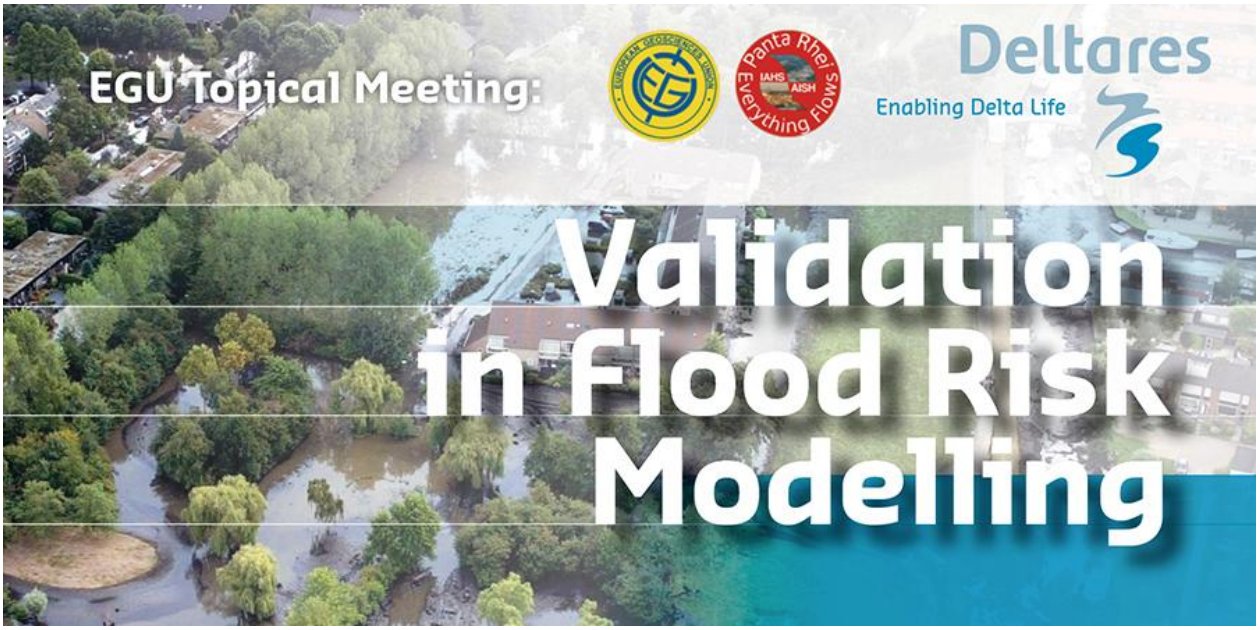

Summary Report

On 9 and 10 December, 2014, an expert workshop was held in Delft, The Netherlands, to discuss the often-neglected topic of flood risk model validation. This meeting was held under the auspices of the European Geosciences Union (EGU), and the Panta Rhei Working Group "Changes in Flood Risk" of the International Association of Hydrological Sciences (IAHS). Over 50 experts from 10 countries covered all the elements of flood risk analysis: (1) hazard and inundation modelling, (2) failure and reliability modelling of flood defences, (3) flood consequence modelling, and (4) the know-how to integrate hazards, failures, and consequences to compute risk.

The workshop was organized in four sessions, covering the four elements outlined above, with a half-day allotted to each session. The sessions began with some short presentations, after which participants split into four groups of about 10 people each, to discuss in-depth the aspects of validation that were relevant for the current topic. Driving questions for these discussion groups were:

- Why do we need validation?
- What techniques for validation are available?
- What is the quality of our flood risk estimates?
- How large is the uncertainty of the risk component (hazard, failure, impact) in relation to the total accuracy?

The most important general conclusions from this workshop are:

- Validation is a good practice in flood risk research, in order to demonstrate the predictive quality of our models, and assess whether we need further improvement
- The development of a platform to share data for flood risk model validation (for all the four components) is highly desired.
- Collection of data on hazard, failure and impacts after events should be promoted, standardized and become common practice.
- Bechmarks for the set-up of hazard, failure and impact analysis should be proposed.

- On the relative importance of the three elements: The uncertainty of hazard/hydraulic models is smaller than those in models for flood defence reliability, breach, and impacts. Still, for certain applications – such as preparing evacuation plans – accuracy of hazard/hydraulics can be critical. Many held the opinion that failure models are the weakest part, as it can have a substantial impact on the risk estimate, but is so highly uncertain.

This report summarizes the main findings from the workshop, which came largely out of the fruitful discussion sessions on hazard modelling, failure modelling, flood damage assessment and integration. Finally it summarizes the main conclusions and proposed next steps of the closing session of the meeting.

Hazard modelling

The complexity of hazard models is partially driven by the resolution of the available input data, partially by the needs of the analysis, and partially by the need to set the model in a probabilistic framework. Running simple hydraulic/inundation models within a probabilistic framework can outweigh the benefits of more complex modelling. The choice likely depends on the problem and purpose of the study at hand. It was uniformly agreed that the complexity of a model should not exceed the resolution of the available data. Also, the type of analysis influences the optimal complexity of the hydraulic model.

To validate inundation models, we need records of flow speeds and water levels following actual inundation events. Opportunities exist to better collect and organize such event data. These included: crowd sourcing (GPS tracks on smartphones), satellite data (flooded area, waves), drones/local airplanes, high water marks, interviews with inhabitants, and security camera footage. Also, the sharing of data between partners and countries increases the possibilities for validation.

For validation in the absence of data, common sense can be used as a yardstick. For instance discussing model results with experts (including those who know the system well) is critical, as they can spot peculiarities or inconsistencies in model results. Ideas for obtaining topographical and bathymetry data for data-scarce areas were also discussed. These included motorcycles fitted with GPS devices, drones which collect LIDAR data, and GPS field work.

Failure modelling

Failure modelling as we considered it in this workshop, includes the physical modelling of a failure mechanism (e.g. erosion or under-seepage), computing the probability that such a mechanism initiates, and the modelling of breach growth once the mechanism has taken place. It was noted that the process from *initiation* of a mechanism to the point where a breach begins to form is largely ignored. That is, the probability of 'failure' is often considered to be the probability of initiation of a failure mechanism. In reality, the mechanism may initiate and not complete, making the flood risk estimates conservative.

Input data for modelling the failure of levees and dunes is generally lacking. Even the simplest of data to collect – dike/levee crest heights – are generally not centrally collected and stored, making them inaccessible (if they are measured at all). But levee failures also depend heavily on soil properties, and in general these are difficult to obtain, and are highly heterogeneous.

A range of model complexities exist for modelling failure mechanisms, from empirical formulas to 3D physically-based finite element models (which can take minutes to hours to compute). Computing the probabilities that failure mechanisms occur can be done with a range of probabilistic methods when failure models (and the model input data) are available (given that they are not too time-consuming to run), or with expert opinion when data/models are lacking.

Because of the scarcity of observations, validating failure models, failure probabilities, and breach growth is a serious challenge. One of the best opportunities we have numerically is to compare our simple models with more complex physically-based models. A rare opportunity has arisen in the Netherlands where a real (long-standing) levee system will be subjected to great loads and allowed to fail (the protected area is being intentionally flooded), allowing us to test both failure and breach models.

Impact models

Models that simulate vulnerability of people and infrastructure, including damages and loss-of-life models possibly have the largest uncertainties. Validation of impact models is rarely performed, but validation and testing is needed, to determine whether the models are applicable in the region of interest. Damage models, in the entire chain of flood risk analysis have probably also the largest potential for improvement. As with failure models, it may be possible to use detailed models to inform more simple models.

Different impact models have been developed for different scales and detail levels. The purpose of the flood risk study in terms of scale and detail (loss categories), as well as the data availability, determine the right approach. In addition, the hazard characteristics for which data is available, or that can be modeled need to be taken into account.Damage models are specific for the region (and flood event) for which they were developed, particularly due to specific building characteristics, but also due to specific precaution, different insurance systems, protection standards and flood characteristics. A key concerns is therefore the transfer of flood impact models in time and space. Most impact models focus on the direct economic losses from floods. Loss of life estimation is not generally taken up all around Europe. Also, indirect damages are often neglected, but are very important, or even of overriding importance, such as in the Thailand and the Somerset floods. Yet, validating models for indirect damages is challenging, due to the lack of observational data on indirect losses and the relevance of case-specific circumstances. Finally, compound events (e.g. earthquake and tsunami, or flood and wind) are usually the most costly, and have a high interest from insurance companies. Good models to simulate these are however often lacking.

One of the weakest points in impact modelling is that the relation between impact and hazard is often depending on other factors as well. This is particularly the case for pluvial flooding. For this reason, researchers have resorted to methods that include more explanatory variables, related to exposure and object characteristics, using decision tree approaches, and Bayesian approaches. These probabilistic, multi-parameter models are the way forward for improving the relations between flood hazard, exposure characteristics and damages. However, these require extensive data sets. Also, the more specific the model becomes, the more difficult it is to transfer the exact configuration.

More coordinated efforts could be made to collect and share high quality data on exposure and flood damage for analysing damaging processes, through standardized data collection campaigns, developing damage models and validating damage models. In many cases, telephone interviews are held to investigate damages. It makes sense to harmonize questionnaires, in order to make wider use of the results possible, of these data which is labour-intensive to collect. Other possibilities are crowd sourcing (e.g. apps by insurers where people can give information) or volunteered information approaches, i.e. polls with affected people, data collection via dedicated web-sites, analysing information from social networks. Finally, physical experiments could be undertaken to analyse flood damaging processes.

Integration to flood risks

In many studies, the components flood hazard, failure, and impacts are not studied separately. Often, all three elements are present, but included in different detail. This so-called integration of the three components is often the final basis for arriving at recommendations for flood risk mitigation.

There are no direct data available to validate risks. However, risks outcomes should be validated by comparing them with common sense and try to falsify them, comparing them with historic events and with risk outcomes of other studies for the same area, or with risk calculations for similar areas. Experts could try to judge whether such numbers seem plausible.

Comparing risk calculations, or benchmarking of different approaches and methods will also provide information on uncertainties and accuracies of the risk estimates, even if it is not clear which (set of) method(s) is better. It also may support insight in the required detail to gain accurate results.

There are many approaches which differ in complexity , in particular with regard to the component that is simplified (i.e. hazard, failure, impact) and which one is considered in more detail. These differences comply with the different aims for which the flood risk calculations are done.

The required model complexity depends on the users of the risk information, the complexity of the area, available data and models and the available time and budget. It is recommended to test simple approaches by using a more detailed model and comparing outcomes of the risk chain for a few events. The simple approach could then be used in a risk framework, e.g. in a Monte Carlo approach.

Benchmark cases could be set up, where the different methods can be applied to, to develop a grand comparison, and to understand which aspects drive differences in the final results.

The way forward and next steps for validation

In the final plenary session the following next steps were discussed:

- Among the meeting participants there was agreement to develop a workshop report, summarising key outcomes, including best practice examples and questions/goals for research.
- There was interest to develop an overview of institutes and people that collect or have access to observations or empirical data. On the basis of the current meeting, input for an overview list will be requested from all participants. The list will be made available in some form, through the Internet via the workshop website for instance.

- The group could consider to further develop benchmarking for flood risk modelling, based on existing proposals for risk analysis benchmarks. This could commence with the collection of existing techniques and standards
- A specific topic is data collection for flood risk models, and practices from recent projects on new data collection techniques and crowd-sourcing. Developing best practice techniques could be a community effort.
- Further substantial activities of this group will probably require a project, perhaps funded by the European Union (e.g. the H2020 programme).
- A next meeting on the topic of flood risk model validation could possibly be held as a session at the EGU General Assembly in 2016. Also, another institute could host a second workshop with this group and others.
- It was proposed that from the meeting report a journal paper could be developed that summarised the main workshop results and delivering some key research questions.
- A final thanks was given to all presenters, participants, moderators and rapporteurs.

Meeting photos

Meeting Agenda

Tuesday 9 December, 2014 (Deltares, Pavilion 1-3, Boussinesqweg 1, Delft)

08:00 - 09:00	**Registration and Coffee**
09:00 - 10:00	**Opening Session**
09:00 - 09:30	**Jaap Kwadijk (Deltares, NL): Welcome presentation**
09:30 - 10:00	**Edmund Penning-Rowsell (Middlesex University, UK) - Keynote Lecture: National scale flood risk assessment - Much improvement is badly needed**
10:00 - 10:30	**Coffee break**
10:30 - 12:30	**Session 1 - Hydrology and Hydraulics (Chair: Matthijs Kok, HKV/TU Delft)**
10:30 - 11:15	**Presentations** Giuseppe Aronica (University of Messina, IT): Specific calibration and uncertainty evaluation for flood propagation models by using distributed information (full presentation) Ferdinand Diermanse (Deltares, NL): Applied validation techniques in the Brisbane River catchment flood study (full presentation) Thomas Willis (JBA Risk Management, UK): Using Risk based methods to analyse uncertainty in flood inundation models (short presentation) Sanne Muis (VU University, NL): Global-Scale Modelling Of Sea Level Extremes To Estimate Coastal Flood Risk (short presentation)
11:15 - 12:15	**Discussion in Groups**
12:15 - 12:30	**Groups present summary of discussion to wider group**
12:30 - 13:30	**Lunch Break (Delta Plaza)**
13:30 - 15:30	**Session 2 - Failure models (Chair: Ben Gouldby, HR Wallingford)**
13:30 - 14:15	**Presentations** Myron van Damme (TU Delft, NL): How to improve the reliability of flood defence systems and obtain a better understanding of their failure mechanisms (full presentation) Michael Hicks (TU Delft, NL): Benchmarking 3D embankment reliability tools (short presentation) Cristina Jommi (TU Delft, NL): The Leendert de Boerspolder project: validation of rural dyke behaviour (short presentation) Kathryn Roscoe (Deltares, NL): Computing the reliability of levee systems: Equivalent Planes method (short presentation) Jessica Castillo (Polytechnic University of Valencia, ES): Flood risk estimation from dam failure: Challenges in risk modelling at the construction stage (short presentation)
14:15 - 15:15	**Discussion in Groups**
15:15 - 15:30	**Groups present summary of discussion to wider group**
15:30 - 16:00	**Coffee Break**
16:00 - 17:00	**Discussion and wrap up of the first day**
19:00 – 22:00	**Workshop Diner (Eet & Proeflokaal De Kurk, Kromstraat 20, Delft)**

Wednesday 10 December, 2014 (Deltares, Pavilion 1-3, Boussinesqweg 1, Delft)

08:00 - 09:00	**Registration and coffee**
09:00 - 11:00	**Session 3 - Damage models (Chair: Andreas Burzel, Deltares)**
09:00 - 09:45	**Presentations** Daniela Molinari (Politecnico di Milano, IT): Towards better knowledge of flood impacts: the RISPOSTA procedure for the collection of data in the aftermath of floods (full presentation) Heidi Kreibich (GFZ Potsdam, DE): How reliable are flood damage models? (full presentation) Sarah Kienzler (University of Potsdam, DE): Flood damage modeling in view of interactions between technical protection measures and private precaution (short presentation) Matthieu Spekkers (TU Delft): Explaining water damage: looking into the effects of urban drainage system (short presentation) Dennis Wagenaar (Deltares, NL): Uncertainty in flood damage estimation: causes, quantification and implications (short presentation) Huub van Verseveld (Deltares, NL): Impact Modelling of Hurricane Sandy on the Rockaways (short presentation)
09:45 - 10:45	**Discussion in Groups**
10:45 - 11:00	**Groups present summary of discussion to wider group**
11:00 - 11:30	**Coffee Break**
11:30 - 12:30	**Session 4 - Integration (Chair: Karin de Bruijn, Deltares)**
11:30 - 12:30	**Presentations** John McAneney (Risk Frontiers, AUS): Validation of Australian Flood Risk (full presentation) Petr Puncochar (Aon Benfield, CZ): Validation of the Impact Forecasting flood model for the Czech Republic after 2013 floods (full presentation) Nathalie Asselman (Deltares, NL): Comparison of the Flemish and Dutch flood risk methodologies, Case study Zuid-Beveland, The Netherlands (short presentation) Sergiy Vorogushyn (GFZ, DE): Development and validation of a large-scale flood model composed of a weather generator and catchment models (short presentation) Martin Jebens (Coastal Directorate, DK): Which level of precision are we aiming for? Uncertainties in vulnerability and risk assessment used to implement the EU Flood Directive in Denmark (short presentation) Nicola Pasquale (Munich Re, DE): Validation of flood models for the Re-Insurance industry (short presentation)
12:30 - 14:00	**Lunch Break (Delta Plaza)**
14:00 - 15:30	**Session 4 - Integration (continued)**
14:00 - 15:00	**Discussion in Groups**
15:00 - 15:30	**Groups present summary of discussion to wider group**
15:30 - 16:00	**Coffee break**
16:00 - 17:00	**Plenary discussion on way forward, wrap-up and conclusions**

See http://eguworkshop.deltares.nl for latest updates and further information.