Surface water intake vulnerability analysis report for the Northern village of Kangirsuk

Water intake number: X2114293

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KATIVIK

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Introduction

Mandate

This drinking water supply vulnerability analysis report (VAR) is the result of an initiative by the Kativik Regional Government (KRG) to support the Northern villages of Nunavik that have not yet completed the analysis. This initiative is part of a process whereby Quebec municipalities responsible for a Category I water withdrawal (those supplying 500 people or more) are required to carry out a vulnerability analysis of their source. In addition, the Water Withdrawal and Protection Regulation (RPEP, Q-2, r. 35.2), adopted in 2014, stipulates that this process had to lead to the transmission of a VAR before April 1, 2021.

The Kativik Regional Government is a key player in the management of natural resources and environmental protection in Nunavik, and has jurisdiction over the entire territory of Nunavik (Act respecting Northern Villages and the Kativik Regional Government [V-6.1]). The main mandate of the Renewable Resources, Environment, Lands and Parks Department (RRD) is to provide technical services to Northern villages in environmental and urban planning matters. The KRG's Public Works Department plays a crucial role in the supply of drinking water, providing the necessary support for infrastructure maintenance in Nunavik's Northern villages. This puts the supramunicipal body in an ideal position to carry out vulnerability analyses[1], in conjunction with the water withdrawal authorities in the Northern villages.

According to the 2024 federal census, the village of Kangirsuk had a population of 597 [1], and the number of people served, as defined in the Regulation respecting the quality of drinking water (RQEP, Q-2, r.40), was 586[2]. It is therefore a Category I water withdrawal. Results from the most recent Canadian census show that the average size of private households in Kangirsuk was 3.5 people per household. The population of Kangirsuk decreased by 1.1% between 2016 and 2021 [2].

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[1] The term *vulnerability analysis* is used instead of the specific term *surface water intake vulnerability analysis* for the sake of brevity.

[2] According to Schedule 0.1 of the RQPE, the maximum number of people served by a water withdrawal is calculated on the basis of the number of residences multiplied by 2.5 people.

Objective

The aim of a vulnerability analysis is to identify weak points, problems, and threats that affect or could affect a drinking water supply source. Ultimately, it helps identify priorities for action to reduce or eliminate certain threats, and consolidates the information needed for a protection plan.

The VAR is focused on the following specific objectives:

- Locating the withdrawal site and describing its layout.
- Drawing up a localisation plan of the inner, intermediate, and outer protection zones.
- Validating the vulnerability levels of surface water used in accordance with section 69 of the RPEP, i.e.,
    - physical integrity of the withdrawal site;
    - vulnerability to microorganisms;
    - vulnerability to fertilizers;
    - vulnerability to turbidity;
    - vulnerability to inorganic substances;
    - vulnerability to organic substances.
- Identifying anthropogenic activities, potential events, and land uses likely to affect the quality and quantity of water withdrawn.
- Assessing the threats associated with the previously identified elements.
- Identifying the probable causes that may explain the levels of vulnerability of specific indicators when vulnerability is medium or high.

To meet ministerial requirements, this VAR is based on the *Guide de réalisation des analyses de la vulnérabilité des sources destinées à l'alimentation en eau potable au Québec* [1] and the supporting document entitled *Analyses de la vulnérabilité des sources destinées à l'alimentation en eau potable au Québec — Cas particulier du Nunavik* [2] (referred to as the *Guide* and the *Supporting document* in this report).

Summary of the field visit

The KRG specialist did not conduct any site visits. However, a number of collaborators helped compile the information presented in this report.

In particular, a collaborator visiting Kangirsuk inspected the withdrawal and treatment infrastructure and documented the visit with images. In addition, the KRG engineers responsible for supporting the water treatment plants (WTPs) in the Northern villages provided technical assistance and facilitated discussions with the operator of the Kangirsuk WTP.

General description of the study area

The village of Kangirsuk is located 13 km from the west coast of Ungava Bay, halfway between Quaqtaq (110 km to the north) and Aupaluk (90 km to the south). The municipality is built on the north shore of the Arnaud River, whose tides can reach 9.8 m [3]. The region is characterized by a high density of small lakes and rocky[3] hills oriented north-west-south-east, reaching altitudes of 100 m to 182 m [3].

The climate in Kangirsuk is characterized by long, cold winters, with a frost period running from 27 September to 14 June, and an average temperature of -18.2 °C [3]. Summers are short and cool, with an air temperature of 3.8 °C. Precipitation levels are higher in summer than in winter, with an estimated 47% of total precipitation (564 mm) falling as rain between June and October [3]. Spring floods are responsible for around 50% of the run-off from rivers and streams.

Located in an area of continuous permafrost, the area around Kangirsuk is particularly sensitive to the effects of freeze-thaw cycles. The depth of the active permafrost layer varies between 1.2 m and 2 m, depending on the type of soil [3]. The freeze-thaw process affects local rock formations, causing shale to break up and creating unstable rock outcrops, which can compromise the integrity of infrastructure.

Kangirsuk lies 150 km north of the tree line, and the vegetation consists mainly of dwarf willow, dwarf birch, moss, and lichen. The area lies on the migration route of caribou, snow geese, and Canada geese.

The municipality of Kangirsuk is divided into two districts by a permanent stream that flows from Lake Majuriarjuaq Qamaninga into Anse Kanik (cove) of the Arnaud River (Appendix 1). The WTP is located near the mouth of the stream, at the intersection of Puppuq and Mivviliariaq streets. Lac Hardy, the source of the drinking water supply, lies at an altitude of 180 m, 4 km (as the crow flies) to the northeast of the WTP (see Figure 1, Figure 2, and Appendix 2).

[3] https://www.environnement.gouv.qc.ca/biodiversite/aires_protegees/provinces/partie4j.htm)

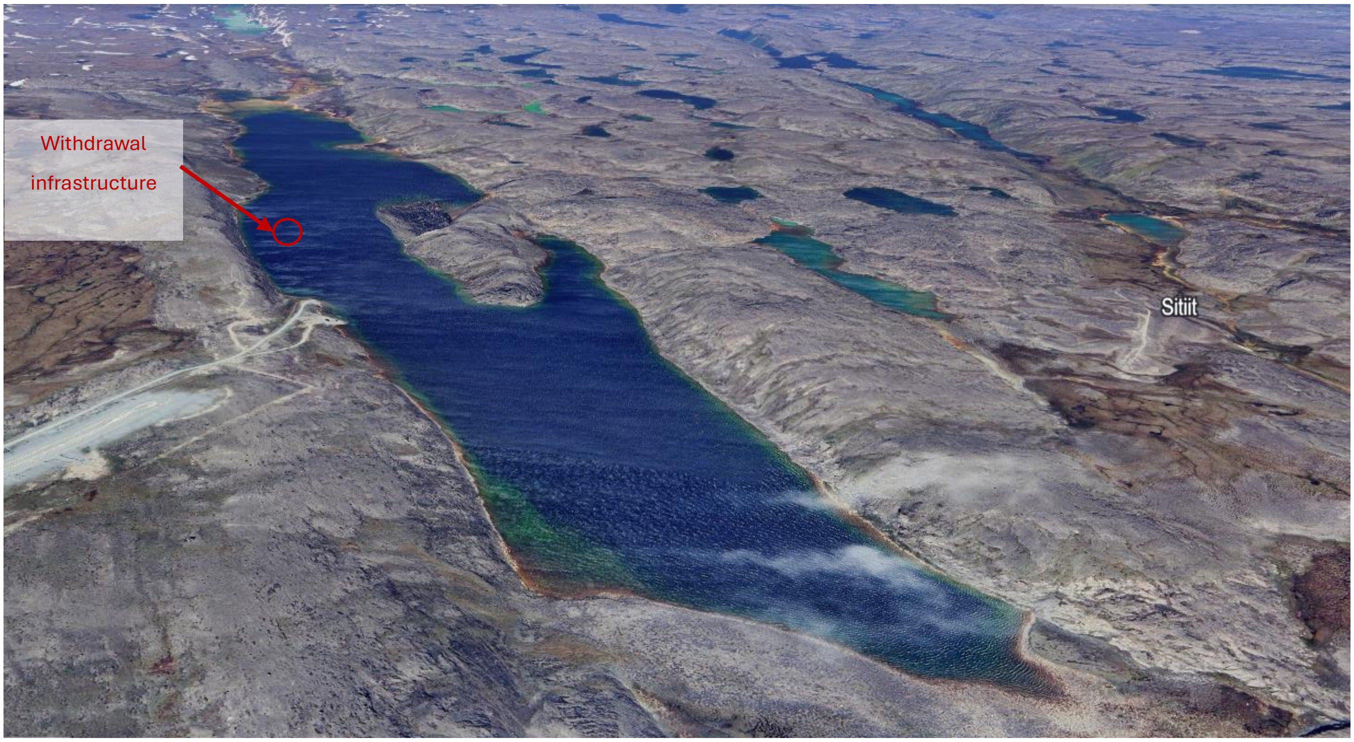
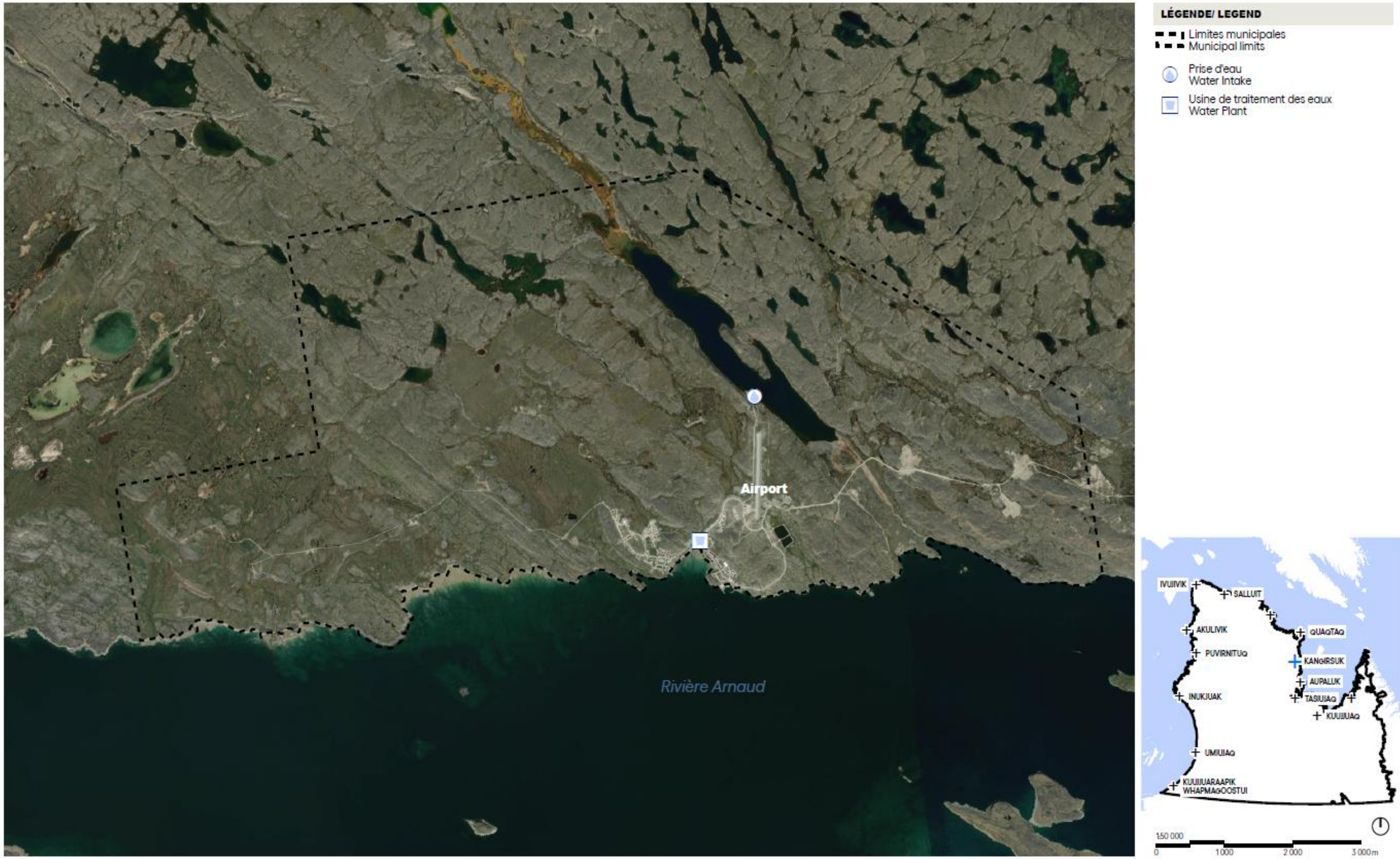


Figure 1. Google Earth image of Lac Hardy (60°01'54 'N 69°58'53 'W; camera elevation: 550 m; image date: 22/8/2024).



BC2 KATIVIK | Village nordique de Kangirsuk
Northern Village of Kangirsuk

Carte de localisation
Localisation Map

2024-09-03 | **PROJECT 20322301**

Figure 2. Localisation map for the Northern village of Kangirsuk

1. Characterization of water withdrawal

1.1 Watershed delimitation of the withdrawal site and brief characterization

The catchment area (CA) of Lac Hardy is part of the Arnaud River CA, which is itself part of the Ungava Bay CA. The Arnaud River CA covers an area of 49,469 km^2 and the Lac Hardy CA covers an area of 68.3 km^2 [3].

The Lac Hardy CA runs parallel to the local geological features, northwest to southeast, originating east of Lac Chaumet and including Lac Tasialuk Tukirsinga, 7 km from Lac Hardy.

The hillsides are characterized by steep southwestern slopes and shallow northeastern slopes. These formations can influence snow accumulation and flooding, since slope and orientation influence the distribution of winter precipitation. In addition, when gelifluction processes take place on steeper slopes, the risk of rockfall is exacerbated [3].

The Lac Hardy CA is located in a zone of continuous permafrost and the active layer varies according to the type of deposit. Lac Hardy is located on basement rock, characterized as being stable to thawing due to its low ice content, but the withdrawal infrastructure is located in a high-risk area (Appendices 4 and 5).

The water in Lac Hardy is strongly influenced by the geological components, which are characterized by an acid pH (pH = 3–4) and a high concentration of iron and magnesium [4]. The lake lies on a geological formation rich in iron and magnesium (phenocryst-phase mesocratic gabbro, olivine gabbro, with mafic intrusion) [5]. The chemical alteration of mafic rocks can lead to the production of acid ions through the oxidation of iron, among other things. This particular characteristic requires advanced treatment to remove iron and magnesium and adjust the pH. Details of the treatment are given in section 1.2.2 Description of drinking water production facility

1.1.1 Method used to produce localisation maps

The Géobase du réseau hydrographique du Québec (GRHQ) has been identified as the best source of hydrographic data available for the region [6]. These data were used to determine the position of water bodies and watercourses, as well as their direction of flow.

Given that Lac Hardy is not part of a secondary catchment area of the Arnaud River in data from “Multiscale hydrographic basins in Quebec,” and that the Ministère des Ressources naturelles et des Forêts (MRNF)

LIDAR data for 2021 does not have sufficient coverage to cover the lake's catchment area, an alternative solution had to be found [7]. The Canadian Digital Elevation Model published by Natural Resources Canada was used to determine the catchment area of the drinking water source [8]. Although these data are less precise, they still give a good estimate.

1.2 Description of the withdrawal site and drinking water production facility

1.2.1 Description of the withdrawal site

The drinking water withdrawal site consists of two buildings. The first (the navy blue building) is 15 m from the lake shore and houses two pumps. From there, a 75 mm-diameter supply pipe carries the water to the pumping station (orange and blue building), located 20 m from the previous building (see Figures 4, 5, 6, and 7).

Figure 3. Drinking water withdrawal infrastructure. The navy blue building houses the pumps (Photo taken on July 18, 2024, by Antoine Thibault)

Figure 4. Connection between the building housing the pumps and the pumping station. Photo taken on July 7, 2024 by Antoine Thibault

Figure 5. Inside the navy blue building: raw water pumping station (Photo taken on July 7, 2024, by Antoine Thibault)

Figure 6. Pumping station on the shore of Lac Hardy. The oil tank is attached to the main building (Photo taken on July 7, 2024, by Antoine Thibault)

Figure 7 shows a cross-section of the pumping infrastructure on the shore of Lac Hardy. The two buildings illustrated in the diagram are shown in Figures 3 to 6.

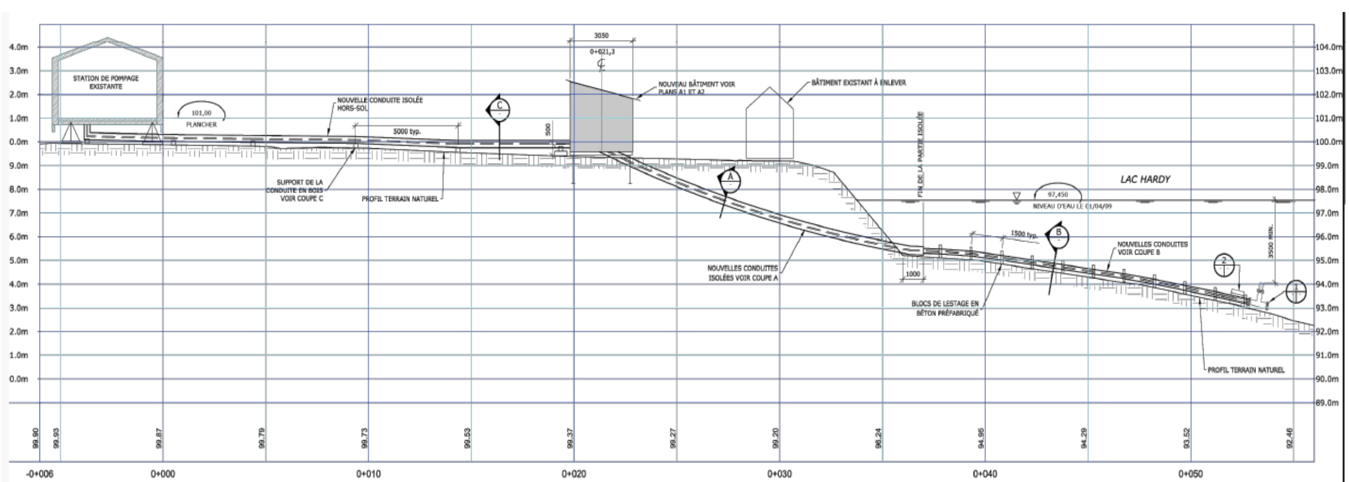


Figure 7 Diagram of water withdrawal infrastructure

The main characteristics of the withdrawal site are shown in Table 1. Data on the critical water level could not be compiled.

Table 1. Main characteristics of the withdrawal site

Withdrawal site feature	Description and details
Water intake name	Kangirsuk - Supply
Water intake number	X2114293-1
Production facility number	X0010380
Production facility category	Category 1 (Surface)
Geographic coordinates	60° 02' 13.98 " N, 69° 59' 50.37 " W
Type of use	Permanent
Type of withdrawal	Submerged perforated casing
Withdrawal depth	6.5 m below normal water level
Distribution	Tank truck (2 trucks)
Population served	586
Authorized daily withdrawal rate	65 m^3/day
Low-water level	Unknown
Number of the most recent authorization issued by the Ministère	2013-06-14; 7314-10-01-99110-01/401030794

1.2.2 Description of drinking water production facility

The Kangirsuk WTP was built in 1994 and completely renovated in 2013–2014. Water is delivered to the WTP from the pumping station upstream, which includes an outdoor reservoir, a pumping area, a chlorination room, a UV treatment and filtration area, a storage area, an electrical room, a generator room, an office laboratory, and sanitary facilities.

The raw water is disinfected using UV lamps, followed by treatment to remove iron and manganese, then chlorinated before being sent to a 330 m^3 storage reservoir. Water is pumped into the reservoir up to its maximum capacity, after which the excess water is drained into a small river. A constant flow of water is maintained in the supply pipe to prevent it from freezing.

Softening involves filtration on media specifically designed to target iron and manganese. The advantage of this system is that no chemicals are used. The only chemical used to treat drinking water is sodium hypochlorite (NaOCl 0.6%).

1.3 Localisation plan of protection zones for water used.

The RPEP defines three protection zones that must be delimited for Category 1 surface water withdrawals. For the water withdrawal in Kangirsuk, the boundaries of the protection zones are as follows:

Inner protection zone (s. 70): 300 m around the withdrawal site, including a 10 m strip of land measured from the high water mark.

Intermediate protection zone (s. 72): 3 km around the withdrawal site, including tributaries and a 120 m strip of land measured from the high water mark.

Outer protection zone (s. 74): The catchment area of the withdrawal site and the portion of the intermediate protection zone located downstream of the withdrawal site. This includes surface water and the entire territory within the boundaries of the catchment area.

Figures 8 and 9 show the location of the inner, intermediate, and outer protection areas of the withdrawal site.

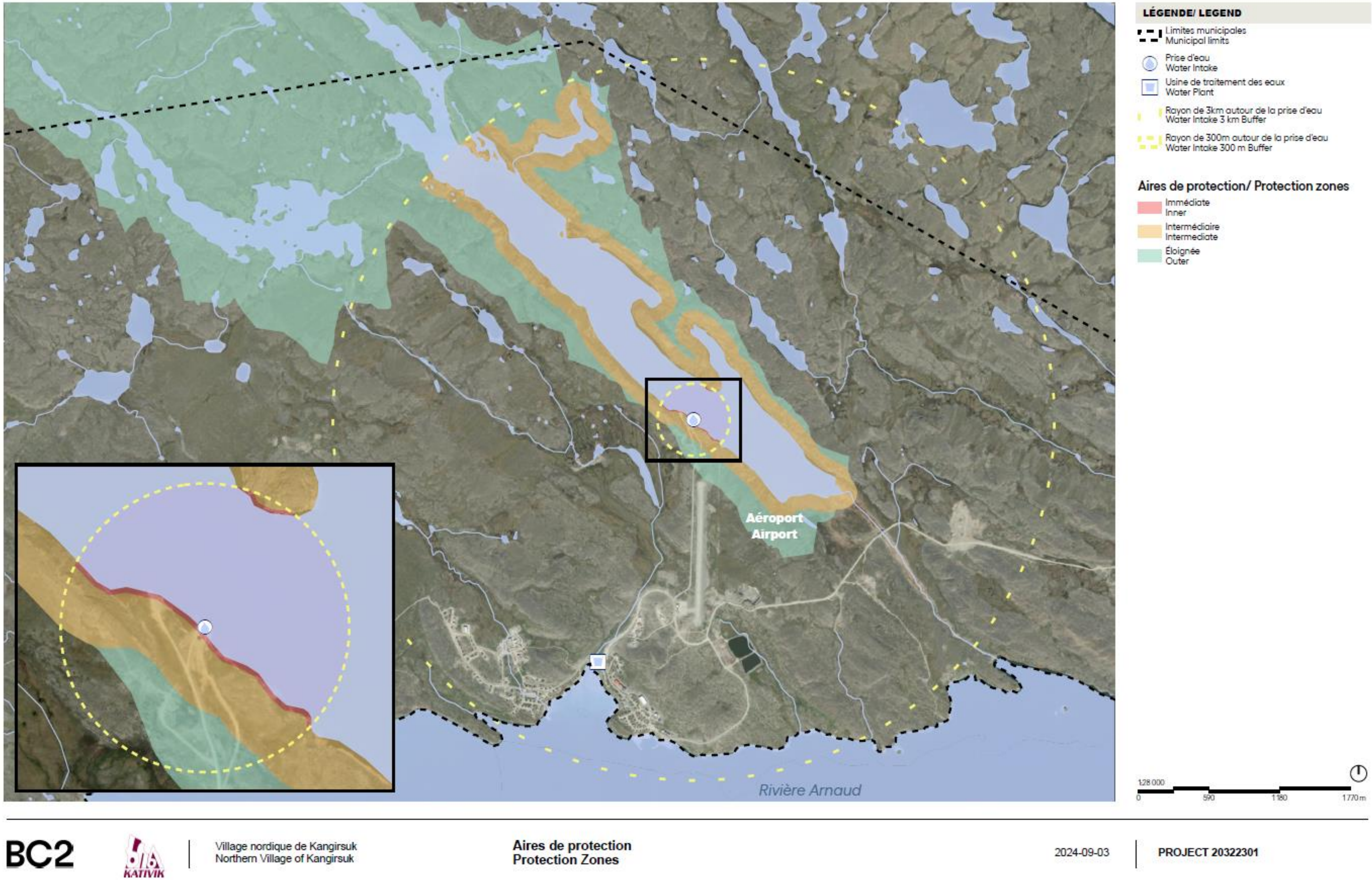


Figure 8 Inner and intermediate protection zones of the Lac Hardy water withdrawal site.

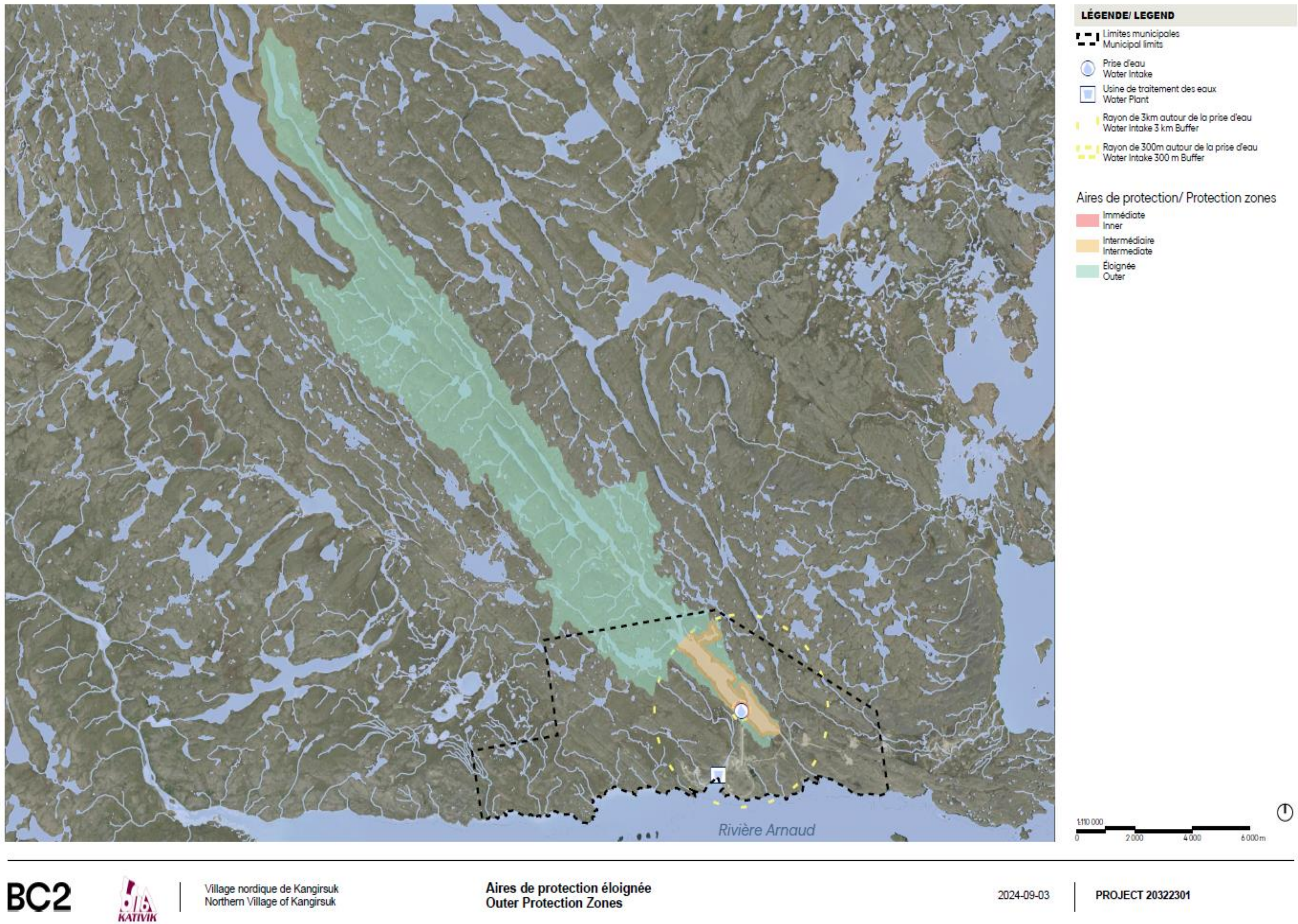


Figure 9 Outer protection zone of the Lac Hardy withdrawal site (Lac Hardy catchment area).

1.4 Vulnerability levels of water used

The final stage in the characterization of the water withdrawal is the analysis of the vulnerability of the watercourse. In accordance with section 69 of the RPEP, the vulnerability of surface water used for water withdrawals is assessed using six vulnerability indicators, which are rated as having a "low," "medium," or "high" level of vulnerability. This section presents the method used for each indicator, and the results obtained (Table 2).

1.4.1 Physical integrity of the withdrawal site

1.4.2 Vulnerability to microorganisms

1.4.3 Vulnerability to fertilizers

1.4.4 Vulnerability to turbidity

1.4.5 Vulnerability to inorganic substances

1.4.6 Vulnerability to organic substances

Table 2. Vulnerability levels of surface water used for withdrawal according to six indicators

Indicator assessed	Method	Level of vulnerability	Justification of the result
Physical integrity of the withdrawal site (A)	Method 3[4]	High	At least three service breakdown events have occurred in the last five years.
Vulnerability to microorganisms (B)	Method 2	Low	No facilities likely to dump pathogenic microorganisms or indicators of fecal contamination into the watercourse.
Vulnerability to fertilizers (C)	Methods 2, 3	Low	No algae or cyanobacteria blooms. No potential sources of ammonia nitrogen in the protection zones.
Vulnerability to turbidity (D)	Method 2	Low	Raw water turbidity consistently below 1 NTU. No seasonal adjustment.
Vulnerability to inorganic substances (E)	Method 2	Low	The surface area occupied by the activity sectors concerned is less than 20% of the intermediate protection zone.

[4] Method 3 is an adaptation for Nunavik.

Vulnerability to organic substances (F)	Method 2	Medium	The presence of a fuel tank in the inner protection zone poses a potentially high risk of contamination.

1.4.1 Physical integrity of the withdrawal site (A)

The *Guide* specifies two methods for assessing the physical integrity of the withdrawal site. The first is based on the number of events affecting the physical integrity of the withdrawal site over the last five years. The main source of information is the record of events kept by those responsible for Category I surface water withdrawals, as specified in section 22.0.4 of the RQEP. The second method is based on a hydrological analysis and must be carried out by a professional in the field.

In addition to these two methods, a third approach adapted to the context of Nunavik was proposed in the *Supporting document*. This approach draws on the collective memory of Northern communities and the knowledge of WTP operators in Northern villages. To highlight this third approach, which includes the knowledge of local stakeholders, it was favoured for the estimation of the physical integrity of withdrawal sites.

The highlights of meetings with municipal and regional stakeholders are as follows:

- There is no event record.
- The supply pipe in the lake froze in 2020.
- Pumps SPP1 and SPP2 have recently stopped working. Repairs took 3 days on each occasion. The technical team pointed out that the service life of the pumps is significantly shorter than the normal expected life. An underwater inspection is scheduled for the summer of 2025 to identify the causes of this problem.
- The withdrawal site’s perforated casing is positioned too close to the shore, which could lead to clogging of the casing and conduits.
- The KRG team stated that communication with the WTP and the withdrawal site is difficult in Kangirsuk. As a result, breakdowns can persist for some time before being detected and reported, exacerbating the overall vulnerability of the site.
- The pumping station has no flooring.

Due to the absence of an event record and the occurrence of several incidents affecting the physical integrity of the withdrawal site, the physical vulnerability of this site is considered to be high.

Table 3. Probable causes of the high level of vulnerability of the withdrawal site.

Identified problem	Vulnerability indicator with which this problem is associated	Identification of causes	Type of cause
Frozen pipes	Physical integrity of the withdrawal site (A)	Blizzards and bad weather	Natural
Blockage of conduits	Physical integrity of the withdrawal site (A)	Particulate matter build-up	Natural
Blockage of the perforated casing	Physical integrity of the withdrawal site (A)	Particulate matter build-up	Natural

1.4.2 Vulnerability to microorganisms (Indicator B)

Surface water can be vulnerable to contamination by pathogenic microorganisms, which are a major source of gastroenteritis and many waterborne diseases. Under section 22.0.2 of the RQEP, those responsible for water supply systems serving more than 1,000 people south of the 55th parallel are required to take periodic samples of raw water and measure their *E. coli* bacterial concentration. Northern villages, however, are not subject to this requirement.

Microbiological analyses carried out by WTP operators are limited to the weekly detection of *E. coli* and total coliforms using Colilert®technology [9]. The results are presented as presence/absence, so Method 1 cannot be used to estimate vulnerability to microorganisms. However, since those responsible for the Northern villages send their results to the KRG for compilation and distribution, we enhanced Method 2 by incorporating the interpretation of qualitative results. A heterogeneous database of 44 Colilert analysis results covering the year 2023 was analyzed and no positive results for the presence of E. coli were reported. In addition, total coliforms were detected once, in the week of May 4, 2023.

In Quebec, residual chlorine must be at least 0.3 mg/L in the water supplied (RQEP, Q-2, r. 40). However, the data consulted indicated a residual chlorine content of less than 0.3 mg/L in the water distributed when the presence of *E. coli* was reported. This observation falls outside the scope of the source's vulnerability, since it is a water treatment issue. Extra vigilance is warranted when total coliforms are detected.

Finally, according to the *Guide* [1], "the level of vulnerability is considered low if, in the catchment area of the withdrawal site, there is no conurbation served by a combined or pseudo-domestic sewer system, no livestock establishment, no food processing industry, or any other establishment likely to discharge pathogenic microorganisms or indicators of fecal contamination into the watercourse."

For all these reasons, the vulnerability to microorganisms of the water used is considered low.

1.4.3 Vulnerability to fertilizers (Indicator C)

Since the Northern village of Kangirsuk is located north of the 55th parallel, the regulations do not require monitoring of total phosphorus in raw water. Vulnerability assessment methods 2 and 3 should therefore be applied.

Method 2 is based on the number of events associated with algal, cyanobacterial, or aquatic plant blooms, and suspected increases in ammonia nitrogen. No proliferation events were observed at the withdrawal site.

The level of vulnerability to fertilizers is considered low.

1.4.4 Vulnerability to turbidity (Indicator D)

Operators of distribution systems supplied with surface water and that are located north of the 55th parallel are exempt from the requirements of section 22.0.2 of the RPEP, which calls for continuous monitoring of raw water turbidity and recording of the value obtained every four hours. The lack of a turbidity log limits the scope of this analysis.

Given that the turbidity of raw water intended for treatment must be less than 5 NTU, that turbidity varies between 0.3 NTU and 0.5 NTU without reaching the threshold of 1 NTU, and that seasonal fluctuations are negligible, the level of vulnerability to turbidity is considered low.

1.4.5 Vulnerability to inorganic substances (Indicator E)

Under section 14 of the RQEP, 11 inorganic substances are subject to quality standards. These include are antimony, arsenic, barium, boron, cadmium, chromium, cyanides, fluorides, mercury, selenium, and uranium. Annual monitoring of these substances is mandatory for all systems serving more than 20 people. Nitrates and nitrites must be measured on a quarterly basis.

As the available data set does not include 5 consecutive years for each of the target substances, method 2 was used. Method 2 uses the proportion of land area occupied by industrial, commercial, and agricultural activities to estimate the source's vulnerability to inorganic contaminants.
The only building in the intermediate zone is the pumping station. According to the spatial analysis, the percentage of the intermediate protection zone occupied by this building is 0.004%.

The level of vulnerability is considered low.

1.4.6 Vulnerability to organic substances (Indicator F)

The municipality of Kangirsuk is exempt from monitoring the organic substances listed in section 19 of the RQEP, since it supplies fewer than 5,000 people. As such, no data are available. Method 2, identical to that used previously (Indicator E), is therefore used to assess the source's level of vulnerability to organic substances.

The only building in the intermediate zone is the pumping station. According to the spatial analysis, the percentage of the intermediate protection zone occupied by this building is 0.004%. However, the presence of a fuel tank straddling the inner and intermediate protection zones between the pumping station and Lac Hardy poses a threat to water quality. The tank involves the handling and storage of 10,000 litres of diesel in an area of permafrost that is unstable to thawing and at risk of flash floods, ice jams, and ice break-up (see section 2.2 Results of the inventory of potential events and assessment of the threats they represent for more details, and Appendices Appendix 3 and Appendix 7 for reference maps).

The level of vulnerability is therefore considered medium.

Table 4. Probable causes of medium vulnerability to organic substances.

Identified problem	Vulnerability indicator with which this problem is associated	Identification of causes	Type of cause
Fuel storage and handling at the water treatment plant	Vulnerability to organic substances (F)	Presence of water treatment plant in the intermediate zone	Anthropogenic

2. Inventory of factors likely to affect the water used

Section 75 of the RPEP requires that the vulnerability analysis include a complete inventory of factors likely to affect the quality or quantity of the water used. The list of potential threats must include anthropogenic activities (sites and establishments that release or are likely to release contaminants into the water intake; section 2.1), potential events associated with anthropogenic activities (unpredictable situations representing a risk to surface water; section 2.2), land uses (land uses that could lead to contamination of the source or a reduction in the quantity of water available; section 2.3). To provide the best reflection of the actual situation, natural hazards and sources of natural contamination are also inventoried.

In addition to identifying threats to water quality and quantity, the vulnerability analysis method proposed by the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs also includes an estimate of the risk associated with each threat. Risk estimation is based on a qualitative assessment of the severity of the impact of a threat, and an estimate of the frequency of contamination (or probability, in the case of potential events).

2.1 Results of the inventory of anthropogenic activities and assessment of the threats they represent

Lac Hardy lies upstream of the village at a relatively high altitude. There are few activities on the lake, whether in summer or winter. Anthropogenic activities in the inner and intermediate zones of the withdrawal site are presented in

Tableau 5. The two main concerns that emerged from this analysis relate to the presence of fuel in the inner zone, i.e., the snowmobile parking area and the fuel tank attached to the pumping station (Figure 7).

There is little activity in the outer zone of Lac Hardy, but it is an area of mining interest. Two active mining titles were identified on the northwestern edge of the catchment area (Appendix 6). These titles are not associated with any activity, so they pose no threat to the water quality of Lac Hardy. However, extra vigilance will be required when it comes to granting titles and approving mining activities in the outer protection zone.

Tableau 5. Anthropogenic activities occurring in the inner and intermediate protection zones of the Northern village of Kangirsuk drinking water withdrawal site.

Anthropogenic activity	Protection zone in which the activity takes place	Contaminant or group of contaminants considered	Determined risk
Snowmobile parking area	Inner protection zone	Organic and inorganic substances (fuel)	Very high
Fuel storage and handling at the raw water supply station	Inner protection zone	Organic substances (fuel)	High
Snowmobile parking area	Intermediate protection zone	Organic and inorganic substances (fuel)	High
Fuel storage and handling at the raw water supply station	Intermediate protection zone	Organic substances (fuel)	Medium
Presence of the landing strip at Kangirsuk northern airport	Intermediate protection zone	Turbidity	Medium
Namminivut hydroelectric power plant project	Intermediate protection zone	Water quantity	Medium

2.2 Results of the inventory of potential events and assessment of the threats they represent

Potential events with a high-risk profile relate to the anthropogenic activities identified in section 2.1, i.e., the snowmobile parking area and the fuel tank at the pumping station (Figure 7). Normal fuel handling and storage activities at the pumping station are liable to lead to a fuel spill in the inner zone between the tank and Lac Hardy.

Table 6. Results of the inventory of potential events and assessment of the threats they represent.

Anthropogenic activity	Anthropogenic activity associated with the potential event	Protection zone in which the activity takes place	Contaminant or group of contaminants considered	Determined risk
Fuel spills	Fuel storage and handling at the raw water supply station	Inner protection zone	Organic substances (fuel)	High
Fuel spills	Snowmobile parking area	Inner protection zone	Organic substances (fuel)	High
Fuel spills	Fuel storage and handling at the raw water supply station	Intermediate protection zone	Organic substances (fuel)	High
Fuel spills	Snowmobile parking area	Intermediate protection zone	Organic substances (fuel)	Low
Particle deposition during aircraft take-off and landing	Presence of the landing strip at Kangirsuk northern airport	Intermediate protection zone	Turbidity	Low
Drop in water level	Namminivut hydroelectric power plant project	Intermediate protection zone	Water quantity	Low

Firstly, the withdrawal infrastructure is located on deposits that are unstable to thawing and contain large quantities of ice (Appendix 3; [3]). Fluctuations in the ground can cause buildings to buckle and pipes to burst.

Some natural hazards have also been identified as potential threats at source. Adverse climatic conditions (blizzards, windstorms, ice storms) can be very intense and last for several days [3]. Given that their annual occurrence is almost certain, it is essential to include them in the planning of measures to protect drinking water supplies. According to the analysis carried out by the Centre for Nordic Studies, the risk potential of climatic hazards is estimated to be high to very high for essential services such as the airport, power lines, and communication towers. Although this assessment does not take account of the withdrawal infrastructure, the geographical isolation of the village and the low winter temperatures (average temperature = -18.2 °C) increase the municipality's vulnerability.

Finally, the map of actual and potential natural hazards produced by the Centre for Nordic Studies indicates a risk of flash floods, ice jams, and ice break-up in the inner withdrawal zone (Appendix 7).

2.3 Land-use inventory results

Analysis of the vulnerability of drinking water supplies requires an inventory of the land uses that cut across the protection zones. In the case of Kangirsuk, no land use was identified in the protection zones (see the Master Plan in Appendix 1).

3 Identification of the probable causes of problems raised by vulnerability indicators

The probable causes of the medium level of vulnerability obtained for Indicators A and F were identified in Section 1. In the case of the physical integrity of the withdrawal site, it should be noted that the problems identified are exacerbated by the complexity of parts supply logistics (air and sea transport only), the lack of local expertise, and the shortage of skilled labour.

The low level of vulnerability obtained for Indicator E (inorganic substances) is debatable as the analysis method does not allow measurement of the pH and the presence of certain metals in the water at the source. It is worth noting that the water in Lac Hardy is strongly influenced by geological features characterized by an acid pH (pH=3–4) and a high concentration of iron and magnesium. This adds to the complexity of the treatment and the associated issues.

4 Missing data

In Nunavik, there is substantially less water quality data than south of the 55th parallel. Some data simply do not exist, while others can be difficult to find. There are two main reasons for this:

1. There are exceptions and exemptions for Northern villages in the RQEP. These exemptions inevitably lead to the absence of data.

2. Transporting water samples for analysis is a complex logistical task in northern environments since air transport is dependent on weather conditions. This means that samples taken in accordance with best practices may not arrive at the laboratory on time, and may be discarded. Some regulatory analyses may therefore be incomplete, making historical analyses impossible.

The approach proposed in the *Supporting document* is designed to overcome this lack of data, and enables local knowledge to be put to good use, including in the analysis of the withdrawal site physical integrity indicator.

Methods 1 and 2 proposed in the *Guide* and the adaptations proposed for Nunavik include sufficient alternatives to complete the VAR, even in the absence of regulatory data.

The lack of knowledge about the potential impacts of climate change on water quality and quantity is a major challenge, and increases the uncertainty associated with estimating the probability of an event. In all cases, a conservative approach based on knowledge of the local context was applied.

The information gathered to estimate vulnerability to microorganisms has highlighted the complexity of this issue in Kangirsuk. Figure 10, which shows the annual proportion of raw water bacteriological tests carried out for each Northern village, illustrates this point [10]. The rate at which bacteriological tests are carried out at Kangirsuk is representative of the average, but several factors can lead to a test not being carried out. Given that these results make up the bulk of the raw water quality database for sources of supply, it is difficult to carry out statistical or trend analyses.

Bacteriological Analysis – Colilert Sampling Results:

	2021 50 weeks	2022 52 weeks	2023 50 weeks	2024 18 weeks
Kangiqsualujjuaq	95%	92%	82%	94%
Kuujjuaq	98%	98%	98%	100%
Tasiujaq	81%	87%	88%	94%
Aupaluk	79%	90%	92%	94%
Kangirsuk	84%	96%	88%	89%
Quaqtaq	65%	96%	82%	83%
Kangiqsujuaq	93%	88%	80%	89%
Salluit	91%	71%	92%	100%
Ivujivik	63%	98%	98%	50%
Akulivik	49%	85%	74%	89%
Puvirnituq	77%	75%	66%	89%
Inukjuak	86%	73%	90%	94%
Umiujaq	79%	85%	60%	61%
Kuujjuarapik	98%	98%	96%	100%
Average Nunavik	**81%**	**89%**	**85%**	**88%**

Figure 10. Annual proportion of bacteriological analyses carried out for each Northern village. Excerpt from the Municipal Public Works Department Activity Report (May 2024) [10].

5 Conclusion and recommendations

The analyses carried out at Kangirsuk confirm that Lac Hardy has few potential sources of contamination. Indicators of vulnerability to microorganisms, turbidity, fertilizers, and inorganic substances show a low level of vulnerability. The main issues identified are associated with the development of the withdrawal site, resulting in high physical vulnerability and medium vulnerability to organic substances. To provide support to the Northern village of Kangirsuk in protecting its only source of drinking water, a number of recommendations and their priority levels are presented in Table 7. In addition, some recommendations are presented in greater detail.

Table 7. Recommended actions to reduce the vulnerability of the Lac Hardy water withdrawal.

Priority	Problem	Possible solutions
1	No event record	• Adapt the event recording model to the context of the village of Kangirsuk (to encourage operators to adhere to

		it) and monitor the recording of events.
2	Fuel storage and handling at the raw water pumping station	• Move the fuel tank away from the inner zone; • Offer targeted training to Fédération des coopératives du Nouveau-Québec (FCNQ), WTP, and Northern village employees, combined with the installation of a spill containment station with the equipment needed to contain the spill and limit the risk of contamination at source.
3	Short service life for pumps SPP1 and SPP2	• Carry out an underwater inspection of the condition of the intake conduit and the perforated casing; • If the blockage in the conduits is not the cause of the short service life of the pumps, continue investigating.
4	Communication difficult	• Implement solutions to improve the quality of communication; • Identify possible problems in the event of poor communication and develop solutions that are independent of problematic technologies.
5	No emergency response plan	• Develop and implement an emergency response plan in the event of source contamination or service disruption.
6	Weakened resilience of the supply chain	• Offer targeted technical training to WTP operators to ensure greater resilience (e.g., ensuring a constant flow to prevent pipes from freezing).

The lack of an event record is a problem in Kangirsuk, as it is in other Northern villages. It is recommended that the KRG encourage the development of this practice, and that the Northern villages comply with it. It's a simple tool that improves knowledge of a withdrawal site.

Very few anthropogenic activities have been identified on the territory, and potential events are comparable to those of other Northern villages for which vulnerability has been analyzed. In this respect, the presence of the diesel tank between the pumping station and the withdrawal site is the main concern. In fact, the tank is located just a few metres from the supply source. A spill at this location could have very serious consequences for the local population as response capabilities are limited.

It was announced that major work is planned for Lac Hardy in the coming years. A hydroelectric power plant with sufficient capacity to meet the energy needs of the water withdrawal infrastructure will be built at the lake's outlet. As well as reducing infrastructure fuel requirements, this work provides an opportunity to move old and new fuel tanks away from the inner zone. A third advantage of this work is the 46 m extension of the feeder pipe to compensate for the drop in water level during the construction of the power plant. Extra vigilance with regard to water levels will be required once the structure is in operation.

The second potential source of organic substance contamination, snowmobile parking in the inner protection zone, poses less of a threat. It is recommended that the public be informed of the threat posed by this practice and that an alternative location be proposed that will offer the same benefits to users, without compromising the source of the drinking water supply. Snowmobile traffic on Lac Hardy should be discouraged and bypass routes put in place where necessary.

The physical vulnerability of the withdrawal site is also attributable to Kangirsuk's geographical location and the natural hazards that this entails. Although hazards are inevitable, better preparation by WTP operators would help limit the consequences of such events. To achieve this, improvements to the communication systems between the pumping station and the WTP could be considered. Finally, the development and implementation of an emergency response plan in the event of community isolation, broken pipes, and contamination of the source would be an asset for the Northern village of Kangirsuk.

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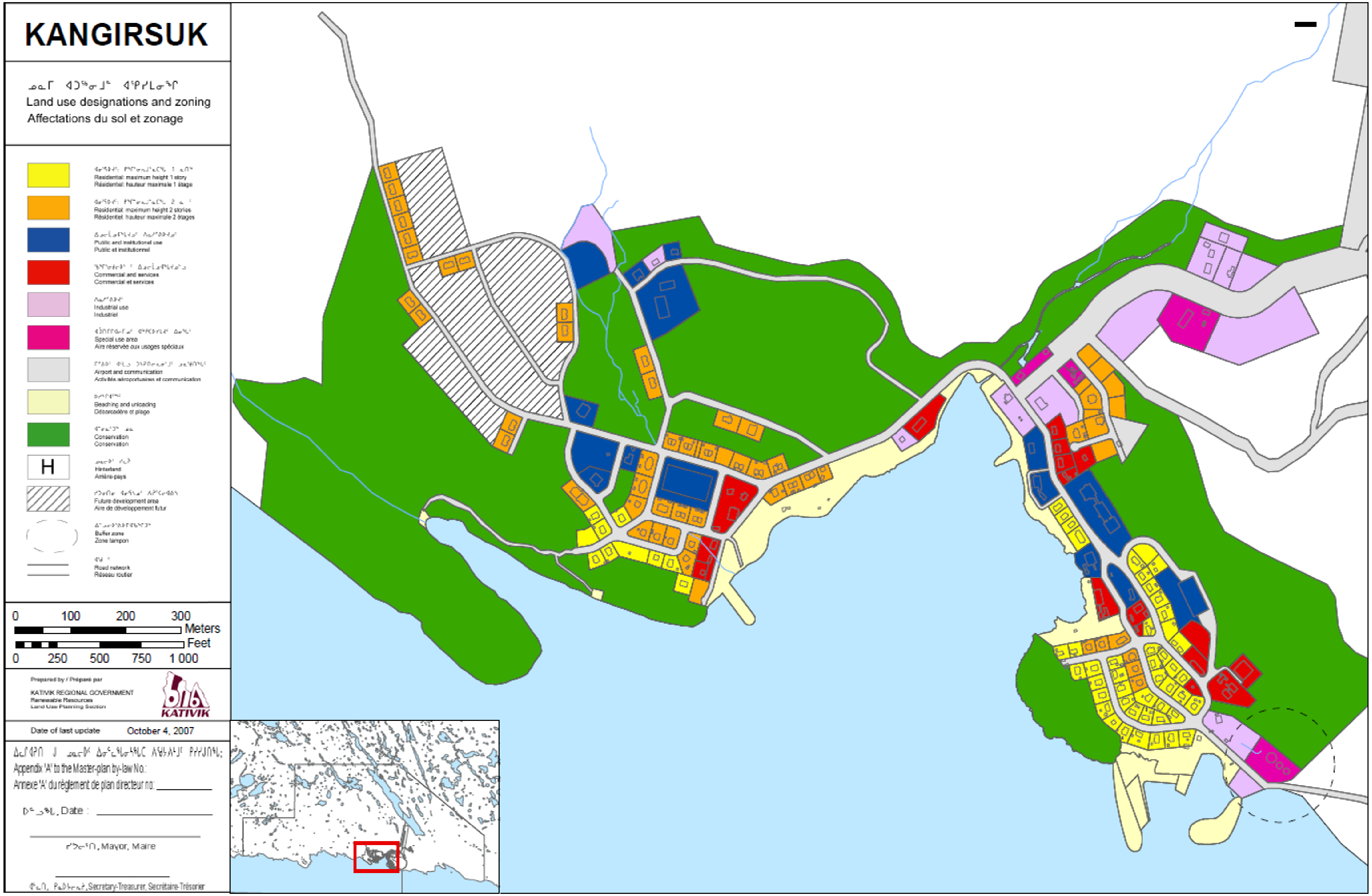
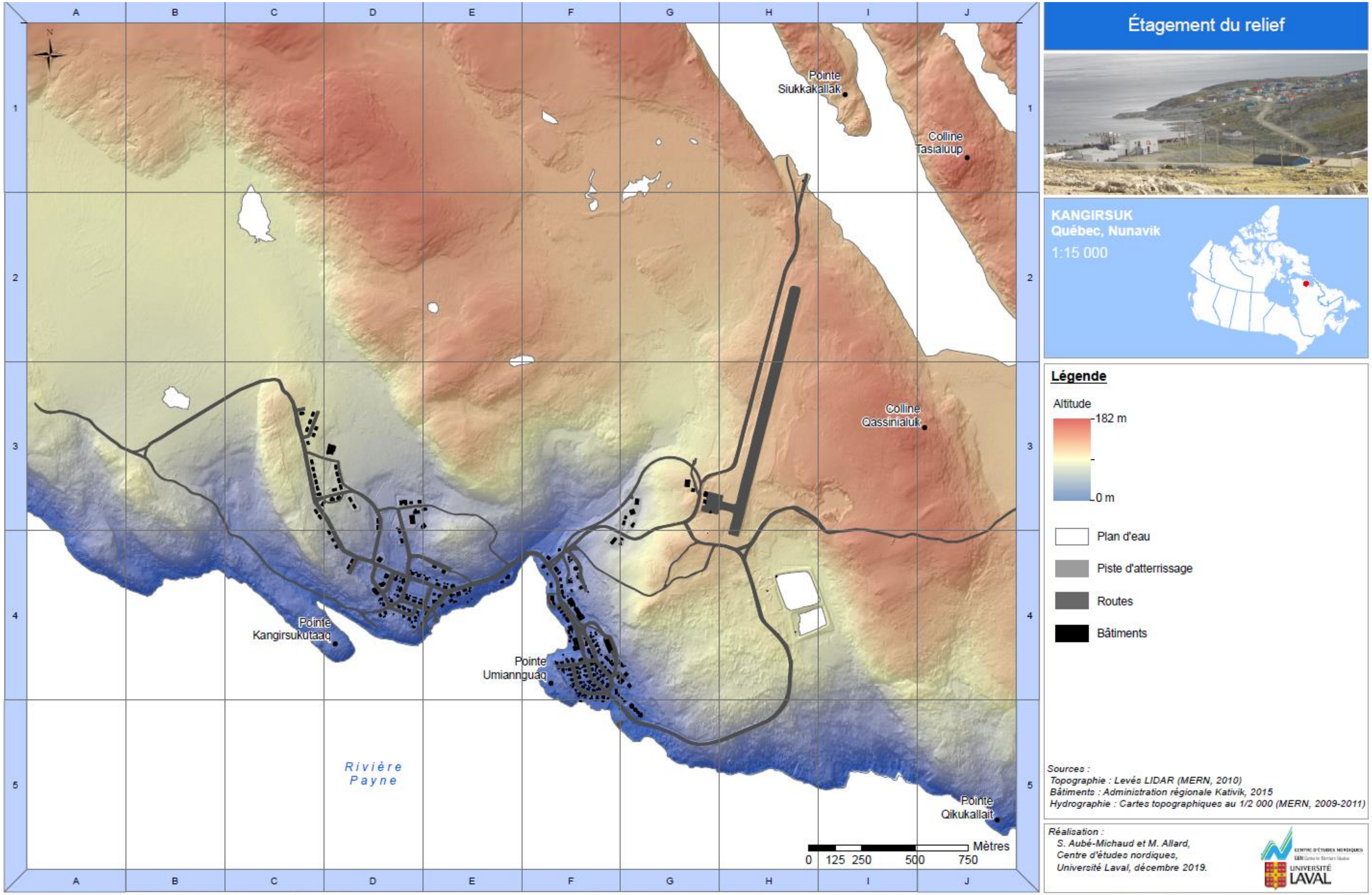
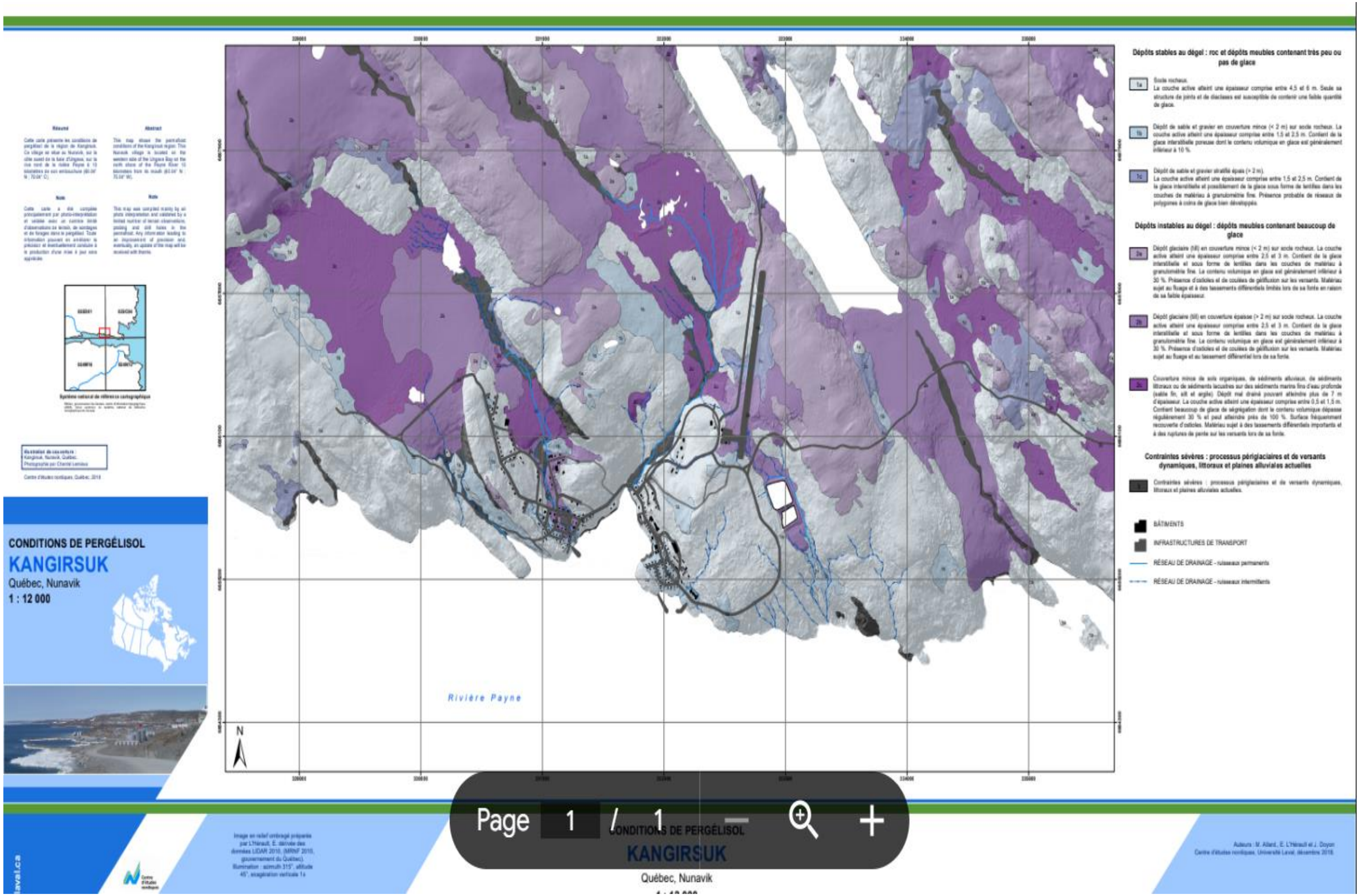
Appendix 1. Master plan for the Northern village of Kangirsuk.

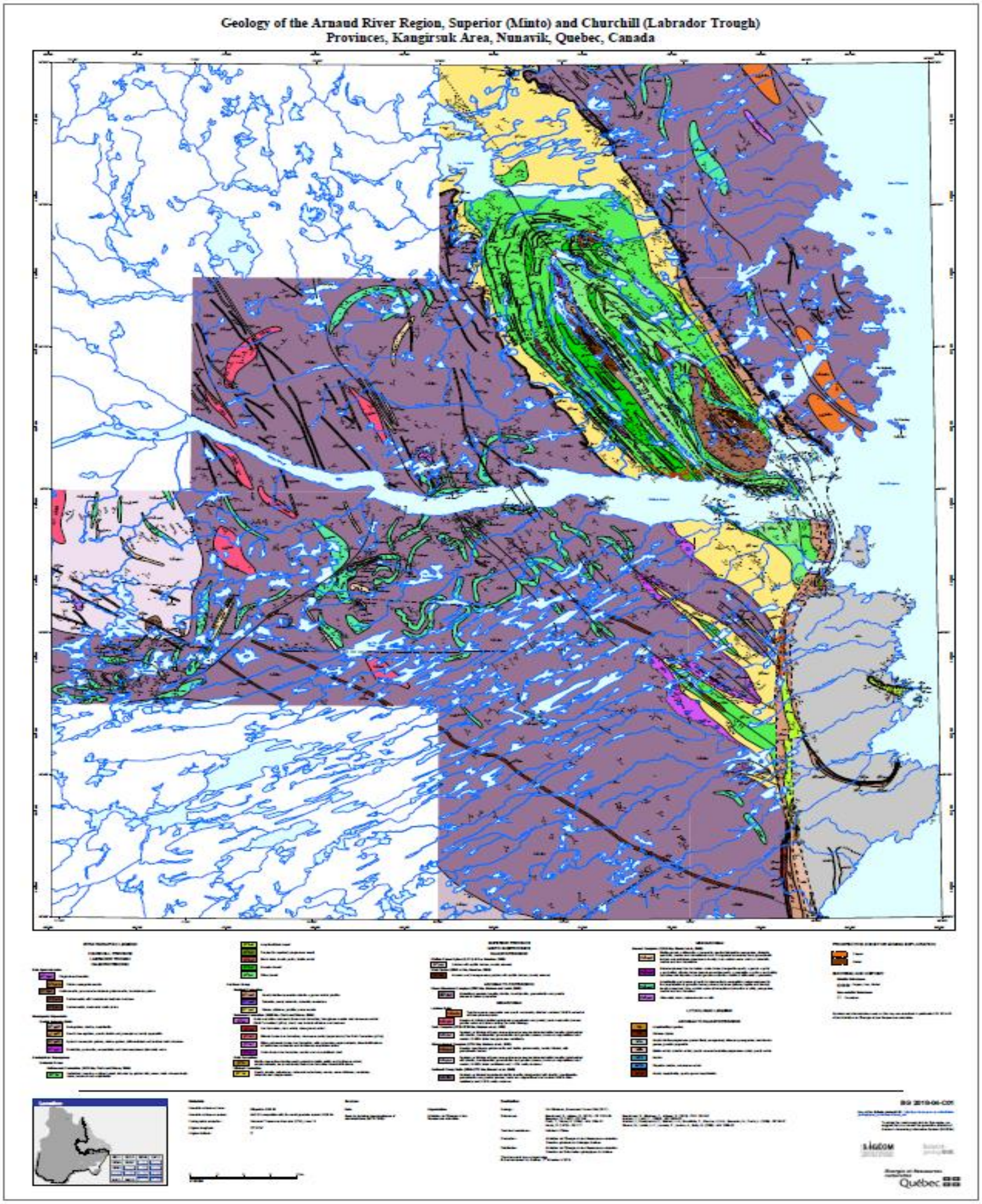


Appendix 2. Topographical map of the Northern village of Kangirsuk

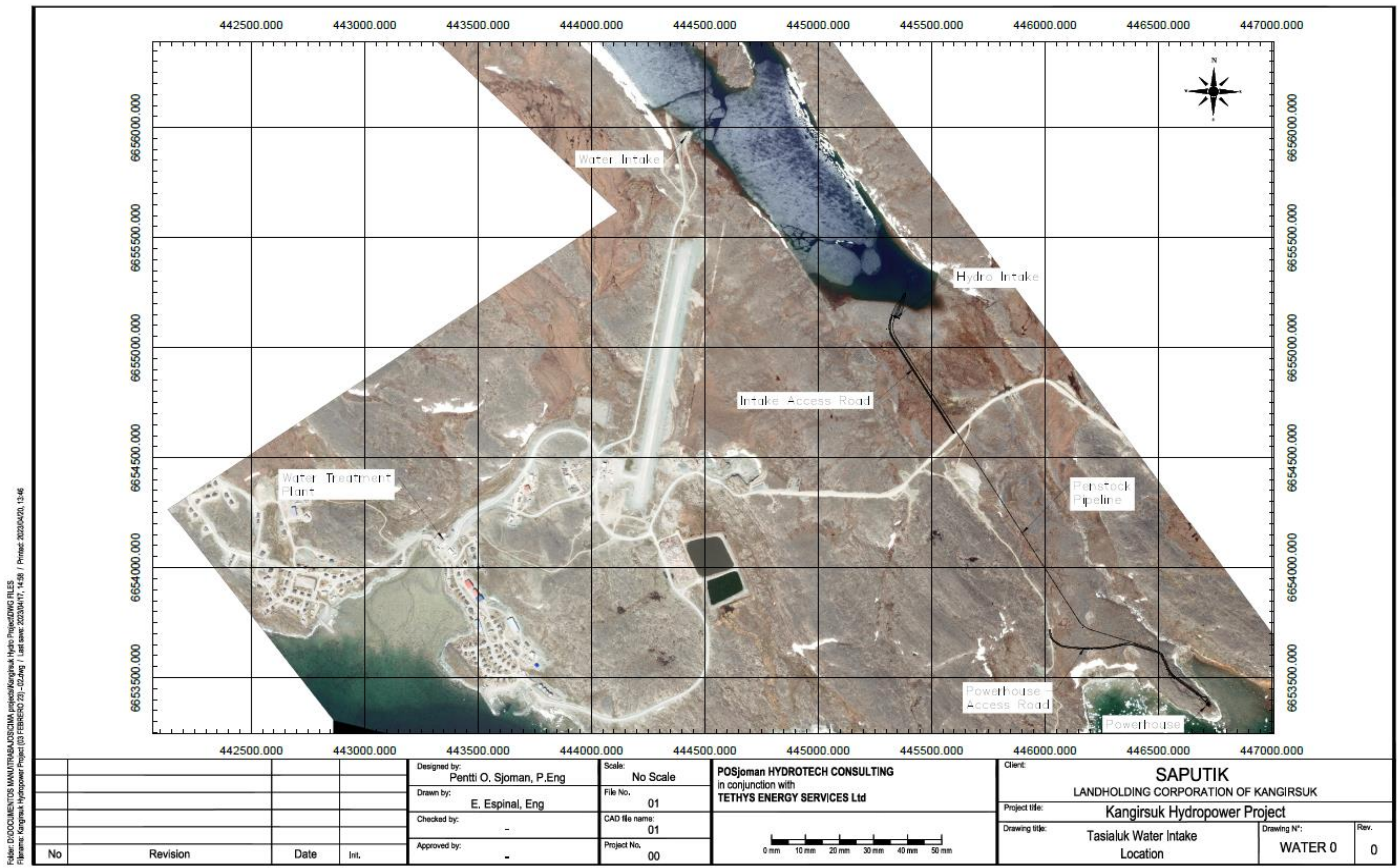



CONDITIONS DE PERGÉLISOL
KANGIRSUK
Québec, Nunavik
1 : 12 000
Rivière Payne
N
Dépôts stables au dégel : roc et dépôts meubles contenant très peu ou pas de glace
Dépôts instables au dégel : dépôts meubles contenant beaucoup de glace
Contraintes sévères : processus périglaciaires et de versants dynamiques, littoraux et plaines alluviales actuelles
BÂTIMENTS
INFRASTRUCTURES DE TRANSPORT
Page 1 / 1

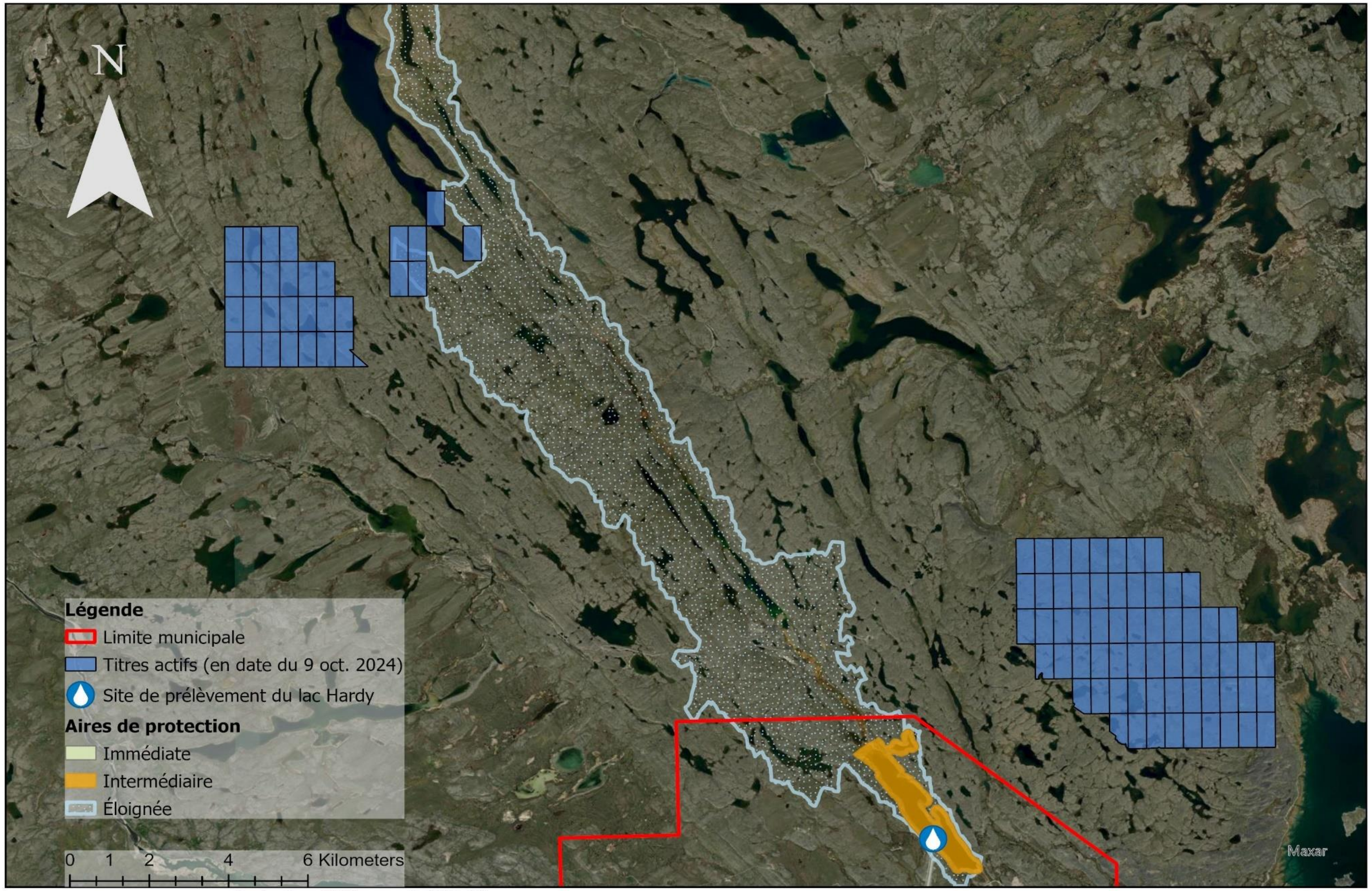
Appendix 4. Geological map of the Arnaud River Region, Superior (Minto) and Churchill (Labrador Trough) Provinces



Appendix 5. Plan of hydroelectric development.



Appendix 6. Mining titles in the Lac Hardy catchment area



1:130 000

Projection MTM zone 7, NAD 83
Sources utilisées: MINISTÈRE DES RESSOURCES NATURELLES ET DES FORÊTS. Titres actifs.2021. [En ligne]. Available: https://sigeom.mines.gouv.qc.ca/signet/classes/I1108_afchCarteIntr . [Accès le 15 11 2024].
MINISTÈRE DES RESSOURCES NATURELLES ET DES FORÊTS. Découpages administratifs, [Jeu de données], dans Données Québec, 2018, mis à jour le 24 octobre 2024. [https://www.donneesquebec.ca/recherche/dataset/decoupages-administratifs], (consulté le 15 novembre 2024).

Appendix 7. Actual and potential natural hazards in Kangirsuk.