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Assessing Cumulative Effects of SAGD Operations in the MacKay Watershed

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The MacKay River Watershed, immediately northwest of Fort McMurray, AB, is a diverse oil sand development region with near-surface minable reserves and both shallow and deep SAGD targets extending under the Birch Mountain headwater area. Significant land development modifications (roads, drill pads) and freshwater diversions from bedrock valleys, channel aquifers, and deeper confined formations are planned to support a range of SAGD operations.

In 2014, Earthfx Inc. was hired by the Cumulative Environmental Management Association (CEMA) to answer the question: *"Is there enough water in the watershed to sustain a responsible level of development?"* To address this question, Earthfx proposed an innovative, high resolution, fully-integrated surface water and groundwater modelling approach. The entire watershed, including 17 subsurface hydrogeologic units, over 4000 km of streams, and all mapped lakes, wetlands, vegetation, land alteration and water diversions, were represented. The GSFLOW model simulates all hydrologic processes (snowpack, infiltration, runoff, ET, subsurface flow), using a fully distributed cell-based representation, and streamflow using a linear channel network routing approach. The model was further modified to simulate the ground freeze and thaw processes that control spring freshet runoff. Three scenarios, representing water diversions and land alteration under pre-development, current and full build development were simulated on a daily basis over a representative 25 year climate period. Groundwater impact was assessed against a threshold of 50% of available drawdown, while stream flow in each reach was evaluated against the 15% threshold defined by the Alberta Desktop Method (ADM).

Comparison of the three model scenarios on a daily, seasonal and interannual basis provides significant insight into the watershed function and response to development. Relatively significant (exceeding 50% of available drawdown) but localized groundwater drawdowns are created by cumulative pumping from channel aquifers, however induced leakage from the stream network and inflows from adjacent units mitigate these effects. The induced reduction in streamflow can exceed 15% of total flow in some reaches. Pumping from the deeper formations creates modest but laterally extensive effects in the aquifers and headwater reaches. The spatially detailed simulation results clearly identify specific targets and sensitive features for future monitoring and management.

The importance of system storage buffering is illustrated in the seasonal and interannual water budgets. Constant winter pumping depletes aquifer storage beneath the frozen ground, and subsequent storage replenishment affects spring groundwater discharge patterns. GW diversions induce leakage from the lakes during the dry fall season. Land development and groundwater pumping are, to a degree, compensating factors. Drought, such as in 2009-2011, creates a multi-year decline in aquifer levels, but subsequent wet years appear sufficient to replenish system storage and water levels.

The analysis indicates that projected water use in the study area is broadly sustainable on a watershed scale. Groundwater drawdowns do not grow over time and accumulated streamflow losses don't exceed the 15% ADM threshold in the main channel of the Mackay River. Ongoing work is needed to manage and mitigate significant local effects. Future applications including permit assessment, climate change, well optimization, monitoring network design and watershed evaluation and management.

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