Communauté métropolitaine de Québec

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Final Report

Transportation of Dangerous Goods in the Communauté métropolitaine de Québec

Prepared for:

Communauté métropolitaine de Québec (CMQ)

Prepared by:

CPCS

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Acronyms and abbreviations

CERCA	Canadian Emergency Response Contractor Association
RAC	Railway Association of Canada
BAPE	Bureau d'audiences publiques sur l'environnement
BLEVE	Boiling liquid expanding vapor explosion
TSB	Transportation Safety Board
CANUTEC	Canadian Transport Emergency Centre
TDG-GPAC	Transportation of Dangerous Goods General Policy Advisory Council
CDTMD	Comité directeur Transport des marchandises dangereuses
CHSLD	Residential and long-term care centres
CMMIC	Joint committee for municipalities, industries and citizens
CMQ	Communauté métropolitaine de Québec
CN	Canadian National
MIARC	Major Industrial Accidents Reduction Council
CSCQ	Comité de sécurité civile du Québec
HSSC	Health and social services centre
DGVRSB	Dangerous Goods, Vehicle & Rail Safety Branch
EIA	Energy Information Administration
ERPG	Emergency Response Planning Guideline
HMS	Hazardous Materials Safety
CSA	Canada Shipping Act, 2001
TDGA	Transportation of Dangerous Goods Act, 1992
MDDELCC	Ministry of Sustainable Development, Environment and Climate Change
RCN	Regional county municipality
MSP	Ministère de la Sécurité publique du Québec
MTQ	Ministère des Transports du Québec
NEB	National Energy Board
ORSC	Organisation régionale de la sécurité civile
OSCQ	Organisation de la sécurité civile du Québec
PHMSA	Pipeline and Hazardous Materials Safety Administration
ERP	Emergency Response Plans
PHAST	Process Hazard Analysis Software Tools
PHMSA	Pipeline and Hazardous Materials Safety Administration
PIPA	Pipelines and Informed Planning Alliance
TDGR	Transportation of Dangerous Goods Regulations
SAAQ	Société de l'assurance automobile du Québec
GIS	Geographic Information System
WHMIS	Workplace Hazardous Materials Information System
ECRC	Eastern Canada Response Corporation

AR/CR	Accident rate/critical accident rate
TEAP	Transportation Emergency Assistance Plan
TQM	Trans-Québec & Maritimes
USDOT	U.S. Department of Transportation
USEPA	U.S. Environmental Protection Agency
USFRA	U.S. Federal Railroad Administration

Executive summary

The work in the present report aims to respond to the Communauté métropolitaine de Québec's (CMQ) need to have a current and representative overview of the dangerous goods circulating its territory by road, rail and marine routes, and by pipeline, as well as an analysis of the related risks. This overview must also suggest preventative measures to reduce the risks and response strategies to minimize the consequences of accidents.

The primary objective of this work is to understand the dynamics of the transportation of dangerous goods in the CMQ, analyze the risks and suggest preventative measures. This objective is broken down into three precise statements:

- *Prepare a current and representative overview of the dangerous goods circulating the networks in the CMQ and those in transit (road, rail and marine routes, and by pipeline);*
- *Analyze the risks related to the transportation of dangerous goods in the CMQ, particularly by identifying the transportation corridors/sections that are at risk;*
- *Suggest preventative measures to reduce these risks and response measures to minimize the consequences of accidents.*

Given the analyses performed, it must be recognized that it is especially complicated to produce a current and representative overview of the transportation of dangerous goods in the CMQ. This can be explained by several factors, including the availability of recent information and the confidentiality of the information itself. Unless there is a specific regulation requiring shippers of dangerous goods to declare the flows of dangerous goods that they generate systematically and regularly, it is unlikely that this will change in the medium or long term. All of this is in a context where the volumes of dangerous goods transported in the CMQ are likely higher than those identified in this report, and they are likely to increase. As a reminder, Chapter 2 suggests that:

- Over a period of one year in 2006-2007, at least 4.5 million tonnes of dangerous goods were transported by road in the CMQ.
- In 2011, approximately 30.6 million tonnes of dangerous goods were transported in the CMQ by marine routes, of which 16 million tonnes were at the port of Québec.
- Approximately 4.3 million tonnes of dangerous goods are transported on rail networks in the CMQ, of which 1.1 million are in transit. The volumes in transit are likely higher and should increase in the short term.

- Between 4 and 5 million tonnes of refined products are sent from Lévis by pipeline. This is in addition to the volumes of natural gas distributed within the CMQ.

Any attempt to precisely determine the risks associated with the transportation of dangerous goods is seriously compromised due to the difficulty of quantifying the actual volumes transported. However, it is still possible to identify the main transportation corridors, and, using historical data on incidents that took place on CMQ transportation networks, the history of spills and estimation of the volumes of dangerous goods transported, a risk portrait can be identified. From the analyses performed in Chapter 3, it is possible to conclude that the overall level of risk associated with the transportation of dangerous goods on the CMQ transportation networks is low to medium.

Regardless of the level of risk, the consequences of a dangerous goods transportation accident could be significant. Section 3.2 of the present report defines the impact radiuses of several accidents according to the type of product, the mode of transportation and the worst-case and alternative (more likely) scenarios. In certain cases, the impact radiuses may extend beyond the territory of CMQ, but generally, the impact radiuses are only a few metres (for example: a hydrogen peroxide road accident) to a few hundred metres (for example: a gasoline rail accident). Evidently, the location of the accident is the factor that determines the magnitude of the consequences on the vulnerabilities. To illustrate the potential consequences, a certain number of locations were selected, and the impacts were modelled in a geographic information system. According to the results generated using this model, certain dangerous goods accidents can have catastrophic consequences because there are residential areas located just tens of metres away from corridors where significant quantities of petroleum products are circulating.

The unfortunate incidents that have occurred over the last years and weeks suggest that measures must be taken to reduce the potential impacts of dangerous goods transportation accidents. Chapter 4 tackles this question and several response measures are suggested. These measures have been formulated with no regard to their practicability, and for some of them, several obstacles/disadvantages would likely arise if they were implemented.

However, such obstacles must not prevent the implementation of efforts to mitigate the risks within the CMQ. Beyond the challenges related to respective competencies of the various levels of the government, the knowledge of manufacturers and carriers, as well as the available resources, all large agglomerations worldwide are facing similar issues. By carrying out these measures over time, the CMQ and its municipalities are likely to pave the way for other territories with respect to the mitigation of risks associated with the transportation of dangerous goods.

1 Introduction

Key message

This final report was prepared for the Communauté métropolitaine de Québec. Its objective is to understand the dynamics of the transportation of dangerous goods in the CMQ, to analyze the risks and suggest preventative measures.

1.1 Background

The Communauté métropolitaine de Québec (CMQ) wants to have a current and representative overview of the dangerous goods circulating its territory by road, rail and marine routes, and by pipeline, as well as an analysis of the related risks. This overview must suggest preventative measures to reduce the risks and response measures to minimize the consequences of accidents.

The team proposed by CPCS was selected to carry out this mandate. The present document constitutes the final report.

1.2 Objectives

The primary objective of this mandate is to understand the dynamics of the transportation of dangerous goods in the CMQ, analyze the risks and suggest preventative measures. This objective is broken down into three precise statements:

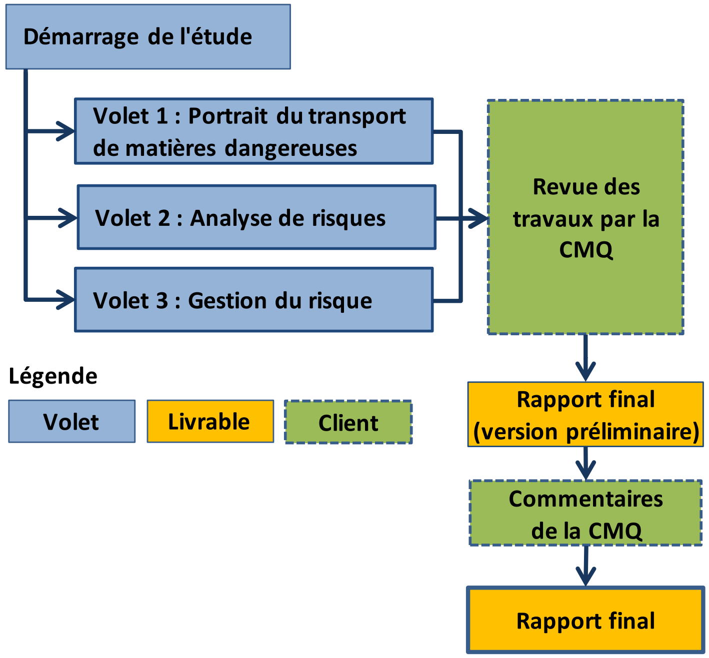
- *Prepare a current and representative overview of the dangerous goods circulating the networks in the CMQ and those in transit (road, rail and marine routes, and by pipeline);*
- *Analyze the risks related to the transportation of dangerous goods in the CMQ, particularly by identifying the transportation corridors/sections that are at risk;*
- *Suggest preventative measures to reduce these risks and response measures to minimize the consequences of accidents.*

The fulfilment of this mandate must not only allow the CMQ to better understand the issues related to the transportation of dangerous goods, but also provide a solid base for knowledge and analysis to allow the municipalities and the constituent RCMs of the CMQ to be aware of the problem areas located in their respective territories. This will allow it to have a better understanding of these problems and take the necessary actions to establish preventative and response measures in their territories.

1.3 Work breakdown structure

The work was carried out according to the three main parts illustrated in the following figure. The present document constitutes the final report.

Figure 1-1: Project sections and steps



Démarrage de l'étude	Beginning of the study
Volet 1 : Portrait du transport de matières dangereuses	Part 1: Overview of the transportation of dangerous goods
Volet 2 : Analyse de risques	Part 2: Risk analysis
Volet 3 : Gestion du risque	Part 3: Risk management
Revue des travaux par la CMQ	Review of the work by the CMQ
Rapport final (version préliminaire)	Final report (preliminary version)
Commentaires de la CMQ	Comments from the CMQ
Rapport final	Final Report
Légende	Legend
Volet	Part
Livrable	Deliverable
Client	Client

1.4 Methodology

Each part of this study was completed by referring to a distinct methodology. In the first part, data on flows of dangerous goods in the CMQ were collected from various official sources and consultations. These were then used to create an overview of the flows on a territorial level. The completion of the second part of the project was based on the development of a risk and consequences analysis model developed in a geographic information system (GIS). The third part is the result of bibliographic analyses and risk management statistics.

The Committee created by the CMQ ensured follow-up on each part. Based on the comments made, the necessary modifications were made to the preliminary version of the final report. These comments were considered when developing the present report.

1.5 Limitations

The results presented in this report are taken from primary and secondary sources. They were collected with great care to ensure accuracy, and the resulting remarks aim to reflect the publicly available information as accurately as possible.

Unless otherwise indicated, all of the opinions put forth in this document are those of CPCS. They do not necessarily reflect those of the CMQ or any other stakeholder consulted during the work completed under the present mandate.

1.6 Structure of the report

This final report is broken down into 5 chapters:

- Chapter 1: Introduction
- Chapter 2: Overview of the Transportation of Dangerous Goods
- Chapter 3: Risk Analysis
- Chapter 4: Risk Management
- Chapter 5: Conclusion

2 Overview of the Transportation of Dangerous Goods

Key message

The data on the transportation of dangerous goods varies considerably in terms of accuracy and reference year.

The main products transported on CMQ transportation corridors are flammable liquids and gases. The Saint-Romauld refinery is the principal flow generator for road, marine, rail and pipeline transportation.

Due to the geographic location of Quebec in relation to the principal railway transportation lines that run from eastern to western Canada, a significant quantity of flammable liquids is also in transit on marine, rail and road routes.

2.1 Data about the transportation of dangerous goods

The main difficulty encountered while preparing this report was the availability and accuracy of the data used. The nature of the information required to prepare an overview of the flows of goods in the CMQ poses confidentiality issues. At times, the stakeholders consulted, as well as public agencies, were reluctant to divulge data that could allow the flow generators to be identified.

The data that allowed the transportation of goods to be characterized might use different product nomenclatures. However, the nomenclatures used to characterize the flows of goods transported in Canada were not developed in terms of the specific properties of dangerous goods. Whether or not a product is likely to be dangerous can only be determined by the product name. In addition, there are other limitations to developing a uniform and intermodal database on the flows of dangerous goods in the CMQ. The following figure provides an outline of the data used to produce the overview of the flows.

Figure 2-1: Limitations of the data used

Mode	Source	Period covered	Limitations
Road	National Roadside Survey	Typical week 2006-2007	Sample did not cover local movements. As such, it is impossible to determine the flows that originated in or were destined for the CMQ, apart from those provided by the respondents.
Rail	Statistics Canada (CANSIM)	Annual – 2012	The point of origin or destination in Quebec could not be determined from the scale. As such, it is impossible to determine the magnitude of the volumes originating in or destined for the CMQ.
Marine	Statistics Canada	2011 – Last issue	The product could not be identified from the data on domestic flows.
Pipeline	No unique source	n/a	Only pipeline operators can provide this data.

Source: CPCS

This does not mean that the transportation of dangerous goods in Quebec is carried out with no regard for the properties of products. In Quebec, just as in Canada, the acts regulate the procedures and standards for the transportation of dangerous goods. However, the regulations associated with the acts are primarily intended to govern the training of employees, supporting documents, mandatory indicators and standard containers. They are not intended to regulate the manner in which the transportation of products is reported to studies about the transportation of goods. In order to make consistent comparisons between the modes of transportation and define the magnitude of the volumes of dangerous goods transported in the territory of the CMQ, it is necessary to rely on the nomenclatures used in the statistics specific to the transportation flows.

Whether it be for road, rail or marine transportation, a table of correspondence was developed between the nomenclature used in the modal data and the classification specified in the

Transportation of Dangerous Goods Regulations (TDGR). Furthermore, these regulations define dangerous goods according to 9 classes and their various subcategories. If the product description did not allow the product to be classified, it was categorized as “Unknown.”

In short, the classification used to describe the flows is that specified in the TDGR, which are defined as follows:

- Class 1: Explosives
- Class 2: Gases
- Class 3: Flammable liquids
- Class 4: Flammable solids
- Class 5: Oxidizers
- Class 6: Toxic and infectious substances
- Class 7: Radioactive materials
- Class 8: Corrosives
- Class 9: Miscellaneous

2.2 Mode specific data

2.2.1 Road

There is little data allowing the volume of flows of dangerous goods transported by road to be quantified and characterized. In Quebec, the most recent data comes from the National Roadside Survey (NRS) from 2006-2007. For one reference week in the fall (typical week), the NRS sampled road vehicles with a minimum gross weight of 3 tonnes that were designed for intercity transportation of goods. The database used to determine the volume of dangerous goods transported within the territory of the CMQ by road excluded local movements. Here, a local movement is defined as being less that 80 km and taking place within one administrative region or census metropolitan area (CMA), in this case Quebec. It is important to note that as the goods transported within the CMQ are not included, the flows of dangerous goods by road presented in this section underestimate the actual quantity of products.

It should also be mentioned that the NRS is first and foremost a sample and does not represent all movements that took place during the study. The number of movements and the quantities of goods recorded in the NRS were calculated by applying an expansion factor that estimates the total number of movements and the quantities of goods transported.[1]

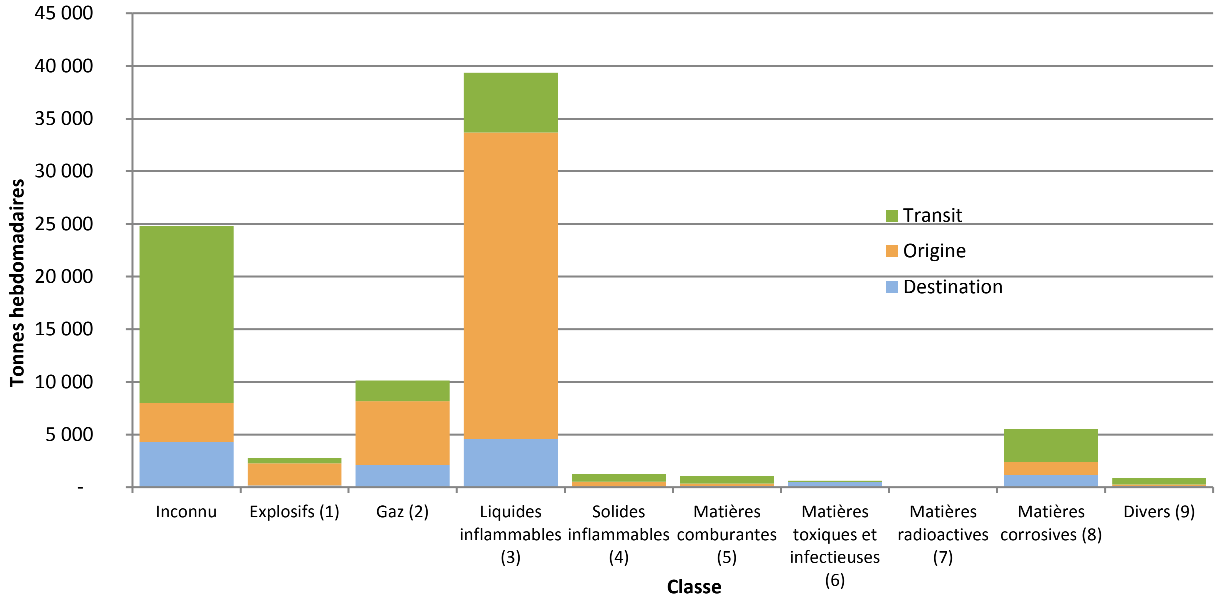
The data from the NRS 2006-2007 indicated that, in a typical week, there were 6,340 movements of trucks identified as containing dangerous goods in the CMQ. As a comparison, the total number of truck movements (including those transporting all types of goods) coming from or going toward/to the CMQ during a typical week was 75,675. This means that the movements associated with dangerous goods made up little more than 8% of the total movements in the CMQ. In terms of the tonnages transported, this ratio is approximately 10.6%, or 86,580 tonnes of dangerous goods out of a total of 817,910 tonnes transported daily in the CMQ.

Returning to dangerous goods, approximately 1,880 movements originated in the CMQ, whereas 2,360 were destined for the CMQ. The other 2,100 movements were in transit and neither originated from nor were destined for the CMQ. Annually, these movements correspond to the transportation of 4.5 million tonnes of dangerous goods by truck.

As suggested by Figure 2-2, dangerous goods from Class 3 (flammable liquids) represented the largest quantity transported during a typical week in 2006-2007. Above all, this consisted of fuels being sent out of the CMQ. However, approximately 17,000 tonnes of products considered to be dangerous goods, but which were not able to be identified with certainty (unknown), were in transit in the CMQ during this period. Nonetheless, they were considered to be dangerous goods, as the driver indicated that this was the case, the truck had a sign, or the product description implied that it was a dangerous good. The data in Figure 2-2 should be interpreted with great caution. In isolating the dangerous goods by class, certain samples appeared to be too small to make valid conclusions on the quantities transported and the movements made. In particular, this is the case for Class 1 (Explosives), for which the tonnages and movements identified relied on only 16 observations. A warning should also be given for the flows of Class 6 (Toxic and infectious substances – 9 observations), Class 7 (Radioactive materials – 3 observations), Class 5 (Oxidizers – 18 observations) and Class 4 (Flammable solids – 21 observations). All the other flows of goods in the following graph are generated from a sample of at least 66 observations.

[1] For a detailed explanation of the data from the NRS, the methodology used and the sample, see: Quebec, 2013, *Les déplacements interurbains de camions au Québec – Enquête nationale en bordure de route sur le camionnage de 2006-2007*, 195 pages.

Figure 2-2: Flows of dangerous goods transported in the CMQ by road during a typical week in 2006-2007 by class (tonnes)



Source: CPCS, from data from the NRS.

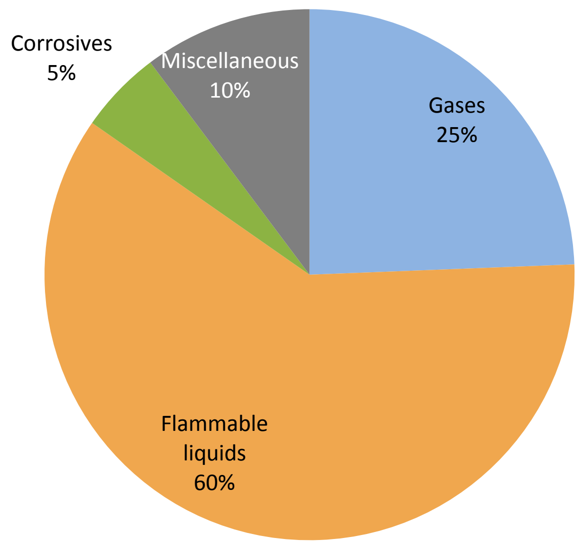
Tonnes hebdomadaires	Tonnes per day
Classe	Class
Transit	In transit
Origin	Origin
Destination	Destination
Inconnu	Unknown
Explosifs (1)	Explosives (1)
Gaz (2)	Gases (2)
Liquides inflammables (3)	Flammable liquids (3)
Solides inflammables (4)	Flammable solids (4)
Matières comburantes (5)	Oxidizers (5)
Matières toxiques et infectieuses (6)	Toxic and infectious substances (6)
Matières radioactives (7)	Radioactive materials (7)
Matières corrosives (8)	Corrosives (8)
Divers (9)	Miscellaneous

2.2.2 Rail

Public data on the transportation of goods by rail can be downloaded from Statistics Canada's socioeconomic database, CANSIM. To maintain shippers' confidentiality, the data on the flows of goods transported by rail offers few details regarding the origin and destination of the products. Furthermore, the flows are presented on a provincial level and it is not possible to determine the volume of flows that originate in or are destined for the CMQ. Figure 2-3 illustrates the portions of each class of dangerous goods in the rail flows in transit in the CMQ.

To isolate the flows of dangerous goods likely to pass through the CMQ rail network (Figure 2-3), it is necessary to make some hypotheses. Firstly, due to the layout of the Canadian rail network, all flows of goods moving between the Atlantic provinces and western Quebec must go through the CMQ. In 2012, CANSIM data revealed that the volume of a flow rose to approximately 6.5 million tonnes, of which 1.1 million tonnes were dangerous goods.

Figure 2-3: Dangerous goods in transit on the rail network in the CMQ



Source: CPCS, taken from CANSIM 404-0021

According to the data from CANSIM (2012), the Jean-Gaulin refinery in Saint-Romuald received between 15 and 21 unit trains[2] of one hundred cars per month. These unit trains were coming from the west and were loaded with crude oil (flammable liquid). Depending on the specific point of origin and type of crude oil, such unit trains transported approximately 7,700 tonnes, which corresponds to approximately 1.4 to 1.9 million tonnes annually. However, this situation has changed since 2015 due to the reversal of Enbridge Line 9B. The refinery no longer receives unit trains loaded with crude oil. These volumes are now transported by boat.[3] In terms of the refined products, two unit trains per week are sent from Saint-Romuald.[4] According to the type of product sent, this amounts to between 10,000 and 12,000 tonnes per week, or 520,000 to 624,000 tonnes of refined products per year. Consultations also determined an approximate

[2] *Source*: http://www.lapresse.ca/le-soleil/actualites/transports/201307/10/01-4669697-lultratrain-dultramar-utilise-les-memes-wagons-que-mma.php, page consulted on 10-04-2014.

[3] Information provided to CMQ in 2016 by a representative of the Jean-Gaulin refinery.

[4] Source: http://virtuel.journallepeuple.canoe.ca/doc/hebdo_le-peuple-levis/peuple_levis_2013_07_17_opt/2013071601/5.html#4, page consulted on 10-04-2014. Before the commissioning of the pipeline between Saint-Romuald and Montréal East, the number of cars of refined products leaving the Jean-Gaulin refinery was higher.

flow of 368,000 tonnes of gas destined for Pintendre,[5] which, from the CANSIM data and consultations, allows the rail flow to be estimated to be at least 3.35 million tonnes.

2.2.3 Marine

The data on marine transportation of dangerous goods is available through Statistics Canada and the publication *Shipping in Canada.*[6] This publication, and the production of relevant data, was discontinued in 2013, and it is still unclear whether another organization will take up this task.

With the most recent (and likely the last) data, it was possible to quantify and characterize marine flows on a national level for 2011. Based on the points of origin and destination of the products, it is possible to isolate the marine flows that passed through CMQ's port facilities and those which were simply transported on the St. Lawrence. The dangerous goods could be isolated with relative precision using the data on international flows. The same cannot be said for domestic flows, as the data is only published according to the 9 classes of products, including fuels and basic chemicals (miscellaneous) as well as coal (flammable solids).

Fortunately, the Québec Port Authority (QPA) keeps accurate records of the flow of goods transported through its terminals. However, for reasons of confidentiality, the port is not able to disclose through which specific terminal the flows were transshipped. Figure 2-4 illustrates the flow of dangerous goods to the port of Québec in 2011.

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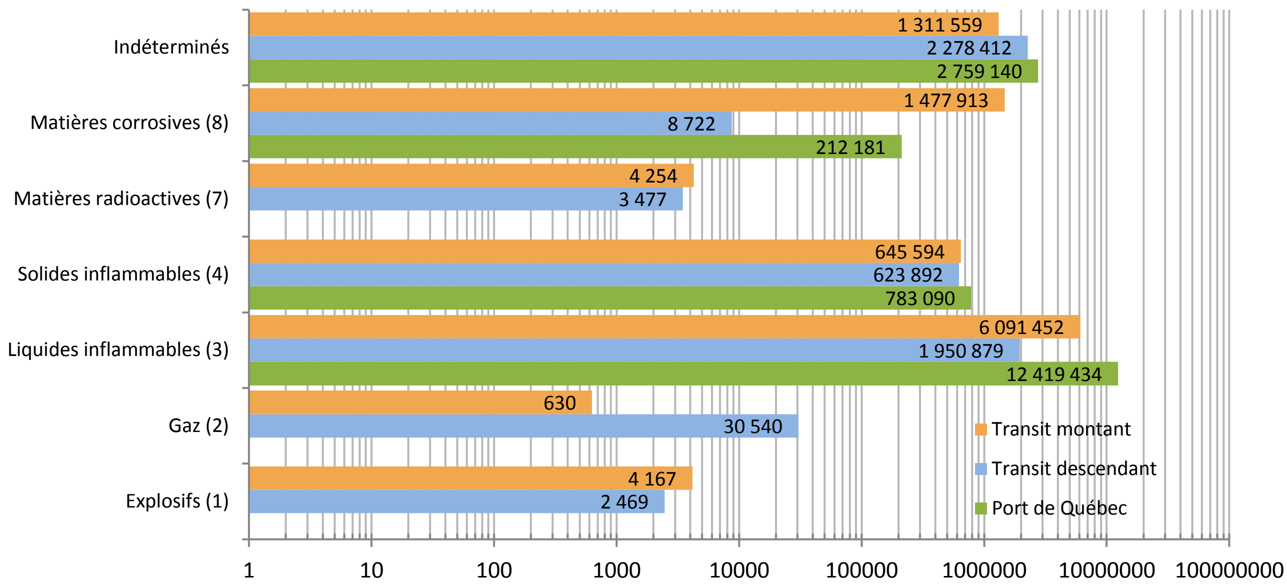
[5] Here it is a question of approximate flow because gases have different weights depending on their temperature. Normally, gas flows are described in terms of cubic metres. To facilitate comparison, the data in cubic metres was converted into tonnes. In this case, this is propane, and the conversion rate used was 0.8 kg/litre at 15°C.

[6] Catalogue 54-205-X.

Figure 2-4: Flow of dangerous goods transported in the CMQ by boat in 2011 (tonnes – logarithmic scale)



Source: CPCS, based on data from Statistics Canada

Transit montant	In-bound
Transit descendant	Out-bound
Port de Québec	Port of Québec
Indéterminés	Unknown
Matières corrosives (8)	Corrosives (8)
Matières radioactives (7)	Radioactive materials (7)
Solides inflammables (4)	Flammable solids (4)
Liquides inflammables (3)	Flammable liquids (3)
Gaz (2)	Gases (2)
Explosifs (1)	Explosives (1)

Since 2011, the situation has changed significantly. The introduction of the Pipeline Saint-Laurent between the Jean-Gaulin refinery and Montreal East transferred the majority of the volumes of fuels formerly transported by ship to the pipeline. This is 1.74 million tonnes less than the quantities transshipped in 2011. With the reversal of Enbridge Line 9B,[7] this portrait should change again over the next few years. In fact, Valero hopes to be able to supply more of North America, and a portion of the volumes that arrive at the end of the pipeline in Montreal should be transported to Quebec by boat. This is approximately 140 loads per year, or approximately 6 to 7.5 million tonnes per year.[8] Furthermore, these quantities would replace the other flows already arriving by boat, but they would come from another point of origin.

[7] Line 9B is a pipeline which transported products from Montreal to Ontario. The flow of this pipeline was reversed and increased.

[8] *Source:* Consultations with Valero.

In addition, the Jean-Gaulin refinery will be primarily supplied by boat. Rather than arriving downstream (from overseas and from Texas), the boats loaded with crude oil will be smaller and arrive in Montreal. As such, the deliveries should be more frequent[BN(1]. This situation may change again if the Energy East Pipeline goes ahead, as Valero could also decide to get their supply from this pipeline.

Otherwise, approximately 14.4 million tonnes of dangerous goods were in transit on boats in the CMQ in 2011. More than half of the goods in transit were flammable liquids.

2.2.4 Pipeline

There is no public database that can be used to quantify the flow of dangerous goods into the CMQ by pipeline. As no information was received directly from the stakeholders, only hypotheses can be made based on accurate information made by public by various mediums.

Since 2012, the completion of the Pipeline Saint-Laurent has allowed approximately 90,000 to 100,000 barrels of refined oil to be transported per day, or between 4 and 5 million tonnes annually, from the Valero facilities to Montreal East. However, the capacity of the pipeline is higher (up to approximately 170,000 barrels per day).[9]

The Trans Quebec & Maritimes (TQM) Pipeline transportation system enters the CMQ from the west on the northern shore, then crosses the St. Lawrence up to Saint-Augustin-de-Desmaures to reach Saint-Nicolas. This system supplies the Gaz Métro distribution network on both sides of the St. Lawrence. According to the company, the volumes distributed in the northern part of the CMQ (Québec, Shannon, Saint-Gabriel-de-Valcartier, Ancienne-Lorette and Saint-Augustin-de-Desmaures) are 15,000 m^3/hour on average in the summer and 50,000 m^3/hour in the winter. In the southern part, meaning Lévis, but also the other municipalities located in the south of the CMQ, the average volumes are 22,500 m^3/hour in the summer and 40,000 m^3/hour in the winter.

2.3 Principal transportation corridors

2.3.1 Road corridors

The following figure provides details on the flow of registered dangerous goods by road in the CMQ.

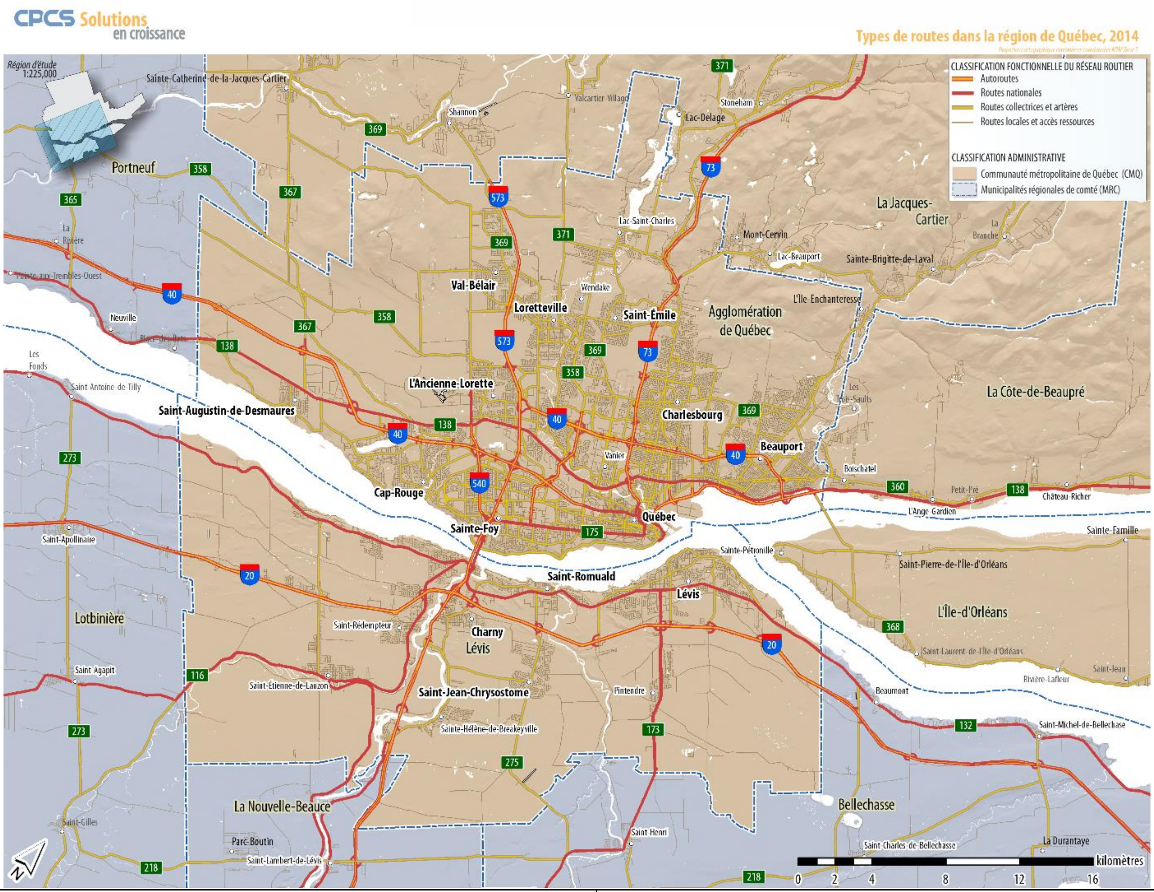
Figure 2-5: Flow of dangerous goods by road in the CMQ

Class	Destined for the CMQ		Originating in the CMQ		In transit in the CMQ		Total	
	Tonnes	Movements	Tonnes	Movements	Tonnes	Movements	Tonnes	Movements
Unknown	4 313	420	3 679	318	16 818	844	24 809	1 582
1	182	12	2 084	152	534	60	2 801	224
2	2 115	427	6 036	337	1 979	374	10 130	1 137
3	4 603	1 370	29 095	972	5 667	424	39 365	2 766
4	-	9	553	17	709	26	1 262	53
5	148	11	214	11	709	50	1 072	72
6	509	25	9	6	101	5	620	36
7	15	3			18	4	33	7
8	1 183	77	1 218	63	3 198	273	5 599	414
9	156	5	118	4	611	39	885	48
Total	13 225	2 358	43 006	1 880	30 345	2 099	86 576	6 337

Source: CPCS based on data from the NRS 2006-2007

With the exception of flows distributed to residents and businesses in the CMQ, the majority of the dangerous goods transported in the CMQ through intercity transportation take the major highways and boulevards (Figure 2-6). This was confirmed by the carriers and distributers consulted, who also indicated that they avoid zones that are potentially congested (as well as times of congestion) and that can make manoeuvring the vehicles complicated. The carriers also cited bridges and downtown for deliveries to businesses. As such, in principle, it is possible to deduce that products in transit in the CMQ will essentially take the A20 on the south of the river and the A40 on the north, moving along the A73, if necessary, to get to either shore or to go from north to south, or vice-versa, depending on the origin/destination combination. In the case of flows originating in or destined for Côte-Nord, route 138 is the natural extension of the A40.

Figure 2-6: CMQ road network



Types de routes dans la région du Québec, 2014	Types of roads in the Quebec region, 2014
CLASSIFICATION FONCTIONNELLE DU RÉSEAU ROUTIER	FUNCTIONAL CLASSIFICATION OF THE ROAD NETWORK
Autoroutes	Highways
Routes nationales	National road
Routes collectrices et artères	Collector and arterial roads
Routes locales et accès ressources	Local and resource access roads
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

For both loaded and unloaded flows, consultations with users of dangerous goods revealed that they preferred highways and boulevards leading to various industrial parks within the territory.

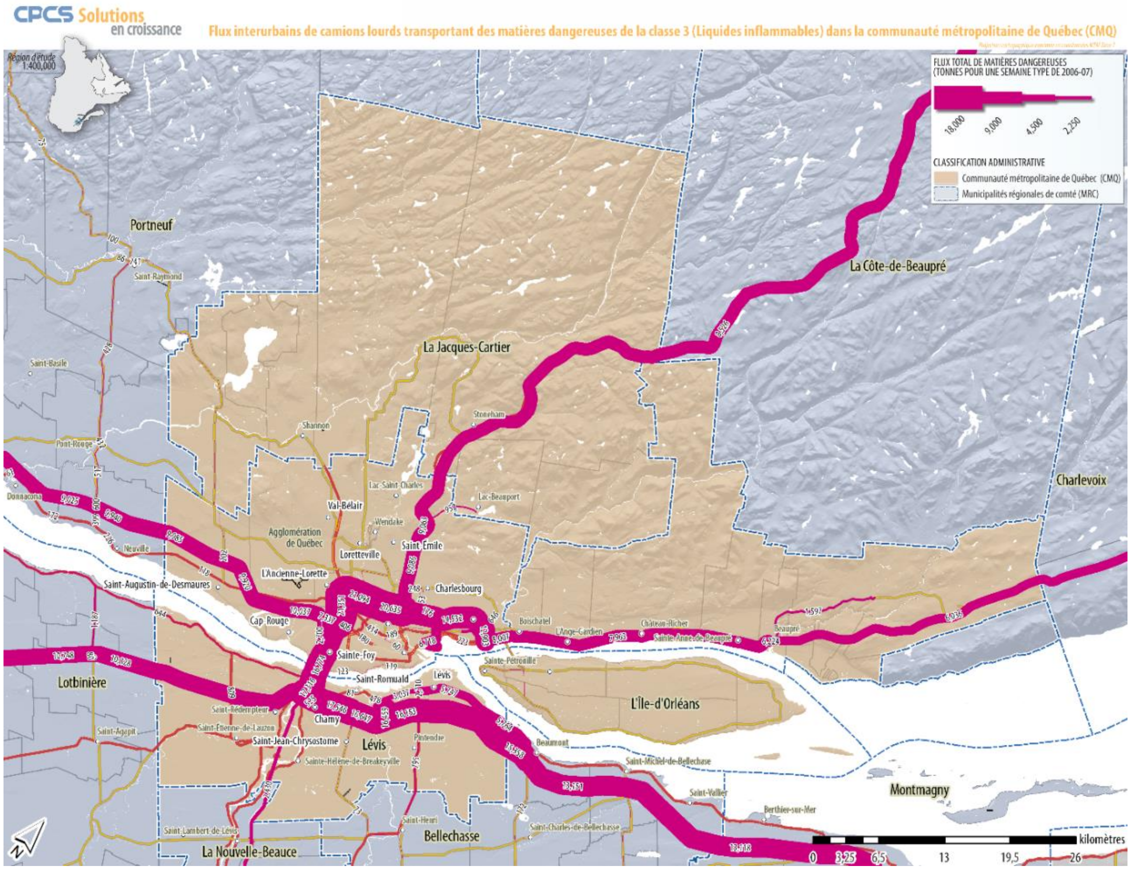
The principal road corridor for dangerous goods is that of flammable liquids (Class 3) transported on CMQ highways. This is primarily petroleum products that are sent from the Jean-Gaulin refinery to the various regions of Quebec on Highway 20. According to the data from the NRS, the volume of petroleum products likely sent out of Saint-

Romuald/Lévis during a typical week in 2006-2007 was approximately 19,394 tonnes, or 67% of the tonnages of all flammable liquids registered as originating from the CMQ. In terms of the number of movements, there were 537 movements registered, primarily tankers, but this number should be viewed with caution, as returning empty tankers still have symbols on the tank providing information about the nature of the dangerous good transported. Due to the methodology used to isolate the flows of dangerous goods by road, these were part of the sample even if they are not transporting dangerous goods. In the case of flammable liquids, approximately 66% of movements in the NRS and destined for the CMQ were declared empty, whereas 1% of those originating in the CMQ were declared empty. For in-transit movements, this ratio was 10%. In this respect, it is preferable to use tonnes rather than movements to quantify the flows.[10]

Furthermore, the flows of dangerous goods by road in the CMQ are, in part, attributable to the volumes of petroleum products distributed from the Jean-Gaulin refinery. By analyzing the origins, destinations and the products, it is possible to estimate that approximately 27% of the tonnage of dangerous goods transported by roads on the CMQ (with the exception of the volumes for retailers and residents of the CMQ) comes from the Jean-Gaulin refinery.

[10] For more information about how flows are quantified, consult Quebec, 2013, Les déplacements interurbains de camions au Québec – Enquête nationale en bordure de route sur le camionnage de 2006-2007, 195 pages

Figure 2.7: Flammable liquids loaded in the CMQ



Flux interurbains des camions lourds transportant des matières dangereuses de la classe 3 (Liquides inflammables) dans la Communauté métropolitaine de Québec	Intercity flows of heavy trucks transporting Class 3 dangerous goods (Flammable liquids) in the Communauté métropolitaine de Québec (CMQ)
FLUX TOTAL DE MATIÈRES DANGEREUSES (TONNES POUR UN SEMAINE TYPE DE 2006-2007)	TOTAL FLOWS OF DANGEROUS GOODS (TONNES IN A TYPICAL WEEK IN 2006-2007)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

As illustrated in Figure 2.7, the flows of petroleum products originating in Saint-Romuald/Lévis are notably destined for Bas-Saint-Laurent, Saguenay – Lac-Saint-Jean, Côte-Nord and Estrie. These flows, destined for the east, north and west of the refinery, leave the CMQ by the main highway routes, allowing them to reach their destination as quickly as possible. According to the consultations, carriers avoid going through areas that are likely to be congested during rush hours, as much as possible.

The other classes of dangerous goods follow similar corridors. Gases (Class 2) make up the second largest flow transported by road in the CMQ (see Figure 2-5). Like petroleum products, a high proportion of these gases are loaded in Saint-Romuald. The results of the NRS indicate, for example, that 39% of the tonnages of gases transported in the territory of the CMQ have Saint-Romuald as their point of origin and 65% of gases originating in the CMQ come from Saint-Romuald. The consultations also revealed that certain propane distributors in the Quebec region are supplied by Saint-Romuald, and the volumes concerned are sent to distributors' storage sites before they are delivered to residential and commercial clients, including those in the CMQ. Regarding propane, the few stakeholders contacted indicated that they mostly make their deliveries during the week and daytime hours, avoiding residential areas in the evening. Other sectors, like Old Quebec, are only served early in the morning before car traffic begins.

Similarly to flammable liquids, gases loaded in the CMQ are distributed throughout Quebec and even as far as the Maritimes. The trucks take the main highways in order to reach the target destinations as quickly as possible. Finally, of the 114 records in the NRS that generated a total of 1,140 movements categorized as Class 2, 52% were also considered empty. The proportion of empty movements was higher (74%) for those heading to the CMQ.

Of the 4,770 tonnes of corrosives (Class 8) identified as circulating through the CMQ road network in the NRS, approximately 54% were in transit in the territory. Therefore, it is the goods that are in transit on the road network, depending on the schedule, which allow them to minimize the distance between the point of origin and the destination. In the case of corrosives being transported toward the CMQ, the 970 tonnes concerned were generated by 17 observations, whereas the tonnages originating in the CMQ were generated by 12 observations. These reduced samples did not allow reliable trends to be distinguished regarding the transportation of corrosives to/from the CMQ.

2.3.2 Rail corridors

There are three principal rail corridors for the transportation of dangerous goods through the CMQ (Figure 2-8). Firstly, there are flows in transit that pass through the south of the CMQ heading east or west. Secondly, there are flows of crude petroleum products destined for the Jean-Gaulin refinery. Finally, an indeterminate quantity of chemical and petroleum products is sent to the west through storage facilities in the Beauport sector.

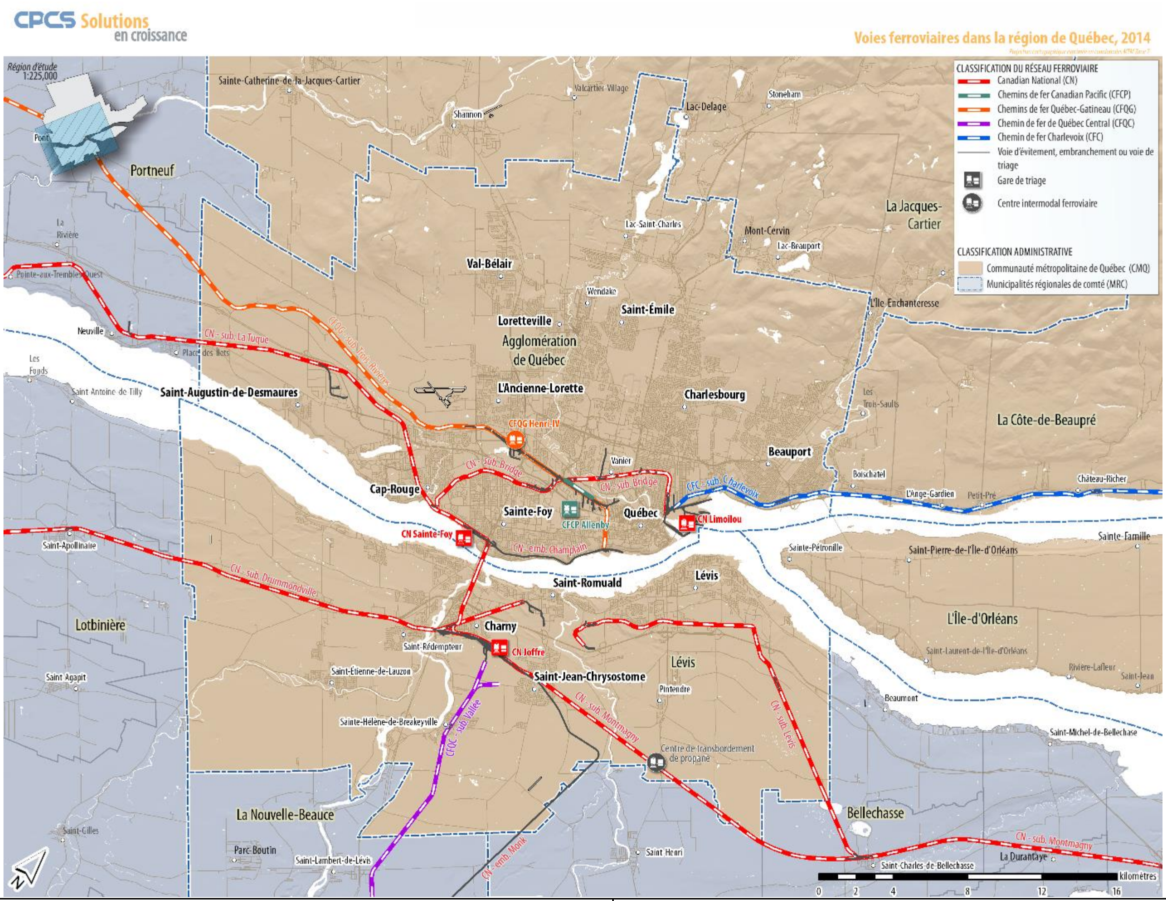
According to CANSIM data, approximately 55% of the flows of dangerous goods in transit by rail in the CMQ were composed of crude oil (flammable liquids – 672,400 tonnes) from Alberta and Saskatchewan. The other flows were notably composed of gaseous hydrocarbons (gases – 272,000 tonnes) being sent from Ontario to the Atlantic provinces, as well as various chemical products. These are, of course, minimal volumes, because other products in transit through the CMQ that were destined for other regions in Quebec could not be isolated. This includes, in particular, chemical products destined for the Lower St. Lawrence, Gaspésie and Côte-Nord (via the train ferry).

The Jean-Gaulin refinery in Saint-Romuald received between 15 and 21 unit trains[11] of one hundred cars per month. These unit trains coming from the north were loaded with crude oil (flammable liquid). According to the specific origin and type of crude oil, such unit trains transported approximately 7,700 tonnes, which corresponds to approximately 1.4 million to 1.9 million tonnes annually. However, with the reversal of Enbridge Line 9B, this situation has changed. Since 2015, the refinery has not received any unit trains loaded with crude oil. These volumes are now sent by boat.[12]

In terms of the refined products, according to the data from CANSIM (2012), two unit trains per week are sent out of Saint-Romuald.[13] Depending on the type of product sent, this is 10,000 to 12,000 tonnes per week, or 520,000 to 624,000 tonnes per year of refined products. In conclusion, depending on the period, the Jean-Gaulin refinery would be responsible for approximately 50% to 60% of the tonnages of dangerous goods transported in the CMQ by rail. Depending on the provision of the refinery's supplies, these proportions can vary significantly and will be called upon to do so in the future.

[11] *Source*: http://www.lapresse.ca/le-soleil/actualites/transports/201307/10/01-4669697-lultratrain-dultramar-utilise-les-memes-wagons-que-mma.php, page consulted on 10-04-2014.
[12] Information provided to the CMQ in 2016 by a representative of the refinery.
[13] *Source*: Consultations with Valero.

Figure 2-8: Rail network in the CMQ

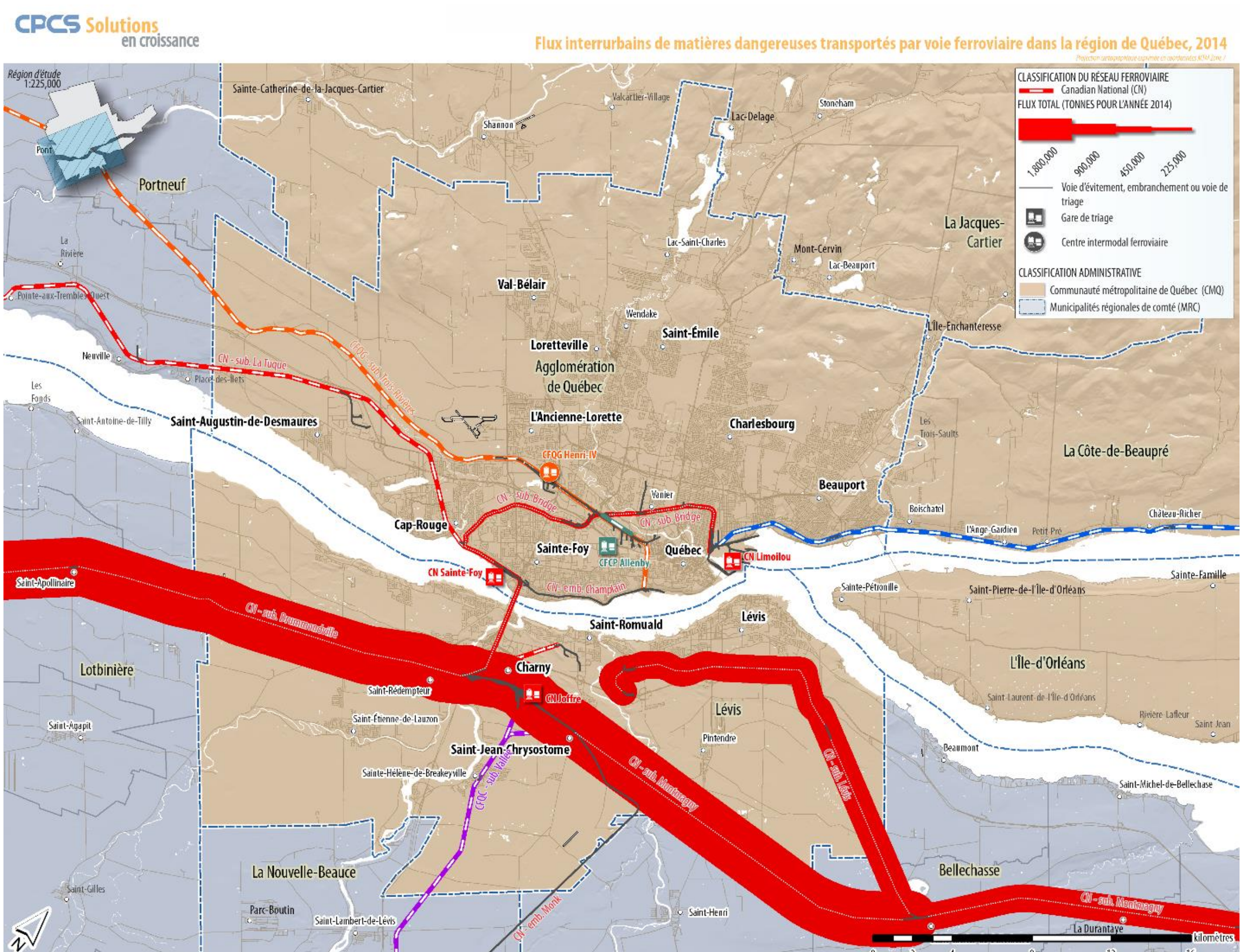


Voies ferroviaires dans la région de Québec, 2014	Rail lines in the Quebec region, 2014
CLASSIFICATION DU RÉSEAU FERROVIAIRE	CLASSIFICATION OF THE RAIL NETWORK
Canadian National (CN)	Canadian National (CN)
Chemins de fer Canadian Pacific (CFCP)	Canadian Pacific Railways (CPR)
Chemins de fer Québec Gatineau (CFQG)	Quebec-Gatineau Railways (QGR)
Chemins de fer de Québec Central (CFQC)	Central Quebec Railways (CQR)
Chemin de fer Charlevoix (CFC)	Charlevoix Railway (CR)
Voie d'évitement, embranchement ou voie de triage	Siding, spur or yard track
Gare de triage	Marshalling yard
Centre intermodal ferroviaire	Intermodal rail centre
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

Finally, the storage facilities in the Beauport sector of the port of Québec are also used to distribute petrochemical products to the North American markets. The flows transported by rail from these facilities are likely take the Canadian National (CN) network to leave the territory.

After taking the short section of the Quebec-Gatineau Railway (QGR) to the Allenby terminal, the cars would then be sent to the south shore of the St. Lawrence on the CN network; from there, they will continue to their final destination. In 2011, approximately one million chemical products and fuels were likely unloaded in the Beauport marine terminals. In theory, the majority of these products were redistributed throughout North America by rail.

Figure 2-9: Flow of dangerous goods within the CMQ by rail

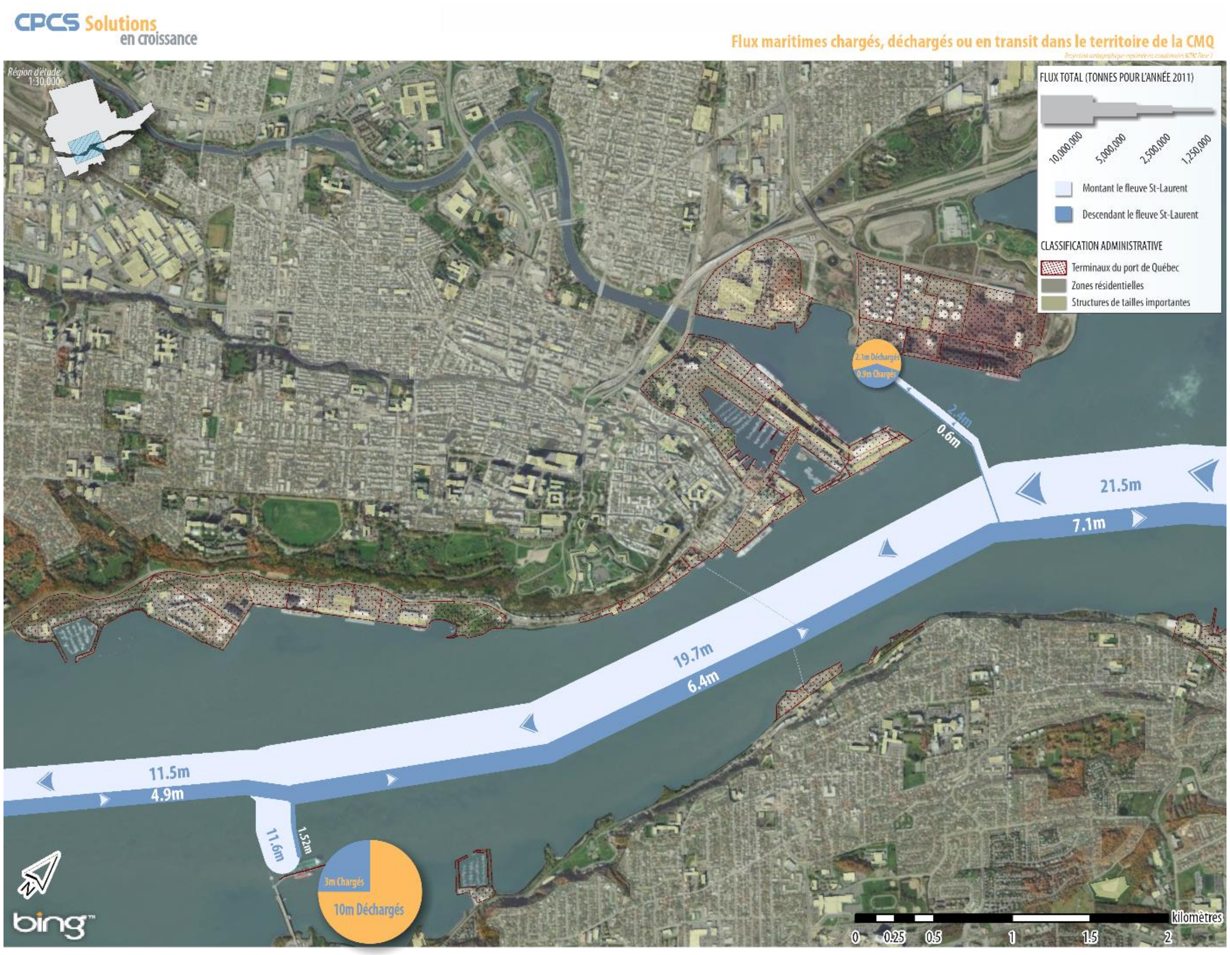


Flux interurbains de matières dangereuses par voie ferroviaire dans la région de Québec, 2014	Intercity flows of dangerous goods by rail in the Quebec region, 2014
CLASSIFICATION DU RÉSEAU FERROVIAIRE	CLASSIFICATION OF THE RAIL NETWORK
Voie d'évitement, embranchement ou voie de triage	Siding, spur or yard track
Gare de triage	Marshalling yard
Centre intermodal ferroviaire	Intermodal rail centre
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

2.3.3 Marine corridors

In terms of marine transportation, there is only one corridor, which is obviously the St. Lawrence River route (Figure 2.10).

Figure 2.10: Flow of dangeous goods within the CMQ by marine transportation



Source: CPCS (2014), estimations[14] made using data from Statistics Canada.

Flux maritimes chargés, déchargeé ou en transit dans le territoire de la CMQ	Marine flows (loaded, unloaded and in transit) in the CMQ
FLUX TOTAL (TONNES POUR L'ANNÉE 2011)	TOTAL FLOWS (TONNES FOR THE YEAR 2011)
Montant le fleuve St-Laurent	In-bound on the St. Lawrence

[14] Which port of Québec terminal the goods were loaded or unloaded on cannot be determined using the data from Statistics Canada. The estimates presented in Figure 2.10 assume that all the crude oil originating from international locations is unloaded at the Valero terminal in Lévis. It is also assumed that all the refined products loaded at the port of Québec and destined for other Canadian ports are loaded at the Valero terminal. According to them, all other shipments of dangerous goods are considered to be loaded/unloaded at the terminals in the Beauport sector.

Descendant le fleuve St-Laurent	Out-bound on the St. Lawrence
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Terminaux du port du Québec	Terminals of the port of Québec
Zones résidentielles	Residential areas
Structures de tailles importantes	Large structures
Kilomètres	Kilometres

Analysis of the data from Statistics Canada revealed that 16.2 million tonnes of dangerous goods were transshipped at the port of Québec in 2011. A significant proportion of this was flammable liquids, as at least 12.4 million tonnes were unloaded. This amount is *at least* 12.4 million tonnes because the categorization of domestic flows (as opposed to international flows) does not allow flammable liquids to be distinguished from the other dangerous goods in the category "Fuels and basic chemicals." In light of Valero's activities in Saint-Romuald, it is nonetheless clear that a significant portion of the 2.76 million tonnes of fuels and basic chemicals shipped in domestic trade at the port of Québec are made up of flammable liquids. Finally, it should be recalled that the situation has changed significantly since 2011 and that it is at risk of changing further in the medium term.[15]

In the case of goods in transit on the river, gases (Class 2) consist mainly of acyclic hydrocarbons (30,500 tonnes).[16] Gasoline represents 53% (4.46 million tonnes) of the flammable liquids in transit. Flammable solids consist mainly of charcoal and anthracite (1 million tonnes). Corrosives consist mainly of oxides and hydroxides (1.37 million tonnes). Finally, the 1.3 million tonnes in the miscellaneous class of products (9) likely consist of petroleum products. As the data from Statistics Canada on domestic flows groups petroleum products under the nomenclature "Fuels and basic chemicals," it is impossible to determine exactly which types of products are in question.

In conclusion, the volumes of dangerous goods generated by supplies and marine distribution from the Jean-Gaulin refinery represent 45% of the total flows loaded, unloaded and in transit by marine transportation within the territory of the CMQ. Like rail transportation, this proportion is highly variable over time and may be called upon to change in the future.

2.3.4 Pipelines

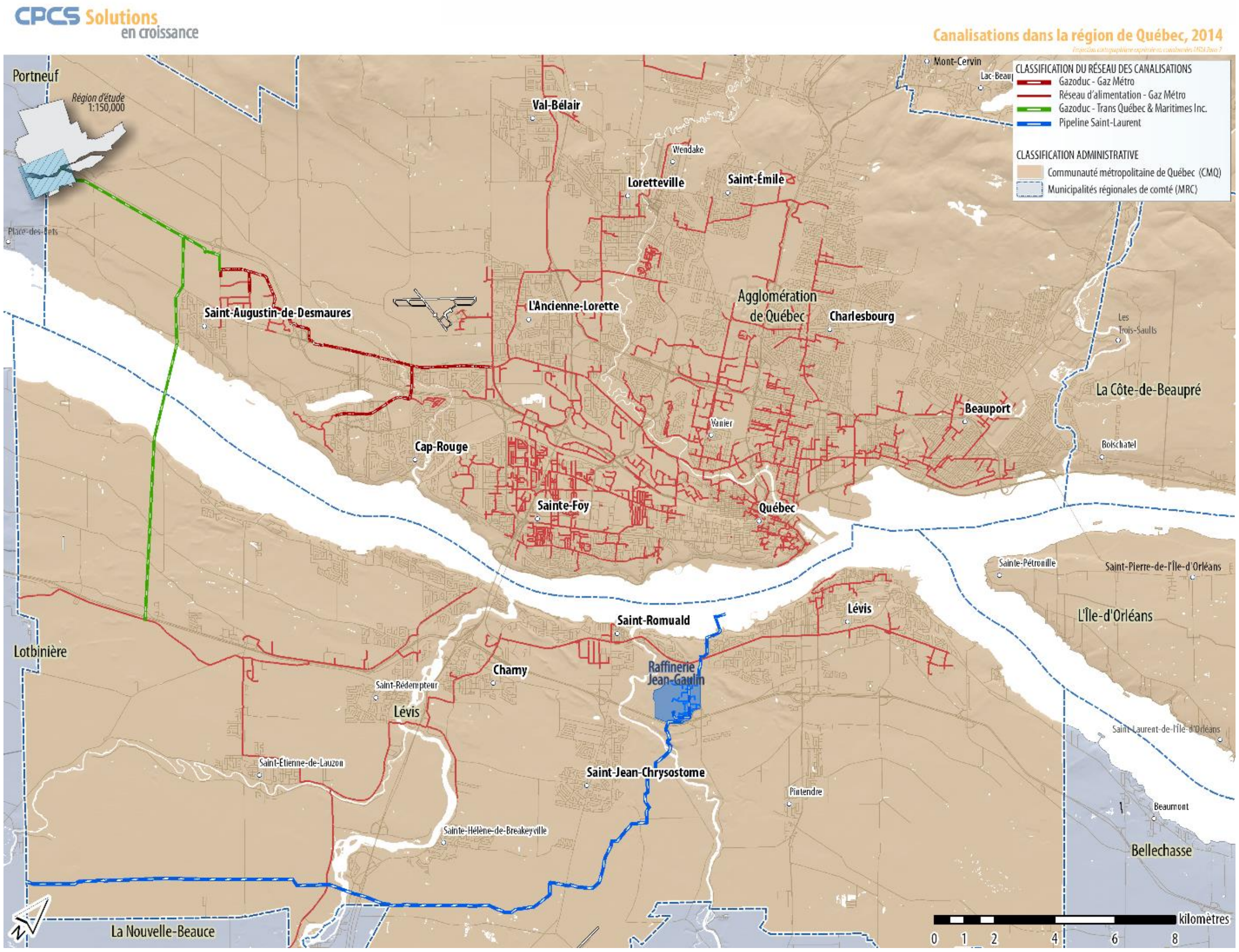
For pipelines transporting dangerous goods, there are two principal networks in the CMQ (Figure 2-11). In terms of gas pipelines, the first network, the TQM, transports the gasoline arriving from western Canada to the Gaz Métro distribution network. This is an average flow of 37,500 m^3/hour during the summer period, whereas in the winter, this volume increases to 90,000 m^3/hour. As for flammable liquids, these are essentially flows leaving from the Jean-Gaulin refinery which are sent on to the consumer markets. The quantity of the flows varies

[15] On this subject, see section 2.2.3.

[16] Acyclic hydrocarbons are organic compounds made up of carbon and hydrogen. Some examples of these are methane, ethane, propane and butane.

depending on the time of year and the type of product sent, but currently this pipeline transports between 90,000 and 100,000 barrels of refined goods per day.

Figure 2-11: Gas pipelines and pipelines in the territory of the CMQ



Source: CPCS (2014), based on data from the CMQ.

Canalisations dans la région de Québec, 2014	Pipelines in the Québec region, 2014
CLASSIFICATION DU RÉSEAU DES CANALISATIONS	CLASSIFICATION OF THE PIPELINE NETWORK
Gazoduc - Gaz Métro	Gas pipeline - Gaz Métro
Réseau d'alimentation - Gaz Métro	Supply network - Gaz Métro
Gazoduc – Trans Québec & Maritimes Inc.	Gas pipeline - Trans Quebec & Maritimes Inc.
Pipeline Saint-Laurent	Pipeline Saint-Laurent
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

2.4 Conclusions about transportation flows

According to the National Roadside Survey (NRS) on Trucking, 2006-2007, as well as consultations, 4.5 million tonnes are transported annually on the road network of the CMQ. These flows consist primarily of flammable liquids, a significant portion of these originating from the Jean-Gaulin refinery in Saint-Romuald.

Despite the undeniable value of the NRS, it is important to recognize that due to the lack of information about local flows in this database, it underestimates the real quantities of dangerous goods transported in the CMQ. Consultations revealed that the missing flows essentially constitute the distribution flows of various fuels to businesses, industries and residences in the territory. However, the carriers and distributers consulted indicated that they were not in a position to provide data on their distribution flows. For some, this would involve a colossal amount of work and complex extractions from their information systems. In the case of producers of dangerous goods, sales often take place at the source, and distributers who come looking for the products are not required to divulge where the products will be distributed, whether it be in the CMQ or elsewhere. As such, the producers do not have part of the specific information on the flows.

As for rail transportation, at least 3.35 million tonnes were transported in the CMQ in 2012. It consisted primarily of gases and flammable liquids. Of the three rail companies present in the CMQ,[17] only one participated in the study, and it does not transport dangerous goods on its network. The other two did not follow up on requests for a meeting, and as such, it was not possible to quantify their flows precisely.

The goods in transit by boat in the CMQ increased to 14.4 million tonnes in 2011. In addition to this amount, 16.2 million tonnes were loaded or unloaded at the port facilities in the territory. These flows are largely dominated by flammable liquids. In 2013, Statistics Canada stopped producing data on the marine transportation of goods, and the data from 2011 is the last edition. Unless this task is taken up by another government authority, there is no evidence that it will be possible to quantify the flows of dangerous goods in transit on the St. Lawrence River in the CMQ from now on. The flows loaded and unloaded in the CMQ can only be quantified using the data from the Québec Port Authority. However, for commercial sensitivity and security reasons, certain details must be kept confidential.

In the summer, an average of 37,500 m^3/hour of natural gas is distributed in/across the CMQ. In the winter, this volume increases to 90,000 m^3/hour. As for petroleum products, the Valero refinery sends out 90,000 to 100,000 barrels of refined products per day via the Pipeline Saint-Laurent. The products transported are composed of gasoline, diesel, domestic fuel oil and jet fuel.

[17] Excluding Canadian Pacific, which only uses certain lines surrounding its Allenby terminal.

In short, there is little modal data that allows the flows of dangerous goods in the CMQ to be quantified and qualified. Nevertheless, it is important to remember that the data used here provides as much detail as possible. In principle and without accessing private and/or confidential data, the limits of the data used herein are based on the details available.

Unless the higher levels of government implement measures requiring companies to systematically transmit data on their flows of dangerous goods following a determined structure, there is nothing to indicate that it will one day be possible to accurately quantify the dangerous goods circulating the transportation networks. According to several factors, it appears that such an enterprise would be difficult to carry out. It is understood that the confidentiality of the data is among the main factors, as well as security issues, and, above all, a lack of resources to carry out such tasks within the organizations, and the fact that the businesses' information systems may not have the features to efficiently produce the required information. Furthermore, if such a database existed, there is no indication that the information it contains could be disseminated for the purposes of research or analysis. The authority responsible for the database should have all of the human and material resources to produce analyses which inform the municipalities in accordance with their needs, all while maintaining the confidentiality of certain manufacturers.

Finally, in accordance with the regulations in place, all of the stakeholders consulted insisted on the fact that they had emergency response plans and that their staff were trained for such events. According to the information collected, carriers systematically avoid rush hours and areas of congestion. Some respondents who use or distribute dangerous goods added that they worked closely and transparently with the first responders concerned by the transportation of dangerous goods. As such, the goal of quantifying the flows of goods for the present work was considered by some to be superfluous because the stakeholders who need to know such information are aware of these flows.

3 Risk Analysis

Key message

The data on accidents is not the same for all modes of transportation, which makes comparing them difficult. However, according to the analysis performed, it is possible to determine that risk to the entire CMQ transportation network is low to medium.

3.1 Accidentology in the CMQ

3.1.1 Indicators of road accidents

The factors contributing to accidents related to road transportation are numerous, but in general, it is important to remember that accidents are rarely caused by one single factor, but rather by several interacting elements. For example, the combination of alcohol and speed is very dangerous and risky, and Transports Québec indicates that they are the two main causes of accidents. Transports Québec also indicates that human behaviour is the cause of 80% of accidents. Furthermore, weather, road conditions, road configuration and transportation equipment can also be contributing factors. Tankers can also pose specific risks due to the movement of the liquids inside the containers, which can have an impact on vehicle stability.

The risk assessment logic model used for road transportation relied on the use of accident rates on road sections and intersections in the CMQ making up part of the MTQ network and excluding municipal networks. The indicator selected to determine which sites on the CMQ road network were most likely to result in an accident was the ratio of the accident rate divided by the critical accident rate determined for similar road sections (AR/CR).

3.1.2 Indicators of rail accidents

The following risk factors (Figure 3-1) were identified as being elements likely to contribute to the risk of rail accidents. Each factor is illustrated on the level of the CMQ in the following maps. These factors are in addition to others, such as the regulatory framework, the human factor and the condition of rail lines.

Figure 3-1: Factors contributing to dangerous goods accidents on rail lines

Factor	Description
Signaling	Accidents caused by broken rails, which are the most common type of accident, less likely to be detected on nonsignaled tracks (tracks that do not have block or interlocking signals to control movements).[18] In fact, "the proportion of car derailments caused by broken rails in signaled track territory is 50% lower than that in nonsignaled track territory."[19]
Speed	Barkan *et al.* indicated that there is a linear relationship between the speed of derailments and the number of cars derailed, as well as with the likelihood of dangerous goods being spilled.[20]
Marshalling yard	The presence of a marshalling yard can increase the level of risk, as cars are frequently displaced, attached and detached.
Volume of dangerous goods	During an accident, the volume of dangerous goods in transit has an impact on the likelihood of an accident involving dangerous goods occurring. In principle, if no dangerous goods were transported by rail, there would be no risk of dangerous goods accidents. However, the volumes of dangerous goods are not considered when determining the risk on rail lines, as they do not influence the risk of an accident occurring, but they do play a role in the severity of the accident.

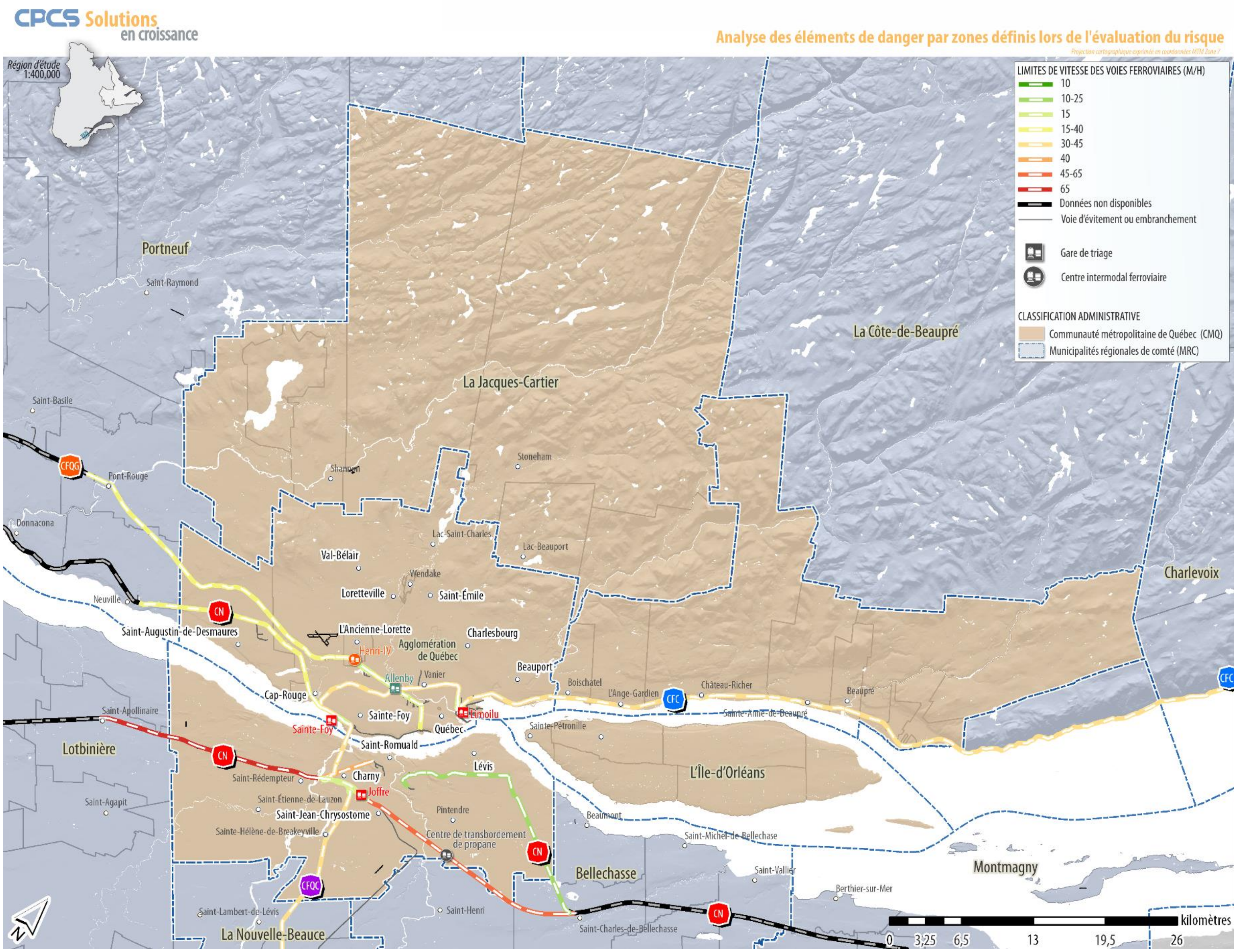
Source: CPCS

[18] Liu, X., M.R. Saat and C.P.L. Barkan. 2013. Analysis of Major Derailment Causes on Heavy Haul Railways in the United States. In: *Proceedings of the 10th International Heavy Haul Association Conference*, New Delhi, India, February 2013.

[19] Liu, X., M.R. Saat and C.P.L. Barkan. 2013. Safety Effectiveness of Integrated Risk Reduction Strategies for Rail Transport of Hazardous Materials. Transportation Research Record: *Journal of the Transportation Research Board. 2374: 102-110.*

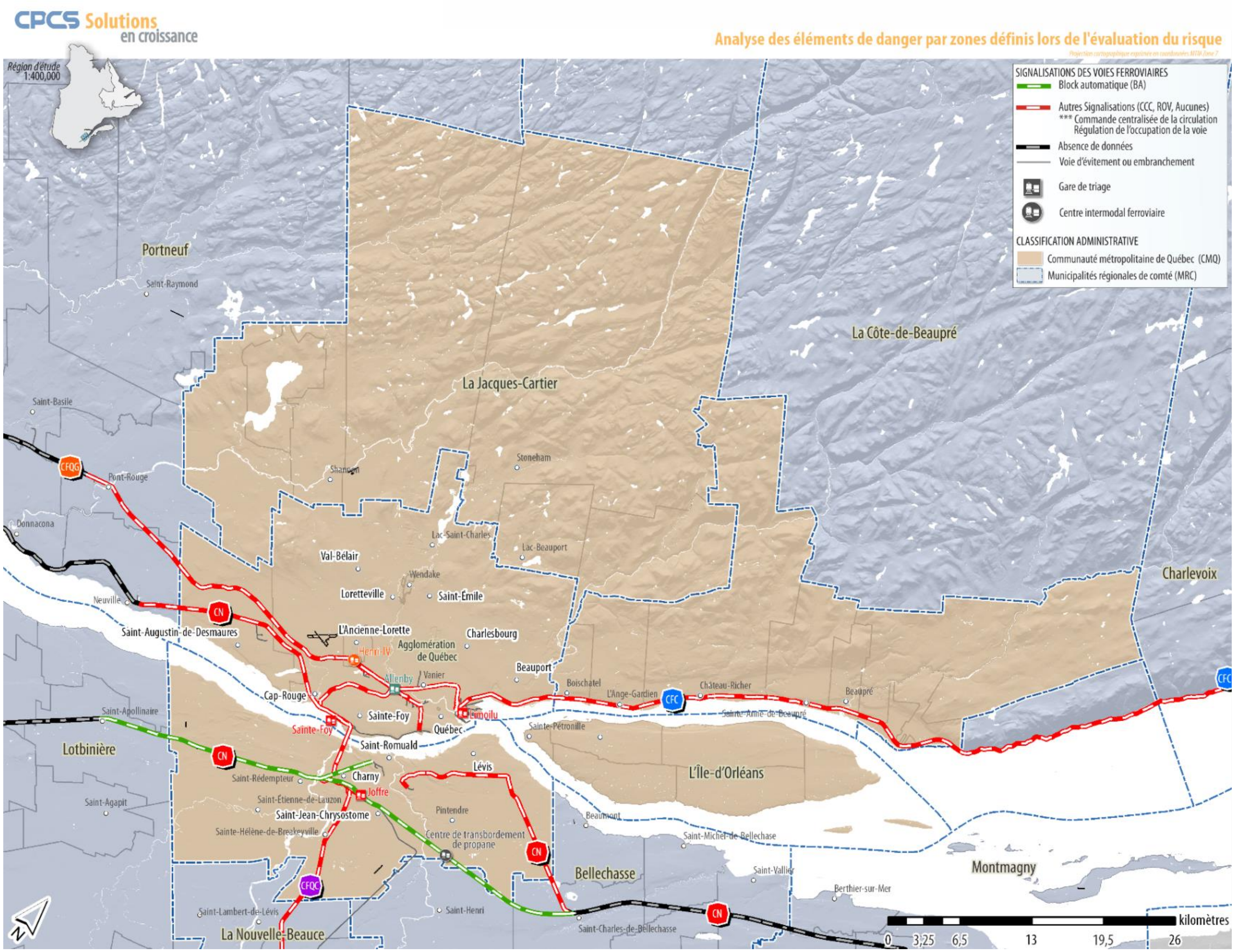
[20] Barkan, C.P.L., C.T. Dick and R. Anderson. 2003. Railroad derailment factors affecting hazardous materials transportation risk. *Transportation Research Record: Journal of the Transportation Research Board.* 1825: 64-74.

Figure 3-2: Speed limits on rail lines in the CMQ



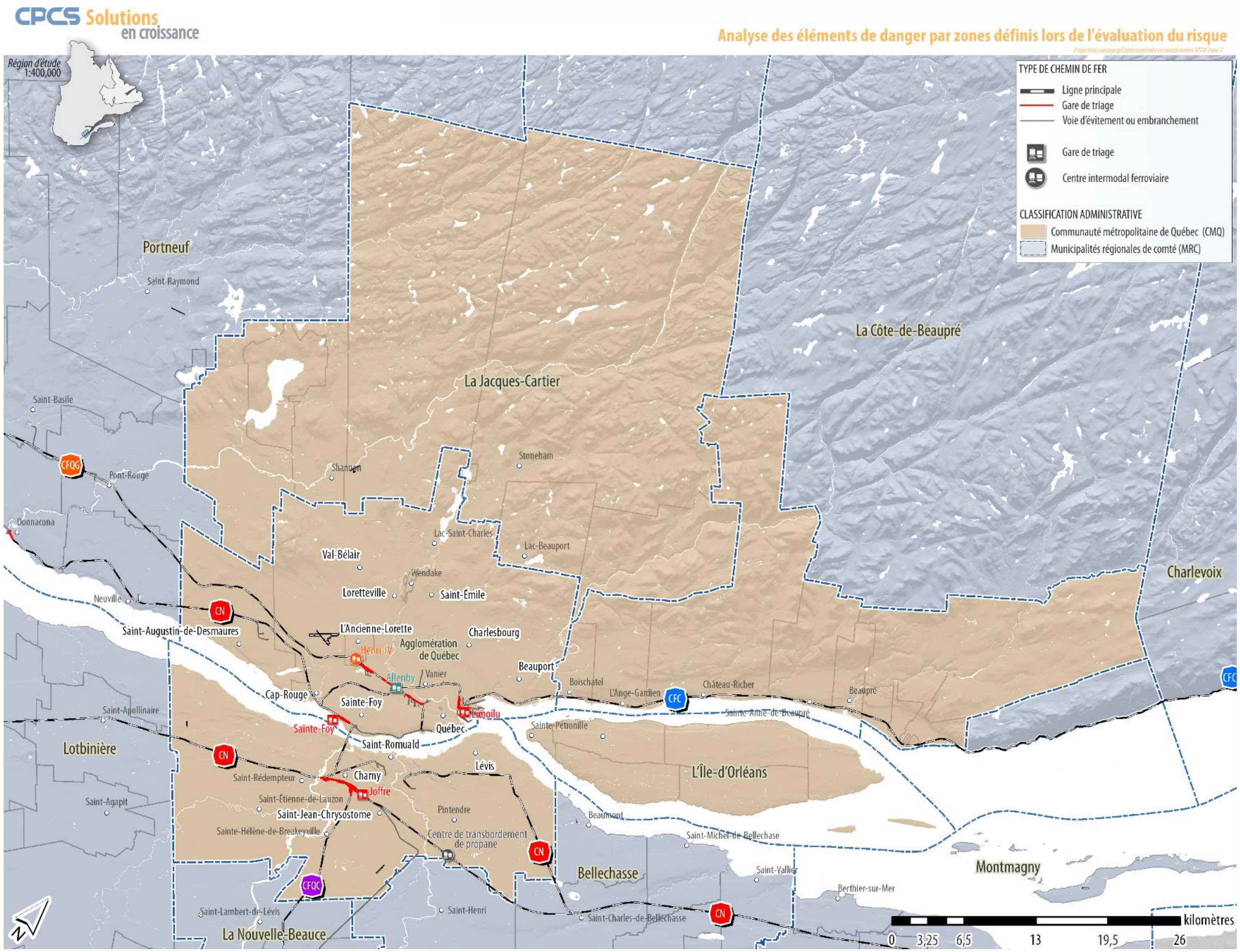
Analyse des éléments de danger par zones définis lors de l'évaluation du risque	Analysis of hazards by areas defined during the risk assessment
LIMITES DE VITESSE DES VOIES FERROVIAIRES (M/H)	SPEED LIMITS ON RAIL LINES (M/H)
Données non disponibles	Data not available
Voie d'évitement, embranchement ou voie de triage	Siding, spur or yard track
Gare de triage	Marshalling yard
Centre intermodal ferroviaire	Intermodal rail centre
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

Figure 3-3: Presence of signaling on rail lines in the CMQ


CPCS Solutions en croissance
Analyse des éléments de danger par zones définis lors de l'évaluation du risque
Région d'étude 1:400,000
SIGNALISATIONS DES VOIES FERROVIAIRES
Block automatique (BA)
Autres Signalisations (CCC, ROV, Aucunes)
*** Commande centralisée de la circulation
Régulation de l'occupation de la voie
Absence de données
Voie d'évitement ou embranchement
Gare de triage
Centre intermodal ferroviaire
CLASSIFICATION ADMINISTRATIVE
Communauté métropolitaine de Québec (CMQ)
Municipalités régionales de comté (MRC)
Portneuf
La Jacques-Cartier
La Côte-de-Beaupré
Charlevoix
Lotbinière
L'Île-d'Orléans
Bellechasse
Montmagny
La Nouvelle-Beauce
Agglomération de Québec
kilomètres
0 3,25 6,5 13 19,5 26

Analyse des éléments de danger par zones définis lors de l'évaluation du risque	Analysis of hazards by areas defined during the risk assessment
SIGNALISATIONS DES VOIES FERROVIAIRES	RAIL LINE SIGNALING
Block automatique (BA)	Automatic block (AB)
Autre Signalisations (CCC, ROV, Aucunes) ***Commande centralisé de la circulation Régulation de l'occupation de la voie	Other signaling (CTC, OCS, None) ***Centralized Traffic Control System Occupancy Control System (OCS)
Absence de données	No data
Voie d'évitement ou embranchement	Siding or spur
Gare de triage	Marshalling yard
Centre intermodal ferroviaire	Intermodal rail centre
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

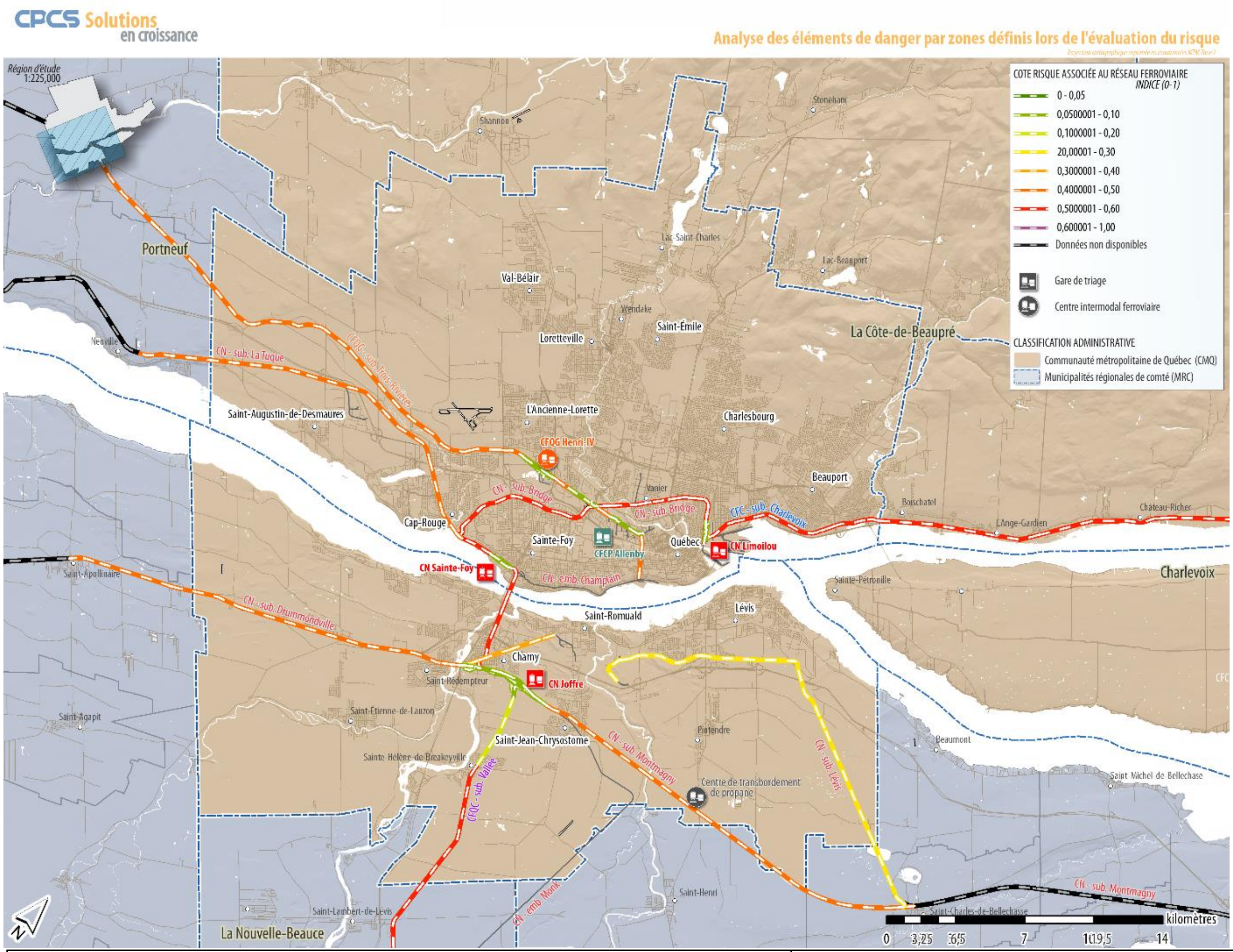
Figure 3-4: Railway marshalling yards in the CMQ


CPCS Solutions en croissance
Analyse des éléments de danger par zones définis lors de l'évaluation du risque
Région d'étude 1:400,000
TYPE DE CHEMIN DE FER
Ligne principale
Gare de triage
Voie d'évitement ou embranchement
Gare de triage
Centre intermodal ferroviaire
CLASSIFICATION ADMINISTRATIVE
Communauté métropolitaine de Québec (CMQ)
Municipalités régionales de comté (MRC)
Portneuf
Saint-Raymond
La Jacques-Cartier
La Côte-de-Beaupré
Charlevoix
Lotbinière
L'Île-d'Orléans
Bellechasse
Montmagny
La Nouvelle-Beauce
Agglomération de Québec
Québec
Lévis
Sainte-Foy
Cap-Rouge
Charlesbourg
Beauport
Val-Bélair
Loretteville
Saint-Émile
L'Ancienne-Lorette
Saint-Augustin-de-Desmaures
Stoneham
Lac-Beauport
Lac-Saint-Charles
Wendake
Shannon
Saint-Romuald
Charny
Joffre
Henri-IV
Allenby
Limoilou
Vanier
Saint-Rédempteur
Saint-Étienne-de-Lauzon
Saint-Jean-Chrysostome
Sainte-Hélène-de-Breakeyville
Pintendre
Centre de transbordement de propane
Saint-Henri
Saint-Lambert-de-Lévis
Saint-Charles-de-Bellechasse
Saint-Michel-de-Bellechasse
Saint-Vallier
Berthier-sur-Mer
Beaumont
Sainte-Pétronille
Boischatel
L'Ange-Gardien
Château-Richer
Sainte-Anne-de-Beaupré
Beaupré
Saint-Basile
Pont-Rouge
Donnacona
Neuville
Saint-Apollinaire
Saint-Agapit
CN
CFC
CFQC
kilomètres
0 3,25 6,5 13 19,5 26

Analyse des éléments de danger par zones définis lors de l'évaluation du risque	Analysis of hazards by areas defined during the risk asses
TYPE DE CHEMIN DE FER	TYPE OF RAIL LINE
Ligne principale	Main line
Gare de triage	Marshalling yard
Voie d'évitement ou embranchement	Siding or spur
Gare de triage	Marshalling yard
Centre intermodal ferroviaire	Intermodal rail centre
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

Based on these factors, an analysis matrix was developed in order to characterize the CMQ rail network, and the results are illustrated in the following map. While little data are available about the volumes of dangerous goods transported on the Quebec-Gatineau Railway (QGR) and the Charlevoix Railway (CR), these networks are considered to present a low level of risk, similar to that observed for the CN's La Tuque subdivision. In the case of the Central Quebec Railway, the consultations completed as part of the present mandate revealed that no dangerous goods are being moved on this network.

Figure 3-5: Risk estimation in the rail lines in the CMQ



Analyse des éléments de danger par zones définis lors de l'évaluation du risque	Analysis of hazards by areas defined during the risk asses
COTE RISQUE ASSOCIÉE AU RÉSEAU FERROVIAIRE Indice (0-1)	RISK SCORE ASSOCIATED WITH THE RAIL NETWORK (Index (0-1)
Données non disponibles	Data not available
Gare de triage	Marshalling yard
Centre intermodal ferroviaire	Intermodal rail centre
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

3.1.3 Indicators of marine accidents

The methodology selected to identify the areas at the most risk in the CMQ was based on elements that could be mapped, using the contributions of a master mariner with a knowledge of the sector being studied and his analysis of the navigational charts. By analyzing various navigation situations, three categories of elements associated with hazards were determined.

The first category, related to the navigable waterway, includes the following elements:

- The available depth
- The width of the canal
- The sinuosity
- The nature of the river bottom
- The presence of obstacles
- The presence of a navigational aid

The second category groups together environmental elements:

- The tides
- The currents
- The effect of the wind
- The presence of ice

The last category is considered to respond to the specific aspects of the area covered. Those discovered were:

- The traffic density
- The ferries
- The visual cues

The CMQ includes a waterway that presents different configurations, and that can also be divided into zones as certain major elements were discovered. This grouping, which was based on particular characteristics, allowed them to be grouped into 7 zones. They are as follows:

1. Downstream from the North Traverse

   Consists of the beginning of the North Traverse to the eastern extremity of the territory of the CMQ. (East of longitude 070°44” W)

2. The North Traverse

   Consists of the dredged area of the waterway. (Long. 070°44” to 070°52” W)

3. St-Pétronille sector

   The zone extending from the end of the North Traverse to the port of Québec (Long. 070°52” to 071°08” W)

4. Port of Québec

   The zone consisting of the port of Québec (Long. 071°08” W to 071°14” W)

5. Marina des Foulons to Anderson Headland

   The zone extending from the end of the port to the inlet near the Quebec Bridge (Long. 071°14" W to 071°16'5" W)

6. Anderson Headland to Pointe-à-Basile

   The confined area including the passage under the Quebec Bridge (Long. 071°16'5" W to 071°20" W)

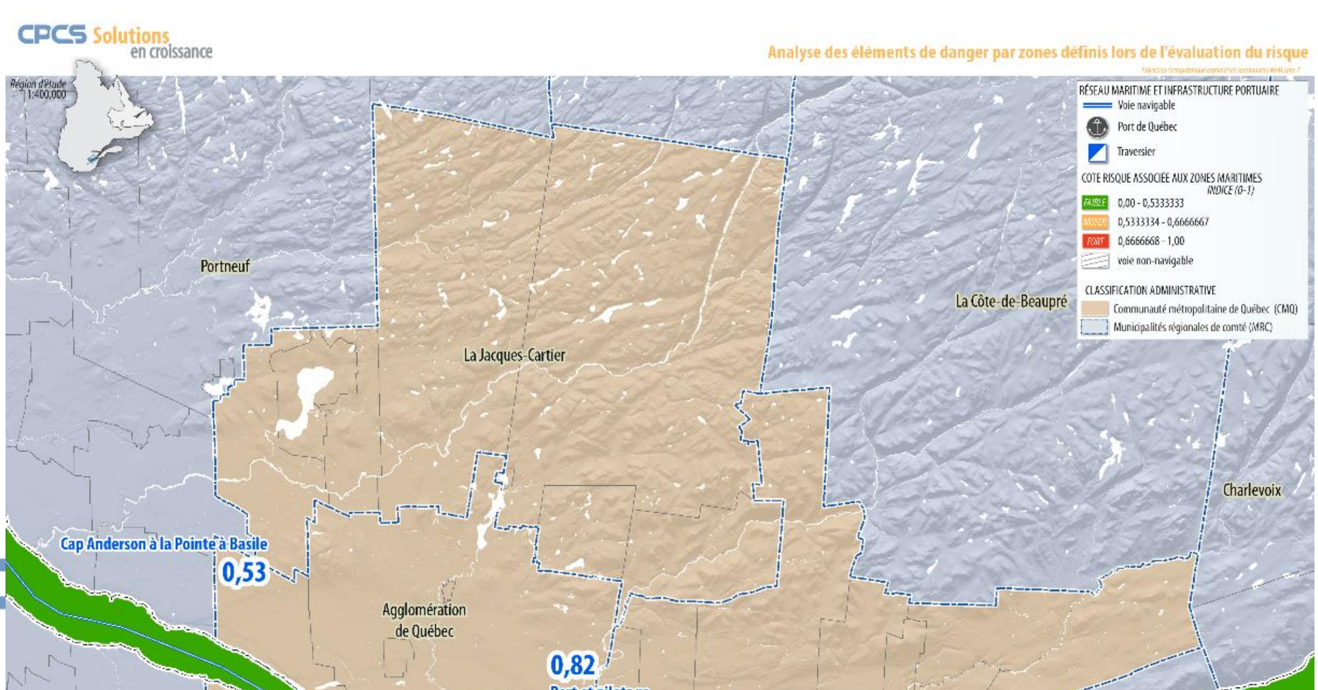
7. Downstream from Pointe-à-Basile

   The zone extending from Cap-Rouge to the western extremity of the territory of the CMQ (West of long. 071°20 » W)

For each of these zones, the risk elements were weighted with a score corresponding to a low, medium or high level. Then, based on the type of gap found, it was possible to designate each zone with a rating to create the following figure:

Figure 3-6: Marine risk assessment for the CMQ

Analyse des éléments de danger par zones définis lors de l'évaluation du risque	Analysis of hazards by areas defined during the risk assessment
RÉSEAU MARITIME ET INFRASTRUCTURE PORTUAIRE	MARINE NETWORK AND PORT FACILITIES
Voie navigable	Navigable waterway
Port de Québec	Port of Québec
Traversier	Ferry
COTE RISQUE ASSOCIÉE AUX ZONES MARITIMES INDICE (0-1)	RISK SCORE ASSOCIATED WITH THE MARINE ZONES INDEX (0-1)
FAIBLE	LOW
MOYEN	MEDIUM
FORT	HIGH
Voie non-navigable	Non-navigable
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres



3.1.4 Indicators of pipeline accidents

When designing structures, design engineers have always taken into consideration the level of risk related to the pipeline route by respecting construction standards and distancing the structures based on the population density and the type of land use that the pipeline crosses through. The recommended approach here is synthetic, based on a commonly used methodology that uses a risk management matrix that allows potential high-risk zones to be identified.

This matrix was developed based on a Bayesian probabilistic approach. Figure 3-7 schematically illustrates the key stages of the risk analysis. The first step consists of associating a "Likelihood classification system" for the occurrence of a previously identified potentially harmful event. This system includes the objective likelihood of occurrence of the event as HIGH, MEDIUM or LOW associated with an indexing factor (which is suggested here as being a level 3 geometric thinking series, beginning at 1). Secondly, a "Severity classification system" needed to be identified with a HIGH, MEDIUM or LOW level associated with the same indexing factor as used previously. As such, the procedure described is repeated for all of the factors which have a potentially significant impact.

Figure 3-7: The rules for the likelihood and severity classification systems

1	**Likelihood classification system associated with the occurrence of the event**		
	Likelihood	**Analysis criterion**	**Index No.**
	HIGH	Experience has shown that the event will certainly occur sooner or later	9
	MEDIUM	The event will probably occur	3
	LOW	It is unlikely or highly unlikely that the event will take place	1
2	**Severity classification system associated with the impact or consequences of the event**		
	Impact	**Description**	
		SOCIAL IMPACT	
	SEVERE	Leads to fatalities or serious injuries	9
	MEDIUM	Damages social fabric, but with no fatalities	3
	LOW	Results in temporary displacement of several households	1
		ENVIRONMENTAL IMPACT	
	SEVERE	Permanent and irreversible damage to the ecosystem	9
	MEDIUM	Reversible damage causing medium term aftereffects	3
	LOW	Damage which can be quickly corrected with no aftereffects	1
		FINANCIAL IMPACT	
	SEVERE	Over 100 million dollars	9
	MEDIUM	Between 1 and 100 million dollars	3
	LOW	Below 1 million dollars	1

Source: Adapted from the General Electric model

The second step consists of calculating the level of risk associated with each damaging event defined as being the product of the likelihood index by the severity index of the impact or the consequences of the occurrence of the event. Therefore, if the likelihood is medium (Index=3) and the social impact is low (Index=1) the level of risk = (3*1=3).

The third step consists of classifying the level of risk and defining the ensuing type of response.

The theoretical approach described above applies to assessing the level of risk associated with a pipeline or a pipeline network in order to identify, if necessary, the areas that potentially are at significant risk and to recommend actions to be taken if these events occur.

The following section proposes a method to be applied to three hydrocarbon pipeline networks in the Communauté métropolitaine de Québec, namely:

- The gas pipeline carrying high-pressure natural gas to the distribution network: A) the TQM Pipeline, steel pipeline, high pressure (7,000 ± kPa), distance covered in the territory of the CMQ is approximately 30 km and B) the Gaz Métro Pipeline, steel pipeline, intermediate pressure (2,100 ± kPa);
- The medium- and low-pressure distribution network carrying natural gas to users consists of 116 ± km of medium-pressure steel pipes and 270 ± km of low-pressure plastic pipes.

The Saint-Laurent Pipeline, a 24-inch, [BN(2]multi-product, high-pressure pipeline made of iron transporting refined liquid hydrocarbons from the St-Romuald refinery to the Montreal East storage tank and covering a distance of 30 ± km in the territory of the CMQ, mainly on agricultural land.

To estimate the likelihood of occurrence, it is recommended to refer to the statistics on the occurrence of accidents on all Canadian pipeline networks reported by the National Energy Board (NEB) and for the United States reported by the Energy Information Administration (EIA) and apply them to the networks in the CMQ (Figure 3-8 to Figure 3-11).

The occurrences are listed under the 5 following categories of risks:

- Extremely low: 0.2
- Low: 0.4
- Moderate: 0.6
- High: 0.8
- Extremely high: 1.0

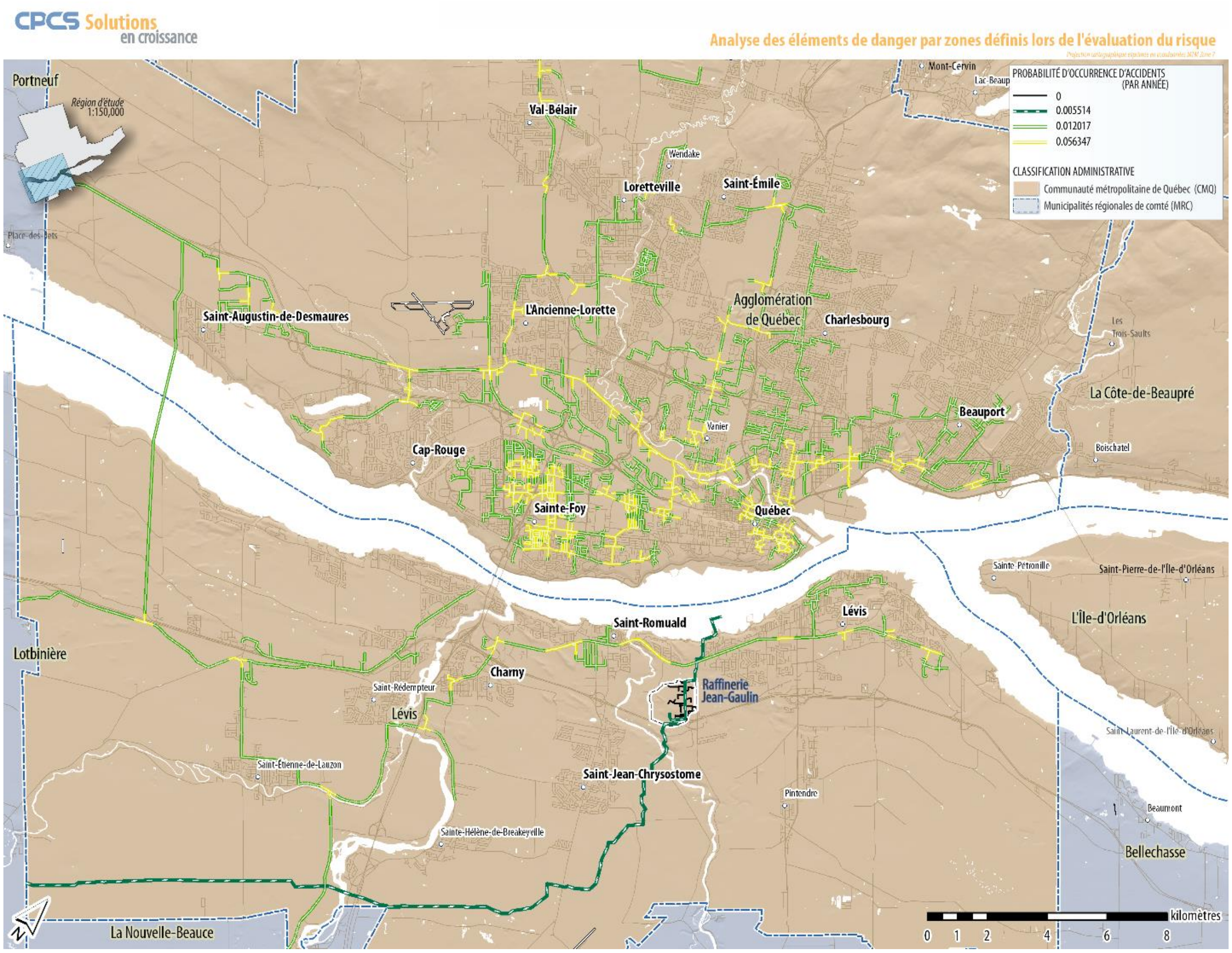
Figure 3-8: Accident occurrence statistics on Canadian pipeline networks

Canadian statistics 2013	Kilometrage	Annual accident occurrence	Frequency per km	Km CMQ	Annual occurrence CMQ	Occurrence per 100 years	Risk (0 – 1)

Liquid hydrocarbons Facilities and pipelines	19 090	3	0.000184	30	0.005514	0.551385	0.2
Natural gas Facilities and pipelines	55 972	6	0.000134	421	0.056347	5.634710	0.4
Pipelines only	75 062	2	0.000027	451	0.012017	1.201673	0.4
Entire network	75 062	11	0.000147	451	0.066092	6.609203	

Source: CPCS/Johnston-Vermette analysis

Figure 3-9: Likelihood of occurrence according to Canadian statistics



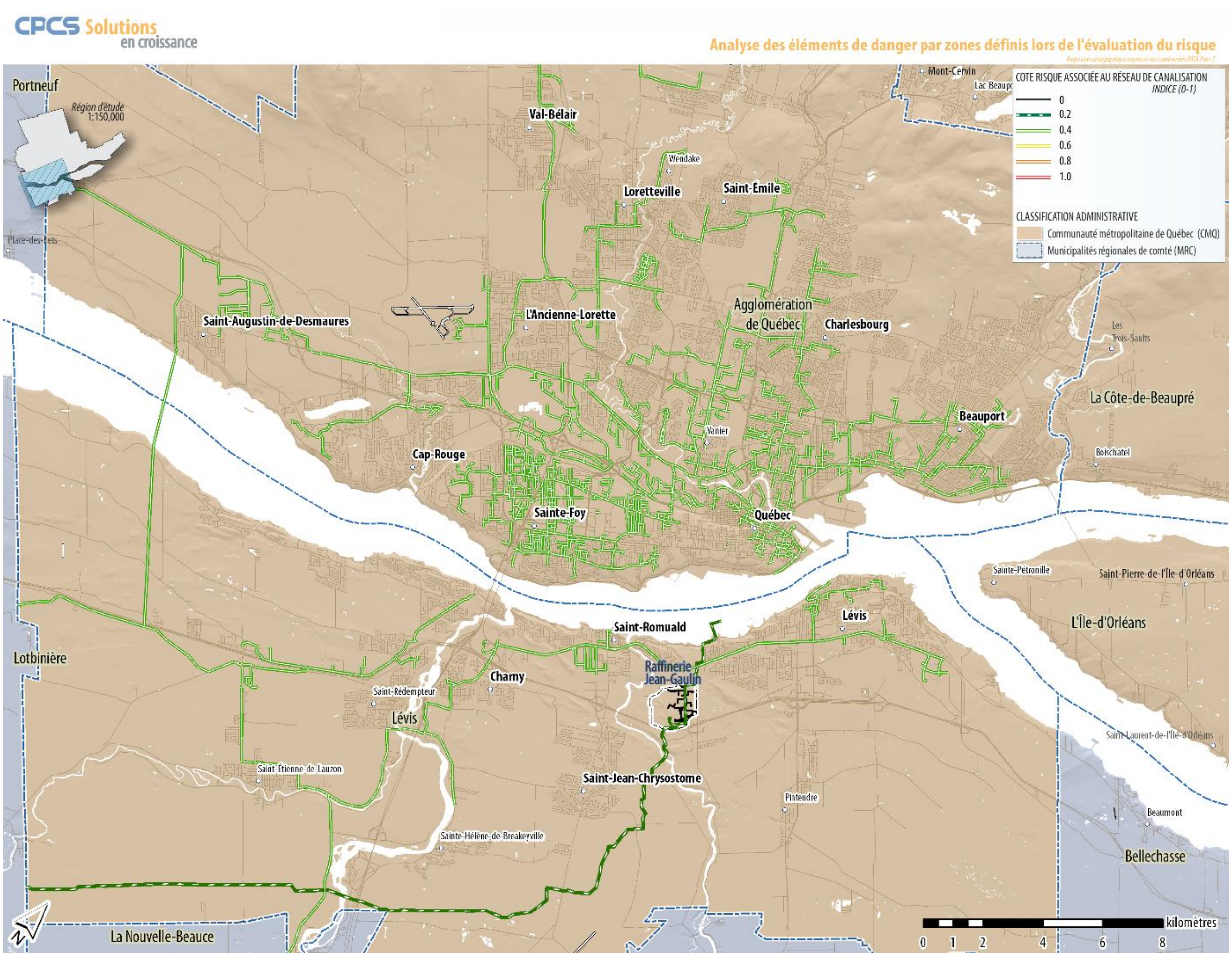
Analyse des éléments de danger par zones définis lors de l'évaluation du risque	Analysis of hazards by areas defined during the risk assessment
PROBABILITÉ D'OCCURRENCE D'ACCIDENTS (PAR ANNÉE)	LIKELIHOOD OF THE OCCURRENCE OF AN ACCIDENT (PER YEAR)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

Figure 3-10: Accident occurrence statistics on US pipeline networks

US statistics 2010-2012	Kilometrage	Annual accident occurrence	Frequency per km	Km CMQ	Annual occurrence CMQ	Occurrence per 100 years
Liquid hydrocarbons	283 333	120	0.000424	30	0.010588	1.058824
Natural gas transportation	510 102	81	0.000159	35	0.007940	0.793959
Natural gas distribution	2 000 400	54	0.000027	386	0.005399	0.539892
Subtotal natural gas	2 510 502	135	0.000054	421	0.013339	1.333851
Total network	2 793 835	255	0.000091	451	0.025100	2.509991

Source: CPCS/Johnston-Vermette analysis

Figure 3-11: Likelihood of occurrence according to US statistics



Analyse des éléments de danger par zones définis lors de l'évaluation du risque	Analysis of hazards by areas defined during the risk assessment

COTE RISQUE ASSOCIÉE AU RÉSEAU DE CANALISATION INDICE (0-1)	RISK SCORE ASSOCIATED WITH THE PIPELINE NETWORK INDEX (0-1)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Communauté métropolitaine de Québec (CMQ)	Communauté métropolitaine de Québec (CMQ)
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

The US experience is significantly different from the Canadian experience. As such, the frequency of liquid hydrocarbon pipeline accidents in Canada is 43% lower than that observed in the United States. However, the situation for natural gas is a more or less reversed, as the US experience indicates an accident frequency per kilometre, which is 40% lower than that reported in Canada. For all networks, all products considered, the US statistics indicated an overall frequency of occurrences which was 38% lower than the Canadian statistics.

Taken out of context, these differences are significant and reflect the impact of a number of parameters, which can vary according to the specific operating conditions between the two countries, despite the fact that the design and operation are similar in both cases. Nonetheless, such disparities are not significant in the context of estimating the likelihood of occurrence of damaging events. In fact, in terms of the likelihood of 2.5 or 6.6 events per century, it is a rare event that can legitimately be associated with a LOW likelihood.

Whether referring to the Canadian or US statistics, both illustrate the fact that the frequency of accidents or incidents that are statistically likely to be expected on the three components of the liquid or gaseous hydrocarbon transportation network is LOW.

In the pipeline section transporting liquid hydrocarbons coming from the Saint-Romuald refinery (but excluding the refinery itself), the frequency of occurrence is around one event per century or one event per two centuries. The statistics include pumping stations and processing centres, including the refineries. However, in the case of the CMQ, the risk analysis is based exclusively on the pipeline and not the Saint-Romuald refinery, for which the level of risk must be handled separately, and it is not considered in the present analysis. As the frequency of accidents reported in the statistics included refinery accidents, the very low rate of occurrence of events per century would be conservative. As such, we concluded that the likelihood of an incident on the Saint-Laurent Pipeline is EXTREMELY LOW.

Furthermore, for the transportation of gasoline, a total occurrence frequency between 0.79 et 1.98 represents a LOW likelihood of occurrence. The frequency of accidents on the distribution network is between 0.54 and 1.34, whether using the US or Canadian statistics, which once again indicates a LOW likelihood of occurrence.

3.1.5 Vulnerability factors

There are three factors that attempt to define the vulnerability facing the transportation of dangerous goods. These factors are used to identify vulnerable locations and classify them quantitatively based on their sensitivity in terms of dangerous goods accidents. The three vulnerability factors in the territory are formulated according to components that encompass the human, material and environmental dimensions. The steps for determining their qualitative vulnerability are completed using decision-making aids in a geographic information system (GIS).

3.1.6 Evaluation logic model

The goal of the modelling is to prioritize targets according to their sensitivity. This method was developed in a GIS, which is very well adapted to model the sensitivity of vulnerable locations. To do this, each component within a determining factor is prioritized separately and then included in a formula, which is used to create a unique indicator for each factor.

From the point of view of risks, the definition of vulnerability integrates the vulnerable zones and their sensitivity to danger. Each vulnerable zone is selected and classified according to its sensitivity following the criteria developed by Griot (2007)[21] and according to the availability of similar data for the CMQ. The following figure presents the three categories and criteria selected.

Figure 3-12: Vulnerability criteria and categories

Human	Material	Environmental
Place of residence	Water infrastructures	Agricultural areas
Place of employment	Industrial areas and commercial areas without housing and material extraction areas	Forests
Public service and educational institution areas	High voltage lines, rail, road infrastructures	Swamps or wetlands
Land use areas	Port and airport areas	Other natural spaces
		Water

Source: CPCS, from Griot (2007)

Each area is defined according to a relative sensitivity to an accident involving dangerous goods. The three categories are expressed according to different units, all have equal weight in the logic model.

Using the GIS, the land use is applied to the sensitivity indicator for each criterion belonging to a specific category. Namely: the number of human lives, the value of the physical goods, and

[21] Griot, C., 2007, Des territoires vulnérables face à un risque majeur : le transport de matières dangereuses. Proposition d'un outil d'aide à la gestion de crise, *Géocarrefour*; vol. 82/1-2, p. 51-63.

the nature of the space concerned by a potential accident. The GIS allows the data to be overlapped and the results allow an overall vulnerability map to be created.

Human dimension

The human areas are classified according to population density. One definite classification is applied using the population density for each block/dissemination area (density of the number of inhabitants per hectare according to the demographics of the 2011 census).[22]

In terms of the public service and health network facilities and educational institutions, the health network and social services facilities that offer housing services are more vulnerable than the facilities that have set weekly hours. For educational institutions, the number of students for the 2011 year is categorized according to a scale similar to the place of employment and place of residence.

The last criterion of the human dimension considers the fact that certain land uses have a tendency to attract the public. This principle is applied to an assessment grid to determine the sensitivity vis-à-vis this attraction.

Material dimension

The second category is related to physical goods according to dissemination block. Of course, each space has a monetary value, to which a financial sensitivity in the event of an accident involving dangerous goods can be attributed. This criterion is set based on the value of the buildings and the grounds. It is important to note that a particular accident could obviously only damage part of a building, but the degree of sensitivity is best estimated by the total cost.

Environmental dimension

The environmental category is formulated according to criteria for which the measure does not allow the impacts, should an accident occur, to be directly quantified. In particular, this issue arises when it is a question of establishing relations between accidents and the environmental criteria. To the extent that the environmental sensitivity (from an anthropogenic perspective) relies on the interaction between humans and their surroundings, the criteria used to define the environmental category are based on the sensitivity of the lithosphere, biosphere and the hydrosphere.

3.1.7 Logic model outcomes

By adding the vulnerabilities in each of these categories, the overall vulnerability indicator is generated (Figure 3-14 and

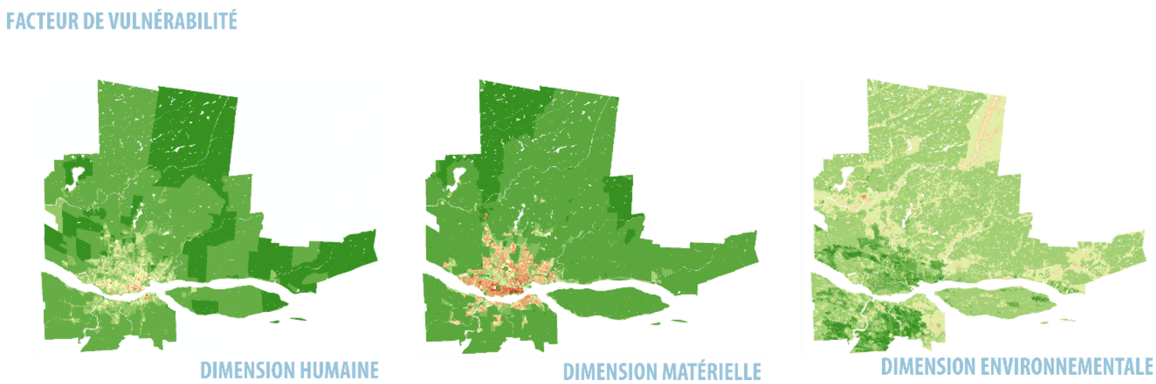
Indicateur de vulnérabilités globales	Overall vulnerability indicator

[22] Statistics Canada, 2011 Census of Population, product No. 98-311-XCB2011026. Gross residential density of the population of dissemination areas in the Communauté métropolitaine de Québec.

PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR DE VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M² DE RÉSOLUTION	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M² OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

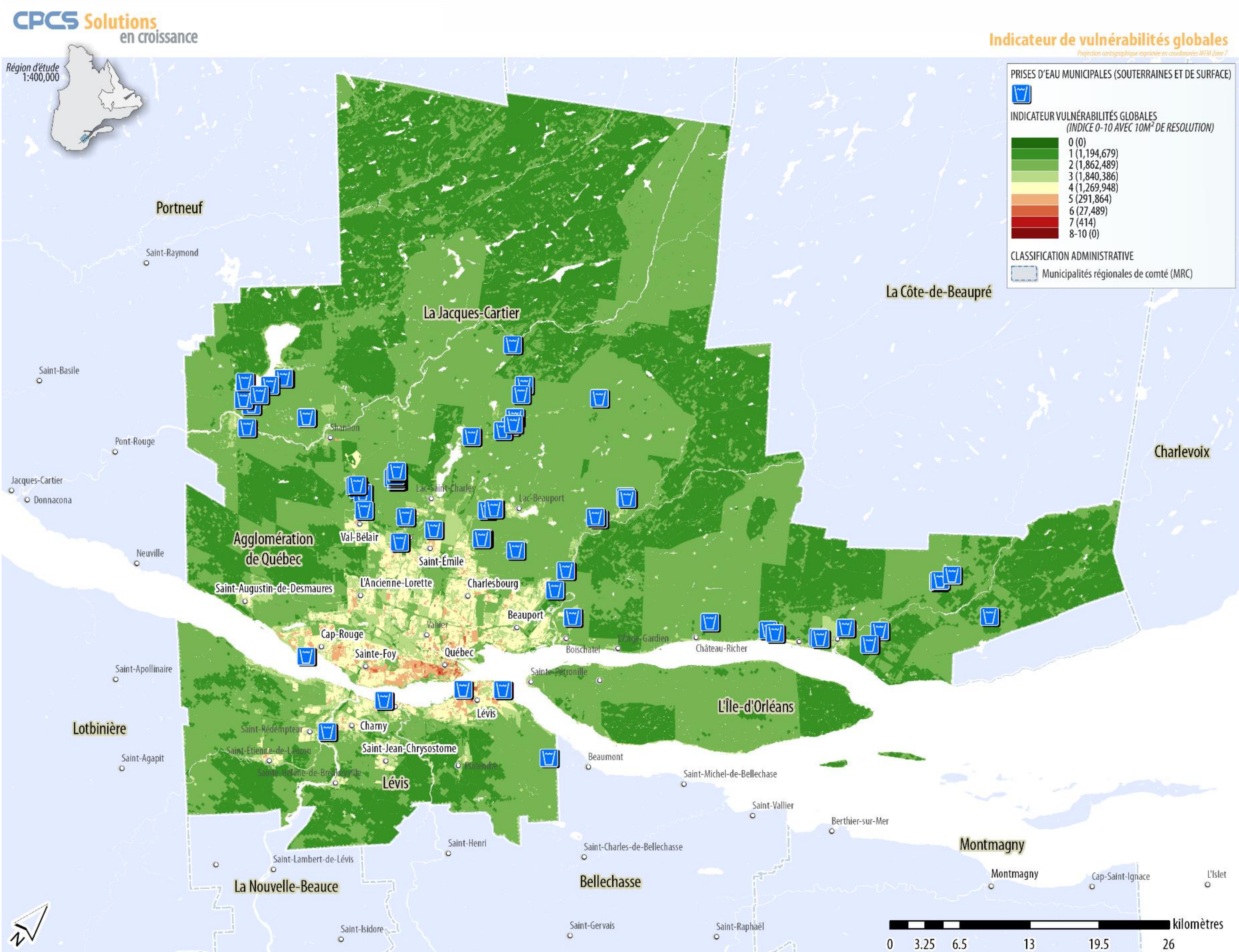
Figure 3-15), the various components of which are presented in Figure 3-13. The procedure is put back into the GIS and is illustrated in the figures on the following pages. The distances between the vulnerable areas and the accident risks attributed to the transportation networks determine the vulnerability of those areas in terms of the transportation of dangerous goods. When analyzing the consequences, the distance between the locations where the accident scenario takes place determines the magnitude of the consequences on these vulnerabilities.

Figure 3-13: Summary of results from the logic model



FACTEUR DE VULNÉRABILITÉ	VULNERABILITY FACTOR
DIMENSION HUMAINE	HUMAN DIMENSION
DIMENSION MATÉRIELLE	MATERIAL DIMENSION
DIMENSION ENVIRONNEMENTALE	ENVIRONMENTAL DIMENSION

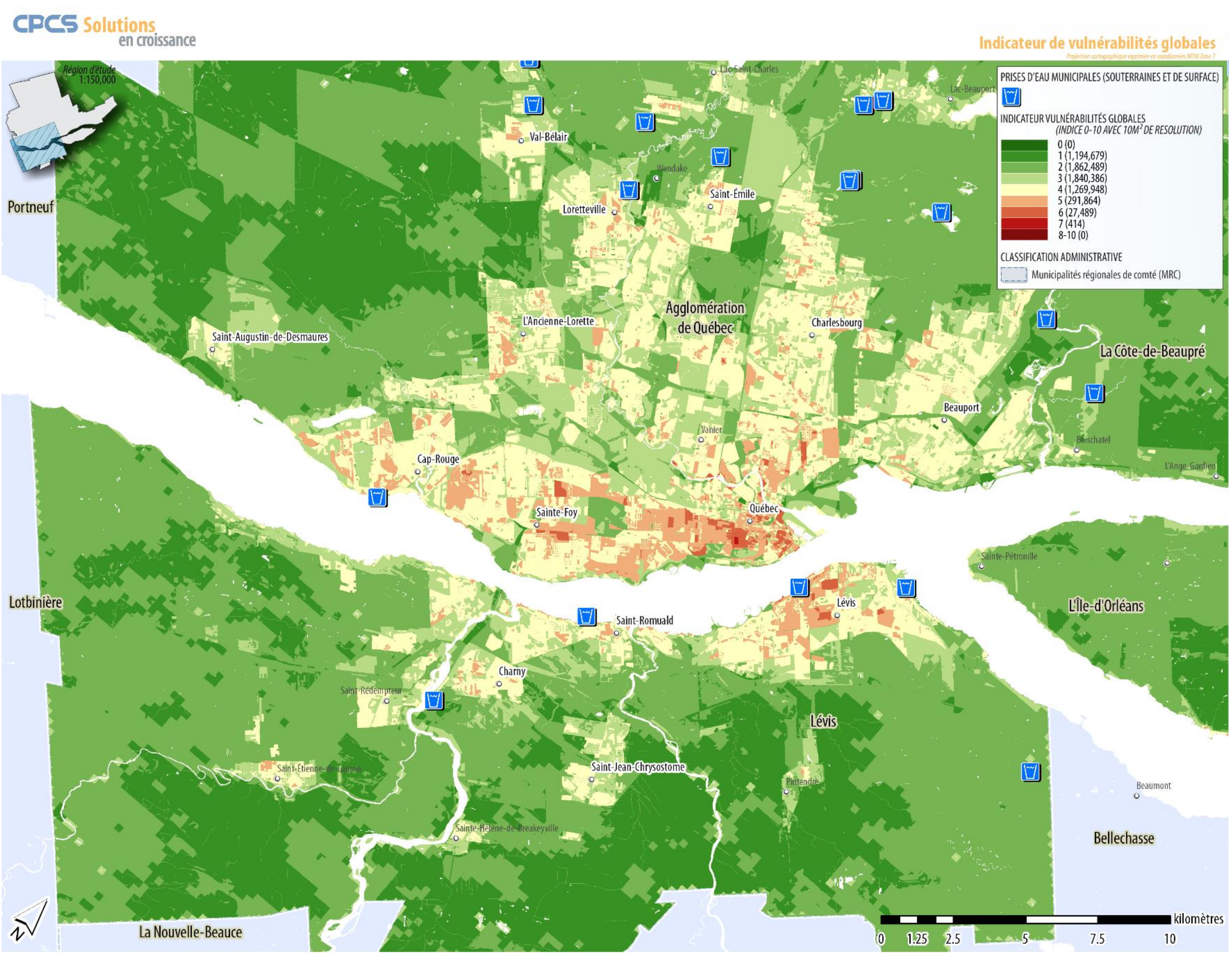
Figure 3-14: Overall vulnerability indicator



Indicateur de vulnérabilités globales	Overall vulnerability indicator
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR DE VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres

Figure 3-15: Overall vulnerability indicator (detailed)

Indicateur de vulnérabilités globales	Overall vulnerability indicator
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR DE VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales du comté (MRC)	Regional county municipalities (RCMs)
Kilomètres	Kilometres


CPCS Solutions en croissance
Indicateur de vulnérabilités globales
Projection cartographique exprimée en coordonnées MTM Zone 7
Région d'étude 1:150,000
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)
INDICATEUR VULNÉRABILITÉS GLOBALES
(INDICE 0-10 AVEC 10M² DE RESOLUTION)
0 (0)
1 (1,194,679)
2 (1,862,489)
3 (1,840,386)
4 (1,269,948)
5 (291,864)
6 (27,489)
7 (414)
8-10 (0)
CLASSIFICATION ADMINISTRATIVE
Municipalités régionales de comté (MRC)
Portneuf
Lac-Saint-Charles
Lac-Beauport
Val-Bélair
Wendake
Saint-Émile
Loretteville
L'Ancienne-Lorette
Agglomération de Québec
Charlesbourg
Saint-Augustin-de-Desmaures
La Côte-de-Beaupré
Beauport
Vanier
Boischatel
L'Ange-Gardien
Cap-Rouge
Sainte-Foy
Québec
Sainte-Pétronille
Lotbinière
Saint-Romuald
Lévis
L'Île-d'Orléans
Charny
Saint-Rédempteur
Saint-Jean-Chrysostome
Pintendre
Beaumont
Bellechasse
Sainte-Hélène-de-Breakeyville
La Nouvelle-Beauce
kilomètres
0
1.25
2.5
5
7.5
10

3.2 Accident scenarios

Following the first stage of identifying the dangerous goods and modes of transportation found in the CMQ, the priority dangerous goods have been identified. They are:

- vinyl acetate monomer;
- hydrochloric acid;
- ammonia;
- chlorine;
- sulfur dioxide;
- gasoline;
- hydrogen fluoride;
- natural gas;
- light crude oil;
- heavy crude oil;
- propane.

These substances have toxic, oxidizing, corrosive, explosive or flammable characteristics and can have significant consequences on the environment and the population if a major accident occurs.

3.2.1 Development of accident scenarios

The methodology selected to develop the accident scenarios is defined in the document "*Risk Management Program Guidance for Offsite Consequence Analysis*" from the United States Environmental Protection Agency (US EPA). This is a risk assessment method based on assessing worst-case scenarios and alternative accident scenarios.

Worst-case scenarios

The worst-case accident scenario for gases and liquids is defined as the release of the largest quantity of a dangerous good resulting from a container or pipe rupturing over a period of 10 minutes, under the worst meteorological conditions. These situations consider the passive protection systems like structures, buildings and dikes, but not active protection systems such as detectors. The worst-case scenario is a preliminary diagnostic tool and is not very likely to occur.

Alternative scenarios

Alternative accident scenarios correspond to situations that are likely, and they take into consideration the active mitigation measures. The alternative scenarios studied correspond to more likely situations, generally associated with a truck overturning and the shell of the tank being ruptured or damaged following a collision with another vehicle (for liquids under atmospheric conditions) or damage to valves creating relatively minor leaks (for compressed gases). In general, the trucks are designed and have equipment and structures to prevent the complete breakage of weak elements (i.e.: valves, etc.) with direct contact, and consequently, the scenarios associated with such breakages are generally considered unlikely.

For substances transported by rail, the most likely situations are associated with a derailment with the shell of the tank being ruptured or valves breaking, resulting in minor leaks. In general, the weak elements (i.e. valves, etc.) are located inside a metal enclosure on the roof of the car, which decreases the likelihood of the complete breakage of these elements in the event of a derailment.

3.2.2 Study of consequences

This section aims to analyze the consequences associated with the scenarios identified in the previous section.

The goal of analyzing the consequences of the worst-case and alternative scenarios is to determine the areas affected or the impact radiuses attributable to an accident. These impact radiuses are determined with modelling tools, such as atmospheric dispersion models for toxic product spills, and overpressure and thermal radiation estimation models for fires and explosions. The danger zone corresponds to the circle centred around the location of the accident.

In this study, the consequences of the accident scenarios that were examined concerned the toxic effects and flammable substances. The applicable vulnerability criteria for these types of substances are presented below.

Toxic effects

For emergency response planning, the Major Industrial Accidents Reduction Council (MIARC) recommended using the *Acute Exposure Guideline Levels* (AEGL – and more specifically, AEGL-2) criteria. The US EPA uses the *Emergency Response Planning Guideline* (ERPG – and more specifically, ERPG-2) criteria. In this context, the AEGLs and the ERPGs are defined below and retained for the present study. The AEGL-2 and AEGL-3 concentration levels were developed by the *American Industrial Hygiene Association* (AIHA). They were developed to be used when creating emergency response plans and to manage emergency situations. The definitions of these threshold values are presented below:[23]

[23] As defined in: MIARC, 2007, *Risk Management Guide for Major Industrial Accidents,* 434 pages.

- "[Translation] ***AEGL-1:*** *Dangerous airborne concentration which may cause those exposed, including susceptible persons, to experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure. Concentrations below AEGL-1 represent exposure levels associated with the perception of a mild odour, taste or other sensory irritations.*
- ***AEGL-2:*** *Dangerous airborne concentration that may cause those exposed, including susceptible persons, to develop irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape. Concentrations below AEGL-2, but equal to or higher than AEGL-1, represent an exposure that can have significant effects, but the recommended reversible threshold for planning emergency measures – MIARC.*
- ***AEGL-3:*** *Dangerous airborne concentration that may result in life-threatening health effects or death for those exposed, including susceptible persons. Concentrations below AEGL-3, but equal to or higher than AEGL-2, represent an exposure that can cause people to develop irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape."*

As for the ERPG, the levels of danger for toxic substances are presented by three levels of concentration – "ERPG-1", "ERPG-2" and "ERPG-3" – by the AIHA. The definitions of these threshold values are presented below:[24]

- *"**ERPG-1**: Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odour.*
- ***ERPG-2**: Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action* (**recommended threshold for planning emergency measures – US EPA**).
- ***ERPG-3**: Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects."*

Fires

A flammable substance can cause a fire; the characteristics depend on the substance involved and the specific conditions of the accident. In these cases, the zone of impact can be defined by the thermal radiation level (expressed in kW/m^2) emitted by the fire. Following prolonged exposure to the heat of flames (thermal radiation), receptors exposed may suffer different degrees of burns according to the duration and the distance between the receptor and the fire.

[24] *Ibid.*

The maximum thermal radiation is at the location of the fire and decreases according to the separation distance.

The recommended impact thresholds for the destruction of equipment, for the estimation of life-threatening consequences and for planning emergency measures are:

5 kW/m²:	Limit that should not be exceeded by a normally clothed human. This threshold corresponds to a 1% mortality rate for exposure longer that one minute **(recommended threshold for planning emergency measures - MIARC)**.
12.5 kW/m²:	This level of radiation can be life-threatening.
37.5 kW/m²:	Sufficient thermal flux to damage process equipment and cause domino effects.

A level of thermal radiation of 5 kW/m² can cause partial thickness burns after 40 seconds of exposure. A level of radiation of 12.5 kW/m² can cause death if the person is exposed for longer than 30 seconds. Finally, it is assumed that radiation of 37.5 kW/m² could cause equipment damage that could cause domino effects, such as the rupture of supports of pipelines transporting dangerous goods.

Explosions

In terms of the explosions resulting from the ignition of a mixture of explosive vapours, the impact area can be defined using the overpressure levels (expressed in psi – pounds per square inch) caused by the explosion. Exposed receptors will suffer mechanical effects (structural collapses, ruptured ear drums, etc.). The overpressure is greatest at the location of the explosion and decreases depending on the separation distance.

The recommended impact thresholds for estimating the life-threatening consequences and for planning emergency measures are presented below:

0.3 psi:	Level defining the indirect impacts, broken windows, on humans.
1 psi:	Level defining the zone presenting “significant danger for humans” (recommended threshold for emergency planning measures - MIARC).
3 psi:	Level defining the zone presenting very serious danger for human life zone.

It is assumed that an overpressure level of more than 3 psi can damage process equipment and structures, which can cause domino effects, for example rupturing supports for pipelines transporting dangerous goods.

Impact radiuses

The following figures present the impact radiuses according to the different thresholds analyzed. While certain impact radiuses for the alternative scenarios can extend over 8 km, it can also be as low as a few tens of metres for others. Since rail accidents involve larger quantities of products, the impact radiuses are often higher than those of road accidents, unless the diameter of the leak in the scenario is larger.

Figure 3-16: Impact radius for worst-case scenarios – Toxic substances

TOXIC SUBSTANCES		Radius (m)		
Transportation	Substance	ERPG -2 (1 hour)	ERPG-3 (1 hour)	AEGL-2 (1 hour)
Road	Hydrochloric acid	***20 ppm***	***50 ppm***	***22 ppm***
		12 435	3 163	11 644
	Ammonia	***150 ppm***	***750 ppm***	***160 ppm***
		4 844	2 214	4 568
	Hydrogen fluoride	**20 ppm**	**50 ppm**	**24 ppm**
		25 639	14 318	22 893
	Hydrogen peroxide	***50 ppm***	***100 ppm***	***NA***
		63	1	Insignificant
Rail	Chlorine	***3 ppm***	***20 ppm***	***2 ppm***
		50 000	39 772	50 000
	Sulfur dioxide	***3 ppm***	***15 ppm***	***0.75 ppm***
		50 000	50 000	> 50 000
	Vinyl acetate monomer	***75 ppm***	***500 ppm***	***36 ppm***
		3 882	1 145	7 735

NA: Not available
Source: CPCS - AECOM

Figure 3-17: Impact radius for worst-case scenarios – Flammable substances and explosives

FLAMMABLE SUBSTANCES AND EXPLOSIVES			Radius (m)				
Transportation	Substance	Worst-case scenario	5 kW/m²	12.5 kW/m²	37.5 kW/m²	1 psi	3 psi
Road	Gasoline	*Fire*	478	302	174	---	---
	Gasoline	*Deflagration and fire-ball*	787	498	287	591	---
	Propane	*Explosion*	465	273	86	773	669

FLAMMABLE SUBSTANCES AND EXPLOSIVES			Radius (m)				
Transportation	Substance	Worst-case scenario	5 kW/m²	12.5 kW/m²	37.5 kW/m²	1 psi	3 psi
	Propane	*BLEVE*[25]	---	---	---	96	50
Rail	Gasoline	*Fire*	629	398	230	---	---
	Gasoline	*Deflagration and fire-ball*	947	599	346	710	---
	Light crude oil	*BLEVE*	1 007	637	368	762	---
	Conventional crude oil	*BLEVE*	991	627	362	757	---
Rail	Propane	*BLEVE*	122	64	---	---	---
	Propane	*Explosion*	595	353	118	1 014	882
Marine	Gasoline	*Fire – Pool fire*	1 164	736	425	---	---

n/a: Not applicable.
(1) The radiuses of thermal radiation correspond to the effects of a fire-ball.

Figure 3-18: Impact radius for alternative scenarios – Toxic substances

TOXIC SUBSTANCES		Radius (m)		
Transportation	Substance	ERPG -2 (1 hour)	ERPG-3 (1 hour)	AEGL-2 (1 hour)
Road	Hydrochloric acid (36%)	***20 ppm***	***50 ppm***	***22 ppm***
		2 157	696	2 036
		3113	987	2 940
Road	Ammonia	***150 ppm***	***750 ppm***	***160 ppm***
		2 160	586	2 037
	Hydrogen fluoride(1)	**20 ppm**	**50 ppm**	**24 ppm**
		8 231	4 459	7 713
	Hydrogen peroxide (70%)	***50 ppm***	***100 ppm***	***NA***
		21	0,6	Insignificant
Rail	Chlorine	***3 ppm***	***20 ppm***	***2 ppm***
		3 261	1 017	4 151
	Sulfur dioxide	***3 ppm***	***15 ppm***	***0.75 ppm***
		2 873	1 104	6 508
	Vinyl acetate monomer	***75 ppm***	***500 ppm***	***36 ppm***
		0	0	0

The meteorological conditions considered for all the scenarios are: 25°C, atmospheric pressure, relative humidity 50%.
(1) The modelling was carried out for a temperature of 20°C.

[25] Boiling liquid expanding vapour explosion

Figure 3-19: Impact radius for alternative scenarios – Flammable substances and explosives

FLAMMABLE SUBSTANCES AND EXPLOSIVES			Radius (m)				
Transportation	Substance	Alternative scenario	5 kW/m²	12.5 kW/m²	37.5 kW/m²	1 psi	3 psi
Road	Gasoline	Fire	91	58	33	---	---
	Propane	Explosion	---	---	---	94	82
Rail	Gasoline	Fire	293	185	107	---	---
	Light crude oil	BLEVE	1007	637	368	762	---
	Crude oil	BLEVE	991	627	362	757	---
	Propane	Explosion	---	---	---	16	13
Pipeline	Natural gas	Explosion	---	---	---	937	805
		Explosion	---	---	---	319	278
Marine	Gasoline	Fire	368	233	134	---	---

The meteorological conditions considered for all the scenarios is: 25°C, atmospheric pressure, relative humidity 50%.

3.2.3 Conclusions about accident scenarios

The analysis of the results obtained for the alternative accident scenarios developed allow us to conclude that the impact radius associated with a toxic cloud spreading can reach up to 8.2 kilometres in the case of hydrogen fluoride (ERPG-2). The impact radiuses for the toxic effects (ERPG-2 or AEGL-2) associated with the spread of the other substances evaluated varied between 0 and 6.5 kilometres. ERPG-2 and AEGL-2 values are relatively safe for a period of one hour, as no irreversible effects are likely to occur. The number of people who could be affected if an accident involving these substances took place will depend on the substance and the location where the accident takes place.

In terms of the impacts associated with an explosion and a fire following an accident, the impact radiuses obtained for the alternative scenarios are substantially lower. However, if such an accident lead to a BLEVE (for example, in the case of crude oil), the impact radiuses would be in the range of 1,000 metres. In this context, depending on the location where the accident occurs, the number of receptors affected could be considerable.

As for petroleum, it is important to highlight that the characteristics of petroleum vary depending on the place of provenance (place of extraction and process used). The composition of petroleum, in particular the percentage of volatile substances, has a significant impact in terms of the consequences of accidents involving this substance. The impact radiuses have been determined using the characteristics of Bakken petroleum and a light crude oil.

Explosions and fires can also cause a domino effect that can lead to much more serious scenarios. For example, the explosions and fires from tanker cars in a rail convoy can have much larger radiuses of impact or can lead to toxic substances being spilled into streams or rivers that are used to supply drinking water to cities and towns located downstream.

The other domino effects caused are associated with essential infrastructures and critical response operation locations in the area potentially affected by the accident being out of order.

3.3 Analysis of consequences

Each accident scenario and its impact radiuses has been integrated into the model developed in the GIS, and these were applied to the CMQ. For each scenario, the indicators selected to quantify the consequences are the following:

- The number of people in the impact radius based on their place of residence
- The number of people in the impact radius based on their place of employment
- The value of real property holdings in the impact radius
- The number of educational institutions in the impact radius
- The number of students attending said educational institutions in the impact radius
- The number of health and social services facilities in the impact radius
- The surface area of the area of impact
- The average environmental vulnerability found in the impact radius
- The average overall vulnerability index found in the accident impact radius

For each scenario, one accident location is allocated based on the accident indicators for the mode concerned, as well as the likelihood that such a load would be in transit on the targeted section of the network. For example, even if certain road sections have a very high accident indicator, if truck trailers are forbidden to use that section, in principle, this eliminates the risk of an accident involving dangerous goods. The details of the consequences and their cartographic representation are presented in the appendix to this document.

Evidently, the location of the accident is the factor that determines the magnitude of the consequences on the vulnerabilities. In certain worst-case scenarios, the impact radius could, for all practical purposes, cover the entire territory of the CMQ. This is particularly the case for rail accidents involving chlorine and sulfur dioxide, which can have a 50-kilometre impact radius. In this chapter, a certain number of locations have been selected to illustrate the consequences. However, the GIS allows the user to position the accident wherever they see fit. As such, the CMQ has a great deal of flexibility to develop a large number of scenarios of consequences. Finally, it is important to note that impact radius does not systematically affect all of the people/buildings that it encompasses. The number of people and buildings affected can vary due to weather conditions and the particularities of the accident itself.

In practice, and without excluding the likelihood that a worst-case scenario will occur, the following will instead discuss the consequences associated with the alternative scenarios. As for hydrochloric acid (Figure 5-3), the alternative scenarios indicate than an accident located on Highway 73 between Highway 740 and Route 973 could have an impact radius that affects more than 74,330 residents according to the ERPG-2 criteria. However, according to the ERPG-3 criteria, the number of residents could potentially be higher on Highway 73 between Highway 573 and Route 138 because there are more residential areas nearby. In short, and depending on the weather conditions, more residents should be evacuated more quickly if an accident were to take place on Highway 73 between Highway 573 and Route 138 compared to between Highway 740 and Route 973.

A similar situation applies in the case of ammonia. That is to say that an accident on Highway 73 between Highway 740 and Route 973 could affect a greater number of residents (31,800) according to the ERPG-2 criteria. However, according to the ERPG-3, the number of residents inside the impact radius is greater on Highway 73 between Highway 573 and Route 138.

For chlorine transported by rail, the most significant impacts for the residential population (based on the locations selected) would be felt in the event of an accident at the marshalling yard in Limoilou. Furthermore, close to 118,800 residents would be in the impact radius according to the ERPG-2 criteria. A sulfur dioxide accident would be equally serious in this location and could impact more than 96,134 people according to the ERPG-2 criteria.

The alternative scenarios for gasoline also indicate that a rail accident at the Limoilou yard would have more impacts than others and that the impact radius would affect up to 944 people. However, in terms of marine transportation, the maximum impact on residents would be 12 people if the incident were to take place at the entrance to the port of Québec.

The magnitude of the alternative scenario for a road accident involving hydrogen peroxide is more significant on Highway 73 between Highway 740 and Route 973. The impact radius of 21 m, according to the ERPG-2 criteria, could have repercussions for more than 105 workers. Under the ERPG-3 criteria, this would be 31 workers.

The alternative scenario involving the rupture of a natural gas pipeline near a valve station in an urban environment could affect approximately 2,470 residents with an overpressure threshold of 3 psi. Fewer than 100 residents would be in the impact radius in the event of a localized rupture near the junction between the supply network (TQM) and the distribution network (Gaz Métro).

The consequences of a conventional crude oil accident and a light crude oil accident are relatively similar. Once again, it is at the Limoilou yard that the magnitude of the consequences would be the most significant. However, it is the on the Lévis side that such an incident is at risk of occurring. The alternative scenario with a BLEVE in the Lévis subdivision has an impact radius affecting approximately 1,600 residents at an overpressure threshold of 1 psi and 3,031 residents at a 5 kW/m^2 thermal radiation threshold. Near the Joffre marshalling yard, these values would be 1,168 residents and 2,387 residents, respectively.

Finally, the impact radiuses of the alternative scenarios for road accidents involving propane can affect up to 18 residents with an overpressure threshold of 3 psi if the accident were to take place on Highway 73 between Highway 573 and Route 138.

In terms of environmental vulnerability, the average maximum vulnerability indicator[26] reached within the impact radiuses of the alternative scenarios is generated by marine mode of transportation. With a 5 kW/m^2 thermal radiation threshold, the marine incident generated an average environmental vulnerability index of 6, which is considered to be very high. This is largely explained by the fact that the surface of water has a considerable weight in calculating the overall environmental vulnerability index. However, the maximum environmental index reached for most of the alternative scenarios is below 4.

[26] This is the maximum index per scenario as certain scenarios have two variations.

4 Risk Management

Key message

Risk management related to the transportation of dangerous goods in the CMQ is ensured by various stakeholders in the private and public sectors. Government stakeholders establish the acts, regulations and programs which guarantee the security of transportation and first-line responses. The private stakeholders are involved in the implementation of the legislation and regulations within their organizations and in the same transportation activities.

The level of integration of risk management processes in the CMQ is relatively well advanced. However, there are gaps in the systematic identification of risks.

4.1 Risk management in the CMQ

Following the analyses performed under the present mandate, it appears that the level of integration of the risk management processes in the CMQ is relatively well advanced. In densely populated municipalities, the civil protection plans are visibly available, and the fire safety cover plans suggest coverage deadlines and set objectives. It is important to note that, in the rural environment, the implementation of civil protection plans is more complicated due to the limited resources within the municipalities. However, all of the RCMs have fire safety cover plans, which provide an overview of the resources available to respond.

The tools, which are the civil protection and the fire safety cover plans, establish the processes allowing the response to incidents involving the transportation of dangerous goods to be brought from the local to the national level. In addition to these processes, the requirement for the shippers to provide an ERAP allows one to believe that necessary resources should be mobilized efficiently in the event of an accident. In all the cases, the site coordinator, supported by the municipality's mission team, the ORSC, the OSCQ and the CSCQ are evidently the stakeholders and decisive coordination mechanisms; the ERAP must, in principle, allow them to access specialized resources likely to be able to support them.

However, in terms of the municipalities and in regard to preparation of potential risks, the fact that the regional authorities are not obligated to prepare civil protection plans certainly poses a problem. While being prepared, civil protection plans must submit:

> *"… the nature of the major disaster risks to which the territory is exposed, including the risks reported pursuant to section 8, specifying for each risk the location of its source, the foreseeable consequences of a major disaster related to the risk and the area that could be affected. The plan shall also mention existing safety measures and the human, physical and informational resources at the disposal of local or regional authorities and civil protection authorities"*.[27]

Without these plans or a process that leads to similar results, it is difficult to adequately integrate the inherent risks of transporting dangerous goods into the land use planning process, which come from, in many regards, a spatial apprehension of social, economic, environmental and physical phenomena. The fire safety cover plans take into consideration the fixed locations where dangerous goods are stored and used. However, it is evident that they do not directly consider transportation routes in their risk analysis criteria. It is certainly a question of the locations, but the transportation routes are not explicitly stated.

In summary, the level of integration of risk management processes related to the transportation of dangerous goods in the CMQ can be assessed from two perspectives. On one hand, the

[27] *Civil Protection Act,* Section 1, http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/S-2.3

internal response to transportation activities is considered to be integrated from the local to the national level. On the other hand, in terms of the integration of land use planning processes on the territories of the municipalities, it important to note that the integration is not optimal. This applies to the risk assessment associated with the principal routes used for the transportation of dangerous goods. However, this risk assessment challenge is not exclusive to the transportation of dangerous goods. It also applies to many other hazards and vulnerabilities for the municipalities, which are waiting to be documented in civil protections plans, or a similar process.

4.2 Best practices

It must absolutely be recognized that the development of the North American ecumene is largely based around major transportation routes, and these are deployed as poles of economic development. Today, these routes pass through large agglomerations and the balance between maintaining certain industries' supply needs in terms of dangerous goods and decreasing the risks sometimes involves difficult choices. The impacts of these choices can even cross the borders of territories, as access to major routes in an agglomeration can impact activities taking place thousands of kilometres away.

According to the research performed as part of the present work and in the North American context, the best practices in terms of land use planning and the inherent risks of transporting dangerous goods are above all the result of experience developed through work on the major industrial risks. As the exception to the recommendations developed under this framework, there are a certain number of initiatives which have been developed by citizen groups or industrial associations. This is particularly the case for the CMMIC, CERCA, MIARC, TEAP or the Railway Association of Canada's *Proximity Initiative*.

Fernet *et al.* (2013) support that the preferred approach should be based on scientific, legislative and administrative tools. Furthermore, the authors recommend that a rigorous analysis based on accident scenarios be implemented and that the levels of acceptable risk be accounted for. Once the risk and its acceptability are known, the legislative tools should be implemented to allow the risks to be mitigated. This consists of the acts, regulations and standards that allow one to act on the risk itself, both in terms of transportation and the land use planning for the territory. In Quebec (and in North America in general), several legislative tools exist for transportation, but little attention has been paid to accounting for dangerous goods transportation routes in land use planning. Regarding the administrative tools, Fernet *et al.* (2013) indicate that groups of experts are able to designate which locations are conducive to development using scientific tools. However, it seems that land use based on vulnerability is already known, but that these designations are not included in the local and regional regulations that govern land use planning.

The 2007 edition of the Major Industrial Accidents Reduction Council's (MIARC) *Risk Management Guide for Major Industrial Accidents* dedicated a chapter to land use issues in the territory.[28] The MIARC stated that the first step of the land use planning process based on the risks (namely those related to the transportation of dangerous goods) consists of creating an inventory of the sensitive areas and the facilities at risk (meaning the transportation corridors). Based on the approaches adopted in Europe, MIARC indicated that local authorities should determine, in collaboration with citizens, the buffer zones around the facilities at risk. As such, it is an approach that takes the local realities and risks into consideration. In 2013 the MIARC published (and reviewed in 2014) "*Les valeurs de références de seuils d'effets pour déterminer des zones de planification des mesures d'urgence et d'aménagement du territoire.*"

4.3 Response measures

A priori, two types of responses are likely to reduce the risks associated with transporting dangerous goods. On one hand, there are the measures that can be taken to decrease the risk of accidents and, on the other hand, there are the measures that can mitigate the potential effects on concerned populations and environment. Furthermore, the measures taken to reduce risks can be active or passive. Passive measures are normally permanent. For example, a protective wall between a rail line and residences can permanently deflect/restrict the trajectory of a derailed car. Active measures require a human or material response. For example, this could be an incident detection system or a system to transmit information to front-line stakeholders.

The response measures suggested in this section have been formulated without regard to their practicability. Should the measures be implemented, several obstacles/disadvantages are likely to arise for several of them. Certain obstacles are anticipated relating to:

- access to information;
- the fact that it is impossible for the principal interested parties to respond to the specific requests of the municipalities of the CMQ unless all the other municipalities in Quebec and Canada do the same;
- the loss of property tax revenues for municipalities;
- the loss of transaction value for the owners of real property holdings;
- the lack of financial resources to implement the measures;

[28]MIARC, 2007, *Risk Management Guide for Major Industrial Accidents,* 436 pages.

- the carriers and shippers lack the human resources to respond to the requests formulated;
- the ministries lack the human resources;
- the CMQ's reduced capacity to attract industrial investments requiring the supply of dangerous goods for their processes, and;
- the opposition of major manufacturers located outside of the jurisdiction of the municipalities of the CMQ and Quebec that use the transportation networks located in the CMQ.

However, such obstacles must not prevent the implementation of efforts to mitigate the risks within the CMQ. Beyond the challenges related to respective competencies of the various levels of the government, the knowledge of manufacturers and carriers, as well as the available resources, all large agglomerations worldwide are facing similar issues. By carrying out these measures over time, the CMQ and its municipalities are likely to pave the way for other territories regarding the mitigation of risks associated with the transportation of dangerous goods.

Sections **Erreur ! Source du renvoi introuvable.** to 4.3.5 present each of the suggested measures. These appear in **bold** font and are preceded by a number (from 1 to 37).

4.3.1 Overall measures

Arguably, as the ecumene of the municipalities has expanded, new vulnerabilities have appeared alongside the hazards associated with the increased transportation of dangerous goods. Evidently, the relationship between the vulnerabilities, hazards and risks is not linear, as the measures, technologies, acts, regulations and processes that act on the vulnerabilities and hazards mitigate the risks. In any event, the risks exist. For the municipalities of the CMQ, this means that measures must be taken to reduce the repercussions of accidents and the potential impacts.

From a global perspective, and while still recognizing the recommendations of the MIARC, it seems that accounting for the risks associated with the transportation of dangerous goods in the CMA must be done in a systematic manner, first and foremost identifying the risks and their consequences. In Quebec, there is already a process to structure and allow such an assessment. However, the ministerial guidelines on the implementation of civil protections plans, which are the cornerstone of this process, are not always known. This has an impact on the implementation of a systematic risk assessment process and it being accounted for in municipalities' civil protection and the fire safety cover plans. In collaboration with the municipalities, the CMQ could **(1) request clear guidelines, implementation deadlines and sufficient funding to develop civil protections plans (or equivalent plans) from the Ministère de la Sécurité publique (MSP)**.

With the specific parameters for land use planning in relation to an assessment of the risks and their acceptability, it is possible to intervene before new hazards and vulnerabilities appear. As for the existing risks, particularly those related to the transportation of dangerous goods that do not originate in or are not destined for the territory and that take the major transportation routes, it can be particularly complicated to mitigate them. Especially when the risk thresholds are considered to be exceeded, the municipalities could **(2) implement long-term restrictive measures so that any amendments are such that they mitigate, or at least do not increase, the risk along the major dangerous goods transportation routes**. For example, the municipalities could **(3) adopt measures so that land use plans prevent the densification of residential uses (or any vulnerable use) along the major transportation routes where large quantities of dangerous goods are circulating.** In particular, this includes highways, rail lines and pipelines dedicated to transportation (as opposed to those used for local distribution). **(4) If municipalities fail to prevent such developments, they could inform the developers and the residents of the inherent potential risks of transporting dangerous goods along the major transportation routes and require developers to plan to construct appropriate protective walls and constructions standards which could mitigate the consequences of an accident.**

Conversely, industrial development should consider the hazards generated by the supply and distribution of products along the routes leading to industrial areas. The municipalities should not only assess the hazards on fixed sites, but also those that could be created by the supply or distribution of dangerous goods to new facilities. The municipalities could **(5) implement approval processes for new industrial or commercial facilities that take into account the impact of the movements of dangerous goods on the security of existing vulnerabilities.** This approval process could involve a citizen committee, ensuring that the concerned populations along the planned routes are represented.

Still taking a long-term perspective, when a generator of flows of dangerous goods closes or moves and decreases the risks in the CMQ significantly, the municipalities can provide for and ensure that the new use for the site in question does not increase the risk again so that it reaches the thresholds that were previously identified as being concerning.

In the absence of a fire safety cover plan for the entire CMQ, the **(6) information contained in the present study can be used as a basic reference to define the security impact of planning of future developments, whether they be commercial, industrial, residential or services.** This information should be used as much as possible when planning new developments based on the risks identified, even if some of the scenarios demonstrate that the accidents can have impacts on the entire territory. When relevant, the municipalities can, for example, ensure that new buildings bordering the at-risk transportation routes respect best practices for protecting against fires and explosions.[29]

As part of this work, for the second stage of this study, an analysis of the consequences was produced for over a hundred typical combinations of scenarios (worst case or alternative)/product/mode/degree of the effects. In the scenarios involving road transportation, the consequences were calculated for four specific sites. For marine and rail transportation, the consequences were calculated for three sites each, whereas two sites were selected for the pipelines. However, despite the fact that the sites were selected because they are considered as being at the most risk, an accident can take place anywhere on the transportation networks. For the purposes of updating the fire safety cover and the civil protection plans, the municipalities should be able to have a precise overview of the consequences of an accident on all of the transportation networks. In this context, **(7) the municipalities of the CMQ could acquire analyses of the consequences on the entire transportation network.** Such analyses would be useful to determine the routes which are at the least risk or to produce impact analyses for alternative scenarios for industrial facilities.

Once the risks have been identified, including those related to the transportation of dangerous goods, the municipalities would benefit from determining what the acceptable level of risk is, and if this level is not met, they should take land use planning measures to bring it to an acceptable level by applying setbacks around specific facilities. In addition to this, **(8) the municipalities should define permitted uses along the transportation routes presenting hazards in a determined radius and implement planning measures that take into account the buffer zones (setbacks).**

The risks associated with dangerous goods transportation accidents are among the various issues to be considered during land use planning, in order to protect the populations, the environment and properties. The characteristics that make this issue particularly challenging are the variety of substances that could be involved, the disparity in the volumes transported, the magnitude of the consequences in the event of an accident, the fact that accidents can take place anywhere in the territory, in addition to the multitude of public and private actors involved at the different levels of managing and handling these goods. Despite these difficulties, prevention at the source, harmonizing uses, land use planning in the territory and the preparing of various actors to intervene in emergencies are measures that can be proposed to decrease the consequences should a major accident occur.

On the subject of land use planning, and in order to harmonize development, the municipalities could manage and determine the vocation of certain sites through zoning by-laws. As such, the municipalities can act to prevent development in at-risk areas and ban the construction of

[29] The Canadian Society for Civil Engineering offers a course on this subject. See: http://csce.ca/custom-content/uploads/2012/04/CSCE-Courses-20121.pdf, page consulted on 2015-04-13.

certain buildings with sensitive uses near the principal transportation corridors where dangerous goods are circulating. At the same time, this type of regulation can aid in the planning of emergency responses and prevent the construction of buildings that require more time to be evacuated (hospitals, residential and long-term care centres, health and social services centres, schools, daycares, recreational centres, etc.), and, decrease the impact on the population in the event of a major accident.

Other measures, such as adopting setbacks for rail lines and roads, could be considered. Furthermore, the Communauté métropolitaine de Montréal (CMM) as well as other Canadian municipalities have adopted a [Translation] "… *minimum setback of 30 metres for new buildings and facilities which have a medium, high or very high sensitivity (…..) calculated from the edge of the railway right-of-way…".*[30] Ideally, the setback should be established considering, among other factors, accessibility in case of emergency, the volume of goods transported, the frequency of transportation, the type of line, the systems to be protected and the land uses of the territory, among others.

Based on the analysis of consequences performed in the second step of this project, it is possible to determine that the impact radiuses vary significantly depending on the good being transported and the mode of transportation used (the volume transported by a truck is very different from that of a train car). As such, in regard to a toxic substance being transported by rail and under the ERPG-2[31] criteria, the impact radiuses for the alternative scenarios vary from 2.1 kilometres in the case of hydrochloric acid to 8.2 kilometres in the case of hydrogen fluoride. In light of this fact, it is evident that establishing a setback would not decrease the impact on populations near the location of the accident in regard to the effects of the toxic cloud (they would be inside the impact radius, despite the setback), with the exception of an accident involving hydrogen peroxide, for which the impact radius is 21 metres under the conditions studied. If the same analysis is performed considering gasoline transported by road with 5 kW/m^2 [32] danger threshold, the impact radius varies between 64 and 91 metres, depending on the type of accident considered in the study.

It is important to consider the fact that accident scenarios can have very different characteristics from real scenarios. These differences result from variations in the volume of substances transported, the weather conditions at the time of the accident, the type of accident (variations in the diameters of the breach in the tank and different reservoirs than those studies), etc. Consequently, it is possible to observe variations in the impact radiuses. The negative impact of

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[30] Comité sur la sécurité du transport ferroviaire sur le territoire de la Communauté métropolitaine de Montréal. Recommendations.

[31] Emergency Response Planning Guidelines 2: Maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

[32] Value chosen for planning emergency measures. Risk Management Program, Guidance for Offsite Consequence Analysis.

the multiple factors previously listed make establishing a universal setback applicable for all situations very difficult. In order to achieve harmonious and sustainable development, public and private stakeholders should consider prioritizing preventative measures, planning future land uses for the territory that consider the principal dangerous goods transportation corridors, as well as sensitive and at-risk uses, the work coordinated in planning emergency measures, information sharing concerning the volumes of dangerous goods circulating the territory, speed limits of the circulation, establishing distribution schedules and routes for dangerous goods, and preparing response teams (competence, resources and training), among others.

In conclusion, it is recommended that:

- **(9) The municipalities consider the risks associated with the transportation of dangerous goods in land use plans and specifically during any zoning changes.** As such, the specific risks for each section of the territory can be considered in this exercise. The generic likely accident scenarios covered in this study can be used as tools to facilitate this exercise;
- **(10) The municipalities should consider a minimum setback of 30 metres[33] as a guide for new buildings and facilities with a medium, high or very high level of sensitivity located alongside a rail line or major transportation route for dangerous goods. The municipalities could also perform an accident risk analysis to justify a smaller setback, or again, assess the need for a larger setback.**

As much as carriers are well positioned to understand the risks inherent with their activities, the risk tolerance comes before all of the populations concerned. It is crucial that this tolerance is known in order to determine which measures should be prioritized. It seems that CMMICs are the appropriate method of integrating the populations in the planning process and developing response measures. Unless otherwise stated, there is no CMMIC in the CMQ. **(11) As such, the municipalities could establish joint committees for municipalities, industries and citizens. If the manufacturers will not collaborate in the presence of citizen representatives:**

- **Form committees for municipalities and citizens to focus and get an understanding of citizens' concerns;**
- **Form committees for municipalities and industries to process the most sensitive elements that manufacturers do not wish to disclose to the public.**

This will allow citizens' concerns to be well understood and focused, all while limiting escalating tensions though the media, in particular, "social" media.

One major problem that the present work was forced to confront was the availability of information on the flows of dangerous goods. **(12) The municipalities of the CMQ could request**

[33] Calculated from the edge of the rights-of-way.

that the Ministère de la sécurité publique and the Ministère des transports du Québec amend acts and regulations so that shippers are required to send information related to the flows of dangerous goods that they generate to an organization related to the Ministre de la sécurité publique: at first only for certain targeted products, and eventually for all products. The required information should include:

- **the nature of the products;**
- **the ERAP registration numbers;**
- **the specific routes;**
- **the quantities per batch, and;**
- **the frequency.**

As part of this initiative, **(13) the municipalities could request that the Government of Quebec provide this organization with sufficient funding, not only so that they can compile the information, but also so that it can produce analyses to inform the municipalities about the inherent risks of transporting dangerous goods in their respective territories.**

In terms of responses, **(14) the fire departments in the municipalities could ask risk generators for information about the sources and procurement timelines for foams, powders or inert gases likely to be used during emergency responses for all of the types of dangerous goods transported on the territory of the CMQ**.

As suggested by the Ministère de la Sécurité publique, civil protection is a shared responsibility. For questions related to transportation of dangerous goods, carriers and their employees are the first ones involved in security. Their understanding of the inherent risks of transportation is essential to establishing measure to protect the public, the environment and property. **(15) The CMQ, still in collaboration with the municipalities, could request that the industry associations already working on transportation security produce specific recommendations for the territory of the CMQ which could mitigate the risks of transporting dangerous goods.** In principle, it is evident that the shippers have a detailed knowledge of the risks posed, but the products transported and the impacts they can have in the event of an accident should also be included in such discussions. This is a win-win-win situation, where the shippers, carriers and the municipal authorities can all achieve their specific objectives, all without having to go through burdensome administrative, regulatory and legislative procedures. However, such an approach is not a substitute for the absolute necessity to implement a strict framework which allows for intervention with the elements which are less concerned with security.

4.3.2 Applicable measures for pipelines

In terms of pipelines, the National Energy Board (NEB) "… *expects that pipeline companies operate in a systematic, comprehensive and proactive manner that manages risks. The Board* *expects that companies have effective, fully developed and implemented management systems and protection programs that provide for continual improvement.*"[34] Compliance with this expectation is verified through various assessment methods. In particular, these methods verify the:

- Policy and commitment of companies.
- Planning in terms of identifying hazards and responses.
- Implementation of checking procedures, including responses during incidents.
- Corrective actions.

Even if all pipeline developments must be approved by the NEB, there are no guidelines regarding the minimum size of rights-of-way. Depending on the diameter of the pipeline and the slope, the right-of-way is normally 12 to 30 metres. Beyond this, pipeline companies can apply a 30-metre safety zone, but it is not forbidden to develop this zone.[35] Under Part I of the *National Energy Board Pipeline Crossing Regulations,* the construction or development of a facility on the right-of-way of a pipeline must be previously authorized by the pipeline company.

In this context, **(16) the municipalities could catalogue and georeference the entire pipeline network on their territories, including the rights-of-way and safety zones adopted by operators**. Once this exercise is completed, they could **(17) request that pipeline operators produce a formal risk assessment according to the current and planned land uses in order to determine whether additional protective or mitigation measures could be developed and integrated into land use plans**.

When the dangerous uses are determined to be too close to their transportation or distribution networks, the municipalities could implement a conversion process for the concerned uses. However, it is useful to remember that the risk assessment performed as part of the present work indicated that the risks associated with pipeline networks in the CMQ are considered to be low or extremely low.

When developments are planned on rights-of-way or safety zones, the municipalities could take steps with the operators to **(18) ensure that the planned uses for rights-of-way and safety areas for pipelines are compliant with potential regulations developed by the municipalities in collaboration with the operators**.

[34] https://www.neb-one.gc.ca/bts/ctrg/gnnb/nshrppln/dtprtcl-eng.html, page consulted 2015-04-14.
[35] *Source: NEB*, 2010, *Pipeline Regulation in Canada: A Guide for Landowners and the Public,* 47 pages.

In the United States, the Pipelines and Informed Planning Alliance (PIPA) prepared various tools for local governments.[36] In a report published in 2010, the organization notably developed 46 recommendations, 29 of which were directly addressed to local governments. These recommendations cover obtaining geospatial data on pipelines for developing emergency response plans, as well as reducing risks for constructing facilities (parking lots, roads, drainage systems, etc.).[37] This document is accompanied by an implementation guide for local governments.[38] In this context, **(19) municipalities that have pipeline networks going through them should become aware of the recommendations of the Pipelines and Informed Planning Alliance and plan to apply them during their land use planning processes**.

4.3.3 Applicable measures for road transportation

There is a very large quantity of flammable liquids originating in the territory of the CMQ, which is then sent across Quebec by road and rail. Specifically, for transportation by road, **(20) the CMQ could, in collaboration with the municipalities, call a meeting with the authorities from the Valero refinery and road carriers in order to develop designated road corridors to lead trucks outside (or across) the territory and to mitigate the risks for the populations. It would also be possible to designate transit times for certain roads in order to mitigate the risks based on human vulnerabilities.**

Evidently, road carriers are aware of the risks associated with the transportation of petroleum products and they normally take the quickest and shortest routes when making deliveries. However, developing designated and voluntary corridors could help contain the risks to certain sections and improve emergency responses planning. Such efforts could also be undertaken with the principal carriers of dangerous goods in Quebec. This would allow the risks to be better understood and allow fire departments to better plan potential responses. However, this is more difficult to apply in the case of multiple deliveries being made within the territory of the CMQ.

According to the Centre for Transportation Engineering & Planning, designated roads should be selected based on the following criteria:[39]

- Functionality
    - Is the route used to transport dangerous goods?
    - Is the route easy to access?

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[36] See: https://primis.phmsa.dot.gov/comm/pipa/pipa_audience_local_government.htm?nocache=9413.

[37] https://primis.phmsa.dot.gov/comm/publications/pipa/PIPA-Report-Final-20101117.pdf, document consulted 2015-04-14.

[38] PIPA, 2012, *Recommended Practice Evaluation Worksheet for Local Governments,* 24 pages.

[39] Centre for Transportation Engineering & Planning, 2005, *Dangerous Goods Route Selection Criteria,* 114 pages.

- Severity
  - What type of route is it?
  - What is the land surrounding the route used for?
  - Are there environmentally sensitive areas along the route?
- Probability
  - What is the road geometry?
  - Does the road allow dangerous goods to be transported efficiently?
  - What is the collision history of the road?

According to the work performed by Opus, municipal regulations regarding designated dangerous goods transportation routes involve the following elements:[40]

1. Definitions
2. References to other relevant acts and regulations
3. Road restrictions
4. Time restrictions
5. Exemptions
6. Fines and the amount of the fine
7. Maps of the network

A better understanding of road carriers and the roads taken could also orient the municipalities of the CMQ regarding alternate uses for lands located near road networks. Depending on the designated dangerous goods transportation corridors, the municipalities would be better equipped to determine the extent to which service and residential development is acceptable near highways. If the risk is determined to be too high, other land uses could be planned.

In the case of the CMQ road network, the present work revealed that most at-risk road sections are:

- *On Henri-IV Highway to the Pierre-Laporte bridge entry/exit on the Quebec side*. This section is not considered to be very vulnerable because there are no residential or service areas nearby. However, these types of vulnerabilities increase once the highway enters Sainte-Foy.

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[40] Opus, 2008, *Dangerous Goods Route Study,* Rapport prepared for the City of Prince George, 53 pages + appendixes.

- *On Henri-IV Highway between Hochelaga Boulevard and Félix-Leclerc Highway*. Between Hochelaga Boulevard and Quatre-Bourgeois Road, there are few houses, but there are several sports facilities in the east. Between Quatre-Bourgeois Road and Versant Boulevard North, the highway crosses a residential area. While the residences on the west side are protected by a wooden wall, the apartment buildings located on the east are only separated from the road by steel mesh fences. Considering this situation, walls should be planned to protect the residents of the apartment buildings. The image below taken from Google Earth illustrates this situation. At this time, it is useful to remember that the alternative scenario involving hydrogen peroxide is likely to create an impact radius of 21 metres (63 metres in the worst-case scenario) at the ERPG-2[41] threshold. For gasoline, the impact radius for an alternative scenario is 41 metres at the 12.5 kW/m^2 threshold (threshold likely to be life-threatening). According to the estimates made based on the data from the National Roadside Survey, approximately 17,000 tonnes of flammable liquids passed through this section on a daily basis in 2006-2007. To illustrate these volumes, and assuming and average weight of 30 tonnes per truck, this is approximately 80 trucks per day, so 3 trucks per hour. These volumes have likely not decreased since then.

Figure 4-1: Trailer truck carrying hydrogen peroxide moving south on Henri-IV Highway at Quatre-Bourgeois Road

- As the highway continues north, the level goes below that of the residences and there are wooden walls on both sides. Despite this, the houses are near the highways and the Versant school building on the east side is 50 metres from the highway (the playground

[41] As a reminder, the ERPG-2 threshold corresponds to the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

is 30 metres away). There is a similar situation (without the school) located at Michelet Road in Ancienne-Lorette. Furthermore, there is space to construct a large protective wall when houses or other vulnerable uses are located less than 30 metres[42] away between Quatre-Bourgeois Road and Félix-Leclerc highway.

- *On Félix-Leclerc Highway between Pierre-Bertrand Boulevard and Henri-Bourassa Boulevard*. Up to Laurentienne highway, Félix-Leclerc Highway primarily passes through commercial areas. Moving east past Laurentienne highway, residential areas appear. On the north side, for the most part the residences are located approximately 60 metres from the highway, but on the south a certain number of residences are closer. However, these are protected by a wall, but these are below the 30-metre setback which is normally recommended. It should be noted that the estimates made based on the data from the National Roadside Survey indicated that more than 20,000 tonnes of flammable liquids were transported in this section in 2006-2007. The following figure illustrates the impact radiuses during a gasoline accident on Félix-Leclerc Highway slightly east of Pierre-Bertrand Boulevard. The results of the analysis of the consequences of such an incident indicate that approximately 40 workers are located within the impacts radius at a threshold of 12.5 kW/m^2. If an accident were to take place two kilometres further east at 3rd and 4th avenue, the consequences could be much more significant as there are residential areas on both sides of the highway.

[42] Calculated from the edge of the right-of-way.

Figure 4-2: Impact radiuses for a gasoline road accident on Félix-Leclerc Highway east of Pierre-Bertrand Boulevard

Autoroute 73/route 973 Scénarios essence et l'indicateur de vulnérabilité globales	Highway 73/Route 973 Gasoline scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M² DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M² OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

- *On Highway 20 at President Kennedy Road*. In this area, the use is mostly commercial and most of the residents are 350 to 500 metres away.

- *On Highway 20 at Pont Road*. In this area there are mostly businesses. The closest residences are more than 200 metres away and they are protected by a relief.

- *On the southern portion of the Pierre-Laporte bridge*. On the east side, a certain number of residences are located less than 100 metres away. An accident involving a truck transporting dangerous goods falling off below the bridge could have impacts on these residences. It is recommended that the development of vulnerable uses be banned in this section.

Furthermore, and **(21) in the sections designated above, the municipalities could prevent residential developments or the installation of public facilities or with sensitive uses (hospitals, schools, daycares, etc.) along the designated corridors less than 30 metres away from rights-of-way. (22) When there are residences, facilities or sensitive uses which are already located less than 30 metres from rights-of way, it is recommended to:**

- **Inform residents of the risks inherent to transporting dangerous goods and inform them of the measures they can take to reduce their risk of exposure;**

- **Inform the responsible authorities of sensitive uses at risk so that they can put evacuation, emergency and containment plans into place, if necessary;**

- **Ensure that they are able to reach the responsible authorities for the sensitive uses at all times to inform them of all incidents and the measures to be taken;**

- **Provide emergency communication plans to all exposed residents and the concerned authorities;**

- **Build protective walls.**

(23) The municipalities could progressively extend the restrictions on residential development for the setbacks of all road networks. As such a measure could have an impact on the transactional value of properties, the municipalities of the CMQ should collaborate on a coherent approach and policy with owners.

(24) When there are sensitive uses (hospitals, residential and long-term care centres, health and social services centres, schools, daycares, recreational centres, etc.) located within the estimated impact radiuses for the alternative scenarios for petroleum products,[43] the municipalities could contact the people responsible for these uses in order to raise awareness about the need to develop an evacuation and containment plan. The municipalities could also ensure that they are able to reach the authorities for these institutions at all times to inform them of any incidents and the measures to take.

[43] This recommendation also applies to the other modes of transportation.

4.3.4 Applicable measures for rail transportation

(25) The municipalities could adapt the guidelines of the *Proximity Initiative* and integrate them into their land use planning process (separation distances, earth berms, protective walls, etc.). Even if these guidelines are not specifically about the transportation of dangerous goods, they include advice about the development of new infrastructures near rail lines. This includes protecting new developments from derailments (e.g.: separation distances, earth berms, walls, etc.). These recommendations also include guidelines for developing rainwater drainage systems, which can compromise the stability of the lines.

In Canada, the Transportation Safety Board (TSB) assessed the number accidents at rail crossings, and trespasser accidents resulted in the highest number of fatalities and serious injuries.[44] In this context, in collaboration with rail carriers, **(26) the municipalities could put measures in place to reduce the number of rail crossings and manage trespassing on rail lines**. For example, it would be possible to:

- constantly watch for developments that could create or require rail crossings;
- ensure that these facilities respect Transport Canada's rail crossing standards and, if necessary, appeal to the Grade Crossing Improvement Program;[45]
- when this is not the case, physically protect accesses to the CMQ rail network and ensure increased surveillance at access points.

Under the *Railway Safety Act,* the *Railway Safety Management System Regulations, 2015* stipulate that rail companies must implement processes to figure out the security concerns through risk assessments. Even if the regulations require that risk assessments identify the people or environmental elements likely to be affected, there are no specific requirements to consider the communities or the reference framework to allow the level of acceptable risk to be defined. Furthermore, the risk classification methodology is defined by the rail companies and the results are only made available to Transport Canada when they perform an audit of the security management systems. In this context, **(27) the municipalities of the CMQ could request to risk assessments for their territories from the rail companies in order to include them in fire safety cover plans.**

If the rail companies are not willing to pass on this information, **(28) the municipalities could undertake proceedings to obtain the risk assessments from Transport Canada (Emergency Directive, Section 33 – *Railway Safety Act*) so that they can be included in fire safety cover plans.**

[44] *Source:* http://tsb.gc.ca/eng/stats/rail/2013/ssro-2013.asp, page consulted 2015-04-13.
[45] https://www.tc.gc.ca/fra/securiteferroviaire/publications-46.htm

Rail companies are also required to develop corrective actions for the risks that they have identified in the risk assessments. The development of these corrective actions must be done in consultation with the employees of the railways concerned, but it is not a requirement for the municipalities to be consulted. Without underestimating how seriously the rail companies take the establishment of these measures, the understanding of the elements of risk and the corrective measures they have undertaken are likely to be very useful, particularly in the development of civil protections plans, as well as in the preparation of fire safety cover plans. **(29) The municipalities could request the list of corrective actions taken in their territories from the rail companies and request to be informed immediately if any corrective actions are required by Transport Canada.**

Under Protective Direction No. 32 from Transport Canada which will end in 2016, "*Any Canadian Class 1 railway company that transports dangerous goods must provide the designated Emergency Planning Official of each municipality through which dangerous goods are transported by rail, with yearly aggregate information on the nature and volume of dangerous goods the company transports by railway vehicle through the municipality, presented by quarter.*"[46] The smallest companies are required to provide this information once a year.

In this context, the Emergency Response Task Force recommends:

> " … *that Transport Canada introduce a permanent requirement for sharing dangerous goods information with municipalities before the expiry of Protective Direction No. 32 in November 2016. The introduction of a permanent regulation should reflect consultation with municipalities and railways on the implementation of Protective Direction No. 32*."[47]

(30) Before the expiry of Protective Direction No. 32, the municipalities of the CMQ could request from Transport Canada and shippers that a permanent mechanism for sharing data related to the transportation of dangerous goods be implemented. Furthermore, (31) the municipalities could request from Transport Canada that the current mechanism be improved so that it would be possible to know not only what was transported, but the frequency and the current routes as well as any changes in the frequency, quantities and routes of targeted convoys before the amendments are made.

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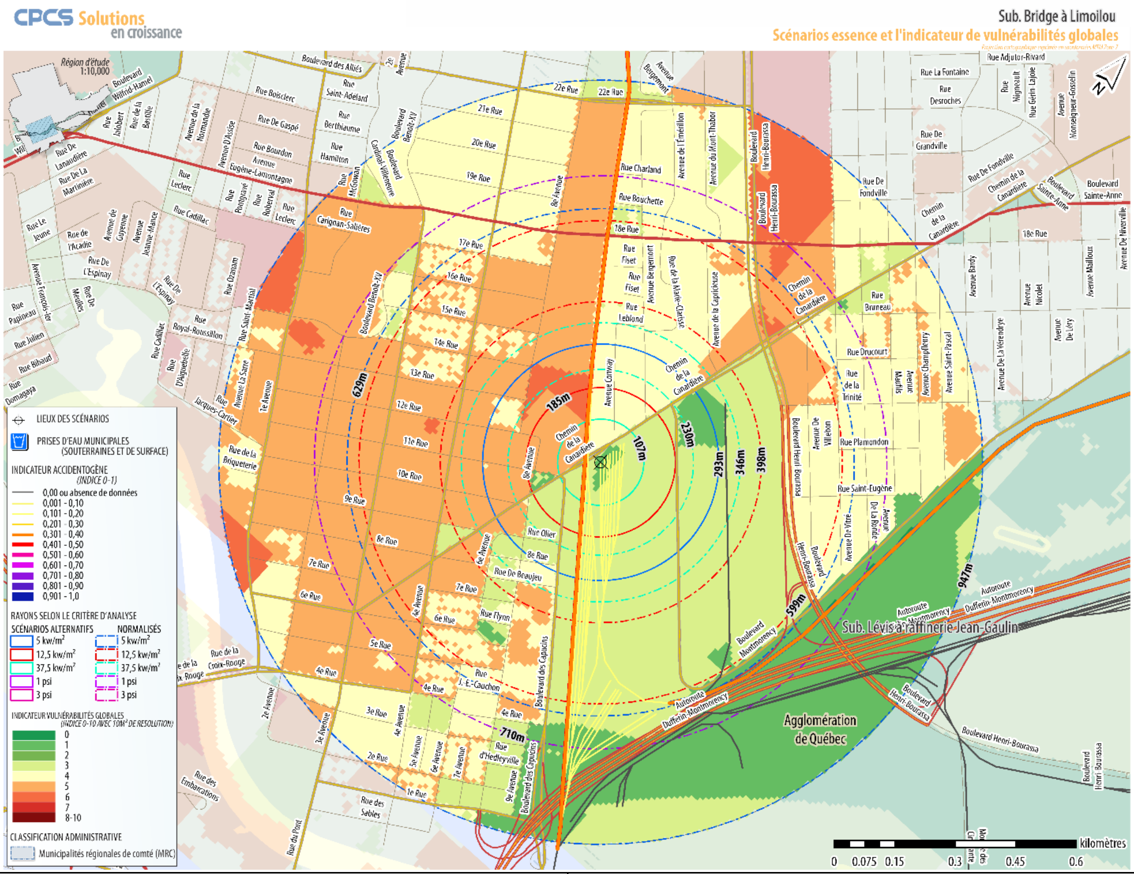
[46] http://nouvelles.gc.ca/web/article-fr.do?nid=829079&_ga=1.9010614.2079113518.1426182461, page consulted 2015-04-13.

[47] https://www.tc.gc.ca/media/documents/tdg-eng/5807-2014-3477-F-BT8821720-ERAP-WG-Report-and-Recommendations-FINAL-21-en-rev-AAA-rev.pdf, page consulted 2015-04-13.

Figure 4-3: Impact radiuses for a gasoline rail accident in Limoilou

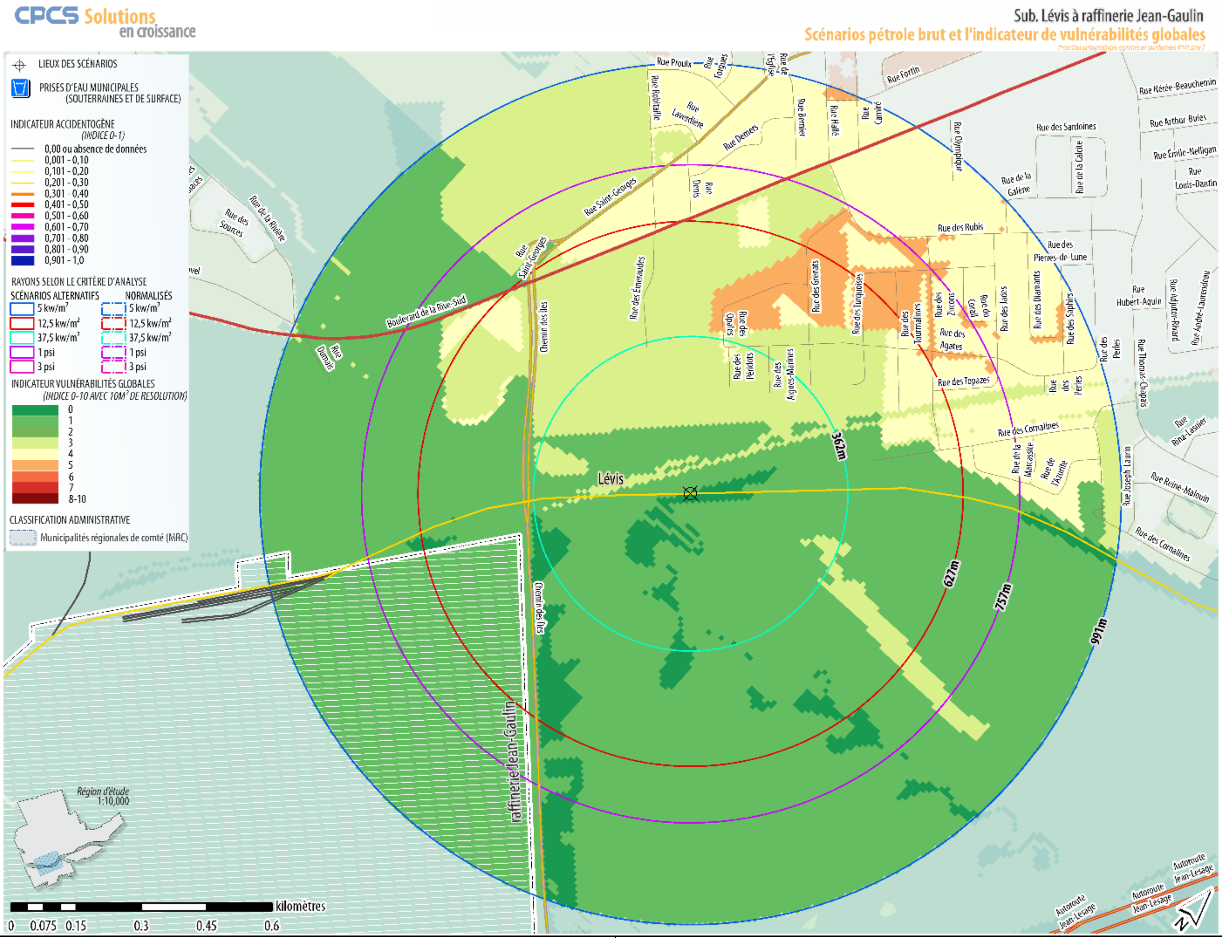


Sub. Bridge à Limoilou Scénarios essence et l'indicateur de vulnérabilité globales	Bridge subdivision in Limoilou Gasoline scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC $10M^2$ DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

In several sectors of the CMQ, including in Limoilou, Vanier, Sainte-Foy and Lévis, numerous residential areas are sometimes located less than 50 metres (and in some cases less than 20 metres) from rail lines on which dangerous goods are transported frequently, if not daily. However, the risks in these sectors are reduced due to the fact that these trains pass through at a reduced speed. Due to the fact that the specific volumes being transported on these lines is unknown, particularly jet fuel shipped from the Beauport sector to the port of Québec, however, it is useful to recall that in the alternative accident scenario involving cars of gasoline indicated an impact radius of 185 metres with a 12.5 kW/m^2 threshold (threshold likely to be life-threatening). At the 35.5 kW/m^2 threshold (thermal flux sufficient to damage process equipment and cause domino effects), the impact radius is 107 metres. The following figure illustrates the impact radiuses of a gasoline accident in which the rail line crosses Canardière Road. In the alternative scenario, approximately 330 residents are located within the impact radius at the 12.5 kW/m^2 threshold. In addition to this, there is an education institution with 300 students. At the 5 kW/m^2 threshold, there is an additional educational institution, also with 300 students, which is located within the impact radius.

In the south sectors of Saint-David and Christ-Roi, near the rail lines that supply the Valero refinery, there are several residences located near the rail line. The alternative scenario for crude oil involves an impact radius of more than 600 metres at a 12.5 kW/m^2 threshold and more than 360 metres at a 35.5 kW/m^2 threshold. The following figure illustrates the impacts radiuses of crude oil rail accidents on the Lévis subdivision in the Saint-David sector. At a 12.5 kW/m^2 threshold, more than 1,000 people would be inside the 627-metre impact radius attributable to the alternative scenario. In addition to this, there are 573 workers.

Figure 4-4: Impact radiuses for a crude oil rail accident in Lévis



Sub. Lévis à raffinerie Jean-Gaulin Scénarios pétrole brut et l'indicateur de vulnérabilité globales	Lévis subdivision at the Jean-Gaulin refinery Crude oil scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M² DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M² OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

In this context, **(32) the municipalities could inform residents of the inherent risks of transporting dangerous goods and inform them of the measures that they can take to reduce their exposure to risks (protective barriers, fire-resistant coatings, personal evacuation plans). In any case, the municipalities could equip themselves with an emergency plan to communicate with all residents exposed to risks.**

Following the impact of a similar measure on the residences located close to at-risk road networks, the municipalities of the CMQ should collaborate to develop on coherent approach and policy with the owners who might potentially have the transactional value of their properties decrease.

On the level of the CMQ, the analyses in the second stage indicated that the sections at the most risk were located in the Drummondville subdivision in the western section of Lévis. This level of risk is influenced by the speed limits, which are higher than elsewhere in the territory and also due to the higher quantities of dangerous goods being transported.

If CN decided to reduce the speed of its train transporting more than 20 cars in census metropolitan areas to 56 km/hr, the risk in the Drummondville subdivision in Lévis would be significantly lower than that estimated in section 3.1. However, the quantity of petroleum products transported in the Drummondville subdivision will grow eventually in the short-term, particularly if[BN(3] the Chaleur Terminals project in Belledune goes ahead as scheduled in 2016. Despite the reduced speed, this could result in the level of risk remaining at the current level.

In this context, **(33) the City of Lévis could request that CN provide a risk assessment resulting from the increased volumes transported on its territory and the measures that the company plans to implement to reduce risk exposure in its territory.** In order to get information to update the fire cover safety plan and the civil protection plan, the City of Lévis could also request that CN provide it information regarding the quantities transported, the frequency and the transit times of trains.

In principle, with the implementation the emergency directive made under section 33 of the *Railway Safety Act* and the order made by the Minister of Transportation under section 19 of the *Railway Safety Act,* CN already has (or will soon have) this information and will be able to inform the City on these subjects.

The quantities of dangerous goods transported by rail from the Beauport sector at the port of Québec toward the North American markets are difficult to determine, and no specific information was able to be obtained from the principal interested parties. As a result, the level of risk assessed in the second stage of this project is an estimate that should clarified.

As with the previous recommendation, **(34) the cities of Québec and Lévis could request that CN provide them its risk assessments, the quantities transported, the frequency and transit times for the concerned trains for the volumes of dangerous goods passing through the Bridge**

subdivision (see Figure 2-8). The cities could use this information to update the fire safety cover and the civil protection plans.

4.3.5 Applicable measures for marine transportation

Marine transportation generates the most significant flows of dangerous goods in the CMQ. It is important to recognize that few measures can be taken in the CMQ or its municipalities to reduce these quantities. Considering that a significant portion of the population of the CMQ gets its drinking water from the St. Lawrence River, the competent authorities of the municipalities, supported by the Ministère de la Sécurité publique, should confirm if additional measures could be planned to protect these drinking water intakes from potential spills in collaboration with Transport Canada, the Canadian Coast Guard, ECRC and the MDDELCC. This could be achieved through the following actions:

- **(35) Preposition protective equipment and systems near water intakes.**
- **(36) Request that Transport Canada validate shipper's ERAPs efficiently taking the existence of water intakes into consideration.**
- **(37) With Transport Canada, the Coast Guard and ECRC that the concerned water treatment plants are immediately alerted in the event of any spill.**

This would allow them to take appropriate actions quickly and avoid introducing pollutants to the pipelines.

Clearly, this assumes that water treatment plants have planned alternative means in case of an interruption.

Finally, certain measures must likely call upon political support. For these cases, the mayors and wardens could formally align themselves and follow-up on common concerns.

5 Conclusion

The present report aims to respond to the Communauté métropolitaine de Québec's (CMQ) need to have a current and representative overview of the dangerous goods circulating their territory by road, rail and marine routes, and pipeline, as well as an analysis of the related risks. This overview must also suggest preventative measures to reduce the risks and response measures to minimize the consequences of accidents.

The primary objective of this work is to understand the dynamics of the transportation of dangerous goods in the CMQ, analyze the risks and suggest preventative measures. This objective is broken down into three precise statements:

- *Prepare a current and representative overview of the dangerous goods circulating the networks in the CMQ and those in transit (road, rail and marine routes, and by pipeline);*

- *Analyze the risks related to the transportation of dangerous goods in the CMQ, particularly by identifying the transportation corridors/segments at risk;*

- *Suggest preventative measures to reduce these risks and response measures to minimize the consequences of accidents.*

Given the results presented in this report, it must be recognized that it is particularly complicated to produce a current and representative overview of the transportation of dangerous goods in the CMQ. This can be explained by several factors, including the availability of recent information and the confidentiality of the information itself. Unless there is a specific regulation requiring shippers of dangerous goods to declare the flows of dangerous goods that they generate systematically and regularly, it is unlikely that this will change in the medium or long term. All of this occurs in a context where the volume of dangerous goods transported in the CMQ is likely higher than identified in this report and are likely to increase. As a reminder, Chapter 2 suggests that:

- Over a period of one year in 2006-2007, at least 4.5 million tonnes of dangerous goods were transported by road in the CMQ.
- Approximately 30.6 million tonnes of dangerous goods were transported in the CMQ by marine routes in 2011, of which, 16 million tonnes at the port of Québec.
- Approximately 4.3 million tonnes of dangerous goods are transported on rail networks in the CMQ, of which, 1.1 million are in transit. The volumes in transit are likely higher and should increase in the short term.
- Between 4 and 5 million tonnes of refined products are sent from Lévis by pipeline. This is in addition to the volumes of natural gas distributed within the CMQ.

The difficulty in effectively quantifying the volumes transported seriously compromises any attempt to precisely determine the risks associated with the transportation of dangerous goods. However, it is still possible to identify the main transportation corridors, and using historical data on incidents on the CMQ transportation network, the history of spills and estimates of the volumes of dangerous goods transported, a risk portrait can be identified. According to the analyses performed in Chapter 3, it is therefore possible to conclude that the level of risk associated with the transportation of dangerous goods on the CMQ transportation network is low to medium overall.

Regardless of the level of risk, the consequences of a dangerous goods transportation accident could be significant. Section 3.2 of the present report defines impact radiuses of several accidents according to the type of product, the mode of transportation and according to the worst-case and alternative (more likely) scenarios. In certain cases, the impact radiuses may extend outside of the territory of CMQ, but in general, they are within a few metres (for example: a hydrogen peroxide road accident) to a few hundred metres (for example: a gasoline rail accident). Evidently, the location of the accidents is the factor that determines the magnitude of the consequences on the vulnerabilities. To illustrate the potential consequences, a certain number of locations were selected, and the impacts were modelled in a geographic information system. According to the results generated using this model, certain dangerous goods accidents can have catastrophic consequences as residential areas are located just tens of metres away from corridors where significant quantities of petroleum products are circulating.

The unfortunate incidents that have occurred over the last years and weeks suggest that measures must be taken to reduce the potential impact of dangerous goods transportation accidents. Chapter 4 tackles this question and several response measures are suggested. They have been formulated without regard to their feasibility, and several obstacles/disadvantages are likely to arise if some of the measures are implemented.

However, such obstacles must not prevent efforts to minimize the risks within the CMQ being implemented. Beyond the problems associated with the respective competencies of the various levels of the government, the knowledge of manufacturers and carriers, as well as the available resources, all large agglomerations worldwide are facing similar issues. To carry out these measures on time, the CMQ and its municipalities are likely to pave the way for other territories with respect to the minimization of risks associated with the transportation of dangerous goods. The table on the following page presents the principal advantages and disadvantages of each of the measures as well as the targeted stakeholder. The number of the measure refers to the statement and contextualization of the measures presented in section 4.3.

Figure 5.1: Principal advantages and disadvantages of the proposed measures

No.	Type	Advantage(s)	Disadvantage(s)	Stakeholder(s)
1.	Overall	Allows for systemic risk analysis	None	MSP
2.	Overall	Keeps the level of risk below a known threshold	Can be limiting for certain manufacturers. Flows in transit cannot be monitored using this measure.	Municipalities
3.	Overall	Prevent vulnerabilities from increasing along routes	Potential loss of property tax revenues	Municipalities
4.	Overall	Transparency and increased preparation in case of incidents	Loss of transactional value of real property holdings. Upgrade costs.	Municipalities and developers
5.	Overall	Better consideration of the impacts associated with facilities' decisions	Can be limiting for certain manufacturers.	Municipalities
6.	Overall	Establish a reference threshold	None	Municipalities
7.	Overall	Precise understanding of the impacts on the entire territory	None	Municipalities
8.	Overall	Better protection for vulnerabilities	Potential loss of property tax revenues	Municipalities
9.	Overall	Consideration if the risks associated with the transportation routes and not just fixed sites	None	Municipalities
10.	Overall	Protection for vulnerabilities	Potential loss of property tax revenues	Municipalities
11.	Overall	Collaboration, transparency and focusing concerns	Difficulty managing and advancing files	Municipalities, manufacturers and citizens
12.	Overall	Better understanding of the risks	Unlikely to be practicable without political will and substantial investments	MSP and MTQ
13.	Overall	Better understanding of the risks	Unlikely to be practicable without political will and substantial investments	Government of Quebec

No.	Type	Advantage(s)	Disadvantage(s)	Stakeholder(s)
14.	Overall	Increased preparation in case of incidents	None	Municipalities and creators of risk
15.	Overall	Involvement of manufacturers in the risk identification process and increased preparation in case of incidents	The industry associations will worry that all the metropolitan communities/municipalities will have similar requests.	Industry associations
16.	Pipelines	Better understanding of risks	None	Municipalities and operators
17.	Pipelines	Better understanding of risks and planning measures possible	None	Operators
18.	Pipelines	Compliance with measures developed	None	Municipalities and operators
19.	Pipelines	Existing recommendations based on a recognized approach	Operational realities and context are different in Quebec	Municipalities
20.	Road	Collaboration while developing measures	None	Municipalities and stakeholders
21.	Road	Better protection for vulnerabilities	Potential loss of property tax revenues	Municipalities
22.	Road	Transparency and increased preparation in case of incidents	Loss of transactional value of real property holdings. Upgrade costs.	Municipalities
23.	Road	Better protection for vulnerabilities	Potential loss of property tax revenues	Municipalities
24.	Road	Better protection for vulnerabilities	None	Municipalities
25.	Rail	Existing recommendations based on a recognized approach	None	Municipalities
26.	Rail	Reduced risks	None	Municipalities and operators

No.	Type	Advantage(s)	Disadvantage(s)	Stakeholder(s)
27.	Rail	Better understanding of risks and planning measures possible	The carriers will worry that all the metropolitan communities/municipalities will have similar requests.	Operators
28.	Rail	Better understanding of risks and planning measures possible	The carriers will worry that all the metropolitan communities/municipalities will have similar requests.	Transport Canada
29.	Rail	Better understanding of risks and planning measures possible	The carriers will worry that all the metropolitan communities/municipalities will have similar requests.	Operators and Transport Canada
30.	Rail	Better understanding of risks and planning measures possible	The carriers will worry that all the metropolitan communities/municipalities will have similar requests.	Operators and Transport Canada
31.	Rail	Better understanding of risks and planning measures possible	The carriers will worry that all the metropolitan communities/municipalities will have similar requests.	Transport Canada
32.	Rail	Transparency and increased preparation in case of incidents	Loss of transactional value of real property holdings. Upgrade costs.	Municipalities and operators
33.	Rail	Better understanding of risks and planning measures possible	The carriers will worry that all the metropolitan communities/municipalities will have similar requests.	Operators
34.	Rail	Better understanding of risks and planning measures possible	The carriers will worry that all the metropolitan communities/municipalities will have similar requests.	Operator
35.	Marine	Better protection for vulnerabilities	None	ECRC
36.	Marine	Better protection for vulnerabilities	None	Transport Canada
37.	Marine	Better protection for vulnerabilities	None	Transport Canada

Appendix: Consequences of Accident Scenarios

Scenarios related to toxic substance accidents

Road accidents

Hydrochloric acid

The worst-case scenario involving hydrochloric acid entails the total volume of a 24,600-litre tank of hydrochloric acid (36%) being spilled on the ground in 10 minutes. The acid forms a puddle 1 cm deep and hydrogen chloride evaporates gradually into the air.

There are two variations of the alternative scenario. In the first, after a truck is overturned on a city road, the shell of a tank filled with 24,600 litres of hydrochloric acid ruptures, forming an opening with a 6” diameter. Gravity causes the acid to leak from the tank, it spreads across the ground and moves toward the closest manhole. The evaporating surface is estimated to be 100 m^2 (1 m in width by 100 m in length). The hydrochloric acid volatizes from this surface. In the second, gravity causes the acid to leak from the tank and it spreads across the ground and moves toward the ditch. As such, the evaporating surface is larger and estimated to be 200 m^2 (2 m in width by 100 m in length). Figure 5-2 presents the consequences of the worst-case scenario and the variation of the alternative scenario with the largest impact radius (200m^2).

These accidents were situated in four different locations (Figure 5-3):

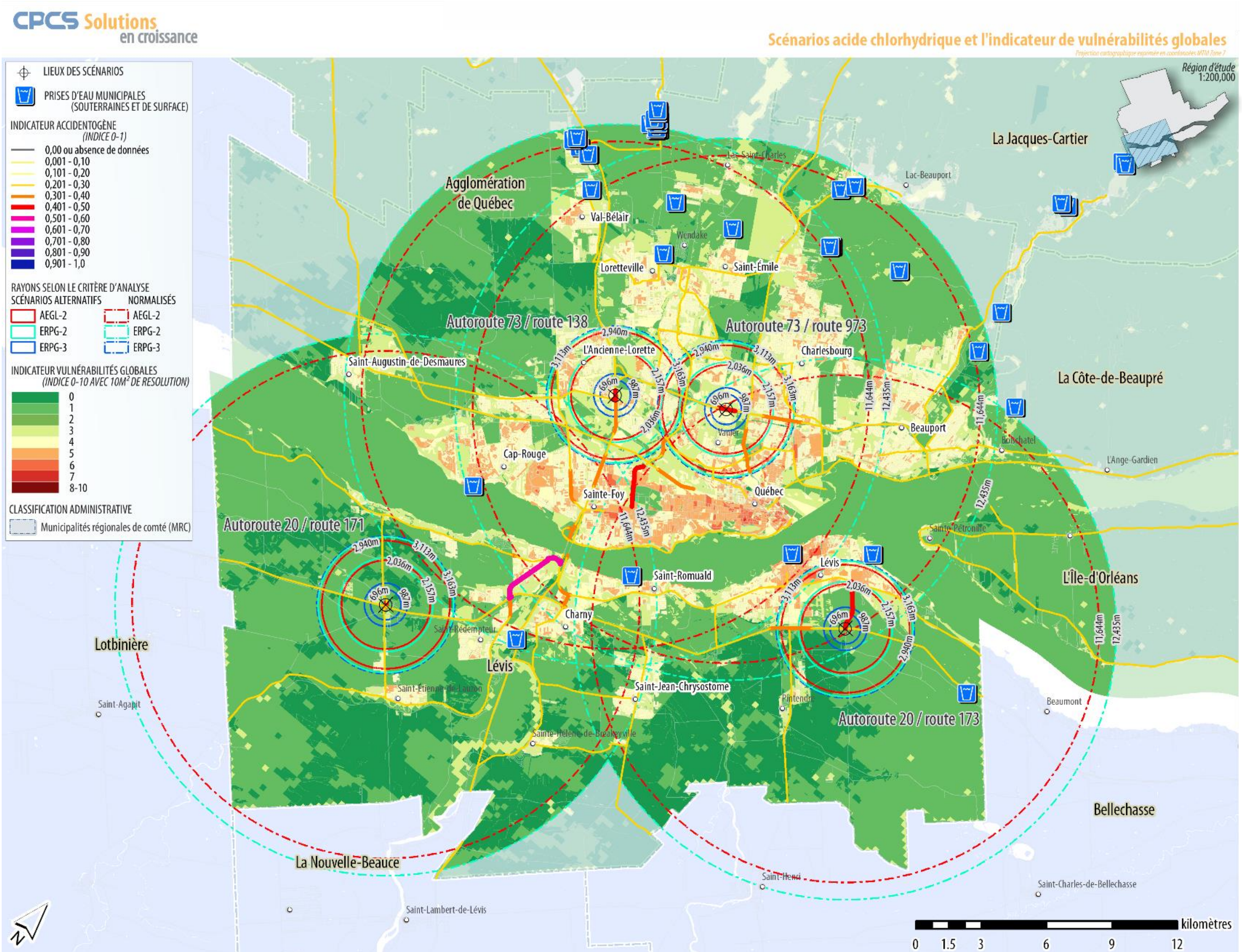
- Highway 20 and Route 171
- Highway 20 and Route 173
- Highway 73 between Highway 573 and Route 138
- Highway 73 between Highway 740 and Route 973

Figure 5-2: Consequences of the hydrochloric acid road accident scenario

Location/scenario/indicator	Analysis criterion		
	AEGL-2	ERPG-2	ERPG-3
Highway 20 and Route 171			
Alternatives			
Number of residents	3 587	4 145	564
Number of workers	2 544	2 726	498
Material value	$47 354 502	$52 569 974	$8 992 049
Number of educational institutions	-	-	-
Number of students	-	-	-
Number of health and social services facilities	-	-	-
Affected area (m^2)	27 154 400	30 441 200	3 059 800
Environmental vulnerability indicator	2.86	2.87	2.72
Overall vulnerability indicator	1.86	1.87	2.04
Worst case			
Number of residents	149 643	169 731	4 258
Number of workers	62 968	83 957	2 774
Material value	$3 794 039 940	$4 436 037 130	$53 685 306
Number of educational institutions	50	59	-
Number of students	21 655	25 220	-
Number of health and social services facilities	25	32	-
Affected area (m^2)	352 351 300	386 995 100	31 426 800
Environmental vulnerability indicator	3.32	3.30	2.87
Overall vulnerability indicator	2.16	2.17	1.86
Highway 20 and Route 173			
Alternatives			
Number of residents	12 154	14 894	191
Number of workers	9 435	11 506	102
Material value	$316 522 025	$383 414 808	$3 135 240
Number of educational institutions	4	6	-
Number of students	5 135	6 358	-
Number of health and social services facilities	6	8	-
Affected area (m^2)	27 153 700	30 442 900	3 061 100
Environmental vulnerability indicator	3.42	3.42	3.87
Overall vulnerability indicator	2.34	2.38	1.97
Worst case			
Number of residents	312 199	351 175	15 724
Number of workers	210 630	244 054	11 990
Material value	$11 775 290 600	$12 853 395 300	$404 408 777
Number of educational institutions	126	140	6
Number of students	52 566	58 378	6 358
Number of health and social services facilities	100	118	8
Affected area (m^2)	360 654 100	400 816 700	31 427 600
Environmental vulnerability indicator	3.39	3.35	3.29
Overall vulnerability indicator	2.38	2.40	2.39
Highway 73 between Highway 573 and Route 138			
Alternatives			
Number of residents	38 042	42 741	3 961
Number of workers	31 542	34 724	5 094
Material value	$978 920 934	$1 099 526 760	$123 278 091
Number of educational institutions	12	13	1
Number of students	5 468	6 536	354
Number of health and social services facilities	4	5	1
Affected area (m^2)	27 155 000	30 442 400	3 059 900
Environmental vulnerability indicator	2.78	2.75	2.92
Overall vulnerability indicator	3.26	3.26	3.30
Worst case			
Number of residents	523 981	557 766	44 184
Number of workers	313 548	329 339	35 653

Location/scenario/indicator	Analysis criterion		
	AEGL-2	ERPG-2	ERPG-3
Material value	$17 303 795 100	$18 037 495 400	$1 141 197 110
Number of educational institutions	196	208	13
Number of students	82 403	89 374	6 536
Number of health and social services facilities	136	147	5
Affected area (m²)	425 937 500	485 776 200	31 428 600
Environmental vulnerability indicator	3.20	3.22	2.66
Overall vulnerability indicator	2.75	2.69	3.20
Highway 73 between Highway 740 and Route 973			
Alternatives			
Number of residents	65 295	74 333	711
Number of workers	49 932	55 456	10 004
Material value	$1 879 808 290	$2 123 906 970	$22 928 517
Number of educational institutions	18	20	-
Number of students	5 707	6 852	-
Number of health and social services facilities	17	21	1
Affected area (m²)	27 153 400	30 443 300	3 060 200
Environmental vulnerability indicator	2.28	2.28	2.23
Overall vulnerability indicator	3.46	3.46	3.27
Worst case			
Number of residents	577 671	602 885	77 007
Number of workers	333 166	339 910	56 799
Material value	$18 863 764 100	$19 299 251 400	$2 195 236 770
Number of educational institutions	210	214	25
Number of students	90 308	91 743	8 478
Number of health and social services facilities	149	156	21
Affected area (m²)	425 943 300	485 776 400	31 427 600
Environmental vulnerability indicator	3.23	3.25	2.25
Overall vulnerability indicator	2.88	2.79	3.46

Figure 5-3: Impact radiuses for the hydrochloric acid road accident scenario



Scénarios acide chlorhydrique et l'indicateur de vulnérabilité globales	Hydrochloric acid scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Ammonia

The worst-case scenario involving ammonia entails the total volume of a 37,800-litre tank of ammonia spilling on the ground in 10 minutes. A portion of the compressed ammonia evaporates instantaneously at atmospheric temperature and the liquid portion forms a puddle on the ground and evaporates gradually.

In the alternative scenario, after a truck is overturned, a leak in the safety valve (4’’ in diameter) of the tank of ammonia occurs over a duration of 30 minutes. The leakage area corresponds to 1% of the surface are of the hole, which is 4’’ in diameter. The gaseous ammonia ejected forms a cloud of toxic gas.

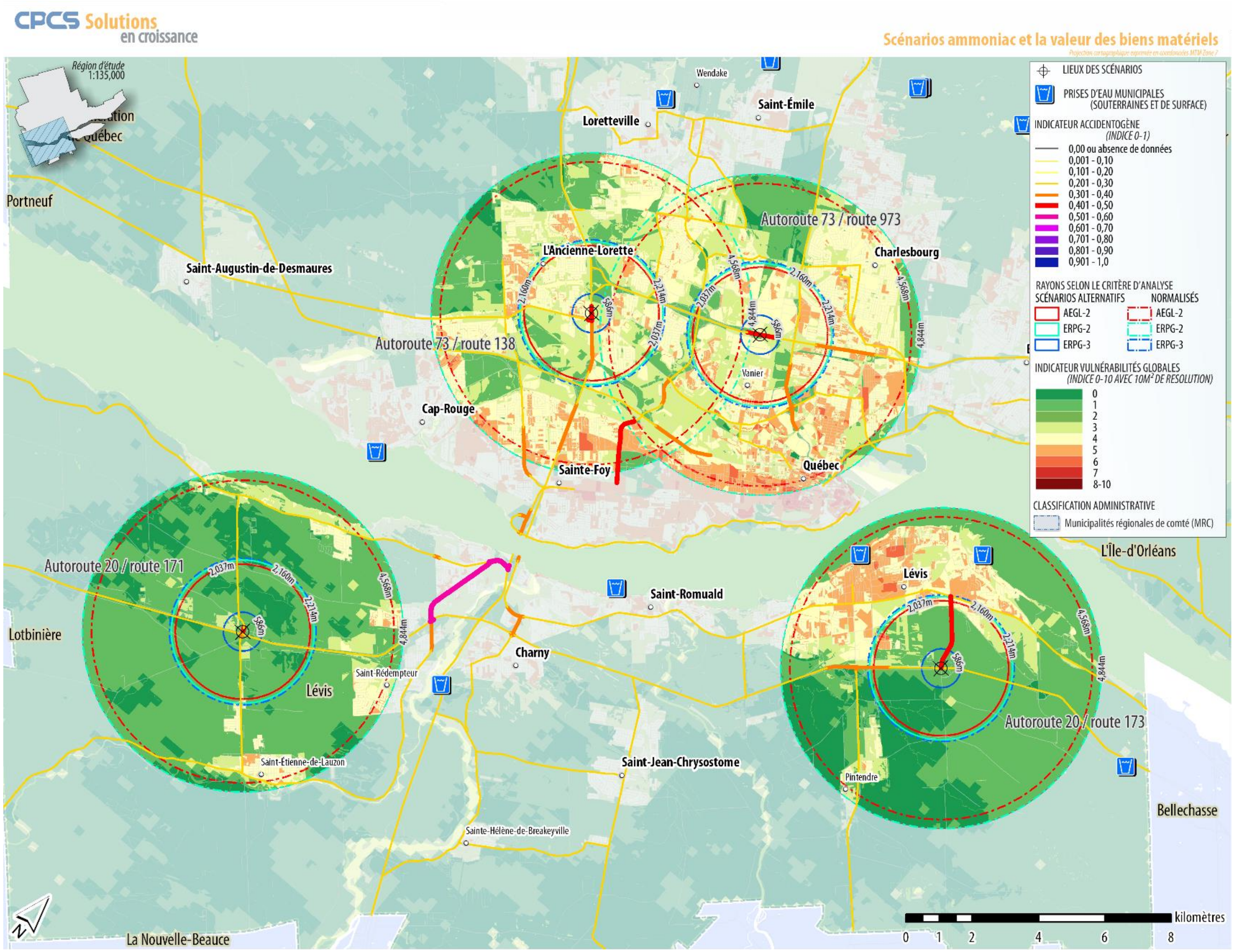
The scenarios are situated in the same locations as for the hydrochloric acid (Figure 5-5) and result in the consequences presented in Figure 5-4.

Figure 5-4: Consequences of the ammonia road accident scenario

Location/scenario/indicator	Analysis criterion		
	AEGL-2	ERPG-2	ERPG-3
Highway 20 and Route 171			
Alternatives			
Number of residents	1 457	1 631	278
Number of workers	1 608	1 720	204
Material value	$20 927 786	$24 199 209	$3 351 542
Number of educational institutions	-	-	-
Number of students	-	-	-
Number of health and social services facilities	-	-	-
Affected area (m²)	13 034 800	14 657 600	1 077 800
Environmental vulnerability indicator	2.74	2.76	2.58
Overall vulnerability indicator	1.81	1.83	2.01
Worst case			
Number of residents	17 396	20 843	1 708
Number of workers	5 393	5 862	1 770
Material value	$370 978 532	$451 932 983	$26 614 042
Number of educational institutions	6	6	-
Number of students	1 964	1 964	-
Number of health and social services facilities	-	-	-
Affected area (m²)	65 554 500	73 713 300	15 398 100
Environmental vulnerability indicator	2.98	3.01	2.77
Overall vulnerability indicator	2.01	2.01	1.83
Highway 20 and Route 173			
Alternatives			
Number of residents	2 468	3 381	41
Number of workers	1 587	2 121	4
Material value	$64 766 540	$91 537 908	$2 687 609
Number of educational institutions	-	-	-
Number of students	-	-	-
Number of health and social services facilities	-	-	-
Affected area (m²)	13 035 100	14 658 100	1 078 200
Environmental vulnerability indicator	3.42	3.42	3.85
Overall vulnerability indicator	2.00	2.05	1.97
Worst case			
Number of residents	43 542	45 467	3 813
Number of workers	23 990	24 639	2 436
Material value	$1 174 764 760	$1 217 104 960	$101 100 545

Location/scenario/indicator	Analysis criterion		
	AEGL-2	ERPG-2	ERPG-3
Number of educational institutions	15	16	1
Number of students	10 188	10 568	3 125
Number of health and social services facilities	18	18	-
Affected area (m²)	65 554 000	73 710 200	15 396 500
Environmental vulnerability indicator	3.42	3.49	3.41
Overall vulnerability indicator	2.39	2.34	2.08
Highway 73 between Highway 573 and Route 138			
Alternatives			
Number of residents	18 241	20 682	1 288
Number of workers	15 797	17 430	1 969
Material value	$467 552 731	$516 520 274	$26 736 047
Number of educational institutions	5	6	-
Number of students	2 221	2 490	-
Number of health and social services facilities	4	4	1
Affected area (m²)	13 036 000	14 656 100	1 078 700
Environmental vulnerability indicator	2.78	2.75	2.83
Overall vulnerability indicator	3.26	3.26	3.26
Worst case			
Number of residents	99 345	112 939	21 795
Number of workers	76 996	90 162	18 208
Material value	$2 826 404 220	$3 190 943 560	$537 958 150
Number of educational institutions	31	38	6
Number of students	15 177	18 614	2 490
Number of health and social services facilities	12	15	4
Affected area (m²)	65 555 000	73 712 700	15 398 100
Environmental vulnerability indicator	2.57	2.57	2.74
Overall vulnerability indicator	3.16	3.16	3.26
Highway 73 between Highway 740 and Route 973			
Alternatives			
Number of residents	27 951	31 794	251
Number of workers	28 501	31 236	3 347
Material value	$758 691 361	$872 511 907	$10 146 754
Number of educational institutions	2	5	-
Number of students	217	1 011	-
Number of health and social services facilities	2	5	-
Affected area (m²)	13 035 200	14 655 700	1 079 000
Environmental vulnerability indicator	2.28	2.28	2.06
Overall vulnerability indicator	3.45	3.45	3.19
Worst case			
Number of residents	173 965	197 669	33 480
Number of workers	115 677	132 207	32 396
Material value	$5 678 316 740	$6 750 807 490	$924 861 412
Number of educational institutions	71	83	6
Number of students	27 304	31 057	1 244
Number of health and social services facilities	50	60	5
Affected area (m²)	65 552 600	73 714 000	15 399 900
Environmental vulnerability indicator	2.30	2.33	2.28
Overall vulnerability indicator	3.46	3.45	3.45

Figure 5-5: Impact radiuses for the ammonia road accident scenario



Scénarios ammoniac et la valeur des biens matériels	Ammonia scenarios and the value of physical goods
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Hydrogen fluoride

The worst-case scenario concerns the total contents of a 17,000-litre tank of hydrogen fluoride spilling on the ground in 10 minutes. The liquefied hydrogen fluoride forms a puddle 1 cm deep and volatizes in the air (the association phenomenon is not taken into consideration in this study). The hydrogen fluoride volatizes from this surface.

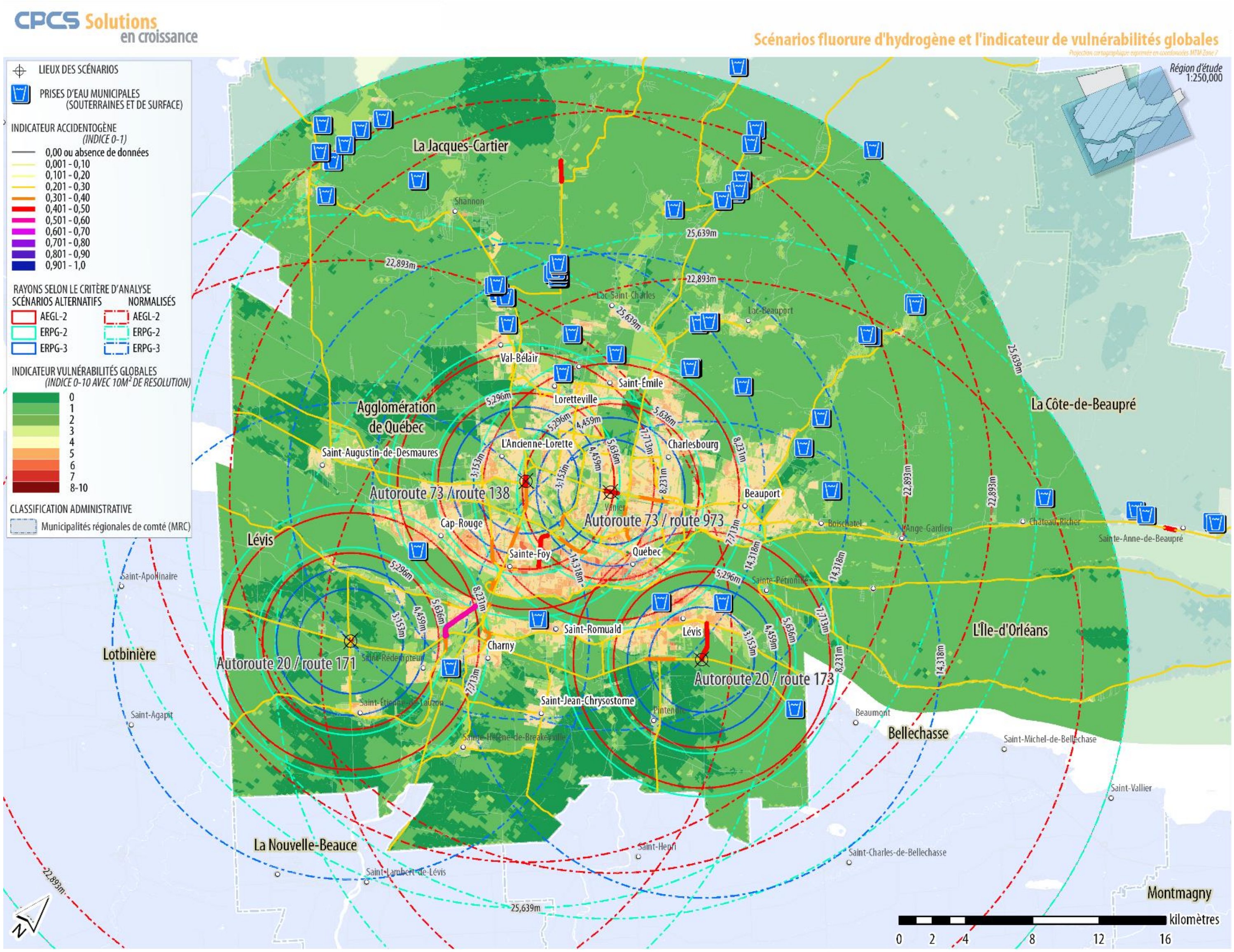
Two variations of the alternative scenario have been produced. In the first, after a truck is overturned on a city road, the shell of a 17,000-litre tank of hydrogen fluoride is ruptured. Due to gravity, the hydrogen fluoride leaks from the tank, spreads across the ground and moves toward the closest manhole. The evaporating surface is estimated to be 100 m^2 (1 m in width by 100 m in length) (the association phenomenon is not taken into consideration in this study). The hydrogen fluoride volatizes on this surface. In the second, due to gravity, the product leaks from the tank, spreads across the grounds and move toward the ditch. The evaporating surface is estimated to be 200 m^2 (2 m in width by 100 m in length). In Figure 5-6, the alternative scenario with the largest impact radius is selected. The scenarios are situated in the same locations as for the hydrochloric acid (Figure 5-7) and result in the consequences presented in following figure.

Figure 5-6: Consequences of the hydrogen fluoride road accident scenario

Location/scenario/indicator	Analysis criterion		
	AEGL-2	ERPG-2	ERPG-3
Highway 20 and Route 171			
Alternatives			
Number of residents	48 662	57 295	15 980
Number of workers	12 748	15 430	5 151
Material value	$1 056 227 370	$1 228 743 960	$328 750 659
Number of educational institutions	20	23	5
Number of students	9 140	9 829	1 503
Number of health and social services facilities	3	7	-
Affected area (m^2)	185 399 800	208 580 900	62 463 500
Environmental vulnerability indicator	3.30	3.33	2.97
Overall vulnerability indicator	2.00	2.03	2.00
Worst case			
Number of residents	575 033	645 602	211 829
Number of workers	339 009	356 272	123 195
Material value	$18 280 017 600	$19 868 443 500	$5 870 409 350
Number of educational institutions	212	229	76
Number of students	91 037	99 054	32 496
Number of health and social services facilities	143	152	45
Affected area (m^2)	867 150 900	1 016 035 400	471 531 700
Environmental vulnerability indicator	3.02	3.13	3.18
Overall vulnerability indicator	2.18	2.20	2.15
Highway 20 and Route 173			
Alternatives			
Number of residents	97 070	127 646	42 580
Number of workers	92 303	105 433	23 793
Material value	$4 944 869 640	$6 054 828 450	$1 152 969 650
Number of educational institutions	40	57	15
Number of students	18 722	25 043	10 188
Number of health and social services facilities	31	41	18
Affected area (m^2)	182 179 700	205 246 000	62 464 200

Location/scenario/indicator	Analysis criterion		
	AEGL-2	ERPG-2	ERPG-3
Environmental vulnerability indicator	3.67	3.68	3.39
Overall vulnerability indicator	2.27	2.24	2.41
Worst case			
Number of residents	688 632	711 778	439 263
Number of workers	361 055	366 301	296 357
Material value	$20 825 463 500	$21 110 470 700	$15 245 139 300
Number of educational institutions	242	248	175
Number of students	103 907	106 180	74 678
Number of health and social services facilities	164	164	133
Affected area (m²)	1 130 782 300	1 375 369 500	507 404 200
Environmental vulnerability indicator	3.34	3.34	3.28
Overall vulnerability indicator	2.25	2.18	2.40
Highway 73 between Highway 573 and Route 138			
Alternatives			
Number of residents	303 694	345 927	94 752
Number of workers	196 333	215 163	71 978
Material value	$9 512 853 480	$11 297 271 100	$2 699 029 070
Number of educational institutions	110	130	30
Number of students	47 828	53 671	14 826
Number of health and social services facilities	74	81	12
Affected area (m²)	186 889 500	212 838 700	62 461 700
Environmental vulnerability indicator	2.79	2.86	2.66
Overall vulnerability indicator	3.16	3.17	3.21
Worst case			
Number of residents	727 803	736 441	626 388
Number of workers	371 111	372 555	350 426
Material value	$21 287 082 200	$21 371 356 000	$19 617 686 900
Number of educational institutions	253	256	229
Number of students	107 386	108 709	99 617
Number of health and social services facilities	165	165	156
Affected area (m²)	1 481 607 400	1 699 563 300	644 039 500
Environmental vulnerability indicator	3.30	3.33	3.23
Overall vulnerability indicator	2.14	2.10	2.54
Highway 73 between Highway 740 and Route 973			
Alternatives			
Number of residents	373 901	407 149	164 205
Number of workers	268 331	280 648	108 921
Material value	$13 903 630 900	$14 896 849 000	$5 196 189 780
Number of educational institutions	151	164	64
Number of students	63 804	69 314	25 203
Number of health and social services facilities	109	115	44
Affected area (m²)	186 892 300	212 838 100	62 460 300
Environmental vulnerability indicator	2.94	3.03	2.29
Overall vulnerability indicator	3.43	3.42	3.46
Worst case			
Number of residents	729 037	737 214	652 481
Number of workers	370 975	372 504	350 428
Material value	$21 275 316 700	$21 312 345 600	$20 225 270 100
Number of educational institutions	252	254	232
Number of students	107 145	108 307	101 385
Number of health and social services facilities	164	165	159
Affected area (m²)	1 547 955 900	1 810 557 200	644 037 000
Environmental vulnerability indicator	3.34	3.35	3.29
Overall vulnerability indicator	2.13	2.08	2.60

Figure 5-7: Impact radiuses of the hydrogen fluoride road accident scenario



Scénarios fluorure d'hydrogène et l'indicateur de vulnérabilité globales	Hydrogen fluoride scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Hydrogen peroxide

The worst-case scenario involves the total volume of a 12,500-litre tank of hydrogen peroxide spilling on the ground in 10 minutes. The hydrogen peroxide forms a puddle 1 cm deep and gradually evaporates into the air.

Two variations of the alternative scenario have also been created. In the first, after a truck is overturned on a city road, the shell of a 12,500-litre tank of hydrogen peroxide (70%) is ruptured, forming an opening which is 6’’ in diameter. Due to gravity, the peroxide leaks from the tank, spreads across the grounds and moves toward the nearest manhole. The evaporating surface is estimated to be 100 m^2 (1 m in width by 100 m in length). The hydrogen peroxide volatizes on this surface. In the second, due to gravity, the product leaks from the tank, spreads across the ground and moves toward the ditch. The evaporating surface is estimated to be 200 m^2 (2 m in width by 100 m in length). The hydrogen peroxide volatizes on this surface. In Figure 5-6, the alternative scenario with the largest impact radius is selected. The scenarios are situated in the same locations as for the hydrochloric acid (Figure 5-9) and result in the consequences presented in following figure.

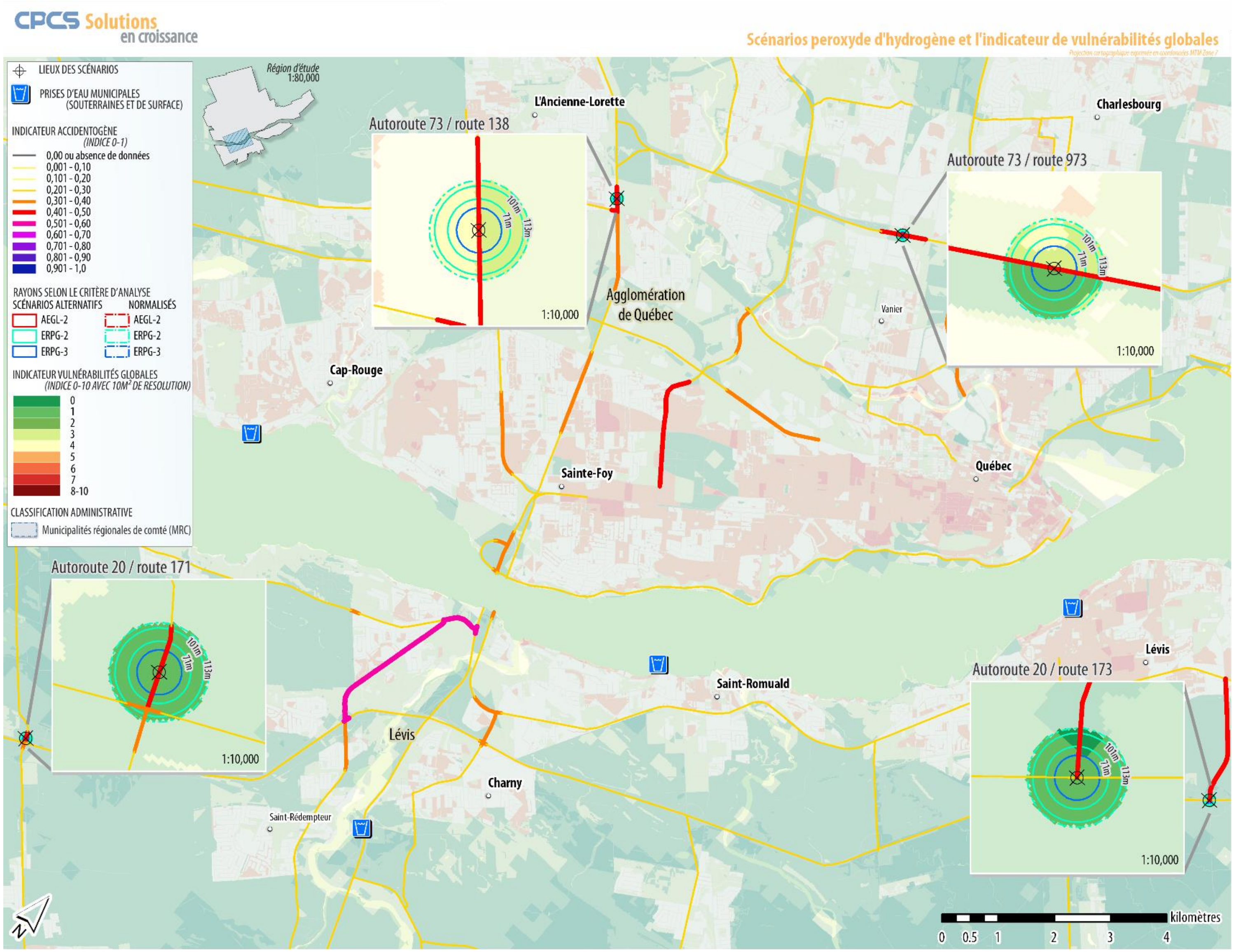
Figure 5-8: Consequences of the hydrogen peroxide road accident scenario

Location/scenario/indicator	Analysis criterion		
	AEGL-2*	ERPG-2	ERPG-3
Highway 20 and Route 171			
Alternatives			
Number of residents		-	-
Number of workers		1	-
Material value		$16 671	$217
Number of educational institutions		-	-
Number of students		-	-
Number of health and social services facilities		-	-
Affected area (m²)		32 100	8 200
Environmental vulnerability indicator		2.22	2.28
Overall vulnerability indicator		1.66	1.71
Worst case			
Number of residents		2	8
Number of workers		3	-
Material value		$29 532	$95 068
Number of educational institutions		-	-
Number of students		-	-
Number of health and social services facilities		-	-
Affected area (m²)		39 800	8 200
Environmental vulnerability indicator		2.19	2.28
Overall vulnerability indicator		1.65	1.71
Highway 20 and Route 173			
Alternatives			
Number of residents		-	-
Number of workers		-	-
Material value		$270	$87
Number of educational institutions		-	-
Number of students		-	-
Number of health and social services facilities		-	-
Affected area (m²)		32 200	8 300
Environmental vulnerability indicator		3.97	4.00

Location/scenario/indicator	Analysis criterion		
	AEGL-2*	ERPG-2	ERPG-3
Overall vulnerability indicator		1.97	2.00
Worst case			
Number of residents		-	-
Number of workers		-	-
Material value		$328	$87
Number of educational institutions		-	-
Number of students		-	-
Number of health and social services facilities		-	-
Affected area (m²)		39 400	8 300
Environmental vulnerability indicator		3.90	4.00
Overall vulnerability indicator		1.90	2.00
Highway 73 between Highway 573 and Route 138			
Alternatives			
Number of residents		26	8
Number of workers		69	17
Material value		$371 167	$94 851
Number of educational institutions		-	-
Number of students		-	-
Number of health and social services facilities		-	-
Affected area (m²)		32 200	8 200
Environmental vulnerability indicator		2.36	2.15
Overall vulnerability indicator		3.32	3.15
Worst case			
Number of residents		32	8
Number of workers		87	17
Material value		$464 456	$95 068
Number of educational institutions		-	-
Number of students		-	-
Number of health and social services facilities		-	-
Affected area (m²)		40 100	8 200
Environmental vulnerability indicator		2.37	2.28
Overall vulnerability indicator		3.34	1.71
Highway 73 between Highway 740 and Route 973			
Alternatives			
Number of residents		-	-
Number of workers		105	31
Material value		$67 977	$16 854
Number of educational institutions		-	-
Number of students		-	-
Number of health and social services facilities		-	-
Affected area (m²)		31 800	8 200
Environmental vulnerability indicator		3.10	3.01
Overall vulnerability indicator		2.59	2.51
Worst case			
Number of residents		1	-
Number of workers		130	31
Material value		$87 160	$16 854
Number of educational institutions		-	-
Number of students		-	-
Number of health and social services facilities		-	-
Affected area (m²)		40 100	8 200
Environmental vulnerability indicator		3.02	3.01
Overall vulnerability indicator		2.55	2.51

*Impact radius insignificant

Figure 5-9: Impact radiuses for the hydrogen peroxide road accident scenario



Scénarios peroxyde d'hydrogène et l'indicateur de vulnérabilité globales	Hydrogen peroxide scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Rail accidents

Chlorine

The worst-case scenario concerns the total volume of a 68,000-litre car transporting chlorine spilling on the ground in 10 minutes. One portion of the compressed chlorine evaporates instantaneously at atmospheric pressure and the liquid portion forms a puddle on the ground and evaporates gradually.

The alternative scenario concerns a leak in a 1'' valve on a tank car of chlorine. The leakage area corresponds to 1% of the area of the valve. The gaseous chlorine ejected forms a cloud of toxic gas.

The locations of these scenarios are illustrated in Figure 5-11, and concern the following locations:

- The intersection of the Bridge, Montmagny and Drummond subdivisions in the Joffre marshalling yard.
- In the Bridge subdivision in Limoilou
- In the Lévis subdivision in the Valero facilities sector.

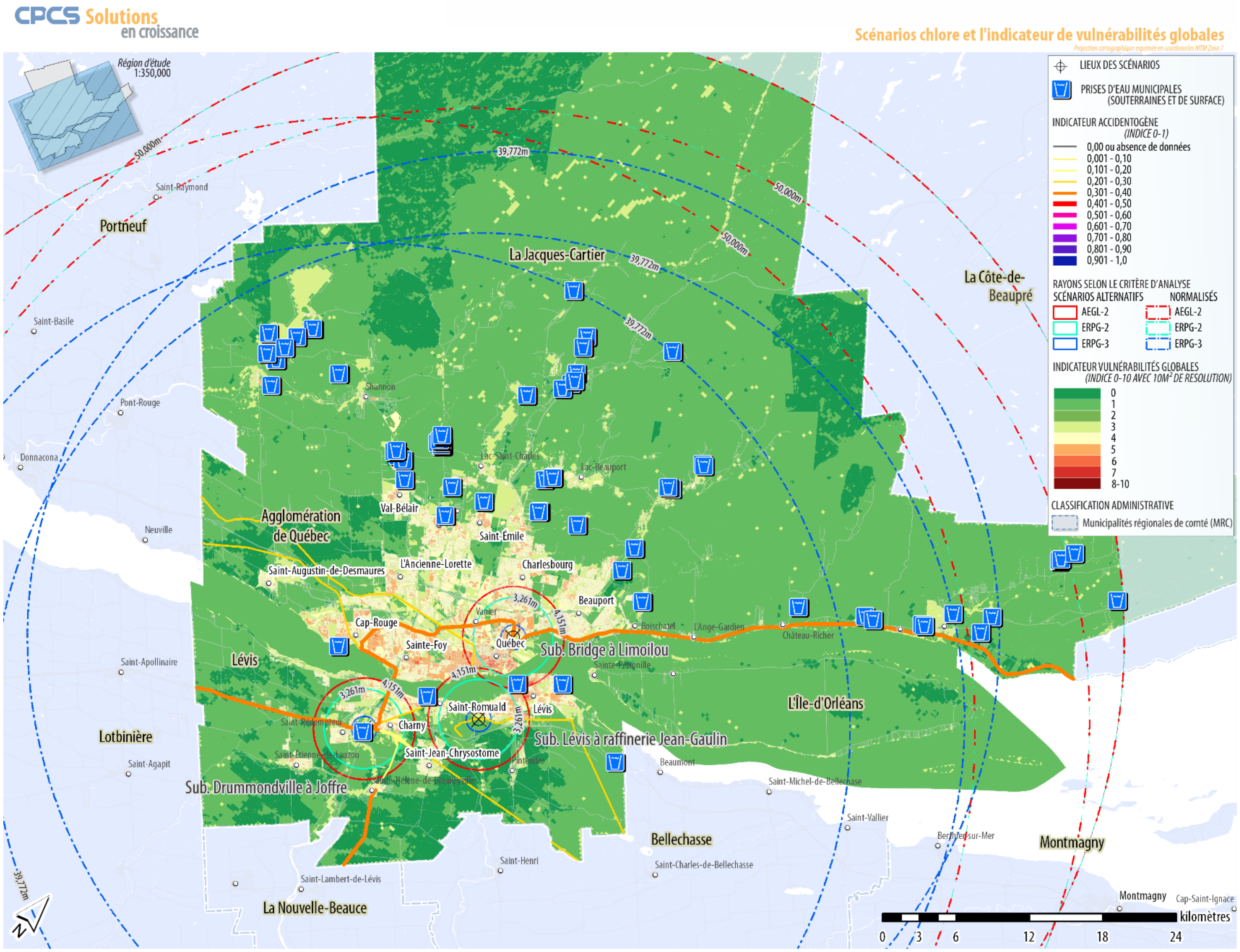
The outlines of the potential consequences of these accidents are presented in the figure below.

Figure 5-10: Consequences of the chlorine rail accident scenario

Location/scenario/indicator	Analysis criterion		
	AEGL-2	ERPG-2	ERPG-3
Intersection of Bridge/Montmagny/Drummond (Joffre yard)			
Alternatives			
Number of residents	34 649	27 400	2 559
Number of workers	11 913	8 989	776
Material value	$743 320 440	$641 187 379	$83 089 253
Number of educational institutions	15	14	3
Number of students	6 035	5 982	760
Number of health and social services facilities	8	6	-
Affected area (m²)	54 129 800	33 406 300	3 248 200
Environmental vulnerability indicator	3.24	3.29	3.24
Overall vulnerability indicator	2.47	2.65	2.60
Worst case			
Number of residents	748 732	748 732	743 953
Number of workers	376 126	376 126	374 004
Material value	$21 425 270 800	$21 425 270 800	$21 413 112 800
Number of educational institutions	260	260	257
Number of students	110 567	110 567	108 997
Number of health and social services facilities	168	168	166
Affected area (m²)	2 867 227 400	2 867 227 400	2 101 452 700
Environmental vulnerability indicator	3.44	3.44	3.39
Overall vulnerability indicator	1.91	1.91	2.05
Bridge subdivision in Limoilou			
Alternatives			
Number of residents	155 923	118 767	15 708

Location/scenario/indicator	Analysis criterion		
	AEGL-2	ERPG-2	ERPG-3
Number of workers	128 577	98 585	8 320
Material value	$7 293 925 420	$5 912 864 310	$669 922 051
Number of educational institutions	72	54	10
Number of students	26 661	17 802	3 224
Number of health and social services facilities	61	48	8
Affected area (m²)	54 129 200	33 405 300	3 248 300
Environmental vulnerability indicator	3.16	2.97	1.88
Overall vulnerability indicator	3.42	3.52	3.80
Worst case			
Number of residents	749 373	749 373	748 854
Number of workers	378 485	378 485	375 513
Material value	$21 426 143 100	$21 426 143 100	$21 425 918 200
Number of educational institutions	262	262	260
Number of students	111 012	111 012	110 567
Number of health and social services facilities	169	169	168
Affected area (m²)	3 469 697 500	3 469 697 500	2 940 158 500
Environmental vulnerability indicator	3.49	3.49	3.45
Overall vulnerability indicator	1.85	1.85	1.91
Lévis subdivision at Valero			
Alternatives			
Number of residents	33 544	20 623	3 186
Number of workers	19 586	8 923	1 020
Material value	$836 408 869	$504 304 959	$66 382 270
Number of educational institutions	11	4	-
Number of students	7 226	1 143	-
Number of health and social services facilities	7	1	1
Affected area (m²)	54 130 400	33 406 600	3 249 600
Environmental vulnerability indicator	3.29	3.29	2.52
Overall vulnerability indicator	2.31	2.31	2.51
Worst case			
Number of residents	749 057	749 057	746 997
Number of workers	376 543	376 543	374 442
Material value	$21 426 093 500	$21 426 093 500	$21 423 952 700
Number of educational institutions	262	262	260
Number of students	111 012	111 012	110 567
Number of health and social services facilities	168	168	168
Affected area (m²)	3 172 481 100	3 172 481 100	2 530 062 100
Environmental vulnerability indicator	3.48	3.48	3.43
Overall vulnerability indicator	1.88	1.88	1.98

Figure 5-11: Impact radiuses for the chlorine rail accident scenario



Scénarios chlore et l'indicateur de vulnérabilité globales	Chlorine scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Sulfur dioxide

The worst-case scenario involves the total volume of a 90,000-litre car of sulfur dioxide spilling on the ground in 10 minutes. The compressed sulfur dioxide evaporates instantaneously in the atmospheric pressure.

The alternative accident scenario concerns a leak in a 1'' valve of a tank car of sulfur dioxide, which corresponds to a leakage area of to 1% of the area of the valve. The gaseous sulfur dioxide ejected forms a cloud of toxic gas.

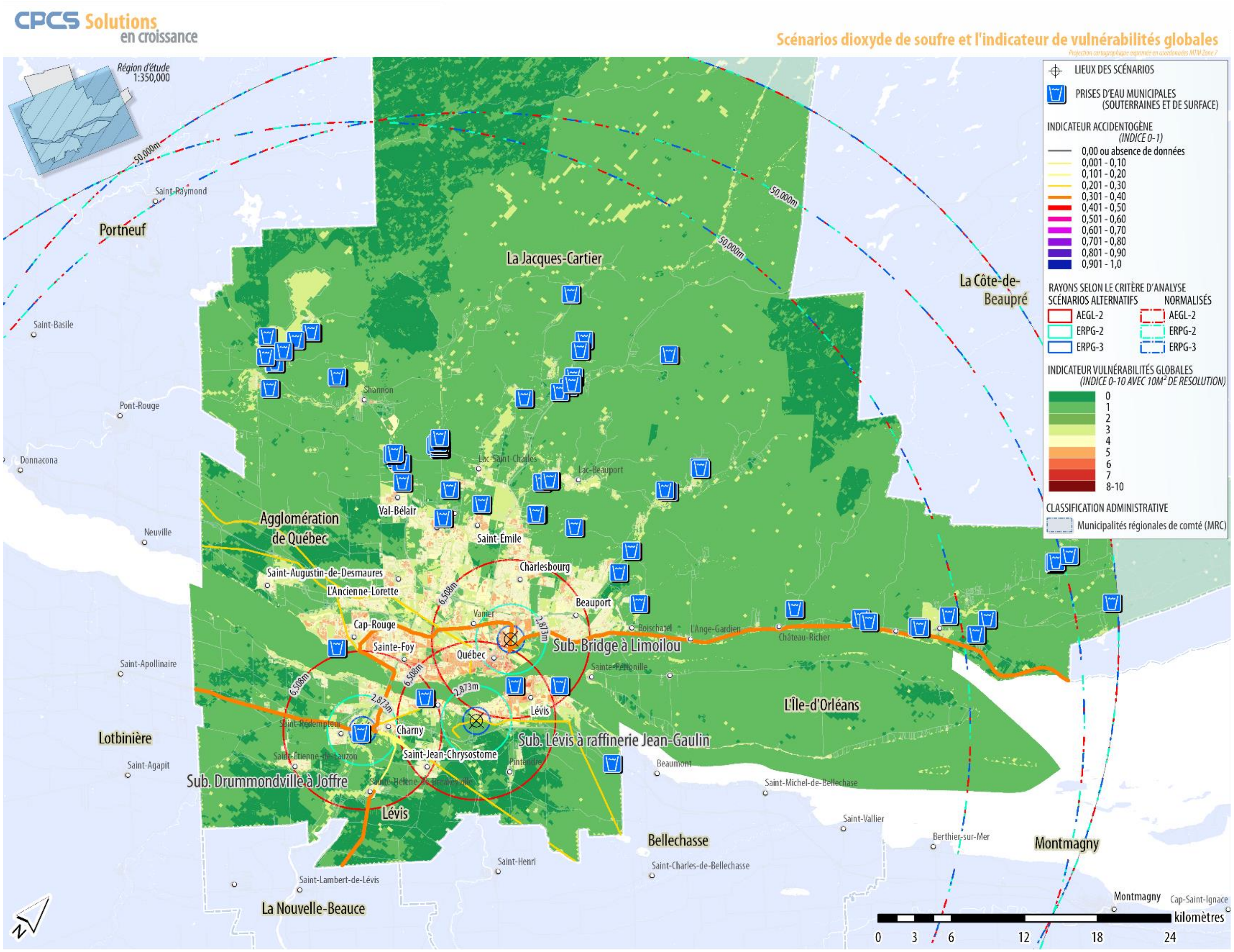
The outlines of the potential consequences of these accidents are presented Figure 5-12 and illustrated in Figure 5-13.

Figure 5-12: Consequences of the sulfur dioxide rail accident scenario

Location/scenario/indicator	Analysis criterion		
	AEGL-2*	ERPG-2	ERPG-3
Intersection of Bridge/Montmagny/Drummond (Joffre yard)			
Alternatives			
Number of residents	78 769	24 332	3 207
Number of workers	25 378	7 401	1 000
Material value	$1 851 149 910	$587 186 078	$106 788 064
Number of educational institutions	31	10	3
Number of students	11 343	4 322	760
Number of health and social services facilities	17	6	-
Affected area (m²)	133 055 000	25 930 100	3 829 100
Environmental vulnerability indicator	3.30	3.25	3.17
Overall vulnerability indicator	2.34	2.72	2.62
Worst case	748732	748732	748732
Number of residents	376 126	376 126	376 126
Number of workers	21 425 270 800	21 425 270 800	21 425 270 800
Material value	$260	$260	$260
Number of educational institutions	110 567	110 567	110 567
Number of students	168	168	168
Number of health and social services facilities	2 867 227 400	2 867 227 400	2 867 227 400
Affected area (m²)	3	3	3
Environmental vulnerability indicator	1.91	1.91	1.91
Overall vulnerability indicator			
Bridge subdivision in Limoilou			
Alternatives			
Number of residents	279 594	96 134	18 225
Number of workers	206 796	88 579	9 931
Material value	$11 080 222 300	$4 969 175 120	$758 450 142
Number of educational institutions	117	48	10
Number of students	49 476	16 241	3 224
Number of health and social services facilities	99	41	9
Affected area (m²)	133 055 400	25 929 700	3 829 600
Environmental vulnerability indicator	3.30	2.80	1.98
Overall vulnerability indicator	3.30	3.60	3.78
Worst case			
Number of residents	749 373	749 373	749 373
Number of workers	378 485	378 485	378 485
Material value	$21 426 143 100	$21 426 143 100	$21 426 143 100
Number of educational institutions	262	262	262
Number of students	111 012	111 012	111 012
Number of health and social services facilities	169	169	169

Location/scenario/indicator	Analysis criterion		
	AEGL-2*	ERPG-2	ERPG-3
Affected area (m²)	3 469 697 500	3 469 697 500	3 469 697 500
Environmental vulnerability indicator	3.49	3.49	3.49
Overall vulnerability indicator	1.85	1.85	1.85
Lévis subdivision at Valero			
Alternatives			
Number of residents	150 114	16 902	3 741
Number of workers	128 154	6 263	1 163
Material value	$7 265 719 520	$416 783 537	$85 127 389
Number of educational institutions	73	3	1
Number of students	33 094	843	287
Number of health and social services facilities	53	1	1
Affected area (m²)	133 059 700	25 929 600	3 827 900
Environmental vulnerability indicator	3.05	3.21	2.51
Overall vulnerability indicator	2.52	2.33	2.52
Worst case			
Number of residents	749 057	749 057	749 057
Number of workers	376 543	376 543	376 543
Material value	$21 426 093 500	$21 426 093 500	$21 426 093 500
Number of educational institutions	262	262	262
Number of students	111 012	111 012	111 012
Number of health and social services facilities	168	168	168
Affected area (m²)	3 172 481 100	3 172 481 100	3 172 481 100
Environmental vulnerability indicator	3.48	3.48	3.48
Overall vulnerability indicator	1.88	1.88	1.88

Figure 5-13: Impact radiuses for the sulfur dioxide rail accident scenario



Scénarios dioxyde de soufre et l'indicateur de vulnérabilité globales	Sulfur dioxide scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Vinyl acetate monomer

In the worst-case scenario, the total volume of a 100,300-litre car transporting vinyl acetate monomer is spilled on the ground in 10 minutes. The vinyl acetate monomer forms a puddle on the ground and evaporates gradually.

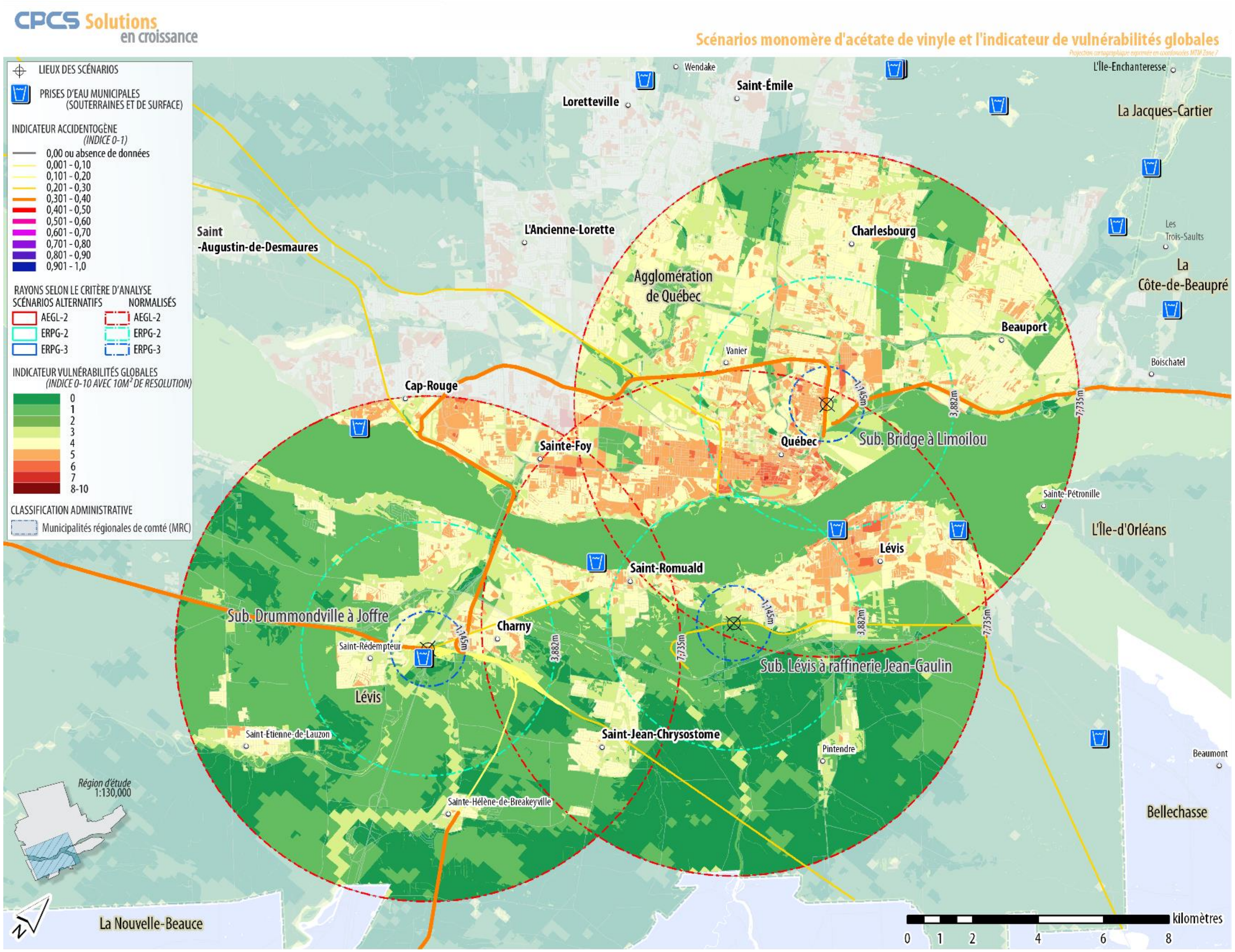
The alternative accident scenario concerns a leak in a 1'' valve of a tank car of vinyl acetate monomer. The leakage area corresponds to 1% of the area of the valve. The vinyl acetate monomer spreads across the ground and forms a 1 cm puddle then evaporates gradually. It should be noted that in the alternative scenarios, the impact radius is non-existent.

The outlines of the potential consequences of these accidents are presented Figure 5-14 and illustrated in Figure 5-15.

Figure 5-14: Consequences of the vinyl acetate monomer rail accident scenario

Location/scenario/indicator	Analysis criterion		
	AEGL-2*	ERPG-2	ERPG-3
Intersection of Bridge/Montmagny/Drummond (Joffre yard)			
Worst case			
Number of residents	116 471	32 323	3 539
Number of workers	57 764	11 073	1 123
Material value	$3 087 085 630	$716 057 403	$120 272 485
Number of educational institutions	46	15	3
Number of students	19 491	6 035	760
Number of health and social services facilities	22	8	-
Affected area (m²)	187 573 700	47 341 500	4 118 400
Environmental vulnerability indicator	3.23	3.25	3.14
Overall vulnerability indicator	2.34	2.51	2.63
Bridge subdivision in Limoilou			
Worst case			
Number of residents	341 299	145 282	19 393
Number of workers	242 597	116 891	11 001
Material value	$12 889 244 800	$6 877 695 280	$799 138 776
Number of educational institutions	137	65	10
Number of students	59 501	22 792	3 224
Number of health and social services facilities	106	57	9
Affected area (m²)	187 959 100	47 340 800	4 118 600
Environmental vulnerability indicator	3.32	3.11	2.03
Overall vulnerability indicator	3.17	3.43	3.78
Lévis subdivision at Valero			
Worst case			
Number of residents	204 422	28 599	4 021
Number of workers	182 177	14 451	1 230
Material value	$9 071 644 090	$708 909 006	$94 330 369
Number of educational institutions	102	9	1
Number of students	43 680	5 957	287
Number of health and social services facilities	76	6	1
Affected area (m²)	187 798 000	47 341 100	4 117 800
Environmental vulnerability indicator	3.00	3.32	2.50
Overall vulnerability indicator	2.51	2.29	2.53

Figure 5-15: Impact radiuses for the vinyl acetate monomer rail accident scenario



Scénarios monomère d'acétate de vinyle et l'indicateur de vulnérabilité globales	Vinyl acetate monomer acid scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Scenarios related to flammable substance accidents

Road accidents

Gasoline

There are two different variations of worst-case scenarios for road accidents involving gasoline. In the first, the total volume of a Super B-Train consisting of 55,000 litres of gasoline takes place over 10 minutes. The gasoline spreads across the ground and forms a puddle 1 cm deep, comes into contact with a source of ignition and the puddle catches fire. In the second, the tanks are instead heated by an external source and the pressure increases until there is a rupture in the shell, which causes the sudden release of the entire quantity of pressurized gasoline from the tanks and an explosion. In Figure 5-16, the consequences are indicated under the 1 psi overpressure endpoint concerning the explosion and the fire-ball, whereas the other analysis criterion concern the fire.

Two variations of the alternative scenarios were also developed. In the first, a truck transporting gasoline in the city is overturned and causes the shell of a compartment of the tanker to rupture, creating an opening with a 6’’ diameter. Due to gravity, the gasoline leaks from the tank, spreads across the ground and moves toward the closest manhole. The evaporating surface is estimated to be 100 m^2 (1 m in width by 100 m in length). The spilled gasoline comes into contact with a source of ignition and the puddle catches fire. The second assumes instead that the gasoline spreads across the ground and moves toward the ditch and the evaporating surface is estimated to be 200 m^2 (2 m in width by 100 m in length). The spilled gasoline comes into contact with a source of ignition and the puddle catches fire. Like the worst-case scenario, the consequences indicated in Figure 5-16 are those of the accident which creates the largest impact radius (gasoline toward the ditches).

These accidents are situated in the same locations as the previous road accidents (Figure 5-17).

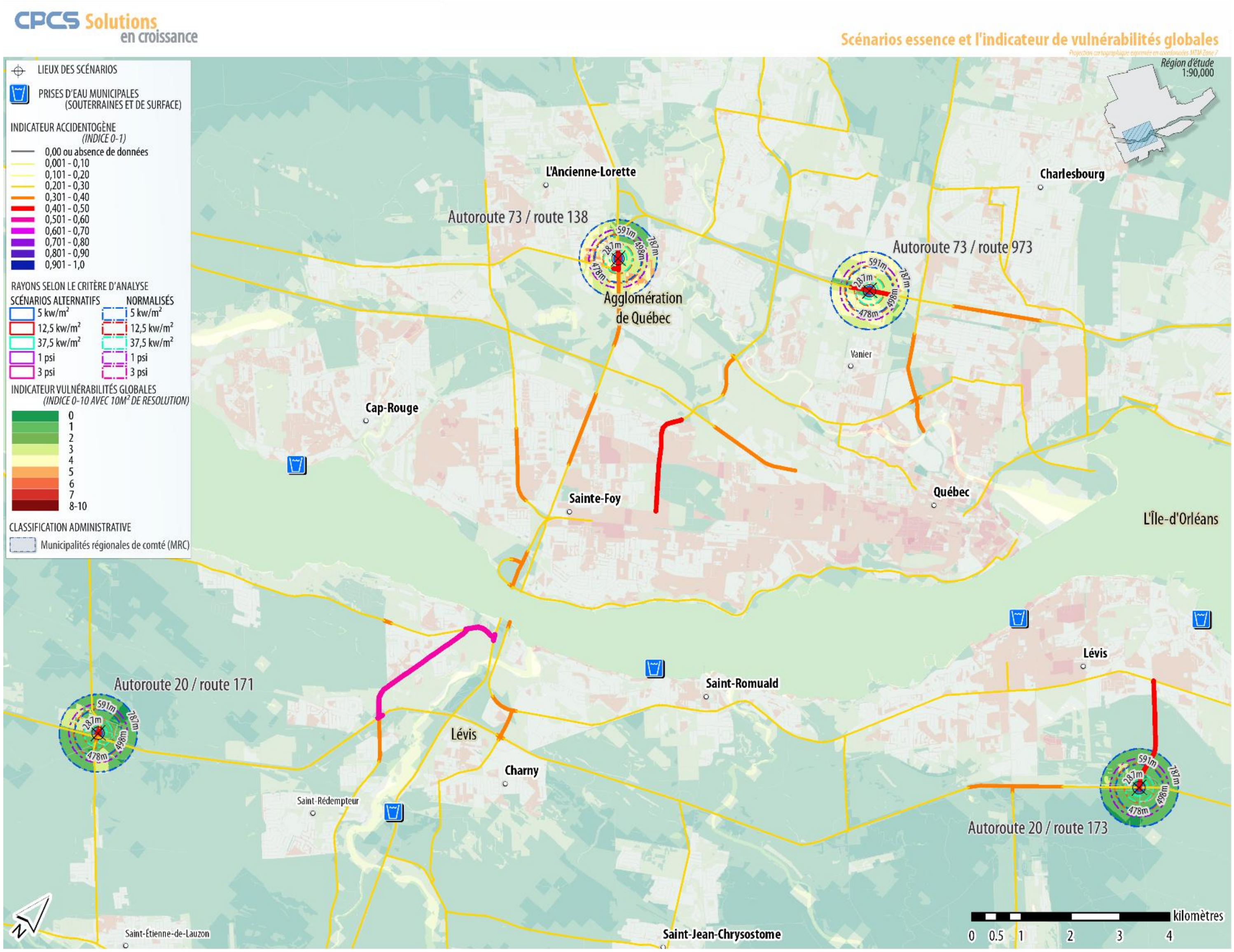
Figure 5-16: Consequences of the gasoline road accident scenario

Location/scenario/indicator	Analysis criterion			
	1psi	5 kW/ m^2	12.5 kW/ m^2	37.5 kW/ m^2
Highway 20 and Route 171				
Alternatives				
Number of residents		-	-	-
Number of workers		1	-	-
Material value		$7 439	$284	$85
Number of educational institutions		-	-	-
Number of students		-	-	-
Number of health and social services facilities		-	-	-
Affected area (m^2)		26 200	10 700	3 200
Environmental vulnerability indicator		2.19	2.31	2.39
Overall vulnerability indicator		1.69	1.74	1.72
Worst case				
Number of residents	283	436	208	73
Number of workers	207	346	149	48
Material value	$3 425 568	$7 407 417	$2 259 717	$444 562
Number of educational institutions	-	-	-	-

Location/scenario/indicator	Analysis criterion			
	1psi	5 kW/ m²	12.5 kW/ m²	37.5 kW/ m²
Number of students	-	-	-	-
Number of health and social services facilities	-	-	-	-
Affected area (m²)	1 097 700	1 945 300	779 700	258 900
Environmental vulnerability indicator	2.59	2.71	2.45	2.27
Overall vulnerability indicator	2.01	2.03	1.98	1.87
Highway 20 and Route 173				
Alternatives				
Number of residents		-	-	-
Number of workers		-	-	-
Material value		$225	$107	$44
Number of educational institutions		-	-	-
Number of students		-	-	-
Number of health and social services facilities		-	-	-
Affected area (m²)		25 900	10 800	3 200
Environmental vulnerability indicator		4.00	4.00	4.00
Overall vulnerability indicator		1.98	2.00	2.00
Worst case				
Number of residents	41	100	24	2
Number of workers	4	38	3	-
Material value	$2 741 862	$3 056 900	$1 384 422	$3 830
Number of educational institutions	-	-	-	-
Number of students	-	-	-	-
Number of health and social services facilities	-	-	-	-
Affected area (m²)	1 097 400	1 946 800	779 900	259 100
Environmental vulnerability indicator	3.86	3.83	3.87	3.89
Overall vulnerability indicator	1.97	1.95	1.95	1.87
Highway 73 between Highway 573 and Route 138				
Alternatives				
Number of residents		22	10	4
Number of workers		55	22	7
Material value		$301 408	$122 610	$39 805
Number of educational institutions		-	-	-
Number of students		-	-	-
Number of health and social services facilities		-	-	-
Affected area (m²)		26 100	10 600	3 400
Environmental vulnerability indicator		2.34	2.21	2.00
Overall vulnerability indicator		3.30	3.17	3.00
Worst case				
Number of residents	1 306	2 357	947	273
Number of workers	2 000	3 376	1 458	529
Material value	$27 129 574	$58 951 974	$19 814 029	$4 788 633
Number of educational institutions	-	-	-	-
Number of students	-	-	-	-
Number of health and social services facilities	1	1	1	-
Affected area (m²)	1 097 000	1 944 800	779 800	258 700
Environmental vulnerability indicator	2.83	2.90	2.74	2.54
Overall vulnerability indicator	3.26	3.32	3.42	3.42
Highway 73 between Highway 740 and Route 973				
Alternatives				
Number of residents		-	-	-
Number of workers		87	39	13
Material value		$54 966	$21 942	$6 845
Number of educational institutions		-	-	-
Number of students		-	-	-
Number of health and social services facilities		-	-	-
Affected area (m²)		26 000	10 600	3 300
Environmental vulnerability indicator		3.11	3.09	3.00

Location/scenario/indicator	Analysis criterion			
	1psi	5 kW/ m²	12.5 kW/ m²	37.5 kW/ m²
Overall vulnerability indicator		2.62	2.54	2.45
Worst case				
Number of residents	253	438	180	54
Number of workers	3 406	6 214	2 378	766
Material value	$10 270 144	$14 605 404	$8 046 917	$2 953 137
Number of educational institutions	-	-	-	-
Number of students	-	-	-	-
Number of health and social services facilities	-	1	-	-
Affected area (m^2)	1 097 100	1 945 000	778 400	258 500
Environmental vulnerability indicator	2.06	2.15	2.25	2.77
Overall vulnerability indicator	3.20	3.28	3.12	2.93

Figure 5-17: Impact radiuses for the gasoline road accident scenario



Scénarios essence et l'indicateur de vulnérabilité globales	Gasoline scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Propane

The worst-case road accident scenarios involve propane cause explosions and BLEVEs. The consequences of the explosions are presented below in the thermal radiation (kW/m^2) analysis criterion, whereas those of the BLEVEs are expressed under the overpressure endpoints (psi) (Figure 5-18). It should be noted that for the explosion, the scenario involves the total contents of a tanker transporting 55,000 litres of propane spilling in 10 minutes. The evaporated propane comes into contact with a source of ignition resulting in an explosion of 10% in TNT. For the BLEVE, the propane contained in the 55,000-litre tank is heated by an external source and the pressure increases the shell ruptures causing the sudden release of the entire quantity of pressurized propane in the tank.

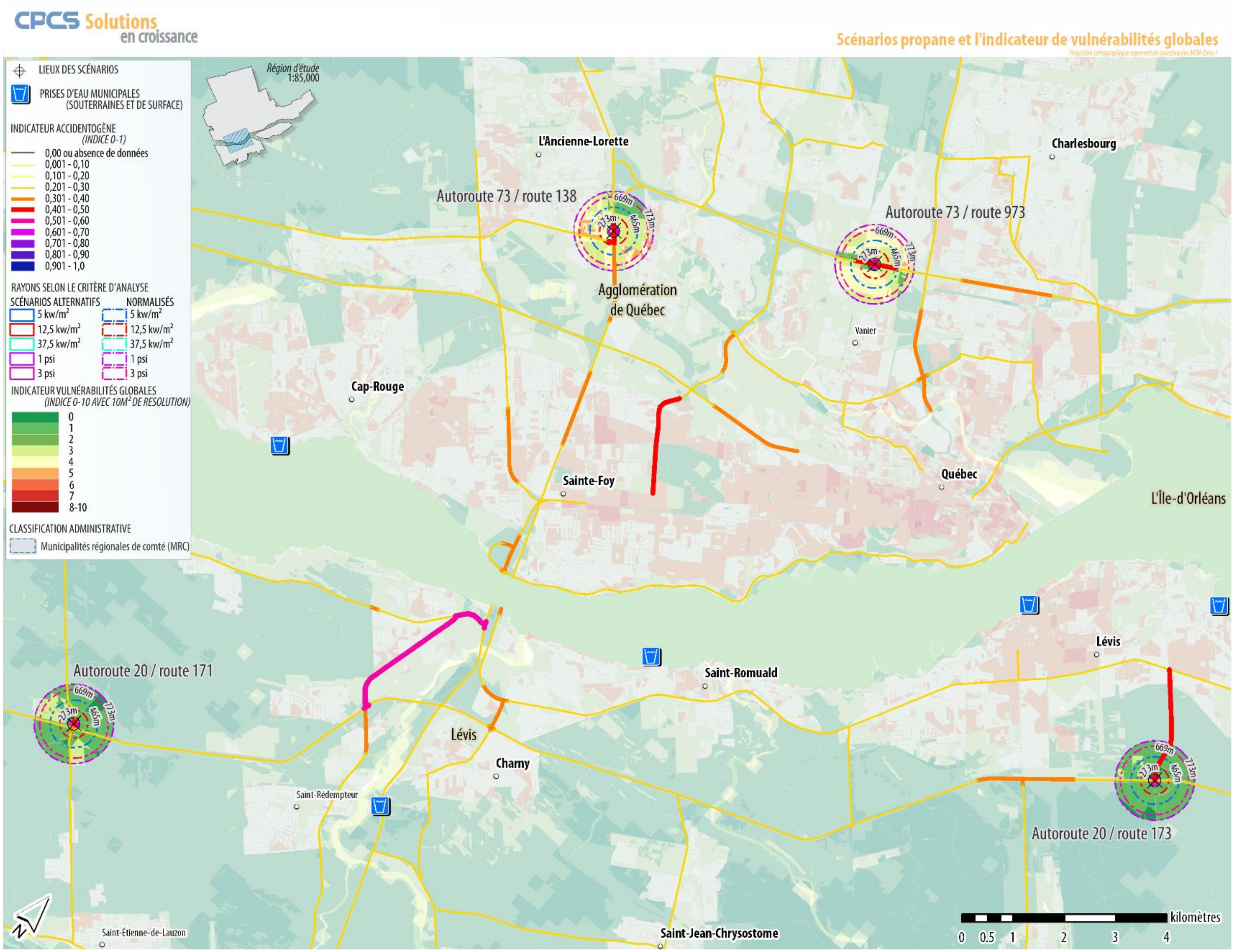
According to them, the alternative scenarios should “only” cause explosions. Furthermore, a partial rupture of the 0.75’’ gauge found on the 55,000-litre tank of propane would cause a hole with a surface area corresponding to 1% of the area of the gauge. The gaseous propane ejected forms a cloud of toxic gas and explodes. These accidents are situated in the same locations as the previous road accident scenarios (Figure 5-19).

Figure 5-18: Consequences of the propane road accident scenario

Location/scenario/indicator	Analysis criterion				
	1 psi	3 psi	5 kW/ m²	12.5 kW/ m²	37.5 kW/ m²
Highway 20 and Route 171					
Alternatives					
Number of residents	-	-			
Number of workers	1	1			
Material value	$9 961	$2 048			
Number of educational institutions	-	-			
Number of students	-	-			
Number of health and social services facilities	-	-			
Affected area (m2)	27 600	21 100			
Environmental vulnerability indicator	2.18	2.19			
Overall vulnerability indicator	1.66	1.66			
Worst case					
Number of residents	428	346	186	66	-
Number of workers	336	261	130	44	1
Material value	$7 129 876	$4 877 503	$1 910 193	$357 004	$4 044
Number of educational institutions	-	-	-	-	-
Number of students	-	-	-	-	-
Number of health and social services facilities	-	-	-	-	-
Affected area (m²)	1 875 400	1 406 100	678 700	233 300	23 200
Environmental vulnerability indicator	2.70	2.67	2.41	2.26	2.19
Overall vulnerability indicator	2.03	2.04	1.96	1.84	1.67
Highway 20 and Route 173					
Alternatives					
Number of residents	-	-			
Number of workers	-	-			
Material value	$238	$189			
Number of educational institutions	-	-			
Number of students	-	-			
Number of health and social services facilities	-	-			
Affected area (m²)	27 500	21 000			
Environmental vulnerability indicator	3.95	3.94			

Location/scenario/indicator	Analysis criterion				
	1 psi	3 psi	5 kW/ m²	12.5 kW/ m²	37.5 kW/ m²
Overall vulnerability indicator	1.93	1.95			
Worst case					
Number of residents	95	61	21	2	-
Number of workers	35	14	3	-	-
Material value	$3 052 088	$3 019 069	$1 031 082	$3 245	$204
Number of educational institutions	-	-	-	-	-
Number of students	-	-	-	-	-
Number of health and social services facilities	-	-	-	-	-
Affected area (m²)	1 876 800	1 406 400	678 700	233 600	23 200
Environmental vulnerability indicator	3.93	4.00	3.83	3.89	3.94
Overall vulnerability indicator	1.96	2.00	1.94	1.87	1.95
Highway 73 between Highway 573 and Route 138					
Alternatives					
Number of residents	23	18			
Number of workers	59	45			
Material value	$321 574	$244 804			
Number of educational institutions	-	-			
Number of students	-	-			
Number of health and social services facilities	-	-			
Affected area (m²)	27 400	21 100			
Environmental vulnerability indicator	2.34	2.32			
Overall vulnerability indicator	3.30	3.27			
Worst case					
Number of residents	2 266	1 663	830	239	19
Number of workers	3 272	2 523	1 291	481	49
Material value	$55 715 017	$36 696 992	$16 757 273	$4 150 640	$269 239
Number of educational institutions	-	-	-	-	-
Number of students	-	-	-	-	-
Number of health and social services facilities	1	1	1	-	-
Affected area (m²)	1 876 500	1 406 200	678 600	233 700	23 200
Environmental vulnerability indicator	2.90	2.87	2.71	2.51	2.36
Overall vulnerability indicator	3.30	3.23	3.33	3.42	3.28
Highway 73 between Highway 740 and Route 973					
Alternatives					
Number of residents	-	-			
Number of workers	92	71			
Material value	$58 707	$44 481			
Number of educational institutions	-	-			
Number of students	-	-			
Number of health and social services facilities	-	-			
Affected area (m²)	27 600	21 000			
Environmental vulnerability indicator	3.11	3.13			
Overall vulnerability indicator	2.61	2.62			
Worst case					
Number of residents	426	324	159	49	-
Number of workers	5 984	4 413	2 053	695	78
Material value	$14 312 001	$12 062 412	$7 357 438	$2 567 736	$49 004
Number of educational institutions	-	-	-	-	-
Number of students	-	-	-	-	-
Number of health and social services facilities	-	-	-	-	-
Affected area (m²)	1 876 900	1 405 200	679 700	234 200	23 000
Environmental vulnerability indicator	3.12	3.01	2.05	2.32	3.14
Overall vulnerability indicator	3.28	3.24	3.09	2.91	2.62

Figure 5-19: Impact radiuses for the propane road accident scenario



Scénarios propane et l'indicateur de vulnérabilité globales	Propane scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Rail accidents

Gasoline

Like the road accident scenarios, rail accidents involving gasoline can cause fires and explosions and the consequences in Figure 5-20 are presented conformity with the applicable analysis criterion. The first worst-case scenario involves the total volume of one car of gasoline containing a total volume of 600 barrels (95,392 litres) spilling on the ground in 10 minutes. The gasoline spreads on the ground and forms a puddle 1 cm in depth and comes into contact with a source of ignition and catches fire. In the explosion and fire-ball variation of the scenario, the gasoline contained in the car, which has a total volume of 600 barrels, is heated by an external source and the pressure increases until the point where there is a rupture in the shell and the entire quantity of the pressurized gasoline in the tank is suddenly released.

The alternative scenarios cause fires. After a car is overturned, there is a rupture in the shell forming an opening 3'' in diameter. The gasoline spilling on the ground forms a 1 cm puddle and comes into contact with a source of ignition and the puddle catches fire.

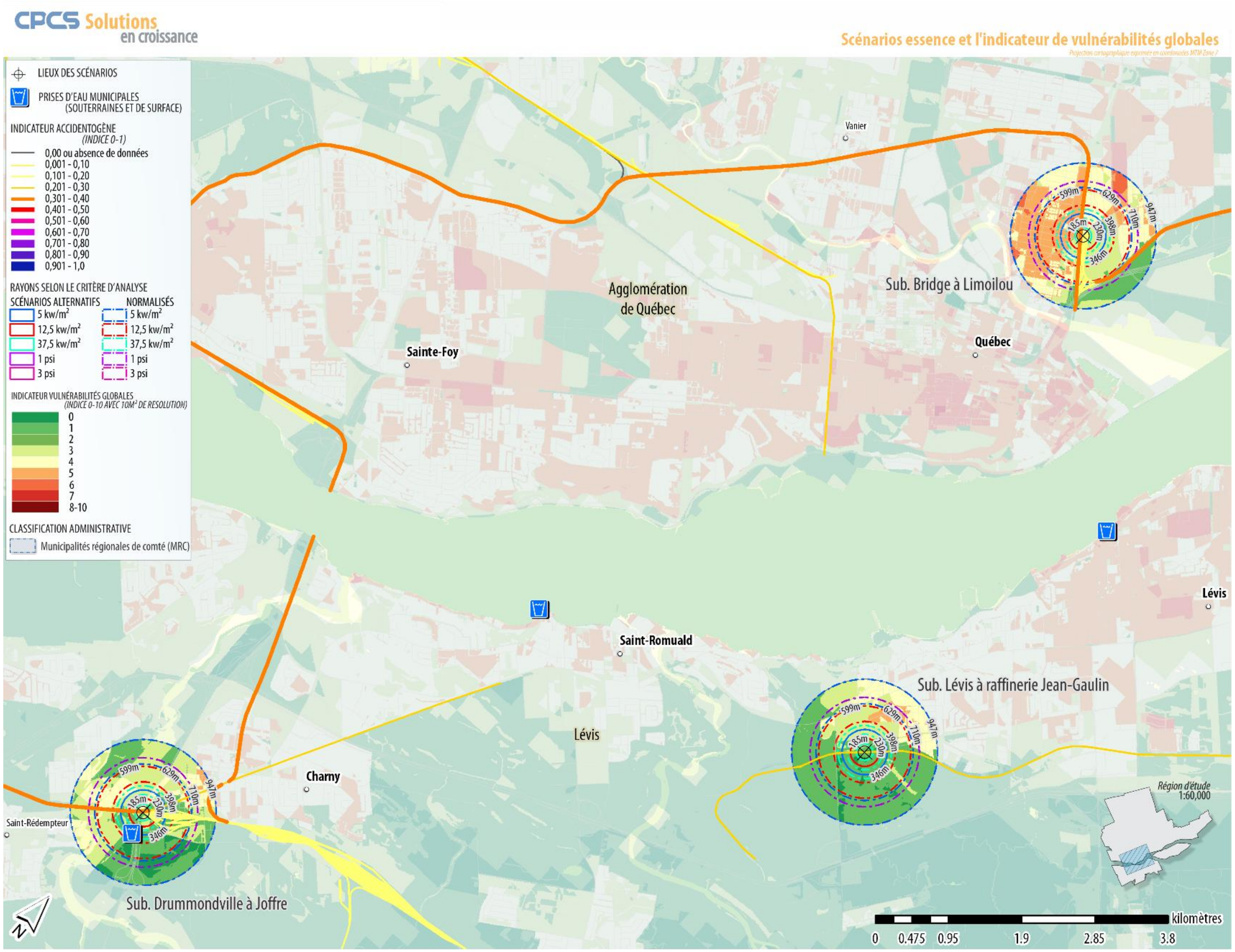
These accidents are situated in the same locations as the previous rail accident scenarios (Figure 5-21).

Figure 5-20: Consequences of the gasoline rail accident scenario

Location/scenario/indicator	Analysis criterion			
	1 psi	5 kW/ m²	12.5 kW/ m²	37.5 kW/ m²
Intersection of Bridge/Montmagny/Drummond (Joffre yard)				
Alternatives				
Number of residents		116	43	15
Number of workers		32	12	3
Material value		$2 656 614	$459 668	$126 922
Number of educational institutions		-	-	-
Number of students		-	-	-
Number of health and social services facilities		-	-	-
Affected area (m²)		269 500	107 600	35 900
Environmental vulnerability indicator		3.68	3.60	3.66
Overall vulnerability indicator		2.46	2.49	2.58
Worst case				
Number of residents	974	2 110	631	169
Number of workers	238	639	163	47
Material value	$29 082 691	$66 757 515	$14 730 845	$3 648 707
Number of educational institutions	-	2	-	-
Number of students	-	440	-	-
Number of health and social services facilities	-	-	-	-
Affected area (m²)	1 583 200	2 816 700	1 126 800	375 800
Environmental vulnerability indicator	3.63	3.75	3.78	3.68
Overall vulnerability indicator	2.56	2.58	2.56	2.47
Bridge subdivision in Limoilou				
Alternatives				
Number of residents		944	329	98
Number of workers		833	328	90
Material value		$43 133 191	$16 049 039	$4 288 177
Number of educational institutions		2	1	-
Number of students		600	300	-

Location/scenario/indicator	Analysis criterion			
	1 psi	5 kW/ m²	12.5 kW/ m²	37.5 kW/ m²
Number of health and social services facilities		-	-	-
Affected area (m²)		269 900	107 800	36 100
Environmental vulnerability indicator		1.66	1.54	1.42
Overall vulnerability indicator		3.75	3.66	3.56
Worst case				
Number of residents	7 916	13 774	5 346	1 404
Number of workers	3 492	6 912	2 602	1 111
Material value	$339 149 065	$597 117 911	$220 767 157	$60 446 958
Number of educational institutions	5	8	4	2
Number of students	2 020	2 945	1 370	600
Number of health and social services facilities	3	8	-	-
Affected area (m²)	1 583 400	2 816 600	1 127 000	375 700
Environmental vulnerability indicator	1.81	1.84	1.85	1.72
Overall vulnerability indicator	3.93	3.96	3.95	3.76
Lévis subdivision at Valero				
Alternatives				
Number of residents		230	86	26
Number of workers		132	43	9
Material value		$585 701	$206 759	$43 282
Number of educational institutions		-	-	-
Number of students		-	-	-
Number of health and social services facilities		-	-	-
Affected area (m²)		269 600	107 300	35 800
Environmental vulnerability indicator		2.57	2.41	2.27
Overall vulnerability indicator		2.11	1.88	1.81
Worst case				
Number of residents	1 378	2 748	964	327
Number of workers	668	929	537	192
Material value	$23 604 391	$54 913 431	$9 551 110	$838 274
Number of educational institutions	-	-	-	-
Number of students	-	-	-	-
Number of health and social services facilities	-	-	-	-
Affected area (m²)	1 584 000	2 817 000	1 126 900	376 500
Environmental vulnerability indicator	2.51	2.51	2.61	2.61
Overall vulnerability indicator	2.45	2.51	2.39	2.17

Figure 5-21: Impact radiuses for the gasoline rail accident scenario



Scénarios essence chlorhydrique et l'indicateur de vulnérabilité globales	Gasoline scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Propane

The rail accident scenarios unfold in the same way as the road accidents, and they are presented in Figure 5-22 following the same logic. For the variations of the worst-case scenarios, the first proposes that the propane contained in one 114,000-litre tank is heated by an external source and the pressure increases until there is a rupture in the shell which leads to the sudden release of the entire quantity of pressurized propane in the tank and a BLEVE. The second mentions, instead, the release of the contents of a 114,000-litre car of propane on the ground in 10 minutes. The evaporated propane explodes in contact with a source of ignition.

Still following the road accident scenarios involving propane, these (alternative) rail scenarios “only” involve an explosion. Furthermore, a leak in a 2’’ valve on a tank car corresponds to a surface area of 1% the area of the valve. The gaseous propane forms a cloud of gas and explodes.

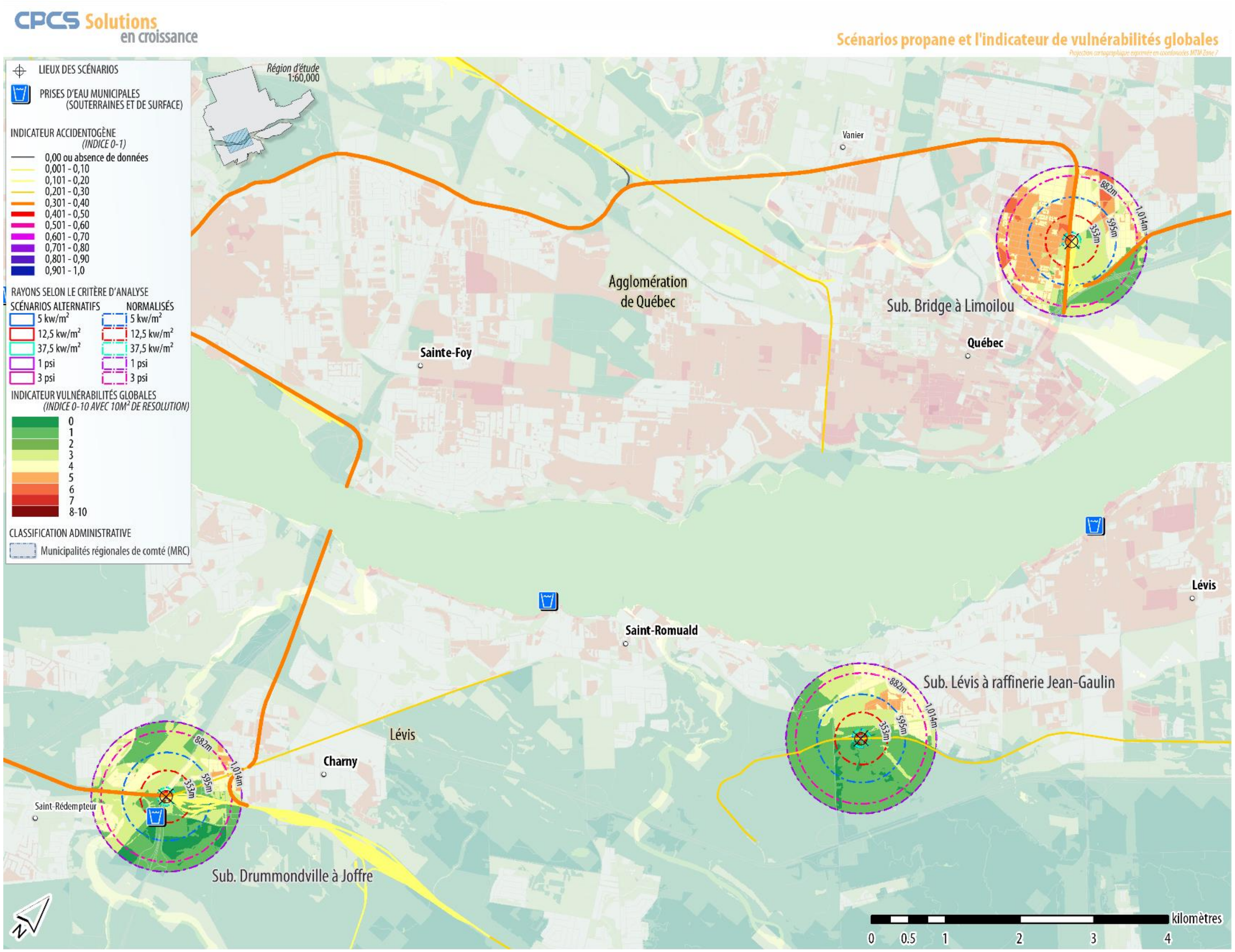
These accidents are situated in the same locations as the previous rail accident scenarios (Figure 5-23).

Figure 5-22: Consequences of the propane rail accident scenario

Location/scenario/indicator	Analysis criterion				
	1 psi	3 psi	5 kW/ m²	12.5 kW/ m²	37.5 kW/ m²
Intersection of Bridge/Montmagny/Drummond (Joffre yard)					
Alternatives					
Number of residents	-	-			
Number of workers	-	-			
Material value	$2 777	$1 828			
Number of educational institutions	-	-			
Number of students	-	-			
Number of health and social services facilities	-	-			
Affected area (m²)	800	600			
Environmental vulnerability indicator	2.00	2.00			
Overall vulnerability indicator	2.00	2.00			
Worst case					
Number of residents	2 539	1 756	623	177	17
Number of workers	771	495	161	49	4
Material value	$82 330 285	$55 055 079	$14 309 573	$3 789 530	$151 943
Number of educational institutions	3	1	-	-	-
Number of students	760	140	-	-	-
Number of health and social services facilities	-	-	-	-	-
Affected area (m²)	3 230 200	2 443 200	1 112 400	391 500	43 600
Environmental vulnerability indicator	3.24	3.41	3.77	3.67	3.63
Overall vulnerability indicator	2.60	2.57	2.57	2.59	2.57
Bridge subdivision in Limoilou					
Alternatives					
Number of residents	1	1			
Number of workers	-	-			
Material value	$5 814	$3 838			
Number of educational institutions	-	-			
Number of students	-	-			
Number of health and social services facilities	-	-			
Affected area (m²)	800	600			
Environmental vulnerability indicator	1.00	1.00			

Location/scenario/indicator	Analysis criterion				
	1 psi	3 psi	5 kW/ m^2	12.5 kW/ m^2	37.5 kW/ m^2
Overall vulnerability indicator	3.00	3.00			
Worst case					
Number of residents	15 626	12 044	5 259	1 471	122
Number of workers	8 266	5 682	2 574	1 151	115
Material value	$666 854 430	$528 643 219	$217 052 398	$63 060 688	$5 548 863
Number of educational institutions	10	7	4	2	-
Number of students	3 224	2 645	1 370	600	-
Number of health and social services facilities	8	4	-	-	-
Affected area (m^2)	3 230 100	2 443 700	1 112 800	391 700	43 200
Environmental vulnerability indicator	1.88	1.79	1.85	1.72	1.46
Overall vulnerability indicator	3.80	3.82	3.95	3.77	3.59
Lévis subdivision at Valero					
Alternatives					
Number of residents	-	-			
Number of workers	-	-			
Material value	$97	$64			
Number of educational institutions	-	-			
Number of students	-	-			
Number of health and social services facilities	-	-			
Affected area (m^2)	800	400			
Environmental vulnerability indicator	2.00	2.00			
Overall vulnerability indicator	1.13	1.25			
Worst case					
Number of residents	3 168	2 328	951	341	32
Number of workers	1 018	853	532	200	12
Material value	$65 885 282	$46 019 995	$9 201 481	$874 937	$59 591
Number of educational institutions	-	-	-	-	-
Number of students	-	-	-	-	-
Number of health and social services facilities	1	-	-	-	-
Affected area (m^2)	3 229 100	2 443 500	1 110 900	391 100	44 100
Environmental vulnerability indicator	2.52	2.52	2.53	2.63	2.25
Overall vulnerability indicator	2.51	2.50	2.38	2.18	1.82

Figure 5-23: Impact radiuses for the propane rail accident scenario



Scénarios propane et l'indicateur de vulnérabilité globales	Propane scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Crude oil and light crude oil

For the worst-case scenarios involving crude oil and light crude oil, both products cause BLEVEs. However, their impact radiuses vary slightly, and Figure 5-24 refers to largest impact radius, or that of light crude oil. In the two variations, the oil contained in a car with a capacity of 714 barrels is heated by an external source and the pressure increases to the point where that the shell ruptures, causing the sudden release of the entire quantity of the pressurized oil in the car and a BLEVE.

As for the alternative scenarios, they are identical to the worst-case scenarios in all respects and in their definition (section 3.2.1), impact radiuses (section 3.2.2) and therefore, their consequences. Evidently, this is incompatible with the definition of an alternative scenario. However, in the hypothesis, regardless of the amount spilled, the fact that the oil catches fire will inevitably cause the container (car) to be heated and cause a BLEVE if the fire is not stopped. A rapid response could prevent the BLEVE and the alternative scenario would have an insignificant impact radius.

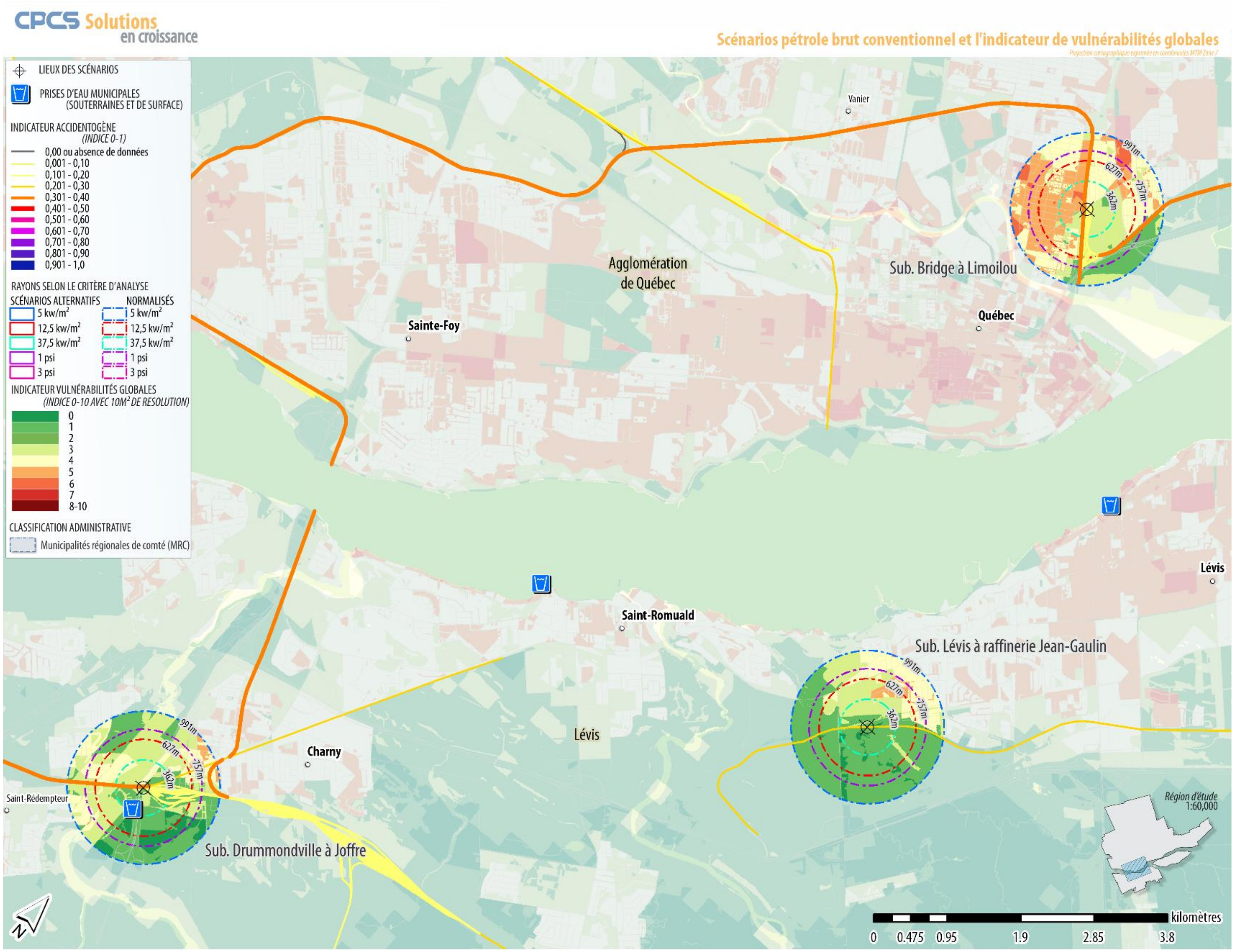
These accidents are situated in the same locations as the previous rail scenarios (Figure 5-25).

Figure 5-24: Consequences of the crude oil and light crude oil rail accident scenario

Location/scenario/indicator	Analysis criterion			
	1 psi	5 kW/ m²	12,5 kW/ m²	37.5 kW/ m²
Intersection of Bridge/Montmagny/Drummond (Joffre yard)				
Alternatives				
Number of residents	1 168	2 387	707	187
Number of workers	276	727	181	51
Material value	$35 606 291	$76 709 200	$17 719 951	$3 973 814
Number of educational institutions	-	3	-	-
Number of students	-	760	-	-
Number of health and social services facilities	-	-	-	-
Affected area (m²)	1 798 900	3 085 000	1 234 300	411 800
Environmental vulnerability indicator	3.57	3.27	3.74	3.69
Overall vulnerability indicator	2.55	2.59	2.56	2.44
Worst case				
Number of residents	1 168	2 387	707	187
Number of workers	276	727	181	51
Material value	$35 606 291	$76 709 200	$17 719 951	$3 973 814
Number of educational institutions	-	3	-	-
Number of students	-	760	-	-
Number of health and social services facilities	-	-	-	-
Affected area (m²)	1 798 900	3 085 000	1 234 300	411 800
Environmental vulnerability indicator	3.57	3.27	3.74	3.69
Overall vulnerability indicator	2.55	2.59	2.56	2.44
Bridge subdivision in Limoilou				
Alternatives				
Number of residents	9 008	14 979	5 962	1 563
Number of workers	4 007	7 806	2 812	1 203
Material value	$388 743 242	$643 018 400	$248 487 617	$66 511 783
Number of educational institutions	7	9	4	2
Number of students	2 645	3 068	1 370	600
Number of health and social services facilities	3	8	-	-
Affected area (m²)	1 799 300	3 085 000	1 234 300	412 000

Location/scenario/indicator	Analysis criterion			
	1 psi	5 kW/ m^2	12,5 kW/ m^2	37.5 kW/ m^2
Environmental vulnerability indicator	1.80	1.86	1.84	1.73
Overall vulnerability indicator	3.90	3.80	3.96	3.77
Worst case				
Number of residents	9 008	14 979	5 962	1 563
Number of workers	4 007	7 806	2 812	1 203
Material value	$388 743 242	$643 018 400	$248 487 617	$66 511 783
Number of educational institutions	7	9	4	2
Number of students	2 645	3 068	1 370	600
Number of health and social services facilities	3	8	-	-
Affected area (m^2)	1 799 300	3 085 000	1 234 300	412 000
Environmental vulnerability indicator	1.80	1.86	1.84	1.73
Overall vulnerability indicator	3.90	3.80	3.96	3.77
Lévis subdivision at Valero				
Alternatives				
Number of residents	1 604	3 031	1 049	358
Number of workers	721	986	573	211
Material value	$29 584 305	$62 001 210	$12 513 733	$923 250
Number of educational institutions	-	-	-	-
Number of students	-	-	-	-
Number of health and social services facilities	-	1	-	-
Affected area (m^2)	1 800 400	3 084 700	1 234 500	411 100
Environmental vulnerability indicator	2.51	2.52	2.51	2.63
Overall vulnerability indicator	2.46	2.51	2.41	2.18
Worst case				
Number of residents	1 604	3 031	1 049	358
Number of workers	721	986	573	211
Material value	$29 584 305	$62 001 210	$12 513 733	$923 250
Number of educational institutions	-	-	-	-
Number of students	-	-	-	-
Number of health and social services facilities	-	1	-	-
Affected area (m^2)	1 800 400	3 084 700	1 234 500	411 100
Environmental vulnerability indicator	2.51	2.52	2.51	2.63
Overall vulnerability indicator	2.46	2.51	2.41	2.18

Figure 5-25: Impact radiuses of the crude oil and light crude oil rail accident scenario



Scénarios pétrole brut conventionnel et l'indicateur de vulnérabilité globales	Conventional crude oil scenarios and the overall vulnerability indicator

Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Marine accidents

Gasoline

The worst-case accident scenarios for marine accidents involving gasoline result in fires/pool fires. After two boats collide, the contents of the cargo hold of a boat transporting gasoline with a volume of 980 m^3 is spilled. The gasoline comes into contact with a source of ignition and catches fire.

In the alternative scenarios, the collision ruptures the side of the cargo hold of a boat transporting gasoline. Gravity causes gasoline to spill down the side of the tank, and it spreads on top of the water, forming a slick that is 3 cm deep. The spilled gasoline comes into contact with a source of ignition and the puddle catches fire.

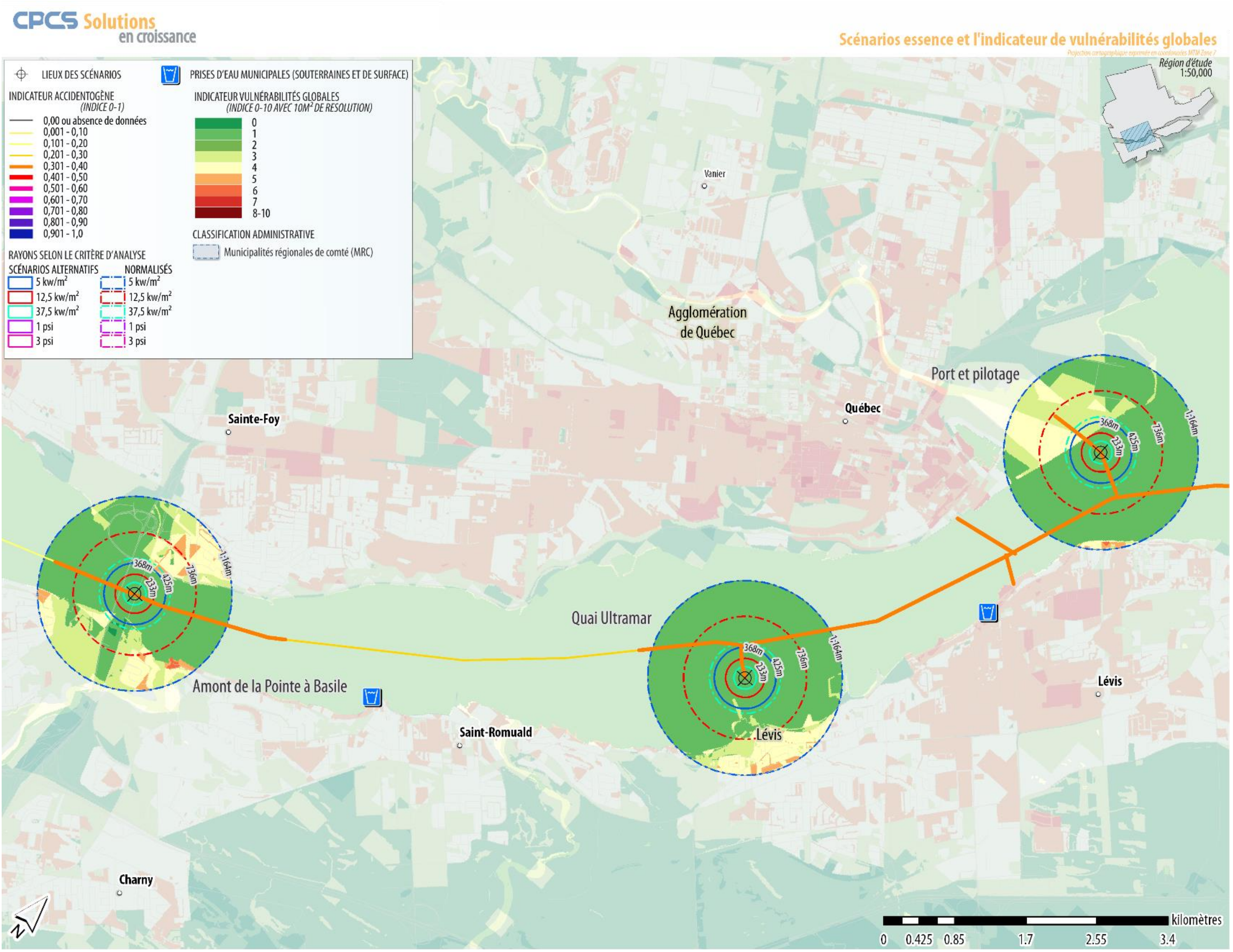
The accidents are located at upstream of Pointe-à-Basile, at the port of Québec entrance and the Valero (Figure 5-29). The consequences are presented in the figure below.

Figure 5-26: Consequences of the gasoline marine accident scenario

Location/scenario/indicator	Analysis criterion		
	5 kW/ m^2	12.5 kW/ m^2	37.5 kW/ m^2
Upstream of Pointe-à-Basile			
Alternatives			
Number of residents	12	-	-
Number of workers	7	-	-
Material value	$25 565	$-	$-
Number of educational institutions	-	-	-
Number of students	-	-	-
Number of health and social services facilities	-	-	-
Affected area (m^2)	425 700	169 900	56 100
Environmental vulnerability indicator	5.84	6.00	6.00
Overall vulnerability indicator	1.99	2.00	2.00
Worst case			
Number of residents	1 884	443	45
Number of workers	760	214	27
Material value	$48 015 201	$3 543 424	$132 766
Number of educational institutions	-	-	-
Number of students	-	-	-
Number of health and social services facilities	-	-	-
Affected area (m^2)	4 255 500	1 701 700	566 600
Environmental vulnerability indicator	4.63	5.03	5.63
Overall vulnerability indicator	2.54	2.27	2.04
Port of Québec entrance			
Alternatives			
Number of residents	16	-	-
Number of workers	57	-	-
Material value	$40 964	$-	$-
Number of educational institutions	-	-	-
Number of students	-	-	-
Number of health and social services facilities	-	-	-
Affected area (m^2)	424 600	170 700	56 300
Environmental vulnerability indicator	6.00	6.00	6.00
Overall vulnerability indicator	2.15	2.00	2.00
Worst case			
Number of residents	700	171	30

Location/scenario/indicator	Analysis criterion		
	5 kW/ m²	12.5 kW/ m²	37.5 kW/ m²
Number of workers	1 568	567	105
Material value	$4 032 342	$421 396	$76 201
Number of educational institutions	-	-	-
Number of students	-	-	-
Number of health and social services facilities	-	-	-
Affected area (m²)	4 256 900	1 701 700	567 700
Environmental vulnerability indicator	5.33	5.80	6.00
Overall vulnerability indicator	2.35	2.37	2.21
Valero dock			
Alternatives			
Number of residents	5	-	-
Number of workers	-	-	-
Material value	$29 868	$-	$-
Number of educational institutions	-	-	-
Number of students	-	-	-
Number of health and social services facilities	-	-	-
Affected area (m²)	425 400	170 400	56 700
Environmental vulnerability indicator	6.00	6.00	6.00
Overall vulnerability indicator	2.01	2.00	2.00
Worst case			
Number of residents	1 065	123	8
Number of workers	219	15	-
Material value	$28 646 665	$656 345	$52 120
Number of educational institutions	2	-	-
Number of students	543	-	-
Number of health and social services facilities	-	-	-
Affected area (m²)	4 256 300	1 701 700	567 500
Environmental vulnerability indicator	5.61	5.86	6.00
Overall vulnerability indicator	2.25	2.05	2.01

Figure 5-27: Impact radiuses of the gasoline marine accident scenario



Scénarios essence et l’indicateur de vulnérabilité globales	Gasoline scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D’EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D’ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)

Pipeline accidents

Natural gas

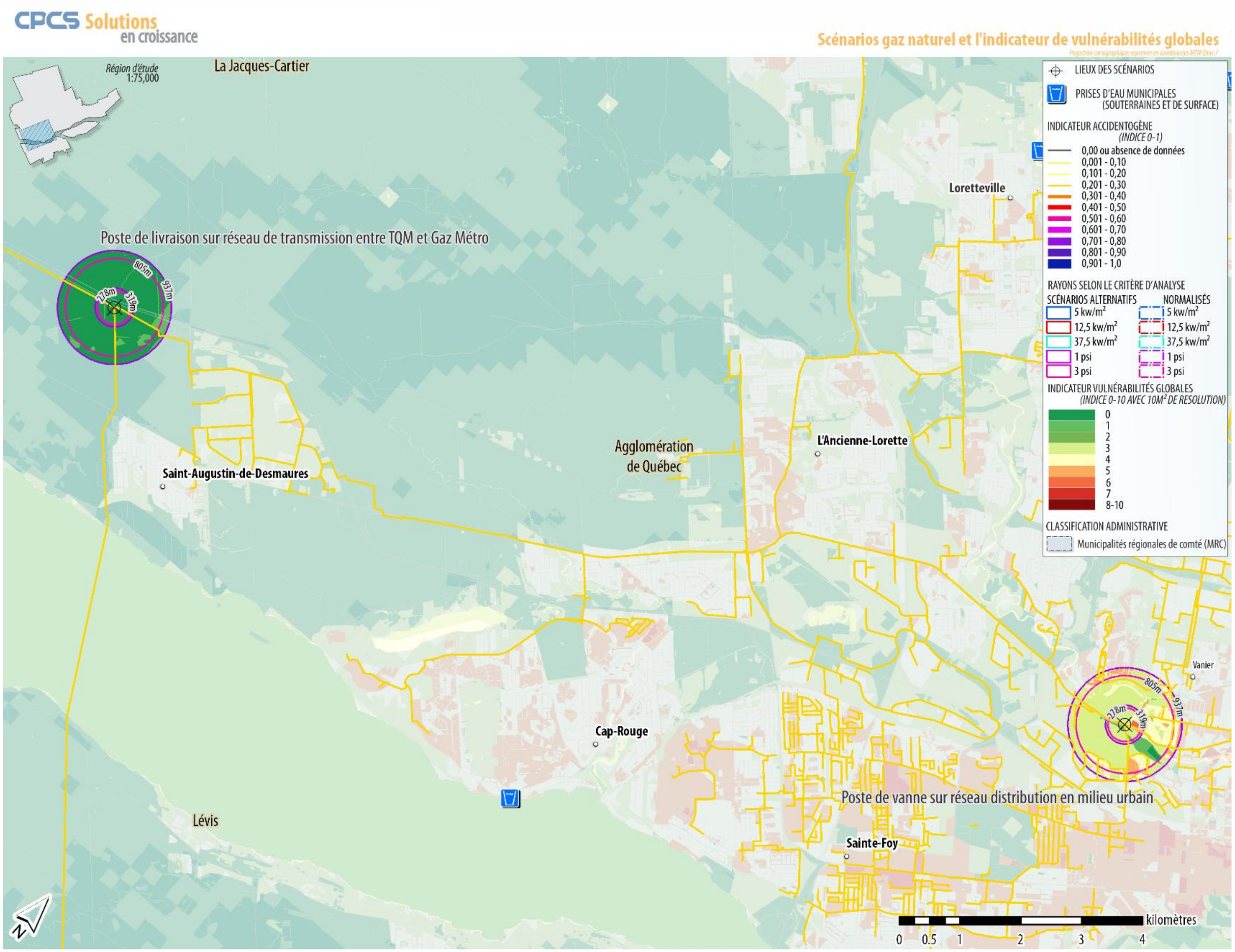
The pipeline accidents only cover the alternative scenarios; however, these are broken down into two variations. In the first, a crash severs a natural gas pipeline 610 mm in diameter. The natural gas ejected forms a cloud of gas and explodes. In the second, the accident perforates the side of a pipeline transporting natural gas, resulting is a hole covering 10% of the surface of the pipe. The natural gas ejected forms a cloud of gas and explodes.

The locations of the accidents are presented in Figure 5-29, whereas the consequences are indicated in the following figure.

Figure 5-28: Consequences of the natural gas pipeline accident scenario

Location/scenario/indicator	Analysis criterion	
	1 psi	3 psi
Distribution station at the intersection of Gaz Métro and TQM		
Alternatives		
Number of residents	86	64
Number of workers	17	13
Material value	$15 347	$11 389
Number of educational institutions	-	-
Number of students	-	-
Number of health and social services facilities	-	-
Affected area (m²)	2 758 700	2 034 300
Environmental vulnerability indicator	1.61	1.54
Overall vulnerability indicator	1.05	1.04
Valve station on the distribution line		
Alternatives		
Number of residents	3 868	2 470
Number of workers	5 127	3 738
Material value	$95 693 810	$58 658 097
Number of educational institutions	1	1
Number of students	203	203
Number of health and social services facilities	1	1
Affected area (m²)	2 757 500	2 036 200
Environmental vulnerability indicator	2.79	2.91
Overall vulnerability indicator	3.28	3.27

Figure 5-29: Impact radiuses of the natural gas pipeline accident scenario



Scénarios gaz naturel et l'indicateur de vulnérabilité globales	Natural gas scenarios and the overall vulnerability indicator
Kilomètres	Kilometres
LIEUX DES SCÉNARIOS	SCENARIO LOCATIONS
PRISES D'EAU MUNICIPALES (SOUTERRAINES ET DE SURFACE)	MUNICIPAL WATER INTAKES (UNDERGROUND AND SURFACE)
INDICATEUR ACCIDENTOGÈNE (INDICE 0-1)	ACCIDENT INDICATOR (INDEX 0-1)
0,00 ou absence de données	0.00 or no data
RAYONS SELON LE CRITÈRE D'ANALYSE	RADIUSES ACCORDING TO THE ANALYSIS CRITERION
SCÉNARIOS ALTERNATIFS	ALTERNATIVE SCENARIOS
NORMALISÉS	WORST CASE
INDICATEUR VULNÉRABILITÉS GLOBALES (INDICE 0-10 AVEC 10M^2 DE RÉSOLUTION)	OVERALL VULNERABILITY INDICATOR (INDEX 0-10 WITH 10 M^2 OF RESOLUTION)
CLASSIFICATION ADMINISTRATIVE	ADMINISTRATIVE CLASSIFICATION
Municipalités régionales de comté (MRC)	Regional county municipalities (RCMs)