Literature Cited

Alberta Agriculture and Development (ARD). 2007. Alberta Irrigation Information – 2007. Alberta Agriculture and Food Technology and Innovation Branch, Lethbridge, Alberta.

Alberta Agriculture and Rural Development (ARD). 2009 Irrigation in Alberta. http://www.albertawater.com/index.php?option=com_content&view=article&id=84. Alberta Agriculture and Food Technology and Innovation Branch, Lethbridge, Alberta. Accessed 20 May 2009.

Alberta Agricultural Operation Practices Act .2004. Definitions. Government of Alberta, Queen's Printer, Edmonton, Alberta.

Alberta Environment (AENV). 1994. A Brief Overview of Involvement of Alberta Environmental Protection with Operation and Maintenance of Provincially Owned Headworks Systems. Alberta Environment Planning Division, Calgary, Alberta.

Alberta Environment (AENV). 1999. Surface Water Quality Guidelines for Use in Alberta. Alberta Environment, Environmental Assurance Division, Science and Standards Branch. Edmonton, AB

Alberta Environment (AENV). 2003. Water for Life: Alberta's Strategy for Sustainability. Website: www.waterforlife.gov.ab.ca. Accessed November 2003.

Alberta Environment (AENV). 2006. Approved Water Management Plan for the South Saskatchewan River Basin (Alberta), Alberta Environment, Edmonton, AB

Alberta Environment (AENV). 2008. Indicators for Assessing Environmental Performance of Watershed in Southern Alberta. Information Centre, Edmonton, Alberta.

Alberta Environment (AENV). 2008. Water Management Plan for the Watersheds of the Upper Highwood and Upper Little Bow Rivers, Volume 1. Alberta Environment Planning Division, Calgary, Alberta.

Alberta Environment (AENV). 2008. Water Management Plan for the Watersheds of the Upper Highwood and Upper Little Bow Rivers, Volume 2: Highwood Diversion Plan. Alberta Environment Planning Division, Calgary, Alberta.

Alberta Environmental Protection. 1999. Environmental Monitoring of the Oldman River Dam: Eight Years of Progress. Publication No. T/447. 74 p + appendices.

Alberta Sustainable Resource Development (SRD). No date. Bull Trout: Salvelinus confluentus http://srd.alberta.ca/BioDiversityStewardship/SpeciesAtRisk/Default.aspx

Alberta Sustainable Resource Development (SRD). No date. http://www.srd.alberta.ca/FishingHuntingTrapping/RecreationalFishing/Default.aspx

Alberta Sustainable Resource Development (SRD). No date. Lake Sturgeon Management Plan. http://www.srd.gov.ab.ca/fishwildlife/fishingalberta/sturgeonmanagementplan.aspx

Alberta Sustainable Resource Development (SRD). 2007. Mountain Pine Beetle Management Strategy. Pub. No. T/154. Edmonton, AB.

Alberta Sustainable Resource Development (SRD). 2009. 2008 Annual Report Forest Health in Alberta. Edmonton, AB.

AMEC Earth & Environment (AMEC). 2005. "Risk to the Environment" Surface Water Runoff and Groundwater Quality Literature Review. Report prepared for Natural Resources Conservation Board, Calgary, AB.

AMEC Earth & Environment (AMEC). 2007. Current and Future Water Use in Alberta, Water for Life, Alberta Environment, Edmonton, AB.

Aquality Environmental Consulting Ltd. 2009. Red Deer River State of the Watershed Report. Report prepared for the Red Deer River Watershed Alliance, Red Deer, Alberta.

Baxter, R.M. and P. Glaude. 1980. Environmental Effects of Dams and Impoundments in Canada: Experience and Prospects. Can. Bull. Fish. Aquatic Science 205. 34 pp.

Beaver Creek Watershed Group. 2006. Water Quality in the Beaver Creek Watershed – 2006. Oldman Watershed Council.

Boucher, K. 2000. Land Use Data Compendium: Inventory Data Description. Prepared for Oldman River Basin Water Quality Initiative. Lethbridge, Alta.

Bradley, C., F. Reintjes and J. Mahoney. 1991. The Biology and Status of Riparian Poplars in Southern Alberta. World Wildlife Fund Canada.

Canadian Council of Ministers of the Environment (CCME). 2005. Canadian water quality guidelines for the protection of agricultural water uses: Sulfolane. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment (CCME). 2007. Canadian Water Quality Guidelines for the Protection of Aquatic Life Summary Table. Winnipeg, MB.

Clipperton, G.K., C.W. Koning, A.G.H. Locke, J.M. Mahoney, and B. Quazi. 2003. Instream Flow Needs Determinations for the South Saskatchewan River Basin, Alberta, Canada. Online edition: http://ssrb.environment.alberta.ca/pubs/IFN_Main_Report.pdf

Coote, D.R. and Pettapiece, W.W. 1989. Wind Erosion Risk, Alberta. Land Resource Research Centre, Research Branch, Agriculture Canada. Publication 5255/B. Contribution Number 87-08.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2006. A Living Fossil at Risk of Extinction: One Part of Canada's Decline in Diversity. Press Release. 28 November 2006.

Cows and Fish Program. 2009. Excel file of Oldman Watershed Riparian Health Assessment Data. February 2009.

Cunningham, E.B. 1988. The Oldman River Dam, Implications for the Fishery. In Economic, Environmental, and Social Aspects of the Oldman River Dam Project S.B. Rood and F.B. Jankunis. Lethbridge, Alberta: University of Lethbridge.

Department of Natural Resources Canada. 2009. Canvec, Canada, Edition 4.0, Website www.geogratis.gc.ca.

Department of Fisheries and Oceans Canada (DFO). 2009. Recovery Potential Assessment of Pure Native Westslope Cutthroat Trout, Alberta Population. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/050.

DMTI Spatial Inc. 2006. Canadian Municipalities. ESRI, Redlands Calif.

Environment Canada. 2002. Climate Normals 1971-2001. Atmospheric Environment Service.

Environment Canada. 2004. Municipal Water Use Survey. Environment Canada. Hull, QC.

Fiera Biological Consulting. 2009. Environmentally Significant Areas of Alberta. http://www.tpr.alberta.ca/parks/heritageinfocentre/environsigareas/default.aspx.

Fitch, L. and N. Ambrose. 2003. Riparian Areas: A User's Guide to Health. Lethbridge, AB. Cows and Fish Program.

Gilbert, R.O. 1987. Statistical Methods for Environmental Pollution Monitoring. John Wiley & Sons. Toronto, ON. 315 pp.

Gill, K.M., C.R. Willms. J.M. Mahoney, S.B. Rood. 2007. River Regulation for the Conservation of Riparian Cottonwood Forests in Southern Alberta. Pp. 166-177 In: H. Epp, D. Healy (eds.), Water:Science and Politics. Proceedings of the conference held by the Alberta Society of Professional Biologists, March 25-28, 2006, Calgary, Alberta.

Government of Alberta. 2007. Bow, Oldman and South Saskatchewan River Basin Water Allocation Order, Alta Reg. 171 / 2007, Queen's Printer, Edmonton, AB.

Guelph Water Management Group. 2003. Oldman River Characterization Report. University of Guelph. http://web.archive.org/web/20051125032854/www.uoguelph.ca/gwmg/wcp_home/Pages/O_home.htm.

Hardy BBT, S.B. Rood and J.M. Mahony. 1992. Riparian vegetation of the St. Mary, Belly and Waterton river valleys, Alberta. Prepared for Planning Division, Alberta Environment. Edmonton, Alberta.

Health Canada. 2009. Water Quality – Report and Publications, Website: http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/index-eng.php. June 2009.

Hebben, T. 2007. Analysis of Water Quality Conditions and Trends for the Long-Term River Network: Oldman River, 1966-2005. Alberta Environment, Edmonton, AB.

Henderson and Sauchyn. 2008. Climate Change Impacts on Canada's Prairie Provinces : A Summary of our State of Knowledge. Prairie Adaptation Research Collaborative, University of Regina, Regina, SK.

Holme, P.J., S.R. Hicock, and L.E. Jackson Jr. 2000. Interaction of Laurentide and Cordilleran Ice in the Beaver Mines Area, Southwestern Alberta. Géographie physique et Quaternaire. V. 54 No. 2: pp 209-218.

Hydroconsult. 2001. Non-irrigation Consumptive Demand Projections in the South Saskatchewan River Basin. Alberta Environment. Calgary, AB.

Jackson, L. Jr. 2008. Alberta Foothills Erratics Train. Website: http://www3.telus.net/lejgeology/etrain/. Accessed July 2009.

International Joint Commission. 2009. http://bwt.ijc.org/index.php?page=boundary-waters&hl=eng). Accessed July 2009.

Irrigation Water Management Study Steering Committee (IWMSSC). 2002. South Saskatchewan River Basin Irrigation in the 21st Century - Volume 1: Summary Report. Alberta Irrigation Projects Association. Lethbridge, Alberta.

Lethbridge Northern Irrigation District (LNID), 1996. Just Add Water. Lethbridge Northern Irrigation District Lethbridge, Alberta.

Lewis, R. 1998. Environmental Monitoring of the Oldman River Dam: Eight Years of Progress. Pub. No. T/447. Alberta Environmental Protection. Edmonton, Alberta.

Ligon, F.K.; W.E Dietrich.; W.J Trush. 1995. Downstream Ecological Effects of Dams. Bioscience 45: 1-13.

Longmore, L.A. and C.E. Stenton. 1981. The Fish and Fisheries of the South Saskatchewan River Basin: Their Status and Environmental Requirements. Alberta Environment, Planning Division. Edmonton, Alberta

Mahoney, J.M. and S.B. Rood. 1993. The Potential Effects of an Operating Plan for the Oldman River Dam on Riparian Cottonwood Forests. Edmonton, Alberta: Alberta Public Works, Supply and Services.

Martz, L., J. Bruneau and J.T. Rolfe. 2007. Climate Change and Water – SSRB Final Technical Report. Climate Change Impact and Adaptation Program, Natural Resources Canada. Ottawa, ON.

Mayhood, D.W. 1998. Following Silver City: Westslope Cutthroat Trout in Canada. On The Wild Side: The Journal of American Wildlands 9(1):7-8.

McCartney, M. 2009. Living with Dams: Managing the Environmental Impacts. Water Policy Supplement 1 (2009): 121-139.

Mitchell, P. 2001. Limnological Assessment of the Oldman Reservoir. Alberta Environment, Water Management Division, Natural Resources Service.

Mitchell, P.A. and E.E. Prepas (eds.). 1990. Atlas of Alberta Lakes. The University of Alberta Press. Edmonton, Alberta

Natural Regions Committee. 2006. Natural Regions and Sub-regions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. T/852. Web Site: http://www.cd.gov.ab.ca/preserving/parks/anhic/Natural_region_report.asp.

Natural Resources Conservation Board. 2009. Confined feeding operations in Alberta. Edmonton, Alta.

Natural Resources Conservation Board. 2008. Board Decision NR 2008-01: Revised Highwood Diversion Plan. Edmonton, Alta.

Nature Conservancy of Canada. 2009. http://www.natureconservancy.ca/site/News2?abbr=ab_ncc_&page=NewsArticle&id=7441. January 2009.

North Saskatchewan Watershed Alliance. 2005. State of the North Saskatchewan Watershed Report 2005 - A Foundation for Collaborative Watershed Management. North Saskatchewan Watershed Alliance, Edmonton, Alberta.

Study Management Committee. 1978. Oldman River Phase 2 Studies -- Final Report and Recommendations. Alberta Environment. Edmonton, AB.

Oldman River Dam Environmental Advisory Committee 2002. Oldman River Dam Environmental Advisory Committee – Final Recommendations. Alberta Environment. Edmonton, AB.

Oldman Watershed Council. 2005. Oldman River Basin Water Quality Initiative – Five Year Summary Report. Agriculture, Food and Rural Development, Lethbridge, Alta.

Oldman Watershed Council (OWC). Proposed Work Plan. http://www.oldmanbasin.org/publications.html Accessed Nov 2009.

Palechek, S. R. 2009. Riparian Cottonwood Forest Along Southern Alberta Rivers. M.Sc. Royal Roads University, Victoria, BC.

Parks Canada. 2009. http://www.pc.gc.ca/pn-np/ab/Waterton/intro_e.asp. Accessed July 2009.

Partners for the Saskatchewan River Basin. 2009. From the Mountains to the Sea: The State of the Saskatchewan River Basin. ISBN 978-0-9730693-7-2. http://www.saskriverbasin.ca/page.php?page_id=70

Rood, S.B., A.R. Kalischuk and J.M. Mahoney. 1998. Initial cottonwood seeding recruitment following the flood of the century of the Oldman River, Alberta, Canada. Wetlands 18(4): 557-570.

Rood, S.B., G.M. Samuelson, J. R. Weber and K. A. Kywrot. 2005. Twentieth Century Decline in Streamflows from the Hydrographi

Sauchyn, D. and S. Kulshreshtha. 2008. Prairies. Chapter 7 in From Impacts to Adaptation: Canada in a Changing Climate, Government of Canada, Ottawa, ON.Seneka, M. 2004. Trends in Historical Annual Flows for Major Rivers in Alberta. Prepared for Environmental Assurance, Alberta Environment. Environmental Monitoring and Evaluation Branch, Evaluation and Reporting Section, Water Assessment Team, February 2004.

Silins, U et al. 2009. Southern Rockies Watershed Project: impact of natural disturbance by wildfire on hydrology, water quality, and aquatic ecology of Rocky Mountain watersheds Phase 1 (2004-2008). Prepared for ASRD, Alberta Water Research Institute, AENV and Oldman Watershed Council. Edmonton, AB.

Soil and Water Conservation Society. 2003. Conservation and Implications of Climate Change: Soil Erosion and Runoff from Cropland. Ankeny, IA: Soil and Water Conservation Society.

Spatial Data Warehouse. 2008. Website: www.altalis.com/prod_base_bound.html. November 2008

Statistics Canada. 2006. Agriculture Profiles and Community Profiles for 2006. Ottawa, Ont.

Stewart, R. E. and H. A. Kantrud. 1971. Classification of Natural Ponds and Lakes in the Glaciated Prairie Region. Resource Publication 92. Bureau of Sport Fisheries and Wildlife. U. S. Fish and Wildlife Service. Washington, D. C.

Sustainable Resource Development (SRD). 1990. IRS Imagery. Alberta Sustainable Resource, Resource Information Branch. CD of data set created December 2008.

Sustainable Resource Development (SRD). 2001. Spray Lakes Sawmills. Forest Management Agreement. July 24, 2001.

Sustainable Resource Development (SRD). 2005. C5 Forest Management Plan. Website accessed, April 3, 2009. http://www.srd.gov.ab.ca/fieldoffices/southernrockies/c5plan/default.aspx.

Sustainable Resource Development (SRD). 2009. Annual Report 2008 - 2009. September 2009.

Sustainable Resource Development (SRD). 2010. Business Plan 2010-13. Budget 2010, Striking the Right Balance. Government of Alberta. 2010.

Sweetgrass Consultants. 1997. Environmentally Significant Areas of Alberta. 3 volumes. Alberta Environmental Protection, Edmonton, AB.

Tajek, J. and Coote, D.R. 1993. Water Erosion Risk, Alberta. Land Resource Research Centre, Research Branch, Agriculture Canada. Publication 5292/B. Contribution Number 92-05.

University of Lethbridge. 2009. Geology and Geomorphology of Waterton Lakes National Park. http://www.uleth.ca/vft/waterton2/Geo.htm. Accessed July 2009.

van Dijk, T. 2009. The Lewis Thrust. http://sciwebserver.science.mcmaster.ca/geo/faculty/boyce/3z03/Lewis_thrust/#Abstract. Accessed July 2009.

Watertight Solutions Ltd. 2006. Hydrological Effects of the Preferred Forest Management Scenario in the C5 Forest Management Unit, Appendix 6C in ASRD 2005. C5 forest management plan 2006-2026. Public Lands and Forest Division, Calgary, AB.

Wheaton, E. 1998. But it's a Dry Cold – Weathering the Canadian Prairies. Fifth House Ltd. Calgary, AB.

Willms, C.R. 1998. The Influence of Geomorphology and Flow Regulation on Riparian Cottonwoods. M.Sc. Thesis. University of Lethbridge. 156 p.

Willms, J., S.B. Rood, W. Willms and M. Tyree. 1998. Branch Growth of Riparian Cottonwoods: A Hydrologically Sensitive Dendrochronological Tool. Trees 12:215-233.

Willms, C.R. and S.B. Rood. 2007. Environmental Impacts of the Oldman River Dam Project. Correspondence between instream flows and riparian cottonwoods. Rept. prepared for Alberta Environment and Alberta Sustainable Resource Development. Lethbridge, AB.

Personal Communication

Best, J. Rangeland Agrologist, Rangeland Management Branch, Alberta Sustainable Resource Development, 16 February 2010.

Jones, B. Forest Health Officer, Southern Rockies Area, Alberta Sustainable Resource Development, 16 February 2010.

Piccin, C. Rangeland Agrologist, Rangeland Management Branch. Alberta Sustainable Resource Development, 16 February 2010.

Rood, S.B. Professor of Plant Biology, University of Lethbridge, 6 August 2009.

Acronyms

AENV	Alberta Environment
AGRASID	Agricultural Region of Alberta Soil Inventory Database
AID	Aetna Irrigation District
AUM	Animal Unit Months
AVI	Alberta Vegetation Inventory
B10, B11	Forest Management Unit of the Bow Forest
BRID	Bow River Irrigation District
C01, C02, C5	Forest Management Unit of the Crowsnest Forest
CFO	Confined Feeding Operations
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
ESA	Environmentally Significant Areas
FLUZ	Forest Land Use Zones
FMU	Forest Management Units
GCM	Global Climate Model
GVI	Grassland Vegetation Inventory
ha/yr	hectare per year
IFN	Instream Flow Needs
IJC	International Joint Commission
IO	Instream Objectives
kph	kilometres per hour
L/c-d	litres per capita-day
LID	Leavitt Irrigation District
LNID	Lethbridge Northern Irrigation District
MD	Municipal District
MPB	Mountain Pine Beetle
MVID	Mountain View Irrigation District
NRCB	Natural Resources Conservation Board
OHV	Off-highway Vehicles
OWC	Oldman Watershed Council
SMRID	St. Mary River Irrigation District
SSRB	South Saskatchewan River Basin
TID	Taber Irrigation District
TSS	Total Suspended Solids
UID	United Irrigation District
WCO	Water Conservation Objectives
WSC	Water Survey of Canada
Y2Y	Yellowstone to Yukon

Glossary

Actual Use: The recorded or estimated actual volume of water diverted from a stream minus the return flow. In the Oldman River 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.

Anthropogenic: Literally, "human origin", such as sewage inputs into a freshwater system.

Confidence Level: The degree of certainty that a statistical prediction is accurate. The higher the confidence level, the more certain the estimate.

Confined Feeding Operations: Refers to fenced or enclosed land or buildings where livestock are confined for the purpose of growing, sustaining, finishing ore breeding by means other than grazing and any other building or structure directly related to that purpose but does not include residences, livestock seasonal feeding and beddingsites, equestrian stables, auction mareketes, race tracks or exhibition grounds (*Agricultural Operation Practices Act* (2004).

Dicamba: 3,6 dichloro-2-methoxy benzoic acid. Dicamba is a herbicide used to control annual and perennial rose weeds in grain crops. It is included in the CCME guidelines for the protection of aquatic life.

Dissolved Oxygen: A measurement of the amount of oxygen available to aquatic organisms. Temperature, salinity, organic matter present, BOD and COD affect DO solubility in water.

Ecological Integrity: See Environmental Integrity.

Ecosystem: An ecological system of an assemblage of plants, animals, bacteria and fungi that are treated together as a functional unit in their natural environment.

Ecoregion: A distinct geographic area characterized by a distinctive climate, ecological features, and plant and animal communities.

Eutrophication: The natural and/or anthropogenic processes by which the nutrient content of natural waters is increased, generally resulting in an increase of biotic productivity and biomass.

Exceedance: A sample, event, or sampling period for which a measurement exceeds a specified guideline or limit.

Fauna: Animals of a particular region, considered as a group.

Fecal Coliform: Refers to the group of bacteria associated with the feces of warm-blooded animals. The extent to which fecal coliforms are present in the source water can indicate the general quality of that water and the likelihood that the water is fecally contaminated. They constitute one of three bacteria commonly used to measure possible contamination of water by human or animal wastes. The others are *Escherichia coli* (*E. coli*) and *Enterococcus* spp.

Fish Rule Curve: A variable flow recommendation based on fish habitat available for various flows and the available supply of water under natural conditions. The recommended flow varies, depending not only on the fish habitat, but also on the hydrologic conditions experienced (wet, dry, average) during the period under consideration.

Forest Management Unit: The defined area of forest located in the Green Area designated by the Alberta government to be managed as a unit for wood fibre production and other renewable resources.

Glacio-fluvial: Pretaining to streams fed by melting glaciers, or to the deposits and landforms produced by such streams.

Glacio-lacustrine: Refers to geological processes and landforms associated with glacial lakes.

Guidelines: Generic numerical concentrations or narrative statements that are recommended as upper limits to protect and maintain the specified uses of air, water, sediment, soil or wildlife. These values are not legally binding.

Hardiness: The concentration of all dissolved metallic cations, except those of the alkali metals, present in water. In freshwater, hardness is primarily a measure of the concentration of calcium and magnesium ions and is frequently expressed in mg/L calcium carbonate equivalent.

Hydrology: The science that relates to the water of the earth.

Instream Flow Needs (IFNs): Scientifically determined amounts of water, flow rates, water levels, or water quality that is required in a river or other body of water to sustain a healthy aquatic environment or to meet human needs such as recreation, navigation, waste assimilation, or aesthetics.

Instream Objectives (IOs): Flows that should remain in the river to protect environmental values, human uses or parts thereof. IOs are maintained through dam operations or by restrictions on licences. Instream Objectives are in place in throughout the SSRB, although some offer only limited protection of the aquatic environment. Instream Objectives have usually been set in response to fish habitat instream needs (the Fish Rule Curve) and/or water quality.

Ion: An atom or particle that is electrically charged (positive or negative).

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

Linear Developments: Human development associated with seismic lines, pipelines, roadways, railways, and utility right-of-ways.

Linear Regression: A statistical test to determine whether there is a linear relationship between two variables, and how strong that relationship is.

Loading: Quantity of nutrient or contaminant entering a water body or river reach in a given period of time.

Mass Loads: The mathematical weight of a pollutant in a water body. The load is the calculated product of the concentration of a pollutant in water multiplied by the water volume.

MCPA: 4-chloro-2-methyl phenoxy acetic acid. MCPA is a herbicide used to control broadleaf weeds in cereal crops and pasture. It is included in the CCME guidelines for the protection of aquatic life.

Median: The middle value of an ordered set of values such that half of the numbers are smaller and the other half are larger.

Natural Region: A region characterized by common geological, ecological and climatological factors.

Natural Flow: The flow in streams that occurs, or would have occurred, in the absence of human use, withdrawals or regulation. Alberta Environment has re-constructed 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.

Nitrogen: A nutrient necessary for the growth and development of animals and plants. Typically, nitrogen is the limiting nutrient in terrestrial systems. In freshwater environments, high levels of nitrogen can be an important contributor to eutrophication.

p or p-value: In statistics, the probability (out of 10) that an observation occurred by chance. Values less than 0.05 are generally considered to indicate a statistically significant result.

Pathogen: An agent that causes disease, especially a living microorganism, such as a bacterium, parasite or fungus.

Permanent Wetland: A wetland that retains water for most of the year in most years. Using the Stewart and Kantrud (1971) classification, these would be class IV or V (lakes).

pH: A logarithmic scale used to measure the acidity of water. Values less than 7 (pH of pure water) are acidic, values greater than 7 are basic (or alkaline).

Phosphorus: A nutrient necessary for the growth and development of animals and plants. In freshwater environments, phosphorus is typically the limiting nutrient for productivity. Excessive phosphorus in aquatic systems can increase plant and algal growth to nuisance levels. It can be measured as several variables: total phosphorus, total dissolved phosphorus and soluble reactive phosphorus.

Plankton: Assemblage of small drifting organisms suspended in the water column, including plants/algae (phytoplankton), animals (zooplankton), and bacteria (bacterioplankton).

Productivity: or Primary Production. The development of organic matter (plants and algae) through the process of photosynthesis.

Ramping: Managing flows downstream from dams to simulate a more natural flow regime that results in good survival of cottonwoods.

Reach: A section of stream, river, lake or wetland with similar physical and vegetative features and similar management influences.

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.

Riparian: The transitional zone between upland and aquatic habitat. Riparian areas perform important ecological functions, contain a diverse assemblage of plant and animal species, provide essential habitat for wildlife and are influenced by seasonal water levels.

Salinity: In fresh waters, the salinity is the sum of the ionic composition of the eight major cations (calcium, magnesium, sodium and potassium) and anions (carbonate, sulfate, chloride and nitrate) in mass or milli-equivalents per liter.

Seismic: An exploration technique to identify oil and gas deposits by producing sound waves at the surface, recording how the waves are reflected from underlying features and interpreting these reflections to produce a computer model of subsurface geological structures.

Sheet Flow: Stormwater runoff flowing overland in an evenly dispersed manner rather than forming channels and rivulets.

Standard: A legally enforceable numerical limit or narrative statement, such as in regulation, statute, contract or other legally binding document, that has been adopted from a criterion or objective.

Sub-basins: Five Sub-basins were delineated for the Oldman River State of the Watershed Report: Mountain, Foothills, Southern Tributaries, Prairie and Mainstem. These were identified using natural drainage patterns and water management history. Within each of the Sub-basins, smaller drainage areas - called a sub-basin - are also defined. For example, the Mountain Sub-basins includes the Castle River sub-basin.

Till: A glacial deposit consisting of unsorted sediment, possibly including clay, silt, sand, gravel, and larger rocks.

Total Nitrogen: A measure of the nitrogen concentration in a solution, as the sum of total Kjeldahl nitrogen and nitrate-nitrite.

Total Phosphorus: A measure of the phosphorus concentration in a solution, as the sum of soluble reactive phosphorus and organic phosphorus.

Total Residue: Material left behind after evaporation of a sample and oven drying.

Trend: Pattern of gradual change or general tendency of an indicator to increase or decrease, in concentration or occurrence, over time. Referred to in terms of confidence levels where significant trends typically occur at a 90% confidence level.

Trophic: Refers to the nutrient availability and productivity status of a water body. See oligotrophic, mesotrophic and eutrophic.

Total Suspended Solids: A quantitative measure of the solid organic or inorganic particles that are held in suspension in wastewater, effluent, or water bodies, determined by tests for "total non-filterable residue."

Watershed: The area of land draining into a stream, lake, wetland or other water body.

Water Conservation Objective (WCOs): As defined in Alberta's *Water Act*, a WCO is the amount and quality of water necessary for the protection of a natural water body or its aquatic environment, or any part thereof. It may also include water necessary to maintain a rate of flow or water level requirements for human instream use. WCOs where established in the Oldman River Basin following completion and government approval of the SSRB plan.

Wetland: A wetland is land where the water table is at, near or above the surface or which is saturated for a long enough period to promote such features as wet-altered soils and water tolerant vegetation. Wetlands include organic wetlands or "peatlands" and mineral wetlands or mineral soil areas that are influenced by excess water but produce little or no peat.

Appendices

Appendix A: Oldman Watershed Council

Oldman Watershed Council

In November 2003, Alberta released "Water for Life: Alberta's strategy for sustainability" (AENV 2003). This strategy is built on three goals:

- safe, secure drinking water supply;
- healthy aquatic ecosystems; and
- reliable, quality water supplies for a sustainable economy.

Key directions and actions of the strategy revolve around three core areas of focus:

- knowledge and research;
- partnerships; and
- water conservation.

As part of this strategy, Watershed Planning and Advisory Councils were established throughout Alberta. The role of these Councils is to lead in watershed planning, develop best management practices, foster stewardship activities within the watershed, report on the state of the watershed, and educate users of the water resource.

The Oldman Watershed Council (OWC) is a not-for-profit organization that works in partnership with communities and residents to improve the Oldman River watershed. The OWC consists of members who live or work within the Oldman watershed (Table A.1). These members provide leadership and guidance in watershed planning and management, water quality monitoring, and stewardship promotion. The mission of the OWC is to:

> *…maintain and improve the Oldman River Watershed through partnerships, knowledge and the implementation and integration of sustainable watershed management and land use practices.*

Stewardship groups (Table A.2) are active throughout the watershed.

As a multi-stakeholder council, the OWC works with government in an adaptive management cycle of watershed planning and evaluation.

Oldman Watershed Council Goals

The Oldman Watershed Council will integrate its activities through knowledge, research, partnerships and education as they relate to water management, water quality, and land-use practices in the following key areas:

1. We understand our watershed.
2. Residents are well informed and actively engaged.
3. Watershed stakeholders have defined the desired outcomes for the Oldman Watershed that will form the basis for the Integrated Watershed Management Plan.
4. The Oldman Watershed Council and stakeholders put into action the capacity and commitment to achieve defined outcomes.
5. Practices that are beneficial to the health and function of the watershed are adopted.

Table A.1: Oldman Watershed Council Membership and Supporters

- Agriculture and Agri-Food Canada
- Agriculture and Agri-Food Canada – PFRA
- Alberta Agriculture and Rural Development
- Alberta Agriculture and Rural Development - Irrigation Secretariat
- Alberta Conservation Association
- Alberta Environment
- Alberta Ingenuity Centre for Water Research
- Alberta Irrigation Projects Association
- Alberta Pork Producers
- Alberta Soft Wheat Producers Commission
- Alberta Sustainable Resource Development
- Aquality Environmental Consulting
- ATB Financial
- Cardston County
- Castle Crown Wilderness Coalition
- Castle Mountain Resort
- Certified Organic
- Chinook Health Region
- City of Lethbridge
- County of Lethbridge
- County of Warner Agriculture Service Board
- Cows and Fish
- Crowsnest Pass Chamber of Commerce
- Crowsnest Pass Quad Squad
- Ducks Unlimited Canada
- EBA Engineering
- Federation of Alberta Naturalists
- Fisheries and Oceans Canada
- Friends of the Oldman River
- Helen Schuler Coulee Centre
- Kairos
- Landwise Inc.
- Lethbridge Community College
- Lethbridge Northern Irrigation District
- Martin Geomatic Consultants Ltd.
- MD of Pincher Creek No. 9
- MD of Taber
- MD of Willow Creek
- MULTISAR
- Natural Resource Conservation Board
- Oldman River Chapter - Trout Unlimited Canada
- Oldman River Regional Services Commission
- Palliser Environmental Services Ltd.
- Paradise Canyon Golf Resort
- Partners for the Saskatchewan River Basin
- Partners in Habitat Development
- Piikani Nation
- Piikani Public Works
- Raymond Irrigation District
- Rogers Sugar Ltd.
- St. Mary's Irrigation District
- Saskatchewan Watershed Authority
- Southern Alberta Community for Environmental Educators
- Southern Alberta Group for the Environment
- Southwestern Alberta Conservation Partnership
- Sukapi Water
- Alberta Sustainable Resource Development
- Taber Irrigation District
- Town of Cardston
- Town of Coaldale
- Town of Granum
- Town of Nanton
- Town of Picture Butte
- Town of Pincher Creek
- Town of Stavely
- Town of Taber
- University of Calgary
- University of Lethbridge
- Village of Barnwell
- Village of Carmangay
- Vulcan County
- Water Rights Inc.
- Waterick 2000 Ltd.
- Windy Hollow Farms Ltd.

Source: http://www.oldmanbasin.org/members.html, accessed November 2009.

Table A.2: Watershed Stewardship Groups and Landuser Groups in the Oldman Watershed

- Battersea Drain Watershed Group
- Beaver Creek Watershed Group
- Beehive Conservation Natural Area
- Bobcreek Wildland Watershed Group
- Castle Crown Wilderness Coalition
- Chaffen Creek Watershed Group
- Chief Mountain Landowner Information Network
- Chinook Area Land Users Association
- Crowsnest Conservation Society
- Drywood/Yarrow Conservation Partnership
- Lee Creek Watershed Group
- Livingston Landowners Group
- Lower Mosquito Creek Water Users Association
- Lyndon Creek Watershed Conservation Partnership Peigan Friends Along the River
- PekiskoGroup
- Pincher Creek Watershed Group
- South Porcupine Hills Landowners Group
- Upper Todd Creek Watershed Group
- Waldron Watershed Group
- Waterton Biosphere Reserve/Belly River Watershed Waterton Watershed Stewardship Group
- West Trout Creek Watershed Group
- Willow Creek Watershed Group

Appendix B: Stakeholder Workshop

The OWC selected key indicators during a workshop held in Lethbridge in June 2008. Selection of indicators was guided by work done on the State of the Watershed work for the North Saskatchewan Watershed and the Bow River Basin, as well as building on information presented in the State of the Watershed Reporting Hand Book; a guide for developing state of the watershed Reports in Alberta, Draft, (AENV 2008) and a guide to indicators in southern Alberta (AENV 2008). Participants were divided into three groups: Terrestrial and Riparian Ecology; Water Quantity; and Water Quality. Each group was tasked with identifying indicators and then acceptable thresholds. When deciding on preferred indicators participants considered a number of questions. These included:

- What indicators are appropriate to use for the Oldman watershed?
- Is there sufficient existing data to use these indicators for every Sub-basins in the Oldman watershed?
- What is a reasonable threshold to identify current conditions as poor, fair, or good?
- What makes that threshold acceptable?

Once identified, indicators were ranked to identify the top two or three.

In addition to the chosen indicators, several others were noted that could be used in some areas of the watershed (e.g., in one or two Sub-basins only) because of limited existing data. These may be appropriate for future use.

Thresholds for each chosen indicator were discussed and, in some cases, identified. Where thresholds were not defined at the workshop, the direction given was to determine thresholds using:

- natural variability;
- existing guidelines; and then
- professional judgment.

During the workshop, the indicators identified by the smaller groups were reviewed and discussed by all participants to determine:

- do they work together to describe the state of the watershed?
- are there too many?
- are some missing?
- are the recommended thresholds acceptable for each indicator?

The workshop concluded the chosen indicators and thresholds represented a cohesive whole that can help stakeholders understand the current state of the watershed and provide accurate, reliable information on which to base future watershed management decisions.

Appendix C: Information Sources

Data have been collected from existing sources including reports, databases, and websites. Data collection was focused on the chosen indicators for terrestrial and riparian ecology; water quantity; and water quality.

Terrestrial and Riparian Ecology

The following information sources were used for the terrestrial and riparian indicators:

Land Cover

- Ecological land classification of Alberta – natural sub-regions (Natural Regions Committee 2006, Oldman Watershed Council 2005).
- Native vegetation on private land – Native Prairie Vegetation Inventory – information on a quarter section basis from interpretation of 1992 and 1993 air photos (Boucher 2000).
- Forest cover on Crown land – Alberta Vegetation Inventory – from interpretation of air photos taken in 1988 and 1998 (Boucher 2000).
- Forest cover data for Waterton National Park – Satellite Images Landsat from 1997 (Boucher 2000).
- Agricultural land cover by municipalities and counties from census data (Statistics Canada 2006).
- Forest Management Units (FMU), Forest Land Use Zones (FLUZ), parks and recreation areas (Spatial Data Warehouse 2008, Sustainable Resource Development website 2009).
- SRD disposition types and areas – pers. comm. J. Best and C. Piccin.

Soil Erosion

- Model predicted soil erosion rates – Alberta Soil Information Centre. 2001, Soil Landscapes of Canada Working Group. 2005.

Riparian Health

- Riparian health assessment sites (Cows and Fish Program 2009).

Land Use

- Infrastructure – roads, railways, powerlines, cutlines, wells (Boucher 2000, Oldman Watershed Council 2005).
- Infrastructure – airfields, sewage lagoons, gravel pits (Department of Natural Resources Canada 2009).
- Urban (DMTI Spatial Inc. 2006).
- Confined feeding operations (Natural Resources Conservation Board 2009).
- Population – 2006 census data (Statistics Canada 2006).

Water Quantity

Data required for computation of the water quantity indices include: natural streamflow data, recorded streamflow data, Instream Objectives, Water Conservation Objectives, licence allocations, estimated actual uses and community population data.

Natural Flow Data Sources

Natural flow data (recorded and reconstructed) for the period 1912 to 2001 are available at 28 locations in the Oldman watershed from AENV (2004). At locations that have insignificant upstream storage, regulation and uses, natural flow is approximately the same as recorded flow. The natural flow database can then be taken as 1912 to 2007.

Recorded Flow Data Sources

For the water quantity indicators, it is important that both natural and recorded data are available at the locations analyzed. Streamflow data are recorded by Water Survey of Canada. Generally, long-term recorded data are available at the locations were natural flows have been reconstructed by AENV. Recorded data at other locations may be available for shorter periods and used for purposes other than the water quantity indicators.

Instream Objectives and Water Conservation Objectives

Instream Objectives and Water Conservation Objectives were provided by Water Approvals, AENV, Lethbridge.

Licensed Allocations

Licensed allocations are available from AENV's licensing database (19 October 2006 data used).

Actual Water Use

Estimates of current water use are available from three sources:

- the report entitled, Current and Future Water Use in Alberta (AMEC 2007);
- municipal water use from AENV's municipal water use reporting system; and
- irrigation district water use and area irrigated from Alberta Agriculture and Rural Development's booklet, Alberta Irrigation Information, 2007 (Alberta Agriculture and Rural Development 2007).

Population Data

Population data for communities in the watershed for census years 2001 and 2006 are available from Statistics Canada (2006).

Data Limitations

As an indicator, *licensed allocation vs. natural flow* does not provide information on:

- the seasonality of water supply and potential demands;
- the use of existing storage and flow regulation for meeting instream and consumptive use requirements; or,
- new storage development as provided in the Bow, Oldman and South Saskatchewan River Basins Water Allocation Order.

This level of information would require additional planning and simulation modeling, which is beyond the scope of this report.

Water Quality

Data were obtained from the Alberta Environment Surface Water Quality Data (on-line) database located at http://www.environment.alberta.ca/2024.html. The sampling periods vary between Sub-basins. Data begins in the mid 1970s or 1980s and extends to the present - in some cases ending in mid 2000s, in other cases in 2009.

Appendix D: Water Quality Data Availability Figures

In this appendix, data availability is presented graphically for each Sub-basins. The figures show data continuity for each water quality indicator sampled in the Sub-basins and at particular sites and streams. Each point on the plot represents a measured value for the associated variable at that point in time. The plots visually demonstrate the amount of information available for analysis, sometimes very sporadic, sometimes relatively continuous. Where monitoring sites are located in the same reach of a stream, data have been combined into one data set for analysis. This is a widely used approach that reduces bias effects when data sets are limited or incomplete and provides increased confidence in the analysis.

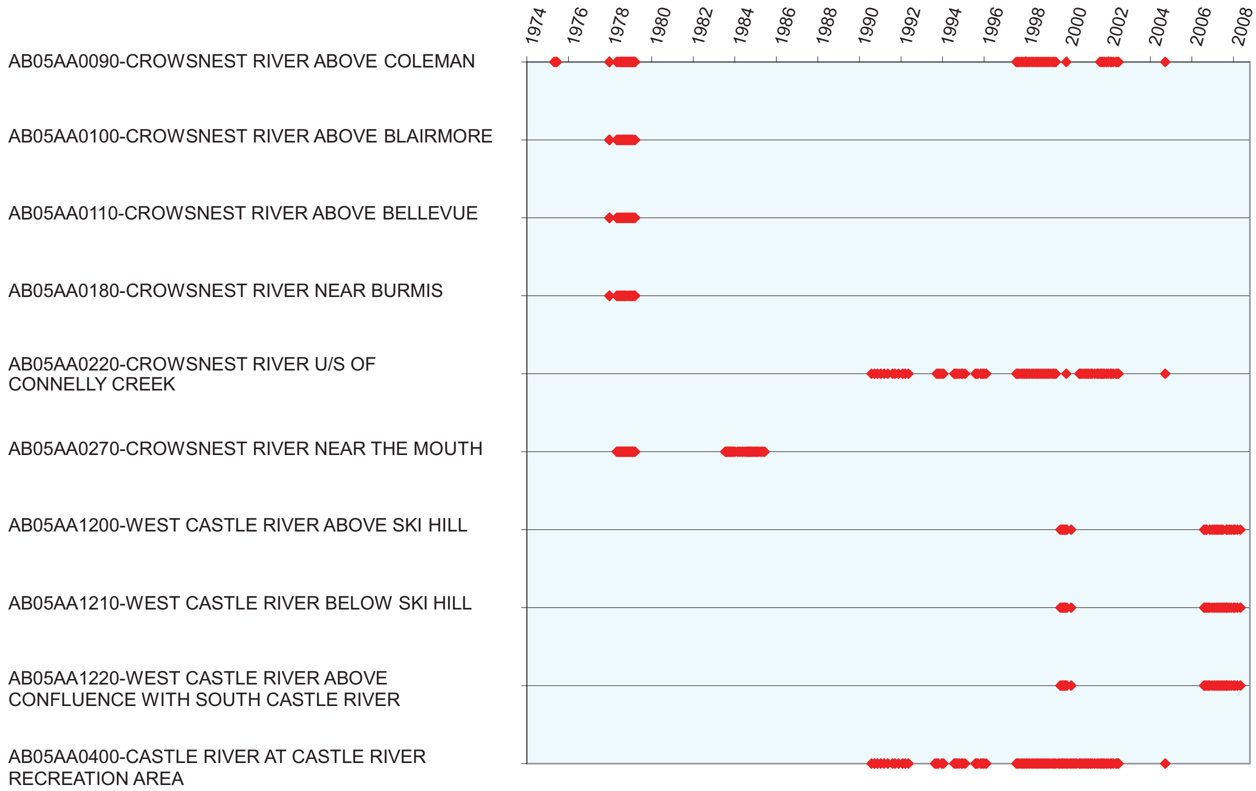

Figure D.1: Total Nitrogen Data Availability Across the Mountain Sub-basins

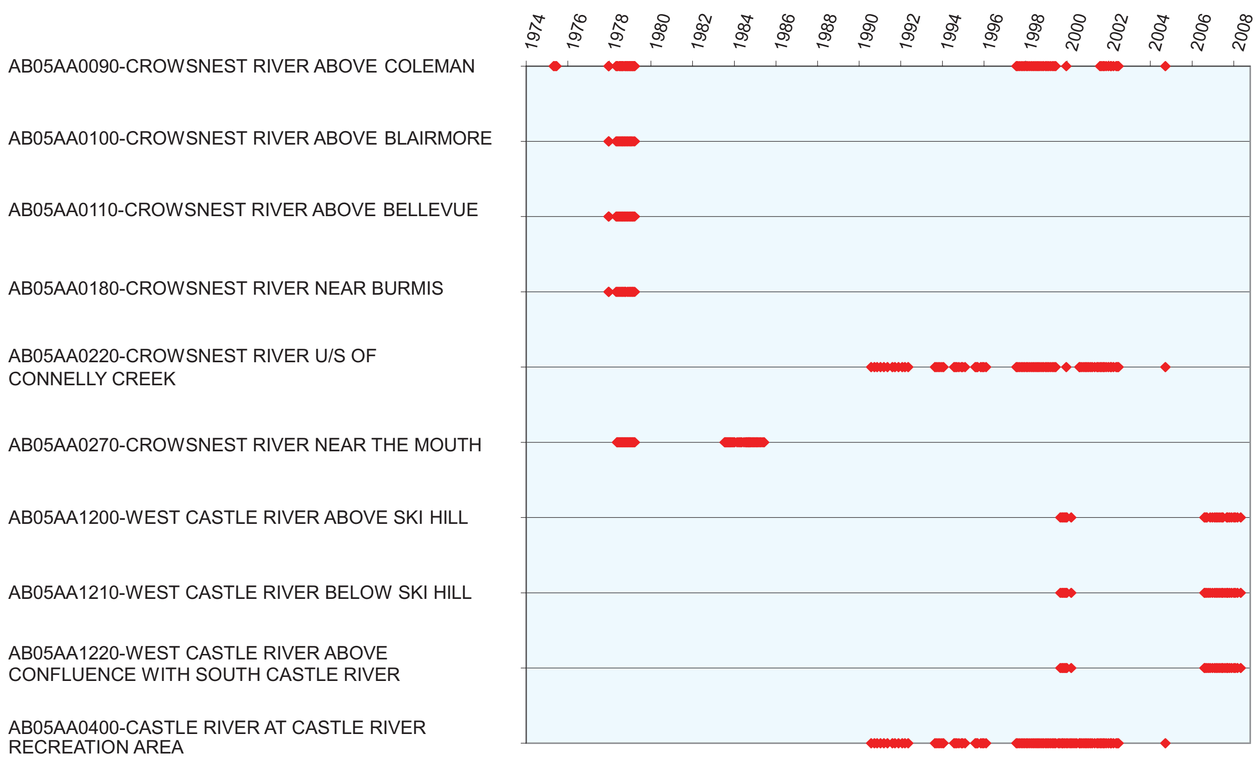

Figure D.2: Total Phosphorus Data Availability Across the Mountain Sub-basins

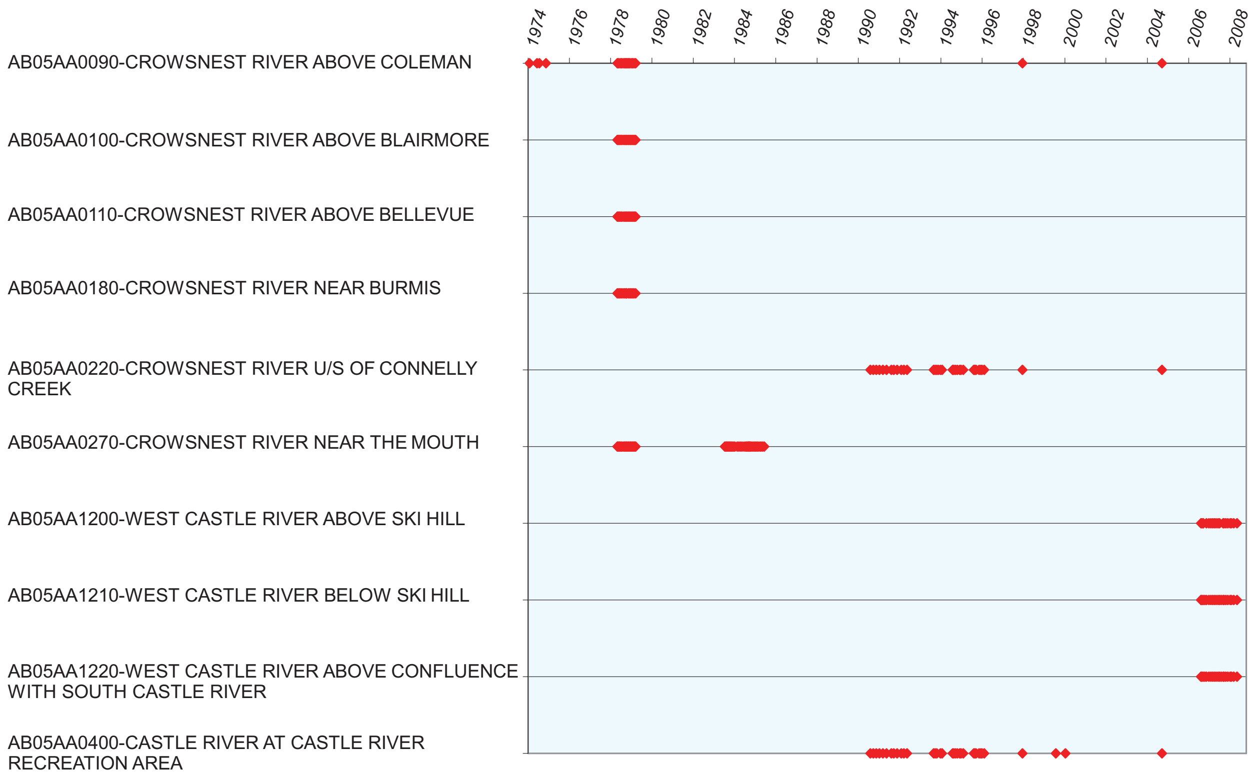

Figure D.3: TSS Data Availability Across the Mountain Sub-basins

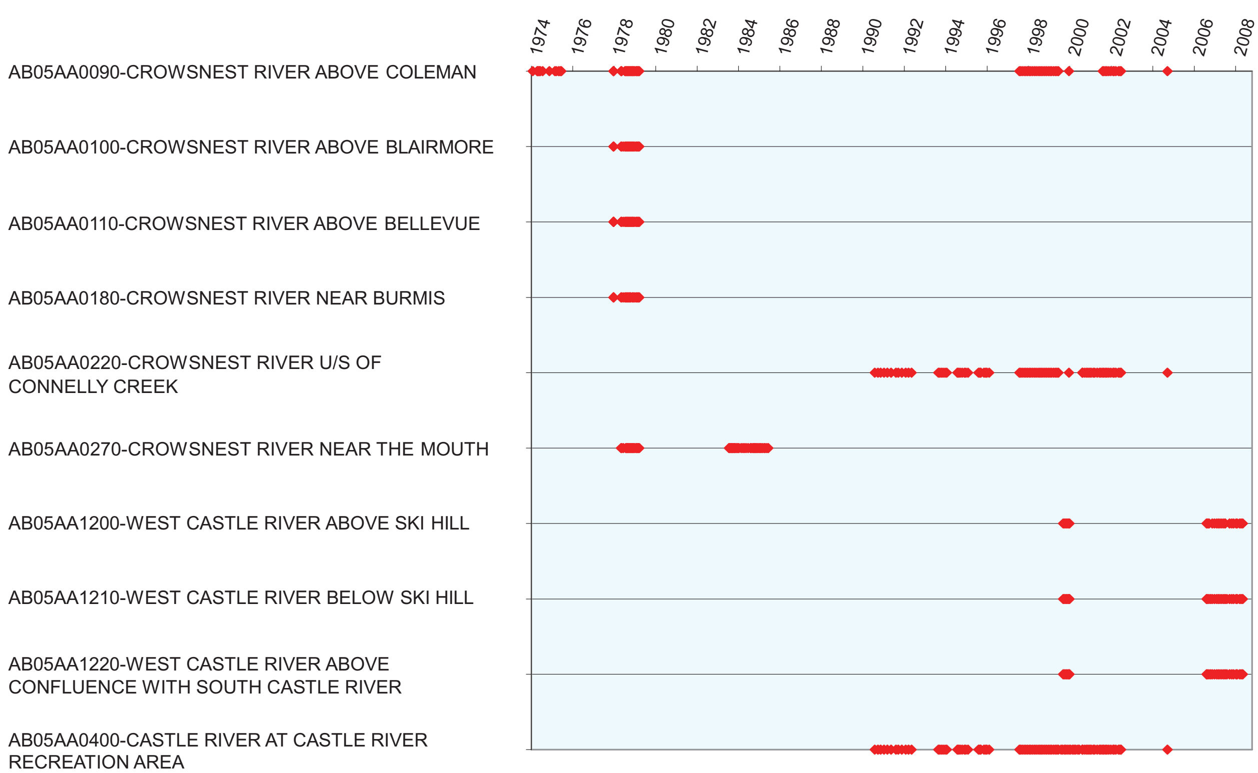

Figure D.4: Fecal Coliform Data Availability Across the Mountain Sub-basins

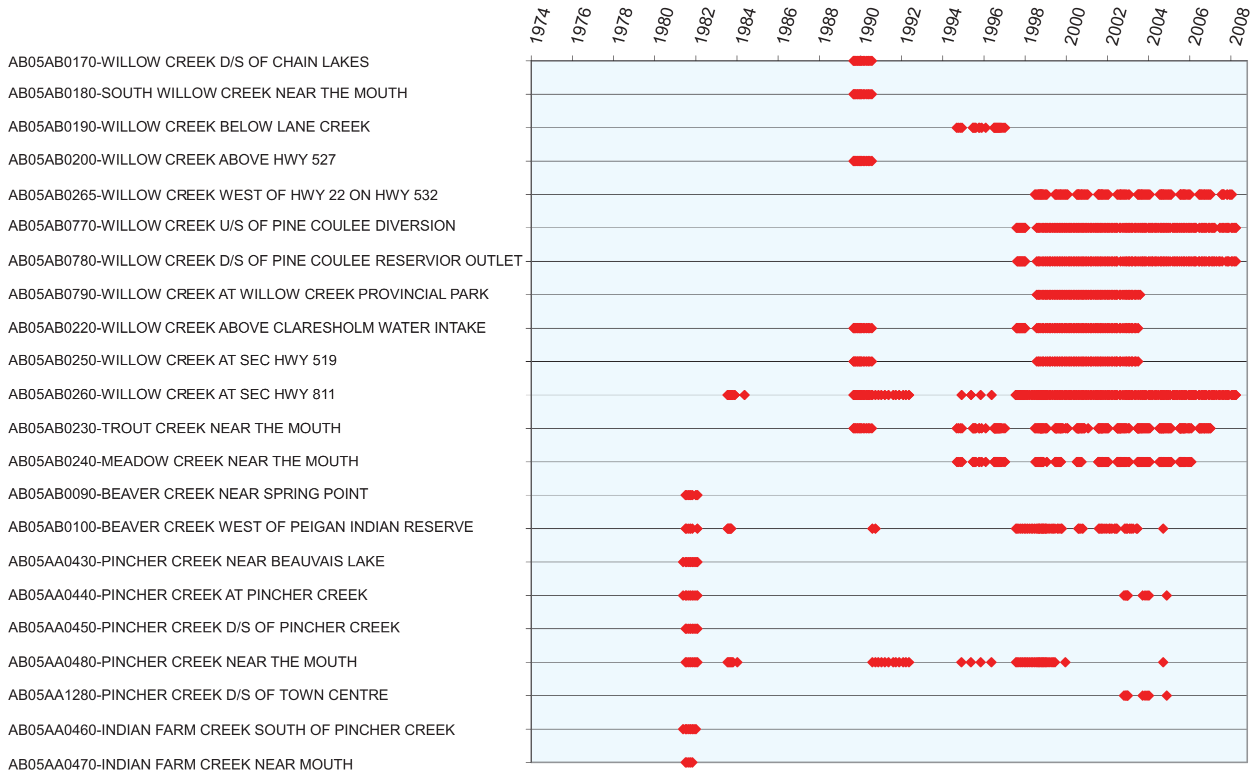

Figure D.5: Total Nitrogen Data Available Across the Foothills Sub-basins

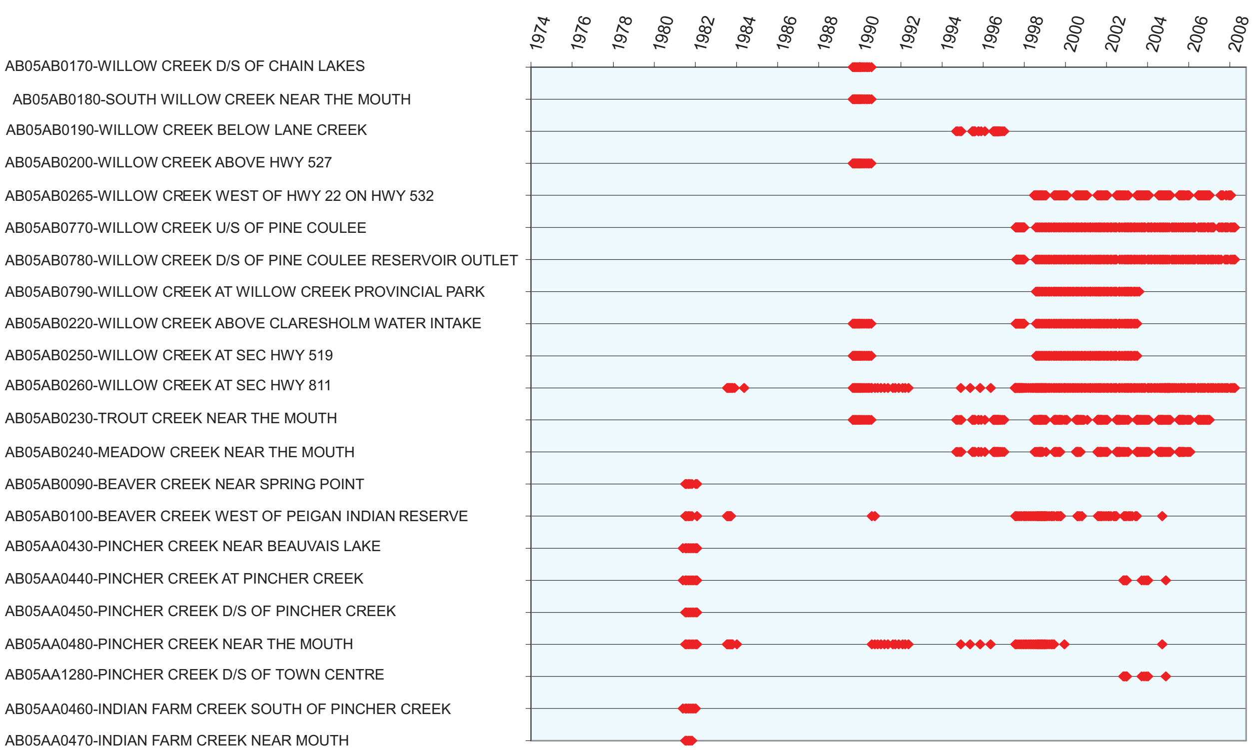

Figure D.6: Total Phosphorus Data Availability Across the Foothills Sub-basins

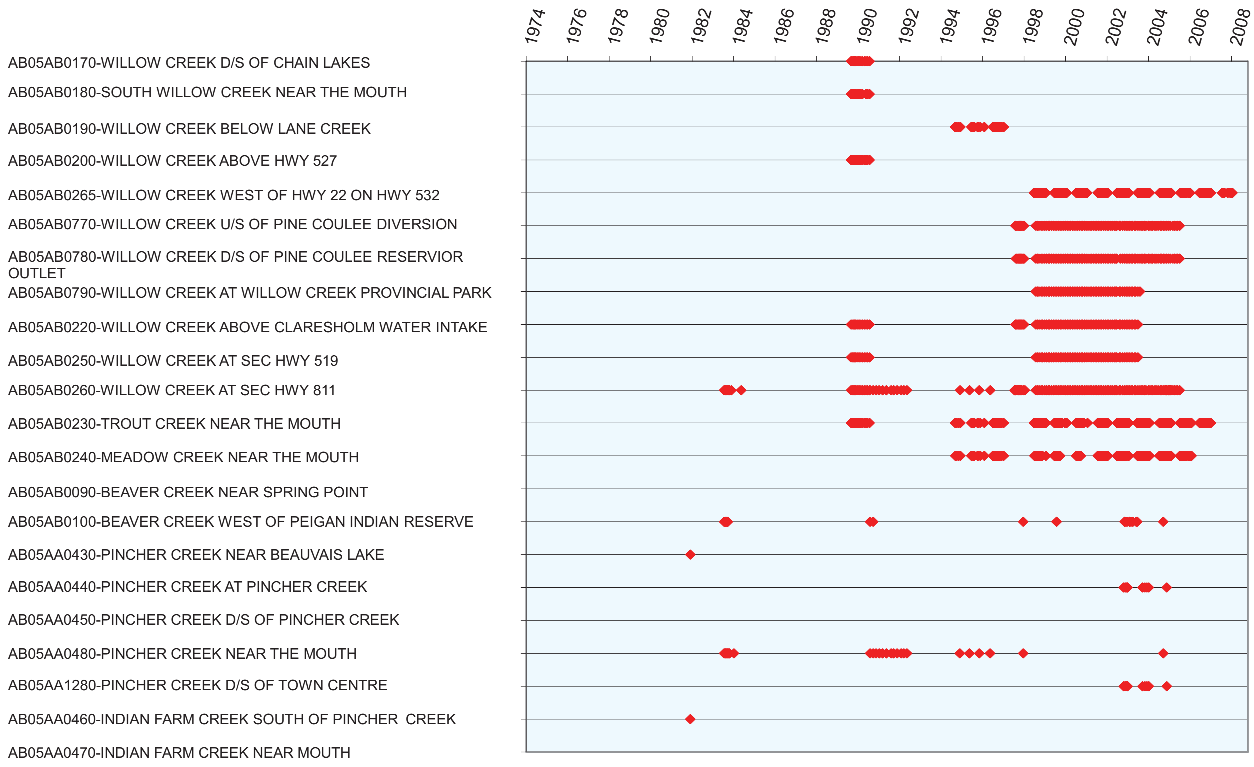

Figure D.7: TSS Data Availability Across the Foothills Sub-basins

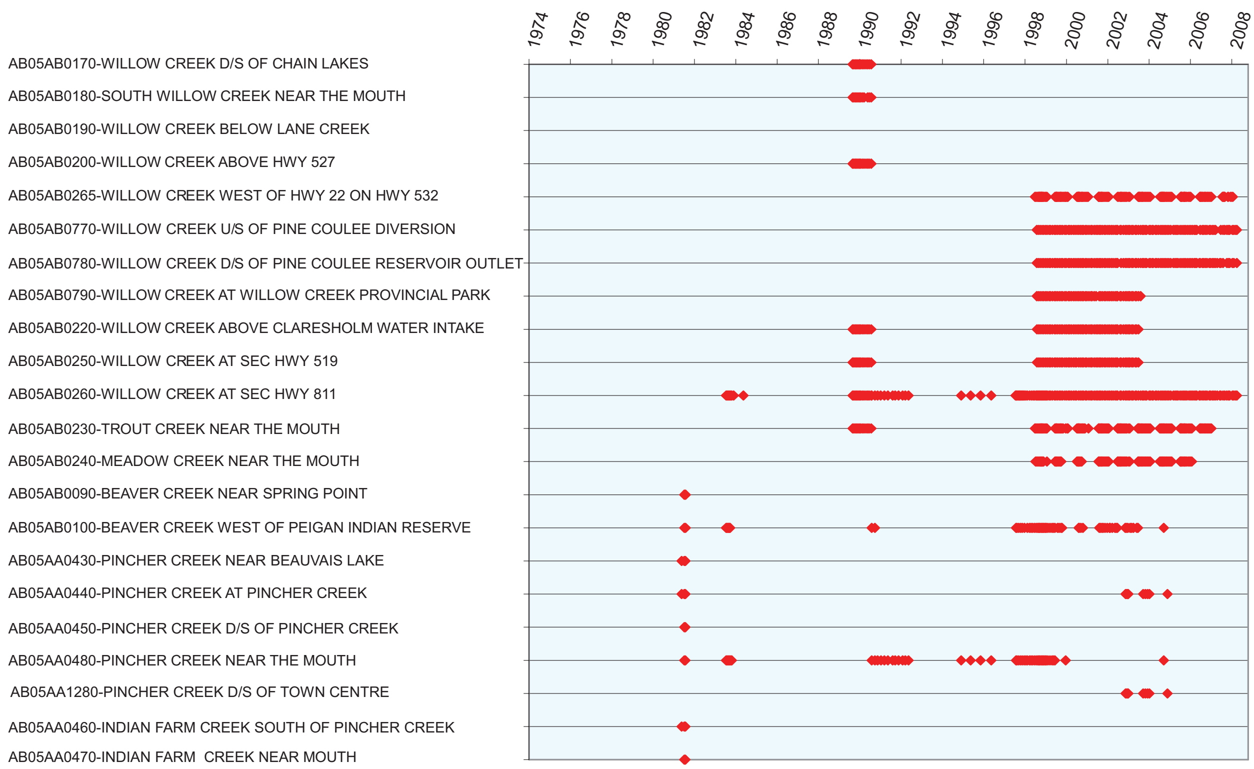

Figure D.8: Fecal Coliform Data Availability Across the Foothills Sub-basins

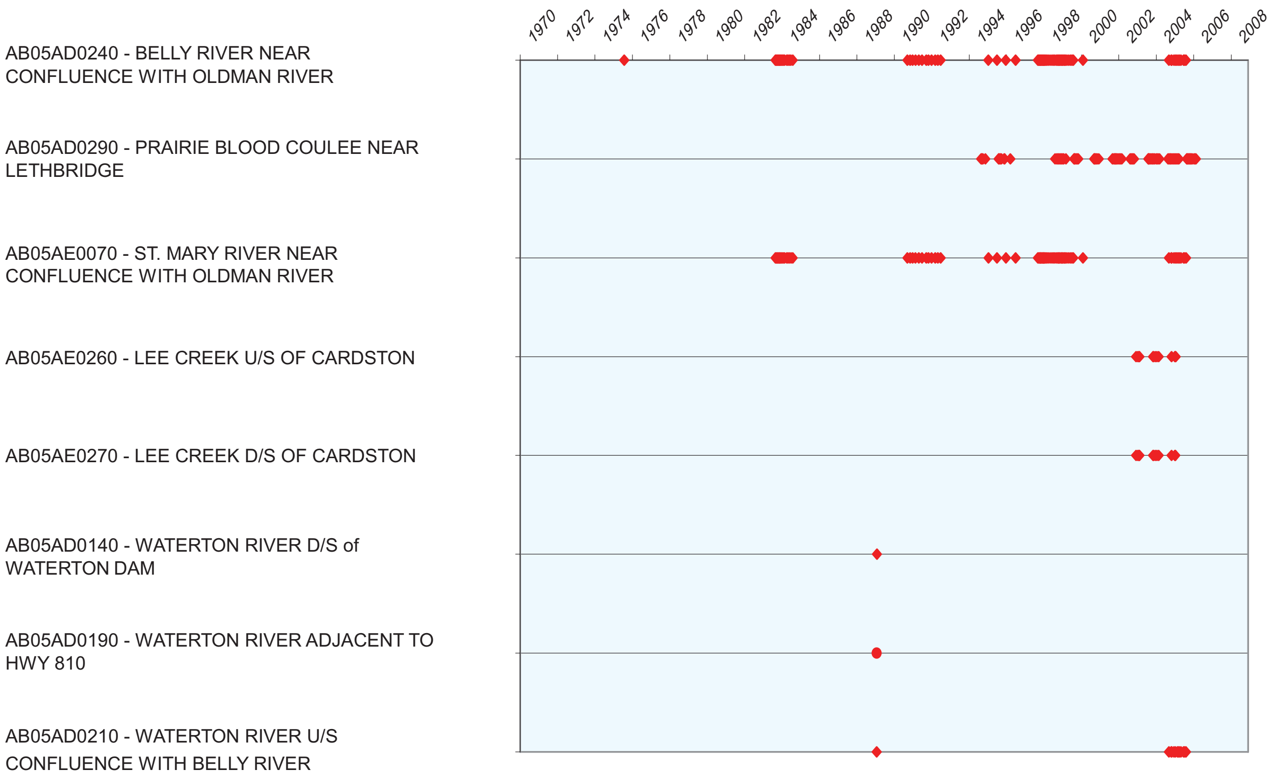

Figure D.9: Total Nitrogen Data Availability Across the Southern Tributaries Sub-basins

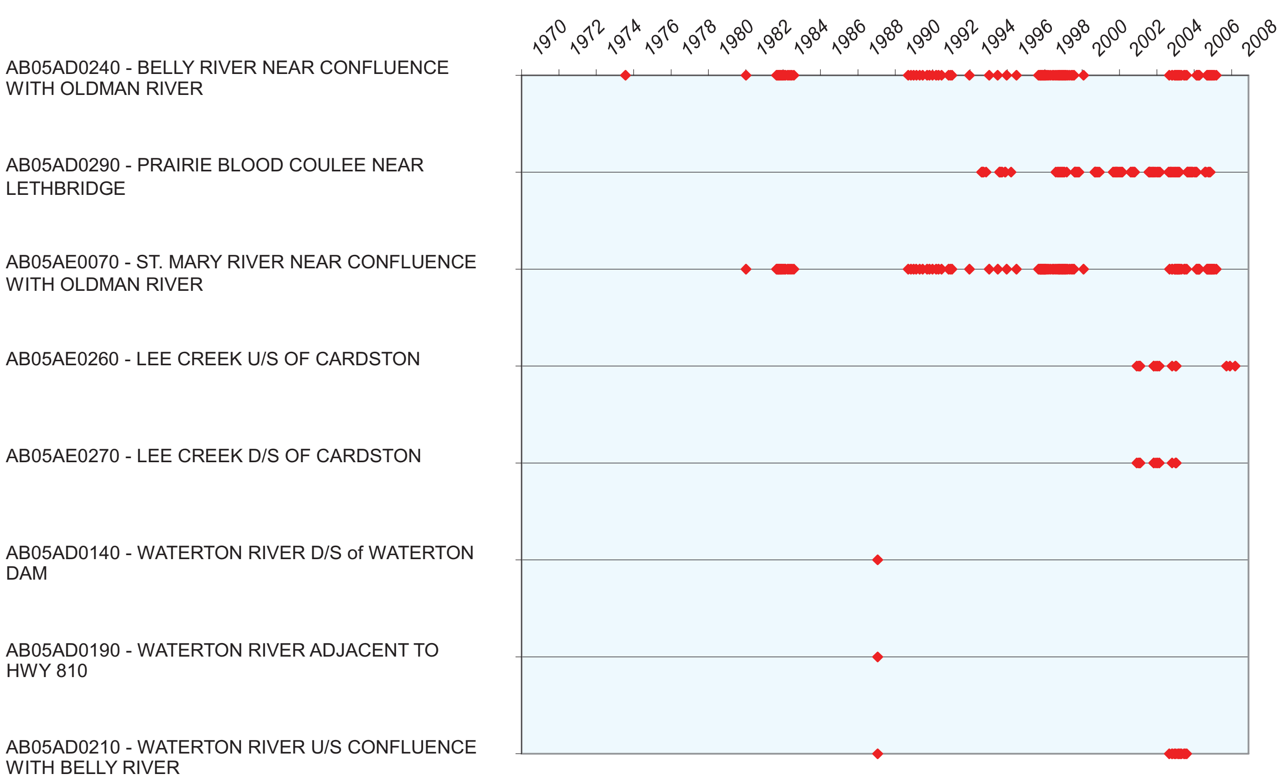

Figure D.10: Total Phosphorus Data Availability Across the Southern Tributaries Sub-basins

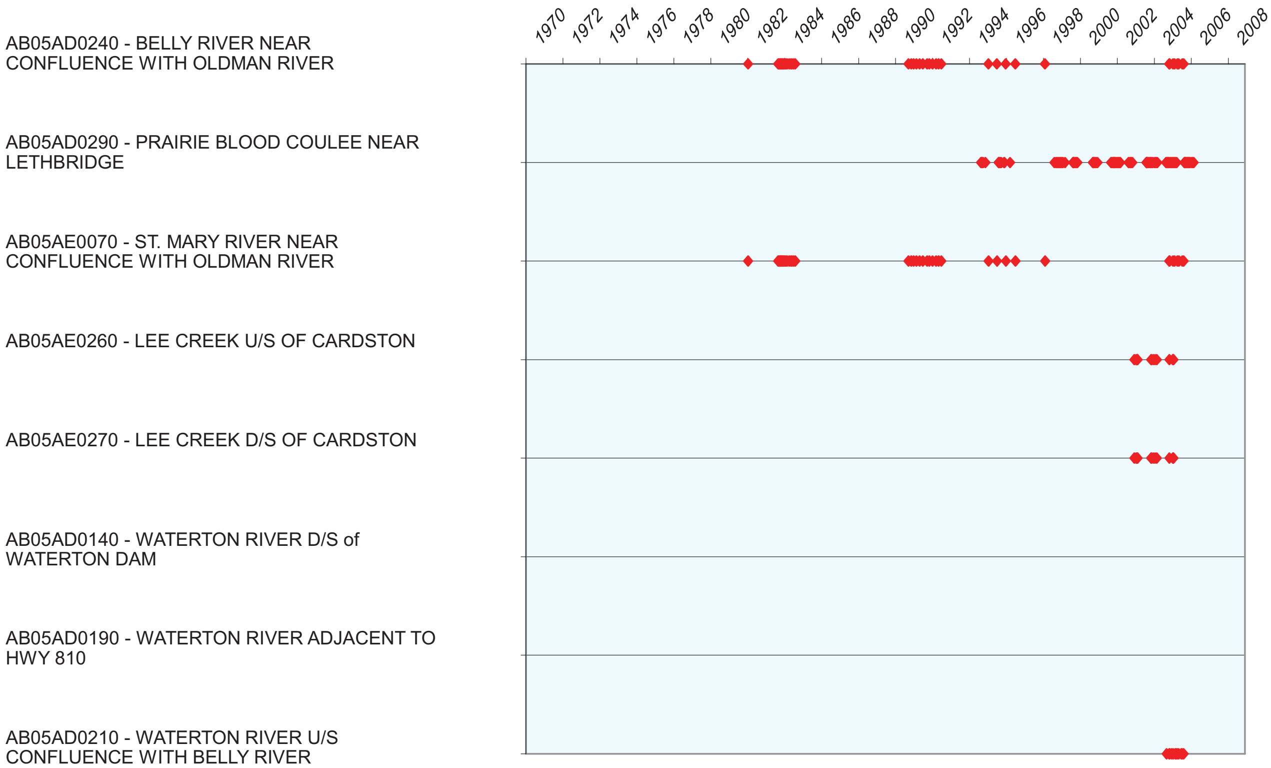

Figure D.11: TSS Data Availability Across the Southern Tributaries Sub-basins

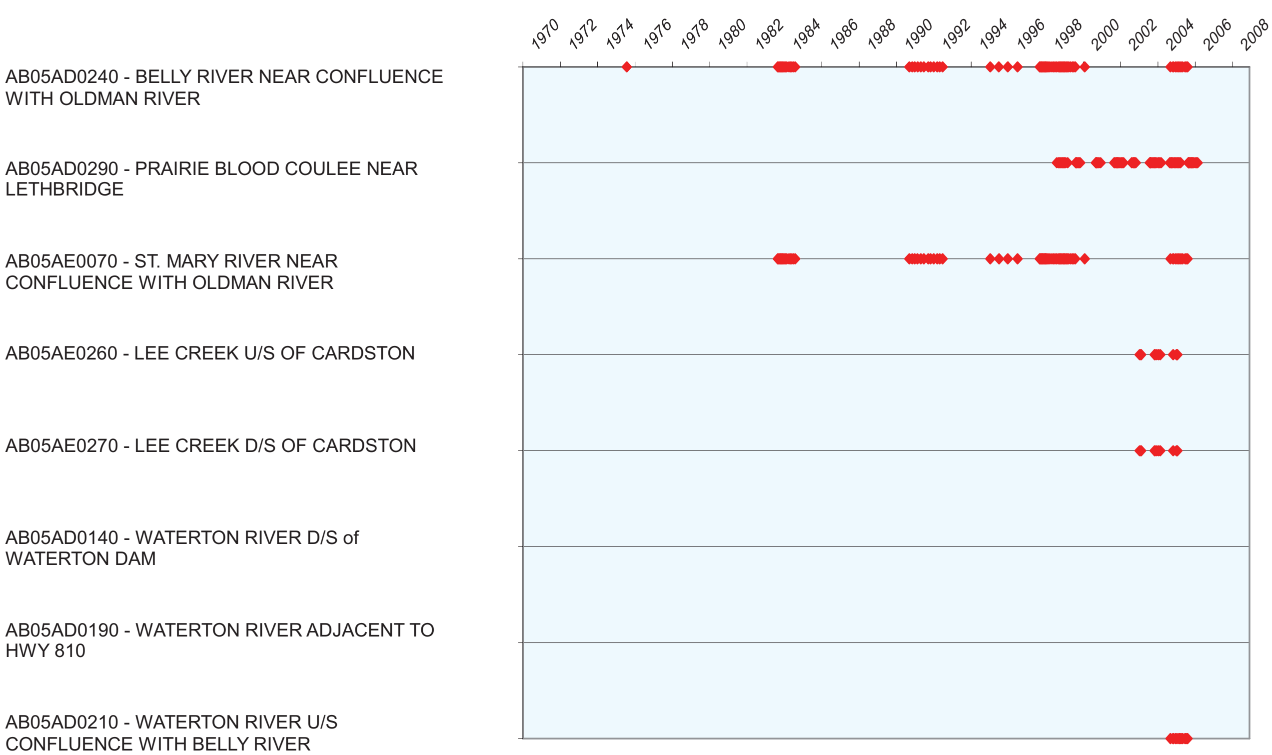

Figure D.12: Fecal Coliform Data Availability Across the Southern Tributaries Sub-basins

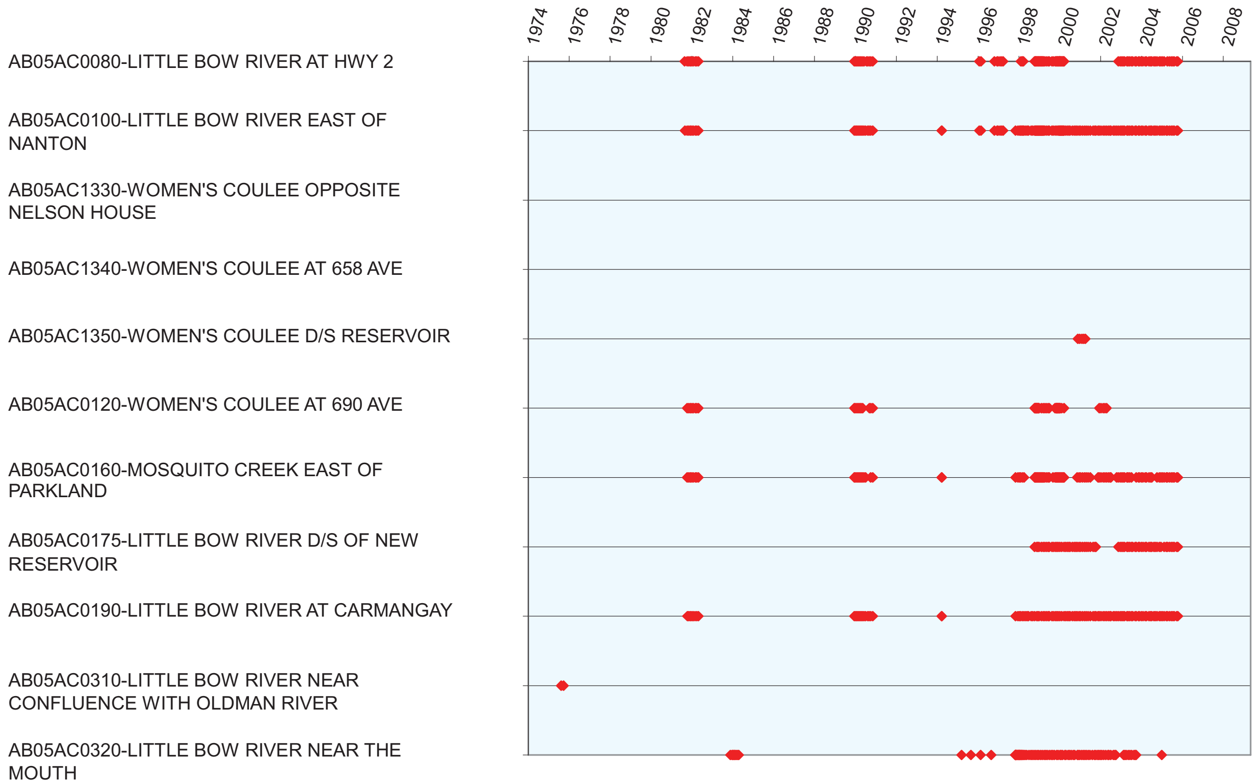

Figure D.13: Total Nitrogen Data Availability Across the Prairie Sub-basins

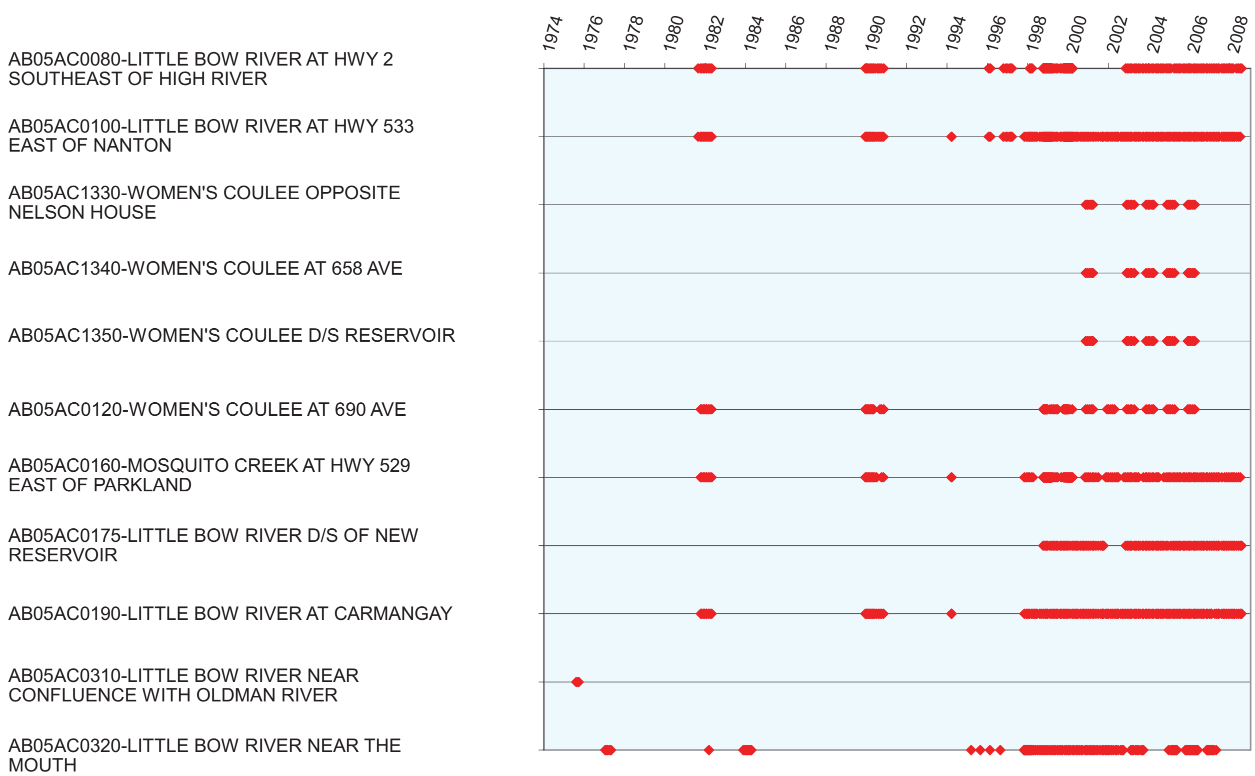

Figure D.14: Total Phosphorus Data Availability Across the Prairie Sub-basins

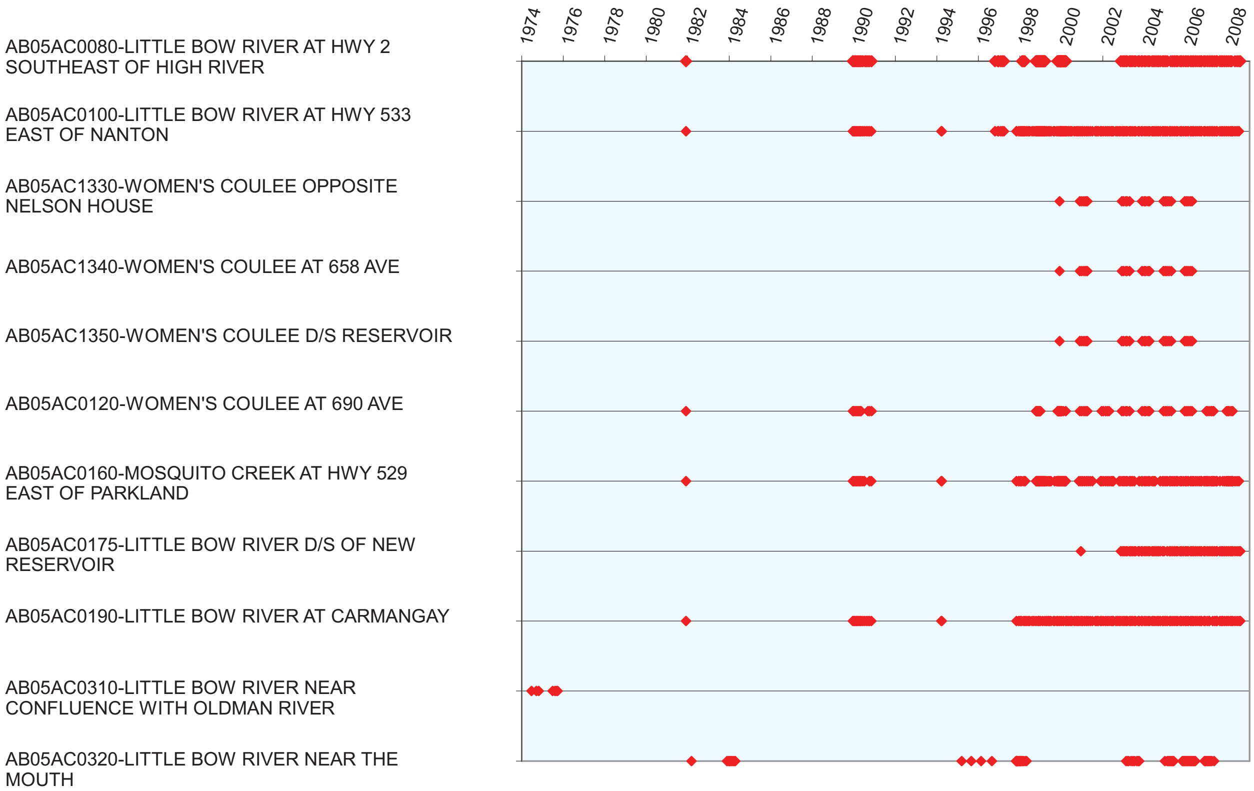

Figure D.15: TSS Data Availability Across the Prairie Sub-basins

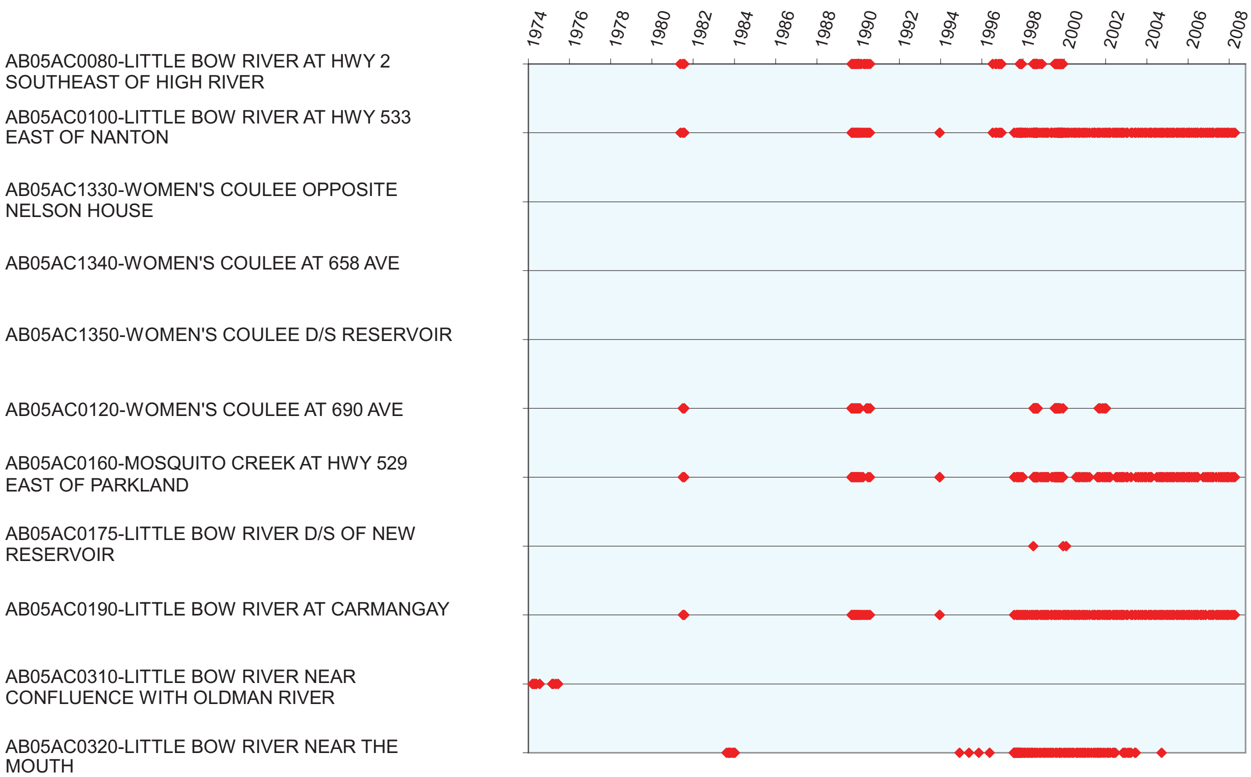

Figure D.16: Fecal Coliform Data Availability Across the Prairie Sub-basins

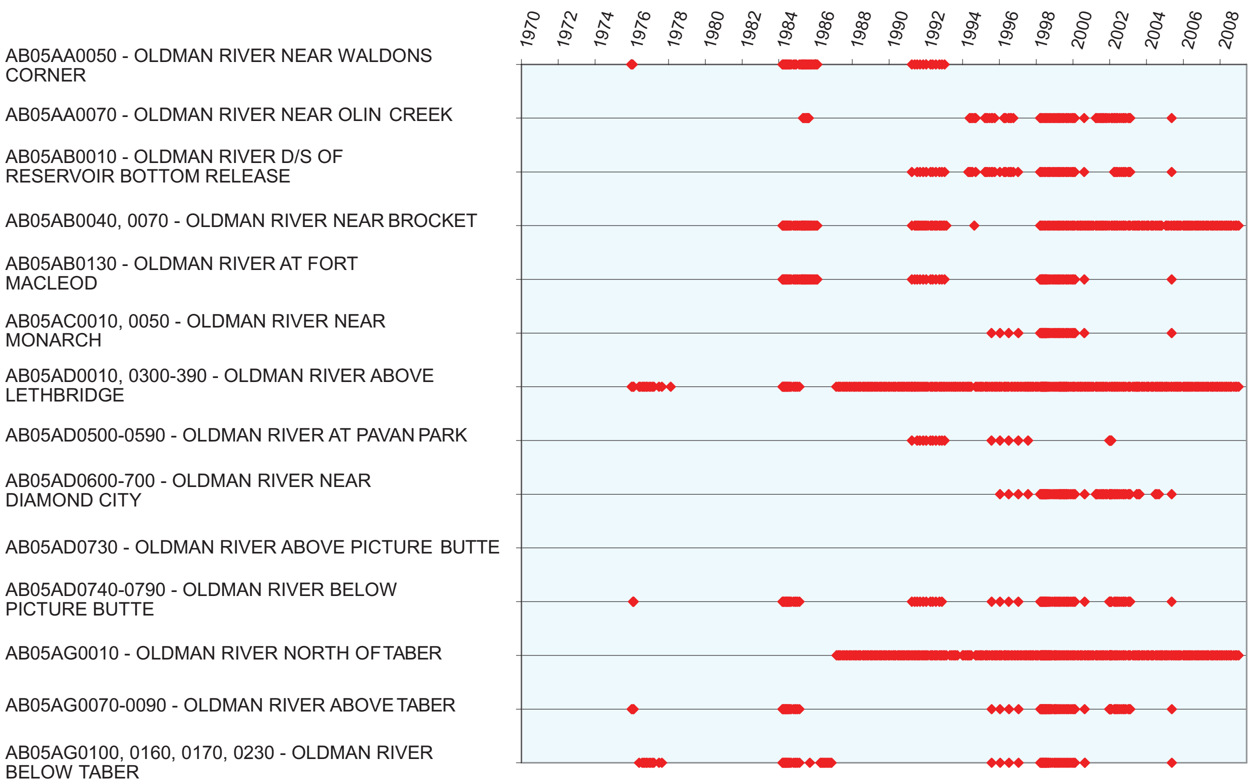

Figure D.17: Total Nitrogen Data Availability Across the Oldman River Mainstem

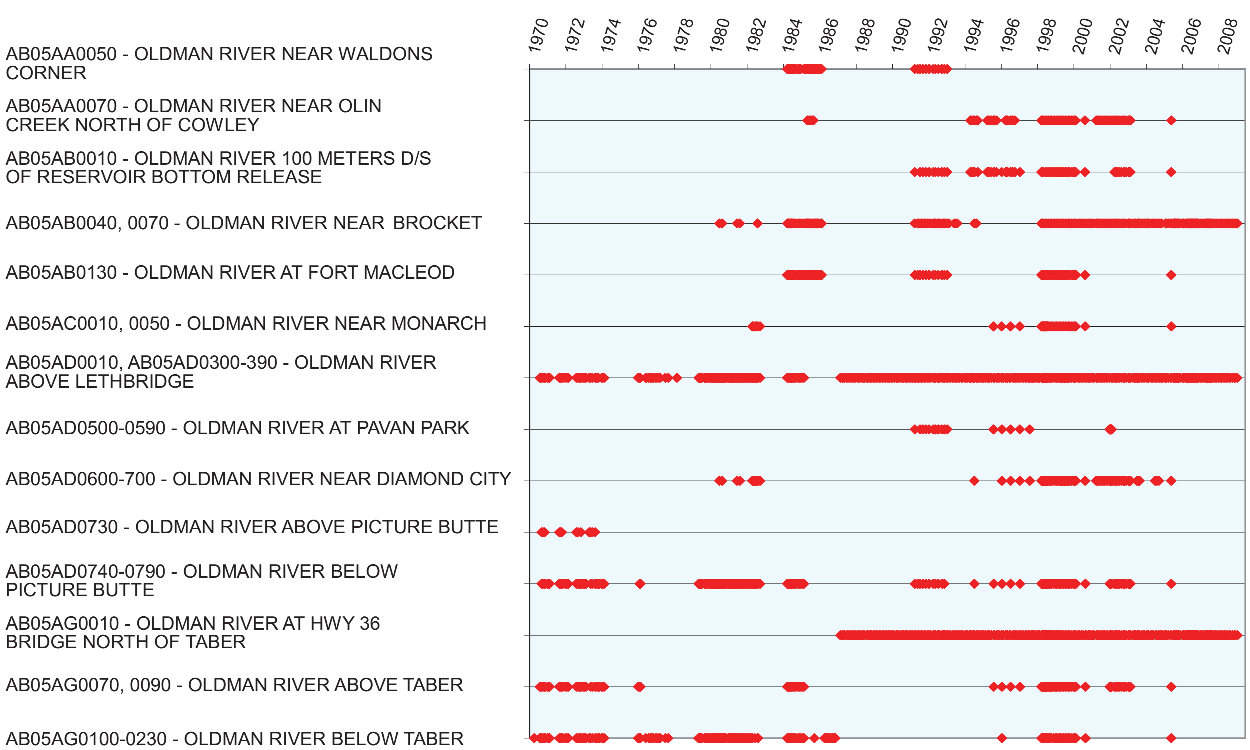

Figure D.18: Total Phosphorus Data Availability Across the Oldman River Mainstem

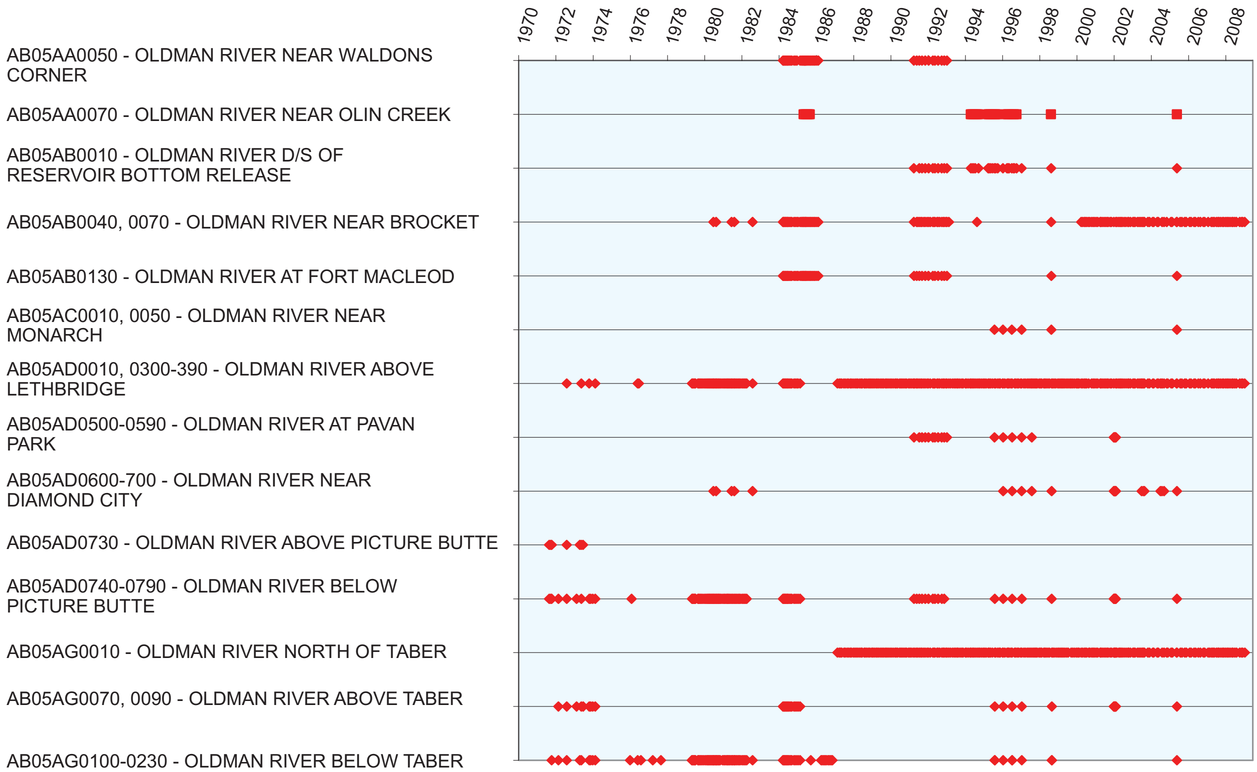

Figure D.19: TSS Data Availability Across the Oldman River Mainstem

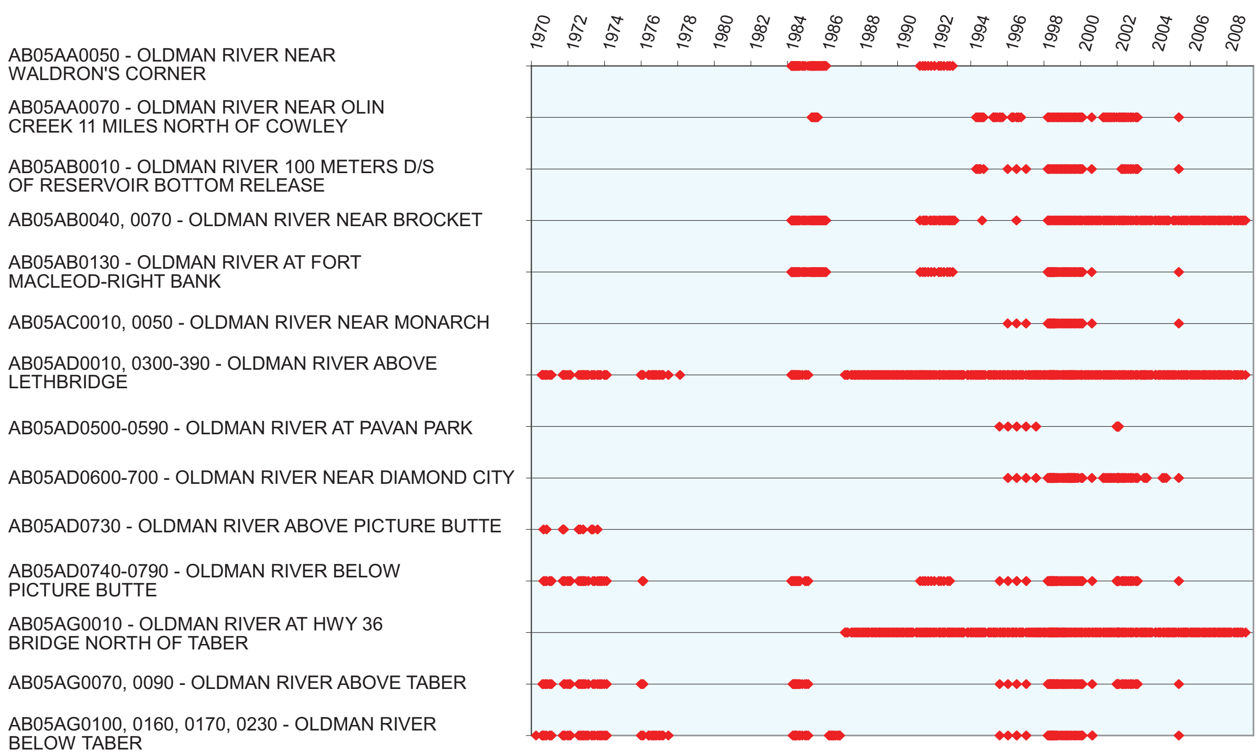

Figure D.20: Fecal Coliform Data Availability Across the Oldman River Mainstem

Appendix E: Overview of Benefits and Impacts of Dams and Reservoirs

Dams and reservoirs are built to provide socio-economic benefits including hydro-electric power, flood control and drought prevention, shipping and transportation, and irrigation. These benefits can bring greater wealth and security to the surrounding region, improving quality of life for many. Ancillary benefits of dams include providing recreational boating, camping, and fishing opportunities and debris control which can lead to enhanced environmental protection and navigation. These ancillary benefits can also have large economic consequences. Most new reservoirs are now built with enhancement features such as parks and boat launches and can be the focal point for new residential housing developments.

Dams and reservoirs can have positive environmental benefits in certain circumstances. Reservoirs increase the area and volume of aquatic habitat available for fish, invertebrates and plankton and, depending on the specific physical, chemical, and biological characteristics of the reservoir, can result in an increase in productivity of the aquatic food-web. Dams can also help prevent the upstream distribution of invasive species such as zebra mussels, sea lamprey, and Asiatic carp for example. If unchecked, invasive species can have huge impacts on native biota and can cause millions of dollars damage to infrastructure and private property.

Biophysical and socio-economic impacts associated with dams and reservoirs are generally divided into upstream and downstream locations. Environmental impacts generally fall into either abiotic or biotic impacts and socio-economic impacts can occur locally or regionally. All impacts are highly site specific and related to the size of project and the affected watershed, the location of the project within and the nature of surrounding ecosystems as well as the socioeconomic condition of affected communities.

Impacts of dams and reservoirs on the upstream environment include those affecting aquatic biota and wildlife (Table E.1). Without fish passage facilities, dams can block migratory fish species and prevent fish from accessing upstream habitat critical for spawning, rearing, and feeding. Reservoirs can also increase the duration of downstream migrations of passively drifting larvae and juveniles, thereby reducing their chances of survival. These two effects can have significant impact on the viability of migratory fish stocks such as salmon, steelhead, and sturgeon. The creation of reservoirs also changes habitat from a river to a lake. For wildlife, this change results in the loss of upland habitat but, generally, creates more wetland habitat for furbearers and waterbirds. For fish and other aquatic biota, this change results in the alteration of the aquatic food-web from one favouring riverine species to one favouring lacustrine species. Flooding can also cause an increase in mercury concentrations in fish. This phenomenon is particularly acute when large areas of organic soils are inundated.

Dams and reservoirs interrupt the natural flow of water, sediment, and nutrients in a river. These interruptions can have dramatic effects on the downstream habitat and on the species living there. Without sediments, the downstream channel begins to degrade and become less diverse. Invertebrate production, and ultimately fish production, becomes reduced with lower nutrient supplies. Reservoirs can also increase or decrease downstream water temperatures and dissolved oxygen concentrations depending on the dam release elevations. Fluctuating water levels can also result in increased shore erosion, stranding of fish and invertebrates, and reduced tributary access. Combined, these effects can result in dramatic changes in the size, distribution, and species composition of the downstream fish community.

Impacts of reservoirs on the upstream and downstream environment can be mitigated in a number of ways. Removal of organic debris and trees prior to flooding reduces the potential for mercury bioaccumulation. Periodic flushing flows can be used to restore natural channel morphology, sediment patterns, and to simulate natural spawning cues in fish. Similarly, run-of-river operations limit stranding and more closely mimic natural daily and seasonal flow fluctuations than peaking operations. Environmentally-based ramping rates are also used to limit stranding of fish and encouraging reestablishment of downstream riparian habitats. Fish passage facilities have been successful in passage of upstream migrant adults and downstream migrating juveniles. Variable discharge elevations are used to mitigate unnaturally low or high water temperatures and dissolved oxygen concentrations. Structures or additional habitat complexing can improve the available habitat for many species of fish, birds, and mammals.

Benefits and impacts are summarized below.

SOCIO-ECONOMIC BENEFITS

Hydroelectric Power	Hydropower is highly efficient (converting <90% of available energy into power), clean (does not create air pollution or toxic by-products), renewable, reliable, and can be used to create multi-use projects, such as creating recreation or habitat-enhancement areas.
Flood Control	Dams prevent flooding, avoiding millions of dollars worth of damages and even loss of life.
Irrigation/Drought prevention	Water impoundment allows for storage of large supplies of water which is made available during times of drought, thus protecting agricultural production, among other benefits. Irrigation systems have resulted in greatly increased farm production in areas surrounding dammed rivers. This results in many benefits to the area, including economic gains, even improved nutrition and education in previously impoverished areas.
Shipping and Transportation	Dams with locks increase shipping channels for transport of goods. Connects inland ports to ocean shipping opportunities.
Recreational Boating and Fishing	Reservoirs provide recreational boating opportunities in previously inaccessible areas and provide boating opportunities for more people than previously available in the river. Warm-water reservoirs typically provide more productive fisheries than cold-water rivers.

ENVIRONMENTAL BENEFITS

Increased Flow Stability	Flow regulation reduces the washing out of redds or newly hatched fry increasing survival and recruitment rates.
Increased Productivity	Increased habitat volume and increased water temperature, sediment and nutrient loading increases productivity of reservoirs over natural river, particularly in warm-water reservoirs.
Prevention of Invasive Species Spread	Dams can limit the upstream spread of harmful invasive species thereby protecting the long-term sustainability of native species.
Habitat Enhancement	Water draw down can result in mud flats preferred by migratory shorebirds. Many governments are now improving habitat around the newly created lakes to mitigate for habitat losses. These areas have been listed as national Parks and protected areas in many cases.

UPSTREAM IMPACTS

Impact	Cause
Physical	
Erosion	Repeated flooding and drawdowns causes shoreline erosion
Sedimentation	Impoundment slows the flow of water resulting in the deposition of fine sediments
Change in Groundwater Flow	Reservoir acts as recharge area for aquifers affecting downstream groundwater quality and quantity.
Water Seepage	Hydrostatic pressure forces water into porous strata below reservoir.
Water Column Stratification / Surface Water Renewal Time	Water retained in deep reservoirs may become stratified; surface water in reservoir is usually warmer and less dense then flowing waters downstream.
Water Evaporation	Solar radiation and dry wind cause water evaporation from reservoir.
Chemical	
Oxygen Depletion	Decomposition of flooded organic matter (vegetation and topsoil) creates anoxic conditions especially in deepest parts of reservoir.
Change in Nutrient Dynamics	Altered residence time, water temperature, depth, and sediment loading results in altered concentrations of nutrients essential for primary productivity (e.g., phosphorus, nitrogen, carbon).
Accumulation of Chemical Contaminants	Bacterial decomposition of flooded organic matter (vegetation and topsoil) produces soluble methyl mercury, other heavy metals, and releases agricultural pesticides from flooded topsoil.
Eutrophication	Runoff/leaching of fertilizer into reservoir increases nitrate and phosphate concentrations.
Release of Greenhouse Gases	Decomposition of flooded organic matter (vegetation and topsoil) releases carbon dioxide and methane.
Biological	
Excessive Plankton and Algae Growth	Decreased flow and increased supply of nutrients.
Alteration to Littoral, Riparian and Wetland Habitat	Upland and floodplain habitat is destroyed when reservoir is filled; repeated flooding and drawdowns alter remaining emergent & shoreline habitat.
Bioaccumulation of Chemical Contaminants	Chemical contaminants such as mercury bioaccumulate in fish.
Change in Wildlife Habitat	Loss of terrestrial wildlife habitat when reservoir is filled; creates habitat for aquatic furbearers and waterbirds along reservoir.
Change in Aquatic Habitat	Flooding changes riverine habitat to lacustrine habitat. Change results in loss of mainstem and lower tributary spawning areas for fish. Reservoir creates greater depth and habitat volume and can create more productive littoral areas for fish and invertebrates in shallow gradient areas.
Change in Fish Community	Fish community changes from one dominated by riverine species to one dominated by lacustrine species. Potential loss of endemic or species-at-risk.
Disruption to Fish Migrations	Impoundment blocks fish from moving upstream and downstream. Increases mortality of downstream migrating juveniles and salmon smolts.
Prehistoric and Historic Features	
Loss of Archaeological Sites	Creation of reservoir can destroy documented & unknown sites.
Loss of Historic Sites	Creation of reservoir can destroy historic buildings.

DOWNSTREAM IMPACTS

Impact	Cause
Physical	
Erosion	Water below impoundment has increased capacity to erode river channel and floodplains.
Change in Daily and Annual Water Level Variation	Reservoir abates natural fluctuations in seasonal water flow; causes above natural fluctuations in daily flows downstream of peaking facilities.
Change in River Geomorphology	Reservoirs capture sediment and cause the downstream degradation and armouring of the river channel. Release of impounded water can affect development of mid-channel bars, and exert high boundary shear stress, which can affect the bed material. Bed material tends to be made up of large size particles that salmonids cannot use for spawning.
Change in Floodplain Connectivity	Attenuation of natural fluctuations in seasonal water flow, particularly the spring freshet, reduces the duration and frequency of flooding in riparian areas and river valley. Disrupts natural nutrient and sediment loading patterns.
Change in Thermal Regime	Downstream water temperature dictated by level of water withdrawals: top-draw increases summer temperatures and lower winter temperatures while bottom-draw decreases summer temperatures and increases winter temperatures.
Chemical	
Impaired Water Quality	Chemical contaminants in water will be carried downstream, especially if reservoir is stratified. Deep-water releases can reduce downstream dissolved oxygen concentrations.
Oxygen Depletion/Supersaturation	Reduced dissolved oxygen concentrations occur when water releases from deeper portion of reservoir. Supersaturation occurs below hydroelectric facilities using spillways or running turbines in synchronous condense modes.
Change in Nutrient Dynamics	Flow of nutrients disrupted by dam. Downstream water deprived of nutrients essential for biological productivity (i.e., phosphorus, nitrogen, carbon).
Biotic	
Alteration to Littoral, Riparian and Wetland Habitat	Absence of natural water fluctuations or sudden release in water flow alters emergent & shoreline habitat.
Bioaccumulation of Chemical Contaminants	Discharge of contaminated water or movement of contaminated fish.
Change in Floodplain Connectivity	Attenuation of natural fluctuations in seasonal water flow, particularly the spring freshet, reduces the duration and frequency of flooding in riparian areas and river valley. Reduces access to flooded habitat by fish and can result in decreased species diversity, lower population densities, and decreased catch rates for fish relying on floodplain habitats for spawning, rearing, or food production.
Loss of Wildlife Habitat	Alteration of riparian habitat and floodplain connectivity affects the survival, growth, and population status of aquatic furbearers and waterbirds.
Change in Aquatic Habitat	Change in channel morphology, tributary access, sediment loading, nutrient dynamics and water temperature, and hydraulic conditions alters fish habitat and fish species assemblage and distribution.

Impact	Cause
Stranding of Fish and Invertebrates	Regulated flows, particularly below peaking facilities, increases the likelihood of fish, eggs, and invertebrates becoming stranded in dewatered areas below dams.
Change in Lower Trophic Communities	Change in channel morphology, tributary access, sediment loading, nutrient dynamics and water temperature, and hydraulic conditions alters density, diversity, and species composition of plankton, periphyton, and benthic invertebrates.
Disruption to Fish Migrations	Impoundment blocks fish from moving upstream to critical habitat.
Change in Fish Community	Change in water quality, habitat quantity and quality, lower trophic communities and disruption of fish migrations results in reduction of species unable to adapt to new environment and an increase in habitat generalist species.

Appendix F: Lists of Tables and Figures

LIST OF TABLES

LIST OF FIGURES