Phase 2 Direction Document

Phase 2 – Human Health Risk Assessment of Oil and Gas Activity in Northeastern British Columbia

Final
7 February 2013
Phase 2 Direction Document

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1.0 INTRODUCTION

In response to concerns expressed by residents of northeastern British Columbia (NE BC), the British Columbia Ministry of Health (MoH) commissioned a human health risk assessment (HHRA) focusing on the potential impacts of oil and gas activity on human health. 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 Northeastern BC. Completed in March 2012 by the Fraser Basin Council.

- **Phase 2 HHRA.** Human Health Risk Assessment of Northeastern British Columbia Oil and Gas Activity. Timeline: October 2012 to March 2014.

- **Phase 3 HHRA Communication of overall results.** Timeline: To Be Determined.

The MoH has contracted Intrinsik Environmental Sciences (Intrinsik) to complete Phase 2 of the HHRA of oil and gas activities in NE BC. In addition to Intrinsik itself, the companies that make up the study team include: RWDI Air, Matrix Solutions, Skystone Engineering, McDaniel Lambert, and Borden Ladner Gervais LLP. The team also includes a three member Advisory Panel to provide an independent perspective on the design and approach of the Phase 2 HHRA, and the eventual interpretation of the results. The Phase 2 HHRA will focus on Local Health Areas 59, 60 and 81 (the region), and is intended to investigate the potential impact of oil and gas activities on human health.

The contents of the Phase 2 Direction Document were proposed as part of Task 2 of the Intrinsik Proposal, and represent an update on the status of some of the initial information collection activities being completed as part of the HHRA. The objectives of the Phase 2 Direction Document are:

- To conduct a detailed review of the Phase 1 report (FBC 2012), identifying key issues of public concern, and to identify specific health and environmental issues to guide the jurisdictional scan, the screening level risk assessment, and the quantitative HHRA that are part of the Phase 2 HHRA work plan.
- To identify the nature and extent of oil and gas activities and their related categorization to aid in the completion of the screening level risk assessment.
- To conduct a search for publicly available information related to emission sources of chemicals of concern (COC), measured data for COCs in environmental media, and baseline health data for residents in the region, and to provide an overview of data gaps.
- To provide an overview of the Geographical Information System (GIS) that will support the Phase 2 HHRA, including information that is currently available to the study team and information that will need to be collected from agencies like the Oil and Gas Commission (OGC).
- To outline a process for developing information requests to source existing data that may not be readily available through public channels.
- To provide an overview of some of the next steps associated with the completion of the Phase 2 HHRA.
Sections 2 through 5 provide an overview of the information that has been collected to date by the study team and how it may be used in future tasks associated with the Phase 2 HHRA, while Sections 6 to 10 introduce the next steps of the Phase 2 HHRA.

2.0 REVIEW OF PHASE 1 REPORT

The Fraser Basin Council (FBC 2012) conducted Phase 1 of the HHRA, which 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 outlining their findings. Area residents, including First Nations residents, were included in the Phase 1 work. Public engagement activities were carried out 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. Outreach activities included: media stories, website postings, advertisements, emails, meeting invitations and household distribution efforts in rural areas to ensure that interested audiences were aware of the HHRA and the Phase 1 public outreach initiative. Interested parties had numerous opportunities to participate including submitting comments online via a web form, through email, calling a toll-free number, and by mail. There was also an open invitation to request a personal meeting (in person or by phone) with the FBC. In total, more than 300 unique comments or submissions were received through the public engagement process. It should be noted that the Phase 1 report did not include analysis or validation of any of the concerns identified therein, and represented a collation of concerns expressed by area residents.

As the findings of Phase 1 will inform the development of the work plan for the Phase 2 HHRA, a summary of the findings of the Phase 1 report are presented in Section 2.1 In addition, a summary table listing the perceived key issues and whether or not they will be addressed as part of the Phase 2 HHRA is provided in Table 2.1 in Section 2.8.

Following the response deadline, all comments and submissions were reviewed and categorized based on several major themes or concerns that were identified. The collective feedback and findings from Phase 1 under each of the identified areas of concern are summarized below.

2.1 Personal Health Issues

A number of different personal health issues were identified by respondents throughout the public engagement process, including concerns about physiological, psychological and cultural/spiritual health. Submissions that identified a particular health concern without identifying an exposure pathway or relating it to a specific activity related to oil and gas development were categorized as personal health issues by the FBC.

Respondents often commented that they were concerned with health impacts in general without giving any details. Overall changes to quality of life were cited in many submissions as a concern, as well as an increase in anxiety due to the unknown. There were some common personal health issues that people perceive as being associated with oil and gas activities including lung-related issues (e.g., asthma and bronchitis), cancer, sinus, throat and eye issues, stress, sleep deprivation, and reduced quality of life.
There were some respondents that provided suggestions as part of their submissions. These included recommendations to conduct public health research and identify mitigation techniques, as well as increasing public awareness and education of health issues.

2.2 Environmental Pathways of Exposure

A number of specific concerns related to health and environmental exposure in relation to oil and gas activity were expressed. These concerns were grouped under air quality, water quality and quantity or food quality by the FBC (2012), and are summarized in the Sections below.

2.2.1 Air Quality

Many of the respondents expressed concern about gas well and facility emissions, fugitive emissions and the implications of higher levels of particulate matter from vehicle emissions. Potential health effects that were cited as being of concern included asthma, sinus infections, coughing, headaches and cancer, among others. Some respondents expressed concern that there are limited air quality monitoring data available for the region of northeastern BC, and that a study of air quality in relation to health would be beneficial. Some of the other concerns included:

- The impact of poor air quality on human health and the health of livestock, wildlife, aquatic species and the natural environment.
- The effects of acute and chronic low-level exposure to hydrogen sulphide and other compounds related to oil and gas activities such as flaring.
- The impacts of sulphur dioxide and hydrogen sulphide on sensitive individuals such as the young, elderly and immune deficient.

In some cases the respondents provided suggestions for mitigation measures including establishment of an air quality monitoring network, conducting local studies on air quality and health and implementing measures to reduce emissions and flaring events.

2.2.2 Water Quality and Quantity

There was a high level of concern from respondents regarding the current and potential impacts of oil and gas resource development not only on water quality, but also on the quantity of water that will be used in processes such as hydraulic fracturing. There is concern that excessive water removals will affect the amount of fresh water available to the local communities. In addition, concerns were expressed about the potential for contamination of water resources from construction, operation, hydraulic fracturing, oil spills and disposal pits associated with oil and gas development. Finally, there were comments about the perceived lack of legislation acknowledging the issue of water extraction for the purpose of hydraulic fracturing and other oil and gas operations.

Some of the suggestions provided by respondents included:

- Conducting water quality studies of the area and assessing the impact of oil and gas development (including oil spills).
- Regular testing of water bodies for polycyclic aromatic hydrocarbons (PAH) and other chemicals.
- Obtaining baseline water quality data for surface and groundwater sources.
2.2.3 Food Quality

The potential health impacts of eating contaminated food, including agricultural products, livestock or fish and wildlife, was a primary concern for some respondents and especially to First Nations communities who rely on fish, moose and other ungulates as a major food source. Specific concerns included potential contamination of agricultural cropland, changes in the health of ungulate populations (e.g., physical abnormalities) and the impact of a decline in the ungulate population due to oil and gas development. A few of the potential activities proposed to mitigate impacts included fencing around well sites and contaminated areas, studies of local ungulate populations and application of dust retardant along residential and agricultural roadways.

2.3 Related Environmental Issues

A variety of different concerns surrounding quality of life and health and safety were voiced by respondents. Issues ranged from accidents and explosions to increased noise and light pollution, traffic and road accidents. Key concerns regarding explosions, spills or accidents included possible pipe failure near water bodies, and soil contamination and health effects from spills, leaks and waste disposal. In addition, light and noise pollution from drilling, hydraulic fracturing and increased traffic were identified as a source of concern by people living in the vicinity of existing well sites. Finally, submissions stated that impacts on ecosystems such as destruction of habitat and effects on aquatic species were important to assess on a cumulative basis.

2.4 Changes to the Community

Alterations in the socio-economic and demographic structure of a community resulting from rapid oil and gas development were a prime concern for some respondents. Issues relating to shifts in community structure include:

- Disruption to traditional cultures and economies in the region
- Rapid population growth and economic inequality
- Problematic substance abuse, crime and social disruption
- Reduced social cohesion due to intensive work-camp and industry-sector scheduling.

2.5 Community Service Issues

Community services include health care services, municipal and regional infrastructure and community and social services. These are potential issues of concern, as drastic changes in a population can put pressure on the local services and infrastructure which can have short or long-term effects on the community and its social programs, especially those that support marginalized populations or populations at risk.

Health Care System

With an ever growing population, the region is experiencing increased pressure on health care services, along with a shortage of medical staff and doctors. Respondents worry that further expansion will
exacerbate these existing issues and lead to increased prevalence of chronic diseases and workplace injuries, higher demand for hospital beds and lack of funding for appropriate healthcare.

Social and Community Services

Due to the influx of well-paying jobs, demanding work schedules, and the attraction of a relatively young work force, respondents are worried about increased pressure on social and community services. These include reduced availability of family services, increased drug and alcohol related problems, decreased family stability and cumulative health effects from high job demands. Suggested mitigation measures included maintaining and reviewing health records, increasing funding to the MoH from the oil and gas industry, and continuation of provincial revenue-sharing to keep up with increasing demands.

Municipal and Regional Infrastructure

Organizations and local governments tended to be the respondents most concerned with infrastructure issues such as increased pressure on local water and sewage treatment facilities, impacts on traffic and parking, lack of adequate housing, additional security requirements, and a transient workforce that lacks commitment to the community.

2.6 Oil and Gas Operational Issues

Respondents were also concerned about the impacts of oil and gas operational activities including exploration, drilling, transportation and pipelines on the environment and nearby communities.

Exploration, Drilling, Pipelines and Processing

Some of the concerns associated with exploration, drilling, pipelines and processing were related to the density of well sites in residential areas, the quantity and composition of waste products, the potential risk of earthquakes, possible sour gas releases, and contamination of water supplies. Overall, many respondents seem to be very concerned about not being properly informed of waste disposal, accidents and spills, potential impacts, and the necessary corrective measures.

Transportation and Traffic

Oil and gas resource development requires intense use of roadways during all phases of the operation. This has caused some concern regarding additional traffic hauling oversized hazardous material loads, increased potential for accidents and an increased number of hazardous spills along public roads.

2.7 Institutional Framework

Institutional framework concerns surround regulations, policies and communications plans that provide guidance for the oil and gas industry and have a direct impact on the effects that industry could have on the surrounding environment. The specific issues were related to monitoring and compliance, regulation and enforcement, communications, emergency response, and tracking and reporting.
Monitoring and Compliance

Some respondents are concerned that the current monitoring and compliance procedures may not have sufficient resources to conduct adequate baseline and on-going assessments of air, water and soil, and that wastewater labelling requirements following a spill are not stringent enough. Suggestions included conducting cumulative health impact studies, increased monitoring, complete disclosure of water used, comprehensive baseline assessments, and regular review of publicly-available site inspections.

Regulation and Enforcement of the Industry

Concerns about how the industry is regulated were shared among many respondents who were worried about the lack of compliance and enforcement personnel, insufficient setback distances from residential areas, lax industry-wide standards, and the release of chemical-specific information. Other suggestions included increasing setback distances from wells, use of an independent agency for monitoring, adherence to Environmental Farm Plan guidelines, and involvement of the BC MoH in all permitting and regulation of the development operations.

Communication

Overall, the concerns regarding communication appear to be related to a lack of available information and transparency when dealing with members of the community. This was considered to be especially critical during leaks or spills where members of the public were able to smell gas. The limited discussion regarding future resource development was also identified as a key concern.

Emergency Response Planning

A number of respondents felt that emergency response measures and site setbacks were not sufficiently protective. Specific concerns included a lack of effective emergency response, management and communication efforts, lack of clarity regarding emergency procedures, and insufficient notification by the MoH on incidents that could affect residents’ health. The one suggestion was to set up a call centre that receives oil and gas emergency calls and re-routes them through the Peace River Regional District 911 call answer service.

Tracking and Reporting of Adverse Health Effects

Respondents were concerned with how a lack of tracking regarding exposure to toxic substances makes it difficult to conduct a realistic assessment of health effects. Suggestions to remedy this include using a system to track community health over time and conducting independent medical tissue sampling on humans and animals in affected areas.

2.8 Incorporation of the Phase 1 Findings into the Phase 2 HHRA

The results of Phase 1 identified many issues of concern related to human health and the environment. Overall, respondents seemed most concerned about not being fully informed of the nature and extent of possible health effects from oil and gas development in the region. Respondents also expressed interest in participating in subsequent phases of the HHRA.
The Phase 2 HHRA will attempt to address many of the health concerns identified in the Phase 1 report. The scope of the Phase 2 HHRA will meet the terms and conditions of the Request for Proposal set forth by the MoH. To provide a better understanding of how the concerns identified in the Phase 1 report will be addressed in the Phase 2 HHRA, a summary table is provided below (Table 2.1).
## Table 2–1  Summary of Perceived Issues Identified from the Phase I Report and Discussion of Potential Inclusion in the Phase 2 Human Health Risk Assessment

<table>
<thead>
<tr>
<th>Issue Identified in Phase 1 Report</th>
<th>Issue to be Addressed in Phase 2 HHRA?</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0 Personal Health Issues</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Lung related issues such as asthma and bronchitis</td>
<td>Yes</td>
<td>The Phase 2 HHRA will evaluate the potential health impacts associated with the chemical emissions from oil and gas activity on human health, including potential respiratory health impacts. Individuals who are potentially sensitive to the effects of airborne chemicals, such as asthmatics and the chronically ill, will be considered in the HHRA. However, it will not quantitatively assess any potential causative relationships between oil and gas activity, specific contaminants and existing respiratory disease in the region.</td>
</tr>
<tr>
<td>b. Cancer</td>
<td>Yes</td>
<td>The Phase 2 HHRA will evaluate the potential health impacts associated with the chemical emissions from oil and gas activity on human health, including potential cancer risks associated with exposure. However, it will not quantitatively assess any potential causative relationships between oil and gas activity, specific contaminants and the existing prevalence of cancer in the region.</td>
</tr>
<tr>
<td>c. Quality of life for local residents</td>
<td>No</td>
<td>The Phase 2 HHRA will focus on health issues potentially related to chemical exposures associated with oil and gas activity.</td>
</tr>
<tr>
<td>d. Stress and sleep deprivation</td>
<td>No</td>
<td>Non-chemical related health determinants are beyond the scope of the HHRA.</td>
</tr>
<tr>
<td><strong>2.0 Environmental Pathways of Exposure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Emissions from oil and gas activity and potential impact on human health</td>
<td>Yes</td>
<td>The Phase 2 HHRA will evaluate the potential health impacts associated with the chemical emissions from oil and gas activity in NE BC.</td>
</tr>
<tr>
<td>b. Acute and chronic exposure to H₂S, SO₂ and other emissions</td>
<td>Yes</td>
<td>Both short-term and long-term exposures to chemicals of concern associated with oil and gas activity will be evaluated in the Phase 2 HHRA, including H₂S and SO₂.</td>
</tr>
<tr>
<td>c. Potential impacts of SO₂ and H₂S on sensitive or susceptible individuals</td>
<td>Yes</td>
<td>Individuals who are potentially sensitive to the effects of airborne chemicals, such as asthmatics and the chronically ill, will be considered in the Phase 2 HHRA.</td>
</tr>
<tr>
<td>d. Characterization of chemicals of concern associated with oil and gas activity</td>
<td>Yes</td>
<td>In addition to the information provided in this report, a jurisdictional scan and literature review are in progress that will help identify chemicals of potential concern associated with oil and gas activities that are relevant to NE BC. Information will also be collected from local health authorities, provincial ministries, and industry in order to identify chemicals of concern for the HHRA.</td>
</tr>
<tr>
<td>Issue Identified in Phase 1 Report</td>
<td>Issue to be Addressed in Phase 2 HHRA?</td>
<td>Comment</td>
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</tr>
<tr>
<td>e. Effects of fugitive emissions on human health</td>
<td>Yes</td>
<td>Consideration will be given to potential fugitive emissions of chemicals of concern, where information is available.</td>
</tr>
<tr>
<td>f. Contamination of water from activities associated with oil and gas development, including the construction, operation, spills, and waste management practices of industry</td>
<td>Yes</td>
<td>Consideration will be given to potential chemical contamination of surface and ground water in association with oil and gas activity, including waste storage and ‘legacy’ or historical sites, where adequate information is available.</td>
</tr>
<tr>
<td>g. Potential impacts of oil and gas emissions on locally grown food, including agricultural products, fish and wildlife</td>
<td>Yes</td>
<td>The Phase 2 HHRA will consider the potential chemical contamination of local soil, water, traditional and country food sources in association with oil and gas activity, where adequate information is available. The assessment of the existing health or potential impacts of oil and gas activities on crop, livestock or wildlife health specifically are beyond the scope of the assessment.</td>
</tr>
<tr>
<td>h. Cumulative impacts of emissions from various sources in the area (transportation, industry, etc.)</td>
<td>In part</td>
<td>The Phase 2 HHRA will be focused on emissions associated with oil and gas activity. Relevant baseline, measured concentrations of chemicals in environmental media from the area will be considered where possible and relevant. The full extent of the cumulative effects assessment will be determined in the screening level risk assessment.</td>
</tr>
<tr>
<td>i. Emissions from oil and gas activity and potential impact on livestock health</td>
<td>No</td>
<td>The Phase 2 HHRA will focus only the potential impacts to human health. Effects on livestock and agricultural operations are outside the scope of the Phase 2 HHRA.</td>
</tr>
<tr>
<td>j. Emissions from oil and gas activity and potential impact on ecological health (wildlife, aquatic receptors, etc.)</td>
<td>No</td>
<td>Effects on ecological receptors are outside the scope of the Phase 2 HHRA.</td>
</tr>
<tr>
<td>k. Impacts of oil and gas activity on water quantity (i.e. Use of large volumes of water)</td>
<td>No</td>
<td>The Phase 2 HHRA will evaluate the potential health impacts associated with the chemical emissions from oil and gas activity on human health. However, the Phase 2 HHRA is not a hydrological assessment. As such, the potential non-chemical impacts on water sources and water availability are beyond the scope of the assessment.</td>
</tr>
<tr>
<td>l. Impact on agricultural operations or adherence to Environmental Farm Plan guidelines</td>
<td>No</td>
<td>The impact of oil and gas activity on agricultural operations is outside the scope of the assessment.</td>
</tr>
</tbody>
</table>

3.0 Related Environmental Issues

a. Explosions and accidental releases | Yes | Consideration will be given to potential human health impacts associated with accidents, in relation to oil and gas activity in the area. Set back distances may be considered as part of the evaluation of issues related to emergency response and/or management. The extent to which accidental releases will be...
### Issue Identified in Phase 1 Report

<table>
<thead>
<tr>
<th>Issue to be Addressed in Phase 2 HHRA?</th>
<th>Comment</th>
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<tbody>
<tr>
<td>assessed will be determined in the screening level risk assessment.</td>
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</tbody>
</table>

**b. Impacts on water bodies and soil from spills, leaks, and waste disposal on health**  
Yes  
The potential impacts of accidental releases and spills of water used by oil and gas activities in the region will be considered in the Phase 2 HHRA. The extent to which these will be assessed will be determined in the screening level risk assessment.

**c. Destruction of wildlife and aquatic habitat**  
No  
An evaluation on habitat impacts is beyond the scope of the Phase 2 HHRA.

**d. Increased traffic**  
No  
The Phase 2 HHRA will be focused on chemical emissions associated with oil and gas activity and potential human health effects. This may include an assessment of traffic (e.g., diesel) emissions as a source of air contaminants, depending on the outcome of the screening level risk assessment. Issues such as increased traffic volume and changing traffic patterns and how these may related to public safety (e.g., fatalities/accidents) will not be evaluated in the Phase 2 HHRA.

<table>
<thead>
<tr>
<th>Potential impact of noise and light pollution on health</th>
<th>No</th>
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</thead>
<tbody>
<tr>
<td>The assessment of non-chemical related health determinants are beyond the scope of the HHRA.</td>
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</tr>
</tbody>
</table>

### 4.0 Changes to Community

**a. Impacts on access to community services, including health care and social services**  
No  
The assessment of non-chemical related health determinants are beyond the scope of the HHRA. The Phase 2 HHRA will be focused on chemical emissions associated with oil and gas activity and potential human health effects.

**b. Increased impacts due to growth on municipal and regional infrastructure (water and wastewater facilities, housing, security, parking, transportation issues)**  
No  
The assessment of non-chemical related health determinants are beyond the scope of the HHRA. The Phase 2 HHRA will be focused on chemical emissions associated with oil and gas activity and potential human health effects.

**c. Impact of oil and gas activity on social endpoints (addictions, family structure, mental health)**  
No  
The assessment of non-chemical related health determinants are beyond the scope of the HHRA. The Phase 2 HHRA will be focused on chemical emissions associated with oil and gas activity and potential human health effects.

### 5.0 Oil and Gas Operational Issues

**a. Impacts of oil and gas exploration activities**  
Yes  
The potential impacts of exploration activities will be considered in the Phase 2 HHRA. The extent to which these will be assessed will be determined in the screening level risk assessment.

**b. Potential for increased road accidents due to increased traffic, including accidents involving**  
No  
The Phase 2 HHRA will be focused on chemical emissions associated with oil and gas activity and potential human health effects. An evaluation of traffic patterns and the potential for accidents is beyond the...
<table>
<thead>
<tr>
<th>Issue Identified in Phase 1 Report</th>
<th>Issue to be Addressed in Phase 2 HHRA?</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>hazardous waste vehicles</td>
<td>scope of this assessment.</td>
<td></td>
</tr>
<tr>
<td>c. Impact of physical aspects of oil and gas activity such as facility density, potential for earthquakes</td>
<td>No</td>
<td>An evaluation of these types of physical hazards is beyond the scope of the HHRA, as the Phase 2 HHRA will be focused on chemical emissions associated with oil and gas activity and potential human health effects.</td>
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### 6.0 Institutional Framework

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<thead>
<tr>
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<tbody>
<tr>
<td>a.</td>
<td>Evaluation of regulations and policies relating to the oil and gas activity in northeastern BC</td>
<td>Yes</td>
</tr>
<tr>
<td>b.</td>
<td>Recommendations regarding emission management and reduction</td>
<td>Yes</td>
</tr>
<tr>
<td>c.</td>
<td>Evaluation of emergency response planning in the area and impacts on people</td>
<td>Yes</td>
</tr>
<tr>
<td>d.</td>
<td>Communication of environmental monitoring information to the public</td>
<td>In part</td>
</tr>
<tr>
<td>e.</td>
<td>Communication between operators, health authorities and the public with respect to operations, emergency response, enforcement and compliance activities</td>
<td>In part</td>
</tr>
<tr>
<td>f.</td>
<td>Establishment of a monitoring program or framework for environmental media (air, water, soil)</td>
<td>In part</td>
</tr>
<tr>
<td>g.</td>
<td>Tracking and reporting of adverse health effects</td>
<td>No</td>
</tr>
</tbody>
</table>
3.0 NATURE AND EXTENT OF OIL AND GAS ACTIVITY IN NORTHEASTERN BRITISH COLUMBIA

To help identify potential emission sources and Chemicals of Concern (COCs,) the type of oil and gas activity in NE BC is reviewed and characterized in Section 3.1. It is not intended to represent a comprehensive evaluation of existing and prospective oil and gas activities in the region. A general overview is provided to provide an understanding of what types of emission sources may be present in the region, to aid in the identification of potential exposure scenarios, COCs and relevant exposure pathways. Section 3.2 provides an overview of the potential emission sources in the region.

3.1 Overview of Oil and Gas Activity in NE BC

The majority of oil and gas production in BC is located in the northeast corner of the Province, with most of the projected growth being related to unconventional activity (BC OGC 2010, BC MEMPR 2009). In the past, over 90% of the natural gas produced in BC has been through conventional means (FBC 2012). Between 1996 and 2011, natural gas production in BC increased by 76 %, with a shift from conventional vertical wells to unconventional horizontal wells over the last 10 years due to the advancement of drilling and production techniques related to tight gas development (BC OGC 2010).

Conventional oil and gas formations are typically porous and permit the flow of the resource to the surface via vertical wells (BC OGC 2010). Unconventional oil and gas projects require the use of methods such as horizontal drilling and hydraulic fracturing to access resources that were previously not readily accessible, such as shale gas or tight gas (BC OGC 2010).

Unconventional resources are found within low permeability tight gas and shale gas reservoirs, such as the Cadomin and Horn River formations, respectively. Hydraulic fracturing involves the high-pressure injection of fluids (known as fracking fluids) into formations of shale, or tight rock. The fluids are mixed with a hard substance (proppant) before injection that will hold open the cracks created in the formation by the high-pressure fluid injection, allowing the movement of gas and/or oil into the wellbore (BC OGC 2010). Figure 3.1 depicts this process with a horizontally drilled well.

Gas reserves will be classified as either “sweet” (low sulphur) or “sour” (high sulphur) depending on the hydrogen sulphide content of the gas. The gas composition and the production rate of the gas will vary, depending on the geological characteristics of the reservoir (Northern Health 2007).
The oil and gas development region to be evaluated in the Phase 2 HHRA encompasses the areas of Fort Nelson/Northern Plains, Liard Basin and Fold Belt, Fort St. John, Deep Basin area, and Northern and Southern Foothills (BC MEMPR 2009). Various oil and gas activities are present within all of these areas. A map of these areas is provided as Figure 3.2.
Figure 3-2  Oil and Gas Reserve Regions for Northeastern British Columbia (source: BC MEMPR 2009)
In the last year, the Montney unconventional play trend has seen the greatest amount of exploration and development in the Province. The Deep Basin area has activity relating to both conventional and unconventional (fracturing) gas. The Horn River Basin and Cordova Embayment are prospective sources for shale gas, and have seen an increase in the sale of PNG rights and drilling activity in recent years (BC MEMPR 2009). The Liard Basin is an area of emerging shale gas exploration (BC MEMPR 2009a).

Unconventional natural gas production was the primary activity in 2011-2012 in the Fort St. John and Dawson Creek regions (BC MEMPR 2009). This was primarily from the Montney Formation and the Cadomin Formation of the Deep Basin. A considerable amount of natural gas liquids and condensate were also produced from unconventional Montney development. Several gas processing plants are also located within the Fort St. John area (BC MEMPR 2009).

Figure 3-3   Coalfields and Coalbed Gas in British Columbia (source: BC MEMPR 2009).

Gas is processed at more than 40 plants and central dehydrators in NE BC. The Province’s major gas plants are located at Taylor, Fort Nelson and Pine River. Some of BC’s oil is processed at a refinery in Prince George, but most is transported by pipeline to Kamloops, then to the Vancouver and Washington area refineries via the Trans Mountain Pipeline and Puget Sound Pipeline. There are approximately 3,000 km of provincially-regulated oil and natural gas pipelines in BC (BC MEM 2005).
Throughout NE BC, conventional oil operations are anticipated to continue to decline (FBC 2012), although there has been an increase in the production of condensate (light oil) and natural gas liquids from the Montney Formation. In summary, the types of oil and gas activities that are of potential relevance to the Phase 2 HHRA include:

- Unconventional oil and gas resources including tight gas, shale gas, natural gas liquids and condensate through horizontal well drilling and hydraulic fracturing.
- Conventional oil and gas drilling and production;

As the potential for oil or gas to be sweet or sour varies with the reservoir characteristics, and as both could be present in the area, all of the above listed activities may also be related to sweet or sour resources.

### 3.2 Potential Emission Sources Associated with Oil and Gas Activity in NE BC

Given the variety of oil and gas activities in NE BC, a number of potential types of emission sources will need to be considered in the Phase 2 HHRA. These emission sources have been divided into two general categories for the purposes of this discussion: (i) potential emission sources to air; and, (ii) potential emission sources to water.

#### 3.2.1 Potential Emission Sources to Air

Facilities, operations and processes relevant to oil and gas activity that could be potential sources of COCs to the ambient air include (Northern Health 2007, Clearstone Engineering 2004a,b,c,d):

- Gas migration to surface
- Gas processing or sweetening plants
- Acid gas releases
- Sulphur recovery plants
- Separator units
- Dehydrator units
- Glycol regeneration units
- Glycol boilers
- Heating equipment
- Combustion Engines
- Flaring and flare pits
- Compressor stations
- Incinerators
- Field Batteries
- Storage facilities
- Accidents and equipment failures.
In addition to the above, the routine or intermittent use of flaring via stacks or pits is a relevant source of emissions at many facilities. Flaring volumes in the region can vary from year to year depending on activity levels, types of recovery techniques used, the locations of the facilities, and flare reduction programs in place (BC OGC 2012). Since 1996, flaring activity has decreased by 36% in BC as part of the BC Energy Plan through reductions in routine gas flaring. The BC Energy Plan strives to further reduce flaring emissions from non-routine flaring where possible (BC OGC 2012).

The major sources of flaring in BC during the 2011 calendar year were identified by the BC OGC (2012) as:

- **Gas processing plants:** Flaring activity at these plants is related to safety and cleanup. Flaring associated with gas processing plants in the Province increased by over 14% from 2010 to 2011 due to increased production.
- **Production Facilities:** Flaring occurs for safety reasons and during process upsets. At production facilities in BC, flaring activity increased by 14.5% between 2010 and 2011 due to increased production.
- **Underbalanced Drilling:** Flaring can occur as part of a drilling process where the wellbore pressure is kept lower than the fluid pressure in the formation being drilled. Between 2010 and 2011, a decrease in flaring activity by 9.3% was reported due to decreased underbalanced drilling activity and gas conservation practices. Since 2004, there has been a reduction of about 86% in flaring in association with underbalanced drilling.
- **Well Cleanup and Testing:** Cleanup flaring is used following the completion of a well, but before production. Flaring is used to remove contaminants from the well, and to help ensure safe operation. Testing flares are used to collect information regarding flow rate and volumes. Due to increased gas conservation associated with inline testing methods, test flaring has been reduced by about 3% between 2010 and 2011.
- **Solution Gas:** Solution gas is gas produced during oil production at wells and batteries. While operators must conserve an amount of solution gas in accordance with regulatory requirements, flaring of this gas does occur. However, solution gas flaring has been declining since 1996 (by 92.5%) due to a decrease in oil production.

In addition to the above emission sources, fugitive emissions to air may occur via pump and compressor seals, connectors, valves, flanges, vents and relief valves (Northern Health 2007; Clearstone Engineering Ltd. 2004a,b,c,d). For fracking operations, when produced water or well fluids are transported to the surface for storage, these fluids may be stored for up to 90 days in either open top tanks with a 1 metre thick freeboard in place, or in a tank with a synthetic impermeable liner, or in open and lined excavation pits (BC OGC 2010). As such, there is potential for airborne fugitive emissions from these storage units.

These scenarios are characterized according to the nature of the oil and gas activities and the type of emission sources associated with these activities. These scenarios will be considered in the Screening Level Risk Assessment for further consideration.
3.2.2 Potential Emission Sources to Water

3.2.2.1 Hydraulic Fracturing

Water is a key component of oil and gas production in NE BC, and is used in drilling and completion of wells, hydraulic fracturing, engine coolant, rig wash water, and for sanitary purposes (BC OGC 2010). Water use by oil and gas producers is regulated by the Province (BC OGC 2010).

Hydraulic fracturing involves the injection into a well of a large amount of pressurized water containing added fluids or particulates that fractures the reservoir leading to increased production rates through enhanced permeability. The targeted formation may be located underneath groundwater resources (see Figure 3.4).

![Figure 3-4 Well Injection In Relation to Drinking Water Sources: Horizontal (a) and Vertical (b) Drilling (source: US EPA 2012)](image)

Waste water or produced water from oil and gas projects are not permitted to be discharged into surface water bodies or introduced into shallow groundwater formations that may be used as a drinking water source. Water produced from hydraulic fracturing is either recycled and re-used, or is injected deep into subsurface formations via a water disposal well. The use and disposal of water utilized in hydraulic fracturing operations are regulated by the BC Oil and Gas Commission.
3.2.2.2 Operating and Legacy Sites

Other potential emission sources include emissions from the infrastructure that supports the oil and gas industry in British Columbia. These sources include emissions to water from the operating and legacy sites that comprise this infrastructure. The reason that operating and legacy sites are separated as emission sources are the fact that many historical practices, which are no longer observed, but at one time included facilities such as flare pits, unlined storage tank areas and onsite disposal facilities can be current sources of emissions to groundwater or surface water. Existing or future operating sites, even if built to present day standards, can be sources of emissions to water, mainly through accidental losses.

The potential exposure scenarios associated with unconventional oil and gas development (e.g., hydraulic fracturing) and operating/legacy sites will be considered in the Screening Level Risk Assessment.

4.0 EXISTING HEALTH AND ENVIRONMENTAL CONDITIONS AND INFORMATION NEEDS

4.1 Existing Health Status

In order to gain an understanding of how current environmental conditions potentially influence human health in NE BC, it is important to gather as much existing environmental data as possible. This data can be in the form of measured chemical concentrations in air, water, soil, vegetation and dietary items (e.g., wild game, fish, etc.). In addition to the environmental data, it is imperative to describe the existing health status of the population of NE BC. In line with the HHRA, whenever possible, the characterization of the population’s health should be relevant to potential environmental exposures, and therefore should focus on such indicators as various types of respiratory disease (e.g., asthma and chronic obstructive pulmonary disease), cancer and cardiovascular disease. The extent to which oil and gas activity in the region may influence a number of these health indices will be addressed, in part, through the findings of this HHRA. Not only does this information help identify critical receptors in the HHRA (e.g., vulnerable or susceptible sub-groups in the population), it also helps to contextualize the eventual risk estimates of the HHRA in terms of the existing or baseline health of the population. The review of this information is not intended to be a detailed investigation as to a potential causative relationship between existing conditions and oil and gas activity.

Baseline community health studies have been undertaken for selected areas of the province. With the exception of the 2007 report from the Medical Health Officer to the Board of Northern Health named “Population Health and Oil and Gas Activities” (Northern Health 2007), similar studies have not been conducted in NE BC. If necessary, the study team will attempt to obtain data regarding health conditions and health issues affecting the local population through consultation with the Northern Health Authority and the BC MoH. In addition, available regional health-related statistics will be considered in the HHRA.

It is important that the data concerning the current health status in the region (i.e., baseline health data) be interpreted with a certain degree of caution, and within the context of the Phase 2 HHRA scope of
work. The Phase 2 HHRA will also consider relevant guidance from other jurisdictions when deliberating on the existing health status in NE BC.

The HHRA study area includes local health areas 59 (Peace River South), 60 (Peace River North) and 81 (Fort Nelson). Whenever possible, environmental data and information related to the current health status of the regional population will be “bound” by these areas. Baseline health data are publicly available on a relatively broad scale, wherein information is presented for the primary urban centres or for large geographic areas. The HHRA study team conducted a preliminary review of various health data for NE BC that are publicly available, the results of which are summarized in Table 4.1. Some of these data provide information on the health status of people living in the HHRA study area (i.e., NE BC) relative to other regions in BC. When relevant and appropriate, the data identified in Table 4.1 will be incorporated in the Phase 2 HHRA discussion of baseline conditions.

As indicated in the table, most of the information sources relate to measures of disease prevalence (i.e., number of cases). At first glance, regional data are available for the prevalence of respiratory disease (specifically COPD and asthma) and cardiovascular disease, while there appears to be a paucity of region-specific data (LHR 59, 60 and 81) for cancer. However, cancer data (including mortality statistics) are available for NE BC in general. The sources of information did not compare NE BC regional health data to other parts of Canada, but comparisons were made to other regions in the Province, or with the Province in general.

In addition to the data and information currently available, through consultation with staff at the Ministries of Health and Environment along with the Northern Health Authority, the study team will determine whether any baseline community health and/or exposure studies have been undertaken in NE BC. In addition, the study team needs to determine whether or not BC offers an interactive electronic health database similar to other jurisdictions, such as Alberta’s Interactive Health Data Application (AIHDA) (http://www.ahw.gov.ab.ca/IHDA_Retrieval/), which provides information on health status and determinants of health. The AIHDA contains numerous health indicators on topics such as demographics, mortality, chronic and infectious disease, and children’s health. In the absence of this type of interactive database, comparable data will be retrieved through direct communication with government staff.
## Table 4–1  Summary of Publicly Available Health Data for NE BC

<table>
<thead>
<tr>
<th>Source</th>
<th>Region</th>
<th>Respiratory Disease Data?</th>
<th>Cardiovascular Disease Data?</th>
<th>Cancer Data?</th>
<th>Data Compared to other Regions?</th>
<th>Resource Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Region</td>
<td>Respiratory Disease Data?</td>
<td>Cardiovascular Disease Data?</td>
<td>Cancer Data?</td>
<td>Data Compared to other Regions?</td>
<td>Resource Link:</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
<td>---------------------------</td>
<td>------------------------------</td>
<td>--------------</td>
<td>--------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>BC Cancer Agency: Northern Health Authority</td>
<td>Northern (general)</td>
<td>No</td>
<td>No</td>
<td>Yes but may not be applicable (cancer incidence projections 2010-2025)</td>
<td>No</td>
<td><a href="http://www.bccancer.bc.ca/NR/rdonlyres/A20EB9FB-0932-4BF4-BA34-141FA6DD5AF6/53195/NorthernHealthAuthority_20102025.pdf">bccancer.bc.ca/ NR/rdomlyres/A20EB9FB-0932-4BF4-BA34-141FA6DD5AF6/53195/NorthernHealthAuthority_20102025.pdf</a></td>
</tr>
<tr>
<td>PHSA - BC Health Indicators Report</td>
<td>Northeast (general)</td>
<td>Yes (COPD, asthma - rates)</td>
<td>Yes (rates)</td>
<td>Yes (rates – also compares BC cancer to other provinces)</td>
<td>Yes (Other BC Regions; with ranking)</td>
<td><a href="http://www.phsa.ca/NR/rdonlyres/393C9C55-F19E-49DF-A566-A48FC8592A00/0/BCHealth_Indicators_Report.pdf">PHSA/BCHealth_Indicators_Report.pdf</a></td>
</tr>
<tr>
<td>BC Cancer Agency (2011) Regional Cancer Report</td>
<td>Northern (general)</td>
<td>No (not applicable)</td>
<td>No (not applicable)</td>
<td>Yes</td>
<td>Yes (Other BC regions)</td>
<td><a href="http://www.bccancer.bc.ca/HPI/CancerStatistics/FF/registats.htm">bccancer.bc.ca/HPI/CancerStatistics/FF/registats.htm</a> (full pdf not available)</td>
</tr>
</tbody>
</table>
4.2 Existing Environmental Conditions

Human health risk assessments are scientific studies that evaluate the potential for the occurrence of adverse health effects from exposures of people to chemicals of concern (COCs) present in environmental media (e.g., air, soil, surface water, groundwater, food, etc.), under existing or predicted exposure conditions. Risk assessment procedures are based on the fundamental dose-response principle of toxicology, with the response of an individual generally increasing in proportion to the magnitude of chemical exposure. The concentrations of chemicals in the target tissues (the dose) are determined by the degree of exposure, which is proportional to the chemical concentrations in the environment where the person resides, works or visits. Therefore, the HHRA will rely on both existing and forecast chemical concentrations in air, water, soil, vegetation and food.

The potential sources of existing environmental data in NE BC are summarized below. The information available from these sources will be reviewed in detail by the HHRA study team in order to adequately characterize the baseline conditions in the region.

1. The Government of BC offers an online data catalogue, DataBC (www.data.gov.bc.ca), which houses data, applications and tools related to:
   o BC Water Resources Atlas – provides information on a community’s water source and how the quality of that community’s water compares to the water quality in other areas
   o Data Distribution Service – this application allows the user to find and retrieve information across various BC datasets, including air emissions, regional census data, locations of hospitals, etc.
   o Geographic Data Discovery Service – linked to the same data as the Data Distribution Service, this application is designed to allow users to search BC geographical data using metadata
   o GeoScience BC

2. The Environmental Monitoring System (EMS) is the Ministry of Environment's electronic repository for the results of chemical, physical and biological analyses performed on air, water, biological, and solid-waste discharge. The system also contains related quality assurance data. Samples are collected by either ministry staff or permittees under the Environmental Management Act and then analyzed in public or private sector laboratories. The majority of this data is entered into EMS electronically via Electronic Data Transfer (EDT).

The link to the EMS is http://www.env.gov.bc.ca/epd/wamr/ems_internet/index.html

EMS data is typically available in formatted hard copy reports or electronically in comma delimited (e.g., .csv) files as:
   o Monitoring location-related data
   o Sample and results-related data
Direct access to EMS is restricted to ministry staff. However, public access to EMS is available upon request through EMS Web Reporting. The HHRA study team will work with staff from the MoH to gain access to the data housed on the EMS.

3. Regional Environmental Assessments (EAs) submitted to the BC Environmental Assessment Office (BC EAO). The BC EAO administers the Environmental Assessment Act. As such, it is responsible for reviewing EAs for proposed industrial projects in BC, including the HHRA study area. In its Project Information Centre (e-PIC), BC EAO offers detailed information on both current and past EA projects, including a mapping feature which allows users to search for projects geographically. Some of the EAs that have been filed in NE BC will have environmental baseline data relevant to the Phase 2 HHRA, possibly including air quality data, water quality data, soil data and/or vegetation data. In addition to retrieving the information from the online source, the HHRA study team will communicate directly with the regional BC EAO representatives to ensure that no data or relevant environmental information is missed (e.g., Executive Project Directors for the BC EAO Oil and Gas Sector and Omineca Region and Power and Industrial Sector and Northeast Region, respectively).

4. The Ministry of Environment’s Background Soil Quality Database, which contains detailed information from the Omineca Peace Region on background sampling locations, descriptions of each sampling site, and detailed analytical data (e.g., metal concentrations).

5. The University of Northern BC First Nations Food, Nutrition and Environment Study (FNFNES) (Chan et al. 2011). The FNFNES involved five components: (i) household interviews for collecting information on dietary patterns, lifestyles and general health status, environmental concerns and food security; (ii) traditional food sampling for a suite of contaminants; (iii) drinking water sampling for trace metals; (iv) hair sampling for exposure to mercury; and, (v) surface water sampling for pharmaceuticals. Results from those components of the FNFNES considered relevant to the Phase 2 HHRA will be reviewed and, when possible, incorporated into the HHRA by the study team.

6. Regional stakeholders, including industry associations like the Canadian Association of Petroleum Producers (CAPP) and organizations like the NE Oil and Gas Health Advisory Committee. For example, through CAPP’s cooperation and encouragement, the HHRA study team will try to petition oil and gas producers in the region to permit the use of their environmental data in the Phase 2 HHRA baseline assessment.

4.3 Information needs

Like all health risk assessments, the Phase 2 HHRA will rely on a combination of measured and predicted concentrations in various environmental media, primarily related to air and water.

4.3.1 Air Quality – Data Availability and Information Needs

Figure 1 shows a map of oil and gas activity in local health areas 59 (Peace River South), 60 (Peace River North) and 81 (Fort Nelson). Most gas plants and compressor stations report to Environment Canada’s National Pollutant Release Inventory (NPRI). Major concentrations of pipeline facilities that do not report to NPRI have also been identified and shown on Figure 4-1. Such pipeline facilities likely have
permits with BC MOE and may report emission monitoring data to them depending on the permit requirements.

Dispersion modelling typically requires meteorological data, topographical data, and source characterization data. Meteorological and topographical data are publicly available. While NPRI data can provide total reported emissions by facility for those gas plants and compressor stations that meet the reporting criteria, most source characterization information need to be obtained from regulators. The Ministry of Environment maintains a database containing permits and supporting operation information. Furthermore, stack testing is typically a requirement within the permits for major sources at industrial facilities and such data are reported regularly to the Ministry of Environment. The permit database and reported stack testing data would provide the bulk of the source characterization information for an air quality assessment. Small and temporary facilities such as well drilling sites and batteries may not need permits through the Ministry of Environment. Although it is likely that the OGC has some information pertaining to the well drilling sites, it is unclear at this point what or how much information OGC actually has. The study team understands that the OGC maintains a database of such facilities and would be able to provide some information to allow inclusion of these facilities in the air quality assessment. As such, the study team will communicate directly with staff at the OGC to retrieve these data.
Figure 4-1  Oil and Gas Industry Locations in NE BC
4.3.2 Groundwater – Data Availability and Information Needs

In the event that the Screening Level Risk Assessment identifies a water resource pathway that is potentially “high risk and significant” and sufficient environmental data for modelling exists, the water resources team will provide input data to the HHRA team. For example, hydraulic fracturing (fracking) associated with the development of shale gas deposits is a concern relating to water quality and human health in NE BC. When hydraulic fracturing operations are carried out properly, it is unlikely that contaminants will reach overlying freshwater aquifers. However, there are potential scenarios where fracking could result in chemical release to the environment; including:

- Leakage from the hydraulic fracturing well casing due to defective installation or cementing;
- Leakage through the geology overlying the hydrocarbon reservoir;
- Leakage from improper handling of chemicals used in the process and from hydraulic fracturing wastewaters (i.e., flow back or produced water from the formation) brought back to the surface at the well site.
- Leakage from waste disposal sites – injection sites and land waste disposal

In addition to the exposure scenario related to the drilling of new wells (e.g., hydraulically fractured), two other primary scenarios that will be examined include:

- Operating facilities including wells, storage areas, gathering/processing facilities and pipelines;
- Historical facilities or “legacy sites”.

The Phase 2 HHRA will assume that the risks to human health will be limited to existing potable use, not aquifers or water bodies that could be utilized for potable purposes in the future. The potential COCs may include hydrocarbons, produce water and other chemicals that are typically stored on industrial sites (e.g., solvents). Information from the GeoFluids database within GeoScout will be sufficient for characterizing the COCs.

In order to conduct an HHRA of oil and gas activity in the region, the study team will need to focus specifically on groundwater and surface water resources in the Western Canadian Sedimentary Basin, which occurs in NE BC. The assessment will involve the superposition of several public-available data sets, most of which can likely be obtained through Geoscience BC or the BC Water Resources Atlas. However, some of the data will have to be provided to the study team in a geo-referenced format, as it is currently available in a web format. These datasets would include the following data:

- Water wells and river intakes in the area by type – industrial, domestic or municipal
- Aquifer and aquifer classification data – the published information is focused on the Dawson Creek-Fort St. John area, but some airborne EM mapping may be available for the Horn River Basin
- Soils – areas of fine grained till versus areas of muskeg/organic soils
- Drift thickness(depth to bedrock
Groundwater and surface water quality.

The extent to which these data currently exist in the BC public is not fully known, but it is assumed that the information can be obtained through GeoScience BC and the Ministry of Environment. The availability and the ultimate extent of the data will be determined by the study team as part of the Screening Level Risk Assessment.

Other data that will be required will be aquifer-specific parameters. Most of these can be obtained through BC Aquifer Classification System mapping, however, individual oil and gas operators may have to be approached for site-specific information. If deemed necessary, this will be accomplished through direct communication with the BC Ministry of Environment, along with representatives of the BC Oil and Gas Commission and the Canadian Association of Petroleum Producers.

4.3.3 GIS – Data Availability and Information Needs

The following information outlines the anticipated GIS-related data requirements necessary to support the HHRA and to provide comments on the implications of oil and gas activities to emergency management. The various data are required to develop an illustrative understanding of current and future oil and gas activities and their related infrastructure (e.g., wells, pipelines, process equipment, gas plants, emissions, etc.). As well, the GIS data will assist the study team in identifying the relationship between the different oil and gas activities and other land-uses in NE BC (e.g., traditional, agricultural, communities, etc.) and their supporting infrastructure (e.g., roads, etc.).

The study team will adopt a staged approach to the data gathering. Initially, for the purpose of conducting the Screening Level Risk Assessment, the team will gather broad-based information and overlay this data onto the four shale plays (i.e., Montney Play Trend, the Cordova Embayment and the Liard and Horn River Basins) for the purpose of determining where the potential impacts are most likely to be realized. The identification of the areas and exposure scenarios of concern will be described in detail in the Screening Level Risk Assessment, which will be reviewed by both the Advisory Panel and ADM Steering Committee. Once the areas of concern have been selected (i.e., those regions advanced to the Phase 2 HHRA), more comprehensive and detailed activity-specific data will be gathered.

It is noted that a projection of future oil and gas activities and the relationship to future land uses will also be required. It will be necessary to establish who will be responsible and the process by which these projections will be developed. This will be determined through consultation between the study team (e.g., Project Manager, GIS lead and air quality lead) and staff at the OGC and Ministry of Energy, Mines and Natural Gas.

Initially, to complete the Screening Level Risk Assessment, the team will require data representing:

- The density of current oil and gas activities overlaying the four regional shale plays. This may include information related to: (i) wells per hundred square kilometers and the distribution of wells by type of fluid produced; and, (ii) pipelines per hundred square kilometers and the distribution by pipes by size and fluid transported
- Characterization of emissions and representative emission volumes (annual and monthly) for individual plants, batteries and associated processing facilities
- Population density by community
Characterization of traditional land uses and estimated seasonal population densities. Table 4-2 summarizes the anticipated data requirements necessary to complete the SLRA and the more detailed data that will be required to complete the HHRA. The table also shows where this data resides and who will be responsible for providing the data.
<table>
<thead>
<tr>
<th>Data Required</th>
<th>Description</th>
<th>Source</th>
<th>Already Acquired?</th>
<th>Required for:</th>
<th>Responsibility</th>
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<tr>
<td>Well data</td>
<td>Fluid composition</td>
<td>National Hydro Network</td>
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<td>Study team</td>
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<td>Pipeline Data</td>
<td>Fluid transported, length, diameter, pressure</td>
<td>EGIS</td>
<td>Yes</td>
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<td>Facilities</td>
<td>Gas plants, batteries, compressors, pump stations, etc.</td>
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<td>SLRA</td>
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<td>Boundary Maps</td>
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<td>Study team</td>
</tr>
<tr>
<td>Population statistics</td>
<td>Number of people by community</td>
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<td>Yes</td>
<td>SLRA</td>
<td>Study team</td>
</tr>
<tr>
<td>General Characterization of Major Emission Sources / Release Rates &amp; Hours / Volume</td>
<td>Major facilities: monthly 7 annual Compressors, dehydrators, etc.: average values</td>
<td>Government</td>
<td>No</td>
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<td>BC Environment</td>
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<td>Government</td>
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<td>SLRA</td>
<td>OGC</td>
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<td>Stats Canada</td>
<td>No</td>
<td>HHRA</td>
<td>Study team</td>
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<td>To be determined</td>
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<td>Boundary Maps</td>
<td>Land-use, Municipal, trap lines, etc.</td>
<td>Government</td>
<td>No</td>
<td>HHRA</td>
<td>To be determined</td>
</tr>
<tr>
<td>Receptor Locations</td>
<td>Individual surface developments, monitoring stations, etc.</td>
<td>To be determined</td>
<td>No</td>
<td>HHRA</td>
<td>To be determined</td>
</tr>
<tr>
<td>Topography</td>
<td>High resolution</td>
<td>To be determined</td>
<td>No</td>
<td>HHRA</td>
<td>To be determined</td>
</tr>
<tr>
<td>Detailed Characterization of Selected Emission Sources</td>
<td>Site-specific source characterizations: e.g., plant capacity, recover efficiency, stack heights and geographic locations, products released and release rate profiles</td>
<td>Government</td>
<td>No</td>
<td>HHRA</td>
<td>BC Environment</td>
</tr>
</tbody>
</table>
5.0 CHEMICALS OF CONCERN AND RELEVANT EXPOSURE PATHWAYS

This section provides a summary of the potential chemicals of concern related to oil and gas activity in NE BC. It also introduces the possible exposure pathways that will be considered in the Phase 2 HHRA.

5.1 Identification of Chemicals of Concern

Given the nature of the potential emission sources, the process of identifying COCs for consideration in the Phase 2 HHRA is divided into three categories: (i) COCs in air; (ii) COCs in groundwater; and, (iii) COCs in surface water.

For the purposes of the Phase 2 Direction Document, a summary of known sources of information has been conducted, with the aim of identifying potential COCs associated with the various oil and gas activities described in Section 3. At this stage of the Phase 2 HHRA, the selection of the potential COCs relied on broad categories of chemicals that are generally related to emissions from the types of oil and gas sources found in NE BC.

It is important to note that the results of the Jurisdictional Scan and the Screening Level Risk Assessment components of the Phase 2 HHRA will further inform and focus the list of COCs for ultimate inclusion in the quantitative HHRA component.

5.1.1 Chemicals of Concern in Air

A number of documents have been reviewed to aid in the identification of airborne COCs associated with oil and gas activity in NE BC. Table 5-1 presents an overview of COCs in relation to the types of oil and gas activities that are known to occur in the region. As mentioned, this list is preliminary, and will be further developed with input from the Jurisdictional Scan and Screening Level Risk Assessment.

Table 5–1 Potential Chemicals of Concern in Air

<table>
<thead>
<tr>
<th>Emission Source</th>
<th>Potential COCs for Consideration in Phase 2 HHRA</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas release to surface</td>
<td>Methane, Hydrogen sulphide (if sour), Reduced sulphur compounds</td>
<td>Clearstone Engineering Ltd. 2004a,b,c,d</td>
</tr>
<tr>
<td>Produced oil and gas</td>
<td>CO₂</td>
<td>Clearstone Engineering Ltd. 2004a</td>
</tr>
<tr>
<td></td>
<td>Volatile Organic Compounds (VOCs) (including but not limited to benzene, toluene, ethylbenzene and xylenes),</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PAHs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aldehydes (e.g., 1,3-butadiene, acrolein)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aliphatic and Aromatic Hydrocarbons</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Metals</td>
<td></td>
</tr>
<tr>
<td>Natural Gas Processing</td>
<td>SO₂</td>
<td>US EPA 1995</td>
</tr>
<tr>
<td>Emission Source</td>
<td>Potential COCs for Consideration in Phase 2 HHRA</td>
<td>Reference</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>(including compressors, glycol dehydrators, acid gas waste and other sources)</td>
<td>H₂S&lt;br&gt;Aliphatic and Aromatic Hydrocarbons&lt;br&gt;VOCs</td>
<td>Clearstone Engineering Ltd. 2004b,c,d</td>
</tr>
<tr>
<td>Fugitive emissions</td>
<td>H₂S&lt;br&gt;VOCs</td>
<td>Clearstone Engineering Ltd. 2004b,c,d</td>
</tr>
<tr>
<td>Flared solution gas (sweet)²</td>
<td>Criteria Air Contaminants (SO₂, CO, NOx, PM)&lt;br&gt;VOCs&lt;br&gt;Aldehydes&lt;br&gt;PAHs&lt;br&gt;Phenols&lt;br&gt;Acids</td>
<td>Clearstone Engineering Ltd. 2004b,c,d; Strosher 1996, 2000</td>
</tr>
<tr>
<td>Flared solution gas (sour)²</td>
<td>Criteria Air Contaminants (SO₂, CO, NOx, PM)&lt;br&gt;Thiophenes&lt;br&gt;Carbon disulphide (CS₂)&lt;br&gt;Carbonyl sulphide (COS)&lt;br&gt;H₂S&lt;br&gt;Other sulphur containing compounds&lt;br&gt;Aromatic and Aliphatic hydrocarbons&lt;br&gt;Aldehydes&lt;br&gt;VOCs (including but not limited to BTEX and biphenyl)&lt;br&gt;PAHs&lt;br&gt;Phenols&lt;br&gt;Acids</td>
<td>Clearstone Engineering Ltd. 2004b,c,d</td>
</tr>
<tr>
<td>Vented gas</td>
<td>Greenhouse gases (primarily methane, with some CO₂, NOx)&lt;br&gt;Hydrogen sulphide (if sour source)</td>
<td>Johnson and Corderre 2011, Clearstone Engineering Ltd. 2004a,b,c,d</td>
</tr>
<tr>
<td>Sulphur recovery units</td>
<td>H₂S</td>
<td>Clearstone Engineering Ltd. 2004b,c,d</td>
</tr>
<tr>
<td>Sulphur blocking</td>
<td>H₂S</td>
<td>Clearstone Engineering Ltd. 2004b,c,d</td>
</tr>
<tr>
<td>Storage losses</td>
<td>Greenhouse gases (primarily methane, with some CO₂, NOx)&lt;br&gt;H₂S&lt;br&gt;VOCs</td>
<td>Clearstone Engineering Ltd. 2004a,b,c,d</td>
</tr>
<tr>
<td>Accidents and malfunctions (excludes flares)</td>
<td>Greenhouse gases (primarily methane, with some CO₂, NOx)&lt;br&gt;H₂S&lt;br&gt;VOCs</td>
<td>Clearstone Engineering Ltd. 2004a,b,c,d</td>
</tr>
<tr>
<td>Loading and unloading losses</td>
<td>Greenhouse gases (CO₂, methane)</td>
<td>Clearstone Engineering Ltd. 2004a</td>
</tr>
<tr>
<td>Off-gassing and Degassing</td>
<td>H₂S (if sour source)</td>
<td>Clearstone Engineering Ltd. 2004b,c,d</td>
</tr>
</tbody>
</table>

¹Clearstone 2004d notes that emission profiles vary for dry gas, sweet gas, sour gas, and conventional oil.

²The composition of emissions from flares can vary depending on the composition of the fuel source, liquid content, flare design, waste gas composition and atmospheric emissions at the time of release (Strosher 1996, Strosher 2000). The list provided in this table is generic based on field studies.
5.1.2 Chemicals of Concern in Surface Water and Groundwater

It is possible that accidental releases to surface water or groundwater may occur in the region in association with oil and gas activity in the region. For example, hydraulic fracturing is a potential source of water releases in the region, above or below surface. Table 5-2 presents a list of potential COCs for consideration in the Screening Level Risk Assessment. This does not represent a full listing, but is intended to serve as a starting point for the Phase 2 HHRA.

Table 5–2 Potential Chemicals of Concern in Surface Water and Groundwater

<table>
<thead>
<tr>
<th>Emission Source</th>
<th>Potential COCs for Consideration in Phase 2 HHRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic Fracturing</td>
<td>Functional classes such as:</td>
</tr>
<tr>
<td></td>
<td>• Acids</td>
</tr>
<tr>
<td></td>
<td>• Brine salts</td>
</tr>
<tr>
<td></td>
<td>• Gelling agents</td>
</tr>
<tr>
<td></td>
<td>• Surfactants</td>
</tr>
<tr>
<td></td>
<td>• Friction reducers</td>
</tr>
<tr>
<td>Operating and Legacy Sites</td>
<td>• Sodium chloride brines</td>
</tr>
<tr>
<td></td>
<td>• Petroleum hydrocarbons</td>
</tr>
<tr>
<td></td>
<td>• Metals</td>
</tr>
<tr>
<td></td>
<td>• Solvents</td>
</tr>
<tr>
<td></td>
<td>• Other inorganics</td>
</tr>
</tbody>
</table>

5.2 Potential Exposure Pathways

As described, there is some potential for COCs to be emitted to air and to water (surface water or groundwater) given the nature of the oil and gas activities in the region. As a result, there are a number of potential pathways by which people in NE BC could be exposed to the COCs. These are discussed separately with respect to the COCs released to air and COCs released to water.

5.2.1 Potential Exposure Pathways Related to Air Emissions

For COCs emitted to air, consideration should be given not only to the direct inhalation pathway, but also to secondary routes of exposure related to the aerial deposition of COCs from air to other environmental media, such as soil, vegetation and water. For example, a list of potential exposure pathways in relation to airborne COCs might include:

- Inhalation of air;
- Inhalation of dust;
- Dermal (skin) contact with soil impacted by aerial deposition;
- Accidental ingestion of impacted soil;
- Dermal (skin) contact with surface water;
• Ingestion of local country and traditional foods (game, fish, plants);

Figure 5-1 provides a visual description of the relationship between these potential exposure pathways and people who reside in the area.

Further consideration will be given to the exact exposure pathways to include in the quantitative HHRA, following the completion of the Jurisdictional Scan and the Screening Level Risk Assessment.
Figure 5-1  Potential Exposure Pathways of Interest for Airborne Chemicals of Concern
5.2.2 Potential Exposure Pathways Related to Water Releases

Emissions from legacy and operating sites can result in the percolation of chemicals into the subsurface, flowing downward through the unsaturated zone, to the water table. Once chemicals enter the zone of groundwater, these compounds can be transported as dissolved constituents in groundwater, as free product (in the case of immiscible organic compounds) or as gaseous substances and can migrate offsite towards receptors or surface water bodies (Figure 5-2). In addition, some releases may directly impact surface water. For hydraulic fracturing, there is potential for chemicals of concern to enter potable aquifers as a result of accidental fracturing upward through confining units or through a well bore failure that allows the movement of chemicals up from a deeper zone via transport along the outside of the well casing.

A list of potential exposure pathways related to the release of COCs to surface water or groundwater includes:

- Dermal contact with surface water while swimming
- Ingestion of surface water as a drinking water source or while swimming
- Dermal contact with groundwater (if groundwater is used as a drinking water source)
- Ingestion of groundwater (if groundwater is used as a drinking water source)
- Ingestion of fish from local surface water bodies
- Ingestion of wild game animals and birds that might be exposed to local surface water bodies
- Dermal contact with soil in contact with impacted water
- Accidental ingestion of soil in contact with impacted water.

As it is possible that some of the COCs may have physical-chemical properties that could have them volatilize from water, inhalation exposure could also be an indirect pathway of exposure to COCs in water. For example, people may be exposed through:

- Inhalation of volatile COCs from impacted water (e.g., from accidental releases from storage tanks or pits);
- Inhalation of volatile COCs from soil impacted by water (e.g., from contaminated groundwater or an above-ground spill).

Figure 5-2 provides a summary of the relationships between some of the exposure pathways and the area residents. Further consideration will be given to what exact exposure pathways to include in the quantitative HHRA, following the completion of the Jurisdictional Scan (Section 6.0) and the Screening Level Risk Assessment (Section 7.0).
**Figure 5-2**  Conceptual Model of Generic Water-Related Pathways
6.0 JURISDICTIONAL SCAN

A comprehensive information search is currently underway to identify available reports that focus on health issues and concerns in people who live in proximity to oil and gas activities. This search will include a search of the ‘grey’ literature available from various jurisdictions, and the peer-reviewed scientific database. Examples of resources that will be consulted include (but are not limited to):

- Northern Health. 2007. Population Health and Oil and Gas Activities: A Preliminary Assessment of the Situation in North Eastern BC, A Report from the Medical Health Officer to the Board of Northern Health.


A specialist/medical librarian will design a systematic search approach according to the Cochrane Guidelines for conducting systematic reviews for retrieval of the peer-reviewed literature. The rapid review will be modelled after the Cochrane Handbook for Systematic Reviews of Interventions (Cochrane Collaboration, 2008). Cochrane reviews adhere to the principle that “science is cumulative” and by considering the available evidence, decisions can be made that reflect the best science available. Rapid screening of the bibliographic database results will be undertaken to identify pertinent health outcome literature. The study team will concurrently retrieve relevant jurisdiction reports on health concerns related to living in close proximity to oil and gas activities.

The results of this review will help focus the risk assessment on those issues that have been identified of greatest potential concern for public health from exposure to relevant oil and gas activities. The reports and peer-reviewed scientific literature will be reviewed by the Intrinsik toxicologists and risk assessors and the study team physician and epidemiologist. A brief report summarizing the findings of the review will be prepared for review by the Intrinsik Advisory Panel and MoH. Ultimately, the findings of this review will help to identify relevant COCs from various upstream oil and gas scenarios and potential health outcomes that need to be taken into consideration in the future steps of the HHRA.

The study team will use the findings of the jurisdictional scan and information search to steer the detailed information retrieval process for the Screening Level Risk Assessment and ultimately the Phase 2 HHRA. The exact types of information/data needed as input for the HHRA will be determined in the first quarter of 2013. The study team will communicate directly with the Provincial agencies or relevant industry associations (e.g., CAPP) in order to facilitate the retrieval of the necessary information.

The jurisdictional scan was started in December 2012, and a final report is proposed to be delivered in March 2013.

7.0 SCREENING LEVEL RISK ASSESSMENT

For this undertaking, all of the gathered information (described in Sections 2 to 6) will be combined to provide a conceptual model of issues surrounding oil and gas activity in NE BC. At this point the oil and
gas activities – historical, current and reasonably predicted to occur in the future – will have been characterized. The chemical emissions to air, water and land will have been identified and human receptors and surrounding land use patterns in the area will have to be categorized (e.g., subsistence First Nations, rural, urban, and those who hunt and fish). Routine and upset conditions will both be considered.

The study team will develop a screening level risk matrix for the different exposure scenarios that may be related to oil and gas activity. Although this risk matrix will be developed on the basis of previously published frameworks, a framework specific to this undertaking will be established.

Prior to screening the various oil and gas activities for relative significance ranking, qualitative definitions of likelihood and magnitude of risk outcome will be established. It is then envisioned that a matrix scoring will be employed, whereby each of the oil and gas activities and their related emissions to the environment will be assessed for exposure to each of the identified receptor categories.

The screening level risk matrices will ultimately provide a potential magnitude of potential health risk to receptor categories on the basis of activity. However, there are two other considerations that need to be accounted for at this stage – significance of the risk and availability of environmental data to complete a quantitative risk assessment.

Hence, each scenario will undergo a significance ranking. The study team plans to employ significance scoring criteria often used in Environmental Assessments undertaken for applications for the BC Environmental Assessment Office (EAO) and the Canadian Environmental Assessment Agency (CEAA). Events and risks are often categorized as significant or insignificant on the basis of: magnitude, frequency, duration, reversibility, and geographic area potentially impacted. Therefore, each activity scored in the screening level risk matrix will also be assigned a significance score.

Finally, an assessment of the availability of environmental data to conduct a quantitative human health risk assessment for each oil and gas activity will be made. It is possible that an activity that receives a “high” risk and “significant” score may not have sufficient environmental data to be assessed quantitatively in the Phase 2 HHRA. In this case, the study team will have arrived at a qualitative assessment of potential risk to those people living in proximity to a particular oil and gas activity in NE BC. Further recommendations for need to collect environmental data and recommendations for monitoring of human health will be provided in a later report.

The results of the SLRA will form the basis on which scenarios will be evaluated quantitatively under the comprehensive HHRA. A draft of the Screening Level Risk Assessment is scheduled to be completed in April 2013.

8.0 QUANTITATIVE HUMAN HEALTH RISK ASSESSMENT

The scope of the detailed or quantitative human health risk assessment (HHRA) will be determined following the completion of the SLRA. The HHRA will follow the standard risk assessment paradigm, which includes a problem formulation, exposure assessment, hazard assessment and risk characterization.
It would be impossible to conduct an absolutely comprehensive quantitative risk assessment of all oil and gas activities, their chemical emissions and resulting risks to people living in such a large geographic area given the budgetary and time constraints. That is not to say that the study team believes that such an undertaking is without merit. In fact, we believe there are a number of generic oil and gas activity scenarios that exist that could be modelled to provide an estimation of potential risk surrounding their operation. This is an approach that has been adopted previously across Canada for a number of industries (e.g., waste-to-energy facilities and natural gas-fired plants) in an attempt to identify those areas that require individual facility assessment or development of comprehensive monitoring or mitigation programs to ensure the ongoing protection of individuals’ health. In addition, it is critical to remember that very valuable qualitative information on activities that could pose an adverse health threat will be identified through the completion of the SLRA.

The types of sources and scenarios that will ultimately get selected will depend on the outcome of the SLRA. Examples of scenarios that could be included are a well blow out, pipeline rupture, hydraulic fracturing, routine flaring and continuous emissions from regular operations, among others. The exposure scenarios may involve air releases of contaminants in the environment, ground-level air concentrations being predicted, potential deposition in soil, and uptake into edible vegetation and wild game/livestock, where appropriate. Human receptor scenarios involving urban, rural and First Nations land use activity patterns may be assessed. Quantification of potential health risk using readily-available chemical-specific toxicology data from recognized regulatory agencies will be completed. It is also possible that if there is enough existing regional airshed data that a quantitative baseline inhalation assessment may be undertaken.

The detailed HHRA is scheduled to be completed in late fall 2013.

9.0 REVIEW OF BRITISH COLUMBIA STATUTORY AND POLICY FRAMEWORKS

Upon completion of the HHRA, Phase 2 of the MoH project requires a review of existing BC statutory, regulatory and policy frameworks that ensure the protection of the health of the population living in proximity to oil and gas activities. Members of the study team will retrieve and provide information related to applicable statutes, legislation and policy frameworks relevant to the oil and gas activities in northeastern BC. For example, the study team will:

- Identify where current statutes, regulations, and policies are sufficient or exceed the necessary level for managing human health risk;
- Identify gaps where statutes, regulations and policies do not currently exist for managing human health risk; and
- Identify where current statutes, regulations and policies may benefit from a change to enable improved management of human health risks with respect to oil and gas activities.

All interpretation or identification of potential science-policy improvements will be made by the study team’s scientific leads.
This task requires experienced environmental professionals that are experts in their fields and have previously contributed to developing science policy for provincial and federal government departments. Intrinsik has specialized in conducting science policy reviews and providing recommendations to protect people from environmental chemical exposure. These recommendations will be in the form of science policy and would not be a line-by-line edit or rewrite of current legislation or policy. Development of such legislative language would need to be undertaken by ministry legal staff or other such legal counsel and departmental representatives.

This review is scheduled to be completed by late 2013.

10.0 PROJECT RECOMMENDATIONS

The final report to be prepared by the study team under Phase 2 of this project will provide recommendations on spatial monitoring programs that could improve efforts to monitor and manage health risks to the people of northeastern BC. Again without presupposing the outcomes of the various tasks to be completed in Phase 2, it is envisioned that there may be recommendations surrounding air quality, water resource and even human health monitoring that could be provided to ensure the ongoing protection of the health of residents in Local Health Areas 59, 60 and 81.

This task may provide additional recommendations or protocols to be employed to assess the potential for future human health impacts in northeastern BC as a result of historical, continued or future oil and gas activities. These recommendations might include:

- Recommendation on spatial monitoring programs that could improve efforts to monitor and manage human health risk;
- Recommendations related to air quality, water quality, and human health monitoring to ensure ongoing protection of public health;
- Recommendations or protocols to be employed to assess the potential for future human health risks resulting from historical, continued or future oil and gas activities.

The formulation of recommendations is scheduled to be completed by March 2014.
11.0 REFERENCES


Northern Health 2007. Population Health and Oil and Gas Activities: A Preliminary Assessment of the Situation in North Eastern BC. A Report from the Medical Health Officer to the Board of Northern Health.


