2015
WATER AND HYDRAULIC FRACTURING
Where knowledge can best support decisions in Canada
## Contents

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Canadian Water Network (CWN) is Canada’s premier water research management organization. CWN is dedicated to advancing important conversations for Canada through collaboration and knowledge mobilization in areas where water and its management are critical to decisions on policy and practice.

When those faced with decisions ask the question, ‘What does the science say about this?’ the answer must move beyond listing the knowns and unknowns to an understanding of the relevance of the existing information, framed in a way that usefully informs the choices being made. That credible prioritization of knowledge to effectively support decisions and inform next steps is central to the CWN process.

The rapid rise in the development of unconventional oil and shale gas reserves over the last decade has been accompanied by a similar explosion in levels of discussion and debate on the topic. Researchers providing the knowledge base to effectively support this debate are challenged to keep up with the needs. Those involved in decisions about the use of hydraulic fracturing for resource development are similarly challenged in determining how to move forward in a way that best addresses needs, opportunities and concerns. Central to the vast majority of conversations about hydraulic fracturing is the issue of water — its use, its management and protection, and its ecological, social and economic importance.

This report provides an important contribution to framing that conversation. It takes a high-level look at where the knowledge base is relative to the key questions being asked to inform decisions. It highlights critical work done to assess the state of the knowledge relative to those decisions, where a lack of information is most impacting progress, and highlights the capacity to advance knowledge priorities to support decisions. The focus is not on what the science says about who is right and who is wrong in the broader debate over hydraulic fracturing. Rather, its focus is on helping to ensure we can get real value out of existing knowledge to support collective decisions about what to do now and where to go next.
DISCLAIMER

This report draws on a broad number of studies and reports produced over the past several years. In particular, much of the information is drawn from five CWN-funded research projects conducted over 2014 and 2015. These five projects are part of a national program, and went through independent expert peer review at the proposal stage as well as at intervals throughout their lifecycles. Among other criteria, the independent reviews focused on assessing the scientific excellence of the approaches employed. CWN also drew on the advice and input of a number of federal, provincial and territorial government and industry representatives to assess the overall relevance of the research program to current decision making needs in Canada.

The majority of the funding and support for these five projects was from CWN through its grant from the federal Networks of Centres of Excellence program.

This report does not necessarily reflect the views of the individual researchers who contributed to the five projects; and the statements in the five research project reports do not necessarily reflect the views of CWN.
Over the past decade, the combination of horizontal drilling techniques and multi-stage hydraulic fracturing has led to a technological revolution in oil and gas development. It has given rise to a huge North American expansion of oil and gas development from unconventional (tight) resources. This rapid expansion has spurred evolution in industry practice, requiring a parallel development, or advancement of, regulations. It has also captured broad public attention, leading to significant debate over the merits and pitfalls of hydraulic fracturing. Concerns about the impact on water resources are at the core of much of this debate.

Ensuring that leading science underpins decisions about hydraulic fracturing represents a significant challenge. This challenge stems from the polarized nature of many discussions, the rapid pace of industry development and technological advancements, the many unknowns involved, and the very recent advent of research focused on its impacts. Given the complex set of questions and knowledge gaps, ensuring that relevant knowledge can effectively support decisions requires strategic prioritization. This includes consideration of what the most important short and long-term needs are for decision making, how the current knowledge base relates to those priority decisions, and insights into where and how advancing that knowledge base can best support effective outcomes. In light of the importance of the decisions being made and the challenging nature of the debate, trust in the sources of knowledge is fundamental.

While there are certainly some commonalities in the questions being asked about hydraulic fracturing and water across Canada, the realities of the different regional contexts have driven both local concerns and potential responses. Specific geological factors, such as the depth and nature of the target formation, dictate overall technological needs and applications. The local ecological, social and economic conditions influence which risks dominate, and which management approaches for those risks will be viewed as acceptable. This reflects, in part, the level of familiarity and history with the oil and gas industry in different regions of Canada.

Regulatory and management responses are highly varied across Canada as a result of these differences. Outright bans on the use of hydraulic fracturing have been imposed in some areas, while in others there has been a move toward development of area-based or play-based regulations and practice that recognize place-based variations and seek to match management responses to regional or local conditions.
Across Canada, there exists a West-East split in terms of the overall experience and comfort with industry development and its proximity to populated centres, as well as geology that impacts industry options, such as wastewater management. Issues related to Aboriginal communities (First Nations, Inuit and Métis) play a large part in discussions, since hydraulic fracturing activities frequently have important repercussions to Aboriginal lands and communities in particular.

In 2013, Canadian Water Network (CWN) established a national program of five projects, engaging teams of leading researchers from across Canada to conduct comprehensive reviews that consider the key questions related to hydraulic fracturing and water being asked by decision makers; assess the most relevant knowledge gaps in the context of advancing those priority decisions; and identify opportunities for research to better inform them. Each team approached the overall task from the vantage point of one of the following four management focus areas:

1. Watershed governance and management approaches for resource development, including Aboriginal issues
2. Groundwater and subsurface impact issues
3. Wastewater handling, treatment and disposal
4. Landscape impacts of development/operations on surface water/watersheds

Taken together, these projects provide a comprehensive and up-to-date assessment of the broad array of issues being faced in Canada and support both the use and generation of knowledge for decision-making going forward.

This report provides a high-level framing to complement the much greater detail provided by the individual CWN-funded teams, as well as other leading international work. Although there are differences in both the focus areas and findings of the various review studies, there is also considerable overlap in the nature of the leading questions being asked and the kinds of gaps that were identified as obstacles to progress. The majority of key questions being asked can be grouped within one of three overall decision contexts:

- Deciding where and when hydraulic fracturing makes sense based on the overall benefits and costs
- Informing best practices and regulations with an understanding of the risks, and how to mitigate them
- Achieving constructive and effective engagement to move the discussion and decisions forward to achieve progress

The key questions being asked within each of these decision contexts provides an accessible entry point and organizing framework for assessing what the overall knowledge base can offer.

Drawing on the findings of the five CWN-funded projects, this report summarizes what we know now, what we most need to know, and what is reasonable for advancement through targeted research. The results of these analyses identify some of the practical opportunities to move the knowledge base forward to directly support decision makers.
CWN acknowledges that the inherent risks and potential impacts of hydraulic fracturing include impacts other than those affecting water resources (e.g., air quality, climate change) and that related decisions also have implications for other issues such as infrastructure, transportation and safety. However, these are not included in this report, which focuses on the centrality of the water-related issues.

DECIDING WHERE AND WHEN HYDRAULIC FRACTURING MAKES SENSE

For many regions of Canada, the primary questions being asked are less about the details of regulatory design or development of industry practices. Rather — though they address many of the same issues — the core conversations are at a higher level, involving consideration of:

What is the expected net benefit of the activity?
How can the pros and cons be effectively weighed?
Should hydraulic fracturing be permitted?

Three broad areas have been identified as practical opportunities to advance knowledge to support decisions being made on the benefits and costs of hydraulic fracturing:

Understanding Net Social and Economic Costs and Benefits of Hydraulic Fracturing
• Develop more credible, broad social and economic analyses that reflect a more complete and socially-relevant balancing of negative and positive elements associated with shale gas development.

Water Use Issues Associated with Hydraulic Fracturing
• Address knowledge gaps in the development of regional, cumulative effects-based water plans, including improved understanding of groundwater conditions and deep saline resources.
• Project current and future water availability from all sources, including methods to estimate future water needs of the industry.
• Assess the lifecycle and impact(s) of strategies for conservation, reuse, or alternatives to freshwater.

Understanding Human Health Risks and Contamination Concerns
• Assess toxicity concerns of leakage of methane or other contaminants from wells to groundwater/drinking water.
• Assess toxicity concerns related to hydraulic fracturing wastewater.
• Advance the effectiveness of risk communications approaches.
INFORMING BEST PRACTICES AND REGULATIONS

In moving from decisions of whether or not to allow hydraulic fracturing to determine how best to oversee and manage the practice, the focus of decision makers shifts to the assessment of best practices and regulations. The emphasis of knowledge needs focuses on what is most needed to identify and evaluate specific risks and impacts, how these risks and impacts should be regulated, and what best practices should and could achieve. In this context the question becomes: *Do we understand the risks and how to manage and/or mitigate them?*

**Several areas of opportunity for knowledge advancement have been identified, which could better support the evaluation of risks and impacts in decision-making:**

**Baseline Data Needs**
- Inform the design of monitoring frameworks for cumulative effects assessment that address hydraulic fracturing considerations, including establishing baseline water quality and availability.
- Develop approaches that more effectively assess and establish baseline groundwater quality to enable the possible detection of methane gas or other contaminant impacts.

**Cumulative Effects and Monitoring, Assessment and Management**
- Assess evolving experience and advance approaches for implementing cumulative effects management that includes the impacts of hydraulic fracturing.
- Assess regulatory approaches to address landscape and watershed-level impacts of hydraulic fracturing.

**Information Availability and Disclosure Needs to Support Knowledge Generation, Best Practices and Regulations**
- Identify how improved data disclosure can advance understanding of human and environmental toxicity and risks.
- Provide recommended data formats and standards that would facilitate better industry-wide comparisons and analyses.

**Managing Risks to Groundwater and Subsurface Impacts**
- Assess pathways of methane or fluid leakage associated with active hydraulic fracturing activities.
- Assess expected groundwater quality issues related to methane migration over the short and long term.
- Develop techniques and technologies to provide practical detections of methane leaks or other contaminants from wells.
- Improve knowledge surrounding induced seismicity due to hydraulic fracturing.

**Managing Wastewater**
- Assess the human and environmental health risks associated with contaminants of concern in injected fluids, flowback and produced water to establish appropriate treatment targets.
- Conduct a comparative assessment of the performance of industrial wastewater treatment technologies for hydraulic fracturing fluid.
ACHIEVING CONSTRUCTIVE AND EFFECTIVE ENGAGEMENT

It is clear from the significant public interest and debates surrounding hydraulic fracturing that, to be effective, regulations and industry practices must be seen to be appropriate from the perspective of the broader stakeholder community. As such, a consideration of what is needed with respect to governance and achieving constructive and effective stakeholder engagement is a critical priority. Increasingly, the question being asked is: How can we move forward in this process in a way that better acknowledges the interests involved and clarifies the rationale for the ultimate decisions made?

Some of the practical areas for knowledge advancement to support constructive and effective engagement for decisions have been identified:

- Assess particular opportunities to advance transparency through effective water governance.
- Evaluate opportunities for collaborative or watershed-based governance in remote and rural regions with industry development potential.
- Establish effective governance approaches for collection and disclosure of baseline data.
- Assess public opinions of water and hydraulic fracturing across Canada to inform the design of engagement strategies.
- Compare and disseminate experiences of Aboriginal communities in North America with respect to water governance and hydraulic fracturing.
KEY DEFINITIONS

**Area-based analysis approach** - The management framework developed by the BC Oil and Gas Commission to embody cumulative effects assessment methodology in northeast British Columbia. The area-based approach is intended to manage the environmental and cultural impacts of oil and gas development as part of the Commission’s application review process.

**Cumulative effects** - The accumulation of changes on the landscape due to multiple stressors (natural and man-made) over scales of time and space and from both past and future perspectives.

**Cumulative effects approach to management or monitoring** - Incorporating consideration of the cumulative effects (present and future accumulation of changes) into environmental monitoring, assessment and decision-making.

**Formation** - The geologic term for a rock body or layer that is distinguishable from other rock bodies and useful for a mapping or description. Formations may be combined into groups or subdivided into members.

**Formation fluids** - Any fluid that occurs in the pores of a rock.

**Horizontal drilling** - A drilling procedure in which the wellbore is drilled vertically to a kickoff depth above the target formation and then angles through a wide 90-degree arc such that the producing portion of the well extends horizontally through the target formation.

**Hydraulic fracturing** - The term hydraulic fracturing is used to maximize the extraction of underground resources, including oil, natural gas, geothermal energy, and even water. The oil and gas industry uses hydraulic fracturing to enhance subsurface fracture systems to allow oil or natural gas to move more freely from the rock pores to production wells that bring the oil or gas to the surface.

In this report and the CWN program, “hydraulic fracturing” is used in the more general sense of the full suite or related activities that accompanies hydraulic fracturing, more commonly used in general discussions. As such, it includes the full lifecycle of activities (exploration, development, decommission) associated with the development and production of hydrocarbon resources that involve hydraulic fracturing.

**Multi-stage horizontal fracturing** - The process of stimulating a well through the injection of liquids or gases at high pressure in order to release hydrocarbons for production. The fracturing takes place in sequential stages along the horizontal length of the well from its toe (furthest extremity) to its heel (where the well enters the producing zone).

**Pad** - Cleared ground surface (usually covered in gravel) used to drill a well and store equipment.

**Play** - A group of identified or suspected oil and/or gas reservoirs sharing similar geologic and geographic properties such as source rock, migration pathways, and hydrocarbon type. Play refers to the extent of reservoirs within regions that are commercially viable, whereas basins are defined according to geological characteristics.

**Tight** (as in tight oil and tight gas) - Oil or gas trapped in a relatively impermeable hard rock such as sandstone or limestone.
There has been something of a revolution in North America over the past decade in the development of vast but previously inaccessible hydrocarbon reserves where gas and oil are trapped within fine-grained “tight” subsurface formations. Although well stimulation technology of hydraulic fracturing has been in use for decades, recent technological advancements — particularly the combined use of horizontal drilling and multi-stage high-pressure hydraulic fracturing — have “unlocked” the potential to develop many of these unconventional reserves (Council of Canadian Academies [CCA], 2014; United States Environmental Protection Agency [U.S. EPA], 2014).

In response to domestic and global drivers, there has been a rapid expansion of oil and gas development in North America over the last twenty years. Despite the volatility of global prices affecting the pace of production, Canada and the United States have exhibited a strong shift away from new vertical wells to predominantly horizontal wells which are largely hydraulically fractured. In the Western Canada Sedimentary Basin, the proportion of new horizontal wells to vertical wells drilled has risen from roughly 8% in 2005 to 83% in 2014 (National Energy Board, 2015). This industry’s development as a whole and the implications of the activities that accompany hydraulic fracturing techniques (beyond the well stimulation procedure) have become the focus of discussion and interest.

The expansion of unconventional oil and gas extraction has resulted in more intensive resource development within traditional oil and gas regions, as well as exploration and development in areas with little experience of petroleum development. This growth has also raised the profile of decisions and increased the focus on questions about the relative merits and risks involved; how to effectively manage and regulate the activity; and what the implications are for broader questions about where hydraulic fracturing developments fit within regional development decisions. For the majority of national discussions surrounding hydraulic fracturing, the use, management and protection of water resources has been largely at the heart of debates. These discussions inevitably expand to encompass larger considerations of environmental, social and economic issues.

In this report and the Canadian Water Network (CWN) program, hydraulic fracturing is used in the more general sense of the full suite or should be of related activities that accompanies hydraulic fracturing, more commonly used in general discussions. As such, it includes the full lifecycle of activities (exploration, development, decommission) associated with the development and production of hydrocarbon resources that involve hydraulic fracturing.
It has been challenging for the research community to generate and interpret the science relevant to many related questions about new and evolving technologies in an effective and timely fashion. The number of research studies specifically focused on hydraulic fracturing and its impacts has dramatically increased within the last five years (Figure 1. Web of Science “Hydraulic Fracturing”). In addition, there has been a recent major spike in public interest and discourse on the issue, with opposing and often polarized views being expressed in the public sphere.

**Figure 1. Web of Science “Hydraulic Fracturing”**

Number of published items per year using the *Web of Science* index topic search for “hydraulic fracturing”

Data retrieved August 25, 2015; Figure adapted from Figure 2, Ryan et al, 2015.
The rapid growth and expansion of this technology, which often involves intensive land and/or water use, has created challenges for decision makers to effectively address the many questions through a strong scientific lens. Sufficient science to fully address the questions is often lacking in many cases. Also, clear alignment of the research community on some of the topics being debated is missing. As discussed further in this report, trust in the way that science is generated and incorporated into decisions is also fundamental to its eventual application.

In order to get the best value from the existing knowledge base and resources, decision makers need to be able to make sense of what we do know and, importantly, the significance of those things we don’t yet fully understand. This must be done within a clear articulation of the key questions being asked and debated, a credible understanding of where and how provision of science can aid in the discussion and how advancements in knowledge could most usefully improve outcomes. The credibility of knowledge informing these decisions is also crucial because the implications of decisions are significant. For example, a go-forward approach may advance domestic energy production, export revenues, employment, government royalties, capital investment and tax revenues, among other benefits. Yet, there are also associated impacts such as the boom-bust effect on communities, landscape alteration and public health concerns. Certain impacts may be short term, while others endure over long periods.

In 2013, CWN initiated a national program to identify which questions were of greatest importance to those involved in decision making, as well as to find the key knowledge gaps related to these questions and the best opportunities to advance them to enable effective decisions related to management of risks and impacts of hydraulic fracturing and water. Five national teams were created with leading academics from across Canada working with international colleagues and consulting representatives from government, industry, Aboriginal communities and non-governmental organizations. The teams conducted comprehensive reviews to determine the key questions, knowledge gaps and opportunities for research approaches from the perspective of four key areas of importance to water and hydraulic fracturing, including:

1. Watershed governance and management approaches for resource development, including Aboriginal issues
2. Groundwater and subsurface impact issues
3. Wastewater handling, treatment and disposal
4. Landscape impacts of development/operations on surface water/watersheds
Five multi-disciplinary teams from across Canada were selected to undertake the work and each of the teams was requested to explore water use and demand management as part of their project.

Development of a water safety framework for watershed and water demand governance and management approaches related to hydraulic fracturing

**Lead Researcher:** Graham Gagnon, PhD, Professor, Dalhousie University
- Ian Mauro, PhD, University of Winnipeg
- Edward Arthur McBean, PhD, PEng, University of Guelph
- Madjid Mohseni, PhD, PEng, University of British Columbia

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**Lead Researcher:** Michele-Lee Moore, PhD, Assistant Professor, University of Victoria
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Hydraulic fracturing and water knowledge integration: Landscape impacts

**Lead Researcher:** Michael Quinn, PhD, Director, Institute for Environmental Sustainability, Mount Royal University
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Subsurface impacts of hydraulic fracturing: Contamination, seismic sensitivity, and groundwater use and demand management

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Other recent reviews have provided extensive and important summaries of the broad knowledge base and gaps around hydraulic fracturing (American Water Works Association [AWWA], 2013; Atherton et al., 2014; CCA, 2014; Royal Society, 2012). The CWN-funded projects continue from where many state-of-the-knowledge summaries leave off, focusing on identifying the most important knowledge gaps and options for decision makers from among the many gaps that exist. This required that the assessment of knowledge gaps start from a consideration of the priority concerns and questions that are most relevant for a given region or circumstance.

The work of the five teams intentionally overlapped. Each CWN-funded project approached the overall issue of decision needs from the perspective of one of the key topic areas listed above, each developing their own methodological approach and scope. The collective result is a highly comprehensive and up-to-date assessment of the knowledge base and its relevance to key decisions facing regions in Canada. The work identifies opportunities to move the knowledge base forward to improve the basis for those decisions.

The reader is referred to the individual stand-alone studies for a detailed consideration of their findings at cwn-rce.ca/reports. The 2015 Water and Hydraulic Fracturing Report provides a high-level framing that complements the greater detail provided by the CWN-funded projects and other leading works, and articulates some highlights from the decisions and discussions that are taking place.
1. THE CANADIAN CONTEXT: A VARIED LANDSCAPE FOR HYDRAULIC FRACTURING

A consideration of how science can best inform decisions related to hydraulic fracturing within different Canadian regions must account for the significant differences that exist across the country. This includes variations in geological, hydrologic and landscape conditions; cultural, social and economic conditions in areas overlying unconventional resources; and the degree of both regulatory development and experience with oil and gas development in different jurisdictions.

Decisions surrounding hydraulic fracturing operations are predominantly under the purview of the provinces and territories, where most resource development decisions are controlled. The federal government also holds some relevant authorities, including responsibility for the regulation of oil and gas activities on First Nation reserves, federal lands and national parks. The federal government also has the authority to assess chemical substances and manage toxic substances under the Canadian Environmental Protection Act, 1999 and administration related to federal legislation such as the Fisheries Act. The federal government, along with provincial counterparts, also contributes to the knowledge base through scientific research and provision of geoscience information for exploration, resource development and environmental protection.

Better recognition and clarification of the role of Aboriginal governments in decision making is increasingly an area of consideration where resource development occurs on or near traditional or Treaty lands. In Canada, unconventional oil and gas development has largely occurred in the west to date (over 80%), where there is a more significant history of oil and gas production and greater regulatory experience. However, in eastern Canada, the identification of significant shale gas reserves, often in close proximity to population centres including Aboriginal communities, has raised serious questions about the application of hydraulic fracturing in those regions. The significant difference in the approach to issues in the West as compared to the East was a repeated finding of several of the CWN-funded projects (Moore et al., 2015, Quinn et al., 2015, & Ryan et al., 2015).

The potential to extract oil and gas reserves using multi-stage horizontal fracturing exists in nearly every province and territory in the country. The regions that show the greatest geological promise based on what is presently known are the Horn River Basin and Montney Shales in northeastern British Columbia, the Colorado Group in Alberta and Saskatchewan, Duvernay formation in central Alberta, the Utica and Lorraine shales in Quebec, the Horton Bluff shale in New Brunswick and Nova Scotia, Green Point shale in western Newfoundland, the Bluefish and Canol shale in the Northwest Territories, and Besa River formation in the Liard Basin in the Yukon Territory (Figure 2. Map of Unconventional Oil and Gas Plays in Canada).

“In our research and workshop, the difference between the western cases of Alberta and British Columbia and the east coast cases of Nova Scotia and New Brunswick arose repeatedly. The regional differences shaped our research.”

(Moore et al., 2015, p. 16)
Figure 2. Map of Unconventional Oil and Gas Plays in Canada

Despite greater overall familiarity with petroleum resource development in the West, hydraulic fracturing has become a controversial process right across Canada, mainly surrounding concerns over its use of, or impacts to, water. Of particular widespread relevance are issues surrounding Aboriginal communities across Canada, since a significant proportion of the areas of oil and gas development are in their traditional territories, and frequently involve impacts on traditional uses and relationships with land, water and ways of knowing (Basdeo & Bhardwaj, 2013; Tobias & Richmond, 2014).

As regulators undertake efforts to ensure responsible management and sustainable resource development, some Canadians have voiced concerns. Opposition is made visible through petitions, social media and protests demanding an outright ban on the practice. In Quebec and the Maritimes, the issue has become highly politicized. Interests in energy independence and job opportunities have been countered by significant public concerns over the potential risks. Even though certain eastern provinces have a history with small-scale oil and gas development, there is less public confidence that hydraulic fracturing is safe and would be beneficial.

Figure 3. Jurisdictional Regulatory Context for Hydraulic Fracturing, illustrates the range of approaches (as of July 2015) from regulated development in the West, and cautious steps toward development in the North, to the establishment of moratoria over the last few years in Eastern Canada. In addition, a summary of the regulatory decision context in each province and territory is provided in table form in Appendix A. A more detailed summary and discussion of regional and regulatory considerations relative to the focus areas of the CWN program can be found in the individual CWN-funded reports (Gagnon et al. 2015, Goss et al., 2015, Moore et al., 2015, Quinn et al., 2015, Ryan et al., 2015).

“Not only are First Nations, Métis and Inuit peoples more likely to experience a problem with their water, they are impacted more significantly than the rest of the non-Native Canadian population when these problems occur.”

(Gagnon et al., 2015, pg. 64)
Considerable variation in factors such as local geology and hydrology are also of importance to understanding the key knowledge needs and the most relevant science for decisions. Differences in these factors significantly impact operational issues such as the volumes of water required and the technology options available for use when considering sustainable development. Variations in the nature and availability of local water resources, proximity of development to important aquifers or surface water bodies, competing uses and local cultural and social and economic considerations shape the concerns that drive decisions and options for response in every region.

Across Canada, significant regional differences exist, such as the general lack of geology suitable for subsurface reinjection of waste fluids in much of the East. Other factors, including the geological characteristics of the reserves themselves and the local demand for, and availability of, water resources exhibit considerable variation between individual hydrocarbon reserves. Attempts to better address local or regional differences, and also begin to manage the cumulative impacts in each region more effectively, have led to recent efforts to develop area-based or play-based regulations. Such efforts are currently being piloted in BC and Alberta.

Figure 3. Jurisdictional Regulatory Context for Hydraulic Fracturing
WeStern caNaDa

In BC and Alberta, where there is an established industry and culture of oil and gas development, regulatory reforms aimed at integrating all land, water and subsurface decisions are being implemented. The BC Oil and Gas Commission has developed an “area-based” framework for approvals, and recently released a collaborative water strategy for the northeast, the predominant area for shale well extraction in the country. To put recent activity in perspective, there were 5,341,635 m³ of water injected into 433 shale wells in BC in 2013, and an estimate of just under 1,400 horizontal shale gas wells drilled in the last 15 years (BC Oil and Gas Commission, 2013).

In September 2014, Alberta initiated a “play-based” regulation pilot project in the Duvernay play near the Town of Fox Creek, comparable with BC’s play-based approach to regulatory approvals. The pilot project is expected to wrap up in September 2015 and learning from the pilot project will be used to advance subsequent development of the play-based regulatory approach.

Alberta’s main shale gas deposits include the Duvernay formation and the Colorado Group along the border with Saskatchewan, and the Montney and Muskwa-Otter Park formation. Tight oil resources are scattered across the province (see Figure 2. Map of Unconventional Oil and Gas Plays in Canada). The number of oil and gas well completions involving multi-stage hydraulic fracturing in the province from 2008 until the end of 2014 is estimated at 10,000 (Moore et al., 2015).

Saskatchewan is Canada’s second-largest oil producer, comprising about 15% of Canadian crude oil production, and is the sixth-largest oil-producing jurisdiction in North America. Saskatchewan is undergoing a broad-sweeping reform of its environmental regulations, moving towards a results-based framework. The new model represents a shift away from prescriptive regulations, toward one that holds proponents accountable for achieving desired environmental outcomes (Government of Saskatchewan, 2012). There are approximately 2,591 producing oil wells in the Bakken play, primarily using horizontal wells with a multi-stage fracturing completion (Government of Saskatchewan, 2012).
TABLE 1: A Snapshot of Status of Hydraulic Fracturing by Regions of Canada

In 1980, tight oil resources were discovered in Manitoba as part of the Bakken formation, which spans the U.S. and Saskatchewan borders. According to Manitoba Mineral Resources, oil production through horizontal wells was introduced in the 1990s and now accounts for over 80% of the province’s production (S. McBride, personal communication, July 20, 2015). The Manitoba Petroleum Branch is presently reviewing the adoption of new guidelines for hydraulic fracturing. Manitoba has two tight oil plays under active development using horizontal drilling and multi-stage hydraulic fracturing technology and shale gas potential. There are currently 1107 wells that employ hydraulic fracturing in the province (S. McBride, personal communication, July 20, 2015).

CENTRAL CANADA

Central Canada has not initiated development of oil and gas reserves involving hydraulic fracturing. In 2011, Quebec was the first province to enact a moratorium on hydraulic fracturing (in place until 2018). The Quebec government continues to study the risks and economic benefits of shale development in the St. Lawrence Lowlands and will pass new legislation on hydrocarbons in 2016. Quebec has also endeavoured to study the full social, economic and environmental costs and benefits of pursuing its shale resources (Bureau d’audiences publiques sur l’environnement [BAPE], 2014).

No unconventional shale gas, tight oil drilling or high volume hydraulic fracturing has occurred in the province of Ontario to date. In 2009, the Ontario Geological Survey initiated in a multi-year project to assess the shale gas potential of southern Ontario. The identified reserves are often shallow (less than 1,000 metres) and located in heavily populated areas (CCA, 2014), two factors which work against development.

EASTERN PROVINCES

Even though it is a smaller part of the overall economic picture, eastern Canada has a significant history of petroleum development going back to the 1800s. New Brunswick has gone the furthest towards developing its shale gas resources. In 2011, the New Brunswick government initiated a public inquiry to discuss both interests and concerns over shale development. The province also established a new research institute.
to address the identified knowledge gaps and baseline monitoring needs, and developed new rules for industry that build upon the existing regulations. New Brunswick has since halted its pursuit of shale gas development and has enacted a moratorium. As of 2015, 38 tight gas wells had been drilled and hydraulically fractured in the province (Government of New Brunswick, personal communication, August 28, 2015).

Exploration for conventional oil and gas in Newfoundland dates back to the early 1800s. Over the last 15 years, Newfoundland and Labrador have experienced significant economic growth due to offshore oil revenues; however, that growth is declining. In November 2013, the government of Newfoundland and Labrador enacted a moratorium for onshore and onshore-to-offshore petroleum exploration using hydraulic fracturing until further review can be completed. A formal review of regulations, rules and guidelines is underway at the same time as several technical assessments and public consultation efforts.

In Nova Scotia, assessments of the potential risks and opportunities, along with consultations with Aboriginal communities and the general public, have also led to an indefinite moratorium that prohibits the practice of hydraulic fracturing in the province.

THE NORTH

Both Yukon Territory and Northwest Territories (NWT) contain largely unexplored oil and gas resources. Due to the remote location of the resources and challenges pertaining to infrastructure, these resources have previously been regarded as having limited commercial value. The Yukon government has expressed an openness to pursuing development in the Liard Sedimentary Basin, but only with the support of its Aboriginal population and further study. NWT has put forward new regulations as part of its ongoing post-devolution work to enhance the regulatory system to reflect the priorities of residents and national best practices. The new regulations, if approved, will apply to hydraulic fracturing projects in the Mackenzie Valley (regulated by the NWT Oil and Gas Regulator) and the Inuvialuit Settlement Region (regulated by the National Energy Board). Residents, First Nations and other relevant stakeholders will be consulted on the proposed regulations through summer 2015.
2. DECIDING WHERE AND WHEN HYDRAULIC FRACTURING MAKES SENSE

For many regions in Canada, the primary questions being asked about hydraulic fracturing focus on whether or not the production of unconventional hydrocarbon resources made possible by hydraulic fracturing yields net benefits.

The fundamental considerations within this context include an understanding of the net social and economic benefits of development; water uses in a given area; whether it is justifiable and sustainable given available resources and likely impacts; and understanding the overall risks to human and ecosystem health. Public opinions and values can be as important in this process as using appropriate methods and accessing relevant information.

2.1 UNDERSTANDING NET SOCIAL AND ECONOMIC COSTS AND BENEFITS OF HYDRAULIC FRACTURING

In regions considering the establishment or expansion of hydraulic fracturing activities, the basic questions shared by decision makers and stakeholders alike are:

‘What is the expected net benefit of the activity? How can the pros and cons be effectively weighed? Should hydraulic fracturing be permitted?’

The entry point to discussions has typically been an estimation of what is economically recoverable, as well as the social benefits that could accrue in terms of revenues and jobs. Estimates of expected social and economic benefit based on these calculations are then considered against the potential risks as identified from the available literature, regional experiences and local considerations. This kind of trade-off approach is inherent to decisions related to resource development, although not always carried out as a formal cost-benefit analysis.

Effectively balancing considerations about whether or not to develop resources using hydraulic fracturing is challenging. Quantifying the costs and benefits of the many social and environmental factors includes important subjective decisions in terms of what should be included. These exercises can therefore range in level of complexity. Nonetheless, a key advantage of taking a broad cost-benefit approach is that less immediate factors such as impacts on natural assets – the ecological good and services that water provides (e.g., food production, biodiversity and

“The true cost of hydraulic fracturing depends on economic and other benefits weighed against various risks.”
(Ryan et al., 2015, p. 124)

“Trust can become limited when, regardless of the outcomes of a consultation process, decisions are made to favour economic values over all other community and Indigenous values.”
(Moore et al., 2015, p. 55)
climate regulation) — can be explicitly considered. However, limitations arise from the difficulty of ensuring appropriate quality of data inputs for such factors. There are challenges pertaining to characterizing and quantifying long-term impacts. There may also be a mismatch between how and where the costs and benefits are experienced within and beyond a given area of potential development. As Ryan et al. (2015) indicate, “unpriced social costs are mainly local in nature, while its benefits are local, national, and global” (p. 124). Furthermore, as Moore et al. (2015) highlight, efforts are being undertaken to assess important values associated with sense of place and community attachment to ecological, cultural and aesthetic values.

Methods exist to provide a systematic approach for evaluating the costs and benefits of resource development, including, but not limited to water costs. However, the most appropriate methods to apply are not yet widely accepted and have had limited application to date as a result (Ryan et al., 2015). The ability to include externalized costs (i.e., environmental and social impacts) and quantify what citizens value in a defensible and accepted manner is a particular challenge. Not just appropriate methodology, but a lack of overall trust in the assumptions of those assessments (and the motivations behind them) hinders more effective application of cost-benefit approaches (Moore et al., 2015).

Achieving more effective and explicit application of cost-benefit approaches to hydraulic fracturing decisions in a way that reflects Canadians’ values provides an opportunity to improve transparency of how net overall benefits of hydraulic fracturing are determined.

**Regional example: Quebec**

*Quebec conducted a comprehensive cost-benefit study (released in 2014) based on several development scenarios. The study considered the value of royalties, taxes, tax credits, flow-through shares, salaries, compensation to landowners and the value of regulatory permits. These potential benefits were compared to the external costs of degradation to the environment, as well as the costs of inconveniencing residents and transporting the gas and emissions. The monetary values for each element were based on the current forecasts and available literature at that time. For example, the study employed the U.S. Environmental Protection Agency’s value of $46 per ton to represent the social cost of carbon. The study concluded that there was no net benefit for Quebec in exploration and exploitation of shale gas in the St. Lawrence Lowlands (the net social value would be minus $397 million in the reference case). The study is part of a broader strategic assessment that will include further public consultation to inform the province’s decision about whether to maintain the existing moratorium (Gouvernement du Québec, 2014).*
NET SOCIAL AND ECONOMIC COSTS AND BENEFITS OF HYDRAULIC FRACTURING

What do we know?
• General estimates can be made of the potential social and economic benefits of development expected for hydraulic fracturing, but they are often based on incomplete data and subject to fluctuations inherent in market forecasts. Long-term impacts, particularly on subsurface conditions, remain largely undefined.
• There are a variety of economic methods and measures that can be used to develop estimates of non-market social and environmental costs and benefits to structure trade-off discussions.

What do we most need to know?
• A clearly articulated definition of what constitutes a sufficient benefit to the overall community that would better inform when those benefits outweigh implicit risks and costs.
• How to incorporate non-market externalities and the uncertainties regarding long-term implications in calculations that address key concerns most effectively.
• How to account for portions of the population that are disproportionately affected.

What is reasonable to expect we could advance?
• Improved, more transparent analysis and discussion about trade-offs in net-benefit considerations, including non-market externalities that encompass the environmental and social aspects.

Opportunity:
• Develop more credible, broad social and economic analyses that reflect a more complete and socially-relevant balancing of negative and positive elements associated with shale gas development.
2.2 WATER USE ISSUES ASSOCIATED WITH HYDRAULIC FRACTURING

One of the issues driving discussions with respect to whether or not hydraulic fracturing activities are sustainable is the amount of water (particularly freshwater) used and the potential for conflicts with competing needs. In some cases, hydraulic fracturing requires large volumes of water. In areas where water resources are scarce, there is concern that water demands for hydraulic fracturing may reduce the resiliency of the natural system or compete with other users, such as agriculture or municipalities.

Water requirements for hydraulic fracturing vary greatly based on the geologic formation, the techniques used and the number of operations in a given area. The requirements can range from no water used (carrier fluids or gases are substituted), to volumes as high as 80,000 m$^3$ per well. These large volumes of water are used when the shale is very thick, as is the case in Horn River Basin (see Figure 4. Map of Average Volume of Water Used Per Well in Canada).

The intensity and timing of water use during the actual hydraulic fracturing procedures are typically more relevant than the overall volume used on an annual basis. Availability and accessibility of groundwater varies between sites. As well, seasonal or annual changes in surface water sources are relevant to ecosystem health and other water users. Therefore, effective water management to support new water uses such as hydraulic fracturing requires a base understanding of the local water balance. Historic knowledge of the natural system, regional climate and water uses that are currently accounted for are part of understanding the balance. The fate of wastewater — whether it is returned to the watershed or becomes a consumptive use — is another dimension of the water balance.

“Special attention is needed in some regions in Canada where water scarcity may exist for municipalities and irrigation districts that rely on surface water supplies for domestic uses and food production.”

(Quinn et al., 2015, p. 51)
Concerns regarding water use have resulted in industry innovations such as opportunities to reduce demand through water conservation measures, use of non-potable water and reuse/recycling strategies. Innovations in freshwater conservation include methods to draw on municipal wastewater sources (e.g., Shell Canada in Dawson Creek) and use of other non-potable sources (e.g., saline groundwater in the Montney). While reuse strategies have obvious appeal from the point of view of conserving freshwater, the longer-term consequences of these approaches are also important. For example, reducing overall water needs through recycling and reuse requires additional treatment, handling activities and energy inputs, and leads to the increased concentration of dissolved constituents, including contaminants in the eventual waste streams. Alternative fluids or gases, such as carbon dioxide, oil or high-vapour pressure fluids, such as propane, exist and are in use in some areas. Their use is largely driven by the local geology, availability of water and economic considerations (Gandossi, 2013). These types of trade-offs are considered in the reports Goss et al. (2015) and Quinn et al. (2015).
A consideration of where and whether hydraulic fracturing activities are sustainable from a water use perspective requires an understanding of other competing water needs and uses. Building the capacity to predict the cumulative impacts of many users, and therefore the incremental effects, is increasingly a goal for many regions. From a water use perspective, a cumulative effects approach can be used to address issues such as the timing of withdrawals relative to periods where rivers tend to be low or groundwater systems are experiencing pressures. For example, in areas that experience seasonal water scarcity such as southeastern BC and Alberta, the connection between surface, groundwater and brackish water is increasingly important for decision makers (United States Geological Survey, n.d.). Estimates of the natural system’s needs, as well as the requirements for other non-permit water uses and values (e.g., cultural uses), and impacts of climate change are an important part of the equation; they represent areas where the science continues to evolve.

Both Alberta and BC continue to update the way water use information is collected and reported for oil and gas sector users. Alberta, BC and Quebec have taken steps toward improving knowledge about local groundwater systems. The opportunity exists to apply groundwater monitoring and modelling techniques to better support the sustainable use of groundwater for hydraulic fracturing. The significant governance challenges of water allocation and use were part of the drive behind BC’s recently developed collaborative water use strategy for the northeastern part of the province (see Regional Example, BC Oil and Gas Commission below).

**Regional example: BC Oil and Gas Commission**

On July 28, 2014, the BC Oil and Gas Commission temporarily suspended short-term water withdrawal by oil and gas companies from several basins in the Peace River Watershed due to significant drought conditions. Most of northeast BC remained under the class IV restriction until September. In BC, Alberta and Quebec, water availability for hydraulic fracturing is currently being investigated on a regional scale. These investigations include efforts to characterize and map groundwater and deep saline aquifer sources.

*(BC Oil and Gas Commission, 2014).*
WATER USE ISSUES ASSOCIATED WITH HYDRAULIC FRACTURING

What do we know?
• Water use for hydraulic fracturing varies greatly by play, reflecting different reservoir conditions and density of development (from no water use to 80,000 m³ per well).
• Methods exist to develop regional water balances (including groundwater) and management plans, which provide the basis for determining if industry needs are sustainable.
• Options for water conservation, recycling and reuse exist, but can also have other implications, such as wastewater treatment issues, or increases in energy consumption.
• Deep saline and brackish water, or alternatives to water, can be used in the fracturing process, but effectiveness will be specific to the formations, and saline waters may require pre-treatment.

What do we most need to know?
• Regional water balances and future development forecasts within cumulative effects management frameworks that address area needs and public values.
• The nature of the anticipated trade-offs associated with water conservation and reuse approaches and the use of alternative fluids/gases, to support more of a lifecycle assessment.

What is reasonable to expect we could advance?
• Monitoring, measuring and forecasting of water availability and use within regions or basins.
• Development of cumulative effects monitoring frameworks.
• An understanding of the nature of trade-offs associated with use of existing or new water recycling and reuse strategies, or the use of alternative fluids and gases.

Opportunities:
• Address knowledge gaps in development of regional, cumulative effects-based water plans, including improved understanding of groundwater conditions and deep saline resources.
• Project current and future water availability from all sources, including methods to estimate future water needs of the industry.
• Assess the lifecycle and impact(s) of strategies for conservation, reuse or alternatives to freshwater.
2.3 UNDERSTANDING HUMAN HEALTH RISKS AND CONTAMINATION CONCERNS

Concerns about potential human health impacts of hydraulic fracturing have been a dominant driver in public debates about whether or not to develop unconventional oil and gas resources. Determining whether or not the overall risks are significant is an area where it is difficult to effectively address concerns through the application of science. The literature surrounding the potential human health risks of gas and oil development involving hydraulic fracturing includes much speculation and is dominated by a discussion of the degree of unknowns. Based on work by Goldstein, Bjerke and Kriesky and Goldstein, Kriesky and Pavliakova, the CCA report, Environmental Impacts of Shale Gas in Canada, concludes that, “the effects of shale gas development on human health have not received much scientific and government attention despite often being cited as an issue of public concern” (CCA, 2014, p. 135). The lack of studies related to hydraulic fracturing and human health in the scientific literature is illustrated in Figure 5. Web of Science Hydraulic Fracturing and Health Quotes.

“In Canada, concern regarding contamination risks is the foremost cause of public opposition to hydraulic fracturing; it is an issue that arose among both survey respondents and workshop participants, as well as in the literature.”

(Moore et al., 2015, p. 31)

Figure 5. Web of Science Hydraulic Fracturing and Health Quotes
Number of published items per year using the Web of Science index topic search for "hydraulic fracturing and health"
Data retrieved August 25, 2015; Figure adapted from Figure 2, Ryan et al, 2015.
The impacts and concerns related to hydraulic fracturing — including human health — extend beyond those related to water. However, this report deals principally with the water-related aspects, as they often represent the central element to discussions and the focus for decision making. The primary water-related issue of concern being expressed from a health perspective is potential exposure to contamination via drinking water, particularly through impacts to groundwater aquifers accessed by drinking-water wells. Research to date has focused on the potential for contamination and exposure pathways via groundwater wells. As discussed in Ryan et al. (2015), it is difficult to fully assess and/or detect aquifer contamination and relate this to health risks and impacts over the short and long term, particularly when based on testing of domestic water supply wells as opposed to dedicated groundwater monitoring systems. The focus of many studies has been on short-term studies interpreting domestic well conditions in relation to nearby drilling activities.

It is the potential impacts of methane gas leakage on potable supplies resulting from either fracturing activities or failed wellbores that likely represents the exposure pathways of greatest concern for impacts to potable water supplies (Ryan et al., 2015, CCA, 2014). As discussed further in Section 3.5, contamination of waters by additive chemicals is often a topic of debate. Contaminant exposures at the surface due to spills or the handling of wastewater may occur as a result of activities associated with hydraulic fracturing and represent more immediate or shorter-term risks than groundwater exposures. Assessment of the risks due to surface spills are not dissimilar from considerations of chemical and wastewater handling issues associated with other oil and gas or resource development issues. What is unique in this case is that some of the potential chemical hazards are unknown as a result of proprietary issues, resulting in fears about the potential effects associated with those unknown constituents (Goss et al., 2015; Quinn et al., 2015).

Several provincial assessments of the potential health impacts of hydraulic fracturing have taken a more holistic view of the determinants of health that extend beyond drinking water impacts and what is strictly regulated by health authorities (e.g., chemical toxicity concerns). Health assessments in BC, Quebec, New Brunswick and Nova Scotia have addressed the need to consider factors such as noise and light pollution, ecosystem impacts, loss of rural and traditional ways of living and stress, as well as longer term social and economic impacts of the boomtown effect. Many of these effects could disproportionately impact certain segments of the Canadian population, including Aboriginal communities. Health studies related to a population’s proximity to hydraulic fracturing operations have been conducted in some jurisdictions.

The timeframe involved is of significance in better framing the relevance of various potential health risks, in addition to considerations like disproportionate impacts to vulnerable communities. Whereas some risks are immediate or short term, such as noise, landscape disruption or surface spills, other risks may be more long-term in nature, such as migration of methane within groundwater, or cross contamination between geological formations that occurs due to wellbore deterioration over time. This is a consideration both for the overall risks to be factored into a decision about hydraulic fracturing, as well as whether the regulation and management practices contemplate mechanisms to deal with the longer-term risks.
UNDERSTANDING HUMAN HEALTH RISKS AND CONTAMINATION CONCERNS IN HYDRAULIC FRACTURING

What do we know?
• Assessing potential human health impacts currently remains an area generating widespread concern, but a direct knowledge base is lacking to fully assess concerns; there is limited peer-reviewed literature on the human health effects of hydraulic fracturing.
• The potential health risks of hydraulic fracturing include direct exposure (e.g., toxicity concerns, noise) and indirect factors of importance (e.g., stress and social and economic impacts).
• Environmental health risk assessment methods and approaches exist that can be drawn upon to support policy development and decision making related to hydraulic fracturing.

What do we most need to know?
• The immediate and long-term human health implications of hydraulic fracturing in Canada, based on the best available understanding of potential risks.
• The potential impacts to either vulnerable or disproportionately impacted communities (e.g., Aboriginal communities).

What is reasonable to expect we could advance?
• Improved characterization of the human health risks associated with direct exposure to chemicals and additives in hydraulic fracturing fluids and flowback water.
• Application of methods from other fields of resource development to better assess the indirect health impacts of hydraulic fracturing.
• Improved risk communication to help focus attention on priority risks.

Opportunities:
• Assess toxicity concerns of leakage of methane or other contaminants from wells to groundwater/drinking water.
• Assess toxicity concerns related to hydraulic fracturing wastewater.
• Advance the effectiveness of risk communications approaches.
Given the considerable concerns expressed over human health effects and hydraulic fracturing, and the many outstanding unknowns, there is significant potential for further study in this area to better support decisions. Additional work should provide direct input to the existing foundations in the public health field for risk-based decision making frameworks. These frameworks and their underlying principles can be used to guide priorities for further research. The growing number of studies that focus on health, such as the work of the U.S. Environmental Protection Agency (U.S. EPA, 2015) to assess the potential impacts of hydraulic fracturing on drinking water resources, will also inform ongoing decisions about risk prevention and management in Canada. There is a significant opportunity to draw from these works to both inform risk assessments and to help prioritize research for studies across Canada.

Identifying and mitigating potential human health risks remains a core focus for further work to address regulatory needs and the best options for risk management. However, the number of unknowns in this area contributes to an overall level of uncertainty in generalized risk calculations. This uncertainty leads to a general concern regarding the magnitude of undefined risks that feed into decisions about whether or not hydraulic fracturing makes sense.
3. INFORMING BEST PRACTICES AND REGULATIONS

When moving from decisions of whether or not to allow hydraulic fracturing, to determining how best to oversee and manage the practice, the focus of decision makers shifts to assessment of best practices and regulations. The emphasis of knowledge needs focuses on what is most needed to identify and evaluate specific risks and impacts, how these risks and impacts should be regulated, and what best practices should and could achieve. In this context the question becomes – Do we understand the key risks and how to manage and/or mitigate them?

The main considerations for prioritizing the particular knowledge needs relevant to both the near and longer-term impacts of hydraulic fracturing include:

- The nature and adequacy of baseline data to support effective impact assessment and monitoring design
- Approaches for effective cumulative effects monitoring and assessment
- Sufficiency of public disclosure and access to information
- Sufficient understanding of the key subsurface risks, including groundwater contamination and seismicity, issues related to wastewater generation and surface management associated with hydraulic fracturing.

3.1 BASELINE DATA NEEDS

Establishment of baseline data is the entry point to decisions regarding natural resource development. Baseline monitoring is crucial to ensuring that development is undertaken in a sustainable manner, that the environmental conditions and cumulative effects are understood and that responsibility for ecosystem changes can be properly attributed. For the purpose of this discussion, baseline data refers to the set of physical, chemical or biological data that sufficiently characterizes either the current or pre-development circumstance in a given area to support effective, forward-moving decisions and assessments. More specifically, baseline data describe overall system conditions in a way that allows for the detection of changes from the baseline condition, outside of what would normally be expected.

With respect to identifying important baseline data needs relative to hydraulic fracturing activities, two areas emerge in particular: 1) data that provide an appropriate baseline to support the design of cumulative effects monitoring within watersheds, and 2) data that support monitoring and assessment of groundwater contamination, particularly with respect to methane.

Although not discussed further in this chapter, it should be noted that, to the extent that there are plans to conduct specific health impact studies, human health baseline data would also be required.

The availability of baseline data for both surface and subsurface conditions varies considerably depending on location. In general, there is significantly more information and a better understanding of surface-water systems compared to subsurface and groundwater conditions. However, some rivers and surface-water systems have been more extensively studied than others.
What do we know?
• There is no one-size-fits-all approach to defining and capturing baseline data needs; it will be a function of a locally-determined assessment and monitoring frameworks.
• Baseline data are necessary to design appropriate monitoring strategies that evaluate the following: risks and impacts, the adequacy of reference sites that will provide a basis for comparisons, and triggers that would signify system changes or impacts.
• The governance and use of baseline data can be an important dimension of the public’s trust in decisions (e.g., ownership of data, establishing indicators of meaning or incorporating traditional knowledge).

What do we most need to know?
• The kinds of data that most effectively allow for monitoring changes — i.e., supporting the design of a cumulative effects approach to watershed management, including long-term impacts.
• The baseline data that will most reliably improve the ability to detect or understand methane contamination and transport in groundwater.

What is reasonable to expect we could advance?
• The design of cumulative effects monitoring frameworks appropriate to hydraulic fracturing areas.
• Advancement of techniques for accurately measuring dissolved gas concentrations in groundwater.
• Best practices in governance structures for baseline data collection and ongoing monitoring to apply to hydraulic fracturing development.

Opportunities:
• Inform the design of monitoring frameworks for cumulative effects assessment that address hydraulic fracturing considerations, including establishing baseline water quality and availability.
• Develop approaches that more effectively assess and establish baseline groundwater quality to enable the possible detection of methane gas or other contaminant impacts.
When it comes to hydraulic fracturing operations, there is often limited or insufficient data to adequately establish baseline conditions. The lack of a common approach for different monitoring programs undertaken in one area — for example, baseline programs versus Environmental Impact Assessment versus post-operational monitoring, can make consolidation and comparison across data sets difficult.

Where baseline data are absent or insufficient, additional data collection is required. This represents a particularly important yet challenging reality in the area of hydraulic fracturing development, particularly for governments. The collection of sufficient additional data to provide adequate baselines, and design effective monitoring frameworks can involve significant time and expense at an early stage, before resource development has even been established. How much is enough and what is most important to collect become critical considerations, and the answers are not prescriptive. As a result, governments are challenged to establish sufficient baseline data within the scope of realistic funds and resources available.

Methods to obtain baseline data to assess methane contamination of groundwater associated with hydraulic fracturing represents a relatively new and contested area of research. Numerous studies exist that either confirm or negate the association between hydraulic fracturing and methane contamination of supply wells. These studies reflect a lack of consensus within the science community, and more importantly, the inability to predict the long-term impacts with existing science and data. Baseline conditions of methane in aquifers or wells prior to oil or gas activity are critical for determining whether or not hydraulic fracturing activities have led to methane contamination of drinking water supplies. Scrutiny of the methods for collecting baseline data through groundwater monitoring systems, as opposed to domestic well testing, are often at the heart of these disputes. Methods used to distinguish between deeper “thermogenic” (associated with petroleum/shale reserves) and shallower “biogenic” (unrelated to deep petroleum deposits) sources have also been contested.

Baseline data needs refer not only to appropriate data collection, but also to effective access to that data as discussed in Section 3.3. Issues of data ownership, handling and disclosure are important to enabling effective assessment of conditions and achieving a sense of transparency of decision processes that are increasingly important when it comes to social license issues (Moore et al., 2015).
3.2 CUMULATIVE EFFECTS AND MONITORING, ASSESSMENT AND MANAGEMENT

A cumulative effects approach to the regulation and management of hydraulic fracturing is particularly important due to the significance of the intensity of level of activity, be it multiple wells, transporting fluids on and off site, or water storage. Development of unconventional plays typically involves the drilling of many wells, with multiple wells per well pad, and staged fracturing stimulations for each well. This can add up to significant overall activity in a region, undertaken by a variety of companies and operators (BC Oil and Gas Commission, 2012). In addition, a significant network of roads is often required, and high volumes of traffic and on-site activities can occur. Although the high levels of activity associated with well stimulation by hydraulic fracturing may be short lived, the longer-term and cumulative impacts are important considerations.

As a result of these considerations, hydraulic fracturing requires a monitoring framework to assess the overall impacts, as well as how effective the cumulative effects from hydraulic fracturing activities are being managed. An integrated monitoring approach that adequately addresses cumulative impacts and needs aspires to be transparent and accessible, holistic and comprehensive, scientifically rigorous, adaptive and robust, and inclusive and collaborative (Environment Canada, 2011).

As discussed regarding baseline data needs, the most effective monitoring frameworks, including a decision on which data to collect and over what timeframes, will be dependent on regional or local conditions. Although there are a variety of monitoring frameworks and approaches for establishing appropriate indicators such as characteristics of the natural environment and the impacts to living creatures, and thresholds of changes in the environment that reflect impacts due to oil and gas development, establishing regional frameworks that consider the cumulative effects of all activities is required. Research can help determine the most effective indicators and how best to monitor them for a given area to establish their expected behaviour or variation (Greig & Pickard, 2014).

Determining the right suite of indicators at multiple locations and various times is a challenging, dynamic and adaptive process. There are practical limits to how much monitoring can be done, and decisions must be made to prioritize the most important factors to monitor over time. Advancements in the analytical frameworks and governance systems to achieve cumulative effects management exist and are evolving. The success of newly established attempts to design and apply cumulative effects approaches for oil and gas development has yet to be determined.

“Large scale unconventional oil and gas development represents the start of what may be several decades of drilling and production involving tens of thousands of wells. As such, environmental impact assessments cannot focus on just a single well or well pad, but must also consider the context of local and regional landscape impacts over time.”

(Quinn et al., 2015, p. 119)
CUMULATIVE EFFECTS AND MONITORING, ASSESSMENT AND MANAGEMENT IN HYDRAULIC FRACTURING

What do we know?

• A cumulative effects management approach is needed to ensure sustainable development of oil and gas resources and water, particularly for intensive activities associated with hydraulic fracturing.

What do we most need to know?

• Specific knowledge elements, including the best indicators and appropriate thresholds, are required to effectively manage the cumulative effects of resource development involving hydraulic fracturing.

• An evaluation of the adequacy of reference sites that will provide a basis for comparisons.

• The governance approaches/models that are most effective for facilitating cumulative effects monitoring.

What is reasonable to expect we could advance?

• Best practices in cumulative effects monitoring and management for areas dominated by hydraulic fracturing.

• Lessons from case studies of governance approaches and cumulative effects assessment.

Opportunities:

• Assess evolving experience and advance approaches for implementing cumulative effects management that includes the impacts of hydraulic fracturing.

• Assess regulatory approaches to address landscape and watershed-level impacts of hydraulic fracturing.
Regional example: British Columbia

A recent example that may provide lessons for the future of development of cumulative effects frameworks through a transparent multi-stakeholder process is BC’s Northeast Water Strategy for areas of intensive gas production. The Strategy defines monitoring needs for state-of-the-environment reporting, cumulative effects assessment, impacts to climate change, compliance and enforcement of ministerial regulations and site operation inspections. The Strategy established a monitoring strategy through extensive engagement with government ministries, industry and Aboriginal communities (Government of British Columbia, 2015).
3.3 INFORMATION AVAILABILITY AND DISCLOSURE NEEDS TO SUPPORT KNOWLEDGE GENERATION, BEST PRACTICES AND REGULATIONS

Several recent studies (CCA, 2014; Freyman et al., 2013; Goss et al., 2015; Quinn et al., 2015; Ryan et al., 2015) have highlighted that gaps in Canada’s current disclosure practices of data pertaining to hydraulic fracturing prohibit a general consideration of certain risks and best management practices. These studies have tended to focus on volumetric water use and disposal, and fate of the chemicals used in the fracture process.

For the purpose of this report, the focus is on public disclosure of industry data that would enable researchers, decisions makers and industry to fill the most important knowledge gaps. The CWN-funded projects highlight a number of key knowledge gaps for decision makers that hinge upon data or access to information. Of particular importance is improving the format and accessibility of data to support analyses for determining human and environmental toxicity issues, and comparative analyses across regions and jurisdictions.

Disclosure of hydraulic fracturing data in Canada takes many forms, both mandatory and voluntary (e.g., FracFocus.ca database, material safety data sheets, spatial web-based tools, annual water use reports, industry corporate sustainability reports, etc.). Disclosure requirements in Canada are also based on a mix of federal and provincial laws.

The CWN-funded projects highlight the need to support key decisions by better filling knowledge gaps for which data access is a key element, including but not limited to:

- Water extraction across plays and watersheds
- Chemical analysis of the major constituents in fracture fluids
- Trends in wastewater production and disposal
- Impacts and trends of deep-well disposal of fracture fluids

Provincial/territorial governments and industry have made efforts to coordinate and improve disclosure practices (for example, BC’s mandatory FracFocus.ca disclosure directive, BC’s NorthEast Water Strategy, Canadian Association of Petroleum Producers Guiding Principles for Disclosure). However, there remains a need for consistent and accessible data disclosure across Canada to support analyses and assessments of risks and current practices.

"While many studies will claim that 'we need more data' to address this concern, the challenges described ... are also related to concerns about the governance of that data."

(Moore et al., 2015, p.ii)
FracFocus online disclosure registries

In Canada and the U.S., the FracFocus online disclosure registries have become the most commonly used public forum for disclosing information pertaining to hydraulic fracturing water and chemical use. FracFocus.org was developed in 2011, and FracFocus.ca soon followed, as adapted in 2012 by the BC Oil and Gas Commission. Since its inception, the Canadian website has signed agreements with the National Energy Board (2013), Alberta (2012), Saskatchewan, Northwest Territories (2015) and Yukon to join the registry, although not all have mandatory reporting requirements. FracFocus.org was developed in 2011, and continues to evolve based on input from end users. FracFocus.ca was developed in 2012, as adapted by the BC Oil and Gas Commission.
INFORMATION AVAILABILITY AND DISCLOSURE NEEDS TO SUPPORT KNOWLEDGE GENERATION, BEST PRACTICES AND REGULATIONS IN HYDRAULIC FRACTURING

**What do we know?**
- FracFocus.org and FracFocus.ca are increasingly becoming the public disclosure mechanism of choice for information on hydraulic fracturing operations, although use is not mandatory in every province/territory.
- There are concerns over the chemical composition in hydraulic fracturing fluids; however, there are legal requirements regarding the proprietary nature of some information.
- Canadian data on the FracFocus.ca website is limited in its ability to support key research.

**What do we most need to know?**
- An understanding of where a lack of data disclosure is most inhibiting decision making regarding water use, wastewater disposal, knowledge of toxicity of hydraulic fracturing fluids and flowback fluids.
- Opportunities relating to proprietary considerations that could lead to better disclosure of data in Canada.
- Consistent data approaches for water use and the fate of wastewater that would support broader comparisons of water management across regions and jurisdictional boundaries.

**What is reasonable to expect we could know?**
- Data disclosure standards or approaches that better support the research that fills key knowledge gaps related to toxicity and exposure to hydraulic fracturing fluids and risks to the environment.
- Identification of the barriers and opportunities to improve data disclosure formats, accessibility and dissemination to support effective research and risk assessment. This could draw from a comparison of practices from other industries.

**Opportunities:**
- Identify how improved data disclosure can advance understanding of human and environmental toxicity and risks.
- Provide recommended data formats and standards that would facilitate better industry-wide comparisons and analyses.
3.4 MANAGING RISKS TO GROUNDWATER AND SUBSURFACE IMPACTS

Quantifying the risks posed by groundwater contamination related to hydraulic fracturing developments is an area for which there is not yet a strong knowledge base. It is also characterized by ongoing scientific debate, which is difficult to resolve given the insufficient data to support an appropriate analysis of key questions. In light of this uncertainty, data gaps most relevant to developing appropriate risk management practices and regulations are those that focus on identifying and managing the most likely contaminant exposure pathways. This supports a risk management approach of prioritizing efforts and resources on assessment and effective management of the most significant factors. In particular, concerns about well integrity and a better understanding of methane gas migration associated with shale gas development on aquifers are indicated as being most important (Ryan et al., 2015).

Although there is some potential for hydraulic fracturing to induce subsurface pathways that could eventually allow contamination of shallower aquifers from injected chemicals or upward migration of methane, or shale-related compounds from depth, migration via leaks in active, old or abandoned wells is the more likely pathway (CCA, 2014). Well integrity issues are known to exist in association with petroleum wells. Although application of evolving best practices can significantly reduce their frequency, faulty casings remain a concern, particularly over the long term.

The degree to which hydraulic fracturing processes contribute to contaminant migration from wells or within formations during well installation, stimulation or when the well is no longer active is not well characterized. Given that faults in well construction can occur and that wells will degrade over time even with current best practices, gas or contaminant migration via leaking wells is a main pathway of concern (Ryan et al., 2015).

Despite a recent increase in peer-reviewed studies investigating the occurrence or absence of “fugitive” methane in groundwater supplies near unconventional oil and gas development, the processes and mechanisms involved and the impacts on groundwater quality remain poorly understood. Technologies exist to distinguish naturally-occurring methane in groundwater from suspected stray gas. However, the majority of field-based studies have relied on sampling of domestic water wells. This limits the ability to determine the sources and contamination pathways when methane is present. Inferring aquifer conditions based on conditions in conventional domestic water wells is largely confounded by their varied conditions (e.g., well age, design and construction including screen intervals, integrity, bacterial contamination, drawdown during sampling, intensity of recent well pumping, etc.) and the fact that they rarely represent the locations, distribution or resolution needed to support an effective scientific analysis.
Moving beyond domestic well testing to better understand subsurface risks involves installation and sampling of monitoring wells or systems specifically designed for the purpose. Decisions should consider what is needed for sufficient baseline data and requirements for short and long-term monitoring data of active or decommissioned wells. The investments could be significant for each of these. Monitoring requirements and costs need to respond to a decision on an appropriate level of risk management and be weighed against the overall economic benefits expected from development. Given the importance of this area, effective knowledge prioritization represents a significant opportunity to inform progress.

In addition to groundwater contamination issues, another area of increasing concern is the issue of induced seismicity (i.e., frequency and magnitude of earthquakes or tremors caused by human activity). The majority of known incidences of induced seismicity to date have been associated with subsurface injection of wastewater, whether from hydraulic fracturing or other industrial activities. The process of well stimulation by hydraulic fracturing itself, particularly when many wells are drilled in sensitive areas of subsurface faults, may also induce seismic activity. Typically, few of the seismic events related to well stimulation activities have been felt at the surface; however, recent events in Canada and the United States have brought this issue to the forefront.

To avoid seismicity, regulators and industry avoid development in known areas of major faults or active seismic zones. Concerns related to deep injection of wastewater is an active area of research (including ongoing collaborative efforts among the federal government, several provinces and academia in Canada) and increased incidences of seismic activity being experienced in some areas of hydraulic fracturing in North America are focusing more attention on the need for additional study in that area (Ryan et al., 2015).
MANAGING RISKS TO GROUNDWATER AND SUBSURFACE IMPACTS IN HYDRAULIC FRACTURING

What do we know?
• The inability to fully characterize the human health risks of groundwater contamination leads to a need for identifying and controlling the most likely exposure pathways.
• Migration of methane gas via leaky wells represents the most likely pathway of contamination of shallow aquifers and potable groundwater.
• Debate on the link between fugitive gas emissions and aquifer contamination has relied heavily on sampling of domestic wells, making it difficult to effectively determine pathways.
• Induced seismicity effects are associated with deep injection of wastewater and hydraulic fracturing in some areas; the relationship between hydraulic fracturing activities and seismicity is still poorly understood and is of concern.

What do we need to know?
• The behaviour and main transport pathways of methane gas associated with hydraulic fracturing relative to aquifers and groundwater supplies.
• How to most effectively monitor aquifer conditions to detect the impacts of fugitive methane or other contaminants.
• Practical expectations and best practices for assessing well performance (such as leak reduction).
• A better understanding of the potential of hydraulic fracturing activities and wastewater injection to induce seismicity.
• An understanding of the significance of long-term behaviour of wells and subsurface conditions and how they can be effectively managed.

see next page
What is reasonable to expect we could advance?

- Improved understanding of the subsurface transport and behaviour of methane and associated water quality impacts of hydraulic fracturing activities.
- Development of testing and analytical techniques that improve the ability to detect methane or other contaminant impacts on aquifers.
- How to best adapt well integrity testing methods to address hydraulic fracturing concerns.
- Improved understanding of the link between hydraulic fracturing and seismic events.

Opportunities:

- Assess pathways of methane or fluid leakage associated with active hydraulic fracturing activities.
- Assess expected groundwater quality issues related to methane migration over the short and long term.
- Develop techniques and technologies to provide practical detections of methane leaks or other contaminants from wells.
- Improve knowledge surrounding induced seismicity due to hydraulic fracturing.
3.5 MANAGING WASTEWATER

Management of risks for wastewater and hydraulic fracturing relate primarily to the surface handling, storage and eventual disposal of recovered fluids. These fluids consist of “flowback” (typically 25%-70% of injected volume) returned to the surface, as well as formation water that is produced during the operation of the well. The quality of the injected water (which may be freshwater, saline or recycled water), plus chemical additives and constituents leached from the formation, combine to form variable flowback water quality. The risks associated with the handling and disposing of flowback fluids must be addressed to ensure that neither human nor environmental health are compromised.

A starting point for evaluating common effects is to understand the substances being used in hydraulic fracturing processes, and also the composition of fluids after they return to the surface. Environment Canada and Health Canada have compiled a list of over 800 substances known or suspected to be used in hydraulic fracturing in Canada, 33 of which have been assessed as toxic. Due to restrictions on access to full disclosure of fracture fluids, ongoing cooperation between industry, regulators, health officials and potentially other key stakeholders is necessary to resolve conflicts and ensure further evaluation can occur. The laws addressing proprietary information differ in Canada and the U.S.; however, experience in the U.S. demonstrates that there is capacity to improve disclosure practices for public access, uniformity and the state of the knowledge surrounding the risks associated with fracturing fluids in consideration of proprietary trade secrets.

For provinces and territories that are in the pre-development or early stages, a primary consideration related to handling of wastewater is which method(s) of disposal to allow. Certain disposal methods may be unsuitable in certain regions. For example, studies have indicated that the geology in parts of eastern Canada is inappropriate for deep-well injection. Past experiences with mining also point to unique regulatory challenges for wastewater containment in areas of permafrost in the North. Therefore, an assessment of these challenges and the advantages of each method under average conditions would better enable decision makers to identify the best practices. For wastewater treatment, this could entail a comparison of waste storage facility standards, evaluation of treatment processes, as well as lab and in situ experiments to better understand the impacts on the environment.

In western Canada, wastewater is generally disposed of through injection into deep formations. In eastern Canada, geological limitations generally preclude deep injection, resulting in the need for treatment prior to disposal (Gagnon et al., 2015; Goss et al., 2015). The efficacy of wastewater treatment methods is a localized issue; however, improvements to the general state of knowledge are warranted. With a baseline of information for comparison, these kinds of studies could then be integrated to provide a more complete picture of the associated trade-offs of each method and the relative nature of the risks.

In general, public wastewater treatment plants are not designed to treat the constituents in hydraulic fracturing wastewater, nor the variability of hydraulic fracturing wastewater properties. Public facilities may be involved in later stages of treatment in some cases (see Examining the efficacy of treatment technologies and disposal options, p. 51), however, use of municipal systems as a main treatment option have largely been ruled out. Industrial wastewater treatment that is tailored to remove unwanted components is an area of active research and development; however, the cost of treatment has been cited as the primary barrier (CCA, 2014).
Another chief concern related to the handling of chemicals and waste commonly cited in public engagement records is that of wastewater spills due to human error or unforeseen vents such as extreme weather. Actions to mitigate spills are effective insofar as the regulations and operation standards in place are sufficient to address these factors. There is an opportunity to quantify the risk through an evaluation of spills data and toxicology information to determine an appropriate response.

Emergency preparedness is another appropriate entry point and area for increased attention, acknowledging that spills sometimes occur and that processes need to be in place to mitigate the risk. A 2014 Water Research Foundation initiative brought together U.S. oil and gas companies with water utilities to guide a discussion on safeguarding drinking water against contamination from hydraulic fracturing activity. The findings of their report highlight the importance of engaging both the regulators and industry, who are aware of the latest practices and considerations on the ground, to ensure that the findings and subsequent actions are relevant.
MANAGING WASTEWATER IN HYDRAULIC FRACTURING

What do we know?

• Data disclosure issues remain a challenge for wastewater toxicology considerations.

• Subsurface chemical reactions change the composition of hydraulic fracturing fluids when they return to the surface in flowback over time.

• The options for treatment, including efficacy of existing wastewater treatment plants, is a greater concern in the eastern provinces where deep well injection is not a possibility.

• Wastewater management is a significant potential challenge in northern communities.

What do we most need to know?

• Improved characterization of the composition of hydraulic fracturing fluids.

• Improved knowledge of the greatest risks related to wastewater handling.

• The efficacy of various on-site treatment methods or existing wastewater treatment plants to ensure wastewaters are acceptable for release.

What is reasonable to expect we could advance?

• Characterization of the range of expected chemical compositions of hydraulic fracturing and flowback fluids.

• The efficacy of treatment methods for hydraulic fracturing fluids.

• The environmental effects of releasing treated wastewater to water bodies.

• A comparison of industry practices/regulations for managing deep well injection.

Opportunities:

• Assess the human and environmental health risks associated with contaminants of concern in injected fluids, flowback and produced water to establish appropriate treatment targets.

• Conduct comparative assessment of the performance of industrial wastewater treatment technologies for hydraulic fracturing fluid.
4. ACHIEVING CONSTRUCTIVE AND EFFECTIVE ENGAGEMENT

It is clear from the significant public interest and debates surrounding hydraulic fracturing that, to be effective, regulations and industry practices must be seen to be appropriate from the perspective of the broader stakeholder community. As such, a consideration of what is needed for achieving constructive and effective stakeholder engagement is a critical priority. Increasingly, the question being asked is: How can we move forward in this process in a way that better acknowledges the interests involved, and clarifies the rationale for the ultimate decisions that are made?

A crucial dimension of the process of achieving effective engagement is the establishment of trust. Unfortunately, concerns and fears about hydraulic fracturing in many regions of the country reflect erosion in the trust of industry or government decisions. All resource development decisions, including those surrounding hydraulic fracturing, come with trade-offs and costs to be considered to satisfy the safety and sustainability of valued social, cultural and ecological components.

Canada has a significant history of resource development to draw on. Experience with different institutional frameworks to support distributed participation in decision making processes, ownership and disclosure of data, relationship building and methods for effectively addressing community concerns and perceptions, are all relevant. Some regions of Canada have been overhauling water and environmental regulations over the last few years in recognition of these needs. As a result, identifying governance and engagement approaches that have been successful in achieving and maintaining trust where resource development is involved is of particular value for this area.

Goss et al. (2015) and Quinn et al. (2015) highlight the fact that there has never been a rigorous and comprehensive national assessment of Canadians’ opinions about hydraulic fracturing or reasons for the held opinions, particularly for remote and rural regions. Recognizing that governments often have limited resources and capacity, the design of meaningful engagement is important. Better understanding of the nature and basis for key concerns and strongly held values of importance to decisions provides a stronger basis to design effective engagement and communication processes, and design regulations and best practices that address the priority concerns.
In Canada, Aboriginal involvement in decisions and the constitutional responsibilities to consult with Aboriginal communities are crucial dimensions of natural resource governance. In the last five years there have been some significant events marking a new era of provincial and Aboriginal cooperation in resource decisions. Most notably, the Supreme Court ruling of the Tsilhqot’in First Nation in 2014 granted Aboriginal title to more than 1,700 square kilometres of land in BC. This decision set a precedent in Canada and its implications are not yet fully understood. Across Canada there are hundreds of unique Aboriginal groups and different models of Aboriginal governance. This complexity poses challenges for governments and industry, who must ensure they effectively engage all the relevant communities as part of resource development decisions.

When these efforts do not effectively incorporate the emotional bonds between people and places that can strongly affect community responses to industrial projects, the result is often a breakdown of trust. Examples of effective engagement between Aboriginal and non-Aboriginal governments and industry that recognize the relational way of experiencing their place in the world (described as ‘sense of place’) exist. As discussed in more detail in Moore et al. (2015) and Gagnon et al. (2015), an improved reflection of the various roles of government ministries, industry, and Aboriginal peoples in the oil and gas approval process would lead to improved cooperation that is so important for contemplated or ongoing hydraulic fracturing developments.

Data ownership and public disclosure play important roles in the degree of public engagement and sense of transparency achieved. Data and knowledge ownership and management are critical elements in establishing and maintaining trust that leads to ‘social license’ for resource development (Moore, et al., 2015). In accessing available data, the priorities and information needs will be different for each user, depending on the specific decisions being made (e.g., impact assessment, compliance, etc.) and consideration of local concerns. Therefore data collection and disclosure mechanisms must be designed with these different interests and needs in mind, to ensure that activities lead to effective engagement.

“Water governance in Canada is shifting in the context of many fast-changing social and ecological dynamics. Many communities are asking for greater authority in water-related decision making, and the overall effects of a complex interplay of developments and uses are challenging for decision makers to address, particularly in the context of unpredictable but likely widespread climate change related impacts on water (Morris and Brandes, 2013). In response to these dynamics, some provincial governments are overhauling current water policy regimes, while others are seeking to adapt existing frameworks to account for new challenges. Federal legislation and municipal by-laws, too, are changing. It is within this complex landscape of water governance that social negotiations and conflicts over hydraulic fracturing now arise.”

(Moore et al., 2015, p. 23)
WHAT DO WE KNOW?

• The complexity of integrating land-water-energy decisions within a framework to address cumulative effects is fundamentally a governance challenge.

• The ability to generate effective and supportable regulations and practice surrounding hydraulic fracturing requires not only the right information base, but also overall trust in the decision making process and entities involved in carrying out the results.

• Public concern and fear about hydraulic fracturing operations is a significant dimension of the resource development, which must be addressed by government decision makers and industry.

• Aboriginal issues and concerns are central to many decisions regarding hydraulic fracturing. Recent developments, such as the precedent set in 2014 by the Tsilhqot’ín Nation v. BC decision, has significant implications for industry and government in their dealings with Aboriginal communities across Canada.

WHAT DO WE MOST NEED TO KNOW?

• How to most effectively address key governance challenges, including transparency, trust, and capacity related to water use in hydraulic fracturing.

• The public’s opinions and major concerns with respect to hydraulic fracturing and how they are informed.

• The most effective means of honouring the legal and constitutionally guaranteed rights of Aboriginal communities across Canada in the governance practices for hydraulic fracturing and water.
ACHIEVING CONSTRUCTIVE AND EFFECTIVE ENGAGEMENT IN HYDRAULIC FRACTURING

What is reasonable to expect we could advance?

• Knowledge of leading practices in governance and community engagement that have proven effective, particularly for water and resource development cases, and are relevant for Canada.

• A more comprehensive and documented understanding of the public’s opinions and basis for concerns regarding hydraulic fracturing.

• Practices to improve Aboriginal involvement, and recognition of both rights and interests in natural resource development.

Opportunities:

• Assess particular opportunities to advance transparency through effective water governance.

• Evaluate opportunities for collaborative or watershed-based governance in remote and rural regions with industry development potential.

• Establish effective governance approaches for collection and disclosure of baseline data.

• Assess public opinions of water and hydraulic fracturing across Canada to inform design of engagement strategies.

• Compare and disseminate experiences of Aboriginal communities in North America with respect to water governance and hydraulic fracturing.
The last decade has seen increased public, government and industry interest in expansion of the use of combined horizontal drilling and multi-stage hydraulic fracturing techniques for extraction of tight oil and gas in North America. With continued technology and practice innovations that better access resource opportunities, reduce costs and enable meeting or exceeding regulations, governments are charged with ensuring sufficiency of those regulations and oversight of evolving industry practices. Regulators are focused on ensuring that existing, modified, or new requirements effectively address both short and long-term needs for the protection of communities and the environment. Public concerns, including those of Aboriginal communities who are often significantly impacted by resource development decisions in Canada, have heightened overall awareness and scrutiny for how decisions are being made.

In 2013, investment in the oil and gas extraction and closely-related industries accounted for more than one-third of business investment in Canada. At current production levels, the oil and gas sector directly accounts for about 5.3% of Canadian GDP (Royal Bank of Canada, 2015). Currently, falling oil and gas prices have slowed the pace of development, and while it is difficult to predict the long-term trajectory for the industry as a whole, continued development of unconventional reserves in Canada can be expected going forward. This slowdown in pace provides an excellent opportunity to focus on key priorities within the industry and undertake the research most needed to inform regulatory, best management and governance decisions, and to re-engage the public in discussions about Canada’s interrelated water and energy sectors.

It is an ongoing challenge for all parties seeking to draw upon best available research, knowledge and experience to keep pace with industry advancements and identify those elements particular to tight oil and gas development that most warrant consideration. This is confounded by the fact that research specific to the current practices related to hydraulic fracturing in tight reservoir development is quite young, as well as the fact that priority questions and needs are dictated to a large degree by regional factors. Therefore, not all unknowns can practically be addressed in a timeframe that will usefully inform decisions. A prioritization of both concerns and knowledge needs to support decisions is critical to ensure the most important issues and gaps receive appropriate attention.
CWN’s focus is on identifying priority knowledge needs to support decision making, where water and its management represent critical aspects of sustaining cultural, social, environmental and economic benefits for Canada. The recent CWN-funded projects indicate clear opportunities to ensure better outcomes for the time, energy and resources invested in decisions related to tight oil and gas development. These opportunities include advancing knowledge and approaches that:

- Improve overall engagement, understanding and buy-in to identifying the key benefits and costs
- Clarify the short and long-term risks or potential negative aspects associated with development choices
- Increase Canada’s capacity to effectively manage the activity

Given the complex set of questions and knowledge gaps surrounding hydraulic fracturing activities and water, critical next steps must include strategic prioritization of knowledge as well as opportunities to pool expertise and resources to effectively support decisions.


## Provincial and Territorial policy development for hydraulic fracturing in Canada

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<thead>
<tr>
<th>Jurisdiction</th>
<th>Jurisdictional Regulatory Contexts Specific to Hydraulic Fracturing</th>
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<tbody>
<tr>
<td><strong>NL</strong></td>
<td>In November 2013, the government enacted a moratorium for onshore and onshore-to-offshore petroleum exploration using hydraulic fracturing — adopting a “go slow” approach. A formal review of regulations, rules and guidelines is underway at the same time as several technical assessments and a public consultation process. Proximity of the Green Point shale play to Gros Morne National Park (a UNESCO designated site) have elevated citizen concerns.</td>
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<td><strong>NB</strong></td>
<td>Opposition to shale development gained national media attention during a violent standoff between police and the Elsipogtog First Nation in 2013. Delivering upon promises made during the September 2014 election, New Brunswick’s newly-elected premier enacted a moratorium on hydraulic fracturing in March 2015. Conditions of the moratorium include the establishment of ‘social license’ particularly with Aboriginal communities. Prior to the moratorium, the government undertook extensive public consultations and legislative review towards the development of industry standards to augment the existing regulations.</td>
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<td><strong>NS</strong></td>
<td>Nova Scotia enacted a moratorium on high volume hydraulic fracturing for onshore oil and gas shale development in November 2014. The moratorium exempts activities related to research. The ban followed the release of an independent review of the costs and benefits of development and public engagement that was requested by the government. The review recommended a precautionary approach to development and further study to address knowledge gaps.</td>
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<td><strong>PEI</strong></td>
<td>There is no specific regulatory framework in place for addressing hydraulic fracturing in Prince Edward Island. In September 2014, PEI’s Environment Minister was quoted as saying that the province had received no applications to develop using hydraulic fracturing, and therefore no action by the province was necessary.</td>
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<td><strong>QC</strong></td>
<td>In 2011, Quebec ratified a moratorium on shale gas development and later extended the moratorium for an additional five years, ending in 2018. During that time, the Minister of Sustainable Development, Environment, Wildlife and Parks requested that the Bureau d’audiences publiques sur l’environnement (BAPE) conduct public hearings (held in 2010-11), the conclusion of which was to conduct a strategic environmental assessment (SEA) on shale gas. The assessment, which concluded in 2014, was designed to understand the social, environmental and economic dimensions of shale gas development. Following the conclusion of the SEA, the BAPE held a second round of hearings on shale gas development in the St Lawrence Valley in 2014. The government continues to study the risks and economic benefits of shale development in the St. Lawrence Lowlands and will pass new legislation on hydrocarbons in 2016.</td>
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<td><strong>ON</strong></td>
<td>Ontario is currently conducting a joint Ministerial review of Ontario’s Policy Framework respecting the use of high volume hydraulic fracturing treatment. There is no specific regulatory framework in place for addressing hydraulic fracturing in the province.</td>
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<td>Region</td>
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<td>MB</td>
<td>The Manitoba Petroleum Branch is reviewing the adoption of new guidelines and regulations for hydraulic fracturing. As of 2013, there have been 1,107 wells that have employed multi-stage hydraulic fracturing (S. McBride, P. Eng., personal communications, July 16, 2015)</td>
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<td>SK</td>
<td>Saskatchewan is currently reforming its environmental regulations with a new environmental code that uses a results-based framework. The revised code accommodates a flexible approach for achieving defined environmental objectives, allowing the industry to provide a strategy that is supported by a qualified professional. A review of the existing oil and gas regulations is to be part of this reform. Saskatchewan saw high activity levels in petroleum exploration and development, the majority of which can be attributed to horizontal drilling and multi-stage fracturing completions.</td>
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<td>AB</td>
<td>In 2014, the Alberta Energy Regulator began piloting a new multi-jurisdictional framework to govern unconventional oil and gas development, building on previous groundwork of the Energy Resource Conservation Board. The new risk- and “play-based” regulatory framework is designed to manage cumulative effects — currently an area-limited pilot project. The framework includes examining/approving permits to address landscape, water, mitigation and transportation issues through a single application process. Alberta, like BC, has moved towards a single-window approach to oil and gas permitting and regulations.</td>
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<td>BC</td>
<td>The BC Oil and Gas Commission adopted the area-based analysis (ABA) approach as a framework for managing the environmental and cultural impacts of oil and gas development in Northeast BC. The framework operates on the basis of outcomes and policy ‘triggers.’ In March 2015, the BC Government released the Northeast Water Strategy for water use and management that encompasses the Liard, Horn River, Montney and Cordova unconventional basins. This strategy was collaboratively designed with land owner and Aboriginal input.</td>
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<td>NT</td>
<td>Exactly one year to the day after the Northwest Territories assumed authority over its resources (Devolution), on April 1, 2015, the government released proposed regulations for projects involving hydraulic fracturing. Residents, Aboriginal communities and relevant stakeholders will be consulted on the proposed regulations through summer 2015.</td>
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<td>YT</td>
<td>In April, the Yukon Territory announced that the government was proceeding with a go-slow approach to pursuing shale resources in the southeast corner of the Territory (Liard Sedimentary Basin). The decision is based on the recommendations of a legislative committee that held public hearings and committee briefings from 2013 through 2014. Yukon Territory has initiated further studies and public engagement on the potential risks of resource development involving hydraulic fracturing in the Liard Sedimentary Basin. The decision to allow exploration and development to occur is contingent upon support of affected Aboriginal communities.</td>
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<td>NU</td>
<td>Oil and gas activities in Nunavut are currently the responsibility of the federal government and are covered under the National Energy Board. Nunavut is in the process of negotiations with the federal government for the transfer of administrative control over public lands, water and resources in the Territory. There has been no high volume hydraulic fracturing in the Territory to date. The extent of potential resources is largely unknown, aside from some preliminary exploration by the Canada-Nunavut Geoscience Office.</td>
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2015 WATER AND HYDRAULIC FRACTURING
WHERE KNOWLEDGE CAN BEST SUPPORT DECISIONS IN CANADA

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