THE ROLE OF MODELLING IN THE PLANNING STRATEGIES, THE CASE STUDY OF POLITECNICO DI TORINO OPEN-LOOP GEOTHERMAL PLANT

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1. INTRODUCTION

Over the past decades, the energy production strategy based mainly on fossil fuels has had an impact on man and the environment in terms of emissions of atmospheric pollutants and depletion of resources. For this reason, energy production from renewable energy sources (RES) has become one of the central themes of European and Italian development policy visions.

Italy plans to supply **30%** of final energy consumption from RES by **2030**, defining a path of sustainable growth for RES and their full integration into the system. The heating sector is expected to play a major role in achieving Italy's medium to long-term RES targets. A decisive technological shift towards ever new RES solutions is required: the diffusion of heat pump systems is a key tool to decarbonise existing thermal energy systems. Italian urban areas are characterised by a century-old infrastructure: 35% of the Italian building stock consists of buildings constructed before 1970, and about 75% are thermally inefficient. **Open-loop groundwater heat pumps** (**GWHPs**) represent one of the most suitable technologies to be applied to heating and cooling buildings in such densely urbanised areas. Besides, the **reinjection** of thermally perturbated water in shallow aquifers has the potential to cause significant **environmental impacts**, even in the short term.

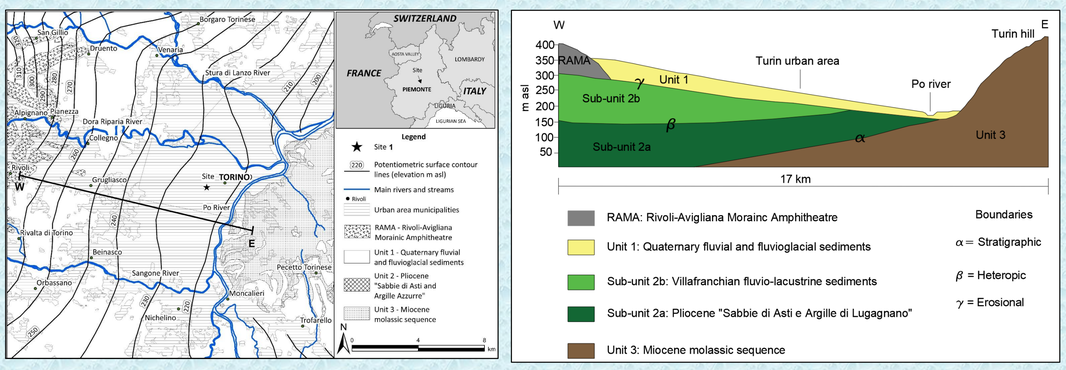
At present, the distribution of ground source heat pumps in Italy is difficult to quantify and approval procedures are long and complex. To date, there is **no national census** of geothermal installations and very few local authorities have a register of installations. In this context, the role of modelling is crucial for the future sustainable development of open-loop geothermal systems and urban management. The developed **urban planning instruments** must pursue a double aim:

1) to allow for **rapid diffusion of open-loop groundwater heat pumps (GWHPs)** open-cycle geothermal systems;
2) to ensure **adequate long-term protection of the groundwater bodies** through an understanding of the subsoil in the decision-making process.

The numerical model of the Politecnico di Torino, obtained with **MODFLOW 6 (1)** and calibrated with **PEST (2)**, includes other neighbouring geothermal plants and shows the actual situation in terms of dewatering and temperature of the shallow aquifer of a large area of Turin and represents the best approach to analyse the **thermal feedback** of open-loop geothermal plants.

2. MATERIALS and METHODS

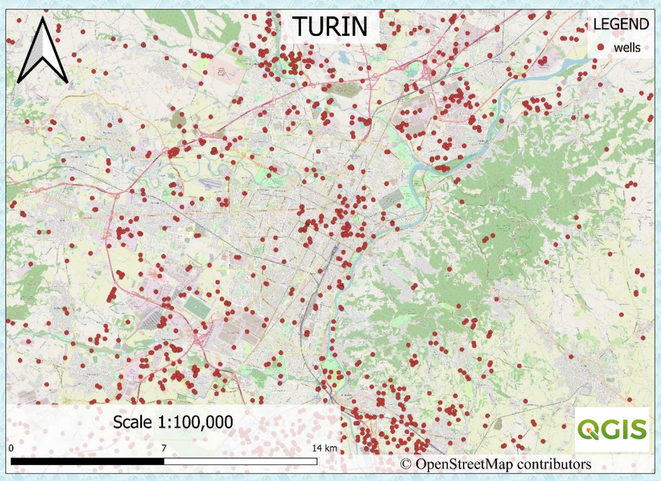
Turin geological and hydrological settings



Geological and hydrogeological maps, modified from (3).

Unit 1: is constituted by fluvial and fluvioglacial coarse gravels with subordinate sands and silts (thickness of about 30-40 m) and contains the unconfined highly productive shallow aquifer hydraulically connected to the main surface water drainage network.

Water wells in Turin



Water wells distribution in Turin Municipality.

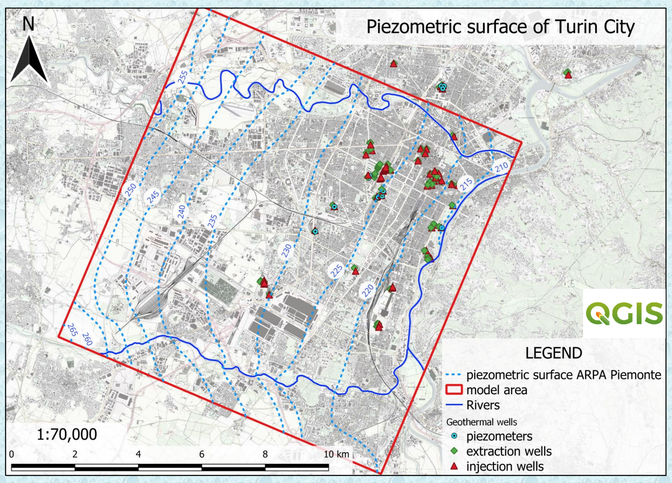
Politecnico di Torino open-loop geothermal wells

12 geothermal wells of Politecnico di Torino.

Model building

Step 1: model area and boundary condition

The model area is a square of 11x11 km with an area of 121 km^2. This is due to the fact that the boundary conditions are contained within the area. From a hydrogeological point of view, the recharge limit of the shallow aquifer lies to the north, the Dora Riparia river to the east, the Sangone river to the west and the Po river to the south.

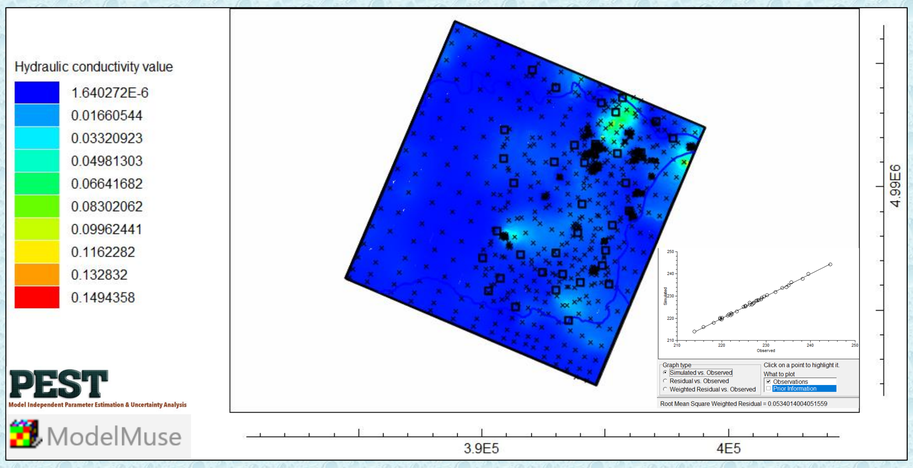


Model Muse (4) settings:

- GHB: 3 boundary condition at N,W and S, defined by the piezometric surface;
- RIV: 3 river packages to simulate the interference of rivers;
- WELL: to simulate geothermal wells;
- 2 layers: model top generate by DTM, and the base of shallow aquifer generate by interpolation (PAST4 software).

Step 2: Calibration with PEST HP

To calibrate the hydraulic conductivity, more than 300 points were analysed and the data were processed using a kriging technique and the PEST HP code. The model was calibrated through the pilot point (PP) technique with over 1000 PPs used represented by the crosses and 50 observation points represented by the squares.



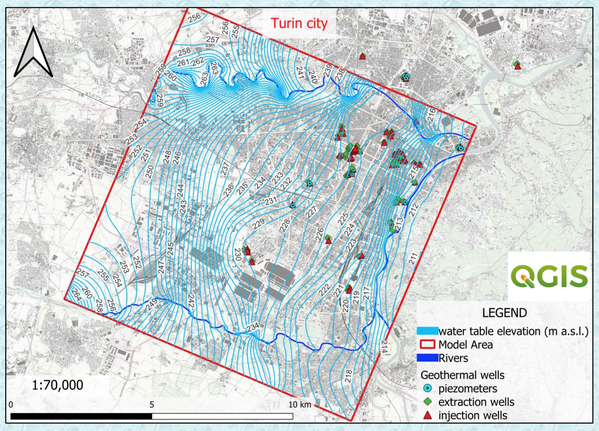
Step 3: Stady State

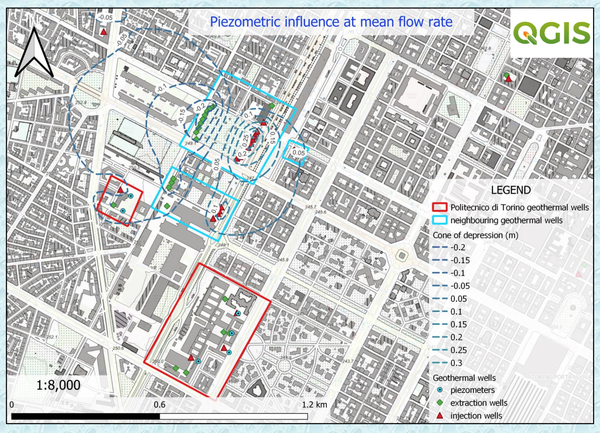
The new calibrated piezometric surface was simulated.

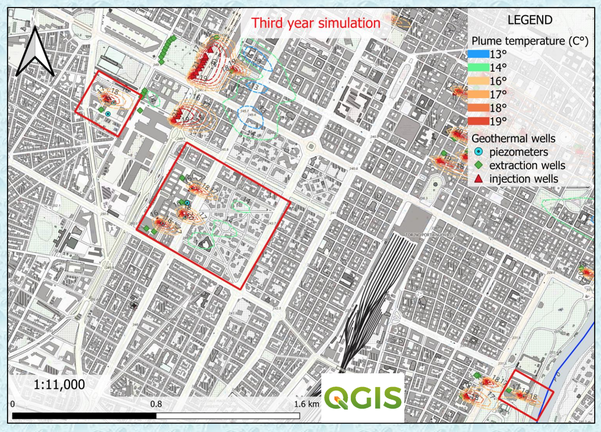
Step 4: Transient State

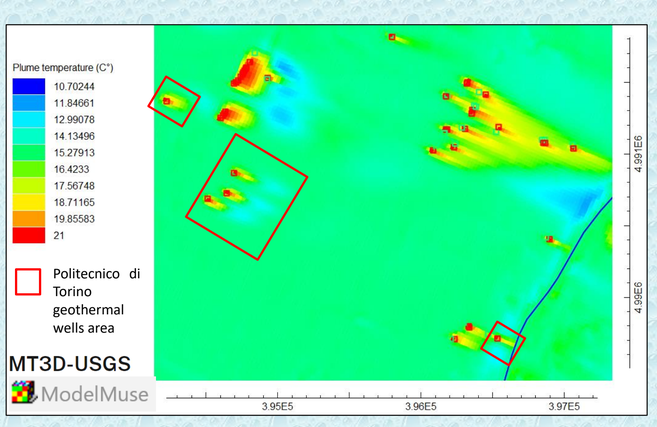
Step 5: Heat transport

End of the third summer simulation year by MT3D-USGS (5)









3. DISCUSSION and CONCLUSIONS

Because of their energy efficiency and sustainability, **open-loop geothermal** systems are one of the main technologies to be promoted for deployment at different scales. In urbanised areas, **aquifers** are becoming a **renewable energy source** for large cities. This study investigates the **anthropogenic impact** of active geothermal systems on the surface aquifer beneath the city of Turin. In particular, whether there is interference from the geothermal wells of the Politecnico di Torino and neighbouring systems. For this reason, a complex numerical model has been set up on an urban scale. Only **open source** software and **open data** were used to create the model. The model includes the **average** flow rate and represents a good approximation to reality in the absence of real information on the operation of geothermal plants. As the simulations show, there is still **great potential** for developing this technology in the Turin area. In conclusion, this type of model can be useful for professionals and local authorities to analyse the thermal feedback generated, both with a **case-by-case** approach and with a **global/urban** approach, with a view to future **sustainable planning**.

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