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MEMORANDUM

TO: Tom Lorz, CRITFC

FROM: David Benner

DATE: March 21, 2016

RE: Review of Canadian Treaty/Non Treaty Operations; Summary of Reservoir Drafts and Flow Augmentation in Columbia and Snake River basins in all Water Years.

The following is a summary of information concerning Canadian Operations[1] in normal and low Water Years. This document also includes reservoir drafts and other flow augmentation in the Columbia and Snake river basins in normal and low water years[2].

Table 1 provides a summary of Canadian Operations and Columbia and Snake River project drafts in normal and low water years.

[1] Overviews, plots, tables, and documents of Canadian Operations were provided by the Bonneville Power Administration.

[2] Details of Upper Columbia and Snake River operations were obtained from the 2016 Water Management Plan at: www.nwd-wc.usace.army.mil/tmt/documents/wmp/2016/Final/20151231_WMP_FIN_NWD.pdf.

Table 1. Summary of Canadian Operations and Columbia and Snake River Reservoir Drafts in Normal and Low Water Years.

	Operation	Normal/Dry Water Year (WY) Critical Forecast	Typical Volume	Volume Released in 2015	Estimated Daily Discharge over Period (Kcfs)
Canadian Treaty	Nonpower Uses	Normal	1 Maf	1.55 Maf	12.8 Kcfs May-June
	Arrow Summer Storage	Dry WY: Reshaping of Proportional Draft	Variable	1.72 Maf	28 Kcfs stored in July, Released in August
	Proportional Draft	Dry WY	Variable	5.3 Maf by end of July (April TSR-August TSR)	22 Kcfs additional draft/ flow April through July
Canadian Non-Treaty Storage Agreement	Dry Year 0.5 Maf	Dry Year: Lowest 20th Percentile WY at TDA using Early May Apr-Aug RFC Forecast (at TDA)	0.5 Maf	0.5 Maf between May 9 and June 26	5.3 Kcfs between May 9 and June 26
Libby	Summer Draft	Upper 80% of WY at TDA using May Final Apr-Aug Forecast at TDA	455 Kaf	NA	455 Kaf between July and September is 2.5 Kcfs per day
	Summer Draft	Lower 20% of WY at TDA using May Final Apr-Aug Forecast at TDA	892 Kaf	121 Kaf	121 Kaf between July & September is 0.7 Kcfs per day; 892 Kaf would be 4.9 Kcfs
Hungry Horse	Summer Draft	Upper 80% of WY at TDA using May Final Apr-Aug Forecast at TDA	246 Kaf	NA	246 Kaf between July & September is 1.3 Kcfs per day
	Summer Draft	Lower 20% of WY at TDA using May Final Apr-Aug Forecast at TDA	481 Kaf	320 Kaf	320 Kaf between July & September is 1.8 Kcfs per day; 481 Kaf would be 2.6 Kcfs
Grand Coulee	Summer Draft	July Final Apr-Aug Forecast at TDA $\geq$ 92 Maf	791 Kaf	NA	791 Kaf between July & August is 6.4 Kcfs per day
	Summer Draft	July Final Apr-Aug Forecast at TDA < 92 Maf	942 Kaf	942 Kaf	942 Kaf between July & August is 7.7 Kcfs per day
Lake Roosevelt Incremental Storage	Summer Flow Augmentation	March Final Apr-Sept Forecast at TDA $\geq$ 60 Maf	28 Kaf	NA	28 Kaf between July & August is 0.2 Kcfs per day
	Summer Flow Augmentation	March Final Apr-Sept Forecast at TDA < 60 Maf	41 Kaf	41 Kaf	41 Kaf between July & August is 0.3 Kcfs per day
Dworshak	Summer Flow Augmentation	All Years Draft 1600 ft to 1535 ft (Aug)	1029 Kaf	1029 Kaf	1029 Kaf between July & August is 8.4 Kcfs per day
		All Years 1535 ft to 1520 ft (Sept)	200 Kaf	200 Kaf	200 Kaf is 3.4 Kcfs over all Sept. and 6.7 Kcfs over half of Sept.
Upper Snake	Summer Flow Augmentation	All years	487 Kaf		

1. Canadian Operations

A. Canadian Treaty Operations

The Columbia River Treaty with Canada provides for cooperative measures between the U.S. and Canada for power generation and flood control in the Columbia River Basin. The Treaty Storage Regulation (TSR) study is prepared twice per month and incorporates operating criteria from the Detailed Operating Plan as well as updates for observed and forecasted river flow and runoff volumes. Canadian storage is operated to the TSR end-of-period targets, assuming no other supplemental agreements. The Columbia River Treaty Operating Committee (CRTOC), with representation from each entity, can negotiate supplemental operating agreements within the operating year which include mutually agreed upon/mutually beneficial changes in operations that result in deviations from the TSR.

For the 2014 operating year (1 August 2014 through 31 July 2015) the U.S. and Canadian Sections of the Treaty Operating Committee developed two supplemental operating agreements that allowed for shaping of Treaty storage releases during the December through August period for mutual nonpower benefits with no financial component.

1. The Nonpower Uses Agreement, signed in November 2014, typically provides for 1 Maf of flow augmentation storage for the U.S. in exchange for improved flows in Canada for whitefish spawning in January, and trout spawning and emergence in the April–June period. Under this agreement, 1 Maf of flow augmentation water was stored in Mica reservoir in January 2015 for release in May through July.

   As of 15 April 2015, 782 ksfd (1.55 Maf) of water above the TSR 15 April level was held in Treaty storage. All flow augmentation storage was released by 31 July under the Nonpower Uses Agreement. This year (beginning January 2016), the 1 Maf under the Nonpower Uses Agreement has already been stored above TSR levels.

2. Due to the low water conditions during the operating year in 2015, the CRTOC developed a second supplemental operating agreement: the Arrow Summer Storage Agreement signed in July 2015. The purpose of the agreement was to limit Arrow discharge in July to no more than 80 kcfs (later raised to 82 kcfs). Any water stored as a result of the flow limitation was to be released in August. A total of 868 ksfd (1.72 Maf) was stored during July and released in August. This supplemental agreement shifted water to be release under the Proportional Draft (see below) from July to August

Proportional Draft: Dry Water Year Canadian Operations

Dry water conditions in Columbia Basin during the spring and summer had a significant impact on Treaty operations in 2015. The TSR study, beginning with the first study run in April, departed from the expected refill operation to one that required releases of additional water from Treaty projects in Canada for power generation in the U.S. (termed “proportional draft”). Figure 1 shows the TSR Composite Treaty Storage results from the 23 April 2016 TSR (red dots) compared to the TSR that finalized results for September (black dots).

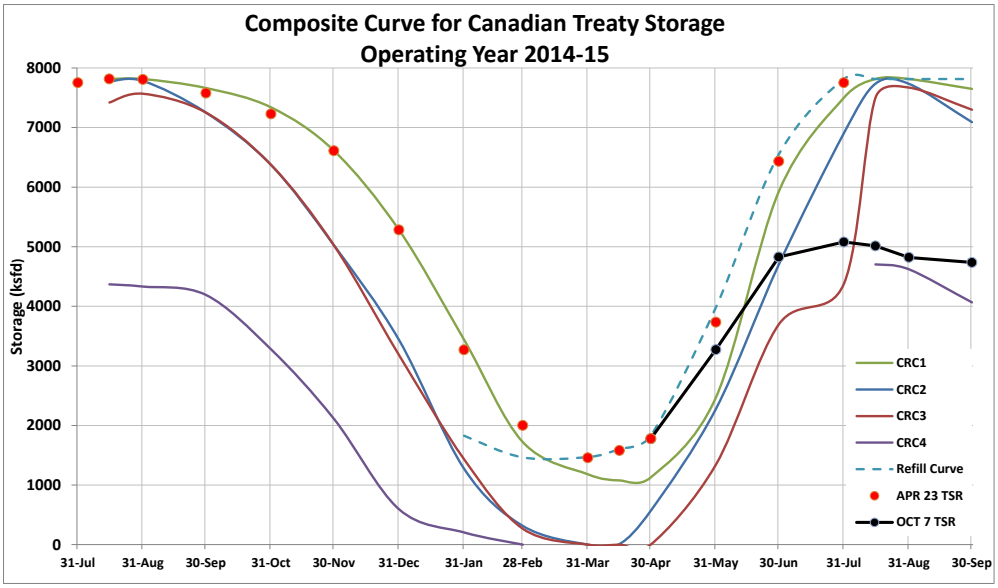

Figure 1. Composite Canadian storage content from the April 23rd TSR (red dots) compared to the TSR in October that finalized results for September (black dots).

Each successive TSR from April through July drafted Canadian projects more deeply. The result was that Treaty outflows were adjusted upward, well beyond expected levels as each month progressed. In addition, construction work at Arrow during May limited outflows, requiring additional flow increases to meet TSR target contents (further adjusted by supplemental agreement: Arrow Summer Storage Agreement). Table 2 below shows each TSR and the change to the end-of-July composite Treaty content compared to what was expected based on the 4/23/16 TSR. The early August TSR finalized the end-of-July TSR composite Treaty Storage Content 5.3 Maf (2673 Ksfd) lower than the results from the 23 April TSR (key points highlighted in yellow in Table1).

Table 2. Summary of TSR study results for May through August, beginning with the 23 April TSR.

Treaty Storage Regulation (TSR) Composite Treaty Storage Content (ksfd)							
TSR Date	May	Jun	Jul	Ag1	Ag2	Additional end of July draft compared to 4/23/15 TSR (Maf)	Additional end of August draft compared to 6/22/15 TSR (Maf)
4/23/2015	3733.5	6434.1	7752.6			-	
5/12/2015	2956.6	5190.9	6615.3			2.3	
5/21/2015	3266.8	5031.3	6474.5			2.5	
6/10/2015	3272.9	5585.1	6101.1			3.3	
6/22/2015	3272.9	5138.8	5968.7	6006.0	5893.9	3.5	-
7/9/2015	3272.9	4828.0	5548.8	5516.6	5308.3	4.4	1.2
7/23/2015	3272.9	4828.0	5422.1	5403.5	5190.3	4.6	1.4
8/7/2015	3272.9	4828.0	5079.6	4956.1	4724.6	5.3	2.3

As can be seen in Figure 2, Canadian storage continued to fill compared to the TSR through mid-July even when Treaty outflows exceeded 80 kcfs. The Treaty storage reached the TSR content in September 2015. In 2015, the maximum storage content reached in the TSR was in July which was 5.4 Maf below full (5.3 Maf below April TSR end of July levels). By the end of September the TSR was 5.8 Maf below full. Progressing through the current operating year

(2016) the TSR is on a path to refill considerably, however spring outflows may be relatively low.

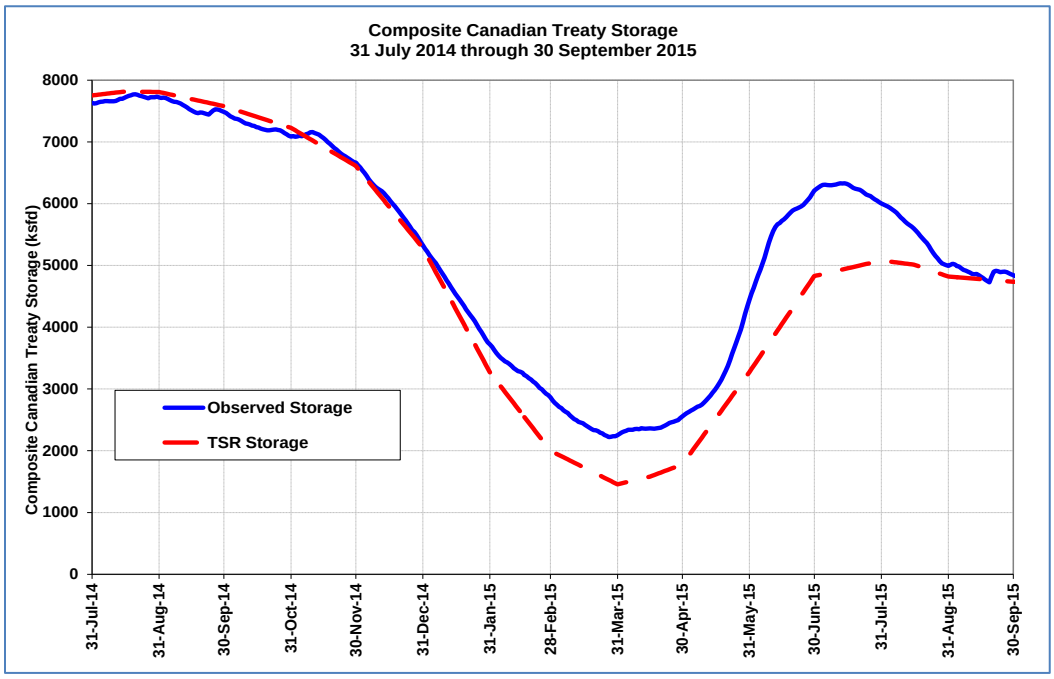

Figure 2. Composite Canadian Treaty Storage as operated compared to the final TSR Composite Treaty Storage.

A review of TSR results from 2000 through present (Figure 3) shows that most years have essentially a drawdown and refill cycle. However, 2001 was another year that started near full in the fall and failed to refill by a large margin (7.8 Maf). Again, by the end of September 2015, the TSR was 5.8 Maf below full.

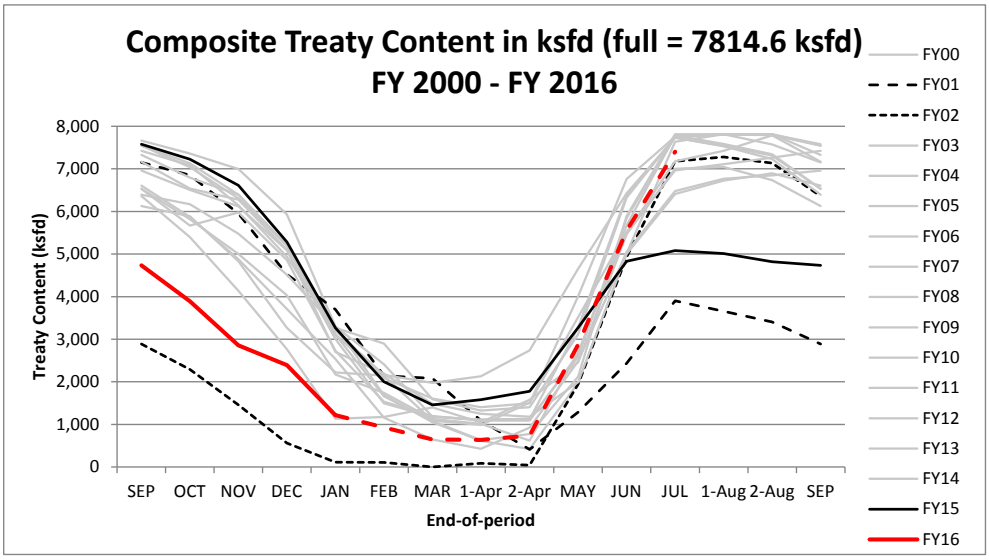

Figure 3. Recent TSR results show the typical variability due to a variety of water conditions.

B. Non-Treaty Storage

The Non-Treaty Storage Agreement (NTSA) between BPA and BC Hydro is an operating agreement enabling use of some space in projects in Canada not governed by the Columbia River Treaty. BPA and BC Hydro executed a new long-term NTSA in April 2012, which provides flexibility in managing river operations through the spring and summer of 2015 (see attached). There are no financial implications under the NTSA contract for release of the 0.5 Maf

The May water supply forecast at The Dalles was below the threshold for the lowest 20th percentile of water years making an additional 0.5 Maf of water available from BPA's Active Non-Treaty storage per Section 9 of the 2012 NTSA (see attached). Following discussion with the Fish Passage Advisory Committee (FPAC), BPA requested release of the 0.5 Maf of dry period water. The water was released at a uniform rate from May 9, 2015, through June 26, 2015. It should be pointed out that there will be no Dry Year Non-Treaty releases this year as the right was exercised last year and cannot be used in consecutive years.

C. Summary

The dry conditions in 2015 presented many operational challenges. One of the most significant was that the TSR which is used to set Treaty rights and obligations changed significantly with each study. In addition, the high flows required to make up for limited outflow capability at Arrow in May, and deeper (lower) TSR targets each month, resulted in very high Treaty outflows in July and August forcing some water to be shifted between months.

The Treaty storage content was 782 ksfd (1.55 Maf) above the TSR level on 15 April 2015, stored under the Nonpower Uses Agreement. The TSR ended September 5.8 Maf below the full level providing more flow due to proportional draft than would otherwise occur. In addition to the Treaty operation, 0.5 Maf of Non-Treaty water was released across May and June.

2. Upper Columbia Projects

Libby Dam

Between July and September, Libby Dam drafts 10 feet from full during the upper 80% of Water Years as dictated by the May Final Forecast at The Dalles Dam. If the May Final Forecast at TDA is $\geq$ 72.5 Maf, then Libby drafts only 10 feet by the end of September. The volume of water in the upper 10 feet of reservoir at Libby Dam is approximately 455 Kaf, which distributed over the 92 days between July 1 and September 30, equates to 2.5 Kcfs per day.

Libby Dam drafts 20 feet from full over the same period mentioned above in the lower 20% of Water Years as dictated by the May Final Forecast at The Dalles Dam. If the May Final Forecast at TDA is < 72.5 Maf then Libby drafts 20 feet by the end of September. The volume of water in the upper 20 feet of reservoir at Libby Dam is approximately 892 Kaf, which distributed over the 92 days between July 1 and September 30, equates to an average of 4.9 Kcfs per day. It should be pointed out that the above volumes assume Libby refilled in any particular year. For example,

in 2015 Libby did not come close to refilling and as a result only 121 Kaf of water was drafted from the project between July and the end of September.

Hungry Horse

Between July and September, Hungry Horse drafts 10 feet from full during the upper 80% of Water Years as dictated by the May Final Forecast at The Dalles Dam. If the May Final Forecast at TDA is ≥ 72.5 Maf, then Hungry Horse drafts only 10 feet by the end of September. The volume of water in the upper 10 feet of reservoir at Hungry Horse is approximately 246 Kaf, which distributed over the 92 days between July 1 and September 30, equates to 1.3 Kcfs per day.

Hungry Horse Dam drafts 20 feet from full over the same period mentioned above in the lower 20% of Water Years as dictated by the May Final Forecast at The Dalles Dam. If the May Final Forecast at TDA is < 72.5 Maf then Hungry Horse drafts 20 feet by the end of September. The volume of water in the upper 20 feet of reservoir at Hungry Horse is approximately 481 Kaf, which distributed over the 92 days between July 1 and September 30, equates to an average of 2.6 Kcfs per day. Again, it should be pointed out that the above volumes assume Hungry Horse refilled in any particular year. For example, in 2015 Hungry Horse did not come close to refilling and as a result only 320 Kaf of water was drafted from the project between July and the end of September.

Grand Coulee

After refilling in late June/early July, Grand Coulee drafts during the summer period to help achieve flow objectives for salmonid out-migration. Grand Coulee drafts to an elevation of 1,280 ft. (10 ft. from full) by the end of August in years when the July Final April–August forecast at The Dalles is ≥ 92 Maf. If the same forecast is < 92 Maf, the end of August draft elevation for Grand Coulee is 1,278 feet. The volume of water in the upper 10 feet of reservoir at Grand Coulee (1,290 to 1,280 ft.) is approximately 791 Kaf, which distributed over the 62 days between July 1 and August 31, equates to an average of 6.4 Kcfs per day. The volume of water in the upper 12 feet of reservoir (1,290 to 1,278 ft.) at Grand Coulee is approximately 942 Kaf, which distributed over the 62 days between July 1 and August 31, equates to an average of 7.7 Kcfs per day.

The Lake Roosevelt Incremental Storage Release Project provides an additional draft of 1 foot at Grand Coulee in non-drought years and 1.8 feet in drought years, of which 1/3 is used to augment flows. The volume of water released by the Lake Roosevelt Storage Project is determined by the March Final April-through-September forecast at The Dalles Dam. When this forecast is ≥ 60 Maf, the project calls for a draft of Grand Coulee of 1 foot or 82.5 Kaf (1/3 for flow augmentation). When the same forecast is < 60 Maf, the project calls for a 1.8 ft draft or 132.5 Kaf (1/3 for flow augmentation). This water can be released in the April through June (spring) period or the July through August (summer) period; as such, it is difficult to assign a constant flow rate to these volumes each associated volume of water. To demonstrate that spring releases came from Grand Coulee, the project misses refill by the amount released over the

spring period. Grand Coulee drafts below the summer draft limit (above) by the amount released in both the spring and summer augmentation periods.

Banks Lake

Pumping from Grand Coulee to Banks Lake is reduced during the summer period. Irrigation demand from Banks Lake will be met by allowing Banks Lake to draft to 1,565 feet (5 feet from full).

3. Snake River Projects

Dworshak

Dworshak refills (1,600 ft.) by late June/early July. Beyond refill, Dworshak is drafted to elevation 1,535 ft. by the end of August for flow and temperature augmentation. At Dworshak, 1,029 Kaf of storage water exists between 1,535 ft. and full (1,600 ft.). If distributed evenly over the 62 days between July 1 and August 31, this volume would equate to an average flow rate of 8.4 Kcfs. Beyond August 31, Dworshak continues to draft to elevation 1,520 ft. by the end of September. 200 Kaf of storage water exists between the elevations of 1,535 ft. and 1,520 ft. at Dworshak. Distributed over the month of September, this volume would lead to an average flow rate of 3.4 Kcfs. It should be pointed out that Dworshak typically reaches elevation 1,520 ft. by mid-September. If distributed over 15 days of September, the 200 Kaf would result in an average flow of 6.7 Kcfs.

Upper Snake River Flow Augmentation

The Bureau of Reclamation attempts to provide 487 Kaf from projects in the upper Snake basins. Table 3 displays the volumes provided over the 2009–2014 period.

Table 3. Flow augmentation released from the Upper Snake River.

Year	Volume of Flow Augmentation released in the Upper Snake River for Flow Augmentation (Kaf)
2014	487
2013	427
2012	487
2011	487
2010	487
2009	487