TECHNICAL MEMORANDUM

Subject: **Wind/Bighorn River Basin Plan**

Task 3D – Available Surface Water Determination

Date: **January 2003 (Modified March 2002)**

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This Technical Memorandum presents the simulation model results for the Wind/Bighorn River Basin Plan, including simulated diversion shortages, simulated streamflow and surface water availability. The document fulfills the reporting requirements of Task 3D from the original contract.

This technical memorandum contains the following sections. Within each section are tables and figures containing the data for each of the main study area basins.

Section 1 - Introduction

As part of the Wind/Bighorn Basin Planning process undertaken by the Wyoming Water Development Commission, spreadsheet models were developed that simulate river basin flows and operations. As shown in Table 1-1, the basin planning area was divided into 12 sub-basin models. The construction, calibration and operation of the spreadsheet models is more fully described in the Task 3B/3C Technical Memorandum Spreadsheet Model Development and Calibration (MWH, 2003). The models are intended as a tool for identifying regional demand shortages and the opportunity for additional water development given major hydrologic and institutional constraints. The models simulate river conditions for dry, average and wet year hydrologic conditions. Development of the hydrologic data is presented in the Task 3A Technical Memorandum Surface Water Hydrology (MWH, 2002).

Table 1-1. Wind/Bighorn Sub-basin Models

Basin	Model
Yellowstone	Madison/Gallatin
	Yellowstone
Clarks Fork	Clarks Fork
Wind	Upper Wind
	Little Wind
	Lower Wind
Bighorn	Upper Bighorn
	Owl Creek
	Nowood
	Lower Bighorn
	Greybull
	Shoshone

The Wind/Bighorn sub-basin models can run in three different modes as described below:

- Calibration (Historical) – Models actual historical diversions. This mode is primarily used for model calibration.

- Full Supply for Existing Irrigated Lands – Models full supply, based on computed Diversion Requirements, for irrigated lands with water rights mapped as part of the planning process.

- Full Supply for Existing Irrigated Lands and Futures Projects - Models full supply, based on computed Diversion Requirements, for irrigated lands with water rights mapped as part of the planning process and Tribal futures projects.

As noted, the Calibration mode is primarily used for calibration of the model. It utilizes historical diversion data and return flows with historical gage flows to calculate ungaged basin gains and losses. It does not recognize whether historical diversions were reduced due to water supply constraints nor does it model full use of irrigated lands with water rights. Per the definition of the Calibration mode, the model does not show any shortages at diversions. Therefore, no results from this run are presented as part of this Technical Memorandum. The results in this Technical Memorandum are for the Fully Supply for Existing Irrigated Lands and the Full Supply for Existing Irrigated Lands and Futures Projects modes.

In reviewing the model results, the limitations of the model should be noted. A brief summary of these limitations follows. More information regarding the model and its limitations is presented in Task 3B/3C Technical Memorandum Spreadsheet Model Development and Calibration (MWH, 2003).

- The model does not explicitly account for water rights, appropriations or compact allocations and is not operated on these legal principals. For instance, the model cannot forego a diversion to an upstream junior water right to satisfy a downstream senior water right. However, due to the construction and calibration procedure, if this situation happened historically, it would be reflected in the model construction (the junior would show a shortage).

- The model does not "operate" storage reservoirs to meet downstream demands, nor can the model differentiate between different owners of storage accounts. The model only uses historical reservoir releases and satisfies the diversions in order of their physical location on the stream. However, as with water rights, the historical operations and diversion of stored water is normally reflected in the historical records.

- Because the model does not contain time-series hydrology, it does not perform a detailed analysis of carryover storage. This is important when a dry year is followed by a dry year. As the model is constructed, it only shows the starting reservoir level as the average during all dry years, which does not necessarily simulate a drought (although this specific scenario could be at least partially analyzed in the model by varying starting storage contents). However, the importance of filling and emptying large reservoirs over a number of years is not explicitly analyzed in the model.

Section 2 - Diversion Shortages

An important result of the Wind/Bighorn River Basin planning models is the calculation of diversion shortages. The model construction allows calculation of shortages at each node in the model. However, it must be realized that the model does not explicitly account for water rights, storage ownership rights or other delivery constraints within the delivery system. Any of the diversions within the Wind/Bighorn River Basin can experience shortages from time-to-time. For instance, in 2001 and 2002, which were drier years than the dry-year used in the modeling hydrology, nearly all diversions within the basins experienced shortages of one degree or another. Therefore, it is best to review this information for the basin as a whole and within the context of the model limitations.

Table 2-1 presents a summary of the shortages within each sub-basin model for the Full Supply condition, while Appendix A contains a reach-by-reach summary of shortages. Overall, shortages are more severe in the Wind River basin than in the other basins, with the exception of the Owl Creek basin, especially in dry years. Shortages occur on the mainstem of the Wind River and Little Wind River, and in most tributaries. The Owl Creek basin experiences shortages during all hydrologic conditions at nearly every diversion point. In the remaining portion of the Bighorn basin, shortages are primarily on smaller tributaries. There are very few shortages on the mainstems of the Bighorn, Shoshone, Nowood and Shell Creek. There are significant shortages on the mainstem Greybull River, especially without the influence of the recently completed Greybull Valley Reservoir, which was included in the model construction, but not included in the model runs. It is expected that the reservoir will alleviate most shortages in normal and wet years, with some remaining shortages in dry years. It should also be noted that there was a significant difference in Full Supply diversion requirements compared to historical diversion requirements in the Greybull model, primarily due to differences in the quantity of irrigated lands.

Table 2-1. Summary of Modeled Diversion Shortages – Full Supply

Basin	Full Supply Diversion (ac-ft)	Reach Shortages (ac-ft)			Reach Shortages (percent)		
		Dry	Normal	Wet	Dry	Normal	Wet
Clarks Fork	106,293	30,402	18,786	11,645	29%	18%	11%
Yellowstone	0	0	0	0	0%	0%	0%
Sub-Total	106,293	30,402	18,786	11,645	29%	18%	11%
Upper Wind	933,909	192,930	54,067	43,948	21%	6%	5%
Little Wind	344,734	97,916	38,741	29,206	28%	11%	8%
Lower Wind	80,635	20,537	15,839	11,634	25%	20%	14%
Sub-Total	1,359,278	311,384	108,648	84,788	23%	8%	6%
Upper Bighorn	329,300	12,220	7,499	5,450	4%	2%	2%
Owl Creek	116,769	39,790	24,919	19,590	34%	21%	17%
Nowood	117,327	7,482	5,273	3,362	6%	4%	3%
Lower Bighorn	170,209	26,747	11,169	6,943	16%	7%	4%
Greybull	505,395	172,142	47,001	29,905	34%	9%	6%
Shoshone	829,711	29,097	18,348	9,801	4%	2%	1%
Sub-Total	2,068,711	287,478	114,210	75,050	14%	6%	4%
Total	3,534,282	629,263	241,644	171,483	18%	7%	5%

Notes:

(1) Shortages are for historical Full Supply Conditions without Futures projects.

(2) The modeled shortages do not include releases from Greybull Valley Reservoir.

Table 2-2 presents a summary of modeled diversion shortages for the Full Supply Condition with Futures Projects, while a reach-by-reach summary of shortages is presented in Appendix A. The Futures Projects were modeled with a Full Supply diversion requirement of approximately 198,000 acre-feet for those projects within the Wind and Little Wind basins. The Futures Projects would increase shortages within the Wind River basin, not including the Popo Agie, by approximately 205,000 acre-feet in dry years, 70,000 in average years and 39,000 in wet years. The dry year value actually exceeds the diversion requirement because return flows for the North Crowheart Project accrue to the river at locations where they cannot be rediverted by downstream entities such as is the current practice.

Downstream of Boysen Reservoir, the model does not show any impacts. This is because Boysen Reservoir acts as a "buffer" between the Wind and Bighorn basins. More storage within the reservoir can be used to meet downstream demands. The model shows, however, as time progresses, there may be more difficulty in filling Boysen Reservoir if all Futures Projects are on-line. A graph depicting storage for the two scenarios during the average year is shown in Figure 2-1. The model starts the reservoir contents the same as historical October beginning-of-month contents. For both the historical and Full Supply simulation, the September end-of-month contents are greater than or approximately equal to the October end-of-months contents, which indicates that the assumption of starting reservoir contents is likely valid. However, the Full Supply with Futures Projects simulated end-of-month contents are less than the October end-of-month contents. Therefore, the assumption of end-of-month contents may not be valid. If this value is continually adjusted downwards to match September end-of-month contents, it is likely that they would not converge. A more detailed carry-over storage analysis is required to analyze the full affects of Futures Projects on storage in Boysen Reservoir.

Again, the model limitations should be recognized. The model does not contain a water rights accounting system. In addition, the model does not "operate" storage to meet downstream demands. It simply releases the historical volumes. For instance, in the Futures scenario, additional releases could be made from Bull Lake to meet some Wind River shortages, or additional water could be stored in Boysen Reservoir during peak runoff, which would impact flows downstream of the reservoir during those months.

Table 2-2. Summary of Modeled Diversion Shortages – Full Supply with Futures Projects

Basin	Full Supply Diversion (ac-ft)	Reach Shortages (ac-ft)			Reach Shortages (percent)		
		Dry	Normal	Wet	Dry	Normal	Wet
Clarks Fork	106,293	30,402	18,786	11,645	29%	18%	11%
Yellowstone	0	0	0	0	0%	0%	0%
Sub-Total	106,293	30,402	18,786	11,645	29%	18%	11%
Upper Wind	1,113,585	399,102	125,825	83,921	36%	11%	8%
Little Wind	348,159	97,916	38,667	29,206	28%	11%	8%
Lower Wind	95,151	20,537	15,839	11,634	22%	17%	12%
Sub-Total	1,556,894	517,556	180,331	124,761	33%	12%	8%
Upper Bighorn	329,300	12,220	7,499	5,450	4%	2%	2%
Owl Creek	116,769	39,790	24,919	19,590	34%	21%	17%
Nowood	117,327	7,482	5,273	3,362	6%	4%	3%
Lower Bighorn	170,209	26,747	11,169	6,943	16%	7%	4%
Greybull	505,395	172,142	47,001	29,905	34%	9%	6%
Shoshone	829,711	29,097	18,348	9,801	4%	2%	1%
Sub-Total	2,068,711	287,478	114,210	75,050	14%	6%	4%
Total	3,731,898	835,435	313,327	211,456	22%	8%	6%

Notes:

(1) The modeled shortages do not include releases from Greybull Valley Reservoir .

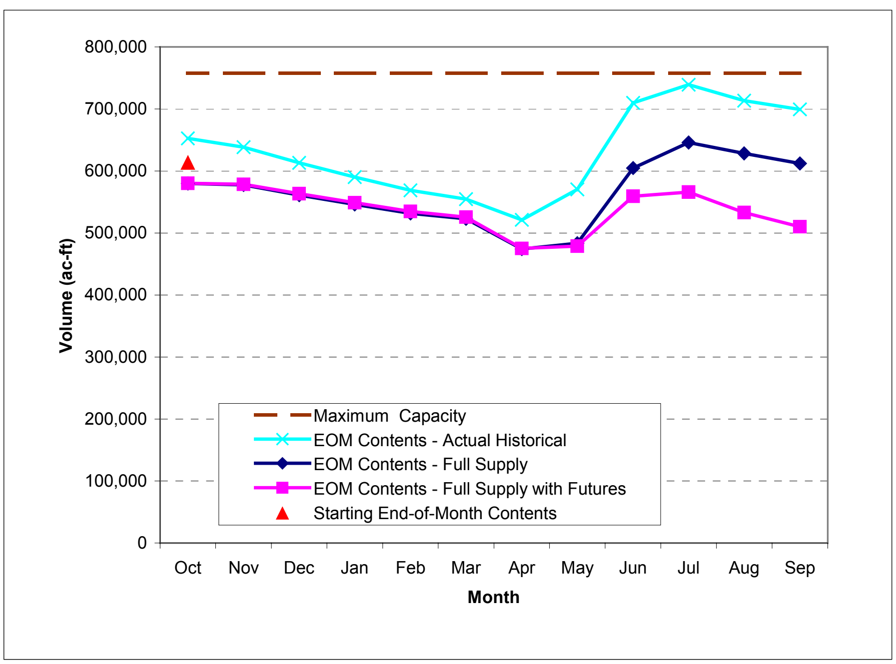

Figure 2-1. Simulated End-of-Month Contents for Boysen Reservoir – Average Year

Section 3 - Streamflow

Streamflow is a fundamental output of any river basin simulation model. The Wind/Bighorn River sub-basin models use streamflow as a calibration measure. This implies that simulated streamflow matches or is very close to measured historical streamflow. The comparison of simulated to measured historical streamflow for historical conditions is presented in the Task 3B/3C Technical Memorandum Spreadsheet Model Development and Calibration (MWH, 2003).

The Wind/Bighorn River sub-basin models are configured to allow the simulation of streamflows given variations in model input parameters, such as diversion requirements. Therefore, for the Full Supply and the Full Supply with Futures Projects scenarios, the impacts to streamflows can be shown. Appendix B contains streamflow graphs for dry, average and wet year conditions at various streamflow gages within the basin. Streamflow impacts at any node within the model can be obtained simply by running the model in the desired modes and comparing the “node inflow” on the reach worksheets at the desired nodes. See Task 3B/3C Technical Memorandum Spreadsheet Model Development and Calibration (MWH, 2003) for more information on the reach worksheets in the model. For sake of brevity within this report, only nodes that represent current streamflow gages that are significantly impacted by irrigation diversions are shown in this summary report.

Section 4 - Available Flow

The available surface water for each basin is defined as the amount of water available for water development after meeting downstream demands. These demands include:

1. Existing irrigation, municipal or industrial demands
2. Compact Requirements
3. Instream Flow Requirements

Available flows under the Full Supply scenario for the Wind River Basin, Bighorn River Basin and Clarks Fork, Yellowstone and Madison/Gallatin river basins are shown in Table 4-1, Table 4-2 and Table 4-3. Available flows under the Full Supply with Futures Projects scenario for the Wind River Basin are shown in Table 4-4. As previously mentioned, the model does not show any affects on streamflow due to the Futures Projects (see model constraints). Monthly shortages for all reaches and hydrologic conditions are presented in the appendices. The development of available flows is discussed in the following sub-sections.

Table 4-1. Wind River Basin Available Flow - Full Supply Scenario

Basin	Location	Available Flow (ac-ft)		
		Dry	Normal	Wet
Upper Wind	Reach 100: Wind River Headwaters to DuNoir Creek	0	32,973	61,735
	Reach 200: Wind River from DuNoir Creek to East Fork	0	52,255	82,993
	Reach 300: Wind River from East Fork to Bull Lake Creek	74,745	249,772	470,811
	Reach 290: East Fork Wind River	2,586	25,922	52,810
	Reach 320: Dinwoody Creek	5,550	40,388	64,188
	Reach 390: Bull Lake Creek	14,327	107,703	161,938
Little Wind	Reach 400: Wind River from Bull Lake Creek to Little Wind	98,817	312,982	528,328
	Reach 500: Little Wind River	26,825	88,499	137,008
	Reach 510: South Fork Little Wind	7,454	15,620	39,709
	Reach 520: North Fork Little Wind	11,641	62,887	94,835
	Reach 530: Trout Creek	2,833	5,717	8,317
	Reach 580: Popo Agie River	26,825	88,499	137,008
Lower Wind	Reach 600: Wind River from Little Wind Confluence to Boysen Reservoir	332,085	748,665	987,068
	Reach 700: Muddy Creek	2,676	3,441	4,131
	Reach 800: Badwater Creek	22,101	22,007	18,305

Notes:

(1) Available Flow in Upper Wind River Basin affected by Instream Flow requirements in Reach 200. The East Fork Wind River is downstream of this Instream Flow segment. However, due to model construction, its impacts are imposed on the East Fork.

Table 4-2. Bighorn River Basin Available Flow - Full Supply Scenario

Basin	Location	Available Flow (ac-ft)		
		Dry	Normal	Wet
Upper Bighorn	Reach 100: Bighorn River to Owl Creek	758,909	1,103,618	1,451,214
	Reach 400: Bighorn River from Owl Creek to Gooseberry Creek	775,972	1,117,130	1,496,273
	Reach 460: Cottonwood Creek	7,275	14,338	30,873
	Reach 480: Gooseberry Creek	7,926	14,601	22,515
	Reach 500: Bighorn River from Gooseberry Creek to Nowood River	840,185	1,266,937	1,659,049
	Reach 900: Bighorn River from Nowood River to USGS Gage	871,488	1,303,478	1,694,604
Owl Creek	Reach 200: Owl Creek from N. & S. Fork Conf. To Mud Creek Conf.	5,477	17,269	26,746
	Reach 220: South Fork Owl Creek	1,468	9,521	16,013
	Reach 250: N. Fork Owl Creek	1,737	6,678	11,483
	Reach 300: Owl Creek from Mud Creek Conf. To Bighorn River	8,907	27,540	48,091
Nowood	Reach 600: Nowood River above Ten Sleep Creek	6,500	15,214	25,902
	Reach 690: Ten Sleep Creek	3,114	12,235	24,183
	Reach 700: Nowood River from Ten Sleep Ck. To Paint Rock Ck.	146,433	169,466	251,569
	Reach 790: Paint Rock Creek	82,113	91,162	112,187
	Reach 800: Nowood River from Paint Rock Ck. To Bighorn Riv.	248,827	295,779	424,924
Lower Bighorn	Reach 1000: Bighorn River at Greybull River	915,630	1,438,245	1,797,531
	Reach 1500: Bighorn River at Shell Creek	917,826	1,463,859	1,829,238
	Reach 1600: Shell Creek	19,218	46,793	57,027
	Reach 1700: Bighorn River at Yellowtail	919,801	1,567,955	1,911,814
	Reach 1740: Crystal Creek	1,025	2,812	6,807
Greybull	Reach 1100: Greybull River Headwaters	29,634	85,629	74,207
	Reach 1200: Wood River	66,134	84,738	104,651
	Reach 1300: Greybull River below Wood River	39,696	94,879	86,534
	Reach 1350: Meeteetse Creek	1,531	3,552	5,828
	Reach 1400: Greybull River Below Roach Gulch	48,053	108,263	96,906
Shoshone	Reach 1800: South Fork Shoshone River Headwaters	6,274	11,667	18,472
	Reach 1900: South Fork Shoshone River below Bob Cat Creek	97,126	260,356	425,296
	Reach 2000: North Fork Shoshone River Headwaters	27,097	55,797	97,618
	Reach 2100: North Fork Shoshone River below Wapati	156,891	348,970	560,480
	Reach 2200: Buffalo Bill Reservoir	196,528	403,274	636,417
	Reach 2300: Shoshone River below Buffalo Bill Reservoir	196,528	403,274	636,417
	Reach 2390: Sage Creek	0	0	103
	Reach 2400: Shoshone River below Sage Creek	302,875	521,599	749,870
	Reach 2500: Shoshone River below Bitter Creek	471,534	748,196	1,082,116

Table 4-3. Clarks Fork, Yellowstone and Madison/Gallatin Basin Available Flow - Full Supply Scenario

Basin	Location	Available Flow (ac-ft)		
		Dry	Normal	Wet
Clarks Fork	Reach 100: Clarks Fork River above Sunlight Creek Confluence	240,422	370,501	528,966
	Reach 190: Sunlight Creek	48,383	70,615	86,899
	Reach 200: Clarks Fork River from Sunlight Creek to Bennett Creek	240,422	370,501	567,608
	Reach 300: Clarks Fork River below Bennett Creek Confluence	294,923	444,004	681,550
Yellowstone	Reach 400: Yellowstone River above Lamar River Confluence	813,647	1,146,594	1,328,581
	Reach 500: Yellowstone River below Lamar River Confluence	1,531,126	2,140,310	2,469,129
	Reach 580: Gardner River	65,111	113,663	144,366
Madison/Gallatin	Reach 600: Madison River	340,745	375,009	437,417
	Reach 620: Gibbon River	89,203	109,391	135,155
	Reach 640: Firehole River	251,542	265,618	302,261
	Reach 800: Gallatin River	501,921	634,324	716,471

Table 4-4. Wind River Basin Available Flow - Full Supply with Futures Projects Scenario

Basin	Location	Available Flow (ac-ft)		
		Dry	Normal	Wet
Upper Wind	Reach 100: Wind River Headwaters to DuNoir Creek	0	28,187	43,626
	Reach 200: Wind River from DuNoir Creek to East Fork	0	47,469	62,968
	Reach 300: Wind River from East Fork to Bull Lake Creek	70,387	150,190	354,645
	Reach 290: East Fork Wind River	2,586	21,858	36,403
	Reach 320: Dinwoody Creek	5,550	37,336	57,003
	Reach 390: Bull Lake Creek	14,327	70,862	111,811
Little Wind	Reach 400: Wind River from Bull Lake Creek to Little Wind	91,783	214,625	406,565
	Reach 500: Little Wind River	26,825	88,499	137,008
	Reach 510: South Fork Little Wind	7,454	15,620	39,709
	Reach 520: North Fork Little Wind	11,641	62,887	94,835
	Reach 530: Trout Creek	2,833	5,717	8,317
	Reach 580: Popo Agie River	26,825	88,499	137,008
Lower Wind	Reach 600: Wind River from Little Wind Confluence to Boysen Reservoir	292,772	684,113	878,067
	Reach 700: Muddy Creek	2,676	3,441	4,131
	Reach 800: Badwater Creek	22,101	22,007	18,305

Notes:

(1) Available Flow in Upper Wind River Basin affected by Instream Flow requirements in Reach 200. The East Fork Wind River is downstream of this Instream Flow segment. However, due to model construction, its impacts are imposed on the East Fork.

4.1 Available Flow in Excess of Existing Demands

As explained in Technical Memorandum 3B/3C – Spreadsheet Model Development and Calibration (MWH, 2003), the Wind/Bighorn sub-basin models are divided into reaches that represent an individual reach of stream. The available flow is calculated as the minimum of the available flow within the individual reach and the available flow of all downstream reaches.

In previous river basin planning models, the available flow within each reach was calculated as the minimum of the outflow from the reach (HKM, 2002). However, it was found that in the Wind/Bighorn sub-basin models, some of the reach outflows were greater than the minimum flow within the reach. Thus, the defining flow availability is the minimum flow within the reach, taking into account compact requirements for the basin and instream flow requirements within the reach. Therefore, for the Wind/Bighorn available flows, the available flow within each reach was taken as the minimum flow at all nodes within the reach. The minimum flow for the individual reach was then calculated as the minimum flow within the reach plus the minimum flow of all downstream reaches.

It should be noted that performing these calculations on an annual basis could result in different results than performing the calculations on a monthly basis. The monthly basis is considered more accurate because of the shorter calculation time period. The annual value of available flow is the sum of the 12 months' available flow.

4.2 Compact Constraints

The Yellowstone River Compact, which was ratified in 1950 by the states of Wyoming, Montana and North Dakota, governs the allocation of the tributaries to the Yellowstone River between the states. The following is a brief summary of the rules for dividing water according to the Compact (WWDC, 2002):

> *To all tributaries the following rules apply:*
>
> 1) *existing rights as of January 1, 1950 maintain their status quo;*
>
> 2) *no water may be diverted from the Yellowstone River Basin without consent from all states;*
>
> 3) *existing and future domestic and stock water uses including stock water reservoirs up to a capacity of 20 acre-feet are exempted from provisions of the Compact.*
>
> *The unappropriated or unused total divertible flow of each tributary after needs for supplemental supply for existing rights are met, is allocated to Wyoming and Montana on a percentage basis.* (WWDC, 2002)

The information used in this study to determine the volume of availability under the Yellowstone River Compact is based upon conversations and information from the U.S. Geological Survey and with the Wyoming SEO office (YRCC, 2002). The details of the calculations are described below.

4.2.1 Clarks Fork

The Yellowstone River Compact allocates the unallocated flows of the Clarks Fork Yellowstone River as calculated using the guidelines above between Wyoming and Montana. Results are shown in Table 4-5 (WWDC, 2002).

Table 4-5. Yellowstone Compact Allocation Percentages for Clarks Fork

State	Percent of Unallocated Flow Allocated to State
Wyoming	40%
Montana	60%

The Yellowstone River Compact Commission calculates the unallocated flows of the Clarks Fork River as follows (YRCC, 2002):

1. The base gage is the Clarks Fork River at Edgar gage (USGS Gage No. 06208500).
2. Add Diversions by the White Horse Canal (06208790) back into the gage.
3. Allocate Flow based upon the Compact percentages.

Based upon the gage flows available from the USGS, the unallocated flow calculation methodology and the Compact percentages, Wyoming's portion of the unallocated flow of the Clarks Fork was estimated for the dry, average and wet year hydrologic conditions. These results are presented in Table 4-6. These values have been included in the available flow calculations for the Clarks Fork River. To simplify model accounting, the calculations were performed on an annual basis, then pro-rated over the year according the flow pattern at the Clarks Fork near Belfry gage (06207500).

Table 4-6. Calculation of Wyoming Portion of Unallocated flow for the Clarks Fork River

	Dry Year	Normal Year	Wet Year
Gaged Flow (ac-ft)	491,713	733,406	1,137,418
Adjusted Flow (ac-ft)	498,664	740,007	1,144,083
Wyoming Portion of Unallocated Flow (ac-ft)	299,199	444,004	686,450

Notes:
(1) Based on 1973 – 2001 data.

4.2.2 Bighorn River

The Yellowstone River Compact allocates the unallocated flows of the Bighorn River as calculated using the guidelines above between Wyoming and Montana. Results are shown in Table 4-7 (WWDC, 2002).

Table 4-7. Yellowstone Compact Allocation Percentages for Bighorn River

State	Percent of Unallocated Flow Allocated to State
Wyoming	80%
Montana	20%

The Yellowstone River Compact Commission calculates the unallocated flows of the Bighorn River as follows (YRCC, 2002):

1. The base gage is the Bighorn River near Bighorn gage (06294500);
2. Remove the Little Bighorn near Hardin gage (06294000) flows from the gage;
3. Adjust the flows for change in storage contents at Yellowtail Reservoir.
4. Allocate Flow based upon the Compact percentages.

Based upon the gage flows available from the USGS, the unallocated flow calculation methodology and the Compact percentages, Wyoming's portion of the unallocated flow of the Bighorn River was estimated for the dry, average and wet year hydrologic conditions. These results are presented in Table 4-8. These values have been included in the available flow calculations for the Bighorn River. To simplify model accounting, the calculations were performed on an annual basis, then pro-rated over the year according to a weighted monthly flow pattern at the Bighorn River at Kane gage (06279500) and the Shoshone River at Kane gage (06286200). In reality, Yellowtail Reservoir serves to balance out Compact requirements over the year, so there could be some deviation allowed from the monthly requirements.

Table 4-8. Calculation of Wyoming Portion of Unallocated flow for the Bighorn River

	Dry Year	Normal Year	Wet Year
Gaged Flow (ac-ft)	1,911,049	2,778,269	3,591,471
Adjusted Flow (ac-ft)	1,686,523	2,559,384	3,382,968
Wyoming Portion (ac-ft)	1,349,218	2,047,507	2,706,375
Wyoming Portion of Unallocated Flow (ac-ft) minus Futures Projects	1,099,218	1,797,507	2,456,375

Notes:
(1) Based on 1973 – 2001 data.
(2) Assumes 250,000 ac-ft of Tribal Futures Projects subtracted annually from unallocated flow.

4.3 Instream Flow Constraints

The Wyoming Water Development Commission permits instream flows for piscatorial uses within the stream reach (Rumsey, 1997). Within the Wind/Bighorn Basin Plan study area, there are four streams with permitted instream flows (one stream with two separate reaches) and two streams with pending instream flow applications. The permitted and pending instream flow reaches and flow rates are shown in Table 4-9 (Brinkman, 2002), while monthly and annual volumetric amounts are shown in Table 4-10. The instream flows are more fully discussed in the Technical Memorandum Recreational and Environmental Uses and Demand (BRS, 2002).

Table 4-9. Permitted and Pending Instream Flow Rates

Instream Flow Segment	Model Reach	Permitted/Pending Instream Flow (cfs)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clarks Fork	200	200	200	200	200	200	200	200	200	200	200	200	200
Tensleep	690	22	22	22	22	22	22	22	22	22	22	22	22
Big Wind	200	102	102	102	110	110	102	102	102	102	102	102	102
Shell 1	1600	19	19	19	45 (1)	70	70	40	40	40	19	19	19
Shell 2	1600	23	23	23	23	23	23	40	40	40	23	23	23
Medicine Lodge Creek (2)	794	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	15	15	8.9
Shoshone River (2)	2300	350	350	350	350	350	350	350	350	350	350	350	350

Notes:

(1) The flow requirement in April for Shell No. 1 is 19 cfs April 1-15 and 70 cfs April 16-30. The calculations assume the average of these two values for the April value.

(2) The Medicine Lodge Creek and Shoshone River instream flow applications are pending

Table 4-10. Permitted and Pending Instream Flows Volumes

Instream Flow Segment	Permitted/Pending Instream Flow (ac-ft)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Clarks Fork	12,298	11,306	12,298	11,901	12,298	11,901	12,298	12,298	11,901	12,298	11,901	12,298	144,994
Tensleep	1,353	1,244	1,353	1,309	1,353	1,309	1,353	1,353	1,309	1,353	1,309	1,353	15,949
Big Wind	6,272	5,766	6,272	6,546	6,764	6,070	6,272	6,272	6,070	6,272	6,070	6,272	74,915
Shell 1	1,168	1,074	1,168	2,648	4,304	4,165	2,460	2,460	2,380	1,168	1,131	1,168	25,295
Shell 2	1,414	1,300	1,414	1,369	1,414	1,369	2,460	2,460	2,380	1,414	1,369	1,414	19,776
Medicine Lodge Creek (2)	547	503	547	530	547	530	547	547	530	922	893	547	7,190
Shoshone River (2)	21,521	19,785	21,521	20,827	21,521	20,827	21,521	21,521	20,827	21,521	20,827	21,521	253,739

Notes:

(1) The flow requirement in April for Shell No. 1 is 19 cfs April 1-15 and 70 cfs April 16-30. The calculations assume the average of these two values for the April value.

(2) The Medicine Lodge Creek and Shoshone River instream flow applications are pending

Instream flows exert a demand on the river the same as any other consumptive use water right. Flow must be passed through the instream flow segment according to the water right priority date. Once that flow is through the segment, the water can be diverted for consumptive use. Therefore, available flows for reaches upstream of the permitted instream flow rights are affected assuming that water rights for use of the available flows would be junior to the instream flow rights.

All available flow calculations assume that both the permitted and pending instream flow water rights are in place. Therefore, any upstream flows that are not in excess of the instream flow right are shown to be unavailable for future uses. Each of the instream flow segments is within a modeled reach as shown in the table. For purposes of the calculations, it was assumed that the entire reach is subject to the instream flow requirement even if the instream flow segment occupies only a small portion of the reach. The reaches most affected by the instream flow water rights are the Upper Wind River, Shell Creek and Tensleep Creek, especially in the winter months.

Section 5 - References

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