CHAPTER 1: SETTING THE STAGE

Oldman River at Maycroft – R. Coffey

Chapter 1: Setting the Stage

1.1 Introduction

Water is essential for life (OWC 2005/2006). Understanding the watershed in which we live is key to appreciating and successfully managing our water resources. The ecological connection of water joins us together. Citizens, communities, industry and government all share responsibility for watershed management. A state of the watershed report gives a "snapshot" of the entire watershed: it is a current accounting of how well a watershed is working.

This report brings together existing information on the ecological function, land-use activities and water quality and quantity for specific indicators within the Oldman watershed. The report describes and assesses the current state of the watershed, identifies existing and emerging issues and trends, and identifies gaps in knowledge needed for making water resource decisions.

This report has been created for all users of the water resource within the Oldman watershed, including regulators and policy makers. It provides information to better understand the inter-relationship among all aspects of the watershed – water, land, ecosystems and human activities. Specifically, the report will:

- raise awareness of the current conditions within the watershed;
- identify issues and opportunities that residents and stakeholders face; and
- form the foundation for the Oldman Integrated Watershed Management Plan.

The Oldman State of the Watershed report was prepared by AMEC for the Oldman Watershed Council (OWC). The goals of the OWC are presented in Appendix A.

Watershed

A watershed is the area of land that catches precipitation and drains into a larger body of water such as a marsh, stream, river or lake.

Watershed Approach

A watershed approach focuses efforts within watersheds, taking into consideration both ground and surface water flow. This approach recognizes and plans for the interaction of land, waters, plants, animals and people. Focusing efforts at the watershed level gives the local watershed community a comprehensive understanding of local management needs, and encourages locally led management decisions.

Pincher Creek Watershed – ARD

1.1.1 Structure of the Report

The Oldman watershed is divided into five regions: four Sub-basins (Foothills, Mountain, Prairie, and Southern Tributaries) and the mainstem of the Oldman River (Figure 1.1).

Chapter 1 provides an introduction to the watershed, giving background and historic information on the formation of the watershed and its land use. The approach to analyzing and presenting data for each of the Sub-basins is provided in Chapter 1. The OWC selected indicators to assess the state of the watershed (see Section 1.3). The indicators were chosen at a workshop held in 2008. Appendix B provides information on the workshop and its outcomes.

In Chapters 2 through 6, each of the five geographic regions (i.e., Sub-basins) that were established for this State of the Watershed report are assessed. Within each Sub-basins, existing data were compiled, synthesized, and evaluated. Issues and trends are discussed within the context of each region. Information sources are provided in Appendix C.

In Chapter 7, information from each Sub-basins is consolidated into an overall watershed assessment and conclusions on the state of the watershed are reached. Chapters 8 and 9 identify knowledge gaps and future trends, respectively. Recommendations are presented in Chapter 10.

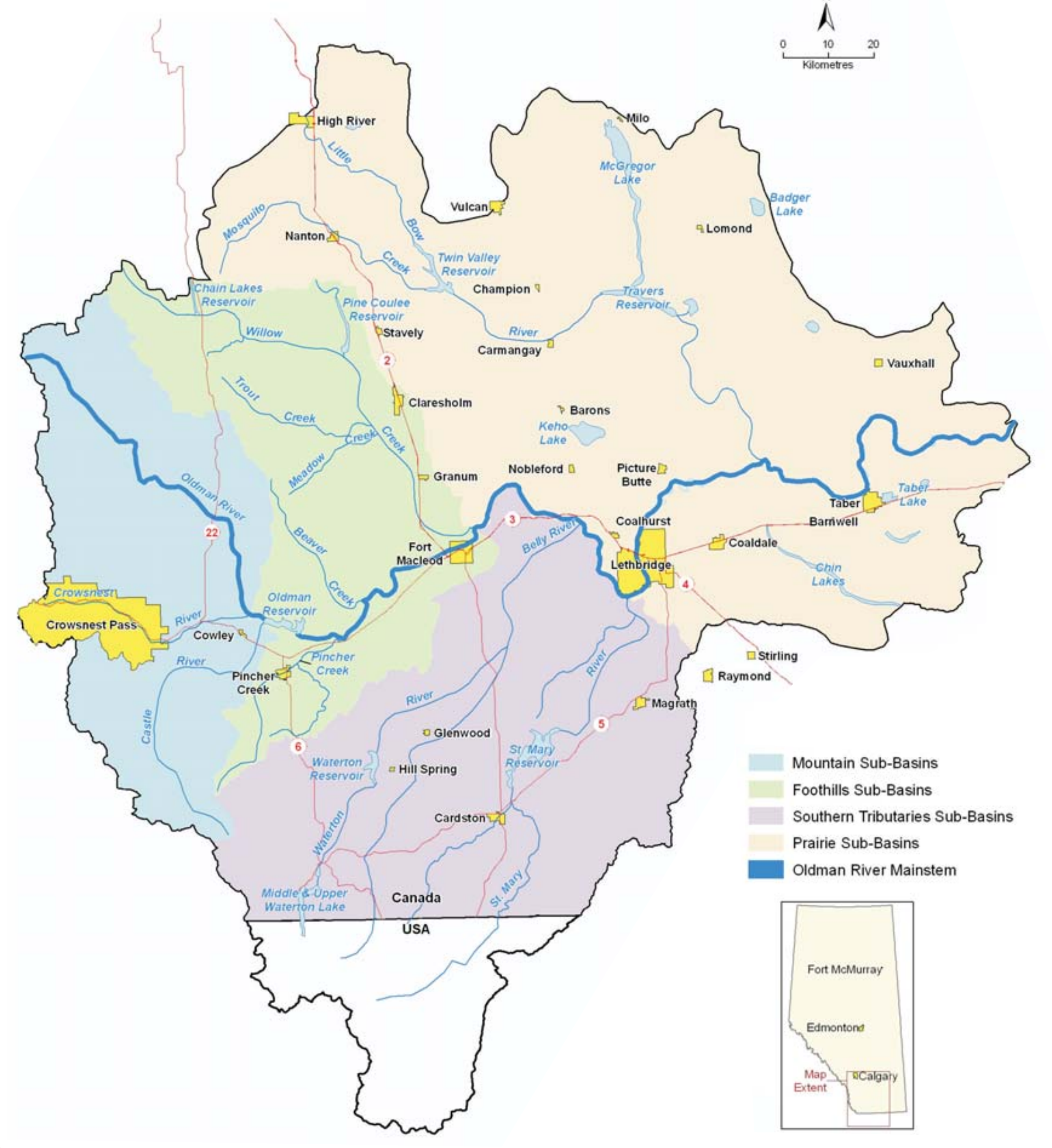


Figure 1.1: Oldman Watershed

Establishing Sub-basins for the Oldman River State of the Watershed Report

In order to assess the state of the Oldman watershed, it was necessary to break the watershed into manageable pieces. This meant looking at regions or Sub-basins in a given area that share similar characteristics. For example, all of the water bodies or sub-basins that flow into the Oldman Reservoir are considered to be within the Mountain Sub-basins due to location. Generally speaking, the Sub-basins were defined primarily by drainage (geography). The delineation of the Foothills Sub-basins and the Prairies Sub-basins followed natural drainage patterns of the land. However, it was necessary to contemplate additional means of stratifying the watershed in the Southern Tributaries Sub-basins. Considering the long history of water management (irrigation) in southern Alberta, and the fact that almost all information gathered on the Waterton, Belly and St. Mary rivers included all three rivers at the same time, these rivers were kept together regardless of location. Discussion of the Oldman River (mainstem) itself was deemed necessary to provide context and show influences of the various Sub-basins.

1.2 Overview of the Oldman Watershed

The Oldman watershed is part of the South Saskatchewan River Basin (SSRB). The South Saskatchewan River is a major Canadian river: it begins in the Rocky Mountains, flows through Alberta into Saskatchewan and merges with the North Saskatchewan River near Prince Albert. From here, as the Saskatchewan River, it continues into Manitoba and eventually empties into Lake Winnipeg.

The watershed drained by the Oldman River and its tributaries covers about 23 000 km^2 in southwestern Alberta and 2100 km^2 northern Montana. It extends eastward from the forested slopes of the Rocky Mountains through the foothills to the plains and prairie grasslands. Within these physiographic regions, there is great diversity of climate, land form, vegetation, wildlife, and human use.

Precipitation in the mountains on the western edge of the watershed feeds the headwaters of the mainstem of the Oldman River and its tributaries (Crowsnest and Castle rivers, Willow and Pincher creeks). The headwaters of the Belly, Waterton and St. Mary rivers rise in Glacier National Park in Montana. The mountains and foothills support coniferous and deciduous forests. The Plains support grassland and prairie vegetation and comprise about 80% of the watershed. The climate is semi-arid, and temperatures vary considerably across the three natural regions. Much of the watershed lies in the rainshadow of the Rocky Mountains, and chinooks are frequent in the winter. Precipitation varies from 110 cm in the mountains to less than 35 cm near Taber. Spring melt in the mountains provides much of the flow of the rivers in the Oldman watershed, and flow declines through the summer to a low in early fall. Extreme drought has occurred in the 1930s, in 1988 to 1989, and in 2001. Flooding in 1995 was caused when heavy rains coincided with spring melt and caused extensive damage in the watershed. First Nations have a long history of occupation of the Oldman watershed, and indeed the Blackfoot legend of creation by Napi, the Old Man, is the source of the name of the watershed and the river. Today, two First Nations' reserves lie within the watershed – the Peigan (North Piikani) Reserve occupies about 430 km^2 near Pincher Creek and the Blood (Kainai) Reserve occupies about 1435 km^2 near Stand Off, southwest of Lethbridge. Both reserves were created under Treaty 7 in 1877.

White settlement occurred in the late 1800s, first as ranching and later farming. Today, agriculture is the dominant land use. Water supply is a concern in much of the watershed, and construction of several onstream dams, including St. Mary, Waterton, Oldman and Twin Valley dams, has regulated river flows to supply the extensive network of offstream storage reservoirs, canals, and pipelines that support irrigation and other uses in the region. In 2006, the total population of the watershed was about 210 000, almost half of whom live in Lethbridge, the regional population centre (74 600). The remainder of the population resides in smaller centers including the towns of High River, Taber, Nanton, Vulcan, Claresholm, Pincher Creek, Magrath and Cardston and surrounding rural areas.

1.2.1 Geology

Before the Rocky Mountains were formed, southern Alberta, and indeed all of Western North America, was covered by a shallow marine sea which laid down thick fine-grained sediments (limestones and shales). The sea drained when the Rockies were uplifted and formed 60 to 70 million years ago, and subsequent erosion from the mountains over a long period covered the marine sediments with thick sandstone layers. Ancestral rivers cut deep valleys into these sediments and drained mostly to the east and south into the Missouri watershed. The area was glaciated repeatedly, and drainage patterns were significantly altered. The present landscape tells the story of the most recent 'Wisconsin' glaciation, which started about 2 million years ago and ended about 10 000 years ago.

1.2.2 Glacial History

The Oldman River is part of the vast drainage system developed across the continent at the end of the last glaciation more than 10 000 years ago. The Oldman and the Bow rivers combine northeast of Taber to form the South Saskatchewan River, eventually draining into Hudson Bay. During the most recent glacial period, the active margin of the continental ice sheet advanced and retreated many times through southern Alberta. About 12 000 years ago, huge ice-dammed lakes were formed along the retreating ice margin, as the glacial ice finally began to melt in the mountains to the west and on the plains to the northeast (Paleo-drainage of the Oldman River http://www.uleth.ca/vft/Oldman_River/GeoHistory.html.).

Glacial Lake Lethbridge was one of these lakes. It formed when the ice margin lay near Lethbridge, and the Belly, St. Mary and Oldman rivers flowed into the lake, covering a vast area and depositing thick layers of fine-grained sediment. The ice margin changed several times during deglaciation, and the shape of the lake and the area covered by glacial-lake sediments varied significantly. Some of the deep pre-glacial river valleys were completely filled with sediment. By 8 000 years ago, Glacial Lake Lethbridge had drained slowly through outlets such as Chin Coulee, forming the extensive coulee landscape seen in the Lethbridge area today. At the same time, the Oldman River and its tributaries established new courses through the thick glacial sediments. These widespread deep glacial sediments are the basis for the extensive agricultural industry that forms the economic backbone of the region.

1.2.3 Hydrology

The Oldman watershed and its component Sub-basins are shown in Figure 1.1. The Sub-basins include the mainstem of the Oldman River and four others defined by the landscape through which their streams flow. The Sub-basins are named Mountain, Foothills, Prairie, and Southern Tributaries. The landscape plays a defining role in determining the energy regime of the river, whether it is eroding its bed or depositing sediment, and the configuration of its channel, bed, and banks. The accumulation of snow in the headwaters determines the flow in the Oldman River in any particular year. Extreme variability in flow through the growing season has resulted in the construction of reservoirs on most major rivers to capture spring run-off and release it throughout the growing season to meet the needs of a growing population, industry, including agriculture, and to augment low river flows in the late summer.

The **Mountain Sub-basins** comprise the western parts of the Oldman watershed from upstream of the confluence of the Castle and Oldman rivers to the headwaters of the Castle, Crowsnest and Oldman rivers at the continental divide. The western and southern portions of the Sub-basins comprise an area that has been called the “Water-tower of the Oldman watershed”. This area includes many headwater streams, rivers and lakes that supply about 75% of the flow of the Oldman River.

In the Mountain Sub-basins, streams are 'energetic' and swift flowing with steep gradients. They have cut deeply into the landscape. Flow varies markedly with the seasons, and spring melt of the heavy snowpack results in a significant 'freshet' through late spring and early summer. These streams generally have rocky beds and can move large rocks and boulders during periods of high flow. Streamflow varies markedly from year to year depending on the amount of snowfall. Urban areas include the Municipality of Crowsnest Pass, comprising the communities of Bellevue, Coleman, Blairmore, Hillcrest, and Frank.

The **Foothills Sub-basins** lie directly to the east and include Willow and Beaver creeks on the north side of the Oldman River and Pincher Creek on the south side. The rolling landscape of the area marks the transition from mountains to prairie and spans several natural regions. The towns of Pincher Creek, Granum and Claresholm are in this Sub-basins.

The **Southern Tributaries Sub-basins** comprise the southern-most areas of the Oldman watershed. The Southern Tributaries include the St. Mary, Waterton, and Belly rivers, their headwaters and tributaries and extends into Montana, United States. Waterton National Park lies in this Sub-basins. The headwater reaches of the Sub-basins are mountainous with swift flowing deeply incised streams, but as the rivers flow eastward through the foothills to the prairies, their gradients decline, velocity is reduced, and the streams begin to meander through wider river valleys, depositing coarser material on the inside of meander bends. The towns of Magrath and Cardston are located within this Sub-basin.

The **Prairie Sub-basins** comprise the northeastern part of the Oldman watershed east of Willow Creek on the north side of the Oldman River and east of the St. Mary River on the south side of the Oldman River. The Little Bow River and its primary tributary, Mosquito Creek, are the significant streams in the Prairie Sub-basins. The Sub-basins include the City of Lethbridge, and several towns including Stavely, Nanton, Vauxhall, Taber, Coaldale, Picture Butte, and High River. Streams in this Sub-basins have a long history of alteration to support irrigation, so recorded flows are significantly altered from natural flows.

1.2.4 Ecology and Climate

The Oldman watershed spans three natural regions – the Rocky Mountains, Parkland, and Grassland (Figure 1.2). A natural region is defined as a group of landscapes that contain similar landforms, hydrology, geology, soils, climate, plants, and wildlife (Natural Regions Committee 2006).

The **Rocky Mountains** lie astride the continental divide that marks the border between Alberta and British Columbia and contain the headwaters of the major rivers of the Oldman watershed. The terrain is the most rugged in the province. Three sub-regions, defined on the basis of elevation, are described:

- the Alpine sub-region lies above the treeline and includes vegetated areas, bare rock, snowfields, and glaciers;
- the Sub-Alpine sub-region extends down from the treeline through closed forests and includes high elevation grasslands; and
- the Montane sub-region comprises open forest and grasslands at the lowest elevations.

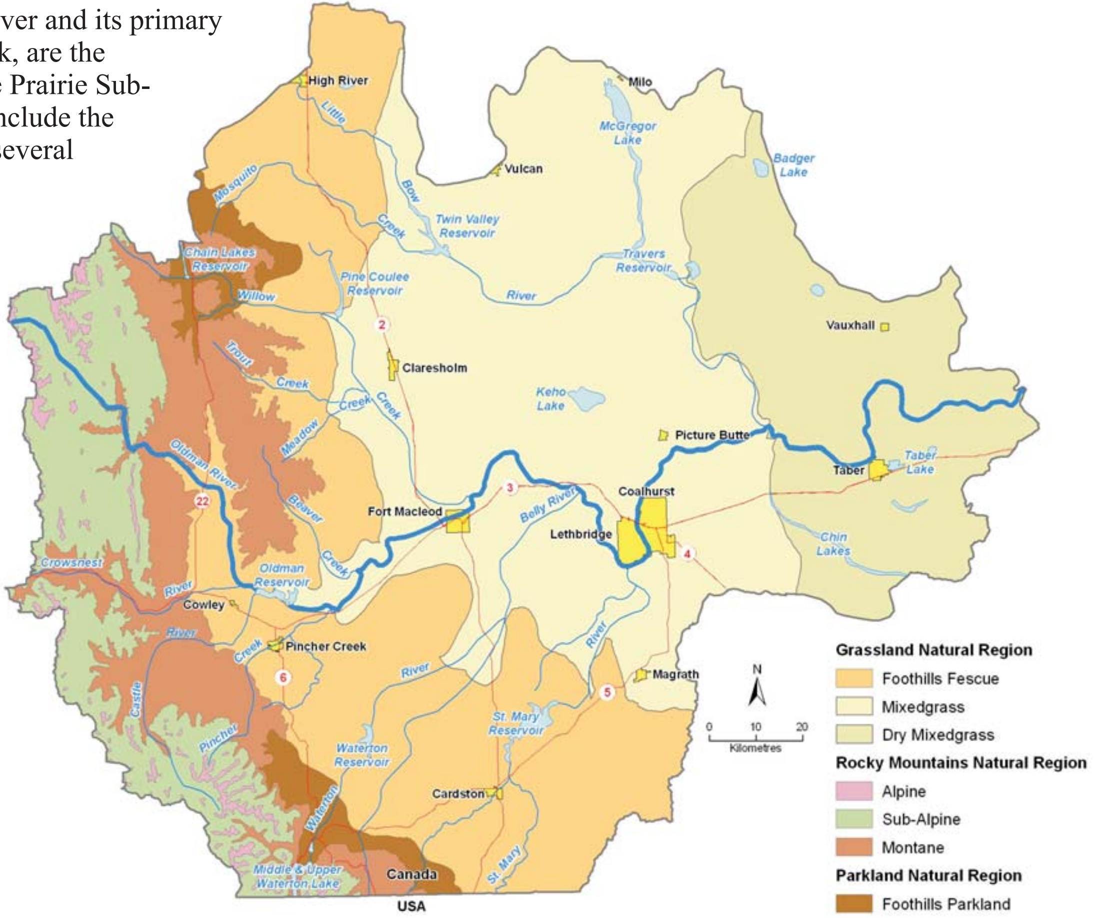


Figure 1.2: Natural Regions of the Oldman Watershed

The **Alpine** sub-region is represented by small high elevation areas and steep mountain slopes, mostly in Waterton National Park. Bedrock is exposed in most areas; surface deposits are thin glacial till or bedrock that has been frost-shattered in place. The area is characterized by a mosaic of microclimates that reflect changes over short distances in substrate, aspect, and moisture conditions. These microclimates are in turn expressed in rapidly changing vegetation communities. Soil development is limited by the harsh climate and steep slopes. The alpine sub-region has the coldest, snowiest winters and shortest growing season in the province. Summers are cold and short. Strong winds are characteristic of the sub-region and control snow accumulation, which affects vegetation distribution. Ice caves, permafrost to a depth of about 100 m, and surface permafrost features occur in the Plateau Mountain area at the south end of Kananaskis Country, west of Nanton. This peak stood above the level of glaciers in the last glaciation. It became an ecological reserve in 1991.

The **Sub-Alpine** sub-region occurs at elevations below the alpine and marks the transition to coniferous forest vegetation. The surface is rolling to inclined and covered by shallow glacial materials over bedrock. Summers are short and cool; winters are cold with heavy snowfall. Vegetation varies from open spruce and fir stands at higher elevations to closed stands of lodgepole pine at lower elevations.

The **Montane** sub-region extends from just north of the Bow Valley to the Montana border and includes the Porcupine Hills. Through much of the Oldman watershed, the Montane intergrades with the Foothills Fescue and the Foothills Parkland sub-regions. It includes the rolling and hilly foothills and the valley floors and lower slopes of the valley floors of eastward flowing rivers in the watershed. Surface materials are mostly till which is thin on sloping and upland areas and deep in the valley bottoms where it is mixed with glacio-fluvial sands and gravels. Summers are mild, and frequent chinooks make winters warmer than most other regions in Alberta. Lodgepole pine, Douglas fir and aspen mixedwood forests occur on easterly and northerly facing slopes. Grasslands predominate on southerly and westerly areas at lower elevations. The variable terrain creates a variety of microclimates that result in rapid changes in vegetation patterns over short distances.

The Rocky Mountain natural region supports a wide range of diverse and complex wildlife habitats and a correspondingly rich fauna. Species are most diverse at lower elevations in the Oldman watershed. The Waterton-West Castle area has a remarkably high number of species at the limits of their range. Grizzly bear, cougar, wolf, bobcat and lynx range throughout the region. Rocky Mountain big horn sheep, moose, elk, white-tail and mule deer are common. The coldwaters of the upper reaches of rivers in the Oldman watershed support mountain whitefish and trout, including rainbows (introduced), native cutthroat trout, and bull trout. Anglers consider these to be some of the finest trout streams on the continent. The fauna of the region are described in detail in the Natural Regions of the Alberta (Natural Regions Committee 2006).

The **Foothills Parkland** sub-region forms a narrow discontinuous band that marks the transition from grasslands to mountains in the areas to the west of High River, south to Stavely, and from Pincher Creek south to the United States border. The topography is rough and the landscape is rolling and hilly. Proximity to the mountains gives this sub-region the highest precipitation, warmest winters and shortest growing season of the parkland areas of the province. Agriculture is limited by the short growing season, and native vegetation remains in many areas. Vegetation varies with latitude, altitude and aspect. Grasslands predominate on dry south- and west-facing slopes, dense willow shrub communities are common on moister sites, and balsam poplar, cottonwood and aspen are found in river valleys.

The Foothills Parkland sub-region provides wildlife habitat for species that use the adjacent regions – both mountains and grasslands. Few species are unique to the sub-region. The varied microclimates create diverse vegetation communities that support distinct habitats and wildlife assemblages (see Natural Regions of Alberta for more details).

Semi-arid **Grasslands** cover most of the Oldman watershed. Three natural sub-regions are described:

- Foothills Fescue sub-region in the west;
- Mixedgrass sub-region around Lethbridge; and
- Dry Mixedgrass sub-region in the east.

The **Foothills Fescue** sub-region comprises rolling grassy uplands along the flanks of the Rocky Mountain foothills. In general, summers are cooler and the growing season is shorter than in other grassland regions. Winters are warmer with more frequent chinooks, and precipitation is greater. Surface materials are glacial till and sandy glacio-fluvial deposits. Shrubs occur on moist well-drained sites, and balsam poplar, aspen and cottonwoods occur on lower terraces and in the river valleys. Black Chernozemic soils with thick organic horizons reflect the greater precipitation and more diverse vegetation.

The Grassland natural region supports many animal species that are found no where else in Alberta and several rare or endangered species occur in the region (e.g., burrowing owl, long-billed curlew, and Sprague's pipit). As well, about 25% of Alberta's rare flora occur in the natural region. Water temperatures increase as you move eastward into the prairie grasslands resulting in a transition zone for coldwater and cool water fish communities. As temperatures increase species such as walleye and pike become more dominant. More details on the wildlife of the grasslands area are found in Natural Regions of Alberta.

The **Mixedgrass** sub-region lies to the west and abuts the foothills. It includes gently rolling and level terrain underlain by glacial lake deposits. Native grasslands were dominated by needle grasses and wheat grasses, and tall shrub and tree growth is restricted to draws and river valleys. Summers are slightly cooler and winters milder than in the Dry Mixedgrass sub-region, and total precipitation and growing season precipitation are both higher. Winter snow can persist on some of the higher elevation areas and contributes to spring soil moisture. Soils are Orthic Dark Brown Chernozemics, and the area includes the most intensively cultivated land in Alberta.

The **Dry Mixedgrass** sub-region has the warmest summers and lowest precipitation in Alberta and takes its name from drought-tolerant short and mid-height grasses that dominate the natural vegetation. Winters are cold, snowfall is low, and chinooks occur less frequently than in areas to the west. Low winter snowfall provides little protective cover for plants and does not contribute significantly to soil moisture recharge. The area has the longest growing season in the province, but total precipitation in the growing season is low. The landscape is level to slightly rolling, dominated by glacial sediments, and cut by coulees and deep river valleys. Shrubs occur in depressions and ravines, often where a northern aspect provides shade and there is reliable water supply in summer from groundwater seepage. Tall shrubs and trees occur only along rivers or in deep coulees again where there is adequate water supply through the growing season. Soils are one of the characteristics that distinguish the three grassland sub-regions. Orthic Brown Chernozemics and solonetzic soils (in the driest and irrigated areas) have developed in the low precipitation, relatively short grassland environment of the Dry Mixedgrass sub-region. This sub-region provides habitat for many plants and animals that do not occur elsewhere in Alberta and supports the greatest diversity of animal species in the grasslands.

Prairie Grassland – ARD

1.2.5 Environmentally Significant Areas

The diversity and uniqueness of the environment of the Oldman watershed has been recognized by the provincial government in the number of environmentally significant areas (ESAs) that have been identified in the region (Figure 1.3). The sites shown on the map correspond to an updated ESA report (Fiera 2009) that is available through the Alberta Government website. In the description of each Sub-basins, ESAs of interest are described with cross-referencing from original sources to this updated report.

The variety of terrain and climate found within the Oldman watershed supports a wide diversity of wildlife, including many species that have special status (Table 1.1).

1.2.6 Fisheries

The fisheries resources of the Oldman watershed and its combination of coldwater and cool water habitats have brought recreational and sport anglers to the region for many years. Recreational fishing contributed more than $350 million to Alberta's economy in 2000 and commercial fishing is a $5 million-per-year industry (Alberta SRD). The high quality of watercourses within the watershed, the presence of desirable sport fish species, and the proximity to a major centre (i.e., Calgary) suggests that fishing pressure within the watershed would be high. In total, the watershed supports 31 species of sport and non-sport fish, some of which are introduced and some of which have special status (Table 1.2).

Parameters related to fish populations or habitat in the Oldman watershed are not used as indicators in this State of the Watershed report, but the continued health of sport and non-sport fish as part of the ecosystem and the local economy are important.

The upper Oldman watershed is characterized as coldwater habitat within fast flowing (i.e., high gradient) mountain streams and rivers with riffle and pool habitat types. This habitat is present from the headwaters downstream to between Brockett and Fort Macleod. Coldwater habitat is found in the upper reaches of the Mountain, Foothills and Southern Tributaries sub-basins. Coldwater species, such as mountain whitefish and various species of trout (Table 1.2) occur in the forested upper reaches of the watershed in the Oldman, Crowsnest, and Castle rivers and their tributaries.

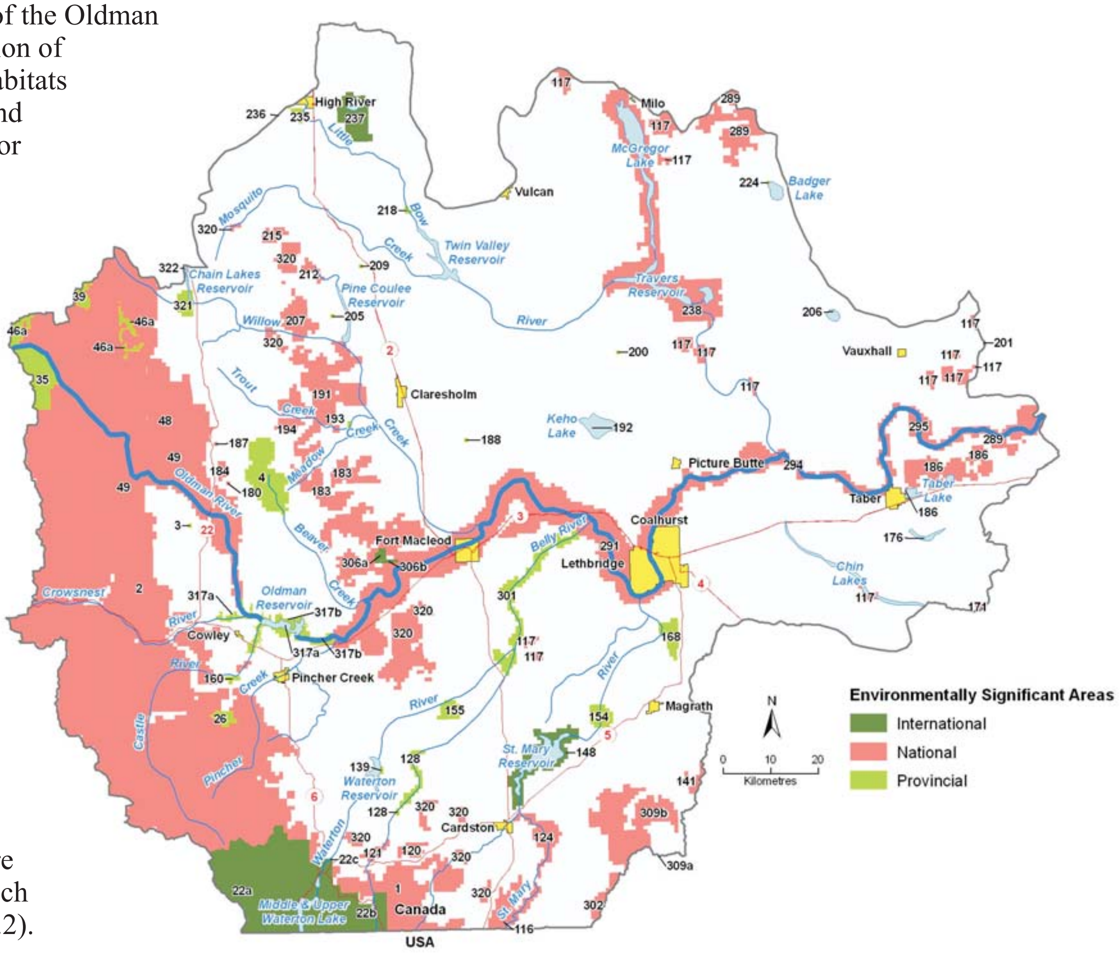


Figure 1.3: Environmentally Significant Areas in the Oldman Watershed

Table 1.1: Rare Species in the Oldman Watershed

Mountain Sub-basins	Foothills Sub-basins	Southern Tributaries Sub-basins	Prairies Sub-basins
Cutthroat Trout Ferruginous Hawk Grizzly Bear Long-tailed Weasel Northern Leopard Frog Peregrine Falcon Short-eared Owl Wolverine	Baird's Sparrow Burrowing Owl Cutthroat Trout Ferruginous Hawk Grizzly Bear Lake Sturgeon Long-tailed Weasel Northern Leopard Frog Peregrine Falcon Plains Spadefoot Short-eared Owl Spoonhead Sculpin Trumpeter Swan Western Hog-Nosed Snake	Baird's Sparrow Burrowing Owl Cutthroat Trout Ferruginous Hawk Grizzly Bear Long-tailed Weasel Northern Leopard Frog Peregrine Falcon Piping Plover Plains Spadefoot Prairie Rattlesnake Pygmy Whitefish Rocky Mountain Sculpin Short-eared Owl Spoonhead Sculpin Swift Fox Trumpeter Swan Wolverine	Baird's Sparrow Burrowing Owl Canadian Toad Ferruginous Hawk Great Plains Toad Grizzly Bear Long-tailed Weasel Northern Leopard Frog Northern Long-eared Bat Peregrine Falcon Piping Plover Plains Spadefoot Prairie Rattlesnake Short-eared Owl Spoonhead Sculpin Swift Fox Trumpeter Swan Western Hog-nosed Snake Lake Sturgeon

Table 1.2: Sport Fish Species of the Oldman Watershed

Coldwater Species		Cool Water Species	
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Brown Trout*	*Salmo trutta*	Goldeye	*Hiodon alosoides*
Cutthroat Trout^	*Oncorhynchus clarki*	Mooneye	*Hiodon tergisus*
Bull Trout^	*Salvelinus confluentus*	Lake Whitefish	*Coregonus clupeaformis*
Lake Trout	*Salvelinus namaycush*	Northern Pike	*Esox lucius*
Brook Trout*	*Salvelinus fontinalis*	Sauger	*Sander canadensis*
Golden Trout*	*Oncorhynchus mykiss aguabonita*	Walleye	*Sander vitreus*
Rainbow Trout*	*Oncorhynchus mykiss*	Yellow Perch	*Perca flavescens*
Mountain Whitefish	*Prosopium williamsoni*	Burbot	*Lota lota*
Arctic Grayling*	*Thymallus arcticus*	Lake Sturgeon^	*Acipenser fulvescens*

* Introduced species
^ species of special status
Source: Partners for the Saskatchewan River Basin 2009.

Most streams in this area are important for coldwater sport fish spawning due to generally high dissolved oxygen concentrations combined with the availability of clean gravel substrates and sufficient water depth and flows (Longmore and Stenton 1981). As a result, trout productivity within this section is generally considered better than other headwater east slope streams north of the Oldman watershed (Nelson and Paetz 1992).

A transition zone occurs in the area of Brockett and Fort Macleod downstream to Lethbridge where the habitat changes from coldwater to cool water. This zone is found in the Foothills, Southern Tributaries and Prairie sub-basins. Within this zone, both coldwater fish species, in particular brown trout, mountain whitefish and rainbow trout, and cool water fish species such as mooneye, lake whitefish, northern pike, sauger and walleye, provide recreational fishing opportunities.

In this transition zone, the Belly and St. Mary rivers discharge to the Oldman mainstem. Fish production within these watercourses is affected by agricultural impacts, particularly water withdrawals. Flows in the Oldman River and tributaries are reduced during the irrigation season, which limits available fish habitat and causes elevated water temperatures and intensified eutrophication (Longmore and Stenton 1981).

The lower reaches of the Oldman mainstem (i.e., in the Prairie Sub-basins downstream of the transition zone) and the only major tributary within the section, the Little Bow River, provide habitat for cool water sport fish such as mooneye, lake whitefish, northern pike, sauger and walleye (Nelson and Paetz 1992). The most abundant species within this section has been mooneye (RL&L 1997), a cool water species. Goldeye are likely only summer residents and migrate downstream to the South Saskatchewan River to spawn and overwinter (Longmore and Stenton 1981). Lake sturgeon occur within the lower section of the Oldman mainstem.

The Oldman mainstem is larger, turbid, and warm flowing at slow velocities through prairie and agricultural lands. The low flows and lack of overstream cover result in increased water temperatures. Fish productivity is moderate due to elevated turbidity and low discharge periods.

The Oldman watershed contains several lakes and reservoirs including, for example, Payne Lake, Beauvais Lake, Oldman Reservoir, Crowsnest Lake, St. Mary Reservoir, Chain Lakes Reservoir, McGregor Lake, Travers Reservoir, Waterton Lake, and Little Bow Lake Reservoir (Mitchell and Prepas 1990).

Several of these water bodies, including Beauvais Lake, Chain Lakes Reservoir, and Payne Lake, have been stocked by the Alberta Government with coldwater salmonid species, in particular rainbow trout, lake whitefish and walleye. As a result of stocking programs, as well as the good quality habitat within most of the water bodies, moderate to excellent recreational fisheries exist. Commercial fisheries exist on McGregor Lake and Travers Reservoir with a substantial lake whitefish fishery on McGregor Lake (Mitchell and Prepas 1990). Commercial fisheries are also present on Keho Lake, Little Bow Reservoir, Milk River Ridge Reservoir, St. Mary Reservoir, and Fincastle Reservoir.

Bull trout are native to the province and have been designated the official fish of Alberta. They are considered a 'species of special concern' in the province by Alberta's Endangered Species Conservation Committee (Alberta SRD). Bull trout populations have been subject to heavy fishing pressure and, as a result, Alberta SRD has implemented a zero possession limit for bull trout.

Native westslope cutthroat trout are listed as 'threatened' in the province and remain a concern in the Oldman watershed. Pure cutthroat trout are only found in a small percentage of tributaries to the Castle, Crowsnest and Oldman rivers, as well as the mainstem of the upper Oldman, above the falls. Mayhood (1998) indicates that they are no longer found in the mainstem and lower tributaries of the Oldman watershed, including the Crowsnest River. Cutthroat trout which have hybridized with rainbow trout exist in the mainstems of the Castle, Crowsnest and Oldman rivers.

In November 2006, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the westslope cutthroat trout as 'threatened' because pure, non-stocked populations had been reduced by as much as 80% by hybridization, competition with introduced trout species, and degradation of habitat (COSEWIC 2006). The species is now being considered by Governor-in-Council for listing under the federal *Species At Risk Act.* A federal-provincial co-chaired recovery team is in place and recovery planning is underway. In September 2009, Fisheries and Oceans Canada released a recovery potential assessment for the species (DFO 2009). The recovery goal is:

> “to protect and maintain all remaining pure native, non-stocked, populations of westslope cutthroat trout in Alberta, each containing at least their current number of fish, with their historical degree of connectivity within drainage systems (except where it would permit invasive non-indigenous species to establish) throughout their current range to ensure their persistence until at least 2020. The aim over the long term is to recover populations within their historic range, where possible.” (DFO 2009).

Lake sturgeon occur as far upstream as the Oldman River Dam, but become more numerous in the cool water zone of the Oldman mainstem downstream of Lethbridge and the St. Mary River confluence. Lake sturgeon in this area are part of the Saskatchewan River basin population of this species**,** which was designated 'endangered' in 2006 by COSEWIC (2006). In Alberta, lake sturgeon are considered 'threatened' under provincial legislation. Alberta has a Sturgeon Management Plan that endeavours to protect the lake sturgeon population from further decline through a strict catch and release policy (Alberta SRD no date). A joint provincial/federal recovery team is currently preparing a recovery plan.

The “Eastslope” or Rocky Mountain sculpin occur only in the St. Mary sub-basin in the Oldman watershed but are also found in the Milk River watershed. This species was designated as “threatened” by Alberta in 2003, by COSEWIC in 2005, and was subsequently listed as “threatened” in the Federal *Species At Risk Act* in September of 2006.

1.2.7 Current Land and Water Use Activities in the Oldman Watershed

The history of settlement and water use in the Oldman watershed has been described eloquently by Lorne Fitch in the Preface to this report. Other sources of historical information are listed in Chapter 11 – Literature Cited.

As part of the Oldman River Watershed Water Quality Initiative, a comprehensive land use inventory of the watershed was conducted to understand the relationships between land use activities and water quality (OWC 2005). The apportionment of various land uses in the watershed is shown in Figure 1.4.

The predominant human use of water in the Oldman watershed is irrigated agriculture. Since the Second World War, the rivers of the watershed have been harnessed to support agriculture in the semi-arid grasslands. There are currently 13 Irrigation Districts in southern Alberta, all drawing water from the South Saskatchewan River system; 9 of these are within the Oldman watershed. About 60% of the land base is devoted to agriculture, and the watershed contains about 40% of the irrigated land in Alberta.

Both license allocations and actual water use are dominated by irrigation (Figure 1.5). As well as providing water for irrigation, irrigation infrastructure provides water to communities, industries, recreational

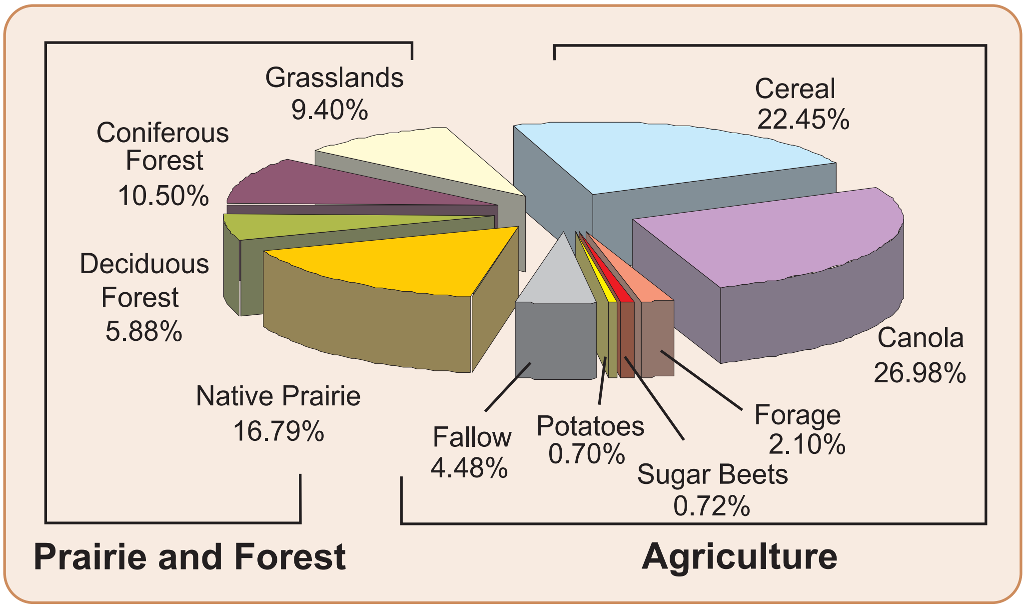
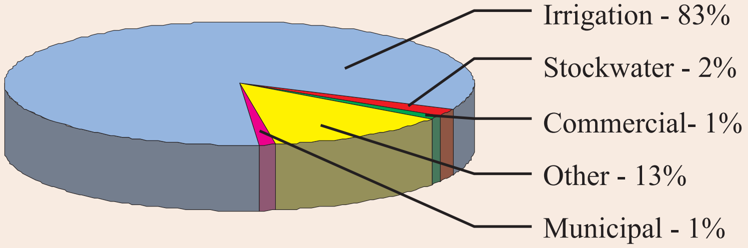
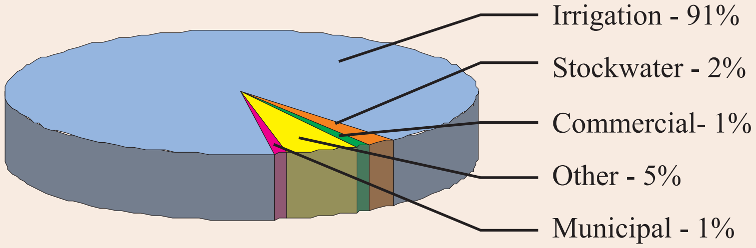


Figure 1.4: Apportionment of Land Uses in the Oldman Watershed

Current (2006) Water Licence Allocations in the Oldman Watershed



Current (2006) Water Use in the Oldman Watershed



Source: SSRB Water Supply Study

Figure 1.5: Water Licence Allocations and Actual Use in the Oldman Watershed

facilities, waterfowl habitat, livestock and hydropower facilities (Irrigation Water Management Study Committee 2002). The second largest water use licensing category is “other”, which includes water management, lake stabilization and wildlife enhancement projects. Municipal and stockwater supplies are two other vital water uses in the watershed, although much less significant in volume of water compared with irrigation. A small amount of water is used for commercial purposes. The combination of irrigated cropland, livestock operations, and processing industries makes the watershed one of the most intensively managed agricultural regions in western Canada (OWC 2005).

Virtually every river in the watershed is part of an extensive network of storage reservoirs, canals and pipelines that store spring runoff and deliver water for irrigation during the growing season. For example, the Oldman River Dam moderates highly variable flows from the Oldman, Castle and Crowsnest rivers by storing water during periods of high runoff and releasing it when flows are lower. It also attenuates peak flows during flood events, although this capability is limited, especially for floods of high magnitude such as occurred in 1995.

As a result of the Oldman River Dam, irrigated land for crop and livestock production increased, hydrologic flows and water temperatures have changed, downstream fisheries were altered, and new recreation opportunities on the reservoir were created. Additionally, the dam increased the province's hydroelectric potential and its capacity to meet downstream flow commitments to Saskatchewan (Mitchell 2001).

The filling of the reservoir on the mainstem of the Oldman River eliminated about 40 km of riverine fisheries habitat. Extensive fisheries mitigation and habitat enhancement programs were put in place to address potential effects. Between 1992 and 1997, almost 600 000 brown trout were stocked in enhanced habitat downstream of the Oldman River Dam (AENV 2006). Over 225 000 m^2 of fish habitat was constructed in the Oldman, Castle and Crowsnest rivers as part of the fisheries mitigation program. The effect of the creation and operation of the reservoir on fisheries has not been fully assessed. An interim report was issued in 1999 by Alberta Environmental Protection (AEP 1999), and summary information is provided in the Oldman Fisheries Management Objectives (AENV 2006). Smaller irrigation structures can also impact fish through impediments to fish movement, stranding of fish in canals as water levels are drawn down, and use of canals for power generation. Alberta Environment (AENV) has installed fish screens at Pine Coulee and on the Highwood diversion to assess the effectiveness of these structures in addressing these issues. Alberta Environment and Trout Unlimited Canada are studying the magnitude of the fish entrainment problem at several locations in southern Alberta.

The critical values of natural and human uses of streamflows are sometimes conflicting; satisfying one value to the fullest extent may impinge on the ability to meet the other. Compromises and trade-offs between instream flows and consumptive uses are required. This matter was addressed in Phase 2 of the South Saskatchewan River Basin Water Management Plan (SSRB Plan) (AENV 2006). Measures have been put in place to balance society's desire for environmental protection while at the same time meeting the needs for economic development.

Two instream flow management measures are being used in the Oldman watershed for the protection of instream values: Instream Objectives (IO) and Water Conservation Objectives (WCO). A third level of protection has been identified, Instream Flow Needs (IFN), but has not been implemented in the Oldman watershed.

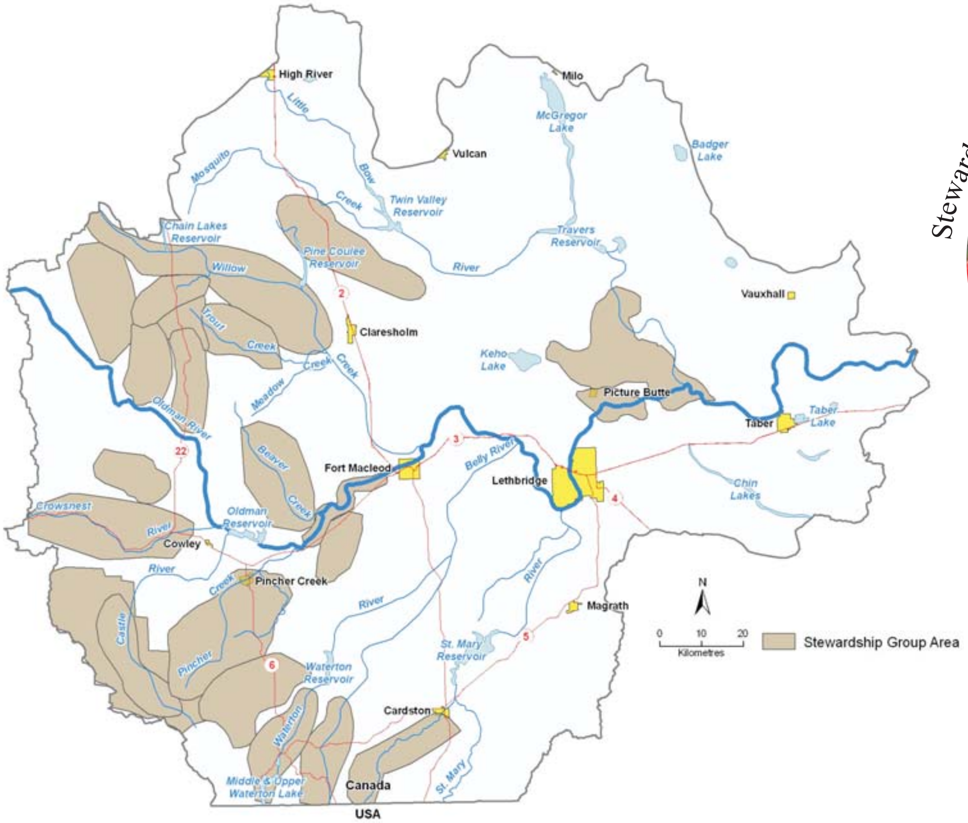
Prior to development of the SSRB Plan, natural and human instream values were protected by specifying minimum flows that are to remain in streams to protect the aquatic ecology or some specific uses of the stream, such as traditional household and agricultural uses (water uses for which licenses are not required), wastewater assimilation, or fish habitat. These minimum instream flows, now referred to as IOs, are implemented through diversion constraints on licenses and flow targets for operation of structures. IOs on some streams are indexed to natural flows, on other streams they are a single value, annual or seasonal minimum flow.

In 2002, it was concluded that the IFN requirements of the major streams would be about 85% of the natural flow with an added constraint of an Ecosystem Base Flow designed to reduce the impact on fish habitat during natural low flow periods. However, it was recognized that the full IFN could not be met in the Oldman watershed given the existing level of water license allocations and potentially severe impacts on water users. The major objective of the second phase of the SSRB Plan was to find the balance between water consumption for social and economic development and the instream needs, or WCOs, for protection (or restoration) of the aquatic environment. Public consultations were a key element of the planning study.

Key recommendations of the approved water management plan pertaining to the Oldman watershed were (AENV 2006):

- The recommended WCO for all streams in the Oldman watershed is 45% of the natural flow or the existing IO plus 10%, whichever is greatest at any point in time. Any licenses issued for applications received after 1 May 2005 would be subject to the WCO. The WCOs are an administrative tool that provides opportunities to increase instream flows through holdbacks on license transfers, voluntary actions by license holders, cancellations, and transfer purchases.
- Alberta Environment stop accepting applications for new water allocations in the Oldman watershed until the Minister of Environment specifies through a Crown Reservation how unallocated water is to be used. A Crown Reservation is now in place (Regulation 171/207; August 2007). The Bow, Oldman and South Saskatchewan River Basins Water Allocation Order stipulates that reserved water may be allocated:
  - for use by First Nations;
  - to contribute toward meeting WCOs;
  - for meeting outstanding completed applications received as of the date of the reservation;
  - for meeting licence applications associated with the Natural Resources Conservation Board (NRCB) approved Little Bow Project/Highwood Diversion Plan and the Pine Coulee Water Management Project; and
  - for storage of peak flows to mitigate impacts on the aquatic environment and to support existing licenses.
- The Director is authorized to consider water allocation transfers in the Oldman watershed. The Director is also authorized to consider withholding up to 10% of an allocation being transferred if the Director is of the opinion that the holdback is in the public interest to protect the environment or to implement a WCO.

Water resource development has provided the foundation for the prosperity of communities in southern Alberta. The provincial and federal governments, irrigation districts, industries, municipalities and individuals have made large investments in infrastructure (water storage, diversion and conveyance works) to use water in support of economic activities (AENV 2006).




Stewardship Meeting – OWC

Lower Little Bow River Field Day – ARD

Figure 1.6: Stewardship Groups and Landowner Associations Activity in the Oldman Watershed

The performance of these works in making available an adequate supply of good quality water is a concern to water managers and residents of the watershed. Climate change has the potential to exacerbate these concerns.

In addition to climate change concerns, landowner activities have direct and indirect impacts on water supply and quality within the Oldman watershed. The OWC works at the grassroots level with landowners and stewardship groups to support ongoing stewardship initiatives. Stewardship groups are active throughout the Oldman watershed (Figure 1.6) and have made many advances. The OWC Rural Team focuses on assisting landowners to evaluate the effectiveness of Beneficial Management Practices (e.g., reducing erosion of agricultural lands with activities such as reduced tillage, addressing cattle access to streams by creating off-stream watering, and reducing noxious weed infestations through weed management programs). Stewardship groups working within the Oldman watershed are listed in Appendix A.

1.3 Approach

1.3.1 Indicators

A watershed performs a number of functions that define an ecosystem. Today, social, economic and environmentally acceptable compromises between various human uses of water and the protection and restoration of healthy aquatic and riparian ecosystems must be reached. Once these are defined, environmental indicators are selected to measure whether or not the goals are achieved. Since goals are often complex, multiple indicators may be needed to reflect the overall state of the ecosystem. Indicators are

An effective indicator is:

Relevant: able to show you something about the system that you need to know.

Reliable: the information the indicator provides is trustworthy.

Easy to understand.

Straightforward.

Timely: the information is available while there is still time to act.

specific physical, chemical and biological attributes for components of the environment that play an important role in affecting environmental outcomes (AENV 2008). Indicators are always part of the cause and effect relationship between human activities on the landscape and the environmental response to those activities. Environmental indicators inform managers and the public about the condition of a watershed compared to desired goals and whether or not management actions are effective. The state of the Oldman watershed was assessed using several indicators that represent elements of watershed health.

For the Oldman watershed, environmental indicators were chosen as general measures of environmental quality to show trends in environmental conditions (Appendix B). These indicators function much like performance measures, and will show how well the ecosystem is operating over time.

The chosen indicators must link to potential management actions because, as noted in the foreword: "the future of water management may well be to become better attuned to the watershed and to see what needs it has, to maintain it's critical functions, upon which we depend."

The indicators chosen for the Oldman River State of the Watershed report are:

- **Terrestrial and Riparian Ecology:** land cover; soil erosion rates; riparian health; and land use;
- **Water Quantity:** trends in natural flow; licensed allocation vs. natural flow; actual use vs. natural flow; performance in meeting IO and WCO in recent years; and irrigation and municipal water use efficiency; and
- **Water Quality:** nutrients (nitrogen and phosphorus); total suspended solids (TSS), E.coli/fecal coliform.

Terrestrial and Riparian Ecology Indicators

Land Cover

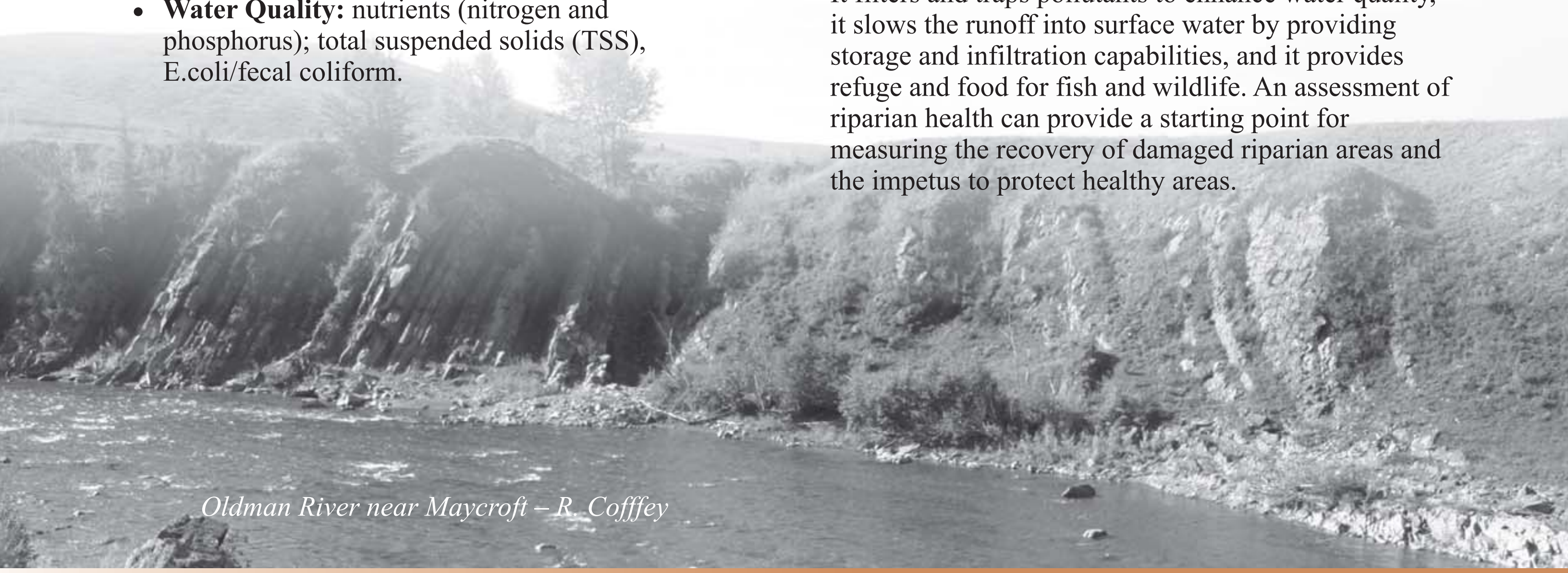
The land cover includes forest, grassland, agriculture (cultivated land), rock/barren, water and urban areas. A land cover map can provide both local and watershed-wide understanding of the current vegetation, ecology and industrial trends and the relationships among land uses, water quality and water quantity. The map can also highlight areas where land uses could be modified to better protect the natural environment or where ecosystem health is at risk and further disturbance in the area should be avoided.

Soil Erosion Rates

Soil erosion is a result of weather patterns and land use practices in a watershed. Land uses which expose the soil, such as agricultural activities, infrastructure, logging, mining, and urban and rural development allow the rain, snow and wind to move sediments into the surface waters. At high erosion rates, suspended sediment in surface water will decrease the ability of aquatic life to flourish. An indication of soil erosion rates across a watershed identifies the areas which are at risk and which may require additional land management practices to ensure the continued health of riparian and aquatic life.

Riparian Health

The transition area between surface water and uplands (the riparian zone) is critical to the health of the watershed. The riparian zone provides a buffer to trap eroded sediment before it reaches the surface water and it helps reduce erosion along the shoreline. It filters and traps pollutants to enhance water quality, it slows the runoff into surface water by providing storage and infiltration capabilities, and it provides refuge and food for fish and wildlife. An assessment of riparian health can provide a starting point for measuring the recovery of damaged riparian areas and the impetus to protect healthy areas.



Oldman River near Maycroft – R. Cofffey

Land Use

The land use is the impact of human activities on the watershed and is closely related to land cover. Land use consists of various activities including agriculture, roads, pipelines, cutlines, urban areas and recreational developments that have permanently removed the native vegetation and/or resulted in its replacement with annual and perennial crops. These changes can influence the magnitude of runoff and water quality as compared to the natural state of the water body. This indicator of the state of the watershed can provide decision making background information on future development in both natural and heavily developed areas.

Forest lands in the Green Zone are managed for watershed protection. Land use pressures, including forest harvesting and grazing, are described along with other disturbances from fire and mountain pine beetle (MPB).

Public lands in both the Green and White zones are managed to remain “healthy and sustainable” (SRD 2010) with success measured by the percent of rangeland leases in good standing. Carrying capacity for grazing is measured as the number of animal unit months (AUMs).

Recreation use is based on designated public areas containing infrastructure including roads, campground and picnic tables, but does not include areas of random use such as off-highway vehicles (OHV) and non-designated camp sites. Linear disturbance resulting from forest roads and cutlines has been included in the assessment of human disturbance for the watershed because these areas may not be reclaimed and may continue to be used for access by a variety of users. These developments may be short or long term and their impacts are treated as a form of fragmentation of the landscape which is quantified via length per unit area (km/km^2). The greater the density of linear disturbance, the larger the risk of erosion and sedimentation.

Alternative Land Use Indicators

Management of public lands in Alberta is based on a shared or multiple use concept that considers environmental factors such as watershed capacity, natural biodiversity, and soil and wildlife habitat conservation. In addition to supporting grazing and some industrial activities and preserving wildlife habitat, Alberta's public lands have become, over time, choice destinations for recreational use (SRD 2009). The effects of random recreational use are not well documented, although the Government of Alberta has recognized the potential importance of this land use and has collected data on some specific activities in localized areas. In future, a more complete understanding of the scale, intensity, and effects of random recreational use, especially in the Green Zone, could provide an alternative and valuable indicator.

Cottonwood forests have declined downstream of dams on the St. Mary and Belly rivers. Studies have indicated that the pattern of operation rather than the presence of dams *per se* determines the downstream impact on cottonwoods (Rood and Mahoney 1991). In 1995 and 2005, high flows provided suitable areas for the establishment of cottonwood seedlings. The practice of flow management for dams called “ramping” was initiated in 1994 and is aimed at restoring a more natural flow regime. This approach has resulted in good survival of cottonwoods downstream of the Oldman and St. Mary dams (Gill et al. 2007, Palechek 2009, Rood pers. comm. 2009).

Public Lands

Public lands in Alberta are divided into two zones – the Green Zone and the White Zone.

The Green Zone in the Oldman watershed comprises the mountains and foothills, while the White Zone comprises the settled agricultural part of the watershed. The Green Zone is managed for timber production, watershed protection, wildlife and fisheries, recreation and other uses. Agricultural use is limited to grazing where it is compatible with other uses. Agricultural land uses dominate in the White Zone, but management practices also provide for recreation, soil and water conservation, and protection of fish and wildlife habitat.

Cottonwoods were not selected as an indicator in this report because they do not occur in all Sub-basins. However, cottonwoods are responsive to changes in flow regime, as documented in several studies in the Oldman watershed (Willms and Rood 2007), and should be considered as an indicator in the Southern Tributaries, Prairie and Mainstem sub-basins in subsequent state of the watershed reports.

Water Quantity Indicators

Trends in Natural Flow

The Oldman watershed is one of Canada's most highly used and most vulnerable watersheds. The watershed is almost entirely within the Palliser Triangle. Water users and environmental interest groups are concerned about the impacts of drought on water supplies, water quality and the aquatic ecosystem. Climate change has the potential to exacerbate these concerns (Martz et al. 2007).

There is evidence that the climate on the Canadian Prairies is changing (Wheaton 1998; Henderson et al. 2008). There appears to be agreement among Global Climate Model (GCM) projections that temperatures will probably continue to rise. There is less certainty about precipitation, particularly on a regional level. Some GCMs project decreases in precipitation, but most project increases. Much of this increase in both temperature and precipitation is weighted toward the winter and spring months.

The National Water Research Institute used GCM projections and hydrologic modelling to assess the effect of forecasted climate change on streamflows in the South Saskatchewan River Basin in Alberta and Saskatchewan (Martz et al. 2007). A range of six climate forecasts for a period centered on 2050 were used to predict the potential range of impacts on surface water supply. The study concluded that changes in annual natural flow volumes in the Oldman watershed would range from minus 13% to plus 8%, with an average among the six scenarios of minus 4%.

Clearly, the various model and scenario results reflect a wide range of potential future conditions. However, on average, the simulations indicate future reductions in flow in the Oldman watershed and all other sub-basins of the SSRB.

Given the wide range of potential impacts of climate change on streamflow in the Oldman watershed, streamflow trends should be analyzed at natural flow stations in the Oldman watershed, and be reassessed from time to time to determine the magnitude, rate and nature of change. Declining flows in the Oldman watershed could have serious economic and environmental consequences. There is significant scope for adaptive management of water delivery and water use systems, but preparation lead time is required (Sauchyn and Kulshreshtha et al. 2008; Martz et al. 2007).

Licensed Allocation and Actual Use vs. Natural Flow

The relationship between licensed allocation, instream use and annual natural flow provides an indication of:

- the relationship between current actual use, potential future use and median natural flow (assuming that future use will be limited to full utilization of existing allocations in light of closure of the watershed to new applications);
- the degree to which natural flow could be used in the future without new allocations;
- the potential for future water supply deficits; and
- a comparison of the relationships at various locations within the watershed and identification of areas within the watershed with potential for future water supply deficits.

Palliser Triangle, is a triangular-shaped semi-arid geographic area in southern Alberta and Saskatchewan. It was determined to be unsuitable for agriculture because of its unfavourable climate and soil. The area was named after John Palliser, who led an 1863 expedition to Canada's west. The triangle began to be settled and farmed at the start of the 20th century. It has been used for cattle grazing and growing crops, many of which are now irrigated.

Source: 29 September 2009,
http://www.thecanadianencyclopedia.com/index.cfm?PgNm=ArchivedFeatures&Params=A220

Results of Recent Streamflow Studies in the Oldman Watershed

Three recent studies have been conducted to identify and quantify streamflow trends in recorded flows in western Canada and the United States, including the SSRB in Alberta. Seneka (2004) assessed the total annual flow at several locations in Alberta, including the Oldman River near Lethbridge and three other locations in the SSRB. The flow analysis used naturalized flows from 1912 to 2001. Seneka found that there was no detectable trend for annual streamflow volumes in the Oldman River near Lethbridge. The South Saskatchewan River at Medicine Hat showed decreasing trends, but the trends were not significant at the 95% level of confidence.

Rood et al. (2005) analyzed natural flow or near-natural flow at three locations in the Oldman watershed:

- Oldman River near Waldron's Corner;
- Castle River near Beaver Mines; an
- Waterton River near Waterton Park.

Rood et al. concluded that, of the three natural flow stations in the Oldman watershed, significant decreasing trends at the 95% level of confidence were indicated for Castle River near Beaver Mines and Waterton River near Waterton Park. The Oldman River near Waldron's Corner showed a decreasing trend but the trend was not significant at the 95% level of confidence.

In a follow-up study, Rood et al. (2007) examined the Waterton River near Waterton Park (1908 to 2005) to investigate historic changes in seasonality of streamflow in relatively pristine watersheds. From this and similar analyses on other streams outside the SSRB, Rood et al. concluded that winter flows have increased slightly, and summer flows (especially late summer flows) have decreased.

Instream Flow Requirements vs. Recorded Flow

The relationship between current instream requirements (Instream Objectives and Water Conservation Objectives) and recorded flow in the most recent 10-year period for which data are available provides an indication of:

- the degree to which instream requirements are currently being met;
- the potential for instream flow water supply deficits; and
- a comparison of relationships at various locations within the Oldman watershed, and identification of river reaches with water supply deficits.

Irrigation and Municipal Water Use Efficiency

Water use efficiency is assessed in Chapter 10. While there is not sufficient information available to document current water use efficiency and progress toward improving efficiencies for all sectors of water use, there is information available to determine per capita water withdrawals for communities, and water withdrawals per irrigated area for the nine irrigation districts in the Oldman watershed. Such indicators provide a baseline for tracking future improvements in efficiencies for these two purposes.

Per capita use from records of withdrawals for urban centres often vary because of factors such as infrastructure design, unrecorded amounts of water

Water for Life

One of the long term goals and expected outcomes stated in Alberta's Water for Life initiative is to improve the efficiency and productivity of water use by 30% from 2005 levels by 2015 (AENV 2003). Monitoring, public awareness and education, and economic instruments (such as pricing structure, incentives and subsidies) are suggested as ways to achieve conservation objectives. For some uses, a 30% reduction in usage may be possible; for others it may not be possible, depending on particular circumstances.

provided for rural domestic and other uses outside the urban centre, watering of parks and golf courses in some communities, and the amount of industrial and commercial uses within the communities.

Most irrigation districts have made major improvements in both on-farm and distribution system efficiencies over the past several decades. Extenuating circumstances within individual districts, over which current district administrators have little or no control, may affect their efficiencies (Irrigation Water Management Study Committee 2002).

Alternative Water Quantity Indicators

Currently, groundwater use is less than 3% of the total license allocations in the Oldman watershed (AMEC 2007). The deep pre-glacial valleys in the Oldman watershed often contain thick deposits of glacial till overlying well-sorted gravels (the Saskatchewan Gravels) that form high-yielding aquifers (Guelph Water Management Group 2003). Unconsolidated glacial sediments cover most of the watershed and in some areas provide near surface aquifers that appear as springs in valley floors. Groundwater in Alberta is particularly important for rural domestic, small community and stockwater use. Groundwater usually requires less treatment than surface water supplies. Preserving groundwater for these purposes is important. Groundwater was not used as an indicator for this State of the Watershed report. However, in subsequent reports, groundwater should be considered as an indicator.

Water Quality Indicators

Nitrogen

Nitrogen is a major naturally occurring nutrient in water and nitrogen-containing compounds act as nutrients in streams, rivers, and reservoirs. The major routes of entry for nitrogen into bodies of water are municipal and industrial wastewater, septic tanks, feed lot discharges, animal wastes (including birds and fish), runoff from fertilized agricultural field and lawns and discharges from car exhausts. The major impact of nitrates/nitrites on fresh water bodies is that of enrichment or fertilization called eutrophication. Nitrates stimulate the growth of algae and other plankton which provide food for higher organisms (invertebrates and fish). However, an excess of nitrogen can cause over-production of plankton and with death and decomposition oxygen is used up which causes other oxygen-dependent organisms to die.

Phosphorus

Phosphorus is one of the key elements necessary for growth of plants and animals. There are different sources of phosphorus in water bodies. Wastewater usually contains phosphorus and enters as point sources. Rainfall can cause varying amounts of phosphates to wash from farm soils (non-point source) into nearby water bodies. Phosphorus will stimulate the growth of plankton and aquatic plants which provide food for fish. This may cause an increase in the fish population and improve the overall water quality. However, if excess phosphorus enters the water body, algae and aquatic plant growth will choke-up the water body and use up large amounts of oxygen. This condition is known as eutrophication or over-fertilization of receiving waters. The aquatic vegetation eventually dies and decomposes lowering dissolved oxygen levels.

Total Suspended Solids

One of the biggest potential sources of water quality deterioration in the Oldman watershed is suspended solids. The geology, vegetation, and landuse of a watershed affect the amount of suspended solids because of accelerated erosion from agricultural land, logging operations (especially where clear-cutting is practiced), and construction sites.

Suspended solids consist of an inorganic fraction (silts, clays, etc.) and an organic fraction (algae, zooplankton, bacteria, and detritus) that are carried along by water as it runs off the land. The inorganic portion is usually considerably higher than the organic. Both contribute to turbidity, or cloudiness of the water.

Environmental effects from elevated suspended solids varies. Suspended solids can clog fish gills, either killing them or reducing their growth rate. They also reduce light penetration. This reduces the ability of algae to produce food and oxygen. When the water slows down, as when it enters a reservoir, suspended solids settle out and drop to the bottom.

Indirectly, suspended solids affect other parameters such as temperature and dissolved oxygen. Because of the greater heat absorbency of the particulate matter, the surface water becomes warmer and this tends to stabilize the stratification (layering) in stream pools, embayments, and reservoirs. This, in turn, interferes with mixing, decreasing the dispersion of oxygen and nutrients to deeper layers.

Suspended solids interfere with effective drinking water treatment. High sediment loads interfere with coagulation, filtration, and disinfection. More chlorine is required to effectively disinfect turbid water. High sediment loads can also cause problems for industrial users. Suspended solids also interfere with recreational use and aesthetic enjoyment of water. Poor visibility can be dangerous for swimming and diving. Siltation, or sediment deposition, eventually may close up channels or fill up the water body converting it into a wetland. A positive effect of the presence of suspended solids in water is that toxic chemicals, such as pesticides and metals, tend to adsorb to them or bind to them which make the toxics less available to be absorbed by living organisms.

E.coli/Fecal Coliform

The most common member of the fecal coliform bacteria is *Escherichia coli*. These organisms have the ability to grow at elevated temperatures and are associated with the fecal material of warm-blooded animals. The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of people or animals. Source water may be contaminated by pathogens or disease-producing bacteria or viruses which can exist in fecal material. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in water bodies as a result of the discharge of domestic sewage or non-point sources of human and animal waste.

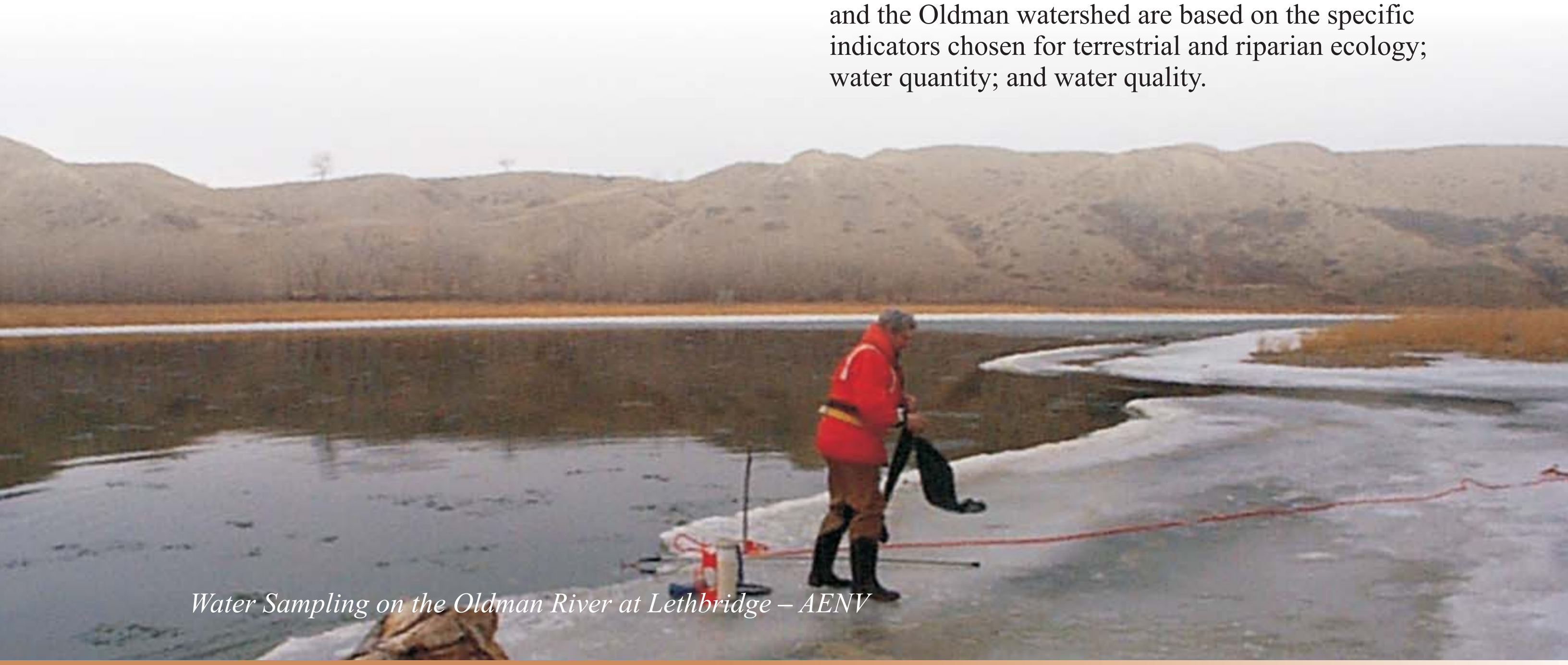
Alternate Water Quality Indicators

Pesticides are a group of chemicals including herbicides, insecticides, rodenticides and fungicides used for many purposes, including pest control and aesthetics in urban areas, golf courses, and in forestry and agricultural production. Pesticides are a common contaminant of streams in high intensity agricultural areas of Alberta.

Pesticides have not been assessed in this report, although pesticide monitoring has been conducted at various locations within the Oldman watershed. However, given the low frequency of detections and the absence of guidelines for some of the pesticides detected, it is difficult to use these data as a meaningful indicator. As well, the cost of analysis is likely to limit basin-wide monitoring in the near future. Monitoring is therefore likely to continue to be focused on specific locations within the Oldman watershed.

Other Parameters

While the focus of the State of the Watershed report is on the chosen indicators, descriptive information about other parameters within the watershed is also provided. For example, within each Sub-basins section a water quality overview is presented with information on parameters such as temperature, pH, dissolved oxygen, water hardness, metals and ions, and pesticides. However, this information is not used in the water quality ranking for each of the Sub-basins, or for the watershed as a whole. Rankings for the Sub-basins and the Oldman watershed are based on the specific indicators chosen for terrestrial and riparian ecology; water quantity; and water quality.



Water Sampling on the Oldman River at Lethbridge – AENV

1.3.2 Analysis and Presentation of Results

Indicators have been ranked as Good, Fair or Poor using thresholds established in the scientific literature or other state of the watershed reports, scientific data, and professional judgment. Within this report, these rankings have been assigned the colours of green, yellow and red, respectively. The specific details of how rankings were assigned are presented below.

Terrestrial and Riparian Ecology

To report on watershed health, each indicator was examined individually.

Land Cover

Land cover data for the Sub-basins is from the Native Prairie Vegetation Inventory and Alberta Vegetation Inventory (AVI) based on aerial photography of 1992 to 1993 and 1988 respectively, while data for Waterton National Park was from interpretation of 1997 Landsat imagery. To present more recent data, the StatsCan census of 2006 for municipalities and counties was used to provide detailed information on agricultural lands and crop types.

There are no established thresholds for land cover. The percent of watershed area that is desirable to be covered in natural vegetation was set using watershed scale soil erosion and runoff models as well as aquatic and riparian ecosystem health in relation to land use intensity (AENV 2008). Clearly the higher proportion native forest and grassland in the Sub-basins the lower the risk of erosion and sedimentation. For assessment purposes the following rankings were used (Aquality 2009 and Saskatchewan Watershed Authority 2006):

- Good: >50% combined land cover of forest, grassland, shrubland and rock/barren;
- Fair: 25 to 50% combined land cover of forest, grassland, shrubland and rock/barren; and
- Poor: <25% combined land cover of forest, grassland, shrubland and rock/barren.

Soil Erosion

Soil erosion rates in the Oldman watershed were modeled using the Universal Soil Loss Equation with the soil information from Agricultural Region of Alberta Soil Inventory Database (AGRASID) based on land uses, meteorological trends and topography.

Soil erosion risk factors prepared for the agricultural area of Alberta were applied to the Oldman watershed to derive potential erosion risk values (negligible, low, moderate, high, severe) for each Sub-basins. These values identify areas of the watershed which may benefit from land use best management practices and areas which may require protection from future development. Soil erosion risk was derived from assessment procedures that integrated wind and water factors with land management practices, specifically by loss of protective land cover. Wind and water erosion risk values were estimated by methods described by Coote and Pettapiece (1989) and Tajek and Coote (1993).

Thresholds are not available in the scientific literature. Using soil erosion values that would exist under natural land cover as a benchmark (AENV 2008), soil erosion risk was subjectively ranked according to the sum of the percentages of moderate, high and severe risk classes. Soil erosion risk rankings used in this report were:

- Good: <25%;
- Fair: 25 to 50%; and
- Poor: >50%.

Riparian Health

Riparian health is determined by assessing the riparian zone for the ability to perform basic and necessary riparian functions including trapping sediment, buffering the impact of flooding, providing primary productivity, and providing fish and wildlife habitat (Fitch and Ambrose 2003). The assessment is a quick observation of the area for vegetation diversity and health with a three-part rating system of:

- healthy;
- healthy with problems; and
- unhealthy.

Thresholds have not yet been determined scientifically, but could be set based on the ability of riparian areas to perform basic water-related functions. Cows and Fish suggest the lower two levels of the classification system are sufficiently unhealthy that they be considered below the threshold for a sustainable functioning riparian ecosystem (AENV 2008).

For this assessment, riparian health was subjectively ranked by using the highest percentage class as follows:

- Good: riparian class healthy;
- Fair: healthy but with problems; and
- Poor: unhealthy.

Land Use

Land use deals with the replacement of native vegetation by annual and perennial crops or permanent infrastructure due to human activities. Natural and disturbed areas were identified using air photos, satellite imagery and census information in the same manner as land cover. Two indicators were selected – the amount of linear disturbance and the total of land use disturbance made up of areas of agriculture, industrial activity, reservoirs and urbanization.

While thresholds are not determined for linear disturbance, for this report they could be set for levels of land used resulting in unsustainable increases in runoff volume, erosion and pollutant loadings as well as degradation of aquatic ecosystem health (AENV 2008). Linear developments were ranked according to the total percent disturbed by roads, pipelines, cutlines, power lines and railways. Rankings used were (Aquality 2009, North Saskatchewan Watershed Alliance 2005 and Saskatchewan Watershed Authority 2006):

- Good: linear disturbance <2%;
- Fair: 2 to 3 % linear disturbance; and
- Poor: >3% linear disturbance.

For total land use disturbance, thresholds are not determined; however, they could be set for levels of land use resulting in unsustainable increases in runoff volume, erosion, and pollutant loadings as well as degradation of aquatic ecosystem health (AENV 2008). Rankings for this assessment were (Aquality 2009, North Saskatchewan Watershed Alliance 2005):

- Good: <50% total land use disturbance;
- Fair: 50 to 90% total land use disturbance; and
- Poor: >90% total land use disturbance.

Turtle Mountain and Sawmill on Crowsnest River – R. Coffey

Water Quantity

The hydrologic characteristics at each location analyzed includes a listing of:

- gross and effective drainage areas;
- mean annual, and 75, 50 and 25 percentile natural flows for the period 1912 to 2001 (the percentile flows are commonly referred to as upper quartile, median and lower quartile flows, respectively); and
- the median runoff yields over the gross drainage area and over the effective drainage area.

The hydrologic characteristics also include a plot of the mean weekly natural and recorded flows for the period 1992 to 2001. This is the most recent 10-year period for which both recorded and natural flows are available for almost all stations analysed. For a few stations, recorded data monitoring was discontinued prior to 2001.

The graphic display used to present the hydrologic characteristics at each location analysed is shown in Figure 1.7.

Trend analyses were conducted based upon:

- Kendall t ('tau') non-parametric rank correlation; and
- linear regression and trend line.

Non-parametric tests are most commonly used for hydrologic analyses because of usual non-normality of streamflow data. The parametric regression analysis and a linear trend line are included because they provide a visual display of the trend pattern (if any) and a quantification of the magnitude of the trend. However, the trend line approach is considered to be a less accurate measure of streamflow trends because the method is highly sensitive to the streamflow conditions at the start and end periods of the streamflow record. For each statistical test, a non-trend

Terms Used in the Water Quantity Analyses

Licence Allocation – The *Water Act* defines allocation as the volume, rate and timing of a diversion of water. For this report, allocation refers only to the maximum quantity (volume) that a licensee is authorized to divert each year, as determined from water licences.

Actual Use – The recorded or estimated actual volume of water diverted from a stream minus the return flow. In the Oldman watershed, recorded use is available for urban municipalities and most irrigation districts. Almost all other uses are estimated based on licensing data and fragmentary recorded data.

Recorded Flow – The discharge of a stream recorded at a hydrometric station. Recorded flow may be natural flow, regulated flow, or a combination of both. It is sometimes referred to as historical flow.

Natural Flow – The flow in streams that occurs, or would have occurred, in the absence of human use, withdrawals or regulation. Alberta Environment has reconstructed natural flows for regulated streams in the SSRB by adjusting recorded flows for upstream actual uses, diversions and regulations. These flows are sometimes referred to as naturalized flows or re-constructed flows.

Instream Objectives (IOs) – Flows that are to remain in the stream to protect instream values or some portion of them. IOs in the Oldman watershed have been developed using a variety of methodologies, some of which have a more scientific basis and provide a higher degree of protection than others. Some IOs provide limited protection of the aquatic environment.

Water Conservation Objectives (WCOs) – The *Water Act* defines WCOs as the amount and quality of water necessary for the protection of a natural water body or its aquatic environment, or any part of them; protection of tourism, recreational, transportation or waste assimilation uses; or management of fish or wildlife. WCOs were established in the Oldman watershed following completion and government approval of the SSRB plan.

Hydrologic Characteristics

Gross DA	km^2	17,000
Effective DA	km^2	15,500
Natural Discharge 1912-2001		
Mean Annual	dam^3	3,454,847
Upper Quartile	dam^3	4,181,722
Median	dam^3	3,338,748
Lower Quartile	dam^3	2,715,311
Median Yield		
Gross DA	dam^3/km^2	196
Effective D	dam^3/km^2	215

DA = Drainage Area

Mean flow diverted out of the basin in US, 1992-2001 = 192,228 dam^3

Mean Discharge of the Oldman River near Lethbridge, 1992-2001

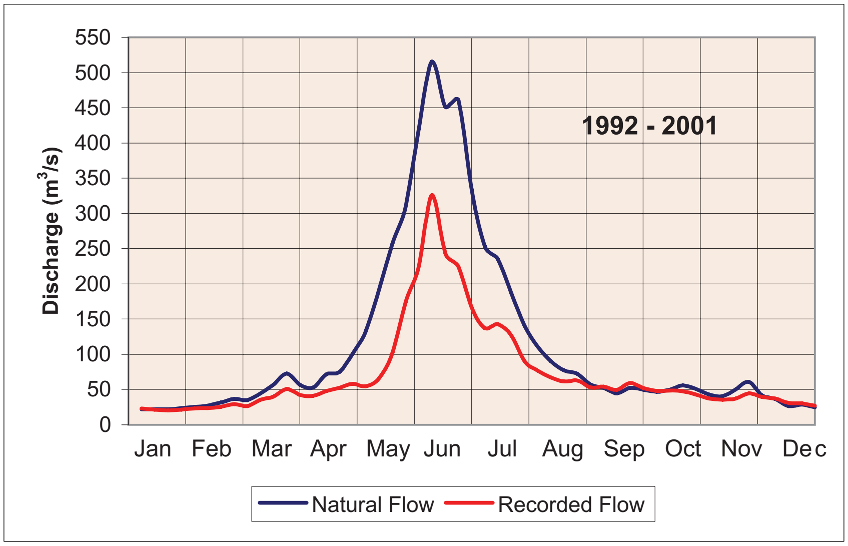


Figure 1.7: Example Showing Hydrologic Characteristics of Stations Analyzed

probability (p) was determined. The analysis concludes that a significant trend exists if p is less than 0.05 or 5%. If p is between 0.05 and 0.10, the analysis concludes that a trend is probable.

An example of the graphic displays used to present the results of the trend analyses is provided in Figure 1.8.

A negative Mann-Kendall statistic indicates declining flows. In the Figure 1.8 example, flow appears to be declining annually and in all months except February. The data indicates a significant decline in April and November, and a probable significant decline in December.

Licence allocations and actual use (recorded and estimated) are tabulated and graphed for six purpose categories:

- irrigation;
- other agricultural;
- municipal;
- commercial;
- industrial; and
- other.

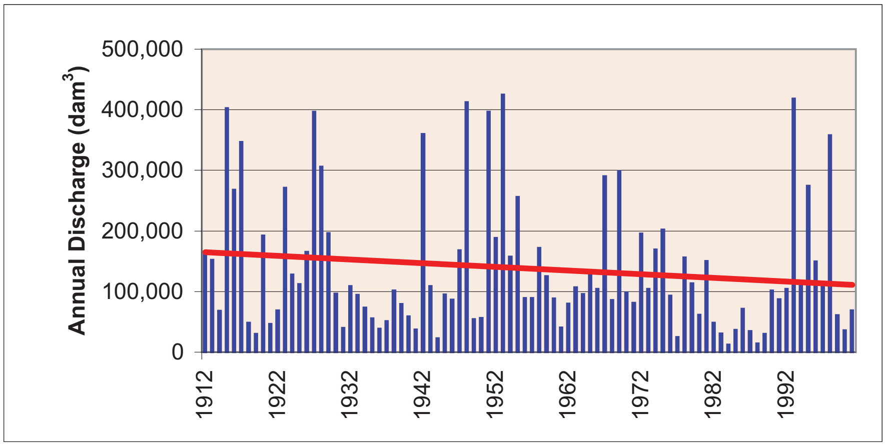
Mann-Kendall Trend Analysis

	MK Stat	p-value
Annual	-1.37	0.17
Jan	-0.38	0.70
Feb	1.18	0.24
Mar	-0.42	0.67
Apr	-3.04	0.00
May	-0.95	0.34
Jun	-1.17	0.24
Jul	-1.14	0.25
Aug	-0.52	0.60
Sep	-0.61	0.54
Oct	-1.41	0.16
Nov	-3.00	0.00
Dec	-1.73	0.08

🟨 Significant Trend

🟩 Probable Trend

Willow Creek near Nolan Annual Flow Volumes and Linear Trend Line



Average annual decrease in flow = 610 dam^3 based on trend line slope.

Figure 1.8: Example Showing Trend Analyses of Stations Analyzed

The total allocation and total actual use is expressed as a percentage of median natural flow.

A typical display of the results of the water allocation and actual use analyses is shown on Figure 1.9. In Figure 1.9, the dominant use is irrigated agriculture. For irrigation districts, current average actual use is taken as the average recorded withdrawals for the period 2004 to 2007 minus the average recorded or estimated return flow. For private irrigation, current average actual use is estimated to be 82% of the licensed use (AMEC 2007). In the Oldman watershed, there is potential for considerable increases in irrigation water use within existing allocations (Irrigation Water Management Study Steering Committee 2002).

The performance in meeting IOs and WCOs is determined by examining the recorded flow data for the 10-year period, 1992 to 2001, to determine the number of years that the IO and WCO were not met in each month. The 1992 to 2001 period is the most recent period for which data are available for determining IOs and WCOs. The period is long enough to represent a variety of hydrological and weather conditions, and water demands representative of current demands. For some locations, computations are done weekly, depending on data availability. Results are displayed monthly. During periods when IOs are not being met, all flow is needed to protect instream values and flow is not available to licensees that are subject to the IO conditions in the stream.

Oldman River near Fort Macleod

Purpose Sector	Allocation dam^3	Est. Actual Use dam^3
Irrigation	422,530	186,958
Other Agric	7,194	5,395
Municipal	4,180	1,663
Commercial	20,788	15,466
Industrial	-	-
Other	8,133	8,133
Totals	462,825	217,616
% of median flow	37.1	17.4

Distribution of Water Allocation and Actual Use by Purpose.

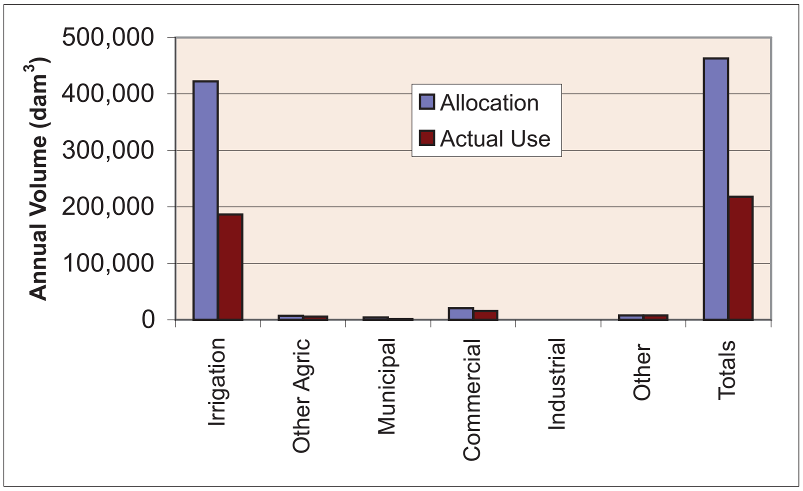


Figure 1.9: Example Showing Current Allocations and Actual Annual Water Use

Center Pivot Irrigation System – R. Coffey

However, there are few if any licensees that are subject to the WCOs in the Oldman watershed since the WCOs were established coincident with closure of the watershed to new allocations.

A typical display of the performance in meeting the IOs and WCOs[1] is shown on Figure 1.10.

For this report, irrigation district efficiency is computed as the gross diversion (withdrawal from the source stream) divided by the irrigated area within each district. The value is expressed in mm of water. Computations were done for each of the eight districts sourced from the waters of the Oldman watershed, and for each year that data are available.

Results for each district are displayed in a bar graph showing annual unit gross diversion and a trend line (Figure 1.11).

Municipal water use efficiency is computed as the average per capita withdrawal from the source. Computations are made for census years 2001 and 2006 for all cities, towns and villages within the watershed, plus those outside the watershed using Oldman water. Communities using surface water and groundwater are included. Some of the communities within the Oldman watershed use water from an adjoining watershed. These are identified.

Performance in Meeting the WCO and IO

IO and WCO

IO is variable.

WCO = MAX(1.1*IO, 0.45*Qnat) m^3/s

Comments:

1. IO and WCO are based on Segment 1 requirements.
2. IO deficits occurred in 1.6% of the months assessed.
3. WCO deficits occurred in 16.4% of the months assessed
4. Deficits were most frequent in May, June and July.

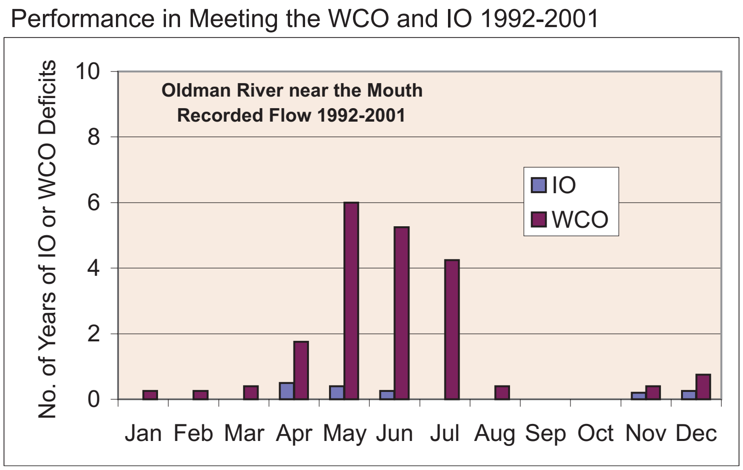


Figure 1.10: Example Showing Performance in Meeting IOs and WCOs

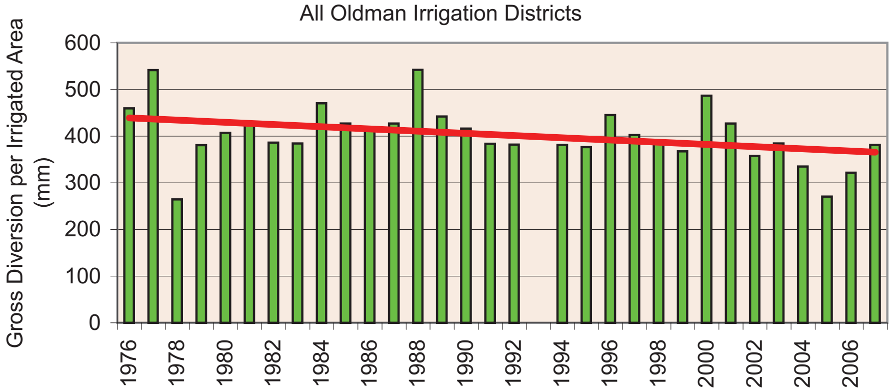


Figure 1.11: Example Display of Unit Gross Diversion to Irrigation Districts Expressed as Depth over the Irrigated Area

---

[1] IOs, WCOs and IFNs are described in section 1.2.7. Generally, the recommended WCO is 45% of the natural flow or the existing IO plus 10%, which ever is greatest at any point in time. These values vary for different reaches of each stream, and may also vary seasonally. The actual IO or WCO used to assess performance is shown on the appropriate figure. The months where data were available to assess performance is also shown on the appropriate figure.

The results of the analysis are displayed in tabular form. Information provided includes:

- watershed Sub-basins;
- community;
- population;
- water source;
- 2001 and 2006 historic use; and
- comments on sources, conveyance works and extenuating circumstances affecting water use.

The overall data were integrated across the watershed (Chapter 10) and thresholds (good, fair, poor) were established using a three step procedure:

1. Rank performance for each indicator and all stations evaluated (about 21). Divide into three groups or terciles, with about seven stations in each group.
2. Examine the data looking for natural breakpoints in the performance. Make adjustments to the groupings on that basis. Rankings of Good, Fair or Poor were then assigned.
3. Rankings were reviewed and an overall ranking was assigned to each of the Sub-basins.

Water Quality

The water quality analysis includes three main components, all of which are complimentary and provide a snapshot of conditions. The analysis includes a dynamic pattern in all three components. They are:

- comparison concentrations of indicators to thresholds (guidelines or background concentrations);
- trend analysis for each indicator over the period of observations; and
- calculation and comparison of loadings for each indicator within the Sub-basins and watershed as a whole and their changes over the years of record.

All assessments are done using annual median concentrations to represent statistically average conditions. The statistical term, median, represents the middle value in a set of measurements. The median value of a data set is often used instead of the average if the record contains extremes (big or small) which are usually outliers. Using the median, these extreme values do not compromise the most frequently observed values.

The median concentrations were calculated on yearly intervals and provide annual values that include all seasons. Comparisons between these values and applicable guidelines for nitrogen, phosphorus and fecal coliforms are presented graphically. These tables illustrate the colour-coded distribution of years when the median concentrations were below the guideline (a blue cell) and above guidelines. The latter are presented as two thresholds for exceedances – values slightly higher than the guidelines (coloured in gold) and values that are substantially higher than the guidelines (a red cell) (Table 1.3).

Trends in these data can be neutral, decreasing, or increasing. Trend analysis usually requires very good and complete data sets. However, this is often not the case with water quality information that has not been collected for such purposes.

The Mann-Kendall test is particularly useful since missing values are allowed, and the data need not conform to any particular probability distribution. Also, data reported as trace or less than the detection limit can be used (it is acceptable in the context of the data population being represented) by assigning them a common value that is smaller than the smallest measured value in the data set. This approach can be applied because the Mann-Kendall test uses only the relative magnitudes of the data.

Table 1.3: Example Showing Annual Median Indicator Guideline Adherence by Site

Monitoring Sites / Years	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
BELLY RIVER NEAR OLDMAN RIVER							🟦 *								🟦	🟦						🟦	🟦	🟦 *		🟦 *	🟦 *	🟦 *	🟦	🟦	🟦					🟦	🟦			
PRAIRIE BLOOD COULEE NEAR LETHBRIDGE																														🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦			
AB05AE0070 - ST. MARY RIVER NEAR OLDMAN RIVER															🟦	🟦						🟦	🟦	🟦 *		🟨 *	🟦 *	🟨 *	🟦	🟦	🟦					🟦	🟦			
LEE CREEK U/S OF CARDSTON																																		🟨	🟨	🟧				
LEE CREEK D/S OF CARDSTON																																		🟨	🟨	🟧				

* median not calculated, results shown are based on less than 3 samples

☐ No Data
🟦 < 100 per 100 mL (below guideline)
🟨 100 - 1000 per 100 mL
🟧 > 1000 per 100 mL

Mann-Kendall Tests

The computation of the Mann-Kendall statistic consists of calculating possible differences between observations in the data population (put in the order in which they are collected over the time) followed by computation of the number of positive differences minus the number of negative differences. Thus, no absolute values are involved, but rather differences are being compared. The Mann-Kendall test can be used to show whether concentrations at the monitoring site are increasing, stable, or decreasing. However it cannot determine the rate in which concentrations are changing over time. The Mann-Kendall test can be used even with a minimum of four sampling results or data points (Gilbert 1987).

The suite of representative parameters is used for trend analysis. It represents inorganic characteristics – TSS; nutrients, including nitrogen and phosphorus; and a microbiologic indicator – E.coli/fecal coliforms.

“Loadings” are an important and informative water quality characteristic. Loading represents the weight of a substance (or parameter or indicator) that moves through a river in a unit of time. Loadings are usually calculated on an annual basis by multiplying annual concentrations (in our case this is median concentration) by the volume of water flowing through this particular site during a year (i.e., median concentration x annual flow). The resultant number shows loadings in units of weight. It is important to keep in mind that loadings depend on both concentration and volume. Loadings can be equal and be a result of low concentration of a substance and very high flows (volumes) or high concentrations and very low flows. Thus, loading characteristics do not repeat information that could be obtained from analysis of just concentrations (exceedances, trends) but rather provide a description of carrying capacity of streams – represented as mass load.

Loadings were calculated for representative years and periods when data were available and presented graphically in bar chart format. A typical example is shown in Figure 1.12.

Figure 1.12: Example Showing Indicator Loadings in Sub-basins – 1991, 2000, 2004

The water quality trend analysis results are shown as a pie chart with four sections assigned to nitrogen, phosphorus, TSS, and fecal coliforms and color codes: decreasing – green; neutral – blue; and red – increasing (Figure 1.13).

The overall water quality conditions for the Oldman watershed were assessed based on comparison with guidelines and background concentrations, levels and frequencies of exceedances, as well as trend analysis with a particular focus on increasing tendencies. The overall water quality as based on these criteria was ranked as follows:

- Good – no exceedances or less than 10% within the data set and neutral or decreasing trend particularly over the last decade;
- Fair – the number of exceedances not more than 50% of the analyzed data set with increasing trends for one or two indicators; and
- Poor – exceedances occur in more than 50% cases and increasing trend pronounced in more than two indicators.

Sub-basins and Watershed Ranking

The rankings based on thresholds established for each of the terrestrial and riparian ecology indicators were used to derive an overall terrestrial and riparian health ranking within each of the Sub-basins. This was a comparative assessment using professional judgement. This same approach was used for determining the ranking based on water quality indicators within each of the Sub-basins.

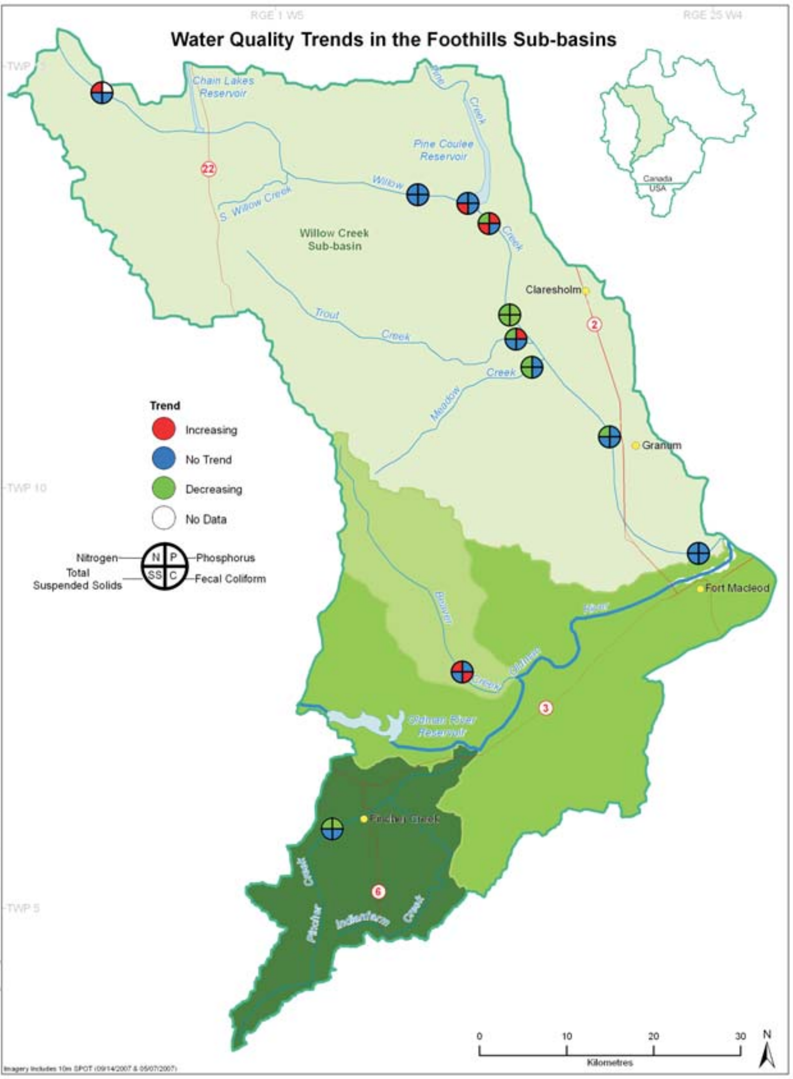


Figure 1.13: Example Showing Indicator Trend in Sub-basins

Thresholds for water quality indicators assessed in this report have not been established in the scientific literature or in other state of the watershed reports completed in Alberta. For this report, data were assembled for all water quantity indicators and all hydrometric stations analyzed in the watershed. Thresholds were established through a ranking process as described previously (Section 1.3.2 Water Quantity). These thresholds were then applied to each individual Sub-basins to derive an overall rank for the Sub-basins (Chapter 10).

Integration across the terrestrial and riparian ecology, water quantity, and water quality indicators was accomplished by combining the overall rankings within each of the Sub-basins to determine an overall value for the health of each of the Sub-basins.

A comparative assessment of the overall rankings assigned to each of the Sub-basins was then used to assess the overall health of the Oldman watershed.