Water Resources Engineering and Management

(CIVIL-466, A.Y. 2024-2025)

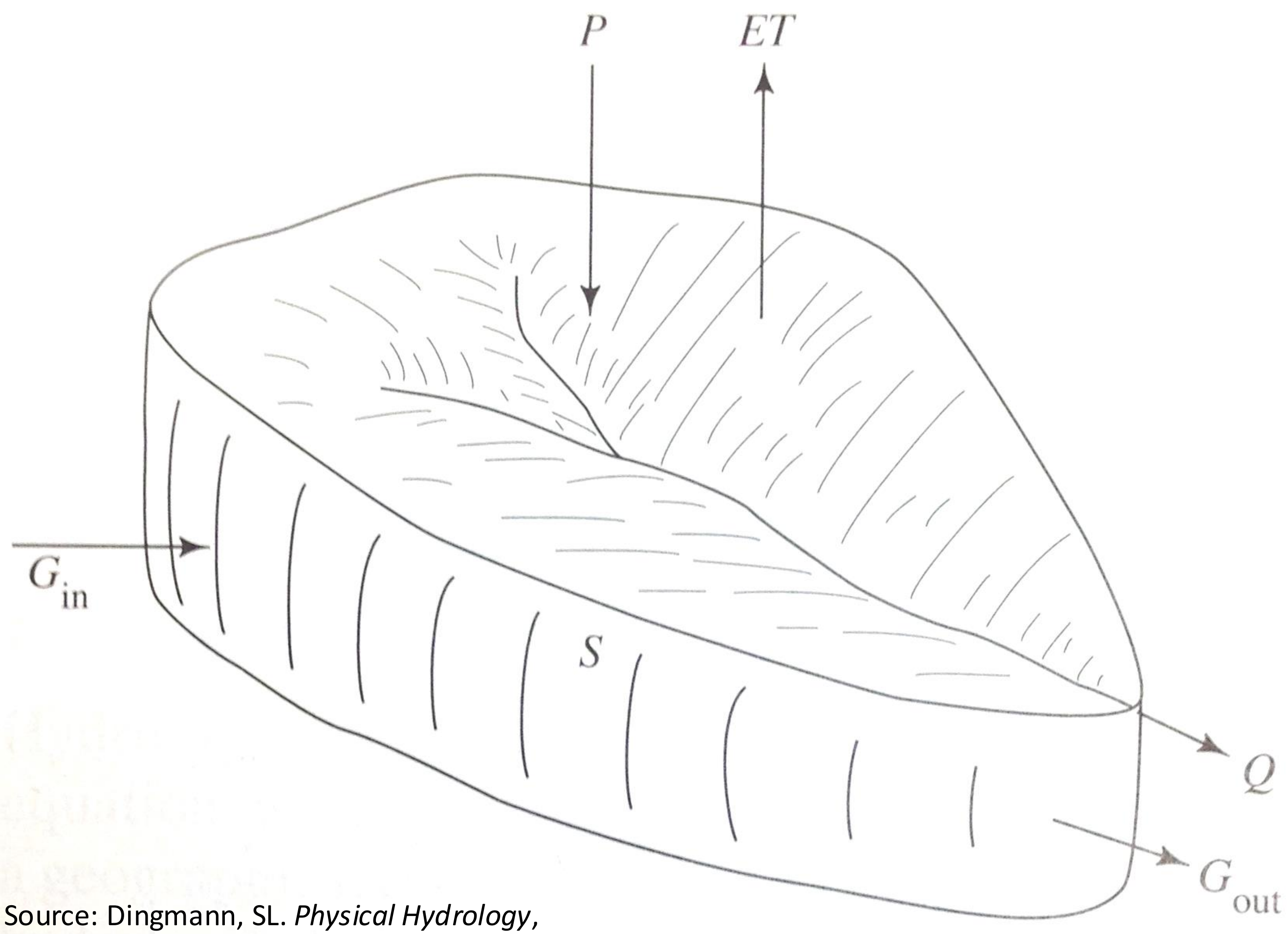
5 ETCS, Master course

Prof. P. Perona
Platform of hydraulic constructions

Lecture 2-2: Water resources: Catchment hydrology and surface water bodies

Catchment hydrology and surface water bodies

Hydrological processes and water budget



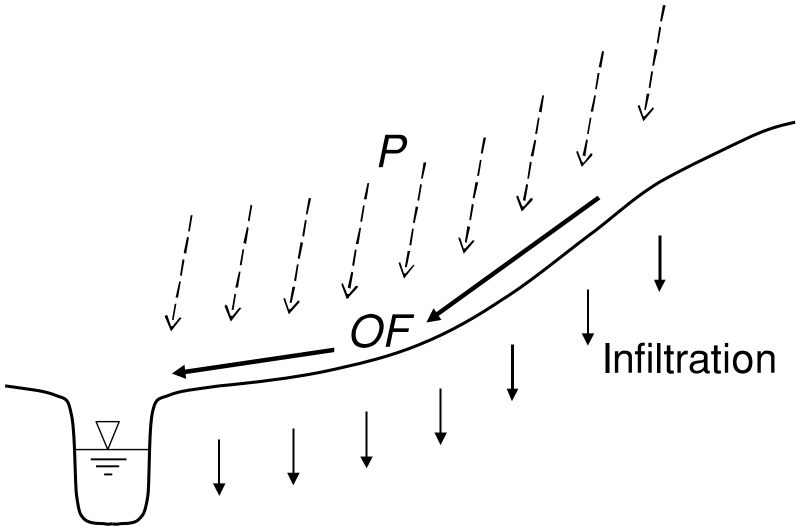
Source: Dingmann, SL. *Physical Hydrology*, Prentice Hall

$$P - ET + G_{in} - G_{out} - Q = \frac{\Delta S}{\Delta t}$$

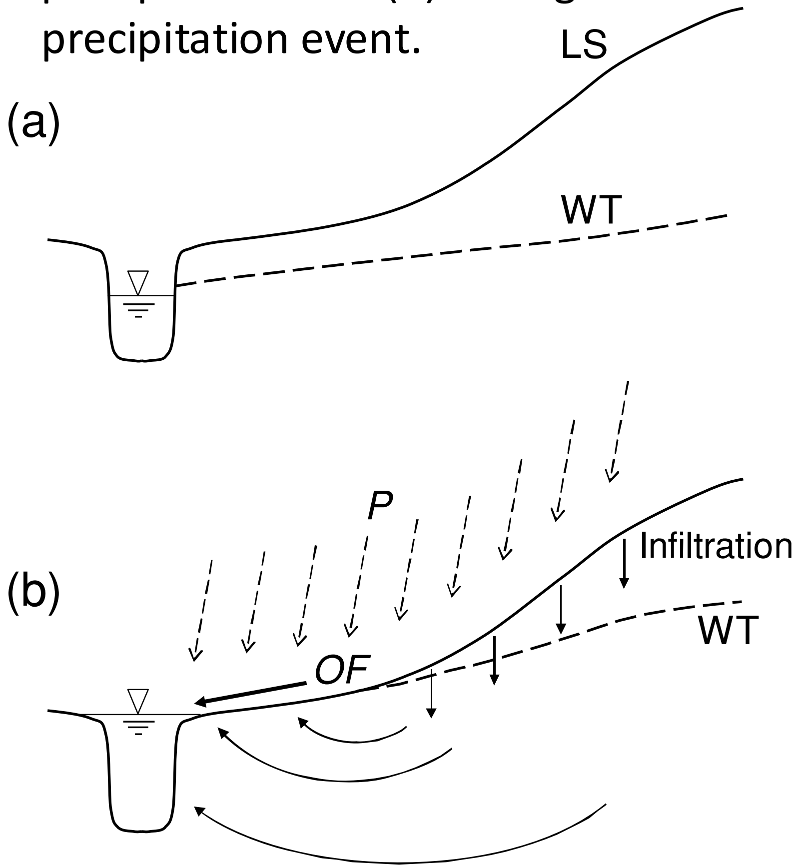
P	mean rate of precipitation
ET	mean evaptranspiration rate
Q	total stream outflow
G_{in}	total groundwater inflow
G_{out}	total groundwater outflow
S	water volume stored in unit area
t	time

Rainfall-runoff processes: three mechanisms

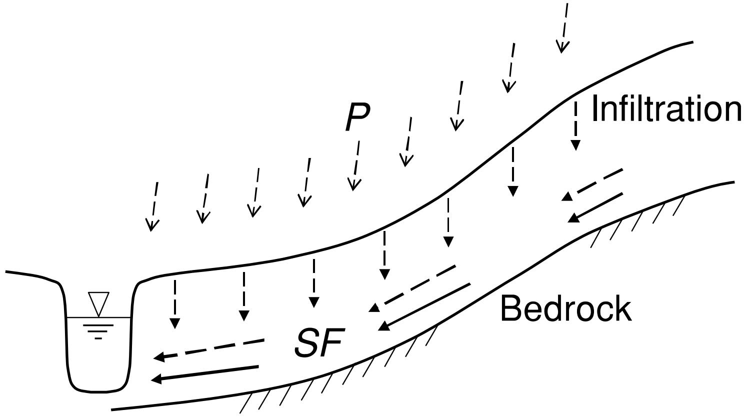
Overland Flow as infiltration excess. The precipitation rate, *P*, exceeds infiltration capacity, and the water table is at the ground surface



Overland Flow as saturation excess. (a) The position of the water table (WT) prior to the onset of precipitation and (b) during the precipitation event.

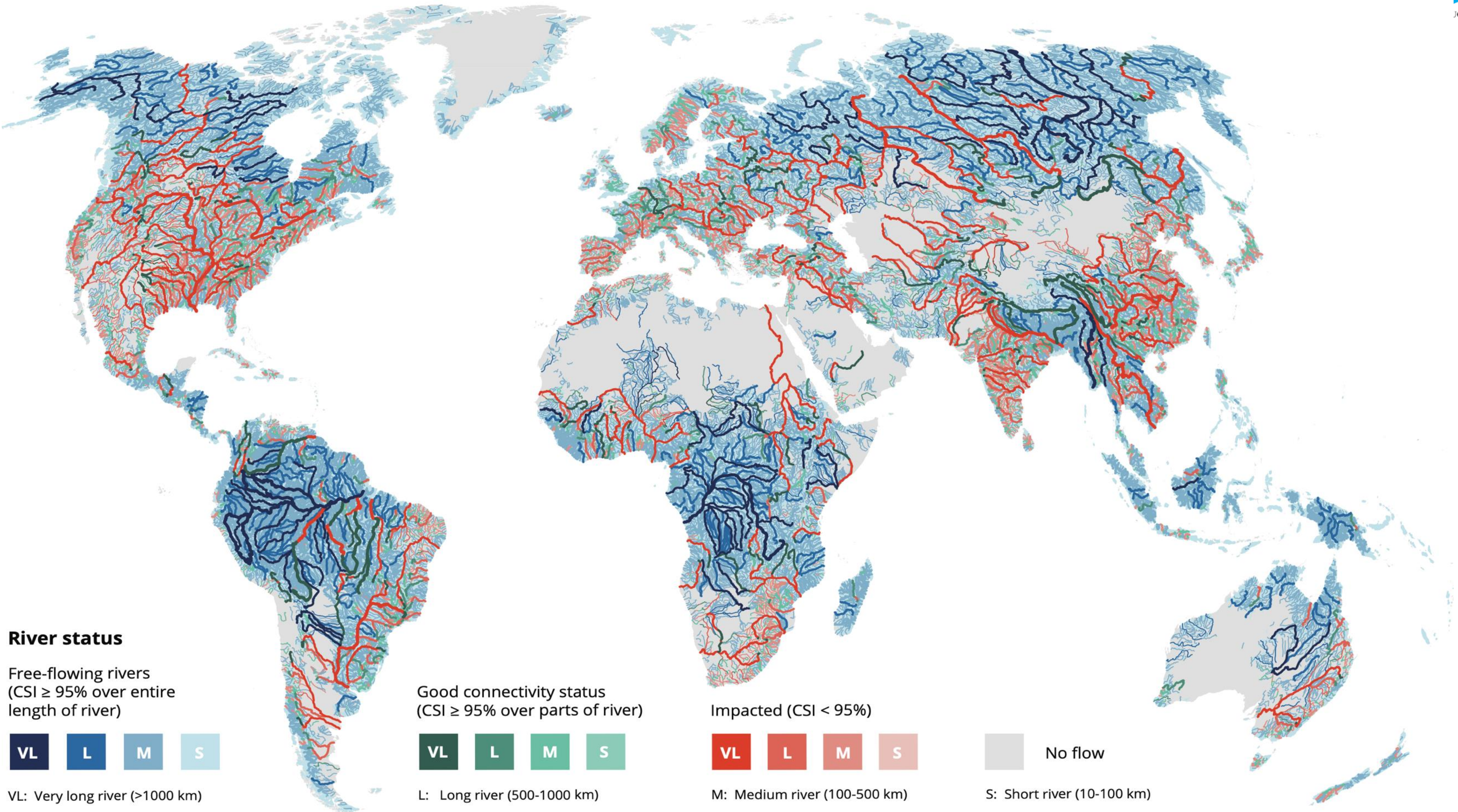


Subsurface storm flow through various types of preferential flow paths, pipes and macropores. The relative amounts of new (dashed arrows) and old (solid arrows) water in the mixing process depend mainly on the precipitation intensity and on the pre-storm soil moisture conditions



Source: Brutsaert, W. *Hydrology*, Cambridge

Status of world rivers (quantity)

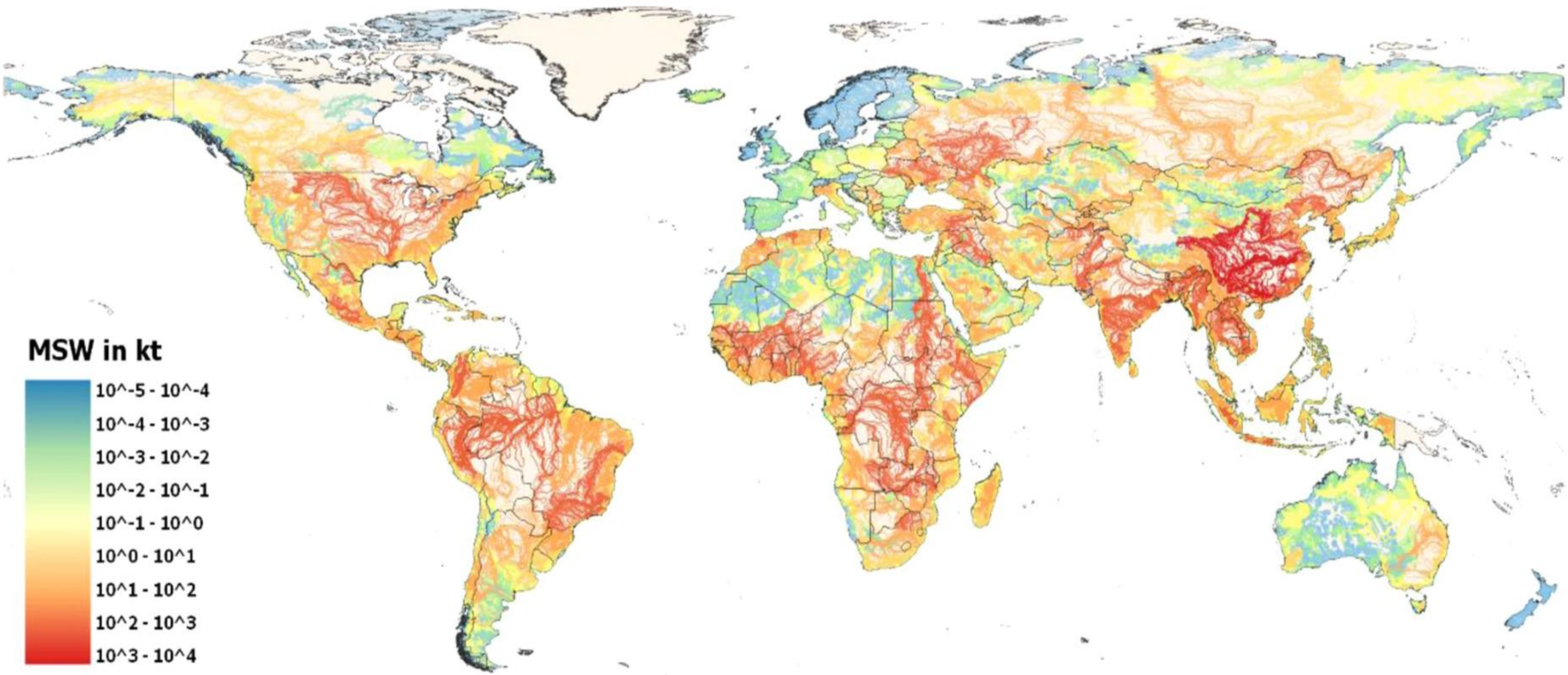


Source:Grill, G., Lehner, B., Thieme, M. *et al.* Mapping the world's free-flowing rivers. *Nature* **569**, 215–221 (2019).©

Status of world rivers (quality)

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Map of potential leakage of Municipal Solid Waste (MSW) into rivers in 2020



Gómez-Sanabria, A., Lindl, F. The crucial role of circular waste management systems in cutting waste leakage into aquatic environments. Nat Commun 15, 5443 (2024). CC-BY 4.0.

What do river ecosystems need

In order to decide environmental water management policies, we must first understand why and how much water is required by the riverine ecosystem.

↓

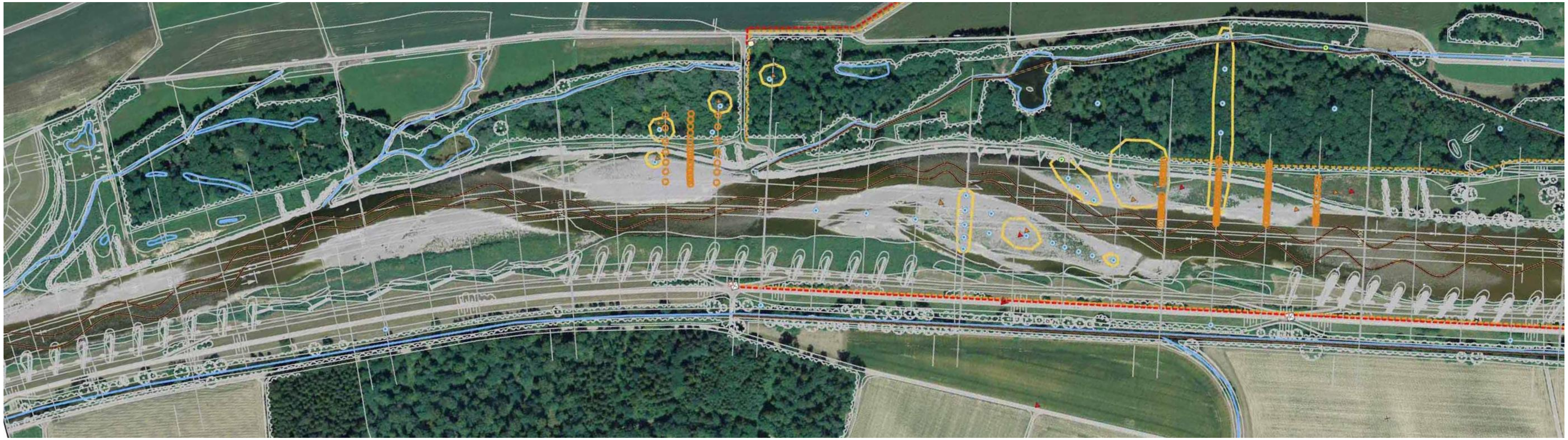
We will primarily focus at rivers and their riparian corridors (exploitation of accessible water resource).

Nowadays research benefits from the sinergies of multiple scientific disciplines (hydrology, hydraulics, ecology, biology, chemistry, etc.)

Alluvial river attributes and the environmental use of water

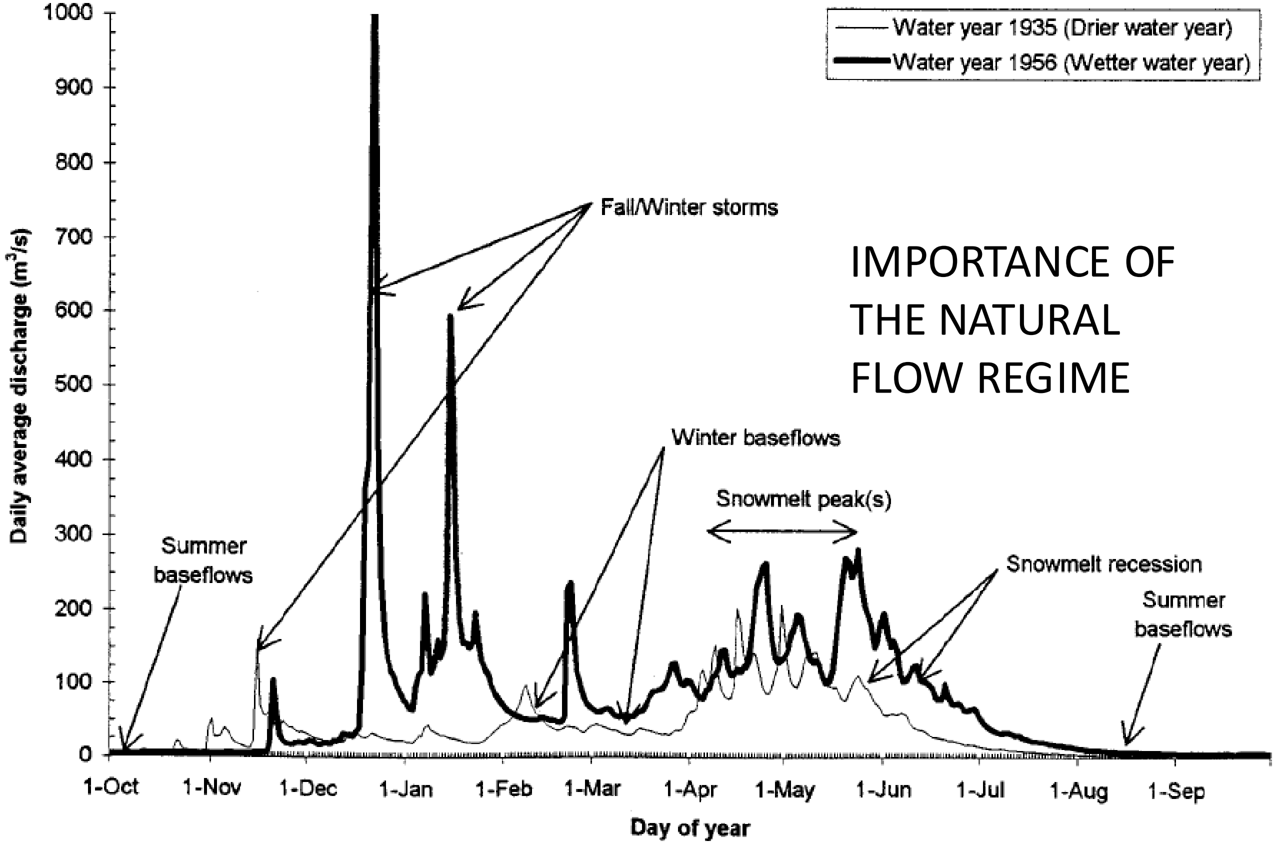
SOURCE: Trush et al. (2000). *PNAS* 97(22):11858-11863

1. <u>The primary geomorphic and ecological unit of an alluvial river is the alternate bar sequence</u>



Bars arise because of flow - bedload transport (convective) instability

2. Each annual hydrograph component accomplishes specific geomorphic and ecological functions

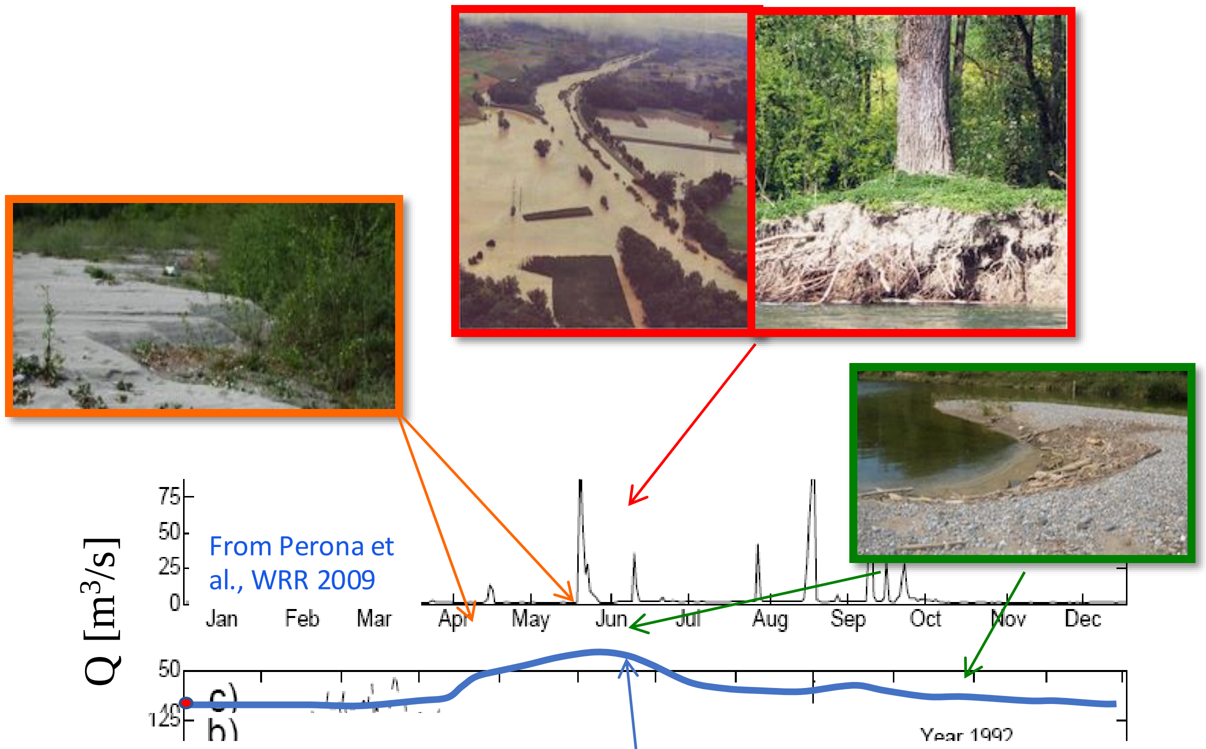


IMPORTANCE OF THE NATURAL FLOW REGIME

Richter et al. hydrological indicators

IHA statistics group	Regime characteristics	Hydrologic parameters
Group 1: Magnitudes of monthly water conditions	Magnitude Timing	Mean value for each calendar month
Group 2: Magnitudes and duration of annual extreme water conditions	Magnitude Duration	Annual minima 1-d mean Annual maxima 1-d mean Annual minima 3-d mean Annual maxima 3-d mean Annual minima 7-d mean Annual maxima 7-d mean Annual minima 30-d mean Annual maxima 30-d mean Annual minima 90-d mean Annual maxima 90-d mean
Group 3: Timing of annual extreme water conditions	Timing	Julian date of annual 1-d maxima Julian date of annual 1-d minima
Group 4: Frequency and duration of high and low pulses	Magnitude Frequency Duration	No. of high pulses each year No. of low pulses each year Mean duration of high pulses per year Mean duration of low pulses per year
Group 5: Rate and frequency of water condition changes	Frequency Rate of change	Means of all positive differences between consecutive daily means Means of all negative differences between consecutive daily values No. of rises No. of falls

Natural flow regime variability

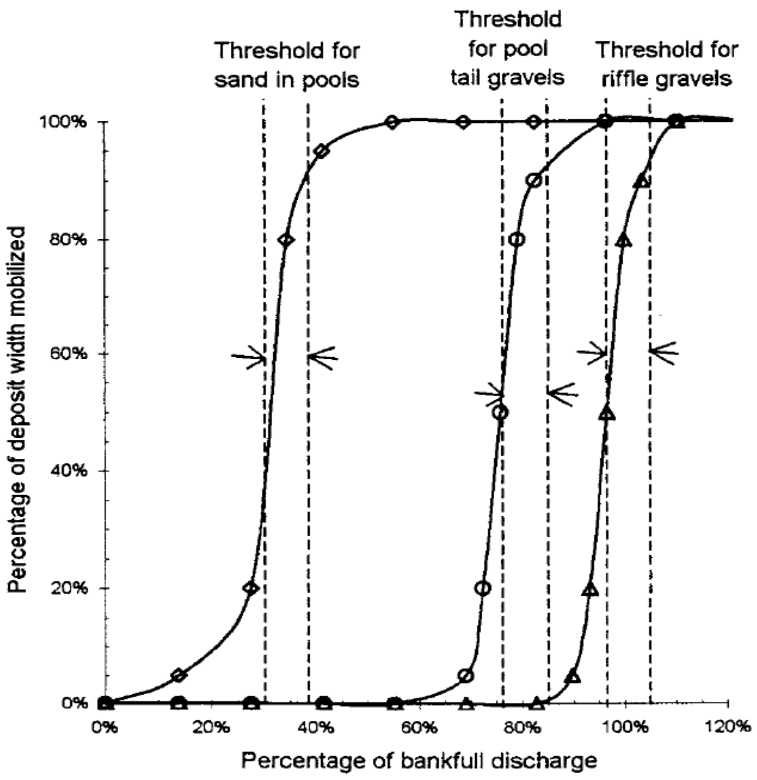


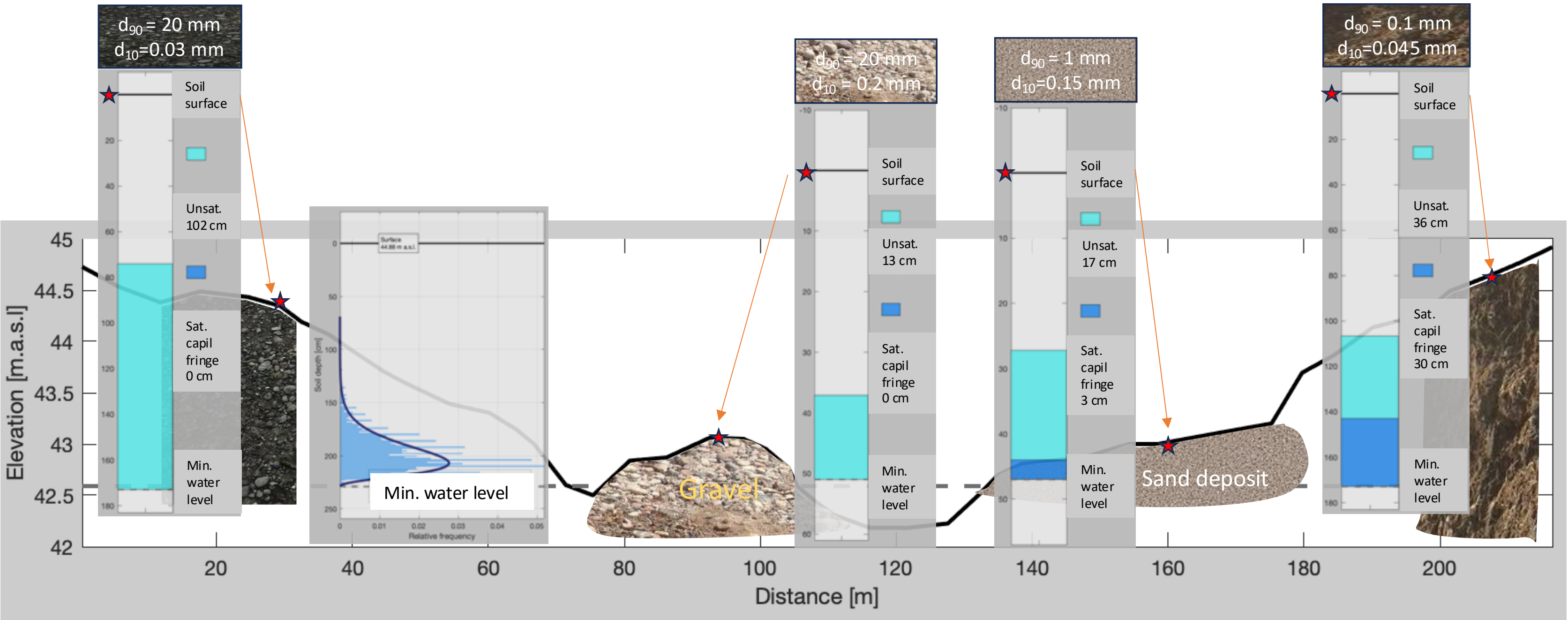
The variability of the signal characterises the "Natural Flow Regime"

To understand the origin of flow variability we need to understand catchment processes

In turn, we can appreciate why human activities may impact water resources and to what extent (future lectures)

3. The channel bed surface is frequently mobilized





Grain size distribution greatly influences soil moisture content and, in turn, biological (animal, vegetal, biogeochemical) processes

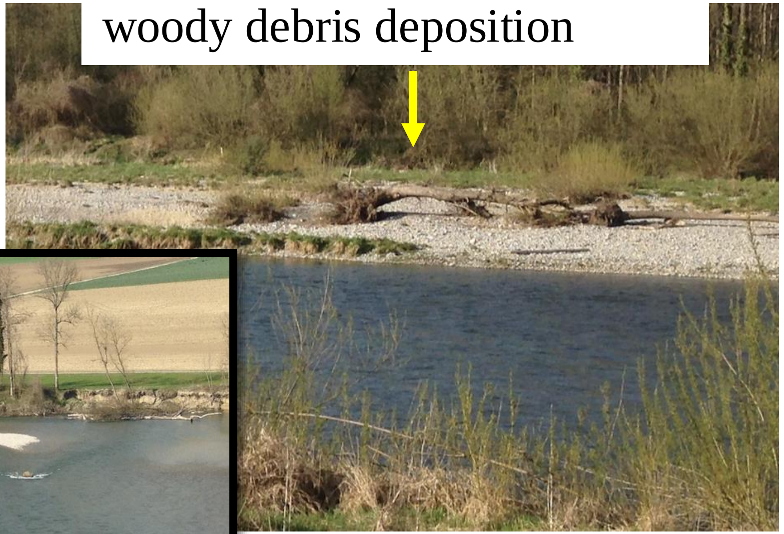
PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

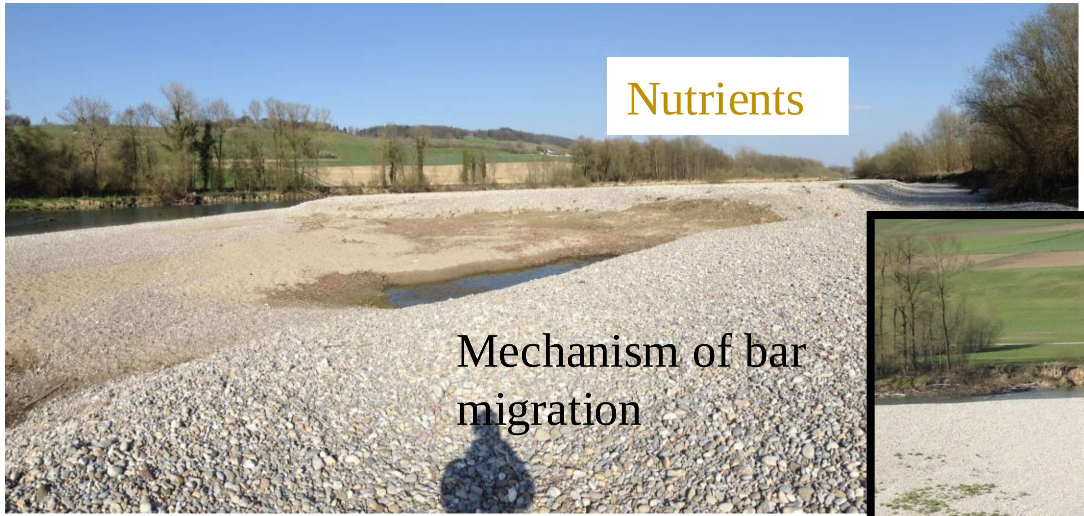
4. Alternate bars must be periodically scoured deeper than their course surface layers

Creation of water pools

Regeneration of sediment at the outer bank (erosion) and at the inner bank (deposition)

Vegetation recruitment and woody debris deposition



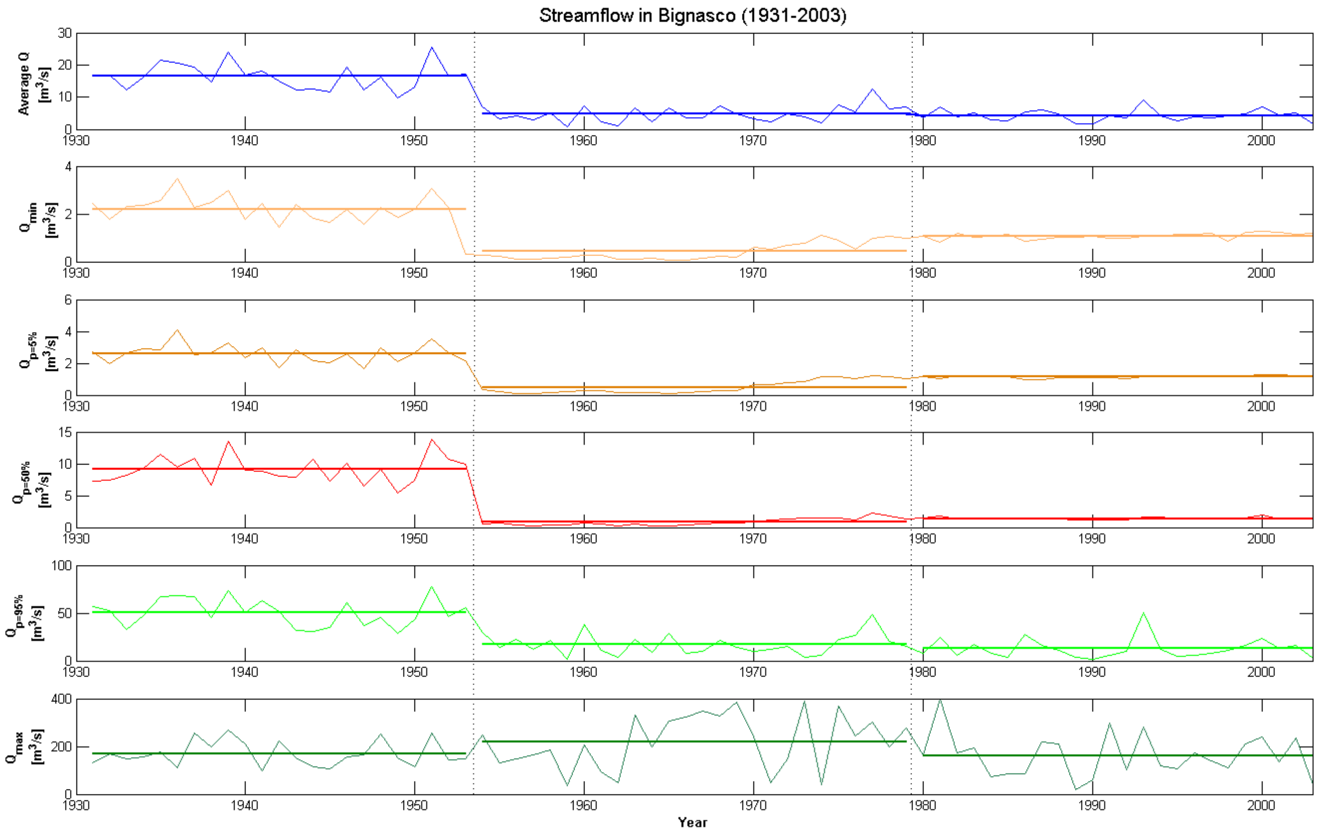


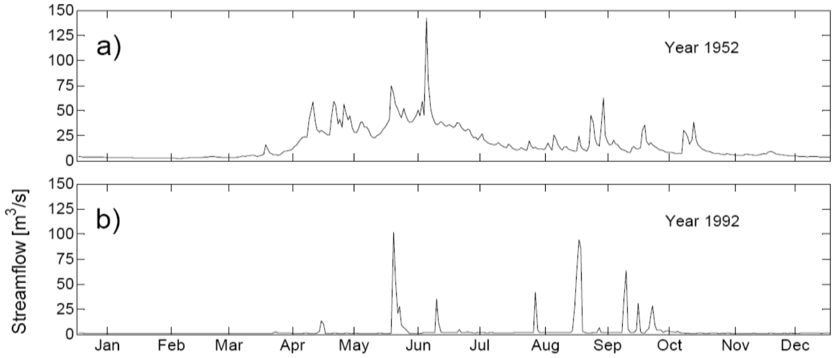
Nutrients

Mechanism of bar migration

Islands formation

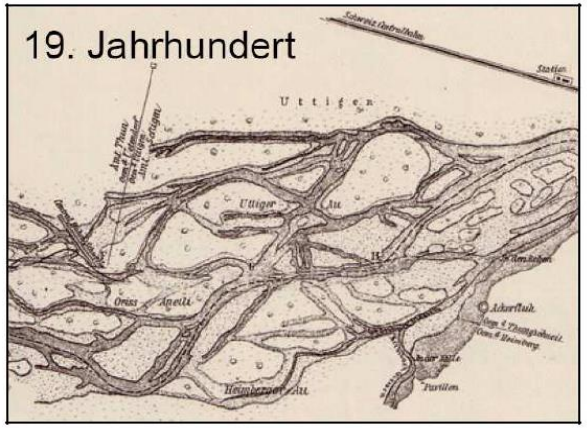
5. Fine and coarse sediment budgets are balanced

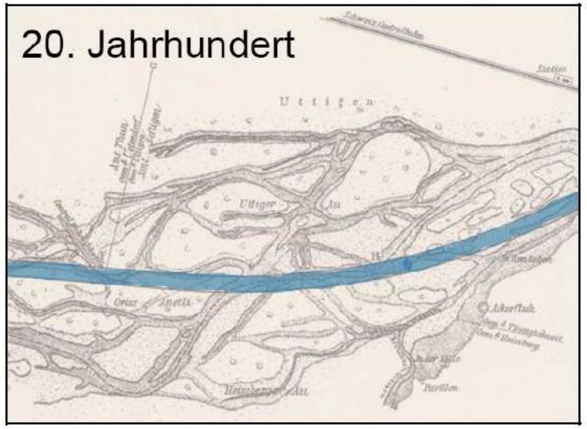


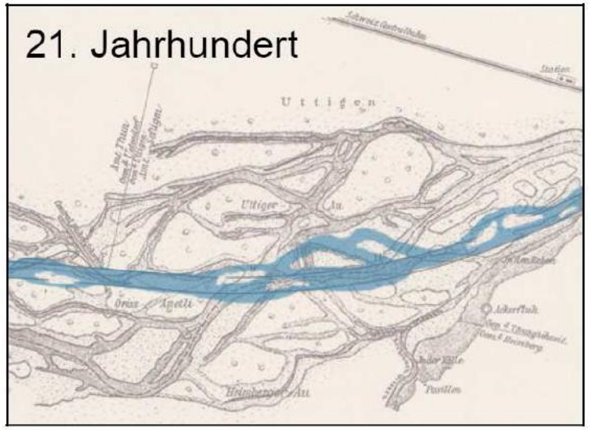


MFR concept removes the mobilization of sediment classes and unbalance the sediment budget

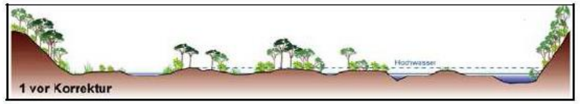
6. Alluvial channels are free to migrate

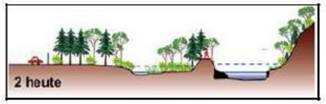


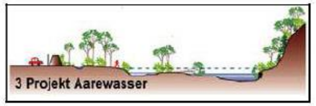


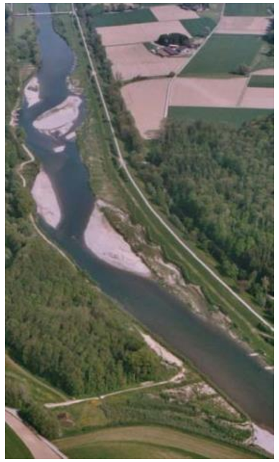


River AARE





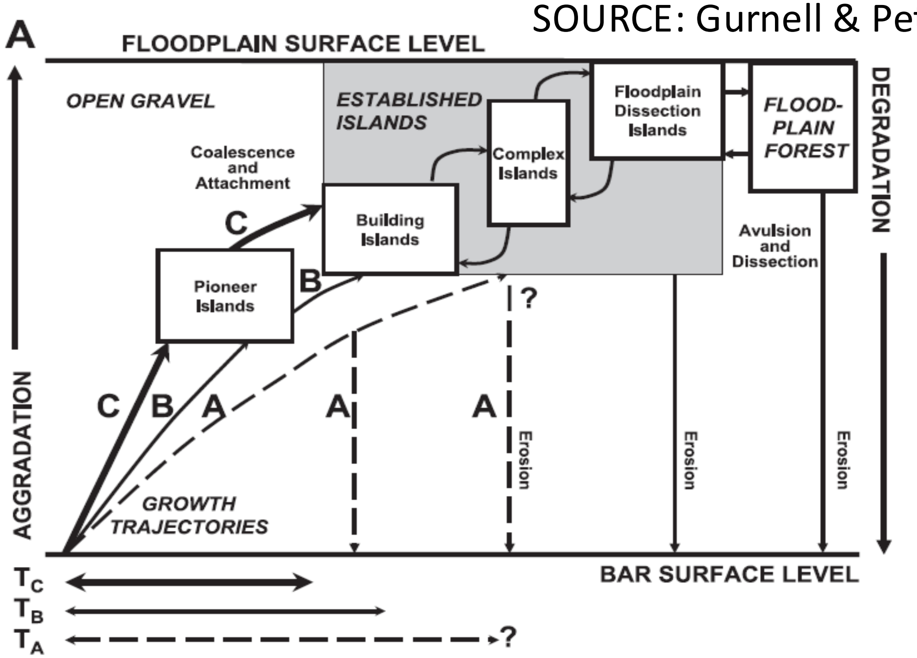


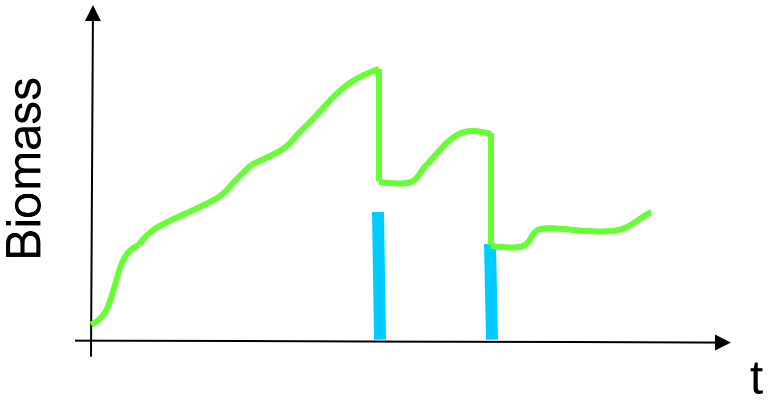


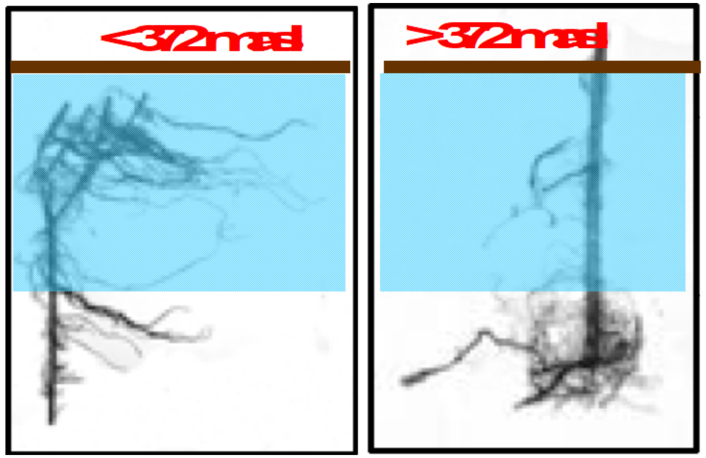
River Thur

7. Floodplains are frequently inundated

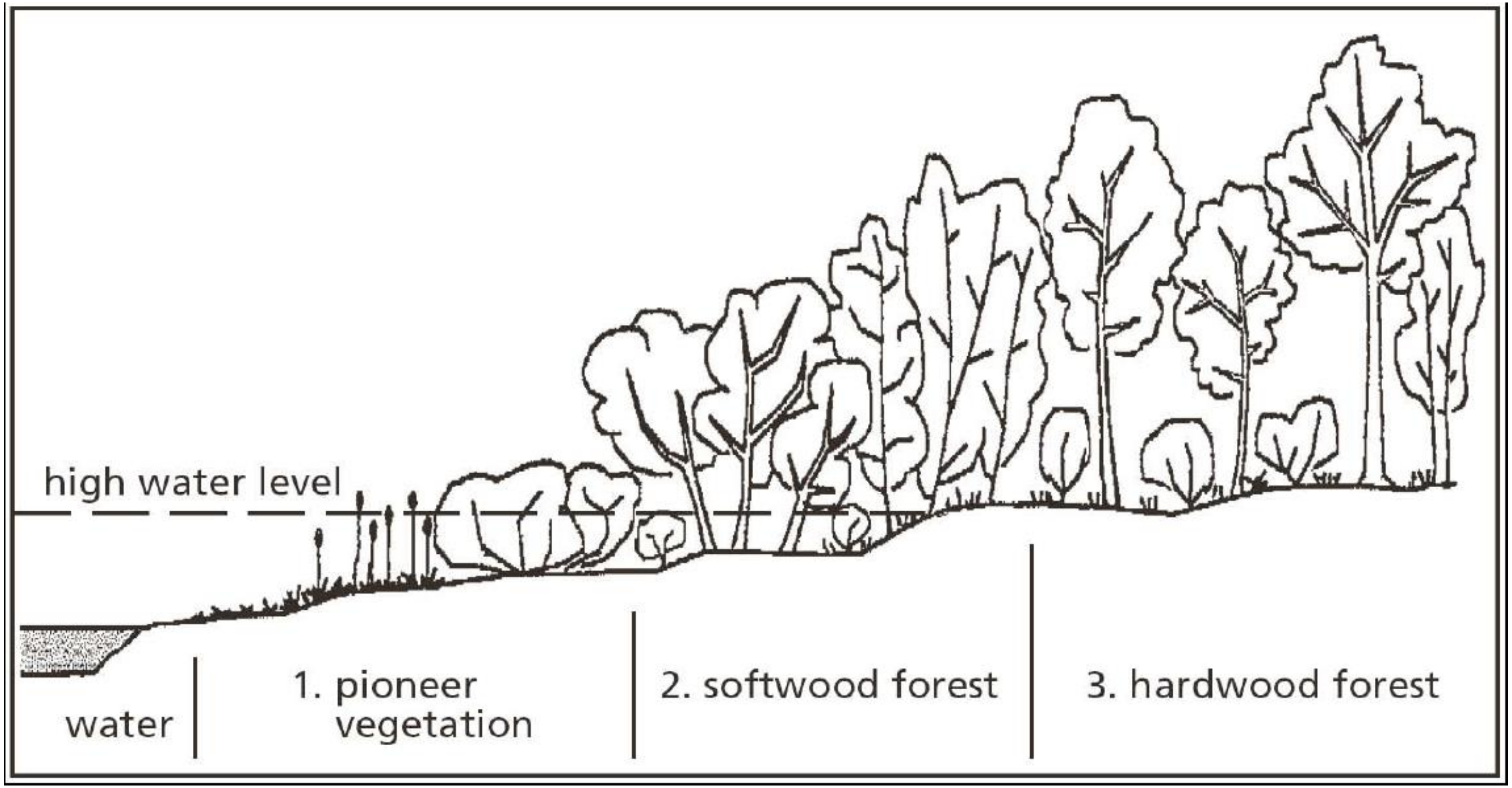
SOURCE: Gurnell & Petts (2006)







8. Large floods create and sustain a complex mainstream and floodplain morphology



9. Diverse riparian plant communities are sustained by the natural occurrence of annual hydrograph components

SOURCE: Glenz, Ph.D. 2005

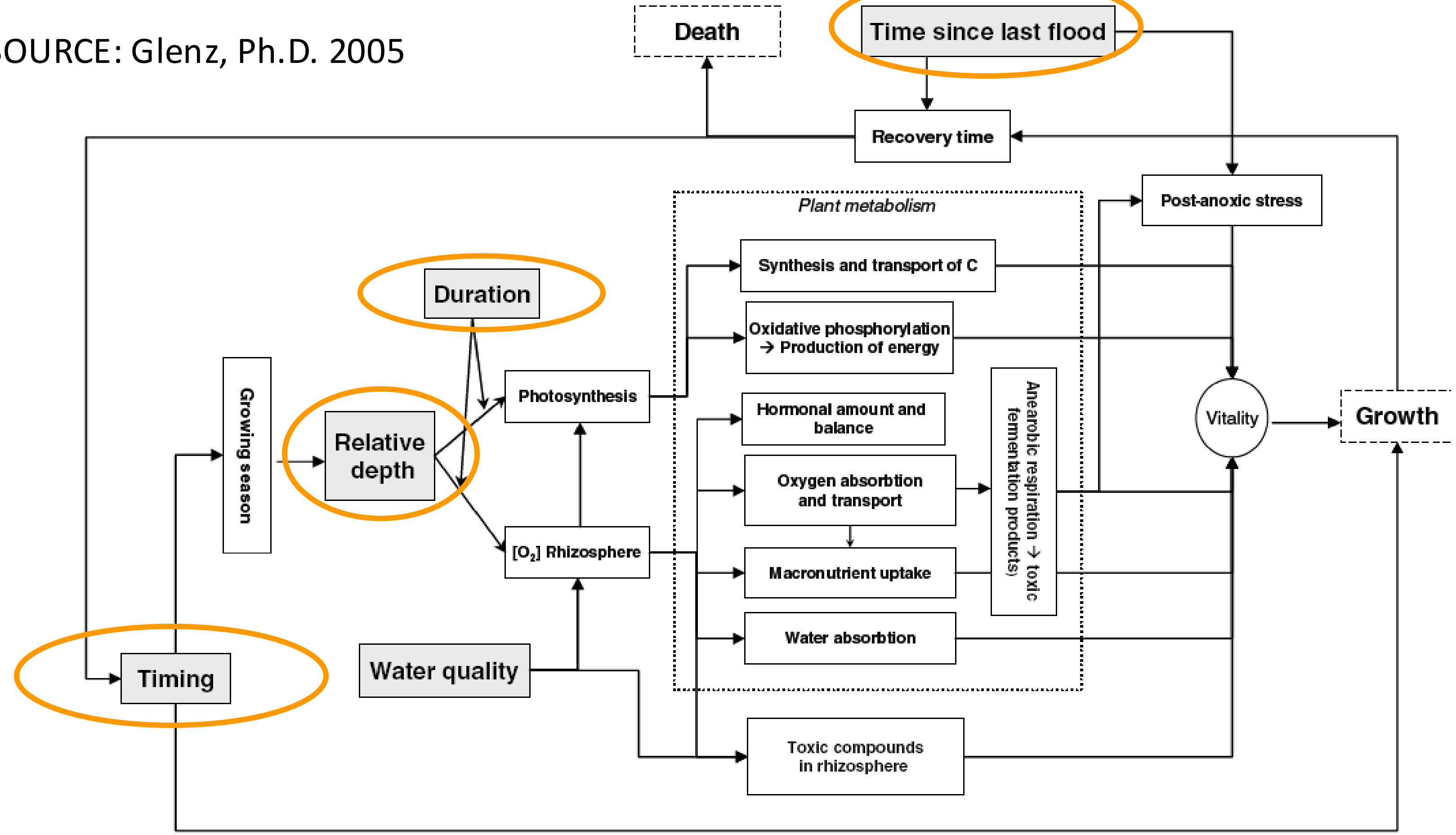
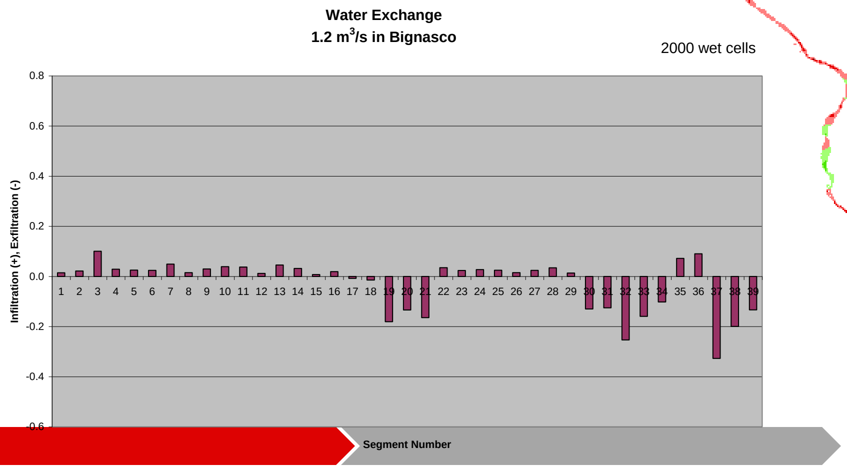
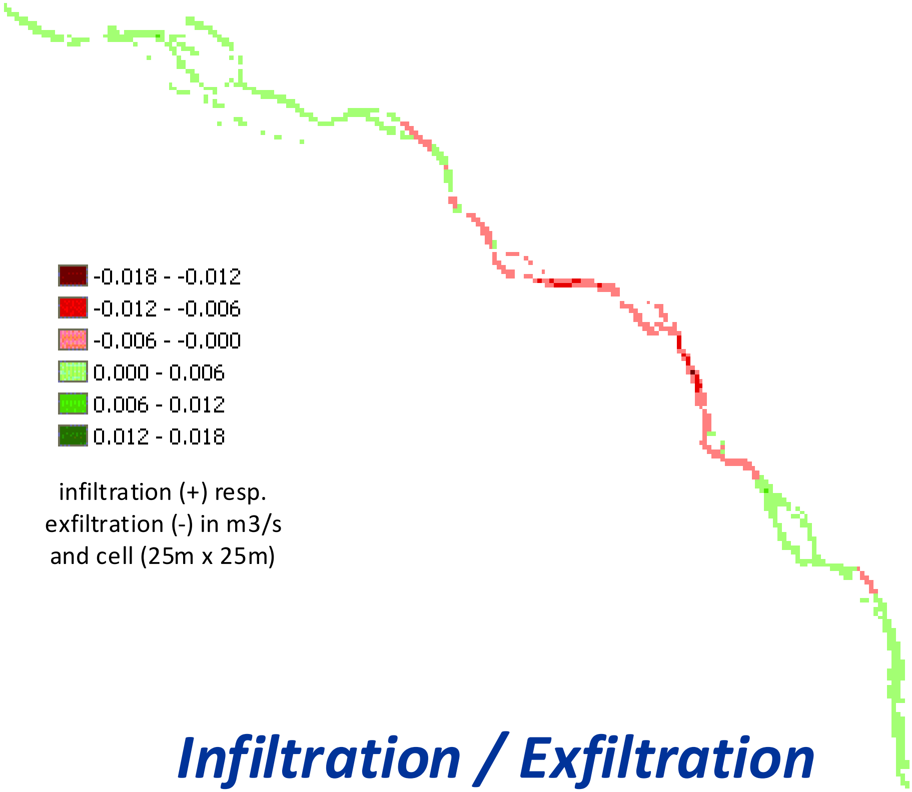


Figure 1: Conceptual model illustrating the main abiotic factors affecting flooding tolerance and their relation to the plant metabolism of tree and shrub species.

10. Groundwater in the valley bottomlands is hydraulically connected to the mainstream channel





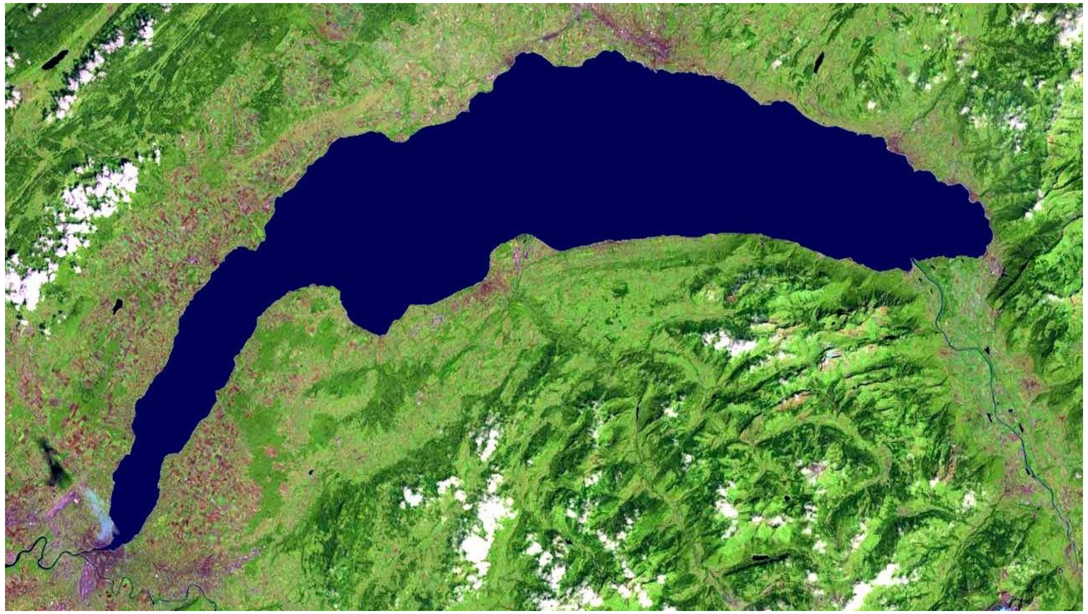
- -0.018 - -0.012
- -0.012 - -0.006
- -0.006 - -0.000
- 0.000 - 0.006
- 0.006 - 0.012
- 0.012 - 0.018

infiltration (+) resp. exfiltration (-) in m3/s and cell (25m x 25m)

Infiltration / Exfiltration

1.2 m^3/s in Bignasco

Lakes and reservoirs

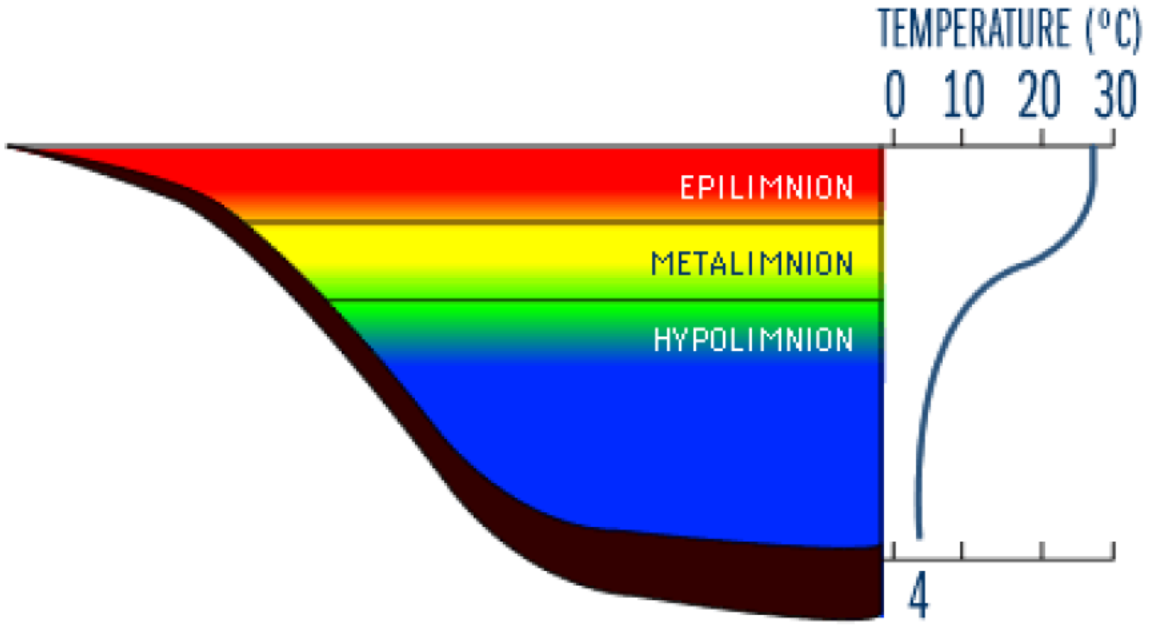


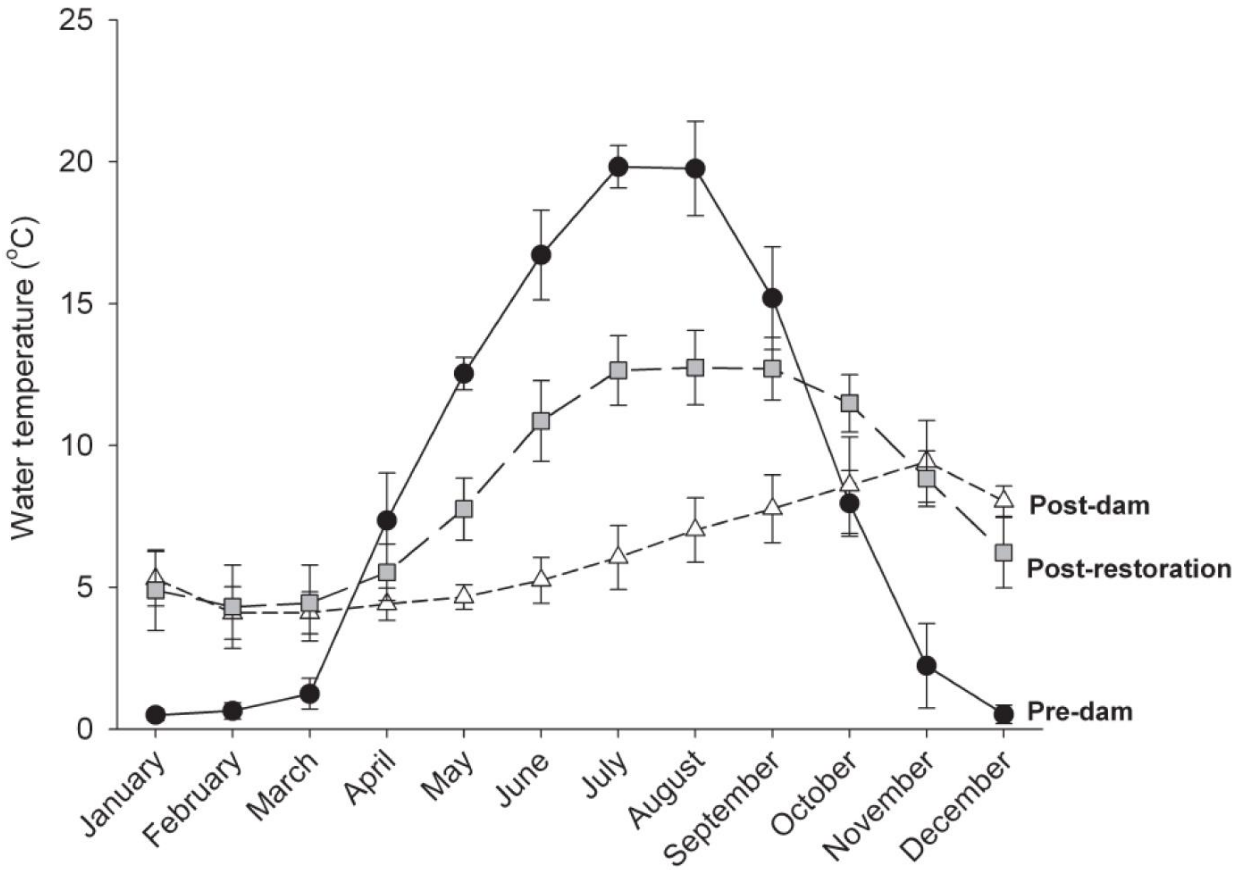
Natural lakes are important ecosystems

Artificial lakes are used to store water and may affect the local climate as well

At the annual scale, evaporation from such water bodies generically equals precipitation as well as infiltration losses balance the lateral flows

Thremal stratification of reservoirs





Selective discharge below Flaming Gorge Dam using a multilevel intake structure has markedly decreased the degree of thermal alteration in the Green River (U.S.A.). Comparisons of monthly water temperature during pre-dam (1958–62,circles), post-dam(1963–77,squares) and post-thermal restoration years (1978–2007,triangles)

Lake mass-balance equation

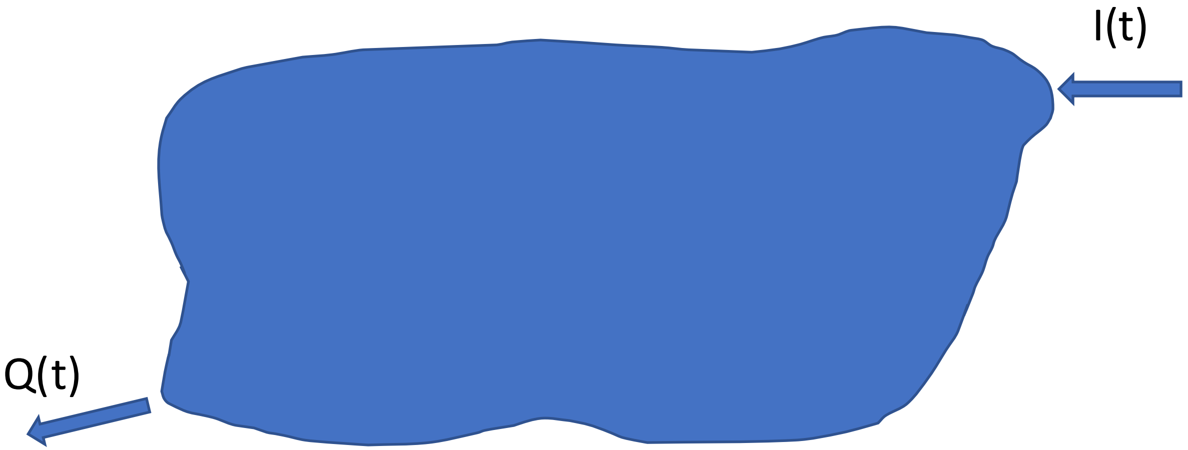
The lumped dynamics of the stored water can be modelled as gathering all inputs and all outputs together

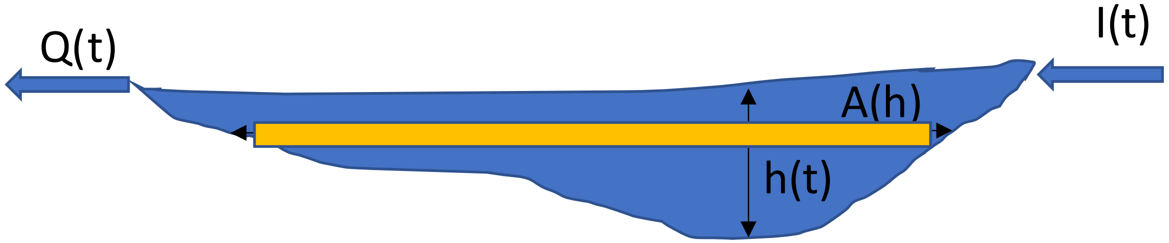
$$\frac{dV(t)}{dt} = I(t) - Q(t)$$

Where $dV(t) = A(h)dh$

$$A(h)\frac{dh(t)}{dt} = I(t) - Q(t)$$

Plus I.Cs.





Barrage de Ksob (Algérie)

Human activities may affect the hydrodynamic circulation of natural lakes, whereas sediment apportion and filling is a major problem of reservoirs, particularly in arid climates where rivers transport a lot of suspended (fine) sediment