Current and future water issues in the Oldman River Basin of Alberta, Canada

Water Science & Technology **Vol 53 No 10 pp 327–334** © IWA Publishing 2006

J. Byrne*, S. Kienzle*, D. Johnson*, G. Duke*, V. Gannon, B. Selinger*** and J. Thomas*****

*Department of Geography, University of Lethbridge, Lethbridge, Alberta, Canada T1K 3M4
(E-mail: *byrne@uleth.ca*; *stefan.kienzle@uleth.ca*; *dan.johnson@uleth.ca*; *guy.duke2@uleth.ca*)

**Laboratory for Foodborne Zoonoses, Population and Public Health Branch, Public Health Agency of Canada, PO Box 640, Lethbridge, Alberta, Canada T1J 3Z4 (E-mail: *gannonv@inspection.gc.ca*)

***Department of Biological Sciences, University of Lethbridge, Lethbridge, Alberta, Canada T1K 3M4
(E-mail: *selibl@uleth.ca*; *thomas@uleth.ca*)

Abstract Long-term trends in alpine and prairie snow pack accumulation and melt are affecting streamflow within the Oldman River Basin in southern Alberta, Canada. Unchecked rural and urban development also has contributed to changes in water quality, including enhanced microbial populations and increased water-borne pathogen occurrence. In this study we look at changing environment within the Oldman River Basin and its impact on water quality and quantity. The cumulative effects include a decline in net water supplies, and declining quality resulting in increased risk of disease. Our data indicates that decreases in the rate of flow of water can result in sedimentation of bacterial contaminants within the water column. Water for ecosystems, urban consumption, recreation and distribution through irrigation is often drawn from water-holding facilities such as dams and weirs, and concern must be expressed over the potential for contaminate build-up and disproportionate potential of these structures to pose a risk to human and animal health. With disruption of natural flow rates for water resulting from environmental change such as global warming and/or human intervention, increased attention needs to be paid to use of best management practices to protect source water supplies.

Keywords Global warming; irrigation; snowpack accumulation; streamflow; water availability; water-borne pathogens

Introduction

The Oldman River basin in southern Alberta is impacted by extensive land use change, large-scale diversions and allocation/reallocation of water supplies, increasing physical, chemical and biological contamination, and declining alpine and prairie snow accumulations. Water managers face the challenges of increasing water usage, exaggerated by declining supplies and less dilution and assimilation capacity. Transition from alpine to a semi-arid prairie landscape in southern Alberta generally is characterized by increased urban development, agricultural activities and industrialization. These activities focus along rivers and streams, critical elements for both social and economic development for the region, and ecological and agricultural sustainability. As a result, a significant increase in chemical and bacterial contamination of surface waters is apparent west to east through the watershed. Moreover, seasonal variation in temperature and flow has potential to exacerbate the situation, resulting in rising levels of contamination from late May through early August. To address some of these concerns, river dams, weirs and reservoirs have been constructed and interconnected by an extensive irrigation system to help control the rate of flow of surface water through the system. The cumulative effects of these combined changes are difficult to quantify, and for the most part, are not monitored on a scientific basis. In this paper, we discuss a series of studies which cumulatively describe current and future water quantity and water quality issues.

doi: 10.2166/wst.2006.328

Methods

Detailed methods are provided in Lapp *et al.* (2002; 2005) and in Gannon *et al.* (2005). In general, the alpine snowpack analysis for western Canada was done by combining a wide area assessment of forecast changes associated with wintertime synoptic conditions over western North America (Lapp *et al.*, 2002) with micro-scale alpine hydrometeorology models (Lapp *et al.*, 2005) to evaluate the impacts of forecast climate change on snowpack conditions in alpine watersheds. The synoptic analysis used to generate long-term climate time series scenarios were developed using the Canadian Centre for Climate Modeling and Analysis (CCCMA) first generation coupled general circulation model (CGCM1). Streamflow data was obtained from Alberta Environment (2002) and analyzed using a 5-year moving average. Water samples used for analysis of water quality, were taken upstream from foothold using a pole, approximately 30 cm below the surface of the water. Samples were collected from monitoring sites within open channel irrigation canals and stream channels and enumerated by a membrane filtration technique at the Provincial Laboratory of Public Health, Foothills Hospital, Calgary, Alberta. Counts represent the total number of bacteria as colony-forming units (CFU) per 100 ml of filtered water.

Study area

The Oldman River Basin is in a semiarid zone located in the southern part of the province of Alberta, Canada (Figure 1). The watershed is 28,000 km^2 and has a population of approximately 161,400 who live on rural farms, in villages, towns and within the city of Lethbridge (Oldman Watershed Council, 2005), located near centre of the basin. Tributaries to the Oldman River, such as the Castle River, originate in the Rocky Mountains to the west, and are fed year round by snow and glacier-melt. Surrounding Lethbridge, a vast network of irrigation canals and associated holding reservoirs pass through the region and eventually drain into the Oldman River. Irrigation is used to support a wide variety of field crops including grains, oil seed, pulse, sugar beets and potatoes. To the north of Lethbridge, there is a highly developed cattle feedlot industry associated with the irrigated land of the Lethbridge Northern Irrigation District.

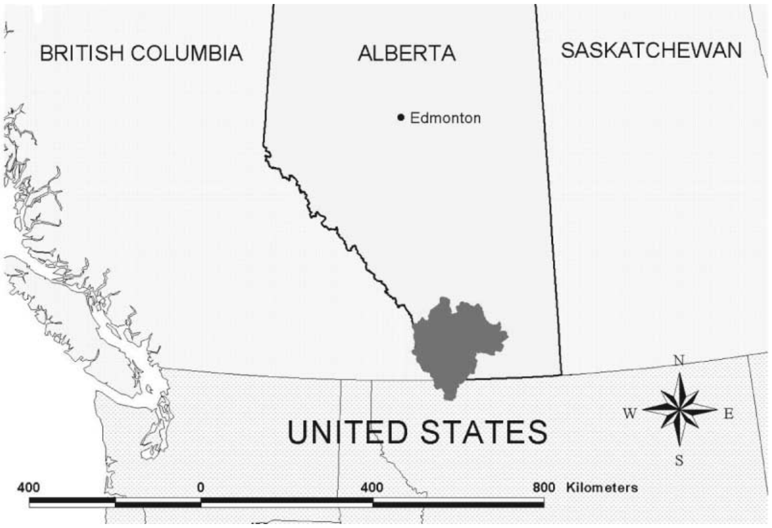

Figure 1 The Oldman River Basin, southern Alberta, Canada. The basin is shown in dark gray

Results and discussion

Alpine snow hydrology

Alpine hydrometeorology models were used to predict changes in wintertime precipitation at the watershed scale. A vapor transfer model was incorporated in the modeling for the Upper Oldman watershed in Alberta (Lapp *et al.*, 2005) to reflect sublimation effects by Chinook winds. The synoptic analysis and GCM output, forecasts a modest increase in both winter precipitation, and substantial winter warming in the study areas in Alberta, and British Columbia's Okanagan basin.

The results of the modeling for the Oldman and Okanagan basins are provided in Table 1. A critical consequence of the analysis in both regions is that increased winter precipitation due to synoptic conditions will not compensate for regional changes in rain to snow ratios. The net result will be a decline in winter accumulations of precipitation as snow, and hence an expected decline in spring runoff.

Streamflow trends

Streamflow in the Oldman River watershed generally is declining. Low flows within the system are getting lower (Figures 2 and 3), and the mean annual flows also are getting lower (Figures 4 and 5). The 5-year moving average of annual minimum monthly streamflow for the Castle River, an unregulated river in the upper reaches of the Oldman River watershed, has declined by ~10% since 1949 (Figure 2), while the 5-year moving average for the annual mean streamflow for this river has declined by ~26% (Figure 4). Consistent decline of the annual minimum monthly streamflow of this system is a clear indication of a reduced snow pack.

When a watershed produces less water for a long time period (Figures 4 and 5), consequences for water resources management are serious. The streamflow in the Oldman River watershed is already utilized to more than 90% of all water. Tributaries such as the Belly, Waterton and St. Mary's Rivers are unable to support additional water allocations (Alberta Environment, 2002), and declining streamflows will make it difficult in the future to respond to increases in demand:

- for irrigation water needed for economic growth,
- for water needed to respond to environmental changes due to global warming,
- for increases in demand for municipal water due to growing human and animal populations, and
- for increased industrial demands used to support activities such as food processing.

Rivers with a declining streamflow have less water available to dilute in-stream pollutants. These decreases can result in increased concentrations of harmful substances in the water (water pollution), negatively affecting aquatic ecosystems, and placing maintenance or creation of a healthy ecosystem at risk. The region of the Oldman River watershed could see a rise in mean annual air temperatures of as much as 5 °C with a doubling of CO_2 levels (Flato *et al.*, 2000). Most, if not all of this warming is likely to occur during winter and spring.

That climate change likely is occurring within the Oldman River basin is signalled by the apparent decline in streamflow within the Castle River (Figure 4), an unregulated

Table 1 Decline in maximum spring snow water equivalent (SWE) volume (million m^3) over the Oldman and Okanagan watersheds due to climate change

SWE	1960–90	2021–50	% decline
Oldman	632	391	38%
Okanagan	11400	8300	27%

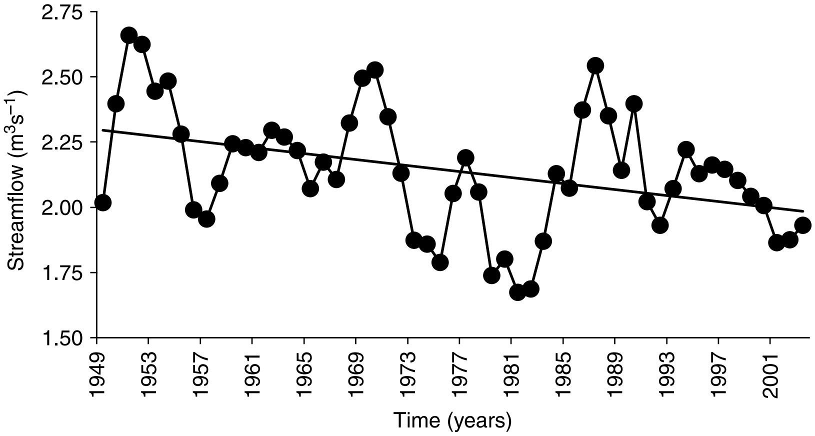

Figure 2 Five-year moving average of annual minimum monthly streamflow for the Castle River (WSC station 05AA022), and associated linear trend line

river in the montane region of the upper Oldman River watershed. This declining streamflow can be attributed to a reduced snow pack in the winter (Table 1), which annually produces between 70 and 90% of the annual streamflow volume within the Oldman River watershed. In addition, the largely reduced volume of glacial ice in the Rocky Mountains, which historically has sustained late summer stream flows within the basin, is expected to exacerbate the long-term trend in declining flows (Demuth *et al.*, 2002).

Microbial ecology and waterborne pathogens

High concentrations of cattle and confined livestock operations within the Oldman River Basin can contribute to a decline in surface water quality. Feces rich in bacteria (Chapman *et al.*, 1994; Van Donkersgoed *et al.*, 1999; Elder *et al.*, 2000; Applebee *et al.*, 2003) has potential to leak into and contaminate surface and ground waters. We have shown (Hyland *et al.*, 2003) that fecal contamination in surface waters from the Oldman River Basin is low during the winter months where less than 5% of the water sampled was contaminated with more than 200 CFU of enteric bacteria/100 ml (Figure 6). While levels of contamination increased during summer months from May through September

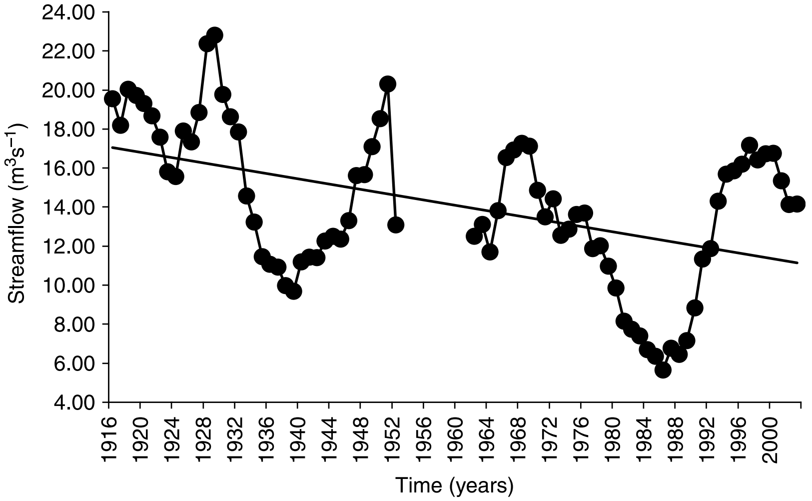

Figure 3 Five-year moving average of annual minimum monthly streamflow for the Oldman River near Lethbridge (WSC station 05AD007), and associated linear trend line

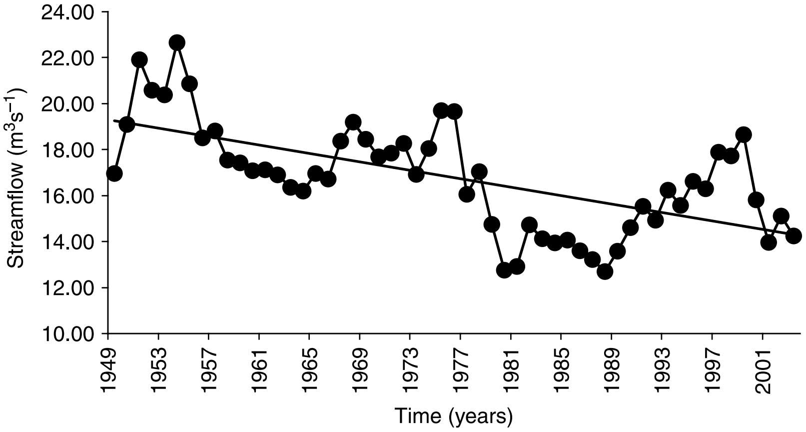

Figure 4 Five-year moving average of annual mean streamflow for the Castle River (WSC station 05AA022), and associated linear trend line

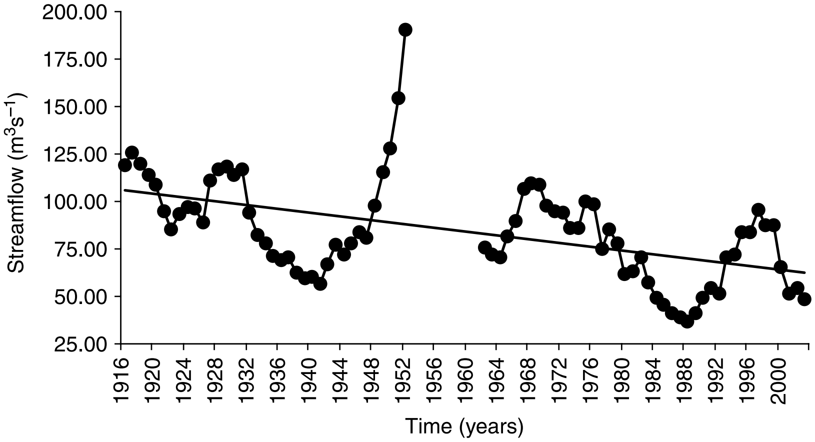

Figure 5 Five-year moving average of annual mean streamflow for the Oldman River near Lethbridge (WSC station 05AD007), and associated linear trend line

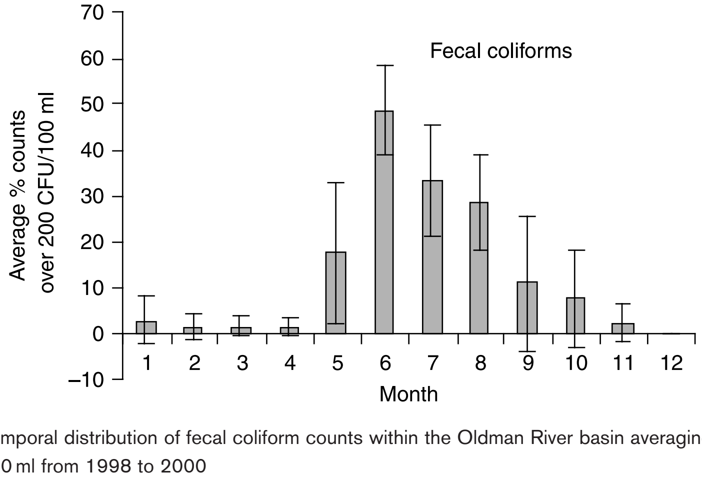

Figure 6 Temporal distribution of fecal coliform counts within the Oldman River basin averaging more than 200 CFU/100 ml from 1998 to 2000

(*i.e.*; from 10 to 50% of the water samples during this period were contaminated with more than 200 CFU of enteric bacteria /100 ml), additional studies have not been able to demonstrate a statistically significant relationship between bacterial water quality and presence of confined livestock operations (Johnson *et al.*, 2003; Little *et al.*, 2003). The unique spatial characteristics between upstream and downstream sites (Little *et al.*, 2003; Gannon *et al.*, 2005), and the rise in bacterial contamination following precipitation events (Hyland *et al.*, 2003; Little *et al.*, 2003), suggest that the bacterial contamination may be the result of a number of factors other than animal density. These factors appear to be affected by runoff topology of the landscape and farm-specific practices, such as animal grazing, access of livestock to streams, and the timing and amount of manure applied to fields as fertilizer.

One factor contributing to contamination may be aggregation of particulate bacteria into sediments that accumulate in areas where water flow is diminished (Gannon *et al.*, 2005); *i.e.,* into slow moving regions of rivers and lakes, and behind weirs and dams. During periods of normal flow, contaminant levels may accumulate at these locations. However, during spring runoff from snow covered regions and following storm events (Figure 7), increased rate of flow and scouring within the drainage system can contribute to an increase in bacterial contamination of the surface water.

These observations suggest that water managers must be prepared to respond to environmental conditions that result in increased turbulence (runoff, storm events or high wind resulting in mixing of the water column), causing deterioration of source waters being used for human or animal consumption. In addition managers also should be alert to extended periods of low turbulence caused by drought or reduced water flow resulting from natural (global warming) or man-made (controlled flows through dams and weirs) disruptions to the drainage system. These reduced-flow conditions also could result in accumulation of water-borne contaminants at water intakes being used to supply drinking water to humans and animals, and deterioration of slow moving regions of lakes and rivers often used for recreational purposes. This suggests that routine scouring through natural or artificial means is required to maintain optimum water quality within a drainage system. Changing trends in streamflow and declines in the annual snow pack will exacerbate these problems and will continue to challenge water managers into the future.

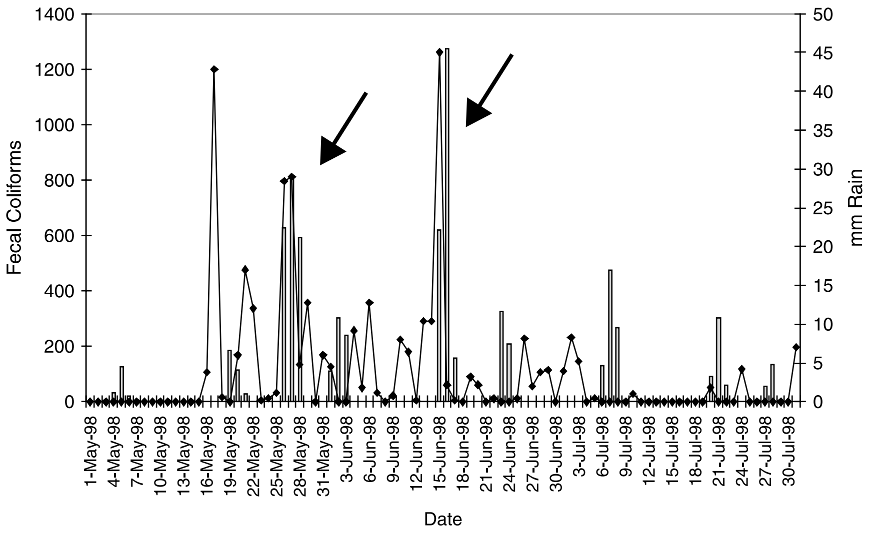

Figure 7 Relationship between fecal coliform counts (■) and precipitation (•– – –•) for the Oldman River Basin in May through July of 1998. Related events are indicated by arrows

Conclusions

Our research indicates that a decrease in snowpack and reduced runoff within the Oldman River Basin is resulting in a reduction in water available for urban and rural applications. Where water allocation within the basin has been established through assessment of historical trends, radical changes in urban, agricultural and industrial practices likely will be required to address decreases in water available within the system. Our research also shows that decreases in the rate of water flow can result in sedimentation of bacterial contaminants within the water column. Reductions in available water within the Oldman River Basin will likely exacerbate this condition, and may lead to increasing levels of contamination of surface waters. As water for urban consumption, recreation and distribution through irrigation often is drawn from water-holding facilities, concern must be expressed over the potential for contaminate build-up, and disproportionate potential of these structures to pose a risk to human and animal health. With disruption of natural flow rates for water resulting from environmental change caused by global warming and/or human intervention, increased attention needs to be paid to use of best management practices which maintain scouring, dredging and/or treatment of critical water sources where contaminate build-up is likely, and to maintain adequate water for urban and rural applications within the Oldman River Basin.

Acknowledgements

This research was funded in part by the Canadian Water Network. The authors would also like to thank Lethbridge Northern Irrigation District, Alberta Agriculture and Alberta Environment for their part in data collection. Their appreciation is also extended to the Public Health Agency of Canada and the Provincial Laboratory for Public Health at Foothills Hospital (Calgary, Alberta) for completing water tests over the last several years.

References

Alberta Environment, Alberta Sustainable Resource Development and Alberta Agriculture, Food and Rural Development (2002) *South Saskatchewan River Basin Water Management Planning.* Phase 2: Basin Advisory Committees and Government Staff Directory. Alberta Environment, Calgary, Alberta, Canada.

Applebee, A.J., Frederick, L.M., Heitman, T.L. and Olson, M.E. (2003). Prevalence and genotyping of *Giardia duodenalis* from beef calves in Alberta. *Can. Vet. Parasitol.*, **112**, 289–294.

Chapman, P.A., Wright, D.J. and Siddons, C.A. (1994). A comparison of immunomagnetic separation and direct culture for the isolation of verocytotoxin-producing *Escherichia coli* O157 from bovine faeces. *J. Med. Microbiol.*, **40**, 424–427.

Demuth M.N., Pietroniro A. and Ouarda T.B.M.J. (2002) *Streamflow regime shifts resulting from recent glacier fluctuations in the eastern slopes of the Canadian Rocky Mountains*, Report prepared for the Prairie Adaptation Research Collaborative, Regina, Saskatchewan, Canada.

Elder, R.O., Keen, J.E., Siragusa, G.R., Barckocy-Gallagher, G.A., Koohmaraie, M. and Laegreid, W.W. (2000). Correlation of enterohemorrhagic *Escherichia coli* O157 prevalence in feces, hides, and carcasses of beef cattle during processing. *Proc. Natl. Acad. Sci.*, **97**, 2999–3003.

Environment Canada (2001) *HYDAT CD-ROM,* Version 2001–2.02, Atmospheric Monitoring and Water Survey Directorate. Downsview, Ontario, Canada.

Environment Canada (2002) *Canadian daily climate data*, CDCD V1.01, Climate Information Branch, Atmospheric Environmental Service. Ottawa, Ontario, Canada.

Flato, G.M., Boer, G.J., Lee, W.G., McFarlane, N.A., Ramsden, D., Reader, M.C. and Weaver, A.J. (2000). The Canadian Centre for Climate Modeling and Analysis global coupled model and its climate. *Clim. Dyn.*, **16**, 451–467.

Gannon, V.P.J., Duke, G.D., Thomas, J.E., VanLeeuwen, J., Byrne, J., Johnson, D., Kienzle, S.W., Little, J., Graham, T. and Selinger, B. (2005). Use of in-stream reservoirs to reduce bacterial contamination of rural watersheds. *Sci. Tot. Environ.*, **348**, 19–31.

Hyland, R., Byrne, J., Selinger, B., Graham, T., Thomas, J.E., Townshend, I. and Gannon, V. (2003). Spatial and temporal distribution of faecal indicator bacteria in Southern Alberta, Canada. *Water Qual. Resour. J. Can.*, **38**, 15–32.

Johnson, J.Y., Thomas, J.E., Graham, T.A., Townshend, I., Byrne, J., Selinger, B. and Gannon, V.P.J. (2003). Prevalence of *Escherichia coli* O157:H7 and *Salmonella* spp. in surface waters of Southern Alberta and its relation to manure sources. *Can. J. Microbiol.*, **49**, 326–335.

Lapp, S., Byrne, J., Kienzle, S. and Townshend, I. (2002). Linking global circulation model synoptics and precipitation for western North America. *Int. J. Climatol.*, **22**, 1807–1817.

Lapp, S., Byrne, J., Townshend, I. and Kienzle, S. (2005). Climate warming impacts on snowpack accumulation in an alpine watershed. *Int. J. Climatol.*, **25**, 521–536.

Little, J.L., Saffran, K.A. and Fent, L. (2003). Land use and water quality relationships in the lower Little Bow River watershed, Alberta, Canada. *Water Qual. Resour. J. Can.*, **38**, 563–584.

Oldman Watershed Council (2005). http://www.oldmanbasin.org/.

Van Donkersgoed, J., Graham, T. and Gannon, V. (1999). The prevalence of verotoxins, *Escherichia coli* 0157:H7, and *Salmonella* in the feces and rumen of cattle at processing. *Can. Vet. J.*, **40**, 332–338.