# Water use development of an oil sands boreal forest reclamation site during the first 12 years following inception

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Following large-scale surface mining operations, large tracts of land in the boreal region of Western Canada need to be reclaimed. A greater understanding of how these novel ecosystems function and develop with regard to water use is crucial to developing defensible regulatory practices and protocols. Ecosystem water use is important to consider during construction and assessment in order to ensure adequate moisture availability for the vegetation while minimizing the potential upward migration of saline groundwater.

The working hypothesis for this study is that ecosystem evapotranspiration (ET) will increase as the vegetation increases at the site and trees become the dominant plant cover. A 12-year eddy covariance measurement record (2003-2014) is analyzed in order to understand how a reclaimed boreal forest has developed during its initial growth period. South Bison Hills is a reclaimed oil sands saline-sodic clay shale overburden depot that was topped with 100 cm of glacial till and 20 cm of peat mineral mix. Soil cover was put down at the site in 2001 and it was subsequently seeded with barley (*Hordeum jubatum* L.) in 2003 to reduce erosion of the soil cover while boreal tree species, aspen (*Populus tremuloides* Michx.) and spruce (*Picea glauca* (Moench) Voss), were planted in 2004. Over the measurement period the site transitioned from a grassland to an aspen-dominated forest. The sub-humid region is characterized by a water deficit and has distinct seasonality with cold winters and warm summers. The average growing season temperature is 15.7 °C and total precipitation is 211.1 mm (Environment Canada, 2013). During the measurement period, the growing season temperature was warmer than average but below the maximum temperature normal while precipitation fluctuated around average with no years indicating drought stress.

Eddy covariance instrumentation has been installed at the site every growing season since 2003. Current equipment includes a CSAT3 sonic anemometer (Campbell Scientific Ltd., Logan, UT (CSI)), an open-path infrared gas analyser (LI-7500, LI-COR Inc., Lincoln, NE (LI-COR)), and a CR3000 data logger (CSI) recording the 10 Hz measurements at half-hour intervals. Before late-growing-season of 2008, a CR23X datalogger (CSI) was in place. Complementary instrumentation collects meteorological and soil moisture characteristics while additional data is available from Environment Canada weather stations at nearby Mildred Lake and Fort McMurray. Two main measurement periods were used for analysis with ET and water use efficiency using growing season data (June-July-August) while canopy conductance and the Bowen ratio were calculated suing mid-day (11:00 h – 14:00 h) growing season data.

Results from this unique long-term record indicate that the reclaimed site underwent step changes in structure and function corresponding to the transition of dominant vegetation cover from grassland to forest. Leaf area index (LAI) increased from a growing season peak of 0.9 in 2003 to 4.0 in 2014 with step increases in 2008 and 2013. As expected, average June-July-August ET increased over the study period (1.7 ± 0.09 to 3.8 ± 0.16 mm $d^{-1}$ (± 1 SE)) with a step increase in 2008 corresponding with the jump in LAI and release of the trees. With regard to the monthly distribution within the growing season, July has a greater ET rate than June or August. This is likely due to July being when full leaf out, optimal temperature, and adequate soil moisture occur. In June leaves are not fully emerged and in August it is often quite dry. During the study period, the Bowen ratio decreased as a result of a greater partitioning of energy to latent heat flux and canopy conductance increased. However, when normalized by LAI, canopy conductance decreased from 274.7 ± 15.3 to 158.7 ± 11.3 mmol $H_2O$ $m^{-2}$ leaf area $s^{-1}$ (± 1 SE). This may be attributed to increased control of transpiration by the trees relative to the earlier grass community. Water use efficiency increased slightly over time until the last four years where it has remained relatively constant around 9.3 g $CO_2$/ kg $H_2O$. Soil volumetric water content dropped to the wilting point zone for the soil covers (~ 0.18-0.20 $m^3$ $m^{-3}$) during August in the latter part of the study period but did not go below the lower limit. This examination of water use indicates that despite early changes following inception ecosystem water functioning has levelled off at values similar to other boreal forest ecosystems. The research outcomes are relevant to reclamation practices that aim to construct large portions of the boreal forest. Future research could include other reclaimed and natural analogue sites in order to explore whether or not a broad range of reclaimed boreal landscapes are functioning in a similar way.

Environment Canada. 2013. Canadian Climate Normals 1981-2010 Station Data - Climate - Environment Canada Available at: http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnName&txtStationName=Fort+McMurray&searchMethod=contains&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=2519&dispBack=1 [Accessed 5 July 2016]