Water quality monitoring: the basis for watershed management in the Oldman River Basin, Canada

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Abstract The Oldman River flows 440 km from its headwaters in south-western Alberta, through mountains, foothills and plains into the South Saskatchewan River. Peak flows occur in May and June. Three major reservoirs, together with more than a dozen other structures, supply water to nine irrigation districts and other water users in the Oldman basin. Human activity in the basin includes forestry, recreation, oil and gas development, and agriculture, including a large number of confined livestock feeding operations. Based on the perception of basin residents that water quality was declining and of human health concern, the Oldman River Basin Water Quality Initiative was formed in 1997 to address the concerns. There was limited factual information, and at the time there was a desire for finger pointing. Results (1998–2002) show that mainstem water quality remains good whereas tributary water quality is more of a challenge. Key variables of concern are nutrients, bacteria and pesticides. Point source discharges are better understood and better regulated, whereas non-point source runoff requires more attention. Recent data on *Cryptosporidium* and *Giardia* species are providing benefit for focusing watershed management activities. The water quality data collected is providing a foundation to implement community-supported urban and rural better management practices to improve water quality.

Keywords Better management practices; monitoring; water quality; watershed management

Introduction

The Oldman River (mean annual flow = 3,191,000 dam^3, 101 m^3/s) is a gravel-bed stream that flows 440 km from its headwaters in south-western Alberta, eastward through mountains, foothills and plains into the South Saskatchewan River (Figure 1) and eventually to the Hudson's Bay/Arctic Ocean. Over this length, the river drops from an elevation of 3,300 m to about 700 m at the downstream end. The upper basin supports a cold water salmonid fishery; the lower basin is warmer and supports northern pike, walleye, and lake sturgeon. Peak flows, fed by mountain snowmelt, occur in May and June. Three major reservoirs, namely, the Oldman, Waterton and St Mary's Reservoirs, together with more than a dozen other water control structures, supply water to nine irrigation districts and other water users in the Oldman Basin. The Oldman River Basin is home to more than 160 000 people, almost half of whom live in Lethbridge, the basin's largest municipality. Human activity in the basin includes forestry, recreation, oil and gas development in the upper basin; and agriculture, including a large number of confined livestock feeding operations, in the mid to lower parts of the basin. About 33% of the watershed's land cover is agricultural, 29% is forested and 17% is native vegetation. Irrigation demand comprises over 80% of the water allocated in the basin.

The Oldman River Basin Water Quality Initiative (OMRBWQI) was formed in 1997 to address the concerns of basin residents regarding perceived deterioration of river water

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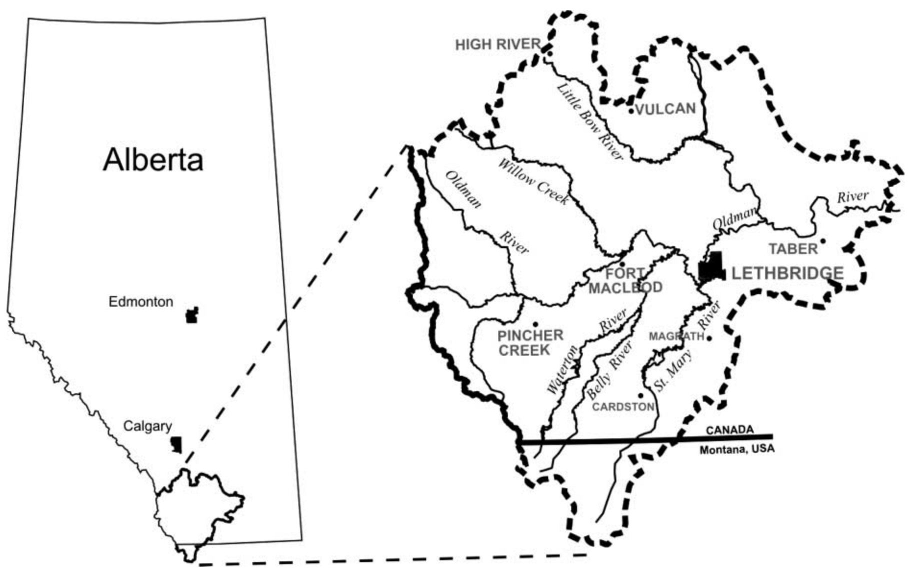

Figure 1 Oldman Basin location map

quality. Questions were being raised about both point and nonpoint sources of contaminant loadings. Residents were concerned about agricultural expansion and urban impacts; there was limited factual information, and at the time there was a desire for finger pointing. The main goals of the OMRBWQI were therefore to document surface water quality and land use throughout the basin, explore land use–water quality relationships, and identify areas of concern. In the first 5 years, the Initiative collected water samples at 108 locations within the basin. Approximately 4600 site visits were made, with analyses of up to 140 biological, physical and chemical variables (Saffran, 2005).

The OMRBWQI was transformed into the Oldman Water Council (OWC) in 2004 when it was decided that both water quality and quantity issues ought to be addressed. There are multiple demands on surface water supplies in the basin. Determining a balance between instream flow needs for protection of the aquatic ecosystem (Clipperton *et al.*, 2003) and economic demands is a significant challenge within the Oldman Basin. The OWC was set up to provide a forum to address these additional issues, to provide State of the Basin reports and to work with a wider range of stakeholders, while still ensuring water quality issues remained at the forefront.

Methods

Water quality sampling. Discrete water quality samples were taken at a wide array of sites in the Oldman Basin, including the river mainstem, tributaries, irrigation return flows, urban stormwater outfalls and treated effluent sources. Samples were collected on a bi-weekly to monthly basis by trained provincial government field staff, from the Departments of the Environment (Alberta Environment) and Agriculture. Water samples were analyzed at a commercial laboratory. Analyses included major anions and cations, nutrients (total and dissolved phosphorus, nitrate-nitrite, ammonia, total nitrogen), total and dissolved sediments, a pesticides scan of more than 50 pesticides (in the four summer months only), fecal coliform bacteria, and E. *Coli*. Field measurements included temperature, dissolved oxygen, electrical conductivity and pH.

River flows and meteorological data. River flows in most cases were obtained from Alberta Environment and Water Survey of Canada permanent gauged sites.

Meteorological data was obtained from Alberta Environment and Environment Canada. At smaller inflows, for example the irrigation return flows to the Oldman River, field staff would take flow measurements while on site.

Cryptosporidium and Giardia. In 2003–04 samples were collected at three Oldman River mainstem sites, namely upstream (a little below the Oldman Dam) at the "near Brocket" site, at Highway 3 at Lethbridge and furthest downstream at Highway 36. These parasites were collected on a "Filtra-Max" module which fits into a custom-made canister (*pers comm.* Ray Walker, Alberta Environment, Calgary). A 12 V electric pump was used to filter approximately 50 L of river water at 75 psi and 4 L/min. Water flowed from an intake (suspended mid-column in the water) through Tygon tubing to the pump, past a pressure gauge, through the filter canister, through the volume counter (Kent) and out through more tubing. Filtering time per sample took approximately 15–20 minutes. After water filtering was completed, the canister was stoppered at both ends, placed in a sealable bag and transported in a chilled container to the Provincial Health Laboratory in Calgary, for analyses. Molecular genetic tools were then used to type these parasites, and were used to assess sources of contamination of *Cryptosporidium* (*pers. comm.* N. Neumann, Provincial Health Laboratory, Calgary).

Water quality index. A water quality index (Wright *et al.*, 1999; Saffran *et al.*, 2001) was calculated based on the select objectives. Water quality data were assessed from up to 24 sites within the basin, depending on the year. An index value was calculated for the data collected from April to the following March. The formula used to calculate index values for each group was based on three statistical attributes of water quality with respect to desirable levels: a) scope, the total number of water quality variables that did not meet guidelines; b) frequency, the number of individual measurements for all variables combined that did not meet guidelines; and c) amplitude, the amount by which measurements did not meet guidelines. Variables are compared to provincial and federal guidelines (Alberta Environment, 1999; CCME, 1999). Variables that make up the index include nutrients, dissolved oxygen, pH, pesticides, and depending on the index, may include major ions and metals. Where a number of guidelines exist for one variable, the guideline for the most sensitive use (recreation, agriculture, or the protection of aquatic life) was chosen.

Results and discussion

Flows varied widely from 1998 to 2002 (Figure 2). Summer flows at Lethbridge ranged from a high of 1554 m^3/sec (in 2002) to more typical summer flows of 50–200 m^3/sec. Similar to the high flows, the precipitation record at Lethbridge also recorded a maximum

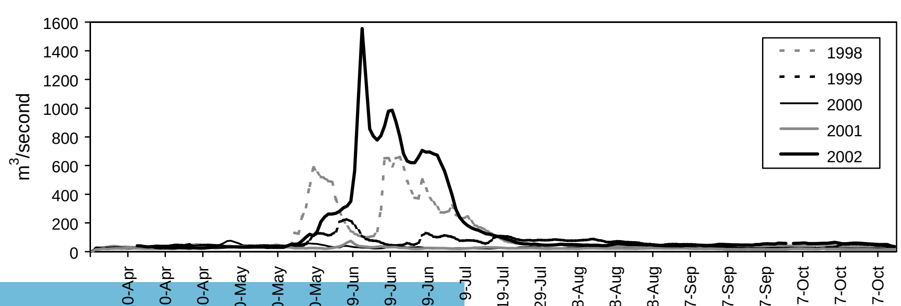

Figure 2 Oldman River flow in Lethbridge (m^3/s)

accumulated precipitation in 2002 (Figure 3). Besides summer precipitation, snow accumulation and melting behavior in the upper parts of the watershed can also influence early summer flow levels as noted by the double flow peaks in 1998 (Figure 2).

Seasonal variability in our water quality results was frequently influenced by flow and precipitation conditions, with wetter years generating a poorer overall water quality index (Table 1), and therefore suggesting that nonpoint source loadings are a significant issue. In addition, the index identifies that water quality in general decreases from upstream to downstream on the mainstem of the Oldman, and that water quality is more challenged in the tributaries and the irrigation return flows. Index values in streams influenced by agriculture and urban runoff were in the 40–60 value range, which is defined as poor to fair water quality. In the upper parts of the basin, where conditions are more pristine, index values were above 80, and therefore in the good to excellent range. These values were expected, but nonetheless were important to document for public communication.

Key water quality data (nutrients and microbes) are identified in Table 2. The tributaries (in the mid to lower basin) and irrigation return flows were found to have median values that were near, or over the specific water quality guidelines, whereas median values at mainstem sites were always below the guidelines (Figures 4 and 5).

The Lower Little Bow River, is a tributary of the Oldman River and is subject to intensive agriculture (Little *et al.*, 2003). In this river, Pearson correlations among land use, soil types and water quality variables identified significant positive relations between the proportion of cereals, irrigated land, confined feeding operation density and maximum concentrations of key nutrients (total nitrogen, nitrate nitrogen and total phosphorous) during wet years. Most nutrient variables were inversely related to the proportion of native prairie (Little *et al.*, 2003).

Pesticides were also detected in the basin. The highest frequency of detections (up to 30 detections per site in a total of four pesticide scans carried out monthly from May to Aug) were found in the irrigation return flows to the mainstem river. Of note, detections were as frequent or more frequent in urban stormwater outfalls at the City of Lethbridge. On the mainstem sites, pesticide detections ranged from zero to 10 detections per year. Most frequently found pesticides were 2,4-D, diclorprop, mecoprop and dicamba, with variation found between urban and rural areas depending on purpose (use in urban lawns or agricultural crops).

A relatively large and sustained flux of *Cryptosporidium* and *Giardia* were present in the Oldman River during sampling in 2003–2004. To date 6 species/genotypes of *Cryptosporidium* have been identified in the Oldman River: *C. andersoni* (cattle), *C. baileyi* (poultry, birds), *Cryptosporidium* skunk genotype, two unknown *Cryptosporidium* genotypes (most likely *Cryptosporidium* genotypes parasitizing wildlife), and C. *parvum* bovine genotype (humans, cattle or other ungulates) (*pers comm.* N. Neumann, Provincial Health Laboratory, Calgary). The data suggest that multiple sources of contamination are entering the river, not all of which can be attributed to agricultural contamination (i.e., wildlife and possibly human sewage contamination). Additional work continues in this area.

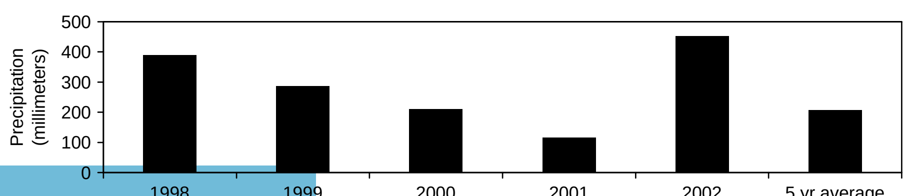

Figure 3 Yearly accumulated precipitation in Lethbridge, 1998–2002

Table 1 Water quality index results, Oldman River and tributaries, 1998–2002 (from upstream to downstream sites)

	General water quality index						Pesticides index					
	1998–99	99–00	2000–01	2001–02	02–03	Average	1998	1999	2000	2001	2002	Average
OMR near Brocket	88	100	94	100	87	94	–	–	91	100	93	95
Beaver Cr. at Hwy 785	72	76	73	72	72	73		92	85	88	93	89
Six Mile Coulee Spillway	64	65	54	61	49	59	32	44	39	38	44	39
OMR at Hwy 3 Bridge	87	100	100	100	85	94	–	92	83	87	80	84
OMR SW of Diamond City	64	88	–	88	74	79	68	–	–	60	81	70
Piyami Drain	49	59	70	58	42	56		54	59	75	42	58
OMR at Hwy 845	76	88	–	–	71	79	59	–	–	–	69	64
Battersea Drain	59	64	67	75	45	62	46	48	48	57	37	47
Little Bow R. near mouth	88	81	81	81	58	78	45	-	47	49	59	50
OMR at Hwy 36 Bridge	75	82	100	100	74	86	63	79	67	79	81	74

OMR = Oldman River. Index ratings: 96–100, Excellent; 81–95, good; 66–80, fair; 46–65, marginal; 0–45, poor
General index includes fecal coliforms, E. Coli, major ions, nutrients and dissolved oxygen; 18 pesticides are in the stand-alone pesticide index

Table 2 Key water quality variables, Oldman River and tributaries, 1998–2002 (from upstream to downstream sites)

	Fecal coliforms			E. Coli			Total phosphorous			Total nitrogen		
	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max
Oldman R mainstem sites												
nr. Olin Creek	2	0.5	100	1	0.5	88	0.007	0.0015	0.051	0.23	0.025	2.7
nr. Brocket	23	1	770	6.5	0.5	600	0.009	0.0015	0.75	0.22	0.08	1.23
u/s Lethb. at Hwy 3	62	1	2200	17	0.5	1601	0.0205	0.0015	1.66	0.3315	0.13	6.49
SW of Diamond City	32	1	2400	18	0.5	1601	0.02	0.003	2.16	0.39	0.11	7.15
at Hwy 36 Bridge	12	1	900	5	0.5	500	0.0125	0.0015	2.37	0.34	0.04	7.33
Oldman R tributary sites												
Castle River	4	1	140	1	0.5	100	0.004	0.0015	0.091	0.27	0.025	0.73
Crowsnest R. u/s Coleman	12	1	520	5	0.5	490	0.009	0.0015	0.312	0.3	0.05	0.99
Beaver Creek	17	1	960	9	0.5	910	0.014	0.0015	0.98	0.49	0.2	1.59
Six Mile Coulee	160	1	20000	98	0.5	10001	0.138	0.0015	2.96	0.77	0.2	10.6
Piyami Drain	200	2	13000	88	1	13000	0.051	0.011	28.9	1.1	0.4	60.1
Haney Drain	33.5	1	1700	13.5	0.5	420	0.026	0.0015	0.351	0.853	0.21	10.5
Battersea Drain	84	1	32000	42	0.5	10001	0.04	0.005	3.6	0.48	0.025	9.33
Little Bow River	48	1	13000	24	0.5	8000	0.0455	0.003	0.876	0.405	0.11	5.6
Expanse Coulee	47	1	4300	31	0.5	3300	0.078	0.024	0.451	0.79	0.32	2.93

Max, maximum value; Min, minimum value. Units: fecal coliform and E. Coli, no./100 mL; total phosphorous and total nitrogen, mg/L

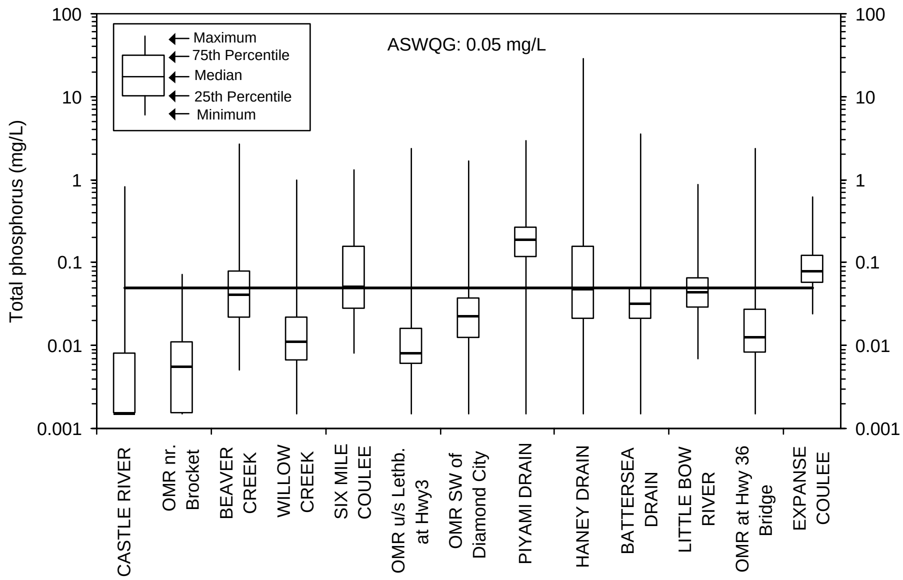

Figure 4 Total phosphorous values in the Oldman River (OMR) and tributaries (1998–2002)

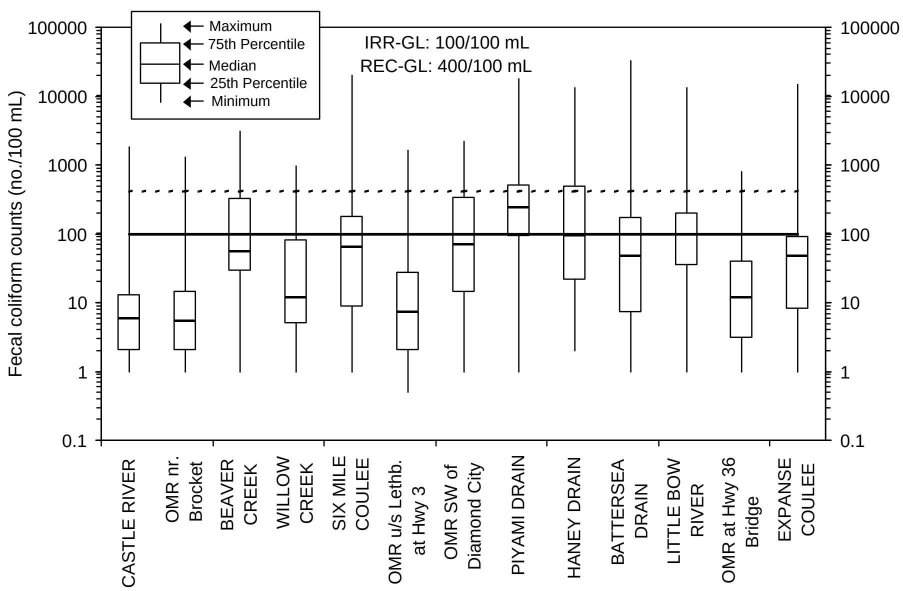

Figure 5 Fecal coliform bacteria in the Oldman River (OMR) and tributaries (1998–2002)

Point source discharges are better managed than nonpoint source loadings. Key improvements to wastewater treatment, in particular at the City of Lethbridge, have had a significant positive impact on downstream water quality.

Conclusions

Based on the water quality data presented at annual conferences for basin residents, and by maintaining close contact with key stakeholders in the basin, better management programs have been implemented both in rural and urban settings in the basin. Industry, agricultural organizations and local operators, academia, various levels of government, local schools, and local Hutterite Colonies have become involved in better protection and management of the watershed.

In collaboration with local producers, industry, counties/municipal districts, and non-government agencies, rural-based better management programs now include the following (*pers comm.*, S. Riemersma, Alberta Agriculture, Food and Rural Development):

- Nose-pumps that are powered by cattle for off-stream livestock watering;
- Windmill pump and livestock exclusion fencing of river;
- Pond aeration to improve water quality in goose pond;
- Livestock relocation project (Turin Hutterite Colony);
- Riparian pasture demonstration with solar-powered, alternative watering system and low-level river crossing to improve livestock distribution and grazing rotation;
- Infiltration well to provide off-stream water to cattle;
- Riparian area restoration project (High River Hutterite Colony);
- Constructed wetland demonstration (AAFRD's demonstration farm, Lethbridge, Alberta);
- Buffer strips adjacent to the Battersea Drain, Picture Butte, AB (Riemersma 2002; Riemersma and Rodvang, in press);
- Chinook Feeder's Ltd. constructed wetland project (Riemersma and Mah, in press).

Members of the Oldman Water Council also took part in hosting Annual Field Days in 2001, 2002 and 2003 in collaboration with the County of Lethbridge and other stakeholders. These tours highlighted environmental stewardship projects adopted by farmers and ranchers.

Urban efforts have focused on education of residents regarding lawn watering and stormwater management. Survey questionnaires have been sent out to City of Lethbridge residents with the results helping to focus "next steps" in the urban better management programs process. Street sweeping in the City is occurring on a more frequent basis. An inventory and inspection of catchbasins within the City identified that the majority of catchbasin sumps in the area being investigated, were full, or near full with sediment and debris. Each basin was cleaned and subsequent monitoring has identified a reduction in pollutants (specifically fecal coliform bacteria) by up to 85%.

The communications team within the Oldman Water Council is involved in toxic substances roundups, in healthy lawn messages, and in promoting urban xeriscaping demonstration sites. They also maintain a very active website: http://www.oldmanbasin.org/about_basin.html.

Water quality issues became a contentious issue back in 1997. Today, with much water quality data, with a good understanding of the issues, and a general desire in the basin to "do the right thing", change is occurring, to the benefit of the environment and the health of the residents. Basin residents accept that all parts of the basin, and many human activities contribute to the contaminant loadings. The water quality data collected is providing a foundation to implement community-supported practices to improve water quality. Water quality data, as part of a stakeholder-driven initiative, can be an effective tool to promote watershed health.

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