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Comparing field, probabilistic, and 2D numerical approaches to assess gravel mobility in a gravel-bed river

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I. Context

- Gravel augmentation is increasingly used to mitigate sediment deficit impacts in river channels below dams
- Field monitoring is required to assess the restoration efficiency
- Hydrodynamic modeling can help understand physical parameters that regulate particle displacements and design restoration scenarios
- **Objective:** analyze gravel mobility in a restored gravel-bed river
- First study using a **high number of PIT tags** in a **90 m wide** meandering gravel-bed river in comparison with expected travel distances from a **probabilistic approach** and results from **2D hydrodynamic modeling**

III. Material & methods

- **RFID particle tracking:** 1063 PIT-tagged gravels released in Nov. 2013. Post-flood surveys in 2014, 2015, 2017. Parameters: recovery rate R , mean travel distance \bar{L} from initial seeding, mean travel distance of mobile tracers in successive surveys \bar{L}_{sm} , virtual velocity V , grain size effect
- **Probabilistic approach:** literature review linking \bar{L} to the dimensionless stream power ω^* (Vazquez-Tarrio et al., 2019). Generation of 10,000,000 tracer displacements using $P(L) = \frac{1}{L} \cdot e^{-\frac{L}{\bar{L}}}$. Cumulated distribution of 10,000 samples of n displacements ($n=862$: analyzed field tracer data)
- **2D hydrodynamic modeling:** Rubar20 software. Topo-bathymetry from LiDAR. Steady flow modeling at 350, 500 and 760 m³/s. Computation of particle trajectories for each grain size class (D_m : 25, 34, 48, 72, 97 mm)
- **Studied period** Nov. 2013–Oct. 2017: 24 floods > Q_1 , 1 flood > Q_2

II. Study site

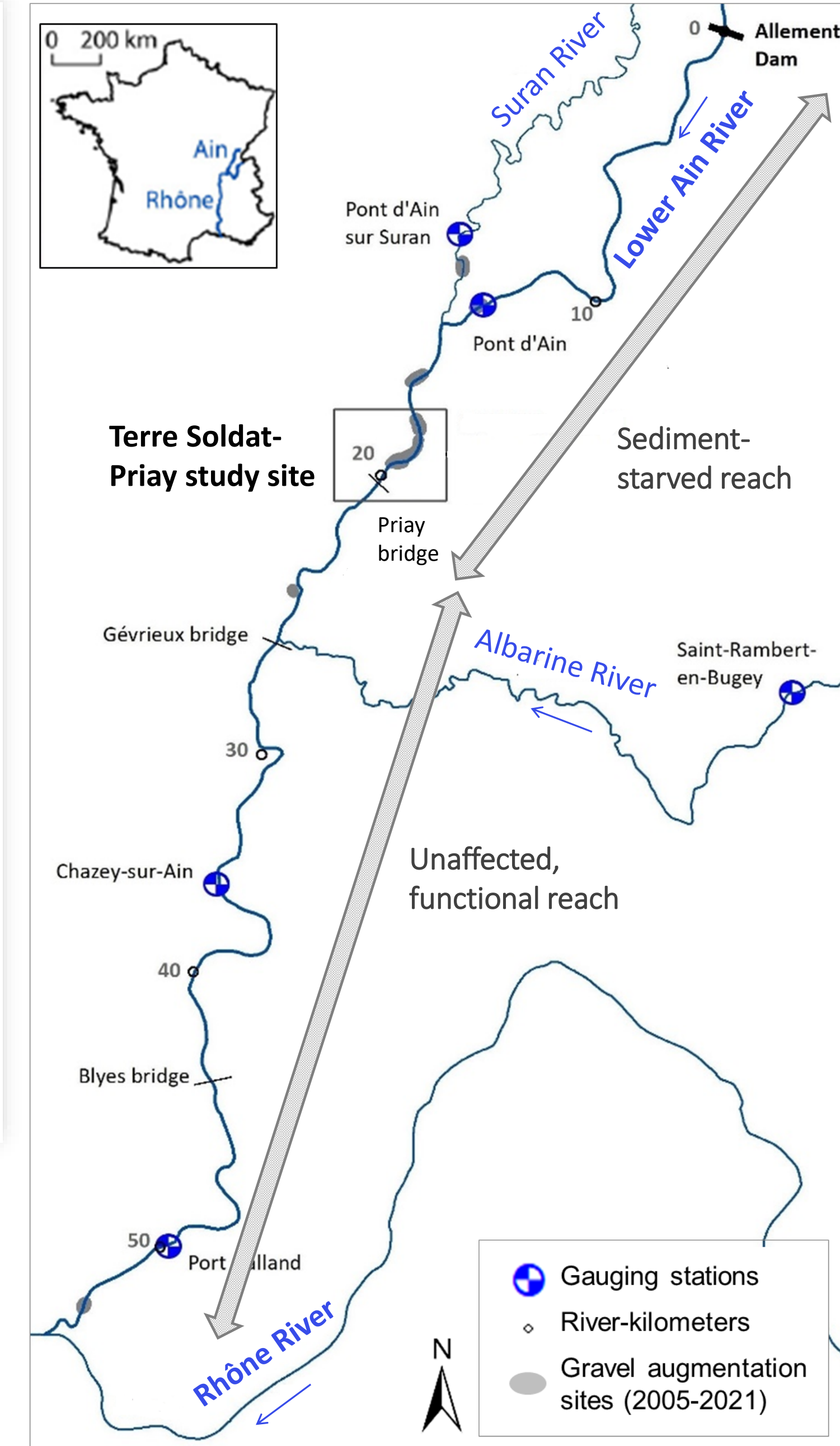
- The **Lower Ain River** in Eastern France (3630 km²)
- Slope: 0,0011 m/m Q_{mean} : 120 m³/s Q_2 : 760 m³/s
- The upper reach below the Allement Dam is sediment-starved and paved ($D_{50} \sim 80$ mm vs. 30 mm on the unaffected reach)
- 95,000 m³ of gravel augmentation in 2005–2021
- **Terre Soldat bank** supplied annually with 400–1400 m³ of sediment from the Albarine River ($D_{50} = 22$ mm)



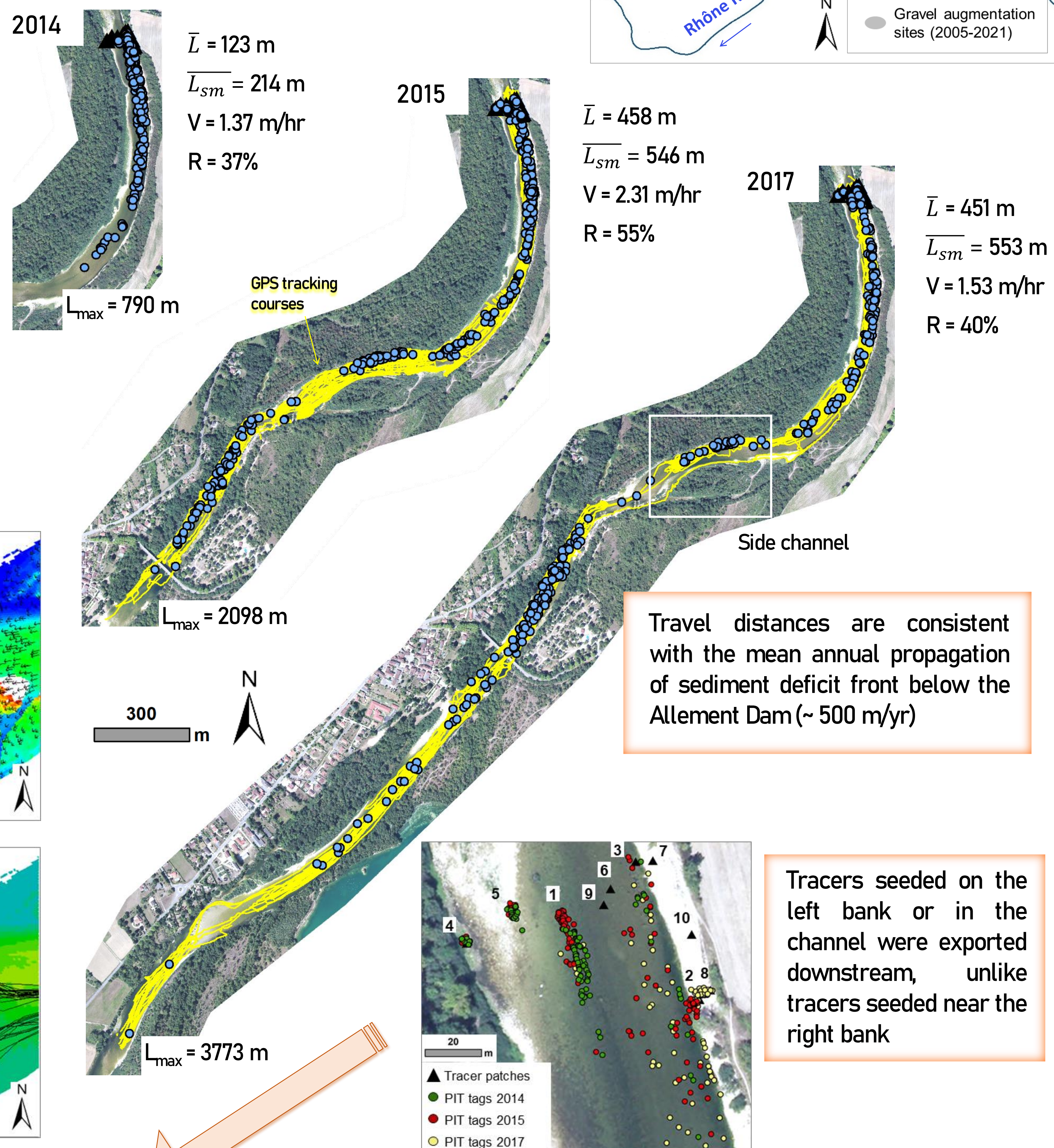
The Terre Soldat restored bank in Nov. 2013



The bank in July 2015 after floods



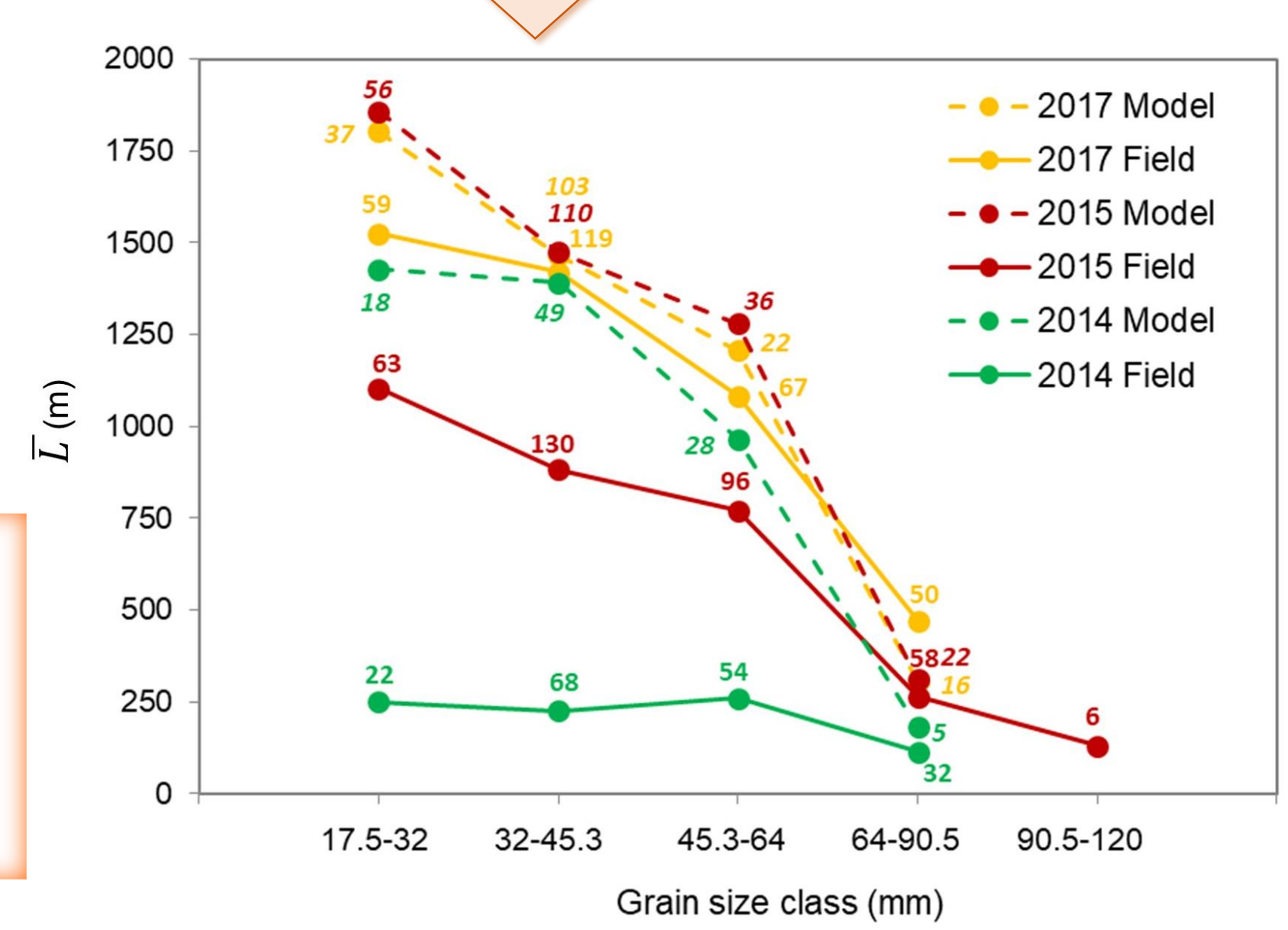
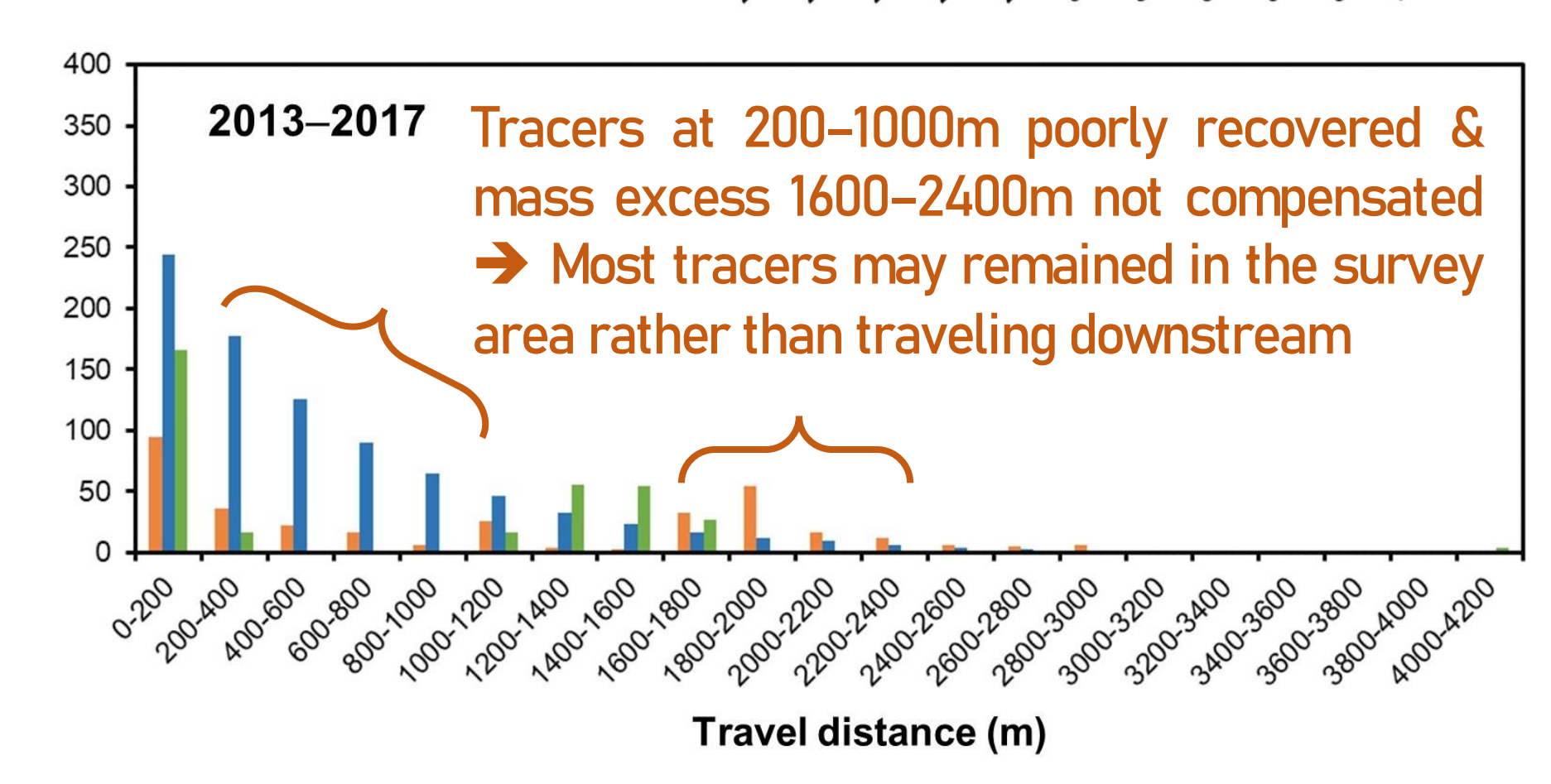
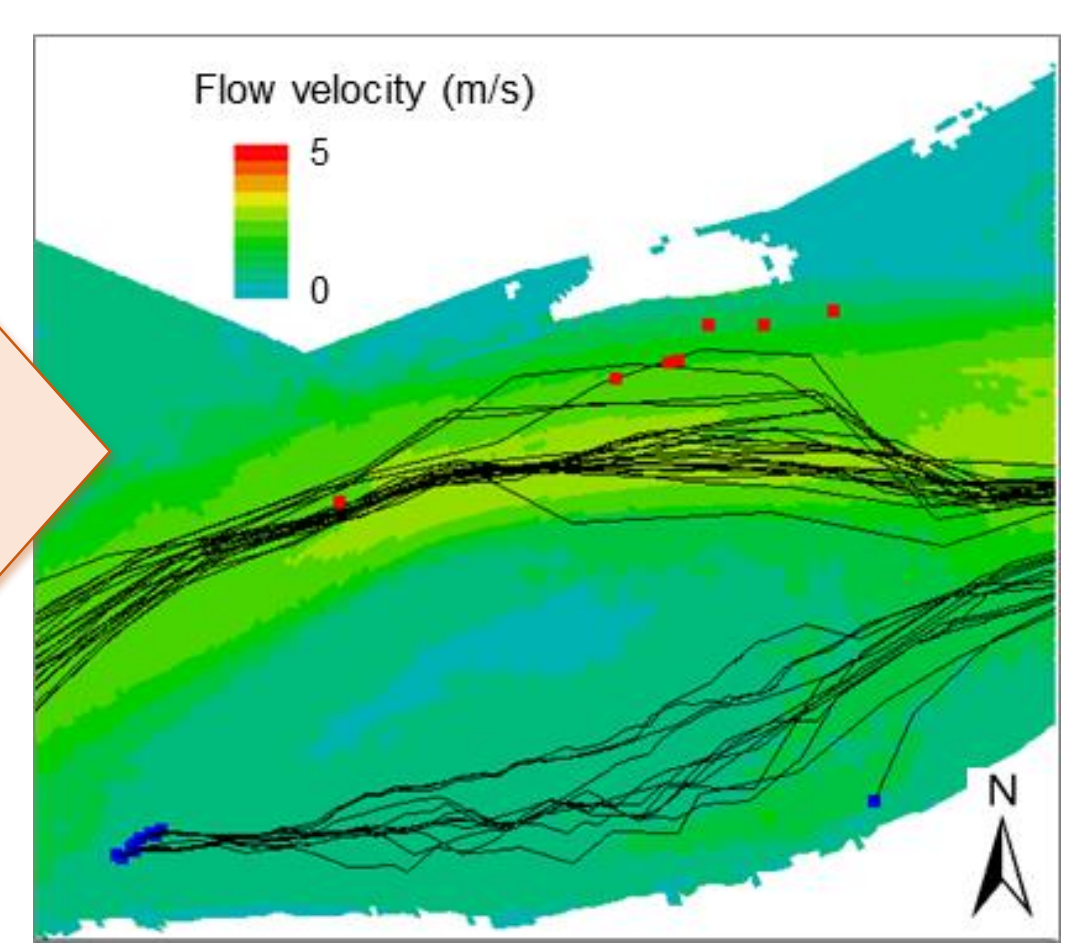
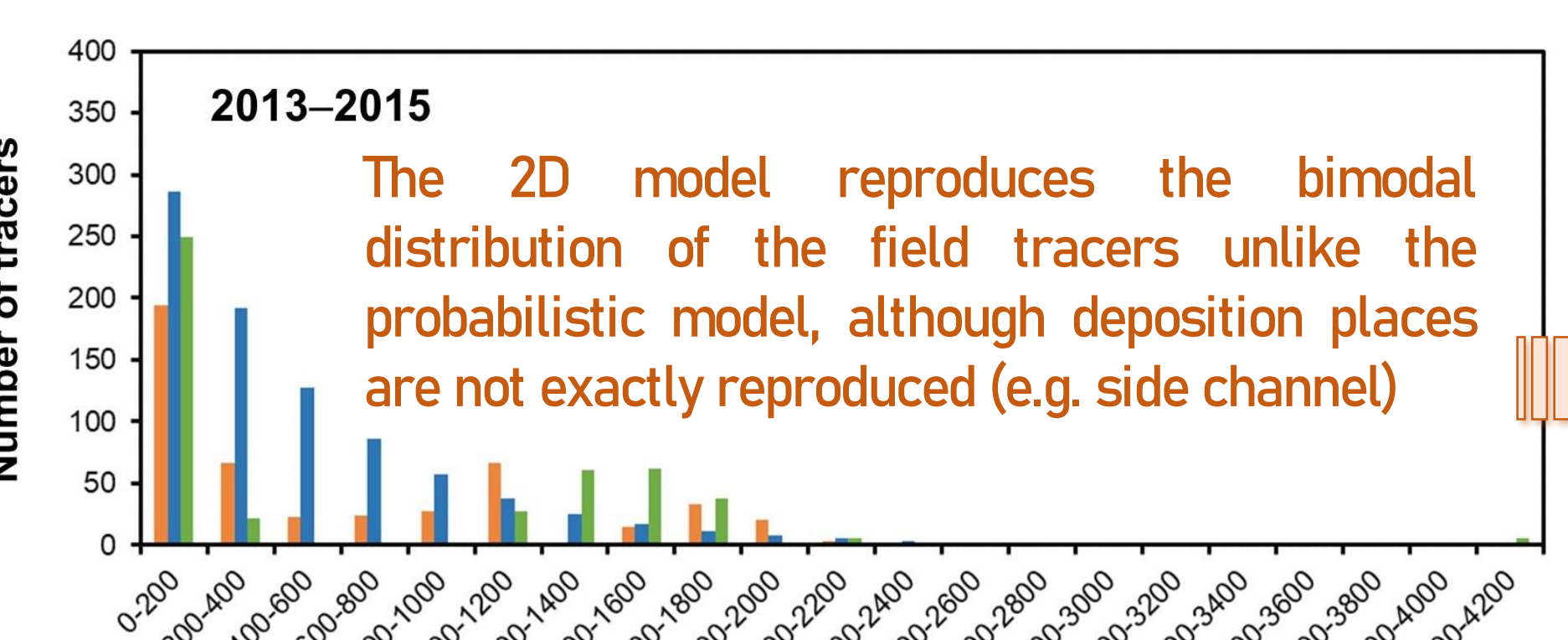
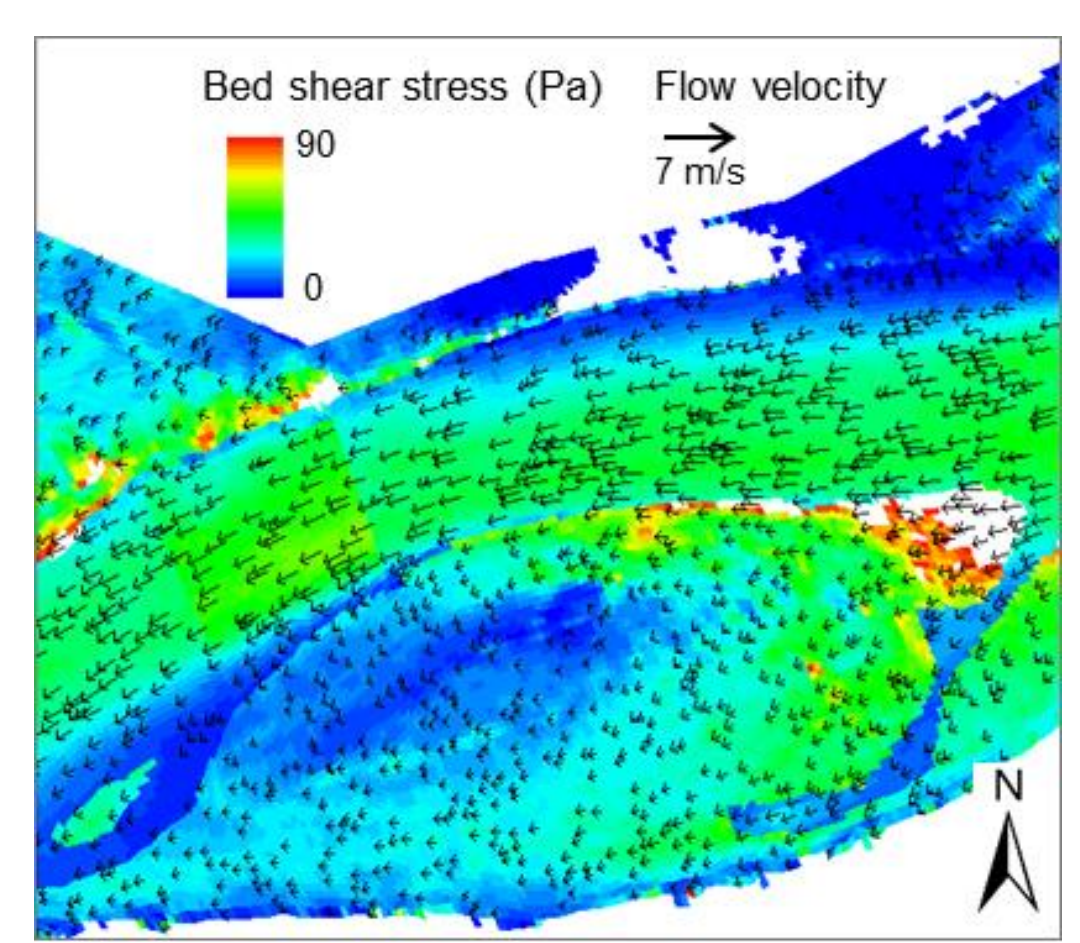
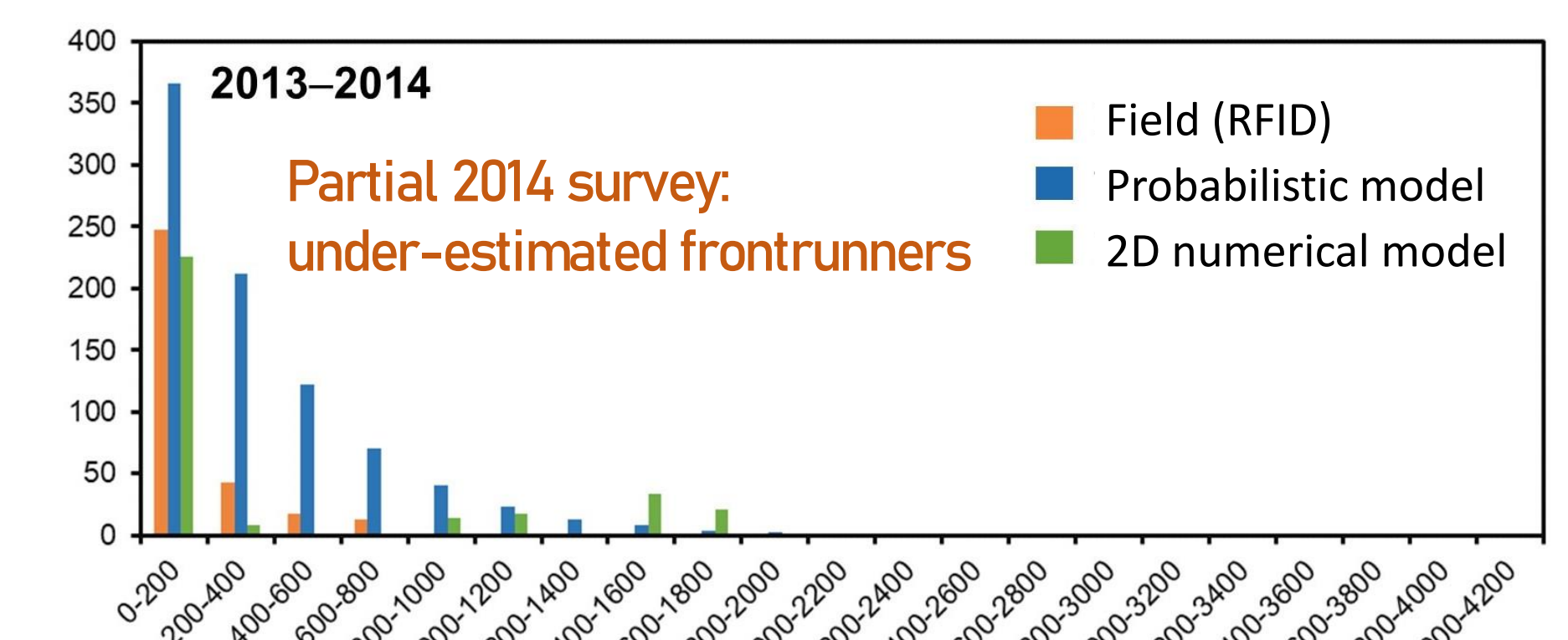
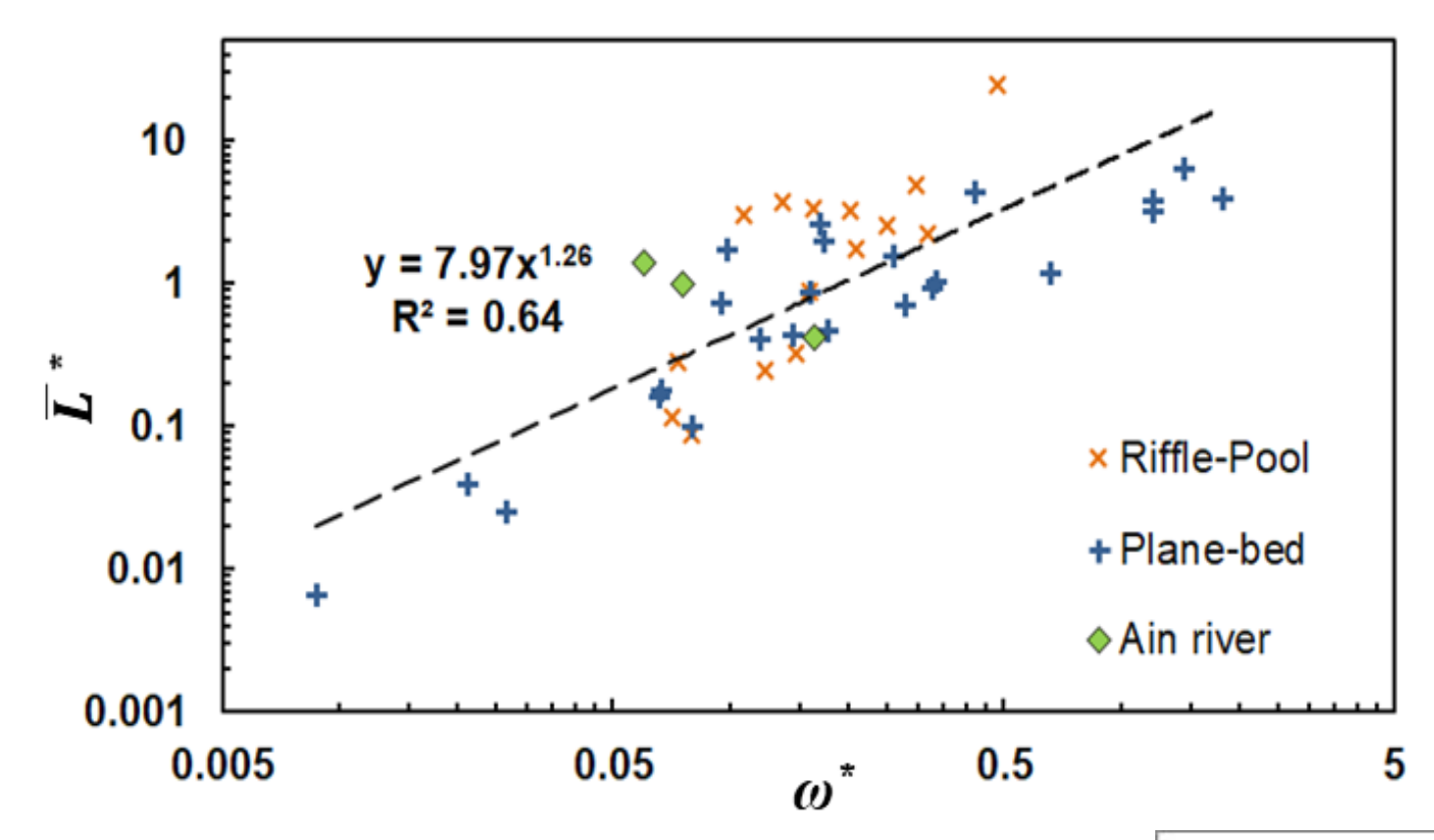
IV. Results



Travel distances are consistent with the mean annual propagation of sediment deficit front below the Allement Dam (~ 500 m/yr)

Tracers seeded on the left bank or in the channel were exported downstream, unlike tracers seeded near the right bank

The Ain River data fit close to the main trend from the literature



V. Outcomes

- RFID particle tracking provides a reliable and accurate representation of the bedload movement useful for monitoring gravel augmentation
- The probabilistic approach correctly reproduces the average trend in travel distances and is permits to discuss the frontrunners
- The 2D modeling accounts for variability of hydrodynamic conditions and simulates realistic displacements with high spatio-temporal resolution
- An effective strategy involves adding a probabilistic transport model in the 2D model to reproduce the scattering of individual particle trajectories

Increasing grain size effect on \bar{L} over time. Travel distances are over-estimated for finer classes in the 2D numerical model. No displacement is modeled for coarser particles