PUBLIC PERCEPTIONS ON FRESH WATER USE FOR HYDRAULIC FRACTURING OF THE DUVERNAY SHALE GAS FORMATION, KAYBOB AREA, ALBERTA

By

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of the requirements for the degree of

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We accept this thesis as conforming to the required standard

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Abstract

The thesis research examined localized socio-environmental perceptions related to amplified fresh water requirements for hydraulic fracturing and subsequent flowback disposal activities. These requirements are associated with increasing shale gas development in the Duvernay formation, located within the Kaybob region of West-central Alberta, Canada. Fresh water refers to surface and groundwater with a total dissolved solids concentration of less than 4,000 ppm. Through recourse to a mixed methods approach, combined with triangulation as a method of further validation, the research demonstrates that there exists a public sensitivity related to fresh water use in the Kaybob region. This sensitivity arises from increasing development activities in the Duvernay shale gas formation. The thesis presents conclusions and recommendations whereby industry may address stakeholder concerns, and provides advice for future research.

Keywords: shale gas, hydraulic fracturing, fresh water, public perceptions, triangulation, mixed methods.

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Public Perceptions on Fresh Water Use in Shale Gas Hydraulic Fracturing

Public demand for more transparent and responsible fresh water management during shale gas development in North America has created a need for technical and social research on benefits and barriers regarding fresh water access, use, and hydraulic fracturing flowback disposal. In light of previous and ongoing stakeholder feedback in similar circumstances, such as the Barnett shale in the southern United States (Theodori, 2009; Theodori, 2012), and the Maritimes basin in New Brunswick (Corporate Research Associates, 2012), one may anticipate similar public interest related to ongoing and increasing shale gas development in Western Canada. In particular, water sourcing, use, and flowback disposal leading to possible groundwater contamination are primary foci of stakeholder interest in North American shale gas development (National Public Relations Inc., 2011). These are matters central to investigations undertaken for this thesis.

A 2011 public opinion poll on oil and gas development in Canada identified that the majority of respondents, 75%, would support more national oil and gas development as long as "environmental impacts were manageable and being reduced" (National Public Relations Inc., 2011). Only 18% of respondents were pro-development on the basis that the economic benefits were significant. In the same poll, respondents showed a strong preference for corporate transparency and accountability (66%) rather than stricter government regulations and penalties (29%) (National Public Relations Inc., 2011). This poll demonstrates that, while the Canadian public is not opposed to continued and increasing oil and gas development, there is a strong sentiment that industry needs to ensure environmental impacts are mitigated.

Shale gas development in regions with a history of oil and gas activity (mature shale gas plays) may display public perceptions that differ from regions where historical oil and gas development is minimal (new shale gas plays). In 2012, Deloitte conducted an online survey of 1,694 individuals in the United States, including samples from the general population, three mature shale gas plays (Texas, Louisiana and Arkansas) and two new shale gas plays (New York and Pennsylvania). According to the survey, 62% of residents in mature shales agree that the "[economic] benefits of shale gas development far outweigh the risks" or "…somewhat outweigh the [economic] risks" whereas 53% of respondents residing in proximity to the new shale gas plays provide the same response (Deloitte, 2012). Conversely, 21% of residents within a mature shale play responded that the "risks far outweigh the benefits" or "…somewhat outweigh the benefits", while 23% of residents within a new shale gas play agreed with this statement (Deloitte, 2012). The results of this research demonstrate that there is a slightly greater negative perception of shale gas development in the new shale gas plays compared with the mature shale gas plays. A limitation of this survey is that it focused only on economic benefits and risks and did not assess socio-environmental perceptions of increasing shale gas development.

Duvernay Shale

Improved economic feasibility of shale gas resource development has generated interest in the oil and gas industry in Alberta's significant shale gas formations. A preliminary study conducted by the Gas Technology Institute in 2004 stated that the Duvernay formation is a "…rich source rock for oils in the WCSB [Western Canadian Sedimentary Basin] and has great potential as a gas shale" (p. 2) Record-breaking land sales were recorded in the Duvernay, a shale formation within the WCSB, in 2011 demonstrates industry commitment to development

of the shale gas play ("Top 10: Drilling", 2011). Estimates published in 2012 that anticipate reserves of up to 477 trillion cubic feet (tcf) of natural gas and 19 billion barrels of oil have drawn major oil and gas companies such as Shell, Chevron, Trilogy and Yoho Resources to the region (Dunn, L., et al., 2012). From this evidence, one may anticipate high levels of development and production in the Duvernay play in the future. As conventional resources such as crude oil are depleted, focus grows on the increasingly economic unconventional resources, including shale gas. Increasing activity in the Duvernay shale gas play can be expected to increase socio-environmental perspectives expressed by residents in proximity to development.

Research Questions

Based upon the imminent and long-term development potential of the Alberta Duvernay shale, the following research questions are proposed:

1. What are the socio-environmental perspectives expressed by residents of the Kaybob region arising from fresh water sourcing, use and hydraulic fracturing flowback disposal in relation to increased development of the Duvernay shale gas play?
2. What interpretations can be made regarding these perspectives as development of the Duvernay shale gas play increases?

Research Study Area

An appropriate study area was required in which to conduct the research. Given that the study area needed to be within the boundaries of the Duvernay shale gas play, a more specific research location was chosen based upon this certainty together with information retrieved from public land sale information (Low, 2010). Based on this information, the Kaybob region of

West-central Alberta was identified as an appropriate location in which to conduct the research. Municipalities within the Kaybob Duvernay area were identified where fresh water use as part of shale gas development may affect residents from either social or environmental perspectives.

Fox Creek and Whitecourt, Alberta provide services and personnel to the oil and gas industry in the Kaybob region of the Duvernay shale gas play. These municipalities are within an area of moderate agricultural development and are centers of rural population settlement. Both municipalities are in proximity to existing and expected Duvernay shale gas development operations (Low, 2010). It is expected that both of these municipalities will be affected by development of the Duvernay shale gas play.

A significant increase in well licenses issued for development of the Duvernay shale confirms the potential of the formation. In 2011, there were 43 licenses issued, whereas in 2012, the number of licensed wells increased 133% to 100 (Dittrick, 2012). By the end of 2012, 80% of the wells drilled in to the Duvernay formation occurred in the Kaybob region (Dittrick, 2012). This growth confirms that the study location is appropriate for the scope and purpose of the research.

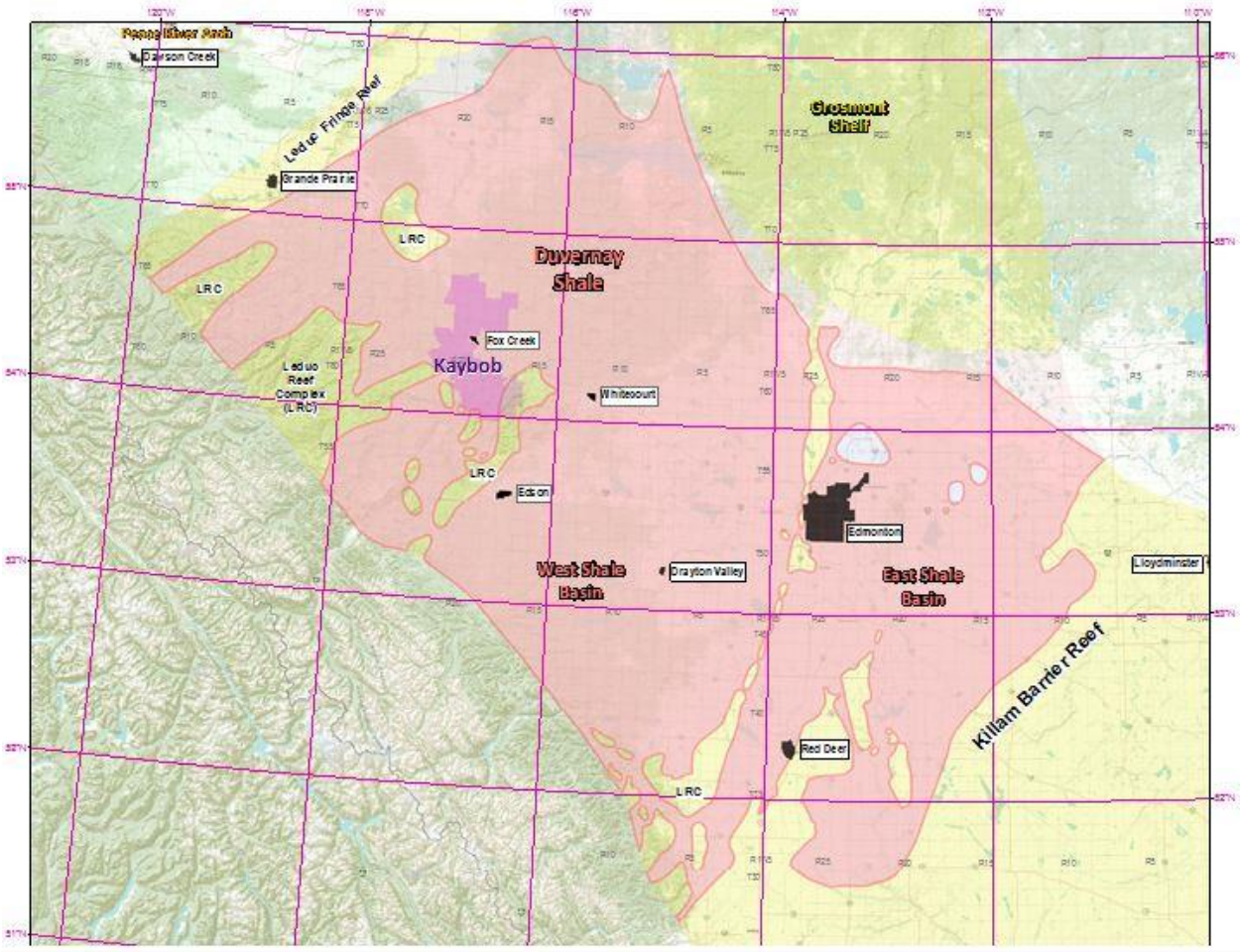


Figure 1: Map of the Duvernay Shale formation in relation to the Kaybob region of West central Alberta, Canada. Copyright 2013 by Divestco. Permission for use and publication obtained.

Fox Creek, Alberta. Fox Creek, Alberta is located 240 kilometers northeast of Edmonton, Alberta (Alberta First, 2012a). The 2011 federal census identifies the total number of residents to be 1,969 with a decrease in population of 13.6% since the 2006 census (Statistics Canada, 2012a). The primary industry is oil and gas, with approximately 75% of residents identifying oil and gas companies as their employer (Alberta First, 2012a). The median age for Fox Creek is 33.8, with a higher percentage of male residents to female (1,085 males; 885 females) (Statistics Canada, 2012a). Approximately 81% of Fox Creek residents have completed some form of secondary education (Alberta First, 2012a).

Whitecourt, Alberta. Whitecourt, Alberta is located 177 kilometers northeast of Edmonton, Alberta at the junction of highways 43 and 32 (Alberta First, 2013b). The town is substantially larger then Fox Creek with a 2011 census population of 9,605, a 7.1% increase from the 2006 population of 8,971 (Statistics Canada, 2012b). The town is primarily supported by the forestry industry (Alberta First, 2012b). In recent years, increasing oil and gas development has affected the community through increased tax based revenue and related operations contributing to the continued growth of the community (Alberta First, 2012b). The median age in Whitecourt is 31.9 years old with slightly more male residents then female (4,990 male; 4,615 female) (Statistics Canada, 2012b). Approximately 76% of Whitecourt residents have completed some form of secondary education (Alberta First, 2012b).

Shale Gas Development Overview

Shale gas is defined by the Canadian Association of Petroleum Producers (CAPP) as a "natural gas found in very fine-grained sedimentary rock" and is often referred to in the oil and

gas industry as “tight gas” (Canadian Association of Petroleum Producers [CAPP], 2009). Natural gas is trapped within the very small pores of the rock and various technologies, including hydraulic fracturing, are used to create fissures in the rock that allow the gas to flow (CAPP, 2009). Hydraulic fracturing was developed in the 1940’s and has been in use in North America in a variety of oil and gas formations to increase well production (Canadian Society for Unconventional Gas [CSUG], 2011). In recent years, advances in chemical technologies and high pressure fracturing techniques have allowed for the development of tight gas formations, such as the Duvernay shale (CSUG, 2011).

The Duvernay formation lies between 2,800 and 3,600 meters below the surface of the Earth (Dunn, L., et al., 2012). A combination of long vertical and horizontal well bore lengths as well as multi-stage shale fracturing requirements increase the water needs for hydraulic fracturing operations. Typical shale gas wells require between 3,500 m^3 and 25,000 m^3 of water per well bore for hydraulic fracturing operations, which is performed prior to production of the well and usually occurs over five to fifteen days (CSUG, 2011). In Alberta, approximately nine million cubic meters of fresh surface and ground water was permitted for use in shale gas hydraulic fracturing operations in 2012 (Government of Alberta, 2013). The Government of Alberta defines *fresh water* as water where the total dissolved solids is below 4,000 ppm (Government of Alberta, 2013).

The use of a variety of chemicals, including friction reducers, biocides, acids and surfactants, allow the transportation of propants (natural or synthetic sands) into the formation fractures without compromising the short or long-term viability of the shale (CSUG, 2011). Once the formation is completely fractured, the fluids are allowed to flow back to surface for disposal.

Hydraulic fracturing flowback fluids, referred to in industry as *frac flowback*, are comprised of the original hydraulic fracturing fluid together with salts and hydrocarbons from the formation (CSUG, 2011). In some cases the fluid is recycled for reuse in future hydraulic fracturing process while the remaining fluid is disposed of via deep well disposal (CSUG, 2011). During the life of the well, smaller volumes of water, called *produced water*, are also captured and disposed of using the same disposal method.

The following chapter will outline the research methodologies chosen to conduct the research and discuss the rationale for each method selected.

Research Methodology

Mixed Methods Approach

The use of mixed methods in research design is applied as a means to engage the strengths of both quantitative and qualitative research paradigms to provide robust research validation and conclusions (Johnson & Onwuegbuzie, 2004; Leech & Onwuegbuzie, 2009). Johnson and Onwuegbuzie (2004) define mixed methods research as "…the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study" (pp. 17-18). According to Leech and Onwuegbuzie's 2009 paper '*A Typology of Mixed Methods Research Designs*', mixed method research designs "…have been utilized to answer questions that could not be answered by one paradigm alone" (p. 266). The mixed methods approach was deemed an effective means to address the research undertaken for this thesis. The researcher believes that the pursuit of mixed methods research design, consisting of a qualitative literature review and semi-structured group interviews, along with a quantitative survey, will increase the validity and strength of the collected data and subsequent data analysis.

In their paper entitled *Mixed Methods Research: A Research Paradigm Whose Time has Come* Johnson and Onwuegbuzie quote Greene et al. (1989) as identifying five purposes for conducting mixed methods research. These purposes are labeled triangulation (corroboration of results from various sources); complimentary (elaboration, enhancement or clarification of the results of one method via the results of the other method); initiation (identifying contradictions that help re-frame the research questions); development (using the results of one method to inform the other); and expansion (expanding the scope of the research by using different

methods). The thesis research has incorporated triangulation in to the overall research design to corroborate the research results.

Dr. Alan Bryman, Professor of Social Research at Loughborough University, defines triangulation as "… the use of more than one approach to the investigation of a research question in order to enhance confidence in the ensuing findings" (Bryman, n.d.). The use of triangulation in mixed methods research allows the researcher to "build upon the synergy and strength that exists between quantitative and qualitative methods to more fully understand a given phenomenon…" (Bartosh, 2012). Webb et al. (1966), as quoted by Bryman, state, "Once a proposition has been confirmed by two or more independent measurement processes, the uncertainty of its interpretation is greatly reduced. The most persuasive evidence comes through a triangulation of measurement processes" (p. 1). These observations suggest that the use of triangulation as part of the mixed methods research design is an approach that will provide additional data verification and robust conclusions and recommendations.

Determination of the degree and order of the qualitative and quantitative data collection and analysis depends upon the researcher's objectives and expected outcomes (Johnson & Onwuegbuzie, 2004). Johnson and Onwuegbuzie propose nine mixed-method research designs, as shown in Figure 2.

		Time Order Decision	
		Concurrent	Sequential
Paradigm Emphasis Decision	Equal Status	QUAL + QUAN	QUAL > QUAN QUAN > QUAL
	Dominant Status	QUAL + quan QUAN + qual	**QUAL > quan** qual > QUAN QUAN > qual quan > QUAL

Figure 2. Johnson and Onwuegbuzie's nine mixed-method research designs and associated paradigm and time order decision basis. From "Mixed Methods Research: A Paradigm Whose Time has Come" by Johnson and Onwuegbuzie. 2004, Educational Researcher, Volume 33(7), p. 22. Copyright 2004 by Sage Publications.

For the purposes of this thesis research, a dominant-sequential design was implemented, with a primary focus on the qualitative stream via literature review and interviews, and a secondary focus on the qualitative data via an online survey, as highlighted in Figure 2. The results of the literature review and interviews (qualitative data set) were used to inform the contents of the online survey (quantitative data set). The results of all data collection methods have been used to frame the research conclusions, while incorporation of triangulation has further corroborated the research results.

Literature Review Methodology

A structured literature review was conducted to identify existing research regarding public perceptions of other shale gas developments in North America. Using Google Scholar, a broad preliminary search was conducted using the search terms "shale gas" and "public perception" with the additional condition that results are "peer reviewed journal articles". This search returned over 14,000 results. The third and seventh articles returned related to public

perceptions on shale gas development in the Marcellus and Barnett shales of Texas. These articles were explored further and using the subject article reference lists, multiple similar articles were identified for inclusion in the literature review.

A second Google Scholar search was conducted to identify similar research within Canada. The researcher had previous knowledge of public interest in shale gas development in New Brunswick, therefore the search terms "New Brunswick", "shale gas" and "public perceptions" were used. The search returned 1,840 results. The first result was directly applicable to the research and the article references were again used to discover additional applicable research for inclusion in the literature review.

Ultimately, the two focus locations, Texas and New Brunswick, were selected based upon availability of data related to public perceptions regarding fresh water use in shale gas development and their direct relevance to the thesis research. Both locations are experiencing an increase of industry interest and activity related to shale gas development, and both identify fresh water use as being important to residents in the area. The public perception research results undertaken in Texas and New Brunswick were used to inform the creation of the semi-structured interview questions.

Interview Methodology

The pursuit of interviews as an aspect of research in public perceptions is employed to gain insight about opinions held by the populations within a specific geographical area. Pierce (2008) defines the semi-structured interview as a "question and discussion" session, where the interviewer prepares a list of open-ended questions that allow for discussion and structured follow-up questions. A semi-structured interview is a valuable technique when the researcher

already has a good understanding of the topic (Leech, 2002). This allows the researcher to explore undiscovered ideas or topics without becoming overwhelmed, while seeking to maintain a focused path through the pre-determined questions (Leech, 2002).

Information collected during the literature review was used as a framework from which to prepare a list of key questions related to fresh water use in hydraulic fracturing specific to the thesis study area. The final interview guide consisted of four control questions, eight open-ended questions and two pre-identified follow up questions, as shown in Appendix D. Questions were ordered in a manner consistent with recommendations found within Leech's 2002 paper *Asking Questions: Techniques for Semistructured Interviews*, wherein he states that question order should begin with the most "non-threatening" question and move towards more difficult or contentious questions (p. 666).

The concept of theoretical saturation was explored to demonstrate the validity of interviews. Theoretical saturation "is the point at which no new insights are obtained, no new themes are identified, and no issues arise regarding a category of data" (Strauss and Corbin, 1990, p. 58). Guest, Bunce and Johnson (2006) undertook a comprehensive study to identify and define the concept of "theoretical saturation" as it relates to the number of interviews required to meet this requirement in social research. The authors draw on Morse's textbook *Handbook for Qualitative Research* (1995) to observe that "saturation is the key to excellent qualitative work" (p. 60). They note, however, that there are "no published guidelines or tests of adequacy for estimating the sample size required to reach saturation" (p. 60).

Guest, Bunice and Johnson (2006) state that "guidelines for research proposals and protocols often require stating up front the number of participants to be involved in a study" (p.

61). The authors caution that using this approach requires that "applied researchers are often stuck with carrying out the number of interviews, for better or worse" (p. 61) which agrees with Bowen's (2008) assertion that "there are no definitive rules for determining saturation [as it relates to number of interviews]" (p. 139). The authors demonstrate, through their own semi-structured, open-ended interviews and data analysis that a minimum of six and maximum of 12 interviews are required to reach theoretical saturation. They define theoretical saturation as the "point in data collection and analysis when new information produces little or no change to the codebook" (p. 65). Their research shows that by the sixth interview, 73% of all codes were identified, with an additional 19% (total of 92%) of all codes identified by the 12th interview (p. 66). They conclude that the "…basic elements for metathemes were present as early as six interviews" (p. 59) with an ideal range of six to 12 interviews.

Leveraging off of the conclusions of Guest, Bunice and Johnson, along with the use of triangulation (literature review, interviews and survey) for the specific purpose of increasing the validation of the research, a minimum threshold of six interviews was identified for theoretical saturation confidence. Ultimately, a total of eight interviews were conducted; six in Fox Creek and two in Whitecourt.

Conducting the Interviews

The researcher chose to conduct interviews in two towns located within or in close proximity to the boundaries of the Duvernay shale and within a localized area called 'Kaybob', as shown in Figure 1. The towns of Fox Creek and Whitecourt, Alberta were identified based upon proximity to existing and anticipated Duvernay shale gas development as well as the regional history of oil and gas development. Fox Creek is located wholly within the active

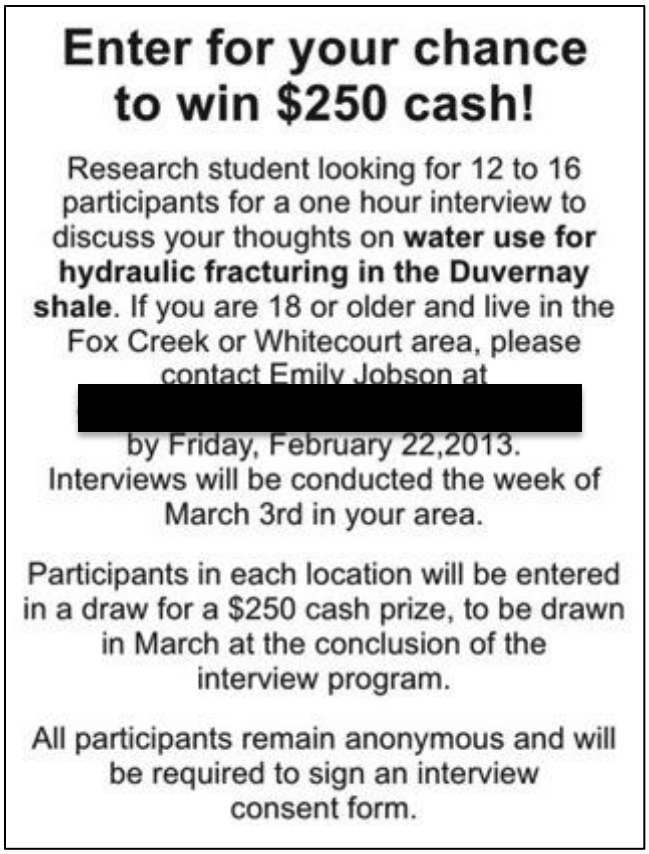
Duvernay shale gas play and identifies itself as a primarily oil and gas town (Alberta First, 2012a). Whitecourt also is located within the Duvernay shale play and provides personnel and services to the oil and gas industry. The town is not in close proximity to current shale gas development however. Whitecourt identifies as primarily a forestry town (Alberta First, 2012b). This focus on two locations with dissimilar levels of localized development is in line with research conducted by Gene Theodori in the Barnett shale of Texas wherein socio-environmental perceptions in a mature shale gas play were compared to a new shale gas play (2009; 2012).

Before conducting the interviews in Fox Creek and Whitecourt, mock interviews were conducted with three volunteers using the draft interview guide. The mock interviews were performed in a group setting on February 17th, 2013 to assess the clarity and applicability of the interview questions. The results of this exercise encouraged the researcher to slightly revise the interview preamble to more fully describe hydraulic fracturing methodology, and to prepare a printed map of the Kaybob region within the Duvernay shale formation to more easily describe the research scope to interview participants.

For two weeks in mid-February 2013, newspaper advertisements requesting interview participants were run in both Fox Creek and Whitecourt (Image 1). As well, eight days of 30-second radio spots were advertised on The Rig 97.9, a radio station catering to both Fox Creek and Whitecourt. Two interview participants were secured via radio and media advertising by the end of February. The use of *snowball sampling*, wherein existing interview participants recruit further participants from their acquaintances ("Snowball Sampling", 2009), resulted in a total of eight interview participants; six residing in Fox Creek and two residing in Whitecourt.

Image 1.

Advertisement requesting interview participants in the Kaybob region.



Semi-structured interviews were conducted between March 4 and 6, 2013. Participants were required to sign an informed consent document outlining ethical considerations such as anonymity, use of the interview data, publishing of the interview analysis results, and conflict of interest (see Appendix A). No participants withdrew at this point.

Participants were asked to complete a background information form to collect demographic data including gender, age range, and place of residence. The form also asked

participants to identify whether they or a close family relative worked in the oil and gas industry. Participants were asked if they would consent to an audio recording of the interview. No participants declined audio recordings.

Interviews were conducted in either a local coffee shop or the interviewee's place of work. Each participant was led through a list of eight open-ended questions pertaining to their knowledge of shale gas hydraulic fracturing, water sourcing and use in shale gas hydraulic fracturing, and frac flowback disposal (see Appendix B for a list of interview questions). The final question allowed participants to add any additional information or comments that had not been covered in the interview.

Immediately following the interviews, the researcher made notes detailing the key topics explored and perceptions related by the interviewee. This data was broadly aggregated following the final interview to identify key themes. These themes were used in conjunction with data gathered during the literature review to design the survey questions, as outlined in the following section.

All participants were entered in to a draw for a $250 cash prize. The draw took place on March 29, 2012. The winner was notified but declined the prize.

Survey Methodology

The use of quantitative methods in research provides "precise, quantitative, numerical data" and is "useful for obtaining data that allow quantitative predictions to be made" (Johnson & Onwuegbuzie, 2004, p. 19). As outlined in *Mixed Methods Research: A Research Paradigm Whose Time Has Come* (2004) qualitative research methods are described as deductive, confirmatory, predictive and useful for statistical analysis. Combining this numerical method of

research design with the more exploratory qualitative research design provides the researcher with pragmatic, holistic and defensible research results.

Couper, Traugott and Lamais (2001) observe, "research on self-administered surveys suggests that the design of the instrument may be extremely important in obtaining unbiased answers from respondents" (p. 231). Survey design and aesthetics were key considerations in the preparation of the quantitative survey and participant invitation letter. The survey incorporated design methods outlined by McKenzie-Mohr (2011) in his social marketing and research textbook *Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing* to align with the theory that visual appeal is an important feature in survey preparation.

Using key terms and concepts identified as part of the literature review and the interviews conducted in Fox Creek and Whitecourt, a short online survey was developed using the online program FluidSurvey. The survey consisted of nine, five point Likert-scale questions (Strongly Disagree to Strongly Agree), two demographic questions (age range and gender), one control question (personal or familial ties to the oil and gas industry), one multiple response question regarding the type of media respondents use to gain information on the topic, and one free text area for additional comments (see Appendix D for a list of survey questions). Survey questions were grouped by theme: Sourcing and Reuse, Disposal, Community Involvement, Other, and Additional.

Participation in the survey required review and electronic confirmation of an informed consent page. Participants were asked if they consented to the research per the informed consent section and asked to check "Yes" to participate in the survey (see Appendix C for the survey

informed consent form). Participants were also notified of their eligibility to be entered in to a draw for a $250 cash prize to be awarded once the survey was closed (pending submission of a valid email address). Multiple responses from the same household were prevented through the use of IP address logging within FluidSurvey functionality.

Printed survey invitation letters were created for both Fox Creek and Whitecourt participants and were manually distributed to homes between May 3 and 5, 2013 (see Appendix E for a copy of the survey invitation letter). Homes receiving letters were randomly selected, however due to the small size of Fox Creek, almost every home received an invitation (640 letters). The large size of Whitecourt allowed for a higher distribution number, with 750 letters being circulated in a variety of neighborhoods.

During the second week of the survey, advertisements were placed in both the Fox Creek Times and Whitecourt Press to remind participants to complete the survey (see Image 2). This served as follow up for residents receiving the survey invitation letters and allowed for additional participant recruitment in an effort to boost the response rate.

Image 2.

Advertisement reminding residents of the survey and requesting participation.

The winner of the $250 participation prize was drawn on June 8, 2013 and notified via email. The winner accepted the prize and an email money transfer was completed on June 11, 2013.

Research Results

Literature Review Results

Texas shale. The Barnett shale, located in the Southern United States, was identified as a location where extensive research has been conducted on public opinions on shale gas development. In particular, differences between more developed and less developed locations within the Barnett (Johnson and Wise Counties, Texas) were studied extensively by researcher Gene Theodori. At the time of the research, the majority of Barnett shale development was occurring within Wise County, whereas Johnson County was recently identified as an emerging "sweet spot", made possible with the use of new and emerging hydraulic fracturing technologies (Theodori, 2009). The research revealed that "individuals residing in places with diverse levels of energy development exhibit dissimilar perceptions of potentially problematic issues" (Theodori, 2009, p. 97). In particular, those residing in the more mature shale gas development area (Wise County) were more likely to display more negative perceptions of environmental issues related to shale gas development then those residing in new shale gas development area (Johnson County).

Theodori (2009) conducted six interviews in Wise County and 18 interviews in Johnson County. Based on the interviews he identified the key social, economic and environmental perceptions related to shale gas development in each area. From this data, he prepared a household survey mailed to 1,533 randomly selected homes (749 in Johnson County and 784 in Wise County). Using the 30 key social and environmental issues identified during the interviews, the survey respondents were asked to review each and identify if the issue was "getting worse", "getting better" or "staying the same". In addition, respondents were asked to respond to four

control variables related to duration of residence, mineral rights ownership, personal or familial ties to the industry and perception of the industry.

The results of the survey were collected and the issues ranked in descending order of overall perceptual score. High scores demonstrate a more negative view of the industry while low scores demonstrate a more positive view of the industry. The survey respondents identified that socio-environmental concerns were getting worse due to shale gas development. Of the 30 issues, *Amount of fresh water used by gas producers*, *Depletion of aquifers* and *Water pollution* were ranked at numbers two, four and six, respectively. These results demonstrate that in both counties, these environmental issues are of great concern to the local population.

It can be inferred from the results of Theodori's (2009) study that perceptions in municipalities located in the Duvernay shale gas play may be similar to those expressed in the Barnett shale. In particular, a comparison between a location more conditioned to oil and gas development (Fox Creek) to a location less conditioned to oil and gas development (Whitecourt) is being made.

New Brunswick shale. New Brunswick oil and gas development began in 1909 with the discovery of the Stoney Oil Field by Corridor Resources, with estimated unconventional shale gas resources of 11 trillion cubic feet (New Brunswick, n.d.). The natural gas rich McCully Gas Field was discovered in 2000 by the same company, with estimated unconventional gas resources of 67 trillion cubic feet (New Brunswick, n.d.). Nine companies currently hold 71 lease agreements for the exploration and development of shale gas over an area of 1.4 million hectares (New Brunswick, n.d.).

Ongoing public debate surrounding the environmental consequences of hydraulic fracturing of New Brunswick shale gas plays has led to discussions and studies on the current moratorium on development of the Maritimes Basin. A 2011 Corporate Research Associates public opinion poll on shale gas exploration in New Brunswick found that while 45% of residents support shale gas development, an equal number oppose it. In addition, the "intensity of feeling" (p. 1) for opposition to shale gas development is greater (Corporate Research Associates, 2011). The study notes that the public concerns about environmental protection seem to outweigh the potential economic benefits to the province (Corporate Research Associates, 2011)

A study released by the University of New Brunswick in April 2012 reviews potential impacts on water resources as part of shale gas development (Al, et al., 2012). The key public concerns outlined in the study relate to water contamination via migration of contaminated water and fracturing fluids left in the formation or improper well casing, water supply and conflicting users, and appropriate disposal of flowback. The authors suggest that cumulative water impact assessments are necessary to fully delineate the overall impact of increased water use by industry in the province, as well as exploration of alternative water sourcing options, including wastewater recycling, saline groundwater, and the use of CO_2 or LPG rather than fresh water.

Social and environmental interests in the development of the Maritimes shale are emerging as the potential development scenario is publicized, similar to the Duvernay shale gas play. The results of the University of New Brunswick study and the public perception research identify a number of public interests related to fresh water use as part of shale gas play

development. These results can be applied to the thesis research as potential topics for assessment as part of the semi-structured interviews and survey.

Interviews

Interview transcription. Recorded interviews were transcribed using a third party during the month of April, 2013. The researcher created a transcription guide outlining general formatting rules and methods to be used for transcribing certain verbal or non-verbal notes. The transcription guide, along with a transcription template, was provided to the transcriptionist (see Appendix F for the interview transcription guide). Transcription data was uploaded in to a Computer Assisted Qualitative Analysis Software (CAQAS), NVivo, for data analysis.

Interview data analysis. Theme identification in qualitative data analysis is a method through which the researcher forms key ideas and conclusions based upon the research (Ryan & Bernard, 2003). Ryan and Bernard (2003) write "themes come both from the data (an inductive approach) and from the investigator's prior theoretical understanding of the phenomenon under study (a priori approach)" (p. 88). Following this definition, ongoing theme identification during and immediately after interviews allowed for modification of follow-up questions as well as preliminary construction of qualitative survey questions, which is covered in later sections.

Inductive content analysis is used in situations where there is "not enough former knowledge about the phenomenon, or if this knowledge is fragmented" (Elo & Kyngäs, 2007, p.88). While existing research related to fresh water use in shale gas exists in other areas (Corporate Research Associates, 2011; Theodori, 2009; Theodori, 2012), research specific to the Duvernay shale gas play does not exist. Using open coding, categorization and abstraction, theme identification and description was performed as part of inductive content analysis.

Analysis of the transcribed interview data was performed per the recommendations in Elo and Kyngäs' paper *The qualitative content analysis process* (2007). The coding process began with an initial review of the transcripts and granular notation of themes (Elo & Kyngäs, 2007) within NVivo. A second review of both the transcripts and theme notations focused on ascribing broader categories to the identified themes (Elo & Kyngäs, 2007). The use of categories allowed for grouping of similar themes as a means of describing the phenomenon to increase understanding through abstraction (Cavenagh, 1997; Elo & Kyngas, 2007). A third and final review for completeness was conducted to ensure appropriate interpretation was made.

Interview Results

In addition to signing an informed consent form, a total of eight participants (five male: three female) aged 40-69 completed a short demographic questionnaire before participating in the interview. Six participants resided in Fox Creek and two resided in Whitecourt.

As shown in Table 1 interview transcript coding resulted in identification of seven parent nodes and 10 child nodes, which represent the key themes identified during analysis of the interview transcript. Water sourcing was the highest coded topic with 40 references comprised of four child nodes. Most of the references (24) were comprised of discussion related to the use of alternative water sources for hydraulic fracturing of shale gas wells. Alternative water sources are defined as recycled fracturing flowback and produced water, and saline water or other non-potable, non-fresh water sources. Water sourcing of groundwater and surface water was referenced 12 times, while use of potable (municipal) water was referenced four times.

Competitive water use was the secondary coded topic with 18 references, equally distributed between discussion of water sourcing competing with municipal water volume

requirements and perceived draw down of local recreational waters. The third node, Regulatory Oversight, was referenced 15 times and relates to the involvement of regulatory bodies (i.e. Alberta Environment and Sustainable Resource Development and the Alberta Energy Regulator) in the licensing and monitoring of water sourcing and use for the purposes of shale gas hydraulic fracturing activities. The fourth and fifth nodes relate to the performance of shale gas hydraulic fracturing operations and concerns related to groundwater contamination (6) and induced earthquakes (5). Water Disposal Causing Earthquakes (2) and Water Volumes Used (1) were referenced sparingly but included in the nodes as they were also identified during the literature review.

Table 1

Interview Transcript Coding Results: Number of Parent and Child Node References

Parent Node	Child Node	No. of Coded References
Water Sourcing		**40**
	Alternative Water Sources (incl. flowback/produced reuse, non-potable water, saline)	24
	Groundwater Use	5
	Potable Water Used for Hydraulic Fracturing	4
	Surface Water Use	7
Competitive Water Use		**18**
	Municiple Competitive Use	9
	Draw Down of Recreational Waters	9
Regulatory Oversight		**15**
	Good Regulatory Oversight	2
	Lack of Government Involvement/Regulations	5
	Government Transparency	8
Groundwater Contamination due to Hydraulic Fracturing		**6**
Hydraulic Fracturing Causing Earthquakes		**5**
Flowback Disposal		**2**
	Water Disposal Causing Earthquakes	2
Water Volumes Used		**1**

Note. Child nodes, if identified, comprise a portion of the total number of references within the Parent node.

Water sourcing. Water sourcing refers to the withdrawal of fresh water from surface or ground water sources, from alternative water sources such as recycled shale gas hydraulic fracturing flowback or produced water, saline groundwater sources, and use of municipal potable water for hydraulic fracturing. Fresh water (predominantly surface water) is the most commonly used source of water for hydraulic fracturing operations in Canada (Canadian Society for Unconventional Gas, 2011). In 2012, Alberta Environment and Sustainable Resource Development issued 917 Temporary Diversion Licenses (TDL's) for approximately 7,000,000 m^3 of surface and subsurface fresh water to oil and gas companies for the purpose of hydraulic fracturing of both shale and non-shale formations (Government of Alberta, 2013). 97% of the fresh water was withdrawn from surface water sources.

The primary discussion points related to water sourcing for hydraulic fracturing in the Duvernay shale gas play relate to the minimization of fresh water use and increased use of non-fresh water or saline sources. Statements such as "fresh surface and groundwater should not be used" and "I believe oil and gas companies need to recycle whenever possible" point to a desire by the public in the Kaybob area to see less fresh water use as part of shale gas hydraulic fracturing activities. While some interview participants understood the economic and technological restrictions of using recycled fracturing flowback and produced water, or saline sources, many have the opinion that industry, as part of environmental stewardship, should work to increase their use of these sources of water through continued research and development of alternative technologies. Some participants discussed their concern with the use of purchased municipal water for hydraulic fracturing activities, and pointed out that in the Town of Fox Creek, this is not permitted per local bylaws (it is permitted by the town of Whitecourt). While

enforcement of these bylaws remains with the town of Fox Creek, resourcing issues prevent appropriate policing of this activity.

Competitive water use. In regard to discussions on water sourcing, use of potable municipal water for hydraulic fracturing activities is identified as a concern based on competitive use. Two participants noted that in the town of Fox Creek, an industrial water supply company had drilled and licensed (through the Government of Alberta) groundwater source wells in a hydrogeographic strata that the interviewees perceived to be below the existing town groundwater aquifer. They both stated that this affected the Fox Creek municipal groundwater wells, and thought that available municipal water volumes would decrease as the town of Fox Creek grew concurrently with increased water needs in the Duvernay shale gas play.

Interview participants also related that they are concerned that high volume groundwater and surface water use is affecting water levels in local recreational lakes and streams. Both Fox Creek and Whitecourt identify as having a strong contingent of hunters and fishermen, and would be significantly impacted by changes to fish-bearing streams and lakes in the region (Alberta First, 2012a; Alberta First, 2012b). In particular, interviewees felt that the consequences of regional water level draw down would considerably affect the town of Fox Creek. The local lakes, Smoke Lake, Iosegun Lake, and Raspberry Lake, are a "source of recreation, and [it is a] source of revenue for the town".

Regulatory oversight. Participants expressed both positive and negative perceptions related to government oversight and transparency of fresh water use for hydraulic fracturing. Some participants expressed the opinion that the governing body, Alberta Environment and Sustainable Resource Development, did not provide appropriate supervision and control of fresh water use by industry, neither was the agency transparent on communication of total water use and sourcing, as well as permitting procedures and practices. Conversely, some participants felt that industry was well regulated and subject to stringent requirements that are consistently and appropriately enforced.

Groundwater contamination due to hydraulic fracturing. Contamination of groundwater following hydraulic fracturing activities was discussed, however the general opinion of all participants was that this is not a significant concern in the Kaybob region. In general participants identified that potable groundwater in the area is significantly shallower than the depth at which hydraulic fracturing activities occur, and that they understand that the "[well] casing goes deeper then [the lower limits of the groundwater aquifer]". While most were aware that groundwater contamination has occurred in other regions where shale gas is being developed, this is not a concern in the Kaybob area.

Hydraulic fracturing causing earthquakes. In a similar vein, most interview participants did not have concerns with the potential for earthquakes resulting from hydraulic fracturing activities, defined by the Canadian Association of Petroleum Producers as "induced seismicity" (Canadian Association of Petroleum Producers, 2009). One participant did relate that there have been small earthquakes in the Fort St. John region (British Columbia Oil and Gas Commission, 2012), an area proximal to the Horn River shale gas play, and that she was concerned about similar events taking place in the Duvernay shale formation. The remainder of the participants did not express any concern or expectation of induced seismicity due to hydraulic fracturing activities though they were aware of induced seismicity concerns in other shale gas plays.

Flowback disposal. Flowback water disposal in Alberta is regulated by the Alberta Energy Regulator (Alberta Energy Regulator, 2006) and must be disposed of at permitted deep well disposal facilities if not recycled for reuse. While some interview participants did not have an understanding of how fracturing flowback was disposed of, those that did only identified induced seismicity as a potential issue related to deep well disposal. Some participants pointed to the positive economic benefits related to deep well disposal of fracturing flowback, recognizing that there were a number of facilities in the region (Tervita, Secure and Newalta) that employed local residents. Overall, disposal of the fracturing flowback is a minor concern.

Water volumes used. One reference to actual volumes of fresh water used during hydraulic fracturing activities was identified. The interviewee recounted the use of "swimming pools" to store the large volumes of water in preparation for the operation. This relates to the use of *c-rings*, defined by the Alberta Energy Regulator as "above ground synthetically-lined wall storage systems", which are used to store large volumes (up to 4,500 m^3) of fresh water on or near the location where shale gas hydraulic fracturing activities will take place (Alberta Energy Regulator, 2011). The participant identifying his concern with the volumes of water used for hydraulic fracturing activities specified that he works in the oil and gas industry and has regular access to hydraulic fracturing operations. He stated that if the public was privy to a visual representation of the water volumes used, such as he is by observing the c-rings, greater concern may be expressed.

Survey

The online survey, housed on the website FluidSurvey, was open for completion for two weeks between May 3, 2013 and May 17, 2013. Following closure of the survey, the raw data from FluidSurvey was downloaded into Excel 2010. A total of 43 survey responses were received with 21 responses each from Whitecourt and Fox Creek. One additional response was received from an individual identifying that they lived in British Columbia, which is outside the geographic boundaries of this research. This response data was rejected and removed from the raw data. Of the adjusted number of 42 responses, 23 participants were male and 19 were female.

Based upon the distribution of 1,390 survey invitation letters in Fox Creek (640) and Whitecourt (750), the response rate for the online survey is 3.2%. Minimum response rates for confirming validity of survey results widely vary and are quoted as being between 10% and 70%

(McKenzie-Mohr, 2011; Visser, et al., 1996). Recent research on survey data validity with lower response rates has demonstrated that, in some cases, response rates as low as 5% will produce similar results as those with higher response rates in the same research (Holbrok, 2007). While the survey results cannot be deemed statistically significant because of the low response rate, it is the researcher's opinion that the views expressed as part of the survey results are valid and contribute to the overall understanding of perceptions related to fresh water use in shale gas hydraulic fracturing in the Duvernay shale. Considered within the overall research context, the survey responses align with what was expected based upon the findings of the literature review and interviews.

The nine survey questions were presented as statements ("question statements") with a five point Likert-scale response section. Available responses were: Strongly Agree, Agree, Neither Agree nor Disagree, Disagree and Strongly Disagree. Answers were not mandatory, however all survey participants answered all questions.

Using Excel 2010, the survey data was aggregated in to histograms for visual review. Due to the low response rate, statistical significance related to the control variable (personal or familial work in the oil and gas industry) was not conducted. Findings that are more substantial relate to survey participant interpretations of fresh water availability in the region as well as perceptions on hydraulic fracturing flowback recycling and reuse in the oil and gas industry. Additional findings regarding groundwater contamination resulting from shale gas hydraulic fracturing activities versus hydraulic fracturing flowback water disposal via deep well disposal demonstrate that there is a difference in perceptions based on type of activity rather than a

general perception about overall water use in hydraulic fracturing. There was no significant difference in responses between residents of Fox Creek or Whitecourt.

Survey Results

The following sections present histograms for individual or analogous survey question statements, a short discussion on the purpose of the question statement, and a brief interpretation of the results.

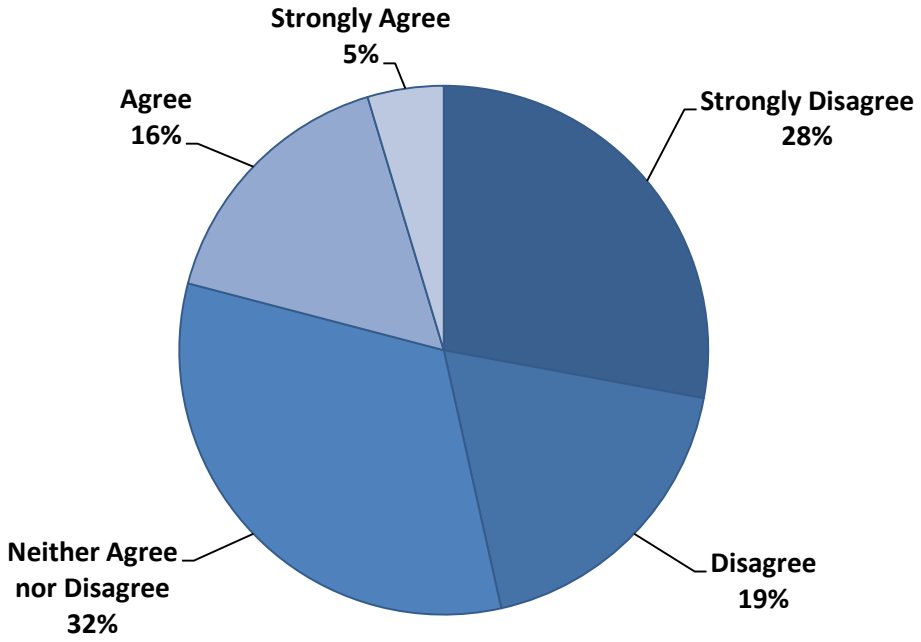


Figure 3. Question Statement 1: Overall, I feel that water sourcing for shale gas hydraulic fracturing is being done responsibly.

The purpose of this question is to gain a general understanding of perceptions related to the research topic: public perceptions related to water sourcing for shale gas hydraulic fracturing. Responses to the statement '*Overall, I feel that water sourcing for shale gas hydraulic fracturing is being done responsibly'* demonstrate that significantly more participants feel that water

sourcing for shale gas hydraulic fracturing is not being undertaken appropriately. Discounting the neutral responses (‘*Neither Agree nor Disagree’)*, 47% of survey participants demonstrated a negative response to the question statement whereas 21% demonstrated a positive response to the question statement.

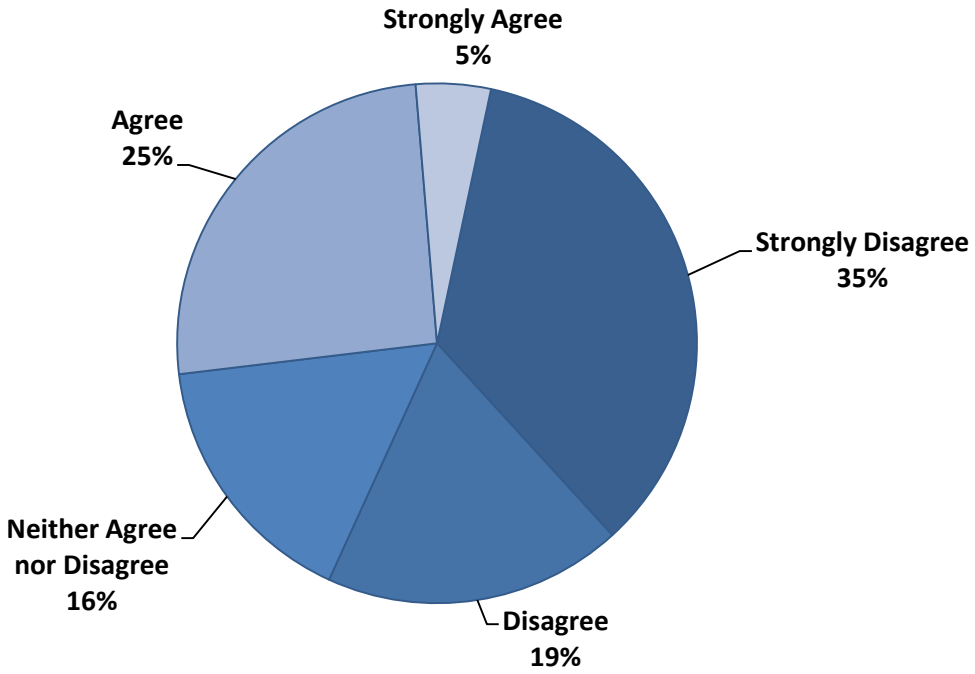


Figure 4. Question Statement 2: I believe that there is enough water for all users in this area for the foreseeable future.

Survey participants were provided with the statement, *‘I believe that there is enough water for all users for the foreseeable future’* to assess the current perceptions related to general water availability and competitive use in the region. Temporal and spatial limitations were not identified in relation to this question to allow for generalized responses. The majority of responses to this statement, 54%, were negative, whereas 30% of responses were positive and 16% were neutral. Some survey participants made comments specific to this question in the final comments section and related that their primary concerns related to water availability pertained

to impacts on recreational water in the region. In particular, water draw down in local lakes and low flows in creeks were perceived as matters of concern.

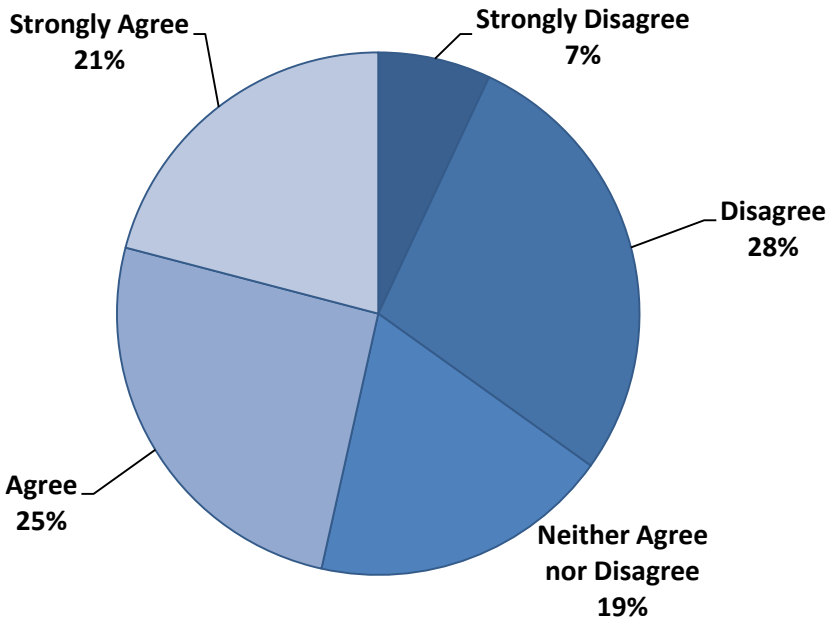


Figure 5. Question Statement 3: I think that the oil and gas industry is disposing of flowback and produced water appropriately.

Survey participants responding to the statement '*I think the oil and gas industry is disposing of flowback and produced water appropriately'* identified greater favour towards the current flowback disposal methods practiced in the region, which were defined within the survey as deep well disposal via third party waste disposal facilities (Secure, Tervita, Newalta, etc.). 46% of respondents believed this was an appropriate disposal method, while 19% remained neutral and 35% viewed it negatively.

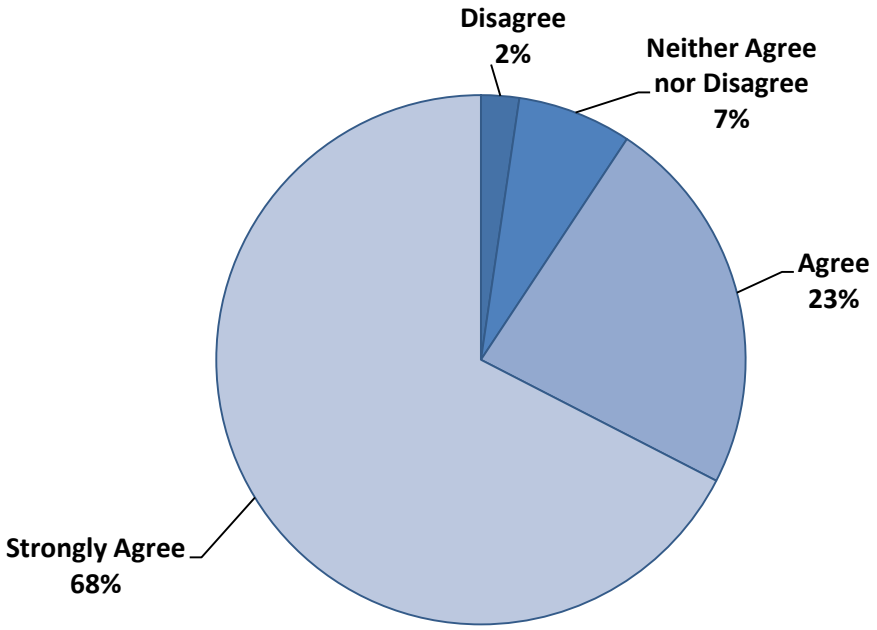


Figure 6. Question Statement 4: I feel that the oil and gas industry should be required to recycle a percentage of their flowback and produced water.

The statement *'I feel that the oil and gas industry should be required to recycle a percentage of flowback and produced water'* was met with very strong agreement, with 91% of survey respondents expressing favorable responses. Discounting neutral responses (*'Neither Agree nor Disagree'),* only 2% of survey participants felt that flowback recycling should not be a requirement of the oil and gas industry. The use of the word 'required' in this statement was deliberate, and implies that the oil and gas industry is not anticipated to recycle flowback as part of normal operations. Instead, regulations would set out the requirement to recycle flowback as part of normal operations.

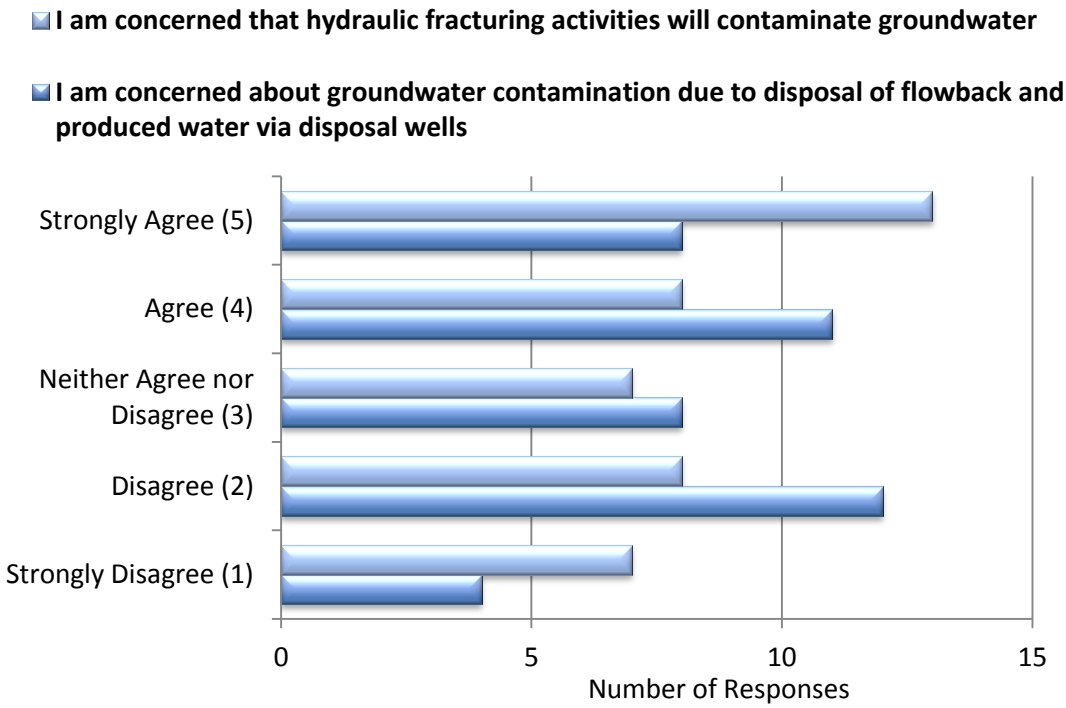


Figure 7. Question Statements 5 & 6: I am concerned that hydraulic fracturing activities will contaminate groundwater; I am concerned about groundwater contamination due to disposal of flowback and produced water via disposal wells.

These two statements are presented together because they demonstrate a slight difference in opinion between groundwater contamination concerns related specifically to shale gas hydraulic fracturing activities within the well versus groundwater contamination resulting from hydraulic fracturing flowback disposal via deep well at a third party facility (Secure, Tervita or Newalta). Survey participants expressed slightly more concern about groundwater contamination resulting from hydraulic fracturing activities compared to disposal activities (21 vs. 19 respectively). Disagreement with the statement in relation to hydraulic fracturing activities was not as strong as for disposal activities (15 vs. 16 respectively). Overall, respondents expressed some concern about potential groundwater contamination via both hydraulic fracturing activities and disposal methods.

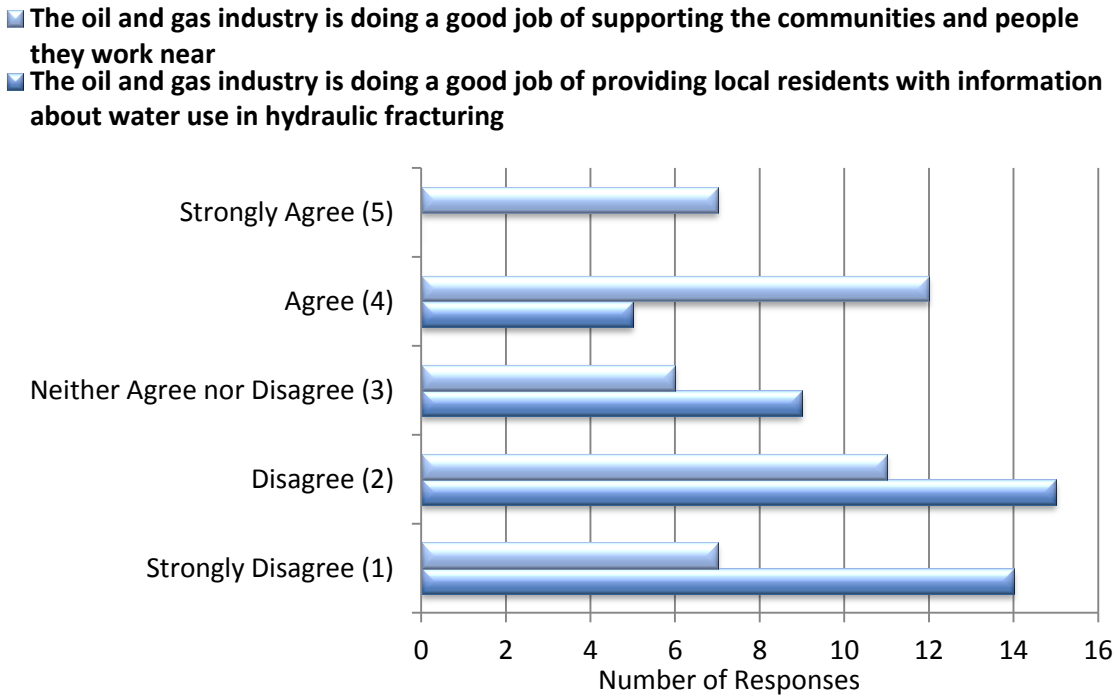


Figure 8. Question Statements 7 & 8: The oil and gas industry is doing a good job of supporting the communities and people they work near; The oil and gas industry is doing a good job of providing local residents with information about water use in hydraulic fracturing.

These statements were combined to demonstrate the difference in perceptions as they relate to both community engagement, and information provision activities and community and resident support (generally monetary) as part of increasing Duvernay shale gas development in the Kaybob region. While survey participants were almost evenly split in perceptions related to community support (19 positive vs. 18 negative), there was a significantly negative perception related to the provision of information and engagement of the communities in association with the increasing shale gas development activities in the region (5 positive vs. 29 negative).

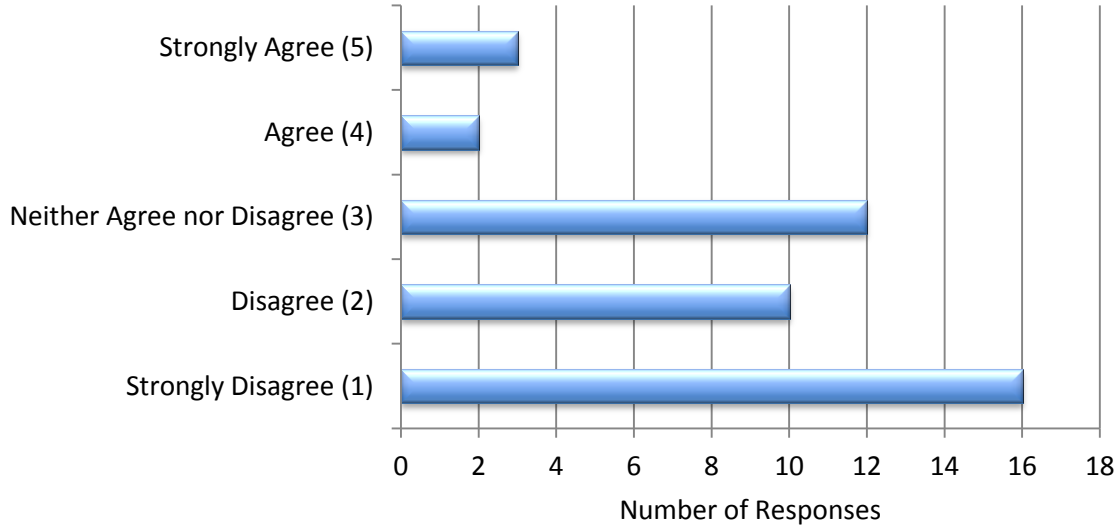


Figure 9. Question Statement 9: I am concerned that hydraulic fracturing activities may trigger earthquakes.

Public perceptions about earthquakes resulting from hydraulic fracturing activities were identified in both the literature review and during one of the interviews. The statement *'I am concerned that hydraulic fracturing activities may trigger earthquakes'* was presented to confirm or deny the researchers assumption that earthquakes are not of significant concern in the Kaybob region. This assumption was confirmed through the survey with a more negative response to the statement. Five participants responded positively to the statement while 26 did not.

Discussion

Development of shale gas resources is expected to increase in the coming years as new technologies allow for more economical extraction of the hydrocarbon resource. Rich source rock in the Western Canadian Sedimentary Basin, which includes the Duvernay, has attracted the attention of major oil and gas development companies. With the intensification in shale gas development, along with a rise in public awareness of these activities, an increased focus on the associated environmental implications, including fresh water use for hydraulic fracturing operations, is expected.

The research assessed the current public perceptions related to fresh water use in shale gas hydraulic fracturing operations within the Duvernay shale, located in the Kaybob region of West-central Alberta. Using mixed-method research design along with triangulation through the use of three separate research modes, literature review, semi-structured interviews, and surveys, a number of topics related to fresh water sourcing, use, and hydraulic fracturing flowback disposal in shale gas activities in the Duvernay shale were identified and explored. The following sections summarize the research findings in order of most referenced to least.

Volumes of Fresh Water Used and Competitive Use

High volume fresh water use, depletion of aquifers, and adequate water supply were identified as key concerns during review of existing research literature related to Texas and New Brunswick shale gas development areas. Interview coding identified “Water Sourcing” and “Competitive Water Use” as the top two concerns of residents in Fox Creek and Whitecourt, Alberta. When Fox Creek and Whitecourt residents were presented with the survey statement ‘*I believe that there is enough water for all users for the foreseeable future’*, the majority of

respondents (54%) disagreed. This aligns with the similarly negative response to the survey statement '*Overall, I feel that water sourcing for shale gas hydraulic fracturing is being done responsibly'* wherein survey respondents expressed disagreement (47%). It can be concluded from these results that the high volumes of fresh water used for shale gas hydraulic fracturing operations in the Duvernay are of interest and concern to residents in the Kaybob area.

During the interviews, a number of participants identified impact to recreational resources due to high volume ground and surface water withdrawal for use in shale gas hydraulic fracturing as a concern. Although participants could not validate this assumption, the perception that lake and creek levels had decreased in recent years remained. Comments made as part of the survey supported the identification of this perception. Statements identifying draw down of the municipal water supply for the Town of Fox Creek, a localized groundwater aquifer, as a concern was observed during the interviews. Claims related to the perceived draw down of local recreational waters were not scientifically validated by the researcher as this matter is not within the scope of the research.

Reuse of Flowback

Review of research and literature based on public perceptions related to development of the New Brunswick shale identified that wastewater (i.e. hydraulic fracturing flowback) recycling was a topic that required further exploration in that region. Similarly, interview participants in both Fox Creek and Whitecourt related that fresh water use should be minimized and expressed frustration that hydraulic fracturing flowback recycling was not an industry standard. Most significantly, 91% of respondents agreed with the question statement '*I feel that the oil and gas industry should be required to recycle a percentage of flowback and produced*

water'. Based upon the research data, it can be expected that hydraulic fracturing flowback recycling, as part of a reduction in fresh water use, is of key interest to residents in the Kaybob region.

Potential for Groundwater Contamination

Groundwater contamination was identified as a significant topic in both the Texas and New Brunswick shale gas development literature. Groundwater contamination was defined as being caused by either migration of fluids from an improperly constructed well bore or inappropriate disposal of hydraulic fracturing flowback or produced water. Interviews of residents in the Kaybob region of the Duvernay shale, however, expressed minimal concern about the potential for groundwater contamination. In general, participants felt that good well bore design and appropriate hydraulic fracturing flowback disposal in the Duvernay mitigated any risks for groundwater contamination.

This sentiment was not supported by the survey responses however, with some agreement being expressed by survey participants in relation to the question statements '*I am concerned that hydraulic fracturing activities will contaminate groundwater'* and '*I am concerned about groundwater contamination due to disposal of flowback and produced water via disposal wells'*. This difference in results may reflect factors such as age, education and knowledge about shale gas hydraulic fracturing practices and hydraulic flowback fluid disposal.

Regulatory Oversight

While regulatory oversight was not identified in the literature review as a topic of interest, interview participants discussed their perceptions related to the involvement of regulatory bodies in the management of shale gas fresh water use in the Duvernay. Participants

seemed to be divided on whether or not there was enough regulatory oversight in shale gas development or not. This topic was not overtly explored within the survey due to minimal discussion during the interviews and it's inapplicability to the research. However, the considerably positive response (91%) to the survey question statement '*I feel that the oil and gas industry should be required to recycle a percentage of flowback and produced water'* may signify that there is a sentiment among the Kaybob population that more regulatory requirements be placed on shale gas developers in the Duvernay.

Provision of Knowledge to Potentially Impacted Residents

Information related to the provision of knowledge about shale gas hydraulic fracturing activities was not explored as part of the research literature review or interviews. However, based upon the knowledge and understanding of shale gas hydraulic fracturing activities expressed by participants of the interviews, the researcher determined that exploration of this topic within the survey may return valuable information about how residents of the Kaybob region perceived the current levels of community engagement and support by companies developing the Duvernay shale. The majority of survey respondents identified that while community support is acceptable, information sharing and community engagement by oil and gas companies was significantly lacking.

Potential for Earthquakes Due to Hydraulic Fracturing Operations

Earthquakes caused by hydraulic fracturing activities was not identified as a concern during review of literature related to the Texas and New Brunswick shale gas public perception research. However, this was identified as a topic during one interview and was explored as part of the survey with the question statement '*I am concerned that hydraulic fracturing activities*

may trigger earthquakes'. The majority of respondents stated that this was not a concern for shale gas development activities in the Duvernay. Concerns regarding hydraulic fracturing activity induced earthquakes are not an issue in the Kaybob region at this time.

Conclusions and Limitations

Development of the Duvernay shale formation in the Kaybob region of West-central Alberta requires high volumes of fresh water for hydraulic fracturing operations. While residents in the area welcome and support oil and gas development, as they have historically, emerging issues related to fresh water use for hydraulic fracturing activities identified in other North American shale gas development areas are also of concern to some members of the communities in vicinity to development within the Duvernay shale. These concerns do not appear to be influenced by proximity to development activities. In particular impacts to regional recreational waters (lakes, creeks, streams), competitive water use, recycling of hydraulic fracturing flowback, groundwater contamination, and the provision of information to the affected communities are key topics identified during the research.

It can be expected that as development of the Duvernay shale formation increases and fresh water volume requirements amplify, resident's concerns will also proliferate. Assumptions by the oil and gas industry that residents in areas where conventional oil and gas development historically has occurred are not likely to express concerns about unconventional development would be a critical misstep. A further assumption that the local economic benefits of a resurgence in industry development in the region will be of greater importance to residents than environmental impact creates a potential for future conflict between Duvernay shale gas developers and residents in the Kaybob region.

Based upon the thesis research, the researcher suggests that conflicts may arise in the future should mitigative measures not be implemented. A lack of information sharing by industry in the Kaybob area conflates existing negative perceptions and will only serve to promote mistrust of oil and gas companies, driving residents to find information from other, potentially less reliable, sources. Presentation of scientifically validated information on shale gas hydraulic fracturing along with fresh water use reduction strategies will serve to minimize the potential for future conflict between Duvernay shale gas developers and residents in the Kaybob region related to fresh water use for shale gas hydraulic fracturing activities.

Limitations of the Research

Notwithstanding the success of the mixed methods and triangulation approach undertaken as part of the thesis research, the researcher has identified a number of limitations that may be overcome during future research efforts. In particular, timing constraints and geographical restrictions resulted in small sample sizes. While the information gained through the interviews and survey is valuable, and many results have been validated through triangulation, it can be expected that a broader cross-section of the residents in the Kaybob region will provide more depth to research results respecting public perceptions on fresh water use during development of the Duvernay shale.

The town of Edson should be of interest to future researchers as a location in proximity to the Duvernay shale gas play and is likely to be impacted by increasing shale gas development. Additionally, some regional inhabitants, such as the farming community, were not included in the research but may provide valuable insight in to implications of increasing fresh water use and the actual or perceived impact on the agricultural industry. Individuals employed by local and

provincial governments were included as individuals in the research, but not as formal representatives of their employers. Including these governmental agencies in future research will provide valuable input on existing and future fresh water use policy and management practices.

References

Al, T., Butler, K, Cunjack, R. & MacQuarrie, K. (2012, April). Opinion: Potential impact of shale gas exploitation on water resources. *Corporate Research Associates, Inc.* Retrieved from: http://cra.ca/public-opinion-in-new-brunswick-divided-on-shale-gas-exploration/

Alberta Energy Regulator. (2006). *Directive 58: Oilfield waste management requirements for the upstream petroleum industry*. Retrieved from http://www.aer.ca/documents/directives/Directive058.pdf

Alberta Energy Regulator. (2011). *Directive 055-Addendum 2011-10-11: Interim requirements for aboveground synthetically-lined wall storage systems, updates to liner requirements, and optional diking requirements for single-walled aboveground storage tanks.* Retrieved from http://www.aer.ca/documents/bulletins/bulletin-2011-30.pdf

Alberta First. (2013a). *Fox Creek: Economic base.* Retrieved from http://www.albertacommunityprofiles.com/Profile/Fox_Creek/4

Alberta First. (2013b). *Whitecourt: Economic base.* Retrieved from http://www.albertacommunityprofiles.com/profile/whitecourt/4

Bartosh, O. (2012). *Mixed methods.* [Power Point Slides]. Retrieved from http://learner.royalroads.ca/moodle/mod/resource/view.php?inpopup=true&id=96684

Bowen, G. A. (2008). Naturalistic inquiry and the saturation concept: A research note. *Qualitative Research*, *8*(1), 137-152.

British Columbia Oil and Gas Commission. (2012). *Investigation of induced seismicity in the Horn River Basin.* Retrieved from www.bcogc.ca/node/8046/download

Bryman, A. (n.d.). *Triangulation in research.* [Published Letter] Retrieved from http://www.referenceworld.com/sage/socialscience/triangulation.pdf

Canadian Association of Petroleum Producers. (2009). *Shale gas.* Retrieved from http://www.capp.ca/canadaIndustry/naturalgas/shalegas

Canadian Society for Unconventional Gas. (2011). *Understanding hydraulic fracturing.* [Digital Version]. Retrieved from: http://www.csur.com/images/CSUG_publications/CSUG_HydraulicFrac_Brochure.pdf

Cavanagh, S. (1997). Content analysis: concepts, methods and applications. *Nurse Researcher*, *4*, 5-16.

Corporate Research Associates. (2011, December). *Public opinion in New Brunswick divided on shale gas exploration.* Retrieved from http://cra.ca/public-opinion-in-new-brunswick-divided-on-shale-gas-exploration/

Couper, M., Lamais, M, Traugott, M. (2001). Web survey design and administration. *The Public Opinion Quarterly*, *65*(2), 230-253. Retrieved from http://www.jstor.org.ezproxy.royalroads.ca/stable/3078803

Deloitte. (2012). Public opinions on shale gas development: Positive perceptions meet understandable wariness. Retrieved from http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/Energy_us_er/us_er_ShaleSurveypaper_0412.PDF

Dittrick, P. (April 1, 2012). Focus: Unconventional oil & gas – Montney, Duvernay will be key to Canada shale oil, gas growth. *Oil & Gas Journal.* Retrieved from http://www.ogj.com/articles/print/volume-111/issue-4/general-interest/montney-duvernay-will-be-key-to-canada.html

Dunn, L., Schmidt, G., Hammermaster, K., Brown, M., Bernard, R., Wen, E., Befus, R., & Gardiner, S. (2012). The Duvernay formation (Devonian): Sedimentology and reservoir characterization of a shale gas/liquids play in Alberta, Canada. Retrieved from:

http://www.cspg.org/documents/Conventions/Archives/Annual/2012/core/280_GC2012_The_Duvernay_Formation.pdf

Duvernay Shale. (2011). *Alberta Oil & Gas.* Retrieved from http://oilshalegas.com/duvernayshale.html

Elo, S & Kyngäs, H. (2007). The qualitative content analysis process. *Journal of Advanced Nursing 62*(1), 107-115. doi: 10.1111/j.1365-2648.2007.04569.x

Faraj, B., Williams, H., Addison, G. & McKinstry, B. (2004). *Gas potential of selected shale formations in the western sedimentary basin.* Retrieved from http://media.godashboard.com/gti/4ReportsPubs/4_7GasTips/Winter04/GasPotentialOfSelectedShaleFormationsInTheWesternCanadianSedimentaryBasin.pdf

Gas Technology Institute. (2002). Gas shale potential of selected upper cretaceous, Jurassic, Triassic and Devonian shale formations, in the WCSB of Western Canada [Technical Report GRI-02/0233].

Government of Alberta. (2013). *Alberta water policy update* [Power Point]. Retrieved from http://www.esaa-events.com/proceedings/watertech/2013/pdf/P3.pdf

Guest, G., Bunce, A. & Johnson, L. (2006). How many interviews are enough?: An experiment with data saturation and variability. *Field Methods, 18,* 59-82. doi: 10.1177/1525822X05279903

Holbrook, A., Krosnick, J., Pfent, A. (2007). *The causes and consequences of response rates in surveys by the news media and government contractor survey research firms.* Retrieved from Stanford University: http://www.stanford.edu/dept/communication/faculty/krosnick/docs/2007/2007%20TSMII%20chapter%20proof.pdf

Johnson, R. & Onwuegbuzie, A. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher, 33,* 14-25. doi: 10.3102/0013189X033007014

Lapan, S., Quartaroli, M., Riemer, F. (2012). *Qualitative research: an introduction to methods and designs.* San Francisco, CA: Jossey-Boss.

Leech, B. (2002). Techniques for semistructured interviews. *Political Science and Politics, 35*(4), 665-668. Retrieved from http://www.justor.org/stable/1554805

Leech, N. & Onwuegbuzie, A. (2009). A typology of mixed methods research designs. *Qual Quant, 43,* 265-275. doi: 10.1007/s11135-007-9105-3

Liamputtong, P. (2009). Qualitative data analysis: Conceptual and practical considerations. *Health Promotion Journal of Australia*, *20*(2), 133-139. Retrieved from http://web.ebscohost.com.ezproxy.royalroads.ca/ehost/pdfviewer/pdfviewer?sid=5bcacbd2-191a-4c02-9a46-a411245b1d3b%40sessionmgr13&vid=2&hid=15

Low, W. (2010). *Duvernay shale: new millennium gold rush* [Power Point]. Retrieved from https://bmo.can.idrsite.com/Login%20Page%20Document%20Library/ADLibrary/Presentations/BMO%20Duvernay%20DUG%20June%202012.pdf

McKenzie-Mohr, D. (2011). *Fostering sustainable behavior: An introduction to community-based social marketing.* Gabriola Island, B.C.: New Society Publishers.

Morse, J. (1994). *Handbook for qualitative research.* Thousand Oaks, CA: Sage

National Public Relations Inc. (2011). *Public opinion and oil and gas in Canada* [Lecture Notes].

New Brunswick. (n.d.). *New Brunswick oil and natural gas.* Retrieved from: http://www2.gnb.ca/content/dam/gnb/Corporate/pdf/ShaleGas/en/History.pdf

Ostlund, U., Kidd, L., Wengstrom, Y. & Rowa-Dewar, N. (2010). Combining qualitative and quantitative research within mixed method research designs: a methodological review.

International Journal of Nursing Studies, 48, 369-383. doi:10.1016/j.ijnurstu.20120.10.005

Pierce, R., (2008). Asking questions: Effective elite interviews, other interviews, vignettes, projective questions, and focus groups. *Research Methods in Politics* (pp. 117-139). doi: 10.4135/9780857024589

Ryan, G. & Bernard, R. (2003). Techniques to identify themes. *Field Methods (15)*1, 85-109. doi: 10.1177/1525822X02239569

Scott, C. A., Pierce, S. A., Pasqualetti, M. J., Jones, A. L., Montz, B. E. & Hoover, J. H. (2011). Policy and institutional dimensions of the water-energy nexus. *Energy Policy, 39,* 6622-6630. doi: 10.1016/j.enpol.2011.08.013

Snowball Sampling. (2009, April). *Explorable*. Retrieved from http://explorable.com/snowball-sampling

Statistics Café. (2011, February). How to use the likert scale in statistical analysis [Blog Post]. Retrieved from http://statisticscafe.blogspot.ca/2011/05/how-to-use-likert-scale-in-statistical.html

Statistics Canada. (2012a). *Fox Creek, Alberta* (Code 4818002). Retrieved from Statistics Canada website: http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/index.cfm?Lang=E

Statistics Canada. (2012b). *Whitecourt, Alberta* (Code 4813030). Retrieved from Statistics Canada website: http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/index.cfm?Lang=E

Strauss, A. & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* Newbury Park, CA: Sage Publications.

Theodori, G. (2009). Paradoxical perceptions of problems associated with unconventional natural gas development. *Southern Rural Sociology, 24*(3), 97-117.

Theodori, G. (2012). Public perception of the natural gas industry: data from the Barnett shale. *Energy Sources, Part B,* 275-281. doi: 10.1080/15567240903030562

Top 10: Drilling Upswing. (2011, December 5). *Energize Alberta.* Retrieved from http://www.energizealberta.com/index.php/departments/top-10/81-top-10-drilling-upswing

University of Melbourne, Faculty of Economics and Commerce. (n.d). *Conducting an interview for data collection purposes.* Retrieved from http://learner.royalroads.ca/moodle/file.php?file=/2964/interviews.doc

Visser, P., Krosnick, J., Marquette, J., & Curtin, M. (1996). Mail surveys for election forecasting? An evaluation of the Colombia dispatch poll. *Public Opinion Quarterly* (60) 181-227