Stable Isotope Techniques for Evaluating Water Yields and Groundwater Surface Water Interaction: Applications in the Athabasca Oil Sands Region

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A major environmental concern for oil sands operators is the potential impact of oil sands extraction and the associated water usage may have on shallow groundwater, lakes, and wetlands. Stable isotope water balance models ($\delta^{18}O$ and $\delta^{2}H$) combined with isotopic (^{222}Rn) and geochemical tracers, age dating tools (^{14}C, ^{3}H) and conventional hydrological and hydrogeological approaches can be used to provide a quantitative assessment of the lake water balance parameters and degree of connectivity to underlying aquifers for boreal lakes and wetlands. These techniques have been valuable tools for determining water yield for evaluating lake sensitivity to acid deposition across the Athabasca Oil Sands Region (AOSR) and for predevelopment baseline hydrological surveys.

Stable isotope water balance models make use of the systematic evaporative isotope enrichment in ^{18}O and ^{2}H that occurs as surface waters undergo evaporation to determine the fraction of water losses by evaporation relative to inflow. Interpolated climate data is then used to scale the water balance, to resolve the vertical fluxes of precipitation and evaporation, and to solve for residual lateral inflow to the lake. The approach can be readily incorporated within geochemical surveys of lakes; providing regional assessments of lake water balance parameters and runoff variability. Combining the results from stable isotope water balance models with indicators of water-rock interaction and water age can be used to identify recharge and discharge zones, and the connectivity of lakes and rivers to underlying aquifers.

This presentation will provide an overview of the application of these techniques using examples from a program of hydrological investigations conducted in northeastern Alberta as a contribution to acid sensitivity studies coordinated by the Cumulative Environmental Management Association NOxSOx management working group. These investigations include a 7-year dataset of regional sampling of 50 lakes in the AOSR and more detailed field work at two intensively-instrumented study basins situated near Fort McMurray in the Stony Mountains (SM8) and Muskeg Mountains (NE7). The water yields determined for the 50 lakes show considerable variability both interannually over the 2002 to 2008 period and spatially across the AOSR region. The water yield for most lakes is less than 50% of the depth of precipitation and most indicate only a weak connection to groundwater systems. Exceptions indicate lakes where the contributing watershed areas have not been correctly accounted for, or alternatively lakes with an additional source of water to precipitation derived runoff. The source of this inflow could include groundwater discharge or possible contributions from melting permafrost. The relationships between water yield and connectivity with groundwater sources and the presence of wetlands and permafrost features was further investigated using more detailed geochemical and isotopic sampling of a subset of these lakes and through field investigations at the study basins.