HOW TO MITIGATE HARMFUL IMPACTS OF FLOODS?

The Nemcicky Catchment Case Study
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Do we have effective tools to mitigate harmful impacts of floods?

The current rationale behind prevention and mitigation of water disasters, i.e. floods and droughts

- In the past 10 years:
  - **450** thousands people lost their lives in devastating flood events
  - **1.5** billions people became affected by floods
  - **0.7** billions people became affected by droughts

- 80% of all world catastrophes were disasters caused by floods and droughts → Damage caused = 370 billions USD

What causes floods?

- Hydrometeorological conditions
  - Small catchments: Torrential rainfalls
  - Large catchments: Combinations of regional and torrential rainfalls
  - Most important criteria: Depth *P* (mm) and Intensity *i* ($mm \cdot min^{-1}$) of rainfall
- Antecedent saturation of the catchment‘s upper soil zone
  - Antecedent precipitation index API (mm) – in 30 days
  - Soil moisture deficit SMD (mm) – continuously
- Measures for increasing retention/accumulation of water
  - Decreasing direct (surface) runoff

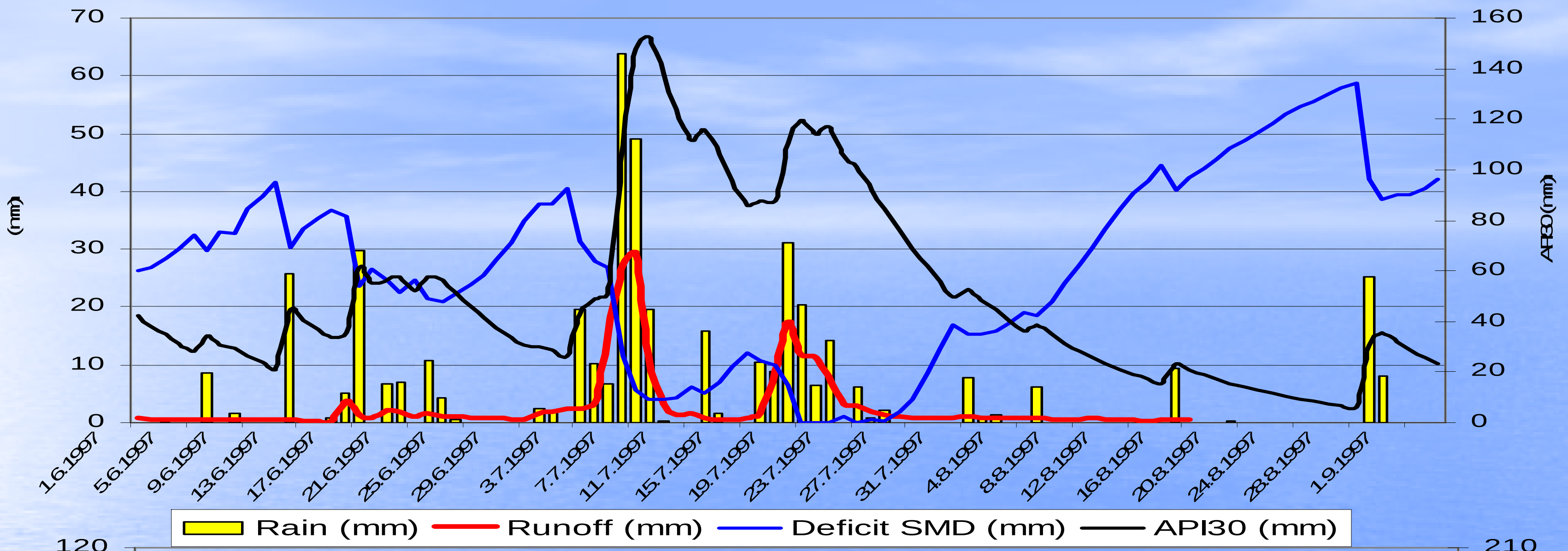
Historic and present hydraulic structures and biotechnical measures

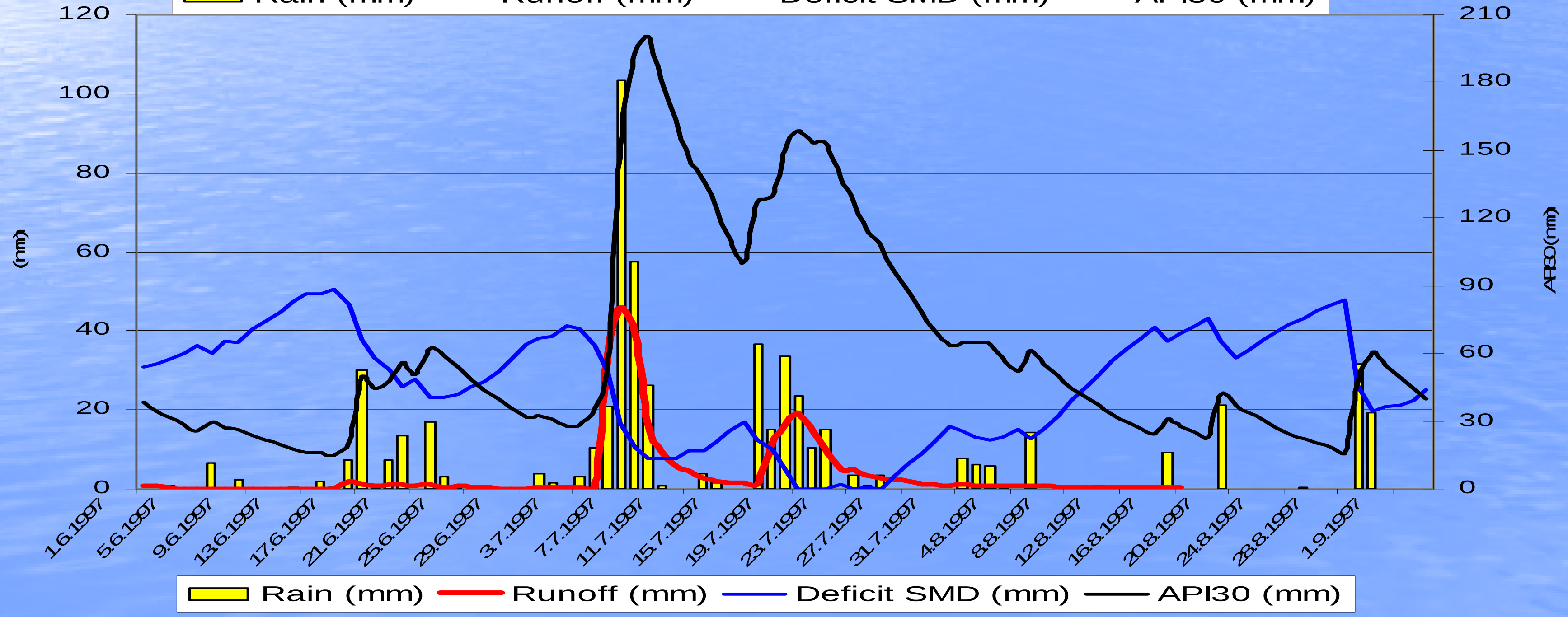
Flood analyses results

Tools: Data processing by means of:

- Remote sensing and GIS methods
  - Orthophotomaps
  - Satellite imaging
  - Rainfall-runoff data processing
  - Analyses of maps using GIS
- Analogy and comparative methods
  - Flood areas and soil maps (match of fluvisols)
- Mathematical models
  - Rainfall-runoff event models ($\Delta t \leq 1$ day)
  - Water balance models ($\Delta t \geq 1$ day)

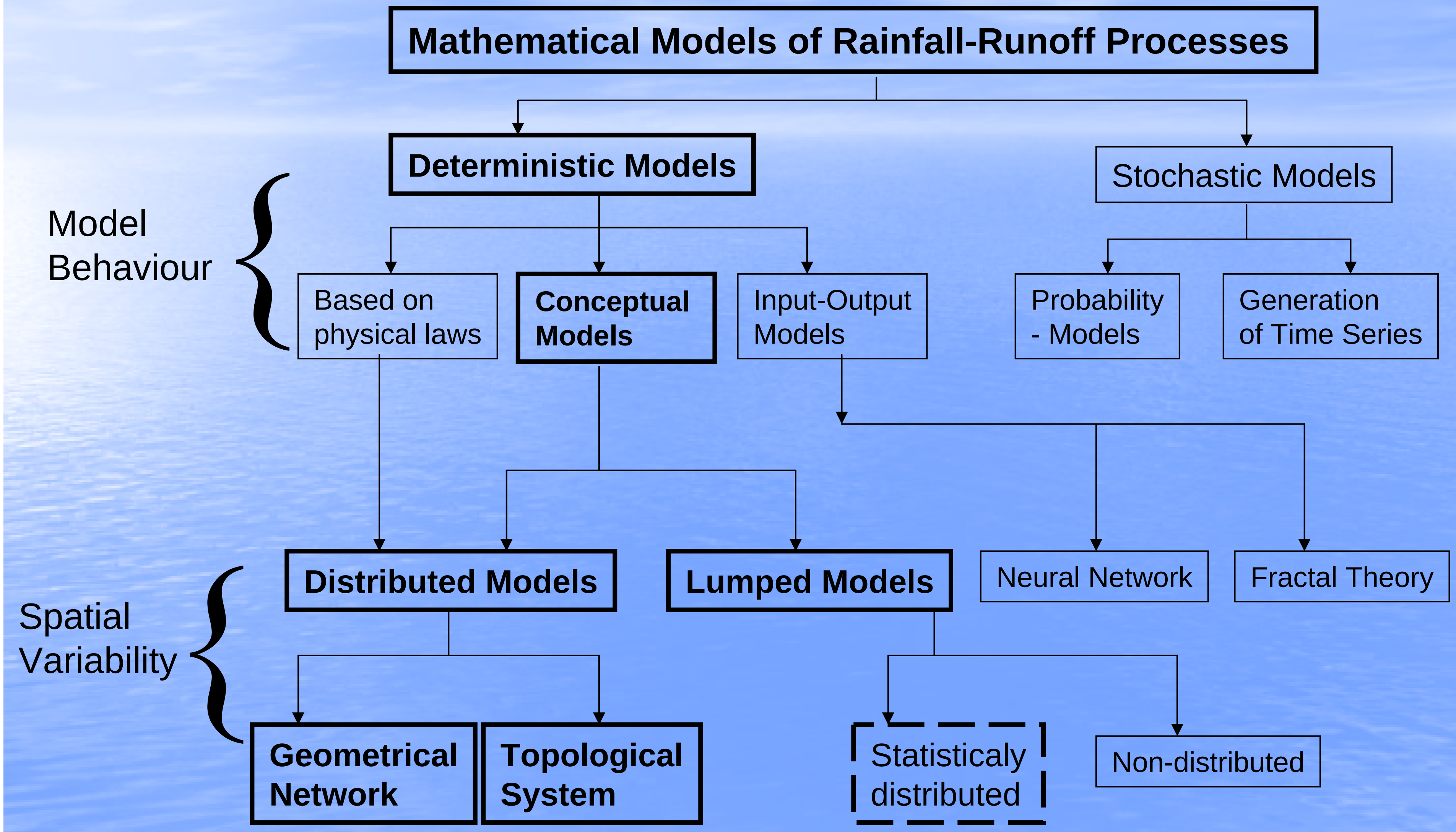
Soil moisture deficits SMD on the Vseminka and Drevnice catchments





Classification of Mathematical Models of Rainfall-Runoff Processes

(according to prevailing principles in a model structure)

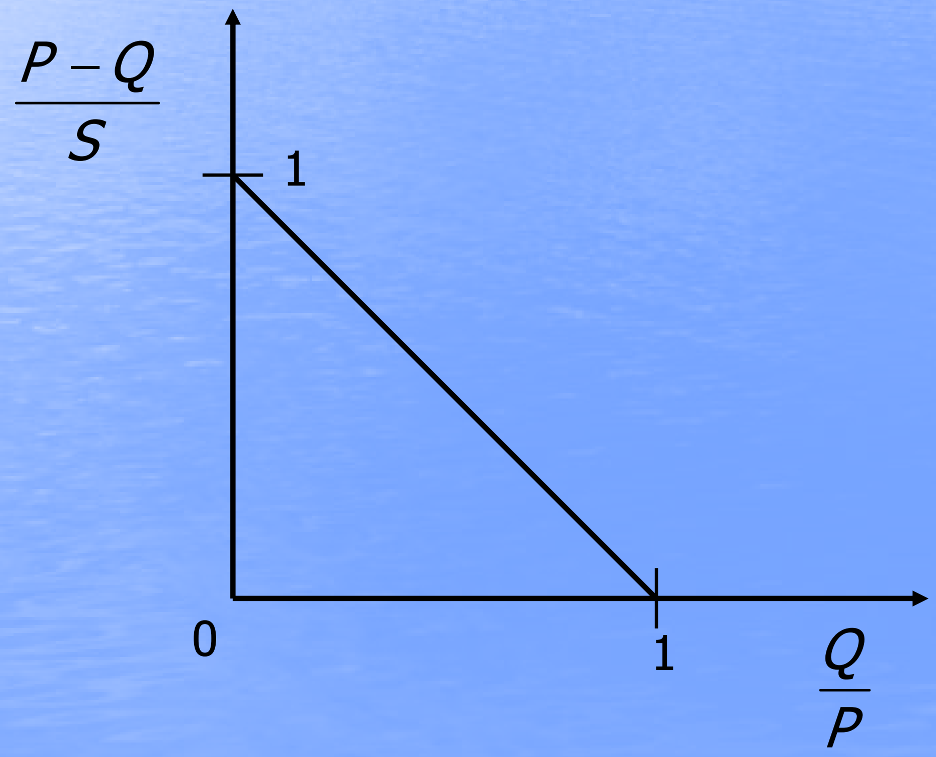


Deterministic models

- Conceptual (+ Lumped)
  - SCS (CN-curves) + standard TUH
    - Ex.: HEC-HMS/WMS, INFIL
  - Reservoir models
    - Ex.: Tank model, NASH, NONLINEAR
- Physically based (+ Distributed)
  - Muskingum-Cunge (conceptual / physically based)
  - HEC-RAS (river channel + inundation (river plain))
  - KINFIL (geometrical network: infiltration + kinematic system
  - MIKE-SHE (universal hydrological model – flexible)

U. S. SCS/NRCS Model: Curve Number Method

- Principle:
  - if $P - Q = S$, $Q = 0.0$ (no runoff)
  - if $P - Q = 0.0$, $Q = P$ (max. runoff)



$$\frac{P-Q}{S} = \frac{Q}{P}$$

$$Q = \frac{P^2}{P+S}$$

U. S. SCS/NRSC Model

Principle:

$$Q = \frac{\left(P - I_a\right)^2}{P - I_a + S} = \frac{\left(P - 0.2S\right)^2}{P + 0.8S} \rightarrow P \geq 0.2S$$

$$S = 25.4 \cdot \left(\frac{1000}{CN} - 10\right),\ CN \in \langle 0; 100 \rangle$$

- CN determination:
  - Hydrological soil group (A–D): soil maps
  - Land use
  - Antecedent soil moisture (3 types)
- Advantages:
  - Rationality, simplicity, data availability
  - Easy application on ungauged catchments
- Disadvantages:
  - Weak physical background
  - Does not include data on rainfall intensity and duration

Principle of the linear reservoir model

- Linear equation

$$S(t) = K \cdot Q(t)$$

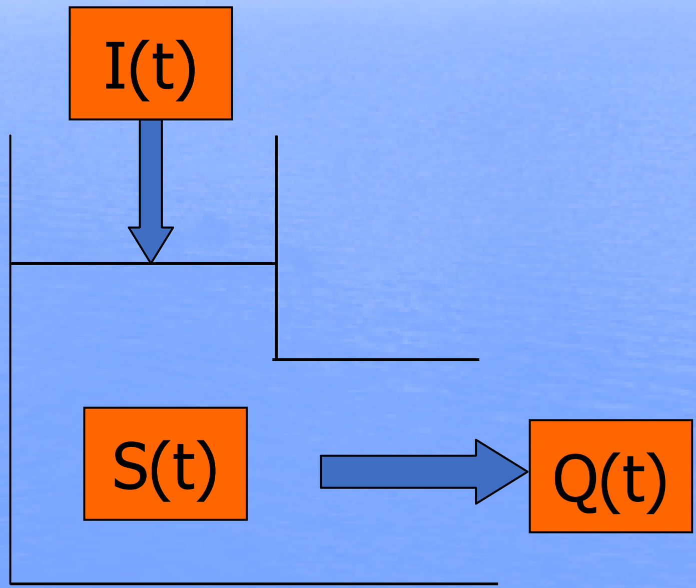
$$\frac{\mathrm{d}S(t)}{\mathrm{d}t} = K\frac{\mathrm{d}Q(t)}{\mathrm{d}t}$$

- Continuity equation

$$\frac{\mathrm{d}S(t)}{\mathrm{d}t} = I(t) - Q(t)$$

- Combination of both

$$K\frac{\mathrm{d}Q(t)}{\mathrm{d}t} + Q(t) = I(t)$$



KINFIL model principle
(Physically based + distributed)

- Infiltration computation
  - Green Ampt and Morel-Seytoux

$$K_s\left(\frac{z_f + H_f}{z_f}\right) = \left(\theta_s - \theta_i\right)\frac{\mathrm{d}z_f}{\mathrm{d}t}$$

$$S_f = \left(\theta_s - \theta_i\right) \cdot H_f$$

$$t_p = \frac{S_f}{i \cdot \left(\frac{i}{K_s} - 1\right)}$$

- Hill-slope flowing-kinematic wave:
  - Lax-Wendroff scheme

$$\frac{\partial h}{\partial t} + \alpha\, m h^{m-1}\frac{\partial h}{\partial x} = r_e(t)$$

Case study of the Nemcicky catchment

- Characteristics of the Nemcicky catchment

Catchment area	3.5 km^2	Min. altitude	556 m a.s.l.
Main channel length	1.9 km	Max. altitude	651 m a.s.l.
Main channel slope	2.1%	Basin perimeter	9.0 km

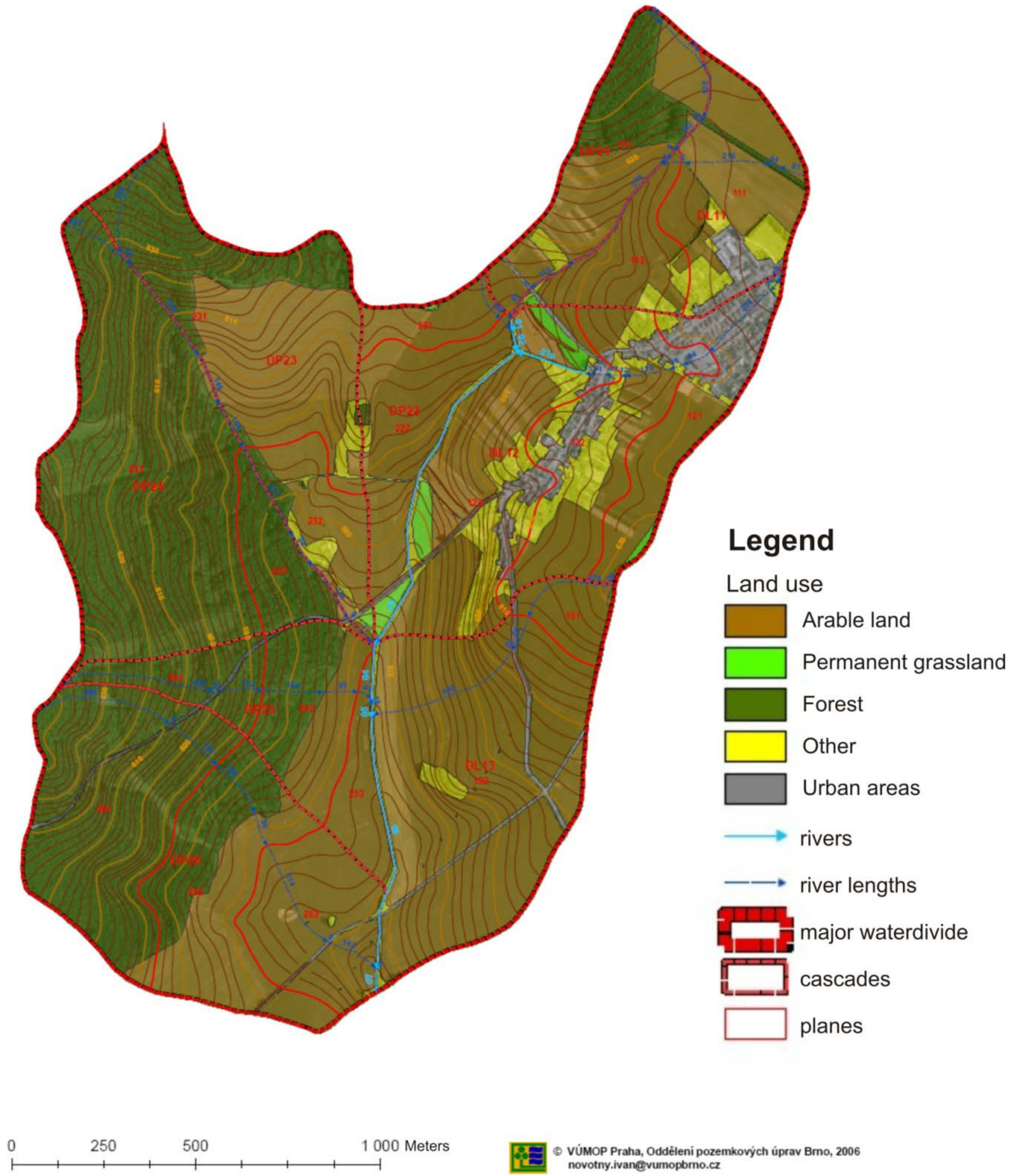
- Land use of the catchment

Arable land	58.9%	Urban area	4.7%
Permanent grassland	0.9%	Other	6.5%
Forest	35.0%		

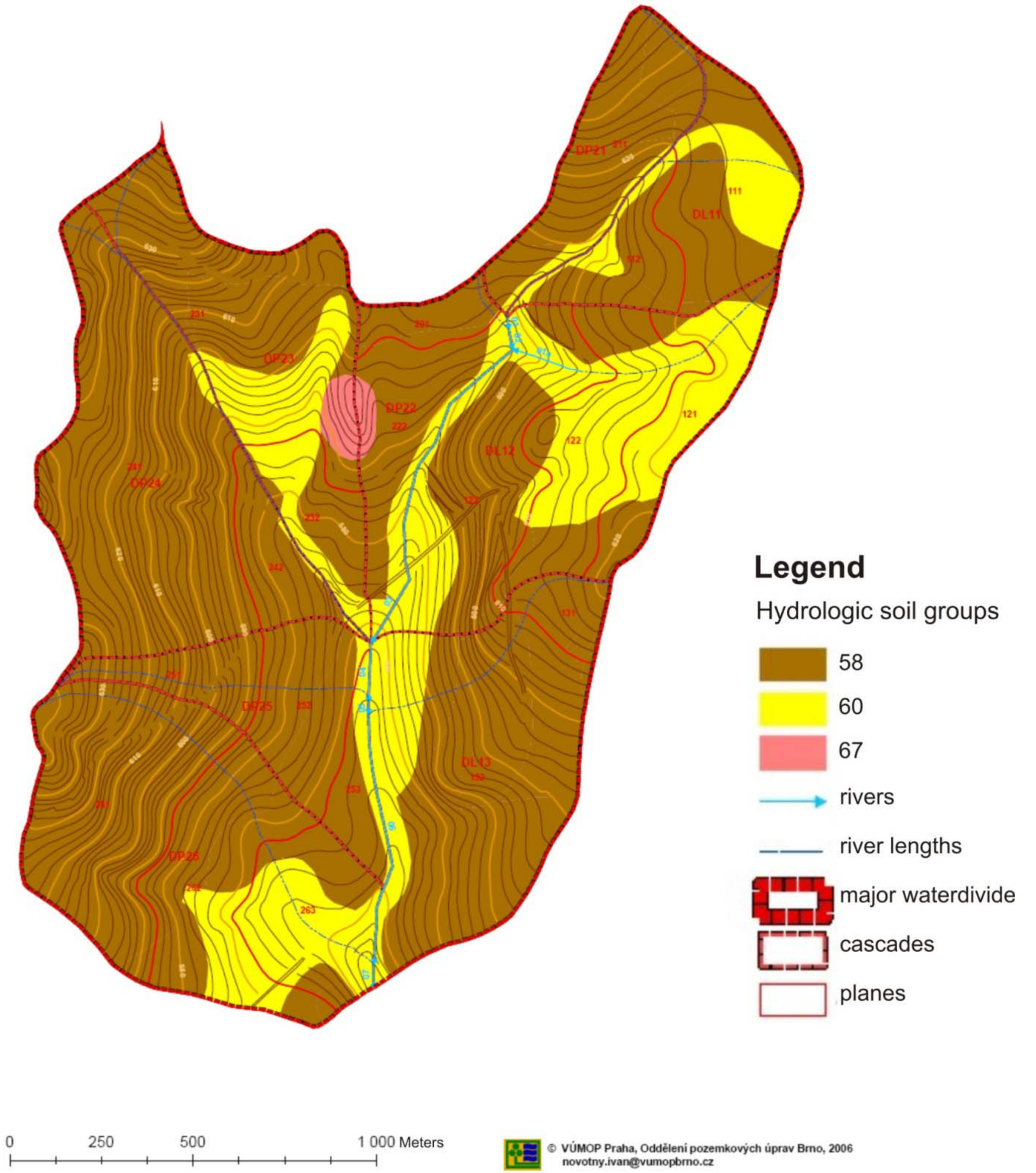
- Hydrologic soil groups

Soil groups	B		C		D	
	%	CN	%	CN	%	CN
Arable land	36.4	81	16.0	88	0.6	91
Permanent grassland	0.4	58	0.5	71	–	–
Forest	31.5	60	0.4	73	0.1	79

Experimental catchment of the Nemcicky Stream: Land Use



Experimental catchment of the Nemcicky Stream: Hydrologic Soil Groups

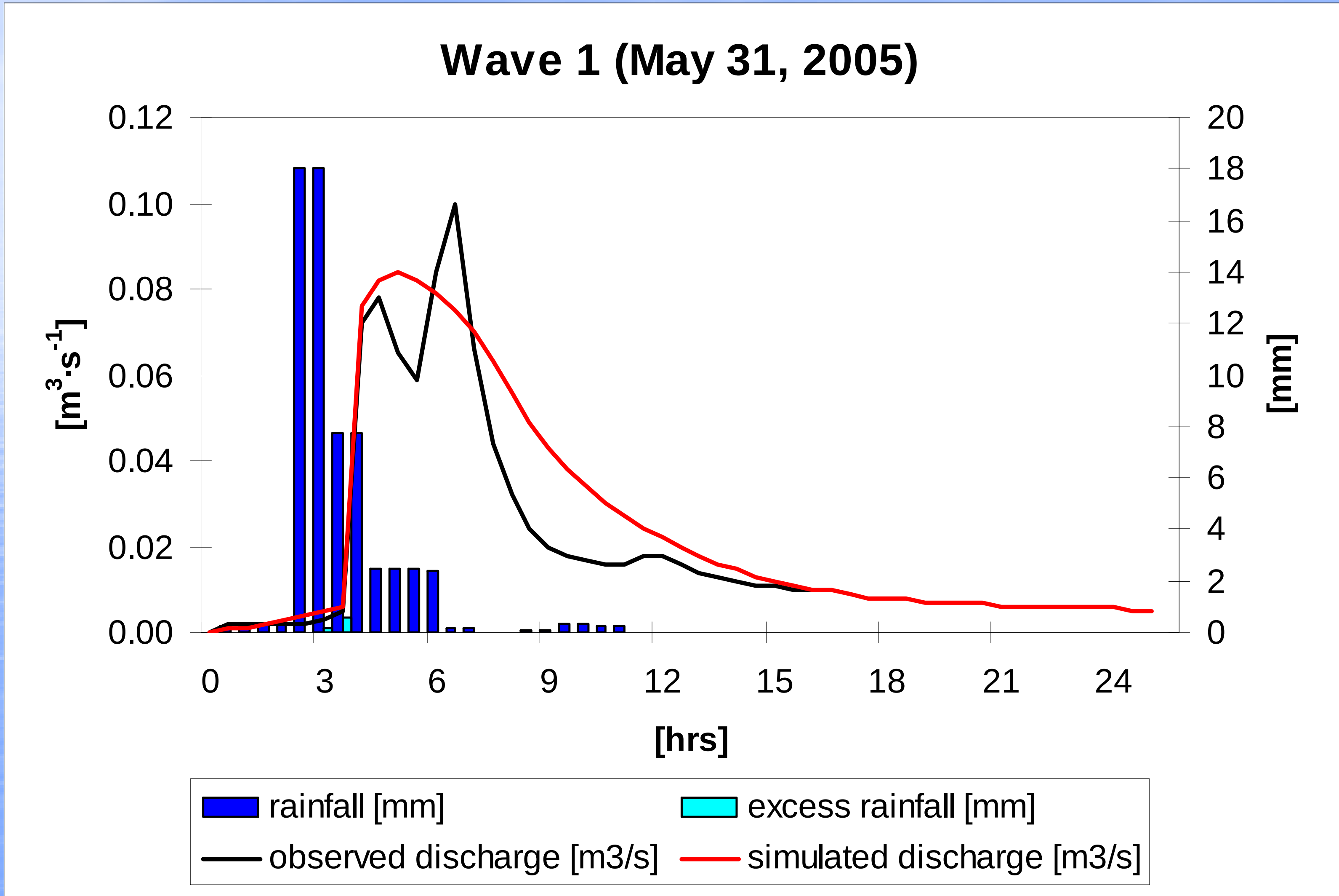


Experimental catchment of the Nemcicky Stream: Curve Numbers

Schematization of the Nemcicky catchment (for the KINFIL model)

Cascade	Plane	Area [km²]	Mean width [km]	Length [km]	Slope [%]	Arable land [%]	Permanent grassland [%]	Forest [%]	Urban area [%]	Other [%]
DL11	**111**	0.176	0.979	0.179	2.2	69.1	0.0	2.6	12.4	15.9
	112	0.088	0.979	0.090	5.3	86.1	1.0	0.0	0.9	12.0
DL12	**121**	0.130	1.027	0.127	2.9	52.9	3.2	0.0	38.7	5.2
	122	0.183	1.027	0.178	4.5	49.2	0.0	0.0	20.8	29.9
	123	0.254	1.027	0.247	10.0	58.1	6.6	0.0	10.0	25.3
DL13	**131**	0.044	0.960	0.046	5.2	95.7	1.7	0.0	1.3	1.2
	132	0.444	0.960	0.463	7.2	93.3	0.0	0.2	3.1	3.5
DP21	**211**	0.187	0.979	0.191	5.5	60.2	0.0	36.3	0.5	3.1
DP22	**221**	0.047	1.027	0.046	2.9	97.7	1.5	0.0	0.0	0.8
	222	0.147	1.027	0.143	5.5	86.4	4.1	0.9	1.3	7.2
DP23	**231**	0.319	1.452	0.220	7.8	55.2	0.0	42.0	0.0	2.8
	232	0.088	1.452	0.060	4.8	73.8	1.8	9.9	0.9	13.5
DP24	**241**	0.462	1.452	0.318	9.7	0.5	0.0	99.5	0.0	0.0
	242	0.070	1.452	0.048	6.4	3.5	0.0	92.9	2.6	1.0
DP25	**251**	0.067	0.694	0.097	10.6	0.0	0.0	96.1	3.9	0.0
	252	0.117	0.694	0.169	6.6	45.8	0.0	53.5	0.4	0.4
	253	0.053	0.694	0.076	3.8	92.8	0.0	0.0	0.0	7.2
DP26	**261**	0.288	0.266	1.084	11.7	1.9	0.0	96.3	1.8	0.0
	262	0.204	0.266	0.767	6.7	59.3	0.0	40.1	0.4	0.2
	263	0.141	0.266	0.530	4.5	95.5	0.0	0.1	1.3	3.1

Calibration of KINFIL parameters (K_s, S_f, L_i, W_i, i, n) – Nemcicky Stream



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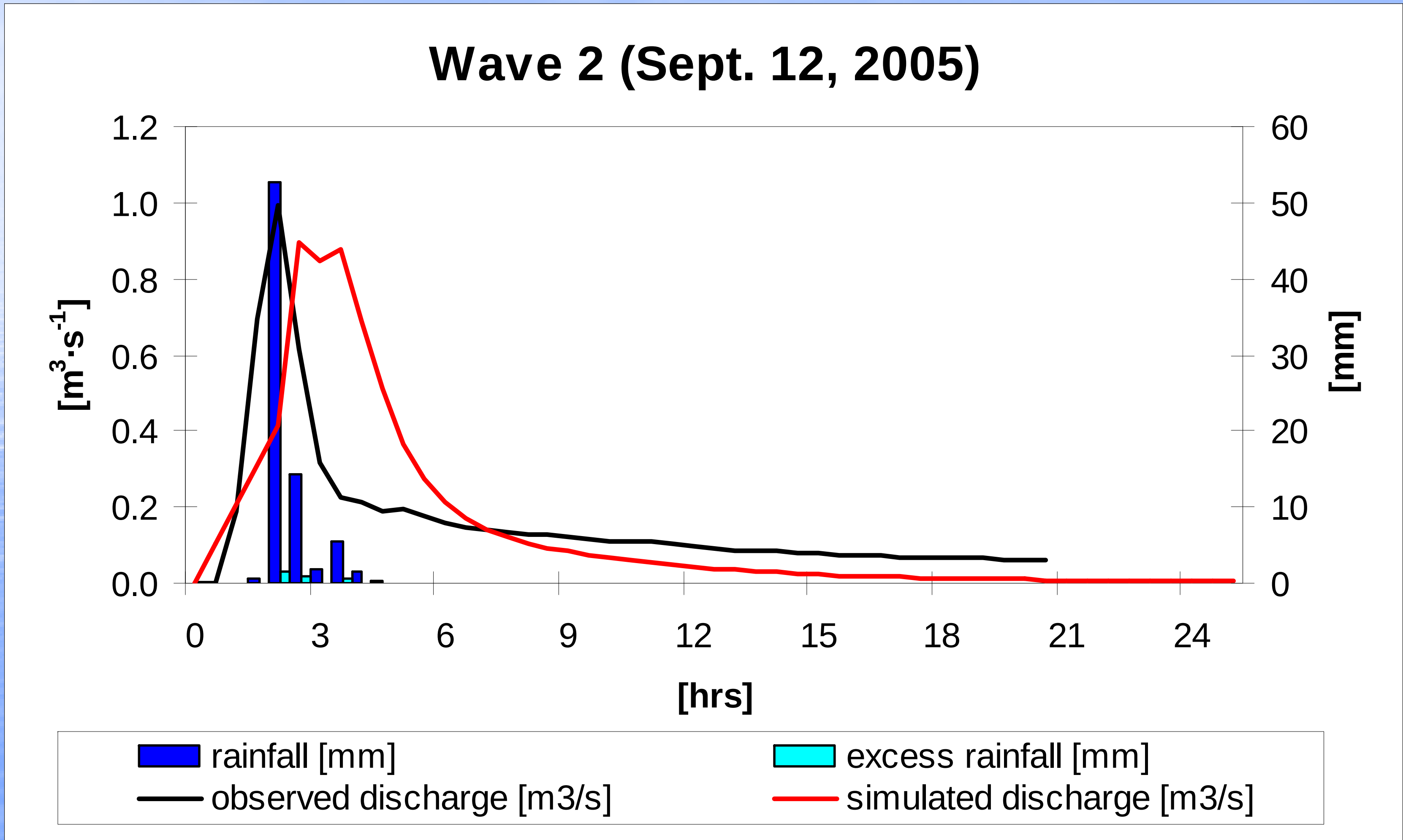


Selection of design rainfalls

- Method of reduction of 1-day maximum rainfall

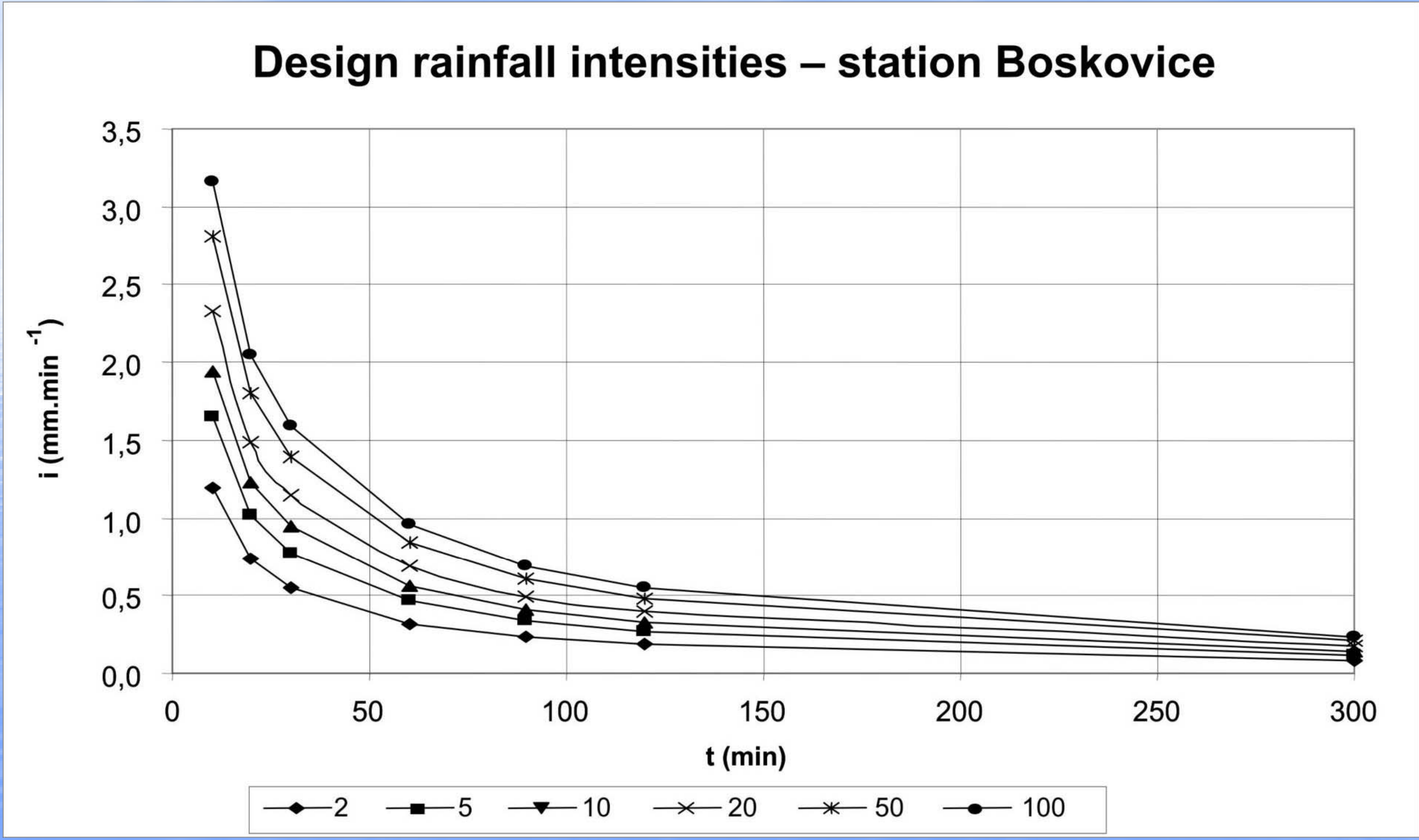
$$P_{t,N} = P_{1d,N} \cdot a \cdot t^{1-c}$$

$$i_{t,N} = P_{1d,N} \cdot a \cdot t^{-c}$$

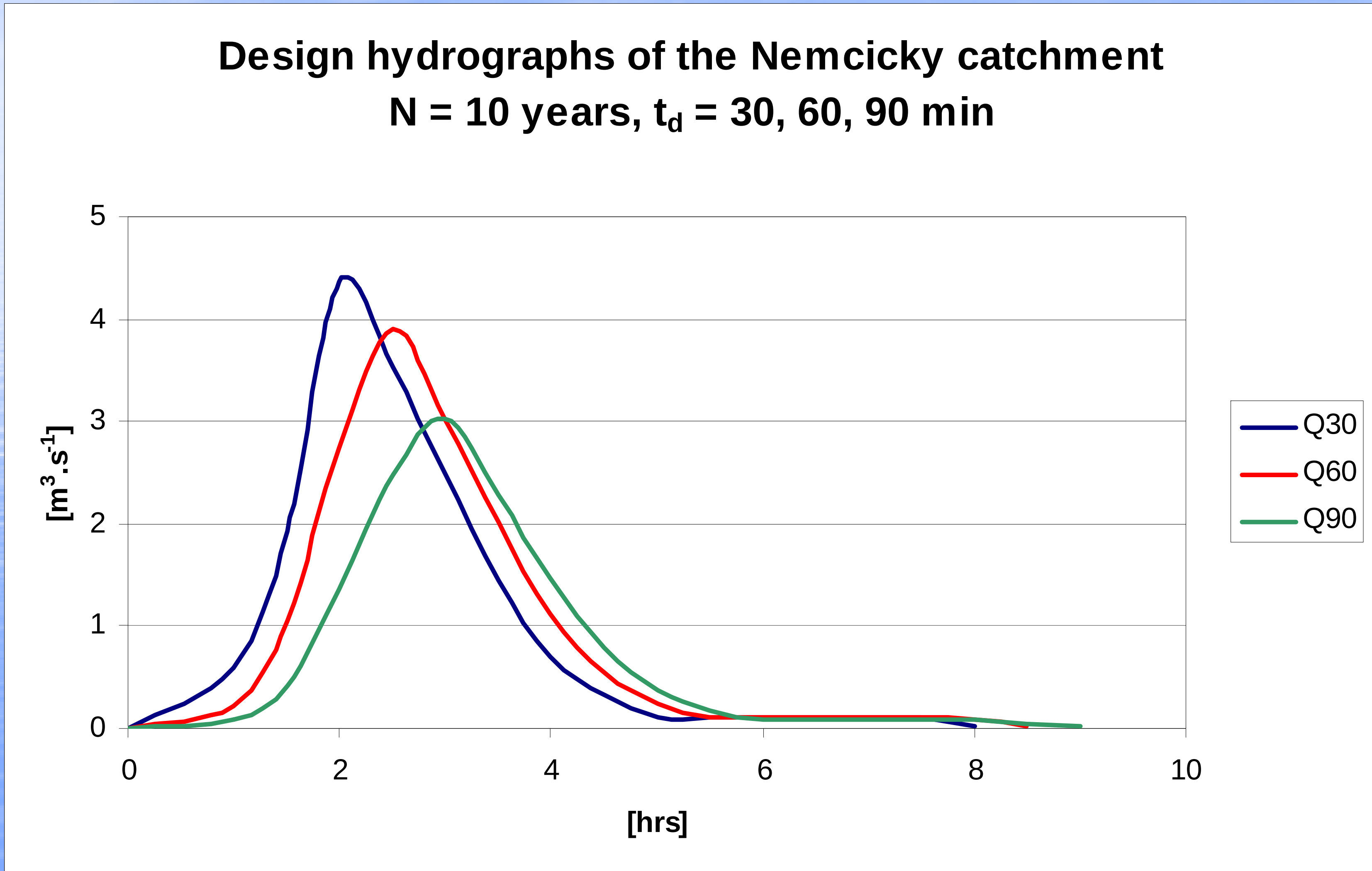
- One-day maximum rainfall $P_{1d,N}$ (mm) at Boskovice station

N – return period (years)					
2	5	10	20	50	100
36.0	46.9	53.9	61.2	70.1	77.1

Selection of design rainfalls



Flood discharge simulation from N-years rainfalls



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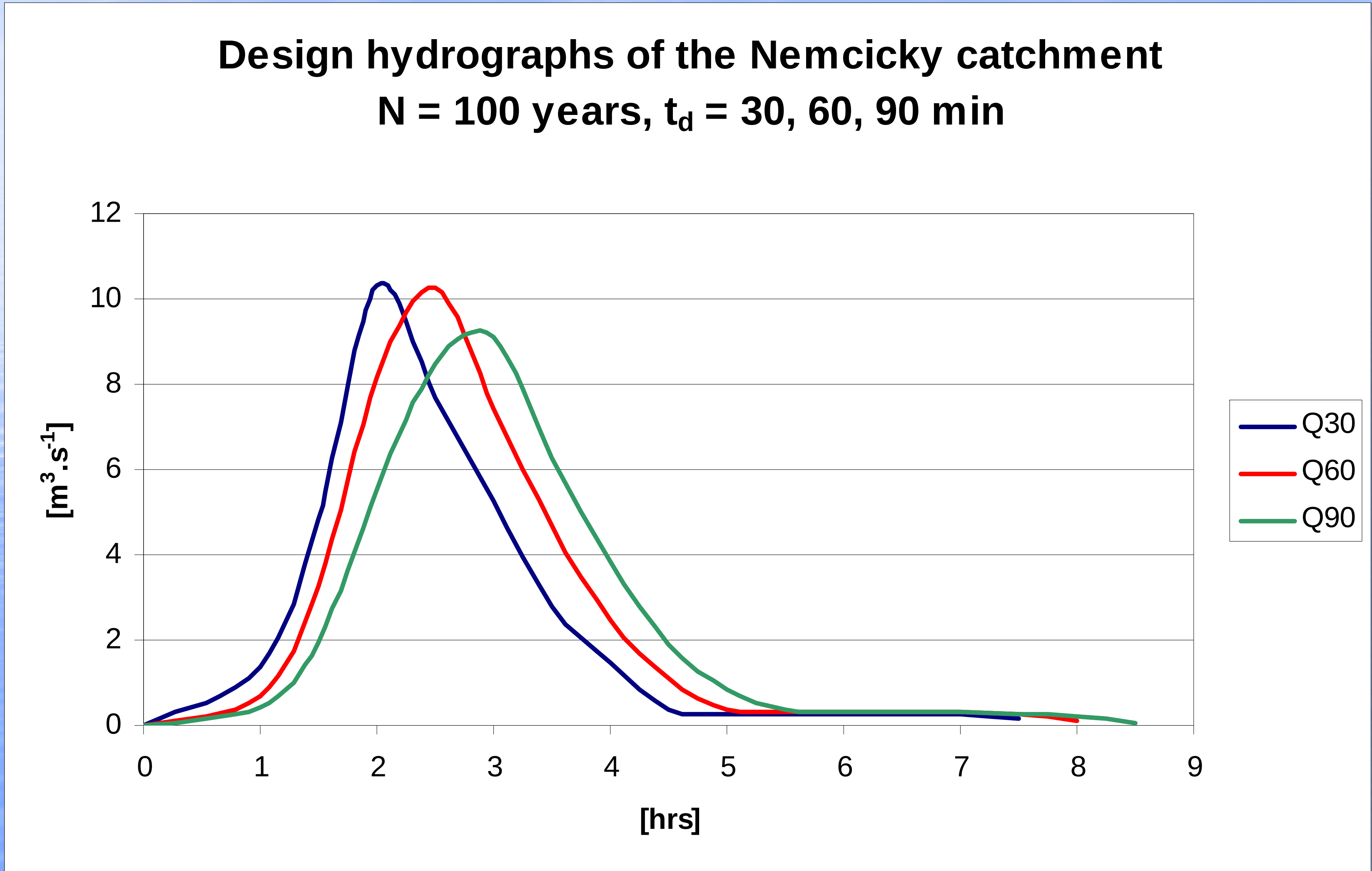
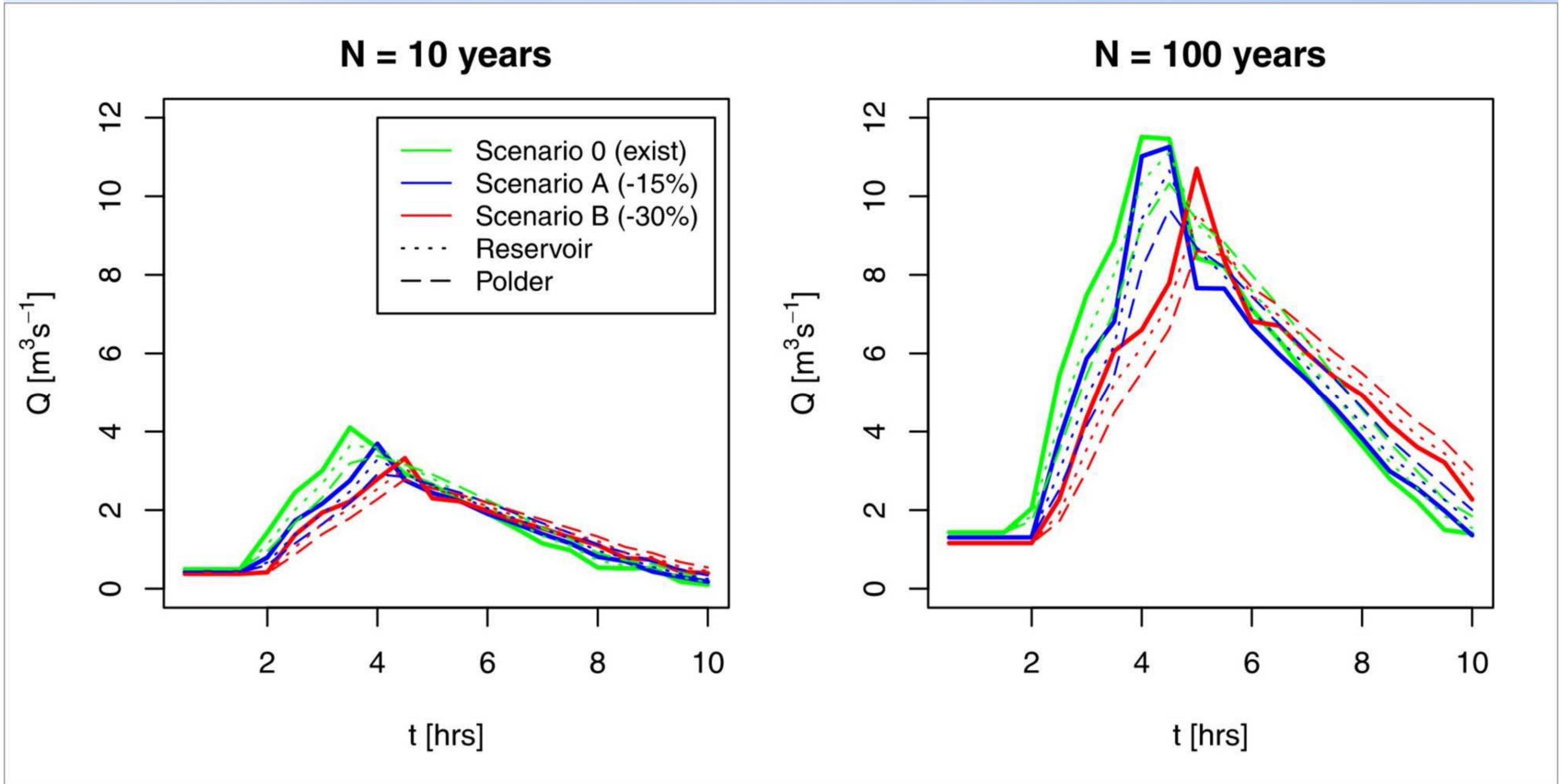
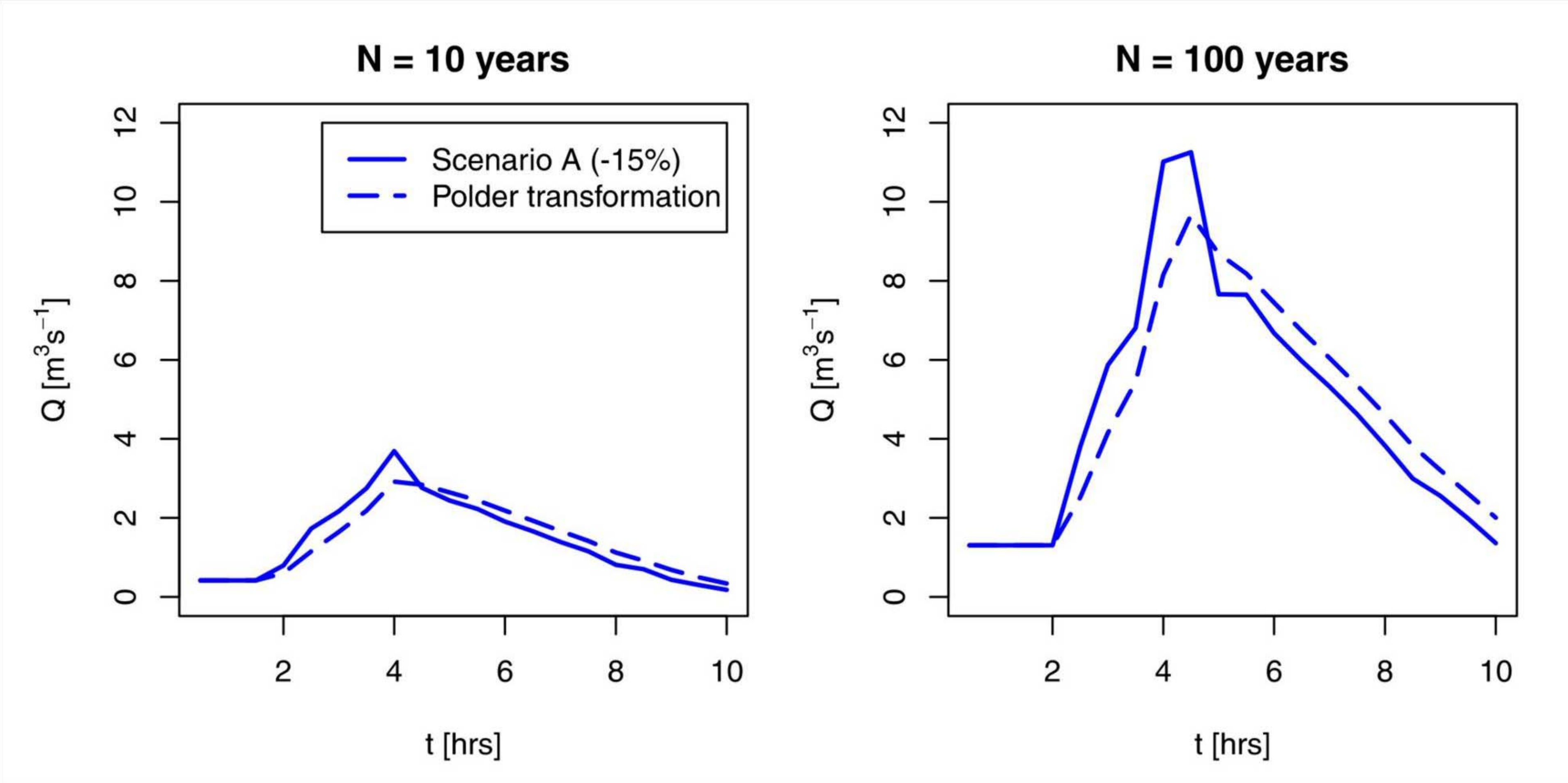
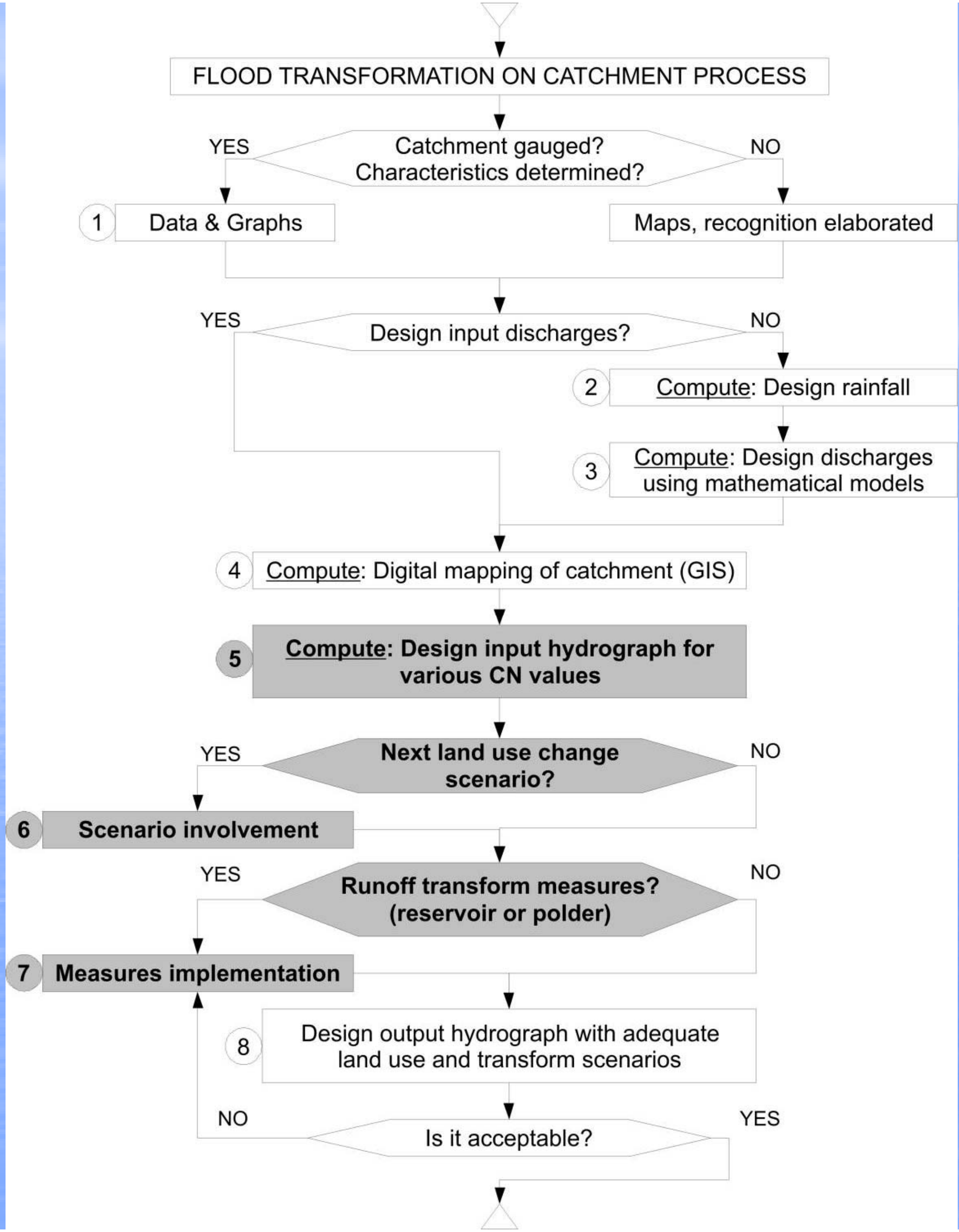


Design inflow/outflow transformation by reservoir/polder in the Nemcicky catchment (Scenario techniques – model validation)



Resulting inflow/outflow hydrographs for time recurrence N = 10 and N = 100 years and for CN, corresponding to 15% reduction of an arable land




FLOOD TRANSFORMATION ON CATCHMENT PROCESS
Catchment gauged? Characteristics determined?
YES
NO
1
Data & Graphs
Maps, recognition elaborated
Design input discharges?
YES
NO
2
Compute: Design rainfall
3
Compute: Design discharges using mathematical models
4
Compute: Digital mapping of catchment (GIS)
5
Compute: Design input hydrograph for various CN values
Next land use change scenario?
YES
NO
6
Scenario involvement
Runoff transform measures? (reservoir or polder)
YES
NO
7
Measures implementation
8
Design output hydrograph with adequate land use and transform scenarios
Is it acceptable?
NO
YES

Conclusions

- The KINFIL model provides a good physical background
- Adaptive management approach is possible
- Application of new findings in hydrology
- Realistic scenario simulation (both human intervention and climate change)

Effective mitigation of harmful flood impacts

- Proper land use policies
- Landscape structure, mosaic displacement, roads network – drainage pattern, natural retention, wetlands
- Natural hydrographical network: geomorphological diversity, conveyance of discharges, channel versus inundation (flood plain)
- Erosion control measures: depressions, dikes, terraces, torrent control, gully control
- River network diversity, bifurcations, blind streams, delta areas, natural depressions/inundations
- Small reservoirs, (fish) ponds, retention barriers
- Dikes and polders
- Weirs and dams

FLOODS

Five types of measures:

- **Early warning:** Information, Warning: four elements of people centred warning systems:
  - Risk knowledge (systematic data collection)
  - Monitoring & warning service
  - Communicate risk information- dissemination
  - Response capability (reaction to warning)
- **Pre-flood measures:** Last time physical prevention:
  - evacuation
  - sand sack providing
  - mobile gates installation

- **Rescue execution:** Continuing flood forecast and warning,
  rescue team- evacuation,
  housing and dormitory facilities

- **Post – flood measures:** flood water drainage, pumping,
  drying

- **Long-time measures:**

Technical: Flood areas zoning, technical measures
from: land use changes
via: river discharge capacities increasing
to: diking, poldering, reservoirs and dams operation

Legislative: EU and national WF Directives, reimburses
of flood damages, insurance companies
involvement, training of integrated teams (firemen,
police,health service, civil service, volunteers,etc.)


WATER DISASTER PREVENTION
THANK YOU FOR YOUR ATTENTION