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

KATIVIK

Water intake number: X2114290

January 2025

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Table of Contents

List of Tables

List of Figures

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 Kangiqsujuaq had a population of 861 [1], and the number of people served, as defined in the Regulation respecting the quality of drinking water (RQEP, Q-2, r.40), was 550.[2] This is a Category I withdrawal. The marked difference between the actual population and the estimated population means that only 64% of the population is taken into account when assessing the village's drinking water requirements. Results from the most recent Canadian census show that the average size of private households in Kangiqsujuaq is 2.8 people.

[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 RQEP, 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 meeting with Naalak Misfud, Municipal Manager of the Northern village of Kangiqsujuaq, was held on April 23, 2024, in Kuujjuaq. The purpose of this meeting was to discuss the general drinking water supply situation and to validate certain information. Mr. Misfud provided an illustration of the most popular ATV trails at this meeting (Appendix 1).

It should be noted that a number of collaborators helped to compile the information presented in this report. In particular, the team from the Public Works Department responsible for supporting the WTPs in the Northern villages contributed to the technical content of this report.

General description of the study area

The Northern village of Kangiqsujuaq is built on the coast of Wakeham Bay, between Ungava Bay and the Hudson Strait. The village is also known as Wakeham Bay. In 2021, the municipality had a population of 837 living on 12.4 km^2, for a density of 67.4 people/km^2 [2]. The municipality's territory stretches from the coast to the 78° 3' 5 W meridian. The area is characterized by rocky outcrops running east-west that formed during the last deglaciation [3].

Kangiqsujuaq lies in a continuous permafrost zone and has a tundra climate. The frost season runs from October 3 to June 20 and the average winter temperature is -16 °C [3]. Summers are short and cool, with maximum temperatures rarely exceeding 10 °C, and an average summer temperature of 2.2 °C [3]. Precipitation is estimated at 545 mm per year, 48% of which falls as snow. Winds, which are often violent, play a key role in shaping the climate and landscape.

The growing season lasts 47–66 days, and the vegetation is typical of herbaceous arctic tundra [3]. The plant life is not very diverse, consisting mainly of mosses, lichens, grasses, and hardy shrubs adapted to the cold and poor soils. This plant life supports a diversity of wildlife, including caribou, Arctic fox, and migratory birds.

The topography of the Kangiqsujuaq region is varied, characterized by valleys running in different directions and converging on Wakeham Bay. Altitude increases gradually from east to west, with higher mountains in the northwest, often reaching over 300 m, while in the east and south it rarely exceeds this height. A relief map is provided in Appendix 2.

The community is located to the north of the mineral-rich region known as the Cape Smith Belt. Mining activities have been carried out intermittently in the region since the 1950s [4]. One hundred kilometres northwest of Kangiqsujuaq lies the Raglan mine, one of the richest base metal mines in the world. A map showing the active mining titles in the region can be found in Appendix 4.

The location of the village in relation to the water withdrawal site is shown on the map below (Figure 1).

Figure 1 Localisation map for the Northern village of Kangiqsujuaq.

1. Characterization of water withdrawal

1.1 Watershed delimitation of the withdrawal site and brief characterization

Kangiqsujuaq's drinking water supply comes from Lake Qurlutuup Tasinga, located in the Wakeham River hydrographic region of the Ungava Bay watershed. Lake Qurlutuup Tasinga covers an area of 0.27 km^2, is 100 m above sea level, and lies 1.5 km southwest of the village (Figure 2) [5]. The lake's catchment area is relatively small, with an estimated surface area of 3.3 km^2 (Figure 8). As a result, most of the water comes from precipitation and the three small lakes upstream.

The hydrology of the Kangiqsujuaq region is dominated by an annual flood in June, when the rivers and streams provide around 50% of their annual flow. From January to May, only 10% of the annual flow of these rivers is recorded, marking a winter low-flow period [3]. There are a number of permanent and intermittent streams flowing through fractures in the rock and into the valleys. Lakes Tasialuk, Tasiukutaaguluk, and Kiviniik (running from northwest to southeast), as well as a number of smaller lakes at higher elevations, are located in the vicinity of Kangiqsujuaq (Appendix 2. Topographical map of the Northern village of Kangiqsujuaq).

Figure 2. 3D representation of the Northern village of Kangiqsujuaq. Modified from a Google Earth image (60°33'53 'N 71°55'33 'W; camera elevation: 117 m; image date: 22/8/2024).

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.

The 2021 LIDAR data of the Ministère des Ressources naturelles et des Forêts's were used to determine the catchment areas of drinking water sources, which correspond to their outer protection zones. [7]

1.2 Description of the withdrawal site and drinking water production facility

1.2.1 Description of the withdrawal site

Water is withdrawn from Lake Qurlutuup Tasinga via a supply conduit with a perforated casing placed in the lake (see Figure 3).

Figure 3 Supply conduit and submersible pump used to withdraw water from Lake Qurlutuup Tasinga

This conduit is connected to a booster pump that allows the water to circulate to a shelter (Shelter #100; Appendix 3. Schematic diagram of the water supply line between Lake Qurlutuup Tasinga and the WTP.), which houses the RP-100 and RP-101 pumps, the power supply, access to the heating cable, and a booster socket (see Figure 4).

Figure 4. Water withdrawal infrastructure (Photo taken on July 26, 2024, by Antoine Thibault)

The conduit that carries the raw water to the drinking water treatment plant (WTP) is positioned above ground between the withdrawal site and Shelter #101 (Figure 5). The rest of the conduit is buried underground and accessible via three access chambers.

The total length of the conduit is 1.6 km. In 2022, emergency work was carried out after the conduit between Shelters #101 and #102 froze. A bypass conduit was installed and the necessary repairs were carried out over the following summer.

Figure 5. Above-ground positioning of the supply conduit between the withdrawal site and the WTP (Photos taken on July 26, 2024, by Antoine Thibault)

The main characteristics of the withdrawal site are presented 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	Kangiqsujuaq—Supply
Water intake number	X2114290
Production facility number	X0010362
Production facility category	Category 1 (Surface)
Geographic coordinates	61° 34′ 56.43 ″ N, 71° 57′ 24.18 ″ W
Type of use	Permanent
Type of withdrawal	Submerged perforated casing
Withdrawal depth	4.5 m
Distribution	Tank truck (2 trucks)
Population served	550
Authorized daily withdrawal rate	100 m^3/day
Low-water level	Unknown
Number of the most recent authorization issued by the Ministère	2006-06-13; 7311-10-01—99130-01/2000085139

1.2.2 Description of drinking water production facility

The Kangiqsujuaq WTP was built in 2005 and upgraded in 2011, 2017, and 2018. The treatment involves dual disinfection using UV and chlorine (sodium hypochlorite-based). There is no filtration system, except for activated carbon filtration for the community tap attached to the building.

The treated water is stored in a 450 m^3 cylindrical tank, from which pumps are used to load the tankers via loading arms. The plant's infrastructure includes an electrical room with a diesel generator, a chlorination room, a UV zone in the machinery room, a boiler room, a laboratory, an office, and a workshop. To prevent the conduits from freezing, the system is also fitted with a gravity siphon transmission conduit with a recirculation system.

Figure 6. Drinking water treatment plant in the Northern village of Kangiqsujuaq [8].

The only chemical used to treat drinking water is sodium hypochlorite (NaOCl 0.6%).

Figure 7. Treated water tank attached to the Kangiqsujuaq WTP (450 m^3). Photo taken on July 26, 2024, by Antoine Thibault.

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 Kangiqsujuaq, 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.

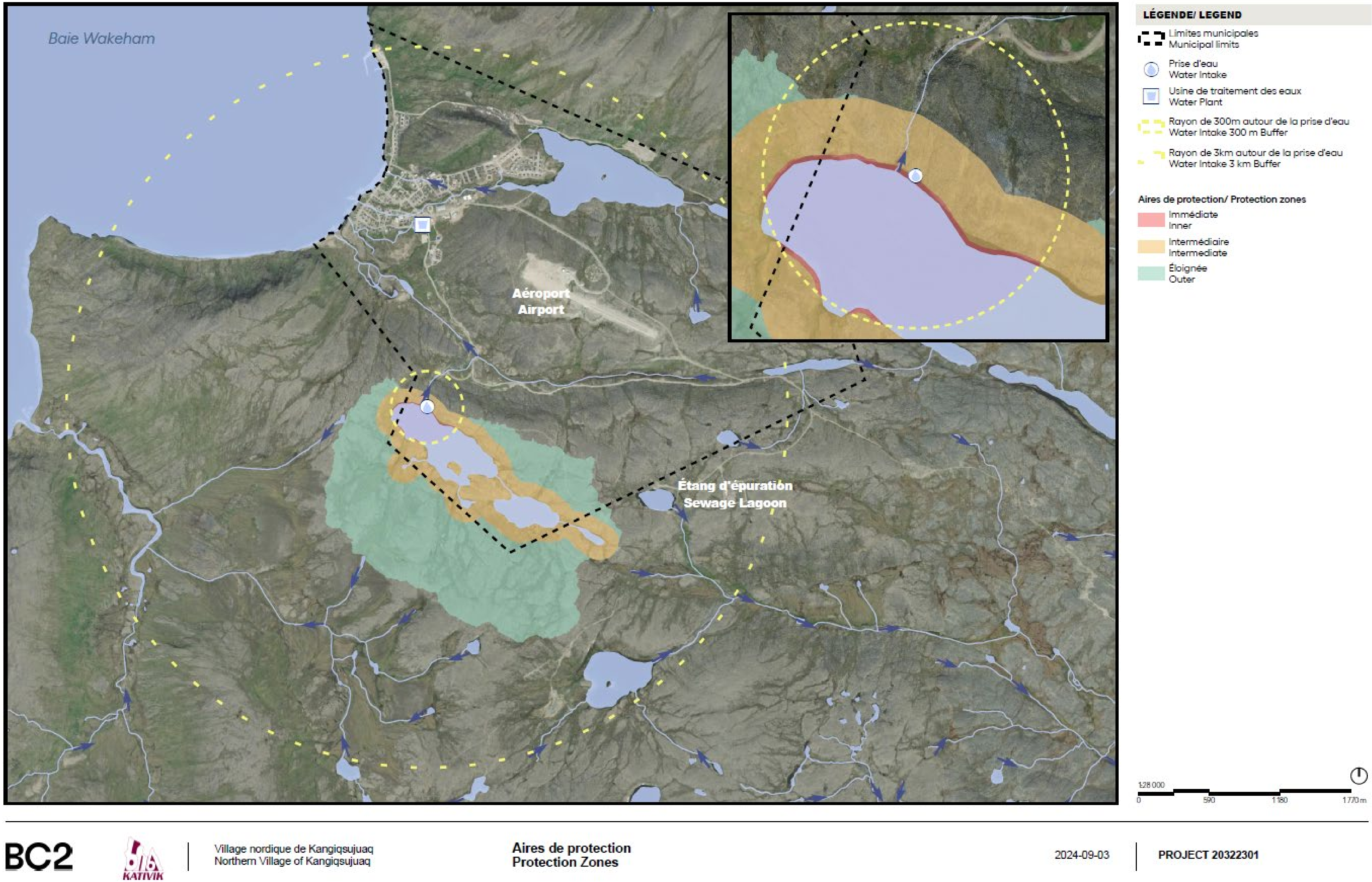

Figure 8. Outer protection zone of the Lake Qurlutuup Tasinga withdrawal site.

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 water used for surface water withdrawal is assessed using six indicators, which are assigned 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	High	At least three service disruption events have occurred in the last five years.
Vulnerability to microorganisms (B)	Method 2	Low	No facilities likely to dump pathogenic microorganisms into the watercourse and no indicators of fecal contamination.
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.
Vulnerability to organic substances (F)	Method 2	Low	The surface area occupied by the activity sectors concerned is less than 20% of the intermediate protection zone.

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 the municipal stakeholders' meeting were as follows:

- There is no event record.
- The conduit between Shelters #101 and #102 froze in 2022.
- Pumps SPP1 and SPP2 have recently stopped working. Repairs took 3 days on each occasion.
- There is no road access to the withdrawal site.

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
Service disruption	Physical integrity of the withdrawal site (A)	Very low winter temperatures and part of the conduit is exposed.	Natural
Increasing turbidity in the supply conduit	Physical integrity of the withdrawal site (A)	Perforated supply conduit resulting in accumulation of particulate matter	Natural
Increasing turbidity in the supply conduit	Physical integrity of the withdrawal site (A)	Perforated supply conduit resulting in accumulation of particulate matter	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 consisting of 43 Colilert analysis results in 2023 and 34 results in 2024 was analyzed. For 2023, 4 positive results for the presence of total coliforms and no detection of *E. coli* were reported. For 2024, the presence of *E. coli* was detected during the weeks of June 13 and June 26, 2024, with the detection of total coliforms on June 20, 2024.

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 Kangiqsujuaq 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. However, the turbidity of the raw water is measured at the WTP and passed on to the KRG team. On November 13, 2024, a discussion with the compound team informally confirmed that the turbidity of the raw water did not exceed 1 NTU.

Given that the turbidity of raw water intended for treatment must be less than 5 NTU, that turbidity varies between 0.1 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 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 inner protection zone is Shelter #100, which contains the distribution infrastructure described in section 1.2.1. This building covers an area of around 5 m^2, meaning that it occupies 0.0004% of the inner protection zone.

The level of vulnerability is considered low.

1.4.6 Vulnerability to organic substances (Indicator F)

The municipality of Kangiqsujuaq 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 distribution station. According to the spatial analysis, the percentage of the intermediate protection zone occupied by this building is 0.0004%. In addition, there are no fuel tanks in the inner and intermediate zones, which provides an advantage over other drinking water withdrawal sites in Nunavik.

The level of vulnerability is considered low.

2. Results of the inventory of anthropogenic activities and assessment of the threats they represent

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), and 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

Lake Qurlutuup Tasinga is located in a remote part of the municipality and there is little activity in the surrounding area. The main anthropogenic activity that threatens water quality is snowmobile traffic in winter. In fact, Lake Qurlutuup Tasinga appears to be the starting point for three different winter routes (Appendix 1). This threat has been identified in all three protection zones (Table 4).

Although the area is active in terms of exploration and mining, which raises concerns about the quality of fresh water and aquatic fauna, the supply source's outer zone is not threatened by these activities.

Table 4. Anthropogenic activities occurring in the inner and intermediate protection zones of the Northern village of Kangiqsujuaq drinking water withdrawal site.

Anthropogenic activity	Protection zone in which the activity takes place	Contaminant or group of contaminants considered	Determined risk
Winter snowmobile traffic on frozen water bodies	Inner protection zone	Organic substances (fuel)	Very high
Winter snowmobile traffic on frozen water bodies	Intermediate protection zone	Organic substances (fuel)	Very high
Winter snowmobile traffic on frozen water bodies	Outer protection zone	Organic substances (fuel)	High
Presence of a Northern landfill	Outer protection zone	Organic substances, inorganic substances	Low

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

Potential high risk events arise from winter snowmobile traffic as identified in section 2.1. Normal fuel handling and transport activities associated with snowmobile traffic are likely to lead to fuel spills on Lake Qurlutuup Tasinga, as well as in the inner, intermediate, and outer protection zones.

Table 5. 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	Winter snowmobile traffic on frozen water bodies	Inner protection zone	Organic substances (fuel)	High
Fuel spills	Winter snowmobile traffic on frozen water bodies	Intermediate protection zone	Organic substances (fuel)	High
Fuel spills	Winter snowmobile traffic on frozen water bodies	Outer protection zone	Organic substances (fuel)	Medium
Deposition of contaminated airborne particles	Presence of a Northern landfill	Outer protection zone	Organic substances, inorganic substances	Very low

Some natural hazards have also been identified as potential threats at the source. Adverse climatic conditions (blizzards, windstorms, ice storms) can be very intense and last for several days [10]. 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 Northern 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 into account the withdrawal infrastructure, the geographical isolation of the village and the low winter temperatures (average temperature = -16 °C) increase the municipality's vulnerability [3].

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 Kangiqsujuaq, the drinking water withdrawal site is not included in the development plans. As a result, no land use was identified. The village development plan in Appendix 5 is provided for information purposes only.

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

All the vulnerability indicators are deemed to be low, except for Indicator A (physical integrity), which is deemed to be high. The probable causes obtained for Indicator A are presented in section 1.4.1. 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 the logistics involved in supplying parts (air and sea transport only), the lack of local expertise, and the shortage of skilled labour.

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 issue:

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 Kangiqsujuaq. Figure 9, which shows the annual proportion of raw water bacteriological tests carried out for each Northern village, illustrates this point [11]. The rate at which bacteriological tests are carried out in Kangiqsujuaq is excellent, 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 9. Annual proportion of bacteriological analyses carried out for each Northern village. Excerpt from the "Municipal Public Works Department Activity Report" (May 2024) [11].

5. Conclusion and recommendations

The analyses carried out in Kangiqsujuaq confirm that Lake Tasinga Qurlutuup has few potential sources of contamination. Indicators of vulnerability to microorganisms, turbidity, fertilizers, and inorganic and organic substances show a low level of vulnerability. The main issues concern the physical vulnerability of the site, and more specifically the 1.6 km long supply conduit that carries the water from the withdrawal site to the WTP. This vulnerability seems to be well known to municipal stakeholders and the KRG.

To provide support to the Northern village of Kangiqsujuaq in protecting its only source of drinking water, a number of recommendations and their priority levels are presented in Table 6. In addition, some recommendations are presented in greater detail. Priority is given to keeping a record of events. This measure is relatively simple to implement and would enable the vulnerability analysis to be improved when it is next updated. As the vulnerability of the supply conduit is a major concern, it is recommended that a detailed analysis be carried out of the conduit's vulnerability to all the threats that could affect its operation. The analysis should be based on natural hazards, changes in permafrost levels, the materials used, and the municipality's ability to identify and intervene quickly in the event of breakdowns.

Table 6. Recommended actions to reduce the vulnerability of the Lake Qurlutuup Tasinga water withdrawal.

Priority	Problem	Possible solutions
1	No event record	• Adapt the event recording model to the context of the village of Kangiqsujuaq (to encourage operators to adhere to it) and monitor the recording of events.
2	Physical vulnerability of the supply conduit	• Increase the effectiveness of the monitoring of the supply conduit. • Increase the resilience of the above-ground section of the supply conduit to adverse weather conditions. • Improve the resilience of the underground section of the supply conduit to ground movement when buried in deposits that are unstable when thawed.
3	No road access to the withdrawal site	• Improve road access to the withdrawal site, or compensate for the lack of road access.
4	No emergency response plan	• Develop and implement an emergency response plan in the event of source contamination or service disruption. • This emergency response plan should include the protection and characterization of Lake Tasialuk, which

		has already been identified as a source of drinking water in the event of a service disruption at Lake Qurlutuup Tasinga.
5	Communications difficult	• Implement solutions to improve the quality of communications between: - Withdrawal site and WTP employees. - WTP and KRG employees; • Identify possible problems in the event of poor communication and develop alternative solutions, regardless of the technologies involved.
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 conduits from freezing).

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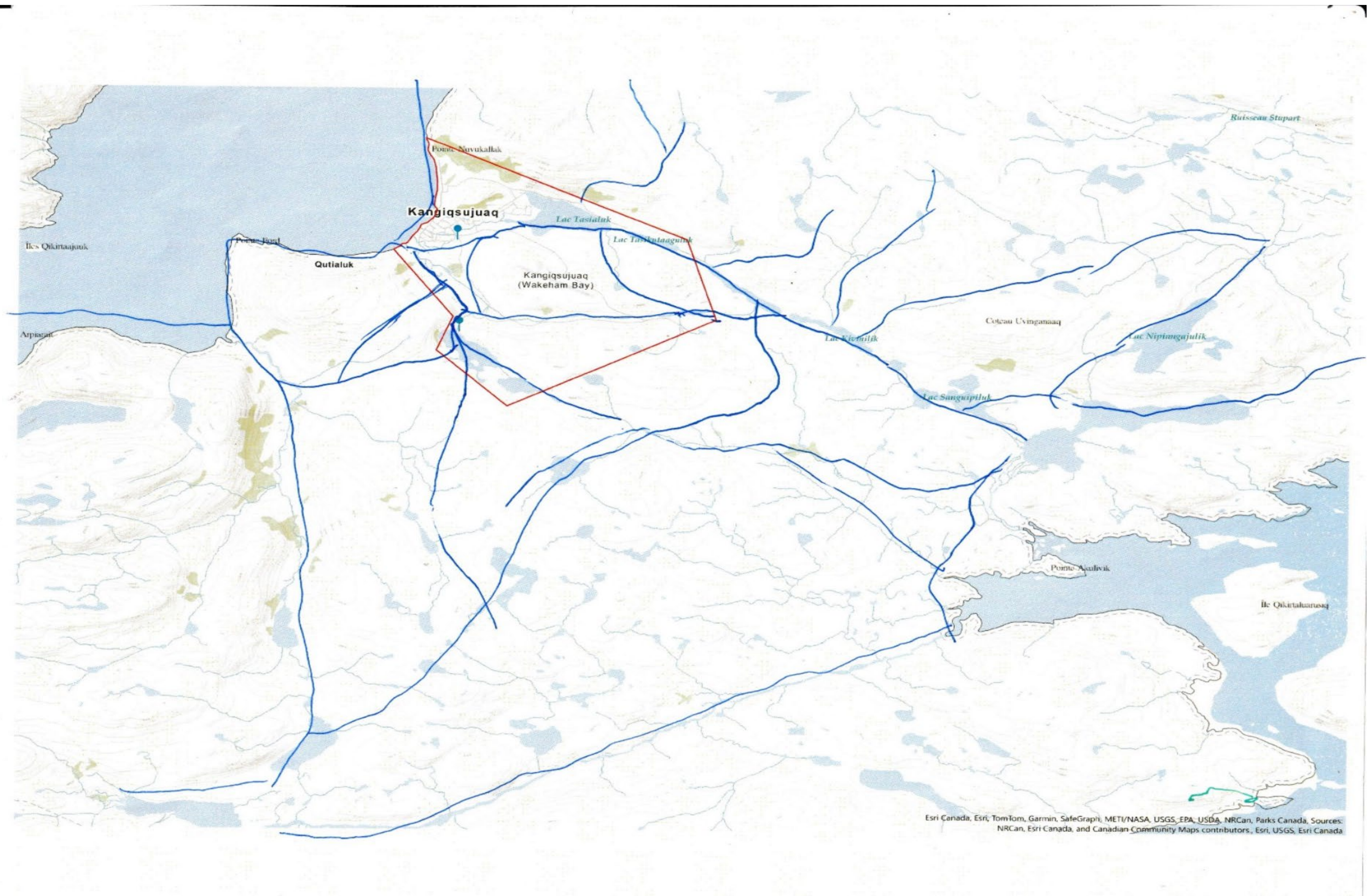
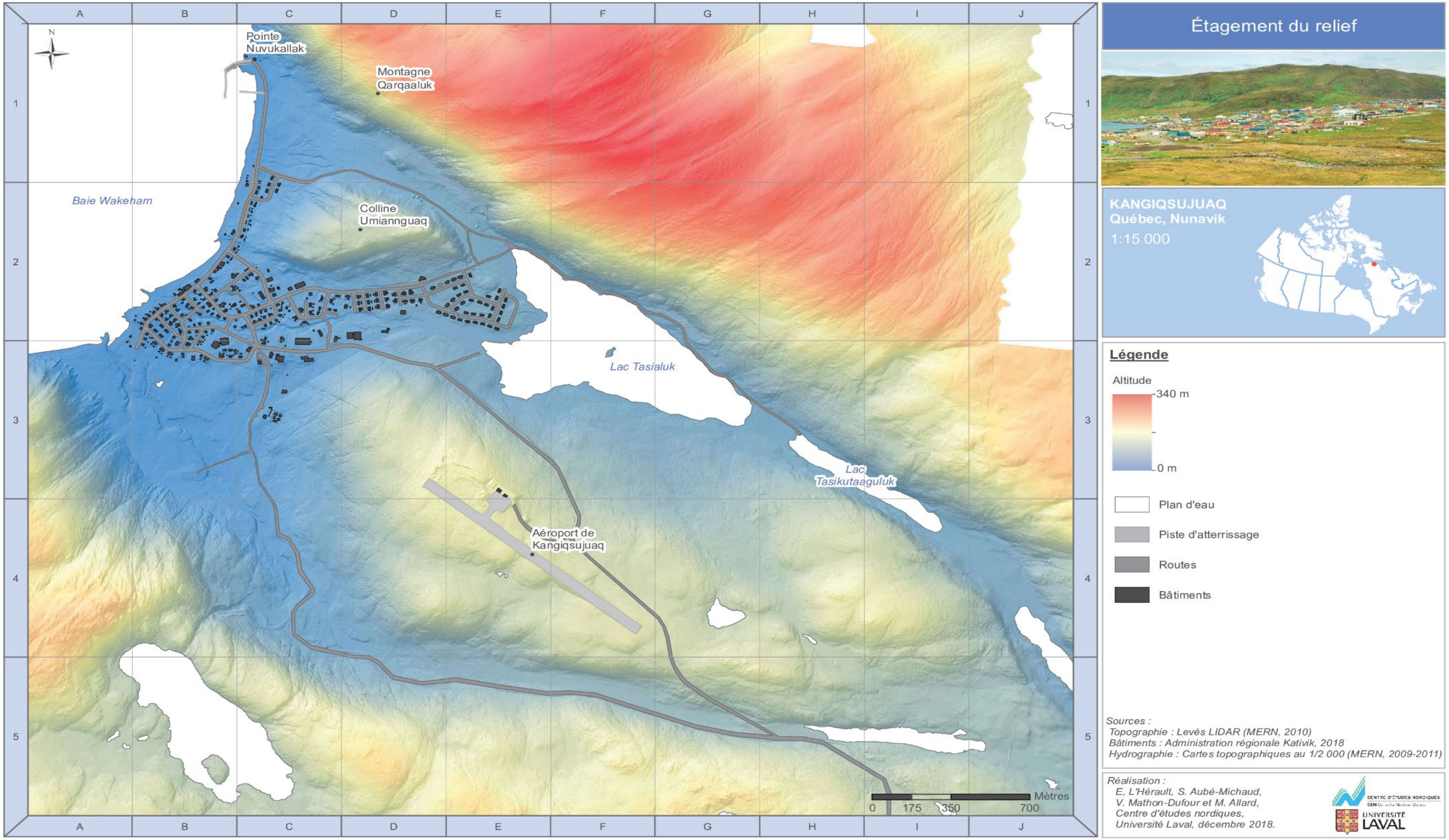
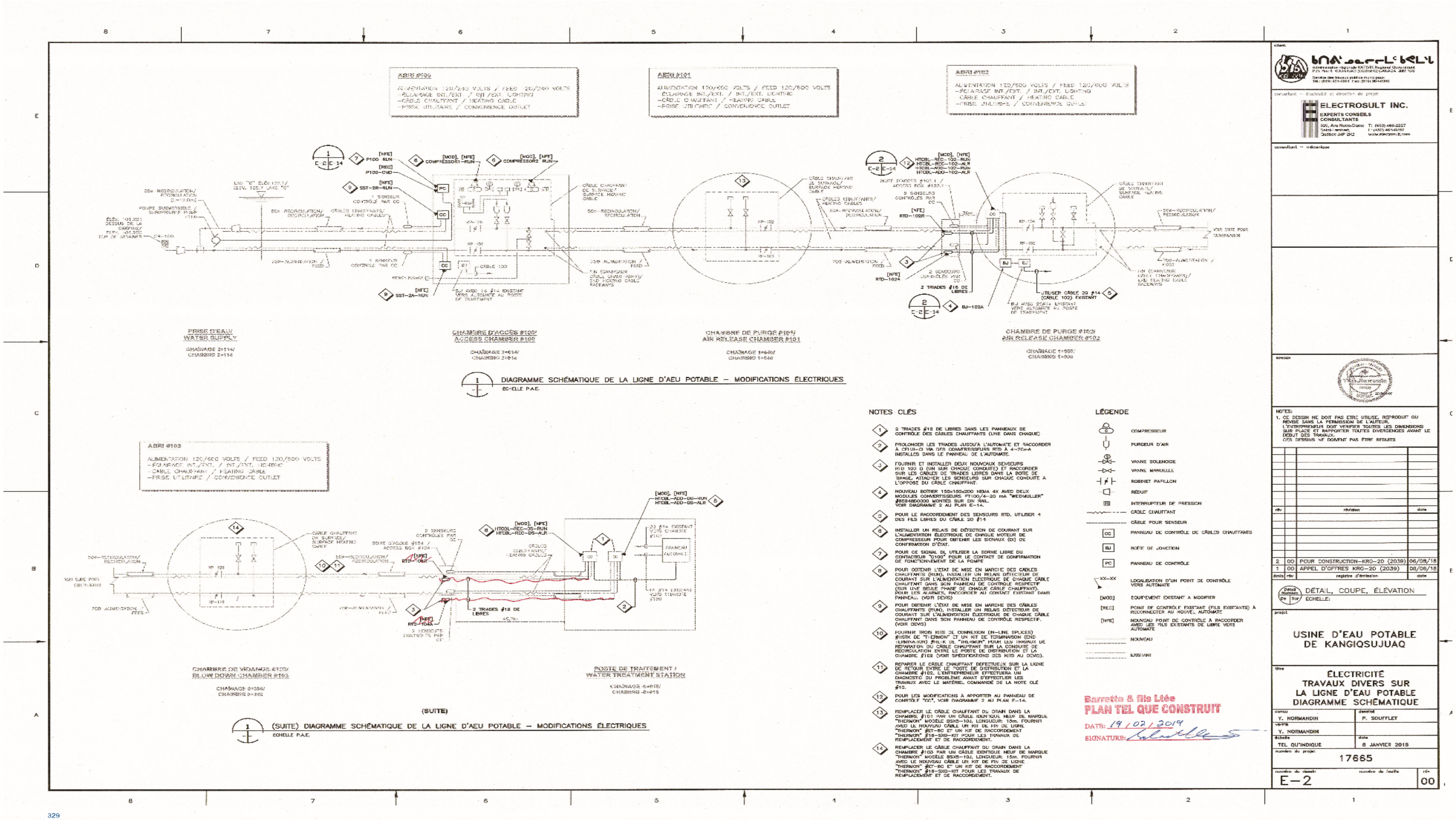
Appendix 1. Illustration of the most popular snowmobile routes in winter. Produced by Mr. Naalak Misfud on April 22, 2024.



Appendix 2. Topographical map of the Northern village of Kangiqsujuaq



Appendix 3. Schematic diagram of the water supply line between Lake Qurlutuup Tasinga and the WTP.



Appendix 4. Mining titles in the Qurlutuup Tasinga catchment area

1:500 000

Projection MTM zone 7, NAD 83
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Appendix 5. Development plan for the Northern village of Kangiqsujuaq (2009).