River restoration: a strategy to flush fine clogged sediments?

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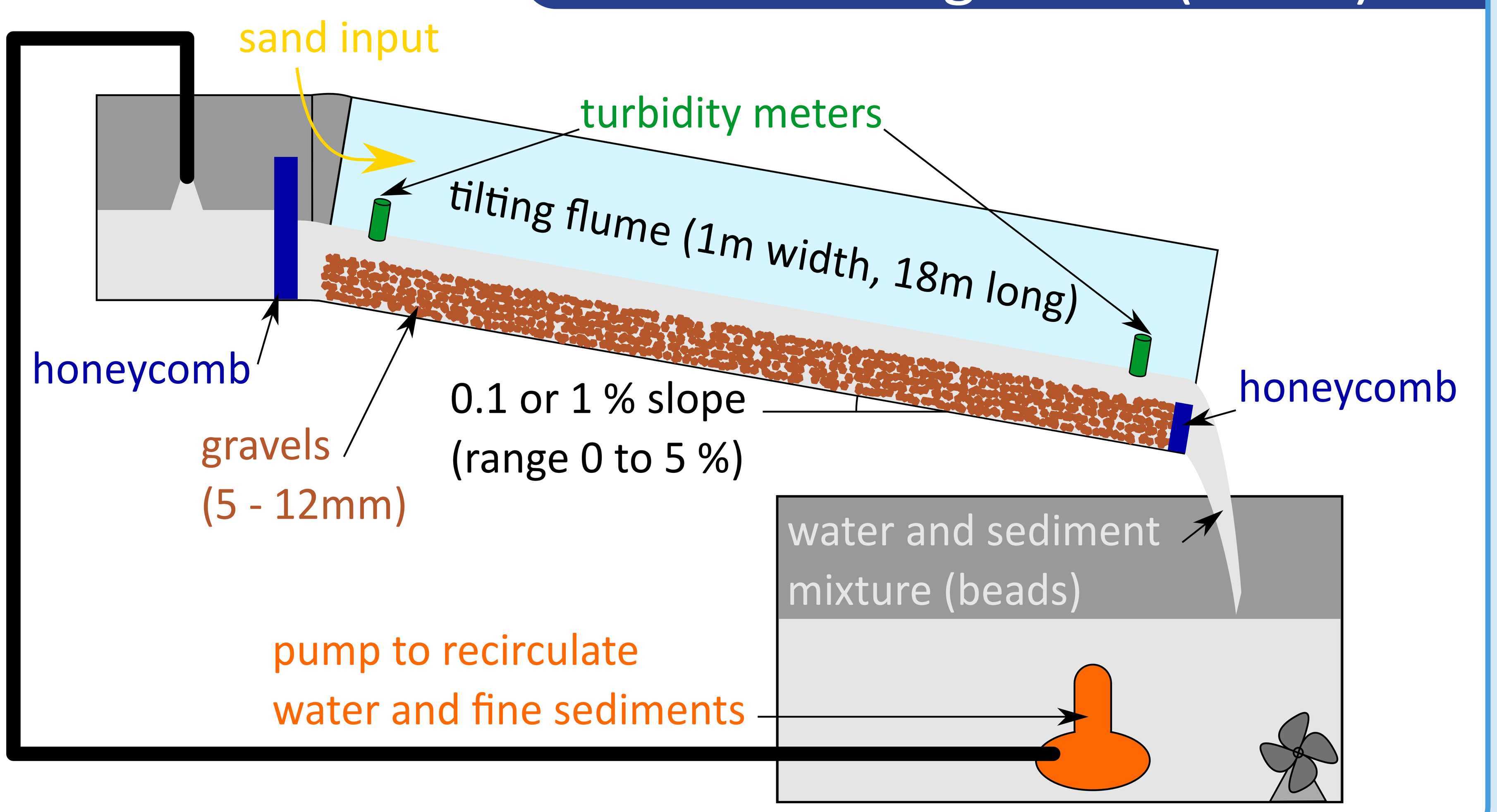
1. Context and objectives of the study

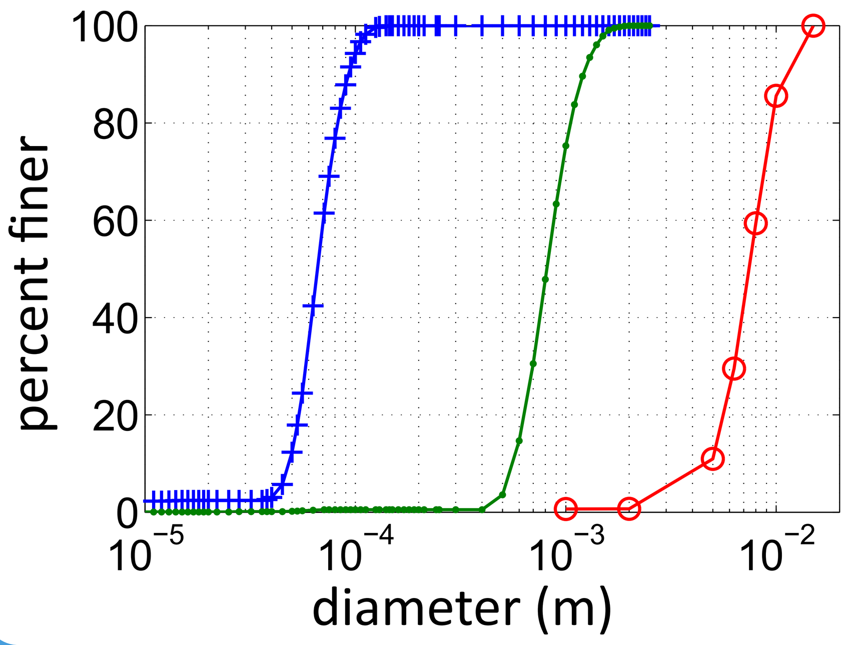
- Anthropogenic activities: fine-grained sediment fluxes modified significantly → environmental and societal issue [1]
- One of the issues: fine sediment infiltration (or clogging) → detrimental for bed structure and permeability
  - → How to restore rivers ? How efficient are flushing operations ?
- Hydraulic conditions for erosion and deposition of fine and coarse mixtures poorly known:
  - → difficulties for optimizing restorations
- Experiments in controlled environment with several strategies at constant cost (same volume of water input) to flush fine sediments in a clogged bed

Fine sediment deposits on a gravel bar in the Arc River (France) after a dam flushing event

2. HHLab tilting flume (Irstea)



3. Bed material characteristics



Sand / gravel & beads / sand: bridging

Beads / gravels: unimpeded static percolation [2,3]

4. Initial conditions

Initial bed = result of infiltration experiment with specific vertical structure [4]

Infiltration experiment: Fine sediment ladden-flow (with constant fine sediment concentration) recirculates over a clean gravel bed for hours, without mobilisation of gravels until the vertical structure of fine sediment deposits is stabilized.

Side view of the bed at the beginning of Exp 1

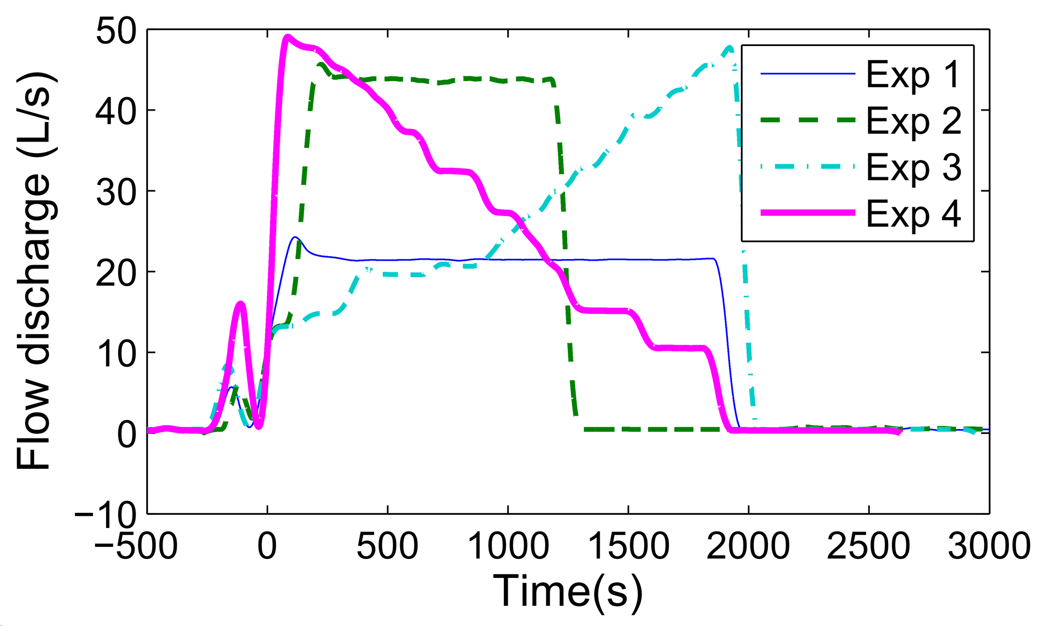
bridge of sand

deposit of beads

Top view of the bed at the beginning of Exp 2

Sand dunes with deposits of beads on top.

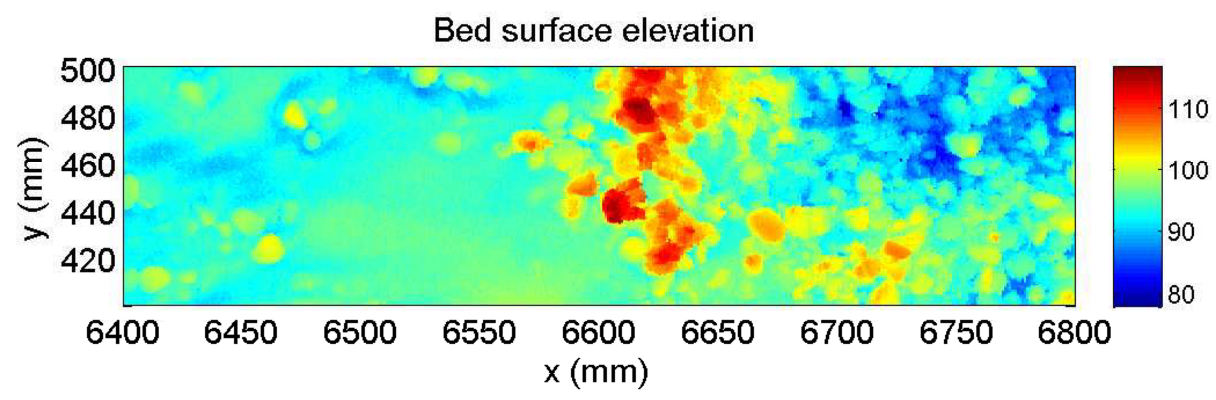
5. Four flows tested



Same volume
Different shapes

Characterization of the bed before and after the hydrograph

6. Bed surface characterization



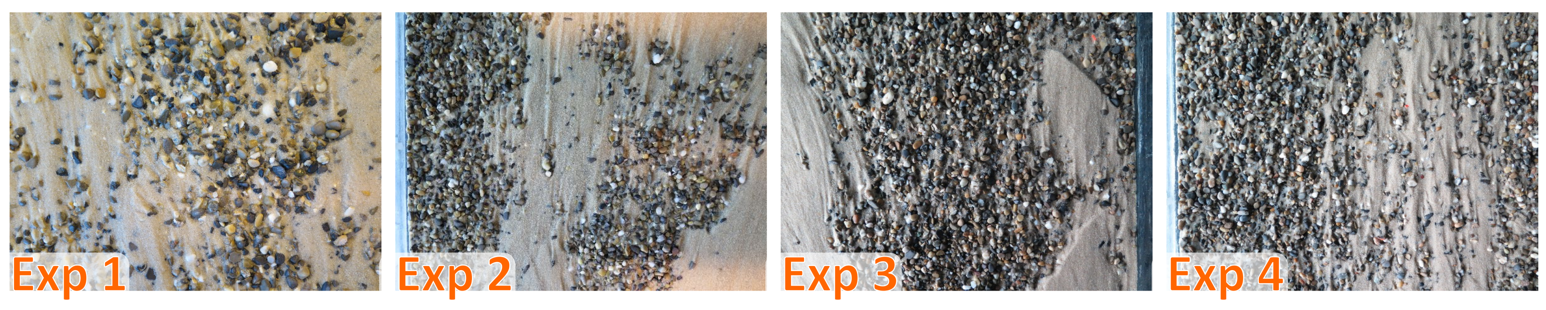
Laser scanner: vertical elevation at high resolution

Average form (k_{sf}) and grain geometrical roughness (k_{sg}) of the bed before and after each flushing experiment and average erosion (E) all along the flume

	k_{sf} (mm)		k_{sg} (mm)		E (mm)
	initial	final	initial	final	
Exp 1	3.3	1.1	0.7	0.5	4.7
Exp 2	1.8	1.0	0.6	0.6	9.0
Exp 3	2.2	2.4	0.6	1.3	9.7
Exp 4	2.2	1.5	0.9	0.8	8.6

For a flat gravel bed: grain roughness k_{ss} = 3.2 mm form roughness $k_{sf} = k_{sg}$

Top view final beds



7. What is the best strategy ?

- With a given amount of water, best strategy to wash fine sediment from the surface with a limited mobilisation of the coarse matrix is a rising hydrograph (increase of k_{sg} to a value close to the one of the gravel bed).
- Gravel bed free of fines over a larger depth than one gravel grain was never obtained (even with higher discharges in a supplementary experiment).
- Increase of discharge between Exp 1 and 2 was inefficient and leads to more erosion (Shields number 0.037 to 0.055 for gravels).
- If the bed needs to be entirely preserved, lower discharges can partially clean the surface.

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[2] Gibson, S., Abraham, D., Heath, R., and Schoellhamer, D. (2009). Vertical gradational variability of fines deposited in a gravel framework. Sedimentology, 56(3):661–676.
[3] Herrero, A. and Berni, C. (2016). Sand infiltration into a gravel bed: A mathematical model. Water Resour. Res., 52.
[4] Perret, E., Berni, C., Herrero, A., El Kadi Aberrezzak, K. Transport of moderately sorted gravel at low bed shear stresses: the role of fine sediment infiltration, Accepted with major revisions in ESPL.

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