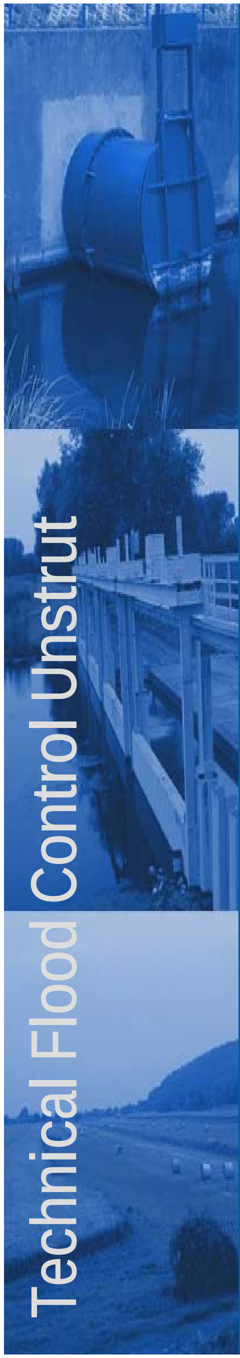
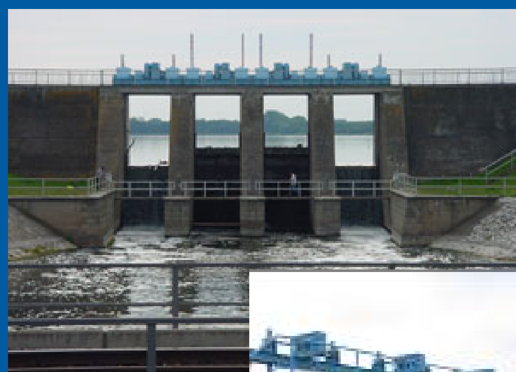
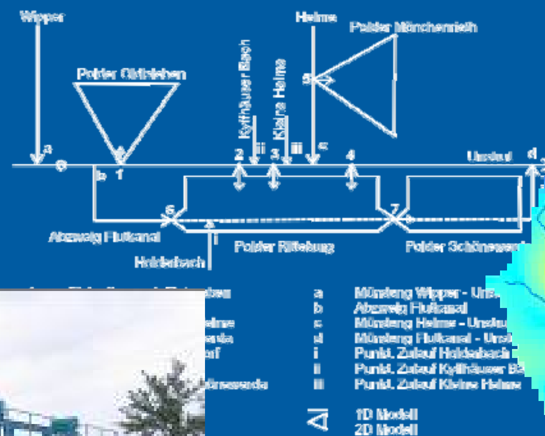
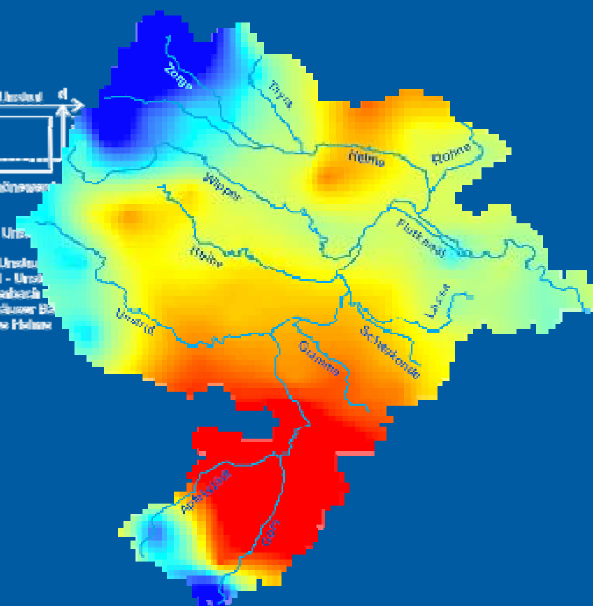
Technical Flood Control Unstrut



Assessment and Optimization of Flood Control Systems: The Unstrut River Case Study







M. Pahlow, Y. Hundecha, D. Nijssen, J. Dietrich, B. Klein, C. Gattke, A. Schumann, M. Kufeld, C. Reuter, H. Schüttrumpf, J. Hirschfeld and U. Petschow
Institute of Hydrology, Water Resources Management and Environmental Engineering
Ruhr-University Bochum; RWTH Aachen University; IÖW Institute for Ecological Economy Research, Berlin, Germany

Bundesministerium für Bildung und Forschung
rimax Risk management of extreme flood events

Technical Flood Control Unstrut

Outline

Flood damage in Germany

Top five most costly flood events from 1990 to 2002

Rank	Month/Year	Most affected river basins	Economic damage [Mio. €]	Insured damage [Mio. €]	Death toll
1	08/2002	Elbe, Danube	9200	1800	21
2	12/1993	Rhine	530	160	n/a
3	05/1999	Danube, Rhine	412	66	n/a
4	07/1997	Oder	330	32	n/a
5	01/1995	Rhine	280	110	n/a

(Source: Kron, 2004)

River Elbe flood, August 2002, Dresden

Safety or Risk-Oriented Approach ?

Safety-Oriented Approach	Risk-Oriented Approach
Choice of design flood Q_{design} (e. g. 100 year flood)	100 % safety can not be achieved by technical means
↓	↓
Design Technical flood control fully functional for $Q \leq Q_{design}$	Risk of failure Hydrological Risk Operational/Technical Risk
↓	↓
Assumption: No risk of failure for $Q \leq Q_{design}$ and negligible beyond Q_{design}	Risk Management required

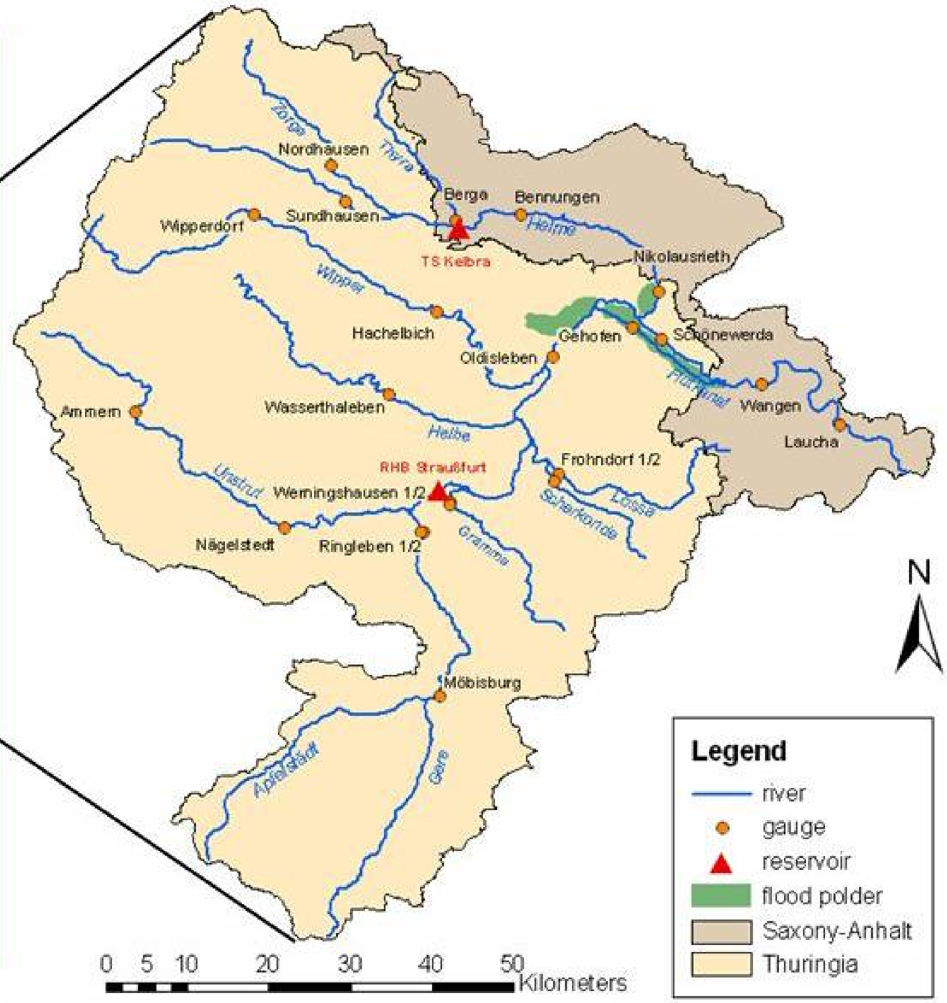
Motivation

Considering Mesoscale Catchemts

Technical Flood Control Unstrut

Germany

Unstrut Catchment in Thuringia and Saxony-Anhalt



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Flood Risk – Flood Protection

→ Thorough assessment requires a broad range of hydrological loads

Altering the flow regime:

Building a new dam

Technical Flood Control Unstrut

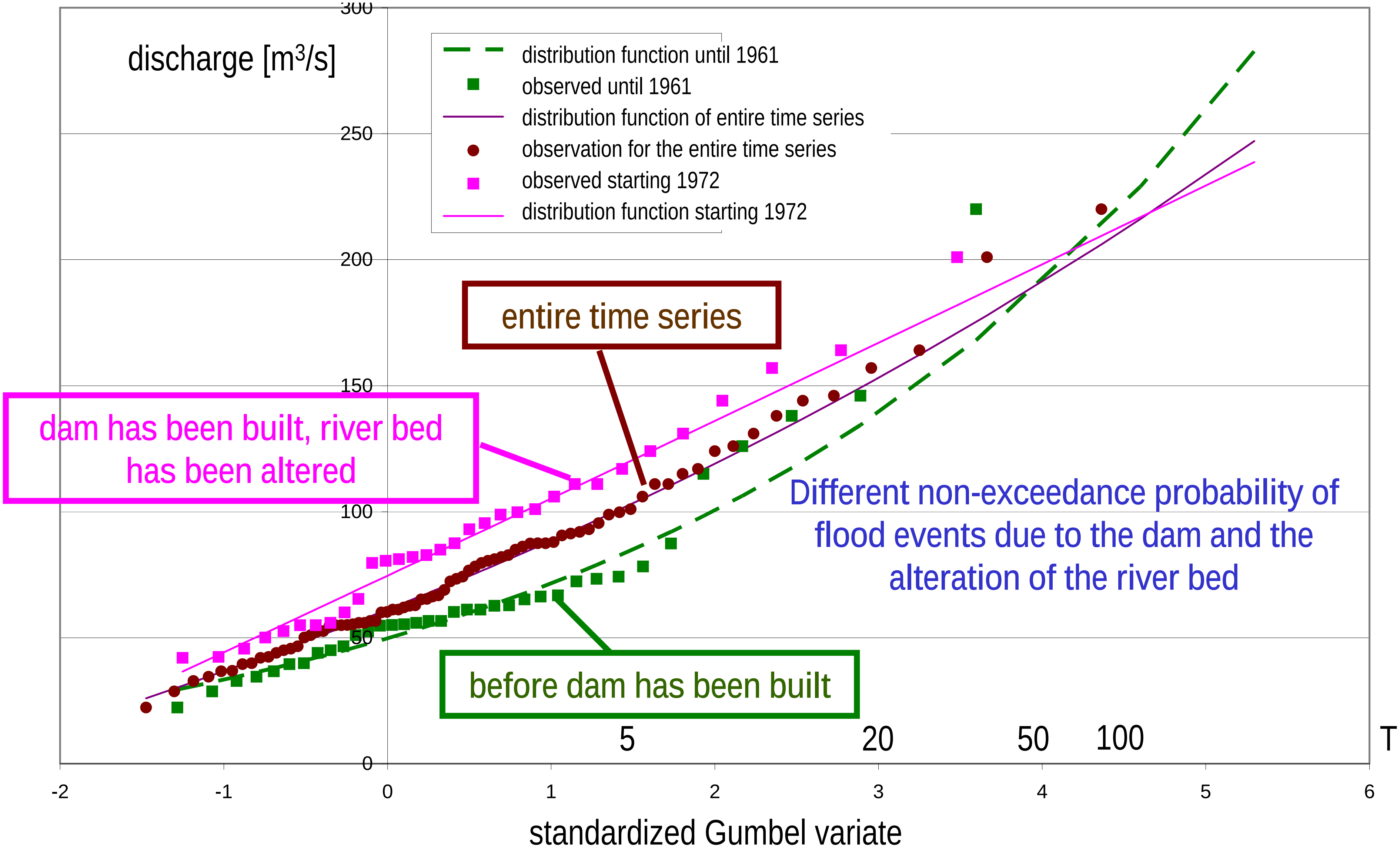
Technical Flood Control Unstrut

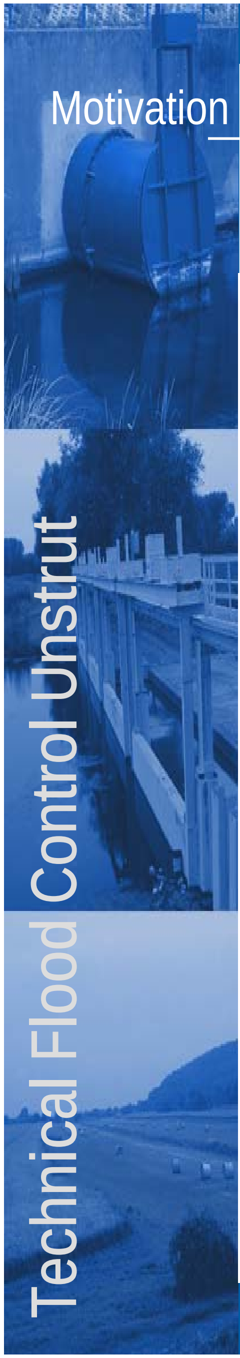
Motivation

Alteration of the River Bed – Example 1

Alteration of the River Bed – Example 2

Gauge Oldisleben: Distribution function of annual discharge maxima before 1961 (dam has been built), after 1972 (river bed has been altered) and the entire time series

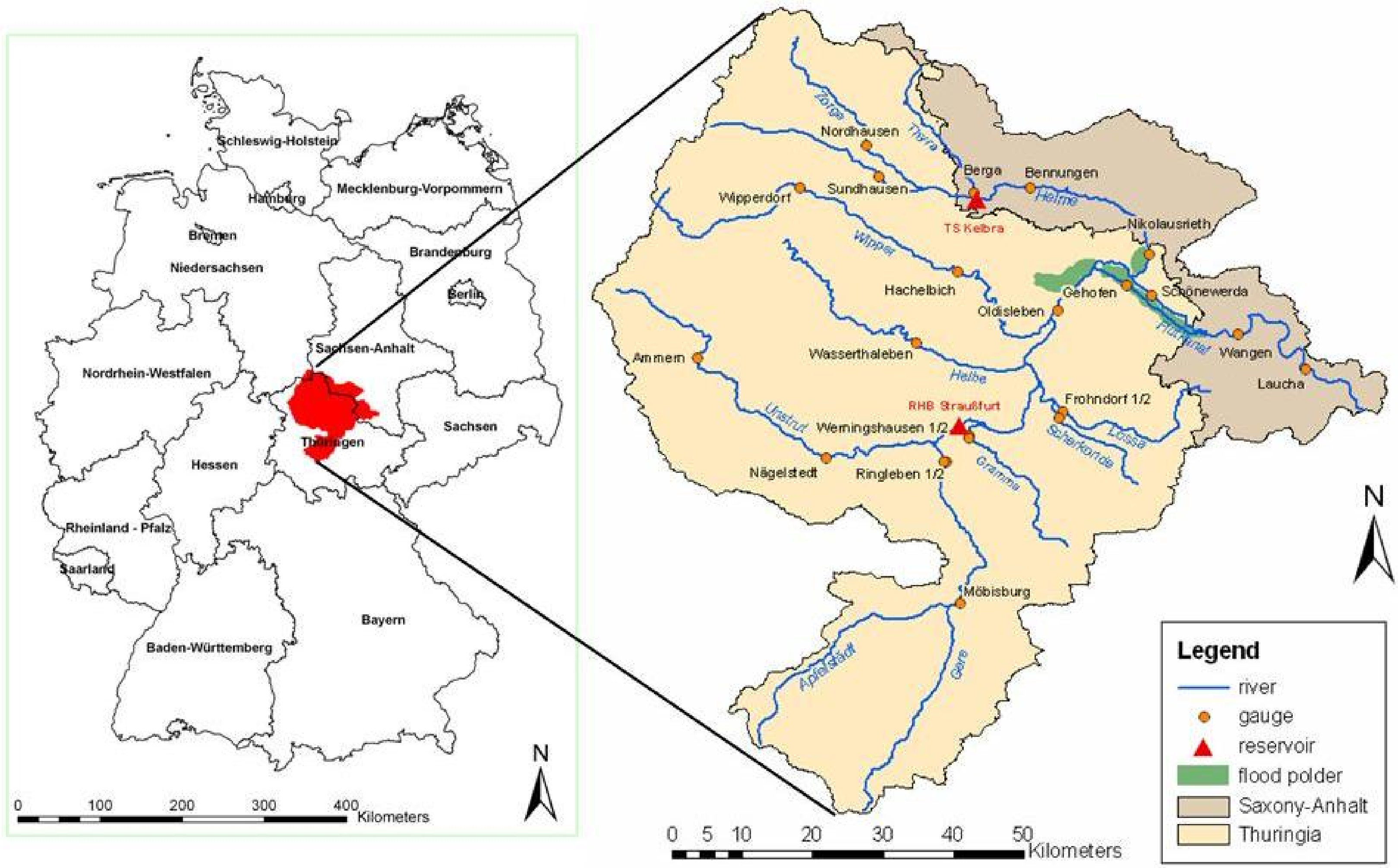




Motivation | Considering Mesoscale Catchemts

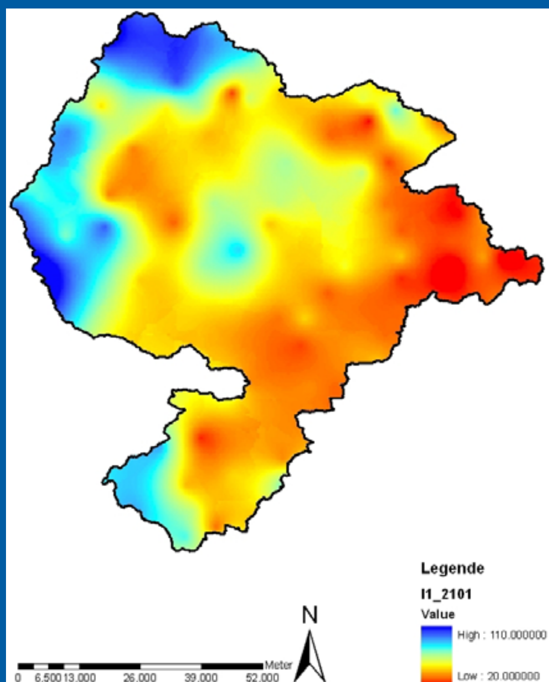
Germany

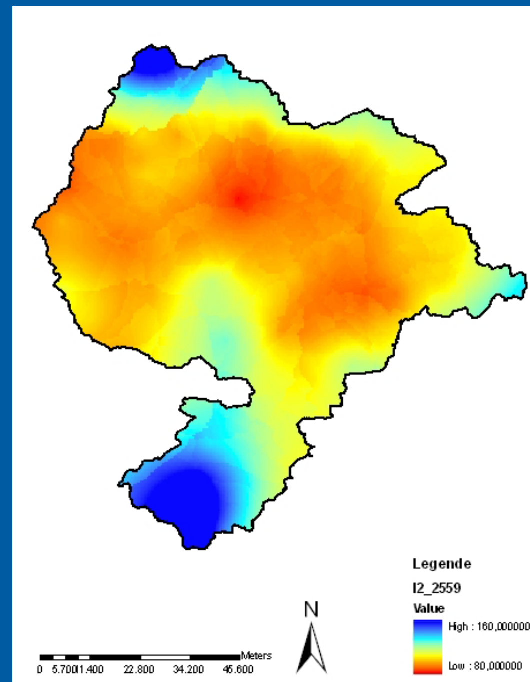
Unstrut Catchment in Thuringia and Saxony-Anhalt

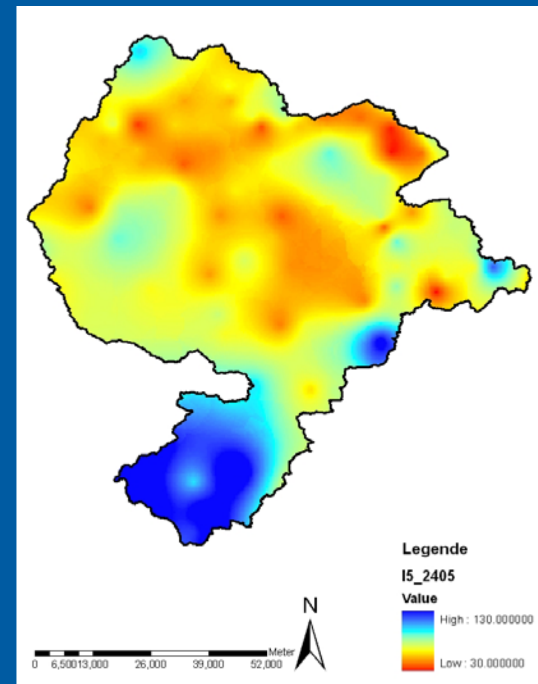


Technical Flood Control Unstrut

Spatial and Temporal Rainfall Distribution







→Has major impact on the development of individual flood events

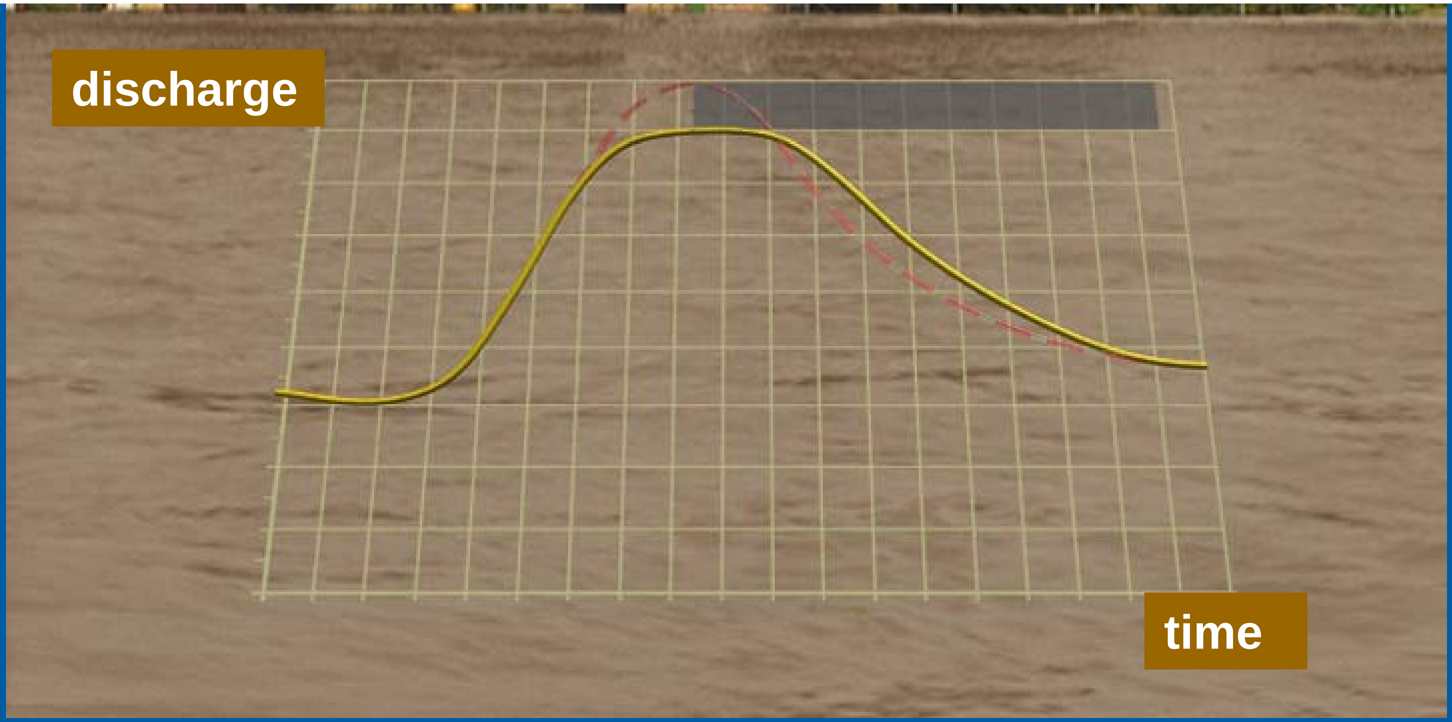
→Drives the interaction of subcatchments

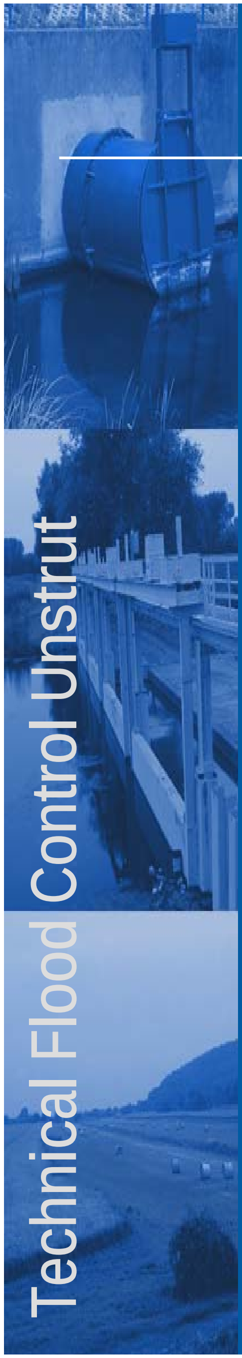
→Needs to be considered when assessing the efficiency of technical flood control systems

Technical Flood Control Unstrut

Goal of using technical measures

To reduce the discharge to a level that does not cause any damage downstream or to at least reduce the damage caused by flooding





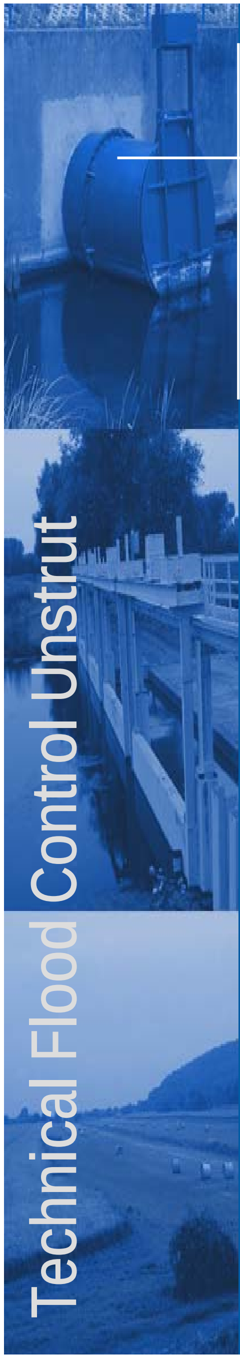
Outline

I. Motivation

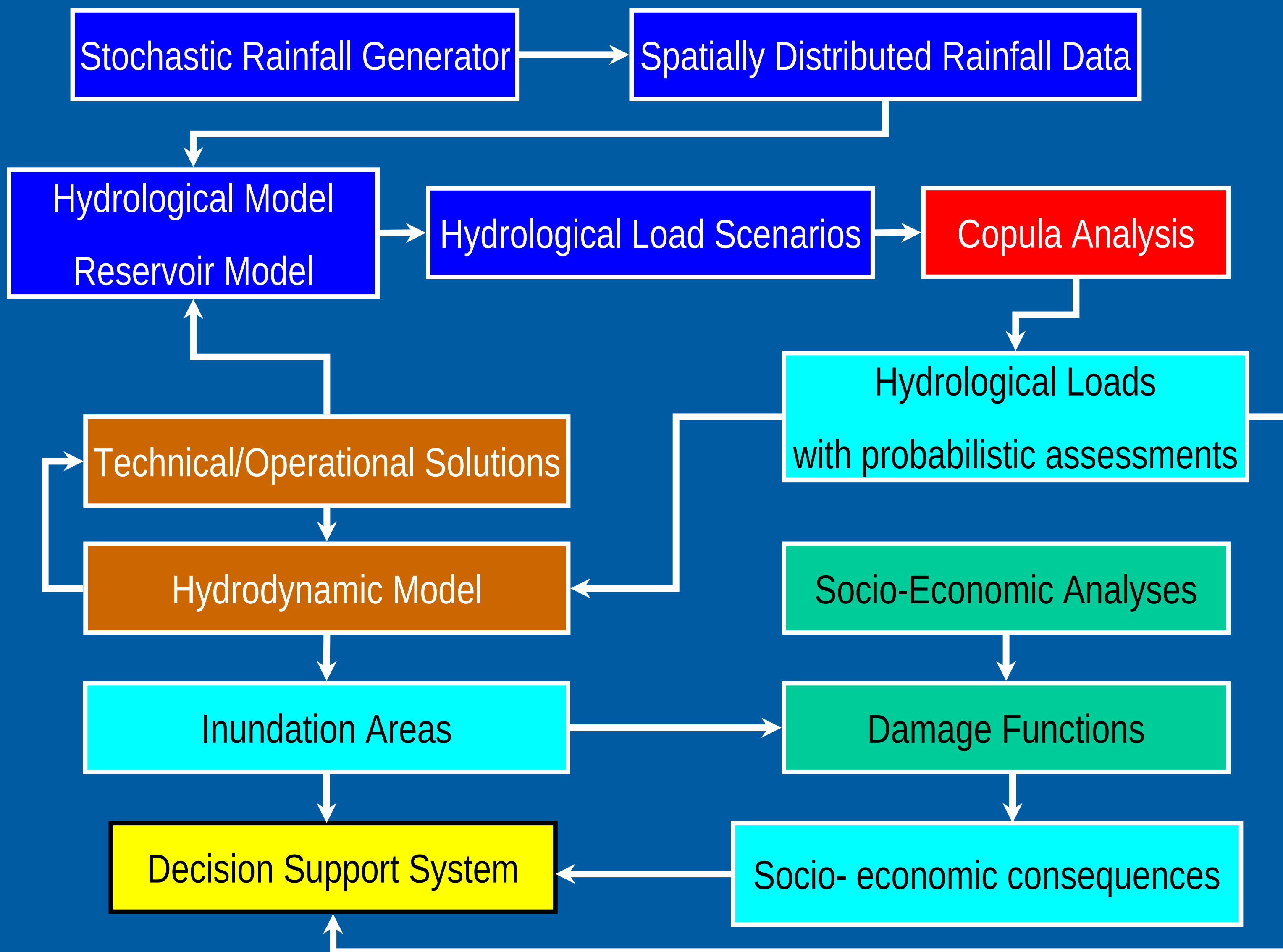
II. Methodology

III. Application

IV. Summary and Outlook



Methodology



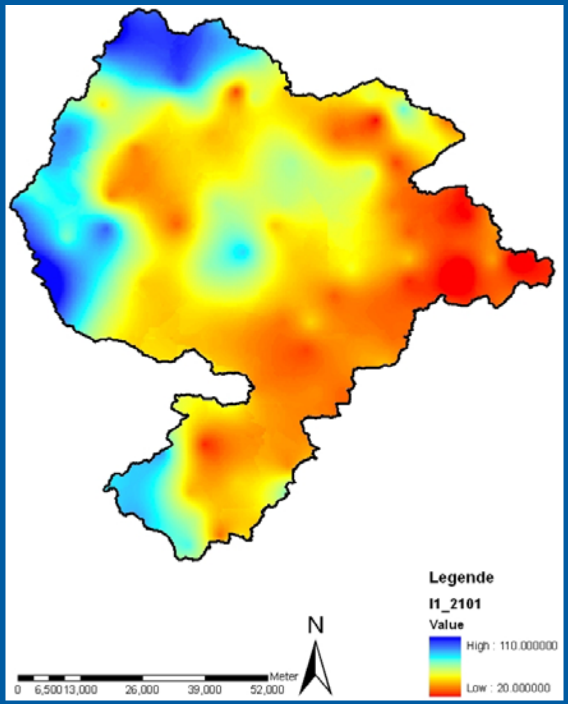
Technical Flood Control Unstrut

Methodology

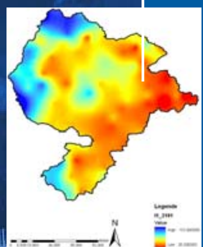
Stochastic Rainfall Generator → Spatially Distributed Rainfall Data

Stochastic Rainfall Generator for Flood Management Studies → Basic Requirements

- The model should reproduce the spatial structure of the precipitation at multiple locations

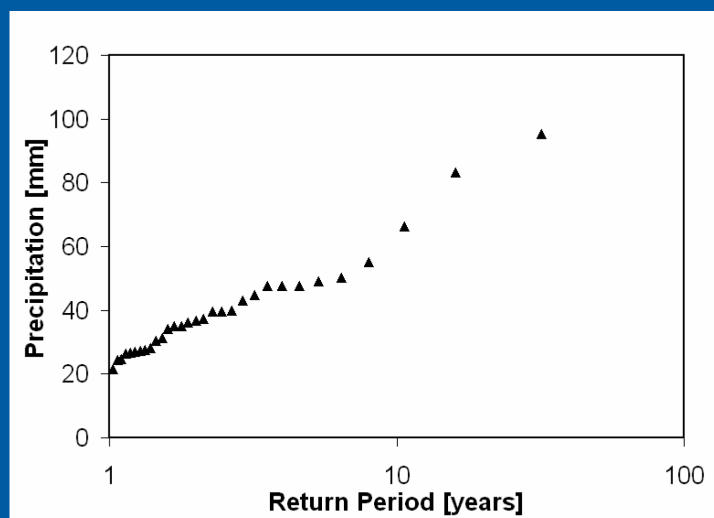


Stochastic Rainfall Generator for Flood Management Studies → Basic Requirements



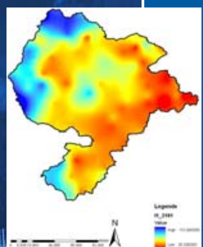
- The model should reproduce the spatial structure of the precipitation at multiple locations

- The extremes of the precipitation should be captured



Technical Flood Control Unstrut

Stochastic Rainfall Generator for Flood Management Studies → Basic Requirements



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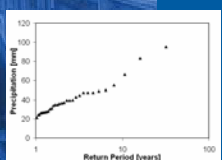

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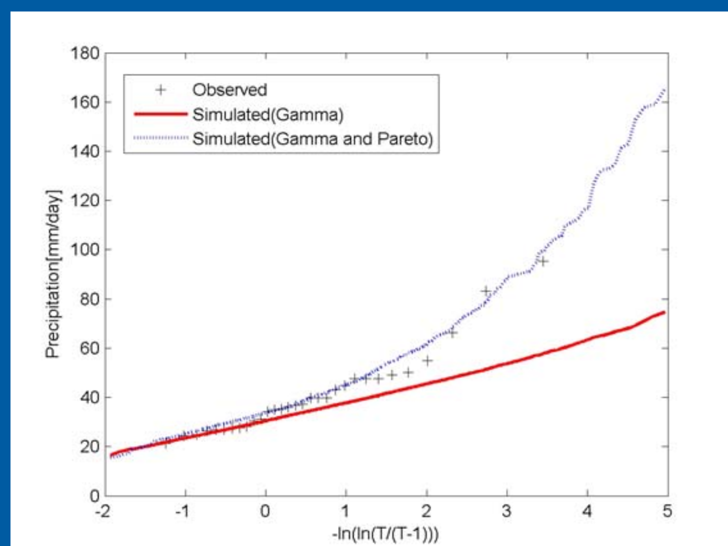


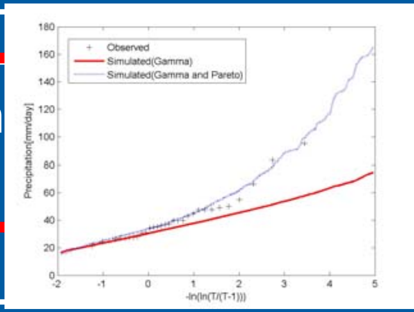
Technical Flood Control Unstrut

Methodology | Stochastic Rainfall Generator

Daily precipitation series at multiple locations

Estimation of parameters

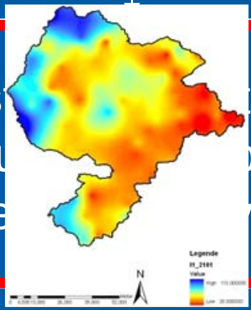
Fittin ution



Transformation of the data into a normal variate

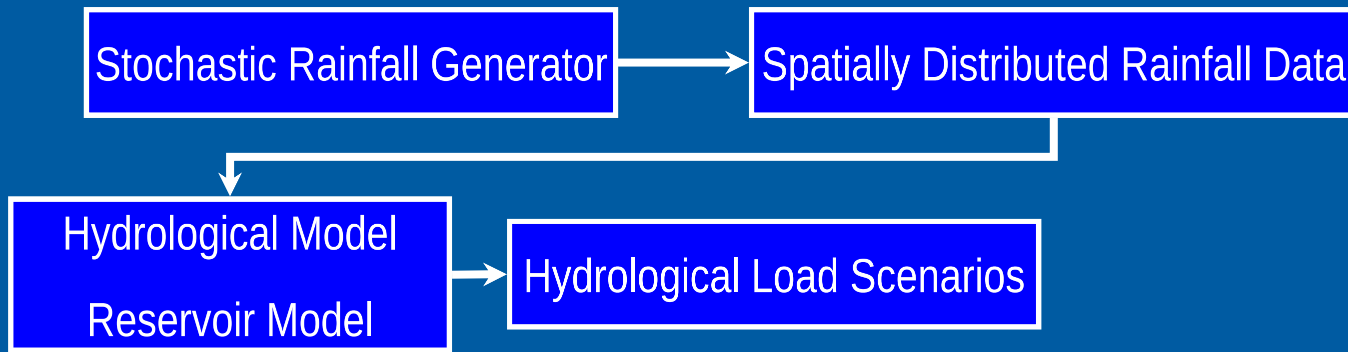
Simulation of a transformed daily series of precipitation using MAR (1) model

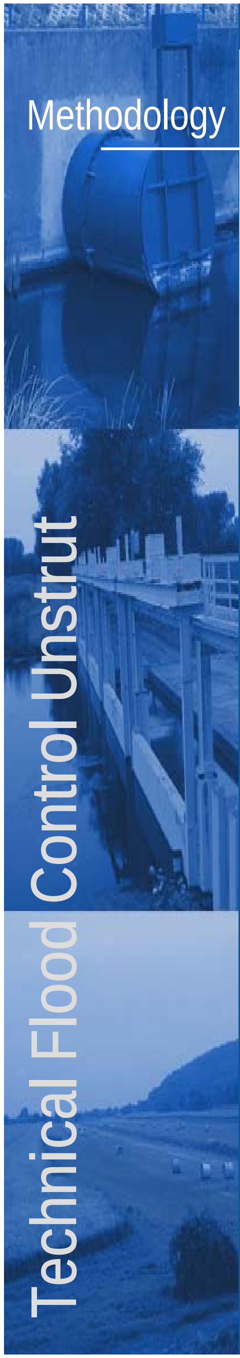
Es he
au on
and the variance



Back transformation

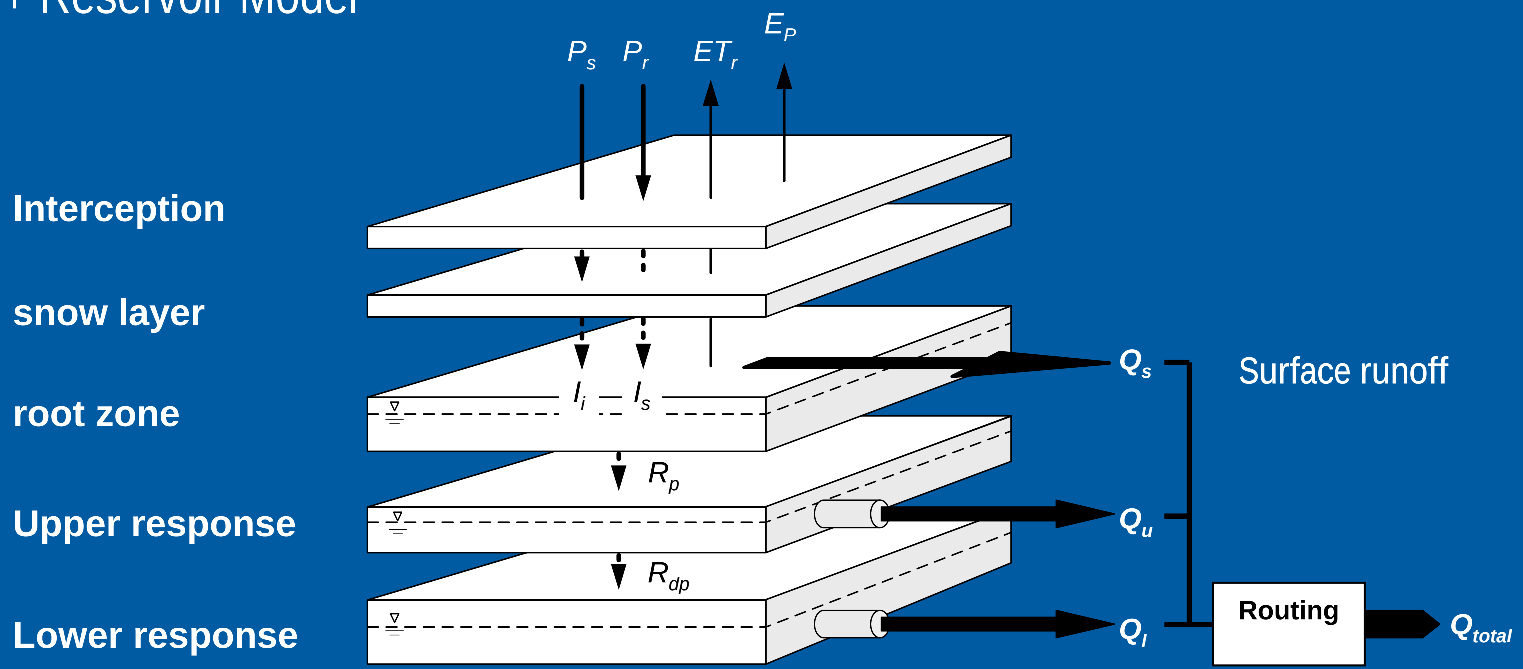
Methodology





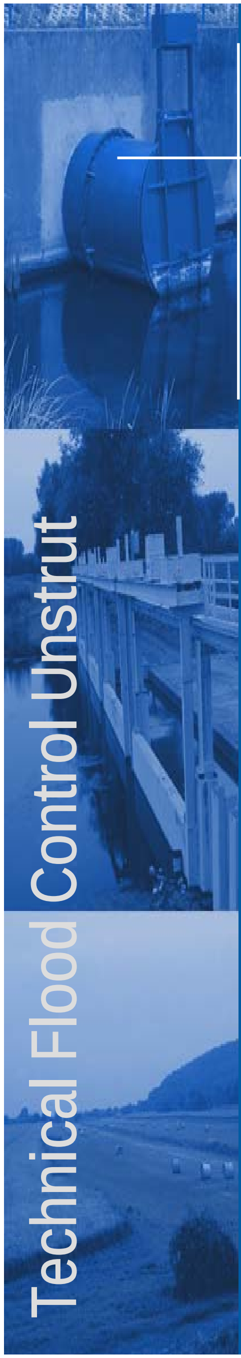
Object Oriented Framework with HBV implementation

+ Reservoir Model

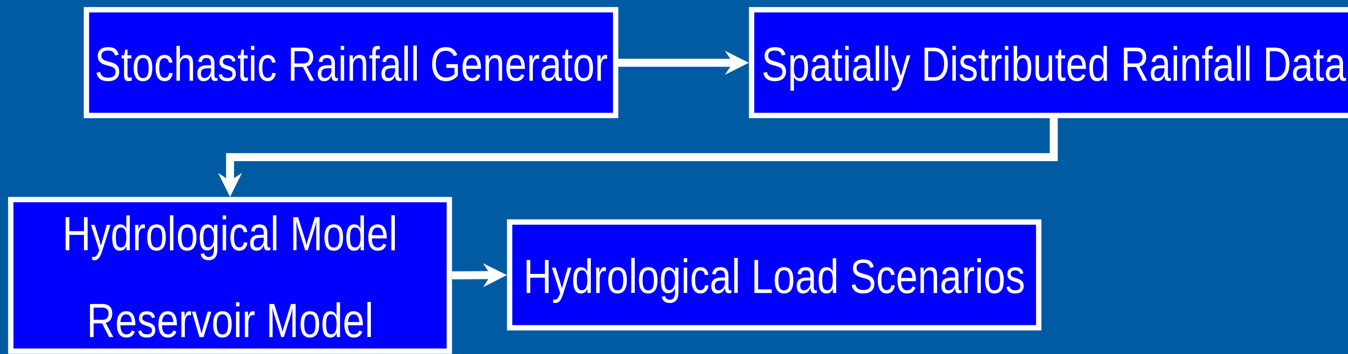


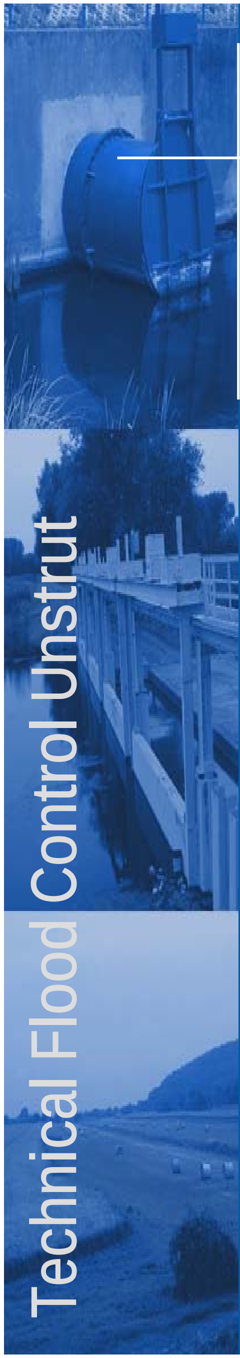
Stochastic Rainfall Generator + Deterministic Rainfall-Runoff Model

→ Stochastic-deterministic generation of hydrological loads

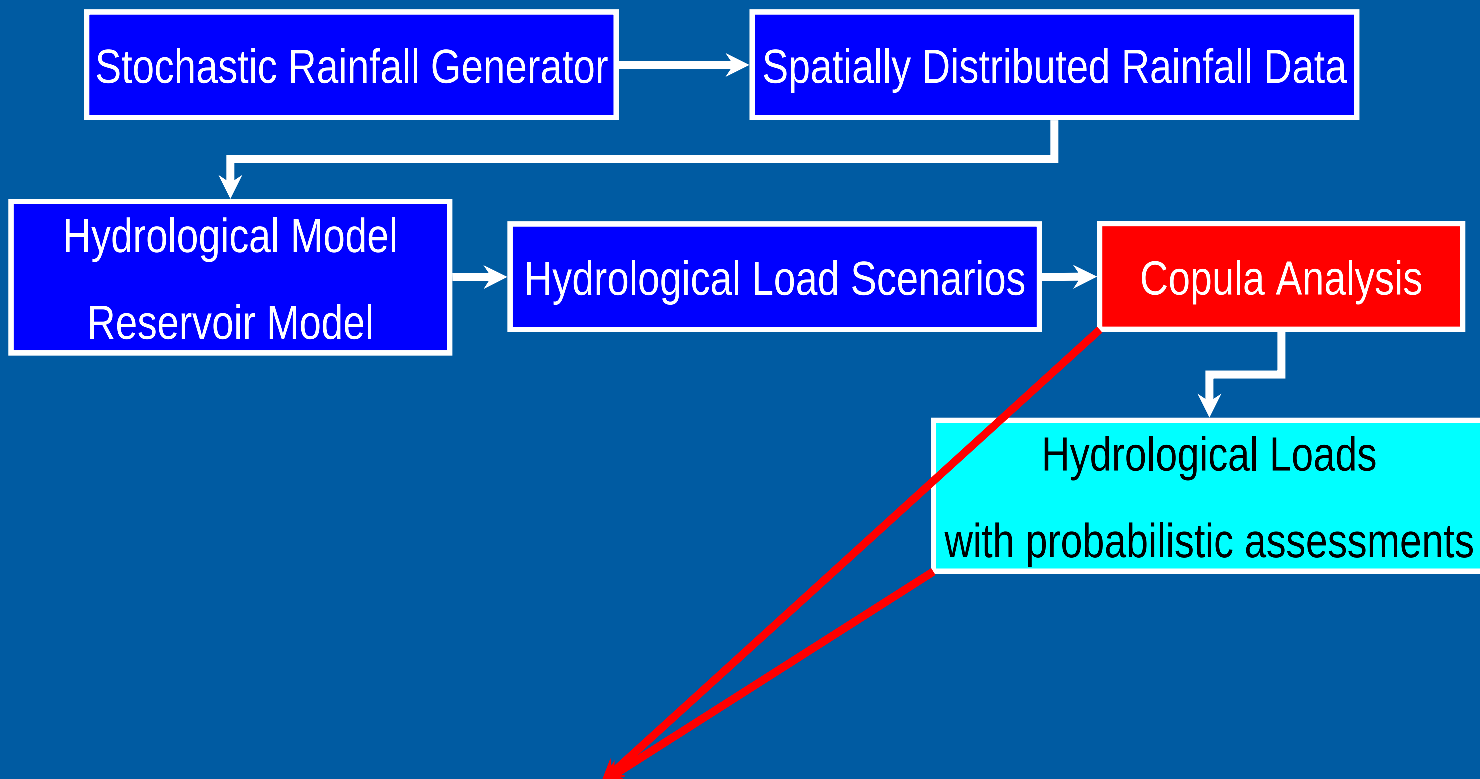


Methodology





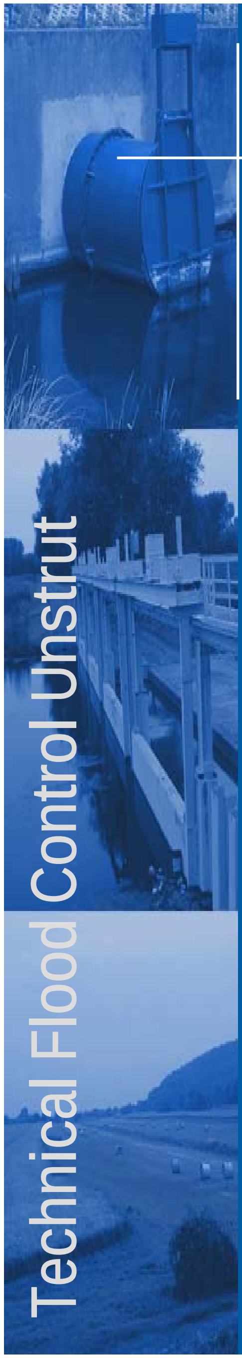
Methodology



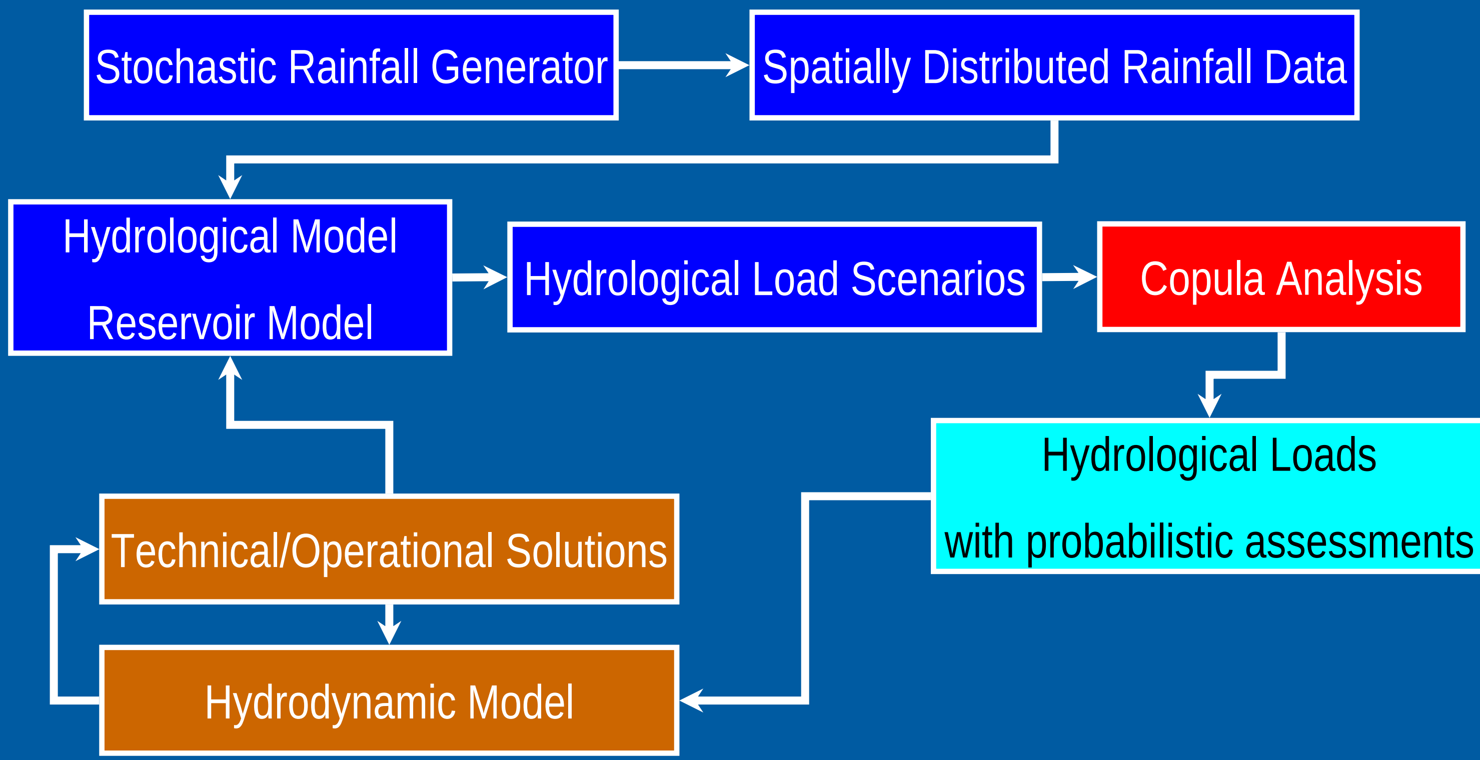
Wednesday, 7 May 2008, 11:00 a.m., Room B

Presentation by Klein et al.

“Probabilistic Analysis of Hydrological Loads to Optimize the Design of Flood Control Systems“



Methodology



Technical Flood Control Unstrut

Methodology | Hydrodynamic Coupled 1D-2D Model

iLMOFlood interlinked model for floods

- 1D Model based on the St.-Venant-equations
- 2D Model with “initially dry land” approach – Storage Cells
- Simplified as ODE System
- Stiff set of eqations
- Implicit integration scheme (efficiency)
- Coupling: 1D-1D / 1D-2D two-directional

Inundation Area

Flood Duration

Flow Velocity

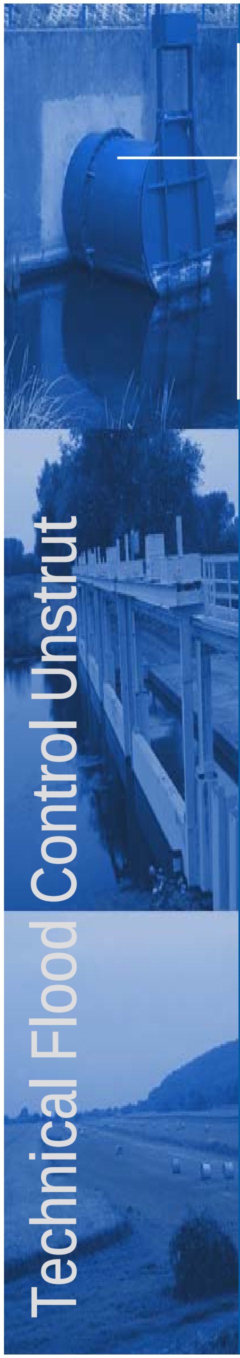
Water Level

←

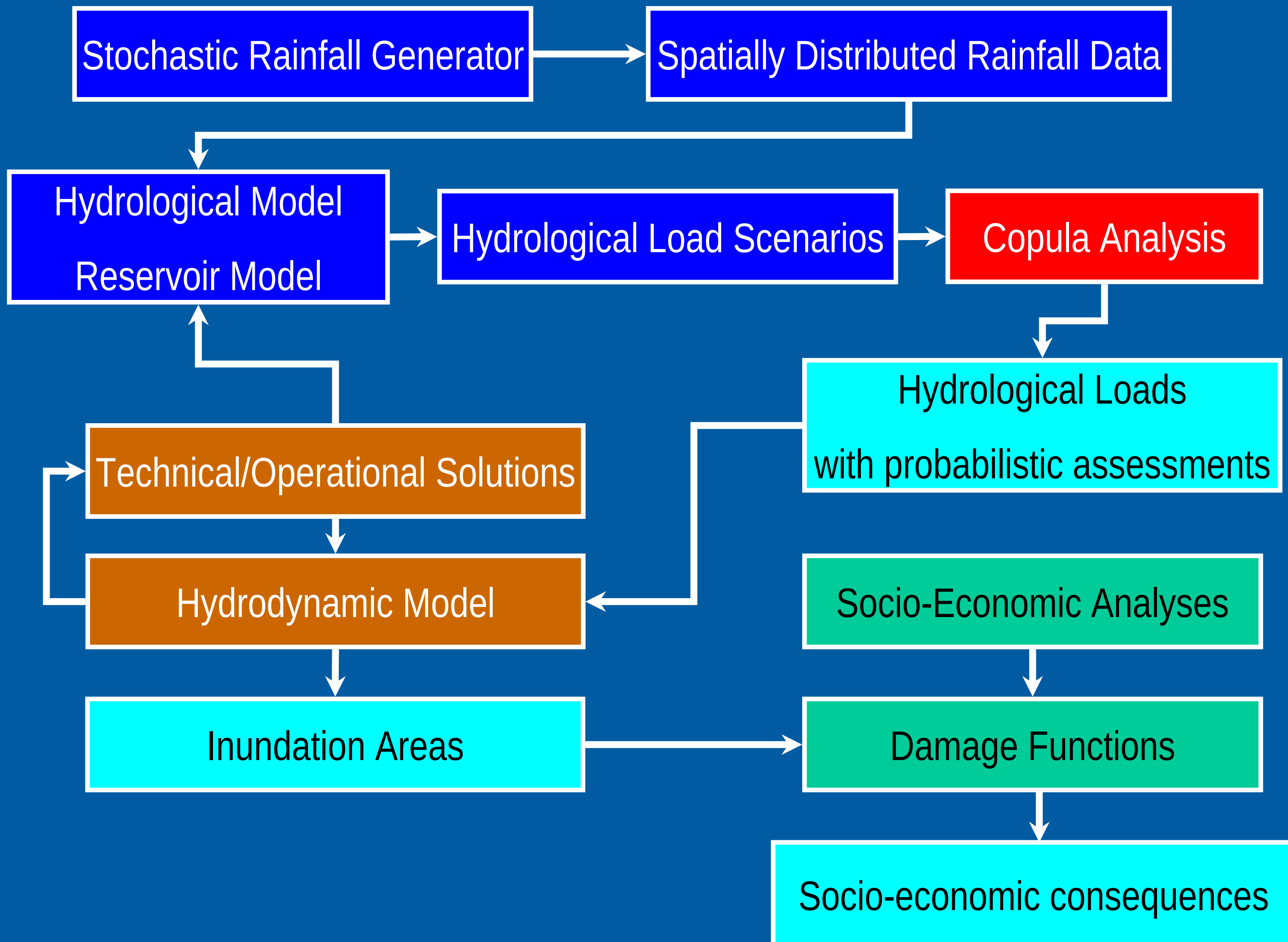
Thursday, 8 May 2008, 8:00 a.m., Room E

Presentation by Kufeld et al.

“Interlinked modelling of large floods by combining one and two dimensional diffusive wave approaches”

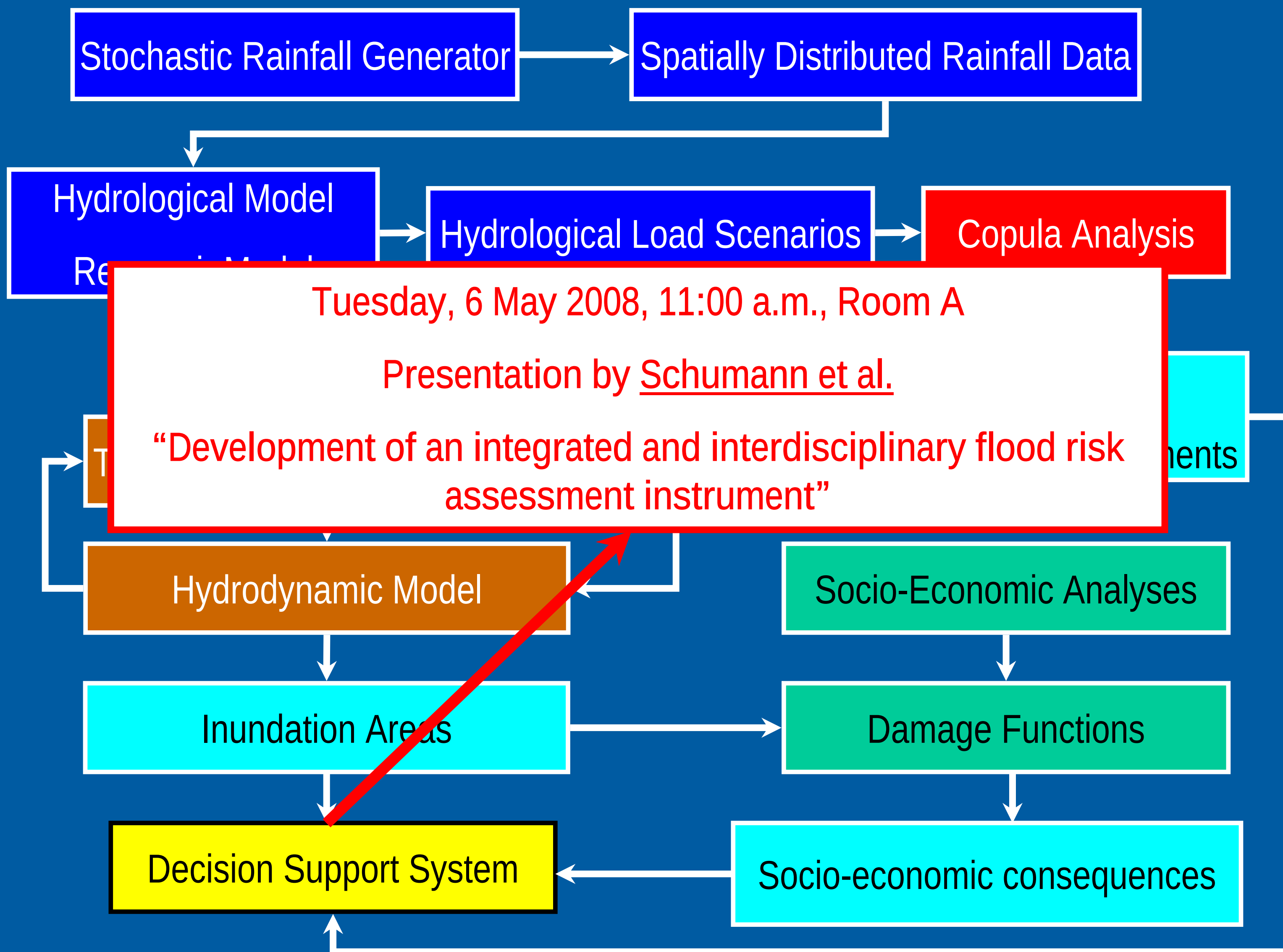


Methodology



Technical Flood Control Unstrut

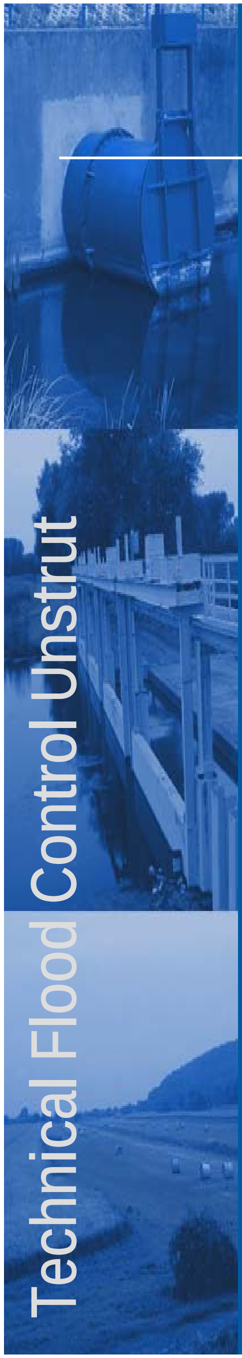
Methodology



Tuesday, 6 May 2008, 11:00 a.m., Room A

Presentation by Schumann et al.

"Development of an integrated and interdisciplinary flood risk assessment instrument"



Outline

I. Motivation

II. Methodology

III. Application

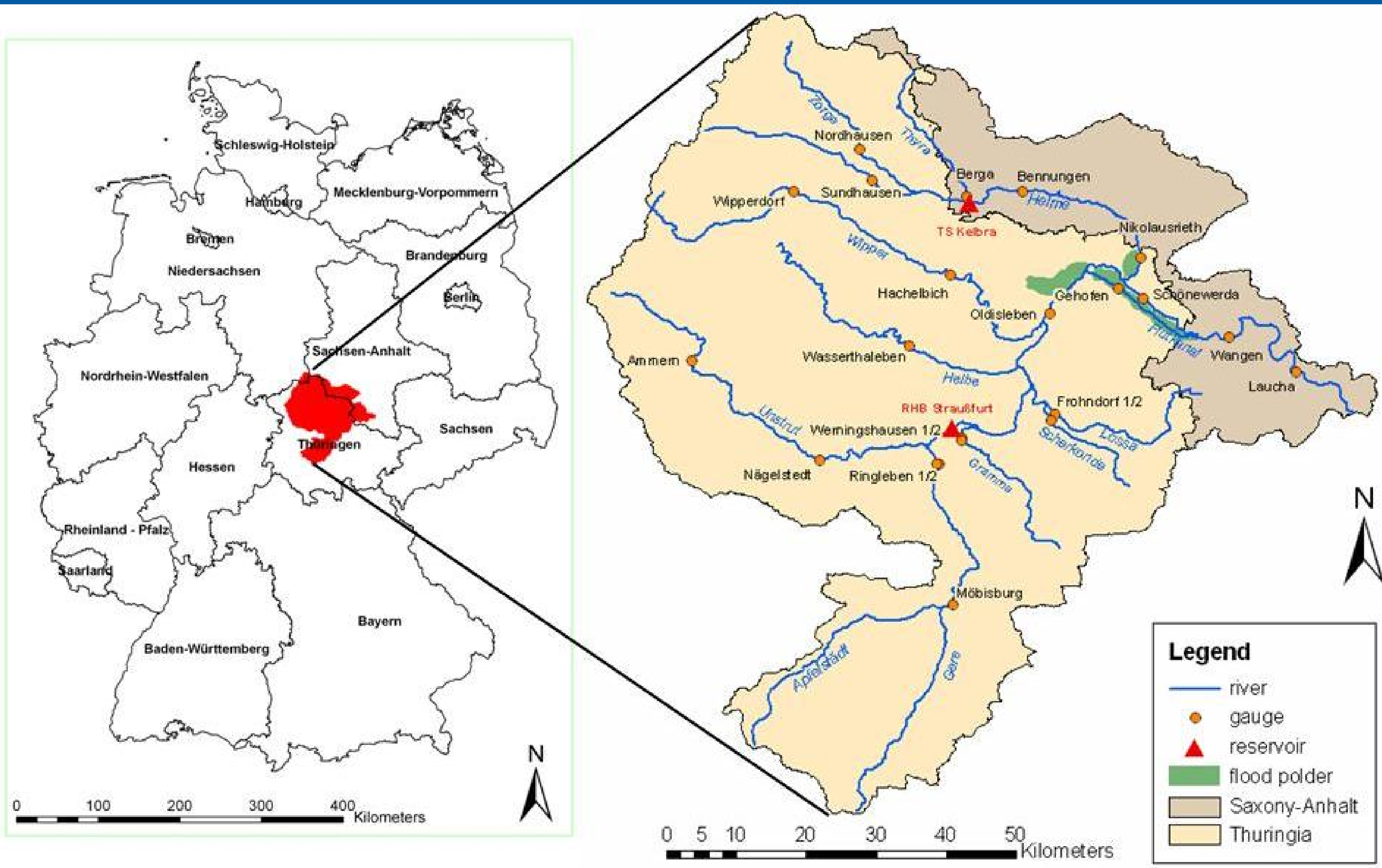
IV. Summary and Outlook

Application | Study area

Technical Flood Control Unstrut

Germany

Unstrut Catchment in Thuringia and Saxony-Anhalt



Application

Current Flood Control System

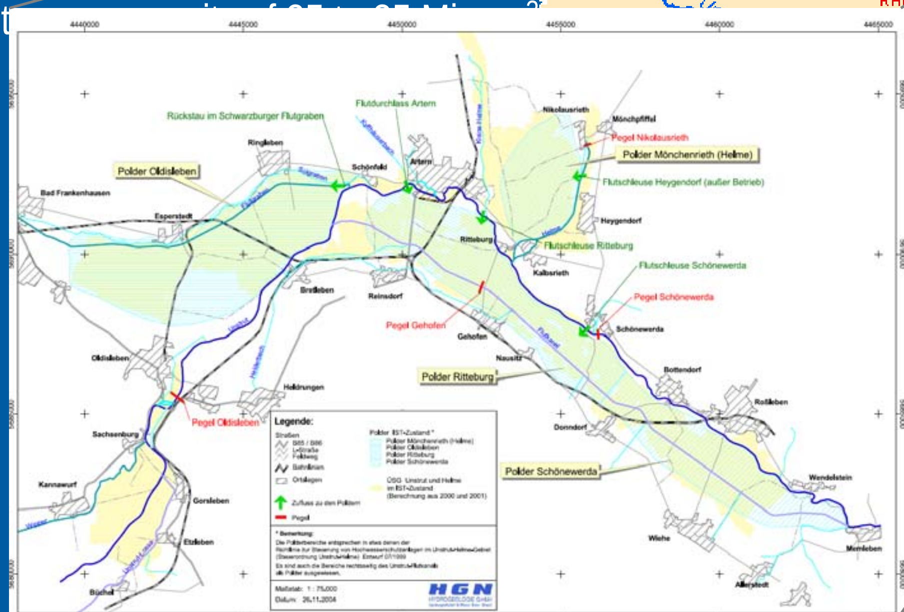
Storage Volume: approx. 100 Mio. m^3

- 2 dams
- 1 flood channel
- 4 polders

Planned:

Additional polders with a

st



catchment area: 6343 km^2

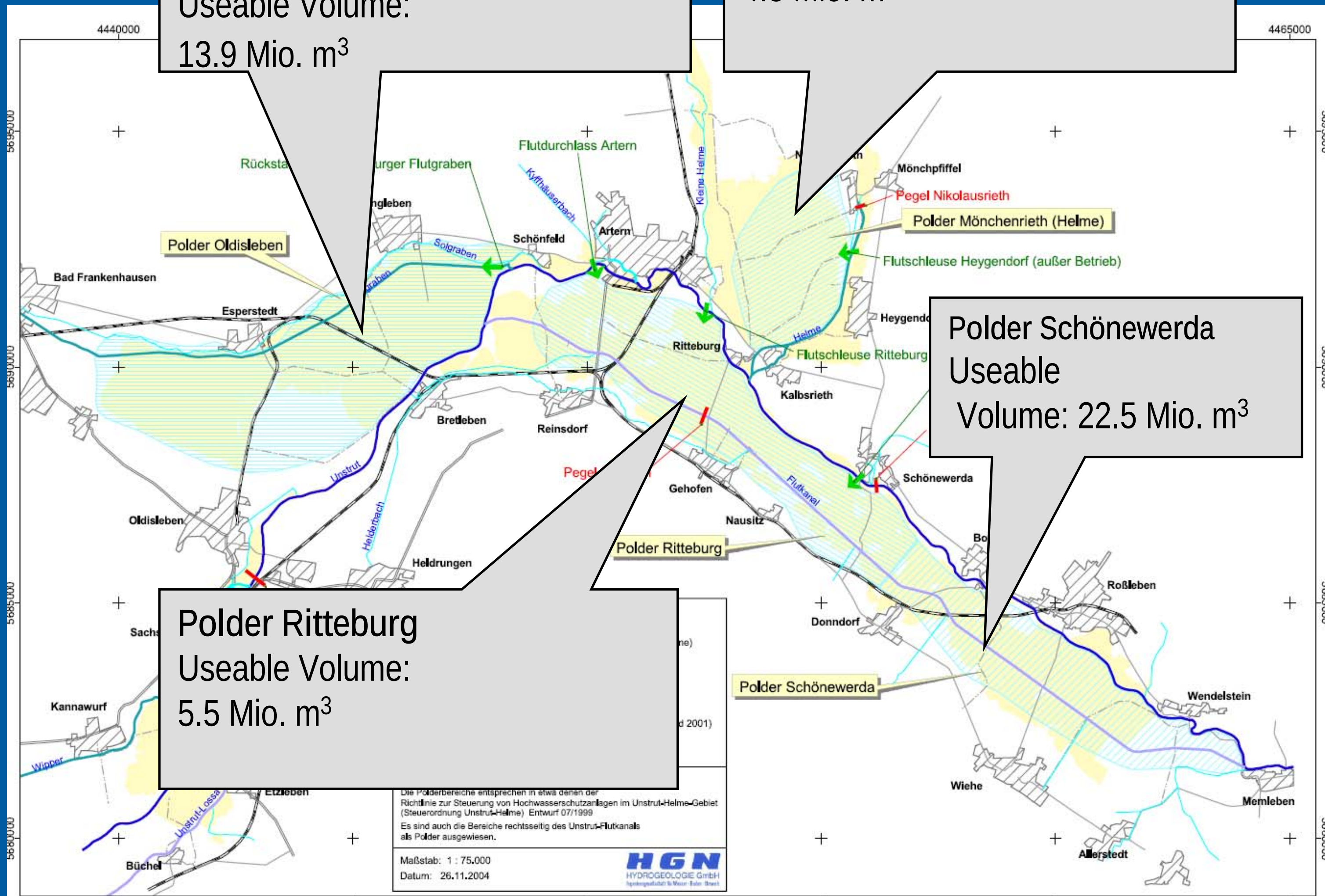
retention capacity 15.7 mm

Technical Flood Control Unstrut

Application

Current polder system

Technical Flood Control Unstrut



Polder Oldisleben
Useable Volume:
13.9 Mio. m^3

Polder Mönchenrieth

Useable Volume:
4.3 Mio. m^3

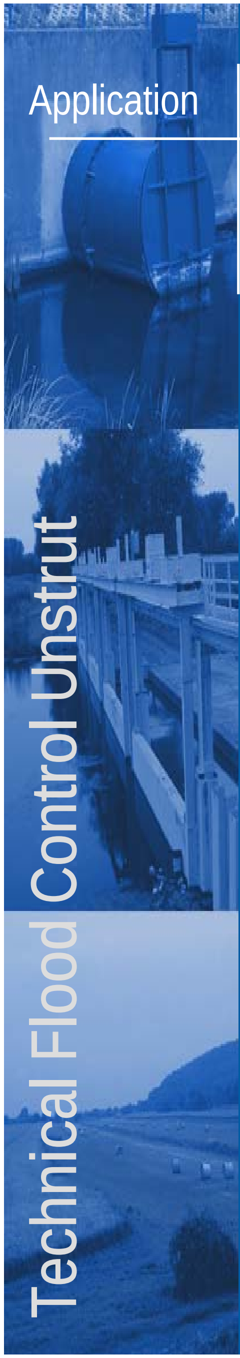
Polder Schönewerda
Useable
Volume: 22.5 Mio. m^3

Polder Ritteburg
Useable Volume:
5.5 Mio. m^3

Technical Flood Control Unstrut

Application

Specific problems



Flood 2002/03: Usage less than 10 %, no controlled operation possible (inlet structure), possibly overtopping of the dike

→ optimization required

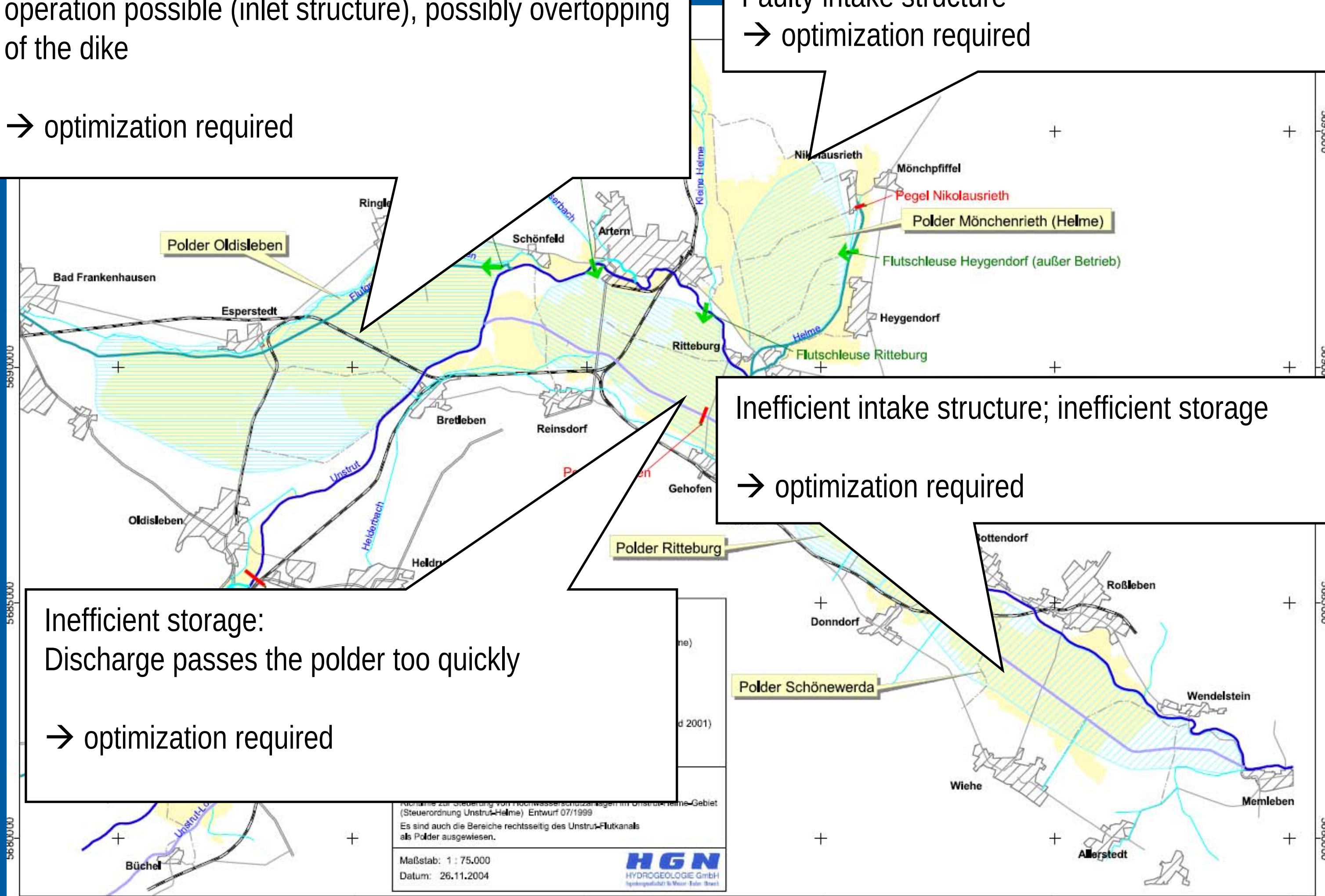
No controlled operation possible:
Faulty intake structure
→ optimization required

Inefficient intake structure; inefficient storage

→ optimization required

Inefficient storage:
Discharge passes the polder too quickly

→ optimization required



Technical Flood Control Unstrut

Application | Stochastic Generation of Rainfall

122 raingauges

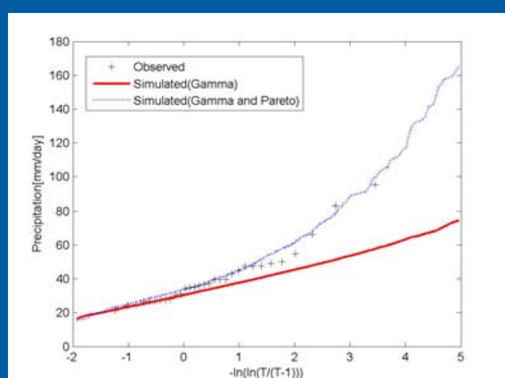
Measurements from 1961-2003

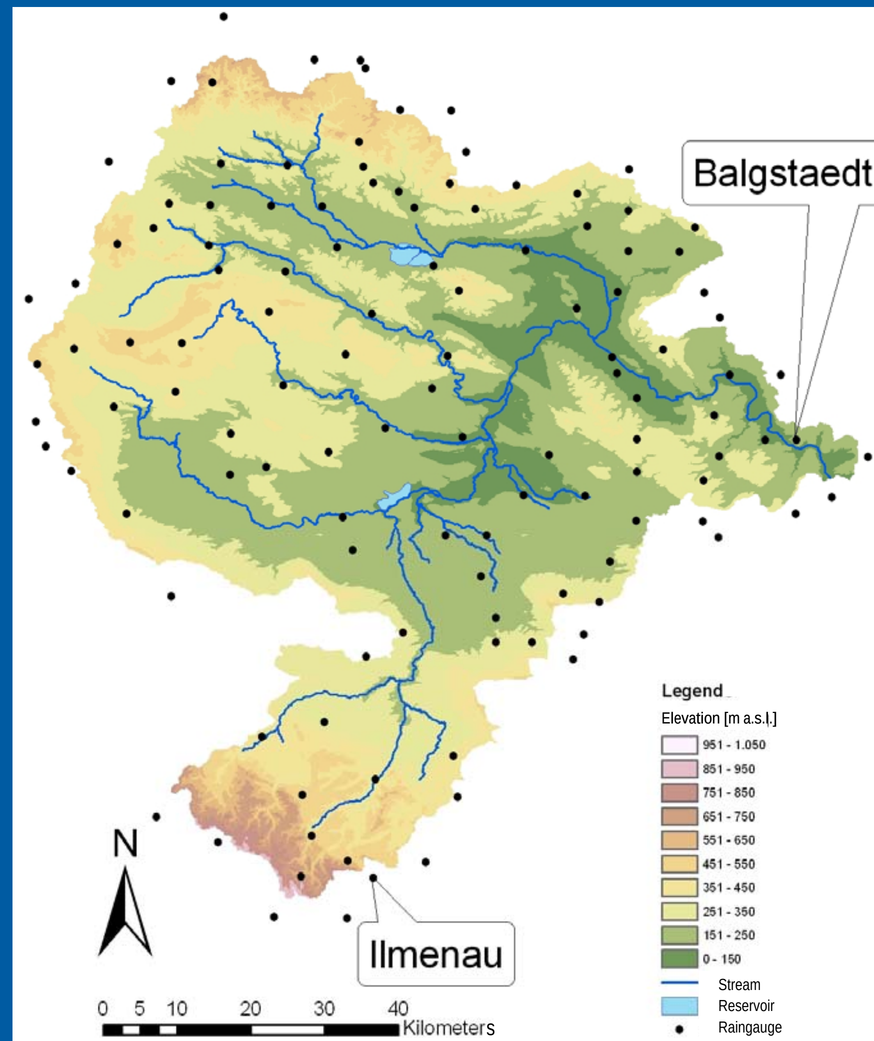
Simulation of 10 time series with a duration of 1000 years each

Distributions used:

- Gamma/Gumbel

- Gamma/Pareto



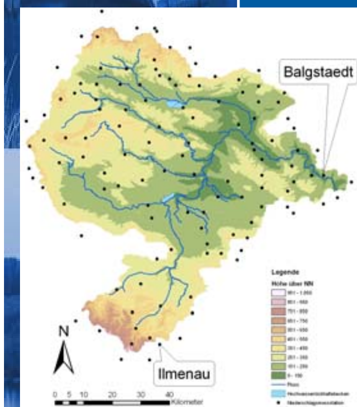


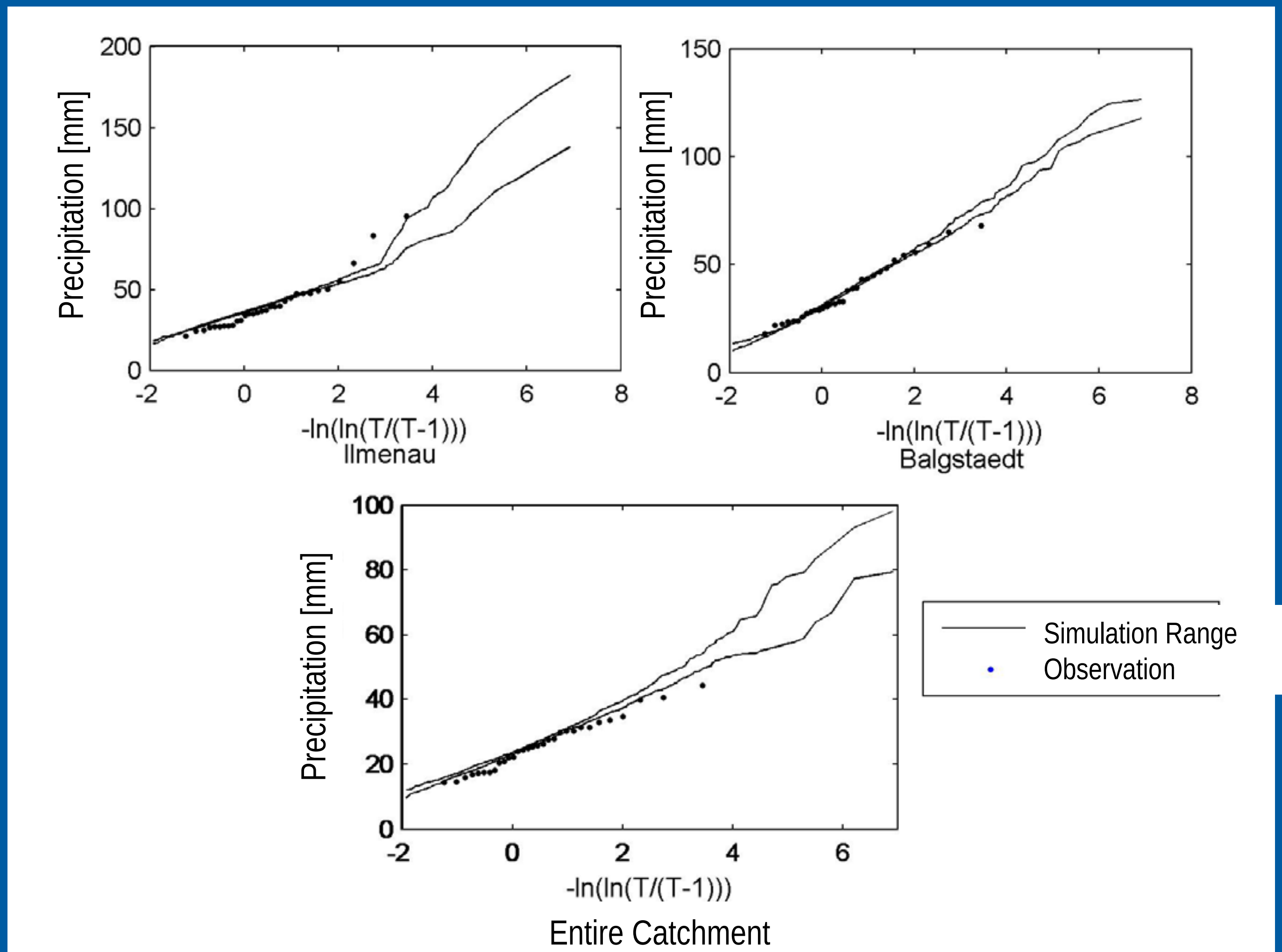
Unstrut catchment area:

6434 km^2

Application

Annual Maximum of Daily Precipitation

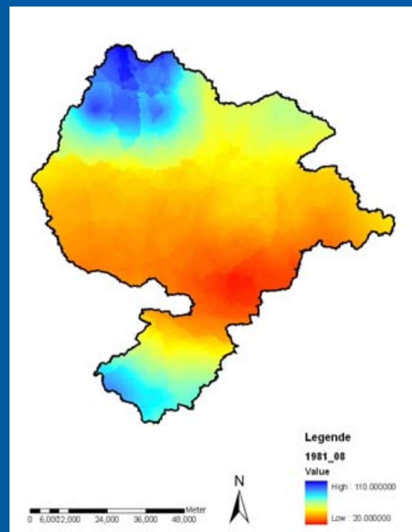


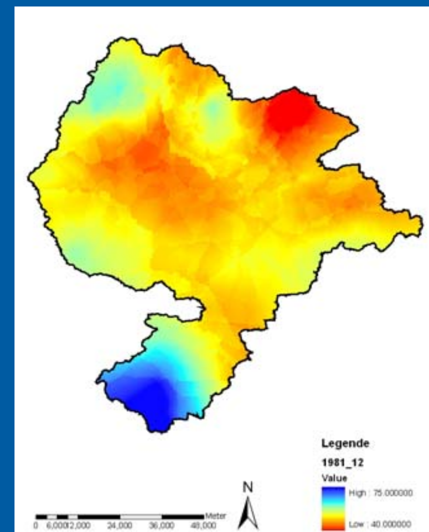


Technical Flood Control

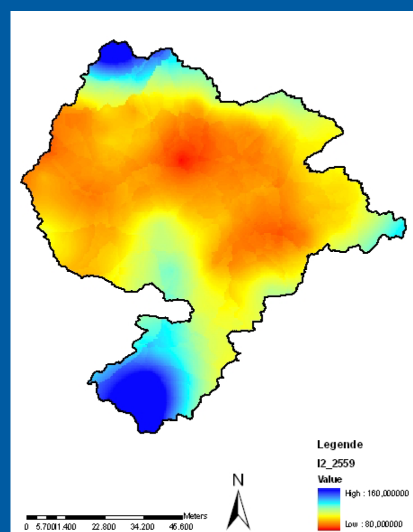
Comparison of the Spatial Rainfall Distribution

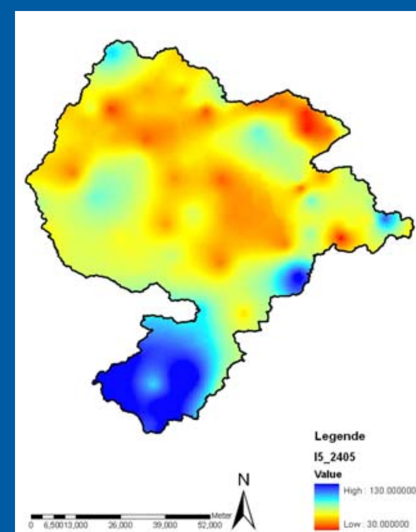
Observed





Simulated

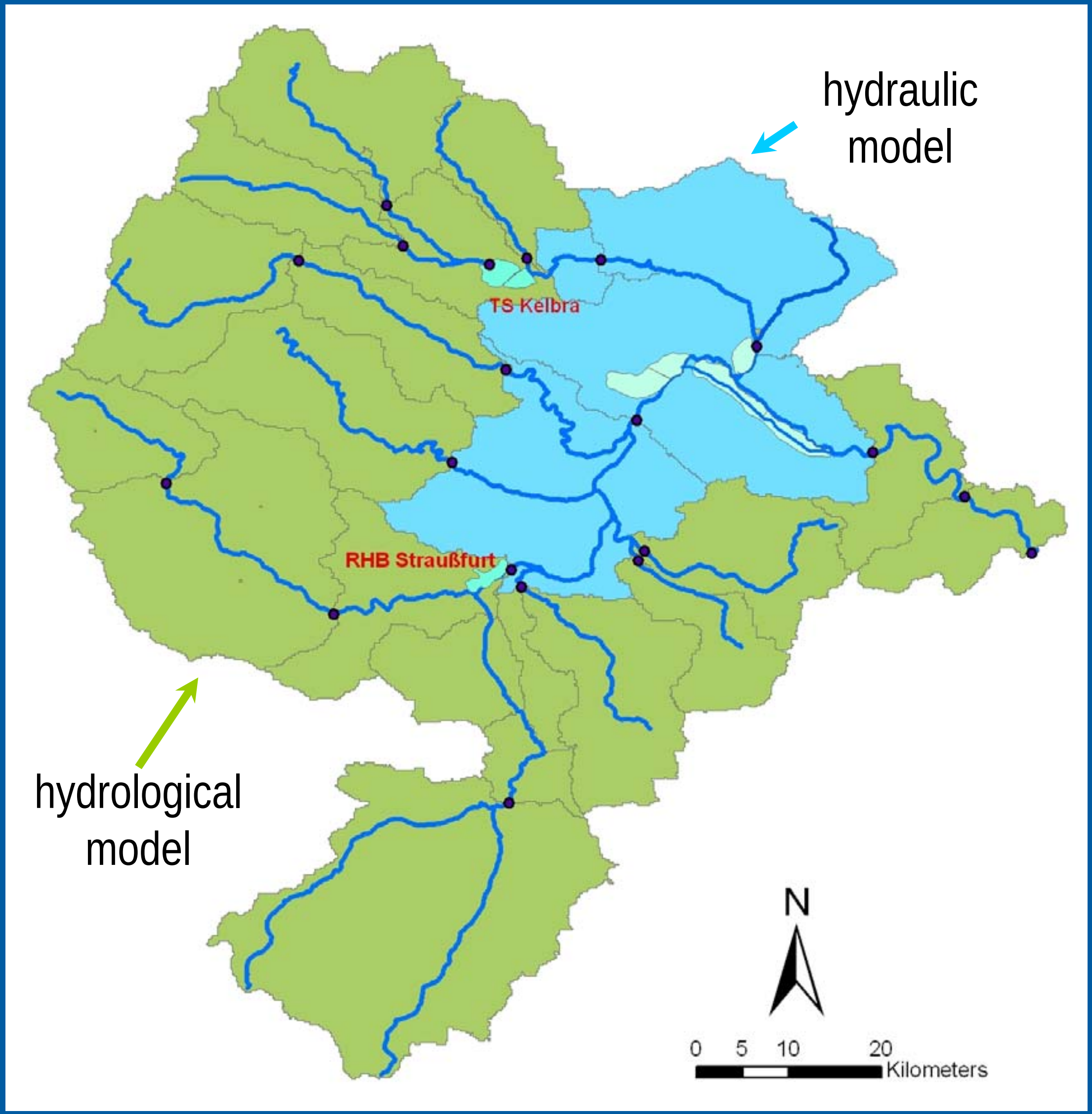




Application

Rainfall-Runoff Modelling

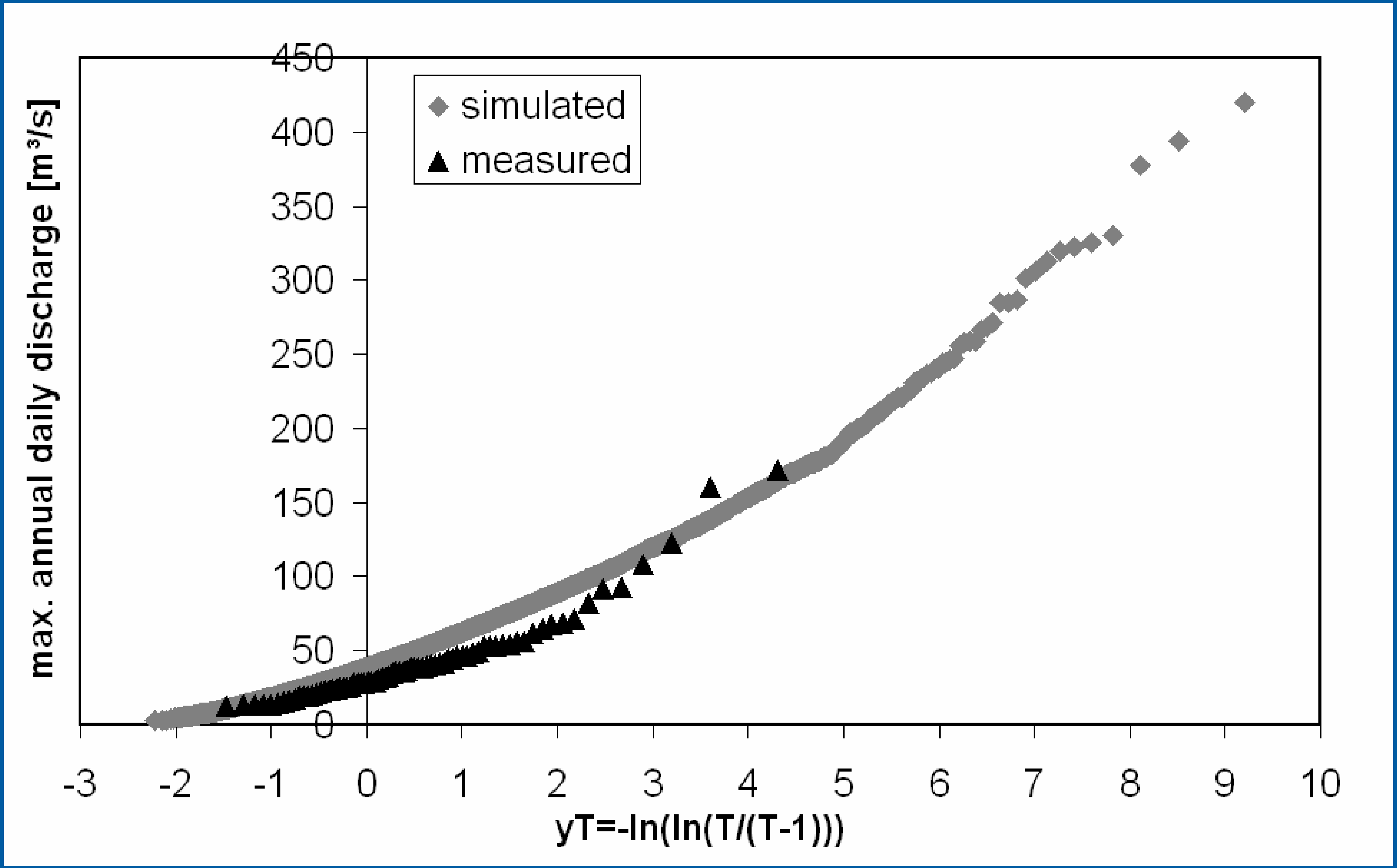
→ Generation of 10 Discharge Time Series of 1000 Years Duration each



Application

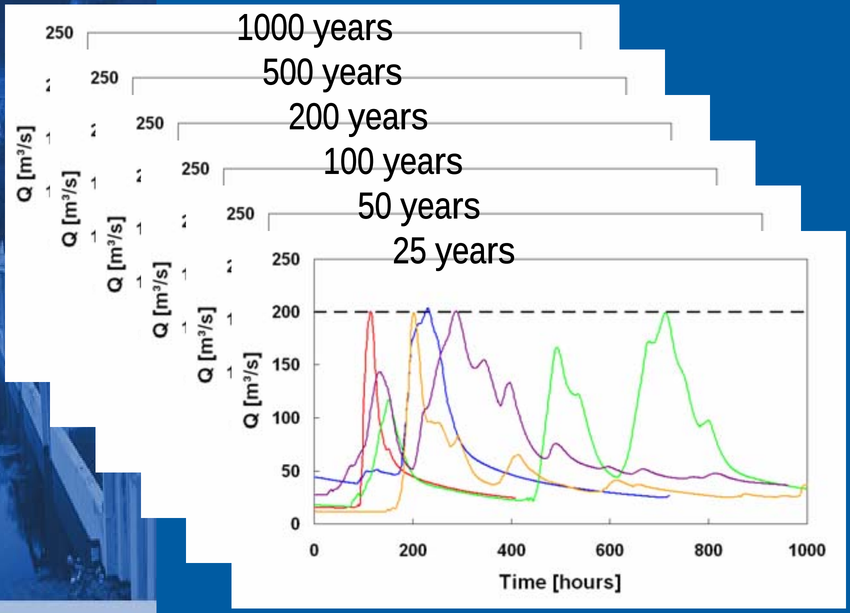
Generation of Hydrological Loads

Maximum Annual Daily Discharge



Technical Flood Control Unstrut

Application | Generation of hydrological loads



Selection of 5 hydrologic events for 6 different return periods:

25, 50, 100, 200, 500 and 1000 years
+ 1 event > 1000 years

→ 31 hydrologic events with :

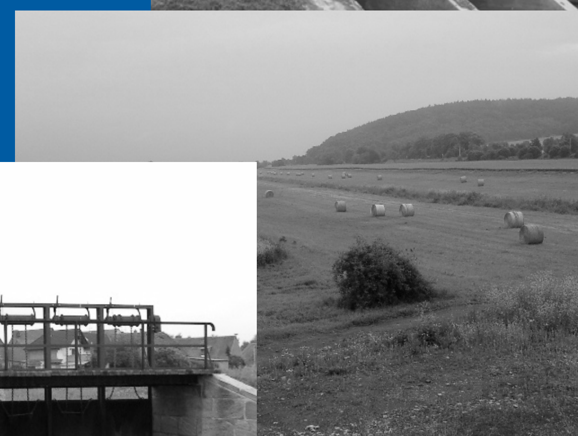
- different *spatial characteristics*
- different *peak*, *shape*, *volume*

Technical Flood Control Unstrut

Application | Structural Measures

→ Polders

- Implementation of new polders
- Subdivision of polders into sections
- Optimisation of intake structures
- Operation mode of polder inundation



Technical Flood Control Unstrut

Application

6 Different System States of the Technical Flood Control System

System State 1:	System State 2:	System State 3:
Status Quo:	Current system is fully functional	Addition of small polders in the upstream region
7 million m³)	2 dams (~57 million m³)	2 dams (~57 million m³)
5 45 million m³)	5 polders (~45 million m³)	9 polders (~77 million m³)

System State 4:	System State 5:	System State 6:
Addition of larger polders in the upstream region	Controlled operation of the polders	Implementation of larger polder inlet structures
2 dams (~57 million m³)	2 dams (~57 million m³)	2 dams (
9 polders (~85 million m³)	9 polders (~85 million m³)	9 polders (~

low cost

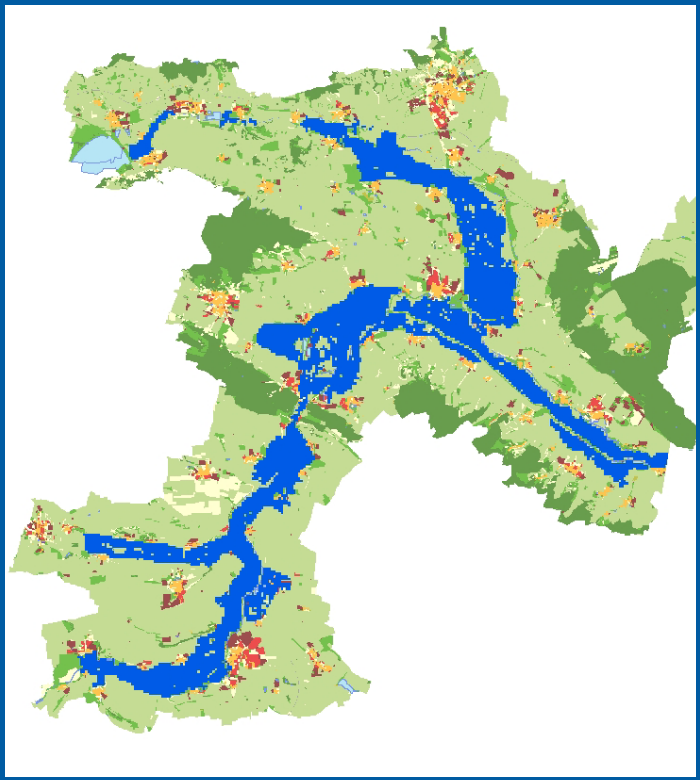
high cost

Application | Scenario Space

Technical Flood Control Unstrut

- 31 Hydrologic Events, i.e. Floods
- 6 Different System States

→ 186 Scenarios

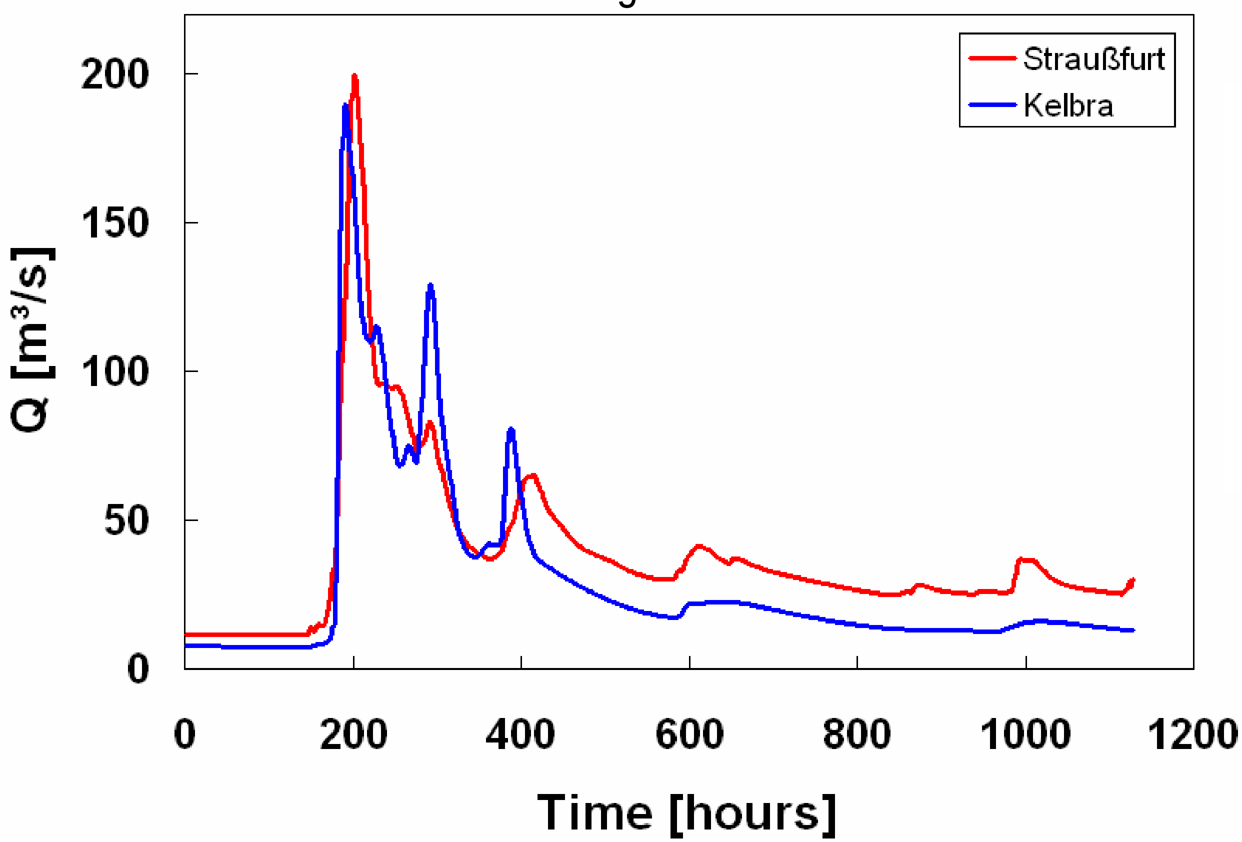


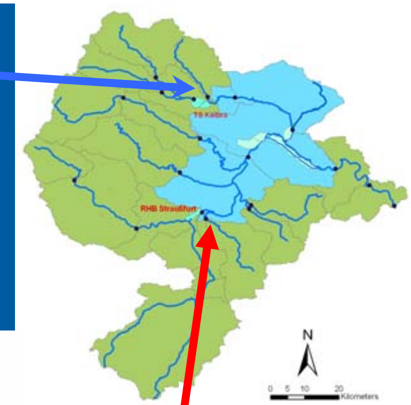
Application

Straußfurt and Kelbra (return period 25 years at Straußfurt)

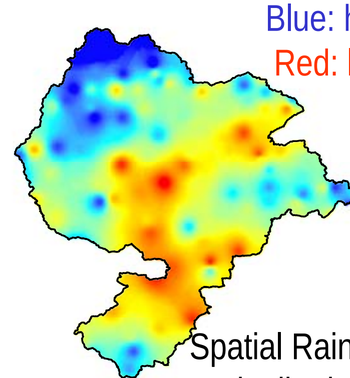
Technical Flood Control Unstrut

Inflow Discharge Time Series



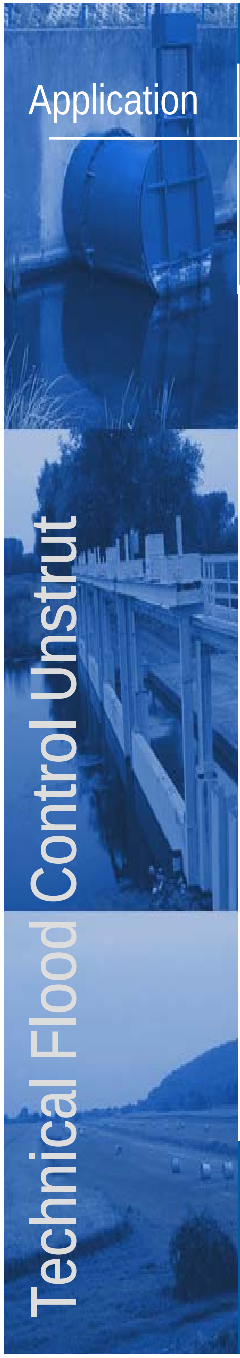


Blue: high
Red: low



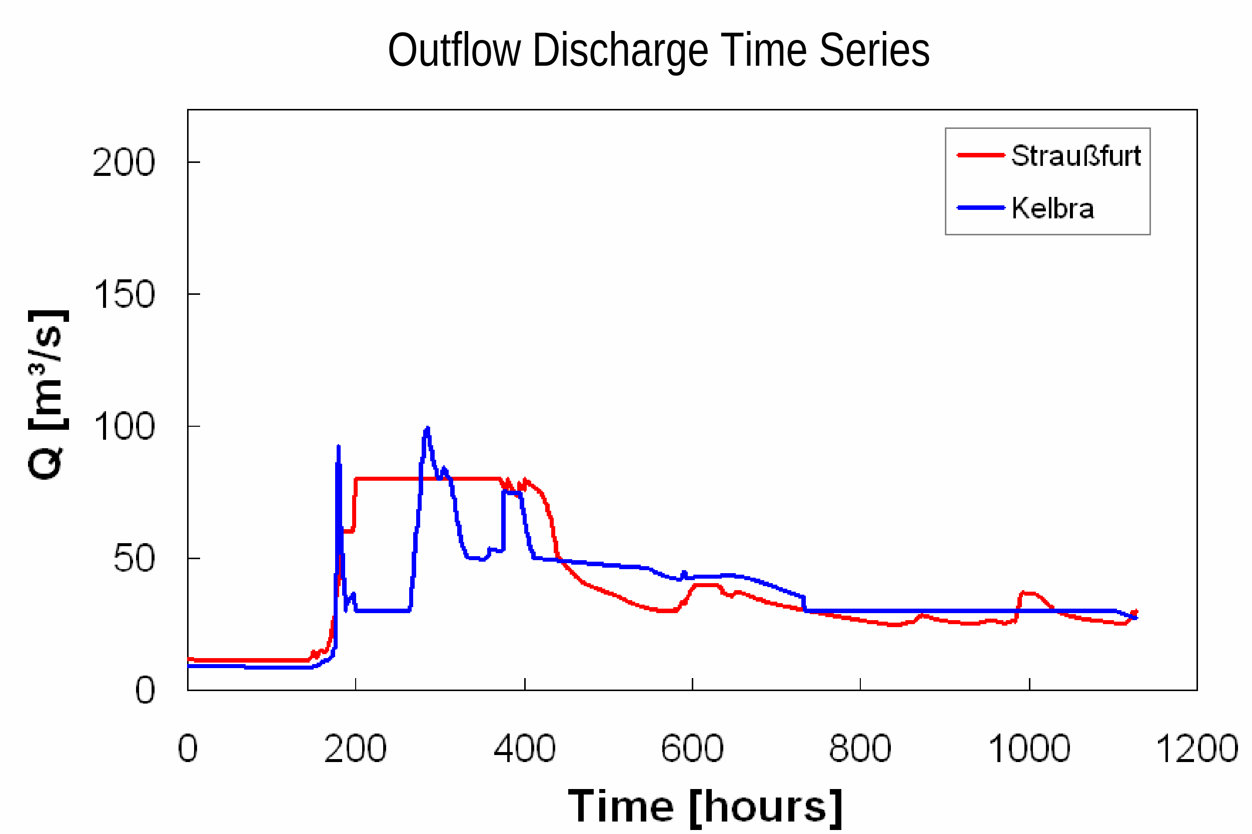
Spatial Rainfall Distribution

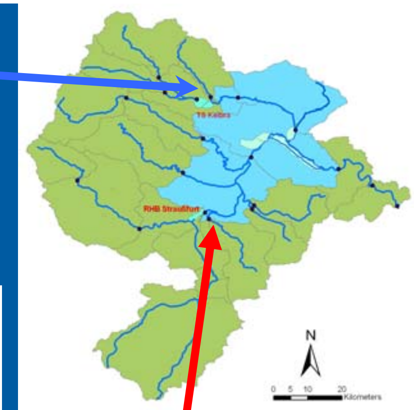
Technical Flood Control Unstrut

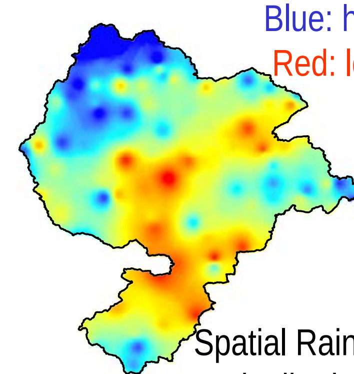


Application

Straußfurt and Kelbra (return period 25 years at Straußfurt)



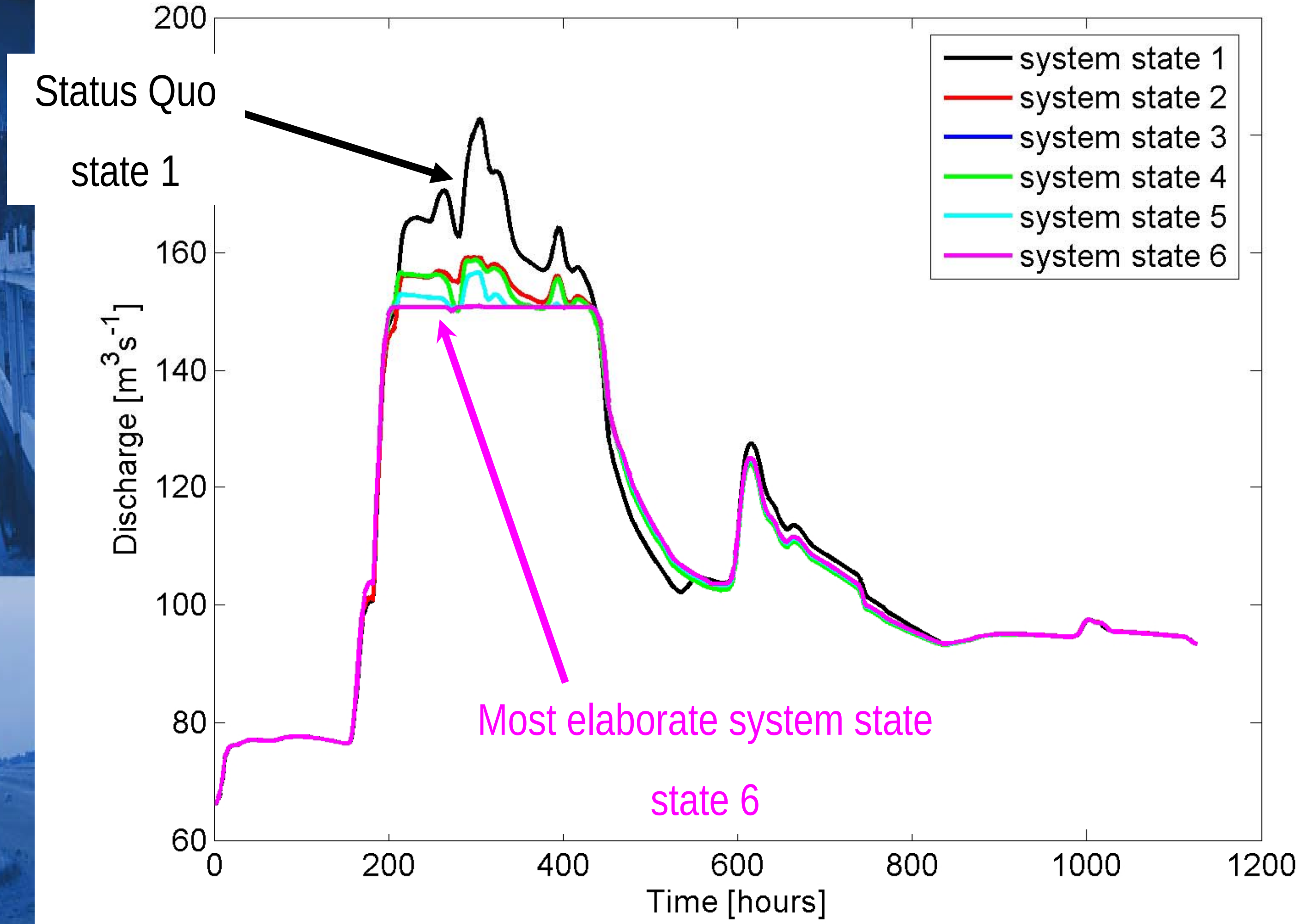


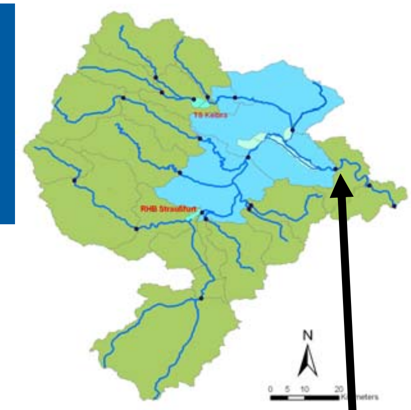


Application

Wangen (return period 25 years at Straußfurt)

Technical Flood Control Unstrut





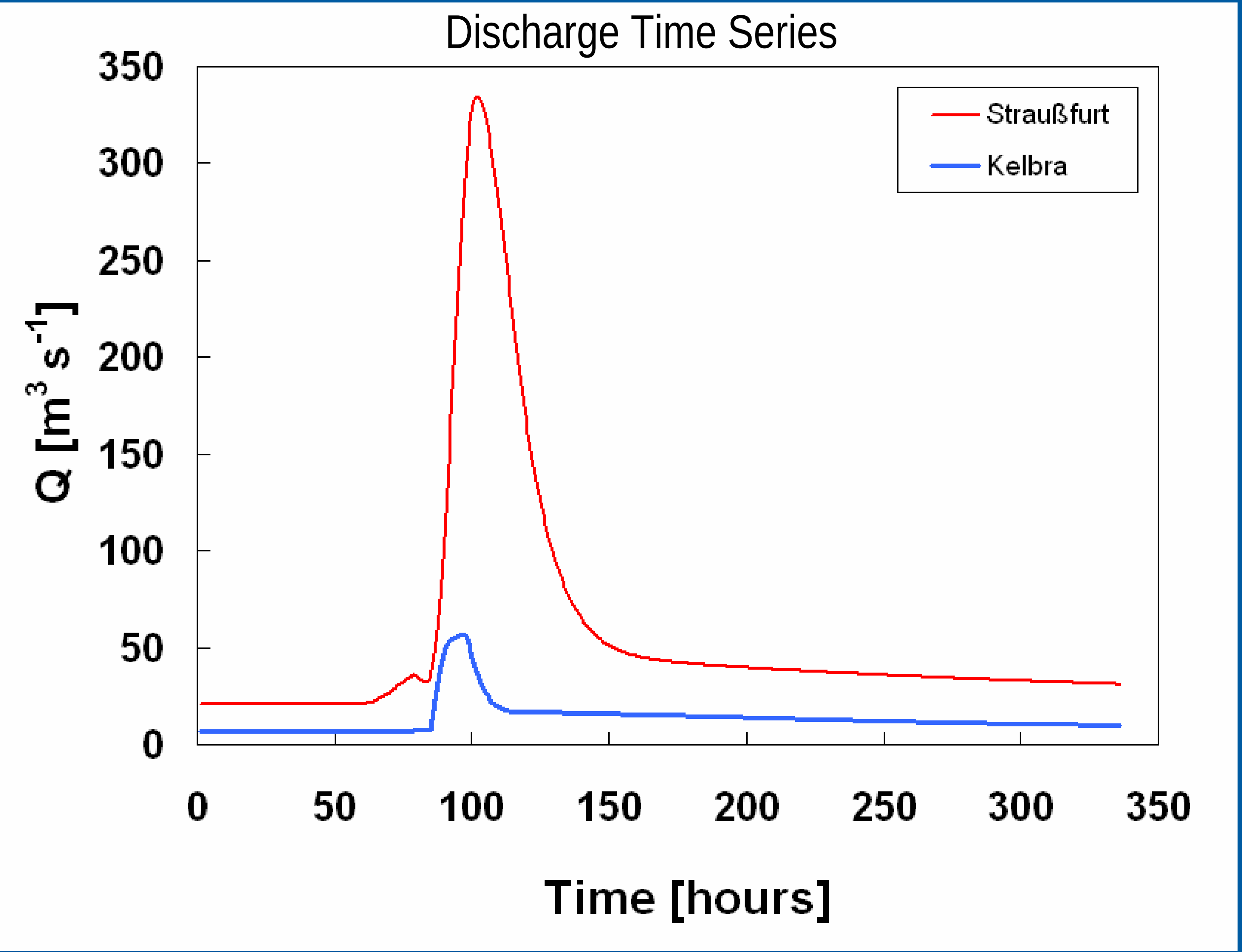
Wangen

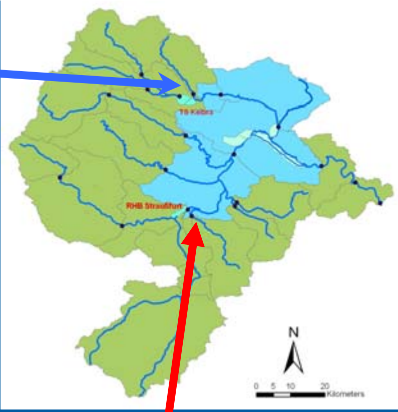
state 1 vs 6

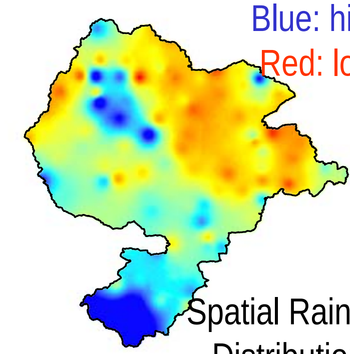
17% peak reduction

Application

Straußfurt and Kelbra (return period 200 years at Straußfurt)







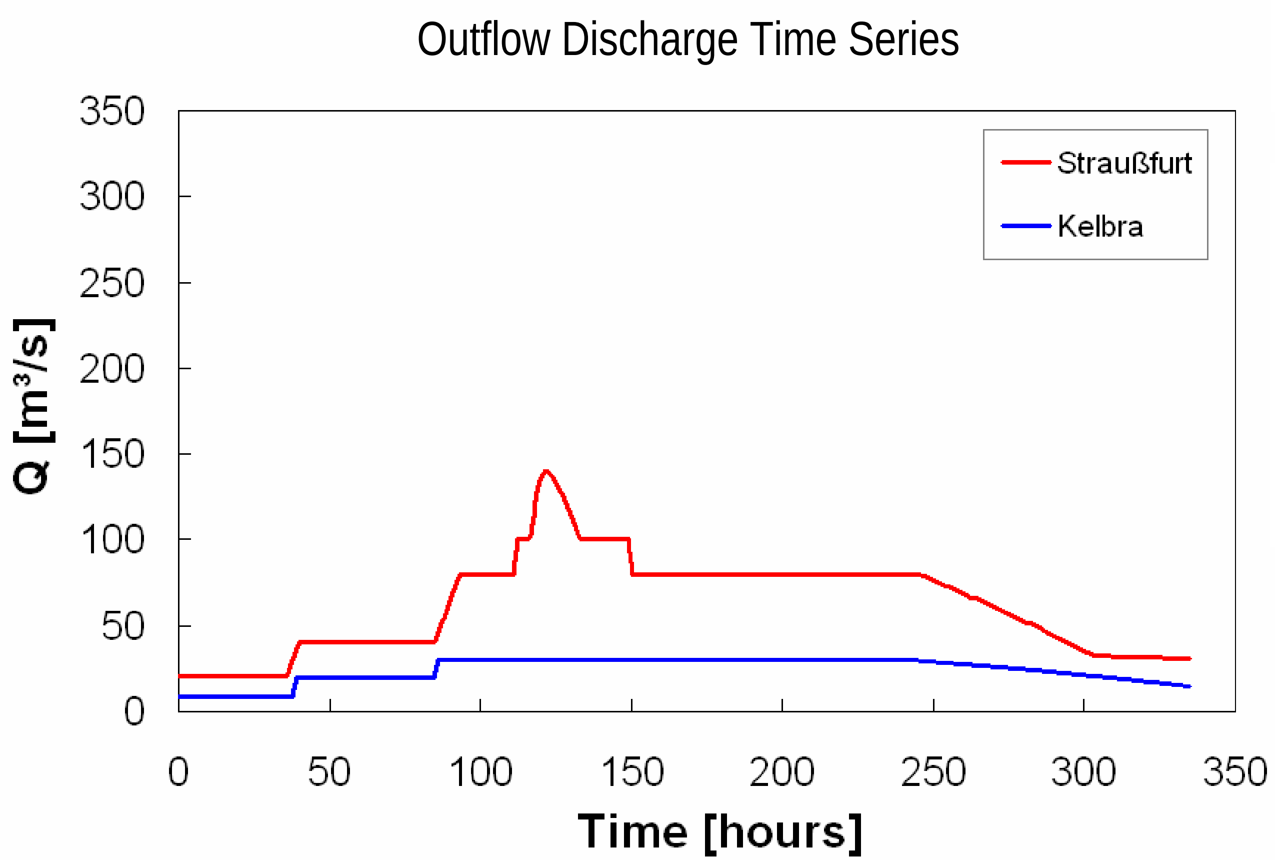
Spatial Rainfall Distribution

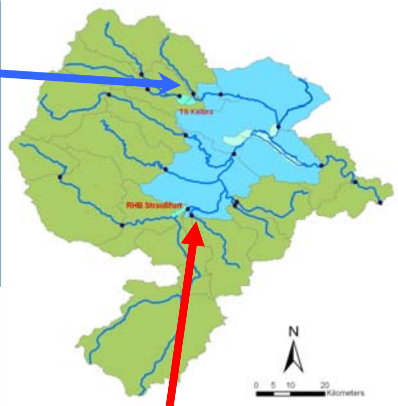
Technical Flood Control Unstrut

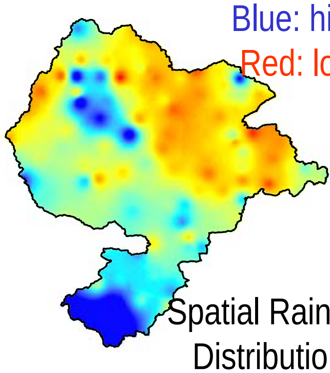
Technical Flood Control Unstrut

Application

Straußfurt and Kelbra (return period 200 years at Straußfurt)



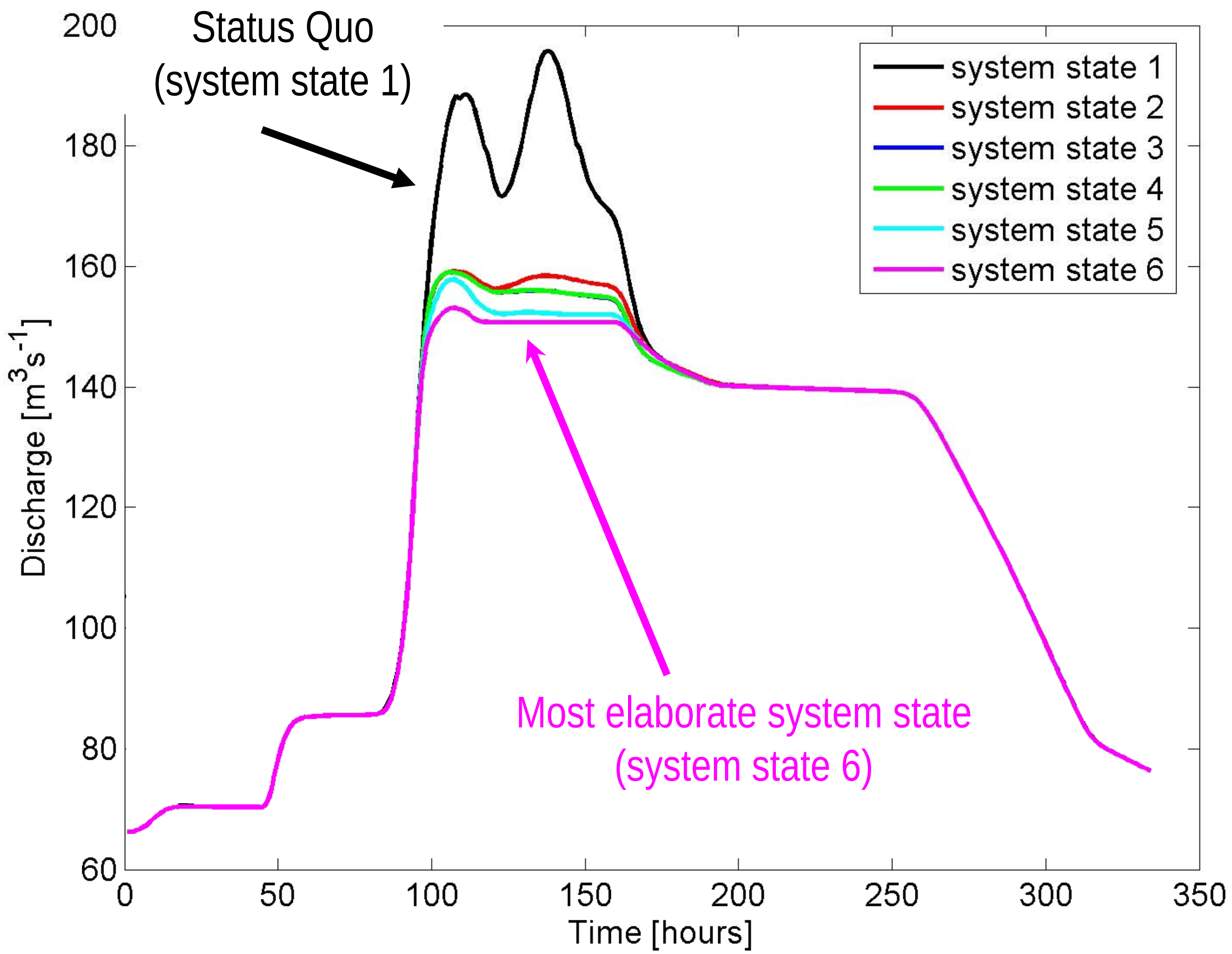




Application

Wangen (return period 200 years at Straußfurt)

Technical Flood Control Unstrut



Wangen

state 1 vs 6

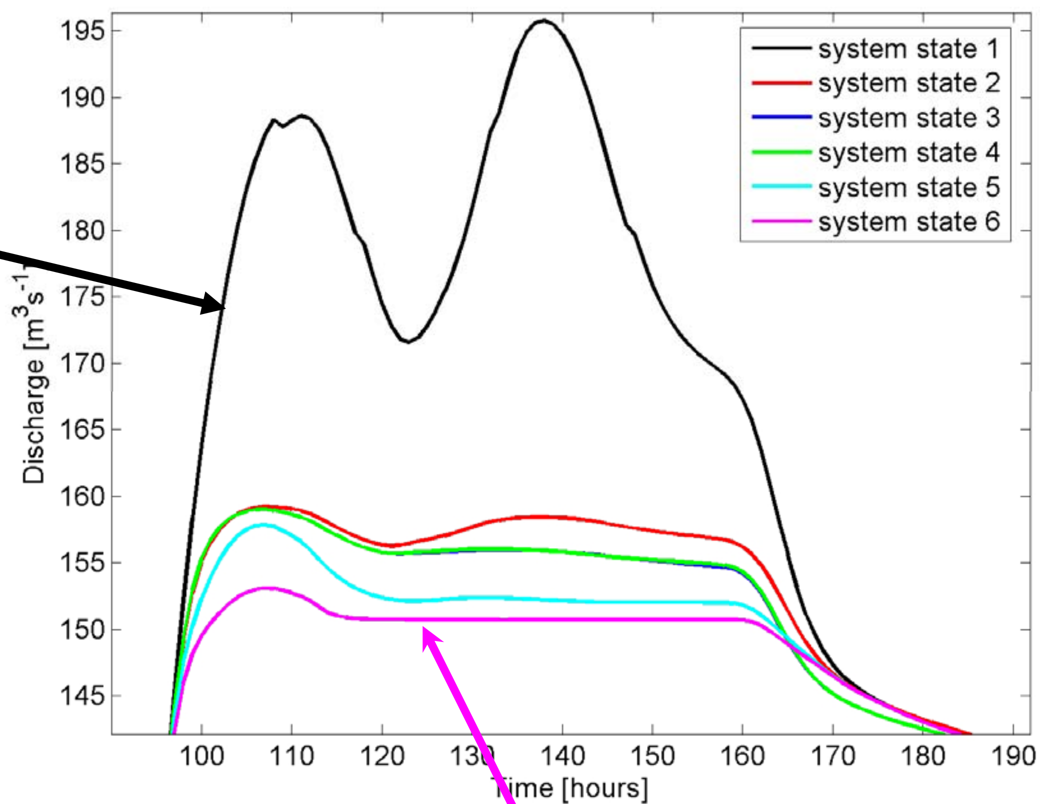
23% peak reduction

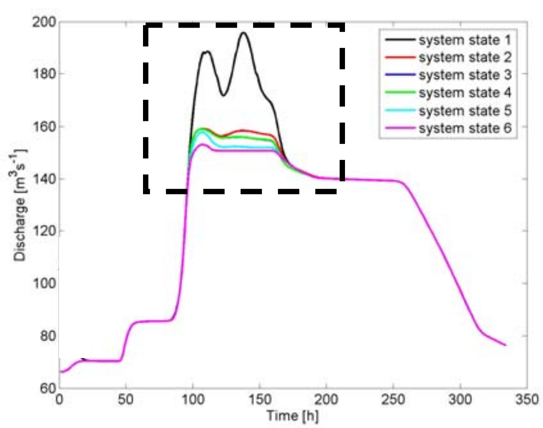
Technical Flood Control Unstrut

Application

Wangen (return period 200 years at Straußfurt)

Status Quo
(system state 1)



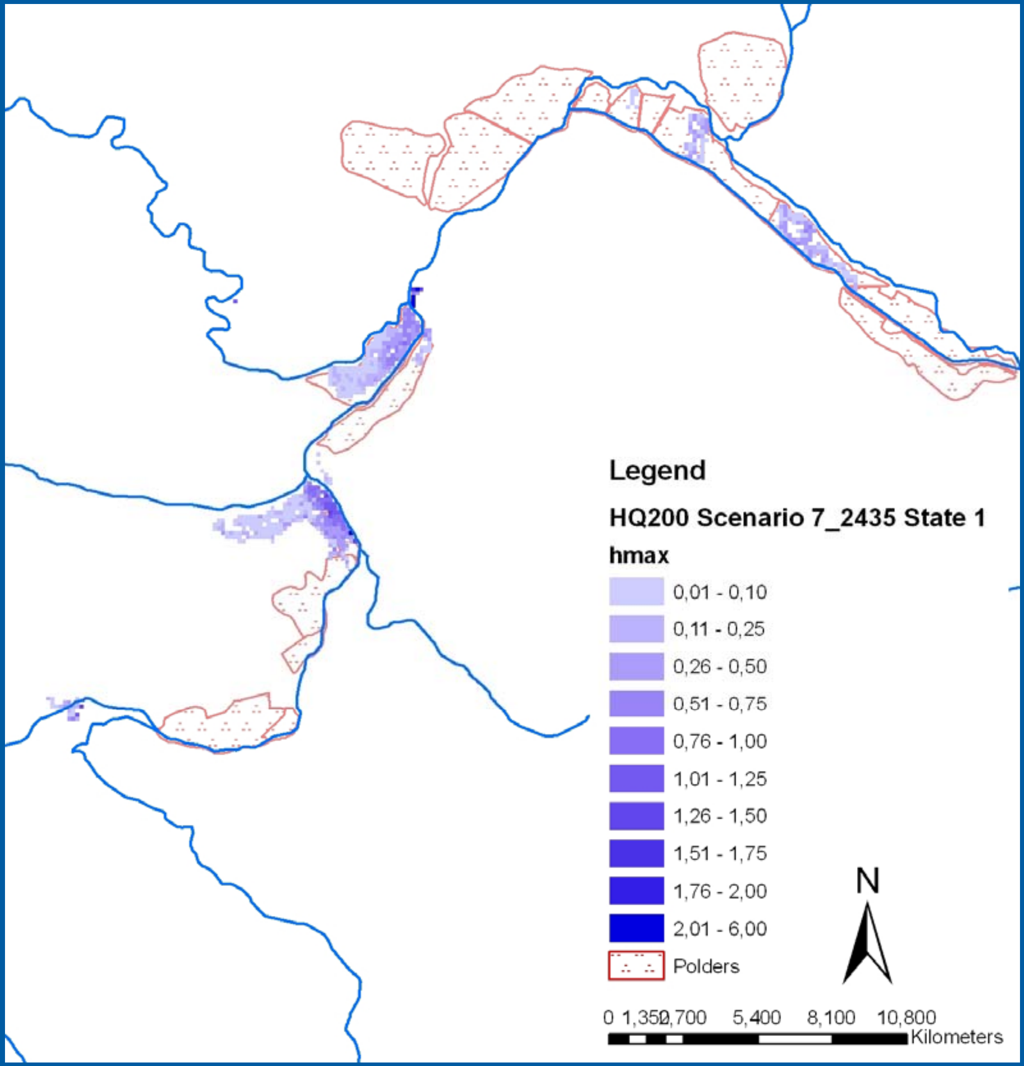


Most elaborate system state
(system state 6)

Technical Flood Control Unstrut

Application

Inundation area (return period 200 years at Straußfurt)

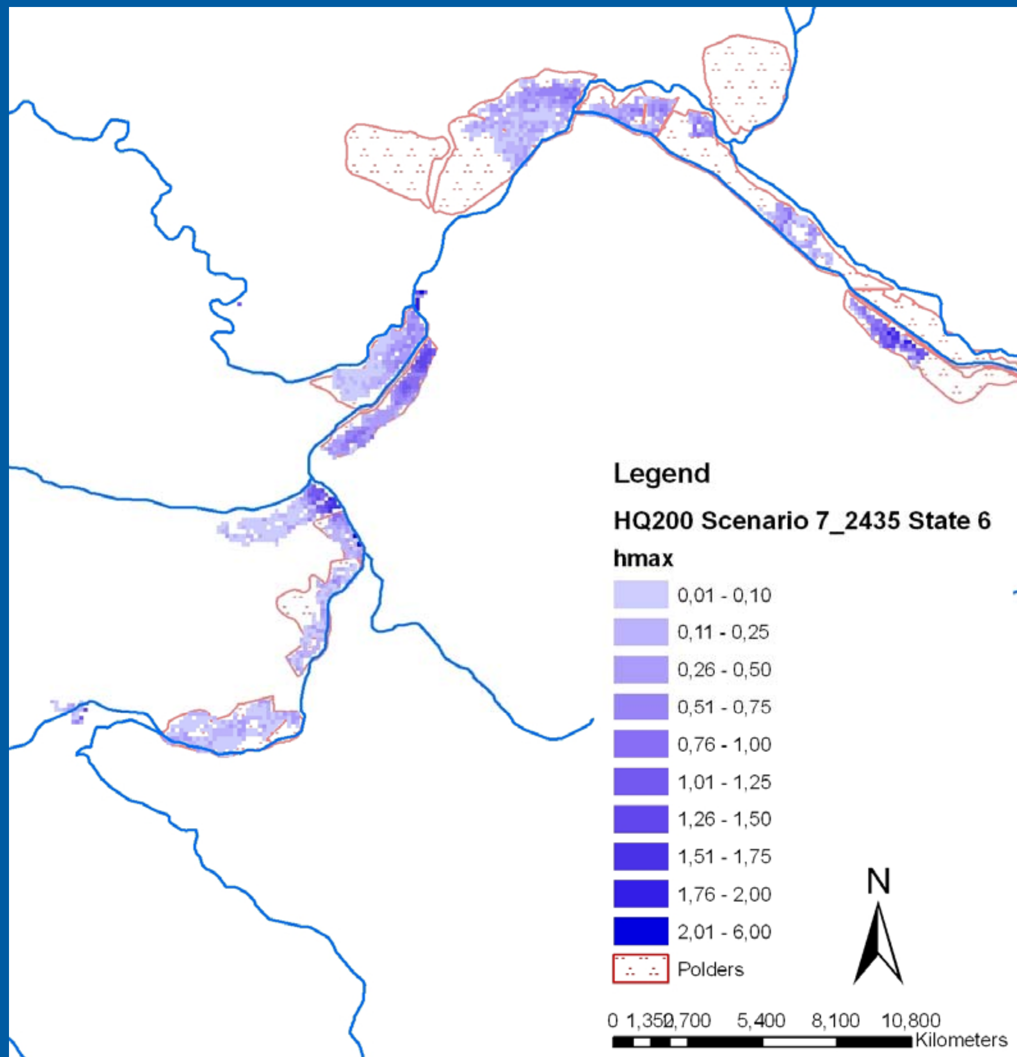


Inundation area for system state 1

Application

Technical Flood Control Unstrut

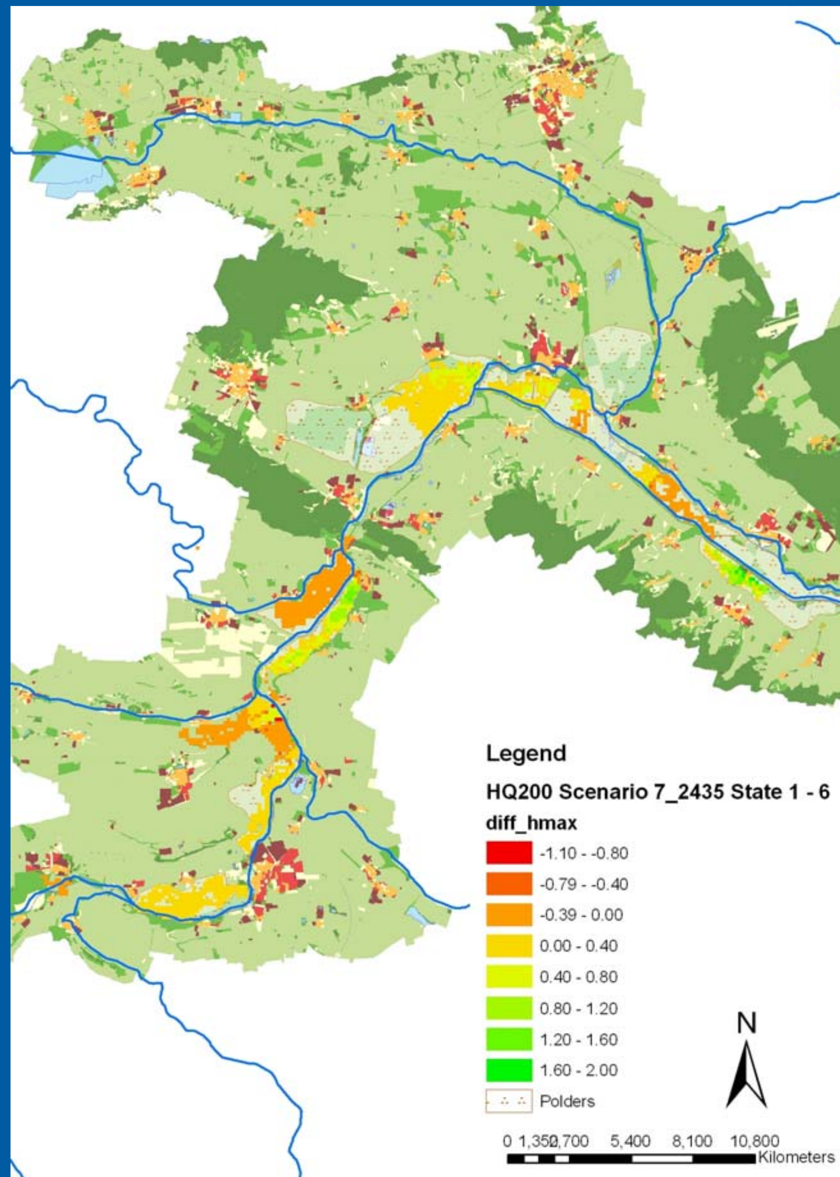
Inundation area (return period 200 years at Straußfurt)



Inundation area for system state 6

Application

Difference in inundation area (return period 200 years at Straußfurt)

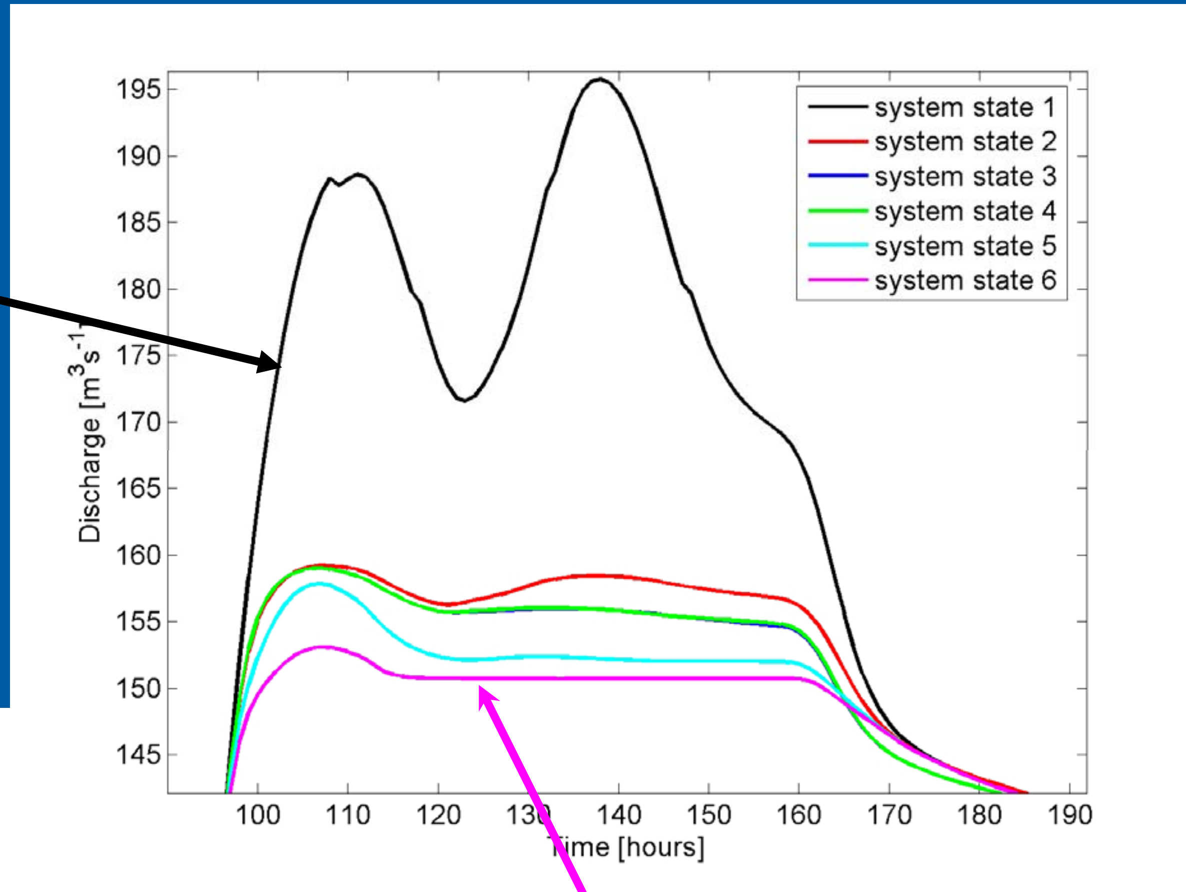


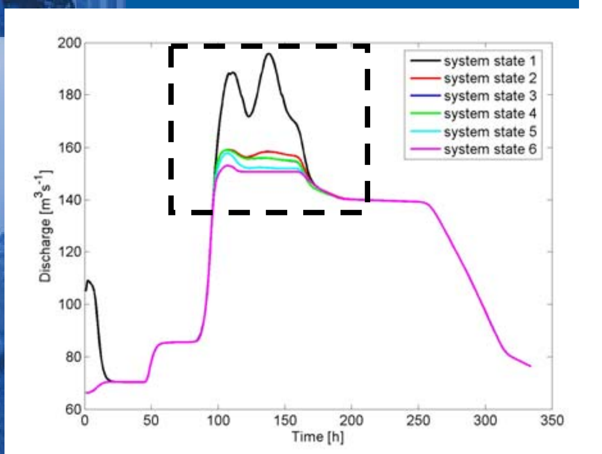
Technical Flood Control Unstrut

Application

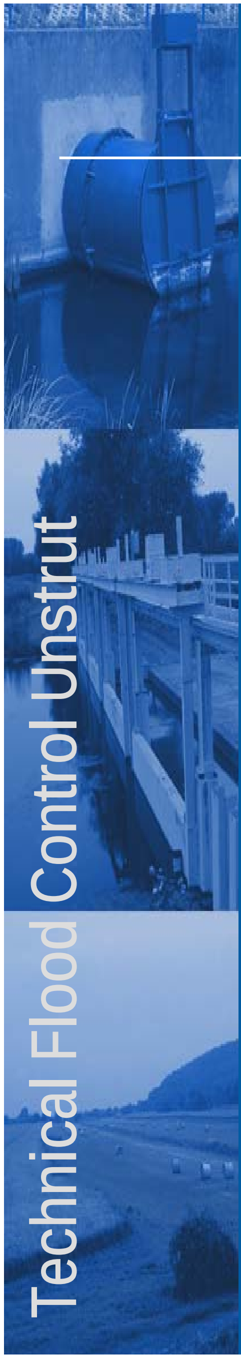
Wangen (return period 200 years at Straußfurt)

Status Quo
(system state 1)





Most elaborate system state
(system state 6)



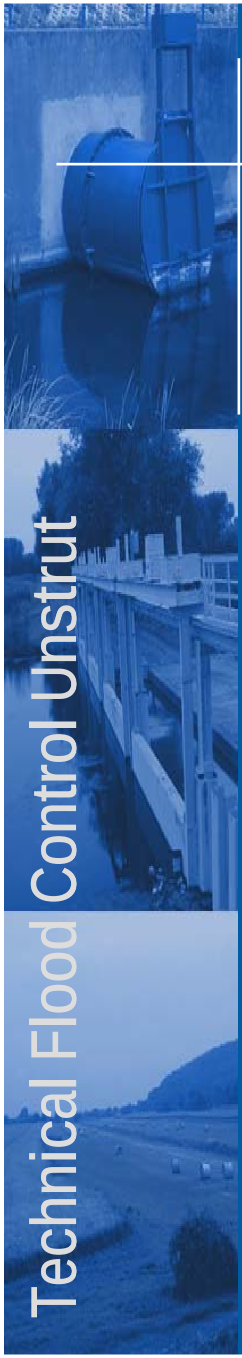
Outline

I. Motivation

II. Methodology

III. Application

IV. Summary and Outlook



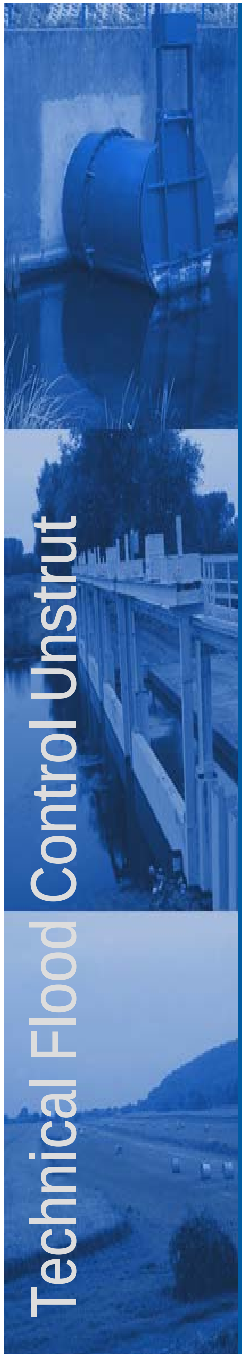
Summary and Outlook

Summary

- Elements of an assessment and optimization methodology for flood control systems have been introduced
- The assessment methodology makes use of a broad range of flood scenarios, rather than using one single design flood
- Combined with socio-economic analysis and multi criteria decision making the methodology is suitable for planning complex flood control systems

Outlook

- Assessment of the entire set of 186 scenarios, in combination with socio-economic analysis and multi-criteria decision making



Funding / Collaboration

- BMBF / RIMAX
- TMLNU, MLU LSA, DWD

Federal Ministry of Education and Research

rimax Risk management of extreme flood events

DWD

Thank you for your attention !