Surface water–groundwater interactions in an alluvial valley: combining tools for a better understanding of the recharge capacity of the Isere River alluvial aquifer for the neighborhood of Albertville city

Interactions rivières/nappes alluviales : approche couplée pour mieux comprendre l'alimentation de la nappe alluviale de l'Isère sur le territoire de la Communauté de Communes de la Région d'Albertville (CoRAL)

Agnès Brenot[1], Emmanuelle Petelet-Giraud[2], Nicolas Coppo[2], Stéphane Orofino[1], Laurence Gourcy[2]

[1]BRGM Rhône-Alpes, 151, boulevard Stalingrad 69626 – Villeurbanne Cedex – France (corresponding author: a.brenot@brgm.fr).[2]BRGM, 3, avenue Claude-Guillemin BP 36009 45060 – Orléans Cedex 2 – France

RÉSUMÉ

L'association de données hydrologiques, hydrogéologiques, chimiques et isotopiques (notamment δ^2H et δ^{18}O de l'eau, $\delta^{34}S_{SO4}$ et $\delta^{18}O_{SO4}$ des sulfates dissous, ^{87}Sr/^{86}Sr du Sr dissous) et géologiques a permis de disposer d'une meilleure compréhension des interactions rivières/nappes alluviales (encore appelées relations nappe/rivières) sur le territoire d'Albertville. Cette amélioration de la connaissance a permis de distinguer des modes de réalimentation de la nappe alluviale de l'Isère différents suivant les secteurs géographiques. A l'amont d'Albertville, la nappe alluviale est alimentée majoritairement via les relations nappe/rivières impliquant la rivière Isère. En revanche à l'aval, l'alimentation de la nappe alluviale de l'Isère est faiblement contrôlée par les relations nappe/rivières et deux unités aquifères peuvent être distinguées. Une unité en rive gauche de l'Isère, alimentée principalement par les versants des massifs du Beaufortain et de Belledonne (apports d'éléments toxiques, arsenic et antimoine présents à l'état naturel dans les roches métamorphiques). Une unité en rive droite de l'Isère, alimentée principalement par les versants du massif des Bauges (roches sédimentaires sans mobilisation d'éléments toxiques). Cette information constitue désormais le nouveau référentiel technique à disposition des gestionnaires des ressources en eau pour engager des mesures de préservation de la nappe alluviale.

ABSTRACT

Combining hydrological, hydrogeological, chemical, isotopic (δ^2H and δ^{18}O of water, $\delta^{34}S_{SO4}$ and $\delta^{18}O_{SO4}$ of sulfates, ^{87}Sr/^{86}Sr) and geological data lead to a better understanding of surface water - groundwater interactions for the neighborhood of Albertville city. Accordingly, various water recharge of Isère alluvial aquifer are evidenced on different space scale. Upstream Albertville, alluvial aquifer recharges mainly through water exchange processes with Isère river water. Conversely downstream Albertville, surface water - groundwater interactions are limited and two aquifer units are distinguished. One aquifer unit for the left river bank of the Isère river, involving mainly Beaufortain and Belledonne hillsides recharge (arsenic and antimony inputs due to weathering of metamorphic rocks). One aquifer unit for the right river bank of the Isère river, involving mainly Bauges hillsides recharge (weathering of sedimentary rocks without mobilization of toxic elements). This information is now the new technical reference used by water resource policy makers for the implementation of preservation measures.

KEYWORDS

Albertville, alluvial aquifer, hydrogeology, isotope, surface water–groundwater interactions

1 INTRODUCTION

Interactions between groundwater and surface water play a fundamental role in the functioning of ecosystems. In the context of sustainable river basin management it is crucial to understand and quantify exchange processes and pathways between groundwater and surface water. Basically in the case of alluvial aquifer exchange processes can proceed in two ways: groundwater flow through the streambed into the stream (gaining stream), and stream water infiltrates through the sediments into the groundwater (losing stream). Often, a stream is gaining in some reaches and losing in other reaches. Knowledge of these exchange processes is fundamental to understand the quality, the flow, the stage and the water temperature of both rivers and groundwater. This can be of crucial importance for implementation of restoration measures and to develop new ways of efficiently using water resources at a basin scale. Numerous methods are currently applied and described in the literature for estimating interactions between groundwater and surface water (see Kalbus et al. (2006) for overview and Brenot et al. (2007) for an example of environmental tools use), but only few studies have combined these methods. Here, we present a combined approach in order to constrain the recharge of the Isère river alluvial aquifer which is expected to be connected with the Isère river flow. Hydrogeological, hydrogeochemical and geophysical data were acquired and combined to study the Isère river alluvial aquifer at the neighborhood of Albertville city.

2 METHODS

2.1 Hydrogeological data

Elevation of the groundwater table of the Isère river alluvial aquifer and of the stream stage of the Isère river were measured for 114 points (99 bore wells and 15 stream stage see Fig. 1), for 2 different water stages (low flow period in September 2011 and high flow period in April 2012).

2.2 Hydrogeochemical data

Groundwater from the Isère river alluvial aquifer (10 sampling points) and inputs of water and dissolved elements that could be involved in the recharge of the Isère alluvial aquifer (8 sampling points including springs from the hillsides and river water) were sampled during two sampling campaigns (September 2011 and April 2012). The concentrations of major cations (Ca^{2+}, Na^{+}, K^{+}, Mg^{2+} by ICP-AES); major anions (Cl^{-}, NO_3^{-}, SO_4^{2-}-, PO_4^{2-} by ion chromatography) and trace elements (As, Sb by ICP-MS) were measured. H, O and S isotope compositions of water and dissolved sulfate (δH_{H2O}, $\delta^{18}O_{H2O}$, $\delta^{18}O_{SO4}$, $\delta^{34}S_{SO4}$) were measured by EA-IRMS. Sr isotope compositions of dissolved Sr ($^{87}Sr/^{86}Sr$) were measured by TIMS.

2.3 Geophysical data

Electrical Resistivity Tomography and High-Resolution Seismic Reflection were carried out, upstream Albertville, to constrain the geometry of the detrital deposits in the Isère alluvial valley (Fig. 1).

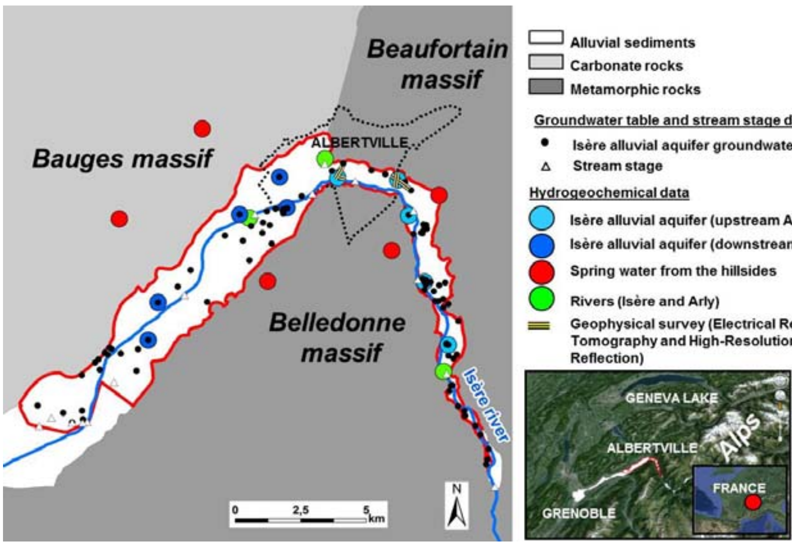

Figure 1: Location of the studied area and data acquired.

3 RESULTS AND DISCUSSION

Upstream Albertville, combining all the approaches, strong exchanges between groundwater of the Isère river alluvial aquifer and the Isère river have been evidenced. This is supported by (1) comparable flow direction for the aquifer and the Isère river, (2) environmental tracers (in particular S and O isotopes of dissolved sulfates, see Fig. 2) suggesting that a significant proportion of water is provided by the Isère river (water signature marked by Triassic gypsum deposits) and (3) geometry of the sedimentary deposits suggesting that stream is gaining in some reaches (rock bar) and losing in other reaches (overdeepened glacial basin).

Downstream Albertville surface water - groundwater interactions are limited and two aquifer units are distinguished (Fig. 2). One on the left river bank of the Isère river where hydrogeological data evidenced that Arly river and Isère river alluvial aquifer are disconnected. Groundwater stages of the alluvial aquifer suggest that exchanges with Isère river could occur but environmental tracers (see for example Fig. 2) evidenced that groundwater recharge involves mainly Beaufortain and Belledonne hillsides (arsenic and antimony inputs due to weathering of metamorphic rocks). On the right river bank of the Isère river, all data suggest that the recharge of the alluvial aquifer is mainly controlled by water coming from the Bauges hillsides. The key role played by the hillsides downstream Albertville is supported by the geometry of alluvial fans documented in the literature.

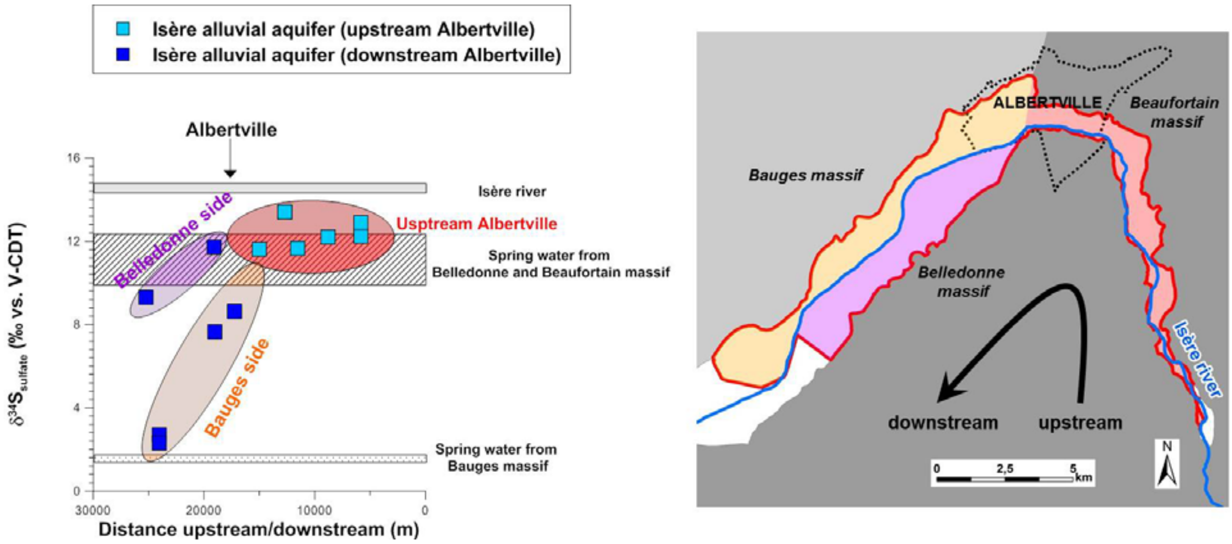

Figure 2: $\delta^{34}S_{sulfate}$ vs. Distance usptream/dowstream for the Isère alluvial aquifer groundwater.

4 CONCLUSION

Understanding of the recharge of the Isère river alluvial aquifer and quantification of the part coming from surface water - groundwater interactions have been significantly improved combining hydrogeological, hydrogeochemical and geological data. The result of this study is now the new technical reference used by water resource policy makers for the implementation of preservation measures. In agreement with the Water Framework Directive (2000/60/EC), areas of the Isère river alluvial aquifer that present outstanding interests regarding quality and quantity for drinking use (in our case, low content of As and Sb) have been listed and mapped. For present or future use, water policy makers are now focusing their water protection measures on these areas.

Similar approach can be applied to other areas/contexts. In particular this approach could be helpful to constrain the key processes and pathways between groundwater and surface water that should be taken into account, for instance in hydrological forecast models of river streamflow.

BIBLIOGRAPHIE

Brenot A., Carignan J., France-Lanord C., Benoît M. (2007). Geological and land use controls on $\delta^{34}S$ and $\delta^{18}O$ of river dissolved sulfates: the Moselle river basin, France. Chemical Geology 244, 25-41.

Kalbus E., Reinstorf F., Schirmer M. (2006). Measuring methods for groundwater-surface water interactions: a review. Hydrology and Earth System Sciences 10, 873-887.