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Wetland drainage and other land use changes: impacts on watershed connectivity in northern landscapes

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Wetland loss has significant impacts on watershed-scale connectivity, as it results in increases in contributing areas, peak flows, nutrient and sediment loadings to streams and greenhouse gas emissions. This is especially true in the province of Manitoba, which hosts $\sim$20% of Canada's wetlands but is also plagued with the continuous loss of wetlands due to agricultural drainage on privately-owned land. While the benefits of wetland restoration are widely agreed on, the strategies adopted to maintain or increase the number of wetlands in the landscape used to rely on a "no net (areal) loss" principle and only recently started to rely on a "no net watershed connectivity degradation" principle, thus creating a need for connectivity models. One of the challenges associated with connectivity modelling is the fact that connectivity is an emergent property of natural systems, i.e. it is the result of local system interactions that give rise to complex causal relations and feedbacks across scales. Because such interactions, causal relations and feedbacks are somewhat unpredictable, traditional equation-based models usually fail to emulate emergent hydrologic connectivity patterns. Conversely, static and dynamic models that rely on complex systems theory have the potential to emulate such emergent patterns. The goal of this study was therefore to apply data-driven models aligned with complex systems theory to simulate wetland-to-wetland and wetland-to-stream hydrologic connectivity as emergent phenomena. Two main types of models were compared, namely graph models and circuit models. Focus was on the Prairie Pothole Region, specifically the Broughton's Creek Watershed (Manitoba, Canada), where the need for connectivity models is especially critical to guide wetland restoration and mitigate flood risk. All models were initialized with the same wetness conditions so that any differences in simulated connectivity patterns would be attributable to the differences between modelling hypotheses. Different wetland restoration scenarios were applied in both cases for comparison purposes. Results show that critical watershed areas where connectivity is especially tenuous could be identified using both model types, either as gatekeeper elements with graph models or as pinch points with circuit models. Most importantly, both models hinted at a lot of uncertainty surrounding land use change impacts on wetland-to-stream connectivity depending on the specific criteria used for draining or restoring wetlands as well as the prediction tool (or model) used. It is therefore recommended that future research focus on combining different complex systems models into ensemble modelling approaches in order to better constrain the uncertainty associated with connectivity predictions in human-impacted wetland landscapes.