FROZEN IN TIME: CONTINUOUS MEASUREMENTS IN A DAM BREACH FLOW

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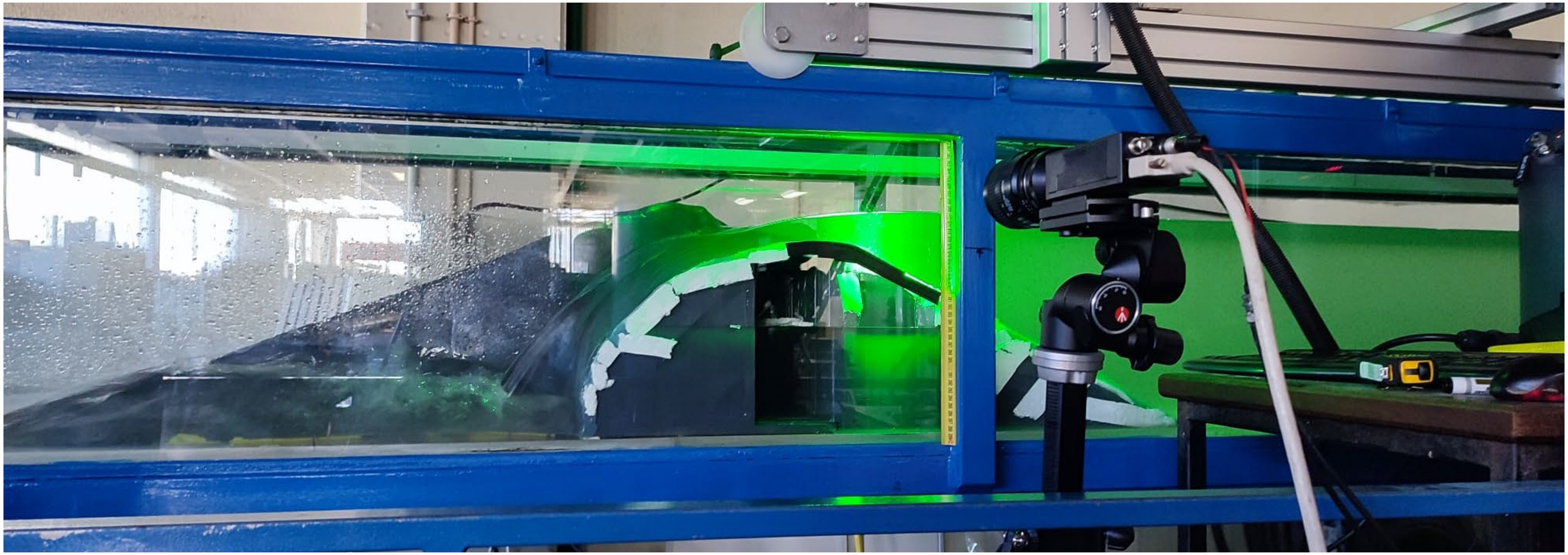
Supervisors: Rui Ferreira (IST), Teresa Viseu (LNEC)



INTRODUCTION

PhD theme: Experimental investigation of embankment failure by overtopping

General objective:

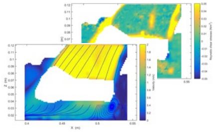
To achieve a more accurate description of the hydraulic and geotechnical phenomena involved in the breach of overtopping embankments.

Influence of the dam elements:

- drainage system
- impervious core

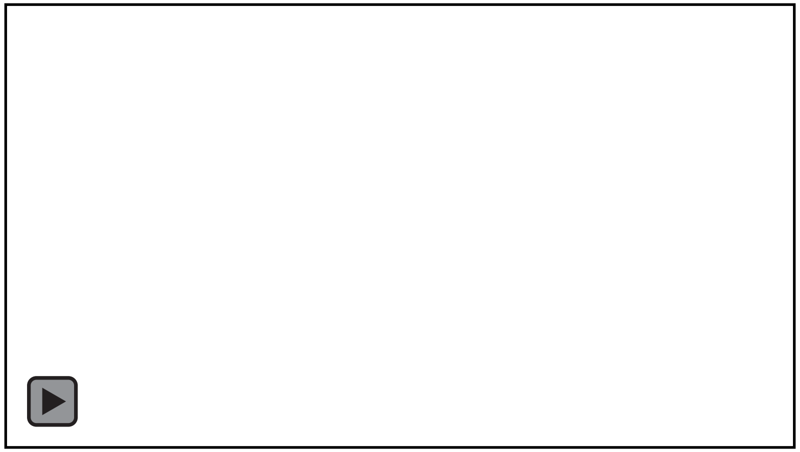
Detailed characterization of the hydrodynamic field:

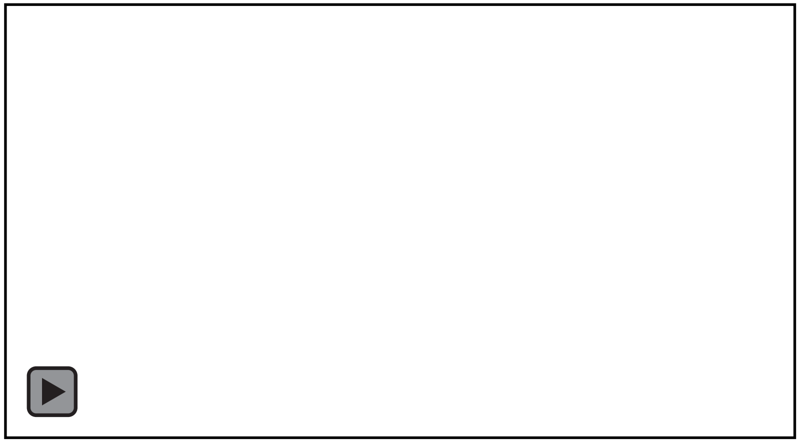
- in a selected instant
- 3D print of the rupture dam



INTRODUCTION

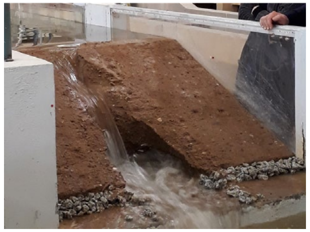
- Embankment dams and dikes often fail by overtopping
- This erosion process is a complex process, with a strong transient character
- The flow-dam interaction may generate the detachment of earth blocks
- Measurements in dam breach flows are not trivial and imaging based techniques are often required
- Due to the complexity of the flow nature, and its transient character it is often impossible to investigate in detail the different phenomena



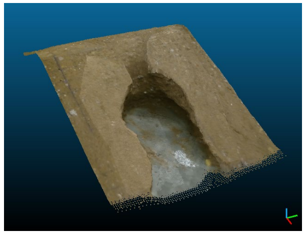


METHODOLOGY

Run a large-scale dam beach experiment



Measure the 3D geometry with a Kinect system



Obtain a scaled model using a 3D printer

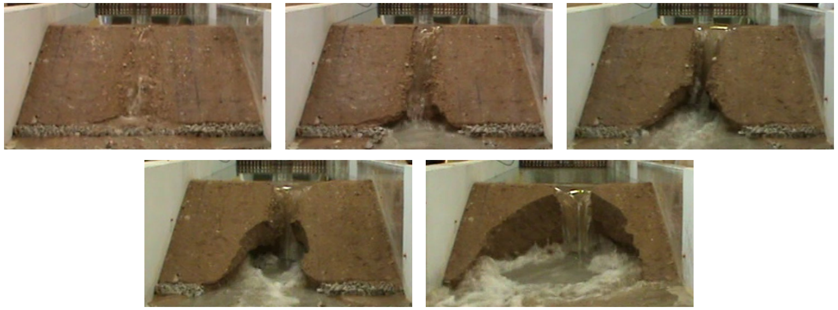
Use the printed model to perform detailed measurements

BREACHED DAM MODEL

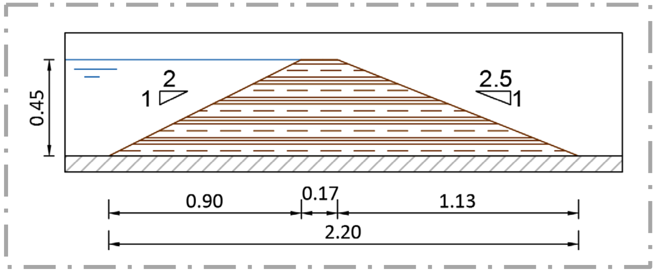
THE LARGE-SCALE DAM BREACH EXPERIMENT

Experimental facility
- Laboratório Nacional de Engenharia Civil

Breaching dam

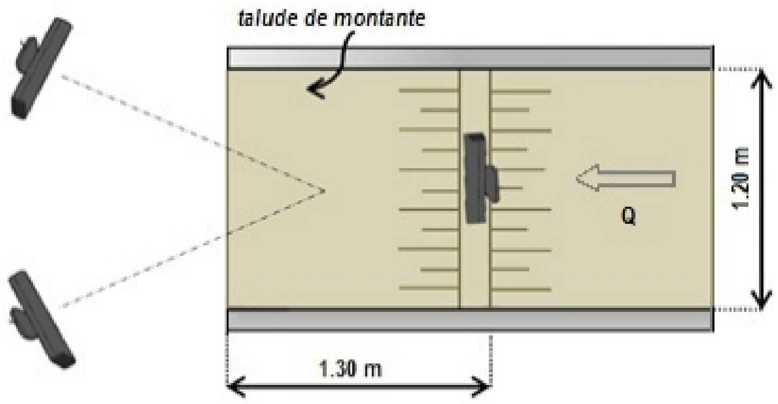


Dam cross section

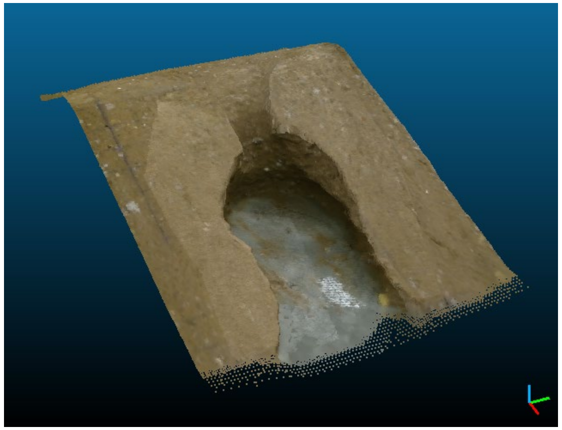


THE LARGE-SCALE DAM BREACH EXPERIMENT

Depth images acquisition with KINECT sensor

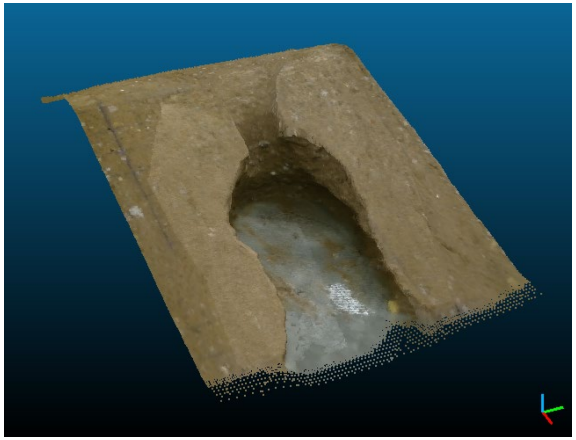


Creation of points clouds with the software CloudCompare

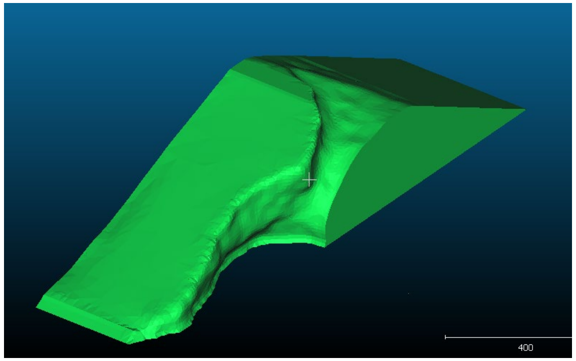


THE 3D MODEL

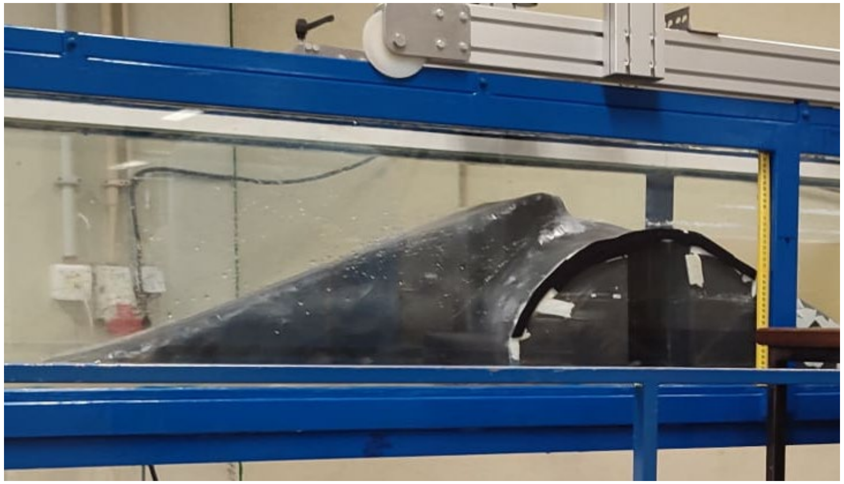
Perspective of the point cloud

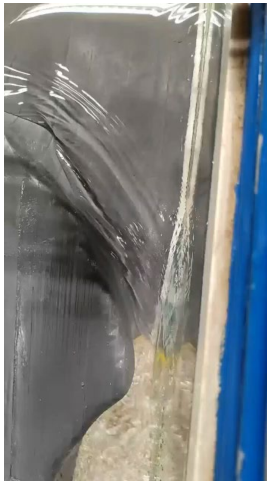


View of the printable 3D model



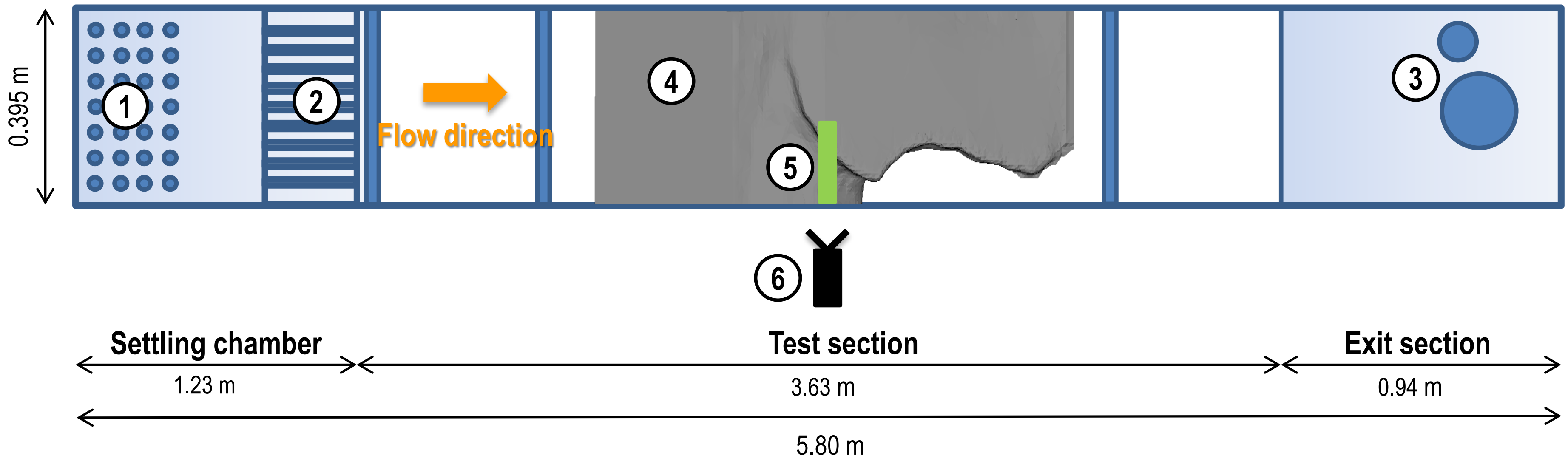
Printed model

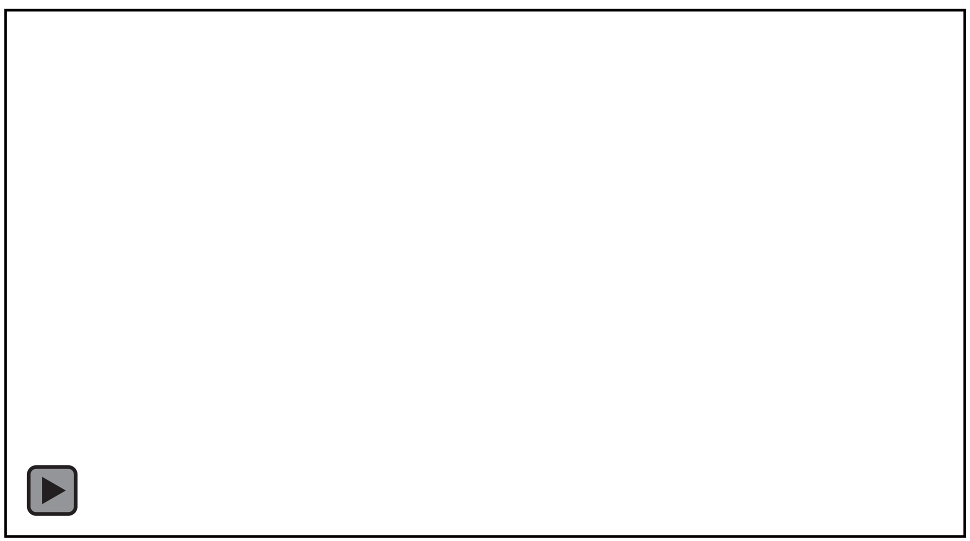




EXPERIMENTAL SETUP

THE FLUME

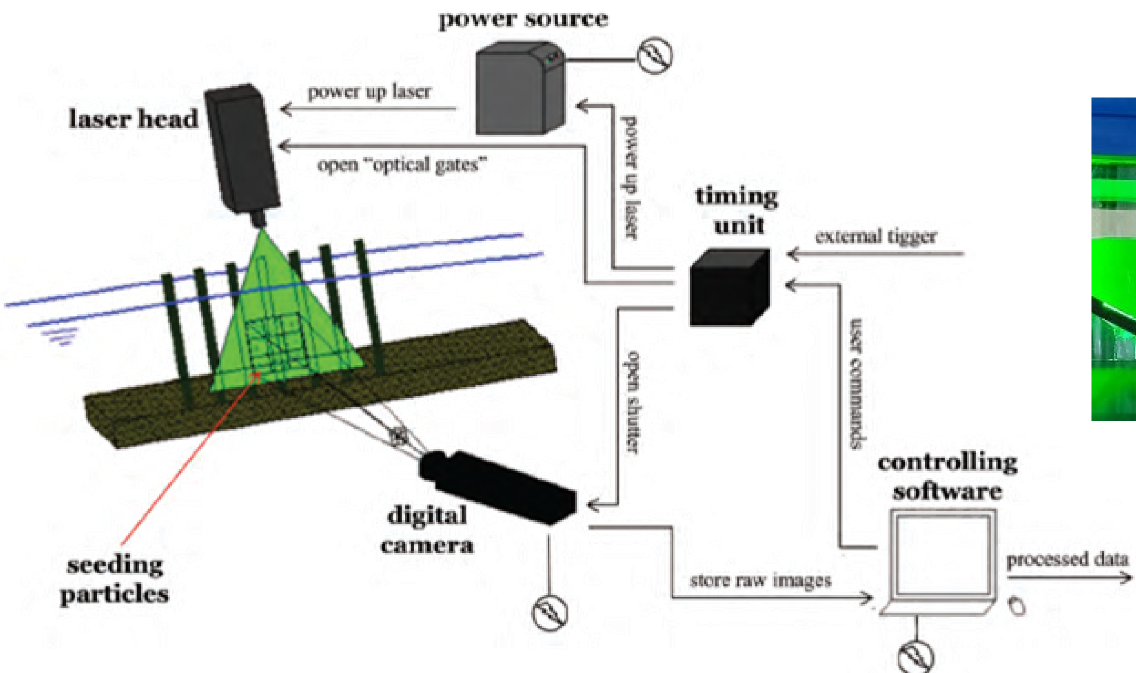




Legend:
1 – Inlet orifices
2 – Honeycomb structure
3 – Outlet orifices
4 – Dam breach model
5 – Laser light sheet
6 – Camera

Particle Image Velocimetry

Dantec’s Particle Image Velocimetry (PIV) system



Camera

Timer box

Laser head

Power sorce

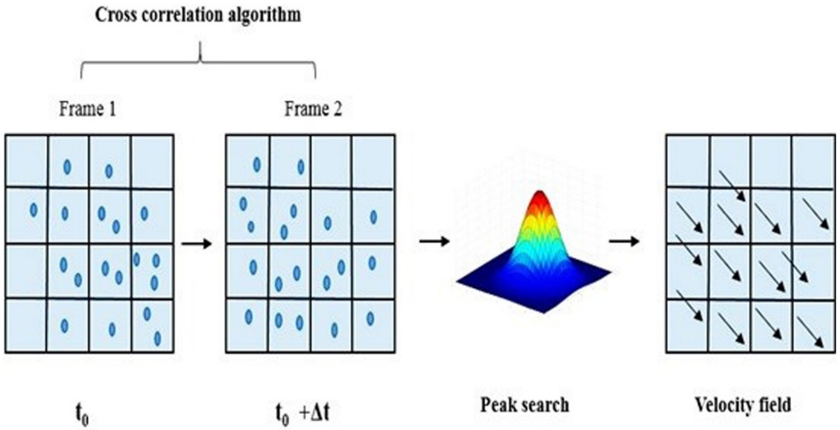
Camera

- Nikon 60 mm/f2.8 lens
- Resolution: 1600 × 1200 pixels

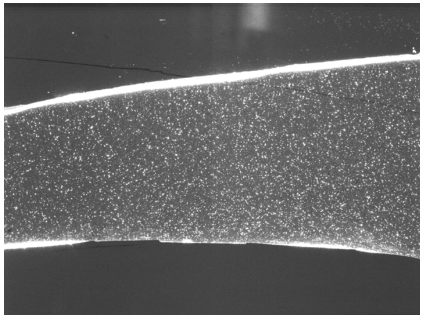
Seeding particles

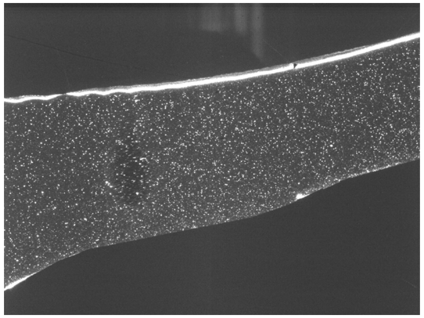
- TiO2 particles / 50 μm

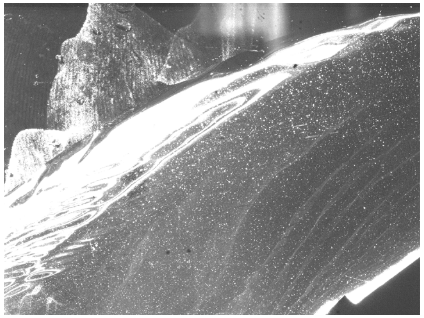
PARTICLE IMAGE VELOCIMETRY



- Interrogation window size: 16 × 16 pix
- Spatial resolution: 0.6 to 1.5 mm
- 4500 images pairs
- 3 repetitions at each panel







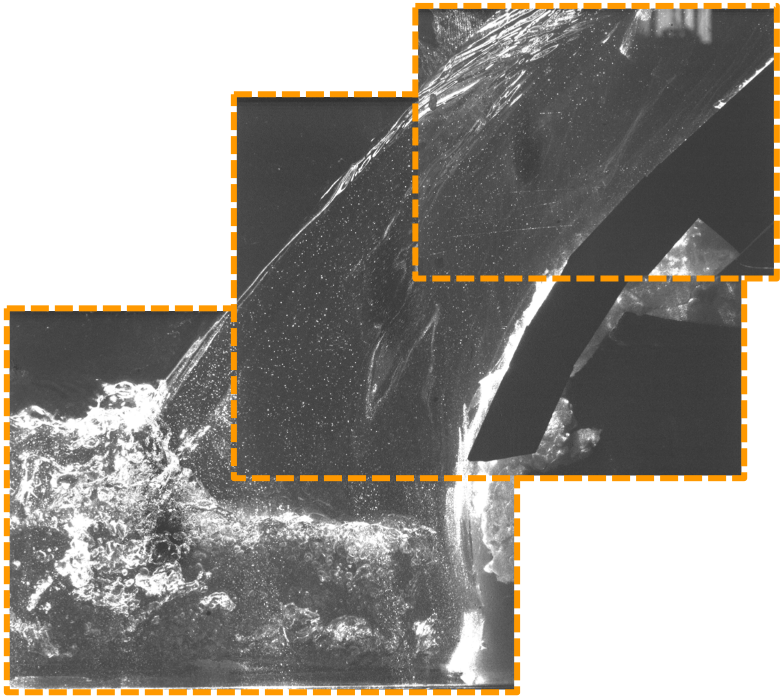
$$\mathbf{V} = \frac{d\mathbf{r}}{dt} \qquad (1)$$

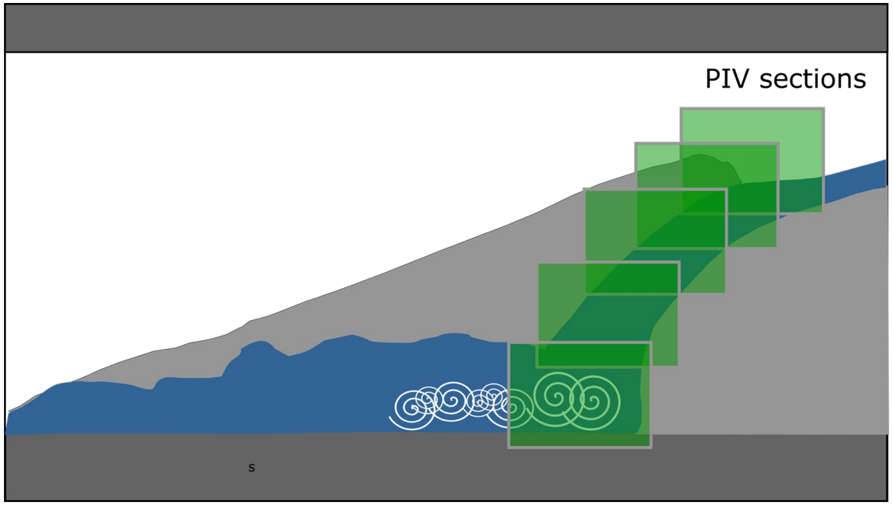
where

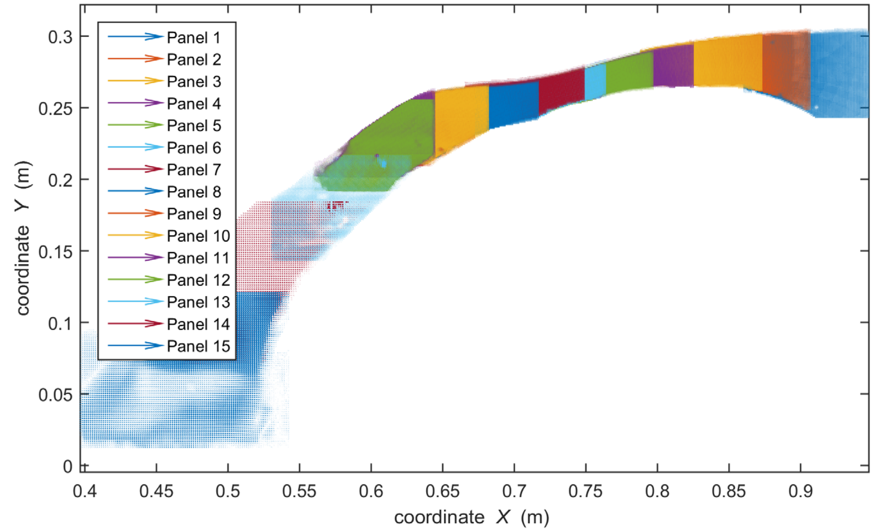
- V is the velocity vector,
- r is the displacement vector of the correlation peak and dt is the time interval between two laser pulses.

VELOCITY MEASUREMENTS SCHEME

- Need to divide the region of interest (ROI) in the camera to distinguish the seeding particles
- ROI was divided in 15 sample regions
- Overlap of at least 10% of the image area



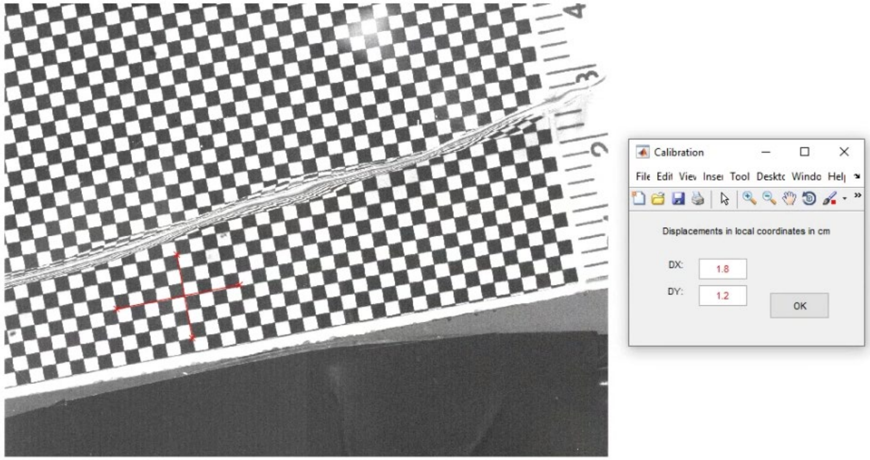




DATA PROCESSING

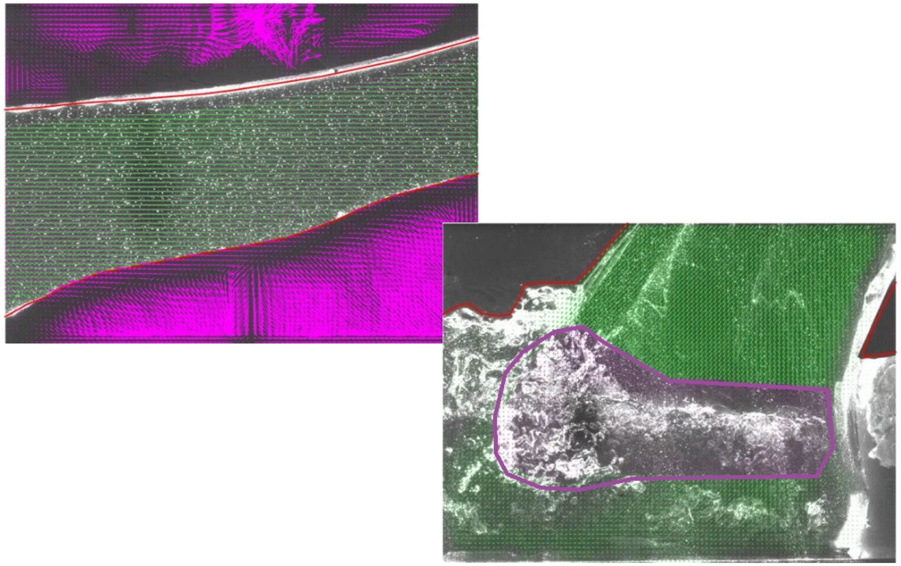
Image calibration

- Checkerboard with 2×2 mm squares
- Distortion in the images was negligible
- Application of a linear conversion algorithm



Mask application

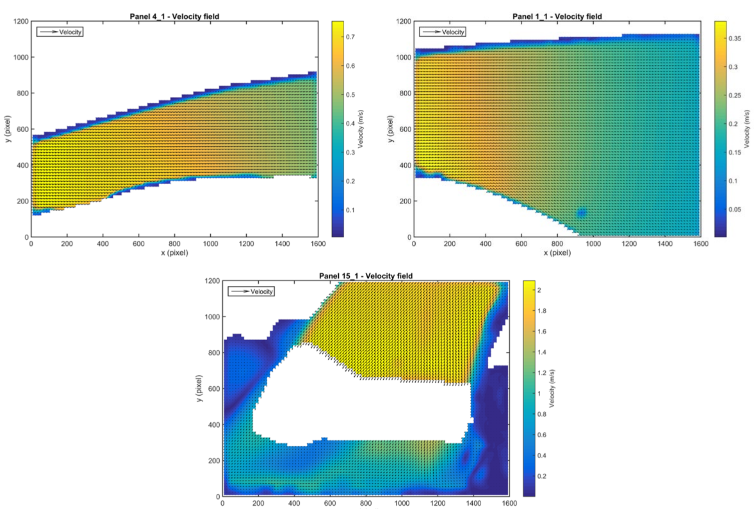
- to restrict the analysis to the ROI, thus reducing the processing time; and
- to remove areas where the velocity measurements could not be trusted due to the excessive aeriation and turbulence

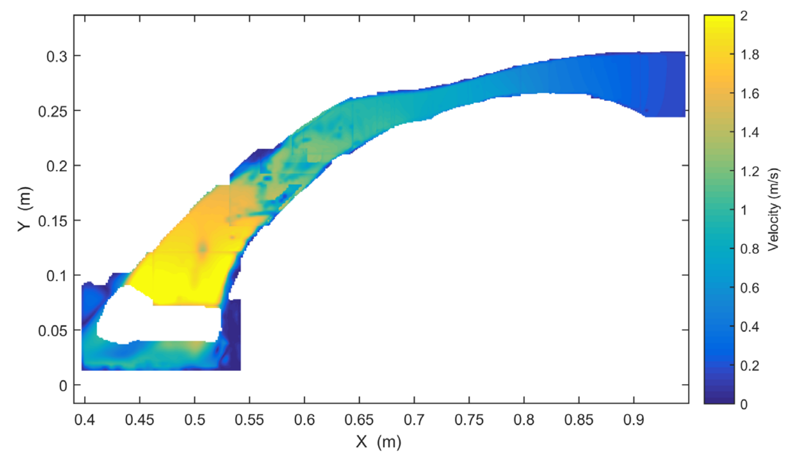


DATA PROCESSING

Assembly of mean velocity / Reynolds shear stresses

- Compute the mean velocity field for each of the 3 repetitions of the 4500 instant velocity fields
- Compute the ensemble average velocity field with the 3 data set for each sample region
- Interpolate the mean velocity from each sample region for a pre-established common grid
- Compute the average velocity using the data from different sample regions for the overlapped areas

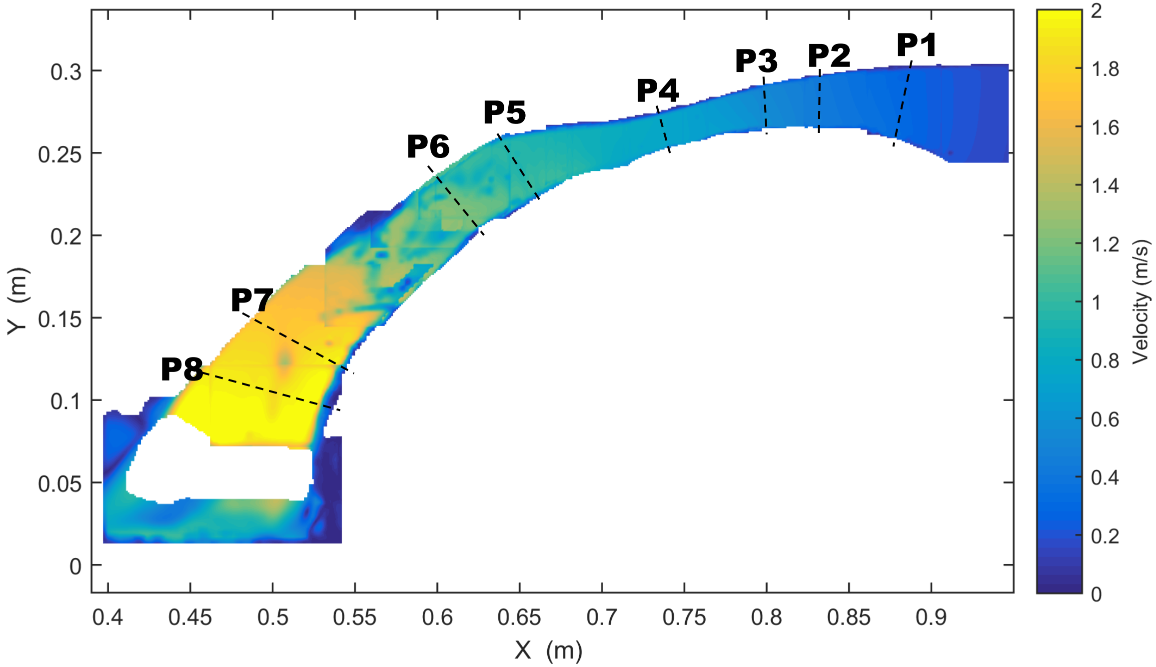




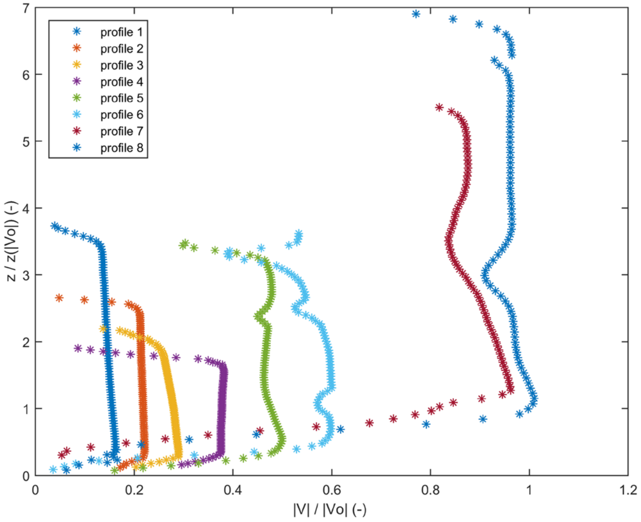
EXPERIMENTAL RESULTS AND DISCUSSION

Longitudinal section

Mean velocity field

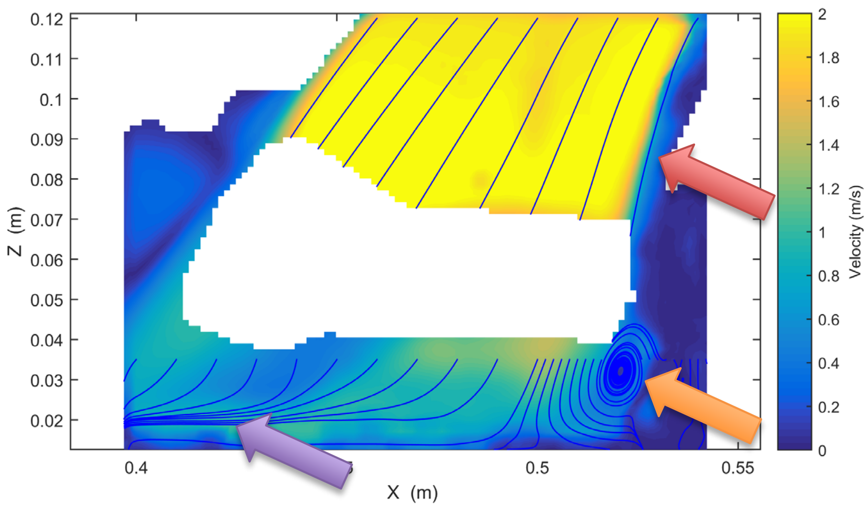


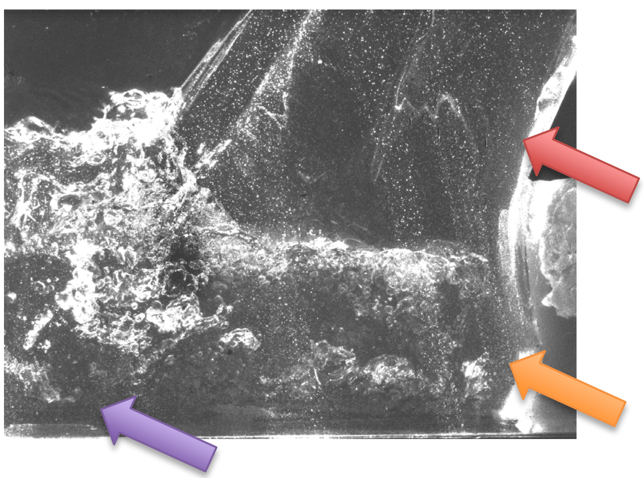
Velocity profiles



JET IMPACT AREA

Velocity and stream lines



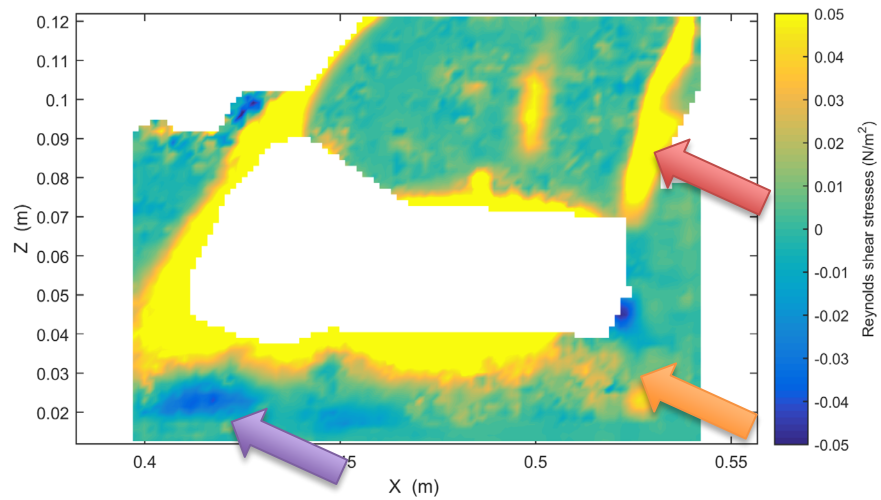


Reynolds shear stresses

$$\tau_{Re} = -\rho\overline{u'w'}$$

were:

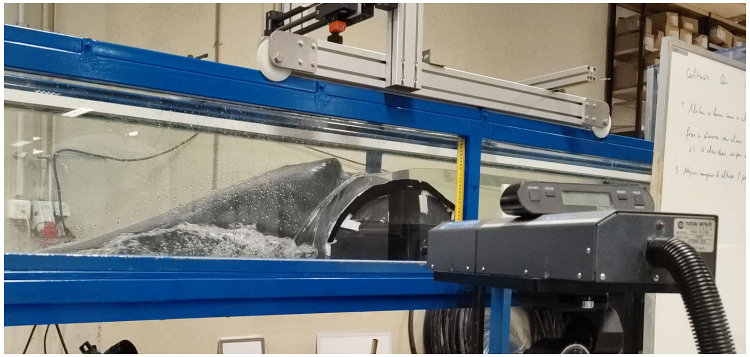
- τ_{Re} - Reynolds shear stresses
- ρ - water density
- u' - velocity fluctuations in x direction
- w' - velocity fluctuations in z direction

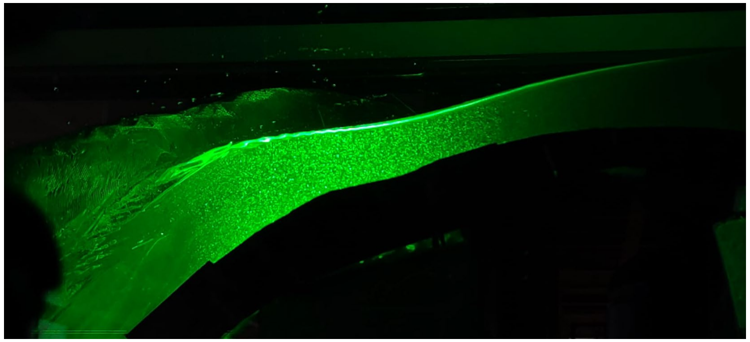


CONCLUSIONS

Conclusions

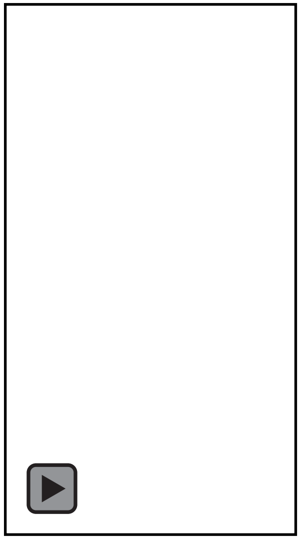
- A printed half-model of a breached dam was used to model a transient flow as a stationary flow
- Perform long-duration measurements using PIV to determine the mean velocity field and the Reynolds stresses
- The division of the region of interest (ROI) in several panels allowed the complete description of the flow
- This approach allowed to identify a boundary-layer flow in the region over the breach and a vortex close to the bottom
- Due to the air-water emulsion at the jet impinging section, it was impossible to characterize the flow in this region
- These measurements will be complemented with measurements in a plane parallel to the bottom and in a plane perpendicular to the flow to better characterize the erosive process.

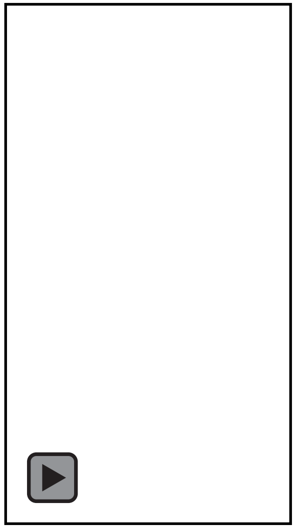


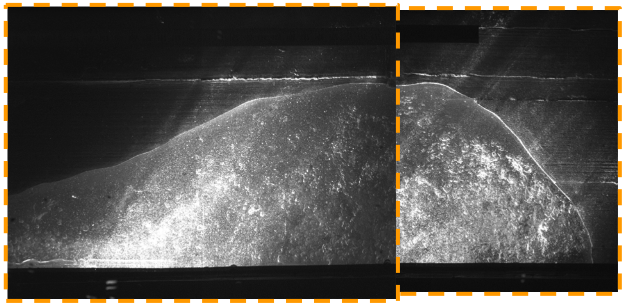


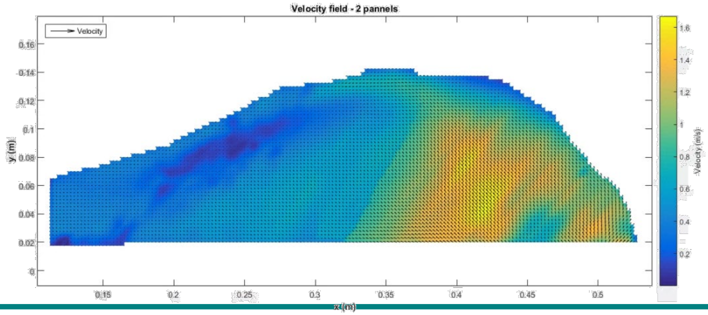
FUTURE DEVELOPMENTS

- Conclusion of the data treatment regarding the hydrodynamic field characterization
- Submission and publication of 3 journal papers:
  - Alvarez, T.; Mendes, S.; Aleixo, R.; Amaral, S.; Caldeira, L.; Viseu, T. and Ferreira, R.M.L. (2022) Breaching of Homogeneous Dams with Chimney Filters. Submission to *Water Resources Research*
  - Alvarez, T.; Aleixo, R.; Mendes, S.; Amaral, S.; Caldeira, L.; Viseu, T. and Ferreira, R.M.L. (2022) Failure of homogeneous and zoned dams subjected to overtopping. Timescales and fundamental morphological processes. Submission to *Water Research*
  - Alvarez, T.; Aleixo, R.; Viseu, T. and Ferreira, R.M.L. (2022) Hydrodynamics of overtopped breaching dams. Submission to *Environmental Fluid Mechanics*
- Delivery of the PhD thesis









Thank You!