



Field report and monitoring plan of the ground-source heat pump system for the community swimming pool in Kuujjuaq (Nunavik, Canada)

Nicolò Giordano
Jasmin Raymond



Institut national
de la recherche
scientifique

Institut national de la recherche scientifique
Centre Eau Terre Environnement
6 November, 2020

Contacts

nicolo.giordano@ete.inrs.ca
felix-antoine.comeau@ete.inrs.ca
jasmin.raymond@ete.inrs.ca

© INRS, Centre - Eau Terre Environnement, 2021
Tous droits réservés

ISBN : 978-2-89146-951-7 (version électronique)

Dépôt légal - Bibliothèque et Archives nationales du Québec, 2021
Dépôt légal - Bibliothèque et Archives Canada, 2021

TABLE OF CONTENTS

- 1. Introduction**
- 2. Geographical setting and general context**
- 3. Geological setting**
- 4. Description of the ground-source heat pump system**
- 5. Local geological observations**
- 6. Thermal response tests and laboratory analyses**
- 7. Thermo-geological interpretation for system's performance**
- 8. Monitoring system**
- 9. Concluding remarks and recommendations**

Appendix

- I. Tutorial for data download of the thermistors cables (RST Instruments Ltd.)*
- II. Tutorial for data download of the heat meter (Kamstrup Metering Solutions Canada Inc.)*

Attachments

1. Zip file named "Monitoring.rar" with all the software needed to read and download data from the monitoring system. Manuals are included in the respective folders

1. INTRODUCTION

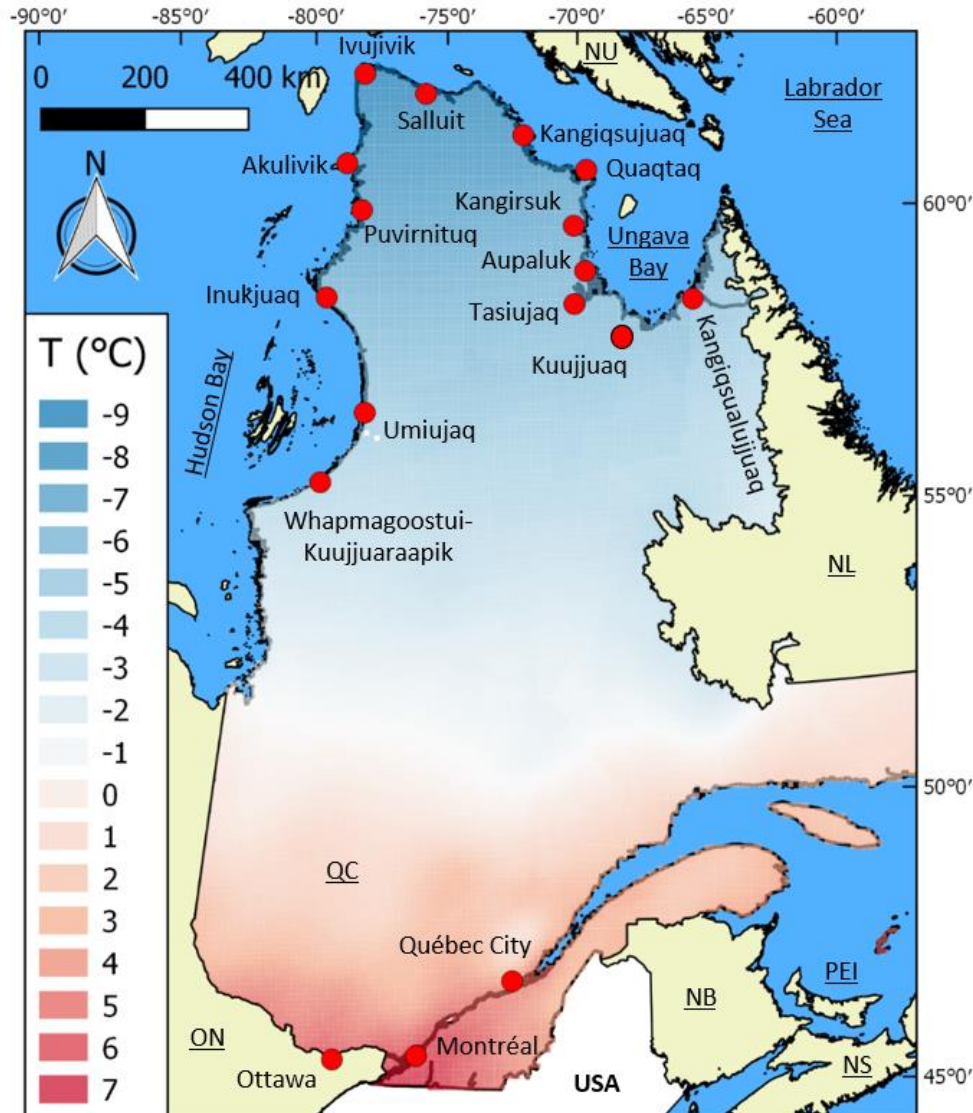


The present field report concludes the contribution of the Institut national de la recherche scientifique (INRS) to the project led by Kuujjuamiut Inc., and funded by the “Impact Canada Indigenous off diesel initiative” federal program. Partners of the project are Nunatech-Englobe and Induktion Géothermie. The activities of the INRS took place in the first and second quarters of the 2020 budget and included: pre-design of the horizontal ground heat exchangers; simulations of the system and optimization of ground loop performance; design and implementation of a monitoring system.

INRS has been studying the geothermal potential of Northern Québec in the last 4 years, thanks to a research chair funded by the Institut nordique du Québec (INQ) and awarded to Jasmin Raymond. The installation of the ground-source heat pump (GSHP) system to the Kuujjuaq community swimming pool is the first of its type in Nunavik and the other Canadian arctic and subarctic territories. This pilot project aims to demonstrate that geothermal is a viable alternative to fossil fuel heating for the indigenous communities living in off-grid villages.

The present report describes the field work activities carried out in September 2020 during the installation of the ground loops of the GSHP. After a basic geographical and geological introduction, the geothermal installation is described through a geological and thermal characterization, crucial elements for the understanding of the long-term system’s behavior. The monitoring devices installed in the ground, the heat pumps and the building are also presented in detail. In order to ensure a long-term and fruitful operation of the monitoring system, a training about the use of the data loggers was given in person to Jason Aitchison (General Manager of Kuujjuamiut Inc.) on September 28, 2020. A tutorial to use the managing software is also provided in the appendix to the present report. Needless to say, the INRS team will always be available to assist the local users.

2. GEOGRAPHICAL SETTING AND GENERAL CONTEXT



Nunavik is the Inuit territory of the Province of Québec standing north of the 55th parallel, where 14 communities rely on fossil fuels (power plants and furnaces) to produce both electricity and heat (**Figure 1**). Moreover, with a population of 12,300, Nunavik has a population growth rate of 40 % since 2000 (SHQ, 2014).

Environmental, social and financial costs can be reduced by the deployment of clean and renewable solutions, such as geothermal technologies, whose reliability has already been demonstrated down south. A profound change toward such a new source of energy in the North requires to better understand the thermal state and properties of the underground in remote communities, where data are barely available. Then, pilot projects are critical to demonstrate the technical viability and monitor the real efficiency of such systems in an environment where the underground is at near-freezing conditions.

Mean annual air temperature in Kuujuaq is -5.8 °C. Underground temperature from -10 to -100 m is about 1°C.

Figure 1 – Mean annual air temperature of all the province of Québec. Inuit-Cree northern remote communities are highlighted in red.

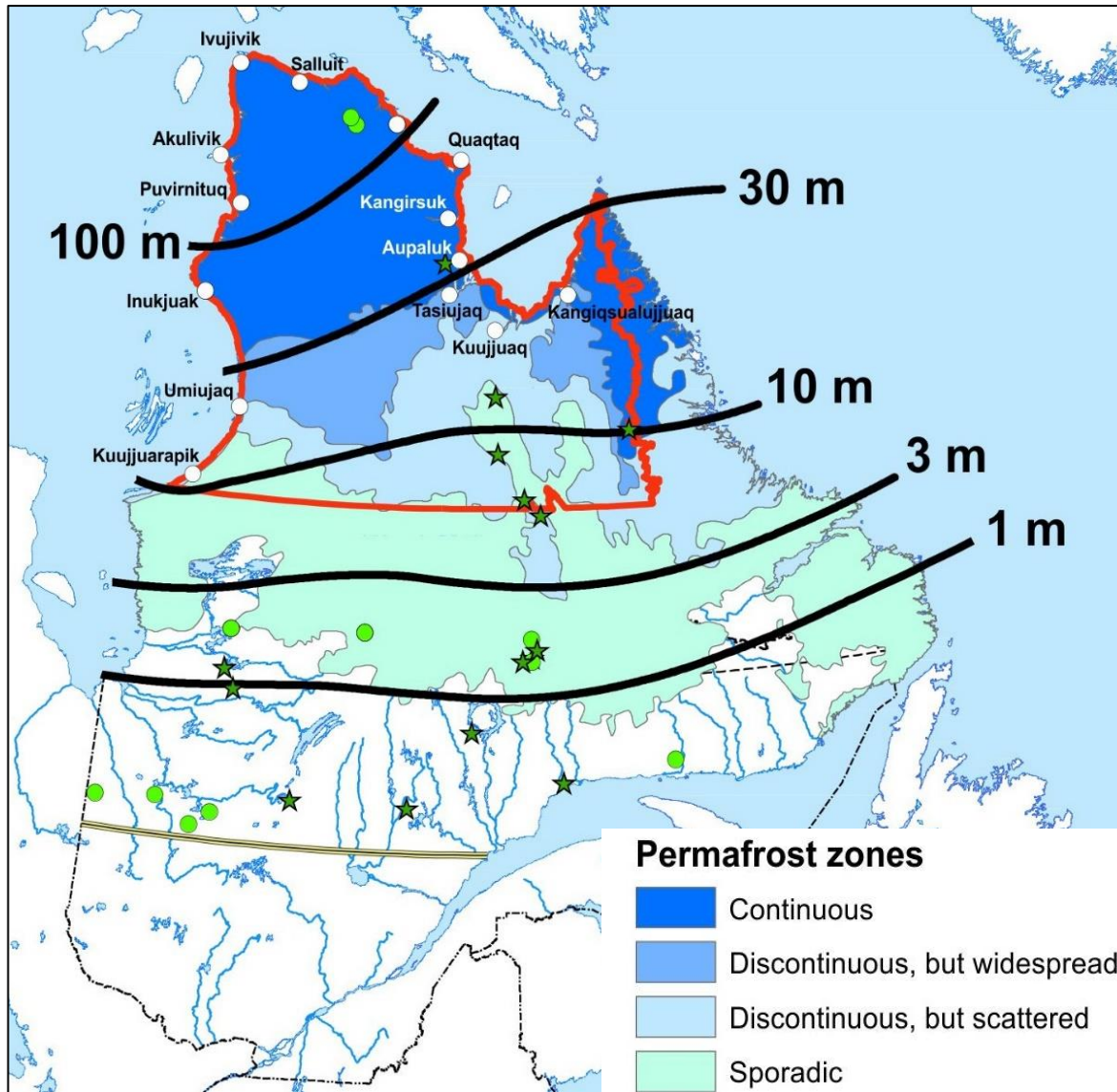


Figure 2 – Permafrost distribution in Québec (Allard and Lemay, 2012; Lemieux et al., 2016; Comeau et al. 2017).

Permafrost in Northern Québec varies between sporadic/discontinuous and 10-30 m thick in the southernmost communities (Whapmagoostui-Kuujuaraapik, Umiujaq, Kuujuaq, Kangiqsualujuaq) to continuous and 30-200 m thick in the northernmost villages (from Aupaluk and Inukjuak to Salluit and Ivujivik).

The presence of discontinuous but widespread permafrost is reported in Kuujuaq (Allard and Lemay, 2012) and its presence is strongly dependent on local geological conditions (Lemieux et al., 2016, Giordano and Raymond, 2019).

By and large, ice-rich permafrost is not a limiting factor for geothermal systems. Nevertheless, its presence must be assessed and taken into account to evaluate the impact of geothermal systems on the stability of buildings' foundations, as well as on the long-term evolution of permafrost in the entire ecosystem.

3. GEOLOGICAL SETTING

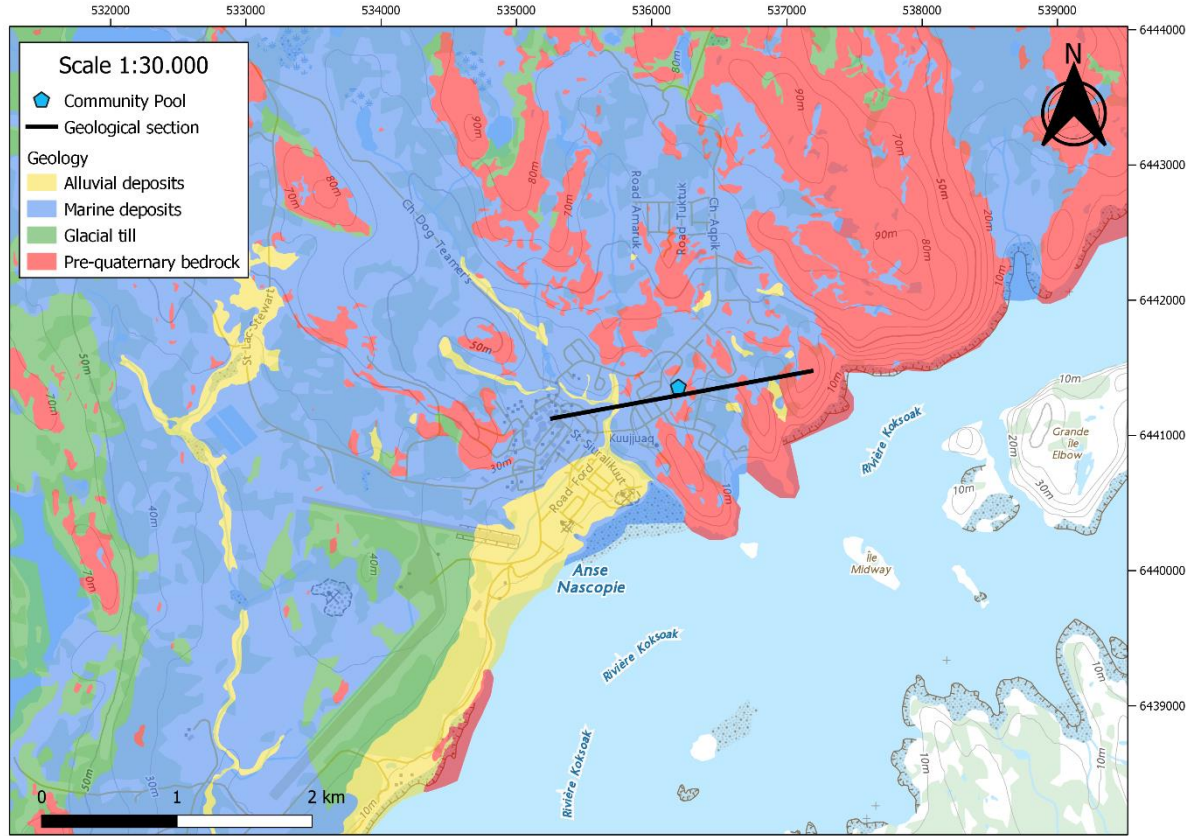


Figure 3 – Distribution of the Quaternary deposits in Kuujuaq.

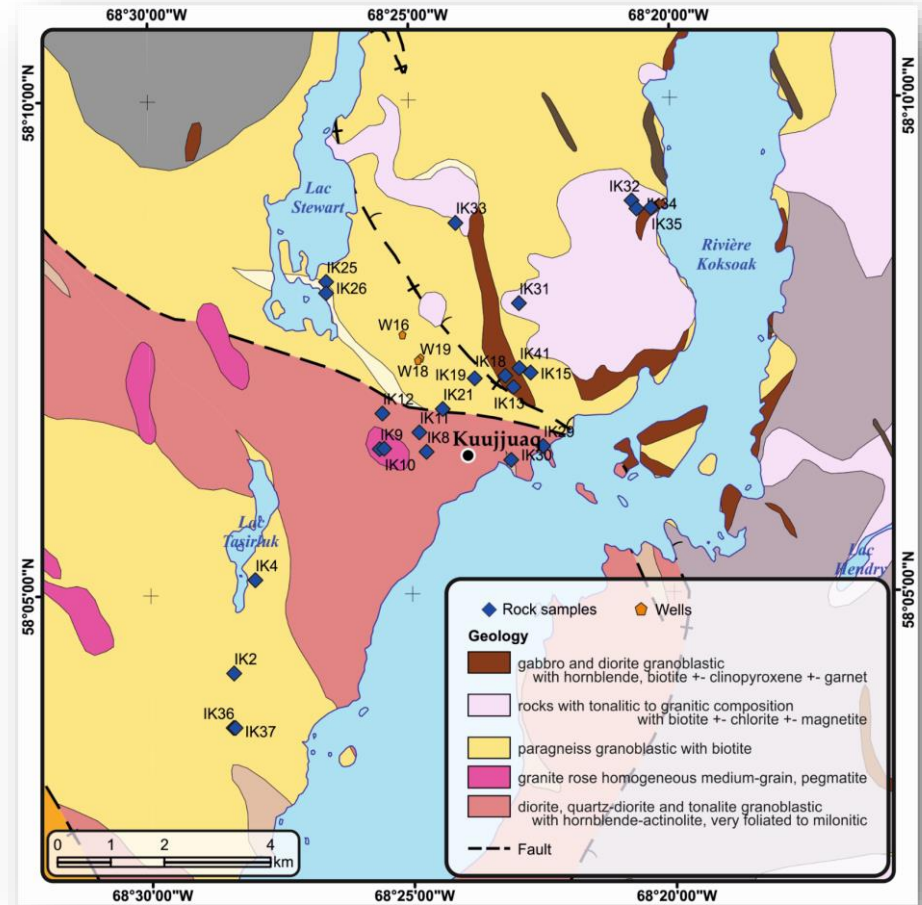


Figure 4 – Bedrock geology in Kuujuaq and surroundings (Miranda et al., 2020).

The main lithological units present in Kuujuaq and the surroundings are diorites and gabbros from Complexe de Kaslac, tonalitic gneisses of Pluton de Kuujuaq and granoblastic paragneisses of the Suite de la Baleine (**Figure 3**). The unconsolidated Quaternary deposits mainly consist of littoral and pre-littoral sediments alternating with intertidal deposits related to different cycles of transgression and regression of the Iberville Sea (**Figure 4**). Glacial till often covers bedrock outcrops and it is common to find till underlying the marine sediments. Coarse-grained alluvial materials are found along small stream valleys.

At the study site we expect to have 1-5 m of quaternary deposits overlying the bedrock. The cross section presented in **Figure 5** (Covelli, 2018) shows the relationships among the different geological units. The stratigraphy at the study site is expected to be made of (from top to bottom): anthropic backfill material; marine deposits (fine and medium sands); glacial till (metric blocks within a silty-sandy matrix); bedrock.

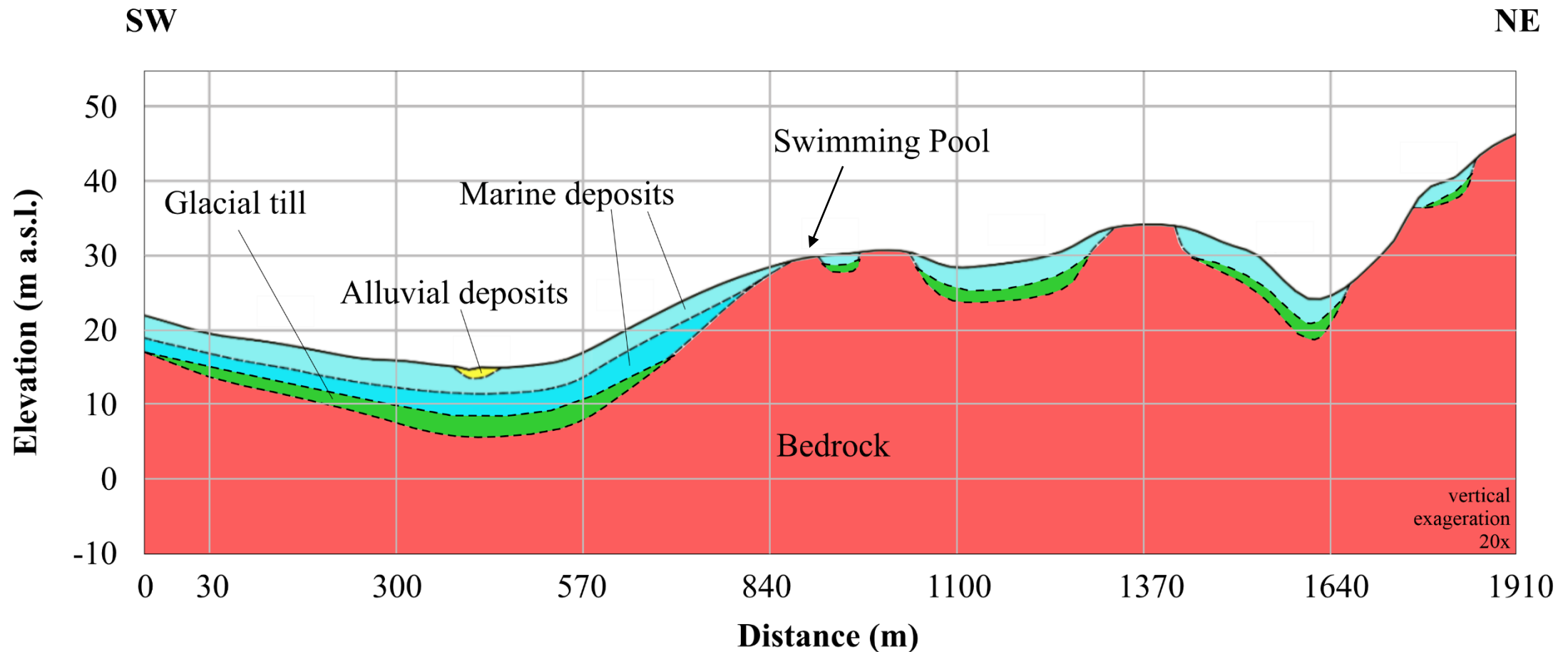
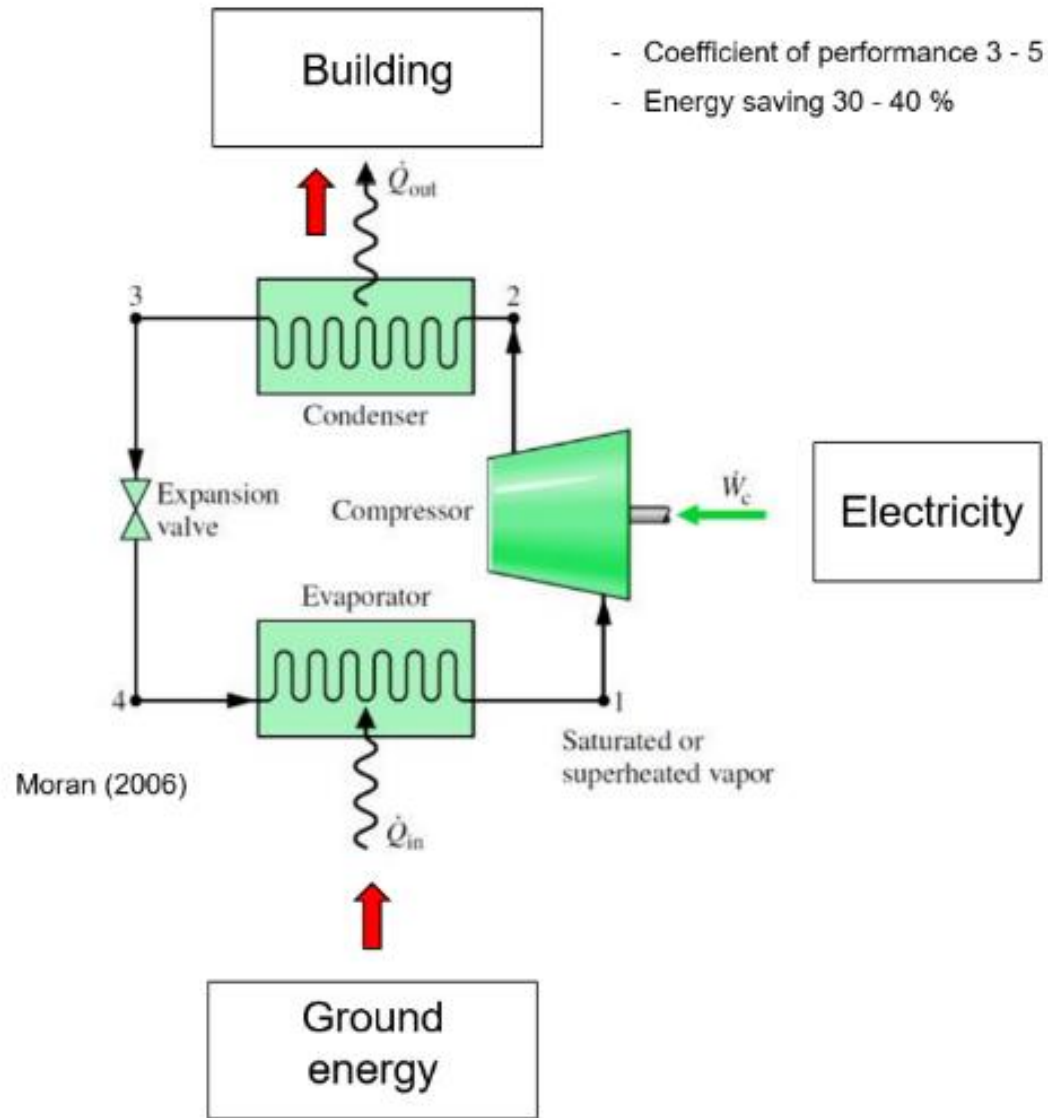


Figure 5 – Cross section close to the study site (Covelli, 2018).

4. DESCRIPTION OF THE GROUND-SOURCE HEAT PUMP SYSTEM



Figure 6 – Aerial view of the ground-source heat pump system at the Pool in Kuujuaq (September 2020, Credits Jason Aitchison, Kuujjuamiut Inc.).



A heat pump (HP) is a mature technology that can transfer heat from a « cold source » (air, surface water or underground) to a « warm sink » (the building to be heated) and produces more energy than the work it does. The HP has 4 main elements: evaporator, compressor, condenser and expansion valve (**Figure 7**). The cold source transfers heat to the evaporator where a low-boiling refrigerant evaporates. The gas is then compressed to increase its temperature, before it gives up the generated heat to the warm sink in the condenser. The expansion valve finally returns the refrigerant at the initial pressure in order to restart the cycle. HP can provide coefficient of performance (COP) bigger than 1. In particular, for each kW of electricity consumed by the compressor, 3 to 5 kW of heat is transferred to the building (COP = 3 - 5). In comparison, the efficiency of a diesel furnace currently used in Kuujuaq and the other northern villages is 0.8.

Figure 7 – Basic working principle of a heat pump (modified from Moran et al., 2018).

Ground-source heat pumps (GSHP) have the advantage that the temperature of the cold source, the underground, has a relatively constant temperature over the year due to the thermal inertia of the subsurface. In order to extract the heat from the subsurface, plastic (High Density Polyethylene, HDPE) pipes have to be buried into the ground. This installation is commonly known as horizontal ground heat exchanger (GHE). The current technical temperature limit of the heat pumps is $-10\text{ }^{\circ}\text{C}$. This means that a mixture water/antifreeze (e.g., 30 % of propylene glycol, freezing point $-14\text{ }^{\circ}\text{C}$) is able to extract heat from a medium at a temperature as low as $0\text{ }^{\circ}\text{C}$. As we will show later in the report, the very shallow subsurface temperature in Kuujuaq varies between $-1\text{ }^{\circ}\text{C}$ (winter) and $5\text{ }^{\circ}\text{C}$ (summer), therefore hot enough to run a GSHP. We can anticipate a gain of around $3\text{ }^{\circ}\text{C}$ in the ground loop and the inlet fluid temperature at the evaporator of the HP would be $-5\text{ }^{\circ}\text{C}$ in winter and $1\text{ }^{\circ}\text{C}$ in summer (**Figure 8**), enough to properly run the HP.

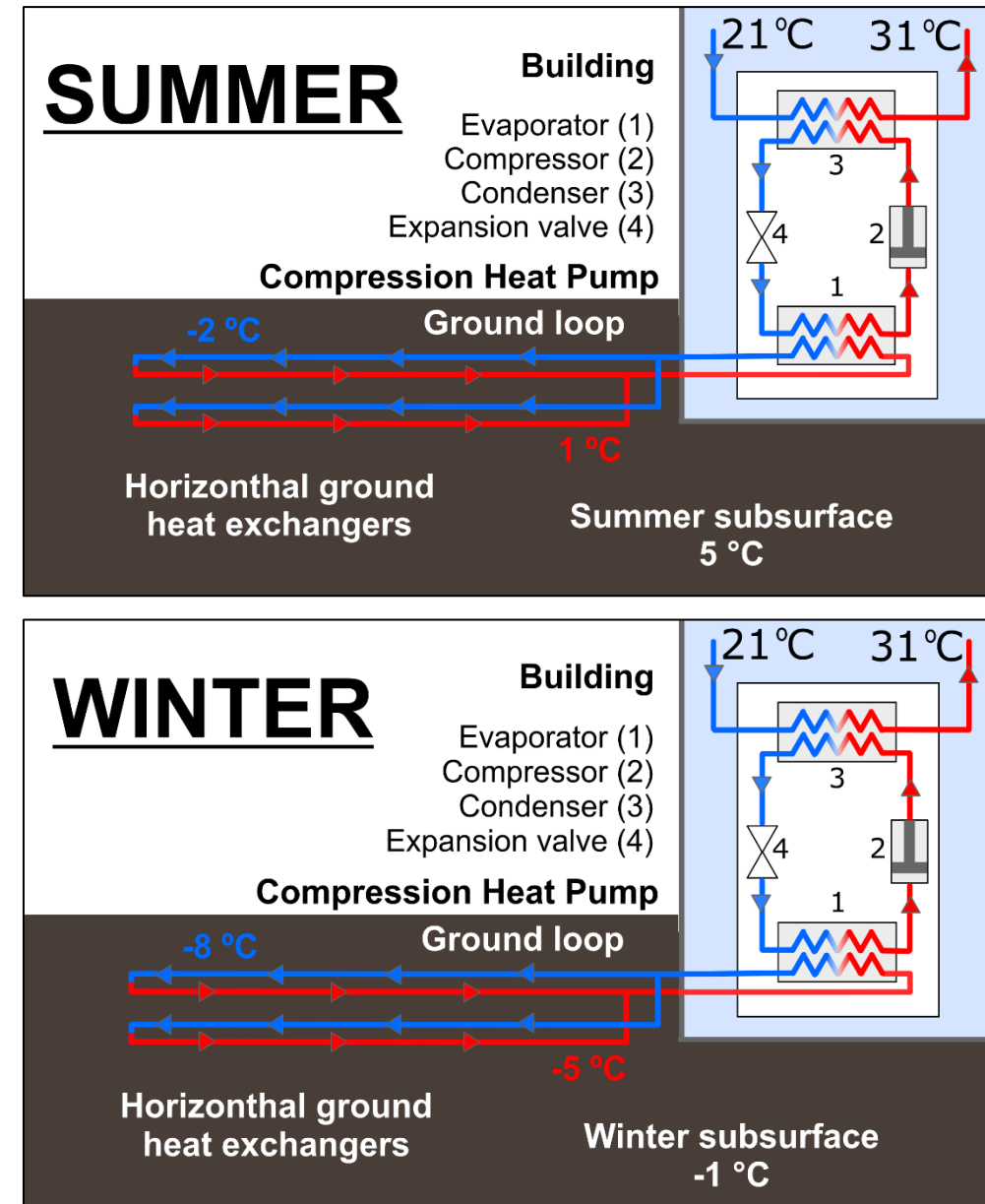


Figure 8 – Diagram of a GSHP system with horizontal heat exchangers.

The Kuujuaq community swimming pool is currently heated with two 130,000 Btu/h (38 kW) diesel-fired burners (**Figure 9**). Since these burners have to be replaced, a GSHP system has been proposed in order to reduce the diesel consumption and to demonstrate the technical feasibility of this technology in such cold climate.

The pool is running from mid-June to mid-September and the annual diesel consumption in 2019 was 3,900 liters, approximately amounting to \$ 5,800 CAD (at subsidized cost of diesel) and 10 tons of equivalent CO₂.

The electricity will be provided by a solar photovoltaic (PV) system that will be placed on the roof of the Arena close by. The total PV system installed capacity will be 100 kW.



Figure 9 – Diesel-fired boilers currently heating the swimming pool water.

The horizontal GSHP system consists of (more details in the “*Rapport technique – Deuxième partie: Design, proposition de concept et estimé budgétaire*” Audy 2020):

- 4 km of HDPE pipes (1 ¼” diameter, SDR11) to serve as the horizontal ground loop. Eight 500-m-long loops have been placed at 1 m depth in the parking lot surrounding the pool (**Figure 10, 11 and 12**), four loops feed one heat pump;
- 2 compression heat pumps with nominal capacity of 6 tons (18 kW), but due to the antifreeze and mean temperature correction factors, the single thermal output is expected to be 15 kW, for a total of 30 kW (**Figure 12**);
- The working fluid is a mixture of water and 33 % antifreeze (propylene glycol, **Figure 13**);
- 2 plate heat exchangers of 15 kW each;
- One diesel-fired boiler is left in place for the first year of operation in order to serve as a back-up. After the first year it will be replaced by a smaller one (lower thermal output) or eliminated if the GSHP is able to cover all the peaks as expected.

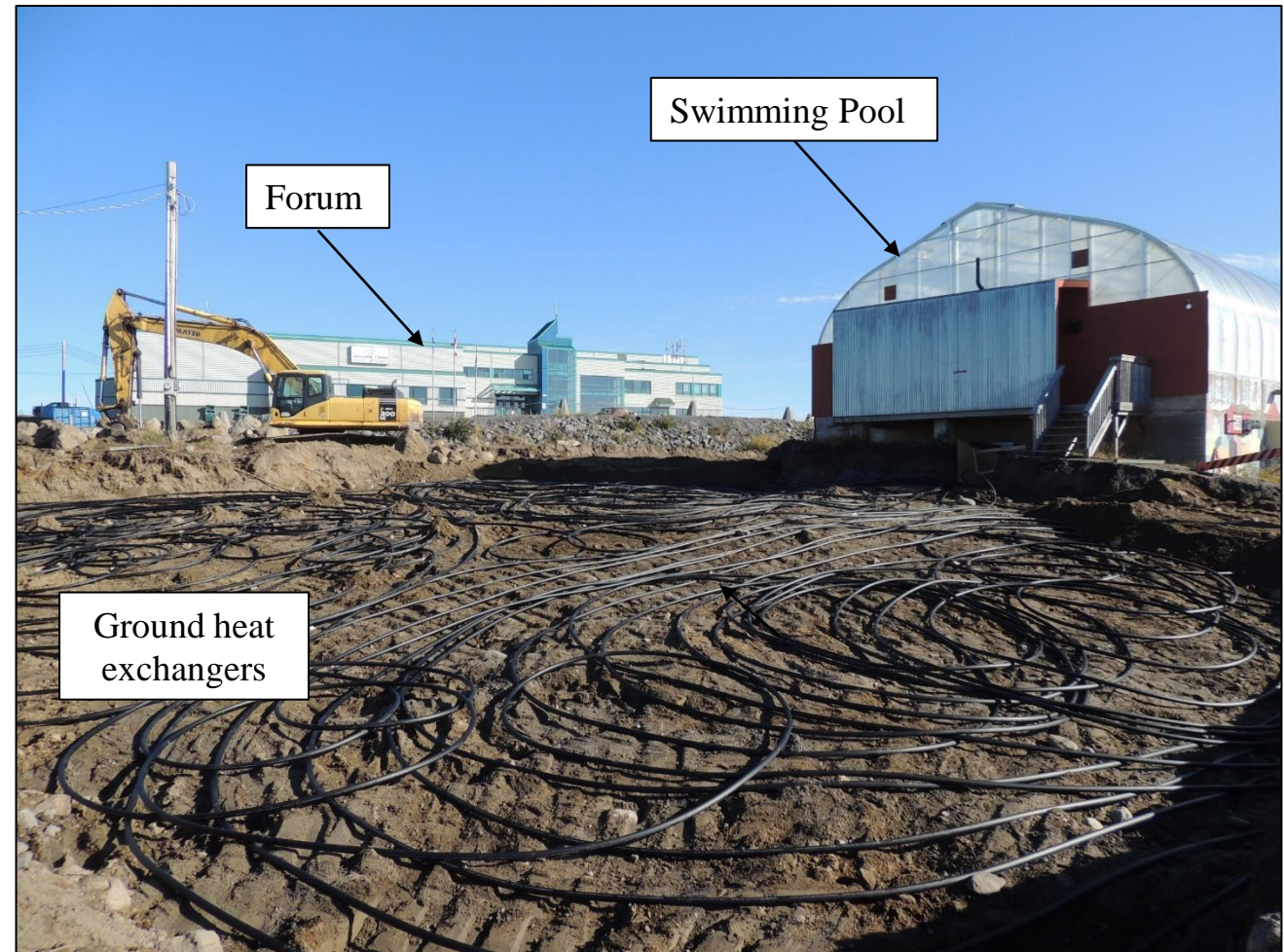


Figure 10 – HDPE loops (ground heat exchangers) installed in the parking lot in front of the pool entrance.

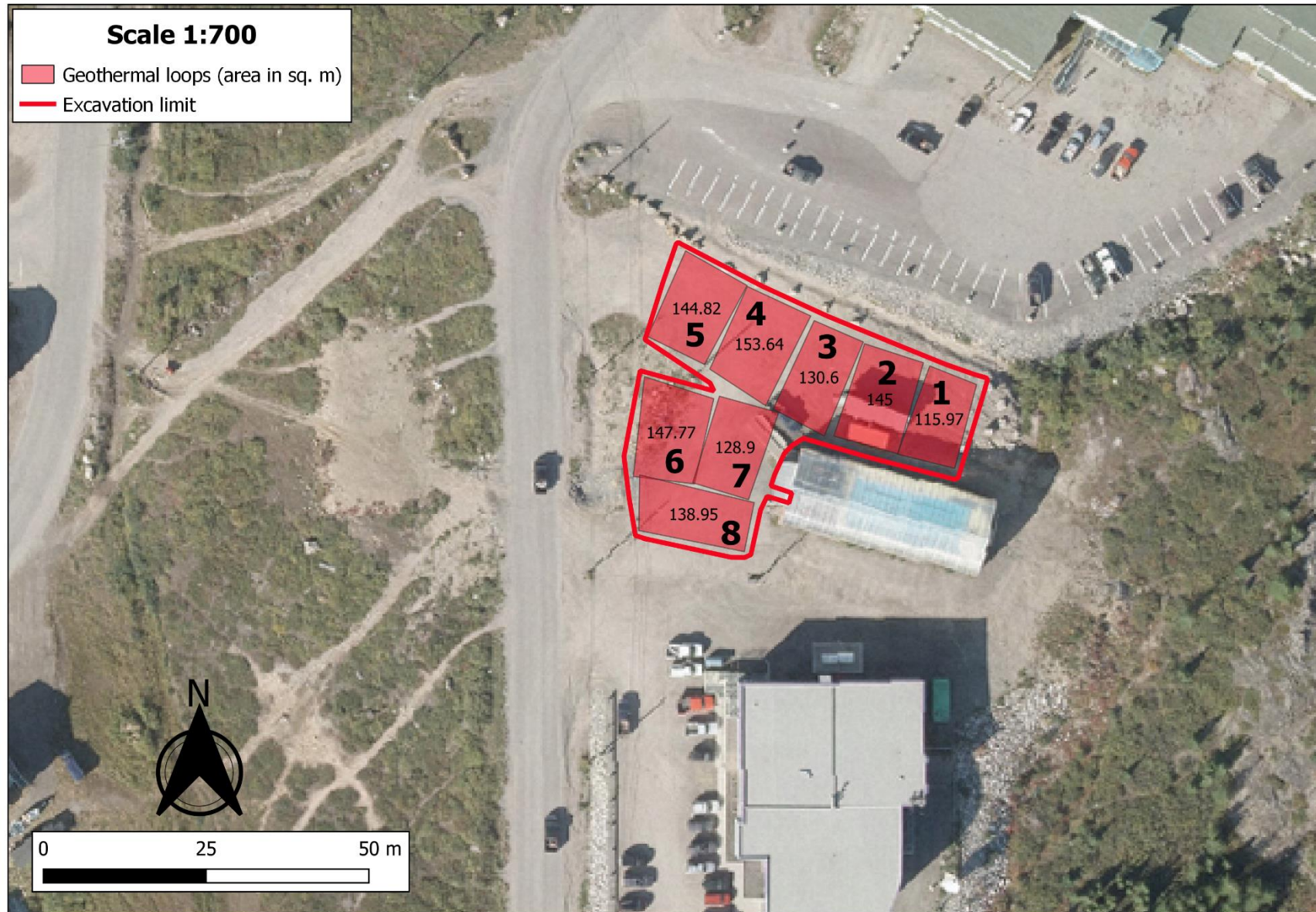


Figure 11 – Number, position and area of the 8 geothermal horizontal loops installed in the parking lot around the swimming pool. The average area the loops is approximately 140 m². The 500 m pipes of each loop have therefore an average spacing of 0.27 m. Loops 1-3-5-7 are connected to the first heat pump; loops 2-4-6-8 to the second one.

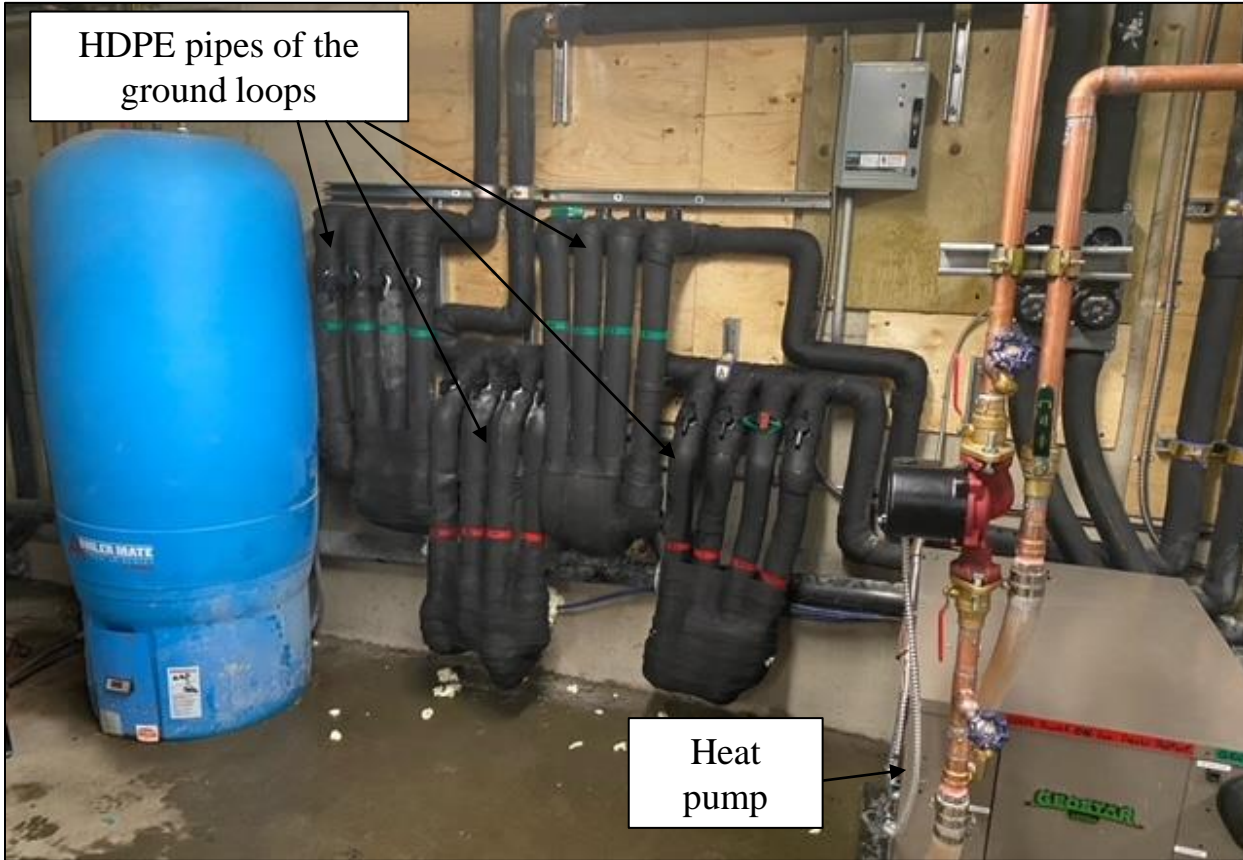


Figure 12 – 16 HDPE pipes (IN and OUT of 8 loops) entering the mechanical room and connected to the two heat pumps (November 2020, Credits Pierre Vallerand, Induktion Géothermie)



Figure 13 – The mixture of water and antifreeze is injected in one of the 8 loops (left). Technical details of the propylene glycol (right).

5. LOCAL GEOLOGICAL OBSERVATIONS

An area of around 1,300 m² was excavated in September 2020 around the swimming pool, area used as parking lot by the users (**Figures 14 and 15**). The average depth of the excavation was 1.2-1.5 m, for a total of 1500-1900 m³ of material. This material (mainly sands, gravels and blocks) has been stored on-site for around 20 days, and then reused for backfilling. By spring 2021, a layer of gravel (10-20 cm) will be placed on top by the Northern Village of Kuujuaq in order to return the area back to its original use (parking lot).

The excavation was meant to host the 4 km of HDPE pipes that will serve as the ground heat exchangers feeding the horizontal GSHP system.



This excavation was used to make some in-situ observations to characterize the underground

from a geological and thermal points of view (**Section 6**). This is crucial to anticipate the behavior of the GSHP and to analyze the data collected by the monitoring system installed (**Section 7**).

A total 20 geological observations have been made throughout the entire excavation. Generally, a 20-50 cm anthropic gravel pad covers the marine and glacial deposits, that in turn overly the local crystalline bedrock (not detected in the excavation and 2-m-deep geological surveys).

Figure 15 – Western part of the excavation.

Figure 14 – Northern part of the excavation.



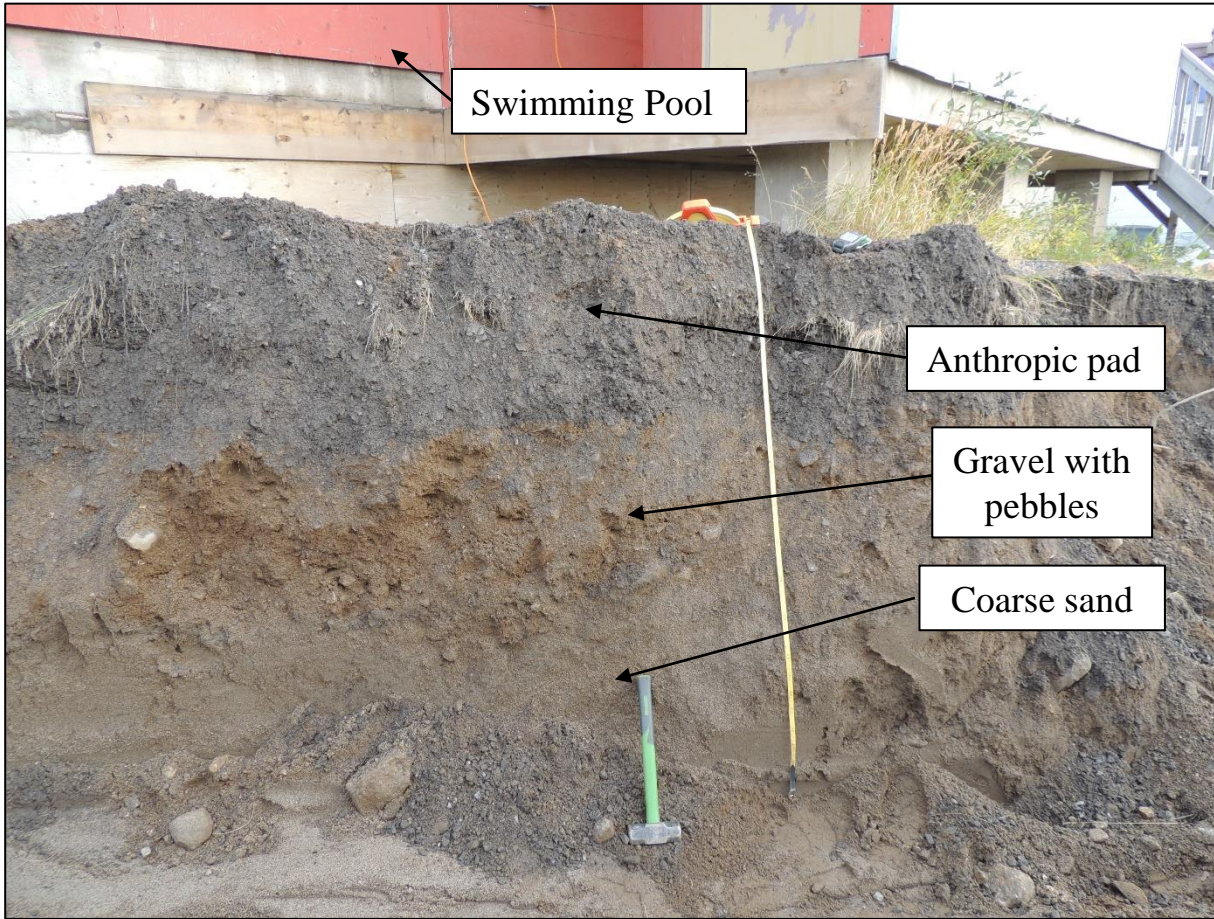


Figure 16 – Geological observation n. 14, coarse sands (see Figure 16 for location).

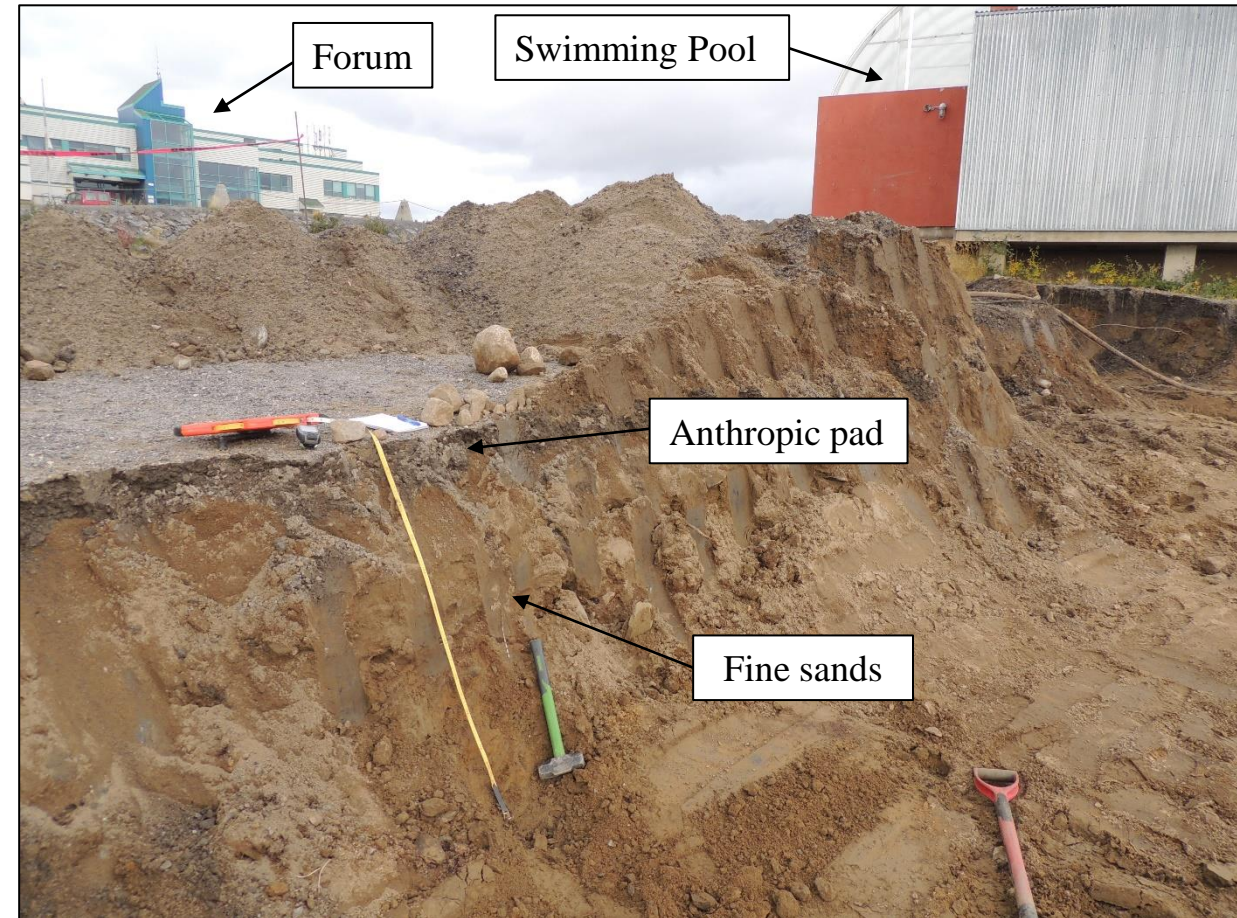


Figure 17 – Geological observation n. 9, fine sands (see Figure 16 for location).

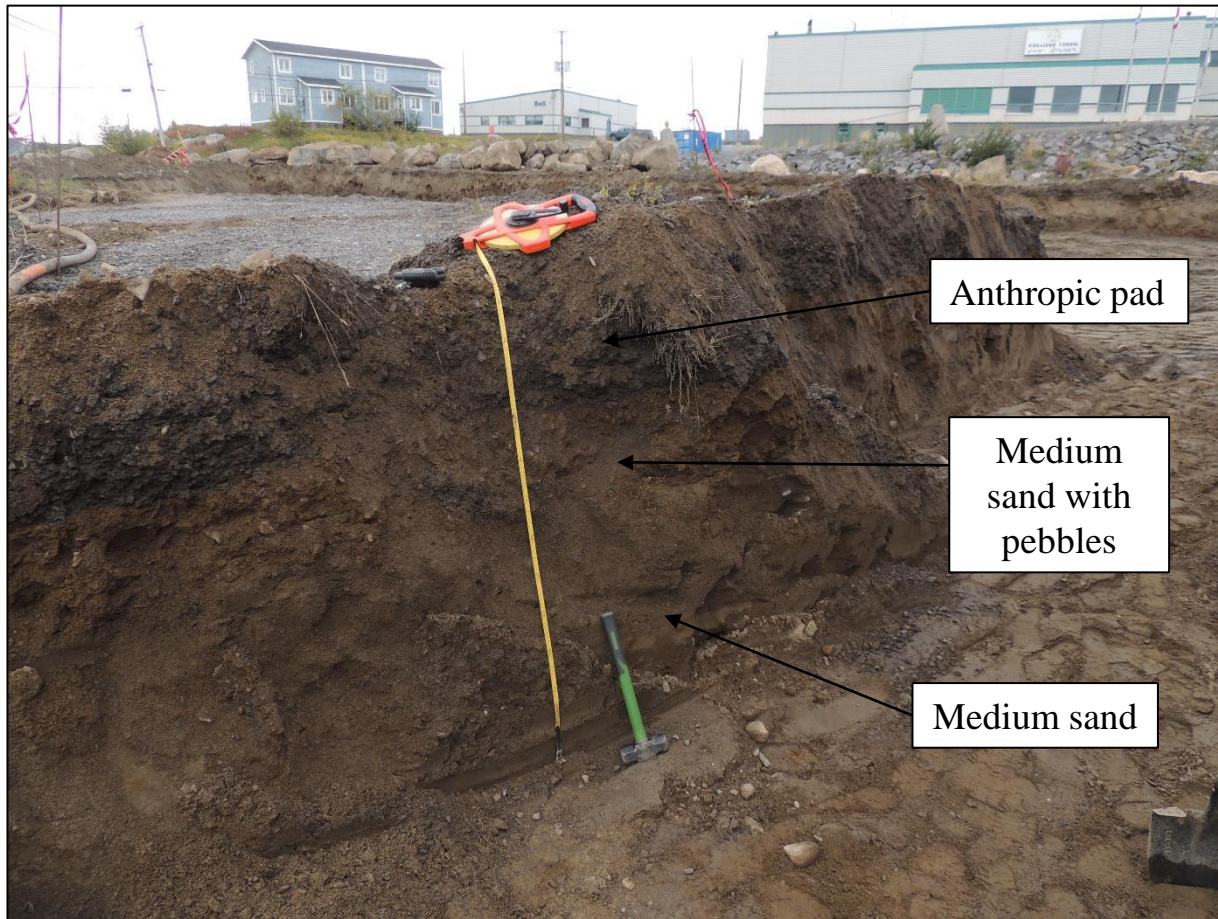


Figure 18 – Geological observation n. 7, transition zone (see Figure 19 for location).

A 3-4 cm layer of insulating material (extruded Styrofoam used for building’s insulation) was found at 1.8 m below ground level (b.g.l.) in the NE side of the excavation (**Figure 19**). This is supposedly related to the old pool building and it seems to be covering an area of 150-200 m² on this side of the excavation.

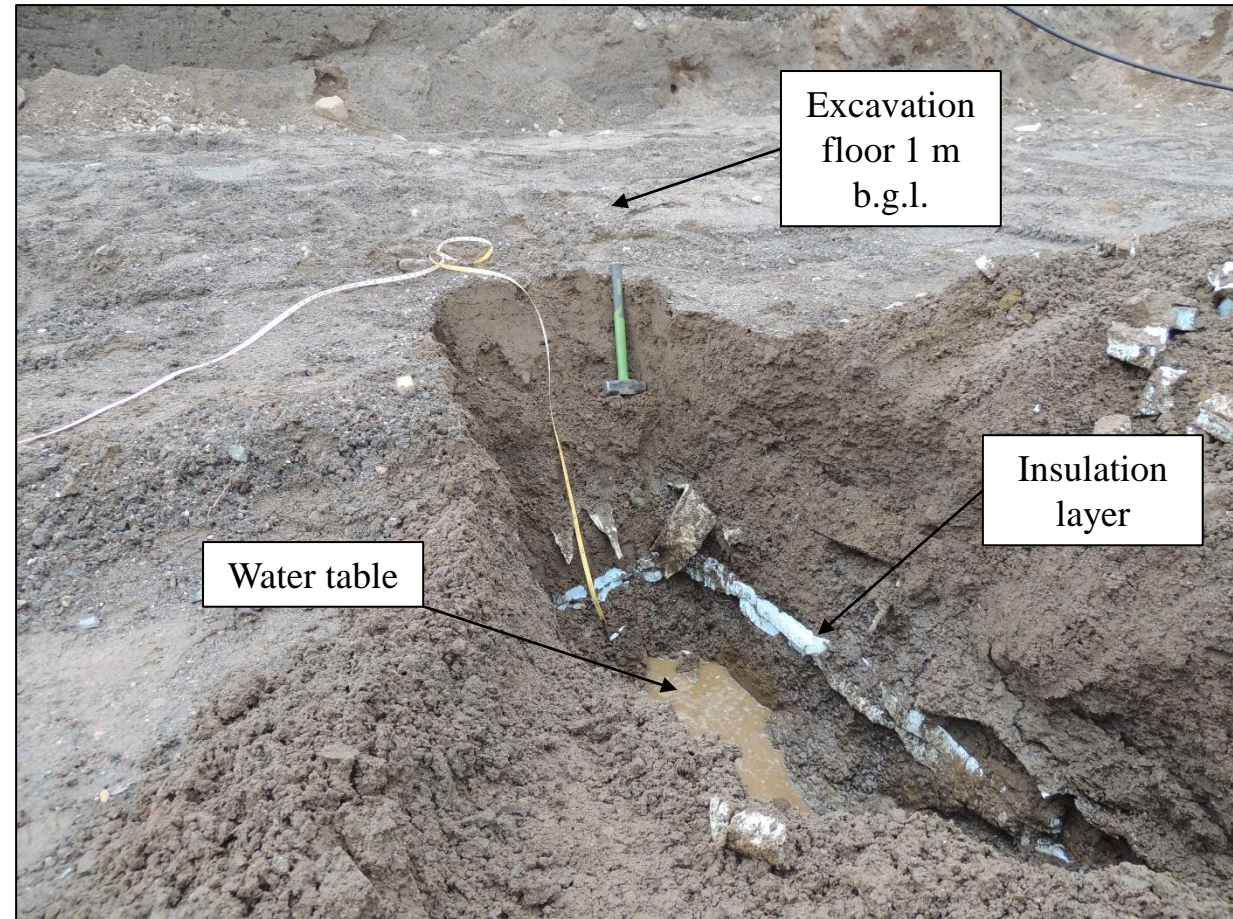


Figure 19 – Geological survey n. 21. Water table is at 2 m b.g.l. and a 3-4 cm insulation layer is located right above it, 1.8 m b.g.l. (see Figure 19 for location).

The punctual observations allowed us to make a wider geological interpretation of the entire area (**Figure 20**). It is clear that the western area (surveys 2-3-4-10-11-17-22) mainly consists of fine material (fine sands and sometimes silts), while the eastern area (surveys 1-6-12-14-15-16-TRT-18-21) presents coarser material (medium to coarse sands and gravels).

Surveys 7-8-13 represent a transition zone between those two geo-types. Pebbles (3-10 cm) and blocks (10-50 cm) are present more or less everywhere in the above-described deposits. Wetness of the deposits is higher in the northern area (surveys 3-4), with 60-70% and more. Rainwater was stable at the depth of the excavation (1.2-1.5 m) in this area at the time of the works, from NW to NE, which means that materials underneath have low permeability (silty sands). Water table is at about 1 m below the pipes floor, i.e. at 2 m from ground level at the time of the works. Since, as anticipated, the Northern Village will place a layer of gravel next spring (2021) to facilitate driving, all the depths mentioned in this report will be increased by 20-30 cm when this work is done.

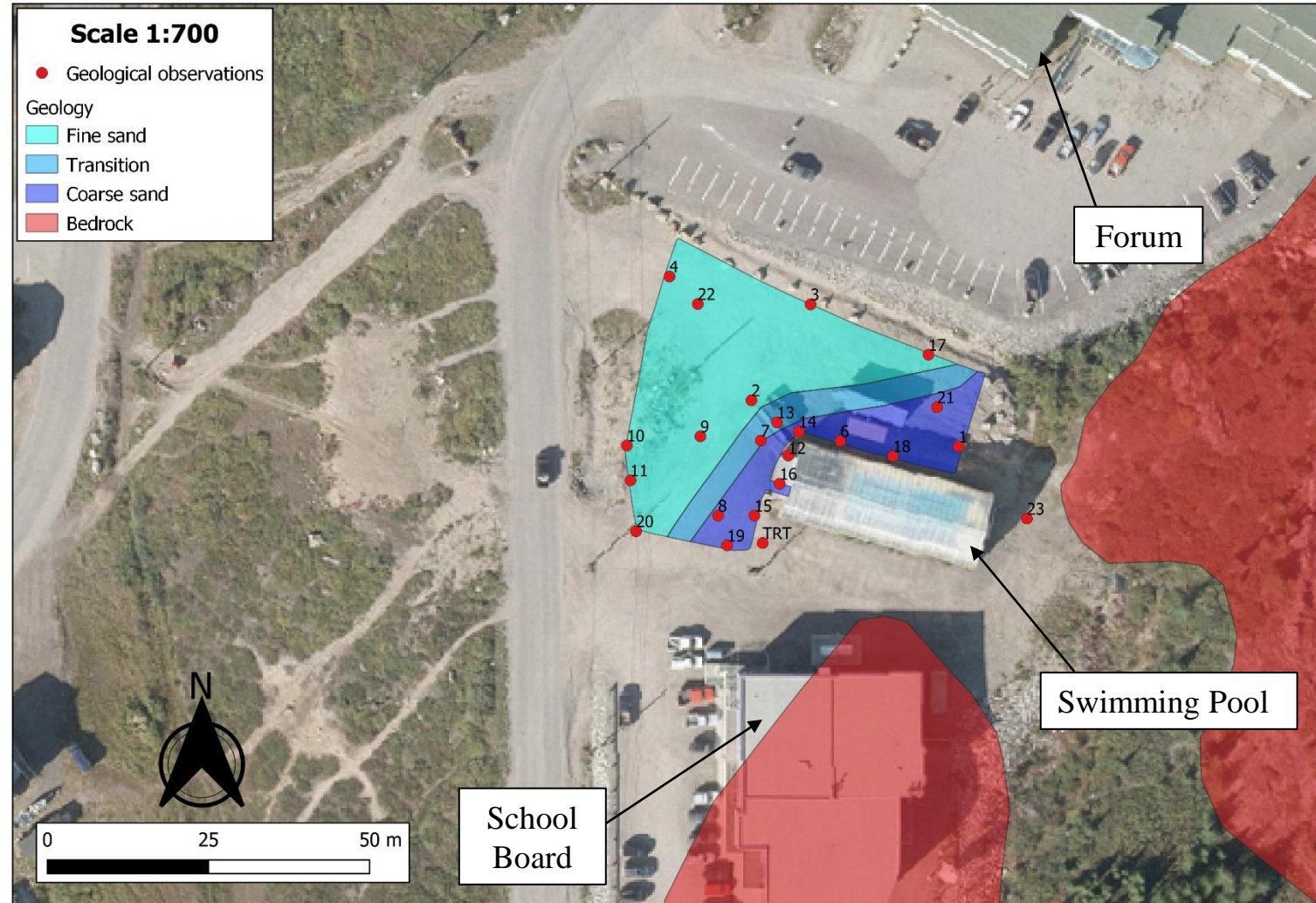


Figure 20 – Geological interpretation of the area hosting the ground heat exchangers around the swimming pool.

6. THERMAL RESPONSE TESTS AND LABORATORY ANALYSES

After a basic geological interpretation (previous section), the entire excavation has been characterized from a thermal point of view. This is critical to anticipate the behavior of both the underground and the system, and to interpret the data of the monitoring system throughout the operation of the GSHP.

Ten samples were collected (**Figures 21 and 22**) to be analyzed in the laboratory via a dual needle probe (**Figure 23**). This analysis allows estimating the thermal conductivity (W/mK) and diffusivity (m^2/s) of the geologic media, and therefore the heat capacity (J/m^3K) which is the ratio of the firsts. An oscillatory thermal response test was also performed at the southern limit of the excavation (red line in **Figure 21**).

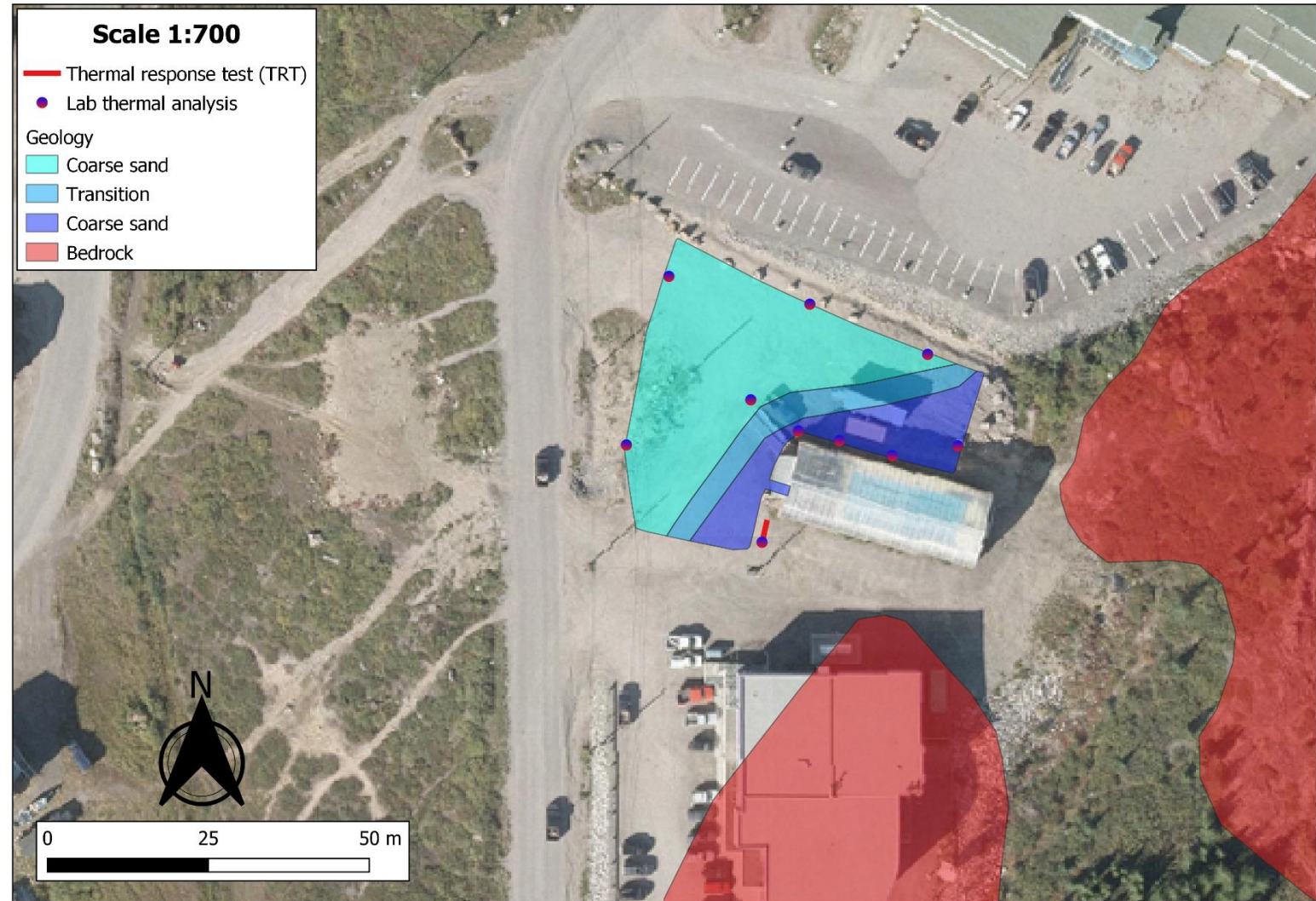


Figure 21 – Characterization of the thermal properties in the excavated area.



Figure 22 – Geological observation n. 10 with samples of fine sands collected for laboratory analysis of thermal properties .

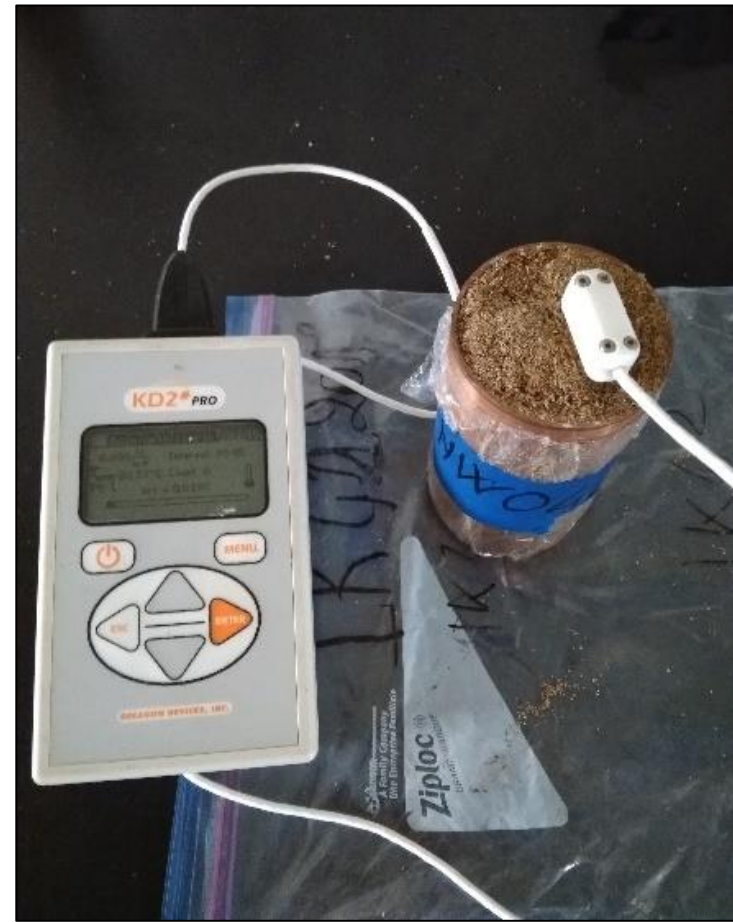


Figure 23 – Thermal property analysis with a dual needle probe.

Samples were collected by means of a copper cylinder (length 12 cm, diameter 6.6 cm) with the aim of minimizing the disturb and preserving the in-situ conditions as much as possible. Thermal analyses were then carried out in the laboratory at ambient temperature (20 °C, **Figure 23**). Nevertheless, the sample scale does not fully represent the in-situ geological heterogeneity. Therefore, an in-situ thermal property evaluation was also performed via a thermal response test with heating cables (**Figure 24**).

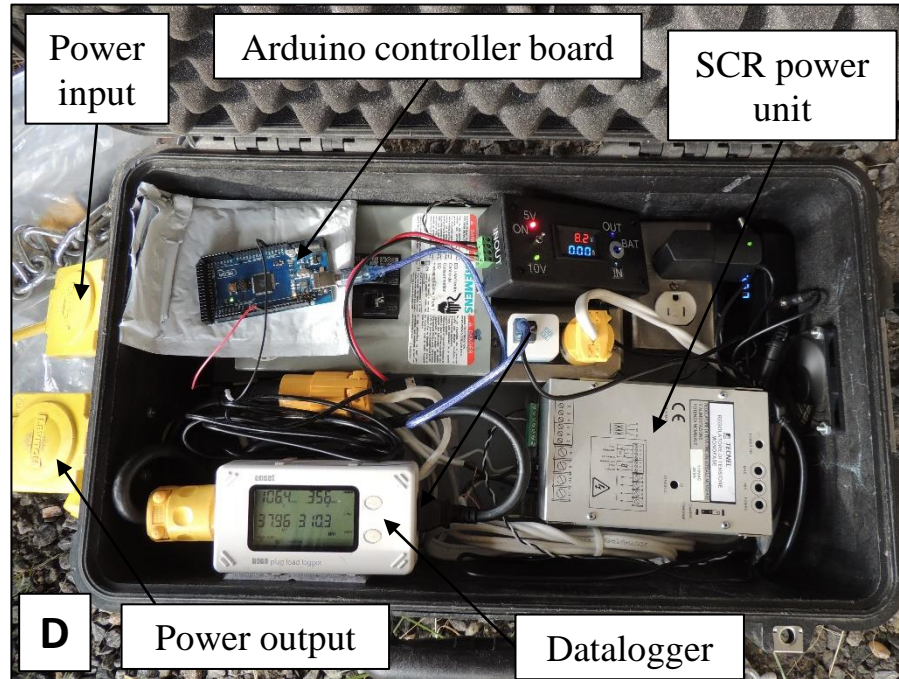
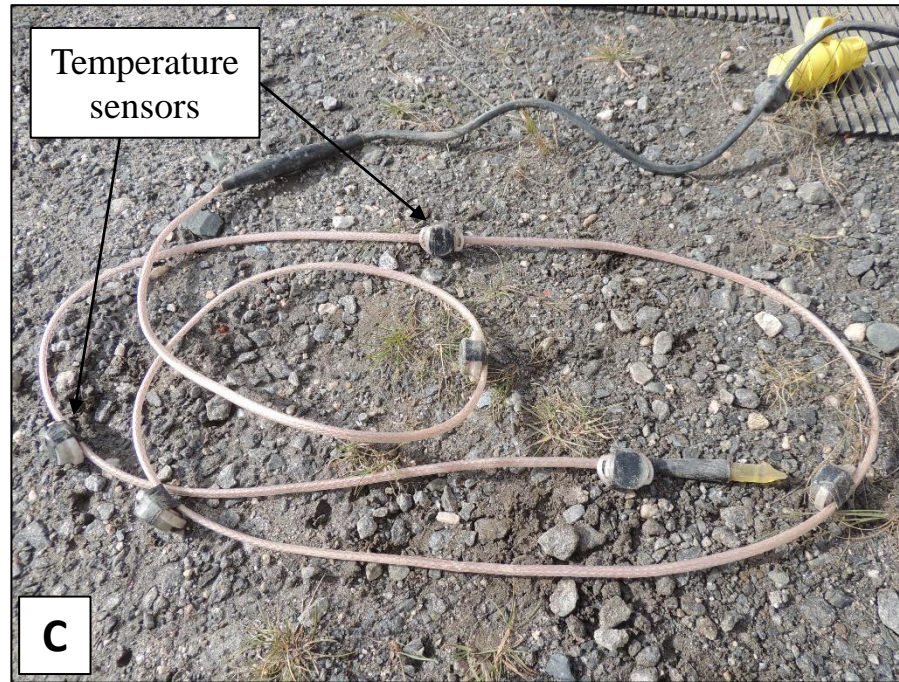
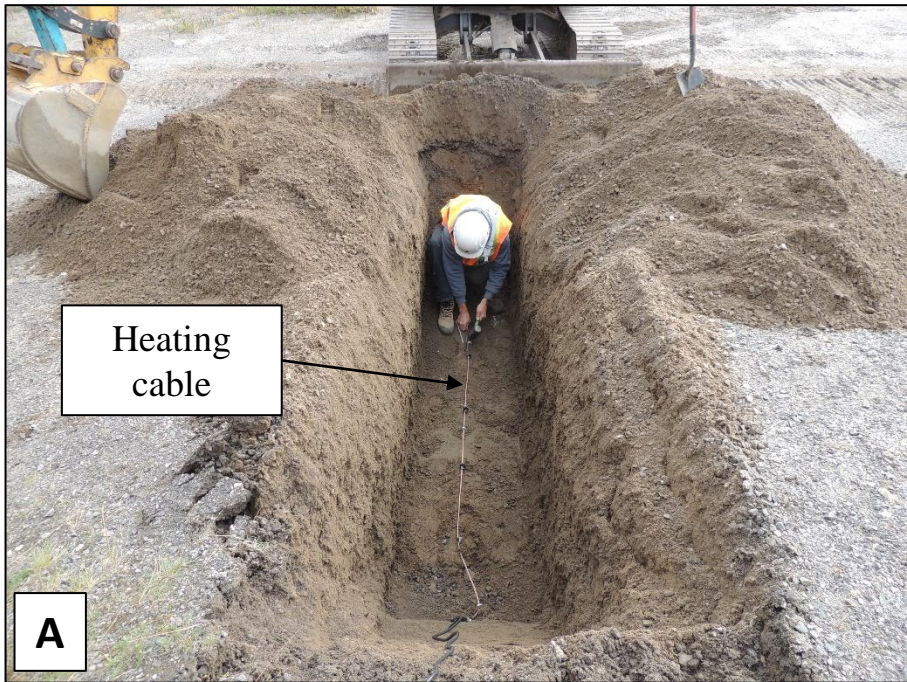


Figure 24 – Thermal response test performed with a heating cable. The cable is placed at the bottom of the excavation (A), which is then backfilled with the same material (B). At the end, the cable is recovered to download and analyze the temperature data (C). The power unit (D) is connected to the 120 V / 15 A network in order to heat the cable and record the data.

Several different oscillatory thermal response tests (e.g. **Figure 25**) were performed close by the swimming pool (location in **Figure 21**). The results show thermal conductivity of 1.58 ± 0.08 W/mK (acc. 3.5 %), thermal diffusivity of 1.24 ± 0.1 mm²/s (acc. 20 %) and heat capacity of 1.27 ± 0.06 MJ/m³K (acc. 20 %). This test gives more accurate information than the laboratory analyses. Therefore, a correction factor has been calculated by comparing these results to the laboratory analysis carried out on the sample taken at the same site. These correction factors have then been applied to all the other samples in order to get the corresponding in-situ thermal properties all over the excavation (results shown in **Section 7**).

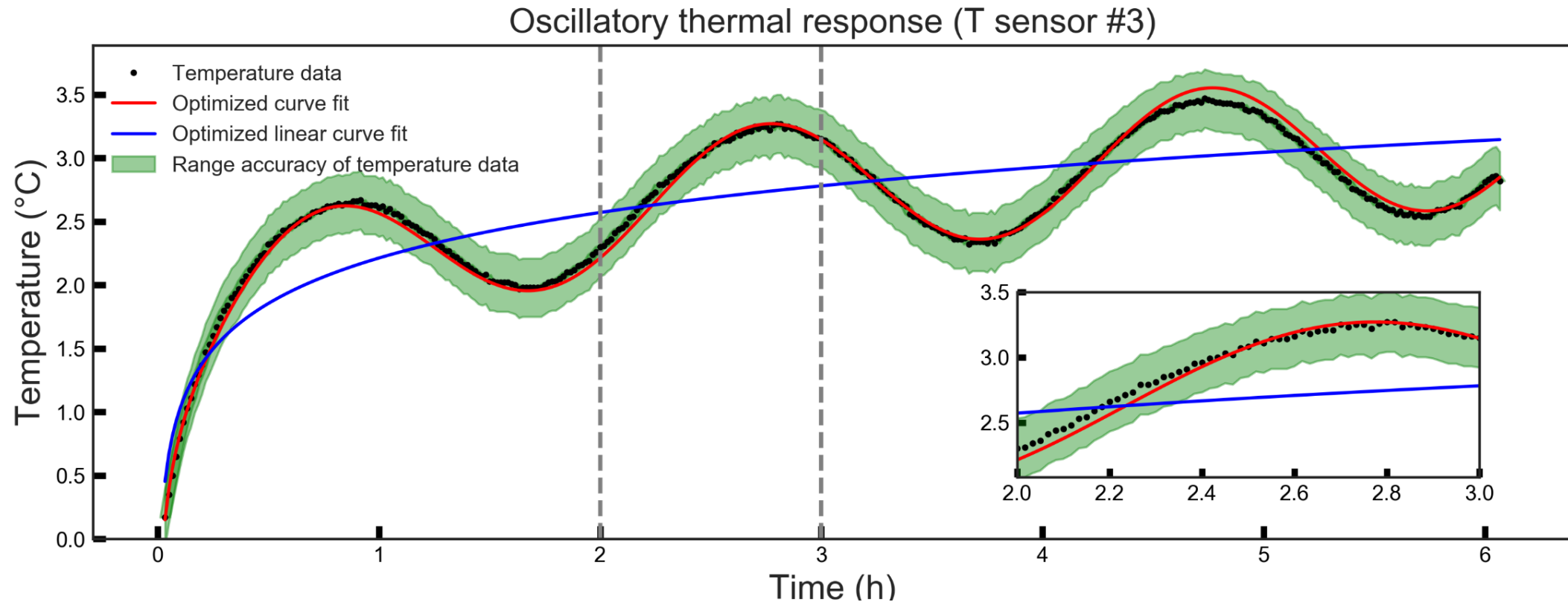


Figure 25 – Results of the oscillatory thermal response test carried out with a period of 2 hours.

7. THERMO-GEOLOGICAL INTERPRETATION FOR SYSTEM'S PERFORMANCE

A detailed geological and thermal characterization was carried out in order to anticipate the behavior of the GSHP system and the underground. The horizontal ground heat exchangers were installed at 1 m b.g.l. in the marine quaternary deposits overlying the bedrock. Fine sandy sediments were observed in the north-western excavated area, while coarser sandy-to-gravelly materials were detected in the eastern side. In the early summer, 80-100% of water saturation is anticipated due to snow melting occurring in late May / beginning of June.

Therefore, higher thermal conductivity and heat capacity are expected all over the area (**Table 1**), and the overall efficiency of the system is foreseen at the beginning of the season (end June - mid July). In this period, a slightly better efficiency is expected in the western area (**Figure 26**). Whereas, later in the season, when the saturation decreases and the water table stabilizes at 2.0 m b.g.l, the difference between the two sides is anticipated to increase, with always better efficiency in the western area (**Figure 27**). Thermistors cables will allow to verify this hypothesis of a higher ground temperature expected in the western side compared to the eastern side. This can also be emphasized by the presence of the insulating material found on the eastern side, which is supposed to underlie the entire geothermal loop n. 1.

Beginning of the season (saturated)

	Thermal conductivity W/(m·K)	Heat capacity MJ/(m ³ ·K)	Thermal diffusivity mm ² /s
<i>Eastern average</i>	1.72	2.21	0.78
1	1.52	1.86	0.82
14	1.71	2.29	0.75
TRT	1.90	2.31	0.82
18	1.75	2.12	0.82
6	1.71	2.50	0.69
<i>Western average</i>	1.62	2.44	0.68
10	1.60	2.37	0.67
2	1.57	2.44	0.64
4	1.54	2.84	0.54
3	1.98	2.12	0.93
17	1.43	2.43	0.59

End of the season (unsaturated)

	Thermal conductivity W/(m·K)	Heat capacity MJ/(m ³ ·K)	Thermal diffusivity mm ² /s
<i>Eastern average</i>	1.34	1.29	1.05
1	1.35	1.16	1.17
14	0.96	1.18	0.82
TRT	1.58	1.27	1.24
18	1.74	1.80	0.97
6	1.08	1.04	1.04
<i>Western average</i>	1.47	2.19	0.68
10	1.48	2.38	0.62
2	1.59	1.99	0.80
4	1.14	1.76	0.65
3	1.72	2.45	0.70
17	1.45	2.35	0.62

Table 1 – Thermal properties corrected by the in-situ.

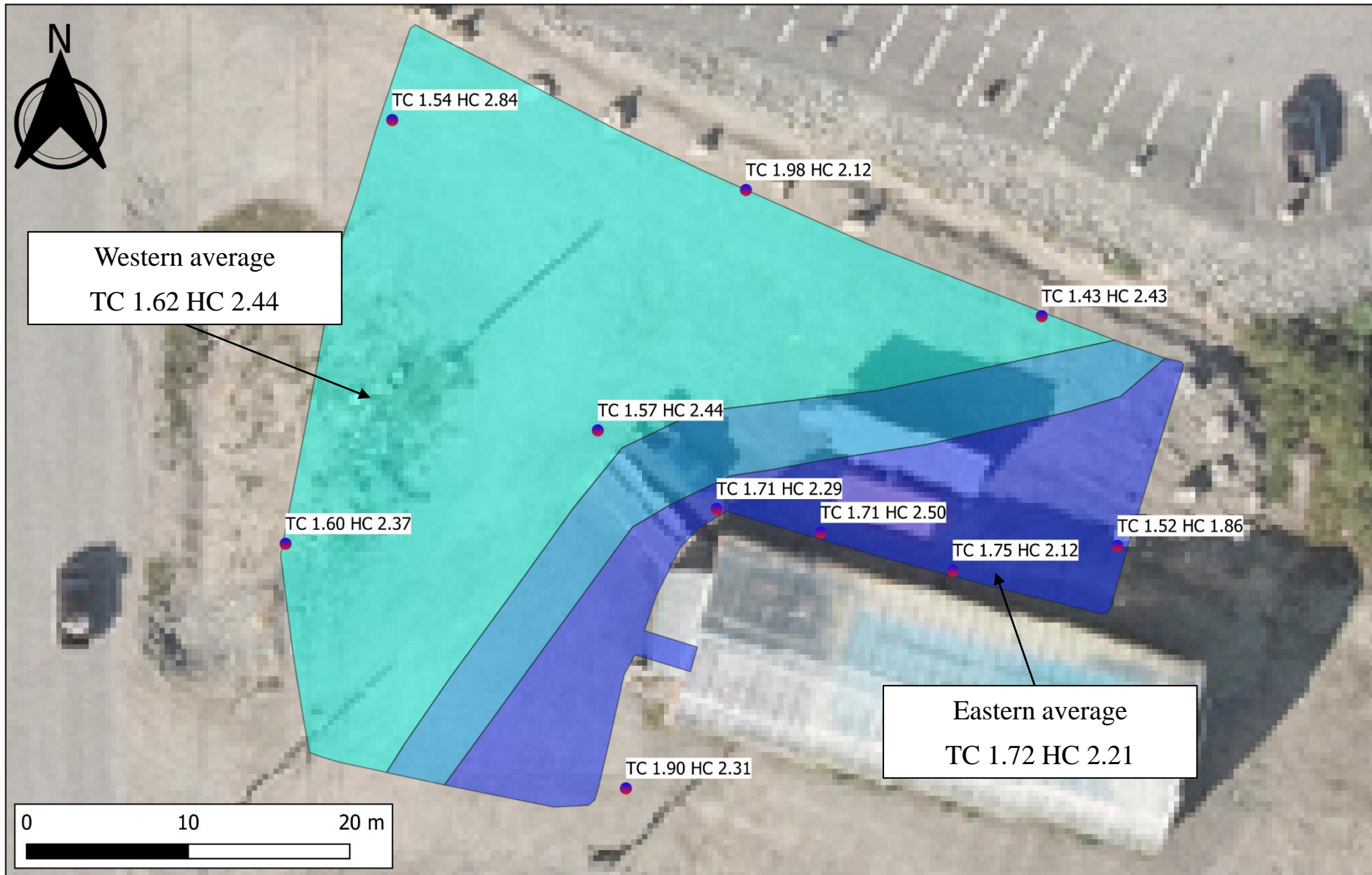


Figure 26 – Thermal properties expected at the beginning of the season (saturated). The efficiency of the system is anticipated to be higher in the western side.

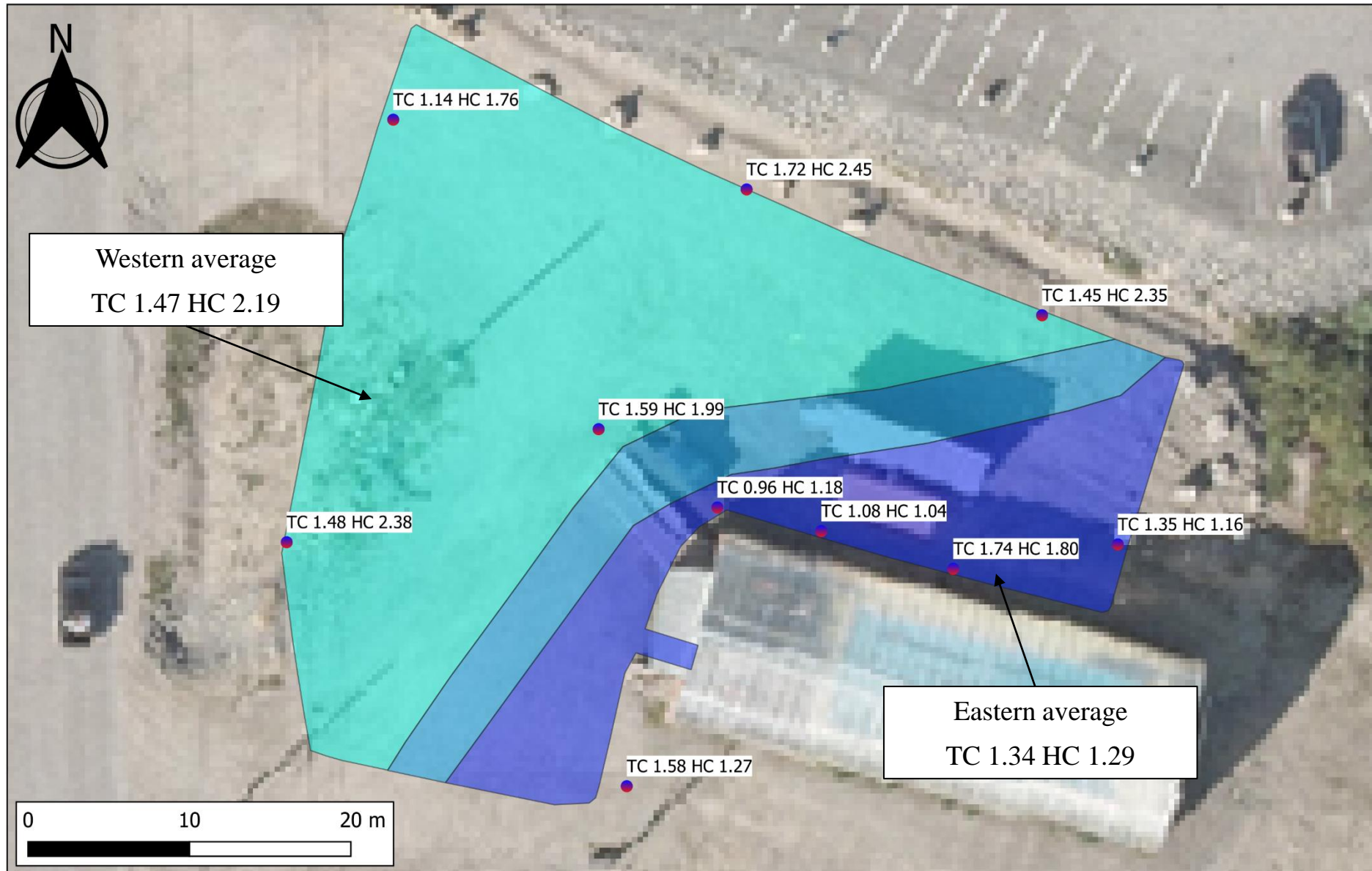


Figure 27 – Thermal properties expected at the end of the season (unsaturated). The efficiency of the system is anticipated to be higher in the western side.

8. MONITORING SYSTEM

This pilot project aims at demonstrating the effectiveness of using very shallow geothermal energy to heat buildings in Nunavik. Therefore, a proper monitoring system was put in place to understand and follow the behavior of the GSHP and the underground. The monitoring system is made of:

- Three thermistors cables to record the underground temperature throughout the year (**Figures 28 and 29**). Two of them are inside the geothermal loops (NW and NE) and one is outside to monitor the undisturbed temperature (UN);
- One heat meter connected to one of the two heat pumps, including two fluid temperature sensors and a flow meter (**Figure 30**);
- Two air temperature sensors places inside and outside the swimming pool (**Figure 31**).

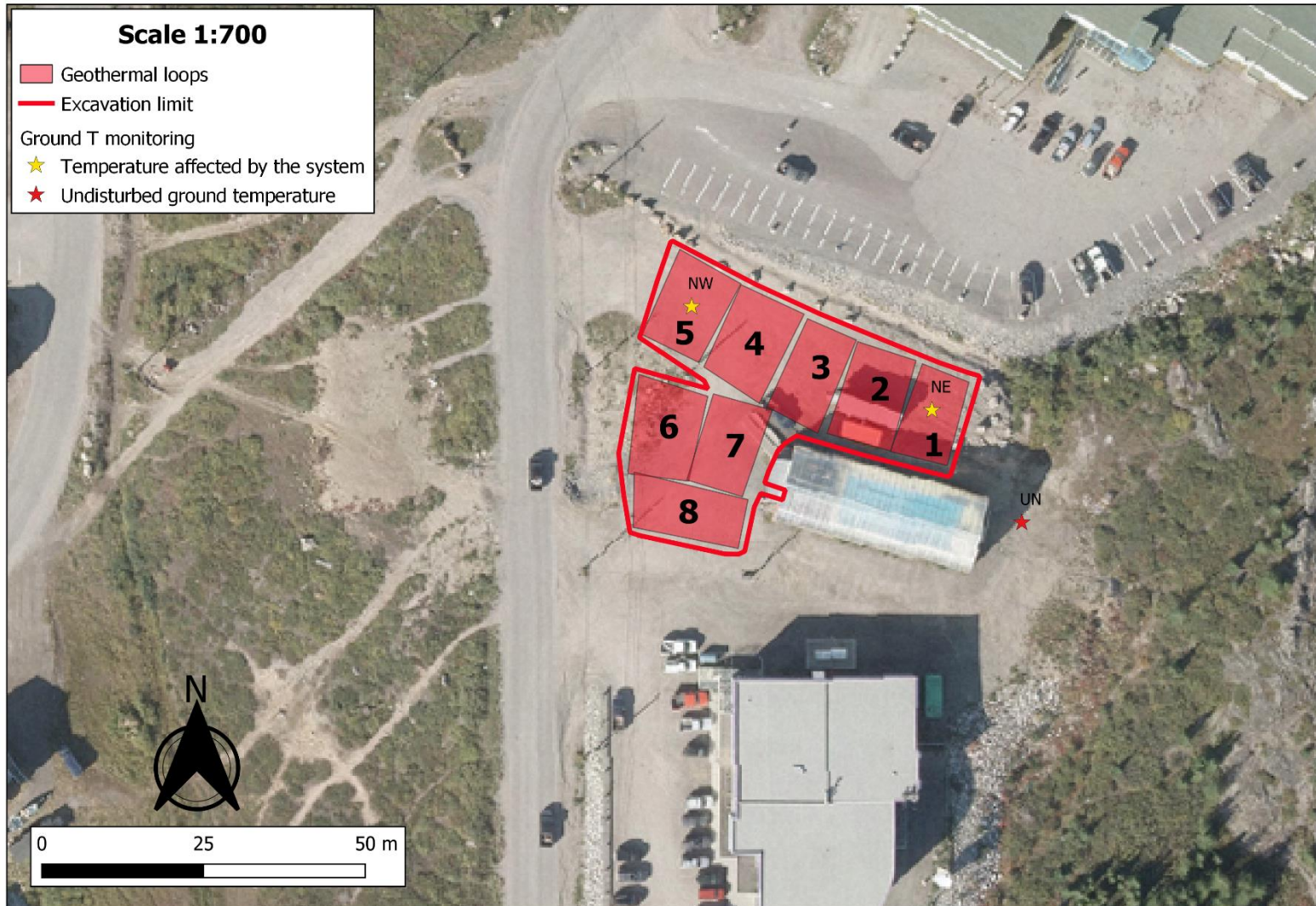


Figure 28 – Position of the ground temperature monitoring cables.

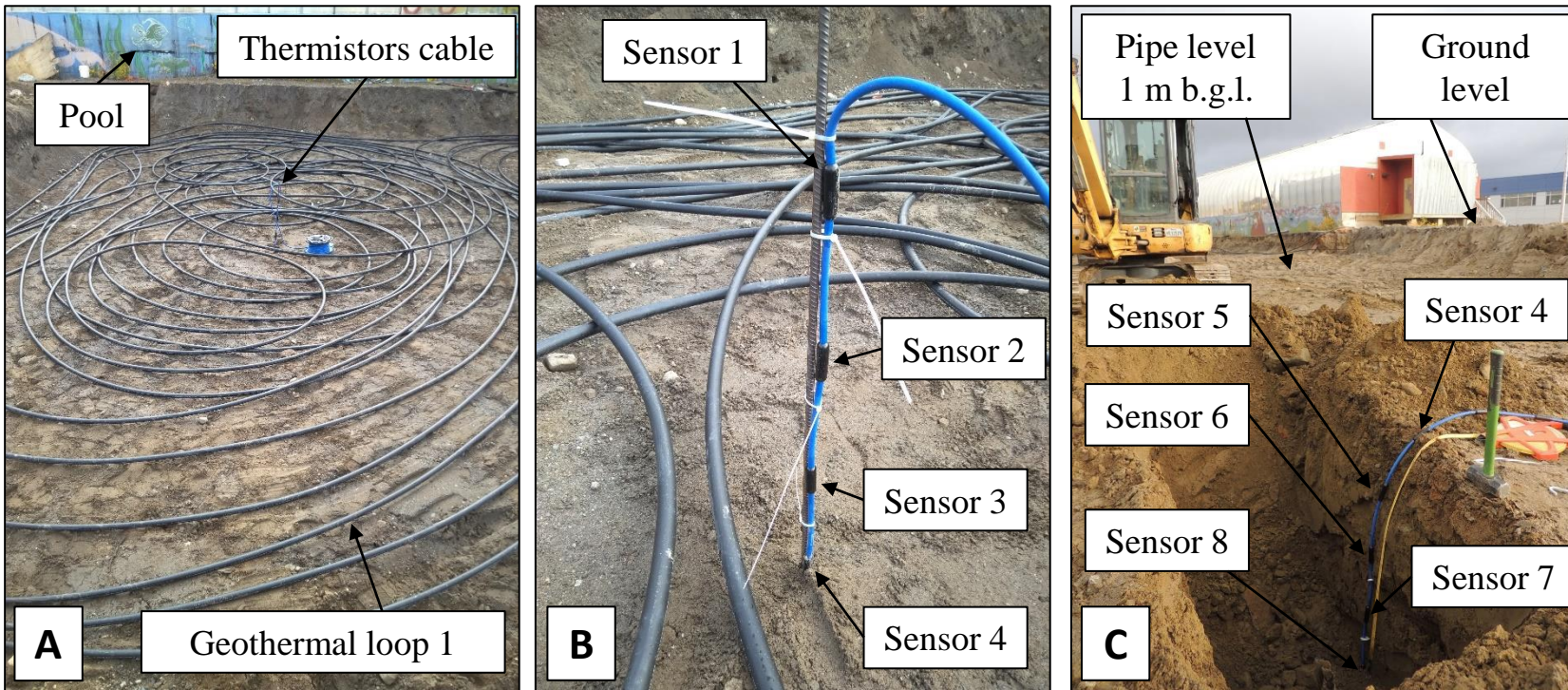
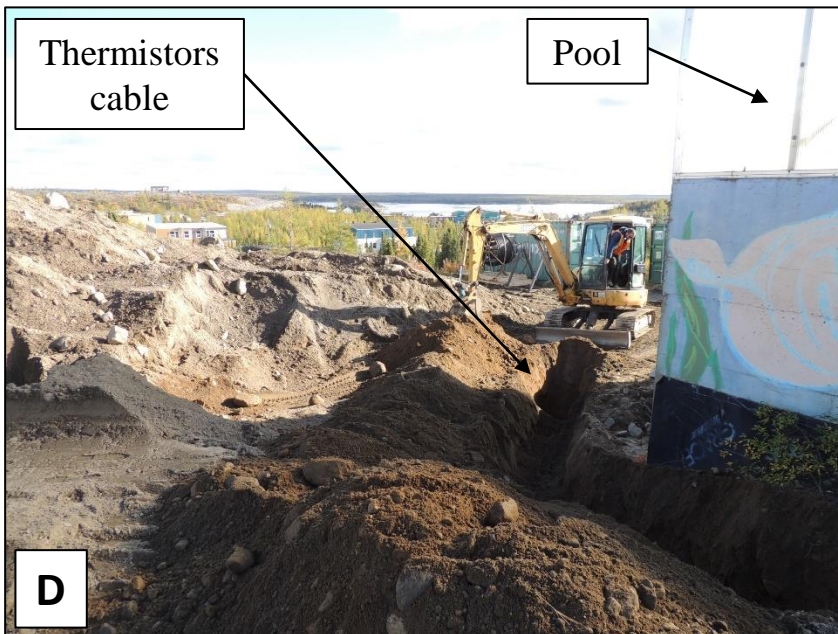


Figure 29 – Ground temperature monitoring cables. A-B: cable NE placed inside the area of geothermal loop n. 1; C: cable NW placed inside the area of geothermal loop n. 5; D: cable UN placed outside the main excavation and the geothermal loop area

Two cables (NE and NW) were installed inside the geothermal loop area. In each cable, there are 8 thermistors (3 kOhm, accuracy 0.1 °C, resolution 0.01 °C, RST Instruments Ltd.) spaced by 25 cm. The deepest sensor (n. 8) is at 2 m b.g.l.,



the shallowest (n. 1) at 0.25 cm b.g.l. (**Figure 29 B and C**). As anticipated in Section 4, these depths will have to be increased by 20-30 cm once the gravel pad is in place. One cable (UN) was installed outside the geothermal loop area (**Figure 29 D**) and has 6 thermistors of the same type but spaced by 50 cm. This cable was supposed to be 3 m deep, but bedrock was encountered at 2 m, so sensors 1, 2 and 3 are at 0.5 m, sensors 4, 5 and 6 at 1.0, 1.5 and 2.0 m b.g.l., respectively. Three dataloggers (DT2055B 10 channel, RST Instruments Ltd.) collect the data of each cable every 3 h. Cables NE and NW switch to a sampling interval of 1 h from mid may to the end of September in order to have more information during the operation of the GSHP.

The heat meter is a Multical 803M calculator (Kamstrup metering Solutions Canada Inc.), coupled with two Pt500 fluid temperature sensors (accuracy 0.1 °C, resolution 0.01 °C) and the Sitrans FM MAG5000 flowmeter (20 m³/h, Siemens, **Figure 30**). The data logger was set up to record hourly values during the operation of the system.

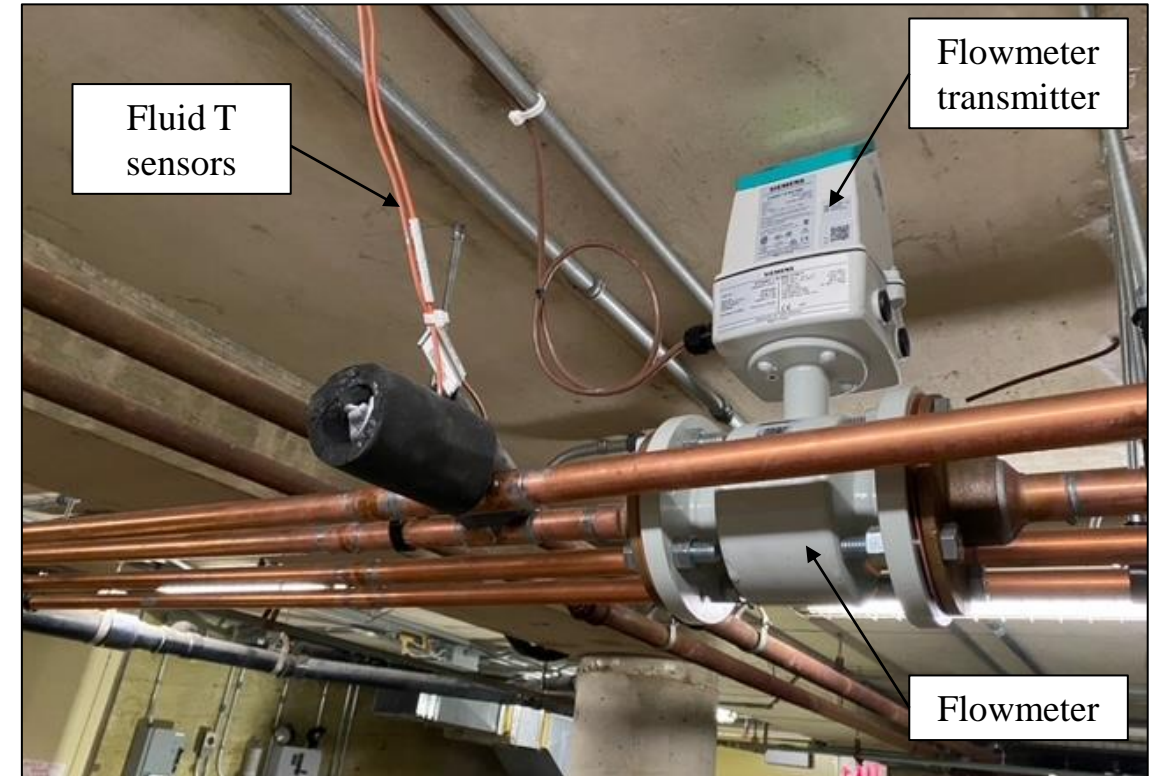
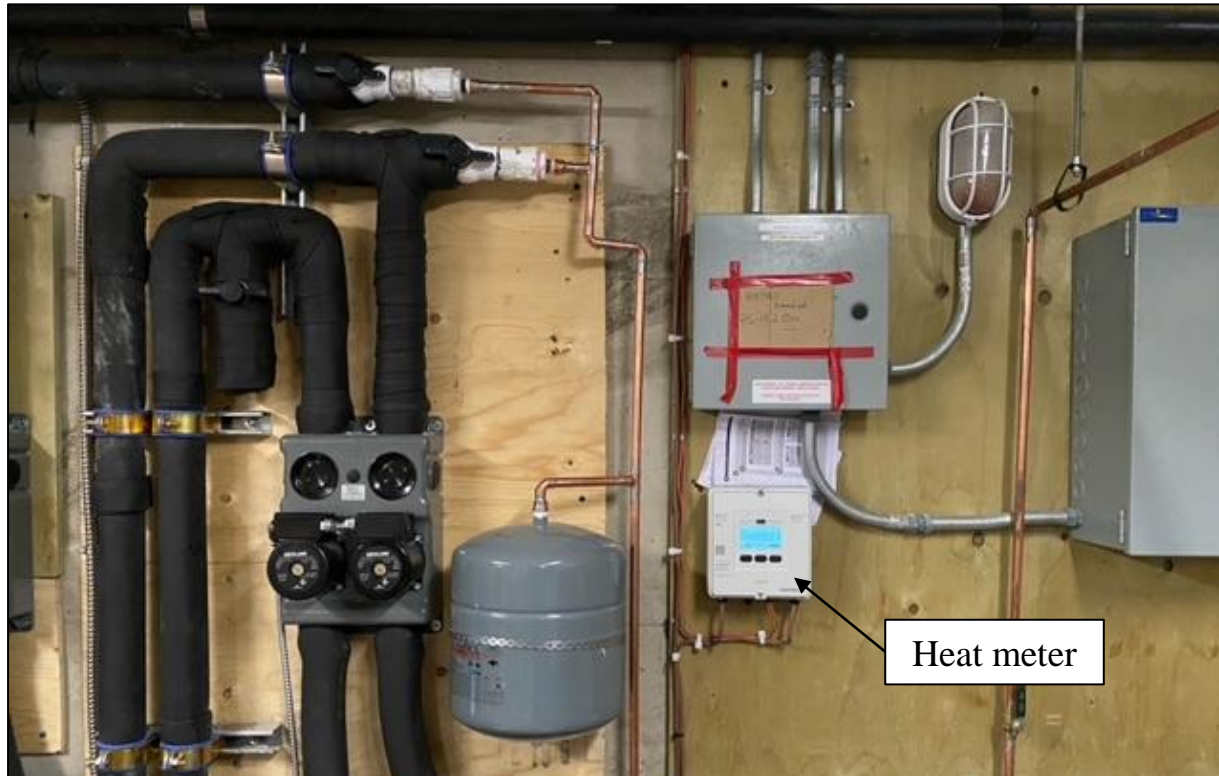


Figure 30 – Heat meter, flow meter and temperature sensors installed on the circuit between the heat pumps and the heat exchangers (load side, Credits Pierre Vallerand, Induktion Géothermie)

The inside and outside air temperature is also monitored via two iBwetland type L temperature sensors, sampling interval 3 h (accuracy 0.5 °C, resolution 0.06 °C, Alpha Mach Inc., **Figure 31**).

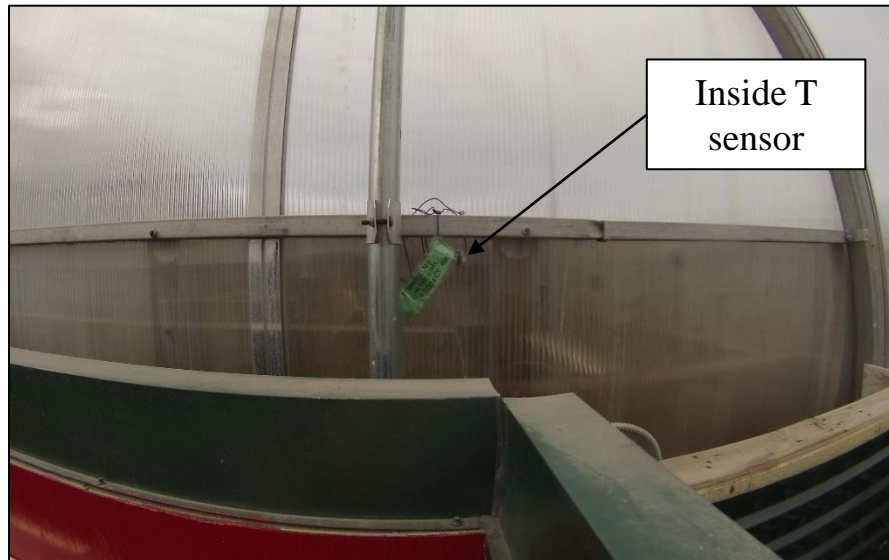


Figure 31 – Inside and outside air temperature monitoring

9. CONCLUDING REMARKS AND RECOMANDATIONS

This first GSHP system was installed in Kuujuaq (Nunavik, Canada) in the summer 2020 in order to heat the water of the community swimming pool operating from end of June to September each year. This pilot project aims at demonstrating the viability of very shallow geothermal energy in the subarctic territories of Canada. Due to the high cost of drilling in Nunavik and the lack of expertise on vertical ground heat exchangers, horizontal loops were installed in the parking lot around the building.

The monitoring of this system is crucial for the future of geothermal, and renewable in general, energy in Nunavik. A proper monitoring will provide critical information about the real behavior of geothermal technologies in this subarctic environment and will be an important benchmark for future installations. Since the storage of the data is local, collecting the data is up to the final users and the project champions of Kuujjuamiut Inc. We greatly encourage them to periodically download the data from the temperature data loggers, the heat meter and the air temperature sensors and to share these data with the INRS, so that they can be analyzed and discussed together to evaluate the behavior of the GSHP. The monitoring system described in the present report already provides a good level of information. However, if in the future there is the possibility to implement it, we take the opportunity to suggest the following items:

- One diesel meter for the back-up boiler (e.g. <https://www.mazoutman.be/>, cost approx. 500 CAD\$, taxes and shipping included);
- Two devices to monitor the electric consumption of the HPs (e.g. https://www.floridaecoproducts.com/products/efergy-e2-classic-power-monitor-e2c-3ct-3-phase?_pos=1&_sid=ab04becb7&_ss=r, cost approx. 800 CAD\$ taxes and shipping included);
- One heat meter on the second HP, of the same type as the one already installed (<https://www.kamstrup.com/en-en/heat-solutions/heat-meters/multical-803>, cost approx. 3,000 CAD\$ taxes and shipping included).

Geothermal energy can guarantee more than 50 % energy savings for heating purposes and progressively reduce the use and transport of fossil fuel up north, with all the positive aspects that come along. Geothermal energy can also be an important job opportunity for the local population, from drilling and installation of vertical ground heat exchangers, to the installation and set up of the heat pumps. We do believe that a decrease in the fossil fuel market, current revenue for local stakeholders, can easily be replaced by the geothermal market. In the next future, a feasibility study for a vertical GSHP system at the Kuujuaq Forum is envisaged to put in place the first vertical pilot plant and provide technological transfer to the local stakeholders.



Contacts

Nicolò Giordano, Post-doc fellow, nicolo.giordano@ete.inrs.ca

Félix-Antoine Comeau, Research professional, felix-antoine.comeau@ete.inrs.ca

Jasmin Raymond, Professor, jasmin.raymond@ete.inrs.ca

REFERENCES

- Allard M., Lemay M. (2012) *Nunavik and Nunatsiavut: From science to policy. An Integrated Regional Impact Study (IRIS) of climate change and modernization*. Quebec City.
- Audy M-A. (2020) *Rapport technique – Deuxième partie: Design, proposition de concept et estimé budgétaire*. Induktion Géothermie, 14 pp.
- Comeau F-A., Raymond J., Malo M., Dezayes C., Carreau M. (2017) *Geothermal Potential of Northern Québec: A Regional Assessment* Transactions Geotherm Resource Council, 41.
- Covelli M. (2018) *Geological and geophysical study of the village of Kuujjuaq (Nunavik, Canada) for geothermal potential evaluation*. Master thesis, University of Torino, Italy.
- Giordano N., Raymond J. (2019) *Alternative and sustainable heat production for drinking water needs in a subarctic climate (Nunavik, Canada): Borehole thermal energy storage to reduce fossil fuel dependency in off-grid communities*. Applied Energy, 252: 113463. <https://doi.org/10.1016/j.apenergy.2019.113463>
- Lemieux J-M., Fortier R., Talbot-Poulin M-C., Molson J., Therrien R., Ouellet M., et al. (2016) *Groundwater occurrence in cold environments: examples from Nunavik, Canada*. Hydrogeol Journal, 24: 1497–513. <https://doi:10.1007/s10040-016-1411-1>
- Miranda, M.M., Giordano, N., Raymond, J., Pereira A.J.S.C, Dezayes C. (2020) *Thermophysical properties of surficial rocks: a tool to characterize geothermal resources of remote northern regions*. Geothermal Energy, 8: 4. <https://doi.org/10.1186/s40517-020-0159-y>
- Moran M.J., Shapiro H.N., Boettner D.D., Bailey M. B. (2018) *Fundamentals of engineering thermodynamics*. John Wiley & Sons Ltd., 9th Ed., Chichester, 1004 pp.

APPENDIX I - Tutorial for data download of the thermistors cables (RST Instruments Ltd.)

The present step-by-step aims at guiding the user to READ (step 9) and DOWNLOAD (steps 10-14) the data. For any more detailed information that is not described in this tutorial, please refer to the manual “*ELM0080L-DT-Logger-Host-Instruction-Manual-PC-platform*” (in the folder “RST_ground” of **Attachment 1**) and/or contact INRS team. If the software is already installed, go directly to step 3.

There are three dataloggers of the type DT2055B named:

1. NW connected to a blue cable;
2. NE connected to a blue cable;
3. UN connected to a black cable;

The loggers are of the same type and the procedure here described is valid for each of them;



1. Install the drivers “InstallRSTDrivers.exe” (folder “RST_ground”). For the latest version, go to the following webpage <https://rstinstruments.com/usb-drivers/>;
2. Install the software “DT Logger Host” by clicking on “RST_DTLogger_Setup_1.18.2.exe”. For the latest version, go to the following webpage <https://rstinstruments.com/software-dt2055B/>;
3. Disable the Bluetooth wireless on the PC. If ON, this might cause some interference and the USB connection might show some issues;
4. Open the “DT Logger Host” software and connect the USB cable between the logger and your PC;
5. In the bottom left corner, two red buttons (Port and Status) flash yellow and green while the connection is being established (**Figure I.1**);
6. After few seconds, the lights Port and Status turn and stay green, and in the upper right corner the “USB Connected” message appears (**Figure I.2**);
7. The datalogger DT2055B is also highlighted in green in the left column below the “USB connected” message;
8. The software includes 6 windows: Connections; Status; Data View; Monitor; Logging; Sensors;

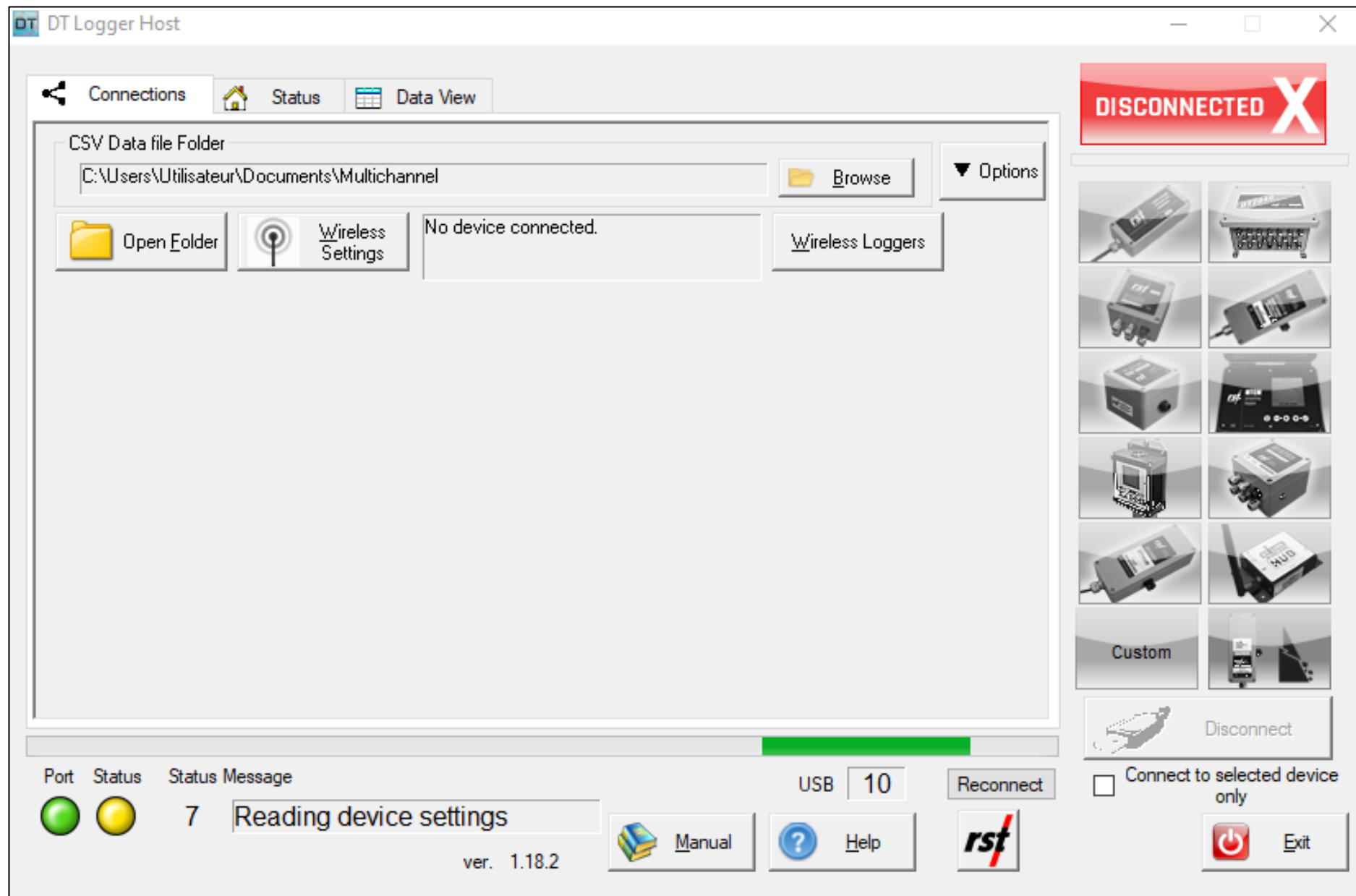


Figure I.1

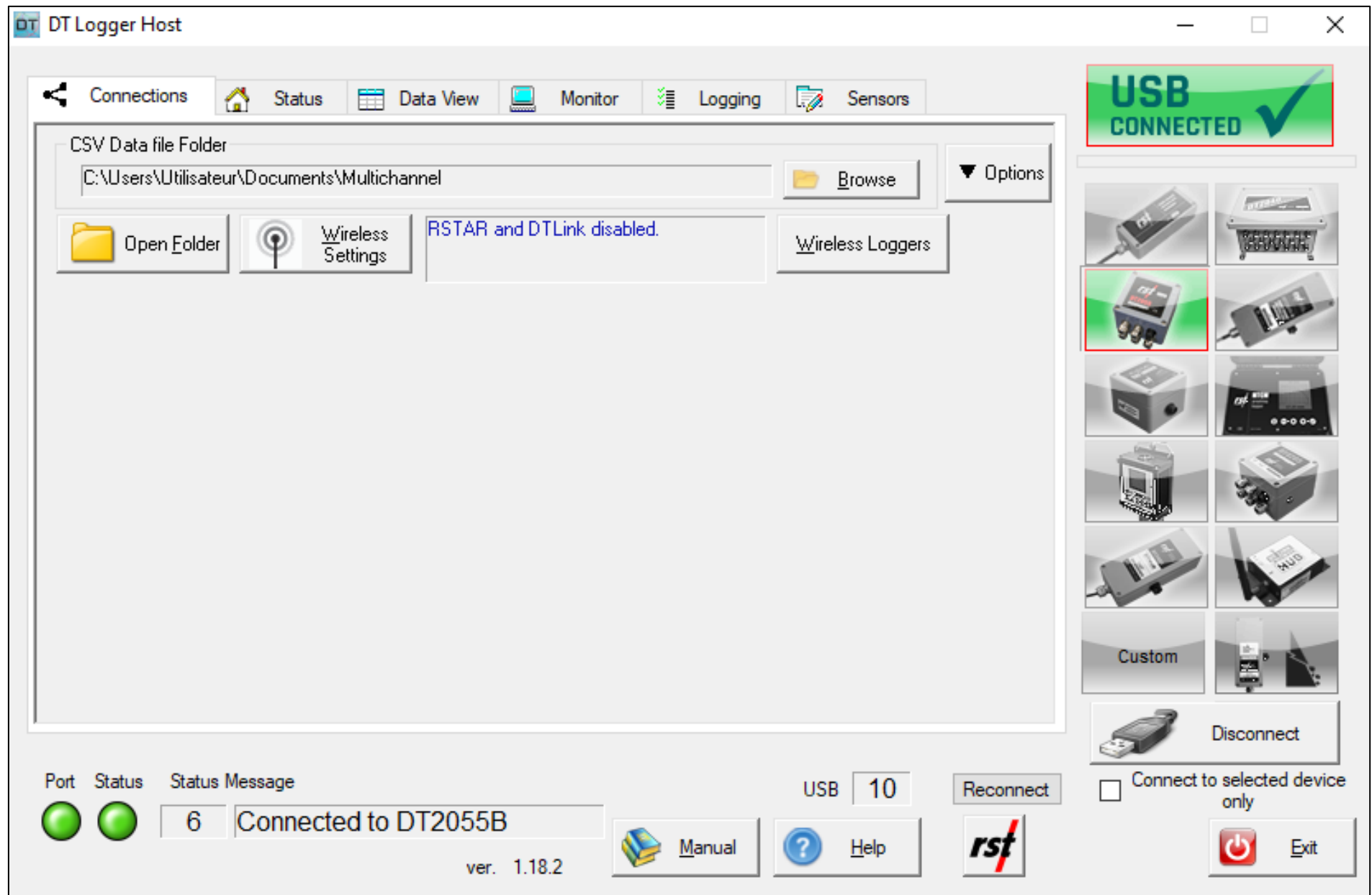


Figure I.2

9. To READ and display the real time data, go to the “Monitor” window. In **Figure I.3**, the Monitor window of the NW cable is shown, where 8 sensors are present. The sensors are numbered from surface to depth, details of each cable are given in the following;

Cable NW, 8 sensors in geothermal loop n. 5, depths: 0.25 m (sensor 1), 0.5 m (2), 0.75 m (3), 1.0 m (4, level of geothermal loops), 1.25 m (5), 1.5 m (6), 1.75 (7), 2.0 m (8);

Cable NE, 8 sensors in geothermal loop n. 1, depths: 0.25 m (sensor 1), 0.5 m (2), 0.75 m (3), 1.0 m (4, level of geothermal loops), 1.25 m (5), 1.5 m (6), 1.75 (7), 2.0 m (8);

Cable UN, 6 sensors outside of the geothermal field, depths: 0.5 m (sensor 1), 0.5 m (2), 0.5 m (3), 1.0 m (4), 1.5 m (5), 2.0 m (6);

Again, as described in **Section 8** of the present report, these depths will have to be increased by 20-30 cm once the gravel pad will be in place.

The screenshot shows the 'DT Logger Host' software interface. At the top, there is a navigation bar with tabs: Connections, Status, Data View, Monitor (highlighted with a red arrow), Logging, and Sensors. The main area displays eight temperature sensor readings in a 4x2 grid:

Sensor ID	Temperature	Units
1 Therm 1	6.4 °C	<input checked="" type="checkbox"/>
2 Therm 2	5.2 °C	<input checked="" type="checkbox"/>
3 Therm 3	5.1 °C	<input checked="" type="checkbox"/>
4 Therm 4	4.2 °C	<input checked="" type="checkbox"/>
5 Therm 5	3.2 °C	<input checked="" type="checkbox"/>
6 TH Sensor	3.7 °C	<input checked="" type="checkbox"/>
7 TH Sensor	3.6 °C	<input checked="" type="checkbox"/>
8 TH Sensor	3.3 °C	<input checked="" type="checkbox"/>

Below the grid are two inactive sensor slots marked with 'XX' and '--', with 'Units' checkboxes that are not checked. An 'Activity' indicator (a green circle) is located to the right of the bottom row. At the bottom left, a status bar shows 'Port 6', 'Status' (two green circles), and 'Status Message: Connected to DT2055B'. Other controls include 'USB 10', 'Reconnect', 'Manual', 'Help', 'rst' logo, 'ver. 1.18.2', 'Disconnect', 'Connect to selected device only' checkbox, and 'Exit' button. On the right side, a 'USB CONNECTED' banner is visible above a grid of device icons, with one icon highlighted in red. A 'Custom' button is also present in the device selection area.

Figure I.3

10. To DOWNLOAD the data, go to the “Status” window (**Figure I.4**);
11. Click on the button “Collect Data”;
12. Chose a folder on your PC to save the file (a .csv extension is ok);
13. Add to the name of the file “NW”, “NE” or “UN” depending on which data logger you are downloading data from;
14. A window will ask “*Do you want to append new data or overwrite existing data records?*” (**Figure I.5**). The first time this does not matter because a new file will be created, but from the second time on, chose “APPEND” in order to keep all the previous data collected;
15. Go to the “Connections” window and click on “disconnect” (**Figure I.6**);
16. Disconnect the USB cable when the message appears;
17. Repeat from step 4 to 16 for the other two data loggers.

The loggers have been set to be able to collect data for at least two years. Cables NW and NE have 3 h sample interval during the operation of the pool, 1 h interval in the rest of the year. Cable UN has always 3 h interval. Please download the data every 2-3 months from October to May, and every 15-30 days during the operation of the pool (June to September). In 2021 and 2022 is not necessary to program a new logging interval, but please contact INRS team in September 2022 to guide you to set a new logging interval.

DT Logger Host

Connections | **Status** | Data View | Monitor | Logging | Sensors

USB CONNECTED ✓

Logger

Model: DT2055B VW Multi Channel Logger Serial Number: 11297
 Name: KUJED NW Geothermal Pool Firmware Version: v4.04
 Installed Sensors: 8 Max Sensor Num: 10
 Supported Features: Load Cell Mode is OFF

Sampling

Status: LOG PENDING Interval Rate: MULTI
 Current Interval: 03 hours 00 minutes 00 seconds
 Start Time: Sunday, September 27, 2020, 12:00:00 PM Logger settings updated on: 2020/09/27 09:58:55
 Current Time: Sunday, September 27, 2020, 10:15:28 AM
 Estimated Fill Time: >30 Years

Battery **Board** **Memory**

Voltage (Past, Present): 3.39 3.39 Rev: 4 Record Num: 0
 Battery Life: 100% Temp: 7.3 °C Num of fills: 0

Collect Data

Port Status Status Message USB 10 Reconnect

 6 Connected to DT2055B

ver. 1.18.2 Manual Help

Disconnect Connect to selected device only

Exit

Figure I.4

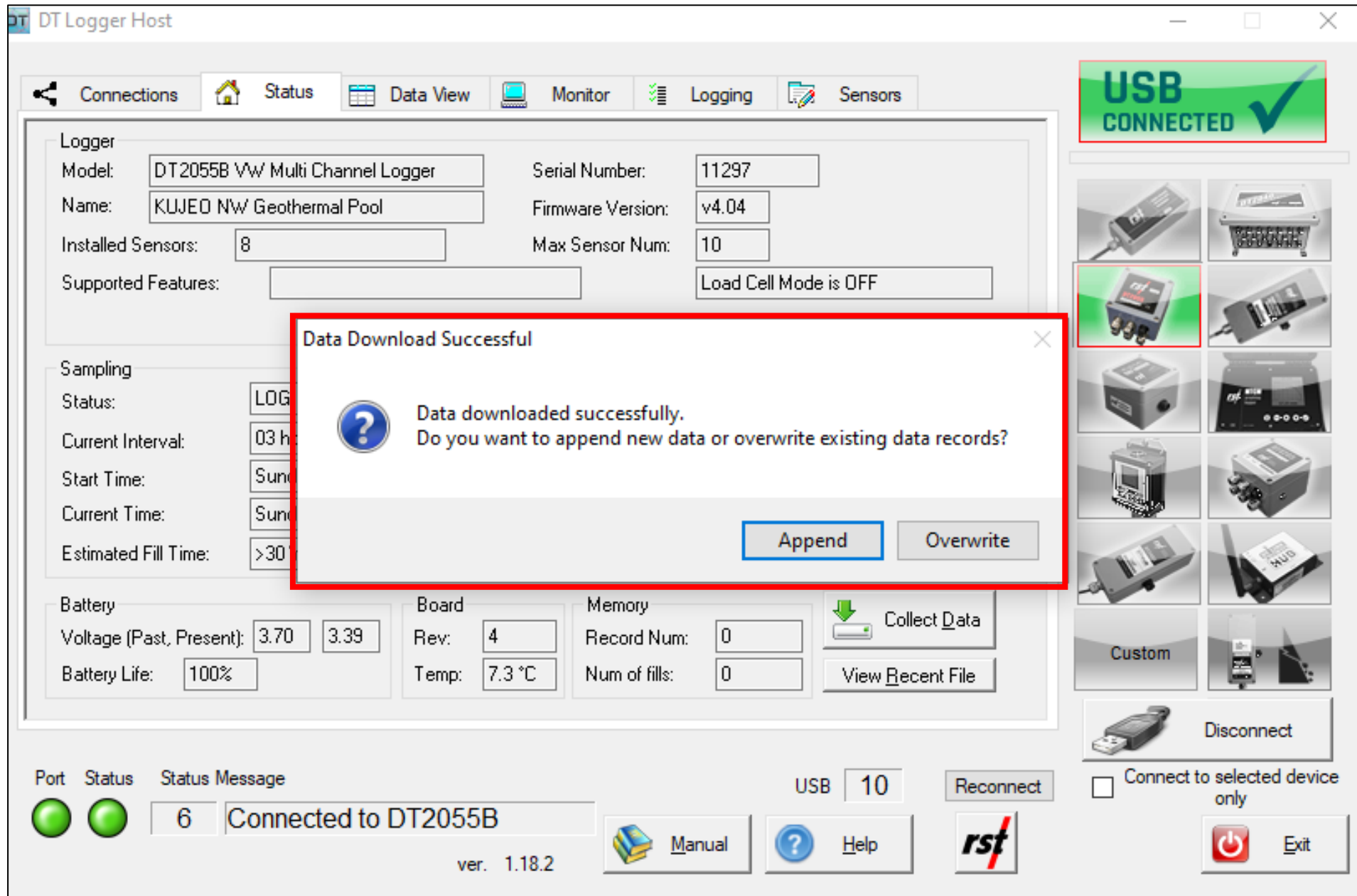


Figure I.5

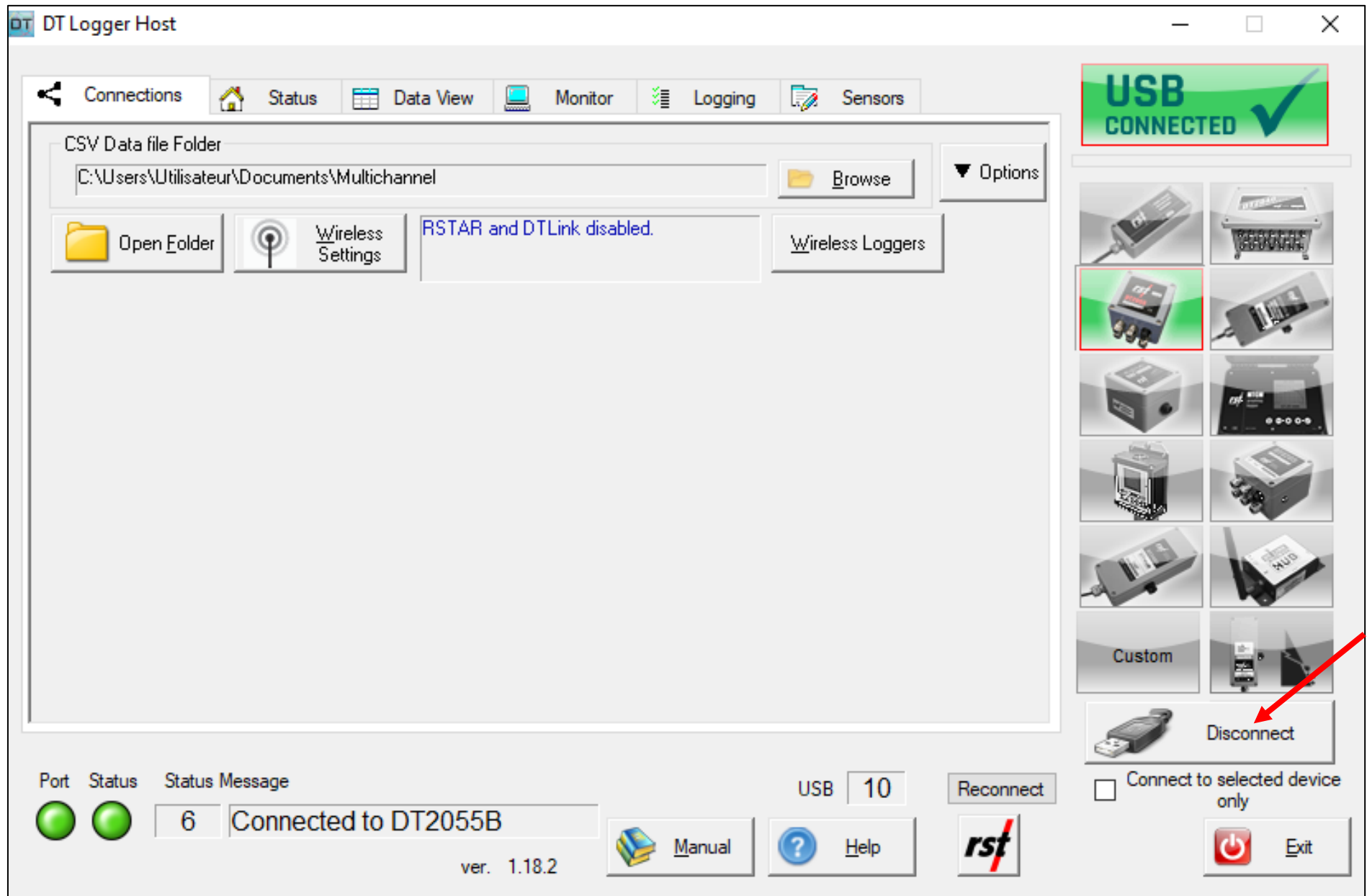


Figure I.6

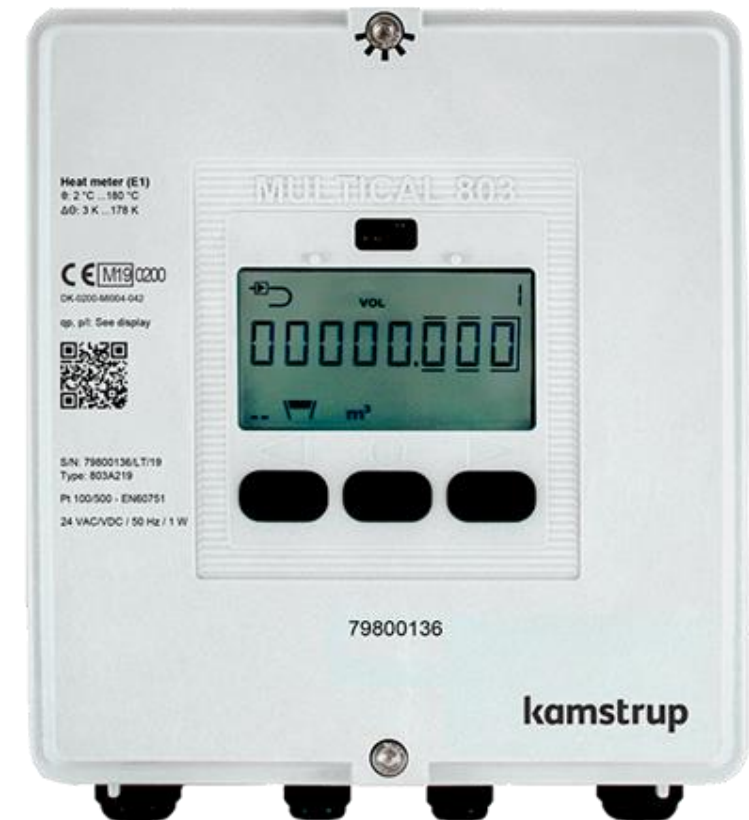
APPENDIX II - Tutorial for data download of the heat meter (Kamstrup Inc.)

The present step-by-step aims at guiding the user to READ and DOWNLOAD (steps 16-24) the data via the software called LogViewHCW. Beforehand, the software MeterToolHCW is explained in order to program the logger (steps 4-14), this part has to be done only once. If the softwares are already installed, go directly to step 4 or step 16. For any more detailed information that is not described in this tutorial, please refer to the manuals “*LogView_Manual*” and “*Metertool_Manual*” (in the folders “Kamstrup_heat pump/LogViewHCW” or “Kamstrup_heat pump/MetertoolHCW” of **Attachment 1**) and/or contact INRS team.

The Kamstrup heat meter includes:

1. A calculator (white box);
2. Two fluid temperature sensors (red wires);
3. A flow meter.

The sensors and the flow meter are connected to the calculator.



1. Install the drivers “Kamstrup-USB-Driver_5098893_C1.exe” (folder “Kamstrup_heat pump”). For the latest version, go to the following webpage <https://www.kamstrup.com/en-en/services-and-support/support/downloads/downloads-usb-driver>;
2. Install the software MetertoolHCW by clicking on “setup.exe” in the folder “Kamstrup_heat pump /MetertoolHCW”;
3. Choose “advanced mode” (**Figure II.1**);

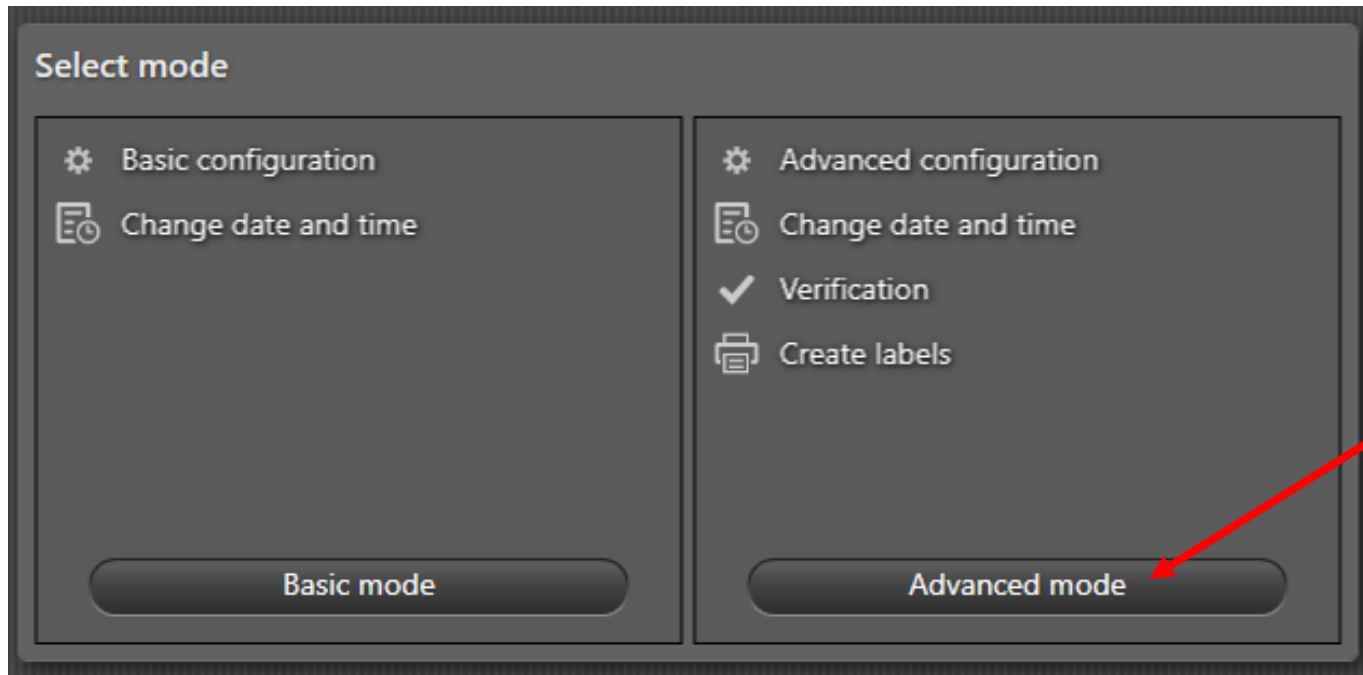
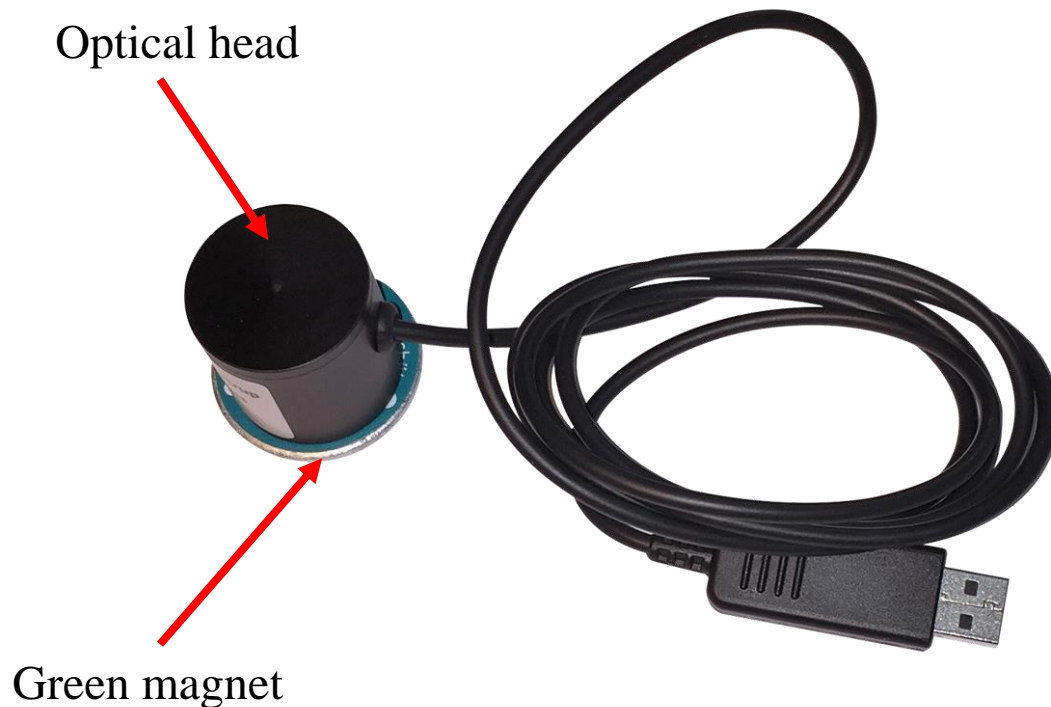


Figure II.1

4. Open MetertoolHCW and connect the optical reader to the PC via the USB port;
5. Remove the green magnet from the optical head and place the optical head on the top of the meter (**Figure II.2**);
6. The software includes several windows, by default the window “”Meter details” opens up (**Figure II.3**);
7. Go to the window “Configuration”, and click on “Read meter” (**Figure II.4**);
8. Change the RR code from 10 (default value) to 11 (**Figure II.5**);



Position of the optical head to communicate with the meter



Figure II.2

METER TOOL HCW

Help About

Meter Settings

MULTICAL® 803M (Advanced) [Connect new meter](#)

- Meter details
- Configuration
- Time / date
- Preset In-A/In-B
- Controlled outputs
- Communication on/off
- Leave transport state
- Bus addresses
- Reset
- Autointegration
- Modules
- Verification
- Verification unit settings
- Verification unit calibration
- Certificate
- Optical Interface
- Hide loggers

MULTICAL® 803M
 SW: 15760201 (B1)
 CRC: 16859

Figure II.3

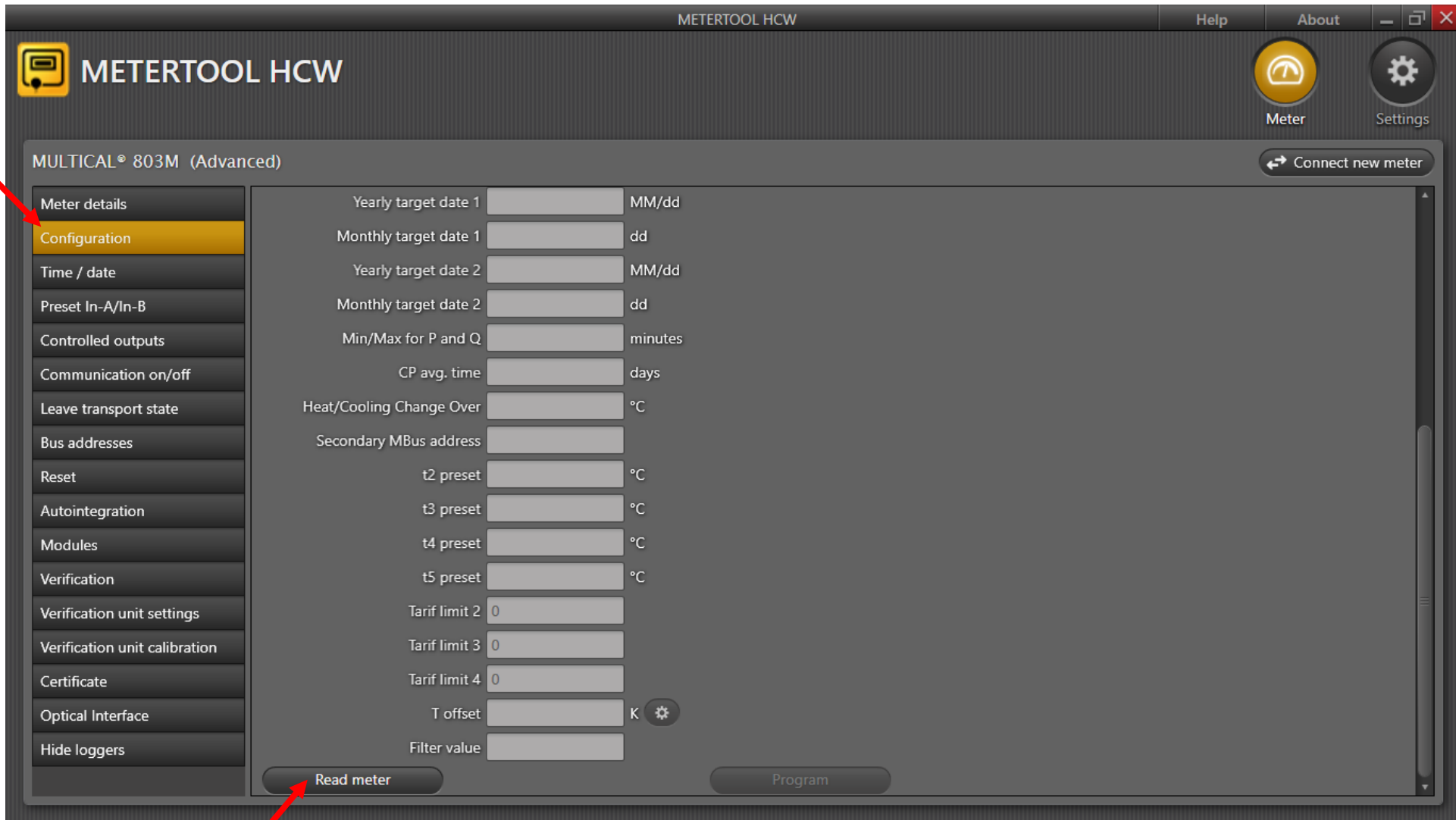


Figure II.4

METER TOOL HCW

MULTICAL® 803M (Advanced)

Serial No. 79807543

Customer No. 1000000179807543

Type No. 803 M 3MD P 33 d 99 99 99 99

Config No. 1 (A) (B) (CCC) (DDD)
4 4 201 305

Config No. 2 (EE) (FF) (GG) (L) (M)
00 24 24 9 0

Config No. 3 (N) (PP) (RR) (T)
0 95 10 3

Config No. 4 (VVVV)
0000

qp 20.0 4.0 / 150.0 m3/h (qp min/max)

Yearly target date 1 01/01 MM/dd

Monthly target date 1 01 dd

Yearly target date 2 00/00 MM/dd

Monthly target date 2 00 dd

Min/Max for P and Q 0060 minutes

CP avg. time 07 days

Heat/Cooling Change Over 250.00 °C

Type No. Temp. connection (M) Pt100/Pt500, 2/4-wire t1-t2-
Country code (3MD) 3 - Heat/Cooling (MID m
Flow sensor (P) Prepared for flow meters w/ 2
Temp. sensor 1 (33) PT500 pocket sensors set Ø!
Temp. sensor 2 (00) No sensor
Power supply (d) 2 x 24 VAC/VDC power suppl
Module 1 (99) No power supply
Module 2 (99) No power supply
Module 3 (99) No power supply
Module 4 (99) No power supply

Config No.
Daylight saving time
Scheduler profile
PT autodetect
Fluid type code

Change this value to 11

Figure II.5

9. Close the software, disconnect the USB cable, replace the green magnet on the optical head;
10. With an Allen wrench, unscrew the top and bottom screws to open the calculator (**Figure II.6**);
11. Detach the white part of the calculator;
12. Wait 30 seconds, then replace the white part and screw the top and bottom screws;
13. The display will erase and reset;
14. The calculator is now ready with the new configuration;

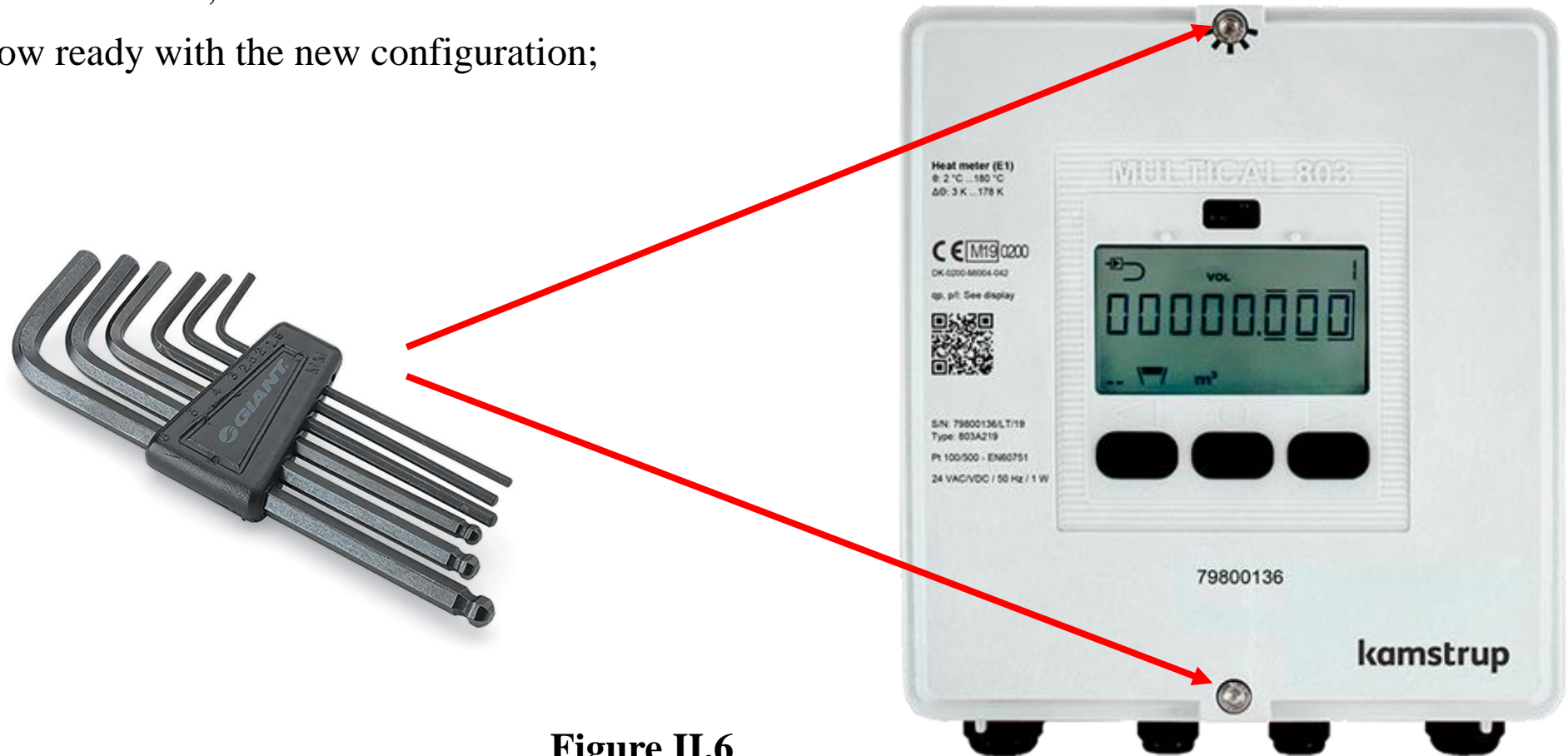


Figure II.6

15. Install the software LogViewHCW by clicking on “setup.exe” in the folder “Kamstrup_heat pump /LogViewHCW”;
16. Connect the optical reader to the PC via the USB port;
17. Remove the green magnet from the optical head and place the optical head on the top of the meter (as previously shown in **Figure II.2**);
18. The software includes several windows, by default the window “Meter details” opens up (**Figure II.7**);
19. Go to the window “Hourly Log” to DOWNLOAD the data (**Figure II.8**);
20. “Select all” the parameters (**Figure II.8**);
21. Choose the maximum available number in the second drop-down menu (**Figure II.9**), which is 1400;
22. Save the file in a chosen folder on your PC (a .csv or .txt extension is ok);
23. Close the software;
24. Disconnect the USB optical head, replace the green magnet on the optical head.

With the configuration set in steps 7-8, the maximum time of logging is 1400 hours, i.e. 58 days. Please download the data (steps 16-24) every 30 days for redundancy and to avoid any possible loss of data due to power outages.

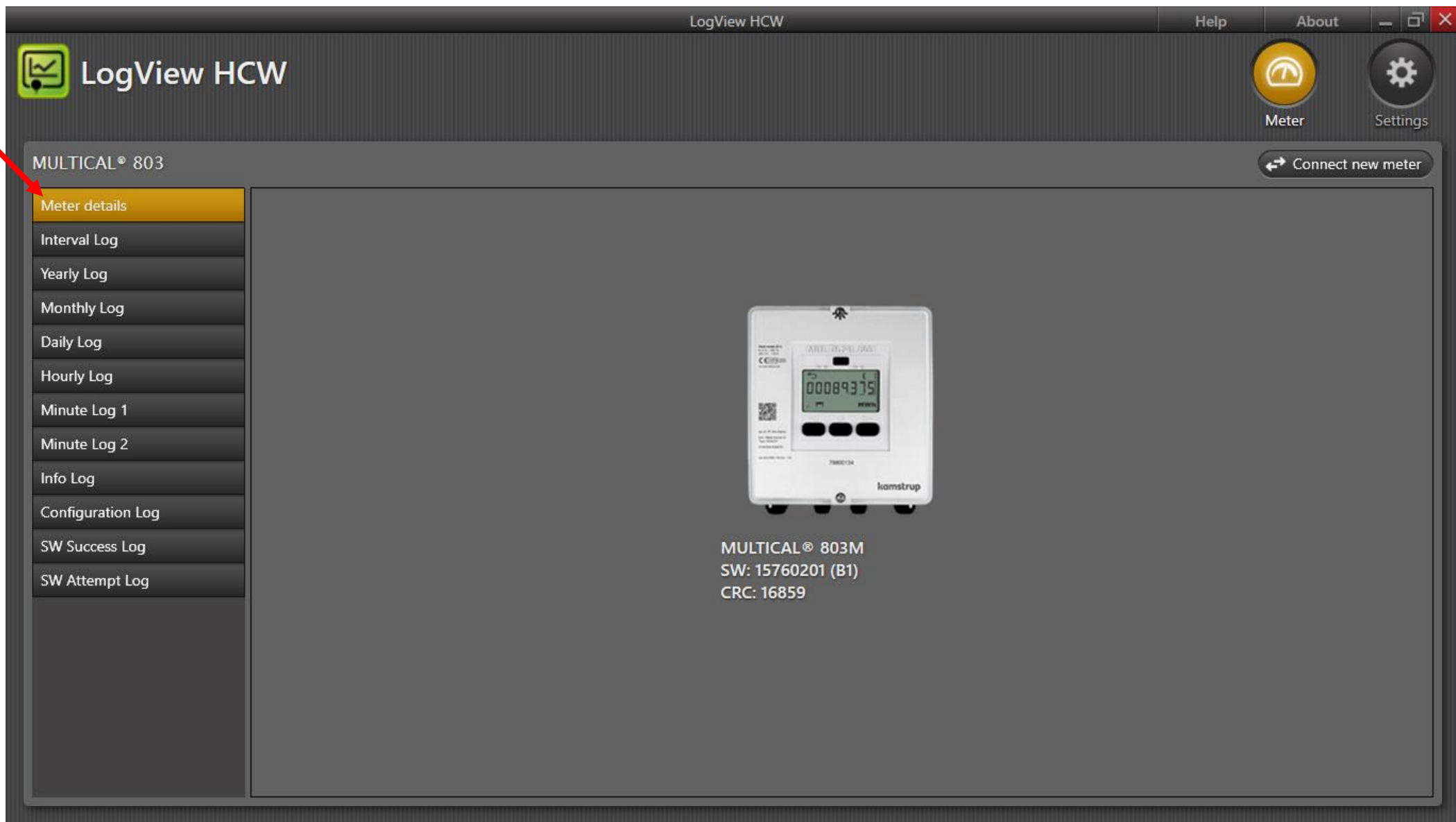


Figure II.7

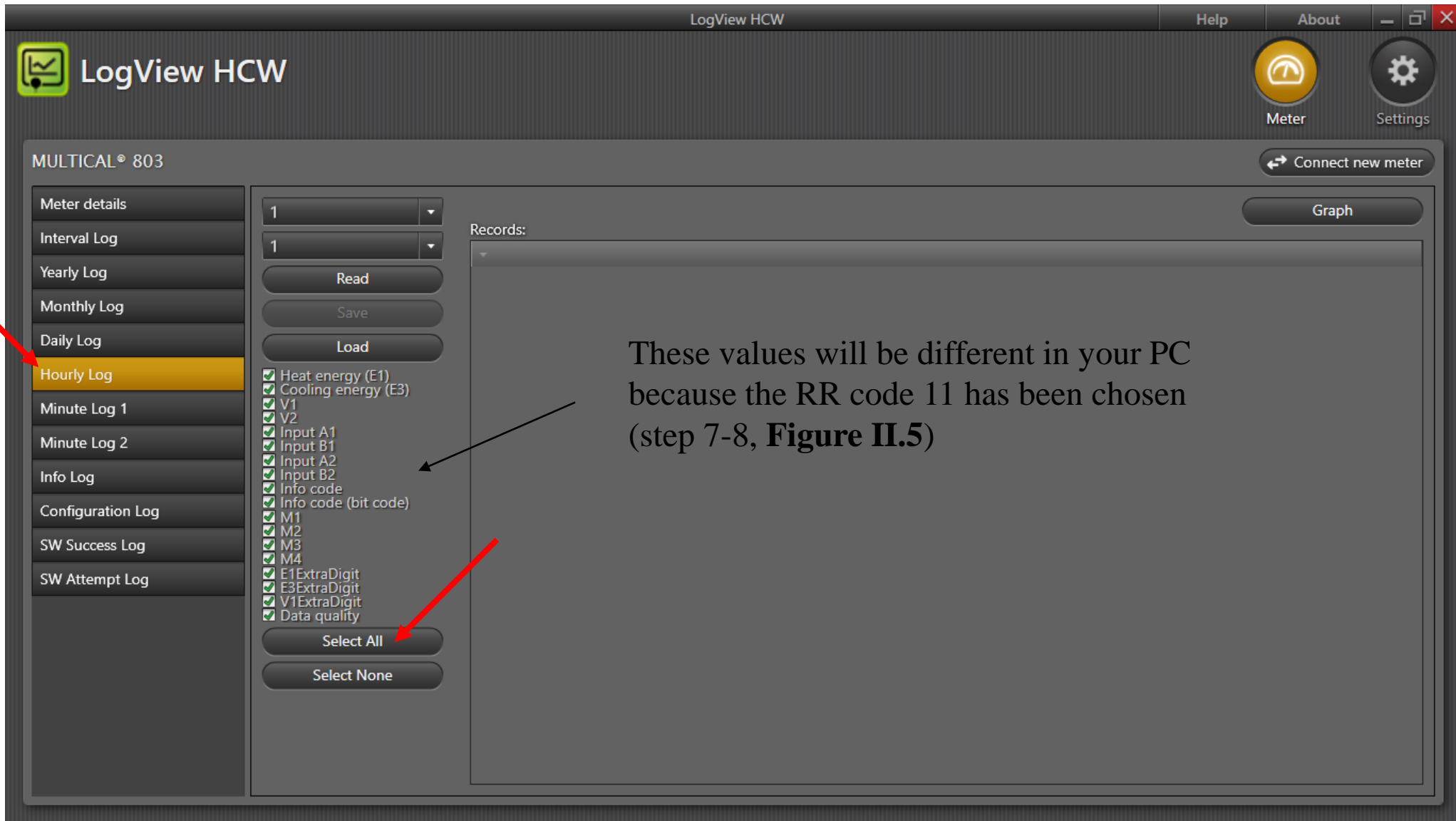


Figure II.8

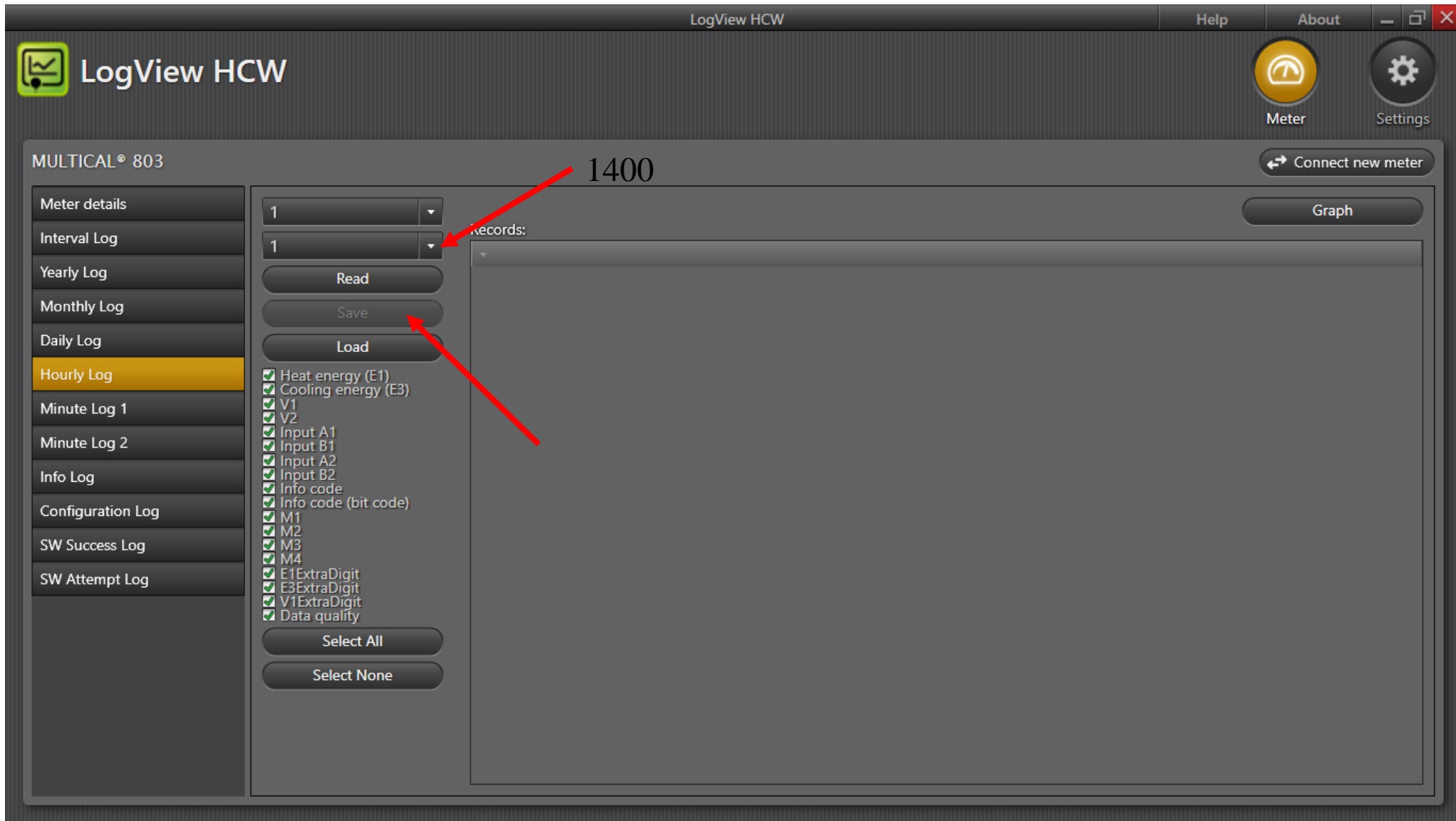


Figure II.9