# Quantification of the sand dynamics in the Lower Isere to the Rhone River

Host laboratory: River Hydraulics Team, RiverLy Research Unit, INRAE centre de Lyon-Grenoble.

Doctoral school: Mechanics, Energetics, Civil Engineering, Acoustics (MEGA), University of Lyon

Duration: 3 years (2020-2023)

## 1. Background and objectives

Sediment transport of fine materials in the Isère River is one of the strongest among French rivers. Together with the Arve and the Durance rivers, the Isère River is the main tributary of the Rhône River in term of sediment input (Poulier et al., 2019, Camenen et al., 2019). Because of these large fine material flues, Electricité de France (EDF) has been managing dam reservoirs of the Lower Isère River for several decades by performing dam flushing according to precise instructions. These have been subject to continuous improvements, taking into account safety, flood risk, usage and environmental issues (Sogreah, 2011). Unfavourable hydrology since the 2000s has reduced the occurrence of flushing event. As a consequence, the two last flushing events (in 2008 and 2015 after 7 years without flushing) released a large amount of fine sediments, which led to large deposits in the Rhône River, and increased risks on operating and navigation activities on the Rhône River managed by the Compagnie Nationale Rhône (CNR). Following these difficulties, joint work was initiated between the two companies for (1) a better understanding of the sediment dynamics of the Rhône-Isère confluence and (2) to improve sediment management and determine new sediment management scenarios. Sedimentary dynamics on the Lower Isère and at the Rhône-Isère confluence is complex due to the different sediment classes involved and their modes of transport.

The main issue clearly turned out to be sand. Indeed, deposits observed in the Rhône River are mainly made of fine sand whereas the actual knowledge of sand inputs from the catchment remains quite low as well as the sand dynamics through the Lower Isere developments and more particularly at the confluence between the Isère and the Rhône rivers (Camenen et al., 2018).

The objective of the PhD project is to better estimate the sand dynamics in the Basse-Isère upstream and downstream of EDF dams and at the Rhone-Isère confluence. First of all, in situ measurements will be developped by applying acoustic methods calibrated by sampling campaigns for measuring sand fluxes. The study will be completed using bathymetric survey and sediment budgets.

This PhD project will be part of the Rhône Sediment Observatory (action B.3.2 of the OSR5, then axis 1 of the OSR6 from 2021).

## 2. Details of the PhD project

### *2.1. Issues et collaborations*

This PhD project is on applied research, i.e. with a main issue for operational needs with high industrial stakes.The first and main objective of this PhD project is to better estimate sediment fluxes upstream and downstream of the dammed Lower Isère; the second objective is to better understand the sand dynamics of the sands at Isère-Rhône close to the Bourg-lès-Valence plant.

Turbidity probes, combined with sampling from the river side (automatic ISCO-type samplers ), make possible to quantify the suspended solid matter (SSM) fluxes on the Isère River on large spatial and temporal scales. However, this type of measurement is very sensitive to particle size and does not allow to evaluate sand fluxes, which have a very high spatial variability throughout the river section.

Moreover, during highly concentrated events in the Isère River, suspended sediments on the Rhône present a relatively complex dynamics due to three-dimensional effects of the flow. Sand transport is currently monitored only occasionally and by intrusive in-situ tools (Helley-Smith type bedload samplers and isokinetic suspension samplers such as the P72 sampler or the Delft bottle). In addition to the measurement uncertainty, extrapolation of such measurements is difficult since sand input is irregular and sediment transport capacity is not necessarily reached. The objective is thus to apply and validate new measurement methods that allow continuous estimation of sand fluxes (Gray & Gartner, 2009). In particular, we will rely on acoustic methods for the indirect measurement of sediment concentration (S. Moore, 2011, A. Vergne, 2017). It will essential to take into account the latest developments in acoustic processes of the sediment suspension including acoustic attenuation (Moore et al., 2013, Topping et al., 2016, Fleckenstein, et al., 2018) and acoustic backscattering (Thorne & Hurther, 2014; Szupiany et al., 2019). These methods and processing will be apply to the Isère River where sand concentration gradient is generally accompanied by high concentrations of silt and clay. This work will be done mainly using the horizontal acoustic measurement stations (HADCP, Aquadopp devices from Nortek) but also through the acquisition and analysis of point acoustic data (in parallel to sampling campaigns) with Aquascat and/or UBMES (in collaboration with Ubertone).

Even if sand is mainly transported as suspension in many reaches of the Isère River(Camenen et al., 2020), bedload fluxes remain important to bed evaluated, at least to confirm the hypothesis of a prevailing suspended load. During this project, we will therefore limit this part of the work to punctual campaigns of bedload sampling (associated with the measurement of sand suspension). However, we will also benefit from a collaboration with Burgeap (T. Geay) and UR ETNA of INRAE (A. Recking) on the use of hydrophone (T. Geay, 2013 ; T. Petrut, 2017, M. Nasr [2019-2022]) at least on the Grenoble-campus site where a hydrophone station has been installed. This collaboration should enable the identification of the size of particles in motion (Petrut et al., 2018), possibly a continuous estimation of bedload fluxes, and a better understanding of the intermittent sand dynamics over a gravel bed (Kuhnle et al., 2017).

The second issue concerns the exploitation of the Bourg-lès-Valence dam reservoir during flushing events of thee Basse-Isère dam series. Particularly, we are interested in the morphological changes at the Isère-Rhône confluence. Some specific instruction were proposed to limit sand deposits during flushing events such as lowering the operating level and/or opening the Isère dam (Naudet et al., 2016). The use of past measurements (mainly bathymetric measurements, cf. Naudet et al., 2016, Camenen et al., 2019) combined with newly acquired measurements (bathymetric surveys, continuous measurements of the bottom level in the downstream Isère River, etc.) will provide a better understanding of the morphodynamics of the confluence (Owens et al., 2005). If future bathymetric campaigns allow it (need for two campaigns carried out with a sufficiently short time interval), it will also be possible to apply an analysis of dune dynamics allowing a 2D view of bedload transport (Le Coz et al., 2020) at the confluence where bedload seems to prevail (Camenen et al., 2019).

Finally, the PhD student will rely on the three-dimensional hydro-sedimentary model of the Isère-Rhône confluence developped by Artelia (with Telemac environment) in order to refine the global understanding of sand dynamics at the Isère-Rhône confluence and to integrate the results of the various measurements carried out. In parallel to the PhD project (via a Master internship), it is also planned to build a 1D model of the Basse-Isère chain with the Mage-AdisTS model (based on the existing Artelia model) in order to help the analysis of the impact of dams on sand transfer. The inputs of the 1D model could also be used for the global understanding of the system.

### *2.2. Details of the PhD project*

The thesis project aims to improve the understanding on sand dynamics as well as the sediment management of the Basse-Isère and the Rhône-Isère confluence. The approach is mainly based on the setting up and exploitation of in-situ observations on the basis of existing tools and developments. This work will be combined with the use of 1D and 3D numerical modelling in collaboration with other students and/or engineers/researchers.

The objectives will be achieved by following the two following axes:

- Realization of sediment measurements allowing the characterization of continuous sediment fluxes, focusing particularly on sands;
- Understanding the sand dynamics of across the Basse-Isère dam series and at the Isère Rhône confluence from Beaumont-Monteux to Bourg-lès-Valence dams.

The methodological and scientific issues of the first axis can be presented as follows:

- What are the existing tools to quantify continuous sediment fluxes (Gray, & Gartner, 2009)? In particular, how can acoustic methods be adapted for the continuous measurement of suspended sand flux on the Isère River?
- The core of the PhD project will thus focus on the adaptation of actual acoustic methods with a horizontal measurement (HADCP). The questions will thus focus on the possibility of using and improving the method proposed by Topping et al. (2016) for the estimation of the total sand flux from an acoustic measurement of an index concentration and in the case of high SSM concentrations;
- What is the proportion of sand in the total flux upstream and downstream of the Basse-Isère dam series as a function of hydrology and sediment management?
- What is the natural variability of sediment characteristics? What is the potential evolution of sedimentary fluxes in a long term perspective?

For in-situ observation, recent developments in acoustic methods for indirect measurement of suspension will be used (ADCP, HADCP and Aquascat, S. Moore, 2011, A. Vergne, 2017, G. Dramais [2016-2020]). A challenge will be to adapt the method proposed by the USGS on the Colorado River with the use of HADCP of different frequencies (Topping et al., 2016). HADCPs will thus be installed at Grenoble-campus station (upstream of the Basse-Isère dam series) and Beaumont-Monteux station (downstream of the Basse-Isère dam series), and the acoustic methods developed more recently will be adapted for the Isère River (Vergne, 2019; Vergne et al., 2020). The validation of this method will require calibration measurements (water sampling, grain size distribution and concentration measurements with a LISST) which will be carried out regularly on the Grenoble site, with a focus on main hydrological events. An important methodological work will also consist in the validation of the index concentration method, i.e. the link between the sand concentration measured with the acoustic station and the total sand flux (bedload and suspended load). In parallel, other vertical acoustic measurements with an Aquascat and/or UBMES (collaboration with Ubertone), in connection with recent results from the ANR Mesures project, will allow a better knowledge of the sand concentration gradient for different hydrological conditions while validating the acoustic process methodologies. On the Beaumont-Monteux site, this validation can only be carried out during flushing events in the Lower Isère River. The installation of the acoustic station and work on this measuring station will therefore be carried out in a second phase, with the exception of the occurrence of a flushing event in 2021. Once the measurement has been validated and a set of data has been acquired over a sufficient period of time, the analysis of the sand dynamics will then be undertaken.

The questions for the second research axis are as follows:

- What is the impact of the Basse-Isère dam series on the temporal distribution of sand fluxes?
- What is the morphodynamics of the Isère-Rhône confluence as a function of sand inputs from the Isère River?
- What are the expected evolutions of the Bourg-lès-Valence dam reservoir in a medium to long term perspective?

For this second axis, we will first rely on bathymetric surveys (existing and future) of the confluence (medium- and long-term dynamics, study of bedforms, assessment of dune dynamics, etc.), on sediment flux measurements carried out at Beaumont-Monteux station and on the Pont-vélo-route located on the widening of the Isère River just upstream of the confluence (sand bedload and suspended load), then on numerical modelling in order to apprehend main parameters acting on the sand dynamics of such a system during and after flushing events (deposition remobilization). On this second axis, the PhD student will synthesize experimental and numerical results through several collaborations (on data acquisition and numerical modelling).

### *2.3. Work program*

The thesis will start in fall 2020. The installation of the acoustic station at Grenoble-campus will be done beforehand with the realization of some test campaigns.

The first year of the thesis (2020-2021) will be devoted to :

- Getting familiar with hydro-sedimentary data carried out during the 2008, 2015 and 2018 flushing events, by exploiting in particular the multi-beam bathymetries (analysis of the bedform dynamics);
- Learning different acoustic theories for measuring suspension (backscattering and acoustic attenuation);
- Identifying measuring devices to be tested in the field;
- Carrying out methodological tests (sampling, horizontal and vertical acoustic systems) during experiments on the Isère River at Grenoble-campus station but also during the Haut-Rhône flushing event (APAVER) planned for the end of May 2021;
- Setting up regular campaigns on the Isère River at Grenoble-campus (continuous acoustic measurements of sand fluxes, sampling of the suspension) to address the methodological and scientific issues of the thesis;
- Processing and analysising acoustic data combined with sampling for the continuous measurement of sand concentrations.

The second year (2021-2022) will focus on :

- Participating in the installation of a second acoustic station at Beaumont-Monteux on the basis of the experience gained with the Grenoble-campus station;
- Improving measurement protocols for sand transport gauging and monitoring of field campaigns, particularly during flooding of the Isère River and any flushing event of the Basse-Isère ;
- Calibrating and validating acoustic measurements of sand concentrations at the two measurement sites; work on the index concentration method to establish the link between the concentration measured by the acoustic tool and the total sand flux (bedload and suspended load) for each of the two sites.

- Writing an international journal article on the calibration and validation of acoustic measurements of sand fluxes on the Isère River at Grenoble.

The third year (2022-2023) will aim at :

- Analysing all the experimental results acquired in terms of sediment fluxes and budgets, grain size distribution;
- Handling numerical models of the site (1D Mage-AdisTS model and Telemac3D model of the confluence);
- Writing a synthesis article on the morphodynamics of the confluence (continuation of Camenen et al., 2019), integrating any additional measurements carried out and numerical modelling;
- Writing the PhD report.

It is understood that this work programmay evolve according to hydrological conditions for the field measurement campaigns. Also, if major methodological problems appear for HADCP measurements, the work will be oriented towards the application of tools such as Aquascat or UBMES.

A valorisation of the work is planned through the OSR (Observatoire des Sédiments du Rhône) and in conferences (RCEM 2021, River Flow 2022, EGU), and the writing of articles for international scientific journals (e.g. : Earth Surface Processes & Landform, Journal of Geophysical Research, Journal of Hydraulic Engineering, River Research & Applications).

## 3. Supervision, student profile,

### *3.1. Supervision*

The funding of the thesis grant will be shared between EDF, CNR and INRAE. The supervision and direction of the PhD thesis will be provided by Benoît Camenen and Jérôme Le Coz with a registration at the University of Lyon, MEGA Doctoral School, specialization in fluid mechanics.

The present PhD thesis will be in connection with the two following committees, mixing scientific and industrial stakeholders :

- The scientific committee, which will judge the scientific approach and qualities of the PhD student, may include:
    - Céline Berni, Guillaume Dramais (INRAE)
    - François Lauters, Magali Jodeau (EDF)
    - Gilles Pierrefeu (CNR)
    - Alain Crave (Geoscience Rennes)
    - Philippe Dussolier (Cerege)
- The industrial committee, who will check if industrial objectives are respected, will include:
    - Sébastien Menu / Gilles Yahiaoui (EDF-CIH) ;
    - Sylvain Reynaud / RémiTaisant (CNR) :
    - Mathieu de Linares (Artelia)

### *3.2. Profile of the PhD candidate*

Candidates should have at least basic knowledge in the following disciplines:

- River hydraulics, sediment transport;
- Experience in in-situ and/or laboratory measurements;
- Numerical hydraulic and sedimentary modelling;
- Programming (Fortran, Python);
- Knowledge of GIS;
- Fluency in scientific French and English.

Knowledge of the acoustic principles would be appreciated.

### *3.3. Application*

Candidates must submit their application by 15th June 2020 to B. Camenen (benoit.camenen@inrae.fr).

## 4. References


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