actors were interested in a larger geographic coverage. Longer lead-times were also requested for longer term preparations, but there was an understanding that lead time and resolution are linked to level of accuracy and uncertainty. There was general agreement that warnings should not be given unnecessarily.

    - MUFFIN can continue to explore the added value of resolution and lead time in terms of accuracy and uncertainty, both nationally (SMHI) and in the case studies.
    - MUFFIN can consider how forecasts can be used as input to authorities to enable them to optimize when and how often warnings are given.

2) Local actors also desired more guidance in how to interpret forecasts (such as ensemble forecasts) and how to interpret levels of uncertainty. Actors also were interested in the consequences of the forecasts.

    - MUFFIN can provide short user-friendly guidance papers about how the project's forecasts and monitoring can be utilized by the various types of actors and how the uncertainly associated with the forecasts can be interpreted.

3) Documentation of flooding events, particularly real-time documentation, is important for flood management.

    - MUFFIN can consider more merging of data not only from rain gauges and from radar, but also real-time observations from the general public, including photos and web-cams at critical locations.

4) End-users expressed the desire to understand how cases could learn from each other, and which methods, experiences and best practices could be transferred. While the case studies focus on various aspects and scales of urban flooding, some of the processes can be compared and contrasted.

    - MUFFIN can consider a framework for comparing and contrasting the processes in each country of how cases work to bridging the gap between urban and large scale hydrological models and specific tools for reducing the impacts of precipitation.

5) The added-value of MUFFIN is to provide input to improve the preparedness for end-users, both before and during flooding events, as well as in the analysis post-event. The knowledge base provided by MUFFIN cannot solve issues such as determining who has responsibility in times of flooding or how agencies co-ordinate their work during a flood. But it can be sensitive to understanding how the MUFFIN results might be used (or misused) during the flood phases and forward the question to the national decision makers.

   - MUFFIN can consider, in a complementary project at the end of the project or shortly thereafter, an evaluation on how results were actually utilized by end-users.

Photo: L. Van Well, SGI

5 ON-LINE END-USER SURVEY

To ensure that the flood forecasting and observations meet the specific requirements of the relevant end-users, the MUFFIN project gathered information on end-user needs in an on-line survey in order to gain an understanding of how urban hydrological observations, simulations and forecasts are used today and where the gaps are.

The on-line end-user survey was the second step in the triangulation process for determining end-user requirements and needs. All project partners in each of the four countries were involved in helping to formulate the survey. Initially this was intended as a first step. But this was delayed due to difficulties in formulating survey questions that were relevant for all case study areas. Thus the survey was performed after the workshop.

The MUFFIN project team was in agreement that any on-line survey should be brief, concise and not take too much of the end-users' time to perform. It was also intended to reach a broader range of potential end-users from those that attended the workshop, but to try to ascertain much of the same information.

The development of early warning systems and urban flood forecasting systems is crucial to the security and sustainability of cities. These systems differ with respect to e.g. temporal and spatial resolution, calculated variables and real-time applicability, and thus their value for various user categories also differs. As in the questions for the workshop, the on-line survey first discussed how the information required by and provided to stakeholders may be divided into three stages:

- **Before the flood**: forecasts of rainfall and the resulting impact on surface and sub-surface water fluxes for early warning (and real-time observations)
- **During the flood**: real-time observations of rainfall and water fluxes for situation awareness and emergency planning (and updated forecasts)
- **After the flood**: historical validated observations of rainfall and water fluxes for post-event analysis and evaluation

It then briefly showed how the MUFFIN project aims at improving the support for users with:

- Improved real-time observation by weather radar, improved forecasts by nowcasting and high-resolution meteorological ensemble forecasts,
- Improved simulation and forecasting of urban flooding;
- Innovative ways to post-process and tailor the information for improved visualization, awareness and communication with different end-users.

The survey was administered on-line with Google Drive during December 2017. It consisted of 11 questions, 10 multiple choice and 1 essay-style question, and a final "any other comments" question. With all questions it was possible to elaborate with written comments as well. The survey was administered in English, but it was possible for respondents to comment in their own languages if desired. See Appendix 3 for the survey questions in full.

5.1 Survey results

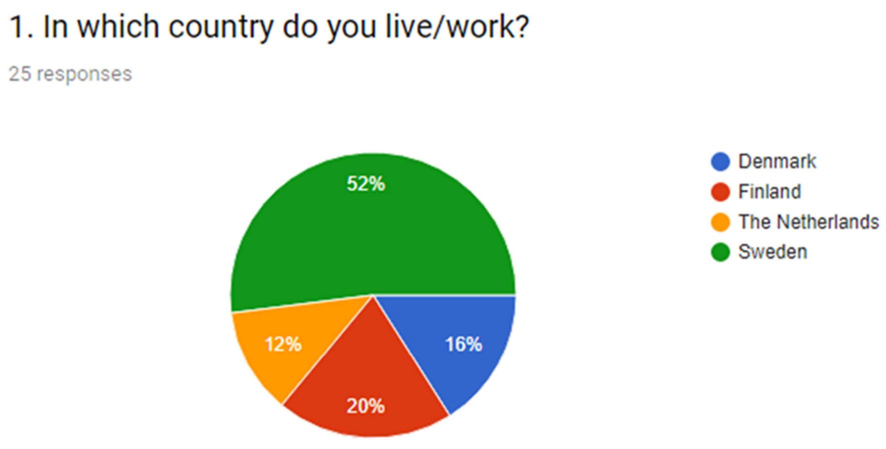
5.1.1 Who answered the survey?

The survey was sent to a total of 82 identified stakeholders and end-users (from the stakeholder identification lists). 25 responded to the survey which is a response rate of 30% (35% if considering the 10 bad e-mail addresses). Table 6 shows the distribution of surveys sent, answered and response rate. Slightly over half of the respondents were from Sweden as the Swedish partners had identified a much larger number of stakeholders (largely since the forecasts produced by Sweden were national in scale rather than local). Demark, Finland and the Netherlands identified more end-users rather than a broad range of stakeholders as these were mainly specific to the cast study sites. Figure 3 shows the percentages of responses per country. Of the 11 of 25 responses to the survey had also participated in the Workshop.

Table 6: Distribution of MUFFIN surveys sent, answered and response rate

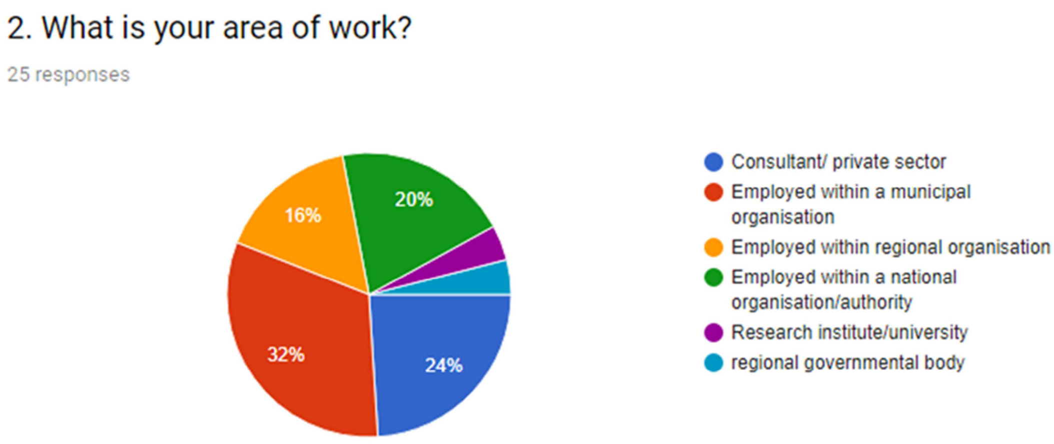
Country	Number Sent	Number Answered	Response Rate
SE	57	13	23%
FI	10	5	50%
DK	10	4	40%
NL	5	3	60%

Figure 3: Percentages of responses per country



There was a fairly even spread with regard to the areas of work of the respondents,. Slightly over two-thirds of the respondents were employed in local, regional or national public organizations and almost 25% were employed within consultancy or other private sector jobs. See figure 4:

Figure 4: Responses to question: "What is your area of work?"



In question 3 respondents were asked to show which areas they directly or indirectly currently used rainfall and flood observations and forecasts in their work. They could check all that apply. Table 7 shows the distribution of these responses by country.

Table 7: Distribution of how rainfall and flood observations and forecasts are currently used, per country. Number of total responses.

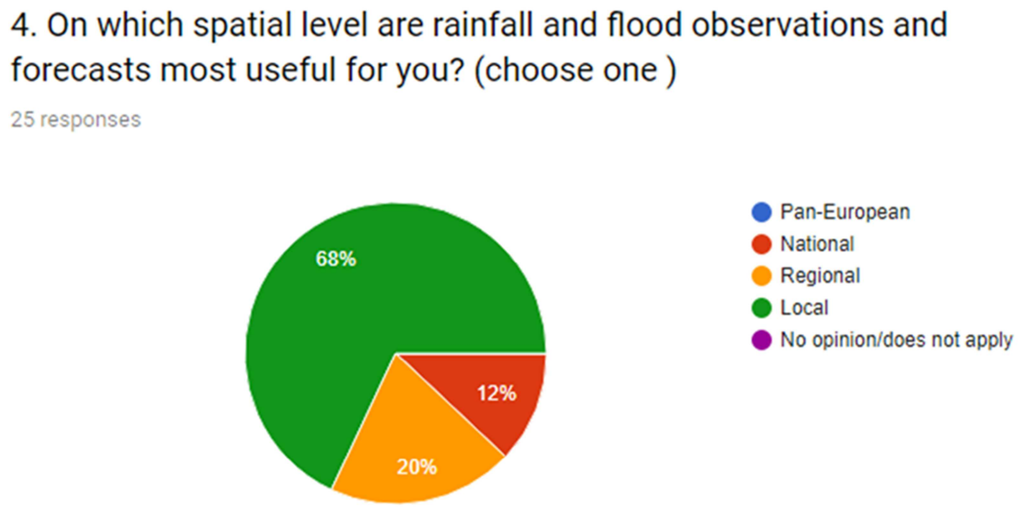
3. In which areas do you currently use rainfall and flood observations and forecasts?						
	SE	**FI**	**DK**	**NL**		**Total**
Climate adaptation	10	2	2	2		16
Flood management	8	4	3	2		17
Storm water management	7	4	3	2		16
Water and sewage management	3	0	2	3		8
Geotechnical security issues	2	0	0	0		2
Risk and vulnerability plans	7	4	3	3		17
Emergency services	1	1	0	1		3
Urban planning	7	3	3	1		14
Research	1	1	1	0		3
I don't use flood simulation and forecast data	1	0	0	0		1
Other	1	0	0	0		1

Respondents used rainfall and flood observations/forecasts in a wide number of areas, mainly those related to local and urban planning, such as climate adaptation, flood management, stormwater, water & sewage management and risk and vulnerability plans.

5.1.2 Spatial level most useful

Question 4 sought to find out on which spatial level rainfall and flood observations and forecasts were most useful to users. The majority (68%) replied that the local level was most useful See figure 5). This answer reflects also the percentage of respondents (32%) which worked for local authorities (and even regional and local authorities felt that local level observations and forecasts were most useful) (Figure 4) as well as the large numbers that stated that they work with these tools in climate adaptation, flood management, water and sewage management and risk and vulnerability plans (see table 7), which are generally tasks for local authorities. No respondent replied that the pan-European level was most important for their work. As respondents could only choose one answer to this question, it does not mean that observations and forecasts on other levels are unimportant. They can be essential complements to local level observations and forecasts.

Figure 5: Responses to question 4: On which spatial level are rainfall and flood observations and forecasts most useful for you?



5.1.3 Temporal stage with greatest need for more guidance or information

One of the basic aspects of the MUFFIN project is to think about observations and forecasts and the need for more knowledge, in three different temporal stages: Before, during and after the flood. This we asked respondents to specify which stage they had a need for more guidance. With the exception of Finland, respondents had the greatest needs before and after the flood. In Sweden, forecasts before the flood were most in need and in Finland, Denmark and the Netherlands data to be used in reconstruction of events was also seen as an area where more guidance and tools was needed. Table 7 below shows that results specified by country.

Table 7: Need for more guidance in stages per country

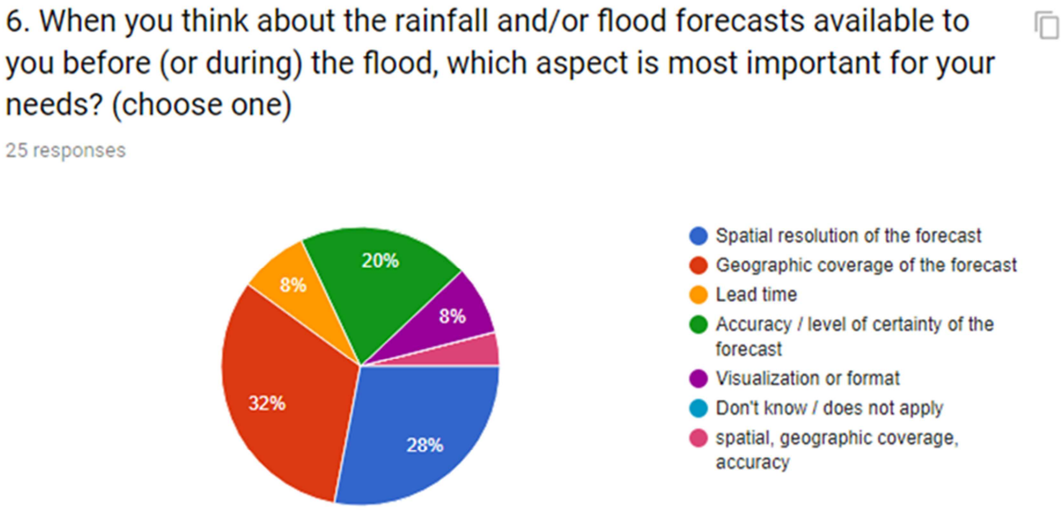
Q5: In which of the following stages do you have the greatest need for more guidance or information tools? (choose 1)					
	Total (%)	Number of responses per country			
		SE	FI	DK	NL
Before	52%	11	0	1	1
During	8%	0	2	0	0
After	32%	1	3	2	2
Don't know	4%	0	0	1	0
All three	4%	1	0	0	0
Total		13	5	4	3

5.1.4 Aspects of information that are most important at each temporal stage

Our assumption was that different aspects of information would be seen as most important at the various temporal stages of a (potential) flooding event. Questions 6,7 and 8 sought to find out which types of knowledge were most important.

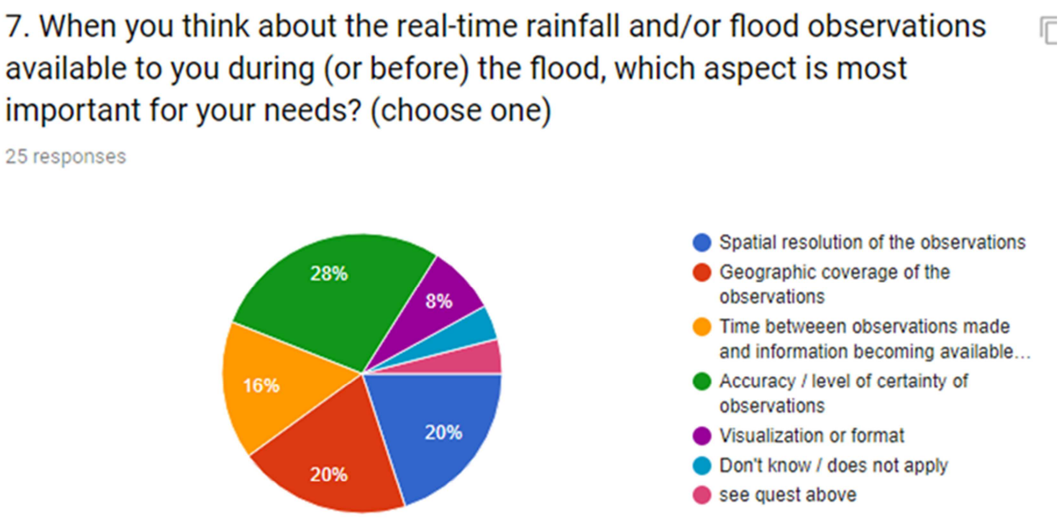
In Question 6 we asked respondents to think about the rainfall and/or flood forecasts available to them before (or in some cases during) the flood and to specify which was more important for their needs. Respondents were able to choose only one answer. See figure 6 below. Answers indicated that before the flood end users felt that rainfall and/or flood forecasts with good spatial resolution (28%) and good geographic coverage (32%) were most important for their needs.

Figure 6: Percentage of respondents who specified their data needs before the flood



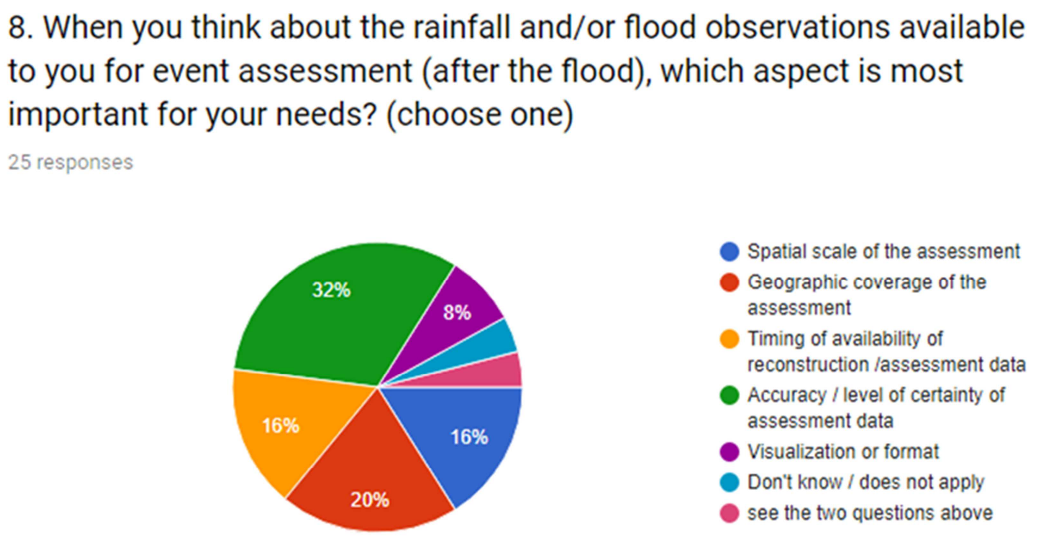
In Question 7 we asked respondents to think about the rainfall and/or flood forecasts available to them during (or in some cases before) the flood and to specify which was more important for their needs. Respondents were able to choose only one answer. See figure 7 below. During this phase, the accuracy of the observations became more important for respondents, although spatial resolution of the observations, their geographic coverage and the time between the observations made and the information becoming available were also deemed important

Figure 7: Percentage of respondents who specified their data needs during the flood



In Question 8 we asked respondents to think about the rainfall and/or flood observations available to them for event assessment (after the flood) and to specify which was more important for their needs. Respondents were able to choose only one answer. See figure 8 below. The responses were very similar to those responses to the question “during the flood”, although after the flood respondents had even more need for accuracy in their assessments.

Figure 8: Percentage of respondents who specified their data needs after the flood



5.1.5 Limitations and room for improvement in observations and forecasts

It was important for the MUFFIN team to understand the limitations in the current observations and forecasts and to learn how these could be make more useful from the end-user perspective. Question 9 asked respondents to specify which limitations they experienced in rainfall observations and/or flood forecasts from a pre-set list. Respondents were able to choose that applied. We then categorized these answers by the number of respondents who specified during which stage there was the greatest need for data (cross-referenced with table 7 above). Table 8 below shows the total number of answers for each limitation as percentage as well as the number of total answer in which stage. Over two-thirds of responds felt that the large degree of uncertainty in the models and data were a limitation and perhaps this limitation was particularly mentioned in the stage *before* the flood. This presumably reflects the larger number of respondents who had need for more guidance during this stage. 40% of respondents felt the observations and forecasts were not sufficiently useful in terms of spatial resolution or scale, again mainly those that needed more information *before* the flood. 20% of respondents felt that even if they had a good forecast, there was not much that they could do with an improved forecasts.

Table 8: Data limitations cross-referenced with respondents' replies to data needs per stage

				Of which				
Q9: What limintations have you experienced in the use of rainfall and/or flood forecasts? Check all that apply	% of total	No. of answers	**Before**	**During**	**After**	**All**	**Don't know**
Not sufficiently useful in terms of spatial resolution/scale	40%	10	6	0	2	1	1
Not sufficiently useful in terms of geographic coverage	28%	7	3	1	2	1	0
Large degree of uncertainty	68%	17	10	1	4	1	1
Lack of availability of data/models	36%	9	5	0	3	1	0
Data / models difficult to interpret	24%	6	4	0	2	0	0
Data not harmonized with local data/information	28%	7	4	1	2	0	0
Need more competency in use them	28%	7	4	0	3	0	0
Even if I had a good forecast, not much I could do	20%	5	3	1	1	0	0
Not applicable	0%	0	0	0	0	0	0
Other							

In question 10 respondents were asked to elaborate on how data for flood forecasting and/or observations could better meet their needs. We then categorized the responses according to four categories: Spatial or geographic needs (S), timing or temporal needs (T), certainty or accuracy needs (C) and availability or communication/visualization needs. Table 9 shows these answers:

Table 9: Categorized answers to question 10: How could data for flood forecasting and/or observations better meet your needs? Please describe.

	Spatial/Geographic	**Timing/temporal**	**Certainty/Accuracy**	**Availability/communication**
Sweden	Possibility to break up forecasts in watershed format	Municipalities need info as early as possible, even uncertain forecasts	Better meteorological predictions	Better availability
	Hydro-morphologic models in all rivers and major streams	Earlier (and more certain)(forecasts of cloudburst events	More reliable data- to be able to take sufficient actions	
	Coverage of all areas, not just larger rivers	Short time intervals 10-15 min) in observations	Higher degree of certainty and higher resolution	
	More meteorological stations in mountains and remote areas. Better resolution (precip. and temp)	Duration and size of precipitation		

	Higher level of spatial resolution (and accuracy)			
Denmark	Temporal and spatial resolution	Lead time and accuracy of forecasts,	Important that forecast models can deliver a reasonably certain forecast in time and space and that we have the necessary tools and possibilities to act on or interpret the forecast	More data for model comparison and calibration
		Longer lead-time, better accuracy and better spatio-temporal resolution and lower runtime for models		
Finland		To have at least a short time forecast of the rainfall amount to predict flood event		Easier access to data
				Interpretation of model results needs real time data as back-up…availability in visualized format
Netherlands		By making combinations of Rotterdam rain radar data and the places where flooding occurs quickly		Better integration within used systems. Help to transfer knowledge and information of different data sources
				I need one platform in which you can combine relevant data

Several answers pointed out the integrated nature of the need for several aspects of knowledge/data. See the text boxes below:

From Denmark: “One of the main challenges are lead-time and accuracy of the forecast. We use data for a range of tasks and the needs differ from one task to another. In some applications both the spatial and temporal resolution are of great importance, whereas in other applications such as the RTC of the drainage system, also lead-time and run-time are important”

From Finland: “Rainfall and snow information are the most important parameters I use for flood forecasting. Models are using same information but the accuracy of forecasts is not always sufficient. So interpretation of model results needs real time data as a backup to understand what is really happening and in what extent you can really trust the models. Rainfall and water content of snow and during the melting season also aerial snow coverage should be available in visualized format. The best option would be that an expert can make these images whenever it is needed”.

5.1.6 Needs for visualization

The final substantive question of the survey asked respondents to specify how they would like to see rainfall and flood forecasts and observations visualized and communicated. Respondents could check all that applied.

Table 10 below show the total percentage of responses for each visualization options, as well as the number of answers for each country. GIS formats and web-based visualizations stood out as the strong formats among respondents.

Table 10: Visualization needs

Question 11: How would you like to see rainfall and flood observations and forecasts be visualized and communicatied?	**Total %**	Number of answers per country				
		SE	**FI**	**DK**	**NL**	Total
GIS- compatible formats	72%	9	5	2	2	18
Table formats	32%	5	2	1	0	8
Web-bsed visualisations	80%	11	2	4	3	20
Internet-based search services, e.g using constant or stochastic rainfall	24%	3	0	1	2	6
On-line analysis of observations	36%	4	2	1	2	9
Probabilistic ensemble-based visualizations	28%	5	1	1	0	7
Photo/webcam documentation	24%	2	2	0	2	6
Aerial images	36%	5	2	1	1	9
Not applicable	0%	0	0	0	0	0

5.2 Summary and analysis of the MUFFIN on-line survey

As the number of respondents was fairly low, it is hard to draw many quantifiable conclusions of the survey, particularly when examining each question and response individually. However by cross-referencing answers we are able to make some interesting observations about how the MUFFIN results could be used, how they might be able to fill the existing gaps for observations and forecasts and how they can better meet end-user needs.

- Respondents used rainfall and flood observations/forecasts in a wide number of areas, mainly those related to local and urban planning, such as climate adaptation, flood management, stormwater, water & sewage management and risk and vulnerability plans.

- The majority of respondents replied that local level observations and forecasts were most useful. Although no responded replied that the pan-European level was most important for their work, they implied that this level can complement to local level observations and forecasts.

- Half of the respondents specified the local level as that where they were in need of more guidance. They felt the need for more guidance mainly before and after the flood. Before the flood end users felt that rainfall and/or flood forecasts with good spatial resolution and good geographic coverage were most important for their needs.

- During the flood and particularly after the flood, the accuracy of the observations became more important for respondents, although spatial resolution of the observations, their geographic coverage and the time between the observations made and the information becoming available were also deemed important.

- Limitations experienced in the use of rainfall forecasts and/or flood observation data mainly centred on the large degree of uncertainty in the forecasts and observations, followed by the insufficient spatial resolution and scale and by a lack of availability of data/models.

- Replying to how knowledge and data could better meet their, Sweden specified wider geographic coverage and coverage in watershed format, earlier predictions and a higher degree of certainty. Denmark specified better temporal and spatial resolution and more data for model comparison. Finland specified easier access to data and help to interpret results. The Netherlands specified better integration within used systems, transfer of knowledge and platforms for knowledge integration. The need for more integrated knowledge was also specified among respondents in all countries.

- GIS formats and web-based visualizations stood out as the desired visualization/communication formats among respondents.

6 TELEPHONE INTERVIEWS WITH END-USERS

To complement the data on needs derived from the workshop and the on-line survey, we performed interviews with stakeholders in Sweden, Denmark and Finland (an interview with a stakeholder in the Netherlands will be forthcoming). The purpose of the interviews was to give different types of end-users the possibility to elaborate more on how they might use the MUFFIN results and how what MUFFIN could do to help meet their needs for urban flood forecasting and larger-scale hydrological modelling. Each MUFFIN partner suggested one interview person and the semi-structured interviews were performed by SGI during December 2017-February 2018.

6.1 Interviewees and interview format

Interviewees were:

- Leen Sänkiaho, Development Engineer , Helsinki Regional Environmental Services Authority (HSY) representing local/ regional end-users

- Niels Aagaard Jensen, EnviDan, representing a private company working with water issues and cooperating with Aalborg municipality
- Ida Andersson, Civil Security Coordinator in Arvika Municipality, representing a local end-user

The questions discussed in the interviews were very similar to those posed in the workshop and in the on-line survey, but the informal and semi-structured nature gave respondents an opportunity to elaborate in more depth. These questions included the following:

1. How do you currently use rainfall and flood observations and forecasts in your work?
2. In which spatial level is are rainfall and flood observations and forecasts most useful for you
3. In which stage do you have the greatest need for more guidance or information tools? Before, during or after the flood? What types of knowledge are most important for you needs in each stage?
4. Which limitations have you experienced in the use of rainfall and flood forecasts?
5. How could data for flood forecasting and/or observations better meet your needs?
6. How would you like to see rainfall and flood observations and forecasts be visualized and communicated?

6.2 Interview results

6.2.1 Working with flood data temporally and spatially

Each of the three end-users worked with rainfall and flood data at different stages.

As responsible for working with Arvika’s risk and vulnerability analysis, Ida Andersson felt that data on extreme precipitation was most important *before* the flood in order to plan for flooding and to prevent the potential socio-economic consequences of a flood. To do this data on *different levels* is necessary, she remarked.

As responsible for the network capacity development of the sewer, wastewater and storm water network Leena Sänkiaho felt that flood data was most important for her work *during* the flood in order to see how a cloudburst is moving, although radar data is quite uncertain. Specifically *local level* data was important to her in order to see the storm patterns, but also even more detailed data at the network level would be interesting for her.

As Niels Aagaard Jensen has worked with urban drainage modelling, the most important information would be that that comes *after* the flood in order to analyze what went wrong. Specifically data at the *local level* is important for EnviDan, although forecasts on *larger spatial scales* might be interesting to combine with local scales.

6.2.2 Gaps in current forecasts/observations and end-user needs

Each respondent also pointed out gaps in the current knowledge base and their needs for further knowledge. Ida Andersson in Arvika would have need of cloudburst and hydrological models linked to more *specific regional specificities* and the probability of extreme rainfall on a smaller geographic scale, since the rain does not fall evenly over the entire municipality.

Leen Sänkiaho was satisfied with the resolution of real-time data rainfall data received, but the *accuracy of their network models* is poor compared to the rainfall data. Using the SWMM modelling programme they can either have a detailed network model with every pipe shown or a branch model with only around 10% of the biggest pipes shown. *Tools for faster aggregation* would be useful.

Niels Aagaard Jensen, felt that the current stage of hydrological forecasts did not provide sufficient results due to *lack of certainty and accuracy* and with inadequate forecast quality there are limited possibilities to perform meaningful real time control. Thus better tools for *higher accuracy within hydrological forecasting* are needed.

6.2.3 Visualizing and communicating forecasts and observations

Regarding how data for rainfall and flood forecasting and observations could be better communicated, Ida Andersson pointed out the need to *show certainty and uncertainty of the forecasts* in a way that could be used more easily, perhaps written in words rather than statistics.

Leena Sänkiaho replied that it would be nice to have f*looding data from users, through citizen observations* and in the form of photos to reduce potential subjectivity.

Niels Aagaard Jensen specified that it would be an advantage to have *direct data flows (forecasts) that can be used in models and/or real time control systems for specific needs*. But this data must be high quality, otherwise it doesn’t provide any value for the end-user.

6.2.4 End-users’ thoughts on the MUFFIN project and what it can deliver

Ida Andersson from Arvika was not asked specifically about the MUFFIN project, but was interested in more help to calculate probability of combined risks and the consequences of the risks. Rather than have a guidance paper, she mentioned that it would be nice to be able to ring directly to the authorities with specific questions for their specific conditions.

Leena Sänkiaho from HSY was interested if MUFFIN could help answer her problem which part of the rainfall-runoff- network modelling was most inaccurate during model folding. Even if she had more detailed rainfall data, the problem is that the network data is still rather unreliable so more accurate and detailed rainfall data might not make so much difference. Leena Sänkiaho also participated in the MUFFIN Workshop and felt that the MUFFIN way of looking at flooding (before, during and after the flood) was a real eye-opener.

Niels Aagaard Jensen from EnviDan felt that MUFFIN was very ambitious, but like most research projects, cannot solve all the problems in Aalborg, although the small steps achieved by the project can drive technology forward. Better tools with higher accuracy within hydrological forecasting are needed, but not all tools are useful. It is difficult to specify which tools are needed before hand, “but if a good tool exists for rainfall and flooding forecasts, we will find a way to use it”.

6.3 Conclusions from the interviews

The interviews with the different potential types of end-users reified the results of the MUFFIN Workshop and the on-line survey. There is not just one type of end-user, rather they all have very specific problems and needs, so there are no one-size-fits all solutions. The MUFFIN project is geared towards helping to meet the specific needs of the end-users in Aalborg, Helsinki and Rotterdam so there are good possibilities that the results can be of at least some direct benefit.

The interviews also mentioned that although local level forecasts and observations geared specifically to local specificities and conditions are most important, there is also scope to integrate data at larger scales to complement local level data.

An observation that came out of the interviews was that the rainfall forecasts and flooding observations are only part of the problem for those working with flood plans for a city, for instance. Although specific and accurate data is needed at a good resolution, there are also needs that MUFFIN can’t take up, such as where the stormwater pipes are leaking, or what the consequence of a flood are. Still end-users appreciated the efforts of MUFFIN and felt that the project can provide societal benefit.

7 CONCLUSIONS FROM THE END-USER SPECIFICATION

Using the triangulation method, we sought specify the end-user needs with a three-pronged approach based on a Workshop, an on-line survey and semi-structured interviews. As seen in the sections above, this implied a mixture of qualitative (workshop and interviews) and quantitative methods and results.

In general end-users and even stakeholders were extremely helpful in spending their time to attend the workshop, perform the on-line survey and engage in the telephone interviews. Perhaps because MUFFIN involves specific end-users in the case studies and joint experiments, this provided an incentive to participate in the end-user specification activities.

As the previous sections have pointed out, all end-users are have different needs and conditions. End-users working within a municipality (or the consultants that provide plans) with stormwater, or sewage water or flood plans need data that is specific to their areas. National and sometimes regional end users, as well as academics are also interested in data on a larger scale and data that can be used for reconstruction of events. There is no one-size-fits all solution. However below are some general conclusions about end-user specifications that can be made from this three-pronged exercise:

- Local level forecasts and observations geared specifically to local specificities and conditions are most important, but there is also scope to integrate data at larger scales to complement local level data.
- End-users require data, forecasts and observations of rainfall/flooding at a very local level or fine scale, which is most specific to their conditions, but also request on a larger scale such as large scale catchment areas. National stakeholders were interested in extended geographic coverage of smaller watercourses and non-urban areas
- The greatest need for more guidance and information tools on rainfall and flooding is during the stage, before the flood, followed by their use after the flood. But methods to integrate observations and reports during the flood are also important to develop.
- Accuracy and certainty of forecasts and observations appeared to take precedence over lead time or timing of observations/analysis becoming available, although end-users and stakeholders were reluctant to specify any trade-offs between accuracy and spatial resolution.
- Visualizations in GIS-formal and web-based visualizations at the different scales would be very useful for end-users. Communication of observations through citizen observations can an important complement to radar and rain gauge data to be further explored.
- MUFFIN is very ambitious, and the small steps achieved by the project can drive technology forward, even if it can't solve all problems in each case study area.
- Better tools with higher accuracy within meteorological and hydrological forecasting and modelling are needed, and if good tools exist for rainfall and flooding forecasts, end-users will find a way to use them.

Appendix 1 MUFFIN Workshop Agenda (long version for Partners)

16 February 2017

09.00-09.30 CET	Partners' test of video *Partners make sure to have one team member testing video and one to ready materials and greet participants*
09.30-10.00 CET	Coffee and registration
10.00-10.45 CET	Plenary: MUFFIN objectives and Brief (5 min) Work Package presentations Lisa is main moderator for morning plenary sessions (after Jonas welcomes everyone); Jonas and Anna take notes 10.00-10.10: Brief intro of all participants (Name and affiliation) 10.10-10.25: SMHI- MUFFIN objectives and multi-scale examples 10.25-10.30: TUD - Hydro-meteorological data 10.30-10.35: AAU- Urban flood forecasting 10.35-10.40: AALTO – Storm water management 10.40-10.45: SGI – End user value and workshop objectives *Partners send ppt slides (2 or 3) till Jonas/Lisa by Feb 27th, noon and we will put them into a single presentation for everyone*
	Block 1: Today's situation: End-user limitations and needs
10.45-11.10 CET	Locally: Today's situation: 2-3 participants present briefly (5-10 min): 1) How do you currently use flood simulation and forecast data in your work? 2) Which type of data do you use today? 3) What limitations have you experienced in this work? *Partners contact 2 or 3 participants beforehand and ask them to present their replies to these questions in the local workshop- suggest 1 slide per question. Other participants can comment and add experiences.*
11.10-12.00 CET	Local brainstorming: What are your current needs? (Template Block 1) 11.10-11.15: Consider template and questions individually 11.15-11.30: Discussion on data needs "Before the flood" 11.30-11.45: Discussion in data needs "During the flood" 11.45-12.00: Discussion on data needs "After the flood" Template filled in (paper, post-its or computer) in groups of 2 or 3 persons. *Partners think about preliminary groupings of participants and how they prefer to record and present the answers. Choose who will present in the plenary after lunch – either a project partner or preferably one of the participants*

12.00-13.00 CET	*Lunch*

	Block 2: "The perfect flood": What can MUFFIN contribute to the local cases?
13.00-13.40 CET	Plenary: Short wrap-up presentations from morning sessions from each city. Jonas is main moderator for afternoon plenary sessions; Lisa and Anna take notes 13.00-13.10: Norrköping 13.10-13.20: Delft 13.20-13.30: Espoo 13.30-13.40: Aalborg
13.40-14.40 CET	Local Brainstorming: How can MUFFIN contribute within each site? (Template Block 2) 13.40-14.00: Presentation from project partner about the case site 14.00-14.40. Discuss and fill in Template Block 2 (whiteboard, post-its , paper or computer) *Partners think about preliminary groupings of participants (can be the same or different from the morning session) and how they prefer to record and present the answers. Choose who will present at final plenary – either a project partner or preferably one of the participants.*
14.40-15.00 CET	Plenary: Reports from each group 14.40-14.45: Norrköping 14.45-14.50: Delft 14.50-14.55: Espoo 14.55-15.00: Aalborg
15.00-15.30 CET	Plenary: General discussion, summing up and next steps and coffee.
Post-workshop	*Partners translate relevant results of discussion and the filled in templates. Send to Lisa by March 7th.*

Template Block 1 Brainstorming: What are your current needs?

To be filled in group-wise (2 or 3 groups) on computer, whiteboard or paper with post-its.

1) How could the data available to you on rainfall forecasts and/or urban flood forecasts (before the flood) better meet your needs with regard to:
    a. Resolution
    b. Geographical coverage
    c. Lead time
    d. Accuracy/level of certainty
    e. Other

2) How could the data available to you for real-time observations (during the flood) better meet your needs with regard to:
    a. Resolution
    b. Geographical coverage
    c. Time between observations made and information becoming available
    d. Accuracy/level of certainty
    e. Other

3) How could the data available to you for event assessment (after the flood) better meet your needs with regard to:
    a. Resolution
    b. Geographical coverage
    c. Timing of provision of reconstruction/assessment data
    d. Accuracy/level of certainty
    e. Other

Template Block 2 Brainstorming: “The perfect flood” and MUFFIN contributions

Think about “the perfect flood” situation and how the MUFFIN could contribute to your local situation. The following are guidance questions and should be answered if relevant. Other questions may also come up and can be discussed.

- How far in advance would you like to get a reliable warning?
- How would you like to stay updated during the flood?
- What information would you need to analyse the system after the flood?
- What specifically would you like to see as an output of MUFFIN?
- In what format should the rainfall forecasts or flood forecasting be visualized?

Appendix 2 List of Participants

Multi-scale urban flood forecasting (MUFFIN): From local tailored systems to a pan-European service

Stakeholder Workshop: 28 February 2017 in Norrköping, Aalborg, Delft and Espoo

Participant list

The list is not attached due to GDPR. If you have any questions, please contact Jonas Olsson at SMHI (Jonas.olsson@smhi.se) or Lisa Van Well at SGI (lisa.van.well@swedgeo.se).

Appendix 3 MUFFIN On-line survey questions

Multi-scale Urban Flood Forecasting (MUFFIN)

MUFFIN User Survey Questionnaire (11 questions; estimated time: 10 minutes)

The Swedish Meteorological and Hydrological Institute (SMHI) together with partners from the Technical University of Delft (TUD), Aalborg University (AAU), Aalto University (AALTO) and the Swedish Geotechnical Institute (SGI) are cooperating in a study on Multi-scale Urban Flood Forecasting (MUFFIN).

The development of early warning systems and urban flood forecasting systems is crucial to the security and sustainability of cities. These systems differ with respect to e.g. temporal and spatial resolution, calculated variables and real-time applicability, and thus their value for various user categories also differs. The information required by and provided to stakeholders may be divided into three stages:

• Before the flood: forecasts of rainfall and the resulting impact on surface and sub-surface water fluxes for early warning (and real-time observations)

• During the flood: real-time observations of rainfall and water fluxes for situation awareness and emergency planning (and updated forecasts)

• After the flood: historical validated observations of rainfall and water fluxes for post-event analysis and evaluation

The MUFFIN project aims at improving the support for users with:

• Improved real-time observation by weather radar, improved forecasts by nowcasting and high-resolution meteorological ensemble forecasts,

• Improved simulation and forecasting of urban flooding;

• Innovative ways to post-process and tailor the information for improved visualization, awareness and communication with different end-users.

To ensure that the flood forecasting and observation meet the specific requirements of the relevant end-users, the MUFFIN project is gathering information on end-user needs in order to gain an understanding of how urban hydrological observations, simulations and forecasts are used today and where the gaps are.

We value your input. All answers will be treated confidentially.

Please feel free to comment (under "other") or answer questions that require written comments in your own language.

More information on the MUFFIN project can be found at: http://www.muffin-project.eu/

* Required

Email address *____

MUFFIN: Multi-scale Urban Flood Forecasting

1. In which country do you live/work? *

- o Denmark
- o Finland
- o The Netherlands
- o Sweden
- o Other:

2. What is your area of work? * (choose one)

- o Consultant/ private sector
- o Employed within a municipal organisation
- o Employed within regional organisation
- o Employed within a national organisation/authority
- o Research institute/university
- o Other:

3. In which areas do you currently (directly and indirectly) use rainfall and flood observations and forecasts in your work? Check all that apply *

- o Climate adaptation in general
- o Flood management
- o Storm water management
- o Water and sewage management
- o Geotechnical security issue
- o Risk and vulnerability plans
- o Emergency services
- o Urban planning
- o Research
- o I don't use flood simulation and forecast data
- o Other:

4. On which spatial level are rainfall and flood observations and forecasts most useful for you? (choose one) *

- Pan-European
- National
- Regional
- Local
- No opinion/does not apply
- Other:

5. In which of the following stages do you have the greatest need for more guidance or information tools? (choose one) *

- Before the flood (rainfall and flood forecasts)
- During the flood (real-time observations)
- After the flood (data/tools for event reconstruction, system performance assessment)
- Don’t know/ no opinion
- Other:

6. When you think about the rainfall and/or flood forecasts available to you before (or during) the flood, which aspect is most important for your needs? (choose one) *

- Spatial resolution of the forecast
- Geographic coverage of the forecast
- Lead time
- Accuracy / level of certainty of the forecast
- Visualization or format
- Don't know / does not apply
- Other:

7. When you think about the real-time rainfall and/or flood observations available to you during (or before) the flood, which aspect is most important for your needs? (choose one)*

- Spatial resolution of the observations
- Geographic coverage of the observations
- Time betweeen observations made and information becoming available to users
- Accuracy / level of certainty of observations
- Visualization or format
- Don't know / does not apply
- Other:

8. When you think about the rainfall and/or flood observations available to you for event assessment (after the flood), which aspect is most important for your needs? (choose one)*

- Spatial scale of the assessment
- Geographic coverage of the assessment
- Timing of availability of reconstruction /assessment data
- Accuracy / level of certainty of assessment data
- Visualization or format
- Don't know / does not apply
- Other:

9. What limitations have you experienced in the use of rainfall and/or flood forecasts? Check all that apply. *

- Data/models are not sufficiently useful in terms of spatial resolution/scale

- Data/models are not sufficiently useful in terms of geographic coverage
- Large degree of uncertaintly in the data/models
- Lack of availability of data/models
- Data/models are difficult to interpret
- Data not harmonized with local data/information
- My organization needs more competency/training in order to better use the models/data
- Even if I had a good forecast, there is not much I could do
- Not applicable
- Other:

10. How could data for flood forecasting and/or observations better meet your needs? Please describe*.

____
____

11. How would you most like to see rainfall and flood observations and forecasts be visualized and communicated? Check all that apply. *

- GIS-compatible formats
- Table formats
- Web-based visualizations
- Internet-based search services, e.g. using constant or stochastic rainfall
- On-line analysis of observations
- Probabilistic ensemble-based visualizations
- Photo/webcam documentation
- Aerial images
- Not applicable
- Other:

Any other comments?

____
____
____
____
____

Thank you for your time.

Appendix 4 How MUFFIN has met the end-user specifications

To ascertain how MUFFIN has addressed the most important end-user requirements and needs, we have divided up the needs into general goals, needs before the flood, needs during the flood, needs after the flood and case-specific needs and briefly listed what MUFFIN can provide.

The MUFFIN advisory group, consisting of one representative from each of the four countries, and a mix of researchers, water authorities and regional and national authorities, was present during most of the project meetings. The group provided active input and quality assurance into how the project results could respond to the needs of both practitioners and academics.

To further specify the end-user value, SGI used a three-prong or triangulation method to understand the needs and requirements of the MUFFIN end-users. After drawing up a list of the relevant stakeholders and end-users in Sweden, Denmark, Finland and the Netherlands, these three methods consisted of 1) an international video Workshop in February of 2017, 2) an End-user survey administered in December 2017 and 3) in-depth telephone interviews with end-users in November 2017- February 2018.

The final conference CITIES, RAIN and RISK provided an opportunity to bring together both end-users and advisory board members involved in the project, as well as potential new end-users and stakeholders. Local and regional stakeholders were also involved in each of the case studies and joint experiments.

End-users are had differing needs and conditions. The project team relied on end-user involvement to help understand how they currently used rainfall and flood observations and forecasts in their work, and which limitations they experienced in using these. Information was also gathered on which spatial levels data was were most useful. Unsurprisingly, local end-users were most interested in rainfall and flood observation and forecasts at a local level, while researchers tended to find the pan-European level forecasts interesting. MUFFIN could not provide a one-size-fits all solution to the problems of urban flooding, but stakeholder and end-user engagement provided added value to the project, by helping to ensure that project results fit the specific needs of the case study areas and could add value to helping communities deal with the risks of flooding and extreme precipitation.

Three Joint Experiments were designed in the MUFFIN project, with the aim to take end-users' needs into account as far as possible:

1. Hydrodynamic vs. high-resolution hydrological modelling
2. High-intensity rainfall in European operational radar observations
3. Development of a multi-scale flood forecasting system

In Sections 1-5 below, the experiments are abbreviated JE1, JE2 and JE3.

1. General goals

General goals	What MUFFIN Provides
Early warning systems and urban flood forecasting systems	JE1, JE3, Development of nowcasting (AAU and AALTO), Rainvis tool (SGI/SMHI).
Bridge the gap between urban and large-scale hydrological modelling communities	Partly, this was the aim with JE1. Which did not fully succeed, but JE3 may do better. Catchment/watershed spatial level is the most important, although forecasts at the pan-European level are also important as complements to local level data (JE3).
Develop innovative tools for reducing urban impacts of extreme precipitation	Rainvis and JE3, as well as local developments in case studies (e.g. Micro Rain Radar at TUD and combined radar at AAU).
More general knowledge about urban flooding	JE1: that the hydrologic model HYPE doesn't seem to give clear added value compared to only rain indata. JE2: that the accuracy operational radar products with respect to describing extreme rainfall is dependent on temporal and spatial scale. JE3: that a hydraulic forecast model can have distinct added value when it is linked to continual hydrological models. Discussion (in final report) about how there is no "one-size-fits-all" solution and that all users and end-users have different need. MUFFIN cannot satisfy all of these.
Explore the added value of resolution and lead time in terms of accuracy and uncertainty	All three experiments, also link uncertainty to return times "How unusual is the rain that is expected?", as done in Rainvis.
Preference for observations and forecasts to be visualized and communicated in web-based formats and GIS-compatible formats	Rainvis and JE 3
Guidance papers on how forecasts and monitoring can be used by various actors and how uncertainty can be interpreted within the forecasts and monitoring	Partly within the Rainvis prototype but more focus on best practices in dealing with uncertainty would have been desireable.
Consider an evaluation of how project results were utilized by end-users	Not within the scope of the project, but will be done in connection with information gathering for a peer-reviewed article by SGI during autumn 2019.
Comparing how cases work to bridge the gap between urban and large scale hydrological models and tools for reducing the impacts of precipitation	All Joint Experiments.

2. Data needs before the flood

Data needs before the flood	What MUFFIN Provides
Higher resolution (SE)	Use of 1h-HYPE and higher spatial resolution.
Better resolution linked to certainty (SE and Aalborg)	High resolution is good, but the added value can be false as observations/models do not have the precision – partly included within JE3.
Updated data on elevation for models (SE)	Has not provided this but can be found in the INXCES project which measures elevation via satellite.
Coordination of classification of warnings among authorities (SE), clear definition of responsibilities (FI)	Not within the scope of MUFFIN.
Info on intensity and duration of precipitation (SE)	Being developed within the Rainvis rainfall visualisation tool prototype*
Clear maps on various scenarios and type of rain	Partly included within JE3, but needs to be further developed outside of MUFFIN
Improved resolution and accuracy of HARMONIE (Rotterdam)	More high resolution meteorological forecasts (Note HYPE).
Better coupling of high resolution rainfall observation forecasts with 3Di hydrology-sewer ground water model (Rotterdam)	This could not be attained due to delay in the 3Di modelling.
Better model-specific data input resolution (Aalto)	In report (HYPE(MIKE/SWMM).
Coverage and (v. Not just larger riversisualization) per catchment/ and or watershed (SE, Aalto and Aalborg)	In Rainvis visualisation tool prototype.
Design rainfalls and search services (Aalto)	MUFFIN hasn't worked with design rain, but refers to the coupled SPEX project.
Preparedness on multi-levels (Aalto)	The multi-scale forecasting prototype developed in JE3 is an effort in this direcation.
More specific use of forecasts and how they can be used for warnings (Aalborg)	The use of rainfall threshold for urban flood warning has been explored in JE1 and locally at TUD (citizen reports). Optimizing how warnings are given is a post-MUFFIN task

*Prototype of a visualization tool, available at: http://hypewebapp.smhi.se/skyfall/

3. Data needs during the flood

Data needs during the flood	What MUFFIN Provides
Info on rain duration (requiring forecast) "When will the rain stop?" (SE)	Rainvis visualization tool prototype
Take soil moisture into account (SE)	This is considered in JE3.
Better resolution in time and space (SE)	In HYPE and by linking HYPE with MIKE (JE3).
Observations linked to forecasts	Report from Rotterdam and work with private weather stations. Also a feature of the Rainvis prototype.
Waterboards interested in making better use of available data (Rotterdam)	Not within the scope of the project, but possible follow up on how Rotterdam City works with this.
Merging of radar and rain gauges (Aalto)	Investigated in JE2.
High resolution (on-line) oxygen measurement (Aalborg)	Outside the scope of MUFFIN.
Photo documentation/web-cam of floods, real-time observations from general public (Aalto)	TUD describes in final report, climate scan events. Further developments within the INXCES project

4. Data needs after the flood

Data needs after the flood	What MUFFIN Provides
Visualise how data collected during an event can be used in the models to reproduce events (SE)	MUFFIN can describe this
Better access to distribution data for re-search "Where does the rain go?" (SE)	Within the Rainvis visualisation tool prototype.
Spatial resolution rainfall products at 100m and 1 minute, to capture storm dynamics (Rotterdam)	Could not be reached in MUFFIN, mainly be-cause of technical problems.
Map-based visualizations, probabilistic en-semble based visualizations (Aalto),	Partly within Rainvis Visualisation tool proto-type and JE3.
Detailed information on which locations need special attention (Aalto)	Complement the cloudburst mapping with field studies when it is raining (levels, flows photo info). Outside the scope of MUFFIN but included in e.g. the INXCES project.
More data at catchment scale (E-radar and rain gauge data?)	Rainvis and local devlopment.
Observations of stream water bed erosion	Outside the scope of MUFFIN.

5. Case specific requests

Specific requests	What MUFFIN Provides
Better land use data to add value (Aalto /ESPOO)	SWMM and HYPE use of the Urban Atlas data.
Better understanding of which parts of the rainfall run-off network modelling was most in/accurate (FI)	To some extent included in JE3, allowing for separation between different water fluxes into and inside the urban basin.
Better tools with higher accuracy within hydrological forecasting (DK)	Rainvis and models linked to JE3, examples from local development at AAU, Aalto and TUD.

6. Final observations from the end-user specification:

End-users are had differing needs and conditions and thus MUFFIN cannot provide a one-size-fits all solution to the problems of urban flooding. However are some general conclusions about end-user specifications that can be made from this three-pronged exercise:

• Local level forecasts and observations geared specifically to local specificities and conditions are most important, but there is also scope to integrate data at larger scales to complement local level data.

• End-users require data, forecasts and observations of rainfall/flooding at a very local level or fine scale, which is most specific to their conditions, but also request on a larger scale such as large scale catchment areas. National stakeholders were interested in extended geographic coverage of smaller watercourses and non-urban areas

• The greatest need for more guidance and information tools on rainfall and flooding is during the stage, before the flood, followed by their use after the flood. But methods to integrate observations and reports during the flood are also important to develop.

• Accuracy and certainty of forecasts and observations appeared to take precedence over lead time or timing of observations/analysis becoming available, although end-users and stakeholders were reluctant to specify any trade-offs between accuracy and spatial resolution.

• Visualizations in GIS-formal and web-based visualizations at the different scales would be very useful for end-users. Communication of observations through citizen observations can an important complement to radar and rain gauge data to be further explored.

• MUFFIN is very ambitious, and the small steps achieved by the project can drive technology forward, even if it can't solve all problems in each case study area.

• Better tools with higher accuracy within meteorological and hydrological forecasting and modelling are needed, and if good tools exist for rainfall and flooding forecasts, end-users will find a way to use them. MUFFIN has attempted to provide this to end-users, as far as possible within the limits of the project.