Comparative Geothermal Study between the Mannville Shallower Aquifer and the Deep Winnipeg/Deadwood Formation

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Sedimentary basins are significant sources of low-carbon energy in the form of geothermal heat. The current trend in harnessing geothermal energy in Canada is basically towards low-enthalpy systems. Geothermal resources with lower temperature gradients and lower enthalpy are dominated in sedimentary basins and continental interiors (Palmer-Wilson et al., 2018). The Western Canadian Sedimentary Basin (WCSB) covers the western Canada provinces including northeastern British Columbia (BC), Alberta, southern Saskatchewan, southwestern Manitoba, and the southwest corner of the Northwest Territories (NWT). The western edge of the basin reaches a depth of 6 km while in the deepest eastern end rises to zero thickness (Majorowicz & Grasby, 2021). Studies have shown that the geothermal temperature gradient and heat flow changes are in the range of 22-35 ℃/km and 50-70 mW/m^2 in the WCSB, respectively. Approximately two-thirds of Saskatchewan overlies the WCSB with a thickness variation of 0 to 3300 m from the Canadian Sheild to the international border near Estevan. Regina is located on the north flank of the Williston Basin (Vigrass et al., 2007a). This Basin is a unique geological structure with three main tectonic zones and contains special features related to age, composition and the depth of burial (Bader, 2019). Seven major aquifer systems divided with a sequential of regional aquitard are identified within the Williston Basin.

In WCSB, the Winnipeg and Deadwood Formations are well-recognized as highly permeable aquifers. They are basically Phanerozoic strata referred to as the “Basal Clastic Unit” composed of fine-bedded sandstone, siltstone, shales and minimal carbonate (Ferguson & Grasby, 2014; Vigrass et al., 2007b; Volcanology et al., 1989). The geothermal test well drilled in 1978 on the University of Regina campus indicated that the depth of this Basal Clastic Unit is above 2200 m and proved its great geological potential for hot water production. The produced brine was recorded to be more than 100,000 ppm (Vigrass et al., 2007a). These two aquifers are great examples of deep geothermal.

The other aquifer in the Williston Basin is the Mannville Aquifer located at a shallower depth around 850 m in the Regina area. The Mannville Formation is the interbedded sandstone and shales formation with southwest to north-easter regional flow of groundwater which contains oil and gas in some regions. However, it is an aquifer roughly at the depth of 600-1200 m, which has been mostly used for water disposal. The Mannville Aquifer is the most permeable aquifer estimated to have 10^{-8} m^2, which makes it the highest permeability within the Mesozoic group of aquifers. Its thickness reaches a maximum of 150 m. The Mannville Aquifer is overlaid by the Colorado Group and underlaid by the Vanguard Formation (Jellicoe, 2020)

The aquifers’ waters’ total dissolved solid (TDS) in the WCSB formation increase with depth. Deeper formations in the region have TDS as high 300,000 ppm while the TDS for formations closer to the surface are significantly reduced. The Mannville’s average TDS is about 65,000 ppm.

This is a main reason why the Mannville has been used as the target injection formation to inject back produced water with higher TDS. By mid-2019, 376×10^6 m^3 of water had been produced from the Manville; however, 726×10^6 m^3 had been injected back to the Mannville Formation causing a remarkable excess amount of water (344 million m^3) in this formation. Through the active lifetime of the Mannville, the production volume has not changed significantly. Therefore, the idea of using the Mannville aquifer with relatively low TDS could be used for harvesting geothermal energy (Woroniuk, 2023).

Method

This study focuses on conducting a comparison between energy extracted from shallow (Mannvile) and deep (Winnipeg-Deadwood) aquifers in the Regina area. The studied model is a 3D geological model made separately for the Mannville and Winnipeg-Deadwood formations developed for the City of Regina, Saskatchewan, and built using Computer Modelling Group Ltd. (CMG) software. The area covers 25 km ×15 km. The required structure and isopach maps were obtained from the publicly available data from Saskatchewan Geological Mapping (Geohub) and geoSCOUT. The model has two injection and production wells placed 1 km apart. Temperature distribution in two targeted formations considers the geothermal thermal gradient of 0.026 ℃/km as illustrated in Fig. 1.

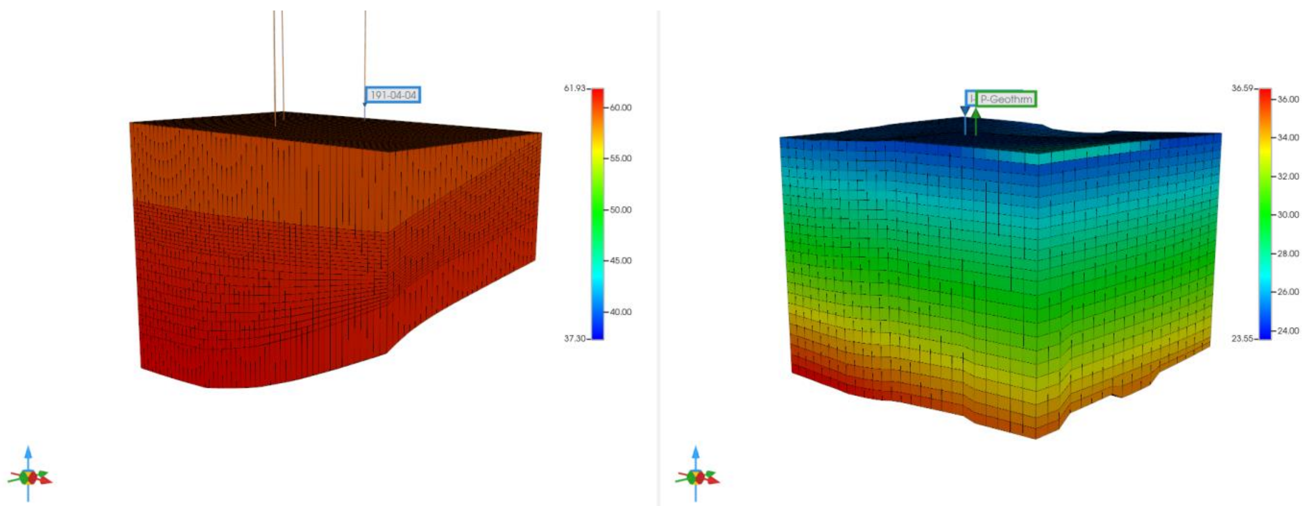

Figure 1. 3D view of temperature distribution a) Winnipeg-Deadwood, b) Mannville geothermal reservoirs

Results

The results showed the Winnipeg-Deadwood Formation with a bottomhole temperature of 61℃ and a production rate of 2400 m^3/day. At surface production the temperature would fall to 56℃. On the other hand, the Mannville formation has a bottomhole temperature of 32.8℃ and results in a surface temperature of 30.7℃ with the same production rate.

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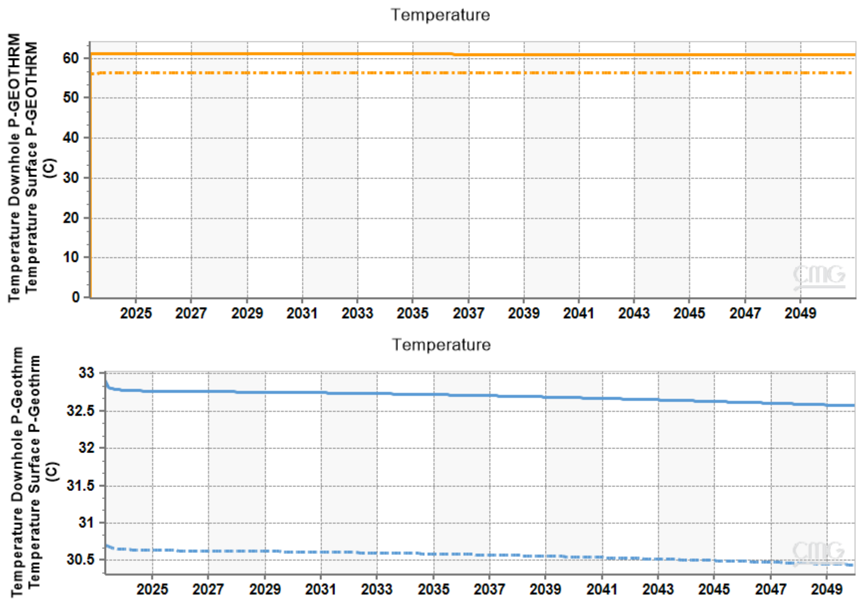

Figure 2. Temperature variation through the years by 2050, a) Winnipeg-Deadwood, b) Mannville Formation. solid line: bottomhole temperature, dashed line: surface temperature

The produced energy rate for Winnipeg-Deadwood and Mannville sources are $4.5\times10^{11}$and 1.74×10^{11} J/day, respectively. With heat pump application, the extracted energy and production temperature could be boosted for the Mannville for geothermal energy utilization.

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