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Synthetic Hydrograph Generator for Reservoirs: Options and Limitations

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Outline

- Introduction
  - Backgrounds of this presentation
  - Synthetic hydrographs
- Simulation of design hydrographs following the German Dam Standard
- Limitations of this method
- Conclusion

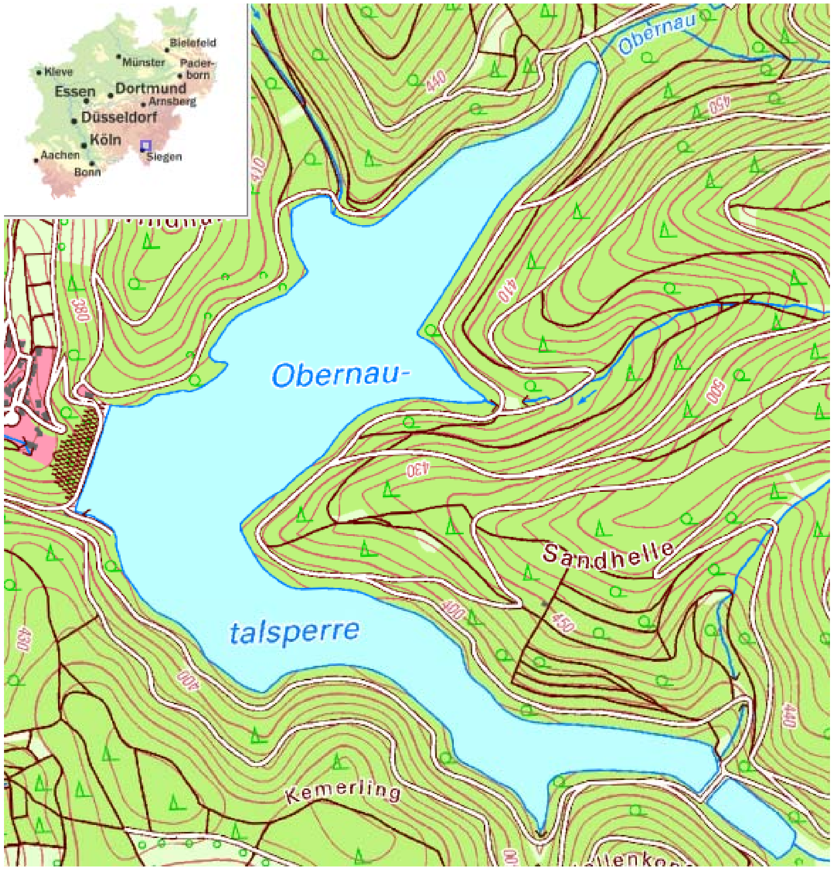
Introduction

The presented results are obtained from master thesis:

"*Development of a stochastic reservoir management tool*"

Case study: Obernau Reservoir

- ➲ Catchment: 21,5 km²
- ➲ Volume: 14,8 Mio. m³
- ➲ Dam height: 46,0 m
- ➲ Purpose: Drinking water supply and flood control



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Introduction

The German Dam Standard (DIN 19700 (2004)) postulates for the design of reservoirs and flood control basins the use of hydrographs instead of peak flows

Advantages

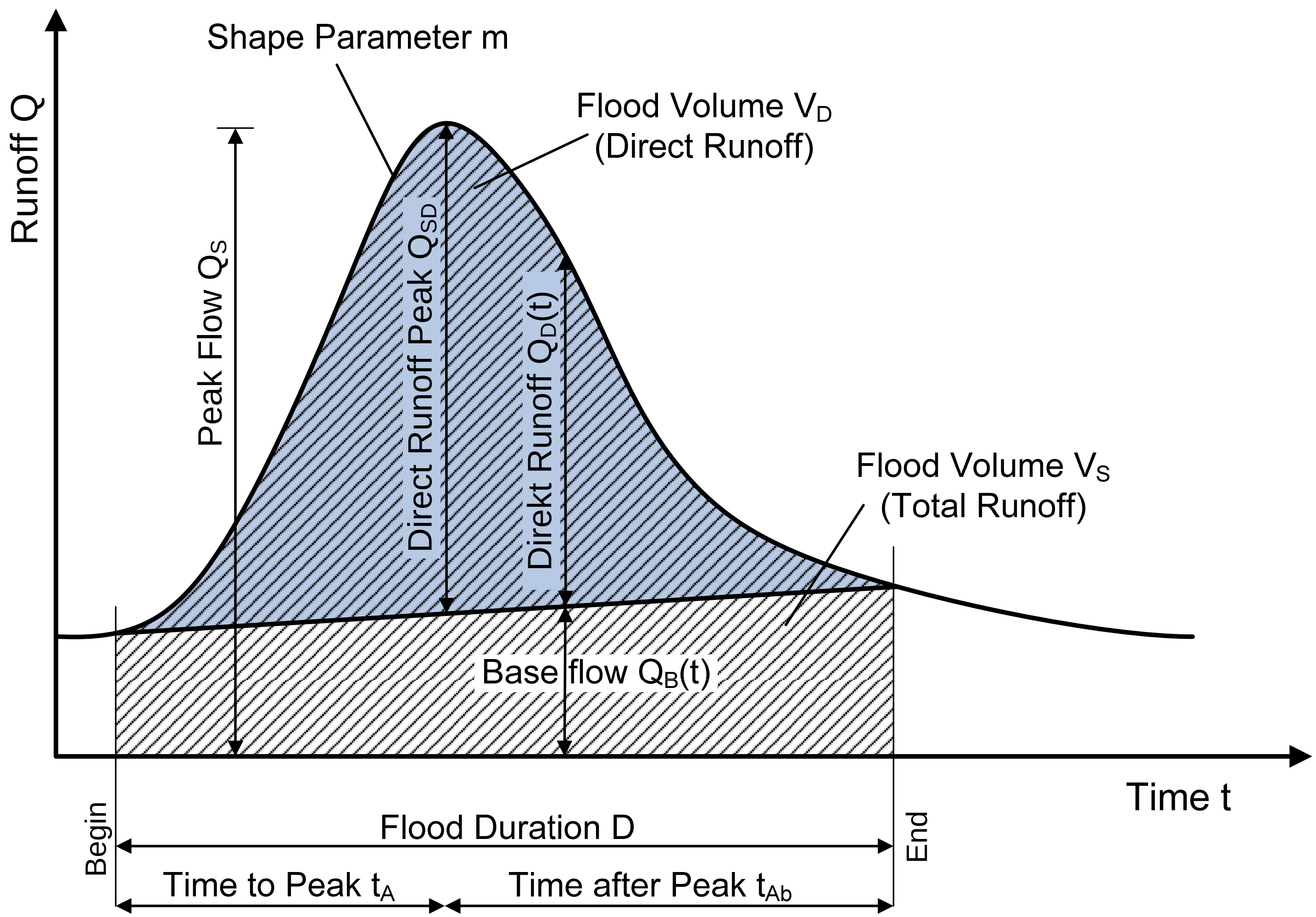
- ➲ Consideration of lake retention and empty flood control storage
- ➲ Detailed information about storage maximizing events

Disadvantages

- ➲ Mostly no information about extreme hydrographs available
- ➲ Hydrographs are substantially more complex than peak flows

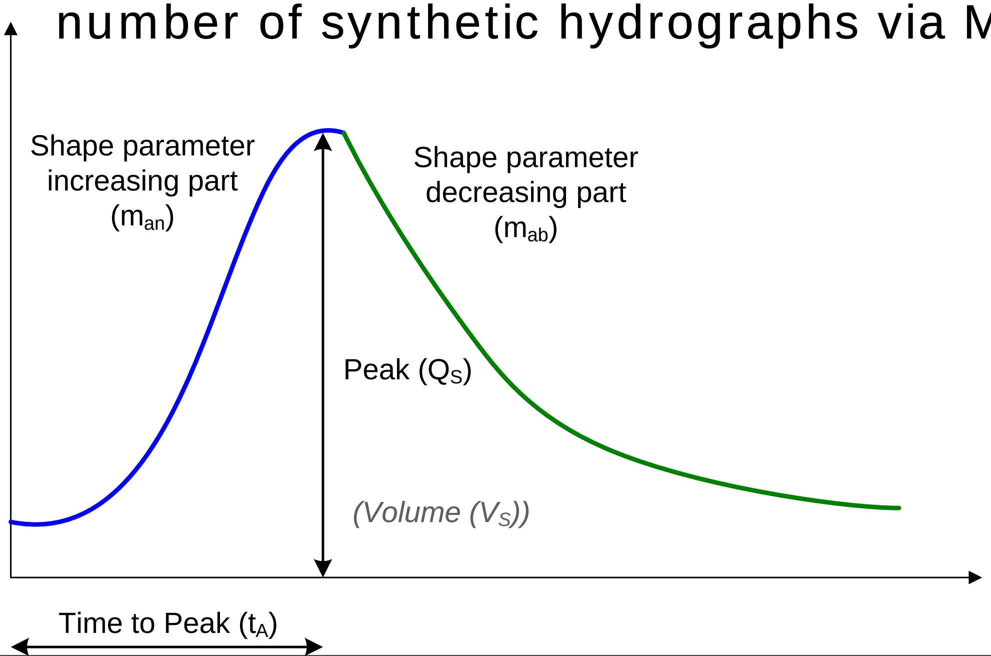
→ **Stochastic methods required!**

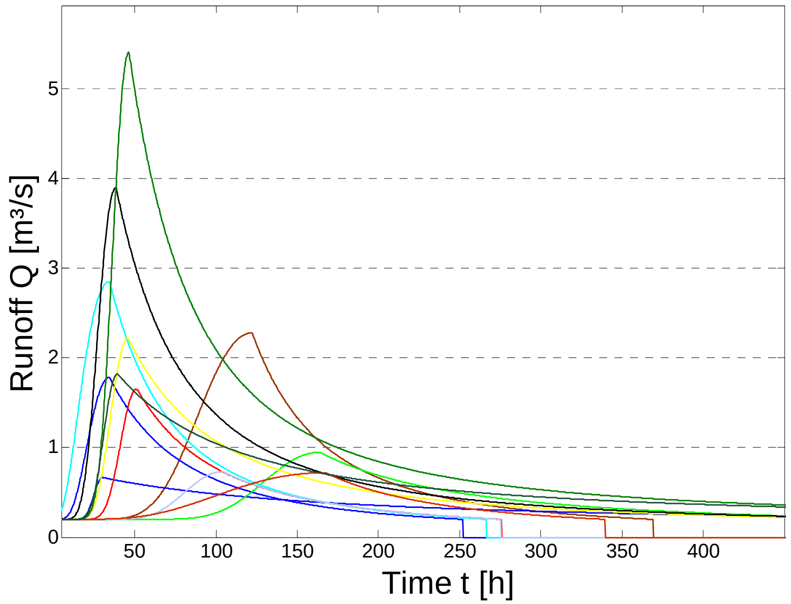
Specific parameters of flood waves



Simulation

- German guideline "Generation of design hydrographs following DIN 19700 in North Rhine-Westphalia" MUNLV (2004)
- Stochastic-deterministic method to simulate design hydrographs for reservoirs as an alternative to rainfall-runoff modells
- Determination of parameter sample based on recorded hydrographs
- Fitting distribution functions to samples allows for generating any number of synthetic hydrographs via Monte-Carlo method





Kozeny-function (Gamma-distribution) by DYCK (1980)

$$Q_D(t) = (Q_S - Q_B(t)) \cdot \left(\left(\frac{t}{t_A} \right)^m \cdot e^{m \cdot \left(1 - \frac{t}{t_A}\right)} \right) + Q_B(t)$$

With

$Q_D(t)$: Runoff at time t [m³/s]

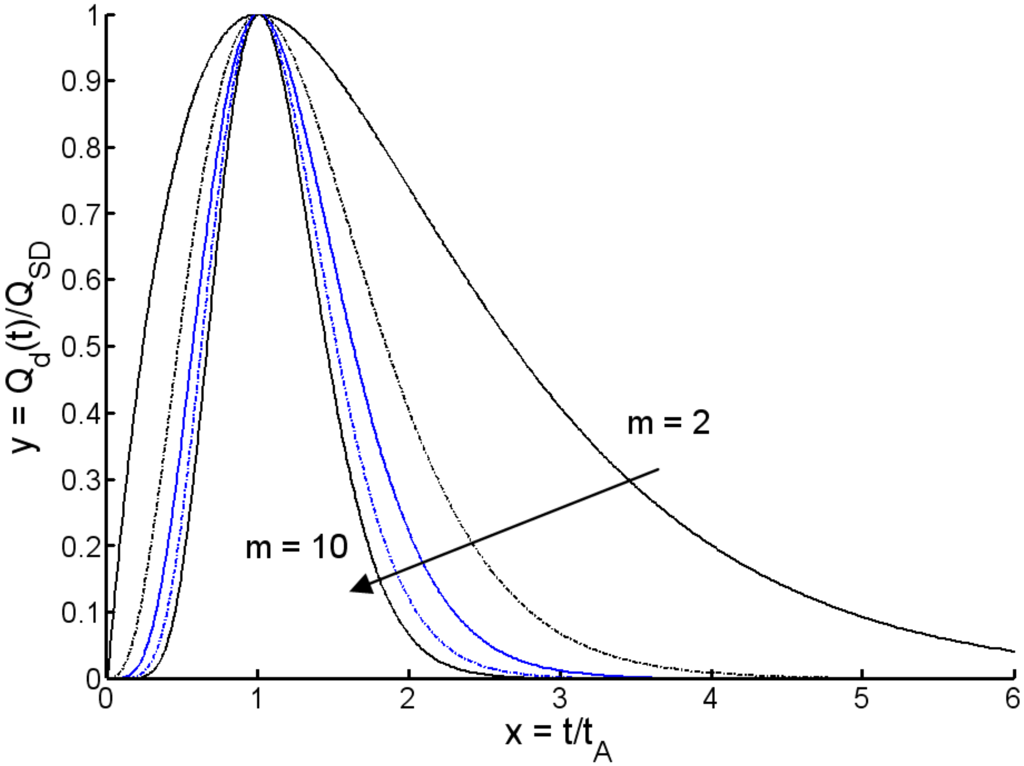
Q_S: Peak flow [m³/s]

m: Shape parameter [-]

t_A: Time to peak [h]

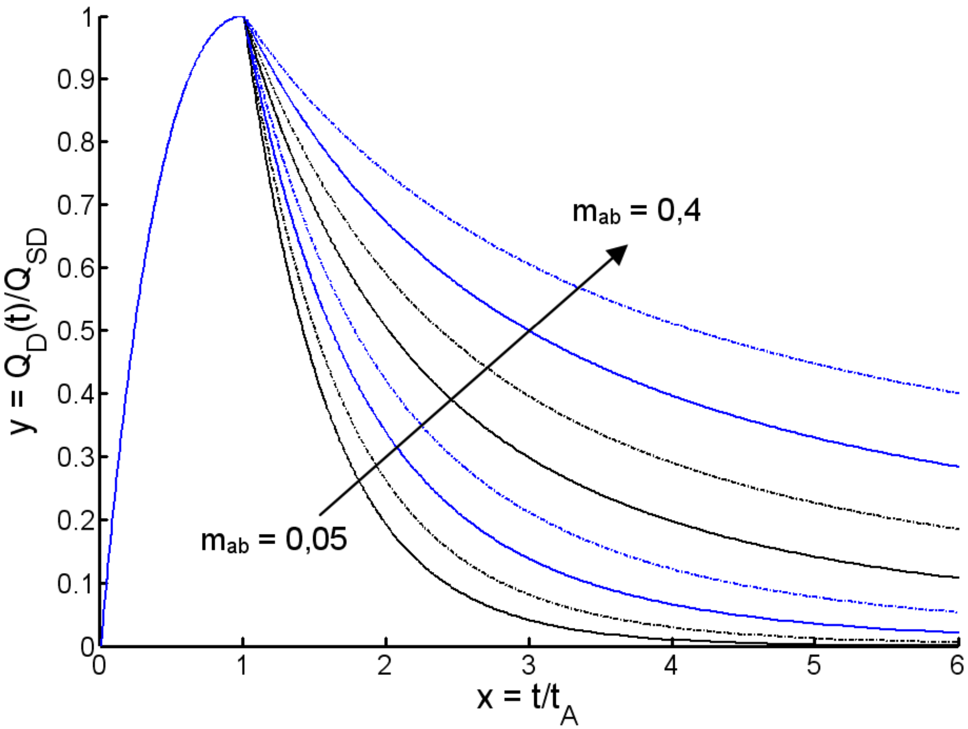
t: Time [h]

$Q_B(t)$: Baseflow [m³/s]



Hyperbolic function by LEICHTFUSS & LOHR (1999)

$$Q_D(t) = Q_0 \cdot \left(1 - \left(\frac{(e^k)^a - (e^{-k})^a}{(e^k)^a + (e^{-k})^a}\right)\right)$$



With

$Q_D(t)$: Runoff at time t [m³/s]

Q_S: Peak runoff [m³/s]

m_{ab}: Shape parameter [-]

t: Time [1d = 1]

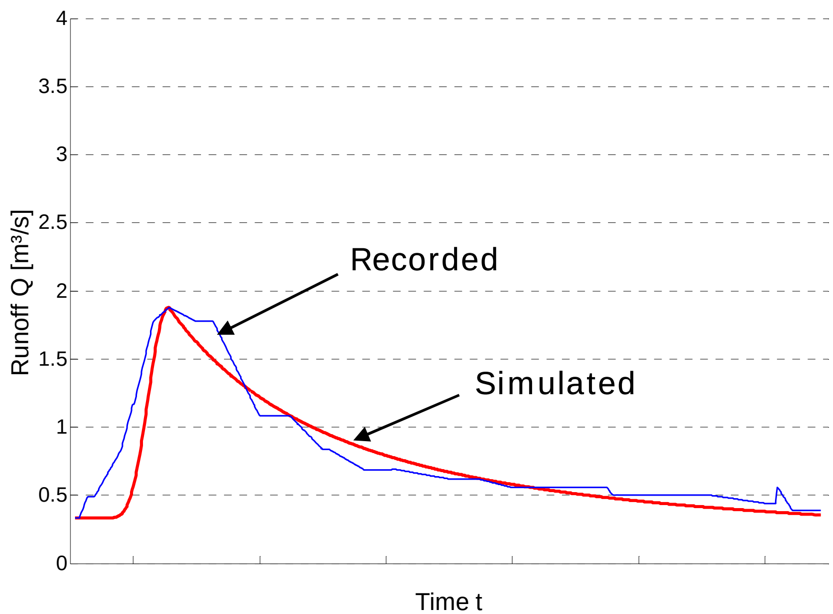
t_S: Start time of decreasing

Q_0: Defined max. runoff [m³/s] e.g. PMF

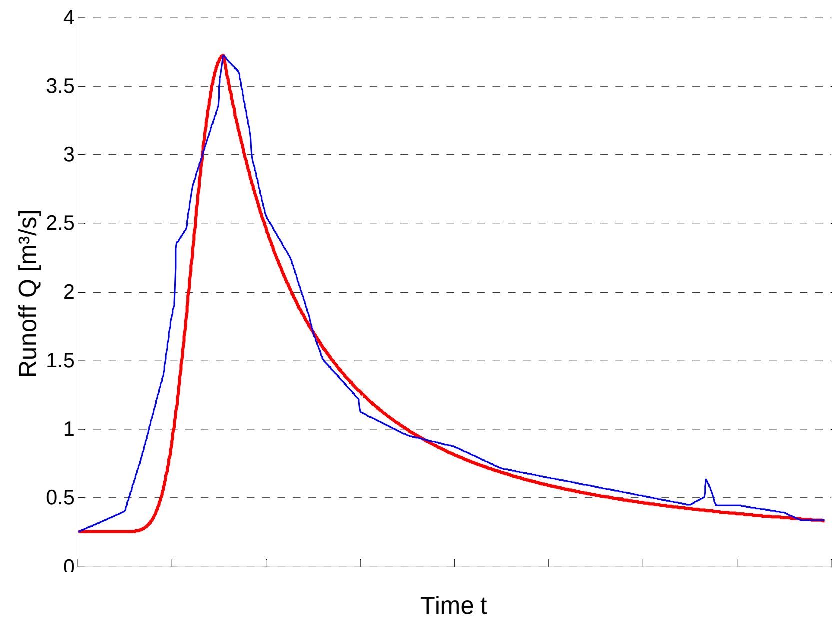
a: Compression (0,95<a<1) [-]

b: Intercept (usually b=1) [-]

Examples of recorded and simulated flood events



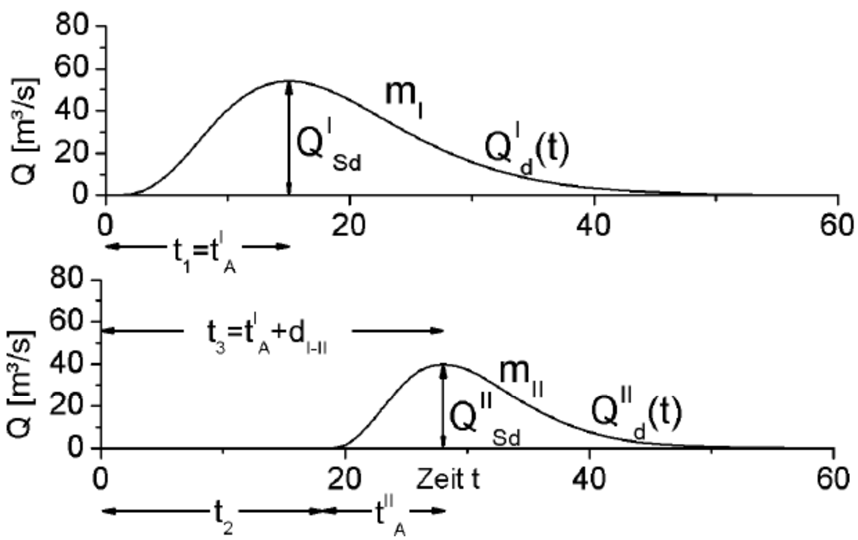
Peak flow Q_S [m³/s]:	1,88
Baseflow Q_B [m³/s]:	0,33
Time to peak t_A [h]:	36,0
Shape parameter bef. peak m_{an} [-]:	5,1
Shape parameter aft. peak m_{ab} [-]:	0,27

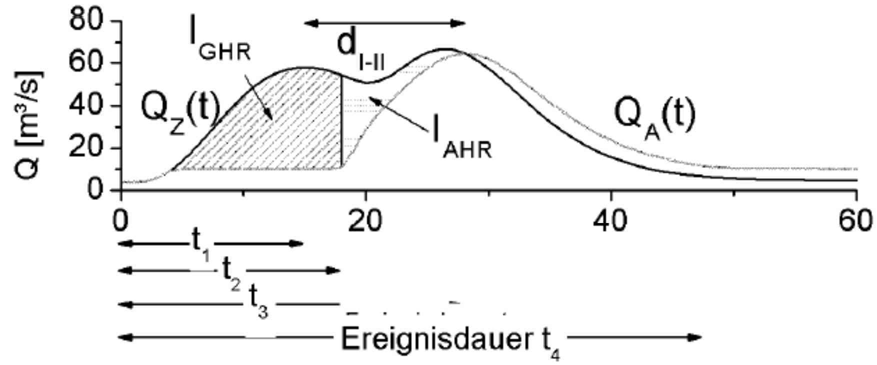


Peak flow Q_S [m³/s]:	3,72
Baseflow Q_B [m³/s]:	0,25
Time to peak t_A [h]:	74,25
Shape parameter bef. peak m_{an} [-]:	8,7
Shape parameter aft. Peak m_{ab} [-]:	0,27

Multi-peak hydrographs

- Multi-peak events can not be simulated
- These events mostly cause maximum water levels (→ structural failure)
  - Approach of overlapping multiple Kozeny-functions (KLEIN 2009)





Source: KLEIN(2009)

Limitations

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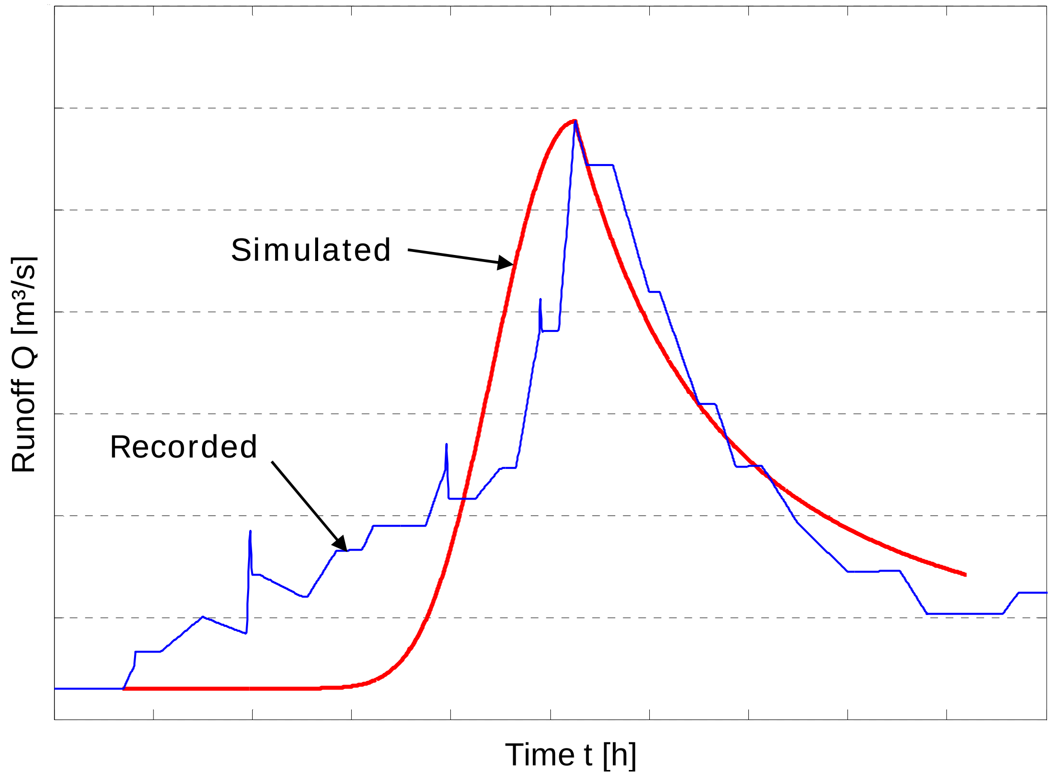
Slowly rising hydrographs

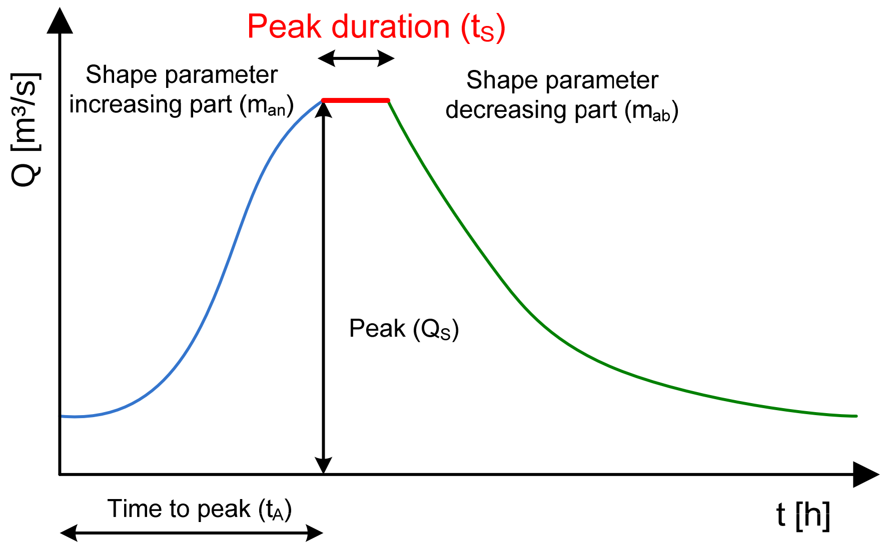
- Slowly rising hydrographs can not be simulated with Kozeny-function
- Resulting in high m-value
  - No existing solution!



Peak flow duration

- Constantly remaining peak flows can not be simulated
- Result: Exposure time of maximum load must be neglected
  - Extending the method by a fifth parameter:

    Peak flow duration t_S (Study in progress)



Conclusion

- Method is applicable for simple (single peak) shaped hydrographs
- Forms an alternativ method to rainfall-runoff modelling

- Not applicable for catchments where:
  - Multi-peak hydrographs
  - Slowly rising hydrographs
  - Long peak flows

  Can be expected

- **Still need for further research existing!**

Thank you very much for your attention!

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