Groundwater and Surface Water Overview of the Lochend Area, Alberta

The Lochend Industry Producers Group (LIPG) conducted a hydrogeological / hydrological study in the Lochend operating field. The objectives of the study were to characterize groundwater and surface water resources in the area and to provide a baseline of natural variations in groundwater chemistry for future comparison. A brief overview of the study is provided below.

Groundwater and Surface Water Overview

The LIPG area is located in the Municipal District of Rocky View within the South Saskatchewan River Basin. The area overlaps two sub-basins including the Red Deer River Sub-Basin in the northern portion of the operating field and the Bow River Sub-Basin in the south. The location of the LIPG area is shown in Figure 1 along with the river sub-basins.

The main creeks within the LIPG operating area include the Beaverdam Creek, Bighill Creek, Bigspring Creek and West Nose Creek. Cochrane Lake is just outside of the western operating boundary and Lochend Lake is to the east. Big Hill Springs Provincial Park is host to many natural springs. Bighill Creek flows through Big Hill Springs Provincial Park and is a tributary of the Bow River to the south.

Groundwater is a significant resource used by local landowners mainly for domestic and agricultural purposes. The main aquifer from which landowners extract groundwater is the Paskapoo aquifer. The Paskapoo aquifer is the shallowest bedrock aquifer in the area and although this aquifer is approximately 465 m thick, water wells are mainly located within the upper 220 m. The average depth of water wells within the LIPG area is 60 m. The location of 1,155 water wells within the LIPG area is shown in Figure 1.

Natural Chemistry of the Paskapoo Aquifer

Groundwater from water wells in the LIPG area has an average Total Dissolved Solids (TDS) concentration of 475 mg/L and a range from 131 to 1,060 mg/L. The average chloride (Cl) concentration is 12 mg/L and the highest chloride concentration is 269 mg/L. Concentration ranges and averages for common chemical parameters measured within groundwater from local water wells are listed in Table 1. Chloride concentrations in shallow groundwater in the LIPG area are presented in Figure 2.

Based on water wells that have been sampled and tested more than once by the LIPG, no significant variation in natural groundwater chemistry has been observed within the Paskapoo Aquifer.

Indictors of Groundwater Chemistry Change

Oil and gas activity may be cause for landowner concern regarding domestic use aquifer quality. Indicators of influence from oil and gas activity may include elevated concentrations of chloride and TDS. Another indicator may be the detection of hydrocarbon compounds, such as BTEX (Benzene, Toluene, Ethylbenzene, and Xylenes), which are not naturally occurring in shallow groundwater.

Chloride is often present in shallow groundwater and elevated levels may be associated with other human activities such as salting roads or agricultural activity. If chloride concentrations were increased as a result of oil and gas drilling activity, the elevated chloride would be accompanied by elevated TDS

concentrations, resulting from the unlikely event of groundwater migrating upward from deeper aquifers. In the LIPG area, groundwater from deep aquifers is characterized by TDS concentrations greater than 4,000 mg/L and chloride concentrations greater than 1,860 mg/L, which is significantly higher than concentrations observed in the Paskapoo aquifer.

Unnaturally high concentrations of chloride, TDS, and BTEX are detectable through groundwater sampling and laboratory analysis.

Natural Geologic Protection

Oil and gas resources in the LIPG area are extracted from the Cardium Formation, which is a rock unit located over 2,000 meters below the deepest water well in the area. Depths of the Paskapoo aquifer and the Cardium Formation in relation to other rock formations in the LIPG area are illustrated as a block diagram in Figure 3. Impermeable shales act as a natural geologic barrier which prevents groundwater flowing upwards from the Cardium Formation to the Paskapoo aquifer.

How Groundwater Quality Concerns are Addressed

The Lochend Industry Producers Group (LIPG) is committed to ensuring the protection and sustainability of local groundwater resources. The LIPG has developed operational guidelines going beyond The Canadian Association of Petroleum Producers (CAPP) guiding principles for Hydraulic Fracturing Operating Practice – Baseline Groundwater Testing. LIPG practices include offering baseline groundwater testing of domestic water wells and springs within 400 m of resource wells prior to drilling. Yield testing and water quality analysis (routine potability, microbiological, total/dissolved metals and BTEX) are included in the LIPG standard procedures.

Definitions from Health Canada (www.hc-sc.gc.ca)

***Total Dissolved Solids (TDS).** Health Canada established an aesthetic objective of less than 500 mg/L for total dissolved solids (TDS) in drinking water. At higher levels, excessive hardness, unpalatability, mineral deposition and corrosion may occur. At low levels, however, TDS contributes to the palatability of water. Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. Principal constituents include: calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate, and nitrate (from agricultural use). TDS in water supplies originates from natural sources, sewage, urban and agricultural runoff.*

***Chloride.** The aesthetic objection for chloride in drinking water is less than 250 mg/L and is naturally present at low concentration in natural surface waters. Higher concentrations of chloride are most often present in drinking water derived from groundwater sources; this could be due to naturally high concentrations or contamination. It is estimated that 25-50% of applied road salt enters groundwater.*

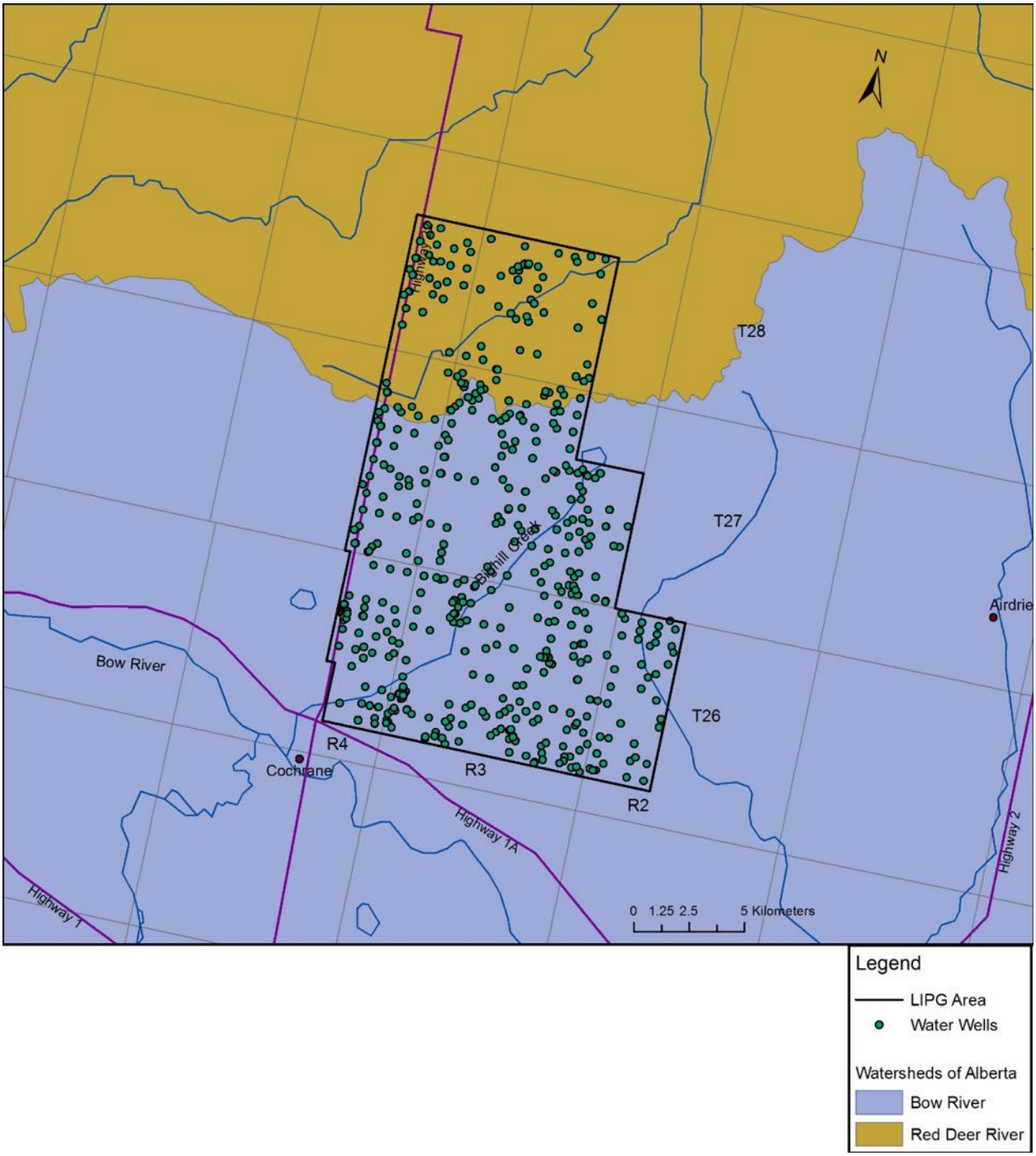

Figure 1. Location of drainage basins and water wells in the LIPG operating field area.

Table 1: Concentrations of dissolved chemical parameters in groundwater from water wells and springs in the LIPG area.

Parameter	Concentration Range (mg/L) Local water wells and springs	Average Concentration (mg/L) Local water wells and springs	MAC or AO* (mg/L)
Ca	0.2 – 177.0	73.5	-
Mg	0.5 - 98.3	33.1	-
Na	3.5 - 360.0	63.8	≤ 200
K	0.85 - 9.74	3.93	-
Cl	< 0.10 - 269.00	12.56	≤ 250
SO_4	< 0.5 - 286.0	33.6	≤ 500
HCO_3	127.0 – 806.0	490.1	-
F	< 0.10 – 3.51	0.279	1.5
Fe	< 0.030 – 1.03	0.015	≤ 0.3
Mn	< 0.0050 – 3.20	0.033	≤ 0.05
TDS	131.0 – 1060.0	475.3	≤ 500
Nitrate + Nitrite (N)	< 0.071 – 41.00	1.78	10
Hardness	< 1.0 – 739.0	319.8	-
Total Alkalinity ($CaCO_3$)	132.0 – 701.1	412.6	-

*MAC = maximum acceptable concentration according to Guidelines for Canadian Drinking Water Quality (GCDWQ), AO = aesthetic objective (Health Canada, 2012).

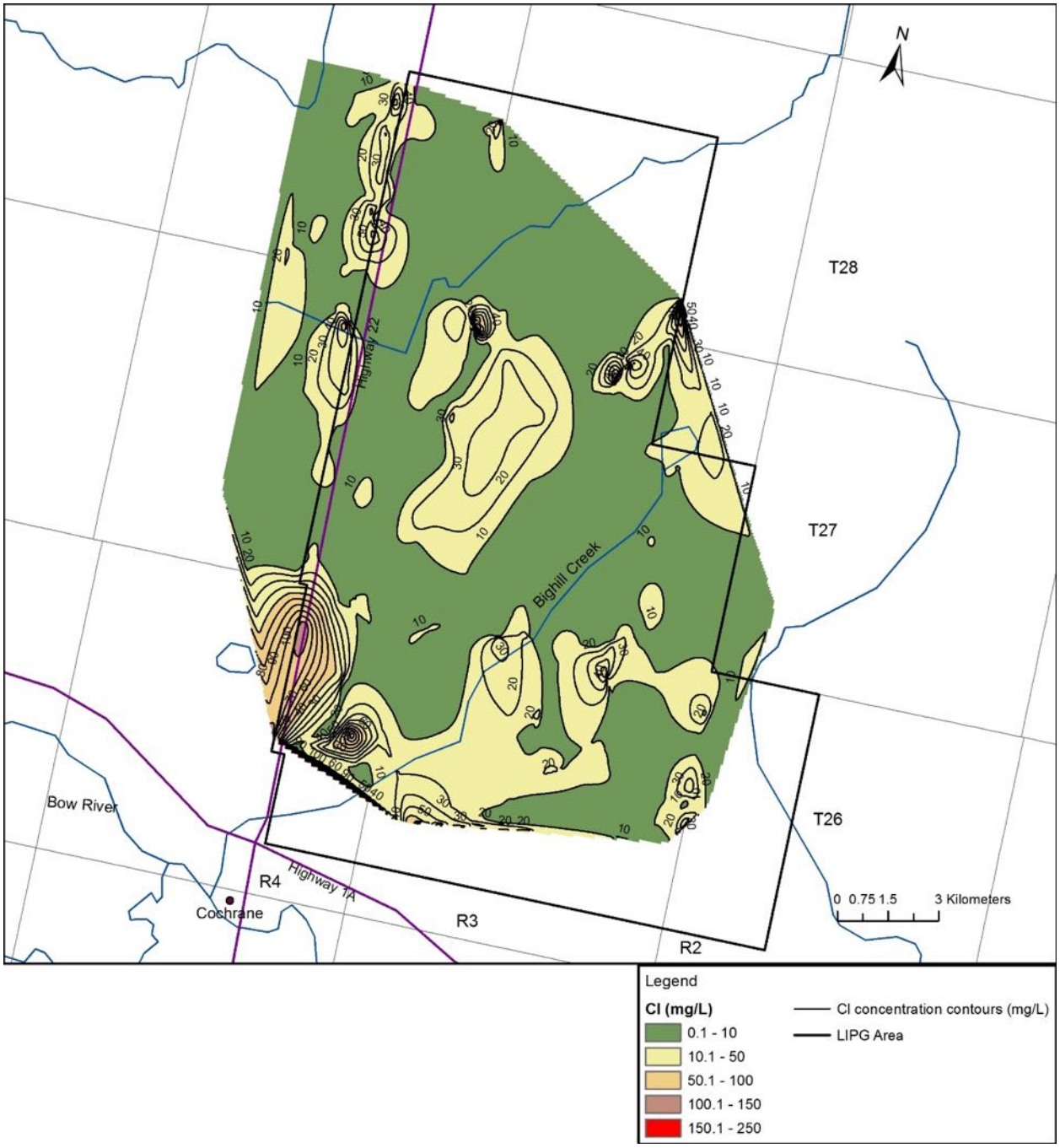

Figure 2. Distribution of chloride concentrations in shallow groundwater within the LIPG operating field area (2011 groundwater data).

> 2 km between water wells and Cardium Formation

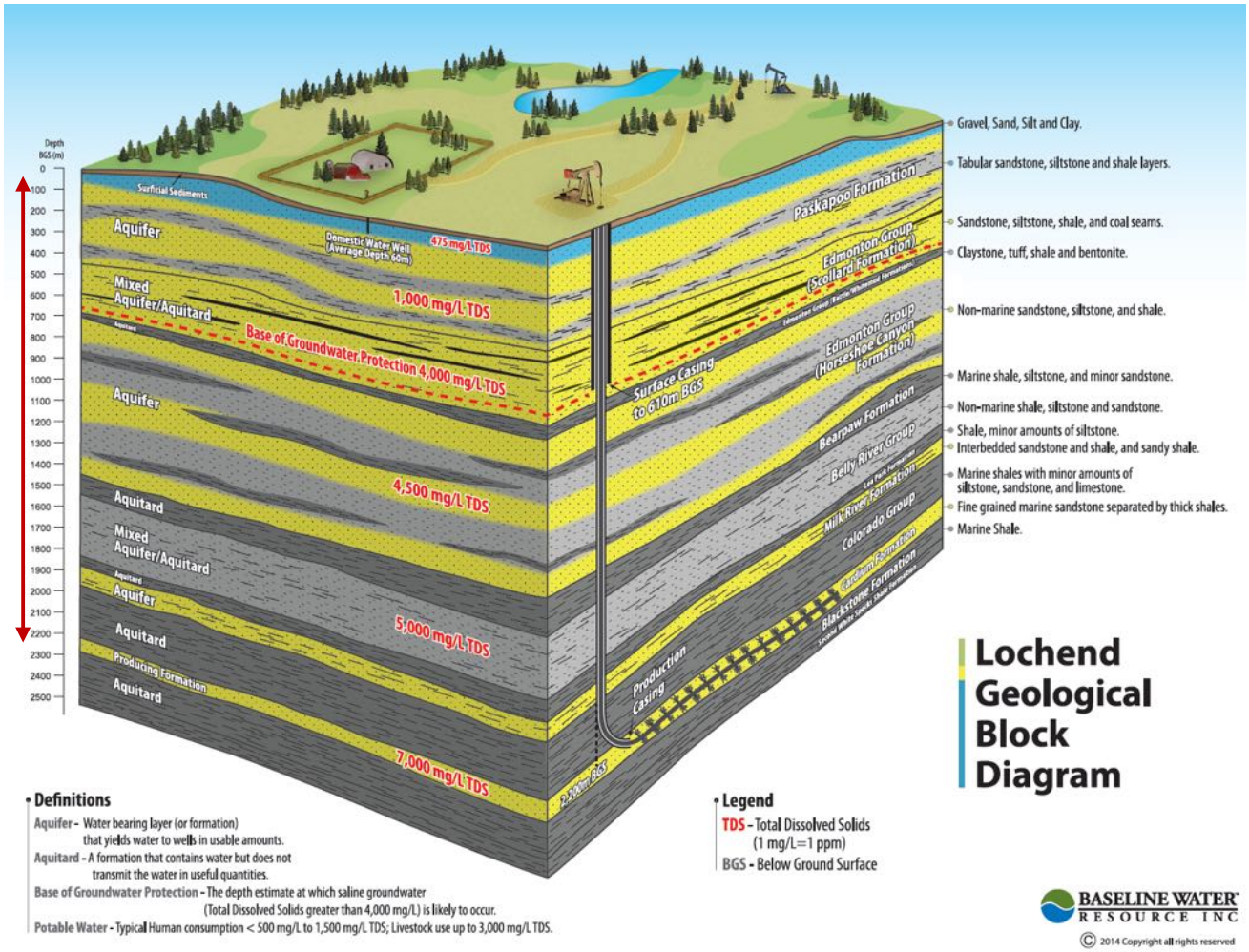

Figure 3. Block diagram showing depth below ground surface of different aquifers and rock formations in the LIPG area.