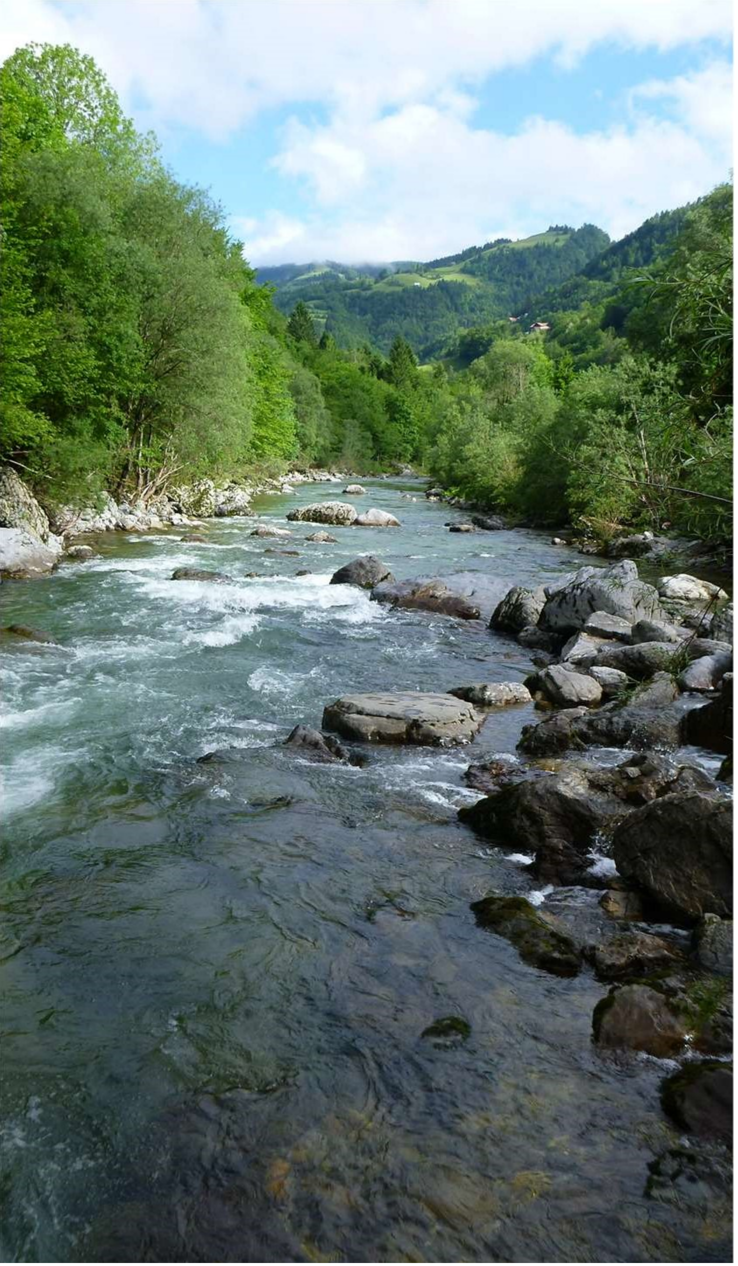

Understanding natural flow patterns and hydrological alteration as an essential basis for e-flow assessment

Daniel S. Hayes

University of Natural Resources and Life Sciences

21 October 2019

INDIA-EU WATER PARTNERSHIP

german cooperation
DEUTSCHE ZUSAMMENARBEIT

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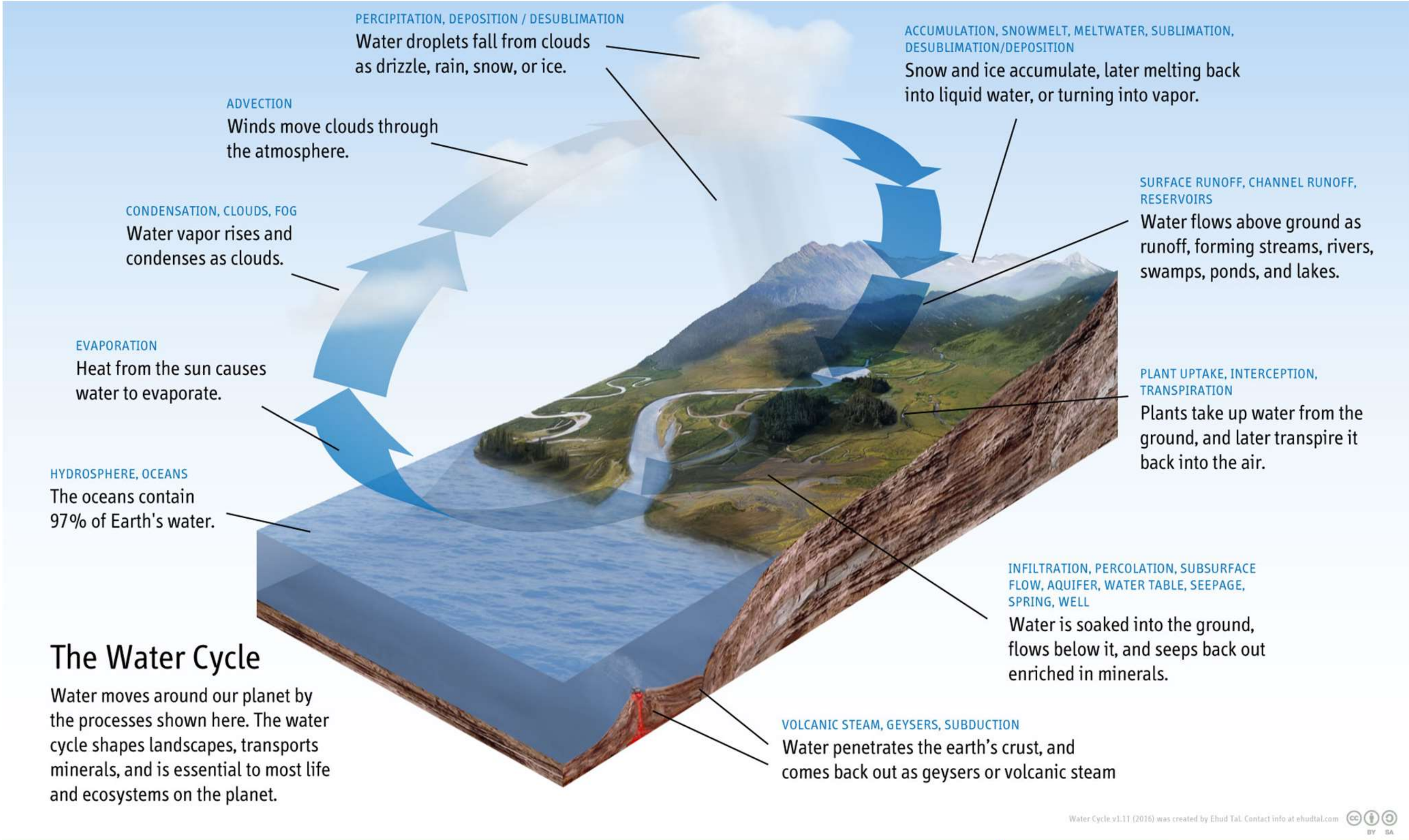

PERCIPITATION, DEPOSITION / DESUBLIMATION
Water droplets fall from clouds as drizzle, rain, snow, or ice.
ACCUMULATION, SNOWMELT, MELTWATER, SUBLIMATION, DESUBLIMATION/DEPOSITION
Snow and ice accumulate, later melting back into liquid water, or turning into vapor.
ADVECTION
Winds move clouds through the atmosphere.
SURFACE RUNOFF, CHANNEL RUNOFF, RESERVOIRS
Water flows above ground as runoff, forming streams, rivers, swamps, ponds, and lakes.
CONDENSATION, CLOUDS, FOG
Water vapor rises and condenses as clouds.
EVAPORATION
Heat from the sun causes water to evaporate.
PLANT UPTAKE, INTERCEPTION, TRANSPIRATION
Plants take up water from the ground, and later transpire it back into the air.
HYDROSPHERE, OCEANS
The oceans contain 97% of Earth's water.
INFILTRATION, PERCOLATION, SUBSURFACE FLOW, AQUIFER, WATER TABLE, SEEPAGE, SPRING, WELL
Water is soaked into the ground, flows below it, and seeps back out enriched in minerals.
The Water Cycle
Water moves around our planet by the processes shown here. The water cycle shapes landscapes, transports minerals, and is essential to most life and ecosystems on the planet.
VOLCANIC STEAM, GEYSERS, SUBDUCTION
Water penetrates the earth's crust, and comes back out as geysers or volcanic steam
Water Cycle v1.11 (2016) was created by Ehud Tal. Contact info at ehudtal.com
BY SA

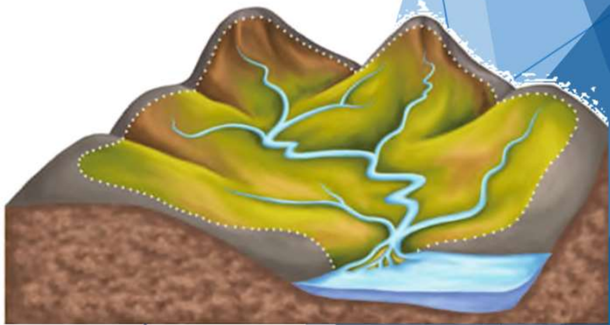
Factors determining river flow

Meteorological factors

Biogeophysical factors

River flow

www.indiatoday.in



stock illustration ID: 1089480320 by stihii

Hydrological regimes

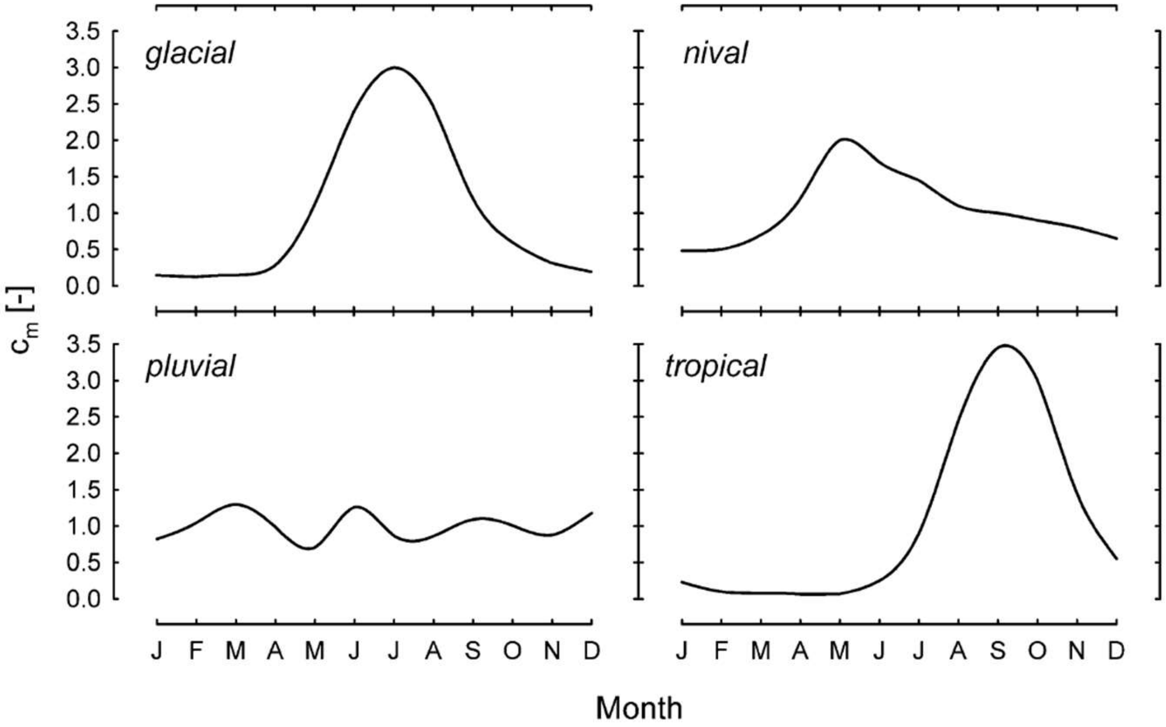
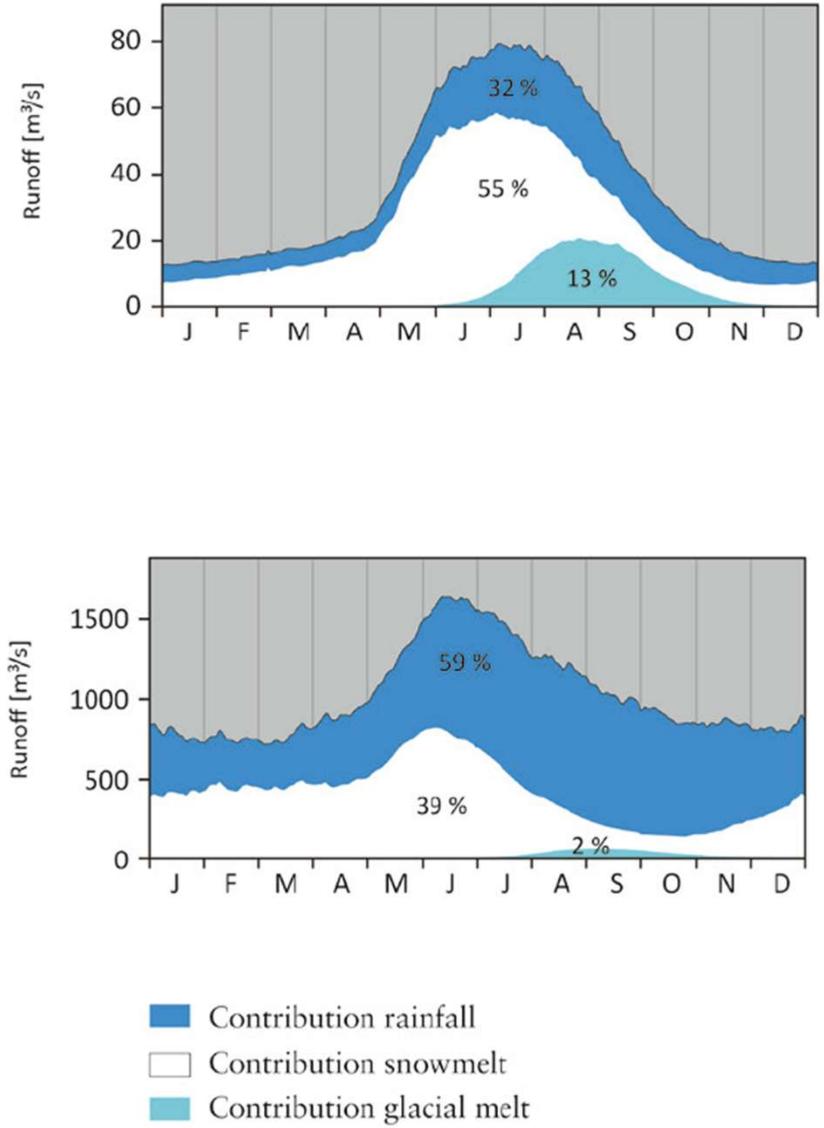


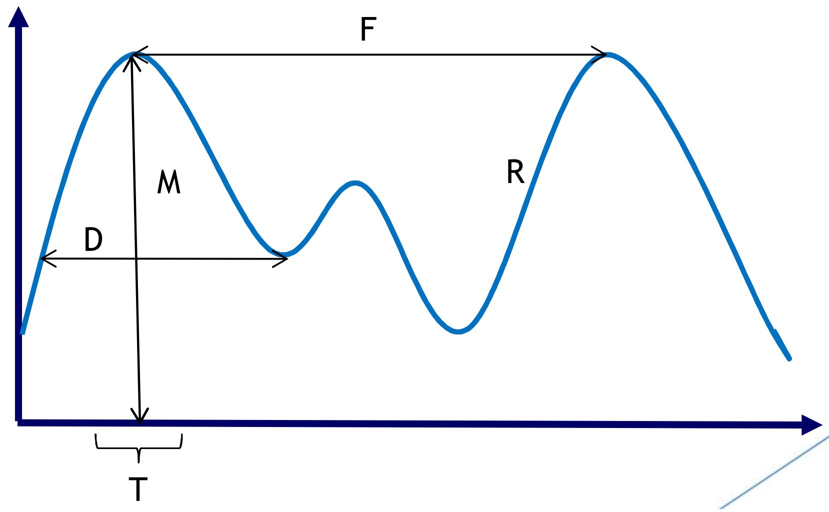
Fig. 4.1 Simple hydrological regimes (glacial, River Ötztaler Ache; nival, River Mur; pluvial, River Stiefing; and tropical, River Niger). The monthly discharge coefficient (c_m) is defined by the ratio of the average monthly discharge and the mean discharge (hydrograph data over several years)

Figure left: Zeiringer et al. (2018). Springer Cham. https://doi.org/10.1007/978-3-319-73250-3_4
Figure right: modified after: Weingartner et al. (in print).



The natural flow regime

5 important criteria[1]	Examples
▶ Magnitude (how much flow?)	HQs or LQs
▶ Frequency (how often do they occur?)	HQ_{10} or MQ
▶ Duration (how long do they last?)	Q_{300} (Q exceeded 300 days/year)
▶ Timing (when do certain flows occur?)	snow melt in spring
▶ Rate of change (how fast do flow levels change?)	flashy  vs. stable  character



1: Poff et al. (1997). BioScience, 47(11), 769-784.

Ecologically relevant flow statistics[1]

- Magnitude
- Duration
- Timing
- Frequency
- Rate of Change

- Magnitude of flow during each month (12 statistics)
- Magnitude of 1-, 3-, 7-, 30-, 90-day minimum and maximum flows (10 statistics)
- Number of days with zero flow (1 statistic)
- Base flow index (1 statistic)
- Timing of 1-day minimum and maximum flows (2 statistics)
- Frequency and duration of high and low flow pulses (4 statistics)
- Rise rate, fall rate, and number of reversals (3 statistics)

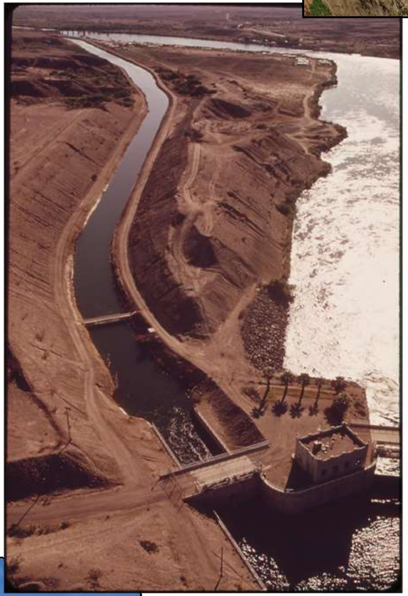
1: Indicators of Hydrological Alteration (IHA): Richter et al. (1996). Conservation biology, 10(4), 1163-1174.

Hydrological stresses
How are river flows altered?

- 41% of European rivers affected.[1]
- Most dominant stressor in rivers.[2]

- Typical sources of flow-regime alteration:
  - **Dams**
  - **Water diversion**
  - Urbanization, sealing, drainage
  - Levees and channelization
  - **Groundwater pumping**

Andrew Parnell CC BY 2.0



United States EPA, Charles O'Rear

Junaidrao (flickr.com)

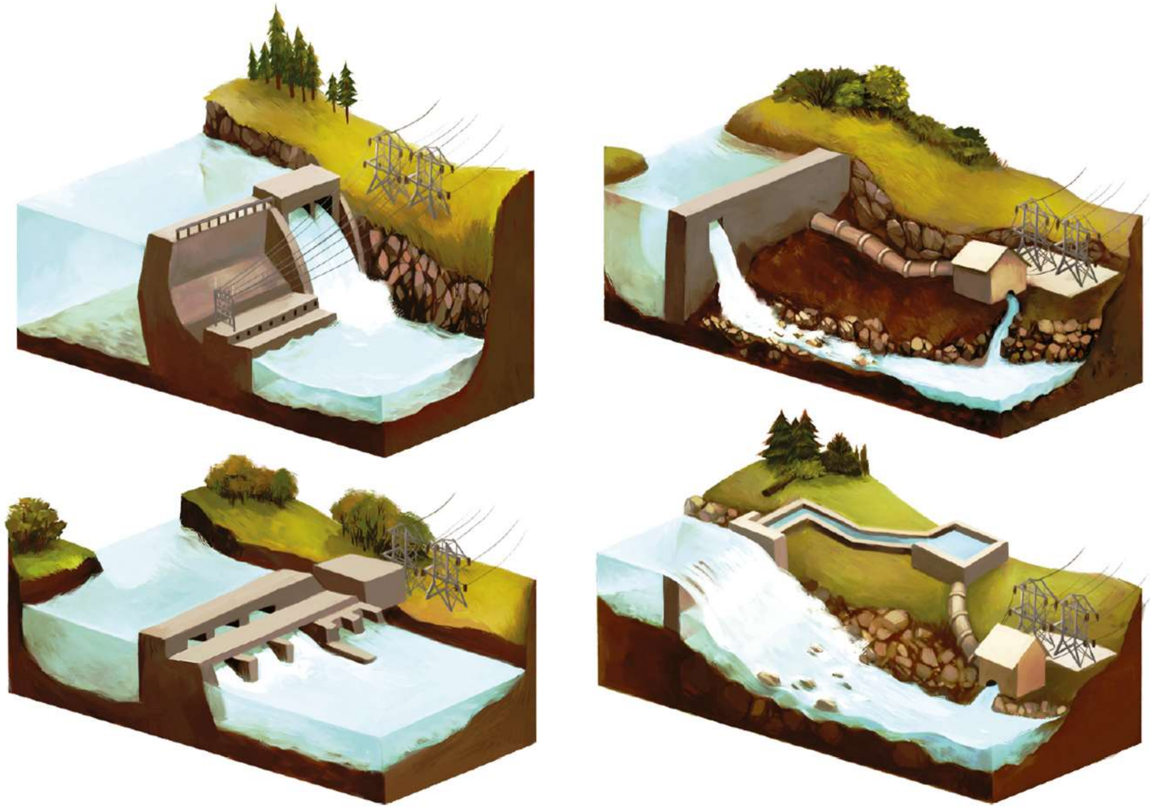
klbz (pixabay.com)

pcdazero (pixabay.com)

1: Schinegger et al. (2012). Water and Environment Journal, 26(2), 261-273.
2: Nõges et al. (2016). Sci. Total Environ. 540, 43-52.

Types of dams: hydropower plants

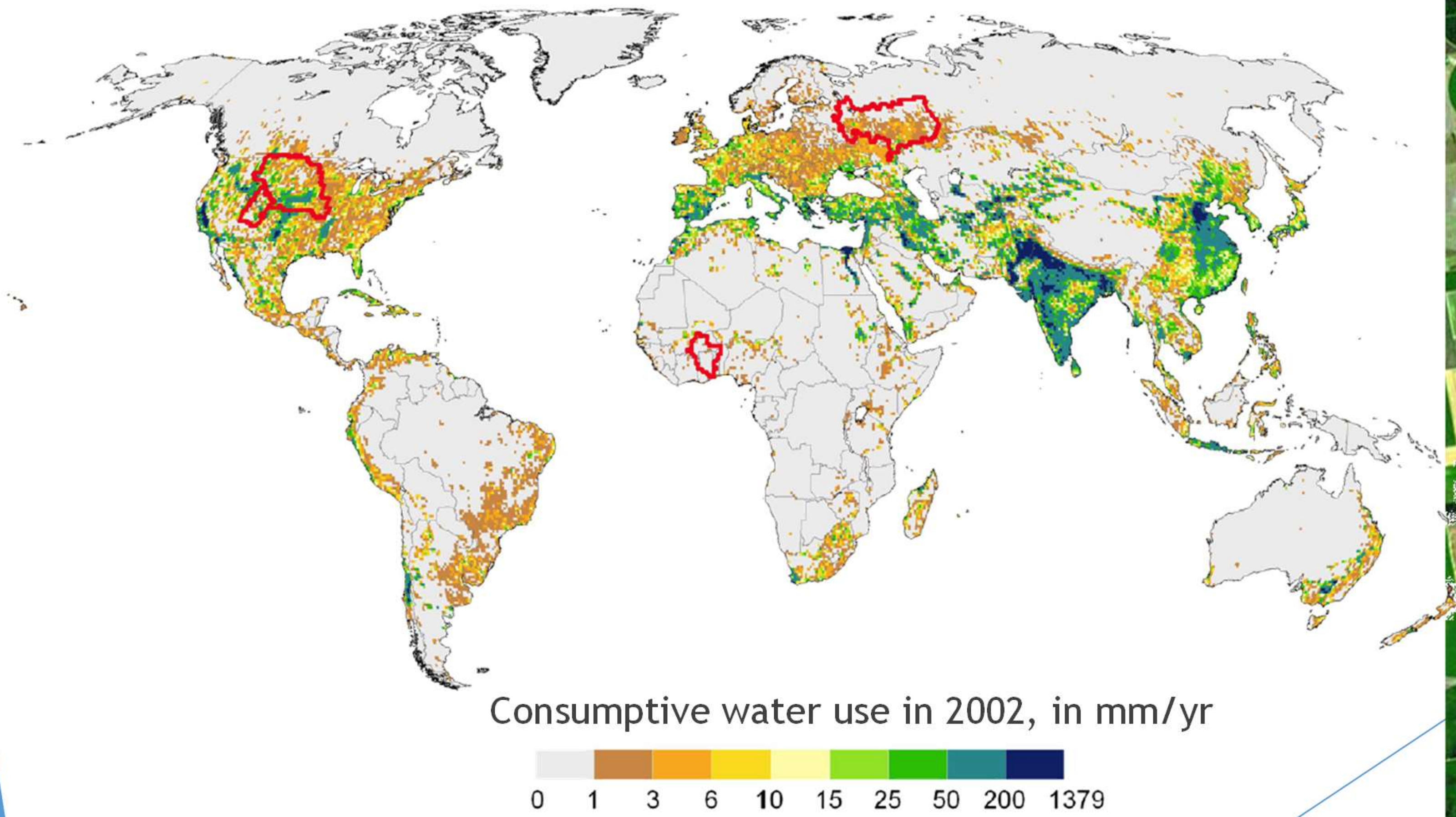
- Run-of-river
- Diversion
  - Non-consumptive (e.g. hydropower)
  - Consumptive uses (e.g. irrigation)



- With storage
- Without storage

Picture: Couto & Olden (2018). Front Ecol Environ; doi: 10.1002/fee.1746

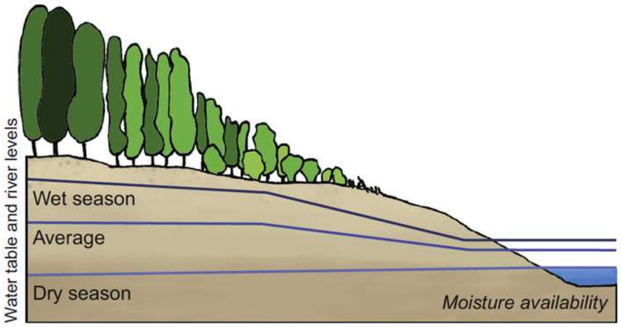
Consumptive water use



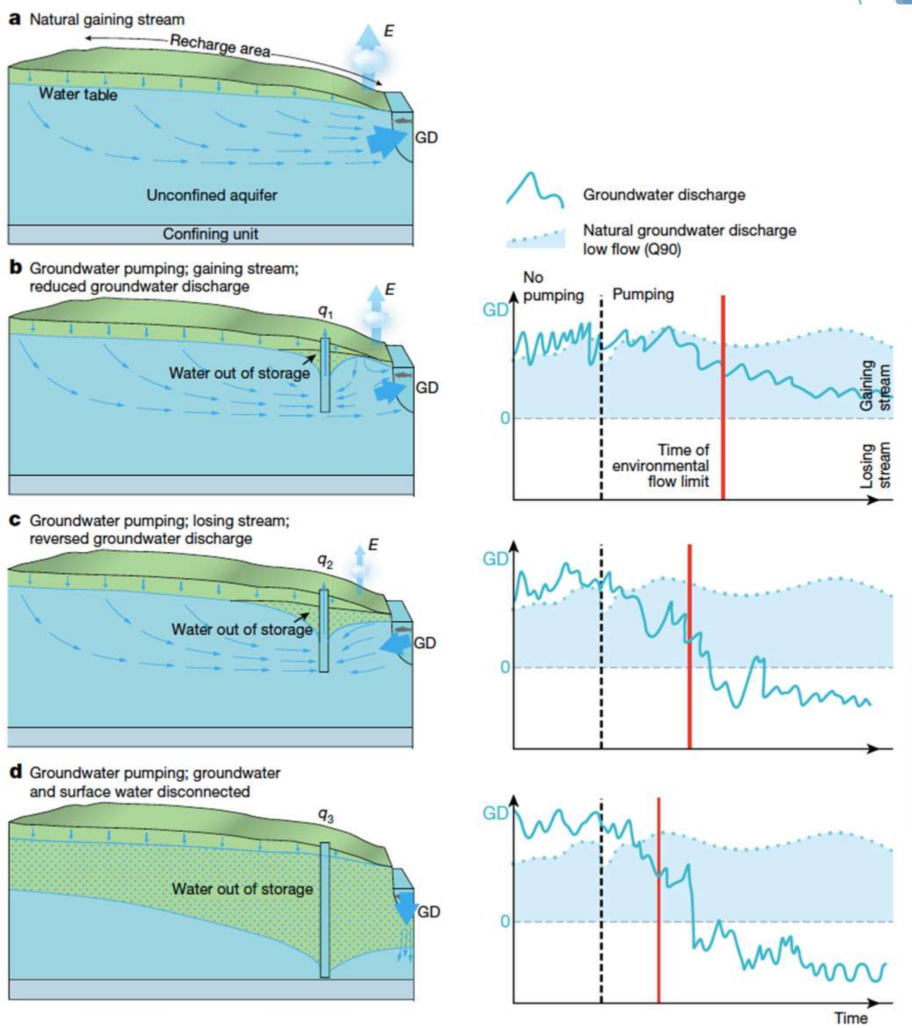
Map: Döll et al. (2009). HESS, 13(12), 2413-2432.
Foto (right): https://water.usgs.gov/edu/pictures/full-size/wuir-centerpivot-aerial-large.jpg

Groundwater–surface water interactions

- The effect of (lacking) flood pulses on groundwater levels.



- Groundwater pumping:
  "Only a very small decline in groundwater level is needed to alter streamflow."[1]
- Plus: surface water withdrawals.



Graph (left): Hayes et al. (2018). Sci. Total Environ. 633, 1089–1104.
Graphs (right) and 1: de Graaf et al. (2019). Nature, 574(7776), 90-94.

Hydrological stresses
How are river flows altered?

Diversion dams

- Reduce high & min. flows
- Homogenize seasonal flow variability

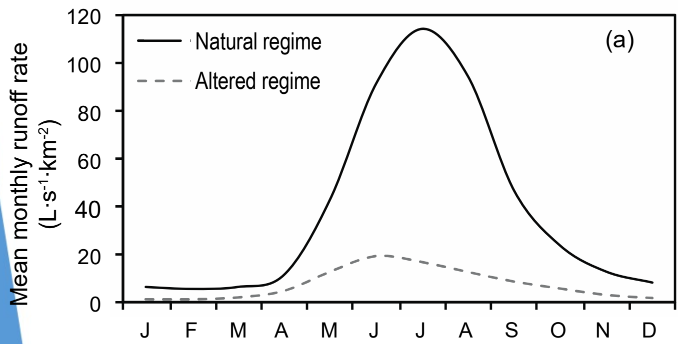
Irrigation dams

- Shift in seasonality

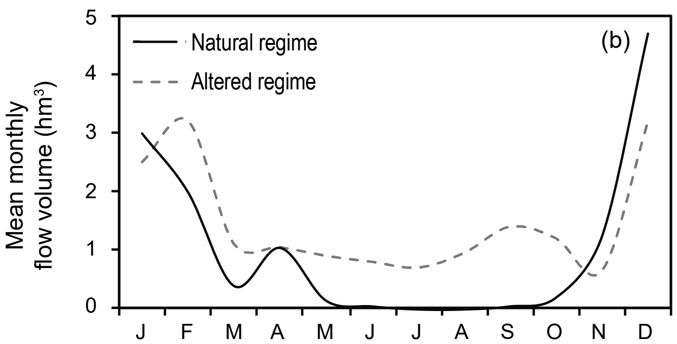
Storage dams

- Sub-daily flow alterations

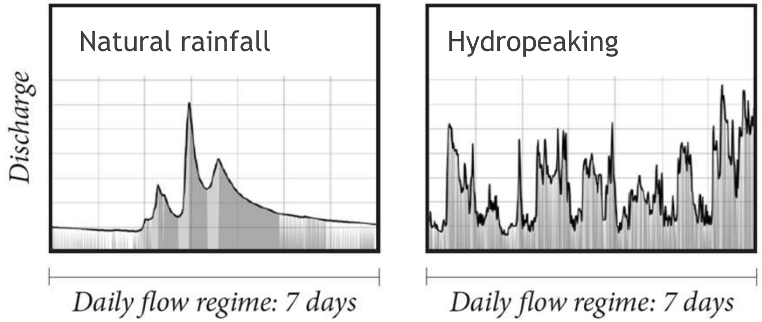
Alpine river



Mediterranean river

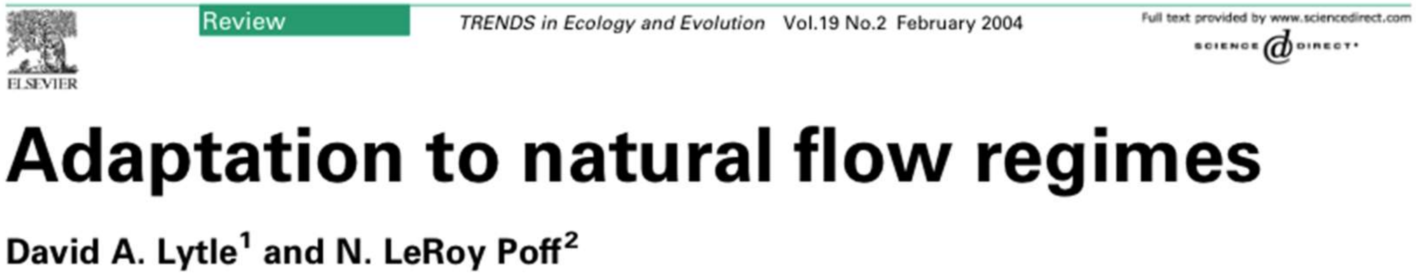


Alpine river



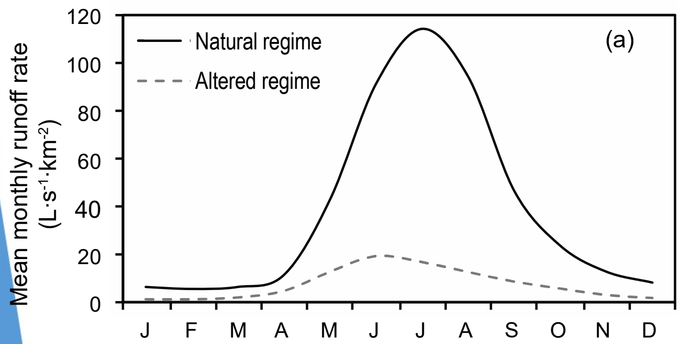
Graphs (left, middle): Hayes et al. (2018). Sci. Total Environ. 633, 1089-1104.
Graph (right) modified after: Greimel et al. (2016). Hydrological Processes, 30(13), 2063-2078.

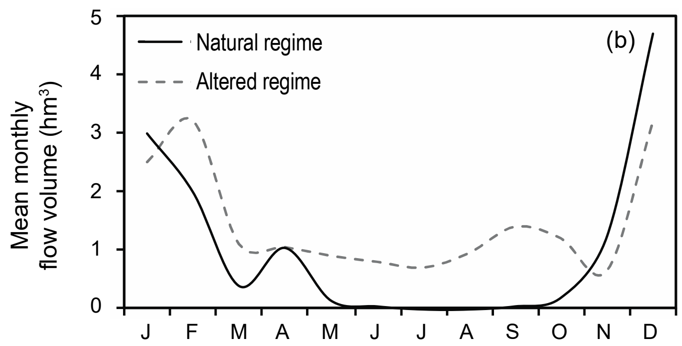
Hydrological stresses

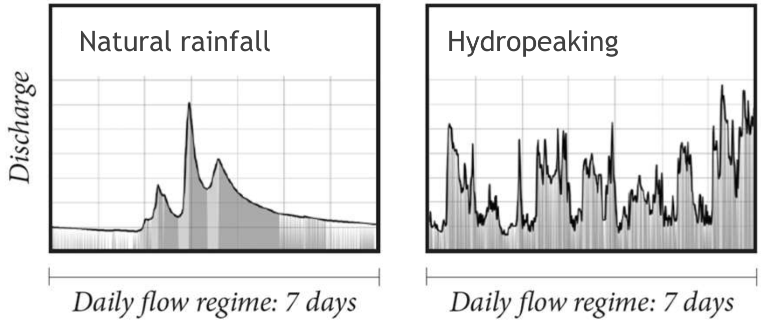

Review
TRENDS in Ecology and Evolution Vol.19 No.2 February 2004
Full text provided by www.sciencedirect.com
SCIENCE @ DIRECT

Adaptation to natural flow regimes

David A. Lytle[1] and N. LeRoy Poff[2]







Graphs (left, middle): Hayes et al. (2018). Sci. Total Environ. 633, 1089–1104.
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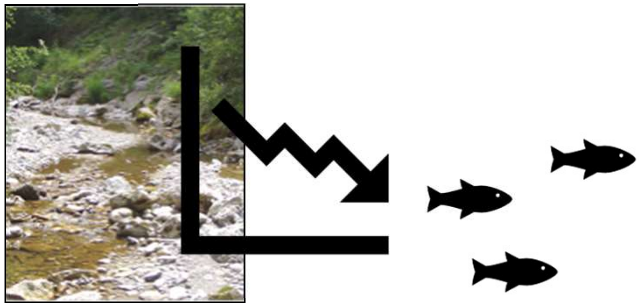
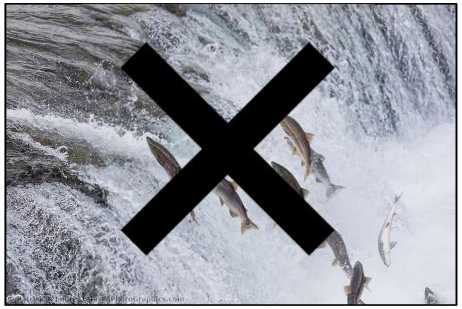
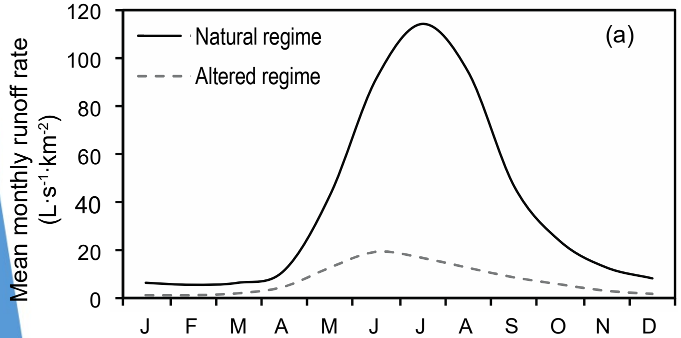
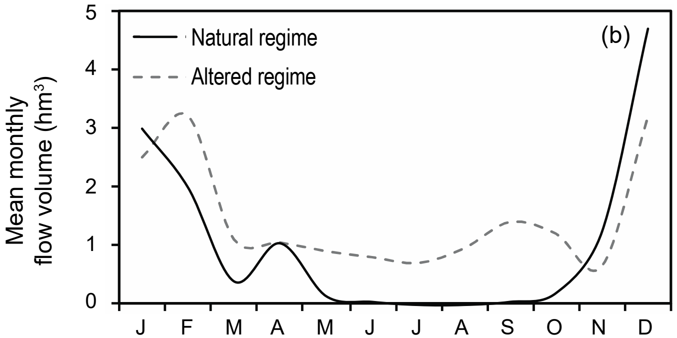
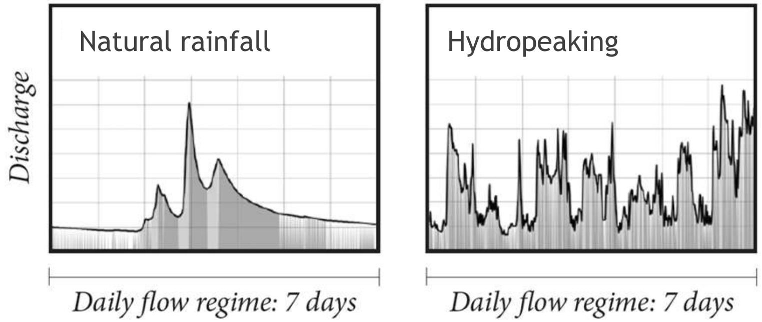
Hydrological stresses
Ecological effects









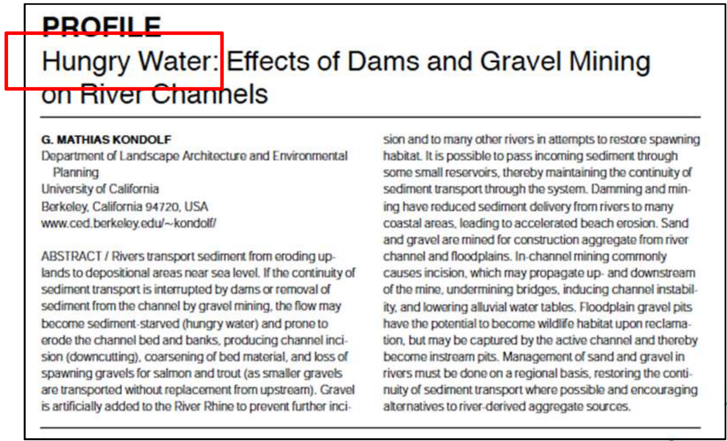


Graphs (left, middle): Hayes et al. (2018). Sci. Total Environ. 633, 1089-1104.
Graph (right) modified after: Greimel et al. (2016). Hydrological Processes, 30(13), 2063-2078.
Foto top middle: Patrick J Endres / AlaskaPhotoGraphics.com; Foto top right: Chessy Knight (www.cbc.ca), dead fish: Gemma Evans.

Sediments and river morphology


- Loss of habitats
- Loss of biodiversity

3 pictures: ©IHG BOKU



PROFILE

Hungry Water: Effects of Dams and Gravel Mining on River Channels

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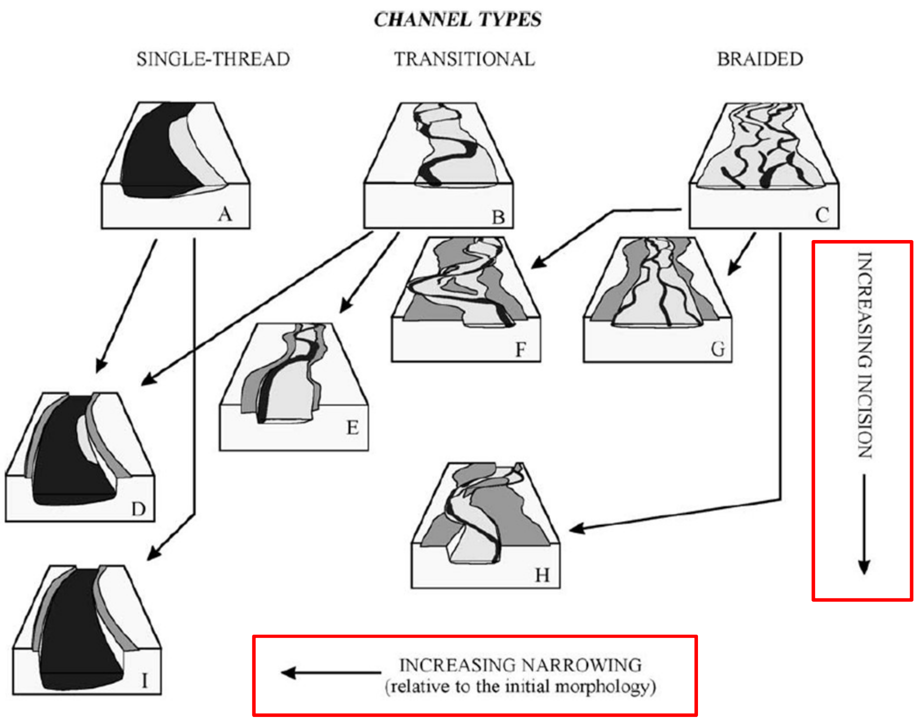
University of California
Berkeley, California 94720, USA
www.ced.berkeley.edu/~kondolf/

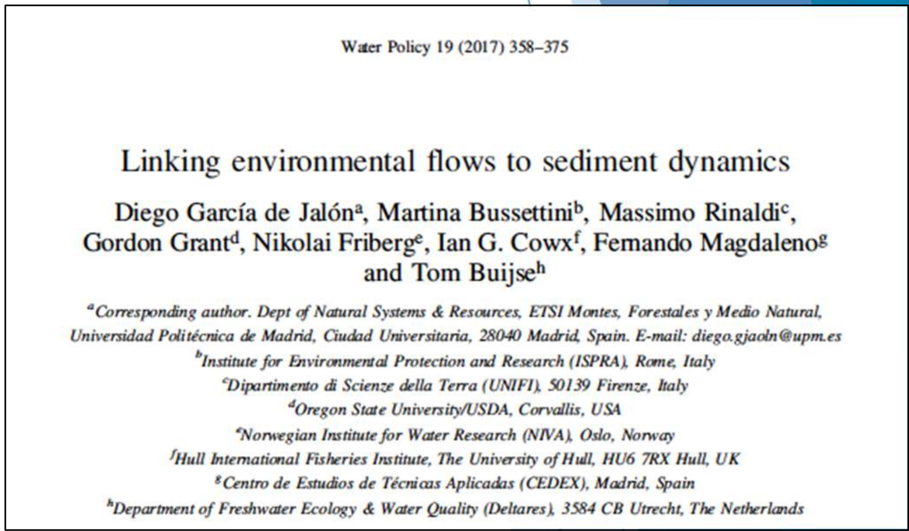
ABSTRACT / Rivers transport sediment from eroding uplands to depositional areas near sea level. If the continuity of sediment transport is interrupted by dams or removal of sediment from the channel by gravel mining, the flow may become sediment-starved (hungry water) and prone to erode the channel bed and banks, producing channel incision (downcutting), coarsening of bed material, and loss of spawning gravels for salmon and trout (as smaller gravels are transported without replacement from upstream). Gravel is artificially added to the River Rhine to prevent further incision and to many other rivers in attempts to restore spawning habitat. It is possible to pass incoming sediment through some small reservoirs, thereby maintaining the continuity of sediment transport through the system. Damming and mining have reduced sediment delivery from rivers to many coastal areas, leading to accelerated beach erosion. Sand and gravel are mined for construction aggregate from river channel and floodplains. In-channel mining commonly causes incision, which may propagate up- and downstream of the mine, undermining bridges, inducing channel instability, and lowering alluvial water tables. Floodplain gravel pits have the potential to become wildlife habitat upon reclamation, but may be captured by the active channel and thereby become instream pits. Management of sand and gravel in rivers must be done on a regional basis, restoring the continuity of sediment transport where possible and encouraging alternatives to river-derived aggregate sources.

BOKU-IWHW

Wasserwirtschaftliche Rahmenuntersuchung Salzach (WRS), Water Management Authority Traunstein

Channel adjustements and ecogeomorphic flows




Water Policy 19 (2017) 358–375

Linking environmental flows to sediment dynamics

Diego García de Jalón[a], Martina Bussettini[b], Massimo Rinaldi[c], Gordon Grant[d], Nikolai Friberg[e], Ian G. Cowx[f], Fernando Magdaleno[g] and Tom Buijse[h]

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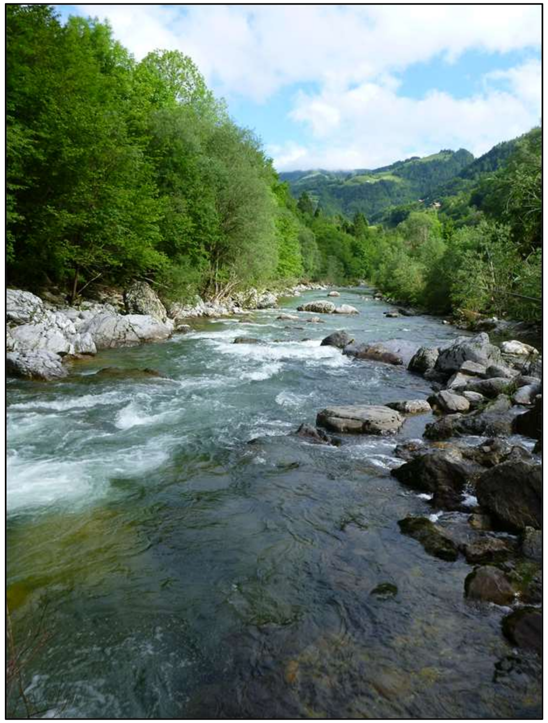
[b]Institute for Environmental Protection and Research (ISPRA), Rome, Italy
[c]Dipartimento di Scienze della Terra (UNIFI), 50139 Firenze, Italy
[d]Oregon State University/USDA, Corvallis, USA
[e]Norwegian Institute for Water Research (NIVA), Oslo, Norway
[f]Hull International Fisheries Institute, The University of Hull, HU6 7RX Hull, UK
[g]Centro de Estudios de Técnicas Aplicadas (CEDEX), Madrid, Spain
[h]Department of Freshwater Ecology & Water Quality (Deltares), 3584 CB Utrecht, The Netherlands

Illustriation left: Surian & Rinaldi (2003). Geomorphology 50, 307–326.

“How much water does the environment need?”



All pictures: D.S. Hayes