Appendix A

Water Allocation/Demands in the Red Deer, Bow, Oldman and South Saskatchewan Sub-basins

Table A.1
Water Allocations/Demands in the Red Deer River Sub-Basin

Mainstream Reaches/Tributaries	Private Irrigation		Urban Municipalities (Cities, Towns, Villages)			Other Purposes[4]	
	Allocation (dam^3)	Irrigated Area (ha)	Allocation (dam^3)	2030 Actual Demand (dam^3)	2030 Actual RF (dam^3)	Allocation (dam^3)	Return Flow (dam^3)
Red Deer River Upstream of Glennifer Reservoir							
Mainstem Red Deer River			167			368	
			572	863	690	1,465	
			124			283	
Red Deer River Tributaries	247	94				3,603	2,391
Glennifer Reservoir to Upstream Medicine River							
Mainstem Red Deer River							
						379	
						889	
Red Deer River Tributaries	614	401				4,236	
Medicine River to Upstream Blindman River							
Mainstream Red Deer River	160	49	24,053			447	
	259	133	26,848	45,613	29,229	1,683	
			14,866			6,6765	
Red Deer River Tributaries[5]	995	616			125	5,633	3,069
Blindman River to Delburn							
Mainstream Red Deer River	27	11				5,204	301
	114	48	1,696	8,518		48,533	1,650
			8,882			677	
Red Deer River Tributaries[5]	484	184			421	12,651	
Delburn to Drumheller							
Mainstream Red Deer River	623	216					
	449	186	1,579	1,356			
	15,000	3,239	909			29,376	
Red Deer River Tributaries	1,976	888					
Drumheller to Upstream Berry Creek							
Mainstream Red Deer River	2,457	585	1,110				
	43,257	6,739	6,630	4,801	2,432	23,376	
	2,450	700				135	
Berry Creek to Bindloss							
Mainstem Red Deer Riverf	7,230	1,735				1	
	7,085	1,786				844	
	2,527	731				105	
	5,306	1,556				14,463	
Blindloss to Saskatchewan Border							
Mainstem Red Deer River	2,743	650	43				
	2,572	720		17		85	
	2,450	700				25	
Acadian Project	56,700	10,926					
Red Deer River Tributaries	1,192	295				929	

Notes:

1. Senior priority licences not subject to significant in-stream requirements.
2. Junior priority licences subject to Dickson Dam operation and IOs.
3. Junior priority licences subject to WCOs. Applicable to licences issued after May 1, 2005.

4. “”Other Purposes” include water management, industrial, commercial, habitat enhancement, recreation, and stock watering projects.
5. Municipal return flows originate from communities on tributaries. Their water sources are aquifers.

Table A.2
Water Allocations/Demands in the Bow River Sub-Basin

Mainstream Reaches/Tributaries	District Irrigation Allocation (dam^3)	Private Irrigation		Urban Municipalities (Cities, Towns, Villages)			Other Purposes[3]	
		Allocation (dam^3)	Area (ha)	Allocation (dam^3)	2030 Demand (dam^3)	2030 Return Flow	Allocation (dam^3)	Return Flow (dam^3)
Bow River Upstream of Bearspaw Reservoir								
Mainstem Bow River		446	159	12,040	15,050	12,040	8,469	5,364
				2,391			2,421	
Bow River Tributaries		236	118				2,767	125
Bow River Bearspaw to Upstream Elbow								
Mainstem Bow River		33	7	347,102	249,882	194,875	12,540	9,534
				1,110			545	
Bow River Tributaries		74	24				288	
Bow River Elbow to Upstream WID Weir								
Mainstem Bow River							697	693
							497	497
Bow River Tributaries								
Elbow River Mainstem		746	298	108,642	58,211	46,568	6,122	2,183
Elbow River Tributaries		228	87				12,5532	11,940
Nose Creek Mainstem							1,514	613
Nose Creek Tributaries		186	156				1,153	
Other Bow River Tributaries								
Bow River WID Weir to Bonneybrook								
Mainstem Bow River	197,853			204	135		6,743	508
							12,272	52
Bow River Tributaries							37	
Bonneybrook to Upstream Highwood River								
Mainstem Bow River		868	291				652	70
		40	16				1,462	
Fish Creek Mainstem		149	80				363	
Fish Creek Tributaries		15	5				858	
Other Bow River Tributaries		215	78				305	
Highwood River to Upstream Carseland								
Mainstem Bow River		1,036	365				12,182	
		1,106	319					
Bow River Tributaries							4	
Highwood/Sheep River Mainstems		3,688	1,618	8,928	9,613	7,690	5,196	
Highwood/Sheep River Tributaries		1,658	1,213				2,106	
Careseland Weir to Upstream Bassano								
Mainstem Bow River	468,723	6,164	1,571	717	442		1,637	
	86,344			739			17,417	
Siksika Expansion		43,173	9,443					
Bow River Tributaries		1,344	472				951	43
Bassano Reservoir to Bow River Mouth								
Mainstem Bow River	939,913	6,350	1,504	6,306	6,548		18,034	
		1,139	301	2,995			28,769	
Bow River Tributaries		402	146				1,462	

Notes:
1. (yellow) Senior priority licences not subject to in-stream requirements of significant magnitude (by today's standards).
2. (blue) Junior priority licences subject to IOs applicable to licences issued since about 1987.
3. ""Other Purposes" include water management, industrial, commercial, habitat enhancement, recreation, and stock watering projects.

Table A.3
Water Allocations/Demands in the Oldman River Sub-Basin

Mainstream Reaches/Tributaries	District Irrigation Allocation (dam^3)	Private Irrigation		Urban Municipalities (Cities, Towns, Villages)			Other Purposes	
		Allocation (dam^3)	Area (ha)	Allocation (dam^3)	2030 Demand (dam^3)	2030 Return Flow (dam^3)	Allocation (dam^3)	Return Flow (dam^3)
Oldman River Upstream of Oldman Reservoir								
Mainstem Oldman River		70	23					
		202	77				1	
Crowsnest River Tributaries		1,394	435	1,256	2,411	1,929	676	
Castle River Tributary		701	256	1,063	973	777	2,693	
Other Oldman River Tributaries		827	314				215	
Oldman River Reservoir to Upstream Pincher Creek								
Mainstem Oldman River		983	309					
		3,528	1,356					
New (Summerview)		13,563	5,425					
Oldman River Tributaries		102	34				278	
Pincher Creek to Upstream LNID Weir								
Mainstem Oldman River		914	257					
		1,106	353				31	
New (Piikani)		43,200	17,280					
Pinch Creek Tributary		437	177	815			1,295	
Beaver Creek Tributary		547	209				117	
Other Oldman River Tributaries		42	18				91	
LNID Weir to Upstream Willow Creek								
Mainstem Oldman River	329,339	1,167	740	2,018	1,144	913	359	
	83,217	4,767	1,547	265			10,720	
Other Oldman River Tributaries							186	
Willow Creek to Upstream Belly River								
Mainstem Oldman River		8,397	2,647					
		6,698	1,842				161	
Willow Creek Tributary								
Mainstem Willow Creek								
Upstream of Pine Coulee Reservoir		226	77					
Downstream of Pine Coulee Reservoir		6,877	1,710	1,486	1,647	1,300	102	
		14,685	4,426	200				
Willow Creek Tributaries		3,825	1,127				1,052	
Other Oldman River Tributaries		165	39				4	
Belly River to Upstream St. Mary River								
Mainstem Oldman River		292	70				454	
		1,358	353					
Waterton River Tributary								
Mainstream Waterton River								
Upstream Waterton Reservoir								
		200	94				36	
Downstream Waterton Reservoir	16,667	2,177	589					
	70,642	3,431	1,251				116	
Waterton River Tributaries		2,236	623				3,439	
Belly River Tributary								

Mainstream Reaches/Tributaries	District Irrigation Allocation (dam³)	Private Irrigation		Urban Municipalities (Cities, Towns, Villages)			Other Purposes	
		Allocation (dam³)	Area (ha)	Allocation (dam³)	2030 Demand (dam³)	2030 Return Flow (dam³)	Allocation (dam³)	Area (ha)
Mainstem Belly River								
Upstream Belly River	70,938	117	26	1,036	1,044	835		
Diversion	25,617						39	
Downstream Belly River	3,704	11,158	2,708				1,633	
Diversion		9,876	3,156				98	
Belly River Tributaries		1,491	374				429	
Other Oldman River Tributaries							73	
St. Mary River to Upsteam Little Bow River								
Mainstem Oldman River		1,607	434	26,556	33,011	26,409	368	
		1,804	557	7,046			1,618	
St. Mary River Tributaries								
Mainstem St. Mary River								
Upstream St. Mary Reservoir		316	85				458	
							85	
Tributaries Upstream St. Mary Reservoir		1,817	526				789	
Downstream St. Mary Reservoir	887,037	470	117	3,453	7,594	4,592	5,125	
	320,988	843	270	5,433			1,787	
Tributaries Downstream St. Mary Reservoir		1,790	460				1,787	
Other Oldman River Tributaries		208	37				31	
Little Bow River to Oldman Mouth								
Mainstem Oldman River		14,316	2,811			30		
Little Bow River Tributary		11,045	3,498				1,106	
Mainstem Little Bow River								
Upstream Twin Valley Reservoir		2,577	826				626	
Twin V Reservoir to Travers Reservoir		10,639	9,768	648	766		287	
Travers Reservoir to Mouth		1,322	529				727	
Little Bow River Tributaries		406	194					
Mainstem Mosquito Creek								
Upstream W C Diversion							5	
W C Diversion to Twin V Reservoir		2,886	788	740	603	482	360	
Clear Lake		5,186	3,660					
Mosquito Creek Tributaries		402	135				635	
Other Oldman River Tributaries		90	16				100	

Notes:

1. (yellow) Senior priority licences not subject to in-stream requirements of significant magnitude (by today's standards).
2. (blue) Junior priority licences subject to IOs applicable to licences issued since about 1987.
3. Urban municipalities may have licences from more than one stream, or from surface and groundwater.
4. Several licences for irrigation districts in the basin are for diversion of water from the Waterton, Belly and St.Mary Rivers without indicating how much from each. In these cases, the allocation has been assigned to the last source stream from which the diversion was delivered.
5. (purple) Water projects in the Little Bow River Basin are supplied primarily by diversions from the Highwood River.

Table A.4
Water Allocations/Demands in the South Saskatchewan River Sub-Basin

Mainstream Reaches/Tributaries	District Irrigation Allocation (dam³)	Private Irrigation		Urban Municipalities (Cities, Towns, Villages)			Other Purposes	
		Allocation (dam³)	Area (ha)	Allocation (dam³)	2030 Demand (dam³)	2030 Return Flow (dam³)	Allocation (dam³)	Return Flow (dam³)
South Saskatchewan Mainstem Upstream Medicine Hat		4,562	1,059	28,246	23,860	16,624	5,951	
		13,833	3,535	745			1,856	527
South Saskatchewan Tributaries Upstream Medicine Hat		433	180				2,464	
South Saskatchewan Mainstem Downstream Medicine Hat		3,197	727				11,521	1,727
		8,676	2,048				9,016	772
Tributaries Downstream Medicine Hat		2,431	643				1,075	
MS Seven Person Creek Tributary								
Upstream Murray Lake Reservoir							14	
Downstream Murray Lake Reservoir		1,436	455				27	
Seven Persons Creek Tributary		2,950	1,157				3,244	
MS Bullshead Creek Tributary		1,699	434				323	
Bullshead Creek Tributaries		941	302				981	
MS Ross Creek Tributary								
Upstream Gros Ventre Confluence		485	201				258	
Downstream Gros Ventre Confluence		1,005	330				16	
MS Gros Ventre Creek Tributary								
Upstream Cavan Lake Diversion		17	12					
Downstream Cavan Lake Diversion	3,701	83	30				1	
Gros Ventre Tributaries		1,486	338				953	
Other Ross Creek Tributaries		1,573	336				1,141	62
Other Tributaries Downstream Medicine Hat		2,431	643				1,075	

Notes:

Senior priority licences not subject to in-stream requirements of significant magnitude (by today's standards).

Junior priority licences subject to IOs applicable to licences issued since about 1983.

The modelling node South Saskatchewan River at Medicine Hat is upstream of its confluence with Ross Creek.

Medicine Hat's licence allocation includes cooling water for the city's power plant. Allocation noted on the table excludes estimated cooling requirement.

Appendix B

Simulation Modelling Background

Caveats

The WRMM has been in use in the SSRB for almost 30 years. Many important water management decisions have been made based on evaluation of its output. It has continually been improved and made more user-friendly. It is the best available tool for furthering the state of water management in the SSRB at this time. It is the only known model capable of simulating priorities and other legal and regulatory requirements in the complex SSRB. While simulation modelling is a powerful analytical tool for assessing water management options in large and complex water resource systems, it has some limitations. In addition to the limitations related to the demand and supply databases noted above, two other limitations must be kept in mind by reviewers of the results of this study.

1) Historical Climate Variability

This study conducts simulation modelling for the historical period of weather and stream flow conditions from 1928 to 2001. The underlying premise is that how well the model performs during the 68-year period of recorded meteorological and stream flow conditions, which includes sequences of high and low runoff and demands, gives an indication how the system will perform in the future. There is reason to believe that the recorded period may not be truly representative of future conditions. Studies of tree rings, lake sediments and other paleo-climatic indicators on the Canadian prairies have shed some light on the climate of past centuries (Sauchyn, 1997; Case *et al*., 2003). Researchers have concluded that stream flows may have been relatively high on the Canadian Prairies during the 20th Century compared with earlier centuries. Sauchyn concludes that:

> ".... the recent occupants of the Palliser triangle have not yet experienced the extremes of summer precipitation that occurred in the 19th and late-18th centuries, and that could reoccur in the near future."

This conclusion suggests that modelling results using the 1928 to 1995 recorded period could present an overly optimistic picture of long-term water supply and demand.

2) Future Climate Change

How will climate change affect the performance of the water management system in the South Saskatchewan River Basin? Studies have been conducted to assess the potential impacts of climate change on stream flow on the Canadian Prairies based on scenarios of economic conditions and societal trends and the output of Global Climate Models. Their findings indicated a wide range of potential impacts on stream flow in the SSRB.

Appendix C

South Saskatchewan River Basin Case Model Update

South Saskatchewan River Basin Base Case Model Update

The Base Case is an update of Scenario 3 from the *South Saskatchewan River Basin Water Supply Study* (AMEC, 2009). The update reflects changes in the demand database, operational practices and a more detailed reach by reach analysis of performance in meeting demands.

It includes relatively high levels of expansion within irrigation districts that would be dependent on improved efficiencies, reduced return flows, and higher unit on-farm crop water applications.

On-farm irrigation applications – It has long been known the irrigators in Alberta apply less water than that considered to be optimal for crop growth in Alberta. Monitoring has indicated that they are currently applying about 80 to 83% of optimal. However, applications are gradually increasing. Alberta Agriculture and Food (ARD) predict that applications will continue to increase to a maximum of 90% of optimal (Irrigation Water Management Study Committee 2002). For this study, simulation modelling assumes 80% of optimal application for current conditions and 90% for future conditions.

Optimal Level of Application – The term "optimal irrigation" is used by ARD to refer to an irrigation application schedule based on the objective of keeping available soil moisture in an irrigated field above 70% for centre pivot systems and above 50% for wheel move and surface irrigation systems (Irrigation Water Management Study Committee 2002A).

Demands for private irrigation, urban municipalities and other non-irrigation projects are based on projected year 2030 levels.

Private irrigation demand includes:

- Implementation of the SAWSP and Acadia Projects in the Red Deer River Sub-basin;
- A small amount of additional private irrigation along the Red Deer River valley;
- Full development of the Pine Coulee Project;
- Development of irrigation projects by the Piikani and Siksika First Nations and full development of the Kainai First Nation project, and
- Irrigation expansion in the Oldman River Reservoir area in accord with the Oldman River Basin Water Allocation Order*, Regulation 319/2003* (Alberta Environment, 2003).

Urban municipal demand is based on current per capita use and population projections to 2030.

Other non-irrigation demand is taken as the licensed consumptive use (allocation volume minus return flow).

The Base Case projected demands are summarized in **Appendix A**.

Base Case infrastructure is taken as existing plus two planned off-stream storage projects within the WID; Bruce Lake (51,000 dam^3) and enlargement of Langdon Reservoir (12,150 dam^3).

Infrastructure operations were updated to reflect the minimum release from Gleniffer Reservoir has been increased by ESRD to 17.5 m^3/s (from 16.0 m^3/s) to improve performance in maintaining the WCO along the full length of the river and to enhance the flood mitigation potential of the reservoir.

Evaluation of Base Case Results

Red Deer River Sub-basin

There are seven reaches with a unique WCO along the Red Deer River from Gleniffer Reservoir to the Saskatchewan border.

Modelling indicates relatively small, infrequent deficits in meeting the WCOs along the river (**Figure C.1**) with deteriorating performance from upstream to downstream. The increased minimum flow release of 17.5 m^3/s from Dickson Dam has substantially improved performance in meeting the WCOs along the river.

Red Deer River Evaluation Reaches
RD1: Gleniffer Res to Medicine R
RD2: Medicine R to Blindman R
RD3: Blindman R to Delburne
RD4: Delburne to Drumheller
RD5: Drumheller to Berry Cr
RD6: Berry Cr to Bindloss
RD7: Bindloss to Sask Border

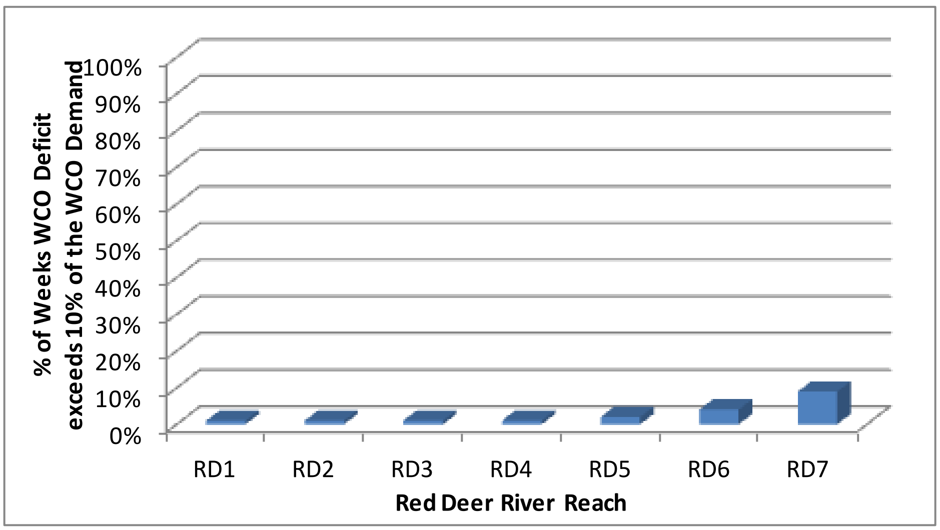

Figure C.1 Base Case; Red Deer River WCO Frequency of Deficits > 10%

No district irrigation licences have been issued from the Red Deer River.

The magnitude and frequency of irrigation deficits greater than 100 mm for junior private irrigation projects are shown in **Table D.8** and on **Figure C.2**. There are no existing junior private irrigation projects in river reaches R1 to R5 (upstream of the confluence with Berry Creek). Modelling indicates that there would be large and frequent deficits to potential future projects along RD5 without storage in this reach. Performance improves for potential future projects downstream of RD5, possibly due to irrigation return flows from the EID.

Performance for the future SAWSP multi-use project (which has an irrigation component) and the Acadia irrigation project would be well within the acceptable range. Both of these projects are supported by off-stream storage.

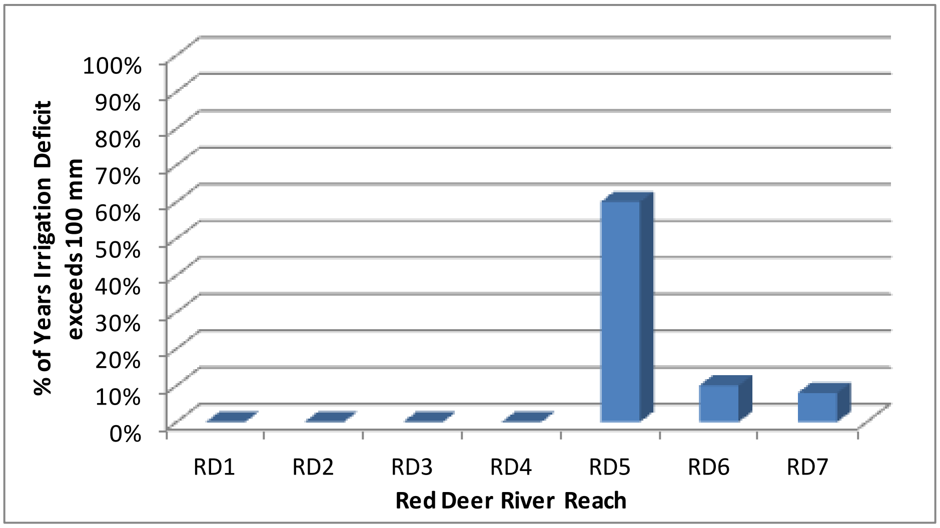

Figure C.2 Base Case; Red Deer River Junior Private Irrigation Projects Frequency of Deficits >100 mm

Junior non-irrigation uses in the Red Deer River Sub-basin include several regional municipal water supply projects. Base Case simulation modelling indicates that junior non-irrigation licences would experience frequent and relatively large deficits for all reaches from Gleniffer Reservoir to the Berry Creek confluence (**Table D.11; Figure C.3**). Deficits in the downstream reaches are less than in the upper reaches, due to irrigation return flows from the Western and Eastern Irrigation Districts in summer months and higher tributary inflows during the winter.

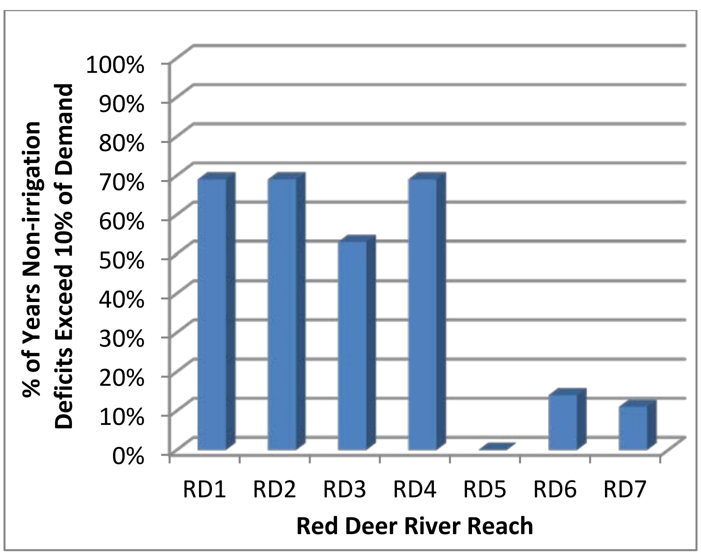

Figure C.3 Base Case; Red Deer River Junior Non-Irrigation Projects Frequency of Deficits >10%

Bow River Sub-Basin

There are five reaches with a unique WCO along the Bow River from Bearspaw Reservoir to the mouth (Oldman River confluence).

Bow River Evaluation Reaches
B1: Bearspaw Reservoir to Elbow River
B2: Elbow River to Highwood River
B3: Highwood River to Carseland Weir
B4: Carseland Weir to Bassano Reservoir
B5: Bassano Reservoir to Bow Mouth

Modelling indicates relatively minor WCO deficits in the Elbow River confluence to Bassano Reservoir reach (**Table D.2**). Deficits are more significant from Bassano Reservoir to the Bow Mouth (**Figure C.4**). Return flows from the WID, EID, and BRID are directed to the Red Deer and Oldman rivers as well as the Bow River.

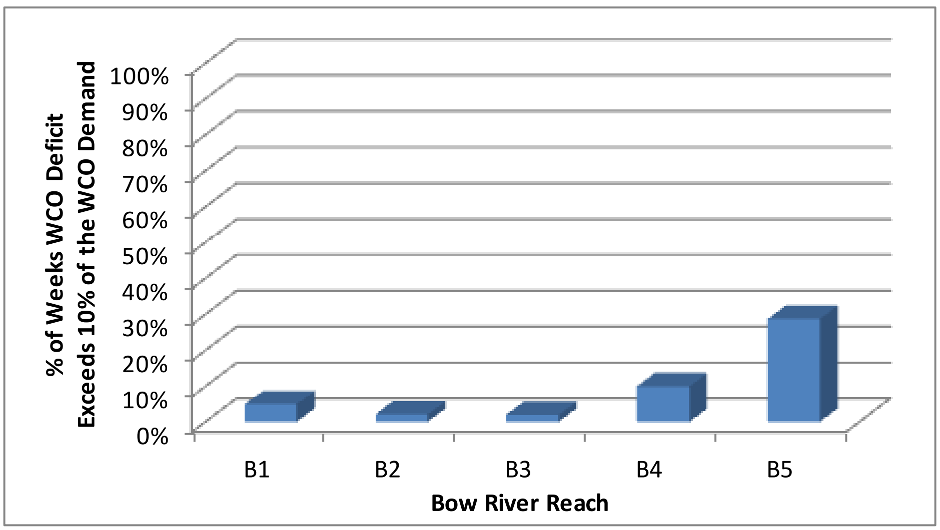

Figure C.4 Base Case; Bow River WCO Frequency of Deficits >10%

Base Case modelling indicates no significant deficits to the three Bow River irrigation districts (**Table D.6**). The simulation assumes improvements in irrigation efficiencies and reduced return flows prior to expansion of the irrigated areas.

There are no junior private irrigation projects along reach B1 Bearspaw to Elbow River and reach B4 Carseland to Bassano. Junior private irrigation projects in reaches B2 to B3 Elbow River to Carseland perform within the guidelines used to assess acceptable performance (deficits >100 mm in no more than 10% of years). Deficits increase substantially in the reach B5 Bassano to Mouth (**Table D.9; Figure C.5**). Irrigation expansion on the Siksika First Nations Reserve would perform well.

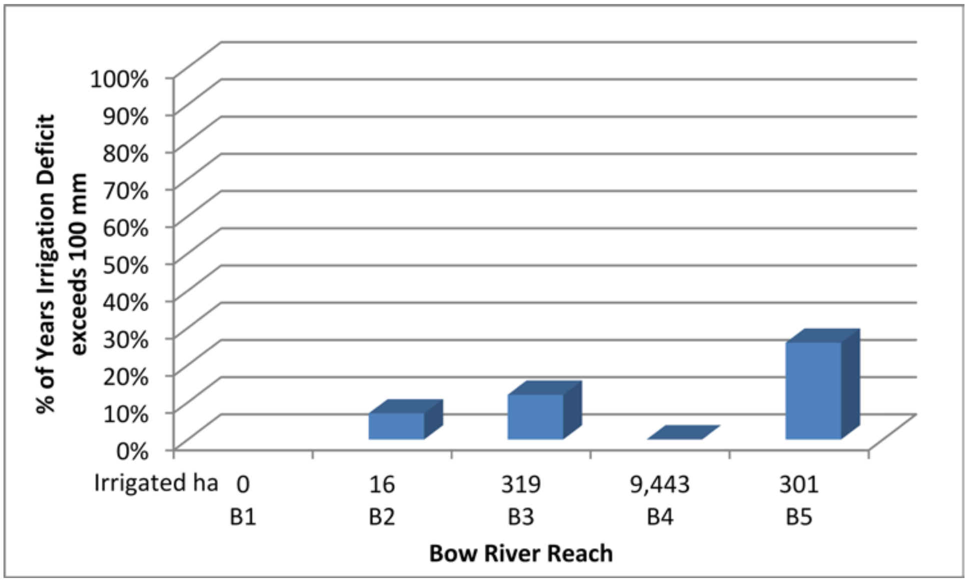

Figure C.5 Base Case; Bow River Junior Private Irrigation Projects Frequency of Deficits >100 mm

There are no junior non-irrigation consumptive use projects in Reach B3 Highwood River to Carseland Weir. In the other four reaches the projects performed poorly (**Table D.12; Figure C.6**). Almost all deficits would occur in the May to October period. Winter flows on the Bow River are relatively high due to hydropower operations upstream of Calgary.

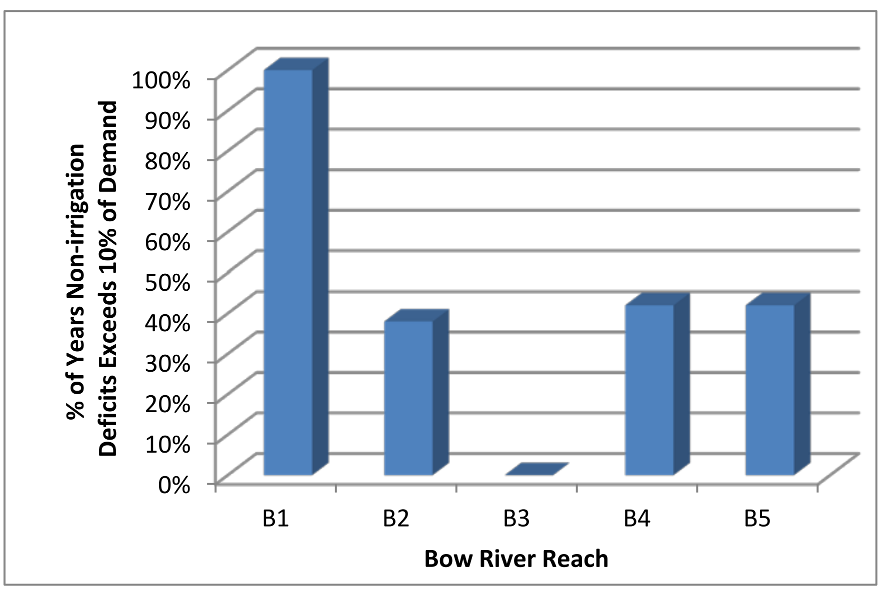

Figure C.6 Base Case; Bow River Junior Non-Irrigation Projects Frequency of Deficits > 10%

Oldman River Sub-Basin

There are six in-stream flow reaches along the Oldman River from the Oldman Reservoir to the Oldman River mouth (Bow River confluence), two reaches along the St. Mary River and two reaches along the South Saskatchewan River. Modelling for the Base Case indicates only minor WCO deficits in the three reaches upstream of the Willow Creek confluence (**Tables D.3, D.4, D.5; Figure C.7**). The deficits increase significantly in the Oldman reaches downstream of the Belly River. The WCO deficits greater than 10% are frequent downstream of the St. Mary Reservoir and the diversions to the four irrigation districts served by the reservoir. Modelling indicates that WCO deficits greater than 10% within the two South Saskatchewan reaches would occur with a moderate frequency of about 25% of the weeks modelled.

Oldman River Evaluation Reaches

- OM1: Oldman Reservoir to Pincher Creek
- OM2: Pincher Cr to LNID Diversion
- OM3: LNID Diversion to Willow Creek
- OM4: Willow Creek to Belly River
- OM5: Belly River to St Mary River
- OM6: St. Mary River to Oldman Mouth
- SM1: St Mary River U/S St Mary Reservoir
- SM2: St Mary River D/S St Mary Reservoir
- SS1: South Sask River U/S Medicine Hat
- SS2: South Sask River D/S Medicine Hat

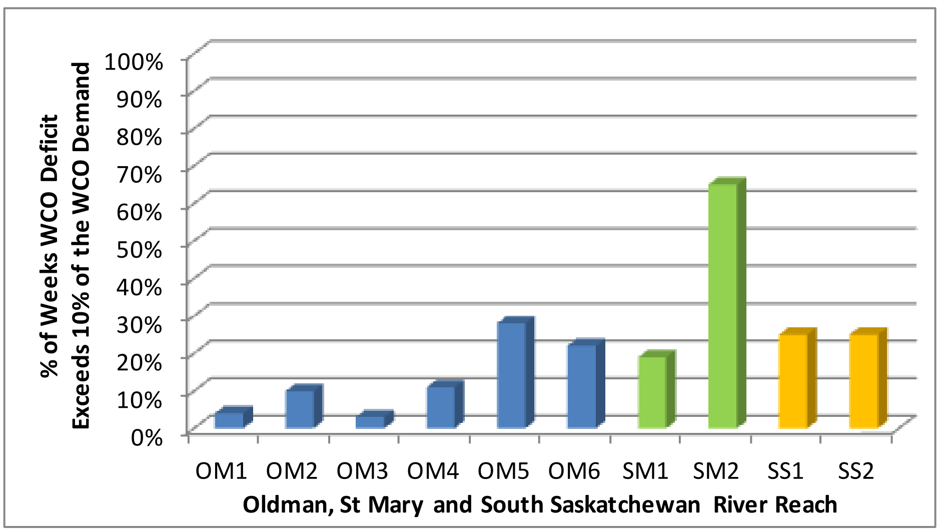

Figure C.7 Base Case; Oldman, St. Mary & S. Saskatchewan Rivers WCO Deficits >10%

Base Case modelling indicates acceptable performance within the Oldman River irrigation districts (**Table D.7**). This conclusion is predicated on improvements in on-farm and district operating efficiencies, reduced return flows, a shift toward higher value crops and increased water applications to generate higher revenues and improve farm financial performance.

For junior private irrigation, modelling indicates that performance would be borderline unacceptable in the Oldman River reaches from the Oldman Reservoir to the LNID diversion (**Table D.10; Figure C.8**). These reaches include the proposed Piikani First Nation and the Summerview irrigation projects. Performance would be unacceptable for the reaches between the LNID diversion and the St. Mary River confluence. The performance improvement in the lower reach OM6 compared with the middle reaches may be due to return flows from the irrigation districts.

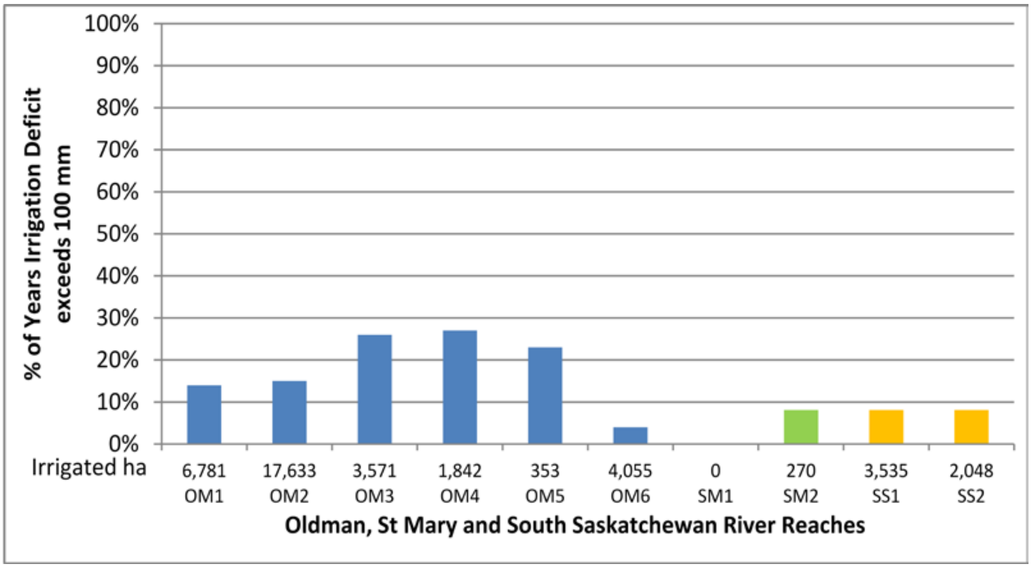

Figure C.8 Base Case; Oldman, St. Mary & S. Saskatchewan Junior Private Irrigation Frequency of Deficits >100 mm

There are no junior private irrigation projects along the St. Mary River upstream of the St. Mary Reservoir. Performance would be unacceptable for the junior private irrigation along the St. Mary River downstream of the St. Mary Dam.

There are no junior non-irrigation projects in reaches OM1 and OM5. Base Case modelling indicates extensive deficits for junior non-irrigation projects within four reaches along the Oldman River and the two reaches along the St. Mary River. Deficits would be less frequent along the South Saskatchewan River (**Table D.13; Figure C.9**).

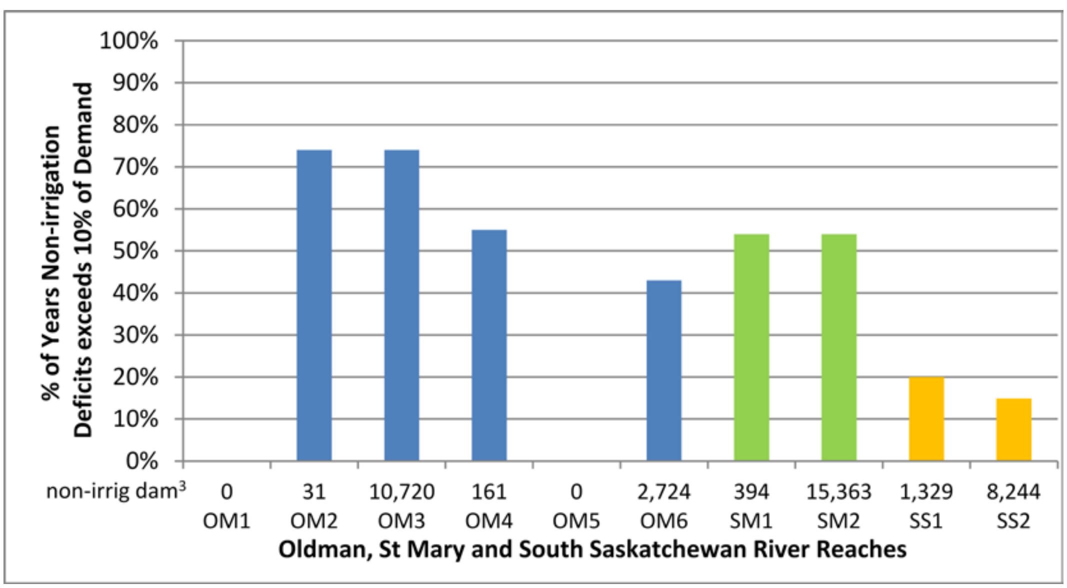

Figure C.9 Base Case; Oldman, St. Mary & S. Saskatchewan Junior Non-irrigation Projects Frequency of Deficits >10%

Base Case Summary of Results

Red Deer River Sub-Basin

Performance in meeting the WCO is significantly improved over the previous study due to the increased minimum flow release from Gleniffer Reservoir.

All existing junior private irrigation projects perform within acceptable limits. The proposed SAWSP and Acadia Irrigation Project perform well due to their associated off-stream storage developments. New irrigation developments subject to the WCO will experience frequent and large deficits unless new storage is developed to support the projects.

Junior non-irrigation projects will experience high deficits in all river reaches upstream of the Berry Creek confluence.

Bow River Sub-Basin

There are only minor deficits to the WCO and junior private irrigation upstream of the Bassano Dam. Deficits are much higher downstream of Bassano Dam. Performance in meeting water needs for the irrigation districts and for Siksika expansion would be acceptable. Modelling indicates high deficits for junior non-irrigation projects along the entire river.

Oldman River Sub-Basin

Modelling indicates that WCO deficits upstream of Willow Creek are minor. Deficits increase downstream of Willow Creek. St. Mary River WCO deficits downstream of the St. Mary Dam are very high.

Junior private irrigation projects, including the Piikani and Summerview projects perform less than adequately along all reaches of the Oldman River except the lowest reach. Projects in the lowest reach probably benefit from irrigation return flows. Junior non-irrigation projects perform poorly in all reaches modelled in the Oldman River Sub-basin.

Appendix D

South Saskatchewan River Basin Base Case Performance Summary

Table D.1
Base Case Scenario (2030 Demand): Summary of Performance in Meeting WCOs in the Red Deer River Based on Simulation Modelling

Reach	Glennifer Reservoir to Medicine River	Medicine River to Blindman River	Blindman River to Delburn	Delburn to Drumheller	Drumheller to Berry Creek	Berry Creek to Bindloss	Bindloss to Saskatchewan Border
Natural Channel	168/105	41	42/151	79/161	43/157	160/459	101/163
WCO April to October	Max(0.45×C5C B07, 16.0 m^3/s)	Max(0.45×C5C C02, 16.0 m^3/s)	Max(0.45×C5C D04, 10.0 m^3/s)	Max(0.45×C5C D04, 10.0 m^3/s)	Max(0.45×C5C E01, 10.0 m^3/s)	Max(0.45×GRD DEN, 10.0 m^3/s)	Max(0.45×C5C K04, 10.0 m^3/s)
WCO November to March	Max(0.45×C5C B07, 16.0 m^3/s)	Max(0.45×C5C C02, 16.0 m^3/s)	Max(0.45×C5C D04, 16.0 m^3/s)	Max(0.45×C5C D04, 16.0 m^3/s)	Max(0.45×C5C E01, 16.0 m^3/s)	Max(0.45×GRD DEN, 16.0 m^3/s)	Max(0.45×C5C K04, 16.0 m^3/s)
X% of WCO Demand	**% of Weeks That Deficits Exceed X% of WCO Demand**						
0%	2%	12%	8%	7%	10%	10%	16%
10%	1%	1%	1%	1%	2%	4%	9%
20%	1%	0%	0%	0%	0%	1%	3%
40%	0%	0%	0%	0%	0%	0%	0%
60%	0%	0%	0%	0%	0%	0%	0%

Tables are read as follows:
For the Red Deer River reach Bindloss to Sask Border,
-- % of weeks that WCO deficits exceed 10% of demand = 9%.
-- % of weeks that WCO deficits exceed 20% of demand = 3%.

Table D.2

Base Case Scenario (2030 Demand): Summary of Performance in Meeting WCOs in the Bow River Based on Simulation Modelling

Reach	Bearspaw Reservoir to Elbow River	Elbow River to Highwood River	Highwood River to Carseland Weir	Carseland Weir to Bassano Dam	Bassano Dam to Bow Mouth
Natural Channel	30/952	37/954	38/955	34/35/956	40
WCO	Max(0.45×C5BH04, 1.1×IO)	Max(0.45×GBO WID, 1.1×IO)	Max(0.45×BEL HWD, 1.1×IO)	Max(0.45×BEL HWD, 1.1×IO)	Max(0.45×BEL HWD, 1.1×IO)
IO	80%* Fish Rule Curve	80%* Fish Rule Curve	80%* Fish Rule Curve	80%* Fish Rule Curve	April – October 11.33 m^3/s; November to March TT
X% of WCO Demand	**% of Weeks That Deficits Exceed X% of WCO Demand**				
0%	9%	5%	5%	24%	31%
10%	5%	2%	2%	10%	29%
20%	2%	0%	0%	6%	27%
40%	0%	0%	0%	1%	22%
60%	0%	0%	0%	0%	17%

GBO WID = C5B H04+C5B J01

BEL HWD = C5B H01+C5B L24

TT = Tennant Tessman

Table D.3
Base Case Scenario (2030 Demand): Summary of Performance in Meeting WCOs in the Oldman and South Saskatchewan Basins Based on Simulation Modelling

Oldman River WCO

Reach	Oldman River Dam to Pincher Creek	Pincher Creek to LNID Diversion	LNID Diversion to Willow Creek	Willow Creek to Belly River
Natural Channel	75	78	164	165
WCO	Max(0.45Qnat or, 1.1×IO)	Max(0.45Qnat or, 1.1×IO)	Max(0.45Qnat or, 1.1×IO)	Max(0.45Qnat or, 1.1×IO)
IO	80%* Fish Rule Curve	80%* Fish Rule Curve	80%* Fish Rule Curve	80%* Fish Rule Curve
X% of WCO Demand	**% of Weeks That Deficits Exceed X% of WCO Demand**			
0%	35%	30%	56%	37%
10%	4%	0%	10%	12%
20%	3%	0%	8%	9%
40%	1%	0%	5%	5%
60%	0%	0%	2%	2%

Oldman River WCO (Continued) St. Mary River WCO

Reach	Belly River to St. Mary River	St. Mary Confluence to Mouth	Upstream St. Mary Dam	St. Mary Dam to Mouth
Natural Channel	166	102	170	172
WCO	Max(0.45Qnat or, 1.1×IO)	Max(0.45Qnat or, 1.1×IO)	Max(0.45Qnat or, 3.0 m^3/s)	Max(0.45Qnat or, 3.0 m^3/s)
IO	80%* Fish Rule Curve	80%* Fish Rule Curve	42.5 m^3/s	42.5 m^3/s
X% of WCO Demand	**% of Weeks That Deficits Exceed X% of WCO Demand**			
0%	31%	32%	23%	91%
10%	28%	23%	19%	65%
20%	24%	19%	14%	61%
40%	17%	12%	6%	51%
60%	10%	6%	1%	38%

South Saskatchewan River WCO

Reach	Upstream of Medicine Hat	Medicine Hat to Saskatchewan Border
Natural Channel	69	469
WCO	Max(0.45Qnat or, 1.1×IO)	Max(0.45Qnat or, 1.1×IO)
IO	42.5 m^3/s	42.5 m^3/s
X% of WCO Demand	**% of Weeks That Deficits Exceed X% of WCO Demand**	
0%	29%	29%
10%	25%	25%
20%	22%	22%
40%	5%	14%
60%	0%	6%

Table D.4
Base Case Scenario (2030 Demand): Summary of Performance in Meeting Bow River Irrigation District Demands in the Based on Simulation Modelling

	Irrigation District Deficits (% of years)			
	WID	**BRID**	**EID**	**Total**
Irrigated Area (ha)	46,134	101,981	138,888	287,003
X	**% of Years that Irrigation District Deficits Exceed X**			Wtd Mean
>50 mm	11%	0%	4%	4%
>100 mm	7%	0%	1%	2%
> 200 mm	0%	0%	0%	0%

Table D.5
Base Case Scenario (2030 Demand): Summary of Performance in Meeting Irrigation District Demands in the Oldman Basin Based on Simulation Modelling

	Irrigation District Deficits (% of years)							
	LNID	**MVLA**	**UID**	**MID**	**RID**	**SMRID**	**TID**	**Total**
Irrigated Area (ha)	78,792	5,342	15,135	8,147	20,700	165,598	36,592	330,306
X	**% of Years that Irrigation District Deficits Exceed X**							Wtd Mean
>50 mm	8%	39%	14%	10%	12%	16%	5%	13%
>100 mm	5%	8%	4%	3%	10%	5%	1%	5%
> 200 mm	1%	0%	0%	0%	1%	3%	1%	1%

Table D.6
Base Case Scenario (2030 Demand): Summary of Performance in Meeting Junior Private Irrigation Demands in the Red Deer River Basin Based on Simulation Modelling

Reach	Upstream of Delburne	Delburne to Drumheller	Drumheller to Berry Creek	Berry Creek to Bindloss	Bindloss to Saskatchewan Border	
		SAWSP	New Project	2 New Projects	Acadian Irrigation	New Project
Block	No junior WCO	606	601	668,635	605	624
Priority	Irrigation projects	Jr WCO	Jr WCO	Jr WCO	Jr WCO	Jr WCO
Irrigated Area (ha)	Upstream of Delburn	3,238	700	731	10,926	700
X mm of Demand	**% of Years That Annual Deficits Private Irrigation Projects Exceed X mm**					
50 mm	N/A	15%	70%	19%	7%	14%
100 mm	N/A	4%	58%	10%	5%	8%
200 mm	N/A	1%	35%	4%	4%	5%

Table D.7
Base Case Scenario (2030 Demand): Summary of Performance in Meeting Junior Private Irrigation Demands in the Bow River Basin Based on Simulation Modelling

Reach	Upstream Bearspaw Reservoir	Bearspaw Reservoir to Elbow River	Elbow River to Bonneybrook	Bonneybrook to Highwood River	Highwood River to Carseland Weir	Carseland Weir to Bassano Dam	Bassano Dam to River Mouth
						Siksika Expansion	
Block	147			769	377	336	378
Irrigated Area (ha)	278	0	0	16	319	9,443	301
X mm of Demand	**% of Years That Private Irrigation Annual Deficits Exceed X mm**						
50 mm	0%	N/A	N/A	16%	23%	0%	31%
100 mm	0%			7%	12%	0%	26%
200 mm	0%			0%	0%	0%	10%

Table D.8
Base Case Scenario (2030 Demand): Summary of Performance in Meeting Junior Private Irrigation Demands in the Oldman River Basin and South Saskatchewan River Based on Simulation Modelling

	Oldman River Junior Private Irrigation					
Reach	**Oldman River Dam to Pincher Creek**	**Pincher Creek to LNID Diversion**	**LNID Diversion to Willow Creek**	**Willow Creek to Belly River**	**Belly River to St. Mary River**	**St.Mary River Confluence to Mouth**
Demand Block	655 (S'view) and 683	667 (Piikani)	345 and 684	685	644	697,660
Irrigated Area (ha)	6,781	15,257	3,581	1,842	353	4,055
X mm of Demand	**% of Years That Annual Deficits Private Irrigation Projects Exceed X mm**					
50 mm	32%	38%	46%	43%	35%	7%
100 mm	14%	15%	19%	27%	23%	4%
200 mm	8%	8%	10%	11%	10%	1%

	St. Mary River Junior Private Irrigation		South Saskatchewan River Junior Private Irrigation	
Reach	**Upstream St. Mary Dam**	**St. Mary Dam to Mouth**	**South Sask. River Upstream of Medicine Hat**	**South Sask. River Downstream of Medicine Hat**
Demand Block		646	661	662
Irrigated Area (ha)	0.0	270	3,535	2,048
X mm of Demand	**% of Years That Annual Deficits Private Irrigation Projects Exceed X mm**			
50 mm	N/A	27%	16%	18%
100 mm		8%	8%	8%
200 mm		1%	3%	4%

Table D.9
Base Case Scenario (2030 Demand): Summary of Performance in Meeting Junior Non-Irrigation Demands in the Red Deer River Basin Based on Simulation Modelling

Reach	Glennifer Reservoir to Medicine River	Medicine River to Blindman River	Blindman River to Delburne	Delburne to Drumheller	Drumheller to Berry Creek	Berry Creek to Bindloss	Berry Creek to Bindloss
Demand Block	669	671	672, 673, 807	951	674	692	605
Priority	Jr WCO	Jr WCO	Jr WCO	Jr WCO	Jr WCO	Jr WCO	Jr WCO
Demand (dam^3)	889	6,765	7,499	909	1,132	105	25
X% of Demand	**% of Years That Deficits Exceed X% of Non-irrigation Demand**						
0%	81%	81%	80%	78%	77%	37%	35%
10%	69%	69%	69%	54%	55%	14%	15%
20%	50%	50%	53%	39%	42%	7%	5%
40%	19%	18%	20%	12%	14%	1%	4%
60%	8%	8%	10%	4%	3%	0%	0%

Table D.10
Base Case Scenario (2030 Demand): Summary of Performance in Meeting Junior Non-Irrigation Demands in the Bow River Basin Based on Simulation Modelling

Reach	Upstream Bearspaw Reservoir	Bearspaw Reservoir to Elbow River	Elbow River to Bonneybrook	Bonneybrook to Highwood River	Highwood River to Carseland Weir	Carseland Weir to Bassano Dam	Bassano Dam to Bow Mouth
Demand Block	284	747	2	235		640	25
Demand (dam^3)	2,421	545	12,220	1,462	0	17,417	28,769
X% of Demand	**% of Years That Deficits Exceed X% of Non-irrigation Demand**						
0%	100%	100%	89%	88%	N/A	100%	62%
10%	88%	100%	47%	37%		45%	42%
20%	64%	97%	27%	22%		27%	30%
40%	38%	78%	12%	3%		11%	14%
60%	14%	47%	1%	0%		0%	5%

Table D.11
Base Case Scenario (2030 Demand): Summary of Performance in Meeting Junior Non-Irrigation Demands in the Oldman River Basin and South Saskatchewan River Based on Simulation Modelling

	Oldman River Non-irrigation			St. Mary River Non-irrigation		
Reach	**Oldman River Dam to Pincher Creek**	**Pincher Creek to LNID Diversion**	**LNID Diversion to Willow Creek**	**Willow Creek to Belly River**	**Belly River to St. Mary River**	**St.Mary River Confluence to Mouth**
Demand Block		20	213	63		65 and 66
Demand (dam^3)	0	31	10,720	161	0	1,618 and 1,106
X% of Demand	**% of Years That Deficits Exceed X% of Non-irrigation Demand**					
0%	N/A	87%	95%	80%	N/A	87%
10%		74%	74%	55%		43%
20%		60%	60%	42%		18%
40%		27%	26%	15%		8%
60%		14%	14%	11%		0%

	St. Mary River Non-irrigation		South Saskatchewan River J Non-irrigation	
Reach	**Upstream St. Mary Dam**	**St. Mary Dam to Mouth**	**South Sask. River Upstream of Medicine Hat**	**South Sask. River Downstream of Medicine Hat**
Demand Block	45	46	67	6
Demand (dam^3)	85	15,363	1,328	8,244
X% of Demand	**% of Years That Deficits Exceed X% of Non-irrigation Demand**			
0%	64%	64%	50%	50%
10%	54%	54%	20%	15%
20%	41%	41%	12%	0%
40%	19%	19%	4%	1%
60%	10%	10%	3%	0%

Appendix E

Oldman Sub-basin Storage Opportunities Performance Summary

Table E.1
Oldman River Basin New Storage Scenarios: Summary of Performance in Meeting WCOs Based on Simulation Modelling

Oldman River WCO

Reach	**Oldman River Dam to Pincher Creek (Natural Channel 75)**								**Pincher Creek to LNID Diversion (Natural Channel 78)**							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	125.8K	490K	490K	324K	160K	0	74K	125.8K	125.8K	490K	490K	324K	160K
Instream Flow	IO=80%× FRC	N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s	IO=80%× FRC	N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
X% of WCO Demand	**% of Weeks That Deficits Exceed X% of WCO Demand**															
0%	35%	35%	35%	36%	37%	38%	38%	38%	30%	30%	30%	30%	31%	33%	33%	32%
10%	4%	4%	4%	4%	4%	4%	4%	4%	0%	0%	0%	0%	3%	3%	3%	3%
20%	3%	3%	3%	3%	3%	3%	3%	3%	0%	0%	0%	0%	0%	0%	0%	0%
40%	1%	1%	1%	1%	1%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%
60%	0%	1%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Oldman River WCO (Continued)

Reach	**LNID Diversion to Willow Creek (Natural Channel 164)**								**Willow Creek to Belly River (Natural Channel 165)**							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	125.8K	490K	490K	324K	160K	0	74K	125.8K	125.8K	490K	490K	324K	160K
Instream Flow	IO=80%× FRC	N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s	IO=80%× FRC	N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
X% of WCO Demand	**% of Weeks That Deficits Exceed X% of WCO Demand**															
0%	56%	56%	56%	57%	60%	67%	66%	65%	37%	37%	37%	38%	41%	47%	47%	45%
10%	10%	10%	10%	10%	11%	12%	11%	12%	11%	11%	11%	11%	12%	13%	13%	13%
20%	8%	8%	8%	8%	9%	10%	10%	10%	9%	8%	9%	9%	9%	11%	11%	10%
40%	5%	5%	5%	4%	5%	6%	6%	6%	5%	4%	5%	5%	5%	7%	7%	7%
60%	2%	2%	2%	2%	2%	3%	3%	3%	2%	2%	2%	2%	2%	3%	3%	3%

Table E.1 Continued

Oldman River WCO (Continued)

Reach	Belly River to St. Mary River (Natural Channel 166)								St. Mary River Confluence to Mouth (Natural Channel 102)							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	125.8K	490K	490K	324K	160K	0	74K	125.8K	125.8K	490K	490K	324K	160K
Instream Flow	IO=80%× FRC	N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s	IO=80%× FRC	N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
X% of WCO Demand	**% of Weeks That Deficits Exceed X% of WCO Demand**															
0%	32%	33%	32%	32%	31%	35%	35%	34%	32%	31%	32%	30%	35%	39%	39%	39%
10%	28%	29%	29%	28%	27%	30%	30%	30%	23%	22%	23%	22%	20%	24%	24%	24%
20%	24%	25%	24%	24%	23%	26%	25%	25%	19%	18%	19%	18%	16%	20%	20%	20%
40%	16%	17%	17%	17%	15%	17%	17%	17%	12%	12%	13%	12%	9%	13%	13%	13%
60%	10%	10%	10%	10%	8%	9%	9%	9%	6%	5%	6%	6%	4%	6%	6%	6%

St. Mary River WCO

Reach	Upstream St. Mary Dam (Natural Channel 170)								St. Mary Dam to Mouth (Natural Channel 172)							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	125.8K	490K	490K	324K	160K	0	74K	125.8K	125.8K	490K	490K	324K	160K
Instream Flow	IO=80% ×FRC	N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s	IO=80% ×FRC	N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
X% of WCO Demand	**% of Weeks That Deficits Exceed X% of WCO Demand**															
0%	23%	23%	24%	27%	23%	23%	23%	23%	91%	67%	91%	63%	91%	91%	91%	91%
10%	19%	19%	17%	24%	19%	19%	19%	19%	65%	62%	64%	59%	65%	65%	65%	65%
20%	14%	14%	14%	20%	14%	14%	14%	14%	61%	58%	59%	54%	61%	61%	61%	61%
40%	6%	6%	7%	7%	6%	6%	6%	6%	51%	49%	49%	45%	51%	51%	51%	51%
60%	1%	1%	2%	6%	1%	1%	1%	1%	38%	36%	37%	33%	38%	38%	38%	38%

Table E.1 Continued

South Saskatchewan River WCO

Reach	Upstream of Medicine Hat (Natural Channel 69)								Medicine Hat to Sask Border (Natural Channel 469)							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	125.8K	490K	490K	324K	160K	0	74K	125.8K	125.8K	490K	490K	324K	160K
Instream Flow	IO=80% ×FRC	N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s	IO=80 %×FRC	N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
X% of WCO Demand	**% of Weeks That Deficits Exceed X% of WCO Demand**															
0%	29%	29%	29%	29%	28%	29%	29%	29%	29%	29%	29%	29%	28%	29%	29%	29%
10%	25%	25%	25%	25%	24%	25%	25%	25%	25%	25%	25%	25%	24%	25%	25%	25%
20%	22%	22%	22%	22%	21%	22%	22%	22%	22%	22%	22%	22%	21%	22%	22%	22%
40%	14%	14%	14%	14%	13%	14%	14%	14%	14%	14%	14%	14%	13%	14%	14%	14%
60%	5%	5%	6%	6%	4%	0%	6%	6%	6%	6%	6%	6%	4%	6%	6%	6%

Table E.2
Oldman River Basin New Storage Opportunities: Summary of Performance in Meeting Irrigation District Demands in the Oldman River Basin

	Irrigation District Deficits (% of years)							
	LNID	**MVLA**	**UID**	**MID**	**RID**	**SMRID**	**TID**	**Total**
Irrigated Area (ha)	78,792	5,342	15,135	8,147	20,700	165,598	36,592	330,306
X	**% of Years that Irrigation District Deficits Exceed X**							Wtd Mean
>50 mm	8%	39%	14%	10%	12%	16%	5%	13%
>100 mm	5%	8%	4%	3%	10%	5%	1%	5%
> 200 mm	1%	0%	0%	0%	1%	3%	1%	1%

Performance within Irrigation Districts for storage scenarios is equivalent to Base Case performance.

Table E.3
Oldman River Basin New Storage Opportunities: Summary of Performance in Meeting Junior Private Irrigation Demands Based on Simulation Modelling

Oldman River Private Irrigation

Reach	Oldman River Dam to Pincher Creek (WRMM Blocks 683 and 685)								Pincher Creek to LNID Diversion (WRMM Block 667)							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	126K	490K	490K	324K	160K	0	74K	125.8K	126K	490K	490K	324K	160K
Instream Flow		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
Irrigated Area (ha)	6,781								12,257							
X% of Demand	**% of Weeks That Deficits Exceed X% of Demand**															
50 mm	32%	32%	39%	38%	32%	20%	22%	23%	38%	38%	38%	37%	34%	24%	24%	26%
100 mm	14%	14%	18%	18%	12%	5%	7%	7%	15%	14%	15%	15%	14%	5%	8%	8%
200 mm	10%	10%	11%	11%	8%	1%	1%	5%	8%	9%	8%	8%	7%	1%	1%	1%

Oldman River Private Irrigation (Continued)

Reach	LNID Diversion to Willow Creek (WRMM Blocks 345 and 684)								Willow Creek to Belly River (WRMM Block 685)							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	126K	490K	490K	324K	160K	0	74K	125.8K	126K	490K	490K	324K	160K
Instream Flow		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
Irrigated Area (ha)	6,781								12,257							
X% of Demand	**% of Weeks That Deficits Exceed X% of Demand**															
50 mm	49%	51%	46%	45%	51%	46%	46%	46%	43%	43%	43%	39%	37%	26%	27%	27%
100 mm	27%	27%	19%	19%	18%	12%	14%	16%	27%	28%	27%	26%	23%	7%	8%	12%
200 mm	12%	11%	10%	10%	11%	3%	3%	5%	11%	12%	11%	11%	11%	3%	4%	5%

Table E.3 Continued

Oldman River Private Irrigation (Continued)

Reach	**Belly River to St. Mary River (WRMM Block 611)**								**St. Mary River Confluence to Mouth (WRMM Blocks 697, 660)**							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	126K	490K	490K	324K	160K	0	74K	125.8K	126K	490K	490K	324K	160K
Instream Flow		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
Irrigated Area (ha)	353								4,055							
X% of Demand	**% of Weeks That Deficits Exceed X% of Demand**															
50 mm	35%	34%	35.1%	31.1%	26%	4%	5%	8%	7%	7%	7%	7%	11%	1%	1%	1%
100 mm	27%	23%	23%	23%	18%	1%	3%	5%	4%	3%	4%	3%	7%	1%	1%	3%
200 mm	11%	9%	9.5%	9.5%	8%	0%	1%	4%	1%	1%	1%	1%	3%	1%	1%	1%

St. Mary River Private Irrigation

Reach	**Upstream St. Mary Dam (No Junior Private Irrigation in This Reach)**								**St. Mary Dam to Mouth (WRMM Blocks 646)**							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	126K	490K	490K	324K	160K	0	74K	125.8K	126K	490K	490K	324K	160K
Instream Flow		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
Irrigated Area (ha)	353								4,055							
X% of Demand	**% of Weeks That Deficits Exceed X% of Demand**															
50 mm	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	27%	8%	18.9%	17.6%	27%	27%	27%	27%
100 mm									8%	4%	8.1%	8.1%	8%	8%	8%	8%
200 mm									1%	0%	0%	0%	1%	1%	1%	1%

Table E.3 Continued

South Saskatchewan River Private Irrigation

Reach	**Upstream of Medicine Hat (WRMM Block 661)**								**Medicine Hat to Sask Border (WRMM Blocks 662)**							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	126K	490K	490K	324K	160K	0	74K	125.8K	126K	490K	490K	324K	160K
Instream Flow		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
Irrigated Area (ha)	3,535								2,048							
X% of Demand	**% of Weeks That Deficits Exceed X% of Demand**															
50 mm	15%	14%	16%	15%	12%	1%	3%	4%	19%	16%	16.2%	16.2%	15%	1%	4%	7%
100 mm	8%	9%	8%	8%	8%	1%	1%	4%	8%	8%	8.1%	8.1%	8%	1%	1%	5%
200 mm	4%	35	35	3%	3%	1%	1%	1%	7%	4%	5.4%	5.4%	4%	0%	0%	1%

Table E.4
Oldman River Basin New Storage Opportunities: Summary of Performance in Meeting Junior Non-Irrigation Demands Based on Simulation Modelling

Oldman River Non-irrigation

Reach	**Oldman River Dam to Pincher Creek**								**Pincher Creek to LNID Diversion (WRMM Block 20)**							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	126K	490K	490K	324K	160K	0	74K	125.8K	126K	490K	490K	324K	160K
Instream Flow		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
Demand (dam^3)	No junior non-irrigation demand in this reach								31							
X% of Demand	**% of Years That Non-irrigation Deficits Exceed X% of Non-irrigated Demand**															
0%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	86%	86%	86%	86%	84%	82%	82%	82%
10%									74%	74%	74%	74%	73%	70%	70%	70%
20%									60%	61%	60%	60%	58%	49%	49%	49%
40%									27%	26%	27%	22%	50%	15%	16%	16%
60%									14%	15%	14%	14%	12%	4%	5%	7%

Oldman River Non-irrigation (Continued)

Reach	**LNID Diversion to Willow Creek (WRMM Block 213)**								**Willow Creek to Belly River (WRMM Block 63)**							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	126K	490K	490K	324K	160K	0	74K	125.8K	126K	490K	490K	324K	160K
Instream Flow		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
Demand (dam^3)	10,720								161							
X% of Demand	**% of Years That Non-irrigation Deficits Exceed X% of Non-irrigated Demand**															
0%	95%	86%	95%	95%	93%	92%	92%	93%	80%	80%	80%	80%	73%	68%	68%	68%
10%	74%	74%	74%	74%	73%	70%	70%	69%	55%	55%	54%	54%	50%	37%	37%	37%
20%	60%	59%	59%	60%	58%	49%	49%	49%	42%	41%	42%	38%	32%	14%	15%	18%
40%	26%	22%	26%	22%	20%	15%	16%	16%	15%	15%	15%	15%	14%	4%	7%	8%
60%	14%	14%	14%	14%	12%	4%	5%	7%	11%	11%	11%	11%	11%	1%	1%	15%

Table E.4 Continued

Oldman River Non-irrigation (Continued)

Reach	**Belly River to St. Mary River**								**St. Mary River Confluence to Mouth (WRMM Blocks 65 and 66)**							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	126K	490K	490K	324K	160K	0	74K	125.8K	126K	490K	490K	324K	160K
Instream Flow		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
Demand (dam^3)	No junior non-irrigation demand in this reach								2,724							
X% of Demand	**% of Years That Non-irrigation Deficits Exceed X% of Non-irrigated Demand**															
0%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	87%	85%	87%	84%	51%	4%	11%	14%
10%									43%	41%	43%	34%	22%	3%	5%	10%
20%									18%	16%	16%	16%	11%	0%	2%	7%
40%									8%	8%	7%	7%	3%	0%	0%	1%
60%									0%	0%	0%	0%	0%	0%	0%	0%

St. Mary River Non-irrigation

Reach	**Belly River to St. Mary River**								**St. Mary River Confluence to Mouth (WRMM Blocks 65 and 66)**							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	126K	490K	490K	324K	160K	0	74K	125.8K	126K	490K	490K	324K	160K
Instream Flow		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
Demand (dam^3)	85								15,363							
X% of Demand	**% of Years That Non-irrigation Deficits Exceed X% of Non-irrigated Demand**															
0%	64%	64%	57%	53%	64%	64%	64%	64%	64%	20%	43%	11%	64%	64%	64%	64%
10%	54%	54%	53%	51%	54%	54%	54%	54%	54%	4%	7%	4%	54%	54%	54%	54%
20%	41%	42%	39%	45%	41%	41%	41%	41%	41%	1%	1%	1%	41%	41%	41%	41%
40%	19%	18%	23%	24%	19%	19%	19%	19%	19%	0%	0%	0%	19%	19%	19%	19%
60%	10%	10%	7%	11%	10%	10%	10%	10%	10%	0%	0%	0%	10%	10%	10%	10%

Table E.4 Continued

South Saskatchewan River Non-irrigation

Reach	Upstream of Medicine Hat (WRMM Block 67)								Medicine Hat to Saskatchewan Border (WRMM Block 6)							
Scenario	Base Case	Chin	Kimball		Belly				Base Case	Chin	Kimball		Belly			
New Storage (dam^3)	0	74K	125.8K	126K	490K	490K	324K	160K	0	74K	125.8K	126K	490K	490K	324K	160K
Instream Flow		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s		N/A	WCO	3.0 m^3/s	WCO	1.03 m^3/s	1.03 m^3/s	1.03 m^3/s
Demand (dam^3)	1,328								8,244							
X% of Demand	**% of Years That Non-irrigation Deficits Exceed X% of Non-irrigated Demand**															
0%	50%	49%	50%	47%	28%	4%	8%	11%	50%	49%	50%	47%	28%	4%	8%	11%
10%	20%	18%	19%	18%	15%	3%	4%	7%	15%	14%	15%	15%	11%	3%	4%	8%
20%	12%	12%	11%	11%	8%	1%	3%	5%	11%	8%	11%	10%	7%	0%	1%	5%
40%	4%	4%	4%	3%	3%	0%	0%	0%	1%	1%	1%	1%	1%	0%	0%	0%
60%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Appendix F

Alberta Environment and Sustainable Resource Development Policies

Alberta ENVIRONMENT

APPROVALS PROGRAM POLICY

REGIONAL SERVICES DIVISION

POLICY NO.: **DATE:** January 16, 2007

Guideline for Implementation of Water Conservation Objectives, established under the *Water Act*, in the South Saskatchewan River Basin.

BACKGROUND:

The *Water Act* was proclaimed in January 1999 with several new approaches from the previous *Water Resources Act*; key provisions were:

- Establishing a framework for water management planning by December 31, 2001 (completed).
- Creation of an Aquatic Environment Protection Strategy (not completed).
- Water Management Planning mandate.
- Establishment of Water Conservation Objectives (WCO).

A WCO is defined as:

"The amount and quality of water established by the Director under Part 2 based on information available to the Director to be necessary for the:

- protection of a natural water body or its aquatic environment or any part of them;
- protection of tourism, recreational, transportation or waste assimilation uses of water; or
- management of fish and wildlife;

and may include water necessary for the rate of flow of water or water level requirements".

Typically a WCO is designed to be a minimum flow or level of water at any instance. These values may be enshrined in licences to divert surface water so that the aquatic environment is protected when there is a water shortage. When licences subject to a WCO have the potential to reduce river flow below the WCO the licensees must curtail diversions.

The Government may apply for an application for an allocation of water equivalent to the WCO. Any licence issued has priority, as of the date of a complete application or as specified in a Crown Reservation, over any other subsequent applicants for water allocations in times of water shortage.

A WCO may also be supported by the addition of licensed water from a transfer where up to 10% of transferred allocations may be re-assigned to a WCO where the protection of the aquatic environment may result.

A WCO usually has a water quality component because it is by nature designed to protect the aquatic environment. An Instream Flow Needs (IFN) assessment and consumptive demand information should form the basis for a WCO discussion. Components of an IFN are habitat, riparian needs, water quality (waste assimilation and fish needs), and channel maintenance. Consumptive demand components are existing licences, apportionment agreements, reservoir operations and potential future demands, including First Nations.

A WCO is either established by a Director based on substantive information followed by public consultation or a public consultation process followed by a recommendation to the Director usually in the form of a Water Management Plan.

The Lieutenant Governor in Council approved the Water Management Plan for the South Saskatchewan River Basin in Alberta on August 30, 2006 through Order In Council (O.C. 409/2006).

The Approved Water Management Plan for the South Saskatchewan River Basin recommends the establishment of a water conservation objective (WCO) for the Red Deer, Bow, Oldman and South Saskatchewan River sub-basins.

Therefore, as recommended in the Approved Water Management Plan for the South Saskatchewan River Basin and as provided for under section 15(1) of the *Water Act*, the Director established the following WCOs, as recommended in the Plan:

- Water Conservation Objective (WCO) for the Red Deer River sub-basin to be:
  - From the Dickson Dam to the confluence with the Blindman River, the WCO for any applications received or licences issued after May 1, 2005 and for existing licences with a retrofit provision is:
    - A rate of flow that is 45% of the natural rate of flow, or 16 cms (cubic metres per second), whichever is greater at any point in time.
  - From the confluence with the Blindman River to the Saskatchewan border, the WCO is:
    - For future licences for withdrawals from November to March, inclusive:
      - A rate of flow that is 45% of the natural rate of flow, or 16 cms, whichever is greater at any point in time.
      - That this WCO apply to any applications received or licences issued after May 1, 2005.
    - For future licences for withdrawals from April to October, inclusive:
      - A rate of flow that is 45% of the natural rate of flow, or 10 cms, whichever is greater at any point in time.
      - That this WCO apply to any applications received or licences issued after May 1, 2005.
    - For existing licences with a retrofit provision:
      - A rate of flow that is 45% of the natural rate of flow, or 10 cms, whichever is greater at any point in time.

- Water Conservation Objective (WCO) for the Bow, Oldman and South Saskatchewan River sub-basin mainstems to be either 45% of the natural rate of flow, or the existing instream objective increased by 10%, whichever is greater at any point in time.

- Water Conservation Objective (WCO) for the headwater reaches and the tributaries of the Red Deer, Bow, Oldman and South Saskatchewan River sub-basins to be not less than the existing instream objective or the WCO downstream on the mainstem, whichever is greater at any point in time.

  - For the Red Deer, the Approved Plan considered the drainage area above the Dickson Dam to be the headwater reaches.
  - For the Bow, the Approved Plan considered the drainage area above the Bearspaw Dam to be the headwater reaches.
  - For the Oldman, the Approved Plan considered the drainage area above the Oldman Dam to be the headwater reaches.
  - For the South Saskatchewan, the Approved Plan considered the tributaries to the mainstem.

ISSUES:

The *Water Act* and the Approved Water Management Plan for the South Saskatchewan River Basin do not provide detailed guidance on how a Director would implement the recommended WCOs.

Some of the issues on implementing the WCOs are:

- Judicious interpretation of the WCOs for tributaries is required, as a literal interpretation suggests that some of these tributaries may solely be held responsible for achieving the targeted WCO downstream on the mainstem;
- How WCOs can practically be implemented in various water bodies, as theoretically it will require natural and recorded flows downstream of each individual licenced diversion (for the purpose of monitoring and compliance), which is not practical.
- Implementation of the WCO requires real-time natural flows but no specifics are provided as how the natural flows will be obtained in real-time basis;
- How to obtain the required natural flows in ungauged watersheds.
- Limited water use information, which makes it impracticable to generate naturalized flows on a near real time basis in gauged watersheds (at gauging station).

MOVING FORWARD:

Tributary WCO

Tributaries contribute the majority of water available in the mainstem of a river system. Tributaries share the common responsibility of meeting the established WCOs on the mainstem of the river system, as without their contribution the mainstem WCOs wouldn't be achieved. Therefore, it is apparent that established mainstem WCOs would naturally be extended to the tributaries as well. There is a need to quantify or establish the fair share of contribution from tributaries required to meet the established WCO on the downstream mainstem of the river system. The logical interpretation of extending the recommended mainstem WCO to the tributaries would be either 45% of the natural rate of flow being generated in the tributary, or the existing instream objective established for the tributary increased by 10%, whichever is greater at any point in time.

Implementation of WCO for the purpose of licensing, monitoring and compliance

Implementation of a WCO requires natural and recorded flow values in the stream at the point of licenced diversion. Significant variation in flow rates along a channel (river, creek, etc.) can be expected and it is virtually impossible to gauge the channel at each and every diversion point along its length. It also precludes the possibilities of natural flow computations at all the licenced diversion locations. However, the Director will be required to identify an appropriate gauging station (where natural and recorded flows values are available) for each applicable (i.e. post May 1, 2005, condition allowing amendment, etc.) licence to implement the WCO.

Therefore, it is recommended to breakdown the stream length into sufficiently smaller reaches making sure that a gauging station at its downstream end represents each reach. Then all the licences with a WCO condition diverting in that reach will be subjected to the WCO established at the representative gauging station located at the downstream end of the reach. This methodology can be applied to mainstems as well as in tributaries. If tributaries are not big enough, they can be considered as a single reach and the WCO can be established at their mouth. It is essential to have a gauging station at the downstream end of established reaches for the purpose of calculating natural flows as well as for knowing the recorded flows at any given time.

Natural flows in gauged and ungauged watersheds:

Gauged watersheds:

In Alberta, extensive naturalization of river flows has been carried out, especially in the southern part of the province. USACE SAAR (U.S. Army Corps of Engineers Streamflow Synthesis And Reservoirs Regulation) and HYSTRA are the models of choice for flow naturalization in the Department. The methodology adopted for reconstruction of natural flow essentially consists of adding back the net diversions made by upstream projects to the recorded flows and routing the flows through the river system to account for travel time. This is a simplified but practical approach and accuracy of reconstructed natural flow is highly dependent on the reliable information about upstream water uses.

Presently, near real-time daily natural flows are being computed by the Department at 4 locations in the Red Deer River Basin, 2 locations in South Saskatchewan River sub-basin, 8 locations in the Bow River Basin and 12 locations in Oldman River Basin. The Department should explore the possibility of computing near real-time naturalized flows at additional gauged locations in the basins (including mainstem and tributaries) using the existing methodology. The requirement of computing natural flows at additional existing gauging sites and/or adding more gauging stations (to compute natural flow and knowing recorded flows) will depend on how many smaller reaches need to be established by breaking down the stream length.

Ungauged watersheds:
Continuous natural daily flow time-series at ungauged sites can be generated by using either a simple approach, such as a flow transportation (from gauged to ungauged basin) technique, to a more complex approach such as comprehensive holistic hydrological modeling. Choice of a particular method is often dictated by various factors including availability of resources (dollars, time); available relevant data; purpose; desired accuracy, etc.

A distributed hydrological modeling approach could be used to simulate natural flow regimes and catchment responses more precisely under different scenarios of climate and land use change but they present some real challenges as these models are excessively data hungry and require extensive calibration and validation, which is again time consuming and labor-intensive. However, inclusion of such models as predictive tools could be identified as a long-term objective.

(a) Rudimentary approach: In hydrological homogeneous basins, natural flows computed at a gauged location can be transported to an ungauged location based on the drainage area proportion method. This is the most simplified approach and may provide some reasonable estimates in true hydrological homogeneous basins. Considering that there may be large number of ungauged basins (especially tributaries) it is recommended that the natural flow in these ungauged basins be estimated based on the drainage area proportion method as mentioned below:

$$Q_{ug} = \frac{Q_g}{A_g} * A_{ug}$$

Where,

Q_g = natural or naturalized flow at gauging station
Q_{ug} = natural or naturalized flow at ungauging station
A_g = drainage area at gauging station
A_{ug} = drainage area at un-gauging station

(b) Pragmatic approach: A simple yet more robust pragmatic approach like spatial interpolation and regionalization methods (using available, albeit limited, observed flow and/or precipitation data) provides a balance between simplistic and sophisticated approaches and could be used to support the implementation of established WCOs. In essence, the spatial interpolation approach also transfers the stream flow time series from the location(s) where the data are available to the location where the time series is needed (i.e. at ungauged sites) but it incorporates the flow variability by making extensive use of Flow Duration Curves (FDCs). It includes three sequential steps: (i) estimation of a representative regional non-dimensional FDC; (ii) calculation of the actual FDC at the required (destination) site by multiplying the non-dimensional regional curve by an estimate of the long-term mean discharge obtained, for example, by a regional regression model; and (iii) conversion of the actual FDC at a site into a continuous stream flow hydrograph.

It is recommended that the above-mentioned methods (a and b) for estimating natural flows only be applied in medium to large size ungauged basins, which depict similar hydrological and watershed characteristics of the basin from where flows are being transported. In other remaining basins (small size ungauged basins) it is recommended to use existing IO (if exists) or a certain percentage (say 90%) of instantaneous flow rate to remain in the stream.

In ungauged watersheds natural flow can be computed based on the techniques outlined above, however, there will still be a requirement of knowing the recorded flows for the purpose of monitoring and compliance. Therefore, it is recommended that:

- WCO be established then measured downstream of the diversion point;
- To establish the WCO, natural flow computations can be based on the methods outlined above;
- Onus will be on licensee to monitor the recorded flows in the stream downstream to the point of diversion for compliance of WCO condition in the licence.

POLICY:

When making a decision regarding developing and applying a WCO for the tributaries in the Red Deer, Bow, Oldman and South Saskatchewan River sub-basins the Director will consider:

- A logical interpretation of extending the recommended mainstem WCO to the tributaries as: either 45% of natural rate of flow being generated in the tributary, or the existing instream objective established for the tributary increased by 10%, whichever is greater at any point in time.

- Natural flow computations at desired locations in ungauged watersheds (i.e. headwater reaches, tributaries, etc.), where existing methodology can't be applied for flow naturalization, should be based on the methods outlined above and onus will be on the licensee to monitor the recorded flows in the stream downstream to the point of diversion for compliance of WCO condition in the licence.

APPROVED: ______________________ **DATE:** January 16, 2007

May Mah-Paulson
Regional Approvals Manager
Southern Region

APPROVED: ______________________ **DATE:** January 16, 2007

Andy Lamb
Regional Approvals Manager
Central Region

Appendix G

The Economic Ramifications of Reducing Potential Water Shortages to Junior Private Irrigation Through Increased Storage in the Oldman River Basin

The Economic Ramifications of Reducing Potential Water Shortages through Increased Storage in the Oldman River Basin for Junior Private Irrigators

Projected water use in the SSRB could increase from the current 1,981,000 to 3,040,000 dam3 by the year 2030 (Refer to page 13). This is expected to increase the frequency of irrigation water deficits to junior licenses particularly in the Oldman River and downstream South Saskatchewan River basins. The impact on senior licenses, primarily through the organized irrigation districts, is expected to be minimal.

Municipal and industrial water with junior licenses in the Oldman Basin may also be affected, however, the quantities required for these users compared to total basin consumption is relatively small. Often these users are supplied through the irrigation districts but are not part of the district's license. The critical needs of these users can be supported through the senior licenses and increased internal storage. (Refer to page 69, 80, and 90).

It is expected that non-structural measures such as modifying operational procedures and on farm management technologies will be inadequate to alleviate these future shortages. Consequently the implications of constructing additional storage options are investigated in this report.

Potential storage sites have been identified through various previous studies. Three sites were identified as representative potential sites in this study, namely: Kimball, Belly, and Chin. (Refer to page 65).

Table G.1
Estimated Current Construction Costs Updated to Current Values

(Million $)*			
	Kimball	**Belly**	**Chin**
Initial Estimate	$98.2	$81.4	$56.1
Year of Estimate	2002	1978	2002
Index Adjustment**	1.51	3.11	1.51
Current (2013)	$148.3	$253.2	$84.7
*Update did not review design for modifications or improvements.			
**Based on average Consumer Price Index (CPI) and Commercial Construction Index. Earth Construction Index no longer available.			

The estimated economic viability of these sites is based on the reduced occurrences of irrigation water deficits for the junior private irrigators in the affected reaches within the basin. Irrigation water deficits were estimated via the WRMM simulation model for the various reaches in the basin. (Refer to page 65).

The percent of irrigation water deficit years for an assumed 90^{th} percentile demand for the simulated period is shown in Table G.2.

Table G.2
Reduction in the Percentage of Years that Deficits Exceed Private Irrigation Demand due to Additional Storage*

		Belly			**Kimball**			**Chin**		
		Change in percent of years								
Reach	Hectare	50mm	100mm	200mm	50mm	100mm	200mm	50mm	100mm	200mm
OM1	6781									
OM2	15256	4								
OM3	3571		9		3	8				
OM4	1842	6	4							
OM5	353	9	9	3		4			4	
OM6	4055									
SM2	270				8			19	4	
SS1	3535	3								
SS2	2048	4		3	3			3		3
* Because of the stochastic nature of the WRMM simulation model, percent changes up to 2% were assumed to be neutral										

The maximum irrigation requirement during 32 years of recorded water use is 690 mm. Average gross diversions are approximately 315 mm with approximately 66% applied to the field. The balance of diverted water is lost through evaporation, seepage, and non-irrigation uses. (Source: Alberta Agriculture and Rural Development).

It assumed for this economic analysis that during periods of extreme water demands that the utilization of diverted water will intensify beyond the 66%. Gross diversion requirements for private irrigators are assumed to be approximately 500 mm for this analysis.

WRMM model results categorize water shortages in terms of 50,100 and 200 mm. Accordingly water shortages in terms of percentages are:

50mm	-10%
100mm	-20%
200mm	-40%

Agricultural impacts in association with water irrigation shortages are shown in Table G.3. These estimated impacts were derived from the analysis of twelve crops typically grown in Southern Alberta and account for changes in yields, crop quality, pumping costs, etc.

Table G.3
Reduced Agricultural Sales, Agricultural Returns and Provincial GDP Associated with Water Shortages

Shortage	Sales	Agricultural Return	Provincial GDP
10%	7%	37%	8%
20%	14%	79%	11%
40%	37%	214%	45%

Source: Regional Implications of Water Shortages, St. Mary Main Canal Supply Region, Feb. 2001 prepared for: Main Canal Advisory Committee by: Russell Consulting & S.N. Kulshreshtha
Values are extremes as subsequent simulation runs through FFIRM model indicates the on farm management ability to mitigate for minor irrigation shortages. The FFIRM model also indicates the increasing financial severity of back to back shortages which are not accounted for in this analysis.
Source: Southern Tributaries, Irrigation Review. March 2002 prepared for: Main Canal Advisory Committee by: Hart Water Management Consulting

Crop mixes for Raymond Irrigation District (RID) and St. Mary Irrigation District (SMRID) were used in this analysis to represent private irrigated crop mixes for the various reaches as reported in the WRMM results. It is assumed that the RID crop mix will represent users in the cooler upper reaches labeled as “OM” and SMRID crop mix will represent the lower reaches labeled as “SM”.

Table G.4
Irrigation District Crop Mix*

Irrigation District	Forage	Cereal	Specialty	Oilseed
RID	0.43	0.36	0.01	0.2
SMRID	0.21	0.36	0.25	0.18
*Source: Alberta Agriculture and Rural Development				

Specific crops were selected to represent each of the general crop categories above. Crop costs and returns were derived from 2013 crop enterprise costs from Alberta Agriculture and Rural Development.

Table G.5
Crop Budgets (per hectare)

	Alfalfa	Feed Barley	Processing Potato	Argentine Canola
Gross Sale	$791	$1,242	$9,384	$1,782
Direct Costs	$582	$821	$5,567	$741
Capital Costs	$450	$499	$529	$499
Net Farm Income	-$241	-$78	$3,288	$542

Total sales, income and provincial GDP per hectare for the representative crops weighted by the respective crop mix for the two irrigation districts are shown in Table G6. The base values are the blended per hectare returns while the 10, 20 and 40 percent values are the reduced values from the base returns.

Table G.6
Reduced Sales Income and Provincial GDP (per hectare)

RID				SMRID			
	Sales	**Income**	**GDP**		**Sales**	**Income**	**GDP**
Base	$799	$1,237	$501	Base	$841	$3,280	$1,328
10%	$87	$296	$191	10%	$230	$311	$506
20%	$173	$631	$263	20%	$459	$664	$696
40%	$458	$1,710	$1,075	40%	$1,214	$1,800	$2,849

Provincial GDP is estimated as a multiple of 1.93 times gross sales. (Source: Regional Implications of Water Shortages) Provincial GDP represents the net provincial societal impact accumulating to all economic entities in the province including: primary agricultural producers, agricultural processors, suppliers, and provincial household incomes. It represents the potential maximum societal loss associated with the expected irrigated agricultural activities arising from water shortages. Farm income is most severely impacted from water shortages as agricultural margins are tight and a slight decrease in revenue results in negative on farm returns.

Table G7 is the accumulated annual savings across all the WRMM reaches anticipated from the respective storage options. (Refer to Table G.9 for detailed calculations).

Table G.7
Total Annual Savings

	Sales	Income	GDP
Belly	$261,707	$679,108	$537,522
Kimball	$80,286	$246,758	$141,286
Chin	$107,854	$161,765	$243,347

Annual savings were discounted to present values as a comparison of the expected costs for each water storage option. Literature and various public decision agencies use discount factors of 5% and higher as representative of public interests for evaluation potential projects. The discount factor used herein is 3% over 50 years to illustrate the maximum potential desirability of the three storage projects.

Table G.8 represents the present value in terms of provincial GDP that will accumulate to each project. It is maximum ability that the provincial society could pay for the project based on potential savings from reduced water shortages.

Table G.8
Present Value of Annual Savings to Junior Private Irrigation Accumulating to each Prospective Project
(3% over 50 years) ($ Million)

	Sales	Income	GDP	Costs	NPV
Belly	$6.7	$17.5	$13.8	$148.3	-$134.5
Kimball	$2.1	$6.3	$3.6	$253.2	-$249.5
Chin	$2.8	$4.2	$6.3	$84.7	-$78.4
NPV is the net present value of provincial GDP minus project costs in 2013 values.					

The economic opportunities of the three storage projects are expressed as the net present value (NPV) of discounted savings in provincial GDP less expected costs. Expected provincial gains associated with each storage option compared to costs, are negative. In conclusion, given the amelioration of expected shortages per the WRMM model and expected savings accumulating to private junior irrigation licenses from each of the storage projects, the savings in provincial GDP will not meet the anticipated costs.

Table G.9
Calculations of Annual Savings (per hectare) Accumulating to the Reaches in the WRRM Model

Belly																	
		Change in percent of years			**Sales ($)**			**TOTAL**	**Net Income ($)**			**TOTAL**	**Provincial GDP ($)**			**TOTAL**
Reach	Hectare	50 mm	100 mm	200 mm	50 mm	100 mm	200 mm		50 mm	100 mm	200 mm		50 mm	100 mm	200 mm	
OM1	6,781				87	173	458	0	296	631	1,710	0	191	263	1,075	0
OM2	15,256	4			87	173	458	52,862	296	631	1,710	180,411	191	263	1,075	116,598
OM3	3,571		9		87	173	458	55,680	296	631	1,710	202,871	191	263	1,075	84,435
OM4	1,842	6	4		87	173	458	22,339	296	631	1,710	79,183	191	263	1,075	40,474
OM5	353	9	9	3	87	173	458	13,105	296	631	1,710	47,555	191	263	1,075	25,799
OM6	4,055				87	173	458	0	296	631	1,710	0	191	263	1,075	0
SM2	270				230	459	1,214	0	311	664	1,800	0	506	696	2,849	0
SS1	3,535	3			230	459	1,214	24,349	311	664	1,800	33,004	506	696	2,849	53,707
SS2	2,048	4		3	230	459	1,214	93,372	311	664	1,800	136,084	506	696	2,849	216,509
TOTAL								**$261,707**				**$679,108**				**$537,522**

Kimball																
		Change in percent of years			**Sales**			**TOTAL**	**Net Income ($)**			**TOTAL**	**Provincial GDP ($)**			**TOTAL**
Reach	Hectare	50mm	100mm	200mm	50mm	100mm	200mm		50mm	100mm	200mm		50mm	100mm	200mm	
OM1	6,781				87	173	458	0	296	631	1,710	0	191	263	1,075	0
OM2	15,256				87	173	458	0	296	631	1,710	0	191	263	1,075	0
OM3	3,571	3	8		87	173	458	58,774	296	631	1,710	212,002	191	263	1,075	95,523
OM4	1,842				87	173	458	0	296	631	1,710	0	191	263	1,075	0
OM5	353		4		87	173	458	2,446	296	631	1,710	8,913	191	263	1,075	3,710
OM6	4,055				87	173	458	0	296	631	1,710	0	191	263	1,075	0
SM2	270	8			230	459	1,214	4,959	311	664	1,800	6,722	506	696	2,849	10,939
SS1	3,535				230	459	1,214	0	311	664	1,800	0	506	696	2,849	0
SS2	2,048	3			230	459	1,214	14,107	311	664	1,800	19,121	506	696	2,849	31,115
TOTAL								**$80,286**				**$246,758**				**$141,286**

Chin																
		Change in percent of years			**Sales ($)**			**TOTAL**	**Net Income ($)**			**TOTAL**	**Provincial GDP ($)**			**TOTAL**
Reach	Hectare	50mm	100mm	200mm	50mm	100mm	200mm		50mm	100mm	200mm		50mm	100mm	200mm	
OM1	6,781				87	173	458	0	296	631	1,710	0	191	263	1,075	0
OM2	15,256				87	173	458	0	296	631	1,710	0	191	263	1,075	0
OM3	3,571				87	173	458	0	296	631	1,710	0	191	263	1,075	0
OM4	1,842				87	173	458	0	296	631	1,710	0	191	263	1,075	0
OM5	353		4		87	173	458	2,446	296	631	1,710	8,913	191	263	1,075	3,710
OM6	4,055				87	173	458	0	296	631	1,710	0	191	263	1,075	0
SM2	270	19	4		230	459	1,214	16,738	311	664	1,800	23,141	506	696	2,849	33,500
SS1	3,535				230	459	1,214	0	311	664	1,800	0	506	696	2,849	0
SS2	2,048	3		3	230	459	1,214	88,670	311	664	1,800	129,710	506	696	2,849	206,137
TOTAL								**$107,854**				**$161,765**				**$243,347**

AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited
Lethbridge, Alberta

Shaping the future