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TO: David Graf, Instream Flow Coordinator
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FROM: Jeff Cowley, Administrator, Interstate Streams Division
Charlie Ferrantelli, River Basin Coordinator, Interstate Streams Division

RE: Wyoming's Depletion Accounting for 2016 – 2020, 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 depletion estimates. However, a different methodology is used in this report that Wyoming considers to be more accurate. The methodology is based on the method that the Wyoming State Engineer's Office's (WSEO) has established to estimate 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 WSEO Consumptive Use Determination Plan (2008), and our subsequent annual consumptive use reports (2011 – 2021).

Total depletions in the Little Snake basin of Wyoming are estimated as the sum of consumptive uses, including irrigated agriculture, livestock, municipal, domestic use, transmountain diversions (exports), and man-made reservoir/wetland evaporation. Since depletions from irrigation makes up the majority, more description is provided herein.

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 the WSEO's fully-sensored weather station near Baggs, WY. 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, 2021).

Irrigated acres for each year are estimated using a Normalized Difference Vegetation Index (NDVI) approach using Landsat data. NDVI is a measure of vegetation health that ranges from -1 to 1 based on the near-infrared and red reflectance bands. High NDVI values indicate healthy (i.e., green), high density vegetation, while low

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

NDVI values indicate low-density vegetation[2]. Non-irrigated lands that are potentially green, such as vegetated riparian, mountainous, or municipal areas, are filtered out through a screening process that relies upon data from the National Landcover Dataset and the USFWS National Wetlands Inventory, as well as manual adjustments as needed. To enhance the difference between irrigated and non-irrigated lands, the analysis is performed using mid to late summer images when the irrigated land is distinctly different than the adjacent lands. The estimated irrigated acres using NDVI for each year is shown in Table 1.

Table 1. Irrigated acres estimated using NDVI for the Little Snake River Basin of Wyoming.

Irrigated Acreage					
2016	2017	2018	2019	2020	**Avg**
15,316	14,996	11,526	16,132	13,733	**14,341**

ET from irrigation is calculated using the Penman-Monteith crop coefficient method and then adjusted using the satellite-based CU method called eeMETRIC[3]. The WSEO believes this to be the most accurate method of calculating depletions in the Little Snake River Basin that is available with current resources. This method uses agricultural climate data collected from the WSEO-managed automated weather station near Baggs, WY to calculate the alfalfa-based reference ET. Crop coefficients for both mountain meadows grass and alfalfa were applied and weighted based on their respective acreage. The mountain meadows crop coefficient is based on work conducted in Wyoming (Pochop and Burman, 1987, and Pochop et al., 1992). The alfalfa coefficients are from the ASCE Manual 70 and customized to have two cuttings, with timing based on local management customs, and customized season length based on temperature data (usually early May to late September). Effective precipitation estimates, calculated using the National Engineering Handbook (2004) Curve Number approach, were subtracted from the calculated crop ET in order to quantify ET solely from irrigation water to determine the irrigation water requirement (NIWR). Multiplying the NIWR by the irrigated acreage results in the potential depletion volume.

The potential depletion is the irrigation water consumption assuming full water supply, i.e., no headgates were regulated, that water was applied to all irrigated lands for the entire length of the season, and that the crop growth and management generally followed the crop coefficient curves. However, the Little Snake Basin water supplies, fields and management practices do not typically match these assumed criteria. Thus, many crops consume less than the potential depletion. Therefore, an adjustment is made to achieve an "actual depletion" estimate. This is done using a relationship that was established through an analysis of potential depletions, using Penman-Monteith, and actual depletions, using satellite-based eeMETRIC data acquired from the Upper Colorado River Commission (UCRC) and the Bureau of Reclamation (Reclamation) 2017-2020 Consumptive Use Study (CU Study). This relationship of actual to potential depletion is relatively consistent, ranging between 76% and 85%. We use the average of 80%. The WSEO plans to continue this method, using additional eeMETRIC data as it becomes available. In the future, the WSEO plans to work with the UCRC and Reclamation to start using eeMETRIC annually, which is widely considered to be one of the most accurate methods available and optimal for the Upper Colorado River Basin, based on the CU Study.

Other water use sectors include livestock, municipal, domestic supply, transmountain diversions (exports), and man-made reservoir/wetland evaporation. 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

[2] For a detailed description of this methods see https://gisgeography.com/ndvi-normalized- difference-vegetation-index.
[3] eeMETRIC, used as part of the ensemble of methods at the online ET tool OpenET, is described generally along with additional publications and references at https://openetdata.org/methodologies/.

adjusted based on the ratio of the irrigated acres in the Little Snake to the entire Green River basin. Since most hay is grown for livestock feed, we feel this is a valid adjustment method. Municipal use (Baggs and Dixon) is obtained from the 2016 and 2018 Water Resources Data System's Public Water System Survey reports (http://wwdc.state.wy.us/surveys/surveys.html), with a 50% return flow assumed here to estimate a net depletion. 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 at the tunnel inflow to Hog Park Reservoir and reported in the WSEO Division I Hydrographer Annual Reports[4]. Industrial water uses are negligible and are generally accounted for in the municipal use values.

For the years 2016 – 2020, the estimated average annual total depletion basin-wide was 38,623 acre-feet per year. This is approximately 1,400 acre-feet greater than the 2011 to 2015 depletion report; however, it is approximately 4,000 acre-feet less than the 2005 PBO. While this difference from the 2005 PBO is significant, it is primarily due to variations 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 (Table 2).

Table 2: Consumptive Water Uses and Basin Depletions (acre-feet) in the Little Snake Basin of Wyoming for 2016 to 2020

Use Sector	Baseline[A]	2016	2017	2018	2019	2020	2016 - 2020 Average
Agricultural (Irrigation)	26,905	31,470	28,533	24,903	26,524	28,731	**28,032**
Agriculture (Livestock)	N/A	322	322	322	322	322	**322**
Municipal	76	45	45	45	45	45	**45**
Domestic	N/A	267	267	267	267	267	**267**
Transbasin Diversions (Exports)	14,400	6,520	5,673	6,170	14,500	7,660	**8,105**
Reservoir/ Wetland Evaporation	1,202	1,852	1,852	1,852	1,852	1,852	**1,852**
TOTAL	42,583						**38,623**

Notes: A) From 2005 Yampa River Programmatic Biological Opinion (USFWS, 2005)

Data supplied in this memo is only for 2016 – 2020 since that is the period requested. We do have similar data for other years from 2011 to 2020, and provisional data for 2021.

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 believe we will approach our depletions "cap" of 66,000 acre-feet anytime in the foreseeable future.

[4] https://seo.wyo.gov/documentsdata/hydrographer-annual-reports

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