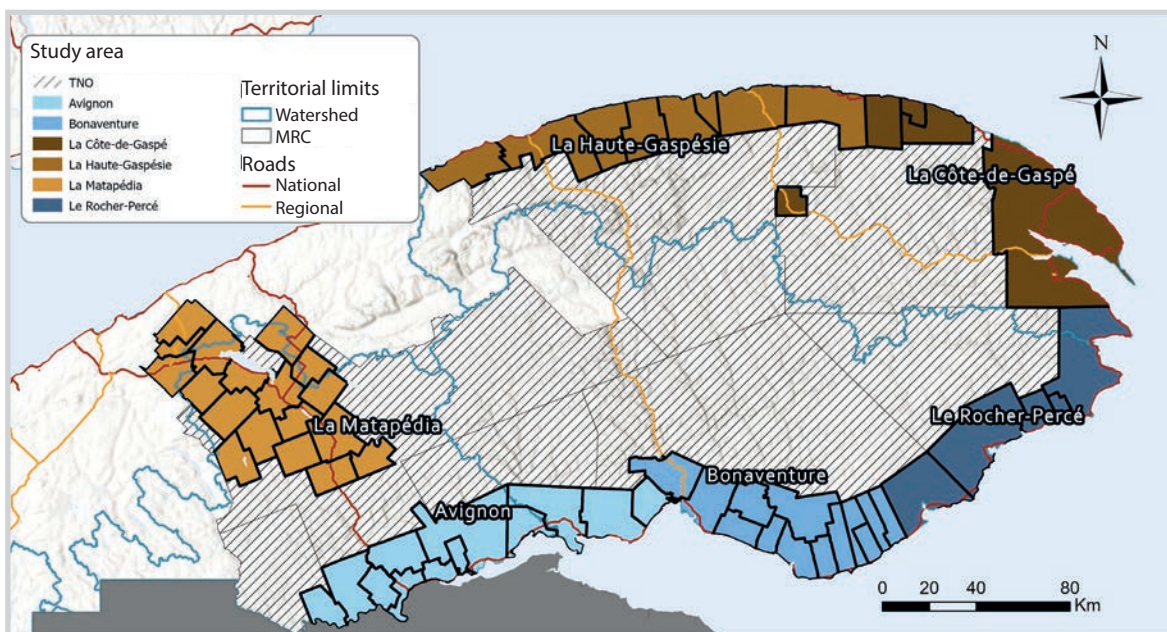


Workshop 1

Discovering our Groundwater Knowledge Acquisition Project and connecting it to our territory's issues

Gaspésie-Matapédia



Workbook
February 2025

We wish to acknowledge that the land on which this workshop is being held is part of Gespe'gewa'gi, seventh district of Mi'kma'ki, ancestral territory of the Mi'gmaq Nation. Through the recognition of this territory, we declare our collective responsibility for this land and for the history, rights and presence of the Mi'gmaq people.

This knowledge transfer and exchange workshop, held as part of the Projet d'acquisition de connaissances sur les eaux souterraines (PACES) Gaspésie- Matapédia, was made possible thanks to funding from the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP). It is the result of joint work by the Réseau québécois sur les eaux souterraines (RQES), researchers from the Department of Biology, Chemistry and Geography at the Université du Québec à Rimouski (UQAR), and the Université du Québec à Trois-Rivières (UQTR) Research Chair in Landscape Ecology and Management:

- Miryane Ferlatte, RQES scientific coordinator, workshop preparation and facilitation
- Julie Grenier, RQES project coordinator, workshop preparation and facilitation
- Julie Ruiz, professor and co-director of UQTR's RIVE research center, workshop design
- Thomas Buffin Bélanger, professor, UQAR, co-coordinator of PACES Gaspésie-Matapédia
- Gwénaëlle Chaillou, professor, UQAR, co-coordinator of PACES Gaspésie-Matapédia
- Yan Boulet, research professional, UQAR, PACES Gaspésie-Matapédia research team
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References to site

All information on fundamental hydrogeological concepts comes from an outreach effort by an RQES working committee. Any use of these concepts must be cited as follows:

Ferlatte, M., Tremblay, Y., Rouleau, A. et Larouche, U. F. 2014. Notions d'hydrogéologie - Les eaux souterraines pour tous. Première Édition. Réseau québécois sur les eaux souterraines (RQES). 63 p.

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Workshop Organizers

Quebec's groundwater network / Réseau québécois sur les eaux souterraines (RQES)

The RQES is a non-profit organization whose mission is to consolidate and expand collaborations between university research teams and the MELCCFP on one hand, and other governmental and non-governmental organizations, consultants, educational institutions, and other groups interested in groundwater in Quebec, with the goal of mobilizing scientific knowledge on groundwater.

The RQES has the following specific objectives:

- Identify the needs of managers and planners in research, practical applications for groundwater resource management, and training;
- Facilitate the transfer of acquired knowledge to managers and planners to support the management and protection of the resource;
- Support the training of qualified personnel in groundwater capable of meeting current and future job market demands in research, management, and consulting

For more information : www.rqes.ca

The Université du Québec à Rimouski

The Université du Québec à Rimouski (UQAR) was founded in 1969 and has since contributed to the training of highly qualified personnel and the development of fundamental and applied knowledge. UQAR has encouraged and supported the implementation of PACES Gaspésie-Matapédia through the Research Laboratory in Geomorphology and River Dynamics, the Research Chair in Coastal Hydrogeosystem Geochemistry and the Institute of Marine Sciences (ISMER).

The Laboratory in Geomorphology and River Dynamics (LGDF) has developed knowledge related to river dynamics in the Bas-Saint-Laurent and Gaspésie regions since 2003. The LGDF has trained around thirty students in master's geography and doctoral environmental sciences programs and includes two research professionals. Surface water-groundwater interactions are among the LGDF's research topics.

For more information : fluvial.uqar.ca

The Research Chair in Coastal Hydrogeosystem Geochemistry develops knowledge leading to a better characterization and quantification of underground geochemical transformations between coastal groundwater tables and oceans. The Chair has trained a dozen students in master's programs in geography and oceanography, as well as in doctoral programs in environmental sciences, biology, and oceanography. Characterizing the evolution of geochemical signatures and studying surface water-groundwater exchanges are among the Chair's research topics.

For more information : www.uqar.ca/recherche/la-recherche-a-l-uqar/unites-de-recherche/geochimie-hydrogeosystemes-cotiers/presentation-objectifs-et-mission-chaire-hydrogeosystemes-cotiers

The ISMER brings together a community of experts in biology, chemistry, physics and geology. The Institute is particularly interested in the functioning of marine ecosystems in relation to climate change, the impact of human activity, the development of marine bioresources, marine geology and natural hazards. Its mission is to contribute to the discovery and advancement of fundamental and applied knowledge of marine and coastal environments, in order to assess the impact of human activity on the environment and its resources.

For more information : <https://www.uqar.ca/institut-des-sciences-de-la-mer-ismer/>

Table of content

Key words definition	3
1. Introduction	9
PACES background and objectives	10
RQES Workshops	12
Workshop objectives	12
Schedule	13
Your training team	14
Introduction to groundwater	15
2. The PACES and the basics you need to know to understand the results	17
The concepts you need to know to understand the PACE results	18
Unconsolidated deposit thickness	19
Confinement conditions	20
Hydrogeological contexts	21
Piezometry	22
Recharge	23
DRASTIC vulnerability	24
Water quality	25
The Gaspésie-Matapédia pilot PACES	26
The Gaspésie-Matapédia PACES	28
RQES and research team roles	33
3. Groundwater protection and management issues in your territory	35
Groundwater protection and management issues	36
Activity 1: Local knowledge and concerns that can help realize the PACES project	37
Activity 2: From local knowledge to regional groundwater characterization	38
Activity 3: Prioritizing groundwater protection and management issues in our territory	39
4. The research team needs and effective ways of communication for the project	41
Researchers' needs from local stakeholders	42
Communication and operating modes for the PACES	44
Bibliography	47

KEY WORDS DEFINITION



Throughout the workbook

Words or expressions in **blue** are defined in the **groundwater** key concepts glossary (p. 4 to 7).

Aesthetic Objectives (AO)

Recommendation for physical or chemical parameters that have an impact on the aesthetic characteristics of water (colour, odour, taste, etc.), but do not have a recognised adverse effect on human health (published by Health Canada). Parameters whose presence may lead to corrosion or scaling of wells or water supply networks are also targeted by these objectives.

Aquifer

A permeable geological unit with a saturated zone that conducts sufficient groundwater to allow significant groundwater flow and withdrawal of substantial quantities of water from a well or a spring. It is the container of groundwater.

Aquifer capacity

The ability of an aquifer system to provide a significant flow of groundwater on a sustained basis.

Aquitard

A geological unit with very low permeability, i.e. very low hydraulic conductivity, in which groundwater flows with difficulty. Typically, the finer the particles in a loose deposit (e.g. clay and silt), the smaller the pores, the less accessible the water and the less permeable the loose deposit. The aquitard acts as a natural flow barrier, protecting the underlying aquifer from surface contaminants.

Base flow

Proportion of a river's flow that comes from groundwater. During low-flow periods, the vast majority of river flow is groundwater.

Captive water table

Groundwater bounded above by an impermeable geological unit. It is subject to a pressure higher than atmospheric pressure, so that when a borehole is drilled through this layer, the water level rises in the casing, sometimes exceeding ground level ('artesian gushing' well). It is not directly recharged by vertical infiltration, and is thus protected from contaminants coming directly from the surface.

Clay

Very fine grain, less than 0.002 mm in size; pores are also very small, making clayey deposits very low in permeability.

Confined aquifer

Aquifer isolated from the atmosphere by an aquitard. It contains a captive water table. It is not directly recharged by vertical infiltration and is therefore protected from contaminants coming directly from the surface.

Discharge (of groundwater)

The emergence of water at the surface, at the end of its journey through the aquifer, when the piezometric level of the water table exceeds the level of the ground surface. Resurgences are generally diffuse, i.e. widespread (e.g. rivers, lakes and wetlands), and are sometimes punctual, i.e. localized at a precise point (source).

DRASTIC

Numerical scoring system used to assess the intrinsic vulnerability of an aquifer, i.e. its potential to be affected by contamination originating directly from the surface. The seven factors considered are: depth to water table, recharge, aquifer nature, soil type, slope, impact of the vadose zone and aquifer hydraulic conductivity. The DRASTIC index can vary between 23 and 226; the higher the index, the more vulnerable the aquifer is to contamination.

Fracture

General term for any fissure, often caused by tectonic forces, in soil, rock or even minerals, with or without relative displacement of the surfaces. These cracks can be filled with air, water or other gaseous or liquid substances.

Fractured bedrock aquifer

A rock aquifer made permeable by the fractures that run through it. Pumping large flow rates in this type of aquifer is sometimes difficult.

GALDIT index

Numerical scoring system to assess the intrinsic vulnerability of a coastal aquifer to saline intrusion. The 6 factors considered are: aquifer type (G), hydraulic conductivity (A), water level height AMSL (L), distance from the coast (D), current salinization of the aquifer (I) and aquifer thickness (T). The GALDIT index can vary between 13 and 130; the higher the index, the more vulnerable the aquifer is to salinization.

Geochemical background

Natural concentration of an element, compound or substance in water, without any external input such as human activity.

Granular aquifer

Aquifer formed by unconsolidated deposits. Typically, the coarser the particles (e.g. sand and gravel), the larger the pores, the more interconnected they are and the more permeable is the granular aquifer. Pumping large flow rates in this type of aquifer is often possible.

Gravel

Coarse grain, with a diameter between 2 and 75 mm.

Groundwater

All water found underground and filling the pores of geological units (with the exception of constitutive water, i.e. water contained in the chemical composition of minerals).

Hydraulic conductivity

The ability of a porous medium to allow water to pass through it under the effect of a hydraulic head gradient. The more interconnected the pores, the more permeable the geological medium, and the more easily water can infiltrate and flow through it.

Hydraulic head

Height reached by groundwater in a well to attain equilibrium with atmospheric pressure; generally expressed in relation to mean sea level. Groundwater flows from a point with highest hydraulic head to a point with lowest hydraulic head. See Piezometric level.

Hydraulic properties (or parameters)

All quantifiable parameters that characterize the ability of a geological unit to store and allow the circulation of water (e.g. porosity, hydraulic conductivity, etc.).

Hydrostratigraphy

Represents an arrangement of unconsolidated deposits and rock units at depth, taking into account their respective permeability.

Maximum acceptable concentration (MAC)

Threshold of bacteriological, physical or chemical parameters that drinking water must not exceed in order to avoid risks to human health (taken from the Quebec government's Regulation on drinking water quality).

Piezometric level

Height reached by groundwater in a well to attain equilibrium with atmospheric pressure; generally

expressed in relation to mean sea level. Groundwater flows from a point with highest hydraulic head to a point with lowest hydraulic head. See Hydraulic head.

Piezometric surface

Surface representing the hydraulic head at any given point of the groundwater.

Pore

Interstice in a geological unit that is not occupied by any solid mineral matter. This empty space may be occupied by air, water, or other gaseous or liquid matter.

Porosity

Ratio, expressed as a percentage, of the pore volume of a material to its total volume. The higher the porosity, the more space is available to store water.

Recharge

Renewal of the water table by infiltration of precipitation into the soil and percolation to the saturated zone.

Residence time

Time during which water remains underground, from infiltration to discharge. The longer the residence time, the more evolved and mineralized the water will be, i.e., more concentrated in dissolved minerals.

Sand

Grain with a diameter between 0.05 and 2 mm.

Saturated zone

Zone below the water table in which the pores of the geological unit are completely filled with water.

Semi-captive water table

An intermediate category between a captive water table and an unconfined water table, it is partially isolated from the atmosphere by a discontinuous or thin geological unit of low permeability. It is moderately recharged and protected.

Semi-confined aquifer

An intermediate category between confined and unconfined aquifers, it is partially isolated from the atmosphere by a discontinuous or thin geological unit of low permeability. It contains a semi-captive water table. It is moderately recharged and protected.

Silt

Grain with a diameter between 0.002 and 0.05 mm, i.e. larger than clay and smaller than sand. Synonym: Loam.

Source

Groundwater naturally emerging from the Earth's surface and localized at a precise point.

Surface formation

See unconsolidated deposits.

Thermal refuge

Cold water zone that provides refuge for certain cold-water fish populations during heatwaves. Groundwater discharge into rivers helps create these habitats.

Till

Granular material generated by a glacier, composed of sediments of all sizes in any proportion, generally in a matrix of fine sediments.

Unconfined aquifer

Aquifer near the surface of the land, in contact with the atmosphere (not isolated by an aquitard). It contains an unconfined water table. It can be directly recharged by vertical infiltration and is generally more vulnerable to contamination.

Unconfined water table

Groundwater located closest to the land surface, and not covered by an impermeable geological unit. It is in contact with the atmosphere through the unsaturated zone of the ground. It can be directly recharged by vertical infiltration and is generally more vulnerable to contamination.

Unconsolidated deposits

Unconsolidated material eroded from and covering the bedrock (e.g. sand, silt, clay, etc.). Synonyms: Overburden, Quaternary deposit, Surface formation, Sediment.

Unsaturated zone

Area between the ground surface and the water table level in which the pores of the geological unit contain air and are not completely filled with water. Synonym: Vadose zone.

Vadose zone

See Unsaturated zone.

Vulnerability

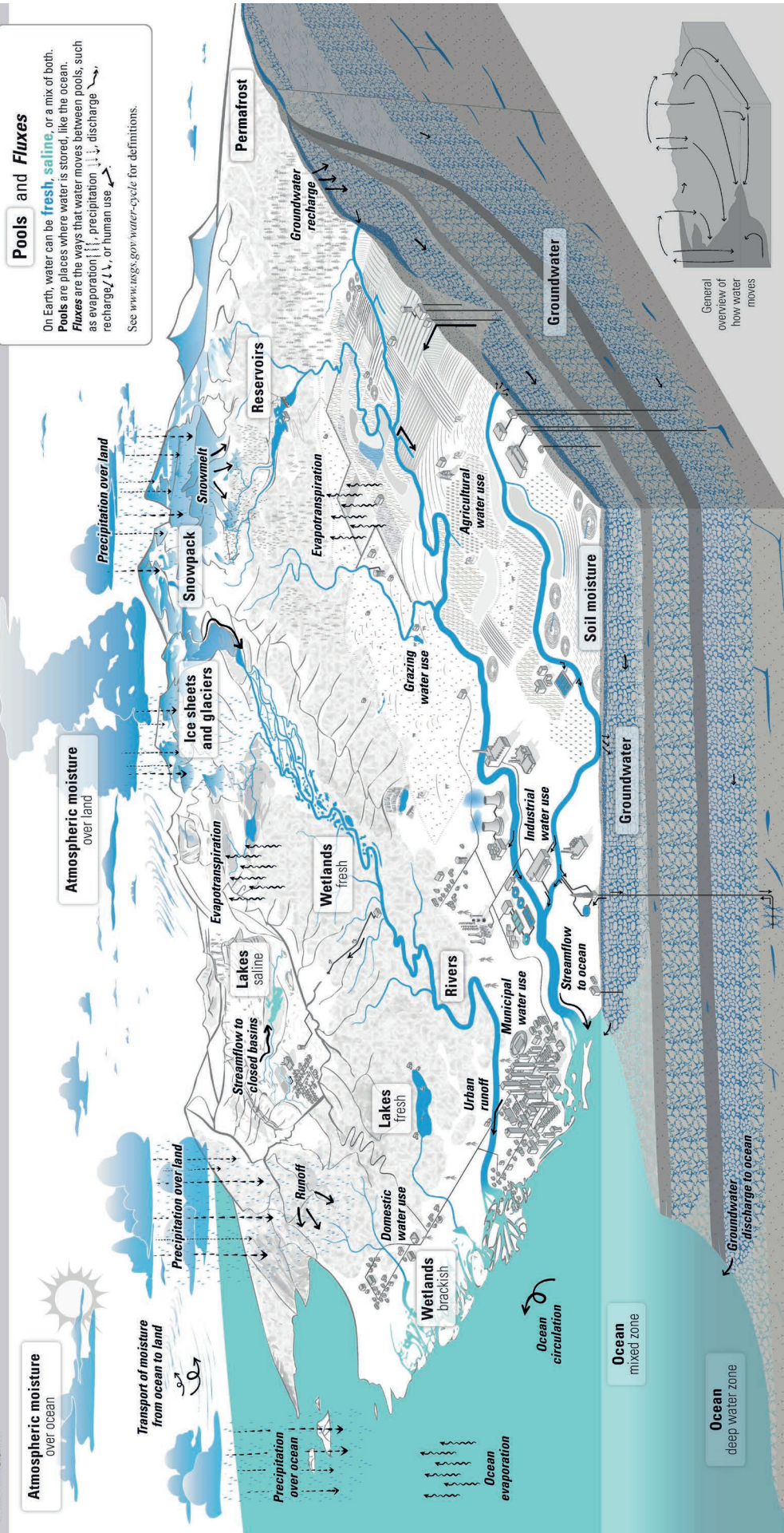
Aquifer sensitivity to groundwater pollution from contaminants released at the soil surface.

Water table (or phreatic water table)

All groundwater within the saturated zone of an aquifer and accessible via wells. It is the content of the aquifer.

Wellhead area

Area within which all the groundwater flowing through it will eventually reach the wellpoint.



The Water Cycle

The water cycle describes where water is found on Earth and how it moves. Water can be stored in the atmosphere, on Earth's surface, or below the ground. It can be in a liquid, solid, or gaseous state. Water moves between the places it is stored at large scales and at very small scales. Water moves naturally and because of human interaction, both of which affect where water is stored, how it moves, and how clean it is.

Liquid water can be fresh, saline (salty), or a mix (brackish). Ninety-six percent of all water is saline and stored in oceans. Places like the ocean, where water is stored, are called **pools**. On land, saline water is stored in **saline lakes**, whereas fresh water is stored in liquid form in **freshwater lakes**, artificial **reservoirs**, **rivers**, **wetlands**, and in soil as **soil moisture**. Deeper underground, liquid water is stored as **groundwater** in aquifers, within the cracks and pores of rock. The solid, frozen form of water is stored in **ice sheets**, **glaciers**, and **snowpack** at high elevations or near the Earth's poles. Frozen water is also found in the soil as **permafrost**. Water vapor, the gaseous form of water, is stored as **atmospheric moisture** over the ocean and land.

As it moves, water can transform into a liquid, a solid, or a gas. The different ways in which water moves between pools are known as **fluxes**. **Circulation** mixes water in the oceans and transports water vapor in the atmosphere. Water moves between the atmosphere and the Earth's surface through **evaporation**, **evapotranspiration**, and **precipitation**. Water moves across the land surface through **snowmelt**, **runoff**, and **streamflow**. Through infiltration and **groundwater recharge**, water moves into the ground. When underground, groundwater flows within aquifers and can return to the surface through **springs** or from natural **groundwater discharge** into rivers and oceans.

Humans alter the water cycle. We redirect rivers, build dams to store water, and drain water from wetlands for development. We use water from rivers, lakes, reservoirs, and groundwater aquifers. We use that water (1) to supply our **homes and communities**, (2) for **agricultural irrigation and grazing** livestock, and (3) in **agricultural** activities like thermoelectric power generation, mining, and aquaculture. The amount of available water depends on how much water is in each pool (water quantity). Water availability also depends on when and how fast water moves (water timing), how much water is used (water use), and how clean the water is (water quality).

Human activities affect **water quality**. In agricultural and urban areas, irrigation and precipitation wash fertilizers and pesticides into rivers and groundwater. Power plants and factories return heated and contaminated water to rivers. Runoff carries chemicals, sediment, and sewage into rivers and lakes. Downstream from these types of sources, contaminated water can cause harmful algal blooms, spread diseases, and harm habitats. **Climate change** is also affecting the water cycle. It affects water quality, quantity, timing, and level rise, and extreme weather. Understanding these impacts can allow progress toward sustainable water use.

1

Introduction



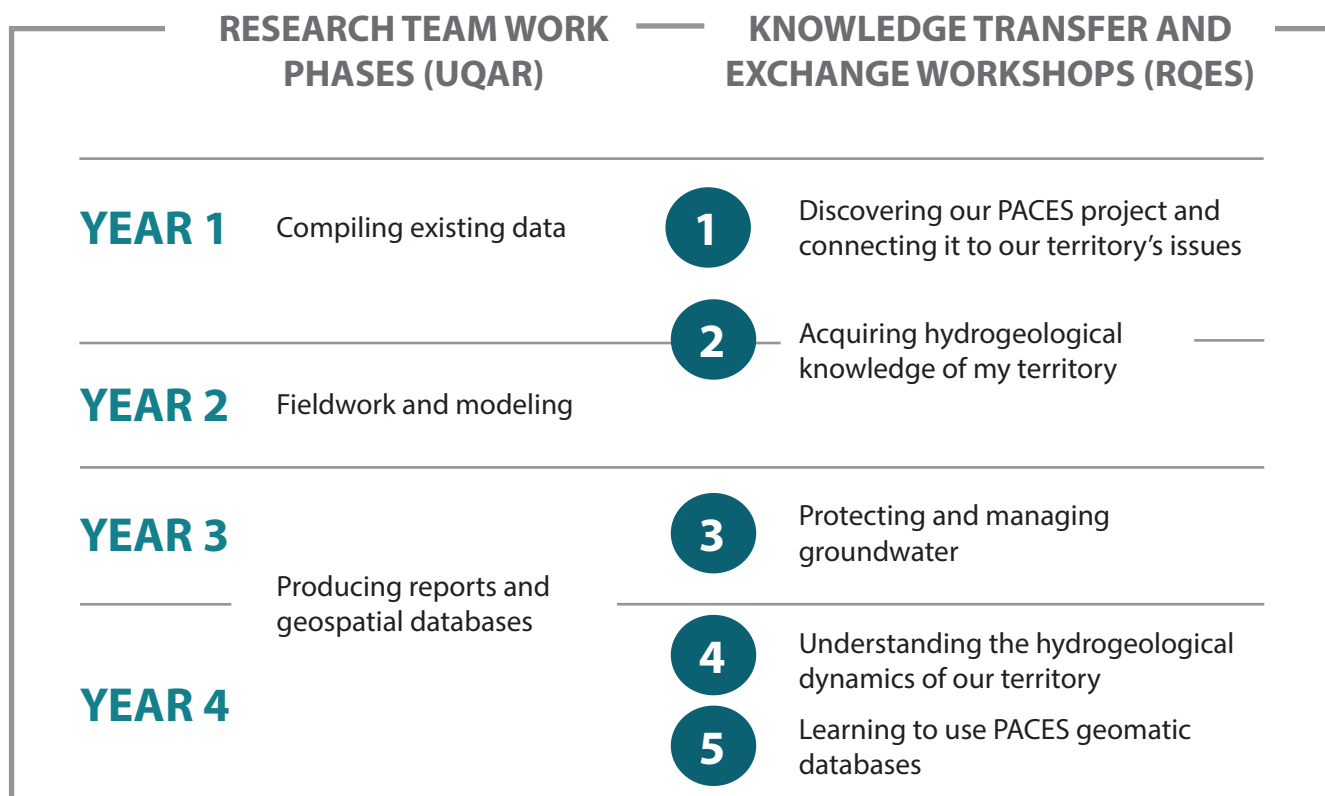


PACES objectives

A portrait of **groundwater** must provide a picture of the resource on a regional scale. This portrait must answer the following fundamental questions:

1. What is the nature of the geological formations that contain it?
2. Where does the water come from (**recharge zones**) and where does it go (**resurgences**)?
3. Is it drinkable, and what uses can it serve?
4. What quantities are exploited and what are the sustainable quantities that can be exploited?
5. Is it vulnerable to human activity?
6. What are the main threats and issues to be considered to ensure the protection and sustainable management of **groundwater** in the region?

RQES Workshops



Workshop Objectives



1. Acquire basic hydrogeology concepts to facilitate communication with your PACES research team and hydrogeologists
2. Present the knowledge that will be generated by PACES and understand what it can be used for
3. Identify current issues related to the protection and management of the region's groundwater
4. Identify expectations regarding PACES
5. Identify desirable and realistic communication methods between researchers and local stakeholders

Workshop schedule

9:00	Attendees arrival
1 - INTRODUCTION	
9:30	Introduction Introduction to the background, objectives and schedule for the day
2 - THE PACES AND THE BASICS YOU NEED TO KNOW TO UNDERSTAND THE RESULTS	
10:00	The basics of hydrogeology RQES presentation
10:20	The Gaspésie-Matapédia pilot PACES UQAR presentation
10:30	Summary of issues highlighted during the pilot project RQES presentation
10:40	COFFEE BREAK 
10:55	The Gaspésie-Matapédia PACES UQAR presentation
11:15	Questions to understand the PACES Question and answer session
3 - GROUNDWATER PROTECTION AND MANAGEMENT ISSUES IN YOUR TERRITORY	
11:30	Local knowledge and concerns that can help realize the PACES project Small group activity
12:30	ON-SITE DINER – BRING YOUR LUNCH ! 
13:30	From local knowledge to regional groundwater characterization Open group activity
14:05	Prioritizing groundwater protection and management issues in our territory Open group activity
14:40	COFFEE BREAK 
4 - THE RESEARCH TEAM NEEDS AND EFFECTIVE WAYS OF COMMUNICATION FOR THE PROJECT	
14:55	Researchers' needs from local stakeholders and finding our own way of communication UQAR presentation and discussions
15:25	Conclusion
15:30	End of workshop

Your training team

Your RQES facilitators



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The participants

A quick tour around the table

Present yourself !



- Name, position and organization
- Are you familiar with the PACES-GM ?
- What are your expectations towards the PACES?

What is groundwater?

A video on the groundwater cycle



The groundwater cycle, flow processes, contaminant migration in groundwater, recharge zones, aquifer vulnerability.

Duration: 7 : 02 minutes



Videos available on Youtube: <https://youtube.com/playlist?list=PLgsfH2EW5nlGpjHZJnYflph-66djGEIV&si=iB9Pr6ymKwX2eETt>

2

**The PACES and the concepts
you need to know to
understand the results**



The concepts you need to know to understand the PACES results

READING GUIDE



Key concepts for understanding the results. The key concepts in hydrogeology are shown in **BLUE**



Examples of map results from PACES in Québec.



WATER TABLE, AQUIFER AND AQUITARD

GROUNDWATER is the water that lies beneath the surface of the ground, filling the voids in the geological formations.

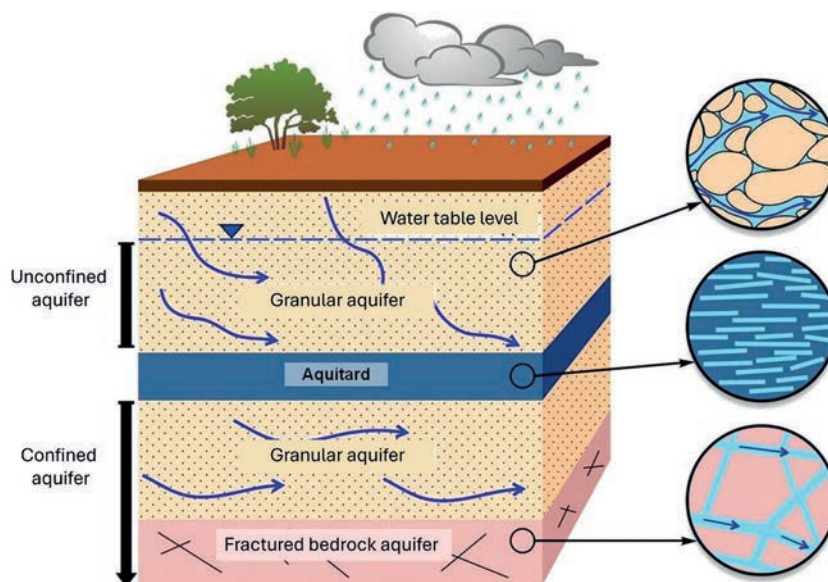
The **WATER TABLE** represents groundwater circulating in an aquifer.

- It's the **content**.

The **AQUIFER** is a permeable geological formation with a saturated zone that allows appreciable quantities of water to be pumped to a well or spring.

- It's the **container**.

The **AQUITARD** is a geological formation of very low permeability, i.e. very low hydraulic conductivity, in which groundwater flows with difficulty. It acts as a **natural flow barrier**, protecting the underlying aquifer from surface contaminants.





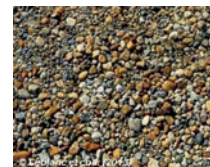
UNCONSOLIDATED DEPOSITS THICKNESS

When the **UNCONSOLIDATED DEPOSITS** are coarse (sand and gravel) and sufficiently thick, they can form an **AQUIFER**. However, if the unconsolidated deposits are fine (clay and silt) and therefore not very permeable and sufficiently thick, they are more likely to form an **AQUITARD**. Information on the thickness and texture of unconsolidated deposits can also prove useful in fields other than hydrogeology, such as geotechnics and building and infrastructure construction.

UNCONSOLIDATED DEPOSITS AQUIFER

When a unconsolidated deposit is made up of **coarse particles** (e.g. sand and gravel), it forms an **AQUIFER**.

- The larger the pores, the more interconnected they are, and the more permeable the unconsolidated deposit aquifer is.
- High flow rates can be pumped from these aquifers, provided the saturated thickness is sufficient.



When a unconsolidated deposit is made up of **fine particles** (e.g. clays and silts), it forms an **AQUITARD**

- The smaller the pores, the less accessible the water and the less permeable the unconsolidated deposit is



clay

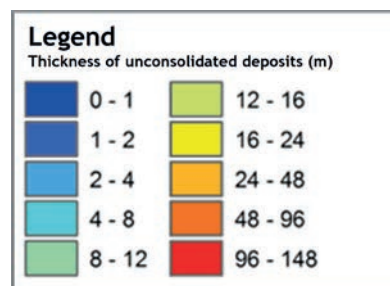
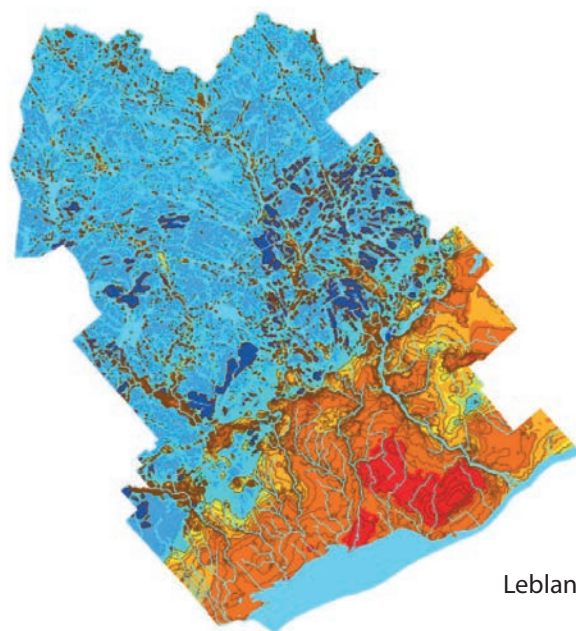
FRACTURED BEDROCK AQUIFER

The **pores** in the rock contain groundwater, forming a large reservoir. Their limited interconnection, however, does not allow for efficient water circulation.

Fractures, which generally represent only a small percentage by volume compared to pores, still allow for more efficient water flow, sometimes sufficient for groundwater pumping.



PACES MAURICIE



Leblanc et al. (2013)



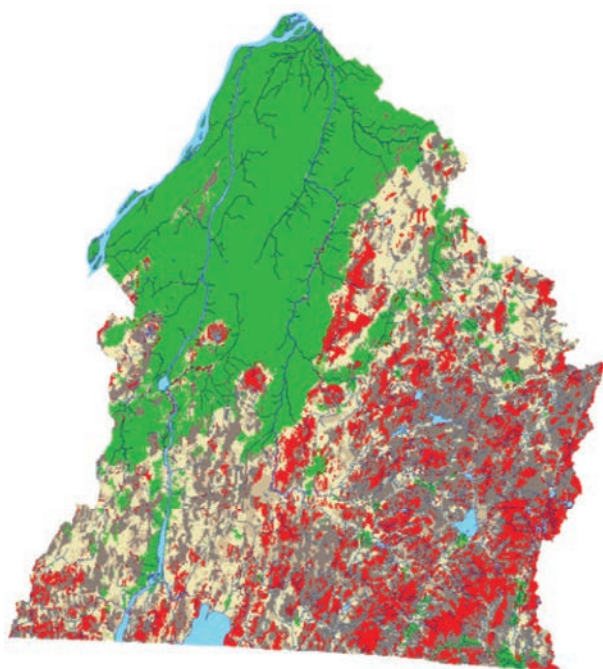
CONFINEMENT CONDITIONS

A **CONFINED AQUIFER** is «trapped» beneath an aquitard. It is not directly recharged by vertical infiltration and **is thus protected from contaminants** coming directly from the surface. Its recharge area is located further upstream, where the impermeable layer is no longer present. The groundwater there is under higher pressure than that of the atmosphere.

A **UNCONFINED AQUIFER** is not covered by an aquitard and is in direct contact with the atmosphere. It can be directly recharged by vertical infiltration and is therefore generally **more vulnerable to contamination**.



PACES MONTÉRÉGIE-EST



Legend

Confinement conditions

-  Confined (> 5m of clay)
-  Semi-confined (1-5m of clay)
-  Semi-confined (<1m of clay; >3m of undifferentiated sediments)
-  Semi-confined (<1m of clay; >3m of undifferentiated sediments); surface till
-  Unconfined

Carrier et al. (2013)

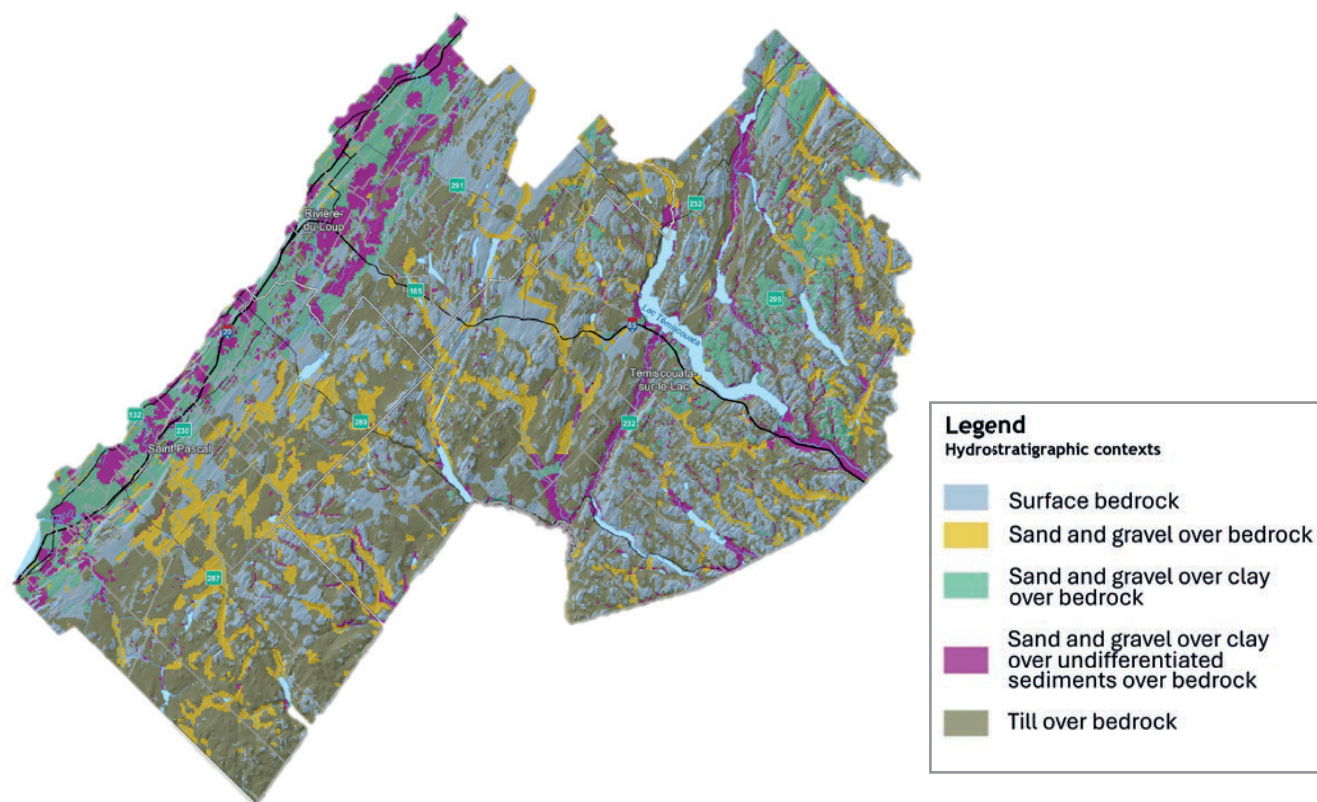


HYDROGEOLOGICAL CONTEXTS

A hydrogeological context (or hydrostratigraphic context) defines a sequence (a layering) of hydrogeological units involving a vertical variation in groundwater behavior. It allows for visualizing how geological units are organized at depth and identifying which sequence of **UNCONSOLIDATED DEPOSITS** covering **FRACTURED BEDROCK** may be encountered in a given area. These contexts influence groundwater flow and quality. They are established to serve as regional indicators of the hydrogeological conditions present in an area



PACES KAMOURASKA - RIVIÈRE-DU-LOUP - TÉMISCOUATA



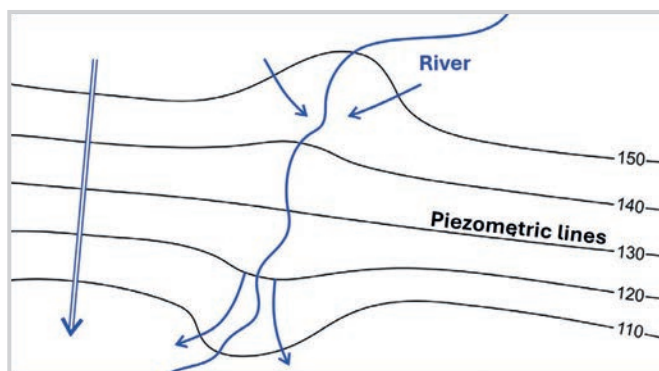
Tommi-Morin et al. (2022)



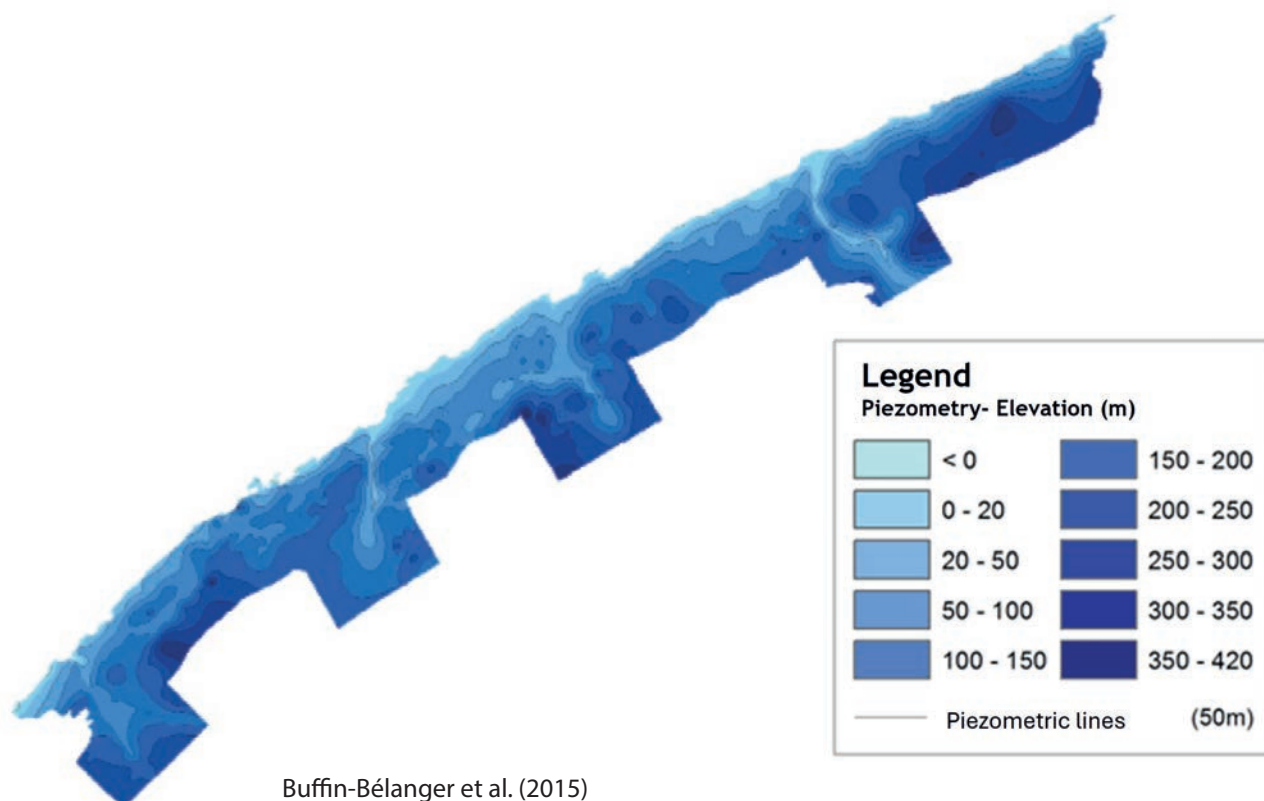
PIEZOMETRY

The **PIEZOMETRIC LEVEL** (or hydraulic head) corresponds to the elevation that the groundwater level measured in a well reaches to be in equilibrium with atmospheric pressure

PIEZOMETRY represents the elevation of the groundwater level in an aquifer, just as topography represents the altitude of the ground. It indicates the direction of groundwater flow in the aquifer, which moves from areas of higher piezometric levels to areas of lower piezometric levels.



PACES NORTHEASTERN BAS-SAINT-LAURENT



Buffin-Bélanger et al. (2015)



RECHARGE

RECHARGE contributes to the renewal of groundwater by replenishing the aquifer through the infiltration of precipitation from the surface. The recharge rate depends on climatic conditions, land use, topography, and the physical properties of the soil. Therefore, it varies across the territory.

- A dry climate, confinement, steep terrain, or impermeable surfaces in urban areas limit recharge.

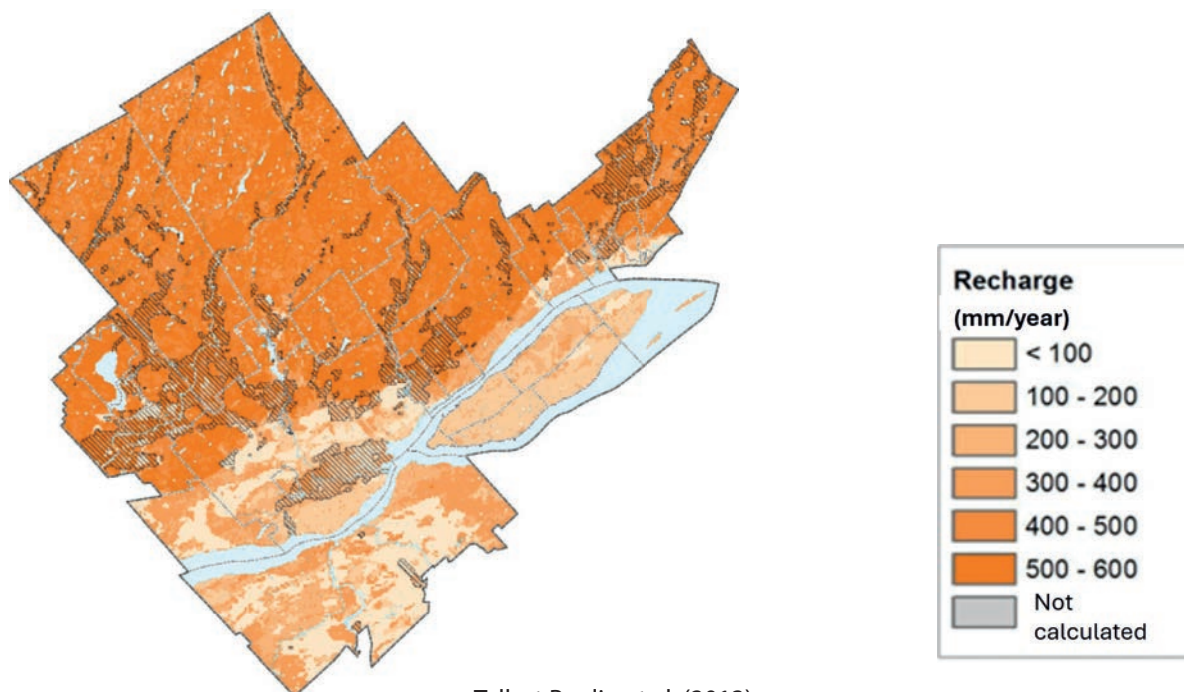
A **RESURGENCE** refers to the outlet of groundwater that comes back to the surface when the piezometric level of the aquifer exceeds the ground surface level.

- Resurgences are generally diffuse, meaning they extend over a relatively large area. For example, rivers often serve as resurgence zones, as do wetlands.
- They can also be punctual, meaning localized at a specific point, and in this case, they constitute springs.

During dry periods, most of the water flowing in rivers comes from the contribution of groundwater. This water then contributes to the base flow of rivers.



PACES COMMUNAUTÉ MÉTROPOLITAINE DE QUÉBEC

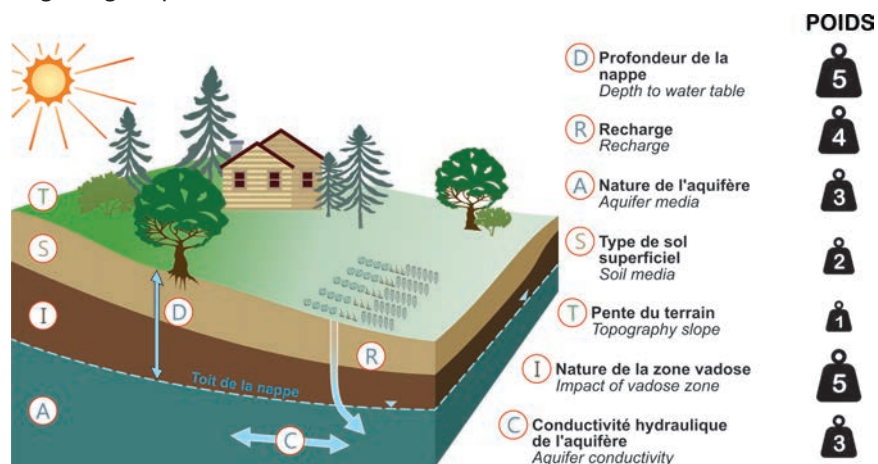


Talbot Poulin et al. (2013)



DRASTIC VULNERABILITY

The **DRASTIC** method provides a relative assessment of the intrinsic vulnerability of an **aquifer**, or its susceptibility to being affected by contamination from the surface. The **DRASTIC** index can vary between 23 and 226. The higher the index, the more vulnerable the aquifer is to contamination. The calculation of the **DRASTIC** index takes into account seven physical and hydrogeological parameters:

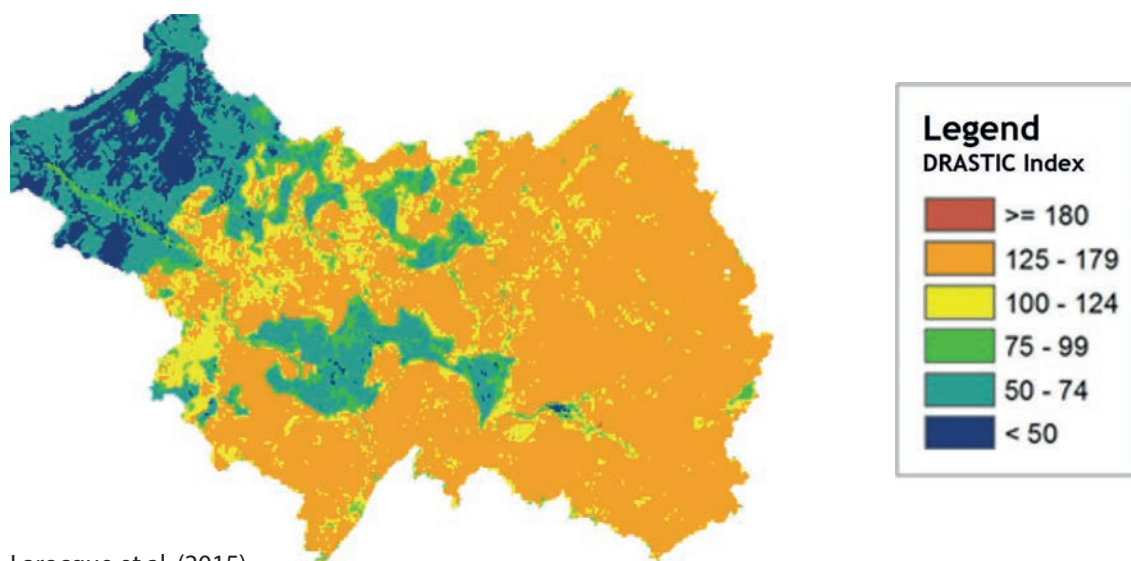


The risk of degradation of groundwater quality can be estimated by combining vulnerability, the impact of human activities that pose a potential contamination threat, and the significance of aquifer exploitation.

The contamination potential of each human activity depends on several factors, including the nature and quantity of contaminants, the area affected, and the frequency of discharge.



PACES NICOLET-SAINT-FRANÇOIS



Larocque et al. (2015)



WATER QUALITY

The geochemical composition of groundwater is largely influenced by the dissolution of certain minerals present in geological materials. The greater the distance traveled by groundwater in the aquifer, the longer its residence time, and the more evolved and mineralized it will be, meaning it will be more concentrated in dissolved minerals.

Water quality criteria

The **MAXIMUM ACCEPTABLE CONCENTRATIONS (MAC)** are bacteriological and physicochemical **standards** aimed at avoiding risks to human health. They are derived from the Drinking Water Quality Regulation of the Government of Québec (2015).

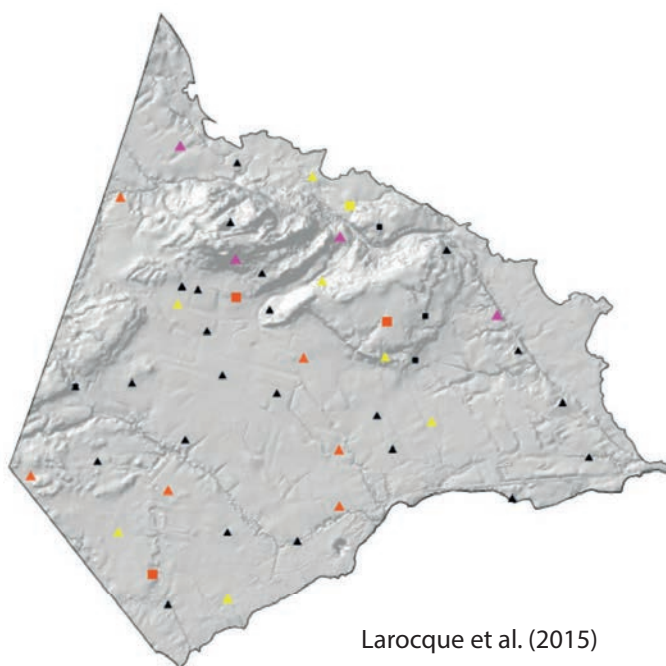
- Ex.: Arsenic < 0.01 mg/L, to avoid certain cancers and skin, vascular, and neurological effects.
- Ex.: Fluoride < 1.5 mg/L, to prevent dental fluorosis.

AESTHETIC OBJECTIVES (AO) are **recommendations** for parameters that impact the organoleptic characteristics of water (color, odor, taste) but have no recognized harmful effects on human health. Parameters whose presence may lead to corrosion or scaling of wells or water supply networks are also addressed by these objectives. They are published by Health Canada (2014).

- Ex.: Iron < 0.3 mg/L, based on taste and stains on laundry and plumbing fixtures.
- Ex.: Chlorides < 250 mg/L, based on taste and corrosion of the distribution system



PACES VAUDREUIL-SOULANGES



Legend

Exceedance of quality guideline

Bacteriology

- Granular- no exceedance
- ▲ Roc- no exceedance

Granular

- Non-compliant
- Non-potable

Roc

- ▲ Non-compliant
- ▲ Non-potable

Inorganic element

Roc

- ▲ Fluor

Larocque et al. (2015)

The Gaspésie-Matapédia pilot PACES

Between 2018 and 2022, the team examined possible strategies for adapting PACES deliverables to the territorial realities of Gaspésie for an eventual PACES. This pilot project represents phase 0, which set the boundaries for the PACES-Gaspésie-Matapédia project. Phase 0 enabled the UQAR team to :

- Draw up a preliminary portrait of the [groundwater](#) resource based on existing data to support information needs concerning groundwater quality, quantity and [vulnerability](#);
- Develop and maintain partnerships between academia, land managers (MRCs and municipalities) and regional organizations (OBV, ZIPSE) to promote the implementation of an integrated PACES in Gaspésie and the Matapédia valley;
- Reflect on how PACES deliverables, as carried out in other regions, can be aligned with territorial realities and regional issues, by exploring geomatic tools and indicators that could potentially be used to map [groundwater](#);
- Propose steps and approaches for the realization of a PACES Gaspésie-Matapédia, taking into account regional needs and available resources.

Related projects

O'salis project: Salinization and potability of groundwater in maritime Quebec

The O'Salis project, which began in 2021, collected some 60 groundwater samples from private wells in the Gaspésie region, located less than 5 km from the coast, to establish the [geochemical background](#) and assess the presence of salt. The sampling and analysis protocols established for PACES were used to ensure data harmonization. These data will be integrated into the PACES Gaspésie-Matapédia database (the 60 geochemical analyses of private wells have already been integrated). For further information: <https://osalis.ca/>

Mapping Quaternary [surface formations](#)

Much of the dynamics of [recharge zones](#) and [groundwater](#) reserves is determined by the layers of Quaternary surficial sedimentary deposits and their sedimentological, geochemical and genetic characteristics, including their vertical and lateral variations. The main objective of this project, conducted by Université Laval, is to map and characterize glacial and postglacial surficial sedimentary deposits in the Gaspésie-Matapédia region. These results will provide the UQAR team leading the PACES Gaspésie-Matapédia project with a precise map of surface deposits and detailed stratigraphic cross-sections of Quaternary sediments.

My water, my well, my health (Mon eau, mon puits, ma santé)

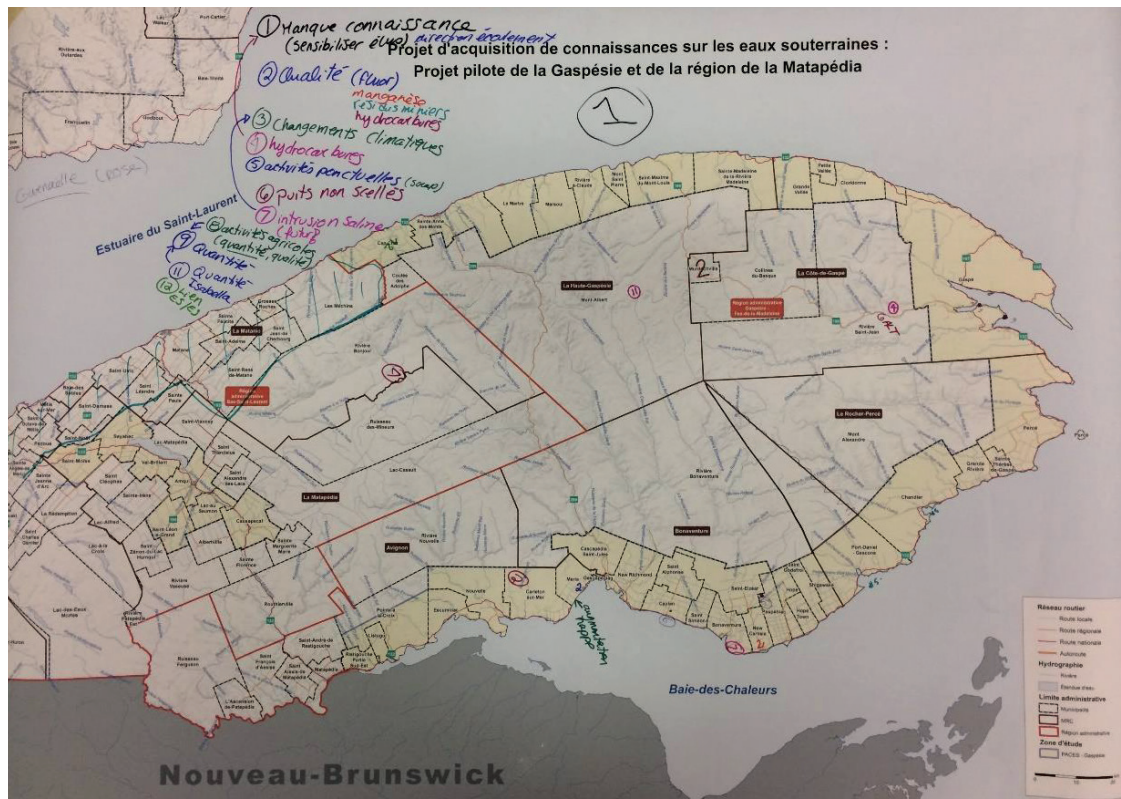
The aim of the ongoing “Mon eau, mon puits, ma santé” project, carried out by UQAR and coordinated by Professor Lily Lessard in several Quebec municipalities, is to encourage private well owners to have their water tested to protect the health of their households. A comprehensive website, written in plain language, is combined with an application to help with the interpretation of test results. It may be possible to scale up the project in the Gaspésie-Matapédia region. Such program would require regional coordination, which could be provided by watershed organizations and municipalities. For further information: <https://moneaumonpuits.ca>

Issues identified during the pilot project

The various meetings held with stakeholders and a knowledge transfer and exchange workshop conducted by RQES (May 2019) within the framework of this pilot project have identified several issues, including:

1. The lack of knowledge about the position and extent of **aquifers**;
2. The lack of knowledge about the location of **recharge zones** and vulnerable aquifers to be protected from potential impacts from logging or mining development activities;
3. The lack of knowledge about **groundwater** quality, in particular the impact of rising sea levels on salinization of coastal **aquifers** and bacteriological contamination of private wells;
4. The lack of knowledge about hydrogeological connectivity (surface water/groundwater) and about the link with hydrocarbon resources and the establishment of **thermal refuges** in salmon rivers;
5. The need for knowledge about the availability of **groundwater** resources and the increase in demand from the perspective of economic development, and the uncertainty about the impact of their exploitation on **wetlands** and their potential losses.

Issues mapping conducted by regional stakeholders attending the workshop of May 2019



The Gaspésie-Matapédia PACES

Description of the territory

With its expertise in regional hydrogeology acquired during PACES-NEBSL (2012-2015) and PACES-KRT (2018-2022), its leadership in the structuring O'Salis initiative on the salinization of coastal aquifers, and its in-depth knowledge of the territory and the various organizations working there, the UQAR team is carrying out a regional groundwater knowledge acquisition project for the Gaspésie region (PACES-GM), which includes the MRCs of La Haute-Gaspésie, La Côte-de-Gaspé, Le Rocher-Percé, Bonaventure, Avignon and La Matapédia. The \$2,077,000 project will last 4 years, from 2024 to 2028.

The Gaspésie and MRC Matapédia territories cover an area of 25,687 km² and have a population of almost 95,000 inhabitants living across 6 MRCs and 67 municipalities, which cover only 40% of the territory (Figure 1). The remainder of the territory (60%, 16,258 km²) is composed of unorganized territories (TNO). These TNOs are mainly located in the central part of the peninsula, in the topographic highlands, which are likely to correspond to the [recharge zones](#) of [aquifers](#) present or exploited in coastal areas. Although these TNOs are sparsely populated, they represent an important part of the region's economic activities, particularly those linked to the exploitation of their natural resources (e.g. forestry, fishing, tourism, and mining exploration). These areas still have strong potential for economic and industrial development, which could have an impact on regional [groundwater](#) resources.

Excluding the MRC Matapédia, nearly 75% of Gaspésie's inhabitants live within 5 km of the coast. Based on data from the MELCCFP's hydrogeological information system (SIH), 46% of the 3,750 wells listed are located within 1 km of the shoreline, and 78% within 5 km. Proximity to the shoreline, and therefore to [groundwater discharge](#) zones, is one of the region's distinctive features.

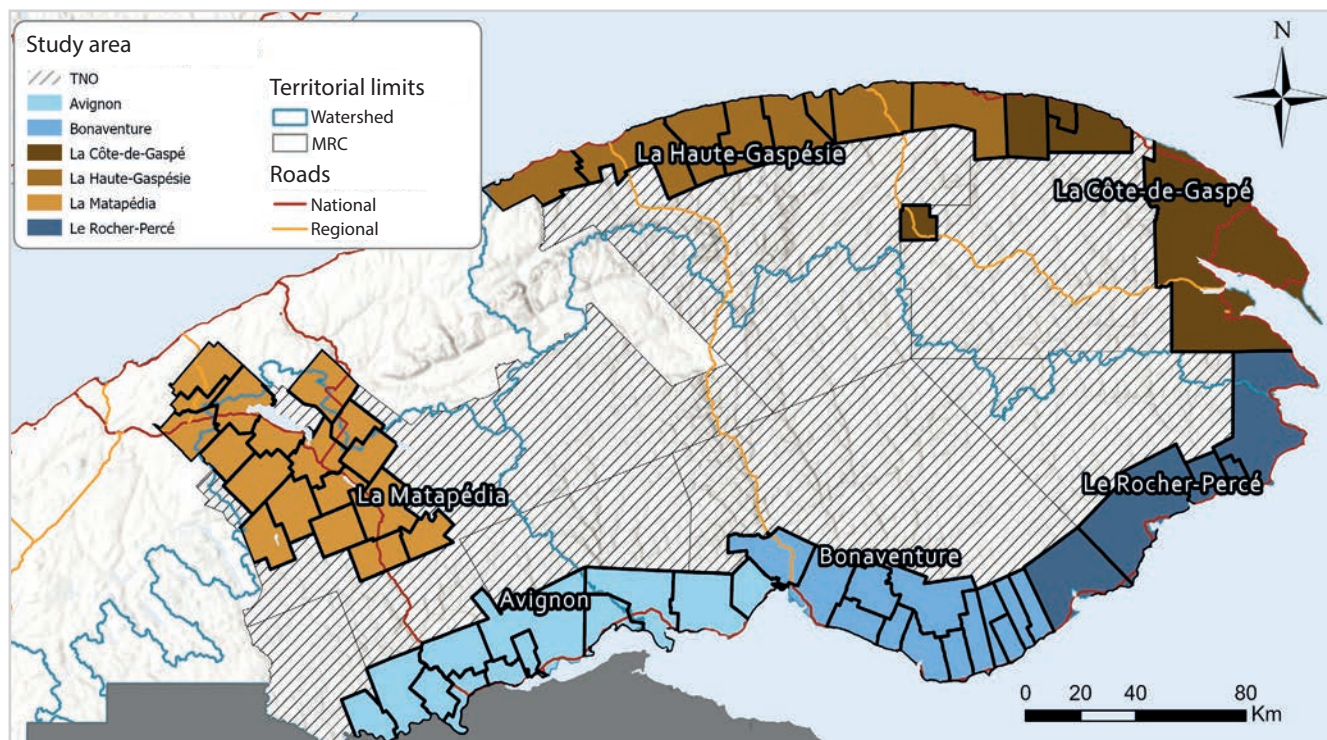


Figure 1. PACES-GM study area

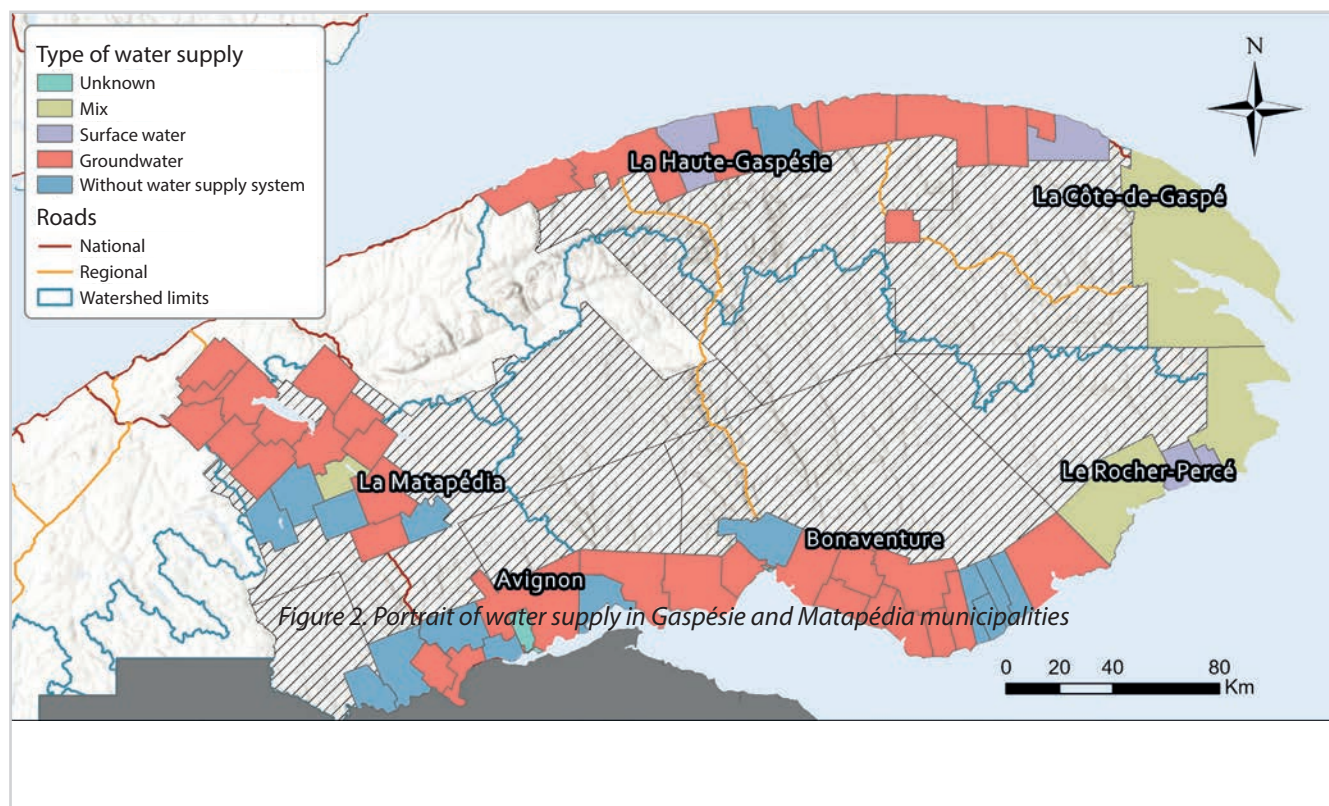
Municipal drinking water supply

According to government data, 36 municipalities supply their population with **groundwater**, representing ~52% of the population (Table 1, Figure 2).

Table 1. Water supply and population covered

Type of water supply	Number of municipalities	Population served
Groundwater	36	51 357 (54.5%)
Surface water	6	4 731 (5%)
Mix	4	19 765 (21%)
Other*	12	18 427 (19.5%)

* Other water supply refers to supplies to the population that are not provided by the municipality



The Gaspésie-Matapédia PACES

Project objectives and work phases

The UQAR research team, composed of professors, research professionals, and students, is mandated by the Ministry of Environment, Fight Against Climate Change, Fauna and Park (MELLFP) to carry out the Gaspésie-Matapédia Groundwater Knowledge Acquisition Project (PACES-GM).

The purpose of the project is to:

- Document the quality, quantity and vulnerability of groundwater resources in [granular](#) and [fractured aquifers](#) to support the protection and sustainable management of the resource;
- Assess the vulnerability of the groundwater resource to ensure its sustainability in a context of environmental change, including climate change and changes in land use;
- Co-construct a responsible, integrated and collective approach to meet the needs of land and water resource managers and other stakeholders, enabling them to ensure the protection and sustainable, equitable management of this resource on a regional scale;
- Raise citizens' awareness of the importance of the quality of the water they consume for their well-being and health, and provide them with the tools they need to ensure the quality of their water supply;
- Build a regional expertise in hydrogeology with highly qualified professionals capable of addressing the needs of users and citizens in terms of groundwater knowledge and water resource protection.

The research project will be carried out in 3 phases:

1. Gather existing data and integrate it into a georeferenced database. This stage ends with the drafting of a report summarizing the existing information, identifying missing data and planning the field work required to complete the portrait.
2. Carry out the field work required to obtain additional or missing information (sampling and testing, where necessary, to determine the parameters characterizing the [aquifers](#), sampling inventory).
3. Integrate and analyze the data and produce a scientific report in which the issues that need to be considered to ensure [groundwater](#) protection and management in the project area are identified, along with a cartographic atlas.

The following projects will be developed to address certain issues that are specific to the territory:

- PhD in environmental sciences - Hydrogeological connectivity and [preferential recharge](#) of alluvial aquifers in the Gaspésie: The role of the great valleys of northern Gaspésie as [granular aquifers](#).
- PhD in oceanography - Hydrogeological and geochemical connectivity in the land-sea continuum: Impact of sea-level rise on coastal water resource salinization.
- M.Sc. in geography - Hydrogeological responses of northern Gaspésie watersheds relative to morphometric, physiographic, sedimentary and land-use characteristics, assessed using flood hydrographs.

The analysis and interpretation of all the data collected during the project will produce a series of information layers, or deliverables, as described in Table 1 on the following page. For each theme, the resulting data analysis and interpretation will be presented in the form of thematic maps combined with a technical text (scientific report) and a simplified text (synthesis report), and a geomatic database.

The information layers that will be produced

Table 1. PACES-GM deliverables

Region description	
1. Topography	7. Land use
2. Roads, municipal boundaries and toponymy	8. Vegetation cover
3. Digital elevation model (DEM)	9. Wetlands
4. Ground slope	10. Land use planning
5. Hydrography	28. Study area boundaries
6. Watersheds boundaries	
Geological context	
11. Pedology	14. Stratigraphic and hydrostratigraphic cross-sections
12. Quaternary geology	15. Unconsolidated sediment thickness
13. Roc geology	16. Roc topography
Hydrogeological context	
17. Hydrogeological contexts (aquifer confinement conditions)	20. Roc piezometry
18. Thicknesses and boundaries of regional aquifers and hydrostratigraphic contexts	21. Hydraulic properties - database or maps (K , T , S , porosity , etc.)
19. Superficial formations piezometry	
Water budget	
26. Location of meteorological, hydrometric and water table monitoring stations	27. Preferential recharge and discharge zones
	25. Water use
Vulnerability	
22. Aquifer vulnerability using the DRASTIC method (synthesis layer + layers for each index component)	
Quality	
23. Quality (drinking water standards - MAC)	30. Galdit index
24. Quality (aesthetic standards)	
Others	
29. Specific data used to produce the various deliverables	31. Data uncertainty
Identification of groundwater protection and management issues and recommendations	

The Gaspésie-Matapédia PACES

Project partners



sensibilisation.
concertation.
action.



Centre intégré
de santé
et de services sociaux
de la Gaspésie



Énergie et Ressources
naturelles



Centre d'expertise
hydrique



... as well as the 67 municipalities located in the area.

RQES and research team roles

Your resource contacts

The RQES team supports the research team in planning and organizing knowledge transfer and exchange workshops with stakeholders/partners during the PACES process. RQES has expertise in developing activities and running workshops to facilitate the transfer and exchange of knowledge. Given the extent of the territory and to ensure an optimal participation rate, it is planned to hold three sessions of each workshop to cover the territory of each watershed organization of the region.

RESEARCH TEAM



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RQES TEAM



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Project timeline

RESEARCH TEAM WORK PHASES (UQAR)

KNOWLEDGE TRANSFER AND EXCHANGE WORKSHOPS (RQES)

YEAR 1 Compiling existing data

1

Discovering our PACES project and connecting it to our territory's issues

YEAR 2 Fieldwork and modeling

2

Acquiring hydrogeological knowledge of my territory

YEAR 3
Producing reports and geospatial databases

3

Protecting and managing groundwater

YEAR 4

4

Understanding the hydrogeological dynamics of our territory

5

Learning to use PACES geomatic databases

Discussion : your questions about the PACES

3

Groundwater protection and management issues in your territory





Global issues



Aquifer
contamination



Aquifer
Recharge



Wellhead area
protection

Examples of issues

- Climate change
- Point source contamination
- Agricultural activities
- Recharge
- Mine
- Water quality
- Overexploitation
- Large-scale withdrawers
- Water shortage
- Lack of knowledge
- Hydrocarbons



What are the groundwater issues in your territory ?

Activity 1: Local knowledge and concerns that can help realize the PACES project



Instructions

1. In small groups, identify and locate on the map the groundwater protection and management (GPM) issues that you are aware of or anticipate in your area. As some issues may be found in several locations, note the numbers on the map and refer to them in a legend at the edge of the map.
2. Specify who is affected by the issue.
3. Exchange with researchers to better understand the issues that have a potential impact on groundwater on a regional scale.
4. Exchange with researchers to identify those that will be addressed by the PACES.



Fictional example of an issue location

Activity 2: From local knowledge to regional ground-water characterization



Open group discussion about the following questions:

1. What did you learn from the concerns and issues raised at your table?
2. How will the PACES contribute to the understanding of the issues, to the lack of knowledge and to the management and protection of groundwater?
3. What are the uses and limits of the knowledge provided by PACES for stakeholders? What are the possible applications for land-use planning?

Activity 3: Prioritizing groundwater protection and management (GPM) issues in our territory



Instructions

You have 2 stickers. Using the stickers, identify the 2 GPM issues you consider to be the top priorities for your region (where action should be taken first).



1st choice



2nd choice

The top priorities for our region :

Issue no. 1: _____

Issue no. 2: _____

The issues ranked as highest priority will be used to develop the 3rd RQES workshop, where we will discuss the GPM measures that can be put in place to address these issues.

4

**The research team needs
and effective ways of
communication for
the project**



Researchers' needs from local stakeholders for the PACES project



The first stage of PACES consists in gathering all existing data, like:

- Description of boreholes or wells
- Pumping tests
- [Piezometric level](#) monitoring data
- Geochemical data ([groundwater](#) quality)
- [Hydraulic properties](#) of the various geological units (porosity, hydraulic conductivity, fracturing, transmissivity, etc.)
- Climatic data
- Hydrometric data
- Land use
- Hydrogeological studies
- Geothermal studies or drilling
- [Groundwater](#) exploration
- Drinking water supply (volumes withdrawn)
- Drinking water source protection
- Drinking water source search (even if inconclusive)
- Drinking water wells (municipal or private)
- Subsurface surveys
- Geological or geotechnical studies or characterization
- [Groundwater](#) flow modeling
- Geophysical studies or geophysical characterization
- [Aquifer capacity](#)
- Application for authorization according to section 7 of the Regulation respecting water withdrawal and protection (RPEP)
- Application for authorization certificate according to section 22 of the Environment Quality Act

The second phase consists in collecting data in the field. For this stage, researchers need :

- Access to locations of interest for well sampling, borehole [hydrostratigraphy](#) characterization and pumping tests;
- A communications plan to raise awareness about groundwater and the PACES-GM among municipalities and the population.

Discussion: how can we meet researchers' needs to have more usable and useful knowledge ?



Communication and operating modes for the PACES



Reminder: your resource contacts

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3

Protecting and managing groundwater

YEAR 4

4

Understanding the hydrogeological dynamics of our territory

5

Learning to use PACES geomatic databases

Finding our own way of communication for the PACES



1. Who are the local resource persons?

2. What other research-related needs do you foresee during the project?

3. What other knowledge transfer needs do you foresee during the course of the project?

4. Do you have any other needs or expectations?

Notes

Bibliography

- Buffin-Bélanger, T., Chaillou, G., Cloutier, C.-A., Touchette, M., Hétu, B. et McCormack, R. 2015. Programme d'acquisition de connaissance sur les eaux souterraines du nord-est du Bas-Saint-Laurent (PACES-NEBSL) : Rapport final. 199p.
- Carrier, M.-A., Lefebvre, R., Rivard, C., Parent, M., Ballard, J.-M., Benoit, N., Vigneault, H., Beaudry, C., Malet, X., Laurencelle, M., Gosselin, J.-S., Ladevèze, P., Thériault, R., Gloaguen, E., Beaudin, I., Michaud, A., Pugin, A., Morin, R., Crow, H., Bleser, J., Martin, A., Lavoie, D. 2013. Portrait des ressources en eau souterraine en Montérégie Est, Québec, Canada. Projet réalisé conjointement par l'INRS, la CGC, l'OBV Yamaska et l'IRDA dans le cadre du Programme d'acquisition de connaissances sur les eaux souterraines du MDDEFP et du Programme de Cartographie des eaux souterraines de la CGC, Rapport final INRS R-1433, soumis en juin 2013.
- CERM-PACES, 2015. Résultats du programme d'acquisition de connaissances sur les eaux souterraines du territoire de Charlevoix, Charlevoix-Est et La Haute-Côte-Nord. Centre d'études sur les ressources minérales, Université du Québec à Chicoutimi.
- Ferlatte, M., Tremblay, Y., Rouleau, A. et Larouche, U. F. 2014. Notions d'hydrogéologie - Les eaux souterraines pour tous. Première Édition. Réseau québécois sur les eaux souterraines (RQES). 63 p. [En ligne], (http://rqes.ca/wp-content/uploads/sites/72/2016/08/HYDROGEOLOGIE_notions_et_figures_oct2014.pdf). Page consultée le 11 mai 2017.
- Gouvernement du Québec. 2015. Règlement sur la qualité de l'eau potable. Loi sur la qualité de l'environnement. Q-2, r. 40. [En ligne], (<http://legisquebec.gouv.qc.ca/fr/ShowDoc/cr/Q-2,%20r.%2040/>). Page consultée le 11 mai 2017.
- Larocque, M., Gagné, S., Barnetche, D., Meyzonnat, G., Graveline, M. H. et Ouellet, M. A. 2015. Projet de connaissance des eaux souterraines du bassin versant de la zone Nicolet et de la partie basse de la zone Saint-François - Rapport final. Rapport déposé au Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques. 258 p.
- Larocque, M., Meyzonnat, G., Ouellet, M. A., Graveline, M. H., Gagné, S., Barnetche, D. et Dorner, S. 2015. Projet de connaissance des eaux souterraines de la zone de Vaudreuil-Soulanges - Rapport scientifique. Rapport déposé au ministère du Développement durable, de l'Environnement et de la Lutte contre les Changements Climatiques. 201 p.
- Leblanc, Y., Légaré, G., Lacasse, K., Parent, M. et Campeau, S. 2013. Caractérisation hydrogéologique du sud-ouest de la Mauricie. Rapport déposé au ministère du Développement durable, de l'Environnement, de la Faune et des Parcs dans le cadre du Programme d'acquisition de connaissances sur les eaux souterraines du Québec. Département des sciences de l'environnement, Université du Québec à Trois-Rivières, 134 p., 15 annexes et 30 documents cartographiques (1:100 000). [En ligne], (https://oraprdnt.uqtr.quebec.ca/pls/public/docs/GSC1456/F1542720878_Rapport_final_05juin.pdf). Page consultée le 11 mai 2017.
- Santé Canada. 2014. Recommandations pour la qualité de l'eau potable au Canada. Tableau sommaire. Préparé par le Comité fédéral-provincial-territorial sur l'eau potable du Comité fédéral-provincial-territorial sur la santé et l'environnement. [En ligne], (http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/sum_guide-res_recom/index-fra.php). Page consultée le 11 mai 2017.
- Siim Sepp. 2005. Wikipédia – Argile. Argilite en Estonie. [En ligne], (<http://fr.wikipedia.org/wiki/Argile>). Page consultée le 11 mai 2017.
- Talbot Poulin, M.C., Comeau, G., Tremblay, Y., Therrien, R., Nadeau, M.M., Lemieux, J.M., Molson, J., Fortier, R., Therrien, P., Lamarche, L., Donati-Daoust, F., Bérubé, S. 2013. Projet d'acquisition de connaissances sur les eaux souterraines du territoire de la Communauté métropolitaine de Québec, Rapport final. Département de géologie et de génie géologique, Université Laval, mars 2013, 172 pages, 19 annexes, 28 cartes.
- Tommi-Morin G., Deschamps C.-E., Dubé, J., Buffin-Bélanger T., Chaillou G. 2022. Projet d'acquisition de connaissances sur les eaux souterraines – Kamouraska - Rivière-Du-Loup - Témiscouata. Rapport synthèse au MELCC. 44p.

The partners of the 1st RQES groundwater knowledge transfer and exchange workshop in Gaspésie-Matapédia :



This initiative is financed by the Fonds Bleu as part of the Quebec Water Strategy's National Water Plan, which deploys concrete measures to protect, use and manage water and aquatic environments in a responsible, integrated and sustainable way.

