Identification and quantification of uncertainties in river models using expert elicitation

J.J. Warmink[1], H. van der Klis[2], M.J. Booij[1], S.J.M.H. Hulscher[1]
[1] *University of Twente, Water Engineering & Management, PO Box 217, 7500 AE Enschede, the Netherlands, j.j.warmink@utwente.nl*
[2] *Deltares, Delft, the Netherlands*

Abstract
The aim of this study is to identify the sources of uncertainty that induce the largest uncertainties in the model outcomes and quantify this uncertainty using expert elicitation. Analysis of expert opinions showed that the Qh-relation and the roughness predictor of the main channel cause the largest uncertainties for design water level computations. For effect studies, the floodplain topography, weir formulation and discretisation of floodplain topography induces the largest uncertainty.

Introduction
Hydraulic–morphological river models are applied to design and evaluate measures for purposes such as safety against flooding. These numerical models are all based on a deterministic approach. However, the modelling of river processes involves numerous uncertainties, resulting in uncertain model results. Uncertainty is defined as any deviation from the unachievable ideal of complete determinism (Walker et al., 2003). Uncertainty in models comprises (1) the difference between a model outcome and a measurement and (2) the possible variation around a computed value. Knowledge of the type and magnitude of these uncertainties is crucial for a meaningful interpretation of the model results. The aim of this study is to identify the sources of uncertainty that induce the largest uncertainties in the model outcomes and quantify this uncertainty using expert elicitation.

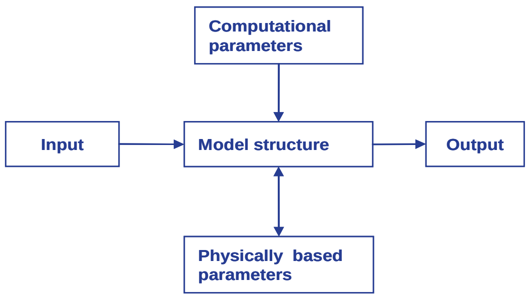

Figure 1. Possible locations of sources of uncertainty in a model that contribute to the model output uncertainty (based on Walker et al., 2003)

Method
The uncertainties in the model outcome are a result of the uncertainties of all parts of the model, called the sources of uncertainty. Figure shows a sketch of a general model. Uncertainties are present in the model input, parameters, computational parameters (e.g. grid size and time step) and model structure (Walker et al., 2003). In this study, the two-dimensional WAQUA model for the River Waal, used for the prediction of water levels is used as an example for the identification of sources of uncertainty.

Expert selection
At first 25 experts are asked for their experience with the WAQUA model. From these 25 experts, 16 are selected based on a Pedigree matrix (Funtowicz and Ravetz, 1990) with 4 criteria:
1. experience with code development,
2. experience with WAQUA projects,
3. number of years experience, and
4. number and type of publications about WAQUA.

On each criterion a score between 4 and 0 is given, based on the information given by the expert. Subsequently, the scores are normalised using a weight factor per criterion from 4 to 1 respectively. The 16 experts with the highest Pedigree scores are invited for an interview. Interviews are held with 11 of these experts. In this report, the results of only 7 experts are shown.

Expert interviews
The experts are asked to list the most important uncertainty sources. These are defined as the sources with the largest contribution to the model outcome uncertainties. The experts are asked to consider the following two situations:
1. the computation of design water levels (DWL), based on a design discharge wave and
2. the computation of the effect of a measure in the river bed, which is done using a constant discharge as input.

To compare the different experts, the experts are asked to comment on the sources of uncertainty on the same level of detail. Subsequently, the experts are asked to indicate the effect of a source of uncertainty on the computed water levels.

Results

The experts stated that the sources of uncertainty are different for the computation of the DWL and effect studies. In case of effect studies, the experts agreed that the sources of uncertainty that do not change between the computation with and without a measure have little influence on the uncertainty in the computed effect. In case of DWL computations, the uncertainties are dominated by the sources that are not compensated during calibration.

Uncertainties in design water levels

The uncertainty in the DWL computations for different sources is shown in Figure 2. Only the five largest sources of uncertainty in the DWL are shown. Clearly, the Qh-relation and the roughness predictor for the main channel have a relatively large uncertainty, according to the experts. Also the data used for calibration is mentioned as an important source. Besides the large values given for the order of magnitude of the uncertainty, also a large scatter is shown in the experts' opinions.

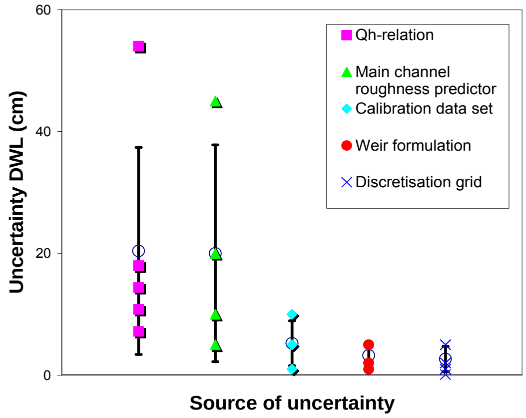

Figure 2. Uncertainty in computed design water level, due to different uncertainty sources. The mean (open circle) and the range of 1 standard deviation around the mean are given for each uncertainty source.

Uncertainties in effect studies

Regarding the uncertainties in effect studies (Figure 3), less experts were able to quantify the sources of uncertainty and the effect of uncertainty sources on model outcomes. This is mainly caused by the large dependency of the uncertainty on the location of the change in the river bed. In general, the uncertainty in an effect study is important if it is different in the situation with a measure compared to the reference situation. If, for example, many weirs are changed, the uncertainty due to weirs has a relatively large influence.

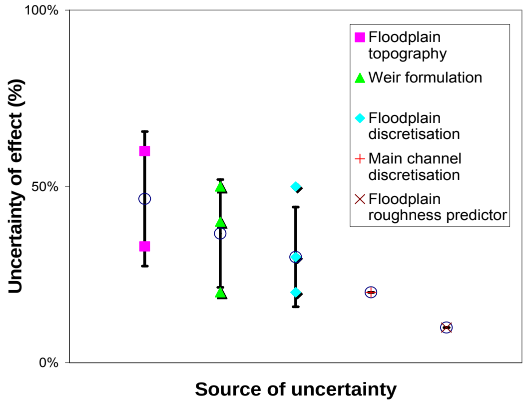

Figure 3. Sources of uncertainty for effect studies, expressed as a percentage of the computed effect. Also the mean (open circle) and the range of 1 standard deviation around the mean are given for each source of uncertainty.

Discussion

The experts are also asked for the uncertainty sources for other models than the WAQUA model for the Waal. They stated that the dominant source of uncertainty is determined by the characteristics of the flow field and river geometry. For example, the experts stated that the uncertainty in the main channel roughness is much larger than the uncertainty in the vegetation roughness. However, for the IJssel, the model outcome is more sensitive for vegetation roughness than for main channel roughness, because the floodplain areas are relatively large compared to the main channel.

Conclusions

It is concluded that:

– The Qh-relation and the roughness predictor of the main channel cause the largest uncertainties for DWL computations.
– For effect studies, the floodplain topography, weir formulation and discretisation of floodplain topography induces the largest uncertainty.

Acknowledgements

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