

Online and Realtime Characterization of Aquifer Dynamic

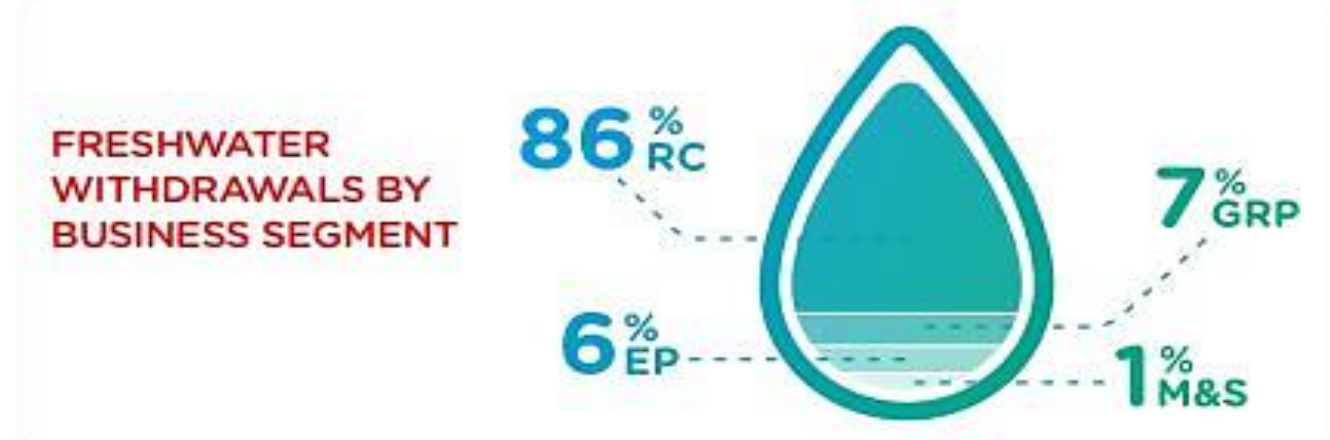
Sustainable water resource management

TotalEnergies PERL Team : Nathalie Nief Bertrand Segues Gilles Pucheu Sébastien Dehez

At TotalEnergies

101 million cubic meters

the volume of freshwater* withdrawn by the TotalEnergies in 2021**.



54% of this volume

was withdrawn from areas of **water stress** based on the definition of the World Resources Institute. The demand for water for human activities, such as agriculture, industry and household use, is **greater than 40% of available supply**. This is mainly the case in highly populated urban areas, for example in Northern Europe.

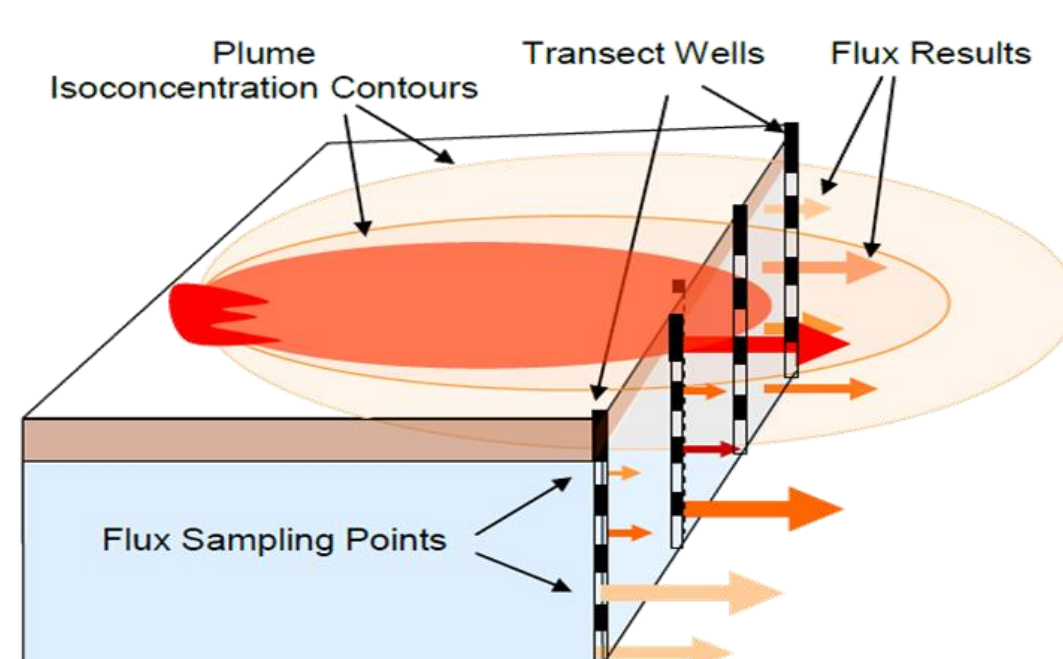


* salinity below 2 g/l
** excluding cooling water used in open-loop systems

Context:

Dynamic & multilevel approach

- Monitoring of groundwater resource
- Better assessment of subsurface environmental impacts
- Compliance with environmental regulations



Objectives:

Development & improvement of innovative sensors and analytical tools for :

- Mass discharge determination of dissolved compounds in groundwater

$$\sum \text{Darcy Flux} \times \text{Concentration} \times \text{X-Sect Area} = \text{Mass Discharge}$$

[m.year⁻¹] [Kg.m⁻³] [m²] [Kg.year⁻¹]

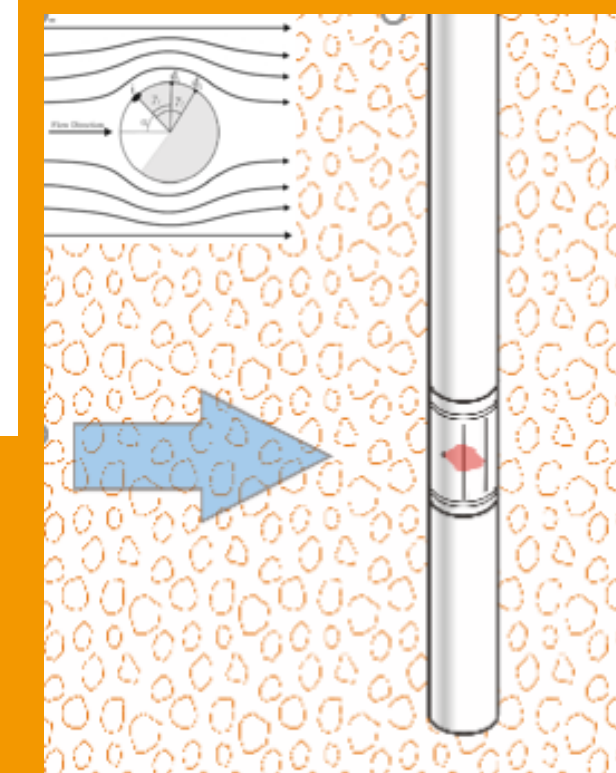
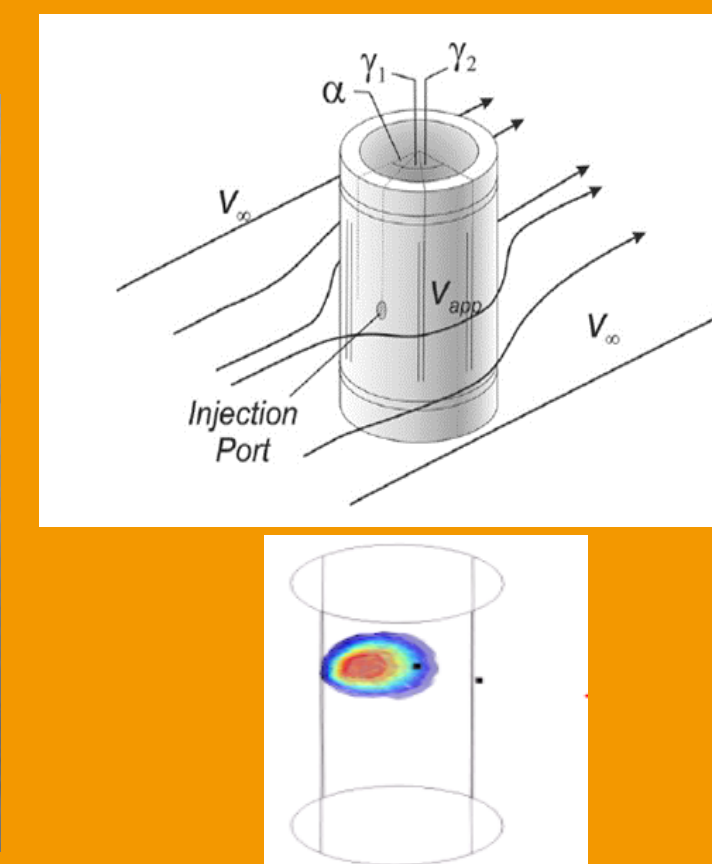
- Better assessment of subsurface environmental impacts
- In-situ, real-time, remote and cost-effective solutions

PERL Labs :
Monitoring tools validation,
development, interactions with
academics and JIP

Mobile lab :
Industrial pilots and missions in
operating sites, technical
expertise, crisis management

**In-situ & online & remote
monitoring :**
for **operating sites** in France
and affiliates

Measuring direct groundwater flow velocity in porous media



Point Velocity Probe (PVP) ,3D printing manufacturing deployment in shallow aquifer and validation by COMSOL simulation

- Designed for unconsolidated porous media to measure 3-D velocity vector
- Tracer test along surface of cylinder in contact with porous media
- Including in situ groundwater sampling points
- Easy implementation in unconsolidated geology (sand, alluvium, sandy silt, ...)

Results

Groundwater

The subject of this paper is the relationship between horizontal water velocity in observation boreholes and Darcy fluxes in the surrounding aquifer by studying the variability of the conversion factor $\alpha = u/q\phi$

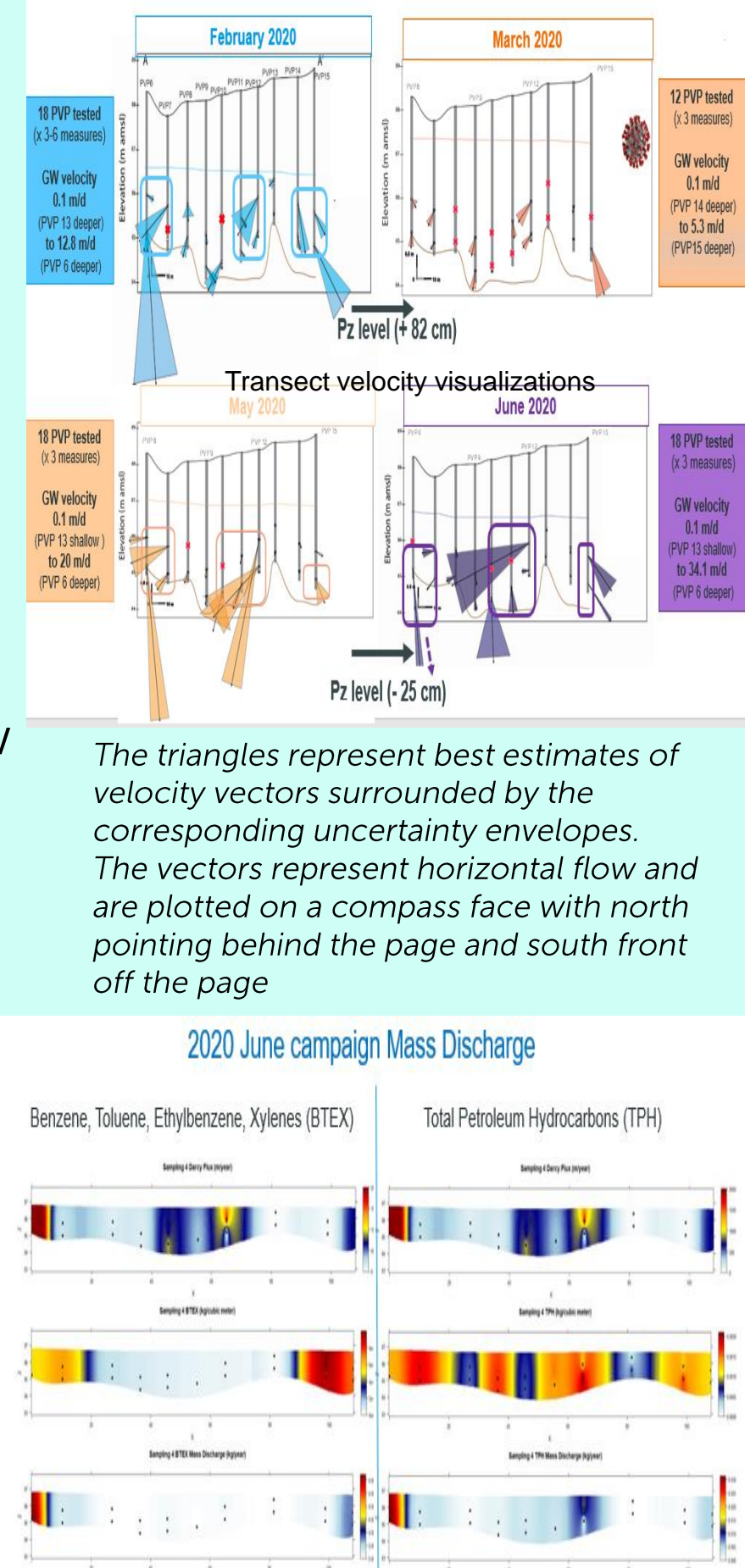
*Marti Bayer-Raich, Anthony Credoz, Jordi Guimerà, Salvador Jordana, Diego Sampietro, Jordi Font-Capó, Nathalie Nief, Matthieu Grossemy - Estimates of Horizontal Groundwater Flow Velocities in Boreholes, 14 August 2018 Ground water 2019 v.57 no.4 ISSN 0017-467X pp. 525-533
<https://doi.org/10.1111/gwat.12820>*

Outcomes of a demonstrator pilot:

- Three preferential path areas identified
- Significant variation in velocity amplitudes but a consistent flow direction
- Big decrease of the velocity amplitude in March related to the increase of the nearby river level: decrease of hydraulic gradient in the area
- Mass discharges through the transect dominated by the distribution of flow, not by the distribution of concentrations
- BTEX and TPH still transported through the edges of the transect predominantly: higher flow rates and low residential times for biodegradation

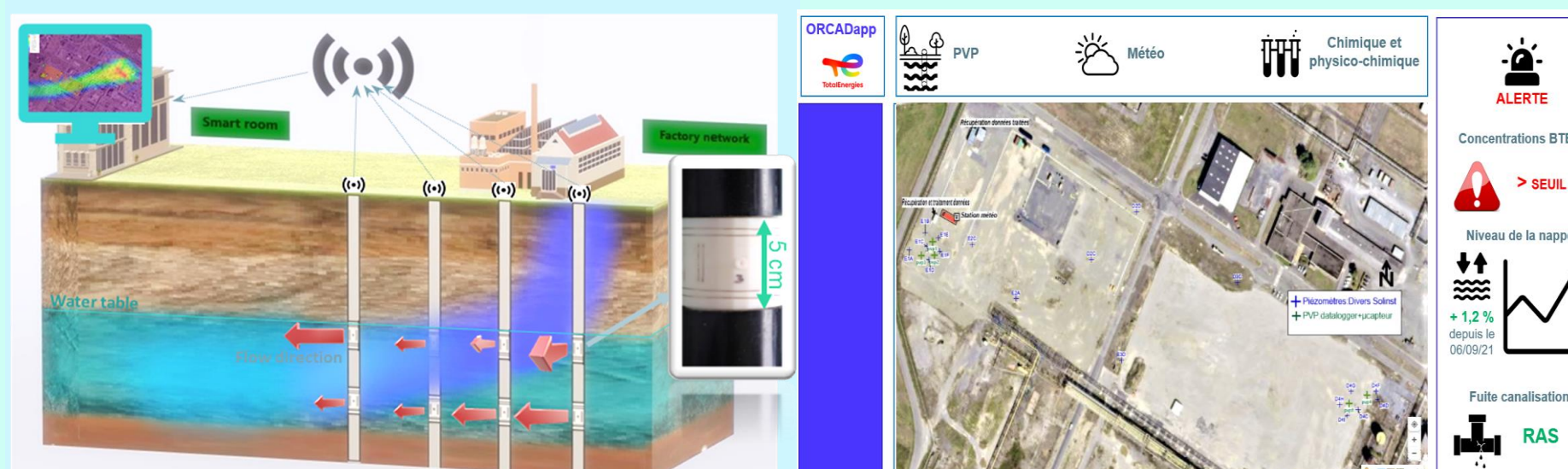
Among the first study to show a high-resolution evaluation of the mass flux in a shallow heterogeneous aquifer, based on in situ centimeter scale velocity and concentration measurements.

- ✓ Direct Groundwater pore velocity magnitude: $\pm 10 \text{ m.day}^{-1}$ / angle $\pm 15^\circ$
- ✓ Groundwater Dissolved organic species including volatile compounds: $\pm 20 \text{ g.m}^{-3}$
- ✓ Dissolved Mass flux calculation : $\text{g.m}^{-2}.\text{day}^{-1}$



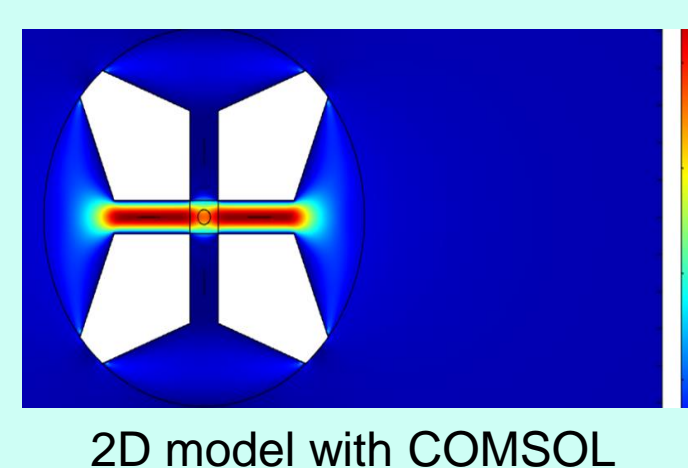
Progress and development

Continuous monitoring of aquifer and dissolved compounds plume dynamic, real-time and wireless



Innovating tools deployment in a network of observation boreholes or in situ PVP probes.
In remote access, fully automated and data visualization in a dedicated TotalEnergies application

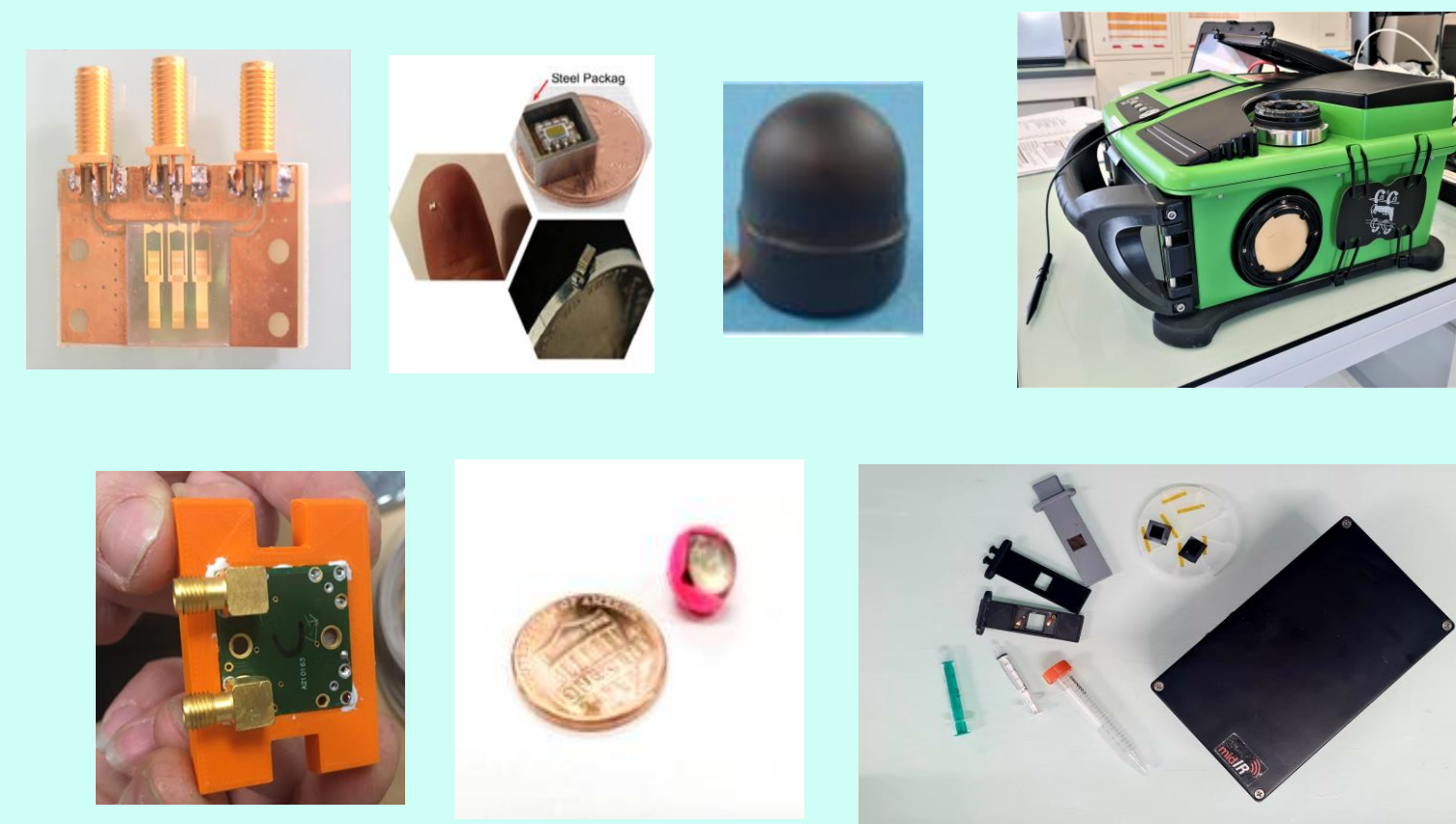
Measuring flow velocity in the monitoring well



In-Well Point Velocity Probe (IWPVP) deployment in monitoring well for 2-D measurement of velocity, useful for a first site screening

The final aim of the studies performed was to provide an in-situ, real-time, continuous and cost-effective solution using innovative in-situ probes and sensors piloted by an intelligent user's interface with optimized data management for groundwater monitoring.

Analyzing in-situ dissolved compounds and physico chemical parameters



COV and COSV analyses with TORION portable GC/MS or Spectro midIR, μ -sensors for BTEX analysis, Temperature, pressure, PH and conductivity