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TO: Don Anderson, Instream Flow Coordinator
Upper Colorado River Endangered Fish Recovery
Program, USFWS

FROM: Steve Wolff, Administrator, Interstate Streams Division
Charlie Ferrantelli, River Basin Coordinator, Interstate Streams Division

RE: Wyoming's Depletion Accounting for 2011 - 2015, Little Snake River Basin; Yampa River PBO

As you know, the Yampa River Programmatic Biological Opinion (PBO; USFWS 2005) requires Wyoming to report to the Upper Colorado River Endangered Fish Recovery Program (Program) every 5-years the average annual volume of depletions (consumptive use[1]; CU) from the Little Snake River Basin within Wyoming. When annual depletions reach 66,000 acre-feet, the Service may reinitiate consultation under Section 7 of the Endangered Species Act. This memo serves to provide the Program with Wyoming's most recent depletion values.

Appendix D of the PBO describes certain accounting protocols to be used to provide depletions estimates. However, a different methodology is used in this report that Wyoming considers to be more accurate. The methodology tiers off of a project initiated by Wyoming in 2011 to provide annual depletion values for the entire Colorado River Basin (Green and Little Snake Basins) in Wyoming. The project was initiated to meet our responsibilities outlined under the Upper Colorado River Basin Compact of 1948 and is outlined in the Wyoming State Engineer's Office's Consumptive Use Determination Plan (2008), and our subsequent annual consumptive use reports (2011 – 2017).

Total depletions in the Little Snake basin of Wyoming are estimated as the sum of consumptive uses, including irrigated agriculture, livestock, municipal, domestic supply, transmountain diversions (exports), and man-made reservoir/wetland evaporation (Table 1).

As with all basins in Wyoming, the majority of CU from the Little Snake Basin is a result of irrigated agriculture. Hence, we have concentrated much of our accounting efforts on this sector of water use. The methods and tools used to assess CU from irrigated lands rely on remote sensed data and fully-sensored weather stations. The methods used to quantify the actual CU from irrigated lands are briefly described below. A more detailed description of methodologies can be found in Wyoming's Green River Basin annual consumptive use reports (Wyoming State Engineer's Office 2017).

[1] - The terms "river depletion" and "consumptive use" are used interchangeably and treated as being equivalent.

Irrigated acres for each year are estimated using a Normalized Difference Vegetation Index (NDVI) approach using infrared aerial imagery. NDVI identifies irrigated areas in agricultural areas based on how "green" the area appears in 4-band aerial imagery (Landsat or NAIP for example). For a detailed description of this methods see https://gisgeography.com/ndvi-normalized-difference-vegetation-index. Non-irrigated lands that are potentially green, such as vegetated riparian, mountainous, or municipal areas, are eliminated from consideration through a manual screening process prior to analysis. To enhance the difference between irrigated and non-irrigated lands, the analysis is performed using late summer images when most adjacent non-irrigated lands are brown. The estimated irrigated acres using NDVI for each year is shown in the table below.

Irrigated Acreage					
2011	**2012**	**2013**	**2014**	**2015**	**MEAN**
16,023	14,335	15,373	14,747	15,969	**15,289**

The total evapotranspiration (ET or CU) from irrigated lands that year is assessed via a couple different methodologies. The first method, like NDVI, can also be measured using Landsat imagery. In the years 2011 and 2015, we estimated CU using the surface energy balance model known as METRIC (Allen et al., 2007). Using Landsat satellite imagery and other datasets, METRIC makes it possible to measure the ET of each 30 m x 30 m parcel of a field, and to estimate CU on a sub-monthly time-scale. Because METRIC measures ET directly, factors like water shortages, growing conditions, and irrigation practices do not need to be separately assessed. In addition, crop coefficients are not used, which removes their associated inaccuracies. While expensive and time consuming, we are currently building a library of METRIC datasets for all years from 2011 forward.

In addition to METRIC, crop ET is calculated using the common Reference ET method under standard conditions. This method is a cross-check on the 2011 and 2015 METRIC results, and provides annual CU estimates via an energy balance approach. A crop reference ET was calculated using the Penman-Monteith equation and climate data collected from automated weather stations near Baggs, WY, managed by the State Engineer's Office. Crop coefficients for both grass hay and alfalfa were applied and weighted based on their respective acre coverage (ASCE, 2016). These crop coefficients from the ASCE Manual 70 were customized based on the May 1 through September 30 season, with one cutting for grass hay and two cuttings for alfalfa. Precipitation is considered to either runoff, transpire, or evaporate, with a negligible amount percolating deeper. Effective precipitation estimates, equal to total precipitation minus runoff, were subtracted from the calculated crop ET in order to quantify ET solely from irrigation water (NRCS, 1986). This is also referred to as the cumulative irrigation requirement (CIR). The CIR results from the Reference ET method were within 3% of the remote sensing method METRIC for 2011 and 2015, which was used to calculate the CIR in the Little Snake basin for those two years.

Livestock use data is not readily available for the Little Snake basin but has been compiled for the greater Green River basin by the Wyoming Water Development Commission (WWDC) in

their 2010 Green River Basin Plan. For the Little Snake Basin, the 2010 Basin Plan value was adjusted based on the ratio of the irrigated acres in the Little Snake to the entire Green River basin. Municipal use (Baggs and Dixon) is measured and reported via the Water Resources Data System's Public Water System Survey (http://wwdc.state.wy.us/surveys/surveys.html). Domestic use was obtained from WWDC's 2010 Green River Basin Plan and is based on population (WWC Engineering et al., 2010). Man-made reservoir/wetland evaporation values are based on estimates of the average surface area of these facilities and the free water surface evaporation rate from the National Oceanic and Atmospheric Administration. Evaporation from High Savery was obtained from the WWDC. The transmountain diversion and export of water is for the City of Cheyenne's Stage II Diversions, and it is measured by the SEO at the Hog Park tunnel inflows to Hog Park Reservoir. Industrial water uses are negligible, but they are generally accounted for in the municipal use values.

For the years 2011 to 2015, the estimated average annual total depletion basin-wide was 37,234 acre-feet per year. This is approximately 6,000 acre-feet less than prior depletion reports (such as the 2005 PBO). While this is significant, it is primarily due to decrease in exports by the City of Cheyenne, and it is not an artifact of methodology or other differences. Note that this decrease in water use by the City of Cheyenne is not expected to be a trend. In fact, the City does have the right to divert just over 20,000 acre-feet per year but have never taken more than 16,000 acre-feet in any given year.

Data supplied in this memo is only for 2011 – 2015 since that is the period requested. We do have similar data for the years of 2016, 2017 and 2018 (provisional).

Potential future uses in the basin are hard to assess. However, at this time they are considered to be nominal. One small new reservoir is being proposed for the basin. If built, this would be to provide late season irrigation water and would probably not support any newly irrigated acres. No significant increase in the basin's population is expected. At present, we don't think there is any reason to think we will approach our depletions "cap" of 66,000 acre-feet anytime in the foreseeable future.

Table 1: Consumptive Water Uses and Basin Depletions (acre-feet) in the Little Snake Basin of Wyoming for 2011 – 2015.

Use Sector	Baseline*	2011	2012	2013	2014	2015	MEAN
Agricultural (Irrigation)	26,905	26,893	30,758	27,464	23,418	21,103	**25,927**
Agricultural (Livestock)	N/A	274	274	274	274	274	**274**
Municipal	76	93	99	105	94	84	**95**
Domestic	N/A	246	246	246	246	246	**246**
Transmountain Diversions (Exports)	14,400	4,611	6,410	18,400	8,590	6,190	**8,840**
Reservoir/ Wetland Evaporation	1,202	1,852	1,852	1,852	1,852	1,852	**1,852**
TOTAL	42,583						**37,234**

* -From 2005 Yampa River Programmatic Biological Opinion (USFWS 2005)

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