

MONITORING THE CONSEQUENCES OF DAM
FLUSHING OPERATIONS ON SUSPENDED
PARTICULATE MATTER AND ASSOCIATED
CONTAMINANTS IN THE RHÔNE RIVER
DOWNSTREAM OF LAKE GENEVA

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Rhône Sediment Observatory (OSR)



- Created in 2009, the mission of the observatory is to **compile** and **manage data on sediment dynamics and associated contaminants**. Overall, these data should help river managers and stakeholders. The observatory is a **multi-partner platform** aiming to carry out collaborative research between scientific researchers and managers.



- Example of objectives within the OSR:
 - To quantify the transfer of suspended and bedload sediments at different time-scales (centennial, inter-annual, event-based).
 - To quantify the flux of organic and mineral contaminants associated with the sediments.
 - To evaluate the impacts of dam flushing operations on concentrations and fluxes of SPM and associated contaminants

<http://www.graie.org/osr/spip.php?rubrique62>

Dams in the Rhône River

21 hydropower plants from Lake Geneva to the Mediterranean Sea (~500 km)

Dams are among the main structures that impact SPM transport by reducing flow velocity and **increasing sediment deposition**

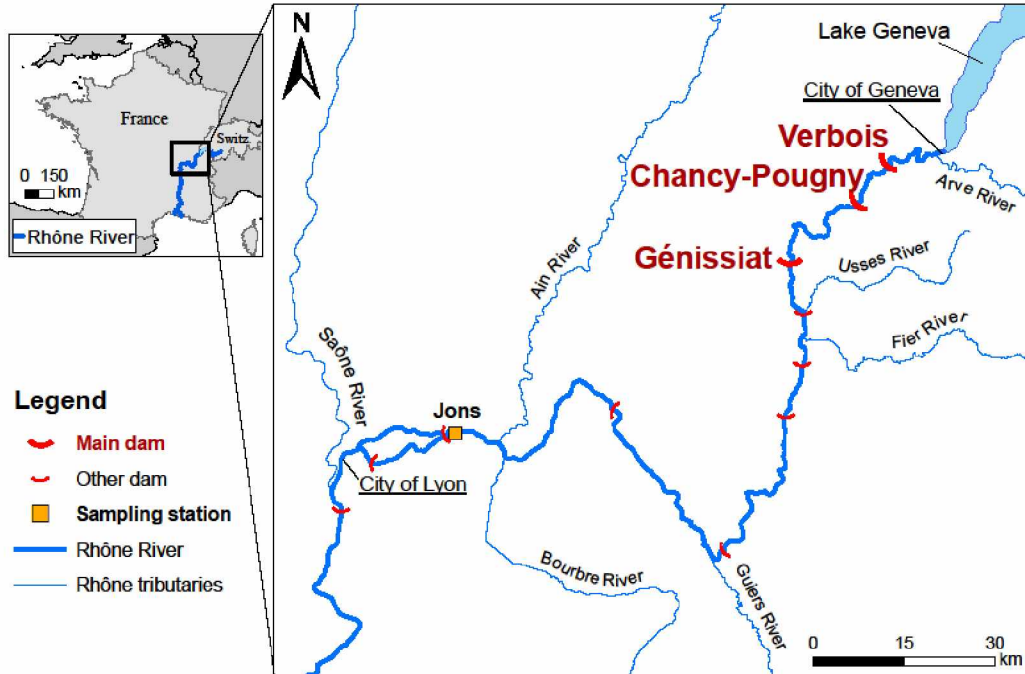
➤ **Dam flushing operations are organized** to remove sediments stored in reservoirs.

Due to the associated increase of turbidity and potential consequences on fish populations **such operations are strictly monitored** to reduce their environmental impact

Survey of SPM transport on a large scale remains difficult and we still need a better understanding of contaminants remobilization and transport processes under such conditions

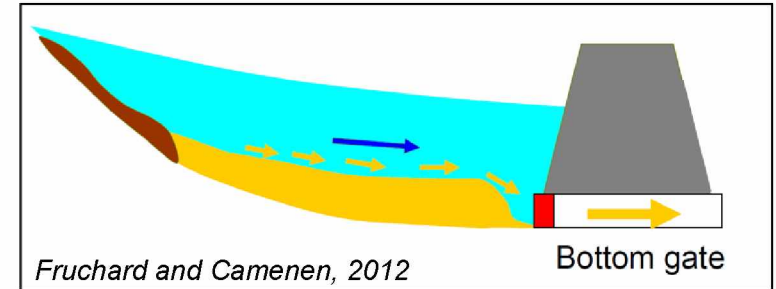


Studied dams: Rhône River downstream the Lake Geneva

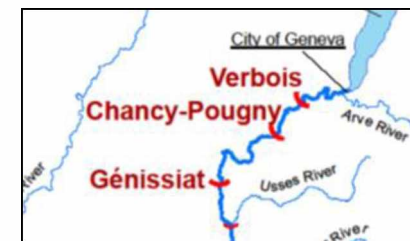


Dam flushing operations of Verbois and Chancy-Pougny dams by the drawdown flushing method **were organized every 3 years from 1945 to 2003** especially to avoid urban flooding in the city of Geneva.

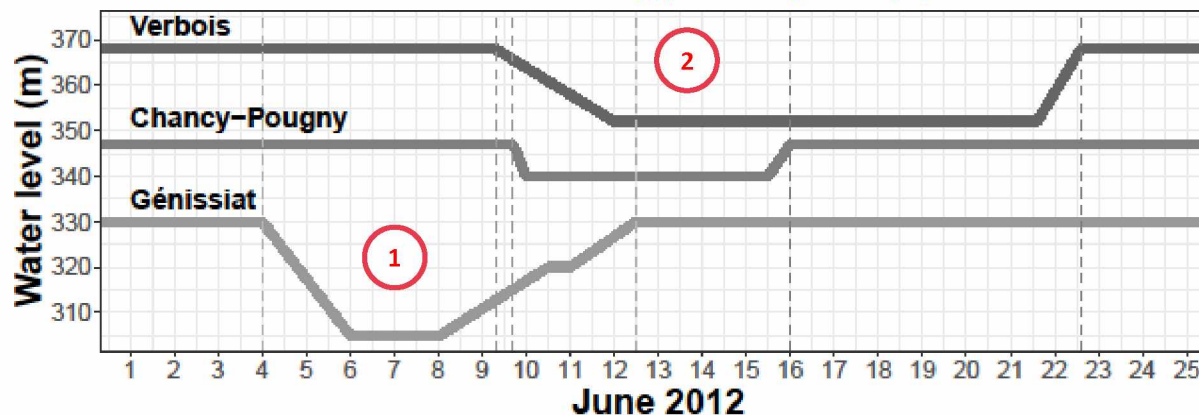
Drawdown flushing method



Studied periods: two flushing operations in June 2012 and May 2016



2012 flushing process (18 days)

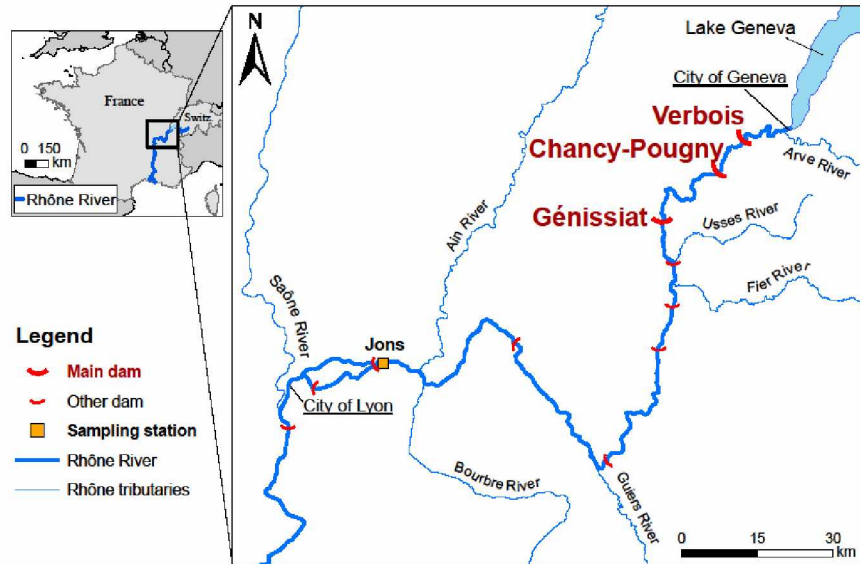


2012: (1) → (2)

2016: (1) ≡ (2)
Less lowering during 11 days

More than $3 \cdot 10^6 \text{ m}^3$ of SPM were stored in the Verbois reservoir between 2003 and 2012, mainly originated from the Arve River

Studied parameters at Jons monitoring station (150 km downstream the studied dams)



The station of Jons is operating since 2011:

- Long term investigation on the main parameters
- Comparison of extreme event impacts

Parameters measured :
(2012 and 2016)

- Water discharge
- SPM content
- Particle size
- Particulate organic carbon

Contaminants measured:
(2012 only)

- Trace metal elements (TME)
- Organic compounds
- Radionuclides

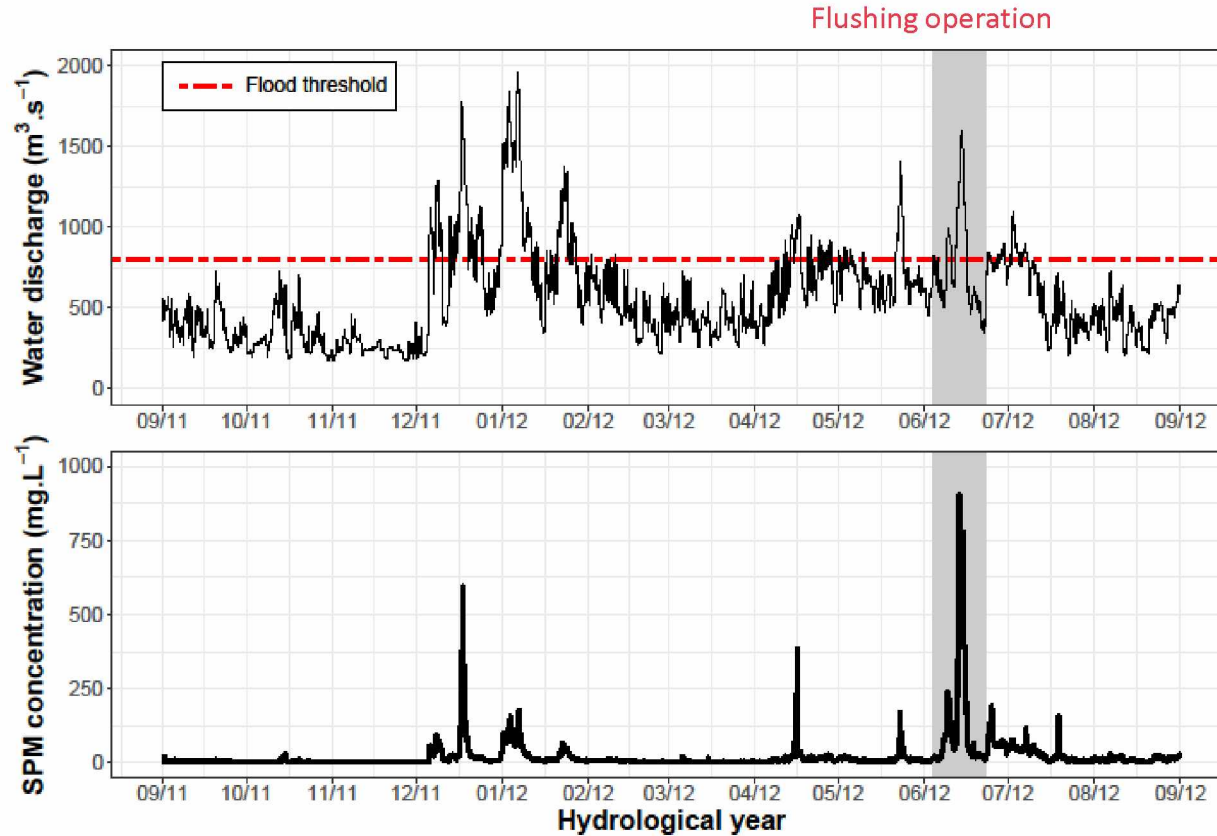


Submerged sediment trap

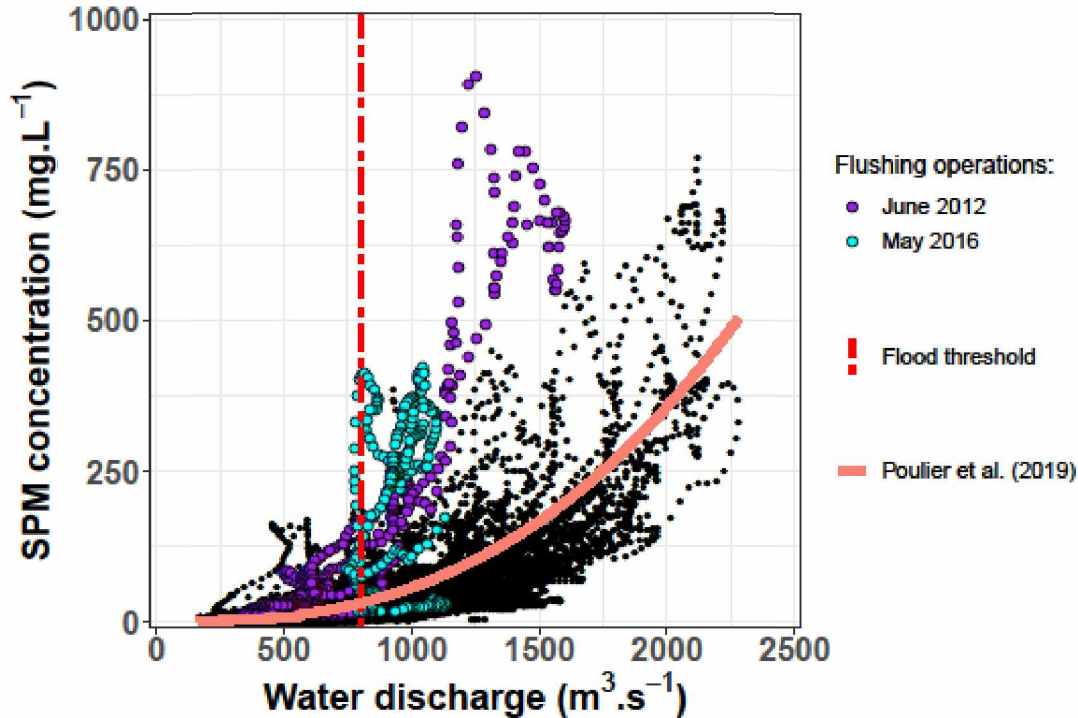


Continuous-Flow Centrifugation

Water discharge and SPM concentration at Jons during 2011 – 2012 hydrological year



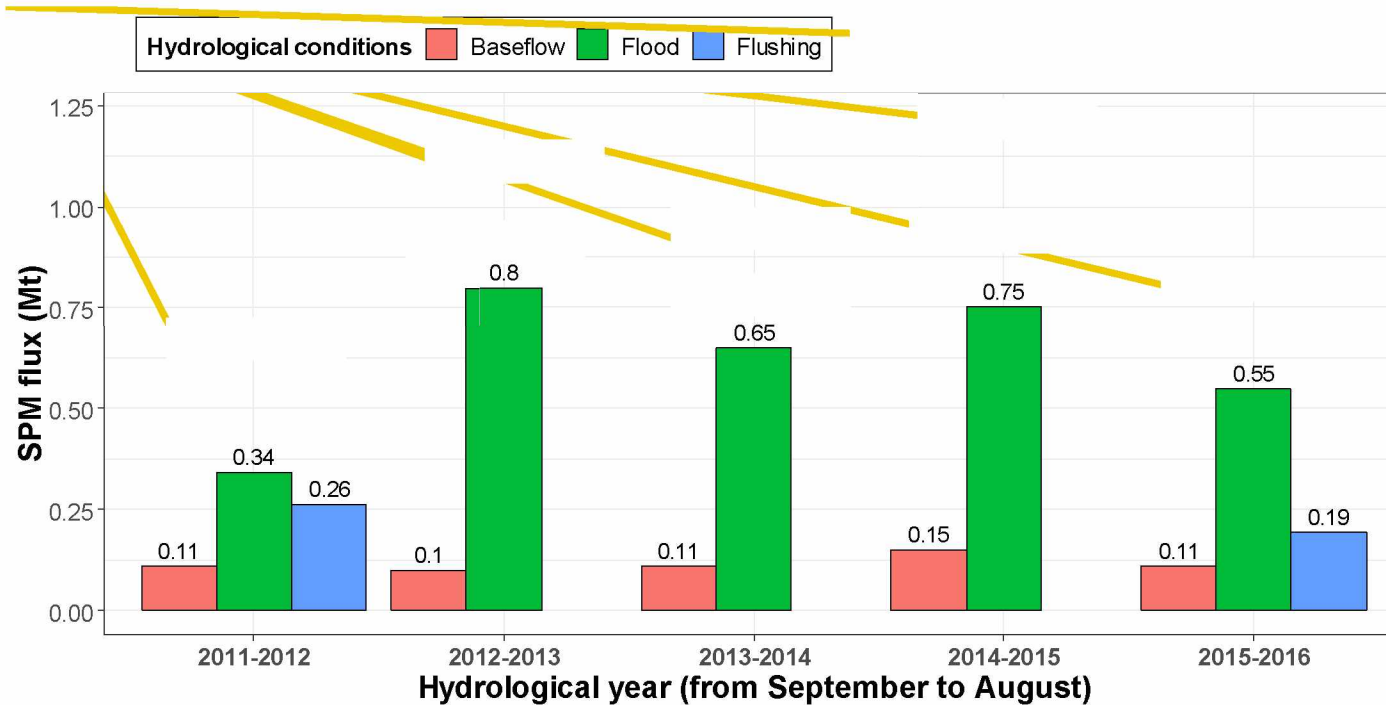
SPM monitoring at Jons



Hydrological processes that occur during flushing operations are **different than during flood events**.

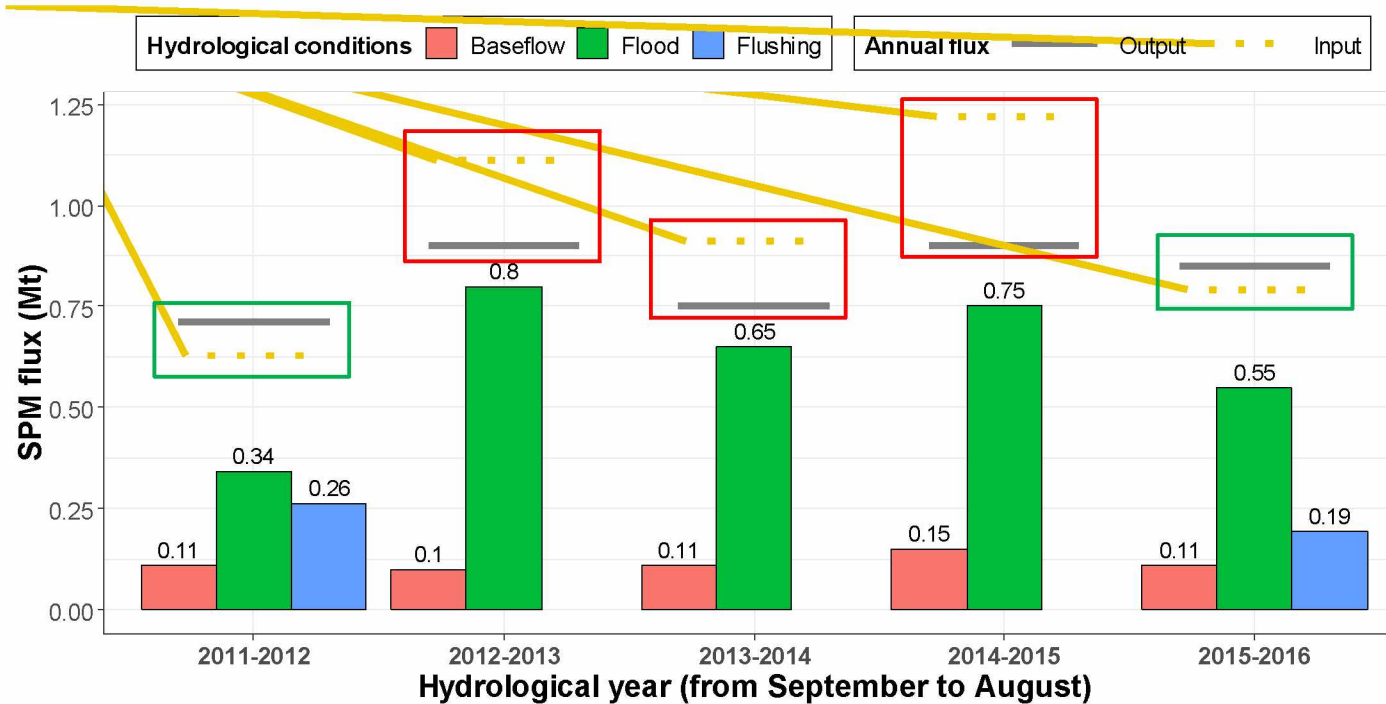
The operations conducted on the dams by drawdown flushing **resuspended sediments that cannot be affected by flood events**.

Annual SPM flux at Jons



A quarter of the annual flux occurs during the flushing operations while it represented **less than 5% of the year**

Annual SPM flux at Jons

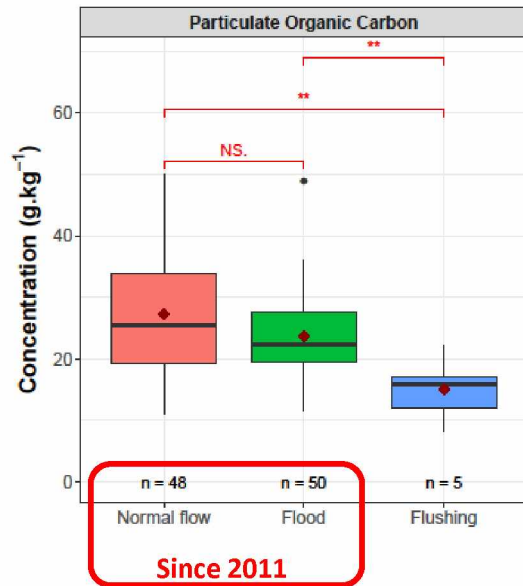


Hydrological year **with** flushing operation: **output > input**
 → resuspension of old deposit

Hydrological year **without** flushing operation: **input > output**
 → storage of sediments

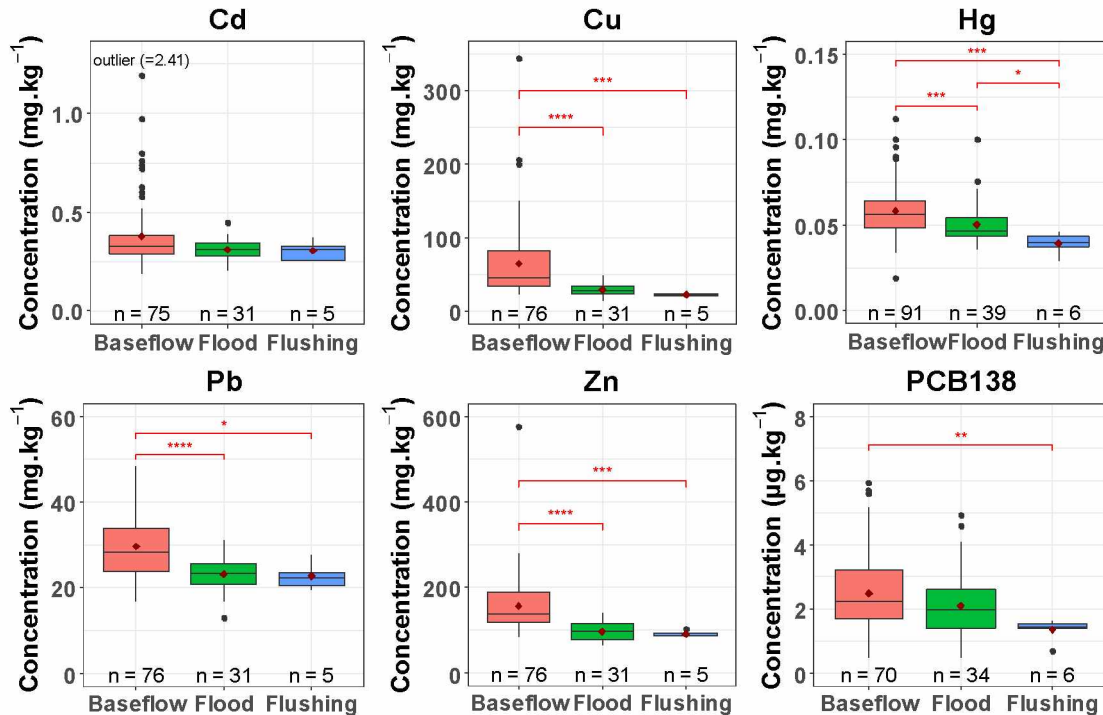
Unbalanced equilibrium over 5 years (-0,44 Mt): **Part of sediment remain stored**

Temporal variation – POC and particle size



	Particle size distribution - Mass proportion (%)		
	Clay (<4 μm)	Fine silt (4 – 15 μm)	Coarse silt (15 – 63 μm)
Baseflow	23 \pm 12	68 \pm 11	12 \pm 12
Flood	29 \pm 12	64 \pm 10	9 \pm 6
Flushing (2012)	17 \pm 8	76 \pm 9	10 \pm 4

Temporal variation – contaminants 1/2



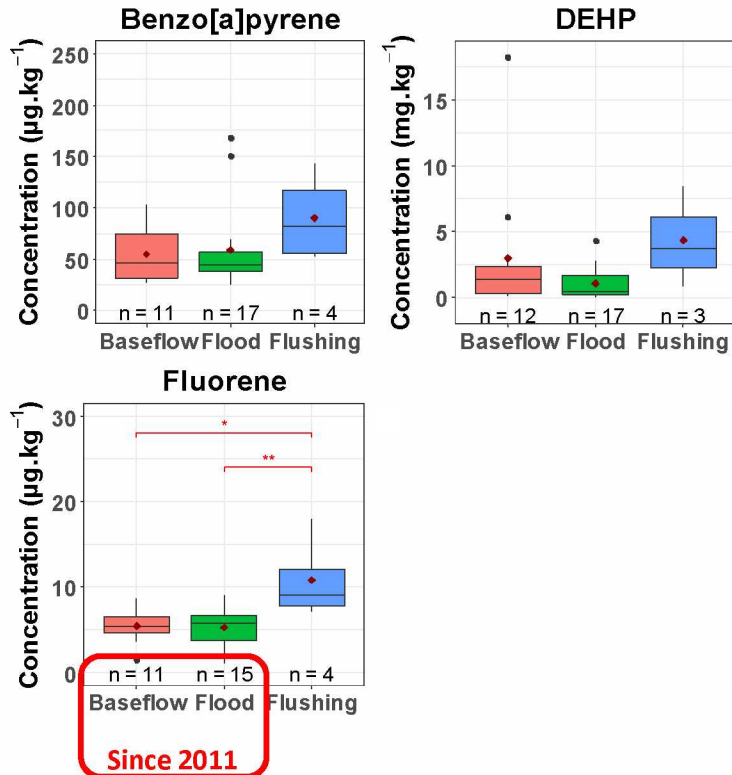
Lower concentrations during the flushing operations for most of the contaminants (TME, Mercury, PolyChlorinated Biphenyls – (PCBs))

Related to the **particle size** and the **origins** of the suspended sediment

In fact in this area, input by tributaries might be characterized by different geochemical signature

Tributary	Hg concentration (mg kg ⁻¹)
Arve River	0.026 ± 0.008 (n = 16)
Bourbre River	0.136 ± 0.040 (n = 6)

Temporal variation – contaminants 2/2



Higher concentrations during the flushing operations for Polycyclic Aromatic Hydrocarbons (PAHs) and DEHP (bis(2-ethylhexyl)phthalate)

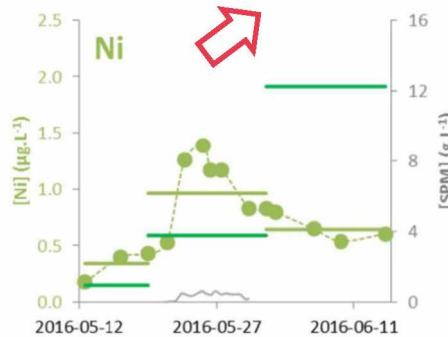
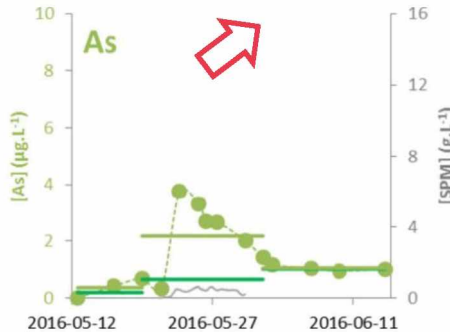
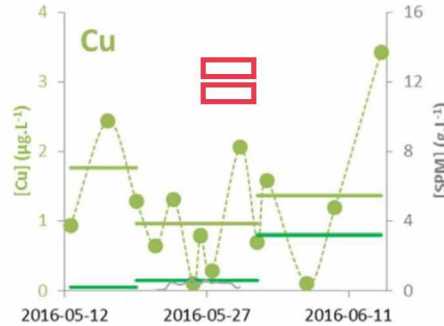
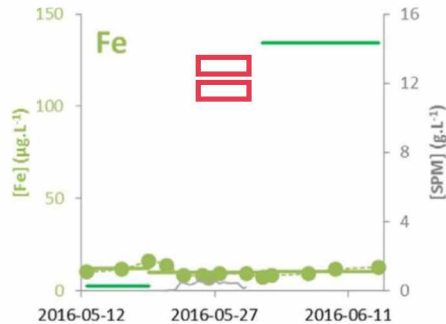
Related to the resuspension of legacy-contaminated sediments stored behind the dams, due to the drawdown flushing method used.

In fact, sediments were stored between 2003 and 2012 while emission regulation was implemented in 2008

→ decrease of PAH emissions observed since 2008 in the Arve River

Temporal variation – dissolved contaminants (study conducted in 2016)

Concentration at Jons



Use of Diffusive Gradient in Thin films (DGT)

Fe, Cu, Cd, Cr, Pb, Zn and Hg dissolved **concentrations were unchanged** during the 2016 flushing event.

Mn, Ni, Co and As dissolved **concentrations increased** during the 2016 flushing operations.

➔ related to the desorption from particulate fraction or from a dissolution of metal bearing phases.

Highlights

- Long term monitoring is useful to understand sediments and associated contaminants transport and behavior, especially during specific event such as flushing operation.
- The operations conducted on the dams by drawdown flushing resuspended sediments that cannot be affected by flood events, and that might contain some legacy contamination.



The impact of dam flushing event on dissolved trace elements concentrations: Coupling integrative passive sampling and discrete monitoring

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Research article

Impact of dam flushing operations on sediment dynamics and quality in the upper Rhône River, France

Hugo Lepage^{a,*}, Marina Launay^{b,1}, Jérôme Le Coz^b, Hélène Angot^{b,2}, Cécile Miège^b,
Stéphanie Gairoard^c, Olivier Radakovitch^{a,c}, Marina Coquery^b

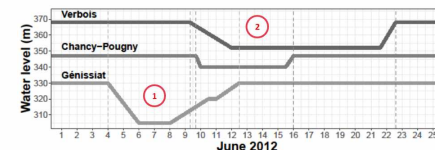
- Submission of a data paper this year with the data presented here
 - You can already access the data here: <https://dx.doi.org/10.17180/OBS.OSR> - <https://bdoh.irstea.fr/OBSERVATOIRE-DES-SEDIMENTS-DU-RHONE/> (french and english)



Thank you

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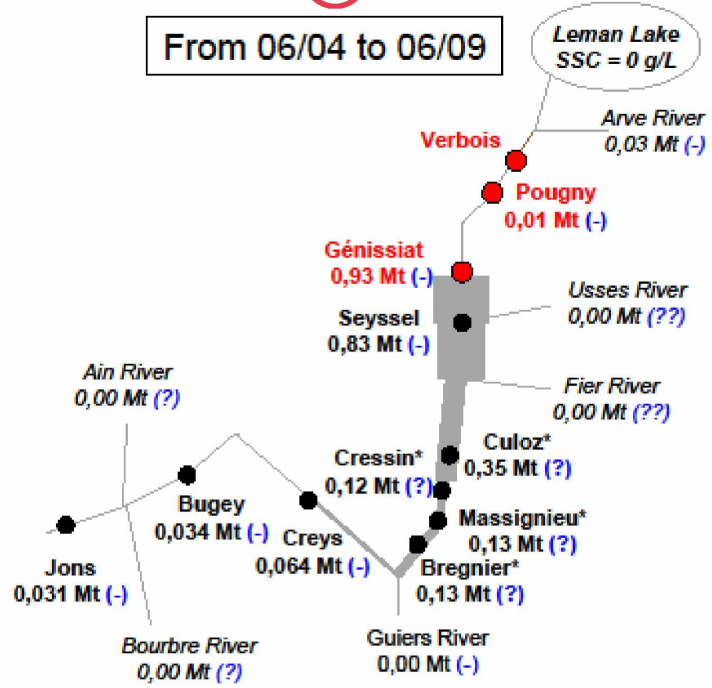
Sediment budget during 2012 flushing operation



1

From 06/04 to 06/09

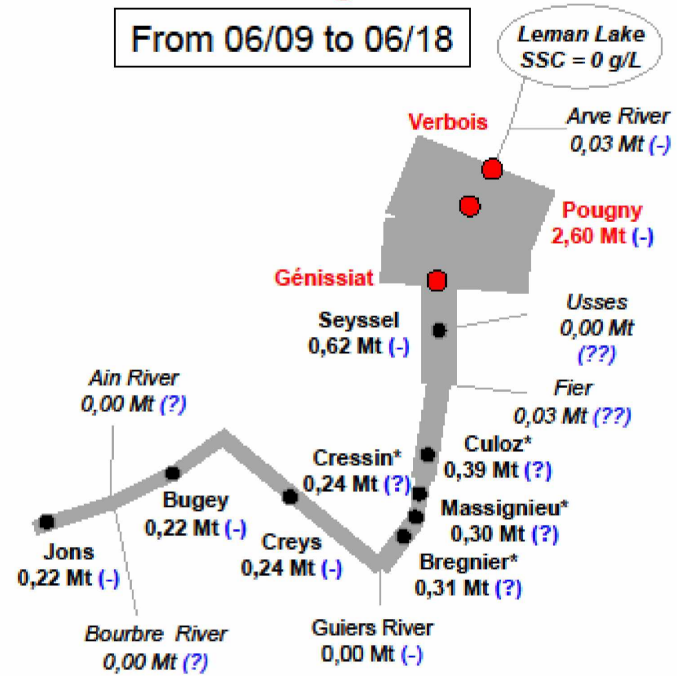
Leman Lake
SSC = 0 g/L



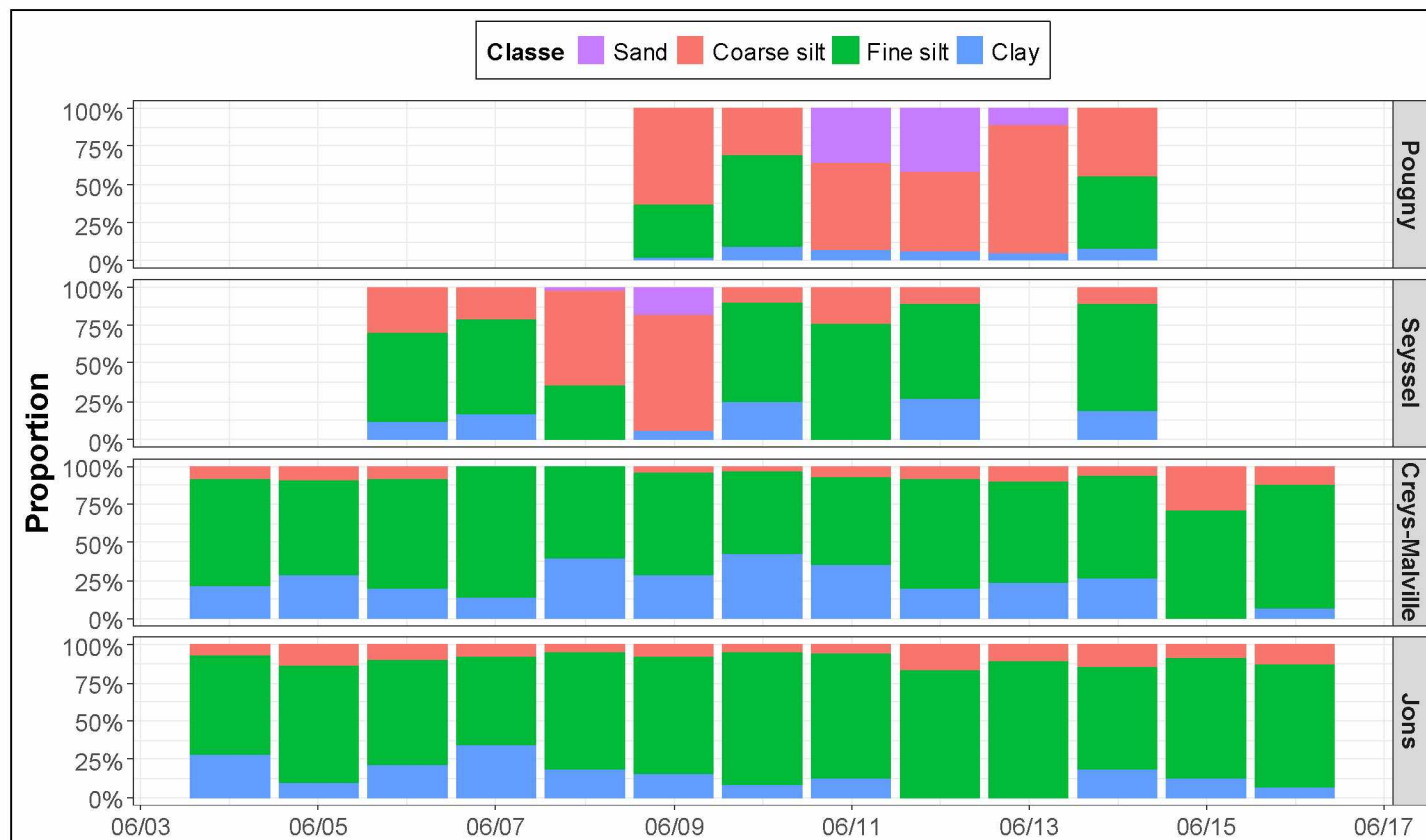
2

From 06/09 to 06/18

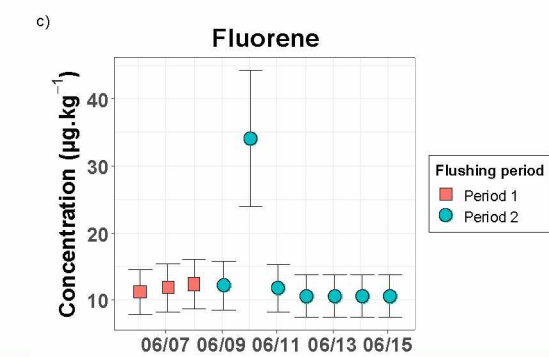
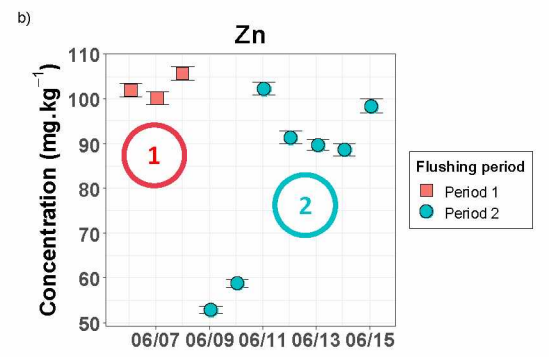
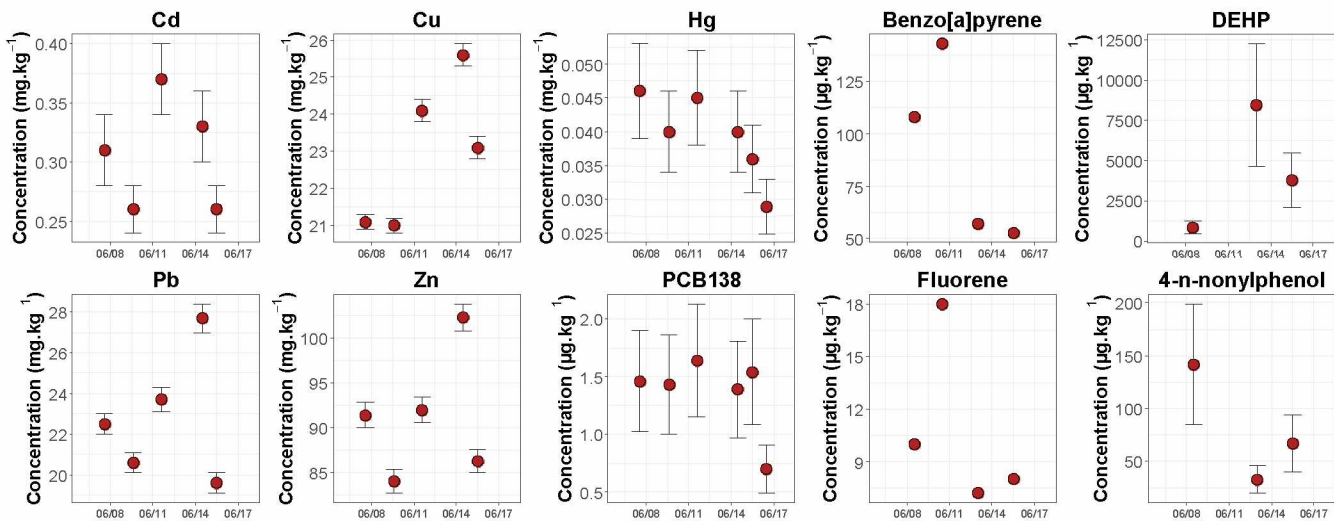
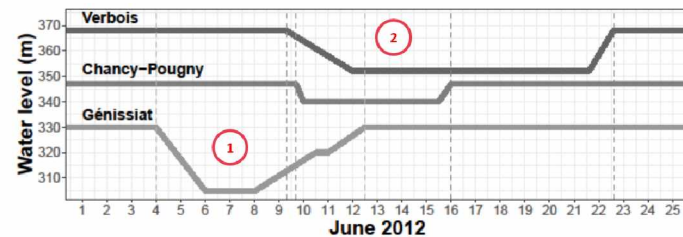
Leman Lake
SSC = 0 g/L



Spatio-temporal variation of particle size during the 2012 event.



Spatial variation



PAH concentrations

