Dissolved Gas Challenges During Aquifer Testing and Depressurization – Basal McMurray Aquifer

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Summary

The Basal McMurray Aquifer (Basal Aquifer) is a water-saturated sand unit underlying the bitumen-bearing ore deposit in the Athabasca oil sands region of Alberta. Surface oil sand mining operations require Basal Aquifer depressurization where the head pressure within the aquifer exceeds the mine pit floor elevation. Pit stability and flooding risks caused by fluid pressure and seepage from the Basal Aquifer are managed by lowering the head pressure in the aquifer using a depressurization pumping well network. However, Basal Aquifer characterization and depressurization operations may be complicated by high concentrations of dissolved gases (primarily colorless and odorless methane and carbon dioxide). As the aquifer head pressure decreases due to pumping, the aquifer pressure may drop below the 'bubble point' required to keep gas in the dissolved phase. This would cause gas exsolution and the formation of Free-Phase Gas (FPG) bubbles in the well and aquifer.

FPG is known to impact aquifer properties, including the effective permeability to water due to pore space being occupied by gas[1], and an increase in the aquifer storativity due to high gas compressibility[2]. Both these changes in aquifer properties under the presence of FPG have the potential to impact well efficiency, pumping test results[3], and long-term depressurization requirements. In addition, FPG may impact electrical submersible pump performance in depressurization wells due to cavitation and 'gas locking' effects. Finally, exsolved gases have the potential to contain methane and hydrogen sulphide, with related constraints for safety and greenhouse gas emissions where the water is pumped and discharged.

Failure to identify FPG exsolution and quantify the bubble point during aquifer testing may result in aquifer property mischaracterization when these tests are analyzed using conventional single-phase analytical solutions. These results would indicate apparent negative (no-flow) aquifer boundaries near the pumping well where there are no associated true geologic boundaries present. Similarly, transient aquifer properties and well efficiencies caused by FPG exsolution inserts additional uncertainty to forward analytical or numerical predictive simulations. Additional conservatism may be required to account for the apparent recharge effects and decreased well efficiencies once aquifer pressures are pumped below the bubble point. However, even if gas exsolution impacts are not observed during modest fluid head declines during short-term aquifer testing, there may still be complications presented by gas exsolution during the larger head declines observed with operational pumping.

A case study will demonstrate a multi-day aquifer testing field operation which was challenged by apparent free-phase gas impacts on well efficiency and near-borehole aquifer properties as aquifer pressure was pumped below the bubble point. Field measurement and sampling for dissolved gases was performed throughout the pumping test using a gas separating flow-through cell. The agitated and depressurized water in the gas separator accumulated a FPG sample which

was sent to an analytical laboratory to determine gas composition. The ratio of accumulated gas to water provided the semi-quantitative gas-water ratio which informed the in-situ dissolved gas concentration. This calculated bubble point elevation aligned with an inflection point in the aquifer head drawdown rate during constant-rate pumping. Results indicate that dissolved gas concentration is an important aquifer property to consider when designing aquifer tests and long-term depressurization plans. In the future, additional (and more accurate) information for the dissolved gas concentration (and therefore the total dissolved gas pressure and bubble point) could be derived from in-situ sampling and dissolved gas pressure sensors. Gas exsolution inside the vertical pumping well could also be indicated by paired pressure sensors, where a decrease in the fluid column density and sporadic fluid resistivity would indicates FPG in the production casing[4].

In conclusion, total dissolved gas concentration is an important aquifer property to consider when performing and analysing aquifer tests in the Basal McMurray Aquifer. Dissolved gas exsolution caused by fluid head declines can lead to changes in well and aquifer properties, with negative impacts on well and site scale depressurization performance. The potential for FPG should be anticipated throughout the oil sand surface mining region (and elsewhere in Western Canada wherever aquifer pumping or depressurization coincide with high dissolved gas pressures). Since the presence of dissolved gas is difficult to predict and is not measured using standard logging tools, dissolved gas should be assumed present unless testing shows otherwise. Field methods to determine dissolved gas properties include gas-separating flow-through cells and in-situ sampling or dissolved gas pressure measurements, in addition to careful aquifer test analysis. Considering the implications on Basal McMurray depressurization success, and more broadly for pumping from other confined aquifers, investigating dissolved gases should be considered as an important component to every aquifer study.

References

1. Marinas, M., Roy, J. W., & Smith, J. E. (2013). Changes in entrapped gas content and hydraulic conductivity with pressure. Groundwater, 51(1), 41-50.
2. Yager, R. M., & Fountain, J. C. (2001). Effect of natural gas exsolution on specific storage in a confined aquifer undergoing water level decline. Groundwater, 39(4), 517-525.
3. Bourne, J.K.G. (2008). Pumping Test Analysis of Fourteen Depressurization and Injection Wells in the Basal McMurray Watersand, Fort McMurray, Alberta. WaterTech 2008.
4. Morais, T. A., et al. (2022). Free-Phase Gas Detection in Groundwater Wells via Water Pressure and Continuous Field Parameters. Groundwater 60(2), 262-274.