ASSESSING THE IMPACT OF CLIMATE CHANGE ON THE MCKENZIE CREEK IN THE GREAT LAKES REGION

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INTRODUCTION

This research is part of the Co-Creation of Indigenous Water Quality Tools (CCIWQT) project. CCIWQT is a GWF Science Pillar-3 project which aims to build water security in two Indigenous communities, including the Six Nations of the Grand River (Six Nations) in southern Ontario (the largest First Nations community by population in Canada).

Regional climate projections indicate that southern Ontario will experience changes in temperature and precipitation patterns throughout the 21st century (overall warming and wetting trend) [1 & 2]. These projections are also observed at the community level scale for the Six Nations area [3]. Warming climate conditions pose a significant threat to water resources including streamflow, water quality, and overall ecosystem health.

This research evaluates the impacts that climate change will have on McKenzie Creek streamflow. Research on the McKenzie Creek has been limited, therefore understanding hydrological changes within the context of climatic change is crucial for future water resource and climate resiliency planning.

STUDY AREA AND METHODS

The McKenzie Creek sub-watershed (MCSW) is an intermediate sized tributary of the southern portion of the Grand River covering a drainage area of 368km^2 (Fig. 1). Land cover of the sub-watershed consists of rural and agricultural (70%), forest and wetland (25%), and urbanized (<5%). The hydrology of the McKenzie Creek is strongly influenced by precipitation, geology, soils, and land cover. The McKenzie Creek provide ecosystem services to its surrounding communities including agricultural irrigation, and commercial and industrial activities [4].

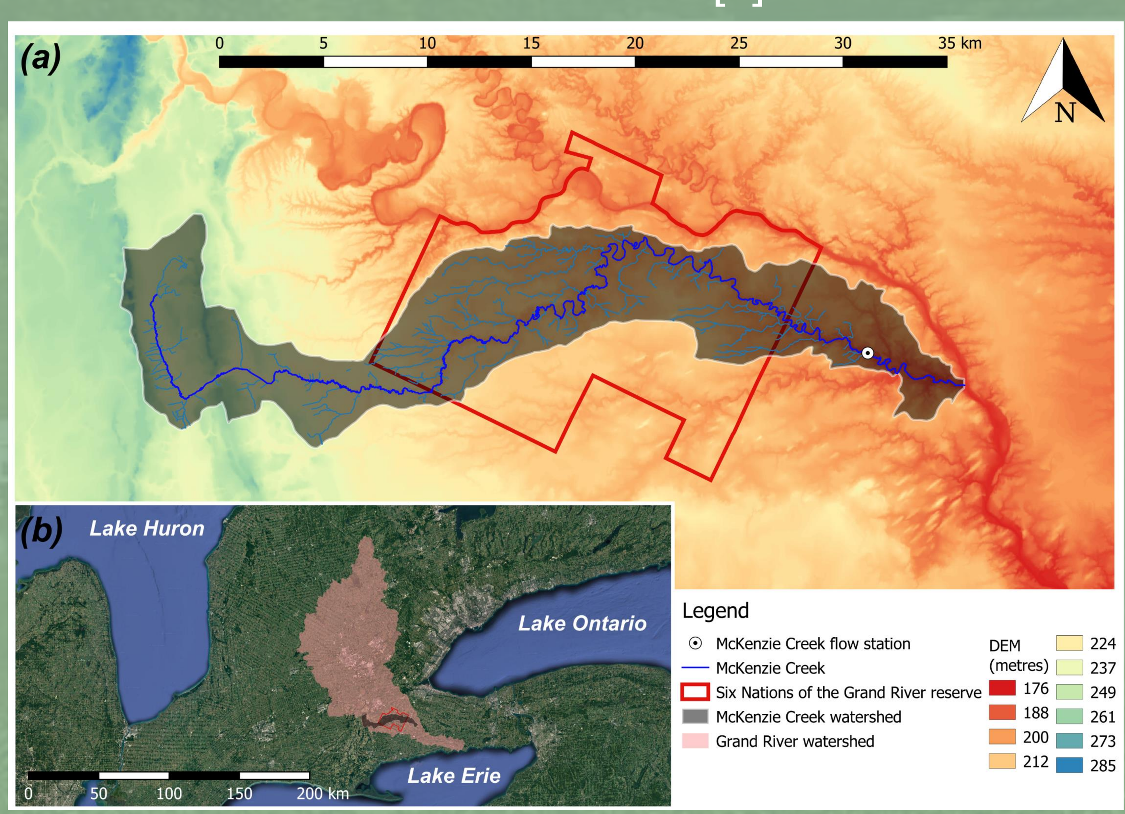

Fig. 1 – Map of study area. (a) DEM map of MCSW (shaded black), with McKenzie Creek (blue) and Six Nations (red). (b) Map of Grand River watershed (pink), MCSW (shaded black) and Six Nations (red). Spatial data from Grand River Conservation Authority's Grand River Information Network (GRIN), and Google Maps.

Modeling of the McKenzie Creek was performed using the Coupled Groundwater and Surface-Water Flow Model (GSFLOW). GSFLOW integrates both Precipitation-Runoff Modeling System (PRMS) and the USGS Modular Groundwater Flow Model (MODFLOW) to simulate ground and surface water flow. Simulations were run from 1951 to 2099 and was forced using precipitation and temperature data from observed NRCAN and ECCC meteorological gridded dataset (NRCANMet), and 11 downscaled Coupled Model Intercomparison Project 5 (CMIP5) Global Climate Models (GCM). Future simulations were run under Representative Concentration Pathways (RCP) 4.5 (intermediate warming) and 8.5 (high warming) scenarios.

The equations used for Fig. 5 and 6:

[Fig. 5] Available water = daily precipitation - daily simulated evapotranspiration

[Fig. 6] Exceedance Probability = m / (n+1), *where m is the ranked data from largest to smallest, and n is the total number of observations*

RESULTS

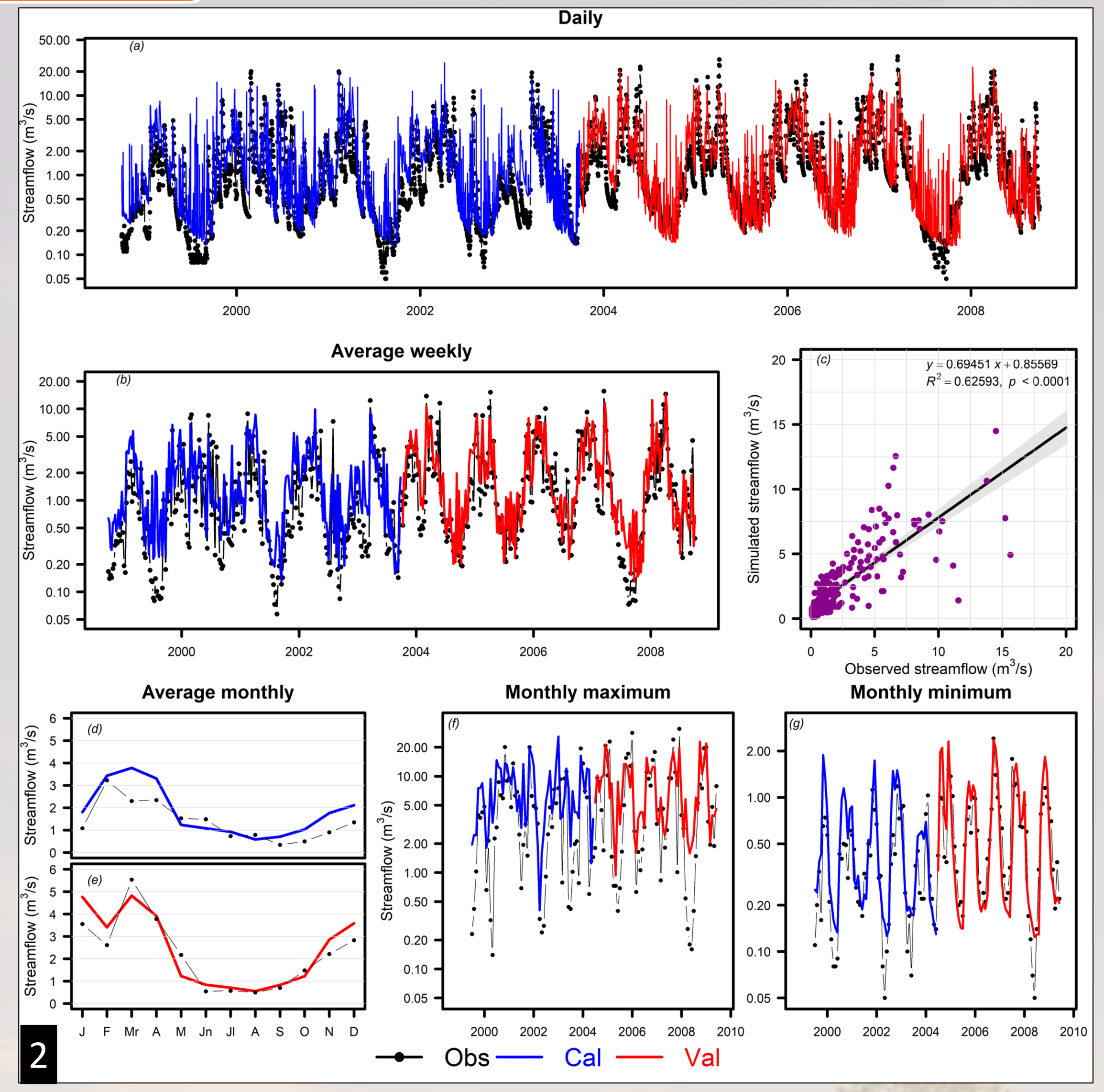

Fig. 2 – GSFLOW calibration and validation results. (a) daily simulations (b) weekly average of daily simulations, (c) scatter plot of observed and validated data, (d and e) average monthly calibration and validated data, (f and g) monthly maximum and minimum simulations results.

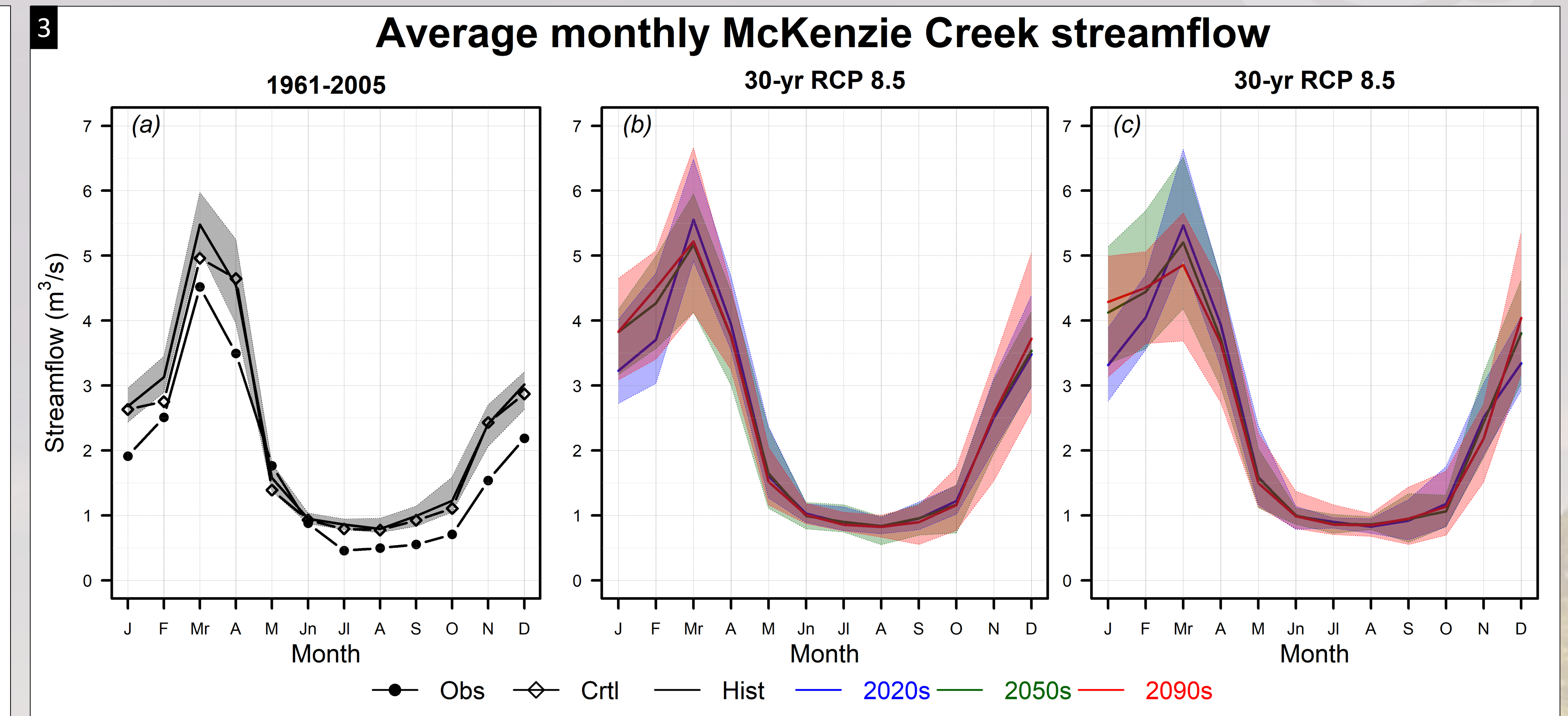

Fig. 3 – Average monthly McKenzie Creek streamflow. (a) 1961-2005 average observed (obs), control (ctrl), and historical (hist) streamflow, and (b and c) projected streamflow under RCP 4.5 and 8.5 for 2020s (2005-2039), 2050s (2040-2069) and 2090s (2070-2099). Shaded areas represent multi model range.

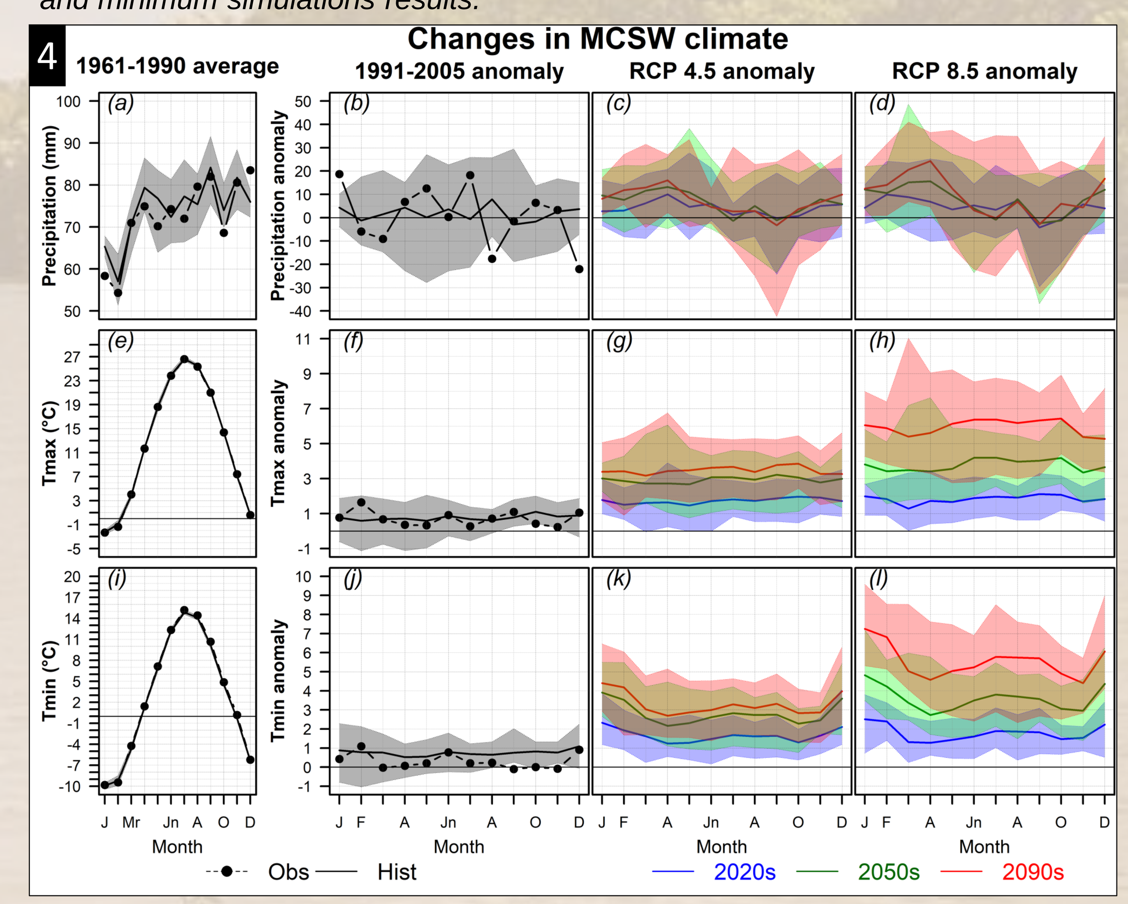

Fig. 4 – Climatic changes in MCSW. (a) Average of total observed (obs) and historical (hist) CMIP5 precipitation from 1961-1990 (baseline), and (b-d) total precipitation anomalies relative to baseline for 1991-2005 and projected precipitation under RCP 4.5 and 8.5 for 2020s, 2050s, and 2090s. (e) 1961-1990 average maximum temperature, and (f-g) maximum temperature anomalies. (i) 1961-1990 average minimum temperature, and (f-g) minimum temperature anomalies. Shaded areas represent multi model range.

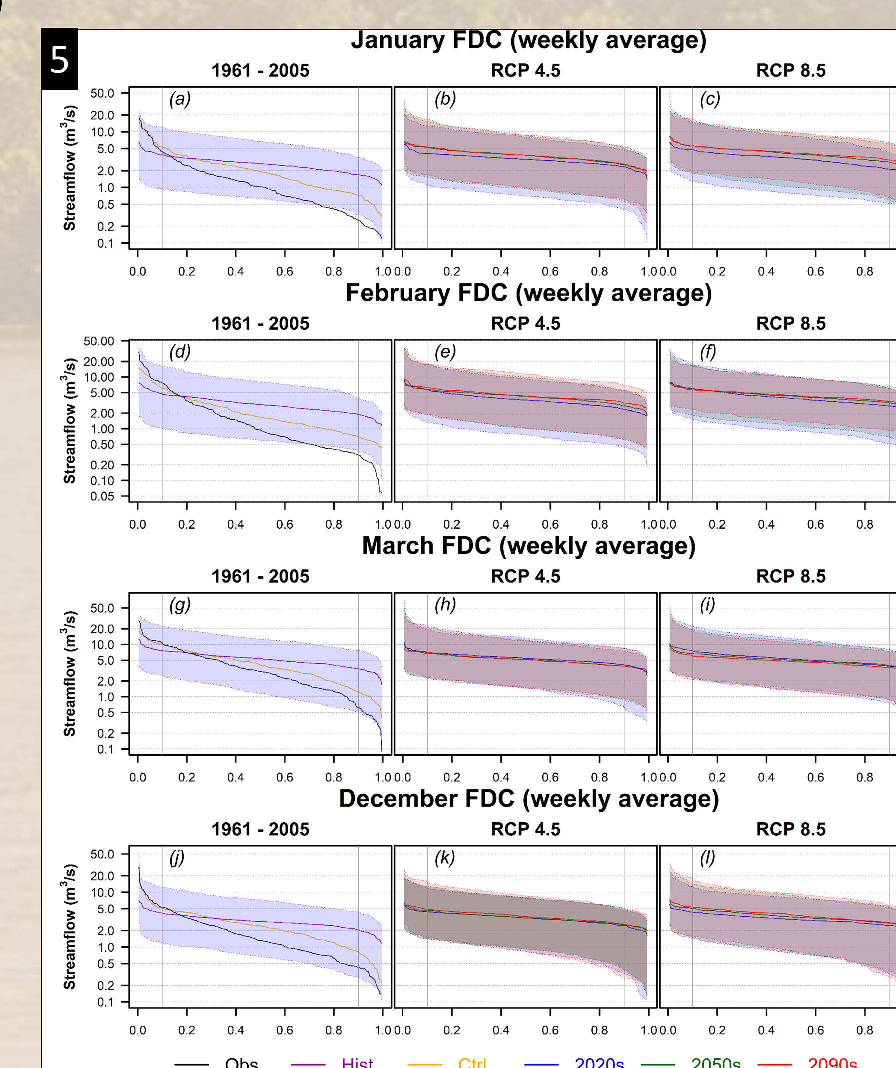

Fig. 5 – Flow Duration Curves (FDC) for weekly streamflow. (a) Average weekly observed (obs), control (ctrl), and historical (hist) FDC for 1961-2005, (b) FDC for average weekly projected streamflow RCP 4.5 for the 2020s, 2050s, and 2090s, and (c) projected FDC under RCP 8.5 for future periods. Shaded areas represent multi model range.

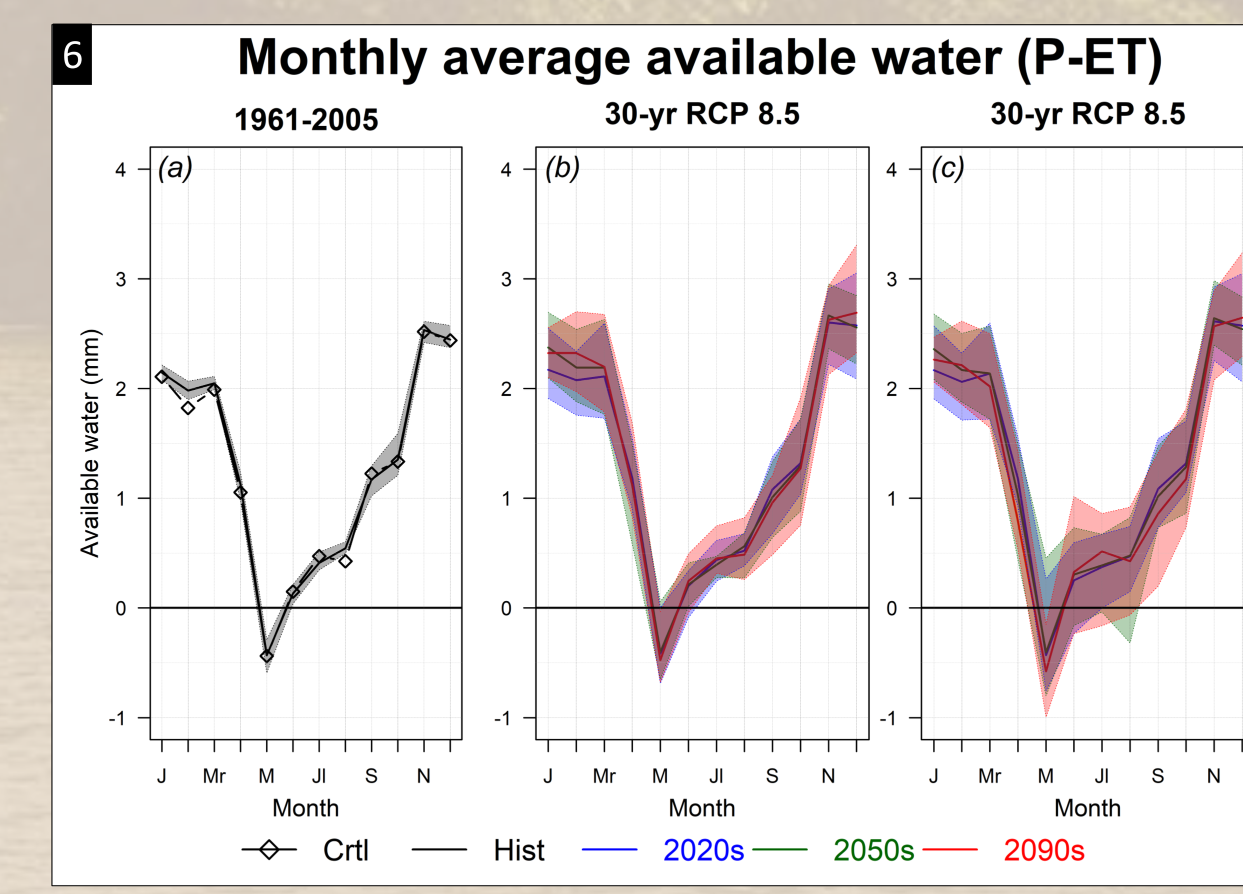

Fig. 6 – Monthly average water availability. (a) Control (crtl) and historical (hist) average available water for 1961-2005, (b) projected average available water under RCP 4.5 for the 2020s, 2050s, and 2090s, and (c) projected average available water under RCP 8.5 for future periods. Shaded areas represent multi model range.

Note: Control (ctrl) refers to GSFLOW simulations using observed data. Historical (hist) refers to GSFLOW simulations using CMIPS data.

SUMMARY OF RESULTS

Based on model validation (Fig. 2) **GSFLOW preformed satisfactory at simulating the McKenzie Creek** (Nash–Sutcliffe model efficiency coefficient of 0.61 and Percentage Bias of 8.3). The model performed adequate at simulating monthly maximum and minimum peaks, however it did **overestimate average winter flow and underestimate March peak flow**.

Future simulations of the McKenzie Creek (Fig. 3) indicates that (relative to 1962-2005 historical average) future **winter streamflow will increase** - 18% and 21% (2020s), 11% and 16% (2050s), and 3% and 4% (2090s) (relative to preceding period) under RCP 4.5 and 8.5, respectively. **However March peak flow will decrease.** Late spring and summer streamflow will experience to little change (under both RCP 4.5 and 8.5). Increased winter streamflow is likely due to the projected increase in winter precipitation and temperature (Fig. 4), however despite this increase winter months FDCs (Fig. 5) suggest that the exceedance probability of high flows will not increase. Therefore, **future winter-spring flood may not be more intense but may occur earlier due to warmer temperatures and increasing precipitation**. Also, warmer summer and decreasing precipitation may result in increased water insecurity. Fig. 6 indicates that **water resources will be stressed in late spring and summer months (especially May) resulting in potential droughts conditions**.

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