HYDROGEOLOGICAL PROCESSES IN THE PARIS BASIN: CLIMATE AND GEOMORPHOLOGIC IMPACTS OF THE LAST FIVE MILLION YEARS.

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In the framework of safe underground storage of radioactive waste in low-permeability layers, it is essential to evaluate the long-term mobility of deep groundwaters over a sufficiently large timescale, namely several million years. On these timescales, the environmental evolution of a repository should depend upon a range of natural processes that have occurred in the past and are likely to extend in the future, and that are primarily driven by climate and geomorphologic variations. In this regard, it is relevant to investigate the past history of the disposal site, in order to determine the implications for climate changes together with geodynamic processes on groundwater systems.
The complex multi-layered aquifer system of the Paris basin, France, provides an excellent framework for testing these impacts on a global scale. The recent use of natural geochemical tracers archived in the basin has provided residence time estimations of several hundreds of thousands years to a few million years in the major aquifers. For this reason and given the spatial expanse and depth of the basin, the timeframe to consider for this study has been set to the last five million years, covering the Plio-Pleistocene epoch. During this period, the evolution of the basin has been governed by 1) the cyclic alternation of glacial and interglacial intervals, combined to eustatic variations, 2) the tectonic uplift due to the Alpine deformation and 3) resulting geomorphologic processes, mainly river-valley incision, that shaped the landscape since approximately one million years. These changes may have a severe impact on groundwater flow patterns in the Paris basin because they affect conditions at boundaries. For instance, the hydraulic gradients may have been altered by temporal variations in recharge and shifting aquifer outlets. The river beds deepening causes a decrease in hydraulic head at the outcrop. In addition, the occurrence of a permafrost under glacial conditions was accompanied by significant changes in the hydrogeological properties of frozen ground.

The aim of the present study is to investigate the response of the Paris basin aquifer system to variations in its hydrodynamic boundary conditions on a time scale of several million years, trying to determine if the system has kept the memory of these past changes. Recent changes at a boundary are more especially of importance when considering its effects on groundwater flow in low-diffusivity regions, as it can generate a lasting transient flow, potentially responsible for abnormal pressures creation.

For the purpose of this work, a 3D transient modelling of the Paris basin groundwater system has been developed using the code NEWSAM (ENSMP). The geometry and hydrodynamic input data of the model

originate from previous studies on a basin model, NEWBAS (ENSMP), built to simulate the 248 My geological history of the basin. Both a geomorphologic and climatic scenarios have been established. Geomorphologic evolution is deduced from digital elevation model analysis, which allows to reconstruct the palaeotopography and measure river-valley incision and alpine surrection. Climate forcing results from a suite of palaeoclimate modelling experiments using the LMDz atmospheric general circulation model (IPSL) with a refined spatial resolution centered on Paris, for the present, the Last Glacial Maximum (21 kyr BP) and the Middle Pliocene (3 My). The water balance is computed by a distributed hydrologic model, MODSUR (ENSMP).

We present the simulated evolution of the transfers in the aquifer system in response to the altered boundary conditions induced by atmospheric and geomorphologic forcing, in the course of the last five million years.