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## Protecting drinking water resources from n-nitrosomorpholine dual migration through the Fécamp – Lillebonne chalk aquifer system in Normandy...

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Chalk aquifer systems in Normandy show characteristics which include darcian, fractured and karst subsurface environment whenever groundwater flow or contaminant transport are being addressed. This triple porosity leads to complex flowfields, which may in turn bring about peculiar contaminants transport.

These complex flowfields are not easily detected through classical hydrogeological approaches such as 2D piezometric maps based on available unevenly distributed wells, with variable open sections located at different depths and groundwater models focusing on darcian flow. On the contrary, these can sometimes lead to biased groundwater flow interpretation, and subsequently, when protecting drinking water wells against pollution plumes is at stake, to partially inefficient solutions.

The Bolbec area laying in this complex chalk setting suffered in 2012 from a severe groundwater and surface water pollution event. Indeed, an emerging pollutant - N-nitrosomorpholine – stemming from a single pollution source in the upper Bolbec valley was found migrating in two opposite directions. Indeed, this pollutant was both found (1) south of the pollution source, downstream according to available groundwater level maps, in the Commerce valley in wellfields used for drinking water purposes and industrial processes, but also (2) way up north, across a « groundwater divide », in a karst channel system at Yport, pumped to provide drinking water for the « Le Havre » urban area, in what was previously believed to be a completely different watershed. This led to a several weeks long rupture or partial rupture the drinking water services, until costly emergency solutions were set in place.

To restore all the polluted water resources, a multi-criteria approach based on innovative combinations of targeted field investigations was implemented in the framework of large scale study, carried out along a major fault system passing through the Bolbec area and extending from the Seine river to the English channel. This paper intends to present and discuss the general innovative methodology used to (1) understand and set up the geological and structural framework and characteristics of the aquifer system, (2) assess the evolving interactions between surface water, 3D groundwater matrix flow and karst flow, (3) determine precise 3D pollutant pathways axes and (4) establish strategic nodal points on which to act upon to design an optimal technico-economical solution aiming at rehabilitating the water resources in the Commerce Valley and in the Yport karst system, in order to secure clean groundwater production for drinking water purpose in the area.