Uncertainty in flood quantiles from basin and river models

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Background

- **Current situation:** flood frequencies of river discharges in the Netherlands derived by fitting extreme value distributions on observed discharges.

- **New (physically based) approach inititisated by RIZA (part of the Dutch Ministry for Transport, Public Works and Water Management).**

- **Contributions from other institutes, such as:**
  - KNMI (Dutch meteorological Institute)
  - BfG (Bundesanstalt fur Gewasserkunde)
  - WL | Delft Hydraulics
Frequency distributions and uncertainties

- **data**
- **central estimate**
- **95% lower**
- **95% upper**

The graph shows the relationship between the return period (years) and the peak discharge at Lobith (m³/s). The data points represent the observed values, while the lines indicate the central estimate and the 95% confidence intervals for the lower and upper bounds.
Uncertainties in the uncertainties !!

![Graph showing discharge Rhine at Lobith (m3/s) vs. return period (years). The graph compares exponential and Pareto distributions.](image)
Problem statement

- Both underestimation and overestimation of flood dangers are very costly

- Therefore the existing uncertainties (confidence intervals) in the design flood are much larger than desired.

- Even the estimated uncertainties are uncertain

- Can this be improved, using a more physically based approach ???
Model instrumentation Rhine (initiated by RIZA)

Stochastic rainfall generator (KNMI) → Hydrological model (HBV; BfG) → Hydraulic model (SOBEK) → frequency curve
Reasons for building the instrumentation

- Generate (very) long series of discharges so extrapolation in frequency analysis won’t be necessary

- More information on:
  - Effects of upstream physical limitations on flood frequencies
  - Flood hydrograph characteristics
  - Confidence intervals of relevant statistics

- Offers options for impact studies on:
  - Climate change
  - Human interventions
So, many potential advantages, but...

First, if possible, we need more information on:

- The validity of the concept
  - How to calibrate the models for extreme conditions?
  - Are the models capable of simulating extreme conditions?

- The reliability and uncertainties ...
  - Of the rainfall generator
  - Of the rainfall-runoff and routing model
  - Of the resulting flood frequencies
Problem

There are no observations of extreme events with return periods of 1000 years or more, so …

- How to calibrate the models for extreme conditions?
- How to validate the models for extreme conditions?
- Are the models capable of simulating extreme conditions?
1. Rainfall generator

- Impossible to validate for extreme events
- Reliability of the model depends on reproduction of observed statistical features
- KNMI has done extensive research on this
2. Hydrological model

- Good possibilities for validation of extreme events …

<table>
<thead>
<tr>
<th>River</th>
<th>highest observed discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oberrhein (incl. Neckar)</td>
<td>5,600</td>
</tr>
<tr>
<td>Main</td>
<td>1,980</td>
</tr>
<tr>
<td>Nahe</td>
<td>1,150</td>
</tr>
<tr>
<td>Lahn</td>
<td>840</td>
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<tr>
<td>Mosel</td>
<td>4,170</td>
</tr>
<tr>
<td>Nette und Wied</td>
<td>202</td>
</tr>
<tr>
<td>Ahr</td>
<td>194</td>
</tr>
<tr>
<td>Sieg</td>
<td>1,053</td>
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<tr>
<td>Wupper</td>
<td>181</td>
</tr>
<tr>
<td>Erft</td>
<td>55</td>
</tr>
<tr>
<td>Ruhr</td>
<td>907</td>
</tr>
<tr>
<td>Emscher</td>
<td>200</td>
</tr>
<tr>
<td>Lippe</td>
<td>370</td>
</tr>
<tr>
<td><strong>total:</strong></td>
<td><strong>16,902</strong></td>
</tr>
</tbody>
</table>
Methods for estimating uncertainty HBV

- Calibration and subsequent validation with “optimal parameter set”
- Validation with multiple satisfactorily parameter set
- GLUE-procedure: Derive model uncertainty by a Bayesian method for estimating parameter uncertainty
Uncertainty in discharge-prediction
3. Hydraulic model

- Design flood conditions are far more extreme than observed conditions

- However, physical processes are quite well-known

- Necessary to have detailed information on cross-sections, dikes and floodplains along all major stretches

- Physical limitations (maximum flow capacity) may well reduce the uncertainties of the model instrumentation as a whole
To conclude

- Existing uncertainties in the design flood of the Rhine are much larger than desired.

- New model instrumentation may help reduce these uncertainties, especially if physical limitations are relevant.

- Instrumentation not necessarily a replacement of the existing method, i.e. combination of both methods is probably most beneficial.