

## Groundwater Recharge Estimates in the Athabasca and Cold Lake Oil Sands Areas

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Alberta has seen rapid growth in the Athabasca and Cold Lake oil sands areas south of Fort McMurray where vast deposits of highly viscous bitumen occur hundreds of meters below ground surface. As published by Oilsands Review (2008) as many as 22 in situ oil sand projects exist or are planned within a 30,000 km<sup>2</sup> area south of Fort McMurray. Oil at these projects is typically recovered using steam assisted gravity drainage (SAGD) technology. This technology requires large volumes of groundwater to sustain the steam generation and oil recovery process. Based on data published in Oilsands Review (2008) these projects are projected to produce a combined total of more than 1,500,000 barrels per day (bpd; 240,000 m<sup>3</sup>/day) of oil (Oilsands Review, 2008). Based on an approximate relationship of 0.6 m<sup>3</sup>/d of make up water per cubic meter of recovered oil approximately 150,000 m<sup>3</sup>/d of groundwater is required to recover bitumen at these rates. Due to the high demand for groundwater and the competition for groundwater resources in this area these projects generally require a large amount of hydrogeology work in order to design a well network suitable for long term groundwater supply and to assess the potential effects of groundwater withdrawal.

Due to the scale and complexity of the work, numerical models are often used to quantify groundwater interference and assess potential environmental effects. Numerical models can predict the future effects of multiple groundwater withdrawals in complex hydrogeologic systems but uncertainties are inherent in the modeling process. One common reason for the uncertainty is the non uniqueness of the model calibration. The same calibration data can be reproduced through multiple realizations of the numerical model, particularly if the calibration is focused on reproducing observed hydraulic heads.

One effective way to make the model calibration more unique and decrease the uncertainty of model predictions is to incorporate groundwater flux data into the calibration. When compiling calibration data, however, it

is much easier to acquire measurements of hydraulic head than it is to estimate or find published estimates of groundwater fluxes. This paper discusses methods of estimating groundwater recharge and looks at the applicability of using these methods in the Athabasca Oil Sands Area.

Methods of estimating groundwater recharge include calculating shallow groundwater recharge using meteorological and land use data, using inverse solutions to constrain vertical groundwater flux through aquitards, and looking at geochemical trends to infer the direction and magnitude of vertical groundwater flow. This paper will present new and previously published estimates of groundwater recharge and will present new work using the relationship between temperature and depth to constrain rates of vertical groundwater flow. This method is particularly attractive as large regional databases with depth and temperature data have already been compiled by industry and can be accessed by the public.

It is hoped that when viewed together these estimates will provide additional constraint on recharge rates in the Athabasca Oil Sands Area, improve the model calibration process, and ultimately improve model predictions.

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Gordon MacMillan is a Professional Geologist with eight years of experience as an environmental consultant. He provides Matrix Solutions Inc. with senior project management, technical review, and technical support for groundwater supply investigations and Environmental Impact Assessments (EIAs). His experience includes developing conceptual models of groundwater flow from local to regional scales and completing analytical and numerical modeling of groundwater flow in support of regulatory applications, groundwater remediation networks and groundwater supply projects.