Romanian Journal of Civil Engineering, Volume 15 (2024), Number 3

The impact of shallow geothermal HVAC systems with heat pump units on the ground and ground water

Impactul sistemelor HVAC geotermale de mică adâncime cu pompe de căldură asupra apei subterane și solului

Răzvan –Silviu Ștefan[1], Daniel Cornea[2]

[1]Engineer- Technical Facility Coordinator ELI-NP, Bucharest, Romania
razvan.stefan@eli-np.ro

[2] Technical University from Bucharest, Romania
danielcornea@hidraulica.utcb.ro

DOI: 10.37789/rjce.2024.15.3.10

ABSTRACT. The paper presents the study conducted to determine the impact of HVAC geothermal systems with heat pumps units on the ground and groundwater. Due its very complexity the HVAC geothermal system with heat pumps units that equips the ELI-NP research infrastructure could be a suitable tool to determining the long-term impact of shallow geothermal systems on the environment. The system has been continuously operating and monitored for 5 years.

Key words: HVAC, heat pumps

Current state of knowledge of the soil and groundwater impact of surface geothermal IVC systems

Geothermal HVAC systems with heat pumps units are now being widely utilized.

Advantages such as very low energy consumption and CO_2 emissions, low maintenance requirements make their use very attractive.

Since the large-scale use of geothermal HVAC systems, especially the high-capacity ones, is of recent date, not many studies and simulations have been carried out regarding their operation.

The thermal transfer between the HVAC System could have an impact on the ground and groundwater in the long run.

In the long run, both the ground and groundwater could be affected by the thermal transfer between the HVAC system and the ground.

Simulations and studies both regarding the evaluation of the thermal loads introduced by the HVAC systems and the long-term response of the ground to the action of these loads, are of particular importance for the determination and evaluation of the possible consequences on the ground and groundwater.

The geothermal HVAC system that equips the ELI-NP research infrastructure has a thermal capacity of 6.2 MW and is made of 1070 geothermal boreholes, each having depth of 120 m. It covers an area of 27,000 m2, the boreholes being grouped within 18 plots (60 boreholes on each plot).

The geothermal HVAC system currently operating at ELI-NP research infrastructure is a suitable tool for determining long-term environmental impacts as well as performing other operational simulations, given its complexity.

The system allows to working out of physical and mathematical models and various simulations with results that contribute to the development of the field.

Hydrogeological monitoring of the geothermal HVAC system built and in operation at ELI-NP

As far as concerning the geothermal HVAC operating at the ELI-NP research infrastructure, monitoring the impact on ground and groundwater is a requirement imposed by the authorities, through the water rights permit.

An important consequence of this fact is that it will be possible to carry out studies and simulations useful for making predictions and forecasts for the behavior of similar systems, in order to evaluate the impact of the systems on the environment, their continuous innovation and optimization.

In order to monitor the hydrogeological geothermal HVAC system in operation at ELI-NP, a hydrogeological monitoring solution was designed and built, as a first step. The monitoring station consists of 8 monitoring boreholes (4 new boreholes and 4 existing boreholes part of a pilot station installed during the execution of the HVAC system).

The design process of the hydrogeological monitoring station was based on the following considerations, models and methods:

- The hydrogeological monitoring station has to capture the impact of the HVAC system on the aquifers in the studied area in terms of quality and quantity.
- The hydrogeological monitoring station has to respond to the need for time tracking of the impact of the HVAC system on the aquifers observed for the entire period of its operation.
- The hydrogeological monitoring station has to be operational at the commissioning of the HVAC system.
- The hydrogeological monitoring station has to comply with the existing regulations and framework (national or European). Currently, the only comparable category that frames the geothermal HVAC system is the waste pits.
- The hydrogeological monitoring station has to take into account the flow directions for each of the previously mentioned aquifers, positioning the boreholes along the main flow direction.
- The hydrogeological monitoring station has to take into account the most unfavorable situation of the thermal impact on the aquifers and be able, in case of hydro-geo-chemical changes, to respond in a timely manner.
- The location of the boreholes within the hydrogeological monitoring station takes into account the direction of groundwater flow for the four aquifers and the possible impact of heat transfer over time.
- Placement of at least two monitoring boreholes, one borehole located upstream of the HVAC system and one borehole downstream of the HVAC system, in the direction of flow.

As a second step, after the construction of the monitoring station, hydrogeological parameters have been permanently recorded aiming the quantitative and qualitative identification of the impact on the ground and groundwater.

Description of the hydrogeological monitoring station that was carried out at ELI-NP

The monitored aquifers are Colentina, Mostiștea and Frătești (A and B). The location of the boreholes within the station related to each of the aquifers (see figure 1) is specified in the project (Stereographic 70).

The monitoring station consists of 8 monitoring boreholes (4 new boreholes and 4 existing boreholes part of a pilot station installed during the execution of the HVAC system).

There are two types of boreholes:

- Monitoring boreholes located upstream in the direction of groundwater flow, which are not influenced by the thermal impact of the IVC system (F0C1, F0M1, F0A1, F0B1)
- Monitoring boreholes located downstream in the direction of groundwater flow, which aim to capture the thermal impact due to the operation of the IVC system (F1C, F1M, F1A, F1B)

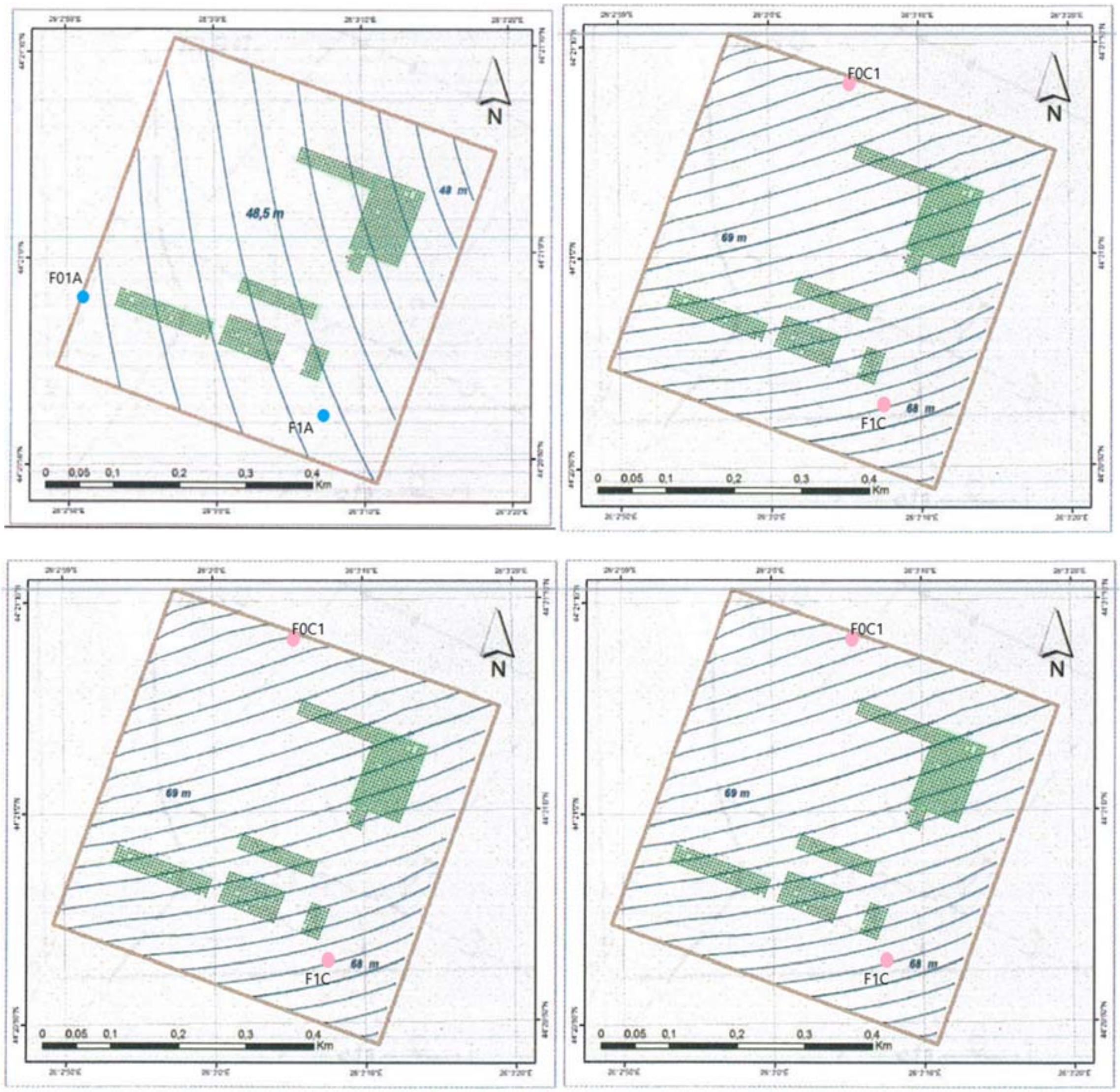
The placement of boreholes took into account considerations such as those briefly listed above, criteria listed in Table 2.

Table 1 Depth of installed boreholes

No.	BOREHOLE CODE	Aquifer	Design Depth (m)	Data aquisition system position/ depth (m)
1	F0C1	Colentina	18	10
2	F1C1	Colentina	20	10
3	F01M	Mostistea	50	35
4	F1M	Mostistea	50	35
5	F0A1	Fratesti A	90	75
6	F1A	Fratesti A	90	75
7	F0B1	Fratesti B	125	105
8	F1B1	Fratesti B	125	105

Table 2 Criteria. Basis of the hydrogeological monitoring station design

CRITERIA	RESULT
Geological and hydrological model	Aquifers monitoring: Colentina, Mostiștea, Frătești A, Frătești B
Water flow model	The flow directions for each of the aquifers, positioning the boreholes along the main flow direction.
Legislation criterium	Placement of at least two monitoring boreholes, one borehole located upstream of the HVAC system and one borehole downstream of the HVAC system, in the direction of flow.
Thermal transfer model	The position of the boreholes towards the HVAC System



Monitored hydrogeological parameters

The design criteria of the monitoring solution are based on the created models. Thus, through the classic numerical modeling procedure of heat transfer or the transport of miscible compounds, in an aquifer layer, a conceptual model has been created in a first stage. Based on the created conceptula model the numerical hydrodynamic model and thermal transfer model have been developed. The hydrodinamic model considers a rectangular shape of 12 km x 12 km that includes the Colentina, Mostiștea, Frătești A and Frătești B aquifers.

Then the thermal modeling of the behavior of the HVAC system has been performed. A geological model of the area has been also created, as the basis for defining the geometry of the hydrodynamic model.

The thermal transfer model was made for the four aquifers, the estimated effect being for 200, 400, 600, 800, 1600 and 4000 days. One-way operation was considered (heat loss from the HVAC system to the environment), this scenario representing the worst situation for the aquifer environment.

Within the monitoring station, two sets of hydrogeological parameters were measured and collected to monitor the impact of the geothermal HVAC system:

- physical parameters - piezometric levels, temperature
- hydro-geo-chemical and microbiological parameters

The frequency of parameter monitoring, the water sampling program and their analysis are presented in table 3.

The reference values, of the quality indicators of the groundwater was set before the commissioning of the facility, through determinations made by approved laboratories on the samples taken from the monitoring boreholes located upstream in the direction of the flow of the underground water in relation to the objective. The monitoring of physical parameters is performed automatically through the data acquisition units, programmed to ensure the consistency of the recorded data (Table 4).

Tabel 1 Hydrogeological parameters monitoring program

		Physical parameters	Bio-chemical parameters
AQUIFER	**Colentina**	Y	Y
	Mostiștea	Y	Y
	Frătești A	Y	Y
	Frătești B	Y	Y
Frequency		Performed automaticaly on daily basis	Water samples to be taken on semester basis In spring (april-may) In autumn (september, october))

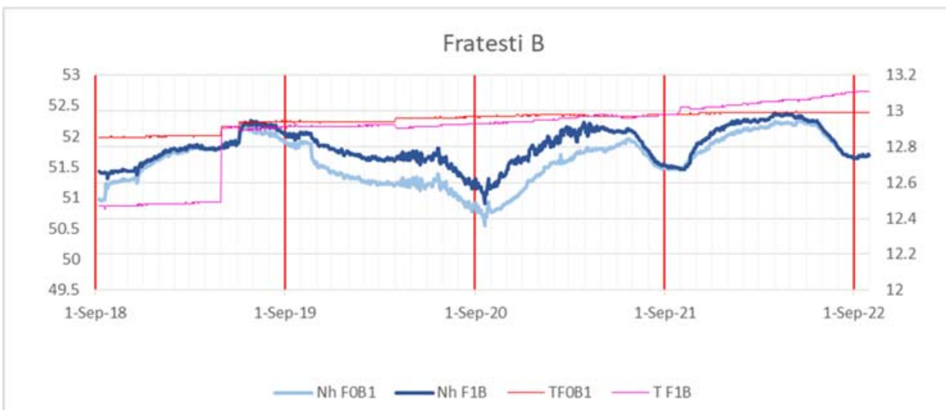
Tabel 2 Data aquisition units specifications

		preasure			temperature		
		Range	Accuracy	Resolution	Range	Accuracy	Resolution
AQUIFER	**Colentina**	0 – 10 mH_20	±1.0 cmH_20	0.2 cmH_20	0 - 50 °C	±0.1 °C	0.01 °C
	Mostiștea	0 – 20 mH_20	±2.0 cmH_20	0.4 cmH_20			
	Frătești A	0 – 100 mH_20	±5.0 cmH_20	2.0 cmH_20			
	Frătești B	0 – 100 mH_20	±5.0 cmH_20	2.0 cmH_20			

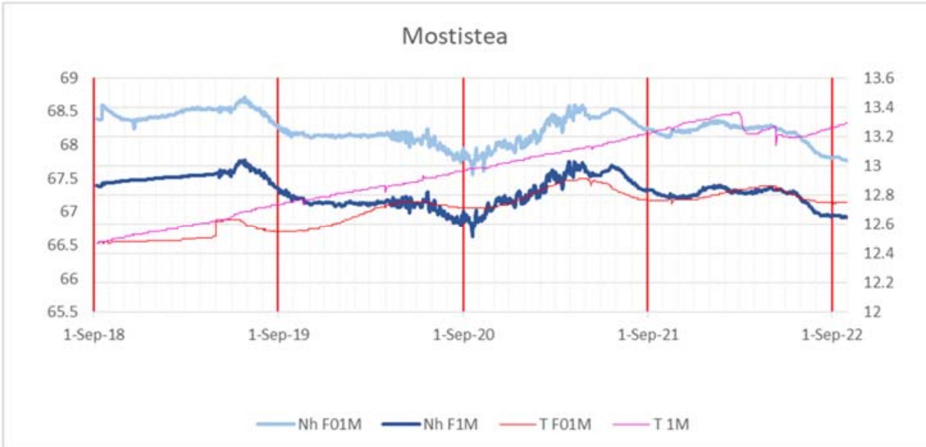
Results obtained from hydrogeological monitoring

The heat transfer models will be refined and calibrated based on real data and considering the operation in both directions (yielding or receiving heat from the HVAC system in the environment). The literature it specifies that the alternation of the two operation regimes will lead to a cancellation of the thermal effects, as well as to a reduction of their impact on the aquifer environment.

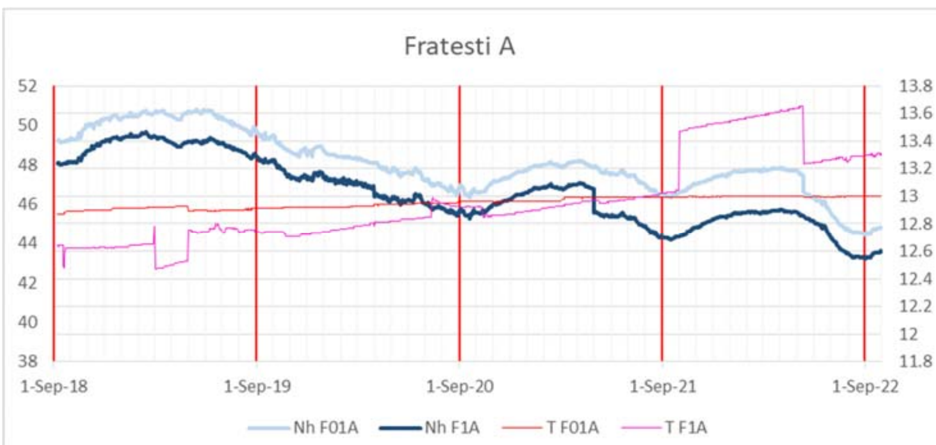
The HVAC system and the hydrogeological monitoring station are in their 5th year of operation. By means of the statistics and monitoring, data are available to highlight the real behavior of the system by comparison with the predictions made based on the physical model. Data acquired from hydrogeological monitoring for each of the aquifers are summarized in the graphs and tables below.



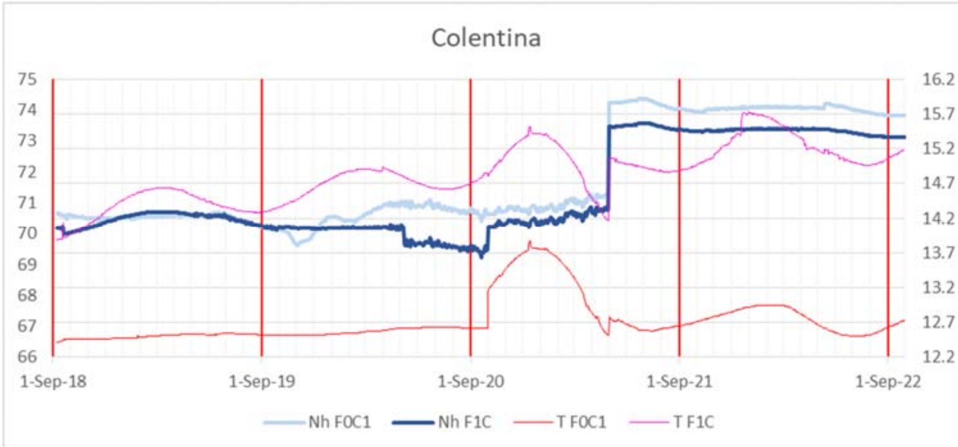
Aquifer Fratesti B				
Borehole	F0B1		F1B	
Date	*Nh* (*mdMN*)	*T* (*Celsius*)	*Nh* (*mdMN*)	*T* (*Celsius*)
62Xju26=	:6	673=:	:639;	6739<
1-Sep-19	51.93	12.94	52.05	12.91
1-Sep-20	50.91	12.97	51.31	12.93
1-Sep-21	51.5	12.98	51.54	12.98
1-Sep-22	51.64	12.99	51.64	13.1



Aquifer Mostistea				
Borehole	F0M1		FM1	
Date	*Nh*	*T*	*Nh*	*T*
	(mdMN)	*(Celsius)*	*(mdMN)*	*(Celsius)*
62Xju26=	;=399	6739<	;<398	6739<
1-Sep-19	68.29	12.55	67.35	12.73
1-Sep-20	67.93	12.71	67	12.97
1-Sep-21	68.25	12.76	67.34	13.22
1-Sep-22	67.8	12.75	66.94	13.26



Acquifer Fratesti A				
Borehole	F0A1		F1A	
Date	*Nh*	*T*	*Nh*	*T*
	(mdMN)	*(Celsius)*	*(mdMN)*	*(Celsius)*
62Xju26=	9>36>	673=<	9=35:	673;9
1-Sep-19	49.64	12.91	48.4	12.74
1-Sep-20	46.94	12.96	45.73	12.92
1-Sep-21	46.49	12.99	44.34	13.02
1-Sep-22	44.49	13	43.25	13.3



Aquifer Colentina				
Borehole	F0C1		F1C	
Date	*Nh*	*T*	*Nh*	*T*
	(mdMN)	*(Celsius)*	*(mdMN)*	*(Celsius)*
62Xju26=	<53;:	6739	<5377	683==
1-Sep-19	70.24	12.52	70.25	14.29
1-Sep-20	70.82	12.62	69.61	14.73
1-Sep-21	74.05	12.65	73.38	14.89
1-Sep-22	73.83	12.63	73.12	15.05