Hydrogeological Mapping of Saline Formations in the Fox Creek Area, West-Central Alberta

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Introduction

In west-central Alberta, particularly the area centred on the town of Fox Creek, the oil and gas industry is developing unconventional resource plays in the Duvernay and Montney formations. Multi-stage hydraulic fracturing has led to an increase in water demand, which has been sourced from both surface water and shallow groundwater in the early stages of development. However, the Alberta government encourages the use of saline groundwater or alternative non-saline water sources, meaning that industry should consider deep aquifers. To better define groundwater conditions in the Fox Creek area, hydrogeological mapping of saline formations has been completed by the Alberta Geological Survey (AGS). The study area extends from Twp. 70 Rge. 5W6 in the northwest corner to Twp. 52 Rge. 7W5 in the southeast corner (Figure 1).

Figure 1: Map of the study area

Formations Mapped

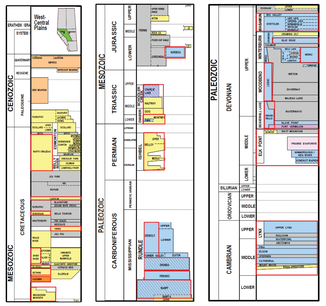

Figure 2: Stratigraphic column of mapped formations in the study area (Modified from Alberta Geological Survey, 2015)

This study mapped hydrogeological properties from the near surface down to the Cambrian Basal Sandstone Unit. This included formations spanning from the Wapiti Formation at depths of less than 500 m to the base of the Cambrian at depths of over 4000 m (Figure 2).

Aquifer mapped as part of the study

Data Allocation and Quality Control

Publically available water chemistry and pressure data were assigned to formations based on stratigraphic surfaces modelled as part of the Alberta Geological Survey's 3D Geological Framework (Figure 3). Once data were allocated, a screening process modified from Jensen et al. (2013) was used to ensure that only representative pressures from drill stem tests (DSTs) and representative water chemistry data were used. Screened data were mapped in ArcGIS using either Simple Kriging or Inverse Distance Weighting, depending on the spatial distribution of data. Pressure data was evaluated using the techniques from Singh et al. (2017) to determine if production influences on pressures were present.

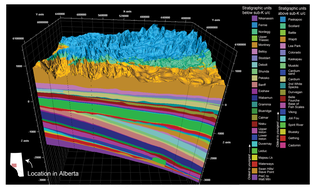

Figure 3: West-Central Alberta 3D Geological Framework (Alberta Geological Survey, 2017)

Hydrogeological Map Series Example

For each mapped aquifer, a water recovery map, potentiometric surface map, total dissolved solids (TDS) map and water driving force (WDF) map were created. Examples from the Cardium aquifer are shown below (Figures 4 to 7).

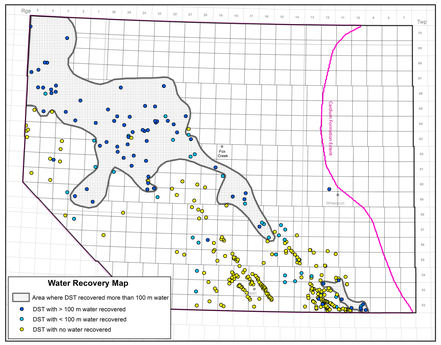

Figure 4: Water recovery map. Recovery maps were created with DSTs plotted according to their water recovery. From these data, areas having more than 100 m of water recovery were delineated. This area served as the aquifer boundary for further mapping and outlines an approximate region where a given formation may be able to produce water.

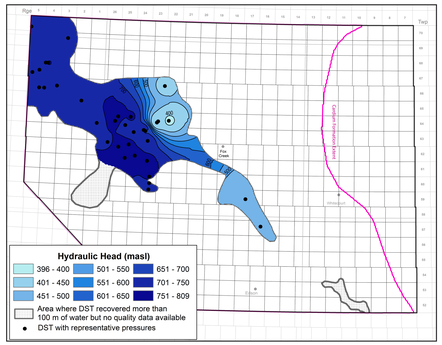

Figure 5: Potentiometric surface map. Potentiometric surface maps were created using freshwater hydraulic head values calculated from the screened pressure data. Where production influences were detected, a second map was created using only pressures representative of initial reservoir conditions. No production influences were noted for the Cardium aquifer.

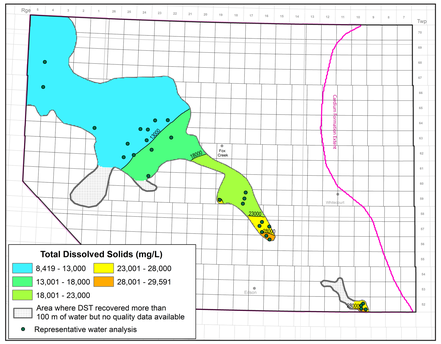

Figure 6: Total dissolved solids (TDS) map. TDS maps were created using screened water chemistry analyses that were representative of formation water.

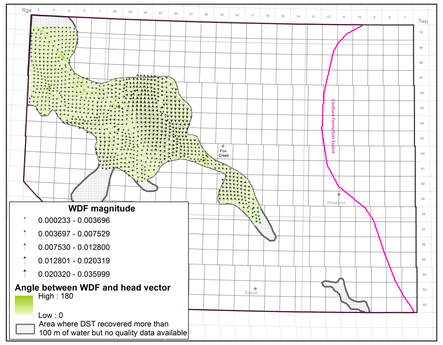

Figure 7: Water driving force map (WDF). WDF maps were created to assess the effects of density on flow. These maps were created from several inputs including, the potentiometric surface, TDS map, structure maps from the 3D Geological Framework, and temperature data from DSTs.

Hydrostratigraphic Cross-sections

Regional hydrostatigraphic cross-sections were generated to illustrate the mapped aquifer zones and distributions of hydraulic head and TDS (Figure 8 and Figure 9).

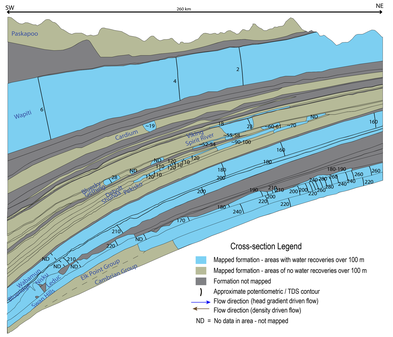

Figure 8: SW to NE total dissolved solids (g/L) cross-section

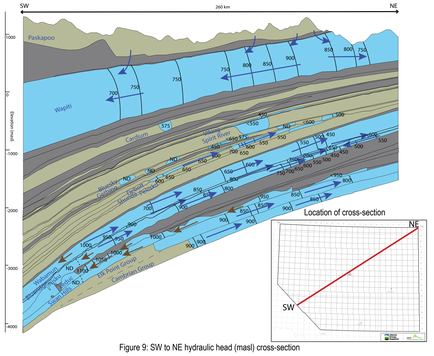

Figure 9: SW to NE hydraulic head (masl) cross-section

Vertical Pressure Gradient and Water Chemistry Analysis

In addition to the hydrogeological mapping, data were also plotted graphically for interpretation. Pressure elevation and pressure depth plots (Figure 10 and Figure 11) were used to examine vertical pressure gradients and hydraulic communication between formations. Water chemistry data were also analyzed using Piper plots to determine the chemical compostion of the formation water (Figure 12).

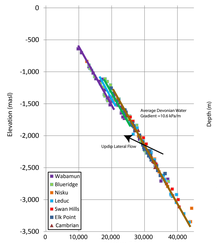

Figure 10: Pressure vs elevation for Devonian - Cambrian system

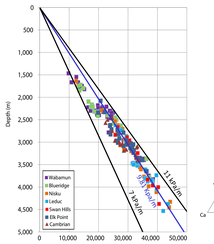

Figure 11: Pressure vs depth for Devonian - Cambrian system

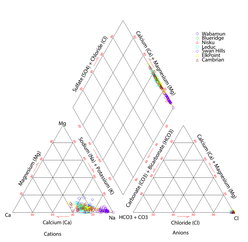

Figure 12: Piper plot for Devonian - Cambrian system

Summary

A technical report and associated digital products will be published on the AGS website in 2017. The regional interpretation has shown:

- Topographically driven flow in the shallow Cretaceous aquifers
- Jurassic - Mississippian aquifers share similar hydrogeological characteristics and form a regional aquifer
- Influence of density driven flow in parts of the Devonian formations, causing sluggish flow in the direction of the head gradient, or flow in the opposite direction of the head gradient
- Increasing calcium composition for near-basement formations

References

Alberta Geological Survey (2017): West Central Alberta Modelling and Mapping. URL <http://ags.aer.ca/west-central-alberta-modelling-mapping> [April 2017]

Alberta Geological Survey (2015): Alberta Table of Formations; Alberta Energy Regulator. URL <http://ags.aer.ca/document/Table-of-Formations.pdf> [December 2016]

Jensen, G.K.S., Rostron, B., Palombi, D. and Melnik, A. (2013) Saskatchewan Phanerozoic Fluids and Petroleum Systems Project: Hydrogeological Mapping Framework; Summary of Investigations 2013, Volume 1, Saskatchewan Geological Survey, Sask. Ministry of the Economy, Misc. Rep. 2013-4.1, Paper A-5, 10p.

Singh, A., Palombi, D., Nakevska, N., Jensen, G. and Rostron, B. (2017): An efficient approach for characterizing basin-scale hydrodynamics, Marine and Petroleum Geology, http://dx.doi.org/10.1016/j.marpetgeo.2017.02.015