Executive summary

Expansion of oil and gas activities into unconventional resource plays has been accompanied by some concerns about the current and future state of groundwater in Alberta and British Columbia. A key step in addressing this concern is characterizing current baseline groundwater conditions in a scientifically sound manner using methods that enable differentiation between natural variations in water and gas geochemistry from those caused by potential anthropogenic impacts. Such a project was recently completed for the province of Alberta. However, a similar assessment has not been conducted for shallow groundwater data in areas of hydrocarbon resource development in British Columbia.

Existing data on shallow groundwater geochemistry from various sources provide a unique opportunity for a comprehensive scientific assessment of baseline aqueous and gas geochemistry of groundwater in British Columbia in areas of past, current and future hydrocarbon resource development, against which future potential impacts, or the lack thereof, by hydrocarbon development can be scientifically documented. The **objective** of this project is to compile, evaluate and interpret all available baseline groundwater testing results on aqueous and gas geochemical compositions using data available for samples collected in British Columbia in its current and future hydrocarbon resource development areas.

The project commenced with a QA/QC data quality check (e.g. electroneutrality) to assess which results are acceptable for scientific evaluation (**milestone 1**; full report section 2). A total of 3585 groundwater samples passing the QA/QC test were identified from industrial, academic and public data sources for an in-depth evaluation and interpretation of baseline groundwater well testing data for the northeastern part of British Columbia and the northwestern part of Alberta overlying the Montney resource play. Subsequently a broad-scale characterization of water types was conducted (**milestone 2**; full report section 3). Multivariate statistical analysis was used to examine geochemical trends in groundwater samples and interpret relations between inorganic aqueous parameters for samples obtained from groundwater wells across the study area. Two multivariate methods were applied using SPSS software: principal component analysis (PCA) and cluster analysis (CA). These methods provide powerful grouping mechanisms and permit to establish a robust water sample classification approach that yield three major water types:

- Type 1 (45%): Geochemically evolved water characterized by a $Na-HCO_3$ water type with a low Ca/Na ratio and often associated with elevated residence times;
- Type 2 (16%): SO_4-rich water samples with elevated total dissolved solids (TDS) and either associated with a) an elevated Ca/Na ratio and shorter residence times, or b) a low Ca/Na ratio associated with elevated residence times;
- Type 3 (39%): Recently recharged water characterized by a $Ca-Mg-HCO_3$ water type.

Subsequently, the data evaluation focused on the occurrence, variability and source of methane in shallow groundwater (**milestone 3**; full report section 4). Of the 3585 groundwater samples with aqueous geochemistry parameters passing the QA/QC test, 297 samples (8%) had accurate gas composition analyses reported. Methane concentrations above the detection limit were observed in 223 of the 297 samples. The dissolved methane concentrations in the 223 groundwater samples varied from 0.0002 to >40 mg/L. More than 85% of the samples with detectable methane contents had concentrations < 1 mg/L. This indicates that the occurrence of elevated concentrations of methane in baseline groundwater samples in the study area is not widespread.

Aqueous geochemistry data were used to determine whether methane occurring in shallow groundwater was produced microbially in-situ by assessing the groundwater redox conditions as opposed to situations where methane transport from underlying stratigraphic units must be postulated (**milestone 4**, full report section 5). Where possible, the research team used the isotopic composition of methane in concert with other indicator parameters (e.g. ethane and propane concentrations, dryness parameter etc.) to differentiate potential cases of thermogenic gas transport (from deeper stratigraphic units) from occurrences of microbial oxidation of biogenic gas that may result in elevated carbon isotope ratios falsely suggesting the occurrence of thermogenic gas (**milestone 5**; full report section 6). 157 samples had sufficient methane to conduct carbon isotope fingerprinting to determine the origin and fate of methane in these groundwater samples. More than 70% of the 157 groundwater samples had a low average $\delta^{13}C_{CH4}$ value of -76.5 ‰ occurring in Na-HCO_3(-Cl) water types or Type 1 indicating that the methane had formed biogenically. More than 25% of the 157 samples had methane concentrations <0.05 mg/L and $\delta^{13}C_{CH4}$ > -55‰ occurring in rather oxidized groundwater environments (e.g. SO_4-rich and Ca-Mg-HCO_3 type samples or Types 2 and 3). This suggests that the elevated $\delta^{13}C$ values of methane in these samples have resulted from oxidation of biogenic methane. Only 4 of the 157 samples (<3 %) were characterized by methane concentrations > 1 mg/L and $\delta^{13}C_{CH4}$> -50 ‰. This may be an indication that this methane is of thermogenic origin.

The **key conclusions** of this study are therefore the following:

- The geochemical and isotopic patterns in baseline groundwater in North-Eastern British Columbia are very similar to those observed in baseline groundwater in North-Western Alberta;
- Methane detected in baseline groundwater in North-Eastern British Columbia has frequently low concentrations (<1 mg/L) and is almost always (>94%) of biogenic (e.g. natural) origin;
- Using a combination of chemical and isotopic techniques is a highly effective approach for assessing whether gas leakage from natural gas resource plays into shallow groundwater occurs in the study area, since natural gas in the Montney and Horn River Formations is of thermogenic origin and characterized by elevated and distinct carbon isotope ratios of methane, ethane and propane.