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South Saskatchewan River

Natural Flow and Apportionment:

Irrigation Return Flows 2001-2005

Phase 1

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Executive Summary

This report produced on behalf of the Prairie Provinces Water Board (PPWB) Committee on Hydrology (COH) reviews the impact of irrigation return flow in the natural flow determinations for the South Saskatchewan River Basin. The report looks in detail at the return flow data obtained from the 13 irrigation districts of southern Alberta as compiled by Alberta Agriculture and from the Water Survey Canada (WSC) with respect to the adequacy of the data in terms of its accuracy and timeliness.

Volumetric flow rates in irrigation return flow channels during the April to October irrigation season were reviewed on an annual basis to compare the difference of utilizing data from all return flow sites to the present approach of using a subset of some of the return flow sites. Results of the analysis of the PPWB return flow sites did not demonstrate any inconsistency in flow in the recent years; however, some individual sites show trends toward increased or decreased return flow which may be due in part to changes in local irrigation practice.

Averaging values from 1994 to 2005 demonstrates that return flow from all the sources comprises approximately 5 percent of the South Saskatchewan River natural flow to the Alberta/Saskatchewan boundary. Further, the data review demonstrated that for this same period approximately 90 percent of the return flow could be accounted for with the combined return flow from the 5 largest districts.

Analysis of the PPWB estimated return flow and current irrigation district's measured flow indicated that PPWB estimates are generally 20 percent more than the return flow compiled by Alberta Agriculture. It should be noted that this is only about 1 percent of total flow; nevertheless, it is recommended that this difference be fully investigated to understand the sources of the difference.

Visits were made to eight irrigation district head offices in order to explore the feasibility of reducing the current annual time step of return flow reporting and the feasibility of incorporating irrigation district return flow data into the PPWB natural flow model.

In 2007, all districts expressed willingness to cooperate in consolidating the irrigation return flow network. It was noted that all the major districts carry out sufficient irrigation return flow monitoring. It is reasonable to assume that if the PPWB was to incorporate these measurements into the natural flow model that the model will produce more accurate results. The level of effort that would be required to demonstrate the overall quality of the numbers and the timeliness of reporting has not been investigated; this would be a major consideration before adopting any new process.

The COH will need to consider their standards for both accuracy and timeliness to assess how much the result can be improved with additional data. Further study is required to understand if the additional information will improve the model and ensure equitable apportionment of the South Saskatchewan River in a timely manner. Nevertheless, this review suggests that the current model tends to under-rate the natural flow and it is expected that a contributing factor may be an over-rating of the irrigation return flow that is being received by the South Saskatchewan River in Alberta. The degree of impact of the difference is likely less than the measurement error in determining the streamflow.

Acknowledgements

The authors would like to express their appreciation to Lawrence Schinkel, Senior Monitoring Technologist for Alberta Agriculture, Food and Rural Development for his generous contributions of time and knowledge that aided greatly in the preparation of this report.

Similarly, the authors thank the managers of the 13 irrigation districts in southern Alberta, who provided both guidance and data that made it possible to complete the comparisons presented in this report.

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Abbreviations

AAFRD	Alberta Agriculture, Food and Rural Development
AID	Aetna Irrigation District
BRID	Bow River Irrigation District
COH	Committee on Hydrology
EC	Environment Canada
EID	Eastern Irrigation District
IJC	International Joint Commission
LNID	Lethbridge Northern Irrigation District
LID	Leavitt Irrigation District
MID	Magrath Irrigation District
MVID	Mountain View Irrigation District
PPWB	Prairie Provinces Water Board
RCID	Ross Creek Irrigation District
RID	Raymond Irrigation District
SMRID	St. Mary River Irrigation District
SCADA	Supervisory Control and Data Acquisition
TID	Taber Irrigation District
UID	United Irrigation District
WID	Western Irrigation District
WSC	Water Survey Canada

Introduction

The Prairie Provinces Water Board (PPWB) is responsible for determining the natural flow of the South Saskatchewan River for apportionment purposes[1]. Senior scientists and professional engineers from the PPWB member agencies form the Committee on Hydrology (COH) which oversees and approves the process by which natural flow is determined. The responsibility for producing regular estimates of natural flow and reports on apportionment surplus and deficit deliveries is held by the PPWB Secretariat. In 2006 the PPWB asked for a review of the return flows used in the South Saskatchewan River Basin natural flow determination. To accomplish this: the PPWB provided approximately 50% of the funds required to conduct the work; the remaining resources were provided by the Water Survey of Canada.

For the 13 irrigations districts in South Saskatchewan River Basin a total of 114 irrigation return flow sites have been identified by Alberta Agriculture. The flow from these sites was represented in the original natural flow model by 42 locations that were expected to comprise the significant proportion of the return flow. Although the original work was not reviewed at the time of writing, the engineer[2] who did the work explained the process in conversation that in an effort to reduce the cost of stream gauging, work completed in the early 1980s demonstrated that there would be no statistical difference in the result if the number of stations was reduced. Least squares regression techniques were employed to select 22 return flow sites with a combined result that was not significantly different from the 42 site result. Some subjectivity was employed in the selection process to ensure that long term sites with large volumes were included.

In 2006 the 114 irrigation return flow sites were still represented by the 22 sites selected in the early 1980s. Of this number, 16 were active sites for which volumetric flow rates are determined by the WSC on a daily basis and 6 sites were discontinued sites for which their individual mean values are used in the PPWB Natural Flow model.

Over time changes have been observed within the irrigation districts: irrigation techniques evolve to improved efficiency (flood to low pressure sprinkler), the amount of irrigated area has generally been increasing although some reductions have also been noted, delivery systems cycle from new to degraded to rehabilitated, some open channel delivery systems have been replaced with pipelines, and demand generally increases both in the agricultural sector and in the municipalities within the basin that use surface water resources. It stands to reason that as the irrigation systems evolve so too should there be evolution in the parameters that are used in the natural flow model.

Two options exist for incorporating return flow data in the natural flow model. One is the current approach which is to monitor a subset of the return flow sites and to estimate the total return flow through periodic statistical re-calibrations where the total return flow is compared to the subset or index stations. The benefit of such an approach is to reduce the level of effort

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[1] The use of the term “natural flow” in this document refers to the quantity of water to be apportioned. This quantity of water does not include the portion that is diverted from the St. Mary River to the Milk River upstream of the Canada/USA international boundary.

[2] Authors’ personal conversation with Vir Khanna, Environment Canada, Calgary, December 2006.

in collecting and reporting the data; however, the downside is that as the irrigation methods and areal extent of the irrigated land evolve, the relationship of the index value to the true value will change, thus requiring the re-calibration of the index values. The alternative is to monitor and report all of the return flow. The benefit of monitoring all of the return flows is to be independent of changes within the irrigation system; however, to accommodate monitoring at all return flow sites the current infrastructure of monitoring and reporting would need to be improved significantly. Currently, the South Saskatchewan River natural flow is computed and reported on a quarterly basis. Arguably, all data sources would need to accommodate the same reporting frequency.

It is expected that the monitoring of all the sites and the reporting of accurate results in a timely manner may be difficult to achieve. This paper attempts to demonstrate the impact of return flow subset monitoring and looks at opportunities for alternative sampling strategies and their impact on natural flow model results.

Background

As specified by the PPWB 1969 Master Agreement on Apportionment:[3] South Saskatchewan River flow apportionment, between the provinces of Alberta and Saskatchewan, is based on estimates of natural streamflow.

Natural flow determinations consider the following:

1. Measured flow present in the stream channel.
2. Changes in storage (impoundments or storage in reservoirs either along the main stem or off stream).
3. Estimates of natural losses from the system due to channel seepage and evapotranspiration.
4. Estimates of natural gains to the system due to precipitation, snow melt, and ground water inflow.
5. Net Diversions from the stream and/or into the stream.
6. Consumptive Use.
7. Return flow to the stream from the irrigation districts.

Alberta Agriculture, Food and Rural Development (AAFRD) reports[4] that *"return flow expressed as a percentage of gross diversion varies substantially from district to district. It is highest in the WID, averaging 56.5%, and lowest in the SMRID averaging 7.2%."* For the years 1997 through to 2000, AAFRD reports an average of 22% return flow as a percent of gross diversion.

Over time the proportion of return flow in the natural flow calculation is impacted by changes to a number of factors:

1. The extent of the irrigation distribution systems.
2. The demand for water (i.e., consumptive use).

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[3] Prairie Provinces Water Board (Canada). *The 1969 Master Agreement on Apportionment and bylaws, rules and procedures.* Regina, Sask: Prairie Provinces Water Board. (1992).

[4] Alberta Irrigation Projects Association, & Irrigation Water Management Study Committee (Alta.). (2002). *South Saskatchewan River Basin irrigation in the 21st century*. Lethbridge, Alta: Alberta Irrigation Projects Association.

3. Changes in application/distribution of the water to the crops (e.g., flood irrigation, sprinkler, low pressure center-pivot, open channel vs. pipeline)
4. Water availability (drought/abundance/flood)
5. Accuracy of the measured values.

Streamflow in an irrigation return flow channel is comprised of four components:

1. Diverted water that is used to fill the irrigation canals and serves to convey water to the field but is not applied to the fields
2. Diverted water applied to the fields in excess of the field's capacity to take up the water and subsequently draining back to the irrigation canal network and ultimately returning to the river.[5]
3. Increased drainage or interception of natural precipitation and snowmelt in quantities greater than would normally contribute to the river.
4. Natural flow in the irrigation return flow channels from ground water and surface drainage.

The proportion of the above components is impacted by natural climatic variation and by changes in agricultural practice over time.

It is well accepted that a better understanding of the water supply and use (precipitation, diversion, storage, conveyance, application, return flow, and losses) will lead to better management practice: increasing agricultural productivity and lessening environmental impacts (Irrigation Water Management Study Committee, 2002)[6].

Historically, apportionment of streamflow requires three things: first is an agreement of how natural flow will be shared; second, agreement as to what the natural flow should be, i.e., the quantity of water that would have naturally been carried by the river in absence of anthropogenic influence cannot be measured but must be estimated; and third, a demonstration of water management performance specifically to show that downstream jurisdictions received their appropriate allotments in terms of both flow volume and timing.

Typically the natural flow determination is achieved by an accounting of water availability and use for the purpose of demonstrating if downstream jurisdictions have received their share of the streamflow in accordance with the apportionment agreement. As demand for the water resources increases the difficulty in meeting downstream commitments also increases; the tolerance for lack of accuracy is reduced and the timing of reporting becomes more critical[7].

In 1948, the Prairie Provinces Water Board Agreement was signed between Alberta, Saskatchewan, Manitoba and Canada. A Board was established to recommend the best use of

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[5] Note: the return is not necessarily back to the source water stream e.g., from Bow River to Red Deer River, from St. Mary River to Oldman River.

[6] Alberta Irrigation Projects Association, & Irrigation Water Management Study Committee (Alta.). (2002). *South Saskatchewan River Basin irrigation in the 21st century*. Lethbridge, Alta: Alberta Irrigation Projects Association.

[7] In the case of the South Saskatchewan River basin, apportionment reporting presently occurs every 3 months. Requirements for natural flow determinations and the associated apportionment computations in real-time are expected to be in place within 10 years.

inter-provincial waters and to recommend allocations between provinces. After 20 years, changes in regional water management perspective resulted in the need to amend the role of the Board, consequently, all parties entered into the Master Agreement on Apportionment on October 30, 1969[8].

Apportionment of the South Saskatchewan River between Alberta and Saskatchewan is based on the October 30, 1969 Master Agreement. Schedule A of the agreement is an apportionment agreement between Alberta and Saskatchewan. According to this schedule:

> "an equitable apportionment of such waters as between the adjoining Provinces of Alberta and Saskatchewan would be to permit the Provinces of Alberta to a net depletion of one-half the natural flow of water arising in or flowing through the province of Alberta and to permit the remaining one-half of the natural flow of water of each such water course to flow into Province of Saskatchewan, subject to certain prior rights as are hereinafter set forth or may hereafter be mutually agreed upon in writing."

The South Saskatchewan River, immediately downstream of the Alberta/Saskatchewan boundary, receives water from three major sub-basin areas: the Oldman River, the Bow River, and the Red Deer basin. The headwaters of the Red Deer and Bow River are entirely in the Alberta portion, and rise on the eastern slopes of the Rocky Mountains. Similarly, the Oldman rises in Alberta's Rocky Mountains, with some major tributaries, i.e., Waterton River, Belly River, Lee Creek, and the St. Mary River, rising in Montana. The St. Mary River is subject to both international apportionment (IJC Boundary Waters Treaty of 1909) and since it is a tributary to the South Saskatchewan River, to inter-provincial apportionment (PPWB Master Agreement, 1969).

It is the responsibility of the PPWB to administer the Master Agreement, which is achieved by application of various procedures, rules, and guidelines, as overseen by the Committee on Hydrology, to apportion eastward flowing inter-provincial waters and to ensure that apportionment is carried out in an equitable fashion.

The apportionment of the South Saskatchewan River Basin is complicated by the St. Mary River Diversion in the United States under the 1909 Boundary Water's Treaty as it pertains to the St. Mary and Milk Rivers. United States entitlements on the St. Mary and to some extent Canadian obligations on the Milk River are managed through a diversion structure upstream of the Alberta/Montana international boundary. The US shares of the St. Mary River[9], as determined under the 1909 Boundary Waters Treaty are considered to be unavailable to Canadian uses; consequently they are not to be included in the South Saskatchewan River Basin apportionment calculations. As such, what is referred to as the PPWB South Saskatchewan Natural Flow Model is misleading as the results are technically the

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[8] Environment Canada PPWB web site (2007), "History of the PPWB" http://205.189.8.19/water/fb01/fb00s52.en.html

[9] The St. Mary River Diversion upstream of Canada is also used to repay Canadian deficit deliveries on the Milk River. It is unclear if the PPWB natural flow model considers any of the activities above the USA-Canada international boundary in its natural flow determinations. For example, all deficits on the Milk are for Alberta uses of water. It needs to be understood how PPWB approaches the question of St Mary River water being diverted in the USA to accommodate Alberta deficits on the Milk River.

“apportionable flow”, and not the natural flow. This report uses the more general term “natural flow” in discussing the approach, understanding that it does not strictly apply to the case of the South Saskatchewan River.

The streamflow depletion introduced through the operations of the 13 irrigation districts is one of the major components in determination of the natural flow and the apportionment of the South Saskatchewan River. Diversions are measured directly while the total irrigation return flows are estimated from a sample of the total. Data from the sample of return flow sites are ingested into a model that was establish from a study of all return flow sites observed in the late 1970s and early 1980s. The model has been amended from time to time.

In analyzing the components of the natural flow model it is important to understand the context for which the model is run.

Natural flow determinations are computed for three purposes:

1. To identify the obligation of upstream jurisdictions to ensure that agreed upon streamflow passes a boundary in terms of quantity, and timeliness.[10]
2. To demonstrate performance, i.e., surplus or deficit flows at the boundary.
3. To demonstrate compliance, i.e., accounting for corrective action when deficits are identified and offsetting surplus flows are required.

For the purpose of apportionment, natural flow is determined at the apportionment boundary. Apportionment boundaries are typical geopolitical boundaries such as the meridian demarking the separation of territory between the province of Alberta and the province of Saskatchewan.

To identify obligations and plan water management operations to meet those obligations, the upstream operator must run a natural flow model to forecast future flows. Consideration of forecast applications is not part of this study. The PPWB Secretariat’s main task is to demonstrate performance and compliance. This work is done after the fact and incorporates a variety of measured values.

A generic schematic for natural flow accounting is presented in Figure 1. The amount of unaccounted streamflow can be used as a measure of the veracity of the model.

Considering that the natural flow includes natural losses and gains i.e., items 1, 3, and 4 in Figure 1; and that the model will account for “Net Diversions” which includes: consumptive uses and other anthropogenic influences, i.e., items 2 and 6; and that streamflow, diversions out[11], and return flow i.e., items 5, 7, and 8 are measured and reasonable accurate, the flow accounting will proceed as follows:

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[10]Obligations for water quality are also of concern but these are tracked separately.

[11] The general case is that diversions are removed from the main stem; however, certain streams, such as the Milk River in northern Montana/southern Alberta receive significant diversions augmenting the natural flow. In the equations shown here the term Net Diversions is the difference between total diversion away from the stream and the total diversions into the basin from external source (i.e., including any storage releases but not including return flow).

Given:

Natural Flow = Gauged Flow downstream + Consumptive Use in the basin + Unaccounted flow

And

Consumptive Use = Net Diversions – Return Flow

Net Diversions = Water Removed from the stream for consumption, storage, or increased losses caused by storage (e.g., evaporation or seepage from reservoirs), less storage released back to the stream from storage facilities and/or water diverted into the stream from some other sources.

Then:

Equation I

Gauged Flow at Boundary + Unaccounted Flow = Natural Flow in Basin – Net Diversions + Return Flow

Regrouping:

Equation II

Unaccounted Flow = (Natural Flow in Basin–Gauged Flow at Boundary) – (Net Diversions – Return Flow)

Understanding that for the South Saskatchewan River Basin: Gauged Flow at Boundary, Net Diversions, and Return Flow to be reasonably accurate results from metering, and that natural flow for this basin is always equal to or greater than gauged flow[12],

Then if:

Unaccounted Flow = 0, the natural flow model accurately accounts for return flow in the basin.

Unaccounted Flow < 0, the natural flow model either under represents the flow in the basin or return flow is also under estimated.

Unaccounted Flow > 0, the natural flow model either over represents the flow in the basin or return flow is also over estimated.

The above assumes all other components of the Natural Flow Model are correct and that diversions and streamflow are gauged to a higher degree of confidence than the return flow. This approach addresses the theoretical differences but does not address the magnitude of the difference. One should also consider the quantity of water in the natural flow determination as compared to the quantity of the return flow and the relative degree of uncertainty when assessing the impact of the unaccounted for flows.

[12] For the South Saskatchewan Natural Flow must always be greater than the gauged flow. This is not always the case as in for the example of the Milk River in which the natural flow during the irrigation season is very much less than gauged flow due to the significant flow diverted to the Milk River from the St. Mary River.

Figure 1. Flow Accounting Schematic

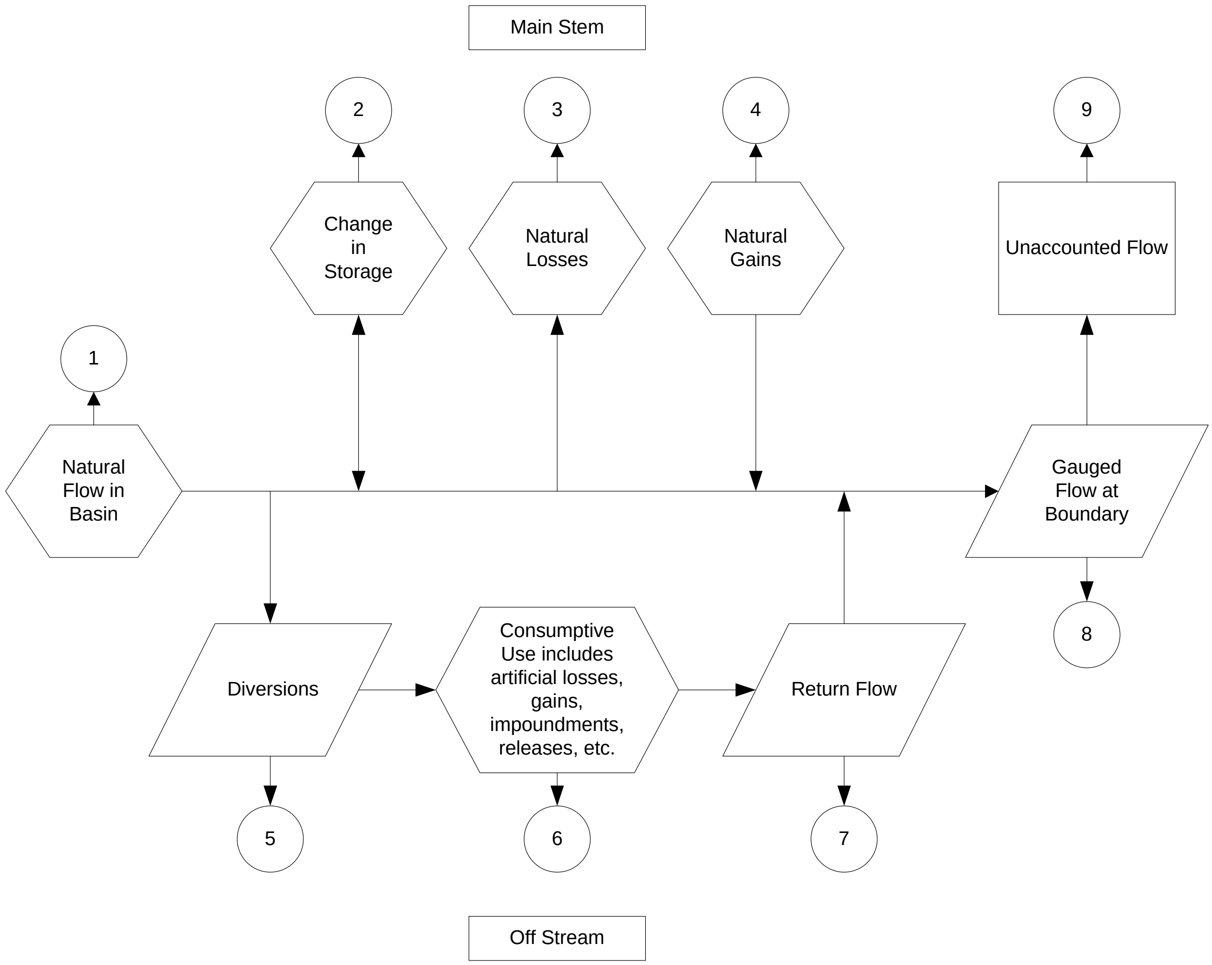
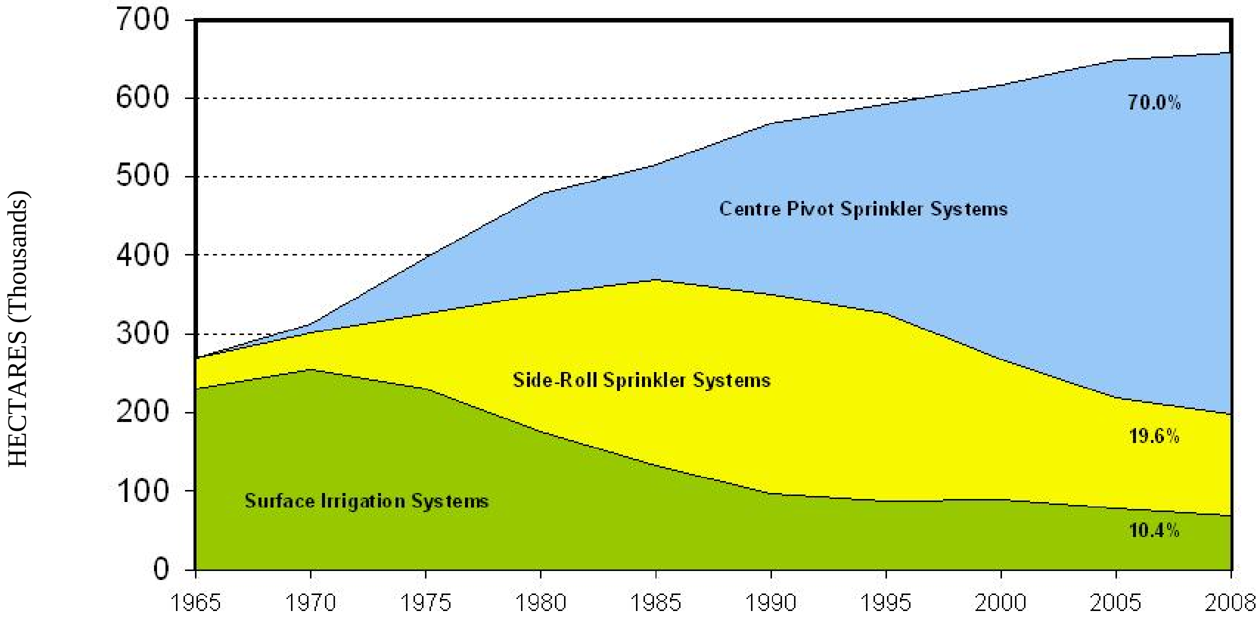


Figure 2: Irrigation System Mix



Source: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/irr4478#top

Once the basic components of the natural flow accounting process are established, one is faced with tracking the dynamic nature of the inter-relationships between model components. In particular the operator of the natural flow model should be aware of the evolution in irrigation practices, e.g. enhanced water distribution systems (Figure 2). Monitoring technologies have evolved as well, creating opportunities for more accurate and timely natural flow determination by incorporating metered diversions from and return flow to the natural water courses in 13 irrigation districts.

The PPWB-COH understands the need for periodic review of the natural flow model for the South Saskatchewan River to ensure that equitable apportionment is carried out with the best possible information. The terms of reference provided by the PPWB-COH for this study divided the work into three phases. This report is restricted to the objectives of Phase 1. It is expected that a decision on the requirement for subsequent work will be made by the PPWB-COH and based in part on the results of Phase 1:

Phase 1:

To review all pertinent data available from the irrigation districts and from the Water Survey Canada with respect to adequacy of the data in terms of accuracy and timeliness; as well as opportunities for network consolidation.

Phase 2:

Subject to Board approval and with agreement from the data providers: implement recommendations from Phase 1 for obtaining more reliable estimates of return flow. This may involve changes to field observation, consolidation of networks, training of field parties, development of improved computational process, development of improved timeliness of reporting.

Phase 3:

Under the direction of the Committee on Hydrology (COH) and applying the results of Phase 1 and Phase 2: establish procedures for the improved estimations of diversion and return flows and to implement the changes in the natural flow model for the South Saskatchewan River Basin.

Again, this study addresses only the objectives of Phase 1, which has been divided into two parts:

1. To evaluate the current data acquisition and analysis process.
    - A review of all the data available from both irrigation districts and the Water Survey Canada was conducted with respect to adequacy of the data in terms of accuracy and timeliness.
2. To investigate the feasibility of consolidating data collection networks from all the irrigation return flow monitoring sites in South Saskatchewan Basin in Alberta.
    - This work was completed through meetings with the 13 irrigation districts and other data collection agencies.

Part 1 Methods

> *To review the pertinent data available from both the irrigation districts and the Water Survey Canada with respect to adequacy of the data in terms of accuracy and timeliness.*

Part one is concerned with the adequacy (representation of total) and accuracy of the existing data. In terms of return flow, 14 separate data sources were reviewed: one supplied by the Water Survey Canada and others supplied from the 13 irrigation districts. The model currently being used relies exclusively on data provided by the Water Survey of Canada as directed by the PPWB.

A list of return flow stations, which were used in previous studies, was prepared from PPWB reports. It's observed that out of 42 stations that were used to develop regression equations only 18 were active in 2007 (Appendix A). Historical daily return flow data for the stations monitored by Water Survey of Canada was obtained from Water Survey of Canada - Data Products and Services website[13]; diversion data for the computation purposes was provided by PPWB; and Irrigation Branch of Alberta Agriculture and Rural Development provided the seasonal irrigation return flow and diversion data for most of the irrigation districts. Data from Water Survey of Canada and the Irrigation Districts were compared in an effort to demonstrate any trends, changes, or other differences.

Part 1 Results

WSC Return Flow Sites

Review of the data from the Water Survey return flow sites in the irrigation districts did not show obvious inconsistencies in flow throughout the recent years as demonstrated by the mass curve of seasonal flows (Figure 3); however, there is variability in the magnitude of seasonal total flow among the sites. Some individual sites show obvious variability in magnitude over the years e.g., 05CE005 Rosebud River at Redland, for other sites the variability is less obvious e.g. 05AG003 Expanse Coulee near the Mouth in the Bow River Irrigation District (Figure 4).

A comparison of the proportion, trends and net seasonal flows of the return flow sites monitored both by Water Survey of Canada and by irrigation districts was made to demonstrate if any significant differences exist between estimated and measured values. Currently, in the 13 irrigation districts, there are a total of 92 active irrigation return flow sites; the distribution of irrigation return flow sites among the districts is shown in Appendix C.

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[13]Canada, Meteorological Service of Canada, & Water Survey of Canada. (2007). *HYDAT Surface water and sediment data*. Ottawa: Environment Canada. Water Survey of Canada website (2007) http://www.wsc.ec.gc.ca/products/main_e.cfm?cname=products_e.cfm

Consolidation of the data collection networks should provide for a better understanding of the quantity of flow from the districts and its variability; more importantly improving the return flow data should result in more accurate natural flow determinations which will lead to more correct apportionment of the flow. Naturally, increasing the extent of the monitoring network will result in increased cost; it is outside the scope of this study to assess costs. Further, it is also expected that at some point the incremental quantity of return flow may be so small as to be masked in the accuracy of the overall result. The benefit of knowing that all return flow is accounted for so that the index model does not require periodic calibration and adjustment needs to be weighed against the acceptable level of uncertainty and the amount of work required to produce the answer.

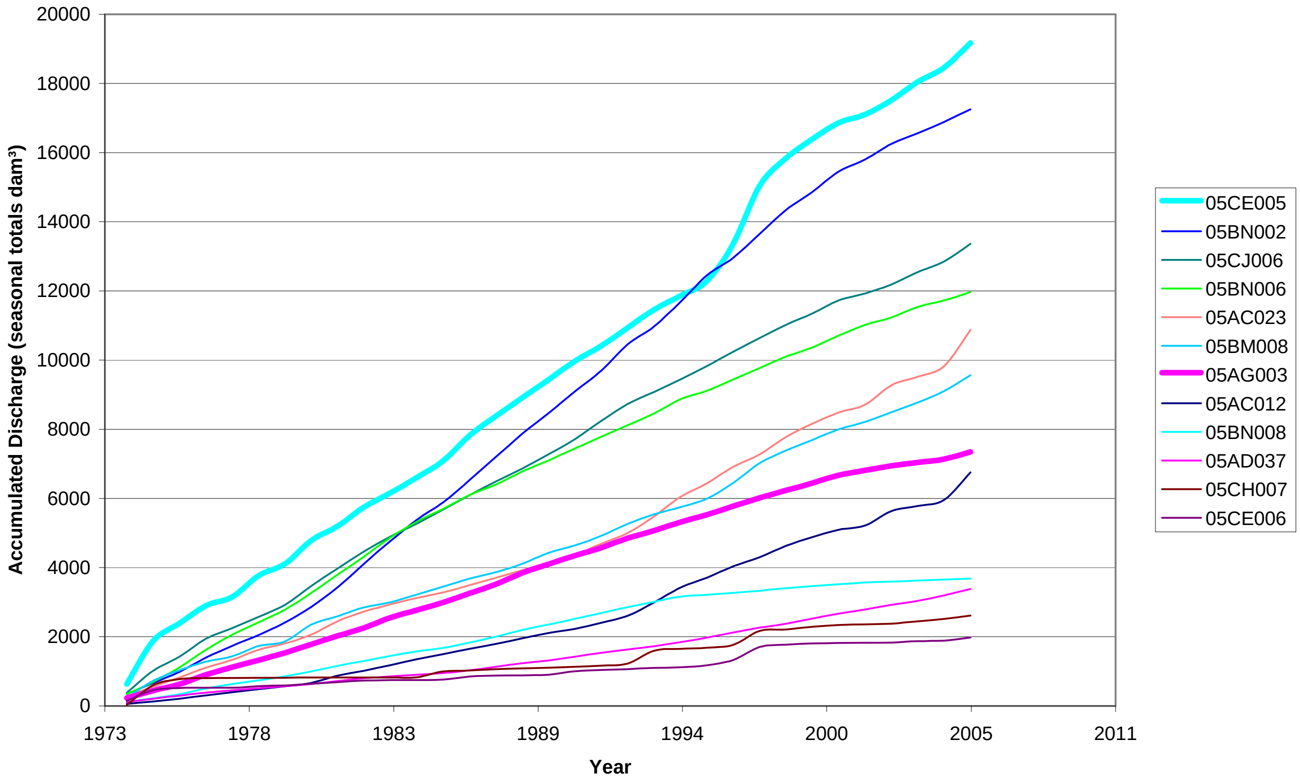
The return flow site 05AG003 Expanse Coulee near the Mouth in the Bow River Irrigation District is provided as an example of changes in return flow rates over time. In Figure 4, the label "A" represents the conditions at the time when the current natural flow model was developed; "B" shows a change in response since 1999. Similar changes for other return flow sites have been observed (Figure 3). For some districts in recent times the return flow rates appear to be increasing; for other districts it is increasing. However, for the most part long terms trends across Southern Alberta are not obvious.

It is important to note in the hydrograph portion of Figure 4 that the seasonal "return flow" for the year 2005 shows a marked increase over surrounding years. This is due to the extremely high rainfall volumes that year causing wide spread flooding in Southern Alberta. This demonstrates that the return flow data is impacted by natural surface drainage. Most years the proportion of natural runoff to return flow is small. The return flow data provided by Water Survey of Canada is limited to the flow in the channel, no attempts are made by the Water Survey to subtract out the contribution from precipitation runoff. It is expected that such corrections should take place in the PPWB computer models that determine the natural or apportionable flow.

Impact of Precipitation on Return Flow

In consideration of the four components of return flow identified in the introduction, it is important to understand the impact of precipitation. A review of 29 climate data sites in the basin for the period from 1986 to 2005 provides an average of 327 mm of precipitation for the 214 days from April 1 to October 31. Over the combined 5250 km^2 that make up the 13 irrigation districts, this would amount to 1,717,000 dam^3 per irrigation season. How much of this volume runs off the land and is intercepted by irrigation return flow channels was not determined in this study. Figure 5 demonstrates no trend in precipitation rates between the years 1986 to 2005, recognizing extremely high rates in the last year of record shown, and the extremely low rate for the year 2001.

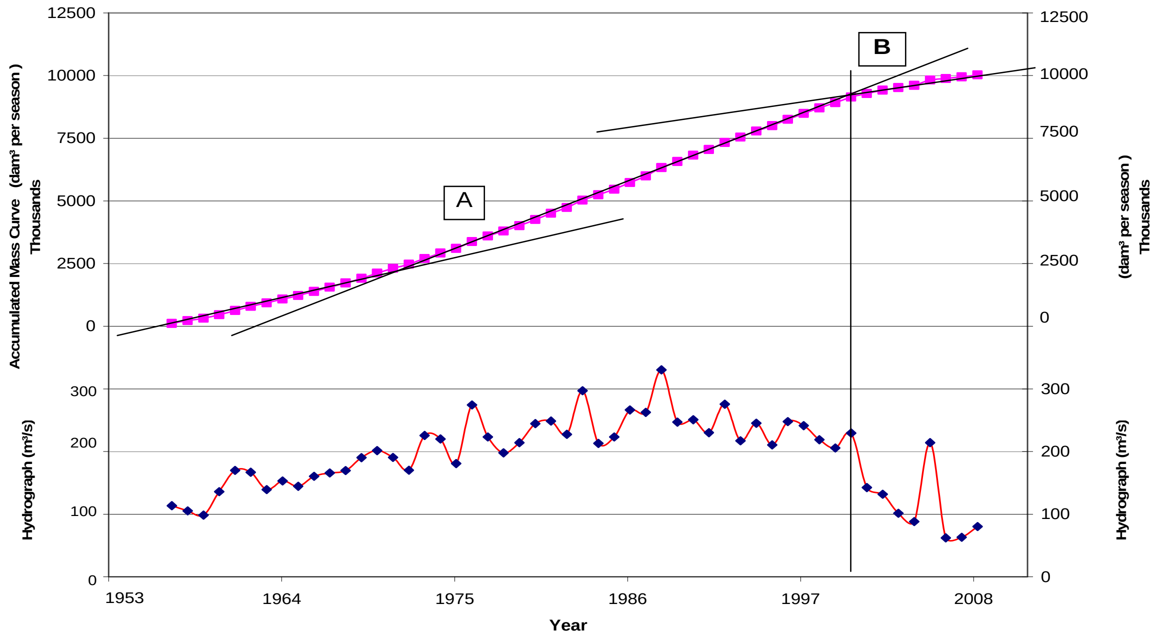
Figure 3: Mass Curve: Accumulative Seasonal Volumes at WSC Sites (dam³/irrigation season)



Line Style	Station Number	Station Name (Irrigation District)	Drainage Area (km^2)
	05CE005	Rosebud River at Redland (WID)	3580
	05BN002	Twelve Mile Creek near Cecil (EID)	2790
	05CJ006	Onetree Creek near Patricia (EID)	496
	05BN006	New West Coulee near the Mouth (EID)	312
	05AC023	Little Bow River near the Mouth (LNID)	5920
	05BM008	Crowfoot Coulee near the Mouth (WID)	1360
	05AG003	Expanse Coulee near the Mouth (BRID)	1920
	05AC012	Little Bow River below Travers Dam (BRID)	5370
	05BN008	Bow River Development Drain D near Vauxhall (BRID)	N/A
	05AD037	Piyami Drain Near Picture Butte (LNID)	N/A
	05CH007	Berry Creek near the Mouth (EID)	3720
	05CE006	Rosebud River Below Carstairs Creek (WID)	753

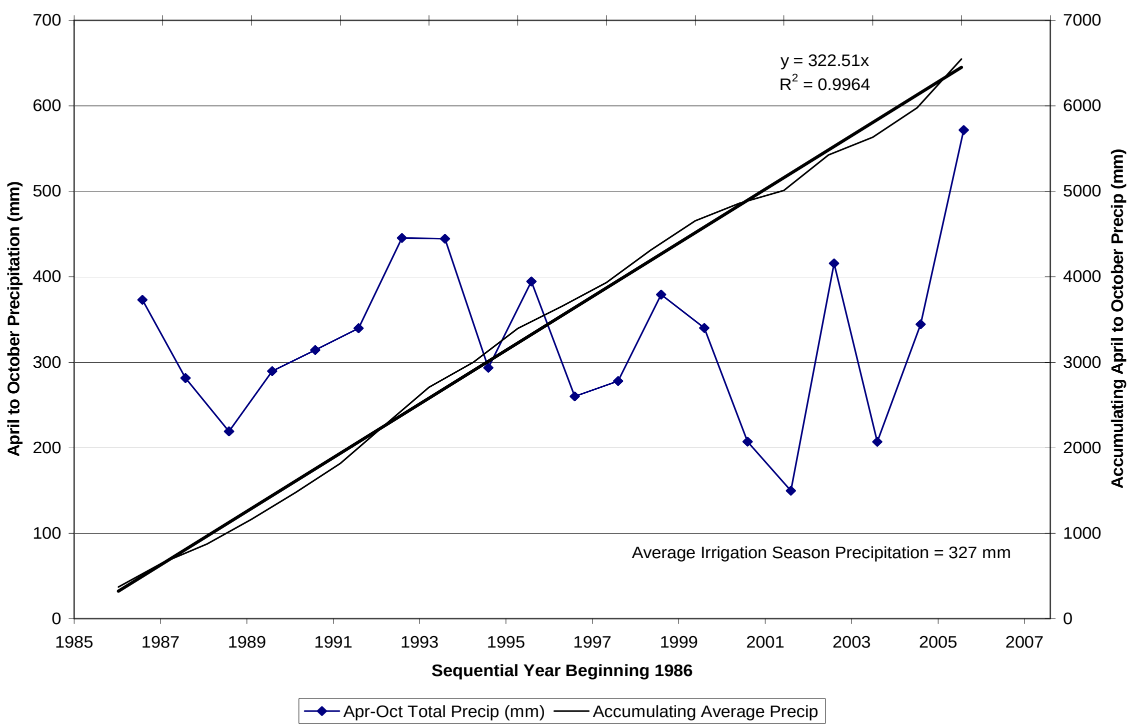
Data Source: Water Survey of Canada

Figure 4: Seasonal Mass Curve Coupled with Daily Return Flow Hydrograph 05AG003 – Expanse Coulee near the Mouth (B.R.I.D)



Data Source: Water Survey of Canada

Figure 5: Alberta Irrigation Districts Average April-October Precipitation (EC Data)



Data Source: Environment Canada

Comparison of the 13 Irrigation Districts

It is observed that not all irrigation districts monitor and report return flow data. In 2007, Ross Creek (RCID) and United irrigation districts (UID) did not have any active return flow stations on their systems. RCID is very small with a total area of 490 hectares and has converted its conveyance to pipeline so significant quantities of return flow are not anticipated. UID has estimated that in the past approximately 10 percent of its diversion becomes irrigation return flow[14]; currently they are in the process of installing some return flow monitoring sites in the district. Bow River Irrigation District (BRID) and Lethbridge Northern Irrigation District (LNID) have the longest period of record for metered return flow. Only data with same period of record was considered for analysis i.e. 2001 to 2005. Return flow data from Lethbridge Northern Irrigation District for 2005 was not available at the time the analysis was carried out.

The quantity of water diverted for irrigation purposes results from a combination of several influences, e.g., total irrigated area, type of crop production, climatic condition of the district, distance from the diversion, canal capacity, and offline storage requirements and/or availability. In southern Alberta, irrigation storage reservoirs are also used to provide for community recreation as parks, swimming, fishing, boating, and for domestic and municipal water supply. Alberta Irrigation (AAFRD, 2006)[15] does not indicate any major shift in the cropping pattern but there was a slight increase of forage production. The report further indicates that the percent of specialty crop (Dry Beans, Potatoes, and Sugar Beets) had not changed since 1999.

The period of record chosen for analysis was influenced by the available record. When reviewing the charts presented it is important to keep in mind that the year 2001 presented one of the driest years on record and the year 2005 presented one of the wettest. Without this context a quick review of total diversion might lead to the conclusion of a declining trend in irrigation diversion rates. It is more likely that very dry years (2001) create higher demand, and very wet years (2005) create a lesser demand. Considering the very short period of record and the extremes of the start and finish years, the total diversion from each district does not show much variability in demand for water that can’t be explained by the range of climatic influence (Figure 6). In terms of the range in quantity of diversion from district to district, the diversions EID (Eastern Irrigation District) and SMRID (St. Mary irrigation District) being the largest districts had higher diversion as compared to the other districts.

Comparison of irrigation return flows among irrigation districts show variation in magnitude (Figure 7) mostly depending upon the size of the irrigation district, the conveyance system, and irrigation methods. The increase in return flow observed for 2005 is due in part to significant overland flow in response to extremely high precipitation events.

Note that for Figures 6 and 7 the ordinate scale is logarithmic. Also note that values for RCID, LID, and UID were not available.

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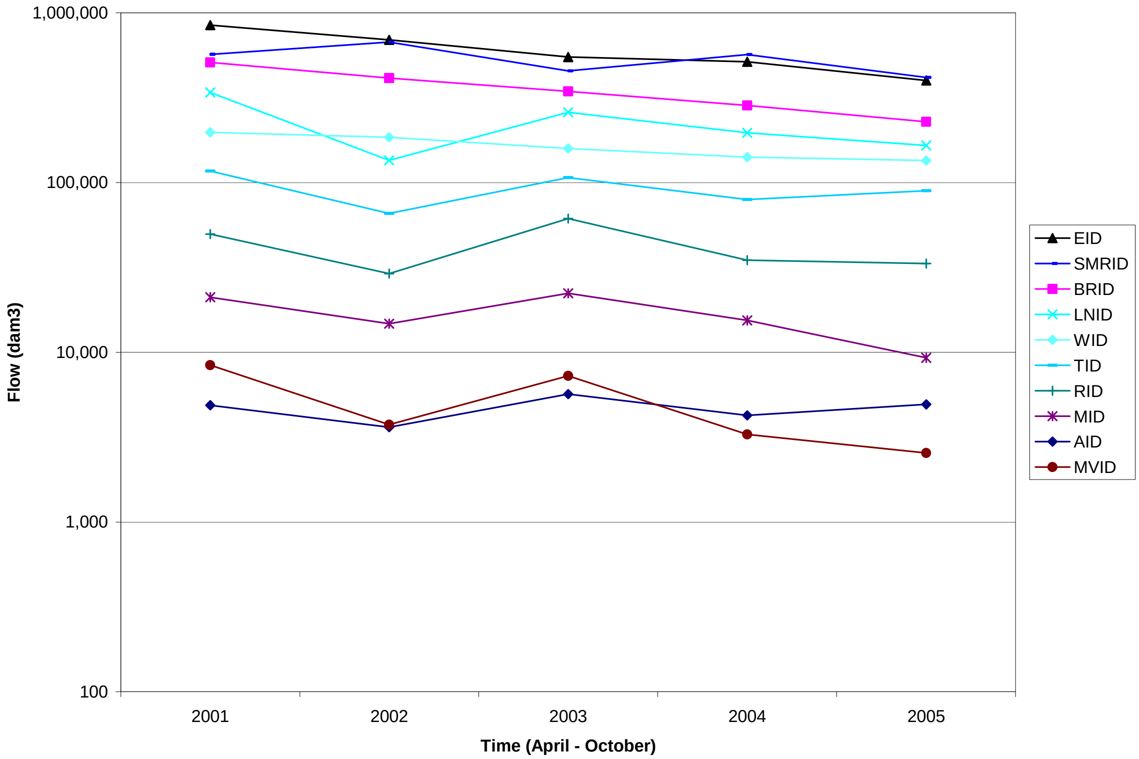
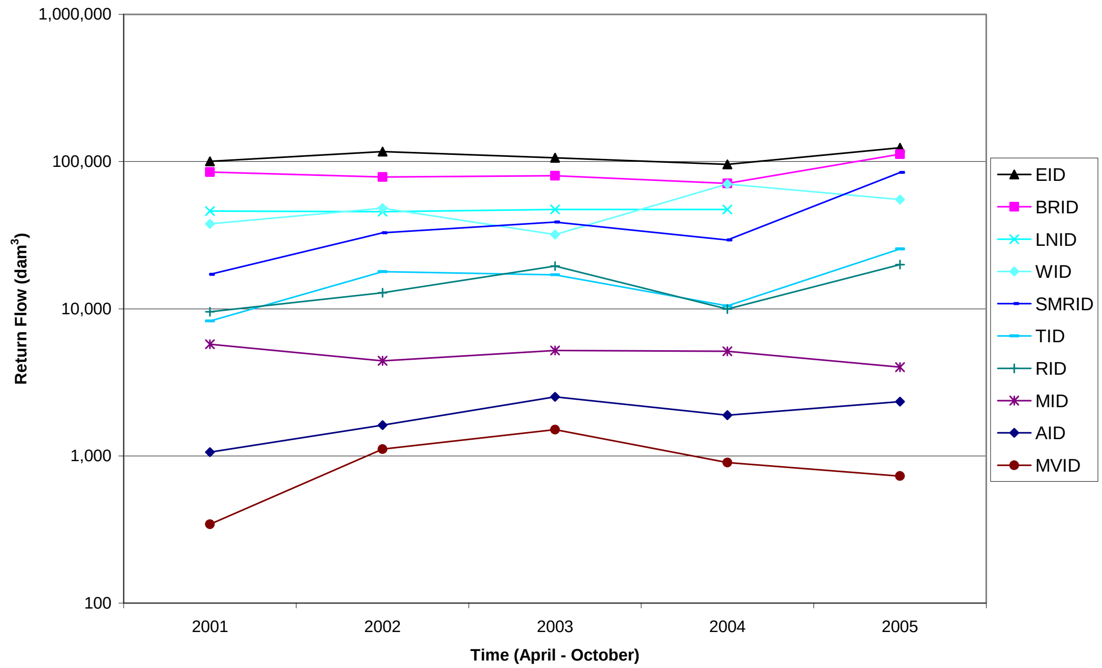
[14] Telephone interview.
[15] Alberta Agriculture Statistics Yearbook (2006)
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sdd11863

Figure 6: Alberta Irrigation District Diversion Comparison



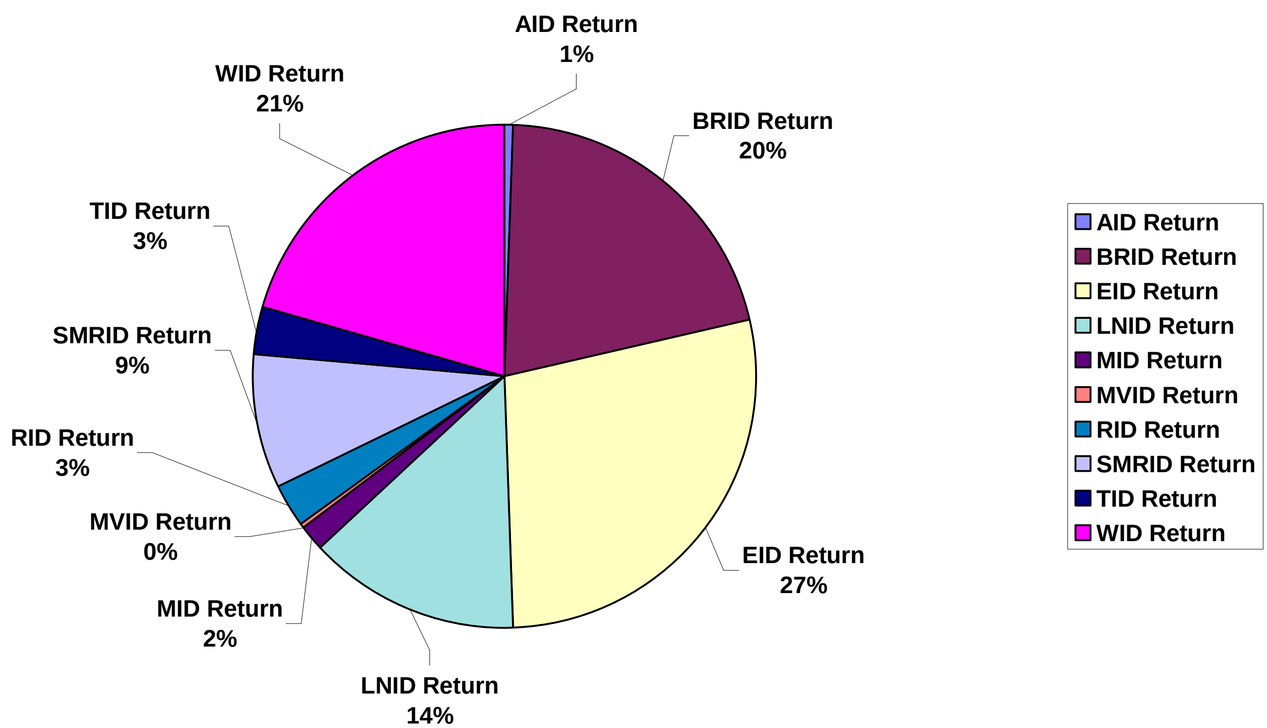
Data Source: Alberta Agriculture

Figure 7: Alberta Irrigation Districts Return Flow Comparison



Data Source: Alberta Agriculture

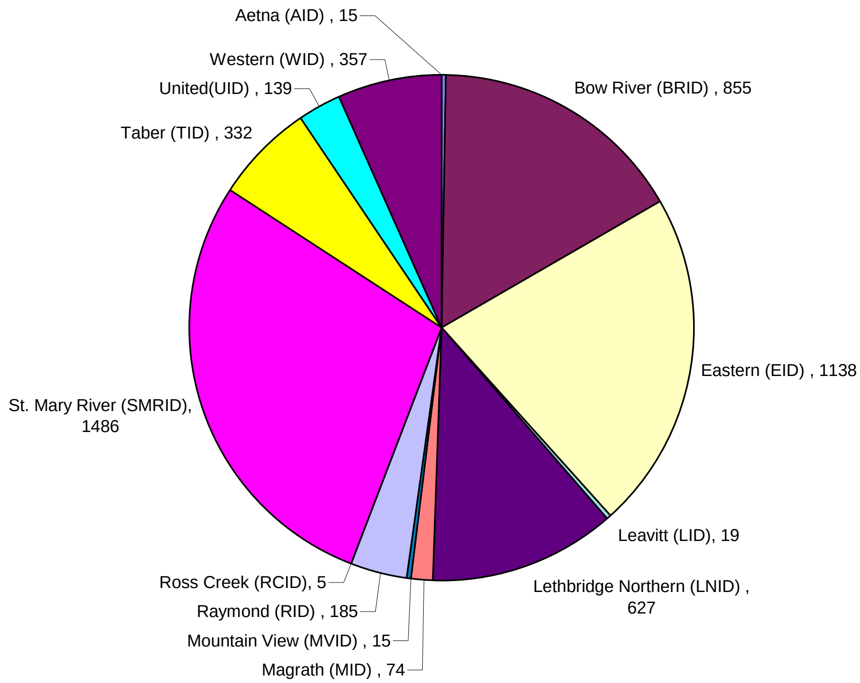
Figure 8: Proportional Comparison of Irrigation Districts Return Flow as percent of total Return Flows for 2004



Data Source: Alberta Agriculture

The proportion of the total irrigation return flow from the 13 Alberta Irrigation Districts for the year 2004 is presented in Figure 8. This year was chosen as the most recent complete year of record that was not impacted by the extremely high precipitation events that occurred in 2005 or the extremely dry period of 2001. For the year shown, approximately 90% of the return flow is generated by five of the districts. These five districts account for more then 85% of the irrigated area within all districts. For the year 2004 EID has the highest return flow among all districts and it is the second largest district in terms of area. It has the longest length of conveyance works, and by far the highest area of the surface irrigation; all these conditions contribute to high return flow values.

Figure 9: Comparison of Irrigation Districts Area (km^2)



Data Source: Alberta Agriculture

Note: Figure 9 demonstrates the proportion of the irrigated area for each of the 13 Alberta Irrigation Districts for the year 2004. This year was chosen to coincide with the year of record shown in Figure 8. For the year shown, approximately 85% of land area falls within the five largest Irrigation Districts: St. Mary River ID (28%), Eastern ID (22%), Bow River ID (16%), Lethbridge Northern ID (12%), Western Irrigation District (7%)

Table 1: Irrigation Districts Seasonal Return Flow as Percent of Diversion (2004)

District	Area (km^2)	Diversion (dam^3)	Ratio: Diversion / Area (dam^3/km^2 i.e., mm)	Return Flow (dam^3)	Ratio: Return Flow / Diversion
Aetna (AID)	15	4,240	283	1,890	45%
Bow River (BRID)	855	285,000	333	71,010	25%
Eastern (EID)	1138	515,000	453	96,000 (estimate)	19%
Lethbridge Northern (LNID)	627	196,000	313	47,000	24%
Magrath (MID)	74	15,400	208	5,140	33%
Mountain View (MVID)	15	3,280	219	900	27%
Raymond (RID)	185	34,800	188	9,940	29%
St. Mary River (SMRID)	1486	568,000	382	29,300	5%
Taber (TID)	332	79,000	238	10,500	13%
Western (WID)	357	141,000	395	70,500	50%
Totals or Average	**5084**	**1,842,000**	**362**	**342,180**	**19%**
Estimates base on Averages[16]		**Estimates**	**Average**	**Estimates**	**Average**
Ross Creek (RCID)	5	1,812	362	337	19%
Levitt (LID)	19	6,884	362	1279	19%
United (UID)	139	50,362	362	9355	19%
Estimated Totals Based on Averages	5247	1,901,000		353,000	
St.Mary / Milk Diversion[17]		228,000		0	
Total		2,129,000		353,000	

Data Source: St. Mary/Milk Diversion Data from WSC, all other data from Alberta Agriculture (note: original data in acre-feet)

[16] Data for United (UID), Leavitt (LID), and Ross Creek (RCID) irrigation districts was not available from Alberta Agriculture at the time of writing. Estimates were produced by Environment Canada based on the areal weighted averages.

[17] The difference between Natural flow on St. Mary River at International Boundary and actual flow for the year 2004 was 283,000 dam^3. Table 1 shows volumes for the April to October irrigation season only for which the difference was 228,000 dam^3. IJC reported irrigation diversions for the irrigation season the 224,000 dam^3 and accounts only for the flow at the end of the diversion canal and does not consider changes to reservoir contents or losses along the way.

Table 1a: Irrigation Districts Seasonal Return Flow as Percent of Diversion (2004)
Note: St. Mary Diversion not included.

District	Area (km^2)	Diversion (dam^3)	Ratio: Diversion / Area (dam^3/km^2 i.e., mm)	Return Flow (dam^3)	Ratio: Return Flow / Diversion
Aetna (AID)	15	4,240	283	1,890	45%
Bow River (BRID)	855	285,000	333	71,010	25%
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Lethbridge Northern (LNID)	627	196,000	313	47,000	24%
Magrath (MID)	74	15,400	208	5,140	33%
Mountain View (MVID)	15	3,280	219	900	27%
Raymond (RID)	185	34,800	188	9,940	29%
St. Mary River (SMRID)	1486	568,000	382	29,300	5%
Taber (TID)	332	79,000	238	10,500	13%
Western (WID)	357	141,000	395	70,500	50%
Totals or Average	**5084**	**1,842,000**	**362**	**342,180**	**19%**
Estimates base on Averages[18]		**Estimates**	**Average**	**Estimates**	**Average**
Ross Creek (RCID)	5	1,812	362	337	19%
Levitt (LID)	19	6,884	362	1279	19%
United (UID)	139	50,362	362	9355	19%
Estimated Totals Based on Averages	5247	1,901,000		353,000	
St. Mary / Milk Diversion[19]		Not counted			
Total		1,901,000		353,000	

Data Source: Alberta Agriculture (note: original data in acre-feet)

[18] Data for United (UID), Leavitt (LID), and Ross Creek (RCID) irrigation districts was not available from Alberta Agriculture at the time of writing. Estimates were produced by Environment Canada based on the areal weighted averages.

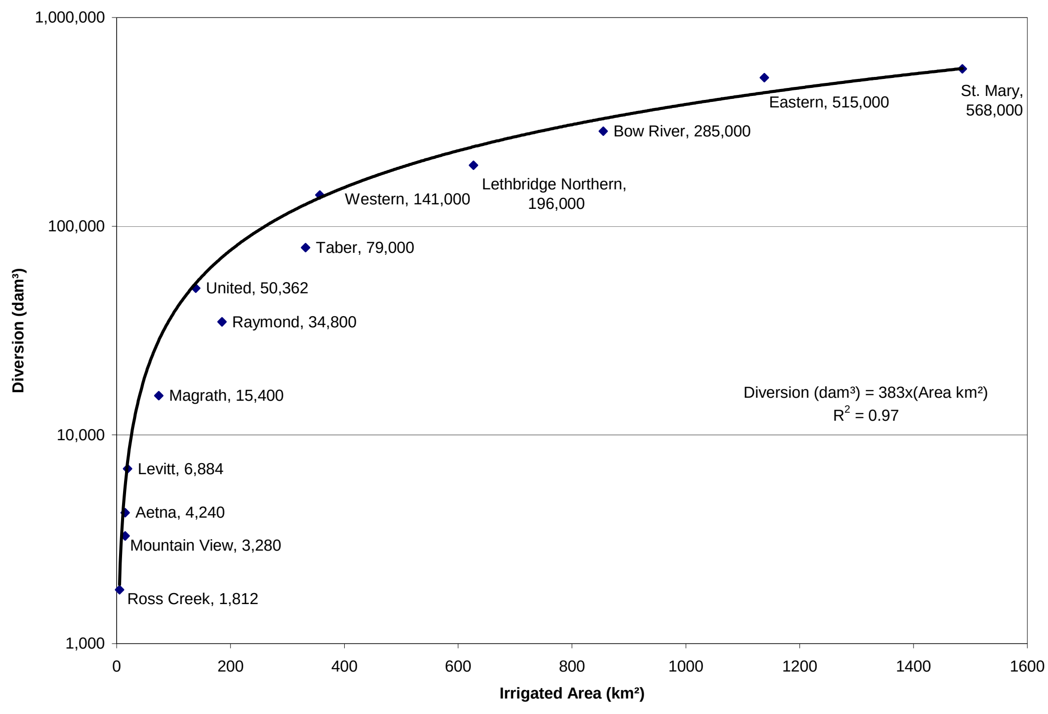
[19] St. Mary River flows contribute to the South Saskatchewan River Basin. However, only the actual flows crossing the boundary are considered in the PPWB Natural Flow model meaning that "Apportionable Flow" is less than the true natural flow that would occur in the absence of St. Mary Diversions. From the years 1994 to 2005 the average ratio of St. Mary River diversions to South Saskatchewan River "Natflo" at the Alberta/Saskatchewan boundary is 3%.

A view of return flow expressed as percent of diversion for the year 2004 indicates return flow to diversion ratio varies substantially from district to district (Table 1a and Figure 11). It is highest in Western Irrigation District, i.e., 50 percent and lowest in St. Mary Irrigation District, i.e., 5 percent.

These variations can be attributed to a combination of several factors, including: the areal extent of the district, water user density and the efficiency of the delivery infrastructure. Return flow, expressed as percent of diversion, tends to be higher in smaller districts, such as for Aetna Irrigation District, which is 45 percent, with low densities of irrigation users.

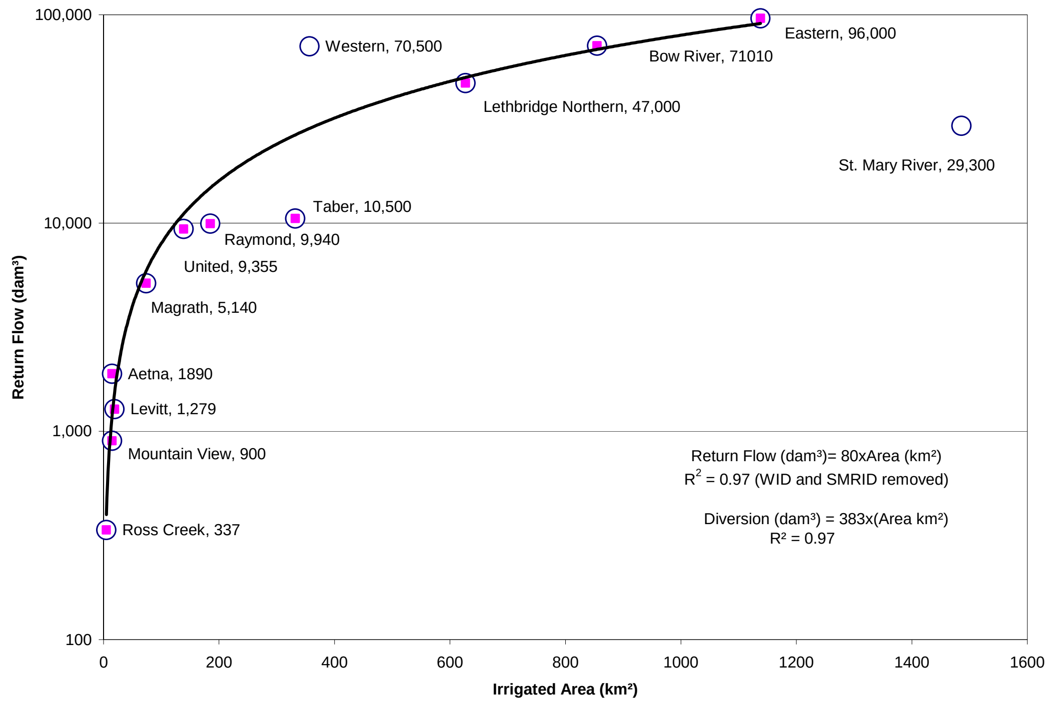
The largest district, in terms of irrigated acres, is the SMRID. It has a relatively high density of water users, a high percentage of pipe laterals, and a low percentage of flood irrigation. These characteristics tend to reduce return flow (5 percent for the 2004) as percent of gross diversion. Moreover, SMRID also has the ability to recapture much of its unused irrigation deliveries in reservoirs which is subsequently released as a diversion to the Taber Irrigation District via Chin Coulee and not registered as return flow.

Figure 10: Irrigation Diversion as a Function of Area for the Year 2004



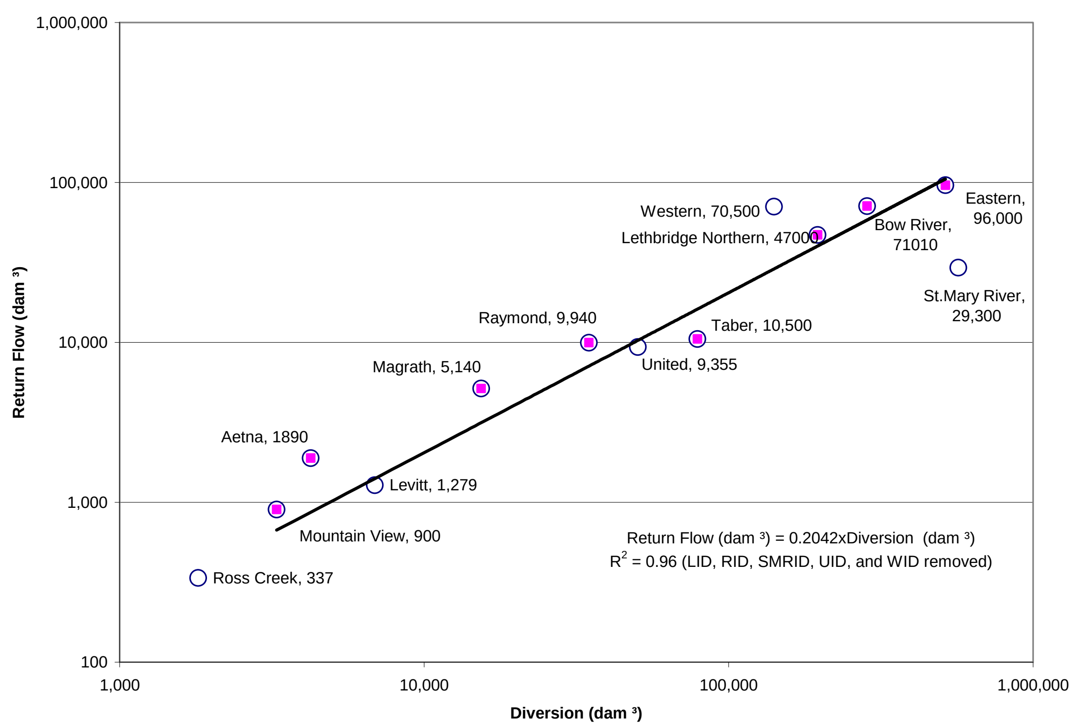
Data Source: Table 1, Alberta Agriculture

Figure 11: Irrigation Return Flow as a Function of Area for the Year 2004



Data Source: Table 1, Alberta Agriculture, including areal weighted estimates for Ross, Levitt, and United Irrigation districts by authors.

Figure 12: Irrigation Return Flow as a Function of Diversion for the Year 2004



Data Source: Table 1, Alberta Agriculture

Comparison of PPWB (Estimated) Return Flow, Return Flow Index Sites, and Return Flow measured by Irrigation Districts:

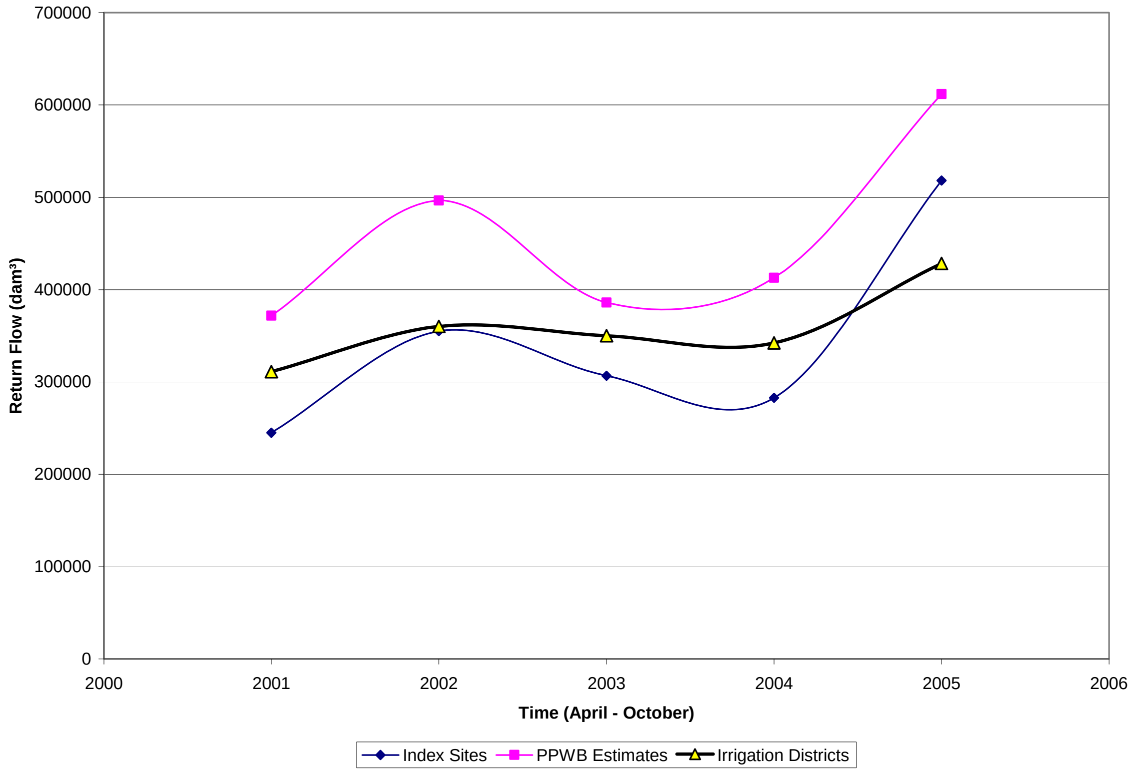
The period of record used in this study is limited by two things: 1. the period of record available from Alberta Agriculture representing all the return flow; and 2. the recent period of time when the degree of change in the irrigation development was small. Due to these limitations only the period form 2001 to 2005 was used. As described in the previous section the risk with this period of record is that the year 2001 was one of the driest on record and the year 2005 was one of the wettest. It is inappropriate to draw conclusion as to trend from 5 years of data under the best of conditions; however, when the first year of the series is at one extreme and the last year of the series is at the other we are presenting the worst case scenario for trend assessment. The year 2004 is most removed from the influence of the extreme low flow year and is not influenced by the wet year that occurs subsequently; as such it may be the best representation of for comparison purposes of the available data.

Comparison of PPWB estimated return flow and the irrigation district measured return flow indicated that PPWB estimates of the return flow are approximately 20 percent greater than the data presented by Alberta Agriculture (Figure 13). As expected, combined flow from index sites is less then the total measured flow, as the index stations are included in the total. However, in 2002 the flow from both sources is approximately the same and the 2005 index station return flow exceeds the return flow measured by the irrigation districts.

It is known that many of the index sites are located in existing natural drains, i.e., creeks and coulees, which can result in high flow due to surface drainage and high runoff during precipitation events. The difference may be attributed to how the PPWB uses the WSC data. The WSC reports flow past the gauge regardless of source, while Alberta Agriculture attempts to adjust the return flow gauged results at source and may not report periods of high runoff from precipitation during which times the irrigation system may not be running. Records show that 2002 and 2005 were high precipitation years (Figure 5).

Alternatively, the difference could be due to different approaches to gauging by the source agencies. Most of the WSC return flow sites are equipped with near real-time telemetry electronic data acquisition systems (EDAS). In general, monthly shift corrections, as determined by direct discharge measurement are applied to the stage-discharge rating curves. In contrast, the irrigation districts use a mix of analog and digital data loggers at their monitoring sites (which are not included in the PPWB South Saskatchewan natural flow model). Some of the districts' return flow sites are operated by district personnel, some are operated by Alberta Agriculture on behalf of the district, and some are operated by contractors. Further, the districts employ rated hydraulic structures as well as open channel stage-discharge approaches. The stream gauging collected by contractors reportedly has significant gaps in the record resulting in a higher degree of flow estimates than other sources.

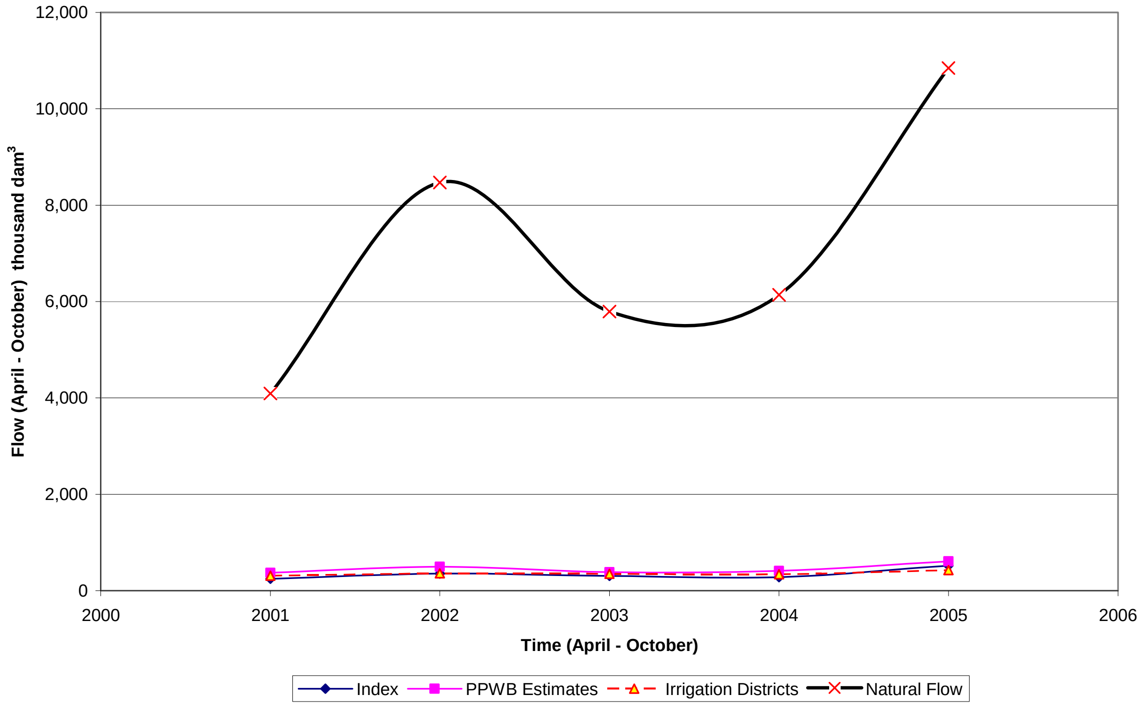
Figure 13: Total Seasonal Return Flow Comparison of Index Sites, PPWB Estimates and the Return Flow measured by the Irrigation Districts



Data Sources: WSC, PPWB, Alberta Agriculture

Note: It is speculated that higher return flow values at index sites in 2002 and 2005 are due to above average precipitation events, especially during 2005 which caused widespread flooding. Consequently, it is expected that gauged flow at all return flow sites should be greater than the results for the index sites alone. However, this is not shown in the data. The difference is caused by the irrigation districts' practice of discounting the natural runoff from the data set while the PPWB Secretariat reports return flow as the gauged data received from WSC without accounting for natural contributions. The WSC reports flow past the gauge regardless of water source.

Figure 14: Comparison of Total Return Flows to SSRB Apportionable Flow (Thousand dam3)



Data Sources: WSC, PPWB, Alberta Agriculture

Comparing return flow from all sources (WSC Index Sites, PPWB estimates, and return flow values provided by the irrigation districts) with the South Saskatchewan River computed apportionable flow demonstrates that, for the period of 2001 to 2005, the totals of all return flows are in the 5 percent range of the natural flow result. The highest value is 9 percent (Table 2). PPWB estimates range between 10% and 50% higher than the irrigation districts' result.

Table 2: Proportion of Return Flow to Apportionable Flow

Year	Irrigation Districts	WSC Index Sites	PPWB Estimates	(Irr.Dist - WSC) / Irr. Dist.	(Irr.Dist.- PPWB) / Irr.Dist.
2001	8%	6%	9%	21%	-19%
2002	4%	4%	6%	1%	-38%
2003	6%	5%	7%	12%	-10%
2004	6%	5%	7%	17%	-21%
2005	4%	5%	6%	-21%	-43%
Averages	5%	5%	7%	6%	-26%

Data Sources: WSC, PPWB, Alberta Agriculture

Figure 15 demonstrates the proportion of measured flows in the Alberta portion of the South Saskatchewan River Basin for the year 2004:

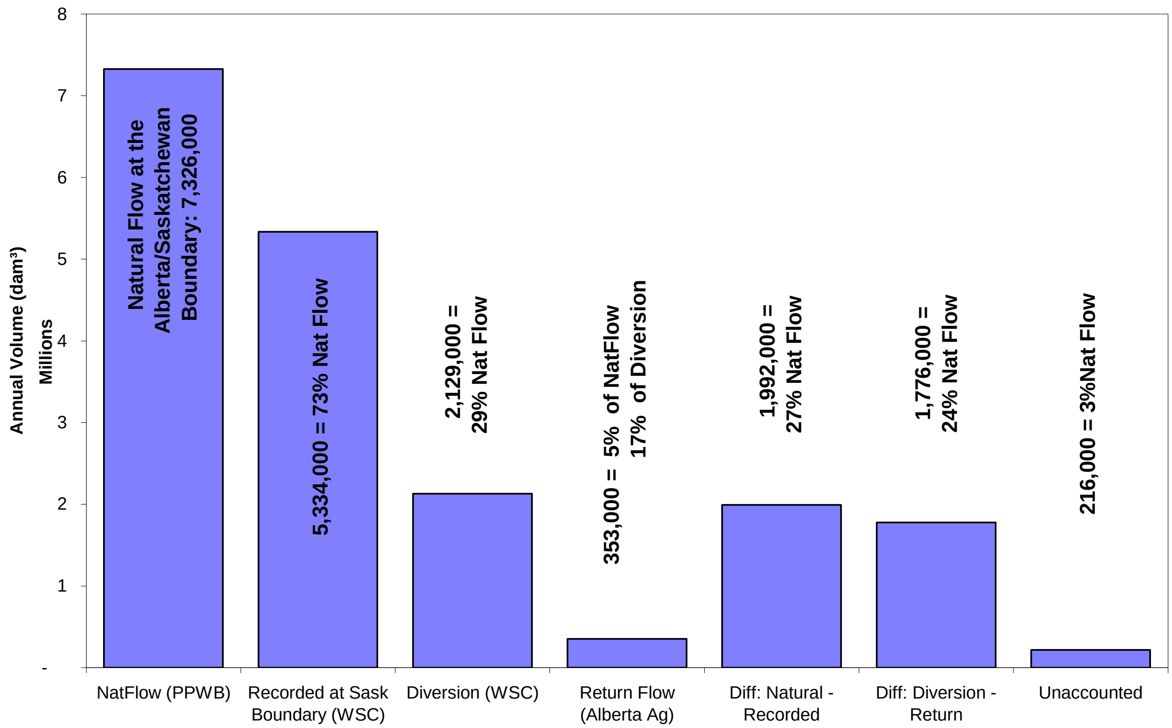
- Net diversion from the basin amounts to 29% of the Natural Flow. This number includes 224,000 dam^3 that was diverted from the St. Mary River in the USA to the Milk River i.e., 3% of the SSRB Natural Flow and amounts to 10.5% of all SSRB diversions upstream of Saskatchewan. There is no return flow from St. Mary/Milk River Diversions.
- At the Alberta/Saskatchewan Boundary 220,000 dam^3 are unaccounted for. That is for the year 2004: the modeled apportionable flow result is greater than the recorded flow at the boundary plus the difference in diversions and return flow by 3%.
- The Return Flow shown in Figure 15 was taken from Alberta Agriculture data. In contrast the PPWB model estimated return flow to be approximately 413,000 dam^3, which is 5.6% of the apportionable flow and 19.4% of diversion.
- For the year 2004 the PPWB estimate of Return Flow is 17% greater than the value compiled by Alberta Agriculture.[20]
- If PPWB Return Flow estimates were used the amount unaccounted for would be 280,000 dam^3 which would be 3.8% of the PPWB estimate for Apportionable Flow and 13% of Diversion.

To better understand if ± 3% of unaccounted for flow is typical it was necessary to observe a larger period of record; to that end, data for the 12 year period from 1994 to 2005 is shown in Table 3.

Figure 16 summarizes the data from Table 3 and demonstrates that the amount of unaccounted flow at the Alberta-Saskatchewan boundary varies considerably from year to year. Of particular note are the two low flow years: 2000 and 2001 where up to 20% of the total natural flow is unaccounted for by the natural flow model. Unaccounted flow could be due to unknown water sources, measurement accuracy, errors in consumptive use determinations, errors in the natural flow model, or combinations of the above.

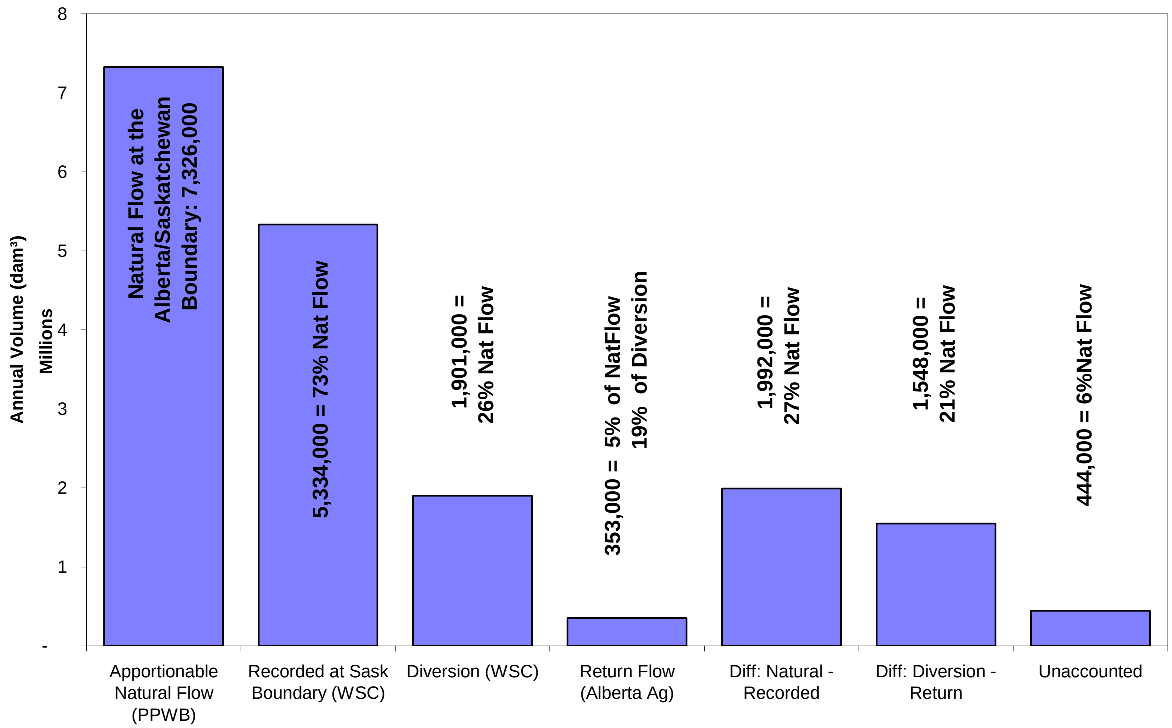
[20] Alberta Agriculture publishes return flow data from reports generated by each Irrigation District and accounts for natural runoff from precipitation. PPWB uses 11 index stations and makes no accounting for precipitation.

Figure 15: Flow Accounting in the South Saskatchewan River to the Alberta/Saskatchewan Boundary for the year 2004 (April to October) Diversion includes St. Mary River impoundments and diversions upstream of the international boundary.



Data Sources: WSC, PPWB, Alberta Agriculture

Figure 15a: Flow Accounting in the South Saskatchewan River to the Alberta/Saskatchewan Boundary for the year 2004 (April to October) St. Mary impoundments and diversions upstream of the international boundary are disregarded.



Data Sources: WSC, PPWB, Alberta Agriculture

Table 3: Flow Accounting South Saskatchewan River at Alberta-Saskatchewan Boundary during the April to October Irrigation Season.
USA St. Mary River Impoundments and Diversions to Milk River are included.

Year	NatFlow (1000 dam3) (PPWB)	Recorded at Sask Boundary (1000 dam3) (WSC)	Diversion (1000 dam3) (WSC)	Return Flow (1000 dam3) (Alta Ag)	Diff: Natural - Recorded (1000 dam3)	Diff: Diversion - Return (1000 dam3)	Unaccounted (1000 dam3)	Unaccounted / Recorded at Boundary	Proportion Return Flow to Natural Flow
1994	7038	5678	2453	492	1360	1961	-601	-11%	7%
1995	11748	10041	2172	417	1707	1755	-48	0%	4%
1996	9398	7932	2660	361	1466	2299	-833	-11%	4%
1997	9778	8282	2573	453	1496	2120	-624	-8%	5%
1998	9126	7500	2573	381	1626	2192	-566	-8%	4%
1999	8661	7093	2254	420	1568	1834	-266	-4%	5%
2000	5577	3698	3097	502	1879	2595	-716	-19%	9%
2001	4612	2656	2899	321	1956	2578	-622	-23%	7%
2002	9144	6854	2452	372	2290	2080	210	3%	4%
2003	7042	5612	2225	361	1430	1864	-434	-8%	5%
2004	7326	5334	2129	353	1992	1776	216	4%	5%
2005	12631	11813	1730	473	818	1257	-439	-4%	4%
Averages	8507	6874	2435	409	1632	2026	-394	-7%	5%

Data Sources: Return flow data in Table 3 was sourced from Alberta Agriculture; Natural Flow Data is from PPWB, all other data is from WSC.

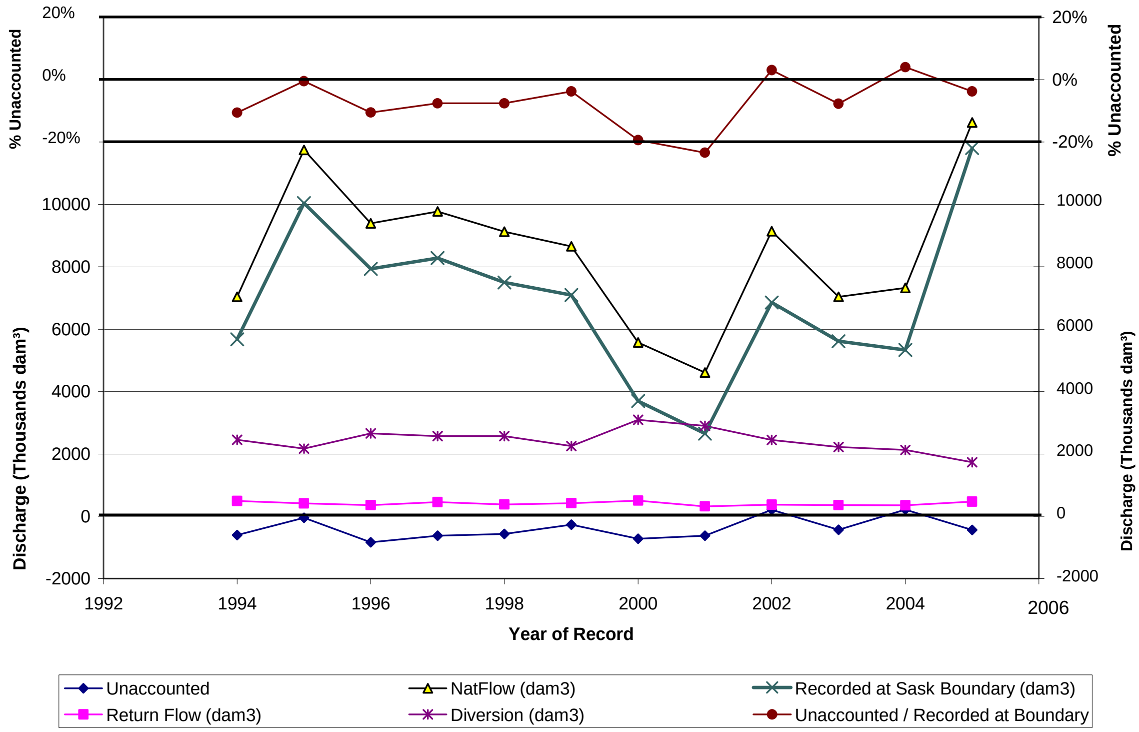
Table 3a: Flow Accounting South Saskatchewan River at Alberta-Saskatchewan Boundary during the April to October Irrigation Season.
USA St. Mary River Impoundments and Diversions to Milk River are disregarded.

Year	NatFlow (1000 dam3) (PPWB)	Recorded at Sask Boundary (1000 dam3) (WSC)	Diversion (1000 dam3) (WSC)	Return Flow (1000 dam3) (Alta Ag)	Diff: Natural - Recorded (1000 dam3)	Diff: Diversion - Return (1000 dam3)	Unaccounted (1000 dam3)	Unaccounted / Recorded at Boundary	Proportion Return Flow to Natural Flow
1994	7038	5678	2289	492	1360	1797	-437	-8%	7%
1995	11748	10041	2060	417	1707	1643	64	1%	4%
1996	9398	7932	2500	361	1466	2139	-673	-8%	4%
1997	9778	8282	2368	453	1496	1915	-419	-5%	5%
1998	9126	7500	2343	381	1626	1962	-336	-4%	4%
1999	8661	7093	2012	420	1568	1592	-24	0%	5%
2000	5577	3698	2898	502	1879	2396	-517	-14%	9%
2001	4612	2656	2748	321	1956	2427	-471	-18%	7%
2002	9144	6854	2283	372	2290	1911	379	6%	4%
2003	7042	5612	2032	361	1430	1671	-241	-4%	5%
2004	7326	5334	1901	353	1992	1548	444	8%	5%
2005	12631	11813	1529	473	818	1056	-238	-2%	4%
Averages	8507	6874	2247	409	1632	1838	-206	-4%	5%

Data Sources: Return flow data in Table 3 was sourced from Alberta Agriculture; Natural Flow Data is from PPWB, all other data is from WSC.

Figure 16: Flow Accounting in the South Saskatchewan River to the Alberta/Saskatchewan Boundary during the April to October Irrigation Season.

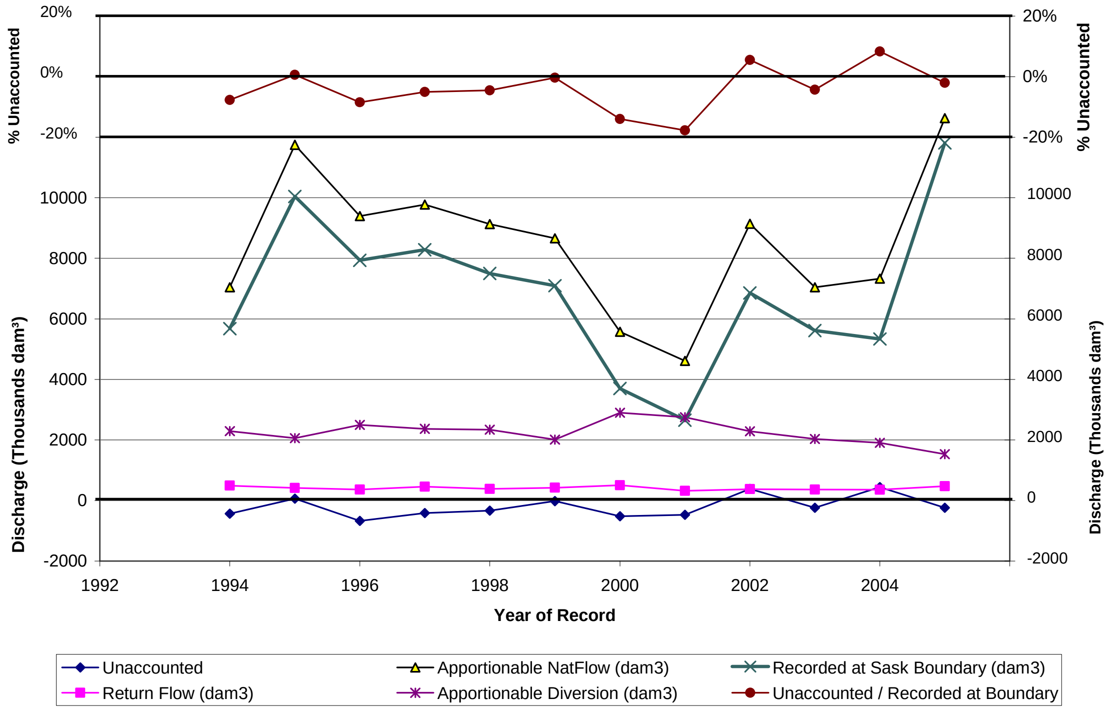
USA St. Mary River Impoundments and Diversions to Milk River are included.



Data Sources: Return flow data in Table 3 was sourced from Alberta Agriculture; Natural Flow Data is from PPWB, all other data is from WSC.

Figure 16a: Flow Accounting in the South Saskatchewan River to the Alberta/Saskatchewan Boundary during the April to October Irrigation Season.

USA St. Mary River Impoundments and Diversions to Milk River are disregarded.



Data Sources: Return flow data in Table 3 was sourced from Alberta Agriculture; Natural Flow Data is from PPWB, all other data is from WSC.

Part 1 Summary

To review all the data from both the irrigation districts and the Water Survey Canada with respect to adequacy of the data in terms of accuracy and timeliness

- PPWB estimates of return flow range between 10% and 50% higher than the irrigation districts' result.
- For the period of review, Table 3a demonstrates that the PPWB natural flow model may be biased to under represent the natural flow, even when USA diversions out of the St. Mary are discounted.
- The proportion of irrigation return flows to natural flow is in the order of 5%
- The proportion of irrigation return flows to diversion in the order of 20%.
- The proportion of unaccounted for flow to recorded flow is in the order of -4%
- The benefits of monitoring all return flow sites cannot be supported in terms of improved accuracy as the quantities are small compared to other flows in the system.
- Accuracy and timeliness of the existing return flow record is likely sufficient, the gaps are more likely due to how the index flows are interpreted in the model.

Part 2 Objective

To investigate the feasibility of consolidating data collection networks from all the irrigation return flow monitoring sites in South Saskatchewan Basin in Alberta.

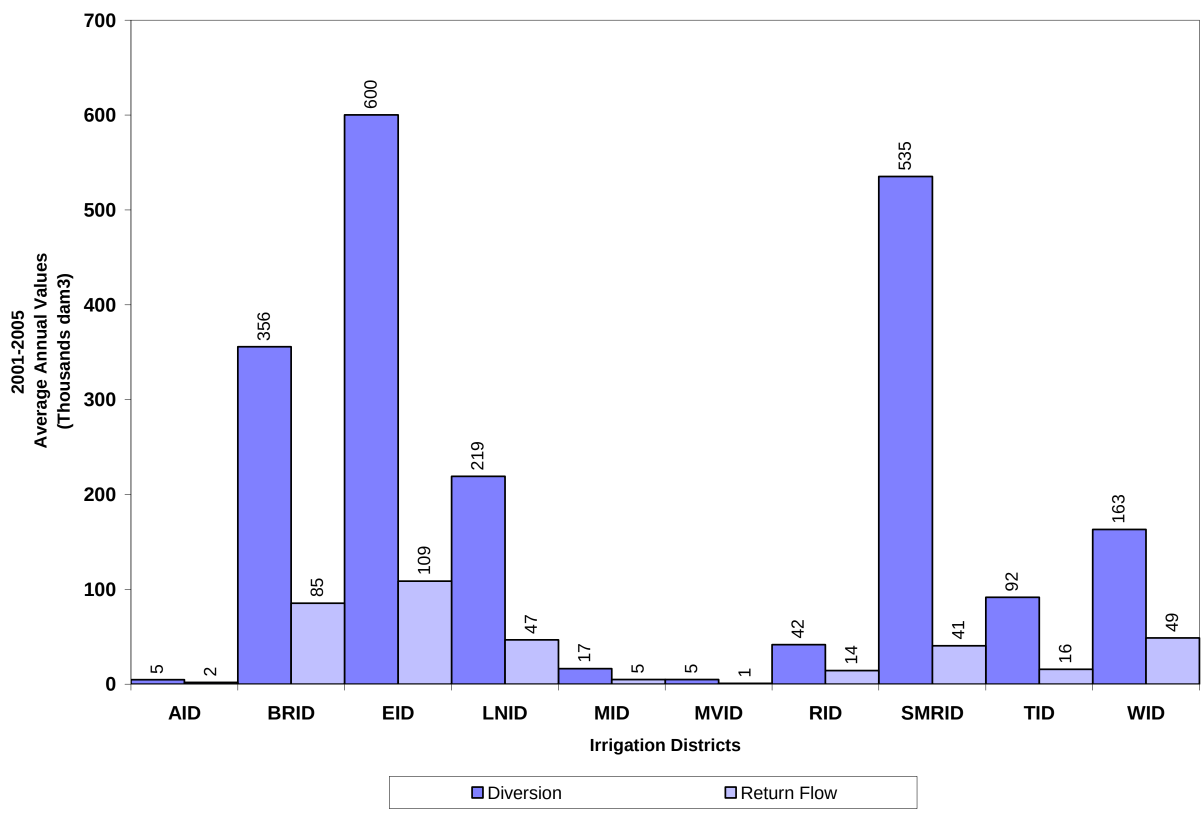
Part 2 Method

1. Review existing network and compare period of record. Analyze network in terms of proportion sampled and how well the data represents seasonal totals.
2. Contact the managers of 13 irrigation districts and explore opportunities for collaborative data reporting in terms of timeliness, accuracy, and overall impact.

Part 2 Results

Visits were made to major irrigation districts in order to explore opportunities to improve the current procedures, and to achieve accurate and timely computations and to ensure more equitable apportionment of the South Saskatchewan River waters.

Figure 17: For the Period 2001-2005 Average Annual Diversion and Return Flow by Irrigation District



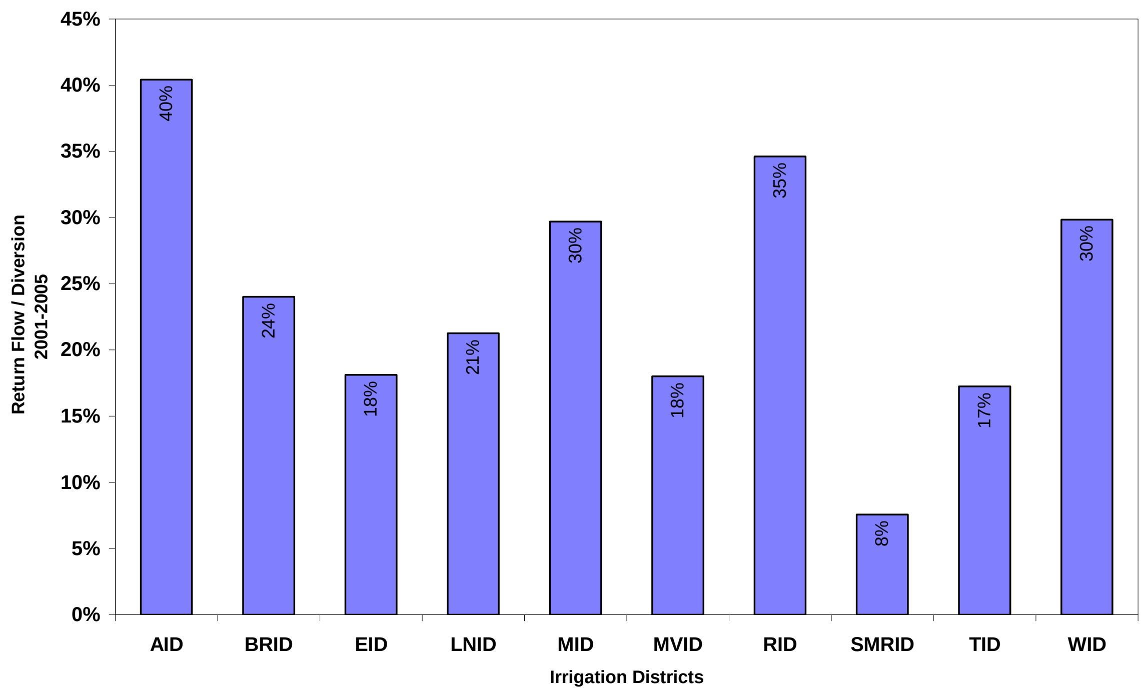
Data Sources: Alberta Agriculture (return flow), PPWB (Diversion)[21]

One result of the visits was the assurance that the 13 irrigation districts with support from

[21] Data for United (UID), Leavitt (LID), and Ross Creek (RCID) irrigation districts was not available from Alberta Agriculture at the time of writing

Alberta Agriculture and Alberta Environment generally have a good understanding of the quantities of water that are diverted into the districts and how much returns back to the receiving streams. The return flow information is not presently available in real-time and there is a degree of subjectivity in estimating the proportions of return flow channel flow that are strictly irrigation return or flow caused by natural or improved runoff from precipitation and snowmelt. It was unclear how the PPWB natural flow models make similar adjustments to return flow data in the model. The print-outs of return flow received from the PPWB Secretariat were the same as the WSC data, but that may simply be a reporting problem not a data use problem.

Figure 18: For the Period 2001-2005 -Ratio of Average Annual Diversion to Average Annual Return Flow by Irrigation District



Data Sources: Alberta Agriculture (return flow), PPWB (Diversion)[22]

Figure 18 results shows ratios of Return flow to Diversion for Alberta Irrigation Districts in the South Saskatchewan River Basin. Values are from the average annual flow rates for the period from 2001 to 2005. Averaging the results from Figure 18 shows that the irrigation districts returned 24% of diversions; this number is skewed high due to the relatively high number of smaller irrigation districts that are disadvantaged by their size in that it is hard to create opportunities to recapture and redistribute the water. If one was to look at the total mean annual return flow for 2001-2005 (367,800 dam^3) and divide that by the total mean annual diversions for the same period (2,033,000 dam^3) the average return flow is 18%. These values are consistent with the 20% regression equation shown in Figure 12 from Table 1 data.

[22] Data for United (UID), Leavitt (LID), and Ross Creek (RCID) irrigation districts was not available from Alberta Agriculture at the time of writing

The variability of return flow to diversion is due to a combination of several factors, including the size of district, water use density and the extent of infrastructure rehabilitation. It's observed that SMRID appears to be the most efficient with a return flow of 8% of diversions (Figure 18). This is largely due to SMRID's unique opportunity to recapture much of its unused irrigation deliveries in reservoirs and subsequently re-release it for downstream use. Among the larger districts WID demonstrated the highest ratio, which is attributed to the very large areal extent of the district, comparatively little internal storage capacity, aging infrastructure, and a high traditional dependence on the district works to supply domestic and municipal water, all of which tend to increase the return flow.

To better understand the impact of the return flow data a comparison was made to demonstrate the proportion of return flow to both irrigation season total natural flow volumes and annual natural flow volumes. These values are shown in Table 4. As apportionment of the South Saskatchewan River is based on an annual accounting, the comparison to annual total natural flow is presented in Figure 19.

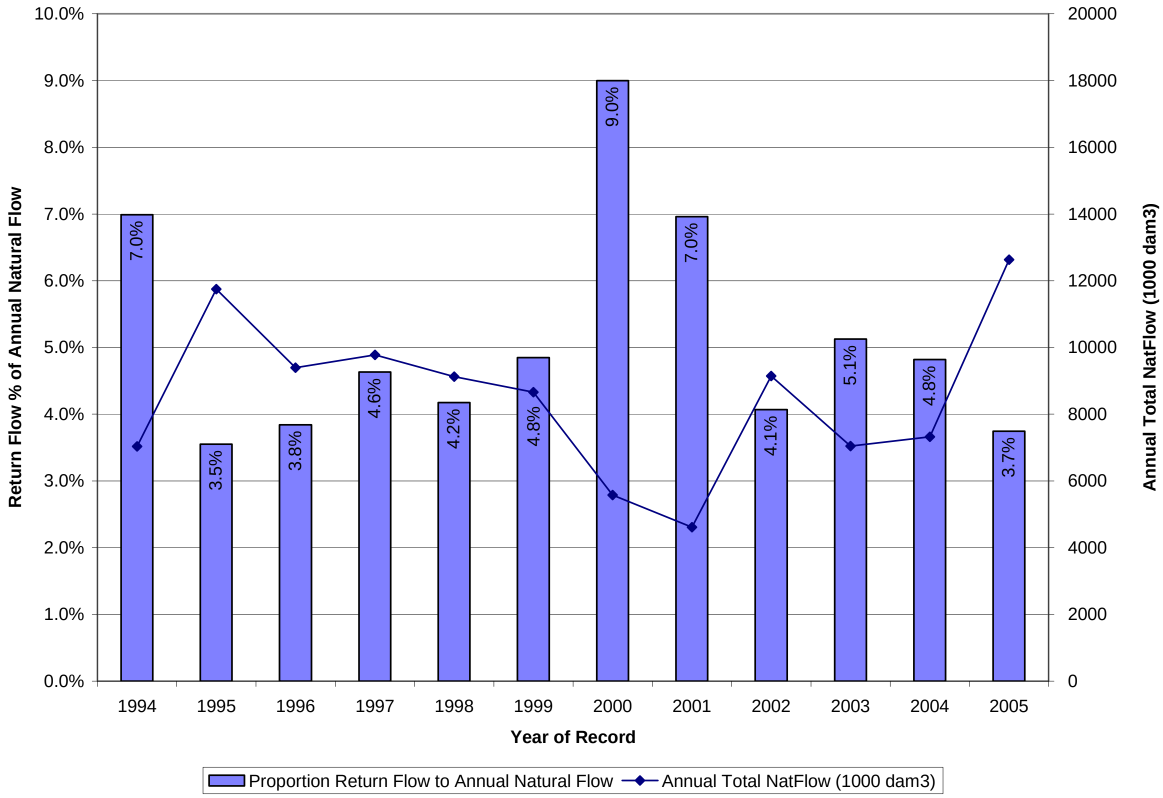
Table 4: Comparison of Annual and Seasonal Totals

Year	Annual Total NatFlow (1000 dam3)	Annual Total Record at Sask Bndry (1000 dam^3)	Alta Ag Total Annual Return Flow (1000 dam^3)	Ratio Return Flow to Annual Natural Flow	Irrigation Season (April-October) Natural Flow (1000 dam^3)	Irrigation Season (April-October) Record at Sask Bndy (1000 dam^3)	Ratio Return Flow to Irrigation Season (Apr-Oct) Natural Flow	Ratio Irrigation Season Natural Flow to Annual Natural Flow
1994	7038	5678	492	7.0%	5739	3961	8.6%	81.5%
1995	11748	10014	417	3.5%	10427	8372	4.0%	88.8%
1996	9398	7932	361	3.8%	8030	6089	4.5%	85.4%
1997	9778	8282	453	4.6%	8169	6246	5.5%	83.5%
1998	9126	7500	381	4.2%	8253	6130	4.6%	90.4%
1999	8661	7093	420	4.8%	7338	5339	5.7%	84.7%
2000	5577	3698	502	9.0%	4777	2408	10.5%	85.7%
2001	4612	2656	321	7.0%	4094	1729	7.8%	88.8%
2002	9144	6854	372	4.1%	8472	5722	4.4%	92.7%
2003	7042	5612	361	5.1%	5793	4113	6.2%	82.3%
2004	7326	5334	353	4.8%	6137	3714	5.8%	83.8%
2005	12631	11813	473	3.7%	10844	9613	4.4%	85.9%
Avg	8507	6872	409	5.1%	7339	5286	6.0%	86.1%

Note: Average proportion of April to October Natural Flow to Annual Total Natural Flow is 86.1%.
The 7 month Irrigation Season from April to October accounts for 7/12 or 58.3% of the year.
St. Mary River USA diversions are discounted.

Data Sources: Return Flow – Alberta Agriculture, Natural Flow – PPWB,
Recorded Flow – WSC

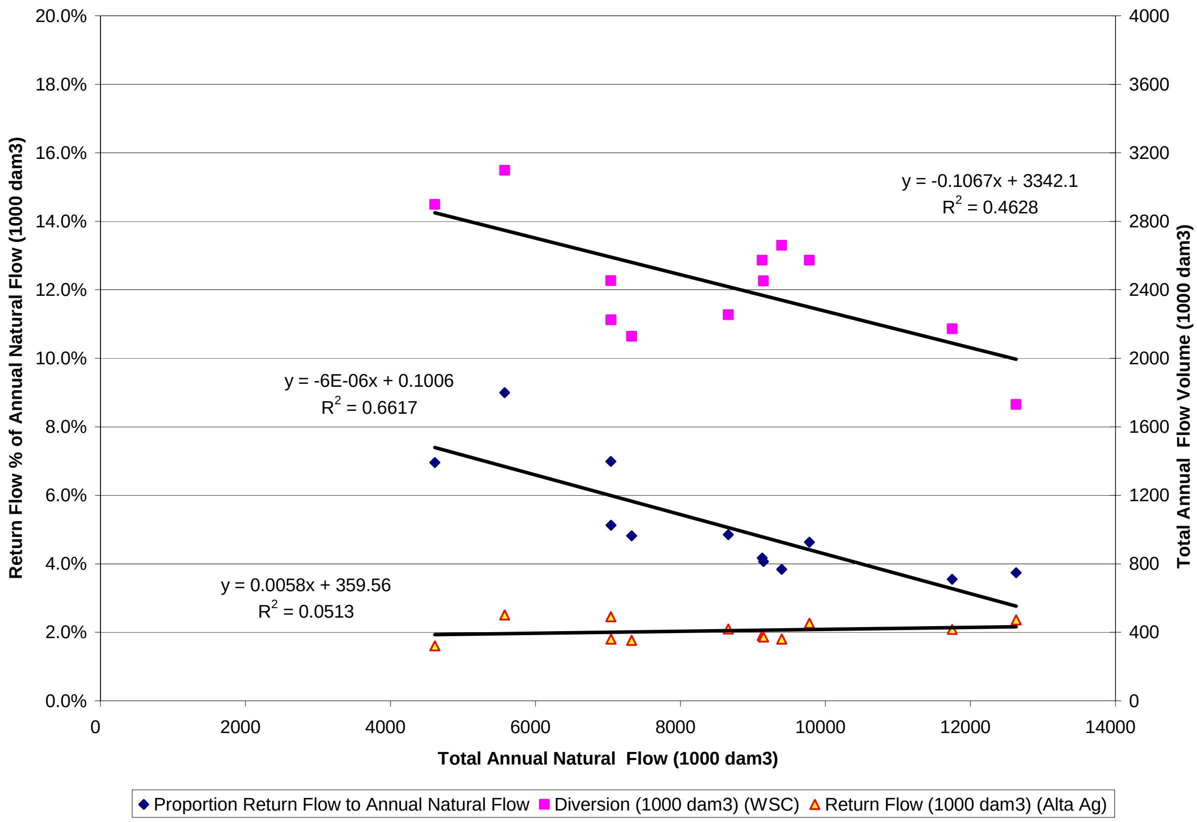
Figure 19: Proportion of Annual Total Return Flow to Annual Total Flow



Data Sources: Return Flow – Alberta Agriculture, Natural Flow – PPWB,
Recorded Flow – WSC.
St. Mary USA diversions are discounted

For the 12 year period from 1994 to 2005 the average ratio of irrigation return flow to total annual natural flow is 5.1%. The distribution for the period of record 1994-2005 as shown in Figure 19 is presented to demonstrate the variability that occurs over time. At first glance it appears that there may be some relationship between annual flow magnitude and total return flow; however this apparent trend is more likely an artifact of the quantity of water in the stream and less demonstrative of irrigation practice. Figure 20 demonstrates that as total flow increases return flow decreases proportionally. One possible interpretation of this is that the flow in the stream is independent of the needs of the water users. Higher flows in the main stem of the river may not be indicative of the local soil conditions as the source water for the South Saskatchewan is predominately based in the Rocky Mountains and Foothills region of Alberta with lesser contributions from the plains area where irrigation demand is high. Another interpretation is that high flows in the main stem are indicative of greater water available throughout the basin; this is supported by the declining trend in the quantity of water diverted as natural flow increases. We also note that the amount of return flow is more or less steady even though the amount of water diverted is in decline; from this one can speculate that diversions are based on demand, that demand may or may not be related to the flow in the main stem, and that return flow is more or less independent of total natural flow as it is for the most part made up of service water used to deliver water to the user. This suggests that with improved understanding of the irrigation systems the estimates of total annual return flow can be improved.

Figure 20: Proportion of Annual Total Return Flow to Annual Total Flow



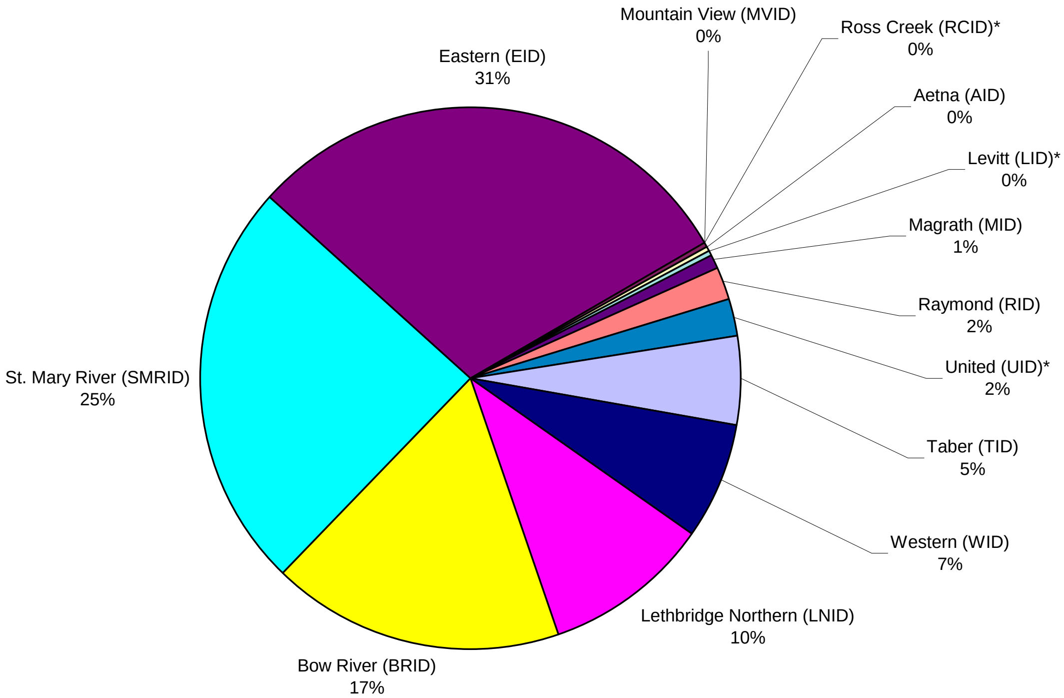
Data Sources: Return Flow – Alberta Agriculture, Natural Flow – PPWB, Diversion - WSC

Table 5: Comparison of Individual District Impact for Diversion and Return Flow (1994-2005)

District	Area under Irrig. (km^2)	Average Diver-sion 1994-2005 (m3/s)	Average Return Flow 1994-2005 m3/s)	Fraction of Total Diver-sion	Fraction of Total Return Flow	Accu. Fraction of Total Diver-sion	Accu. Fraction of Total Return Flow
Ross Creek (RCID)*	5	1827	685	0%	0%	0%	0%
Mountain View (MVID)	15	4149	834	0%	0%	0%	0%
Aetna (AID)	15	5066	2257	0%	1%	0%	1%
Levitt (LID)*	19	6942	1660	0%	0%	1%	1%
Magrath (MID)	74	16927	5785	1%	1%	2%	3%
Raymond (RID)	185	44534	11989	2%	3%	4%	6%
United (UID)*	139	50785	10015	2%	2%	6%	8%
Taber (TID)	332	119125	24057	5%	6%	11%	14%
Western (WID)	357	157375	54383	7%	13%	18%	27%
Lethbridge Northern (LNID)	627	222931	38039	10%	9%	28%	37%
Bow River (BRID)	855	390604	97373	17%	24%	46%	60%
St. Mary River (SMRID)	1486	545943	31447	24%	8%	70%	68%
Eastern (EID)	1138	670436	130063	30%	32%	100%	100%
Total	5247	2236644	408587				

Data Sources: Alberta Agriculture
**Note: Areal weighted averaging was used to estimate Diversion and Return Flow data for districts marked with an asterisk.*
Note also that the average St. Mary River Canal diversion above the international boundary for the same period amounts to 201,400 dam^3. This amounts to 9% of total shown for the rest of the basin.

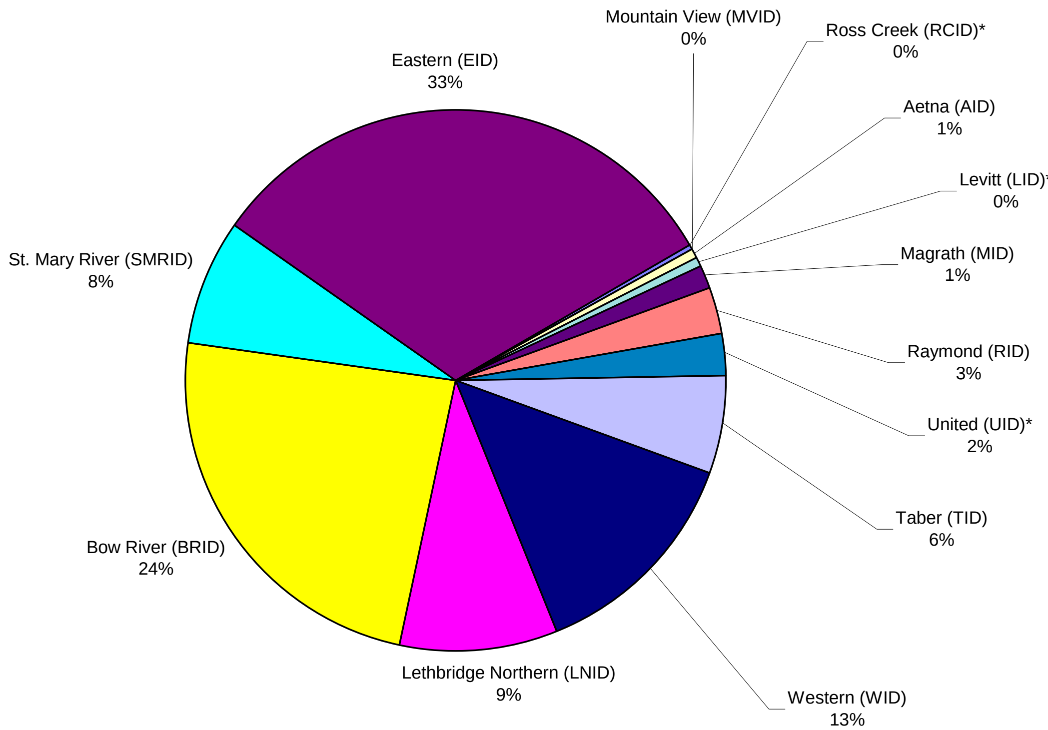
Figure 21: Proportion Individual District Diversion as Fraction of Total Diversion (1994 – 2005)



Data Source: Alberta Agriculture
**Note: Areal weighted averaging was used to estimate Diversion and Return Flow data for districts marked with an asterisk.*
Note also that the average St. Mary River Canal diversion above the international boundary for the same period amounts to 201,400 dam^3. This amounts to 9% of total shown for the rest of the basin.

Diversion to the 13 irrigation districts depends upon demand, availability, and capacity. These elements are influenced by a combination of factors such as: the total irrigated area, density of the irrigation projects, types of crop production and length of the conveyance system etc. Figure 21 shows the amount of water diverted to the irrigation districts as a proportion of total diversion, for the period of 1994 to 2005. The chart demonstrates that more the 95 percent of the water is diverted to the six largest irrigation districts ranging from 5 percent to 31 percent. The largest portion (31 percent) of the total diverted water goes to EID followed by SMRID (25 percent). Only a small portion is diverted to the 6 smallest districts i.e., less then 6 percent in total to UID, LID, RCID, AID, MVID, and MID.

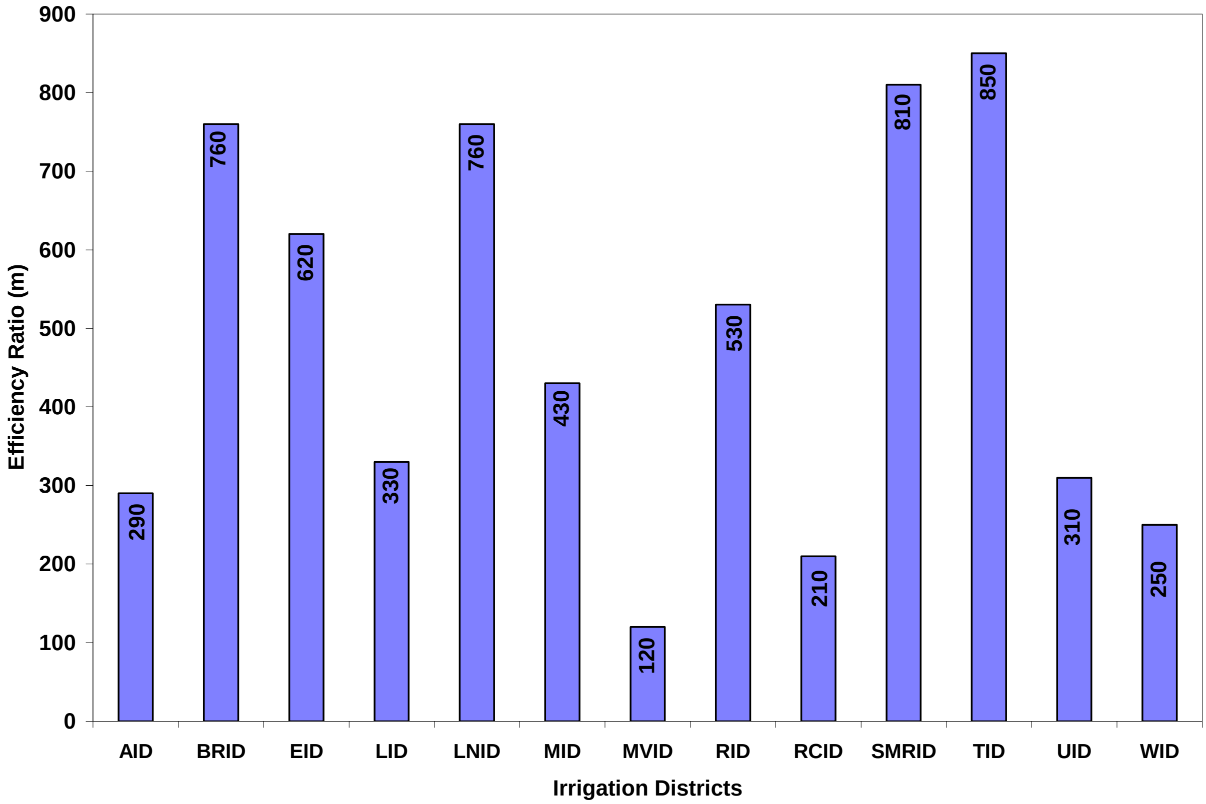
Figure 22: Proportion Individual District Return Flow as Fraction of Total Return Flow (1994 – 2005)



Data Source: Alberta Agriculture
**Note: Areal weighted averaging was used to estimate Diversion and Return Flow data for districts marked with an asterisk.*

It is expected that the irrigation districts receiving the most water will also produce the highest volume of return flow. Figure 22 demonstrates that 95% of all return flow for the period from 1994 to 2005 can be accounted for by six of the 13 irrigation districts.

Figure 23: Distribution Systems Geometric Efficiency



Data Source: Alberta Agriculture

The distribution system geometric efficiency is presented in units of meters and is determined by the ratio of the total area under irrigation to the length of the conveyance system. This was calculated for each of the 13 irrigation districts in Southern Alberta. Essentially, the higher the ratio: the more efficient (i.e., compact) the network.

Geometrical efficiency was investigated as a parameter to aid in the prediction of return flow volumes. Figure 24 plots the average return flow for the period from 1994 to 2005 against the logarithm of geometric efficiency. When the geometric efficiency is compared to the logarithms of annual flow we can infer a trend but this is not conclusive. Arguably, the apparent trends are due to the scale of the various projects as evidenced by the similar escalating values of the ratio of diversion to return flow. It is expected that larger districts divert more water and return more water so it would be risky to assume that there is a strong enough relationship on which to base improvements in a natural flow model.

Figure 24: Distribution Systems Geometric Efficiency Compared to Diversions and Return Flow

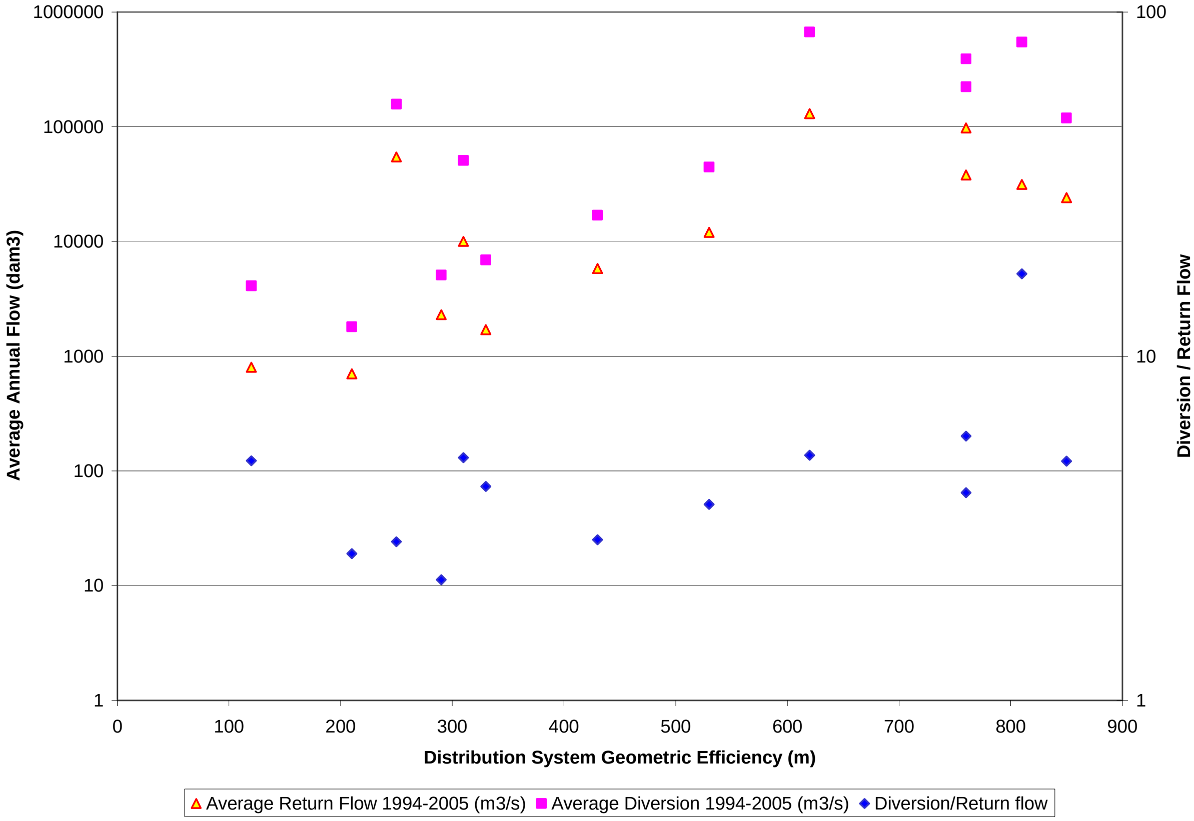
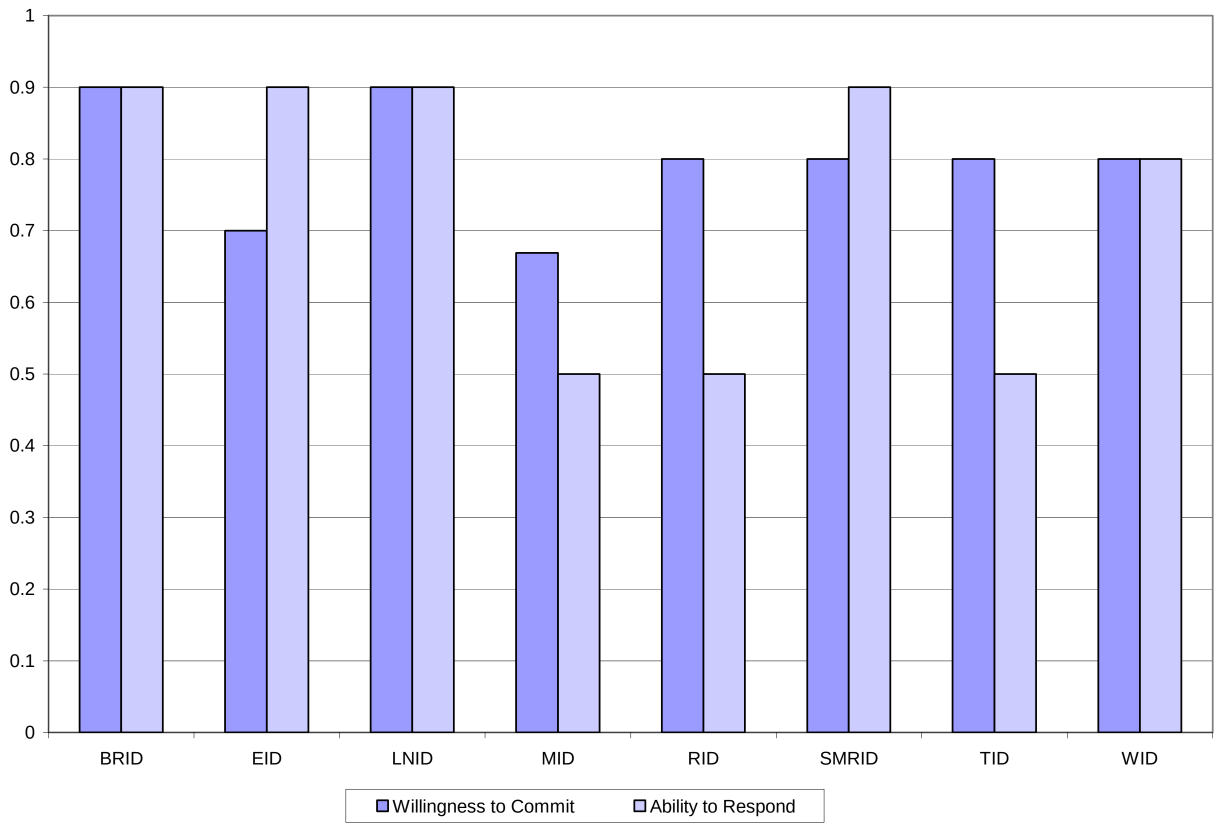


Figure 25: Alberta Irrigation Districts Willingness and Ability to Respond to Consolidation of Irrigation Return Flow Network



Attempts were made to contact all 13 of the irrigation districts but only 8 were able to respond in the time allowed for this study. District managers were asked to indicate on a scale of 1 to 10 their willingness to work toward consolidation of the return flow network (i.e., shared data reporting for the districts, Alberta Agriculture, and Environment Canada); however, not all districts have the ability to respond.

Irrigation return flow measurement for some districts (MID, RID, TID and other smaller districts) is carried out by Alberta Agriculture. These districts do not have the primary resources to collect the data thus limiting their ability to respond in a timely manner. Larger districts have the capacity to collect, analyze, and disseminate irrigation return flow data as they require this information to better manage the water resources of large and complicated distribution schemes. Some of the larger districts are working on improving the timeliness and accuracy of the data by installing more real time monitoring systems coupled with Supervisory Control and Data Acquisition (SCADA) systems. Installing these systems will also enhance their ability to respond to PPWB's return flow concerns.

As shown in Figure 25, all of the respondents view a consolidation of the irrigation return flow data as a good idea with 6 of the 8 scoring 80 percent willingness to commit, the lowest ranking was 65 percent favorable. However, 3 of the 8 respondents consider that they have only a 50 percent chance of being able to respond to increased demand for more timely and more accurate data; further, there is an expectation that this means that they will require some degree of support both financially and technically to be able to deliver the data if required.

Four of the 8 districts have 90 percent confidence that they have the ability contribute. No one is 100 percent confident as the format of the data and the common data management system is not presently specified. Clearly, some changes will be required to standardize the data formats.

As for the districts that were not included in the survey a conservative conclusion would be that they will need some level of support to provide accurate data on a timely basis.

Summary of Part 2

To investigate the feasibility of consolidating data collection networks from all the irrigation return flow monitoring sites in South Saskatchewan Basin in Alberta.

- Return flow data provide by Alberta Agriculture is adjusted to account for natural drainage.
- On average, for the period 1994-2005, irrigation return flow amounts to 18% of diversions.
- A better understanding of how the irrigation projects are operated would be of value to improve the irrigation return flow estimates.
- For the period 1994-2005: no discernable trend in annual return flow volume was observed.
- On average, for the period 1994-2005, 95% of all diversions go to the six largest irrigation districts.
- Similarly, on average, for the period 1994-2005, 95% of all irrigation return flow is generated from the same six largest irrigation districts.
- The geometric efficiency of the distribution system is not a significant factor in aid of the prediction of total annual return flow volume for this basin and the period reviewed.
- There is sufficient interest in collaborating on return flow data production with the irrigation districts that this option should be pursued as a way to improve return flow estimates.

Conclusions/Recommendations

1. Analysis, for the period of 2001 to 2005, of the Water Survey of Canada return flow sites within the irrigation districts did not indicate any inconsistency in terms of flow magnitude; however, historical data of some individual sites show a change in pattern in recent years. It is speculated that this could be due to evolution in irrigation practices. At the time of the review it was observed that LID, UID and RCID do not monitor return flow; UID was in the process of installing return flow monitoring sites.

Recommendation 1: *Periodic reviews of the relationship between the index sites and the total return flow are warranted.*

2. On average, return flow from all the sources comprise approximately 5 percent of the South Saskatchewan River natural flow to the Alberta/Saskatchewan boundary. PPWB – COH requirement for accuracy is 4 percent[23] of mean monthly natural flow. This indicates that the since the return flow contribution is relatively small that there may be an opportunity to relax the flow determination accuracy required for return flow and still provide an improved result overall.

Recommendation 2: *A sensitivity analysis should be carried out to fully demonstrate accuracy requirements leading to a specification of needs.*

3. Analysis of PPWB estimated return flow and irrigation district's measured flow indicated that PPWB estimates are generally 20 percent more than the return flow compiled by Alberta Agriculture. It is fair to say that this demonstrates that the PPWB accuracy specification is not being met in terms of the return flow component; however, 20 percent of 5 percent amounts to 1% of the total flow, so the overall accuracy is not highly impacted. What is important is that the PPWB estimate of return flow is generally over-rated (i.e., a bias or systematic error), therefore an improvement to the index rating could reduce the error in the result. It is understood that uncertainty in streamflow determinations are also at play; at present it is likely that the PPWB accuracy target is not being met, even though the impact should be minor.

Recommendation 3: *The difference between the PPWB return flow estimate and Alberta Agriculture reports should be investigated to understand the source of the difference.*

4. There is an identified difference in approach between PPWB and Alberta Agriculture in the way return flow is reported. PPWB reports are the same values as they receive from WSC which includes all water in the channel regardless of source. By contrast Alberta Agriculture selects "pertinent" return flow and does not always report flow in the channel that may have resulted from natural drainage e.g., runoff from significant precipitation events. This may be relevant to the positive bias demonstrated in PPWB return flow values as compared to Alberta Agriculture results.

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[23] Prairie Provinces Water Board (Canada) (2006). *PPWB Report No. 84 Handbook for Administration of the Apportionment Agreement, Revised Edition July 2006,* Regina, Environment Canada,Transboundary Waters Unit, 2006, pp.23

Recommendation 4: *Before agreement on a consolidated network can be reached there is a need to address the 4 components of water in the return flow channel and to gain agreement as to what should be reported as "Return Flow".*

5. The data review demonstrates that approximately 90 percent of the return flow volume is generated from the five largest districts. Incorporating just the measured irrigation return flow values from these districts into the natural flow model could well improve present results. Further, these five large districts report that they are between 80% and 90% able to respond to the call for a consolidated irrigation return flow network. The next two largest districts account for a further 6 % of the total return flow, for a total of 96%; but they are only 50% confident that they will be able to respond to the call for a consolidated network.

   For the period from 1994 to 2005 irrigation return flow estimates by Alberta Agriculture amount to 5% of the Apportionable Flow[24].

   During the same time period PPWB Return Flow estimates amount to 7% of the Apportionable Flow.

   If return flow data from the 4 largest districts can be provided in a timely manner the natural flow model would be improved over the existing computational process.

Recommendation 5: *Before a decision to progress the project to Phase 2 it will be required to confirm that the five largest irrigations districts are willing and able to participate.*

6. Meeting with Alberta Irrigation Branch in Lethbridge, AB on February 13, 2007 was encouraging and they are ready to contribute towards the consolidation of the irrigation return flow network (Appendix E).

7. The development of a more comprehensive network of monitoring is seen to be of benefit to the irrigation district operators as well as to the apportionment determination. Participants in this study agree that more accurate measurement and faster reporting will lead to better resource management. Presently, irrigation managers report that estimation techniques for measuring water losses (or savings) in conveyance systems tend to suffer from high level of uncertainty which requires more conservative approaches to water use. Consequently, there is a need to develop a robust system of measurement for monitoring and verification for the most beneficial use of a limited resource.

Recommendation 6: *Irrigation districts must be included in the development of monitoring approaches to provide maximum benefit of the results.*

8. Visits were made to major irrigation districts (BRID, SMRID, EID, LNID, RID, and WID) in order to identify opportunities for the return flow network consolidation and for this purpose a questionnaire was prepared for the district managers (Appendix I). Each of

[24] Table 3 b.

the district managers visited showed interest and offered their cooperation (Appendix F – Appendix K).

9. To be of benefit, the timeliness of data reporting has to be improved. Currently, irrigation districts collect and report data annually. It was observed that completeness of the irrigation return flow record varies from district to district (75% to 90%); however, improvement is expected due to awareness of the benefits of return flow data and a concerted effort by district managers and operations staff to improve the management of the infrastructure and to increase irrigation efficiency. No measures of results accuracy are available.

Recommendation 7: *Improvements to Irrigation District's data recovery to above 95% of the volume is required.*

Recommendation 8: *Objective statements of PPWB stream gauging results accuracy need to be developed.*

10. Irrigation districts are concerned about the irrigation return flow for several other reasons. Some are operational e.g., uncontrolled spills and sudden changes in canal water levels can damage the canals and increase maintenance cost. Some are social e.g., they are concerned about the public perceptions of wasteful management practices and impacts on the source streams. Some are economic e.g., they are also concerned that inefficient operations could jeopardize further expansion of irrigation.

In summary:

1. Improved monitoring should be of benefit to address the concerns and needs of the individual irrigation districts.
2. Districts are concerned that the return flow data includes natural runoff and would like to understand how this may impact their allocation.
3. Many Irrigation Districts employ the same contractor to provide data. All participants in the 2007 survey reported opportunities for improvement.
4. Presently, PPWB specifications for overall accuracy are being met partly due to the scale of the numbers. However it is clear that a systematic bias exists that overrates the return flow component when compared to Irrigation district results.
5. To achieve better results for the return flow it is recommended to improve the current index approach and periodically review the result.

Appendices

Appendix A: WSC Irrigation Return Flow Stations

Station #	Name	Status	Available Record	Average Apr - Oct Total Discharge (dam^3)
	LNID			
05AD037	L-6: Piyami Drain	Active	(1972 - 2005)	8,846
05AD038	L-13: Battersea Drain	Discontinued	(1973 -1994)	5,948
05AC023	Little Bow River near the mouth	Active	(1973 - 2006)	28,463
05AD040	Drain L-5 near Diamond City	Discontinued	(1985 - 1994)	648
05AC012	Little Bow River below Travers Dam	Active	(1957 - 2005)	15,321
	S.M.R.I.D			
05AJ003	Drain S - 10 near Bow Island	Discontinued	1973 - 1990	3,918
05AH005	Seven Persons Creek at Medicine Hat	Discontinued	(1909 - 31)(1935 - 56)(1973 - 06)	13,783
05AG007	S - 2 Lateral 10 spillway near Chin	Discontinued	1966 - 1995	4,311
05AJ002	Drain S - 4 near Grassy Lake	Discontinued	1972 - 1986	3,671
05AG008	Bountiful Coulee near Cranford	Discontinued	1966 - 1984	6,209
05AG025	Drain T - 11 nr Fincastle	Discontinued	1973 - 1984	2,684
05AH049	Ross Creek at Medicine Hat	Discontinued	1985 - 1995	10,401
05AD020	Six Mile Coulee Spillway near Lethbridge	Discontinued	1951- -1979	5,200
05AG026	Bountiful Coulee Inflow near Cranford	Active	(1980 - 1995) 2006	2,911
	W.I.D			
05CE005	Rosebud River at Redland	Active	1951 - 2005	18,046
05BM009	Twelve Mile Coulee Spillway Near Carseland	Discontinued	1951 - 1988	9,026
05BM005	Hammer Hill Spillway near Gleichen	Active	(1922 - 22)(1957 - 86)(191989 - 07)	4,984
05CE006	Rosebud River below Carstairs Creek	Active	1957 - 2005	9,737
05BM012	Cairn Hill Spillway near the mouth	Discontinued	1960 - 1988	6,768
05BM008	Crowfoot Creek near Cluny	Active	1951 - 2006	26,761

Appendix A: WSC Irrigation Return Flow Stations (continued)

Station #	Name	Status	Available Record	Average Apr - Oct Total Discharge (dam^3)
	E.I.D			
05BN015	Rolling Hills Canal # 1	Discontinued	1968 - 1986	7,150
05BN019	Rolling Hills Canal # 2	Discontinued	1965 - 1986	3,179
05BN014	Coal Creek at Bow City	Discontinued	(1965 - 86)(1989 - 95)	2,742
05CJ007	Matzhiwin Creek above Ware Coulee	Discontinued	1954 - 1988	70,287
05CJ008	Ware Coulee above Matzhiwin Creek	Discontinued	1954 - 1988	13,940
05CJ006	Ontree Creek Near Patricia	Active	1951 - 2006	35,703
05BN002	Twelve Mile Creek Near Cecil	Active	1951 - 2007	37,189
05BN010	Antelope Coulee Spillway	Discontinued	1959 - 1988	3,979
05CJ012	Matzhiwin Creek below Ware Coulee	Active	1989 - 2006	52,100
05CH007	Berry Creek near mouth	Active	1964 - 2005	9,311
	B.R.I.D			
05BN006	New West Coulee near the Mouth	Active	1957 - 2005	25,113
05BN007	Ronalane Wasteway near Hays	Discontinued	1957 -1995	11,961
05AG003	Expanse Coulee near the Mouth	Active	1957 - 2005	16,974
05AG004	Bow River Development Drain 'A' near Hays	Active	(1957 - 66)(1972 - 84)(1989 - 07)	2,585
05BN023	Bow River Development Drain 'E' Near Vauxhall	Discontinued	1970 - 1984	2,627
05BN008	Bow River Development Drain 'D' Near Vauxhall	Active	1958 - 2005	8,426
05BN009	Bow River Development Drain 'K' Near Vauxhall	Discontinued	1958 - 1988	9,577
05AG005	Bow River Development Drain 'T' near Hays	Discontinued	1958 - 1995	5,734
05BL025	Highwood Diversion Canal near Headgates	Active	1977 - 2006	10,219
	T.I.D			
05AG023	Drain T - 2 near Taber	Discontinued	1972 - 1984	28,463
	R.I.D			
05AE016	Pothole Creek at Russell's Ranch	Active	(1919 - 56)(1972 - 2005)	21,572
	M.I.D			
05AE041	Dry Coulee near Magrath	Discontinued	1980 - 1994	4,744

Appendix B: Average Seasonal Irrigation Return Flow as % of SSR Natural Flow

District	Avg. Seasonal Irrigation Return Flow	SSR Avg. Seasonal Natural Flow	% of SSR
L. N.I.D	17020.8	1003888	1.69
W.I.D	26068.6	1003888	2.6
E.I.D	35337.6	1003888	3.52
B.R.I.D	17673.12	1003888	1.76
R.I.D	12623.12	1003888	1.25

Appendix C: Comparison of Active Return Flow Sites between the Irrigation Districts and WSC

District name	**Number of Stations**		
	District Operated	WSC Operated	Total in District
Aetna Irrigation District	1	0	1
Bow Irrigation District	11	5	16
Eastern Irrigation District	11	3	14
Lethbridge Northern Irrigation District	10	3	13
Magrath Irrigation District	2	0	2
Raymond Irrigation District	3	1	4
St. Mary River Irrigation District	15	1	16
Taber Irrigation District	13	0	13
Western Irrigation District	26	3	29
Total	**92**	**16**	**108**

Appendix D: Meeting with Alberta Irrigation Branch Notes

A meeting was held with Alberta Irrigation branch in Lethbridge on February 13, 2007, Barkat Khan representing the PPWB and Lawrence Schinkel who is Senior Monitoring Technologist in Irrigation Development Section. The purpose of the visit was to get first hand information about the 13 irrigation districts in Southern Alberta and discuss the PPWB natural flow project and its goals. Mr. Schinkel is in frequent contact with the district managers and receives and analyzes the district's return flow data.

Summary of discussions:

- Alberta Irrigation showed interest and were ready to assist in this investigation.
- Not all the irrigation districts measure the irrigation return flows.
- In general, farmers are pro-irrigation and are very protective of allocation of water.
- Data collection in the districts is conducted by individuals who are trained by Alberta Irrigation Branch. Consequently, some consistency of approach is assured leading to better quality results.
- Three small districts i.e. LID, RCID and UID don't monitor return flow; however, United Irrigation District is in process of installing return flow gauging sites.
- Alberta Irrigation intends to install small gauges on pivot sprinklers to measure how water is being used for irrigation.
- Gaps in the return flow data occur infrequently but when they do it is often due to shortage of manpower at the individual districts.

Appendix E: Bow River Irrigation District Visit Notes

The Bow River Irrigation District (B.R.I.D.) contains the third largest area under irrigation of Alberta's thirteen irrigation districts, approximately 86,360 hectares (213,400 acres) in 2004. In 2003, the B.R.I.D. irrigators voted to expand the area of the District. Final expansion is scheduled to be complete by 2007. When complete, the total irrigated area will be approximately 93,890 hectares (232,000 acres). Where practical, the district is in the process of converting the conveyance system from open channels to pressurized pipelines. This work is expected to significantly improve delivery efficiency and to reduce return flow. Prior to 1992 the district was supplied exclusively by open channels; however, by 2004 approximately 11,578 hectare (28,609 acres) of land was served by pipeline.

According to district data the return flow in 1992 was approximately 127,050 dam ^{3} (103,000 acre-feet), which was reduced to less then 74,000 dam ^{3} (60,000 acre-feet) in 2004. Water diversion demand to the district is variable and inversely proportional to the precipitation during the irrigation season. Recent diversion data indicates a decrease in diversion demand.

Bow River Irrigation District has 24 return flow sites, however, out of these 24 sites only 12 sites are considered to have significant enough flow to be measured. The 12 metered sites account for approximately 90% of the total return flow volume for the district. In the BRID, natural runoff is included in the return flow data. The district has one real-time monitoring station and the district is confident that level of data accuracy for the rest of the monitoring stations (data loggers) is within the range of ± 5%. Data is collected at the end of the irrigation season and reported to Alberta Agriculture annually.

Return flow monitoring is considered by the district to be of no benefit to its operation; however, they are interested in consolidation of the return flow networks, on cost sharing of the monitoring program, on shared training of the monitoring staff, and shared work i.e., providing additional man power. The BRID is willing to share the data on a timely basis.

Appendix F: Eastern Irrigation District Visit Notes

The Eastern Irrigation District has the largest land base and the second largest number of irrigated acres of the 13 irrigation districts in southern Alberta. Presently, the total area under irrigation has slightly decreased to 109,461 hectares (270,478 acres) from 113,760 hectares (281,101 acres) in 1999. Average water use for 1999 was 2.16 dam^3 per hectare (0.71 acre-foot per acre).

The district is incrementally shifting from traditional methods of irrigation to more advanced techniques. The area under flood irrigation has decreased to approximately 31 percent of the district compared to 34 percent in 2002 while the area irrigated by low pressure pivot increased by 9%.

There are 17 irrigation return flow stations which cover 100 percent of the return flow channels. Currently the return flow monitoring stations are data loggers which were upgraded last year and maintenance check is carried out every month. The EID reports that its flow measurement accuracy is considered by the district to be in the ± 5% range. EID management indicated that they have the capacity to collect, analyze, and disseminate/distribute and post the results.

Most of the return flow locations are in located in creeks and coulees which make the line-of-sight radio communication challenging and installation of alternatives such as telephone or satellite systems are expensive. Two return flow locations are connected with Supervisory Control and Data Acquisition (SCADA) system in the district and the district intends to bring more sites under this network. The district collects the return flow data from stand-alone loggers at the end of the irrigation season (once a year) and in order to improve the timeliness of data acquisition the district suggests installation of real time monitoring system.

There are three WSC return flow monitoring sites in the district and EID management is not pleased with timely access to the data and that they have to wait a long time before the data is provided; however, they suggest that these three sites cover more then 80% of the return flow volume.

The district is ready to share their data to a common return flow network on the basis of shared cost of the existing irrigation district collection programs.

Appendix G: Lethbridge Northern Irrigation District Visit Notes

Lethbridge Northern Irrigation District (LNID) is the fourth largest irrigation district, with 70,933 hectares (175,205 acres) under irrigation. Continued rehabilitation of irrigation works improved water delivery but also brought more acres under irrigation and the district has seen approximately 12% increase in irrigated area in since 1999. Currently, the district has 10 irrigation return flow sites, all of them are equipped with electronic data loggers operated by a contractor. These return flow sites cover approximately 80 percent of the known return flow channels in the district; however, the district is planning to set up more monitoring sites to cover all return flow channels. LNID is in process of moving some of the return flow monitoring location due to the close proximity to Alberta Agriculture monitoring sites. Data recovery (i.e., lack of missing record) for the return flow data is 60 percent to 70 percent, but the district has a goal to improve this percentage to at least 95 percent data recovery.

In the last few years the district was only able to achieve 60 percent viable data due to problems with the monitoring equipment, consequently frequent visits are made to the sites in order to make sure that data loggers are working properly. There are some sites connected to Supervisory Control and Data Acquisition System (SCADA) but this system does not work satisfactorily for the sites located in deep coulees and creeks, this is likely due to radio signal problems. To improve the signal, the district is considering moving the sites to higher locations. To improve the timeliness of the data acquisition the district is planning to bring more sites under this system. The district management states that improved data recovery of the return flow is in the interest of the district.

The district has the capacity to collect, analyze, and distribute/post the results. Currently, the results are posted once a year; however, connecting return flow network to SCADA will improve the timeliness of the data. The district is willing to share the data and is looking forward to be a part of common data base.

Appendix H: Raymond Irrigation District Visit Notes

The Raymond Irrigation District is a part of St. Mary's system receiving water from the St. Mary River. The delivery system has evolved from gravity to buried PVC pipelines (approximately 91 km or 56.5 miles). The most common irrigation method is sprinkle irrigation, however, a small percent of land is still flood irrigated. The District has been increasing its areal extent throughout its history, currently approaching its allotment of approximately 18,600 hectare (46,000 acres).

RID started measuring the irrigation return flow since 1999, currently there are four irrigation return flow monitoring sites in the district; two thirds of the return flow drains into Etzikom Coulee and rest drains into the main St. Mary Canal. The district is confident that these four sites cover most of the return flow; however, they recommend setting up an additional monitoring station at Middle Coulee.

The average return flow since 1999 is 29 percent of the diverted water; however, it also includes high precipitation years (2002 and 2005). All monitoring stations are data loggers and there is no real time reporting. Data is collected once a year; i.e. at the end of irrigation season, by Alberta

Agriculture. The district does not have required equipment; e.g. laptop computers, to carry out monitoring. Natural runoff is included in current return flow readings. The addition of more irrigated area every year is expected to require setting up additional return flow sites.

The district has no objection to the establishment of a common data base for irrigation return flow for all the districts and willing to share their data; however, in order to get the data in timely basis the district reports that others will have to arrange for it.

Appendix I: St. Mary River Irrigation District Visit Notes

The St. Marry River Irrigation District (SMRID) is the largest district among all 13 irrigation districts in Southern Alberta delivering water through 2,060 km (1280 miles) of canals and pipelines to approximately 150,000 hectares (371,000 acres) of land. The major conveyance system within the district is the St Mary River Irrigation District Main Canal. It is 283 km (176 miles) in length and has the capacity to carry 91 cubic meters per second (3200 cubic feet per second) at the start of the system. Capacity in the Main Canal decreases along the system as deliveries are made to the Raymond and Taber Irrigation Districts and various secondary canals and storage reservoirs.

The district currently has eight irrigation return flow sites equipped with electronic data acquisition systems. These sites monitor 90 percent to 95 percent of the known return flow channels in the district. All monitoring systems are data loggers which records the return flow data on an hourly basis. Irrigation return flow data is collected once a year as required by Alberta Agriculture; however, the district has the capacity to collect the data on two week basis if required. In general, data recovery is found to be about 85%.

The SMRID has the capacity to collect, analyze and distribute the results once a year; however, the biggest concern for the district is to separate the surface drainage of precipitation (snow melt and rainfall) component from the irrigation return flow data. Currently, surface drainage is included in the return flow data. In order to assess their water use efficiency and to improve water management schemes, the district requests the PPWB to look into their concern about ways to separate the flow components. In this way only the returning diverted water would be reported.

The district is in favor of setting up a common data base for irrigation return flow for all the entire 13 irrigation districts in Southern Alberta and willing to cooperate in providing the data on timely basis.

Appendix J: Western Irrigation District Visit Highlights

The Western Irrigation District are very willing and looking forward to collaborate on the consolidation of irrigation return flow network. Currently, the district is collecting return flow data on the annual basis; however, they are in the process of installing real time telemetry and will soon be able to get the data on shorter time step. One of their concerns was the security of the monitoring station if PPWB were to obtain data direct from the stations. Presumably this concern is about vandalism to the site, but also, since the data is crucial to their water management schemes they are also concerned about “finger poking” errors that may ensue if individuals not trained on their specific systems are granted access. They would appreciate training of the data collection staff which would improve their QA/QC. If cooperative gauging occurs, the district requests that their participation be acknowledged.

Currently, 75% - 80% of the return flow channels are measured; work is in progress to identify better locations to measure more of the return flow. The level of data recovery is approximately 80% but their goal is to achieve 95%; establishing real time telemetry would be helpful in this regard. Improving the level of data recovery would help their resource management schemes by providing a better understanding of irrigation efficiency and efficient use of diverted water. The district is interested in establishing more return flow sites, currently, 28 monitoring sites are in operation.

The district operates some of its sites and contracts the operation of the others. At present, the district is not satisfied with maintenance of the data loggers and other equipment that is currently carried out by the contractor and reports that a considerable amount of data was lost due to poor maintenance. To improve the timeliness of the data reporting and communication between the monitoring stations, the district has already spent $160,000 on establishing a SCADA system and it intends to invest more in the near future.

The district is ready to collaborate if a common database or any other alternative method of sharing the data is established on timely basis.

Appendix K: Questions posed to the irrigation district managers

1. Under what conditions would the Irrigation District support collaborative data collection and reporting? (The following are expected responses; the questionnaire will have a blank form for this question so as not to bias the result).

   Expected responses:
    a. Shared reporting of results
    b. Shared training of data monitoring staff.
    c. Support from PPWB for monitoring and reporting
    d. Shared cost of existing Irrigation District diversion and return flow data collection programs
    e. Improved timeliness of reporting
    f. Improved accuracy of flow determinations
    g. Reduced workload for monitoring and reporting
    h. Recognition of contribution
    i. Participation in technique development
    j. Other?
2. What proportion of all return flow channels are monitored in your district?
3. What is the timeliness of reporting both interim values and final results? E.g., real-time (daily), weekly, monthly, annually?
4. What level of accuracy do you expect for your return flow data?
5. How is the level of accuracy demonstrated? Expected responses are as follows a)WSC says 5% so we say 5%, b) we sample at a high frequency, c) we compare to established ratings for structures and channels, or d) we accept theoretical ratings for flumes and

weirs together with the designer's estimates for accuracy. Again, the questionnaire will not provide a selection of responses so as not to bias the result.

6. How do you determine if this level of accuracy is sufficient for you needs?
7. Would improved accuracy of return flow data be of benefit to your water management scheme? (e.g., improved accuracy may benefit the accuracy of the natural flow model, but because return flow sites are at the "end-of-the-line" some irrigators may not see a direct benefit, others may be able to use the information to regulate flows in their systems to respond better to obligations to both their customers and to the natural flow apportionment needs). Typically irrigation is regulated by how much is diverted not by how much is spilled, however, in the run of river reservoir on the Eastern Tributaries of the Milk River for example; impoundments are frequently released to meet apportionment obligations. (example from outside the area of study is provided to keep from creating an internal focus)
8. What level of effort and/or resourcing would be required to monitor all return flow sites in your district?
9. What level of effort and/or resourcing would be required to improve the timeliness of the data reporting? E.g., various opportunities exist: SCADA (Supervisory Control and Data Acquisition, duplex radio sets), land line telephone, cellular telephone, GOES satellite, more frequent site visits).

Note: Although it was intended to gain an understanding of the tolerance for the daily flow values e.g., ±5% of the value or ±0.01 m^3/s, all responses to the question on accuracy were interpreted to be related to the amount of data recovered, and not to be the degree of accuracy for which the mean daily flowrate data may have been derived.

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