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Rivers in an uncertain future

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Water injection for dredging sediment in reservoirs – insights from preliminary experiments

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Introduction

River dams have been largely implemented to store water for energy production, irrigation, flood control, and human and animal water supply; albeit some environmental implications. A negative consequence of damming rivers is the associated loss of connectivity. Several concerns can be raised in terms of sediment entrapment, among others: the continuous reduction of reservoirs' storage capacity, the altered morphodynamics and the impact on ecosystems of the river reach. Therefore, the ultimate goal of sediment management frameworks for river water reservoirs is granting sediment continuity through the dams. Nevertheless, choosing the most suitable strategy is complex, and a comprehensive knowledge about techniques and the environment is necessary to successfully achieve this goal.

This ongoing experimental research focuses on turbidity currents triggered by a water jet. The proposed experimental framework is an idealized conceptual model of Water Injection Dredging (WID), which can potentially be applied in water reservoirs as a sediment management technique. Other current sediment management techniques are described in *Annandale, Morris and Karki* (2016), and the history and application of WID is discussed by the World Association for Waterborne Transport Infrastructure (PIANC) in *PIANC Report n^o 120* (2013).

Problem definition

Scouring may happen when injecting water into a partially compacted mobile bed. Particles can be suspended and finally transported downstream by a buoyancy-driven flow, which is commonly known as a turbidity current. Flow processes occurring during application of WID are presented in Figure 1.

In this study, these processes are spatially divided in water (i) injection, (ii) impact zone, (iii) near field, and (iv) far field. The inlet velocity of the water jet defines the initial input of energy that can trigger the aforementioned processes. The jet impact in the scouring hole will lead to a resuspension of sediment that may be conceptualised as the upstream boundary condition of the triggered turbidity currents (near field). These processes together will define the transport of mass, momentum, and turbulence into the far field. Ultimately, these will determine the feasibility of the technique in a specific site. An example of this modelling approach application is described in *Winterwerp et al* (2002). A set of preliminary experiments were performed to refine the experimental design, and are presented below.

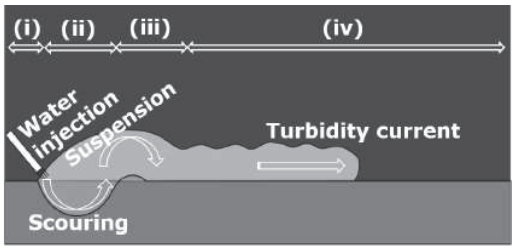

Figure 1: Sketch and problem definition. (i) injection, (ii) impact zone, (iii) near field, and (iv) far field.

Methodology

The experimental setup consisted of:

- A flume 4 m long, 2 m high, and 22 cm width equipped with a sediment damping tank;
- A 3D-printed diffuser device positioned at 45^o reproducing a 2D water jet, with the discharge recorded upstream by a flowmeter;
- A lighter-weighted sediment (D_{50} = 0.548 mm and ρ = 1243 kg/m^3) was used to build the mobile bed of – roughly horizontal – slope .

The flume before the beginning of the experiment, the diffuser, and sediment are shown in Figure 2.

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Figure 2: Experimental setup: (a), the 2D and 3D-printed water jet (b), and sediment (c).

Preliminary results

Three exploratory experiments are presented below (for a short video of these experiments, see *Buffon*, 2020).

- Experiment 1 (Figure 3a): in the first experiment, a pulse in the water discharge was released (approximately 9 l/s), triggering a non-desired situation in which a large quantity of sediment was abruptly suspended;
- Experiment 2 (Figure 3b): insufficient discharge was applied (approximately 2 l/s), also leading to a non-desired situation in which the sediment was suspended in a controlled way, but it was not efficiently transported in the downstream direction by the turbidity current;
- Experiment 3 (Figure 3c): in the third experiment, an intermediate discharge was achieved (approximately 4 l/s), triggering the desired situation that will be further investigated. In this case a cloud of sediment was suspended, and plunged in a turbidity current that transported sediment in the downstream direction.

Future work

Adaptations have been conducted in the flume, and a series of new experiments (similar to Figure 3c) will follow, attempting to quantify key hydrodynamic processes and optimum conditions to apply the technique.

Figure 3: Set of preliminary experiments: (a) Experiment 1 - peak of discharge; (b) Experiment 2 - low discharge; (c) Experiment 3 - intermediate discharge.

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