The role of lowland tributaries & bank storage on the Hungarian Danube

Flood attenuation revisited

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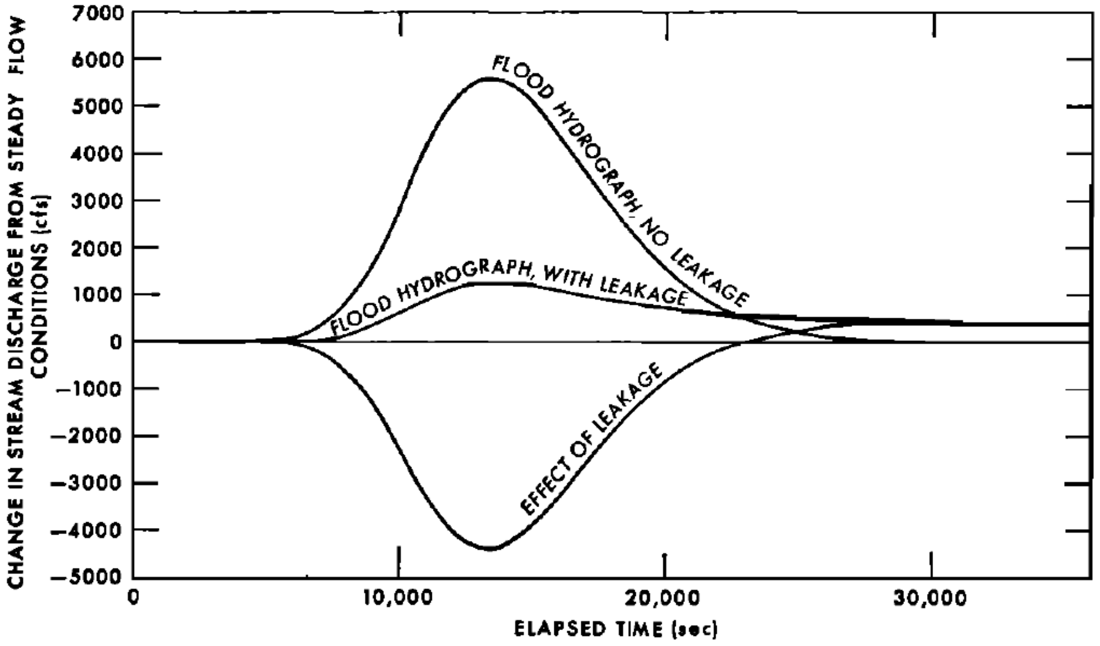
Tamás Krámer, Ph.D.

kramer.tamas@emk.bme.hu

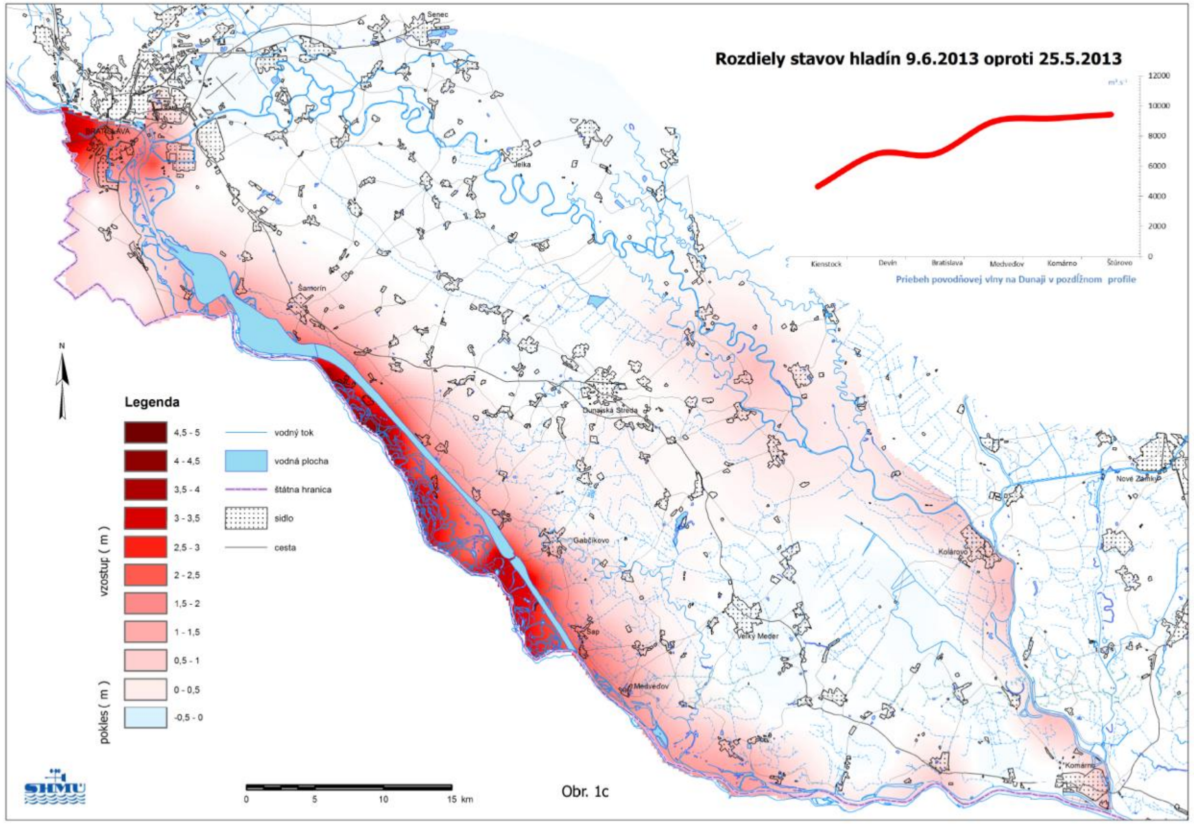
Department of Hydraulic and Water Resources Engineering

BME | FACULTY OF CIVIL ENGINEERING

River flood forecasts may be miss peaks and timing because some lateral storage is omitted in models.

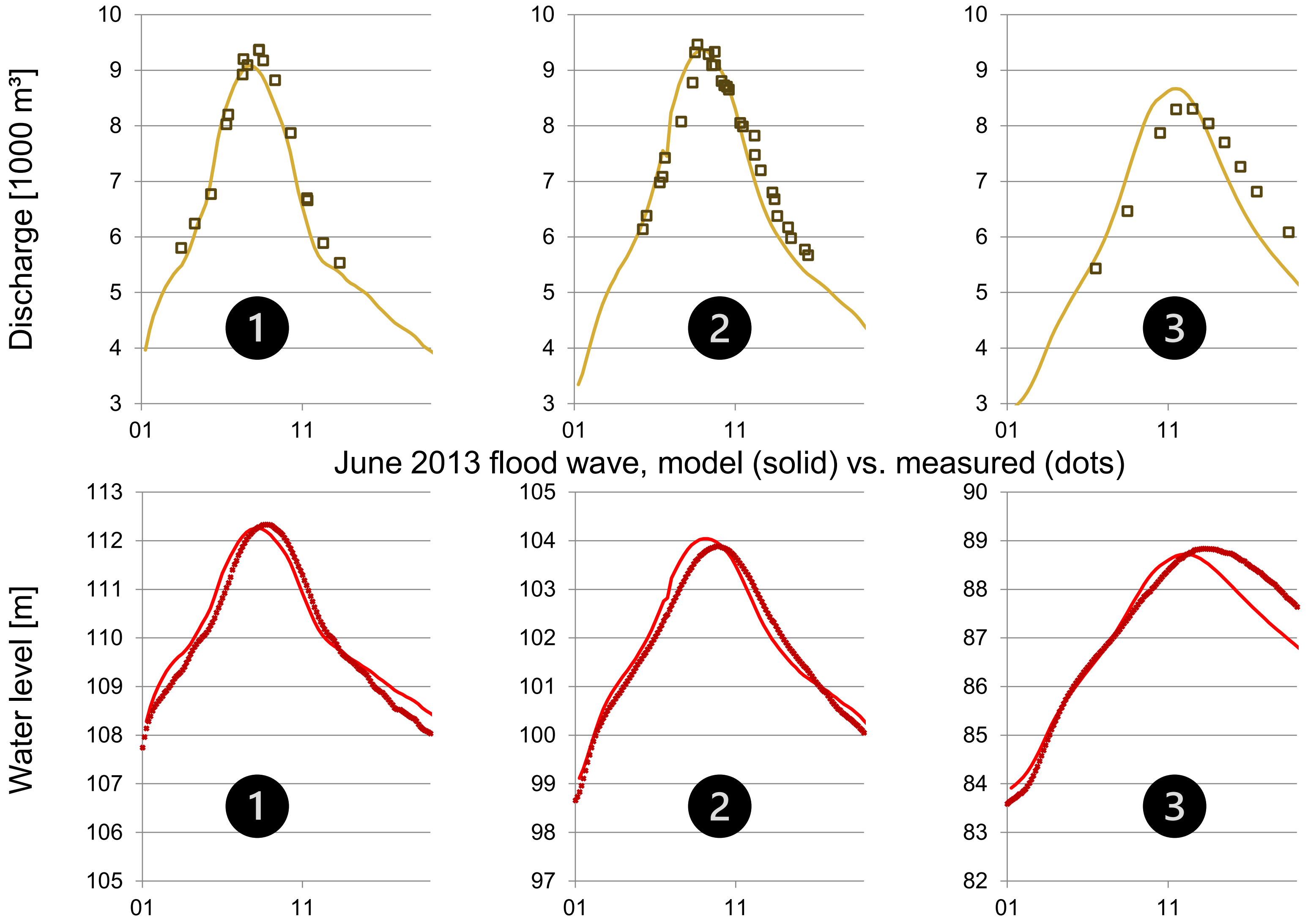


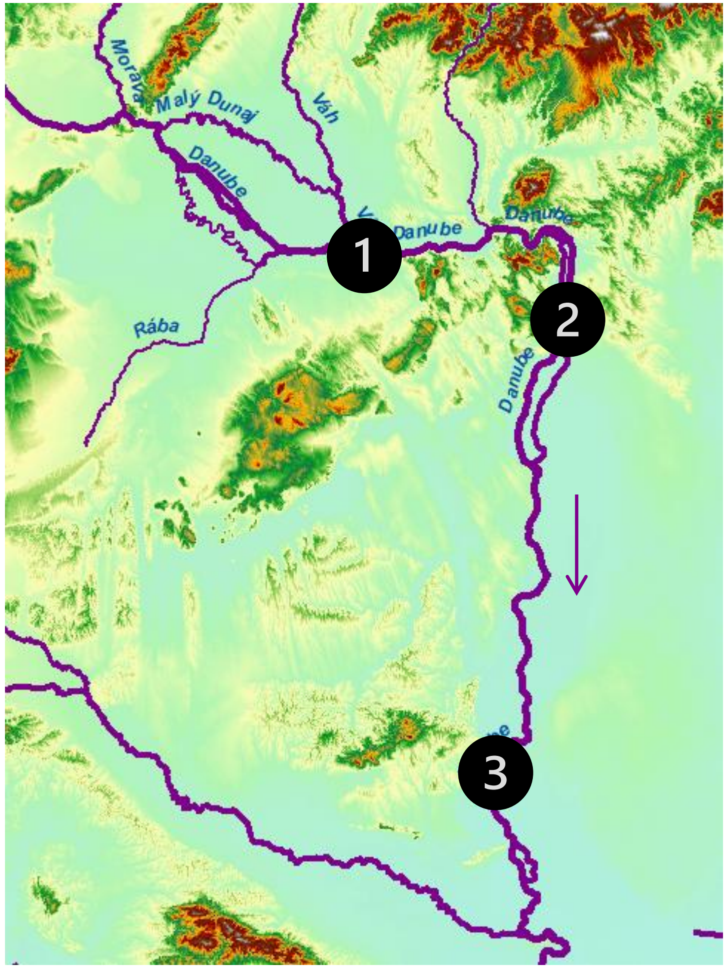
Pinder & Sauer (1971)



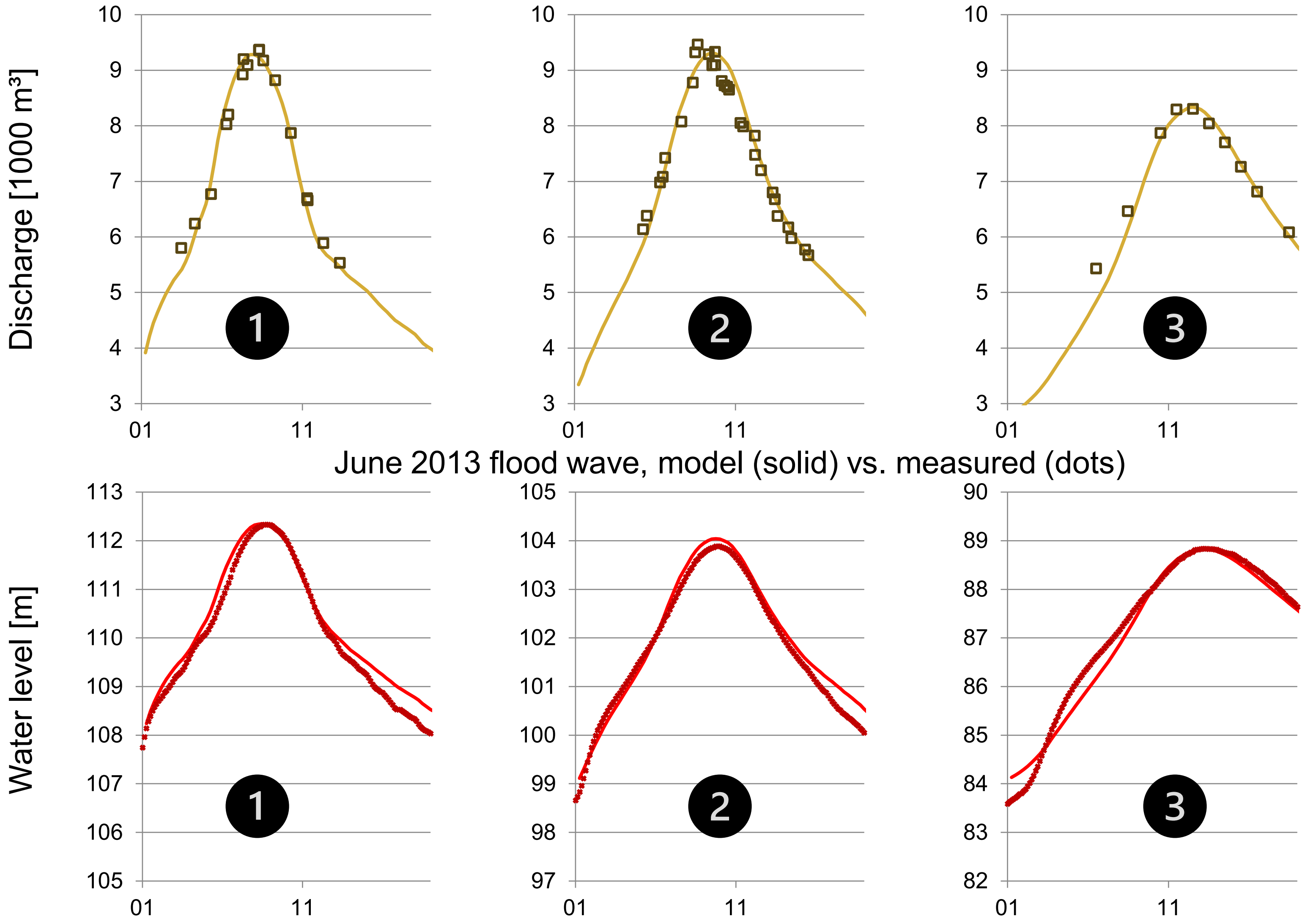
SHMÚ (2013)

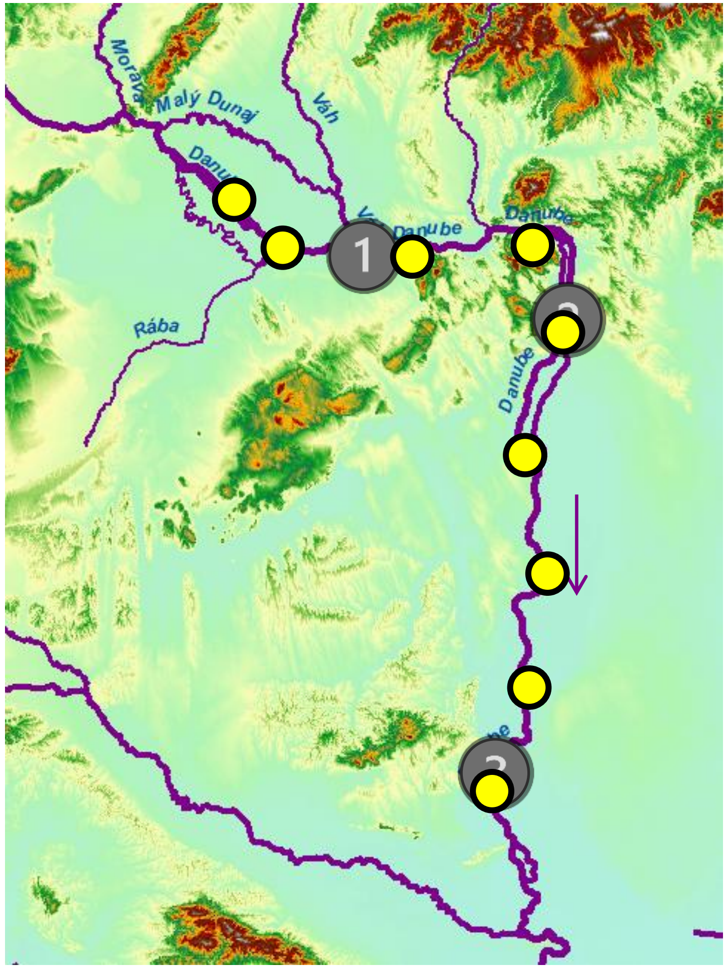
Without lateral storage, we could match peak discharge or peak water level — but not both.



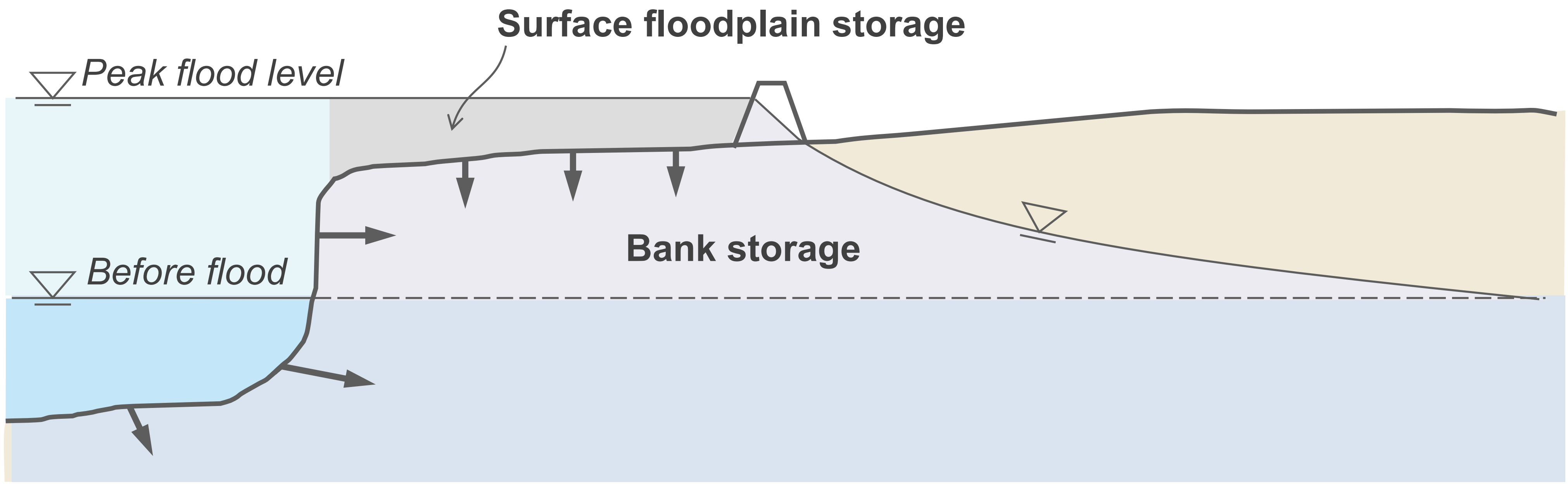


A proxy lateral-storage grid (~every 50 rkm) fixed amplitude and phase — yet isn't portable.

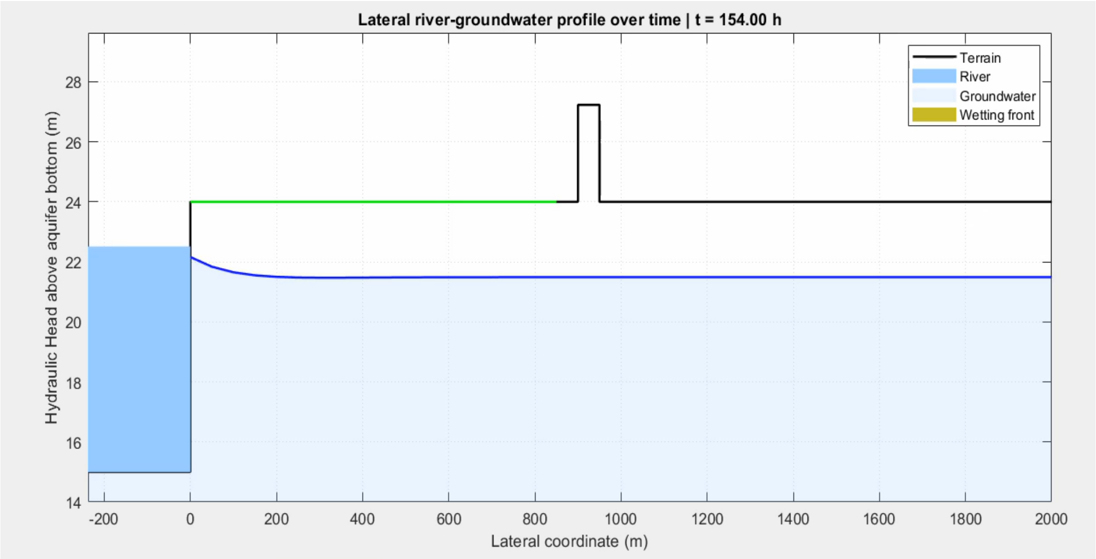




Surface and subsurface (bank) storage attenuate flood peaks.



A 5-parameter process-based lateral exchange model reproduces the essential of the missing physics.



River model
h_R, Q_R
(Saint.Venant eqs)

↑↓ ↑↓

Horizontal infiltration
$f_H(\frac{K_{rb}}{m})$
(via channel)

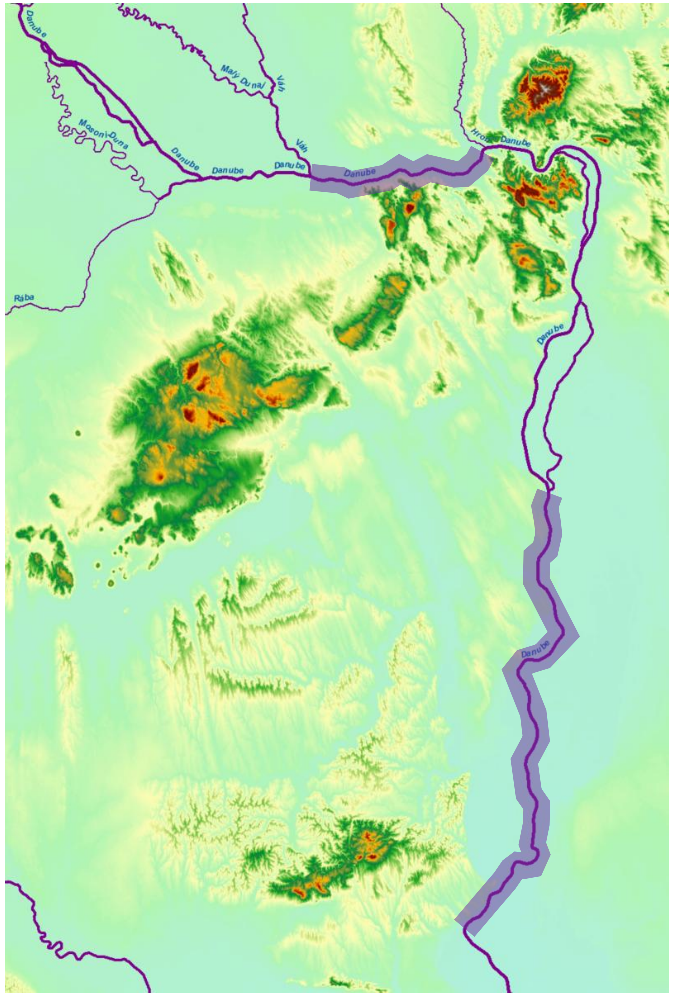
Vertical infiltration
$f_V\left(\frac{K_{cl}}{m}\right)$
(via flooded floodplain)

↑↓ ↑↓

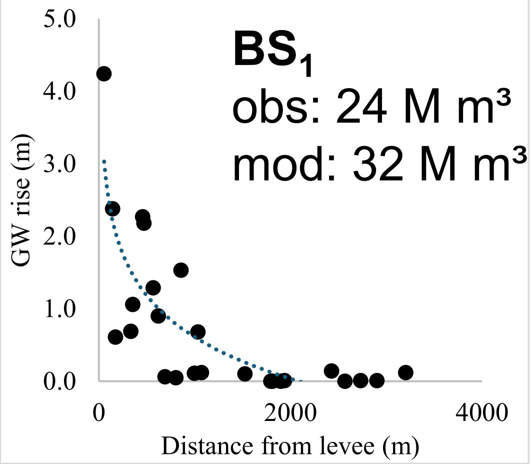
Groundwater model
h_A
(Darcy eqs)

Physically meaningful aquifer parameters: $K_x, \frac{K_{rb}}{m}, \frac{K_{cl}}{m}, S_s, H$

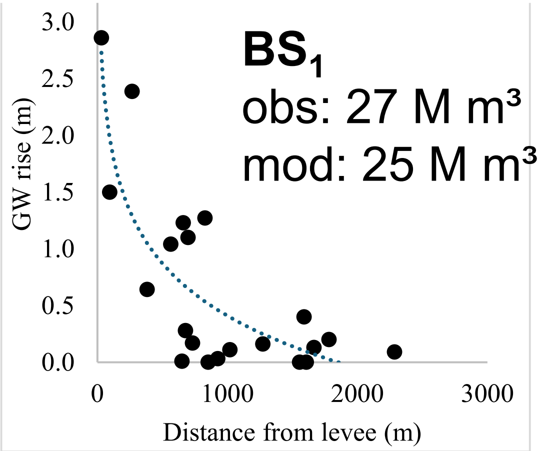
Simple prismatic model estimated bank storage reasonably well over two distinct Danube reaches for record 2013 flood.

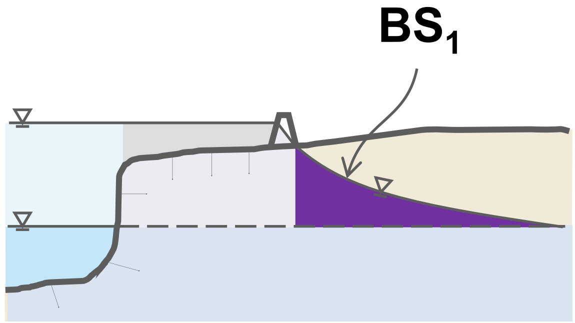


Upper reach (validation)
$L = 42$ rkm
$b_f = 240$ m



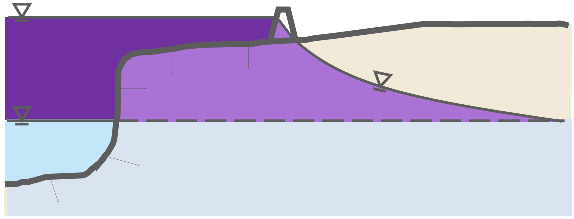
Lower reach (calibration)
$L = 134$ rkm
$b_f = 1800$ m



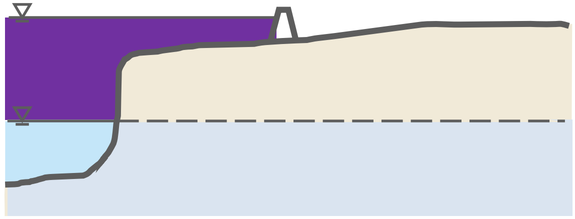


Aquifer properties transferred Lower ⟶ Upper

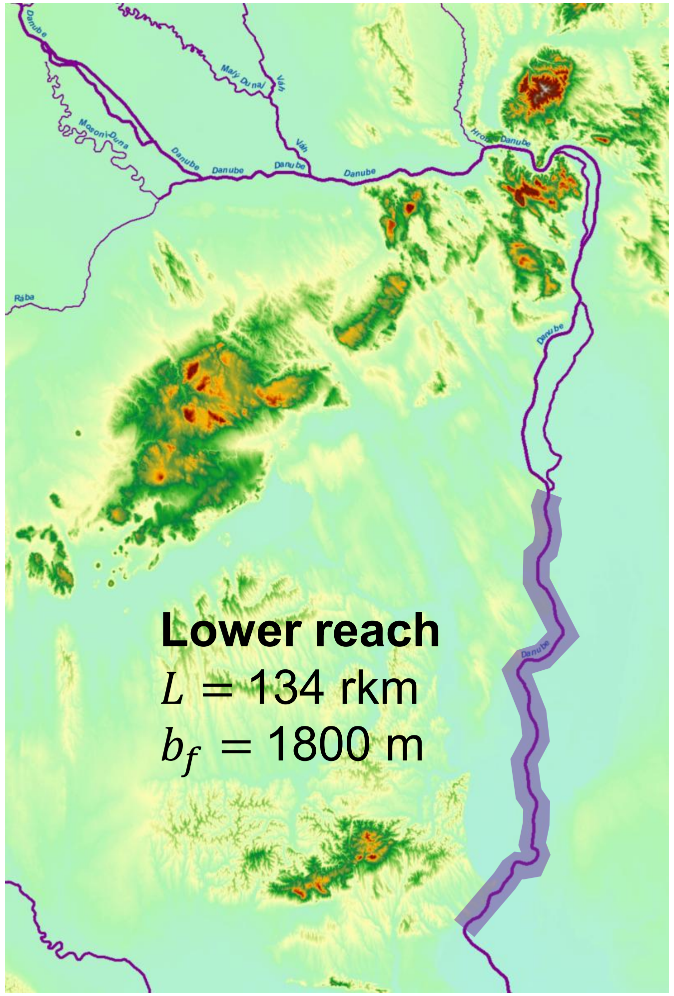
On the Hungarian Danube, bank storage ≈ 26% of surface storage during a simulated 100-year flood.



River linked with aquifer

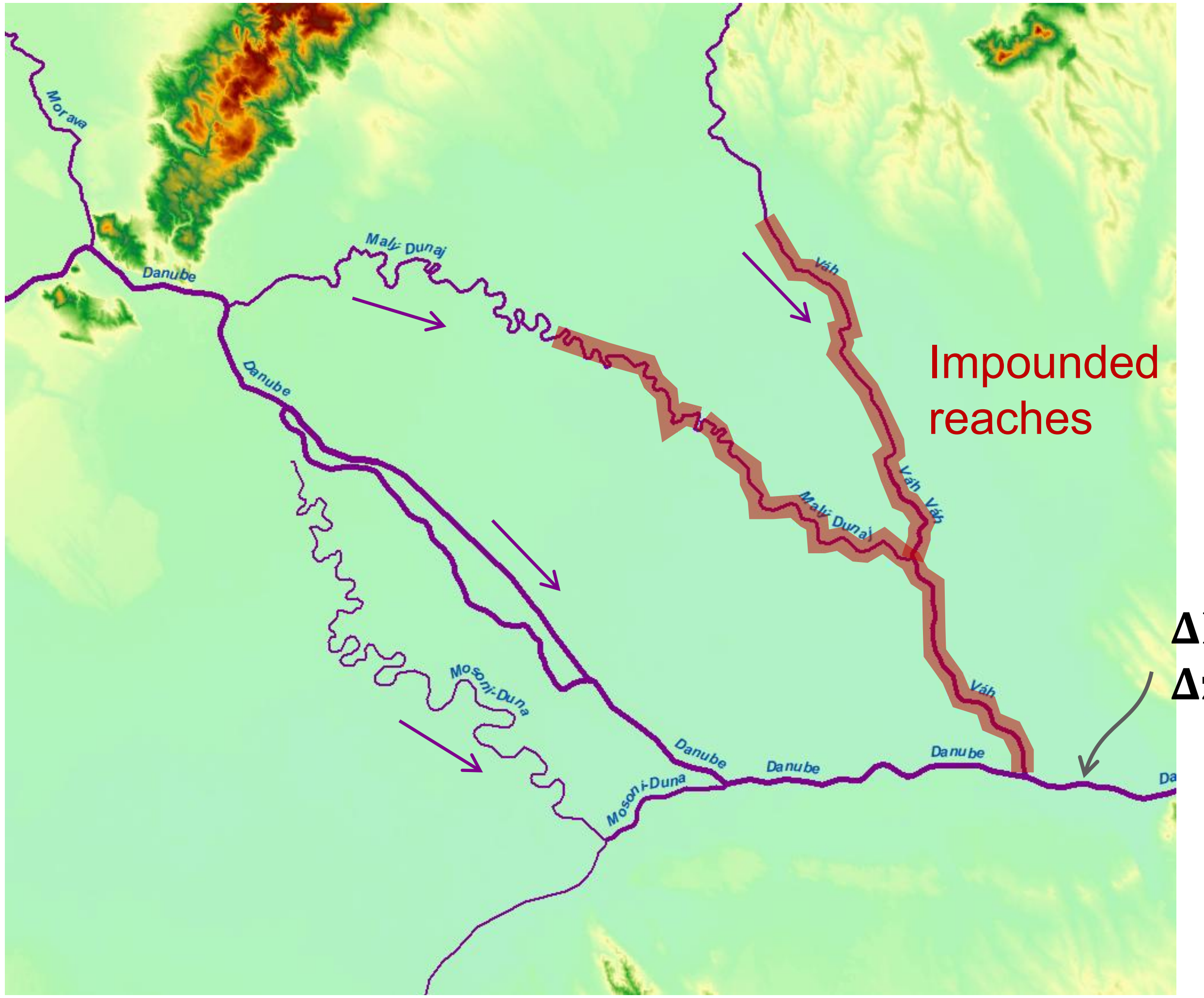


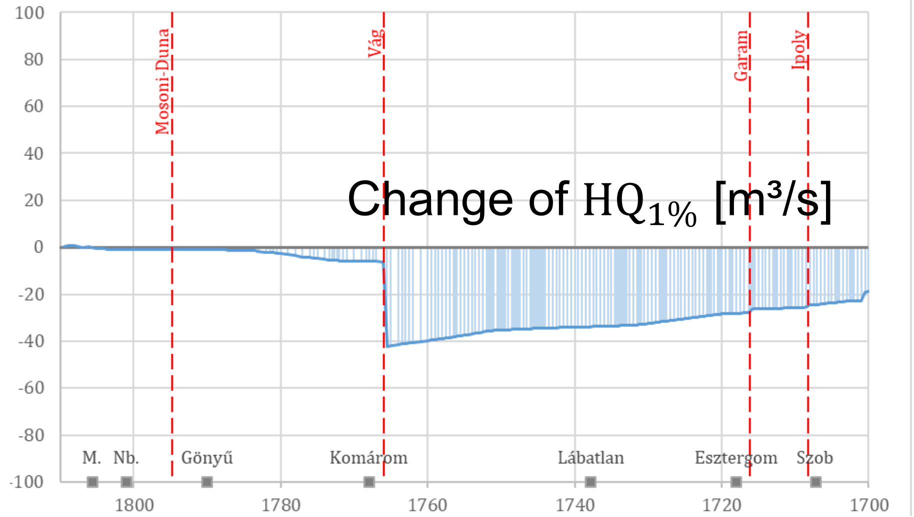
No link to aquifer



	River linked with aquifer	No link to aquifer	
$Q_{R,peak}$ **attenuation**	6.2%	5.7%	/50 rkm
$h_{R,peak}$ **reduction**	0.23 m	0.20 m	/50 rkm
Bank storage	80 M m³ (90% from f_V)	0	/50 rkm
Bank storage / Surface storage	26%	0%	

Impounded tributaries and side branches act as large lateral reservoirs filled with back-flow.

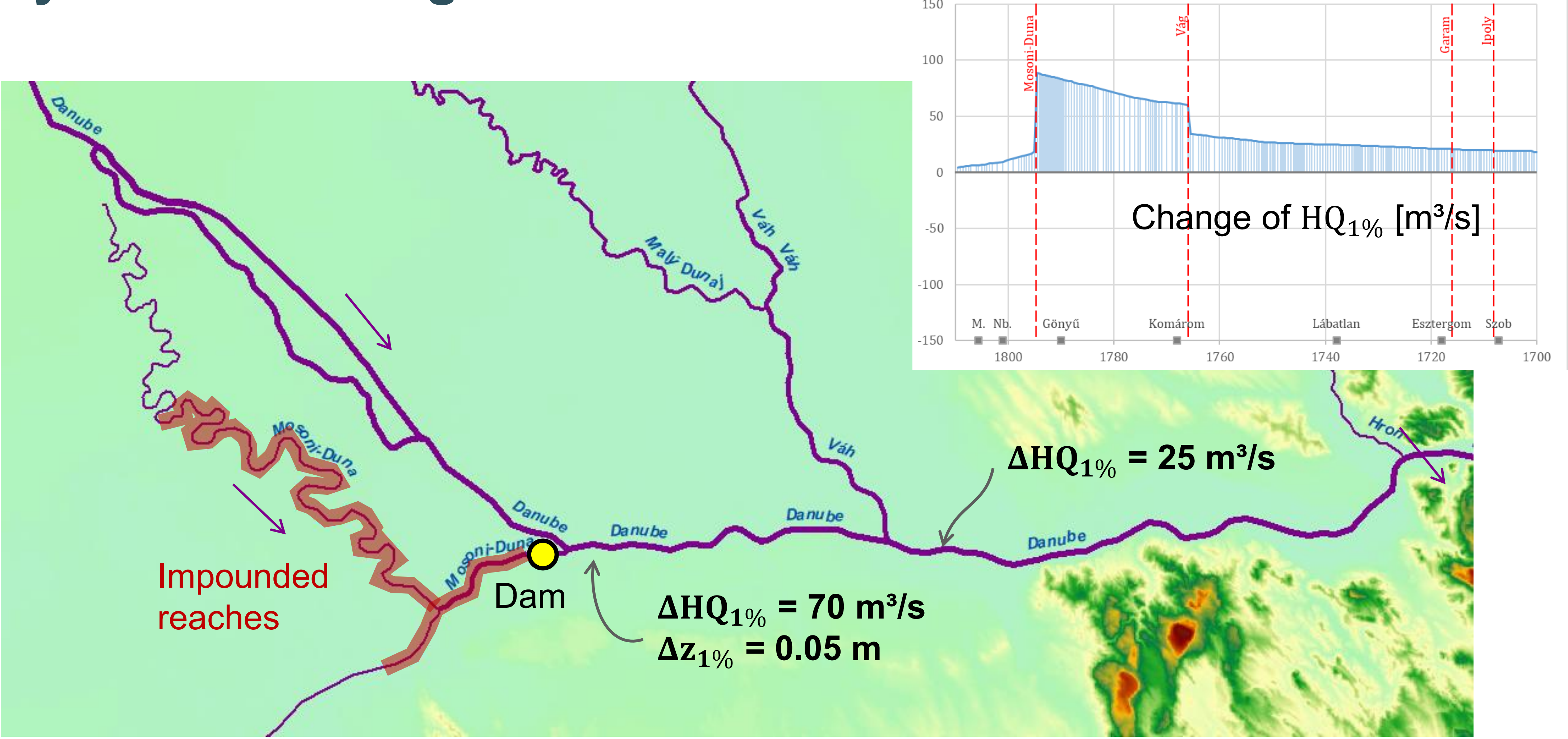




$\Delta HQ_{1\%}$ = −40 m³/s

$\Delta z_{1\%}$ = −0.02 m

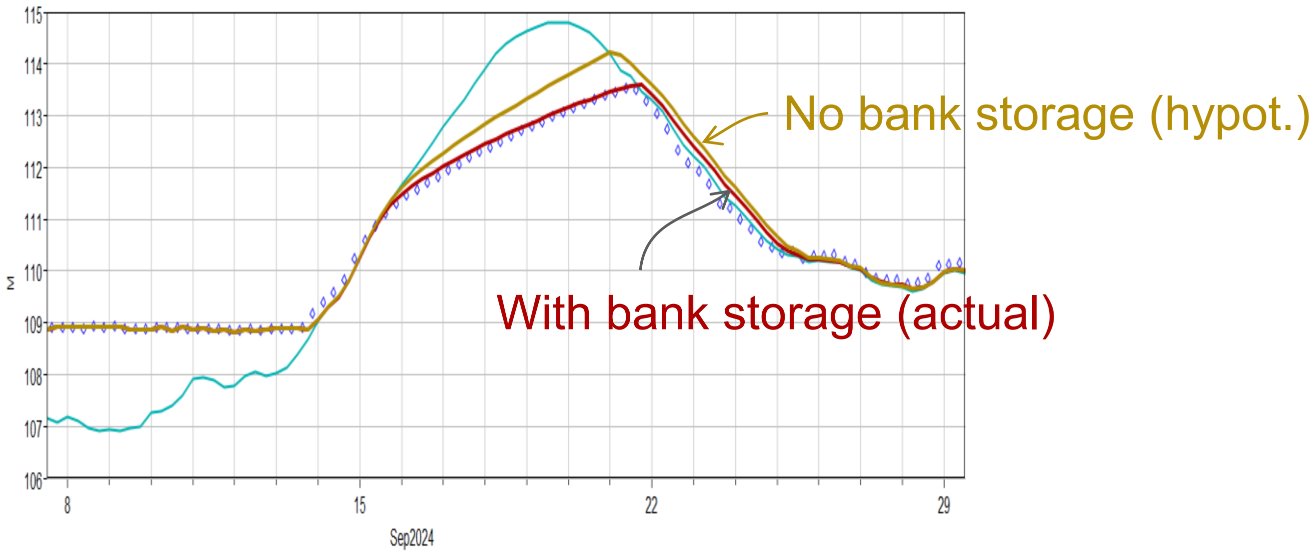
Closing the Mosoni-Duna gate increased Danube flood levels by ~0.05 m during the 2024 flood.

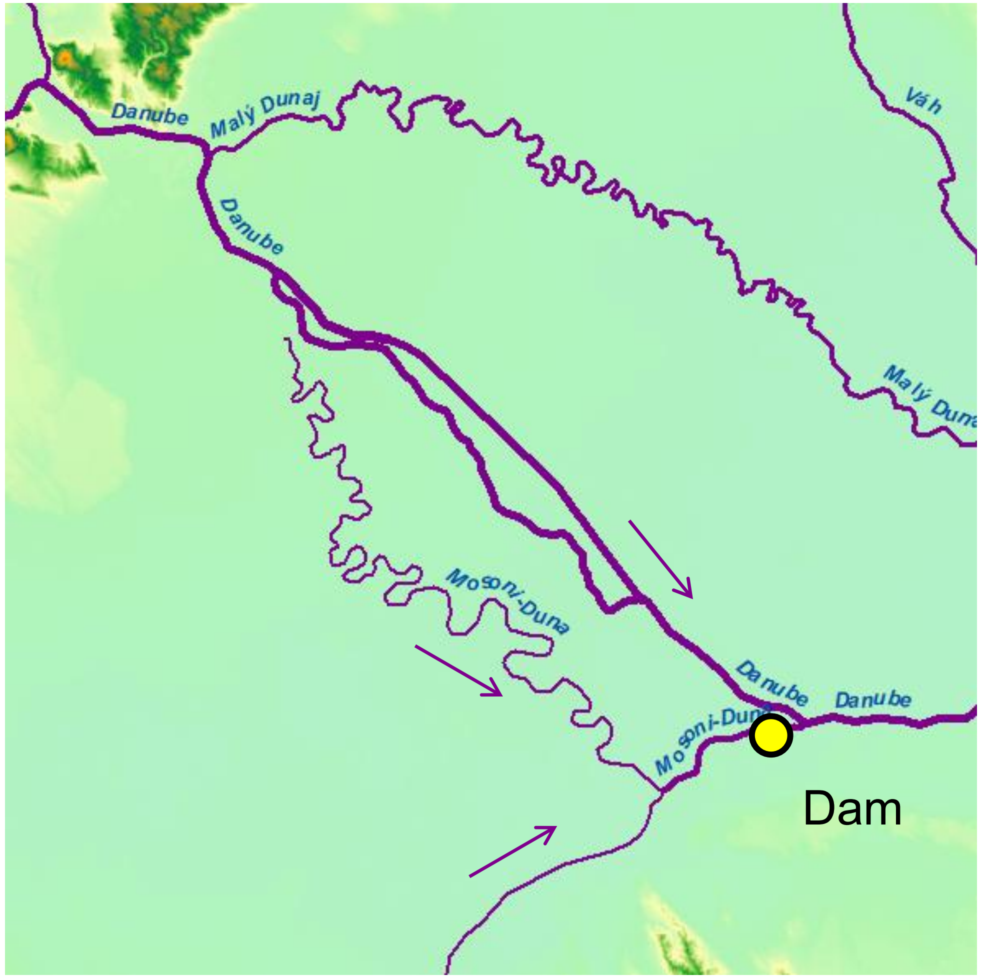


Bank storage increases effectiveness of the Mosoni-Duna flood gate by a 1/3 (~0.5 m).

Storage distribution upstream of the dam [M m³]

Head and tailwater level hydrographs at the dam





Gains of flood conveyance improvement measures (~0.1 m) compare with natural attenuation (~0.08 m; BS ~0.03 m).

ÉDUVIZIG 2023

Floodway on the Rába river

How to model lateral storage in (event-based) simulations?

Tier 1 (most software): Storage areas + lateral weirs/links at tributaries

Tier 2 (light GW): Darcy-style leakage + linear reservoir (2 parameters)

Tier 3 (full): MIKE SHE / MODFLOW / FEFLOW couplings when needed

Mainstream river modelling software already support light/full groundwater exchange.

HEC-RAS

Lateral storage areas + Green-Ampt infiltration (no interaction between the two)

MIKE 11 / Mike Hydro River / MIKE+

Native river–aquifer leakage, clean coupling to MIKE SHE or FEFLOW

SOBEK / D-Flow 1D:

GW via external coupling when needed (using OpenMI)

In summary, bank storage is estimated at 26% of total storage on the Hungarian Danube for a 100-year flood.

Bank storage: long researched, but less attention to vertical (overbank) infiltration, which often prevails.

Flood attenuation due to bank storage and tributary backflow: same order of magnitude as floodplain management measures.

Acknowledment

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