ASSESSMENT OF NATURAL FLOW COMPUTATION PROCEDURES AND MONITORING NETWORK FOR ADMINISTERING APPORTIONMENT OF THE SOUTH SASKATCHEWAN RIVER BASIN AT THE ALBERTA-SASKATCHEWAN BOUNDARY

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1. INTRODUCTION

The South Saskatchewan River, immediately downstream of the Alberta/Saskatchewan border, receives waters from three major sub-basin areas: the Oldman River, the Bow River, and the Red Deer River basin (Figure 1 in the jacket at the end of the report). The headwaters of the Red Deer and Bow River are entirely in the Alberta portion of the eastern face of the Rocky Mountains while the Oldman River receives flow from the Waterton, Belly, and St. Mary Rivers which have their headwaters in Montana.

The sharing of waters in the South Saskatchewan River is governed by the 1909 Boundary Waters Treaty which permits the U.S.A. to divert 25% of the flow of the St. Mary River for flow rates of up to 666 cubic feet per second (cfs) and 50% of the flow in excess of 666 cfs., and by the 1969 Master Agreement On Apportionment which divided the waters of eastward flowing interprovincial streams, including the South Saskatchewan River, equitably between Alberta and Saskatchewan.

Administration of the Master Agreement is carried out by the Prairie Provinces Water Board (PPWB) through the use of a number of administrative procedures, rules, and guidelines which were developed to improve the Board's ability to apportion eastward flowing interprovincial waters, and to ensure that apportionment is carried out in an equitable fashion. One of these procedures is the "South Saskatchewan River Below Red Deer River Natural Flow Calculation Procedures" which use data from 55 hydrometric stations to compute the apportionable flow (natural flow minus U.S.A. diversions) for the South Saskatchewan River at the Alberta-Saskatchewan boundary.

In view of the large number of hydrometric stations required in the administrative procedure for this watercourse, the PPWB requested the Committee on Hydrology (COH) to review the administrative procedures and to evaluate the apportionment monitoring network required to administer the South Saskatchewan River basin. The purpose of the review is "... to determine the appropriate level of the hydrometric network required for apportionment monitoring".

This report provides the results of the evaluation using the terms of reference established by the COH (listed in Appendix A) as a guideline. The evaluation begins by examining the 1969 Master

Agreement On Apportionment as it relates to the South Saskatchewan River. It then examines the natural flow computation procedures, which form the basis for apportionment, as well as the level of licensing in the basin. Lastly, the current hydrometric monitoring network is examined and recommendations are made on the location and number of hydrometric stations required in the basin to administer the Agreement.

2. THE MASTER AGREEMENT ON APPORTIONMENT

2.1 Pertinent Clauses

The 1969 Master Agreement on Apportionment divided the waters of eastward flowing interprovincial watercourses equitably between Alberta and Saskatchewan. The general principle of the Agreement, outlined in Article 3, Schedule A, is that; "Alberta shall permit a quantity of water equal to one-half of the natural flow [less U.S.A. consumptions] of each watercourse to flow into the Province of Saskatchewan...".

In the case of the South Saskatchewan River, the Agreement listed a number of additional conditions. These are:

1. Article 2C which states; "...the point at which the natural flow of the watercourses known as the South Saskatchewan and Red Deer Rivers is to be determined may be, at the option of Alberta, at a point at or as near as reasonably may be below the confluence of the said two rivers."

2. Article 4A which states; "Alberta shall be entitled in each year to consume, or to divert or store for its consumptive use a minimum of 2,100,000 acre-feet net depletion out of the flow of the watercourse known as the South Saskatchewan River even though its share for the said year ... would be less than 2,100,000 acre-feet net depletion, provided however Alberta shall not be entitled to so consume or divert or store for its consumptive use, more than one-half the natural flow... if the effect thereof at any time would be to reduce the actual flow... at the common boundary... to less than 1500 cubic per second."

3. Article 4B which states; "The consumption or diversion by Alberta provided for under the preceding subparagraph shall be made equitably during each year, depending on the

actual flow of water in the said watercourse and the requirements of each Province, from time to time".

2.2 Interpretation of Pertinent Clauses

As the interpretation of these conditions can have a significant influence in the number of hydrometric stations required to monitor compliance to the Master Agreement, a brief description as to how these special provisions have been applied to the South Saskatchewan River in past years is provided.

1. Article 2C, in the past has been interpreted to imply that the waters of the South Saskatchewan and Red Deer Rivers, for apportionment purposes, may be treated as a single entity. That is, Alberta's delivery of Saskatchewan's entitlements during a particular year may be made entirely from the Red Deer River or entirely from the South Saskatchewan River, or any combination thereof, at the discretion of Alberta.

2. Article 4A contains two conditions, one on the minimum flow rate and another on the annual volume. The interpretations of these conditions was provided by A.J. Chen and B. Godwin in their paper, "Interprovincial Water Management In Drought Periods", which was presented at the 1986 Canadian Hydrology Symposium in Regina.

   Within that paper the minimum flow rate condition is described as follows: "When natural flow [less U.S.A. diversions] of the South Saskatchewan River at the boundary is greater than 85 m^3/s (3,000 cfs), minimum flow is to be 42.5 m^3/s (1,500 cfs). When natural flow at the boundary is less than 85 m^3/s (3,000 cfs) minimum flow would be one-half of the natural flow at the boundary." Figure 2, adopted from the above noted paper, graphically illustrates the minimum flow requirement of this provision.

The volume provision in Article 4A, also discussed in the above noted paper, permits Alberta to store or consume a minimum of 2,100,000 acre-feet (2,590,000 dam^3) of water even though this may be more than 50% of the annual volume, provided that the minimum flow constraint is satisfied. Figure 3, adopted from the above noted paper, illustrates the distribution of annual flows for a condition where the flow rate is uniform (constant) throughout the year.

3. Article 4B which states that, "The consumption or diversion by Alberta provided under the proceeding sub-paragraph shall be made equitably each year..." is quite vague on the meaning of "equitable" although the phrase "...equitably each year..." could imply that the calendar year is the balancing period. Chen and Godwin's discussion of Alberta's delivery to Saskatchewan in the two dry years of 1977 and 1984 states "In both of these years the Board's Secretariat maintained a close watch on monitoring procedures to ensure that Alberta's obligations were adequately and equitably met". In this context the term "equitable" appears to have been used to imply that fair and reasonable steps were taken by Alberta to fulfill its obligations under Article 4A.

These interpretations of the special provisions provided for the South Saskatchewan River in the 1969 Master Agreement On Apportionment have been used in assessing the hydrometric requirements for administering the Agreement.

SASKATCHEWAN AND ALBERTA'S ANNUAL SHARE OF SOUTH SASKATCHEWAN RIVER AT THE ALBERTA - SASKATCHEWAN BORDER

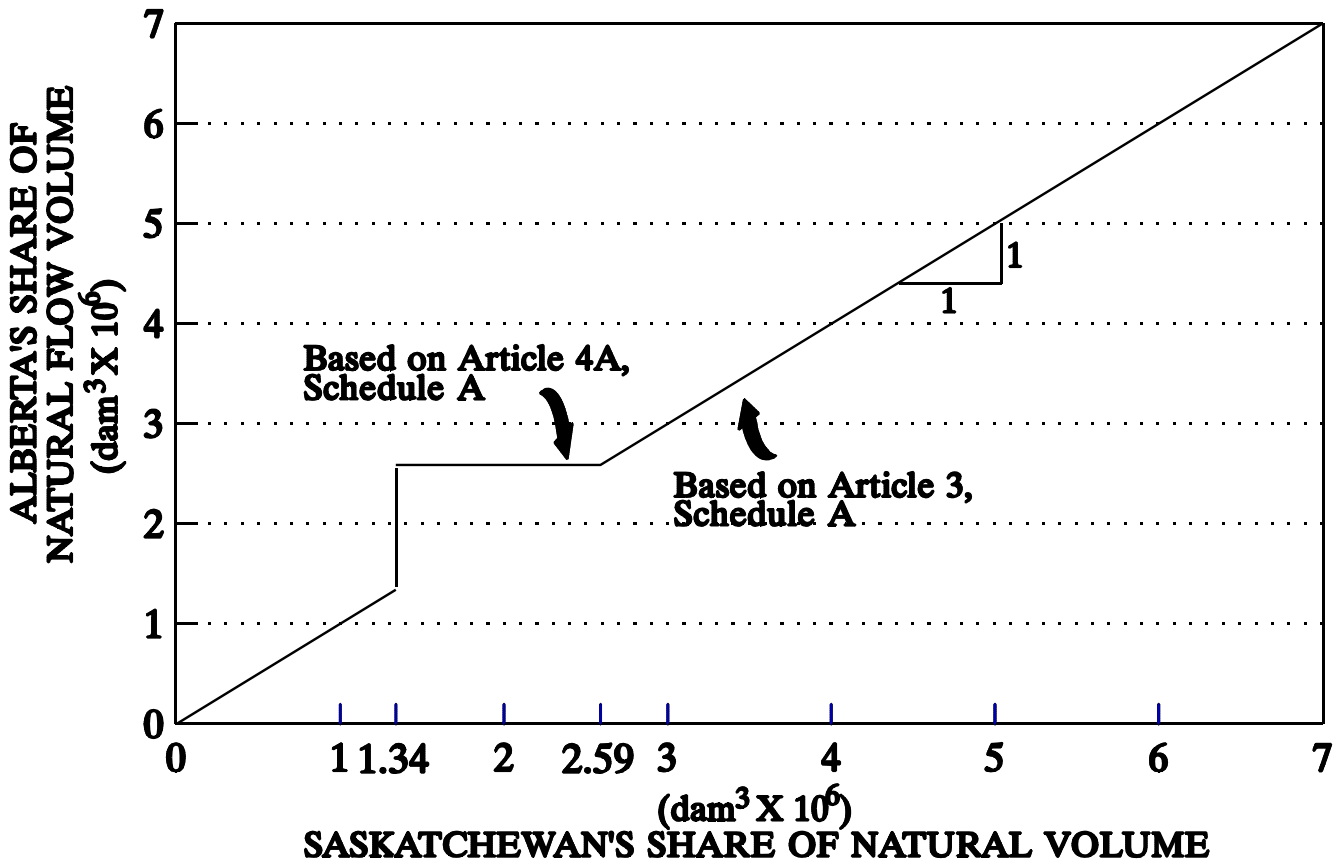

Figure No. 3

3. AUDITING OF APPORTIONMENT

Special provisions within the 1969 Master Agreement place the point of apportionment for the South Saskatchewan River at the Alberta-Saskatchewan boundary to a point below the confluence of the South Saskatchewan and Red Deer Rivers. The Agreement also makes special provisions in terms of a minimum volume which may be consumed by Alberta and in terms of a minimum flow rate which must be delivered to Saskatchewan.

3.1 Projects Depletion Method

Adherence to the Agreement is monitored by the Secretariat of the PPWB based on quarterly audit reports. The auditing period reverts to one-month or less when the recorded mean daily flow at the point of apportionment drops below 42.5 m^3/s. The auditing of apportionment is based on the apportionable flow (natural flow less U.S.A. diversions) which is computed using a procedure known as the Project Depletion Method. The Project Depletion Method calculates depletions (adjustments) due to consumptive use, diversions, and reservoir storage and evaporation, from selected projects. The adjustments are then routed (using simplified routing procedures) to the point of apportionment and are applied to the recorded flow to determine the apportionable flow. The routing of the adjustments is carried out using flows for indicative main stem stations to estimate the approximate travel time and the subsequent time shift to be applied to individual adjustment items. Due to limitations in the routing capabilities of the model, the current natural flow computation procedure does not include non consumptive diversions (ie: Ghost River diversion to Lake Minnewanka, Mud Lake diversions to the Spray River, Waterton-Belly River diversions to the St. Mary River, etc.) which may alter the time of travel or flow rate but not the volume. As such, the current procedure is essentially a volume balance model which is acceptable in the computation of natural flows for extended time periods (about one month or longer) but which has significant limitations in its ability to compute accurate natural flows for relatively short time periods. Therefore, while the procedure is acceptable in administering the volumetric portion of the Agreement it cannot be used for administering the minimum flow provision.

3.2 Monitoring Network

Table 1 provides a list of the hydrometric stations and projects currently included in the computation of apportionable flow as well as the role of the hydrometric stations in these procedures. The location of these stations is indicated in Figure 4 along with a schematic of the South Saskatchewan River and of major projects within the basin.

Of the 55 stations used in the computation of natural flows 39 are fully funded by Environment Canada (EC), 11 are provided by other agencies, while 5 are designated as federal/provincial. Of the 39 stations totally funded by the EC, 13 are used to gauge diversions, 4 are on major reservoirs, 3 are used as routing index stations, two are at natural flow points of interest, while the remaining 17 are used in assessing return flows.

3.3 Problems with Procedures

Two discrepancies were noted in the natural flow computation procedures for the South Saskatchewan River Below the Red Deer River Confluence. The first discrepancy involved the computation of diversions for what is termed the "Bow River Development". In computing this item, the model sums the recorded flows for stations 05AC004 - BRD Main Canal, 05BL015 - Little Bow Canal at High River, 05BL025 - Highwood Diversion Canal near Spring Coulee, and 05AC003 - Little Bow River near Carmangay. As the diversions gauged by stations 05BL015 and 05BL025 are believed to reach the hydrometric station 05AC003 without any appreciable depletions, the inclusion of both the Highwood diversions as measured by stations 05BL015 and 05BL025 and the flow for the Little Bow River at Carmangay is believed to be a double counting in the computation of diversions for the Bow River Development. Station 05AC003 should therefore be adjusted to reflect the natural flows which occur in the Little Bow River if this station is to be included in the computation of diversions by the BRID.

The second discrepancy is that the releases from Travers Reservoir to the lower reaches of the Little Bow River are not included in the computation of return flows for the BRID. This results in an overestimation of the consumptive depletions by this project. To alleviate this inconsistency, releases from Travers Reservoir to the lower reaches of the Little Bow River need to be included in the estimation of return flows from the BRID.

TABLE 1

PROJECTS INCLUDED
IN THE COMPUTATION OF APPORTIONABLE FLOWS AND
RELATED HYDROMETRIC STATIONS

Storage Projects	Agency[1]	Hydrometric Stations
Oldman River Dam Reservoir	EC	05AA032 Oldman Dam Reservoir at Pincher Creek
Waterton Reservoir	EC	05AD026 Waterton Reservoir
St. Mary reservoir	EC	05AE025 St. Mary Reservoir at Spring Coulee
Spray Reservoir	TAU	05BC006 Spray Reservoir at Three Sisters Dam
Lake Minnewanka	TAU	05BD003 Lake Minnewanka near Banff
Ghost Reservoir	TAU	05BE005 Ghost Lake near Cochrane
Upper Kananaskis Reservoir	TAU	05BF005 Upper Kananaskis Lake at Main Dam
Lower Kananaskis Reservoir	TAU	05BF009 Lower Kananaskis Lake at Pocaterra
Barrier Reservoir	TAU	05BF024 Barrier Lake near Seebe
Bearspaw Reservoir	TAU	05BH010 Bearspaw Reservoir near Calgary
Glenmore Reservoir	Cal	05BJ008 Glenmore Reservoir at Calgary
Gleniffer Reservoir	EC	05CB006 Gleniffer Reservoir Near Dickson

Irrigation Projects	Agency	Hydrometric Station
WESTERN IRRIGATION DISTRICT		
• Diversions	EC	05BM003 W.I.D. Canal at Chestermere L.
• Return Flows	EC	05BM008 Crowfoot Creek near Cluny
	EC	05BM005 Hammer Hill Spillway at Gleichen
	EC	05CE005 Rosebud River at Redland
	AEP/EC	05CE006 Rosebud River below Carstairs
EASTERN IRRIGATION DISTRICT		
• Diversions	EC	05CJ001 EID North Branch Canal at Bassano
	EC	05CJ003 EID East Branch Canal near Lathom
	EC	05CJ004 EID Springhill Canal near Lathom
• Return Flows	AEP/EC	05CJ006 Onetree Creek near Patricia
	EC	05CJ012 E-32; below Matzhiwin and Ware Coulee Junction
	EC	05BN014 Coal Creek at Bow City

[1] AEP=Alberta Environmental Protection, EC=Environment Canada, Cal=City of Calgary, TAU=Trans Alta Utilities, AP=Alberta Power

TABLE 1 (Continued)

Irrigation Projects (Continued)			
BOW RIVER DEVELOPMENT (INCLUDING HIGHWOOD DIVERSIONS)			
• Diversions	EC	05AC004	BRD Main Canal
	EC	05AC003	Little Bow River at Carmangay
	EC	05BL015	Little Bow Canal at High River
	EC	05BL025	Highwood Division Canal near Spring Coulee
• Return Flows	EC	05AC012	Little Bow River below Travers
	EC	05AC023	Little Bow River near The Mouth
	EC	05AG003	Expanse Coulee near The Mouth
	EC	05AG004	BRD Drain 'A' near Hays
	EC	05BN008	BRD Drain 'D' near Vauxhall
	AEP	05BN006	New West Coulee near The Mouth
UNITED IRRIGATION DISTRICT			
• Diversions	EC	05AD013	United Irrigation District Canal
MVID (INCLUDING LEAVITT-AETNA)			
• Diversions	EC	05AD017	Mountain View Irrigation District Canal
LETHBRIDGE NORTHERN IRRIGATION DISTRICT			
• Diversions	EC	05AB019	LNID Canal above Oldman Flume
• Return Flows	AEP/EC	05AD037	Piyami Drain near Picture Butte
	EC	05AD038	Battersea Drain near The Mouth
	EC	05AD040	Drain L-5 near Diamond City (05AC012 & 05AC023 listed for the BRD also have an LNID return flow component)
ST. MARY IRRIGATION DISTRICT INCLUDING MAGRATH, RAYMOND AND TABER			
• Diversions	EC	05AE021	Magrath Irrigation District Canal near Spring Coulee
	EC	05AE026	Canadian St. Mary Canal near Spring Coulee
• Return Flows	EC	05AE016	Pothole Creek at Russell's Ranch (for Raymond Irrigation District)
	EC	05AE041	Dry coulee near Magrath (MID)
	EC	05AG026	Bountiful Coulee Inflow near Cranford (for Taber I.d)
	EC	05AH005	Seven Persons Creek near Medicine Hat
	EC	05AH049	Ross Creek near Medicine Hat

Irrigation Projects (Continued)			
SHEERNESS AND DEADFISH PROJECTS			
• Diversions	AP	05ID016	Deadfish Irrigation Diversion
	AEP	05ID017	Sheerness Power Diversion
• Return Flow	AEP/EC	05CG003	Bullpound Creek near The Mouth
	AEP/EC	05CH007	Berry Creek near The Mouth
Routing Index Station			
BOW RIVER PROJECTS	EC	05BH004	Bow River at Calgary
	EC	05BN012	Bow River near The Mouth
OLDMAN RIVER PROJECTS	EC	05AD007	Oldman River at Lethbridge
Natural Flow Stations			
RED DEER RIVER	EC	05CK004	Red Deer River near Bindloss
SOUTH SASKATCHEWAN RIVER	EC	05AJ001	South Saskatchewan River at Medicine Hat

Insert Figure 4

4. MEAN ANNUAL VOLUME, 1:10 YEAR LOW FLOW VOLUME, AND 1:20 YEAR LOW FLOW VOLUME

Historical monthly and annual natural flows have been computed by the Surface Water Assessment Branch of AEP for the 1912 to 1986 period and by Environment Canada for the 1987 to 1992 period. The procedure used by AEP in the computation of natural flows are somewhat different than the "South Saskatchewan Natural Flow Calculation Procedures" used by EC, in that AEP includes U.S.A. diversions as well as giving consideration to a greater number of water use and modification projects. As the two data sets are not compatible, only the natural flows computed by AEP were used in the analysis. In conducting this analysis, the historical natural flows computed by AEP for the Red Deer at Bindloss (05CK004) and for the South Saskatchewan River at Highway #41 (05AK001), were summed to produce a complete 1912 to 1986 natural flows data set for the South Saskatchewan River at the Alberta-Saskatchewan boundary. These three data sets are summarized in Appendix B, Tables B-1 to B-3 respectively.

The mean annual volume, 1:10 year low annual flow volume, and 1:20 year low annual flow volume for the South Saskatchewan River at the Alberta-Saskatchewan boundary were computed by applying a Pearson III frequency distribution to the 1912 to 1986 annual flow volumes noted above. The resulting mean, 1:10 year low, and 1:20 low annual flow volumes computed by this procedure were 9,326,000 dam^3, 6,046,000 dam^3 and 5,458,000 dam^3 respectively.

5. WATER ALLOCATIONS

The current apportionment procedures consider solely the flow adjustments due to major projects in the computation of natural flow. To assess the adequacy of these procedures in estimating the natural and apportionment flow, an investigation was undertaken on the degree of licencing and water allocations included and omitted from the natural flow computation procedures, for each of the major sub-basin areas of the South Saskatchewan River basin.

A list of all licensed water use projects within each of the Red Deer, Bow, Oldman, and Lower South Saskatchewan (below the Bow-Oldman confluence) River basins was obtained from AEP's Water Rights Branch. The licensed projects were separated into two categories: projects included in the natural flow computation procedures and projects not included in the natural flow computation procedures. The latter category was separated into two subcategories based on the licensed diversion volume: moderate uses, for projects having an allocation greater than 500 acre-feet (616 dam^3), and minor uses, for projects having allocations of less than 500 acre-feet (616 dam^3). These latter categories were further sub-divided into Main Stem and Tributary projects, a distinction which was felt to be necessary to reflect the availability and potentially the actual water use in future analyses. The resulting assessment of licensed water uses within the South Saskatchewan River basin and its major tributaries is summarized in Table 2. As indicated in Table 2, a total of 7,412 licences have been issued in the Alberta portion of the South Saskatchewan River basin.

TABLE 2
SUMMARY OF LICENSED WATER USES
FOR THE SOUTH SASKATCHEWAN RIVER AND ITS MAIN TRIBUTARIES

SUB-BASIN	Number of Licences	Licensed Diversion (dam^3)	Licensed Return Flow (dam^3)	Licensed Consumptive Use (dam^3)
RED DEER	2,504	246,279	49,438	196,841
BOW	1,059	2,306,892	593,373	1,713,519
OLDMAN	2,137	2,014,506	136,544	1,877,962
LOWER SOUTH SASKATCHEWAN	1,712	246,378	73,784	172,504
TOTAL	7,412	4,814,055	855,139	3,960,826

The consumptive use allocated to the 7,412 licences is about 3,960,826 dam^3. Nearly 91% of this total is allocated in the Bow River and Oldman River basins while the remaining 9% is allocated almost equally between the Red Deer and lower South Saskatchewan River basin. Table 3 provides a detailed breakdown of these licences by basin.

TABLE 3 (a)
LICENSED WATER USES IN THE RED DEER RIVER BASIN

TOTAL NUMBER OF LICENCES = 2504

	Licensed Diversion (dam^3)	Licensed Return Flow (dam^3)	Licensed Consumptive Use (dam^3)
Projects Included In Natural Flow Calculation			
1. Sheerness • AEP	22,203	0	22,203
• Alta Power	21,956	8,388	13,568
2. Deadfish	6,168	0	6,168
3. Dickson Reservoir Evaporation	3,034	0	3,034
Sub Total	53,361	8,388	44,973
Projects Not Included In Natural Flow Calculation			
Moderate Allocation Projects on the Main Stem			
1. City of Red Deer	20,970	18,873	2,097
2. City of Drumheller	4,108	3,286	822
3. Anthony Heneday Water Supply	9,954	5,970	3,984
4. Buffalo Lake Diversion[2]	22,573	0	22,573
5. Others	26,494	4,550	21,944
Sub Total	84,099	32,679	51,420
Moderate Allocation Projects on Tributaries			
1. Gull Lake Diversions	5,181	0	5,181
2. Others	31,548	5,456	26,092
Sub Total	36,729	5,456	31,273
Minor Allocation projects			
• On Main Stem	22,220	862	21,358
• On Tributaries	49,870	2,053	47,817
RED DEER TOTAL	246,279	49,438	196,841

[2] Not yet active

TABLE 3 (b)
LICENSED WATER USES IN THE BOW RIVER BASIN

TOTAL NUMBER OF LICENCES = 1059

	Licensed Diversion (dam^3)	Licensed Return Flow (dam^3)	Licensed Consumptive Use (dam^3)
Projects Included In Natural Flow Calculation			
1. WID	197,853	0	197,853
Through works of WID	2,810	970	1,840
2. BRID	468,730	123,350	345,380
Through works of BRID	2,673	210	2,463
3. EID	939,927	0	939,927
Through works of EID	7,914	3,749	4,165
4. Highwood Div[3] • Squaw Coulee	13,599	0	13,599
• Little Bow Canal	32,799	0	32,799
5. Trans Alta Ghost River Diversion	43,173	43,173	0
Sub Total	1,709,478	171,452	1,538,026
Projects Not Included In Natural Flow Calculation			
Moderate Allocation Projects on Main Stem			
1. City of Calgary (Bow & Elbow)	461,820	368,693	93,127
2. University of Calgary	10,485	8,912	1,573
3. Others	50,099	19,338	30,761
Sub Total	522,404	396,943	125,461
Moderate Allocation Projects on Tributaries			
1. Others	32,138	21,110	11,028
Minor Allocation Projects			
• On Main Stem	18,303	3,519	14,784
• On Tributaries	24,569	349	24,220
BOW RIVER TOTAL	2,306,892	593,373	1,713,519

[3] Average Volume as the licence is for a rate. Volume is assigned to projects in the Little Bow River (a tributary of the Oldman River)

TABLE 3 (c)
LICENSED WATER USES IN THE OLDMAN RIVER BASIN

TOTAL NUMBER OF LICENCES = 2137

	Licensed Diversion (dam^3)	Licensed Return Flow (dam^3)	Licensed Consumptive Use (dam^3)
Projects Included In Natural Flow Calculation			
1. Mountainview, Leavitt-Aetna	30,529	0	30,529
Through works of MV ID	465	413	52
2. LNID	391,020	43,173	347,847
AEP Headwork Losses	18,503	0	18,503
Through works of LNID	4,459	392	4,067
3. SMP • St Mary ID	890,587	0	890,587
• Raymond ID	99,914	6,168	93,746
• Taber ID	194,893	24,670	170,223
• AEP Headworks	45,640	0	45,640
• Others	20,578	10,009	10,569
4. Magrath Irrigation District	41,939	6,168	35,771
5. United Irrigation District	62,909	0	62,909
Through works of UID	9	0	9
6. Oldman Reservoir Evaporation	7,820	0	7,820
Sub Total	1,809,265	90,993	1,718,272
Projects Not Included In Natural Flow Calculations			
Moderate Allocation on Main Stem and Southern Tributary Projects			
1. City of Lethbridge	30,838	22,511	8,327
2. Blood Indian Projects[4]	49,673	4,317	45,356
3. Others	38,556	1,573	36,983
• less Highwood projects	- 8,759	- 0	-8,759
Sub Total	110,308	28,401	81,907
Moderate Allocation Projects on Tributaries			
1. Chain Lakes Reservoir	6,143	6,100	43
2. Others	28,222	6,991	21,231
Sub Total	34,365	13,091	21,274
Minor Allocation Projects			
• On Main Stem and South Tributary	36,898	360	36,538
• On Minor Tributaries	61,309	3,699	57,610
• less Highwood projects	-37,639	0	-37,639
Sub Total	23,670	3,699	19,971
OLDMAN RIVER TOTAL	2,014,506	136,544	1,877,962

[4] Not yet active

TABLE 3 (d)
LICENSED WATER USES IN THE SOUTH SASKATCHEWAN RIVER BASIN

TOTAL # OF LICENCES = 1712

	Licensed Diversion (dam^3)	Licensed Return Flow (dam^3)	Licensed Consumptive Use (dam^3)
Projects Included In Natural Flow Calculation			
	0	0	0
Projects Not Included In Natural Flow Calculation			
Moderate Allocation Projects on Main Stem			
1. City of Medicine Hat	164,857	64,669	100,188
2. Others	33,888	3,916	29,972
Sub Total	198,745	68,585	130,160
Moderate Allocation Projects on Tributaries			
1. Ross Creek I.D.	3,701	247	3,454
2. Others	11,891	2,710	9,181
Sub Total	15,592	2,957	12,635
Minor Allocation Projects			
• On Main Stem	13,930	762	13,168
• On Tributaries	18,111	1,570	16,541
LOWER SOUTH SASKATCHEWAN TOTAL	246,378	73,874	172,504

6. COMPARISON OF CONSUMPTIVE ALLOCATIONS TO THE MEAN, 1:10 YEAR LOW, AND 1:20 YEAR LOW APPORTIONABLE ANNUAL FLOW VOLUME

The U.S.A. mean annual diversions of 228,000 dam^3 from the St. Mary River were subtracted from the natural flows for the South Saskatchewan River at the Alberta-Saskatchewan boundary, computed in Section 3, to obtain the mean, 1:10 year low, and 1:20 year low apportionable annual flow volume. The computed apportionable annual volumes, for the indicated return periods, are 9,098,000 dam^3, 5,818,000 dam^3, and 5,230,000 dam^3 respectively.

The licensed consumptive uses for projects identified in Chapter 5, were expressed as a percentage of these apportionable flows, as well as a percentage of the total licensed consumptive uses, so as to provide a basis for evaluating the relative importance of each project to the natural flow computation procedures. The results are summarized in Table 4. The licensed consumptive uses represent 43.54%, 68.08%, and 75.73% of the mean, 1:10 year low, and 1:20 year low apportionable annual flow volume respectively or 87.08%, 136.16%, and 151.46% of Alberta's share for the indicated return periods.

The projects currently included in the apportionment procedures represent about 83.35% of the total licensed uses. This percentage could be increased by about 5%, to about 88.5% of licensed consumptive uses, if consumptive uses by Calgary, Medicine Hat, and Lethbridge, all of which are readily available, are included in the natural flow computations.

TABLE 4 (a)
ASSESSMENT OF LICENSED WATER USES FOR THE RED DEER BASIN

TOTAL NUMBER OF LICENCES = 2504

	Licensed Consumptive Use (dam^3)	Licensed Consumptive Use as % of Mean Annual Flow (%)	1:10 Year Low Flow (%)	1:20 Year Low Flow (%)	Total Allocated Consumptive Use (%)
Projects Included In Natural Flow Calculation					
1. Sheerness • AEP	22,203	.24	.38	.42	.56
• Alta Power	13,568	.15	.23	.26	.34
2. Deadfish	6,168	.07	.11	.12	.16
3. Dickson Reservoir Evaporation	3,034	.03	.05	.06	.08
Sub Total	44,973	.49	.78	.86	1.14
Projects Not Included In Natural Flow Calculation					
Moderate Allocation Projects on Main Stem					
1. City of Red Deer	2,097	.02	.04	.04	.05
2. City of Drumheller	822	.01	.01	.02	.02
3. Anthony Heneday System	3,984	.04	.07	.08	.10
4. Buffalo lake Diversion[5]	22,573	.25	.39	.43	.57
5. Others	21,944	.24	.38	.42	.56
Sub Total	51,420	.57	.88	.98	1.30
Moderate Allocation Projects on Tributaries					
1. Gull Lake Diversions	5,181	.06	.09	.10	.13
2. Others	26,092	.29	.45	.50	.66
Sub Total	31,273	.34	.54	.60	.79
Minor Allocation Projects					
• On Main Stem	21,358	.23	.37	.41	.54
• On Tributaries	47,817	.53	.82	.91	1.21
RED DEER TOTAL	196,841	2.16	3.38	3.76	4.97

[5] Not yet active

TABLE 4 (b)
ASSESSMENT OF LICENSED WATER USES FOR THE BOW RIVER BASIN

TOTAL NUMBER OF LICENCES = 1059

	Licensed Consumptive Use (dam^3)	Licensed Consumptive Use as % of Mean Annual Flow (%)	1:10 Year Low Flow (%)	1:20 Year Low flow (%)	Total Allocated Consumptive Use (%)
Projects Included In Natural Flow Calculation					
1. Through works of WID	199,693	2.19	3.43	3.82	5.04
2. Through works of BRID	347,843	3.82	5.98	6.65	8.78
3. Through works of EID	944,092	10.38	16.22	18.05	23.84
4. Highwood Div[6] . Squaw Coulee	13,599	.15	.23	.26	.34
. Lower Bow Canal	32,799	.36	.56	.63	.83
Sub Total	1,538,026	38.83	26.43	29.41	38.83
Projects Not Included In Natural Flow Calculations					
Moderate Allocation Projects on Main Stem					
1. City of Calgary (Bow and Elbow)	93,127	1.02	1.60	1.78	2.35
2. University of Calgary	1,573	.02	.03	.03	.04
3. Others	30,761	.34	.53	.59	.78
Sub Total	125,461	1.38	2.16	2.40	3.17
Moderate Allocation Projects on Minor Tributaries					
1. Others	11,028	.12	.19	.21	.28
Minor Allocation Projects					
• On Main Stem	14,784	.16	.25	.28	.37
• On Tributaries	24,220	.27	.42	.46	.61
BOW RIVER TOTAL	1,713,159	18.83	29.45	32.76	43.26

[6] Average Volume as the licence is for a rate. Volume is assigned to projects in the Little Bow River (a tributary of the Oldman River)

TABLE 4 (c)
ASSESSMENT OF LICENSED WATER USES FOR THE OLDMAN RIVER BASIN

TOTAL NUMBER OF LICENCES = 2137

	Licensed Consumptive Use (dam^3)	Licensed Consumptive Use as % of Mean Annual Flow (%)	1:10 Year Low Flow (%)	1:20 Year Low Flow (%)	Total Allocated Consumptive Use (%)
Projects Included In Natural Flow Calculation					
1. Through works of MVID	30,581	.34	.53	.58	.77
2. Through works of LNID	370,417	4.07	6.37	7.08	9.35
3. Through works of SMRID	1,210,765	13.31	20.81	23.15	30.57
4. MAGRATH ID	35,771	.39	.61	.68	.90
5. Through works of UID	62,918	.69	1.08	1.20	1.59
6. OLDMAN Reservoir EVAP.	7,820	.09	.13	.15	.20
Sub Total	1,718,272	18.89	29.53	33.85	43.38
Projects Not Included In Natural Flow Calculations					
Moderate Allocation Projects on Main Stem					
1. City of Lethbridge	8,327	.09	.14	.16	.21
2. Blood Indian Projects[7]	45,356	.50	.78	.87	1.15
3. Others	28,224	.31	.49	.54	.71
Sub Total	81,907	.91	1.41	1.57	2.07
Moderate Allocation Projects on Minor Tributaries					
1. Chain Lakes Reservoir	43	.00	.00	.00	.01
2. Others	21,231	.23	.37	.41	.53
Sub Total	21,274	.23	.37	.41	.54
Minor Allocation Projects					
• On Main Stem and South Trib.	36,538	.40	.63	.70	.92
• On Minor Tributaries	19,971	.22	.34	.38	.50
OLDMAN RIVER TOTAL	1,877,962	20.64	32.28	35.91	47.41

[7] Not yet active

TABLE 4 (d)
ASSESSMENT OF LICENSED WATER USES FOR THE LOWER SOUTH SASKATCHEWAN RIVER BASIN

TOTAL # OF LICENCES = 1712

	Licensed Consumptive Use (dam^3)	Licensed Consumptive Use as % of Mean Annual Flow (%)	1:10 Year Low Flow (%)	1:20 Year Low Flow (%)	Total Allocated Consumptive Use (%)
Projects Included In Natural Flow Calculation					
	0	.00	.00	.00	.00
Projects Not Included In Natural Flow Calculations					
Moderate Allocation Projects on Main Stem					
1. City of Medicine Hat	100,188	1.10	1.72	1.92	2.53
2. Others	29,972	.33	.52	.57	.76
Sub Total	130,160	1.43	2.24	2.49	3.29
Moderate Allocation Projects on Tributaries					
1. Ross Creek Irrigation District	3,454	.04	.06	.07	.09
2. Others	9,181	.10	.16	.18	.23
Sub Total	12,635	.14	.22	.24	.32
Minor Allocation Projects					
• On Main Stem	13,168	.14	.23	.25	.33
• On Tributaries	16,541	.18	.28	.32	.42
LOWER SOUTH SASKATCHEWAN TOTAL	172,504	1.90	2.97	3.30	4.35

TABLE 4 (e)
TOTAL LICENSED WATER USE

	Licensed Consumptive Use (dam^3)	Licensed Consumptive Use as % of Mean Annual Flow (%)	1:10 Year Low Flow (%)	1:20 Year Low Flow (%)	Total Allocated Consumptive Use (%)
RED DEER TOTAL	196,841	2.16	3.38	3.76	4.97
BOW RIVER TOTAL	1,713,159	18.83	29.45	32.76	43.26
OLDMAN RIVER TOTAL	1,877,962	20.64	32.28	35.91	47.41
LOWER SOUTH SASKATCHEWAN TOTAL	172,504	1.90	2.97	3.30	4.35
SOUTH SASKATCHEWAN BASIN TOTAL ALLOCATIONS	3,960,826	43.54	68.08	75.73	100.0

TOTAL # OF LICENCES = 7,412

7. EVALUATION OF HYDROMETRIC MONITORING NETWORK

This section examines the hydrometric monitoring network for administering apportionment in the South Saskatchewan River basin. The section begins by evaluating the hydrometric requirements for assessing adjustments due to storage projects, diversion projects, return flows and for routing. As the current apportionment procedures are of limited value in administering the minimum flow condition of the Agreement, the section also examines the hydrometric requirements for a daily simulation model which would permit the administration of all aspects of the Agreement.

7.1 Storage Projects

Table 5 provides a list of the 13 major on-stream reservoirs in the South Saskatchewan River basin along with their live storage capacity. Included in Table 5 is the EC water level station name and number and the agency providing the data. With the exception of the Chain Lakes Reservoir, all of these reservoirs are included in the apportionment procedures. Of the 12 reservoirs included in the apportionment procedures, water level information for 8 of the reservoirs is supplied by outside agencies while 4 are supplied by EC.

TABLE 5

MAJOR ON-STREAM STORAGE PROJECTS
IN THE SOUTH SASKATCHEWAN RIVER BASIN

Storage Project	Live Storage (dam^3)	Agency[1]	Hydrometric Stations	
1. Oldman River Dam Reservoir	493,400	AEP	05AA032	Oldman Reservoir at Pincher Creek
2. Waterton Reservoir	114,400	EC	05AD026	Waterton Reservoir
3. St. Mary Reservoir	369,300	EC	05AE025	St. Mary Reservoir at Spring Coulee
4. Spray Reservoir	188,000	TAU	05BC006	Spray Reservoir at Three Sisters Dam
5. Lake Minnewanka	224,500	TAU	05BD003	Lake Minnewanka near Banff
6. Ghost Reservoir	92,500	TAU	05BE005	Ghost Lake near Cochrane
7. Upper Kananaskis Reservoir	125,000	TAU	05BF005	Upper Kananaskis Lake at Main Dam
8. Lower Kananaskis Reservoir	63,200	TAU	05BF009	Lower Kananaski Lake at Pocaterra
9. Barrier Reservoir	24,800	TAU	05BF024	Barrier Lake near Seebe
10. Bearspaw Reservoir	13,800	TAU	05BH010	Bearspaw Reservoir near Calgary
11. Glenmore Reservoir	26,000	Cal	05BJ008	Glenmore Reservoir at Calgary
12. Gleniffer Reservoir	200,000	EC	05CB006	Gleniffer Reservoir Near Dickson
13. Chain Lakes Reservoir	15,300	AEP/EC	05AB037	Chain Lake Reservoir near Nanton

[1] AEP=Alberta Environmental Protection, EC=Environment Canada, Cal=City of Calgary, TAU=Trans Alta Utilities, AP=Alberta Power

The four reservoirs monitored by EC are the Oldman River Dam, Waterton, St. Mary, and Gleniffer Reservoir. Historical water level information for these reservoirs indicate modifications in the mean weekly flow rates of as much as ±50 m^3/s for the Waterton Reservoir, ±60 m^3/s for St. Mary Reservoir, and ±30 m^3/s for the Gleniffer Reservoir as well as significant modification to the annual flow volume due to over year storage. While the period of operation of the Oldman River Dam is too short for assessing its impact on flows, it is believed its potential impact will be in the same range as for St. Mary Reservoir. In view of the large modifications which these reservoirs exert on the apportionable flow, it is imperative that these stations be retained in the hydrometric monitoring network.

Water levels for the Chain Lakes Reservoir have been monitored by EC since 1966. The reservoir, has a live storage capacity of about 15,300 dam^3 and has introduced modifications to the mean weekly flow rates of as much as ±1.3 m^3/s. Carryover storage has modified the annual apportionable flow by as much as ±8,000 dam^3. Because of this comparatively small influence on natural flows, it is recommended that Chain Lakes Reservoir not be included in the PPWB list of apportionment stations.

7.2 Diversion Projects

Diversion projects in the South Saskatchewan River basin are summarized in Table 6. Table 6 also provides a summary for each project in terms of the hydrometric stations used to gauge the diversion and the licensed consumptive use; and expresses the licensed use as a percentage of the mean annual apportionable flow and of the total licensed consumptive use. Table 6 also provides the cumulative percentage of allocated consumptive uses.

The two largest diversion projects, the SMRID and the EID, when combined account for 55.31% of all allocated consumptive diversions in the South Saskatchewan River basin. Currently, two hydrometric stations are being used to monitor the Magrath/SMRID diversions even though these two project have a common diversion canal from the St. Mary Reservoir. However, as the two monitoring

sites are located at drop structures which have stable, calibrated rating curves, the two structures are deemed to be more cost effective than having a single station upstream of the Magrath diversion. It is recommended that both station 05AE026 and station 05AE021 be retained.

The monitoring of EID diversions currently requires a hydrometric station on each of three main laterals due to variable backwater effects throughout the main canal. Environment Canada is currently testing the potential use of an acoustic flow meter for monitoring flows in the EID main canal. If the use of this device proves successful, the monitoring of diversions for the EID could potentially be consolidated to a single hydrometric station and a reduction of two stations could be realized. It is recommended that the EID diversions continue to be monitored under the present format until EC's tests of the acoustic flow meter are complete.

Next to the SMRID and the EID, the largest water use allocations are to the LNID, BRID and WID with each accounting for about 5 to 10% of all consumptive diversions. These districts combined with the SMRID and EID account for nearly 81% of all consumptive diversions in the South Saskatchewan River basin. Due to the large allocations assigned to these districts, these projects must be retained in any apportionment computation. However, as discussed in Chapter 3, the inclusion of station 05AC003, Little Bow River at Carmangay, in the computation of BRID diversions is questionable and should be examined in more detail.

Next to the above noted irrigation districts, three of the largest consumptive use allocations are to the Cities of Medicine Hat, Calgary, and Lethbridge. The three municipalities, combined, account for about 5.09% of all licensed consumptive diversions. While information on their water use seems to indicate that actual consumptions are substantially lower than the allocations, these projects represent a significant portion of all allocated consumptive uses and should be included in the apportionment computations. As water use data for these projects is readily available from AEP's Water Rights Branch, their inclusion in the computation of natural flows could be implemented without any additional monitoring. These three municipalities, together with the five major irrigation districts noted above account for about 86.09% of all water use allocations in the South Saskatchewan basin.

The City of Red Deer and the Anthony Heneday Water Supply, which serves communities in the vicinity of Red Deer, have licensed consumptive uses of 2,097 dam^3, and 3,984 dam^3 respectively or a combined total of 0.06% of the mean annual flow in the South Saskatchewan River. While water use data for these projects is readily available from AEP's Water Rights Branch, it is felt that these projects represent relatively minor diversions and, in order to minimize input data requirements, should not be included in the apportionment computation.

The Blood Indian Project and the Buffalo Lake diversions combined account for about 1.72% of licensed consumptive diversions. As these projects are not yet in place, they need not be included in the apportionment procedures at this time. These projects should be included in the apportionment computation when they become operational.

The six remaining gauged projects consist of the United Irrigation District (UID), the Sheerness project, the Highwood diversions via the Little Bow and Squaw Coulee canals, the Mountainview Irrigation Districts and the Deadfish diversions which combined account for about 4.6% of all allocations. Of these, only the United Irrigation District, at 1.59%, monitors more than 1.0% of all allocated uses. The two smallest projects, the Highwood Squaw Coulee diversion and the Deadfish diversions, account for 0.34% and 0.16%, respectively, of allocated consumptive uses. For the Highwood Squaw Coulee Project, annual diversions in the 1976 to 1990 period have varied from 1,940 dam^3 to 15,800 dam^3 with a mean of about 8,800 dam^3. For the Deadfish Project, annual diversions have varied from 1,760 dam^3 to 6,130 dam^3 with a mean of about 4,830 dam^3. Maximum rates of diversions for both of these project have peaked at about 1.5 m^3/s while their averages have been in the order of about 0.5 m^3/s for Squaw Coulee and 0.23 m^3/s for Deadfish. In view of the comparatively small influence of the Deadfish project on natural flows, this station is not deemed to be vital to the computation of natural flows. However, as the station data is required by AEP to manage this project, it is recommended that this hydrometric station be retained in apportionment computations as long as AEP continues to contribute the data.

Small to moderate sized projects on the Main Stems, (Red Deer River, Bow River, Oldman River, and the Southern Tributaries consisting of the Waterton, Belly, and St.Mary Rivers) account for

about 5.01% of allocated consumptive diversions. As projects in this category likely receive their full water requirements during most years, their consumptive use should be included in the apportionment computations. However, since it is impractical to monitor the numerous projects in this category, and since actual consumptions may differ substantially from the allocated volume, a study should be carried out to determine how best to include these allocations in the apportionment procedures.

Small to moderate sized projects on tributaries account for about 4.67% of allocated consumptive diversions. However, as these projects are located on streams which do not have an assured supply, the actual consumptive diversions are likely substantially lower than the allocated volumes. Natural flow analyses of the Berry, Sounding, and Monitor Creek basins, conducted by AEP's Surface Water Assessment Branch in 1993, indicate actual consumption to be about 10% of the allocated volumes with most of the actual use occurring in average to above average runoff years. In this regard, the inclusion of this category of licensed allocations in the apportionment procedures is not recommended.

TABLE 6

ASSESSMENT OF LICENSED WATER USES
FOR THE SOUTH SASKATCHEWAN RIVER

Diversion Project	Hydrometric Station #	Licensed Consumptive Use (dam^3)	Licensed Consumptive Use as % of		
			Mean Annual Flow	Total Licensed Consumptive Use	Cumulative Licensed Consumptive Use
SMRID (including Raymond & Taber)*	05AE026	1,210,765	13.31	30.57	30.57
Magrath Irrigation District*	05AE021	35,771	0.39	0.90	31.47
EID*	05CJ001 05CJ003 05CJ004	944,092	10.38	23.84	55.31
LNID*	05AB019	370,417	4.07	9.35	64.66
BRID*	05AC003 05AC004	347,843	3.82	8.78	73.44
WID*	05BM003	199,693	2.19	5.04	78.48
City of Medicine Hat	--	100,188	1.10	2.53	81.01
City of Calgary	--	93,127	1.02	2.35	83.36
UID*	05AD013	62,918	0.69	1.59	84.95
Blood Indian Projects	--	45,356	0.50	1.15	86.10
Sheerness*	05ID017	35,771	0.39	0.90	87.00
Highwood/Little Bow Canal*	05BL015	32,799	0.36	0.83	87.83
MVID*	05AD017	30,581	0.34	0.77	88.60
Buffalo Lake Division	--	22,573	0.25	0.57	89.17
Highwood/Squaw Coulee*	05BL025	13,599	0.15	0.34	89.51
City Of Lethbridge	--	8,327	0.09	0.21	89.72
Oldman Dam Evaporation*	--	7,820	0.09	0.20	89.92
Deadfish Diversion*	05CH012	6,168	0.07	0.16	90.08
Anthony Heneday Water Supply	--	3,984	0.04	0.10	90.18
Dickson Reservoir Evaporation*	--	3,034	0.03	0.08	90.26
City of Red Deer	--	2,097	0.02	0.05	90.31
City of Drumheller	--	822	0.01	0.02	90.32
Small to Moderate Projects on Main Stem	--	198,322	2.18	5.01	95.33
Small to Moderate Projects On Tributaries	--	184,759	2.03	4.67	100.0

* denotes projects included in current natural flow procedures

7.3 Return Flows

The apportionment procedures for the South Saskatchewan River include return flows from the Sheerness and Deadfish projects as well as from each of the irrigation districts in their computation of natural flows. As the return flows cannot be fully monitored, due to the large number of return flow channels, total return flows from the Sheerness and Deadfish projects and from each of the irrigation districts are estimated by means of regression equations which correlate total returns to the flow recorded at 23 selected return flow monitoring stations. Within this section, the relative need for each of these stations is evaluated by assessing the procedures used in the estimation of return flows and the role of each of the 23 stations in the computation of apportionable flow. The 23 stations used in estimating return flows include 17 stations which are fully funded by EC, 3 which are designated as F/P, 2 which are contributed by AEP and one which is contributed by Alberta Power. The 23 stations are listed in Table 7.

TABLE 7
HYDROMETRIC STATIONS USED TO ESTIMATE RETURN FLOWS

Project	Station #	Station Name
WID	05BM008	Crowfoot Creek near Cluny
	05BM005	Hammer Hill Spillway at Gleichen
	05CE005	Rosebud River at Redland
	05CE006	Rosebud River below Carstairs
EID	05CJ006	Onetree Creek near Patricia
	05CJ012	E-32; below Matzhiwin and Ware Coulee Junction
	05BN014	Coal Creek at Bow City
BRID	05AG003	Expanse Coulee near The Mouth
	05AG004	BRD Drain 'A' near Hays
	05BN008	BRD Drain 'D' near Vauxhall
	05BN006	New West Coulee near The Mouth
LNID	05AC012	Little Bow River below Travers
	05AC023	Little Bow River near The Mouth
	05AD037	Piyami Drain near Picture Butte
	05AD038	Battersea Drain near The Mouth
	05AD040	Drain L-5 near Diamond City
SMRID	05AE016	Pothole Creek at Russell's Ranch (Raymond Irrigation District)
	05AE041	Dry coulee near Magrath (MID)
	05AG026	Bountiful Coulee Inflow near Cranford (Taber I.D.)
	05AH005	Seven Persons Creek near Medicine Hat
	05AH049	Ross Creek near Medicine Hat
SHEERNESS/DEADFISH		
	05CG003	Bullpound Creek near The Mouth
	05CH007	Berry Creek near The Mouth

7.3.1 Assessment of Sheerness/Deadfish Return Flow Stations

Alberta Power Ltd. is licensed to divert 21,956 dam^3, from the Red Deer River through the Sheerness project of which 8,388 dam^3 is return flow via the cooling pond blowdown canal. Alberta Environmental Protection is licensed to divert 13,815 dam^3 from the Red Deer River, through the Sheerness Project as well as the 8,388 dam^3 return flow from Alberta Power's cooling pond, for uses in the Bullpound and Berry Creek Basins. In recent years, the annual volume actually reaching Berry and Bullpound Creek through the Sheerness project has varied from 5,710 dam^3 to 12,000 dam^3 with most of the diversions going into the Berry Creek Reservoir. Releases from the Berry Creek Reservoir in recent years, have averaged about 5,600 dam^3 with most of it being consumed within a short distance downstream of the reservoir. In addition to these allocations, AEP is licensed to divert 6,l84 dam^3 from the Red Deer River to Berry Creek, through the Deadfish diversion canal for irrigation and stockwater in the lower portions of Berry Creek. In recent years diversions through Deadfish project have averaged about 5,000 dam^3. Return flows from the Sheerness Project and the Deadfish project are monitored by two hydrometric stations; 05CH007, Berry Creek near the Mouth, and 05CG003, Bullpound Creek near the Mouth. In recent years, the flow measured by 05CG003, Bullpound Creek near the Mouth has average about 510 dam^3, most of which occurs in the April-May period and is likely due to local runoff rather than return flows. The flow measured at station 05CH007, Berry Creek near the Mouth, has averaged 1,860 dam^3 with a substantial portion occurring in the April-May period as a result of local runoff. It is felt that the return flow from the Sheerness and Deadfish projects is relatively minor and that the flow recorded by stations 05CH007 and 05CG003 is not representative of the return flow but rather is due to local runoff. It is recommended that return flows from these project be set at zero and effectively removed from the apportionment computations. It is further recommended that these two stations be dropped from the PPWB list of apportionment stations.

7.3.2 Assessment of Irrigation Districts Return Flow Stations

The assessment of the irrigation districts return flow monitoring network was carried out by applying all available data in the 1981 to 1992 period to the return flow equations for each of the districts. The results were then used to assess the relative contribution of each of the hydrometric stations to the district and total return flows. Table C-1 in Appendix C, provides a detailed analyses of the equations used in the computation of return flows for each of the irrigation districts, of the volume and percentage contribution of each of the hydrometric stations to the estimated district returns and the average annual volume recorded for each of the stations. Table 8 provides a summary of the results including the recorded average annual return flow volume, the weighted volume contributed by each of the stations to the volume computed by the regression equations and its percentage relative to the returns for the individual district and to the total returns from all gauged irrigation districts. As indicated in Table 8, the Eastern Irrigation District accounts for 45.46% of all irrigation district returns, this is followed by the St. Mary Projects at 19.23%, the BRID at 17.50% the WID at 13.07%, and the LNID at only 4.74%. Table 8, in conjunction with Table C-1 further indicate the following:

Eastern Irrigation District

The regression equations for the EID display large variations in the weight assigned to the monthly values of the regression constant and the regression coefficients for stations 05BN014 and station 05CJ006. For example, the regression constant for the month of June is +18214.20 while for the month of July it is -3714.56. Similarly, for station 05CJ006 the regression coefficient, or station weight, is 0.000 for June and 1.917 for July while for station 05BN014 the regression coefficient is 0.000 for June to August and 7.468 for September and October. As this level of variability raises some concerns as to their accuracy, the regression equations for the EID should be re-examined. The re-examination of the regression equation may be conducted using continuous flow measurements which are being collected by the EID.

The return flow for station 05BN014, Coal Creek at Bow City, accounts for less than 5% of the return flows from the EID and for less than 1% of the total returns from the five major irrigation districts. This station should be discontinued and its recorded long term mean used in the regression equations.

The Eastern Irrigation District has implemented an extensive return flow monitoring program. It is recommended that discussions be initiated with the EID to assess partnership opportunities in the monitoring of return flows for the EID.

Western Irrigation District

The regression equations for the WID display large variations in the weight assigned to the monthly values of the regression coefficients for station 05BM005 and for station 05CE006. The return flow for each of these stations accounts for less than 5% of the return flows from the WID and for less than 1% of the total returns from the five major irrigation districts. These stations should be discontinued and their recorded long term mean used in the regression equations. As the regression coefficients for the remaining stations exhibit reasonably stable monthly values the regression equations for the WID do not need to be re-examined.

Bow River Irrigation District

The regression equations for the BRID display large variations in the weight assigned to the monthly values of the regression coefficients for all stations. It is of special concern that the regression coefficients for stations 05BN006 and 05BN008 alter their relative contributions to the computed returns to 11.8% and 264.4%, respectively, of their recorded values. As the level of variability in the monthly regression coefficients and the magnitude of the difference between the recorded and computed return flow contribution for these stations raises concern as to their accuracy, the return flow equations for the BRID should be re-examined.

The computed and recorded return flow for station 05AG004, B.R.D. Drain 'A' near Hays, accounts for less than 5% of the return flows from the BRID and for less than 1% of the total returns from the five major irrigation districts. This station should be discontinued and its recorded long term mean used in the regression equations.

Lethbridge Northern Irrigation District

While the regression coefficients for the LNID are constant for all months there is some question as to the need of a regression equation for this district since 1) 81% of the returns from the LNID are recorded and 2) the district returns account for only 4.74% of the returns from

all districts. It is felt that the return flows from the LNID can be adequately represented by summing the recorded flow for stations 05AD037, 05AC023, and the long term average for station 05AD038 minus the recorded flow for station 05AC012.

The return flow for station 05AD040, Drain L-5 near Diamond City, accounts for less than 5% of the return flows from the LNID and for less than 1% of the total returns from the five major irrigation districts and therefore should be discontinued. While the computed return flow for station 05AD038, Battersea Drain near the Mouth, represents 1.2% of the total returns from the five major irrigation districts the recorded return flow represents only 0.92 of this total and, for the period analyzed shows relatively minor variability (±2000 dam^3) from the recorded mean. It is, therefore, recommended that this station be discontinued and that its recorded long term mean be used in the regression equations.

St. Mary River Irrigation Projects

While the regression coefficients for the SMRIP are constant for all months, the regression equations for the SMRIP's should be re-examined since the coefficient assigned to station 05AG026, Bountiful Coulee Inflow near Cranford, results in this station contributing 20,477 dam^3 to the districts return flow estimate as opposed to the recorded value of 3526 dam^3.

The return flow for station 05AE041, Dry Coulee near Magrath, accounts for less than 5% of the return flows from the SMRIP's and for less than 1% of the total returns from the five major irrigation districts and therefore should be discontinued. Station 05AG026, Bountiful Coulee Inflow near Cranford, while accounting for 18.2% of the computed SMRIP's return flow and 3.50% of total returns from all irrigation districts, shows relatively minor variability (±1000 dam^3) in the recorded annual volumes and,subject to a re-examination of the SMRIP's regression equations, should be considered for discontinuation.

Based on the above discussion it is recommended that that the regression equations for the EID, BRID, and SMRIP's be re-examined and that the regression equations for the LNID be modified as indicated in the above text. It is also recommended that the following stations be discontinued and that their long term mean be used in the regression equations:

05BN014 Coal Creek at Bow City

05BM005 Hammer Hill Spillway near Gleichen

05CE006 Rosebud River below Carstairs Creek

05AG004 B.R.D. Drain 'A' near Hays

05AD038 Battersea Drain near the Mouth

05AD040 Drain L-5 near Diamond City

05AE041 Dry Coulee near Magrath

In view of the reduced return flow monitoring network being recommended and its reliance on regression equations for its estimation, there is a need to periodically verify the validity of the equations. It is recommended Environment Canada establish a detailed monitoring program to verify the return flow equations as the need arises based on such factors as changes in licensed consumptive use, changes in water use efficiencies, changes in internal storage, and significant changes in crop.

TABLE 8
STATION CONTRIBUTION (BASED ON REGRESSION EQUATIONS)
TO DISTRICT AND TOTAL RETURN FLOWS

IRRIGATION DISTRICT		RETURN FLOWS			
		Recorded Volume (dam^3)	Weighted Volume Based on Regression (dam^3)	Weighted Volume as % of District Returns	Weighted Volume as % of Returns From all Districts
EASTERN IRRIGATION DISTRICT					
	Regression Constant		25556	9.7	4.36
05BN002	Twelve Mile Creek	54048	82372	31.0	14.06
05BN014	Coal Creek at Bow City	3535	6134	2.3	1.05
05CJ006	Onetree Creek	38810	44753	16.8	7.64
05CJ012	Matzhiwin Creek downstream Ware Coulee	80770	107557	40.3	18.36
	EID total	177163	266372	100.0	45.46
WESTERN IRRIGATION DISTRICT					
	Regression Constant		6746	9.0	1.15
05BM005	Hammer Hill Spillway	3558	404	0.5	0.07
05BM008	Crowfoot Creek near Cluny	21383	26421	34.4	4.51
05CE005	Rosebud at Redland	43671	44559	58.2	7.61
05CE006	Rosebud River downstream Carstairs	-3556	-1570	-2.0	-0.27
	WID total	65056	76560	100.0	13.07
BOW RIVER IRRIGATION DISTRICT					
	Regression Constant		21115	20.7	3.60
05AG003	Expanse Coulee	21388	40416	39.3	6.90
05AG004	B.R.D. Drain 'A'	4361	1461	1.4	0.25
05BN006	New West Coulee,	36473	4293	4.2	0.73
05BN008	B.R.D. Drain 'D'	13341	35277	34.4	6.02
	BRID total	75563	102562	100.0	17.50

TABLE 8 (Continued)

LETHBRIDGE NORTHERN IRRIGATION DISTRICT					
	Regression Constant		2368	9.4	0.40
05AD037	Piyami Drain	8088	7724	28.4	1.32
05AD038	Battersea Drain	5376	7032	25.5	1.20
05AC023	Little Bow at Mouth	21943	27144		
05AC012	Little Bow d/s Trav.	-13637	-17061	34.8	1.72
05AD040	Drain L-5 Near Diamond City	658	547	2.0	0.09
	LNID total	22428	27754	100.0	4.74
ST. MARY RIVER IRRIGATION PROJECTS					
	Regression Constant		1847	1.7	0.32
05AH005	7-Persons Creek at Medicine Hat	20752	50926	45.5	8.69
05AG026	Bountiful Cl. Inflow near Cranford	3526	20477	18.2	3.50
05AH049	Ross Creek at Medicine Hat	9730	21846	18.7	3.73
05AE041	Dry Coulee near Magrath	5490	5490	5.0	0.94
05AE016	Pothole Coulee near. Mouth	12095	12095	10.9	2.06
	SMP total	51593	112681	100.0	19.23

7.4 Routing Index Stations

In the current apportionment procedures, the adjustments due to diversions and return flows are computed for a centralized point near the project location for each month. The adjustments at the Alberta-Saskatchewan boundary are computed by applying a time shift to the project adjustment for the time it would have taken them to travel from the project location to the interprovincial boundary. The time of travel is based on recorded flows for the latter part of the month at selected main stem stations. The stations currently used as routing index stations are; 05BH004-Bow River at Calgary, 05BN012-Bow River near the Mouth, and 05AD007-Oldman River at Lethbridge. These stations are adequate for determining time of travel adjustments for the Bow River and Oldman River. An additional station is required, even for the current administration procedures, for routing flow adjustments in the Red Deer River. It is recommended that the hydrometric station 05CC002-Red Deer River at Red Deer be included in the PPWB list of monitoring stations.

7.5 Minimum Flow Provision

The minimum flow provision of the Master Agreement on the South Saskatchewan River requires Alberta to maintain a minimum flow which is equal to or greater than the lesser of 42.5 m^3/s or 50% of the apportionable flow. Therefore, at any time when the recorded flow at the interprovincial boundary falls below 42.5 m^3/s, adherence to the minimum flow provision needs to be verified. During the 1970 to 1982 period, prior to the construction of the Dickson Dam, there were 21 such occurrences at the interprovincial boundary. Of these, 17 had a duration of less than 5 days while the remaining 4 had a duration of 6 to 10 days. Of the 21 occurrences, only one, which occurred from April 30 to May 4, 1977, occurred outside of the winter months. Since 1983, Alberta's capability to manage minimum flows in the South Saskatchewan River has been enhanced by the construction of the Dickson Dam. Also, since 1983 Alberta has operated its system so as to maintain a minimum flow of 42.5 m^3/s at the interprovincial boundary, even though this flow rate may have been greater than 50% of the apportionable flow. As a result of these two items, there were only three occasions in the entire 1983-

1990 period during which flow at the interprovincial boundary fell below 42.5 m^3/s. These were; October 30 to November 6, 1984, December 16 to 22, 1987, and November 27 to December 3, 1990.

In models which use discrete time steps for their computation, a flow or flow adjustment introduced at a upstream point may not be fully realized at a downstream point during the same computational time step due to the time required to travel the distance between the two points. This can lead to a volume imbalance between the upstream and downstream node for that computational period. Discrete time models, such as the one currently used to administer apportionment, compensate for this occurrence by introducing a 'routing adjustment item' which shifts the volume that is in transport to the subsequent computational time step. The routing adjustment concept works reasonably well for instances in which time of travel is a relatively minor portion of the computational time step. In instances where the time of travel is significant however, a situation is created in which the 'routing adjustment item' may span two or more computational time steps. This leads to a situation in which flows or routing adjustments from one computational time step begin to catch-up to or lag behind the flows in adjacent computational time steps which results in gaps and overlaps in the computed downstream flow. Because of these difficulties, discrete time models are not recommended for instances where the required computational time step begins to approach, or is shorter than the time of travel. While continuous simulation models are generally recommended for these instances, they should be used with some degree of caution since minor inaccuracies inherent in the input data for short time intervals, (i.e.: round-off and wind set-up in reservoir elevations), can introduce significant error in the computed daily streamflow values.

In the South Saskatchewan River basin, approximately one to two weeks is required for relatively low flows to travel from the headwater areas, where many of the water use projects are located, to the interprovincial boundary. Given this time of travel constraint, the current apportionment procedures for the South Saskatchewan River should not be used for computational time steps which are shorter than about three weeks. However, since most of the occurrences in which a flow of less than 42.5 m^3/s was recorded at the interprovincial boundary had a duration of less than 5 days, a computational time step of less than 5 days is required to verify if any of these occurrences were violations. Since the computational time step required for this verification is shorter than the minimum

recommended computational time step, the current apportionment procedures are not able to identify which, if any, of the above noted occurrences were violations. If monitoring for adherence to the minimum flow provision of the Agreement is deemed necessary for the South Saskatchewan River, then a continuous simulation model is required in the computation of natural flows.

A continuous simulation model recently used by AEP to compute 1912-1988 daily natural flows at various locations in the South Saskatchewan River, including the interprovincial boundary, is the U.S. Army Corps of Engineers "Streamflow Synthesis And Reservoir Regulation" (SSARR) model. Daily streamflows from these simulations indicate that of the 23 instances, in the 1970 to 1988 period, in which recorded flows at the interprovincial boundary fell below 42.5 m^3/s, 18 had a flow rate which was greater than the natural flow, 3 had a flow rate which was below natural but greater than 50% of natural, and that two had a flow rate which, for some of the time, was below 50% of natural. The two instances during which a minimum flow violation is believed to have occurred are: an average shortfall of about 7.3 m^3/s for the 5 days between April 30th to May 4th, 1977, and an average shortfall of about 11.6 m^3/s for the 7 days between October 30th to November 5th 1984, inclusive. When U.S.A. diversions are taken into account, however, the 1977 shortfall remains virtually unchanged while the 1984 shortfall is reduced to a shortfall of about 11.0 m^3/s with a duration of 5 days between October 30th and November 3rd. (All of these shortfalls were made up within a relatively short period of their occurrence.) The historical daily natural flows computed in this study also indicate that while there have only been 23 instances in the December, January, and February period in which the recorded flows at the interprovincial boundary fell below 42.5 m^3/s, nearly 87% of all daily natural flows in this period are of a magnitude which would permit Alberta to deliver a flow rate of less than 42.5 m^3/s. The study further indicates that nearly 15 % of the natural flows in the shoulder months of April, October, and November are of a magnitude which would permit Alberta to deliver less than 42.5 m^3/s and that all natural flows in the May to September period were of a magnitude which would require Alberta to deliver at least 42.5 m^3/s.

The SSARR model, discussed previously, is currently used by AEP's Surface Water Monitoring Branch to provide AEP's water managers with real time continuous simulation of natural and regulated flows throughout the South Saskatchewan River basin, including the Alberta-Saskatchewan boundary. In its present format, the model computes the natural flow at the interprovincial boundary using a total

of 38 hydrometric stations. The model, however, does not consider local inflows (including channel losses due to evaporation and ice formation) nor does it use the project depletion method, currently used by the Board, in its assessment. To include local inflows and to operate in a project depletion format, the model would require some minor modifications as well as real time data for both the monitoring stations being recommended for the discrete time model and for 19 additional stations required for continuous real time simulations. The 19 additional stations, most of which are already in place, are indicated in Table 9 (b) and (c). The additional monitoring stations required to implement a real time continuous simulation model could be reduced to only those in Table 9 (b) if real time, hourly, natural flows computations carried out by Trans-Alta Utilities, for the Bow River upstream of the Bearspaw Reservoir, were to be incorporated in the South Saskatchewan River model.

If administering the minimum flow provision of the Master Agreement for the South Saskatchewan River basin is required, then it is recommended that the PPWB implement a continuous simulation model which computes daily natural flows on a real time basis. It is further recommended that a partnership with AEP's Surface Water Monitoring Branch, be considered, whereby AEP would carry out simulations of daily natural flows on a monthly basis for the Board and on a real time basis when required. This would avoid duplicating AEP's efforts which would be required for managing the South Saskatchewan River Basin. Lastly it is recommended that TAU's daily natural flow simulations and real time simulations be incorporated whenever possible so as to avoid duplications and to reduce the number of monitoring stations required for the simulations.

7.6 Need for Daily Simulation Model

During the 1970 to 1982 period (prior to the construction of the Dickson Dam) there were a total of 21 occurrences during which the flow at the Alberta - Saskatchewan boundary fell to below 42.5 m^3/s and would have required verification for adherence to the minimum flow provision of the Master Agreement. Of these 21 occurrences (about 1.62 occurrences per year) only one was a violation. During the 6 years analyzed for the period subsequent to the construction of the Dickson Dam (1983 to 1988) there were three such occurrences (about 0.5 occurrences per year) of which only

one was deemed to be a violation. In view of the relatively infrequent occurrence of potential and actual violations of the minimum flow provision of the Agreement, it is felt that a continuous daily simulation model is not warranted at this time. However, due to the numerous developments and initiatives which are currently underway or being considered for the South Saskatchewan River Basin, it is recommended that the relative need for a continuous daily simulation model be re-examined annually. The initiatives which are currently underway which should be considered in determining the need for a continuous simulation model include:

- The U.S. Bureau of Reclamations ongoing upgrading of the U.S. St. Mary Canal which will increase the canal capacity from 17.0 m^3/s to 22.7 m^3/s thus increasing the U.S.A. diversions from the South Saskatchewan River.

- The potential approval of 180,000 dam^3 (about 4% of Alberta's mean annual entitlement) in licence pending for irrigation diversions to various irrigation districts in the South Saskatchewan River Basin.

- The year 2000 review of current limits to irrigation expansion in the South Saskatchewan River Basin.

- The implementation of instream flow needs and allocation (IFN/IFA) for various reaches of the South Saskatchewan River and/or its major tributaries.

TABLE 9 (a)

MONITORING SITES RECOMMENDED FOR
ANNUAL WATER BALANCE OF THE SOUTH SASKATCHEWAN RIVER BASIN

Storage Projects	Agency[2]	Hydrometric Stations
Oldman River Dam Reservoir		05AA032 Oldman Dam Reservoir at Pincher Creek
Waterton Reservoir		05AD026 Waterton Reservoir
St. Mary reservoir		05AE025 St. Mary Reservoir at Spring Coulee
Spray Reservoir		05BC006 Spray Reservoir at Three Sisters Dam
Lake Minnewanka		05BD003 Lake Minnewanka near Banff
Ghost Reservoir		05BE005 Ghost Lake near Cochrane
Upper Kananaskis Reservoir		05BF005 Upper Kananaskis Lake at Main Dam
Lower Kananaskis Reservoir		05BF009 Lower Kananaskis Lake at Pocaterra
Barrier Reservoir		05BF024 Barrier Lake near Seebe
Bearspaw Reservoir		05BH010 Bearspaw Reservoir near Calgary
Glenmore Reservoir		05BJ008 Glenmore Reservoir at Calgary
Gleniffer Reservoir		05CB006 Gleniffer Reservoir Near Dickson

Irrigation Projects	Agency	Hydrometric Station
WESTERN IRRIGATION DISTRICT		
• Diversions		05BM003 W.I.D. Canal at Chestermere L.
• Return Flows		05BM008 Crowfoot Creek near Cluny 05CE005 Rosebud River at Redland
EASTERN IRRIGATION DISTRICT		
• Diversions		05CJ001 EID North Branch Canal at Bassano 05CJ003 EID East Branch Canal near Lathom 05CJ004 EID Springhill Canal near Lathom
• Return Flows	EC	05CJ006 Onetree Creek near Patricia 05CJ012 E-32; below Matzhiwin and Ware Coulee Junction

[2] Only indicated if funding agency is to be changed from the current status
EC=Environment Canada

TABLE 9 (a) (Continued)

Irrigation Projects (Continued)			
BOW RIVER DEVELOPMENT (INCLUDING HIGHWOOD DIVERSIONS)			
• Diversions		05AC004	BRD Main Canal
		05AC003	Little Bow River at Carmangay
		05BL015	Little Bow Canal at High River
		05BL025	Highwood Division Canal near Spring Coulee
• Return Flows		05AC012	Little Bow River below Travers
		05AC023	Little Bow River near The Mouth
		05AG003	Expanse Coulee near The Mouth
		05BN008	BRD Drain 'D' near Vauxhall
	EC	05BN006	New West Coulee near The Mouth
UNITED IRRIGATION DISTRICT			
• Diversions		05AD013	United Irrigation District Canal
MVID (INCLUDING LEAVITT-AETNA)			
• Diversions		05AD017	Mountain View Irrigation District Canal
LETHBRIDGE NORTHERN IRRIGATION DISTRICT			
• Diversions		05AB019	LNID Canal above Oldman Flume
• Return Flows	EC	05AD037	Piyami Drain near Picture Butte
ST. MARY IRRIGATION DISTRICT INCLUDING MAGRATH, RAYMOND AND TABER			
• Diversions		05AE021	Magrath Irrigation District Canal near Spring Coulee
		05AE026	Canadian St. Mary Canal near Spring Coulee
• Return Flows		05AE016	Pothole Creek at Russell's Ranch (for Raymond Irrigation District)
		05AG026	Bountiful Coulee Inflow near Cranford (for Taber I.d)
		05AH005	Seven Persons Creek near Medicine Hat
		05AH049	Ross Creek near Medicine Hat

TABLE 9 (a) (Continued)

Irrigation Projects (Continued)		
SHEERNESS AND DEADFISH PROJECTS		
• Diversions	05ID016	Deadfish Irrigation Diversion
	05ID017	Sheerness Power Diversion
Routing Index Station		
RED DEER RIVER PROJECTS EC	05CC002	Red Deer River at Red Deer
BOW RIVER PROJECTS	05BH004	Bow River at Calgary
	05BN012	Bow River near The Mouth
OLDMAN RIVER PROJECTS	05AD007	Oldman River at Lethbridge
Natural Flow Stations		
RED DEER RIVER	05CK004	Red Deer River near Bindloss
SOUTH SASKATCHEWAN RIVER	05AJ001	South Saskatchewan River at Medicine Hat

TABLE 9 (b)
ADDITIONAL MONITORING SITES REQUIRED FOR
CONTINUOUS SIMULATION OF THE SOUTH SASKATCHEWAN RIVER
IF TAU'S NATURAL FLOW COMPUTATIONS ARE ACCEPTED

STATION NAME	STATION #	AGENCY
1. Red Deer River Below Dickson Dam	----	replace 05CB007
2. Fish Creek Near Priddis	05BK001	AEP/EC
3. Highwood River near The Mouth	05BL024	AEP/EC
4. Oldman River near Brocket	05AA024	AEP/EC
5. Waterton-Belly Diversion Canal	05AD027	AEP
6. Belly-ST. Mary Diversion Canal	05AD021	AEP
7. Belly River near Mountain View	05AD005	EC
8. Belly River near Glenwood	05AD041	AEP/EC
9. St. Mary River below St. Mary Reservoir	----	
10. Waterton River near Glenwood	05AD028	AEP
11. Elbow River Below Glenmore Reservoir	05BJ001	AEP

TABLE 9 (c)
MONITORING SITES, IN ADDITION TO TABLE 9 (b), REQUIRED FOR
CONTINUOUS SIMULATION OF THE SOUTH SASKATCHEWAN RIVER
IF TAU'S NATURAL FLOW COMPUTATIONS ARE NOT ACCEPTED

STATION NAME	STATION #	AGENCY
1. Bow River at Banff	05BB001	EC
2. Spray River near Banff	05BC001	AEP
3. Cascade Power Diversion near Banff	05BD004	TAU
4. Spray Power Diversion at Canmore	05BE007	TAU
5. Ghost River Diversions to Lake Minnewanka	05BG003	TAU
6. Ghost River Above Waiporous Creek	05BG010	AEP/EC
7. Mud Lake Diversion Canal	05BF013	TAU
8. Kananaskis River Below Barrier Dam	05BF025	TAU

8. CONCLUSIONS

1. The mean annual flow volume, the 1:10 year low flow volume, and the 1:20 year low flow volume for the South Saskatchewan River (including the Red Deer River) at the interprovincial boundary are approximately 9,326,000 dam^3, 6,046,000 dam^3, and 5,458,000 dam^3 respectively. Subtracting U.S.A. diversions from the St. Mary River, which are in the order of 228,000 dam^3 per year, from the natural flow volumes at the interprovincial boundary reduces the apportionable flow (natural flow less U.S.A. diversions) to approximately 9,098,000 dam^3, 5,818,000 dam^3, and 5,230,000 dam^3 respectively for the previously indicated return periods.

2. Water use within the South Saskatchewan River basin is very extensive with Alberta having issued over 7,400 water use licences with an allocated diversion volume of about 4,814,000 dam^3 of which nearly 3,961,000 dam^3 is for consumptive use. The consumptive uses licensed in Alberta represent 43.54%, 68.08% and 75.73% of the apportionable volume for mean annual, 1:10 year low flow, and 1:20 year low flow condition respectively or 87.08%, 136.16%, and 151.46% of Alberta's share for the indicated return periods.

3. In addition to the licensed consumptive uses, depletions can occur due to potential storage in fourteen on-stream reservoirs, having a live storage capacity of about 2,000,000 dam^3, and in reservoirs on tributaries and within the irrigation districts, having an additional 1,500,000 dam^3 live storage capacity. Combined, licensed uses and depletions due to storage can significantly impact the flow delivered to Saskatchewan and an administrative procedure is required to monitor adherence to the Master Agreement.

4. The current PPWB procedures account for 3,301,271 dam^3 or 83.35% of all consumptive allocations in the computation of natural flows for the South Saskatchewan River. Allocations to the Cities of Medicine Hat, Calgary, and Lethbridge are not included in the PPWB procedures and account for 201,642 dam^3 or 5.09% of all allocations. Licensed allocations to projects which are not yet in place, such as the Buffalo Lake diversions and the Blood Indian Projects, account for 67,929 dam^3 or 1.72% of all allocations. Licensed allocations to small and

moderate sized projects, which are not included in the current procedures, and which are located on the South Saskatchewan River and its major tributaries (streams which have a reliable supply) account for 198,322 dam^3 or 5.01% of all allocations while similar sized projects on tributary streams (streams not having a reliable supply) account for 184,759 dam^3 or 4.67% of all consumptive use allocations.

5. The five largest irrigation districts in the South Saskatchewan River basin are the St. Mary Projects (SMP), the EID, LNID, BRID, and WID. These district have a combined consumptive use allocation of about 3,108,581 dam^3 or 78.5% of the 3,960,820 dam^3 total consumptive use allocations in the basin. The SMP and EID allocations represent 13.70% and 10.38%, respectively, of mean annual apportionable flow while allocations to the LNID, BRID, and WID are, individually, less than 5.0% of the mean annual apportionable flow. The only other projects having an allocation which is greater than 1% of the mean annual apportionable flow are the City of Medicine Hat (1.10%) and the City of Calgary (1.02%).

6. The hydrometric station 05CH007-Berry Creek Near The Mouth, and 05CG003- Bullpound Creek near The Mouth, monitor minor quantities of water and are not representative of return flows from the Sheerness and Deadfish projects.

7. Station 05AG026 - Bountiful Coulee Inflow near Cranford, while accounting for 18.2% of the computed SMRIP's return flow and 3.50% of total returns from all irrigation district shows relatively minor variability (±1,000 dam^3) in the recorded annual volumes and, subject to a re-examination of the SMRIP's regression equations for return flow, should be considered for discontinuation.

8. The following hydrometric stations are used in return flow equations to estimate less than 1.0% of total irrigation district returns and less than 5.0% of the returns from the district in which they are located:

    05BN014 - Coal Creek at Bow City

    05BM005 - Hammer Hill Spillway near Gleichen

05CE006 - Rosebud River Below Carstairs Creek

05AG004 - B.R.D. Drain 'A' near Hays

05AD038 - Battersea Drain near the Mouth

05AD040 - Drain L-5 near Diamond City

05AE041 - Dry coulee near Magrath

9. The PPWB procedure uses flows at representative 'routing index stations' to determine the time required for a project adjustment to be transported from the project site to the interprovincial boundary. Since project adjustments in the Red Deer River are significant and since there is a relatively long river reach between the location of water use projects and the point of apportionment, a routing index station is required for the Red Deer River.

10. The procedure currently used by the PPWB to compute natural flows is essentially a volume balance model which, to maintain a balance, defrays water which is in transport to the subsequent computational time step through the use of a 'time of travel adjustment item'. This procedure works reasonably well for instances where the time of travel is a relatively minor in comparison to the computational time step. However, in instances where the time of travel approaches, or exceeds, the computational time step a situation is created in which the 'time of travel adjustment item' spans two or more computational time steps which creates an instability leading to creation of gaps and overlaps in the computed downstream flow.

During periods of relatively low flows, approximately one to two weeks time is required for adjustments to travel from the headwater areas of the South Saskatchewan River, where most of the water use projects are located, to the interprovincial boundary. Therefore, to avoid the previously noted instability, the PPWB procedure should not be used for computational time steps shorter than three to four weeks.

Since for all recorded occurrences of potential violation of the minimum flow provision of the Master Agreement, flow at the interprovincial boundary of less than 42.5 m^3/s, had a duration of less than 10 days, with over 70% being of less than 5 days in duration, the current PPWB procedures could not determine if any of these occurrences constituted a violation. The current

PPWB procedures are of limited value in administering the minimum flow provision of the Agreement.

11. Administering for the minimum flow provision of the Agreement in the South Saskatchewan River will become increasingly important in the future. To monitor and administer this aspect of the Agreement will require the use of a real time, continuous simulation model. The implementation of a real time, continuous simulation model will require that an additional 19 existing stations be designated as PPWB stations. Two of these stations are currently funded by EC, 5 are cost shared between EC and AEP, 5 are contributed by TAU, 6 are funded by AEP, and 1 is a new station.

12. The following Tables 11 (a) to 11 (c) provide a list of the monitoring stations required for administering the Master Agreement for the South Saskatchewan River Basin.

TABLE 10 (a)

MONITORING SITES RECOMMENDED FOR
ANNUAL WATER BALANCE OF THE SOUTH SASKATCHEWAN RIVER BASIN

Storage Projects	Agency[3]	Hydrometric Stations
Oldman River Dam Reservoir		05AA032 Oldman Dam Reservoir at Pincher Creek
Waterton Reservoir		05AD026 Waterton Reservoir
St. Mary reservoir		05AE025 St. Mary Reservoir at Spring Coulee
Spray Reservoir		05BC006 Spray Reservoir at Three Sisters Dam
Lake Minnewanka		05BD003 Lake Minnewanka near Banff
Ghost Reservoir		05BE005 Ghost Lake near Cochrane
Upper Kananaskis Reservoir		05BF005 Upper Kananaskis Lake at Main Dam
Lower Kananaskis Reservoir		05BF009 Lower Kananaskis Lake at Pocaterra
Barrier Reservoir		05BF024 Barrier Lake near Seebe
Bearspaw Reservoir		05BH010 Bearspaw Reservoir near Calgary
Glenmore Reservoir		05BJ008 Glenmore Reservoir at Calgary
Gleniffer Reservoir		05CB006 Gleniffer Reservoir Near Dickson
Irrigation Projects	**Agency**	**Hydrometric Station**
WESTERN IRRIGATION DISTRICT		
• Diversions		05BM003 W.I.D. Canal at Chestermere L.
• Return Flows		05BM008 Crowfoot Creek near Cluny 05CE005 Rosebud River at Redland
EASTERN IRRIGATION DISTRICT		
• Diversions		05CJ001 EID North Branch Canal at Bassano 05CJ003 EID East Branch Canal near Lathom 05CJ004 EID Springhill Canal near Lathom
• Return Flows	EC	05CJ006 Onetree Creek near Patricia 05CJ012 E-32; below Matzhiwin and Ware Coulee Junction

[3] Only indicated if funding agency is to be changed from the current status
EC=Environment Canada

TABLE 10 (a) (Continued)

Irrigation Projects (Continued)			
BOW RIVER DEVELOPMENT (INCLUDING HIGHWOOD DIVERSIONS)			
• Diversions		05AC004	BRD Main Canal
		05AC003	Little Bow River at Carmangay
		05BL015	Little Bow Canal at High River
		05BL025	Highwood Division Canal near Spring Coulee
• Return Flows		05AC012	Little Bow River below Travers
		05AC023	Little Bow River near The Mouth
		05AG003	Expanse Coulee near The Mouth
		05BN008	BRD Drain 'D' near Vauxhall
	EC	05BN006	New West Coulee near The Mouth
UNITED IRRIGATION DISTRICT			
• Diversions		05AD013	United Irrigation District Canal
MVID (INCLUDING LEAVITT-AETNA)			
• Diversions		05AD017	Mountain View Irrigation District Canal
LETHBRIDGE NORTHERN IRRIGATION DISTRICT			
• Diversions		05AB019	LNID Canal above Oldman Flume
• Return Flows	EC	05AD037	Piyami Drain near Picture Butte
ST. MARY IRRIGATION DISTRICT INCLUDING MAGRATH, RAYMOND AND TABER			
• Diversions		05AE021	Magrath Irrigation District Canal near Spring Coulee
		05AE026	Canadian St. Mary Canal near Spring Coulee
• Return Flows		05AE016	Pothole Creek at Russell's Ranch (for Raymond Irrigation District)
		05AG026	Bountiful Coulee Inflow near Cranford (for Taber I.d)
		05AH005	Seven Persons Creek near Medicine Hat
		05AH049	Ross Creek near Medicine Hat

TABLE 10 (a) (Continued)

Irrigation Projects (Continued)		
SHEERNESS AND DEADFISH PROJECTS		
• Diversions	05ID016	Deadfish Irrigation Diversion
	05ID017	Sheerness Power Diversion
Routing Index Station		
RED DEER RIVER PROJECTS EC	05CC002	Red Deer River at Red Deer
BOW RIVER PROJECTS	05BH004	Bow River at Calgary
	05BN012	Bow River near The Mouth
OLDMAN RIVER PROJECTS	05AD007	Oldman River at Lethbridge
Natural Flow Stations		
RED DEER RIVER	05CK004	Red Deer River near Bindloss
SOUTH SASKATCHEWAN RIVER	05AJ001	South Saskatchewan River at Medicine Hat

TABLE 10 (b)
ADDITIONAL MONITORING SITES REQUIRED FOR
CONTINUOUS SIMULATION OF THE SOUTH SASKATCHEWAN RIVER
IF TAU'S NATURAL FLOW COMPUTATIONS ARE ACCEPTED

STATION NAME	STATION #	AGENCY
1. Red Deer River Below Dickson Dam	----	replace 05CB007
2. Fish Creek Near Priddis	05BK001	AEP/EC
3. Highwood River near The Mouth	05BL024	AEP/EC
4. Oldman River near Brocket	05AA024	AEP/EC
5. Waterton-Belly Diversion Canal	05AD027	AEP
6. Belly-ST. Mary Diversion Canal	05AD021	AEP
7. Belly River near Mountain View	05AD005	EC
8. Belly River near Glenwood	05AD041	AEP/EC
9. St. Mary River below St. Mary Reservoir	----	
10. Waterton River near Glenwood	05AD028	AEP
11. Elbow River Below Glenmore Reservoir	05BJ001	AEP

TABLE 10 (c)
MONITORING SITES, IN ADDITION TO TABLE 10 (b), REQUIRED FOR
CONTINUOUS SIMULATION OF THE SOUTH SASKATCHEWAN RIVER
IF TAU'S NATURAL FLOW COMPUTATIONS ARE NOT ACCEPTED

STATION NAME	STATION #	AGENCY
1. Bow River at Banff	05BB001	EC
2. Spray River near Banff	05BC001	AEP
3. Cascade Power Diversion near Banff	05BD004	TAU
4. Spray Power Diversion at Canmore	05BE007	TAU
5. Ghost River Diversions to Lake Minnewanka	05BG003	TAU
6. Ghost River Above Waiporous Creek	05BG010	AEP/EC
7. Mud Lake Diversion Canal	05BF013	TAU
8. Kananaskis River Below Barrier Dam	05BF025	TAU

9. RECOMMENDATIONS

1. The current procedure for computing apportionable flow in the South Saskatchewan River contains a number of inconsistencies in its treatment of diversions from and releases to the Little Bow River. In order to correct these inconsistencies, the following is recommended:
   - that Highwood diversions to the Little Bow River (05BL025 plus 05BL015) be subtracted from the recorded flow at Carmangay (05AC003) prior to the computation of diversions to the BRID
   - that releases from Travers Reservoir (05AC012) be subtracted from the computed BRID diversions. (This recommendation may require further modification if a review of the BRID return flow equations as recommended in item #5 is implemented.)

2. The current procedure, in the computation of apportionable flow in the South Saskatchewan River, accounts for 83.35% of all consumptive uses in the basin. To increase this percentage it is recommended:
   - that consumptive uses by the Cities of Medicine Hat, Calgary, and Lethbridge, which account for 5.09% of all allocations, be included in the procedure
   - that additional investigations be undertaken to assess ways for including the 5.01% of consumptive allocation licensed to small and intermediate sized projects on the South Saskatchewan River and its major tributaries

3. Consumptive allocations to small and intermediate sized projects on minor tributaries and intermittent streams account for 184,759 dam^3, or 4.67% of all consumptive use allocations. Due to the non-reliability of the water supply for these allocations, their actual consumption is relatively minor during average to below average years. It is recommended:
   - that allocations to small and intermediate sized project in this category not be included in the computation of apportionable flows

4. The return flow stations 05CH007-Berry Creek near the Mouth, and 05CG003- Bullpound Creek near the Mouth, monitor minor quantities of water, and are not representative of return flows from the Sheerness and Deadfish projects. It is recommended:
   - that return flows from these projects be set to zero in the computation of apportionable flow and
   - that both of these stations be discontinued.

5. The following hydrometric stations which are currently used in regression equations to estimate return flows from the major irrigation districts each account for less than 1.0% of the total returns and for less than 5.0% of the returns from the district in which they are located:

   05BN014 - Coal Creek at Bow City

   05BM005 - Hammer Hill Spillway near Gleichen

   05CE006 - Rosebud River Below Carstairs Creek

   05AG004 - B.R.D. Drain 'A' near Hays

   05AD038 - Battersea Drain near the Mouth

   05AD040 - Drain L-5 near Diamond City

   05AE041 - Dry coulee near Magrath

   It is recommended:
   - that the PPWB drop the above noted stations from its list of apportionment stations and use their long term averages where required in the computation of return flows
   - that the PPWB review the regression equations for the EID, BRID, and SMRIP
   - that the PPWB modify the procedures for computing return flows for the LNID to a summation of station flows rather than regression
   - that the PPWB examine the possibility of utilizing return flow information collected by the EID for estimating return flows for the district
   - that the PPWB review the regression equations used in the computation of return flows as conditions warrant

6. Station 05AG026 - Bountiful Coulee Inflow near Cranford, while accounting for 18.2% of computed SMRIP's return flow and 3.50% of total returns from all irrigation districts, shows

relatively minor variability (±1,000 dam^3) in the recorded annual volumes. Subject to a re-examination of the SMRIP's return flow equations, this station should be considered for discontinuation.

7. Since project adjustments in the Red Deer River are significant and since there is a relatively long river reach between the location of the water use projects and the point of apportionment, a routing index station is required for the Red Deer River. It is recommended:
   - that the hydrometric station 05CC002 - Red Deer River at Red Deer be included in the list of PPWB apportionment stations
   - that it be utilized as an index routing station for routing adjustment items in the Red Deer River Basin.

8. The current procedures for computing apportionable flow in the South Saskatchewan River do not provide the PPWB with the ability to administer the minimum flow provisions of the 1969 Master Agreement On Apportionment. Given the relatively low frequency of occurrence of flows below 42.5 m^3/s at the Alberta - Saskatchewan boundary administering for minimum flows on a continuous basis is currently not justified. It is recommended:
   - that the PPWB continue its current practice of quarterly reports in monitoring for adherence to the Master Agreement.
   - that the relative need for a continuous simulation model be re-examined annually.

9. Since the removal of station 05AK001 - South Saskatchewan River at Highway No. 41; flows at this site have been computed by AEP by routing recorded flows for stations 05AJ001 - South Saskatchewan River at Medicine Hat, 05AH049 - Ross Creek at Medicine Hat and 05AH005 - Seven Persons Creek at Medicine Hat. It is recommended:

   - that these stations be retained on the PPWB list of apportionment stations and that the period of operation for the latter two stations be extended to cover the February to November period.

10. BIBLIOGRAPHY

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2. Environment Canada. 1992: Natural Flow - South Saskatchewan River Update Report -User Manual and Program Documentation. Technical Report To The PPWB Committee On Hydrology.

3. Alberta Environment. 1982: South Saskatchewan River Historical Natural Flows 1912 To 1978.

4. Alberta Environment. 1984: South Saskatchewan River Historical Natural Flows 1979 To 1982 Update.

5. Alberta Environment. 1988: South Saskatchewan River Historical Natural Flows 1983 To 1986 Update.

APPENDICES:

Appendix A - Study Terms of Reference

TERMS OF REFERENCE
FOR
A REVIEW OF THE SOUTH SASKATCHEWAN AND THE QU'APPELLE RIVERS APPORTIONMENT MONITORING NETWORKS

FINAL

MAY 10, 1994

TERMS OF REFERENCE

These Terms of Reference have been developed to guide the evaluation of the apportionment monitoring networks for the South Saskatchewan River and the Qu'Appelle River. The purpose of the review is to determine the appropriate hydrometric network for apportionment monitoring. The methodology to be used for the evaluation is:

1. estimate the annual natural flow volume and categorize major diversions and consumptive uses which are less than 5%, between 5-10%, and greater than 10% of the annual natural flow for:

    a) a moderate drought year (one in ten years low flow or the annual flow which is exceeded 90% of the time), and

    b) a more critical drought year (e.g. one in twenty years low flow or the annual flow which is exceeded 95% of the time or some recent historical events);

2. identify apportionment related criteria (e.g. flow to be apportioned, apportionment period, minimum flow criteria, etc.).

3. identify hydrometric stations used for calculating natural flow for apportionment purposes as well as stations that are primarily for water management purposes (flow records of such stations can be useful in apportionment calculations during critical drought periods);

4. identify various scenarios for estimating/considering moderate and minor depletions;

5. establish procedures for determining moderate and minor project depletion to be used in the modelling process;

6. establish a natural flow calculation computer model for testing various alternatives and scenarios;

7. conduct a sensitivity analysis on calculated natural flow to assess various configurations and scenarios for adding or removing monitoring stations;

8. examine alternative means and implications for obtaining project depletion data (e.g. estimate depletion using historical patterns, user supplied data as part of a licence agreement, etc.);

9. provide progress report at the Fall 1994 COH meeting, and a draft report by November 1994.

Appendix B - South Saskatchewan River Basin Historical Monthly Natural Flows

TABLE B-1

SOUTH SASKATCHEWAN RIVER @ HIGHWAY #41 - C5AK01
NATURAL MONTHLY MEAN FLOWS EXTENDED - M^3/S

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	%	ANNUAL ^{3}]DAM
1912	45.803	57.635	112.222	202.418	324.531	559.068	634.104	390.227	265.721	174.638	150.857	64.836	249.045	106.	7875401.
1913	45.457	53.795	62.282	257.278	344.600	851.122	503.127	360.691	234.693	170.268	136.859	84.720	259.206	111.	8174329.
1914	78.657	40.532	115.839	168.796	411.722	587.229	436.908	212.002	148.377	227.422	167.616	61.850	222.389	95.	7013247.
1915	69.303	53.000	171.686	158.506	554.407	921.950	961.517	531.323	278.726	220.656	142.751	65.642	346.171	147.	10916864.
1916	45.180	169.573	168.279	212.385	333.942	1303.127	1091.964	451.148	406.889	222.551	168.723	91.011	388.464	165.	12284153.
1917	67.388	54.241	60.804	185.132	607.510	1210.656	614.580	260.335	171.086	152.007	91.291	29.696	292.673	125.	9229729.
1918	88.759	58.053	142.758	150.183	294.185	652.369	334.691	240.039	170.582	122.893	73.818	50.315	198.676	85.	6265458.
1919	45.907	41.507	54.717	144.287	361.067	491.698	281.059	274.860	132.346	67.616	51.602	47.695	166.796	71.	5260094.
1920	40.435	51.354	126.249	243.442	525.088	625.927	739.865	302.136	142.567	128.457	81.525	54.901	256.077	109.	8097763.
1921	52.973	55.869	75.192	164.073	432.478	738.704	419.886	212.286	110.962	86.456	72.457	53.390	206.747	88.	6519980.
1922	50.807	31.908	51.468	133.623	381.157	708.884	371.392	199.373	125.005	76.450	59.826	34.616	185.854	79.	5861089.
1923	40.199	28.544	61.222	111.938	311.284	1532.603	631.625	309.234	182.976	125.303	80.521	49.504	288.822	123.	9108276.
1924	35.472	58.182	66.174	97.487	357.839	644.904	418.364	334.860	157.219	90.446	78.850	55.790	199.914	85.	6321751.
1925	67.013	60.964	167.305	331.365	521.676	692.497	387.243	236.072	167.522	188.986	111.426	83.970	252.086	108.	7949794.
1926	51.693	46.435	90.134	150.688	197.418	307.008	299.303	135.151	425.019	318.375	149.252	91.171	188.876	81.	5956401.
1927	83.364	65.996	120.276	200.829	525.618	1267.748	725.428	445.093	493.089	271.682	165.242	95.236	372.391	159.	11743728.
1928	270.039	109.209	231.084	176.330	565.360	871.497	811.516	268.108	191.336	178.051	113.284	50.044	320.603	137.	10138239.
1929	51.090	43.591	114.886	95.375	415.671	982.790	288.347	148.127	97.679	52.356	42.922	48.100	198.519	85.	6260497.
1930	40.064	123.291	114.304	237.933	403.975	645.789	446.173	182.532	113.266	82.469	53.117	58.834	208.587	89.	6577992.
1931	43.529	37.661	58.538	89.802	199.371	405.913	225.754	127.472	113.030	82.041	68.199	40.568	124.543	53.	3927598.
1932	48.863	51.439	82.917	156.854	455.712	944.439	349.967	182.360	157.575	100.481	83.656	58.996	222.475	95.	7035179.
1933	49.925	39.531	69.412	164.436	399.857	771.515	440.809	168.225	120.361	98.792	159.145	93.281	215.068	92.	6782393.
1934	131.063	137.741	121.724	404.296	616.188	663.634	286.002	150.370	107.631	94.256	164.278	61.019	244.743	104.	7718211.
1935	67.603	125.879	73.572	159.822	286.779	625.400	421.236	227.052	104.259	71.353	50.979	37.654	187.620	80.	5916771.
1936	31.415	16.644	112.661	219.273	343.824	485.760	191.543	121.395	88.808	47.939	34.656	14.824	142.375	61.	4502235.
1937	6.926	20.722	55.702	118.484	233.674	658.283	305.687	170.683	92.373	77.748	95.276	55.143	157.768	67.	4975357.
1938	60.605	28.717	94.610	217.392	486.831	770.112	480.167	180.506	135.544	112.939	68.986	43.991	224.148	96.	7068745.
1939	31.319	18.611	86.860	141.955	295.439	545.680	369.089	145.947	93.080	74.623	84.936	49.882	162.024	69.	5109575.
1940	22.779	34.558	90.620	185.855	377.082	391.166	237.889	141.844	171.592	141.833	77.211	53.229	160.657	69.	5080360.
1941	35.900	37.541	97.056	123.209	179.978	319.289	207.236	121.511	135.751	137.600	90.129	73.057	130.205	56.	4106154.
1942	48.835	36.731	62.004	145.551	644.910	960.736	687.748	361.279	253.381	187.127	80.886	53.714	294.957	126.	9301760.
1943	36.824	63.243	101.905	375.691	328.463	642.249	618.912	243.637	120.006	76.627	48.344	39.118	225.122	96.	7099453.
1944	37.721	24.906	42.448	73.114	161.415	364.714	233.275	190.572	117.079	77.040	50.742	38.549	117.769	51.	3724129.
1945	30.552	26.374	75.165	72.652	304.940	852.439	501.010	178.994	164.937	136.796	77.272	63.867	207.640	89.	6548128.
1946	63.811	42.946	102.787	123.321	390.906	761.253	396.558	185.812	212.150	137.034	98.101	90.556	217.640	93.	6863498.
1947	71.382	100.987	239.382	269.659	659.648	744.544	456.440	214.957	203.601	279.953	151.612	69.136	289.392	123.	9126254.
1948	64.144	37.541	93.560	418.603	1080.899	1515.961	528.357	371.543	153.005	96.038	65.463	34.561	371.644	158.	11752286.
1949	54.045	28.860	48.117	174.963	380.377	476.168	233.130	139.088	109.898	86.662	79.215	51.988	155.647	67.	4908472.
1950	41.213	57.956	91.619	211.941	344.140	890.324	639.717	265.225	135.189	121.674	111.797	77.618	249.638	106.	7872570.
1951	59.690	53.572	97.431	316.331	871.325	1054.753	1035.915	373.308	669.728	421.040	238.375	111.791	443.729	189.	13993442.
1952	110.873	101.515	136.405	542.330	507.246	645.733	514.601	294.357	156.536	110.356	66.275	43.964	269.186	115.	8512304.
1953	45.699	69.595	81.207	205.543	589.849	1707.073	748.955	290.128	180.420	121.912	87.531	56.140	348.812	149.	11000127.
1954	47.436	86.412	70.626	182.654	624.487	881.612	806.411	376.279	319.197	219.393	139.615	57.245	318.822	136.	10054375.
1955	49.678	41.935	51.043	232.253	433.381	832.490	659.399	236.638	139.455	139.985	110.002	68.249	250.383	107.	7896075.
1956	85.718	41.172	127.194	222.535	542.049	827.027	551.822	242.334	141.559	103.237	60.903	54.469	250.454	107.	7919959.
1957	48.309	40.441	127.876	130.804	715.334	641.447	288.464	164.708	120.124	104.838	119.519	67.228	215.092	92.	6783148.
1958	43.119	41.080	81.289	296.434	598.113	668.615	514.572	228.897	140.048	109.525	102.902	86.086	243.561	104.	7680942.
1959	56.853	56.639	106.549	161.249	426.949	864.040	531.587	233.463	207.989	150.522	148.215	101.836	254.442	109.	8024074.
1960	65.519	61.191	149.554	214.709	334.717	598.067	456.267	224.442	122.224	83.915	61.592	52.716	202.332	86.	6398211.
1961	56.708	49.622	86.047	87.626	449.964	879.580	303.088	229.038	128.053	165.274	115.236	50.422	217.154	93.	6848155.
1962	66.527	102.326	100.434	252.963	306.483	581.240	354.605	206.542	144.049	104.897	85.516	61.661	197.298	84.	6221991.
1963	39.862	77.762	101.798	84.244	248.051	703.617	688.915	225.833	145.857	95.061	63.631	66.314	212.435	91.	6699341.
1964	52.332	54.783	46.834	105.148	469.942	1150.078	552.678	204.182	149.534	154.516	104.937	38.169	256.715	109.	8117959.
1965	49.397	68.337	82.515	219.798	313.143	987.323	759.151	340.592	260.252	247.049	144.602	68.196	295.710	126.	9325499.
1966	50.101	44.453	123.147	214.405	427.191	897.423	543.230	261.492	173.602	128.080	99.194	65.667	253.012	108.	7978999.
1967	53.575	50.857	109.787	204.632	623.036	1409.850	667.754	260.761	145.976	102.493	99.392	31.007	313.754	134.	9894554.
1968	58.559	55.048	128.768	87.717	280.150	710.860	442.088	243.474	207.936	218.011	121.706	51.310	217.312	93.	6871923.
1969	53.179	59.041	127.610	358.151	522.140	810.745	842.010	225.725	137.592	121.171	89.396	45.675	283.815	121.	8950388.
1970	35.538	49.016	73.862	124.158	374.994	918.482	384.956	174.732	109.555	93.049	72.916	27.949	203.406	87.	6414617.
1971	41.541	105.594	88.216	223.397	509.145	924.593	449.048	254.447	132.741	89.903	92.568	25.287	244.769	104.	7719043.
1972	28.883	35.283	231.244	212.385	569.010	1139.790	603.902	352.018	206.954	154.330	108.652	45.987	307.659	131.	9728915.
1973	61.787	55.076	111.710	120.248	381.708	675.523	401.603	202.296	154.803	90.351	68.300	71.840	200.188	85.	6313117.
1974	44.712	67.592	75.181	210.966	538.326	1107.812	633.867	312.091	189.219	115.881	75.153	48.394	285.504	122.	9003664.
1975	35.849	27.326	56.379	155.887	468.151	1015.586	657.789	282.990	186.090	126.528	93.899	81.383	266.548	114.	8405866.
1976	85.347	85.007	100.208	158.110	483.827	492.475	470.620	465.591	252.583	135.955	59.947	47.855	237.241	101.	7502128.
1977	38.568	58.418	65.469	85.707	223.060	334.674	194.010	213.583	192.249	121.021	60.711	38.313	135.755	58.	4281172.
1978	24.494	28.034	127.936	195.106	417.223	716.886	536.465	286.221	232.300	159.486	79.910	78.353	241.223	103.	7607220.
1979	26.929	22.908	138.809	140.820	421.779	570.896	328.504	178.339	126.321	75.663	56.690	30.242	177.237	76.	5589345.
1980	25.966	37.010	60.938	189.921	571.972	745.271	283.904	195.188	163.983	149.881	99.024	58.559	215.186	92.	6804687.
1981	93.729	96.164	110.945	112.729	754.049	825.521	599.949	368.799	163.190	103.980	77.418	32.338	279.550	119.	8815893.
1982	9.345	31.403	52.414	128.105	271.106	718.257	518.849	219.229	148.437	125.698	54.000	37.237	193.407	83.	6099278.
1983	33.046	45.930	79.712	81.156	273.144	510.496	385.109	209.205	121.564	82.374	76.795	21.747	160.550	69.	5063113.
1984	24.041	56.577	60.598	86.565	173.639	470.201	355.575	191.988	128.672	113.352	67.422	38.369	147.298	63.	4657908.
1985	29.450	29.308	88.660	142.519	323.633	477.394	247.716	188.279	263.318	195.301	124.991	74.303	182.561	78.	5757253.
1986	69.065	63.571	223.392	154.270	393.236	796.553	367.694	207.591	171.515	229.508	101.233	86.536	239.383	102.	7549184.
MIN	6.9	16.6	42.4	72.7	161.4	307.0	191.5	121.4	88.8	47.9	34.7	14.8	117.8		3724129.
MAX	270.0	169.6	239.4	542.3	1080.9	1707.1	1092.0	531.3	669.7	421.0	238.4	111.8	443.7		13993442.
MEAN	54.0	56.3	101.2	185.5	433.0	782.4	491.8	247.3	179.2	136.8	95.5	57.3	235.5	100.	7432770.

TABLE B-2

RED DEER RIVER NEAR BINDLOSS - C5CK04
NATURAL MONTHLY MEAN FLOWS EXTENDED - M^3/S

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	MEAN	%	ANNUAL (DAM^3)
1912	5.163	5.867	18.947	101.292	138.880	115.474	444.644	170.163	170.648	108.578	40.937	17.821	112.161	187.	3546786.
1913	10.733	10.350	14.983	210.848	145.025	145.736	195.420	107.717	60.618	42.736	25.747	9.397	81.876	137.	2582031.
1914	6.247	6.678	13.744	46.281	58.493	106.922	71.307	39.305	35.230	51.990	24.388	9.428	39.281	66.	1238763.
1915	6.247	5.768	23.359	64.938	160.073	374.572	841.252	290.580	146.623	122.234	37.814	24.884	176.459	295.	5564803.
1916	10.226	11.439	40.379	101.952	110.080	388.115	459.574	284.187	320.313	162.102	68.616	22.425	165.191	276.	5223730.
1917	18.147	22.903	23.942	259.269	410.158	324.293	125.591	62.645	57.240	38.624	30.865	12.205	115.677	193.	3647979.
1918	12.431	12.261	73.850	112.078	54.000	84.158	47.006	34.093	28.005	28.657	19.680	8.552	42.951	72.	1354512.
1919	6.201	6.060	8.297	103.017	85.800	49.441	32.253	60.740	40.182	16.650	8.552	7.731	35.488	60.	1119159.
1920	8.438	10.760	11.383	211.272	402.524	118.902	151.269	51.140	28.685	18.179	9.656	6.088	86.031	144.	2720494.
1921	4.021	5.409	10.506	135.015	76.427	61.617	42.249	29.138	15.121	6.088	4.729	3.766	32.833	55.	1035412.
1922	1.671	0.991	6.343	48.450	87.159	70.198	50.404	57.823	34.235	13.960	6.286	3.540	31.920	54.	1006622.
1923	1.642	1.557	3.200	40.889	42.192	332.072	158.744	120.970	60.060	32.678	19.057	9.911	68.645	115.	2164786.
1924	3.596	5.522	6.739	32.225	90.189	76.512	82.402	81.411	37.378	23.588	14.130	9.628	38.775	65.	1226157.
1925	4.644	4.276	12.261	178.906	57.568	93.276	57.257	78.834	85.630	74.898	39.700	20.954	59.025	99.	1861401.
1926	14.611	16.141	139.885	102.649	47.374	92.624	73.454	43.721	294.778	123.008	57.965	27.326	86.146	144.	2716692.
1927	16.056	7.532	19.992	276.882	158.574	185.362	159.962	118.987	114.910	70.198	33.980	22.795	98.927	165.	3119766.
1928	20.275	18.576	116.241	137.167	85.602	456.241	337.395	70.311	51.537	28.090	17.047	11.157	112.403	188.	3554462.
1929	6.201	3.879	17.670	40.720	70.934	156.819	26.052	19.878	17.358	10.619	8.325	6.683	32.067	54.	1011260.
1930	4.106	12.912	23.022	55.926	46.553	65.214	45.958	17.641	18.151	10.591	14.951	7.731	26.883	45.	847795.
1931	6.032	5.720	9.118	20.162	31.913	94.012	116.212	43.863	35.226	19.652	13.479	10.121	33.947	57.	1070560.
1932	7.489	6.247	11.738	36.897	119.364	267.620	75.102	49.986	42.771	27.578	18.695	10.941	56.089	94.	1773684.
1933	8.985	4.271	11.025	100.140	168.542	93.883	60.828	44.708	34.459	18.117	14.802	7.449	47.472	80.	1497086.
1934	6.568	6.916	36.718	93.512	52.827	62.163	28.894	26.367	18.038	13.110	9.988	7.648	30.249	51.	953917.
1935	4.078	4.857	10.030	41.285	42.305	99.808	137.504	72.661	40.267	27.835	6.938	6.230	41.383	69.	1305063.
1936	4.021	4.276	7.391	195.188	82.034	100.440	31.779	29.999	22.056	13.668	7.988	2.605	41.559	70.	1314194.
1937	1.725	1.299	8.230	39.060	28.345	73.087	47.967	40.359	34.018	33.082	15.346	7.991	27.617	47.	870945.
1938	6.428	2.966	15.608	46.600	65.391	109.036	128.884	47.036	39.289	22.178	9.795	5.853	41.801	70.	1318232.
1939	4.433	3.256	20.533	41.179	27.116	207.617	111.078	37.204	27.328	22.253	18.823	10.198	44.265	74.	1395952.
1940	3.575	3.229	10.905	206.622	102.041	51.403	45.624	32.029	35.874	19.647	11.394	8.600	44.119	74.	1395143.
1941	4.766	5.063	21.832	34.784	12.828	36.532	38.507	54.033	42.443	29.381	13.444	7.445	25.179	42.	794051.
1942	3.998	2.685	5.252	22.548	60.169	108.190	214.054	106.101	103.983	50.779	28.991	15.271	60.578	101.	1910382.
1943	6.367	6.712	27.608	360.183	62.331	144.151	121.697	57.461	31.218	22.554	12.087	7.535	71.477	120.	2254112.
1944	4.627	3.980	10.902	48.224	33.810	199.067	99.817	157.215	52.245	38.879	20.137	10.290	56.632	95.	1790843.
1945	6.946	7.132	30.724	43.438	91.407	113.749	85.828	42.589	53.575	55.897	25.229	16.384	47.952	80.	1512212.
1946	13.168	11.249	58.441	114.910	42.985	172.704	106.924	32.055	60.145	40.805	14.838	12.218	56.705	95.	1788251.
1947	11.636	8.220	76.342	181.936	118.279	115.788	82.912	50.461	69.037	61.278	30.390	20.200	69.038	116.	2177193.
1948	11.706	8.145	10.760	345.154	588.566	206.458	102.960	82.997	38.851	28.742	17.097	8.356	121.092	202.	3829223.
1949	6.008	5.801	15.659	60.995	44.033	33.839	33.131	29.903	12.063	12.035	15.121	6.739	23.002	39.	725388.
1950	2.917	3.426	4.927	50.546	44.684	72.491	78.551	41.088	17.330	18.179	4.785	2.945	28.610	48.	902233.
1951	3.993	3.993	3.625	167.126	165.512	127.086	162.312	94.607	165.540	75.153	45.279	27.071	87.022	146.	2744336.
1952	14.696	13.054	26.873	412.350	83.846	239.730	174.715	88.292	47.686	34.235	21.209	11.327	96.889	162.	3063859.
1953	7.079	8.835	13.649	67.111	134.703	331.363	190.799	102.026	70.650	35.311	23.701	13.620	83.411	140.	2630445.
1954	10.194	10.959	18.519	105.112	203.230	284.244	134.052	268.047	353.479	102.507	64.874	28.713	132.223	221.	4169773.
1955	11.836	15.433	13.450	250.123	214.755	134.873	113.890	54.142	33.924	31.290	8.722	6.258	74.180	124.	2339335.
1956	6.569	8.410	35.509	252.133	83.591	107.972	101.912	66.856	44.004	29.506	25.145	12.799	64.373	108.	2035636.
1957	8.014	6.598	21.068	110.861	96.532	73.142	48.648	41.739	32.791	29.506	27.382	14.187	42.632	72.	1344429.
1958	5.862	6.230	12.035	198.359	95.145	101.063	115.136	50.149	36.274	23.786	10.137	6.796	55.139	92.	1738852.
1959	5.210	3.256	23.673	41.909	34.207	83.110	152.543	60.003	27.184	30.412	15.744	15.291	41.346	69.	1303873.
1960	8.127	9.118	55.303	149.824	65.582	81.354	75.266	55.841	30.497	17.132	12.431	5.663	47.153	79.	1491087.
1961	7.192	6.116	25.145	34.745	49.356	67.932	20.048	40.578	19.284	18.491	16.395	5.154	25.937	44.	817937.
1962	4.134	6.060	9.798	80.561	41.767	72.972	67.706	56.152	39.049	22.767	15.178	4.870	35.138	59.	1108125.
1963	3.228	6.513	46.496	92.851	45.307	98.996	111.653	79.485	40.380	25.542	13.677	5.635	47.664	80.	1503120.
1964	6.116	6.173	8.608	46.241	108.312	175.480	102.479	43.863	37.492	36.331	20.501	8.410	50.022	84.	1581821.
1965	8.127	7.164	19.567	277.222	108.680	234.775	337.084	101.516	113.947	87.471	41.767	23.871	113.720	190.	3586266.
1966	12.091	10.392	122.357	189.411	73.794	118.619	162.793	80.986	43.296	37.690	20.331	9.430	73.737	123.	2325379.
1967	12.091	9.458	13.677	137.507	173.582	218.323	84.837	46.213	27.807	25.627	18.066	6.173	64.504	108.	2034212.
1968	4.531	5.947	32.847	31.092	30.526	73.907	78.494	65.638	38.822	41.059	21.068	8.523	36.146	61.	1143013.
1969	7.815	7.731	7.362	243.525	101.431	95.258	277.477	73.964	46.496	34.462	14.555	12.120	77.164	129.	2433457.
1970	6.569	5.833	12.063	129.521	66.658	191.705	133.372	44.967	31.064	25.683	13.960	6.201	55.649	93.	1754939.
1971	6.371	7.900	14.243	361.918	86.508	137.110	73.567	47.289	28.940	24.267	11.921	8.099	67.092	112.	2115813.
1972	3.596	4.446	40.125	88.943	58.248	139.177	152.345	75.040	49.413	32.140	17.443	4.474	55.528	93.	1755924.
1973	9.854	8.892	25.598	151.920	102.507	151.382	96.079	58.672	49.611	25.825	14.187	10.704	58.818	99.	1854869.
1974	8.523	8.410	9.939	290.163	241.118	157.696	96.107	51.990	40.323	33.357	15.206	9.939	80.321	134.	2533018.
1975	6.796	6.173	6.541	73.992	107.293	52.783	55.444	41.314	26.476	20.983	11.497	5.607	34.736	58.	1095429.
1976	6.003	7.589	28.798	68.187	31.148	50.347	49.838	82.034	37.293	25.315	12.516	5.550	33.770	57.	1067876.
1977	4.899	6.853	15.942	40.380	69.546	78.806	34.178	40.748	39.927	34.575	13.167	6.201	32.189	54.	1015118.
1978	6.966	6.258	13.281	107.915	75.578	124.169	80.278	59.267	64.761	37.690	15.942	10.647	50.284	84.	1585765.
1979	4.984	4.163	20.615	45.902	57.200	56.549	45.902	29.280	24.183	14.413	10.675	5.890	26.747	45.	843486.
1980	3.653	3.625	8.467	104.886	48.082	158.036	82.232	47.402	42.447	31.686	21.974	8.552	46.606	78.	1473785.
1981	10.562	12.828	38.653	41.852	131.560	120.545	137.167	193.659	51.310	37.095	26.221	8.070	67.991	114.	2144169.
1982	2.945	4.729	8.467	112.390	72.434	91.520	206.826	64.194	45.449	41.258	16.905	6.513	56.444	95.	1780018.
1983	7.731	11.242	28.288	73.539	73.171	67.649	111.993	43.353	25.485	19.001	11.723	0.566	39.654	67.	1250540.
1984	6.909	9.514	14.980	43.523	24.579	74.388	38.058	30.639	29.676	27.099	9.316	2.379	25.866	44.	817944.
1985	3.511	2.577	23.276	120.771	51.169	40.861	25.938	39.445	71.811	42.419	13.762	7.929	36.966	62.	1165764.
1986	8.325	4.814	50.659	36.727	113.721	117.770	181.086	98.373	61.448	122.272	31.177	15.603	70.793	118.	2232543.
MIN	1.6	1.0	3.2	20.2	12.8	33.8	20.0	17.6	12.1	6.1	4.7	0.6	23.0		725388.
MAX	20.3	22.9	139.9	412.3	588.6	456.2	841.3	290.6	353.5	162.1	68.6	28.7	176.5		5564803.
MEAN	7.2	7.2	24.8	121.6	99.6	135.9	123.5	71.1	58.6	38.6	19.9	10.3	60.0	100.	1893376.

TABLE B-3

SOUTH SASK @ HWY. 41 + RED DEER NR. BINDLOSS - C5AK01+C5CK04K
NATURAL MONTHLY MEAN FLOWS - M^3/S

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	MEAN	%	ANNUAL (DAM^3)
1912	50.965	63.502	131.169	303.709	463.412	674.542	1078.748	560.390	436.368	283.216	191.794	82.656	361.205	123.	11422182.
1913	56.190	64.145	77.266	468.126	489.625	996.858	698.547	468.408	295.311	213.004	162.606	94.117	341.082	116.	10756364.
1914	84.904	47.210	129.583	215.076	470.215	694.151	508.215	251.307	183.608	279.412	192.004	71.277	261.669	89.	8252008.
1915	75.550	58.769	195.045	223.444	714.480	1296.523	1802.769	821.903	425.349	342.890	180.564	90.526	522.630	177.	16481663.
1916	55.407	181.012	208.659	314.337	444.022	1691.242	1551.539	735.335	727.203	384.653	237.339	113.436	553.655	188.	17507885.
1917	85.534	77.144	84.745	444.400	1017.668	1534.949	740.171	322.980	228.326	190.631	122.157	41.901	408.349	139.	12877706.
1918	101.190	70.314	216.608	262.261	348.185	736.527	381.697	274.133	198.587	151.550	93.498	58.866	241.628	82.	7619969.
1919	52.108	47.567	63.014	247.304	446.867	541.139	313.312	335.599	172.527	84.267	60.154	55.425	202.285	69.	6379253.
1920	48.873	62.114	137.633	454.714	927.612	744.829	891.133	353.276	171.252	146.636	91.181	60.989	342.107	116.	10818256.
1921	56.994	61.278	85.698	299.088	508.906	800.322	462.134	241.424	126.083	92.544	77.186	57.156	239.580	82.	7555394.
1922	52.478	32.899	57.811	182.073	468.316	779.081	421.796	257.196	159.240	90.410	66.112	38.155	217.774	74.	6867709.
1923	41.841	30.102	64.422	152.827	353.476	1864.674	790.369	430.203	243.036	157.980	99.578	59.415	357.466	121.	11273057.
1924	39.068	63.704	72.914	129.712	448.028	721.417	500.766	416.271	194.597	114.034	92.980	65.418	238.689	81.	7547910.
1925	71.657	65.240	179.566	510.271	579.244	785.773	444.500	314.906	253.152	263.884	151.126	104.925	311.111	106.	9811197.
1926	66.304	62.576	230.019	253.336	244.793	399.632	372.757	178.873	719.798	441.384	207.217	118.497	275.022	94.	8673096.
1927	99.419	73.528	140.268	477.711	684.192	1453.111	885.390	564.081	607.999	341.879	199.223	118.031	471.318	160.	14863493.
1928	290.314	127.785	347.325	313.496	650.962	1327.738	1148.911	338.419	242.873	206.141	130.330	61.201	433.006	147.	13692701.
1929	57.291	47.470	132.556	136.095	486.605	1139.609	314.399	168.006	115.037	62.975	51.247	54.783	230.586	79.	7271758.
1930	44.170	136.204	137.325	293.858	450.528	711.003	492.132	200.173	131.417	93.059	68.068	66.565	235.470	80.	7425787.
1931	49.561	43.381	67.656	109.964	231.284	499.925	341.966	171.335	148.256	101.693	81.678	50.689	158.491	54.	4998159.
1932	56.352	57.686	94.655	193.751	575.076	1212.060	425.069	232.346	200.346	128.059	102.351	69.937	278.564	95.	8808864.
1933	58.910	43.803	80.437	264.577	568.399	865.398	501.637	212.933	154.820	116.909	173.947	100.730	262.541	89.	8279483.
1934	137.631	144.657	158.442	497.807	669.014	725.797	314.896	176.737	125.669	107.366	174.266	68.666	274.991	94.	8672130.
1935	71.681	130.736	83.602	201.107	329.085	725.208	558.740	299.713	144.525	99.189	57.917	43.884	229.003	78.	7221833.
1936	35.436	20.920	120.052	414.461	425.858	586.200	223.322	151.394	110.864	61.607	42.644	17.429	183.934	63.	5816430.
1937	8.651	22.021	63.932	157.545	262.019	731.370	353.655	211.042	126.391	110.829	110.622	63.134	185.385	63.	5846304.
1938	67.032	31.683	110.218	263.993	552.222	879.148	609.050	227.541	174.833	135.116	78.781	49.844	265.949	90.	8386977.
1939	35.752	21.868	107.393	183.134	322.555	753.297	480.168	183.151	120.408	96.876	103.759	60.080	206.289	70.	6505529.
1940	26.354	37.787	101.525	392.477	479.123	442.569	283.513	173.873	207.465	161.480	88.606	61.829	204.776	70.	6475502.
1941	40.666	42.604	118.888	157.992	192.805	355.822	245.743	175.544	178.195	166.981	103.573	80.502	155.385	53.	4900208.
1942	52.833	39.417	67.256	168.099	705.079	1068.926	901.802	467.380	357.364	237.906	109.877	68.985	355.535	121.	11212139.
1943	43.192	69.955	129.514	735.874	390.793	786.399	740.609	301.098	151.224	99.182	60.431	46.653	296.600	101.	9353565.
1944	42.347	28.886	53.350	121.337	195.225	563.782	333.092	347.788	169.324	115.919	70.879	48.839	174.401	60.	5514974.
1945	37.498	33.506	105.888	116.090	396.347	966.187	586.839	221.582	218.513	192.693	102.501	80.251	255.592	87.	8060337.
1946	76.979	54.195	161.229	238.231	433.891	933.958	503.483	217.866	272.295	177.838	112.939	102.773	274.345	93.	8651749.
1947	83.018	109.206	315.724	451.595	777.928	860.331	539.351	265.418	272.637	341.230	182.003	89.336	358.430	122.	11303445.
1948	75.851	45.686	104.320	763.757	1669.465	1722.420	631.317	454.539	191.855	124.780	82.561	42.917	492.736	167.	15581510.
1949	60.054	34.662	63.776	235.957	424.409	510.007	266.260	168.990	121.962	98.697	94.336	58.727	178.648	61.	5633859.
1950	44.129	61.383	96.546	262.487	388.824	962.815	718.268	306.313	152.519	139.854	116.583	80.563	278.247	95.	8774806.
1951	63.682	57.565	101.056	483.457	1036.837	1181.839	1198.227	467.915	835.268	496.193	283.654	138.862	530.751	180.	16737779.
1952	125.569	114.569	163.277	954.680	591.092	885.464	689.316	382.649	204.222	144.591	87.484	55.291	366.075	124.	11576160.
1953	52.778	78.430	94.856	272.654	724.552	2038.437	939.754	392.153	251.070	157.223	111.232	69.761	432.223	147.	13630569.
1954	57.630	97.371	89.146	287.766	827.717	1165.856	940.463	644.326	672.676	321.901	204.489	85.959	451.045	153.	14224153.
1955	61.514	57.367	64.494	482.375	648.136	967.363	773.290	290.780	173.378	171.275	118.724	74.507	324.563	110.	10235407.
1956	92.288	49.582	162.703	474.668	625.640	934.999	653.734	309.190	185.563	132.743	86.048	67.268	314.827	107.	9955593.
1957	56.323	47.039	148.944	241.664	811.866	714.589	337.112	206.447	152.915	134.344	146.902	81.415	257.724	88.	8127577.
1958	48.980	47.310	93.324	494.793	693.258	769.678	629.708	279.046	176.322	133.311	113.039	92.882	298.700	102.	9419796.
1959	62.063	59.895	130.222	203.158	461.155	947.150	684.130	293.467	235.174	180.934	163.959	117.127	295.787	101.	9327945.
1960	73.646	70.309	204.857	364.534	400.299	679.421	531.534	280.283	152.721	101.047	74.023	58.379	249.484	85.	7889299.
1961	63.901	55.738	111.192	122.371	499.320	947.512	323.136	269.616	147.337	183.765	131.632	55.576	243.090	83.	7666092.
1962	70.661	108.386	110.231	333.524	348.250	654.212	422.310	262.695	183.098	127.664	100.694	66.532	232.436	79.	7330114.
1963	43.090	84.275	148.294	177.095	293.358	802.612	800.568	305.318	186.237	120.603	77.308	71.950	260.098	89.	8202459.
1964	58.449	60.956	55.442	151.390	578.254	1325.557	655.156	248.045	187.026	190.847	125.438	46.579	306.738	104.	9699781.
1965	57.524	75.502	102.082	497.020	421.823	1222.099	1096.235	442.108	374.199	334.520	186.369	92.067	409.430	139.	12911771.
1966	62.192	54.846	245.504	403.816	500.984	1016.042	706.024	342.478	216.898	165.770	119.525	75.096	326.750	111.	10304376.
1967	65.667	60.315	123.464	342.138	796.618	1628.173	752.591	306.974	173.783	128.119	117.458	37.180	378.259	128.	11928763.
1968	63.090	60.994	161.616	118.809	310.675	784.767	520.582	309.112	246.759	259.071	142.773	59.833	253.457	86.	8014932.
1969	60.994	66.771	134.972	601.676	623.571	906.003	1119.486	299.689	184.088	155.632	103.951	57.795	360.979	123.	11383843.
1970	42.107	54.850	85.925	253.679	441.652	1110.187	518.328	219.699	140.619	118.732	86.876	34.150	259.055	88.	8169553.
1971	47.912	113.494	102.459	585.315	595.653	1061.703	522.615	301.736	161.681	114.171	104.489	33.385	311.861	106.	9834855.
1972	32.479	39.729	271.369	301.328	627.258	1278.967	756.247	427.057	256.367	186.469	126.095	50.461	363.187	123.	11484840.
1973	71.642	63.968	137.308	272.167	484.215	826.905	497.683	260.968	204.414	116.176	82.487	82.544	259.005	88.	8167989.
1974	53.236	76.002	85.120	501.129	779.444	1265.508	729.974	364.081	229.542	149.238	90.359	58.333	365.826	124.	11536681.
1975	42.645	33.499	62.920	229.879	575.444	1068.369	713.234	324.304	212.566	147.511	105.395	86.989	301.284	102.	9501296.
1976	91.350	92.596	129.006	226.297	514.976	542.823	520.458	547.625	289.877	161.270	72.463	53.406	271.011	92.	8570008.
1977	43.466	65.270	81.411	126.086	292.607	413.480	228.188	254.331	232.175	155.596	73.879	44.514	167.944	57.	5296291.
1978	31.460	34.292	141.216	303.021	492.801	841.056	616.744	345.488	297.061	197.176	95.853	89.000	291.508	99.	9192990.
1979	31.913	27.071	159.424	186.721	478.979	627.445	374.405	207.619	150.504	90.076	67.366	36.132	203.984	70.	6432831.
1980	29.619	40.635	69.405	294.807	620.054	903.307	366.137	242.590	206.430	181.568	120.998	67.111	261.791	89.	8278475.
1981	104.291	108.992	149.598	154.582	885.609	946.066	737.116	562.458	214.500	141.075	103.640	40.408	347.541	118.	10960067.
1982	12.290	36.132	60.881	240.495	343.540	809.777	725.676	283.423	193.885	166.956	70.905	43.750	249.851	85.	7879296.
1983	40.776	57.172	108.000	154.695	346.315	578.145	497.102	252.558	147.049	101.374	88.519	22.314	200.205	68.	6313651.
1984	30.950	66.092	75.578	130.088	198.218	544.590	393.633	222.627	158.348	140.452	76.739	40.748	173.164	59.	5475860.
1985	32.961	31.885	111.937	263.290	374.802	518.255	273.654	227.724	335.130	237.720	138.753	82.232	219.528	75.	6923020.
1986	77.390	68.385	274.050	190.997	506.957	914.323	548.781	305.964	232.963	351.780	132.410	102.139	310.177	105.	9781730.
MIN	8.7	20.9	53.4	110.0	192.8	355.8	223.3	151.4	110.9	61.6	42.6	17.4	155.4		4900208.
MAX	290.3	181.0	347.3	954.7	1669.5	2038.4	1802.8	821.9	835.3	496.2	283.7	138.9	553.7		17507885.
MEAN	61.2	63.6	126.0	307.1	532.5	918.2	615.4	318.4	237.8	175.4	115.4	67.6	295.5	100.	9326147.

Appendix C - Evaluation of Station Contributions to Estimated District Return Flows

TABLE C-1 (a)

EASTERN IRRIGATION DISTRICT
STATION CONTRIBUTION (BASED ON REGRESSION EQUATIONS)
TO ESTIMATED DISTRICT RETURN FLOWS

Regression Equations Used For Estimating District Returns

Apr	3266.95+	$1.609*X_1$+	$2.492*X_2$+	$1.193*X_3$+	$1.217*X_4$
May	3266.95+	$1.609*X_1$+	$2.492*X_2$+	$1.193*X_3$+	$1.217*X_4$
Jun	18214.20+	$1.404*X_1$+	$.000*X_2$+	$.000*X_3$+	$1.230*X_4$
Jul	-3714.56+	$1.820*X_1$+	$.000*X_2$+	$1.917*X_3$+	$1.238*X_4$
Aug	5708.21+	$1.061*X_1$+	$.000*X_2$+	$.903*X_3$+	$1.870*X_4$
Sep	-593.07+	$1.790*X_1$+	$7.468*X_2$+	$1.577*X_3$+	$1.063*X_4$
Oct	-593.07+	$1.790*X_1$+	$7.468*X_2$+	$1.577*X_3$+	$1.063*X_4$

where X_1=05BN002 Twelve Mile Creek
X_2=05BN014 Coal Creek at Bow City
X_3=05CJ006 Onetree Creek
X_4=05CJ012 Matzhiwin Creek d/s Ware Co.

HYDROMETRIC STATION CONTRIBUTION TO RETURN FLOW ESTIMATE (dam^3)

year	regression constant	BN002	BN014	CJ006	CJ012	Total Returns
1981	25555.6	77975.6	5861.2	52689.4	118576.4	280658.2
1982	25555.6	88349.9	6694.1	51156.3	125785.2	297541.2
1983	25555.6	86479.6	7229.1	42595.2	123132.8	284992.2
1984	25555.6	78965.2	4797.6	35703.4	112606.9	257628.7
1985	25555.6	66071.6	1964.8	37683.6	120331.9	251607.5
1986	25555.6	84376.5	3673.5	41272.1	108634.4	263512.1
1989	25555.6	77873.0	6999.9	39799.8	77066.5	227294.8
1990	25555.6	85411.0	4748.9	44951.4	86101.8	246768.7
1991	25555.6	78066.2	12019.0	51419.2	102169.8	269229.9
1992	25555.6	100150.9	7354.3	50261.7	101172.8	284495.3
AVG	25555.6	82372.0	6134.2	44753.2	107557.8	266372.9
RECORDED AVG		54048.0	3535.0	38810.0	80770.0	177165.0

HYDROMETRIC STATION CONTRIBUTION TO RETURN FLOW ESTIMATE IN %

year	regression constant	BN002	BN014	CJ006	CJ012	Total Returns
1981	9.1	27.8	2.1	18.8	42.2	100.0
1982	8.6	29.7	2.2	17.2	42.3	100.0
1983	9.0	30.3	2.5	14.9	43.2	100.0
1984	9.9	30.7	1.9	13.9	43.7	100.0
1985	10.2	26.3	0.8	15.0	47.8	100.0
1986	9.7	32.0	1.4	15.7	41.2	100.0
1989	11.2	34.3	3.1	17.5	33.9	100.0
1990	10.4	34.6	1.9	18.2	34.9	100.0
1991	9.5	29.0	4.5	19.1	37.9	100.0
1992	9.0	35.2	2.6	17.7	35.6	100.0
AVG	9.7	31.0	2.3	16.8	40.3	100.0

TABLE C-1 (b)

WESTERN IRRIGATION DISTRICT
STATION CONTRIBUTION (BASED ON REGRESSION EQUATIONS)
TO ESTIMATED DISTRICT RETURN FLOWS

Regression Equations Used For Estimating District Returns

Apr-May	411.83+	.917*X_1+	1.099*X_2+	1.035*X_3+	-1.134*X_4
Jun	971.84+	.000*X_1+	.915*X_2+	1.086*X_3+	.000*X_4
Jul	3045.24+	.000*X_1+	.970*X_2+	.959*X_3+	.000*X_4
Aug	1365.48+	.000*X_1+	1.073*X_2+	1.119*X_3+	.000*X_4
Sep-Oct	270.00+	.000*X_1+	1.975*X_2+	.937*X_3+	.000*X_4

where X_1=05BM005 Hammer Hill Spillway
X_2=05BM008 Crowfoot Creek near Cluny
X_3=05CE005 Rosebud at Redland
X_4=05CE006 Rosebud River d/s Carstairs

HYDROMETRIC STATION CONTRIBUTION TO RETURN FLOW ESTIMATE (dam^3)

	ESTIMATED RETURN FLOWS TO THE BOW RIVER						ESTIMATED RETURNS TO RED DEER RIVER	
year	regression constant	BM005	BM008	CE005	CE006	Total Returns	CE005	CE006
1981	6745.7	609.0	24644.8	36813.7	-2368.3	66444.8	-36379.6	3666.8
1982	6745.7	587.3	26943.4	47970.7	-3913.7	78333.4	-47269.3	4335.1
1983	6745.7	620.0	14918.7	35428.9	-862.4	56850.9	-35093.1	972.5
1984	6745.7	39.1	25559.5	39802.0	-280.2	71866.1	-38881.7	270.4
1985	6745.7	561.1	25513.5	42526.0	-313.5	75032.7	-41860.0	1189.4
1986	6745.7	466.5	27578.6	62678.4	-3091.9	94377.3	-63124.7	7286.8
1989	6745.7	581.5	31676.0	46433.2	-1501.8	83934.6	-45405.6	2036.5
1990	6745.7	450.4	22518.1	48032.3	-1536.0	76210.6	-46194.0	8991.0
1991	6745.7	76.1	28977.5	39248.5	-1606.4	73441.3	-38097.9	2814.0
1992	6745.7	46.6	35876.7	46656.7	-230.8	89094.8	-45309.9	2005.5
AVG	6745.7	403.8	26420.7	44559.0	-1570.5	76558.6	-43761.6	3356.8
RECORDED AVG		3558.0	21383.0	43671.0	-3556.0	65056.0	-43672.0	3356.8

HYDROMETRIC STATION CONTRIBUTION TO RETURN FLOW ESTIMATE IN %

year	regression constant	BM005	BM008	CE005	CE006	Total Returns
1981	10.2	0.9	37.1	55.4	-3.6	100.0
1982	8.6	0.7	34.4	61.2	-5.0	100.0
1983	11.9	1.1	26.2	62.3	-1.5	100.0
1984	9.4	0.1	35.6	55.4	-0.4	100.0
1985	9.0	0.7	34.0	56.7	-0.4	100.0
1986	7.1	0.5	29.2	66.4	-3.3	100.0
1989	8.0	0.7	37.7	55.3	-1.8	100.0
1990	8.9	0.6	29.5	63.0	-2.0	100.0
1991	9.2	0.1	39.5	53.4	-2.2	100.0
1992	7.6	0.1	40.3	52.4	-0.3	100.0
AVG	9.0	0.5	34.4	58.2	-2.0	100.0

TABLE C-1 (c)

BOW RIVER IRRIGATION DISTRICT
STATION CONTRIBUTION (BASED ON REGRESSION EQUATIONS)
TO ESTIMATED DISTRICT RETURN FLOWS

Regression Equations Used For Estimating District Returns

Apr	1480.86+	$1.711*X_1$+	$4.353*X_2$+	$.683*X_3$+	$1.310*X_4$
May	1480.86+	$1.711*X_1$+	$4.353*X_2$+	$.683*X_3$+	$1.310*X_4$
Jun	-8211.47+	$6.708*X_1$+	$.000*X_2$+	$.000*X_3$+	$.000*X_4$
Jul	9045.15+	$.000*X_1$+	$.000*X_2$+	$.000*X_3$+	$5.071*X_4$
Aug	8078.66+	$.000*X_1$+	$.000*X_2$+	$.299*X_3$+	$3.553*X_4$
Sep	4621.02+	$1.730*X_1$+	$.000*X_2$+	$.000*X_3$+	$1.975*X_4$
Oct	4621.02+	$1.730*X_1$+	$.000*X_2$+	$.000*X_3$+	$1.975*X_4$

where X_1=05AG003 Expanse Coulee
X_2=05AG004 B.R.D. Drain 'A'
X_3=05BN006 New West Coulee
X_4=05BN008 B.R.D. Drain 'D'

HYDROMETRIC STATION CONTRIBUTION TO RETURN FLOW ESTIMATE (dam^3)

year	regression constant	AG003	AG004	BN006	BN008	Total Returns
1981	21115.4	38187.6	757.5	3825.2	36871.9	100757.5
1982	21115.4	33897.0	404.3	5360.1	33502.6	94279.3
1983	21115.4	48860.9	590.5	3807.6	33703.3	108077.7
1984	21115.4	38974.9	1200.5	4608.6	29150.6	95050.0
1989	21115.4	37464.9	2872.6	3566.7	36489.8	101509.4
1990	21115.4	35623.3	1030.1	3554.3	40328.3	101651.4
1991	21115.4	44055.6	883.5	2698.6	36305.2	105058.3
1992	21115.4	46266.3	3952.1	6920.1	35866.1	114120.0
AVG	21115.4	40416.3	1461.4	4292.6	35277.2	102563.0
RECORDED AVG		21388.0	4361.0	36473.0	13341.0	75563.0

HYDROMETRIC STATION CONTRIBUTION TO RETURN FLOW ESTIMATE IN %

year	regression constant	AG003	AG004	BN006	BN008	Total Returns
1981	21.0	37.9	0.8	3.8	36.6	100.0
1982	22.4	36.0	0.4	5.7	35.5	100.0
1983	19.5	45.2	0.5	3.5	31.2	100.0
1984	22.2	41.0	1.3	4.8	30.7	100.0
1989	20.8	36.9	2.8	3.5	35.9	100.0
1990	20.8	35.0	1.0	3.5	39.7	100.0
1991	20.1	41.9	0.8	2.6	34.6	100.0
1992	18.5	40.5	3.5	6.1	31.4	100.0
AVG	20.7	39.3	1.4	4.2	34.4	100.0

TABLE C-1 (d)

LETHBRIDGE NORTHERN IRRIGATION DISTRICT
STATION CONTRIBUTION (BASED ON REGRESSION EQUATIONS)
TO ESTIMATED DISTRICT RETURN FLOWS

Regression Equations Used For Estimating District Returns

Apr	338.30+	.955*X_1+	1.308*X_2+	1.237*X_3+	-1.251*X_4+	.830*X_5
May	338.30+	.955*X_1+	1.308*X_2+	1.237*X_3+	-1.251*X_4+	.830*X_5
Jun	338.30+	.955*X_1+	1.308*X_2+	1.237*X_3+	-1.251*X_4+	.830*X_5
Jul	338.30+	.955*X_1+	1.308*X_2+	1.237*X_3+	-1.251*X_4+	.830*X_5
Aug	338.30+	.955*X_1+	1.308*X_2+	1.237*X_3+	-1.251*X_4+	.830*X_5
Sep	338.30+	.955*X_1+	1.308*X_2+	1.237*X_3+	-1.251*X_4+	.830*X_5
Oct	338.30+	.955*X_1+	1.308*X_2+	1.237*X_3+	-1.251*X_4+	.830*X_5

where X_1=05AD037 Piyami Drain,
X_2=05AD038 Battersea Drain
X_3=05AC023 Little Bow River near the Mouth
X_4=05AC012 Little Bow downstream Travers Reservoir
X_5=05AD040 Drain L-5 near Diamond City

HYDROMETRIC STATION CONTRIBUTION TO RETURN FLOW ESTIMATE (dam^3)

year	regression constant	AD037	AD038	AC023	AC012	AD040	Total Returns
1985	2368.1	4049.9	3965.3	19080.1	-15909.9	308.7	13862.2
1986	2368.1	6697.2	5187.2	23871.7	-16621.5	471.4	21974.1
1987	2368.1	8006.3	6690.9	24728.0	-15747.6	473.3	26519.0
1988	2368.1	9043.6	7095.3	25666.1	-17520.2	571.4	27224.4
1989	2368.1	6904.6	5992.8	26298.7	-17006.0	512.3	25070.5
1990	2368.1	9001.1	8664.6	24047.8	-12917.2	464.7	31629.0
1991	2368.1	9009.8	8845.7	35774.9	-18901.6	621.4	37718.3
1992	2368.1	9077.4	9814.9	37686.9	-21862.3	950.5	38035.5
AVG	2368.1	7723.7	7032.1	27144.3	-17060.8	546.7	27754.1
RECORDED AVG		8088.0	5376.0	21943.0	-13637.0	658.0	22428.0

HYDROMETRIC STATION CONTRIBUTION TO RETURN FLOW ESTIMATE IN %

year	regression constant	AD037	AD038	AC023	AC012	AD040	Total Returns
1985	17.1	29.2	28.6	137.6	-114.8	2.2	100.0
1986	10.8	30.5	23.6	108.6	-75.6	2.1	100.0
1987	8.9	30.2	25.2	93.2	-59.4	1.8	100.0
1988	8.7	33.2	26.1	94.3	-64.4	2.1	100.0
1989	9.4	27.5	23.9	104.9	-67.8	2.0	100.0
1990	7.5	28.5	27.4	76.0	-40.8	1.5	100.0
1991	6.3	23.9	23.5	94.8	-50.1	1.6	100.0
1992	6.2	23.9	25.8	99.1	-57.5	2.5	100.0
AVG	9.4	28.4	25.5	101.1	-66.3	2.0	100.0

TABLE C-1 (e)

ST. MARY RIVER IRRIGATION PROJECTS
STATION CONTRIBUTION (BASED ON REGRESSION EQUATIONS)
TO ESTIMATED DISTRICT RETURN FLOWS

Regression Equations Used For Estimating District Returns

Apr	307.93+	2.454*X_1+	5.807*X_2+	2.245*X_3+	1.000*X_4+	1.000*X_5
May	307.93+	2.454*X_1+	5.807*X_2+	2.245*X_3+	1.000*X_4+	1.000*X_5
Jun	307.93+	2.454*X_1+	5.807*X_2+	2.245*X_3+	1.000*X_4+	1.000*X_5
Jul	307.93+	2.454*X_1+	5.807*X_2+	2.245*X_3+	1.000*X_4+	1.000*X_5
Aug	307.93+	2.454*X_1+	5.807*X_2+	2.245*X_3+	1.000*X_4+	1.000*X_5
Sep	307.93+	2.454*X_1+	5.807*X_2+	2.245*X_3+	1.000*X_4+	1.000*X_5
Oct	307.93+	2.454*X_1+	5.807*X_2+	2.245*X_3+	1.000*X_4+	1.000*X_5

where X_1=05AH005 Seven Persons Creek at Medicine Hat,
X_2=05AG026 Bountiful Cl. Inflow near Cranf.,
X_3=05AH049 Ross Creek at Medicine Hat,
X_4=05AE041 Dry Coulee near Magrath,
X_5=05AE016 Pothole Coulee near Russel's Ranch

HYDROMETRIC STATION CONTRIBUTION TO RETURN FLOW ESTIMATE (dam^3)

year	regression constant	AH005	AG026	AH049	AE041	AE016	Total Returns
1985	1847.4	45520.4	11814.6	23705.0	5668.7	10267.9	98824.1
1986	1847.4	65594.4	25747.0	42422.9	4072.8	11400.7	151085.3
1987	1847.4	59696.0	22322.2	16490.0	4391.7	12137.4	116884.8
1988	1847.4	48839.2	22209.9	11904.4	6331.0	10423.9	101555.8
1989	1847.4	44375.7	13447.2	14319.1	4504.9	11370.2	89864.6
1990	1847.4	42640.3	21333.3	10658.9	5249.0	12021.6	93750.5
1991	1847.4	51463.5	24141.0	28210.5	5810.3	16098.5	127571.2
1992	1847.4	49277.5	22800.4	27056.6	7893.8	13043.5	121919.3
AVG	1847.4	50925.9	20477.0	21845.9	5490.3	12095.5	112681.9
RECORDED AVG		20752.0	3526.0	9730.0	5490.0	12095.5	51593.0

HYDROMETRIC STATION CONTRIBUTION TO RETURN FLOW ESTIMATE IN %

year	regression constant	AH005	AG026	AH049	AE041	AE016	Total Returns
1985	1.9	46.1	12.0	24.0	5.7	10.4	100.0
1986	1.2	43.4	17.0	28.1	2.7	7.5	100.0
1987	1.6	51.1	19.1	14.1	3.8	10.4	100.0
1988	1.8	48.1	21.9	11.7	6.2	10.3	100.0
1989	2.1	49.4	15.0	15.9	5.0	12.7	100.0
1990	2.0	45.5	22.8	11.4	5.6	12.8	100.0
1991	1.4	40.3	18.9	22.1	4.6	12.6	100.0
1992	1.5	40.4	18.7	22.2	6.5	10.7	100.0
AVG	1.7	45.5	18.2	18.7	5.0	10.9	100.0