
MEMORANDUM

**Subject: Bear River Basin Plan
Task 3D. Available Surface Water Determination**

Date: July 21, 2000

1.0 Introduction

The Bear River Spreadsheet Model is a complex spreadsheet which incorporates multiple diversions, reservoirs, gaging stations, and other water resources within the Bear River located in the extreme southwest corner of Wyoming (see Figure 1). The purpose of the model is to provide a planning tool to the State of Wyoming for use in determining those river reaches in which flows may be available to Wyoming water users for future development. The purpose of this task is to assess the availability of water in the Bear River Basin for future development.

Individual spreadsheet models were developed which reflect each of three hydrologic conditions: dry, normal, and wet year water supply. As discussed in the Task 3A Memorandum, Surface Water Data Collection and Study Period Selection, each model relies on historical data to estimate the hydrologic conditions. Such factors as streamflow, diversions, and irrigation returns are analyzed to determine the type of hydrologic condition. The development of the model is discussed in the Memorandum for Task 3B, Surface Water Spreadsheet Model Development. The calibration of the spreadsheet model is discussed in the Memorandum for Task 3C, Water Model Calibration.

2.0 Basin Hydrology Overview

The development of an accurate and extensive database was an important objective of this study. The model serves as a repository for this database, particularly useful for looking at different typical hydrologic conditions in the basin. To gain a general understanding of the basin, a basin-wide water budget can be estimated from this database. In a typical or average normal year, the basin diversions use virtually all the water produced in the Upper and Central Divisions of the Bear River Basin. The average annual gross diversions total about 750,000 acre-feet, while the flow passing Stewart Dam is less than 10,000 acre-feet. The base hydrology for the normal year condition shows inflows to the

system of about 525,000 acre-feet, which indicate the return flows from diversions are used several times before the river flows past Stewart Dam.

During dry years this same pattern of water use occurs, with water management being increasingly difficult to effectively deliver the diminished supply. Inflows to the system average almost 200,000 acre-feet. Diversions equal 389,000 acre-feet and the flow passing Stewart Dam is only 7,000 acre-feet. During wet years, however, basin inflows average about 1,015,000 acre-feet, with significant annual flows averaging over 58,000 acre-feet passing Stewart Dam. Diversions are equally increased to 1,169,000 acre-feet on average.

3.0 Available Flow

Several forms of model output can be accessed and utilized to determine the available water supply. These include river flow data (nodes or reaches), target (average historic diversions used in the model as demands and fulfilled if water available) and actual diversions (nodes, reaches, or comparison to historic), and evaluations of Compact Allocations (Upper or Central Divisions). These will be used to determine the available flow in the basin on a monthly basis at various points or reaches and during various hydrologic conditions.

Although the model simulates the water emergency conditions identified by the Bear River Compact under present levels of basin development, there are additional stipulations in the Amended Compact that address the authority and ability of upper basin states to store water and develop new projects. These will be summarized in Section 4.2, in particular, the affects of Article VI, paragraphs A, B, and C. Also of concern for the development of new projects is the timing of diversions. Most of the language addressing water emergency conditions in the Compact is associated with irrigation season flows, that is, divertible flow. The available water determination is shown on a year-round basis, with some assumptions about the Compact limitations during non-irrigation season for both divisions. In particular, the ability of upstream basin states to store water based on the levels in Bear Lake was not modeled in the spreadsheets.

3.1 Available Water Determination

An effort was made to incorporate sufficient detail in the spreadsheet models to determine whether water emergency conditions exist as defined in the Bear River Compact for either the Upper or Central Divisions. Table 1 is the output table for the normal year hydrology of the Bear River Commission's Water Allocation: Upper Division, which uses the Water Commissioner's worksheet to determine if a water emergency exists in the Upper Division under the present level of basin development. Table 2, similarly, is the output table for the normal year hydrology of the Bear River Commission's Water Allocation for the Central Division. These tables determine whether an emergency condition exists; however, no attempt was made in the model to restrict diversions based on this determination.

Some assumptions that were made to facilitate the assessment of available water follow. In reviewing the water allocation worksheets for each division, any month where a water emergency occurs under the present development level will not allow for any new development. All three hydrologic conditions were reviewed and the divisions were analyzed separately, although in reality, a diversion in the Upper Division may affect the available flows and, hence, the divertible flow in the Central Division. The Water Allocation worksheets for Compact purposes are only imposed during the irrigation season, May through September, so a further review of non-irrigation season flows is made to determine the water available on a yearly basis.

After the available water supply for each division based on compact limitations for present development levels is assessed, a review of another output table from the model, Table 3, the Outflow Worksheets by Reach is analyzed to determine which reaches are preferable based on available water. The table shows the summary of outflow by reaches for the normal year condition and is referenced to determine where in each division available flows may be diverted.

3.2 Results

Tables 4 and 5 show the water availability for the Upper and Central Divisions, respectively. The Upper and Central Divisions were addressed separately, although the development of a new project in the Upper Division will inevitably impact the available flows in the Central Division. In the Upper Division, Table 4 lists the model flows at Pixley Dam for the three hydrologic conditions. The second item of information in the table is the Total Divertible Flow as defined by the Compact.

This is the total diversions by Wyoming and Utah plus the flow passing Pixley Dam (see also Table 1). The third item is the flow of 1,250 cfs as compared to the total divertible flow identified in the compact, below which an emergency condition is triggered. The fourth item is the determination of available flow by month for each condition. Lastly, from a review of the flow by reach tables of model output, the preferable reaches where this flow is available are listed in order of maximum available flow to minimum.

Similarly, Table 5 for the Central Division lists the flow at the Border Gage in item 1. Item 2 is the flow below Stewart Dam, item 3 is the total divertible flow as identified in the Compact, item 4 is an assumption of the Compact's limiting flow on a year-round basis, and items 5 and 6 are the same as for the Upper Division.

From these tables, it can be seen that dry year yields (yield is defined here as the water available for diversion and future permanent use) for the Upper Division are essentially only available during the non-irrigation season and total about 27,000 acre-feet. Available water is non-existent in the Central Division. For all three hydrologic conditions the available flows in the Upper Division are available lower in the basin (reaches 7 and 8 are higher; see Figure 1) during the non-irrigation season and are available higher in the basin during the runoff period (early irrigation season). This is reasonable as the flows are generally more available during the peak runoff months and the available flows later in the year are a result of irrigation returns and baseflow. In the Central Division, the flows are available mainly on the mainstem reaches of 9, 11 and 12, since the Smiths Fork generally captures and uses all available flow and the Thomas Fork was not explicitly modeled (the reach gain in reach 12 is a result of Thomas Fork and could yield available water).

Yields during normal and wet years are available in both divisions, although year round yields are still not available, particularly in the upper division. During a typical normal year, the available water is about 150,000 acre-feet in the Upper Division and about 190,000 acre-feet in the Central Division, distributed as shown in the tables.

In wet years, which for this study were the three wettest years (1983, 1984, and 1986) in the study period, there is no water available in August and September in the Upper Division and no water available in the Central Division in September based on Compact Allocations. There is about 325,000 acre-feet available in the Upper Division, mainly during the runoff period. In the Central Division, the water available exceeds 500,000 acre-feet.

4.0 Potential Projects and Model Utilization

Many of the potential projects that divert available flow during high flow months (spring runoff) versus a year-round diversion will require storage projects. The retirement of existing diversions or water uses that serves to increase the water availability was not assessed during this project task, however, the model is fully capable of addressing this scenario.

The type of new water use will limit the divertible flow, e.g., a large diversion with small consumptive use, which returns most of the diversion before water-short reaches of the system are impacted, may be easier to develop than a small, but large, consumptive use. For the purposes of this task assessment, the divertible flow was assumed to be a net diversion, i.e., only the consumptive use is assessed.

4.1 Direct Diversion Versus Storage Projects

There are essentially 8 dry years in the 28 year study period, during which a direct diversion project would not receive any water (about 3 out of every 10 years there are no divertible flows). In reviewing Tables 4 and 5, there are virtually no available flows in either division during dry year periods, in any months, therefore a direct diversion without storage offers limited supply. To guarantee a firm yield during these dry year periods, a storage project, which would capture flows during normal or wet years, would be required.

Turning to the normal year hydrologic study, the best development plan would be to build storage of about the yield available during these years - 150,000 to 190,000 acre-feet in either the Upper or Central Divisions. The yield that is available for firm contract out of the facility would be about half of this volume. There would be the need to carry over some storage to guard against dry year yields (zero) and to take into account losses from the reservoir which would decrease the available water. The firm yield would be on the order of 75,000 acre-feet in the Upper Division and 95,000 acre-feet in the Central Division.

A review of the wet years shows much higher available flows, but they occur only in three years out of 28 years or about 11 percent of the time. Planning and constructing facilities on these occurrences would oversize the storage vessel and would not substantially increase the firm yield of a water supply, although there is up to 500,000 acre-feet available during these wet periods.

4.2 Additional Considerations

Article VI of the Amended Bear River Compact allocates additional storage to the states, above that which existed as of February 4, 1955, which for Wyoming was determined to be 2,150 acre-feet. Additionally, the paragraphs of this article allocate additional depletions to the states for any diversions after January 1, 1976. These new depletions and storage projects must be assessed relative to the available flows and the Compact allocations. Existing conditional projects of Wyoming-s which have been approved since January 1, 1976, must also be reviewed as they may decrease the available flows.

According to paragraph A of Article VI, Wyoming-s apportionment of 35,500 acre-feet would be 17,750 acre-feet, a portion of which has been committed to reservoir enlargements since February 4, 1955. The additional storage rights under paragraph B allocated to Wyoming of 35,000 acre-feet are limited by the depletions they cause above Stewart Dam in excess of depletions as of January 1, 1976. For Wyoming, this additional depletion is 13,000 acre-feet, again further limited by potential projects approved by Wyoming, but not constructed and operating, and, therefore, not modeled during this study. This study includes all existing depletions made by river diversions and mapped by irrigated lands. A further limitation under paragraph B is that diversions to storage can not be exercised when the storage in Bear Lake is below elevation 5,911.00 feet. The operation of Bear Lake is not incorporated in the model, although this needs to be assessed in planning for new developments in the basin.

5.0 Summary

Given the limitations and restrictions on new developments delineated in the Amended Bear River Compact and the language in Article VI of the Compact that states that "Water depletions permitted under this Paragraph B shall be calculated and administered by a Commission-approved procedure", it will be difficult to model the impact and affect of potential projects *a priori*. This spreadsheet model will, however, be useful in screening new projects and estimating impacts.

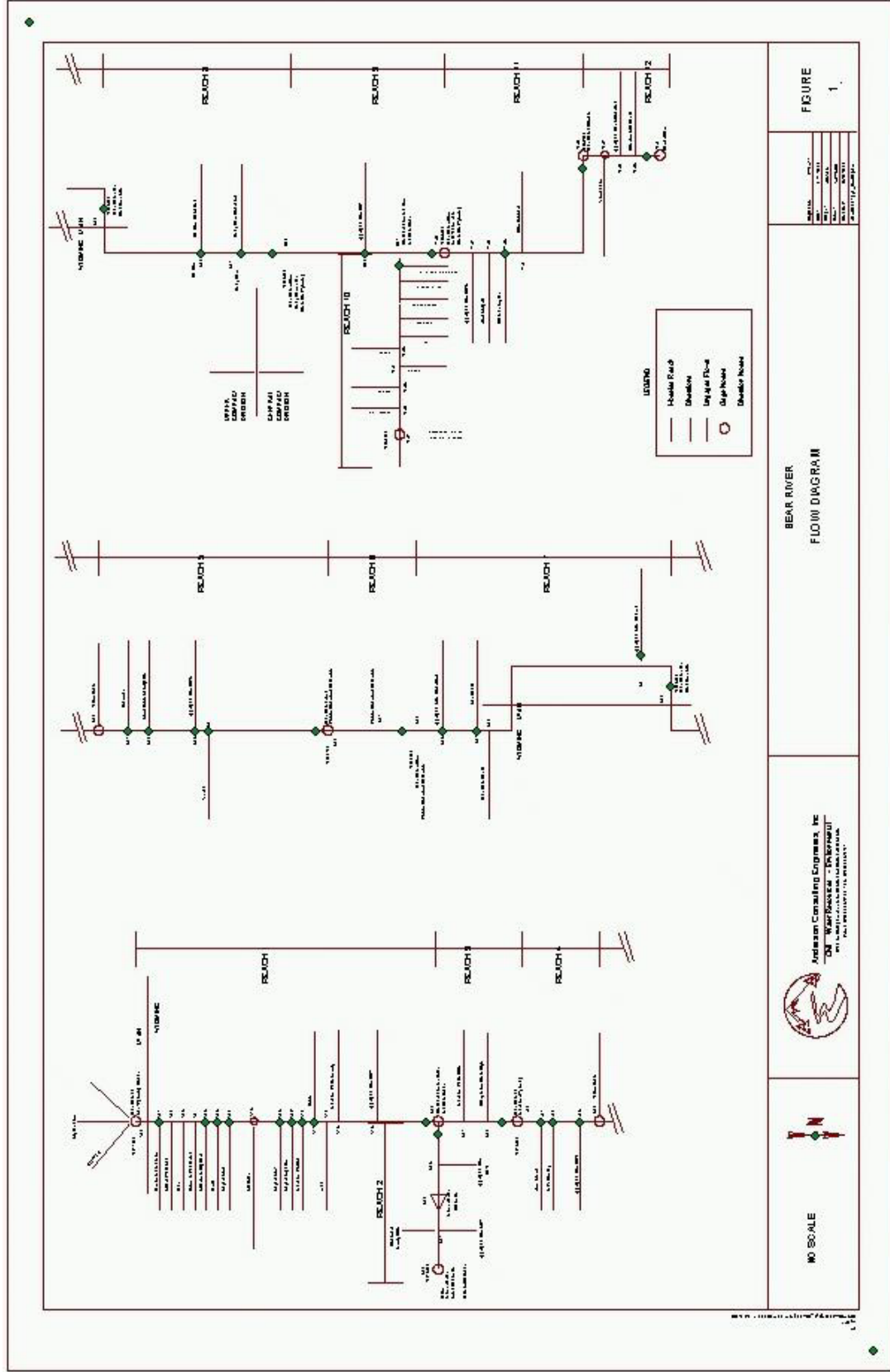
The determination of available flow is assessed based on the simulations of the spreadsheet models for the three hydrologic conditions. Simulations based on these estimated water availabilities to determine the impacts of the potential new diversion or projects was not performed with the models during this task. These should be configured in the model and simulated for each with and without

project condition. The resultant flows in each reach should be analyzed, as well as any shortages to existing diversions that may occur or the creation of a water emergency condition. These assessments will be made during later tasks after potential projects are better defined.

FIGURES

Figure 1. Bear River Model Node Diagram

Bear River Basin Plan
July 21, 2000



TABLES

- Table 1. Normal Year Bear River Commission Water Allocation Upper Division**
- Table 2. Normal Year Bear River Commission Water Allocation Central Division**
- Table 3. Bear River Basin Water Availability - Summary of Outflow by Reach for Normal Year Hydrology (AF)**
- Table 4. Bear River Basin Water Availability - Upper Division**
- Table 5. Bear River Basin Water Availability - Central Division**

Results Options

**Table 1. Normal Year
Bear River Commission Water Allocation
Upper Division**

May	Jun	Jul	Aug	Sep	
169	760	675	372	79	Upper Utah Section Diversion (1)
10,165	26,939	22,844	11,022	8,280	Upper Wyoming Section Diversion
2,319	-4,475	-5,977	-2,085	-1,460	Woodruff Narrows Reservoir Change in Storage Water
38,158	68,215	30,566	4,633	6,239	Lower Utah Section Diversions
5,077	10,927	3,324	147	162	Lower Wyoming Section Diversions
40,023	38,213	25,526	9,038	5,950	Bear River Below Pixley Dam
95,910	140,578	76,958	23,128	19,250	Total Upper Division Divertible Flow (ac-ft)
1,560	2,362	1,252	376	324	(cfs)

Is Total Upper Division Divertible Flow less than 1250 cfs? If so, Water Emergency (W.E.) exists.

	May	Jun	Jul	Aug	Sep	
	No W.E.	No W.E.	No W.E.	W.E.	W.E.	
				139	116	Upper Utah Section Allocation
				11,402	9,490	Upper Wyoming Allocation
				9,367	7,796	Lower Utah Section Allocation
				2,220	1,848	Lower Wyoming Section Allocation

NOTE: (1) Upper Utah Division is not modeled explicitly in this model. Diversion data are included here for computation of Compact allocations.

Results Options

**Table 2. Normal Year
Bear River Commission Water Allocation
Central Division**

	May	Jun	Jul	Aug	Sep	
	9,409	23,804	21,358	11,988	5,567	(1) Wyoming Diversions
	+	+	+	+	+	
	14,094	27,139	14,878	7,282	6,947	(2) Idaho Diversions
	+	+	+	+	+	
	83,291	70,058	40,810	16,886	12,117	(3) Rainbow Inlet Canal plus Bear River Main Stem Flow below Stewart Dam
	=	=	=	=	=	
	106,795	121,001	77,046	36,155	24,631	Total Central Division Divertible Flow (ac-ft)
	1,737	2,033	1,253	608	414	(cfs)
				W.E.	W.E.	
Is Total Divertible Flow (2) < 870 cfs? If so, Water Emergency (W.E.) exists.						
OR						
	89,113	91,543	50,541	19,337	13,898	Flow of Bear River at Border Gaging Station (ac-ft)
	1,498	1,538	822	325	234	(cfs)
				W.E.	W.E.	
Is Flow at Border < 350 cfs? If so, Water Emergency (W.E.) exists.						
				15,547	10,591	Allocation in the State of Wyoming
				20,609	14,039	Allocation in the State of Idaho

**Table 3. Bear River Basin Water Availability
Summary of Outflow By Reach for Normal Year Hydrology(AF)**

Flow Downstream of Each Reach	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Reach 1	3,772	3,734	9,086	18,659	48,550	51,850	13,527	3,064	2,660	5,072	4,203	3,985
Reach 2	396	491	1,305	3,251	5,239	2,387	187	1,291	1,547	864	657	386
Reach 3	4,168	4,225	10,391	21,921	53,606	54,331	14,865	3,051	3,304	4,877	4,941	4,373
Reach 4	4,675	4,753	11,805	23,207	57,940	58,764	17,047	2,723	2,855	5,172	5,221	4,783
Reach 5	4,675	4,753	11,805	23,199	56,646	57,017	16,545	3,138	3,182	5,494	5,325	4,783
Reach 6	3,447	3,544	7,158	20,048	53,673	60,309	22,031	4,371	4,119	4,150	3,578	3,365
Reach 7	6,813	7,466	16,963	28,230	33,156	18,920	1,789	577	1,516	6,868	7,553	6,901
Reach 8 - Pixley Dam Release	4,745	4,836	11,520	18,627	40,023	38,213	25,526	9,038	5,950	6,162	5,932	5,260
Reach 9	13,649	13,859	28,008	52,402	88,566	92,123	50,178	19,419	14,348	16,943	16,393	14,929
Reach 10	7,177	7,113	12,258	25,619	40,329	40,813	16,436	6,485	6,443	9,072	8,590	7,872
Reach 11 - Flow at Border Gage	14,320	14,374	28,460	55,596	89,113	91,543	50,541	19,337	13,898	17,291	16,919	15,260
Reach 12 - Stewart Dam Release	299	291	485	378	646	2,506	1,004	691	949	659	513	422

**Table 4. Bear River Basin Water Availability
Upper Division**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1. Flow below Pixley Dam (AF)													
Dry	1,972	1,665	3,744	3,934	1,693	7,601	6,842	2,572	1,492	1,735	2,255	1,959	37,464
Normal	4,745	4,836	11,520	18,627	40,023	38,213	25,526	9,038	5,950	6,162	5,932	5,260	175,832
Wet	6,098	7,736	20,226	32,192	83,950	92,935	40,990	20,293	18,027	15,040	13,319	8,975	359,781
2. Total Divertible Flow (AF)													
Dry	-	-	-	-	56,919	83,905	33,057	12,208	7,619	-	-	-	193,708
Normal	-	-	-	-	95,910	140,578	76,958	23,128	19,250	-	-	-	355,824
Wet	-	-	-	-	144,576	213,983	90,951	35,618	28,889	-	-	-	514,017
3. Min. Compact Flow Required (AF)													
(cfs)	0	0	0	0	76,861	74,381	76,861	76,861	74,381	0	0	0	379,344
4. Available Flow for WY (AF)													
Dry	1,972	1,665	3,744	3,934	0	9,524	0	0	0	1,735	2,255	1,959	26,788
Normal	4,745	4,836	11,520	18,627	19,049	66,197	97	0	0	6,162	5,932	5,260	142,426
Wet	6,098	7,736	20,226	32,192	67,715	139,602	14,090	0	0	15,040	13,319	8,975	324,994
5. Preferable Reaches	7,8,3,4,5	7,8,3,4,5	7,8,3,4,5	7,8,3,4,5	4, 5, 6 & 7	4, 5, 6 & 7	4, 5, 6 & 7	none	none	7,8,3,4,5	7,8,3,4,5	7,8,3,4,5	

- Notes:** 1. Flow below Pixley Dam is gage 10028500 Bear River below Pixley Dam. This constitutes the flow out of the Upper Division.
2. Total Divertible Flow is combined diversions (*present development*) of Wyoming and Utah in Upper Division including flow below Pixley Dam (1,250 cfs limit).
3. Minimum Compact Flow is minimum of flow above 1,250 cfs (Total Divertible Flow, including Pixley Dam release) or zero for non-irrigation season.
4. Available Flow is *physically available flow*, based on present development, above required Compact flows, which is flow in item 1 during non-irrigation season or flow in item 2 minus item 3 in irrig. season.
5. Preferable reaches are stream reaches where flow physically occurs, but may be impacted by potential projects in other reaches of this division.

**Table 5. Bear River Basin Water Availability
Central Division**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1. Flow at WY/ID Border Gage (AF)													
Dry	8,348	7,587	12,348	13,549	18,140	22,467	14,131	6,274	5,638	6,792	8,400	8,060	131,734
Normal	14,320	14,374	28,460	55,596	89,113	91,543	50,541	19,337	13,898	17,291	16,919	15,260	426,652
Wet	18,950	22,400	51,690	75,760	156,070	218,602	81,847	37,510	32,103	34,320	32,543	24,390	786,185
2. Flow below Stewart Dam (AF)													
Dry	581	644	624	451	490	666	663	796	706	721	407	309	7,058
Normal	299	291	485	378	646	2,506	1,004	691	949	659	513	422	8,843
Wet	188	201	495	430	11,587	29,122	13,762	640	742	511	384	314	58,376
3. Total Divertible Flow (AF)													
Dry	-	-	-	-	35,843	43,034	29,962	15,945	10,623	-	-	-	135,407
Normal	-	-	-	-	106,795	121,001	77,046	36,155	24,631	-	-	-	365,628
Wet	-	-	-	-	197,323	257,533	110,055	57,043	43,434	-	-	-	665,388
4. Min. Compact Flow Required (AF)	21,521	19,438	21,521	20,827	53,495	51,769	53,495	53,495	51,769	21,521	20,827	21,521	411,199
(cfs)	350	350	350	350	870	870	870	870	870	350	350	350	
5. Available Flow for WY (AF)													
Dry	0	0	0	0	0	0	0	0	0	0	0	0	0
Normal	0	0	6,939	34,769	53,300	69,232	23,551	0	0	0	0	0	187,791
Wet	0	2,962	30,169	54,933	134,549	197,775	56,560	3,548	0	12,799	11,716	2,869	507,881
6. Preferable Reaches	none	9, 11 & 12	9, 11 & 12	9, 11 & 12	9, 11 & 12	9, 11 & 12	9, 11 & 12	9, 11 & 12	none	9, 11 & 12	9, 11 & 12	9, 11 & 12	

- Notes:** 1. Flow at WY/ID Border Gage is gage 10039500 Bear River at Border, above Idaho diversions. One of Compact flow limitations/triggers is flow of 350 cfs at this gage.
2. Flow below Stewart Dam reported by PP&L, is referenced in compact as part of other minimum of 870 cfs in item 4 (other part is Total Divertible Flow).
3. Total Divertible Flow is combined diversions (*present development*) of Wyoming and Idaho in Central Division plus flow below Stewart Dam.
4. Minimum Compact Flow is minimum of flow above 350 cfs at Border Gage or flow above 870 cfs (Total Divertible Flow, including Stewart Dam release).
5. Available Flow is *physically available flow*, based on present development, above required Compact flows, which are minimum of flow in item 3 above 870 cfs or flow in item 1 above 350 cfs.
6. Preferable reaches are stream reaches where flow physically occurs, but may be impacted by potential projects in Upper Division and potential projects in other reaches of this division.