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Alberta Energy Regulator

Environmental Isotope Sampling of the Saddle River and the Groundwater Observation Well Network in the Upper Peace Region, Northwestern Alberta

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- Don Jones (InnoTech Alberta) for sampling the Alberta Environment and Parks Groundwater Observation Well Network wells in March 2018.

Abstract

Waters samples were collected for isotopic (δ^2H, $\delta^{18}O$, ^3H, ^{14}C) and geochemical analysis from five locations on the Saddle River during low flow conditions in 2017 and four Groundwater Observation Well Network (GOWN) wells in 2018, in the Upper Peace Region of northwestern Alberta. The Saddle River is composed of relatively young water with a total dissolved solids (TDS) concentration that varied from 731 to 902 mg/L and a mixture of young (^3H) and old (^{14}C) naturally occurring tracers. The downstream trend of increasing TDS and decreasing ^{14}C indicates that the Saddle River receives baseflow from progressively older water sources in the downstream direction, suggesting that groundwater from the underlying bedrock formations has varying residence times. Groundwater from an observation well completed in surficial sediments (sand) also indicates relatively young water most likely recharged from snowmelt in the region. Groundwater from observations wells completed in the Wapiti Formation did not detect any ^3H, had lower ^{14}C values, and had moderate TDS values (910 to 2600 mg/L). These findings indicate the presence of older groundwater in the Wapiti Formation at these locations, potentially in the order of 15 000 to 25 000 years before present. This water sampling in the Upper Peace Region provides a ‘snapshot’ of conditions for the 2017/2018 period.

1 Introduction

The Upper Peace Region in northwestern Alberta encompasses a variety of land uses (Chowdhury and Chao, 2018) including agriculture, forestry, rural residential, urban, and land developed for oil and gas activity. The cumulative effects of population growth and economic development occurring from the co-location of different land uses will increase pressure on land and water resources in this region. Groundwater is an important source of water for many residents in the Upper Peace Region, and also for tributaries of the Peace and Smoky river systems. Yet, baseline knowledge of nonsaline groundwater is limited in this region (Mighty Peace Watershed Alliance, 2018).

To contribute to a better understanding of groundwater in this region, the Alberta Geological Survey (AGS) sampled water at selected locations in 2017 and 2018. Collection of these data was intended to provide a ‘snapshot’ of conditions and continue advancing the knowledge of water resources in this region. Water sampling focused on a tributary river that flows over several bedrock formations and groundwater wells, which are part of the Groundwater Observation Well Network (GOWN) operated by Alberta Environment and Parks. The water sampling approach utilized geochemistry and naturally occurring environmental tracers to allow detection of water of different residence times, aimed at differentiating relatively young water cycling through the shallow subsurface and potential older groundwater associated with deeper bedrock formations. A more regionally comprehensive analysis of groundwater quality was not the focus of this study.

1.1 Study Area

The study area encompassed an extent of the Saddle River and four GOWN wells located in the vicinity of Grande Prairie, Alberta (Figure 1). The physiography (Pettapiece, 1986) is predominantly within the Peace River Lowlands with some of the study area in the Wapiti Plains in the southwest and the Saddle Hills Upland in the centre and west. The bedrock geology in this area consists predominantly of Upper Cretaceous formations, including the Wapiti, Puskwaskau, Muskiki, and Kaskapau formations. These formations generally dip to the south and subcrop in a progressively northward direction in the study area (Figure 1). The dipping structure of these formations is expected to have an influence on hydrogeological conditions and water chemistry as the successive, subcropping formations may contain groundwater with a greater circulation depth and residence time. Within the Peace River valley at the northern edge of the study area, the Shaftesbury and Dunvegan formations also subcrop or potentially outcrop.

2 Water Sampling

Water samples were collected from the Saddle River and GOWN wells in 2017 and 2018. Each sampling program used the same analytical schedule including major and minor ions (i.e., routine water chemistry), stable isotopes of water (^{18}O and ^{2}H), tritium (^{3}H), and carbon 14 (^{14}C). The naturally occurring isotopic tracers were analyzed to allow detection of water with different residence times, aimed at identifying young water cycling through the shallow groundwater system and older baseflow sources potentially coming from a deeper groundwater flow system. Each analyte was collected for a different purpose as described in Table 1.

2.1 Saddle River

Synoptic sampling of rivers during low flow periods has the potential to identify variation in the sources of baseflow along the river, which helps to better understand groundwater conditions at the regional scale (Solomon et al., 2015; Beisner et al., 2018). For the Upper Peace Region, field investigation focused on the Saddle River, which has headwaters in the study area (Saddle Hills Upland) and drains into the Peace River (Figure 1). Sampling locations spanned many of the bedrock formations present in the study area, with the distance between locations varying from 6 to 22 km, depending on access to the river by roads and trails. A 57 km segment of the Saddle River was sampled in September 2017, with samples collected using a peristaltic pump with the intake tubing located on the riverbed and at the middle of the river.

2.2 GOWN Wells

Groundwater samples from the four GOWN wells were collected in March 2018 by InnoTech Alberta under contract with the AGS. Depending on depth of water within each well, either a peristatic pump or bladder pump was used to collect groundwater samples. Wells were pumped until measured field parameters (temperature, electrical conductivity, pH) were stable, at which point the samples were collected.

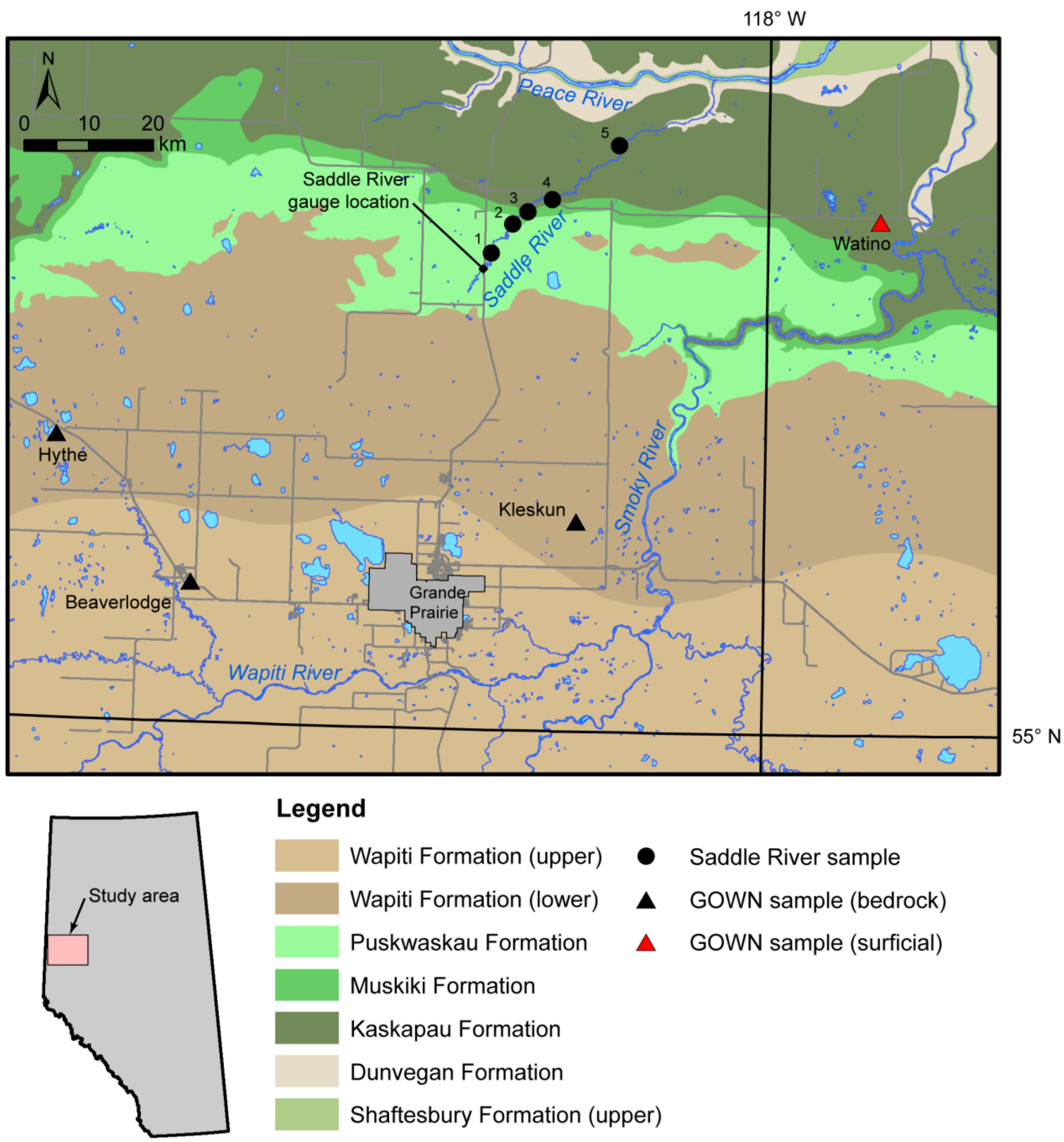

Figure 1. Location of river and groundwater samples relative to bedrock formations. The location of Groundwater Observation Well Network (GOWN) wells are differentiated based on completion in a bedrock formation or surficial sediment.

Table 1. Summary of water sampling.

Analyte	Purpose	Laboratory
Routine water chemistry	Dissolved major ions and alkalinity analyzed to understand the general geochemical composition of the water.	IsoBrine Solutions Inc. (Edmonton, Alberta) for river water Maxxam Analytics (now Bureau Veritas Laboratories; Grande Prairie, Alberta) for groundwater
Stable isotopes of water ($\delta^{18}O$ and $\delta^{2}H$)	Help understand the origin and movement of the stable isotopes within the hydrological cycle. All values are expressed as δ values representing deviations in per mil (i.e., parts per thousand) from Vienna standard mean ocean water (VSMOW).	IsoBrine Solutions Inc. (Edmonton, Alberta) for river water InnoTech Alberta (Victoria, British Columbia) for groundwater
Tritium (^{3}H)	Present in the atmosphere with concentrations that peaked in the 1960s due to atmospheric atomic bomb testing. The decreasing concentration in the atmosphere helps distinguish pre-1960s waters from post-1960s waters.	IT2 Isotope Tracer Technologies Inc. (Waterloo, Ontario)
Radiocarbon (^{14}C)	A radioactive isotope produced in the atmosphere that enters the subsurface through plant respiration. It is an ideal tracer for groundwater movement on the time scale of thousands of years.	IT2 Isotope Tracer Technologies Inc. (Waterloo, Ontario)

3 Results

Geochemical and isotopic results are tabulated in Appendix 1. The results plotted and briefly discussed in this section focus on the potential circulation of groundwater in the study area and its interaction with surface water. Additional sampling of water wells completed in these bedrock formations is needed for further interpretation of the hydrogeological conditions.

Water in the Saddle River had a total dissolved solids (TDS) concentration that ranged from 731 to 902 mg/L at the time of sampling. By comparison, groundwater from the only GOWN well completed in surficial sediments (Watino location shown on Figure 1) had a TDS value of 550 mg/L, and the groundwater from GOWN wells completed in bedrock formations had TDS values that ranged from 910 to 2600 mg/L. These results indicate that the quality of groundwater is related to the geological material, with higher TDS concentrations being generated in the bedrock formations.

The results for stable isotopes of water are shown on Figure 2a relative to local meteoric water lines (LMWLs) developed for the Utikuma Region Study Area (URSA), which is located 140 to 180 km east of the study area (Smerdon et al., 2012), and Edmonton, which is located 350 to 450 km southeast of the study area (Maulé et al., 1994). Water samples from the Saddle River plot in the upper part of Figure 2a in a trend that is parallel to the LMWL, possibly indicating a minor evaporative effect. Groundwater samples plot in the transition between rainfall and snow segments of the URSA LMWL.

The results for ^{3}H and ^{14}C are shown on Figure 2b and begin to reveal the relative age difference in water sources. Groundwater from surficial deposits (Watino location shown on Figure 1) and water in the Saddle River have relatively high ^{3}H and ^{14}C values, which is typically associated with younger water. The cluster of results in the uppermost part of Figure 2b indicates water sourced primarily from snowmelt and rainfall in recent years. In contrast, groundwater from the bedrock GOWN wells had ^{14}C values of 15 percent of modern carbon (pMC) or less, and less than 0.8 tritium units (TU). This indicates older groundwater, potentially in the order of 15 000 to 25 000 years before present.

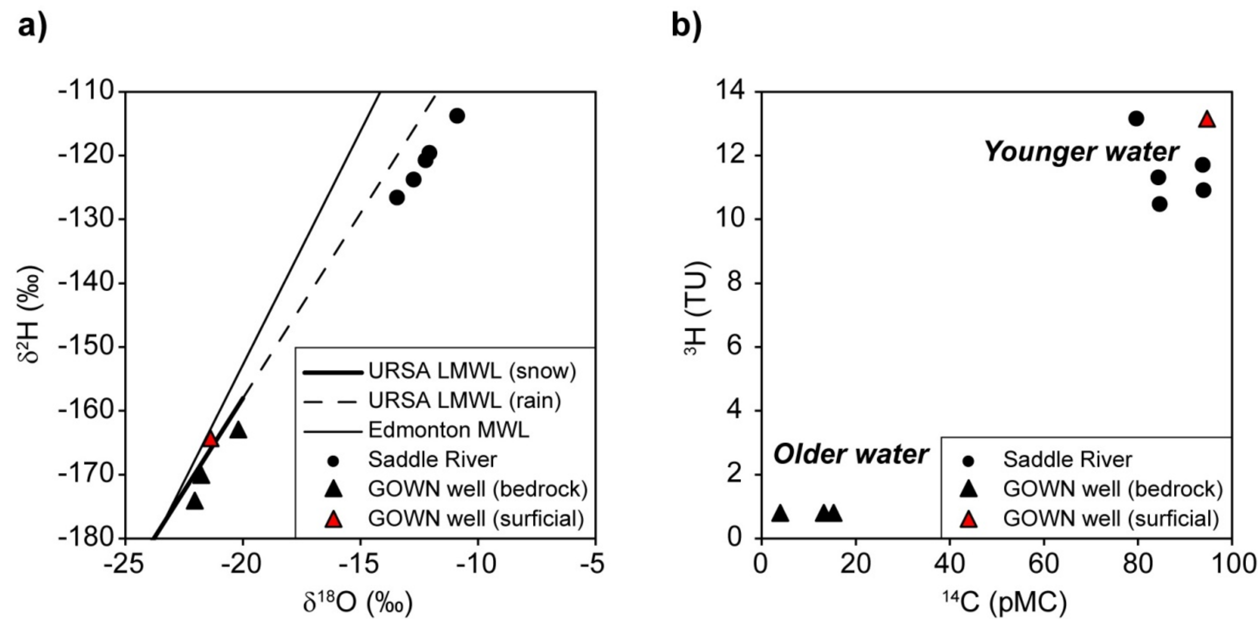

Figure 2. a) Stable isotopes of δ^2H and δ^{18}O for water samples relative to Local Meteoric Water Line (LMWL) from the Utikuma Research Study Area (URSA), reported in Smerdon et al. (2012), and Meteoric Water Line (MWL) for Edmonton, by Maulé et al. (1994). b) The ^{3}H and ^{14}C values for water samples indicating the relative age. Samples from Upper Peace Region, northwestern Alberta. Abbreviations: GOWN, Groundwater Observation Well Network; pMC, percent of modern carbon; TU, tritium units.

As noted above, the TDS concentration in water from the Saddle River was greater than 700 mg/L at the locations sampled, and also appeared to have an increasing trend in the downstream direction (Figure 3a; river distance plotted relative to the river gauging station shown on Figure 1). At the same river sample locations, the concentration of ^{14}C was found to have a decreasing trend in the downstream direction (Figure 3b). Together, these data imply that the source of baseflow to the Saddle River is progressively older in the downstream direction. Based on the regional bedrock geology (Prior et al., 2013), the Saddle River crosses the approximate subcrop edges of the Puskwaskau and Muskiki formations (shown on Figure 3). These geochemical and isotopic data suggest that the older baseflow could originate from the underlying Kaskapau Formation, which may contain groundwater having a longer residence time. Additional groundwater sampling of water wells completed in these bedrock formations would aid further interpretation of groundwater conditions in the region.

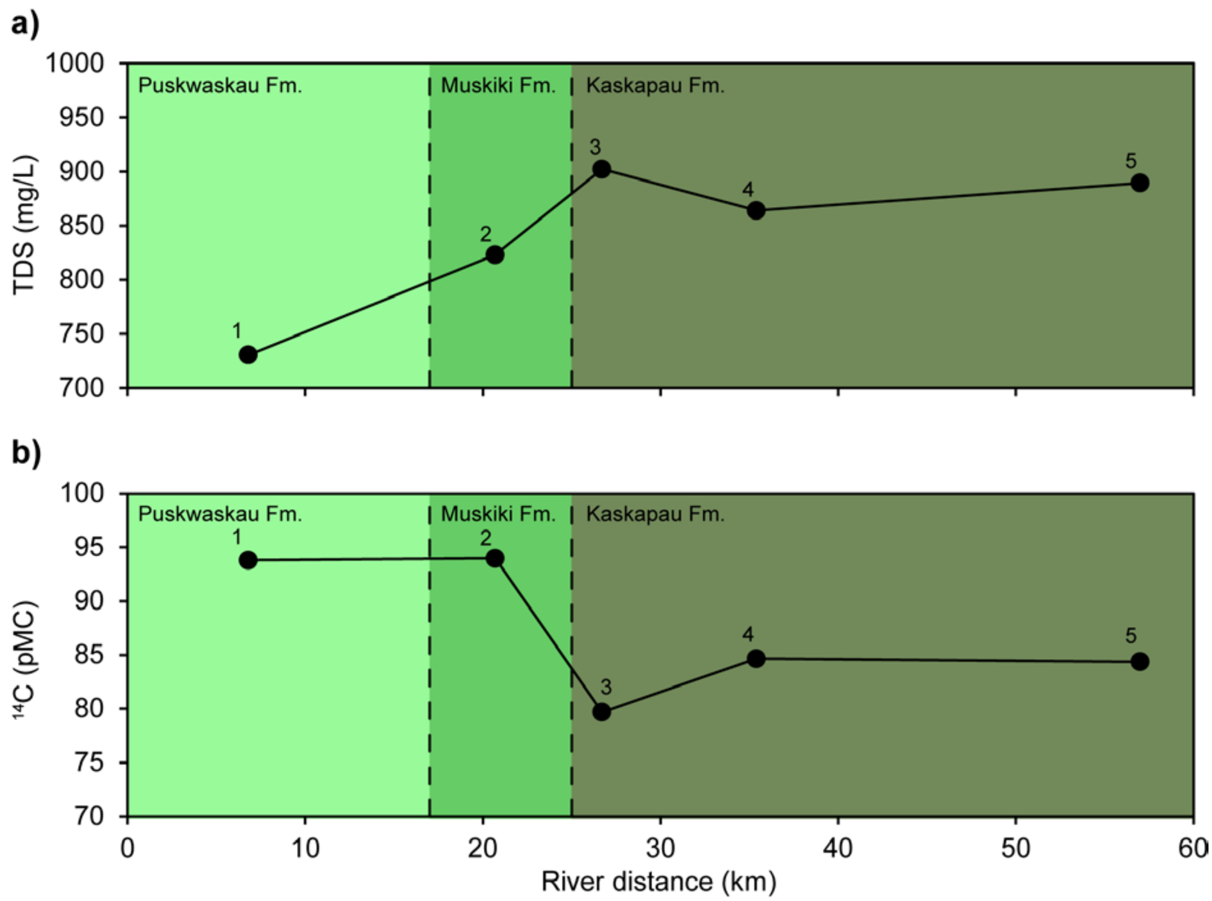

Figure 3. a) Total dissolved solids (TDS) and b) ^{14}C concentrations in river water plotted as distance along sampled segment of the Saddle River, Upper Peace Region in northwestern Alberta. Numbered river sample locations correspond to Figure 1. Bedrock formations that the river flows over are shaded with the same colour as shown in Figure 1, with the approximate edge of bedrock formations identified by the vertical dashed line. River distance is plotted relative to the gauging station location shown in Figure 1. Abbreviation: pMC, percent of modern carbon.

4 Conclusions

Water samples were collected from five locations on the Saddle River during low flow conditions and four GOWN wells in the Upper Peace Region. The Saddle River is composed of relatively young water with a TDS concentration ranging from 731 to 902 mg/L and a mixture of young (^{3}H) and old (^{14}C) naturally occurring tracers. The downstream trend of increasing TDS and decreasing ^{14}C indicates that the Saddle River receives baseflow from progressively older water sources in the downstream direction, suggesting that groundwater from the underlying bedrock formations is a contributing factor. Groundwater from an observation well completed in surficial sediments (sand) also indicates relatively young water most likely recharged from snowmelt in the region. Groundwater from observations wells completed in the Wapiti Formation did not detect any ^{3}H, had lower ^{14}C values, and moderate TDS values (910 to 2600 mg/L). These findings indicate the presence of older groundwater in the Wapiti Formation at these locations, potentially in the order of 15 000 to 25 000 years before present. This water sampling in the Upper Peace Region provides a snapshot of conditions for the 2017/2018 period. The findings suggest that baseflow to rivers in this region may originate from groundwater of varying residence time depending on the specific geological formation. Additional sampling of rivers and water wells completed in these bedrock formations is needed for further interpretation of the hydrogeological conditions, including a better understanding of surface water and groundwater interaction.

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Appendix 1 – Geochemical and Isotopic Data

Table 2. Sample locations in the Upper Peace Region, northwestern Alberta, and field measurements.

Sample ID	Latitude	Longitude	Location	Temperature (°C)	pH	Electrical Conductivity (µS/cm)
Saddle River 1	55.6655	-118.6835	SE15-77-05-W6[a]	10.1	7.96	868
Saddle River 2	55.7061	-118.6319	NE25-77-05-W6	8.8	7.42	997
Saddle River 3	55.7241	-118.5953	SW05-78-04-W6	10.9	7.81	1070
Saddle River 4	55.7414	-118.5350	SW10-78-04-W6	9.0	7.95	1050
Saddle River 5	55.8188	-118.3718	NE03-79-03-W6	9.1	7.89	1100
Watino (GOWN 369)	55.7175	-117.7233	NW31-77-24-W5	5.1	7.22	898
Kleskun (GOWN 379)	55.2935	-118.4612	SW06-73-03-W6	5.8	8.85	1575
Beaverlodge (GOWN 341)	55.1961	-119.3974	NE36-71-10-W6	5.7	7.57	3799
Hythe (GOWN 376)	55.3961	-119.7375	NW11-74-12-W6	4.7	8.47	2176

[a] Abbreviated form of SE¼, Sec. 15, Twp. 77, Rge. 05, W 6th Mer. Abbreviations: GOWN, Groundwater Observation Well Network; S, siemens.

Table 3. Isotopic results for water sampling in the Upper Peace Region, northwestern Alberta.

Sample ID	$\delta^{18}O$ (‰)	$\delta^{2}H$ (‰)	^{3}H (TU)	^{14}C (pMC)
Saddle River 1	-12.22	-120.74	11.71	93.80
Saddle River 2	-13.44	-126.61	10.91	93.97
Saddle River 3	-12.74	-123.78	13.16	79.68
Saddle River 4	-12.06	-119.62	10.47	84.66
Saddle River 5	-10.88	-113.78	11.32	84.38
Watino (GOWN 369)	-21.37	-164.31	13.14	94.78
Kleskun (GOWN 379)	-22.05	-174.08	<0.8	4.02
Beaverlodge (GOWN 341)	-21.76	-170.06	<0.8	13.25
Hythe (GOWN 376)	-20.20	-162.96	<0.8	15.34

Abbreviations: GOWN, Groundwater Observation Well Network; pMC, percent of modern carbon; TU, tritium units.

Table 4. Water chemistry results (part 1) for water sampling in the Upper Peace Region, northwestern Alberta.

Sample ID	pH	EC (µS/cm)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Fe (mg/L)	Mn (mg/L)	Cl (mg/L)
Saddle River 1	8.07	907	109	28.8	45.7	6.5	0.06	0.011	37.3
Saddle River 2	7.64	1013	132	35.8	41.1	9.8	0.1	0.15	28.4
Saddle River 3	7.95	1112	128	39.2	67.2	7	0.03	0.041	28.6
Saddle River 4	7.97	1086	125	37.7	61.7	7.1	0.05	0.035	22.0
Saddle River 5	7.95	1140	142	40.5	51.5	7.7	0.08	0.09	31.6
Watino (GOWN 369)	7.99	920	93	66	28	2	2.9	0.27	3.2
Kleskun (GOWN 379)	9.05	1600	3.1	1.2	380	1.5	0.32	0.004	9
Beaverlodge (GOWN 341)	8.18	3800	30	5.9	870	2.3	10	0.44	2.7
Hythe (GOWN 376)	8.47	2200	25	11	450	3	0.10	0.15	3.6

Abbreviations: EC, electrical conductivity; GOWN, Groundwater Observation Well Network; S, siemens.

Table 5. Water chemistry results (part 2) for water sampling in the Upper Peace Region, northwestern Alberta.

Sample ID	SO_4 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	TDS (mg/L)	T-Alkalinity (mg/L as $CaCO_3$)	P-Alkalinity (mg/L as $CaCO_3$)	Bicarbonate (mg/L)	Carbonate (mg/L)
Saddle River 1	203	0.015	0.016	731	245	<5.0	298	<6
Saddle River 2	261	0.010	0.015	823	256	<5.0	312	<6
Saddle River 3	356	0.012	0.014	902	225	<5.0	274	<6
Saddle River 4	364	0.024	0.012	864	200	<5.0	244	<6
Saddle River 5	437	0.017	0.018	889	145	<5.0	177	<6
Watino (GOWN 369)	190	0	0	550	290	0	350	0
Kleskun (GOWN 379)	0	0	0	910	850	70	870	84
Beaverlodge (GOWN 341)	1100	0	0	2600	910	0	1100	0
Hythe (GOWN 376)	670	0	0	1400	440	8.2	520	9.9

Abbreviations: GOWN, Groundwater Observation Well Network; TDS, total dissolved solids.