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Threshold responses in regional runoff from a heterogeneous low relief terrain – Western Canada's Boreal Plains

Kevin Devito (1), Axel Anderson (2), Nick Kettridge (3), Carl Mendoza (4), Rich Petrone (5), Uldis Silins (6), Kevin Smith (7), and Mike Waddington (8)

(1) Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada. (kdevito@ualberta.ca), (2) Alberta Environment and Sustainable Resource Development, Edmonton, AB.(Axel.Anderson@gov.ab.ca), (3) School of Geography, Earth and Environmental Sciences University of Birmingham, Edgbaston, Birmingham, UK, B15 2TT (n.kettridge@bham.ac.uk), (4) Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2E3 (cmendoza@ualberta.ca), (5) Department of Geography and Environmental Management University of Waterloo, Waterloo, Ontario, Canada N2L 3G1, (6) Department of Renewable Resources, University of Alberta, Edmonton, Alberta, Canada (Uldis.Silins@ualberta.ca), (7) Ducks Unlimited Canada, Western Boreal Program, Edmonton, AB. (k_smith@ducks.ca), (8) School of Geography & Earth Sciences, McMaster University, Hamilton, Ontario, Canada, L8S 4G5

Runoff from larger catchments (>1000km) in the continental Boreal Plains (BP) eco-region of Western Canada, although low, can range over 3 orders of magnitude (4 mm to 350 mm/yr) among years and be difficult to predict. This region of western Canada is experiencing unprecedentedly rapid and large-scale industrial development. There is a need to assess and understand the dominant controls on the temporal and spatial threshold responses of regional runoff generation to be able to predict and mitigate the potential impacts of land use and effectiveness of reclamation practices on surface water quantity and quality. The Boreal Plain climate has regional moisture deficit (P< PET) and decadal wet and dry cycles. There are dynamic and complex surface and groundwater interactions because the landscape is made up of large spatial Hydrologic Response Areas (HRA's) characterized by heterogeneous deep glacial deposits with different storage and water transmission properties. These HRAs are below a mosaic of surface Hydrological Units (HUs) of deciduous and conifers forests, with some areas greater that 50 % of the surface is covered be wetlands ecosystems, mostly peatland.. Process based and experimental studies of forest-wetland hydrologic linkages show that at the local scale forested areas infrequently generate runoff because of high storage capability of the deep soils and effective transpiration capabilities of the trees. This contrasts wetlands that saturate readily due to lower soil storage capabilities and less effective evaporative processes, which results in persistent lateral surface or near surface runoff from wetland complexes.
We examine the interaction among the wetland and forest HUs, the glacial landforms HRAs and decadal climate cycles on the threshold response of regional runoff in a range of catchments (50 ha to 50000 km2) from the Boral Plain of Alberta. Annual runoff (mm) and efficiency (RC) were poorly correlated with annual precipitation, but showed a strong threshold relationship with multi-year cumulative moisture deficit (CMD). Changes in precipitation patterns result in decadal cycles of dry (CMD < -200 mm) and mesic (CMD $\sim$ 0 mm) states, with wet (CMD > 200 mm) states occurring every 2-3 decades. The differing CMD states altered the hydrologic connectivity among different portions of HRA's and HUs within catchments. During dry states base flow conditions ranged by over an order of magnitude (2 to 80 mm/yr), and increased with percent area of coarse textured HRAs. In fine textured landforms significant runoff was observed only in catchments with >30% wetland area. During mesic conditions catchment runoff coefficients were positively correlated with percent wetland area, suggesting that wetland networks were the primary source areas of surface water to regional runoff. During the infrequent wet states, runoff coefficients were similar among all catchments indicating that storage in forest HUs was exceeded and both forestlands and wetlands contribute to catchment runoff. Integrating the CMD with the configuration of wetland and forestland HUs and the type of glacial landforms HRAs rather than topographic drainage networks appears to better represent water cycling and sink source dynamics controlling runoff in low relief glacial landscapes such as the Boreal Plain.