Extreme Scenarios and Flood Risk Management

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Contents

- Which extreme scenarios are of interest?
- How should extreme scenarios be considered in flood risk management?
- How can extreme scenarios be quantified?
- How can extreme scenarios be validated?
### Who needs which (extreme) scenarios?

<table>
<thead>
<tr>
<th>Use</th>
<th>Required Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood design for dams</td>
<td>Site-specific statements about extreme discharges / hydrographs, e.g. 10000-year flood</td>
</tr>
<tr>
<td>Building insurance</td>
<td>Building-specific statements about flood hazard, e.g. 10 – 200-year floods</td>
</tr>
<tr>
<td>Re-insurance</td>
<td>Probable Maximum Flood, large-scale events</td>
</tr>
<tr>
<td>Local disaster management</td>
<td>Local scenarios including extraordinary situations and implications for disaster management, e.g. disruption of infrastructure</td>
</tr>
<tr>
<td>Federal disaster management</td>
<td>Large-scale, extraordinary scenarios that cannot be handled by regional agencies</td>
</tr>
</tbody>
</table>
Large-scale flood scenarios
Example ICPR Rhine Atlas

T = 10 a                  T = 100 a                  extreme flood event

[Map showing flood scenarios along the Rhine River]
Spatial heterogeneity of flood events
Example August flood 2002
Variation of return period

<table>
<thead>
<tr>
<th>Fluss</th>
<th>Pegel</th>
<th>Zeitreihe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhein</td>
<td>Maxau</td>
<td>1922-1999</td>
</tr>
<tr>
<td>Rhein</td>
<td>Worms</td>
<td>1937-1999</td>
</tr>
<tr>
<td>Rhein</td>
<td>Mainz</td>
<td>1931-1999</td>
</tr>
<tr>
<td>Rhein</td>
<td>Kaub</td>
<td>1931-1999</td>
</tr>
<tr>
<td>Rhein</td>
<td>Andernach</td>
<td>1931-1999</td>
</tr>
<tr>
<td>Rhein</td>
<td>Köln</td>
<td>1880-1999</td>
</tr>
<tr>
<td>Rhein</td>
<td>Rees</td>
<td>1931-1999</td>
</tr>
<tr>
<td>Neckar</td>
<td>Plochingen</td>
<td>1919-1999</td>
</tr>
<tr>
<td>Main</td>
<td>Schweinfurt</td>
<td>1845-1999</td>
</tr>
<tr>
<td>Nahe</td>
<td>Grolsheim</td>
<td>1845-1999</td>
</tr>
<tr>
<td>Lahn</td>
<td>Kalkofen</td>
<td>1936-1999</td>
</tr>
<tr>
<td>Mosel</td>
<td>Cochem</td>
<td>1901-1999</td>
</tr>
</tbody>
</table>
Variation of return period and "severity" of floods

Data: 29 floods in the Rhine basin
(1940-1999, 12 gauges)
<table>
<thead>
<tr>
<th>Component</th>
<th>Damage Cause</th>
<th>Consequences</th>
<th>Possible Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood retention basin</td>
<td>Volume of flood &gt; available retention volume</td>
<td>Spillway discharges; moderate inundations downstream (industrial site, urban area)</td>
<td>Monitoring and early warning; damage-reducing measures downstream, e.g. mobile flood walls for particularly vulnerable objects</td>
</tr>
<tr>
<td>Flood retention basin</td>
<td>Volume of flood &gt; available retention volume</td>
<td>Overtopping of dam; possibly dam break; severe inundation downstream</td>
<td>Monitoring and early warning; damage-reducing measures downstream, e.g. evacuation</td>
</tr>
<tr>
<td>Flood retention basin</td>
<td>Obstruction of the outlet due to sediment, driftwood etc.</td>
<td>Spillway discharges; moderate inundations downstream</td>
<td>Monitoring and clearance operations during floods</td>
</tr>
<tr>
<td>Industrial site</td>
<td>Inundation causes release of chemicals</td>
<td>Pollution downstream of chemical release</td>
<td>Flood proofing of chemical storages</td>
</tr>
<tr>
<td>Bridge (urban area)</td>
<td>Obstruction of the profile due to driftwood etc.</td>
<td>Backwater effects; local inundation in urban area</td>
<td>Monitoring and clearance operations during floods</td>
</tr>
<tr>
<td>Flood wall (urban area)</td>
<td>River water level &gt; height of wall</td>
<td>Inundation in urban area</td>
<td>Damage-reducing measures in the urban area</td>
</tr>
<tr>
<td>Private households (urban area)</td>
<td>Leakage of flooded oil fuel storages due to buoyancy</td>
<td>Contamination in the respective household and in its neighbourhood</td>
<td>Flood proofing of oil fuel storages</td>
</tr>
<tr>
<td>River segments with high velocity in case of flood (urban area)</td>
<td>Erosion of river bed</td>
<td>Damage to foundation of buildings; loss of structural stability</td>
<td>Protection of erosion-prone river segments</td>
</tr>
</tbody>
</table>
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Expected annual flood damage [€/a] as risk indicator
Contents

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Flood frequency analysis and uncertainty

Annual maximum flood, 1880-1999, gauge Köln/Rhine

Mann-Kendall-Test: Hypothesis „no trend“ is rejected ($\alpha=0.05$)
Consideration of uncertainty

• 2 time periods:

• 7 distribution functions:
  Generalised Extreme Value, Gumbel, Log Pearson
  Typ 3, 3-parametric Lognormal, General Logistic,
  Exponential, General Pareto distribution

• goodness-of-fit test:
  Kolmogorow-Smirnow (α=0.05)

• Probability bounds as uncertainty estimation:
  Envelope, including all cdf that are not rejected

• Best estimate:
  weighted flood frequency curve (weights based on
  agreement between empirical and theoretical values)
Uncertainty of extrapolation

Return period [a]

Discharge [m$^3$/s]
Additional information

Extreme Hochwasser in Europa (Stanescu, 2002)
Hochwasser Odra Sommer 1997
Hochwasser Donau/Elbe Sommer 2002
Extreme Hochwasser in Köln - historisch vor 1880 (nach Krahe, 1997)
Extreme Hochwasser in Köln - gemessen (1880-1999)
Flood frequency analysis and additional information

- Stanesu, 2002
- Kleeberg & Schumann, 2001
- DVWK 251, 1999
- Lammersen, 2004

The graph shows a log-log plot of return period (years) on the y-axis and discharge (m^3/s) on the x-axis. The shaded area represents the range of data points from different studies, with specific markers indicating the data sources.
Linking process simulation and probabilistic methods (Example Lower Rhine)

- Gauge Rees
- Tributary Lippe
- Levee breach location Polder Mehrum
- Levee breach location Krefeld
- Tributary Ruhr
- Gauge Cologne

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Flood Frequency Curve Gauge Rees

- observed discharges 1961 - 1995
- extreme value statistics (Pearson III)
- extreme value statistics (Gumbel)
- probabilistic model
Contents

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Possibilities for validation

Water balance simulation

Decreasing repeatability of system states

System state may be repeated many times

System state cannot be repeated

Decreasing precision with which the system state can be identified

System state is precisely measurable

System state is only measurable in vague terms

Decreasing relevance of available measurements to the phenomenon of interest

Measured system state is the variable to be predicted

Measured system state is not relevant to prediction

(Fall & Anderson, 2002, Blockley, 1980, modified)
Some aspects concerning model validation for extreme flood scenarios

- Possibilities for “validation”:
  - Sensitivity analysis to identify important input / processes
  - Probabilistic analysis to identify the effects of uncertainty on model results
  - Comparison of alternative models
  - Reporting on model assumptions and uncertainty

- Optimistic models may be dangerous

- Be aware: we tend to overestimate our knowledge
Conclusions

- Lack of certain types of extreme scenarios:
  - Large-scale flood events
  - Unusual events, failure situations (blockage of weirs, human error in emergency management, etc.)

- Use of extreme scenarios in flood risk management:
  - Risk awareness, ‘low frequency – high damage’ events

- Quantification of extreme scenarios:
  - Integration of different sources of information (historical events, formal expert knowledge, etc.)
  - Linking of process understanding and probabilistic methods

- Lack of methods for validation in data-sparse situations
Definition of ‘extreme events’

- Extreme events are inherently contextual
- Extreme means ‘something rare, big, different’
- ‘Extremeness’ implies an event’s behavior to cause change

(Sarewitz & Pielke, 2000)

Community damage (household inventory)
Meuse floods
Wind et al., 1999
### Choice / development of scenarios

<table>
<thead>
<tr>
<th>Schweregrad</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normaler Verlauf (95%)</strong></td>
</tr>
<tr>
<td><strong>Schwerer Verlauf (4%)</strong></td>
</tr>
<tr>
<td><strong>Katastrophaler Verlauf (1%)</strong></td>
</tr>
<tr>
<td>Prozess verläuft sehr unüblich. Schutzmaßnahmen funktionieren nicht oder kommen zu spät. Schwierige Einsatzverhältnisse. Viele Personen exponiert und direkt betroffen (z.B. Direkttreffer)</td>
</tr>
</tbody>
</table>

### Eintretenswahrscheinlichkeit

- **Häufig**
  - Schlimmstes erlebtes Ereignis
  - (einmal innerhalb von 10 bis 50 Jahren: Wahrscheinlichkeit für die nächsten 25 Jahre ca. 100%)

- **Selten**
  - Schlimmstes Ereignis, an das man sich erinnern kann
  - (einmal innerhalb von 50 bis 200 Jahren: Wahrscheinlichkeit für die nächsten 25 Jahre ca. 25%)

- **Sehr selten**
  - Schlimmstes vorstellbares Ereignis
  - (einmal innerhalb von einigen 100 Jahren: Wahrscheinlichkeit für die nächsten 25 Jahre ca. 2%)

Bähler et al. (2001)