Assessment of groundwater contribution to surface water quantity, quality and temperature in rivers of northern Quebec

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1. Introduction

Rivers in northern Quebec are recognized for their abundance of salmonids (trouts, chars, and salmons). The optimal temperature range for Salmonidae growth varies between 7°C and 17°C depending on species. In summer, salmonids can experience thermal stress in rivers when the water temperature goes above 25-27°C. This can affect their growth and even threaten their survival. Some specific zones with groundwater discharge in the rivers constitute thermal refuges allowing fish to be more comfortable, to grow and to survive in the extreme temperature conditions. Extreme conditions are likely to occur more frequently in several rivers in Quebec due to predicted climate warming. Change in rivers and groundwater condition can have an effect on fish habitats for example change of spawning locations or delay in fish migration from or to the sea. The objective of this PhD project is to check for the presence of thermal refuges in two rivers located in different permafrost condition. Other objectives are characterizing the groundwater contribution to the river heat budget and hydraulics to better understand the temperature evolution and to anticipate changes and predict the probable effects on fish habitats.

1.1. Study sites

To consider the effect of altitude, climate and permafrost condition on groundwater refuges, two rivers one in the south and one in the north of Quebec province has been selected for detailed studies (Figure 1). The river in the south is Sainte-Marguerite River that is located in subpolar temperature condition and no permafrost zone. The river in the North is the Berard River that is located in polar temperature condition and discontinues permafrost zone.

1.2. Fieldwork

Fieldwork contains two main parts, first taking aerial thermal imagery of rivers and second instrumentation of river. The aerial imagery helps us to detect zones with cold zones or thermal refuges and detect a suitable site for further studies and instrumentation of the river. The instrumentation of the river is for detailed analysis and collecting information about soil and water temperature, chemical components and hydraulic characteristics.

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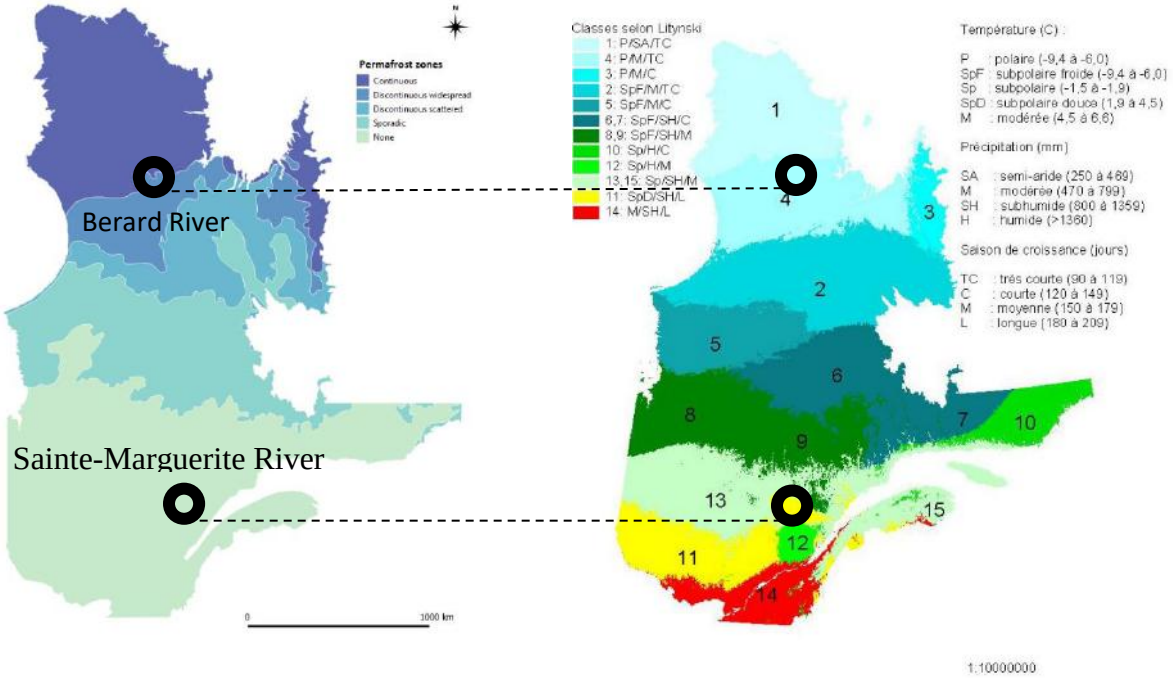

Figure 1 - Location of selected rivers on permafrost (left) and climate (right) maps.

2. Fieldwork at Tusijaq

Fieldwork at Tasiujaq has been done between 5th and 20th of August 2019. Preparation and taking aerial imageries has been done from 5th to7th August, and from 8th to 18th the site selection and instrumentation of river has been done on Berard river.

2.1. Aerial imagery

Aerial imagery of Berard River has been taken twice to ensure the quality of images. Once by flying from the lake to the sea and the next time by flying from the sea to the lake. There are two cameras set on the helicopter that will give us optical (normal) images and thermal images. Thermal images show the temperature of objects by using a colour scale.

Figure 2 - Preparation for survey and setting cameras on the helicopter.

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Base on the thermal imagery results two zones with cold-water refuge (colder zone in the river) have been detected, which are both close to the airport and along the road which goes to the lake.

Figure 3 - Detected sites with thermal refuges on Berard River.

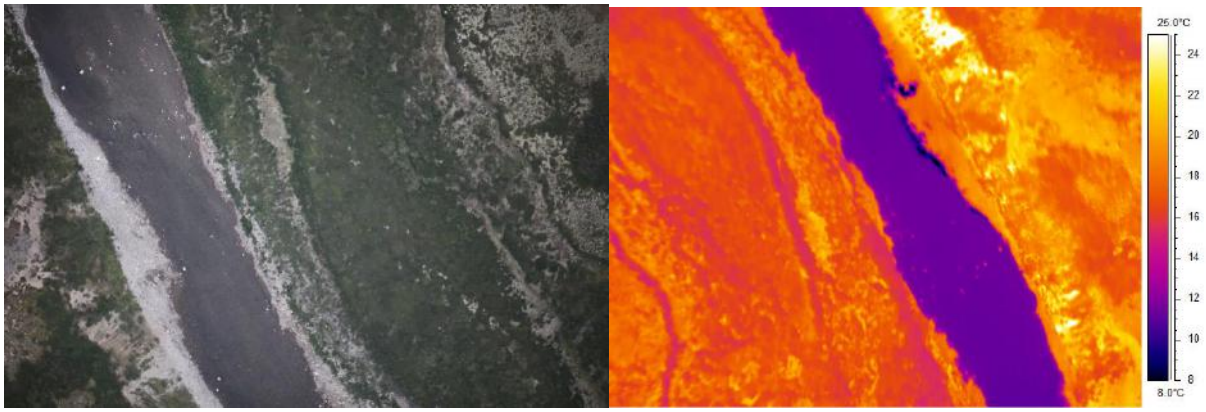

Figure 4 - Optical image (top) and thermal image (bottom) of detected site B1.

In site B1, the average temperature of the river is about 11-11.5°C and some colder zones with a temperature of about 7-8.5°C can be seen. Since this could be a potential site, the site has been

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visited. However, in the end, this site has not been peaked for doing the instrumentation. Because the cold zone is on the other side of the river and moving all equipment to the other side was difficult. Also, there are many rocks and stones covering the area, and this makes the installation of piezometer and drilling difficult.

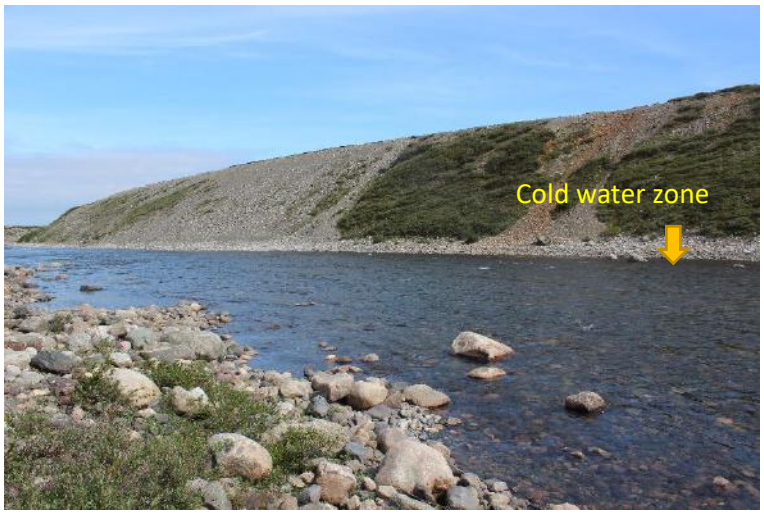

Figure 5 - Image taken from the B1 site after the visit.

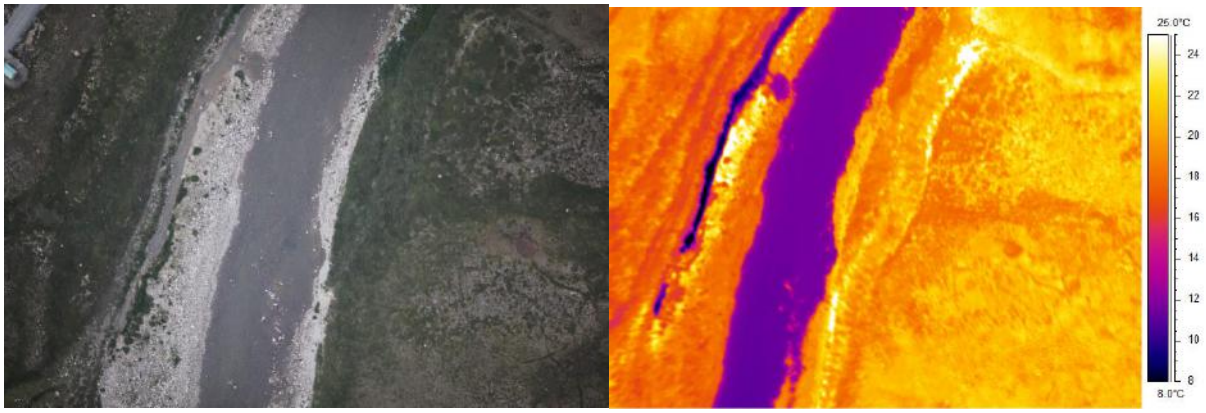

Figure 6 - Optical image (top) and thermal image (bottom) of detected site B2.

In site B2, the average river temperature is again around 11-11.5°C, but the cold zone is even colder with a water temperature of 6.5-8.5°C. In addition, the zone is larger compared to B1. In this site, there are some sand and fewer rocks that are more suitable for drilling and installation of piezometers. Moreover, the river is closer to the road and town and cold zone is at the side along the river. Considering the ice condition of the river during winter and movement of ice in the river after winter is also an important factor. After talking to local community members at Northern Village office in Tasiujaq, it has been mentioned that this site (B2) is more suitable and safer from fast movement of big ice sheets during the melting season compared to the other site upstream of the river (B1). Because of the mentioned reasons this site has been selected to instrumentation and installing the equipment.

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Figure 7 - Image taken from the B2 site after the visit.

2.2. River instrumentation

2.2.1. Seepage meters

Seepage meters have been installed at several locations at the bottom of the river. By measuring the amount of water in the plastic bags at the end of each day, the rate at which groundwater is infiltrating to the river can be calculated.

Figure 8 - Installed seepage meter at the bottom of the river (left), measuring the collected water at the end of the day (right).

2.2.2. Collecting soil samples

At some location in the study site, some drilling with auger has been done that enabled us for collecting soil samples at different depths.

The soil samples will be analyzed later for finding their hydraulic and thermal characteristics.

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Figure 9 - Drilling and collecting soil samples.

2.2.3. Installation of piezometers

At the location where the drilling has been done, piezometers have been installed.

Piezometers are stainless steel pipes that have a screen at the end of it, which can let the water in them. The piezometers have been hammered to the ground as much as possible. The depth of piezometers varies between 1.5 to 3 meters below the ground.

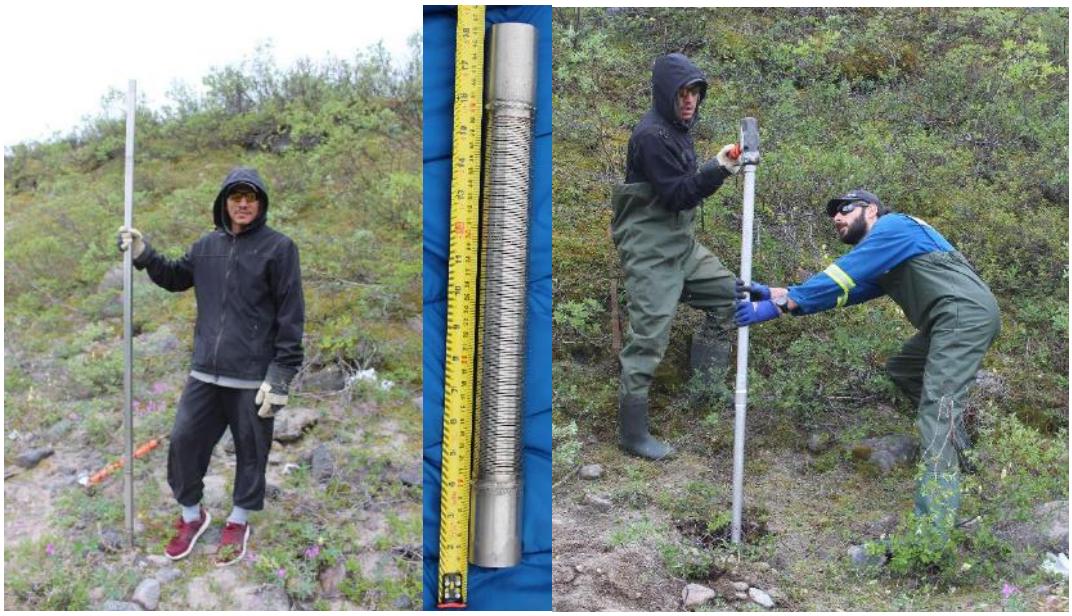

Figure 10 - One stainless steel pipe (left), piezometer screen (middle) and piezometer installation.

2.2.4. Installation of data loggers

After that in each piezometer, one water level logger has been installed. The water level loggers will measure the depth of water in the pipe and the temperature of water continuously every 15 minutes. In addition to water level, logger temperature sensors have been also installed. The temperature sensors were installed in a pipe at different depths below the ground and the pipe has been filled with soil so that it gives closer result to the natural temperature of the soil at different

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depths. Moreover, some water level loggers and temperature sensors have been installed outside the pipes and in the river. These sensors will measure the river depth and river water temperature at different depths.

Figure 11 - The type of water level logger (left) and temperature sensor (right) used at the site.

Figure 12 - Temperature sensors inside the pipe for measuring ground temperature (left) and attached to the pipe for measuring the temperature inside and below the river (right)

Figure 13 - Installation of water level loggers outside piezometers for measuring river water level (left) and inside pipe for measuring groundwater level (right).

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2.2.5. Collecting water samples

Water samples from each piezometer and from river water at different points have been collected for later laboratory analysis for different parameters.

Figure 14 -Groundwater sampling from piezometers.

3. Long term data collection (equipment left at the site)

For have more water level and temperature data over different seasons, some data loggers have been left in site for collecting data over time. The sensors will be collected in summer of 2020, this way the data for a period of one year will be collected.

In total 9 pipes have been left at the site that contain data loggers (water level and temperature sensor) inside and outside of them. Five water level loggers are in piezometers and two are outside piezometers in the river. Several temperature sensors have been also placed inside and outside pipes. All the pipes left at the site and their location can be seen in the photos below.

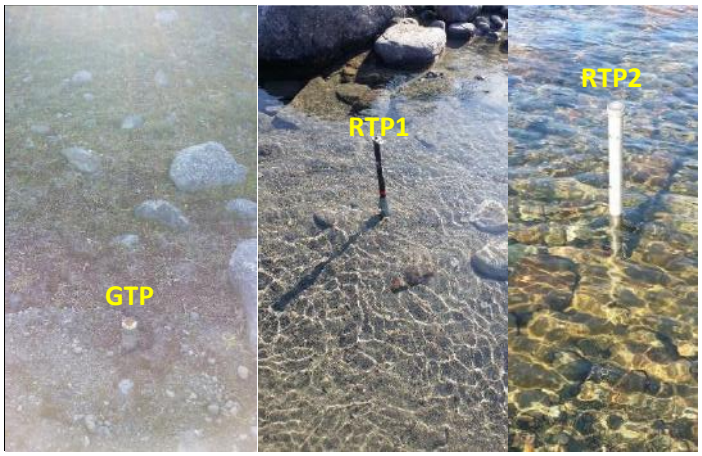

Figure 15 – Pipes used for the installation of temperature sensors below ground inside and outside the river

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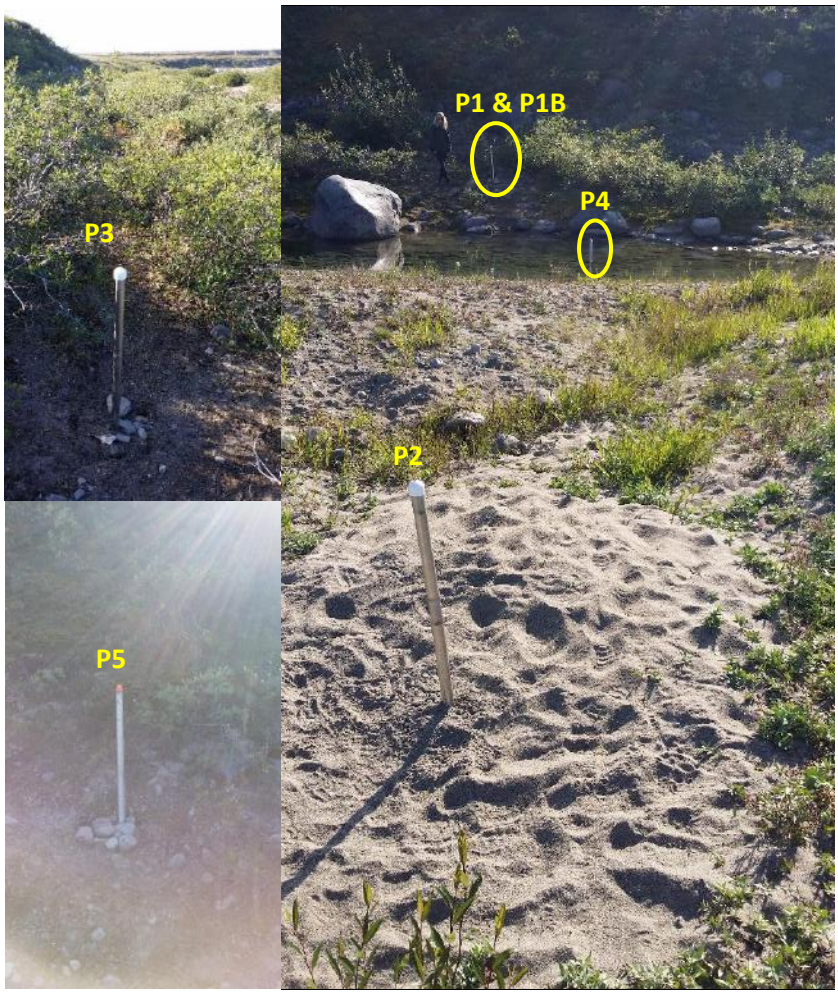

Figure 16 - Al piezometers left at the site.

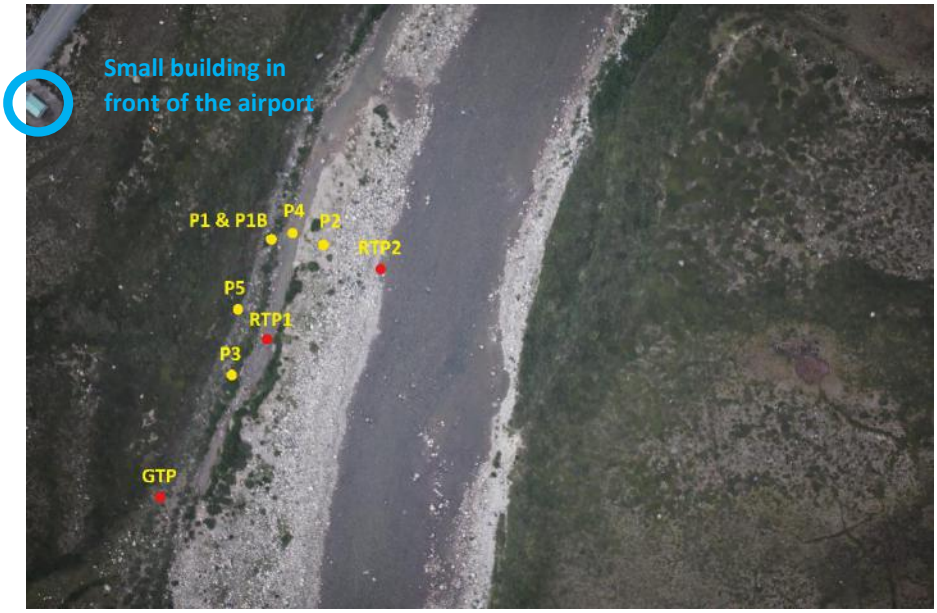

Figure 17 - Location of all pipes on the aerial photo of the study site.

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4. Summary

4.1 List of activities

- Helicopter flights and taking aerial thermal imagery
- Installation of seepage meters
- Taking soil samples
- Installation of piezometers (stainless steel pipes in the ground)
- Mapping the location of pieces of instruments at the site with GPS and laser
- Measuring river flow rate (only in the small section)
- Installing data loggers for temperature and water level
- Taking water samples

4.2 List of pieces of instruments left at the site

- Eight steel pipes including:
    - Six 1.25 inch pipe as piezometers (P1B & P1-P5)
    - One 2 inch pipe for installation of temperature sensors in the ground (GTP)
    - One 1.25 inch pipe for installation of temperature sensors in the main riverbed (RTP2)
    - One steel pipe with temperature sensors attached outside of it in the small part of the river (RTP1)
- Seven water level loggers including:
    - Five water level logger in piezometers (P1-P5)
    - Two water level logger in the small part and the main part of the river (attached outside RTP1 and RTP2)
- 30 temperature sensors including:
    - Several temperature sensors inside GTP and RTP2
    - Several temperature sensors attached to RPT1 in the river (above ground) and below ground

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