Using old coal mines for geothermal energy: underground flow and heat transfer simulations as a pre-feasibility study in Liège (Belgium)

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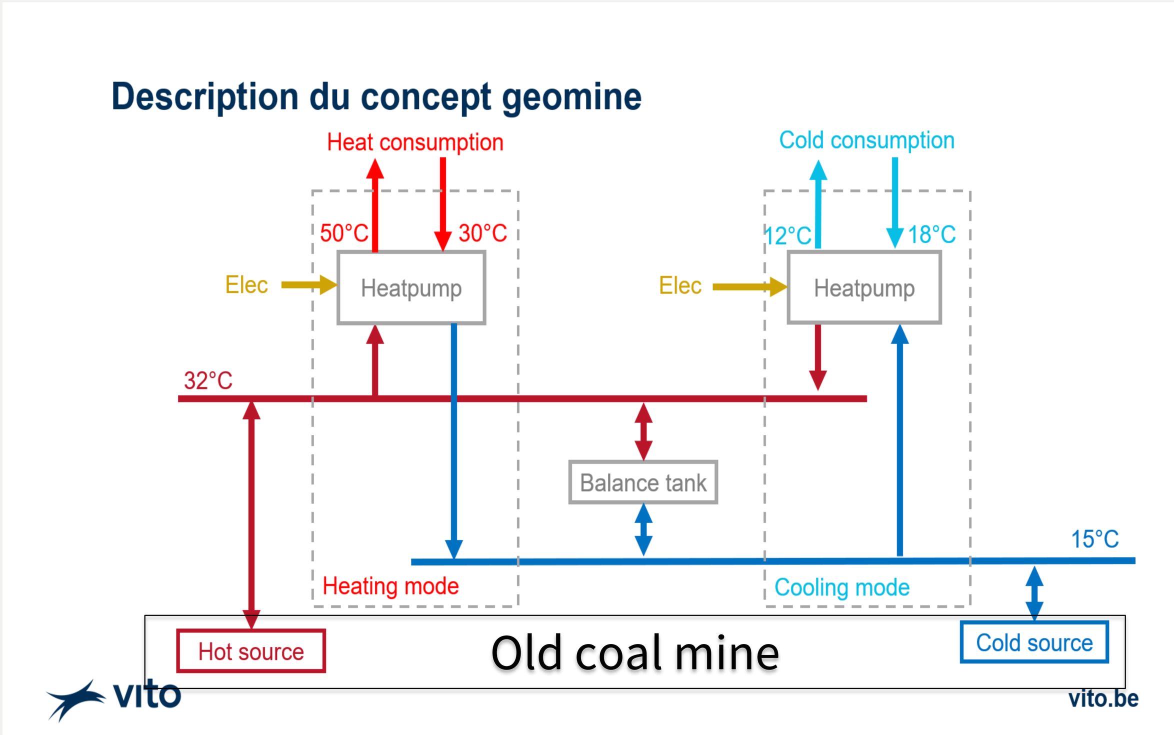
ABSTRACT

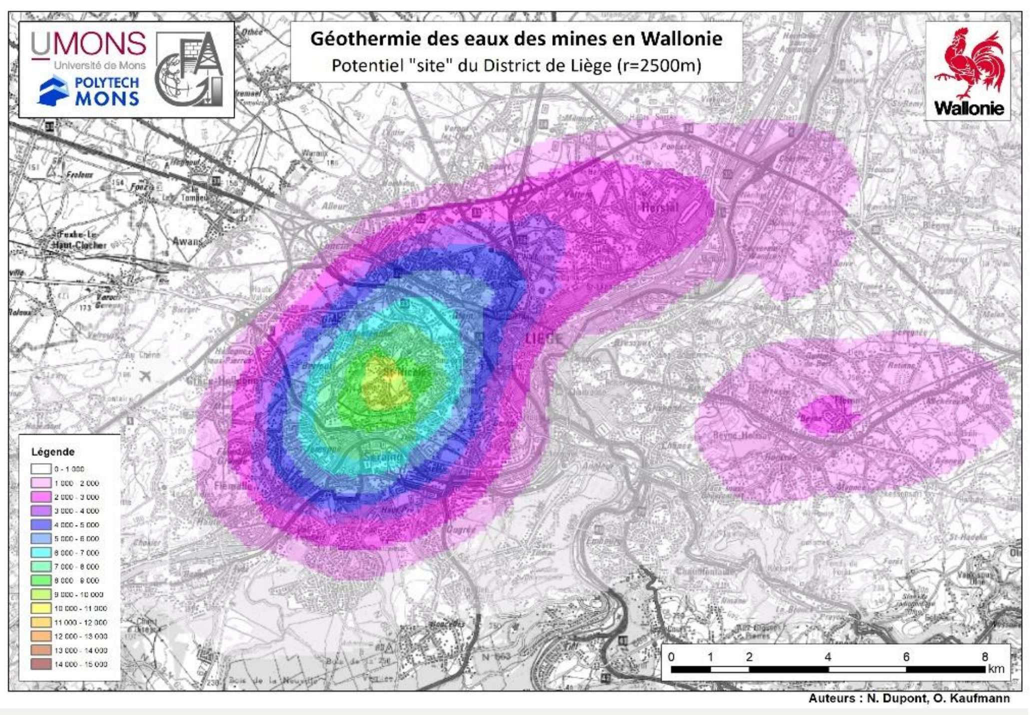
Groundwater in flooded legacy coal mines can be used for heat and cold production and storage in combination with heating and cooling networks. In the Walloon Region of Belgium, three cases are currently being investigated with the financial support of the Recovery Plan (Walloon Government, SPW Energy) to assess the potential of mining geothermal pilot projects in Liège, Charleroi, and Mons. The case of Liège is detailed here. The heat and cold users/producers to be connected were identified as well as their demand profiles. The model of the mine reservoir was elaborated by digitizing and conceptualizing the geometry of the interconnected galleries, shafts, and extracted coal panels of the flooded mine in the fractured Westphalian formations. The mine reservoir must be described as realistically as possible to ensure the reliability and robustness of the results and its behavior under defined exploitation scenarios. For the simulation of the groundwater flow coupled to heat transfer, the 3D highly heterogeneous rock domain is complemented with discrete 1D elements representing mine galleries. Feflow© is used to allow temperature-dependent density and viscosity, in a complex 3D heterogeneous domain. The system concept foresees using a reversible heat pump and a geothermal doublet. Hot water is pumped in the deepest parts of the open network, and cold water is re-injected in the shallower parts (galleries or fractured rocks). A seasonal inversion is planned to cool the buildings during summer. The main challenge to design the whole geothermal project and to assess its future efficiency and impact is the uncertainties inherent to such a highly heterogeneous underground reservoir. They can impact the simulation results of short-, mid-, and long-term temperature evolution in pumping and injection zones. This case study highlights the importance of relying on modeling approaches using detailed mine data to provide reliable predictions.

1. Open geothermal system in flooded old mines coupled to a 5th generation heat/cold network

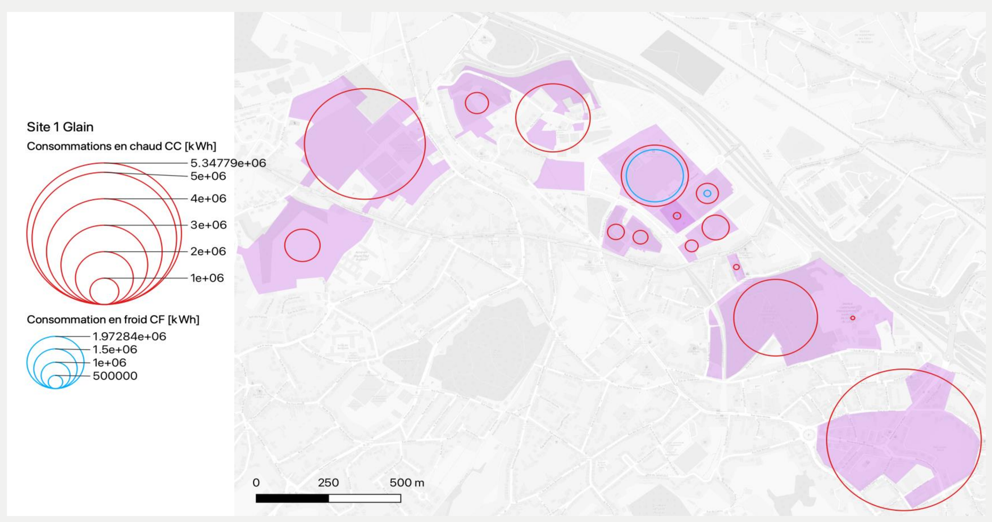


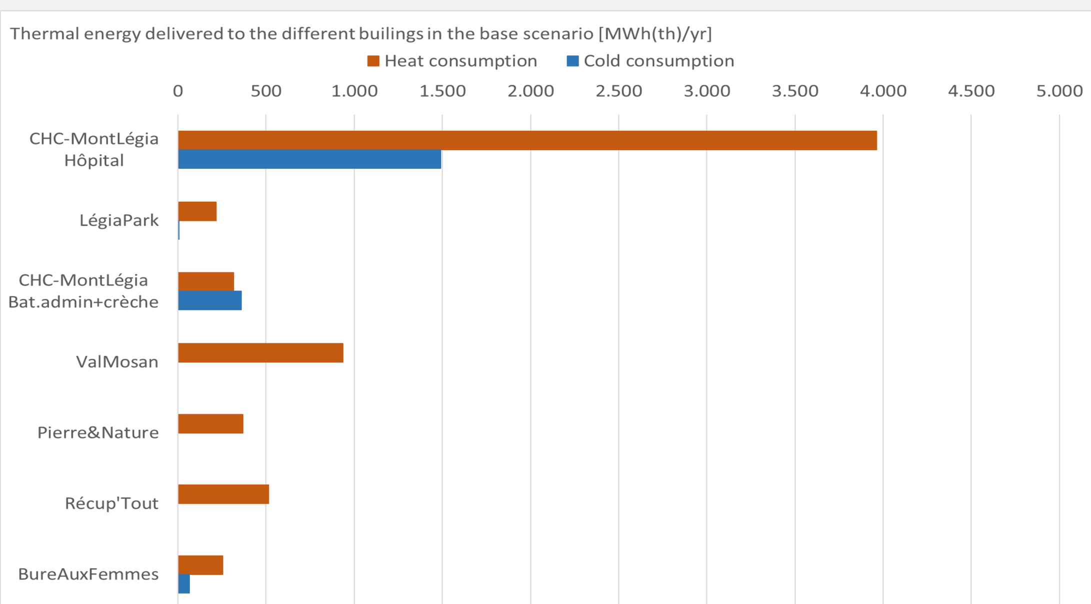
2. Opportunities in the old mines of the Liege region

- theoretical geothermal potential, previously assessed on the basis of exploitation data (depths and extracted volume of coal), new housing
- in Liège, the best zone is located in the North-West suburbs of the city
- existing old mines works with filled shafts and open (but probably collapsed) galleries in a fractured sandstone/ siltstone/claystone/coal massif
- the coal layers were folded and faulted in some areas
- the exploited coal layers are partially collapsed



3. Potential users at the surface (and their needs)





Large hospital (heat and cold needs), new housing, new retail surfaces, new services … + North and South possible extensions

For each building, the heat and cold consumptions are defined based on real data or estimated

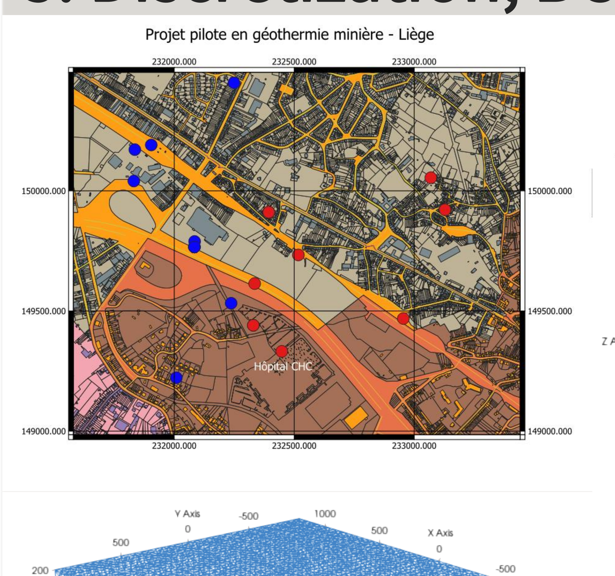
The volumes of water to extract from the geothermal reservoir (the old mine) are estimated.

4. Codes used

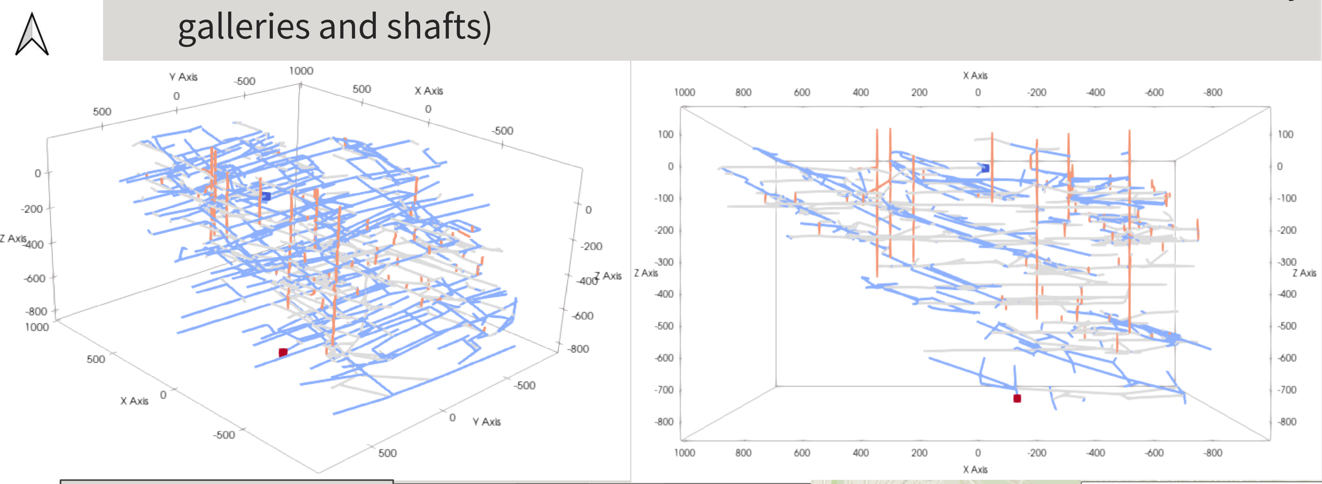
The use of the old mine as a geothermal reservoir is studied using numerical models :

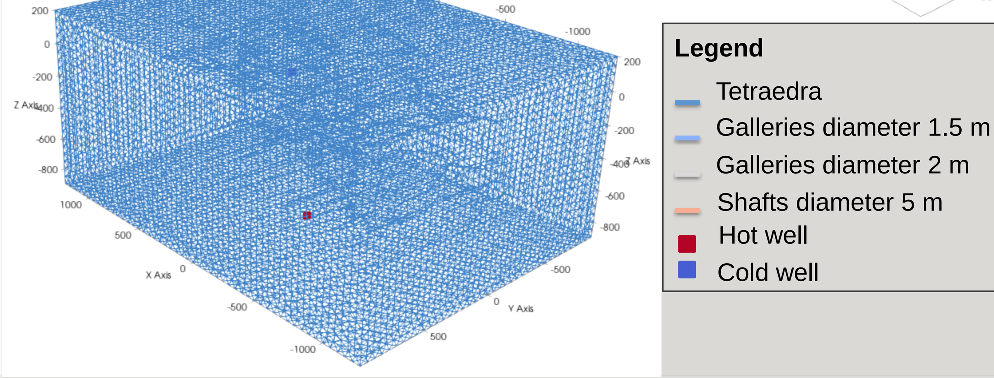
- EPANET is used to model the flow and heat transfer in the galleries and shafts only
- The FEM code Feflow is used to model galleries – shafts using 1D elements and the surrounding rocks using 3D finite elements and coupling groundwater (density/viscosity dependent) flow with heat transport.

5. Discretization, BC's, choice of the optimum doublet

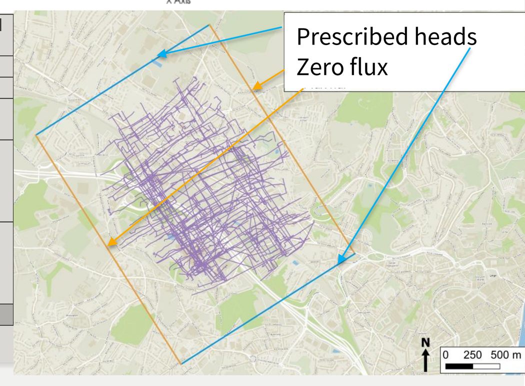


→ Hot well ~ 1000m depth, cold well ~ 100m depth, position optimized based on surface conditions and EPANET simulations (i.e. with only galleries and shafts)





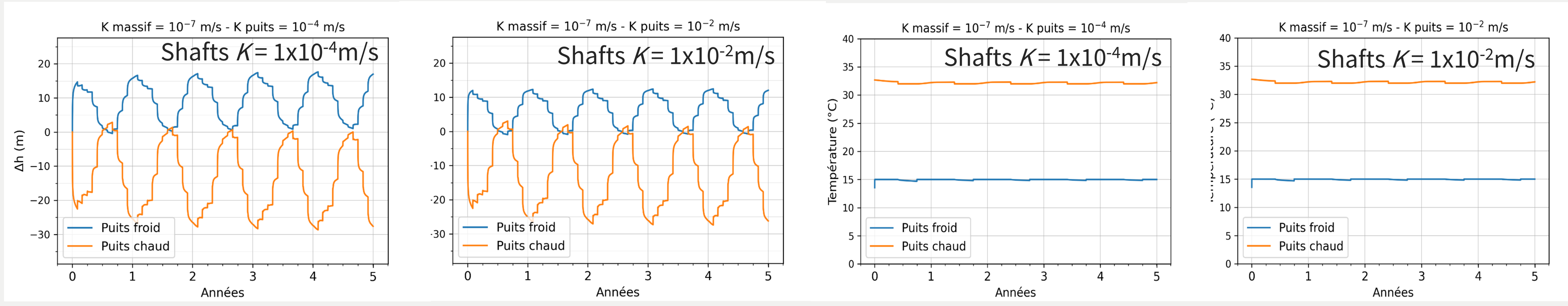
	Bed-rock	Galleries		Shafts	Fractured zones
K (m/s)	10^{-7}	10^{-1}		10^{-2}	10^{-4}
Ss (m^{-1})	10^{-4}	10^{-4}		10^{-4}	10^{-4}
Transport effective porosity (%)	1.5	100		10	5
Volumic thermal capacity of the solid matrix ($MJ/m^3°K$)	2.25	2.25		2.25	2.25
Thermal conductivity of the solid matrix (W/m°K)	2.78	2.78		2.78	2.78
Diameter (m)	///	1.5	2	5	///



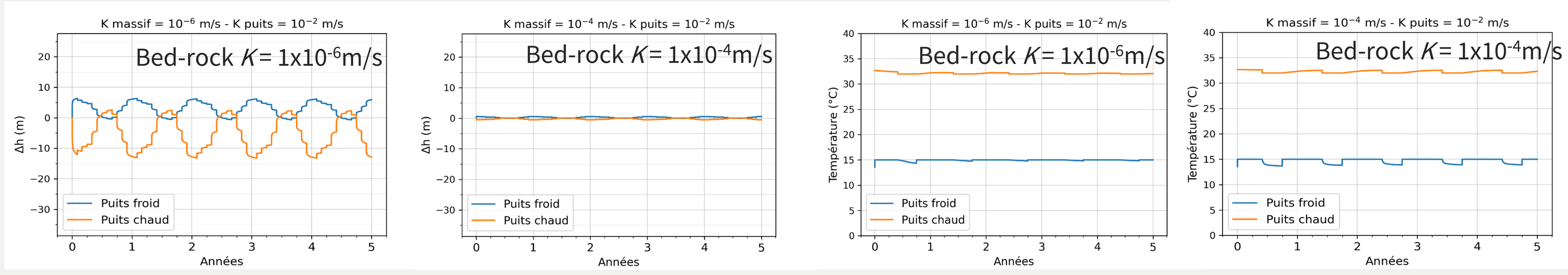
6. Results in terms of Δh and T, sensitivity analysis to K

Galleries $K = 1x10^{-1}$m/s, Shafts $1x10^{-4} < K < 1x10^{-2}$m/s, Bed-rock $1x10^{-7} < K < 1x10^{-4}$ m/s

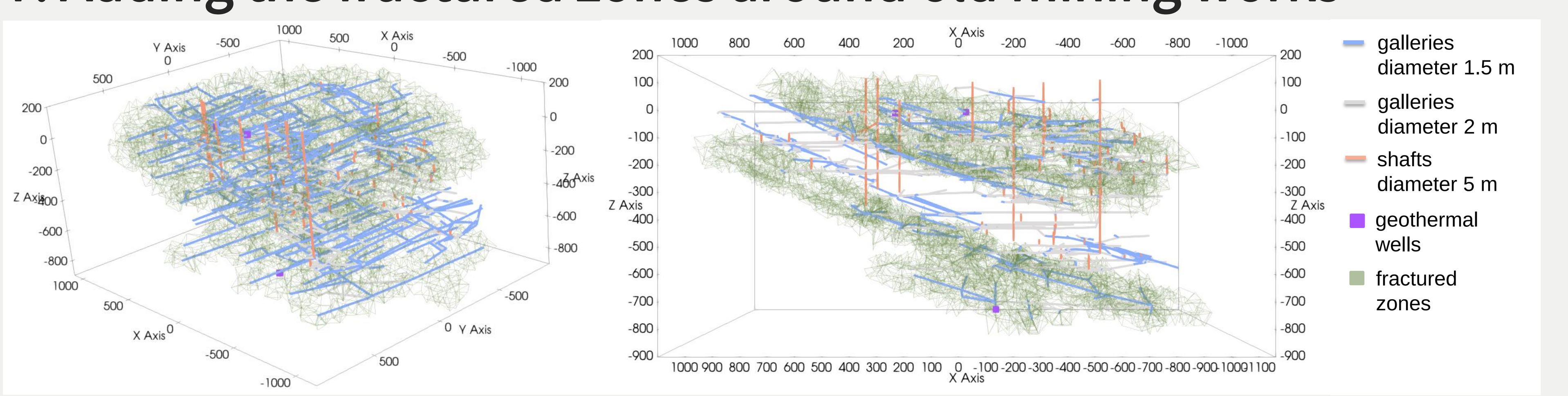
→ 1) for a bed-rock with $K = 1x10^{-7}$ m/s

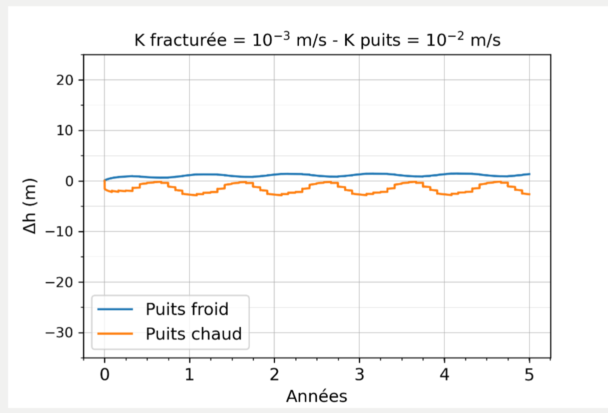


→ 2) for shafts with $K = 1x10^{-2}$ m/s



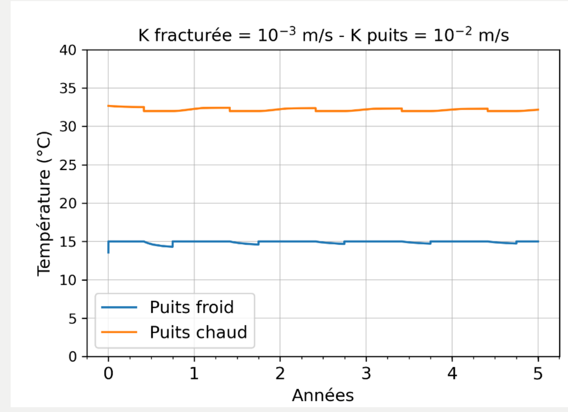
7. Adding the fractured zones around old mining works





Fractured zones $K = 1x10^{-3}$m/s

Galleries $K = 1x10^{-1}$m/s
Shafts $K = 1x10^{-2}$m/s
Bed-rock $K = 1x10^{-6}$m/s



8. Conclusions and perspectives

- first results show a relatively robust efficiency (not too large variations of T° in time
- collect field local hydrogeological data (K) for bed-rock, fractured zones, galleries and shafts)
- update the 3D groundwater flow and heat transport model
- test different exploitation scenarios
- a full feasibility study will follow

This study is carried out in the framework of the GEOMINE project: « feasability study in the Liège basin in view of a pilote geothermal project in old coal mines » funded by SPW Wallonie Energie