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Modelling of permafrost penetration, permafrost properties over one climate cycle on the Meuse/Haute-Marne underground laboratory site, East of France

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In France, one of the direct consequences of long-term climate changes is permafrost that could develop during glacial periods. Such a question is studied by Andra in the framework of the geological long-life nuclear waste repository project because it may impact both hydrogeology and surface environments. For that purpose, a permafrost model is applied to Andra underground research laboratory site, excavated in a Jurassic argillite formation, 500 m deep, in Bure, NE of France. This model is established together with long-term (up to one million years) climate, geomorphologic and surface environment evolution scenarios, to take into account the changes that might occur in the future. In a first approach, a thermal modelling of permafrost penetration has been performed with the LCPC Gelsol program, based on two paleoclimate approaches (vegetation and cryosols) and the in situ rock properties. This modelling has been completed through mapping of the permafrost extent stages along the whole Last Glacial based upon cryosols data. The mapping has been performed at two rested scales: the Paris Basin and the regional scale taking into account the topography. A second approach is based on a simplified thermal modelling throughout a "complete glacial cycle" applied to the site geological characteristics (Jurassic limestones and marls formations) to understand frost dynamic and development to take in account for hydrogeological modelling. A conceptual model for frost penetration in the weakly fractured limestones and in the marls has been proposed to control the evolution of the permeability of these rocks, taking in account the water salinity, the overburden pressure and the potential depth reached by the zero isotherm in the first model. The

probability of gas hydrate formation is very low. The conclusion of this work shows that the potential penetration of the 0°C isotherm is circa 300 m at the LGM, with some ice in the vertical fissures up to 100 m in depth. The high viscosity of water below that depth limits water circulation.