University of Victoria | Graduate Studies

# Notice of the Final Oral Examination for the Degree of Master of Science

of

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BSc (Dalhousie University, 2013)

## "Mapping Aquifer Stress, Groundwater Abstraction, Recharge, and Groundwater's Contribution to Environmental Flows in British Columbia"

School of Earth and Ocean Sciences

Thursday, November 29, 2018
9:30 A.M.
Bob Wright Centre
Room A319

Supervisory Committee:
Dr. Tom Gleeson, Department of Civil Engineering, University of Victoria (Supervisor)
Dr. Jon Husson, School of Earth and Ocean Sciences, UVic (Member)
Dr. Yonas Dibike, Department of Geography, UVic (Outside Member)

External Examiner:
Dr. Grant Ferguson, Department of Civil and Geological Engineering, University of Saskatoon

Chair of Oral Examination:
Dr. Kathryn Chan, Faculty of Law, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

## Abstract

Groundwater is considered a reliable resource, relatively insensitive to seasonal or even multi-year climatic variation, however quantifying aquifer-scale estimates of stress in diverse hydrologic environments is particularly difficult due to data scarcity and the limited number of techniques in deriving stress parameters, such as use and availability, which can be applied over a large spatial area. The scope of this project is to derive aquifer-scale estimates of annual volumes for groundwater withdrawal, recharge, and groundwater's contribution to environmental flows as a means to provide screening level estimates of aquifer-scale stress using the groundwater footprint. British Columbia (BC) has mapped and classified more than 1100 aquifers, but the level of development for each aquifer has always been subjectively based on well density or the anecdotal knowledge of groundwater use.

Sectoral groundwater use is critical for local regions and aquifer-scale groundwater stress studies which are significantly impacted by changes in the groundwater use nominator. Results suggest that BC uses a total of ~562 million cubic metres of groundwater annually. The largest annual groundwater use by major sectors is agriculture (38%), finfish aquaculture (21%), industrial (16%), municipal water distribution systems (15%), and domestic private well users (11%).

Estimating recharge uses multi-scale methods to examine the recharge mechanisms and provide a more reliable recharge estimate in complex mountainous terrain. Local-scale recharge was estimated using the water table fluctuation (WTF) method outlined by (Cuthbert 2014). Aquifer-scale recharge was quantified using a quasi-2D water balance model and generalized aquifer parameters of soil and aquifer material, regional climate, and water table depth. Regional scale aquifer recharge was attributed the areal average recharge flux modelled by the global hydrologic model, PCR-GLOBWB. Results show that generally recharge predictably varies with precipitation and that the average recharge is 791 mm for the local-scale method, 462 mm (32% of precipitation) for the aquifer-scale and 393 mm (33%) for the global hydrologic model.

This study estimates groundwater's contribution to environmental flows across the province for this first time using two separate approaches. The first approach uses the groundwater presumptive standard, which is a general standard for managing groundwater pumping. The

second method introduces a novel approach for estimating the contribution of groundwater to environmental flows using the existing environmental flow needs framework and an understanding of low flow zone hydrology. In general, both methods show larger contributions from groundwater to environmental flows in the Lower Mainland and southern Vancouver Island compared to the Interior.

For each aquifer, the groundwater footprint (expressed as the unitless ratio of groundwater footprint to aquifer area) is calculated four times; using results from each of the two methods used to estimate recharge and each of the two methods used to estimate the groundwater contribution to environmental flows. Of the unconfined aquifers (n = 404) in the province, 43 aquifers (11%) are stressed with high certainty, 32 aquifers (8%) are stressed with low certainty, 296 aquifers (70%) are less stressed, and 29 aquifers (11%) were not included due to missing parameters or issues where modelled recharge was less than environmental flows.