CAPE BRETON UNIVERSITY

VERSCHUREN CENTRE
For Sustainability in Energy and the Environment

REPORT of the NOVA SCOTIA INDEPENDENT REVIEW PANEL on HYDRAULIC FRACTURING

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Submitted to:

The Province of Nova Scotia
Department of Energy

For the Attention of:

The Honourable Andrew Younger, Minister of Energy

28th August 2014

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"The health of the people is the highest law."

Cicero (106 - 43 BC)

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Finally we would like to thank all those stakeholders – individuals and organisations – who devoted significant time and energy to engaging with this Review through the submission of evidence, providing commentary on our discussion papers and attendance at public meetings.

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Executive Summary

This report represents the conclusion of six months of intensive research and analysis overseen by an independent panel of experts assembled by the Verschuren Centre for Sustainability in Energy and the Environment at Cape Breton University. The report represents the considered views of the panel who represent expertise in a broad ranges of disciplines: Aboriginal wisdom, economics, environmental geography, water science, environmental science, public health, social science, social ecology, petroleum geology, geoscience, law (including Aboriginal law), and knowledge of the natural gas industry itself. Our experience was diverse; six of our 11 panelists were academics (including the Chair), four were independent consultants and one was a provincial employee (acting in an independent capacity). All of us had experience in domains beyond our primary discipline and professional affiliations.

The work of our panel was supported by a project coordinator, an Aboriginal outreach worker, a number of graduate researchers, an undergraduate student assistant, and four technical consultants. Our research was assisted by a number of experts working for the Province of Nova Scotia in the Departments of Energy, Natural Resources and Environment, who were asked to provide information on various aspects of our Review. We received 238 unique submissions from individuals and organisations to our review and an additional 170 unique responses from 96 individuals and organizations to discussion papers that were released between April and July 2014. More than 1,200 people attended 11 public meetings that were held across the Province to discuss our methods and our emerging conclusions and recommendations. We also benefited from advice from individuals deeply familiar with the work of the Council of Canadian Academies (2014) report for Environment Canada on the *Environmental Impacts of Shale Gas Extraction in Canada* and the Nova Scotia Commission on Building Our New Economy (2014) report, both of which were released during the period of our research. However, we note that the final Report of our review remains the responsibility of the panel.

In the **Introduction to the Report** we describe our mandate from the Province of Nova Scotia and we define "the process of hydraulic fracturing" (from our mandate) as, "*The process of hydraulic fracturing and its directly associated activities and technologies for the purpose of unconventional gas and oil development.*" We describe the methodology employed by the panel as consistent with that of previous public participatory energy policy research projects commissioned by the Province of Nova Scotia. Our methodology embraced public participation in: i) agreement of the expertise required for the panel; ii) nomination of panel members; iii) receipt of direct submissions by the citizens and organizations; iv) public commentary on discussion papers, electronically and via other mechanisms; and v) attendance at public meetings. We envisage that further public engagement with our findings will occur after the publication of this report, both via the Province of Nova Scotia and by continued engagement of panel members in presentations, including in Aboriginal communities. We describe demographics and the economy of Nova Scotia to provide context for our review; and we relate our review directly to the Report of the Nova Scotia Commission on Building Our New Economy (2014): Now or Never: An Urgent Call to Action for

Nova Scotians. We discuss the question of externalities and how with any industrial development every effort must be made to reduce or eliminate costs that might be transferred to society or the environment. We summarize current energy policy in Nova Scotia, and we describe the current state of the art on environmental, health, and social risks of unconventional gas and oil development using hydraulic fracturing and associated techniques, drawing on the Council of Canadian Academies (2014) report: *Environmental Impacts of Shale Gas Extraction in Canada*. Finally, we provide some reflections on public feedback and future discussion of our review before introducing the rest of the report.

In Chapter 1, we describe **The Process of Hydraulic Fracturing**, setting out the primary industrial uses of the technology, the history of its application, the different components of the process, and matters relating to fracturing fluids and "flowback" waters. We note that the global demand for natural gas may grow by 45 per cent to 50 per cent by 2035, compared to 2010 figures. Under current public policy trajectories, Canada's production of natural gas may rise to around 17 billion cubic feet (bcf) per day by 2035 and consumption to around 12 bcf per day.

In Chapter 2, we describe the **Potential Oil and Gas Resource Base in Nova Scotia**. We note that knowledge of the subsurface, including sedimentary rocks and hydrocarbons in Nova Scotia, is extremely limited at the present time. Thus, it is very difficult to quantify the potential or even to rank various basins in terms of overall prospectivity.

In Chapter 3 – **Development Scenarios and Potential Economic Impacts** – we describe four plausible scenarios: zero case (no economically or technically exploitable resource for the foreseeable future); lower-medium case (one basin, fully developed with up to 4,000 wells developed and exploited over a 40 year period); upper-medium case (three basins fully developed with up to 12,000 wells developed and exploited over a 50 year period) and maximum case (five basins fully developed with up to 20,000 wells developed and exploited over a 60 year period). We discuss the potential direct regional economic benefits of exploration and development of a minimum 50 well development and we extrapolate that to the lower medium case (4000 wells). Under that scenario, direct benefits to regional economies may top $1 billion per annum with a steady state of 740-1,480 direct jobs during the development phase. Royalties to the Province would peak at just over $200 million per annum around 40 years after commencement of drilling, and would deliver just under $6 billion in total over a 60 year development and production timescale under the lower-medium case. We describe a range of potential costs resulting from externalities that would also accompany development, and we note that further work would need to occur at the regional level to more fully elucidate these costs.

Chapters 4, 5 and 6 deal with the key questions of **Public Health Protection, Socio-Economic and Social Ecological Impacts on Communities** and **Water Resource Impacts**. In each case we note that risks and benefits of development would be variable according to social, demographic, and geographic factors. Although none of the potential negative impacts could be defined as catastrophic, there remain many outstanding questions requiring further research to fully elucidate effects on populations and ecosystems.

There is insufficient knowledge at the present time to describe how theoretical or actual risks and benefits may fall both in the short and the long term at the community level. And thus before any unconventional gas and oil development activity were to be permitted in the Province, adequate baseline monitoring would need to be instituted, effective regulations put in place (and enforced), and formal health, social and environmental impact assessments conducted following a precautionary approach. Subject to the above, and of course to the consent of any affected communities, we believe that challenges associated with the industry could be addressed through the design of appropriate regulatory regimes, risk management, and mitigation systems and indeed benefit distribution policies.

Chapter 7 discusses the question of **Well Integrity**, a topic which gives rise to significant concern because of the direct potential link between well integrity failure and methane emissions and the contamination of groundwater. We concluded that it is a relatively straightforward task to establish good regulatory practices (guidelines and enforcement), quality control, and monitoring to ensure that potential sites are geologically understood, that wells are properly installed, and that well abandonment is done according to regulatory requirements. However, this is not a risk-free activity and hence the establishment of an appropriate monitoring and regulatory system would clearly be needed if large-scale unconventional oil and gas resource development were ever to take place in the Province.

Chapter 8 gives voice to the legitimate concerns of stakeholders to our process in a **Public Participatory Risk Assessment**. Two hundred and thirty-eight unique submissions received by our panel were analyzed and issues of concern to citizens and other interested parties were ranked and related to the literature on each expressed concern. We concluded that given the known and potential environmental impacts associated with hydraulic fracturing across different time scales – as outlined by both citizens and the literature – a precautionary approach in Nova Scotia is both prudent and required by Nova Scotia legislation (i.e. the Environmental Goals and Sustainable Prosperity Act 2007 and the Green Economy Act 2012). We conclude that having citizens and communities involved in the risk assessment and decision-making processes regarding unconventional gas and oil development would be an important first step co-generating the knowledge that may help to unlock and mitigate potential problems before they occur, while increasing trust amongst stakeholders. We note that a detailed life cycle assessment of the potential positive and negative climate change impacts of developing an unconventional gas and oil industry would be needed in Nova Scotia in order to properly assess the uncertainties that currently exist (e.g. reduced carbon dioxide emissions versus fugitive methane emissions).

Chapter 9 describes the **Regulatory Issues** that apply to hydraulic fracturing for the development of unconventional gas and oil resources. We describe the respective roles of all levels of government in regulating the industry and note different approaches to regulation in a number of Canadian jurisdictions. We link principles of effective regulation to the need for comprehensive and publicly trusted systems for risk management, for example, monitoring, inspection, and enforcement, which in turn depend on political will and adequate resourcing by government.

Chapter 10 sets out the **Aboriginal, Treaty and Statutory Rights of the Mi'kmaq**. We note that the Mi'kmaq possess inherent Aboriginal rights, as well as treaty rights, and that the Mi'kmaq did not cede any land rights through treaties. We observe that their traditional territory extends to all of contemporary Nova Scotia. While it is unlikely that the Mi'kmaq have an Aboriginal right to subsurface gas on traditional territories, their treaty and Aboriginal rights must be respected by the government. These rights trigger an obligation for the government to consult with them, and to accommodate their rights. If there was a proposal for hydraulic fracturing for the purpose of unconventional gas and oil development to occur on reserve land or on land over which the Mi'kmaq people hold Aboriginal title, then their consent would likely be necessary and they have a right to economic benefits.

Chapter 11 – **Report Conclusions and Recommendations** - summarizes what is known of the relative risks of unconventional gas and oil development in all important domains of concern to Nova Scotia citizens and stakeholders. We summarize the conclusions of the review chapter by chapter, and we note that the industry may bring benefits from climate change, public health, and community economic development perspectives. But we also note that as with any industrial activities there a range of risks and costs. In addition, there are significant unknowns and therefore a need for ongoing research.

We describe a situation that is currently characterized by mistrust and conflicting information, and where (according to independent opinion research) only roughly 40 per cent of Nova Scotians are in favour of proceeding with unconventional gas and oil development at the present time, even if regulations are stringent. We confirm that there are significant challenges in accurately estimating or predicting risks and benefits for people and ecosystems in Nova Scotia. And yet we believe that: i) risks and impacts can be described in semi-quantitative or qualitative terms in most cases; ii) outstanding global and local research needs are reasonably clear; and iii) regulatory frameworks exist or can be developed for most if not all significant impacts. We summarize 16 of the most commonly cited hazards associated with the industry in a table which also describes current knowledge with respect to the frequency and severity of the hazard occurring, mechanisms for risk reduction (mitigation) and other relevant factors. We then synthesize this analysis in a frequency versus severity matrix to allow the various hazards to be compared.

Consequently, we advocate a precautionary approach and make the following top level recommendations:

- Based on the analysis described in this report a significant period of learning and dialogue is now required at both provincial and community levels, and thus hydraulic fracturing for the purpose of unconventional gas and oil development should not proceed at the present time in Nova Scotia.
- Independently conducted research of a scientific and public participatory nature is required to model economic, social, environmental, and community health impacts of all forms of energy production and use - including any prospect of unconventional gas and oil development in Nova Scotia - at both provincial and community levels.

- Nova Scotia should design and recognize the test of a community permission to proceed before exploration occurs for the purpose of using hydraulic fracturing in the development of unconventional gas and oil resources.

We strongly suggest that whatever time is needed for each of these steps that it should be taken, without any sense of deadline-setting or impatience by any actor. Some might interpret this as a "go slow" approach or even a de facto moratorium. However, we are not proposing a moratorium or any other political device e.g. a referendum, although we note that both have been proposed. Instead we encourage Nova Scotia municipalities, Aboriginal governments, and communities to spend whatever time is necessary learning about these issues, keeping an open mind on future developments, and research and engaging with the possibilities as well as the risks of this activity. We express the hope that this report is used as a basis for the informed debate which must now commence in Nova Scotia. And we note that time and effort must be devoted specifically to allow the Mi'kmaw community to deliberate and conclude their discussions respecting the recommendations in this report.

Finally, if at some point in the future communities and the Province wish to proceed with unconventional gas and oil development, we make 32 general and specific recommendations to safeguard community health, local economies, ecosystem health, and the environment.

INTRO

Introduction

I.1 | **Mandate from the Province and Scope of the Review**

On August 28, 2013, the Province of Nova Scotia and the Nova Scotia Department of Energy signed an agreement with the Verschuren Centre for Sustainability in Energy and the Environment at Cape Breton University to conduct an external review on the environmental, socio-economic, and health impacts of hydraulic fracturing. Simultaneously, Dr. David Wheeler, President and Vice Chancellor of Cape Breton University, was asked to convene and Chair the review and expert panel on a voluntary and unpaid basis.[1]

The mandate for the review was to: create a panel of technical experts based on input from the public and hire technical consultant(s) to facilitate the work of the panel; hire a part-time project administrator; conduct public consultations on the process of hydraulic fracturing with online tools and face-to-face meetings with stakeholders; and conduct a literature review on the health and socio-economic impacts of hydraulic fracturing. These activities would result in a final report to the Government of Nova Scotia with recommendations on the potential of hydraulic fracturing to develop unconventional gas and oil resources in the Province.

The scope of work included, but was not limited to, the following areas of research: effects on groundwater - including both water quality and quantity issues; effects on surface water; impacts on land; management of additives to hydraulic fracturing fluids; waste management; site restoration; requirements for hydraulic fracturing design including chemicals used; and the engineered design and financial security considerations that operators are required prior to conducting activity in the Province.

The intended outcome for the project was for the Province of Nova Scotia to be able to make an informed decision on the future of hydraulic fracturing activity in Nova Scotia, based on input from technical experts and the public on environmental, health, and socio-economic impacts. The original end date for the review was June 30, 2014, but the deadline was extended until August 31, 2014.

In this report, we define "the process of hydraulic fracturing" (from our mandate) as: "the process of hydraulic fracturing and its directly associated activities and technologies for the purpose of unconventional gas and oil development." Directly associated activities and technologies would include the drilling and finishing of exploration and development wells, but exclude detailed consideration of the construction and management of pipelines and distribution networks.

Throughout the document we use the term "unconventional gas and oil development," and by this we infer "by hydraulic fracturing." Also, except when specified, we also use the term "hydraulic fracturing" to infer "and its directly associated activities and technologies." In particular cases, we use the term "hydraulic fracturing" to mean the specific technical activity. See Chapter 1 for more details and definitions. These various uses should be self-evident in the text.

Activities and technologies associated with exploration and development of conventional oil and gas resources, which may include some of the same technologies used in exploration for unconventional resources e.g. the acquisition of seismic data and the drilling vertical wells, are not addressed in this report. These activities were outside the scope of our review.

Not included in our scope, were changes some stakeholders would like to see in provincial climate change strategy, energy strategy, or detailed consideration of the relative merits of alternative fuel sources. We did, of course, pay particular attention to relevant provincial legislation, including the Environmental Goals and Sustainable Prosperity Act (2007). And an underpinning assumption of our work was that the legislated 2020 40 per cent renewable electricity target for the Province[2] remains in place, and thus, any future development of unconventional gas and oil resources would not diminish the existing provincial commitment to renewable electricity generation.

I.2 | **Methodology**

I.2.1 Philosophy of Approach

The question of hydraulic fracturing as a mechanism to develop unconventional gas and oil resources is dominated by mistrust and conflicting information. In part, this is because the rapid growth of the "shale gas" industry is simultaneously potentially threatening e.g. from a community or environmental perspective, and potentially attractive e.g. from an industry or governmental perspective.

In his 2014 State of the Union Address, President Barack Obama said, "the energy strategy I announced a few years ago is working, and today, America is closer to energy independence than we've been in decades ...one of the reasons why is natural gas, if extracted safely, it's the bridge fuel that can power our economy with less of the carbon pollution that causes climate change."[3] In response to this statement, Michael Brune, Executive Director of the Sierra Club said, "We can't drill or frack our way out of this problem. Make no mistake — natural gas is a bridge to nowhere."

The lines of debate are also subject to divisions in communities, governments, and industry where potential benefits and risks are weighed according to differing world views based on deeply held and sincere beliefs. The media reflect the intensity of the debate, especially the controversial elements, simply because their job is to report on the public debate, as much as on the issues.

In our panel, we believe we reflected and debated all dimensions of the arguments for and against hydraulic fracturing for unconventional gas and oil development. Our panel represented expertise in a broad range of disciplines: Aboriginal wisdom, economics, environmental geography, water science, environmental science, public health, social science, social ecology, petroleum geology, geoscience, law (including Aboriginal law), and knowledge of the natural gas industry itself. Our experience was diverse; with six of our 11 panelists being academics (including the Chair), four were independent consultants, and one was a provincial employee (acting in an independent capacity). All of us had experience in domains beyond our primary discipline and professional affiliations. We were able to listen to and embrace different world views, ranging from the technocentric, through to the anthropocentric and the ecocentric,[4] because we recognized that only through shared learning and respectful dialogue would we be able to produce a report that was able to inform further learning and dialogue in the province of Nova Scotia and perhaps beyond. We embraced and integrated the legitimate fears of Nova Scotians and put those in the context of the scientific evidence where it exists (see Chapter 8). We were also able to identify where scientific uncertainty remains and express views on what that uncertainty means in terms of the development of public policy in Nova Scotia.

Throughout the review we have sought to convey complex scientific, social, and political issues in non-technical terms. We tried to write discussion papers with minimum jargon and academic language.

One of our greatest challenges, as a panel, was the resolution of complex issues of science and engineering when we know that i) technology and scientific knowledge are changing rapidly; ii) what has happened in the past may not be a good guide to what may happen in the future; iii) what happens in other jurisdictions may not be relevant in the Nova Scotia context; and iv) societal attitudes and economies change constantly. Simply stated, everything is a moving target.

Nonetheless, we know that society depends a great deal on reliable scientific evidence to make informed decisions on risks and opportunities. Unfortunately, the generation of good scientific knowledge is not instantaneous; it is a careful and deliberate process. Proof of claims is required, and unsubstantiated claims and unfounded speculations are often not considered by other scientists. Before scientific knowledge is widely accepted, it goes through a formal process called "peer review." Results are documented in papers, carefully scrutinized by others in the same discipline, and then published in refereed scientific journals for all to read. A reviewed paper does not guarantee the conclusions will be accepted, other scientists may question the results and do calculations or tests to verify or disprove them. Over time, new results are accepted if they stand up to the rigour of repeatability and careful scrutiny.

In the case of hydraulic fracturing and its associated activities and technologies, scientific observations are lacking in many areas (CCA, 2014). For example, there is no literature on methane gas toxicity from hydraulic fracturing because toxicologists consider the gas to be inert; there is no indication that it is a significant health hazard if methane is inhaled in small concentrations, therefore toxicologists do not study it. In other domains, results may be lacking because of neglect or a lack of awareness, or simply because negative or positive effects may take decades to emerge and be measured. We need only reflect on the decades it took for the links between smoking and cancer to be accepted to understand the problem. Scientists try to fill gaps in knowledge with rigorous study and publications so that society can continue to progress in matters of health and general welfare, but these studies take time and resources. Therefore, we are not in a position today where we can declare that all risks associated with hydraulic fracturing and its associated activities are fully understood, still less, that they can be perfectly controlled.

Noting all of the above, and of course our mandate from the Province, we have applied general principles to managing questions of uncertainty, risk and the public good.

1) No Preconceptions. Every panel member agreed to abide by a code of conduct to eliminate any suggestion of bias or a need to represent the opinions of any group or organization outside the panel. Each member has completed a biography,[5] which sets out their prior experience on this or related topics and describes any relevant affiliations, which readers of this report may wish to consider as informing the individual and collective world views of the panel. Finally, all panel members started and ended their involvement in the work of the panel in a spirit of inquiry and learning within an ethos of public service to the Province of Nova Scotia. There were no assumptions of what would be an optimum outcome of our deliberations except, for the provision of good counsel to Nova Scotians and their Government.

2) Legitimacy of All Views. We have accepted all public commentary and all submissions received by our panel as legitimate, the only very rare exceptions being where commentary was disrespectful or insulting. Each of our 10 published discussion papers – which now form the basis of Chapters 1-10 of this report – have been subject to both public and professional "peer review." How that review has been absorbed is described in each chapter of this report, where relevant. We received 170 unique pieces of feedback on our discussion papers from 96 individuals. We have devoted an entire chapter of our report to an analysis of the 238 formal public submissions[6] received from citizens and organizations during the course of the review and we related the concerns of stakeholders to what is known in the literature. Finally, we summarized questions posed at our public meetings and we have related those questions to relevant parts of the Report where answers may be found (see Appendix B).

3) Transparency. We have maintained a public record of all formal submissions received by the panel and we have been transparent in our deliberations each step of the way. We have published minutes of our meetings, participated in 13 public meetings and three on line forums. We have been available to the media at all times to explain our process and the content of discussion papers produced by the panel.

4) Evidence Based. We have diligently explored, summarized, and presented relevant scientific, technical and other literatures in our review. We have sought knowledge from technical experts, both within Nova Scotia and across Canada. These experts have been within government, industry, and Aboriginal communities. We have benefited significantly from the publication of the Council of Canadian Academies report: Environmental Impacts of Shale Gas Extraction in Canada (CCA, 2014). We have presented the best of the evidence that we have been able to secure and analyze through our own research, supported by graduate researchers and advisors. Evidence submitted to our review included government reports, academically peer reviewed journal articles, technical reports, news reports and magazine articles, 170 unique comments from 96 individuals on our discussion papers, and the 238 formal stakeholder submissions noted above. We are grateful for all of the submissions. Although we were not able to cite all of them because of their varied nature, they were all considered and the formal submissions will remain as part of the public record on the project website.

5) Interdisciplinarity. We are conscious that all of the disciplines of knowledge represented on our panel have their own logic, assumptions, and associated world views. Through robust but respectful debate and dialogue within our panel, we believe we have been able to forge new understandings between these disciplines, and we have been able to present syntheses between the natural sciences, the social sciences, and the humanities. The benefits of this process should be evident throughout our report, but may be seen especially in Chapter 11 where we synthesize our knowledge on risks and how they may be addressed should hydraulic fracturing ever proceed in the province of Nova Scotia. An important part of understanding this report is that the lead author for each chapter has been able to maintain their disciplinary integrity, whilst embracing the interdisciplinarity of our broader process. Each author accepted editorial suggestions from fellow panelists, as well as, external feedback that would not be normal in their discipline, and therein lies much of the strength of our report.

6) Precautionary Approach. Although the term "the Precautionary Principle" is enshrined in law in some jurisdictions, e.g. the European Union, it is actively resisted elsewhere e.g. the U.S. We also understand that the term has been used in Canada in ways that are not always appreciated by our First Nations; therefore, we do not use this term. Instead, we will be clear on what we mean by a "Precautionary Approach." Principle 15 of the final declaration of the UN Conference in Environment and Development states that, "In order to protect the environment, the precautionary approach shall be widely applied by [UN Member] States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." (UN, 1992).[7] Two tests are sometimes used in the application of the "Precautionary Approach" where there is significant scientific uncertainty and potentially significant risks to public and environmental health. One is the burden of proof, and one is proportionality. In the case of hydraulic fracturing and its associated activities and technologies, we can safely say that proper application of a precautionary approach means that the burden of proof on avoiding public harm rests with developers and those governments (i.e. federal, provincial, municipal and Aboriginal governments) that may wish to pursue the possible application of the technology in the future. Proportionality means that questions of risk, cost, and feasibility need to be weighed when considering a course of action or inaction. Elements of a precautionary approach exist in Nova Scotia legislation i.e. the Environmental Goals and Sustainable Prosperity Act (2007) based on the UN formulation, and indeed in the Mi'kmaq concept of Netuklimk (see Chapter 9), and that is the sense that we have interpreted the application of the approach in our work.

I.2.2 Approach to Participation by Stakeholders

Following the approach to participatory energy policy development in Nova Scotia described by Adams et al. (2011), and the recommendations of North et al. (2014) on the potential "benefits of sound dialogue and learning among publics, stakeholders, industry, and regulatory decision makers" on the question of unconventional gas and oil development in the U.S., our review took an active approach to the inclusion of stakeholder views in our research.

Having been appointed by the Nova Scotia Government in August 2013 (see Section I.1), the Verschuren Centre for Sustainability in Energy and the Environment (VCSEE) at Cape Breton University undertook the following activities by way of preparation for the review: i) appointment of a project manager; ii) confirmation of our brief from the new energy minister (there was a change of Government and minister in October); and iii) announcement of the mechanisms for stakeholder engagement in the review. In late October 2013, the VCSEE announced that stakeholders would be welcome to participate in the process in the following ways:

- Commenting on skill sets to be incorporated into the selection process for panelists to serve on the Expert Panel,
- Recommending candidate expert panelists,
- Bidding for technical advisory work commissioned by the expert panel,
- Submitting written evidence,
- Participating in online discussions and surveys,
- Participating in public forums; and
- Commenting on recommendations.

The VCSEE also requested that stakeholders register for updates on the process in one of the following categories:

- Interested citizen,
- Environmental group/civil society organization,
- Industry,
- Consultant,
- University/affiliate,
- Government departments/agency,
- Municipality,
- Aboriginal community; and
- Other.

On November 13, and following feedback on the list of skills to be included on the panel, we called for nominations for the panel in the following categories of expertise:

- Hydrogeology,
- Water quality management/wastewater treatment,
- Oil and gas engineering (focus on unconventional gas engineering),
- Climate science,
- Environmental management,
- Economics,
- Public health,
- Environmental psychology,
- Community engagement; and
- Knowledge of Aboriginal wisdom.

On December 6, 2013, we announced the appointment of a Technical Advisory Group – a primary technical advisor (Geologist Mr. Fred Baechler), a pro bono senior advisor (petroleum engineer and shale gas resources/reserves assessment consultant Mr. Keith MacLeod) and a special advisor (Economist Mr. Michael Gardner). The criteria and method used for these appointments are described in section I.2.4.

On February 6, we announced the appointment of nine members of the panel who represented as nearly as possible the desired list of skills identified through consultation with stakeholders. And on April 29, we announced a tenth member of the panel, supplementing the range of skills with legal expertise (special focus on Aboriginal Rights and Treaty Law). The criteria and method used for these appointments are described in section I.2.4.

The full panel membership appointed and principal affiliations were:

- Dr. Frank Atherton- Deputy Chief Medical Officer of Health, Department of Health & Wellness, Halifax, NS
- Dr. Michael Bradfield - Professor, Retired, Dalhousie University, Halifax, NS
- Mr. Kevin Christmas - Special Contract Services, Membertou Band Council, Dartmouth, NS
- Dr. Shawn Dalton - Principal & Senior Consultant, Thrive Consulting, Fredericton, NB
- Dr. Maurice Dusseault - Professor, Department of Earth and Environmental Services, University of Waterloo, ON
- Dr. Graham Gagnon - Director, Centre for Water Resource Studies, Dalhousie University, Halifax, NS
- Dr. Brad Hayes - President, Petrel Robertson Consulting, Calgary, AB
- Prof. Constance MacIntosh - Director, Dalhousie Health Law Institute, Associate Professor Schulich School of Law, Dalhousie University, Halifax, NS
- Dr. Ian Mauro - Associate Professor, Department of Geography, University of Winnipeg, MB
- Mr. Ray Ritcey - President, Lighthouse Energy Inc., Halifax, NS

From February 6 to April 29, we explored the opportunities for deeper efforts in obtaining input from Aboriginal opinion. This was identified for us by Aboriginal member of our panel Mr. Kevin Christmas, and so we obtained a further mandate from the Province of Nova Scotia to make provision for more effective outreach to Aboriginal leaders and communities. This allowed for the appointment of an Aboriginal resource management expert (Senior Aboriginal Oil and Gas Management Consultant Mr. John Snow Jr.) who would be available to Mr. Christmas and the panel for advice as required. It also allowed for the appointment of an Aboriginal outreach worker, Ms. Debra Ginnish, of the Membertou First Nation and for the provision of expenses for Mr. Christmas to reach out to Aboriginal leaderships and communities. This was also announced April 29. In the subsequent period, informal and formal contact was made with the Assembly of Nova Scotia Mi'kmaq Chiefs and the Nova Scotia Native Council (referenced in Chapter 10). The process of Aboriginal outreach, based on the output of this report, is envisaged to be ongoing throughout the latter part of 2014 and will be done according to the desires and needs of the Assembly of Nova Scotia Mi'kmaq Chiefs, the Nova Scotia Native Council, elders, and communities.

Two public meetings were held in April, one in Sydney (April 11) and one in Halifax (April 15), in order to share details of the review process. On June 11, we announced updates to the sequence of release of discussion papers and we set out preliminary dates for public presentations on our process, our preliminary conclusions, and our preliminary high level recommendations. The full list of public meetings and venues that occurred between July 16 and 29 are listed in Table I.1.

Throughout the process, we released minutes of our panel meetings as soon as they were available. The panel met five times between February 12 and July 11 (for two consecutive full days on July 10 and 11).

We conducted three on line forums on discussion papers. The topics and timings were:

- Forum Topic 1: The Potential Oil and Gas Resource Base in Nova Scotia Accessible by Hydraulic Fracturing. June 5, 9 a.m. 2014 to June 6, 5 p.m. 2014,
- Forum Topic 2: Energy Well Integrity. July 2, 9 a.m. to July 3, 5 p.m.; and
- Forum Topic 3: Hydraulic Fracturing and Public Health in Nova Scotia. July 7, 9 a.m. to July 8, 5 p.m.

Table I.1 List of public meetings and venues

Town	Date	Time	Location
Sydney	July 16	5 to 7 p.m.	Room CS 104, The Verschuren Centre at CBU
Port Hawkesbury	July 17	6:30 to 8:30 p.m.	Port Hawkesbury Civic Centre
New Glasgow	July 21	12:00 to 2:00 p.m.	Pictou County Wellness Centre
Tatamagouche	July 21	6:30 to 8:30 p.m.	Tatamagouche Centre
Amherst	July 22	12:00 to 2:00 p.m.	The Dominion Public Building
Truro	July 22	6:00 to 8:00 p.m.	Rath Eastlink Community Centre
Kennetcook	July 23	12:00 to 2:00 p.m.	Noel Legion
Halifax	July 23	6:00 to 8:00 p.m.	Kings College
Yarmouth	July 24	11:00 to 1:00 p.m.	Art Gallery of Nova Scotia, Yarmouth
Windsor	July 24	6:30 to 8:30 p.m.	Windsor Community Centre (Hants County War Memorial Community Centre)
Whycocomagh	July 29	6:00 to 8:00 p.m.	Whycocomagh Waterfront Centre

I.2.3 Results of Participation by Stakeholders

Twenty two stakeholders commented on skill sets to be incorporated into the selection process for panelists to serve on the expert panel, and 47 stakeholders recommended a total of 69 candidate expert anelists. Eight firms submitted bids for technical advisory work.

During the period for submission of written evidence, stakeholders also submitted material on hydraulic fracturing and its associated activities and technologies from a wide range of sources. This material may be found on the project website which will be archived for a period of at least three years.[8] Over 260 journal articles and reports[9] were submitted along with hundreds of news articles,[10] websites,[11] videos, and other material.[12] Formal submissions to our panel were received from 215 citizens, 10 professional organizations, six environmental organizations, three industry associations, two municipalities, and two community organizations (see Chapter 8).

Ninety-six stakeholders sent in comments on discussion papers. Many of these stakeholders made multiple submissions for each discussion paper, for a total of 170 unique contributions of feedback on discussion papers (Table I.2).[13]

Table I.2 List of discussion papers released and number of stakeholders submitting feedback

Discussion Paper Title	Release Date	Public Feedback Deadline	Total Number of Unique Submissions
Primer on the Process of Hydraulic Fracturing	March 10	April 18	35
The Potential Oil and Gas Resource Base in Nova Scotia Accessible by Hydraulic Fracturing	May 20	June 5	16
Petroleum Operations, Costs and Opportunities in Nova Scotia	May 16	June 2	22
Hydraulic Fracturing and Public Health in Nova Scotia	June 16	July 4	18
Potential Socioeconomic Effects of Unconventional Gas and Oil Development in Nova Scotia Communities	June 26	July 14	17
What are the Interactions Between Unconventional Gas Resources and Water Resources? Input quality and quantity requirements and water treatment needs and impacts.	June 3	June 20	19
Energy Well Integrity	June 3	June 20	14
The Environmental Impacts of Hydraulic Fracturing in Nova Scotia – A public participatory risk assessment	July 1	July 20	15
Understanding General Regulatory Issues of Hydraulic Fracturing	July 11	July 25	11
Hydraulic Fracturing and the Aboriginal, Treaty and Statutory Rights of the Mi’kmaq	July 11	July 25	3
Total			**170**

Five stakeholders participated in three on-line discussions on published discussion papers. Owing to the relatively low level of participation in these discussions and constraints on the availability of the panel members, we did not conduct them for all papers. These discussions are archived and available via http://www.cbu.ca/hfstudy/events.

As noted in the previous section, we conducted two public meetings in early April and we estimate that the combined total attendance at these meetings was 65 people. We conducted 11 public meetings across the Province between July 16 and 29 to discuss our preliminary conclusions and recommendations, and we estimate that the total attendance at these meetings exceeded 1,200.

The number of registered stakeholders in our process (people who received regular updates of progress on our review) reached at 290 by August 11, 2014. The numbers of registered stakeholders by category are listed in Table I.3.

Table I.3 Registered stakeholders by category to August 11, 2014. Those not self-identifying were added to the Interested Citizen/Other category

Stakeholder Category	Number of Registered Stakeholders
Aboriginal Community	9
Consultant	27
Environmental Group	13
Government	10
Industry	21
Interested Citizen/Other	145
Municipality	5
University Affiliate	50
Media	10
Total	290

The results of our Aboriginal outreach will be published in due course. But we are able to recognize in this report the wise advice offered by Chief Paul Prosper of the Assembly of Nova Scotia Mi'kmaq Chiefs (ANSMC) and energy portfolio holder; members of the Assembly's Hydraulic Fracturing Committee: Elder Albert Marshall, Unama'ki Institute of Natural Resources; Diana Campbell, Union of Nova Scotia Indians; Jim Walsh, Confederacy of Mainland Mi'kmaq; Twila Gaudet, Kwilmu'kw Maw-klusuaqn (KMK) Negotiations Office and Michael Cox, Kwilmu'kw Maw-klusuaqn Negotiations Office. We were also very grateful for the advice of Chief and President Grace Conrad, Native Council of Nova Scotia, and

Roger Hunka, Director of Intergovernmental Affairs of the Maritime Aboriginal People's Council. We wish to acknowledge the considerable time spent by leaders and staff of ANSMC, KMK, NCNS and MAPC in conducting research and outreach in this area to date and for sharing the results of their research with us. We look forward to ongoing dialogue after the publication of this report.

I.2.4 Appointment of Panel, Employees, and Consultants

As noted above, stakeholders were asked to nominate panel members whose qualifications mirrored the final list of required skill sets. Sixty-nine nominations were received and nominees were sorted into the most relevant category of expertise. Where nominees' participation would have been inconsistent with the Code of Conduct, for example if they were personally associated with a prior advocacy position (either for or against hydraulic fracturing for the development of unconventional gas and oil), or because they would be representing an institutional perspective rather than their personal expertise they were disqualified. The remaining nominees were then ranked by best qualifications and the first ranked was contacted by the chair of the panel and interviewed. Unfortunately, this process did not achieve gender balance. However, all first ranked, qualified individuals agreed to serve on the panel and were provided with details of their honorarium ($1,500) and their need to attend up to six panel meetings in person or by telephone/Skype. Nine members were selected in this manner. The tenth panel member was co-opted through recommendation to the panel when it emerged that legal and regulatory expertise would be needed, in particular expertise in Aboriginal and Treaty Rights. This resulted in the appointment of our tenth panel member who joined the panel from the third meeting onward.

Employees of the project (Ms. Margo MacGregor and Ms. Debra Ginnish) were appointed following a normal advertisement and competitive application process. Mr. Fred Baechler (Primary Technical Advisor) was appointed following an advertisement and competitive application process. Mr. Keith MacLeod (Senior Advisor) is a member of the Advisory Board of the Verschuren Centre for Sustainability in Energy and the Environment, who has special expertise that he was willing to volunteer on a pro bono basis. Given the highly specialized nature of energy economics in Nova Scotia and the relatively modest dollar value of the contracted service, Mr. Michael Gardner, (Special Advisor) was invited to make a proposal for the provision of services, which was accepted. Given the highly specialized nature of First Nations knowledge of the western Canadian oil and gas sector and the relatively modest dollar value of the contracted service, Mr. John Snow Jr. was invited to make a proposal for services, which was accepted.

I.2.5 Writing of Discussion Papers and Final Chapters

Ten discussion papers were written for the panel to debate and discuss before release to the public for further discussion. Panel members volunteered to author or co-author the papers according to their specialized academic and professional knowledge, and they were provided with research support where necessary.

The original titles of the discussion papers and the number of stakeholder responses received per paper were described in Table I.2 above. The titles of the papers changed over time to better reflect their content and scope. All 10 are now featured as Chapters 1-10 of this report. As in any academic review, they represent the considered view of the lead author(s) including their view of feedback received. As in any piece of scholarly or applied research, the final version of each chapter remains the primary responsibility of the lead author(s).

Chapter 11 summarizes chapters 1-10 in brief detail, discusses issues of public risk perception, and provides a comparative assessment of risks and recommendations. As with this Introduction, Chapter 11 was drafted through iterative discussion with the entire panel and represents the collective view of the panel.

We consider Chapters 1-10 to have been through at least two levels of "peer review" already – first within our panel, second with stakeholders, and in some cases in the professional circles of the lead authors. Each time a paper was released, all stakeholders were informed, and thus, professional and academic audiences had the opportunity to read the papers and provide feedback. When this entire report goes into the public domain it will receive a third level of peer review from all interested parties: citizens, policy makers, civil society organizations, professionals, industry and academics in Nova Scotia and beyond. We look forward to those reviews. We expect that the Nova Scotia Department of Energy will also invite feedback on this report directly.

I.2.6 Unfolding of the Process from the Publication of this Report

On completion of the panel's work, the report was submitted to the provincial government (Nova Scotia Department of Energy) and stakeholders were informed that this had occurred. With the publication of the report, the panel is released from its obligations and individuals are free to reflect publicly on their learning from this process and publish scientific papers based on their own work if that is their wish. The chair of the panel undertook to make presentations on the findings of the report to interested stakeholder groups and communities as appropriate, with a specific promise being made to present our findings to Aboriginal communities and organizations.

We do not see the publication of this report as definitive or conclusive. On the contrary, this report is the starting point for what we hope will be a more deeply informed debate on the potential risks and benefits of hydraulic fracturing for the development of unconventional gas and oil resources, which must now happen at both provincial and community levels in Nova Scotia.

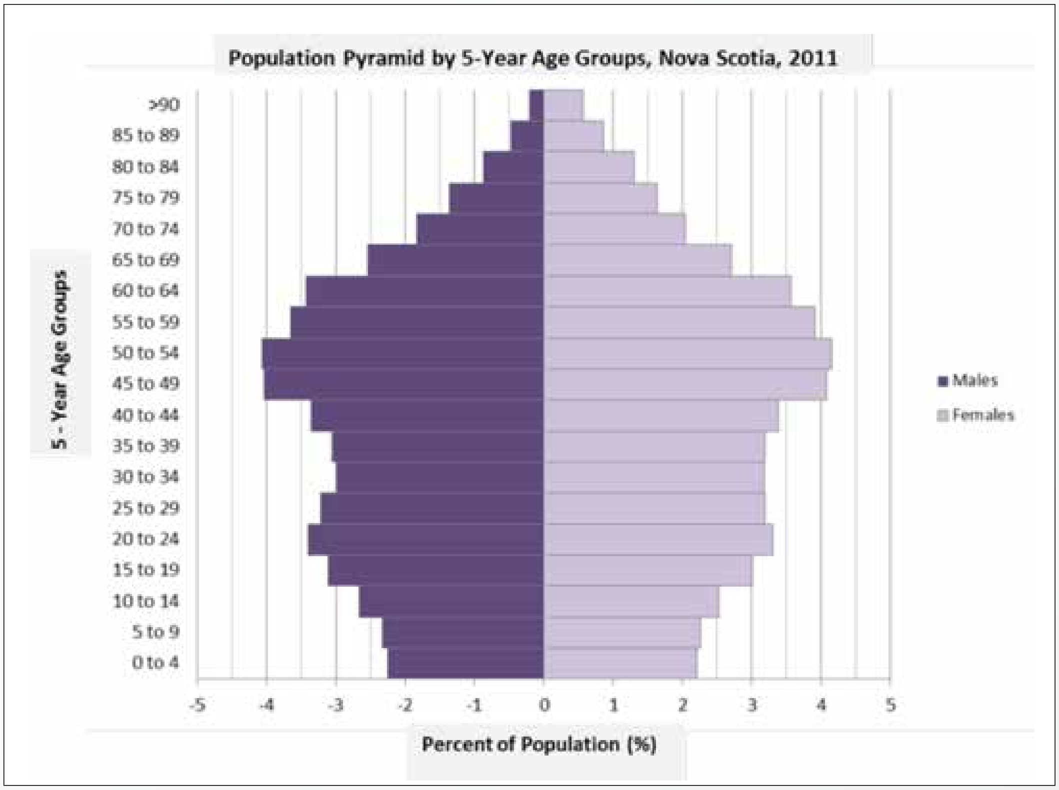
In following sections, we deal with important elements of context for our review, starting with a brief description of the demographics of the Province.

I.3 | The People and Places of Nova Scotia

Nova Scotia is one of the four Atlantic Provinces (Nova Scotia, New Brunswick, Prince Edward Island, Newfoundland) on Canada's East Coast. It is located approximately halfway between the equator and the North Pole. Nova Scotia is Canada's second smallest province with a land area of 52,939 square kilometres.

According to the 2011 Statistics Canada census, the population of Nova Scotia was approximately 921,725. Between 2006 and 2011, the population grew by 0.9 per cent,[14] although now it is in decline (see Section I.4).

Figure I.1 Population pyramid for Nova Scotia in 2011



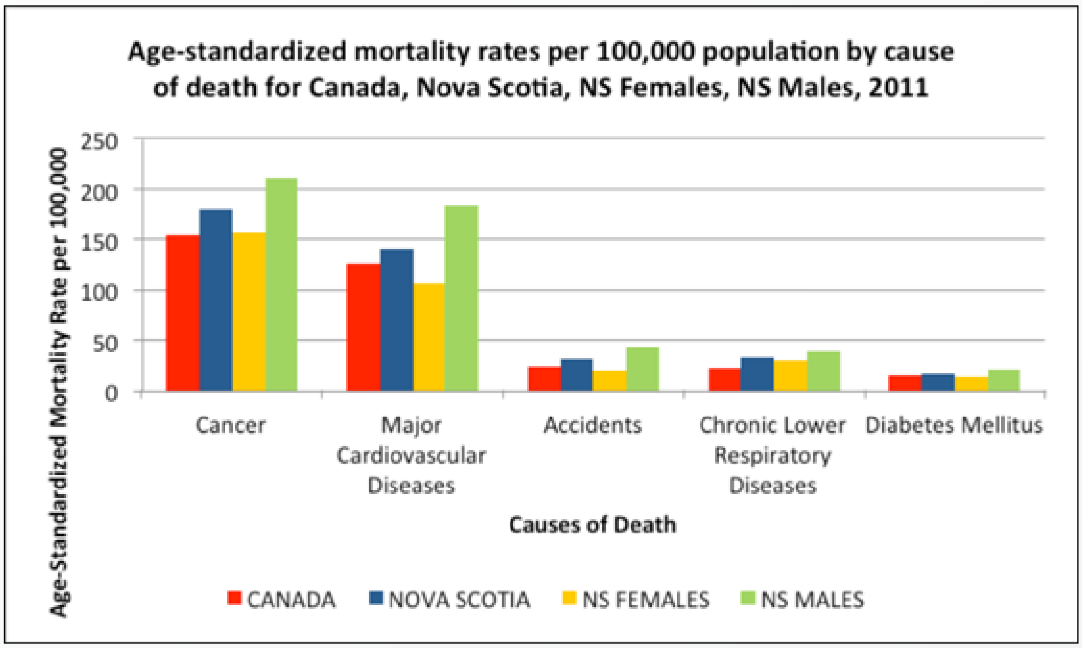
The population of Nova Scotia is aging; in 2000 the proportion of the population aged 65 and over was 13.5 per cent, and by 2011, it was 16.4 per cent. Today, Nova Scotia has the highest proportion of people age 65 and older in Canada and the lowest percentage of population under 15 (14.5 per cent). Some 5.2 per cent of the Nova Scotia population identify themselves as visible minorities and 3.7 per cent are of Aboriginal origin.

Life expectancy at birth (accepted internationally as a key marker of population health) is steadily improving, but is slightly lower than the average for Canada as a whole. Life expectancy is lower for males than females.

Between 2007 and 2011, there were an average of 8325 deaths per annum in Nova Scotia. The top 5 causes of death were:

- Cancer
- Cardiovascular diseases
- Accidents (unintentional injuries)
- Chronic lower respiratory diseases
- Diabetes Mellitus

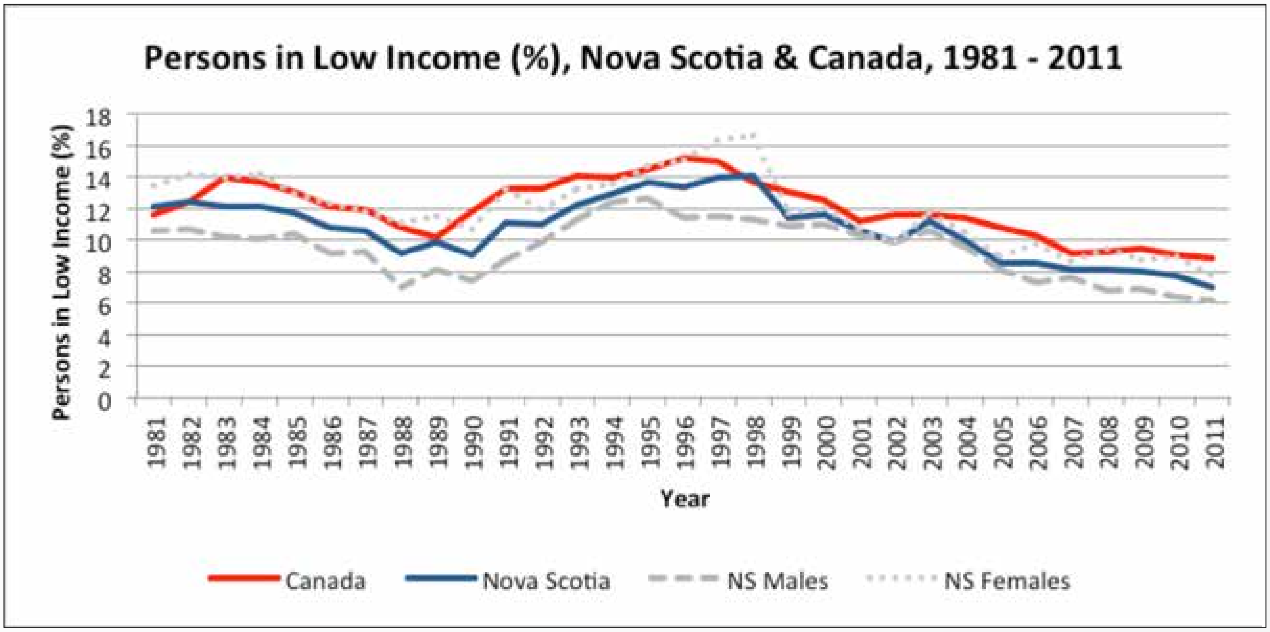
Figure I.2 Mortality rates for Nova Scotia 2011



In 2011, around 64,000 people (7.0 per cent) in Nova Scotia were living on low incomes compared with 8.8 per cent across Canada as a whole. The proportion of people living on low incomes is the lowest it has been in 30 years. (See Figure I.3)

Some of the relatively poor health outcomes in Nova Scotians can be attributed to the fact that we tend to live less healthy lives than Canadians in general; for example we have lower consumption of fruit and vegetables (34 per cent of Nova Scotians consume the recommended five portions per day compared with 40.3 per cent of Canadians), we have high levels of heavy drinking (28 per cent of Nova Scotians consume more than five drinks on a single occasion compared with 25 per cent of Canadians), and smoking rates are relatively high (22.3 per cent in Nova Scotia compared with 19.8 per cent in Canada).

Figure I.3 Percentage of people on low incomes in N.S. compared to the rest of Canada 1981-2011



The Province's population is unevenly distributed, with some 42.3 per cent of Nova Scotians living in Halifax County i.e. Halifax Regional Municipality. See Table I.4. Thus, while Nova Scotia is the second most densely populated province in the country, most of the landscape is rural or forested.[15] Of the 5.3 million hectares of land comprising the Province, some 1.53 million hectares, or 29 per cent of the land base are designated Crown land. See Figure I.4.

Table I.4 County of residence for Nova Scotians 2011

County	Area (km²)	Population (2011)	Population Density (Persons/km²)	Percent Total Population
Halifax[b]	5,495.54	390,328	71	42.3
Cape Breton[a]	2,470.62	101,619	41	11.0
Kings	2,122.18	60,589	29	6.6
Lunenburg	2,907.93	47,313	16	5.1
Pictou	2,845.26	45,643	16	5.0
Colchester	3,627.69	50,968	14	5.5
Hants	3,049.08	42,304	14	4.6
Antigonish	1,457.82	19,589	13	2.1
Yarmouth	2,123.25	25,275	12	2.7
Richmond	1,244.24	9,293	7	1.0
Cumberland	4,271.14	31,353	7	3.4
Digby	2,515.23	18,036	7	2.0
Annapolis	3,184.97	20,756	7	2.3
Shelburne	2,464.65	14,496	6	1.6
Inverness	3,830.40	17,947	5	1.9
Queens[c]	2,392.36	10,960	5	1.2
Victoria	2,870.85	7,115	2	0.8
Guysborough	4,044.22	8,143	2	0.9
Total	52,917.43	921,727.00	17	100.0

The landscape of the Province is undergoing anthropogenic "man made" change, in particular in central regions. Figure I.5 below shows the level of human-induced landscape change by watershed. Reduction in forest cover and potential loss of agricultural land affects the structure and function of ecosystems, and potentially diminishes the capacity of the landscape to provide ecosystem services such as carbon sequestration, air and water filtration, stormwater absorption, and flood control. Some of the most significantly changed areas lie above potentional sources of unconventional gas and oil.

Figure I.4 Nova Scotia Crown land[16]

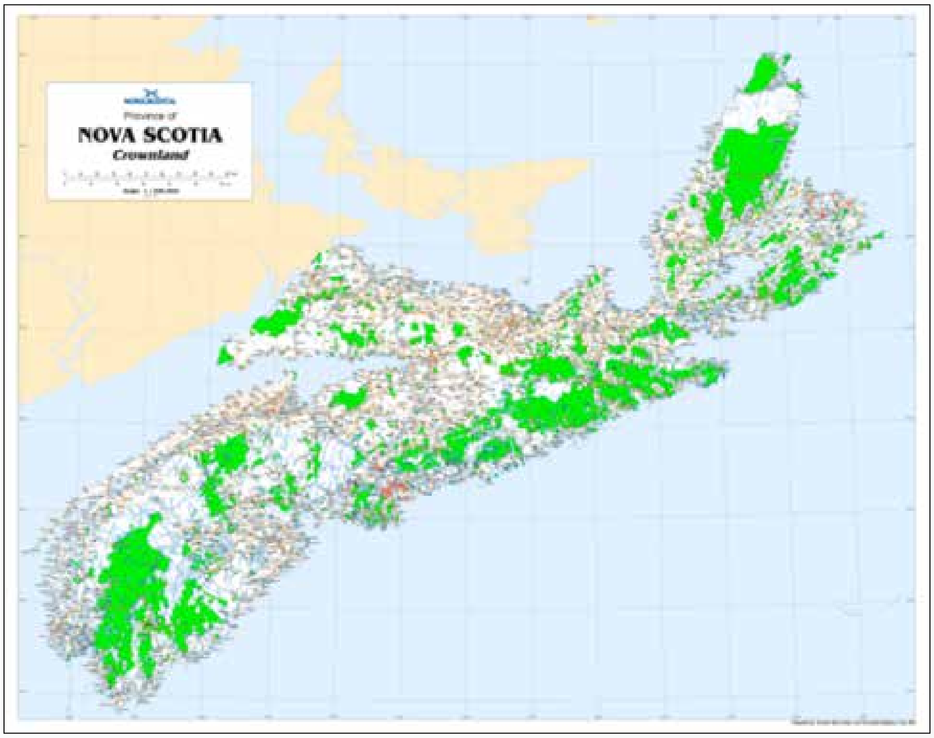
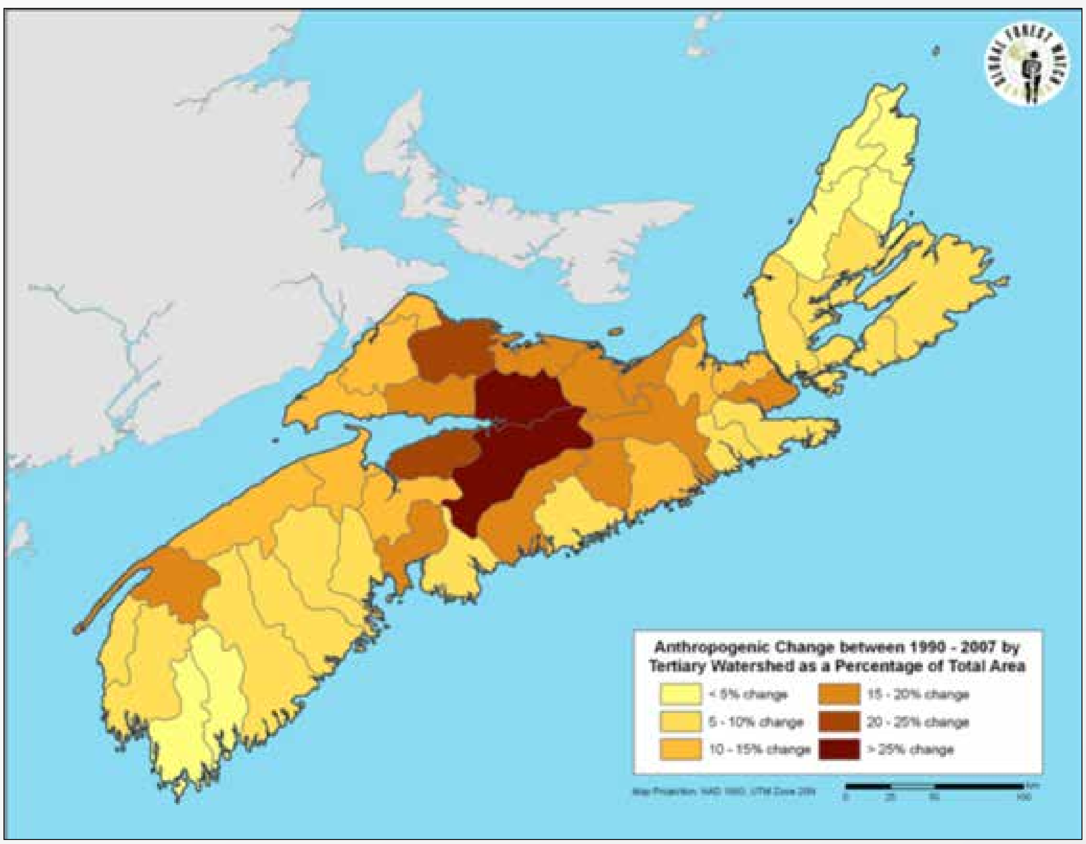


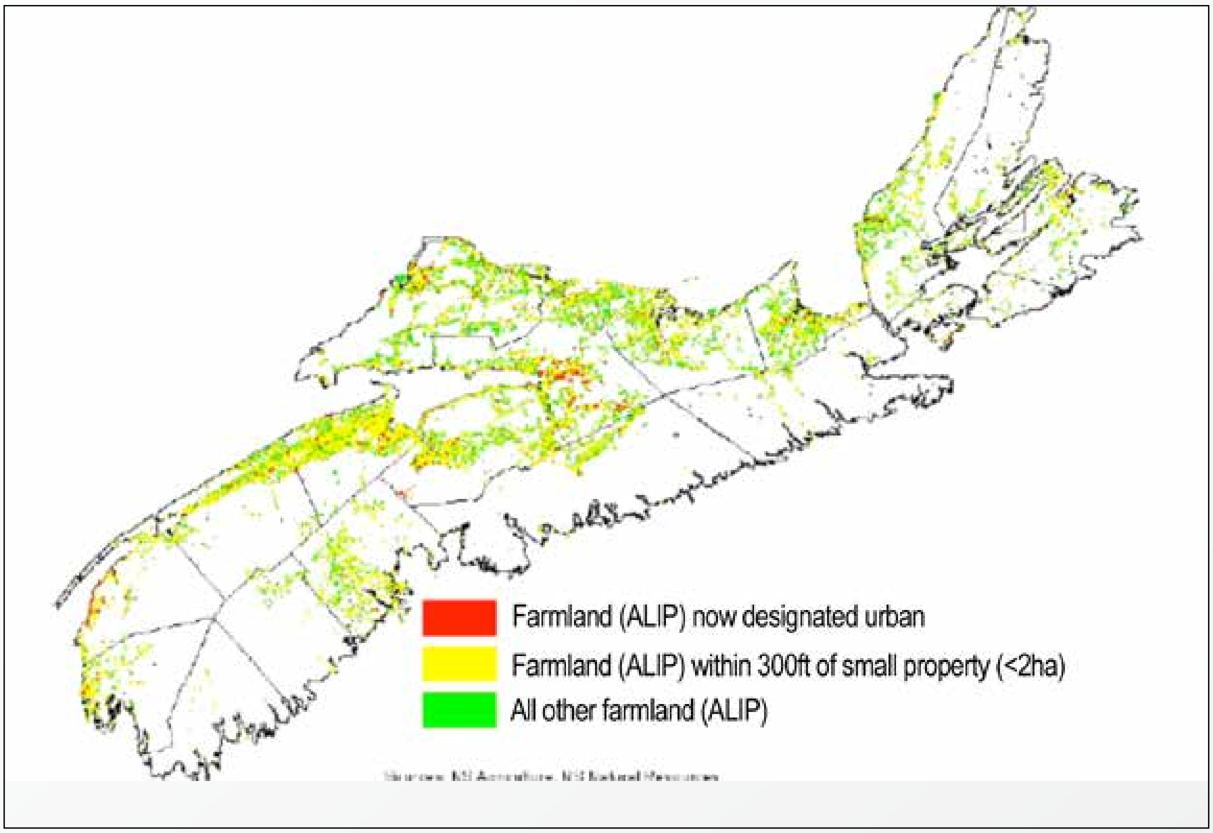
Figure I.5 Anthropogenic change by watershed[17]



Nova Scotia supports a thriving agricultural sector, in fact, in 2012, farm cash receipts totaled $586 million. Figure I.6 shows areas where existing farmland is threatened due to urban encroachment or residential development. Note that much agricultural land coincides with potential areas of unconventional gas and oil resource development in central Nova Scotia (see Chapter 2).

Nova Scotia also supports a robust tourism industry. In 2012, room nights sold i.e. accommodations in hotels, motels, etc. amounted to $2.458 billion, and visitor entries i.e. entrance fees for attractions and facilities, totaled $1.993 billion.[18] Again, much of the tourism and hospitality industry operates in areas of central Nova Scotia that might be subject to development of unconventional gas and oil resources (see Chapter 2).

Figure I.6 Lost or threatened farmland[19]



I.4 | The Economy of Nova Scotia

I.4.1 The Economic Context

I.4.1.1 Nova Scotia Commission on Building Our New Economy

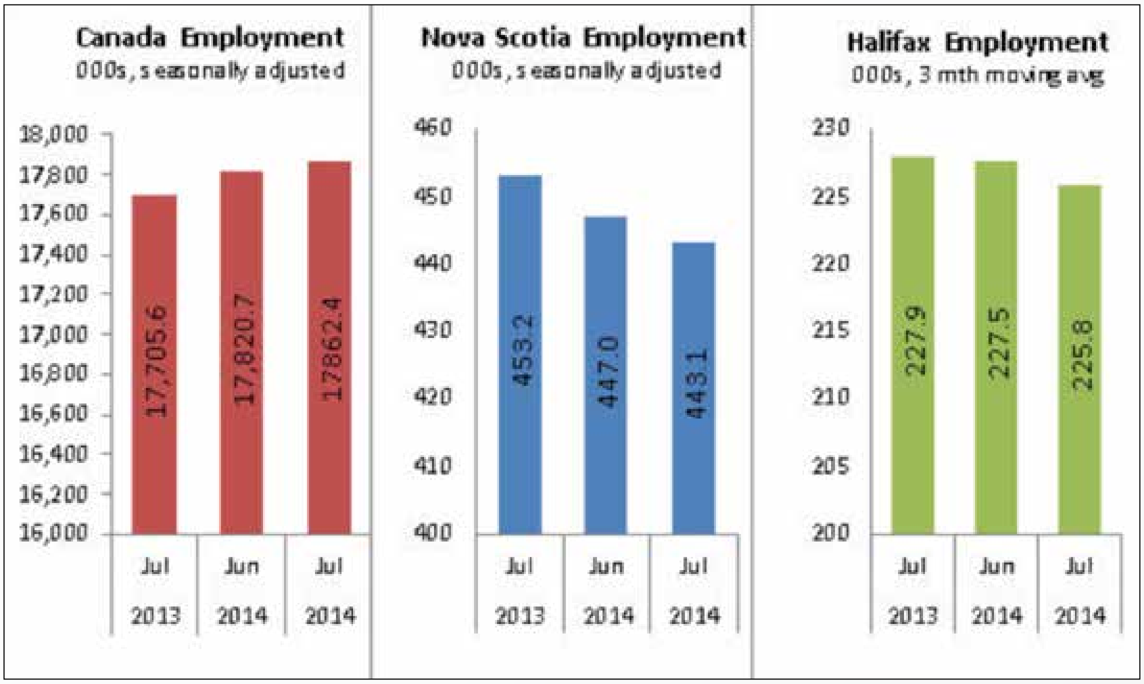
In February 2014, Nova Scotians received a clear message about economic under-achievement and precarious population demographics in the Province. The report of the Commission on Building Our New Economy (2014) was titled: Now or Never: An Urgent Call to Action for Nova Scotians.[20] The report represented 14 months of research and engagement by the Commission examining a number of fundamental challenges facing Nova Scotia.

There were many observations in the ONE NS Report that illustrate the size of the economic and demographic challenges facing the Province. For example, with respect to demographics:

- Nova Scotia's population appears to have peaked in July 2012; the 2013 population was 0.5 per cent lower than 2012 at 940,789,
- Nova Scotia has the highest proportion of people age 65 and older in Canada, the lowest percentage of population under 15 (14.5 per cent) and is tied with New Brunswick for the second oldest median age at 43.3 years (2012 data),
- Nova Scotia is the third most rural province in Canada. In 2011, 19 per cent of Canadians lived in a rural area, compared to 43 per cent of Nova Scotians,
- In the last 10 years, 13 counties had population losses, while five had population gains. With the exception of Antigonish (0.1 per cent gain), it was only those counties within a 60 minute drive of downtown Halifax that showed growth.
- Although Halifax has seen modest population growth, in terms of the 33 Census Metropolitan Areas (CMAs) across Canada, it was in the bottom third.

Recent analysis by the Province suggests that these population trends are also reflected in Nova Scotia's employment statistics. According to the Nova Scotia Finance and Treasury Board (2014): "Nova Scotia's seasonally adjusted employment declined by 3,900 to 443,100 in July 2014. With employment decreasing at a faster pace than the labour supply, the net result was a 0.7 per cent increase in the seasonally adjusted unemployment rate to 9.4 per cent in July." See Figure I.7.

Figure I.7 Seasonally-adjusted, month-over-month and year-over-year employment trends

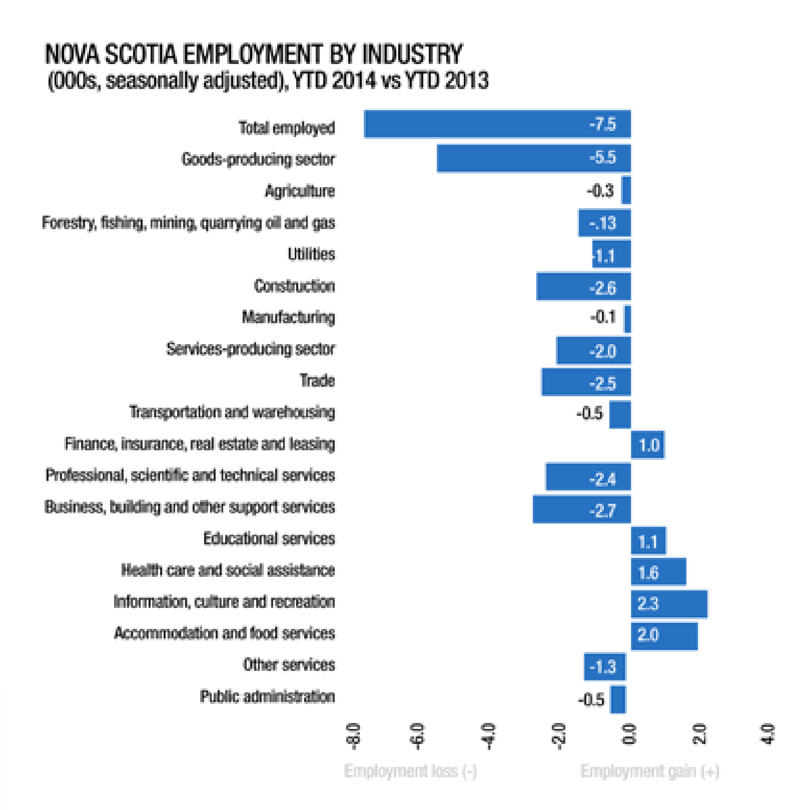


Source: CANSIM Table 282-0001

As the ONE NS Report confirms, Nova Scotia is a service-based economy. Based on 2012 statistics, the service sector represented 81.3 per cent of employment, compared with the goods-producing sector which represented just 18.7 per cent (primary industries, utilities, construction and manufacturing). The top five sector employers in Nova Scotia are: 1) wholesale and retail trade; 2) health care and social assistance; 3) educational services; 4) manufacturing; and 5) accommodation and food services.

None of these sectors is totally immune from the demographic and employment challenges described above. Although it is clear from the latest statistics that employment related to health care and social assistance, education, financial services, and tourism and hospitality-related industries have shown modest year to date increases, most private sector activities have been in decline. See Figure 1.8.

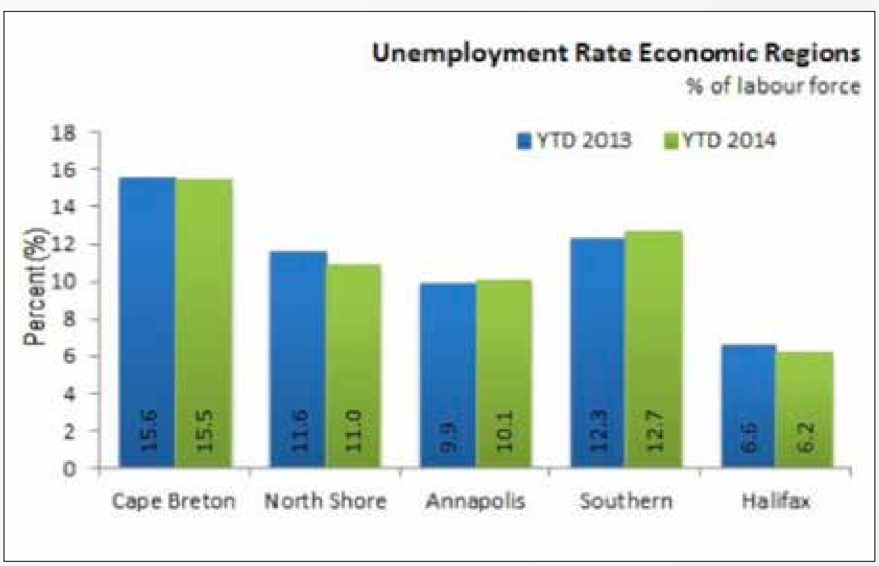
Figure I.8: Nova Scotia employment trends by industry



Source: Statistics Canada Labour Force Survey (2014)

But perhaps one of the most troubling aspects of the employment and unemployment statistics in Nova Scotia is the disproportionate spread of unemployment across the Province, with non-HRM regions experiencing significantly higher unemployment rates than in the HRM regional economy. See Figure I.9.

Figure I.9 Nova Scotia employment trends by industry



Source: Statistics Canada Labour Force Survey (2014)

I.4.1.2 The ONE NS Report and the Context for Natural Resource Management

While calls to pursue or oppose the development of unconventional gas and oil resources in the Province preceded the work of the ONE Commission, it may be argued that based on the statistics described above, the imperative of creating significantly more economic prosperity is now clearer and more widely understood as part of the economic context for our review. As the most comprehensive recent assessment of the Province's need for economic renewal, it is therefore appropriate that the ONE NS Report be used as a lens through which to assess courses of action that may hold potential for addressing economic under-achievement in Nova Scotia.

It is important to note that although the report does draw attention to the potentially positive economic prospects of certain "new economy" sectors, including renewable energy production, the ONE NS Report does not explore in any depth Nova Scotia's designated growth sectors, nor indeed future prospects for the oil and gas industry, either offshore or onshore. Instead, the report focuses primarily on the need to innovate and expand traditional sectors such as tourism, agriculture, and food production.

It is also important to note that while the ONE NS Report represents an evidence-based inquiry into the state of the Nova Scotia economy, it does not provide a blueprint for the future. The report presents 19 aspirational goals for transformation that have been widely welcomed, including through a throne-speech declaration by the current government. These elements of the report provide an assessment lens that can inform decision-makers on proposed courses of economic activity. Later in this section, we connect some of the ONE NS perspectives, goals, and conclusions to questions addressed by this review.

Clearly, it would be a mistake to view unconventional gas and oil development – or indeed any other complex development – as a "now or never" decision. Moreover, context matters: understanding of impacts, prospects for technological innovation, cost-benefit analyses, community attitudes, and emerging policy alternatives are all subject to change over time. What may not be appropriate now, may be appropriate in the future and vice versa.

Nevertheless, the crystal clear message delivered by the Commission is that as a Province we must turn our attention immediately to the generation of new wealth to share, to pay for services that underpin our quality of life, and to provide the opportunities for individuals and families to choose Nova Scotia as their home and place of work. The Commission argues that a turn-around must take place before decline becomes a permanent norm. Some economic renewal is underway and can be seen in the Commission's analysis, but it is insufficient. The ONE NS Report suggests a 10 year planning and measurement horizon for transformation to a more sustainable economy.

As noted above, the ONE NS Report structures the Commission's vision for a new economy in Nova Scotia around 19 aspirational goals. Nothing short of serious re-invention of our economy is prescribed and this must be anchored in a shared vision of the future: "How does a province, with its complex social make-up and diverse regions and sectoral interests, go about choosing a different path?"[21]

The Nova Scotia Commission on Building Our New Economy process was the most extensive combined research and public engagement effort Nova Scotia has undertaken in recent times. The ONE NS Report reveals deep passion for Nova Scotia as a place among its citizens; it also notes significant fault lines (see pages 9, 10 of the ONE NS Report) that impede the emergence of the shared vision called for in the Commission's report. For example, notable both in the ONE NS community sessions and among those discussing the possibility of an unconventional gas and oil industry in the Province, was a sense of mistrust in Nova Scotia that is often manifested in topics that involve government policy, industrial activity, environment, and community well-being. We address the implications of this mistrust in Chapters 8, 9, and 11.

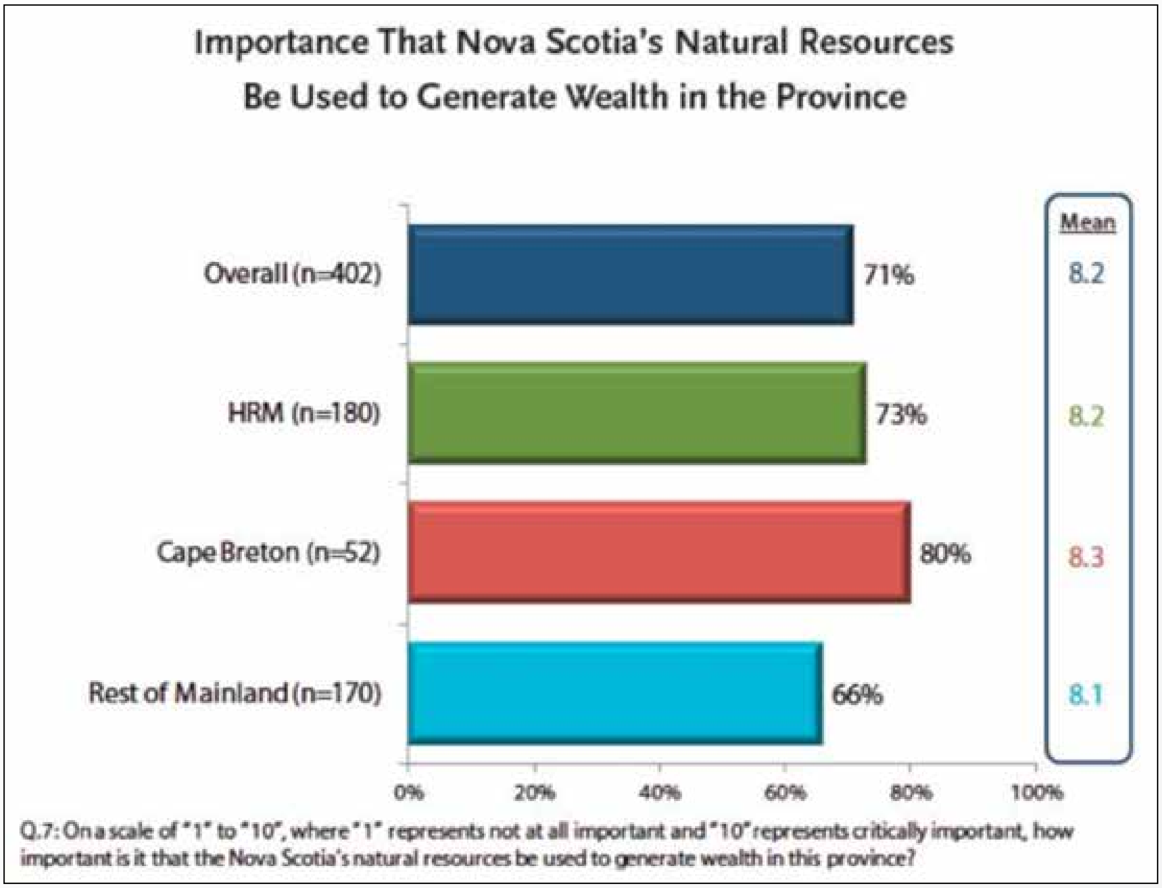
Nova Scotia's "trust deficit" has developed not only through experience of regulatory and industrial failures, but – argues the Commission – by insufficient positive articulation of a vision that citizens can support. Interestingly, both the Nova Scotia Commission on Building Our New Economy and our own review, reference Nova Scotia's Environmental Goals and Sustainable Prosperity Act (EGSPA) as one important example of shared vision. EGSPA sets out parameters for the pursuit of prosperity within a set of place-based values, "The health of the economy, the health of the environment, and the health of the people of the Province are interconnected."[22] When considering economic activity, EGSPA does not call for unanimous agreement or risk aversion; but rather calls for innovative solutions "to mutually reinforce the environment and the economy."[23]

I.4.1.3 The ONE NS Report and Public Attitudes to Natural Resource Management

The ONE Commission commissioned Corporate Research Associates (CRA) to study the opinions of Nova Scotians on a range of factors relating to economic development. The description of the CRA survey is the only place within the ONE NS Report that "unconventional gas and oil" is specifically addressed.

One section in the CRA survey was dedicated to Attitudes Towards the Use of Natural Resources.[24] An initial question on the importance of natural resources for wealth generation was followed by a set of questions designed to elicit further opinions. The importance of developing natural resources to "generate wealth in the Province" was clearly understood, with the sample of 403 Nova Scotians averaging 8.2 on a scale of 1-10 (where 1 represented "not at all important" and 10 represented "critically important"). See Figure I.10.

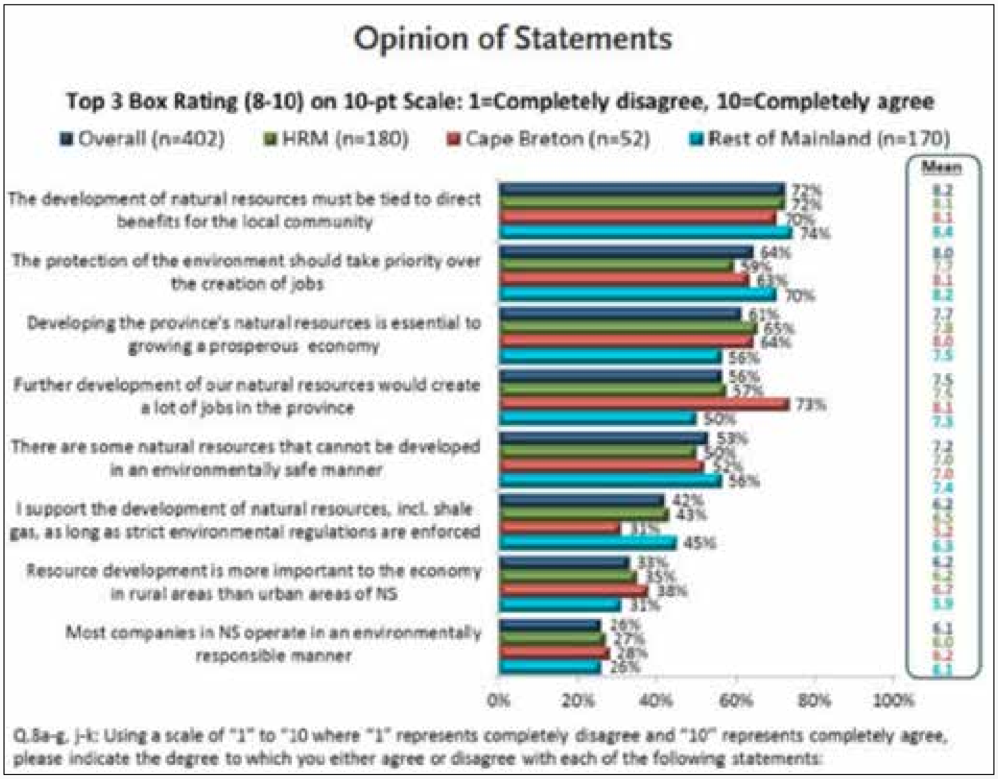
Figure I.10 Results of CRA research for the ONE Commission on the importance of natural resources for generation of wealth in the province.



Courtesy of the Nova Scotia Commission for Building Our New Economy

A further question asked participants to indicate the level of their agreement or disagreement with the following proposition, "I support the development of natural resources, including shale gas, as long as strict environmental regulations are enforced." Figure I.11 depicts results from this and other questions divided into three samples: Overall (n=402), Halifax Regional Municipality (n=180), Cape Breton (n=52), and the rest of Nova Scotia (n=170).

Figure I.11 Results of CRA research for the ONE Commission on attitudes to natural resource development in Nova Scotia.



Courtesy of the Nova Scotia Commission for Building Our New Economy.

The results of this survey, conducted in early August, 2013, indicated an overall favourable view of natural resource development in Nova Scotia, particularly where it is tied to community benefits (72 per cent in favour). But only 42 per cent supported the development of unconventional gas and oil "as long as strict environmental regulations are enforced." Meanwhile only 26 per cent of the total sample believed that "most companies in NS operate in an environmentally responsible manner." Just over half of respondents (53 per cent) conveyed that there are some resources that "cannot be developed in an environmentally safe manner."[25]

I.4.1.4 The ONE NS Goals and Relevance for Unconventional Gas and Oil Development

If the unconventional gas and oil industry in Nova Scotia achieved regulatory and social license (which in this report we describe as "community permission to proceed"), and if market demand continues to be buoyant, the realization of numerous goals of transformation in the ONE NS Report would be affected. One of the most notable of these is Goal 5: Value of Exports. The Report calls for a 50 per cent increase in the dollar value of exported goods and services, expanding Nova Scotia's current annual $14 billion amount to a figure over $20 billion over the next 10 years. Assuming a significant percentage of unconventional gas and oil production was available for export, a significant contribution could be made to the export target set by the ONE NS Report.

We should note here that the ONE analysis only deals with gross exports rather than net exports. A complete assessment of the impact on exports from unconventional gas and oil development to the Nova Scotia economy would include the costs of imports necessary to drive the industry, which are substantial (see Chapter 3). This would allow a more sophisticated assessment of the economic benefits and costs of the industry with respect to domestic use versus exports in comparison with, e.g., domestic use and export of electricity derived from coal, wind and other sources that also rely on imported raw materials and capital items.

Progress on a number of key ONE NS goals could accompany the development of unconventional gas and oil development in the Province. Significant direct gains in employment opportunities (Goal 7) could help achieve improvement in areas such as inter-provincial migration numbers (Goal 1), business start-ups (Goal 4), labour force participation rate (Goal 7), and youth employment (Goal 9).

Goal 8: Employment Rate – First Nations and African Nova Scotians could be positively affected by development that holds the potential for systemic programs of inclusion, whether through industry-led partnerships or as part of negotiated approvals among businesses and governments, or as a conditional term of governmental support.

Goal 11: Universities Research and Development and Goal 12: Research and Development Partnership, are most likely to be supported by the arrival of large scale (including capital intensive) and technically challenging activities such as that the unconventional gas and oil industry would introduce.

The ONE NS goal of doubling gross business revenues from tourism, Goal 14: Tourism Expansion could – in theory - be affected in several ways. First, at the various stages of unconventional gas and oil development, significant numbers of business travelers and new temporary residents may spend time and money as tourists. Second, greater family prosperity could translate indirectly to more domestic tourism. Third, given Nova Scotia's increasing reputation as a nature and adventure travel destination, the perception of the Province as a place of large scale gas and oil development could adversely impact the Province's image and reduce tourism in certain parts of the Province – especially those counties that were most affected by the industry. Similarly, domestic markets for agricultural products (Goal 16) could also be compromised through competition for land use in affected geographies.

Goal 17: A Province-wide Plan to Achieve Nova Scotia's New Goals for Sustainable Economic Growth and Population Renewal could be positively impacted by the development of an onshore unconventional gas and oil industry. However, the comprehensive economic plan envisioned by the ONE Commissioners is yet to materialize. So this would be a topic to be explored in due course for consistency in public policy-making and would therefore be the responsibility of the provincial government to resolve.

Finally, Goal 19: Fiscal Health would clearly be impacted by the development of a significant unconventional gas and oil industry in Nova Scotia. The Commission chose to measure the health of the Province's accounts by looking at net debt to GDP ratio, proposing a decrease of 7 per cent or more in the coming decade. No doubt, direct investments into employment in communities that resulted in increased taxation revenues and the potential royalties envisioned in Chapter 3 could help in reducing net debt. However, a full analysis would also need to take into account externalities, opportunity costs, and unanticipated losses, which accompany the uncertainty of energy markets and the environmental and social costs of extractive industries.

In summary, the Nova Scotia Commission on Building Our New Economy encouraged Nova Scotians to embark on urgent economic reinvention. Consistent with this call, any development possibilities holding the promise of new wealth creation and of living-wage employment – especially in rural Nova Scotia - warrants serious consideration. However, that consideration needs to occur within a values-based discussion that creates a shared vision for economic, environmental, and social well-being harnessed to appropriate industrial policy. The ONE Nova Scotia Commission noted in both their written and presentation materials that the preferred route to economic prosperity and resilience in the Province, as exemplified by some prominent growth-oriented companies, is that of developing home-grown entrepreneurial initiative that adds value to our assets to connect to the world. Major projects too were highlighted as catalysts to develop multiple layers of sustainable opportunity. Whether the development of an onshore unconventional gas and oil industry is part of that transition remains to be resolved.

I.4.1.5 Summary of Economic Context

As with most of Canada, it may be argued that Nova Scotia has two distinct economies: one urban and one rural, or HRM and the rest. According to the latest employment statistics noted above, rural Nova Scotia suffers roughly twice the unemployment rate compared to HRM. Other labour market characteristics, such as wages and participation rates, follow this long-established pattern, although historically we have performed better than the Canadian average in a few areas, such as measures of income inequality and the percentage of 24 to 44 year olds in the labour force who have post-secondary education (Nova Scotia Department of Finance, 2012).

Halifax is a modern economy, primarily based on services, especially health and education. The rest of the Province tends to be resource-based, with government employment offering some stability. Smaller communities have suffered from the collapse of the fisheries and of pulp markets and from increased competition in international markets because of the rise in the Canadian exchange rate.

Related to the economic condition of the Province has been the impact of demography, with young Nova Scotians unable to find jobs in Nova Scotia consistent with their education and training. There is a long understood practice of seeking better-paying jobs elsewhere, to build up a “stake” with which to eventually return to Nova Scotia. Until job prospects and wages improve in Nova Scotia, we cannot expect sufficient numbers of youth or immigrants to stay and the birth rate will continue to decline.

An economic issue which attracts considerable attention, including in the ONE NS Report, is government debt. High deficits and debt servicing costs of the 1980s, up to the beginning of this century, were caused almost totally by federal government tax cuts and high interest rates (Mimoto & Cross, 1991).

These were accompanied by the downloading of programs to the provinces and the reduction of federal transfer payments. This trend has also directly disadvantaged municipalities in Nova Scotia, many of whom are now struggling to provide appropriate levels of service, especially with a declining tax base. Moreover, because the provincial definition of taxable income is determined by federal tax deductions, federal tax cuts have further eroded the provincial tax base and its capacity to provide necessary services. It has been shown that the result of taxation policy has made the entire tax system less progressive (Lee, 2007).

Nonetheless, Nova Scotia has steadily reduced its deficit and improved its capacity to manage its debt; the ratio of debt-to-GDP is a now 36.7 per cent and is falling with continued, albeit weak, economic growth (CCPA, 2014). Assisted by low interest rates, our debt servicing charges have fallen from 20 per cent of government expenditures in 2002, to 8.7 per cent in 2013/14. Our small business taxes are among the lowest in Canada, and Halifax is one of the most competitive locations for business in the country (KPMG, 2014), despite its higher cost of transportation.

However, whatever advantages we may enjoy, given the analysis of this section, it is clear that the Province of Nova Scotia has much to do to improve the economic prospects for Nova Scotians, particularly those who live in rural regions. While the relative success of HRM may be attributed to its high level of public sector employment, rural regions of Nova Scotia continue to be challenged by the absence of a sufficiently vibrant private sector. One of the biggest challenges for the entire Province is, therefore, to understand what will be the role of the private sector in the future, and – specific to this Review – how will the natural resource management sector factor into that vision alongside services, manufacturing, agriculture, and tourism.

I.4.2 Externalities

I.4.2.1 Market Imperfections and Externalities

It is difficult to separate economic from social and environmental issues as they are completely intertwined. All of our “economic” activities occur within social and environmental contexts, which are themselves affected by the structure and nature of our economic activities. The basic challenge of economics is how our production and consumption activities use resources directly, but also have significant effects on human health and on well-being, on social structures, and on the environment, which supports all life.

In our research for this review, we were constantly challenged by difficulties of measurement and uncertainty over time, and many of those paradoxes are reflected in this report. For example, in our research on public health (Chapter 4) we identified that hydraulic fracturing for the development of unconventional gas and oil could bring economic prosperity to individuals whose health outcomes may then be enhanced. Conversely, local atmospheric pollution effects (e.g. linked to drilling operations or increased traffic) could be deleterious to health and invoke costs for our health systems. In our research on community socio-economic and social ecological impacts (Chapter 5), we identified that community economic benefits and costs could be significant in terms of greater local spending on community development, schools and other infrastructure; in contrast new costs may fall on municipalities for roads and other infrastructures that they may not easily recover.

The discipline of economics studies how we organize our activities and use our resources (human, built, and natural) to determine what goods and services will be produced and in what quantities, how they will be produced, and how they will be shared.

One way to do this is through the "free market," free of government interference, because the "perfectly competitive" market of economic theory predicts that individual self-interest will be controlled by competition in the market place to allocate resources to those goods which are in the public interest (usually defined in a market economy as "consumption goods").

However, the conditions required for markets to even approximate the theoretical model are stringent. For example, no one should have dominant market (or political, legal, or social) power, there are no barriers for firms to enter an industry, everyone has full technical and market information, and all prices should reflect the true costs of a product and of its consumption. These conditions are seldom, if ever, satisfied in the real world. Exceptions to these conditions in a private market are the source of "market failure" and require intervention (Tietenberg et al., 2009). Nonetheless, some commentators drop the "perfect" and ignore the "competitive" and put their faith in "the market" for ideological or other reasons.

Because of market imperfections, we need a "mixed" economy with the majority of activities in private markets, but where governments produce some goods and services, levy taxes, and make purchases from the private sector. In addition, governments make and enforce regulations for personal and commercial activities, such as the rules of ownership and contracts.

Most economic activities involve some degree of market failure. Hydraulic fracturing for the development of unconventional gas and oil resources raises legitimate concerns among stakeholders (see Chapter 8) because it does not meet many of the necessary conditions of the idealized perfectly competitive market. One of the industry's most important limitations is the possibilities for externalities – costs that are not borne by the seller and buyer but (as noted in Chapters 4 and 5) are imposed on someone (or "thing" in terms of the environment) outside a market transaction. While externalities impose real costs (depleted resources or the use of resources to avoid damage or to mitigate it), they may not be reflected in the price of the activity creating these external costs. Thus the price - the market's measure of value - fails to reflect the costs to all those affected by a transaction (Jaffe et al., 2005; Vojnovic, 2014). A strictly market transaction may ignore the health, social, and environmental impacts it may impose on others, even though society may put a very high value on the impacted areas.[26]

When externalities exist, market prices no longer reflect the full cost of a good. As most of our economic measures are based on prices, we cannot say that something is "efficient" simply because the producer makes a profit and the consumer is satisfied with the price paid. When externalities are present, society bears additional costs which must be recognized and factored into the price for an activity to truly maximize the benefits for society.

With hydraulic fracturing and its associated activities and technologies, as with all industrial activities, there are potential externalities at each stage, from exploration to development to production to decommissioning. The costs of such externalities must be estimated to decide if this is a viable way to access an energy source. These costs vary with respect to their geographic impact, their duration, and timing, e.g., at the time of an activity or much later, perhaps long after production of unconventional gas has ceased at a given site.

In our public consultations, significant concerns were expressed that while we were able to estimate direct economic benefits and royalties on a range of scenarios based on replicable industry formulae, we were not able to estimate the potential economic impacts of externalities with anything like the same precision, because i) potential direct costs will be entirely driven by local geographic and demographic factors; and ii) some may be intangible, unknowable, or simply long term and, therefore, not possible to calculate. See Chapter 3 and Chapter 11 for further discussion of these points.

We were also challenged by the fact that existing economic activities, including the burning of coal for electricity and oil for home heating, are not without their local and global externalities and local environmental and social risks. And yet these activities are difficult to compare directly with the development of unconventional gas and oil resources which may, in theory, reduce dependency on coal and oil but with an entirely different spread of global and local effects and externalities.

For example, the development stage may affect the immediate geographic area – the movement of trucks and equipment affect the enjoyment people have from their homes along the highway or near the well site. In addition, the more rapid deterioration of roads and other common infrastructure generate increased construction or maintenance costs. Congestion on roads may impose social (time) rather than direct financial costs on its users, but these are costs nonetheless (see Chapter 5 for a fuller discussion of these questions).

The operation of a well site involves bringing water and chemicals in and taking product and waste water out. This generates increased truck traffic with external costs, including safety concerns. The production stage may mean the flaring of gas (if permitted), which may affect the health of people and their animals, as well as of wild life in the area (see Chapters 4 and 5).

The geographic impact of the production externalities may be much broader than the immediate area and may have longer term, and even intergenerational effects. For example, methane may eventually work its way into the atmosphere in greater quantities than at present, thereby reducing or eliminating any climate change benefits of burning natural gas rather than e.g. coal or oil, and thus further exacerbating climate change, with all of the attendant risks this posed on communities at the global level (see Chapters 4, 7 and 8). In this case, if hydraulic fracturing for the development of unconventional gas and oil resources were pursued in the wrong way by Nova Scotia, the Province would be externalizing its economic impacts on the rest of the planet, as well as potentially being in contravention of the Environmental Goals and Sustainable Prosperity Act (see Chapters 8 and 9).

I.4.2.2 Dealing with Externalities

There are many ways to deal with externalities within the market, with government setting upper limits on the level of externalities or on the activities that generate them, through the regulation of those activities, or through an outright ban on those activities.

Some argue that market failure due to externalities can be solved by the market itself. They propose self-regulation by the firms involved, jointly agreeing on behaviours to avoid generating externalities in order to enhance their individual competitive position. Self-regulation has limited potential, particularly if we wish to apply a precautionary approach (see above) and is not recommended in this report as a core element in the regulation of the industry (see Chapter 11).

One solution is for the market to internalize the externality, i.e., force the market transaction to include the costs of the externalities. In this situation, the function of government is to establish the legal framework – effectively to set up "auctions" for pollution rights or require full legal liability to compensate those forced to bear the external costs. This is the rationale for the Nova Scotia Environment Act requiring that those who pollute must pay the costs they impose. Faced with these additional costs, firms would choose the production method which imposes the lowest financial cost, typically employing the most efficient or "best available" technologies. Thus, the real cost of production and distribution would now include this financial cost.

Externalities may also be lessened, but not totally removed, by a liability-driven approach in which the potential polluter is required to obtain full liability insurance. The theory is that the insuring company will conduct due diligence and assess the probability of an event generating externalities, their likely impacts and costs, and the possibility of an expensive legal battle to establish the liability and the amount. These estimated costs would then be part of the cost of the liability insurance premiums for the potential polluter. If these premiums are too high, production will not occur and the externalities will not be generated – the product is not worth its cost and the interests of society are protected.

But even this does not mean that the premiums will accurately reflect the probable external costs. The insurance company's estimate may be lower than the actual costs, and if liabilities are only recognized in the long-term future there are no guarantees that either the industry or their insurers will still be in existence in 50 or 100 years time when the true costs may become apparent.[27]

This is not to argue that driving "best available technology" or seeking to put in place full liability have no place in the policy tool kit. It is simply to note that these approaches do not eliminate all of the causes of market failure. Approaches must be carefully crafted to avoid the limitations of relying primarily on market solutions. Taking a precautionary approach, the need for strong regulation of hydraulic fracturing and its associated activities and technologies should be obvious (see Chapters 4,5,6,7 and 8 for the evidence and Chapter 9 for a broad discussion of best approaches in regulation and enforcement).

Many stakeholders told us very clearly throughout this review that they do not trust industry, regulators or politicians to protect their interests when it comes to the development of unconventional gas and oil resources. This was certainly reflected in formal submissions to our review (see Chapter 8) and in numerous questions raised and comments made at public meetings, most poignantly in the Kennetcook/ Noel meeting (see Appendix B).

As we saw from the polling for the Commission on Building Our New Economy (2014) there is a low level of public trust in industry generally in Nova Scotia, only 26 per cent of respondents believing that "most companies in NS operate in an environmentally responsible manner." This reflects a broader concern around corporate influence – "regulatory capture" – on the integrity of regulation (e.g. Egilman and Druar, 2011) where corporations influence politicians and regulators even when that may compromise the public interest (Church and Ware, 2000). These fears are clearly in the minds of Nova Scotians, they are the subject of media and legal commentary (East Coast Environmental Law, 2014; *The Chronicle Herald,* 2014), and they need to be addressed. We discuss these matters further in Chapter 11 where we also make specific recommendations for effective regulation and the protection of public health and the environment.

And of course, even the most effective regulations still do not guarantee that externalities will be eliminated or fully compensated for. Without rigorous enforcement and political will, they may only mean that producers will meet the standards if they do not cost too much and/or the penalties for ignoring the regulations are high (see Chapter 9). Similarly, the promise of mitigation (reduction of risk) is no more than a promise to try to minimize or to make up for externalities. Mitigation lessens the impact but does not remove it. As some of the externalities could involve health, social, and environmental impacts that may not be reversed, mitigation is not a guarantee that externalities will be fully accounted for.

I.4.2.3 Outstanding Questions on Externalities

There are outstanding issues that we need to consider in addressing the question of externalities and their control in the context of hydraulic fracturing for unconventional gas and oil development. We discuss some in greater detail in the following chapters, and we will return to them in Chapter 11, where we discuss questions of risk and we relate them to our recommendations in more precise detail:

- Will developers build and maintain all infrastructure specific to their needs? Will they pay the taxes (or will royalties be deployed) to build and repair roads and other public infrastructure that they will burden by their additional use?

- Will there be an impact of this industry on other taxpayers? Tax revenues may be lost by giving potential employers tax concessions or direct cash subsidies.

- Does the provincial government simply apply a fixed percentage of the federal profit tax or does it have its own corporate tax form as it does for personal income tax?

• Do trade agreements, such as the NAFTA and the CETA, give a company the right to sue a government for lost profits if, because of health or environmental issues, a government passes legislation which restricts fracking?

I.4.2.4 Benefits of Unconventional Gas

Of course, to assess any project, we must weigh its benefits against its cost. In a "free market" this is the private calculus in which there is deemed to be a net benefit to society if the producer can sell its product at a price which covers all the financial costs and leaves a profit. As there are significant concerns about the externalities involved, this market test is not necessarily adequate for the oil and gas industry (including hydraulic fracturing for unconventional gas and oil resources), or indeed for many other industries.

One of the primary potential benefits of hydraulic fracturing is that it gives access to a new source of energy, to unconventional gas and oil resources. As Nova Scotia is heavily dependent on imported energy, some with a high carbon footprint, at the right cost, unconventional gas may be an important alternative source of energy, at least in the short term. Without detailed evidence of its potential and real costs, the net benefits of unconventional gas in Nova Scotia are as yet undetermined; however our analysis supports the contention that further work should be done to explore the possibility that these net benefits may indeed exist.

If – based on further analysis - it is indeed desirable to develop unconventional gas, subject to community rights to full, prior and informed consent (see Chapter 11), we may reasonably ask whether Nova Scotians have access to it. We may also question whether the size and location of the gas deposits justify an internal distribution system or whether the bulk of the supply will simply be exported.

If the gas is exported, the energy advantage of the sector would be that the export dollars could be used to import other sources of energy whose price and sustainability are better than our own energy supplies. This depends on the amount of the export revenue which stays in Nova Scotia. This, in turn, depends on the capital intensity of the industry (revenue/capital costs), the wages and the lease rentals paid to Nova Scotians for the placement of wellpads and pipelines, the extent to which the industry is owned within Nova Scotia, and the royalty revenues.

Taking an ideal economic development perspective, and assuming finance was to be available, the industry could be locally owned, perhaps by municipal utilities and employ local workers (men and women) who would have the necessary skills when needed. Their average wages could be above current levels, and many of the physical capital requirements could be met locally, increasing the possibility of developing a long-term capital-goods industry. Similarly, the financial capital for the industry could come from local investors in addition to capital markets, so that both dividends and control remain in Nova Scotia.

The ideal scenario would include other spin-offs to the local economy, such as supplying the input needs of the industry and engaging in research on the production technology and alternative uses for this technology and the gas itself. Of course, the ideal scenario assumes that the unconventional gas reserves would be viable for at least a generation, so that the capital, worker, and infrastructure investments can be fully paid for within the life-time of the sector.

To achieve the necessary conditions for such an ideal, the sector would need to develop slowly, allowing local interests to adjust to its demands and expectations. Slow growth lengthens the duration of the sector, allowing a more cautious approach to dealing with the externalities. In some cases, as in Germany, strict environmental laws led to the emergence of "green" industries, which began by serving local needs and developed expertise which today generates exports of both green products and green consulting services. Denmark has grown a very significant international export market for wind turbines based on an initial set of public policy measures that prioritized local use and local market development. Exports were not the initial goal in Denmark; meeting community needs for renewable energy was the early priority (Lewis and Wiser, 2007). Export spin-offs are often an indication of success in meeting local needs and the competitive edge this gives firms who participate. This point is well supported in the economics and strategic management literatures (Porter & Van der Linde, 1995 and 1996; Hart, 2007; Hart & Milstein, 2003; Wheeler et al., 2003).

I.5 | **Energy Policy in Nova Scotia**

I.5.1 Energy Policy Context

The current Energy Strategy for Nova Scotia was issued by the government in 2009: Toward a Greener Future: Nova Scotia's Energy Strategy. The strategy outlined eight broad policies with specific goals and timelines. This energy strategy is closely related to the Environmental Goals and Sustainable Prosperity Act (EGSPA 2007) and its amended legislation, the Green Economy Act (2012). EGSPA links environmental and economic activities to specific sustainable goals and the Province issues progress reports yearly.

The Renewable Electricity Plan (2010) led to the establishment of a legislated goal of having 25 per cent of electricity production from renewable sources by 2015, increasing to 40 per cent by 2020. This is one of the most aggressive renewables targets established in North America. Two other relevant elements of the Province's approach to energy policy were: i) the establishment of Efficiency Nova Scotia (ENS), an independent regulated organization committed to energy conservation and efficiency; and ii) the Community Based Feed-In Tariffs (COMFIT), which promotes the introduction of local renewable electricity generation across the Province, including wind, hydro, bio-mass, and tidal (Adams et al., 2011).

Much of the focus of government and other key energy stakeholders, in recent times, has been on the establishment of the Maritime Link Project, which will bring hydroelectricity from Newfoundland and Labrador's Muskrat Falls Generation facility to markets including Nova Scotia.

Meanwhile, in early 2014 the government also began a review of the electricity system for the Province. The government has been supportive of natural gas use and promotes natural gas as a cleaner burning fuel. The government is also active in converting many of its public buildings to natural gas as have municipal governments and other public bodies that have access to natural gas.

The government monitors energy development activities in the broader region by maintaining an active involvement with other key stakeholders at the provincial and federal government levels.

I.5.2 The Role of Fossil Fuels in Nova Scotia

Nova Scotia has had a long history of fossil fuel dependency and therefore carbon intensity. For many years Nova Scotia also had an active coal mining industry. Today, Nova Scotia uses fossil fuels primarily for electricity generation, transportation, and home heating purposes.

Electricity is generated at power plants throughout the Province, using fossil fuels e.g. coal, oil, natural gas, and local renewable sources of energy e.g. wind, hydro, biomass, and tidal. Nova Scotia Power generates 59% of the province's electricity from coal, 21 per cent from natural gas, 18 per cent from renewables, and 2 per cent from other sources such as oil and imported energy. The vast majority of the coal and all of the oil used in electricity generation is now imported (Nova Scotia Power, 2014).

With the recent conversion of the only oil refinery in Nova Scotia to a marine terminal, all gasoline, heating oil, and other petroleum products consumed in Nova Scotia are sourced from New Brunswick, Newfoundland and Labrador, and international markets. The product is delivered by ship, rail, and truck.

Over the last 100 years, the majority of Nova Scotia homes and businesses have transitioned, for space heating purposes, from wood to coal to oil and more recently to natural gas, similar to other jurisdictions in North America and around the world. In many rural areas, wood is still a primary fuel source for domestic heating, and, in recent years, wood pellet stoves have been increasingly used to offset the high cost of energy. Electricity is also used for heating purposes and in very recent years, due to technology advances, the heat pump has become increasingly popular and cost effective.

Natural gas was introduced in the Maritimes when the Sable Island and Maritimes and NorthEast Pipeline became operational in 2000. According to the Canadian Association of Petroleum Producers (CAPP, 2014)[28] over $1.8 billion in royalties were collected by the Nova Scotia government from offshore gas production between 1996 and 2012. Initially, the majority of Sable's gas was delivered to the U.S. northeast and to large direct access industrial customers in Nova Scotia and New Brunswick, primarily for electricity generation. Local gas distribution companies (LDCs) were established in the early 2000's in New Brunswick (Enbridge Gas New Brunswick) and Nova Scotia (Heritage Gas Limited), as they built out their smaller diameter and lower-pressure systems to residential, commercial and industrial customers.

I.5.3 The Potential Role of Unconventional Gas in Nova Scotia

The majority of natural gas consumption in Nova Scotia is for the generation of electricity. The North American market for natural gas continues to experience strong growth for both the local distribution market and for electricity generation. Indeed, natural gas use in power generation is expected to grow by 60 per cent in the United States over the next quarter century, largely at the expense of electricity generation from coal (Jackson et al., 2014). In response to the increase in gas-fired power generation, U.S. carbon emissions from fossil-fuel combustion fell by 430 million tonnes of CO_2 between 2006 and 2011 (Wang et al., 2014). The growth in the natural gas distribution market is strongly related to the price advantage of natural gas over alternative fuels (primarily oil and electricity), along with inherent environmental benefits, including cleaner burning, elimination of oil fuel tank leaks, and greater convenience.

In Canada, gas imports to Ontario from the Marcellus unconventional gas play in the Northeastern United States are increasing, displacing more expensive Western Canada gas, which in turn had been replacing coal burned for electrical generation and gas used for local distribution purposes. It is expected that gas volumes sent via pipeline from Western Canada to Ontario will continue to decrease as the Marcellus gas continues to be available and less expensive. Portions of the existing TCPL mainline pipeline from Western Canada to Ontario are planned to be converted to carry oil and new oil pipelines added in Ontario, Quebec and New Brunswick to move Western Canadian oil to New Brunswick for shipments to export markets.

Meanwhile, the price of hydro-electric power exported by Manitoba and Quebec has decreased because of competition from power generated from unconventional gas. Thus, unconventional gas has had the effect of reducing electricity costs for many households, but less so in the Maritimes, where gas has limited market penetration, and current pipeline bottlenecks in the U.S. northeast keep prices higher than that experienced in other parts of North America. With capacity improvements to the pipeline system, or development of more gas resources in Nova Scotia, similar price reductions could occur if coal and fuel oil for electrical generation and heating were displaced.

The recent introduction of electric heat pump technology has become a competitor to natural gas in some applications. The gas distribution infrastructure continues to expand to new markets and communities across the Province. In addition, compressed natural gas "CNG" deliveries by truck now occur in both Nova Scotia and New Brunswick and provide access to areas not currently served by LDC pipelines. Natural gas provides significant environmental and financial benefits to the Province and customers who use the fuel.

Table I.5 Four scenarios of potential unconventional gas and oil development in Nova Scotia

	Scenario			
	Zero	Lower Medium	Upper Medium	Maximum
Basins developed	-	1	3	5
Total potential reserves in place	-	100 TCF	300 TCF	500 TCF
Recovery factor	-	10%	10%	10%
Recoverable reserves/well	-	2.5 BCF	2.5 BCF	2.5 BCF
Recoverable reserves	-	10 TCF	30 TCF	50 TCF
Number of development wells	-	4,000	12,000	20,000
Development phase (years)	-	40	50	60

The Maritimes market now takes up to 50 per cent of production from offshore Nova Scotia, or 200-300 mmcf/day. The declining indigenous natural gas supply in the Maritimes is currently projected to be insufficient to meet existing demand, absent incremental production from either existing offshore Nova Scotia or onshore New Brunswick and Nova Scotia. Declining domestic gas supplies will create the likelihood that new supplies will be sourced from unconventional gas resources in the U.S.

Should unconventional gas and oil development be pursued in Nova Scotia, it would provide one potential solution to the current projected supply shortfall. Alternative natural gas solutions would likely all be from energy obtained outside the Province and would carry additional costs for transportation. In Chapter 3, we describe four possible scenarios for unconventional gas and oil development should it ever be pursued in Nova Scotia. The range of potential trajectories is wide: from zero development to the highest estimate of potential resource development identified in Chapter 2. These are illustrated in Table I.5 below.

The two most plausible scenarios for the purposes of this review (assuming that reserves could be proven) are the lower and upper medium cases, where between 10 and 30 trillion cubic feet (TCF) may in theory be recovered over a period of 40-50 years. Thirty TCF is equivalent to 10 years of natural gas consumption for Canada at 2013 rates of consumption. Clearly, the availability of this size of resource in Nova Scotia could fundamentally alter the possibilities for electricity generation and home heating in the future.

I.6 | **Environmental, Health and Social Risks**

The most comprehensive assessment of the environmental, health and social risks of hydraulic fracturing for unconventional gas and oil development in Canada undertaken to date was published by the Council of Canadian Academies (CCA, 2014). The CCA issued the report in response to a question posed by Environment Canada: "What is the state of knowledge of potential environmental impacts from the exploration, extraction, and development of Canada's shale gas resources and what is the state of knowledge of associated mitigation options?"

The CCA is an independent, not-for-profit organization set up by the federal government to address questions of a complex scientific or technical nature through developing reports that can be used as a guide to public policy development in Canada. For this purpose, a group of independent experts and a chair are convened in a panel and asked to deliberate and provide their response to the assessment question on a pro bono basis. Staff members of the CCA support expert panels by managing the assessment process, including facilitating panel meetings, handling logistics, helping with research and writing, and managing the publication process. All CCA reports undergo a peer-review process prior to publication.

A 16-member multidisciplinary panel was formed to address the question outlined above, chaired by Dr. John A Cherry, a world-renowned hydro-geologist. The 262 page report was released following a 24-month period involving panel meetings and other research activities. The report provides a comprehensive examination of the environmental aspects of unconventional gas and oil development up to November 2013 and offers observations and conclusions. The panel's mandate excluded primary research, the making of recommendations, and discussing the safety aspects or economic costs and benefits of unconventional gas and oil development.

The report contains an executive summary followed by 10 chapters: (1) Introduction; (2) Shale Gas Development in the Canadian Context: What is Shale Gas; (3) Shale Gas Technology and Well Integrity; (4) Water; (5) Greenhouse Gases and Other Air Emissions; (6) Land and Seismic Impacts; (7) Human Health; (8) Monitoring and Research; (9) Management and Mitigation; and (10) Conclusions.

Chapters 3 to 7 conclude that the scientific basis for assessing the environmental impacts of unconventional gas and oil development is deficient in terms of baseline data, monitoring, analysis, appropriate feedback loops, and research. Gaps in knowledge and scientific understanding, were noted, where applicable in each of the chapters. Chapters 8 and 9 outline what an effective monitoring, research, and risk management framework might look like.

Of interest is that the report does not describe the risk associated with the process of deep hydraulic fracturing itself as being of greatest concern, but does identify environmental risks in surface activities e.g. transportation, chemical spills, noise and traffic, and in wellbore integrity. The report cites a number of environmental issues, and two in particular were the focus of heightened attention: potential shallow water impacts associated with surface activity and wellbore integrity, and greenhouse gas (GHG) emissions related mainly to well integrity and operational practices (fugitive emissions). While no cases of water contamination from unconventional gas and oil development have been identified in Canada to-date, the report cites, "Claims there are no proven adverse effects on groundwater from shale gas development lack credibility for the obvious reason that absence of evidence is not evidence of absence."

Since the CCA Report was issued, all sides of the unconventional gas and oil development debate have taken excerpts to support their perspectives. But the conclusions of the CCA Report do not lend themselves easily to simple advocacy positions, still less to detailed policy prescriptions. They do not support suspension of the activity; but neither do they give hydraulic fracturing unequivocal support. The CCA conclusions are very nuanced, but they are clearly precautionary. One way of summarizing the sentiment of the report would be to say the potential scale of unconventional gas and oil development in Canada is unprecedented, that we need to proceed slowly, take measurements, understand the science, be guided both by facts and by public acceptability.

As the report notes, "Public acceptance of large-scale shale gas development will not be gained through industry claims of technological prowess or through government assurances that environmental effects are acceptable. It will be gained by transparent and credible monitoring of the environmental impacts." The CCA also notes that the, "rights of Aboriginal peoples may be affected in several provinces and need to be protected." The last words in the executive summary of the report say, "Because shale gas development is at an early stage in Canada, there is still an opportunity to implement management measures, including environmental surveillance, that will reduce or avoid some of the potential negative environmental impacts and permit adaptive approaches to management."

The CCA report was signed by 14 of the 16 original panel members who represented a broad range of disciplinary backgrounds and perspectives. The CCA Report is not prescriptive; it identifies gaps in knowledge, and says that these gaps should be addressed as the practice of unconventional gas and oil development moves forward in Canada.

In a presentation at the University of Toronto on May 29, 2104,[29] Dr. John Cherry, Chair of the CCA Panel, provided an in-depth overview of the Report and made a very interesting observation from a risk management and governance perspective. Cherry noted that every industrial society has risks and advocated the gathering of information, monitoring, and establishing of feedback loops with research as industry and development moves forward. The statement represents the "go-slow" approach that characterizes the essence of the report.

Our review benefited significantly from the publication of the CCA Report. In addition, one individual (Dr. Maurice Dusseault) served on both panels and was able to reflect insights from the CCA process in our Nova Scotia deliberations. The Nova Scotia Review looked at the risks and benefits of oil and gas development using hydraulic fracturing techniques and we quote liberally from the CCA report in our own report. Our review explored similar areas to those covered in Chapters 3-9 of the CCA Report. Our review did not review the physical environment to the same extent as the CCA Report, although the risks and impacts are expected to be similar to those identified by CCA. Our review did however look at one area that the CCA did not: potential regional and provincial economic benefits and costs; and we explored two areas to a much deeper extent: Aboriginal Treaty and Statutory Rights and public participation in risk assessment (based on the 238 formal submissions received through the NS process). See Chapters 10 and 8 respectively.

Neither the CCA process nor the NS Hydraulic Fracturing Review carried out primary research. Our review provides Province-specific recommendations should the Government of Nova Scotia decide to proceed further in considering the prospects for development using hydraulic fracturing techniques; the CCA did not provide any such specific recommendations.

I.7 | **Reflections on Public Feedback and Future Discussions**

The best sense that we have of general public opinion on the question of hydraulic fracturing for unconventional gas and oil in Nova Scotia is the February, 2013 polling data from Corporate Research Associates (CRA) which concluded, "Nova Scotia residents were asked whether they support or oppose this practice if they believed that government regulations were stringent enough to protect the environment. Results indicate just over one half (53 per cent) of Nova Scotia residents oppose this practice. Meanwhile, four in 10 (39 per cent) residents support this practice, while eight per cent do not offer a response or are unsure" (CRA, 2013). This survey was released in April, 2013 based on a telephone sample of 400 adult Nova Scotians, as part of CRA's quarterly survey of Atlantic Canadians (overall results accurate to within ± 4.9 percentage points, 95 out of 100 times).

As we noted above, CRA also conducted research in August, 2013 for the Commission on Building Our New Economy and found that only 42 per cent supported the development of unconventional gas and oil even if "strict environmental regulations are enforced." A poll in New Brunswick in 2012 yielded similar data. What this information tells us is that Nova Scotians are divided on the question of hydraulic fracturing for the development of unconventional gas and oil, but with a majority against.

Militating against the case for learning and dialogue and consensus building are the kind of stark differences in experience, language, and world views between proponents and opponents of hydraulic fracturing and its associated activities and technologies that we normally associate with extractive industry operations in frontier regions of the world (Wheeler et al., 2002). A continuing global decline in public trust in institutions, reflected in Nova Scotia in the ONE NS Report also negatively impacts the quality of public discourse. These observations reinforce the case for independent, transparent, and stakeholder-inclusive processes like this review if public policy is to move forward in areas of significant contention.

The specific question of lack of trust in Nova Scotia regulation was raised by stakeholders throughout our process and has also become a point of noted concern from a public policy perspective. We discuss these points in detail in Chapters 8 and 11. Consequently the recommendations we make in Chapter 11 are intended simply as a starting point for deeper dialogue and learning in the province of Nova Scotia.

Requests for presentations on the contents of this report should be addressed to Dr. David Wheeler at Cape Breton University.

I.8 | **Report Structure**

Chapter 1 describes key aspects of the process of hydraulic fracturing and its associated activities and technologies. It focuses primarily on the technical aspects of fracturing. It does not address the oil and gas resource potential in Nova Scotia nor the associated economic, social, community, health, environmental, or regulatory issues – including Aboriginal treaty questions.

Chapter 2 builds on our understanding of the process of hydraulic fracturing described in Chapter 1 and looks at the resource and infrastructure potential for onshore oil and gas extraction in Nova Scotia, including the use of hydraulic fracturing techniques. The chapter also lays the ground for a range of plausible scenarios that illustrate the potential economic impacts and royalty streams associated with potential future development of unconventional gas and oil in the Province. We note that as knowledge of the subsurface, including sedimentary rocks and hydrocarbons in Nova Scotia is extremely limited, it is very difficult to quantify the potential or even rank the various basins in terms of overall "prospectivity." However, the shales in basins closest to New Brunswick will likely be of most interest to developers to date because New Brunswick basins have demonstrated commercial production of both gas and oil, and pipeline infrastructure is in place.

Chapter 3 builds on our analysis of potential unconventional gas and oil resources and describes four "plausible scenarios" of development, should the province of Nova Scotia ever decide to proceed with developing these resources. The four scenarios range from zero development, i.e. no commercial development in any basin, through to maximum development, i.e. five basins successfully developed for gas, and one for oil. We then consider the nature of petroleum operations associated with unconventional gas and oil development: exploring for and producing hydrocarbons, with a focus on economic costs and benefits. We describe each phase of activity – exploration, field development, production and abandonment – and we set out the costs and benefits of such activities for regional economies including opportunities for involvement by the local workforce and contractors. We use an illustrative 50 well "minimum development" and we extrapolate that minimum development to impacts that would apply in a full development (our lower medium case scenario) to give a sense of the economic impact over a 40-year period. Finally we use our lower medium case scenario to estimate possible royalties to the Province that might accrue over that timeframe if development were to occur at that scale.

Chapter 4 summarizes the current state of knowledge about potential benefits and harms to human health associated with hydraulic fracturing and its associated activities and technologies. Development of unconventional gas and oil resources in Nova Scotia has implications for the health of individuals and communities. Economic growth, improved energy security, and a shift away from coal-based energy generation may indirectly improve population health. But exposures to industrial materials and processes constitute risks to health which would need to be carefully assessed, monitored, managed, and mitigated before a decision to pursue hydraulic fracturing was ever to be made in Nova Scotia. We describe the main risks to physical human health as arising from potential exposures to toxic materials through contamination of drinking water sources and atmospheric exposure. Although the physical risks of unconventional gas and oil development have much in common with those of conventional developments, these relatively new technologies bring a number of potential health challenges through issues such as the proximity to human habitation, the potential for large numbers of wells to have a cumulative impact, and the nature of chemicals deployed.

In Chapter 5 we build on the analysis of Chapter 4 and, similar to questions of public health protection, we note that community impacts of energy development may be both positive and negative. We describe those impacts in four key areas: the local economy, social and physical infrastructure, the natural environment, and social relations within communities. We also note that the "energy boomtown" literature of the 1970s and 1980s focused on the negative impacts of the boom-bust-recovery cycle, but that subsequent research has shown positive impacts in most impact categories. We summarize potential community effects of unconventional gas and oil development through hydraulic fracturing, and offer insights into appropriate monitoring and evaluation approaches that can help establish adaptive management and improved control of outcomes within communities.

In Chapter 6 we address one of the central concerns of stakeholders – the potential impacts on water quality and water resource use through hydraulic fracturing and associated techniques. We review key policy instruments designed to protect water quality and water resources in Nova Scotia and describe the potential impacts unconventional gas and oil resource development may have on those resources. In particular the chapter addresses i) the current status of water in Nova Scotia; ii) specific water related concerns raised by unconventional gas and oil development; iii) water regulations for hydraulic fracturing in other jurisdictions; iv) current water regulations in Nova Scotia; and v) water resource management issues raised by hydraulic fracturing in a Nova Scotia context.

Chapter 7 describes how unconventional gas and oil development using modern cementing and completion techniques usually leads to good wellbore integrity, but we note that as in any industrial activity, there will never be 100 per cent success in sealing all wellbores against all possibilities of future leakage. Technological advances have helped reduce the incidence of leaking wells and provide better quality control and leak detection capabilities. The most common long-term well integrity issue after abandonment is slow gas seepage around the external casing. We note that the consequences of such leaks, though negative from a climate change perspective, are not a major public health threat because natural gas is not a toxic substance, the number of wells that display high-rate leaks is low, and the overall average leakage rates appear to be low. When leakage is identified, corrective measures can rectify problems. Though rigorous statistics remain elusive (and therefore this issue requires more quantitative study), there is, as yet, no evidence that the number of significant problems encountered in the relatively mature regulatory environments of Alberta and British Columbia, is large. We conclude that the establishment of an appropriate monitoring and regulatory system for well integrity will be needed if large-scale unconventional gas and oil resource development ever takes place in Nova Scotia.

In Chapter 8 we describe a participatory risk assessment approach to understanding environmental and other impacts associated with hydraulic fracturing in Nova Scotia. Analyzing 238 unique public submissions to our review, we note that a significant majority of those submitting evidence opposed hydraulic fracturing and wanted to see a continued moratorium or ban in the Province. The main perceived risks by those submitting comments on hydraulic fracturing in order of significance were related to: water, community and infrastructure, economy, waste and clean-up, human health, climate change and other environmental issues like increased potential for earthquakes and habitat fragmentation. These citizens' and organizations' perspectives were compared to and cross-referenced to available scientific literature suggesting that hydraulic fracturing poses credible threats to human and environmental systems.

Chapter 9 identifies some of the factors which make it more or less likely that a regulatory regime on hydraulic fracturing in Nova Scotia will serve its purpose. The chapter describes the roles of different levels of government in the decision-making process around hydraulic fracturing activities, and provides an overview of some of the approaches to regulating hydraulic fracturing in various provinces, including Nova Scotia. We then explore the relationship between regulations and risk-management, and in particular we identify how the efficacy of regulations for protecting health and the environment turns on: i) the adequacy of the knowledge base; ii) political will and responsiveness of the regulations to the knowledge base; and iii) whether and how regulations are implemented, resourced, and enforced. The chapter provides examples of these elements in action, drawn from hydraulic fracturing experiences in Canada and the United States.

In Chapter 10 we describe how the Mi'kmaq people possess robust Treaty rights as well as Aboriginal rights in Nova Scotia. These rights have considerable consequences for provincial deliberations over hydraulic fracturing, as the Province is constitutionally obliged to honour these rights. As a result, the Province would need to engage in a consultation process so that it can understand how treaty rights and Aboriginal rights could be affected by activities associated with hydraulic fracturing, and make decisions in a way that respects those rights. In some circumstances, the Province may infringe upon the Mi'kmaq's Aboriginal rights, but only if a strict justification test is met. If the Mi'kmaq people possess Aboriginal title rights over portions of Nova Scotia where there is subsurface unconventional gas, they have the right to decide whether that gas will be exploited and to receive the economic benefits. Similarly, if there is unconventional gas and oil located below reserve land, hydraulic fracturing can likely only take place on reserves with the full consent of the relevant First Nation.

ENDNOTES

1. All project documents, including provincial contracts are available on the project website at http://www cbu.ca/hfstudy/resources/project-documents. Accessed August 11, 2014.
2. See Renewable Electricity Regulations 2010 as amended 2014: http://www.novascotia.ca/just/regulations regs/elecrenew.htm. Accessed 11th August 2014.
3. See http://thehill.com/policy/energy-environment/196790-natural-gas-big-winner-in-speech-to-green groups-dismay#ixzz386hiOOpY. Accessed 12th August 2014.
4. These world views differ in seeing technological progress, human relations and nature as most important frames of reference in solving the world's challenges.
5. See Appendix A
6. We also received 507 very similar letters as a result of a campaign initiated by the Council of Canadians.
7. United Nations (1992). Final declaration of the UN Conference in Environment and Development. Available from: http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm. Accessed 12th August 2014.
8. Verschuren Centre for Sustainability in Energy and the Environment (2014). Written submissions to the Hydraulic Fracturing Review. Available via http://www.cbu.ca/hfstudy/resources/correspondence. Accessed 12th July 2014.
9. See www.openmine.ca/hfs-resources
10. http://www.cbu.ca/hfstudy/resources/news-articles
11. http://www.cbu.ca/hfstudy/resources/websites
12. http://www.cbu.ca/hfstudy/resources/other
13. Unique submissions were calculated by discussion paper. Multiple submissions of feedback from one stakeholder were counted as one submission for that discussion paper.
14. http://www.cbc.ca/ns/news/interactives/2011census/
15. a county boundaries contiguous with municipal unit Cape Breton Regional Municipality.
b county boundaries contiguous with municipal unit Halifax Regional Municipality.
c county boundaries contiguous with municipal unit Region of Queens Municipality.
16. http://www.novascotia.ca/snsmr/land/images/CMC_197.gif
17. http://www.globalforestwatch.ca/files/images/20090625A_fig23_ns_change_by_watershed_GFWC.png
18. http://www.novascotia.ca/finance/statistics/stats/default.asp
19. http://www.novascotia.ca/agri/elibrary/nsalrc/AppendixF-AgriculturalProfiles-NS.pdf
20. The ONE Report is sometimes referred to as the Ivany Report, the Commission having been chaired by Acadia University President Ray Ivany. We refer to it in this Report as the ONE NS Report.
21. Commission on Building Our New Economy (2014). Now or Never: An Urgent Call to Action for Nova Scotians, p. 46
22. Environmental Goals and Sustainable Prosperity Act, SNS 2007, Section 3 (2) (a)
23. Ibid., Section 3 (2) (e)
24. Commission on Building Our New Economy (2014). Now or Never: An Urgent Call to Action for Nova Scotians, pages 218 – 233.

25. For a more extensive analysis of the CRA new economy study, see Commission on Building Our New Economy (2014). Now or Never: An Urgent Call to Action for Nova Scotians, pages 224 - 225. Available from: http://onens.ca/wp-content/uploads/Now_or_never_short.pdf. Accessed 20th August 2014.
26. This contradiction demarcates the fields of 'ecological' versus 'environmental' economics; typically he first attempts to reflect intangible values while the second attempts to relate impacts to pricing in monetary terms. Both fields are relevant to public policy making to protect the environment.
27. Experience in the U.S with the Comprehensive Environmental Response, Compensation, and Liability Act (1980), or 'superfund' illustrates the serious inefficiencies of relying on insurance to cover unknown future liabilities. The inability of the nuclear industry in many jurisdictions to fully insure against its long term liabilities is another example of the limitations of this approach.
28. See http://www.capp.ca/getdoc.aspx?DocId=241178&DT=NTV. Accessed 12th August 2014.
29. This speech is available on the web site of the Munk School of Global Affairs, and may be accessed at: http://hosting.epresence.tv/MUNK/1/Watch/543.aspx
30. Available from: http://cra.ca/slight-majority-of-nova-scotians-opposed-to-hydrofracking-in-the-province/. Accessed July 19, 2014.
31. See: http://www.amiando.com/eventResources/K/v/W2ojaVE1OigLPm/FORUMe_-_Research_Results English.pdf. Accessed July 19, 2014.
32. See also: http://www.edelman.com/trust-downloads/press-release/. Accessed 19th July 2014.
33. See: http://thechronicleherald.ca/editorials/1228689-editorial-lazy-regulation-spells-stagnation. Accessed August 12, 2014.
34. See Glossary.

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CHAPTER

1

The Process of Hydraulic Fracturing: An Overview[1]

Fred Baechler

1.0 | **Chapter Summary**

This chapter describes key aspects of the process of hydraulic fracturing. It focuses primarily on the technical aspects of fracturing. It does not address the oil and gas resource potential in Nova Scotia or the associated economic, social, community, health, water, environmental, regulatory issues, or questions of Aboriginal and treaty rights. These are the subjects of later chapters in the report.

1.1 | **Introduction**

This chapter is intended solely as a description of the technical aspects of hydraulic fracturing, sometimes referred to as "fracking" or "fracing." As noted by the Council of Canadian Academies (CCA, 2014), the industry is continually improving its methods. This chapter represents an overview as of summer 2014. Thirty-seven comments were received from stakeholders following the original publication of this chapter as a "primer" on hydraulic fracturing. These comments, like all other submissions and comments, are publically available on the review website, and we would like to acknowledge the time and care taken by stakeholders in providing the feedback.

We were able to address a number of the comments we received, although it was not possible to accommodate all of them directly, as they addressed issues outside the scope of this chapter. In many cases, requests for more detail, e.g. on specific impacts of hydraulic fracturing, are now described in significant detail later in this report.

1.2 | **What is Hydraulic Fracturing?**

Hydraulic fracturing is designed to open existing natural fractures and create new fractures within a rock formation, typically by pumping large quantities of fluids (water and other components) down a well at high pressure. In doing so, it is intended to generate an interconnected, open network of fractures within the rock formation that stimulates the return flow of gas and/or fluid to the drilled well(s) or "wellbore(s)," thereby increasing the volumes of oil or gas that can be recovered. Fractures are generally already present in these underground rock formations (similar to hairline cracks seen in concrete sidewalks). Hydraulic fracturing through the wellbore creates pathways to these existing fractures while also creating additional fractures to increase oil and gas recovery.

Hydraulic fracturing methods have been addressed by a number of different countries as they develop approaches to this new technology, including Canada (NEB, 2009; CCA, 2014), the United Kingdom (The Royal Society, 2012), United Nations (Perduzzi & Harding, 2012), the United States (USEPA, 2013), and Australia (Cook et al, 2013).

1.2.1 What Industries use this Technology?

Hydraulic fracturing has a number of applications:

1) The oil and gas industry uses it to recover oil and gas resources from subsurface reservoirs. These reservoirs may be deep underground or, in the case of coal bed methane, relatively shallow (Adams and Rowe, 2013).
2) The process is also applied occasionally in water well development, for example, to enhance well productivity to obtain groundwater for domestic, municipal, and industrial purposes (Adams and Rowe, 2013).
3) Sequestration of CO2 by capturing this greenhouse gas, liquefying it, and pumping it down boreholes into deep geological formations does not require initial fracturing of the formation. It does, however, require pumping the fluid out into existing fractures under pressure within the rock (Adams and Rowe, 2013).
4) Development of deep, geothermal energy in low permeable rocks, requires hydraulic fracturing of the rock mass to allow the more rapid extraction of the heat energy (Adams and Rowe, 2013).

Therefore, any discussion of the application and implications of hydraulic fracturing necessitates defining which industry and use is being referred to.

1.2.2 Which Industrial Use are we Dealing with in this Review?

Our review relates to the use of hydraulic fracturing by the oil and gas industry. Specifically, it refers to that part of the industry that focuses primarily on extraction of natural gas (or oil) from "unconventional" or poor quality (low permeability) reservoir rocks. This is also referred to as unconventional gas and oil production. While the potential for unconventional gas and oil production may exist in offshore Nova Scotia, our review is focused on land-based or "onshore" extraction.

1.3 | What are "Shale Gas" and "Shale Oil"?

Natural gas is a general term for the mixture of methane gas (typically 85 per cent of the total) and other hydrocarbons such as ethane; propane; butane; pentane; as well as carbon dioxide; and trace amounts of nitrogen, helium, and hydrogen sulphide (Speight, 2013). Oil and natural gas resources are commonly divided into two categories: conventional (i.e. formations with high permeability that are relatively inexpensive and easy to develop via traditional extraction methods) and unconventional. The term "unconventional" is used since these oil and natural gas resources are found in reservoirs with low permeability and, therefore, cannot be extracted using traditional methods (Mokhatab et al., 2006; Speight, 2007; Speight, 2014). Unconventional gas and oil are broad descriptors used for the more popular terms "shale gas" or "shale oil" (CCA, 2014).

Shale is a sedimentary rock composed primarily of silt, clay, and organic matter (algae, plant and animal derived) deposited over millions of years in deep water basins (Davis, 1992; Arthur et al., 2008). Shale gas is generated from organic matter that cracks at deeper depths under high pressure and temperature (thermogenic gas) or by the anaerobic decomposition of organic matter at more shallow depths (biogenic gas) (Hoefs, 2009; Jackson et al., 2013). Like conventional gas, most shale gas produced is thermogenic in nature (CCA, 2014). Shale rock formations are tightly cemented with low permeability making it difficult for fluids like oil and gas to migrate towards the reservoir surface. The pore size in a shale formation can be up to 1,000 times smaller than the pores in a conventional gas reservoir (CCA 2014). Therefore, shale gas was not historically considered a resource that could be extracted economically. As a result, unconventional extraction methods such as hydraulic fracturing have been developed (Speight, 2013). Further discussion of potential resource development is provided in Chapter 2 as it relates to Nova Scotia.

Unconventional reservoirs currently being pursued in Canada and the United States are typically found in rocks of Devonian to Mississippian age (300 to 400 million years old), although some are as young as Cretaceous (about 100 million years) (Cardott, 2008; Speight, 2013). As shale is not homogeneous, its unique character causes each basin to be different with great variations in mineral composition and geochemical behaviour. Therefore, extraction methods must be continuously adapted in order to develop such a broad range of shale gas resources (Speight, 2013). The relevant geologies and potential resource profiles in different oil and gas bearing basins in Nova Scotia are described in Chapter 2.

1.4 | **Is the Exploitation of Unconventional Reservoirs Something New?**

Hydraulic fracturing and horizontal wells are not new tools for the oil and gas industry (NEB, 2009; Rivard et al., 2013; CCA, 2014). The origins of hydraulic fracturing can be linked back to the 1860's when nitro-glycerine was used in various U.S. states to break up oil-bearing formations and increase initial flow and recovery rates (Montgomery and Smith, 2010). This was followed by similar experiments using acid that etched fractures into the formation, enhancing overall oil production. In 1947, the "hydrafrac" process was established by Stanolind Oil, who used a combination of napalm and gasoline to ease the production from a limestone formation. The hydrafrac process was patented in 1949, and soon after, there were over 300 wells treated with an average production increase of 75 per cent (Montgomery and Smith, 2010). In Canada, hydraulic fracturing was used in the development of the Pembina oil and gas field in Alberta as early as 1953 and has been used in Western Canada ever since (Montgomery and Smith, 2010; Nielsen, 2012).

The increased popularity of large-scale shale production was a direct result of the combination of horizontal drilling and multi-stage, hydraulic fracturing, pioneered in the late 1990's in the Texas Barnett Shale (CCA, 2014). Multi-stage, hydraulic fracturing involves the drilling of a vertical well to an optimal depth, at which the direction is gradually changed to horizontal, allowing several horizontal wells to be drilled from a single vertical surface location (Speight, 2013). A fluid is then injected into the well bore at an appropriate rate and pressure which allows existing fractures to open and creates additional fractures extending from the well bore out into the formation. These fractures are typically propped open with a proppant (commonly sand), which allows fluids such as oil and gas to flow more freely out of the well bore to the surface (Sydansk, 1998).

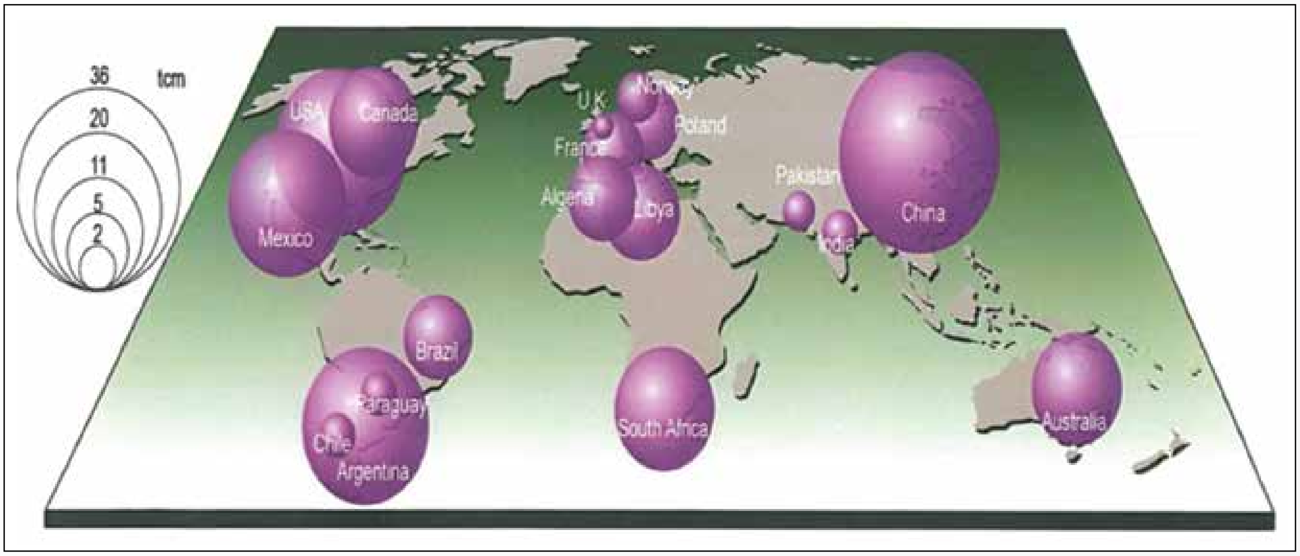
To achieve commercialization and improve the effectiveness of hydraulic fracturing, special formulations of fracturing fluids and micro-seismic monitoring (to gauge the extent of fracturing) were developed alongside more rapid drilling methods (CCA, 2014). In addition to unconventional gas and oil, the multi-stage hydraulic fracturing technology has also been applied to a wider spectrum of unconventional resources such as "shale oil," "tight oil," and "tight gas." As a result, vast unconventional reservoirs became exploitable, and oil and gas activity moved into new large land areas. Massive exploitation by the new methods first took place in the Texas Barnett Shale and, more recently, in the Marcellus Shale underlying Ohio, Pennsylvania, and southern New York. Numerous unconventional reservoirs throughout the continental U.S. and western Canada are now under development (CCA, 2014). Of the over 150,000 horizontal wells completed in recent years across North America, only one quarter are for shale gas exploration (CCA, 2014). To date, it has been estimated that over 2.5 million "fracs" have been carried out worldwide, with over one million in the United States alone (CCA, 2014).

Between 2007 and 2013, approximately 35,000 horizontal wells were drilled in Canada, almost all stimulated with hydraulic fracturing (CCA, 2014). In Nova Scotia, 11 wells (not necessarily horizontal) have been hydraulically fractured, eight for coal bed methane production evaluation and three for assessing shale gas potential (Drage, NSE, e-mail communication 23 May 2014).

1.5 | **Why is the Exploitation of Unconventional Reservoirs Increasing?**

Fossil fuels are the world's main source of energy, accounting for over 80 per cent of global primary energy use in 2010 (IEA, 2011; Perduzzi & Harding, 2012). As conventional reserves are depleted and the demand for energy rises, there is increasing pressure to exploit unconventional energy sources for both economic and energy security reasons. Factors such as depletion of oil reserves, population growth, increases in individual demand, and additional demand from emerging economies have caused the global demand for gas to increase by up to 50 per cent by 2035 compared to 2010 figures (IEA, 2012). The world production of gas from unconventional reservoirs was approximately 472 billion cubic metres as of 2010, 89 per cent of which was produced in North America (76 per cent and 13 per cent for United States and Canada, respectively) (Perduzzi & Harding, 2012). The technically recoverable unconventional gas resources, in trillions of cubic metres (tcm), for the top 18 countries globally in 2012 is provided in Figure 1.1

Figure 1.1 Technically recoverable shale gas resources in trillion cubic metres (tcm) in the top eighteen countries around the world



Cartography reproduced with permission of UNEP/GRID-Geneva (Royal Society Data, 2012)

1.6 | How are Wells Drilled to Access Unconventional Gas Reservoirs?

1.6.1 How is the Site Prepared for the Well Drilling Stage?

A well pad must be constructed prior to the drilling of a production well, similar to a conventional oil and gas program. In particular, the well pads used in unconventional gas and oil production are typically larger in order to accommodate multiple wells (multi-well pads), in addition to the large amount of equipment, chemicals, and sand (EIA, 2011). For example, a well pad in a conventional oil and gas development may be 0.5 to 1 hectares, while those for unconventional gas and oil development can be between 2 to 3 hectares (CCA, 2014).

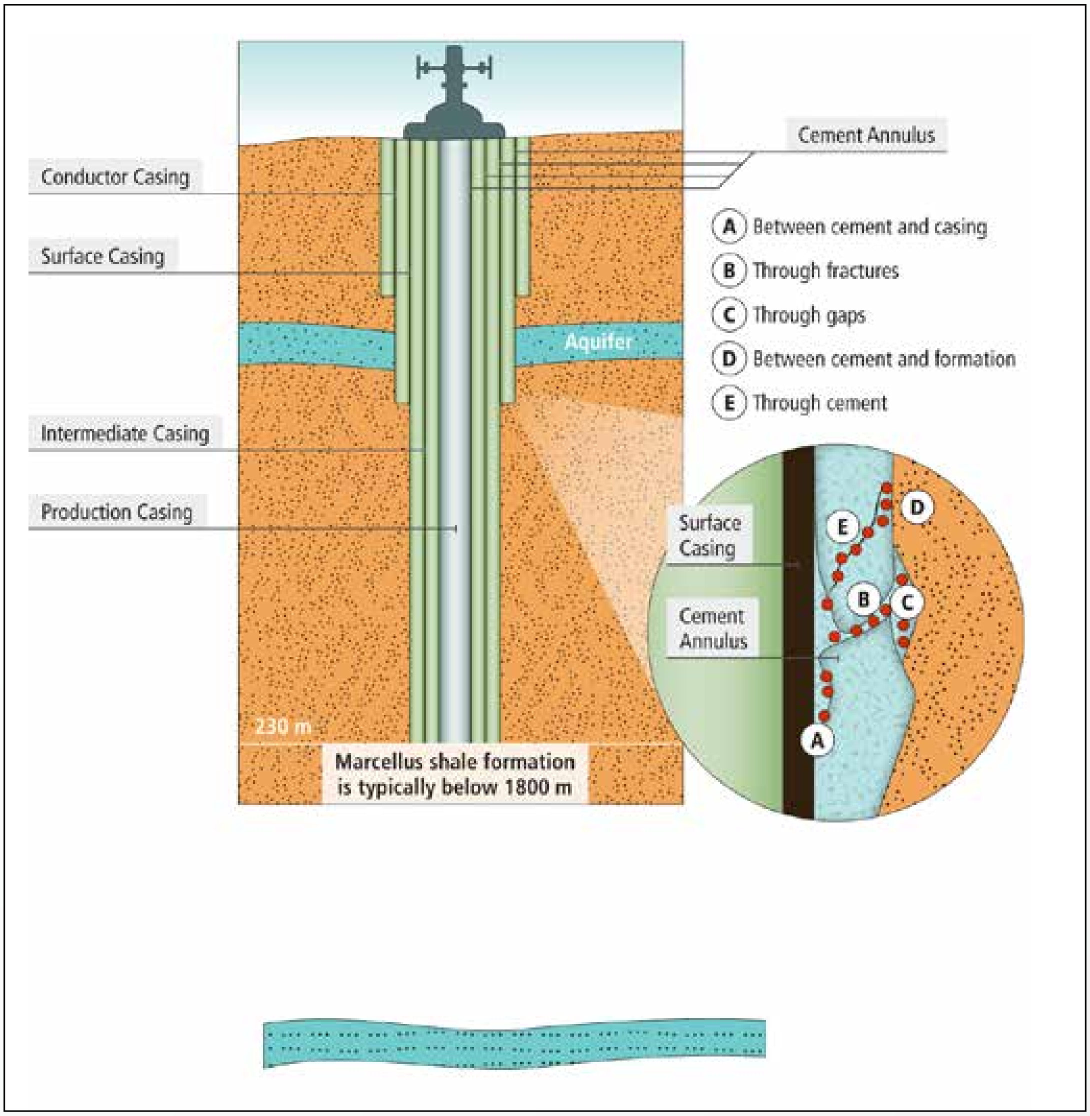
Due to the low permeability of shale, natural gas will not flow naturally from vertical wells. Therefore, horizontal wells can be drilled to expose the wellbore to as much of the reservoir as possible (EIA, 1993; Speight, 2013).

1.6.2 How is Drilling Accomplished?

Many unconventional gas reservoirs are relatively thin (i.e. 15 to 60 metres thick) and require horizontal drilling to access as much of the reservoir as possible (Speight, 2013). This is accomplished by drilling vertically to an optimal depth where the drill bit is gradually curved until it reaches 90 degrees allowing the wellbore to become horizontal (Speight, 2013; CCA, 2014). Therefore, horizontal drilling allows a larger area to be covered compared to vertical drilling in the same formation resulting in the ability to increase production rates.

In unconventional gas and oil, drilling it is common to use a single well pad to develop a large reservoir area resulting in the drilling of multiple wells from one surface location, often referred to as "pad drilling," "multi-well pad drilling," or a "resource play hub." Typically 6-8 horizontal wells can come from one pad (Speight, 2013). In addition to increased production rates, multi-well pads may reduce the negative impact on the environment by reducing land use and surface disturbances, impacts to wildlife, noise, dust, and traffic (Spellman, 2012; Speight, 2013; CCA, 2014). It has been estimated that a pad with four horizontal wells would have approximately one tenth of the land disturbance compared to sixteen vertical wells to produce the same volume of shale gas (Spellman, 2012). Figure 1.2 below depicts a typical well construction.

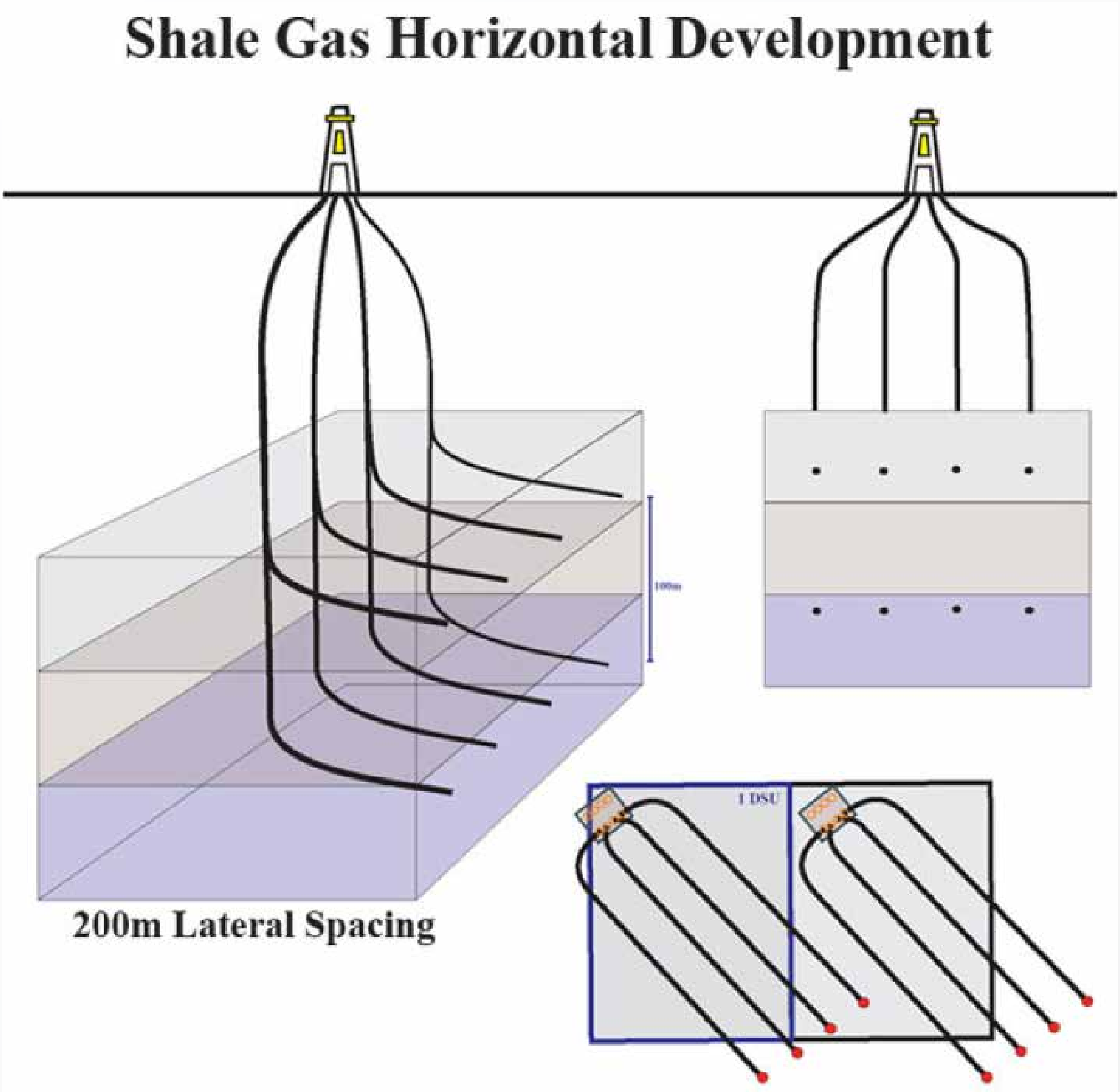
Figure 1.2 Typical Marcellus Well Construction



Courtesy of and adapted by the Council of Canadian Academies. Reproduced with permission of AAAS (Data Source: Vidic et al, 2013)

In addition to pad drilling, stacked horizontal wells, known as "stacked drilling" is also possible in areas where the shale is thick. One vertical well can be used to drill stacked horizontal wells at different depths (Speight, 2013). Moreover, multiple stacked wells can be drilled on a single well pad. Figure 1.3 portrays a schematic of multiple stacked horizontal wells originating from their respective single vertical wells.

Figure 1.3 Multiple stacked wells originating from their respective single vertical wells



Reproduced with permission: NEB, 2009

Like stacked drilling, multilateral drilling is another variation of horizontal well exploration where two or more horizontal wells originate from the same vertical well bore. While the drilling depth remains constant, the drilling direction is multilateral (i.e. in different directions) (Speight, 2013).

After the rock has been drilled, a steel casing is installed in "strings" that are usually cemented in place in order to ensure well integrity (CCA, 2014). The length of each drill string is site dependent and is associated with the depth of unconsolidated material, depth of fresh groundwater sources, depth of non-freshwater zones that may cause instability, and depth to the production zone. Regulators typically advise industry on the surface casing size and depth required to ensure isolation of the groundwater resources to avoid contamination during or after the drilling process (Hayes & MacLeod, pers. comm., 2014). Further detailed discussion of groundwater protection and the importance of well integrity is provided in Chapters 6 and 7.

1.7 | How is Hydraulic Fracturing Accomplished?

After the casing has been cemented in place, it is perforated to allow communication between the rock and the well to be established (Leonard et al., 2007; Britt and Smith, 2009; LeCompte et al., 2009). This causes the well pressure to decrease, creating a pressure differential between the rock and the well, causing the hydrocarbons to flow from the rock formation to the well surface. However, the low permeability of shale causes the flow of gas to be very slow (NEB, 2009; Speight, 2013; CCA, 2014). Hydraulic fracturing is a necessary and effective method to increase the flow of the gas into the well.

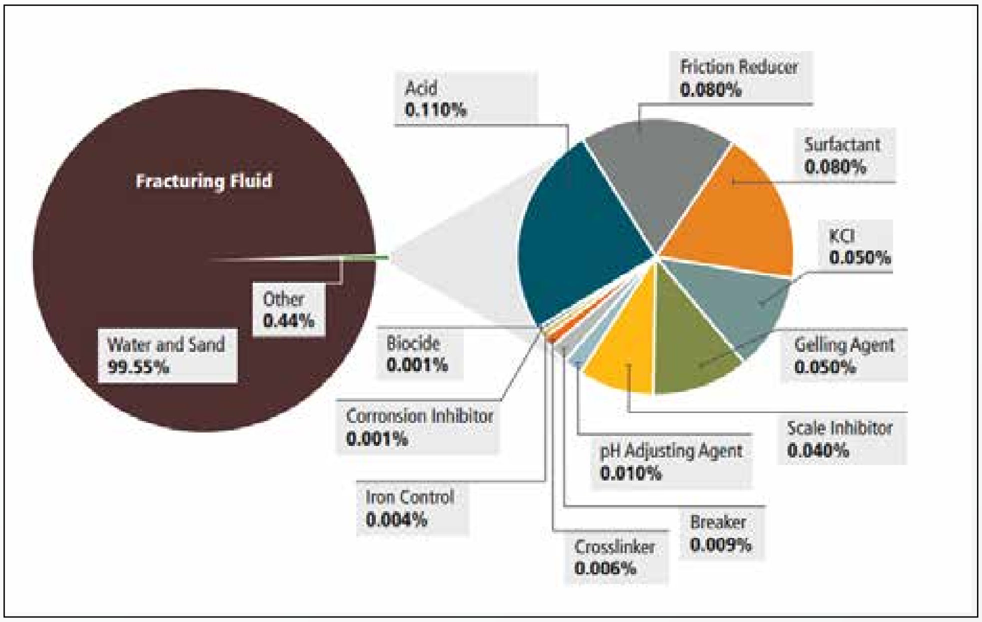
Fractures are created by pumping large quantities of fluids at high pressure down the well and into the target rock formation. The injection of fluid generates pressure in the rock pores that exceed the minimum reservoir stress field (CCA, 2014). The fractures may extend a 100 metres vertically into the rock and perhaps several hundred metres laterally, depending on the volume of the treatment (CCA, 2014). The newly created fractures are propped open and supported by a fracturing fluid mixed with varying sizes of "proppants" such as sand that are pumped down the hole (CCA, 2014; NEB, 2009). Proppants are described in the next section.

The extent of fracturing in the formation is typically monitored by micro-seismic surveys that are interpreted to show how fractures have propagated (NEB, 2009). This technology is typically used to assist operators in the optimization of future frac programs by ensuring that the fractures remain within the target formation and that they are effectively stimulated. The micro-seismic surveys are generally used on the initial wells in a new area to monitor seismic activity to minimize the chances if creating noticeable seismic events (CCA, 2014).

1.7.1 What is the Fracturing Fluid Composed Of?

Hydraulic fracturing fluids commonly consist of water (98-99.5 per cent), "proppants" and chemical additives that vary depending on the operator and the reservoir, and are often proprietary (King, 2012; Speight, 2013; CCA, 2014). Common chemical additives are acids to clean the shale, biocides to prevent organisms from growing in the fractures, corrosion and scale inhibitors, gels that increase viscosity to keep the proppant suspended, and friction reducers (Speight, 2013; CCA, 2014). Figure 1.4 provides a summary of fracturing fluid composition.

Figure 1.4 Fracture Fluid Composition



Courtesy of and adapted by the CCA 2014. Reproduced with permission from Arthur et al. (2008)

The proppants – sand, ceramic pellets, or other small incompressible particles – hold the newly created fracture open. The fracture widths are generally equal to a few diameters of the grains used in the fracturing fluid (typically less than 1 mm). Generally, proppants are comprised of high purity, well rounded quartz sand that has been sieved and provided in large quantities in a narrow range of grain sizes (CCA, 2014). Other material used can include commercially produced sintered aluminum oxide beads, hollow glass beads, and special fibres (CCA, 2014).

The selection of fluids used are constantly evolving between companies and conditions encountered (CCA, 2014). More recently, propane, nitrogen, and/or CO2, have been applied for fracturing purposes in hydraulic fracturing processes. The most commonly used chemicals are water based and are added at selected stages of the fracturing operation. During multi-stage fracturing, a series of fracturing fluids with varying volumes and compositions are injected allowing each stage to address local conditions, such as the presence of natural faults and proximity to other wells (Rivard et al., 2012).

In some countries, the chemicals used in fracturing fluid are considered trade secrets – but others require disclosure. In Canada regulators are actively moving towards a higher degree of disclosure. See Chapter 4 on the protection of public health and Chapter 9 on regulatory issues for more detailed discussion of this issue.

Hydraulic fracturing is a water-intensive practice, and large withdrawal volumes must be approved by regulators. The exact volume varies depending on the size of the area being exploited, the depth of well, and the geological characteristics of the formation. See Chapter 6 for a discussion of permitting, regulation, and water resource management questions in Nova Scotia.

Recently, alternative hydraulic fracturing fluid chemistries have been developed allowing for the use of saline water (Hayes et al., 2014), the recycling of fracturing fluids from previous operations, as well as treated municipal wastewater, all used to reduce the consumption of fresh water resources (CCA, 2014). Although alternatives to water are being attempted and more water is being recycled and reused in the hydraulic fracturing process, large quantities of fresh water are still necessary, as salt water has been associated with formation damage and equipment failure (Stark et al., 2012).

1.7.2 What is Brought Back to the Surface after Fracturing?

Once the injection process is completed, the internal pressure of the rock formation causes fluid to return to the surface through the wellbore, referred to as "flowback" water (Speight, 2014). In addition to the water naturally present in the formation (i.e. produced water), approximately one-quarter to one-half of the water used in hydraulic fracturing returns to the surface as flowback water (CCA, 2014). This water contains hydraulic fracturing chemicals, hydrocarbons (benzene and other aromatics), salt, metals, metalloids, and natural, radioactive constituents that have leached from the shale (Speight, 2013; CCA, 2014). In addition to the type of fracturing fluid used, the volume of flowback water depends on the properties of the reservoir and the fracturing program design. Initially, the flowback water resembles the hydraulic fracturing fluid, and over time, it takes on the properties of the produced water that is naturally present in the rock formation (Speight, 2013). Produced water continuously returns to the surface over the lifetime of the well; however, the majority returns to the surface within the first three weeks of production as flowback water (Lee et al., 2014).

Natural gas, predominantly methane, from the formation also returns to the surface with the flowback water. The methane is typically flared on-site or cold vented directly to the atmosphere until the flow is sufficient to capture for processing (Broderick et al., 2011). In the United States, "green completion technologies" are being developed to reduce venting or flaring of the gases (USEPA, 2011). It is of note that Drage and Kennedy (2014) found that methane was also naturally, commonly present at low levels in shallow groundwaters in Nova Scotia.

Shale rock contains naturally occurring radioactive material (NORMs) such as uranium and thorium that decay into radium 226 and radium 228, respectively (Irvin, 1996). The concentrations of NORMs in the flowback water depends on the nature of the shale formation as well as physical and chemical conditions such as temperature, pressure, and pH (Irvin, 1996). These NORMs can leach into the fracking fluid and return to the surface in the flowback water. In addition to flowback water, NORMs can be found in drilling mud and in evaporation ponds or pits. They can also be found as a part of scale or sludge deposits in pipes at production facilities (Irvin, 1996). The public health implications of NORMs are discussed in Chapter 4. Implications for water treatment and disposal are discussed in Chapter 6.

1.7.3 What is Done with the Flowback Water?

The flowback water and produced water are typically stored on site in tanks or in lined surface ponds before treatment, disposal, or reuse (Holloway and Rudd, 2013; Speight, 2013; CCA, 2014). The main concern with on-site storage, particularly in clay-lined ponds, is the potential for leakage into the local groundwater as the salinity of flowback water can increase the liner permeability (Folkes, 1982). Typically, the industry goal is to reuse all flowback water during subsequent hydraulic fracturing stages, although the practical method for disposal in industry is deep well injection when the geology is suitable (Speight, 2013; CCA, 2014). This may not be a viable option in Nova Scotia as geological conditions may not be favourable (see Chapter 7). The high salinity and levels of contaminants results in the requirement of treatment and processing of flowback water before it can be reused, and even then, it is generally less effective for fracturing than fresh water (CCA, 2014). Treatment for discharge into a surface water or wastewater treatment facility is challenging due to the high cost of treatment, the variable composition of the flowback water, and the presence of NORM components (CCA, 2014).

Most hydraulic fracturing operations are now employing practices which minimize water use by implementing water management strategies, avoiding the removal of water from supplies that may be under stress, and by recycling wastewater when possible (The Royal Society, 2012). See Chapter 6 for further discussion of water resource management questions in Nova Scotia.

ENDNOTES

1. Comments for improving the document ranged from deletions of entire sections to requests for enhanced descriptions or the development of additional sections. Some felt the Primer was too basic and required additional technical information, while others felt the level was acceptable, but the language was such as to imply the activity was benign and used to disarm the reader. While some felt the figures provided a good synopsis, others felt that since they were obtained from the oil/gas industry they were not acceptable.

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CHAPTER 2

The Potential Oil and Gas Resource Base in Nova Scotia

Brad Hayes

Ray Ritcey

2.0 | **Chapter Summary**

This chapter builds on our understanding of the process of hydraulic fracturing described in Chapter 1 and looks at the resource and infrastructure potential for onshore oil and gas extraction in Nova Scotia, including the use of hydraulic fracturing techniques. The chapter also lays the groundwork for a range of plausible scenarios that illustrate the potential economic impacts and royalty streams associated with any future development of unconventional gas and oil in the province; those scenarios are used to introduce Chapter 3 on Development Scenarios and Potential Economic Impacts.

The physical geology does recognize resource potential for conventional and unconventional gas and oil in specific areas (sedimentary basins) in the province, mostly in rural areas. Limited on-shore petroleum exploration has occurred to date, but no commercial oil and gas production has been established. Local and export markets exist for both oil and natural gas with demand growing.

As knowledge of the subsurface, including sedimentary rocks and hydrocarbons, is extremely limited, it is very difficult to quantify the potential or even rank the various basins in terms of overall "prospectivity."[1] The shales in basins closest to New Brunswick are of most interest to developers to date, because New Brunswick basins have demonstrated commercial production of both oil and gas and because pipeline infrastructure is in place (M&NP, 2014). Using published information, potential gas volumes have been estimated at 17-69 TCF in the Windsor-Kennetcook Basin and coal bed methane volumes at .28-1.18 TCF in the Sydney, Stellarton and Cumberland Basins. Other basins may or may not have potential, but very limited data or information exists. Exploration activity is likely to be limited, at least for the next several years, until such time as the moratorium on hydraulic fracturing is reviewed, additional seismic and well data are acquired, and the complexities of developing frontier basins are addressed.

This chapter also lists a number of outstanding questions that could arise should the government decide to pursue the development of onshore oil and gas extraction in Nova Scotia through hydraulic fracturing.

2.1 | **Introduction**

An understanding of the prospective oil and gas resource base of onshore Nova Scotia was required for the review panel to develop assessments of the issues and opportunities that may exist with the development of unconventional gas and oil using modern oilfield techniques, including hydraulic fracturing. In this chapter, we describe in-place oil and gas potential for the prospective areas of Nova Scotia and also provide context regarding the infrastructure in the province relevant to petroleum industry activities.

The oil and gas industry in Nova Scotia dates back to 1869, when the first exploration well was drilled in the Lake Ainslie area on Cape Breton Island. While a few discoveries have been made onshore in the Maritime provinces, such as the Stoney Creek and McCully fields in New Brunswick, onshore Nova Scotia has not been seen as highly prospective for conventional oil and gas, and no commercial discoveries have been made to date. Commercial discoveries have been made in the offshore, where oil has been produced from the Cohasset and Panuke fields and where gas is produced today from the Sable Island complex and Deep Panuke field.

In recent years, the development of horizontal drilling and hydraulic fracture completion technologies has rendered low-quality "unconventional" reservoirs capable of production at commercial rates. Exploration companies are thus re-evaluating the production potential of many areas, including onshore Nova Scotia.

2.2 | **Nova Scotia Infrastructure and Markets**

2.2.1 Terrain

Nova Scotia is 55,000 km2 in size; the second smallest province in Canada. It is connected to the province of New Brunswick by the Isthmus of Chignecto and is surrounded by the Atlantic Ocean (Figure 2.1). The Canso Causeway joins mainland Nova Scotia with Cape Breton Island. Nova Scotia has a mixed landscape including farmlands, rolling hills, forests, rivers and lakes, and rocky coasts, with occasional cliffs and mountains. There are over 3,000 lakes in the province, with Bras d'Or Lake in Cape Breton the largest.

Hydrocarbon development potential exists largely in rural areas (see Figure 2.3), where the terrain is a mixed landscape, mostly fertile, with rolling hills and watercourses. Farming, livestock, tourism, and some industry exists in the prospective areas.

2.2.2 Roads, Bridges, and Railways

There are over 23,000 km of roads and 4,100 bridges in Nova Scotia. The province has responsibility for the 100-series highways; secondary highways; local paved and gravel/dirt roads; and many concrete, steel, and wooden bridges. The 100-series of highways, including the Trans-Canada, connects all parts of the province. They are in generally good condition and have capacity to move large volumes of traffic, including oversized vehicles. Secondary highways, trunks, routes, and local municipal roads are important links to communities around the province. They are less travelled and are in varying states of repair. The Department of Transportation and Infrastructure Renewal five-year plan (2014) outlines a road repair priority program for the province. Each municipality has its own plan for road and bridge repair.

Nova Scotia has a core railway infrastructure in place to ship goods by connecting parts of Cape Breton as well as eastern and central locations of the province to Central Canada and the U.S. Midwest.

Hydrocarbon development would utilize a cross section of this highway, road, bridge, and railway infrastructure, plus roads and bridges on privately owned lands. Many of the roads and bridges have weight and height restrictions in place.

2.2.3 Pipeline Infrastructure

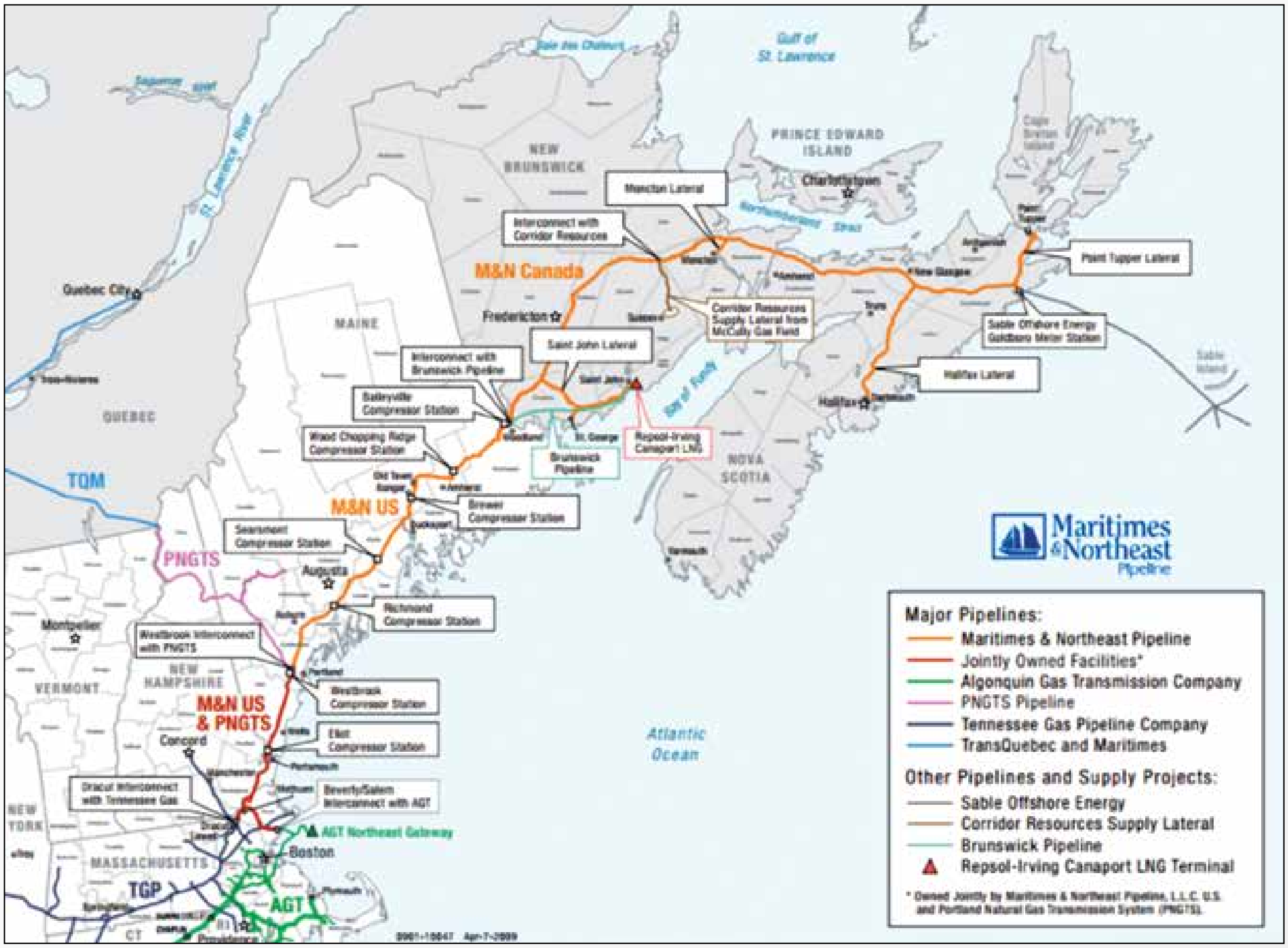
Natural gas was introduced into the Maritimes with the completion of the Maritimes & NorthEast Pipeline (M&NP) in December, 1999. The 1,100 km pipeline moves natural gas from Goldboro, Nova Scotia, where it lands from the Sable Offshore Energy Project (SOEP) and Encana's Deep Panuke facilities, located 225 and 250 km offshore, respectively. Gas is transported to markets in Nova Scotia, New Brunswick, and New England (Figure 2.1).

The M&NP 30″ Canadian line (567 km) traverses both Nova Scotia and New Brunswick, supplying natural gas to local gas distribution companies (LDCs) and several direct connect customers in both provinces. It has an operational capacity of 524 million cubic feet of gas per day (mmcf/day), and there are no compression facilities on the system. There are several lateral pipelines off the mainline (Figure 2.1). In Nova Scotia, the 12″ Halifax Lateral is 124 km long and has a design capacity of 115.3 mmcf/day. The 8″ and 6″ diameter Point Tupper Lateral is 60 km long, with an operational capacity of 28.2 mmcf/day (M&NP, 2014).

The M&NP US system (capacity 783.3 mmcf/day) includes approximately 534 km of 24″ and 30″ diameter pipeline extending from St. Stephen, New Brunswick, to interconnections with Tennessee Gas Transmission near Dracut, Massachusetts, and the Algonquin Gas Transmission Company near Beverly, Massachusetts. M&NP US also receives natural gas from the Emera Brunswick Pipeline, which transports regasified Liquid Natural Gas (LNG) from the Repsol/Irving-owned Canaport terminal (1,200 mmcf/day) near Saint John, New Brunswick.

Prior to the Sable Gas connection in 1999, M&NP flowed natural gas from western Canada through the TransCanada PipeLines (TCPL) Canadian mainline onto the Portland Natural Gas Transmission System (PNGTS) and back into the M&NP Canadian system via the M&NP U.S. system. U.S. natural gas supply can also be accessed from the Marcellus and Utica shale gas areas through inter- and intra-state U.S. and Canadian pipelines in eastern Canada.

Figure 2.1 Maritimes & Northeast Pipeline System Map



Reproduced with permission of Maritimes and Northeast Pipeline (2009)

To date, natural gas service in Nova Scotia has been provided from offshore fields. With current pipeline capacity constraints in the U.S. northeast and increasing shale gas production from the Marcellus, there is a growing interest in moving western Canadian and/or U.S. shale gas to the Maritimes for three reasons: i) to meet increasing domestic demand for natural gas; ii) to replace declining offshore volumes; and iii) for conversion to LNG for export. Recent geopolitical tensions in Ukraine and elsewhere tend to heighten interest in these kinds of development opportunities. Several developers are assessing LNG development proposals in Nova Scotia and are looking to secure natural gas supply and pipeline and downstream market commitments, both domestic and international.

New domestic onshore and offshore natural gas production in the Maritimes would support these development opportunities and would supplement a declining offshore SOEP and Deep Panuke production profile. New onshore natural gas production that is not used locally would require gathering lines and an interconnection with either M&NP or local LDC infrastructure. Hydrocarbon exploration in Nova Scotia has been undertaken in areas close to existing pipeline infrastructure, just as it has in New Brunswick. Without local supply, the cost for acquiring natural gas in Nova Scotia would increase by the added cost of transportation in having the gas sourced from outside suppliers, most likely shale gas producers in the Marcellus.

2.2.4 Oil Infrastructure

With the recent conversion of the only oil refinery in Nova Scotia to a marine terminal, all gasoline, heating oil, and other petroleum products consumed in Nova Scotia are sourced from New Brunswick, Newfoundland & Labrador, and international markets. The product is delivered by ship, rail, and truck.

2.2.5 Markets

Natural gas consumption in Canada dates back over 150 years, with significant growth in domestic use beginning in the late 1950's. The use of natural gas is the culmination of an evolution from coal to oil to natural gas, driven largely by affordable pricing and convenience. It is the fuel of choice for residential, commercial, and industrial applications in most of Canada. Domestic natural gas was produced originally from conventional sources in western Canada, and, over time, sales volumes for both domestic and exports increased significantly. Prior to the SOEP project in Nova Scotia, natural gas expansion to the Maritimes was pursued by moving western Canadian gas through an expansion of the TCPL system beginning in the early 1970's and culminating with the Trans Quebec and Maritimes Pipeline system (TQMP), terminating near Quebec City. Expansion to the Maritimes at the time could not be justified on economic grounds.

Natural gas was introduced in the Maritimes when the SOEP and M&NP facilities became operational in 2000. Initially, the majority of SOEP gas was delivered to the U.S. northeast and to large direct access industrial customers in Nova Scotia and New Brunswick primarily for electricity generation. Local Distribution Companies (LDC's) were established in the early 2000's in New Brunswick (Enbridge Gas New Brunswick) and Nova Scotia

(Heritage Gas Limited), as they built out their smaller diameter and lower-pressure systems to residential, commercial, and industrial customers. While the majority of natural gas consumption in Nova Scotia is for the generation of electricity, the core natural gas distribution market continues to experience strong growth. This growth is due largely to the price advantage of natural gas over alternative fuels (primarily oil and electricity), along with some inherent environmental benefits, including cleaner burning/lower emissions, elimination of oil fuel tank leaks, and convenience. In addition, compressed natural gas (CNG) deliveries by truck now occur in both provinces and provide access to areas not currently served by LDC pipelines.

The Maritimes market now takes up to around 50 per cent of production from offshore Nova Scotia, or 200-300 mmcf/day (Statistics Canada). See also Chapter 3 for recent projections on natural gas production and consumption in Canada.

2.3 | **Oil and Gas Resource Assessment - Background**

Historically, assessments of oil and gas resources have targeted "conventional" reservoirs – those with characteristics that allow production of oil and/or gas at commercial rates from wells drilled vertically. The key measures of reservoir quality are:

- Porosity – the amount of pore space between mineral grains making up the rock – a measure of the rock's capacity to hold oil and gas;
- Permeability – a measure of how readily fluids can flow through the pore spaces in a rock – and, therefore, how rapidly oil and/or gas can be produced.

There are well-established procedures for conducting resource assessments for conventional reservoirs. Agencies such as the Geological Survey of Canada (e.g., Lee, 1993; Lavoie et al., 2009; Hu & Dietrich, 2010; Hannigan et al., 2011) have completed conventional oil and gas resource assessments for most prospective areas in Canada.

The combination of horizontal wells with multiple hydraulic fracture completions now offer the potential to produce from "unconventional" reservoirs, which feature much poorer porosity and permeability characteristics. Procedures to assess petroleum resources existing within unconventional reservoirs are being developed, as geologists are working to understand exactly how the resources are contained within a reservoir (Lavoie et al., 2012). For example, gas molecules within an unconventional reservoir are held not only in pore spaces and naturally-occurring fractures but may also be "adsorbed," or chemically bonded, to organic material within the rock. In addition, there is often uncertainty about whether a particular reservoir contains oil or gas, or a mixture of both, until after horizontal wells with hydraulic fractures are completed.

Under appropriate conditions, coal seams represent a special class of unconventional reservoirs and can host significant resources of methane gas. While production techniques vary, both vertical and horizontal wells employing small fracture stimulations, usually with a gas such as nitrogen as opposed to water, are common.

It must be emphasized that most assessments of unconventional gas and oil resources address only the quantity of oil and gas existing within the reservoir – termed "in-place" resources. These volumes are calculated using parameters that can be measured or reasonably estimated – including, for example, volume of reservoir rock, porosity, reservoir pressure, and temperature. In fact, where even these parameters cannot be estimated with confidence, many assessments of oil and gas potential in unconventional reservoirs do not attempt to quantify potential but, instead, are more descriptive in nature (e.g., Hamblin, 2006; Hayes, 2011; Hayes & Archibald, 2012).

For unconventional reservoirs in areas where abundant data are available from conventional wells, quantitative analyses of oil and gas in place have been published, but with wide ranges of probabilistically-generated estimates reflecting inherent uncertainties in key reservoir parameters (e.g., B.C. Ministry of Energy and Mines and National Energy Board, 2011; Rokosh et al., 2012; U.S. EIA, 2013; National Energy Board et al., 2013).

2.3.1 Recovery Factors

Once one has calculated the volumes of oil and gas in place in a reservoir, a recovery factor – the percentage of the resource in place that can actually be extracted – must be assigned in order to estimate the actual oil and gas volumes that may be produced. Regardless of the reservoir type, recovery factor estimates depend upon many assumptions, including reservoir characteristics, development methods and costs, and oil and gas prices.

Based on production histories of conventional reservoir types, one can make standard assumptions about recovery factors for many conventional reservoirs. These can range up to more than 90 per cent of in-place resources for gas reservoirs and greater than 50 per cent for the best oil reservoirs.

Conversely, oil and gas have been produced from unconventional reservoirs only over the last decade or so, and so we have little guidance to understanding how much of the in-place resource can be produced and, thus, what recovery factors might be. Where data are scarce, most unconventional resource assessments published to date routinely assume relatively low recovery factors – typically on the order of 5-25 per cent. Where more data are available, the assumptions listed above are commonly assigned ranges of values to reflect associated uncertainties and recoverable resource estimates are calculated statistically using these ranges. For example, the National Energy Board's assessment of marketable volumes from the unconventional Montney Play in Alberta and British Columbia (316 to 645 TCF gas, 9.7 to 21 billion barrels of natural gas liquids, and 452 to 2,430 million barrels oil) spans wide ranges, even though thousands of wells have been drilled into the Play so far.

Some stakeholders reviewing the first draft of this report have questioned the ranges of recovery factors assigned to unconventional plays, stating that industry estimates are too high and actual recoverable volumes from unconventional plays will be substantially lower. Several stakeholders made reference to papers by Hughes (2013a, 2013b). Hughes reviewed production data from a number of unconventional gas and oil plays in the United States and suggested that most of the major known plays are in decline or soon would be and would not recover the large volumes generally projected. While Hughes' work can certainly be considered to add a cautionary note, he does not undertake any analysis to supply estimates of recoverable resource nor does he consider economic factors. By comparison, a much more rigorous and complete assessment of the Barnett Shale play undertaken by the Bureau of Economic Geology and the University of Texas, incorporating geology, reservoir engineering, and economic analysis, produced a statistical model of wells drilled, annual production, and ultimate recovery through 2050 (Browning et. al., 2013). This analysis showed some interesting results, including:

- Active development (drilling) will continue through at least 2030 and production until at least 2050;
- Expected total gas recovery of about 45 TCF (compared with 12.1 TCF produced through 2012). Actual final recovery could be smaller or greater, depending on gas prices;
- Recovery factors within the Barnett play ranging from 4 per cent to 55 per cent, depending upon reservoir quality variations throughout the play area.

As another example of recovery factor variability, there was considerable media in May/June, 2014 to the announcement by the U.S. Energy Information Administration (EIA) that they plan to drastically reduce projected recoverable oil volumes from the Monterey Shale play in California (e.g. Reuters, 2014). While the revised report was not released at the time this chapter was completed, the news release indicates that the EIA has not changed their assessment of oil in place but has reduced the estimated recovery factor for the play, based on poor performance of wells drilled to date. In other words, in their 2011 assessment report (U.S. EIA, 2011), the EIA judged that drilling/completion technologies existed to extract significant oil volumes from the Monterey. By 2014, when production results failed to produce the estimated volumes, the EIA revised their estimates of ultimate recovery downward to reflect these results.

Some stakeholders have suggested that unconventional reservoirs in Nova Scotia, and in particular the Windsor-Kennetcook Basin (W-K), are comparable to the Monterey, and that the downgrade in recoverable volumes from the Monterey implies that recoverable volumes from Nova Scotia reservoirs may be small.

This comparison is not appropriate. If we want to compare a particular formation within the W-K Basin with the Monterey Shale, we would need to compare numerous factors that are important to the prospectivity of unconventional reservoirs. Such a detailed comparison has not been advanced, and therefore, it is not correct to say that the Monterey is similar to anything in the W-K Basin. An inspection of the key geological variables – such as rock composition and properties, organic content and maturity, burial depths, and histories – demonstrate that the Monterey is very different from Nova Scotia rocks (Chaika and Williams, 2001).

Based on our extensive experience in unconventional resource evaluation and the limited information available, there is very little basis for comparison between the Monterey Shale and any of the formations in the W-K Basin. Although our knowledge is limited by scarcity of data, shales and sandstones in New Brunswick and American plays, such as the Marcellus, are likely far better comparisons.

Regardless of specific comparisons, it is critical to realize that there has been no change to the assessment of oil in place in the Monterey reservoir. The expectation is that industry efforts will continue to improve drilling and completions so that the oil can be produced economically. If those efforts succeed, recovery factors for the Monterey will be revised upward to reflect this advance. There is, however, no guarantee that this will occur.

In general, potential to attain higher recovery factors in any unconventional play will be governed by the economic viability of greater well density, more effective fracturing, and development of more effective extractive technologies. While technological advances cannot be predicted with certainty, as we noted in our introduction to this report, they have happened throughout human history and to assume that no further advances will occur is not realistic.

2.3.2 Summary

Our assessment of oil and gas resources that may be available for production from unconventional reservoirs in Nova Scotia is subject to several uncertainties:

- Calculation of volumes of oil and/or gas contained within each reservoir;
- Whether oil or gas or both will be produced in commercial quantities;
- What fraction of the in-place resource can actually be extracted economically.

In this chapter, we use available information to describe in-place oil and gas potential for the prospective areas of Nova Scotia. However, we do not attempt to generate area-specific recovery factor estimates, as we lack appropriate data and comparisons to do so.

2.4 | **Prospective Petroleum Basins in Nova Scotia**

2.4.1 Regional Petroleum Geology

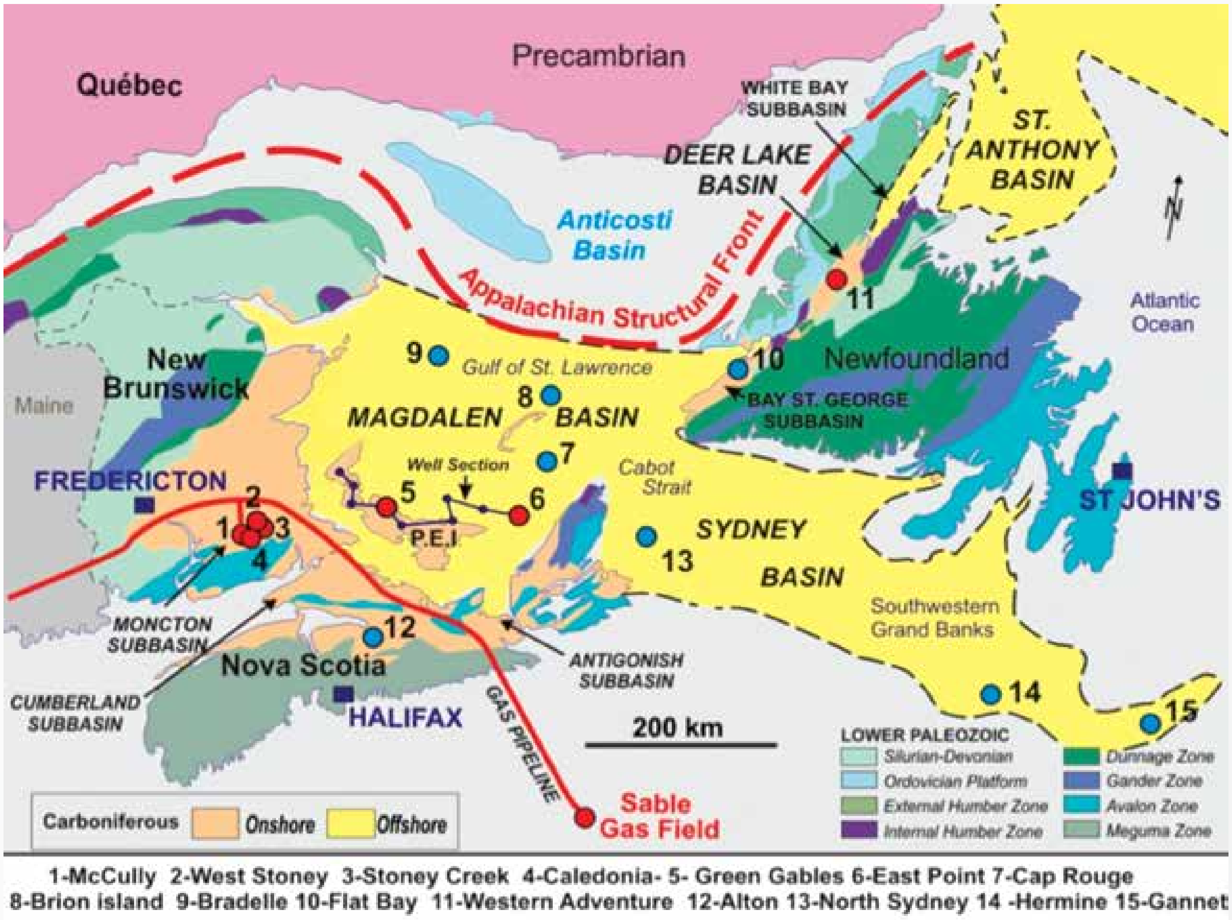
Oil and gas were generated over tens of millions of years as heat and pressure acted upon organic material deposited in sediments – such as sands deposited in a river delta – which later evolved into sedimentary rocks. Organic content is dominated by remains of plankton and algae in marine settings and by plant materials in land settings. Oil and gas are thus almost always hosted in reservoirs made up of sedimentary rocks (including coal) buried at depths of hundreds to thousands of metres. These occur in discrete areas known as sedimentary basins.

Figure 2.2 shows the major sedimentary basins of eastern Canada. The prospective basins of Nova Scotia are part of a complex of basins (Maritimes Basin), which underlies parts of the offshore, much of the Maritimes, and western Newfoundland. Figure 2.3 shows in more detail the sedimentary basins of onshore Nova Scotia and the locations of oil and gas wells drilled and geophysical (seismic) data acquired to date. Note that very few wells have been drilled and very little seismic data acquired, compared to more mature, or developed, petroleum-bearing basins. In areas outside the major sedimentary basins, the bedrock is composed of older sedimentary rocks and/or metamorphic rocks, which have little or no potential to contain oil and gas.

The Maritimes Basin, formed during late Paleozoic time (about 350 to 300 million years ago), in response to movements of large plates on the earth's crust carrying the North American and African continents. Stresses arising from these movements deformed the earth's crust, causing some areas to sink and form basins. Many basin boundaries are sharp discontinuities, now expressed as breaks, or faults (shown as heavy black lines in Figure 2.3; note as a particular example the Minas Fault Zone, which crosses Nova Scotia from west to east). Sedimentary rocks in Nova Scotia basins range up to several thousand metres thick, but they are understood only in very general terms because only a small sampling of rocks can be examined at the surface and there are relatively few deep boreholes drilled through them (Figure 2.3). Seismic data, acquired along the lines shown in Figure 2.3, can assist in mapping subsurface rock units but impart only limited levels of detail. Other geophysical remote sensing methods, such as magnetic and gravity surveys, provide additional broad support but relatively little detail.

Figure 2.2 Sedimentary basins of Eastern Canada.

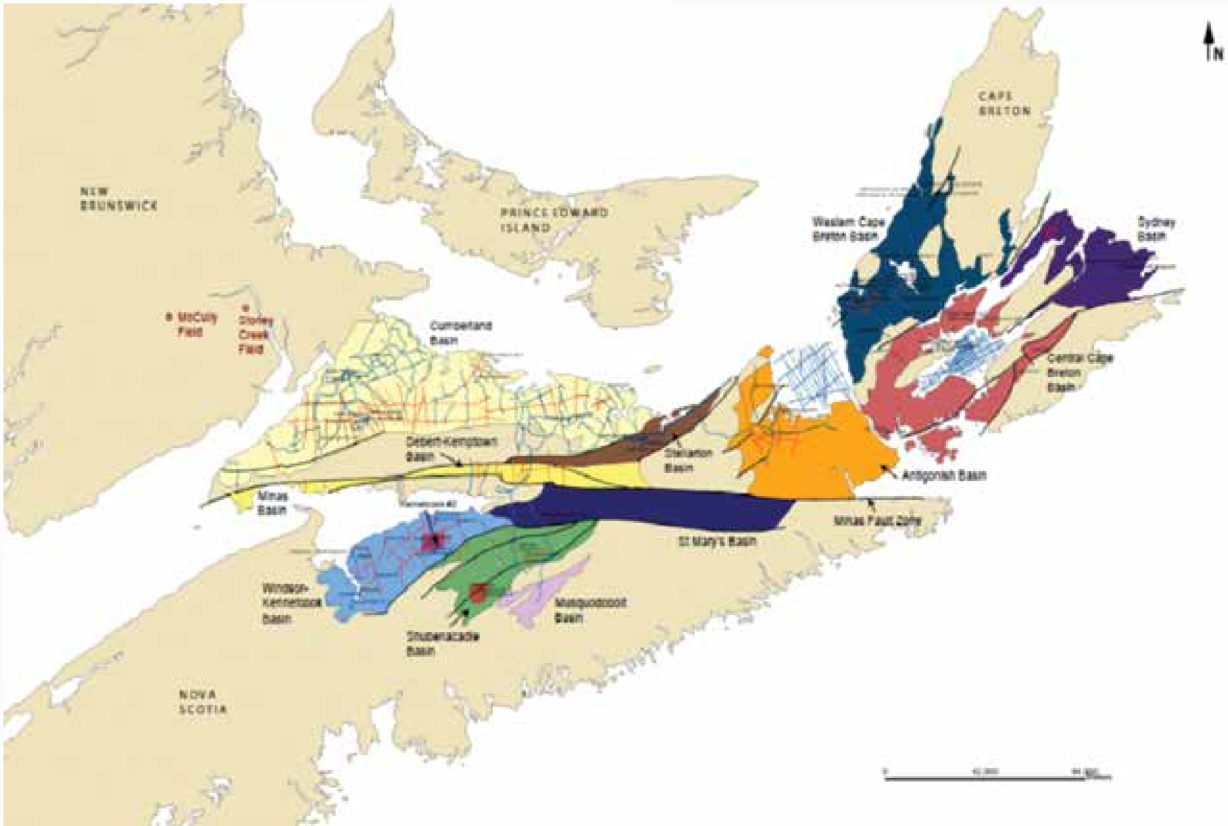
Red dots indicate hydrocarbon discoveries, while blue dots show key exploration wells.



Courtesy of Natural Resources Canada: Lavoie et al., 2009

Figure 2.3 Sedimentary Basins of Nova Scotia

Oil and gas exploration wells drilled to date are labelled. Red and blue lines show seismic data acquired to date. Note the numerous faults (black lines), which disrupt continuity of sedimentary rock layers and add structure complexity to the basin.



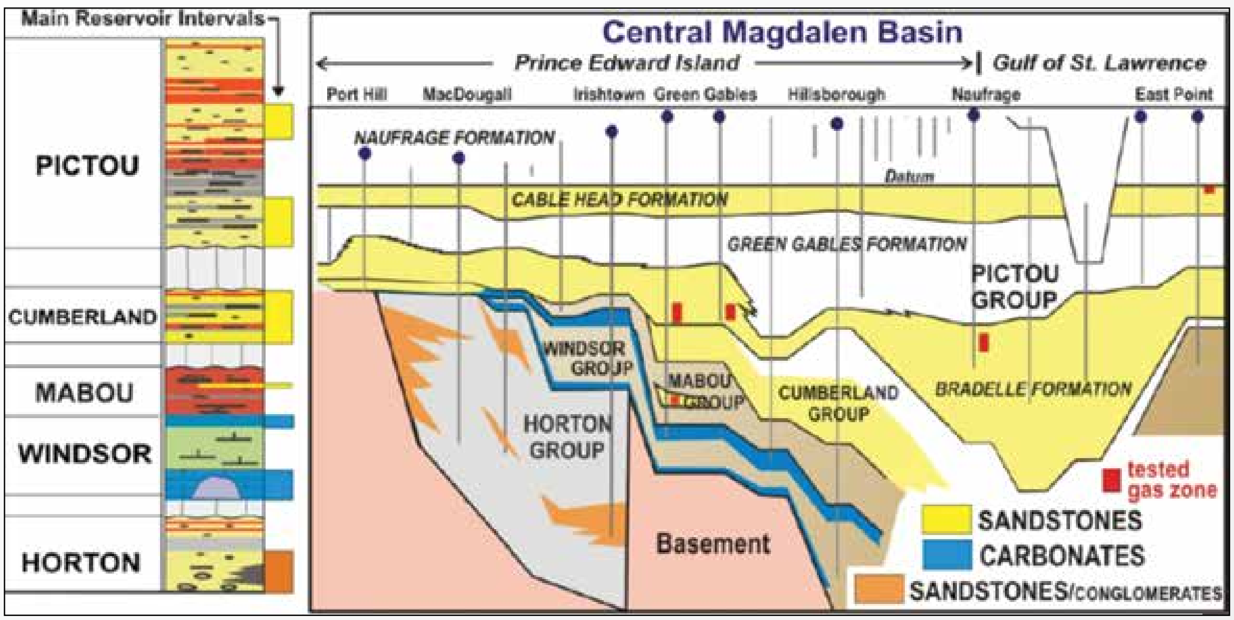
Map courtesy of the Nova Scotia Department of Energy

Nova Scotia basins are structurally complex – that is, there are many faults within each basin that disrupt continuity of the sedimentary rock layers. Selective dissolution of soluble rock layers, such as salts and some carbonates, further complicates structures (Baechler & Boehner, in review). Structural complexity has profound implications for the nature and continuity of petroleum reservoirs. In order to better understand basin architecture, geologists draw schematic cross-sections based on known geological data to represent their understanding of basin geometries and the sedimentary rocks filling them (e.g., Figure 2.4). At cross-section scale, only the most general relationships can be shown. Waldron et al. (2010) mapped structural complexity in the Windsor-Kennetcook Basin, and Figure 2.5 illustrates analogous subsurface complexity in the Stoney Creek and McCully Fields of New Brunswick. Given this general understanding of stratigraphic and structural complexity, we can infer many important features from the study of better-known sedimentary basins of similar age and genesis in the eastern United States and even northwestern Europe. This approach is potentially helpful in Nova Scotia where data on specific basins are not readily available.

Some stakeholders have expressed the view that structural complexity in Nova Scotia basins makes them less prospective for oil and gas or makes hydraulic fracturing riskier and less likely to succeed in stimulating production. Oil and gas occurrence and production around the world shows us that these views are not supported by current knowledge and experience. Most structurally complex sedimentary basins are prospective for conventional and unconventional gas and oil, and we expect this to be the case for Nova Scotia basins. Even where numerous faults are present, most do not have sufficient permeability or size to serve as conduits for fluid (gas or liquid) flow – and the proof of that is in the fact that oil and gas remain trapped far below the surface. We see oil and gas occurring in many structurally-complex situations, such as the giant Hibernia Field (offshore Newfoundland/Jeanne d'Arc Basin), or in the Foothills of Alberta and British Columbia. In Section 2.6 below, we discuss how horizontal drilling and hydraulic fracturing methods are typically tailored to individual reservoir situations, including structural complexity.

Figure 2.4 Stratigraphic cross-section of the Central Magdalen Basin

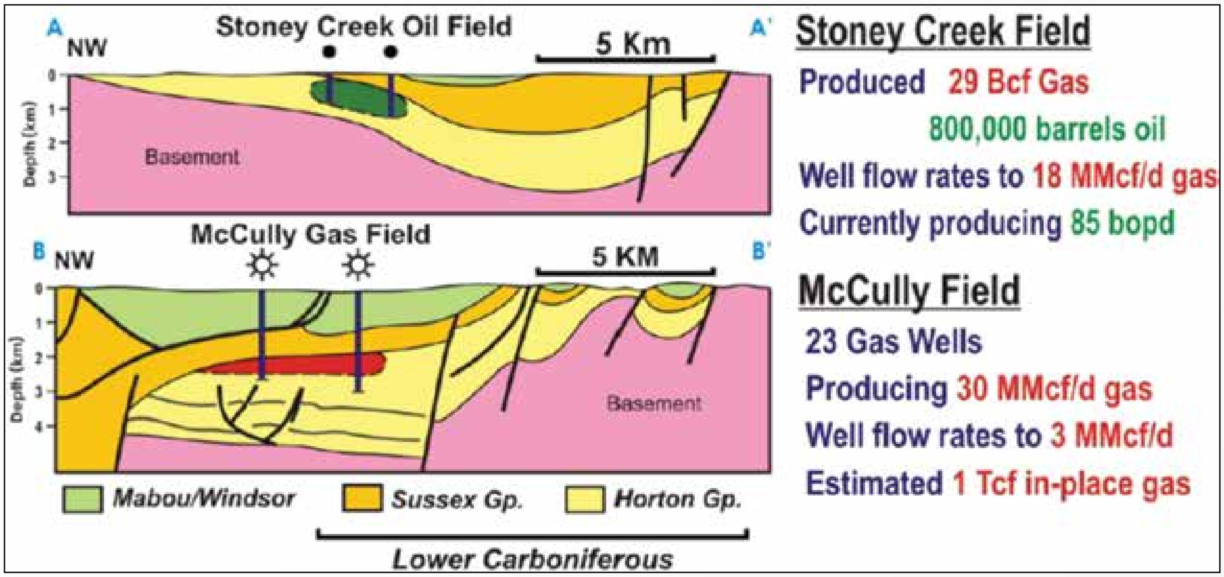
Stratigraphic cross-section illustrating geological interpretations of sedimentary rocks filling the offshore Maritimes Basin complex, linking information from wells drilled on the northern flank of Prince Edward Island. See Figure 2.2 for location of section.



Courtesy of Natural Resources Canada: Lavoie et al., 2009.

Figure 2.5 Stratigraphic cross-sections across Stoney Creek and McCully Fields in New Brunswick.

Illustrates numerous faults (black lines), which disrupt continuity of sedimentary rock layers and add structural complexity to the basin.



Courtesy of Natural Resources Canada: Lavoie et al., 2009.

2.4.2 Unconventional Gas and Oil Potential in Nova Scotia Basins

Appendix C reviews the technical work underpinning unconventional gas and oil potential estimates for Nova Scotia basins. With reference to the stratigraphic column showing prospective sedimentary rocks in Nova Scotia basins (Figure C1, Appendix C), we summarize unconventional gas and oil prospectivity as follows:

- Horton Group
    - Medial shales – Most prospective unconventional reservoir identified; regionally extensive, generally favourable reservoir characteristics, and gas and oil potential
        - Frederick Brook Formation (New Brunswick) – producing from three wells at McCully Field.
        - Horton Bluff Formation (Windsor-Kennetcook Basin) – gas in place resources tabulated; test wells by Triangle Petroleum failed to produce.
        - Strathlorne Formation (Cape Breton basins) – oil seeps at surface indicate hydrocarbons are present but shales not specifically assessed.
    - Upper sandstones – Producing gas at McCully Field in New Brunswick. Analogous potential seen in Nova Scotia basins but not tested.

- Windsor-Mabou Groups
  - Oil and gas potential has been discussed for several unconventional reservoir intervals, but no exploration has taken place, nor have estimates of oil and gas volumes been published.
- Cumberland and Pictou Groups
  - Coalbed methane (CBM) has been tested, and several assessments of CBM resources on specific properties have been completed, but commercial production has not been established. Tight sandstones may be prospective but have not been assessed.

Available quantitative estimates of unconventional in-place oil and gas are very scarce as noted below.

Table 2.1 Quantitative Estimates of Unconventional in-place Oil and Gas

Windsor-Kennetcook Basin	Horton Bluff Fm (shale)	17 TCF[2] risked[3] (U.S. EIA)
		69 TCF (Ryder Scott)
Sydney Basin	Pictou – Cumberland	0.98 TCF (CBM)
Stellarton Basin	Pictou – Cumberland	0.28 TCF (CBM)
		0.43-0.48 TCF (CBM) (Stealth, Amvest)
Cumberland Basin	Pictou – Cumberland	0.42 TCF (CBM)
		1.18 TCF (CBM) (Stealth)

2.5 | **Industry Activity**

Companies operating in the oil and gas industry routinely make decisions to employ large amounts of capital – tens to hundreds of millions of dollars – in a business where success can be highly profitable and failure can mean complete loss of the investment. They carefully analyze the various factors influencing their decisions and are highly attuned to uncertainties or risks in weighing these factors.

To attract industry investment, there must be good promise of large, potentially profitable discoveries and appropriate knowledge and management of risks. To realize the potential value of new discoveries, it is necessary to maximize the certainty of large oil and gas resources in place and to establish that they can be extracted economically. To minimize uncertainties and risk, industry looks to find successful comparable situations or "analogues" – places where oil and gas have been extracted economically from similar reservoirs using recognized techniques. In "frontier areas" like the basins of Nova Scotia where there is little existing subsurface information and petroleum infrastructure, potential rewards are poorly defined and uncertainties and risks are large, and so the search for successful analogues, is particularly important.

Nova Scotia basins hold the potential for large conventional and unconventional gas and oil resources. Exploration companies are thus attracted to but yet hesitant to move quickly in light of the high levels of geological and economic risk and uncertainty. In fact, there are only four existing exploration agreements between companies and the province and three more for CBM exploration. Technical risks – the existence of the hydrocarbon resources and the existence of technology capable of extracting those resources at economic rates – have been addressed to some extent by the successful development of reasonable analogues. These include:

- Commercial development, through horizontal drilling and hydraulic fracturing of gas and liquids production from Marcellus shales in analogous, structurally-complex basins of the eastern United States, and
- Commercial development of low-permeability Horton Group sandstones in the Moncton Basin (McCully and Stoney Creek fields) and initial success in developing gas production from Horton Group (Frederick Brook) shales, also in the Moncton Basin.

The closer the analogue, the better – so Corridor Resources' success in New Brunswick is focusing industry's attention on the nearest analogues. Thus, the comparable or "correlative" shales in basins closest to New Brunswick, such as the Horton Bluff shales in the Windsor-Kennetcook Basin, are attracting the most attention and activity.

2.6 | **Application of Hydraulic Fracturing Technology**

Hydraulic fracturing is employed in both vertical and horizontal wells to enhance production rates and recovery volumes from oil and gas reservoirs, both conventional and unconventional. Hydraulic fracturing design is dictated primarily by the nature of the reservoir. As the ultimate goal of developers is to maximize the economic value of production from a well, the cost of the fracturing treatment must be balanced off against the estimated gains in production.

In conventional reservoirs, small fracture stimulations may be used to enhance productivity of the reservoir. These use relatively small volumes of water (tens to hundreds of cubic metres), or either inert gas (such as nitrogen), or hydrocarbons (such as propane) to transmit pressure to fracture the reservoir rock.

In unconventional reservoirs, stimulation scenarios include:

- For coals, CBM drilling targets are generally quite shallow (usually less than 500 metres), and the coal is very brittle, so relatively small fracture stimulations are needed. Nitrogen gas is commonly used, as introducing water to the coal may inhibit production.

- For reservoirs that have been fractured naturally through large-scale rock movements (as in basin formation, discussed above), wells are drilled to intercept a maximum number of natural fractures and little or no induced fracturing is attempted. Some of Alberta and British Columbia's (BC) longest-producing and most prolific gas reservoirs fall into this category, as do some of the current oil plays in shales.

  In structurally-complex Nova Scotia basins, it appears likely that there will be at least some naturally-fractured plays that could be developed without hydraulic fracturing.

- For many unconventional reservoirs, particularly tight sandstones and siltstones, relatively small fracture jobs are required to optimally stimulate the very brittle rocks. Long horizontal wells may be drilled and several, perhaps tens of hydraulic fractures will be emplaced, but each may employ only small water volumes or will use gas or hydrocarbon-driven fracturing, as discussed above. Some of western Canada's most significant unconventional plays, including the Cardium, Montney and Bakken, are treated this way. For example, industry commonly uses 12,500 to 37,500m^3 water per Montney well where the reservoir section is thick but much lower volumes (2500 to 4000m^3 water) for thinner Cardium reservoirs (additional information regarding water volumes used to frac specific wells is available at www.fracfocus.ca). Chapter 6 (Impacts on Water) provides context, comparing these water volumes with surface water and domestic volume demands in Nova Scotia.

  In Nova Scotia, tight sandstone reservoirs in the Horton and Cumberland-Pictou groups would likely require stimulation using this methodology, as would tight carbonates in the Windsor and Mabou groups.

For shale plays, larger hydraulic fracture stimulations are employed, including "slickwater" fracturing, which uses the largest water volumes but relatively low concentrations of supporting chemicals. The major Canadian shale plays – the Duvernay of Alberta and Horn River of northeastern BC – use 30,000 to 100,000m3 of water for each horizontal wellbore. In Nova Scotia, Horton Group shales (Frederick Brook, Strathlorne), in settings without structural complexity, would likely be most effectively stimulated using large-volume hydraulic fracs.

Canadian operators are very experienced in the application of hydraulic fracturing. Between 2007 and 2013, approximately 35,000 horizontal wells were drilled in Canada, almost all of them stimulated with hydraulic fracturing.

2.7 | **Summary and Conclusions**

The sedimentary basins of onshore Nova Scotia are prospective for oil and gas in unconventional reservoirs. The essential elements – thick unconventional reservoir rocks and organic materials to generate oil and gas – are present and widespread. As knowledge of the sedimentary rocks and hydrocarbons in these basins is extremely limited, it is very difficult to quantify unconventional potential, or even to rank the basins in terms of overall prospectivity. More exploration, and particularly more deep wells targeted to investigate unconventional reservoirs, would be required to add to our knowledge.

Prospectivity occurs in three major rock units within the basins outlined in Figure 2.3:

- Horton Group (oldest)
    - Production of oil and gas occurs from Horton Group sandstones in the Moncton Basin of New Brunswick. While these reservoirs are technically conventional, horizontal drilling and hydraulic fracturing have been used to enhance production.
        - Resources in conventional Horton reservoirs are estimated at 300 to 1185 million barrels of oil and from 6.1 to 23.7 TCF of gas.
    - High gas flow rates have been attained from hydraulically-fractured horizontal wells in Horton Group shales in the Moncton Basin. Vertical test wells (with small hydraulic fractures) drilled into analogous shales of the Windsor-Kennetcook Basin in Nova Scotia did not produce gas.
        - Resources in Horton Group shales are estimated at 17 to 69 TCF over much of the Windsor-Kennetcook Basin.
        - Analogous shales in other Nova Scotia basins are seen as generally prospective, but no resource assessments have been published.
    - Thick, tight sandstones occur in the Horton Group across all Nova Scotia basins, but no assessment of their oil and gas resource potential has been published.

- Windsor and Mabou Groups
  - Carbonate reefs in the basal Windsor Group are the targets for oil exploration, and exploration wells have been drilled in the Shubenacadie Basin. As a productive pool has not been encountered, it is unclear whether fracturing would be required to produce it.
  - Oil and gas potential may occur in tight carbonate (and sandstone) reservoirs in the basal and upper parts of the Windsor-Mabou section, but no assessment of their resource potential has been published.

- Cumberland and Pictou Groups (youngest)
  - Widespread coals are prospective in several basins for coalbed methane, and resource estimates on the order of 1 TCF have been published.
  - Resources in conventional Cumberland/Pictou sandstone reservoirs (including offshore areas) are estimated at 317-1230 million barrels of oil and 12.1 36.8 TCF of gas.
  - Thick, tight sandstones occur in the Cumberland and Pictou groups across all Nova Scotia basins, but no assessment of their resource potential has been published.

Nova Scotia has limited existing pipeline infrastructure, which was built primarily to bring offshore gas onshore and services both domestic and export markets. Additional pipeline infrastructure would need to be built to gather gas from new onshore discoveries. Existing road, bridge, and railway infrastructure is extensive, although it has not been designed to handle the demands of an active petroleum industry.

Given regional petroleum geology, existing resource assessments, industry activity to date, and logistics of creating new infrastructure, we conclude:

1. Exploration companies may perceive attractive oil and gas potential in the unconventional reservoirs of Nova Scotia. Every new basin and new play starts from very little hard information, and there are many uncertainties. Exploration, whether for conventional or unconventional reservoirs, happens because economic potential is envisioned in the minds of people in exploration companies.

2. Exploration activity is likely to be limited, at least for the next several years, because technical risks are considerable, little petroleum production infrastructure is in place, and companies see challenges in commencing operations in a frontier area.

3. While Nova Scotia basins are considered to be gas prone, developments expected to have greater oil or gas liquids potential will focus interest more sharply, as economics for oil development tend to be more favourable than gas development in North America.

4. Reservoirs of the Horton Group, and particularly the medial shale formations, will attract the most industry interest because of large assessed gas in place volumes and the existence of oil and gas production in nearby New Brunswick.

5. The Cumberland, Windsor-Kennetcook, and Shubenacadie basins, being relatively close to existing production in New Brunswick and having experienced exploratory activity already, will likely be the focus of unconventional exploration activity for the foreseeable future. Most existing pipeline infrastructure is close to these basins.

6. The market for natural gas in the Maritime provinces has grown significantly over the past 10 years and continues to demonstrate strong growth potential. LNG exports also present a potential market for Nova Scotia discoveries.

7. Cape Breton and Antigonish basins are likely to see little or no exploratory activity in the near future, as their CBM potential does not appear to be economic and other unconventional prospectivity has not been tested.

ENDNOTES

1. See Glossary.
2. Trillion Cubic Feet (TCF). For comparative purposes, Canada consumed 3 TCF of natural gas in 2013.
3. See Glossary.

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CHAPTER 3

Development Scenarios and Potential Economic Impacts

Michael Gardner
Brad Hayes

3.0 | **Chapter Summary**

This chapter builds on our analysis of potential unconventional gas and oil resources described in Chapter 2 and sets out four "plausible scenarios" of development, should the Province of Nova Scotia ever decide to proceed with developing these resources. The four scenarios range from zero development, i.e. no commercial development established in any basin, through to maximum development, i.e. five basins successfully developed for gas and one for oil. We then consider the nature of petroleum operations associated with unconventional gas and oil development: exploring for and producing hydrocarbons, with a focus on economic costs and benefits. We describe in general terms what is involved in each phase of activity – exploration, field development, production, and abandonment – and we set out the costs and benefits of such activities for regional economies, including opportunities for involvement by the local workforce and contractors. We use an illustrative 50 well "minimum development," but then we extrapolate that minimum development in to impacts that would apply in a full development (our lower medium case scenario), to give a sense of the economic impact of developments that would occur over a 40-year period. Finally, we use our lower medium case scenario to estimate possible royalties to the Province that might accrue if a similar timeframe development was to occur at that scale.

3.1 | **Unconventional Gas and Oil Development Scenarios**

3.1.1 The Art of Scenario Planning

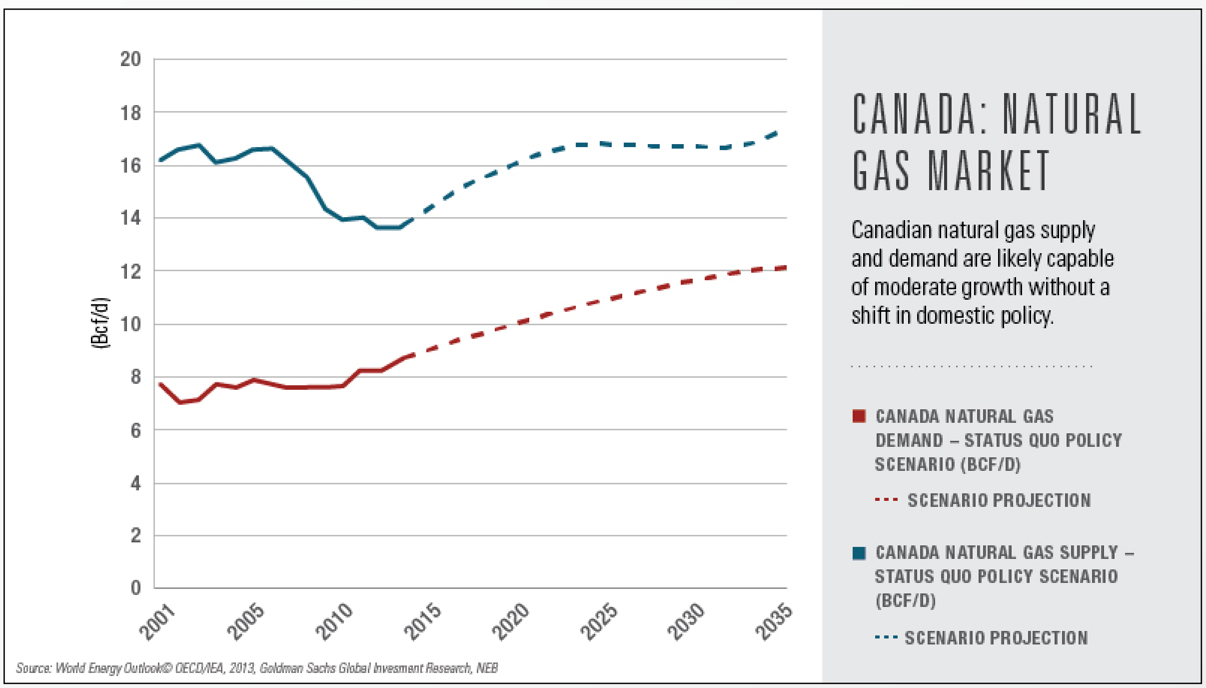
For many years, governments and other organizations have used "scenario planning" as a mechanism to explore the implications of complex global political, social, economic and environmental trends, market forces, and other factors impacting the way the world is unfolding (Schoemaker, 1995). The purpose of scenario planning is not to predict the future, rather it is to develop plausible scenarios that may be used to aid policy development or strategy in the short-term. The optimum use of scenarios is to challenge organizations or governments to think strategically and long-term whilst making short- and medium-term decisions that allow for all eventualities.

The Global Scenario Group, originally convened by the Tellus Institute and the Stockholm Environment Institute, applied scenario planning techniques to global sustainability challenges and produced an influential document in 2002: Great Transition: the Promise and Lure of the Times Ahead (Global Scenario Group, 2002). The report set out three possible global scenarios: i) Conventional Worlds; ii) Great Transitions; and iii) the rather more apocalyptic Barbarization. More locally, in previous work for the Province of Nova Scotia which resulted in the Nova Scotia Renewable Electricity Plan, four plausible scenarios were developed, which informed the process of research and public policy development (Adams et al, 2011). That process helped with the establishment of 25 per cent and in due course 40 per cent targets for renewable electricity in the Province, targets which are likely to be exceeded.

The use of scenario planning in the oil and gas industry is famously associated with Shell, a company that pioneered the process in the corporate world and has been producing scenarios for 40 years (Shell 2012). The current "New Lens" Shell scenarios (Shell, 2014), envisage two strongly divergent outcomes, one (termed "Mountains") is predicated on more coordinated international public policy and where natural gas becomes the dominant global energy resource by the 2030s. The other (termed "Oceans"), is built on more of a market driven set of outcomes, with oil and coal remaining central to global energy supplies for several decades, leading to eventual dominance for renewables and solar energy towards the end of the century.

More recently, the Goldman Sachs Global Markets Institute (2014), released scenarios for natural gas production and consumption in North America, including Canada (Figure 3.1). Goldman Sachs posed a number of questions of politicians in the U.S., Canada, and Mexico which would need to be addressed in order to reconcile economic, energy, transportation, and environmental policies, noting that investments in downstream (distribution) infrastructure lag far behind investments in production, where there is a much quicker return on investment to be made. The point of the Goldman Sachs scenario analyses was to illustrate the economic consequences of failure to capture the full value of natural gas production, if longer term demand side investments do not occur. In the chart below, Goldman Sachs sets out the "status quo" public policy scenario for Canada, the implication being that under current policies natural gas production will continue to outstrip domestic consumption.

Figure 3.1 Canada: Natural Gas Market



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3.1.2 Plausible Scenarios for Unconventional Gas Development in Nova Scotia

Although it is outside the remit of our panel to develop formal scenarios for the Government of Nova Scotia on energy futures for the Province, we have decided to embrace the logic of scenario planning to describe four possible trajectories or "plausible scenarios" for unconventional gas and oil development, should it ever be pursued. This is important because the range of potential trajectories is so wide: from zero development, to the highest estimate of potential resource development identified in Chapter 2. We believe we need to offer Nova Scotians some realistic scenarios within which to consider the possible scale of impacts that may be involved.

So, based on the evidence we presented in Chapter 2, we have developed four plausible scenarios that we offer for consideration for potential unconventional gas and oil development in Nova Scotia. These are designed to span the range of foreseeable exploration and development trajectories and form the basis for describing a realistic range of potential economic outcomes in this chapter, as well as the scale of possible human health, environmental (including water), and community impacts that we address in later chapters.

Because the petroleum geology of Nova Scotia basins is not well constrained, our four scenarios are rather generic in nature and we focus primarily on unconventional gas potential. While unconventional gas and oil development is a clear possibility, it is included only in the highest estimate scenario (maximum production). No estimates are made for coalbed methane (CBM), as projected volumes are small, relative to those in unconventional gas and oil wells and tight sandstones/carbonates.

In developing our scenarios we have made the following somewhat conservative assumptions:

- If the appropriate drilling and completions technology is developed to produce hydrocarbons economically in any particular basin, then development will take place throughout the basin (subject of course to suitable impact studies and regulatory approvals). In other words, there will either be a lot of development or none at all in each basin. The "none at all" case would likely entail the drilling of several wells, testing different drilling/completion methods, but with no significant production.
- Building on the only quantified resource estimate we have – 69 TCF in the Horton Bluff shale in the Windsor-Kennetcook Basin, we assume a total potential in place resource base of 100 TCF in all unconventional reservoirs in each major basin or group of basins.

  - Cumberland
  - Windsor-Kennetcook
  - Shubenacadie / Musquodoboit
  - St. Mary's
  - Stellarton / Debert-Kemptown / Minas
  - Antigonish
  - Cape Breton basins

- Oil production at Stoney Creek (New Brunswick) and conventional oil prospectivity tabulated in the Maritimes Basin, dictate that some oil potential must be considered. We assume that in the maximum development case, one oil-bearing unconventional reservoir in one basin, containing an in-place resource of 1000 MMBO, is developed.
- We assume a 10 per cent recovery factor for gas and 5 per cent for oil. Thus, the potential recoverable resource is 10 TCF gas in each basin successfully developed and 50 MMBO in the single oil development.
- Based on projected reservoir depths in the 2,000-3,000 metre range, we estimate ultimate recoverable reserves of 2.5 BCF/well – thereby requiring 4,000 wells to recover the 10 TCF resource. These wells would likely be grouped in clusters of 6-10 wells per pad, meaning that in a 4,000 well development over 40 years, there would be an average of 10-15 pads established per annum, with an average of 100 wells drilled and fractured per annum over that time frame.
    - We have designed our economic analysis around wells fitting these specifications – but it is important to note that many unconventional plays currently being pursued in Canada (particularly the Montney Formation in Alberta and B.C.), demonstrate larger recovery volumes and require relatively small hydraulic fracture stimulation, thereby reducing well costs and improving economics.
- We do not have a good basis for estimating associated condensate production. As marine source rocks should yield significant liquids, one could assume a ratio of 20-30 barrels of condensate per million cubic feet (mmcf) of gas produced.
    - Such condensate ratios would greatly improve the economics (and therefore the royalties paid) of wells drilled under our various scenarios, because of the relatively high prices paid for liquids in the current markets. Most unconventional plays currently under development in North America are focused toward maximizing recoveries of hydrocarbon liquids.
- Recoverable reserves per well for oil are even less quantifiable. A 200 MBO/well would necessitate drilling 250 wells to capture the 50 MMBO recoverable resource. Given these assumptions, our four plausible scenarios for consideration are:

1. ZERO CASE: No commercial development established in any basin i.e. no production
2. LOWER/MEDIUM CASE: One basin - fully developed
    - 10 TCF recoverable resource, plus condensate
    - 4,000 wells
    - All within one basin outline – most likely Windsor-Kennetcook or Cumberland
3. UPPER/MEDIUM CASE: Three basins fully developed
    - 30 TCF recoverable (plus condensate), 4,000 wells in each (total 12,000 wells)
    - Cumberland, Windsor-Kennetcook, and Stellarton/Debert-Kemptown/Minas
4. MAXIMUM CASE: Five basins successfully developed for gas, one for oil
    - 50 TCF recoverable, 4,000 wells in the five gas-bearing basins (total 20,000 wells)
    - 50 MMBO recoverable, 250 wells in the oil-bearing basin

Both Scenario 1 and Scenario 4 are extreme cases and are our least plausible scenarios. Based on the conclusions of our resources assessment paper, we believe Scenarios 2 and 3 to be the most likely outcomes if hydraulic fracturing was ever to be pursued in Nova Scotia - subject of course to economic feasibility, community assent, environmental and health impact assessments, and regulatory approval.

3.2 | Petroleum Operations Costs and Opportunities in Nova Scotia

The technical information in this section is derived from published materials, with cost and local content estimates for conducting the various hydrocarbon activities based on information obtained directly from industry sources in Atlantic Canada and elsewhere in North America. Providing even a rough guide to what onshore petroleum exploration and development could mean for Nova Scotia requires a range of assumptions, given the limited onshore activity in the Province, as noted in Chapter 2. Accordingly, the reader is cautioned that the activity and associated cost and content estimates are highly speculative and should at best be considered indicative, rather than definitive, of what could occur if this activity were ever to be pursued in Nova Scotia.

3.2.1 Exploration

3.2.1.1 Obtaining Exploration Rights

The first step in conducting an exploration program is to acquire exploration rights. Hydrocarbons, in or under Nova Scotia lands, are normally considered to be owned by the Crown, so rights to explore must be obtained from the Province regardless of whether they are on Crown land or land owned privately (permission from the landowner is required to enter private land). See also Chapter 9, where we describe regulatory issues in greater detail. The Department of Energy (DOE) issues and manages rights under the Petroleum Resources Act and Regulations (2013). The process of acquiring exploration rights involves the following:

- A petroleum company nominates the parcel(s) of land it wishes to explore.
- DOE issues in the Royal Gazette and media a competitive Call for Exploration Proposals for the parcel(s nominated.
- Companies interested in the land have 60 days to submit a bid specifying their work commitment (activity and expenditures) and information related to experience and technical/financial capability.
- The company meeting the criteria and submitting the best proposal would be awarded an exclusive
  right to explore through an Exploration Agreement (EA), a contract between the company and the Minister of Energy.

The EA is typically for an initial period of three years, during which time the company must drill at least one well. Two renewals of three years are available, provided the company continues to explore. The land reverts to the Crown at the end of the EA period, or if terms and conditions of the EA are not met.

- If hydrocarbons are discovered in commercial quantities, a Production Agreement (PA or lease) may be issued on submission of a satisfactory development program. The lease is typically for 10 years, with renewals on agreed terms and conditions.

- Prior to carrying out any work under the EA and PA, the company would have to complete any required environmental impact assessments. Also, as part of the process, consultation and accommodation of First Nations may be necessary at various stages.

3.2.1.2 Identifying the Hydrocarbon Resource

As noted in Chapter 2, hydrocarbons are trapped in geological structures far beneath the surface. Surface features of the land provide indications that an area might hold potential, but it is only through detailed analysis of sub-surface conditions that potential structures can be identified. This analysis, typically costing $1-2 million, is carried out by integrating several types of information:

- Geological: petroleum geologists conduct field surveys, examining surface features and rock formations, possibly taking core samples of rock, interpreting the data to determine the types of rocks that may be present at depth, and mapping the area.
- Geochemical: geochemists collect rock and core samples, subjecting these to laboratory tests to determine the potential of source rock to generate petroleum.
- Geophysical: geophysicists conduct seismic and magnetic surveys to create 3D images of sub-surface structures to identify potential hydrocarbon traps and reservoirs. The size, thickness, and characteristics (porosity and permeability) of the reservoir rock are estimated in order to determine the hydrocarbon volume (reserves) in place. The analysis would also determine the type of hydrocarbon present (natural gas and/or oil).

Depending on the location and complexity of the geology, it could take several months to several years to complete geological and geophysical assessments. Conducting the seismic survey tends to be one of the more costly aspects of the work, requiring specialized companies (and individuals) with substantial investments in equipment and technical expertise. A seismic survey is conducted using “vibroseis” trucks (Figure 3.2), often complemented by other means. Wherever possible, trucks operate on existing roads, but can operate off-road if necessary, with the permission of landowners.

Vibroseis trucks have heavy metal plates installed underneath and operate by lowering these plates and vibrating simultaneously for a few seconds, emitting sound waves over a range of frequencies. This is repeated at regular intervals several hundred times during a typical day. These sound waves are picked up by small microphones “geophones” set out along pre-determined seismic lines. Cables linking the geophones carry the signal to a recording truck that measures the sound waves. The data are sent to a computer centre for processing, resulting ultimately in images of the subsurface geological structure.

Figure 3.2 Vibroseis Trucks

Reproduced with permission Ronald Clowes, University of British Columbia

3.2.1.3 Drilling the Exploration Well

If the geological analysis identifies a potential hydrocarbon bearing structure, then the next step is to determine the best location to drill an exploration well. It is only by drilling a well that a petroleum company can confirm a structure's content. Further wells may be needed to determine the size of the reservoir. Consultations with First Nations are almost certainly required at this stage. See Chapter 11 for a discussion of Aboriginal and Treaty rights and title.

Nova Scotia is very much a "frontier" jurisdiction with respect to land-based petroleum exploration, with fewer than 30 wells drilled in the past decade. Consequently, the equipment needed would not ordinarily be available locally, at least not in the early days of exploration. Once the petroleum company selects a drilling contractor, the drilling rig and associated equipment would likely be brought in from Western Canada (where hundreds of rigs are available), or possibly the U.S. Mobilizing and de-mobilizing a rig is a major operation involving over 50 transport trucks and costing several hundred thousand dollars.

The exploration drilling contractor could be hired either on a turnkey basis, or cost per day or per metre drilled. A turnkey approach with a fixed price for the well is common where the geology is well known and the contractor is familiar with the area. The contractor would be responsible for hiring the sub-contractors who provide the various goods and services needed to complete the well. The cost per day/metre approach would be more common in frontier areas, where less is known about the geology and contractors would be reluctant to take on the risk of a fixed price contract. In such cases, the petroleum company is more likely to act as the general contractor and hire the sub-contractors.

Once a site for a well is determined, environmental and safety assessments conducted, and all approvals received, the land is cleared and a pad is constructed for the drilling rig and associated equipment and facilities (generator, pump house, trailers, and various storage tanks). A typical drill site is shown in Figure 3.3.

Depending on the depth of the hydrocarbon bearing structure, the well could take 3-5 weeks to drill. Drilling is a 24-hour, seven day a week operation. It starts with drilling a starter hole and installing conductor pipe or surface casing, and then bolting or welding a wellhead/blowout preventer to the casing. The drill bit, collar, and a section of drill pipe are lowered into the hole and connected to the rig assembly. A rotary table turns the drill pipe and bit, causing it to penetrate the earth. Successive sections of drill pipe are threaded to the string until the desired depth is reached. Drilling mud is pumped through the drill pipe to lubricate the wellbore, to float rock cuttings out of the hole, and also to add weight to counteract any reservoir pressure. The rock cuttings are tested to determine when reservoir rock is reached. The formation is assessed using logging techniques (data gathering) as the drilling progresses.

If the initial geological assessment (or experience) suggests the hydrocarbons are located in flat reservoirs characterized by low natural permeability, then the eventual drilling strategy would rely on a combination of horizontal drilling and hydraulic fracturing. Advances in drilling technology and the use of rotary steerable bits in particular, make it possible to deviate from the initial vertical wellbore and drill horizontally a kilometre or more. Penetrating a flat reservoir horizontally, greatly increases the effective area that a well is able to reach, thereby increasing its potential productivity.

At various stages of drilling, the integrity of the well is maintained by running strings of casing (steel pipe) and cementing them in place. The final stage consists of running production casing the length of the wellbore and cementing it in place. Casing serves the dual purpose of stabilizing the wellbore and creating a pressure barrier designed to keep hydrocarbons inside the well tubulars (and water outside). Proper design, construction, and testing of the casing are critical to well integrity and preventing a potential source of groundwater contamination. See Chapter 7 for a full discussion of Well Integrity.

Figure 3.3 Corridor Resources Drill Site near Sussex New Brunswick

Courtesy of Corridor Resources

As noted above, if the first well produces results that eventually justify commercial development, the usual practice would be to directionally drill, i.e. up to ten wells from a single pad. Not only does this extend the reach into different parts of the reservoir and optimize hydrocarbon recovery, it minimizes the footprint of surface activity and reduces drilling costs. Pads vary in area, but are typically in the range of one hectare. Drilling multiple wells is simply a matter of "skidding" the rig to its new location on the pad and repeating the process described above.

Drilling for hydrocarbons involves a combination of highly technical activities carried out by specialized companies. Typically, as many as 70 or so individuals employed by about 20 sub-contractors are required. The drilling crew usually consists of two crews of six, plus two supervisors. Sub-contractors include companies with expertise in mud logging, wireline logging, directional drilling, casing, cementing, perforating, fishing, flow testing, transportation, construction, repair and maintenance, and catering. Nova Scotians could fill many of the jobs based on their experience offshore, in Western Canada, the U.S., and abroad.

3.2.1.4 Hydraulic Fracturing

Once the wells have been cased and cemented, the pad is cleared of the drilling rig and associated equipment to make way for the hydraulic fracturing equipment needed to complete the well. Technical aspects of hydraulic fracturing were described in detail in Chapter 1. Hydraulic fracturing operations are conducted by highly specialized contractors using a suite of equipment designed specifically for this purpose. With limited demand for services and the high cost of equipment, there are no hydraulic fracturing contractors in Eastern Canada, so equipment would need to be brought in from Western Canada, or possibly the U.S (HF contractors might eventually locate in the Atlantic Provinces if demand for services justified the investment). A hydraulic fracturing operation would see several trucks fitted with powerful high-pressure, high-volume pumps connected to the well(s) with high pressure hoses; a slurry blender (for mixing the fracturing fluid and proppant, usually sand or ceramic particles of varying size); various storage tanks for fracturing fluids and proppant; and a monitoring unit. A typical hydraulic fracturing "spread" is depicted in Figure 3.4.

Figure 3.4 Hydraulic Fracturing Operation - Equipment and Layout

Courtesy of the Canadian Society for Unconventional Gas

As described in Chapter 1, hydraulic fracturing requires significant volumes of water. The water is typically obtained from nearby lakes or rivers, or from municipal water supplies and transported to the well site by tanker trucks. This process can involve 40-60 tanker movements per day to and from the site, over a 2-3 week period. Increased traffic on local roads resulting in higher road maintenance costs, congestion, and greater risk of accidents were among concerns expressed by stakeholders in our review and are addressed briefly in this chapter and in more detail in Chapters 5 (Socio-Economic Effects) and 8 (Public Participatory

Risk Assessment). On the economic benefit side, trucking activities represent an economic opportunity for local contractors.

Wells with long horizontal sections in the reservoir would be fractured in stages, starting at the end of the wellbore. Each stage of 100 m or so would be isolated from the rest of the well with a cement plug. A perforating tool would be used to create openings in the casing and cement in that stage and then the fracturing job begins. The fracturing fluid is pumped at high pressure (up to 100 megapascals or 15,000 psi, reaching up to 265 litres/sec) for 20 minutes to a few hours, depending on the rock properties and the properties of the fluid and proppant. When that stage is complete, it is plugged and the process moves to the next section, until the length of the well formation in the reservoir has been completed. The entire hydraulic fracturing operation may take 2-3 weeks.

At this point, the plugs would be drilled out and a short flow test of the well may be performed to evaluate its productive capacity. The final steps would be to remove the blowout preventer from the wellhead and replace it with a "Christmas Tree"– an assembly of valves and fittings used to control flow from the well and install production tubing inside the casing. Tubing protects the casing from corrosion and provides an efficient flow conduit for hydrocarbons. The wells would then be ready for production – to be tied into a gas plant (using small diameter gathering lines) for processing and shipment via pipeline.

Depending on the absorptive capacity of the reservoir into which the fracturing fluids have been pumped, a percentage of the fluid will flow back out of the well when the pressure is released (known as "flowback"). Most of this flowback occurs in the early stages of production and is stored in tanks or pits onsite. Flowback water can be re-used in subsequent hydraulic fracturing operations, though this would depend on its composition (suitability) and the economics of other management alternatives i.e. treatment and disposal (King, 2012).

3.2.2 Development and Production

Since exploration began in Nova Scotia over 135 years ago, some 125 wells have been drilled without a significant discovery (Nova Scotia Department of Energy, 2012). This is typical of frontier areas. It can take many years and considerable seismic exploration and drilling before the geology of a region is understood. Even after an initial discovery, it could be many years, if ever, before sufficient reserves are proved to justify commercial development. Our Nova Scotia offshore experience serves as a good example. Twenty years of exploration (1959-1979) occurred before natural gas was discovered in commercial quantities near Sable Island. It took almost 20 years of further assessment before the decision was taken to develop the Sable field. Field development took two years, with production beginning in late 1999.

In the case of onshore exploration and development, the experience of Corridor Resources in New Brunswick offers the only example in the region. Following geological assessment in the 1990s that identified hydrocarbon potential, Corridor drilled an initial exploratory well near Sussex in 2000 that confirmed the potential. Over the next several years, further drilling led to the discovery of sufficient reserves to justify field development. By mid-2007, Corridor had built a gas processing plant (Figure 3.5) and gathering system tying in these wells and linking its facilities via a 50 km lateral line to the Maritimes & Northeast Pipeline (M&NP) system. Today, Corridor has 29 producing wells on 10 well pads and is continuing its exploration and development work.

Figure 3.5 Natural Gas Processing Plant

Courtesy of Corridor Resources

As noted in Chapter 2, it is premature to say whether commercial quantities of natural gas or oil exist in onshore areas in Nova Scotia, but if land-based exploration were to lead to natural gas discoveries with commercial potential, then it is reasonable to expect that development and production might follow a similar pattern to New Brunswick:

- Geological assessment leading to identification of areas of hydrocarbon potential;
- Drilling and testing an exploration well if the geological assessments were favourable;
- Drilling and testing further wells, possibly over a period of years, if the initial well provided encouraging results;
- Determining the size of the recoverable reserves and conducting preliminary planning work for production wells (number, location, timing) and ancillary production facilities to develop the field (including gathering lines, gas plant, and link to a pipeline or to industrial customers/local distribution companies);
- Determining whether the discovery offers commercial potential (estimating and comparing development and operating costs with projected revenues based on production levels and market price forecasts);

- If the project economics are favourable, meeting all pre-project regulatory and legal requirements (conducting consultations with First Nations and communities, carrying out environmental and socio-economic impact assessments), preparing a development plan and filing it with the regulator, securing financing, and developing a project implementation plan (detailed development plan, procurement strategy, hiring contractors, etc.), and implementing the project;
- Abandonment: carrying out abandonment activities would typically cost in the range of $175-200,000 per well. Local contractors would carry out this work.
- Operating the project, including drilling new wells and bringing them into production as existing wells are depleted;
- Implementing abandonment and reclamation work according to regulation once wells have reached the end of their productive lives. This involves removing gathering lines and all surface equipment (the wellhead), removing surface casing, capping the well by filling it with cement, and restoring the land to its pre-development state. Monitoring requirements are typically prescribed in regulations.

3.2.3 Petroleum Development Costs and Benefits – Industry Perspective

The economics of petroleum exploration and development are challenging, given the level of expenditures required, in the light of uncertainties surrounding such factors as resource, market, technology, environment, and financing. Costs rise at each stage in the process, while revenues (and significant economic benefits) could be years away. Tens or hundreds of millions of dollars could be spent before a discovery is made, if one is made at all. If hydrocarbons are found, then from the petroleum company's perspective, it comes down to whether the recoverable reserves are high enough and long-term market conditions favourable enough, to generate sufficient revenues to justify the further costs needed to develop and operate the field.

Using a mimimum viable development example based on 50 wells, Table 3.1 provides an indication of the scale of the costs of each phase of activity, moving through the process from geological assessment to production. Using industry data, approximate costs by activity are presented in detail for drilling and fracturing a single well. This provides a basis for identifying and quantifying local spending and associated sub-contracting and employment opportunities.

An estimate of the capital and operating costs for what might be considered a minimally attractive development is also provided in Table 3.1, to give a sense of scale. This estimate requires assumptions to be made about the size of recoverable reserves in a discovery, likely production rates per well, the number and layout of wells needed, the size of the plant needed to process the gas (assuming a natural gas discovery), the length of gathering lines to tie the wells to the gas plant, and the size and length of the pipeline linking the gas plant to the main transmission line or distribution system.

By applying industry standard percentage estimates of local participation to expenditures, it is possible to derive an approximate estimate of the work that could be carried out by Nova Scotian contractors and individuals (this is referred to as local content). To summarize:

- Assessing resource potential: local consultants would be expected to provide support services, but the scientific expertise for much of this work resides mainly in Western Canada, where most of the petroleum exploration and production takes place. Unless and until an industry develops in Nova Scotia, local content would be confined to support services. Content is estimated at 25-30 per cent of the $1.0-2.0 million needed to conduct the geological and geophysical assessment.

- Exploration Drilling: many Nova Scotian companies and individuals have capabilities and experience based on offshore work and work in Western Canada, placing them in a good position to supply early stage environmental assessment, First Nations Traditional Ecological Knowledge (TEK) consultations, and site development, as well as various drilling support services. The more technical and higher cost inputs would be imported to the Province (drilling rig, directional drilling services, drill bits, casing). Local content is estimated at 30-35 per cent of the $5.0-6.0 million needed to drill an exploration well. Content would be expected to increase over time if exploration leads to discoveries and development. Drilling contractors and service companies would set up in the Province as demand increased.

- Hydraulic fracturing: whereas several individual sub-contractors provide the technical services required for drilling, hydraulic fracturing services are supplied by a limited number of companies with substantial investments in equipment and expertise and form a major sub-contract in their own right. Established companies from Western Canada (or possibly the U.S.) would perform the work in Nova Scotia. Local content is estimated at 20-25 per cent of the $3.0-3.5 million needed to hydraulically fracture a well (below 20 per cent if propane were to be used instead of water as the fracturing fluid).

- Development: moving beyond a single discovery well to a full field development, assumes on-going drilling success over a period of years, such that a minimum economic volume of recoverable reserves is found that is likely to generate an adequate return on the investment in the production facilities needed to process the gas and carry it to market. Based on the assumptions in Table 3.1, this investment could range between $500-600 million for a 50-well development, of which 35-40 per cent could represent Nova Scotia content. Drilling the assumed 50 wells needed for development forms a major component of this investment. The higher content during development is attributable to higher levels of participation in drilling development wells and in construction activities related to the gas plant (assumed capacity of 40-50 MMcf/day), gathering lines and transmission line lateral. Between 715 and 1,080 full-time equivalent jobs would be created during the assumed 4-5 year initial development phase. The variation is due to uncertainty over the length of time it might take to drill and frac a well (2 or 3 months).

- Production: unconventional gas wells experience more rapid declines in production than conventional wells, though what this means in terms of the overall productive life of a well is unclear because of limited experience. A field development strategy would anticipate the need for on-going drilling to replace production as wells were depleted. The costs in Table 3.1 make no assumption about the overall duration of production, simply providing an annual operating cost estimate of $5-6 million annually based on a 50-well development. The 25-35 personnel and

Table 3.1 Shale gas drilling and hydraulic fracturing activities and cost estimates

Phase/Activity	Cost ($000)	Source of supply: Nova Scotia			Other Canada	% US
		%	$000s	Jobs (FTE)		
Assess resource potential	**1,000-**		**350-**		**650**	
Duration: 8-12 months	**2,000**		**500**	**1-2**	**1,500**	
Permitting & lease agreements	25	1.00	25			
Environmental survey & approvals	50	1.00	50			
Geological survey/analysis	1,500	0.25	375		0.75	
Exploration well	**5,000-**		**1,500-**		**3,000-**	**500-**
Duration: 1-2 months	**6,000**		**1,900**	**2-3**	**3,500**	**600**
Site planning & construction	150	1.00	150			
Drill rig mobilization	500	0.40	200		0.60	
Drill rig operations	1,250	0.00	0		1.00	
Directional drilling services	550	0.00	0		1.00	
Supervision	350	1.00	350			
Wellhead	100	0.00	0		1.00	
Drilling fluids	400	0.50	200		0.50	
Logging services	250	0.30	75		0.70	
Casing (pipe and installation)	750	0.05	38		0.25	0.70
Cementing	200	0.60	120		0.40	
Drill bits	200	0.00	0		1.00	
Fuel	250	1.00	250			
Fluid & cutting disposal	225	1.00	225			
Equipment rental & services	425	0.50	213		0.50	
Hydraulic fracturing (2/well)	**3,000-**		**900**		**2,100-**	
Duration: <1 month	**3,500**		**1,100**	**1-2**	**2,400**	
Equipment mobilization & set-up	500	0.40	200		0.60	
Stimulation services	1,250	0.00	0		1.00	
Propane & sand supply/transport (option)	500	0.00	0		1.00	
Water & sand supply/transport (option)	500	1.00	500		0.00	
Coiled tubing services	225	0.00	0		1.00	
Monitoring & control services	200	0.00	0		1.00	
Well test & flowback recovery	300	0.70	210		0.30	
Security & fire protection	50	1.00	50		0.00	
Equipment rental & services	50	1.00	50		0.00	
Development (50 wells@5 wells/pad)	**500,000-**		**200,000-**	**715-**	**300,000-**	
Duration: 2-3 months/well	**600,000**		**250,000**	**1,080**	**350,000**	
Drill/frac production wells ($8MM/well)	400,000	0.30	120,000	625-920	0.70	
Build gas plant	35,000	0.60	21,000	50-100	0.40	
Install flowlines and lateral (100km@$1MM/km)	100,000	0.50	50,000	35-50	0.50	
Land restoration	3,000	1.00	3,000	5-10	0.00	
Production (operations)	**5,000-**		**5,000**			
Duration: 10-20 years (annual cost/personnel)	**6,000**		**6,000**	**25-35**		
Personnel	1,500	1.00	1,500	20-25		
Operations & Maintenance	3,500	1.00	3,500	5-10		
Property taxes	500	1.00	500			
Abandonment (50 wells)	**8,000-**		**8,000-**			
Duration: <month	**10,000**		**10,000**	**3-4**		
Services	5,000	1.00	5,000			
Land prep & restoration	4,000	1.00	4,000			

1. Phase totals expressed in ranges to reflect uncertainty; activities expressed as point estimates to simplify content estimation.
Source: various industry sources.

services needed during operations would be sourced in Nova Scotia. In addition, under the terms of the production agreement, the Province would receive royalties based on a percentage of the fair market value of gas produced each month.

3.2.4 Petroleum Development Impacts – A Community Perspective

3.2.4.1 Risk Factors and Potential Costs

Completing wells using hydraulic fracturing techniques is controversial because of the actual and perceived risks posed. Among the costs to the petroleum company is the acquisition of large-scale insurance coverage and/or bonding, to meet regulatory requirements regarding unforeseen incidents. Though hydraulic fracturing would be subject to regulation in Nova Scotia (see Chapter 9), including requirements for petroleum companies to take measures to address factors contributing to risk, many submissions to our review panel indicate clearly that public concern exists about the potential for hydraulic fracturing to result in significant and even irreparable environmental and/or social costs (see Chapters 5 and 8).

Among the concerns highlighted in submissions to our review and also in the literature concerning hydraulic fracturing experience in other areas of North America that have economic implications are the following (Clark et al, 2012):

- Water requirements: most hydraulic fracturing operations require substantial quantities of water. Water requirements can range up to 20 million litres per well and are usually obtained locally from lakes, rivers or municipal systems. Though amounts used per well may be small in comparison with other uses or in relation to overall supply (in Nova Scotia volumes are regulated), volumes used for hydraulic fracturing are nonetheless a matter of public concern. To address this concern and also because in many cases it makes economic sense (i.e. it is cheaper than disposal/treatment), companies are increasingly recycling flowback water for use in further hydraulic fracturing operations. Industry is also using propane or liquefied petroleum gas (LPG) instead of water as the hydraulic fracturing fluid (in gel form). After fracturing, the LPG becomes a vapour under pressure, returning to the surface with the natural gas where it is recaptured. See Chapter 6 for a detailed discussion of water impacts.
- Transportation and roads: related to the volume of water, are concerns about the method of transportation – typically by tanker truck – and the implications for traffic levels, safety, and road conditions. These implications vary from location to location depending on the distance between drill sites and water sources and on the types of roads travelled. Local roads in rural areas tend not to be designed to withstand the stresses imposed by heavy truck traffic. That the community would bear the costs of repair is a matter of public concern. Traffic congestion, safety risks, additional road noise, and dust are also matters of public concern. Some of these potential adverse consequences can be reduced or eliminated through traffic management and with respect to road damage, by establishing a compensatory framework requiring petroleum companies to pay their share of repair costs (See Chapters 5 and 8 for more discussion on these points).

- Chemical ingredients: chemical ingredients typically account for about 1 per cent by volume of the hydraulic fracturing fluid. Specifics about which chemicals and at what concentrations, have been matters of public concern, specifically with respect to the risk of toxicity and effects on groundwater.
  The unwillingness of some companies to reveal ingredient details (where not required to by regulation) has served to heighten concern. Full disclosure is required by regulators in some provinces, while in others (including Nova Scotia), companies must provide the information at the request of the regulator. We discuss this issue in more detail in Chapter 4 (Public Health), Chapter 6 (Water Impacts) and Chapter 9 (General Regulatory Issues).
- Storage/treatment of chemicals and flowback water: chemicals are stored onsite before blending with water and flowback water is stored onsite before disposal/treatment (or recycling). The concern is about improper storage, with the risk of leaks and contamination of soil, surface water, and groundwater. Where possible, flowback water is re-cycled for use in other hydraulic fracturing operations. It may also be injected into disposal wells, assuming the rock formation is suitable. We discuss this issue in more detail in Chapter 4 (Public Health) and Chapter 6 (Water Impacts). Issues of well integrity are discussed in Chapter 7.
- Effects on drinking water: this is one of the greatest concerns expressed by stakeholders, resulting in part from uncertainty about how hydraulic fracturing works and the nature and security of the safeguards in place (casing and cementing), and in part from reports of drinking water contamination in areas where hydraulic fracturing operations are taking place (whether resulting from hydraulic fracturing or other factors). If contamination was to occur, the fear is that it would impose costs arising from impaired health, the need to secure alternative water sources for those affected, and also from remediation efforts. We discuss this issue in more detail in Chapter 4 (Public Health) and Chapter 6 (Water Impacts). Issues of well integrity are discussed in Chapter 7.

Quantifying any possible costs that could arise from these risk factors is impossible, without reliable information on the probability of a triggering event and the dollar value of any resulting damage. Such information is not available for Nova Scotia, because the limited drilling and hydraulic fracturing that have occurred do not provide an adequate statistical basis for computing probabilities and nor is there information on any environmental costs related to this experience. But even on the much larger scale of activities elsewhere in Canada and in the U.S., the data needed to reliably assess environmental impacts is not available. As the recent report of the Council of Canadian Academies (2014) concludes, "While tens of thousands of shale gas wells have been drilled across North America over the last two decades…there has been no comprehensive investment in the research and monitoring of environmental impacts."

3.2.4.2 Benefits

The expenditures set out in Table 3.1 represent potential benefits when viewed from the perspective of the community. This is because they create opportunities for local suppliers of goods and services, who in turn

generate employment and income. Like other industrial activities, these direct expenditures lead to demand elsewhere in the economy, creating the spinoff effects contributing to economic growth.
Our experience in Nova Scotia with the benefits associated with hydrocarbon development is based on 50 years of offshore activity, including the drilling of some 225 exploration and development wells and the implementation of one oil project (Cohasset-Panuke) and two natural gas projects (Sable and Deep Panuke). Industry in the Province has benefitted from these projects through the supply of goods and services during field development and production. Overall, project expenditures have run to the billions of dollars (Canada-Nova Scotia Offshore Petroleum Board, 2013).

Projects exhibit a characteristic pattern of 2-3 years of intense development activity (high capital investment and employment), followed by several years of stable operations (relatively low levels of spending and employment). Over the years, these projects have created employment for thousands of workers in Nova Scotia, providing them with valuable and highly portable skills and experience. Access to natural gas has contributed to a more diversified energy portfolio in the Province. The Province has also benefitted from royalty payments in the $1.5-2.0 billion range.

Any potential future onshore hydrocarbon exploration and development in Nova Scotia would share some of these characteristics, but would differ greatly in terms of scale. Onshore activity has the characteristic expenditure profile associated with capital intensive industries: a period of high demand for contractors, sub-contractors and their employees during initial field development (4-5 years), followed by several years of production featuring relatively low, but steady expenditure and employment. This pattern is evident in the figures in Table 3.1, which suggest annual spending exceeding $100 million during the few years of a 50 well minimum development and then dropping to the $10 million range annually during production. The experience in Western Canada with conventional natural gas, shows that as discoveries continue to be made and the industry matures, this spending pattern tends to become less evident because of the continual flow of projects. In the case of our lower medium case scenario the annual spending over a 40 year development cycle (averaging 100 wells per year) would range between $1.0 and 1.2 billion (essentially doubling the amounts in Table 1). The same proportional increase holds for employment since it is directly linked to the number of wells drilled and fractured, and to the number of wells in production. Taking the lower end of the range shown in Table 1, total employment (expressed in full-time equivalent jobs) would double from 740 to 1,480 per year.

This chapter does not take the question of economic impact beyond the stage of direct expenditures for a single development set out in Table 3.1 and its extrapolation to a 4,000 well development over 40 years. The impacts would be larger and extend more deeply into the economy should an unconventional gas and oil gas industry actually develop. A study of the economic impact of unconventional gas and oil development in Québec offers some guidance on the nature and scale of impacts in a frontier area, though it is purely speculative in nature (Canadian Energy Research Institute, 2013). We could look to Alberta and British Columbia for some insights into what development could mean in terms of economic impact, though even in those provinces, development is still at a fairly early stage.

Looking to the experience in jurisdictions outside Canada where development is more advanced, may be helpful in understanding the economic impacts. For example, much has been written about the impacts arising from the Marcellus and Barnett developments in the U.S. (Center for Business and Economic Research of the University of Arkansas, 2008). Indeed, studies of these developments tend to play an important role in informing public perceptions about the pros and cons of unconventional gas and oil exploitation. But readers of these various studies should be cautioned about two things: first, the U.S. experience springs from a particular set of rules governing resource exploitation (ownership of sub-surface rights and industry regulation); and second, the analysts are not always as objective or thorough as we would like them to be.

Directly related to the rules governing resource exploitation in the U.S. is the concern that unconventional gas and oil is prone to a boom-bust cycle of development characterized by periods of intense activity when the drilling and related developments take place, followed by a sharp decline in activity (employment) once production begins. This phenomenon is discussed in detail in Chapter 5. Though the increase in economic activity has its positive aspects, there are negative ones as well. These include a rise in administrative and service costs as communities deal with more intensive use of infrastructure and an influx of workers and adverse economic effects as rising demands for goods and services "crowd out" existing businesses.

Central to the rapid and seemingly uncontrolled pace of development in the U.S., is the ownership of subsurface rights where the unconventional gas is found. The decision to allow exploration and exploitation in the U.S. rests largely with landowners, who own the subsurface rights. By contrast, in Canada, subsurface rights are normally assumed to belong to the Crown. This provides provincial governments, through the regulatory process (issuing exploration licences), with a means of controlling the pace of development. Controlling the pace of development, in turn, provides an important mechanism for mitigating many of the potential adverse economic consequences that could arise.

3.3 | **Royalties**

3.3.1 The Nova Scotia Royalty Regime

Royalty payments are among the benefits that could accrue to Nova Scotia if any onshore natural gas fields were developed. A royalty is a tax on the production of a natural resource. Another way of thinking of a royalty, is the price that a resource owner – in this case, the Government of Nova Scotia – charges for the right to develop the resource.

The royalty regime covering onshore hydrocarbons is set out in Regulations under Nova Scotia's Petroleum Resource Act. Part I (Sections 17 and 18) provides that, subject to stated exceptions pertaining to use in operations, all petroleum produced under the authority of a lease is subject to royalties. Part II, Sections 63 and 64, specifies the royalty rate at 10% of the fair market value of the petroleum that is produced each month. In the case of natural gas, the 10% is applied to the wellhead value after gathering and processing costs have been deducted. Payment of the royalty begins two years from the date a first lease is granted with respect to lands subject to an exploration agreement (in other words, the lease-holder would have a two-year tax holiday on the first production lease, but on any subsequent lease on lands within the exploration agreement, would pay royalties from the commencement of production).

It is important to note that royalties are based on the value of production measured at the wellhead and not on the profitability of a development. Wellhead value is determined simply by netting out specified operating costs from the value of the gas entering the pipeline. It excludes consideration of the capital costs to develop the field. These would be taken into consideration in determining taxes on corporate profits (a share of which would also accrue to the province).

3.3.2 Estimating Royalty Revenues

The size of any stream of royalty payments would depend on several key factors: the size of the resource and production levels over time, natural gas prices, pipeline costs to major markets, and the costs of gathering and processing the natural gas before it enters the pipeline system (or is sold directly to customers in local markets). Information on current prices and costs is available and various agencies make projections out to 2040 on how these variables may change. The key unknowns are the size of the resource and possible production levels.

The development scenarios described earlier in this chapter provide a basis for addressing the resource and production unknowns, allowing for the derivation of speculative estimates of royalty revenues. The assumptions used to create each scenario are summarized in Table 3.2. Scenario 2 (Lower Medium Case), for example, assumes a single basin with potential reserves of 100 trillion cubic feet (TCF) of natural gas. With a recovery rate of 10 per cent, this basin would produce 10 TCF. With each well assumed to produce 2.5 billion cubic feet (BCF), 4,000 wells would be required. These would be drilled over a development period of 40 years, with an average well life of 25 years.

Table 3.2 Nova Scotia Onshore Petroleum Development Scenarios

	Scenario			
	Zero	Lower Medium	Upper Medium	Maximum
Basins developed	-	1	3	5
Total potential reserves in place	-	100 TCF	300 TCF	500 TCF
Recovery factor	-	10%	10%	10%
Recoverable reserves/well	-	2.5 BCF	2.5 BCF	2.5 BCF
Recoverable reserves	-	10 TCF	30 TCF	50 TCF
Number of development wells	-	4,000	12,000	20,000
Development phase (years)	-	40	50	60

Under the Lower Medium Case and based on the values set out in Table 3.2, the Government of Nova Scotia could expect royalty revenues around $5.9 billion over the productive life of the development. As noted above, this royalty estimate is highly speculative, turning as it does on several key resource and market assumptions. These are explained below with reference to the columns in Table 3.3 (all values are in Canadian funds, assuming exchange rate parity with the U.S. dollar to simplify the analysis):

- Col. 1: 100 wells are drilled before production commences in year 5. Given the rapid depletion rate, 100-125 wells are drilled each year to sustain annual production levels at the design rate of processing and pipeline facilities.
- Col. 2: daily production (in Year 5 the 100 wells drilled are brought into production) is based on a starting rate of 6 million cubic feet (MMCF) per well, with 85 per cent of the reserves in each well produced by the end of year 1 (with a steady decline over the balance of well life). This rapid initial decline is characteristic of unconventional gas and oil wells (though decline rates vary depending on specific geological characteristics).
- Col. 3: annual production equals daily production times 365. For example, in Year 5 with 100 wells producing: 100 X (6 MMCF X.85) X 365 = 186,150 MMCF.
- Col. 4: Henry Hub (Louisiana) is one of the most commonly cited pricing points for natural gas deliveries in the U.S. pipeline system. For this reason, it is widely used as the basis for price projections. The projection in Col 4 is based on the U.S. Energy Information Administration, Annual Energy Outlook 2014.[2] The EIA projection provides price points for 2025, 2035 and 2040. Prices in other years are linear extrapolations or interpolations.
- Col. 5: Natural gas prices elsewhere in the U.S. are based on pipeline differentials from Henry Hub. The price differential on the pipeline system supplying the U.S. northeast (New England) has been in the $2.50/MCF range in the last year or so, so this amount is added to the Henry Hub price to arrive at the so-called City Gate price for Massachusetts (a proxy for New England, a major market for Nova Scotia natural gas). To simplify the analysis, this differential is held constant over the projection period. The differential could change over time in response to additions to pipeline capacity and changes in natural gas demand and supply in the region.

- Col. 6: this sets out the sum of Col 4 and 5, giving the market price of natural gas entering the distribution system in New England.
- Col. 7: the cost to deliver natural gas to the New England market is deducted from the Massachusetts City Gate price as a first step in deriving the wellhead price in Nova Scotia. The cost is the toll on the Maritimes and Northeast Pipeline, currently $1.245/MCF for the U.S. and Canadian portions of the line ($0.540 and $0.805/MCF, respectively).
- Col. 8: the final step in deriving the wellhead price is to deduct gathering and processing costs from the value of gas entering the M&NE system. An initial cost of $1.00/MCF dropping to $0.30/MCF over the life of field is used, based on typical costs experienced in Western Canada.
- Col. 9: the sum of Col. 7 and 8 is deducted from Col. 6 to derive the wellhead price used as the basis for computing royalty payable.
- Col. 10: this shows the total wellhead revenue, derived by multiplying annual production from Col. 3 by the wellhead price in Col. 9.
- Col. 11: gives the royalty payable each year, based on 10 per cent of the wellhead revenues shown in Col. 10. The analysis assumes this is the first production lease, so royalties are payable in the third year after the production lease commences.

Table 3.3 illustrates the royalty revenues generated by the hypothetical development of a 4,000 well natural gas basin. Using the same approach, royalty levels under the upper medium and extreme cases could reasonably be expected to be three and five times higher than the Table 3.3 result (possibly higher with the prospect of oil in the maximum Case).

It is worth noting that this analysis focuses on the derivation of royalties only. Royalties are linked directly to production, not to the profitability of a project or development. The results in Table 3.3 reflect nothing about whether it would make economic sense to carry out the development under the given resource and price assumptions.

Table 3.3 Derivation of Nova Scotia royalty payments under the Lower Medium Case

Year	Production			Market Price US Northeast			Nova Scotia wellhead revenue				NS Royalty
	Wells	Per day	Per year	Henry Hub (1)	Mass. City Gate diff. (2)	Total	M&NE toll	Gather & process (3)	Wellhead price	Revenue	10%
		MMCF	MMCF	$/mcf	$/mcf	$/mcf	$/mcf	$/mcf	$/mcf	$000s	$000s
	1	2	3	4	5	6	7	8	9	10	11
1	5	0	0	4.00	2.50	6.50	1.245	-	-	-	-
2	10	0	0	4.05	2.50	6.55	1.245	-	-	-	-
3	20	0	0	4.10	2.50	6.60	1.245	-	-	-	-
4	25	0	0	4.16	2.50	6.66	1.245	-	-	-	-
5	40	510	186,150	4.21	2.50	6.71	1.245	1.00	4.46	830,850	-
6	100	587	214,073	4.26	2.50	6.76	1.245	0.99	4.53	969,083	-
7	100	725	264,798	4.31	2.50	6.81	1.245	0.98	4.59	1,215,544	121,554
8	125	755	275,429	4.36	2.50	6.86	1.245	0.97	4.65	1,281,849	128,185
9	125	766	279,579	4.42	2.50	6.92	1.245	0.95	4.72	1,318,931	131,893
10	125	776	283,229	4.47	2.50	6.97	1.245	0.94	4.78	1,354,152	135,415
11	125	785	286,377	4.52	2.50	7.02	1.245	0.93	4.84	1,387,405	138,741
12	125	792	289,069	4.57	2.50	7.07	1.245	0.92	4.91	1,418,819	141,882
13	125	798	291,122	4.63	2.50	7.13	1.245	0.91	4.97	1,447,400	144,740
14	125	801	292,536	4.68	2.50	7.18	1.245	0.90	5.04	1,473,025	147,303
15	125	805	293,814	4.73	2.50	7.23	1.245	0.89	5.10	1,498,132	149,813
16	125	808	294,954	4.78	2.50	7.28	1.245	0.87	5.16	1,522,695	152,270
17	125	811	296,095	4.83	2.50	7.33	1.245	0.86	5.23	1,547,403	154,740
18	125	814	297,235	4.89	2.50	7.39	1.245	0.85	5.29	1,572,256	157,226
19	125	817	298,376	4.94	2.50	7.44	1.245	0.84	5.35	1,597,254	159,725
20	125	821	299,517	4.99	2.50	7.49	1.245	0.83	5.42	1,622,397	162,240
21	125	824	300,657	5.04	2.50	7.54	1.245	0.82	5.48	1,647,684	164,768
22	125	827	301,798	5.09	2.50	7.59	1.245	0.80	5.54	1,673,117	167,312
23	125	702	256,401	5.15	2.50	7.65	1.245	0.79	5.61	1,437,741	143,774
24	100	686	250,561	5.20	2.50	7.70	1.245	0.78	5.67	1,420,919	142,092
25	100	687	250,655	5.25	2.50	7.75	1.245	0.77	5.73	1,437,381	143,738
26	100	687	250,883	5.42	2.50	7.92	1.245	0.76	5.91	1,482,964	148,296
27	100	688	251,248	5.58	2.50	8.08	1.245	0.75	6.09	1,529,460	152,946
28	100	690	251,704	5.75	2.50	8.25	1.245	0.74	6.26	1,576,657	157,666
29	100	691	252,252	5.91	2.50	8.41	1.245	0.72	6.44	1,624,603	162,460
30	100	693	252,890	6.08	2.50	8.58	1.245	0.71	6.62	1,673,346	167,335
31	100	695	253,666	6.24	2.50	8.74	1.245	0.70	6.79	1,723,244	172,324
32	100	695	253,666	6.41	2.50	8.91	1.245	0.69	6.97	1,768,010	176,801
33	100	695	253,666	6.57	2.50	9.07	1.245	0.68	7.15	1,812,775	181,278
34	100	694	253,438	6.74	2.50	9.24	1.245	0.67	7.32	1,855,871	185,587
35	100	694	253,210	6.90	2.50	9.40	1.245	0.66	7.50	1,898,885	189,889
36	100	693	252,982	7.05	2.50	9.55	1.245	0.64	7.66	1,938,025	193,802
37	100	692	252,753	7.20	2.50	9.70	1.245	0.63	7.82	1,977,091	197,709
38	100	692	252,525	7.35	2.50	9.85	1.245	0.62	7.98	2,016,083	201,608
39	100	691	252,297	7.50	2.50	10.00	1.245	0.61	8.15	2,055,001	205,500
40	100	691	252,069	7.65	2.50	10.15	1.245	0.60	8.31	2,093,846	209,385
41		180	65,691	7.80	2.50	10.30	1.245	0.59	8.47	556,278	55,628
42		103	37,540	7.95	2.50	10.45	1.245	0.58	8.63	323,957	32,396
43		91	33,124	8.10	2.50	10.60	1.245	0.56	8.79	291,193	29,119
44		80	29,246	8.25	2.50	10.75	1.245	0.55	8.95	261,823	26,182
45		71	25,915	8.40	2.50	10.90	1.245	0.54	9.11	236,190	23,619
46		63	22,949	8.55	2.50	11.05	1.245	0.53	9.28	212,867	21,287
47		56	20,349	8.70	2.50	11.20	1.245	0.52	9.44	192,030	19,203
48		50	18,113	8.85	2.50	11.35	1.245	0.51	9.60	173,858	17,386
49		45	16,425	9.00	2.50	11.50	1.245	0.50	9.76	160,307	16,031
50		43	15,513	9.15	2.50	11.65	1.245	0.48	9.92	153,906	15,391
51		40	14,600	9.30	2.50	11.80	1.245	0.47	10.08	147,210	14,721
52		38	13,688	9.45	2.50	11.95	1.245	0.46	10.24	140,219	14,022
53		35	12,775	9.60	2.50	12.10	1.245	0.45	10.41	132,934	13,293
54		33	11,863	9.75	2.50	12.25	1.245	0.44	10.57	125,355	12,535
55		30	10,950	9.90	2.50	12.40	1.245	0.43	10.73	117,480	11,748
56		28	10,038	10.05	2.50	12.55	1.245	0.41	10.89	109,311	10,931
57		25	9,125	10.20	2.50	12.70	1.245	0.40	11.05	100,847	10,085
58		23	8,213	10.35	2.50	12.85	1.245	0.39	11.21	92,088	9,209
59		20	7,300	10.50	2.50	13.00	1.245	0.38	11.37	83,035	8,304
60		18	6,388	10.65	2.50	13.15	1.245	0.37	11.54	73,687	7,369
61		15	5,475	10.80	2.50	13.30	1.245	0.36	11.70	64,044	6,404
62		13	4,563	10.95	2.50	13.45	1.245	0.35	11.86	54,107	5,411
63		10	3,650	11.10	2.50	13.60	1.245	0.33	12.02	43,875	4,388
64		8	2,738	11.25	2.50	13.75	1.245	0.32	12.18	33,348	3,335
65		5	1,825	11.40	2.50	13.90	1.245	0.31	12.34	22,527	2,253
66		3	913	11.55	2.50	14.05	1.245	0.30	12.51	11,411	1,141
Total	**4,000**		**10,000,635**							**60,613,786**	**5,881,385**

1. http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf
2. http://www.eia.gov/dnav/ng/ng_pri_sum_a_epg0_pg1_dmcf_a.htm
3. Sproule Associates Limited, pers. comm., June 2014.

ENDNOTES

1. An exception arises in the case of federal lands that are located within provinces, such as national parks and Indian reserves. Resources located under federal lands are considered to fall under federal jurisdiction. See Chapter 9 for a full discussion of Federal jurisdiction and Chapter 10 for a detailed discussion of Aboriginal and Treaty rights and title.
2. http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf

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CHAPTER 4

The Protection of Public Health

Frank Atherton[1]

4.0 | **Chapter Summary**

This chapter summarizes the current state of knowledge about potential benefits and harms to human health associated with the practice of hydraulic fracturing. The prospect of development of unconventional gas and oil resources in Nova Scotia has implications for the health of individuals and communities. Economic productivity, improved energy security, and a shift away from coal-based energy generation may indirectly improve population health. Exposure to industrial materials and processes constitutes risks to health, which would need to be carefully assessed, monitored, managed, and mitigated before a decision to pursue hydraulic fracturing is ever made in Nova Scotia.

In this chapter, we describe the main risks to physical human health arising from potential exposures to toxic materials through contamination of drinking water sources and atmospheric exposure. Although the physical risks of unconventional gas and oil development have much in common with those of conventional developments, these relatively new technologies bring a number of potential health challenges, through issues such as the proximity to human habitation, the potential for large numbers of wells to have a cumulative impact, and the nature of chemicals deployed. All of these factors lead to increased public concern (see also Introduction, Chapter 8 and Chapter 11).

We note that psychological harms and social disruption can also be anticipated and may be more difficult or impossible to manage if attempts are not made to address them before industrial activity begins. This requires deep engagement and dialogue with individuals and communities in the earliest stage of any potential development.

Although the current state of knowledge does not identify issues with hydraulic fracturing which would pose a catastrophic risk to human health in the short or medium term, uncertainties around long-term environmental effects, particularly those related to climate change and their impact on the health of both current and future generations, are considerable and should inform government decision making. While a decision in Nova Scotia to proceed, delay, or abandon future resource extraction will not, of itself, affect the pattern of global climate change, there is an opportunity for Nova Scotia to raise the profile of this important public health and environmental consideration.

We describe that, in the event that Nova Scotia does ever decide to exploit onshore unconventional gas and oil resources, a number of mitigation measures are available which, if effectively adopted, could reduce the potential for negative impacts on human health. It would take time, effort, and investment to put these measures in place to protect the public's health but, as we have noted elsewhere in this report, the resources have been in place for millennia and are not going to disappear any time soon. In the interest of public health, Nova Scotia must take the time and make the necessary investments to ensure that proper regulation, modelling, monitoring, management, and mitigation measures are established and, through health monitoring and research, contribute to the evolving global knowledge base on the relationships between unconventional gas and oil extraction, hydraulic fracturing, and human health. We conclude by noting that the extent to which exposures can be reduced through effective regulation and best industrial practice should be key considerations in any government decision of whether to allow or encourage the development of hydraulic fracturing in Nova Scotia.

4.1 | Introduction: Context and State of Knowledge

The final text of this chapter of the report benefitted from 18 comments that were received from members of the public following publication of the discussion paper on which this chapter is based. These comments have contributed to editing of the text and/or specific citations and have supported the modification and addition of recommendations. Particular areas of concern included the potential for unconventional gas and oil extraction to support economic development in Nova Scotia, the implications of an incomplete knowledge base on health impacts, and the extent to which current regulatory standards and processes would be adequate if this technology were to be developed in the Province.

Clearly, the development of unconventional gas and oil resources through the use of hydraulic fracturing, in common with other modern industrial technologies, has the potential to bring benefits and harms to individuals, communities, and populations (CCA, 2014). This chapter attempts to summarize, from a population health perspective, the current state of knowledge about the potential benefits and harms. The paper draws on recent reviews of the health implications of unconventional gas and oil development; particularly the report of the Chief Medical Officer of New Brunswick (Cleary, 2012), a review by Public Health England (Kibble et al., 2014), a report by the European Parliament (2011), and the recent report by the Council of Canadian Academies (2014).

Consistent themes running through all of these compilation reports are that the science of hydraulic fracturing is relatively new, that it has evolved rapidly over recent years, and that neither the benefits nor the harms to health and the environment are fully known and may not be for many years or even decades. Consistent with the application of a precautionary approach (discussed in our introduction) in the face of this uncertainty, we need to identify whether evolving knowledge suggests that there are risks which are so extreme that hydraulic fracturing should not be undertaken. A secondary consideration, if hydraulic fracturing is ever to be carried out in Nova Scotia, is to determine the regulatory, monitoring, and mitigation measures which should be put in place to minimize risks to the health of the public and to place the burden of proof of relative safety on the developer or any level of government promoting the activity.

4.2 | Public Health Principles

Health has been broadly defined as, "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (World Health Organization [WHO], 1948). Public health concerns extend to communities and populations as well as to individuals. In broad terms, a public health approach gives a higher weight to collective, rather than individual effects.

A public health approach requires public policy decisions based on evidence, where available; there is a hierarchy of evidence with randomized trials providing the most compelling evidence. Such trials would be impossible to design and construct for hydraulic fracturing, and so, secondary levels of evidence have to be considered, including descriptive population health status reports, individual case reports, and anecdotal records. Where evidence is incomplete, decisions should involve risk assessment based on the knowledge which does exist, together with an explicit acknowledgement of information which is missing and which should be developed.

Known harms (those which have been shown to exist) and potential harms (which are theoretical and may or may not be realized) both require consideration. In assessing risk of harm, a public health approach indicates that particular attention should be given to the avoidance of catastrophic consequences where they can be identified or predicted. Ideally, risks should be quantified, but in the case of hydraulic fracturing, this is rarely possible because of the relatively recent expansion and development of this technology. Public health concerns extend to both the current communities and populations and to the interests of future generations.

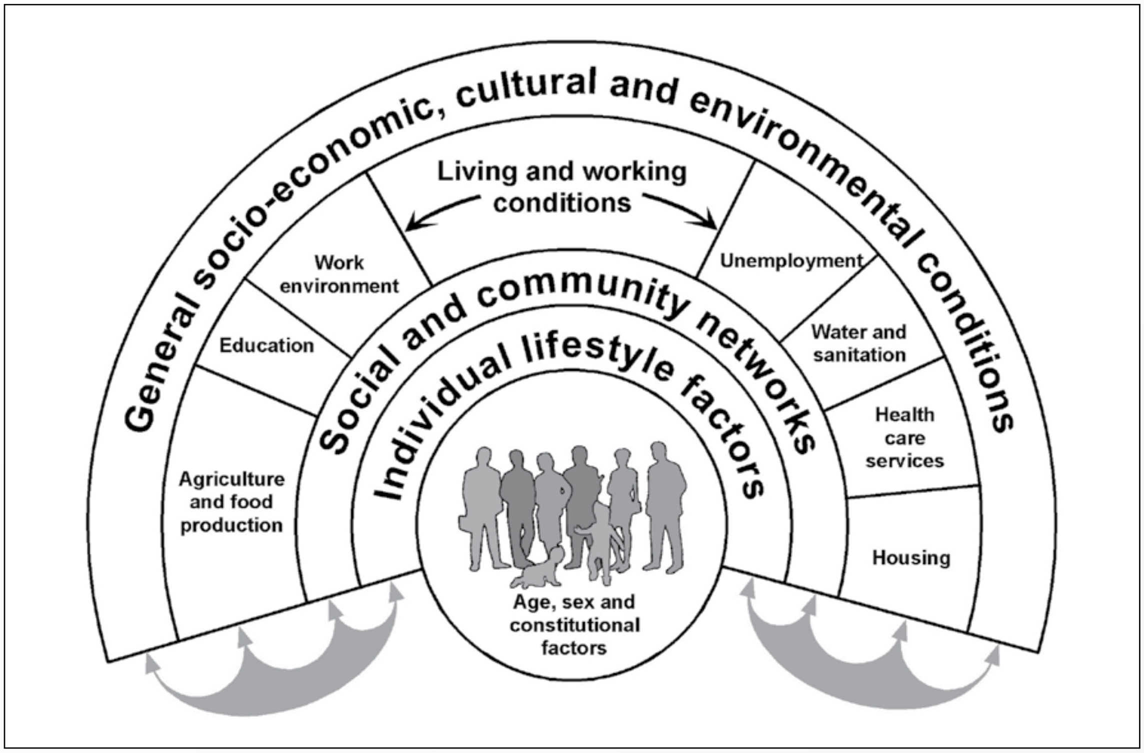
A consideration of health inequities lies at the heart of modern public health systems and, in the case of hydraulic fracturing, suggests that there should be a clear understanding of which groups benefit and which might be harmed, particularly where the harms and benefits are differentially allocated. Inequities can be defined as differences in health experiences which cannot be explained by biological differences and which are inherently unjust and correctable. Some communities in Nova Scotia have a poorer health experience than others, and it is important that the impact of new technologies, such as hydraulic fracturing, is assessed so as to ensure the benefits and risks are equitably distributed. Economically disadvantaged rural communities and First Nations communities are among those with poorer health outcomes and so deserve particular attention in decision making and in the monitoring and management of economic and social changes.

Finally, it should be noted that maintenance of the status quo is not a neutral act; if current circumstances are damaging to public health, then there may be a case for action to correct them, even where an evidence base has significant gaps. This notion is also embedded in the precautionary approach.

4.3 | **Determinants of Public Health**

The health of Nova Scotians depends on a wide range of factors; access to good quality healthcare is necessary, but accounts for only about a tenth of what we need to be healthy. The broader determinants (summarized in Figure 4.1) on which the health of Nova Scotians depends, include general living and working conditions, including access to affordable, sustainable sources of energy. By contrast, fuel poverty (the need of individuals or families to spend an excessive portion of their income meeting basic energy needs) is severely damaging to health (Dear & McMichael, 2011).

Figure 4.1 Determinants of Health



Reproduced with permission Dalgreen & Whitehead, 1993.

It is increasingly apparent that the economic well-being of nations and communities is intimately related to the health of their populations (WHO, 2001). The development of unconventional gas and oil in Nova Scotia has potential to benefit the health experience and outcomes of the population through improved economic circumstances and energy security.

No source of energy is completely safe, and so the real and potential harms from existing and potential sources deserve consideration. Table 4.1 gives examples of the types of occupational and population health risks which can arise from those energy sources which currently make a significant contribution to Nova Scotia's energy supply, compared to unconventional gas and oil and nuclear energy which is a major contributor to electricity generation in many jurisdictions, including France (which has banned hydraulic fracturing) and New Brunswick (which has not). The table does not include reference to solar power and other future potential sources of energy at this time and is not intended to imply equivalence in scale. The hazards and risks are listed simply for qualitative consideration.

Table 4.1 Energy Sources and Health Implications[2]

Energy	SourceOccupational Health Hazard	Population Risks and Health Effects
Nuclear	Construction risks/industrial accidents Individual radiation exposure	Catastrophic failure Long-term disposal
Coal	Mining accidents Silicosis Pneumoconiosis	Atmospheric pollution Mine collapse/fire
Conventional gas/oil	Construction risks/industrial accidents Occupational exposures to chemicals and hydrocarbons	Oil spills Explosions
Wind	Construction risks/industrial accidents	Noise Light flicker Mental health effects Turbine failure
Hydro	Construction risks	Dam failure
Unconventional gas/oil	Construction risks/industrial accidents Occupational exposures to chemicals and hydrocarbons	Air pollution Water source contamination Mental health effects

4.4 | **Hydraulic Fracturing: A Lifecycle Approach to Health Risks**

At different stages of the hydraulic fracturing process, it is possible to identify both real and potential risks to health and to plan for mitigations which may reduce them. The planning phase for any industrial development can allow local concerns and anxieties to surface which will impact on both community cohesion and individual mental well-being. This phase should be an opportunity for community involvement in planning (either directly or through local government involvement) to maximize benefits and minimize risks and to allow participation in the evaluation of whether the risks and benefits are acceptable to affected communities. In our recommendations (Chapter 11), we make explicit how a 'community permission to proceed' may be formulated in order to reflect the precautionary approach we advocate in this report.

During the exploration and development phases, there is the potential for harm from exposure to the chemicals and by-products of the fracturing process, from the disposal of wastewater, from the disturbances occasioned by the drilling process itself, and from the ongoing social and community changes resulting from any industrial activity (see also Chapter 5).

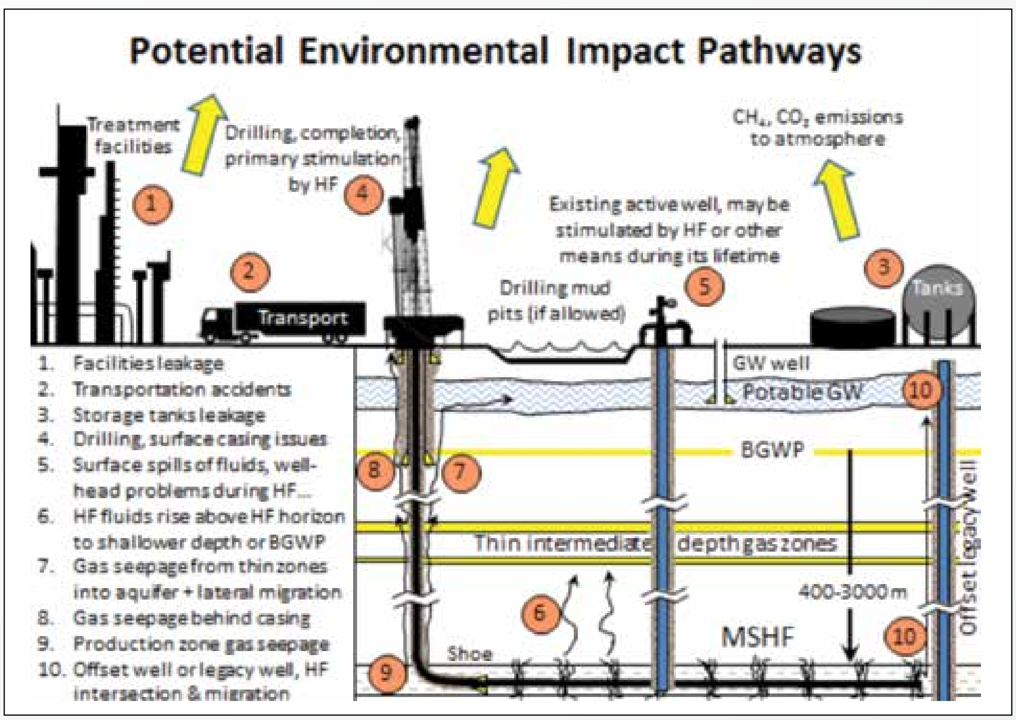
Even when wells are decommissioned, there remains the risk of long-term environmental and human health harm at an individual and global level if they continue to have an impact on climate change.

4.5 | **Exposures and Risks**

4.5.1 Exposure Pathways

Elsewhere in this report, we highlight the exposure pathways which could result in exposure to potentially hazardous chemicals used in hydraulic fracturing (see Chapter 5, 6 and 7). The two main direct pathways from a human health perspective are through contamination of drinking water supplies and through air pollution. Indirect effects from the drilling and fracturing process and from the consequences of industrial development constitute a further set of pathways, whereby individuals and communities can experience harm. The following sections identify the known and potential health consequences associated with these pathways as well as what is known about how negative consequences might be mitigated or avoided.

Figure 4.2 Potential Environmental Impact Pathways



Courtesy of Maurice Dusseault

4.5.2 Chemical Contamination of Water Sources

Concerns have been raised about the potential risks to human health associated with the chemicals used in the hydraulic fracturing fluid. Reports on possible health impacts from chemical exposure document the chemicals used and characterize them according to their potential impact on human health (Colborn et al., 2011). As an example, a report for Health Canada (Carrier, 2012) cites a list of the 750 chemical components of hydraulic fracturing products used between 2005 and 2009 by 14 oil and gas companies in the United States (Waxman, Markey & DeGette, 2011) and classifies them according to whether they are known to be acutely toxic, mutagenic (causing genetic damage), teratogenic (causing developmental changes), or carcinogenic (causing cancer). This approach to listing possible adverse events is limited, as it takes no account of quantitative exposure and is incapable of showing causal links between exposure and illness (Colborn et al., 2011).

The mixtures of chemicals used in fracturing fluid are not standardized and can be complex, with the result that there is no direct evidence of harm, or lack of it, from any specific mixture being deployed. As noted in Chapter 1, companies do not always release information on the contents of their fracturing fluids, citing proprietary considerations. Technological changes continue in the oil and gas extraction industry and, as a response to concerns about toxic materials in fracturing fluids, new, less toxic formulations are being developed and deployed.

In addition to concerns about the contents of the fracturing fluid, there are considerations of the composition of flow-back water returning to the surface, as this can include dissolved gases, liquids, and solids that are naturally found in underground oil and gas deposits (Colborn et al., 2011). These can include naturally occurring radioactive materials (NORMs), heavy metals, high levels of salts, liquid and gaseous petroleum hydrocarbons, and other gases such as hydrogen sulfide (Finkel & Hays, 2013; Howarth, Ingraffea & Engelder, 2011). Some of these compounds are also known to have toxic or carcinogenic effects.

In view of the potential toxicity of both hydraulic fracturing fluids and flow-back waters, good industrial practice and regulatory frameworks need to ensure that human exposures are maintained at as low a level as possible and should not be allowed to exceed national environmental exposure standards where these exist. Regulators in Alberta, British Columbia, and the Northwest Territories require companies to register chemical use for all wells via an online chemical disclosure registry (FracFocus). Nova Scotia's drinking water criteria are aligned with the Canadian Drinking Water Quality Guidelines, while air quality criteria are regulated under the Environment Act, SNS 1994-1995, c. 1. See Chapter 6 for more details on water quality standards and impacts on water more generally. The industry has examples of companies publicly releasing information on the chemical compositions and mixtures deployed. It has been suggested that this should be a requirement for all companies, so that proper human health risk assessments can be undertaken prior to, during, and after hydraulic fracturing operations (Cleary, 2012).

Industrial accidents, surface spills, and migration into surface groundwater all represent routes by which chemicals used in hydraulic fracturing may affect human health through contact with or ingestion of water.

Issues of wastewater disposal and groundwater contamination are also dealt with in Chapter 6. Accidents and surface spills should be controlled by adoption of safe working practices and effective regulation but also require robust incident management/response systems to ensure that their impact on human health is limited.

One submission to this review provides a detailed overview of radioactivity and natural gas globally and in Nova Scotia and concludes that there is a great deal of uncertainty as to the levels of radioactivity existing in shale and coal gas deposits in the Province. An assessment of drilling equipment and extracted materials in New York concluded that NORM contamination was insignificant and did not constitute an environmental or health risk (New York State Department of Environmental Conservation, 1999). Similarly, the review by Public Health England concluded that, although hydraulic fracturing can produce process residues and waste that contain NORMs, it is not to be expected that the extraction of gas and oil would pose a significant radiological risk to the public. However, it noted the need for an adequate regulatory framework to ensure the protection of the health of workers and the public from the radiological consequences of unconventional gas and oil reserves development (Kibble et al., 2014). Health Canada has produced guidelines for the management of NORMs, and these could form the basis for provincial regulation (Health Canada, 2011).

4.5.3 Atmospheric Pollution

Air contaminants also pose a potential exposure route, which might adversely affect human health. The industrial processes involved in hydraulic fracturing result in chemicals becoming airborne, with possible health impacts through direct contact (e.g. to eyes, skin) or through inhalation e.g. respiratory tract, gastrointestinal tract (Colborn et al., 2011). The industrial processes associated with hydraulic fracturing involve increased traffic and the use of diesel-fuelled machinery, producing consequent emissions of particulate matter, carbon monoxide, and oxides of nitrogen. Site emissions include volatile organic compounds (VOCs) and fugitive emissions, which lead to the release of methane and other gases (de Melo-Martin, Hays & Finkel, 2014).

Additional impacts might be caused when air contaminants associated with hydraulic fracturing come into contact with other pollutants. Ozone, recognized as a cause of respiratory illness, can be formed as a secondary air pollutant caused by the mixing of precursor gases such as methane, nitrous oxides, and VOCs (Kemball-Cook et al., 2010; Finkel, Hays & Law, 2013). There is the potential for large-scale, hydraulic fracturing development to significantly increase local and regional ozone levels and consequently impact respiratory health, with the greatest burden falling on the elderly and other vulnerable groups (Medina-Ramón & Schwartz, 2008).

Studies of air quality around fracturing wells indicate the presence of chemical contaminants (Colborn et al., 2011; Wolf Eagle Environmental, 2009). While many contaminants in the air have potential to cause harm to human health, a number of issues should be noted. Firstly, although the amounts of contaminants in the air may be within safety standards, these standards are often constructed to allow for single dose exposures on an adult, rather than for chronic, long-term exposure to people who work or live around natural gas installations (Colborn et al., 2014). There may also be sub-groups of the population (e.g. children, pregnant women) who have increased susceptibility to environmental toxins by virtue of their physiological and immunological states (Lauver, 2012). Secondly, as with water as an exposure route, the potential interactions between numerous chemicals have not been studied (Colborn et al., 2014). Thirdly, it should be recognized that all the pollutants arising from hydraulic fracturing can also be released by other industrial processes and may be detectable in background air quality surveys undertaken prior to new developments. This highlights the need to develop and implement systems for high-quality baseline data and ongoing longitudinal environmental and health outcomes monitoring (see recommendations section of Chapter 11).

It is possible to combine data on atmospheric levels of hydrocarbons with information from exposure/toxicity databases, to derive estimates of human cancer and non-cancer effects from the potential atmospheric exposures caused by proximity to gas and oil production sites. One study estimated the cumulative cancer risk for residents living in proximity to active wells as 10 per million for those living within half a mile of the nearest wellpad, compared with 6 per million for those living at a distance greater than half a mile (McKenzie et al., 2012). This study also noted that most of the exposures (and therefore the adverse health effects), would likely occur during well completion activities, suggesting that the avoidance of human exposure during this phase of operations is a particular concern to be addressed by companies and regulators.

A further study reporting a potential association between atmospheric exposures and birth outcomes has also been undertaken (McKenzie et al., 2014). This study did not utilize environmental monitoring data and so proximity to well developments was again used as an indirect measure for environmental exposures. Statistical associations with a range of birth defects were observed (particularly congenital health defects), but commentators (Kibble et al., 2014) have noted that such associations are relatively weak and could be chance findings. The authors acknowledged that causal relationships cannot be inferred from the study and made recommendations for further research.

It should be noted with regard to atmospheric exposures, that the current reliance on coal as a source of energy is particularly polluting. Long-term exposure to particulate matter from coal-fired power stations is associated with increased long-term mortality (Crouse et al., 2012) and is a frequently noted source of environmental concern to many Nova Scotians. A significant switch from coal and oil towards either natural gas or renewable resources could reduce particulate pollution with beneficial health consequences.

4.5.4 Noise and Other Nuisance Impacts

Hydraulic fracturing brings with it an increase in nuisances that may affect human health. An increase in noise, light, and traffic are all associated with hydraulic fracturing, and these, in turn, have the potential to impact quality of life.

Light pollution, which is an excess exposure to artificial light, is a concern for those living near wells that are being hydraulically fractured and in cases of multiple wells on a pad, the fracture stimulation period may last for prolonged periods (100 days or more). During certain phases of development, well sites are operational and brightly illuminated throughout the day and night (Bloomfield, 2012). Light pollution has the potential to affect people physically and psychologically and can cause sleep deprivation, mental anguish, and stress-related illnesses (Berg, 2009)[26]. Appropriate setback distances for well pads could mitigate the impact of light pollution on local residents.

Noise, which is any unwanted sound, is a common complaint from people living near natural gas drilling operations. An increase in noise reduces quality of life and can cause inconvenience, annoyance, and stress. Excessive and continuous noise has the potential to affect sleep patterns, increase fatigue, cause people to have difficulty concentrating, impact speech, and increase blood pressure (New York State Department of Environmental Conservation, 2011). Those who work from home, children, seniors, and people with auditory problems are generally more affected by noise than other groups. Loud, continuous noise also has the potential to impact those working at drill sites (Brisson et al, 2010).

Sources of noise around well sites can include heavy equipment, compressors, diesel powered generators, and truck traffic. While all stages of well development generate noise, the greatest impact generally comes from well drilling. Drilling an unconventional gas well typically takes four to five weeks of continuous activity. This time period can increase to several months if multiple wells are drilled per pad (Council of Canadian Academies, 2014). Noise levels during horizontal drilling can exceed 64 decibels of sound pressure (dB) at 75 metres from the drill site, far exceeding the World Health Organization's recommendation of an indoor noise level of 30dB (roughly equivalent to the noise generated by a whispered conversation) from a continuous source to avoid impacts such as sleep disturbance (Berglund & Schwela, 1999; Bloomfield, 2012). Even at distances of 1.5 kilometres from drill sites noise levels can still average 40dB.

4.5.5 Traffic

The development of unconventional gas and oil resources also brings increased vehicle traffic. A single hydraulically fractured well could use thousands of trips by trucks to deliver equipment and associated fuels, water, chemical additives, and sand to the site, and to remove extracted products and waste material (Bloomfield, 2012). This can lead to a significant increase in noise in areas surrounding well developments (Council of Canadian Academies, 2014). Increased vehicular traffic on mainly rural roads has, in some jurisdictions, been shown to increase the number of accidents and fatalities and also increases the potential for exposure to contaminants from spills of hazardous materials (Cooley et al., 2012; New York State Department of Environmental Conservation, 2011). It may also exacerbate air quality issues, as emissions from truck traffic can decrease air quality surrounding well sites (Finkel, Hays & Law, 2013). Diesel particulates from truck traffic and on-site equipment can have adverse health impacts. Increased vehicular traffic can also reduce available play space, green space, and active transport opportunities, thus undermining the public health goal of developing healthier built environments, which are known to reduce levels of chronic diseases such as diabetes, heart disease, and obesity (Renalds, Smith & Hale, 2010). Conversely, there are examples of industry sponsored recreation and community centres, which could positively impact the communities served.

To minimize impacts of noise, light, and traffic on local residents, mitigations would need to be put in place if unconventional gas and oil exploration was ever to be undertaken in Nova Scotia. Well pad sites would need to be carefully selected to avoid sensitive areas, with minimum separation distances from residences and community facilities must be stipulated in regulations. Vehicular traffic can be reduced by using pipelines, where practical, rather than trucks to carry water (although this comes with its own associated costs), use of waterless fracturing processes, treatment of produced water on site, or re-injection of fracturing fluids into spent wells (which is not currently an approved activity in Nova Scotia). Effective traffic management schemes, including speed reduction and the avoidance of peak hours, have the potential to reduce road accidents and traffic disruption (New York State Department of Environmental Conservation, 2011).

4.5.6 Impact on Climate Change

Unconventional gas and oil are fossil fuels and their extraction and use will generate greenhouse gases (GHGs), which may impact the rate of global climate change. Fuel sources which generate more GHGs have greater potential to harm future generations. Although the end use of natural gas generates less GHGs than coal, there is currently a lack of consensus on the question of whether the complete lifecycle of extraction and use of unconventional fuels would make this technology more or less polluting than conventional coal and oil energy sources in the short/medium term (see Chapter 8). A global concern, rather than one which relates specifically to Nova Scotia, is that although regulatory and engineering solutions may reduce fugitive emissions of methane and other GHGs from unconventional gas/oil wells during operation (see Chapter 7), there is no understanding of the long-term (100+ years) effectiveness of well decommissioning. The sealing materials used in closing off wells may degrade over future decades, raising the prospect of an unknown number of abandoned wells discharging some levels of methane into the atmosphere – this could result in a (currently unquantifiable) future environmental impacts. (Council of Canadian Academies, 2014).

4.5.7 Community Impacts

Many communities in Nova Scotia suffer from a lack of income, high rates of unemployment, and poor access to health and social services. At both community and individual levels, health status is closely correlated with income (Marmot, 2011). Tax revenue is required to maintain and improve public services needed by an ageing population. The injection of additional income into rural economies can be expected to improve health, if the economic benefits are shared with local communities and provided other economic activities (e.g. tourism and agriculture) are not displaced. On the other hand, it is possible to envisage a pattern of development of unconventional gas and oil reserves occurring without significant benefit to local communities, if the workforce is imported (and then moves away post-development) or if goods and services are drawn from remote, rather than local sources and suppliers (see Chapter 5 for a more in-depth discussion of these issues).

Large scale industrial developments over short periods of time have led to "boomtown effects" (Jacquet, 2009), where communities experienced rapid social changes with increase in costs of basic commodities, increased levels of crime, increased violence, and deteriorating health indicators. However, more moderate, gradually evolving patterns of gas development can also lead to community disruption, through physical changes in the local environment (e.g. increased traffic, increased noise, etc.), weakening of tight community bonds (e.g. from in-migration and population increase), by perceptions of loss (e.g. tranquility, asset values, access to natural environment, control/autonomy), through fear of the unknown, and distrust of industry and its regulators.

4.5.8 Occupational Health

The exploration and extraction of oil and gas resources in Nova Scotia would have implications for the health of the workforce involved. Many of these potential occupational health effects are common to workers engaged in the oil and gas industry and other similar industries in Canada. Such workers have relatively high levels of occupation-related morbidity and mortality. U.S. data show mortality rates of two and a half times that of the construction industry or seven times that of general industry (Adgate, Goldstein & McKenzie, 2014). The workforce engaged in hydraulic fracturing will also be exposed to higher levels of air pollution and increased chemical/radiological exposure compared with the general public. Methane and hydrogen sulphide releases during well operation pose the risk of explosive accidents and may be the greatest acute risk to workers. Long-term occupational exposures to silica (commonly used as a proppant in fracturing fluids) can lead to silicosis and lung cancer. Occupational exposures to petroleum hydrocarbons have been associated with increased risks of eye irritation, headaches, and respiratory symptoms.

In Nova Scotia, occupational exposure limits are addressed within the Workplace Health and Safety regulations under the Occupational Health and Safety Act. These standards would need to be reviewed to ensure that they take account of the specific exposures arising from unconventional gas and oil extraction. It should also be noted that occupational limits generally relate only to physical exposures or safety. However, the health of workers should be regarded more broadly, and, if developments were to take place in Nova Scotia, there would be opportunities to proactively build workforce health.

4.5.9 Accidents and Incidents

Onshore unconventional gas and oil exploration and extraction bring the possibility of accidents and incidents which can pose a risk of harm to the workforce and to the general population. Spills of waste-water and well blow-outs are known to have occurred and have the potential to cause significant exposure of populations through direct contact, surface water contamination, or airborne materials. An example of this is the well blow-out at Crosby, Wyoming (Colborn et al., 2011). Standards for clean-up operations following spills would need to be built into regulatory processes. In Nova Scotia, the municipal tier of government is responsible for mounting a response to industrial accidents and incidents which extend beyond the boundaries of the operator or company. The Department of Health and Wellness All-Hazards Emergency Response Plan would guide the health system in responding to an industrial accident or incident which posed a threat to the health of the public. See Chapter 11 for specific recommendations on emergency management.

4.6 | **Mitigation Measures**

The following mitigation measures should be considered essential to reduce the risk of harm to the public in the eventuality that a decision should ever be taken to explore and exploit potential gas and oil energy resources in Nova Scotia. Specific recommendations arising from these mitigation measures are presented in Chapter 11 based on our assessment of risks.

4.6.1 Health Impact Assessment

Health impact assessment (HIA) is concerned with improving the health of populations and the reduction of health inequalities. It is best defined as a combination of procedures, methods, and tools by which a policy, programme, or project may be judged as to its potential effects on the health of a population and the distribution of those effects within the population (Lehto, 1999). HIA identifies and encourages policies and practices to promote health and well-being in a way that is sensitive to local conditions and communities. It is flexible, practical, and systematic using a combination of procedures, methods, and tools to identify the likely effects of a proposed intervention (policy, programme, or project) on a population's health. Most important, it considers the distribution of those effects across population sub-groups. HIA then considers what changes are needed to maximize the health benefits and reduce health risks, with particular emphasis on the reduction of inequalities of health and the promotion of socially just, evidenced-based interventions. Ultimately, HIA seeks to inform and influence decision-making, ensuring that health impacts, and the distribution of those impacts, are considered during the policy planning process (European Commission. 2004).

The literature contains few systematic health impact assessments of hydraulic fracturing initiatives. A notable exception (and a potential model for good practice) is the health impact assessment undertaken by the Colorado School of Public Health (Garfield County, Colorado, 2011). In British Columbia, the government has commissioned a human health risk assessment of oil and gas development in the northeast part of the province. Regulatory systems do not usually require formal health impact assessments as part of their approval systems, and, in the absence of such a requirement, health impacts are often assessed (albeit superficially) as part of a broader environmental impact assessment process.

A challenge in Nova Scotia is that although HIA methodology has been deployed for specific issues, it is not yet established as a standard methodology to be used whenever large scale developments are planned. There is a pressing need to increase capacity in the public, academic, and private sectors to commission, design, implement, and evaluate HIAs. We make specific recommendations on the development and application of HIAs in the context of hydraulic fracturing in Chapter 11.

4.6.2 Health Status Monitoring

Population health status in Nova Scotia is currently monitored by the Department of Health and Wellness. Community health profiles are prepared by district health authorities to summarize local health experiences. A Provincial Health Profile Report is currently in preparation. None of these tools are currently sufficiently developed to capture the local health effects which might arise from specific unconventional gas and oil well placements in particular geographies in Nova Scotia. In other jurisdictions where hydraulic fracturing has taken place, baseline data have rarely been collected proactively prior to commercial development, making it difficult or impossible to properly evaluate subsequent health-related concerns. Assessments carried out subsequent to the development of fracturing technology tend to consider mainly physical impacts. A more holistic approach would require the consideration of physical, mental, and social aspects of health status. A specific concern with hydraulic fracturing is the need to link health status with environmental changes. An effective health monitoring system would allow changes to the environment to be related to changes in health status. We make specific recommendations on the development and application of health status monitoring in the context of hydraulic fracturing in Chapter 11.

4.6.3 Emergency Preparedness

Nova Scotia has a good track record of responding to public health threats and incidents, but the development of hydraulic fracturing could increase the risk of harm to the workforce and the general public if/when accidents occur. We make a specific recommendation on the development and application of emergency preparedness procedures in the context of hydraulic fracturing in Chapter 11.

4.6.4 Research

There is a compelling case for more studies to determine the long-term effects of exposure to contaminants associated with hydraulic fracturing. Nova Scotia should contribute to the global understanding of the risks and benefits arising from unconventional gas and oil extraction. We make specific recommendations on research needs in the context of hydraulic fracturing in Chapter 11.

ENDNOTES

1. It should be noted that Dr. Atherton has authored this paper as an independent expert and therefore the analysis presented here is independent of the views of the Province of Nova Scotia. See project website for relevant documentation. <http://www.cbu.ca/sites/cbu.ca/files/docs/hfstudy/Nova%20Scotia%2 Department%20of%20Health%20and%20Wellness%20RE-%20Hydraulic%20Fracuturing%20Review.pdf>
2. See for example OECD 2010: Comparing Nuclear Accident Risks with those from Other Energy Sources

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CHAPTER 5

Socioeconomic and Social Ecological Impacts on Communities

Shawn Dalton

5.0 | **Chapter Summary**

This chapter builds on the analysis of Chapter 4 and, similar to questions of public health protection, it notes that community impacts of energy development may be both positive and negative. We describe those impacts in four key areas: the local economy, social and physical infrastructure, the natural environment, and social relations within communities. We also note the fact that the "energy boomtown" literature of the 1970s and 1980s focused on the negative impacts of the boom-bust-recovery cycle, but that subsequent research has shown positive effects in most impact categories.

Following publication of the discussion paper on which this chapter is based, 17 comments were received from members of the public and the chapter was revised accordingly. Particular areas of concern included recent publications that had not been included in the review of available literature, as well as literature in related areas that had not been reviewed. As well, a number of submissions expressed interpretations of the available literature that differ from those reported here. In some cases, these concerns were addressed in the present iteration of this chapter through review and inclusion of information from additional references; in others, the chapter has been edited to reflect broader interpretations of available information. Finally, in cases of differing interpretations of the literature, we respectfully acknowledge the public submissions, but have not changed this document to include them.

The chapter summarizes potential community effects of unconventional gas and oil development through hydraulic fracturing and offers insight into appropriate monitoring and evaluation approaches that can help establish adaptive management and improved control of outcomes within communities.

5.1 | **Introduction**

Oil and gas extraction through the combination of horizontal drilling and hydraulic fracturing, as a profitable industry, has emerged only in the past decade (see Chapters 1 and 2; Prud'homme, 2014). As such, it is far from a mature industry and therefore the medium- and long-term effects it may have on community health (Chapter 4), ecosystems (Chapter 8), and economies – especially with respect to incurred costs in particular geographies (see Introduction and Chapter 3), are unknown. As well, there is limited peer-reviewed research on the short-term effects of unconventional gas and oil development through hydraulic fracturing on communities is only just emerging in the literature. In this chapter we report on our understanding, to date, on the effects of unconventional gas and oil development on people and places and suggest means by which we can systematically consider potential cascading effects over various spatial and temporal scales and among different social groups, in the Province of Nova Scotia.

To say that hydraulic fracturing for unconventional gas and oil is a contentious issue globally is an understatement. As we have seen from submissions to this review and as we have heard in public meetings (see Introduction), the stakes are high at all levels of society, with the potential to completely alter existing international geopolitical power structures, as well as within and between countries, states, provinces, and communities. Nova Scotia currently faces fiscal and demographic challenges (The Nova Scotia Commission on Building our New Economy, 2014) and is therefore subject to strong pressure to explore and, if viable, develop its unconventional gas and oil resources.

There is very strong community interest in, and concern about, this industry in Nova Scotia, with public opinion divided on whether the resource should be developed. An April 2013 poll carried out by Corporate Research Associates, Inc. indicated that 53 per cent of Nova Scotians opposed "hydraulic fracturing even if the Province had adequate regulations in place to protect the environment," while 39 per cent were not opposed, and 8 per cent were undecided.[1] However, Nova Scotia relies 100 per cent on imported oil. Until 10 years ago, natural gas was not available and only imported oil and primarily coal fired electricity generation were in place. That coal is now almost entirely imported as well (see Introduction). Nova Scotia domestic gas use has had significant financial and environmental benefits for those that have access to it and use it. Natural gas is now being used in Cumberland, Colchester, Pictou, Hants, Guysborough and Richmond counties and an application has been made to extend service to Antigonish county. These are all areas where unconventional resources exist. Whether or not they can be extracted commercially is a different question. The Halifax Regional Municipality (HRM) is not a prospective area – although it is a large consumer (see Introduction).

According to industry proponents, hydraulic fracturing can be carried out safely, with minimal environmental impacts. Elsewhere, the review panel has identified baseline monitoring and effective regulations and enforcement as central to protecting human health and the environment (see Chapters 4, 6, 7, 8 and 9 and recommendations section of Chapter 11). The petroleum industry has adopted hydraulic fracturing, coupled with directional drilling, as a potentially profitable way to extract oil and gas from previously inaccessible resources (see Chapters 1 and 2; Prud'homme, 2014). Hydraulically fractured oil and gas reserves are described by industry as sound investment opportunities, a means by which domestic energy costs can be lowered, and a path to reduced reliance on foreign energy supplies – especially in the United States (Stedman, 2012).

The U.S. federal government views natural gas from unconventional gas and oil deposits, which was unavailable prior to the development of hydraulic fracturing technology, as a transition fuel from conventional fossil fuels to alternative energy a means by which greenhouse gas emissions can be reduced in the meantime, and an opportunity to become a net exporter of energy, rather than relying on foreign sources of fossil fuels (United States Environmental Protection Agency, 2014). In Canada, the federal government actively promotes the development of the energy sector as a component of its broader economic development goals. Unconventional gas and oil are seen as both important sources of energy for domestic industrial and residential needs and as potential exports (Natural Resources Canada, 2014). Provincial governments, in particular those in Eastern Canada, are not consistent in their support or lack thereof for hydraulic fracturing as a path to economic relief or prosperity. On November 4, 2013, Newfoundland's Minister of Natural Resources announced that the province would not,

....be accepting applications for onshore and onshore to offshore petroleum exploration using hydraulic fracturing. This measure provides an opportunity for government to undertake a balanced review of regulations, rules and guidelines in other jurisdictions, to complete the technical work necessary to fully assess the geological impact in Western Newfoundland, and, following this process, to undertake public engagement to ensure that our residents have an opportunity to comment and are fully informed before any decision is made.[2]

After allowing test wells to be drilled in Kennetcook, the government of Nova Scotia suspended hydraulic fracturing in unconventional gas and oil formations and postponed a decision on whether to allow hydraulic fracturing to take place, pending the completion of the investigations that are described in this review. The government of Prince Edward Island has not made a decision on whether to allow hydraulic fracturing on the island.[3] Quebec has a moratorium in place, pending the outcome of its Strategic Environmental Assessment (Gouvernement du Quebec, 2012).

New Brunswick has moved ahead with natural gas exploration and development, including hydraulic fracturing in unconventional reservoirs, but not without considerable resistance from various groups in the community. The Province cites challenging economic circumstances, and the need to develop its resources in general, as a rationale for permitting unconventional gas and oil exploration: the prospect of royalties and increased tax revenues is perceived to be a strong incentive to move forward (Government of New Brunswick, 2014).

The public debate in New Brunswick has largely focused on the activities of SWN Resources and the company's exploration work in the past two years, yet Corridor Resources has been delivering natural gas derived through hydraulic fracturing to customers for over a decade.[4] In recent months, NB has produced its Oil and Natural Gas Blueprint, intended to guide the responsible development of these resources;[5] and a new set of regulations, claimed as the most stringent in the world: Responsible Environmental Management of Oil and Natural Gas Activities in New Brunswick: Rules for Industry. In addition, the Province created the New Brunswick Energy Institute (NBEI) and the Office of the Chief Medical Officer of Health (OCMOH) of the New Brunswick Department of Health produced a report called, "Chief Medical Officer of Health's Recommendations Concerning Shale Gas Development in New Brunswick."[6]

The decision to develop, or not, unconventional gas and oil resources in Nova Scotia is a complicated one, with costs and benefits that may be unevenly distributed on the landscape in terms of visual impact, environmental, social, and economic effects and so forth; within and between governmental jurisdictions and across generations of Nova Scotians. The goals of this Chapter are as follows:

- Articulate the potential differential, beneficial, and deleterious effects of unconventional gas and oil development within and between communities, as these are currently understood;
- Highlight knowledge gaps in the literature and assessments reviewed;
- Recommend means by which knowledge gaps can be addressed in Nova Scotia and future changes in socio-economic and social ecological[7] conditions monitored, should this Province ever elect to develop its potential natural gas resources.

This paper is based on a review of peer-reviewed literature, grey literature[8], and to some extent media coverage on the effects of unconventional gas and oil development through hydraulic fracturing. It is not exhaustive, but attempts to cover the wide range of effects of this industry at different scales. It should be noted that there is not yet a particularly robust peer-reviewed literature on this subject, as the industry itself is immature (CCA, 2014). In addition, because community research is often oriented toward problem-solving, there is a dearth of information regarding when unconventional gas and oil extraction utilizing hydraulic fracturing has gone well and a relative abundance of reports on challenges and problems – most of it centred on communities in the U.S. Thus, it is possible that there is disproportionate representation of the negative effects associated with unconventional gas and oil development and underrepresentation of its positive effects in the literature.

For the purposes of this document, community is defined as a "society where people's relations with each other are direct and personal and where a complex web of ties link people in mutual bonds of emotion and obligation. In the social sciences, especially sociology, the idea of community has provided a model to contrast to the emergence of more modern, less personal societies, where cultural, economic, and technological transformation has uprooted tradition and where complexity has created a less personal and more rationalized and goal-directed social life."[9] In Chapter 11, we also address the concept of community in the context of recommendations related to the application of the precautionary approach to the notion of a "community permission to proceed.

5.2 | Socioeconomic Effects of Unconventional Gas and Oil Development at Various Scales

Development of modern horizontal drilling and multi-stage hydraulic fracturing techniques took place primarily in Texas, spanning a period between the mid-1990's and early 2000's. While the techniques expanded to, and were further refined in other areas of the United States and Canada over the next several years, much of the literature about the industry, and its various consequences, derive from research conducted in the U.S. For the purpose of this chapter, there are at least three contextual items that must be kept in mind:

1) Landowners in most parts of the U.S. own the rights to subsurface minerals on their land, so they can therefore lease their property to oil and gas companies for exploration and development and derive royalties from the produced gas (Kargbo et al., 2010). This can create strife and inequities between neighbours and communities, as some participate and others do not and as some become dramatically financially better off as a result, while others do not. In Canada, most prospective lands are held by the Crown, which controls access and leasing, and collects royalties and rentals. Some prospective lands are held as freehold, where individuals or corporate entities (e.g., Canadian Pacific Railway and Hudson's Bay Company), were granted surface and mineral rights before

settlement and they are entitled to royalties. Prospective lands under First Nations Reserves are administered by Indian Oil and Gas Canada (see Chapter 10 for a more detailed discussion of exploitation rights as they relate to Aboriginal communities).[10]

2) Regulatory framework(s) differ between U.S. states and Canadian provinces (CCA, 2014; see also Chapter 9), thus, some of the incidents and accidents that have happened in the U.S. may be less likely to occur here. Canada's regulatory regimes tend to be more restrictive and because of the observed experiences in the U.S., more safeguards were adopted in Canada before horizontal/multiply-fractured wells became common in this country.

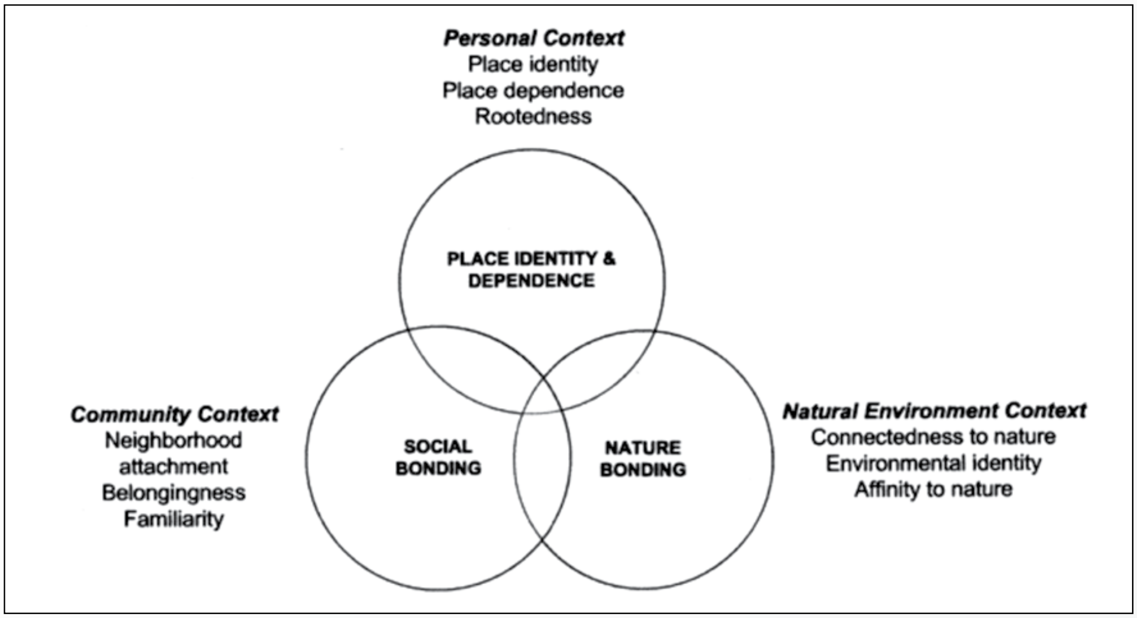
3) There is a patriotic theme underlying some people's decisions to allow oil and gas development on their land in the U.S. – i.e., people may feel that it is their patriotic duty to allow development on their property, even though they would rather not do so – to do their part to reduce American dependence on foreign sources of energy (Perry, 2012). Canadians are unlikely to feel this particular type of pressure to develop unconventional gas and oil.

Effects on communities can be direct – for example increased truck traffic can lead to longer travel times and cost community members time they might normally spend doing something else (a direct effect). Effects on communities can also be indirect – increased truck traffic leads to longer travel times, leads to less time to participate in civic life, leads to a reduction in volunteer hours at the local library (an indirect effect). Both types of effects are important to understand. As the second example shows, indirect effects can "cascade" through communities and impact variables that initially appear to be unrelated to the initial driver, in this case, an increase in vehicular traffic.

In this context, community effects include sociocultural, environmental, and economic components – it is difficult for most people to distinguish among these aspects of their community and for that reason, all are included here (see also Chapter 8). This is in part because of a phenomenon broadly described as place attachment, which is, "a measure of the emotional bonding that people have to their neighborhood or other places" (Mooney, 2009).

A variety of factors contribute to a person's attachment to place, including one's personal context (economic parameters such as the ability to earn an income), community context, and the natural environment context (see Figure 5.1). Most of the community effects of unconventional gas and oil exploration and development identified in the literature fall within one of these categories: the local economy, social and physical infrastructure, the natural environment, and social relations within communities" (Brasier et al., 2011).

Figure 5.1 Conceptual model of place attachment



Reproduced with permission from Elsevier. Raymond, 2010

We examine these in detail in the following sections. The phases of unconventional gas and oil development can be felt in different ways by different members of a community, or by different communities within a region. Most vulnerable members of communities are often poor, elderly, sickly, or a combination of these and are disproportionately likely to bear the costs of industrial development and accrue minimal, if any, benefits. In this chapter, we consider three broad phases of unconventional gas and oil development: preparation/exploration, active development and extraction, and decommissioning/abandonment.

Communities' anticipation of, and response to, energy development, particularly in rural areas, has been shown to follow a fairly predictable trajectory in four stages: enthusiasm, characterized by "positive expectations," uncertainty, as expectations and realized experience diverge, panic, as people begin to understand the true magnitude of impact on their community, and adaptation, as people come to see the changes as permanent (Brasier et al., 2011). Should Nova Scotia ever chose to develop an onshore unconventional gas and oil industry, it would be important to ensure that the highs and lows associated with these different phases are mitigated by working with stakeholders to align expectations and likely outcomes, and through anticipatory and participatory planning in advance of any development. In this part of the world, and at this point in history, there has been an additional sociopolitical process underway: opposition. This has benefits and burdens, discussed later in the chapter.

The map (Figure 5.2) shows where unconventional gas is known to be located in North America (United States Energy Information Administration, 2011). Most of the research and experimentation on unconventional gas and oil extraction in the United States has taken place in Texas. Recently the Marcellus Shale in the Eastern U.S., particularly in Pennsylvania, has seen a tremendous investment in unconventional gas and oil development. Thus, it is here that most of the research on community effects of unconventional gas and oil development has been conducted. With the caveats described earlier, we explore the literature reporting on these effects.

Figure 5.2 Map of North American Shale Plays

Courtesy of the United States Energy Information Administration (2011)

5.3 | **The Local Economy**

During preparation and exploration, direct jobs and increased business activity to serve industry representatives may increase.[11] Direct jobs may be related to airborne gravity and magnetic surveys, analysis of surface geochemistry, seismic imaging, and the drilling of exploratory wells.[12] Some of these require highly trained personnel, so their contribution to direct local jobs and economic conditions may be minimal, depending upon the level and availability of local human capital. Increased business activity during this phase of development may also benefit the service industries: restaurants, hotels, transportation, etc. Generally, service jobs are relatively low paying, with limited job security and poor, if any, benefits (see also Chapter 3 for a discussion of the direct economic impacts of employment in regional economies).

During active development and extraction more activity is evident in communities. Truck drivers, mechanics, heavy equipment operators, labourers, etc., are all required by the unconventional gas and oil industry (Kargbo et al., 2010; see also Chapter 3). This can increase incomes for those with requisite skills, thereby increasing government revenue from income, property, and sales taxes. However, small communities may have limited numbers of people with appropriate skill sets, as they are attracted to higher-paying jobs in the oil and gas industry, and drawn away from their previous employer(s). As such, local businesses and government agencies may be hard pressed to find workers to fill vacant positions.

> "Key staff from the Conservation District, County Planning office, and courthouse, school bus drivers, and local law enforcement personnel had taken jobs with gas companies, leaving county and local officials and programs struggling to keep up with less staff but an increasing work load (Perry, 2012)."

Industrial activity attracts workers with a variety of backgrounds and can lead to rapid population growth and increased sociocultural diversity (Perry, 2012). This can have both positive and negative effects on communities, for example: increased demand for housing can lead to increased revenue on rental properties, as well residential sales. Landowners, however, can also increase the rental prices on housing, which can push lower-income renters out of their homes. In places that have experienced a dramatic increase in population, coupled with an increase in average household income, real estate prices and property values have increased to a point where long-time homeowners were no longer be able to afford their property taxes and were forced to sell (Powers, 1991).

Increases in income and property values can increase tax revenue overall. In addition, in the U.S. a severance tax is sometimes paid by gas companies.[13] The increased revenue from property, income, and severance taxes, however, may be offset by the increased demand for public services – aspects of the social infrastructure described below.

These possible effects can be felt throughout a local economy, from businesses providing goods and services from groceries to new cars, to wedding planning to insurance coverage expanding to serve the burgeoning population. They are also likely to contract once the industry has completed its life cycle and moved on to other locales. Unless forward thinking and planning takes place from the outset, this cycle is unlikely to be different in the context of unconventional gas and oil development than in other industry developments. These cycles and their effects can be very difficult to predict, because of variability within and between communities and jurisdictions. "Overall, research on economic impacts indicates that actual benefits are often smaller than initially anticipated and some sectors experience negative effects" (Thompson and Blevins 1983, cited in Brasier et al., 2011). Nova Scotia has a long history of industry cycles and their effects on communities and thus has an experiential basis from which to consider this new industry.

5.3.1 Social and Physical Infrastructure

Social infrastructure includes services such as, "schools, housing assistance, [medical services], law enforcement, emergency services, administration, and records" (Perry, 2012). In some cases, these services can be overtaxed by a growing and diversifying population and unequipped to handle the additional demand.

Likewise, physical infrastructure such as roads, public buildings, bridges, water and sewer lines, the electric grid, etc., can be overburdened by a burgeoning population. The pressure on public agencies to respond to increased demand for these services, and the infrastructure that supports them, makes it extremely difficult to take the time to plan for additional changes (both expansion and contraction) in a community. These pressures are felt differentially throughout the industry cycle, with the greatest burden placed on social and physical infrastructure during, and just after, rapid population growth occurs (Brasier et al., 2011; Brasier et al., 2013). In Chapter 3, we described a range of scenarios that could play out in Nova Scotia over a 40-60 year period. The scale of the potential activity and the timescale over which it might occur would create the opportunity to manage and smooth these effects. Clearly it could also create unacceptable local impacts if poorly handled.

Much unconventional gas and oil development has taken place in rural areas. However, there are many unconventional basins beneath densely populated areas. Evidence from Pennsylvania suggests that urban populations are more readily able to absorb newcomers into their mix, as well as respond more effectively to increased demands for public goods and services. Public service providers in urban settings are already accustomed to serving a larger clientele, with a much wider distribution of needs than those in rural communities. The influx of new workers represents a proportionately smaller population growth rate (Brasier et al., 2011).

5.3.2 The Natural Environment

The potential impacts of hydraulic fracturing on the natural environment may represent the most contentious concerns about unconventional gas and oil development, locally, regionally, nationally, and perhaps internationally (see Introduction and Chapter 8). The bases upon which opinions on this subject are formed include direct experience, social media, rumours, hearsay, political debate, books, magazines, and other popular publications, media coverage (TV, radio, newspaper, online), and peer-reviewed journal articles. Many governments have undertaken jurisdictional regulatory reviews, comparative analyses, cost-benefit analyses, consideration of impacts on human health, etc. Non-profit organizations have done the same, and the oil and gas industry has also been active in producing and disseminating detailed information about its activities, both in peer-reviewed literature and elsewhere. Chapter 8 describes many of the potential impacts of unconventional gas and oil development on ecosystems, in particular as concerns about environmental effects were expressed in submissions by Nova Scotians to this review. We also heard very strong and clear opinions from public meetings on this topic (see Introduction) and Aboriginal organizations (see Chapter 10). In this section, we present several additional potential ecological effects and discuss how these might impact communities.

A 2012 report of the Pembina Institute, summarized the "major environmental concerns related to shale gas development," at the local scale in Canada as follows (Pembina Institute, 2012):

Figure 5.3 Summary of local environmental concerns with shale gas development in Canada

Local Environmental Concerns associated with Shale Gas Development

- Water use
  - Contamination of water from methane
  - Contamination of water from fracturing fluid
- Waste treatment and disposal
- Local air quality
- Land use and biodiversity impacts
- Induced seismicity

Source: The Pembina Institute 2012: Shale Gas in Canada (adapted by author).

Deleterious changes in water quality and quantity can affect communities directly, by impacting availability and quality of drinking water, the quality and levels of recreational waters (e.g. for fishing, swimming, etc.), availability of water for other large-scale applications such as agriculture, and overall quality of life. According to our analysis of impacts on water, residential use and leaks account for the highest use or loss of fresh water in Nova Scotia. "Human land use and acid rock drainage is the predominant threat to water quality..." (see Chapter 6). Although we foresee no catastrophic threats to water resources, improved modelling, monitoring, and management of current water uses, will be important before any additional burdens are placed on the system (see also recommendations section of Chapter 11).

Creation, storage, and treatment or disposal of waste, whether contaminated water, land/soil, or other by-products of development, pose a tremendous challenge for communities. It may also create a profitable opportunity for business development, as treatment techniques improve and local capacity increases. To date, the one experience in Nova Scotia in this regard has been poorly managed by government and industry. The community of Kennetcook remains the site of two open ponds containing fracking wastewater and the company that created the ponds (at the direction of the government) is no longer operating in Nova Scotia (Harris, 2013).

Changes in land use and reduction in air quality and biodiversity, as well as habitat loss and/or fragmentation, can change both the character of the landscape and its ecological structure and function. In addition, large scale changes in land use and land cover can affect agricultural productivity, hydrologic patterns, and flows of energy and nutrients. These issues may be of particular concern in rural areas, where farming, forestry, tourism, recreation, or other land/resource-based activities could be diminished. However, natural gas emits fewer greenhouse gases when burned, thereby potentially reducing the carbon footprint per unit of energy; assuming (on a lifecycle basis) that fugitive emissions from production and distribution (e.g. methane) are controlled and do not negate the carbon savings. The question of actual contributions to climate change through the entire life cycle of natural gas exploitation and use remains a subject of scientific debate (CCA, 2014, see also Chapter 8 and recommendations section of Chapter 11).

A recent literature review in British Columbia of the environmental effects specifically of road construction and maintenance, documents 29 distinct negative impacts in the following categories: soils, water, and aquatic wildlife and habitat, terrestrial wildlife and habitat, and "Other negative effects of roads" (Daigle, 2010). Examples include:

- Increased fish mortality caused by expanded angling pressures, poaching, and management actions;
- Increased number and extent of landslides and debris flows, which can affect aquatic and terrestrial systems;
- Increased invasive alien plants and animals that establish along the colonization corridors provided by roads; and
- Increased human disturbance of sensitive wildlife (e.g. from noise, traffic movement, lights) resulting in habitat effectiveness being degraded (Daigle, 2010).

The potential requirements for road construction and maintenance associated with unconventional gas and oil development are dramatic. For example, in one county in Pennsylvania, permitted well pad density is 37 wells per square mile (Perry, 2012). It is important to consider these and other effects of road construction on Nova Scotia's landscapes. Ecosystem services can also be compromised by any large-scale development activities. Healthy ecosystems produce food and other biomass; sequester carbon; capture, store, and release water, thereby, regulating water levels in rivers, stream, and lakes; control flooding, regulate climate; and cycle nutrients. These important functions of ecosystems usually are not included in economic modeling of the costs of various human activities on landscapes. This has been raised as a concern in the context of hydraulic fracturing by the non-profit organization, Environment North Carolina Research and Policy Centre (ENCRPC, 2012). It is also a significant concern for our Aboriginal communities and directly relates to their Treaty, Aboriginal and Title rights (see Chapter 10). The issue was raised many times in our public meetings.

5.3.3 Social Relations within Communities

Rapid population growth and subsequent depopulation can change people's patterns of interactions with one another. This can have both positive and negative impacts on communities and depends in part, upon pre-existing social structures and behaviours.

During the exploration phases of unconventional gas and oil development, newcomers may be a small group of highly trained engineers and technicians whose entry into a community may have minimal impact. But even if a "steady state" workforce emerged over a 40-year development period (see Chapter 3), during the active development and extraction phase, more people arrive and the social characteristics of a community begin to shift. "There is an influx of "foreigners" who work in the unconventional gas and oil industry and in some cases hold different social values and cultural norms than the local residents"

(Perry, 2012). This is more likely to cause social disruption in small, rural communities, than in larger urban centres. In addition, there is the possibility that an influx of industry workers (a group sometimes disproportionately composed of single men) may also attract a variety of new, and not always welcome, service providers to a given locale.

It is difficult to predict the effects of unconventional gas and oil development on social relations within Nova Scotia communities, especially over the long-term. Estimates indicate that a given well produces economically viable levels of unconventional gas and oil for 10-20 years (Browning et al. 2013). In Chapter 3, we put forward scenarios with 40-60 year timescales, which equates up to three full human generations in the sociological literature. In this time, a "new normal" will take shape in a community. This is also enough time for former newcomers to a community (i.e. industry workers and their families) to develop an attachment to place and a desire to stay and/or for their children to do the same. This may create a social and economic deficit in their communities of origin, as we noted in our Introduction, the Maritime Provinces are losing their young people to western opportunities at a significant rate (see also Commission on Our New Economy, 2014). The energy boomtown literature, however, indicates that many aspects of social life return to pre-boom levels upon industry termination. These include community satisfaction, trust in other community residents, and social ties (Brown et al. 2005; Smith et al. 2001; cited in Brasier et al., 2011).

5.3.4 Opposition

There has been substantial resistance to unconventional gas and oil development in many parts of the world. Because it is a relatively new means of accessing fossil fuels and because of some highly publicized incidents in small communities, both in North America and elsewhere, the possibility of unconventional gas and oil development has caused alarm in Atlantic Canada. In New Brunswick communities, for example, some stakeholders have invested substantial amounts of resources, including their leisure time, social capital, and money (Anonymous, 2013) to organizing (e.g. Conservation Council of NB), speaking out (e.g. Voice of the People Tour in NB), blocking roads (Poitras, 2013), and otherwise protesting unconventional gas and oil development. They have educated themselves and shared their knowledge with others, have held community suppers to raise funds, and supported one another in various other ways (Anonymous, 2013). Arguably, this may create opportunity for meaningful dialogue and industry representatives are beginning to realize that business as usual is not sufficient to gain social license[14] to operate in many communities. Some of the publications coming from industry are clear indications that government, private, and public stakeholder reactions to hydraulic fracturing are having an effect among operators and associations of which they are members:

> "The natural gas and oil extraction industry is facing ever-increasing scrutiny from governments, the public and non-governmental organizations (NGOs). These stakeholders rightly expect producers and service companies to conduct hydraulic fracturing operations in a way that safeguards the environment and human health" (ALL Consulting, 2012)."

The Canadian Association of Petroleum Producers issued a 140-page Guide for Effective Public Involvement in 2003: "This Guide is intended for CAPP member company employees, contractors, community relations practitioners, project managers, and others new to public involvement and who may find themselves dealing with stakeholders less knowledgeable, or very familiar with the upstream oil and gas industry" (CAPP, 2003).

In a related theme, in 2007, The World Resources Institute[15] invested substantial resources to produce a publication entitled, "Development without conflict: the business case for community consent" (Sohn, 2007). This document "illustrates how a company's ability to gain the approval of the host community can affect the project's success," and demonstrates that there is a strong business case for ensuring that host community's approval is based on "free, prior and informed consent (FPIC)." That is, community members are fully aware of the commitments they are making prior to the commencement of industrial development. One of the case studies in this document focuses on an offshore natural gas development project and 500 km undersea pipeline in the Philippines. The requirement for a "community permission to proceed" is a core recommendation in our review (see Chapter 11).

Initiating an unconventional gas and oil development project, particularly in unproved areas with little or no existing gas industry services or infrastructure, may be extremely risky for companies under current fiscal and political conditions. Not only do they sometimes face vociferous opposition to their activities, but they are engaged in a very expensive business, which may or may not return the profits their investors expect.

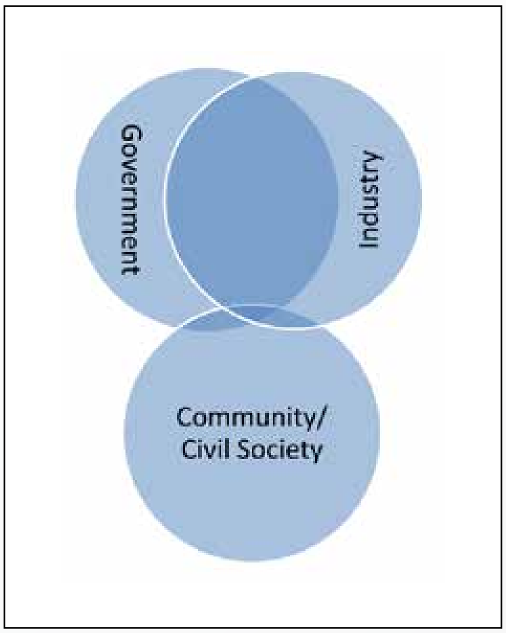
> ...[E]ach pilot horizontal well can easily cost between $10 and $20 million. Even these costs escalate in new areas without oil and gas service industries. The successful shale gas companies have met the challenge of creating or changing corporate cultures. A successful corporate culture is one that encourages, respects, and rewards innovations and avoids the fear of failure, while at the same time maintaining financial control (Binnion, 2012; see also Chapter 3).

In addition, gas companies working in the unconventional arena are on a steep learning curve, regarding not only the extraction of oil and gas from deep shales, but also in terms of policy and politics, public engagement, and long-term planning:

> "Suddenly, oil and gas companies not only need to understand public policy, they need to understand the politics of how public policy is set. Just as petro-physicists need to understand the rock in greater detail than ever before and just as engineers need to understand just-in-time delivery systems, and just as facilities people need to be able to plan years in the future rather than waiting for the well results, everyone's jobs are more complicated (Binnion, 2012)."

A recent series of articles published in the Journal of Political Ecology has documented, in detail, the process by which the relationships among government, industry, and community/civil society can result in the level of distrust and conflict recently exhibited in Kent County, NB. These events are not unique to New Brunswick, as research results "suggest that ever-increasing segments of the world's population now contend with environmental challenges that they did not authorize and do not benefit from" (Willow, 2014). At the heart of the matter are unequal distributions of power, agency, profits, benefits, and burdens, with "citizens' common resources...used by and for corporations," (Hudgins and Poole, 2014), in a governance arrangement, "where the state is the handmaiden to the market..., water, land, air community, quality of life, health, wildlife, family relationships, food, and more are reframed such that their utility or fulfillment is defined around the market logic required to extract maximum profit" (Hudgins and Poole, 2014).[16] That is, community, needs, wants, values and attachment to place are given less weight by government authorities than corporate goals, in a decision-making framework that minimizes public input and essentially looks something like this:

Figure 5.4 Perceived Hydraulic Fracturing Decision-making Structure in Many Small, Rural Communities



Courtesy of Shawn Dalton

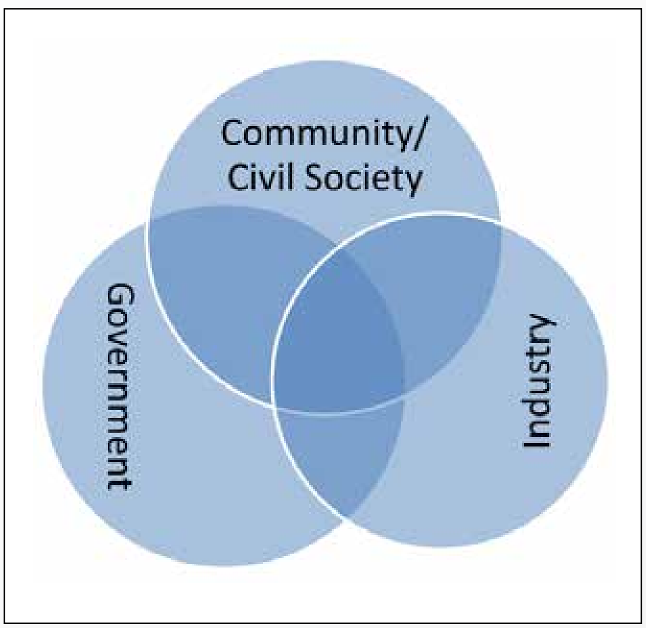
In this report we argue that local communities should have the opportunity to decide whether, when, and how unconventional gas and oil will be developed in areas that directly affect their livelihoods, well-being, quality of life, and sense of and attachment to place, consistent with a precautionary approach. Given the level of opposition to unconventional gas and oil development exhibited in communities across the globe (Simonelli, 2014; Mercer et al., 2014; Wylie and Albright, 2014; Willow, 2014) and witnessed in our public meetings, it should be apparent to both government and industry that pushing forward in the absence of social licence to do so, is likely to be both time-consuming and expensive.

If this industry ever develops in Nova Scotia, it would be necessary to invest significant time and resources up-front, to develop the mutual trust and respect that can lead to strong working relationships among the different sectors (see also recommendations section of Chapter 11). Community concerns often include, "ecological and human health concerns around water quality and availability, discharges of toxic substances into the environment, air emissions released during production and processing, explosions from methane build-up, and earthquakes" (Willow and Wylie, 2014). See also Chapter 8. These are perceived to have been challenged or ignored by industry, thus rendering trust, respect, and strong working relationships difficult to achieve, even in areas new or relatively new to the industry.

According to the International Association for Public Participation, "Public participation means to involve those who are affected by a decision in the decision-making process. It promotes sustainable decisions by providing participants with the information they need to be involved in a meaningful way and it communicates to participants how their input affects the decision."[17] A well-tested framework for public participation in decision-making demonstrates how conflicts may arise, as decision-makers often wish to "inform" or "consult" with local communities, whereas community representatives push for empowerment on the spectrum shown in Figure 5.5

That is, the decision-making framework regarding unconventional gas and oil development would be driven by community needs and wants and would look like more like this:

Figure 5.5 Potential model for improved, community-driven decision-making framework in Nova Scotia communities



Courtesy of Shawn Dalton

In small, rural communities such as those in the Maritime Provinces, the spectrum described below in Table 5.1 may be useful, not only as an example of different types of public participation, but in fact, may better serve as a guide to a better process. Thus, reciprocal information sharing and consultation begin a dialogue, with the end goal being collaboration and community empowerment. We discuss these approaches in Chapter 11, as part of our explanation of how to create the "community permission to proceed," consistent with a precautionary approach.

Table 5.1 Public Participation Spectrum[18]

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problems, alternatives and/or solutions.	To obtain public feedback on analysis, alternatives and/or decision.	To work directly with the public throughout the process to ensure that public issues and concerns are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision-making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and issues are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for direct advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.
EXAMPLE TOOLS	Fact sheets Websites Open houses	Public comment Focus groups Surveys Public meetings	Workshops Deliberate polling	Citizen Advisory committees Consensus-building Participatory decision-making	Citizen juries Ballots Delegated decisions

5.4 | Implications for the Nova Scotia Community Context

Community impacts of energy development may be both positive and negative in the key areas noted above (Jacquet et al., 2013; Popkin, 2013). The energy boomtown literature of the 1970s and 1980s focused on the negative impacts of the boom-bust-recovery cycle (Jacquet, 2009). Although subsequent research has shown some positive impacts in most categories, local biophysical and regulatory conditions and communities' social and economic characteristics, affect investor risk and communities' perception of risk on the ground (Jacquet, 2014; Stedman et al., 2012). Table 5.2, below, summarizes the findings of a research paper by Brasier et al., (2011), which draws on earlier literature on energy boomtowns and documents actual and perceived future effects of unconventional gas extraction in four counties in the Marcellus region in Pennsylvania, as articulated by residents. This project compared the experiences of communities at different stages of the industry's development and with different levels of unconventional gas activity. These are shown during the phases of development: preparation/ exploration, active development and extraction, decommissioning and abandonment. Positive and negative effects on communities are shown in separate columns (+/-). The table also indicates where these phases of development fall along the boom-bust-recovery trajectory. Different members of the community experience these effects in different ways, depending upon "social class, gender, age, length of residence, and degree of direct benefit from the development" (Brasier et al., 2011).

Table 5.2 Positive (+) and negative (-) community effects of unconventional gas and oil and other energy development

BOOM	
Preparation/Exploration	
	Direct jobs and business activity in industry
+	Good for those with appropriate skills/higher paying
-	Takes skilled employees out of other local businesses
	Goods and services for workers
+	Provides work for some
-	Generally lower paying, poorer benefits
	Collatoral business activity
+	Increased profits within community
-	Competition for limited work force (mechanics, heavy equipment operators, etc.) Strains ability of local business owners to pay higher wages
	Increased traffic - trucks
+	Increased profits within community
-	Traffic / Noise / Air Pollution / Road Damage
Active Development and Extraction	
	Tax revenue
+	Increases government revenue through property and income tax
-	Actual benefits are often less anticipated; taken up in increased expenditures on infrastructure, schools, etc.
	Physical infrastructure
+	Increased income houseing (often rental)
-	Drives prices up, leaving some people unable to afford their homes; increases homelessness / Can increase stress
	Rapid population growth and increased diversity
+	Change people's patterns of interactions
-	Change people's patterns of interactions / Decreases community cohesion Change character of community / Increase in social problems (substance abuse, crime, etc.) / Decrease in quality of life / Lowers standard of living for some Strains community services/organizations
	Economic growth
+	Bolsters social and economic cohesion
	Increase traffic - trucks, immigrants
+	Contributes to local economy
-	Traffic / Noise / Air Pollution / Road Damage

BUST

Decommissioning/Abandonment*

Housing built to accommodate workers is vacated

+ Open space and lower prices for lower income people
- Loss of revenue for property owners

Community satisfaction

+ Return to pre-boom levels

Trust in other community residents

+ Return to pre-boom levels

Social Ties

+ Return to pre-boom levels

Developed by author based on Brasier et al. (2011)

The literature regarding socioeconomic effects of unconventional gas and oil development on communities is just beginning to emerge (Multi-State Shale Research Collaborative, 2014). Much of the recent research is on the negative aspects of unconventional gas and oil development, in terms of social-psychological processes, community perceptions of the industry, environmental degradation and accidents, and regulatory frameworks. Two examples of detailed ethnographic research were found, both by the same author (Perry, 2012; Perry, 2013) and focused on the same county in Pennsylvania (PA).

We have much to learn.

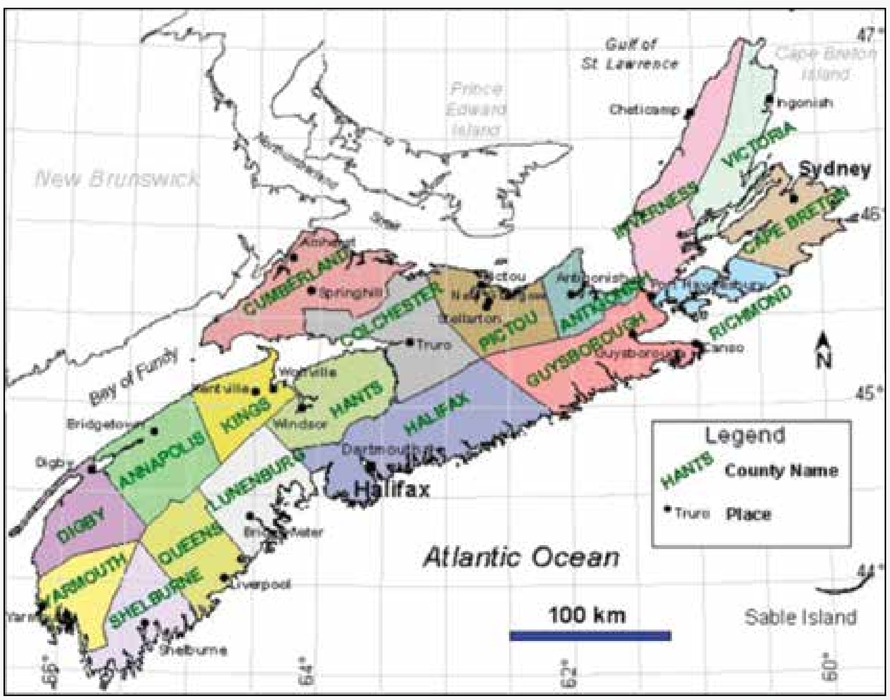
Concurrent to publications reporting community effects research, the industry itself is evolving. New technologies are being developed to reduce the environmental risks associated with hydraulic fracturing. These include using less toxic substances in fracking fluid, reducing the amount of water used, and improving technologies to treat and re-use wastewater. Measuring and mapping community effects is a moving target and will continue to evolve as the industry matures. Clearly significant gaps exist in the current state of knowledge globally. But how does all this information pertain specifically to Nova Scotia?

Public submissions to this review panel suggest that many of the community effects described above, concern and interest Nova Scotians, including our Aboriginal communities (see Chapters 8 and 10). Our public meetings echoed these concerns in a vivid way (see Introduction).

Given the earlier discussion regarding increasingly organized opposition to unconventional gas and oil development, these concerns should not be overlooked by any government or developer interested in onshore unconventional gas and oil development in the Province. It is not possible to determine to what extent respondents are representative of Nova Scotia's general population, nor to provide demographic information or spatial distribution of responses; however, the number of responses, the attention to detail, and the hard work that went into the submissions, indicate that many Nova Scotians are extremely interested in and concerned about this subject. For that reason, we have made a clear recommendation on the need for community level research on attitudes to risks and benefits, before any exploration occurs (see recommendations section of Chapter 11).

Nova Scotia is the second most densely populated province in Canada, after Prince Edward Island. However, in 2011, 390,000 of the 921,000 inhabitants of Nova Scotia lived in the Halifax Regional Municipality, where population density is 71 people/sq km. In contrast, Queens County (see Figure 5.6, below) has a population density of 4.6 people/sq km. Some 60 per cent of the population of Nova Scotia lives in rural areas.[19] As well, Nova Scotia is home to 13 First Nations communities, whose rights and traditional practices differ from those of the majority of Nova Scotians. First Nations communities are particularly vulnerable to the effects of landscape changes, not only because of pressing socioeconomic challenges within communities, but also because they hunt, harvest, gather, and eat animals and plants across the landscape. These foods are only as healthy as their habitats. Finally, traditional use and occupancy by First Nations must be addressed in the context of any resource development plans. Research into Aboriginal community perspectives in Nova Scotia will be presented separately in due course.

Figure 5.6 Map of Counties and Places in Nova Scotia



Courtesy of Service Nova Scotia and Municipal Relations, 2012

According to the analysis and scenarios described in Chapters 2 and 3, the most likely prospects for unconventional gas and oil development lie partially, or completely, within Cumberland, Colchester, Pictou, Antigonish, Guysborough, Hants, and Kings Counties. It is beyond the scope of this chapter to characterize Nova Scotia communities, counties, or economic development regions. However, demographic and socioeconomic data can be obtained through Statistics Canada, as well as the Province of Nova Scotia's website.[20]

As with biophysical characteristics such as water quality and quantity, biodiversity indices, forest composition and cover, etc., it is possible to create a baseline dataset on socioeconomic parameters at different scales (e.g. household, community, region, province) and to monitor conditions and track changes in a social system over time. To do so effectively and systematically, however, it is necessary to select a set of variables, indicators, and measures. One example of an organizing framework for integrated social-ecological monitoring is the Human Ecosystem Framework[21] (Appendix D); there are additional models which may be fruitfully used in this context. The Human Ecosystem Framework is mentioned here by way of example only. Regular monitoring would begin with agreement on indicators and collection of baseline data. The goal of monitoring would be to include timely information in adaptive decision-making, so that problems are identified and addressed early, successes can be replicated, and subsequent implementation improved.

5.5 | **Summary and Outstanding Questions**

In this chapter we have tried to describe the complex and multi-layered nature of community and social-ecological phenomena that may unfold in response to industrial developments such as unconventional gas and oil exploitation. We have also suggested means by which that complexity can be addressed complexity, in ways that would empower, rather than disempower, communities and maximize benefits, while reducing risks and impacts. However a number of questions remain to be answered before the Province of Nova Scotia could proceed with exploration or development:

- What are the community effects of hydraulic fracturing and unconventional gas and oil development in other jurisdictions within Canada and what does this mean for Nova Scotia?[22] Most of this research has been carried out in the United States. What have been lived experiences in communities such as Sussex/Elgin, NB, for example, where hydraulic fracturing has been taking place for approximately a decade. Further afield, how have hydraulic fracturing and unconventional gas and oil development affected communities in Western Canada? Has this industry had primarily positive effects on communities in Canada in terms of the local economy, social and physical infrastructure, the natural environment, and/or social relations within communities? If so, why? If not, why not?
- Does the regulatory framework make a difference in people's lives on the ground? If so, how and what would this mean for regulation in Nova Scotia? It would be useful to compare the lived experiences in communities under different regulatory and enforcement regimes (e.g. strong/weak rules with strong or weak enforcement capacity).
- How can community and regional planning effectively maximize the benefits and minimize the costs of potential unconventional gas and oil development in Nova Scotia throughout the life cycle of the industry?
- At a fine scale, how would people in the Nova Scotia communities most directly affected by possible

unconventional gas and oil development feel about having this industry in their communities/countryside/towns?

- What would be the hidden costs of unconventional gas and oil development in Nova Scotia – ecosystem services, landscape values, changes in environmental legislation, etc.
- How can benefits and burdens of possible unconventional gas and oil development in Nova Scotia be equitably distributed among communities and regions?
- How would we avoid disproportionately allocating the negative impacts of unconventional gas and oil development in Nova Scotia on the most vulnerable members of our communities?
- These questions require context-specific research and communities will expect answers before committing to the possibility of unconventional gas and oil development in their geographies. For this reason we make clear recommendations on how these research needs should be met prior to any consideration of development (see Chapter 11).

5.6 | **Conclusion**

Human communities are dynamic and complex, as are the biophysical ecosystems of which they are a part. This document describes some of the potential and observed effects of unconventional gas and oil development on communities, with an eye toward understanding the possible social-ecological costs and benefits of unconventional gas and oil development through hydraulic fracturing in Nova Scotia. Possible community effects are described in the areas of the local economy, social and physical infrastructure, the natural environment, and social relations within communities. Examples of community effects are found to be both positive and negative.

Absent from our understanding are the potential medium- and long-term community effects of unconventional gas and oil development and peer-reviewed research on these, as well as short-term effects closer to home.

Should Nova Scotia ever move forward with unconventional gas and oil development, we recommend that this absence of knowledge be addressed through the creation of an independent, community-driven, long-term social-ecological monitoring program and other research activities (see Chapter 11). This will allow communities, the Province, and other stakeholders to understand, predict, and if desired, proactively control the effects of unconventional gas and oil development at local, regional, and provincial scales.

ENDNOTES

1. Source: http://cra.ca/slight-majority-of-nova-scotians-opposed-to-hydrofracking-in-the-province
2. http://www.releases.gov.nl.ca/releases/2013/nr/1104n06.htm
3. http://www.theguardian.pe.ca/News/Local/2014-01-18/article-3580716/The-fracking-debate/1
4. http://www.corridor.ca/operations/mccully-field.html
5. http://www2.gnb.ca/content/dam/gnb/Corporate/pdf/ShaleGas/en/RulesforIndustry.pdf
6. http://www.documentcloud.org/documents/468812-recommendations-shalegasdevelopment.html#document/p1
7. "Social-ecological" refers to the reciprocal relationships among social, environmental, and economic parameters of human-dominated ecosystems.
8. See Glossary
9. Source: Online Dictionary of Sociology: http://bitbucket.icaap.org/dict.pl
10. Indian Oil and Gas Canada, or IOGC, is a special operating agency charged with the obligation to manage oil and gas resources on First Nation reserve lands. IOGC is completely funded by the Government of Canada and no fees are charged to First Nations (Source: http://www.pgic-iogc.gc.ca/eng/1100110010458/1100110010464#transcript).
11. See, for example, http://www.cbc.ca/m/touch/canada/new-brunswick/story/1.2678163
12. https://www.swnnb.ca/exploration.html#exploration-fact-sheet
13. See Glossary. Severance tax may be charged even if there is no net profit on investment (http://www.investopedia.com/terms/s/severance-tax.asp). Members of our Review Panel are unaware of any severance tax arrangements in Canada.
14. See Glossary
15. See Glossary
16. This was a recurring theme in our public meetings; see Introduction and Chapter 11 for further discussion of the public perception of risk and unfair distribution of benefits.
17. http://www.iap2.org/
18. http://iap2canada.ca/page-1020549
19. Source: Statistics Canada.
20. See for example: http://www.novascotia.ca/finance/communitycounts/geogpage.asp; http://www.statcan.gc.ca/start-debut-eng.html
21. Human Ecosystem Framework figure and descriptive text adapted with permission from Machlis, G.E., Force, J.E., and Dalton, S.E. (1994). "Monitoring Social Indicators for Ecosystem Management." Technical paper submitted to the Interior Columbia River Basin Project under Order #43-0E00-4-9186.
22. The literature review for this was based on peer-reviewed academic literature and did not yield any community effects analyses in Canada. Several communities self-report on websites and blogs, but they are not reported here.
23. See, for example, the work of the Canaan-Washademoak Watershed Association in New Brunswick: http://nbwatersheds.ca/cwwa/images/documents/MacLaughlinAug068X11Aug2006.pdf

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CHAPTER 6

Impacts on Water

Graham Gagnon

6.0 | **Chapter Summary**

This chapter builds on the analysis of Chapter 5 on public health and notes that water quality and quantity concerns are regularly cited as the top issues for the public in considering the potential impacts of hydraulic fracturing. The Nova Scotia government has developed many policies to ensure water safety and security are protected. The chapter reviews key policy instruments, the state of water resources in Nova Scotia, and the possible impacts hydraulic fracturing may have on those resources. In particular, the paper addresses the current status of water resources in Nova Scotia, concerns with water and unconventional gas and oil development, water regulations for hydraulic fracturing in other jurisdictions, current water regulations in Nova Scotia, and, water management with hydraulic fracturing in a Nova Scotia context.

This chapter benefited from the input of 19 comments from stakeholders after it was released as a discussion paper and open for feedback. The primary concerns from stakeholders related to regional use of water in the Province and wastewater management. This feedback was incorporated in relevant sections in the document. During the open-period for public submissions many of the general submissions were related to water issues as well—a full analysis of those submissions is provided in Chapter 8 of this report.

6.1 | **Current Status of Water in Nova Scotia**

6.1.1 Regulatory Framework and Water Use

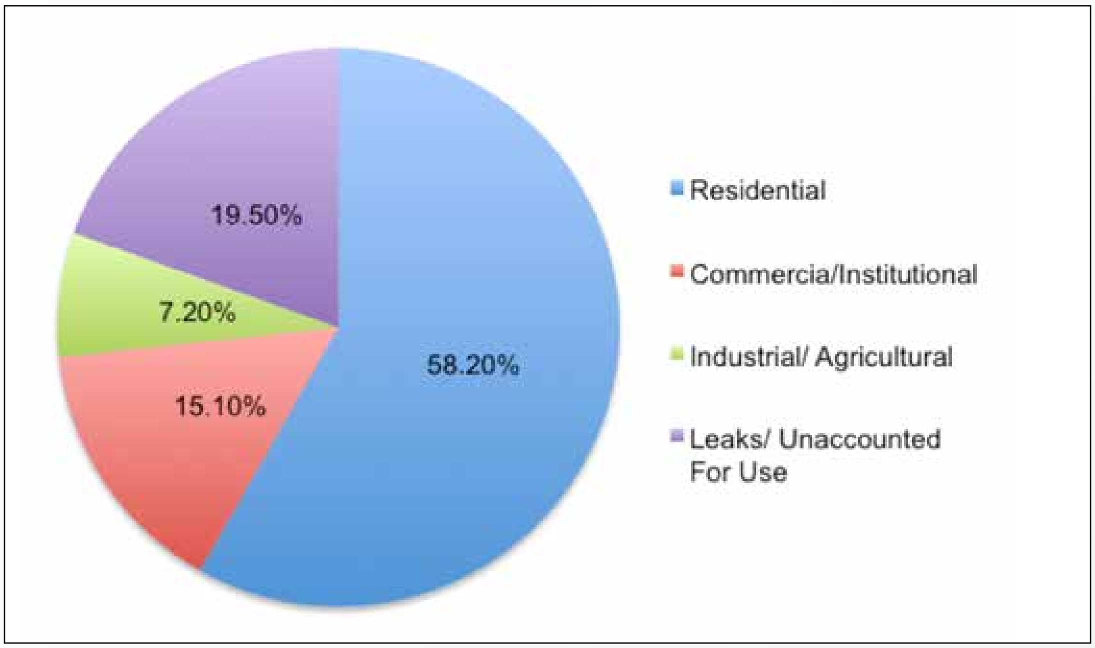
In Nova Scotia, the *Environmental Goals and Sustainable Prosperity Act (EGSPA*) recognizes the importance of integrating environmental sustainability and economic prosperity and the importance of a "precautionary approach" (see Introduction; see also Chapters 8 and 9). One of the principles of the act states that, "the health of the economy, the health of the environment, and the health of the people of the Province are interconnected" (EGSPA, 2007). Within this Act, water quality was highlighted for drinking water safety, safe wastewater disposal, and to create a comprehensive water resources strategy.
In December 2010, NS Environment prepared *Water for Life: Nova Scotia's Water Resource Management Strategy*. Development of a water resource strategy was a goal identified through *EGSPA* and the Water for Life Strategy outlines the integral role that water has on our health, our ecosystems, and our economy in Nova Scotia. Commonly used definitions for water (e.g., watershed) were described in the Water for Life Strategy and are presented in a glossary to this report.

Three themes from the strategy identify short-term actions and long-term directions. The three are:

a) Understand the quality and quantity of our water;
b) Protect the quality and quantity of our water; and
c) Engage in caring for our water.
(NS Environment, 2010)

As noted in an Environment Canada (2009) report (Figure 6.1) and the Water for Life Strategy, approximately two thirds of water consumption is for residential purposes. To provide context, the Halifax Water Annual Report provides a thorough analysis of drinking water, wastewater, and stormwater flow rates on an annual and daily basis for the Halifax Regional Municipality. For example, the average daily consumption for drinking water for metro Halifax (Halifax, Dartmouth, Bedford, Sackville) in the 2012 fiscal year was 135.6 million litres per day (or 135,600 cubic meters per day), on an approximate population size of 355,000. The magnitude of metro Halifax daily consumption is a useful metric to understand the rate at which approximately 50 per cent of Nova Scotians use water (Halifax Water, 2013).

Figure 6.1 Water use in Nova Scotia by sector



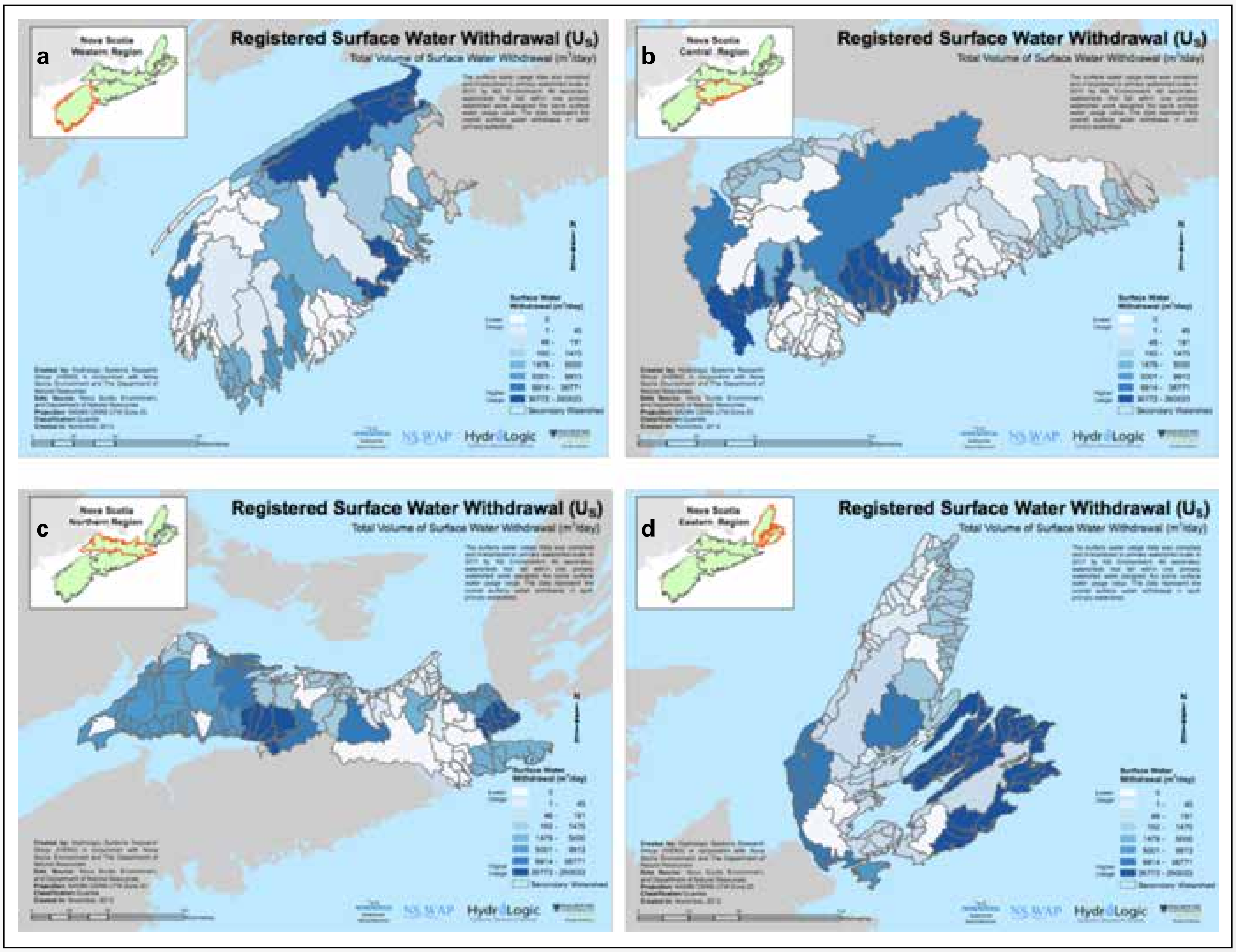
(Adapted from Environment Canada, 2009)

The Environment Canada (2009) report highlights leaks or unaccounted for uses, as the next largest consumer of water in Nova Scotia, utilizing approximately one fifth of water consumption. Generally speaking, leaks and unaccounted uses fall under residential use, based on water utility practices for municipal sources.

Water resources in Nova Scotia support many other industries including: agriculture, pulp and paper, manufacturing, energy production, mining, aquaculture, fish processing, tourism, and recreation (NS Environment and Labour, 2008). Thus, any new industrial activity, such as onshore petroleum resource development of oil and gas, including the use of hydraulic fracturing to extract unconventional resources, would need to fit within the context of available water and *EGSPA*.

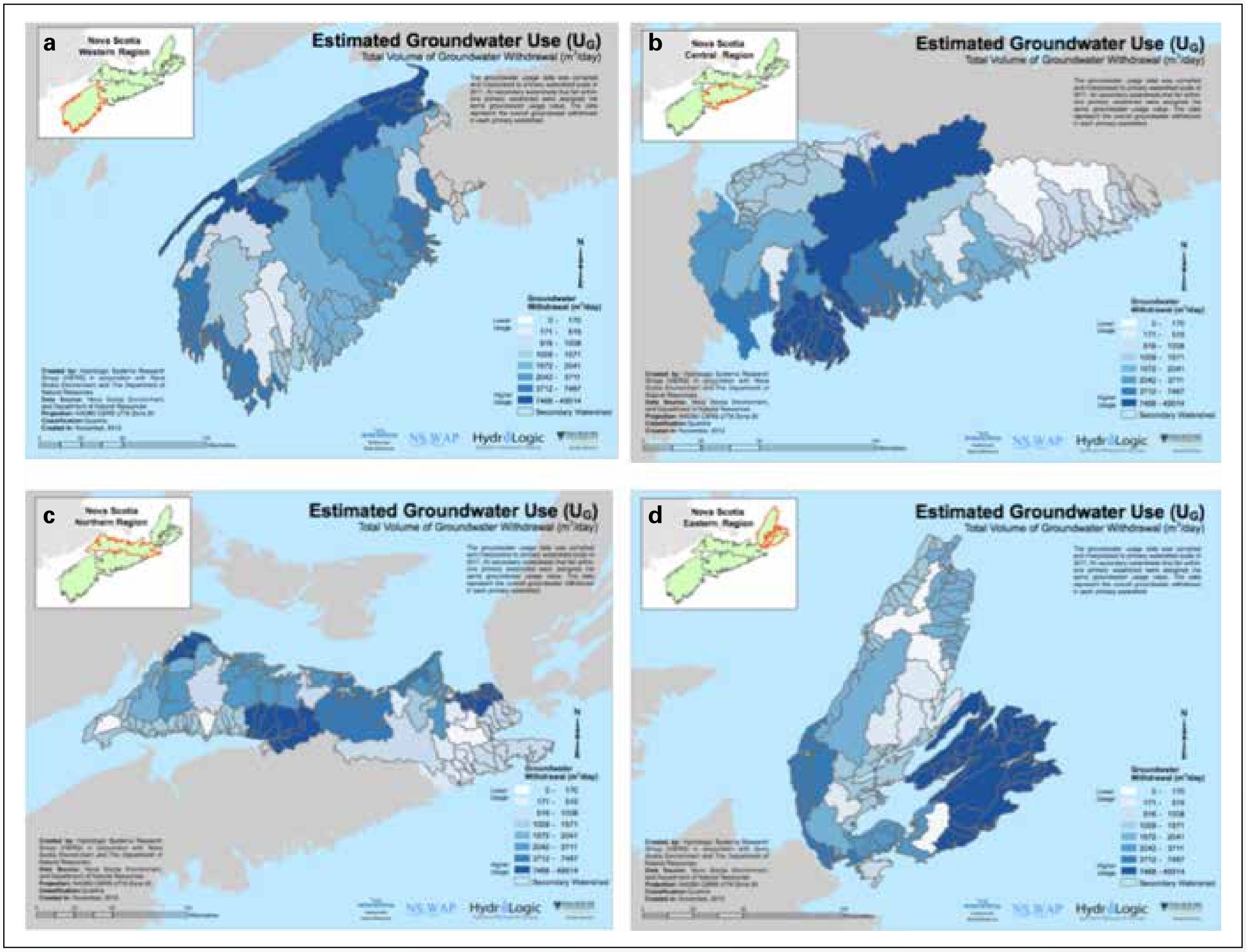
The Nova Scotia Watershed Assessment Program was a result of the Water for Life Strategy, as part of the theme Understanding Our Water, led by Dr. Shannon Sterling of Dalhousie University. Water withdrawals from surface water and groundwater in Nova Scotia were characterized. Figure 6.2 indicates that most of the surface water withdrawal occurs in areas where there is significant residential usage (e.g., metro Halifax, CBRM), agricultural activity (e.g., Annapolis Valley) or both (e.g., Truro). For other areas of the Province, surface water withdrawals are much lower. Similarly, groundwater usage is low except in areas of significant agricultural intensity or residential use (Figure 6.3) (Sterling et al., 2014). As shown in Figure 6.4, the vast majority of Nova Scotia only uses up to 4 per cent of the total groundwater available in each watershed (Kennedy et al., 2010).

Figure 6.2 Surface water withdrawals in a) Western, b) Central, c) Northern, and d) Eastern Nova Scotia



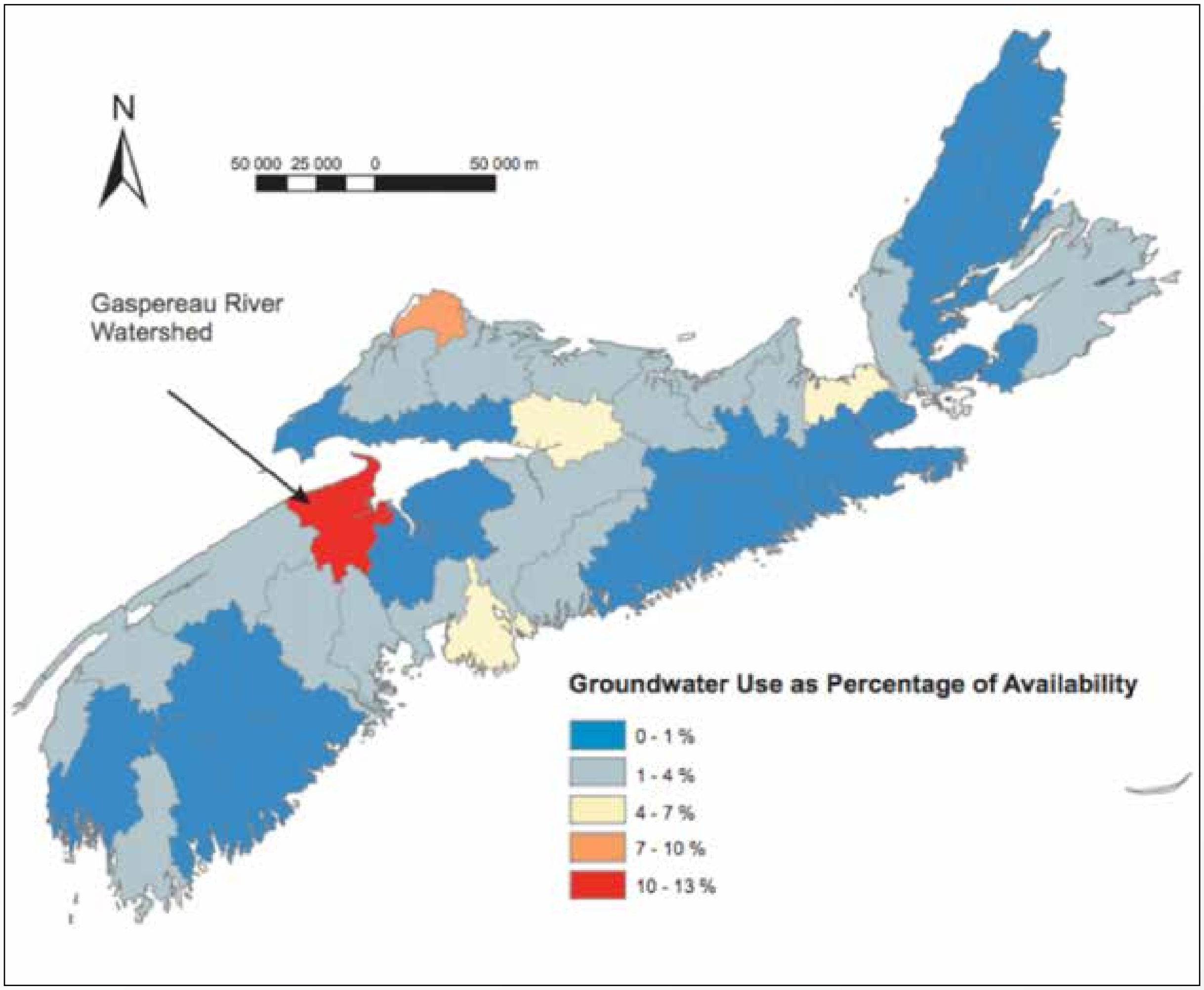
Courtesy of Sterling, S. M., et al. (2014). Reproduced with permission from Elsevier.

Figure 6.3 Groundwater withdrawals in a) Western, b) Central, c) Northern, and d) Eastern Nova Scotia



Courtesy of Sterling, S. M., et al. (2014). Reproduced with permission from Elsevier.

Figure 6.4 Total groundwater use for each watershed as a percentage of groundwater available



Courtesy of the Department of Natural Resources: Kennedy, Garroway & Finlayson (2010).

The Nova Scotia Watershed Assessment Program also resulted in a comprehensive inventory entitled the Nova Scotia Watershed Assessment Atlas (NS Environment and Dalhousie University, 2014), which details the present threats to water quality and aquatic life in the 46 primary watersheds and 295 secondary watersheds in the Province. Through this analysis, it is evident that human land use and acid rock drainage is the predominant threat to water quality for the regions identified in the watershed atlas.
Overall, this analysis demonstrates that:

a) The EGSPA, along with the Water for Life program, recognize the specific value water has on public health, the environment, and the economy; however, these documents have not specifically accommodated for onshore unconventional gas and oil activities;
b) Most of the water in the Province is used for residential purposes, with leaks or unaccounted for uses being the next highest user of water;
c) The majority of threats arise from land use activities.

6.1.2 Drinking Water Quality

There are 82 municipal water suppliers in the Province (NS Environment, 2014b), supplying drinking water to approximately 60 per cent of the Province's population. The majority of municipal supplies obtain water from surface water systems (e.g., lakes, rivers) and their treatment performance is required to meet standards set out by the Province. The NS Auditor General found that municipal audits were generally conducted within the planned three-year timeframe (Office of the Auditor General Nova Scotia, 2014). As well, the NS Auditor General also found that municipal systems are generally meeting NS treatment standards.

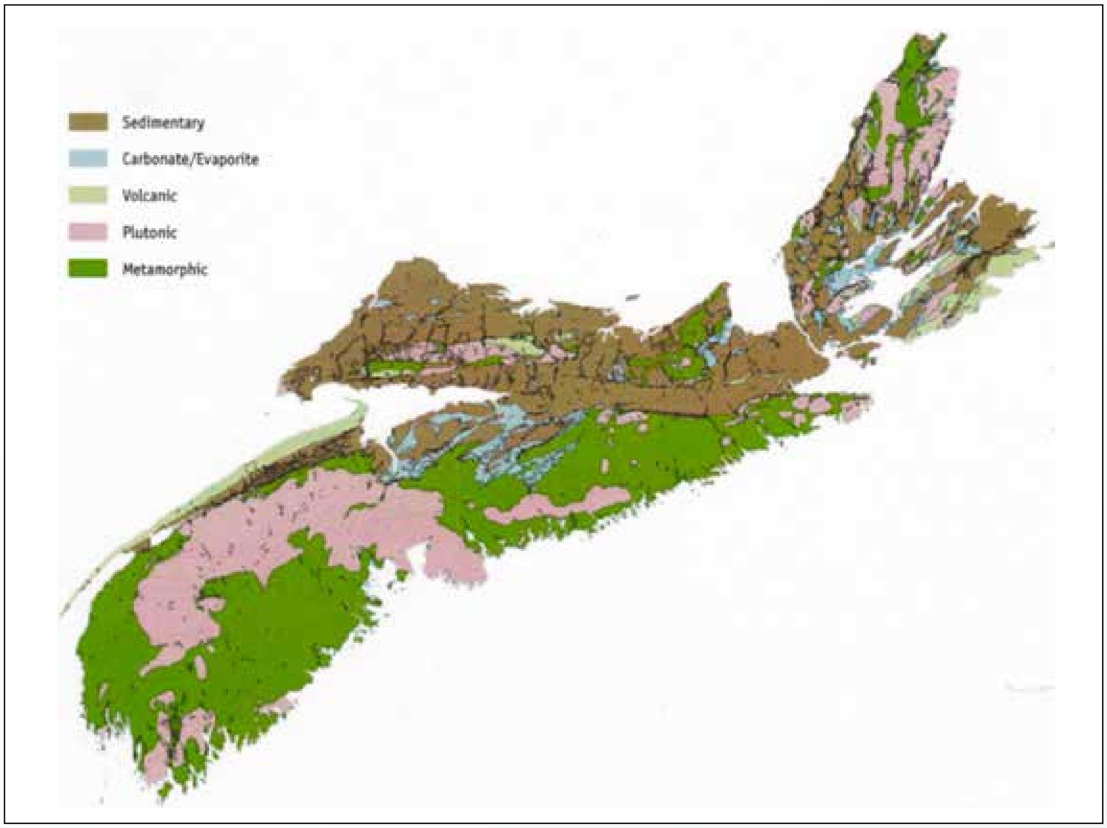
The remaining 40 per cent of the Province's population is either on a private water supply (e.g., individual home) or a registered water supply. The Auditor General found that the greatest vulnerabilities were for the 1,600 registered water supply systems. A registered water supply is defined as a system that provides drinking water to at least 15 service connections or serves 25 or more individuals per day for at least 60 days of the year. Some of the registered systems are for permanent residents (e.g., mobile home communities) and some are more transient (e.g., food establishment) populations. The vast majority of registered systems rely on groundwater for their drinking water source (Office of the Auditor General Nova Scotia, 2014). As compliance is generally being achieved in the surface water municipal systems, groundwater quality is the focus of this chapter.

Groundwater is typically contained within a layer of bedrock that is permeable, or in loose soil and rock above a layer of impermeable bedrock (NS Environment, 2014b). A layer that holds and conveys groundwater is referred to as an aquifer (Oxford Dictionaries, 2014). Precipitation (falling rain and snow) and groundwater levels, typically sustain lakes, rivers, and springs (NS Environment, 2014d). According to the Nova Scotia "Well Logs Database," approximately 90 per cent of wells in Nova Scotia are drilled into deep-water aquifers while the remaining wells are dug.[1] Dug wells are shallow, typically three to nine meters deep, and one meter in diameter. Deep-water aquifer, wells typically extend far deeper, through rock where the water is confined under pressure (New Brunswick Department of Environment, n.d.). It is estimated that over 99 per cent of all drilled water wells in Nova Scotia are completed at depths less than 150m (Kennedy, G., 2014, personal communication). Groundwater wells supply individual private homes, public water supplies, and other uses, including agriculture, industry, and institutions such as rural schools, day cares, nursing homes, and businesses such as restaurants and campgrounds (NS Environment, 2014b).

Forty groundwater monitoring stations have been established around the Province to track groundwater quantity and quality, through the Nova Scotia Observation Well Network program (NS Environment, 2014a).

Data collected through the well network program are analyzed and utilized to prepare regional maps and publications that describe the quality, availability and vulnerability of groundwater. In addition, NS Department of Natural Resources (DNR) collects data about aquifer properties, groundwater chemistry, recharge rates, flow patterns, and groundwater quality. DNR classifies Nova Scotia groundwater into five major bedrock aquifer groupings and these are displayed in Figure 6.5 (NS Environment and DNR, 2009).

Figure 6.5 Groundwater regions of Nova Scotia



Courtesy of NS Environment and NS Department of Natural Resources (2009)

The naturally occurring chemical composition of the groundwater of any given area depends on the local geology (NS Environment and DNR, 2009). Within areas of sedimentary or carbonate/evaporite deposits, wells typically generate groundwater with moderate to high hardness and dissolved solids. Trace metals (e.g. arsenic, iron, manganese, uranium, fluoride) occur in all groundwater regions (Kennedy and Drage, 2009).

Methane is a naturally occurring component of groundwater, with approximately 15 per cent of wells in sedimentary or carbonate/evaporite deposits containing methane (J. Drage, personal communication, February 4, 2014). Results from a methane survey by Dyck et al. (1976) in the on-shore sedimentary basin areas of Nova Scotia, indicate that dissolved methane was detected in approximately 15 per cent of water wells. The highest methane concentration reported was 9.2 mg/L (Dyck et al., 1976). Recently, Drage and Kennedy (2013) reported detectable methane levels in 21 per cent of all wells owned and operated by the Government of Nova Scotia. The highest reported methane concentration reported by Drage and Kennedy (2013) was 6.0 mg/L.

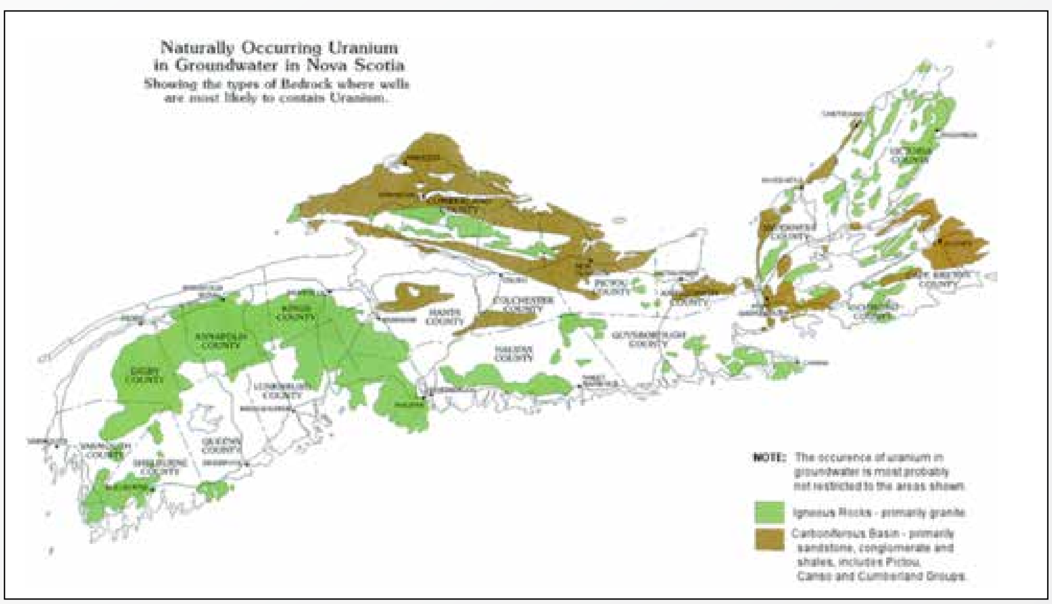
The U.S. Department of the Interior, Office of Surface Mining (Eltschlager et al., 2001) recommends the following action levels for dissolved methane:

- Less than 10 mg/L—no action required, other than periodic monitoring;
- 10 mg/L to 28 mg/L—well owners should consider removing potential ignition sources from the immediate area; and
- Greater than 28 mg/L—take immediate action to reduce methane levels.

Methane has been reported to be a contaminant of concern for the hydraulic fracturing industry in some jurisdictions. For example, Jackson et al. (2013) reported that average methane concentrations were six times higher in homes less than one km from natural gas wells in Pennsylvania compared to homes more than one km away. In particular, 12 out of the 141 homes studied by Jackson et al. (2013) had well water concentrations greater than 28 mg/L. At this time, Health Canada does not have a guideline for methane in drinking water. Because Nova Scotia utilizes Health Canada's guidelines for regulatory purposes, the Province would need to consider this, as required, for regulatory development (see Chapter 11 section on recommendations).

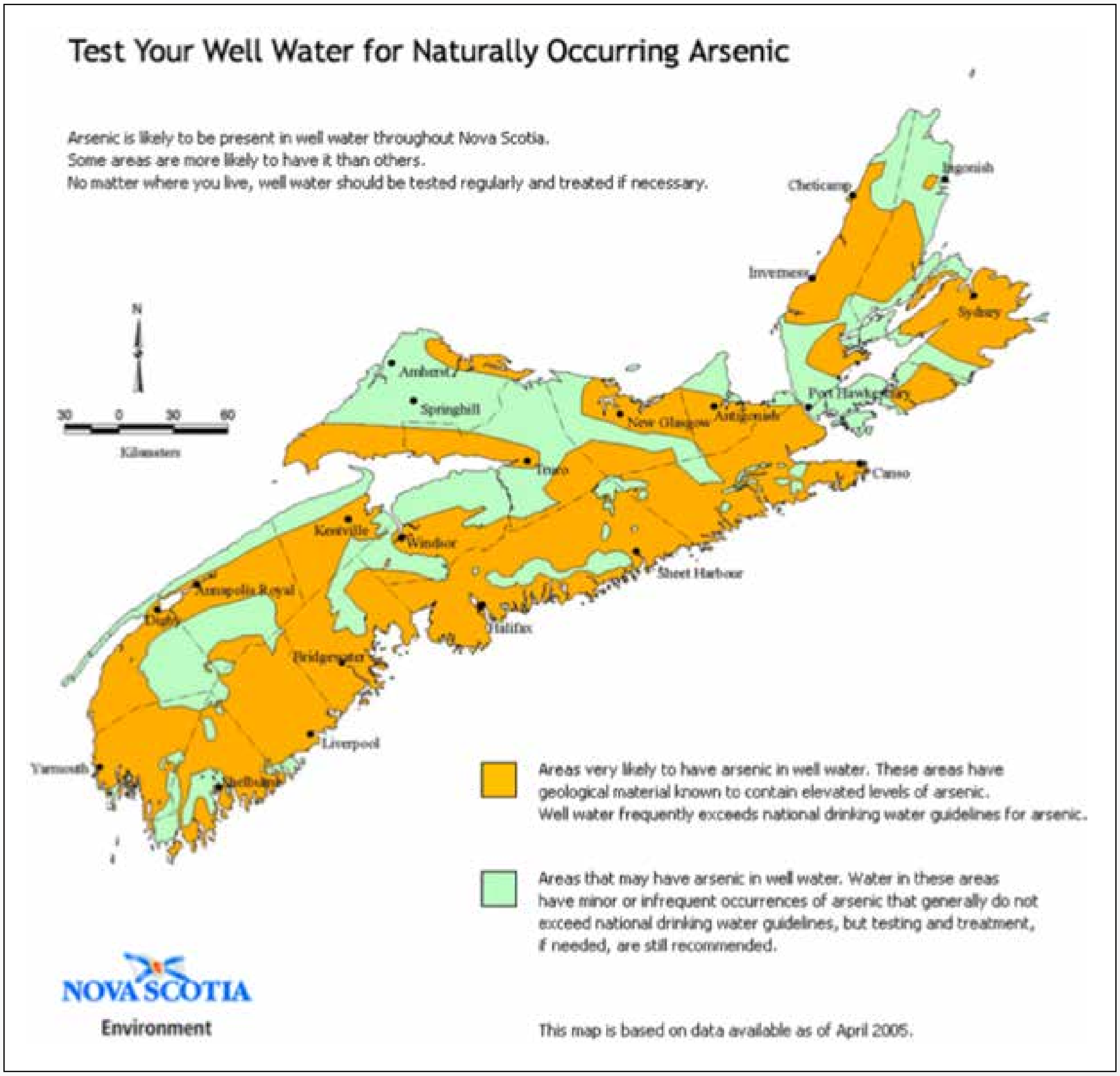
Water quality in the Province is also subject to many issues, including contamination with uranium (Figure 6.6), antimony, arsenic (Figure 6.7), boron, chloride, copper, fluoride, hydrogen sulphide, iron, manganese, magnesium, nitrate, nitrite, and other bacterial contaminants (NS Environment, 2014d). Many of these contaminants arise either as a result of natural occurring conditions, or are brought on through man-made activities. While it is too difficult to review the occurrence of all of the possible contaminants in groundwater, arsenic can be used as a case study contaminant that has occurred due to natural and man-made conditions in Nova Scotia.

Figure 6.6 Areas where naturally occurring uranium may be found in groundwater



Courtesy of the Nova Scotia Department of Environment (NS Environment, 2014a): http://www.novascotia.ca/nse/groundwater/default.asp#maps

Figure 6.7 Areas where naturally occurring arsenic may be found in groundwater



Courtesy of the Nova Scotia Department of Environment (NS Environment, 2014a): http://www.novascotia.ca/nse/groundwater/default.asp#maps

Arsenic contamination in Nova Scotia was first discovered in 1976, when an ill patient exhibited symptoms of arsenic poisoning and an analysis of the patient's private well revealed an arsenic concentration of 5000 µg As/L (Meranger and Subramanian, 1984). In Atlantic Canada, arsenic contamination is mainly attributed to natural contamination due to bedrock formations and partly attributed to anthropogenic contamination due to poor disposal of mine tailings (Grantham and Jones, 1977). In a hydrologic study of the region, Bottomley (1984) attributed arsenic contamination of groundwater in New Brunswick and Nova Scotia to oxidation that occurs when new groundwater wells are drilled, causing arsenic releases from the bedrock. In areas with a history of gold mining, arsenopyrite-containing residual tailings and waste rock were reused on roads, left in piles, and even used to line water wells, causing eventual arsenic contamination of groundwater (Bottomley, 1984).

Since these older studies were completed, drinking water quality criteria for arsenic in Nova Scotia have been reduced from 50-ug/L to 10-ug/L (Gibbons and Gagnon, 2010). As well, the NS Department of the Environment developed fact sheets and treatment guidelines to help home owners remedy arsenic in their groundwater supplies. Further, most site inspections on new properties are required to have testing for arsenic in Nova Scotia. While the occurrence of naturally occurring arsenic is still as likely as it was over 40-years ago, the Province and other stakeholders have developed mitigative strategies to reduce exposure of Nova Scotians to arsenic (NS Environment and Labour, 2004a). Further information for the general chemistry and water quality of groundwater in Nova Scotia can be found in Kennedy and Drage (2009). It is important to recognize that individual homeowners are not required to test for arsenic by the Province, though some mortgage companies may require arsenic testing.

6.2 | What are the Concerns with Water and Unconventional Gas and Oil Development

There are numerous environmental considerations regarding hydraulic fracturing, as there are with most industrial processes. Implications for water quantity and quality have been frequently raised concerns regarding hydraulic fracturing in Nova Scotia (see Introduction and Chapter 8)

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6.2.1 Water Quantity

Unconventional gas and oil extraction requires water during the fullcycle of operation. Water in hydraulic fracturing is typically withdrawn from surface bodies, such as lakes and rivers, or from aquifers via deep-water wells. Where withdrawals are made from aquifers, it is possible that the aquifer could be overdrawn and create drawdown in localized areas of the watershed. If this were to occur near the coast, salt water from the ocean may intrude into the aquifer. Intrusion may also occur if non-potable water is drawn in from hydraulically connected aquifers.

Ziemkiewicz et al. (2014) completed a study of waste streams from multiple Marcellus unconventional gas and oil facilities in northern West Virginia. Findings from the Ziemkiewicz et al. (2014) study provide a sense of water usage at the Marcellus unconventional gas and oil facilities, which are described below by way of example. It is recognized that water usage varies for different unconventional gas and oil plays, the analysis below from Ziemkiewicz et al. (2014) provides a general sense of water activities. Not counting proppant sand, which is considered a biologically inert substance (quartz of Al_2O_3), a typical hydraulic fracture fluid formulation will contain more than 98 per cent water and less than 2 per cent (sometimes less than 0.5 per cent) additives, the majority of which are neither toxic nor hazardous e.g. potassium chloride. Makeup water can be any combination of stream water, recycled flowback water, water from a saline aquifer or co-produced with oil, municipal wastewater after primary treatment, or municipal water. In the Marcellus unconventional gas and oil play, between 10 and 30 per cent of injected frac fluid returns to the well head and about 80 per cent of that fluid is currently recycled as makeup water. The flowback return rate decreases rapidly from an initial monthly average of 52 m^3 per day to 4.3 m^3 per day within about 60 days. Thereafter, flowback yields to produced water as gas production begins and fluid recovery rates gradually decline to less than 1 m^3 per day. Thus, water co-production (fracture fluid flowback plus formation water), is at its highest during the start-up phase for a gas well.

As reported by the Council of Canadian Academies (2014), the total amount of water needed for unconventional gas and oil development is generally small in the Canadian hydrological context (i.e. relative to annual, total surface water flows). It was recognized in that report that hydraulic fracturing requires large volumes of water over short periods of time (weeks to months). Within the context of Atlantic Canada, the Council of Canadian Academies (2014) reported that the average volume of water used per unconventional gas and oil well varied from 2,000-20,000 cubic metres in New Brunswick and 5,900-6,800 cubic metres in Nova Scotia. As noted earlier, Halifax Water provides over 130,000 cubic metres of drinking water to metro Halifax each day. Al et al. (2013) placed water use into perspective for New Brunswick as follows: to supply water on a year-round basis for the drilling and hydraulic fracturing of 1,000 wells would require a water supply capable of providing a continuous flow of about 0.6 to 2 [cubic metres] per second, compared to the average summer low flow in a large river like the Saint John River at Fredericton (about 400 [cubic metres] per second).

Given this analysis and the water use information provided earlier, at a provincial level there appears to be sufficient capacity for Nova Scotia to maintain its current water use in the event that hydraulic fracturing were ever to be pursued; however, there are specific areas of the Province that may face demand issues due to extensive agricultural operations and limited surface water sources. In areas, of identified water stress it would still be possible to consider the use of lower grade water to create make-up water. Mauter et al. (2014) have noted that maximizing the use of low-quality or impaired waters (e.g., brackish water; reuse of produced) in hydraulic fracturing fluids will alleviate some of the stress imposed on fresh water resources. Mauter et al. (2014) further noted the use of impaired water in the hydrualic fracturing process is being encouraged by both industry and independent groups as a means to reduce water footprints in shale gas development. Regardless, to better understand water demand at the watershed level, the specific water capacity in areas where hydraulic fracturing could occur should undergo improved water demand analysis to support future decision making by the Province. This increased analysis of water use would also be helpful for future and ongoing development across all sectors (see Chapter 11 recommendations).

Finally, as noted previously, water withdrawals for hydraulic fracturing, or any other industrial activity, require approval from NS Environment and are subject to public scrutiny. In New Brunswick, water requirements, potential source, and potential impacts are required for submission to government prior to any hydraulic fracturing development (Government of New Brunswick, 2013). For Nova Scotia, a program for water demands for the hydraulic fracturing industry could also be developed to, ensure transparency for stakeholders at the watershed level and across the Province.

6.2.2 Water Quality

In Nova Scotia, drinking water aquifers are usually less than 150 m below the surface (J. Drage, personal communication February 04, 2014). The target zone for unconventional gas and oil exploration in the Horton formation, a bedrock formation within the sedimentary grouping where the hydraulic fracturing could occur, is between 900 and 1,500 m below the surface (Ryder Scott, 2008). See also Chapter 2.

Due to the compressive stress of the weight of the soil and rock (or lithostatic stress) that exists at the depth of these geological formations (such as the Horton formation), the fractures generated by hydraulic fracturing typically extend approximately 100 m vertically and approximately 200 - 300 metres laterally (King, 2012). Therefore, the fractures could be hundreds of metres away from the underside of the aquifer. Flewelling and Sharma (2014), conducted a numerical analysis and literature review and found that where upward flow occurs within the fracture, both permeability and flow rates are low and therefore, timescales for transport are long. The authors estimated the travel time would be on the order of 10^5 to 10^8 years to travel across a 100 metres thick layer (Flewelling and Sharma, 2014). In contrast to this study, others (e.g., Myers, 2012) have suggested shorter time scales for vertical flow, based on modeling under case specific conditions.

Osborn et al. (2011), while studying methane occurrence in shallow Pennsylvania groundwater wells, ruled out migration through the shale formation as a possible explanation for methane occurrence in groundwater wells. The authors cited leaky well casings and naturally occurring methane as more likely scenarios for methane occurrence (Osborn et al. 2011). However, based on current knowledge and documented evidence, it is anticipated that flow through the fractures would not likely extend from the shale to the aquifer and thus direct contamination from hydraulic fracturing fluids would appear less likely than other pathways (e.g., accidental spills; well bore stability). Furthermore, the greatest risk of gas or fluid migrating out of the production zone along existing faults and fractures occurs either during hydraulic fracturing when new flow paths are being opened and the formation fluids are at the highest pressure they will experience, or if a well is shut-in (indefinitely closed) immediately after fracturing, allowing pressures to decrease gradually. Once gas production begins, pressure drops and gas and fracturing fluids tend to migrate towards the wellbore, rather than to the surface by some undefined pathway (Council of Canadian Academies, 2014).

Based on this information, it is recognized that the risk to water quality from unconventional gas and oil operations is more related to operational practices (e.g. chemical handling or waste management), rather than the fracturing and extraction process. The Council of Canadian Academies (2014), reported that the risks that shale gas infrastructure and related operations pose to surface water and groundwater stem from:

- Accidental spills of chemicals, oils, drilling muds, and fracture fluids during transportation, storage, or use;
- Spills of condensates (where these are present) or flowback or produced water from the producing well; and
- Inadequate storage, treatment, or disposal of flowback water, which includes both fracturing fluids and saline formation water, and leaks from surface storage ponds or other storage facilities.

In addition, improper well construction, which allows hydraulic connection of deeper strata and the shallower drinking water aquifer that drilling operations pass through, is an important consideration (see Chapter 7).

Accordingly, many regulators have required hydraulic fracturing companies to register chemicals and provide transparency to chemicals that may be used during operations. For example, as noted in Chapter 4, FracFocus.org[2] provides public access to lists of chemicals used during hydraulic fracturing. Ten U.S. states (i.e. Colorado, Oklahoma, Louisiana, Texas, North Dakota, Montana, Mississippi, Utah, Ohio, and Pennsylvania) use Fracfocus as a means of official chemical disclosure for hydraulic fracturing. The website FracFocus.ca is a project of the BC Oil and Gas Commission and is intended to provide similar information for the BC industry. The Fracfocus program has also been adopted by Alberta and the Northwest Territories. Wiseman (2013), reviewed the FracFocus program from a policy perspective and described it as one of the most successful efforts to date. In particular, Wiseman (2013), viewed the combination of voluntary industry disclosure, combined with an expanding array of jurisdiction specific disclosure laws, as very promising policy for governance of the hydraulic fracturing industry. However, it was noted by Wiseman that tough challenges still remain with this industry disclosure approach (e.g. trade secrets) and future policy development and research remains.

If handled incorrectly, many of the chemicals utilized in the unconventional gas and oil industry could contaminate water supplies. However, this statement is consistent with many industrial processes that occur in Atlantic Canada. For example, according to fracfocus.org, sodium hydroxide (or caustic soda), is a chemical used in the unconventional gas industry as an agent to adjust the pH of a fluid. Caustic soda is also used to process drinking water in some facilities in Nova Scotia, as it is highly effective at adjusting pH and poses minimal health risks at the low doses required. In the case of drinking water facilities, regulations and inspections are required by government to ensure that this chemical is safely applied and handled. Therefore, under the assumption of a strong regulatory framework (see Chapter 9), it would be anticipated that chemical agents could be safely managed and applied for hydraulic fracturing.

The Council of Canadian Academies, 2014 noted:

> "Of the wide range of views on the actual and potential impacts of shale gas development on groundwater quality, a common statement in the non-peer reviewed literature is that no impacts have been proven or verified. For example, the American Water Works Association's *White Paper on Water and Hydraulic Fracturing* states: "At this time, AWWA is aware of no proven cases of groundwater contamination directly attributable to hydraulic fracturing" (AWWA, 2013).

The above statement should not be misinterpreted as declaring hydraulic fracturing a risk-free process. Indeed, there are risks to water quality from this industrial activity (as noted previously). Risk management plans need to consider the safety of the industrial process itself and the development of water safety plans for the protection of neighbouring groundwater and surface water systems. The latter water safety plans would ensure that chemicals used by the industry are publicly declared and appropriate monitoring programs and risk mitigation programs are designed and available for public scrutiny. This approach would provide transparency and consistency as they exist in other industries and processes, such as drinking water treatment practices (see Chapter 11 recommendations).

6.3 | How Are Water Issues Addressed in Other Jurisdictions?

A *Jurisdictional Review of Hydraulic Fracturing Regulation* did not make recommendations, but instead provided the context of how hydraulic fracturing is being regulated in other regions (Precht and Dempster, 2012). The jurisdictions reviewed include Alberta, British Columbia, New Brunswick, Saskatchewan, New York, Ohio, Pennsylvania, Texas, and Wyoming. Some of the topics covered by Precht and Dempster included: well casing and cementing; protecting water; water allocation; disclosure of flowback contents; flowback fluid handling and management; and public concerns.

Well infrastructure integrity was considered important across all jurisdictions and as such, surface casings and requirements for subsurface casings were compulsory in all locations. There were many similarities across the jurisdictions, however, discrepancies include:

- Land use setbacks. The setback differences from a drill operation conducting hydraulic fracturing to numerous objects, such as occupied dwellings, water bodies, drinking wells, and property lines are highly variable. In some jurisdictions, such as Pennsylvania and New York, only a 30 metre setback is required to an occupied dwelling without the owner's consent.
- Assessment of well integrity. Techniques used to ensure wall casing and cement integrity included: cement quality/strength standards, daily drilling logs, inspections, engineering certifications, and emissions testing.
- Permission to have on-site holding ponds. Some jurisdictions (e.g. BC Information Letter # OGC 09-07) permit only holding fresh water, prior to use in the fracturing fluids mixing and injection. In other locations where ponds are permitted for flowback fluid temporary storage, there is variation in the design requirements for the construction of the pond. For example, legislation or best management practices could mandate the use of clay or other low-permeability construction materials, the use of a geo-membrane or other lining, and the requirement of a cover.
- Water management tools. The BC Oil and Gas Commission has several water management tools specifically for hydraulic fracturing. These tools include, a map-based water information tool, water quality reporting, and water approvals documents (BC Oil and Gas Commission, 2012b)
- Water withdrawal permits. Several jurisdictions require a permit for any withdrawal from a surface or ground water source, while others trigger the need for a permit based on various total quantities to be removed or the rate at which the water would be withdrawn. There is a great deal of variation with regards to required baseline testing of both water withdrawal sources and surface and groundwater bodies proximal to the proposed drill site. In many locations, this is deemed voluntary, or would be decided on a case-by-case basis. Additionally, only one jurisdiction requires post completion monitoring at three-month, six-month, and 12-month intervals.
- Financial bonding and insurance. Most of the interviewed jurisdictions require companies to put up a financial bond in the case of accidents, prior to drilling. Where required, the typical amount was $25,000 per well, which may be capped at $75,000, if the company operates multiple wells within the same formation or within a proximal distance. Dutzik et al. (2013) describe costs of $700,000 or more to plug abandoned wells. The requirement of liability insurance is not consistent, nor is the required value of that insurance.

- Disclosure of fracturing fluid composition. Most jurisdictions require full disclosure to regulators of the chemicals and their concentrations within fracturing fluid formulas, as well as the sample testing results of their flowback fluids. In most jurisdictions, this information would be held in confidence for a period of six months, which could be extended to a period of two years. If the formulas were deemed a trade secret, they might never be released to the public. In many jurisdictions, the flowback fluids are not treated, they are re-used in multiple operations and when drilling is completed they are injected into designated deep injection wells. In the few jurisdictions where deep-well injection is not the common practice for disposing of flowback fluids, most state that the flowback fluids have to be treated to meet the quality of the natural environment.

In British Columbia, a surface hydrological modeling program has been developed to provide estimates on the monthly, seasonal, and annual runoff quantities, using gridded climate data and land and vegetation cover for watersheds in north-eastern British Columbia. The tool was developed by the BC Oil and Gas Commission as a decision-making support tool, particularly regarding water availability for water use approvals (Chapman et al., 2012).

This jurisdictional review identifies topics that policy makers must address, should hydraulic fracturing ever become a permitted activity in Nova Scotia (see also Chapter 9). In addition, the Province would need to consider any acts that may affect water in First Nation lands. For example, the Safe Drinking Water for First Nations Act was promulgated in 2013 and may require consideration by the Province (see also Chapter 10). A more in-depth review of regulation in Alberta and British Columbia reveals interesting directives regarding hydraulic fracturing pertaining to water.

The Alberta Energy Regulator (AER, 2014) lists directives that include:

- Specific well casing requirements (Directives 008 and 009) that prescribe a surface casing depth calculation form, specific reporting requirements, and minimum casing cementing requirements (conductor pipes and surface, production, intermediate and liner casings);
- Surveillance, sampling and analysis of water (Directive 044) that includes the method of collection and the specific items for which each sample must be analyzed; and
- Drilling waste management (Directive 050) that sets the sampling requirements, assessment, and toxicity requirements of waste samples, handling of cement returns, subsurface disposal, and requirements to send water to an approved waste management facility.
- AER is currently developing their play-based regulations, which mandate that operators must develop regional approaches to water usage in unconventional plays. All potential sources of water – surface, shallow non-saline, and deep saline – must be considered in developing a water usage plan to support unconventional development activities.
- Regulators in both British Columbia and Alberta are participating in regional studies, along with industry groups, to characterize potential water sources and deep disposal zones in major unconventional play basins. Such studies provide background knowledge to support the play-based approach described above.

Alberta's Water Act (2000), requires that the Alberta Environment and Sustainable Resource Development Department issue a licence for all water diversions, including withdrawals and storage.

The British Columbia Oil and Gas Commission (2012a) lists:

- Specific applications for water licensing and the authority to suspend short-term water use by the oil and gas industry during drought conditions;
- Setbacks to maintain distance between water wells and drilling operations;
- Requirements for casings and cementing of casings, as well as casing integrity testing; and
- Requirements that produced water be disposed of in deep injection wells or temporarily stored (both subject to strict regulations).

In conclusion, this regulatory overview, while not exhaustive, demonstrates the types of regulatory tools and instruments that have been adopted in other jurisdictions to protect water quality. Clearly, the need for a strong, transparent and balanced governance system, underpinned by a precautionary approach, would be required for unconventional gas and oil development and for the protection of both water quality and quantity (see Chapter 9 and Chapter 11 recommendations).

6.4 | **How Are Water Issues Addressed Currently in Nova Scotia**

6.4.1 Surface and Groundwater Approvals in Nova Scotia

NS Environment (NSE) is the lead agency for water resource management, including drinking water, groundwater, surface water, and wastewater. Permission to utilize and dispose of water in Nova Scotia is governed through the NS Environment Act. In particular, Section 107 in the NS Environment Act states the following:

> Notwithstanding any enactment, or any grant, deed or transfer made on or before May 16, 1919, whether by Her Majesty or otherwise, or any possession, occupation, use or obstruction of any watercourse, or any use of any water by any person for any time whatever, but subject to subsection 3(2) of the Water Act, every watercourse and the sole and exclusive right to use, divert and appropriate any and all water at any time in any watercourse is vested forever in Her Majesty in right of the Province and is deemed conclusively to have been so vested since May 16, 1919.

This statement asserts that the significance of water in the Province and that water resources on non-First Nations lands are a vested responsibility of the Province.[3]

Under the Activities Designation Regulations, Section 66 of the Environment Act, any water withdrawals greater than 23,000 L per day must be approved by NSE. It is the goal of NSE to, "ensure that water resources are developed in a sustainable manner…that can be maintained indefinitely without causing unacceptable environmental, economic, or social consequences" (NS Environment Act, 1994-1995). Both surface and groundwater withdrawal applications must identify potential environmental, economic, and social impacts. All withdrawal approvals are guided by the following principles:

1. Withdrawals must be sustainable without causing environmental, economic, or social harm.
2. New withdrawals must not cause significant adverse effects on the environment or existing water users.
3. Allocations are based on a first-come, first-served basis, with priority for drinking water applications.
4. Allocations are based on the applicant's current withdrawal needs and the applicant cannot typically save or store water for use after the approval has expired (approvals last a maximum of 10 years).

Surface water approval applications require an in-depth description of the surface water supply source that includes a water quantity assessment, sustainable yield (including timing of withdrawal), potential effects, and must meet all requirements of the *Fisheries Act,* to protect fish habitat and fish passage. For example, all municipal drinking supplies must have a source water protection area that is approved by NS Environment.

For groundwater withdrawal approvals, the proponent must complete a hydrogeological study to determine all potential effects on the environment and other well users, including sustainable yield of the aquifer, well interference effects, water quality effects, the potential for sea water intrusion, and groundwater-surface water interaction. Both applications must also contain a long-term monitoring plan and contingency plan to detect and mitigate unexpected adverse effects. In many cases, the protection of groundwater aquifers is achieved through the establishment of wellhead protection areas (WHPAs). WHPAs outline the areas that contribute to the well or well field and are used to identify and manage potential sources of contamination. The WHPA is broken up into smaller zones that are based on the amount of time it takes groundwater to migrate to the well, thus zones closer to the well have less travel time and require more protection. Residents who receive their water from a private well, are encouraged to have their water regularly tested and use the best practices for well construction outlined on the NSE website (NS Environment, 2014c).

NS Environment additionally recommends that if water withdrawal may be the focus of public concern, that public consultation be conducted prior to the water withdrawal approval, otherwise the Minister or administrator may require a consultative process before approval is given (NS Environment and Labour, 2004b). Consistent with the *Activities Designation Regulations,* the water requirements for hydraulic fracturing would require proponents to provide a comprehensive groundwater and/or surface water technical analysis and would also be required to provide public consultation prior to water withdrawal.

6.4.2 Wastewater Management of Hydraulic Fracturing in Nova Scotia

Within the context of Nova Scotia, Elmworth Energy Corporation (Elmworth) conducted an exploration campaign in 2007-09 to assess the feasibility of sustainable, commercial development of gas from the Horton Bluff Shale Formation in the Windsor Basin, Hants County, Nova Scotia (Elmworth Energy, 2014). During this process, wastewater from the test wells was contained in waste contaminant lagoons in Kennetcook, NS.

Elmworth has undertaken additional research on treatment of naturally occurring radioactive material (NORM) and has identified three tested and proven effective procedures to treat the water to meet environmental standards (Elmworth Energy, 2014). Atlantic Industrial Services (AIS), a waste management company in the Province, reports that it is able to treat the wastewater from the fracturing process up to the standards of NSE, Health Canada, and the Canadian Council of Ministers of the Environment standards for release into a water body. NSE states that this claim was confirmed through testing conducted by independent and accredited labs in Canada and the United States (NS Environment, 2014e). However, Colchester County has denied the application of AIS to discharge the treated wastewater into the municipal system, over concerns of inadequate treatment and potential for unknown long-term effects (CBC News, 2013).

The Province of Nova Scotia is currently involved in a pilot project, where a cement-making company, Lafarge, may use the wastewater as a coolant in their kiln and evaporate it at 700°C. The equipment used will then be tested for residual inorganic material, to determine if this practice is suitable for flowback wastewater disposal (Government of Nova Scotia, 2014). In the short-term, this specific wastewater issue requires appropriate treatment and management.

In the longer term, should this industry ever develop in Nova Scotia, the possible future approach to the disposal of wastewater from hydraulically fractured wells is still a source of uncertainty. For many reasons, industry prefers to dispose of wastewater using deep well injection (King, 2012). However, no approvals have been given for this practice because it is against the environmental best management practices for formation water from coal bed methane exploration and production activities established by NS Environment. Furthermore, there are concerns regarding unsuitable geology in the region (NS Environment, 2008).

There are very few regulations in Nova Scotia that pertain *directly* to wastewater produced by onshore oil and gas operations. Environmental protection is offered under the *Environment Act* section 67: "No person shall knowingly release or permit the release into the environment of a substance in an amount concentration or level or at a rate of release that causes or may cause an adverse effect, unless authorized by an approval or the regulations" and "No person shall release or merit the release into the environment of a substance in an amount concentration or level or at a rate of release that causes or may cause an adverse effect unless authorized by an approval or the regulations." In addition, Section 69 requires that anyone who releases the substance, owns or controls the substance, must report it to the Department of Environment as well as anyone who might be affected by the release as soon as possible. Protection is also offered by the *Fisheries Act,* which protects waters where commercial, recreational, or Aboriginal fisheries exist by making it an offence under Section 36(3) to "deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where the deleterious substance or any other deleterious substance that results from the deposit of the deleterious substance may enter any such water."

There are two main types of wastewater produced from unconventional gas and oil development practices. Flowback water is water that returns to the surface after fracturing operations, while produced water is water produced during the productive life of the well. Flowback water has a short-term higher flow rate than produced water, but has lower salinity and lower levels of NORM (Jiang et al., 2014). Flowback water is composed of fracturing fluid and formation water and varies in composition due to the local geology and company practices, but generally comprises approximately 98 per cent sand and water and less than two per cent chemical additives (Council of Canadian Academies, 2014). Fracturing fluid chemical additives can include acids, corrosion inhibitors, friction reducers, gelling agents, scale inhibitors and surfactants. Flowback water contains these compounds, as well as petroleum hydrocarbons, high salinity and NORM, due to the formation water.

The water quality of waste fluids from hydraulic fracturing activities differs substantially from waters typically received by municipal wastewater treatment, generally due to the presence of petroleum hydrocarbons, increased salinity and the presence of NORM from the naturally occurring formation water associated with formations used for natural gas production (Haluszczak et al., 2013). In 2011, it was estimated that 70 per cent of flowback and produced waters were reused. Water reuse is generally increasing for the industry (Rahm et. al., 2013; Maloney and Yoxtheimer, 2012). Although reuse reduces the overall quantity of water required for fracturing operations, it results in a more concentrated wastewater requiring treatment or storage. Due to the nature and concentration of these waste fluids, standard municipal wastewater treatment processes are generally not appropriate for treating waste fluids from hydraulic fracturing and are being used with decreasing frequency to treat waste fluids in the Marcellus Shale formation (Rahm et al., 2013).

A survey of oil and gas wastewater management in the Marcellus formation, suggested that water reuse is not inhibited by high concentrations of total dissolved solids, that wastewater transport accounts for the majority of the cost associated with off-site wastewater treatment and disposal, and that prices for commercial wastewater treatment are anticipated to decrease as water technologies develop over the next five years (Mauter and Palmer, 2014). Wilson and VanBriesen (2012), analyzed produced water management in Pennsylvania from 2006 through to 2011 from surface-discharging facilities and observed a significant increase in bromide in surface waters in Pennsylvania following the beginning of the unconventional gas and oil industry. However the authors have also noted decline in bromide in surface waters during the period of 2010 through 2011, as compared to the high period of 2008 to 2009, as a result of changes to wastewater management regulations. Not surprisingly, research is underway to develop technologies to selectively remove contaminants, such as bromide, from waste streams generated during hydraulic fracturing (e.g., Sun et al., 2013). The range of water technologies used to treat waste fluids from hydraulic fracturing activities generally include energy intensive desalination technologies such as reverse osmosis and thermal distillation and crystallization techniques (Gregory et al., 2011).

In addition to evaluating technological options for Nova Scotia, innovation and development is a recognized pillar of *EGSPA*, (2007). Consistent with this *EGSPA* principle, Nova Scotia established the Clean Technology Fund, which was developed to support, "the development, demonstration, commercialization, and implementation of innovative clean technologies." The Province has defined Clean Technology as, "a diverse range of products, services and processes, all intended to provide superior performance at lower costs, while greatly reducing or eliminating negative ecological impact, at the same time as improving the productive and responsible use of natural resources" (InnovaCorp 2014).

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In summary, the Province of Nova Scotia has several regulatory instruments in relation to water resources that could begin to support an onshore unconventional gas and oil resource sector. In its broadest sense, the *Environment Act* is an Act that could be complemented with specific regulations for enforcement and compliance of an onshore unconventional gas and oil resource sector. Further, as per the *Activities Designation Regulations,* the water requirements for hydraulic fracturing would require proponents to provide a comprehensive groundwater and/or surface water technical analysis and would also be required to provide public consultation prior to water withdrawal. Finally, the Clean Technology Fund, through *EGSPA*, is designed to support Nova Scotia companies to develop innovative ideas to protect the environment and develop broader economic activity. However, it is recognized that these legislative documents offer starting points for regulatory development and significant efforts would be required to develop a robust regulatory system to support an unconventional gas and oil sector in Nova Scotia (see Chapter 9 and Chapter 11 recommendations).

6.5 | **Can Water Issues Related to Unconventional Gas and Oil Development be Adequately Managed in a Nova Scotia Context?**

It is our view that many of the water-related issues raised by concerned citizens (see Introduction and Chapter 8) can be managed in the Province. Some of these issues may be covered under current regulations and operations of the government, however, some may need the implementation of new rules, regulations, and standards. Other issues still require further research and modelling to determine the best course of action (see Chapter 11).

Provided that intensive water modelling and forecasting are completed as designated in the withdrawal application process, current regulations regarding water withdrawal are adequate. Independent monitoring throughout the withdrawal process would need to be established to ensure compliance with the conditions set out in the withdrawal approval. NS Environment would need to develop more data to confirm water availability and demand pressures for specific watersheds in Province as outlined by Sterling et al. (2014). Further research is needed to determine how (or if) wastewater produced by hydraulic fracturing can be safely returned (without long-term effects) to the watershed from which it was removed, to help maintain a balanced water budget. Hydrologic analyses and modelling should also consider that not all of the water used for fracturing returns to the surface, effectively removing it from the water cycle.

Disposal of wastewater from unconventional gas operations is currently being investigated at institutions across North America. In British Columbia's Horn River Basin, Encana and Apache have developed a proprietary system that uses non-potable water from a saline underground aquifer for hydraulic fracturing activities, treats the water to its original condition, and injects the water back into the same aquifer. It is unclear if the geology of Nova Scotia could support such a system. This would need to be investigated and considered as a potential option for water withdrawal and disposal, if the industry was ever to develop in Nova Scotia (see also Chapters 7 and 11).

Some insight into the management of wastewater can be gained by examining the Nova Scotia offshore oil and gas industry. For example, according to the Offshore Petroleum Board and National Energy Board (2010) best practices report, wastewater produced from offshore oil and gas operations should be described chemically and include regular toxicity testing or modelling studies that are reported to the Canada-Nova Scotia Offshore Petroleum Board annually. These types of provisions may provide a starting point that would require further exploration by NS Environment to determine their suitability for hydraulic fracturing developments.

If hydraulic fracturing ever proceeds in the Province, thorough baseline conditions of current water levels, flow, and quality must be established, before any withdrawals should be approved. Additionally, hydrogeologic modelling of the watershed would need to be conducted to determine the response to potential withdrawals (see Chapter 11 recommendations).

A baseline assessment would include taking samples at different times of the year and under variable weather conditions, as the concentrations of contaminants (including naturally occurring methane) vary throughout the year. Thorough monitoring using the performance, sentry, and receptor approach outlined in the Council of Canadian Academies (2014) report, should be adhered to and carried out by third parties. Residents must also play a monitoring role, by having their water regularly tested and before any production activity, which should already be a best practice. It would be important for government to provide tools to ensure that this process is managed correctly and is properly resourced. This would ensure that residents are aware of what is already present in their drinking water supply and also provide evidence of any contamination from future industrial practices. In addition, industries and government should be required to work with private well owners to establish water safety plans for wellhead protection areas and proactively protect groundwater wells. Water safety plans are broadly accepted procedures that were originally developed by the World Health Organization and have been applied as regulatory documents in some jurisdictions (e.g., the Province of Alberta). It is conceivable that a water safety plan approach could be used as a groundwater protection mechanism (see Chapter 11 recommendations).

6.6 | **Summary**

Both quality and quantity of water are of great public concern and the government has an obligation to ensure water safety is upheld, regardless of any decision made regarding hydraulic fracturing.

If hydraulic fracturing was ever pursued in Nova Scotia, the government of Nova Scotia would need to develop a robust, responsive, and transparent regulatory environment that offers water security and protection for future generations and that is consistent with the Nova Scotia Environment Act (see also Chapter 9 and Chapter 11 recommendations). In addition to this regulatory development, the following activities would be pre-requisites to the start up of any potential hydraulic fracturing activity:

- Detailed water balance in areas of the Province where hydraulic fracturing is likely to occur to confirm availability within the watershed;
- Detailed analysis of water demands from hydraulic fracturing processes in a Nova Scotia context and comparisons to water availability in the watershed;
- Development of an environmental effects monitoring program (inclusive of water quality indicators and biological indicators) for watersheds in the Province where hydraulic fracturing is likely to occur;
- Identification of any potential adverse impacts on water quality (both ground and surface water) due to operations;
- Evaluation of wastewater treatment technologies and strategies to mitigate risks to aquatic species and the receiving body;
- Development of clear design standards for well installation and decommissioning to mitigate potential groundwater contamination (see Chapter 7);
- Development of clear design standards and operation requirements for wastewater disposal and/or treatment, and;
- Development of water safety plans to help individual home owners ensure and sustain clean drinking water.

ENDNOTES

1 See http://www.novascotia.ca/nse/groundwater/welldatabase.asp <http://www.novascotia.ca/nse/groundwater/welldatabase.asp> . Accessed 31st July 2014.

2 See www.fracfocus.org <http://www.fracfocus.org> . Accessed 31st July 2014.

3 See Chapter 10 for how this may be viewed from a Treaty and Title perspective on non-reserve lands.

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CHAPTER

7

Well Integrity

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7.0 | **Chapter Summary**

Cased, cemented wells are designed and drilled to access various types of resources beneath the surface of the Earth. Groundwater, oil and gas, thermal energy, salt, sulphur, and even deeply-buried leachable mineral ores can be accessed through designed wellbores. This chapter focuses on typical onshore unconventional gas and oil wells, which are generally similar to wells used for conventional oil or coal bed methane production. The major topics covered in this chapter are well design, construction, use, and decommissioning. Issues of cementing practices and gas migration pathways are given special emphasis, because they are key aspects in establishing and understanding well integrity. As noted in Chapters 4 and 6, and raised by many submissions to this review (Chapter 8), issues of well integrity are central to an understanding of the nature of risks associated with hydraulic fracturing and its attendant processes such as drilling, well design and implementation, and rehabilitation.

This chapter describes how unconventional gas and oil development, using modern cementing and completion techniques, usually leads to good wellbore integrity. However, as in any industrial activity, there will never be 100 per cent success in sealing all wellbores against all possibilities of any future leakage. Technological advances have helped reduce the incidence of leaking wells and provide better quality control and leak detection capabilities. The most common, long-term well integrity issue after decommissioning is slow gas seepage around the external casing. Such leaks appear not to lead to a major public health threat because methane is not a toxic substance, the number of wells that display high-rate leaks is low, and the overall average leakage rates appear to be low. Significant gas leakage from a well is usually easily identified at the surface, and corrective measures can then rectify the problem. Though rigorous statistics remain elusive and, therefore, require more quantitative study (CCA, 2014), there is as yet no evidence that the number of significant problems encountered in Alberta and British Columbia, relatively mature regulatory environments, is large. However, the long-term behavior of cemented wellbores remains of interest because the rates and consequences of gradual steel and cement deterioration at depth remain ill-defined.

Possible future unconventional resource development in Nova Scotia would take place using modern technology with multiple wellbores installed at each drilling site to diminish the surface impacts. It is important to establish good regulatory practices (guidelines and enforcement), quality control, and monitoring to ensure that sites are geologically understood, that wells are properly installed, and that well decommissioning is done according to best practice guidelines. As noted in other chapters, and described further in Chapter 9, the establishment of an appropriate monitoring and regulatory system for onshore Nova Scotia would be necessary if large-scale, unconventional gas and oil resource development ever takes place.

Nova Scotia geological conditions are reasonably stable; this should lead to a relatively lower incidence of poor wellbore integrity compared to some other jurisdictions for the following reasons:

- Moderate tectonic stresses and dense competent rock in the subsurface mean that wellbore quality should be excellent (good stability, little drill-hole sloughing), facilitating installation of high-quality steel well casings and, hence, resulting in fewer cases of leaking wells.
- Except in Nova Scotia's coalbed areas, there appear to be few gas sands at shallow to intermediate depth that might lead to problems with long-term gas migration behind the casing
- Oil and gas in Nova Scotia are likely to be sweet (little or no associated hydrogen sulphide gas), making all operations easier and casing life longer, compared to some other jurisdictions.

7.1 | **Introduction**

We received 14 responses to the discussion paper upon which this chapter is based. The responses ranged from strong disagreement with the conclusions in this chapter to general agreement with the conclusions, combined with recommendations for improvements. Some of the issues raised have been addressed in other chapters, but a number of changes have been made in this chapter to reflect the constructive criticisms and recommendations. Some of the comments were necessarily left unanswered. Hopefully, the chapter has been substantially improved because of these inputs from various contributors, who are collectively thanked.

Cased, cemented wells are designed and drilled to access various types of natural resources beneath the Earth's surface. Groundwater, oil and gas, geothermal energy, salt, sulphur, and even deeply-buried leachable mineral ores are, nowadays, accessed through designed wellbores used for injection and production. This introduction to well construction and integrity will focus on typical onshore unconventional gas and oil wells, which are generally similar to wells used for conventional oil or coalbed methane production. The major topics covered are well design, construction, use, and decommissioning. Issues of cementing practices and gas migration pathways are given special emphasis, because they are key aspects in establishing and understanding well integrity.

Well design is carried out through a process that involves assessment of the subsurface geology, knowledge of the shallow groundwater hydrology, understanding of the nature of the fluids to be produced (oil, gas, water), and knowing the nature of the service to which the wells will be exposed (temperatures, pressures, fluid chemistry). This engineering design process is informed by decades of experience for several million oil and gas wells worldwide, perhaps 500,000 in Canada alone, and approximately 163 in onshore Nova Scotia.[1] Of these Nova Scotia wells, only 37 penetrated more than one kilometer deep, which is relevant because well depths exceeding two kilometres are likely if unconventional gas and oil development were to take place in Nova Scotia.

Once a design has been established to meet specific development needs, the chosen site is prepared, a drilling contractor hired, and well construction begins. A drill rig is erected, and the borehole is advanced by rotating a drill bit at the bottom of the drill pipe, while circulating out the drill cuttings using a drilling fluid pumped down the centre of the drill pipe. During this process, the borehole is protected through the installation of a set of concentric steel casings cemented into place. Drilling and well construction practices have evolved over many decades, as experience has been gained in different geological conditions and as new materials and techniques have been developed (Cochener, 2010). For example, using modern practices and polycrystalline diamond bits, a vertical three kilometres deep borehole that took six weeks to drill in 1985 might now be completed in two to three weeks. This also means that borehole quality concerns are reduced because the strata are exposed to drilling fluids for shorter periods. This is important to well integrity, because a better quality borehole is more likely to lead to better quality well construction.

Well completion practices, such as perforating and hydraulic fracturing, are designed to provide access from the cased wellbore to the potentially productive geological formations. After the last casing has been cemented into place, another final wellbore section may be drilled and special equipment installed to produce the resource, or more conventional perforation technology may be directly used to provide access to the target strata that contain the hydrocarbon. Once the well is ready, hydraulic fracture stimulation is implemented to increase the surface contact area with the formation so that fluids may be produced more effectively – ideally giving a commercially viable recovery rate and a higher recovery factor (i.e. higher percentage of the resource in place that can be ultimately produced). The hydraulic fracturing process is part of the well completion activity, and it is described in Chapter 1.

Since the technique was first introduced in the late 1940's, more than a million wells have been hydraulically fractured worldwide, most of them in the U.S. As of 2014, about 175,000 wells have been hydraulically fractured in Alberta (Canadian Association of Petroleum Producers, 2012; Government of Alberta, 2014; Petroleum Services Association of Canada, 2014), starting with the Pembina Oilfield in the early 1950's. In Nova Scotia, a total of 11 wells have been hydraulically fractured, eight for coalbed methane production evaluation and three for assessing unconventional gas and oil potential.[2] However, current hydraulic fracturing approaches are substantially larger in volume and injection rate, compared even to a decade ago. Some have speculated that in the future, 95 per cent of all wells in North America will be hydraulically fractured.

Well operation comprises the period of time from initiation of formation fluid production to the end of commercially viable production. During this time, the well may be re-stimulated to encourage more production, and there may be periods when the well is shut-in for one of a number of technical or commercial reasons. For example, the well may be deliberately held in an inactive status to conform to agreed-upon limits (prorated production), awaiting a decision to re-stimulate or to develop another formation intersected by the wellbore, awaiting equipment availability, or awaiting decommissioning.

Once the resource that can be accessed by a single well has been developed and depleted, the well must be decommissioned properly and the ground rehabilitated. Well decommissioning involves making sure that the wellbore possesses integrity; rectifying any problems that might exist; then placement of a series of sealing plugs, usually only within the innermost open part of the cased well, to ensure that there is no pathway for fluids to migrate from one zone to another or to migrate up to the surface. Decommissioning also implies that all surface disturbance that does not constitute infrastructure of local value (access roads for example) be returned to stipulated standards set by regulatory agencies.

Well integrity, as used in this discussion, refers to external integrity, i.e., maintaining the sealing purpose of the cemented steel casing strings. These casings are intended to isolate zones to prevent fluid flow between them, to confine flow to the interior of the cased well, to facilitate detection and remediation of any breaches arising from operational wear or installation flaws, and to protect the surface (atmosphere, ground surface, and groundwater) from fluid migration from depth. Internal well integrity is of operational interest (tubing condition, packer reliability, etc.) and is far more easily monitored and managed because the well is active when issues of internal integrity might arise.

This design, construction, operation and decommissioning process, like all activities involving the exploitation of deep fluid or mineral deposits, takes place within a regulatory framework that is a provincial responsibility (see Chapters 6 and 9). Regulatory guidelines have been developed in all provinces that have a significant oil and gas industry, although by virtue of the size and age of its oil industry, Alberta's regulatory body, the AER (Alberta Energy Regulator), is the senior one in Canada. Many provinces take advantage of the vast amount of work that has gone into development of AER regulatory guidelines.[3] Modern provincial regulatory bodies in Canada have broad authority for the setting and enforcement of guidelines covering all active wells, suspended wells (inactive but not plugged and decommissioned), and decommissioned wells. Complete documentation of different provincial practices can be downloaded from the websites of the major regulatory agencies.[4] See Chapter 9 for a more detailed discussion of regulation of hydraulic fracturing in Canada.

It should be noted that industry-led initiatives to establish good industrial practices have led to industry publication of recommendations for well construction, operation, and decommissioning. These recommendations[5] may, in part, be even more demanding than official regulatory guidelines. However, adherence is neither compulsory nor enforced by the industry, therefore, this chapter will only refer to regulatory agency guidelines that are mandatory.

Wells drilled to access unconventional gas and oil resources are not significantly different from other wells used in the oil and gas industry around the world. However, the relatively recent developments of long horizontal wells, multi-stage high-rate hydraulic fracturing, and multi-well pad design are novel, compared to the old paradigm of one vertical wellbore per surface site and a limited volume of fracture injection, so consideration should be given to the impacts of changing development practices (CCA, 2014).

7.2 | **Well Design**

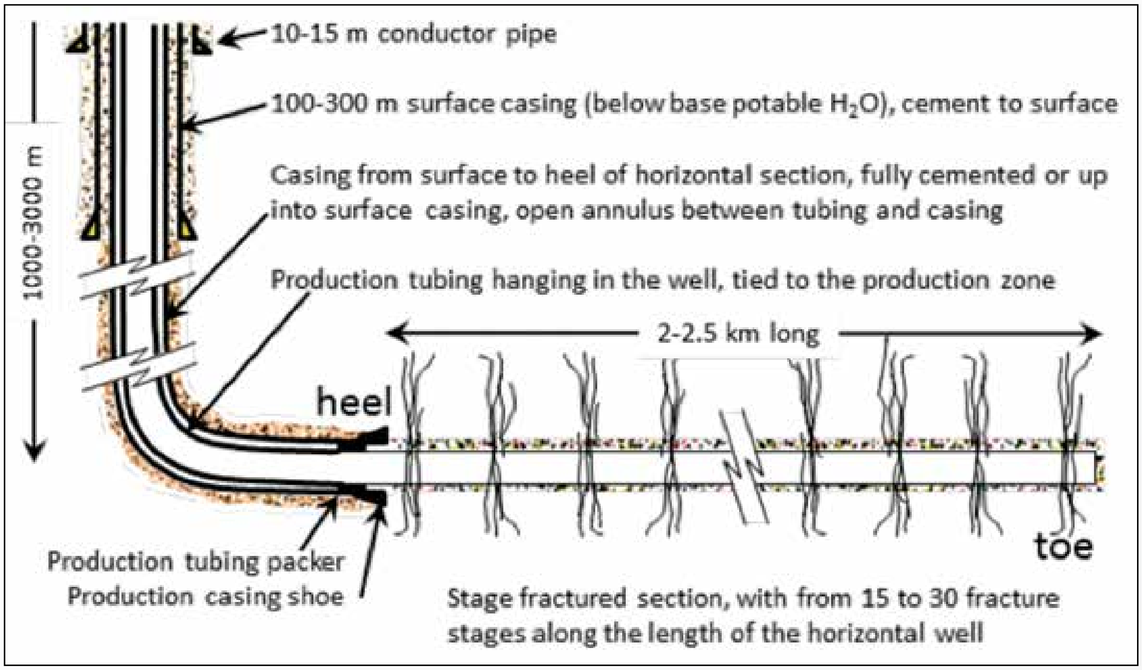
The design of an unconventional gas and oil well requires that decisions be made in advance for the size of the steel casings to be placed in the wellbore. This depends on many factors, several of the most important are listed here:

- What is the desired diameter of the final wellbore? Different completion technologies may require different borehole diameters for the installation of well completion equipment.
- What is the depth to the base of the ground water protection zone (BGWP)? This depth may be stipulated by regulation (e.g. 150 m from surface) or by the geochemistry of the groundwater, as is done in Alberta for example.[6]
- Are there formations between the surface casing depth and the target formation that are prone to instability during drilling and must, therefore, be protected with an intermediate casing?
- What is the target formation and depth of the well, and if a horizontal leg is to be drilled, where will it be and how long will it be?

Once the design is finalized, the permit application for regulatory approval is filed. The design details must allow for some flexibility; for example, if the length of the horizontal well is designed to be two kilometres, drilling difficulties may lead to some premature truncation of this length.

Two possible designs for new wells targeting unconventional resources in Nova Scotia are sketched in the following diagrams, one with a long horizontal section in the producing horizon (Figure 7.1) and one entirely vertical (Figure 7.2). The horizontal configuration in Figure 7.1 is becoming a standard design for unconventional energy wells, but vertical wells (Figure 7.2) are still widely used if the unconventional resource is in a very thick reservoir (hundreds of metres) and is best accessed through a number of perforated zones and hydraulic fractures spaced vertically along the wellbore.

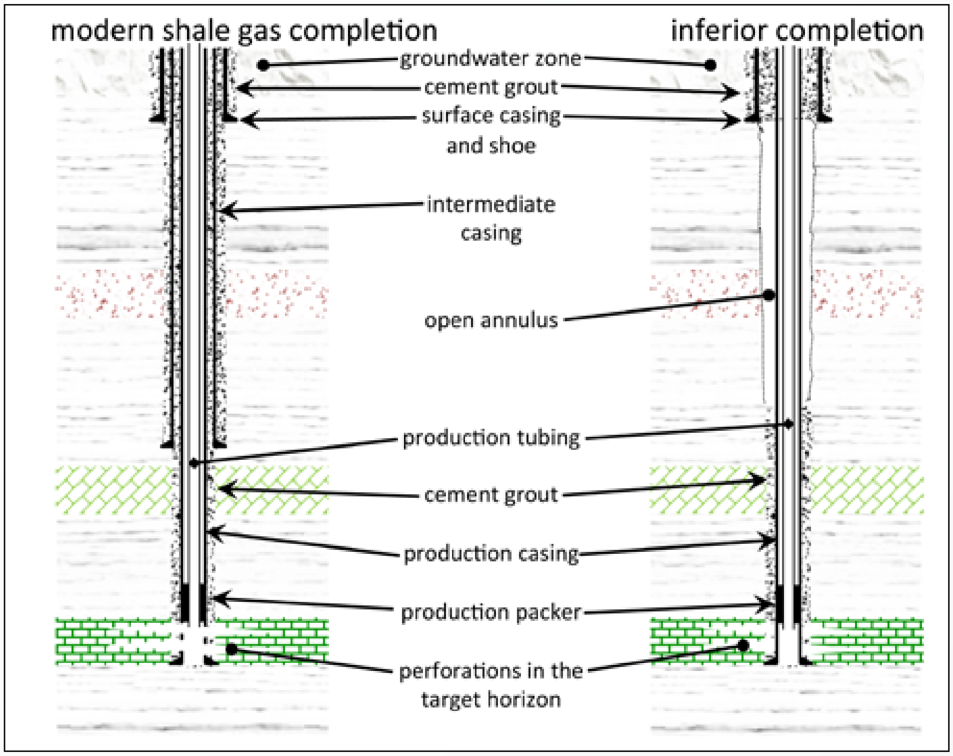
Figure 7.1 A Typical Unconventional Gas and Oil Well with a Long, Horizontal Section and no Intermediate Casing String (perhaps not needed in Nova Scotia)



Courtesy of Maurice Dusseault

In onshore Nova Scotia, large volumes of gas at depth and pressures far above hydrostatic pressure (i.e., far above 10-11 MPa/km) are not known to exist, but it is important to remember that there are, as yet, insufficient onshore data available to confirm that this is indeed the case throughout the region of potential interest. Hydrostatic pressure is considered "normal" in contrast to the condition of "overpressure," which refers to formation fluid pressures substantially greater than the pressure from a static column of saline water. Thus, in contrast to offshore Nova Scotia, where pressures far above hydrostatic[7] are well-known (Mudford & Best, 1989), it would not be necessary to take exceptional measures onshore in Nova Scotia to guard against a gas blowout; standard well designs and safety measures would be sufficient to address the small risk of a blowout if overpressures are absent.

Figure 7.2 Contrasting Older and Newer Vertical Wellbore Designs



Courtesy of Maurice Dusseault

7.3 | **Well Construction**

7.3.1 Drilling and Casing the Well

A finished oil or gas well has several casing sections that are cemented in place to the surrounding rock or to the previous casing section. Each casing section is assembled from many joints of steel pipe and the total length of a casing section, comprising many joints, is referred to as a "casing string." The major casing strings that might be used in an onshore Nova Scotia energy well are discussed here.

The first element in creating good wellbore integrity is to make sure each casing joint is properly connected to the previous one, so that no fluid leakage can take place through the threaded connections. To this end, the casing strings are assembled by experienced crews with specialty equipment to provide the right make-up torque and avoid any cross-threaded connections. Regulatory guidelines may stipulate certain grades of casing and casing thread connection types for specific conditions, although in general, regulations are not so detailed. Instead, regulations tend to stipulate performance goals, as determined by measurements, such as a measurement of casing string pressure integrity before it is cemented into place (British Columbia Oil and Gas Commission, 2014). A properly assembled casing string has adequate pressure integrity for its entire length, and this integrity is tested to meet regulatory standards before well assembly is complete. If there is concern that integrity has been impaired during the service life, or if the nature of the service is changed, the casing is re-tested, and certain types of cased-borehole geophysical logs may be run to identify leaks (e.g. 'noise logs') or to detect cement impairment behind the steel casing. For example, if a producing oil well is converted to an injection well, the production casing must be scanned with geophysical logging devices "cement bond log" to verify zonal isolation (Abbas et al., 2002; Bellabarba et al., 2003).

The conductor pipe is a thin, steel casing placed into a large diameter hole drilled to a depth of 10 to 20 metres using a typical water-well drilling truck. The pipe is lowered into the open hole with some sacks of cement or concrete and gravel placed to fill the gap between the steel and the soil. This conductor pipe is then connected to the drill rig circulation system, so that as the surface casing hole is drilled, the drilling fluids can be contained and circulated through the tanks to remove cuttings.

To install the surface casing, a suitable diameter vertical hole, 12¾" (324 mm) is a typical size, is drilled with a bentonite-water fluid (drilling 'mud') to a depth below BGWP, or to a stipulated depth such as 150 or 200 m. A strong steel casing, perhaps 10¾" (273 mm) diameter, is placed into the hole and cemented to the surface. When the cement has set adequately, a flange is welded on to the casing. Then, a blow-out preventer and other sealing equipment for assurance of pressure security and unimpeded fluid circulation are firmly bolted to the flange so that deeper drilling and later operations, such as well stimulation and production, can be executed with minimal risk.

In Nova Scotia, because essentially all of the groundwater being used in the province is less than 100 metres deep, mandating a specific depth such as 150 metres or 200 metres for the base of surface casing would seem to be an appropriate minimum, but such stipulated depths must be based on collection and analysis of adequate geological and hydrogeological data. Risks to groundwater relating to well integrity were addressed in Chapter 6.

An intermediate casing string may be required if there are unstable formations to be traversed during drilling, if there are numerous thin and uncommercial oil and gas zones in the rocks above the production zone that must be more carefully isolated, or if there are high formation pressures that could lead to drilling risks. In Nova Scotia, because the rocks from the surface casing shoe to the potential targets at depth are competent and pressures are most likely to be moderate, an intermediate casing string would probably not be required, although it could be mandated by regulatory policy if concerns about integrity were justified by performance data. If an intermediate casing string is needed, the surface casing has to be larger than 10¾" (273 mm) diameter to accommodate the additional concentric casing string. Generally, the intermediate casing string is cemented all the way to surface in modern practice (Figure 7.2).

The production casing is the final cemented casing string placed in the bore hole. It may be placed all the way to the end of the horizontal section or the horizontal part may be left open for placement of special equipment, as in Figure 7.1. In either case, the production casing is cemented, either all the way to the surface or well into the previous intermediate casing string (Figure 7.2, left-hand side) so that a seal is ensured. The high alkalinity of the cement also protects the steel casing from deterioration if there are acidic gases in the formation such as carbon dioxide (CO_2) or hydrogen sulphide (H_2S) dissolved in the water.

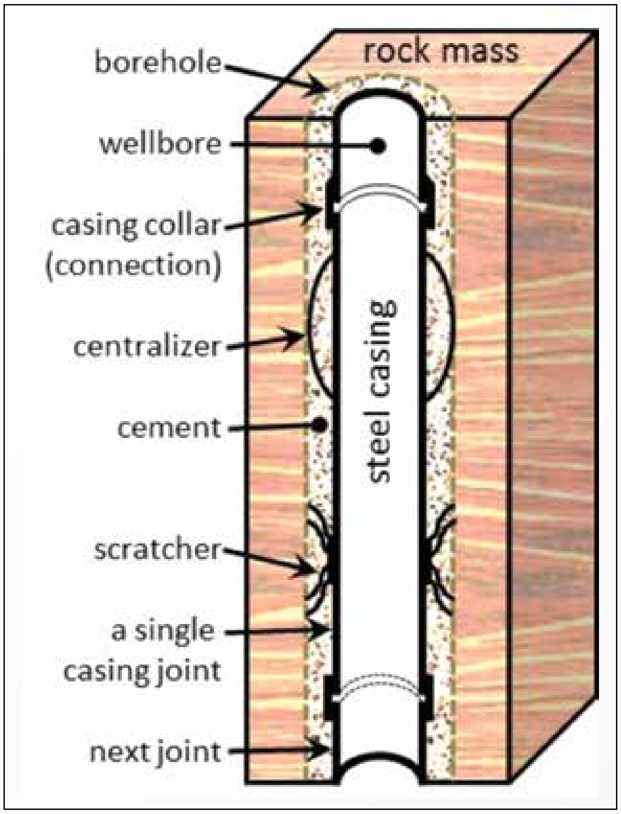
7.3.2 Cementing Practices

Well cementing requirements and integrity testing are areas covered in part by mandated regulations. The goal is to achieve a continuous, effective seal between the casing and the rock mass or between the current casing and the previous casing, so that the steel-cased wellbore has full pressure integrity along its entire length for the period of time it will be operational and for the range of conditions it will experience (Dusseault et al., 2014). If this integrity is inadequate at the beginning of the process, just after the hole is completed, or if this integrity is breached any time during active well operation, the operator must fix the problem. With modern cementing practices and quality control, having to immediately repair a new well is not common, but during operations, impairment may take place. Because the production casing is not exposed to mechanical wear, wellbore integrity for a gas well is seldom an issue after the well is properly completed. Nevertheless, as discussed later, behind-the-casing gas migration continues to be an issue for an unknown, but likely small percentage of wells. The long-term integrity of wells at a time scale of many decades after decommissioning remains poorly understood; this is an area where further measurements, experiments, and monitoring efforts are needed to evaluate risk and establish means of addressing these risks if they are found to be significant. It is a widely held view among technical persons that current well completions are of substantially better quality than a decade or several decades ago, and this is echoed in conference articles and discussions with professionals working in these areas. Nevertheless, in the absence of clear metrics, it is an area where additional quantification is advisable. This point is also addressed in the recommendations section of Chapter 11.

As each casing string is assembled and lowered down the borehole, centralizers and scratchers are attached to the steel casing (Figure 7.3). The tendency in the industry is to increase the number of centralizers and scratchers to assure a better seal for the region between the casing and the rock mass. Regulatory guidelines are not so proscriptive as to specify the number of centralizers or scratchers, rather, the guidelines require a specific level of performance. There is considerable merit in "…getting it right the first time…" with a high-quality casing and cementation, as this apparently greatly reduces the chances of wellbore integrity impairment later in the life of the well.

Centralizers are springs designed to keep the casing in the centre of the hole so that the drilling fluid is adequately displaced and the cement slurry can completely surround the casing to set and form an integral sheath. Before the cement slurry is pumped, the casing string is lifted up and down 25-35 metres (reciprocated) and rotated, while fluids are circulated to clean the borehole wall and flush out residual drilling fluids. Scratchers help remove drilling mud caked on to the borehole wall, and often special chemical solutions precede the cement placement to help dislodge this mud cake. To place the cement, a rubber plug is placed inside the casing, then cement slurry is placed on top of the rubber plug as it is pumped to the bottom of the casing (the shoe). When the plug hits the shoe at the bottom of the casing, it opens and the cement slurry flows through the shoe and up and around the casing. Once the appropriate volume of cement is mixed, a second wiper plug is placed in the casing to displace all of the cement into the exterior annulus while wiping the inside of the casing clean.

Figure 7.3 Casing-Cement-Rock System, with Centralizers and Scratchers



Courtesy of Maurice Dusseault

Once the cement is placed around the casing, it is allowed to set for a stipulated time period and drilling proceeds. If it is the production casing, it is logged with special acoustic tools called "cement bond logs" (Abbas et al., 2002; Bellabarba et al. 2003) to assure that a good cement-rock seal has been achieved and pressure tested before completing the well.

Well cement is placed as a water-based, Portland cement slurry; most energy wells in Canada use Class "G" Oilfield cement and a slurry density of about 2.0 to 2.05 g/cm^3. In some applications, additives may be used to improve the properties of the cement. Replacing 70-75 per cent of the cement with silica flour (finely ground quartz – SiO_2) is required in thermal wells to create cement that is stronger and more resistant to thermal dehydration. Special cement formulations are used in the presence of salt beds to avoid dehydration and shrinkage. Latex-based additives are said to lower the permeability of the cement and give it more ductility (the ability to deform without losing sealing characteristics). In cases where natural gas entering the cement is a concern, chemicals are added to scavenge the gas and resist the development of gas channels. Foamed cements counteract the natural tendency of neat cement slurries to shrink a small amount when setting. Use of additives is typically not mandated or controlled by the regulatory agency; it is the responsibility of the owner of the well to ensure that appropriate cement formulations and additives are used in the conditions encountered so that the energy well is properly sealed, ready for service, and resistant to impairment.

The best guarantee against future leaky well problems is a high-quality initial well installation (primary cementation); so, attention should be paid to well casing and cementing. Although well cementing does not have to take place under direct supervision of a professional engineer, it is important to verify that the appropriate materials and procedures are used and that the installed well meets mandated performance criteria (pressure tests, bond log quality). In this way, future issues relating to well integrity and risks of interaction with shallow aquifers are reduced.

In Nova Scotia, there appear to be no exceptional conditions such as very unstable shales, high pressures, numerous gas zones, or serious lost-circulation[8] zones that would impede installation of high-quality, cement-sealed casings. Nevertheless, as in any complex industrial activity, there will always be some cases where sealing of all leakage pathways for the entire life of the well, including the post-decommissioning period, is not achieved. Quality control and assurance, good quality materials and placement, and good surveillance are needed to achieve good performance, and regulatory guidelines and enforcement are needed to ensure the process. The importance of good regulatory practice supported by adequate resourcing, enforcement, and political will is described in Chapters 6 and 9 and is a clear recommendation arising from this review (see Chapter 11).

7.4 | **Well Completion**

Once a wellbore has been drilled and cased, it is necessary to "complete" the well, linking it to the rock mass so that oil or gas can flow at a rate that is commercially viable. Pathways must be created between the wellbore and the rock mass at many locations (Figure 7.1) so that a large rock volume of rock is accessed. From 15 to 40 "stages" (locations – see Figure 7.1) will be fractured along the horizontal well for unconventional gas and oil development, spaced as closely as 30-40 metres in some low-permeability fields, and as much as 120-150 metres apart in other formations of higher permeability. There are several different methods to do this, of which the two most common are described in Appendix E. Well completion generally has no effect on well integrity in the long term or the short term, as all the activity is taking place at the bottom of the well. The critical part of the wellbore, where good seals are needed and casing must be intact, is the section from the producing formation to the surface. Later in this chapter, the possibility of interwell communication during hydraulic fracturing is discussed, as this involves a potential impairment of wellbore integrity.

7.5 | Well Integrity during Production

Production of gas or oil may take place directly into the production casing. More commonly, a production tubing string is anchored to the bottom of the production casing, and all the fluids being produced (gas or oil, plus some deep formation water in many cases) pass through this production tubing out of the wellhead to be processed. This means that the annulus between the production tubing and the production casing is inactive and can be monitored for any pressure changes that might indicate a loss of pressure integrity during the production life, which may extend to two or three decades.

7.5.1 Gas Migration During Production

With some technologies, and in some geological environments, maintaining wellbore integrity is challenging because of severe demands placed on the casing-cement system. For example, this occurs in thermal wells for heavy oil production, where steam at temperatures as high as 325°C may be injected through the production/injection tubing. Not only does this cause thermal expansion and contraction, it accelerates electrochemical corrosion of the steel casing and can dehydrate shales around the wellbore, leading to a loss of wellbore integrity through the opening of a pathway outside the casing and cement. Other reasons for casing integrity loss include large-scale reservoir compaction and casing rupture or the triggering of formation shear between the reservoir and the overlying rock as the result of large changes in pressure (Dusseault, Bruno & Barrera, 2001).

There is a low likelihood of casing integrity loss in Nova Scotia because the formations are low porosity and, therefore, resistant to shearing; the temperature effects that would be imposed upon the wellbore are minor; and the volume changes associated with the depletion of an unconventional gas reservoir are very small compared to a conventional gas reservoir, simply because the reservoir rock is stiff. All these factors, plus the fact that the pressure in the productive horizon is being lowered because of continued depletion, mean that maintaining well integrity is expected to be relatively straightforward. Also, any well integrity problems that arise will most likely be associated with seepage of gas, not oil or saline water, because gas is buoyant, whereas oil and saline water are dense and do not possess buoyancy in normal environments.

If loss of casing integrity is observed at any time during production, or while the well is inactive (suspended) but not decommissioned, the operator must fix the problem. This involves identifying the location and nature of the leakage problem then implementing a suitable method to stem the leak such as perforating the casing and pressure-squeezing a sealant into the region behind the casing "perf-and-squeeze." This may be followed by placement of an expanding steel sleeve (a casing patch) to restore the pressure integrity of the production casing.

During production, the annulus between the surface casing and the production casing in Canada is monitored for gas flow (called SCVF – Surface Casing Vent Flow). There is usually a small amount of gas escaping from this annulus during the production period, and often much of the SCVF gas is coming from intermediate depth zones, thin gassy zones that are not commercially exploitable. Gas may even be coming from organic matter deterioration at depths as shallow as a few hundred metres; this is called biogenic gas because if comes from biological activity that is degrading plant matter. There are regulatory guidelines for how much SCVF is permitted during production, and it is important not to allow this gas pressure to build up, as this would promote the forcing of the gas outside of the surface casing shoe where it can migrate toward lower-pressure regions, such as shallow aquifers and the surface (Harrison, 1985).

Gas wells have no moving parts (pumps or sucker rods), unless they produce a lot of liquids which must be lifted to the surface to allow gas production to continue unimpeded. Oil wells, however, may have such equipment. In wells so equipped, production tubing is invariably installed, so although there can be some mechanical wear of the tubing, wear of production casing is extremely rare because all the moving parts reside inside the production tubing string or right at the bottom of the wellbore (Figure 7.2).

There is a reasonable chance that producing wells will be entered during their life span, probably to do some stimulation of production to extend the economic usefulness of the wellbore. In the extreme, a new horizontal section could be drilled from the existing cased wellbore or the previously stimulated horizontal section could be entirely re-fractured to open new pathways for oil or gas to flow to the wellbore. In such cases, the practices followed are similar to those discussed in Appendix E. Before the activity, it is common (or it could be mandated) to run another cement bond log to give some assurance that the behind-the-casing pathway has remained sealed.

7.5.2 Leakage Behind the Casing

One of the major wellbore integrity issues in the unconventional gas and oil industry is related to gas migration (or 'stray gas') outside of the production casing, up around the surface casing shoe, and interacting with shallow groundwater or venting to the surface (Watson & Bachu, 2009; Dusseault, et al., 2000). This pathway is common to all oil and gas wells (Dusseault & Jackson, 2014, in press) and is now discussed in more detail. Although "stray gas" or "gas migration" has been studied in the literature (Gorody, 2012), there is little quantitative information about the behind-the-casing pathway, and this suggests that assessment of groundwater and natural methane occurrences would be an important activity in areas that may experience oil and gas development. SCVF flow data must be registered with the regulatory agency; for example, the AER keeps records of all occurrences; therefore, there are excellent statistics available in this area, in contrast to gas migration behind casing, where there are data or observed incidents, but data based on surface observations only are insufficient to draw strong quantitative conclusions about the overall rate of well leakage.

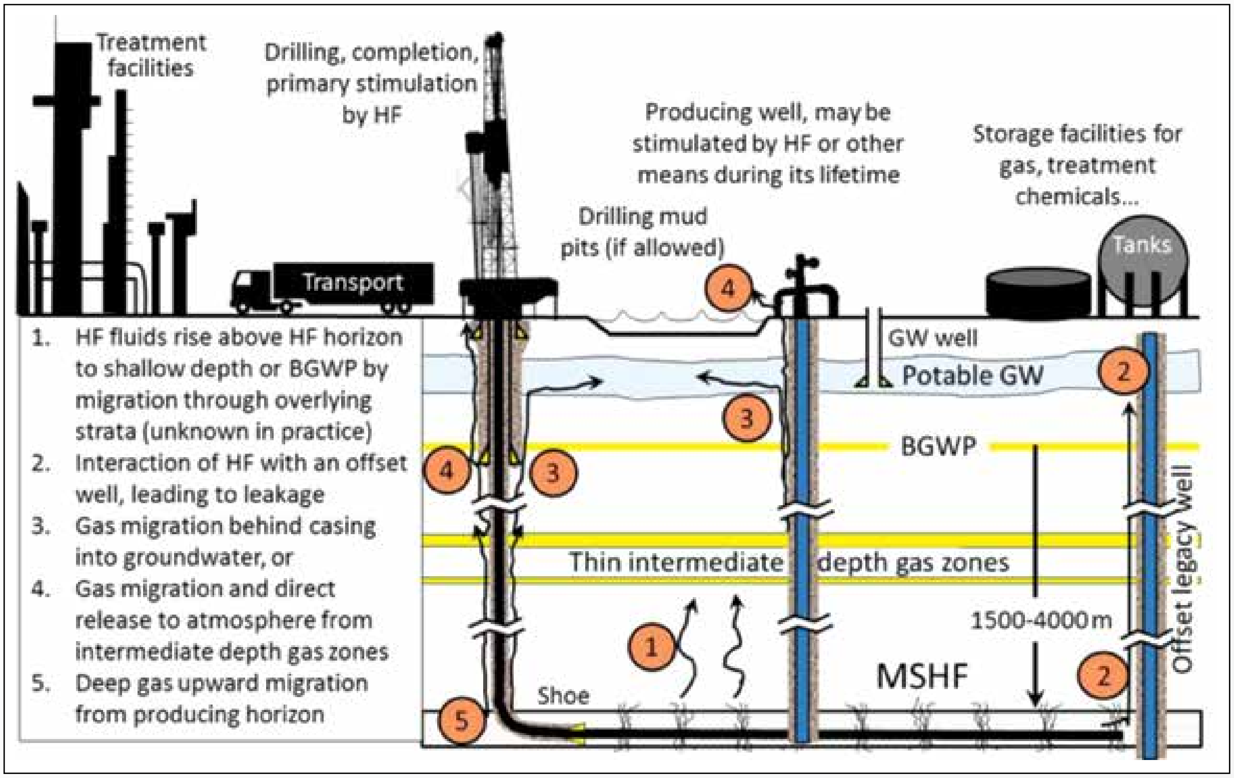
At this point, it is important to mention that risk in wellbore integrity is evaluated not only as the probability of a gas migration incident but also as the consequences of an incident. For example, although gas migration is well-known and there are instances reported regularly in Alberta, there is a great deal of indirect evidence suggesting that gas leaking into groundwater wells is not a major public health issue. Much of this indirect evidence is a general lack of morbid effects noted despite many hundreds of thousands of known cases of naturally-occurring methane seepage into water wells around North America.

One approach to a better understanding of methane in groundwater wells is to sample the wells. However, because many water wells are improperly sealed and the wells may access multiple zones or only one non-defined zone, such data cannot be considered to be scientific baseline data. An example of a recent survey of wells above an American oilfield (Wattenburg, CO) that has been active since 1970 and has more than 19,000 producing wells and more than 7,500 decommissioned wells was published in early 2014 (Li & Carlson, 2014). The study found that in a sample of 223 groundwater wells, a number of which were resampled over a period of five years, 78 per cent had dissolved methane. The occurrence of methane did not correlate with proximity to energy wellbores, and the methane was found to be more than 98 per cent of biogenic (shallow) origin, therefore, not from thermogenic sources (deep, from the intermediate or the producing zone). Even for the few cases where the gas was of thermogenic origin, the specific pathway (natural or man-induced) could not be deduced.

In contrast, some work has shown that methane found in groundwater wells in certain areas in Pennsylvania is somewhat correlated to the distance from recent energy wells drilled in the five- to six-year period before the study was done (Jackson et al., 2013). Specifically, methane occurrences in groundwater wells were found to be statistically more common nearer to energy wells in this region, although the authors did not prove that the methane actually came from the proximal energy wells.

These different results may reflect geological differences, as the strata in Colorado are quite different from the strata in Pennsylvania. The results are reminders that vigilance is needed, baseline data must be established (it is too late in many oil and gas areas to collect true baseline data), and careful scientific analysis performed before wide-sweeping conclusions about well integrity, groundwater contamination, and gas migration pathways can be drawn. Furthermore, there is an inherent danger in taking well-documented cases in the U.S. as suitable analogues for Canadian plays, as the regulatory environment and the resource ownership in the two countries are radically different. See Chapters 6, 9, and 11 for further discussion of the implications of this issue.

Figure 7.4 Potential Subsurface Contamination Pathways



Courtesy of Maurice Dusseault

Clearly, potential pathways should be understood and assessed in order to develop rational regulatory guidelines and to execute safe and reliable well installation and management practices.

Pathway 1 in Figure 7.4 has triggered much concern among stakeholders (see Chapter 8). However, there is apparently no known case of fracturing liquids or gas migration from the target horizon directly up through the rock mass to the surface or into shallow aquifers during or after well stimulation (CCA, 2014). A typical induced fracture height may range from tens of metres to perhaps several hundred metres, whereas the well interval fractured is 1.5 to 4 kilometres deep. Monitoring of the active fracturing process for hydraulic fracture rise shows that induced fracturing terminates in the zone just above the target formation and induced fractures do not rise a thousand metres or more to the surface (Fisher & Warpinski, 2012). There are many reasons why this should be the case, but perhaps the most important one is that to double the height of an induced hydraulic fracture, one must pump in about eight times the liquid,[9] and this is not done because there is no economic incentive to propagate fractures into the non-productive strata above the target formation. Thus, Pathway 1 remains speculative and extremely unlikely, compared to other pathways. It can reasonably be judged to be of far less interest than other pathways in the context of possible onshore Nova Scotia oil and gas development.

Pathway 2, fluid migration up an offset well during hydraulic fracturing, has happened at least once in practice in Canada.[10] In 2012, injected fluids rose to the surface in an offset legacy well producing from the same formation during active fracturing of a horizontal well north of Calgary, AB. This incident caused the

Alberta Energy Regulator (AER) to initiate and publish a detailed study of the event (AER, 2012) and also led to the issuance of new guidelines to reduce the probability of such an incident in the future (AER, 2013). In Alberta alone, about 440,000 oil and gas wells have been drilled and approximately 175,000 hydraulic fracturing operations have been performed to date, so the presence of nearby active or legacy wells must be considered during planning for drilling and well stimulation in order to preserve the integrity of the offset wells. By contrast, in Nova Scotia, there are only a few decommissioned legacy wells that penetrate deep into the unconventional gas strata, and the locations of these wells are well known, so the chances of fluid migration into these wellbores during hydraulic fracturing or other production activities are likely minimal. Furthermore, if development was ever to be undertaken, Nova Scotia regulators would need to adopt appropriate regulatory policies to assure well integrity (see Chapter 9).

Pathways 3 and 4 are the pathways of greatest concern (Dusseault et al., 2000; Dusseault et al., 2014; Dusseault & Jackson, 2014), especially after well decommissioning when the inside-the-casing pathway has been plugged with several long cement plugs and mechanical packer seals. Because of cement placement issues and cement shrinkage (Reddy et al., 2009), gas influx from intermediate-depth gas zones can lead to the development of gas columns behind the external casing. Then, the buoyancy of the gas leads to slow seepage, perhaps into shallow aquifers or to the surface where methane enters the atmosphere. The seepage rates are generally slow because the aperture (width) of the pathways is small, far less than a millimeter (based upon cement bond logs, laboratory tests, and other sources). General methane emissions, including all fugitive gas sources from natural gas development, has recently been studied in the U.S. (Petron et al., 2012), but there exist few systematic regional studies of gas migration from energy wells in Canada or elsewhere. Such studies have been suggested (CCA, 2014) and would serve as an important guide to development of regulatory requirements to reduce the incidence and rate of gas migration. In Nova Scotia, because there are probably none or few intermediate-depth gas-bearing zones, except in the coalbeds of the northern part of the province, these two pathways might be expected to be far less frequent and problematic compared to some other jurisdictions, such as eastern Alberta and western Saskatchewan, where there may be a half-dozen thin gas sands at depths of 200 to 1000 m, i.e., below the surface casing shoe but above the producing zone (Erno & Schmitz, 1996).

Pathway 5 in Figure 7.4 comprises leakage of the targeted producing formation gas upward along the outside of the casing toward the surface. Such cases seem to be associated with poor primary cementation of wells or in wellbores that were subjected to severe conditions during service. Because a reservoir is depleted by production, the fluid pressure in the target horizon is reduced over time to much lower values than in the fluids above the reservoir. This inhibits gas migration and acts against development behind the casing of a continuous buoyant gas column having its origin in the producing formation. In addition, the lower 1,000 metres of a 2,000-4,000 metres deep casing string (Figure 7.1) is likely to be well-sealed because of the high pressure generated in the column of liquid cement during primary cementation of the production casing. Pathway 5 would be of limited concern in Nova Scotia, providing that good quality assurance of the primary cementing operation is maintained.

Pathways 3 and 4 are also significant concerns, and indeed there is good evidence that a significant percentage (from a few to as many as 10 per cent - Bexte et al., 2012) of oil and gas wellbores in some areas in Canada experience gas migration (Dusseault et al. 2014; Dusseault & Jackson 2014). It is generally straightforward to differentiate between shallow biogenic or coalbed methane and the deep gas found in unconventional gas and oil formations (Molofsky et al., 2013). Once a gas migration event has been identified during operations or at a later date (by the company or a plaintiff), sampling and analysis help reveal the source and give clues about the pathway. It is a standard regulatory requirement that the operator report gas migration events. Once the source is located, perf-and-squeeze operations (see above) can be used to shut the pathway above the source and greatly reduce the chances of further gas seepage.

Although an undesirable event from a greenhouse gas and aesthetic perspective, the impact of methane entering potable water sources is not a serious health issue, in comparison to many other chemical contaminants (Goldstein et al., 2014). See Chapter 4 for a discussion of this issue. Gas in groundwater is a widespread natural phenomenon, especially in geological conditions where there are deep or shallow methane sources, such as coalbeds or peat layers, intermediate depth gas accumulations, and other non-thermogenic sources. The gas in water wells may even come from great depth under the right geological circumstances (Stahl et al., 1981; Wilson, 2014). Gas entering shallow groundwater wells may be a nuisance and can, exceptionally, be an explosion hazard if gas accumulates in poorly ventilated spaces. However, other than making groundwater unpalatable in some cases, no severe health impacts appear to have been recognized at this time (see also Chapter 6 for a detailed discussion of water quality standards and regulation).

However, a recurring issue in well integrity assurance and development of unconventional gas and oil in new areas is the lack of scientific-quality, baseline groundwater data (Jackson et al., 2013). Often, the only data available are from local water wells, which may be tapping only one zone, may be mixing water from several undifferentiated groundwater zones, or may be contaminated by organic matter in the well. If only this quality of data is available, it becomes more challenging to address cases where there is a concern over the source of methane (or other compounds) in the groundwater. We address the importance of baseline monitoring in Chapters 4, 6 and 11.

Good quality data on the composition and geochemical nature of the gases in the ground is a valuable source of information needed to address cases of claimed seepage of gas from energy wells into groundwater wells. This information is relatively straightforward to collect through what is referred to as "mud-gas logging," which is the collection of samples of gas released from the rocks during drilling (Rowe & Muehlenbachs, 1999). However, energy companies regard this information as strategic, of economic interest, and, therefore, confidential. Means can easily be established within a regulatory framework to store this data and make it available under controlled conditions when claims are made related to fugitive gas emissions, in order to protect the resource owners (people of NS), the claimant, and the operator. For example, many types of confidential information are regularly filed with the AER and the BCOGC, and this information is used for regulatory purposes but not released publicly.

7.6 | **Well Decommissioning and Long-Term Integrity**

7.6.1 The Decommissioning Procedure

Once the commercial life of an unconventional gas well is over, usually 15 or more years, it must be decommissioned according to stipulated practices laid down by the regulatory body. If there is any detectable SCVF, which occurs in perhaps 10-15 per cent of wellbores,[11] or evidence of seepage or loss of pressure integrity between the intermediate string and the production string, remediation must be implemented to reduce such flows to negligible values before the well is sealed. This would typically involve “perf-and-squeeze” (see above) of neat cement slurry into the location of the casing above where the gas is percolating. Cement bond logs, temperature logs, and noise logs may be used to identify the source of the gas migration to guide the location of the perforating action, and the well will have to be monitored again for SCVF before decommissioning. Several perf-and-squeeze episodes may be required to reduce seepage rates to mandated levels.

Perf-and-squeeze operations are likely to be less frequently needed in Nova Scotia in potential future developments than they have been in regulatory jurisdictions in Western Canada for geological reasons discussed before, and because general oilfield practice continues to improve. If they are required, there is a concern that, in very stiff dense rocks, the high pressures needed to force the cement into the cement-rock system will tend to wedge open natural fractures that could serve as future seepage pathways behind the casing. This is less of a concern in jurisdictions such as Alberta, where the rocks in the upper portion of the wells tend to be ductile and granular in nature (ductile shales, clayey high-porosity sandstones, porous coaly seams…). Better sealing agents that can flow into small cracks, and which tend to wet the surfaces of the cracks, would be more effective than cement to seal wellbores, but such materials (low viscosity resins for example) have not been widely adopted. As in many other cases, more publicly available data on the efficacy of practices such as cement squeezing over time are needed. As in any industry concerned about costs, there may be reluctance to adopt more demanding and expensive techniques for sealing wells, although a regulator could always choose to mandate them, in addition to specifying performance criteria. Although current practices appear to generate good results, given the very small number of verified cases of water well interactions in Canada, heightened public concern over issues such as gas migration would suggest that energy companies, regulators, and the public, might benefit from enhanced developments in this area. There is even good reason to believe that better materials and methods could lower industry aggregate costs of leaky well remediation in the long term. Most regulatory bodies, recognizing that there are many options and materials available for this task, stipulate performance criteria without specifying a particular product or method.

Once these activities to assure well integrity are done, or if the well has displayed no SCVF gas emissions and it is not necessary to attempt to seal the behind-the-casing pathway, the wellbore can be plugged and decommissioned. Plugging a well requires that the geological information for the well be used to locate zones above where plugs should be placed, and there are regulatory criteria that must be followed. Each plug includes a mechanical seal, a metal or polymer bridge plug or packer placed inside the casing, and an amount of cement sufficient to seal 30 to 50 metres of casing on top of the bridge plug. A number of these seals will be placed along the length of the production casing so that the interior of the wellbore has no vertically continuous path.

Statistics are available on the total number of wells that have been drilled, that are active, and that have been plugged and decommissioned. Worldwide, the majority of wells drilled have been in the United States, over 2.5 million since 1950 and on the order of 500,000 in all of Canada (mainly in Alberta). In a recent Society of Petroleum Engineers Land Well Integrity Conference in Banff, Alberta (April 2014), the AER said there have been about 440,000 wells drilled in Alberta, of which about 260,000 are active. Thus, about 40 per cent of wells in Canada have been plugged and decommissioned, and although there are many instances of gas migration (about 1400 quoted by AER, or less than 1% of decommissioned wells), the number of private wells that have been demonstrated to be contaminated by methane from an energy well remains extremely small, perhaps a handful of verified cases. Gas migration issues must be fixed when noted, but based on many years of history in Alberta and elsewhere, there is no evidence of major environmental problems arising from the existence of these decommissioned wells at this time. Nevertheless, the fact that sufficient data may not exist to verify the absence of such an issue remains a concern. This is one of the unknown factors that would need to be explored and quantified in order to more carefully develop and manage any future Nova Scotia monitoring and regulatory regime (see Chapters 9 and 11).

We do know that methane seepage has not been considered by toxicologists as an issue worthy of their attention, and this is supported by the lack of publications in this area. There are many areas in the world (Pennsylvania, central Alberta, central Colorado) where natural seepage of methane is endemic, and major health concerns have not been identified at this time. The responsibility is that the owner fix the leaking decommissioned well to the standards set by the regulatory agency. Most jurisdictions also have "orphan well" funds, provided by a levy on production, that are used to fix leaking wells for which an owner cannot be found. Interaction of wells with the surface through leakage was discussed in the Introduction as a possible externality of the industry and in Chapters 9 and 11 on regulation and insurance recommendations.

7.6.2 Long-term Wellbore Integrity

Once a well is properly decommissioned and there is no detectable leakage, is there a chance that Pathways 3 and 4 sketched in Figure 7.4 could develop? The answer to this question is yes. There is evidence that the development of slow gas migration can take place years after decommissioning if a buoyant gas column gradually develops behind the casing. In such cases, the gas seepage rate may be small, but it may remain entirely undetected if the gas is entering shallow aquifers rather than venting visibly at the surface. Furthermore, if gas migration is detectable at the surface, there is a high probability, almost a certainty, that some gas is also entering into shallow sandy aquifers behind the surface casing. In Alberta, especially in the Lloydminster area and the heavy oil fields of east-central Alberta, gas migration long after decommissioning is not uncommon (see references listed in Dusseault et al., 2014 and in CCA, 2014). Only if surface-visible evidence of a leaking well is noted is it re-entered and re-sealed. Nevertheless, the gas seepage rates are low (or else they would be widely noted) and may only be detected as slow bubbling after rainfall saturation. This suggests that the environmental impacts may be small compared to other natural sources of methane, but as mentioned previously, the incidence and rates of such events remains worthy of quantification as a precautionary measure.

How long after decommissioning will the sealed wellbore integrity be maintained? The answer to this question is not known at present. Modern well cementation practices are barely 60 years old, and the life-span of steel in the ground, perhaps subjected to electro-chemical corrosion (the steel is a good electrode), is not known, nor is it known if gas migration pathways could develop once the casing has corroded and is breached in many places. The products of steel corrosion and cement degradation are solid materials, so energy well deterioration over many decades or centuries will not lead to wide open channels to the surface, but there is a possibility, perhaps small, that additional pathways for slow gas seepage could develop. Liquid seepage is far less probable because liquids are not buoyant.

Long-term well integrity is a complex question that requires investigation, starting with assessment of old wells in Ontario, New Brunswick, and Alberta, for example. At the present time, there is no evidence of significant increases in the incidence of leaky wellbores with time, but the studies remain at the anecdotal level, in large part, because old wellbore sites are not subjected to systematic re-examination over time. This should be studied to allow quantification of the long-term risks, i.e. more than 100 years, associated with this industry (see Chapter 11 for further discussion of this point). As mentioned earlier, the report issued by the Council of Canadian Academies (2014) deals with many issues related in particular to unconventional gas wells, but which are also common to all conventional and unconventional gas and oil wells. They suggest baseline studies to quantify groundwater conditions and quantification of gas migration: how many wells, how large a leak, what conditions, what is the age of the well, and so on (CCA, 2014).

7.7 | **Discussion and Conclusions**

Unconventional gas and oil development using modern well cementing and completion techniques leads to generally good wellbore performance, but there will never be a 100 per cent success level in sealing all wellbores against all possibilities of future impairment. Continued technological advances may help to reduce the incidence of well leakage, through use of better quality casing (better threads in particular), improvements in cementing methods (for example more centralizers, more consistent and denser cement formulation and placement, etc.), new materials for correcting leakage problems, better methods for detecting poor-quality cement behind the steel casing, and even better methods of detecting slow methane seepage around decommissioned wellbores. Vigilance and explicit quality assurance are necessary to keep incidents of human error low and to rectify problems that may have arisen because of such an error. Regulatory guidelines must aid this process and should be re-examined as technical developments continue to be made in the oil and gas industry

The most important integrity problem, after wellbore decommissioning, appears to be gas seepage along the outside of casing. The numbers of leaking decommissioned energy wells and the rates of leakage are not well-understood, and it appears that this varies with geology and geographical region (and probably age of well and quality of cement, etc.). Probably from 1 to 10 per cent of energy wells may be slowly leaking natural gas, most likely sourced from intermediate depth uncommercial gas zones, and such leaks are difficult to detect if they have little or no surface expression. The risks associated with inadequate well integrity are not known to be great, as shown by years of experience with hundreds of thousands of wells in the western provinces, although further research is needed to validate this tentative observation (CCA, 2014). Three known significant consequences exist: contamination of groundwater, turning it unpalatable; escape of natural gas to the atmosphere, where it has a greenhouse gas effect; and direct safety risk associated with potential explosion of an accumulation of gas in a confined space. The latter is extremely rare (no cases for gas sourced from a leaking energy well could be confirmed in Canada).

Although not desirable, groundwater souring is not a serious public health issue because methane itself is not toxic. Hundreds of thousands, perhaps millions, of groundwater wells in North America have methane present in free form or dissolved in the water without evidence of widespread ill effects. There are other geochemical effects that could be associated with methane in water wells, depending on particular locations, but it seems that there are no reports of serious negative health effects in areas that are naturally affected by methane in well water.

The strong greenhouse gas effect of fugitive methane is well known (CCA 2014), and in the first 20 years after emission, its impact is many times that of CO_2, on a weight basis, perhaps as much as 100 times (less after 20 years because methane is gradually destroyed in the upper atmosphere).

The GHG effect of the amount of methane escaping into the atmosphere from leaking energy wells can be shown by reasonable estimates and calculations to be small compared with other well-defined sources (e.g., automotive fuels, coal combustion, cattle husbandry). For example, assume that the 600 MW Lingan power plant in Nova Scotia operates at a yearly average of 300 MW. Coal-generated electricity produces about one tonne of CO_2 for each MWh (megawatt-hour), which gives about 2,700,000 tCO_2/yr for Lingan (365 days × 24 hr/d × 300 MW × 1 tCO_2/MWh). Dividing by 100 (the GHG impact factor of CH_4), this is roughly the equivalent of 27,000 tCH_4/yr. Probably, there are about 100,000 head of cattle in Nova Scotia generating about 10,000 tCH_4/yr (about 100 kg/yr each). Suppose that 10% (a high estimate) of the approximately 175,000 decommissioned and suspended energy wells in Alberta are slowly seeping methane at a mean rate of 500 kg/yr (this is a very high estimate); this gives about 9,000 tCH_4/yr, similar to the cattle herd emissions in Nova Scotia and about a third of the CH_4 equivalent of the Lingan plant.

Such comparisons and calculations of well leakage effects are essential in making energy choices for the future. Not only should the negative impacts be assessed, but the positive impacts of reducing emissions or impacts from other sources must be weighed and well leakage numbers and rates, as widely recommended (CCA 2014; Dusseault et al. 2014), should be more carefully quantified. Improved practices in primary well cementation and decommissioning could reduce gas migration to substantially lower levels than at present, and the many recent Society of Petroleum Engineers conferences on well integrity indicate that there is increasing sensitivity to this subject.

Because any potential future unconventional gas and oil development in Nova Scotia would take place using modern technology, with multiple wellbores installed at each drilling site, good regulatory guidelines and enforcement practices can be stipulated in advance to ensure that the site is geologically understood, that wells are properly installed with good quality assurance, that well decommissioning is done according to best practice guidelines, and that the groundwater is monitored. The mature practices of jurisdictions such as Alberta could serve as a guide to the establishment of a regulatory system in Nova Scotia, with modifications as deemed necessary by local regulators, scientists, and engineers. Operators are always required to be vigilant and relevant environmental data collected (e.g. groundwater quality, gas analyses, cementation reports) must be made public so that industrial activities and impacts may be subject to transparent oversight to assure citizens that environmental and public health protection is taking place as their resources are developed. The principles of good regulation were discussed in Chapter 6 with specific respect to water quality and are further elaborated in Chapter 9.

Developments in regulatory practices continue to be made. For example, a multi-level groundwater monitoring well at each multi-well drilling site may be required in the future in some jurisdictions and is currently being debated in the regulatory world (CCA, 2014; ASERD, 2014). If this is mandated, the groundwater well should be installed under the supervision of a licensed third-party before the first energy borehole is drilled. The groundwater monitoring well should be sampled and analyzed initially and each two to three years thereafter and perhaps until 10 years after the last well is decommissioned. In this way, a problem with energy wellbore integrity that impacts groundwater could be identified promptly and corrective measures taken before a more severe problem develops over a larger area. Because each unconventional gas and oil multi-well pad would be draining the gas from an area of several square kilometres (4-6 km^2), the number of sites will remain few and fairly widely spaced, so that it would be easier to detect issues and rectify them compared to single well – single site approaches.

If hydraulic fracturing is pursued in Nova Scotia, the natural advantages that exist in the Province's unconventional gas regions should lead to a lower incidence of poor wellbore integrity compared to historical practices in other jurisdictions. A few of these are listed here:

- Moderate tectonic stresses and strong rock mean that wellbore instability during drilling will be largely absent; this means high-quality wellbores, which is an aid to establishing high quality-primary cementing operations, and, therefore, should lead to fewer cases of leaking wells.
- Except in the coalbed areas of Nova Scotia, there appear to be few gas sands at intermediate depths that could lead to severe problems with gas migration behind the casing (as in the Lloydminster region of Alberta for example).
- Unconventional gas in Nova Scotia is likely to be sweet gas (little to no H_2S), making all operations easier, and less sulphide corrosion should lead to better wellbore integrity.

According to the analysis described in Chapter 2, any significant development of Nova Scotia's unconventional gas and oil resources would not take place before several years, perhaps much longer. This would give Nova Scotia time to establish appropriate monitoring and regulatory systems if the possibility of such development emerges and to benefit from more technical advances in cementation, measurements, and general scientific knowledge about well integrity.

ENDNOTES

1. These numbers were provided by Government of Nova Scotia personnel.
2. These numbers were provided by Government of Nova Scotia personnel.
3. An idea of how the oil and gas industry is regulated in Canada can be obtained by studying the AER website and their various guidelines and enforcement actions: http://www.aer.ca/ As an example, the rules for land reclamation can be found at this webpage: http://www.aer.ca/decommissioning-and-reclamation/reclamation
4. For example: British Columbia: https://www.bcogc.ca/industry-zone/documentation; and for Alberta: http:/ www.aer.ca/rules-and-regulations/directives
5. For example, the following sites contain information about recommended practices from Canadian industry sources: http://www.capp.ca/getdoc.aspx?DocId=218135&DT=NTV; http://www.enform.ca/safety_resources publications/PublicationDetails.aspx?a=29&type=irp
6. Alberta defines the BGWP as 4000 ppm tds (parts per million total dissolved solids such as sodium chloride). "Water containing TDS concentrations below 1000 mg/litre is usually acceptable to consumers…"; quote from WHO 1996, Total dissolved solids in drinking-water. In Guidelines for drinking-water quality, 2nd ed. Vol. 2. Health criteria and other supporting information. World Health Organization, Geneva, 1996. WHO/SDE WSH/03.04/16.
7. For good geological reasons, oil and gas-bearing formations offshore Nova Scotia are much younger than the potential unconventional oil and gas strata onshore and often have exceptionally high pressures, sometimes approaching twice the pressure that would be expected from a vertical water column. Such high pressures require great care in drilling, extra safety devices and techniques, and probably the installation of one or two additional casing strings.
8. See glossary.
9. The fluid volume in an induced fracture is $\approx (V=4/3 \cdot \pi \cdot (H \cdot L \cdot a)$; to double the height, it is necessary to double the length and the aperture (width) as well, giving eight times the volume.
10. Fluid migration is not the same as a detectable pressure pulse. High pressure fracturing operations can create a pressure response some distance away, certainly hundreds of meters in some cases, but because water is relatively incompressible, a pressure response can be detected at great distance and is not proof that a breaching of a barrier has taken place by direct flow of significant volumes of fluid.
11. In Alberta and British Columbia, surface casing vent flow data are registered with the regulatory agency; therefore, there are excellent statistics available in this area, in contrast to gas migration behind casing, where there are few data, insufficient to make strong quantitative conclusions. Other jurisdictions may not be as comprehensive in demanding full reporting of SCVF incidences as AB and BC; hence, data from elsewhere are viewed as less reliable in comparison to data from western Canada.

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CHAPTER 8

Public Participation in the Assessment of Risk

Ian Mauro

8.0 | **Chapter Summary**

This chapter builds on the foregoing chapters, especially those dealing with health, community, and water-related risks and takes a participatory risk assessment approach to understanding the impacts associated with hydraulic fracturing in Nova Scotia. Analyzing 238 unique public submissions to the review, it was found that a significant majority of these stakeholders oppose hydraulic fracturing and want to see a continued moratorium or ban in the Province. The main perceived risks by those submitting comments on hydraulic fracturing, in order of significance, were related to: water, community and infrastructure, economy, waste and clean-up, human health, climate change, and other environmental issues like increased potential for earthquakes and habitat fragmentation. These perspectives were related to available scientific literature suggesting that hydraulic fracturing poses credible threats to human, social, and environmental systems.

Subsequent to the initial publication of this paper, we received 15 comments about the content, which helped to further refine this chapter. Comments were received from industry, environmental organizations, government officials, academics, and citizens. In most cases, perceived gaps in this chapter have been filled by other sections of the overall synthesis, for example, more nuanced information about geology, water, well integrity, health, economics, regulations and guidelines can be found in other chapters and the final recommendations. There were various interpretations of this paper, with both industry and environmental groups highly critical of the findings, suggesting that it did not adequately represent public perceptions, environmental impacts, and other risks associated with hydraulic fracturing. While some suggested that the entire chapter should be re-written, others believed its tone, observations, and conclusions are critical to the overall report, which made integration of comments challenging and ultimately demonstrates the highly contested nature of this issue.

Given the multi-faceted nature of this type of development, the relationship of hydraulic fracturing to future energy and environmental policy in the province of Nova Scotia may be considered a complex or "wicked problem" that is difficult to resolve in purely scientific terms. We conclude by noting that ongoing public consultation, interdisciplinary research and careful consideration of policies and regulations moving forward is required to ensure the balance between sustainability and economic renewal in Nova Scotia.

8.1 | An Introduction to Complex or “Wicked” Problems

Many leading scientists have warned, in recent years, that human activity is quickly and perhaps irrevocably undermining biodiversity and climate stability and suggest that fundamental changes in society are required to avert threats to the long-term sustainability and resiliency of human and ecological systems (MEA, 2005; IPCC, 2014). Given the challenging, complex, and interrelated nature of the multiple global crises, some suggest we have entered the Anthropocene, a new geological epoch dominated by humans and fossil fuel use (Steffen et al., 2007), characterized by complex or “wicked” problems that are increasingly difficult to solve using traditional approaches to science, technology, and governance (Levine et al., 2012).

While energy is a necessity, the resolution of energy use with associated environmental, social, and economic impacts is one of the most significant wicked problems facing all societies.(Coyle and Simmons, 2014). In this context, it is very challenging to assess the potential benefits and costs of hydraulic fracturing – or “fracking” – for unconventional gas and its environmental and social impacts (North et al., 2014). A holistic and inter-disciplinary approach exploring potential benefits and risks within the geography, ecology, culture, policy frameworks, and public perspectives in Nova Scotia is therefore required.

8.2 | Nova Scotia’s Natural Resources, Energy and Environmental Goals

8.2.1 Ecozone and Natural Resources

Nova Scotia is part of the Atlantic Maritime Ecozone and is characterized by: a cool, moist climate that is heavily influenced by the Atlantic Ocean; mixed forests with red spruce, balsam fir, yellow birch, sugar maple, and some boreal species; representative wildlife such as white-tailed deer, moose, black bear, racoon, blue jay, and eastern bluebird (Webb and Marshall, 1999). With an abundant natural resource-base, much of the economic activity within the region is based on primary industries, such as forestry, fisheries, and agriculture (Beck, 2009). Given the biophysical environment of the region, it is promoted as “Canada’s Ocean Playground,” and the tourism industry also benefits significantly from the natural resource base and scenery.

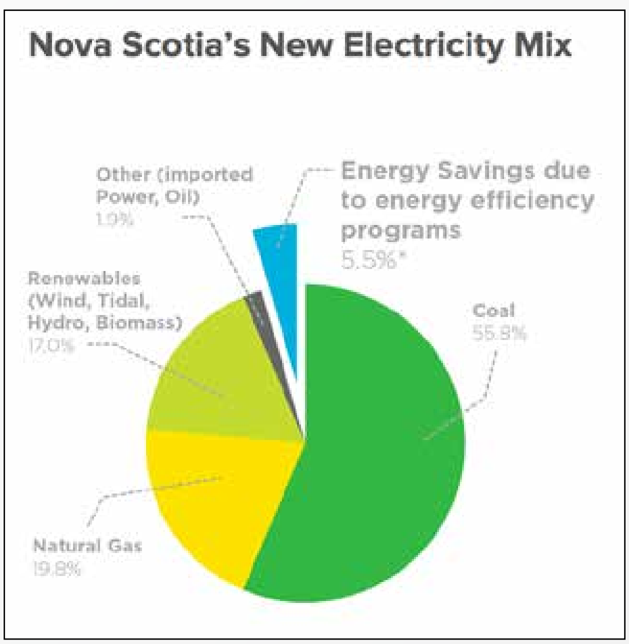
Photo 8.1 Nova Scotia, "Canada's Ocean Playground," has an economy largely predicated on its natural resources

Photo Credit: Dennis Jarvis

8.2.2 Regional Energy Mix

As we noted in the introduction to this report, Nova Scotia's electricity comes from a variety of sources (Figure 8.1). Principally coal and petcoke (55.8 per cent), followed by natural gas (19.8 per cent) and renewables like wind, tidal and hydro (17 per cent), with some imported power and oil (1.9 per cent), and energy efficiency programs helping offset 5.5 per cent of the annual demand (Efficiency Nova Scotia, 2013). Since 2006, coal fired power generation declined from its high at 80 per cent, with an anticipated reduction to 40 per cent or lower by 2020 (Government of Nova Scotia, 2012a).

Figure 8.1 Nova Scotia's 2013 electricity production including energy conservation programs



Courtesy of Efficiency Nova Scotia, 2013

8.2.3 Environmental Goals and Planning

In 2007, Nova Scotia positioned itself as a national and international leader on environmental and sustainability policy by enacting the Environmental Goals and Sustainable Prosperity Act (EGSPA), also known as the Green Economy Act. This legislation created an ambitious plan to achieve environmental and economic prosperity – to have one of the cleanest and most sustainable environments in the world and to improve the Province's economic performance to a level that is equal to or above the Canadian average by the year 2020 – and the Province claims it is making significant progress in this regard (Government of Nova Scotia, 2012b).

EGSPA states 21 short- and medium-term goals, binding the government to follow through on policy commitments in five broad categories (Lahey and Doelle, 2012): 1) energy use and sources; 2) greenhouse gas (GHG) emissions and air pollutants; 3) resource conservation and protected areas; 4) water treatment and management; and 5) government initiatives to realize goals on a set timeline. Nova Scotia's regulations and associated activities to shift away from coal to cleaner energy sources received recognition and awards (Government of Nova Scotia, 2012b), yet beyond the legislated requirement for 40 per cent renewable electricity generation commitment by 2020, the question of what mix of energy sources will replace it remains. The Government of Nova Scotia (2012a) views expansion of natural gas as an important way to diversify energy production; thereby, reducing coal use and associated environmental and human health effects. However, there are distinct differences between "conventional" (e.g. Sable Island) and "unconventional" (e.g. hydraulic fracturing) natural gas production. EGSPA provisions have implications for whether hydraulic fracturing is an appropriate technology given the potential environmental impacts – positive or negative – this technology may have on GHG emissions and air quality (Table 8.1).

Table 8.1 Example Provisions within Nova Scotia's Environmental Goals and Sustainable Prosperity Act that have Implications for Hydraulic Fracturing

Table 8.1: Example Provisions within Nova Scotia's Environmental Goals and Sustainable Prosperity Act that have Implications for Hydraulic Fracturing

GOAL	Progress	Potential Implications
Greenhouse gas emissions will be at least 10% below the levels that were emitted in the year 1990 by the year 2020	While NS has a declining GHG profile, the province is still at 5.2% above 1990 levels	What are the implications of hydraulic fracturing on provincial GHG emissions? Will hydraulic fracturing contribute or detract from this goal?
Emission of nitrogen oxides to be reduced by 28% by 2015 and 44% by 2020, relative to emissions in 2000.	NOx emission were 32.6% below 2000 levels in 2011	What are the implications for hydraulic fracturing on air quality, specifically NOx, will hydraulic fracturing enhance or detract from emission targets?
By 2015, 25% of Province's electricity will be supplied by renewable energy sources, and this will increase to 40% by 2020	Renewable are up, from 13.5% in 2010, to 17% in 2013, goal achievement still in progress.	What are the implications of hydraulic fracturing on overall energy production? Will hydraulic fracturing and associated natural gas undercut renewable energy development and associated opportunities?
Sources: Government of Nova Scotia 2012a+b; EGSPA		

Data source: Government of Nova Scotia, 2012b

Given the importance of public participation in policy issues regarding unconventional gas and consistent with the mandate of the review, this report responds to the expressed views of 215 individual Nova Scotians and 23 organizations and groups, and combines this with scientific scholarship, a process advocated in the literature on participatory environmental risk assessment (Mauro et al., 2009; NRC 2008; NRC 1996). This "analytic-deliberative approach" is effective for emerging technologies, for example, unconventional gas, as it helps identify potential problems at the onset, generating "collaborative science" that increases the quality and legitimacy of results (North et al., 2014). The importance of this approach is developed further in Chapter 11 when we discuss our approach to risk assessment, risk perception, and risk communications in more detail.

8.3 | **Environmental Perspectives of Nova Scotians**

8.3.1 Public Input and Approach

As described in our introduction, the review engaged in a range of public engagement activities throughout the process, including public meetings and the encouragement of submissions from citizens and stakeholders. In addition, a separate and complementary process was initiated with Aboriginal leaders and communities (see Introduction). Between October 30, 2013, and April 30, 2014, the review received 745 submissions, comprising 507 form letters sent in response to a call from the Council of Canadians and 238 unique comments from citizens, professional organizations, environmental organizations, industry, municipalities, and community groups (see Table 8.2). Although not everyone indicated their locations, it was clear from the content that nearly all unique submissions were from Nova Scotia, with a handful from outside the Province, but with an expressed interest in the region (e.g. owned property in Nova Scotia or were considering moving to the region). Some citizens stated their profession, demonstrating a diversity of stakeholder input, with submissions from academics, farmers, labourers, entrepreneurs, medical doctors and veterinarians, chemists, engineers, faith workers, retirees, and others. If the same individual or group made multiple contributions, all this content was counted as a single "unique comment," with submissions ranging from short emails to multi-page letters, some containing references to scientific studies, popular articles, and other media. It is important to note that the results may not be representative of the perspectives of all Nova Scotians given that data were not generated from a randomly selected sample of the population, rather, it was a self-selecting group of interested citizens and organizations. However, individuals and groups submitting provided deep insights and knowledge of various topics related to hydraulic fracturing. To better appreciate the diversity and depth of unique submissions (n=238), social science research techniques were used to code, tabulate and categorize content from submissions into themes (Maxwell, 2013). This facilitates a quantitative assessment of topics presented to the review, creating a ranking of the 10 most commented upon hydraulic fracturing-related issues within the submissions and presentation of associated qualitative comments.

Table 8.2 Type of Unique Submissions that have been made the Hydraulic Fracturing Review

Table 8.2: Type of Unique Submissions to the Expert Panel on Hydraulic Fracturing (n=238)	
Group Type	**Number**
Citizen	215
Professional Organization	10
Environmental Organization	6
Industry	3
Municipal	2
Community Group	2
Total	238

8.3.2 Findings from Public Submissions

Nova Scotians that made submissions to the review were largely concerned about risks associated with hydraulic fracturing. Individuals submitting form letters (n=507) suggested that hydraulic fracturing presents serious risks and asserted that gains made through the Environmental Goals and Sustainable Prosperity Act would be threatened. They called for an outright ban on the industry. This is, perhaps, not surprising given that form letters were coordinated by the Council of Canadians, which is a social action organization focused on water, energy, health, and democracy and is known for its active opposition to hydraulic fracturing. Of the 238 unique submissions, 183 individuals also mentioned a moratorium on unconventional gas and oil development, with 179 of these supporting a moratorium and four against having one in place. Overall, 92.1 per cent of submissions call for either a moratorium or ban on hydraulic fracturing in Nova Scotia, with only 0.5 per cent against this type of initiative, and the remainder not commenting on this issue (see Table 8.3).

Table 8.3 Support for and Against a Moratorium or Ban on Hydraulic Fracturing, Based on Submissions to the Review

Table 8.3: Support for and against a moratorium or ban on fracking, based on submissions to the Expert Panel (n=745)		
Support for a moratorium or ban	686	92.1%
No mention	55	7.4%
Against a moratorium or ban	4	0.5%
Total	745	100.0%

Since the form letters were very similar, it was easy to document concerns being repeatedly expressed by these individuals. However, the emails and letters from Nova Scotians were highly personalized, with individuals and stakeholders from across the Province offering a diversity of views on hydraulic fracturing that were quantified through the coding analysis (see Table 8.4).

Table 8.4 Ranking of Public Issues and Concerns Mentioned in Unique Submissions (n=238) to the Hydraulic Fracturing Review

Table 8.4: Ranking of Public Issues and Concerns Mentioned in Unique Submissions (n=238) to the Expert Panel on Hydraulic Fracturing

Rank	Main Themes	Coded Sub-Themes ranked by the number of comments (in brackets)	Total Number of Comments
1	Water	Contamination (79), Massive usage (36), General (29), through well failure (7), fluid migration (4), access (3).	158
2	Community and Infrastructure	Damage to roads and other infrastructure (33), social impacts (32), urban and rural industrialization (17), noise pollution (13), First Nation consultation (13), increased traffic hazards (10), fear of becoming locked into industry (8).	126
3	Economy	Impact on: Agriculture (30), tourism (20), forestry (2), fisheries (1), distillery (1); property value decrease (21), overall negative impact on economy (9), questions abundance of resource (8), job creation overblown (5), vacancy rate decrease (2), self sufficiency + (1)	100
4	Waste and Cleanup	Wastewater disposal/storage (66), spills (7), NORM (6), Contamination (5), tailing leakage (3), concern for what is left behind (2).	89
5	Human health	Air quality (36), General (20), effect of close proximity (10), NORM effect (8), effects from fluids (6), mental health (4), impact on marginalized (2), Birth defect and fertility (2)	88
6	Climate change	Methane leaks/GHG contribution (31), Bridge fuel (18), climate impact (14), fossil fuel dependence (12), ozone (6), machine emissions (3).	84
7	Policy and regulation	Enforcement/monitoring (24), Precautionary principle (13), Enhance/update regulation (13), Impact/spill insurance (8), consultation between parties (8), balanced approach (3), best practices policy (3), education (2), need for chemical content disclosure (1).	75
8	Other Environmental Issues	General impact (19), Earthquake concerns (15), Habitat fragmentation (10), soil contamination (8), chemical composition of fluid/waste and effects (8), Animal Health/SARA (6), industrialization (3), risk to geology (1), sand usage (1)	71
9	Industry deception	Perceived dishonesty (28), Profit motives (9), Chemical composition disclosure (8), non-disclosure agreements (8), Disregard for Community and worker safety (8)	61
10	Inadequacy of Science	Inadequate data (13), long term unknown (12), casing failure (9), no evidence for concern + (6), new technique (3), hydrology of NS unknown (2), geology (1)	46

Notes: For each submission, discrete topics were coded, and totals for the themes and sub-themes represent the number of times unique issues were raised within all 238 public comments. Numbers in brackets indicate how many times sub-themes were mentioned and add up to the total for that theme.

Concerns regarding water resources, specifically its contamination from hydraulic fracturing, were the highest ranked (158 comments), followed by risks associated with industrial activities on community and infrastructure (126 comments), such as damage to roads, increased traffic, noise pollution and other issues. Citizens worried about adverse impacts on the economy (100 comments) – especially for land-based industries such as farming, forestry, fishing, and tourism – and also had concerns that potential job creation was inflated and that home values would decrease in areas with active hydraulic fracturing. Waste and clean up was also of high concern (89 comments), with a number of people expressing their dissatisfaction with the Kennetcook situation, where exploratory hydraulic fracturing waste water containment ponds had leaked, and waste byproduct remains on site and continues to be of concern. Human health (88 comments) was presented as a significant concern, given potential for poor air quality for those in close proximity to hydraulic fracturing sites and larger questions about the effects on mental health and marginalized peoples. Many were worried that hydraulic fracturing will exacerbate climate change (84 comments), through fugitive methane emissions nullifying natural gas as a "bridge fuel," although 2/18 reporting on this sub-theme thought that natural gas would help in the transition to a more sustainable energy system. Many were concerned hydraulic fracturing reinforces societal dependence on hydrocarbon-based energy. The cost and complexities of creating effective policy and regulation (75 comments) were also expressed, specifically regarding enforcement and monitoring and a desire to see a precautionary approach to developing the unconventional gas industry. Other environmental issues (71 comments) expressed more general concerns, as well as the potential for seismic events, habitat fragmentation, soil contamination, and associated effects on animal health and regional geology, with much of the commentary focusing on cumulative and long-term impacts. Industry deception (62 comments), in the form of dishonesty and non-disclosure of impacts in order to maximize profit was mentioned, and the effect this might have on worker and community safety was presented as an issue. Finally, some believed, an inadequacy of science (46 comments) on this issue (e.g. new industry, few studies, etc) made it difficult to gain credible knowledge on the issue of hydraulic fracturing and its long-term consequences. However, a minority of contrasting submissions (6/46) argued that an absence of evidence regarding negative impacts is proof that the industry is safe. Overall, the vast majority of submissions expressed concerns over negative impacts with only a few speaking to positive aspects of hydraulic fracturing, largely those stakeholders linked to industry associations.

This paper explores the science of hydraulic fracturing, specifically looking at environmental impacts and their relationship to other intersecting issues, in order to determine if expressed public concerns regarding unconventional gas and oil development are justified based on the literature. Seven of the 10 themes from submissions are explored in detail, and the issues of regulation, scientific uncertainty and concerns about industry deception are woven throughout the text and addressed specifically in the summary remarks. The discussion in the chapter builds on analyses in foregoing chapters and acts as a link to questions of precautionary legislation and regulation, Aboriginal rights, and risks and recommendations in subsequent chapters

8.4 | **Environmental Impacts of Hydraulic Fracturing**

Until recently, few systematic studies on the environmental impacts of unconventional gas and oil development existed in the Canadian context. In the spring of 2014, the Council of Canadian Academies (CCA), an independent, not-for-profit organization designed to offer expert assessments of pressing public issues released a report entitled *Environmental Impacts of Shale Gas Extraction in Canada*. While the report acknowledges that unconventional gas is a "game changer," it states that hydraulic fracturing in Canada over the past decade has not been accompanied with appropriate investments in research and monitoring to better understand the environmental, community, and health effects of the industry and outlines key knowledge gaps regarding impacts on water, climate, air contaminants, land (CCA, 2014). The CCA report provides an important in-depth analysis of many of the concerns presented by those Nova Scotians who participated in the review, and thus is a key resource for this paper. Where available, newer studies on hydraulic fracturing are included, and to the best degree possible relevant issues for Nova Scotia are taken into account.

8.4.1 Impacts on Water

According to the literature, there are legitimate concerns regarding potential impacts hydraulic fracturing may have on groundwater contamination and possible subsurface and surface contamination (Figure 8.2), although these vary by region and situation (CCA, 2014). While hydraulic fracturing is generally water intensive, overall volumes are not expected to put a burden on water resources in most Canadian jurisdictions, including Nova Scotia (see Chapter 6), yet there is cause for concern at seasonally specific peak demand times, or in the case of droughts (CCA, 2014). Groundwater contamination is a legitimate risk, from gas leaking alongside or through damaged or incorrectly sealed well casings and potentially upward long-term migration of gas within natural fractures in the earth into the water table (CCA, 2014). At the surface, contaminant concerns relate mostly to spills associated with: 1) industrial activities and chemical storage at hydraulic fracturing well pads and; 2) concerns over the storage and handling of "flowback water" that returns to the surface – after initially being injected under high pressure into the well in order to hydraulically fracture unconventional gas and oil deposits – that contains hydraulic fracturing fluids and salts, and may contain naturally occurring radioactive materials (NORMS), and trace metals like arsenic and barium (CCA, 2014). These issues are discussed in greater detail in Chapters 6 and 7.

According to Nova Scotia Environment (2014) approximately half of the Province uses groundwater for water supply, and many correspondents felt water should not be put at any risk. They questioned whether or not the short-term economic benefit is worth the long-term environmental risk of contaminating water supplies, including this quote from a local engineer who advocated a precautionary approach regarding groundwater:

> "Do you discount future costs (the potential contamination of an aquifer in 50 years' time as contaminants work their way to the surface through failed casings and cement) to a possible short economic boom over 10 years?" (Submission 206)

It is important to note here that the rural geography of Eastern Canada plays an important role in framing citizen risk perceptions regarding water issues and associated risk profiles for communities. As noted by the (New York State Department of Environmental Conservation, 2011):

> "In the eastern provinces of Canada, where there are substantial shale gas resources, shale gas development would make unavoidable the drilling of gas wells relatively close to water wells relied on for drinking by rural residents." (Council of Canadian Academies, 2014)

Thus, rural communities, with well-based water systems, are likely at greater risk, especially if living near areas with substantial unconventional gas and oil resources. Submissions to the review note the adverse impacts of hydraulic fracturing on rural communities and water, including this from a family physician:

> "I am concerned about potential contamination and overuse of public water supplies, both drinking water and agricultural irrigation water, with many Nova Scotia communities already painfully aware of their lack of sustainable potable water supplies…" (Submission 211)

The science regarding contamination of well water from hydraulic fracturing is controversial and inconclusive. Two U.S. studies indicate homes within one kilometre of uncoventional gas production may be six times more likely than homes further away to be contaminated with stray gases such as methane, ethane, and propane (Jackson et al., 2013; Vengosh et al., 2013). Contrasting studies suggest stray gases are naturally occurring in aquifers and cannot be definitively linked with unconventional gas activities (Baldassare et al., 2014; Molofsky et al., 2013). Concerns regarding water, communities, and wellbeing, especially those within rural and remote regions, were voiced clearly in submissions received by the review. The second most frequently cited concern in submissions was impacts on communities and infrastructure.

8.4.2 Community and Infrastructure

Unconventional oil and gas development often takes place in rural communities, and that would certainly be the case in Nova Scotia (see Chapter 2). These smaller populations are often more susceptible to adverse impacts, given the limited resources of these areas combined with the potential for rapid industrialization that may require specialized equipment, workforces and infrastructure (Jacquet, 2014). A major concern of residents near active hydraulic fracturing sites is truck traffic and damage to roads – usually not designed for industrial activities – as a single hydraulically fractured well may require as many as 2,000[1] one-way truck trips to supply construction materials, equipment, chemicals, workers, and mostly water (NYSDEC, 2011). This issue was germane to Nova Scotians contributing to the work of our review, many whom saw a conflict between the physical environment and what would be required to support the hydraulic fracturing industry in the future:

> "…we can be certain that the documented wear and tear on existing roads will be severe beyond the current budget allocations of the country/municipality. Are we expecting such a landfall from the increased taxes on the oil drilling that these expenses will be covered? What is the plan here? The roads are already falling apart. (Submission 74)

In rural areas of the U.S., communities have often been underprepared for rapid growth (Shafft et al., 2013), and it is acknowledged that, "…implementing a large-scale new industry such as oil and gas in Eastern Canada would have required much more preparation and prior public consultation" (Rivard et al., 2014). Submissions indicated that the push to industrial-scale hydraulic fracturing in the Province is too rapid and they wanted more input, as noted by this comment:

> "Nova Scotians deserve, at the very least, a referendum on this most serious of environmental issues." (Submission 27)

Thematic analyses on stakeholder perceptions of socio-environmental impacts of unconventional gas in the U.S., document similar patterns of negative concerns, yet there has also been a positive association between perceptions of risks and opportunity, suggesting hydraulic fracturing may be a "double edged sword" for communities (Schafft et al., 2013; Ladd, 2013; Wynveen, 2011; Braiser et al., 2011; see also Chapter 5). Uneven distribution of benefits and risks, combined with environmental attitudes, can create polarizing views regarding energy development and lead to "corrosive communities" (Jacquet, 2014). Concern over this type of scenario was present in the public submissions:

> "[Hydraulic fracturing] has the potential to divide communities between those who support and those who oppose its use. In rural areas here we rely on relationships to live together this can be poisonous." (Submission 36)

Chapter 5 elaborates on these themes in greater detail; they will also be explored in forthcoming discussions with Aboriginal leaders. The economic context of the Province and the importance of externalities were discussed in the introduction to this report. Economic benefits (direct and indirect) and costs were presented in Chapter 3 based on four development scenarios. So economic impacts – the third most cited concern by those submitting evidence will only be described briefly here.

8.4.3 Economy

Since the 1970s, the sociological literature on oil and gas development indicates that industry may increase job prospects and cash flow, while simultaneously creating adverse impacts on community-level institutions and municipal services, increasing risks of pollution and contamination events, which can result in out-migration and loss of other types of development and investments (Jacquet, 2014). The hydraulic fracturing industry in the U.S. is following a similar pattern, creating concerns over the possibility of a boomtown scenario (Jacquet, 2014; Weber at al., 2014; Christopherson and Rightor, 2012), and submissions to our review indicated concerns about this:

> "I am convinced that the long-term risks and costs of this industry will outweigh the short-term economic benefits…It seems economic benefits are the sole reason our government is considering allowing this industry into our province…I worry that hydraulic fracturing would cause a boom bust industry cycle."(Submission 182)

U.S. studies on community perspectives of hydraulic fracturing often provided more balance on the issue, noting both the pros and cons, whereas submissions to the review were largely negative. A lack of positive attitudes might relate to differences in socio-economic opportunity, as studies have found U.S. citizens who hold land leases and collected royalty payments view local unconventional oil and gas energy development positively, while those who do not receive income perceive the industry negatively (Jacquet, 2014; Kriesky et al., 2013). Submissions often weighed the benefits and risks in their submissions and largely identified with the latter:

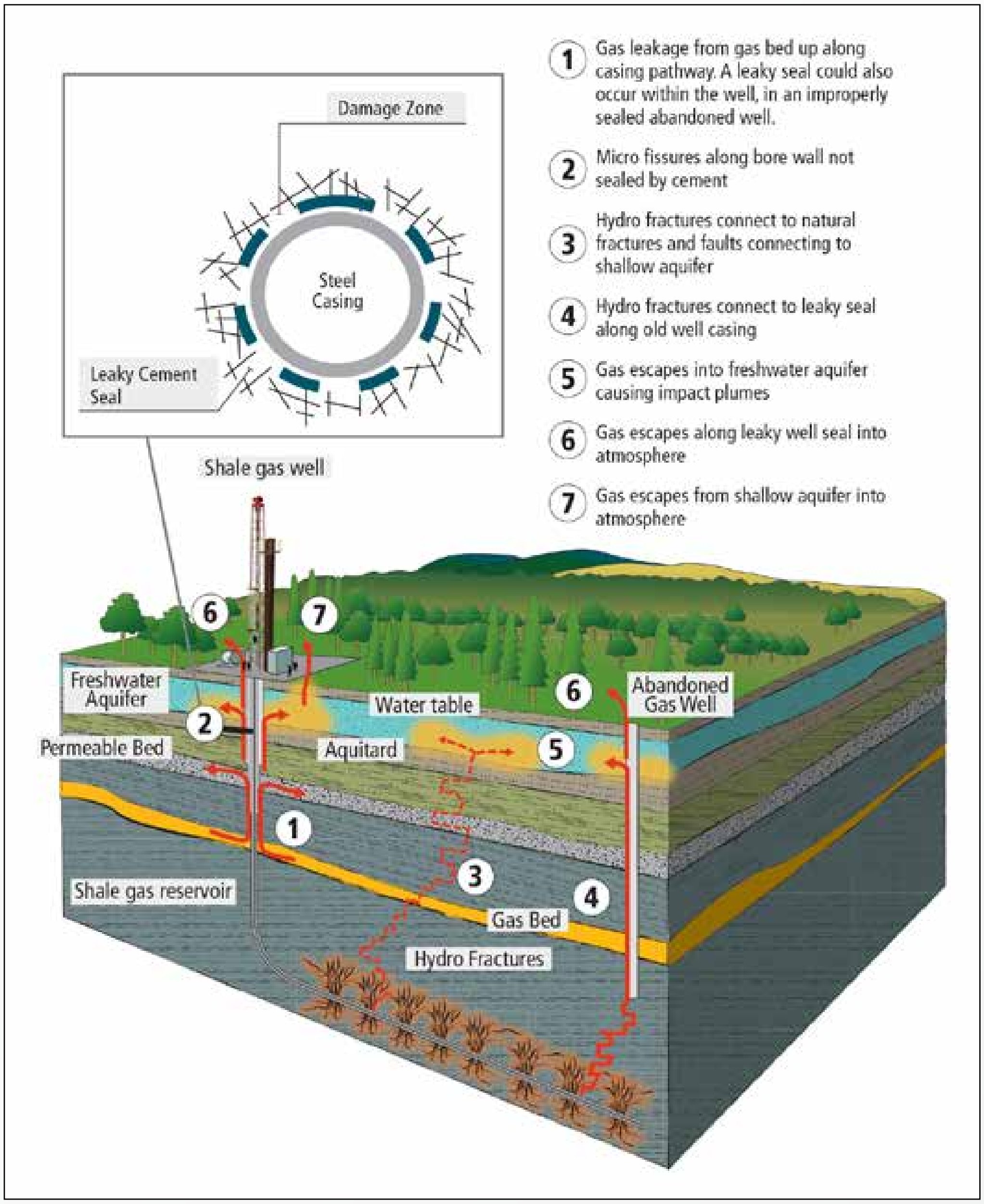
> "…Nova Scotians are speaking out and saying that economic benefits are not enough to outweigh the costs of creating a shale gas industry…" (Submission 143)

As Nova Scotia's provincial government claims ownership of hydrocarbons within the ground, royalty payments would not flow directly to individuals as they do in the U.S. (Cherry, 2014; Jacquet, 2014), and this difference, combined with concern regarding overhyped job creation and economic underperformance of the industry (Mauro et al., 2013; Kinnaman, 2011), may contribute to a lack of perceived local opportunities and hence greater perception of risk amongst the public. A paper on environmental concerns regarding hydraulic fracturing in Canada (Rivard et al., 2014) notes this tension between citizens and governments, "economic benefits for provincial jurisdictions no longer sway public opinion if there is a perception of environmental degradation should the industry be allowed to proceed."

The major economic concern in submissions was that hydraulic fracturing would adversely affect environmentally based industries – such as agriculture, tourism, forestry, and fishing – a possibility also discussed by the CCA (2014) who speculated that these conflicts would be particularly pronounced in Nova Scotia given a rural population higher than the national average. This fear figured prominently in our public meetings (see Introduction). Summing up the conflict between unconventional gas and these land-based industries, one submission said:

> "Fishing, forestry, agriculture, and tourism are the mainstays of the local community economy and none of those industries are compatible with developing a shale gas industry over the same landscape." (Submission 1)

Figure 8.2 Conceptual Water Contamination Pathways



Courtesy of G360 Centre for Applied Groundwater Research, University of Guelph

Conceptual Groundwater Contamination Pathways

There are several pathways by which potable groundwater could become contaminated by shale gas development, as shown in the schematic above. Note that this schematic is not to scale and does not imply that any of these pathways are necessarily present at any given site. The pathway marked by a dashed line is hypothetical as there is no known case of migration of hydraulic fracturing fluids from the deep shale zone to the groundwater level directly through the overburden rock.

Numerous citizens making submissions to our review worried that hydraulic fracturing's environmental impacts would threaten property values, especially in areas where industry was active. A representative from a regional economic development association captured this point:

> "If poor air quality and a lack of potable water quality drives away people and residents, one can only imagine what that will do to property values and resales. The municipalities will experience reduced valuations and property values." (Submission 68)

Hydraulic fracturing may indeed adversely affect property valuation and salability, given it makes land more difficult to plan, subdivide and use, and can create (actual or perceived) concerns over water quality that is "a key driver of property value," especially in rural areas (Lipscomb et al., 2012). In one U.S. study, many prospective buyers would not purchase homes close to hydraulic fracturing operations, and those that might would likely reduce their bids by 5-15 per cent in a robust real estate market, with losses increasing by another 10 per cent in weaker markets (Thourpe et al., 2013). Although no Canadian studies were found in the literature reviewed, the Canadian Association of Energy and Pipeline Landowner Associations has published a warning for property owners about prematurely entering contracts with industry over concerns with oil and gas development and associated home devaluation and waste and clean up costs (CAEPLA, 2010). This factor would be one of many that would need to be evaluated in any detailed assessment of economic costs in an area subject to development.

8.4.4 Waste and Clean up

Approximately one quarter to half of the water injected into a fracked well returns to the surface, known as "flowback," and it contains potentially hazardous materials from hydrocarbons (such as benzene and other aromatics), hydraulic fracturing fluids that may include toxics, and substances dissolved from the shale including salts, trace metals (e.g. arsenic and barium), and naturally occurring radioactive materials, or NORMs (CCA, 2014). Given the complexity of dealing with these waste streams, industry has found ways to recycle the flowback waters to refracture wells, yet a proportion of this remains at the surface and is sometimes stored in containment ponds or treated if the proper facilities exist regionally. In Nova Scotia, the issue of waste and clean up of flowback waters have been particularly sensitive topics, as outlined by the CCA (2014):

> In Nova Scotia, managing the flowback water from the two hydraulically fractured wells near Kennetcook has emerged as a major issue. The flowback volume was unexpectedly high… and the Province did not have regulations in place concerning options for its disposal or treatment. About 14 million litres of flowback water was produced, most of which was saline water from an intersected permeable fault zone; NORM were also detected in the open, lined storage pits. (Council of Canadian Academies, 2014).

Nova Scotians' submissions to the review referred to the issues taking place at Kennetcook. From concerned citizens across the Province, to locals directly witnessing the impacts of this exploratory hydraulic fracturing, many expressed frustration and dismay:

> "I also live five km from one of the waste ponds, left behind by a fracked test well. After 6 years that pond is still there, waiting for remediation. During this winter that waste pond overflowed into a local stream and that made its way into the Minas Basin. Our communities have watched as our regulators have failed to act on our behalf. They are scrambling to find a solution for millions of liters of waste water left behind from two fracked test wells. If hydraulic fracturing is allowed in Nova Scotia, the same company who has not found an acceptable solution for water from two fracks, would seek to develop hundreds of well sites. How? And if the province can not deal with two test wells, how can it ever regulate an entire industry?" (Submission 70)

Similar points were made very powerfully in our public meeting in Kennetcook/Noel. Flowback waters are often stored in lined containment ponds, but even when double lined, can be expected to leak over time, or can overflow due to precipitation events such as intense rainfall (CCA 2014). Based on access to information requests, No Frac (2013) prepared the Out of Control report about the situation in Kennetcook, which indicates that the containment ponds were originally designed to hold fresh water for hydraulic fracturing and Nova Scotia Environment (NSE) granted permission for storage of flowback waters after the fact. These containment ponds were first known to leak in 2011 (No Frac, 2013) and then again in early 2014, after heavy rain and snow weighed down containment pond covers, causing the wastewater to spill out from underneath (CBC, 2014a+b). A U.S. study suggests application of these flowback waters to the land may adversely affect soil chemistry by increasing sodium, chloride, and acidity causing damage and/or mortality to ground vegetation, although more research is required on this issue (Adams, 2011).

Prior to the containment pond leaks, NSE was trying to determine how to best deal with the flowback waters, and some of this effluent was ultimately shipped to the Town of Windsor to be processed by the local water treatment plant. In a submission from The Town of Windsor, there were concerns expressed regarding how and why this happened:

> "Between March 2010 and August 2011, the Town of Windsor processed approximately seven million litres of fracking wastewater through the Windsor Sewage Treatment Plant. At no time had the Town been advised of NORMs or any concerns with fracking water until the news broke in late 2011 that indeed radioactivity or other unmentioned chemicals may be prevalent in the water…All along, we were under the impression that Nova Scotia Environment were monitoring the fracking waters and entire process…[The Nova Scotia] Government needs to address how this byproduct should be disposed of safely through sewage-treatment plants before one can even address the issue of fracking itself!" (Submission 7)

Municipal treatment plants are not designed to treat flowback waters, as the salinity adversely affects microbial activity that breakdown normal waste and because NORMs and other inorganic contaminants would typically flow right through the treatment plant into the municipal water system and/or the environment (CCA, 2014).

Desalination processes and other advanced methods are being developed to treat flowback waters (Shaffer et al., 2013) and are now being considered by the Nova Scotia Government to deal with the approximately 25 million litres of remaining hydraulic fracturing waste water in the Province (CBC, 2014c). The high costs and uncertain efficacy of these approaches make them less desirable to industry than deep-well disposal, where the waste is permanently injected into the ground, a process that may not be feasible in Nova Scotia based on unsuitable geology (CCA, 2014). However, NSE has repeatedly refused to allow deep well injection of these flowback waters, arguing that they need to be processed at an approved facility, which is a decision lauded by environmental groups. The CCA (2014) corroborates the significant challenges and costs associated with handling, treating, and cleaning up of hydraulic fracturing flowback waters, which can also lead to conflict and confusion as the Nova Scotia example indicates:

> "The operator and the [Nova Scotia] government have been unable to agree on how to dispose of the flowback water...this stalemate has become a symbol of the difficulties of wastewater disposal associated with shale gas development in Eastern Canada." (Council of Canadian Academies, 2014).

According to one of the few papers in the literature on well site reclamation, "improperly abandoned gas wells threaten human health and safety, as well as pollute the air and water," and more advanced regulatory options (e.g. cash bond, predrilling fee, severance tax) are advocated to ensure industry adequately pays for the proper closure and cleanup (Mitchell and Casman, 2011).

8.4.5 Human Health

Issues of risk to public health were described in Chapter 4. Nova Scotians interacting with the review were most concerned about air quality, given the contaminants generated by hydraulic fracturing, increased truck traffic, creation of ground level ozone, and the impacts this would have on human health, both physical and mental. Comments were often very holistic in nature, as outlined by this medical doctor:

> "The health impact of increased air pollution, noise pollution, increased road traffic, loss of peaceful country vistas can not easily be measured. That does not mean it is not important and does not exist. Impact on the mental health of residents affected by fracking must also be considered. Fracking disproportionately affects rural residents, who in general have lower incomes and less mobility, and less of a voice. For these reasons I cannot support hydraulic fracturing in Nova Scotia." (Submission 78)

Although air emissions from hydraulic fracturing are derived from similar sources as conventional gas, unconventional gas and oil development requires additional effort and emissions are more intensely produced, given longer drilling times, more truck traffic, stronger pumps, and larger holding ponds (CCA, 2014). Nitrogen oxides (NOx), Sulphur Oxides (SOx), Volatile organic compounds (VOC), particular matter (PM), and air toxics will enter the air during well development and gas production, although it's difficult to calculate exact emissions due to poor data quality (Figure 8.3).

Figure 8.3 Intensity of air emission sources from hydraulic fracturing during the well development and gas production stages, based on U.S. data

Source	NOx	VOC	PM	Air Toxics	Data Quality
Well development					
Drill Rigs	●	○	●	●	Medium
Frac Pumps	●	○	●	●	Medium
Truck Traffic	●	○	●	●	Medium
Completion Venting		●		●	Poor
Frac ponds		○		?	Poor
Gas Production					
Compressor Stations	●	○	○	●	Medium
Wellhead compressors	○	○	○	○	Medium
Heaters and dehydrators		○	○	○	Medium
Blowdown venting		●		●	Poor
Condensate Tanks		●		○	Poor
Fugitives		●		○	Poor
Pneumatics		○		○	Poor

● = major source ○ = minor source

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When combined, NOx, VOCs, and carbon monoxide can contribute to ground-level ozone that can cause respiratory health issues and certain VOCs have been found in much higher concentrations than Health Canada recommendations during the completion phase of hydraulic fracturing (CCA, 2014). Citing health surveys conducted in Texas, (Wilson, Subra & Sumi,2013) notes that the most commonly reported health issues associated with unconventional gas included, "sinus problems, throat irritation, allergies, fatigue, eye and nasal irritation, joint pain, muscle aches and pains, difficulty breathing, and vision impairment." Air pollutants associated with unconventional gas may also contribute to small increases in the risk of cancer and other diseases for those living in close proximity to wells, largely due to cumulative and long-term ambient exposure to chemicals like benzene (McKenzie, Witter, Newman & Adgate, 2012). The potentially cumulative and long-term impacts of hydraulic fracturing were a consistent theme across many submissions, with health concerns particularly expressed from those living in regions with prospective hydraulic fracturing development:

> "As a community member, home-owner, and parent living on the North Shore of Nova Scotia, I see hydraulic fracturing as a direct threat to public health and the future well-being of my family and my community. Health concerns go beyond dangerous toxins in our water and air to the unknown compounded health effects of this unprecedented combination and magnitude of extraction technologies. (Submission 164)

The externalities associated with air emissions are not well known, however, data are becoming available. One study from Pennsylvania (Litovitz et al., 2013) estimates that environmental and health damages for a single year of hydraulic fracturing across the region range from $7.2 to $32 million (USD). While a significant impact – financially and biophysically – this is less than similar estimates for coal in the same area (Litovitz et al., 2013). Although localized emissions from natural gas increase near production areas, ambient ozone and particulate matter are reduced for communities upwind of electric power generation because overall emissions decrease (Allen, 2014). Understanding emissions from hydraulic fracturing is a key issue, especially as it relates to climate change and its long-term consequences.

8.4.6 Climate Change

Production and consumption of unconventional gas increase carbon dioxide and methane that contribute to climate change. After a well has been initially fractured, the "flowback" stage occurs with residual water and natural gas and carbon dioxide coming back to the surface, and how these emissions are handled is central to the greenhouse gas (GHG) emissions debate. Natural gas produces less CO_2 than coal per unit of energy produced, given the efficiencies of single and combined cycle gas turbine power and, compared to coal fired power plants on an energy equivalency basis, can reduce emissions by 48 per cent to 70 per cent depending on technologies used (CCA, 2014). However, methane leakage across the entire supply chain (e.g. production, transport, and storage) of natural gas – known as "fugitive emissions" – can reduce the greenhouse gas benefits of lower emissions at the consumption stage (Allen, 2014). This is of particular concern, because methane is a more potent greenhouse gas (GHG) than CO_2, especially over short time frames: approximately 84 times more potent at the 20 year timescale compared to 28 times over a 100 year period (IPCC, 2014). The heat-trapping potential of methane was raised in submissions to the review:

> "…methane which is released in the process of fracking, is a much more potent greenhouse gas, in the short-term, than is carbon dioxide. It will accelerate, not reduce, the effects of climate change we are beginning to see in our world." (Submission 94)

There is no debate that methane is a powerful GHG and given the urgency to address climate change some scientists model its impact using the more aggressive 20-year value (CCA, 2014). The most high profile – and controversial – research using these modeling assumptions is by Howarth et al. (2011) and Howarth (2014) and states the GHG footprint of both unconventional and conventional natural gas are higher than coal and oil. Fugitive emissions and their impact on GHG continues to be debated – with studies advocating both for and against natural gas from a climate perspective (CCA, 2014) – and there is an increasing acknowledgement that methane leakage is poorly understood and largely underestimated in both the U.S. and Canada (Brandt et al., 2014). The international scientific community studying climate change now questions the benefit of switching fully to natural gas, but acknowledges it may play a role in transitioning away from coal when fugitive emissions can be kept low and when combined with renewables (IPCC, 2014). Despite this, many submissions indicated that the overall risks outweighed benefits and many people wanted to see the government pursue an energy plan based more on renewables:

> "If we take strong and proactive steps now, by rejecting [fracking], we can look forward to a new energy future based on renewable hydro, wind, and even tidal power, while avoiding the crushing defeat of communities…" (Submission 17)

One recent study suggests that unconventional gas and oil development can lead to lower energy prices, higher overall consumption of energy, and may displace the use and investment in renewables citing U.S. examples where wind projects had trouble competing against natural gas plants despite incentives for the wind turbine industry (Newell and Raimi, 2014). Given these factors, the researchers found that the net climate impacts of unconventional gas could be either positive or negative depending on the situation, and that strict climate policy and regulations on fugitive emissions are critical if benefits are to be realized (Newell and Raimi, 2014). To achieve a net benefit, natural gas would have to displace more coal and petroleum than nuclear, hydro, and renewables known for their low GHG emissions (Newell and Raimi, 2014). In the U.S., wells were initially vented, sending methane and other air emissions directly into the atmosphere, but flaring has become a transition practice to burn off pollutants at source, with regulations taking effect in 2015 so that wells have "green completions" in place that will capture gas and other chemicals before commercial production begins (O'Sullivan and Palsev, 2012). In the Canadian context, Alberta and British Columbia largely prohibit venting and also have flaring reduction targets (CCA, 2014), although the quality of reporting and regulation of these processes has been questioned, with suggestion that the "transition fuel" description used in BC is a ruse for carbon-intensive natural gas development (Stephenson et al., 2012). Many submissions simply did not accept that unconventional gas was part of the solution to climate change:

> "Climate change is the greatest threat to our generation and future generations. Every country in the world has agreed to a 2 degree limit of warming. In order to meet this target, we need to leave 80 per cent of the proven fossil fuel reserves in the ground. Allowing fracking in the province of Nova Scotia will accelerate us towards climate chaos." (Submission 82)

According to the Copenhagen Accord, global temperatures must not surpass two degrees Celsius in order to avert climate destabilization; thus society has five times more oil, coal, and gas than can be used if we are to meet this target (Berners-Lee and Clark, 2013). Rapid efforts to decarbonize human society are required to avoid serious impacts on human and natural systems, with low-carbon energy needing to nearly quadruple by 2050, relative to 2010, in order to stabilize the global climate (IPCC, 2014). At the present time, it is unclear how the province of Nova Scotia plans to further reduce its reliance on coal for electricity generation and oil for home heating.

8.4.7 Environment

Many submissions comment on environmental issues associated with hydraulic fracturing, as well as concerns of the potential for earthquakes (aka seismicity), habitat fragmentation and impacts on agricultural lands and livestock. According to the CCA (2014), hydraulic fracturing may cause an unintended earthquake through the injection of liquids into wells under pressure, that triggers (or induces) a seismic event related to pre-existing geological conditions (e.g., fault), or inducing a new fracture that destabilizes a formation. While earthquakes as a result of hydraulic fracturing have been documented in the U.S., UK and Canada, they are usually too small to cause property damage, although some have been felt at the surface and this has heightened public concern (CCA, 2014; Sumy et al., 2014). In some jurisdictions, industry has settled with homeowners claiming that hydraulic fracturing induced earthquakes damaging their properties (Trotman, 2013), and some are concerned "man made" earthquakes caused by hydraulic fracturing would not be covered by conventional insurance (Roach, 2014). Citizens and environmental groups commented on earthquake potential, citing the possibility of deep wastewater disposal from the Kennetcook site, one submission stated:

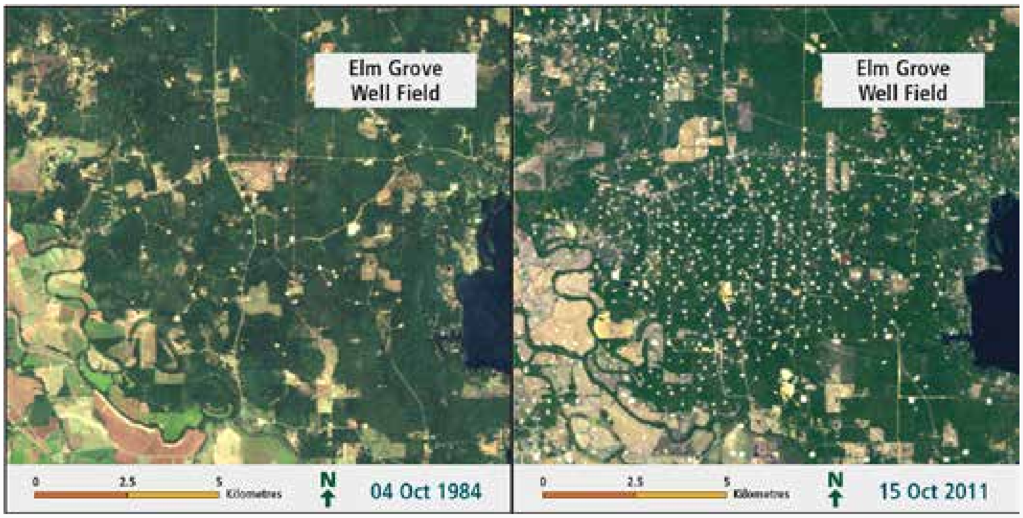
> "Our group commended the previous Minister of Environment for his strong stance on not allowing wastewater to be injected into wells. The association of disposal wells with earthquakes has been recognized and has recently been expanded to include concern about the process of fracking actually triggering earthquakes." (Submission 194)

While the overall earthquake potential from hydraulic fracturing is considered to be small _– especially in areas considered tectonically stable like the east coast (Rast, 1979) – the long-term consequences of multiple deep waste water disposal wells in a region is not well understood and there may be a delayed reaction associated with these activities (CCA, 2014; Ellsworth, 2013). Research demonstrates that of all activities related to hydraulic fracturing wastewater disposal via well fluid injection has the greatest risk for seismicity "with maximum magnitudes sometimes exceeding five" (McGarr, 2014). Since little is known about why earthquakes occur in Eastern Canada (NRCan, 2013), questions remain about the safety of wastewater disposal, and quoting the CCA (2014) at length here is useful:

> "...whether wastewater injection can be safely carried out in all regions of Canada – specifically, Quebec, New Brunswick, and Nova Scotia – is unknown. More information on the potential for geological formations in these provinces to receive large volumes of injected fluids without over-pressurizing reservoirs is needed to determine whether this waste disposal option is possible." (Council of Canadian Academies 2014).

Given that hydraulic fracturing infrastructure takes up considerable physical space (3 ha/well pad), combined with the fact that wells are productive for a relatively short time and new ones are often added to keep production stable (Hughes, 2013), industry can have significant impacts on land and associated habitat fragmentation (CCA, 2014). While technology is allowing for more wells per wellpad – decreasing the footprint of industrial activities – satellite imagery from established unconventional gas plays in the U.S. demonstrate how lands have significantly changed over time in intensive developments (Figure 8.4). Further surface disturbances are caused by road and pipelines linked to wellpads that extend into the surrounding landscape (Mitchell and Casman, 2011).

Figure 8.4 Satellite images showing an increase in well density and associated habitat fragmentation due to unconventional gas development between 1984 and 2011 in Louisiana



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Intrusive impacts to the landscape were of concern to some people making submission to the review:

> "Seeing the fracturing process underway from an aerial view shows the devastation to the landscape. Wildlife are already being pushed farther away due to habitat destruction caused by human encroachment. This is producing pockets of wilderness areas which separates groups of animals from each other and thereby weakens the species. The fracturing equipment dots the landscape like a cancer and spreads its deadly pollution into the waterways and air." (Submission 10)

Research from the Eastern U.S. demonstrates that intensive hydraulic fracturing poses "many threats to biodiversity" – including extirpation or extinction - especially for species with restricted geographic ranges that overlap with industrial activities largely due to degradation of water quality and fragmentation of forests (Gillen and Kiviat, 2012). This has special significance for Aboriginal Rights, Treaty Rights and Title perspectives (see Chapter 10).

Top soil and proper re-vegetation is required to reclaim old well sites, otherwise forest fragmentation and loss of biodiversity will be exacerbated, specifically for migratory birds and other animal species requiring canopy protection (e.g. shade and humidity) within a deep forest environment (Mitchell and Casman, 2011). In Nova Scotia, habitat fragmentation has led to the mainland moose, American marten, and the Canada lynx being listed as endangered, and concern exists that, these along with other endangered species, might further be pressured by hydraulic fracturing (EAC, 2014). Mitigating energy development impacts on wildlife requires species-specific studies, with a focus on reducing human activity, creating and maintaining refuge habitat, and modifying the timing of industrial activities to account for ecologically sensitive periods (Northrup and Wittemyer, 2013). In Nova Scotia, biodiversity considerations have been mapped across the Province, indicating that approximately 60 per cent of the region should be actively managed to conserve "genes, species and ecosystems over time" (Beazley et al., 2005). More recent spatial analysis, adapted for both Canada and the U.S., can quickly and effectively map how hydraulic fracturing activities fragment both forested and agricultural lands (Raciot et al., 2014). These considerations are particularly important given some regions of Nova Scotia contain old growth Acadian forest (Stewart et al 2003), and significant changes are expected to the forestry sector due to climate change that require adaptive management (Steenberg et al., 2013; Steenberg et al., 2011; Bourque and Hassan, 2008). Citing similar issues presented in this report, a woodlot association made a submission to the review:

> "Members of our Association have expressed significant concerns with the development of hydraulic fracturing in Nova Scotia and its potential for negative impact to their homes and forest land…the risks of hydraulic fracturing highlighted above lead our Association to recommend that this practice not take place in Nova Scotia." (Submission 218)Submissions also expressed concern over the impact that hydraulic fracturing may have on agricultural lands, like this one from a veterinarian and farmer:

> "Because there are so many important reasons to preserve agricultural land, we feel that it is vital at this time to make a case for farmland…all the negative impacts that hydraulic fracturing can have on rural communities and how it could create excessive fragmentation of our agricultural land base." (Submission 23)In areas with hydraulic fracturing, farmers are often concerned about pollution and its impacts on humans, animals, and soil, and in some regions, agriculturalists compete with industry for land and water resources (Russell, 2013). Researchers have documented mortalities and reproductive difficulties (e.g. irregular cycles, stillbirths, failure to breed) in a variety of livestock and companion animals in close proximity to hydraulic fracturing across six U.S. states, usually linked to surface spillage of flowback waters and other chemicals. One situation caused the death of 17 cows in a single hour from accidental but direct exposure to hydraulic fracturing fluids (Bamberger and Oswald, 2012). As noted by the CCA (2014), veterinary literature can "serve as a sentinel for human health," given similar exposure pathways. Citing concerns, one regional agricultural association made a submission indicating they had passed a motion calling for a 10-year moratorium on hydraulic fracturing because of potential for adverse impacts on water quality and supplies; safe disposal of waste waters; concern over devaluation of rural property; destruction of habitat; and ordered for a full review on hydraulic fracturing to be completed. Indeed, farmers in Nova Scotia making submissions to our review saw hydraulic fracturing and farming as incompatible, and one who had recently moved to the Province indicated that her family would have no choice but to leave if unconventional gas was developed:

> "My husband and I moved to the Upper Stewiacke area in Nova Scotia…We left our well established professional careers to come to this area to pursue our dream of farming…If [fracking] happens, sadly I will have to shut my farm operations down, sell my home and

land, and leave. I will not stay around to witness the imminent destruction. I refuse to stay and be poisoned." (Submission 93)

While some farmers may never accept hydraulic fracturing and decide to leave the region, research suggests that those remaining normalize adverse impacts given their economic vulnerability and limited ability to influence industrial activities near their farms (Malin, 2014). This documented lack of ability to shape how hydraulic fracturing unfolds in communities, speaks to the need to consider social justice and its linkages with environmental degradation for indigenous and non-indigenous peoples alike (Willow, 2014). The land-based, inter-generational, and often sacred connections that many indigenous peoples have with their environment has led some communities to assert their indigenous rights and resist hydraulic fracturing claiming lack of proper consultation (Ornelas, 2014). Indeed, it is important for the public to have effective input in decision-making regarding emerging technologies and development within their region. This is the rationale for taking a participatory risk assessment approach to this report and it is why in our recommendations we advocate a precautionary approach and a community right to decide.

8.5 | **Risk, Responsibility and Renewal**

Unconventional gas and oil development is controversial – given significant regulatory and scientific uncertainty – yet available research indicates that hydraulic fracturing presents credible threats to human and environmental systems with real and immediate impacts for local communities and longer-term consequences for climate stability and future generations. Indeed, unconventional gas and oil development, within this context, presents a complex or "wicked" problems for citizens and decision-makers, which is difficult to solve using traditional approaches to science and governance. Indeed, technological innovation can produce environmental risks that are difficult to predict, regulate and manage, and a broader and more democratic and citizen-based approach to risk decision-making is required (Beck, 1992; Beck, 1995). Combining the "two cultures" of risk analysis – linking science-based assessments with broader psychological, sociological, cultural and economic factors (Jasonoff, 1993) – this chapter integrates submissions to our review with research studies in order to create dialogue between citizens, science and the larger issue of the environmental impacts of hydraulic fracturing in Nova Scotia. This important theme is further developed in Chapter 11.

A critical finding is that 215 citizens interacting with the review were well informed and many of their socio-environmental concerns are substantiated by the available literature. Research on "perceptions of risk" – across a diversity of emerging technologies that are similar to unconventional gas (Pidgeon et al., 2006) - demonstrate that the public is rational and influenced by a diversity of factors including emotion, worldviews and trust (Slovic, 1999). While early risk research assumed scientific knowledge was superior to that of the public (Zinn and Taylor-Gooby, 2006), it is increasingly clear that citizens are highly capable of estimating hazard potential and the assumption that experts have superior risk judgment is now questioned (Wright et al., 2002). Dismissal of the public, assuming they are "uneducated" and need to “get the facts” regarding hydraulic fracturing, has been documented as a form of stakeholder silencing used by industry advocates to generate a pro-development discourse (Hudgins and Poole, 2014). As noted by the CCA (2014), holistic approaches to risk assessment are needed, as the history of science and technology regarding major energy developments demonstrates that environmental impacts were largely not anticipated, especially by those expecting benefits:

> “What is perhaps more alarming is that where substantial adverse impacts were anticipated, these concerns were dismissed or ignored by those who embraced the expected positive benefits of the economic activities that produced those impacts.” (Council of Canadian Academies 2014)

While the 215 individual submissions and 23 submissions from organizations and groups are not necessarily representative of Nova Scotians generally, they provided detailed accounts of the types of concerns that exist amongst the public and demonstrate that many citizens are engaged in this issue and want to play an active role in decision-making. Increasing public and stakeholder participation regarding unconventional gas and oil development is advocated as a way to manage and reduce risks (North et al., 2014) and is an approach that will benefit Nova Scotia in its ongoing deliberations on this issue. This is a central part of our recommendations (see Chapter 11).

That 92 per cent of submissions support maintaining a moratorium or ban on unconventional gas – largely due to concerns over environmental impacts and their broader implications – speaks to the need for government to further consult with the public. A 2013 poll of 1,300 Nova Scotians found 69 per cent support for a moratorium or ban until risks can be mitigated (Colley, 2013). Even with stringent government regulations, a slight majority (53 per cent) of Nova Scotians still oppose the development of hydraulic fracturing in the Province, with 39 per cent supportive, and another 8 per cent largely undecided (Corporate Research Associates, 2013). These data, combined with submissions to the review, indicate that many Nova Scotians are not currently persuaded by potential economic opportunities from unconventional gas in the face of perceived and documented environmental risks. This finding is supported by representations quoted in the recently released Now or Never report – based on various public outreach and data collection approaches – regarding the Nova Scotia economy that states:

> “There is general consensus of the importance of using Nova Scotia’s natural resources to generate wealth in the Province, although the protection of the environment trumps job creation in the development of such resources. It is also clear that there is a significant segment of the population that believes some natural resources, such as shale gas, cannot be developed in an environmentally safe manner regardless of how strict the regulations” (The Nova Scotia Commission on Building our New Economy, 2014)

Many submissions to the review expressed concern about the lack of scientific evidence to prove the safety of hydraulic fracturing and advocated a "precautionary approach." Given a lack of peer-reviewed data on both social and environmental issues – combined with an absence of baseline information to assess and monitor if hydraulic fracturing is having negative, long-term and cumulative effects – the recently released Council of Canadian Academies expert panel report on hydraulic fracturing also highlighted the advantages of a "go slow" approach to ensure a holistic and rigorous evaluation of unconventional gas and oil development (CCA, 2014). In other jurisdictions, unconventional gas controversies were exacerbated because the speed and scale of development did not provide enough time for a thorough consideration of unforeseen impacts (North et al., 2014). Cumulative impacts – across human and ecological systems – are often difficult to assess and perhaps even harder to regulate, thus, increasing complexity and unpredictability in ways that undermine communities, environments, and associated governance (Jacquet, 2014; Malin, 2014). Given the known and potential environmental impacts associated with hydraulic fracturing across different time scales – as outlined by both citizens and the literature – a precautionary approach in Nova Scotia is essential. This will not only increase public trust in the process, it will ensure that much needed time to better assess environmental risks, their interconnections with society, and an appropriate response moving forward.

More regionally specific data are required to better assess the long-term environmental consequences of hydraulic fracturing and this forms a key recommendation of our review (see Chapter 11). To date, as referenced in this paper, the majority of peer-reviewed literature available on hydraulic fracturing is U.S.-based, and more Canadian and Nova Scotia focused studies and associated data is essential. Groundwater contamination from hydraulic fracturing is a major concern amongst the public and risks through upward migration of natural gas, leaky well casings, and abandoned wells are possibilities associated with this industry, and additional information on this as well as the impacts of flowback waters on human health and the environment is required (CCA, 2014). Given that unconventional gas development in Nova Scotia would largely take place in populated rural and semi-rural areas (CCA, 2014), a better appreciation of the potential impacts and monitoring of private wells and potable water are needed to mitigate adverse effects (see Chapter 6 and Chapter 11). Given concerns that hydraulic fracturing may compete with water use at seasonally specific peak demand times, consideration must be given to how regulations would be designed to account for this, and the potential for drought conditions that are anticipated with climate change (IPCC, 2014) and already beginning to affect Nova Scotia with water shortages and adverse impacts on farming (e.g. Delany, 2012). See also Chapters 6 and 11.

If it was ever pursued in Nova Scotia, the unconventional gas industry would likely have a significant impact on community and infrastructure, as hydraulic fracturing produces contaminants, excessive noise, heavy truck traffic, and the potential for a "boom-bust" economic scenario (see Chapter 5). With many costs often externalized – e.g. road maintenance, environmental cleanup, groundwater contamination, human health – uncertainties regarding net benefits for local and regional economies remain and "far more research is required" to determine the balance of risks and benefits (Barth, 2013). See also Introduction and Chapter 3. This research must consider the unique nature of externalities associated with unconventional natural gas, which are often "non-point source" in nature, and hence difficult to identify, predict, control and account for within the economic system. This makes it difficult to establish cause-and-effect linkages, undermining the ability to establish responsibility and potential liability for adverse environmental impacts caused by industry. Therefore the unique nature of externalities associated with hydraulic fracturing need to be considered in regulatory frameworks that are responsive and precautionary (Holahan and Arnold, 2013). Determining what impact hydraulic fracturing might have on other competing land-based industries - such as forestry, agriculture and tourism - must be considered in advance to ensure sustainable development across the entire natural resource-based economy. Studies on the potential habitat fragmentation caused by hydraulic fracturing in Nova Scotia must be coordinated and carried out, to determine the net impact of this industry on biodiversity in both natural and managed ecosystem. Examples of these approaches and their importance are becoming available (e.g. Raciot et al., 2014). (See Chapters 5 and 11.)

While transitioning from coal to natural gas may have benefits from a climate change perspective, available literature suggests this is highly dependent on the efficacy of regulations and monitoring, given possible fugitive methane emissions and increased use of abundant natural gas supplies. Furthermore, since cheaper natural gas is known to displace investment in and use of renewable energy, a strict regulatory framework would be needed to ensure that hydraulic fracturing does not undermine the Province's ambitions in wind and tidal energy that are crucial to its hopes for an emerging green economy. A detailed life cycle assessment of the potential positive and negative climate change impacts of developing an unconventional gas and oil industry would be needed in Nova Scotia in order to properly assess the uncertainties that currently exist with respect to the control of fugitive emissions. Carefully traversing this natural gas "bridge" - with high quality data and carefully designed regulations - is an absolute must and the Environmental Goals and Sustainable Prosperity Act (EGSPA) is an important tool in this regard.

Speaking about climate change to the media (CBC, 2014d), Christine Lagarde, the Managing Director of the International Monetary Fund, advocated a full cost accounting of energy projects:

> "…externalities such as wastage of water, congestions on the roads, additional risks to mortality and so on, need to be included in the thinking process that applies to policies encouraging the use of one or another form of energy." (Christine Lagarde, Managing Director, IMF)

Climate change is a real and present danger for Atlantic Canadians already affecting their culture, livelihoods, community infrastructure, and economies (Mauro, 2013). A new study suggests research and policy are massively underestimating the financial costs to society of inaction on mitigation of greenhouse gases (Dietz and Stern, 2014). Indeed, continued public commitments to the fossil fuel industry may be a "failing strategy," given that climate change will force society to curtail GHG emissions, and some academics are now encouraging citizens and their governments to begin shifting investments away from fossil fuel industries in order to protect the environment and long-term civic well-being (Arbuthnott and Dolter, 2013).

Prior to any potential commercial development of hydraulic fracturing, pathways and technologies for wastewater treatment and well pad clean up must be determined in consultation with all relevant stakeholders, and research is increasingly available on these topics (e.g. Shaffer et al., 2013, Mitchell and Casman, 2011). The experience at Kennetcook demonstrates the political and ecological consequences of not having a well-developed plan in place and these issues must be promptly resolved given that leaking and improperly disposed of hydraulic fracturing sites are known to adversely affect human and environmental health (Mitchell and Casman, 2011). Furthermore, negative experiences with resource development amplify public risk perception of unconventional gas (Braiser et al., 2011) and increase awareness of negative environmental impacts (Willits et al. 2013) that will make it difficult to pursue commercial-scale hydraulic fracturing in Nova Scotia without first dealing with the issues created by exploratory drilling at Kennetcook. Efforts to increase public confidence in governance and industry specifically as it relates to waste water treatment and site clean up are crucial. See Chapter 11 for further discussion of these points and relevant recommendations.

Many submissions were generally critical of industry and its track record, a point also made in Now or Never:

> "The reputation of most companies in Nova Scotia in terms of operating in an environmentally responsible manner is perhaps underwhelming, demonstrating an area of opportunity. If the general public had a more positive opinion of the environmental practices of private business, there would be less resistance to the development of natural resources."

(The Nova Scotia Commission on Building our New Economy, 2014)Trust in industry, combined with increasing local benefit, are key variables influencing overall environmental risk perception of unconventional gas. In many submissions, people believed that potential opportunities were simply overstated, and that costs for communities were substantial, specifically impacts on human health and infrastructure like roads and bridges, and other municipal services. Having a clear plan in place for distribution of financial benefits, ensuring that both individuals and municipalities receive much-needed funds from development of their natural resources is essential (see Chapter 11 recommendations). As Jacquet (2014) points out, some communities may benefit from unconventional gas development, while others may not, and determining the factors that create successful development of natural resources while ameliorating risks is needed. That some U.S. communities have experienced both benefits and risks from unconventional gas development – seeing it as a "double edged sword" – speaks to the possibility of harnessing opportunities especially if externalities can be properly accounted for and risks effectively mitigated. At present, there is an open debate in the scientific literature about the manageability of environmental risks and externalities associated with unconventional gas, and that is the knowledge gap Nova Scotians need to be aware of and their governments need to work on prior to commercial development of this industry. While tens of thousands of hydraulic fracturing wells exist in North America, very little data exist on their environmental impacts due to a lack of testing and monitoring as noted by the CCA (2014):

> "Despite a number of accidents and incidents, the extent and significance of environmental damage is difficult to evaluate because the necessary research and monitoring have not been done. Data are lacking for characterizing and assessing the environmental impacts of shale gas development adequately, particularly in relation to groundwater contamination and fugitive methane emissions. There are no vulnerability identification and management systems in place to identify those areas in Canada where hydraulic fracturing will be so risky that it should not be undertaken." (Council of Canadian Academies, 2014)

As this chapter demonstrates, having citizens and communities involved in the risk assessment and decision-making process regarding unconventional gas is an important first step co-generating interdisciplinary knowledge that may help to unlock and mitigate potential problems before they occur, while increasing trust amongst stakeholders. New approaches in the social sciences may help create awareness and understanding of hydraulic fracturing and its impacts on socio-ecological issues and should be utilized (Willow and Wylie, 2014). See also Chapter 11. As noted in Now or Never, reducing conflicts over extractive industries will only be achieved through public input, enhanced regulations, and when necessary the courage of citizens and their governments to decide against certain natural resource development opportunities if the balance between benefits and risks cannot be achieved:

> "The opposition to uranium mining and fracking as extractive resources comes from a genuine concern for the environmental impacts of such industries, as well as a desire to explore alternatives to such extraction for our energy needs. Yet, we see other jurisdictions financially benefiting from such industries and governments are receiving much needed revenues to contribute to public infrastructure, health care, transportation, and education. Nova Scotia must find a way forward in these conflicts. There are a variety of mechanisms to decrease conflict and ensure community benefit. In some cases, it may mean that we do not develop some resources where in other cases it may mean that we have enhanced regulatory frameworks that ensure community input and environmental protection." (The Nova Scotia Commission on Building our New Economy, 2014)

ENDNOTES

1. "Wicked problems" are part of the social planning literature, first mentioned in the late 1960s, andused to characterize multidimensional issues where there is incomplete or contradictory knowledge, a diversity of opinions involved, interconnections with other complex problems, and significant economic considerations at stake. This makes wicked problems difficult to resolve and requires interdisciplinary approaches, respect for differing perspectives, active inclusion of stakeholders that are directly affected, and recognition that while it may be possible to improve a situation it is rare to find a true solution. Energy is seen as a wicked problem with complex interrelationships with social, economic and environmental factors and "no easy answers" for its intersection with sustainability (Coye and Simmons, 2014). Indeed, "super wicked problems" have been used to characterize climate change because of the urgency of the issue, existence of irrational policies that discount the future, lack of effective and adequate decision-making, and irony that people causing the problem must also find the solution (Levin et al., 2012). Scientists and decision-makers are increasingly using the wicked problems framework to better assess the integrated and multidimensional nature of environmental risks, including the US Environmental Protection Agency regarding the challenges associated with air quality management (Stahl and Cimorelli, 2012).
2. The number of truck trips will vary by well, depending on how many wells have been fractured, what techniques are being used, and increasingly operators are also electing to use temporary water pipelines to reduce traffic and impacts on roads.

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CHAPTER

9

Regulatory Issues

Constance MacIntosh

9.0 | **Chapter Summary**

Building on a number of observations in preceding chapters on the importance of effective regulation of the hydraulic fracturing industry, should it ever proceed in Nova Scotia, in this chapter, we start from the assumption that regulations are a key method by which governments protect and promote the interests of their citizens. Ideally, regulations serve to prevent harm from occurring and include measures to mitigate the impact or consequences of harms which may nonetheless take place. In submissions to this review and in public meetings, Nova Scotians have expressed concerns about whether regulations can provide a satisfactory level of protection from the known and suspected risks associated with hydraulic fracturing (see Introduction and Chapter 8). We believe that these concerns must be addressed.

This chapter does not project a regulatory regime for Nova Scotia. Rather, it explains the limits of regulating and identifies some of the factors which make it more or less likely that a regulatory regime will serve its purpose. We identify the roles of different levels of government in the decision-making process around hydraulic fracturing activities and provide an overview of some of the approaches to regulating hydraulic fracturing in various provinces, including Nova Scotia. We then explore the relationship between regulations and risk management, and we identify how the efficacy of regulations for protecting health and the environment turns on, (i) the adequacy of the knowledge base, (ii) political will and responsiveness of the regulations to the knowledge base, and (iii) whether and how regulations are implemented, resourced, and enforced. The paper provides examples of these elements in action, drawn from hydraulic fracturing experiences in Canada and the United States. We conclude that since the adequacy of protection from risks is a matter of degree (resting both on the actions of industry and of the state), where risk is intensified in the regions where hydraulic fracturing takes place, and because hydraulic fracturing lacks social license to proceed at the moment, that decisions about the terms under which hydraulic fracturing may or may not take place in Nova Scotia ought to be regionally specific and community driven.

9.1 | **Introduction**

Our panel has benefited significantly from a range of public engagement activities, in which many members of the public have chosen to participate. Many of those who made formal submissions to the panel expressed concerns about whether regulations can adequately protect public health and safety and the environment (see Chapter 8). The concerns were echoed in submissions to individual discussion papers and in our public meetings (see Introduction).

A number of submissions described adverse experiences with hydraulic fracturing in Kennetcook, Nova Scotia, where hydraulic fracturing wastewater has sat in open pools for years and asked who was responsible for letting such problems arise and why the situation remains outstanding. People also questioned the value of enacting regulations if there is no guarantee that the regulations will be followed or enforced. We saw submissions that focused on knowledge gaps, with members of the public asking about the value of regulations in light of unknown risks. Submissions also expressed concerns that some types of risks cannot be fully mitigated by regulation. This point was fully recognized in our Introduction when we considered the issue of externalities.

As we noted in the Introduction (Section I.4), only 26 per cent of Nova Scotians believe that "most companies in NS operate in an environmentally responsible manner." We related this to the literature on corporate influence, "regulatory capture", which results in politicians and regulators being unduly influenced against the public interest. Regulations not only set the baseline standard for industry practices, they are also a key way that the state fulfils its responsibility to citizens by protecting and promoting their interests. One role of regulations is to prevent harm from occurring, so that citizens are not forced to pursue remedies through lawsuits, where their legal rights often only materialize after harms have already occurred and those harms may not be reversible (Gerkin, 2013). If the harms, or potential harms, are environmental, the ability of citizens is quite limited if their private interests are not at stake. Many citizens who attended the panel's public meetings expressed concern that private, court-based remedies are inadequate to address the range of harms that might impact on matters of public value, such as protecting watersheds or sustaining ecosystems. They also raised the related issue that even when protective regulations exist, the public is dependent upon the Province to enforce them. Some members of the public voiced the opinion that enforcement practices reflected an unacceptable level of discretion. Thus, the issues that are raised above are fundamental and are reflected in the content of some aspects of this chapter.

The chapter starts by addressing some informational issues about regulating. In particular, it identifies the roles of different levels of government in decisions about hydraulic fracturing and, then, briefly surveys how hydraulic fracturing is currently regulated in a few sample Canadian jurisdictions, including Nova Scotia. We, then, turn to the relationship between regulations and risk management, and we explore these issues pursuant to a framework that was presented by the Council of Canadian Academies in their recently released study, which we have referenced throughout this Report (CCA, 2014). This section of the chapter, in particular, provides some insight into the public concerns that are described above. It discusses the limits of regulation, as well as some of the factors or conditions that are more likely to make regulation successful. We have also prepared an appendix to this chapter (Appendix F), which provides a brief survey of the public and corporate litigation that has been generated around hydraulic fracturing in the United States and in Canada, including suits against government bodies that have been brought by corporate entities and citizen groups.

While this chapter draws on experiences in other jurisdictions, it is not a comprehensive evaluation of the regulations, rules, policies, and guidelines that are relied upon in other jurisdictions, nor does it project a regulatory regime for Nova Scotia. As referenced at various points in this chapter, if Nova Scotia continues to explore the possibility of hydraulic fracturing, a key part of that exploration should be a comprehensive regulatory review and deep consultation process, which draws heavily on community participation and also respects the Aboriginal and treaty rights of the Mi'kmaq (see also Chapter 10).

9.2 | What Levels of Government have a Decision-making Role about Hydraulic Fracturing?

Many of the public submissions focused on the provincial government's decision-making role and responsibilities, vis-à-vis hydraulic fracturing activities. However, all levels of government – federal, provincial, municipal, and Aboriginal – have a degree of authority which may be triggered by activity associated with hydraulic fracturing. It is essential to note that the federal and provincial exercises of powers described below are potentially restrained or ousted where Mi'kmaq Aboriginal and treaty rights are present. Because of the complexity of this particular issue, it is described separately in Chapter 10.

The overview below is a general one. As noted in Chapters 1-3, unconventional gas and oil activities entail several steps or phases where decisions are made.

9.2.1 The Federal Government

The federal government has jurisdiction over natural resources on federal lands. In Nova Scotia, this means that the federal government would have a role if ever there was a proposal for hydraulic fracturing activities to take place in national parks, such as the Cape Breton Highlands, on First Nations reserve land, or on other federal land such as military bases. This explains why United Nations Educational Scientific Cultural Organization's efforts to create a hydraulic fracturing buffer zone around Gros Morne Park in Newfoundland have primarily involved the federal government (Canadian Press, 2014). The federal government's mandate is also triggered if there are any interprovincial or international aspects that fall under the purview of the National Energy Board, as might be present if there was a proposal to transport gas from hydraulic fracturing out of Nova Scotia via pipelines.[1]

Subject to the exceptions described below, the federal government plays a limited role in regulating or responding to hydraulic fracturing activities taking place on provincial lands. Canada does not, for example, have an entity that is the equivalent to the U.S. Environmental Protection Agency (EPA).[2]

One of the few examples of when the federal government's jurisdiction would be triggered by proposed hydraulic fracturing activities on provincial lands would be if the activity was to occur within a wildlife area or migratory bird sanctuary. The impacts which would be studied are limited to matters under federal jurisdiction, such as fish habitat.[3] The federal government is also responsible for air quality issues. At this point, it has exercised its regulatory authority, primarily vis-à-vis greenhouse gas emissions and smog, and as a general matter, and has not directed its attention to other air contaminants associated with unconventional gas and oil production (see Chapter 8). Nor has it, for example, apparently exercised its authority to address cumulative impacts of air emissions by multiple operators. The federal government also has authority to assess whether substances are toxic to human health or the environment and to control the use of such substances.[4]

This last power could be quite relevant in the hydraulic fracturing context, because it means that the federal government can restrict or prohibit certain chemicals from being used in the hydraulic fracturing process due to their toxicity. However, a 2013 audit of the federal government's chemical management program, which is intended to assess chemicals which were already identified as high priority, found it was well governed and planned but has been progressing slowly and so questioned whether it would achieve its goal of assessing the priority chemicals by 2021 (Health Canada, 2013). This raises practical concerns about the chemical management program's resources and support.

On a related note, on July 4, 2014, Environment Canada posted a revised list of chemicals to be traced under the National Pollutant Release Inventory, a publicly available inventory which is used, among other purposes, to "identify pollution prevention priorities" (Environment Canada, 2014a). Environment Canada declined to include toxic chemicals associated with hydraulic fracturing, as they concluded that the quantities of reportable substances, "used at individual wells are unlikely to meet the existing reporting thresholds for individual substances." Environment Canada noted, however, that work is continuing to help better understand the composition of fracturing fluids, so as to determine whether mandatory reporting for the purposes of this inventory would be appropriate (Environment Canada, 2014b). As such, Nova Scotia may wish to exercise its own authority over environmental protection, as no other entity appears to be controlling for cumulative effects.

9.2.2 The Provincial Government

The provincial government has a very significant decision-making role. In Nova Scotia, the provincial government owns all underground resources as against private landowners. This includes the unconventional gas which the hydraulic fracturing process is intended to release. The Province also has authority to pass laws regarding the management, control, and exploitation of natural resources within the provincial jurisdiction.[5] The Province further has authority over areas including environmental protection, water protection, emissions, occupational health and safety, emergency measures and roads, as well as industry permitting and licensing. This includes authority to approve - or prohibit - the release of toxins into the environment.[6] This is relevant for considering how hydraulic fracturing chemicals may be regulated, including the terms for disposal of chemicals and wastewaters. Nova Scotia's current approach to regulating in some of these areas is described in several of the other chapters of this report, for example those regulations designed to safeguard water resources (see Chapter 6). To fulfill its responsibility to regulate the use of natural resources and to provide for the health of its residents, Nova Scotia has also passed some over-arching legislation.

For example, the province passed a statute called the Environmental Goals and Sustainable Prosperity Act. This statute makes a commitment, "to fully integrate environmental sustainability and economic prosperity."[7] It identifies three principles for attaining this objective. These principles state:

> "The health of the economy, the health of the environment, and the health of the people are interconnected";
>
> "Environmentally sustainable economic development that recognizes the economic value of the Province's environmental assets is essential to the long-term prosperity of the Province;" and
>
> "The environment and economy must be managed for the benefit of present and future generations, which is in keeping with the Mi'kmaw concept of Netukulimk, defined by the Mi'kmaq as the use of the natural bounty provided by the Mi'kmaq for the self-support and well-being of the individual and

the community by achieving adequate standards of community nutrition and economic well-being without jeopardizing the integrity, diversity, or productivity of our environment."[8]

Thus, our regulatory framework starts with recognizing the value of long-term prosperity and environmentally sustainable economic development, as well as a recognition of how economic, human, and environmental health are interconnected. This interconnection is also noted in other chapters of this report, which flag associations between economic well-being and population health (Chapter 4) and also urge long-term thinking about the relationship between hydraulic fracturing and environmental sustainability (Chapter 8).

Nova Scotia's Environment Act also places an explicit cap on how much environmental risk can be tolerated. The act states that, "the precautionary principle will be used in decision-making so that where there are threats of serious or irreversible damage, the lack of full scientific certainty shall not be used as a reason for postponing measures to prevent environmental degradation."[9] We defined the meaning of a "precautionary approach" in our introduction to the report. Taken together with the provincial endorsement of the Mi'kmaq concept of Netuklimk, Nova Scotia has effectively committed itself to approaching hydraulic fracturing with an eye to the long term and exercising considerable caution.

9.2.3 Municipalities

While municipal by-laws cannot be inconsistent with provincial law,[10] municipalities also have a decision-making role around many of the activities associated with hydraulic fracturing. For example, they have authority over local transportation issues, such as how municipal roads may be used and some emergency measures. Municipalities in Nova Scotia also control local environmental matters. These include wastewater management, solid waste management, noise, and local drinking water protection. This latter power extends to designating protected water supply areas.[11] They also have authority to enact by-laws to protect health, well-being, and safety.[12]

Any provincial decision to authorize hydraulic fracturing activity in proximity to a municipality could trigger situations where the municipality would have to decide whether and how to exercise its jurisdiction, given the interests of its constituents. For example, the Municipality of the County of Inverness passed a by-law, based in part on its authority to protect local public health, which is intended to prohibit hydraulic fracturing.[13] Municipalities could also pass by-laws that mitigate certain aspects of hydraulic fracturing activities, such as noise control, or could enter agreements for compensation for the use of municipal roads. However, municipal by-laws in other jurisdictions, which were found to actually regulate drilling, have been struck down, due to conflicts with provincial law and a more tenuous connection with municipal authority. A lawsuit was recently launched by an oil and gas company against a municipality in Quebec, challenging its lawful authority to enact a by-law that established a two kilometre, no-drilling zone around its municipal water supply. The company was allegedly issued provincial authorizations to drill in the zone falling within the by-law, creating a situation where there appears to be a conflict between provincial and municipal regulations. Unfortunately for the municipality, the authorizations are allegedly not affected by provincial legislation which was subsequently passed that banning drilling within 500 meters of potable water sources (CBC News, 2014).

9.2.4 Aboriginal Governments

Aboriginal governments would have significant roles in decision-making processes about hydraulic fracturing if there is a reasonable chance that their rights could be infringed upon, if unconventional gas is located under lands over which they do, or may hold, Aboriginal title, or if there is unconventional gas under reserve land. The Mi'kmaq of Nova Scotia are likely to have a particularly weighty role, given the robust nature of the Mi'kmaq's treaty rights and the fact that their traditional territory takes in the whole province. Their guidance may also support understanding how the concept of Netukulimk can be realized in practice. The specific question of how Mi'kmaq rights relate to provincial and federal decision-making processes and authority is discussed in detail in Chapter 10.

9.3 | How is Hydraulic Fracturing Currently Regulated in Canadian Jurisdictions; including Nova Scotia?

There are several jurisdictions in Canada where hydraulic fracturing is occurring or has taken place. There is currently no hydraulic fracturing taking place in Nova Scotia, but the Province has approved some operations in the past. Unlike off-shore activity, which is regulated by an independent board, called the Canada-Nova Scotia Offshore Petroleum Board, onshore oil and gas activity within Nova Scotia is regulated by a number of provincial departments. The central authority is the Department of Energy. It administers the Petroleum Resources Act, which determines whether petroleum rights may be granted and also gives the Minister of Energy the authority to enact regulations.[14]

There are several other government departments that regulate activities that are associated with hydraulic fracturing. For example, as discussed in the chapter on water (Chapter 6), a project proponent would apply to the Department of the Environment for permits if they sought to withdraw water to use in a hydraulic fracturing operation.[15] There is, however, minimal legislation in Nova Scotia that was specifically drafted to address the unique aspects of hydraulic fracturing activity. One of the few examples is a statute which bans transporting hydraulic fracturing wastewater into the Province.[16] As discussed below, it is clear that Nova Scotia would have to pursue significant regulatory development if it chose to permit hydraulic fracturing.

Owing to their long history of onshore oil and gas development, British Columbia and Alberta have the most experience with onshore oil and gas regulatory frameworks in Canada. In British Columbia, the Province created a single regulatory body, the Oil and Gas Commission (BCOGC), to oversee oil and gas activities. The BCOGC is authorized to enforce certain provisions of legislation that would otherwise be spread across multiple government departments and agencies. These include the Environmental Management Act, Forest Act, Heritage Conservation Act, Land Act, and the Water Act. As a result, a hydraulic fracturing operator must apply for well permits and water withdrawal permits through the BCOGC instead of through another department. Most of the BGOGC regulations apply to all oil and gas activities and are not specifically tailored to hydraulic fracturing. However, in the past few years, the BGOGC has issued several guidelines that refer specifically to the hydraulic fracturing industry (B.C. Oil and Gas Commission, 2014).

Regulation of oil and gas activities in Alberta used to be spread out across several government ministries and involved the Energy Resources Conservation Board (under Alberta Energy), Alberta Health, and Alberta Environment and Sustainable Resource Development. In 2013, Alberta combined the regulatory duties of these boards and departments into a single regulatory body, the Alberta Energy Regulator (AER), under the aegis of the Alberta Energy Ministry, which is now responsible for all aspects of oil and gas activities. For example, it regulates environmental issues, deep injection wells, and water withdrawals. The AER also has the power to enact new regulations and guidelines with respect to drilling, completing, producing, and abandoning hydraulic fracturing wells (CCA, 2014).

Like Nova Scotia, New Brunswick regulates onshore oil and gas activity through a series of departments and statutes, with its Department of Energy and Mines being a central authority. Key statutes include the Clean Water Act, the Clean Air Act, the Pipeline Act, and the Oil and Natural Gas Act. New Brunswick recently completed a process for creating a regime to oversee all oil and gas activity in the Province, including the extraction of unconventional gas through hydraulic fracturing. They developed a "blueprint" which focuses on policy issues (Province of New Brunswick, 2013a), as well as rules for industry which address operational issues (Province of New Brunswick, 2013b). The rules for industry build on many aspects of Alberta's regime and explicitly adopt all of the Alberta Energy Regulator's Directives relating to oil and gas drilling and completion (Province of New Brunswick, 2014a). New Brunswick describes many of its rules as more stringent than requirements in Alberta and British Columbia (Province of New Brunswick, 2014b) and industry representatives have expressed concern that the rules are onerous (CBC News, 2013). These rules are, however, not in the form of a statute or regulation. This means they are not directly enforceable.

New Brunswick's officials have indicated that the rules, "for the most part, will be implemented as conditions to approvals and certificates," that are issued under existing statutes (CBC News, 2013). In theory, this creates discretion to not apply the rules. This issue has apparently been identified by opposition political parties as a source of concern (CBC News, 2013).

As a part of its regime, New Brunswick created an independent organization, the New Brunswick Energy Institute. The Institute's mandate is, "to review and assess the environmental, social, economic, and health issues relating to energy extraction, development, or production," and, thereby, serve as an advisory body to the province (New Brunswick Energy Institute, 2014).

New Brunswick's new regime is not without public controversy. Two separate lawsuits were launched against the province in June, 2014. The allegations which are made in these lawsuits include claims that New Brunswick's authorization process violates Aboriginal, environmental, and constitutional law.

Nova Scotia has compiled information which describes the similarities and differences in several Canadian and U.S. regimes (Precht & Dempster, 2012). It has not yet, however, produced a formal public evaluation of that information. One point of contention is whether regimes are best consolidated under a single regulator. Concerns were expressed during the public input process that the benefits of a single regulator model may be outweighed by other factors. In particular, that where the same entity is both the regulator and the promoter of an industry, conflicts of interest may arise. Similar concerns lead the authors of the provincial Aquaculture Report (currently in draft form) to conclude that responsibilities for regulating aquaculture should not remain in one department. In particular, they recommended that while responsibility should primarily rest with the Minister of Fisheries, that responsibility for environmental monitoring ought to be transferred to the Department of the Environment, "to improve public confidence in the independence and objectivity of the oversight that government brings to bear on compliance" (Lahey-Doelle Panel, 2014). If Nova Scotia was ever to decide to permit hydraulic fracturing, it would benefit from a comprehensive study of the strengths and weaknesses of existing regimes for regulating industry practice and protecting health and the environment and consider their applicability to the geological, environmental, and social conditions in various regions of Nova Scotia.

9.4 | **The Role of Regulations and Risk Management**

Nova Scotia's legislated commitment to the precautionary approach and focus on the long term, is consistent with the proposals put forth by the Council of Canadian Academies (CCA, 2014) in their report on the state of knowledge of potential environmental impacts of hydraulic fracturing and associated mitigation options (CCA, 2014). This peer-reviewed document has been referenced throughout this report. It was produced by an independent and arms-length panel of 14 experts, who engaged in a two-year process of working through the evidence on potential environmental impacts of unconventional gas and oil development, including the use of hydraulic fracturing. They have effectively produced a new Canadian baseline for understanding the environmental risks and challenges associated with hydraulic fracturing.

While their report is comprehensive, the CCA chose not to provide an exhaustive list of regulatory requirements. Instead, the CCA identified a framework for regulatory goals and risk management. This framework identifies key issues to consider and benchmarks against which to make decisions about regulating unconventional gas, including hydraulic fracturing (CCA, 2014). It is important to note that the CCA offers principles, not solutions. They write:

> Advanced technologies and practices that now exist could be effective to minimize many impacts, but it is not clear that there are technological solutions to judge the efficacy of current regulations because of the lack of scientific monitoring. The research needed to provide the framework for improved, science-based decisions concerning cumulative environmental impacts has barely begun (CCA, 2014).

As such, their five element framework is helpful for deliberations about whether, how, and the extent to which regulating can protect human health and the environment to the satisfaction of Nova Scotians. These five elements are discussed below.

9.4.1 Technologies to Develop and Produce Unconventional Gas.

The CCA explains that, "Equipment and products must be adequately designed, installed in compliance with specifications, and tested and maintained for reliability" (CCA, 2014). In practice, technological developments are often achieved outside of the regulatory regime. For example, companies invest in research and development to improve their economic return, to advance industry best practices, and to improve their social license by identifying ways to operate, which are more likely to be acceptable to members of the public. The CCA provides several examples of industry-driven technological developments in British Columbia, including reducing chemical additives in fracturing fluids (CCA, 2014). That said, regulators have a role to play with respect to hydraulic fracturing technology. For example, regulators can require industry to use specific technologies, can prohibit or limit the use of certain chemicals, can require the testing of new technologies, and can impose monitoring systems and thresholds for interventions, such as requiring a "traffic light" approach to micro-seismic events (Zoback, 2012).

9.4.2 Management Systems to Control the Risks to the Environment and Public Health.

The CCA identifies the following threshold for risk management systems, "The safety management of equipment and processes associated with the development and operation of unconventional gas and oil sites must be comprehensive and rigorous" (CCA, 2014). Risk and safety management systems are essential for environmental protection and worker safety. The National Energy Board, which regulates hydraulic fracturing on federal lands, recently adopted filing requirements for hydraulic fracturing operators intended to ensure that areas of risk, especially risks caused by accidents and errors, are pre-emptively addressed. The operators must submit a i) safety plan, ii) risk assessment and risk management plan, iii) environmental protection plan, iv) waste management plan, and v) spill contingency plan (National Energy Board, 2013).

Not unlike technological developments, industry entities also drive elements of safety management, having, "developed standards, codes, and guidance to embed risk safety management into the management systems of shale gas operators" (National Energy Board, 2013) For example, the Canadian Association of Petroleum Producers (CAPP) has published a set of operating practices and guiding principles related to hydraulic fracturing activities. Government regulators can benefit from these voluntary risk management systems. They can adopt them directly as a regulation or can use them and the data collected around their efficacy as guidance when creating their own mandatory management system.

9.4.3 An Effective Regulatory System.

The third element of the CCA's five-part management framework is an effective regulatory system. The CCA report concludes that, "Rules to govern the development of shale gas must be based on appropriate science-driven, outcome-based regulations, with strong performance monitoring, inspection, and enforcement" (CCA, 2014, p. xix). The CCA highlights several specific regulations that must be included in an effective regulatory system. For example, it identifies well integrity as an important component of hydraulic fracturing regulatory requirements (see Chapter 7 for a detailed discussion of well integrity issues, including the importance of regulation). Ensuring well integrity involves regulating, at a minimum, surface casing depth, casing strings, and logging and must be sensitive to different geological conditions (CCA, 2014). Regulations in British Columbia, Alberta, and New Brunswick impose well integrity requirements to varying degrees (CCA, 2014). However, for the most part, the CCA's framework emphasizes identifying the right principles for establishing regulatory requirements.

For example, the CCA's report highlights the importance of sound science when establishing regulations. They write that standards should refer to, "the level of emissions acceptable from a human health or environmental protection point of view" (CCA, 2014, p. 223) The CCA cautions that establishing these standards can be challenging because of a lack of scientific understanding, changing conditions, and insufficient resources (CCA, 2014). These points merit elaboration.

As noted above, many public submissions to our review raised the question of whether regulations can protect human health and the environment from adverse consequences that may arise from, or be associated with, hydraulic fracturing. Seventy-five individual submissions (of 238) directly referenced this issue, making it the seventh most cited concern (Chapter 8). It is important to note from the start that some environmental issues are beyond the reach of regulatory protection, and so assessments must seek to use the best available data to weigh the likelihood of an event occurring with the range of its potential consequences. As the CCA states, "However sophisticated or well-intentioned, government and industry managers cannot guarantee that all environmental risks will be alleviated or all impacts avoided if development proceeds" (CCA, 2014, p. 191). The answer to the question of whether regulations can protect human health and the environment from adverse consequences that may arise from, or be associated with, hydraulic fracturing is, thus, a matter of degree, which relates in turn to the "proportionality" dimension of the precautionary principle discussed in our introduction. Discussed below are three factors for understanding the effectiveness of regulations for addressing risk. They are: (i) the adequacy of the knowledge base, (ii) political will and responsiveness of the regulations to the information base, and (iii) implementation, resourcing, and enforcement. In some cases, these factors overlap.

9.4.3.1 Adequacy of the Knowledge Base

The degree to which regulating can protect human health and the environment turns, in part, on whether there is adequate information to understand how human health and the environment may be adversely impacted by hydraulic fracturing activities, as well as whether there is adequate information to understand how those risks can be mitigated. On the one hand, provinces such as Alberta appear to have gathered evidence so as to enable them to create a detailed and extensive set of standards for well casing and cementing, including prescribing acceptable materials, details for integrity testing, and performance and monitoring requirements (Luft, O'Leary & Laing, 2012), which have reduced risk to a degree that is acceptable to the Alberta Energy Regulator and the Alberta provincial government. On the other hand, there is abundant literature that documents knowledge gaps in other areas associated with hydraulic fracturing.

For example, in their review of unconventional gas and oil development and regulating in Canada, Philips and Goldberg (2013) note that a "lack of reliable, scientific data to accurately determine the environmental and health effects of…hydraulic fracturing continues to be a key obstacle to effective regulation of the natural gas industry" (Philips & Goldberg, 2013, p. 403). The CCA report similarly concludes, "it is evident that more science is needed on which to base regulations and that such regulations will only be effective if they are informed by timely monitoring and enforced rigorously" (CCA, 2014, p. 219). Effective regulation requires reliable information about the in situ risks associated with hydraulic fracturing. It also requires an understanding of how rules, standards, and prohibitions can effectively minimize these risks.

One knowledge gap, which impairs effective regulation, or at least assurance that regulations are effective, concerns monitoring. The CCA notes, "it is difficult to judge the efficacy of current regulations because of the lack of scientific monitoring" (CCA, 2014, p. xx). In situ and geologically specific environmental monitoring is necessary to clarify the nature and extent of environmental and health impacts associated with hydraulic fracturing, so as to understand how effectively they can be eliminated or mitigated, or else to determine whether those risks are unacceptable. In Chapter 4, we outlined a process of Health Impact Assessment (HIA), which may address part of this regulatory gap by ensuring that health consequences, and their distribution, are identified and used as part of the decision-making process. In Chapter 11, we specifically recommend that if the Province was ever to consider permitting hydraulic fracturing, that the regulatory process require site specific HIAs be conducted. Ensuring effective monitoring of hydraulic fracturing development has been identified as an important component of an effective regulatory regime (CCA, 2014).

9.4.3.2 Political Will and Responsiveness of the Regulations to the Knowledge Base

The question of the efficacy of regulations for protecting human health and the environment also turns on whether the regulatory regime responds adequately to the knowledge base. This is, in part, about designing a good system and, in part, about political will to take on regulatory challenges. For example, it is now known that if the fracturing process impinges on a near by hydraulic fracturing well, there may be induced pressure pulses or, in an extreme case, oil, gas, and fracturing fluid may be propelled up that well. This is called "interwell communication." One interwell communication incident occurred in Innisfail, Alberta, in 2012, resulting in approximately 500 barrels of oil and hydraulic fracturing fluid being sprayed over a field (CBC News, 2012). An investigation by EnergyWire found 10 such incidents had occurred in Canada and the United States since 2009 (Vaidyanathan, 2013). Although extremely uncommon, the consequences of interwell communication can be dire, because if the fluid is not contained, it could contaminate shallow aquifers. In the United States, many states see interwell communication as a matter which does not even need to be reported. The Arkansas Oil and Gas Commission, for example, apparently sees the issue as a matter, "for companies to resolve between themselves because it affects production" (Vaidyanathan, 2013).

Alberta's response has been strikingly different. One month after the Innisfail incident, Alberta issued an industry bulletin stating that operators must, "maintain well integrity at all times so as not to impact the environment [and] public safety" (ERCB, 2012) and then went on to invest in developing extensive new technological requirements to prevent the likelihood of unintentional interwell communication and to enhance overall well integrity (Alberta Energy Regulator, 2013). Under Directive 83, operators are usually now required to construct their wells differently in a number of ways. For example, requirements are now in place to create multiple barriers to contain any disrupted fluids so they will not enter the environment. As well, operators are required to implement a monitoring system which will detect if the first barrier fails. The political will to respond to this risk, and to impose new and costly changes on industry, has been very different between Arkansas and Alberta.

It is unclear what role political will played, as opposed to regulatory gaps, in the Kennetcook situation, where two hydraulically fractured wells generated an unexpectedly high volume of hydraulic fracturing wastewater. This wastewater, usually called flowback, cannot safely be released directly back into the environment. Instead, it must be processed through a treatment plant or is sometimes disposed of through deep well injection. It is known that with any hydraulic fracturing operation there will be flowback. In the case of the hydraulic fracturing operation in Kennetcook, the high flowback volume resulted in a need to store 14 million litres of fluid. At the time, the Nova Scotia government must have been aware of the nature of the flowback fluid and its potential for causing risks. The company wanted to inject the fluids in a nearby deep well, but the Nova Scotia Department of Environment refused because of the uncertainties involved with using this process to dispose of flowback fluids (CCA, 2014). Meanwhile, the wastewater has sat for over two years in open, lined storage pits near Kennetcook, a storage practice that would not be permitted in other Canadian jurisdictions, such as New Brunswick. In January, 2014, heavy rain and snowfall caused the hydraulic fracturing wastewater to leak out of these ponds. Once again, this event was foreseeable. The wastewater remains in these ponds. This situation was discussed, with alarm, in many of the public submissions. A number of stakeholders forwarded a report on the Kennetcook situation to the panel. The report documents various moments of regulatory inaction, gaps, or potential regulatory violations (Nova Scotia Fracking Resource and Action Coalition, 2013).

The Kennetcook situation appears to have resulted from an absence of regulatory requirements to conclusively address the storage, treatment, and disposal of hydraulic fracturing wastewater, despite the knowledge that if Nova Scotia issued permits for hydraulic fracturing activities to take place, wastewater would be produced and require treatment and disposal. It highlights the importance of political will to ensure that there is a comprehensive regulatory framework and emergency response capabilities in place before hydraulic fracturing activities occur and flags the sorts of problems which may be worsened by a piece-meal approach to regulation. Based on public submissions and our public meetings, this situation has drastically eroded public trust, as have other high profile environmental remediation failures, such as the situation at Boat Harbour. Members of the public indicated that re-building their trust in regulatory efficacy may require a provincial review of its regulatory enforcement and remediation abilities and practices, as well as the province producing open public reporting on such activities.

A related issue is that sometimes regulatory systems may be drafted in a way that could permit knowledge gaps to occur or persist. For example, although the Minister of the Environment's approval is required for many of the activities to take place which are associated with hydraulic fracturing, the existing provincial regime appears to leave it to the Minister's discretion to determine whether a proposal to engage in hydraulic fracturing should undergo an environmental impact assessment.[17] If Nova Scotia ever decides to permit hydraulic fracturing, it is highly unlikely that this status quo would be acceptable to its citizens, especially given how many public submissions referenced serious concerns about environmental impact and fear that government discretion has not been consistently exercised to protect citizen's environmental interests in the past. The panel notes that emerging best practices appear to be a requirement for an environmental assessment for each proposed well,[18] as well as considering the well in terms of cumulative impact.

Another example of a regulatory response, which appears to respond to specific known risks, is Alberta and British Columbia's regulations regarding certain disclosure requirements. Until recently, there was limited disclosure of hydraulic fracturing fluid composition to governments and minimal public access to this information, especially in the United States (Luft, O'Leary & Laing, 2012). The result is that the ability to monitor for public health risks has been impaired.

The situation is changing in many U.S. states, and Canadian provinces are also developing regimes to address this issue. For example, as of 2010, British Columbia began requiring public disclosure (British Columbia Ministry of Energy and Mines, 2012). Its regime has been described as the current high water mark level of disclosure, requiring the reporting of all fluid ingredients, CAS numbers, concentrations, whether the chemical is deemed hazardous, and other use details (Luft, O'Leary & Laing, 2012). Companies are required to post on a public website, the chemical additives used in their fracturing fluids, along with their maximum concentration, within 30 days of completing a fracturing job on a public website (www.fracfocus.ca) (CCA, 2014). In some U.S. states, such as Wyoming, pre-operation chemical disclosure is required when a company first applies for a permit,[19] adding another level of key regulatory oversight. These are important and responsive improvements on previous disclosure requirements. They advance the public interest in allowing regulators and members of the public to be aware of the composition of fracturing fluid. See Chapter 11 for our recommendations on this topic.

On the other hand, the directives and regulations currently in force in Alberta and British Columbia do not appear to require the monitoring and full disclosure of compounds that are brought to the surface with flowback after fracturing fluid has initially been injected.[20] This may be a cause of concern, as some naturally occurring compounds can be hazardous and little is known about the interactions between chemical additives and natural compounds (CCA, 2014). While this gap is addressed to some degree by a requirement in British Columbia, for example, to submit information on "fluid recovery," if an operator tests such fluids,[21] the CCA notes that, "information is also required on potentially hazardous chemicals produced down-hole by chemical interactions under high temperature and pressure" (CCA, 2014, p. 19). Thus, regulatory practices in other jurisdictions respond well to some of what is known about mitigating risks associated with the chemicals that are added to water in the hydraulic fracturing process but do not appear to have mandated practices to address the full knowledge base about potential chemical risk. See Chapter 11 for our recommendations on the topic of wastewater treatment and disposal.

9.4.3.3 Implementation, Resourcing, and Enforcement

Finally, the question of whether regulations can protect human health and the environment, turns on whether the regime is effective in practice. This third question is partially one of government priorities and capacity. If compliance is not monitored and enforced, industry incentive to comply will likely diminish and public confidence that they are protected will be lost (Konshnik & Boling, 2014). A report published by East Coast Environmental Law (ECELAW) in June 2014, investigated the Department of the Environment's enforcement activities under the Environment Act. Their report indicates that they were unable to access information that is submitted to the public registry and were forced to instead rely on formal requests under the Freedom of Information and Protection of Privacy Act. The information which they did receive was incomplete, and so, "was insufficient to provide a picture of environmental enforcement in Nova Scotia" (ECELAW, 2014). As a result, ECELAW was unable to determine whether, "the government is holding polluters accountable for the true cost of environmental harms" (ECELAQ, 2014). Such an apparent lack of transparency raises questions about government priorities and undermines public confidence that harms are indeed being prevented or effectively mitigated by virtue of a regulatory regime. There have been a number of audits of regulatory enforcement agencies in recent years, which appear to document a general trend of some agencies not acting in response to identified and potential environmental violations.[22] Not surprisingly, these situations bring into question whether governments are protecting and promoting citizens' private and public interests and values.

Enforcement requires an adequate budget. The experience in some U.S. states has been that already overburdened agencies are unable to effectively monitor with their existing staff and funding (Gerkin, 2013; Wiseman, 2012). Some models levy companies for the cost of regulatory enforcement. Nova Scotia, for example, uses this model for offshore oil and gas. Given the lack of an existing onshore industry and uncertainties as to potential profits, this approach may or may not be viable for onshore activities in Nova Scotia. Regardless, mechanisms must be in place to ensure adequate and high-quality resourcing. If not, then the best regulations, based on the best science, are unlikely to be effective. As well, the experience in other jurisdictions when governance responsibility is shared across multiple agencies, as it currently is in Nova Scotia, is that strong mechanisms must be in place to address information sharing and action, as well as a mechanism to ensure responsiveness in the face of apparent mandate gaps (Konschnik & Boling, 2014).

Enforcement also requires expertise. This issue was raised by members of the public who questioned how Nova Scotia could secure the services of a sufficient number of independent topic experts to perform the required monitoring activities. Others pointed to the expertise that is required if sites become contaminated, or are contaminated and abandoned, and noted that, unlike the United States, we do not have an entity such as the U.S. Environmental Protection Agency that is resourced and charged with matters such as expertly addressing uncontrolled hazardous waste sites.[23]

Effectiveness is also a matter of identifying appropriate sanctions for violations. A study of environmental regulatory violations by companies operating in the Marcellus Unconventional Gas play in Pennsylvania makes several recommendations to enhance compliance and reduce risk. These recommendations include, increasing funding to ensure that independent inspections take place prior to drilling, and at key moments such as when wells are being sealed, as well as increasing penalty levels and bonding to further incentivize compliance (PennEnvironment Research & Policy Centre, 2012). If a company is legislatively responsible for the costs of all negative impacts, they will be more diligent about compliance. Such an outcome is more likely to occur where companies are required to post bonds, which must be framed to provide security that costs will be addressed even if a company goes bankrupt. The BC Oil and Gas Commission, for example, has a process for identifying permit holders, "whose estimated oil and gas decommissioning liabilities exceed their estimated oil and gas estimates" and requires such holders to post bonds (BC Oil and Gas Commission, 2010). While bonds act both as an incentive and reduce the likelihood of the public bearing financial burdens, the public also raised concerns about the efficacy of bonding. They pointed to three major deficiencies. First, that bonds are only valid for a certain period of time and harm may materialize long after a bond has expired. Second, that only government, and not citizens, are usually able to recover against a bond. Third, that bonds provide specific coverage, and costs are difficult to predict given knowledge gaps about long-term consequences and uncertainty about remediation costs. These last two points, and the challenges which they raise, are discussed in our introduction and in the recommendations section of Chapter 11.

Given the above factors, the effectiveness of a regulatory system to protect human health and the environment is a matter of degree. Some elements are controlled by government, while others are in the hands of operators. As discussed throughout this report, there are different levels of scientific consensus regarding risk levels and certainty and the effectiveness of mitigation vis-à-vis aspects of hydraulic fracturing. The decision about whether regulations can result in an acceptable level of risk and whether the risks are offset by potential benefits, is primarily a question that must be answered in conversation between government, communities, scientists, individuals, industry, economists, and other stakeholders and the answer may vary in different regions of Nova Scotia. The need for public participation cannot be over-emphasized. This ties in with the fourth and fifth elements of the CCA's framework.

9.4.3.4 Regional Planning

The CCA Panel's fourth element for regulating risk management is regional planning. They write that, "To address cumulative impacts, drilling and development plans must reflect local and regional environmental conditions, including existing land uses and environmental risks. Some areas may not be suitable for development with current technology, whereas others may require specific management measures" (CCA, 2014, p. xix). They go on to note that Canadian jurisdictions, "are recognizing the need to take a regional approach to managing the cumulative impacts of unconventional gas and oil development" (CCA, 2014, p. 205). Individual companies are not well placed to make such assessments, and regardless, this is a matter which requires democratic oversight and accountability. The Alberta Energy Regulator has begun to identify some strategies for addressing cumulative effects. However, the Chief Executive of the Alberta Energy Regulator was explicit that more is needed, having recently commented that, "I need a regional plan (from government) [for] the northwest" of the Province (Ewart, 2014). British Columbia has developed oil and gas land use plans for various regions (BC Oil and Gas Commission, 2013). They determined that there are some regions where oil and gas activities are permissible but others where it should not take place in the foreseeable future due to knowledge gaps or unacceptable impacts or risks (CCA, 2014). Regions are unlikely to align with political boundaries such as counties. Rather, they ought to be determined based primarily on natural features, such as geology and watersheds, with attention to current uses such as farming. It is important to note that regional planning is not a substitute for specific decisions about specific proposals, and that community participation in regional planning does not oust public involvement at other decision-making stages. Nova Scotia is fortunate to be considering whether it ought to engage in hydraulic fracturing at a time when it can benefit from these and other experiences, especially in other provincial Canadian jurisdictions.

9.4.3.5 Engagement of Local Citizens and Stakeholders.

Regional planning ties in with the role of municipalities and citizens. In describing the fifth element of their framework, the CCA states that, "Public engagement is necessary not only to inform local residents of development but to receive their input on what values need to be protected to reflect their concerns and to earn their trust. Environmental data should be transparent and available to all stakeholders" (CCA, 2014, p. xix). The Nova Scotia Review has supported a significant level of public engagement, but, as discussed below, public engagement is required on a continuing basis as the province continues its deliberations.

The CCA seems to contemplate situations where hydraulic fracturing is already taking place, urging that, "public engagement ideally involves a dialogue between the promoter and residents (including their municipal, First Nations, and regional governments) that recognizes that these people have a legitimate stake in the management of the lands the industry wants to use. Successful public engagement starts early in the development process and continues until decommissioning" (CCA, 2014, p. 209). They contemplate that regulators can impose public engagement requirements, especially with regard to information sharing and good neighbor practices (CCA, 2014).

Given the clear division of public opinion on this topic in the Province (CRA, 2013) and the level of concern in Nova Scotia about hydraulic fracturing that was expressed by those who participated in our public consultation process, public engagement regarding hydraulic fracturing must be substantial and should not be left to occur only between citizens and individual oil and gas proponents. If Nova Scotia was ever to permit hydraulic fracturing in the future, various publics must play significant roles in developing the regulatory process and so determining the rules and terms by which hydraulic fracturing can (and cannot) take place.

There have been a number of studies in the United States about the public's role when a state is considering whether to permit hydraulic fracturing activities. In particular, they state that a public participation process which, "combines scientific analysis and broadly based deliberations is a promising avenue for developing robust and credible information about the risks and supporting governance systems that are responsible to public concerns …" (North, Stern, Webler & Field, 2014). The CCA also identifies an on-going role for the public in areas where hydraulic fracturing is occurring and recommends regulations to ensure that the public is part of the monitoring process, through influencing what is monitored, accessing monitoring results, and commenting on these results (CCA, 2014). In the United States, a guide that was requested by energy companies and created by the investor groups goes further, concluding that hydraulic fracturing activities require social license (that is, approval or acceptance by the local community). The guide states:

> Companies must be publicly transparent about managing their environmental footprint and social impacts and engage with key community stakeholders to earn and maintain their social license to operate. Transparency requires full disclosure of steps being taken to minimize risks, acknowledgement of challenges and failures, and clearly defined steps to continually improve operations (Gerken, 2013).

From this perspective, the social license to operate is thus a precondition and a continuing condition for hydraulic fracturing to occur in any given community. It is also how we interpret the proper application of a "precautionary approach," which implies (in this case) that the most important level at which risks and benefits must be adequately modelled and decisions understood is at the community/ecosystem level. We have styled this as the need for a "community permission to proceed."

There are several potential models that could be pursued to assess whether social license is present. A key question is identifying who ought to participate in any given decision. While some types of questions may lend themselves to a provincial referendum, for example, many are best asked and answered locally, because it is the local community who will bear many of the identified risks, burdens, and benefits associated with hydraulic fracturing. For example, the risk of surface water contamination through spills and hazards associated with increased trucking traffic, including heightened local air pollution. If this route was pursued, the public role ought to be specifically inscribed in legislation. Further input is needed to identify whether such decisions are best made by regional populations or by their proxies (e.g. municipal councils or other representative organizations). Regardless, such a model would require project proponents and the Province to make out their case and to support the regional decision-makers in developing expertise. In Chapter 5, we identified a spectrum of community engagement models and showed how processes that start with information sharing can ultimately enable collaborative and community empowering decision making.

The recent aquaculture review suggests a model that does not rely on community consent, but rather places considerable onus on projects proponents to generate and demonstrate community support to the decision maker. It is unclear whether such an approach would be acceptable to Nova Scotians for hydraulic fracturing decisions – if so, it is likely that they would expect the level of community support to be explicitly identified in a regulatory regime as pivotal for the decision as to whether to proceed.

Finally, the benefits of creating a clear role for the public in any dispute or complaint resolution have been recognized in a variety of fields. Such mechanisms need to be carefully designed and include not only a structured and accessible dialogue process that gives voice to the public, but also has clear mechanisms to support coming to a settled outcome, as well as follow-up mechanisms to monitor and enforce any outcome (Braithwaite, 2011). Of course, while some disputes can be resolved at this level, not all disputes or complaints ought to be taken through this route, especially those which may require immediate action or sanction. See also Chapter 11 for recommendations on how to develop the "community permission to proceed."

9.5 | **Concluding Comments**

Nova Scotians are asking complex and challenging questions about the role and value of regulations. The answers to their questions are not straight forward. This is, in part, because the effectiveness of a regulatory system turns on the adequacy of the knowledge base, the practical responsiveness of regulations to the knowledge base, and whether the regulatory system is sufficiently supported by resources and also enforced. It is essential that these questions continue to be asked.

ENDNOTES

1. Eg. National Energy Board Act Part VI (Oil and Gas) Regulations SOR/96-244.
2. For example, the EPA was recently directed by Congress to conduct a study into the potential impacts of hydraulic fracturing activities on drinking water. To this end, the EPA is currently pursuing 18 research projects on this matter. See "Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources: Progress Report" at www2.epa.gov/hfstudy-potential-impacts-hydraulic-fracturing-drinking water-resources-progress-report-0.
3. Canadian Environmental Assessment Act 2012, sections 5(1), Regulations Designating Physical Activities, SOR/2012-147
4. Canadian Environmental Protection Act, 1999 (S.C. 1999, c.33)
5. Constitution Act, 1867 s.109. All Lands, Mines, Minerals, and Royalties belonging to the several Provinces of Canada, Nova Scotia, and New Brunswick at the Union, and all Sums then due or payable for such Lands, Mines, Minerals, or Royalties, shall belong to the several Provinces of Ontario, Quebec, Nova Scotia, and New Brunswick in which the same are situate or arise, subject to any Trusts existing in respect thereof, and to any Interest other than that of the Province in the same.
6. Environment Act SNS 1994-95, c.1., s.67.
7. Environmental Goals and Sustainable Prosperity Act 2007, c.7, s 4(1). To be achieved by -"… having one of the cleanest and most sustainable environments in the world by 2020" (s 4(1)(a)) And "provid[ing] certainty to all sectors of the economy through the Government's economic development strategy… and establish clear environmental goals while improving the provinces economic performance to a level that is equal to or above the Canadian average by the year 2020" (s4(1)(b)).
8. Environmental Goals and Sustainable Prosperity Act SNS 2007, c.7,s. 3(2)(a), (c) and (d).
9. Environment Act SNS 1994-95, c.1.
10. Municipal Government Act SNS 1998. C.18, s. 171(2).
11. Municipal Government Act SNS 1998. C.18, s. 180.
12. Municipal Government Act SNS 1998. C.18, section 172. See also Spraytech v Town of Hudson 2001 SCC 40 where a by-law that prohibited the use of pesticides for cosmetic purposes was found to fall within municipalities' power to provide for the general welfare of its constituents.
13. Municipality of the County of Inverness, By-Law #45, Being a by-law to prohibit the use of chemical (slickwater) hydraulic fracturing, otherwise known as high volume hydraulic fracturing (HVHF) or fracking, to extract methane gas or petroleum. (May 6, 2013).
14. Petroleum Resources Act (R.S.N.S., c.342). See also Petroleum Resources Regulations (NS Re 147/2013), Onshore Petroleum Geophysical Exploration Regulations (NS Reg 24/2000), and the Onshore Petroleum Drilling Regulations (NS Reg 29/2001). Nova Scotia has processes in place for matters such as obtaining exploration rights. See "Regulatory Road Map: Onshore Petroleum Tenure in Nova Scotia" (Dec 2011).
15. Activities Designation Regulations, N.S. Reg. 47/95, s 5(1).
16. Importation of Hydraulic Fracturing Wastewater Prohibition Act 2013 (S.N.S. c. 36).
17. Hydraulic fracturing would likely be considered a "Designated Activity" under the Activities Designation Regulations (NS Reg 47/95), either pursuant to Section 17(2)(j), which applies to "a petroleum or natural gas exploration or recovery operation where it is necessary to inject water, brine, or chemical agents in order

to produce or enhance the recovery of petroleum or natural gas," or (k) "a petroleum or natural gas operation utilizing deep well injection for disposal of liquid production wastes." Pursuant to Part V of the Environment Act (and the Approval Procedure Regulations, NS Reg 48/95), all "designated activities" require ministerial approval. This process involves applications, approvals (with or without conditions), or denials. It does not require an environmental assessment.

18. See, for example, European Parliament Directorate General for Internal Policies, "Impacts of Shale Gas and Shale Oil Extraction on the Environment and Human Health" (2011) at page 78.

19. Wyoming Oil and Gas Conservation Commission, Rules and Regulations, ch 3, s.45.

20. Oil and Gas Activities Act [S.B.C. 2008, chapter 36], Drilling and Production Regulation B.C. Reg 282/2010 (Updated February, 2014); AER (Alberta Energy Regulator) (2012f) Bulletin 2012-25. Amendments to Directive 059: Well Drilling and Completion Data Filing Requirements in Support of Disclosure of Hydraulic Fracturing Fluid Information.

21. British Columbia Drilling and Production Regulation, BC Reg 282/2010, s. 34(4)(b) and 34(6).

22. See, for example, government audits such as the Report of the Commission of the Environment and Sustainable Development, December 2011, Chapter 3, Enforcing the Canadian Environmental Protection Act, 1999, as well as audits by NGOs such as Global Forest Watch "Environmental Incidents in Northeastern Alberta's Bitumen Sands Region, 1996-2012" (2013-07-23). Online at www.globalforestwatch ca/files/publications/20130723A_Envir_Incidents_July-22-2013.pdf

23. See Environmental Protection Agency Superfund "Cleaning up the Nation's Hazardous Waste Sites" at www.epa.gov/superfund/index.htm.

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CHAPTER 10

Aboriginal, Treaty, and Statutory Rights of the Mi'kmaq

Constance MacIntosh

10.0 | **Chapter Summary**

This chapter builds on, and extends, the analysis in Chapter 9 on regulatory issues. We start from the established fact that the Mi'kmaq people possess robust treaty rights, as well as Aboriginal rights in Nova Scotia. These rights have considerable consequences for provincial deliberations over hydraulic fracturing, as the Province is constitutionally obliged to honour these rights. Recent jurisprudence has created uncertainty as to whether the province has lawful authority to take actions that infringe upon the Mi'kmaq's treaty rights without consent. Regardless, we note that if the possibility of hydraulic fracturing was ever to be pursued in Nova Scotia, the Province would need to engage in a consultation process, so that it can understand how treaty rights could be affected by activities associated with the activity. The province is also constitutionally required to respect the Mi'kmaq's Aboriginal rights and to consult with the Mi'kmaq, so as to understand those inherent rights. In each case, the province is required to seek to honour and accommodate those rights. In some circumstances, the Province may be able to infringe upon the Mi'kmaq's Aboriginal rights but only if a strict justification test is met. If the Mi'kmaq people possess Aboriginal title rights over portions of Nova Scotia where there is subsurface unconventional gas, unless an exceptional justification test is met, the Mi'kmaq have the right to decide whether that gas will be exploited. Regardless, they have the right to receive any economic benefits arising from the land. Similarly, if there is unconventional gas located below reserve land, we observe that hydraulic fracturing can likely only take place on their reserves with their full consent.

10.1 | **Introduction**

Last year, the Maritimes witnessed extensive protests by Mi'kmaq people and others in New Brunswick, in response to New Brunswick's decision to allow seismic testing for the purpose of locating unconventional gas. Members of the Elsipogtog First Nation asserted that this decision had the effect of unlawfully authorizing exploratory activity for hydraulic fracturing purposes on their traditional territory (Schwartz & Gollom, 2013). The Elsipogtog First Nation's claim was that the Province failed to properly consult with them about the potential impacts of hydraulic fracturing on their Aboriginal and treaty rights. In late June, 18 individuals, including several Mi'kmaq people, launched a lawsuit against the government of New Brunswick. They are asking the court to issue an injunction prohibiting New Brunswick from issuing hydraulic fracturing exploration permits, as well as other damages. Whatever the outcome of these various incidents and the lawsuit, the relationship between the Aboriginal and treaty rights of Mi'kmaq people and hydraulic fracturing continues to be in the headlines.

Nova Scotia is also the home of many Mi'kmaq people. The government of Nova Scotia notes that when the Europeans and Mi'kmaq first encountered one another, the Mi'kmaq's traditional territory, "stretched from the southern portions of the Gaspé Peninsula eastward to most of modern-day New Brunswick and all of Nova Scotia and Prince Edward Island" (Nova Scotia Office of Aboriginal Affairs, 2011). There are currently 13 Mi'kmaq communities here that are oriented around reserves, the two largest being Indian Brook and Eskasoni. There are also Mi'kmaq people who live in communities off reserve, who are similarly spread across the Province. The 2006 federal census indicated that approximately 24,000 people in Nova Scotia self-identified as Aboriginal, with most self-identifying as Mi'kmaq. As discussed in this chapter, the Mi'kmaq people have constitutionally protected rights, many of which are formally guaranteed through historic treaties.

During our review, the Chair of our review panel, Dr. Wheeler; Panel Member, Kevin Christmas; Aboriginal Outreach Worker, Debra Ginnish; and Project Coordinator, Margo MacGregor, were invited to meet with Chief Paul Prosper, Assembly of Nova Scotia Mi'kmaq Chiefs (ANSMC), Lead of the Energy Portfolio and the Assembly's Hydraulic Fracturing Committee. The ANSMC comprises the 13 Mi'kmaq Chiefs of Nova Scotia and is the highest level of decision making for the Mi'kmaq of Nova Scotia (Kwilmu'kw Maw-klusuaqn Mi'kmaq Rights Initiative, 2014).

Committee members included Elder Albert Marshall, Unama'ki Institute of Natural Resources; Diana Campbell, Union of Nova Scotia Indians; Jim Walsh, Confederacy of Mainland Mi'kmaq; Twila Gaudet, Kwilmu'kw Maw-klusuaqn Negotiations Office; and Michael Cox, Kwilmu'kw Maw-klusuaqn Negotiations Office, who presented the Mi'kmaq view on hydraulic fracturing, with Chief Prosper introducing the position of the ANSMC. In each case, the Mi'kmaq representatives were clear that the Mi'kmaq are opposed to all activities associated with hydraulic fracturing taking place on their traditional lands, and their priority is to protect the lands and the waters. Chief Prosper was clear that the Mi'kmaq of Nova Scotia have an established consultation process, and it is the expectation of the ANSMC to have full and meaningful consultation prior to any decisions being made by the Province of Nova Scotia on hydraulic fracturing.

The Native Council of Nova Scotia (NCNS) also made direct representations to the panel. The NCNS represents the voice of the organized communities of Mi'kmaq and Aboriginal people, who continue to live on their traditional ancestral homelands in Nova Scotia off reserves.

They too raised concerns about impacts to water and biodiversity and were explicit that their legal rights had to be respected. After holding a number of community meetings, they requested that the following statement be included in the panel's report:

> "The community of Mi'kmaq/Aboriginal peoples continuing on traditional ancestral homelands organized as the Native Council of Nova Scotia oppose the practice of hydraulic fracturing for oil and gas in Nova Scotia."

This is a strong and clear statement.

These positions are not explicitly commented upon in this chapter, except to note that they alert the Province and others as to the current position of key representative Mi'kmaq political/governance organizations. The follow up to the review process will include more Aboriginal outreach activities and meetings, which will continue in the coming months based on the content of this report and requests that we receive from leaders, elders, and communities. Nonetheless, in the discussion of the law that follows, it should be readily apparent that the positions described above have direct consequences for decisions about hydraulic fracturing in Nova Scotia.

In this chapter, we discuss the likely interplay between some of the Aboriginal, treaty, and statutory rights of the Mi'kmaq in Nova Scotia and hydraulic fracturing. The discussion is largely based on decisions made by the Supreme Court of Canada about the legal rights of the Mi'kmaq and other Aboriginal peoples in Canada and about the consequences of these rights for provincial and federal governments. We focus on describing what is deemed to be settled law – or at least, settled in the eyes of Canadian courts, for the moment. These decisions are sometimes controversial, in part, because they do not always reflect international law on the rights of Indigenous peoples and often only draw indirectly on Indigenous law as a source of authority.

Another important context is that Canada, the Mi'kmaq, and Nova Scotia are in a negotiation process to address outstanding questions about Mi'kmaq rights. The goal is to enter into a modern day treaty. It is likely that such an agreement will include explicit terms about resource conservation, management, and ownership, including the treatment of subsurface minerals such as unconventional gas and oil. It is not clear when an agreement will be concluded.

We start by considering some of the Aboriginal and treaty rights that Mi'kmaq people have, or likely have, on traditional territory and the potential interplay of these rights with provincial decision making and the provincial and federal government's duty to consult. We then consider the legal implications if the Mi'kmaq people have a specific Aboriginal right, called Aboriginal title, over portions of Nova Scotia. Next, we examine the situation with respect to Indian reserves, for which there is a developed (but out-dated) oil and gas regulatory regime, which would be relied upon if Mi'kmaq communities decide they want to engage in oil and gas development activities on reserve lands. There is, then, a brief description of how consultation is currently carried out in Nova Scotia and the role of project proponents, concluding by briefly canvassing the role of energy regulators in overseeing or assessing the adequacy of consultation.

This discussion is illustrative, not exhaustive. For example, it does not consider how the Aboriginal rights of the Mi'kmaq people would play into a provincial environmental assessment process, which could be triggered if a company sought permits to withdraw large quantities of water to use in a hydraulic fracturing operation. It is also illustrative because it largely refers to rights that have already been recognized by Canadian courts and not rights that may be recognized in the future, or, for example, the full implications of United Nations Declaration of the Rights of Indigenous People (UNDRIP) for Canada. A final caveat is that this report is intended to provide a general description of the law and is not a formal legal opinion. Most importantly, neither this chapter nor our review process form part of a formal consultation process with Mi'kmaq people.

10.2 | Aboriginal and Treaty Rights and Traditional Lands

10.2.1 What are Aboriginal and Treaty Rights?

In Canadian law, the term "Aboriginal rights," refers to the inherent rights of Aboriginal peoples. These rights are described as inherent or "pre-existing" because they have been held and exercised by Aboriginal people since before European contact. They were not bestowed upon Aboriginal peoples by the British or Canadian government or otherwise derived from an external source. The Supreme Court of Canada explains that these rights exist and persist because, "Canada's Aboriginal peoples were here when Europeans came and were never conquered. Many bands reconciled their [pre-existing] claims with the sovereignty of the Crown through negotiated treaties. Others, notably in British Columbia, have yet to do so."

The Supreme Court of Canada's recognition that Aboriginal peoples possess rights which were not displaced merely by the arrival of settlers and the creation of colonial governments, is consistent with international legal instruments including the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP).
Canada endorsed UNDRIP in 2010.

In Canadian court cases, Aboriginal rights are identified as practices or traditions integral to Aboriginal societies and which have a level of continuity with historic practices prior to contact with Europeans. One distinct type of Aboriginal right, called Aboriginal title, is linked to the historic use and occupation of land. Aboriginal title is discussed in section 10.3. The specific scope and form of Aboriginal rights is defined both with reference to Indigenous law and Canadian common law.

Aboriginal rights are held by communities or collectives. As a result, they are also sometimes framed as human rights. Canadian courts are beginning to draw on UNDRIP to understand the consequences of this for Canada.

The term "treaty rights," usually refers to historic promises and obligations that Aboriginal peoples and Britain or Canada, formally enshrined in treaties prior to 1930. It is also used to refer to the rights arising under modern day treaties, such as the Nisga'a Agreement, which came into effect in one portion of British Columbia in 2000. Treaties reflect negotiated agreements about how Aboriginal and non-Aboriginal peoples will live together. While it was the British who signed many of the historic treaties and not the Canadian government, when Canada separated from Britain, it inherited legal responsibility for honouring all the treaties.

In 1982, Aboriginal rights and treaty rights became protected under section 35 of Canada's Constitution Act, 1982. Section 35(1) states that the, "existing Aboriginal and treaty rights of the aboriginal people of Canada are hereby recognized and affirmed." Constitutional recognition has substantial consequences. It requires that the federal and provincial governments act in accordance with honouring these rights. In the Haida case, the Supreme Court of Canada provides this description of what section 35 requires:

> Section 35 represents a promise of rights recognition, and "[i]t is always assumed that the Crown intends to fulfill its promises". This promise is realized and sovereignty claims reconciled through the process of honourable negotiation. It is a corollary of s.35 that the Crown act honourably in defining the rights it guarantees and in reconciling them with other rights and interests. This, in turn, implies a duty to consult and, if appropriate, accommodate.

Canadian courts have concluded that this constitutional protection results in significant obligations but does not create an absolute shield. In the 1990 Sparrow case, the Supreme Court of Canada determined that these rights can be infringed upon by the state in narrow circumstances.

In particular, an infringement can be lawful if it is made in circumstances that are consistent with the Crown having honoured the protected rights. In practical terms, this means that the reason for the infringement must reflect a pressing and substantial government objective, and the government must have followed a decision-making process where they sought to understand, minimize, and avoid any potential adverse impacts by accommodating the right. As discussed below, according to the 2004 Haida case, a key aspect of determining whether this test is met involves considering the nature and extent of government consultation with the affected Aboriginal people and how the information that was gathered through the consultation process guided the decision-making process. Both Aboriginal and treaty rights also have internal limits. For example, treaty or Aboriginal rights to hunt do not include a right to hunt unsafely, with thresholds for what constitutes safe hunting changing with hunting technologies and circumstances. Such limits may also reflect the laws or traditions of the Aboriginal peoples in question.

There are many important differences between Aboriginal rights, which derive from historic practices and treaty rights. One difference is that courts have explicitly concluded that both the federal and provincial governments may have authority in certain circumstances to make decisions which ultimately infringe upon Aboriginal rights and can pass regulations that reflect how rights are defined.

However, the situation for treaty rights has recently become less clear. The Indian Act prohibits provincial governments from infringing on treaty rights.

As a result, unless the treaty says otherwise, courts have concluded that provinces have at most, only the right to make decisions that place "a modest burden" or impose an "insignificant interference" on Treaty rights.

However, 2014 Supreme Court of Canada decisions in Tsilhqot'in and Grassey Narrows may call this conclusion into question. In Grassey Narrows, the treaty in question indicated the Crown had the right to take up land for various purposes and that this would result in diminishing the area over which the Indigenous signatories could practice rights to hunt. The court concluded that as Ontario had jurisdiction over land and resources – as against the federal government – the Province had the authority to act on the Crown's treaty right to take up land and thereby make decisions that infringe on hunting rights, as long as the infringement was consistent with Crown obligations under section 35. Unfortunately, the court did not discuss the interplay between treaties and the statutory shield which is found in the Indian Act.

In all cases, the practices or promises are not "frozen" in their historic form, but rather evolve over time in response to changing circumstances and technologies to stay relevant.

This is why, for instance, a historic practice of trading fish, where historic storage practices may have been limited to salting or smoking the fish, does, "not exclude preparation and sale of the frozen product when the technology became available"
and why fishing with a spear, for instance, would find its contemporary expression in fishing with modern gear. The fact that Aboriginal rights evolve is consistent with Canada's constitutional traditions (Borrows, 2012). Our constitution was described by the Supreme Court of Canada as a "living tree which, by way of progressive interpretation, accommodates and addresses the realities of modern life."
Aboriginal rights also support ancillary rights to ensure they can be exercised meaningfully.

A final, general point about Aboriginal rights, is that some have been affirmed outside of lawsuits. For example, the Canadian government recognized in 1973, that Aboriginal peoples have a right to self-govern and subsequently affirmed that they recognize this right as having constitutional protection under section 35. The existence of this right is one of the reasons the federal government seeks to conclude modern treaties with Aboriginal peoples, so that the right of Aboriginal peoples to self-govern can be better understood,
vis-à-vis its interplay with provincial and federal governance powers. A 2010 Federal Government position paper states:

> The Government of Canada recognizes the inherent right of self-government as an existing Aboriginal right under section 35 of the Constitution Act, 1982. It recognizes, as well, that the inherent right may find expression in treaties and in the context of the Crown's relationship with treaty First Nations. Recognition of the inherent right is based on the view that the Aboriginal peoples of Canada have the right to govern themselves in relation to matters that are internal to their communities, integral to their unique cultures, identities, traditions, languages and institutions, and with respect to their special relationship to their land and their resources.
>
> (Aboriginal Affairs and Northern Development Canada, 2010a).

While Indigenous peoples and international law define the right to self-govern more broadly and through the language of a right to self-determination, in this statement the Federal government is clear that it agrees that Aboriginal peoples' inherent right to self-govern extends to matters affecting their relationship with land and resources.

10.2.2 What Mi'kmaq Aboriginal and Treaty Rights could be affected by Hydraulic Fracturing?

The Mi'kmaq have many Aboriginal and treaty rights that could be impacted by hydraulic fracturing activities, if those activities took place on, or near, the traditional territory of the Mi'kmaq people. The law requires that their rights be honoured. The discussion below first considers their treaty rights, and then, their likely Aboriginal rights. Aboriginal title rights are discussed in section 10.3.

The treaty situation in Nova Scotia is unique. It is marked by a series of Peace and Friendship Treaties entered into during the 1700s. The enforceability of two of the historic Peace and Friendship Treaties has been litigated: the Supreme Court of Canada affirmed that the agreements are legally binding and enforceable.

These treaties were motivated by mutual interests in cooperation and the Mi'kmaq continuing to have self-sufficient communities, as well as Britain's strategic military interests. Their central promises oblige the British signatories to not interfere with the Mi'kmaq in their hunting, trapping, and fishing activities and to support a certain amount of commercial trade in the products of these activities, in exchange for which the Mi'kmaq agreed to a political alliance. The treaty text extracted in the box illustrates some of the promises which the British asked the Mi'kmaq to make. This content is strikingly different from the promises and obligations that were recorded in written versions of the treaties signed in the west. Many western treaties include text which describes relinquishing existing rights to land or resources in return for the Crown agreeing to provide agricultural equipment or preserve certain rights to hunt or trap. These statements of relinquishment have prompted many lawsuits over whether the written text of the western treaties accurately reflected the promises that were exchanged. However, in Nova Scotia, the situation is not controversial. The Canadian government has acknowledged that, "the Peace and Friendship Treaties did not involve First Nations surrendering rights to the lands and resources they had traditionally used and occupied" (Aboriginal Affairs and Northern Development Canada, 2010b).

Another example is that many of the treaties signed in the west include written provisions that state that the territory over which hunting and other activities could take place would be diminished over time, as the government took up tracts of land for public purposes including mining.

The Peace and Friendship Treaties contain no such written provisions. They do not contemplate or authorize reductions of the territory over which treaty rights would be exercised for any purpose, much less for mining.

Given that the treaties do not involve relinquishing rights, Mi'kmaq people have both treaty rights and also continue to have Aboriginal rights through their traditional (or historic) territory (Reid & Hickman, 2007). These Aboriginal rights may include Aboriginal title, a unique sort of Aboriginal right that is discussed in section 10.3.

Court cases confirm the nature of at least some of the Mi'kmaq's protected treaty rights. In particular, courts concluded that treaties from the 1750s and 1760s support a right to engage in a commercial fishery so as to earn a moderate livelihood and support a right to hunt.

The Peace and Friendship treaties also support the right to sell whatever the Mi'kmaq gathered. All of these protected activities could be affected by hydraulic fracturing activities if hydraulic fracturing either directly or indirectly, affected the wildlife, fish, or plants that the Mi'kmaq depend upon and for which they have a treaty right to access. A direct impact could arise if an access road cut through a berry-picking area. An indirect impact could occur if an increase in noise due to hydraulic fracturing activity resulted in game animals fleeing the area. There could be both direct and indirect impacts on Mi'kmaq rights if hydraulic fracturing resulted in waters or other aspects of the ecosystem being compromised.

Canadian courts also recognize that the Mi'kmaq possess Aboriginal rights independent of their treaty rights. For example, in certain instances, Mi'kmaq people have the right to harvest wood from Crown land for domestic purposes such as home building. Hunting rights have also been independently affirmed.

Most of the conflicts which have gone to court centered on resource use and usually started as a prosecution of a regulatory violation (e.g. hunting out of season). However, there are grounds to assume that Mi'kmaq rights extend more broadly and certainly embrace whatever is necessary to keep their rights meaningful. For example, an Aboriginal right to hunt that was promised in a treaty in Quebec was found to support an ancillary right to harvest trees to build a temporary hunting shelter.

Treaty rights to hunt in the north were found to imply a right to hunt in an area that was reasonably accessible and to not have animal corridors unduly disrupted. Thus, the health of the animals that are harvested by the rights holder, as well as the integrity of the ecosystem which is necessary to sustain the animals, is relevant when considering potential impacts. There are also likely areas that hold special cultural or spiritual relevance for Mi'kmaq peoples. The continuing use or protection of such areas may be shielded by section 35. There are also calls for recognizing a more general right to the improvement of health and well-being, as recognized by UNDRIP. As noted above, the federal policy on Aboriginal self-government recognizes a right of Aboriginal people to self-govern their relationship with their land and their resources.

Overall, this indicates that activities associated with hydraulic fracturing could adversely impact Mi'kmaq treaty and Aboriginal rights, either directly or indirectly.

Given that the Mi'kmaq never relinquished any rights, it is worth considering whether they might have a claim to exploit subsurface oil and gas deposits. There is no case on point, however, the Supreme Court of Canada has made comments about the limits of how historic practices evolve into contemporary ones. They wrote, "A 'gathering right' to berries ...would not, for example, 'evolve' into a right to 'gather' natural gas from within the traditional territory. The surface gathering of copper from the Coppermine River ...would not, I think, support an 'Aboriginal right' to exploit deep shaft diamond mining on the same territory..."

Absent evidence of analogous historic activities, while Mi'kmaq people have Aboriginal rights that impact on how decisions must be made on their traditional territories, it is unlikely that the Mi'kmaq have an Aboriginal right to exploit subsurface gas on traditional territory. However, as discussed in previous sections, the situation changes if Mi'kmaq people have Aboriginal title rights or if the unconventional gas is located under Mi'kmaq Indian reserve lands.

10.2.3 What are some of the Implications of Aboriginal and Treaty Rights on Mi'kmaq Traditional Lands for Provincial Regulation?

As noted above, the Mi'kmaq possess many Aboriginal and treaty rights, which could be affected by hydraulic fracturing activity and their traditional territory historically covered all of Nova Scotia. There has been considerable litigation about what it means for governments to be constitutionally, obliged to "respect and affirm" Aboriginal and treaty rights. One clear finding, arising from the 2004 Haida decision, is that provincial and federal governments are under a fiduciary duty to consult with Aboriginal people prior to making any decision that the government knows, or ought to know, could adversely affect their proven or claimed constitutionally protected rights and must seek to accommodate those rights.

This duty to consult is grounded in the honour of the Crown, a phrase which refers, in part, to a specific obligation that rests on the federal and provincial governments to pursue a course of reconciliation with Aboriginal peoples.

As a result, provincial and federal powers to authorize hydraulic fracturing must be exercised in a way that is consistent with honouring section 35 rights.

Several sorts of decisions trigger this obligation. They include decisions that are authorized under statute, such as responding to a request to issue a license or permit. For example, a duty to consult could arise if a hydraulic fracturing company asked the Province to grant them a permit to withdraw water from a lake where Mi'kmaq people have a right to fish. It could arise if the Province is asked to issue an exploration permit, depending on the character of the exploration activities and the claimed or known rights that may be present.

The duty to consult also arises when a provincial or federal government is making high-level management decisions or contemplating structural changes to the management of a resource, where these decisions may ultimately have an adverse impact on Aboriginal rights, "even if later opportunities for consultation exist in relation to specific actions."

For example, the Federal Court of Appeal affirmed that the duty to consult over the Mackenzie Gas Pipeline materialized when the federal government contemplated formulating a "Cooperation Plan" which would coordinate environmental and regulatory processes. Although the plan itself did not grant any permissions or authorize activity, it established, "the means by which a whole process will be managed," where that process would likely engage with the rights of First Nations.

As a result, it is probable that if Nova Scotia decided to create a regime to oversee hydraulic fracturing activities, the Province would be required to consult with the Mi'kmaq people.

In all cases, the depth and extent of the duty to consult varies and is context and fact dependent. In particular, it turns on the answers to two key questions. The first is the strength of the claim that a right is present. This is a matter of evidence arising from sources, including oral history, archeology, historic documents, Indigenous laws, and treaties. If a right is present, or likely present, the next question is whether, and to what extent, the right would likely be impaired if the government approved the requested activity. The stronger the likelihood that an Aboriginal right is present and the more significant the likely impact, the greater the obligation on the government to consult with the Aboriginal people in question.

In practical terms, where the proposed activity is not likely to have a serious impact, then the duty to consult may be fulfilled by the government providing information to the affected First Nation and discussing that information.

Where the right has already been recognized – which is the case for treaty rights and some of the Mi'kmaq's Aboriginal rights – then the depth of consultation can be extensive, especially where there is potential for a more serious adverse impact. In such cases, the consultation process may extend to meetings, commissioning studies, submissions and discussion of those submissions, and attempts to accommodate and compensate, and the provincial or federal government must be open to declining to approve the proposed activity. There must, however, be grounds to conclude that there is likely a causal connection between what would happen if the proposal is approved and the potential adverse impact. A finding that there will be habitat destruction – as may occur if an access road is built – may be sufficient to determine that hunting rights will be affected and, thus, trigger a consultation process.

In some instances, following a consultation process, the Supreme Court of Canada has concluded that it is constitutional for the federal government to make decisions that adversely affect Aboriginal and treaty rights. However, as noted above, the Indian Act states that provincial governments cannot regulate in a manner that infringes upon treaty rights.

According to the 2006 Morris decision, this means a province can only place "a modest burden" or impose an 'insignificant interference' on treaty rights. If Morris still determines the relationship between treaty rights and section 88 of the Indian Act, then if Nova Scotia were considering approving hydraulic fracturing activities that could adversely infringe on the Mi'kmaq's established treaty rights to hunt and fish, it is likely that the Province would have to engage in deep consultation to understand the nature of the Treaty right and magnitude of any potential impact and make decisions in a way that avoids anything more than an "insignificant interference" with treaty rights without permission from the Mi'kmaq. However, if the 2014 Supreme Court of Canada decision in Grassey Narrow's findings on treaty rights apply more broadly, and, in particular, beyond situations where the question is which level of Crown can exercise Crown rights to take up land under a treaty, then Nova Scotia would still be required to respect the Mi'kmaq's treaty rights but, like the federal government, could infringe upon those rights as long as it does so in a manner that is consistent with upholding the honour of the Crown.

Lower courts have commented that the duty to consult is not engaged when the government contemplates enacting legislation. The Supreme Court of Canada expressly avoided commenting on whether this conclusion was correct. It is, thus, legally uncertain whether Nova Scotia would be constitutionally obliged to consult with the Mi'kmaq if it chooses to draft legislation to regulate hydraulic fracturing. However, in practical terms, if the government fails to consult and the legislation creates an infringement in practice, then the legislation will likely fall on a constitutional challenge.

This obviously results in a very complex regulatory and decision-making process for the province of Nova Scotia.

10.3 | **Aboriginal Title and Oil and Gas Regulation**

There is a unique type of Aboriginal right called Aboriginal title. It is discussed separately in this chapter because the consequences of Aboriginal title being present are profound. Aboriginal title derives from traditional occupation and use of lands and reflects the fact that "Aboriginal land rights survived European settlement and remain valid unless extinguished by treaty or otherwise."

As the Peace and Friendship treaties do not surrender rights to land, the Mi'kmaq people continue to hold any Aboriginal title rights, which they may possess in their traditional territory. In a 2014 decision regarding a First Nation in British Columbia, the Supreme Court of Canada agreed that the Tshilqot'in First Nation possessed Aboriginal title rights to portions of their traditional territory. The court was explicit that the rights of Aboriginal title holders include:

- The right to decide how the land will be used;
- The right of enjoyment and occupancy of the land;
- The right to possess the land;
- The right to pro-actively use and manage the land; and
- The right to "profit from its economic benefits."

The Court was also explicit that title has significant governance aspects and that provincial or federal governments who seek to use Aboriginal title land will usually be required to obtain the consent of the Aboriginal title holders. Aboriginal title has one important restriction, which is that the title holders cannot develop the land in a way that would "substantially deprive future generations of the benefits of the land."

If the Mi'kmaq possess Aboriginal title rights in areas where unconventional gas is located, this could have considerable consequences for hydraulic fracturing activities in Nova Scotia.

The test for proving title rests on asking whether the Aboriginal people in question occupied the land in a sufficiently regular and exclusive fashion prior to the assertion of Crown sovereignty in the area. The threshold for sufficient occupation is defined both by common law perspectives on occupation as well as by Aboriginal perspectives, as illustrated by their laws, practices, and traditions. It is also responsive to the way of life of the Aboriginal people, "including those who were nomadic or semi-nomadic." The Supreme Court of Canada noted that, "regular use of territories for hunting, fishing, trapping, and foraging," may be sufficient to ground a claim to Aboriginal title.

In cases arising in British Columbia and Alberta, the Supreme Court of Canada has confirmed that, when present, Aboriginal title rights include ownership of mineral rights. This extends to the right to exploit underground oil and gas subject to the inherent limit noted above (Wright & White, 2012). There is no reason to think this conclusion would not hold true in any other part of Canada where Aboriginal title is present, including Nova Scotia.

In the 2014 Tshilqot'in decision, the Supreme Court of Canada considered what would happen if a province wanted to do something on Aboriginal title lands that infringed upon the rights of the First Nation. The Court found that the province must seek the consent of the First Nation through a consultation process. If the First Nation ultimately declines their consent, then the province can only proceed if a complex justification test is met. In brief, the infringement must be for a compelling and substantial objective that serves, "the broader public goal ...of reconciliation."

To this end, it must be "consistent with the Crown's fiduciary duties towards Aboriginal people," which means that incursions on Aboriginal title cannot be justified if, "they would substantially deprive future generations of the benefits of the land," and, in any event, will not be justified unless the incursion is necessary and the benefits will outweigh any adverse effects on the Aboriginal interests.

In the Tshilhqot'in case, the court found that provincial forestry laws that granted interests in Crown timber could not grant interests in timber on Aboriginal title lands. The court noted that provinces could amend legislation to refer to granting interests in resources located on Aboriginal title lands but that such legislation (and decisions taken under such legislation) would have to pass the justification tests described above. Provincial oil and gas laws would be similarly constrained.

The Supreme Court of Canada determined one title claim involving the Mi'kmaq of Nova Scotia and denied the claim. They found that there was inadequate evidence to prove that the Mi'kmaq used and occupied the tract of land in dispute to the required degree. In particular, the Court concluded that the Mi'kmaq had only used the land that was at issue seasonally and that more consistent use was required. At the trial level, the judge noted that the Mi'kmaq could likely make out an Aboriginal title claim in the areas close to their communities. There may be evidence of the required level of occupation and control in other parts of Nova Scotia. There is a growing scholarship on Mi'kmaq law (Battiste, 2008) that, along with testimony from elders and others, will be relevant for understanding this issue.

The Supreme Court of Canada observed in the Tsilhqot'in case that if Aboriginal title rights are claimed, but have not been confirmed through an agreement or court order, that provincial land use laws would apply. Accordingly, in Nova Scotia, provincial laws continue to operate in any areas the Mi'kmaq have claimed as Aboriginal title. The honour of the Crown, nonetheless, requires the Province to engage in a good faith consultation process as is described above. In practice, this consultation process may in fact require consent, or risk uncertainty.

This is because the Court noted that if the provincial or federal government "begins a project without consent prior to Aboriginal title being established, it may be required to cancel the project upon establishment of the title if continuation of the project would be unjustifiably infringing." Thus, in any instance where the claim to Aboriginal title may be made out, if the province proceeds without consent, it risks violating its constitutional obligations, incurring liability, and creating commercial uncertainty, vis-à-vis any rights it grants to third parties, such as industry proponents. The Court makes a similar comment about provincial legislation being rendered inapplicable upon title being established, if the legislation unjustifiably infringes Aboriginal title. The potential Aboriginal title rights of the Mi'kmaq people would need to be addressed in any provincial decision-making process regarding hydraulic fracturing.

10.4 | **Oil and Gas Development on Reserve Lands**

The above sections discuss the sorts of rights that arise, or may arise, on Mi'kmaq traditional territory and their interplay with hydraulic fracturing. While Mi'kmaq people live in communities that are located across the Province, some Mi'kmaq are part of communities which have "Indian reserve" lands. Indian reserves are tracts of land that were specifically put aside for First Nation communities. Under Canada's 1867 Constitution, these lands are under federal jurisdiction, despite being located within provinces.

In Nova Scotia, there are 13 Mi'kmaq communities which have reserve land. Several of these communities possess multiple reserves, and there are over 40 Indian reserves in the Province. While some reserves are very small, there are several that are over 500 hectares in size, with one of the largest reserves being Indian Brook, which is over 1,000 hectares. Acadia First Nation's reserve lands are near Yarmouth, while Membertou First Nation's reserve lands are proximate to Sydney. The current negotiations to establish a contemporary treaty between Canada, Nova Scotia, and the Mi'kmaq, may result in Canada and Nova Scotia recognizing that the Mi'kmaq possess greater rights over a specific and expanded land base. In that case, the parties will have to decide how to recognize or designate that land. One option would be to designate the land as reserve land. However, the negotiating parties may agree to recognize the Mi'kmaq's land rights in a different fashion, especially given the recent Supreme Court of Canada decision on Aboriginal title.

As Indian reserve lands are considered to fall under federal jurisdiction, provincial laws about land and resources, including oil and gas activities, presumptively do not apply on reserve land and federal law does (Banks, 1998). The federal government enacted a regime for oil and gas development on reserve lands (the Indian Oil and Gas Act 1985 and the Indian Oil and Gas Regulations 1985), overseen by Indian Oil and Gas Canada. This regime is outdated on a number of regulatory fronts, and a new act was passed in 2009

It received strong reviews for its potential to support First Nation economic development and for explicitly recognizing that First Nations' consent is required for oil and gas activity on reserve land (Wright & White, 2012). However, this new act does not come into force until new regulations are also passed. As of July, 2014, this has not happened (Indian Oil and Gas Canada, 2014a), but the federal government anticipates that the regulations will soon start being phased in (Indian Oil and Gas Canada, 2014b). Regardless of the legislation not being in place, it seems extremely unlikely that hydraulic fracturing could take place on reserve land without the explicit consent of the affected First Nations. Reproduced with permission Nova Scotia Office of Aboriginal Affairs (2013)

Pursuant to the 1985 Indian Oil and Gas Act, the federal government oversees and gives final approval for the terms for leases, permits, licenses, and royalties in consultation with the affected First Nation. Given that under the Indian Act, interests in reserve land cannot be alienated without Band consent and given the common law, it seems improbable that such authorizations could be granted over the objections of an affected First Nation.[1] The regulations include comprehensive consultation guidelines. In terms of operations, the regulations bind oil and gas operators to comply with provincial laws for environmental protection and oil and gas exploration, unless those laws conflict with the federal regime or unless the Minister agrees to grant an exemption.[2]

As Nova Scotia's oil and gas laws are general in nature, the importation of these laws does not create a hydraulic fracturing-specific regulatory regime for reserve lands. However, there are federal laws and practices which mandate that reserve land be scrutinized for impacts, and there are also specific protocols for hydraulic fracturing activities on reserve land.

First, unlike provincial lands, a federal decision to consider authorizing hydraulic fracturing on Indian reserve land automatically triggers an environmental assessment.[3] The assessment process explicitly requires consultation with the affected First Nation and would consider any environmental changes, as well as any effect which a change in the environment may have on a variety of factors, including:

(a) Health and socio-economic conditions;

(b) Physical and cultural heritage; and

(c) Current use of lands and resources for traditional purposes by Aboriginal persons.[4]

The scope of an environmental assessment,over potential impacts to reserve lands, will likely overlap with aspects of the informational needs required for the federal government to fulfil its constitutional duty to consult First Nations with regard to impacts on their traditional territories. This will likely include and extend well beyond reserve land. The process may not, however, fulfill the Crown's obligations to consult, because the legislation does not explicitly include a mandate to assess the full range of known and potential Aboriginal and Treaty rights.

Another difference between provincial lands in Nova Scotia and Indian reserve lands, is that specific protocols for hydraulic fracturing have been developed, "to safeguard both the environment on reserve, as well as protect First Nation citizens from adverse effects of oil and gas activities on reserve lands"

(Indian Oil and Gas Canada, 2013). Indian Oil and Gas Canada (IOGC) requires baseline water testing for all drinking water wells within 500 meters of a proposed hydraulic fracturing well. Also, the hydraulic fracturing applicant is required to, "demonstrate that the environment will be protected" (Indian Oil and Gas Canada, 2013). Although the threshold for meeting this requirement is not clear, it is evident that Mi'kmaq reserve residents benefit from certain legislated protections in the face of hydraulic fracturing activities. These protections are not currently legally mandated for other communities in Nova Scotia.[5]

There are two other pieces of legislation that may be relevant. First, the First Nations Land Management Act[6] (FNLMA) expressly recognizes the right of First Nations to develop comprehensive land codes, including the granting of interests and licenses, managing natural resources, and receiving revenue. This is an optional regime with two phases. Membertou First Nation completed the first step for opting in to this regime by signing a framework agreement. Membertou's rights will be realized once it completes a series of steps, including enacting a land use code and bringing it into effect. Other First Nations in Nova Scotia may opt in to this regime in the future, but entry is currently limited by a federal approvals process and the availability of federal funding.

A final piece of reserve-specific legislation is the First Nations Oil and Gas and Moneys Management Act (FNOGMMA). It recognizes the right of First Nations to directly manage oil and gas resources, and revenues, on reserve lands. If opted into, then the federal Indian Oil and Gas Act and the FNLMA cease to apply, and the First Nation effectively ousts federal control. However, this legislation has only been opted into by one First Nation in Canada, the Kawacatoose First Nation in Saskatchewan. As of May, 2014, no First Nation in Nova Scotia has opted in (CBC News, 2014).

Both the legislative regimes and the common law support a consultation process which would likely require First Nation consent for oil and gas development to occur on reserve land.

10.5 | How the Duty to Consult is Handled in Nova Scotia and the Role of Project Proponents

In 1998, Canada, Nova Scotia, and the Assembly of Mi'kmaq Chiefs, met following the negotiations that had surrounded the Sable Offshore Energy Project and the Maritime Northeast Pipeline (Reid & Hickman, 2007). They agreed to develop a process to address treaty, title, and Aboriginal rights questions in Nova Scotia. The goal was to negotiate a modern treaty. Nova Scotia and the Mi'kmaq signed an umbrella agreement in 2002 and entered into a framework agreement in 2007. During this process, the Mi'kmaq, Nova Scotia, and Canada developed terms of reference for consultation activities, effective in 2010 (Nova Scotia Office of Aboriginal Affairs, 2010).

The Nova Scotia Department of Energy has oversight of key aspects of onshore oil and gas activity, including hydraulic fracturing. The department explicitly recognizes that energy projects, including petroleum development, may impact on Mi'kmaq's rights. Although the terms of reference are invoked on a voluntary basis, the provincial Department of Energy has committed to adhering to them. The terms of reference reflect the developing law on consultation and formalize the obligation of the government to provide the Mi'kmaq with relevant information and sufficient time to assess whether a proposed decision could impact on Aboriginal or treaty rights. They require the Mi'kmaq to communicate their concerns to the government and for the government to identify potential accommodations. The terms of reference contemplates that it will be reviewed every three years; however, the author of this chapter was unable to locate a review, and so it is not clear if the terms of reference are proving satisfactory for the parties.

While the obligation to fulfill the duty to consult rests with the government, project proponents play a significant role and often undertake procedural aspects of consultation. To this end, Nova Scotia's Office of Aboriginal Affairs worked with the Mi'kmaq to produce a guide for project proponents (2012). The guide refers to the need for affected Aboriginal communities who may bear the risk and impact of projects to also receive benefits.

Impact benefit agreements are standard practice in development activities that may affect Aboriginal rights. These agreements are enforceable private contracts. While not regulated, they often touch on regulatory matters. For example, these formal contracts may require the industry proponent to mitigate adverse environmental or cultural effects, as well as provide for employment, decision-making rights, compensation for adverse impacts, and capacity-building opportunities for an affected First Nation. Some communities describe positive experiences with these relationships, as well as developing skilled partnerships.[7] Such agreements often remain confidential, resulting in different First Nations receiving different arrangements (Wright & White, 2012).[8]

As noted above, the depth and scope of consultation and the extent of accommodation, varies on the facts. Where the evidence of a right is weaker, or the likely adverse effect is less serious, the duty to consult may be met by the province providing information to the First Nation and discussing issues that the First Nation raises. Where there is a strong claim, or a right has been acknowledged as existing (e.g. through litigation or is known to exist because it is promised in a treaty), or the proposed activity would have a serious adverse impact, then the consultation process will need to be a substantive one. It would likely require studies and the opportunity for the First Nation to make formal submissions and have those submissions considered. The consultation process may result in a series of accommodations, such as modifying the project or mitigating certain effects. The consultation process may result in the province concluding that it cannot permit the proposed conduct to occur.

10.6 | **The Role of the Energy Regulator and the Duty to Consult**

Some jurisdictions have specialized regulatory bodies to oversee oil and gas decision-making. For example, the National Energy Board (NEB) is the regulatory body that determines whether hydraulic fracturing may take place on federal lands and the Alberta Energy Regulator plays the same role for Alberta. There has been an enormous amount of litigation over the role of energy regulators in light of the duty to consult.

The duty on an energy regulator to consider the adequacy of consultation depends on the regulator's legislated mandate.[9] The legislature may delegate the Crown's duty to consult to the regulator; it may choose to give the regulator a more limited role, such as evaluating the adequacy of the consultation;[10] or it may purport to restrain the regulatory body from assessing consultation at all. In all cases, the ultimate legal obligation – to fulfill the duty to consult – rests with the government.

There are several ways that the duty to consult has been wrapped into the decision-making process of energy regulators. The NEB process involves the regulator receiving evidence directly from affected Aboriginal peoples regarding the potential impact of a proposed project and making a recommendation to the Governor in Council.[11] Under the act, it is the Governor in Council who then makes the actual decision. That decision can be challenged by judicial review to the Federal Court of Appeal if, for example, a First Nation believes that their right to be consulted was not respected. [12] This situation has attracted considerable litigation, suggesting dissatisfaction with the issues being parsed between different decision-makers and concerns about whether recommendations can be made without a clear assessment of whether the duty to consult has been met. The constitutionality of the NEB's process, including its approach to Aboriginal and treaty rights, is likely to be challenged vis-à-vis its recommendation for the Northern Gateway project.[13]

As of June, 2013, the Alberta Energy Regulator became legislatively precluded from engaging in, or assessing the adequacy of, Crown consultation with Aboriginal peoples.[14] The lawfulness of making a decision that may infringe upon Aboriginal and treaty rights, without considering whether the duty to consult had been met, was quickly challenged in court.[15] However, the parties settled, and the case was dropped. The question of whether this regime will stand is left unanswered. Practically speaking, divorcing the decision of whether to approve a project from an assessment of whether the Crown has fulfilled its constitutional obligations surrounding consultation seems likely to create uncertainty and prolong any decision-making process.

A counter-example can be found in the British Columbia Utilities Commission, whose previous enabling statute was interpreted to give it jurisdiction to consider whether adequate consultation had taken place.[16] This Commission, unlike the National Energy Board, had the authority to make a final decision instead of a recommendation.

Where there is no regulatory body involved, if a First Nation has questions about the adequacy of the consultation process, they must turn to court actions (the decisions of regulatory bodies can also be reviewed by the courts). If the provincial or federal government issues a license and the license is subsequently found to have been issued without the duty to consult having been fully discharged, then the license will be ineffective. The government may be liable to the industry license holder. This occurred in a recent case in British Columbia. It resulted in the Province being ordered to pay a company $1.7 million in compensation, because while the company was waiting to act on its ultimately illegitimate license, it lost the opportunity to pursue other work.[17]

Nova Scotia will clearly want to study these different approaches if it ever chooses to go ahead with hydraulic fracturing.

10.7 | **Concluding Comments**

If Nova Scotia were to pursue hydraulic fracturing, it would be advisable to carefully study existing models to determine the most effective and timely mechanism for ensuring that the Mi'kmaq's rights are respected, that adequate consultation does indeed take place, and that the Province does not inadvertently authorize activity that violates its constitutional obligations. The Peace and Friendship Treaties recognize a very strong set of rights and do not involve the Mi'kmaq ceding or giving up any land rights. It should not be assumed that the sorts of arrangements and practices that may be lawful in other parts of Canada would be constitutionally valid here. Protocols will need to be reviewed in light of the Supreme Court of Canada's recent decision on how provinces are to engage Aboriginal title claims and treaty rights.

Nova Scotia should also consider how it can successfully build on the existing Mi'kmaq- provincial relationship. Nova Scotia is fortunate in that the Mi'kmaq and the Province continue to work together to address outstanding questions about rights, resources, and jurisdiction.

If Nova Scotia was ever to pursue hydraulic fracturing, it is recommended that the Province and the Mi'kmaq consider whether the existing decision-making process is robust enough to honour the Mi'kmaq's Aboriginal and treaty rights in any instances where those rights may be engaged by hydraulic fracturing activities. The existing consultation protocol may be adequate. On the other hand, the parties may see value in adding more specific provisions. For example, they could choose to add a provision that identifies how the Mi'kmaq and the Province will address consultation rights for higher level strategic decisions, as well as a process for resolving situations where the Crown and the Mi'kmaq reach diverging conclusions and identify mutually acceptable mechanisms for addressing after-the-fact compliance concerns and title issues. Alternately, they may need to develop a distinct protocol to address the unique aspects of hydraulic fracturing.

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12. R v Marshall No 1, [1999] 3 SCR 456 at para 61, R v Marshall No 2 at para 37, Tsilhqot'in Nation v British Columbia 2014 SCC 44 at para 150.
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62. Indian Oil and Gas Regulations, 1995 (SOR/94-753), section 4.
63. Canadian Environmental Assessment Act, 2012 (S.C. 2012, c.19).
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65. Some gaps are, in principle, addressed by industry operating standards. For example, the Canadian Association of Petroleum Producers operating practices include baseline water sampling. See http://www capp.ca/getdoc.aspx?Docid=218135&DT=NTV.
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CHAPTER 11

Conclusion and Recommendations

11.0 | **Chapter Summary**

In this chapter, we reprise the most important conclusions of our report with respect to potential benefits, costs, risks, and outstanding questions concerning the possibility of hydraulic fracturing for the development of unconventional gas and oil resources in Nova Scotia. We also synthesise the results of our academic reviews with the views of Nova Scotia stakeholders who contributed to our study. We conclude that the Province is not able to make fully informed decisions, either for or against, the development of unconventional gas and oil resources by hydraulic fracturing at the present time.

Based on current knowledge we believe that the cost-benefit equation can only be estimated in very general terms at the provincial level. Geographically bounded studies would be needed to model more accurately the possible direct and indirect community health, economic, social, and environmental benefits and costs – including possible negative impacts on current economic activities and livelihoods. We set out our assessment of risks in matrix form and describe how particular hazards associated with hydraulic fracturing could be reduced in frequency or severity of impact through effective monitoring, management, regulation, and enforcement, should the development of unconventional gas and oil resources ever be pursued in Nova Scotia. Finally, we list our recommendations on the topic of hydraulic fracturing for the consideration of the government and the people of Nova Scotia.

11.1 | **Conclusions from our Research**

In Chapter 1, we presented an overview of hydraulic fracturing and its associated activities and technologies for the development of unconventional gas and oil.

In Chapters 2 and 3, we developed estimates of the resource potential and economic benefits which might flow from hydraulic fracturing should it ever be pursued in our province. We noted that knowledge of the subsurface, including sedimentary rocks and hydrocarbons, is extremely limited, and thus it is very difficult to quantify the potential or even rank the various basins in terms of overall prospectivity[1]. Although our knowledge is limited by scarcity of data, we believe that shales and sandstones in New Brunswick and U.S. plays such as the Marcellus, provide the basis for some comparison. We know that the Horton Group reservoirs have the largest assessed unconventional gas volumes. Cumberland, Windsor-Kennetcook and Shubenacadie basins are relatively close to existing production in New Brunswick and have experienced exploratory activity already. If hydraulic fracturing ever moves forward, we suggested that these basins would likely be the focus of exploration activity. They are also the closest basins to existing pipeline infrastructure.

Based on limited direct knowledge from exploration but with the benefit of reasonable assumptions drawn from analogous geologies, we were able to construct four scenarios to describe possible outcomes should hydraulic fracturing proceed: from zero commercial development through to 20,000 wells developed in five basins over 40-60 years. In our "lower medium case" (4000 wells developed over 40 years i.e. 100 wells drilled per annum) we calculate annual investments of around $1 billion and steady state employment of between 750 and 1,500 full-time equivalent (FTE) direct employees. These jobs might be distributed over a geographic area which could extend over one or more of Colchester, Cumberland, Hants, and Pictou Counties. We estimate that approximately one third of the $1 billion annual spending under this scenario would be for local (Nova Scotia) content.

We noted the fact that there are very few empirically grounded, peer reviewed economic studies of regional economic impacts of natural gas development, but that pre-publication and "grey literature"[2] studies show a wide variety of contradictory academic estimations of jobs resulting from unconventional gas and oil development in the U.S., from less than four direct jobs to more than 30 jobs created per well drilled over a seven year period in the U.S. (Mauro et al., 2013).

For comparative purposes, it may be noted that Pennsylvania averaged 1,650 new wells drilled per annum in the three year period 2010-2012 (i.e. 16 times our lower-medium case) and averaged direct employment in the unconventional gas and related industries of more than 23,000 over the same period (14 jobs per new well drilled). We also noted the recent observation that one "non-mining job" may be created for every "mining job" in the unconventional gas industry (Weber, 2014). Our estimate for potential job creation (750-1,500 FTE direct employees in the lower-medium case i.e. 7.5-15 jobs per new well drilled) is thus in the low-to-mid range compared with data for Pennsylvania but well below more optimistic claims (Mauro et al., 2013). If we add the 1:1 multiplier suggested by Weber (2014), we might conservatively estimate total jobs at 1,500-3,000 total jobs at steady state in the lower medium case.

Also in Chapter 3, building on the discussion of externalities in the Introduction, we listed a range of unquantified economic costs that could accrue to local residents or the Province. Externalities may include negative impacts or costs incurred through: water resource use; transportation and road use; chemical spills; wastewater storage and treatment; damage to drinking water; adverse impacts on human and environmental health; and the costs of regulation. There may also be displacement activities in other sectors of the economy e.g. tourism, through "crowding out." In a series of case studies, the Multi-State Shale Research Collaborative (2014) extended this list to include impacts on the educational system, the emergency health care system, and crime. Against the problem of externalities may be set i) the greater spending abilities of municipalities and Aboriginal governments and councils through increased direct revenues and benefits; and ii) the potential availability of some share in provincial royalty payments – perhaps as much as $150 million per annum in our lower medium case.

We recognize it was frustrating for some stakeholders who submitted comments on our discussion papers and in public meetings that, given funding constraints, we were not able to model the costs of externalities in as much detail as potential benefits (for reasons we describe in Chapter 3). Many stakeholders were concerned that we might either be exaggerating benefits or underplaying costs. To address this concern, we have made a clear recommendation in this report that benefits, costs, and externalities should be modelled in great detail for identified geographies as an immediate research priority. And certainly economic, social, community health, and environmental impacts would all need to be assessed within rigorous health, social, and environmental impact assessments before development could occur. We have also recommended that relevant communities would need to be confident that identified benefits would really accrue and that any social, community, health, economic, and environmental costs and externalities would be adequately minimized or compensated before giving "permission to proceed."

In Chapter 4, we explored the protection of public health from the perspective of the possible development of unconventional gas and oil resources in the Province. We noted that in common with other modern industrial technologies, hydraulic fracturing and its associated activities and technologies has the potential to bring both benefits and harms to individuals, communities, and populations. Economic growth, improved energy security, and a shift away from primarily imported coal and oil based generation may all indirectly improve population health. Conversely, physical risks associated with hydraulic fracturing may include potential exposures to toxic materials through contamination of drinking water sources and atmospheric exposure. And psychological and social disruption may represent hazards for mental health, for example precipitated by noise or light pollution.

Consistent with the analyses of the report of the Chief Medical Officer of New Brunswick (Cleary, 2012), a review by Public Health England (Kibble et al., 2014), a report by the European Parliament (2011) and the Report of the Council of Canadian Academies (2014), we noted that a number of the potential long-term and cumulative public health impacts of hydraulic fracturing and its associated activities and technologies are simply unknown at the present time. However, there is currently no evidence of catastrophic threats to public health in the short-to-medium term that would necessitate the banning of hydraulic fracturing outright. Nevertheless, there is a clear need to put in place comprehensive baseline health and environmental monitoring, management and mitigation (risk reduction), strict regulations, and enforcement. In addition, there should be a clear understanding of which groups benefit and which might be harmed as the relative impacts on community members, including the poor and less poor, will likely be different. And finally, uncertainties around long-term environmental effects, particularly those related to climate change and its impact on the health of both current and future generations, are considerable and should inform government decision making and regulation consistent with the provisions of the Environmental Goals and Sustainable Prosperity Act (2007).

In the recommendations section of this chapter, we set out a number of mechanisms to protect public health given the known and theoretical pathways for hazards to impact on affected populations. We make a specific call for health impact assessments to be conducted before any consideration of developing unconventional gas and oil resources by hydraulic fracturing in the Province. We also make specific recommendations for health status monitoring, formal emergency preparedness, and further research.

In Chapter 5, we noted that it is still far too early to predict what will be the long-term impacts on communities of unconventional gas and oil development in different jurisdictions around the world. Case studies on specific communities are only just beginning to emerge in the peer reviewed and grey literature, even in those areas most subject to intensive development (Multi-State Shale Research Collaborative, 2014; Perry 2012 & 2013). Currently, there is very little peer-reviewed literature that is general in nature that we can relate directly to Canada (CCA, 2014), still less to the specific situation in Nova Scotia.

We discussed different provincial approaches to unconventional gas and oil development in Canada and we noted that there are significant differences between Canada and the U.S. with respect to socio-economic drivers and outcomes. We also listed a wide range of potential positive and negative local social and economic effects: on employment patterns, incomes, property values, and cultural and social diversity. Possible positive and negative impacts on social and physical infrastructure, the natural environment and ecosystems, social relations, and the role of opposition within communities were discussed with reference to the existing literature on natural resource development, as well as, the emerging literature specific to hydraulic fracturing and the development of unconventional gas and oil resources (e.g. Hudgins & Poole, 2014; Jacquet, 2013; Jacquet & Stedman, 2014; Perry, 2012 & 2013; Willow & Wylie, 2014).

In response to uncertainty and the need to establish a "community permission to proceed" criterion for any future development in Nova Scotia, (see Chapter 9 and Section 11.3 later in this chapter) we summarized potential positive and negative community effects of unconventional gas and oil and other energy development based on the work of Brasier et al. (2011), and we related this to a range of public participation goals which would be important to consider in any future work in Nova Scotia. We raised questions that would need to be addressed and answered in a Nova Scotia context, and we suggested ways in which long-term monitoring of socio-economic and social-ecological effects could be undertaken should this activity ever proceed in Nova Scotia with community consent.

In Chapter 6, we described the potential impacts on water resources and water quality of hydraulic fracturing and its associated activities and technologies, relating those impacts to public concerns and Nova Scotia policy on water resource protection and management. We reviewed regulatory frameworks for water use in the Province, relating them to Environment Canada (2009) and Nova Scotia Environment (2010) policies, as well as the Environmental Goals and Sustainable Prosperity Act (2007). We also reviewed regulations in other jurisdictions for comparative purposes.

Drinking water quality management practices in the Province were described with specific reference to potential contaminants arising from hydraulic fracturing and its associated processes (including wastewater treatment and disposal). We discussed water resource use issues related to the practices of fracturing and wastewater treatment and disposal. We concluded that if effective prior modelling of the resource, proper monitoring, regulation, and enforcement were put in place, there is no reason to fear catastrophic risks related to hydraulic fracturing with respect to threats either to water quality or water resource use.

We concurred with findings of the Council of Canadian Academies (2014), who reported that the most relevant infrastructure risks that unconventional gas and oil development and related operations pose to surface water and groundwater stem from three sources:

- accidental spills of chemicals, oils, drilling muds, and fracture fluids during transportation, storage, or use;
- spills of condensates (where these are present) or flowback water from the producing well; and
- inadequate storage, treatment, or disposal of flowback water, which includes both fracturing fluids and saline formation water, and leaks from surface storage ponds or other storage facilities.

We concluded that several outstanding issues remain which requires further research. This could be achieved either through geographic-specific modelling (see Section 11.3), or through a formal environmental impact assessment process (see Section 11.3). To address the concerns of stakeholders, development of effective regulations, planning, permitting, and monitoring is required. The importance of ensuring the application of best available technologies for well integrity and wastewater treatment was emphasized.

In Chapter 7, we addressed the question of well integrity in significant detail. We noted that issues of well integrity are central to our understanding of some of the most significant long term risks to the environment arising from hydraulic fracturing and its associated processes. Consistent with the work of the Council of Canadian Academies (CCA, 2014), we also noted the deficiency of data on the long-term well integrity or the effectiveness of current management practices e.g. on well completion or decommissioning.

We discussed questions of well design, construction, operation, completion, assurance of well integrity, and regulatory guidelines, linking these topics to developing industry best practices. We discussed well integrity during production with specific reference to gas migration and leakage, and we described a range of potential sub-surface contamination pathways, noting the risks of each (i.e. potential frequency and impact), and paying particular attention to the concerns of stakeholders on issues such as groundwater contamination and contributions to climate change (e.g. through fugitive emissions).

The problem of leaking wells through gas migration both in production and after decommissioning was recognized, and the importance of effective long-term management, baseline (and ongoing) monitoring and regulation was stressed. Due to lack of knowledge regarding long-term material resilience in deep wells, the potential longer term (e.g. greater than 100 years) liabilities of future gas leakage into the atmosphere or seepage into local groundwater cannot be calculated at this time; this emphasizes the need for effective long-term monitoring, as well as the local level modelling of risks in the short, medium, and long terms.

Building on the analysis of foregoing chapters dealing with economic, public health, socio-economic, social-ecological, water and, well integrity issues, in Chapter 8, we synthesized stakeholder views of risk with the academic literature and our own research. We introduced the notion of complex or "wicked" problems which characterize the intersection of environment, energy, economic, social and other systems. We described some of the natural resource, energy and regulatory context for the Province and then set out the results of our public consultation with respect to formal submissions that were received by our review.[3]

We presented our analysis of 238 unique submissions to our review from individuals (n=215), organizations, and groups with a perspective on what hydraulic fracturing could mean in our Province. We also noted our receipt of 507 very similar form letters following a campaign initiated by the Council of Canadians. Our analysis focused on the 238 unique submissions which were, for the most part, written by Nova Scotia based stakeholders or organizations with a stake in the Province. The top six issues of greatest concern to stakeholders submitting evidence to our review were water (158 comments), community and infrastructure impacts (126 comments), the economy (100 comments), waste and clean up (89 comments), human health (88 comments), and climate change (84 comments). We then related all of these topics to the current literature on environmental and social impacts of hydraulic fracturing, particularly as summarized by the Council of Canadian Academies (2014).

We noted that in many areas of concern to those making submissions to our review it is impossible to be conclusive about the frequency or scale of risks – particularly over the long term – as there are simply insufficient studies in the literature at the present time. Where literature does exist it is often conflicting. As we noted in Chapters 4 and 5, public health and community impacts from hydraulic fracturing may not represent catastrophic threats, but they do have significant potential benefits and risks. However, the fact that there may be winners and losers at the community and county level, and that this may lead to a shift in social relations is not in question.

The question of climate change impacts of hydraulic fracturing is especially complex. In our Introduction we noted that there are claims of very significant reductions in U.S. climate change impacts from electricity production due to reductions in coal burning because of unconventional gas exploitation. However, the possibility of significant fugitive emissions of methane from hydraulic fracturing operations and associated downstream infrastructure – now or far in the future – does not enable us to make definitive claims about natural gas as a potential "transition fuel" for Nova Scotia with the present state of knowledge. Indeed, some (e.g. Howarth, 2014) have claimed controversially that the carbon footprint of natural gas may actually be higher than that of coal or oil because of the methane emissions issue. Stakeholders also expressed concerns that abundant natural gas may undercut the further development of renewable technologies – such as wind power – and so further steps that continue Nova Scotia's trajectory towards a low carbon energy mix may be needed. However, it should be recognized that both the IPCC (2014) and Council of Canadian Academies (2014) note that with effective control of emissions a case can be made for natural gas as part of a transitional strategy for this low carbon future.

We concluded that the legislative and policy framework in Nova Scotia requires a highly precautionary approach, consistent with the 238 formal submissions received by our review. Such an approach would necessarily require a much fuller understanding of all environmental and social hazards and the full involvement of communities in assessing and ultimately agreeing to the mix of economic, social, community health, and environmental benefits and risks (North et al., 2014).

In Chapter 9, we explored regulatory issues relevant to hydraulic fracturing and the unconventional gas and oil industry. Building on regulatory commentary in previous chapters, we set out the role of regulations in preventing and reducing harm to populations and the environment. We recognized from formal submissions to our review and the feedback from public meetings that many in Nova Scotia lack faith in their government and regulators, the situation in Kennetcook representing a highly salient example of direct relevance to the topic of hydraulic fracturing.

We described the respective roles of the federal government, the provincial government, municipalities and Aboriginal governments in regulating hydraulic fracturing and its associated activities. And we described how hydraulic fracturing is currently regulated in various jurisdictions in Canada.

We related the role of regulations to the concept of risk management, paying special attention to the precautionary approach embedded in Nova Scotia legislation and the framework recommended by the Council of Canadian Academies for regulatory goals and risk management. Best practices in technology, management systems, regulatory system design, regional planning, and citizen engagement were recommended by the Council (2014). In our analysis we emphasised the importance of: i) the adequacy of the knowledge base; ii) political will and the responsiveness of regulations to the knowledge base; and iii) implementation, resourcing, and enforcement, as key aspects of effective regulatory design. We noted that even if the knowledge base was considered sufficient and regulations enacted which responded to the satisfaction of Nova Scotians, that inadequate resourcing would undermine public confidence in the regime. We also noted that public confidence in the regime will likely turn on public reporting on decisions, monitoring, and enforcement activities.

We concluded with a discussion of how transparency and social licence "community permission to proceed" in our terminology) would be preconditions to maintaining public trust on hydraulic fracturing and its associated activities and technologies.

In Chapter 10, we described the particular situation of Aboriginal communities in Nova Scotia with respect to their Aboriginal, treaty and statutory rights. We noted the very clear stated opposition of the Assembly of Nova Scotia Mi'kmaq Chiefs to hydraulic fracturing for the development of unconventional gas and oil resources, their priority being, "to protect the lands and the waters." We also noted the similar sentiments of the Native Council of Nova Scotia, who "oppose the practice of hydraulic fracturing for oil and gas in Nova Scotia." We hope to present the findings of our review to leaders, elders, and communities who request such presentations in the future.

We described the differences between Aboriginal and treaty rights (including the Aboriginal right of title) with reference to historic precedent, treaties, the Canadian Constitution, Supreme Court of Canada decisions, and the UN Declaration on the Rights of Indigenous Peoples – to which Canada is a signatory. We also detailed the implications of activities associated with hydraulic fracturing for Mi'kmaq Aboriginal and treaty rights noting that adverse impacts could occur both directly and indirectly.

It is clear that Mi'kmaq Aboriginal and treaty rights are very robust in Nova Scotia, with no rights ever having been ceded under the Peace and Friendship treaties with the British. Thus there are considerable consequences for provincial deliberations over hydraulic fracturing, as the Province is constitutionally obliged to honour these rights through formal consultation. And if Aboriginal title is established a range of other implications arise as a direct consequence of recent Supreme Court decisions. These include the ability of Aboriginal communities to assert rights to decide on land use in traditional territories, the right to occupancy, the right to possession, the right to use and manage the land, and the right to "profit from its economic benefits."

We described the particular issues that would arise if hydraulic fracturing was ever to occur on reserve lands as these would fall under federal, rather than provincial jurisdiction. And we noted how the "duty to consult" would likely play out provincially from the perspective of both proponents and regulators.

Finally, we concluded that a review would be required of the adequacy of existing arrangements for joint decision making between the Province and Mi'kmaq, given the complexity and range of issues raised by hydraulic fracturing for Aboriginal and treaty rights.

11.2 | **Synthesizing Stakeholder Feedback and Risk**

As noted above, in Chapter 8, we explored public attitudes to risks associated with hydraulic fracturing in Nova Scotia. Building on the scientific analyses of risks relating to public health (Chapter 4), community (Chapter 5), water (Chapter 6), and well integrity (Chapter 7), we were able to demonstrate a high level of congruity between risks as assessed by 238 unique formal submissions to our review and risks identified in the literature.

In addition to the formal submissions, we received 170 separate written submissions from 96 individuals and organizations after discussion papers were released (see Introduction). These "discussion paper responses" were taken into account by lead authors of final chapters in this report, and in most cases the authors have included direct reference to specific feedback received. Finally, we conducted 13 public meetings with Nova Scotians, two in April and 11 in July, 2014, which were attended by more than 1,200 Nova Scotians (see Introduction and Appendix B).

This section aims to synthesize our scientific analyses with questions of public attitudes to risk received throughout our process: formal submissions, responses to discussion papers, and feedback from public meetings. It does not include details of our discussions with Aboriginal leaders, elders and communities as that will be the subject of a future report. In this section we introduce notions of risk management, risk perception, and risk communication, which help explain why we have concluded that for reasons predating this review, but reinforced by our research, that Nova Scotia should not proceed with hydraulic fracturing for unconventional gas and oil resources at this time.

This conclusion derives, in part, from our observation that hydraulic fracturing currently lacks adequate social license among the majority of the citizens in the Province (e.g. CRA, 2013; Nova Scotia Commission on Building Our New Economy, 2014) and is actively opposed by many hundreds of stakeholders – indeed the overwhelming majority who expressed views through formal submissions, responses to our discussion papers, and in our public meetings. Our research did not explore perspectives of those who might support hydraulic fracturing except in so far as they participated in this review. Thus, further research is required to elucidate at a deeper level community attitudes to the prospect of hydraulic fracturing for the development of unconventional gas and oil resources (see recommendations in Section 11.4). Below we describe some of the issues underpinning citizens' concerns about new technologies with poorly understood risk profiles.

11.2.1 The Risk Society

According to German sociologist Ulrich Beck we live in a "risk society" (Beck, 1992; Beck and Van Loon, 2000) – a society "increasingly preoccupied with the future" which – together with questions of environmental and human safety – drives our perceptions of industrially created or "manufactured risk" in modern society (Giddens, 1999a).

The management of risk and the social dynamics of risk perception by the public were discussed in Chapter 8. They represent significant challenges for policy makers and corporations alike who wish to establish public trust (Cvetkovich, 2013; Renn, 2008). Equally challenging are questions of how to effectively communicate risk information to citizens (Fischoff, 1995; Slovic, 1987 and 2000). Much of the commentary around our own review reflected a low level of trust in government or experts.[4]

It has been known since the 1950s that the public perception of health and environmental risks is subject to significant social and psychological influence (Frewer, 1999). In 1987, Sandman described how that the "risks that kill you are not the risks that frighten or anger you." He noted that principles like voluntariness (self-imposed risk),[5] control (personally managed risk), and fairness (equitably distributed risk), have a significant positive impact on risk acceptance. The converse is also true. Thus, someone with a lifetime habit of smoking may object strongly to fluoridation of his or her water supplies, although the first activity carries a 50 per cent chance of premature death and the second may only improve his or her dental wellbeing. Health conscious citizens may accept a quite high annual chance of death through driving a motor vehicle (1 in 6,700 in the U.S.)[6] but spend significantly more on their weekly grocery bills to avoid eating foods containing additives at concentrations below a detectable health risk for a lifetime of exposure.

Since the 1980s a range of new environmentally and technologically mediated health hazards has emerged to challenge the risk sensitivities of citizens: ozone depleting chemicals, electromagnetic fields, genetically modified organisms, nanotechnology, and now hydraulic fracturing. The very unfamiliarity of the activity or potential hazard, coupled with the unknown severity of the risks, guaranteed that each of these developments would result in popular concern. Such phenomena have become the focus of significant academic interest in recent years. Gupta et al. (2012) reviewed research on 10 controversial technologies and found that the majority of socio-psychological research studies focused on a common list of factors such as risk perception, trust, perceived benefit, knowledge, individual differences, and attitude.

For example, in a study on electromagnetic fields related to mobile phone use and base stations, Wiedemann and Schütz (2005) found that precautionary measures actually helped trigger concerns, amplifying EMF-related risk perceptions and lowering trust in public health protection measures.

In a study on attitudes to nanotechnology, Schütz and Wiedemann (2008) found that the issue of differential benefits was unimportant, but that characterizing the enterprises profiting from the technology as large multinational firms versus small-or-medium sized enterprises led to differences in risk perception. The authors speculated that in the absence of specific knowledge of the technology, citizens were influenced by more familiar contextual information.

In response to these challenges, academics and others have developed models and theories to explain the factors at play and how they might be managed. One interesting phenomenon, long noted in the literature on public attitudes to novel risks, but predating the emergence of social media, is the notion of "social amplification" (Kasperson et al., 1988; Frewer et al., 2002; Pidgeon et al., 2003).

We noted in the Introduction (Section I.4) and in Chapters 8 and 9 that public trust in the environmental performance of companies in Nova Scotia is generally low and that many are deeply concerned about the regulations and their enforcement in the province to adequately oversee the unconventional gas and oil industry. We also know from the literature that expert opinion may diverge dramatically from public opinion on risk (Flynn et al., 1993) and that there is often a deep alienation of the public in the face of possible understatement of risk by scientific experts (Wynne, 2001).

Addressing the observation that relatively minor risks (as assessed by technical experts) often produce strong public concerns, Kasperson and co-workers (1988) described how the technical assessment of risk may be linked to psychological, sociological, and cultural perspectives of risk perception and risk-related behaviour. They argued that, "hazards interact with psychological, social, institutional, and cultural processes in ways that may amplify or attenuate public responses to the risk or risk event." They describe how, "Amplification occurs at two stages: in the transfer of information about the risk, and in the response mechanisms of society. Signals about risk are processed by individual and social amplification stations, including the scientist who communicates the risk assessment, the news media, cultural groups, interpersonal networks, and others."

The amplification framework has been successfully applied to the issue of genetically modified organisms which flared in the UK media in 1999 (Frewer et al., 2002). Amplification in the world of social media and the Internet is certainly a powerful factor in discussions of the risks of hydraulic fracturing for unconventional gas and oil development, as we have witnessed throughout our review.

11.2.2 Hydraulic Fracturing and Public Attitude to Risk

Unquestionably, the topic of hydraulic fracturing is fast becoming one of the defining challenges for modern society in terms of risk assessment, risk perception, and risk communication, with all the attendant socio-political implications and "threat dynamics" that are associated with the emergence of significant concerns with the technology (Jaspal and Nerlich, 2014). In Chapter 8, we referred to this as a "wicked problem." The activity of hydraulic fracturing for the development of unconventional gas and oil resources has many elements that have been identified as problematic in the literature: unfamiliarity, the external and potentially unfair imposition of risk, lack of community or individual control, and the perception of benefit-taking by a large industry. In the case of Nova Scotia, as described in Chapters 8 and 9, we must also note the lack of faith in regulation and protection by government invoked by the Kennetcook situation and recent incidents in nearby (and therefore familiar) New Brunswick.

"Waste and clean up" and "policy and regulation" were the fourth and seventh most cited concerns for those individuals and organizations submitting formal evidence, mentioned in 89 and 75 of the original set of formal submissions respectively (Chapter 8). These issues were raised regularly at the public meetings (see Introduction and Appendix B), and in the public submissions that we received in response to the discussion papers.

To these concerns may be added recent observations directly relevant to hydraulic fracturing that suggest, "the threat of disruption to place-based identities may spur oppositional behaviour" (Jacquet & Stedman, 2014). We described this phenomenon in Chapter 5, and it was clear from our public meetings across the Province that perceived threats to farming, tourism, fisheries, and other identity-making activities are likely to make the technology even more difficult to accept for individuals and communities in rural Nova Scotia. One hundred of the 238 formal written submissions to our panel noted this as a significant concern (Chapter 8) and the issue came up many times in our public meetings (see Introduction and Appendix B).

Because of the danger of fundamental polarization of communities that can occur on the question of unconventional gas exploitation (Schafft et al., 2013) – often linked to density of drilling and place-related threat dynamics – researchers have advanced ideas for new approaches to risk governance (Sidortsov, 2014). One of these approaches is the analytic-deliberative prescription of North et al. (2014) which we described and followed in Chapter 8, albeit with a relatively small sample. Another is the public participatory approach taken in Nova Scotia with respect to energy efficiency and renewable electricity (Adams et al., 2011).

Clearly, on issues as complex and polarizing as hydraulic fracturing, it is essential to address questions of equity, trust, and power with respect to risk perception and management (Slovic, 2000). As Frewer (1999) noted, "Ethical concerns, trust and distrust (in scientific institutions, risk regulators, and information providers) and perceptions of social exclusion from risk-management processes should be incorporated into theoretical models used to explain the evolution of public resistance to emerging technologies." Frewer also stressed the importance of involving the public in risk-management processes as potentially the optimum means to redress issues "associated with perceptions of social exclusion."

Also of relevance to the situation in Nova Scotia, is the fact that opponents and supporters of hydraulic fracturing for the development of unconventional gas and oil resources may represent different worldviews and have different backgrounds and experiences. Recent evidence from the U.S. (Boudet et al., 2014) suggests that in one study, "women, those holding egalitarian worldviews, those who read newspapers more than once a week, those more familiar with hydraulic fracturing, and those who associate the process with environmental impacts are more likely to oppose fracking." Conversely, supporters, "tend to be older, hold a bachelor's degree or higher, politically conservative, watch TV news more than once a week, and associate the process with positive economic or energy supply outcomes." What this tells us is that issues of political philosophy may also be significant factors in attitudes to hydraulic fracturing. We heard many times in our public meetings stakeholders expressing hopes for a more sustainable, fossil free world based on their personal values.

In this review we were deeply cognisant of the social, cultural, and political context in which our work was occurring. For that reason we sought maximum engagement with different publics: through the media and through direct involvement of stakeholders. We understand that at this time, hydraulic fracturing has unresolved issues of risk assessment and risk perception. But we also note that risk is a feature of modern society. As Giddens (1999b) states, "Risk needs to be disciplined, but active risk-taking is a core element of a dynamic economy and an innovative society." That is why in our chapters dealing with evidence of risk (4,5,6, and 7) we noted both potential positive and negative aspects of the topic. And it is why we worked hard to identify the potential economic implications (benefits and costs) in our chapters describing the potential resource (Chapter 2) and its economic impacts (Chapter 3).

In his article on "facing public outrage," Sandman (1987) concluded, "When people are treated with fairness and honesty and respect for their right to make their own decisions, they are a lot less likely to overestimate small hazards…..But when people are not treated with fairness and honesty and respect for their right to make their own decisions, there is little risk communication can do to keep them from raising hell – regardless of the extent of the hazard."

We know from independent public polling (CRA, 2013, Nova Scotia Commission on Building Our New Economy, 2014) that Nova Scotians are split on the issue of hydraulic fracturing, and that – based on our public meetings – some in our communities are indeed at the point of outrage. We heard sentiments of outrage and fear in all of our public meetings, and in the case of our meeting in Kennetcook/Noel there was direct justification for those emotions. In publishing the findings of our review we are seeking to ensure that this debate continues as a respectful exploration of a precautionary approach. We seek to help create the conditions under which all participants in the debate are informed by a broad base of knowledge and are supported in their expectations of a high level of engagement and exchange. And we make specific recommendations on this point, including the establishment of a "community permission to proceed" as a final check and balance on the quality of that engagement. These conditions will, we hope, make it more likely that the continuing conversation between the public at large, specific communities, and the Province will be experienced as, and be in fact, a fair and honest one.

11.3 | Summary of Risks of Hydraulic Fracturing and Unconventional Gas and Oil in Nova Scotia

As part of our review we spent a significant amount of time attempting to summarize and synthesise the risks of hydraulic fracturing and the development of unconventional gas and oil resources in Nova Scotia based on all of our research and deliberations.

Table 11.1 below provides our best assessment of the majority of hazards and associated risks that we can comment on at this time. The table is based on risk assessment approaches and definitions which are used by the World Health Organization in the context of food safety[7] and other applications and adapted for our use in the context of hydraulic fracturing:

- Hazard Identification: The identification of known or potential environmental or health effects associated with a particular pathway associated with hydraulic fracturing and its associated activities and technologies for the development of unconventional gas and oil resources.
- Hazard Characterization/Frequency Rating: The qualitative and/or quantitative evaluation of the frequency of the adverse effects associated with the pathway.
- Exposure Assessment/Severity Rating: The qualitative and/or quantitative evaluation of the severity of risk likely to occur.
- Risk Mitigation: measures that may be taken to reduce the likelihood of exposure to the hazard and/or reduce the severity of exposure if it occurs.
- Risk Characterization: Integration of hazard identification, hazard characterization (frequency and severity), and risk mitigation into a description of how the risks need to be understood and managed, including attendant uncertainties and how those uncertainties would need to be resolved.

Table 11.1. Hazards associated with hydraulic fracturing and associated activities and technologies related to likelihood and severity of impacts, mitigations, and risk characterization. Hazards are listed A-R for identification purposes. Frequency rating and severity rating are described in the table on the following 3 pages.

Identified Hazard	Frequency Rating (see definitions below)	Severity Rating (see definitions below)	Risk Mitigation	Risk Characterization
A Direct migration of pollutants from deep zone to shallow aquifer	Rare - no evidence of occurrence to date.[8]	Significant negative impact.	Local EIA[9] required Monitoring required.	Further general research required to properly characterise the risk. Site specific geological research required to estimate and manage risks adequately.
B Well integrity failure leading to shallow groundwater well contamination by chemicals	Rare to unlikely based on current Canadian data.[10]	Significant negative impact.	Existing regulations exist but need review. Local EIA required. Monitoring required. Emergency planning required.	Further research required on possible bioaccumulation and ecosystem effects. Risk relatively low to population health if detected and removed. Risk relatively low to ecology if detected & remediated and assuming effective liability regime in place.
C Surface activity risks to shallow groundwater well contamination	Certain[11]	Significant	Existing regulations exist but need review. Local EIA required. Monitoring required. Emergency planning required.	Wastewater treatment, water protection and remediation research required. Risk relatively low to population health if malfunctions detected and removed. Risk relatively low to ecology if detected & remediated and assuming effective liability regime in place.
D Wastewater treatment[12]	Certain	Minor to moderate impacts on receiving waters assuming properly operated and regulated system.	Effective design and operation with effective monitoring, reporting, regulation and enforcement.	Wastewater treatment, water protection and remediation research required. Risk relatively low to population health if malfunctions detected and corrected. Risk relatively low to ecology if malfunctions detected and remediated and assuming effective liability regime in place.
E Water resource impacts	Certain	Minor to significant impacts – highly dependent on water system used.	Detailed water balance required at the local watershed level. Withdrawal regulations to be enforced.	Local hydrologic and hydrogeologic studies required to assess demand. Risk relatively low to population health if regulations enforced. Risk relatively low to ecology if regulations enforced.

F Industrial air pollution	Certain	Minor to moderate short-term negative impact according to proximity	Existing regulations exist but need review. Local EIA, SIA and HIA[13] required. Planning required. Monitoring required.	Risk very low to population health if managed effectively. Risk relatively low to ecology if managed effectively and assuming liability regime in place.
G Vehicular traffic effects e.g. accidents, emissions, disruptions, noise, ecology, quality of life	Certain	Minor to very significant medium-term negative impact according to proximity and nature of effects and incidents.	Existing regulations exist but need review. Local EIA, SIA and HIA required. Planning required. Monitoring required. Adaptive management required.	Risk low to population health if managed effectively. Risk relatively low to ecology if managed effectively.
H Industrial nuisance e.g. light & noise	Certain	Minor to very significant short-term negative impact according to proximity	Existing regulations exist but need review. Local EIA, SIA and HIA required. Planning required. Monitoring required.	Risk low to population health if managed effectively. Risk relatively low to ecology if managed effectively.
J Community economic impacts e.g. incomes, employment versus threats to existing economic sectors)	Certain	Minor to very significant short-term and long-term positive and negative impacts according to social scale and location	Community level economic analysis required re: interaction with existing economic sectors. Community participatory planning and adaptation required. Monitoring required.	There will be economic winners and losers who will require evidence-based adaptive management, remediation and mitigation.
K Community economic impacts e.g. unequal distribution of benefits and costs possibly leading to social divisiveness)	Certain	Moderate to significant long-term impacts according to individual and location	Community level analysis required re: social cohesion Community participatory planning and adaptation required. Monitoring required.	There will be social winners and losers who will require evidence-based adaptive management, remediation, and mitigation.

L Climate change CO_2 emissions (through industrial activity including transportation)	Certain	Moderate	Requires modelling, monitoring and mitigating measures.	Equivalent to many industrial activities therefore requires investigation to ensure consistency with EGSPA (2007) as updated by the Green Economy Act (2012) and provincial climate change goals.
M Climate change CO_2 emissions (through exploitation of resource) *versus* fossil fuels used in electricity generation and home heating	Certain	Significant positive[13]	Requires modelling and monitoring.	Capable of significantly affecting provincial climate change impacts therefore requires investigation to ensure consistency with EGSPA (2007) as updated by the Green Economy Act (2012) and provincial climate change goals.
N Climate change CO_2 emissions (through exploitation of resource) *versus* extension of renewables commitments beyond current targets	Certain	Significant negative	Requires modelling and monitoring	Capable of significantly affecting provincial climate change impacts therefore requires investigation to ensure consistency with EGSPA (2007) as updated by the Green Economy Act (2012) and provincial climate change goals.
P Climate change CH_4 emissions (through fugitive emissions from wells or distribution)	Certain	Moderate negative impact[14]	Requires modelling and monitoring and effective regulation and enforcement of well integrity and distribution leaks	Requires investigation to ensure consistency with EGSPA (2007) as updated by the Green Economy Act (2012) and provincial climate change goals.
Q Seismicity associated with	Certain	Inconsequential	Requires geological modelling and	Inconsequential physical risk to population health. Moderate risk of
R Seismicity associated with deep waste water injection (if permitted)[16,17]	Likely	Minor to moderate	Requires geological modelling and monitoring and effective regulation (existing regulations do not exist). Local EIA required.	Minor physical risk to population health, but more research required. Moderate risk of anxiety mitigated by public communication. No risk to physical infrastructure.

- Hazard Identification: The identification of known or potential environmental or health effects associated with a particular pathway associated with hydraulic fracturing and its associated activities and technologies for the development of unconventional gas and oil resources.
- Hazard Characterization/Frequency Rating: The qualitative and/or quantitative evaluation of the frequency of the adverse effects associated with the pathway.
- Exposure Assessment/Severity Rating: The qualitative and/or quantitative evaluation of the severity of risk likely to occur.
- Risk Mitigation: measures that may be taken to reduce the likelihood of exposure to the hazard and/or reduce the severity of exposure if it occurs.
- Risk Characterization: Integration of hazard identification, hazard characterization (frequency and severity), and risk mitigation into a description of how the risks need to be understood and managed, including attendant uncertainties and how those uncertainties would need to be resolved.

Table 11.1. Hazards associated with hydraulic fracturing and associated activities and technologies related to likelihood and severity of impacts, mitigations, and risk characterization. Hazards are listed A-R for identification purposes. Frequency rating and severity rating are described in the table below.

Frequency Rating	Description	
Rare (1)	Theoretical chance	1 in 10,000 chance per activity based on experience to date
Unlikely (2)	Most likely will not occur. Infrequent occurrence in the past.	1 in 1,000 chance per activity
Medium (3)	Possible to occur.	1 in 100 chance per activity
Likely (4)	Likely to occur. Has occurred in the past.	1 in 10 chance per activity
Certain (5)	Highly likely to occur. Has occurred in the past and conditions exist for it to re-occur.	1 in 1 chance per activity

Frequency Rating	Description
Inconsequential (1)	Requires application of effective regulation, management and mitigation
Minor (2)	Requires application of effective regulation, management and mitigation
Moderate (3)	Requires application of effective regulation, management and mitigation
Significant (4)	Requires application of a precautionary approach with legal safeguards
Very significant (5)	Requires application of a precautionary approach with legal safeguards

Taking the sum of the frequency rating (FR) and the severity rating (SR) we are able to categorize hazards on a scale 1-25, where the lowest risk score is 1 (FR = 1 x SR = 1) and the highest Risk Score is 25 (FR = 5 x SR = 5). This allows us to set out the risks of most potential concern from a public policy perspective. Table 11.2 below is set out to allow easy interpretation of where risks may spread into more than one severity column and where attention may need to be placed by regulators and planners with respect to risk reduction.

Thus, hazard G (vehicular traffic effects e.g. accidents, emissions, disruptions, noise, ecology, quality of life), hazard H (industrial nuisance e.g. light and noise), and hazard J (community economic impacts e.g. incomes, employment versus threats to existing economic sectors) all appear as "certain to occur" but their severity ranges quite widely from "minor" to "very significant" depending on a range of geographic, economic, and population distribution factors. Hazards E (water resource impacts), K (community economic impacts e.g. unequal distribution of benefits and costs), and N (climate change CO_2 emissions through exploitation of resource versus extension of renewables commitments beyond current targets) all appear as "certain to occur" with either "moderate" or "significant" severity. Hazard C (surface activity risks to shallow groundwater well contamination) appears as "certain to occur" over a 40-year development period with significant severity of impact.

In contrast, hazard A (direct migration of pollutants from deep zone to shallow aquifer) and hazard B (well integrity failure leading to shallow groundwater well contamination by chemicals), whilst significant in severity if they do occur are deemed to be rare (A) or rare to unlikely (B) based on existing data.

These assessments need to be understood as simply directional and subject to a range of caveats and contingencies. However we hope they provide some guidance to readers of the report how risks associated with unconventional gas and oil development through the application of hydraulic fracturing would need to be addressed in the province.

Table 11.2 Severity ratings for different hazards associated with hydraulic fracturing and associated activities and technologies for the development of unconventional gas and oil resources

1-5 = Very Low Risk >5-10 = Low Risk >10-15 = Medium Risk >15-25 = High Risk		SEVERITY				
		Inconsequential (1)	Minor (2)	Moderate (3)	Significant (4)	Very Significant (5)
FREQUENCY	Certain (5)	Q	D,E,F,G,H,J	D,E,F,G,H,J, K,N, L, P	E,G,H,J K,N C	G,H,J
	Likely (4)		R	R		
	Medium (3)					
	Unlikely (2)				B	
	Rare (1)				A,B	

11.4 | Recommendations

We have noted throughout this report that a precautionary approach must underpin provincial policy on hydraulic fracturing for the purpose of development of unconventional gas and oil resources. That stems from our mandate (which specifically references the Environmental Goals and Sustainable Prosperity Act), the analysis of the Council of Canadian Academies (CCA, 2014), and other government reports which recommend caution, and our own assessment of the uncertainties surrounding the application of hydraulic fracturing for unconventional gas and oil development at this time.

We also believe that the only level at which the precautionary approach becomes truly meaningful is at the community level where costs and benefits can be weighed in a local context. In this context, we are very cognisant of the clearly expressed views of our Aboriginal leaderships, some municipal leaders, more than 200 individuals and organizations submitting formal evidence to our review, 96 individuals and organisations providing feedback to our discussion papers, and more than 1,200 attendees at our public meetings, and indeed Nova Scotians more broadly for whom there is evidence of a majority opposed to hydraulic fracturing in the Province (CRA, 2013; Nova Scotia Commission on Building Our New Economy, 2014). We recognize that further polling is now appropriate, ideally with a regional focus. We are also cognisant that we have heard less from those in Nova Scotia – around 40 per cent based on CRA polling – who support hydraulic fracturing as a means to develop unconventional gas and oil provided stringent regulations are in place. Their views should also become known at the community level where benefits and risks will be managed.

We also note that there is a direction of travel in energy and environmental policy in our Province which assumes increasing sustainability of energy production and use i.e. a lower carbon footprint while keeping energy costs affordable for Nova Scotians, especially those on low incomes.

And finally, we note that our provincial economy is stressed (see Introduction) and that there are no simple answers to achieving economic growth in the future, whether that is through existing or new industries – including the sustainable exploitation of natural resources.

In view of the above, and consistent with our mandate and the analysis described in this report, we recommend the following:

Top Level Recommendations

Based on the analysis described in this report, a significant period of learning and dialogue is now required at both provincial and community levels, and thus hydraulic fracturing for the purpose of unconventional gas and oil development should not proceed at the present time in Nova Scotia.

- Independently conducted research of a scientific and public participatory nature is required to model economic, social, environmental, and community health impacts of all forms of energy production and use – including any prospect of unconventional gas and oil development in Nova Scotia – at both provincial and community levels.
- Nova Scotia should design and recognize the test of a *community permission to proceed* before exploration occurs for the purpose of using hydraulic fracturing in the development of unconventional gas and oil resources.

Contingent General Recommendations

If at some point in the future communities and the Province wish to proceed with seismic testing with a view to permitting exploration for unconventional gas and oil resources using hydraulic fracturing, the following recommendations would come into play:

CGR1: If new knowledge persuades communities to welcome the prospect of examining the potential benefits and costs of developing unconventional gas and oil resources then seismic testing for the purpose of pursuing exploration using hydraulic fracturing would proceed only when full, prior, and informed community consent was established and comprehensive baseline health, socioeconomic, socio-ecological, and environmental monitoring and regulatory protections were in place.

CGR2: If new knowledge persuades communities to welcome the prospect of developing unconventional gas and oil resources through the application of hydraulic fracturing techniques then there would be a need to design and establish:

- Comprehensive baseline monitoring, ongoing monitoring, regulatory, and enforcement regimes;
- Rigorous health, social and environmental impact assessments – including economic assessments of direct and indirect costs and benefits and externalities and site-specific geological assessments, prior resource extraction activities etc.;
- A detailed life cycle assessment of the potential positive and negative climate change impacts of developing an unconventional gas and oil industry in Nova Scotia;
- Specific risk reduction and benefit sharing systems by identified population and community;
- Participatory planning and adaptive management frameworks, including for socio-economic and social-ecological aspects;
- Bond and insurance protections in the event of damage ever being caused to people, fauna, flora, or the environment.

Contingent Specific Recommendations (subject to the above)

Health and Environmental Impact Assessments

CSR1: A standard process for health, social and environmental impact assessment of hydraulic fracturing and its associated activities and technologies should be designed and adopted as part of a robust regulatory regime and to ensure the compilation of adequate baseline monitoring information. Government should undertake a formal HIA, SIA and EIA at the provincial level before any commercial exploitation of unconventional oil/gas resources is undertaken. Industry should be required to submit community-based, site specific HIAs, SIAs and EIAs for approval by the regulatory body as part of the planning process for the development of new areas of commercial extraction.[19]

CSR2: Government and regulators should increase their capacity to plan, commission, interpret, and act on the results of HIAs, SIAs and EIAs conducted in the Province as they relate to the possible application of hydraulic fracturing and associated techniques for the development of unconventional gas and oil resources.

Environmental Risk Reduction

CSR3: Detailed baseline studies and ongoing environmental monitoring (air, soil, and water quality, ecosystem health etc.) should be undertaken prior to, during, and after any application of unconventional gas and oil development activity in Nova Scotia, conducted independently, made public and paid for by the developer.[2] Rigorous data management strategies should be developed to ensure full access to information for all stakeholders.

CSR4: Government should review, revise, and monitor standards for environmental exposures (chemical and radiological) and environmental nuisance (noise, odour, vibration, light pollution) which should be applied to protect the public's health from the effects of all industrial processes including unconventional gas and oil extraction through the application of hydraulic fracturing and associated techniques.

CSR5: Companies should be obliged to place records of all chemicals used in hydraulic fracturing (including identities, concentrations, quantities and toxicity data) in the public domain. Regulatory processes should specify requirements for chemical disclosure and consider the use of publically available chemical disclosure registries.

CSR6: Government should use its regulatory process to require developers of unconventional gas and oil resources to use most environmentally benign fracturing fluids available and should retain its ability to prohibit the use of specific chemicals either as a general prohibition or with regard to use at specific sites.

CSR7: Traffic management plans should be developed to the satisfaction of community representatives, municipalities and the Province, wherever unconventional gas and oil developments through hydraulic fracturing and associated techniques have the potential to require significant increases in vehicular movement affecting communities. Increased costs should be assigned to the project proponent.

CSR8: Appropriate set-back distances for hydraulic fracturing well-pad placement should be determined to reduce exposure to industrial materials and nuisance (light and noise) to levels which are acceptable to communities. Set-back distances should be informed by exposure risk assessments through community engagement.

CSR9: Government should build on Health Canada guidelines to establish environmental and occupational standards for the management of NORMs and incorporate these into regulatory and monitoring processes for unconventional gas and oil development through hydraulic fracturing.

CSR10: A process for baseline health, social, economic, and ecological status assessment and monitoring for people living, working, attending school, taking recreation (e.g. hunting and fishing), or playing in proximity to industrial activity should be designed and implemented wherever unconventional gas and oil development through hydraulic fracturing is being considered.

CSR11: Government should develop and adopt an appropriate methodology to link and track environmental, social, economic, and community health status monitoring in order to properly assess short term, long term and cumulative risks and any new mitigation strategies and regulatory approaches required by unconventional gas and oil development through hydraulic fracturing

CSR12: Government should apply an equity lens to its monitoring of the economic, social, community health and environmental impacts of unconventional gas and oil exploration, extraction and remediation so that there is a clear understanding of when, where and to whom the benefits and harms may accrue.

Emergency Preparedness

CSR13: The Government of Nova Scotia should work with relevant municipalities and Emergency Management Organizations (EMOs) to review, revise, and implement the plans for incident management if unconventional oil and gas extraction through hydraulic fracturing is planned in the Province.

Water Resource Management

CSR14: Comprehensive baseline conditions of current water levels, flow, and quality must be established before any withdrawals are approved for hydraulic fracturing operations. Additionally, hydrologic and hydrogeologic modelling of the watershed would need to be conducted to determine the response to potential withdrawals and to ensure the protection of human and ecological water requirements.

CSR15: Consistent with the *Activities Designation Regulations,* water requirements for hydraulic fracturing for the purpose of unconventional gas and oil development would require proponents to pay for a comprehensive groundwater and/or surface water technical analysis; proponents would also be required to provide for public consultation prior to water withdrawal.

CSR16: A water safety plan should be developed to ensure transparency and understanding of operations and processing chemicals used, and identification of any potential adverse impacts on water quality (both ground and surface water) due to hydraulic fracturing operations. Protection of groundwater aquifers should be accomplished through the establishment of conservative wellhead protection areas (WHPAs) wherever unconventional gas and oil resources are developed through hydraulic fracturing.

CSR17: Full transparency and prior regulatory approval of all procedures and requirements for wastewater disposal and/or treatment and discharge to open waters or other disposal should be in force before any exploration or development of unconventional gas and oil resources occurs through hydraulic fracturing.[21]

Industry Best Practices

CSR18: Best practices in unconventional gas and oil development operations (technologies, logistics, pollution control etc.) should be mandated within a regulatory framework,[22] to drive best practices for: well construction; access road and well pad construction; road maintenance; rig operations, including fluid handling; emergency response with periodic testing; operational quality control, evaluation and reporting; administrative and operational policy development and reporting.

Government Best Practices

CSR19: Government would need to create certainty through developing clear policies, legislation, and regulations in advance if it ever intends to develop its unconventional onshore gas and oil resources through hydraulic fracturing.[23] These should be set within consistent policies and strategies for all upstream resource development. Adequate funding must be committed to supporting these regulations, and a sufficient number of qualified persons must be assigned to monitor and enforce these regulations.

CSR20: Government must ensure that its monitoring and enforcement activities are accessible through a public database and that expectations are fully understood in order to avoid future contestation of regulations by developers of unconventional gas and oil resources through hydraulic fracturing.

Liabilities of Developers

CSR21: Developers of unconventional gas and oil resources through hydraulic fracturing must be able to discharge their full liabilities for harms caused to people, fauna, flora, or the environment consistent with governmental assessment of risks, and there should be adequate liability coverage that prevents the transfer of excessive costs to the public purse.

CSR22: Developers of unconventional gas and oil resources through hydraulic fracturing should be required to post a restoration bond commensurate with the potential costs of "worst case" restoration needs.

CSR23: Government should determine how it will fund clean-up, remediation or other harms where a surety has expired or where no single operator can be identified as the certain source of the harm through the development of unconventional gas and oil resources using hydraulic fracturing.

CSR24: Developers of unconventional gas and oil resources using hydraulic fracturing should make appropriate investments in new infrastructure costs (roads, pipelines etc.) plus renewal/maintenance costs as agreed with government.

CSR 25: Government and industry should make adequate provision to support community involvement in participatory planning and adaptive management activities, including their involvement in economic diversification strategies to avoid dependency on the unconventional gas and oil industry.

CSR26: Developers of unconventional gas and oil resources using hydraulic fracturing must expect punitive fines for violations of regulations and under-reporting of system weaknesses or breakdowns e.g. well integrity.

Participation in Benefits

CSR27: The government of Nova Scotia should develop a policy of benefit allocation from the activities of the unconventional gas and oil industry e.g. through royalty sharing to ensure that communities affected by development receive adequate compensation for risks and costs and tangible benefits in terms of community health and social investments for hosting the activity.

Aboriginal Engagement

CSR28: The rights of the Mi'kmaq people must be respected. The Province must ensure that it engages in a consultation process that is fully responsive to the nature and extent of the Mi'kmaq's inherent and constitutionally protected Aboriginal rights in the event that exploration or development of unconventional gas and oil resources using hydraulic fracturing ever occurs in Nova Scotia.

CSR 29: Time and effort must be devoted specifically to allow the Mi'kmaw community to deliberate and conclude their discussions with respect to the recommendations in this Report. Aboriginal communities should be supported in developing further capacity and expertise in assessing all issues of specific concern raised by the development of unconventional gas and oil resources using hydraulic fracturing through a method that is endorsed by Aboriginal communities and provides full access to independent advice.

Defining Community and Community Permission to Proceed

CSR30: The Province must work with municipalities, Aboriginal leaderships, and other community-based organizations to define mechanisms through which community opinion on the development of unconventional gas and oil resources may be defined and voiced. The Province should also work with communities to develop a process for determining the level of community support for hydraulic fracturing for the purpose of developing unconventional gas and oil resources. Community "permission to proceed" should presumptively be a pre-condition for hydraulic fracturing to proceed and should be clearly defined.

ENDNOTES

1. See Glossary
2. See Glossary
3. These formal submissions were in addition to direct feedback on discussion papers, input via public meetings and in our outreach to Aboriginal communities. See Introduction for more details.
4. See for example: Deep well of distrust on fracking. Editorial in the Chronicle Herald 5th August 2014. Available at http://thechronicleherald.ca/editorials/1227492-editorial-deep-well-of-distrust-on-fracking. Accessed 5th August 2014.
5. The British Medical Association (1987) noted that the risk tolerance of individuals decreases several orders of magnitude for an externally imposed risk versus a self-imposed risk.
6. Statistic from http://www.besthealthdegrees.com/health-risks/ Accessed 26th July 2014.
7. See for example: http://www.who.int/foodsafety/micro/riskassessment/en/ Accessed 27th July 2014
8. This observation does not guarantee this phenomenon will not happen in the future given the current inadequacy of monitoring and data (CCA, 2014).
9. Environmental Impact Assessment
10 .This observation does not guarantee this phenomenon will not become more of an issue in the future, recognizing there is a lack of data and associated monitoring on this issue (CCA 2014).
11. Over a 40 year development.
12. It is assumed deep well disposal is not permitted, so all flowback and produced water will be treated.
13. Environmental Impact Assessment, Social Impact Assessment and Health Impact Assessment.
14. Assumes CCA (2014) and IPCC (2014) assumptions prevail.
15. Assumes fugitive emissions can be effectively controlled over the long term (CCA, 2014).
16. Mercalli scale II-III ie felt only by persons at rest (II) or indoors only (III)
17. Mercalli scale II-III ie felt only by persons at rest (II) or indoors only (III)
18. This is likely to be deemed not appropriate or desirable in Nova Scotia (see Chapter 7)
19. "Community" and "community permission to proceed" are described in Recommendation CSR 29.
20.The cost of undertaking HIAs and EIAs should be borne by companies as part of cost of resource extraction in Nova Scotia.
21. The performance, sentry, and receptor approach outlined in the Council of Canadian Academies (2014) report, should be adhered to and carried out by third parties.
22. The U.S. EPA is in the process of creating wastewater discharge standards expected to be released later this year
23. See Alberta and British Columbia regulatory regimes; also New Brunswick guidelines
24. Reference points would include provincial regulations in Alberta, British Columbia and New Brunswick.

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APPENDIX A – Panel Member Biographies

Dr. David Wheeler – Panel Chair

Dr. David Wheeler is President and Vice-Chancellor of Cape Breton University. He has a BSc in Microbiology and a PhD that focused on researching water quality and health issues in developing countries.

Prior to his current role Dr. Wheeler worked in the UK water industry as a scientist for 4 years, in water quality and health research for 9 years (Surrey University, UK), as a senior executive in the cosmetics industry for 7 years (The Body Shop International), as Chair of Business and Sustainability at York University (Toronto) for 7 years, as Dean of Management (Dalhousie University) for 3.5 years, as Pro Vice-Chancellor (Sustainability) and Dean of Business (Plymouth University, UK) for 3.5 years.

During Dr. Wheeler's career he worked as an advisor to a number governments: Canada (various Departments and Provinces), the United Kingdom, Botswana, Brunei, Mexico, Nicaragua, Nigeria, Peru and Tanzania. He worked with a range of international development agencies including the World Health Organization, the Pan American Health Organization, the Red Cross/Red Crescent, Oxfam, the International Development Research Centre, the United Nations Development Program and the International Finance Corporation (World Bank). Dr. Wheeler has consulted with a number of companies on their sustainability strategies. He worked with a range of research organizations including the National Round Table on the Environment and the Economy (Canada), the UK Science and Engineering Research Council, the British Geological Survey, the UK Water Research Centre and the UK Building Research Establishment. And he has worked with a wide range of professional, civil society and other organizations and individuals including HRH The Prince of Wales, the World Business Council on Sustainable Development, Climate Change Central, Greenpeace, the Pembina Institute, Pollution Probe, Amnesty International, Human Rights Watch, the Sierra Club, the Movement for the Survival of the Ogoni People, the National Association of Local Government Offices, the Canadian Institute for Chartered Accountants, the Lancashire County Council, and the Devon and Cornwall Police.

Dr. Wheeler became involved in this review at the request of the Deputy Minister of Energy acting on behalf of the Province of Nova Scotia.

Salient to this Review, as a small part of his work the last two decades Dr. Wheeler has been directly and indirectly involved in the training of representatives of the energy industry, most notably via the Sustainable Enterprise Academy (York University) for which York University received sponsorship from Suncor and PetroCanada, among others.   He has an unpaid advisory role with the European Bank for Reconstruction and Development (Environment and Social Advisory Committee) which maintains investments in many sectors, including energy industries. And he is the unpaid non-executive Chair of LearnCorp International (a Provincially owned affiliate of Cape Breton University which trains petroleum engineers).   He is the non-active founding partner in Stakeholder Research Associates (UK) which has served a range of clients, including energy industry clients interested in sustainability and stakeholder inclusion. Cape Breton University maintains relationships with a number of energy companies (including in the oil and gas industry) that recruit its graduates and/or support its students.

As an academic, Dr, Wheeler has written extensively on corporate social responsibility and sustainability, including in the oil and gas sector where he co-authored several critical publications on the Ogoni/Shell Nigeria case. Dr. Wheeler has been active in the fields of energy efficiency and renewable energy for many years, having overseen one of the first corporate CO_2 offset projects though a significant wind farm investment in the UK in 1992. He has been an active advocate for marine renewables in Nova Scotia and the UK for reasons of economic development and climate change mitigation. Dr. Wheeler oversaw the Province of Nova Scotia stakeholder inclusive policy development projects in energy efficiency (2008) and Renewable Electricity (2009). In his current role he is active in promoting Aboriginal learning in Higher Education, through direct responsibility for Unama'ki College and the Purdy Crawford Chair in Aboriginal Business (both constituent parts of CBU) and he is active in promoting renewable energy and other clean technology developments through the Verschuren Centre for Sustainability in Energy and the Environment. Dr. Wheeler is not affiliated with any advocacy organizations and expects no advantage to accrue personally or professionally because of his work in this Review.

Frank Atherton

Dr Frank Atherton, MBChB, MRCGP, FFPHM, is the Deputy Chief Medical Officer of Health in the Department of Health and Wellness, Nova Scotia; a post he has held since 2012

Frank graduated in medicine from Leeds University, UK and worked in hospital and primary care posts around the North of England for a number of years before undertaking voluntary work as a District Medical Officer in Malawi. On his return to the UK, Frank completed specialist training in Public Health Medicine in the Yorkshire Region and then worked on international health and development issues for WHO and the UK Department for International Development in postings to the Former Yugoslavia, Tanzania, and Bangladesh. From 2002 to 2012 Frank was a Director of Public Health in Lancashire and from 2008 to 2012 he also acted as President of the UK Association of Directors of Public Health (ADPH). He holds honorary academic appointments at Dalhousie University (Adjunct Assistant Professor) and Lancaster University (Honorary Lecturer) and he is a member of the technical review panel for the Global Fund for TB, Malaria and HIV. He has undertaken short term consultancy work on international public health in several low-income countries.

Michael Bradfield

Michael Bradfield has a B. Comm. (McMaster) and Ph. D. in Economics (Brown). He taught Economics for 39 years at Dalhousie, retiring in 2007. He was a visiting scholar at Simon Fraser, the University of Virginia, and Monash, Australia. He has been President of the Canadian Regional Science Association and an associate editor of the Canadian Journal of Regional Science.   He was ranked in the international list of the top 100 of most-cited authors in regional science.

Michael's specialty is Regional Economics, but his research interests and publications cover many applications of economics, particularly the impacts of market imperfections on regional development and on market performance generally, and macroeconomic policy. His publications include a text*, Regional Economic Policy and Analyses in Canada* and the *7th Annual Review* of the Atlantic Provinces Economics Council (on Industrial Development Strategies in Atlantic Canada);13 book chapters on job creation in Atlantic Canada, technological change, financing self-reliance, constitutional change, the commercialisation of university research, and the need for new definitions and approaches to economic development. Michael's articles and commentaries in refereed journals cover a variety of topics such as foreign investment, imperfect competition in labour markets, the sources of wage differentials between regions, and Canada's energy policies.

Michael has worked with civil society groups involved in social justice, the environment (natural and built) and prepared briefs for them to municipal, provincial, and federal committees and Royal Commissions, including the National Energy Board and the Ontario Energy Board. He has also served as a consultant to private organizations, including unions. In addition, he has been an invited witness to committees of both the House of Commons and the Senate, on finance and technological change, respectively.

Kevin Christmas

Mr. Christmas has extensive experience working in all aspects of aboriginal title and treaty rights respecting the inherent rights and entitlements of the Mi'kmaw in Nova Scotia. He has served in a number of capacities, related to taxation negotiations, gaming agreements, specific and comprehensive land claims, professional development of commercial fishing enterprises, hunting and fishing guidelines, and small business development on reserves. He has served as senior advisor to the Union Nova Scotia Indians, special advisor to the chiefs on natural resources, director economic development and has served additionally in a number of government appointments with the National Economic Development Board, the NS Gaming Commission, and as Director Native Employment Nova Scotia, for the Employment and Insurance Commission and previously as Coordinator native programs for the Atlantic Region of the Secretary of State Department.

Mr. Christmas has conducted and designed numerous innovative approaches to economic development in the natural resources sectors in New Brunswick and Nova Scotia, including forestry, community engagement, and policy planning in the fields of treaty rights, industrial benefit agreements and various issues related to environmental protection of habitat and industrial pollution of Boat Harbor, in Pictou County.

Mr. Christmas is a private consultant and lives in Membertou. He is currently engaged in a number of project initiatives related to increasing public education related to treaty awareness, interpretation and land claims development with a number of interested public partners. Mr. Christmas was formally involved in the development of the UINR, the Ulnooeg Development Corporation, Gaming and Taxation Interim Agreements, Elsipoqtoq Fisheries, Listigouche Fisheries, and support for the Treaty and Aboriginal Rights office, and subsequent court cases related the SCC Marshall; SCC Simon; Denny, Paul, Sylliboy; and various specific Indian Act claims in the province.

Shawn Dalton

Since 2007, Dr. Dalton has been Owner and Senior consultant at Thrive Consulting in Fredericton, NB. She is a graduate of Sarah Lawrence College (Biology, 1988), the Yale University School of Forestry and Environmental Studies (Masters of Environmental Studies, 1992), and The Johns Hopkins University (Doctorate, Dept. of Geography and Environmental Engineering, 2002). She has led collaborative research teams conducting applied research in urban and rural communities, and uses an interest-based approach to the application of social sciences in resource management.

Dr. Dalton spent 10 years as a Research Associate, and eventually Director of the Environment and Sustainable Development Research Centre, at the University of New Brunswick. She has worked in the areas of integrated and community-based urban resource management, watershed management, climate change adaptation and mitigation, the application of social ecological models to a variety of human ecosystems, and environmental conflict resolution.

As well, Dr. Dalton has led or participated in a variety of applied research programs and project, include the Urban Resources Initiative, Baltimore MD (1992-1999); the National Oceanic and Atmospheric Administration's National Estuarine Research Reserve Network Social Assessment Training Program for Natural Resource Managers (2007); a NATO Advanced Research Workshop on Warfare Ecology: Synthesis, Priorities, and Policy Implications for Peace and Security, Vieques, Puerto Rico (December, 2009), which led to the world's first textbook on the subject -- Warfare Ecology: A New Synthesis for Peace and Security, in which Dr. Dalton's chapter is entitled, "Application of the Human Ecosystem Model in Warfare Ecology"; and the first U.S. Strategic Sciences Working Group, Deepwater Horizon Oil Spill, Gulf of Mexico (2010).

Her interest in participating on this panel stems from her broad commitment to and interest in measuring, documenting, and effectively communicating the community effects of natural resources management, with the goal of improving decision-making and governance arrangements.

Maurice Dusseault

After an unsuccessful attempt at first-year chemistry, Maurice spent three years working on Alberta drilling rigs, first as a roughneck and then as a drilling fluids technician. After returning to study engineering, he began working summers as well as the year following graduation at the Alberta Research Council as a junior geologist. He was awarded a PhD in Civil Engineering in 1977 from the University of Alberta, started teaching there, and was funded by the Alberta Government to study oil sands issues. Since 1982, he has been Professor of Geological Engineering, Earth and Environmental Sciences Department, at the University of Waterloo.

Maurice carries out research in rock mechanics, oil production, mining, and deep waste disposal technologies. Recent research areas include geomechanics issues in borehole stability, carbon sequestration, hydraulic fracturing, deep biosolids disposal, and salt cavern analysis. In carbon sequestration, several new approaches have been developed and patented to make storage of CO_2 in deep saline aquifers safer and more feasible.

Pressure pulsing of wellbores is another patented process that Maurice helped to develop; this method has been used many times in the United States over the last decade to help clean petroleum-based liquids from shallow groundwater aquifers. Another patent that Maurice holds with others is for deep disposal of biosolids with co-generation of methane for energy recycling and sequestration of solid carbon; this procedure is being used in a trial project in Los Angeles. Related concepts he developed involving deep injection are now used to guide solid waste disposal in areas like the North Sea, Indonesia and the Middle East. Previous work in hydraulic fracturing for well completion has led to a recent patent that proposes a slower but more prolonged approach to fracturing than is used currently.

His three major research areas now are hydraulic fracturing, energy storage in salt caverns, and wellbore integrity. In 2013 he received a four-year award from the federal government to develop better analysis and monitoring methods for hydraulic fracturing. A multi-university and multi-province project on compressed air energy storage using dissolved salt caverns to store energy is being initiated in 2014. This approach will allow renewable sources such as solar, wind and wave energy to be better accommodated in provincial electrical grids. In the area of wellbore integrity, he is studying mechanisms that may lead to slow seepage of natural gas from depth, and expects to initiate a multi-year research program in 2015 to develop better ways of modeling and mitigating such problems.

Overall, Maurice holds about 10 patents, has co-authored two textbooks with John A Franklin (former ISRM President, deceased 2012), and has published over 500 full text conference and journal articles, plus many hundreds of consulting reports, briefing documents, critiques of reports and articles, and scientific commentaries.

Maurice has been employed by governments and companies as a teacher of professional short courses in petroleum geomechanics, heavy oil production, wellbore stability, reservoir geomechanics, sand control and waste disposal in more than 20 different countries during the last 20 years. Maurice has given talks at conferences and other events in the Middle East, Europe, Australia, Asia and the Americas, as well as serving as one of the lecturers for the SPE annual lecture tour of 2002-2003, visiting 19 countries and 28 separate SPE sections, speaking on New Oil Production Technologies. He is currently an advisor to government agencies in Alberta, Quebec and New Brunswick, where he is a member of the Scientific Advisory Council of the New Brunswick Energy Institute.

Maurice's university pension plan and his personal holdings have some energy-related stocks. He has no ties to any oil and gas sector company active in the Maritimes.

Graham Gagnon

Graham Gagnon, Ph.D., P.Eng., is the NSERC/Halifax Water Industrial Research Chair and Professor in the Department of Civil and Resource Engineering at Dalhousie University in Halifax. He is also the Director for the Centre for Water Resources Studies at Dalhousie University. Dr. Gagnon holds a B.Eng. in Environmental Engineering from the University of Guelph, a Ph.D. in Civil Engineering from the University of Waterloo and is a licensed Professional Engineer in Nova Scotia.

Dr. Gagnon's professional and research interests focus on the management of water quality and treatment for natural and engineered systems. Throughout his career he has worked on applied water research projects for municipalities in Atlantic Canada, private companies, provincial departments, federal agencies and First Nation Communities. In 2014, Dr. Gagnon received the George Warren Fuller Award from the American Water Works Association (AWWA) in recognition of his exceptional contributions in water research throughout his career.

Dr. Gagnon has published over 100 peer reviewed journal papers and trained over 50 graduate students related to the areas of drinking water quality, drinking water treatment and wastewater management. In particular, he has worked on several research projects related to drinking process design and treatment, municipal wastewater, seafood process wastewater, aquaculture process water, wastewater from hydro-electric processes, agricultural wastewater, and produced water from offshore natural gas platforms. He has applied his knowledge and skills in water quality and treatment to this review to assist the panel in reviewing aspects related to water resources, water quality and wastewater management.

Dr. Gagnon lives in Halifax where he has coached his children in basketball and baseball. He also enjoys running with his friends and walking in Point Pleasant Park with his partner, Ruth, and their dog Skye.

Brad Hayes

Brad Hayes earned a B.Sc. (Geology) from the University of Toronto, and a PhD (Geology) from the University of Alberta. Brad began work in the Canadian oil industry in 1981, and worked 15 years with several operating companies: Shell Canada Resources; Canadian Hunter Exploration; Dorset Exploration; Canadian 88 Energy and Chauvco Resources. At Canadian Hunter, he was instrumental in drilling gas wells to open up the B.C. Deep Basin as a major producing area. In 1996, Brad joined Petrel Robertson Ltd., and in 1998 was a founding partner in its successor firm, Petrel Robertson Consulting Ltd (PRCL). Since 2007, Brad has served as President of PRCL.

Petrel Robertson Consulting Ltd. holds memberships to the Association of Professional Engineers and Geoscientists of Alberta APEGA (Permit to Practice) and Canadian Society for Unconventional Resources. Brad became a Professional Geologist with the Association of Professional Engineers and Geoscientists of Alberta in 1984. He is professionally obligated to be bound by the APEGA Code of Ethics, which strictly prohibits undertaking any work that would expose him to a conflict of interest. He is also registered as a Professional Geoscientist in British Columbia (APEGBC) and Nova Scotia (APGNS), which have similar codes of ethics. Neither Brad nor PRCL have worked in the past, or presently work on, or anticipate working on, any project relating to petroleum exploration and development in onshore Nova Scotia. Neither Brad nor PRCL have any financial interest in any organization engaging in, or planning to engage in petroleum exploration or development in onshore Nova Scotia. Neither Brad nor PRCL are members of any advocacy groups.

Brad has completed a wide variety of technical and strategic studies for oil and gas companies, investors, Crown corporations, and regulatory agencies. A few examples of the clients he has worked with are: BC Oil & Gas Commission; BC Ministry of Energy Mines and Petroleum Resources; Geoscience BC; Alberta Energy Resources Conservation Board; Yukon Geological Survey; Northwest Territories Geoscience Office; Newfoundland Hydro; National Energy Board; Department of Indian Affairs and Northern Development; Australia Northern Territory geoscience office; and Canada Hibernia Holding Corp. His project work has included: expert witness work for numerous legal firms, addressing petroleum geoscience issues in litigation and regulatory matters, and advisory work to numerous investment firms, concerning technical and strategic merits of investment in petroleum assets. While much of the work has been in Canada, projects range throughout North and South America, New Zealand / Australia, Africa and Asia.

With the evolution of the petroleum industry toward unconventional oil and gas reservoirs, Brad and PRCL have completed numerous evaluations of unconventional reservoir prospectivity and unconventional oil and gas resource assessment. In the past three years, PRCL has also completed a number of projects characterizing subsurface aquifers as potential water sources and disposal zones to support unconventional hydrocarbon development. Brad has published numerous papers and reports on these and other aspects of petroleum geology.

Brad has extensive volunteer experience at both professional and community levels. He is a member of the Canadian Society of Petroleum Geologists, and served as its President in 2001. He currently serves on APEGA Council. Brad also serves on the Oil and Gas Technical Advisory Committee for Geoscience BC, and is a member of the American Association of Petroleum Geologists and the Geological Association of Canada. Brad joined the Nova Scotia Expert Panel to lend his expertise to a complex and engaging process, and to learn from other experts on issues important to the oil and gas industry.

Brad lives in Calgary with his wife Carol, and they have two sons attending university in Vancouver.

Constance MacIntosh

Constance MacIntosh is the Director of Dalhousie's Health Law Institute, and an Associate Professor at the Schulich School of Law at Dalhousie. She holds a master's degree in anthropology, and graduated as her class gold medalist from Osgoode Hall Law School. Before coming to Dalhousie, she worked as a lawyer. Most of her practicing career involved being at a firm that only worked on Aboriginal law issues. She has worked at Dalhousie for just over 10 years and has taught a variety of courses, including contract law and Aboriginal law. As well as being a long time member of the Health Law Institute, she is also a research associate with Dalhousie's Marine and Environmental Law Institute.

Her research and scholarship pursues a number of related matters. One central research theme is on understanding what makes regulatory regimes successful (or unsuccessful), a matter which she has largely pursued with regard to the public health experiences of Aboriginal Canadian communities. This work has most often engaged with regulatory regimes that are intended to address water quality and living standards. She has published extensively in this area, in a variety of forums including peer-reviewed articles and chapters in leading textbooks. An example of one recent major project was her work as an Expert Panel Member for the Council of Canadian Academies report on the state of food security for Northern Aboriginal communities. That report was finalized and released in 2013.

Constance joined the review while it was in progress. This decision was made in part in response to many members of the public raising issues about regulatory regimes, and also by the panel's recognition that it was essential to have a panel member with expertise regarding the law surrounding Aboriginal and treaty rights. This is the only project that she has worked on that involves hydraulic fracturing and the energy industry.

Ian Mauro

Dr. Ian Mauro is an Associate Professor in the Department of Geography at the University of Winnipeg. He holds a BSc in Environmental Science and PhD in Geography, from University of Manitoba, and was a SSHRC Postdoctoral fellow in Ethnoecology at the University of Victoria. He previously held a Canada Research Chair in Human Dimensions of Environmental Change at Mount Allison University.

As both a community-based researcher and filmmaker, Mauro works at the interface between the social and ecological sciences, and is a pioneer of multi-media methodologies, scholarship and education. He uses participatory video to collect, communicate and conserve local and indigenous knowledge, an approach that allows people who live on the land to tell their own stories, in their own language, and within the landscapes where their knowledge has been generated. He was awarded an "Apple Distinguished Educator" award for his approach in 2011.

Mauro's research focuses on emerging technologies, climate change and food security issues. His PhD research remains one of the largest farmer-focused risk analyses on genetically modified (GM) crops, involving over 2000 Canadian prairie farmers, and included the production of the documentary *Seeds of Change*. He has consulted with numerous countries, civil society organization and companies about biodiversity, rural communities, and agriculture. He has also collaborating extensively with Inuit communities, specifically in Nunavut, and witnessed the warmest decade on record while living in the Canadian Arctic.

He co-directed the influential Inuktitut language documentary *Qapirangajuq: Inuit Knowledge and Climate Change* (www.isuma.tv/ikcc) with acclaimed Inuk filmmaker Zacharias Kunuk (*Atanarjuat The Fast* Runner) and continues research focused on industrial development in the Canadian Arctic. Over the past year, Mauro released *Climate Change in Atlantic Canada* (www.climatechangeatlantic.com), which explores the impacts of extreme weather on coastal communities and local-level approaches to mitigation and adaptation. He toured across Canada with David Suzuki, presenting this film as a fundraiser for local environmental groups, and plans to release his third climate change film focused on British Columbia in 2015.

His films on biotechnology and climate change have been translated into numerous languages and screened globally at academic conferences, film festivals and venues such as the United Nations, Smithsonian Institution, National Geographic and the Royal Ontario Museum. Mauro was also a panelist on the Council of Canadian Academies Expert Panel on *Food Security in Northern Canada: An Assessment of the State of Knowledge.*

Mauro is currently working on research and filmmaking initiatives across the country and he continues to collaborate with various academic partners and environmental, indigenous and community groups. He is an avid cyclist, in both summer and winter months, and lives in Winnipeg with his partner and two young children.

Ray Ritcey

Ray Ritcey, President of Lighthouse Energy Inc., has a Bachelor of Commerce and Masters of Business Administration from Saint Mary's University and he is a Chartered Professional Accountant/Certified General Accountant. Ray was born and raised in Halifax, worked in Toronto for 20 years then returned to Nova Scotia in 1998 where he continues to live with his wife Debbie and they have two grown children.

Following his initial career with the Bank of Nova Scotia, he has over 30 years' experience in the energy industry in Canada. He has held executive positions in both the natural gas and electric industries working with such industry leaders as TransCanada Pipelines, Ontario Hydro, Enbridge and AltaGas. Ray has a broad based utilities background mostly in the mid and downstream sectors focused primarily on business development opportunities.

Ray wanted to participate in the Review in the hope that he would learn more about the relationship between the upstream oil and gas sector and our water resources. He was especially interested to hear the scientific evidence of whether the oil and gas sector was in fact contaminating our water resources and to bring his learnings and perspective to the issues at hand.

From 1998 until 2010, Ray led the development and build-out of natural gas distribution in Nova Scotia, in part through his own consulting company, providing natural gas customers hundreds of millions of dollars in savings over time while significantly improving the environment by reducing emissions 30-50% over historic levels. Natural gas in Nova Scotia began some 75-100 years after most markets in North America and is one of the last jurisdictions where the majority of homes and businesses are heated by fuel oil and where coal is the dominant source of fuel for generating electricity. Ray was the first President of Heritage Gas Limited, Nova Scotia's local natural gas distribution company from 2003 until 2010. In January 2009 he received the Halifax Chamber's Bronze Award for Business Person of the Year.

Lighthouse Energy Inc. (established in 2000) provides energy consulting to government and industry in Atlantic Canada. Since January 2013 Ray has been developing several energy related initiatives including one to increase the level of energy knowledge for government and regulators through Atlantic Canada based universities and community colleges. In November 2013, Ray became a volunteer Co-Chair of QUEST Nova Scotia. Quality Urban Energy Systems of Tomorrow (QUEST) is a collaborative network of stakeholders actively working to make Canada a leader in the design, development and implementation of smart energy communities.

Ray has an extensive history of being involved in numerous energy committees and industry organizations as well as appearing before various regulatory agencies in Eastern Canada. He has a long history of volunteering with a number of organizations including the IWK Foundation, the Halifax Chamber of Commerce and Prostate Cancer Canada.

APPENDIX B – List of most frequently asked questions from the public meetings and where to find more information on those questions.

List of most frequently asked questions at the public meetings: July 16 to 29, 2014

Question	Answer and Related Information
How was the panel selected?	By public nomination following public consultation on skills required on the Panel. Candidates were then categorised by skill set and the best qualified candidate on each short list was selected. See Introduction Sections I.2.2 and I.2.4. See also Appendix A for Panel biographies.
Who pays for this review?	The Province of Nova Scotia paid for the Review. Introduction Section I.1 describes the mandate. Contracts are available on the project web site: http://www.cbu.ca/hfstudy/resources/project-documents.
How much is Dr. Wheeler and the panel paid?	Panellists get paid an honorarium of $1500 for their work. Dr Wheeler is unpaid. Cape Breton University has only its direct costs covered. See Introduction Sections I.1 and I.2.4.
What about Maurice Dusseault's patent, isn't that a conflict of interest?	Dr Dusseault is an academic engineer and an inventor. Filing patents is normal in his field. He was selected and approved as a member of the Panel of the Council of Canadian Academies as a national expert on well integrity. He has no direct personal interest in the future of hydraulic fracturing in Nova Scotia. See Introduction Section I.2.4 and Appendix A
How many panel members are from industry?	Several members of the Panel have industry experience and/or have consulted with industry. Others have professional relationships with civil society organisations. All Panel members are bound by the project Code of Conduct. See Introduction Section I.2.2 and Appendix A and project web site: http://www.cbu.ca/hfstudy/resources/project-documents.

Why isn't the panel at the meetings?	This was not in the mandate of the project or that of the individual panellists. It would also have added significant extra costs to the project. Two panellists attended the Halifax meeting. One panellist attended three other meetings. See also Introduction Section I.2.2 and I.3.3.
What happens with the information from the meetings and are they recorded?	Most were recorded (variable quality and therefore not transcribed). See Introduction I.2.2 and 1.2.3 and project website for recording of Halifax session: http://www.cbu.ca/hfstudy/resources/project-documents. Notes were produced for each event and submitted to the Panel.
Why can you include estimates on the revenue and royalties but not the costs to communities?	Revenues and royalties are driven by standard formulae and experience elsewhere. Costs to communities are geography and population specific and would require further research to model and calculate. See Introduction Section I.4.2, Chapter S Sections 3.2 and 3.3 and Chapter 11 Sections 11.1 and 11.4 (Recommendations).
What about the expenses to municipalities and local residents (i.e. infrastructure costs and externalities)?	Externalities and direct costs to communities are described in the Introduction Section I.4.2, Chapter 3 Sections 3.2 and 3.3, Chapter 5 Sections 5.3, 5.4 and 5.5 and Chapter 11 Sections 11.1 and 11.4 (Recommendations).
Have you considered the loss of agricultural land and impacts on tourism and real estate (i.e. externalities)?	Yes. See Introduction Section I.3 and Section I.4.1 and I.4.2 and Chapter 5 Sections 5.3, 5.4 and 5.5.
Who pays for the externalities?	This would be a matter for the provincial government in consultation with affected communities. See Introduction Section I.4.2, Chapter 5 and Chapter 11 Sections 11.1 and 11.4 (Recommendations).
What about considering renewable energy options instead of hydraulic fracturing?	It is assumed that the existing targets for renewable electricity in Nova Scotia remain. See Introduction Section I.1 for what was not included in the mandate. See also Chapter 8 Section 8.5 for a discussion of climate change issues and Chapter 11 Section 11.3 (Summary of Risks) for some comparative analysis.

Why are we even considering this when there are other more sustainable options?	See Introduction Section I.1 for what was not included in the mandate. See also Chapter 8 Section 8.5 for a discussion of climate change and other sustainability issues and Chapter 11 Section 11.3 (Summary of Risks) for some comparative analysis.
Are you considering NS historical background on industry development (namely poorly regulated and monitored examples)?	We address the importance of effective regulation throughout the Report, for example in Chapters 1, 4, 6, 7, 8 and 9. We also make a number of recommendations relating to the importance of effective regulation in Chapter 11, Section 11.4.
What about seismic events?	See Chapter 5 Section 5.3.2, Chapter 8 Sections 8.4.4 and 8.4.7, Chapter 9 Section 9.4.1, and Chapter 11 Section 11.3 (Summary of Risks) for some comparative analysis.
What about Duncan Keppie's work and the fault lines in our geology?	Dr Keppie's material was reviewed and the issues raised are dealt with in Chapter 2.
Are you considering Duncan Keppie's work?	Dr Keppie's material was reviewed and the issues raised are dealt with in Chapter 2.
How much money would a community receive from hydraulic fracturing?	We estimate potential revenues and royalties and possible levels employment based on a range of scenarios in Chapter 3. We also discuss some of the challenges of making these estimates in Chapter 11 Section 11.1.
Shouldn't we be looking at other ways to make money (i.e. renewables, agriculture and tourism)?	See Introduction Section I.1 for what was not included in the mandate. See also Introduction Sections 1.3 and 1.4 and Chapters 5 and 8 for discussions of possible tensions between competing land uses and economic opportunity.
Are you looking at the health impacts from naturally occurring radioactive materials (NORMs)?	Yes. This issue is described in Chapter 1 Section 1.7.2, Chapter 4 Section 4.5.2, Chapter 8 Sections 8.4.1 and 8.4.4 and is dealt with in Chapter 11 Section 8.4 (Recommendations).

Are you considering the health impacts on animals?	This is discussed in the Introduction Section 1.4.2, Chapter 5 Section 5.3.2, Chapter Section 8.4.7 and Chapter 10 Section 10.2.2. This issue is the subject of recommendations in Chapter 11 Section 11.4.
Is fracking harmful to health?	The protection of public health is described in detail in Chapter 4. See also Chapter 8 Section 8.4.5, Chapter 11 Section 11.3 for comparative risk assessments and Section 11.4 for a number of recommendations.
Isn't one injury, one accident, one life-lost too many?	Occupational health issues are addressed in Chapter 4. See also Section 11.4 for relevant of recommendations.
How do you define community?	Chapter 5 deals with impacts on communities. Chapters 8, 9, 10 and 11 create the basis for establishing a 'community permission to proceed' consistent with Nova Scotia legislation. We address how community should be defined in Section 11.4.
How are you going to give communities control over the decision to develop for oil and gas extraction using hydraulic fracturing?	Chapter 5 deals with impacts on communities. Chapters 8, 9, 10 and 11 create the basis for establishing a 'community permission to proceed' consistent with Nova Scotia legislation and the 'precautionary approach'. We address how the community permission to proceed should be developed in Section 11.4.
How can you know how communities are impacted when "gag-orders" and non-disclosure agreements are signed and communities are not able to talk about their experience?	The situation in the US with respect to litigation and compensation is not analogous to Canada so we based our assessments more on Canadian experience and the emerging literature on positive and negative experiences in communities affected. See Chapters 5 and 11 Section 11.1 for further discussion.
What are the possible impacts to groundwater?	Chapters 6 and 7 deal with water quality protection and the maintenance of well integrity. Chapter 11 Section 11.3 provides comparative information on risk frequency and severity. Relevant recommendations are made in Chapter 11 Section 11.4.

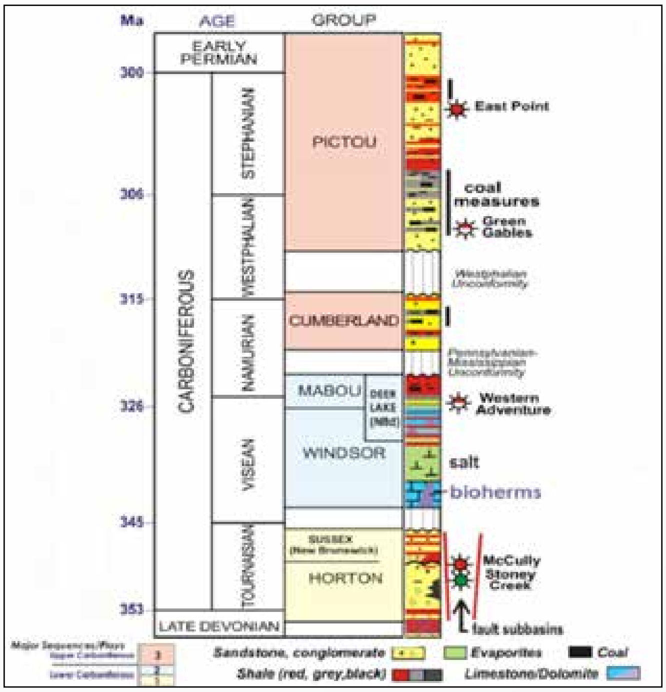
All water is connected so if you do something underground won't it still impact the surrounding communities?	Chapters 6 and 7 deal with water quality protection and the maintenance of well integrity. Chapter 11 Section 11.3 provides comparative information on risk frequency and severity. Relevant recommendations are made in Chapter 11 Section 11.4.
What will fracking do to my farm, water and wells?	Chapters 6 and 7 deal with water quality protection and the maintenance of well integrity. Chapter 11 Section 11.3 provides comparative information on risk frequency and severity. Relevant recommendations are made in Chapter 11 Section 11.4.
How can you be sure that the wells won't leak?	Well integrity is the subject of Chapter 7, both with respect to possible water contamination pathways and the escape of methane from poorly finished wells or disused and capped wells at the end of their life. Chapter 11 Section 11.3 provides comparative information on risk frequency and severity. Relevant recommendations are made in Chapter 11 Section 11.4.
All wells leak so why are we even considering this? (many different statistics on well-leakage were stated by different individuals at each meeting)	Well integrity is the subject of Chapter 7, both with respect to possible water contamination pathways and the escape of methane from poorly finished wells or disused and capped wells at the end of their life. Chapter 11 Section 11.3 provides comparative information on risk frequency and severity. Relevant recommendations are made in Chapter 11 Section 11.4.
Are you looking at greenhouse gas (GHG) emissions and climate change issues?	Yes See Introduction Section I.1 for what was not included in the mandate. See also Chapter 8 Section 8.5 for a discussion of climate change and other sustainability issues and Chapter 11 Section 11.3 (Summary of Risks) for some comparative analysis and Section 11.4 for relevant recommendations.
Have you considered risks to fish, wildlife and ecosystems?	Yes. See Chapters 5 and 8 for consideration of these issues and Chapter 10 for relevance to Aboriginal communities. See Chapter 11, Section 11.3 for comparative risk issues and Section 11.4 for relevant recommendations.

How do you establish proper regulation and monitoring?	We address the importance of effective regulation throughout the Report, for example in Chapters 1, 4, 6, 7, 8 and 9. We also make a number of recommendations relating to the importance of effective regulation in Chapter 11, Section 11.4.
NS has a bad track record with regulation, monitoring and enforcement so why should be trust them to do a good job now?	We address the importance of effective regulation throughout the Report, for example in Chapters 1, 4, 6, 7, 8 and 9. We also make a number of recommendations relating to the importance of effective regulation in Chapter 11, Section 11.4.
All aboriginal communities are saying NO so why are we even talking about it?	See Chapter 10 for a detailed discussion of Aboriginal rights, Treaty rights and Title issues. The importance of involving Aboriginal communities and leaderships in the topic is the subject of recommendations in Chapter 11 Section 11.4.
Will you call for a moratorium on fracking?	No, this would be overstepping our brief as it is a political decision. That choice is available to the provincial government.
Why won't you call for a moratorium on fracking?	This would be overstepping our brief as it is a political decision. That choice is available to the provincial government.
Will you call for a ban on fracking?	No, this would be overstepping our brief as it is a political decision. That choice is available to the provincial government.

APPENDIX C: Geological Review of Oil and Gas Potential in Nova Scotia Basins

Figure C.1 is a stratigraphic column, or chart, depicting ages and compositions of sedimentary rocks filling the Maritimes Basin and serves as a guide to discussing unconventional oil and gas prospectivity. Prospectivity of major subdivisions, termed ‘groups’, are reviewed from oldest to youngest.

Figure C.1: Schematic Stratigraphic Column



Adapted with permission from Natural Resources Canada: Lavoie et al, 2009

Horton Group

Horton Group rocks are of Early Carboniferous age, about 353 to 345 million years old. They were deposited when the Maritimes Basin complex was first being formed and consist generally of:

- Sandstones and conglomerates (deposited as sands and gravels) at the base,
- Shales (deposited as organic-rich muds in widespread lakes) in the middle, and
- Sandstones and finer-grained sedimentary rocks (deposited as sands, silts, and muds on river floodplains) at the top.

Gas and oil occur in both conventional sandstone/conglomerate reservoirs and in unconventional ‘tight’ (low-permeability) sandstones and shales of the Horton Group, throughout the Maritimes Basin. Organic-rich material in the medial Horton Group shales provided a source for oil and gas in the Horton

Group; some of these fluids have been retained within the shales and some have migrated into other sedimentary rock layers. Locally, Horton Group rocks have been exposed to so much heat and pressure that they have no petroleum potential.

Conventional Oil and Gas

In the Moncton Basin of New Brunswick, Corridor Resources produces gas from upper Horton Group sandstones at McCully Field and Contact Exploration produces oil from reservoirs of the same age at Stoney Creek Field (locations shown in Figure 2.3). While reservoir quality in both fields is viewed as conventional, horizontal drilling and hydraulic fracturing have enhanced productivity and improved economics. Based on data from these fields and other mapping, Lavoie et al., (2009), estimated hydrocarbon potential in conventional Horton Group reservoirs in the Maritimes Basin complex (including offshore) ranges from 300 to 1185 million barrels of oil and from 6.1 to 23.7 TCF of gas.

Unconventional Oil and Gas

Distribution and quality of unconventional Horton sandstone reservoirs is not well understood and no estimates of their resource potential have been published. We assume, however, that unconventional oil and gas potential is widespread, as all the necessary components exist – thick sandstone reservoirs, which exhibit low permeability in many areas, a rich source of oil and gas in the organic material of the medial Horton shales, deep burial depths, and impermeable rocks in the overlying Windsor Group to prevent hydrocarbons from escaping. In a similar fashion, Hayes (2011), postulated the presence of unconventional gas and oil plays in the Northwest Territories based on knowledge gained from existing boreholes (drilled for conventional reservoir targets). Lacking more specific information about Horton sandstones, we assume greater prospectivity in the basins closest to the known production.

The most widespread and well recognized Horton Group unconventional prospectivity occurs in the medial shales. They have abundant organic material and are at sufficient depths to generate oil and gas, as discussed by Hamblin (2006), and Lavoie et al. (2009). There is sufficient information to merit reviewing medial Horton shale prospectivity for specific basins.

- Moncton Basin (New Brunswick) – In the Moncton Basin, where the medial Horton Group is called the Frederick Brook Shale, Corridor Resources (2014), estimated in-place gas resources of 67 TCF on lands where they hold petroleum rights, while Contact Exploration (2014), estimated 10.9 TCF gas in place on their lands. Corridor is producing gas from the Frederick Brook in three wells stimulated with hydraulic fractures. Martel (2013), provided additional detail on assessment work by Corridor and recent news releases indicate Corridor will spend significantly in 2014, on developing Frederick Brook shale resources. To the northwest of the Corridor and Contact operations, Southwestern Energy is prospecting for oil and gas in the Frederick Brook and other Horton Group unconventional reservoirs.

U.S. E.I.A. (2013), assessed prospectivity of the Frederick Brook in the Moncton Basin, and found positive indicators, in that the shales contain reasonably abundant organic material and experienced sufficient burial and heating (termed "maturity"). However, they found no available information on Frederick Brook shale mineralogy and thus its general suitability for stimulation by hydraulic fracturing ("brittleness") could not be assessed.

Keighley and St. Peter (2003), cited a "long-identified but still undeveloped" 67 million barrels of shale oil in the Moncton Basin, but gave no background for derivation of this volume.

- Windsor-Kennetcook Basin (Figure 2.3) – In the Windsor-Kennetcook Basin, the medial Horton Group shale is called the Horton Bluff Formation. U.S. EIA (2013), made the following observations:
    - The regional extent of the Horton Bluff shale is poorly understood, but a 520 mi^2 prospective area is a best estimate;
    - There is a thick prospective shale section, ranging up to about 150m;
    - Organic material is abundant and has experienced significant heat and pressure, making it prospective primarily for gas.

Using this information, U.S. EIA (2013), assigned a 'risked' gas in place of 17 TCF for the basin. The 'risk' factor is a discount applied to the total gas in place, calculated (about 43 TCF) to reflect uncertainties in shale reservoir parameters.

By comparison, Ryder Scott (2008), calculated ('unrisked') gas in place of 69 TCF over a property of about 580 mi^2 held by Triangle Petroleum. Ryder Scott based their assessment on shale reservoir parameters measured from cores taken at the Kennetcook #1 well. However, relatively small hydraulic fracture stimulations in three wells drilled by Triangle failed to result in any gas production. Instead, water injected during the hydraulic fracturing process, plus some saline formation water, flowed back from the wells after stimulation. Technical staff working the Triangle operations reported indications that induced fractures did not propagate in the subsurface exactly as expected and therefore may not have effectively stimulated the reservoir.

While Triangle's results do not support the existence of productive capacity in the Horton Bluff, they do not conclusively condemn the reservoir. Additional work, including horizontal drilling and re-designed multiple hydraulic fracture stimulations, are required to further assess the shale.

- Cape Breton Basins (Figure 2.3) – Mukhopadhyay (2004), surveyed petroleum potential of the various basins on Cape Breton Island, although primarily from a conventional reservoir point of view. Very few wells and limited seismic data are available and so much has been inferred from surface studies and the few (generally old) boreholes available. While no quantitative estimates of oil and gas potential were made, it is important to note that oil shows at the surface in many of these basins demonstrate that oil is present. Geochemical analysis demonstrates that much of this oil originated from the Horton Group shales, here called the Strathlorne Formation.

Significant prospectivity for medial Horton (Strathlorne) shales is inferred for Cape Breton basins, as all the necessary ingredients for unconventional prospectivity are present, even though quantitative measures are lacking.

General Observations on Horton Group Prospectivity in Nova Scotia

MacDonald (2011), reported that the Nova Scotia Department of Energy had undertaken an effort to more systematically understand the gas in place resource potential in the Horton Bluff shales of Nova Scotia basins. Although results of this study are not yet available, MacDonald noted that examination of the available seismic data and ongoing studies on outcrops of the potential reservoirs flanking the basin would be important in better understanding productive potential. While the focus has been on gas potential, it is important to note that oil may occur as well, depending largely on the heat and burial maturation affecting the organic source materials.

Hamblin (2006), cited studies indicating that the medial shales of the Horton Group are well-developed in all Nova Scotia basins and that they include substantial thicknesses of organic-rich, prospective shale reservoirs. He also noted that shale maturities in some basins indicate oil potential as opposed to gas, but additional work is necessary to better understand both oil and gas potential.

Windsor and Mabou Groups

Windsor-Mabou rocks are of Early Carboniferous age, about 345 to 326 million years old. They were deposited in open marine waters that flooded the Maritimes Basin and consist generally of:

- Fossil-rich limestones (carbonate rocks), including local reef build-ups at the base,
- Salts (evaporite minerals), indicating reduced marine water supply and drying-up of the basins, in the middle, and
- Sandstones and finer-grained sedimentary rocks (deposited as sands, silts, and muds on river floodplains and in lakes) at the top.

Lavoie et al. (2009), noted that marine rocks in the Windsor Group above the basal limestones grade to more continentally-derived (river and delta) sandstones in northeastern New Brunswick and adjacent Nova Scotia. However, the Windsor Group can range up to several thousand metres thick and is prospective in many areas.

Carbonate reefs in the basal Windsor, termed the Gays River Formation, are viewed as prospective oil reservoir targets in the Shubenacadie Basin (Figure 2.3). Forent Energy has explored for oil in Gays River reefs on their Alton property, using seismic and other geophysical methods (Forent, 2014). As reservoir properties of Gays River reefs have not been assessed in the subsurface, it is unknown whether hydraulic fracturing would be required to establish commercial flow rates from a reef discovery. However, Forent was not successful in finding a reef reservoir in two wells drilled to date and has elected to suspend exploration operations in Nova Scotia. Mukhopadhyay (2004), noted that basal Windsor carbonates and shales deposited in deeper areas in Cape Breton basins may have similar oil potential, but was not able to quantify it. Lavoie et al. (2009), confirmed analogous basal Windsor carbonate prospectivity throughout the Maritimes Basin complex.

Salts (evaporite minerals) in the medial Windsor Group have essentially no reservoir quality and therefore are not prospective. However, they are important in providing an impermeable barrier between under- and overlying rocks, meaning that oil and gas generated in the organic-rich shales of the Horton Group generally cannot migrate upward through the salts to charge overlying reservoirs.

In the upper Windsor Group and Mabou Group, limited shale and carbonate reservoir potential may exist in thin beds, continuous over large areas, deposited in shallow marine waters. Mukhopadhyay (2004), noted oil and condensate (very light petroleum liquids) potential in these rocks in Cape Breton basins, but did not consider their potential as tight reservoirs. Most interesting from an unconventional point of view, Hamblin (2006), noted that widespread shales up to 325m thick, deposited in organic-rich lake settings, might have oil and gas prospectivity similar to underlying Horton Bluff shales.

In conclusion, while both conventional and unconventional reservoirs prospective for oil and gas exist in lower and upper Windsor Group and the Mabou Group, they have not been explored for their unconventional potential, nor have estimates of oil and gas volumes been published.

Cumberland and Pictou Groups

Cumberland and Pictou rocks are of Middle to Late Carboniferous age, about 320 to 300 million years old and cap the prospective reservoir section in the Maritimes Basin. They consist primarily of thick sandstones with siltstones and shales, deposited by rivers over broad floodplains and large deltas. Total thicknesses range up to thousands of metres. Also in this setting, thick coal seams formed through accumulation of wood and related materials in vast coal swamps. Nova Scotia's historic coal mining industry has tapped into these seams in many coalfields, particularly in Sydney, West Cape Breton, Stellarton, and Cumberland basins.

Coalbed Methane

When buried, coal-based organic material can produce natural gas, primarily methane (CH_4). Where hosted within coal seams – within pores, fractures, and adsorbed onto organic matter – this gas is termed coalbed methane (CBM) (Dawson et al., 2000). There is little potential for more hydrogen-rich hydrocarbons, such as gas liquids or oil, when coaly material is the source.

Dawson et al. (2000), noted substantial CBM potential in Nova Scotia basins, but data available at the time did not support quantitative assessments. Lavoie et al. (2009), characterized Cumberland-Pictou coals as having "major natural gas source potential".

In the Cumberland Basin, two vertical wells and three horizontal wells were drilled by Amvest Nova Scotia, Contact Exploration, and Stealth Ventures. Stealth (2014), estimated CBM gas in place in the Cumberland Basin coals as 1.18 TCF.

In the Stellarton Basin, after drilling three wells and undertaking extensive analyses, Amvest Nova Scotia (1999), estimated Stellarton Basin CBM gas in place resources at 0.480 TCF. Stealth Ventures acquired Amvest's interests and after additional drilling, commissioned a report estimating 0.426 TCF CBM gas in place in the basin (http://www.stealthventures.ca/pdf/StealthVentures_StellartonCBMProject.pdf). East Coast Energy Inc. continues to drill and evaluate the commercial viability of this project (http://www.ngnews.ca/News/Local/2014-03-10/article-3643227/Update-on-East-Coast-Energy-Inc.-coal-bed-methane-project/1).

Hughes (2003), completed an extensive analysis of coal beds and their reservoir properties in three basins and tabulated the following gas in place resources:

- Sydney Basin: 0.977 TCF
- Stellarton Basin (Pictou coalfield): 0.284 TCF
- Cumberland Basin: 0.422 TCF

Despite this widely-recognized potential and the drilling of more than 30 CBM test wells, there is, at present, no commercial coalbed methane production in Nova Scotia.

From the perspective of the present study, any CBM accumulations developed will likely not be hydraulically fractured. Where fracture stimulation of coal seams is deemed necessary, a gas such as nitrogen is generally used instead of water, particularly at relatively shallow depths (500m or less). Where gas fracturing is used, naturally-occurring formation water may flow from coal seams, but there will be no input or flowback of other waters or chemicals associated with hydraulic fracturing.

Sandstone Reservoirs

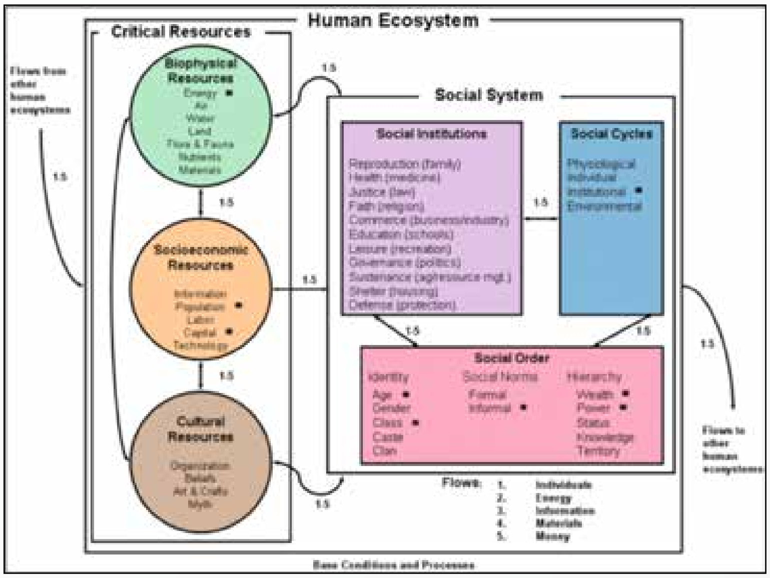
Lavoie et al. (2009), estimated oil and gas in place in conventional sandstone reservoirs of the Cumberland and Pictou groups, throughout the entire Maritimes Basin complex, at 317-1230 million barrels and 12.1-36.8 TCF, respectively.

There has been no assessment of unconventional sandstone reservoir potential and it is very difficult to make definitive statements about such potential without more exploratory well drilling and detailed knowledge of individual basins. If regionally-extensive tight sandstone plays do exist in the Cumberland and Pictou group rocks in Nova Scotia basins, oil and gas in place volumes could be quite large – and prospectivity might exist in several basins, particularly in Cape Breton.

APPENDIX D – Example of indicators and measures for variables in the Human Ecosystem Framework

A human ecosystem is defined as a coherent system of biophysical and social factors capable of adaptation and sustainability over time. For example, a rural community can be considered a human ecosystem. If it exhibits boundaries, resource flows, social structures, and continuity over time. Human ecosystems can be described at different spatial scales and these scales are hierarchically linked. Thus, a family unit, community, county, region, nation, and even the global population, can be treated as human ecosystems (see Figure D.1).

Figure D.1: Human Ecosystem Framework



Reproduced with permission, Machlis et al. (2005)

The Human Ecosystem Framework is used by social ecologists to examine and measure the interactions between human communities and the biophysical systems we inhabit. It is used in many ways and for a variety of purposes. Should Nova Scotia proceed with unconventional oil and gas development, we recommend that the Human Ecosystem Framework be considered as an organizing framework for establishing baseline conditions and monitoring social-ecological changes over time. The variables provide the basic structure. For each variable, indicators are selected and for each indicator, measures are chosen. These measures can then be monitored over time, to detect trends in the system of interest and to provide an effective tool for adaptive management.

An example of indicators and measures for the variables in the Human Ecosystem Framework is provided below (Table D.1). It is important to consider the specific context when selecting indicators and measures for the variables. For example, in an urban setting in North America, it may not be useful to monitor the per cent of homes heated with wood; however, this might be a useful indicator of energy consumption and its effects on the landscape in rural Nova Scotia. Indicators and measures are selected based on local conditions. Best available data at appropriate resolution are obtained through regularly collected, reliable sources. Data may be presented in a variety of formats, including tables, narratives, maps, and spatial analyses. Particulars depend upon location, scale, access to data, resources, and skill sets.

Variable	**Indicator**	**Measure**
CRITICAL RESOURCES		
Natural Resources		
Air	Quality	# ozone warnings per year
	Respiratory illness	% population with chronic respiratory ailments
Energy	Electricity consumption	quarterly average kilowatt hours per capita
	Oil consumption for heat	% households heated with fuel oil
	Natural gas consumption for heat	% households heated with natural gas
	Distance travelled to work	Average distance travelled to work by employed members of population
Land	Public ownership	% land in public ownership
	Land coverage	% impervious surface
Water	Water consumption	Litres per capita per year
	Water quality	# health warnings per year
Materials	Material dependence	Total value of consumer goods imported annually
Nutrients	Nutritional dependence	Tons of food imported annually (regional, national, international)
Flora	Forest cover	% total land in forest cover
		% public land in forest cover
		% private land in forest cover
Fauna	Pests	# animal-related complaint calls to Parks and Trees per capita per year

	Pet ownership	# households with either a dog or cat in residence
Socioeconomic Resources		
Information	Newspaper subscription rate	% households subscribing to a daily or weekly newspaper
	Literacy	% population more than 18 who are functionally literate
Population	Total resident population	Total resident population
	Change in population	% increase or decrease in population per five years
Labour	Unemployment	Civilian labour force unemployment rate
Capital	Bank deposits	Total bank deposits (June)
	Income	Median household income (adjusted for inflation)
	Bank investments	# New mortgages issued in past fiscal year per 1,000 population
Cultural Resources		
Organization	Community involvement	% population claiming membership in formal or informal group
Beliefs	Votes by political party	% votes cast for Conservative, Liberal, or NDP party in provincial election
Art	Access	# museums
Craft	Support for craft	# craftpersons studios per 1,000 population
Myth	Cultural celebrations	# public festivals, fairs, picnics held in communal spaces annually
SOCIAL INSTITUTIONS		

Reproduction	Average number of children per household (of those with children)	Sum of children in residence divided by the total number of households with children
Health	Infant mortality	Number infant deaths per 1,000 live births
	Physicians	Number physicians per 1,000 population
	Access	% population without family doctor
Justice	Law enforcement	Number police officers on patrol per capita per district
Faith	Access	Number churches of established religions per 1,000 population
	Religious affiliation	% population who claim affiliation with an established religion
Commerce	Earnings	Earnings in all industries
Education	Public school enrollment	Public school enrollment
	High school graduates	% high school graduates (persons 25 or older)
Leisure	Recreation services	Number recreational programs per 1,000 population
	Recreational land use	Number public beaches per 1,000 population
Government	Voting rate	% population (>18 years of age) participating in most recent National elections
	Local government finances	Expenditures on capital projects per capita
Sustenance	Food availability	Number grocery stores per 1,000 population
SOCIAL ORDER		

Identity		
Age	Median age	Median age
	Dependency ratio	% persons less than 18 and greater than 64 years of age
Gender	Women in labour force	% women in labour force
	Sex ratio	Ratio of females to males
Class	Professional and skilled employment	% workers that are professional and skilled workers
Caste	Ethnic/racial composition	Ratio First Nations + Asian + African American + Hispanic + other races to White Population
Clan	Household composition	% households of single parents with children under 18
Social Norms		
Formal	Crime	Number serious crimes known to police per 1,000 population
Informal	Cohabitation	% households composed of unmarried couples (with or without children)
Hierarchy		
Wealth	Poverty rate	% persons living below poverty level
	Childhood poverty rate	% children living below poverty level
Power	Access to power	% population with income greater than $100,000 per year
Status	Will not be measured separately from class	
Knowledge	College graduates	% college graduates (persons greater than 25 or older)
Territory	Home ownership	% owner occupied housing units
Social Cycles		
Physiological	A constant	

Individual	Employment terms	Ratio of part-time workers to full-time workers
	Work days	Average number of days worked per year
Institutional	Term time of elected officials	% elected officials with less than one term in office
Environmental	Precipitation	Number of years in last decade above average precipitation (or below)
	Temperature	Number of days in last year with temperatures greater than 30 degrees C

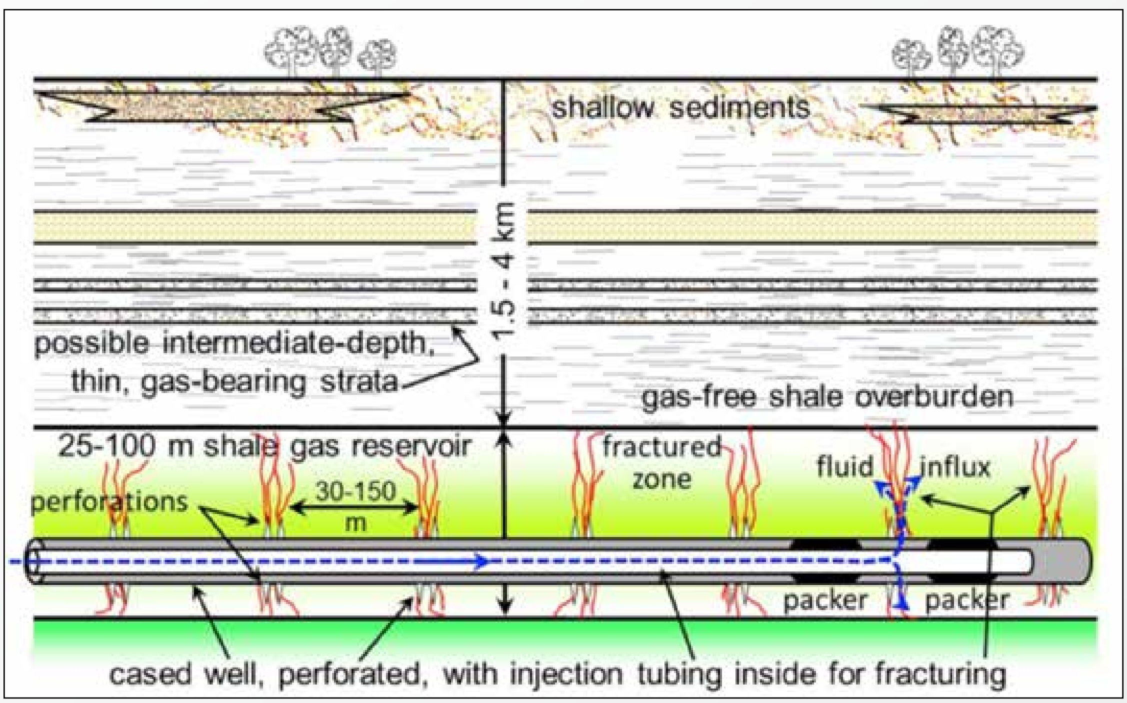
APPENDIX E: Well Completion for Unconventional Oil and Gas Wells

Different approaches are available to provide access from the wellbore to the formation, and these approaches are implemented only in the productive horizon. The productive horizon in a vertical well case can be quite thick (several hundred meters vertically upward from the bottom of the wellbore), and in vertical wells there is almost always fully cemented production casing from the surface to the bottom of the borehole. Geophysical logs combined with geological modeling, core and cuttings examination, and hydraulic fracture simulations are used to decide where to place perforations and carry out a hydraulic fracture stimulation.

E.1 Perforate-Isolate-Fracture

In this approach (Figure E.1), the production casing is installed to the toe of the well and cemented. To pierce it, perforating devices in a linear array about 3-4 m long are sequentially placed at each location and detonated to create a set of 30 to 60 holes 15 to 20 mm in diameter over the length of 3-4 m. Then, another section is perforated, and so on until all the locations for well stimulation are finished. Now, injection tubing with a double packer system is lowered into the wellbore, and the packers are expanded against the inside of the casing to isolate one or several of the perforated zones. These perforations now become the channels through which hydraulic fracturing is carried out. Note that the production casing is protected against any issues that might arise from repeated high pressure flexing of the cemented casing.

Figure E.1: Completing a Multi-Stage Well Using Perforating and a Packer Fracturing System



Courtesy of Maurice Dusseault

Once hydraulic fracturing is carried out successfully at one site along the horizontal wellbore, the packers are released, moved to isolate another section of the horizontal well, and the hydraulic fracture well stimulation process is repeated. There may be various flow tests done during or after the process for evaluation, and the procedure can allow for flow-back fluids to return to the surface immediately after each fracturing period. Once the well is completed, the injection tubing is removed, production tubing is installed if required (Figure E.1), and the well placed on production.

E.2 Sliding Sleeve Fracturing

The most widely adopted new method for completing an unconventional oil and gas well is the sliding sleeve and drop-ball method (Figure E.2 - http://www.packersplus.com/). This method was developed in Alberta and usually makes completing a well easier and quicker.

As in Figure E.1, the horizontal section is left as an open hole but a special assembly with fluid ports, sliding sleeves, and chemically expanding packers is installed and tied into the production casing and attached to a tubing string. To access the formation, after the packers have swelled, a small ball is dropped to seal an internal seat, pressure is increased on the sealed seat to slide a sleeve towards the toe of the horizontal section to open the ports, and hydraulic fracturing is carried out. For the next stage, a slightly larger ball is dropped to seal the next internal seat, and pressure is used to open the next sleeve, and so on. The balls dissolve slowly in water and debris is flushed out so the wellbore can produce freely.

Figure E.2 The Sliding Sleeve and Ball Method for Shale Gas Well Completion

APPENDIX F: A survey of litigation

As the pace of hydraulic fracturing activities increases in Canada and the United States, so too do the number of lawsuits. Most the cases have been launched in the United States. It is important to note that Canada and the United States have very different legal systems. For example, in Canada if a person launches a lawsuit and loses, they will be responsible for paying a portion of the legal fees of the party who they sued. However, in the United States, if a person launches a suit and loses, they will not be responsible for any of the costs incurred by the defendant. This feature was identified as one of the reasons why Americans sue more than citizens of any country in the European Union. There is also a strong tradition of contingency fee relationships in the United States, where the plaintiff's lawyer will be paid a portion of any settlement instead of being paid a fee. The result is that if a suit is unsuccessful, the plaintiff may not be substantially out of pocket. Also, as illustrated at a few points in this paper, American regulatory standards are also not always as strict as those which are present in Canadian jurisdictions, with, for example, the American state governments often left in the dark as to what chemicals are used in hydraulic fracturing fluids, and indeed there is a "current absence of federal regulations of several stages of the fracing process."

Most of the lawsuits involve private landowners seeking compensation for property damage, and in some cases personal injury, allegedly arising from hydraulic fracturing operations. There are also some actions against regulatory bodies or government. For example, there are currently two outstanding claims against New Brunswick. One draws on alleged violations of the Canadian Charter of Rights and Freedoms, while another cites violations of environmental and aboriginal law. There is also an on-going suit against Alberta that claims Alberta failed in its duty to protect the claimant against harm. As well, there is one significant claim against Canada brought by an American company based on the North American Free Trade Act.

Very few claims have actually gone to trial. This results from a combination of many claims being settled out of court, and some claims being dismissed before reaching the trial stage. There are also some cases waiting to be tried. Some jurisdictions, such as Alberta, also have out-of-court dispute resolution processes to address claims or concerns by private landowners, where the claims are heard by committees that are intended to represent various stakeholder groups. In so far as such processes are experienced as producing just outcomes, they divert individuals from pursuing a court action.

There has only been one case which went to trial and resulted in a finding in favour of a landowner. The Texas-based Lisa Parr v Aruba Petroleum claim, which was determined in April 2014, resulted in the landowner being awarded $2.9 million in compensation. However, as the verdict was reached by a jury (on a 5-1 split) there are no written reasons explaining how the evidence was weighed, or what factors lead the jury to be convinced that causation had been made out. The company which was sued has indicated that it will appeal this decision.

Overall, at this point, the cases do little to confirm or deny the existence of the claimed injuries. That said, the cases are informative for helping to reveal issues where the public may have either not felt protected by the existing regulatory regime, or else has perceived a regulatory failure. As such they point to a need to pro-actively regulate. Regulations can prevent harms from occurring, while actions in tort are only successful if a harm has already occurred. The cases also illustrate that the public will seek to hold the state accountable if there is a perception that the state has failed to enforce its own rules, or otherwise abide by the law. Where appropriate, some comments are made about the relevance of the cases for regulating.

I. Contamination Cases

In the United States, most lawsuits related to hydraulic fracturing are brought by private landowners, who seek compensation for alleged contamination arising from hydraulic fracturing operations. The typical claim is that the use of toxic chemicals during the hydraulic fracturing process contaminated groundwater or caused air and surface pollution. These lawsuits rely on several causes of action in tort, including nuisance, trespass, and negligence. The landowner typically seek compensation for alleged reduction in property value, personal injury, punative damages or an injunction. However, these cases seldom go to trial.

Mitchell v. EnCana Oil & Gas Inc is a representative American example. EnCana Oil and Gas Inc operated

hydraulic fracturing activities near Grace Mitchell's property in Johnson County, Texas. After hydraulic fracturing had commenced, Ms. Mitchell alleged that her well water smelled like gasoline, was slick, and was contaminated with various chemicals similar to diesel fuel. She brought claims in nuisance, trespass, negligence, fraud, and strict liability. She sought compensation for loss of use of groundwater, loss of market value of property, remediation, and punitive damages. Like many others, she reached an out-of-court settlement with EnCana, and so the case was dropped.

In addition to groundwater contamination, air, surface and noise pollution are common concerns being raised in hydraulic fracturing litigation in the United States. These claims all rely on common law tort causes of action (similar to groundwater contamination) and could also be brought in Nova Scotia.

Of the contamination cases that do go before courts, many are unsuccessful because the landowner plaintiff failed to establish legal causation. To win their case, the landowner must usually prove that the hydraulic fracturing activity directly caused contamination of their property. However, many harmful substances exist naturally in groundwater in low concentrations. As landowners are unlikely to be able to refer to pre-development baseline testing, they are challenged to provide evidence that the presence of a particular harmful substance resulted from hydraulic fracturing, instead of being a natural occurrence. As well, if there are multiple producers in an area, "it may be difficult, if not impossible, to pinpoint the source of any specific substances, particularly given the natural subsurface movement of groundwater and hydrocarbons." There are at least two cases in the United States that were voluntarily withdrawn when the plaintiffs realized they could not meet the evidentiary threshold for proving causation. In terms of the development of the law, it is frustrating that the Texas case was determined by a jury, as juries do not produce written reasons so no one can see how the jury was persuaded that the evidence in this case proved causation.

As flagged above, many of these cases end in confidential settlements before they reach the court. This makes it impossible to draw conclusions about the merits of the different claims, because a company may settle for a variety of reasons including avoiding the high costs of a court case which they are unlikely to recover even if the claim is not made out, or avoiding negative publicity. Though these cases provide little guidance in the form of settled case law, they are indicative of the wide range of public concerns relating to the hydraulic fracturing industry.

There appears to have only been one lawsuit brought by a private landowner in Canada over hydraulic fracturing. Ms. Ernst alleges that her water supply was contaminated by hydraulic fracturing operations carried out by EnCana near her home in Rosebud, Alberta. She initiated this case in 2007; it has yet to be heard on its merits. Ms. Ernst's claims are similar to those seen in the American lawsuits. These include negligence, nuisance, and trespass. She sought monetary compensation for the loss of use of her property, environmental damage to her property, reduction in property value, and mental and emotional distress.

The outcome of the Ernst v EnCana contamination case will be of interest to governments, citizens, and hydraulic fracturing companies across Canada. The causes of action that were relied upon by Ms. Ernst are available to all Canadian private landowners, including Nova Scotians. The types of relief sought by Ms. Ernst are also available in Nova Scotia. Contamination cases in Nova Scotia will likely face similar difficulties with respect to proving causation as seen in American contamination lawsuits.

These cases point to a need - in areas where hydraulic fracturing is permitted - for regulations to require baseline testing and monitoring of groundwater, as well as other key environmental indicators before, during and after hydraulic fracturing activities, so that there is at least some clarity on whether changes have taken place. Such testing would in turn help identify whether current regulatory practices do in fact adequately mitigate contamination.

II. Trespass and the Rule of Capture

In the United States, there has been significant litigation between oil and gas producers with respect to subsurface trespass and the 'rule of capture'. The rule of capture is an established common law principle. It states that an oil and gas producer is not liable if gas migrates from an adjacent property to the property where the producer is operating. In other words, a gas rights owner loses rights to the gas below their property if/when it migrates to another property. In the United States, the decision in Coastal v Garza established that the rule of capture applied in situations where hydraulic fracturing caused natural gas drainage. In Canada, the rule of capture has been established through oil and gas litigation in Alberta. It has not yet been applied to migration as a result of hydraulic fracturing.

As private property owners in Nova Scotia, unlike the United States, do not own the minerals which rest under their property, the rule of capture is unlikely to provoke much litigation here if the province choses to permit hydraulic fracturing. However, there could be litigation as between oil and service companies. The question of whether this requires regulatory intervention is a question for industry and government to consider.

III. Corporate litigation

There is one hydraulic fracturing suit in Canada where a corporate party is suing Canada. It is a free trade dispute under the North American Free Trade Agreement (NAFTA). Lone Pine Resources Inc, an American company, was issued natural gas exploration permits in the Utica shale gas basin underneath the St. Lawrence River in Quebec. In 2011, Quebec's Bureau d'audiences publiques sur l'environement issued a report on hydraulic fracturing that prompted Quebec to place a moratorium on all new drilling permits until a strategic environmental evaluation was completed. Then, in April 2012, Quebec announced a moratorium on all hydraulic fracturing in the province.

Lone Pine subsequently filed notice that it intends to sue the Government of Canada under the investor rights chapter of NAFTA. (They are suing the Government of Canada – not the Quebec government – because the federal government is a party to NAFTA.) The section of NAFTA that they are relying upon "protect[s] investors against arbitrary expropriation and expropriation without compensation by the NAFTA member states." They claim the moratorium is an "arbitrary, capricious, and illegal revocation of its valuable right to mine for oil and gas." They seek $250 million in compensation for their investment in these permits and loss of expected profit from exploiting these resources.

This dispute is on-going, and likely will be for years. Regardless of its outcome, it will identify some of the rights which American hydraulic fracturing companies may possess under NAFTA if they are granted exploration or other rights within Canada. At present, Nova Scotia is not at risk of becoming involved in a NAFTA dispute. However, if Nova Scotia issues licenses or otherwise authorizes American companies to operate here, it should anticipate that liabilities may be incurred if the province subsequently wishes to modify its position on hydraulic fracturing. This is an important consideration for regulators: once a practice is authorized and licenses issued, it may be very costly to change course.

IV. Litigation against governments

In the United States, environmental public interest organizations have brought several cases against both federal and state government departments with respect to hydraulic fracturing issues. For example, the Center for Biological Diversity and the Sierra Club launched a case against the Bureau of Land Management. This action was successful, as they proved the government department had leased land for hydraulic fracturing oil and gas extraction without adequately assessing the risks posed by hydraulic fracturing in the area.

In Canada, the Wilderness Committee and Sierra Club BC brought a similar lawsuit against the BC Oil and Gas Commission. Their claim was that it breached the Water Act by granting hundreds of short-term water permits to hydraulic fracturing companies each year. They allege that the cumulative impact of these permits will endanger lakes, rivers and streams in northeastern B.C. As a remedy, they are requesting that specific water use authorizations are revoked. This case was filed in November 2013, and has yet to be heard.

A lawsuit has also been launched against the government of New Brunswick by the New Brunswick Anti-Shale Gas Alliance. The statement of claim was filed on June 23, 2014. It argues that that the provincial government's decision to authorize hydraulic fracturing activities violates section 7 of the Canadian Charter of Rights and Freedoms. Section 7 protects "life, liberty and security of the person." In particular, they argue that the government's decision to invest "social, political and economic capital and resources owned by the people of New Brunswick in unconventional oil and gas development" impairs the right to life because it is inconsistent with protecting air and water, and because hydraulic fracturing will contribute to climate change. This case raises the familiar issues of water and air contamination, but is novel for framing those issues as violating Charter rights. The remedy they are seeking is for an injunction that would place a moratorium on all shale gas activities until the province can establish "beyond a reasonable doubt and with scientific certainty that unconventional oil and gas development cannot and will not contribute to climate change nor to the contamination of the water, air and land use which causes harm to the health of the Plaintiffs and their future generations in New Brunswick". If this case proceeds to a hearing, it will be of tremendous interest across Canada.

Another lawsuit was launched against New Brunswick on June 26, 2014. This suit was brought by a collection of 18 individuals, including several Aboriginal people. Like the claim brought by the Anti-Shale Gas Alliance, it seeks a court ordered injunction prohibiting shale gas activity unless the government can establish beyond a reasonable doubt and with scientific certainty that hydraulic fracturing will not contribute to climate change or environmental or health contamination. It also seeks various other orders, including compensation for damage caused to Mi'kmaq traditional lands due to exploration activities. The claim alleges violations of environmental, constitutional, and international laws, and also claims violations of the duty to consult which is owed to Aboriginal peoples.

Finally, Ms. Ernst, whose claim against a hydraulic fracturing company was described above, also claimed against the Alberta Energy Regulator (AER). Ms Ernst alleged the AER had acted negligently in its statutory obligations, and in particular was negligent in its response to Ms. Ernst's concern that the Rosebud aquifer had suffered water contamination. The AER sought to strike the claim on the basis that its enabling statute made it immune from negligence actions. This argument was successful. Ms Ernst appealed this decision, and her appeal was heard on May 8, 2014.

Ms. Ernst's claim also named Alberta's Department of Environment and Sustainable Resource Development. She claimed the Department owed her a duty to protect her water well from foreseeable contamination caused by drilling for shallow methane gas. She alleges that the Department breached its duty to her, in part by allegedly failing to conduct a reasonable investigation and to take remedial steps to correct damage. This claim has not been determined.

Claims against government departments and regulatory boards for failing in their obligations are becoming more common. These cases may allege that government bodies are violating existing environmental laws or negligently performing their duties. Similar sorts of claims could be brought against provincial depa

Glossary

Anthropocene: An informal or proposed term to define the current geologic epoch during which human activities have begun to impact the natural environment and eco-systems.

Additive: Any substance(s) made up of chemical ingredients found in a hydraulic fracturing fluid which is added to a base fluid in the context of a hydraulic fracturing treatment (including proppants).

Aquifer: Underground geologic formation made of soil or rock that can yield significant quantities of water to wells. Aquifers should not be thought of as underground rivers or lakes. A more realistic image is a firm sponge made of soil or rock in which groundwater moves very slowly through a connected network of pores or fractures.

Basin: A closed geologic structure in which the beds dip toward a central location; the youngest rocks are at the center of a basin and are partly or completely ringed by progressively older rocks.

Bedrock: Solid rock either exposed at the surface or situated below surface soil, unconsolidated sediments and weathered rock.

Biocide: An additive that kills bacteria.

Biogenic: A substance produced by life processes.

Blow Out Preventer (BOP): A large valve at the top of the well that can be closed during loss of control of formation fluids.

Casing Shoe: The bottom of the casing string, including the cement around it.

Casing String: The total length of a casing section, comprising many joints of steel pipe. Each casing section is cemented in place to the previous section or to the surrounding rock.

Cement Bond Log: A log that measures the quality of cement bond on the exterior casing wall by recording the changes in amplitude of an acoustic signal traveling along the casing wall.

Centralizer: A device used to ensure efficient placement of a cement sheath around the casing string, it keeps the casing or liner in the center of the wellbore.

Completion: The activities and methods to prepare a well for production and drilling.

Corrosion Inhibitor: A protective chemical additive used to prevent corrosion of iron and steel components in the wellbore and treating equipment.

Disposal Well: A well for injecting produced water into an underground formation for disposal.

Divalent Cations: An ion that has two less electrons than a normal atom.

Flowback: A process that occurs when the internal pressure of the rock formation causes fluids to return to the surface through the wellbore after an injection process.

Flowback Water: Wastewater that is produced and returns to the surface after fracturing operations. The composition varies due to the local geology and company practices, but generally comprises approximately 98 per cent sand and water and less than two per cent chemical additives.

Formation Fluids: Any fluid that occurs in the pores of a rock.

Formation: A distinguishable rock body often used for mapping or description.

Fracturing Fluids: The fluid used to hydraulically induce cracks in the formation and includes the applicable base fluid and all additives such as chemicals and proppants.

Gas Migration: All possible routes for gas movement through and around the cement casing that is detectable at the surface outside of the outermost casing string.

Green Completion Technology: A method of capturing methane at the well-head for storage and later use or sale which reduces overall methane emissions during well completions.

Groundwater: Is water found below the ground surface and is stored in semi-permeable rocks called aquifers.

Horizontal Drilling: A procedure which first requires drilling vertically to a depth above the target formation and then angling to 90 degrees so that the well extends horizontally through the target formation at the producing end.

Hydraulic Fracturing: Well stimulation from injecting fracturing fluids into a formation at a force to induce a network of fractures through which oil or natural gas can flow to the wellbore.

Hydrocarbons: A naturally occurring organic compound comprising hydrogen and carbon. The most common hydrocarbons are natural gas, oil and coal.

Injection Well: A well, used to inject fluids into an underground formation either for recovery or disposal.

Intermediate Casing: A casing string that is generally set in place after the surface casing and before the production casing to provide protection against caving of weak or abnormally pressured formations.

Lost-circulation: A situation when drilling fluid, known commonly as "mud", flows into one or more geological formations instead of returning to the surface.

Mud Gas Logging: The gathering (or logging) of data from hydrocarbon gas detectors to determine the level of gas recovered from the mud.

Pad: Cleared ground surface used for the drilling rig and associated equipment.

Permeability: A measure of how readily fluids can flow through the pore spaces in a rock – and, therefore, how rapidly oil and/or gas can be produced.

Play: A conceptual model to describe hydrocarbon accumulation in prospective basins or regions.

Porosity: The amount of pore space between mineral grains making up the rock – a measure of the rock's capacity to hold oil and gas.

Produced Water: Wastewater produced as a co-product when gas or oil is produced during the productive life of the well.

Production Casing: The final cemented casing string places in the bore hole for production purposes.

Propping Agents/Proppant: Natural or synthetic non-compressible grains that are pumped into a formation during a hydraulic fracturing operation to hold fractures open and maximize flow.

Prospectivity: The likelihood that oil and/or gas will exist in an area, and can be economically recovered with current technology.

Recovery Factor: The percentage of the resource in place that can actually be extracted.

Risked Gas: The volume of gas being discussed, multiplied by the risk factors associated with being able to produce it.

Severance Tax: A tax imposed on the removal of non-renewable resources such as crude oil, condensate and natural gas, coalbed methane and carbon dioxide. Severance tax is charged to producers, or anyone with a working or royalty interest, in oil or gas operations in the imposing states.

Shale Gas: Natural gas produced from low permeability shale formations.

Slickwater: A water based fluid mixed with friction reducing agents, commonly potassium chloride.

Social License: When a project has the ongoing approval within the local community and other stakeholders.

Stray or Fugitive Gas: Unwanted gas that has migrated into shallow groundwater or venting to the surface.

Surface Casing: A large diameter, strong steel casing that is placed into the well hole and cemented to the surface. A flange is welded to the casing and a blow-out preventer and other sealing equipment are bolted to the flange for safety.

Surface Water: Water visible at the surface of the earth, e.g. a stream, river, lake, or ocean, as opposed to groundwater.

Technically Recoverable Resources: The total amount of resource, discovered and undiscovered, that is thought to be recoverable with available technology.

Thermogenic: Tending to produce heat.

Water Cycle: The circulation of water from the atmosphere to the earth, and back into the atmosphere. Water falls as precipitation, seeps into aquifers as groundwater, or runs into rivers, lakes, and eventually the ocean as surface water. Along the way, the water evaporates back into the atmosphere and the cycle continues.

Water Resources: According to Nova Scotia's Environment Act, includes all fresh and marine waters that comprise all surface water, groundwater, and coastal water.

Watershed: The area of land from which surface water drains into a common lake or river system or directly into the ocean. The flow is generally inwards and downwards, according to the topography of the surrounding landscape. The boundaries of a watershed area are known as a drainage divide. Precipitation falling on opposite sides of a divide falls into different watersheds.

World Resource Institute (WRI): WRI is a global research organization that works closely with leaders to turn ideas into action to sustain a healthy environment, create economic opportunity and provide human well-being.

List of Abbreviations

ANSMC: Assembly of Nova Scotia Mi'Kmaq Chiefs

BCF: Billions of cubic feet (measure of gas volume)

BOP: Blow out preventer

CAPP: Canadian Association of Petroleum Producers

CCA: Council of Canadian Academies

CBM: Coalbed methane (natural gas occurring in coal seams)

CMA: Census metropolitan area

CNG: Compressed natural gas

CRA: Corporate Research Associates

DNR: Department of Natural Resources

DOE: Department of Energy

EA: Exploration agreement

EGSPA: Environmental Goals and Sustainable Prosperity Act

EIA: Environmental impact assessment

FNLMA: First Nations Land Management Act

FNOGMMA: First Nations Oil and Gas and Moneys Management Act

FPIC: Free prior and informed consent

GHG: Greenhouse gas

HIA: Health impact assessment

HRM: Halifax Regional Municipality

KMK: Kwilmu'kw Maw-klusuaqn

IOGC: Indian Oil and Gas Canada

LDC: Local distribution company

LNG: Liquified natural gas

LPG: Liquified petroleum gas

mmbtu: Millions of British thermal units (measure of gas energy content)

Mmcf: Million cubic feet

NEB: National Energy Board

NGO: Non-governmental organization

NORM: Naturally occurring radioactive material

PA: Production agreement

SCVF: Surface casing vent flow

SOEP: Sable Offshore Energy Project

TCF: Trillions of cubic feet (measure of gas volume)

TCPL: TransCanada PipeLines

TQMP: Trans Quebec and Maritime Pipeline

UNDRIP: United Nations Declaration of the Rights of Indigenous People

UNESCO: United Nations Educational, Scientific and Cultural Organization

USEPA: United States Environmental Protection Agency

VCSEE: Verschuren Centre for Sustainability in Energy and the Environment

VOC: Volatile organic compounds

WHPA: Wellhead protection area