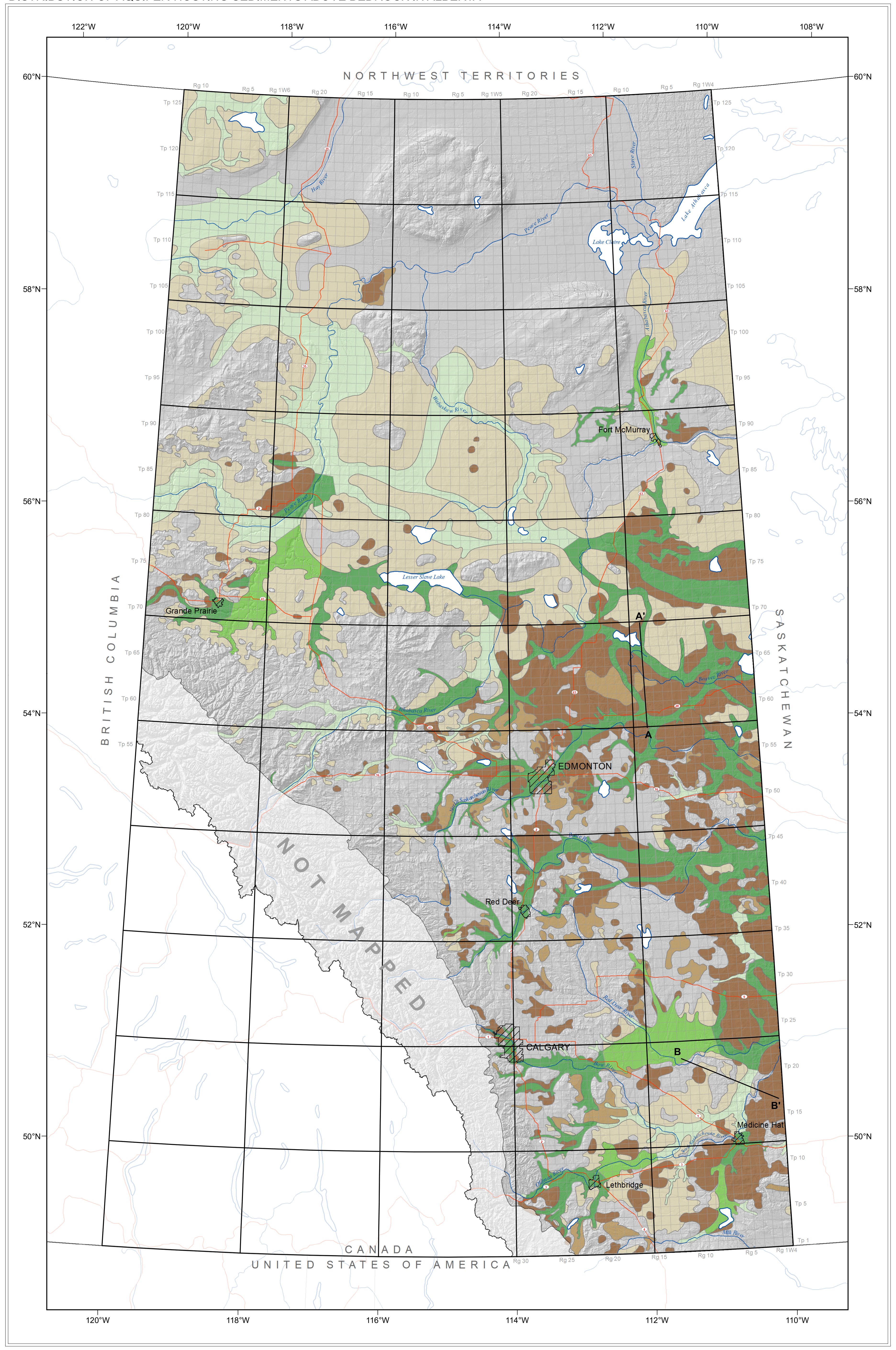
DISTRIBUTION OF AQUIFER-HOSTING SEDIMENTS ABOVE BEDROCK IN ALBERTA



SYMBOL LEGEND

Aquifer-hosting sediments

Known	Inferred	Potential	Buried valleys / Plains and uplands

Hillshaded land surface

Cross-section line A —— A'

Introduction

This map shows the distribution of sediments above bedrock that are either known or are inferred to contain aquifers. Sediments are defined as being aquifer hosting if they contain sufficient permeable material to supply groundwater to wells. Evidence of permeable material is based on the geologically determined occurrence of sand and gravel deposits and the distribution of water supply wells completed above bedrock (indicative of groundwater production from sediments above bedrock). Aquifer-hosting sediments are further classified according to their physiographic position on the bedrock surface: those within buried bedrock valleys, and those on the surrounding bedrock plains and uplands. The bedrock plains and uplands physiographic positions are grouped together in this map.

Areas containing thick sediments, such as buried valleys, may host multiple aquifers, which typically vary in thickness and lateral extent. However, delineating individual aquifers or the degree of vertical and lateral hydraulic connectivity of aquifer systems is beyond the purpose of this map.

Background

Sand and gravel deposits occupying buried valleys represent significant aquifer systems across Alberta. Most buried valleys were eroded by eastward-flowing, pre-glacial river systems. Following their initial formation, the valleys were further modified by glacial and fluvial processes (Leckie, 2006; Cummings et al., 2012) including infilling with a range of sedimentary deposits of different stratigraphic complexity, depending on the depositional history of the valley (Figure 1). The most complex infill sequences occur in the deeply buried (up to 300 m) valleys of northeast Alberta which contain multiple layers of gravel, sand, clay, and diamict, as well as displaced bedrock (Andriashek and Fenton, 1989; Parks et al., 2005; Figure 1: A–A'). Elsewhere, infill sequences generally consist of sand and gravel units at the base of the valley, which are overlain by poorly sorted glacial diamicts and fine-grained glaciolacustrine sediments (Figure 1: B–B'). Regardless of the depositional history, basal sands and gravels are widely distributed along buried valleys and when saturated, commonly represent units with high aquifer potential.

While the distribution of aquifer systems in buried valleys are well-constrained by the bedrock physiography, the distribution of aquifers on the surrounding bedrock plains and uplands is less predictable. Across much of southern Alberta, sediments are typically thin and aquifers, if present, are more localized, either comprising small, discrete sand and gravel bodies deposited directly on the bedrock surface (e.g., Atkinson et al., 2017, Hartman et al., 2020) or disconnected sandy lenses within lower permeability glacial diamicts. Locally, sand and gravel deposits at the modern land surface (Pawley et al., 2015) can host aquifers provided they are saturated. Conversely, in northeast Alberta, sediments are thick and contain laterally extensive aquifers that may extend across buried valleys as well as the surrounding bedrock plains and upland physiographic settings (e.g., Figure 2, Andriashek and Fenton, 1989; Andriashek and Atkinson, 2007).

Data Sources and Methods

This work builds on previous regional mapping of sand and gravel deposits and aquifers by the Alberta Geological Survey (AGS; Figure 2) and the Alberta Research Council (ARC; see Lemay and Guha, 2009). Incorporating new provincial scale mapping and predictive modelling (Figures 3, 4, and 5) has filled the gaps between previously mapped areas and delineated aquifer-hosting sediments throughout the province.

The cumulative thickness of sand and gravel in the sediments above bedrock (Figure 3) was modelled using a predictive machine learning approach. Lithology information from over 310 000 water wells (Government of Alberta, 2021a) and AGS/ARC borehole logs were compared against physiographic and geological characteristics of the bedrock and overlying sediments. Physiographic characteristics are primary (e.g., elevation, slope, relief), derived (e.g., topographic roughness, relative heights between valleys and/or ridges), and qualitative (e.g., morphological setting, boundaries of buried valleys). Geological characteristics include those from provincial-scale surficial and bedrock geological mapping (Fenton et al. 2013; Prior et al. 2013) and sediment thickness modelling (Atkinson et al., 2020a; Figure 5). The model is well constrained where the density of lithological data is high (populated, agricultural, and industrial areas; Figure 3), but relies more heavily on the correlation between lithology and the physiographic and geological characteristics in areas where lithological data density is low.

In addition to mapped and modelled sand and gravel deposits, the density of water supply wells above bedrock (Figure 4) and sediment thickness distribution (Figure 5) also inform the delineation and classification of aquifer-hosting sediments. A high density of supply wells (generally greater than 1 well per 10 km²) is interpreted as indicative of the presence of aquifer-hosting sediments. In the populated urban, agricultural, and industrial areas of Alberta (i.e., outside the Green [forested] Area, Figure 4) high densities of supply wells are often associated with thick sediments, even where cumulative thickness of sand and gravel is low. Presumably, sufficient water can be extracted from thick sediments that are finer than sand and gravel (e.g., silt), are fractured, or contain sand and gravel bodies that are too thin or discontinuous to map/model at regional to provincial scales. Consequently, sediment thickness greater than 15 m is considered corroboratory evidence of aquifer-hosting sediments and informs its classification in this map; however, thick sediment alone does not necessarily imply the presence of aquifer-hosting sediments.

Aquifer-Hosting Sediment Classification

Aquifer-hosting sediments are primarily classified according to the confidence by which they can be mapped. Within the buried valleys, aquifer-hosting sediments are well-constrained by the bedrock topography (Atkinson et al., 2020b), bedrock physiographic regions (Atkinson, 2021), and province-wide modelling of sand and gravel in the sediments above bedrock (Figure 3). Their classification primarily relies on the density of supply wells within the buried valley (Table 1). Aquifer-hosting sediments mapping and classification on the surrounding bedrock plains and uplands uses a combination of supply well density (Figure 4), the distribution of mapped sand and gravel deposits (Figure 2), predictive modelling of sand and gravel (Figure 3), and sediment thickness (Figure 5) as shown in Table 1.

Table 1: Aquifer-hosting sediment classification.

Confidence	Bedrock physiographic setting			
	Buried bedrock valley	Bedrock plains and uplands		
	Supply well density[1]	Supply well density[1]	Cumulative sand and gravel thickness[2]	Sediment thickness[3]
Known	high	high	high	high
Inferred	low to high	high	low	high
		high	high	low
Potential	low	low	high	high

[1] Supply well density (Figure 4) generally above 1 well per 10 km² is considered high.
[2] Cumulative sand and gravel thickness (Figure 3) generally above 3 m is considered high.
[3] Sediment thickness (Figure 5) generally above 15 m is considered high.

In some areas aquifer-hosting sediments are classified as known or inferred despite low supply well density if geological evidence of the presence of aquifers is available. This includes the area between Cold Lake and Fort McMurray, where previous geological investigations and water license data indicate the occurrence of important aquifers for industrial use (Figure 2, studies 9-13).

The large areas of potential aquifer-hosting sediments in northern Alberta are reflective of modelling results indicating both thick cumulative sand and gravel and fine-grained deposits, with total sediment thickness commonly exceeding 15 m. However, these areas are associated with significant uncertainty due to a low density of lithological information (Figure 3) and lack of previous aquifer studies in the region.

Unclassified areas of this map are either unlikely to contain aquifer-hosting material (e.g., limited cumulative sand and gravel thickness or low total sediment thickness), or are areas with limited lithological data (e.g., northernmost Alberta).

This map is intended for use at the provincial scale. Aquifer-hosting sediments polygons do not delineate individual aquifers and may include significant internal variability. For example, a buried valley classified as containing known aquifer-hosting sediments may have localized areas where the basal sand and gravel aquifer has been eroded by former fluvial or glacial processes, or by present-day rivers. This map also does not consider water quality or aquifer yield in the sediments above bedrock. Thus, although sediments may host aquifers, the water quality in these sediments may be undesirable for its intended use or yield may be insufficient.

Summary

This provincial map identifies areas where the sediments above bedrock are known, inferred, or have potential to supply groundwater to wells. It builds on provincial groundwater mapping from the 1970s and 1980s (see Lemay and Guha, 2009) by incorporating regional stratigraphic investigations with recent bedrock topography and physiography maps and new province-wide predictive sandiness models for sediments above bedrock. While this map does not delineate specific aquifers, regional studies have focused on mapping the thickness and extent of aquifers and their hydraulic and chemical properties such as yield, hydraulic conductivity, and water quality.

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Recommended Reference Format

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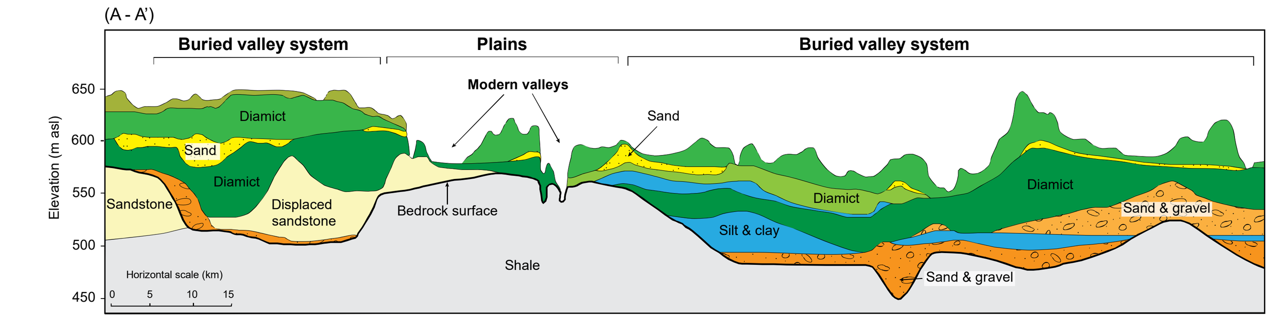

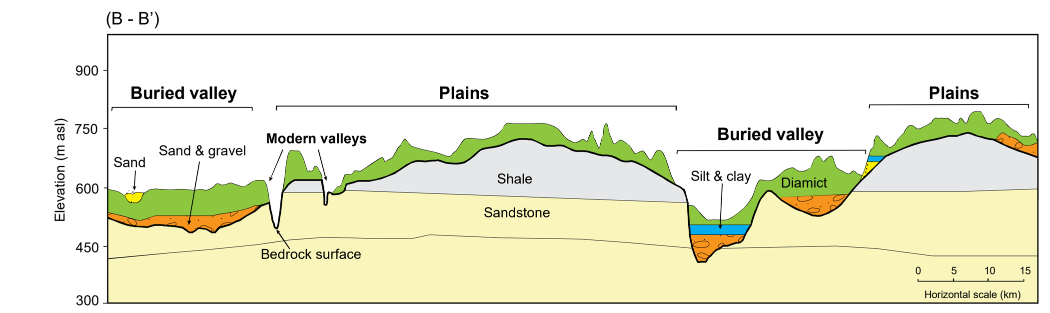

Figure 1: Cross-sections through the Cold Lake (A–A', Andriashek and Fenton, 1989) and Medicine Hat (B–B', modified from Stevenson and Borneuf, 1977) areas. The buried valleys in the Cold Lake area are large and filled with a thick, complex assemblage of sediments containing many regionally mappable aquifers. The buried valleys in the Medicine Hat area are smaller and do not contain the same complex assemblage of sediments, nevertheless they provide an important water source in this area.

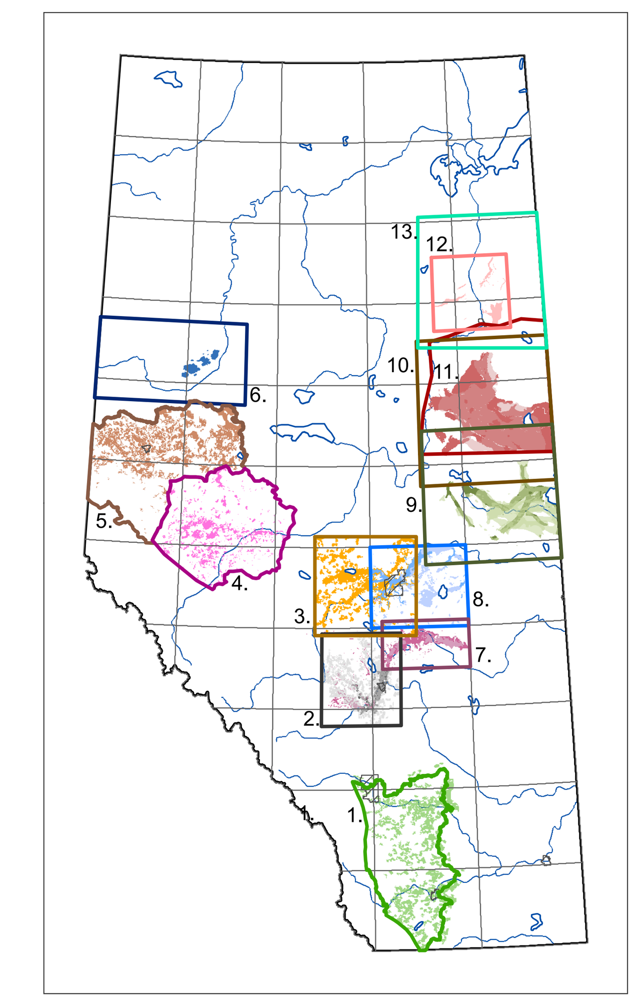

Figure 2: Aquifers and buried sand and gravel deposits previously mapped by the Alberta Geological Survey: 1. Atkinson et al. (2017); 2. Atkinson and Glombick (2015); 3. Hartman (2020); 4. Atkinson and Hartman (2017); 5. Hartman et al. (2020); 6. Slomka et al. (2018); 7. Alberta Geological Survey (unpublished); 8. Andriashek (1988), Alberta Geological Survey (unpublished); 9. Andriashek and Fenton (1989), Parks et al. (2005); 10. Parks and Andriashek (2002), Andriashek (2003); 11. Utting (2021); 12. Andriashek and Atkinson (2007); 13. Utting and Andriashek (2020). Different shades within a project area represent different mapped units.

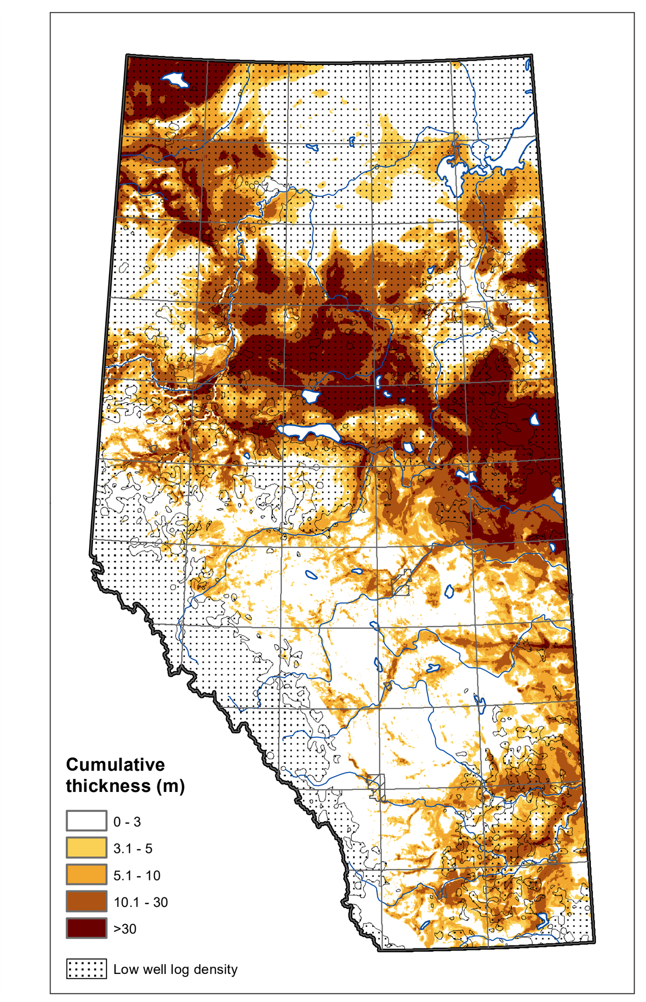

Figure 3: Cumulative thickness of sand and gravel within the sediments above bedrock based on machine learning models. Stippled areas indicate very low water well and borehole log density (less than 1 well per 10 km²) hence little to no lithological information is available.

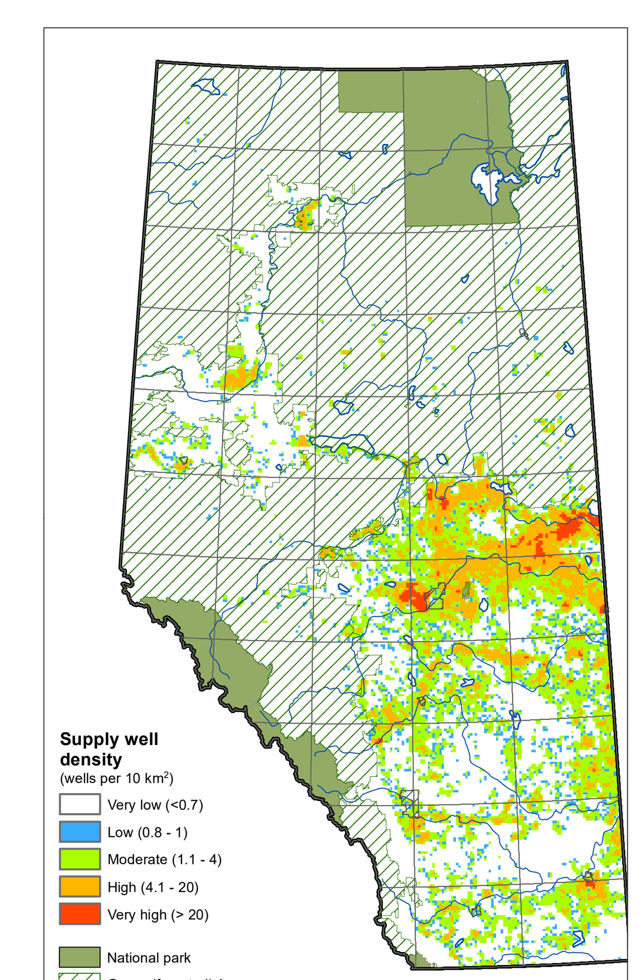

Figure 4: Density of supply wells in the sediments above bedrock from the Alberta Water Well Information Database (AWWID), the Baseline Water Well Testing database, and the domestic water well testing database (Government of Alberta, 2020a, 2020b, 2020c, respectively). Only supply wells (following methods in Atkinson et al., 2017, Appendix 1) were included from the AWWID. Water well density is influenced by urban, agricultural, and industrial development, therefore well density is generally low in the Green Area of Alberta (forested area) and national parks.

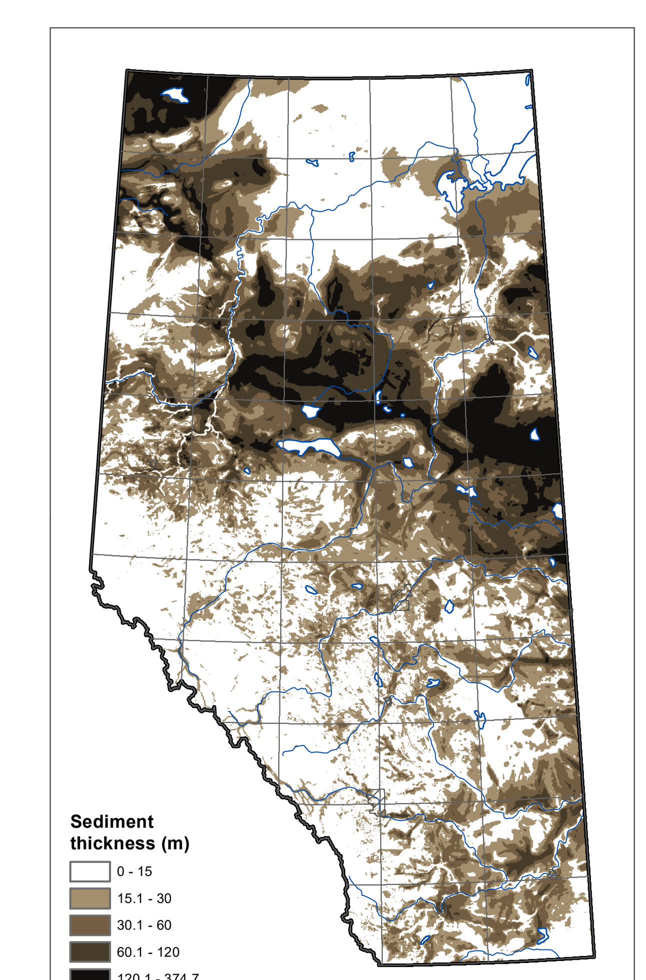

Figure 5: The distribution of sediments exceeding 15 m thickness across Alberta (Atkinson et al., 2020a). Outside the Green (forested) Area (Figure 4), a high density of supply wells completed above bedrock is commonly associated with sediment thickness greater than 15 m.

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MAP 632

Distribution of aquifer-hosting sediments above bedrock in Alberta

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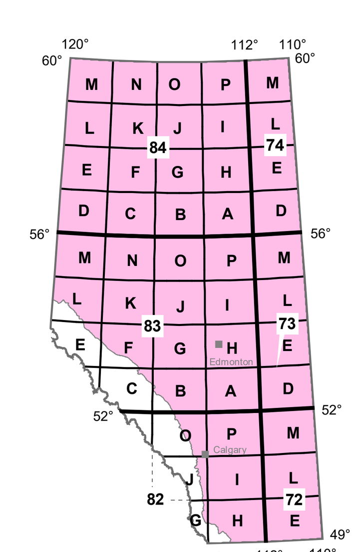
Scale 1:3 000 000

Projection: 10 Degree Transverse Mercator
Datum: North American Datum, 1983



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