Hydraulic engineering solutions for withdrawal and permanent storage of solid carrying water from seasonal flash floods in semi-arid regions

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Overview

- Introduction in rural and urban flash floods
- Methods for risk analysis
- Method application on semi-arid regions
  - Flood risk management
  - Storage of water
- Conclusion
Rural and urban flash floods

- High intensity rain of short duration (e.g. >100 mm / 6 h)
- Multiple events in 2016, increasingly frequent
- Injuries (e.g. seven dead) & high level of damage

Flash flood in June 2016, Germany/Simbach

Source: Südwest Press

Source: deutsche-wirtschafts-nachrichten.de
Rural and urban flash floods

- Risk analysis
- Preventive measures
  - public administration measures and communication
  - regional planning and area development planning
  - engineering flood prevention, facility protection

Storage capacity of roads

multi-functional use

mobile flood barriers

Source: DWA

Source: Fa. Blobel
Risk analysis - Method

- 2D-HN-Simulation (flow velocity, water depth)

\[
\begin{align*}
\frac{\partial u}{\partial t} + \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} &= -\frac{g}{2} \frac{\partial h^2}{\partial x} + h \frac{\partial u}{\partial x} + h \frac{\partial v}{\partial y} - g \frac{h}{\rho} \frac{\partial z_b}{\partial x} - \tau_{bx} \\
\frac{\partial v}{\partial t} + \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} &= -\frac{g}{2} \frac{\partial h^2}{\partial y} + h \frac{\partial u}{\partial x} + h \frac{\partial v}{\partial y} - g \frac{h}{\rho} \frac{\partial z_b}{\partial y} - \tau_{by} \\
\frac{\partial h}{\partial t} + \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} &= 0
\end{align*}
\]

Flood 1984, Lahn river, Germany/Roth
Risk analysis - Method

- Coupling the hydrologic and hydraulic process
- Large scale 2D-HN-model to simulate the surface runoff (not only streams, entire catchment area)

risk analysis

Preventive measures
- flood protection
- water intake

Source: DWA

Source: WWA Bayreuth
Large scale 2D-HN-modelling - Data

- Surface elevation (DEM) and stream bathymetry
- Land use, soil parameter (roughness, infiltration, evaporation)

Exemplary catchment area (120 km²)

Surface elevation [m]
- 100
- 200
- 300
- 400
- 500
- 600
- 700

Land use

Computational mesh (250,000 elements, 5 to 10,000 m²)
Simulation Tool - Input

- Spatial precipitation loads
  - Duration, distribution, compass direction and velocity
- Time and soil variable runoff coefficient

![Graph showing spatial precipitation loads](Image)

- precipitation losses
- effective precipitation

Source: Ihringer
Simulation Tool - Input

- Movable precipitation load and runoff process

Spatial distribution
\[ A_N = 4 \text{ km}^2 \]

Precipitation load
\[ h_N = 20 \text{ mm}, \psi = 0.25, t_N = 1 \text{ h} \]

speed of precipitation movement
\[ v = 1 \text{ m/s} \]
Simulation Tool - Results

Impact of the precipitation movement

Discharge $[\text{m}^3/\text{s}]$ vs. time $[\text{h}]$

- Steady $v = 1 \text{ m/s}$
- $v = 2 \text{ m/s}$
- $v = 4.5 \text{ m/s}$

Different scenarios of precipitation movement

- Gauge
- $v \text{ [m/s]}$
Simulation Tool - Results

surface runoff, flow path, water depth

T = 1 h
T = 3 h
T = 5 h

flow velocity

T = 1 h
T = 2 h
Simulation Tool - Output

- Basin reaction (runoff formation and concentration)
- Travel times of flash floods and catchment outlet
- Surface runoff (flow velocity and water depth)

Risk analysis and planning preventive measures

Planning water intake structure
Application on semi-arid regions

- Seasonal and short-term precipitation of high intensity
- Exploitation of flash flood runoff (Rainwater harvesting)
- Identify the watershed area and flow paths
- Find sites for flood protection measures and decentralized water withdrawal structures

Source: Michael Mett, University of Innsbruck

Source: Google earth
Reservoir - Problems

- Sedimentation (& salinization)

Source: Tewedros Fikre Zenebe, Delft
Storage of water

- Separate water flow from solids
- Rainwater harvesting (reservoirs, underground storage, infiltration)
- Identify flow zones prone to special phenomena of sediment transport and fluvial morphology
  - Design and operation of hydraulic structures used for water abstraction and infiltration
  - Consider the effects of suddenness, sediment transport and clogging

Source: KKL-JNF
Source: zek 2017
Water intake

- Separate solids (sediments and debris) from water flow
- Minimize sediment input into the reservoir
- Reservoir desedimentation is increasingly important

Source: Giesecke, 2012
Water intake

- Water intake structures in the Alpine region
- Reduced bedload transport
Water intake

- Water abstraction from the river bed with coanda-screen and sand trap

Source: Giesecke, 2012

Source: Eberl, ZEK, 02/2017
3D-HN-modelling / laboratory model

- Flow optimized design of hydraulic structures
- Simulation of erosion and sedimentation
3D-HN-modelling / laboratory model

- Morphologic investigations at the river Rhine on a hydraulic model with mobile bed
Conclusion

- Models help to understand complex systems
- Proposed application of robust and efficient 2D-HN-modelling was experimentally applied on watersheds of several hundred km²
- Site identification for flood protection and water withdrawal
- Optimization of design of water abstraction
- Construction design and dimensioning
  - sand trap, screen / trash-rack, pipelines, reservoir
Thank you for your attention

This wonderful falaj is in Wadi bani Khalid, Al Sharqiyyah Region.