Assessment of the interplay of structural, climatic and topographic controls in hard-rock aquifers - Implications for groundwater partitioning, recharge and resources

General information

The research project is to be carried out within the **Magister de Ciencias de le Ingenieria** of the *Pontifical Catholic University of Chile* (UC).

The research project and the Magister are to start at the **beginning of 2018**.

The supervisor is **Sarah Leray**, Assistant Professor of the *Department of Hydraulic and Environmental Engineering* (DIHA) of the *Escuela de Ingenieria* (IngUC) of the *Pontifical Catholic University of Chile* (UC).

Links / contact:

sarah.leray1@gmail.com

https://www.researchgate.net/profile/Sarah_Leray2

http://www.ing.uc.cl/hidraulica-y-ambiental/

Subject

Context: Highly heterogeneous and fractured media, e.g. hard-rock aquifers, have been historically the poor relation of hydrogeology (Neretnieks, 1990). Recently, they turned out being seen as potential viable water resources mainly because of: (1) the increasing demand and contamination over traditional aquifers (Naik et al., 2001); (2) their productivity surprisingly high in various cases (Ruelleu et al., 2010) and (3) their global abundancy (approximately half of the global surface, Singhal and Gupta, 2010). Considering as well the uncertain impact of climate variability over water resources, these underground media are to gain in importance over the century going (Gleeson et al., 2012).

Hard-rock systems typically develop in mechanically active regions including tectonic, unloading, intrusion of igneous rock and fracturing that can induce a significant permeability (Taylor et al., 1999). Significant advances have been made recently in characterizing their structure and understanding their hydrogeological functioning. Three conceptual models based on field studies have been proposed so far. The first one attributes the resource to the presence of sub-vertical large-scale tectonic faults (Sander, 2007). The second model is closer to a stratiform conceptual scheme in which underlying local fissures collect the water born by the weathered sub-superficial compartment (Wyns et al., 2004). The last and more recent one is based on slowly dipping geological contacts or fractured zone (Leray et al., 2013).

Scientific question: Existing conceptual representations only address part of the problem since they specifically focus on either one, or the other, of the structural units. If they surely give insights about the geological controls, they constitute only partial solutions. Some efforts still have to be made in understanding the geological controls of the productivity; more precisely about the respective role of water-bearing and water-conductive structures when they are coexisting, which is the case in most field sites. There is therefore a real need for addressing thoroughly and quantitatively the controls of water resources in hard-rock aquifers through a theoretical framework. It should not only include geological controls but also topographical and climatic controls to propose a more integrative answer. The main research question to address is: **how the conjoint and competing effect of geological units, topography and anthropic/climate affect the groundwater resources in hard-rock aquifers?**

Objectives: The main objective of this proposed research is to develop a quantitative and unifying framework addressing the interplay of structural, topographical and climatic effects on water resources in hard-rock aquifers. While the main expectation is to provide quantitative insights to understand the parameters controlling the resource, it is also to help in identification of favourable conditions for groundwater exploitation. The idea is to produce generic expressions and identify common behaviours that would later help for groundwater exploration and protection.

Some specific objectives are:

- To understand the partitioning of water between local and regional flow patterns; the interplay of water-bearing structures and water-conductive structures; and more generally speaking, the mechanisms of groundwater recharge in hard-rock aquifers,
- To quantify the impact of geological units characteristics (structural and hydrodynamic) on the occurrence of water resources;
- To incorporate field observations from literature into a general framework and discuss it.

Work plan: The research will rely on numerical tools and will hinge on three main activities, which are:

- Studying with extensive numerical simulations groundwater productivity in an arbitrary pumping well (and other metrics that can be of interest) under various geological, topographical and climatic conditions;
- Identifying key properties and extracting dimensionless characteristic estimates;
- Analysing the conditions and the limits under which key properties control groundwater productivity;
- Confronting this framework to field sites from literature, among which the Pirque site (50 km south of Santiago) and the Ploemeur aquifer (Britany, France), the latter being specifically well-known by the supervisor.

Perspectives and significance of the study: The strength of the study is its attempt to be as generic as possible and of wide range. Hard-rock aquifers cover half of the global surface and, in the particular case of Chile, sprinkle all along the country. They are surely of interest for groundwater resources (Moreno et al., 2007) and an active research theme (Bense et al., 2016). Even when being local kilometric structures, they can constitute an attractive alternative resource satisfying for instance water need of local communities or scattered settlement (say about 10,000 inhabitants), constituting as well a less contaminated temporary resource, or an in-situ and easily-accessible resource for irrigation in agricultural settings (Lachassagne, 2008).

References

Bense, V., Z. Shipton, et al. (2016) “Fault zone hydrogeology: introduction to the special issue”. Geofluids 16, 655–657. doi: http://dx.doi.org/10.1111/gfl.12205.

Gleeson, T., Y. Wada, et al. (2012). "Water balance of global aquifers revealed by groundwater footprint." Nature 488(7410): 197-200. doi: http://dx.doi.org/10.1038/nature11295.

Lachassagne, P. (2008). "Overview of the Hydrogeology of Hard Rock Aquifers: Applications for their Survey, Management, Modelling and Protection. Groundwater Dynamics in Hard Rock Aquifers". S. Ahmed, R. Jayakumar and A. Salih. Dordrecht, Springer Netherlands: 40-63.

Leray, S., J. R. de Dreuzy, et al. (2013). "Numerical modeling of the productivity of vertical to shallowly dipping fractured zones in crystalline rocks." Journal of Hydrology 481: 64-75. doi: http://dx. doi.org/10.1016/j.jhydrol.2012.12.014.

Moreno, T., W. Gibbons, et al. (2007). "The Geology of Chile", Geological Society of London.

Naik, P. K., A. K. Awasthi, et al. (2001). "Hydrogeologic framework of the Deccan terrain of the Koyna River basin, India." Hydrogeology Journal 9(3): 243-264. doi: http://dx. doi.org/10.1007/s100400100123.

Neretnieks, I. (1980). "Diffusion in the rock matrix: An important factor in radionuclide retardation?" Journal of Geophysical Research: Solid Earth 85(B8): 4379-4397. doi: http://dx. doi.org/10.1029/JB085iB08p04379.

Ruelleu, S., F. Moreau, et al. (2010). "Impact of gently dipping discontinuities on basement aquifer recharge: An example from Ploemeur (Brittany, France)." Journal of Applied Geophysics 70(2): 161-168. doi: http://dx. doi.org/10.1016/j.jappgeo.2009.12.007.

Sander, P. (2007). "Lineaments in groundwater exploration: a review of applications and limitations." Hydrogeology Journal 15(1): 71-74. doi: http://dx. doi.org/10.1007/s10040-006-0138-9.

Singhal, B. B. S. and R. P. Gupta (2010). Applied Hydrogeology of Fractured Rocks. Dordrecht, Netherlands, Kluwer Academic Publishers (Springer)

Taylor, W. L., D. D. Pollard, et al. (1999). "Fluid flow in discrete joint sets: Field observations and numerical simulations." Journal of Geophysical Research: Solid Earth 104(B12): 28983-29006. doi: http://dx. doi.org/10.1029/1999jb900179.

White, B. A. and T. J. Burbey (2007). "Evidence for structurally controlled recharge in the Blue Ridge Province, Virginia, USA." Hydrogeology Journal 15(5):929-943. doi: http://dx. doi.org/10.1007/s10040-006-0150-0

Wyns, R., J.-M. Baltassat, et al. (2004). "Application of proton magnetic resonance soundings to groundwater reserve mapping in weathered basement rocks (Brittany, France)." Bulletin de la Société Géologique de France 175(1): 14. doi: http://dx. doi.org/10.2113/175.1.21.