

# Monitoring of a sediment replenishment operation:

## The case of the Saint-Sauveur dam in the Buëch River (Southern Alps. France)



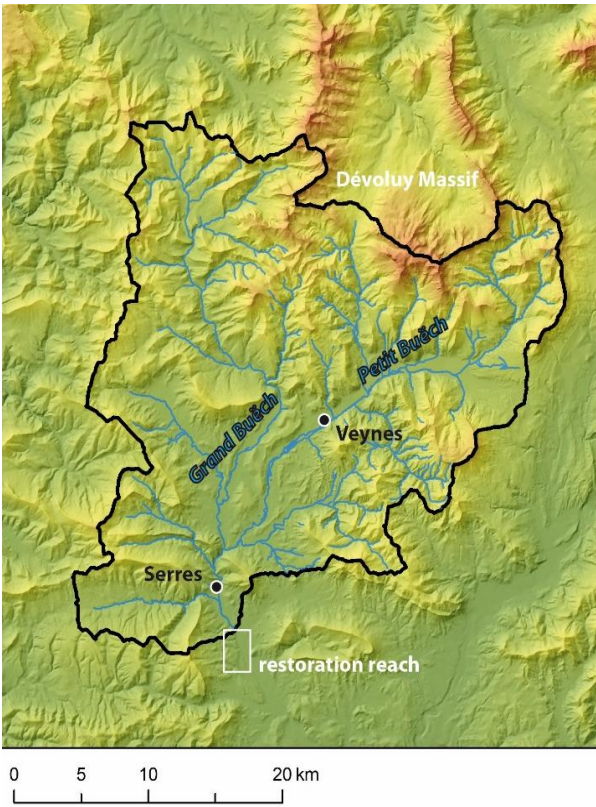
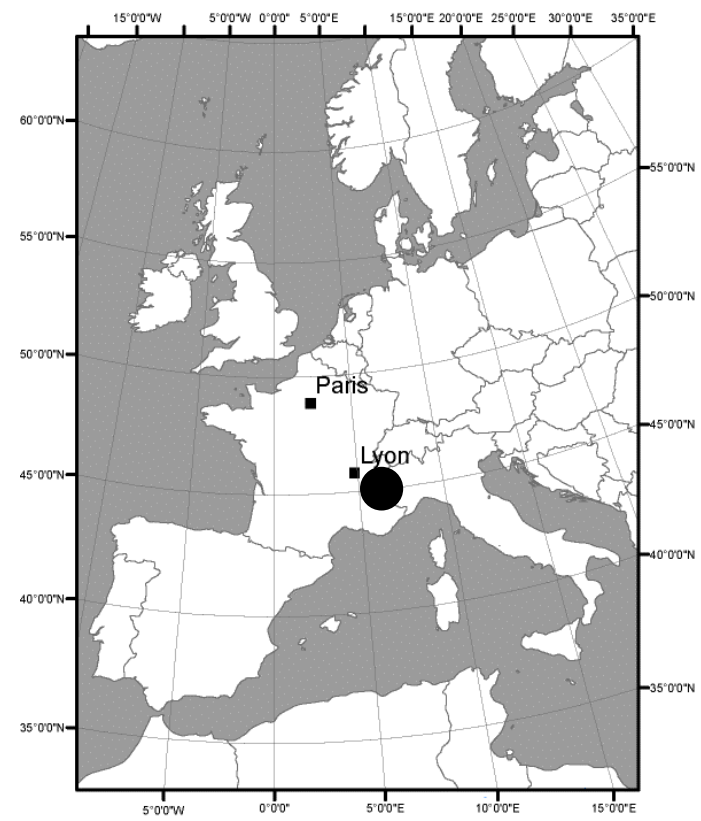
G. Brousse ; M. Bertrand ; G. Arnaud-Fassetta ; F. Liébault ;  
L. Borgniet ; G. Melun ; R. Loire ; J.R. Malavoi ; G. Fantino

- Research context
- Why restore - How to restore ?
- Monitoring approaches
- Hydromorphological evolution of the restored reach
- Feedback and prospects





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Geology dominated by sedimentary rocks with black marls

A hot spot of the Alpine biodiversity with a mosaic of ecological habitats

Multiple economic uses (irrigation, hydro-electricity. Hunting, fishing, tourism ...)

## Human alterations of the physical fluvial corridor :



- **Gravel mining**
  - > 3 Mm<sup>3</sup> in the upper catchment
  - > 6 Mm<sup>3</sup> in the lower catchment
- **Flood protection and hydropower equipments**

River regulation (before 20<sup>th</sup> century)

Saint-Sauveur dam (1991 and 1992) => dredging of 600,000 m<sup>3</sup> of sediment

- **Bedload has been strongly impacted**

## Rapid channel responses :

- Alluvial fan is aggrading upstream the reservoir
- Narrowing and degradation of the active channel with downstream propagation
- Marly bedrock outcrops are observed along the degraded reach
- A shift from a braided to a wandering pattern



## THE REPLENISHMENT OPERATION

- September 2016: 1 million euros
- Dredging the alluvial fan of the Saint-Sauveur reservoir
- Clearing alluvial bar
- Sediment replenishment downstream of the dam (**44,000 m<sup>3</sup>**)
- 2,500 m<sup>3</sup> by day (7 tip-truck)
- **Limiting flood risk**
- **Stop incision**



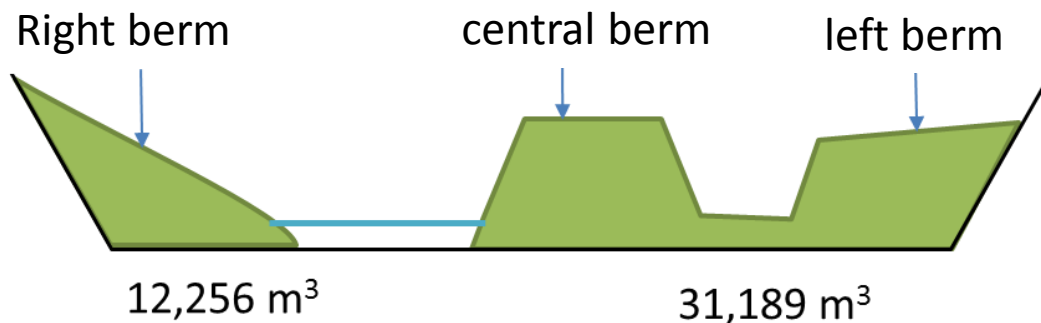
## NEW RULES OF DAM EXPLOITATION

1997 : transparency for  $Q > 80 \text{ m}^3/\text{s}$   
(without forecast)

2015 : transparency for  $Q > 60 \text{ m}^3/\text{s}$   
(according to forecast on 24h)

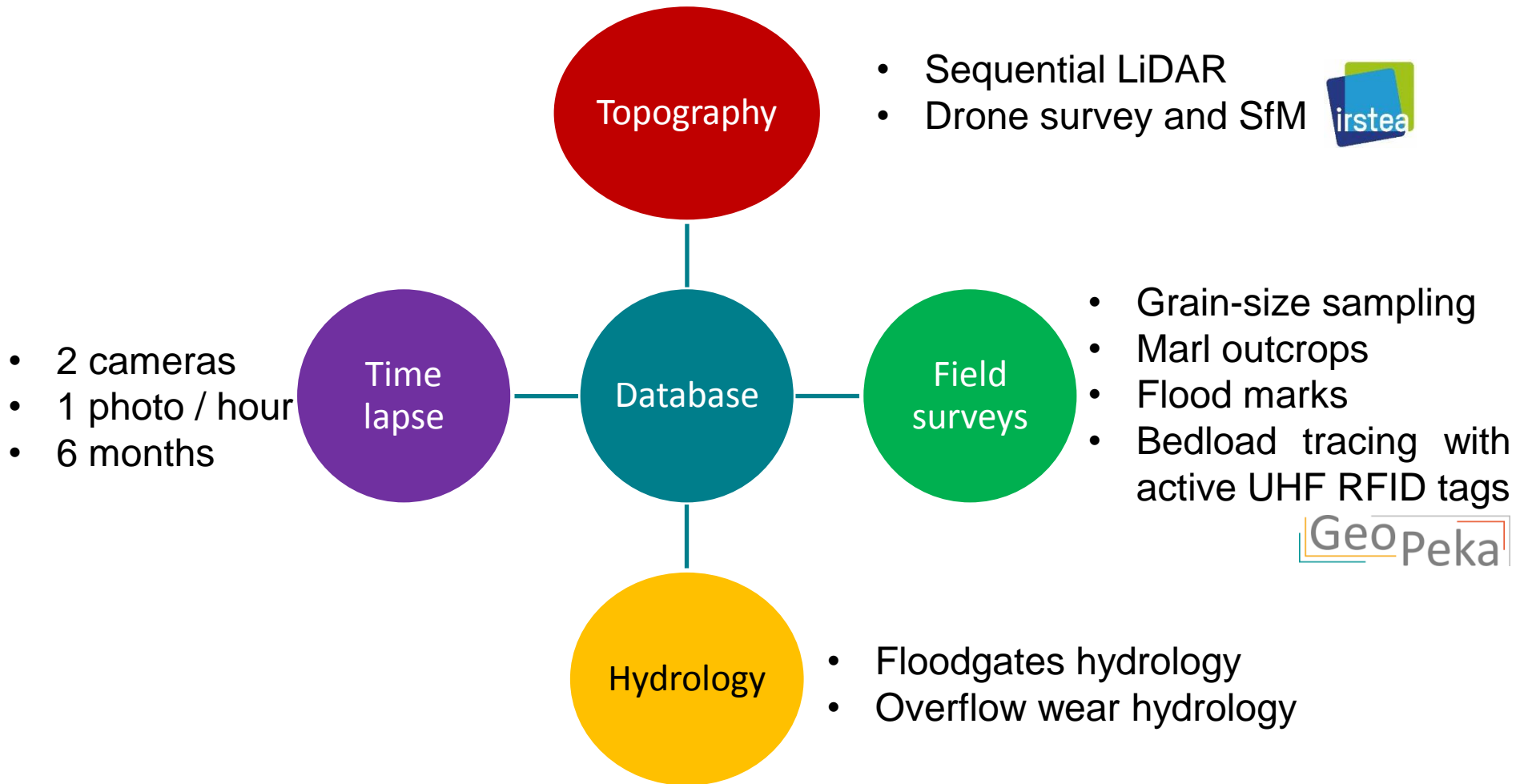
Frequency and magnitude of transparency are higher in order to optimize sediment continuity

« Point bar stockpile method » (Ock *et al.* 2013)



## OBJECTIVES :

### CAPTURE THE GEOMORPHOLOGICAL AND BIOLOGICAL RESPONSES OF THE DEGRADED REACH TO THE ARTIFICIAL GRAVEL RECHARGE



# REPETITIVE DATA ACQUISITION


5 Airborne LiDAR

1 SfM

3 bedload tracing inventory

3 field surveys

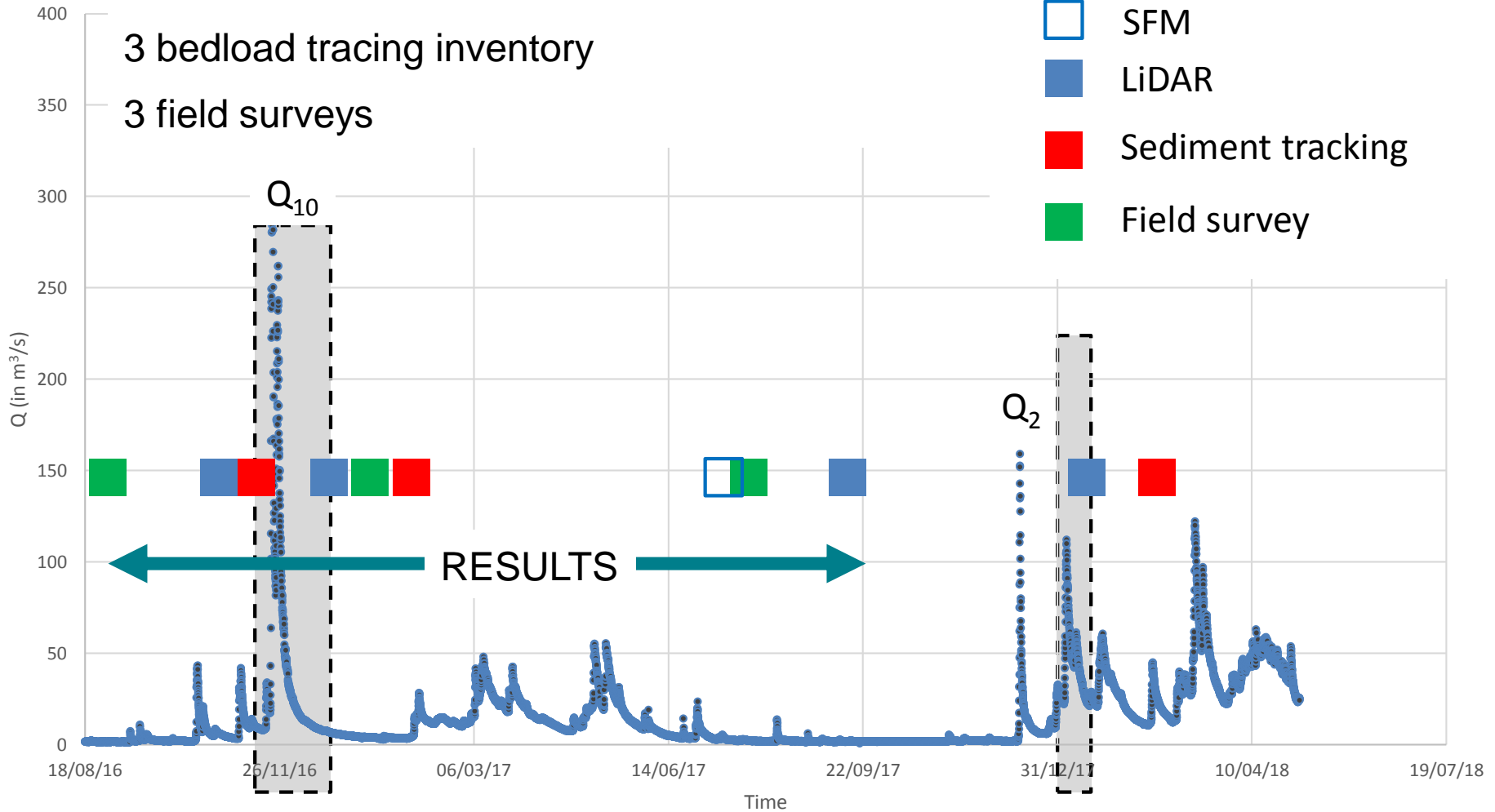
 Hydraulic transparency

 SfM

 LiDAR

 Sediment tracking

 Field survey



# CHARACTERIZATION – Just after restoration (September 2016)





# CHARACTERIZATION – During flood (November 2016)



Berms erosion



Hydraulic transparency

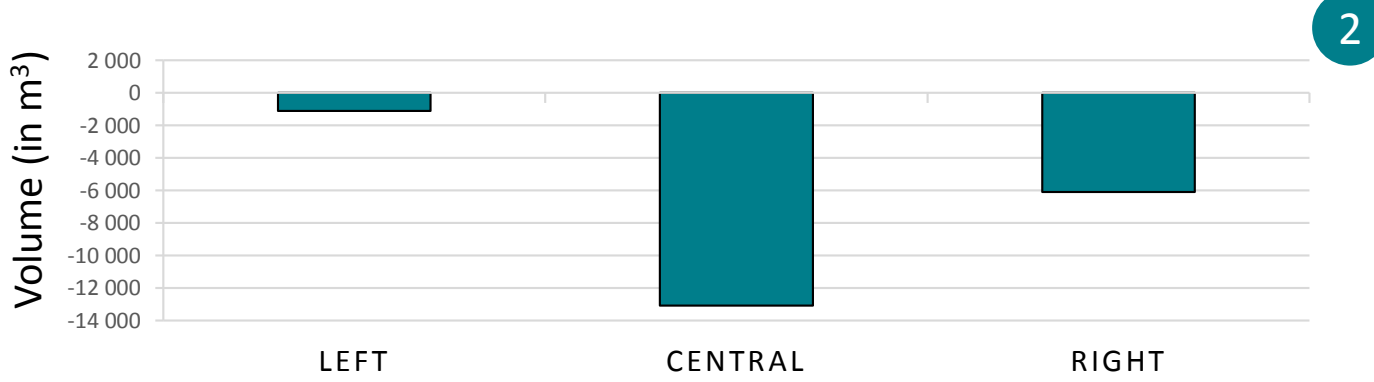
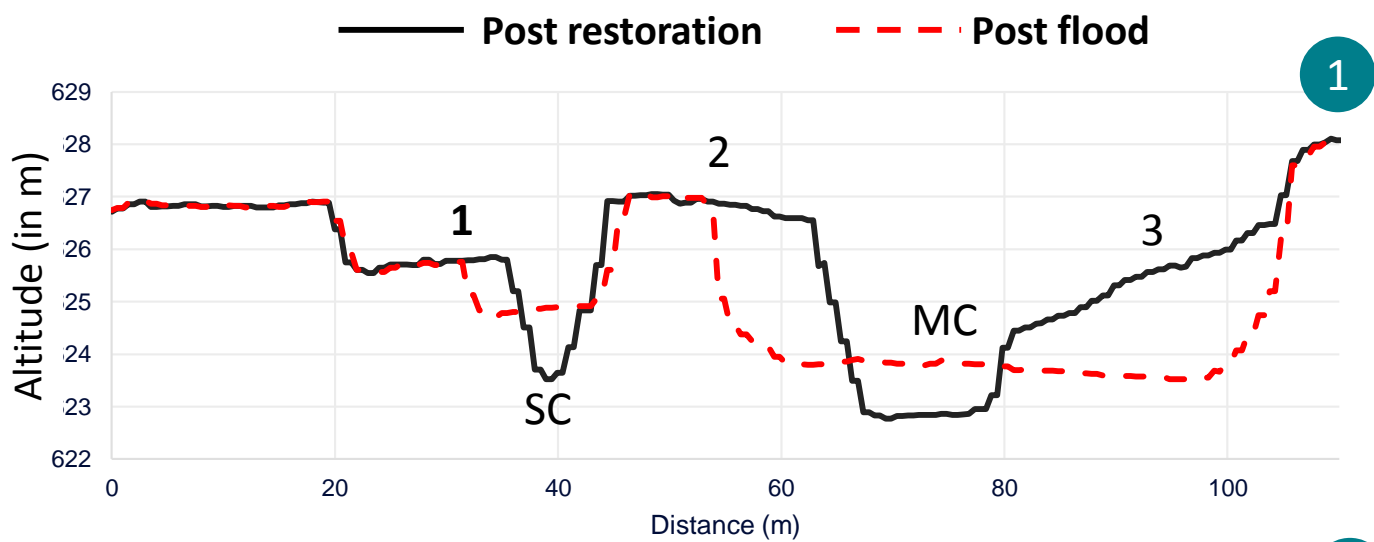
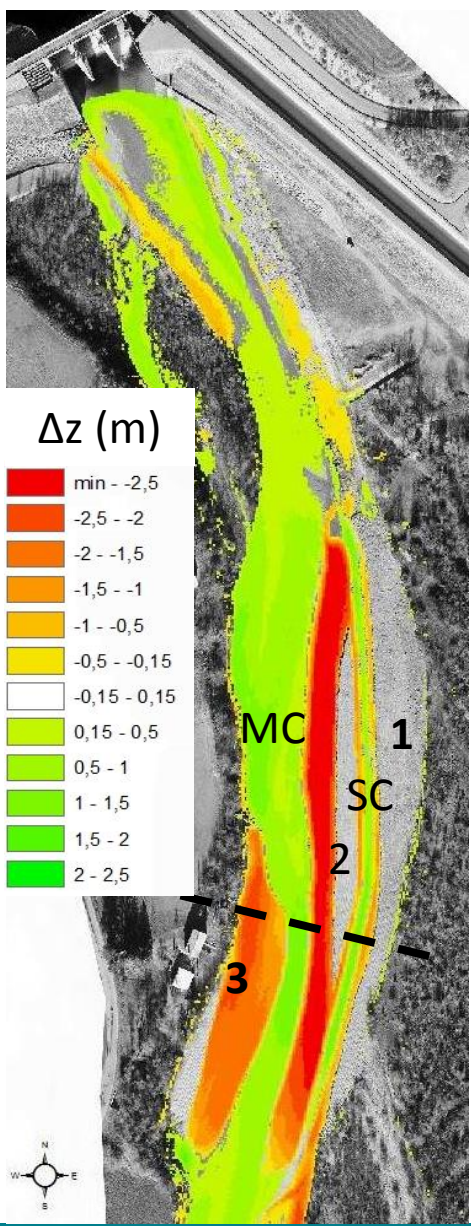


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# CHARACTERIZATION – Just after flood (December 2016)



# THE REPLENISHMENT SITE – Post flood (December 2016)



**Very high erosion on the central and on the right berm during flood**  
**→ 20,000 m<sup>3</sup> (46% of initial berms)**  
**Net sediment budget → -11,000 m<sup>3</sup>**



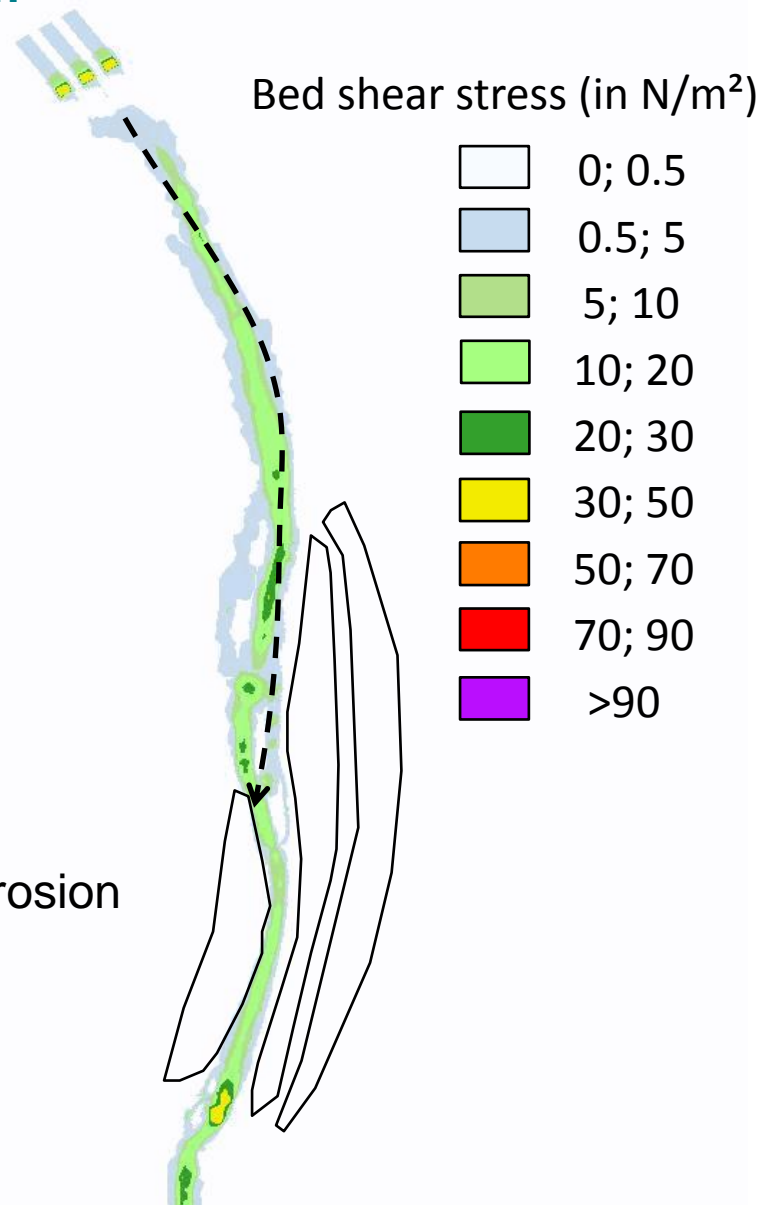
# THE REPLENISHMENT SITE – Flood modelization



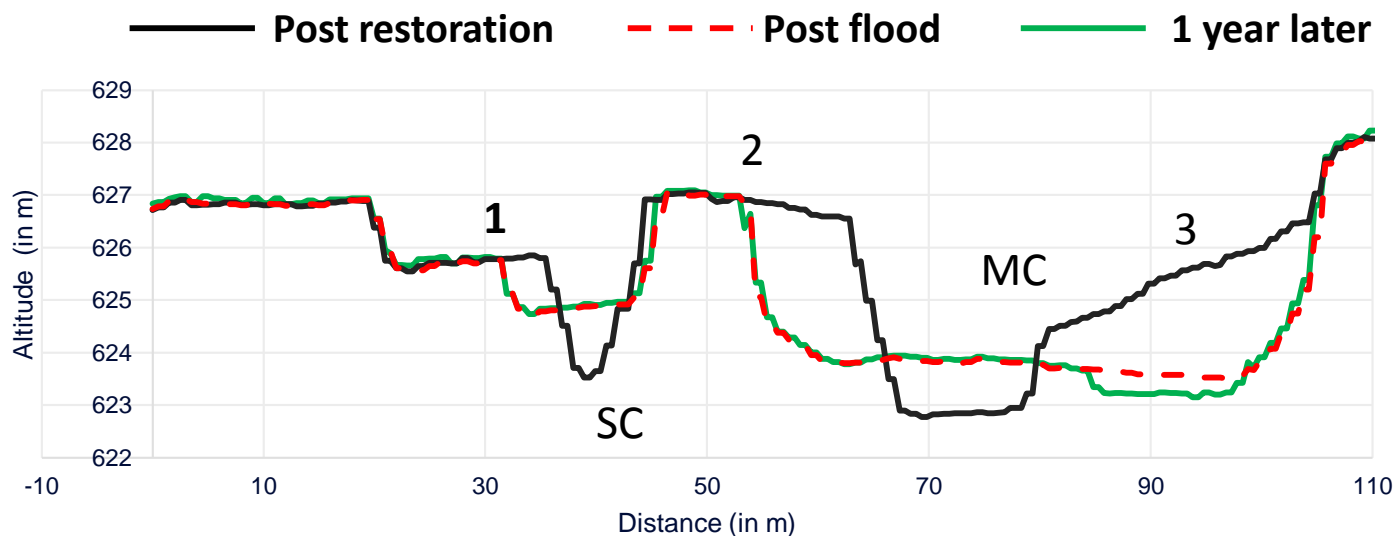
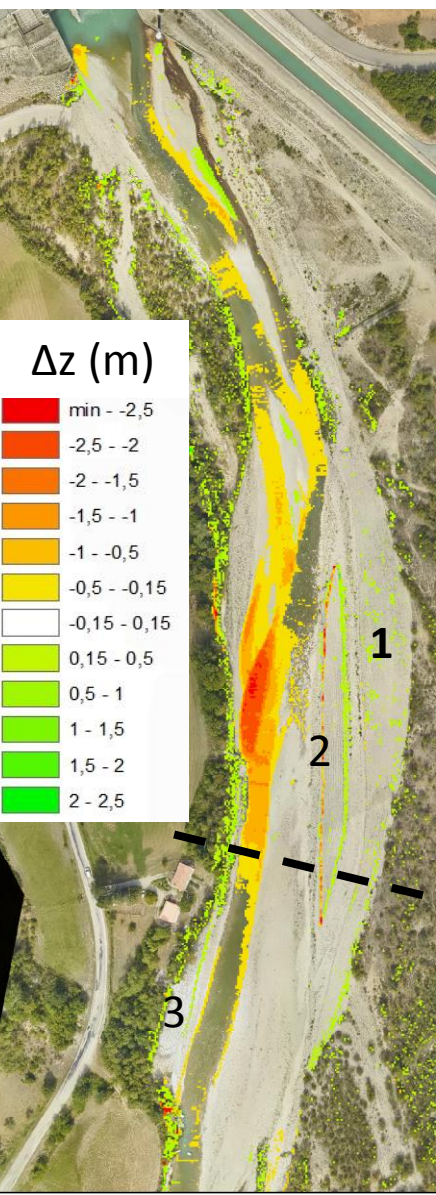
- 2D Telemac model of the  $Q_{10}$  flood (Durand-Gasselin. 2017)
- Field calibration (grain size and flood marks)

## Shaping of the secondary channel?

- A net limit between MC and SC
- Flow dividing
- Minimize erosion in SC
- Erosion of SC du to lateral and regressive erosion
- No linear erosion
- Too far of the flow axis



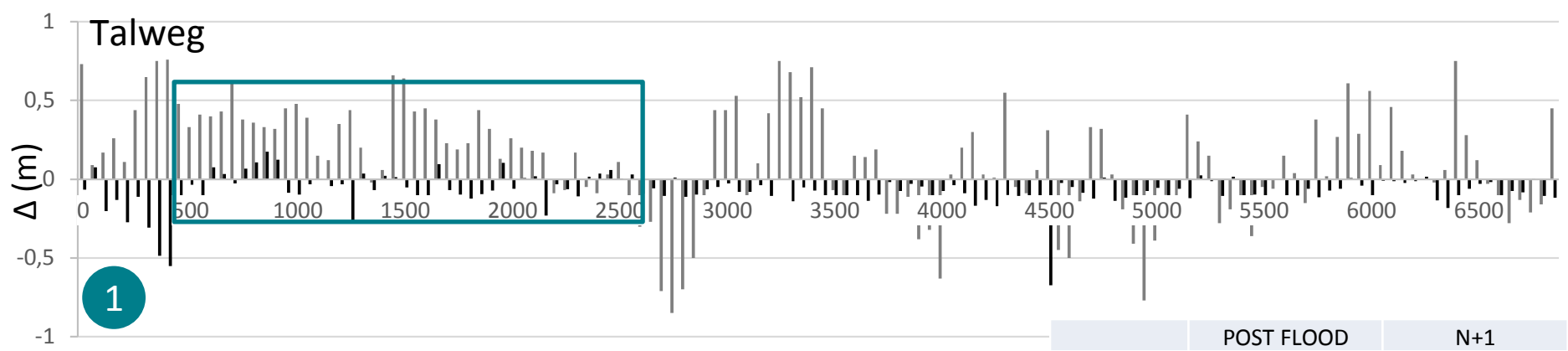
# THE REPLENISHMENT SITE – One year later (September 2017)



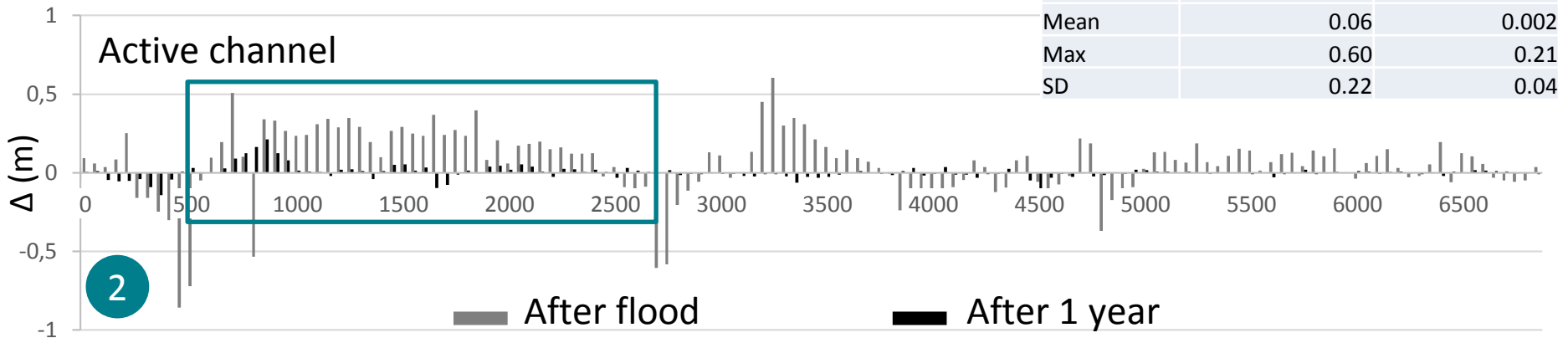
**Very small evolution during last year But the main channel erode the right bank**

**Net sediment budget → -150 m<sup>3</sup>**

# THE DOWNSTREAM REACH – Longitudinal profile



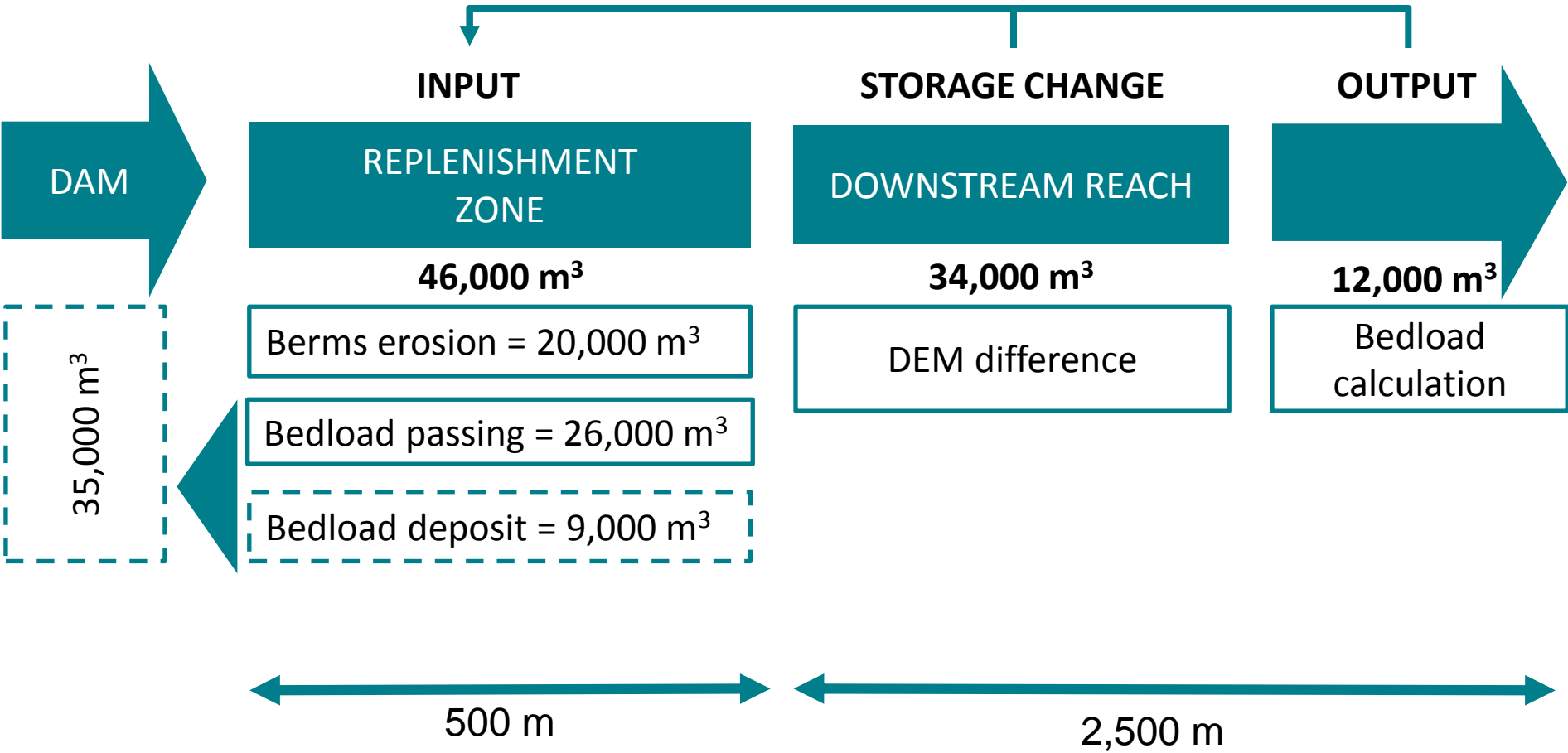
**Aggradation max in the 2.5 km downstream reach**  
**Global net deposition**



# THE DOWNSTREAM REACH – Sediment budget

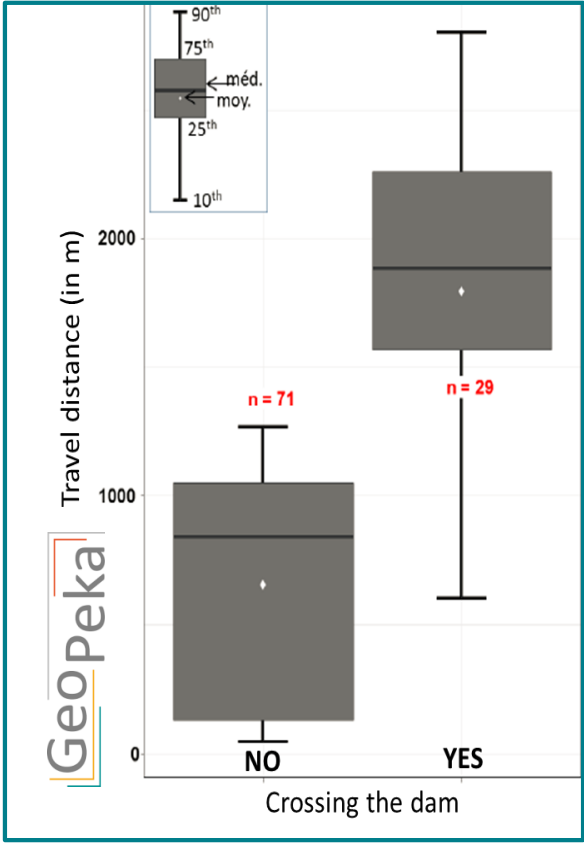
$$I = \Delta S + O$$

Hypothesis: Sediments from eroded berms have been exported to the downstream reach

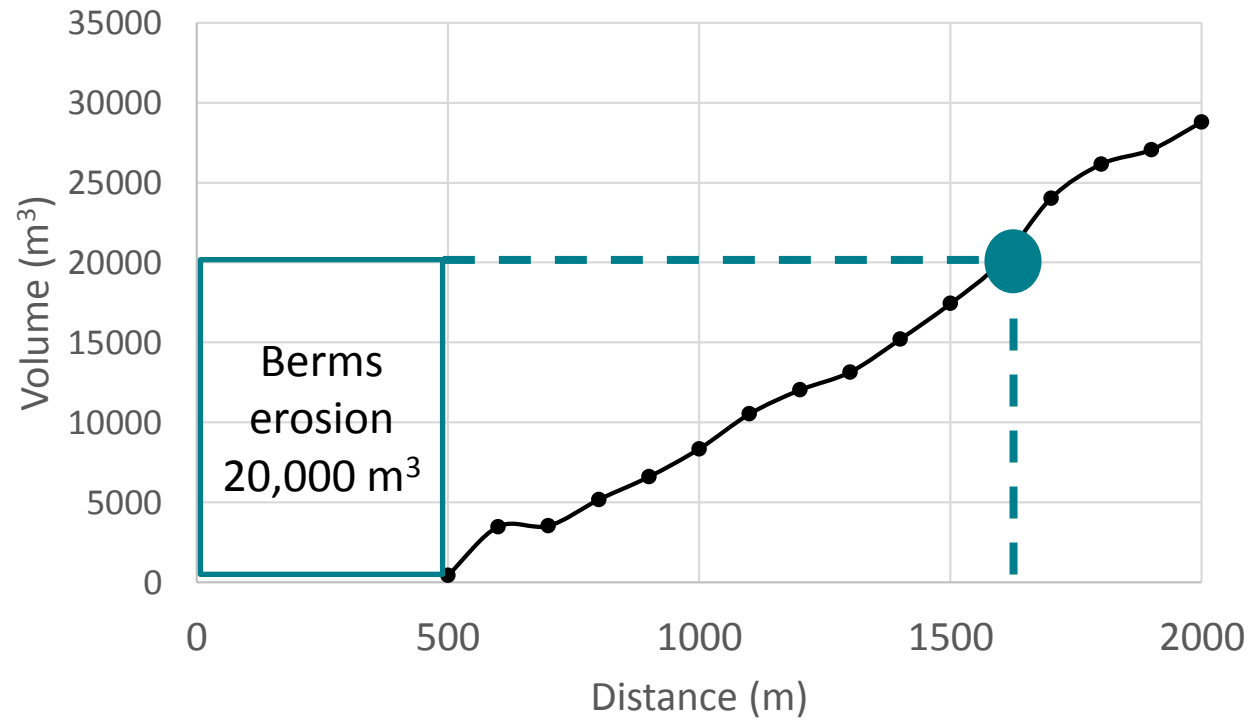


# THE DOWNSTREAM REACH – Travel distance from berms erosion

Only informations upstream the dam



**Distance travel from berms erosion: [0; 1600] m**



n = 148  
 Recovery rate = 68%  
 Mean travel distance = 1,150  
 Max = 3,240 m

Cumulative sediment budget





## In one year: Hydromorphological objectives are achieved

- Great erosion of initial berms → sediment input to the downstream reach
- Net aggradation on the 6 km downstream reach (main channel and active channel)
- Change are more important in the upper part (2.5 km)
  - Aggradation is greater
  - Main channel erosion

Real impact of hydraulic transparency which permits a net gain of the sedimentary budget



# Exploitation feedback

## Positive

- Monitoring show the efficiency of the replenishment operation
- Efficiency is link to ideal conditions (hydrology and exploitation)
- New knowledge about the area of influence of hydraulic transparency

## Negative

- Shaping of a secondary channel is not a good solution in this site
- Left berm are now non erodable for frequent flood

## Prospects 2018-2020

- Distinguish impact of frequent flood with or without hydraulic transparency
- Monitoring of the channel degradation
- Monitoring of the left berm pushing in the active channel (september 2018)



## Thank you for your attention

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