Beaver River Watershed Alliance

Summary Report

2013

The State of the

Beaver River Watershed

CONTENTS

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The State of The Beaver River Watershed – A Summary
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STATE OF THE BEAVER RIVER WATERSHED

INTRODUCTION

The Beaver River watershed is located in the boreal plain of east-central Alberta and west-central Saskatchewan, about 300 km northeast of Edmonton. The name beaver is likely a translation from the Cree name, *amisk*, and appears as such on maps from as early as 1790. The Beaver River originates near the town of Lac La Biche as the outflow from Beaver Lake and flows generally east for about 250 km passing to the south of Cold Lake – the largest lake in the Alberta portion of the watershed – to enter Saskatchewan. The Cold River originates at the east end of Cold Lake in Saskatchewan and flows east, eventually to join the Beaver River. It turns north joining the Churchill River at Île-à-la-Crosse to flow to Hudson Bay.

For this report, the geographic area of interest is the watershed upstream of the Beaver River at the interprovincial boundary and upstream of the Cold River at the outlet of Cold Lake. To measure and monitor conditions in the watershed environmental indicators are used so that present conditions can be assessed and compared to desirable outcomes. Water management plans can then define management actions required to improve environmental conditions, where required, to achieve these outcomes. However, indicators used in this summary are relative not absolute; that is, the results may not compare to results for other watersheds in the province. Figure 1 depicts the individual sub-watersheds discussed in this summary.

Figure 1 Sub-watersheds of the Beaver River Watershed, Alberta.

LANDFORM AND LAND COVER

The Beaver River watershed in Alberta is triangular-shaped, with the base on the interprovincial boundary and the apex pointing into Alberta. The lowest portion of the watershed is along the Beaver River itself. Higher lands lie along the southern fringe of the watershed and in the north within the Cold Lake Air Weapons Range. Elevations in the watershed range from 750 m to 500 m above sea level. For the most part, the landscape is an undulating to moderately rolling plain, with some hummocky uplands. This landscape is formed by glaciation and, indeed, there are surface features formed as glacial meltwater channels that do not reflect current runoff patterns. For example, a channel containing a chain of small lakes and undersized streams runs into Moose Lake and out of the lake to the Beaver River. Contemporary lakes such as Kehiwin, Bangs and Thin lakes partially occupy the channel.

Although the watershed is dominated by deciduous forest, it lies in Alberta's boreal forest natural region marking the southern limit of closed forest and the northern advance of agriculture. Generally, the southern portion of the watershed is in the dry

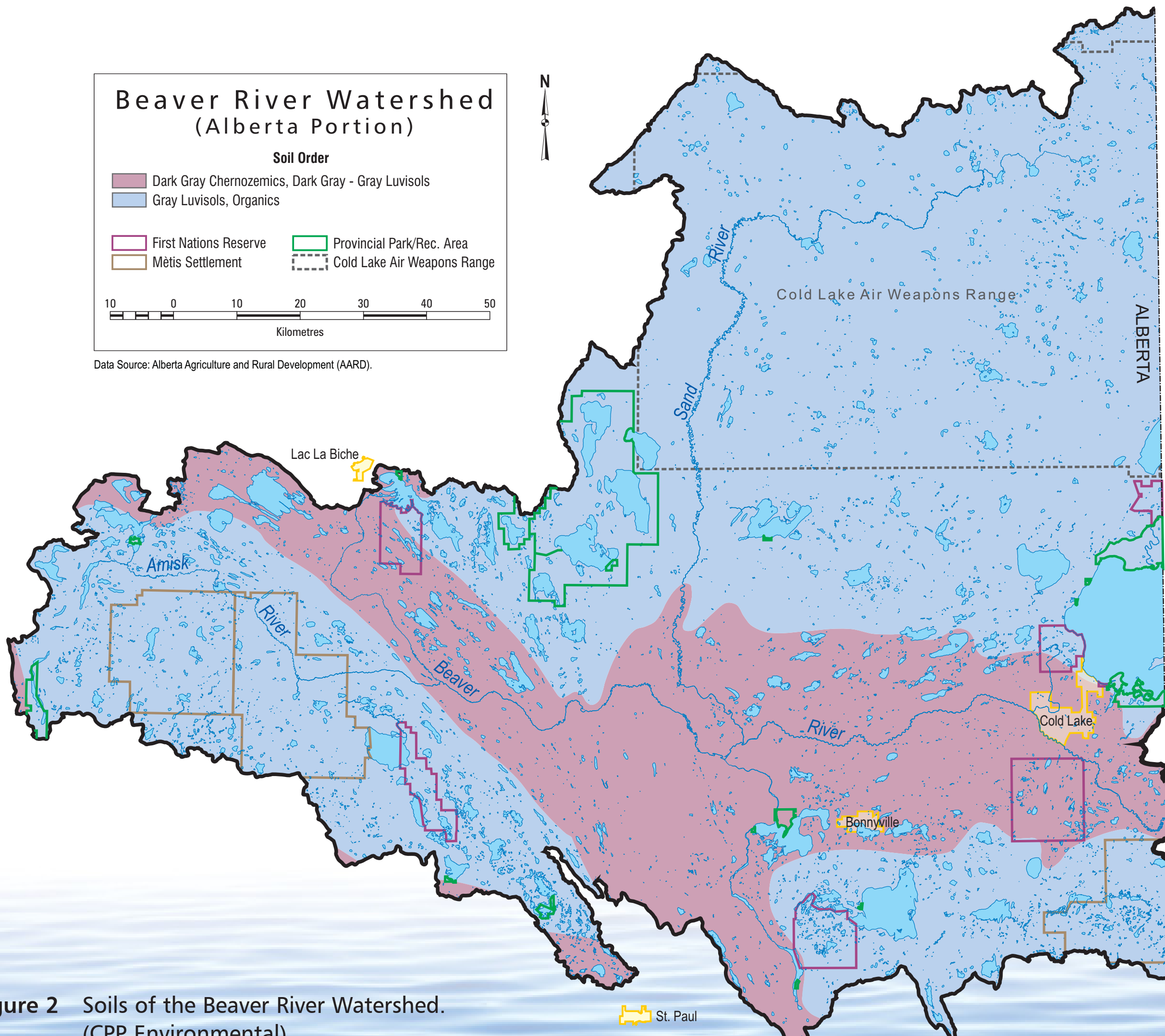


Figure 2 Soils of the Beaver River Watershed. (CPP Environmental)

mixedwood natural subregion while the northern portion of the watershed is in the central mixedwood natural subregion. Although the dry mixedwood subregion tends to have been transformed by agriculture, natural vegetation consists of aspen forest with a shrubby understory. Some white spruce and jackpine occur in dry sites. Natural vegetation in the central mixedwood sub-region consists of a closed cover of tall, trembling aspen, balsam poplar, white birch, and white spruce, with a thick understory of mixed sedges and tall shrubs. The extensive, poorly drained peatlands are usually covered with sedges, willow, black spruce, and tamarack. Jackpine is common in sandy sites.

As shown in Figure 2, the watershed is dominated by grey luvisol soils in well-drained upland areas, both in the north and along the southern boundary. These grey soils are associated with the forests of the central mixedwood sub-region. Wet depressional areas contain significant organic soils. The portion of the watershed extending from Cold Lake towards Beaver Lake and to the north closely aligns with Alberta's designated Green Zone – a less settled area of forested provincial crown land.

Agricultural lands cover one-third of the watershed, much of this associated with the dark grey chernozemic soils and dark grey luvisols of the Beaver River lowlands and the Mooselake River watershed. A good deal of this land is devoted to pasture as cattle operations are the dominant agricultural land use, accounting for 57 percent of all farm operations. Natural and improved pastures cover one half of the agricultural lands while crop lands account for 36 percent. Summer fallowing is rarely used.

The current landcover of the Beaver River watershed is shown in Figure 3. Clearly evident are the large areas where significant human influences predominate,

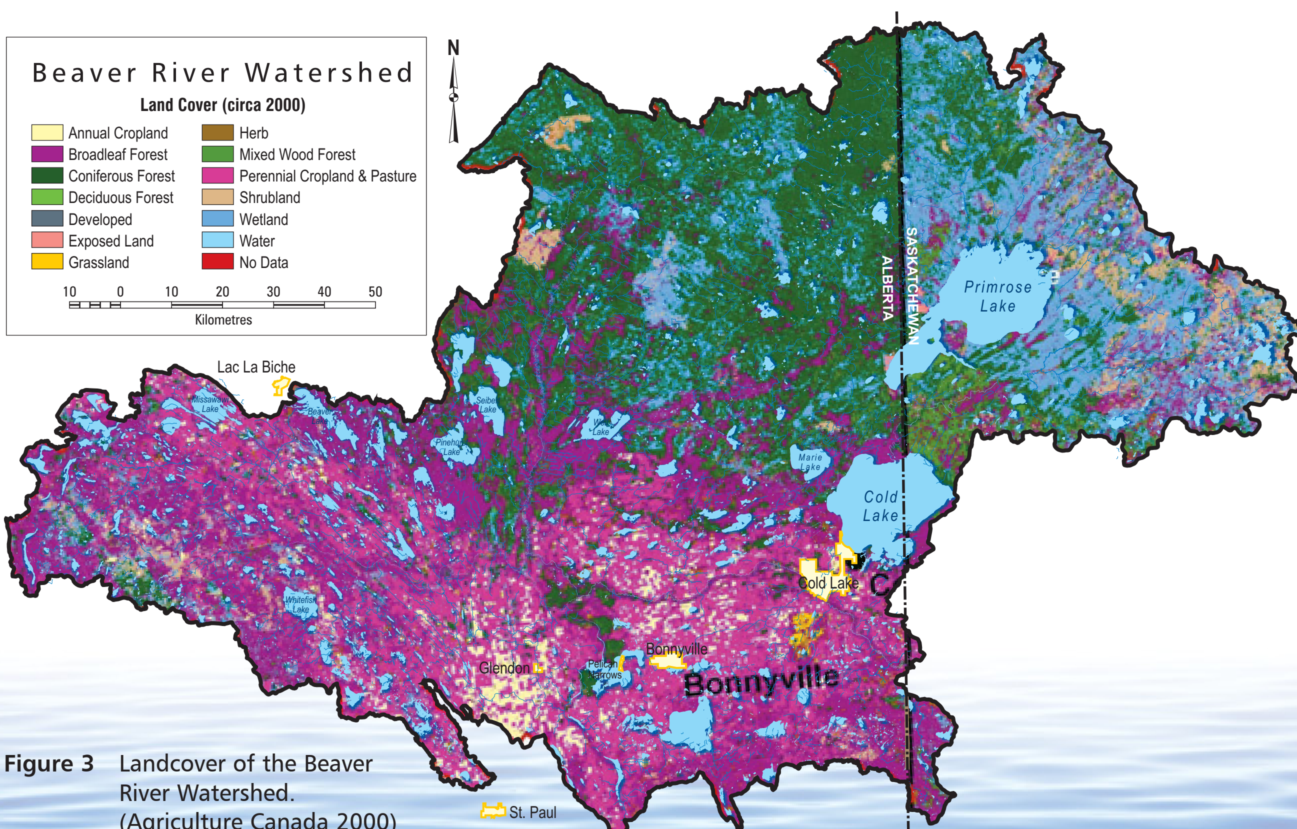


Figure 3 Landcover of the Beaver River Watershed. (Agriculture Canada 2000)

particularly in the Beaver River lowlands and the Mooselake River sub-watershed. This modified landscape is the result of agricultural activity. Indicators of agricultural activity such as cultivation and manure production shown in Figure 4 are very closely aligned with the soils classification.

Significant wetlands are found in the watershed. The northern portions are almost completely forested and contain ecologically important areas of poorly drained fens and swamps. Ducks Unlimited Canada has classified the water and wetland features of the Alberta portion of the watershed. Sixty-seven percent is considered upland, the remaining portion being open water or wetland. Of this portion fens comprise 46.5 percent; swamps, 23.5 percent; marshes, 4.5 percent; bogs, 3 percent; and open water 22.5 percent.

Linear features such as roads and seismic lines also alter the landscape. Linear features may lead to increased erosion or may fragment habitat and effects may influence runoff, water quality and ecological integrity. Within the Beaver River watershed, linear features are minimal in the Sand River sub-watershed and relatively sparse in the Cold River sub-watershed. Elsewhere in the watershed linear features are relatively dense, sufficient to give rise to concerns about environmental effects.

An approach to addressing concerns about linear features is to consider stream crossing density. Stream crossings are a potential indicator of road density and may influence fish movement if not well designed. Figure 5 illustrates stream crossing density in the Beaver River watershed. As is the case with linear features, crossing density is low in the Sand River sub-watershed. It also tends to be low in the sub-watersheds north of the lower Beaver River. Crossing density is particularly high in the Muriel and Reita creek sub-watersheds.

Another attribute of a watershed's landscape is riparian health. The condition of riparian zones has significant influence on ecological integrity. The customary surveys of diversity, structure, and health of riparian plant communities have not been carried out in the Beaver River watershed. Riparian conditions on the mainstems of the Beaver and Sand rivers are generally good. While there is some

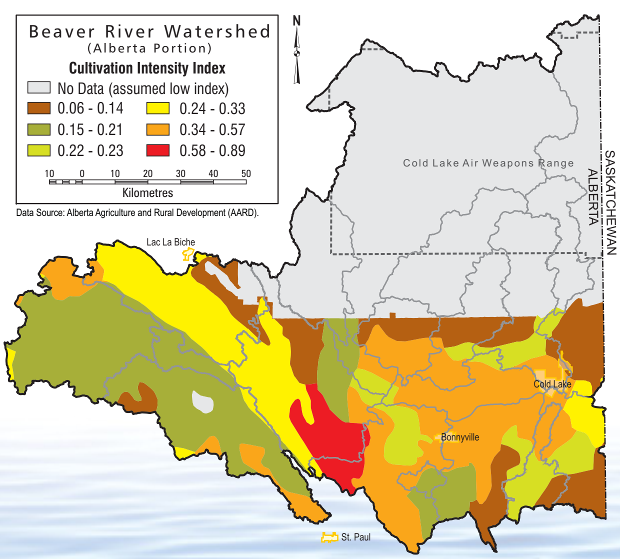


Figure 4a Cultivation Intensity. (CPP Environmental)

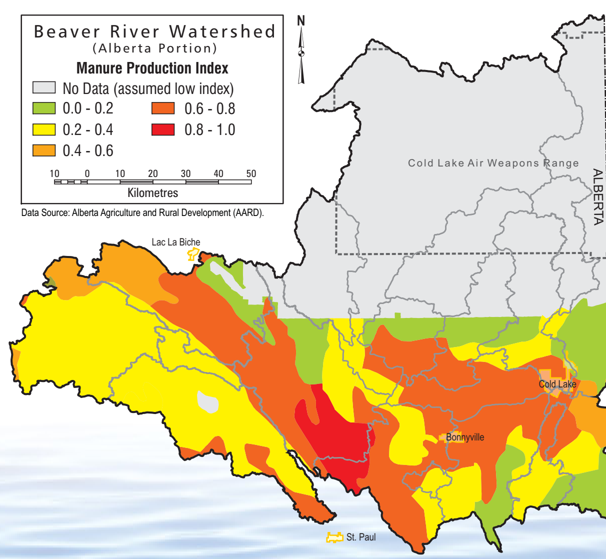


Figure 4b Manure Production. (CPP Environmental)

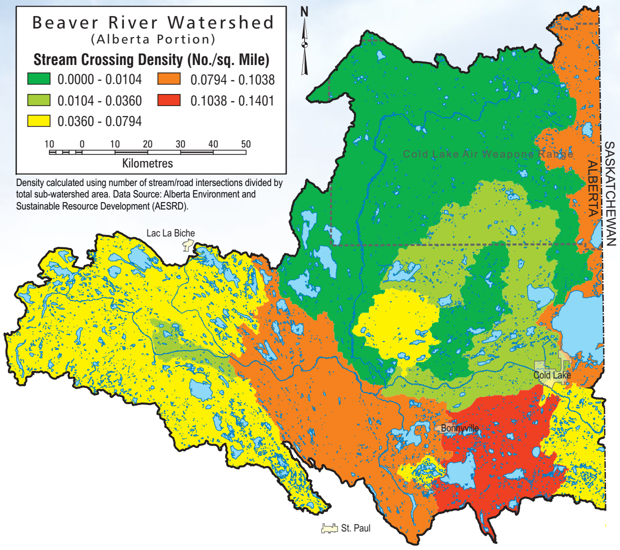


Figure 5 Stream Crossing Density. (CPP Environmental)

exposed soil, an average of seven percent exposed, there is little bank erosion or bank disturbance.

A small number of lakes have been assessed using aerial videography. Results are shown in Table 1.

Emissions of substances such as oxides of sulphur and nitrogen associated with oil and bitumen production may affect both soils and vegetation in parts of the watershed. The deciduous and jack pine forests of the watershed are sensitive to these emissions and to long-term acidification of soils. Some sandy soils south of the Beaver River in the Moose and Muriel lake areas are also sensitive to acidification

CLIMATE

The Beaver River watershed experiences a humid continental to subarctic climate typical of the Canadian interior plains. Winters are long and cold, but sunny, while summers are short and cool. The average annual temperature at the city of Cold Lake is 1.6°C with the summer mean being 15.8°C and the winter mean, -14.5°C. The highest recorded temperature is 36.3°C in June 2002 while the lowest is -48.3°C in January 1954. Typically, there are 105 to 115 frost-free days and 1251 growing degree-days each year. The average annual temperature has increased by more than one degree in the last 50 years.

Table 1 Riparian Health of Marie, Crane, Hilda and Ethel Lakes.

Lake	Healthy (%)	Moderately Impaired (%)	Highly Impaired (%)
Muriel	0	76	24
Marie	82	9	9
Crane	79	7	14
Hilda	78	13	9
Ethel	80	11	9

Average annual precipitation is 400 to 600 mm. This includes the water equivalent of the annual snowfall, whose average depth is about 120 cm. In general, precipitation increases from east to west and from south to north in the watershed. Annual precipitation at Cold Lake is 440 mm, three-quarters of which falls as rain. Rain in the months of June, July and August accounts for one-half of the annual precipitation. Precipitation trends at Cold Lake indicate that average annual precipitation in the last 50 years has declined. Annual gross evaporation in the watershed ranges from 500 to 750 mm each year. On average, therefore, the entire watershed experiences a moisture deficit.

Harry Keess

SURFACE WATER

The principal tributaries of the Beaver River are the Sand River plus Manotokan, Jackfish, and Marie creeks, which enter from the north. The Amisk River drains the western portion of the watershed and, together with the Mooselake River plus Muriel and Reita creeks, enters the Beaver River from the south. The Cold Lake portion of the watershed includes the Medley and Martineau rivers, which enter the lake from the north. Cold Lake itself straddles the Alberta-Saskatchewan boundary.

Unlike many Alberta rivers, the Beaver River originates on the boreal plain rather than on the eastern slopes of the Rocky Mountains. Because of this, runoff is not subject to the stabilizing influence of mountain snowmelt and shows considerable variability from year to year and within the year. The typical runoff pattern is shown in Figure 6, which is a plot of median daily discharge for the period of record. The river rises to a peak in the latter part of April because of spring snowmelt and rain during the snowmelt period, then generally recedes through the remainder of the year. Unlike prairie streams of southern Alberta , however, the Beaver River will respond to summer rainstorms with dramatic increases in flows. Indeed, in some years the summer flow may be greater than the peak flow during spring runoff.

The streamflow record for the Beaver River and its tributaries is relatively short. The Prairie Provinces Water Board, however, has calculated naturalized flows for the Beaver River at Cold Lake Reserve based on statistical correlations with other streams. This record, shown in Figure 7, begins in 1912 and shows an overall slightly decreasing trend, as does the instrumental record beginning in the 1950s.

The streams within the Beaver River watershed flow naturally, unimpeded by dams and other works. As illustrated in Figures 6 and 7, there is considerable variation in flow both within a given year and between years. Annual streamflow in 1992 was the lowest in 100 years while that in 1997 was the third highest. Annual water yield tends to be highest for streams rising in the Cold Lake Air Weapons Range and is lowest for tributaries such as Mooselake River and Muriel Creek.

An indicator of annual streamflow reliability can be calculated by comparing the range in streamflow values to the median. The larger the calculated number, the less reliable the streamflow. There is insufficient data to perform such calculations for the ephemeral southern tributaries of the lower Beaver River; nonetheless, their flows are very unreliable. Streamflow reliability for various sub-watersheds is shown in Table 2. The Cold River has the most reliable flow in the watershed.

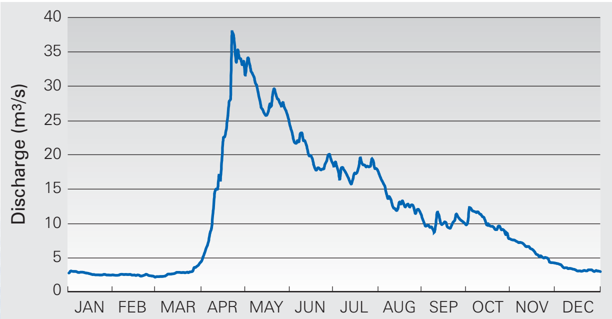


Figure 6 Median Daily Discharge for the Beaver River at Cold Lake Reserve.

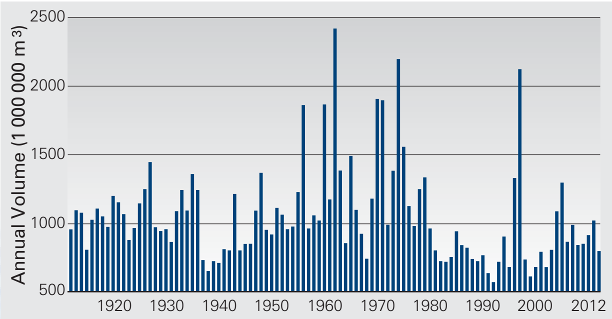


Figure 7 Annual Naturalized Flow of the Beaver River at Cold Lake Reserve.

Table 2 Annual Streamflow Reliability in the Beaver River Watershed.

River	Minimum (1000 m^3)	Median (1000 m^3)	Maximum (1000 m^3)	Range as % of Median
Southern Tributaries such as Mooselake River, Muriel Creek and Reita Creek	- -	- -	- -	very high
Beaver River near Goodridge	146	52 554	478 230	910
Amisk River at Hwy 36	456	29 097	188 320	646
Wolf River at Outlet of Wolf Lake	92	17 560	105 000	441
Sand River at the Mouth	41 072	247 590	1 016 954	394
Jackfish Creek near Le Corey	148	11 117	46 464	417
Beaver River at Cold Lake Reserve	68 226	471 513	1 918 408	392
Cold River at the Outlet of Cold Lake	12 700	421 000	1 410 000	331

Streamflows of the lower Beaver River are also quite reliable due to the significant contribution from the Sand River.

The Beaver River watershed has an abundance of lakes: more than 2000 can be identified with 1:250 000-scale mapping. In general, these lakes can be identified as one of three types. The most common is a typical prairie lake or slough with shallow depths and gently sloping sides. These shallow depressions may be occupied by wetlands or beaver dams in parts of the basin. Such lakes are very sensitive to climate-driven, water level fluctuations.

The second type of lake is one that is deep and has very steep sides. These lakes have been carved by glacier action. (Not all lakes fitting this general description are necessarily ice-carved.) Because they intercept and interact with multiple aquifers, these lakes do not fluctuate widely from year to year. Cold Lake, which is over 100 m deep, is one such lake. The third type is one that lies in glacial meltwater channels. These are often shallow and tend to form chain lakes in the larger meltwater channel. Kehiwin Lake is an example.

The lakes in the watershed provide significant recreational opportunities for residents and visitors. Some are fished to support domestic consumption by aboriginal people. Several, such as Beaver and Wolf lakes, are fished commercially. A few of the lakes supply water for communities and industry. Water levels of a few lakes are regulated by weirs at the lake outlet. Little documentation exists for Primrose Lake, the largest lake in the entire watershed, which lies almost entirely in Saskatchewan.

There are 28 lakes for which sufficient data are available to consider trends in lake levels. In general, lakes in sub-watersheds entering the Beaver River from the north tend to contain lakes whose levels are stable. Some even show very slight increases in water levels. Lakes in the sub-watersheds entering the Beaver River from the south may have either stable or declining water levels. Muriel Lake exhibits the most significant decline of all the monitored lakes.

GROUNDWATER

The bedrock beneath the Beaver River watershed consists of a succession of sedimentary deposits, mainly sandstones, shales and limestone, resting on the Pre-Cambrian shield. The McMurray Formation at a depth of about 600 m is variously water saturated, and a source of brackish water, or bitumen saturated. The heavy oil recovered in the watershed originates mainly in the Clearwater Formation, which overlies the McMurray Formation. The Grand Rapids Formation lies above the Clearwater Formation. These Lower Cretaceous formations range in age from 144 to 97.5 million years.

The uppermost bedrock of the watershed is composed of dark grey marine shales, known as the Lea Park Formation, and underlain by Colorado shales. The Lea Park Formation is a silty marine shale with ironstone concretions. In the southwest part of the watershed, the Lea Park Formation is overlain by the Belly River Group. This consists of a grey to greenish grey non-marine sandstone or mudstone, also with ironstone concretions. These formations date from the Upper Cretaceous period, some 97.5 to 66.4 million years in age.

Prior to glaciation, the bedrock surface was eroded by predominantly eastward flowing rivers. This produced broad paleovalleys with shallow side slopes and low gradients. The dominant valley in the watershed is the Helina Valley, known as the Hatfield Valley in Saskatchewan. Others include the Beverly, Sinclair, Wiau, Kikino, and Vermillion valleys. Original sediments on the valley walls may have originated from as far away as the Rocky Mountains. During the earliest glacial periods these valleys were filled with substantial deposits of sediments as the glaciers advanced and retreated.

Glacier meltwater also scoured new channels in the bedrock surface during the earliest interglacial times. These scoured channels tend to have concave longitudinal profiles and steep side slopes. Their original sediments tend to be derived from the Pre-Cambrian Shield. These channels include the Sand River, Bronson Lake, Big Meadow, Moore Lake and

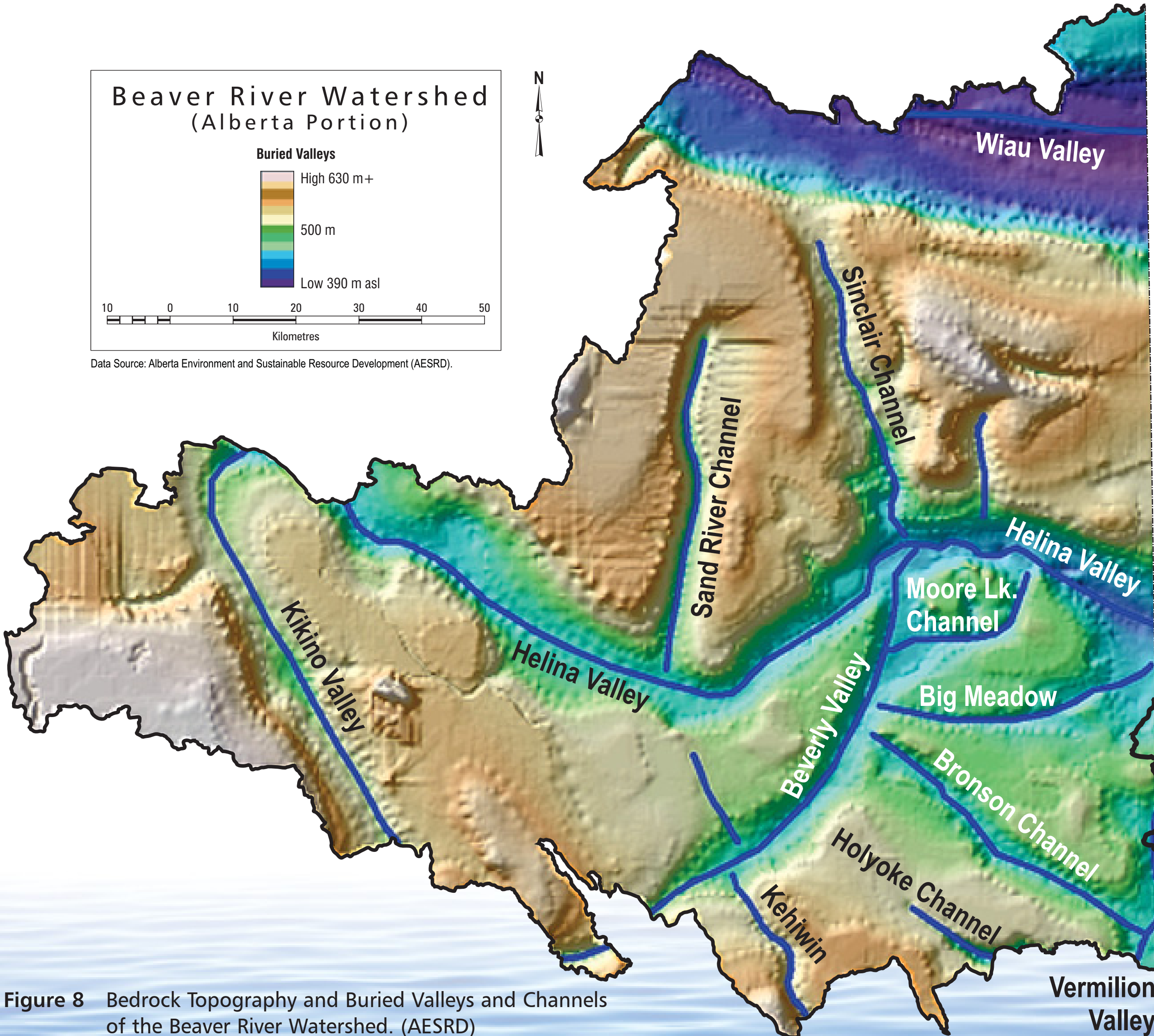


Figure 8 Bedrock Topography and Buried Valleys and Channels of the Beaver River Watershed. (AESRD)

Period	Glacial Event	Stratigraphy		Lithology
Quaternary	Cold Lake	Surficial Stratified Sediment		Sand, gravel, silt
		Grand Centre Formation		Till
		Sand River FM		Sand, till
	Ardmore	Marie Creek FM		Till
		Ethel Lake FM		Silt, clay, sand, gravel
	Fort Kent	Bonnyville Group	Unit 2	Till
			Unit 1	Sand, gravel
			Unit 1	Till
	Cherry Grove	Muriel Lake FM		Sand, gravel, silt, clay
		Bronson Lake FM		Diamict, clay
		Empress Group	Unit 3	Sand, gravel, till
	Preglacial		Unit 2	Clay, silt
Tertiary			Unit 1	Sand, gravel
Upper Cretaceous	n/a	Bedrock (Lea Park or Belly River Formation - depending on location within watershed)		

Figure 9 Chart of Drift Formations (adapted from Parks *et al* 2005).

Kehiwin channels. The bedrock topography, as well as the valleys and channels, is shown in Figure 8. It is essential to recognize that the pre-glacial and glacial paleovalleys are independent of present-day surface topography.

The bedrock topography of the watershed is covered by unconsolidated sediments, known as drift, deposited over the last 2.5 million years. The thickness of this drift may vary from zero, where bedrock is visible, to 200 metres in the Sinclair and Wiau valleys. The greatest thickness is in the Moostoos Upland. Layers of drift can be mapped based on the origin and nature of the materials of the various formations. By definition, in Alberta the materials that overlie the bedrock and underlie glacial till comprise the Empress Formation. This formation intersects the bed of Cold Lake. The regional units in the watershed and their basic composition are shown in Figure 9. The Empress, Bronson and Muriel Lake formations lie within the buried valleys and channels of the watershed. The Bonnyville Formation is notable as it is the first formation that extends beyond the buried valleys. Formations above the Bonnyville Formation, from oldest to youngest, include the Ethel Lake, Marie Creek, Sand River and Grand Centre formations.

Groundwater use in the watershed is a significant portion of overall water use and it is the drift formations that govern the presence and characteristics of groundwater. An aquifer can be defined as a water-bearing formation sufficiently porous to yield water to a well. Aquifers can be either bedrock aquifers or drift aquifers. To simplify, drift aquifers may be classified as buried valley aquifers, intertill aquifers and surficial aquifers. Buried valley aquifers are capable of very high water yields. Because of this, petroleum companies have used the Empress and Muriel Lake aquifers as sources of water. In addition, brackish or saline groundwater from much deeper sources is widely used in the petroleum industry.

The water yield from intertill aquifers varies considerably. The sands comprising a surficial aquifer may be at, or just a few metres below, the surface. These aquifers vary in size but, in general, do not yield significant water supplies. Some intertill aquifers have only sufficient sustainable water to supply domestic needs while others may yield sufficient sustainable supply to meet some commercial needs. The surficial aquifers tend to be very responsive to climate conditions. Wells in surficial aquifers are often critically important to on-farm water users.

One other aspect of groundwater in the watershed is the use of deep well disposal of wastewater or excess-produced water (water produced with bitumen) from conventional oilfield and thermal *in situ* operations. The waste water is generally saline and contains oil and soluble organic compounds. Excess-produced water tends to be brackish. Regardless of the source, this water may not be disposed of in a manner that threatens the environment. Deep well disposal into a deep, well-contained, saline aquifer is considered the safest practice. The general approach is to return the water to deep formations below the bitumen-bearing formations. Deep well disposal is regulated by Alberta's Energy Resources Conservation Board.

Water-well density is one indicator of groundwater usage, particularly from the surficial aquifers of the watershed. This well density, shown in Figure 10, coincides almost exactly with the soils and land cover maps shown earlier in this summary. Well density is not directly linked to water consumption but, in general, water use from the shallow wells that dominate the figure tends to be for agricultural and related purposes and is relatively small. These wells tend to respond to climate factors rather than human use. The roughly 100 deep wells whose water is used for industrial purposes tend to draw down with pumping activity then rebound when pumping ceases.

HUMAN SETTLEMENT

People have lived in the Beaver River watershed since the retreat of the Laurentide ice sheet thousands of years ago. Archeological sites indicate human habitation for at least 7500 years. During the late 1700s, Cree seeking furs as trade goods displaced the nomadic Beaver, Blackfoot and Slavey people. The Woodland Cree, residing in forested areas, fished, hunted and trapped while travelling along waterways in birch bark canoes. They established themselves as intermediaries between the Hudson's Bay Company and the People of the Plains. They also acted as guides for the early European visitors to the northern plains.

The Beaver River trade route from Île-à-la-Crosse at the confluence of the Beaver and Churchill rivers formed one of three important connections between the Churchill River and Athabasca River systems in the

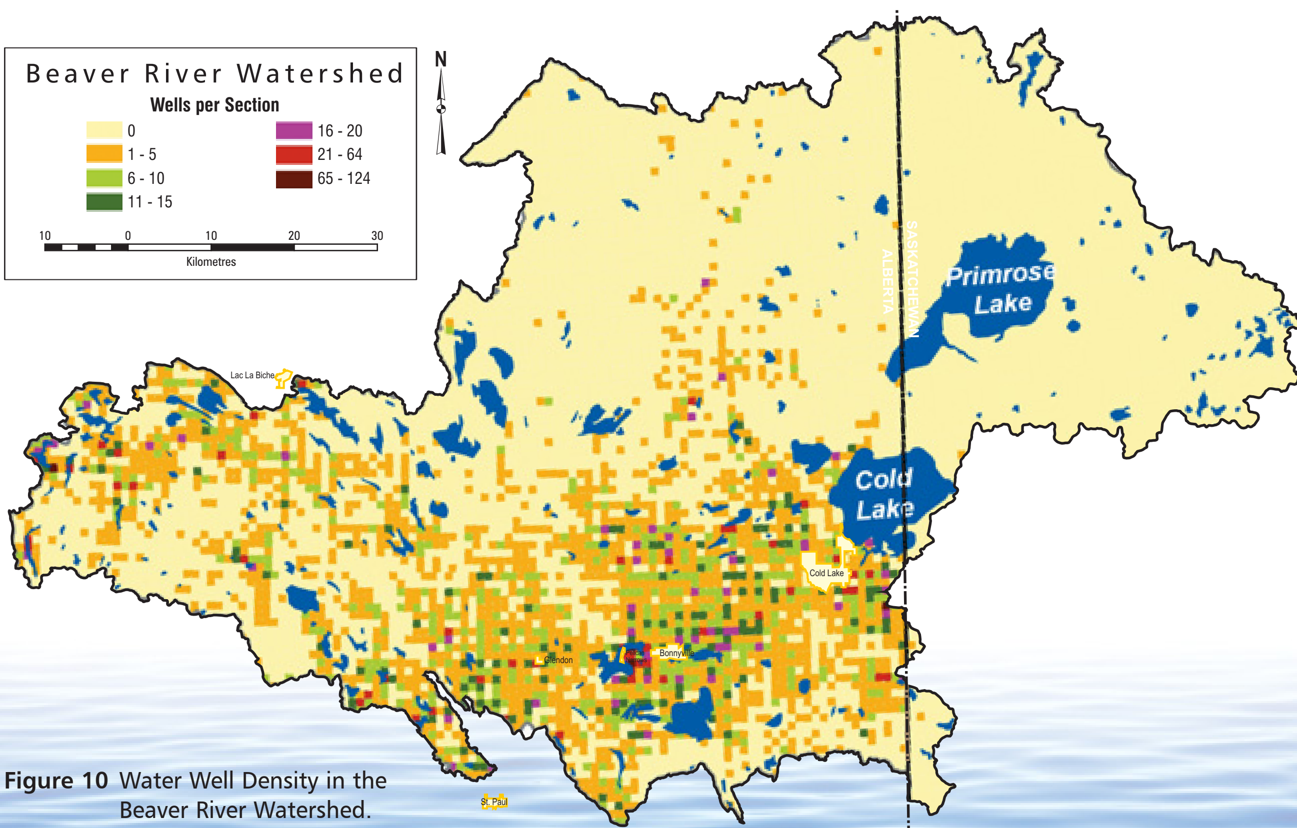


Figure 10 Water Well Density in the Beaver River Watershed.

early days of the fur trade. The route was a means of travelling into the upper Athabasca watershed and the Lesser Slave Lake and Peace River areas, while circumventing the northern plains. The route ran up the Waterhen and Cold rivers to Cold Lake with a portage from the south part of Cold Lake to the Beaver River. Access to the Athabasca watershed was over Portage La Biche near Lac La Biche. The portage was designated a Provincial Historic Resource in 1993 – the only such designation in Alberta.

The North West Company established a trading post, Cold Lake House, near present-day Beaver Crossing in 1781 and a second, Shaw House, at Moose Lake in 1789. By the time David Thompson of the North West Company mapped the route in 1798 it was well established. Another early traveller through the watershed was Gabriel Franchère, a fur-trader, merchant and author who travelled the Beaver River on a trip from Fort Astoria at the mouth of the Columbia to Montreal.

The First Nations communities in Beaver River watershed are in the Treaty 6 area. (The Cold Lake Air Weapons Range lies in Treaty 10 lands, but contains no permanent population centres.) The numbered treaties of western Canada originated with the transfer of Rupertsland from the Hudson's Bay Company to Canada in 1870 and the construction of the first transcontinental railway. There are four First Nations reserves in the watershed.

Oblate colonizing priests played an important role in encouraging agricultural settlers to the watershed in the late 1800s and early 1900s. An early mission was established at Lac La Biche in 1853 but 50 years later St. Paul had become the centre of activity. Father Joseph Thieren established a settlement at Moose

Lake in 1907. The settlement was renamed Bonnyville in 1908 after Father Francis Bonny. Settlement was driven by the arrival of the railway at Lac La Biche in 1914, St. Paul in 1919 and Bonnyville in 1929.

Among the first settlers in the Bonnyville-Cold Lake area were French-Canadian homesteaders. These were followed by immigrants from Ukraine and many other parts of Europe. Logging and road work provided some wage labour, but the economy was largely based on agriculture. A second wave of settlers arrived in the 1930s as agricultural areas of southern Alberta were struck by drought.

Commercial fishing started in the watershed in 1916 and was essentially unregulated until 1939. The dominant catch then was whitefish, as it is today. Fur farming and an associated feed fishery based on tullibee (lake cisco) operated from time to time after the Second World War until the 1990s. First Nations and Métis people continue to operate a domestic subsistence fishery as well as participating in the commercial fishery.

Several sawmills operated in the watershed from the 1920s to 1950s. Handhewn railway ties made from jackpine was the early product. Small portable sawmills operated north of the Beaver River, notably on Touchwood, Pinehurst, Siebert, Jackson, and Blackett lakes. These operations were often conducted from winter ice cover. Poplar and spruce lumber as well as fence posts were the main product.

Métis settlements were created in Alberta in 1938 under the authority of the Métis Population Betterment Act. One-half of the eight existing settlements are in the Beaver River Watershed. Elizabeth and Fishing Lake settlements lie in the municipal district of Bonnyville south of the city of Cold Lake. Buffalo Lake and Kikino share a common boundary and are in Smoky Lake County south of Lac La Biche. In 1990 the province proclaimed additional legislation aimed at securing a land base, gaining local autonomy, and achieving self sufficiency for Métis people.

In 1952, Cold Lake was selected as a site for an air weapons training base. It was chosen because of the flat terrain, good drainage, gravel deposits, low population density, similarities of geography to Europe, accessibility, weather, and the possibility of future economic development in the region. Now known as 4 Wing Cold Lake, it attracts air forces for training from the North Atlantic Treaty Organization (NATO) and around the world. Some 2000 military personnel are stationed at Cold Lake. The associated 11 700 km^2 Cold Lake Air Weapons Range straddles the Alberta-Saskatchewan boundary, including the northern part of the Beaver River watershed. The range is on provincial crown land leased by the federal government.

More recently, Cold Lake has been a centre for oil exploration and development. Imperial Oil began production of bitumen in 1975 and significantly increased production in the mid-1980s. The current cyclic steam stimulation operation has a capacity of 170,000 barrels of bitumen a day. Production is transported to the United States using the Primrose Pipeline. Several companies now conduct *in situ* recovery operations from the Cold Lake oil sands, including areas within the Cold Lake Air Weapons Range.

WATER USE

Water use is a broad term that includes any use of water for any activity, economic or otherwise. Water use can include withdrawal or diversion of water from a source, or water used in place. Water uses may be considered consumptive or non-consumptive. For example, water used in stock-watering is almost entirely consumed, while water used in urban water supplies is almost entirely returned to the environment. Alberta considers the likely consumption of water for a specific use in its

Table 3 Water Allocation from Surface and Groundwater (m^3).

Purpose	Surface Water	Groundwater
Municipal	13 555 000	1 985 000
Agriculture	816 000	1 481 000
Commercial	8 559 000	356 000
Industrial	8 577 000	12 530 000
Other	23 334 000	239 000
Registration	1 123 456	813 586
Totals	58 158 000	17 931 000

licensing process. Summing up of the quantities of water allocated by water licences will overestimate water consumption in a watershed as many licensees do not consume or otherwise use their entire entitlement in a given year.

Water licences are registered by various sectors and sub-sectors. The principal water use sectors in Alberta are municipal, agriculture, commercial, industrial, and other. The latter includes water for flood control, lake stabilization, and wildlife enhancement projects such as Ducks Unlimited Canada projects. There are 346 surface water licences and 4789 registrations allocating 58 158 000 m^3. In addition, there are 458 groundwater licences and 1092 registrations allocating 17 931 000 m^3 in the watershed. Table 3 and Figure 11 show the allocation by use.

The largest single surface water allocation is for 'other,' closely followed by municipal then industrial. Industrial use in the petroleum sector dominates the groundwater allocation. In some cases, these industrial groundwater licences are standby arrangements for use when surface water supplies are low.

Considering the Beaver River watershed in Alberta as a whole, annual water diversions are less than licensed quantities and actual consumption is low compared to the natural flow of the river and its tributaries. In a median year, consumption is less than two percent of the annual runoff. This overall favourable situation must be placed in the context of flow reliability discussed earlier. Because of the unreliable flows of the Beaver River upstream of the confluence with the Sand River and of the flows in the southern tributaries of the Beaver River, water needs may not be met entirely in dry years, despite the allocation being modest.

Concerns about declining lake levels have led to moratoriums on water withdrawals from Manatokan, May, Muriel, Reita, and Tucker lakes. Diversions for steam injection purposes are not permitted from any of the lakes, wetlands or streams of the watershed, except for Cold Lake. This policy is aimed at protecting fish, wildlife, recreational values, and ecosystem function.

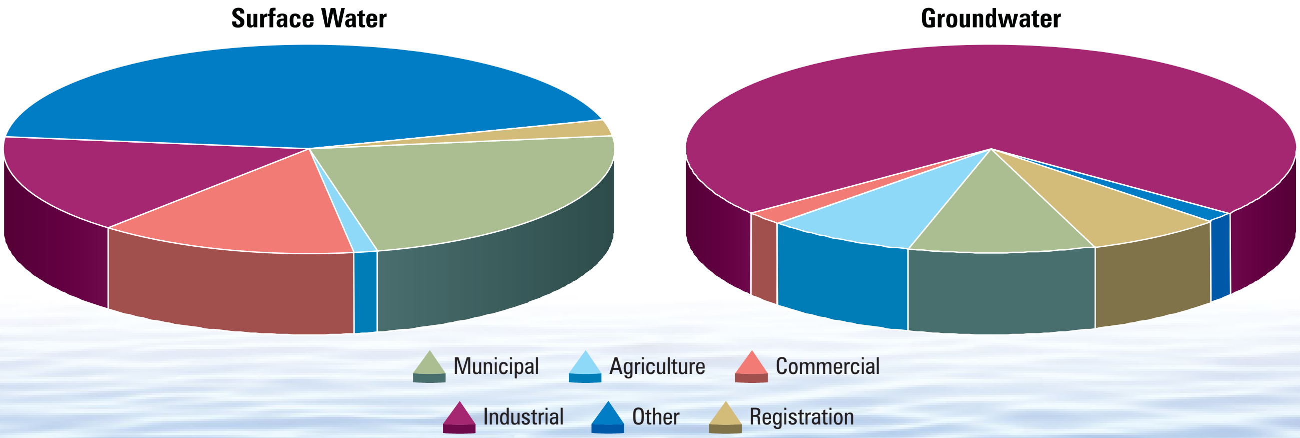
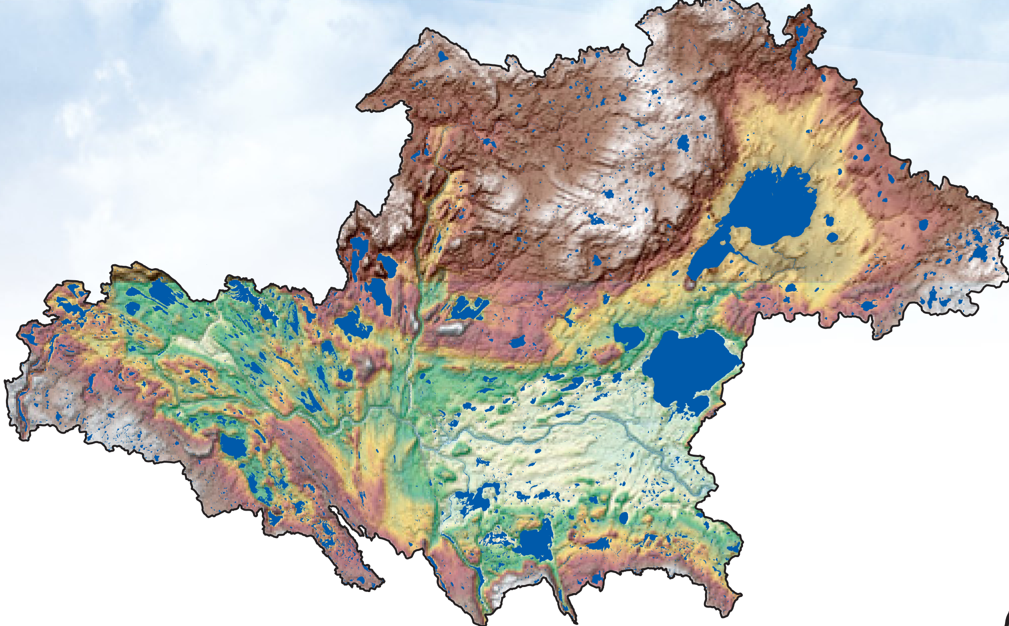
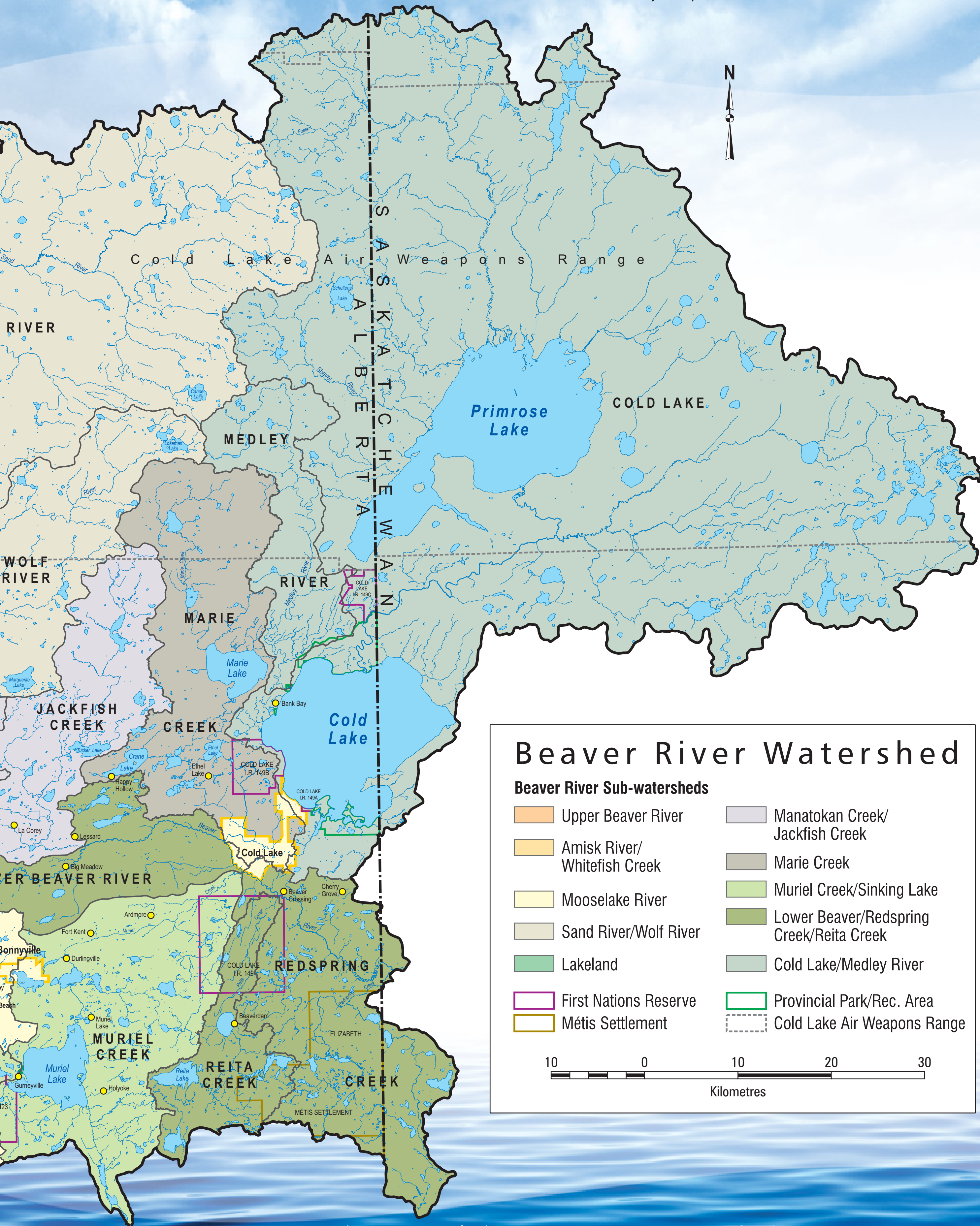


Figure 11 Water Allocation by Water Use Sector.




Lac La Biche
Missawawi Lake
Beaver Lake
Beaver Lake
BEAVER LAKE I.R. 131
North Buck Lake
Burnt Lake
Venice
Hylo
Noral
Caslan
Mewatha Beach
Bondiss
Amisk River
Craigend
Normandeau
UPPER BEAVER RIVER
AMISK RIVER
BUFFALO LAKE
MÉTIS SETTLEMENT
Long Lake
Rich Lake
Fork Lake
Helina
Brieresville
Kikino
KIKINO MÉTIS SETTLEMENT
Whitefish Lake
WHITEFISH LAKE I.R. 128
McRae
Sugden
WHITEFISH CREEK
Goodfish Lake
Boyne Lake
St. Lina
Goodridge
Glendon
Therien
Mallaig
St. Vincent
Bayview Beach
Abilene
Owlseye
St. Paul
Touchwood Lake
Spencer Lake
Seibert Lake
LAKELAND
Pinehurst Lake
Snug Cove
Wolf Lake
Caribou Lake
SAND
MANATOKAN CREEK
Truman
Iron River
LOW
Moose Lake
MOOSELAKE RIVER
Anshaw
Franchere
Pelican Narrows
Bonnyville
Beacon Corner
Rife
Haselaw
SINKING LAKE


Beaver River Watershed
Beaver River Sub-watersheds
Upper Beaver River
Amisk River/
Whitefish Creek
Mooselake River
Sand River/Wolf River
Lakeland
Manatokan Creek/
Jackfish Creek
Marie Creek
Muriel Creek/Sinking Lake
Lower Beaver/Redspring
Creek/Reita Creek
Cold Lake/Medley River
First Nations Reserve
Métis Settlement
Provincial Park/Rec. Area
Cold Lake Air Weapons Range
10 0 10 20 30
Kilometres
N
Cold Lake Air Weapons Range
SASKATCHEWAN
ALBERTA
Primrose Lake
COLD LAKE
MEDLEY
RIVER
MARIE
CREEK
Marie Lake
JACKFISH
CREEK
WOLF
RIVER
RIVER
Cold Lake
Bank Bay
COLD LAKE I.R. 149B
COLD LAKE I.R. 149A
COLD LAKE I.R. 149C
Cold Lake
Happy Hollow
Ethel Lake
Crane Lake
Tucker Lake
La Corey
Lessard
Big Meadow
ER BEAVER RIVER
Beaver Crossing
Cherry Grove
Ardmore
Fort Kent
Bonnyville
Durlingville
COLD LAKE I.R. 149
REDSPRING
Beaverdam
ELIZABETH
Muriel Lake
MURIEL
CREEK
REITA
CREEK
CREEK
Reita Lake
Gurneyville
Holyoke
MÉTIS SETTLEMENT

Actual water consumption varies from sector to sector. Water consumption as a fraction of available supply also varies from sub-watershed to sub-watershed. It can be assumed that almost all of the water diverted for municipal use returns to the ecosystem although in the specific case of the cities of Cold Lake and Bonnyville, water diverted from one water body is returned to another. Almost all of the water diverted for agricultural purposes is consumed: that is, it is not returned to the stream. The industrial and commercial sectors, largely petroleum-related activity, withdraw and consume about one half of their annual allocation.

The water consumption associated with 'other' purposes is no more than 10 percent of the licensed diversion. The reason for this low consumption relates to the way in which lake stabilization projects are licensed in Alberta. In some cases, such as when the current lake level is below the natural sill elevation of the lake, the calculated evaporative loss related to lake stabilization is effectively zero.

Water consumption has been calculated to be about 16 800 000 m^3 from surface water and 14 300 000 m^3 from groundwater in 2005. Figure 12 illustrates water consumption based on 2012 allocations in comparison to the median annual flow. This flow includes the discharge of both the Beaver River and its Alberta tributaries and the discharge of the Cold River at the outlet of Cold Lake.

SURFACE WATER QUALITY

The quality of water flowing in streams or contained in lakes is the consequence of both natural processes and human activity. Water may contain dissolved substances as a result of natural processes. It may also contain plant nutrients, such as nitrogen or phosphorus, as well as trace elements such as selenium, chromium or arsenic. Naturally occurring substances can affect the appearance or taste of water, and may also be harmful to human health and aquatic life, if found in sufficient concentration. Water also contains dissolved gases such as oxygen.

Human activities such as agricultural, urban development, industrial development, and resource development related to petrochemicals, mining, and forestry may degrade the quality of natural waters. Land-use change, of itself, may also affect water quality. The biological quality of water can be changed by the introduction of bacteria normally found in the intestinal tract of humans or animals, or by water-borne pathogens such as *Giardia lamblia* or *Cryptosporidium parvum*. In recent years, concern has increased about pharmaceuticals and personal care products in aquatic systems.

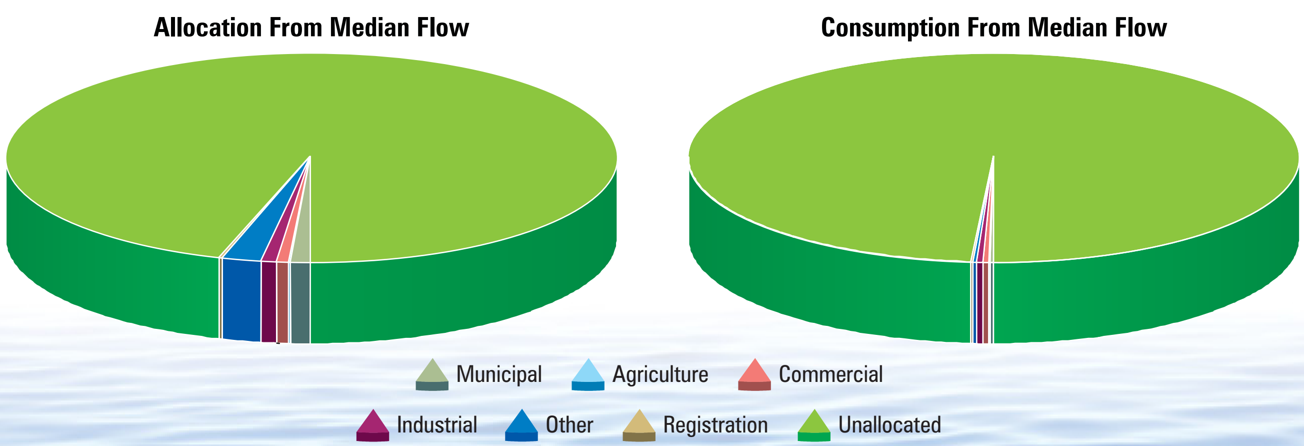


Figure 12 Annual Allocation and Consumption from Surface Water Compared to Median Flow.


Ducks Unlimited Canada

Harry Keess

P.K. Gregory

The Beaver River and its tributaries, as well as the many lakes in the watershed, tend to be naturally high in nutrients. Like other Alberta streams, concentrations of iron, manganese and copper in the Beaver River watershed are naturally high.

One general descriptor of water quality in a lake is trophic status. This classification, based on biological productivity, has been applied to lakes for many years, and, more recently, has been applied to streams. Trophic classification represents a continuum of biological production ranging from oligotrophic to mesotrophic to eutrophic to hypereutrophic. Oligotrophic systems exhibit very little biological production; the water tends to be clear and well oxygenated. Mesotrophic waters may be moderately clear, but oxygen may be depleted in the deepest parts of lakes. Eutrophic systems may contain high densities of plants and algae. Lakes may produce algae blooms and be low in oxygen. Hypereutrophic lakes are very nutrient rich and will show significant persistent algal blooms. Oxygen depletion can lead to fish kills. Alberta has classified the trophic status of its lakes based on total phosphorus and phytoplankton chlorophyll *a*. Total nitrogen and Secchi depth (a measure of water transparency) criteria have also been added.

About 30 lakes in the watershed, primarily lakes that are accessible and have high recreational value, have been assessed and the trophic status determined. Cold Lake is considered oligtrophic to mesotrophic.

Most of the lakes, however, are mesotrophic or eutrophic. Kehiwin Lake is hypereutrophic. Aside from natural factors influencing their trophic status, lakes in parts of the watershed may also be affected by runoff from agricultural lands. The surface area of the watershed devoted to agriculture is increasing, as is the land area where fertilizer is applied. This in turn increases the nutrient loading to the lakes and hence their vulnerability to eutrophication.

Figure 13 provides an index of lake water quality based on phosphorus and chlorophyll concentrations.

In recent years, incidents leading to serious illnesses and even fatalities arising from poor management of a few municipal water treatment systems in Canada have led to increased public concern over safety of drinking water. A priority outcome of Alberta's *Water for Life Strategy* is safe, secure water supplies. Good quality water, however, has many other uses, including food production, sustaining aquatic life, and water contact recreation, such as swimming or boating. The known uses of a body of water are employed as the basis for determining water quality objectives.

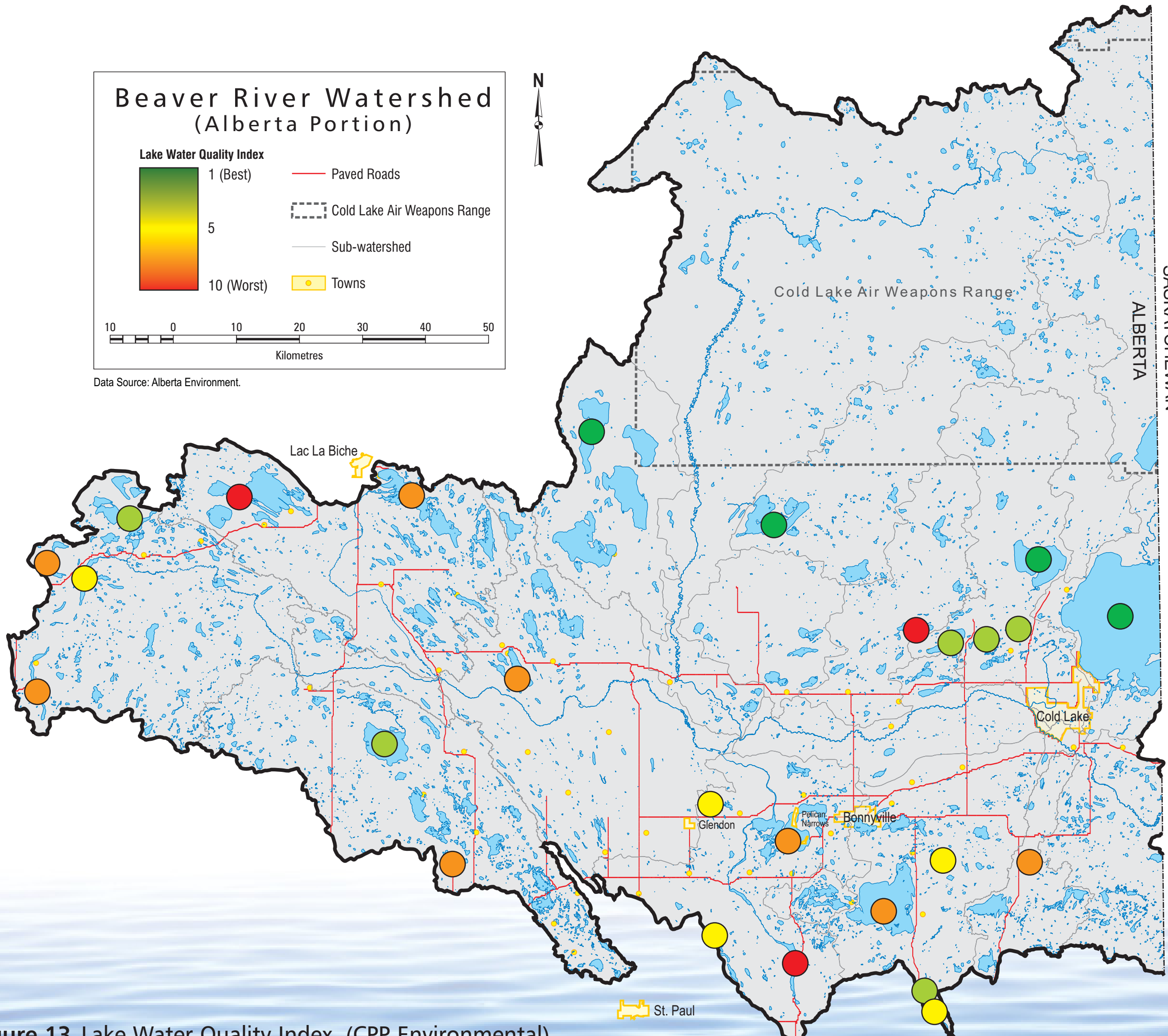


Figure 13 Lake Water Quality Index. (CPP Environmental)

These uses may include contact and non-contact recreation, protection of aquatic life, irrigation, and livestock watering.

Determining water quality requires analysis of field samples for a number of chemical and biological constituents. The sampling period varies, depending on the nature of the monitoring program. Water quality monitoring of natural streams may depend on performing a broad range of tests on water samples obtained several times a year over many years. In addition, routine monitoring may be augmented by short-term surveys. Government agencies, at all levels, and private sector groups operate water-quality data collection programs. Monitoring and reporting to government regulators are often requirements for industrial and natural resource developments.

Water quality is monitored at the Beaver River 24 km upstream of the interprovincial boundary and at the Cold River at the outlet of Cold Lake by Environment Canada on behalf of the Prairie Provinces Water Board. Water-quality objectives are established for the Beaver River and the Board routinely reports on whether these objectives are being met. The Board also performs periodic analyses of the data for trends. Water quality objectives have not been determined for the Cold


R.A. Halliday

River. Water quality in the Beaver River is generally good with rare exceedances of objectives being attributable to natural conditions. That said, the overall quality of the river is strongly influenced by the inflow from the Sand River tributary, an almost pristine source. The Sand River and, hence, the Beaver River are subject to naturally low, dissolved oxygen levels in winter.

For the most part, water quality can be considered as improving for the Beaver River near the interprovincial boundary. Nutrient concentrations have declined because of improvements to wastewater treatment facilities at Cold Lake and at 4 Wing Cold Lake. Further improvements to the City of Cold Lake facility are underway. On the other hand there are increases in ions and salinity. Increasing trends have been observed for total dissolved solids, conductivity, pH, sodium, chloride, calcium, and alkalinity. These increases may be attributable to an increasing groundwater component in the river flow.

GROUNDWATER QUALITY

Groundwater quality is dependent on a number of natural factors including:

- quality of the recharging water – whether snowmelt, rainfall, standing water or flowing water
- type of geological material that the groundwater contacts along its flow path
- length of time spent in contact with these materials
- order of the materials in which the groundwater made contact
- degree of mixing with groundwater from other sources
- unique geochemical conditions at the discharge zone, spring or well.

As water infiltrates, it interacts with subsurface materials, including gases, thereby changing its chemical composition. Metals, minerals and organic compounds may be oxidized or altered by other reactions. As water enters the saturated zone, even more complex reactions take place in the absence of oxygen. The effects of these reactions on groundwater quality in the Beaver River watershed are generally known.

Groundwater quality can also be influenced by human factors such as point or non-point sources of contamination related to urban development, agricultural land use, industrial sources, transportation, and spills or plant upsets.

Groundwater quality is often described in terms of quantity and type of dissolved materials. For example, salinity may be expressed in terms of total dissolved solids (TDS). Fresh water has a TDS of 0 to 100 mg/L, brackish water 1000 to 10 000, and saline water over 10 000 mg/L. For comparison, sea water has a salinity of 35 000 mg/L. Potable water is considered to be any water having a TDS of less than 4000 mg/L although the *Guidelines for Canadian Drinking Water Quality* identify 500 mg/L as a preferred upper limit. Most of the wells in surficial aquifers in the watershed can be considered as having moderate to poor quality water on the basis of elevated TDS levels.

Groundwater quality in the drift aquifers varies in quality from recharge areas to discharge areas. Young groundwaters tend to be naturally hard with high levels of calcium or magnesium. This hardness is reduced as the groundwater comes in contact with clay minerals, losing calcium or magnesium and gaining sodium. Similarly bicarbonate is lost and sulphate is gained as waters age. This situation is typical of prairie groundwaters. In general, groundwaters in drift aquifers in the basin can be considered as potable. On the other hand, groundwaters in the bedrock aquifers are brackish or saline. These latter groundwaters are now often used in bitumen recovery operations.

In comparing the chemical characteristics of groundwaters to drinking water and other guidelines some other characteristics are evident. Chloride content exceeds the guidelines for six percent of the samples taken. This is typical of farm wells across Alberta. In rare cases, the chloride content exceeds the upper guideline for irrigation water although irrigation is not a significant water use in the watershed. The arsenic content is naturally high and may exceed the drinking water guideline of 10 μg/L in some parts of the watershed. Elevated arsenic levels are most often associated with areas directly underlain by the Lea Park Formation. That is, most of the watershed. Of all the samples taken in the watershed, the drinking water guideline is exceeded in 20 percent of the samples while 63 percent of the samples exceed the freshwater aquatic wildlife guideline. This is high compared to samples from other parts of the province but naturally elevated concentrations of arsenic do occur in other watersheds. The source of the arsenic has been linked to the underlying marine shales. Phenols may be produced either naturally or through contamination from petroleum operations. Phenol concentrations exceed the aquatic life guideline for 16 percent of the samples and the livestock water criteria in 44 percent of the samples.

Alberta Conservation Association

As one means of reducing impacts of human activity on aquifers, aquifer sensitivity maps have been prepared for much of the basin. These maps designate areas that have high sensitivity to inter-aquifer contamination or surficial aquifer contamination. Surficial aquifers are particularly subject to contamination when surface materials consist of sands and gravels, porous soils, or fractured clays. Areas of high sensitivity having organic surface deposits such as peat have also been identified. The sensitivity information has also been overlain with information on potential contaminant sources to produce vulnerability maps.

AQUATIC RESOURCES

The riparian areas of the Beaver River itself and most of those of the Sand, Medley and Martineau rivers are considered key wildlife areas with respect to biodiversity. Other important riverine riparian environments include smaller tributaries such as the upper Amisk River as well as Mooselake River, Jackfish Creek, and Muriel Creek downstream of Muriel Lake. Particularly important lake areas include Wolf and Frenchman lakes.

Although the watershed has been altered by human activity, much of the watershed north of the Beaver River remains in a near-natural state. The landscape provides habitat for many birds and mammals. Lakes, wetlands and streams and their associated riparian areas support many aquatic species. Natural and improved pastures adjacent to wetlands also provide habitat. The variety of living things and the ecosystems that support them is a reflection of the biodiversity of the watershed.

Biodiversity also includes the genetic diversity within a single species and the interaction among species.

Biodiversity is threatened by loss of habitat and habitat fragmentation. Draining of wetlands and loss of old growth forests through fire, disease or harvesting are examples of habitat loss. Linear features such as roads and seismic lines fragment habitat as do construction of dams and weirs. Road crossings, either bridges or culverts, can also isolate or fragment habitat. The southern part of the watershed is particularly subject to habitat altering influences.


Ducks Unlimited Canada

Providing protected areas is one part of taking action to sustain biodiversity. Protected areas are lands identified by governments as having natural and associated cultural values. They are managed legally or by other means to sustain those values. The Alberta portion of the watershed contains Long Lake, Lakeland, Cold Lake and Moose Lake Provincial Parks, the Lakeland Provincial Recreational Area and the White Earth Valley Natural Area. The provincial parks provide habitat for many bird and animal species. Recreational areas also provide some protection.

The myriad lakes of the watershed are a key factor in considering its aquatic resources. Fisheries, wildlife and water-based recreation all depend on the sustainability of those lake systems. Traditionally, the lakes have supported First Nations and Métis traditional use of the watershed, including domestic and commercial fisheries.

Wildlife

Large carnivores in the watershed include the black bear, wolf, and lynx. The most common large herbivores are elk, mule deer, white-tailed deer, moose, caribou, and bison. Smaller carnivores include the coyote, least weasel, river otter, badger, striped skunk, muskrat, marten, and fisher. There are many rodents, such as the northern pocket gopher, beaver, woodchuck, Richardson's ground squirrel, thirteen-lined ground squirrel, Franklin's ground squirrel, least chipmunk, porcupine, eastern cottontail, and snowshoe hare.

Fish and Fish Habitat

The streams connecting lakes in the watershed are generally small, shallow, and slow moving. During the summer, flows may be intermittent and water stagnant with low dissolved oxygen levels that will

Table 4 Fish Species of the Watershed.

Species Type	Common Name
Coldwater Species	Lake Cisco (tullibee) Lake Trout Lake Whitefish
Coolwater Species	Burbot Northern Pike Walleye Yellow Perch
Non-game Species (*rare)	Brook Stickleback Ninespine Stickleback Lake Chub Spottail Shiner Pearl Dace Fathead Minnow Longnose Dace Emerald Shiner River Shiner Finescale Dace Northern Redbelly Dace Slimy Sculpin Spoonhead Sculpin Trout-perch Iowa Darter Logperch* Longnose Sucker White Sucker

not sustain fish populations. The fish species in the watershed are shown in Table 4. Predominant cold-water species are lake whitefish, cisco and lake trout – the latter in Cold Lake. Cool-water species include walleye, northern pike, yellow perch, burbot, and suckers. Walleye, northern pike, lake trout, and yellow perch are most appealing for recreational interests. Lake whitefish are the primary catch for First Nations domestic and commercial interests.

Fish populations are sensitive to lake level fluctuations and their effect on the shallow shoreline area of the lake. These areas provide spawning and feeding habitat for adult fish and rearing habitat for young fish. Low lake levels can lead to loss of habitat and increase the risk of fish kills in both summer and winter. Lake fisheries may also be affected by land use in upland areas that drain into the lake. Nutrients and other contaminants draining from the land will affect water quality.

Alberta's fish and wildlife policy stipulates that the priorities of fisheries management are, first, conservation of fish stocks, then domestic use by First Nations, then resident recreational and commercial fishing of any surplus stock. Under adverse lake level conditions, fish populations are particularly vulnerable to over-harvesting as the sustainable yield tends to decline with lake levels. Fisheries management then becomes a complex lake-by-lake and species-by-species enterprise. Specific provincial policies are aimed at managing walleye and northern pike stocks.

Domestic fishing licences are issued to First Nations and Métis people on request. About 1000 licences were issued annually in the early 1980s and that number has declined to about 190 today. There is no requirement to report annual catch, but it is understood that a small proportion of the licence holders catch a large proportion of the annual catch.

The watershed is a significant recreational fishery for the province, accounting for one-quarter of the annual provincial harvest. Although detailed information is not available, it is believed that recreational fishing effort remains fairly constant, although success has declined. One indicator of recreational fishing activity is the sale of sport fishing licences. Sales to residents have declined from a 1989 peak while non-resident sales are steady. Non-resident sales constitute only three percent of the licences sold.

There has been a pronounced decline in commercial fishing activity from 1989 when consistent record keeping began. The lakes in the southern portion of the watershed generally are not fished annually. At present, only seven commercial licences are issued covering eight lakes in the watershed. Spencer and Primrose lakes account for most of the commercial catch. No new licences are available, but existing licences can be transferred. The target species for commercial fishing is lake whitefish, most of which are processed and sold to the Freshwater Fish Marketing Corporation. Sport fish caught as commercial by-catch are usually sold locally.

The Alberta Conservation Association has developed a fish-based index of biological integrity (IBI) as a basis for assessing ecological condition of the Beaver River and some major tributaries. Thousands of fish were sampled at 47 locations on the Beaver River itself and on the Amisk and Sand river tributaries. The fish sampled comprised 17 species from 6 families. The species composition and fish size can be related to watershed factors such as agricultural development and road density, riparian factors such as bank disturbance, and water quality factors such as water chemistry. Figure 14 shows the distribution of IBI scores for the sampled streams in the watershed.

Waterbirds

The Beaver River Naturalist Society has identified some 292 bird species in the watershed, including many waterbirds. The boreal lakes and wetlands present many viewing opportunities for waterfowl

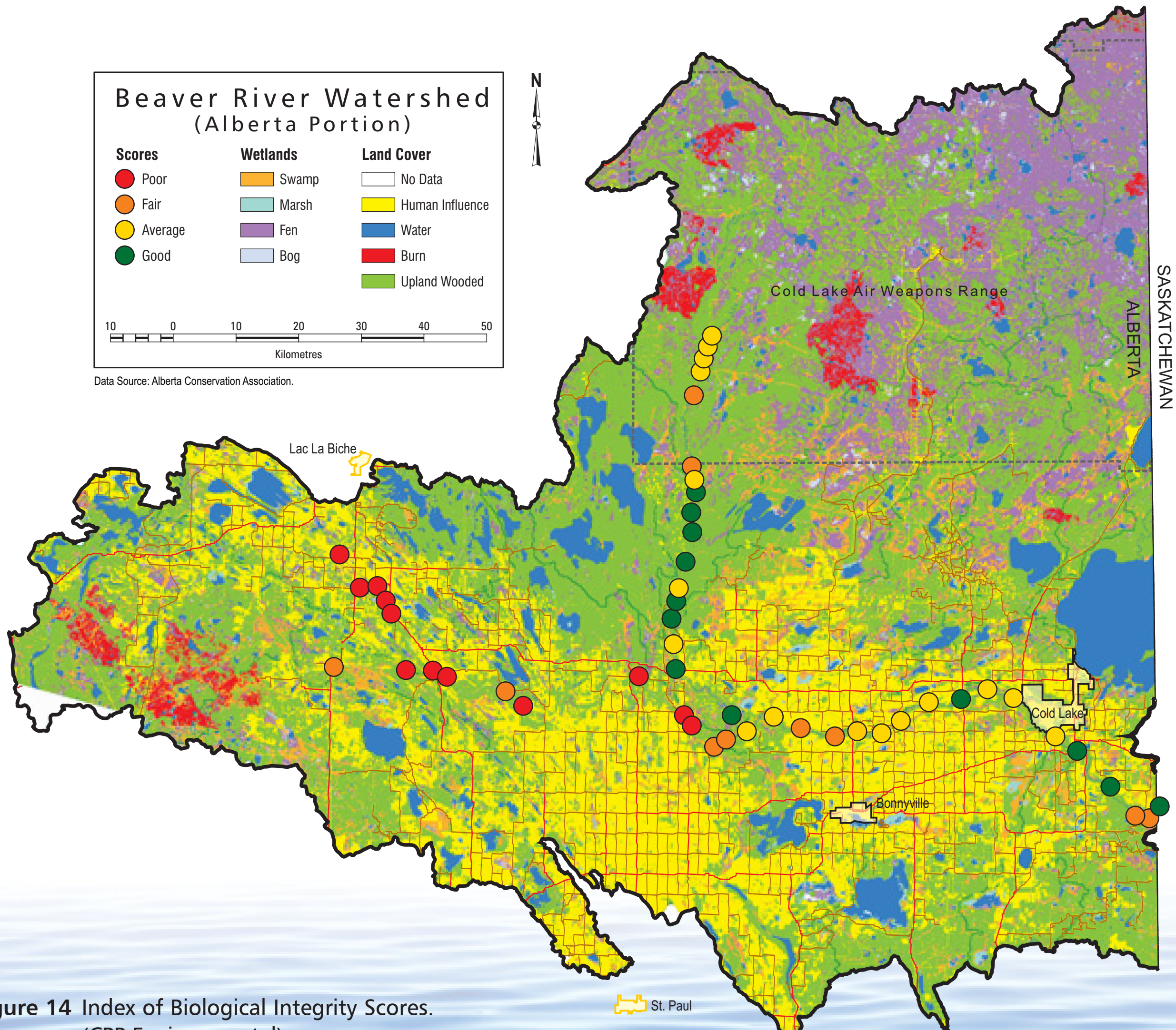


Figure 14 Index of Biological Integrity Scores. (CPP Environmental)

and other waterbirds. These viewing areas are associated with the aquatic values of the watershed. In particular, the Beaver River plain is considered nationally important habitat for ducks and colonial species such as pelicans and cormorants. The Moostoos Upland is considered regionally important. In the 1980s, assessments of water-based wildlife values were made at 57 lakes. These assessments were repeated at 28 of these lakes in 2003. In general, of the 49 bird species surveyed, increased numbers were observed for gladwall, eared grebe, Franklin's gull, white pelican, double-crested cormorant, and Canada goose. Decreased populations were noted for lesser scaup, American coot, and white-winged scoter. These trends are consistent with those observed throughout the prairie pothole region.

For the specific lakes surveyed in the watershed, the presence or abundance of a species was strongly related to changes in lake level or habitat, or both. Lakes maintaining the same level showed very little change in bird populations. Even for lakes showing significant decreases in level two quite different results were evident. Habitat losses led directly to species decline or, in the case where decreased water levels resulted in new shallows and increased emergent vegetation, the results proved beneficial for the birds.

Ducks Unlimited Canada

Water-based Recreation

The watershed contains the highest concentration of recreational lakes and high-quality beaches in Alberta. Recreational opportunities include swimming, fishing, picnicking, canoeing, sailing, nature study, and general relaxation. Powerboating and water skiing have been joined by other motorized activities such as personal watercraft and wake boards. There is increasing use of mountain bikes and all-terrain vehicles. Winter recreation, although relatively minor, includes ice-fishing, snowmobiling and cross-country skiing.

In the upper watershed, Lakeland Provincial Park and Lakeland Provincial Recreation Area cover some 590 km^2. Most of the park, except for Helena Lake is outside the Beaver River watershed while most of the recreation area lies within the Sand River sub-watershed. The recreation area is the largest such area in Alberta. Principal lakes include Touchwood, Pinehurst, Seibert, and Ironwood. Of these, only Ironwood Lake is not in the Lakeland watershed. Long Lake Provincial Park and the White Earth Valley Natural Area also provide outdoor recreation opportunities in the upper watershed.

Fourteen lakes in the lower watershed have been studied to identify how water levels may affect recreational facility development and activity. These include major lakes, defined as those generating 30 000 user-days of activity a year. These lakes may feature public facilities, whether provincial (Moose Lake and Cold Lake) or municipal, private facilities such as cottage development, institutional development, or commercial facilities such as campgrounds or boat rentals. The major recreation lakes include Cold, Ethel, Marie, Crane (Moore), Moose, and Muriel lakes.

Secondary lakes have fewer facilities and generate fewer than 30 000 user-days of activity a year. These include Angling, Manatokan and Wolf lakes. Minor lakes have few facilities and user activity is low. These include May, Reita and Tucker lakes. Two inaccessible lakes in the Cold Lake Air Weapons


R.A. Halliday

Range, Burnt and Cariboo, were also studied for comparison purposes. Access to these two lakes for sport fishing has now been closed for both the public and military personnel.

There are campgrounds within the three provincial parks, twelve provincial campgrounds in designated provincial recreation areas, and six municipal campgrounds in the watershed. These sites provide 915 campsites.

Recreational opportunities are very sensitive to water level changes of individual lakes. Low water levels on Manatokan, Moose and Muriel lakes have clearly affected recreational values.

KNOWLEDGE GAPS

Environmental conditions in the watershed are vulnerable to landscape modification, water quality degradation and climate change. Additional information is required if progress on meeting environmental goals under a water management plan is to be tracked and trends determined.

Landscape Modification

The recent wetland classification project carried out by Ducks Unlimited Canada (DUC) is an exceptional resource; however, the information could be improved in two ways. First, the human influence classification should be modified to provide a better understanding of the nature of the influence. Land covers such as annual cropland, and perennial cropland and pasture should be distinguished. This refinement would allow trends in land cover in the southern part of the watershed to be identified. Another refinement of the DUC work would be the inclusion of the portion of the watershed that lies in Saskatchewan but that contributes to flow in Alberta.

Riparian conditions have significant ecological value but, in general, there has been relatively little attention devoted to systematically classifying riparian conditions along principal streams and recreational lakes. The recently obtained aerial photography of the Beaver River itself is an important first step. Studies related to biological integrity could be expanded slightly to ensure stream riparian condition reports are included. Aerial videography surveys of key recreational lakes could also be expanded, especially where there are known development pressures.

Water Quality Degradation

Nutrient concentrations driven by both natural factors and by human activity are an important concern in the watershed. While there have been synoptic water quality surveys of some streams and periodic sampling of some lakes, there is very little systematic monitoring of water quality in the watershed, except for industry monitoring in some sub-watersheds. Monitoring should be sufficient to understand human and natural influences on nutrient levels in principal streams and lakes.

Public concern has been expressed about arsenic concentrations in shallow groundwater wells in the watershed. This is a natural phenomenon but further investigation of mitigation measures for water users is required.

Climate Change

A major concern is the decline in the lake levels of recreational lakes in the watershed. While there has been a consistent increase in temperatures and some apparent decrease in runoff over several decades, it is not entirely certain that the declining lake levels are a response only to climate. Other contributing factors include land-use change. It would be instructive to examine the water balance at say, Muriel Lake, to obtain a better appreciation of the effects of climate and land use on lake levels. This could include an examination of land use trends in the sub-watershed, direct measures of evaporation using eddy covariance instrumentation and hydrological modelling.

CONCLUSION

This summary provides a condensed version of information contained in a larger report on the state of the Beaver River watershed, produced as a tool to assist the Beaver River Watershed Alliance in creating a plan to safeguard healthy aquatic ecosystems in the watershed. The report describes the current state of the watershed, existing and potential factors that may affect its ecosystems, and knowledge gaps that inhibit the decision-making needed to secure a healthy future. This information, along with the indicators of environmental performance provided in the report, can advance implementation of Alberta's *Water for Life Strategy* in the Beaver River watershed.

Water For Life

The information presented in this report can assist implementation of Alberta's Water for Life Strategy in the Beaver River watershed.

Goals

- Safe, secure drinking water
- Healthy aquatic ecosystems
- Reliable, quality water supplies for a sustainable economy

Key Directions

- Knowledge and research
- Partnerships
- Water conservation

Beaver River Watershed Alliance

Beaver River Watershed Alliance

LICA
Lakeland Industry & Community Association

Alberta
Environment and Sustainable Resource Development