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Alberta Energy Regulator

Maps of Fresh Groundwater Chemistry, Edmonton-Calgary Corridor, Alberta: VI – Belly River Aquifer

AGS ALBERTA GEOLOGICAL SURVEY

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Maps of Fresh Groundwater Chemistry, Edmonton-Calgary Corridor, Alberta: VI – Belly River Aquifer

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Abstract

In 2008, the Alberta Geological Survey, in collaboration with Alberta Environment and Sustainable Resource Development, began an inventory of groundwater resources within the Edmonton-Calgary Corridor (ECC). One of the products of this inventory is a series of maps showing fresh (maximum of 4000 mg/L total dissolved solids) regional groundwater chemistry of the major bedrock aquifers and overlying sediments aquifer within the ECC.

We assembled more than 20 000 chemical analyses of groundwater within the ECC available from Alberta Environment and Sustainable Resource Development, Alberta Geological Survey, Alberta Innovates – Technology Futures, and the Energy Resources Conservation Board. Chemical analyses were culled using temporal, sampling interval, and geochemical criteria. We created high-quality datasets by assigning usable chemical analyses to the major aquifers in the ECC based on well location and sampling depth. The resulting datasets contain information on groundwater quality within the surficial sediments aquifer and the major bedrock aquifers, including the Paskapoo, Horseshoe Canyon, Belly River, and Bearpaw. We used these datasets to produce hand-contoured maps showing concentration ranges of sodium, potassium, calcium, magnesium, chloride, and sulphate; total dissolved solids; total hardness as calcium carbonate; and total alkalinity as calcium carbonate within the entire thickness of the surficial sediments aquifer and the upper 50 m of each major bedrock aquifer. Maps showing concentration ranges for the upper 50 to 100 m of the Horseshoe Canyon aquifer were also produced. Insufficient data were available within the ECC to map regional groundwater chemistry in the Scollard aquifer. This report presents concentration ranges of sodium, potassium, calcium, magnesium, chloride, and sulphate; total dissolved solids; total hardness as calcium carbonate; and total alkalinity as calcium carbonate in the Belly River aquifer.

1 Introduction

In 2008, the Alberta Geological Survey (AGS), in collaboration with Alberta Environment and Sustainable Resource Development (ESRD), began an inventory of groundwater resources within the Edmonton-Calgary Corridor (ECC). The ECC occupies approximately 50 000 km^2 within central Alberta. The ECC is approximately 200 km wide from west to east and 300 km long from north to south (Figure 1 on page 5). Among the products of this inventory is a series of reports containing maps showing fresh (maximum of 4000 mg/L total dissolved solids) regional groundwater chemistry of the major bedrock aquifers and overlying surficial sediments aquifer within the ECC. The most basic definition of an aquifer is a geological unit from which a sufficient volume of water can be produced over a sufficient duration to meet a given need. Geological units are commonly heterogeneous in nature, making some parts of a unit classifiable as an aquifer while other parts, not. The scope of our mapping efforts was limited to parts of geological units classifiable as an aquifer.

We assembled more than 20 000 chemical analyses of groundwater within the ECC available from ESRD, AGS, Alberta Innovates – Technology Futures (AITF), and the Energy Resources Conservation Board (ERCB). Chemical analyses were culled using temporal, sampling interval, and geochemical criteria. We created high-quality datasets by assigning usable chemical analyses to the major aquifers in the ECC based on well location and sampling depth. The resulting datasets contain information on groundwater quality within the Paskapoo, Horseshoe Canyon, Belly River, and Bearpaw aquifers. We used these datasets to produce hand-contoured maps showing concentration ranges of sodium, potassium, calcium, magnesium, chloride, and sulphate; total dissolved solids; total hardness as calcium carbonate; and total alkalinity as calcium carbonate in each aquifer. Sufficient data existed to map groundwater chemistry within the entire thickness of the surficial sediments aquifer. The sediments were considered an aquifer where sediment thickness exceeded 10 m. Available data was concentrated within the upper 50 m of each major bedrock aquifer. Therefore, groundwater chemistry maps were constructed using data within the upper 50 m of the bedrock aquifers with the exception of the Horseshoe Canyon aquifer, for which sufficient data were available to map an additional interval representing the upper 50 to 100 m.

This is the sixth in a series of reports that will document the chemistry of fresh groundwater within the ECC. Throughout these reports, fresh water is defined as water containing up to 4000 mg/L dissolved solids. This report focuses on results obtained for the Belly River aquifer.

The geology of the ECC is mainly characterized by consolidated sedimentary rocks of Cretaceous age to Paleogene age overlain by unconsolidated deposits of Neogene to Quaternary age. Table 1 describes the various geological units mapped and discussed in the ECC area, with the youngest layer at the top.

The subcrop area of each unit in the bedrock surface below the surficial sediments is shown in Figure 2 on page 6. This report serves two purposes: to describe data sources and sample selection techniques used in developing maps of fresh groundwater chemistry within the ECC and to present a series of maps describing fresh groundwater chemistry within the Belly River aquifer within the ECC.

2 Compilation of Groundwater Chemical Analyses

2.1 Data Sources

We assembled more than 20 000 chemical analyses of groundwater within the ECC available from ESRD, AGS, AITF, and the ERCB.

Table 1. Geological units and associated selected characteristics within the ECC.

Unit Name	Period	Rocks and Selected Physical Properties
Surficial sediments	Quaternary to Neogene	• nonmarine • highly variable grain size and mineralogy • mixed aquifer/aquitard
Paskapoo Formation	Paleogene	• nonmarine, calcareous, cherty sandstone, siltstone and mudstones • generally a coarse-grained formation • aquifer
Scollard Formation	Cretaceous to Paleogene	• nonmarine feldspathic sandstone • mudstone containing the clay mineral bentonite • coalbeds • mixed aquifer/aquitard
Battle Formation	Cretaceous	• bentonitic mudstone interbedded with consolidated silica-rich, volcanic ash (siliceous tuff) • aquitard
Horseshoe Canyon Formation	Cretaceous	• nonmarine, feldspathic, clay-rich sandstone • bentonitic mudstone • carbonaceous shale • mixed aquifer/aquitard
Bearpaw Formation	Cretaceous	• marine shale and sandstone • mixed aquifer/aquitard
Belly River Group	Cretaceous	• nonmarine feldspathic sandstone • clay-rich siltstone and mudstone • aquifer

2.2 Culling Process

Assembled chemical analyses were culled based on geochemical, sampling interval (screened interval), and temporal (time of sample collection) criteria.

2.2.1 Geochemical Criteria

Geochemical culling criteria were modified from those of Hitchon and Brulotte (1994) as follows:

1) Analytical values for all reported constituents were required (no calculated values).
2) The presence of carbonate ion in usable analyses was permitted only if reported pH was greater than 8.3.
3) Sample density was ignored as a culling criterion.

Acceptable charge balance of chemical analyses was constrained to greater than or equal to −5% and less than or equal to +5%. Samples with total dissolved solids greater than 4000 mg/L were removed from the data to create maps of the chemicals characteristics for only freshwater resources.

2.2.2 Sampling Interval

Wells with a screened interval greater than 15 m in length or with multiple screened zones were excluded from the dataset in order to more accurately assign chemical analyses to a single geological formation. Restricting screened length to a maximum of 15 m also helps to control for the possibility of vertical heterogeneity in groundwater chemistry.

2.2.3 Temporal

Available data have sampling dates as far back as the 1920s. After screening the data, we determined that data with sampling dates going back to 1980 were sufficient to suitably represent the geochemistry of the selected aquifers.

3 Assignment of Water Wells to Hydrogeological Units

3.1 Hydrogeological Units

The hydrogeological units mapped include the surficial sediments, Paskapoo, Horseshoe Canyon, Bearpaw, and Belly River aquifers. Water wells are the source of data in these aquifers within the ECC. The mapped extent of aquifers in this report was defined by a combination of the ECC boundary, the subcrop area of the aquifers, and the westward extent of fresh groundwater. Sediments were considered to form an aquifer where sediment thickness reached a minimum of 10 m, as determined from Slattery and Barker (2011).

Assignment Process

Data which passed the geochemical, temporal, and sampling interval culling criteria were imported into ArcMap. Using mapped hydrogeological units, data were assigned to the appropriate aquifer. Data were assigned to an aquifer using the elevations of the hydrogeological units and of the open well intervals. If data were associated with a well that straddled more than one aquifer, the data were removed from the dataset.

4 Mapping Chemical Constituents

4.1 Geostatistical Analysis

Chemistry data for each formation was analyzed using the Geostatistical Analyst function in ArcMap. Each chemical constituent was examined to determine how the data were distributed. If the data were skewed, a log or Box-Cox transform (Sakia, 1992) was applied to approximate a normal distribution, further highlighting spatial trends within datasets. Duplicate data were left in the dataset because there was no scientifically robust way to choose just one value per location. The Geostatistical Analyst function uses the mean value where duplicate data are present. Once the data were prepared, the distribution of each chemical constituent for each formation was assessed. Ordinary Kriging methods (Deutsch and Journel, 1998) were used to generate a statistical model that minimized root-mean-square error between the generated model and available data.

4.2 Chemical Concentration Maps

Chemical maps generated from the statistical models were manually corrected in order to better honour the available data. The manually corrected chemical maps showing concentration ranges of selected constituents in fresh groundwater of the Belly River aquifer are the final products of this report. Mapped chemical constituents and attributes for the Belly River aquifer include calcium (Figure 3), magnesium (Figure 4), sodium (Figure 5), potassium (Figure 6), chloride (Figure 7), sulphate (Figure 8), alkalinity (Figure 9), iron (Figure 10), total dissolved solids (Figure 11), and hardness (Figure 12). Control points used in construction of each map are shown on Figures 3–12.

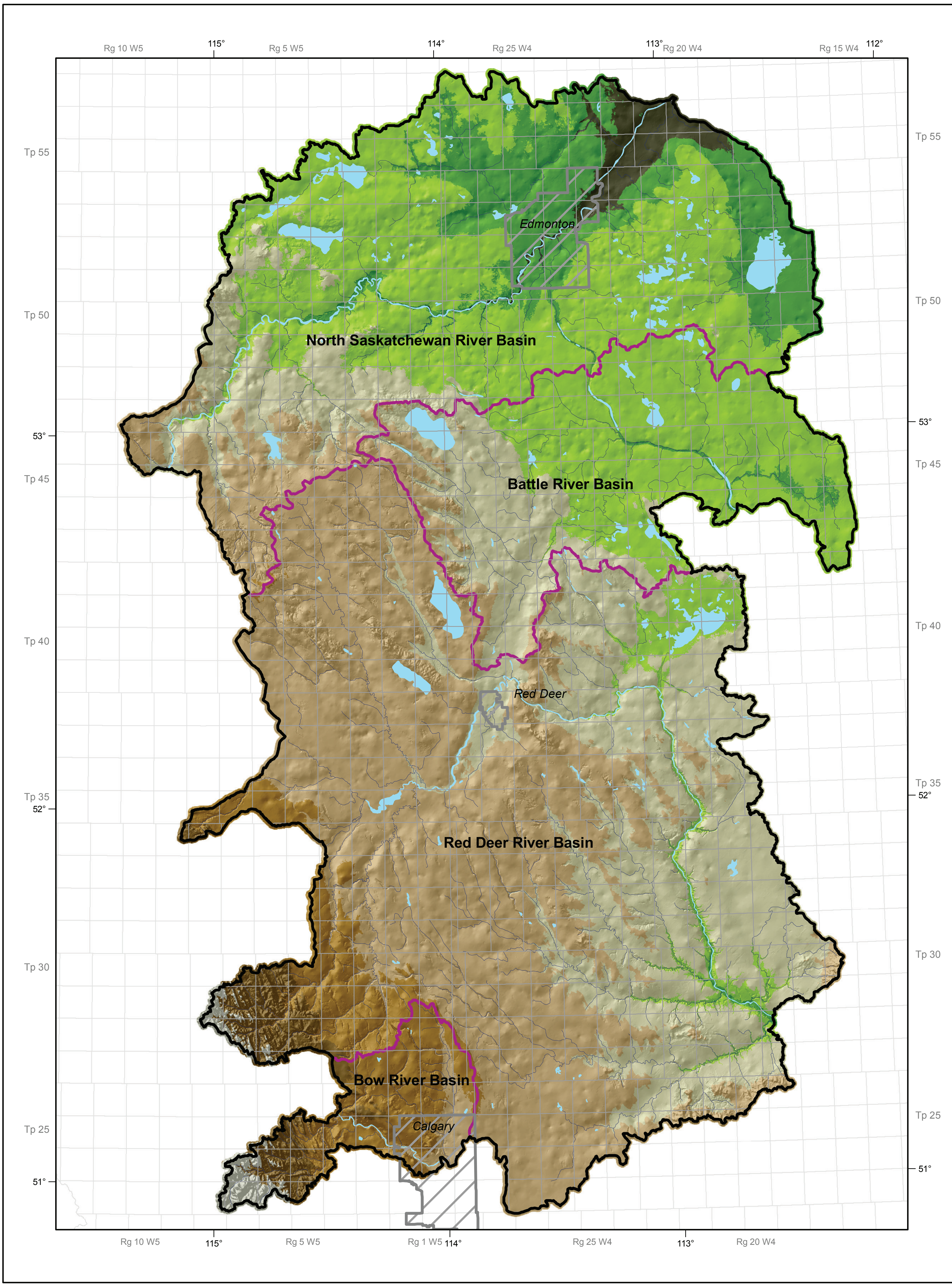

Figure 1. Edmonton-Calgary Corridor study area with topography and major drainage basins.

Ground Elevation (m asl)

- 582 - 650
- 651 - 700
- 701 - 800
- 801 - 900
- 901 - 1100
- 1101 - 1300
- 1301 - 1500
- 1501 - 2450

Major Basin Boundary

0 20 40 60 80 100 km

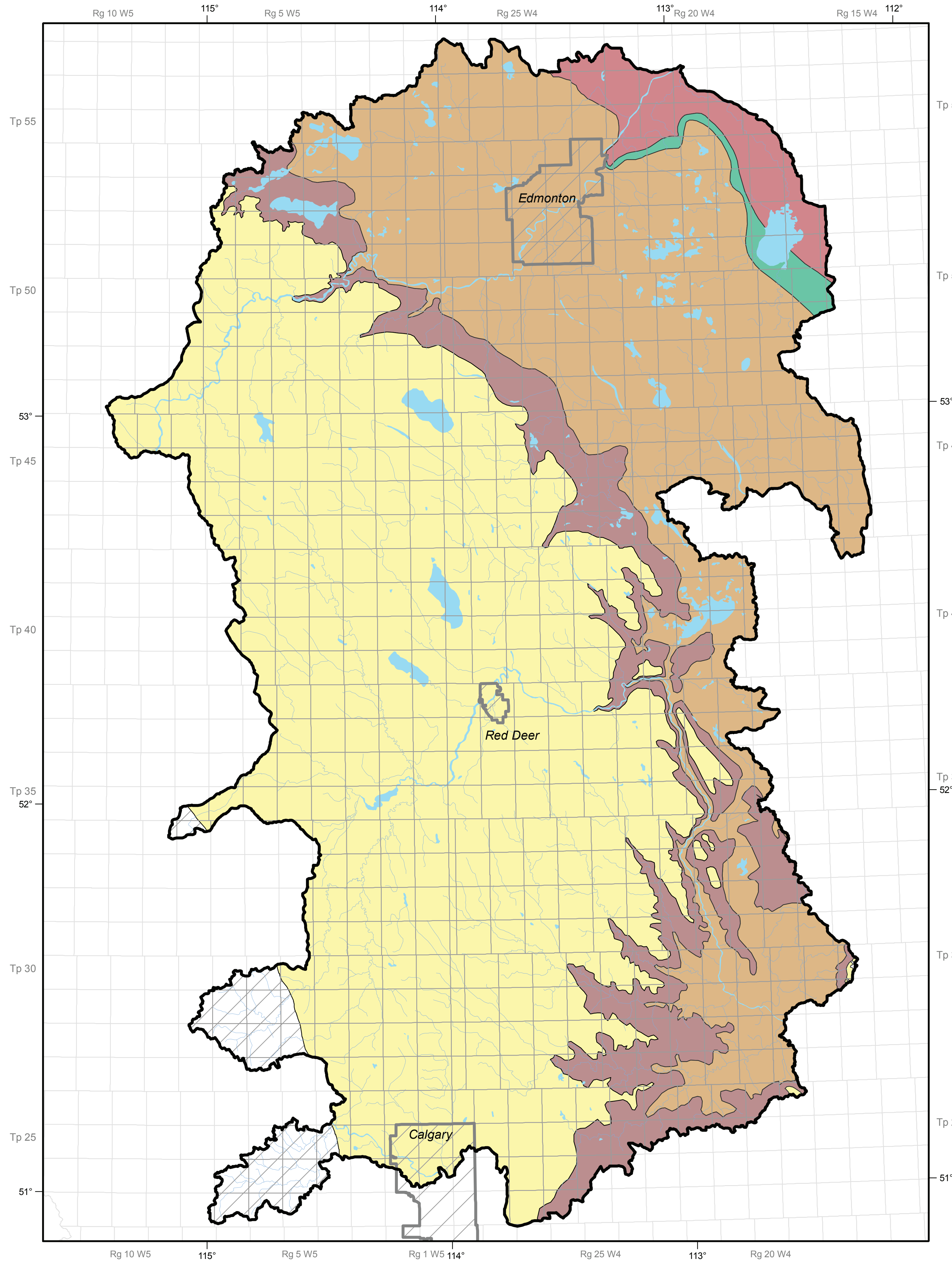

Figure 2. Bedrock geology in the Edmonton-Calgary Corridor.

Geological Formations

- Bedrock in deformed zone
- Horseshoe Canyon Formation
- Paskapoo Formation
- Belly River Group
- Scollard Formation
- Bearpaw Formation

0 25 50 75 100 km

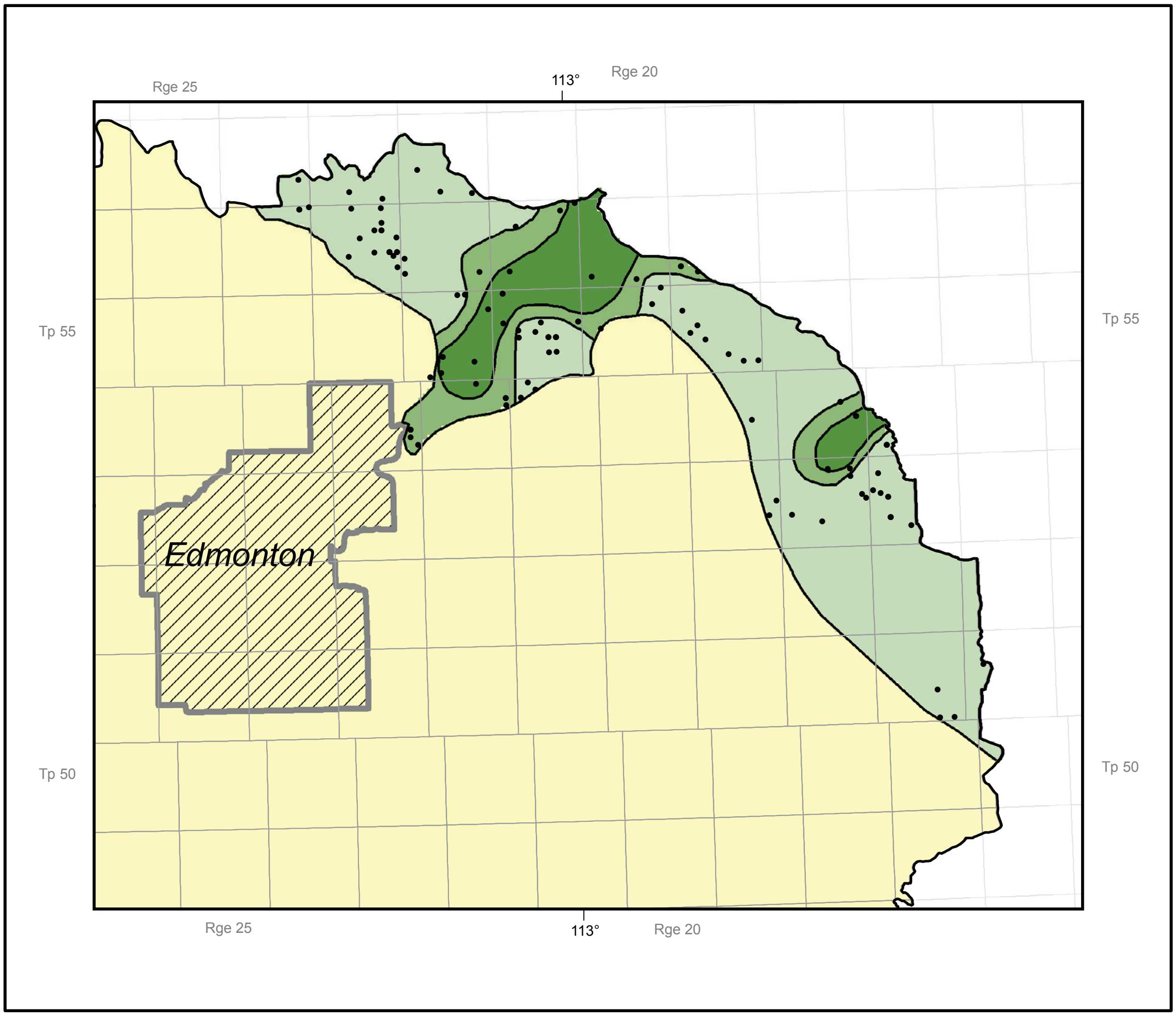

Figure 3. Ranges of calcium concentration in fresh groundwater in the Belly River aquifer.

• Control Point

Range Boundary (dashed where inferred)

Ranges of Calcium Concentration (mg/L)

<40

40-100

>100

Belly River Group Not Mapped

0 10 20 30 40 50 km

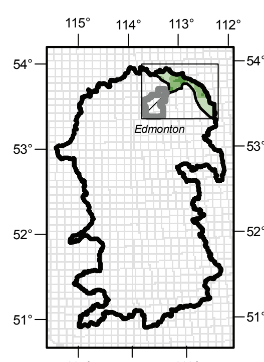

Figure 3 Map Area

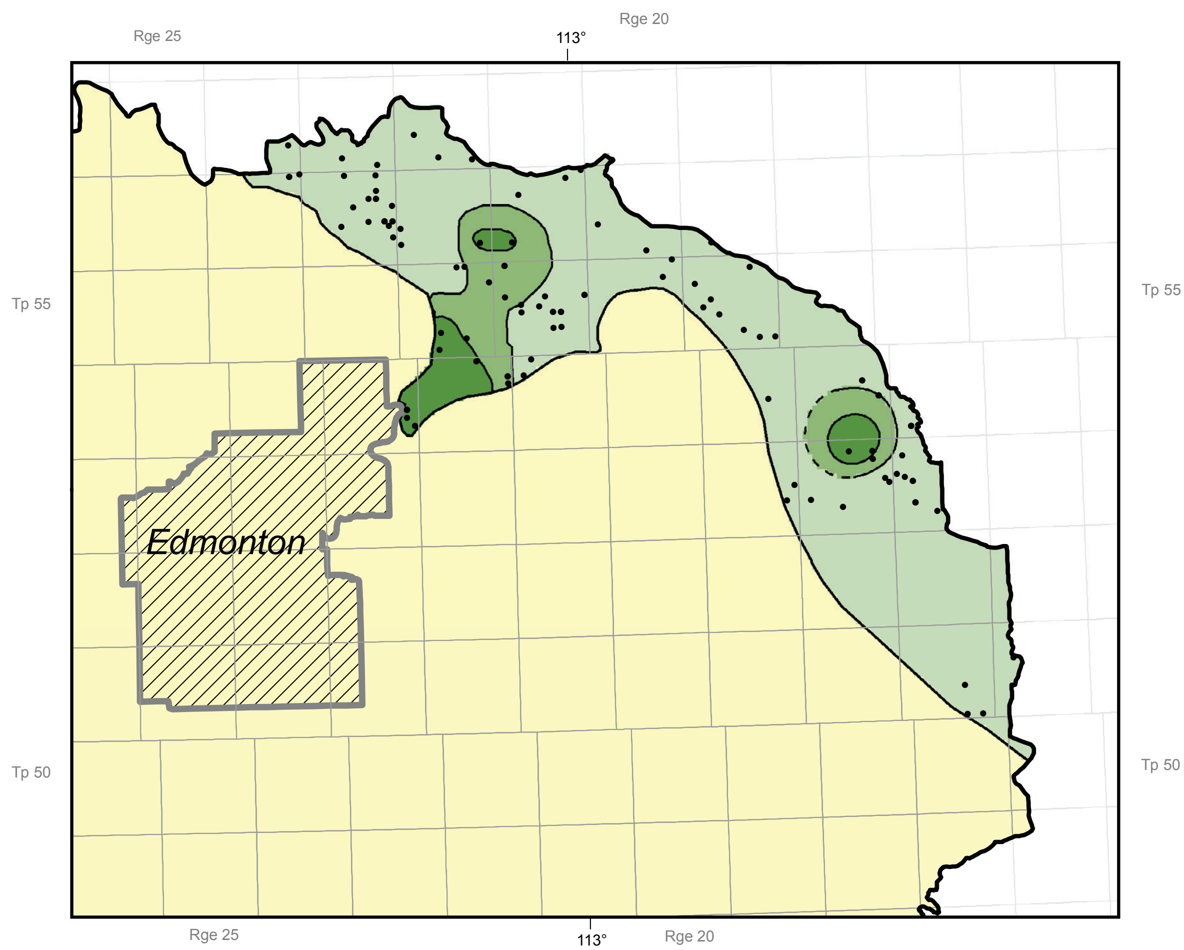

Figure 4. Ranges of magnesium concentration in fresh groundwater in the Belly River aquifer.

• Control Point

Range Boundary (dashed where inferred)

Ranges of Magnesium Concentration (mg/L)

<20

20-40

>40

Belly River Group Not Mapped

0 10 20 30 40 50 km

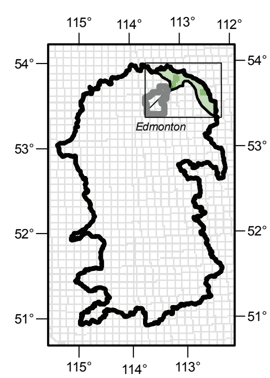

Figure 4 Map Area

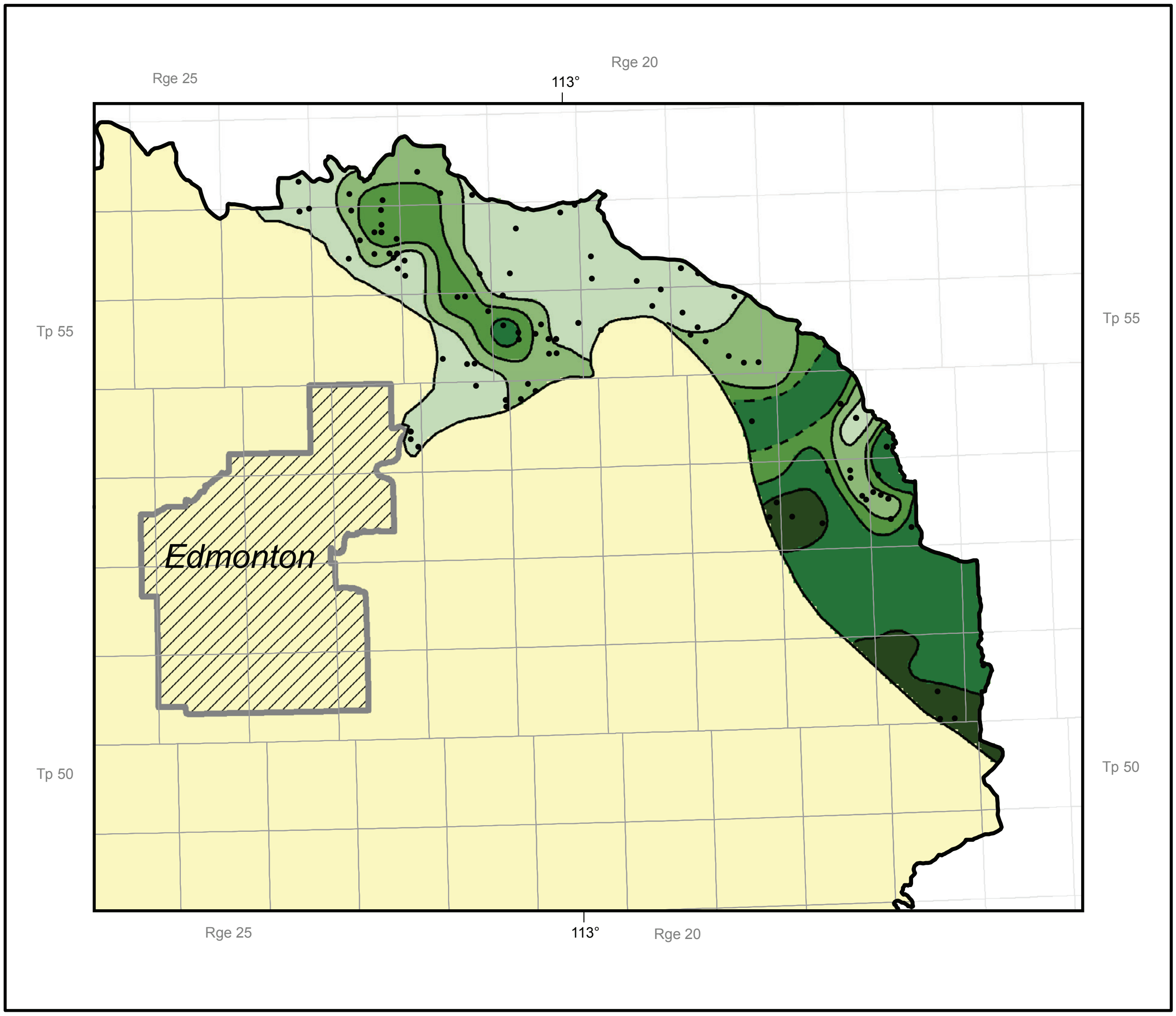

Figure 5. Ranges of sodium concentration in fresh groundwater in the Belly River aquifer.

• Control Point

—— Range Boundary (dashed where inferred)

Ranges of Sodium Concentration (mg/L)

- <400
- 400-500
- 500-600
- 600-700
- >700
- Belly River Group Not Mapped

0 10 20 30 40 50 km

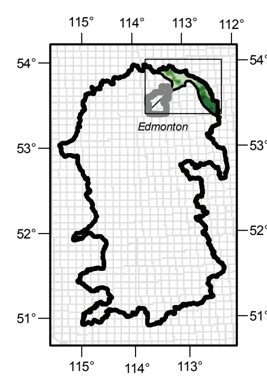

Figure 5 Map Area

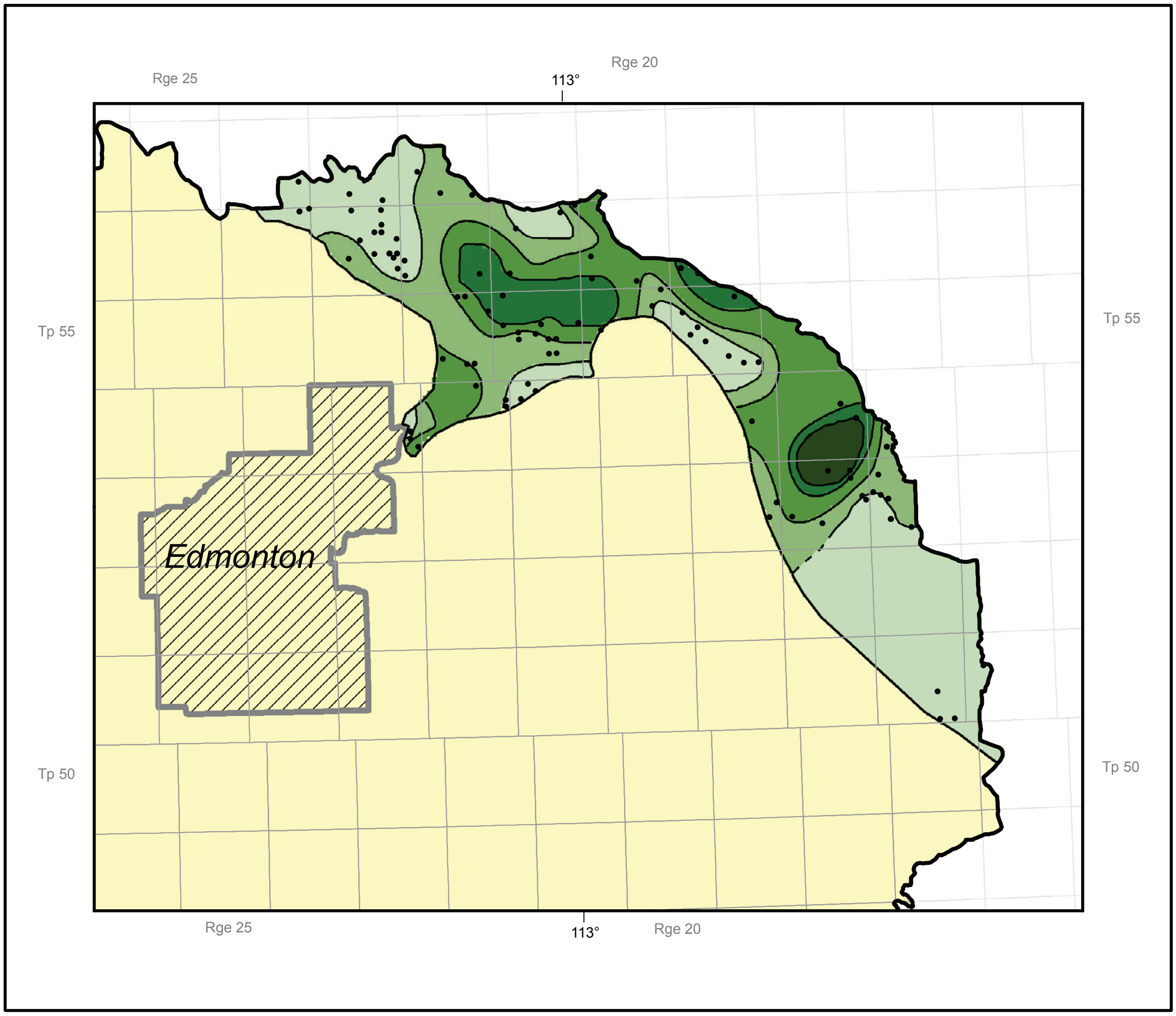

Figure 6. Ranges of potassium concentration in fresh groundwater in the Belly River aquifer.

• Control Point

—— Range Boundary (dashed where inferred)

Ranges of Potassium Concentration (mg/L)

- <3
- 3-4
- 4-5
- 5-6
- >6
- Belly River Group Not Mapped

0 10 20 30 40 50 km

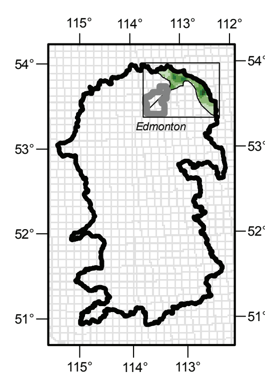

Figure 6 Map Area

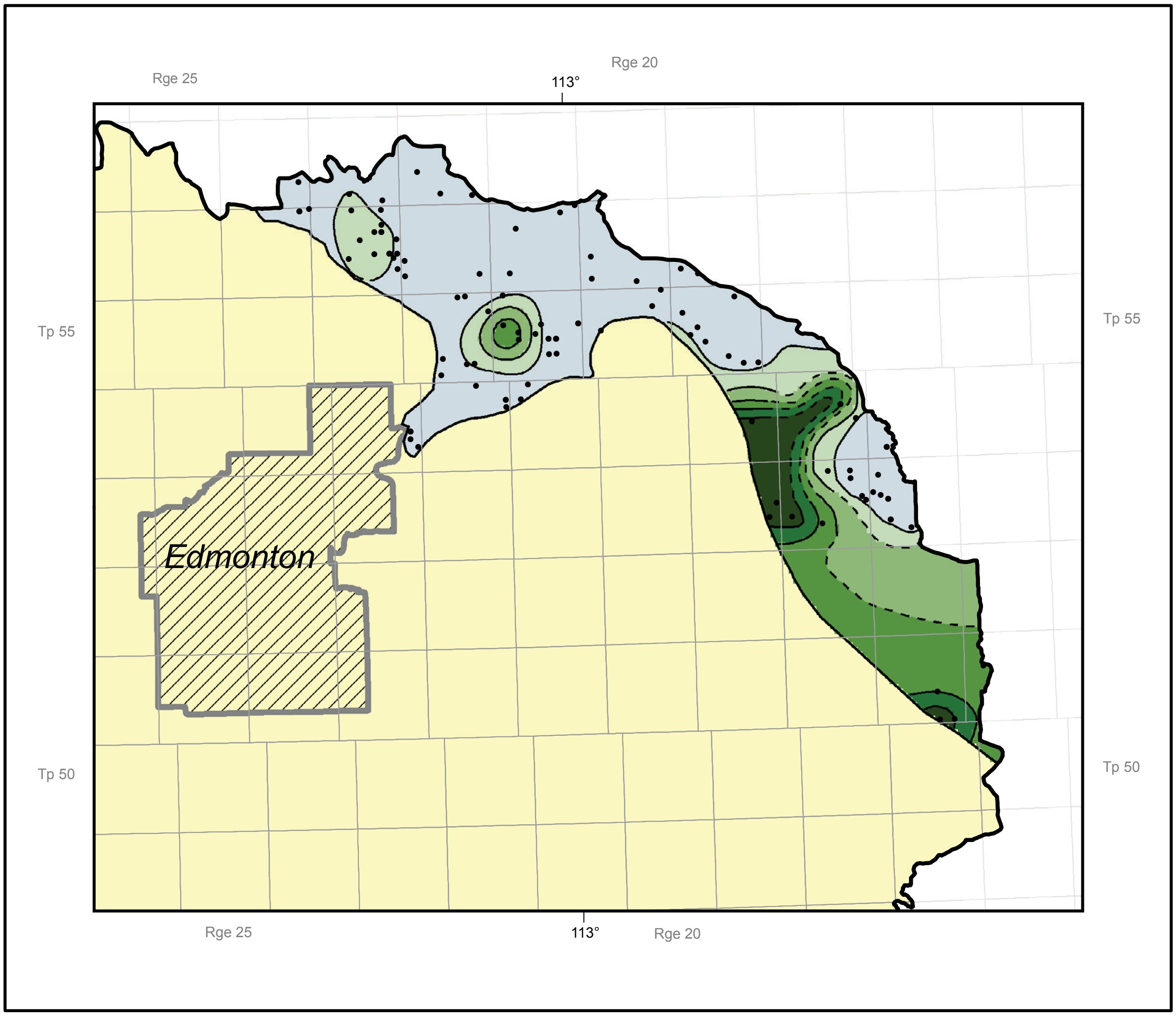

Figure 7. Ranges of chloride concentration in fresh groundwater in the Belly River aquifer.

• Control Point

——— Range Boundary (dashed where inferred)

Ranges of Chloride Concentration (mg/L)

<200

200-400

400-600

600-800

800-1000

>10000

Belly River Group Not Mapped

0 10 20 30 40 50 km

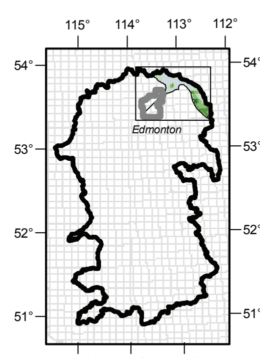

Figure 7 Map Area

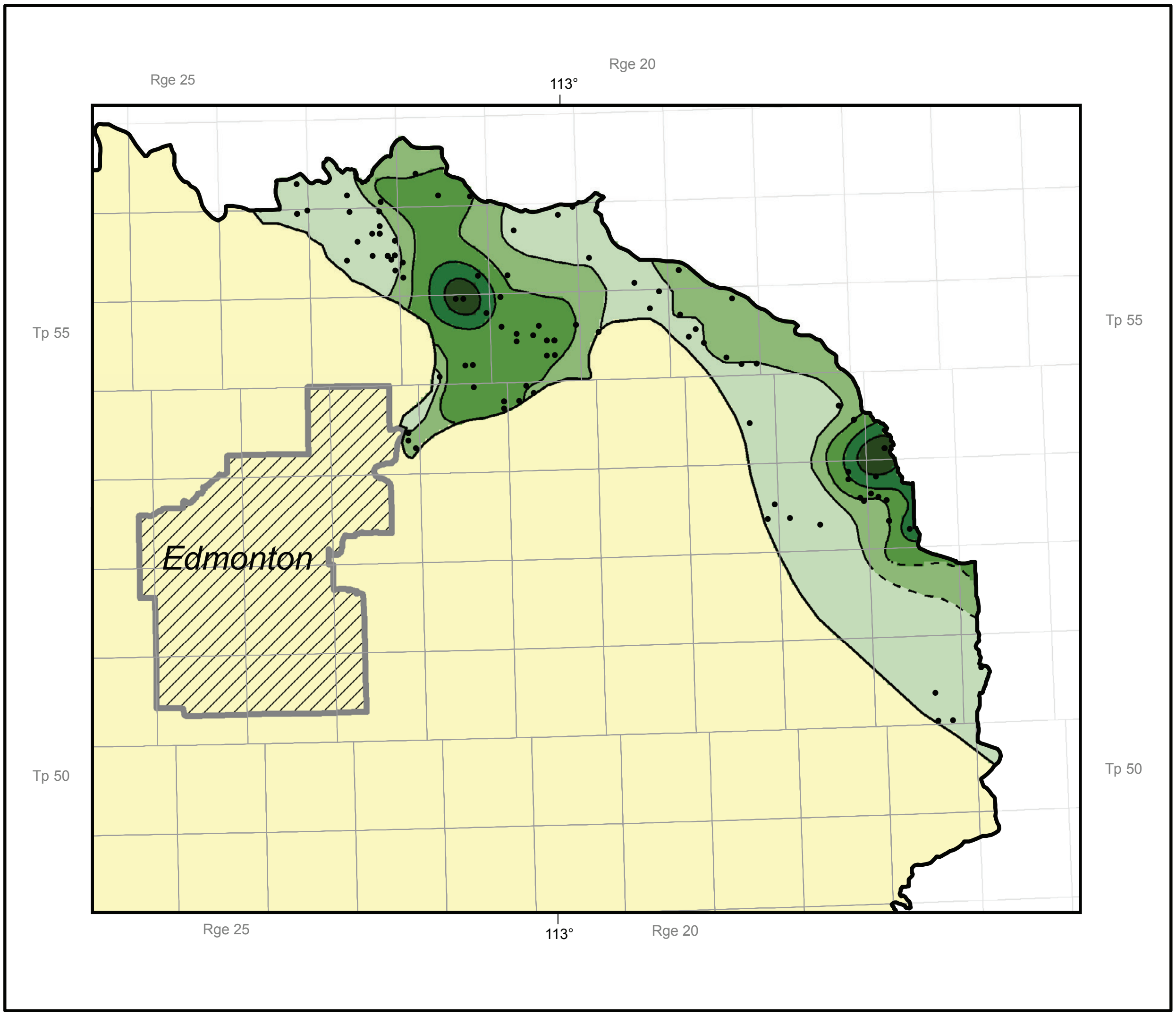

Figure 8. Ranges of sulphate concentration in fresh groundwater in the Belly River aquifer.

• Control Point

—— Range Boundary (dashed where inferred)

Ranges of Sulphate Concentration (mg/L)

- <150
- 15-300
- 300-450
- 450-600
- >600
- Belly River Group Not Mapped

0 10 20 30 40 50 km

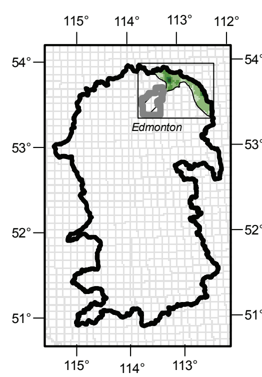

Figure 8 Map Area

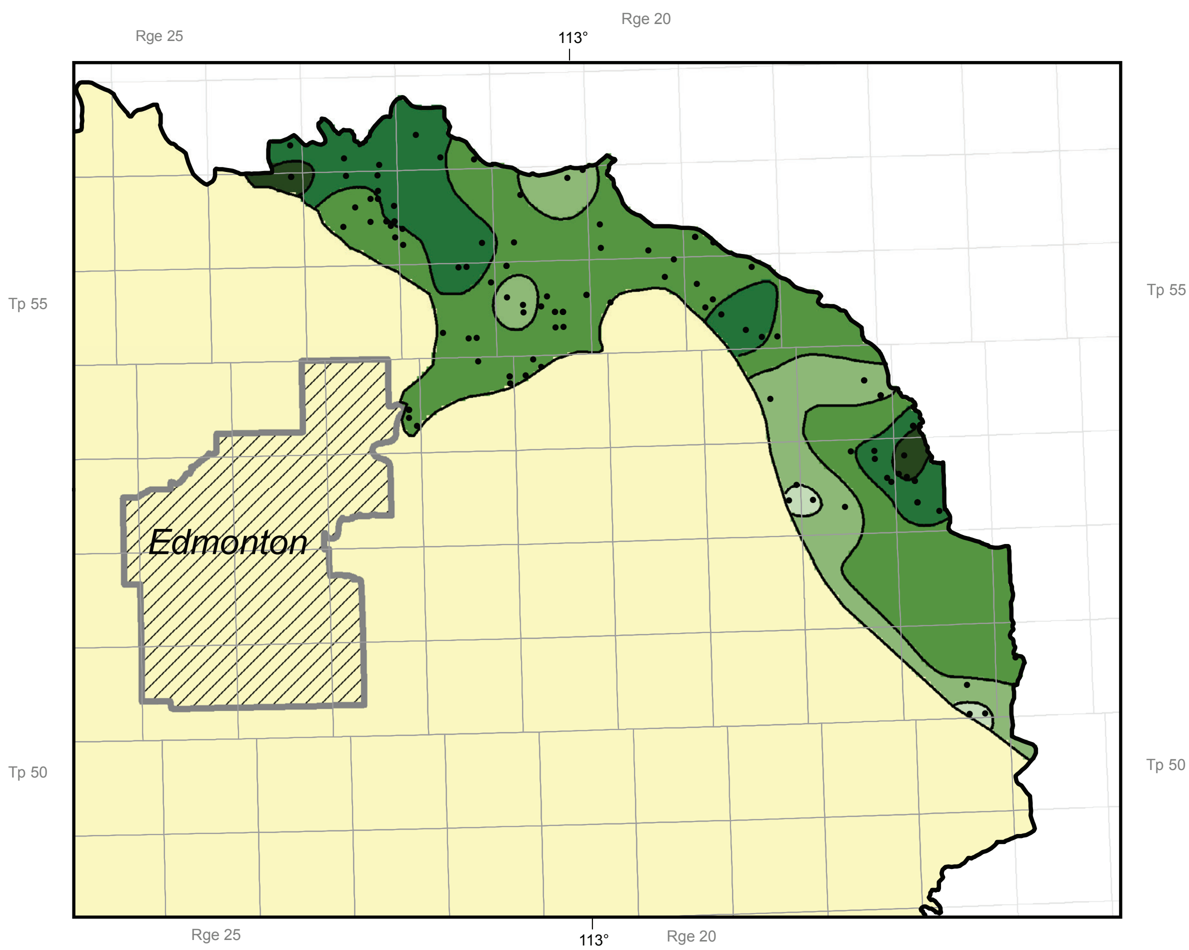

Figure 9. Ranges of alkalinity as calcium carbonate in fresh groundwater in the Belly River aquifer.

• Control Point

—— Range Boundary (dashed where inferred)

Ranges of Alkalinity as Calcium Carbonate (mg/L)

- <350
- 350-450
- 450-550
- 550-650
- >650
- Belly River Group Not Mapped

0 10 20 30 40 50 km

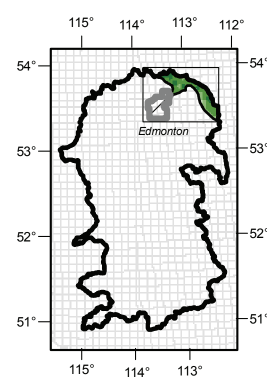

Figure 9 Map Area

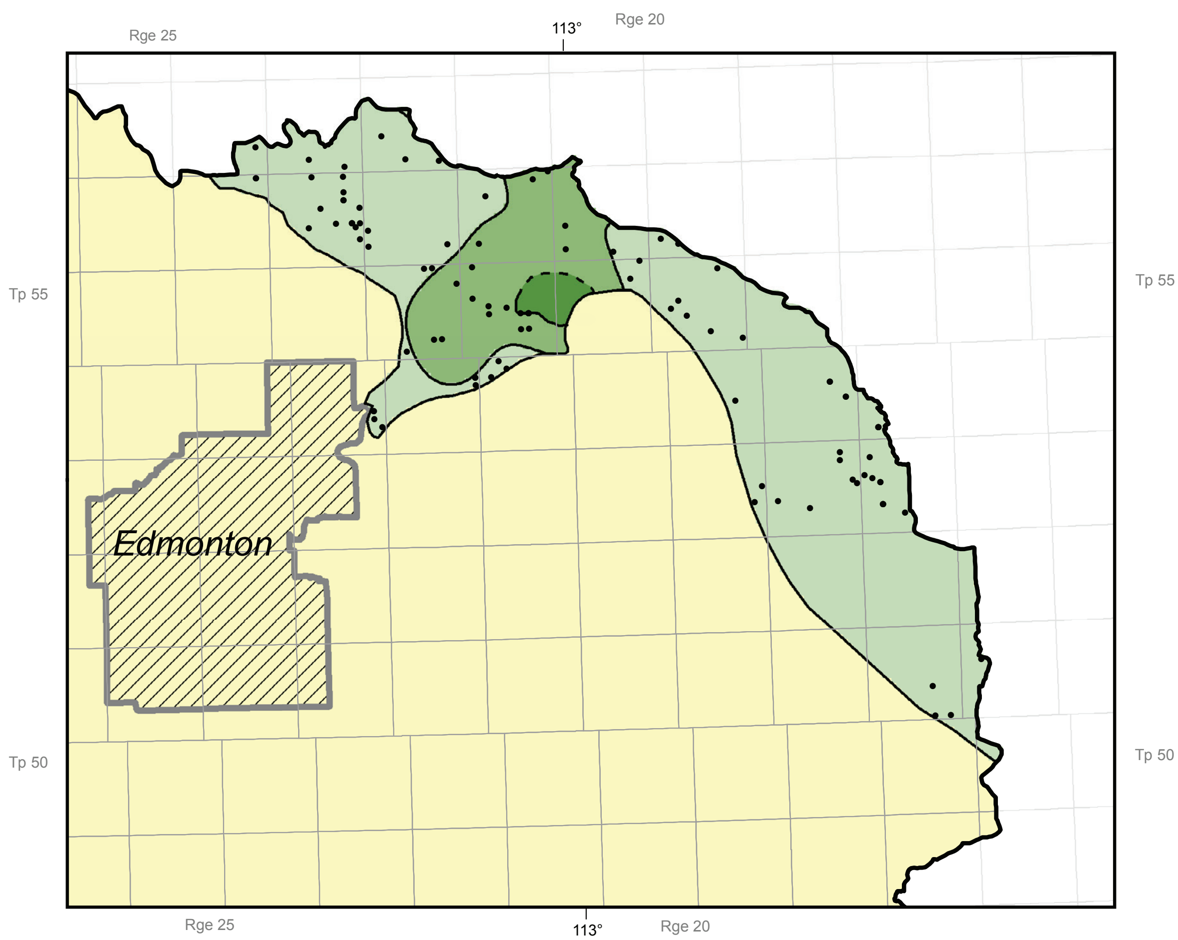

Figure 10. Ranges of iron concentration in fresh groundwater in the Belly River aquifer.

• Control Point

Range Boundary (dashed where inferred)

Ranges of Iron Concentration (mg/L)

- <1
- 1-2
- >2
- Belly River Group Not Mapped

0 10 20 30 40 50 km

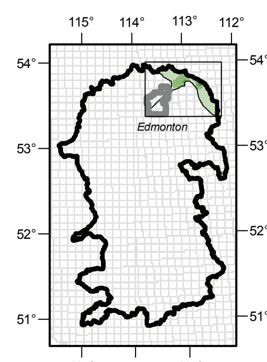

Figure 10 Map Area

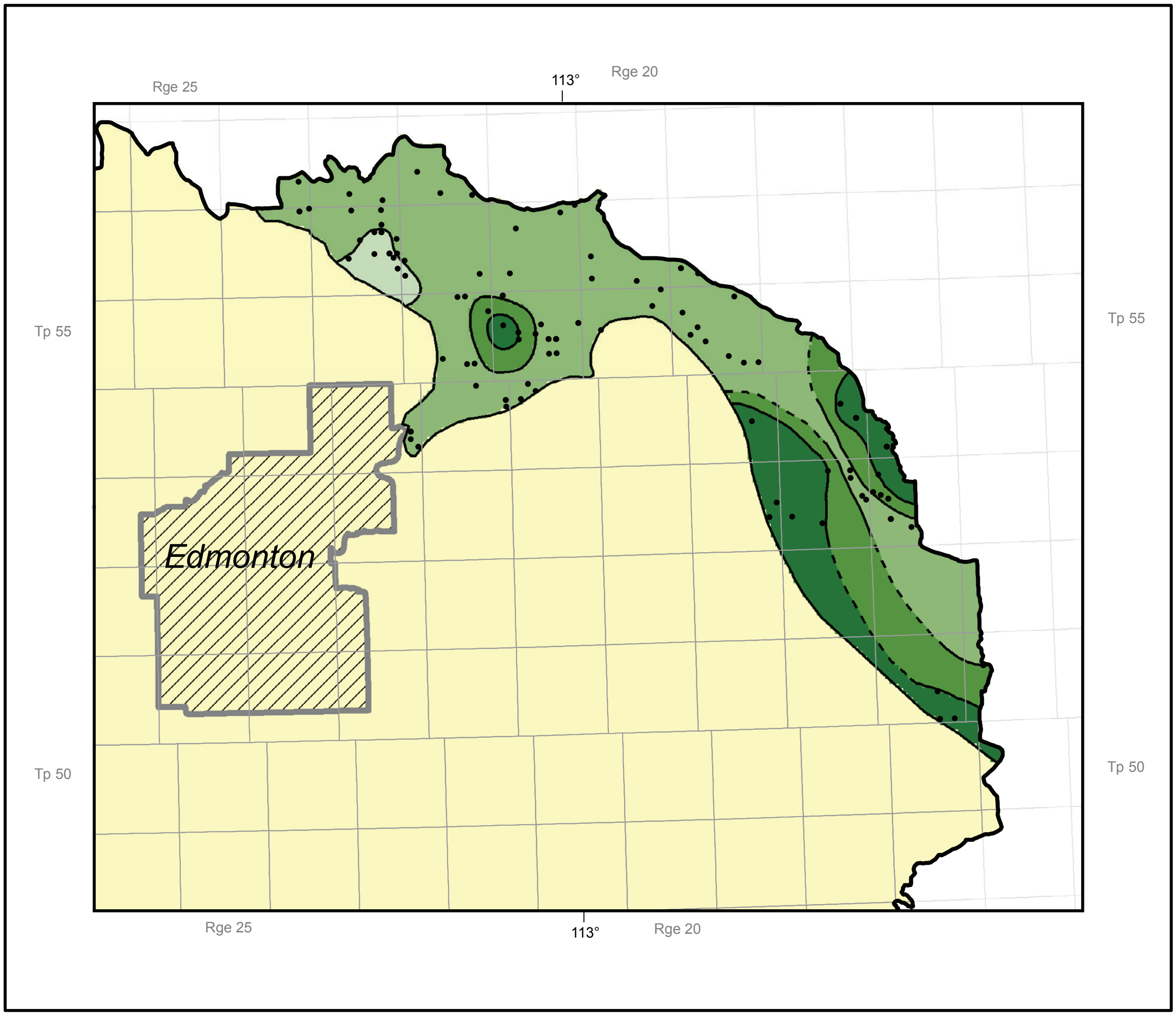

Figure 11. Ranges of total dissolved solids concentration in fresh groundwater in the Belly River aquifer.

• Control Point

Range Boundary (dashed where inferred)

Ranges of Total Dissolved Solids (mg/L)

<1,000

1,000-1,500

1,500-2,000

>2,000

Belly River Group Not Mapped

0 10 20 30 40 50 km

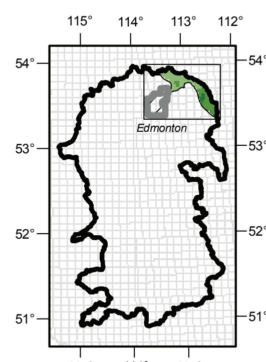

Figure 11 Map Area

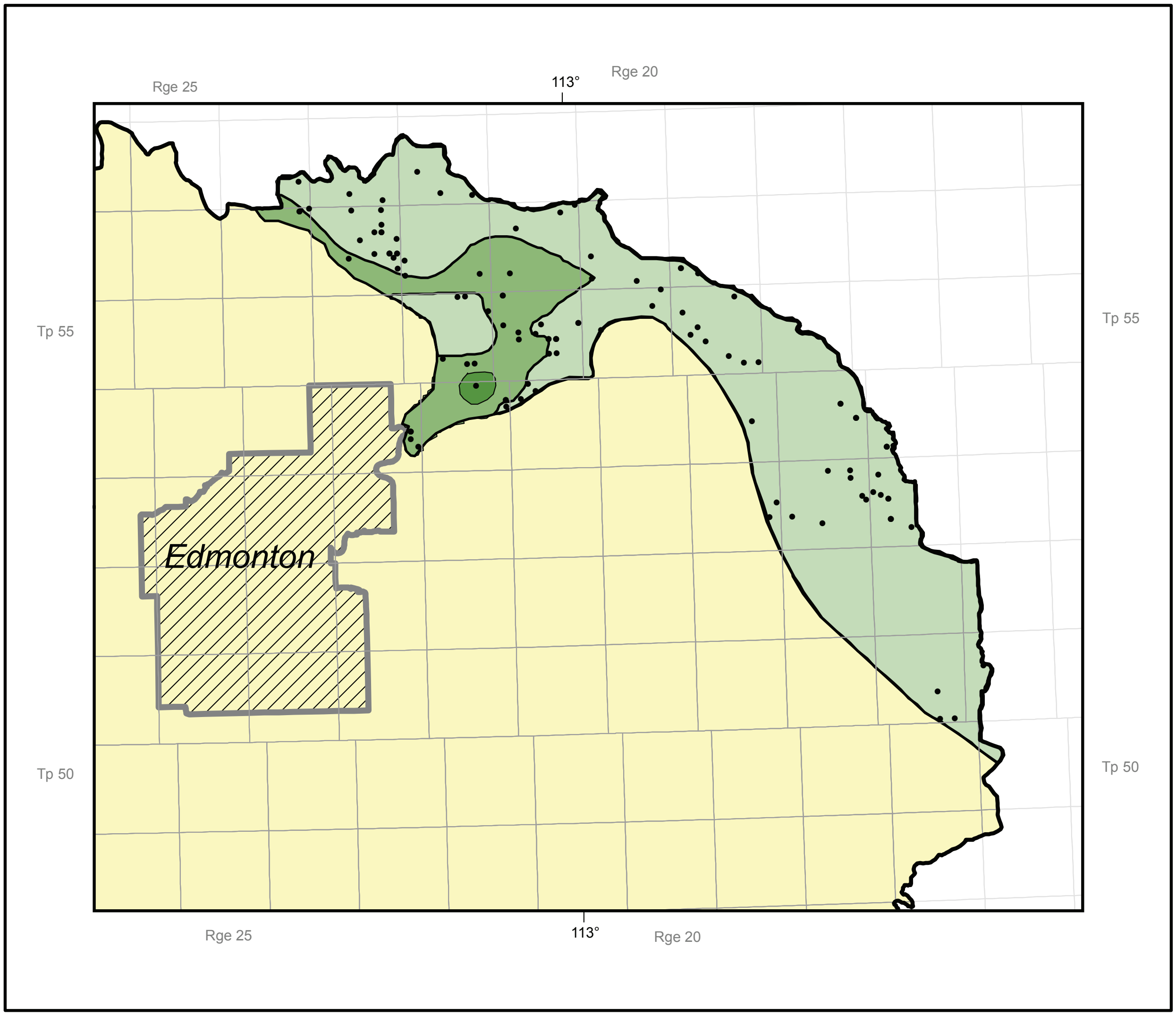

Figure 12. Ranges of hardness as calcium carbonate in fresh groundwater in the Belly River aquifer.

• Control Point

Range Boundary (dashed where inferred)

Ranges of Hardness as Calcium Carbonate (mg/L)

- <250
- 250-500
- >500
- Belly River Group Not Mapped

0 10 20 30 40 50 km

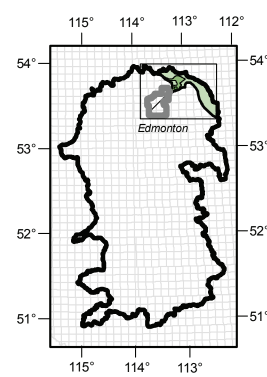

Figure 12 Map Area

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