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# Reconstructing river discharge trends from climate variables and prediction of future trends

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S U M M A R Y

A number of studies suggest a significant decline of river discharge in the Canadian Plains that drain the eastern slopes of the Canadian Rocky Mountains, and elsewhere in Canada. Analyses of these trends suggested that apparent decline rates may represent long-term discharge variation as a result of anthropogenic induced change in seasonal flow and/or may also represent true long-term declines in annual flow. Potential for significant declines in river discharge raises concern over future water supply for this region. However, extracting accurate trends in river discharge is challenging for basins with relatively short periods of record as quasi-periodic decadal and multi-decadal oscillations are found to be important components of long-term natural variability. In order to reconstruct historic river flows, a correlation model between river flow and climate variables (that normally have longer periods of record) was developed. This empirical relationship was used as a proxy to reconstruct natural modes of river discharge, allowing a means to extend short term discharge records further back in time. The Athabasca River was used as an example to demonstrate the application of the proposed methods. The resulting long-term Athabasca River flow trends show variation is strongly related to the Pacific Decadal Oscillation. Previous studies suggesting decline flows on this river have been biased by examining short-term records of flow, that by chance corresponded with the down limb of a long term cycle.



## 1. Introduction

A number of studies suggest a significant decline of river discharge in the Canadian Plains that drain the eastern slopes of the Canadian Rocky Mountains (Fig. 1). For example, 33% decline is claimed for the summer discharge of the Athabasca River downstream of Fort McMurray from 1970–2003, 47% for the Peace River at the town of Peace River during 1915–2003, 83% for the South Saskatchewan River at Saskatoon from 1912 to 2003 (Schindler and Donahue, 2006). Many of these apparent decline rates are a result of management decisions and may represent anthropogenic induced change in seasonal flow only. For instance, the decline rate in the South Saskatchewan River is only apparent during the spring months when dam filling occurs. There is little observable change in the total annual flow of the South Saskatchewan River as stored water is released in the same year for hydro power generation. Still, declines in total annual flow are reported elsewhere, such as 13% decline in the annual mean discharge rates for rivers flowing to the western Hudson Bay from 1964 to 2003 (Déry and Wood, 2005), 27% decline of annual average river flow of the Oldman River from 1949 to 2002 (Byrne et al., 2006), and a decline of 33% for the Red Deer River at Red Deer in the last 90 years (Rood et al., 2005). This suggests that possible long-term declines in annual flow through the Canadian Plains, one of the driest regions of the country, are indeed occurring. Such potential changes are raising significant concern over future water supply for this region, especially in basins where surface waters are already considered fully allocated, or those that face rapidly growing water demand.

There are significant challenges, however, to extract accurate trends in river discharge in basins with relatively short periods of record. The Mann–Kendall (M–K) test (Mann, 1945, and Kendall, 1975) and Theil–Sen (T–S) test (Thiel, 1950 and Sen, 1968) are commonly used to extract trends from historic data sets. However, real hydrologic time series data are more complicated than a simple mixture of a linear trend and random white noise as inherently assumed by the M–K and T–S tests. Flow trend analyses needs to account for long-term natural variability in run-off generation (Chen and Grasby, 2009a). Studies of climate and hydro-meteorological time series have found that quasi-periodic decadal and multi-decadal oscillations are important components of long-term natural variations (Schlesinger and Ramankutty, 1994; Mann and Park, 1994; Mann et al., 1995; Mann and Lees, 1996; Chen et al., 2004, 2006; Novotny and Stefan, 2007; Wilson et al., 2007; Labat,

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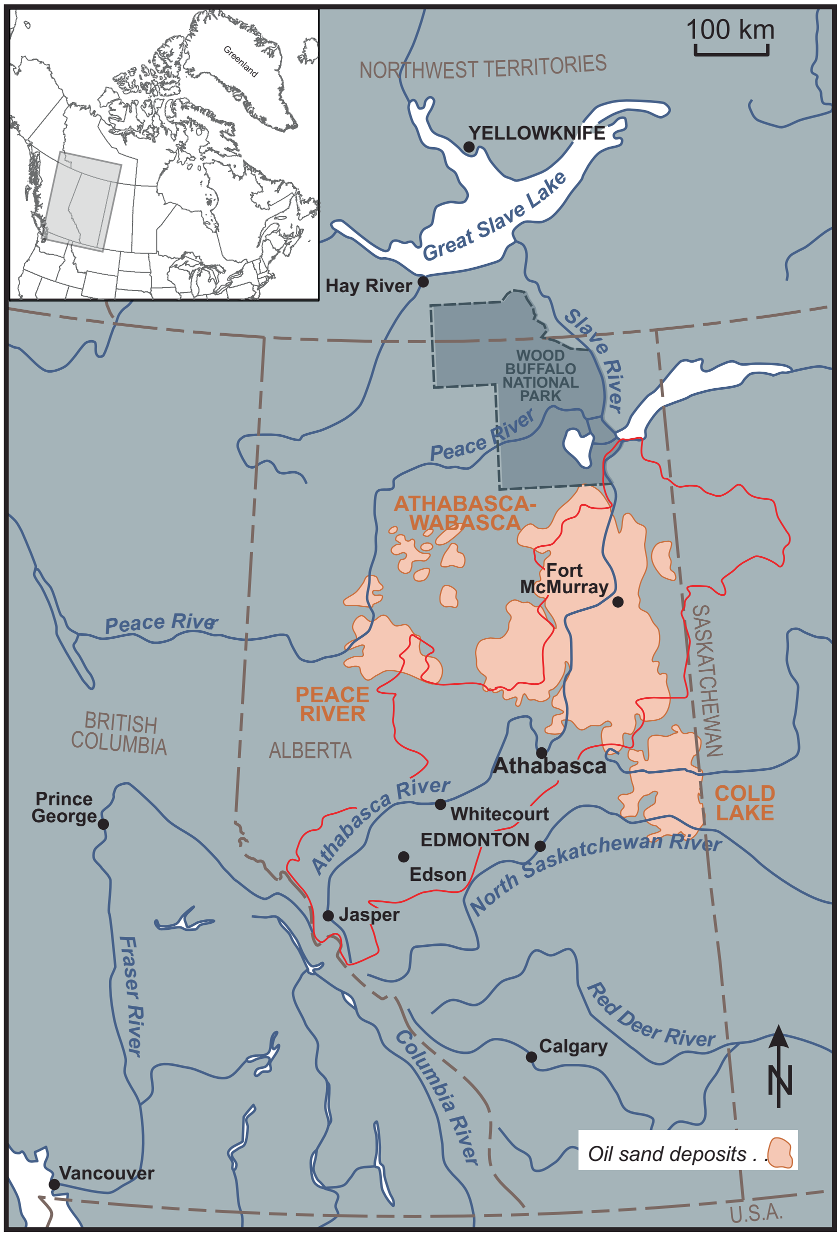


**Fig. 1.** Map showing the study area and the locations of the Athabasca River and major oilsand deposits in Alberta, Canada. The Athabasca River Basin is outlined in red.

2006). Using a decomposition method, Chen and Grasby (2009b) found that multi-decadal (45–60 years variability) cycles are common features in river discharge in the Canadian Plains. Although these multi-decadal cycles are generally recognised, the impacts that they have on trend analyses are commonly ignored. As discussed by Chen and Grasby (2009a), this can easily lead to misinterpretation of short term climate cycles as long term trends (Fig. 2). This problem is particularly exacerbated in northern Alberta since many hydrometric stations started records in the 1960s (Statistics Canada, 2003; Chen and Grasby, 2009a), during the peak of a long term cycle of river discharge. Subsequent trend analysis of river discharge in the Canadian Plains, conducted in the early 2000s (e.g. Schindler and Donahue, 2006), were by chance on a down-limb of a long term cycle (similar to the example in Fig. 2b). This has the impact of creating artificial decreasing trends (Chen and Grasby, 2009a).

To counter effects of cyclicity induced by processes such as the Pacific Decadal Oscillation, Chen and Grasby (2009a) argue that trend analyses should be restricted to hydrometric stations with records >60 years. This creates the immediate problem however that the majority of hydrometric stations in Canada and elsewhere have too short a period of record for any trend analyses to be conducted. Here we examine empirical relationships between temperature, and precipitation time series to test if these longer climate records can be used as a proxy to reconstruct natural modes of river discharge. This would allow a means to extend short term discharge records further back in time, based on typically longer term climatic records. This would allow better estimation of temporal trends of river discharge affected by multi-decadal oscillations. Once a relationship between climate variables and discharge is established, it can also be used to generate a simple first order future forecast model based on existing predictions of climate change impacts on climate. This would provide an initial view of potential range of flow based on multi-decadal variability, as well as stochastic features of climate variables.

For this study we use the Athabasca River as an example because it is one of the few large rivers in the Canadian Plains that has no flow control structures that would alter natural seasonal