Study of Erosion and Sedimentation on the Milk River

Prepared by: AMEC Earth and Environmental and Milk River Watershed Council Canada, 2009

Research & Science Note 2

The St. Mary—Milk River Diversion

The Milk River receives much of its annual flow volume from a diversion that transfers water from the St. Mary River into the Milk River just south of the Canada/USA border, near Babb, Montana. The St. Mary diversion was initiated as part of the Boundary Waters Treaty of 1909 between the United States and Canada and its subsequent intent was clarified by the 1921 Order . Construction of the St. Mary diversion was completed in 1917. The design capacity was 24.1 m^3/s (850 cfs). The diversion works have since deteriorated to the extent that the current operating capacity is 18.4 m^3/s to 19.1 m^3/s (650 to 675 cfs). The U.S. is undertaking plans for rehabilitation and possible enlargement of the diversion works (up to 1000 cfs to 1200 cfs).

Study Objectives

Landowners living next to the Milk River are concerned with the amount of streambank erosion occurring each year. The Milk River Watershed Council Canada (MRWCC) commissioned a Study of Sedimentation and Erosion on the Milk River to:

1. Document the extent of erosion and sedimentation along the Milk River, and identify processes that have contributed to changes in the river width and streambank structure (i.e., channel morphology)
2. Develop a model capable of predicting erosion and sedimentation processes to assist in the protection of existing infrastructure, and plan future projects.
3. Identify critical erosion sites or hot spots and explore management options.
4. Review impacts that may result from a potential future increase in St. Mary River diversion flows into the Milk River.

This factsheet summarizes the findings of the study, including the impacts of increased diversion discharges on river morphological processes (erosion and sedimentation) and the resulting effects on ice processes, riparian vegetation, water quality and fisheries. To view the complete report, please visit the Milk River Watershed Council Canada's website at: www.milkriverwatershedcouncil.ca.

Gauging station upstream of the siphon that delivers water to the Milk River from the St. Mary River. Photo: S. Riemersma

Siphon, constructed in 1917, that delivers water to the Milk River from the St. Mary River. Photo: S. Riemersma

The Milk River was named by the American explorers Lewis and Clark on account of its high sediment concentrations during spring runoff. Their journal entry for May 8, 1805 states:

"The waters of the river possess a peculiar whiteness being about the colour of a cup of tea with the admixture of a tablespoon of Milk. From the colour of its waters, we called it Milk River."

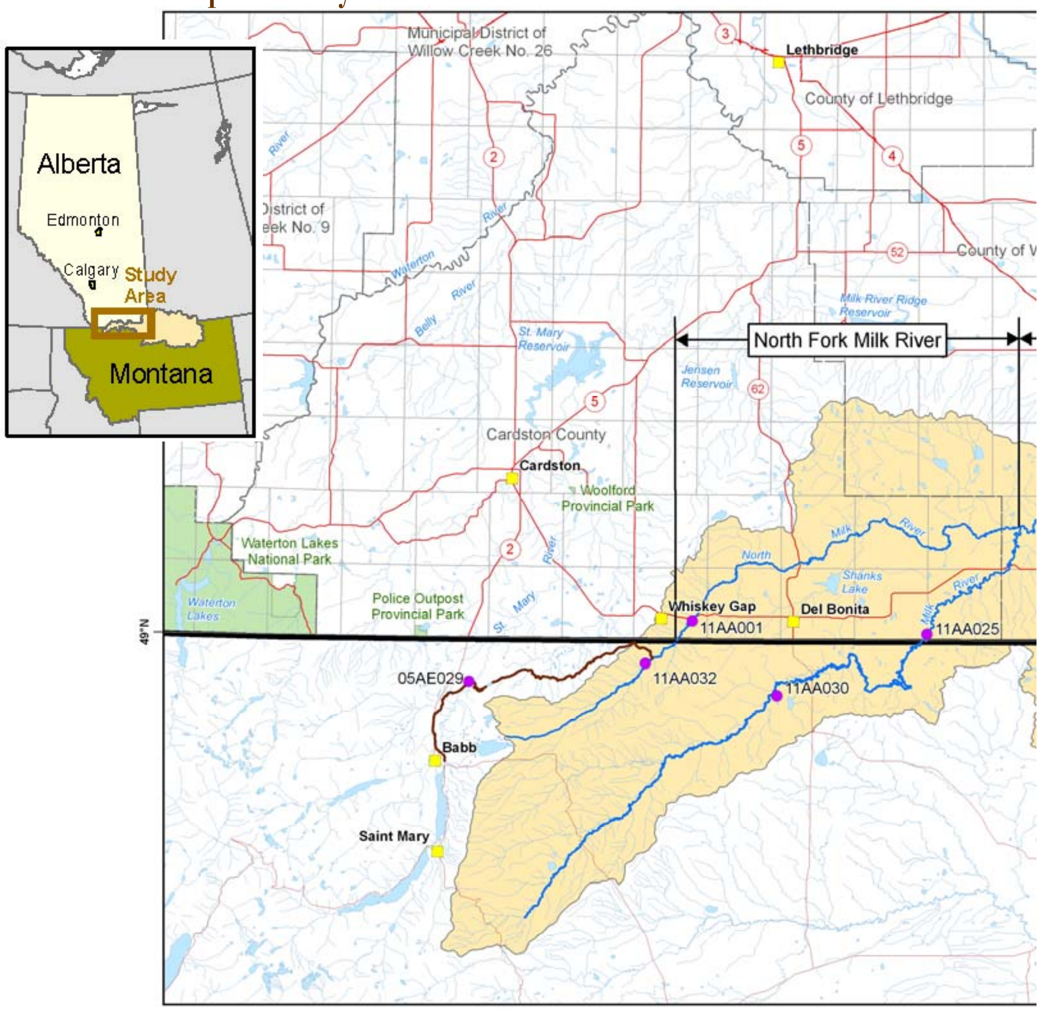
Study Area

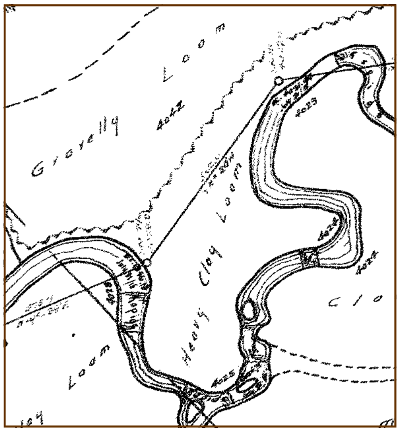
A map of the Milk River watershed is shown below. Water from the St. Mary River is conveyed by a siphon and canal to the North Milk River in Montana. After crossing the International Boundary the water from the North Fork flows 80 km before meeting the larger unregulated mainstem Milk River (often referred to as the south fork). The combined north and south branches meet and flow east as the mainstem. The mainstem has been further divided into the Milk River (Gravel Bed Reach) and the Milk River (Sand Bed Reach) (Map 1).

The Milk River (Gravel Bed Reach), drains 100 km to Writing-on-Stone Provincial Park. The Milk River (Sand Bed reach) flows an additional 130 km eastwards through the Badlands before re-entering Montana at the Eastern Crossing. These badland areas contribute large quantities of sediments to the river due to a combination of erodible valley wall deposits and lack of vegetation.

The Fresno Reservoir is located 50 km to the southeast. The Milk River is a tributary to the Missouri River, which joins the Mississippi River and eventually empties into the Gulf of Mexico.

Map 1. Study area.





1915 Milk River survey lead by F.H. Peters. Peters was instrumental at setting up the streamflow gauging stations on the Milk River, and later, Peters became Survey General of Canada.

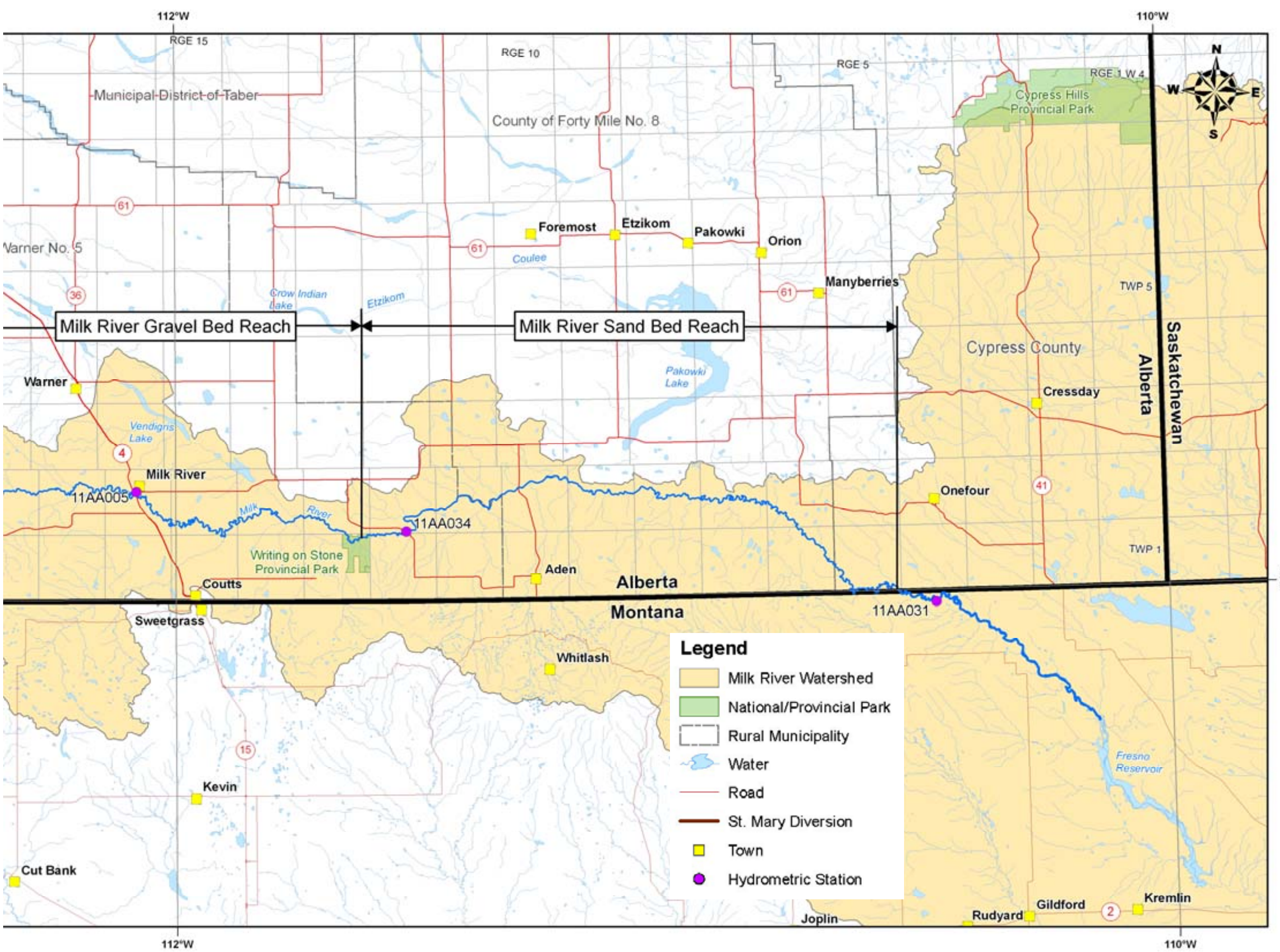
Methods

A comparison between natural (prediversion) and present-day channel characteristics was made to assess Milk River response to increased flow volumes occurring since 1917.

Prediversion channel characteristics were determined using the F.H. Peters 1915 surveys and from an initial reconnaissance survey also completed by Peters. Between July 6 and November 27, 1915, Peter's crews surveyed the entire Canadian portion of the Milk River. A detailed map was prepared showing the channel and Milk River floodplain. Bed and bank materials, vegetation and other cultural features were frequently noted.

Model scenarios compared natural (pre-1917) and existing channel conditions (2008) with those that may occur if diversion infrastructure is upgraded and flow volumes increase to 850 cfs (24.1 m^3/s) (e.g., the original diversion capacity),1000 cfs (28.3 m^3/s) or greater (e.g., 1200 cfs (34.0 m^3/s)).

The model examined maximum flow volumes and flooding events that may occur, as well as how the Milk River channel may respond to increased flows in the future.



"There can be no doubt that additions to the supply of a meandering river increase the meandering tendency, and so result in bank erosion that would not occur otherwise. The release from the St. Mary's River into the North Fork of the Milk River, must have caused noticeably increased erosion of the banks of that fork."

Prof. T. Blench, Univ. of Alberta, 1954

Results

Expected Changes to Streamflow with Increased Diversions

Table 1 summarizes the results of the modeled scenarios. Median annual flow is a typical flow occurring over a period of a year. The flow is greater or less than this value 50% of the time. With increased diversion, median annual flows would be less than existing flows (13 m^3/s)

Typical May/June flows represent the period when the majority of precipitation occurs, which generates much of the Milk River runoff. An increase of over 50% above existing flows (recorded flows since 1917) along the entire length of the river within Canada during this period is projected.

Seasonal (spring) and peak flood discharges will increase. Peak flood discharges could increase by as much as 65% for the typical spring flood event on the North Milk River as a result of increased diversion discharges. The effects on flood frequencies diminish for greater return period events (e.g., the 1:100 year flood) and for locations further downstream.

Table 1.	Natural (Prediversion)	Existing	850 cfs (24.1 m^3/s)	1000 cfs (28.3 m^3/s)	1200 cfs (34.0 m^3/s)	Natural (Prediversion)	Existing	850 cfs (24.1 m^3/s)	1000 cfs (28.3 m^3/s)	1200 cfs (34.0 m^3/s)	Natural (Prediversion)	Existing	850 cfs (24.1 m^3/s)	1000 cfs (28.3 m^3/s)	1200 cfs (34.0 m^3/s)
Streamflow (m^3/s)	**North Fork Milk River**					**Milk River Gravel Bed Reach**					**Milk River Sand Bed Reach**				
Median Annual	0.72	13	6.3	6.3	6.3	2.5	16	9.8	9.8	9.8	3.1	16	11	11	11
Typical May/June	1.5	18	24	26	26	7.7	20	27	30	31	10	21	29	32	34
Typical Spring Flood	8.9	25	31	35	41	49	58	65	68	72	75	84	93	96	100
1:100-Year Flood	92	100	110	120	120	280	280	290	290	300	350	360	360	360	360

Expected Changes to Channel Characteristics with Increased Diversions

The existing diversion to the Milk River resulted in channel widening, increased channel sinuosity, and an increase in cut-off activity immediately following the initiation of the diversion. This study indicates that the channel is still widening, some 90 years after the original diversion was initiated.

Table 2 shows channel widths and suspended sediment concentrations for natural and existing conditions and potential future diversion scenarios.

The predicted increase in width for the 850 cfs scenario is 18% for the North Milk River and 8% for the Milk River Gravel Bed Reach. The corresponding range for the 1000 cfs scenario is 23% and 13% , and for the 1200 cfs scenario is 28% and 18%. Greater increases in width are expected for the Sand Bed Reach (ranging from 13% to 23%) compared to the Gravel Bed Reach (ranging from 8% to 18%).

Table 2.	Natural (Prediversion)	Existing	850 cfs (24.1 m^3/s)	1000 cfs (28.3 m^3/s)	1200 cfs (34.0 m^3/s)	Natural (Prediversion)	Existing	850 cfs (24.1 m^3/s)	1000 cfs (28.3 m^3/s)	1200 cfs (34.0 m^3/s)	Natural (Prediversion)	Existing	850 cfs (24.1 m^3/s)	1000 cfs (28.3 m^3/s)	1200 cfs (34.0 m^3/s)
Characteristic	**North Fork Milk River**					**Milk River Gravel Bed Reach**					**Milk River Sand Bed Reach**				
Width (m)	22	35	41	43	45	52	62	67	70	73	70	91	103	107	112
Mean Width Increase (m)	—	15	6.0	8.0	10	—	11	5.0	8.0	11	—	21	3.2	4.3	5.6
Mean Width Increase (%)	—	69	18	23	28	—	25	8	13	18	—	36	13	18	23
May/June Daily Mean Suspended Sediment (mg/L)	16	49	57	57	57	73	220	360	360	360	560	1200	1800	1800	1800
Modeled Range of Mean Annual Sediment Transport (tonnes)	96 to 410	5,500 to 41,000	9,600 to 41,000	14,000 to 41,000	21,000 to 100,000	1,300	27,000	36,000	41,000	55,000	96,000 to 260,000	300,000 to 680,000	340,000 to 820,000	380,000 to 930,000	420,000 to 1.0×10^6

Channel Migration & Suspended Sediment

The effects of the existing diversion, which commenced in 1917, on channel morphology included erosion leading to channel widening, sedimentation and increased frequency of meander bend cut-offs. In order to compare long-tem erosion rates over the approximately 85 years, the recent study measured erosion rates based on the 1915 survey and historic air photos.

The air photo below (Map 2) shows the historic banklines and clearly shows the meander bend cutoffs that occurred during this period. While the rate of change has decreased over time, changes due to the St. Mary River diversion are still occurring. Measured erosion rates calculated from the air photos varied from 0.2 to 2.5 metres per year. Landowners reported similar rates of erosion in a survey that was conducted in support of this study. Landowner comments indicated that erosion on the Milk River is intensified by:

- Early release of water into the North Fork
- Flooding and natural spring seepage
- High water levels during spring ice break-up and scouring by ice jams at natural and man-made constrictions
- Unconsolidated streambank material (e.g., sand)

Suspended Sediment

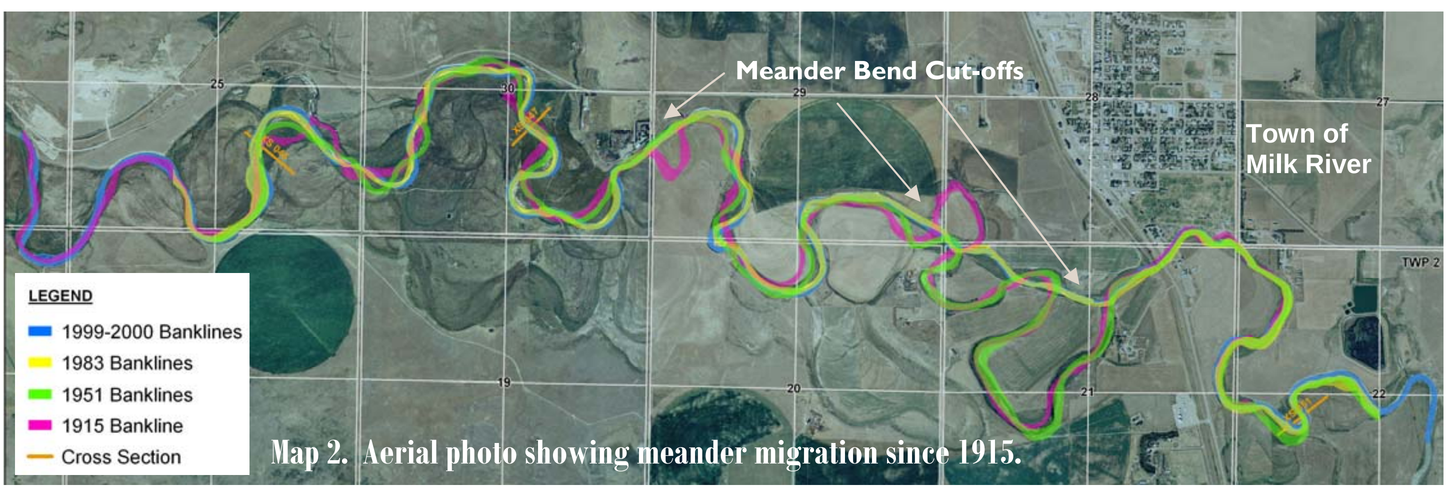
Eroded streambank material and streambed material transport increases suspended sediment (i.e., sand and silt) in the Milk River. Suspended sediment concentrations during the May/June high water period are now two to three times the natural (pre-diversion) levels. A further increase of 20 to 30 percent in the May/June suspended sediment concentrations is estimated for the potential future diversion scenarios.

For the existing diversion conditions, Water Survey of Canada have estimated the mean annual sediment transport in the Gravel Bed Reach and Sand Bed Reach to be 111,000 tonnes and 642,000 tonnes, respectively (Spitzer 1988). It is evident that the greatest contribution of the suspended sediment load arises between the Town of Milk River and the Eastern Crossing (Alberta-Montana border). The modeled sediment transport values shown in Table 2 were not primarily intended to estimate actual sediment transport. Rather they were used in a relative manner as an indicator of channel stability for the different diversion scenarios.

"If this volume of water (from the St. Mary's River) was turned into the North branch, the North Milk River would be running with banks practically full and the velocity of the stream would create a very heavy scour. The river banks are everywhere of soft material which is liable to erosion and in a short time the river channel would adopt itself naturally to the new conditions of the flow. This would mean a decided change in its average cross-section and also the river channel would change its course in many places"

F.H. Peters, 1910

Note: To convert from tonnes to acre-feet of reservoir storage, multiply by 0.000541. For example 100,000 tonnes x 0.000541 = 54.1 acre-feet reservoir storage. It is important to note that the above conversion is for reservoir storage and is for the submerged density. The conversion would would be different on dry land. The above conversion should be considered approximate. It assumes that the material is mostly sand, which has a submerged density of 1,500 kg/m^3 (93 lbs/ft^3).



Map 2. Aerial photo showing meander migration since 1915.

Environmental Impacts of Increased Flow


Photo: S. Riemersma

Increased flows into the Milk River will result in increased erosion, occurrence of meander bend cut-offs, sinuosity, sediment transport and silt deposition These increased flows would appreciably alter ice jam activity, riparian vegetation, water quality and fish communities.

Sediment

As the Milk River channel continuously and gradually adjusts towards a new dynamic equilibrium, sediment eroded from the upstream banks will be deposited to form point bars or deposited on the floodplain and in oxbow lakes during periods of overbank flooding. In-channel sediment will continue to move downstream and sediment previously deposited on uplands during flood events may re-enter the river through bank erosion or during the formation of meander bend cut-off channels.

Ice

Ice jam activity frequently occurs at various locations along the Milk River during spring break-up. As flows increase, ice is freed and is carried downstream, scouring and eroding streambanks. An increase in streamflow volumes will likely result in an incremental increase in the rate of streambank erosion due to ice jam activity.

Riparian Vegetation

Channel widening by erosion processes caused by increased flows could result in an additional 10% loss in adjacent vegetation (i.e., red fescue, needle-and-thread grass, northern wheat grass, bluegrass, buckbrush, sagebrush flats and, saline meadows). Increased flows may result in more frequent flooding, which would favour plains cottonwood (*Populus deltoides*) regeneration with optimal seed dispersal conditions.

Water Quality

Recent water quality data indicates that increased flow in the Milk River due to the St. Mary River diversion improves (i.e., decreases concentrations) some parameters, such as nitrogen and salts, and deteriorates (i.e., increases concentrations) other parameters, such as phosphorus. When water is not released from the diversion, the opposite trend in those water quality parameters occurs. Increased diversion flows result in greater total suspended solids (TSS) concentrations. Phosphorous is mainly present in the particulate form and is associated with TSS. Hence, phosphorous concentrations increase with flow.

Fish

Common fish species in the Milk River include fathead minnow, longnose dace, longnose sucker, flathead chub, sauger and mountain sucker. Special status species include the western silvery minnow, eastslope sculpin and stonecat.

Increased suspended sediment concentration could negatively affect the fish population since increased sediment may lead to:

- reduced feeding rates and success,
- siltation of spawning gravels,
- increased egg mortality, reduction in pool quality, abundance and diversity of aquatic macrophytes,
- changes to benthic invertebrate communities, and
- Note that high turbidity favours the Western Silvery Minnow.

Increased turbidity is generally inversely related to the abundance of aquatic macrophytes. In highly turbid water, aquatic macrophytes and algae do not have enough sunlight for growth and productivity. High levels of suspended sediment may alter the species present or eliminate the benthic invertebrate community, entirely, by changing habitat conditions.


Photo: S. Riemersma

Managing Streambank Erosion

Erosion mitigation strategies can be used at locations where infrastructure is potentially threatened due to channel widening or shifting. These strategies include traditional approaches, such as armouring with rip rap or concrete blocks, as well as bioengineering techniques that include live material (e.g., willow) in their design. Mitigation strategies have limitations and some are more suited for specific reaches than others.

North Fork and Milk River Gravel Bed Reach

Mitigation strategies for the North Fork and Milk River Gravel Bed Reach are limited by the degree of ice action that can occur in these reaches. Ice movement can tear wire mesh and scour out live plant material. Vegetation could be integrated into bank armouring at the time of construction.

Milk River Sand Bed Reach

Spurs or groynes are used to deflect streamflow away from eroded banks. They are suitable for rivers where sediment loads are high. The spurs are constructed from impermeable material such as sand/gravel or as permeable structures made from timber frames filled with trees and branches.

Bioengineering Techniques

Bioengineering uses live plant materials to perform an engineering function such as slope stabilization, soil erosion control or seepage control. Although bioengineering techniques offer a greater benefit compared to traditional techniques, by providing wildlife habitat, water temperature regulation (shading) and aesthetic value, they can be vulnerable to ice action.

Bioengineering project on the Oldman River. “Live stakes” are planted while dormant.

Photo: S. Riemersma

Future Steps

The Study of Erosion and Sedimentation on the Milk River identified data gaps with respect to ice jam events, water quality data, information on particular fish species and riparian vegetation surveys. Monitoring programs should be undertaken to fill data gaps. Monitoring programs may include:

- Documenting ice jam events,
- Charactierizing riparian vegetation along the entire river length, and
- Investigating water quality, fish populations and habitat use to specifically assess diversion effects.

Overall, the Milk River is a dynamic system that is in constant flux. Increases in diversion flows will accelerate river migration and erosion and sedimentation processes. Understanding governing processes of the Milk River channel dynamics and the aquatic environment, in advance, will allow stakeholders to consider and potentially mitigate long-term impacts as well as provide a basis for discussions with water managers in Montana, U.S.A. .

Montana-Alberta Water Management Initiative

Environmental benefits of various water management options will be considered in future work undertaken by the MRWCC. Opportunities exist to reduce erosion and sedimentation on the Milk River through water management.

Recently the St. Mary and Milk River Water Management Initiative was struck to assist Montana and Alberta to identify water management options that benefit both countries. In December 2008, Montana Governor Brian Schweitzer and Alberta Premier Ed Stelmach approved the Terms of Reference.

The Initiative will ‘explore and evaluate options for improving both Montana’s and Alberta’s access to the shared water of the St. Mary and Milk Rivers, and make joint recommendation(s) on preferred options to both governments for their consideration and approval’. Focus will be on timing and access to each country’s share of water from the two rivers under Article VI of the *Boundary Waters Treaty Act* (1909).

Photo: S. Riemersma

Glossary of Terms

Bioengineering: A method of streambank stabilization that uses live material (e.g., willow cuttings) or a combination of live material and traditional techniques (e.g., riprap).

Discharge: The volume of water per unit of time that is conveyed in a stream channel; it is typically measured in m^3/s or cubic feet per second.

Equilibrium: A stream channel is considered to be in equilibrium when it develops a stable dimension, pattern and profile. When a stream laterally migrates but maintains these characteristics, it is considered to be in 'dynamic' equilibrium. The introduction of increased diversion flows could lead to a period of instability where lateral erosion, bed scouring and sediment deposition is occurring, until such time as the stream achieves a new equilibrium with the greater flows.

Floodplain: The strip of relatively flat land bordering a stream, built of sediment carried by the stream and dropped in the slack water beyond the influence of the swiftest current. This lowland that borders a river is usually dry but is subject to flooding.

Morphology: The characteristics of a stream channel including its dimensions (width and depth), pattern, profile and sediment transport.

Peak Flood Discharge (Peak Flow): A relatively high flow as measured by either height or discharge. The annual flood is the highest peak discharge in a year and typically occurs during the spring high water period.

Profile: The stream profile or slope is the longitudinal gradient of the channel, usually expressed as metre per metre or percent.

Reach: A section of the river that has consistent characteristics of size, bed and bank materials, pattern and shape.

Return Period Events: The average interval of time within which the given flood will be equaled or exceeded once. For example a 2-year return period means that a flood of this magnitude or greater can be expected to occur on average once every two years. A 100-year return period means that a flood of this magnitude or greater can be expected to occur on average once every one hundred years.

Sinuosity: A measurement of the degree of meandering. It is defined as the ratio of channel length to valley length.

Photo: Water Survey of Canada

amec

Canada

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Milk River Watershed Council Canada

Box 313
Milk River, AB T0K 1M0

Phone: 403-684-3117
Fax: 403-684-3117
E-mail: sandi@milkriverwatershedcouncil.ca

Our Water ~Our Legacy