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Phase 2

Recommendations Report

Prepared for: British Columbia Ministry of Health

RWDI
CONSULTING ENGINEERS & SCIENTISTS

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GLOSSARY

AAQO	Ambient Air Quality Objective
AMS	Authorization Management System
API	American Petroleum Institute
BC MoE	British Columbia Ministry of the Environment
BC MoH	British Columbia Ministry of Health
BC OGC	British Columbia Oil and Gas Commission
BC	British Columbia
CAC	criteria air contaminants
CAPP	Canadian Association of Petroleum Producers
CAS	Chemical Abstract Service
COPC	chemicals of potential concern
CCA	Canadian Council of Academies
e.g.	Latin “for example”
EDR	Electronic Data Transfer
EMS	Environmental Management System
EPEA	Alberta Environmental Protection and Enhancement Act
EPZ	emergency planning zone
ERP	emergency response plans
etc.	Latin for “and other”
FBC	Fraser Basin Council
FN	First Nations
H_2S	hydrogen sulphide
HHRA	human health risk assessment
HIA	Health Impact Assessment
i.e.	Latin for “such as”
ID	identification
IRIS	a database available through the BC OGC
KERMIT	Knowledge, Enterprise, Resource, Management, Information Technology
km	kilometres
LRDW	Land Resource Data Warehouse
m	metres
MAML	Mobile Air Monitoring Laboratory
MIACC	Major Industrial Accidents Council of Canada
MNGD	Ministry of Natural Gas Development
MPOI	maximum point of impingement
NAPS	National Air Pollution Surveillance Network (Environment Canada)
NE BC	Northeastern British Columbia
NEWT	North East Water Tool
NO_2	nitrogen dioxide
O_3	ozone
PM_{10}	fine particulate matter less than 10 µm in diameter
$PM_{2.5}$	fine particulate matter less than 2.5 µm in diameter
SLRA	screening level risk assessment
SO_2	sulphur dioxide
SW	south west
TRS	Total Reduced Sulphur compounds
TRV	toxicological reference values
US EPA	United States Environmental Protection Agency
VOC	volatile organic compounds
WCSB	Western Canadian Sedimentary Basin

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1.0 INTRODUCTION

In response to concerns expressed by residents in northeastern British Columbia (NE BC), the BC Ministry of Health (MoH) commissioned a human health risk assessment (HHRA) with a focus on the potential impacts of oil and gas activity on human health through environmental pathways of exposure. The HHRA scope of work was segregated into three phases by the MoH:

- **Phase 1 HHRA.** Identification of Health Concerns Relating to Oil and Gas Development in NE BC. Completed in March 2012 by the Fraser Basin Council
- **Phase 2 HHRA.** Human Health Risk Assessment of NE BC Oil and Gas Activity. Timeline: 2012-2014
- **Phase 3 HHRA.** Communication of overall results. Timeline: To Be Determined

The MoH contracted a team led by Intrinsik Environmental Sciences Inc. (Intrinsik) to complete Phase 2 of the HHRA of oil and gas activities in NE BC. In addition to Intrinsik, the companies that make up the study team include: RWDI Air, Matrix Solutions and Skystone Engineering. The team also includes a three member Advisory Panel to provide an independent perspective on the design and approach of the Phase 2 HHRA project, and the interpretation of the results.

In accordance with the MoH terms of reference, the Phase 2 HHRA is intended to investigate the potential impact of oil and gas activities on human health in Local Health Areas 59, 60 and 81 (the Region).

This report presents the Recommendations task for the Phase 2 project, which is intended to compile the overall findings from the various tasks into a focused report with the aim of providing suggestions to the MoH and other Ministries in relation to mitigating potential human health impacts in the region. The material presented within this document has been drawn from the collective experience of the study team in the completion of the Phase 2 project to date, with particular focus on the material presented in the following three documents:

- Screening Level Risk Assessment. Phase 2 Human Health Risk Assessment of Oil and Gas Activity in NE BC British Columbia (Intrinsik 2014a)
- Phase 2 Review of Regulatory Framework (Intrinsik 2014b)
- Detailed Human Health Risk Assessment. Phase 2 Human Health Risk Assessment of Oil and Gas Activity in NE BC (Intrinsik 2014c)

In addition to these reports, the final Recommendations consider the findings of the Phase 1 HHRA, along with concerns that were raised by stakeholders throughout the Phase 2 HHRA process.

In preparing this report, the study team has drafted a summary of key findings related to the protection of human health and potential impacts from oil and gas activities in NE BC that have been identified throughout the course of this project. While these findings are framed within the context of human health protection in NE BC, some of the recommendations within may have implications or applications in the Province as a whole.

An overview of the work completed to date as part of the Phase 2 HHRA project is provided in Section 2.0.

The key findings and recommendations addressed within this report have been organized into the following categories:

- Emergency management and setback provisions (Public Safety)
- Flaring, venting and fugitive emissions
- Hydraulic fracturing
- Legacy Sites
- Information management
- Environmental monitoring
- Standards Development
- Other considerations

2.0 OVERVIEW OF WORK COMPLETED TO DATE

2.1 Summary of the Phase 1 Human Health Risk Assessment

Phase 1 of the HHRA project included a public engagement process to identify issues of concern surrounding human health and potential changes in land, air, drinking water and food quality and preparation of a report that laid out the key findings (FBC 2012). Public engagement activities were carried out by the Fraser Basin Council from mid-January to early March 2012 in order to provide the public, governments, organizations, and other stakeholders with the opportunity to voice their concerns regarding current and future oil and gas development in NE BC.

The key perceived issues that were identified include:

- Personal health issues (*e.g.*, respiratory health, cancer, quality of life, stress, sleep)
- Environmental pathways of exposure (*e.g.*, emissions of chemicals from oil and gas activities, impacts on sensitive individuals, water quality and quantity, food quality, cumulative impacts, environmental health)
- Related environmental issues (*e.g.*, explosions or accidental releases, , destruction of environmental habitat, traffic, noise, light)
- Changes to communities (*e.g.*, impacts on the access and delivery of health services, impacts due to population growth and strain on infrastructure, social health)
- Oil and gas operational issues (*e.g.*, impacts of oil and gas exploration activities, accidents, facility density, earthquakes)
- Institutional frameworks (*e.g.*, existing regulations and policies, emission management and reduction, emergency response practices and protocols, monitoring, tracking and reporting of health issues)

In accordance with the assigned scope of work for the overall Phase 2 HHRA project that was developed by the MoH, these issues were considered in the development of the scope of work for the various tasks within the HHRA where possible.

2.2 Phase 2 Direction Document

This document represented a revised work plan for the Phase 2 HHRA, with additional depth on some topics. An overview of the content of this document is as follows:

- Oil and gas production has been an important and prevalent source of economic development in western Canada since the early part of the 20th century. Traditional products of the oil and gas industry have included oil, natural gas, natural gas liquids and sulphur extracted from the large geological feature referred to as the Western Canadian Sedimentary Basin (WCSB). Technological advances in well drilling, completions and stimulation have allowed the exploitation of less traditional reservoir types, including shales and 'tight' (geological formations having naturally low primary permeability) clastic formations.
- NE BC contains the western edge of the WCSB, and as such, has seen considerable oil and gas activity. Gas production in BC continues to increase over time.
- In 2008 through 2010, significant increases in BC's gas reserves were booked, or recorded as assets by oil and gas companies. These increases are primarily 'unconventional' reserves, with the primary drivers for these new reserves being the widespread drilling of horizontal wells in these shales, combined with multi stage hydraulic fracturing as a production stimulation method.
- Significant oil production is sourced in NE BC; however, this production peaked in the late 1990's, and has declined steadily. Oil reserves have also declined since 2001.
- Both sweet and sour oil and gas resources in conventional and unconventional forms are present in NE BC, and thus are of potential relevance to the Phase 2 HHRA project.

2.3 Summary of Literature Review

A literature review was completed in spring 2013 by the study team (Intrinsik 2013), consisting of a comprehensive search of reports that involved the assessment of potential health effects associated with oil and gas development. This search and review was designed to be consistent with the Cochrane Handbook for Systematic Reviews of Interventions (Cochrane 2008), and included a critical review of the available scientific peer reviewed literature as well as 'grey' literature (reports published by government, academia, non-profit organizations or industry). A comprehensive list of search terms was developed by Intrinsik and sent to a professional medical librarian. The abstracts collected during this search were critically reviewed. Only documents that met pre-defined inclusion criteria were selected for further review. The inclusion criteria were as follows:

- Published in English
- Published 1990 to present
- Human health study – community or occupational studies

The original draft document included a total of 27 peer reviewed articles and 11 documents from the grey literature, all of which met the study criteria. Additional documents were suggested by the Advisory Panel based on their review of the draft, and were subsequently incorporated into the final report.

The general conclusions of the literature review were as follows:

- In the studies that evaluated cancer morbidity and mortality, the types of cancer most frequently reported in the literature evaluated included bladder, kidney, acute myelogenous leukemia, other leukemias and melanoma. At times, the results of these studies were conflicting, where some community and occupational studies found some evidence of an association between oil and gas activities and cancer, while other studies did not. Some variation was observed in results in relation to the types of effects observed. There is an apparent need for additional studies with case control or cohort study designs to evaluate the potential association between cancer incidence and oil and gas activity.
- There is an overall lack of published research regarding respiratory health effects and oil and gas activities. Although there is a wealth of information regarding hydrogen sulphide (H_2S), sulphur dioxide (SO_2) and exposure to petroleum hydrocarbons from downstream oil and gas activities (*i.e.*, refineries), there is limited information with respect to other chemicals, and emissions from upstream oil and gas facilities and respiratory health.

Other health outcomes of interest reported within the key studies included autoimmune diseases, reproductive, cardiovascular and neurological effects. Those studies that were identified in the literature review that evaluated autoimmune diseases and cardiovascular effects were sometimes of low quality.

The diseases of concern in relation to upstream oil and gas activity that needed to be considered in the Phase 2 HHRA, in order of priority, were identified as:

- Respiratory diseases and cancers
- Reproductive, neurological and acute (short term, mild, transient) effects
- Autoimmune diseases and cardiovascular effects

The majority of the studies evaluated as part of this review lacked information regarding exposure pathways of interest, exposure concentrations, or chemicals of potential concern (COPC). As such, the results of the literature review did not provide any recommendations regarding chemicals or exposure pathways of concern in relation to oil and gas activity and human health.

2.4 Screening Level Risk Assessment

The intention of the screening level risk assessment (SLRA) was to identify the potential oil and gas related emission sources in the region that presented the greatest potential risk to human health, and to provide a means for prioritizing scenarios for a quantitative assessment in the detailed HHRA. In order to do so, a comprehensive qualitative analysis of a spectrum of potential emission sources to air and water was completed, with the aim of identifying those sources that pose the greatest potential risk to people in NE BC. This screening exercise was conducted through the use of risk matrices, statistics and professional judgment. Particular consideration was given to potential adverse health impacts, likelihood of occurrence, scale of potential impacts, and magnitude of potential exposures in order to identify the emission sources and scenarios presenting the greatest potential risk.

A study area for the detailed HHRA work was proposed within the SLRA, taking into consideration a number of different factors, including:

- Population density
- Estimates of emission density of Criteria Air Contaminants (CACs) and total Volatile Organic Compounds (VOCs) from air emission sources.
- Known locations of wells, pipelines, gas plants, and oil and gas processing facilities (*e.g.*, batteries and compressor stations)

The identified study area is centered on Fort St. John, and also included several of the larger communities in the region: Dawson Creek, Pouce Coupe, Hudson's Hope and Taylor, the Blueberry and Doig River First Nations, and the northern boundary of the Tumbler Ridge area. This area represented the most densely populated area in the region under study, as well as the area with the highest density of continuous air emission sources. Additional information regarding this map and selected study area was provided in Section 6.0 of the SLRA (Intrinsik 2014a).

The SLRA identified a series of potential emission scenarios related to oil and gas activity in the region that could present risks to human health. Risk based matrices were developed in order to qualitatively evaluate and rank the potential risks associated with the different air emission and water release scenarios in the study area. Each of the identified scenarios was assessed according to its potential exposure and health hazard, and relative numerical rankings or 'scores' were assigned to each scenario to qualitatively describe potential human health risk (Intrinsik 2014a).

The exposure scores used to assign the numerical risk rankings were based on a combination of the likelihood of an emission/release event occurring, the duration and aerial extent of impact associated with that event, and the overall magnitude of the event's exposure. On the hazard side, the score was based entirely on the potential health impact associated with a particular event. To the greatest extent possible, numerical risks were based on actual data, predominantly as these relate to the likelihood of events occurring. However, when such data were unavailable, the scoring system relied on a combination of past experience, information retrieved from oil and gas related HHRAs and exposure studies, and professional judgment. The risk matrices provided the relative 'score' of the potential health risks on the basis of varying types of oil and gas activity. However, whether or not an exposure scenario ultimately would be included in the HHRA depended not only on the significance of the risk (*i.e.*, its relative numerical ranking in the matrix), but also on the availability and adequacy of environmental data that allowed for the health risks to be quantitatively assessed on a regional scale.

Based on the findings of the risk matrix for the air emissions, two scenarios emerged as the top priorities for further evaluation in the detailed HHRA:

1. Continuous emissions associated with gas processing plants, and
2. Continuous emissions from oil and gas production facilities (including batteries, storage tanks, compressors, dehydrators, *etc.*).

The estimated risks for all the other emission scenarios considered in the risk matrix were orders of magnitude less than the two continuous (or ongoing) emission scenarios.

The SLRA completed for water emission sources determined that the two scenarios with the highest numerical rankings included:

1. In-ground fluid pits and flare system overflows, and
2. Pipeline ruptures.

When considering past fluid management practices (e.g., in-ground fluid pits and flare system overflows), the variability that exists between sites with respect to emission sources, contaminant types, geology and hydrogeology, and soil types meant that these sources could not be reliably assessed at a regional scale. The potential health risks associated with such site-specific issues can only be assessed on a case-by-case basis using measured, site-specific data. As discussed in the SLRA, there are a number of data gaps in publicly available information regarding groundwater and surface water resources in NE BC that may impact the ability to complete site-specific assessments, such as aquifer mapping, information regarding localized groundwater flow, well records, etc. As a result, these scenarios could not be carried forward into the detailed HHRA, which was intended to have a regional focus (as opposed to a local or site-specific focus). An approach that is currently in place in BC for assessment of oil and gas sites was recommended as part of the SLRA to aid in the evaluation of in-ground fluid pits and flare system overflows and legacy sites in general within the region.

The water scenario with the second highest qualitative ranking, pipeline ruptures, was associated with a relatively lower likelihood of occurrence, but a higher potential consequence to human health in the event of a release. However, pipeline release events can be mitigated through emergency planning and response practices, communication, and site-specific activities (such as evacuation or closure of drinking water intakes) to reduce the potential for human exposure. As a result, such scenarios were excluded from quantitative analysis in the detailed HHRA.

A total of eight water emission scenarios evaluated in the SLRA were related to well drilling, completions and stimulation. Leaks and spills to groundwater and surface water that could arise from operating oil and gas facilities were evaluated within two scenarios in the SLRA, and truck and rail accidents were evaluated under an additional scenario. All of these 11 distinct emission scenarios are of relevance to hydraulic fracturing activities in the region. In the SLRA of water emissions, these 11 scenarios were assigned qualitative risk rankings at least 10 times lower than the two highest ranked scenarios (in-ground fluid pits and flare system overflows at legacy sites, and pipeline ruptures). The issues related to site-specific assessment and data-gaps for the NE BC region are also of relevance to hydraulic fracturing operations, as the fluid and mud compositions may vary between sites, and limited information is available regarding aquifers and baseline water quality. As a result, these scenarios were excluded from quantitative analysis in the quantitative HHRA.

Although the health risks associated with the water-related scenarios, including in-ground pits and flare system overflows, could not be further assessed in the detailed HHRA, their implications with respect to human health were qualitatively addressed in the study team's Review of the Regulatory Framework.

Based on the emission scenarios selected in the SLRA, a proposed approach to the detailed HHRA was formulated, following methods consistent with those established by regulatory organizations such as Health Canada (2012, 2010, 2009) and the United States Environmental

Protection Agency (US EPA 1989, 2005). Based on the findings of the Literature Review (Intrinsik 2013) and an additional review completed as part of the SLRA (see Intrinsik 2014a, Appendix D), a list of representative chemicals that are known to be associated with the selected emission sources and have the potential to, at high enough concentrations, cause a number of the health effects identified in the Literature Review were included in the detailed HHRA. A number of potential exposure pathways were also identified, and conceptual models were constructed.

2.5 Detailed Human Health Risk Assessment

The detailed HHRA involved a comprehensive and focused assessment of the potential adverse health risks in relation to oil and gas activity in NE BC. The scope of the HHRA was developed iteratively in collaboration with the study team, MoH, Steering Committee, and the Advisory Panel.

Based on the findings of the SLRA, the detailed HHRA was designed to evaluate the potential human health impacts associated with continuous emissions from gas plants and production facilities within the study area. A comprehensive air emission inventory of the continuously emitting oil and gas facilities was compiled for the study area. Several thousand continuous air emission sources were included in the air quality dispersion modelling completed at locations throughout the study area (as summarized in Appendix A of the detailed HHRA, Intrinsik 2014c).

In addition, to further characterize air quality on a cumulative basis and in order to compare air quality associated with oil and gas activities with those associated with non-oil and gas emission sources, available data from Environment Canada databases for non-oil and gas emission sources in the area were included. Thus, a total of two assessment scenarios were evaluated in the detailed HHRA:

1. Oil and Gas Scenario: includes all on going emissions from gas processing plants and various production facilities within the HHRA study area. These sources include, but are not limited to significant emitters such as sweet and sour gas plants, compressor stations, and fugitive emissions from tank storage facilities.
2. Cumulative Scenario: includes the oil and gas sources from the oil and gas scenario, as well as emissions from background sources such as other industries (*e.g.*, forestry and mining), transportation, and community activities (*e.g.*, residential wood burning).

The total emission inventory information collected for oil and gas and non-oil and gas sources in the area were combined with site-specific, detailed meteorological and geographical information for the area. The subsequent air dispersion modelling exercise produced location-specific air concentrations of the COPC that were identified in the SLRA for short-term and long-term exposure periods.

A total of 26 community locations were evaluated individually within the HHRA along with the maximum predicted ground-level air concentrations of each COPC (*e.g.*, the maximum point of impingement or MPOI). A brief review of existing health status in the region conducted as part of the HHRA revealed that there are a number of possible sensitive sub-populations within the study area.

To account for potential differences in exposures between individuals in the area, consideration was given to differences in exposure parameters between age groups and community type (*e.g.*, residents in Aboriginal, rural/agricultural, or more urban communities).

Results were presented and described for inhalation on a short-term and long-term basis, and for all possible routes of exposure on a long term basis. Consideration was also given to both cancer and non-cancer related effects over the long-term, where possible. The predicted risk estimates involved the comparison of estimates of exposure with health-based exposure limits developed by various regulatory organizations (*e.g.*, Health Canada, United States Environmental Protection Agency, World Health Organization). Separate assessments were completed for short-term and long-term exposures, and for carcinogenic and non-carcinogenic COPC.

A brief summary of the detailed HHRA results is as follows:

- On a short-term basis, the predicted air concentrations of the COPC generally were less than their health based exposure limits. The potential combined effects of these COPC were also not predicted to result in adverse health effects in people living or visiting the study area. However, the predicted exposures at some locations in the study area were found to exceed exposure limits for some of the COPC (acrolein, formaldehyde, NO_2, SO_2, $PM_{2.5}$). When combined exposures to the COPC were evaluated, potential risks were identified for the chemical mixtures that these COPC were part of (the eye, nasal and respiratory irritants). The exceedances for formaldehyde, NO_2 and SO_2 were found to be attributable to Oil and Gas emission sources, with some contributions from other sources in the area. The identified exceedances for acrolein and $PM_{2.5}$ were associated with non-Oil and Gas emission sources in the study area. Based on the margin of safety built into the HHRA and the fact that the likelihood of these exceedances occurring was considered to be rare, the risks for these COPC were not expected to result in adverse health effects.
- Long-term inhalation exposures to the COPC were generally predicted to be associated with a low potential for adverse health effects. For fine particulate matter ($PM_{2.5}$), exceedances of ambient air quality guidelines were predicted for only the Cumulative Scenario, at two remote locations where people are unlikely to spend appreciable periods of time. For formaldehyde, potential cancer risks were predicted for a remote location in close proximity to an oil and gas site. However, further analysis of this exceedance indicating that the probability for people to be exposed to formaldehyde concentrations at the predicted level over a lifetime was very low. When the potential combined, additive effects of the COPC were evaluated, nasal and respiratory irritant mixtures were predicted to have elevated risk estimates. However, given the locations of where the maximum concentrations for these chemicals were expected to occur (*e.g.*, formaldehyde), and the degree of conservatism incorporated into the assessment, the potential mixture risks were determined to have a low potential for adverse health effects.
- In the assessment of potential exposures to the COPC that people in the area might receive over the long term through the consumption of local foods, drinking water, contact with soils and water, it was determined that the potential for adverse human health effects is low.

The overall findings of the detailed HHRA of oil and gas activity in NE BC suggest that, while there is some possibility for COPC concentrations to occur at elevated levels, the probability that adverse health impacts would occur in association with these exposures is considered to be low.

As described in Section 2.4, other than aerial deposition onto regional water bodies, direct releases to water (groundwater or surface water) were not included in the detailed HHRA as a result of: their relatively low risk rankings; challenges related to data limitations (e.g. aquifer mapping, baseline water quality, site-specific considerations); and, the potential for these emissions to be managed through other frameworks (e.g. pipeline ruptures and emergency response interventions). The SLRA provided a qualitative analysis of many of these issues, thus further discussion was not specifically included in the detailed HHRA.

2.6 Regulatory Review

A review of existing statutory, regulatory and policy frameworks related to oil and gas activity in NE BC was completed in tandem with and as an adjunct to the detailed HHRA (Intrinsik 2014b). The objective of this review was to identify potential deficiencies in the existing regulatory framework as it relates to the potential influence of oil and gas development on public health. This review included oil and gas activities in NE BC associated with potential emissions to air and water from both historical and operational sites, normal operations, and emergency scenarios. The existing framework in BC was compared with various other jurisdictions and industry best practices documentation from the Canadian Association of Petroleum Producers (CAPP) and the American Petroleum Institute (API).

Overall, the review found that the existing regulatory framework in BC is extensive and broadly protective of human health. However, some policy and regulatory measures were identified that warranted further consideration with respect to their potential to strengthen the Province's capacity to prevent and mitigate health impacts from oil and activities.

3.0 KEY FINDINGS AND RECOMMENDATIONS

The sections below outline the key findings identified by the study team throughout the completion of the Phase 2 HHRA project tasks. The general topic areas that the study team has highlighted for additional discussion include:

- Public Safety (Emergency Management and Setbacks)
- Flaring, Venting and Fugitive Emission Management
- Hydraulic Fracturing Operations
- Legacy Sites
- Information Management
- Environmental Monitoring
- Standards Development
- Other Considerations

For each of these topics, a brief contextual summary of the key findings of the study team are presented, followed by suggested actions.

3.1 Public Safety

According to the findings of the SLRA (Intrinsik 2014a), uncontrolled releases to air and water were not evaluated as part of the detailed HHRA, based on their relatively low risk ranking which considered magnitude, likelihood, frequency, nature and hazard of this type of event. Uncontrolled release scenarios were evaluated in the regulatory review, within the context of determining if the existing emergency response framework in BC is adequate to protect public safety (Intrinsik 2014b).

As discussed in the Regulatory Review, a 'setback' is the minimum distance that must be maintained between oil and gas facilities and (i) locations where people may be present (dwellings, housing developments, urban centres, public facilities); and, (ii) water resources.

An emergency planning zone (EPZ) is the geographical area within which the potential for immediate danger to the life or health of a person could exist in the event of a release of a hazardous material from a well, facility or pipeline. Currently, oil and gas operators are required to develop and submit emergency response plans (ERP) to the BC Oil and Gas Commission and the BC OGC will determine the plan's fitness for use.

Through the regulatory review (Intrinsik 2014b), it was determined that the current requirements and methods used to calculate EPZs in BC may not reflect current best available practices. Based on the findings of the Intrinsik review, the current approaches do not properly account for the source conditions, the physical properties (*i.e.*, density) of the gas released, and the concentration exposure profiles. The current approaches are also based on H_2S, and thus only apply to sour operations. There are differences in the methods for calculating EPZs for wells and pipelines that make it difficult to define a common level of public safety protection for these applications. In addition, the current methods do not account for or provide incentives to operators to use additional control devices and mitigation measures (*e.g.*, emergency shut-down or prompt ignition of uncontrolled well) as a means of reducing the calculated EPZ to reduce potential hazards (Intrinsik 2014b).

As discussed in the Regulatory Review (Intrinsik 2014b), the Municipalities and regional Districts within BC have not implemented a reciprocal setback agreement framework, as has been done in other jurisdictions such as Alberta. In BC, the oil and gas industry has an obligation to ensure that setbacks are in place; however, the Municipalities and Regional Districts are not obligated to ensure that development within cities, counties, towns, *etc.*, do not encroach on oil and gas development (Intrinsik 2014b). Note that within the context of this report, the term "encroach" or "encroachment" refers to increasing risk resulting from additional potential hazards associated with new oil and gas infrastructure overlaying existing land uses and/or increasing land uses overlaying an existing risk space associated with existing nearby oil and gas facilities. The use of these terms is not being applied according to their legal or land-use based definitions.

The review of the organization and delivery of public safety as implemented in BC, within the overall regulatory framework for managing health, safety and the environment, indicates that this framework is appropriate and reasonable. The public safety recommendations put forward in this report relate, and are limited to, the applied "tools" that form the basis of public safety decisions.

With increasing proliferation of oil and gas infrastructure and/or alternatively, increasing land development near oil and gas facilities, it is our view that the Province should consider the following recommendations.

- **Recommendation 1** The tools applied to the calculation of EPZs representing the range of hazards associated with oil and gas infrastructure and activities should be updated and use scientifically supportable methods and emergency-based consequence endpoints.
- **Recommendation 2** Land-use and setback provisions applied in BC should be updated and use scientifically supportable methods along with individual and societal risk-based endpoints consistent with accepted risk norms, guidelines and standards applied in other developed industrialized countries. Further, it is recommended that these land-use and setback provisions be applied equally to both oil and gas and land development activities.

3.2 Flaring, Venting and Fugitive Emission Management

In the SLRA and Regulatory Review (Intrinsik 2014a,b), venting and flaring were identified as *controlled* releases to air, while fugitive emissions represented *uncontrolled* releases to air. Venting, flaring and fugitive emissions were not selected for inclusion in the detailed HHRA based on their relatively low risk ranking which considered magnitude, likelihood, frequency, nature and hazard of this type of event. Instead, these were included for further evaluation in the Regulatory Review (Intrinsik 2014b). Currently, there are a number of regulations regarding intentional releases through controlled venting and flaring in BC. There are also regulations outlining requirements around fugitive emissions from oil and gas activities.

The existing regulatory framework in BC provides guidance with respect to venting. The *Drilling and Production Regulation* outlines that venting is permissible as long as it is conducted in a manner that does not constitute a safety hazard, does not cause off-site odours, and minimizes both the quantity and duration of the venting. These requirements appear to limit the potential for intentional venting to impact the health of those in surrounding communities; however, the regulation provides no clear description as to what constitutes an actual “safety hazard”.

The Province has established several non-statutory (*i.e.*, not legally binding) ambient air quality objectives (AAQO) that may be used for permitting purposes, to help guide decisions on environmental impact assessments and authorizations, and to inform regulatory decisions.

In general, the Regulatory Review found that BC’s AAQO are comparable to those set in other jurisdictions and/or recommended by key public health and environmental agencies, with a few notable exceptions. However, there appears to be a lack of clear supporting documentation (*i.e.*, written justification) for the BC values and there is no clear guidance offered on the appropriate objective to be adopted in specific situations.

Further, the existing restrictions with respect to venting and fugitive emissions, flaring limits, flaring notification and reporting, and flaring performance requirements currently do not explicitly reference the BC air quality objectives. It may strengthen BC’s regulatory framework if the link between permitted emissions and the air quality objectives was clarified.

The following recommendation is based on the study team's review of the Province's existing flaring, venting and fugitive emissions management procedures:

- **Recommendation 3** The BC Ambient Air Quality Objectives should guide the development of regulations, directives and policies pertaining to venting, fugitive emissions, flaring limits, flaring notification and reporting, and flaring performance requirements. This should be done in a transparent manner that demonstrates how the objectives are considered.

3.3 Hydraulic Fracturing

Reviews of hydraulic fracturing with respect to potential impacts on health were completed in the SLRA (Intrinsik 2014a, Section 5.2.4.5) and the Review of the Regulatory Framework (Intrinsik 2014b). As described in these reports, the key health-related issues pertaining to hydraulic fracturing reports appear to be:

- Fracture fluid composition and disclosure
- Potential impact on the quality of water resources

Potential impacts from water emission scenarios related to hydraulic fracturing were not explicitly evaluated in the detailed HHRA, as these were assigned relatively low risk rankings in the SLRA (Intrinsik 2014a). Overall, the probability of adverse human health impacts occurring in relation to fracturing-related water emissions was determined to be low.

Some of the key findings that arose from the regulatory review related to pre-drilling water well testing and chemical disclosure.

3.3.1 Pre-Drilling Water Well Testing

The collection and analysis of water in wells surrounding a planned drilling site prior to the drilling activity can provide a valuable metric for baseline conditions for water quality. If problems are later reported or detected in that water well, availability of baseline information can help determine whether the problem existed before drilling took place or if it was exacerbated by drilling activities. The Province requires pre-drilling water well testing only when a fracturing operation will be carried out at a depth of less than 600 m below ground level (see Section 3.2.4 of Intrinsik 2014b). An industry 'best practices' document, the *CAPP Hydraulic Fracturing Operating Practice: Baseline Groundwater Testing,* recommends that companies undertake domestic water well sampling programs and participate in regional groundwater monitoring programs, including the testing of "water wells within 250 m, or as specified by regulation, of a wellhead before drilling shale gas, tight gas or tight oil wells."

In May 2014, the Canadian Council of Academies (CCA 2014) published a review of the potential environmental impacts of shale gas extraction in Canada. As part of this review, the CCA noted that there is currently a lack of baseline monitoring data for groundwater in the vicinity of shale gas development in Canada, and that this lack of information makes the assessment of potential environmental impacts associated with shale gas activity challenging. The CCA (2014) notes that any completed baseline studies must be analyzed regularly and the results of the monitoring used to "inform policy, improve regulations and ensure compliance", or the baseline studies have the risk of being ineffective and of limited value.

- **Recommendation 4** The implementation of baseline, pre-drilling ground water testing requirements for oil and gas activity in BC should be considered. Whenever possible, the process for collecting the information should be transparent, and the results publicly available, and reviewed on a regular basis. To facilitate the interpretation of results, it may also be beneficial to encourage the collection and reporting of well information in addition to sample data.

It is recognized that access to domestic wells can only be granted with permission from landowners, and that this can present challenges with respect to on-going well testing programs. As such, pre-drilling water testing of domestic wells will rely on the consent of the landowner, but should not be the responsibility of the landowner.

3.3.2 Chemical Disclosure

As described in the SLRA, the likelihood of people being exposed directly to hydraulic fracturing fluids is generally quite low (Intrinsik 2014a). In literature reviewed as part of the SLRA, it was noted that spills or issues with containment of hydraulic fracturing fluids or flow-back water at the surface could impact ground water resources (Intrinsik 2014a). Other potential pathways of exposure to fracturing fluids include the migration of fluids through induced or existing faults or fractures, migration through porous media, improperly constructed wells, and unanticipated blowouts during operations. All of these were determined to have a low likelihood of impacting human health (Intrinsik 2014a).

The study team also reviewed the regulations and practices associated with hydraulic fracturing fluid disclosure (Intrinsik 2014b). Currently, permit holders are required to submit information on their fracturing fluids (including: fluid ingredients, concentrations of each ingredient, total injection volume, CAS#, trade name and supplier of each chemical) to the BC Oil and Gas Commission (BC OGC) within 30 days of well completion. Some reporting exemptions are possible under the Hazardous Material Information Review Act if the chemical identity or concentration of any ingredient in a controlled product is considered to be confidential business information. Similar exemptions have been identified in other jurisdictions.

Before the requirement for fracturing fluid disclosure was put into place by the BC OGC, the composition of fracturing fluids used in the region was uncertain. The SLRA (Intrinsik 2014a, Section 5.2.6) noted that although some components of fracturing fluid composition are disclosed, the composition and quantities of fluids changes in relation to the local geology in the vicinity of a well site. The FracFocus database does provide some information regarding fluid composition, but for confidential ingredients, no information is available. Thus, there appears to be some variation between wells within the region. These factors make it difficult to assess the mobility and toxicity of potential fluids in the event that an aquifer or water source has been impacted.

Industry publications from CAPP and API both promote the full disclosure of hydraulic fracturing fluids. The API (2011) supports an approach that balances the needs of industry and the public with respect to disclosure, and advises that proprietary formulations of fracturing fluids should be disclosed to designated governmental representatives and health professionals in the event of an emergency. In theory, this information could be of value in diagnosis and treatment of patients. However, it is stipulated by the API (2011) that these designated individuals should be required to keep the supplied information confidential.

- **Recommendation 5** The Province should consider refining its fracturing fluid disclosure process so that designated authorities and health professionals can gain access to needed information about fluid ingredients, without compromising confidential business information.

3.4 Legacy Sites

As noted in the SLRA, historical activities at current and former operating facilities may have resulted in environmental contamination at sites across BC (Intrinsik 2014a). Potential release of chemicals primarily related to historical fluid handling practices at oil and gas sites have resulted in sites that are characterized by their "legacy" environmental issues. In the past, the following practices may have introduced unintended contamination at these legacy sites:

- Storing and disposing of liquids in earthen ('flare') pits or sumps
- Disposing of storage 'tank bottoms', spent drilling fluids, processing waste products and other materials in unlined landfills or pits
- Changing out engine oils, particularly at compressors, without proper containment of the waste oil
- Use of in-ground sumps to contain drilling mud systems during well drilling

Additionally, flare system overflows and issues related to produced water injection systems may have introduced various dissolved constituents into groundwater.

In the SLRA, in-ground fluid pits and flare system overflows, in-ground drilling fluids storage and on-site subsurface storage of wastes (all relevant to legacy sites) were assigned relatively high risk rankings in comparison to other water-related scenarios (Section 5.3.1, Intrinsik 2014a).

The assessment and management of legacy sites presents a challenge to both regulators and industry. Regional-scale data related to historical activities and practices, and the potential impacts of these activities, are not available. As well, there exists some uncertainty about the completeness of the available dataset for historical oil and gas activities in the region.

The SLRA (Intrinsik 2014a) described a six-step process that could be adapted and applied to aid in the management of legacy sites. The BC OGC (2009) has a site classification tool for the characterization and prioritization of potential human health and environmental risks associated with oil and gas sites in BC. It is intended to aid in the identification of sites for management by the British Columbia Ministry of the Environment (BC MoE), and was developed by the BC OGC in relation to the provisions of the Petroleum and Natural Gas Act, and a Memorandum of Understanding that is in place between the BC OGC and the BC MoE. The Province appears to have an established approach for the assessment and management of contaminated sites that is both rigorous, effective and scientifically based (Intrinsik 2014b).

- **Recommendation 6** When possible, the site classification tool and the existing framework for the management of contaminated sites should be used together in the assessment and management of legacy sites in NE BC.

3.5 Information Management

In the preparation of the SLRA and the detailed HHRA, the study team worked with the BC MoH, BC MoE and BC OGC to collect information regarding various types of oil and gas activities in the region. Through this information collection process, the study team gained some insight into current and past data-sharing practices and formats used by these organisations when sharing data with each other and the public. It is acknowledged that several information management systems exist in relation to oil and gas activities and the environment that are managed primarily by the BC OGC and BC MoE. Many of these systems appear to have been developed or enhanced after promulgation of the Oil and Gas Activities Act in 2010. A brief summary of some of the systems is presented in the following sections.

3.5.1 Management of Data Regarding Permitting, Operations and Incidents

3.5.1.1 KERMIT Database

Currently, the BC OGC operates a database known as KERMIT (*Knowledge, Enterprise, Resource, Management, Information Technology*). One of the objectives of this database is to provide the oil and gas industry with a means of submitting electronic documents in relation to facilities and pipelines (BC OGC 2014). Applications, amendments and notices of intent for oil and gas projects must be submitted to the BC OGC through KERMIT (BC OGC 2014). Details for oil and gas facilities are tracked through three categories of information: site, detail and activity. Records within the KERMIT system provide information regarding legal locations, facility type (*e.g.*, gas plant, compressor, dehydrator), maximum hydrogen sulphide content (H_2S percentage within the product), and facility equipment (*e.g.*, piping, vapour recovery units, gas sweetening units, compressors, generators). This system does not track waste discharge permits, but the need for a permit is flagged as part of the KERMIT documentation process. The proximity of the facility to populated areas is also included as part of the KERMIT application process (BC OGC 2014).

Although there is a public user-interface for electronic submissions, access to the full contents of the database appears to be limited. Based on the study team's communication with the OGC, the database stores about six years of data. It is not user-friendly in the sense that data from the system cannot be easily shared through an accessible data format (Personal Communication 2013a).

For facilities approved before 2010, facility specific equipment and stack details for gas plants and compressor stations are not available in electronic formats. Hard-copy records are stored in Fort St. John at the BC OGC office (Personal Communication 2013b). The tracking of facility emissions and parameters are managed by both the BC OGC and the BC MoE; although BC OGC manages most of the information, with the BC MoE only holding information for large facilities (Personal Communication 2013a). The information for the BC MoE-managed oil and gas facilities are not within KERMIT (Personal Communication 2013a). Hard copies of approval documents before 2010 are available at the Prince George office of the BC MoE (Personal Communication 2013b). Some gas plants are permitted by the National Energy Board, and as a result, no information is available from the BC government regarding these facilities (Personal Communication 2013c).

The KERMIT database is also used to track incidents that required emergency response, such as accidental releases, including pipe failures, well blowouts, fires, and releases from drilling or servicing operations (Personal Communication 2013d). Public reporting of some of this information takes place on an annual basis in the form of Public Safety Reports released by the BC OGC.

Based on the information available to Intrinsik, the KERMIT database does not appear to be linked to other databases managed by the BC OGC and BC MoE, although upon their review of a draft of this report, the BC OGC noted that the Emergency Response and Safety portal project in 2014 has implemented complaints and incident reporting into KERMIT.

3.5.1.2 Waste Permits Management – Authorization Management System

The Authorization Management System (AMS) is a waste permit administration system for the BC MoE. It maintains data related to the administration of facility waste permits issued under the Environmental Management Act, and registrations under various other regulations where dischargers of waste are required to register. The permits within this system are not limited to oil and gas activities. The information that is contained within the AMS includes:

- Companies or individuals permitted to discharge waste
- Type of business and locations at which waste disposal is permitted
- The types, amounts and frequency of waste products that are permitted to be discharged at given locations
- Fees associated with a discharge

The first step in finding information for a particular facility in the AMS is to access DataMart (BC MoE 2014a), a series of four spreadsheets that are accessible on-line that list information organized by Authorization Number, discharges, facility names, or fees. Using the Authorization Number identified from the DataMart spreadsheets, a different BC MoE database for Publicly Viewable Authorizations (BC MoE 2014b) can be searched, and electronic copies of permits viewed.

This system does not appear to be linked to other BC OGC permit systems.

3.5.1.3 Public Complaints and Feedback Tracking Data

The BC OGC tracks public complaints and feedback regarding oil and gas activities in the region. A database is maintained in electronic format at the BC OGC Community Relations Branch. The complaints that are received are usually application specific and are filed before a project is approved. Complaints that are made after a project is operating are also tracked, and passed along to other departments within the BC OGC. The types of issues tracked include concerns or incidents relating to: air quality, flaring, safety, odours, fracking, setbacks, and visual issues (Personal Communication 2013e,f).

3.5.1.4 Wells and Flaring Databases

The BC OGC has a database known as IRIS that is accessible to a limited number of Commission staff, and provides information regarding short-term well testing, and well authorization numbers. A separate database system is used to store information regarding well

flaring, organized by well authorization number. The Land Resource Data Warehouse (LRDW, which is now part of the Environmental Management System (EMS)) can be searched publicly to identify well locations. To collect information on any given well and associated flares, it is the understanding of the study team that separate inquiries using well authorization numbers need to be completed. Some of the information in these databases is considered to be confidential.

The database that is currently used by the BC OGC to track major flaring or venting events in the region is in various formats, and it is not readily available (Personal Communication 2013g). This information does not seem to be linked with the public complaints database maintained by another division of the BC OGC (described in Section 3.5.1.3). Some information regarding flaring is submitted and reviewed as "Notice of Flares" reporting through IRIS, although these do not require regulatory approval.

The LRDW can be searched with respect to well locations as part of the BC MoE EMS (BC MoE 2014c, described in Section 3.5.2.1), but the well testing and flaring information does not appear to be readily available or linked to other database systems.

3.5.2 Ambient Environmental Monitoring Databases

3.5.2.1 Environmental Management System

The BC MoE Environmental Management System (EMS) is the primary data repository for the BC MoE. Data stored within this system includes information regarding solid waste discharges, and ambient monitoring data for the Province. It contains information from the previous LRDW, GeoBC Data Discovery, and BC Geographic Warehouse databases. Read-only access is provided through an EMS Web Reporting interface, and a system that permits the transfer of data from permit holders and laboratories to the EMS also exists (Electronic Data Transfer system). Access to the EMS is restricted, although public health and environmental professionals may request access (BC MoE 2014c).

This system is searchable via many different methods. Data reports for individual queries can be generated by EMS and are available to the user for download, which is convenient. Overall the system is not particularly user-friendly as a result of its database interface. Examples of areas for improvement that were identified include:

- Several search criteria are not well defined or described.
- The parameter list was large, inconsistently presented, and included inconsistent chemical naming (*e.g.*, NO_2, nitrogen dioxide, N.diox) that made searching for chemical data challenging.
- If more than one parameter was downloaded at a time, the download report provided by the system would not necessarily export the data consistently or accurately (*e.g.*, columns of data shifted).
- Locations of samples often were not clear. An EMS ID was presented, but it was not readily apparent from the database information where samples were from due to the coding used in the EMS database. Latitude and longitude data had to be used to sort and locate where samples were from in some situations. No map interface was available.

The EMS has the potential to be a useful and powerful information tool; however, its usefulness is limited by its current format and content.

3.5.2.2 BC MoE Air Data Archive

The BC MoE has developed the Air Data Archive Database (BC MoE 2014d), which provides access to historical data from ambient air quality and meteorological stations in BC.

It appears that the data from the Air Data Archive for air quality parameters such as Criteria Air Contaminants are not captured within the BC MoE EMS Database (BC MoE 2014c). Other problems encountered include:

- Search results frequently turned up monitoring stations with no current data available
- Search limited to 2-year increments only
- System timed out when searching for multiple chemicals
- Several database errors occurred that were associated with unknown causes
- Challenges with searching for certain averaging periods (*e.g.*, hourly or daily maximums)
- Inconsistencies in the presentation and listing of chemicals contained within the database, sometimes due to different methods used for data collection
- Interface was very slow to use

It is worth noting that technical support was available on line for this system, and the response was timely and helpful.

The BC Air Quality Archive dataset appeared to overlap with the Environment Canada National Ambient Air Pollutant Survey (NAPS) data. The NAPS system is also challenging to use, and provides data in a unique format that requires conversion, via various software programs, in order to be viewed and summarized.

3.5.2.3 BC OGC North East Water Tool (NEWT)

The BC OGC has created an on-line tool for the NE region of BC known as the North East Water Tool (NEWT). The database within NEWT consists of hydrology data, and is designed to query locations of rivers or lakes throughout the NE BC region to allow for the estimation of monthly and annual runoff. NEWT can also be used for watershed mapping. Areas or water bodies of interest can be searched by their geographic coordinates or through manual selection from an online map.

3.5.2.4 BG OGC Water Information Portal

The BC OGC Water Information Portal is an on-line, interactive database that provides data related to both water quantity and water quality for the NE BC region. The water quality information linked to this tool appears to include both surface water and ground water data, ranging from relatively recent data to historical data (1960s to early 2000s). The parameters included in these data sets include aesthetic parameters and metals. The data sources that link to the Water Information Portal include the BC MoE EMS and the Northern Health Authority water quality database.

3.5.3 Identification of Key Findings and Recommendations Regarding Information Management

Since the implementation of the 2010 Oil and Gas Activities Act, both the BC OGC and BC MoE have developed and maintained several data systems that relate to oil and gas facilities, permitting, wells, wastes, incidents, complaints or ambient data. Some of these are publicly accessible while others have restricted access. In some instances (*e.g.*, IRIS, flaring database, KERMIT), there is limited access to data for the general public, but the site is not easy to use or transparent. The BC OGC (BC OGC and MNGD 2014a) notes that not all data within KERMIT can be accessed by public users due to proprietary information concerns.

Based on communications from various individuals within the BC OGC and BC MoE and first-hand experience from the study team during the course of this project, the user-interface and data output formats can be challenging to work with. Before 2010, the data management practices as they relate to oil and gas activities appear to involve hard copy documents that are now stored in various locations.

- **Recommendation 7** The overall objectives and efficient use of the various databases that manage permits, facility information, wells and flare data should be reviewed, with the aim of identifying means to make the systems more accessible and user-friendly.

The development of clear standards for data collection and management might be of assistance in this review. It may be of value to the BC OGC, BC MoE, and other Ministries to assess their current document management and storage practices associated with historical permits, incident reports and other documentation related to oil and gas facilities. In addition, the Province could consider combining data from the BC OGC, BC MoE and other Ministries into a more consolidated database, with a user-friendly interface perhaps with a spatial format that can provide government, industry and third-party environmental professionals with available data regarding incidents, complaints, environmental monitoring and compliance. Another approach might be to establish a common portal for this information. The existing BC OGC Northeast Water Portal is a good example of how a collaborative effort has resulted in a database wherein water data are readily available.

3.6 Environmental Monitoring and Health Surveillance

As part of the SLRA and detailed HHRA, the study team made attempts to collect ambient data for a number of environmental media (air, water, soil, vegetation, food) for several chemicals of potential concern (COPC) from local, regional, provincial and national data sources. Through this process, the study team gained an understanding of the availability and format of ambient data. The findings regarding environmental monitoring data availability for NE BC are summarized below by environmental media.

3.6.1 Air Quality Monitoring

It is recognized that the development of air quality monitoring network in NE BC is both a recent and an on-going initiative. With the permission of the BC MoH, the isopleth maps formulated during the SLRA were provided to the BC MoE as part of a data-sharing agreement. At the time of the request, and at the time of the publication of the BC MoE reports (BC MoE 2014a,b) regarding the design of the NE air quality network, the detailed emissions inventory and

dispersion modelling results utilized for the detailed HHRA were not available[1]. To help provide context as to how the newly implemented monitoring program by the BC MoE is integrated into the existing air quality monitoring framework for the region, Table 1 presents locations added in 2014. Table 2 presents a summary of all known air quality monitoring locations for the selected COPC in the region.

Table 1 Summary of BC MoE Air Quality Monitoring Locations Added in 2014

Monitor Site	Parameters Measured	BC MoE Rationale for Site	Comment
Parkland Community Hall (located between Taylor and Dawson Creek)	SO_2, TRS	Number of test facilities, gas plants, sour pipelines and other oil and gas activities in vicinity. No known monitors in area.	Small rural population
Tomslake (SW corner of study area)	SO_2, TRS	Number of gas plants and sour gas pipelines in area, number of compressor stations, test facilities, waste disposal facilities and well sites in vicinity. No known monitors currently in area.	Small rural population. Some MAML data available for 2010.
Doig River Cultural Centre (north portion of study area, near FN)	SO_2, TRS	Number of batteries, facilities and sour gas pipelines in vicinity. Terrain features that could concentrate pollutants under some conditions. No known monitoring in area.	Small First Nations community

Adapted from BC MoE (2014a,b). TRS: total reduced sulphur compounds

Table 2 Summary of Existing Air Quality Monitoring of COPC for the HHRA Study Area

Monitor Site	Organization Responsible	Parameters Measured	Type of Monitoring	Availability of Data to Public	Notes
Existing Monitoring					
BC Hydro Site C Station 1	BC Hydro	$PM_{2.5}$, PM_{10}	24-hour	No	Monitor located along Peace River between Hudson's Hope and Fort St. John.
BC Hydro Site C Station 8	BC Hydro	$PM_{2.5}$, PM_{10}	24-hour	No	Monitor located about 5.5 km south of Fort St. John along Peace River.
Buick Creek	CNRL	SO_2, H_2S	Hourly	No	
Dawson Plant	Spectra	SO_2, H_2S	Hourly	No	

[1] This information has since been provided to the BC MoE by the BC MoH.

Monitor Site	Organization Responsible	Parameters Measured	Type of Monitoring	Availability of Data to Public	Notes
Dawson Creek	BC MoE (EMS)	$PM_{2.5}$	24-hour	Yes	Available from 2011-2014. Collection method and statistics of sampling not clear.
Doig River Cultural Centre (north portion of study area, near FN)	BC MoE	SO_2	Hourly	Yes	
Hasler	Spectra	SO_2, H_2S	Hourly	Yes	
Kwoen Gas Plant	Spectra	Meteorology	Hourly	Yes	
Parkland Community Hall (located between Taylor and Dawson Creek)	BC MoE	SO_2	Hourly	Yes	
Taylor South Hill	Spectra	SO_2, H_2S	Hourly	Yes	
Taylor Townsite	Spectra	SO_2, H_2S	Hourly	Yes	
Tomslake (SW corner of study area)	BC MoE	SO_2	Hourly	Yes	
Historical Monitoring (Data not available for 2014)					
Chetwynd Pine Gas Plant	Spectra	SO_2, H_2S	Hourly	Yes	Data only available up to 2012.
Chetwynd Pine Gas Plant	Environment Canada and BC MoE	SO_2, H_2S	Hourly	Yes	Data only available up to 2012.
Farmington	BC MoE (MAML)	NO_2, O_3, $PM_{2.5}$, SO_2	24-hour	Yes	Monitoring limited to part of 2010. Discontinued.
Fort St. John	BC MoE (EMS)	$PM_{2.5}$	Not clear	Yes	Monitoring discontinued in 2003.
Groundbirch	BC MoE (MAML)	NO_2, O_3, $PM_{2.5}$, SO_2	Hourly	Yes	Monitoring limited to part of 2010. Discontinued.
Hudson's Hope	BC MoE (EMS)	$PM_{2.5}$	24-hour	Yes	Monitoring discontinued in 2006. Available data for 2003-2006. Collection method and statistics of sampling not clear
Kelly Lake	BC MoE (MAML)	NO_2, O_3, $PM_{2.5}$, SO_2	Hourly	Yes	Monitoring limited to part of 2011. Discontinued.
Rolla	BC MoE (MAML)	NO_2, O_3, $PM_{2.5}$, SO_2	Hourly	Yes	Monitoring limited to part of 2010. Discontinued.
Tomslake	BC MoE (MAML)	NO_2, O_3, $PM_{2.5}$, SO_2	Hourly	Yes	Monitoring limited to part of 2010. Discontinued.
Taylor	BC MoE	NO_2	Hourly	Yes	Monitoring of NO_2 discontinued in 2002.

Monitor Site	Organization Responsible	Parameters Measured	Type of Monitoring	Availability of Data to Public	Notes
Taylor Townsite	BC MoE	H_2S, O_3, SO_2	Hourly	Yes	Data available up to 2012.
Taylor Townsite	Environment Canada	SO_2	Hourly	Yes	Data available up to 2012.
Taylor South	BC MoE	H_2S, SO_2	Hourly	Yes	Data available up to 2012.

Overall, the existing air quality monitoring framework appears to "capture" some of the COPC identified in the HHRA in relation to air quality emissions, such as H_2S and SO_2. However, the monitoring of other COPC appears to be limited. In addition, the degree of monitoring in the areas where the population density is the greatest (the Fort St. John - Dawson Creek areas) appears to be limited with respect to the amount of data publicly available and the number of COPC associated with airborne emissions from oil and gas emissions and other industrial activities (*e.g.*, NO_2, SO_2, $PM_{2.5}$). No regular monitoring for O_3 appears to occur within the NE BC region beyond Prince George. Respiratory health has been identified by area residents as part of the Phase 1 HHRA project as being of concern (FBC 2012), and COPC such as NO_2, $PM_{2.5}$, O_3 (as well as H_2S and SO_2) may be associated with adverse respiratory effects in humans under certain exposure conditions. Accordingly, the monitoring of these COPC is relevant to the characterization of health risks in the region.

The Province of BC, in collaboration with industry and the community, is currently re-evaluating the ambient air monitoring program in NE BC with the goal of capturing the required air quality data to make the best informed decisions regarding public health, pollution management and impacts to sensitive ecosystems. The project is being implemented in three phases:

- Phase 1 (June 2012 to March 2014) focused on establishing new temporary monitoring stations, information assessment, and initial engagement with representatives of the local communities.
- Phase 2 (July 2014 to July 2015) will focus on ongoing community engagement, characterizing air quality in the study area, developing long-term funding/management options, and refining air quality monitoring and reporting.
- Phase 3 (July 2015 onward - TBD) will consider the information gathered from Phases 1 and 2 to implement a refined monitoring network, informed by best available science, that would include, but not be limited to, such elements as: where monitoring stations would be placed (BC OGC and MNGD 2014a).

The following recommendation is based on the study team's review of the environmental monitoring that is currently conducted in NE BC:

- **Recommendation 8** The Province's on-going air monitoring program in NE BC should continue to follow the principles outlined in BC MoE's *Framework for the British Columbia Air Monitoring Network*. Consideration should be given to the air quality contour maps provided in the detailed HHRA in the placement of future air quality monitors. As well, the identification of specific air contaminants for inclusion in the air monitoring program should consider the findings of the detailed HHRA.

When evaluating the future placement of air quality monitors in the region, consideration should be given to: (i) locating additional monitoring stations in the most populated and potentially impacted areas and communities associated with the COPC exceedances (Fort St. John, Dawson Creek, Taylor); and, (ii) ensuring that these stations monitor for criteria air contaminants other than just SO_2 (*e.g.*, COPC that were identified in the HHRA as having exceedances or being of interest to the region: NO_2, $PM_{2.5}$, SO_2, O_3). Consideration may also need to be given to monitoring a number of non-criteria air contaminants that, according to the findings of the HHRA, are potentially relevant to human health (*e.g.*, formaldehyde, acrolein). In addition to continuous air quality sampling in the region, monitoring could involve short-term or passive sampling in more remote areas where some of the higher air concentrations are predicted to occur. The monitoring of COPC at both populated (continuous and/or passive sampling) and remote locations (passive sampling) will provide more information as to whether or not exceedances are indeed occurring and, if so, with what frequency and magnitude.

The detailed HHRA was based predominantly on air quality predictions (*i.e.*, modelling results). Although measured data were used for comparison purposes, due to issues with data quantity and quality, health risk predictions based on measured data could not be completed as part of the detailed HHRA.

- **Recommendation 9** Once additional data for the NE BC region are available from new monitoring stations or are made available from regulatory submissions, the air quality predictions and human health risk estimates from the detailed HHRA should be revisited.

The models and approaches used in the detailed HHRA could be used with measured data and the outcomes compared. This approach might be helpful in directing future monitoring programs in the region. It is important to note that the detailed HHRA is based on a “snapshot in time”; meaning that the air quality predictions stem from emission estimates from current sources in the region. In other words, health risks were described for existing conditions in NE BC. As oil and gas development evolves in the region, up-to-date ambient measurements should prove helpful when revisiting the findings of the Phase 2 HHRA.

3.6.2 Water Quality Monitoring

Some drinking water data were available from the various communities in the region. However, no data were identified for the COPC included in the detailed HHRA. Overall, the available data appeared to be limited to aesthetic and microbial parameters, and metals.

In the SLRA (Intrinsik 2014a), it was recognized that water quality monitoring for chemicals known to be related to oil and gas development is limited. Few ambient groundwater data for the NE BC region are available with respect to the specific chemical parameters evaluated in the HHRA. What were available was limited to aesthetic and microbial parameters, and some metals. In the absence of an established, consistent database of groundwater quality, it is difficult to evaluate the potential impacts of oil and gas development on a regional basis.

The SLRA conceptualized water quality risk on a ‘well-by-well’ or ‘activity-by-activity’ basis. This conceptualization resulted in a relative ranking of each scenario, but did not address the potential risks associated with the density and distribution of facilities and their proximity to water intakes or wells. One approach that could be followed to assess the potential cumulative risk would be to overlay known domestic and municipal groundwater well locations with historic

or operating facilities and other oil and gas activities. This overlay would identify wells that are close to existing or historical facilities. Consideration of topography and vulnerability mapping, along with other site-specific information, could then be used to assess the potential for contaminants, if present, to migrate to a well on a case-by-case basis.

The evaluation of potential contamination from oil and gas sources on aquifers is difficult to complete without information regarding the vulnerability of the aquifer (Intrinsik 2014a). To date, aquifer mapping has only been completed in the areas surrounding Fort St. John and Dawson Creek. However, several municipal and domestic wells are located beyond these mapped areas (*e.g.*, Fort Nelson, Taylor, Chetwynd, Tumbler Ridge). As noted in the SLRA (Section 5.2.6), there is some uncertainty with respect to areas of local groundwater recharge and discharge. Although some data is available regarding shallow groundwater from the Provincial WELLS database, some of this information is dated and may not provide the level of detail required to do a complete assessment of local groundwater conditions.

- **Recommendation 10** While some aquifer mapping has been completed in NE BC, it is recommended that the existing aquifer mapping (and vulnerability mapping) be expanded for the NE BC region to help enhance the protection of groundwater resources in relation to oil and gas development. This information would aid in regional and site-specific assessments of potential risks to groundwater. As one of the limitations with the current aquifer mapping relates to an overall absence of subsurface data, it is suggested that surficial geology mapping (on an appropriate scale) for the region be completed as well.
- **Recommendation 11** Additional study of groundwater and surface water interactions within shallow aquifers and local ground water flow conditions in the NE BC region should be completed. This information could contribute to a better understanding of potential contaminant fate and migration. As well, studies could be carried out to investigate the location and sources of groundwater recharges.

3.6.3 Monitoring of other Environmental Media

A limited amount of soil data for the COPC assessed in the HHRA were identified for the study area. Of all the COPC included in the detailed HHRA, data were only available for a limited number of polycyclic aromatic hydrocarbon compounds from the BC MoE EMS database. No other information sources were identified.

The information that is available from the BC MoE EMS system does not appear to provide much detail with respect to biota or the types of tissues sampled, nor does it offer much information regarding the sampling or analysis itself.

- **Recommendation 12** Consideration should be given to the overall goals of the existing environmental monitoring programs for soil, water, and biota, along with the presentation and quality of these data within the existing databases, specifically as these relate to the value that these data could provide with respect to human and environmental health.

With respect to biota, the database could be improved with information regarding sample weights, species, tissue type, etc., for the various samples, which might help the existing data within the EMS database be more useful for evaluating potential health risks. For the collection

of new data it may be of value for the various ministries to implement a requirement for the collection of multimedia samples (e.g., soils and vegetation). This could be done in association with new environmental assessments or approvals. Such a requirement would serve to gradually grow the database of multimedia ambient data within the region and the Province as a whole.

3.6.4 Health Surveillance

The Literature Review and detailed HHRA completed for this project both suggested that respiratory diseases and related health effects (short-term and long-term) are of interest with respect to oil and gas activities. Currently, monitoring of disease rates, *etc.,* is completed by regional and provincial health authorities.

- **Recommendation 13** The Province should explore tailoring their health surveillance to determine whether or not there are any differences in disease rates in those areas identified in the HHRA with the highest predicted air concentrations. If possible, such future health surveillance would help verify the conclusions of the HHRA.

3.6.5 Standards Development

As part of the Regulatory Review (Intrinsik 2014b), the study team evaluated the existing environmental quality standards in BC for air and other environmental media (soil and water).

The standards for soil and groundwater, and their derivation process appeared to be scientifically-based and generally comparable to the approaches used by other jurisdictions.

The current provincial framework for developing air quality objectives (as described in: http://www.bcairquality.ca/reports/pdfs/aqo-framework-information-sheet.pdf) specifies that air quality objectives should reflect a science-based evaluation of the potential for adverse health effects as well as applicable economic, technical, ethical, social, legal, ecological and achievability considerations. In general, air quality objectives in BC are comparable to those set in other jurisdictions, with a few notable exceptions. The use of three separate levels of acceptable air quality concentrations (as air quality objectives) appears to be out of date, as it is no longer applied in other jurisdictions. Supporting documentation (*i.e.*, written justification) for a given health or environmental effect for the various air quality objectives is not available, and there is no clarity on the appropriate guideline to be adopted in specific situations.

Based on discussions between members of the study team and personnel at the BC MoE, the Province is committed to updating its air quality objectives for NO_2 and SO_2.

It is important to note that the exposure limits or toxicological reference values (TRVs) used in the detailed HHRA do not necessarily represent ambient air quality objectives or environmental standards, and thus do not take into consideration other aspects relevant to standards development, such as economic and technological considerations. In addition, the TRVs selected for use in the detailed HHRA are not intended to represent the position or policy of the MoH or any other provincial agency, and are specific to the HHRA completed as part of this project. The selection of TRVs for use in HHRAs conducted in NE BC or in other parts of the Province needs to be done on a case-by-case basis. In other words, the TRVs used in the

Phase 2 HHRA should not automatically be used as the framework or basis for the development of future standards or completion of future HHRAs.

The following recommendation is based on the study team's review of how the Province currently develops its air quality objectives:

- **Recommendation 14** The BC air quality objectives should be reviewed and updated based on the existing provincial framework for developing air quality objectives.

In order to do so, it may be worthwhile for the Province to work with other regulatory authorities (*e.g.,* Health Canada, the World Health Organization) as part of working-groups for the review and derivation of environmental standards, through which information could be shared on a regular basis. The development, selection and implementation of the air quality objectives should be a transparent process, wherein all supporting documentation is publicly available. Further, consideration should be given to replacing the multi-level approach with a "single value per air contaminant per averaging period" approach (commonly used in other jurisdictions). Finally, it is suggested that air quality objectives be developed and implemented for other air contaminants commonly associated with oil and gas activities. As long as BC ensures that their air quality objectives are kept up to date and remain health based, they should provide a good metric for characterizing potential health risks.

It is worth noting that effective October 21, 2014, BC has adopted new interim ambient air quality objectives for NO_2 and SO_2 to guide decisions on new and expanding industrial facilities. These objectives will be reviewed once new national standards are available, following a process outlined in the provincial framework for developing air quality objectives. BC is currently an active participant in the process to develop national ambient standards for NO_2 and SO_2.

3.7 Other Considerations

Concerns have been raised relating to potential non-chemical impacts on health in the region that may be associated with oil and gas activities. The scope of work for the Phase 2 HHRA did not include an analysis of how oil and gas activity in NE BC could influence other determinants of health (*e.g.,* housing, access to community services, sexually transmitted infections, stress, mental health, addictions, quality of life, *etc.*) or other non-chemical hazards (*e.g.,* noise, light, traffic accidents). Concerns related to these non-chemical risks were identified in the Phase 1 HHRA and were conveyed by representatives from Northern Health during consultation on the Phase 2 HHRA. In order to ensure that local interests are captured, regional organizations such as Northern Health should be actively engaged in the development of the scope of work for any future work.

Finally, based on the concerns expressed by the communities and the feedback that has been received from a number of stakeholders throughout the completion of the Phase 2 HHRA, it is apparent that area residents have a keen interest with respect to the potential health impacts of oil and gas activity in NE BC. In light of this, follow-up work could involve communication and outreach activities wherein the findings of the Phase 2 HHRA are explained. Such activities can serve as effective tools for communicating upcoming, ongoing and completed monitoring and assessments related to potential health impacts in NE BC.

4.0 SUMMARY OF RECOMMENDATIONS

The overall findings of the Phase 2 HHRA indicate that the health risks associated with oil and gas activity in NE BC are generally low. A review of the Province's existing statutory, regulatory and policy frameworks was completed in tandem with and as an adjunct to the detailed HHRA. The primary objective of the review was to identify potential deficiencies in the existing regulatory framework as it relates to the potential influence of oil and gas development on public health. Overall, the review found that the existing regulatory framework in BC is extensive and broadly protective of human health. However, some policy and regulatory measures were identified that warranted further consideration with respect to their potential to strengthen the Province's capacity to prevent and mitigate health impacts from oil and activities.

Along with the health-related concerns that were shared during consultation on the Project, the final recommendations are based on the findings of the detailed HHRA and the Review of the Regulatory Framework. The final recommendations put forward to the Province include:

- **Recommendation 1** The tools applied to the calculation of EPZs representing the range of hazards associated with oil and gas infrastructure and activities should be updated and use scientifically supportable methods and emergency-based consequence endpoints.
- **Recommendation 2** Land-use and setback provisions applied in BC should be updated and use scientifically supportable methods along with individual and societal risk-based endpoints consistent with accepted risk norms, guidelines and standards applied in other developed industrialized countries. Further, it is recommended that these land-use and setback provisions be applied equally to both oil and gas and land development activities.
- **Recommendation 3** The BC Ambient Air Quality Objectives should guide the development of regulations, directives and policies pertaining to venting, fugitive emissions, flaring limits, flaring notification and reporting, and flaring performance requirements. This should be done in a transparent manner that demonstrates how the objectives are considered.
- **Recommendation 4** The implementation of baseline, pre-drilling ground water testing requirements for oil and gas activity in BC should be considered. Whenever possible, the process for collecting the information should be transparent, and the results publicly available, and reviewed on a regular basis. To facilitate the interpretation of results, it may also be beneficial to encourage the collection and reporting of well information in addition to sample data.
- **Recommendation 5** The Province should consider refining its fracturing fluid disclosure process so that designated authorities and health professionals can gain access to needed information about fluid ingredients, without compromising confidential business information.
- **Recommendation 6** When possible, the site classification tool and the existing framework for the management of contaminated sites should be used together in the assessment and management of legacy sites in NE BC.
- **Recommendation 7** The overall objectives and efficient use of the various databases that manage permits, facility information, wells and flare data should be

reviewed, with the aim of identifying means to make the systems more accessible and user-friendly.

- **Recommendation 8** The Province's on-going air monitoring program in NE BC should continue to follow the principles outlined in BC MoE's *Framework for the British Columbia Air Monitoring Network*. Consideration should be given to the air quality contour maps provided in the detailed HHRA in the placement of future air quality monitors. As well, the identification of specific air contaminants for inclusion in the air monitoring program should consider the findings of the detailed HHRA.
- **Recommendation 9** Once additional data for the NE BC region are available from new monitoring stations or are made available from regulatory submissions, the air quality predictions and human health risk estimates from the detailed HHRA should be revisited.
- **Recommendation 10** While some aquifer mapping has been completed in NE BC, it is recommended that the existing aquifer mapping (and vulnerability mapping) be expanded for the NE BC region to help enhance the protection of groundwater resources in relation to oil and gas development. This information would aid in regional and site-specific assessments of potential risks to groundwater. As one of the limitations with the current aquifer mapping relates to an overall absence of subsurface data, it is suggested that surficial geology mapping (on an appropriate scale) for the region be completed as well.
- **Recommendation 11** Additional study of groundwater and surface water interactions within shallow aquifers and local ground water flow conditions in the NE BC region should be completed. This information could contribute to a better understanding of potential contaminant fate and migration. As well, studies could be carried out to investigate the location and sources of groundwater recharges.
- **Recommendation 12** Consideration should be given to the overall goals of the existing environmental monitoring programs for soil, water, and biota, along with the presentation and quality of these data within the existing databases, specifically as these relate to the value that these data could provide with respect to human and environmental health.
- **Recommendation 13** The Province should explore tailoring their health surveillance to determine whether or not there are any differences in disease rates in those areas identified in the HHRA with the highest predicted air concentrations. If possible, such future health surveillance would help verify the conclusions of the HHRA.
- **Recommendation 14** The BC air quality objectives should be reviewed and updated based on the existing provincial framework for developing air quality objectives.

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