Appendix E

Indicator Gage Method

Reclamation's Method of Estimating the Effects of Irrigation Water Shortage on Agricultural Consumptive Water Use in the Upper Colorado River Basin

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Introduction

Water for irrigation in the In Upper Colorado River Basin (UCRB) comes primarily from snowmelt in adjacent mountains. Some irrigated lands receive an abundant water supply, while a significant portions of the irrigated acreage experience supply limitations every year. Whether due to an inadequate water supply, poor distribution facilities, or junior water rights, these lands receive water in the spring snowmelt season, but are usually shorted when stream flows decrease in July, August, and September. The purpose of this memo is to describe the 'indicator gage method' used by Reclamation in conjunction with its XCONS (Modified Blaney-Criddle) model to estimate consumptive water use of shorted irrigated lands in the Wyoming, Utah, and Colorado portions of the Upper Colorado River Basin (UCRB). Reclamation has not performed these calculations for the New Mexico portion of the UCRB since 1981, when Reclamation began publishing Consumptive Uses and Loses (CU&L) data provided by the state of New Mexico. The indicator gage method is used to estimate if and when shortages occur for pasture/hay and alfalfa crops based upon stream discharge measurements from stream gages in the vicinity of the shorted lands. This memo describes the origin of the indicator gage method, how it has evolved over time, and how the shortage information is used in Reclamation's overall consumptive use estimation process.

Origin of the Indicator Gage Method

The indicator gage method was developed using the irrigated lands statistics that were reported in the Final Report of the Engineering Advisory Committee to Upper Colorado River Basin Compact Commission (1948), and the "Type 1 study" performed in the 1960s. The Type 1 study was one of the reports and investigations collected for the Upper Colorado Region Comprehensive Framework Study (1971) which describes current (ca. 1970) water and land resource development in the region, and outlines methods and procedures for future development out to the year 2020.

The Type I study generated estimates of irrigated acreage for 57 contiguous 'evaluation units', which when taken, together cover the entirety of the UCRB (Figure 1). These geographic areas are referred to in many different ways in the reports of that era, including 'evaluation units', 'evaluation subareas', 'hydrologic subunits', and 'hydrologic subregions'. When a given evaluation unit crossed a state boundary, it was split so that each of the final evaluation units fell within only one state. The irrigated acreage within each evaluation unit was broken out by crop type, and whether the land received a full irrigation water supply or had supply limitations. All crops with the exception of pasture/hay and alfalfa were assumed to receive a full supply. Acreage estimates were obtained from tax records, census of agriculture data and Bureau of Reclamation crop reports, which were all reviewed by county extension agents and other people familiar with the areas under study.

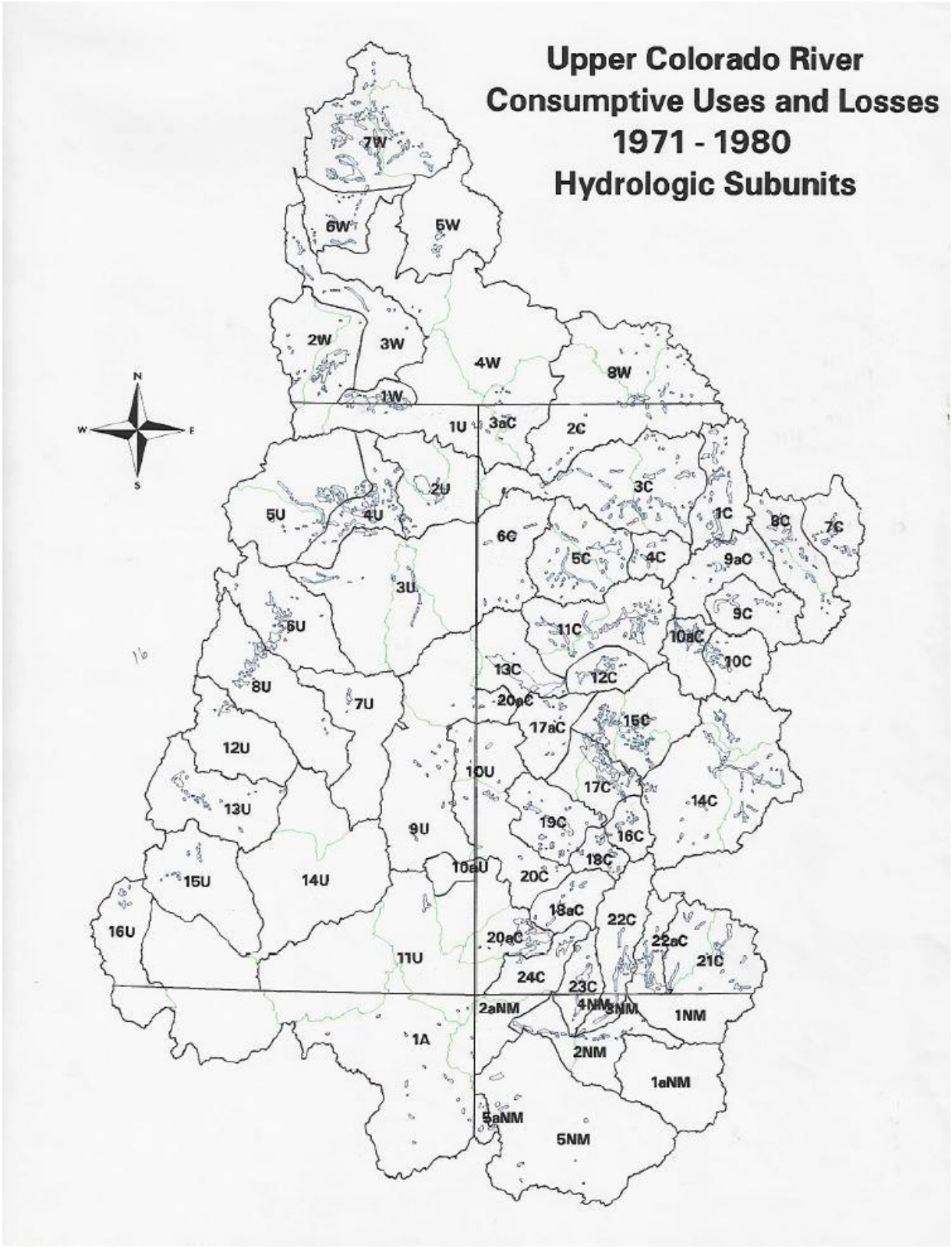

Figure 1. Upper Colorado River consumptive uses and losses evaluation units from the Type 1 study.

During the course of the Type 1 study, multiple years of data were obtained from local sources regarding the dates at which irrigation ceased for shorted lands within each evaluation unit. These cutoff dates varied from year to year, and required a laborious data gathering process. Reclamation desired a more efficient method to estimate cutoff dates, so Reclamation identified USGS gages on streams in the vicinity of shorted lands and developed empirical relationships between the irrigation cutoff dates and the late spring and summer flow rates in nearby gaged streams. For each evaluation unit, the average historical streamflow that had occurred on the average irrigation cutoff date for pasture/hay and alfalfa fields became the 'cutoff flows'. The dates at which cutoff flows at indicator gages are reached define the end of the irrigation seasons for shorted pasture/hay and alfalfa acreage. In all cases, cutoff flows for pasture/hay were greater than those for alfalfa (i.e. pasture/hay was shorted before alfalfa). Usually, a single stream gage was assigned to an entire evaluation unit; but occasionally two or more gages were used to identify cutoff dates for specific regions within an evaluation unit, or were averaged to define a single cutoff date for the entire evaluation unit.

It is unclear when the indicator gage method was first applied. For the 1971-75 Upper Colorado (UC) CU&L Report, Reclamation used the cutoff dates from the Type 1 study, but "with some adjustments made in each reporting year after taking into account the apparent magnitude of water supply in each evaluation subarea". The report provided no description of these 'adjustments'. The 1976-1980 CU&L report also provided no information on the procedure used to quantify water use on shorted lands. The first description of Reclamation's current 'indicator gage method' appears in the 1981-1985 UC CU&L report.

Evolution of the Indicator Gage Method

The indicator gage method has evolved over the past half century, and documentation of the initial work and the changes that have occurred since then are incomplete. The strength of the initial empirical relationships used to estimate irrigation cutoff dates from stream flows, or the specific procedures that were employed to change them in subsequent years are unknown. The information in this report was derived through analysis of consumptive uses and losses reports and technical appendices, archived XCONS model inputs and outputs, geospatial data, and hundreds of pages of miscellaneous notes and data sheets, many hand-written, that are stored at Reclamation's Technical Service Center in Denver, CO. It constitutes Reclamation's current understanding of the indicator gage process, but could be revised if additional relevant information is discovered.

This document discusses three aspects of the indicator gage method that have changed since its inception in 1971: 1) the geographic areas for which irrigation shortage is estimated, 2) the percentage of irrigated pasture/hay and alfalfa subject to shortage, and 3) the indicator gage and associated cutoff flow rates assigned to pasture/hay and alfalfa crops within each geographic area.

1) Changes to the geographic areas for which Irrigation shortage is estimated

When Reclamation first began estimating agricultural water use for the 1971 UC CU&L report, computations were performed and reported for each evaluation unit defined in the Type 1 study (Figure 1). But starting in 1981, the geographic areas for which agricultural water use was computed were changed from evaluation units developed during the Type 1 study to the intersection of counties and USGS 8-digit hydrologic units (county/HUC8s). The motivation for this change is unknown, but it appears

that Reclamation wished to standardize the boundaries of the spatial units for which it estimated agricultural consumptive use with the newly available hydrologic units first published by the USGS in the late 1970s. Also starting in 1981, Reclamation chose to simplify the indicator gage method. Whereas multiple stream gages and cutoff flows were sometimes used to estimate pasture/hay and alfalfa irrigation cutoff dates for a single evaluation unit (this occurred for 10 of the 57 evaluation units), the decision was made to assign only a single stream gage with a single set of pasture/hay and alfalfa cutoff flow rates to each county/HUC8.

The Type 1 evaluation units typically shared boundaries with HUC8s, but not always. When one or more county/HUC8s were entirely contained within a single evaluation unit that was assigned to a single stream gage, the transition from evaluation unit to county/HUC8 was unambiguous. Stream gage identifiers, cutoff flow rates, and percentages of pasture/hay and alfalfa acreage subject to shortage from the evaluation unit were transferred directly to the county/HUC8(s). When a particular evaluation unit had more than one associated stream gage and set of cutoff flows (which occurred in 10 out of 57 evaluation units), or when a single county/HUC8 contained irrigated acreage from more than one evaluation unit (which occurred in 22 of 81 county/HUC8s) decisions had to be made regarding which stream gage and flow rate data would be assigned to the county/HUC8(s) contained within the evaluation unit.

2) Changes in percentage of irrigated pasture/hay and alfalfa subject to shortage

The earliest documentation Reclamation was able to find related to the percentage of irrigated pasture/hay and alfalfa land that is subject to shortage was in a notebook titled "UC CU&L 1971-75 Data". Loose leaf pages contained hand-written acreages of all irrigated crops within each evaluation unit for the years 1971-74, plus the ca. 1970 irrigated crop acreages used in the Type 1 Study. For the pasture/hay and alfalfa classes, acreages for full-supply and shorted lands were tallied separately. Although there were significant differences for a few of the evaluation units, the Type 1 and 1971 percentage of shorted lands for pasture/hay and alfalfa generally corresponded well. For Colorado, 86% of the evaluation unit shortage percentages were within 5% of the listed Type 1 values, while 78% and 75% of the Utah and Wyoming shortage percentages, respectively, were within 5% of the Type 1 values.

Because Reclamation's CU&L Reports for the Upper Colorado Basin are published every five years, most major changes in percentage of shorted acreage values tended to occur between years ending in 00 and 01, or 05 and 06 (Figures 2 through 7). However, there was significant variation in shortage percentage estimates from year to year from 1971 to 1980. 1971 to 1975 showed moderate year-to-year variation, but the drought year of 1977 produced some severe anomalies. The increases in shorted percentages make sense given the reduced availability of irrigation water for that year. But there were apparent errors as well, where estimated shortages dipped to zero for several evaluation units – the opposite of what would normally occur during a drought year. 1981 to 1985 values generally stayed near the levels of the previous period, except half of the evaluation units in Utah showed significant decreases for shortage percentages for pasture/hay. While Utah's pasture/hay percentages recovered to previous levels in 1986, shortage percentage values for both pasture/hay and alfalfa in Colorado and Wyoming dropped precipitously that year. Wyoming's pasture/hay values returned to values seen in the early 1980s in 1996, while alfalfa values remained at zero. 1996 brought a slight further reduction to Colorado's pasture/hay and alfalfa classes, while Utah's percentages stabilized at levels similar to the original Type 1 values.

There is no record as to why the percentage of shorted pasture/hay or alfalfa acreage within any given evaluation unit or county/HUC8 was changed from one year to the next. The drastic nature of these changes from one five-year period to the next was most likely the reasoned opinion of the person performing the work; but such abrupt changes, especially when reversed a few years later, raise questions as to the reliability of the values. The current low shortage percentages for Colorado (typically 5% shortage for pasture/hay and 0% for alfalfa) seem questionable given estimates provided by the state of Colorado, the contrast to values in neighboring Utah and Wyoming (Figures 9 through 12), and the assessment of the Comprehensive Framework Study that 37% of the irrigated lands in the Upper Basin receive less than a full water supply in a typical year.

Figures 2 through 7 show how estimated percentages of pasture/hay and alfalfa subject to shortage have changed over time. However, as described in section 1) above, the spatial units for which shortage is estimated changed in 1981 from evaluation units from the Type 1 study (as shown in Figure 1) to county/HUC8s (as shown in Figures 8 – 12). Because county/HUC8s are not always neatly contained within single evaluation units, differences can be found between the shortage percentages for the evaluation units plotted in Figures 2 – 7, and shortage percentages for the county/HUC8s depicted as three-digit number pairs in Figures 9 – 12.

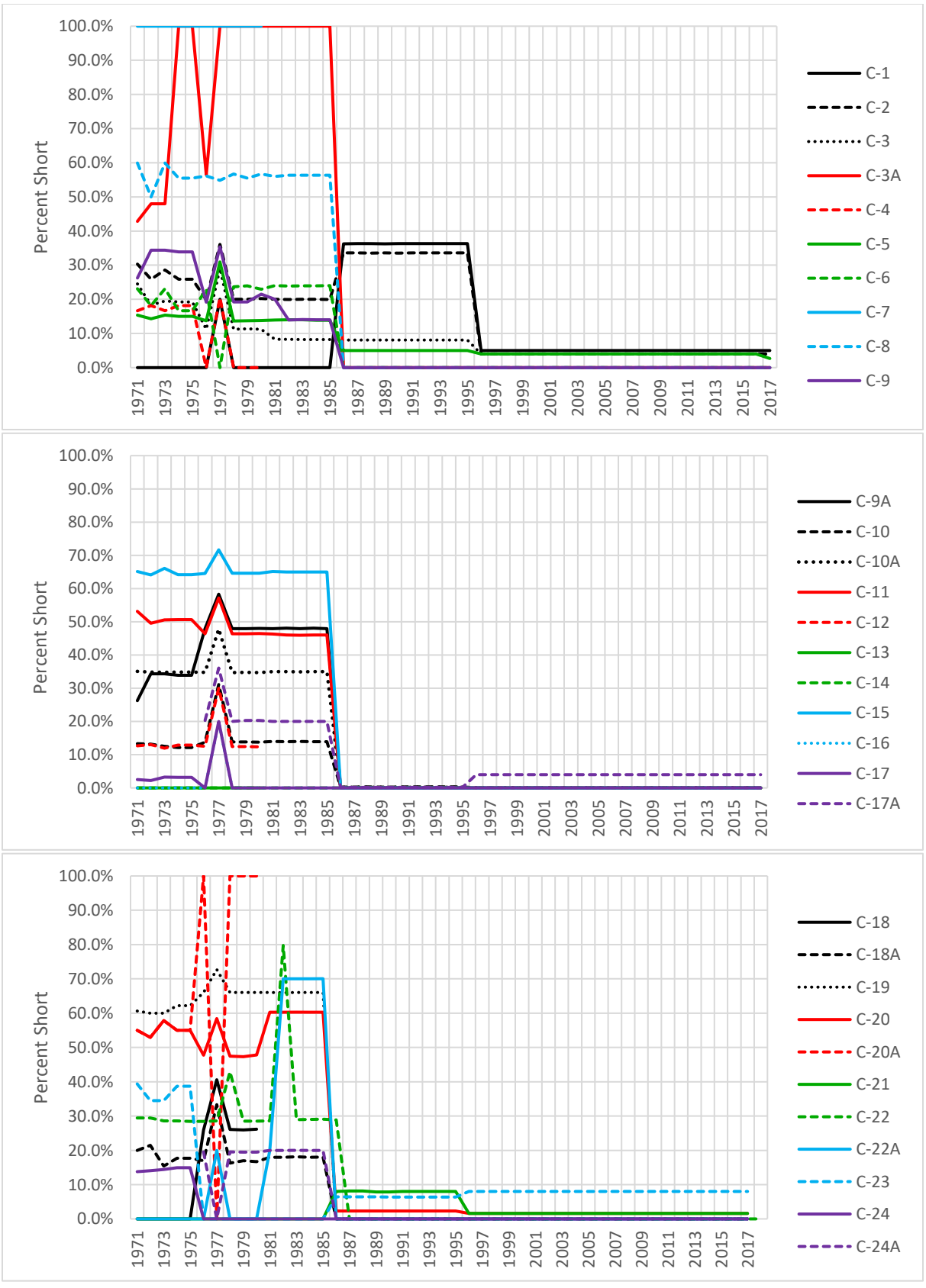

Figure 2. Change in percent of Alfalfa acreage that is shorted in Colorado from 1971 to 2017 by evaluation unit.

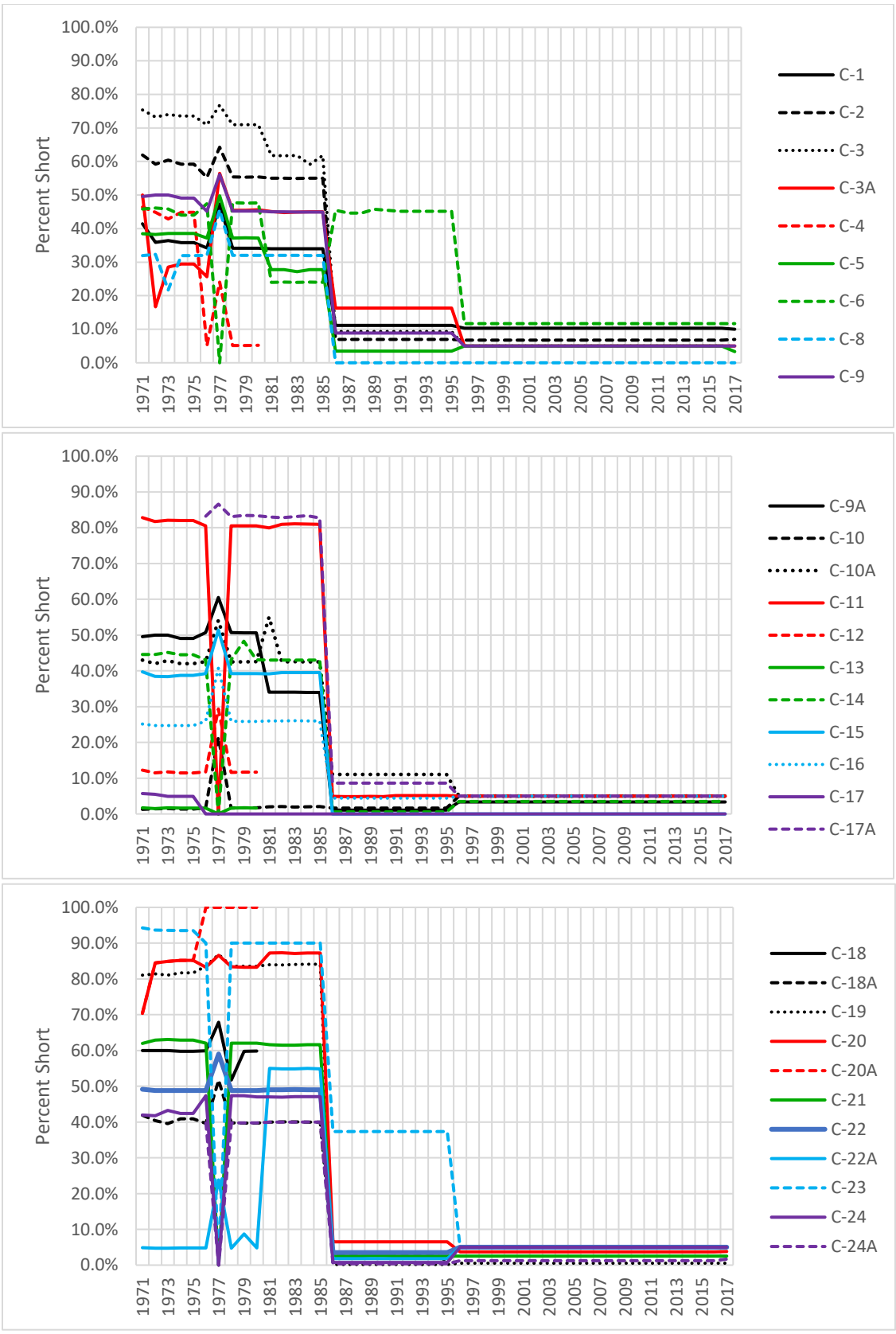

Figure 3. Change in percent of pasture/hay acreage that is shorted in Colorado from 1971 to 2017 by evaluation unit

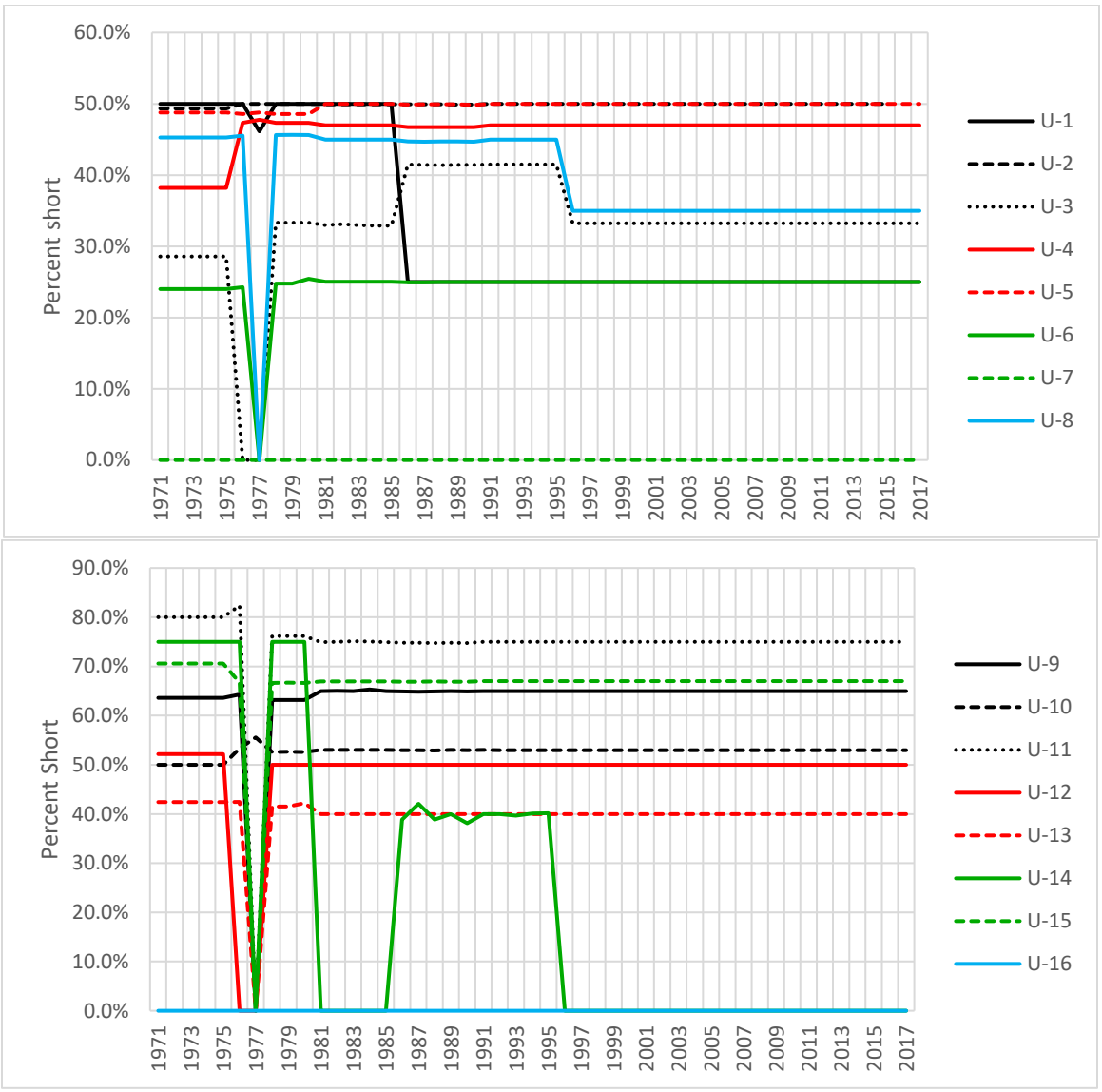

Figure 4. Change in percent of alfalfa acreage that is shorted in Utah from 1971 to 2017 by evaluation unit

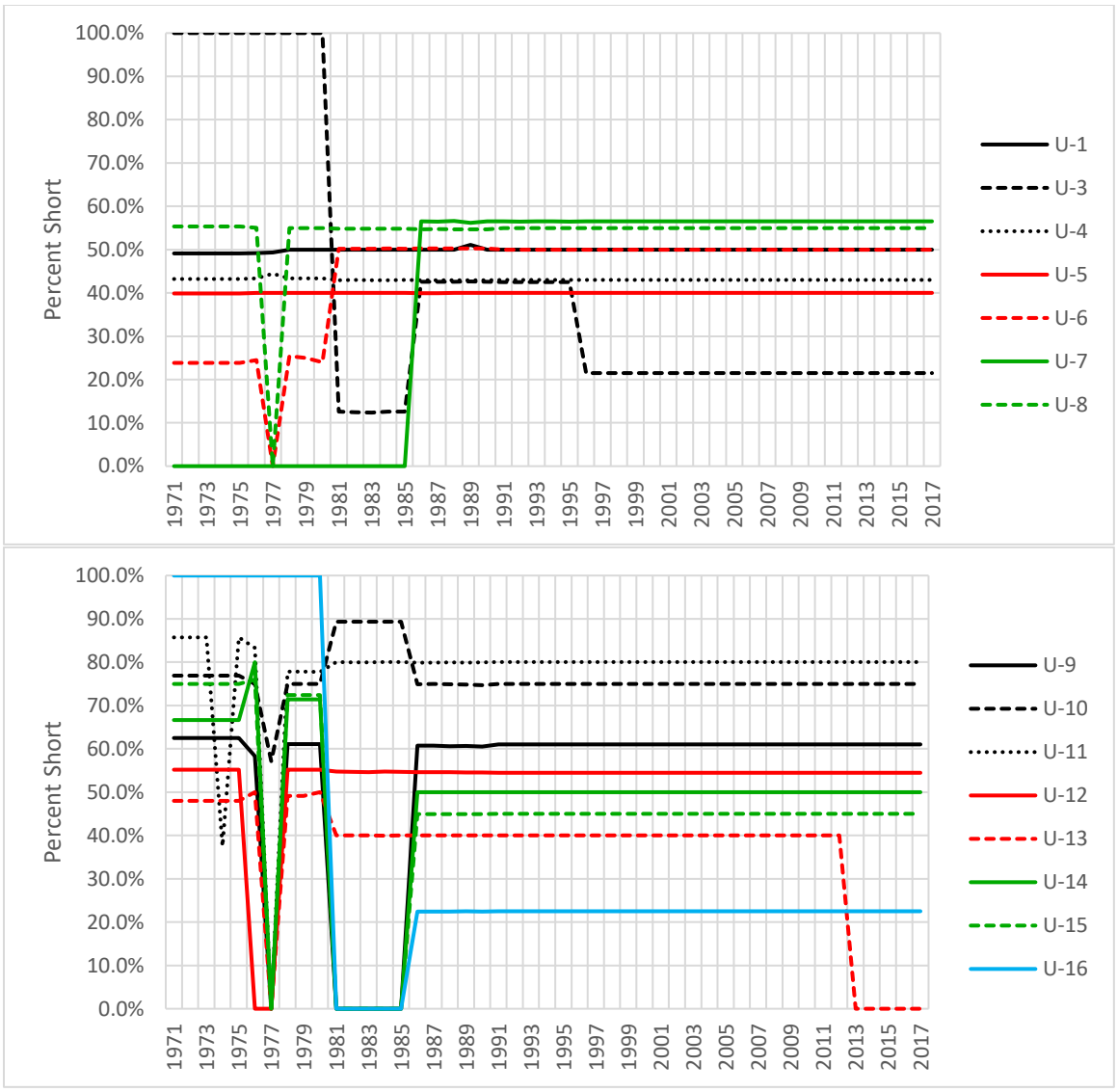

Figure 5. Change in percent of pasture/hay acreage that is shorted in Utah from 1971 to 2017 by evaluation unit

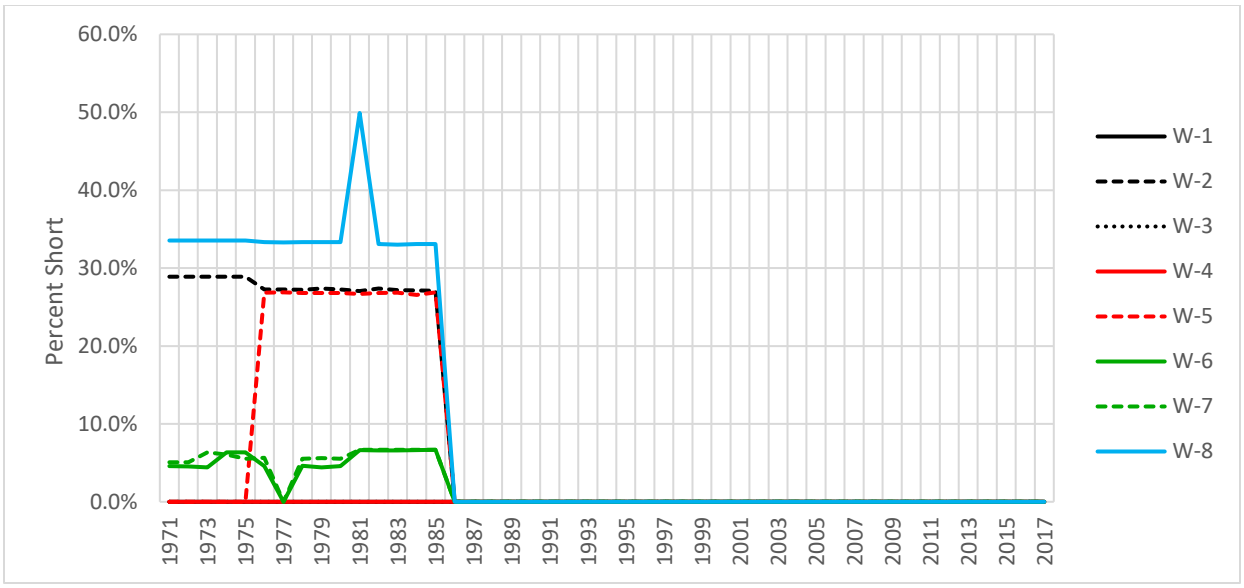

Figure 6. Change in percent of alfalfa acreage that is shorted in Wyoming from 1971 to 2017 by evaluation unit

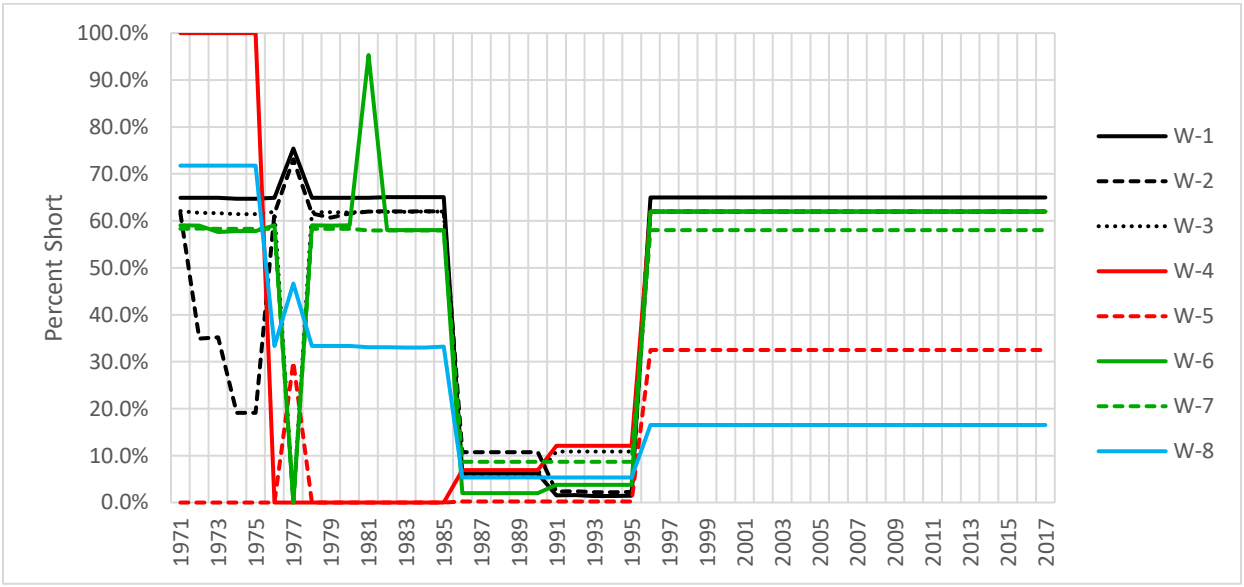

Figure 7. Change in percent of pasture/hay acreage that is shorted in Wyoming from 1971 to 2017 by evaluation unit

3) Changes to indicator gages and cutoff flow rates

Due to changes in conditions on the ground and the retirement of some indicator stream gages, the original set of indicator gages and associated cutoff flows have had to evolve over time. Although Reclamation has located some documentation of indicator gage assignments from the mid-1980s and early 1990s, analysis of changes to the shortage percentages, stream gage assignments, and cutoff flows is hindered by the lack of reliable historical data. There is a complete lack of information on the original stream gage assignments and cutoff flows, and no documentation exists that explains the reasoning behind changes between current and historical databases.

Reclamation was able to locate just one undated data sheet containing a full set of indicator gages and cutoff flows for each evaluation unit. From the dates of operation of the listed USGS stream gages, this data sheet appears to have been compiled in the mid-1990s. Comparison of the stream gages and cutoff flows on this list to those currently being used by Reclamation provides some insight into the speed at which the indicator gage method has evolved. This comparison shows that 43% of the stream gages used in the mid-1990s have been replaced by other gages. Of the 57% of the current stations that were being used in the mid-1990s, the current cutoff flows matched the documented flows for 74% of the stations. Of the remaining 26% of current gages, 10% used alfalfa cutoff flows for pasture/hay, and the remaining 16% used completely different cutoff flows. The origins of those different cutoff flows are unknown. Cutoff flows are provided in Table 1.

The characteristics of indicator gage assignments and percentages of pasture/hay and alfalfa crops that are subject to shortage are best conveyed graphically. Figures 8 through 12 show indicator stream gage locations and associated irrigated lands for the entire UCRB and for the individual states of Colorado, Utah, and Wyoming. Color coding was used to associate indicator gages with associated acreage. Fields depicted in black are not subject to shortage, and assume a full irrigation water supply (226,319 acres). Fields depicted in grey are those within the state of New Mexico, which Reclamation does not include in their analysis (100,576 acres). Fields depicted in the three shades of purple identify fields without an associated stream gage.

- Agricultural fields for which no shortage information is present in the Reclamation database (7,481 acres) are shaded in the lightest shade of purple. These fields are assumed to have a full water supply.
- Fields that are using historical average cutoff dates because the identified stream gage is no longer in operation are shown in the medium shade of purple (192,530 acres).
- Fields with a suspected incorrect stream gage association are shown in the darkest shade of purple (30,151 acres). The dark purple fields in the Roaring Fork Valley near Aspen Colorado are associated with a gage on the White River in Utah (about 200 km away), and the dark purple fields in Utah along the Utah/Wyoming border are associated with a stream gage on a tributary to the Green River above Fontenelle Reservoir in Wyoming (about 140 km away). The locations of the erroneously assigned gages are not shown on the map.

Figures 9 through 12 also show two 3-digit numbers associated with county/HUC8 polygons. These numbers identify the percentage of pasture/hay acreage (first three numbers) and alfalfa acreage (second three numbers) within each county/HUC8 that is subject to shortage.

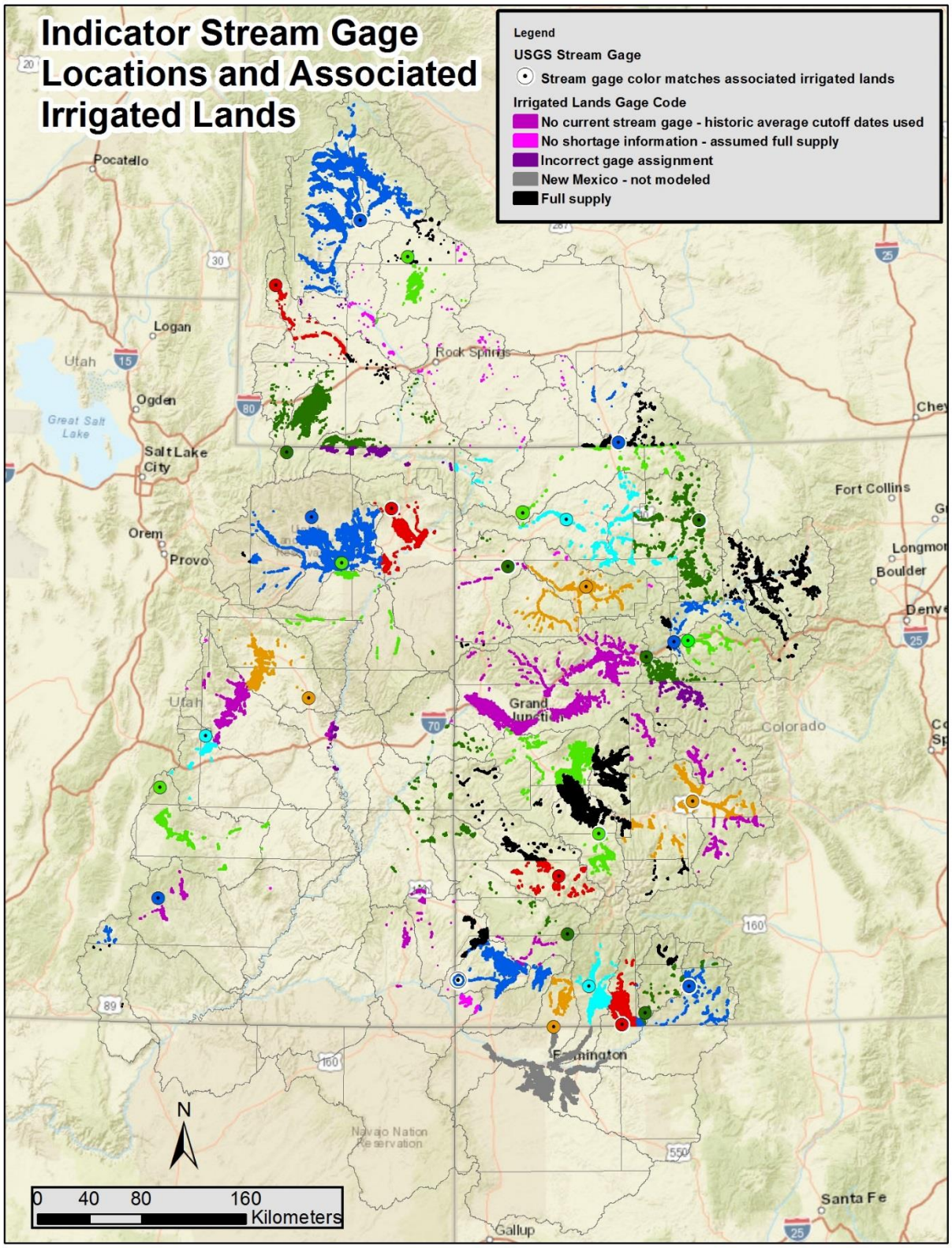

Figure 8. Indicator stream gage locations and associated irrigated lands within the Upper Colorado River Basin. Light grey lines show County/HUC8 boundaries.

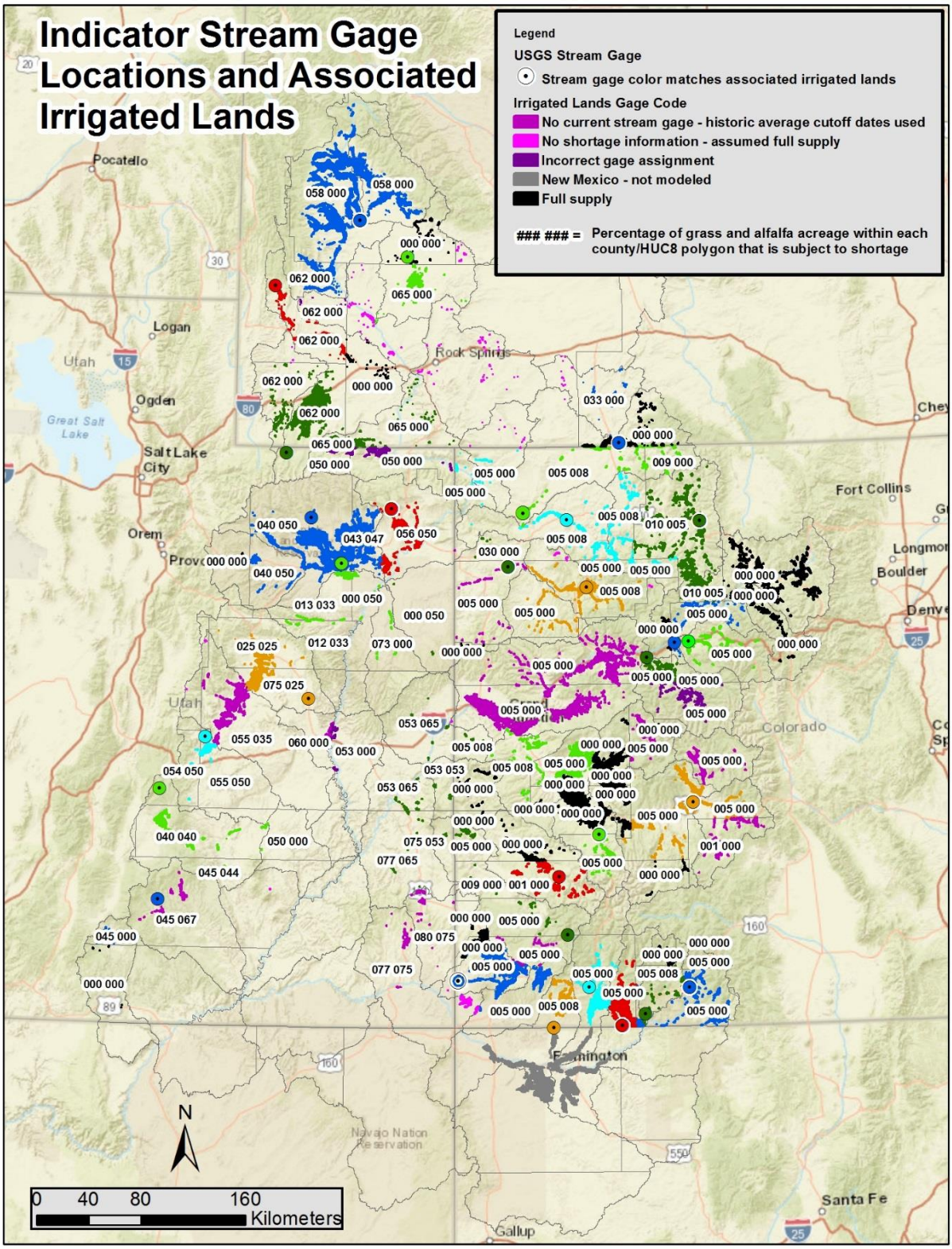

Figure 9. Indicator stream gage locations and associated irrigated lands within the Upper Colorado River Basin. Light grey lines show County/HUC8 boundaries. Consecutive 3-digit numbers indicate the percentage of pasture/hay and alfalfa acreage that is subject to shortage within each county/HUC8.

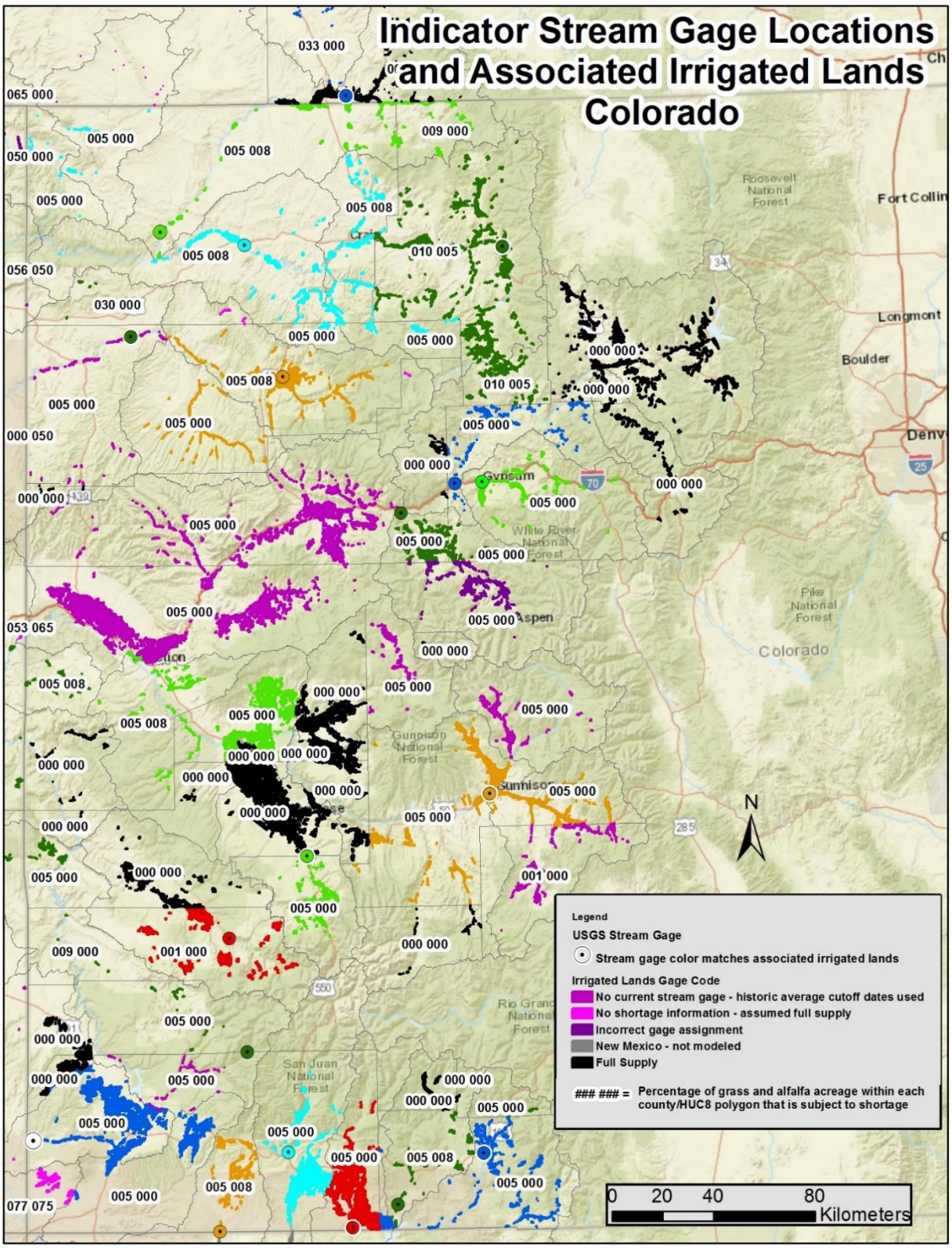

Figure 10. Indicator stream gage locations and associated irrigated lands within the Upper Colorado River Basin in Colorado. Light grey lines show County/HUC8 boundaries. Consecutive 3-digit numbers indicate the percentage of pasture/hay and alfalfa acreage that is subject to shortage within each county/HUC8.

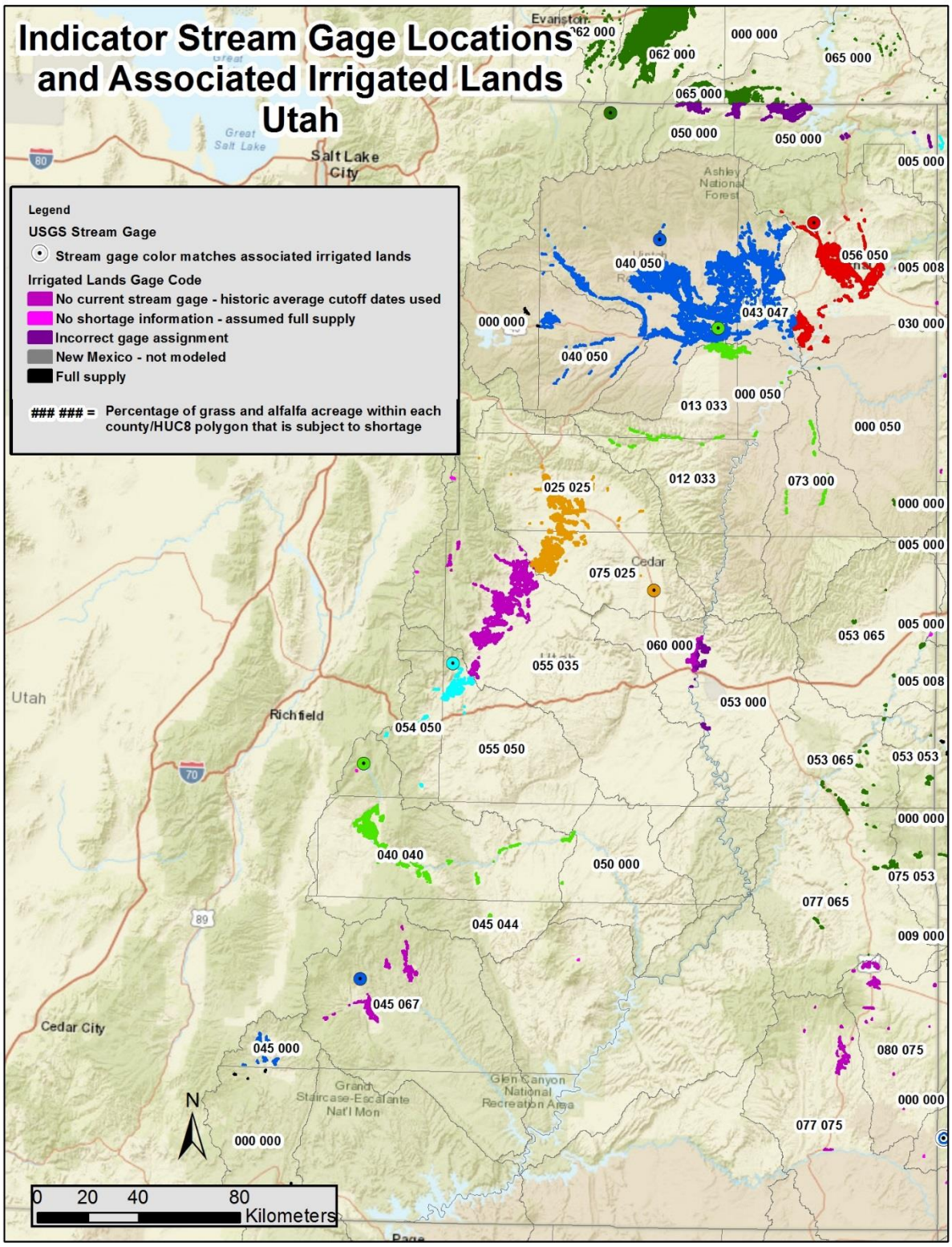

Figure 11. Indicator stream gage locations and associated irrigated lands within the Upper Colorado River Basin in Utah. Light grey lines show County/HUC8 boundaries. Consecutive 3-digit numbers indicate the percentage of pasture/hay and alfalfa acreage that is subject to shortage within each county/HUC8.

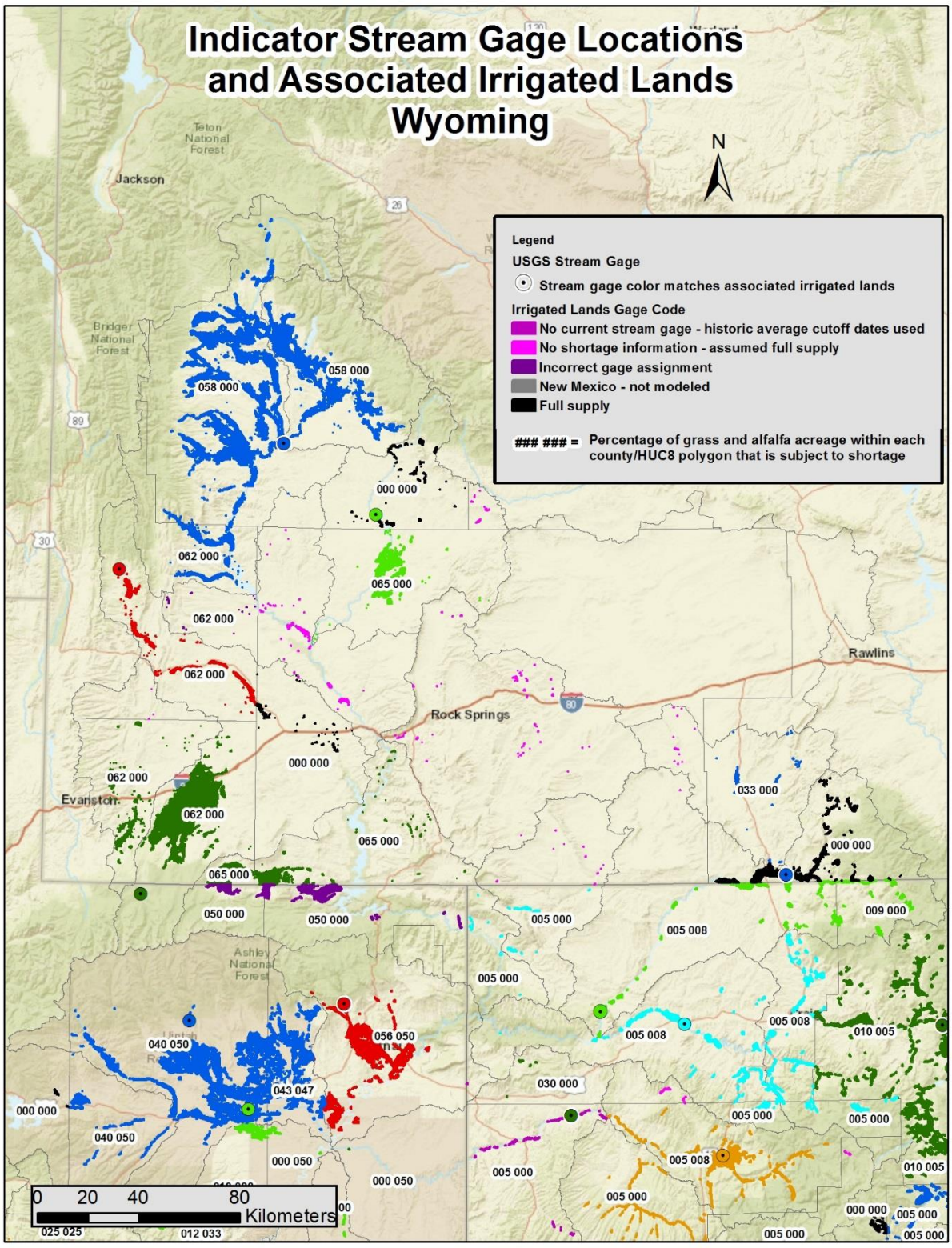

Figure 12. Indicator stream gage locations and associated irrigated lands within the Upper Colorado River Basin in Wyoming. Light grey lines show County/HUC8 boundaries. Consecutive 3-digit numbers indicate the percentage of pasture/hay and alfalfa acreage that is subject to shortage within each county/HUC8.

Current Status of the Indicator Gage Method

When it was developed nearly 50 years ago, the indicator gage method was an innovative way to estimate the effect of variable irrigation water supplies from year to year on agricultural consumptive use. But its accuracy has likely degraded over time for a number of reasons.

In all likelihood, the switch from Type 1 evaluation units to county/HUC8 polygons resulted in a significant degradation of the accuracy of the original indicator gage method. The most extreme example of error introduced by this switch was the assignment of a stream gage on Buzzard Creek on the north side of the Grand Mesa in Colorado as the indicator gage for agricultural lands within Mesa County, Colorado and hydrologic unit 14010005. This county/HUC8 contains all irrigated acreage within the Plateau Creek drainage north of Grand Mesa and the entire Grand Valley of Colorado (over 78,000 irrigated acres). Buzzard Creek is a minor, unregulated tributary to Plateau Creek upstream of the Grand Valley whose cutoff flows were set at 13 and 10 cfs for pasture/hay and alfalfa. Its flow is not likely to be well correlated with water supply for the agricultural lands with senior water rights on the Colorado River in the Grand Valley.

There is also some question as to reliability of the stream gage and cutoff flow assignments that are used in current Reclamation calculations. It is impossible to definitively assess the severity of the problem given the lack of documentation, but some general trends can be identified. Of the 85 county/HUCs for which Reclamation currently calculates shortage:

- 5 are linked to stream gages that have been inactive for a minimum of 8 years
- 7 have almost certainly been assigned to incorrect stream gages
- 1 has cutoff flows developed for a gage on the Gunnison River main stem being applied to a gage on an upstream tributary.

There has also been significant water resources development in the UCRB since the indicator gage method was developed. Flood irrigation has been replaced by sprinkler irrigation in many areas, and five new reservoirs have been completed in the UCRB: Starvation Reservoir, UT (1970), Strawberry Reservoir, UT (1972), McPhee Reservoir, CO (1985), Ridgway Reservoir, CO (1987), and Wolford Mountain Reservoir, CO (1996). These changes might affect historic relationships between discharge in selected indicator streams and shortage onset dates.

Finally, when calculating consumptive water use, Reclamation assumes that agricultural consumptive use on shorted lands within any county/HUC8 simply stops on the date at which flows in the associated indicator stream reach their pasture/hay and alfalfa cutoff values. However, this may not be the correct procedure. Members of the UCRC Consumptive Use Working Group have mentioned that this processing protocol does not account for the ability of crops to utilize moisture remaining in the soil after the final irrigation event. A memo from John E. Redlinger to the Chief of Reclamation's Water Resources Branch (May 16, 1978) indicates that the original indicator gage method may have accounted for use from the soil reservoir. The memo says:

> "As expected, this shortened season will vary considerably throughout the basin depending upon the local irrigation practices and streamflow conditions. Both the Engineering Advisory Committee's Report in 1948 and the 1965 Type I study addressed this irrigation characteristic in their estimates of consumptive use. Their primary means for estimating the short supply crop's

consumptive use was to establish a cutoff date which would prematurely end the growing season **two to three weeks after the estimated date of final irrigation** *(emphasis added)*."

Current Application of the Indicator Gage Method

Reclamation currently uses the Modified Blaney-Criddle model without an elevation adjustment to generate estimates of irrigated crop consumptive use across the UCRB on a county/HUC8 scale. The Modified Blaney-Criddle model requires inputs that define the growing season start and end dates. Typically, the start date of a crop (i.e., the date at which calculation of evapotranspiration begins) is determined by the model using linearly interpolated mean monthly temperatures. When the threshold monthly average temperature is reached for a given crop, the model begins calculating the water consumed by that crop. Temperature-based growing season end dates can be determined by the model in a similar fashion. Alternatively, they can be determined by a fixed growing season length, or they can be defined by the user. The last option allows for modeling the effect of shortage. The cutoff date determined by the indicator gage method is specified as the end date for modified Blaney-Criddle calculations, effectively zeroing out ET from all shorted lands after the cutoff date.

Cutoff dates for each county/HUC8 are determined by analyzing its associated indicator stream flow data, which is obtained from the USGS at https://waterdata.usgs.gov. Many streams show significant variation in their yearly recessional hydrographs, which can result in difficulty in determining when the flow in the stream falls below the cutoff rate. In an attempt to eliminate the subjective nature of this determination and to make the results more reproducible, an exponential smoothing procedure was adopted in 2005 that looks at stream flow data +- 13 days from the date for which an estimate is being calculated. This procedure utilizes an averaging scheme which assigns a higher weight to data points close to the date in question. Equation 1 shows the calculation for day 14 of an arbitrary 27-day time series.

Equation 1.

$$Qs14 = (\text{sum}(Q10{:}Q18) - ((\text{sum}(Q1{:}Q9) - 2*\text{sum}(Q10{:}Q18) + \text{sum}(Q19{:}27)) * (((9-1)^2) / (24 * (9^2)))))/9$$

Where:

Qs14 = smoothed stream flow for day 14 in an arbitrary 27-day time series

Q# = measured stream flow at day # (+- 13 days from the central value of 14)

By performing this smoothing, cutoff dates become easier to select. Figure 12 is a graph of the hydrograph of USGS gage 09205000, New Fork River near Big Piney, WY for 2017. The circles indicate raw data and the line shows the data smoothed using the procedure developed.

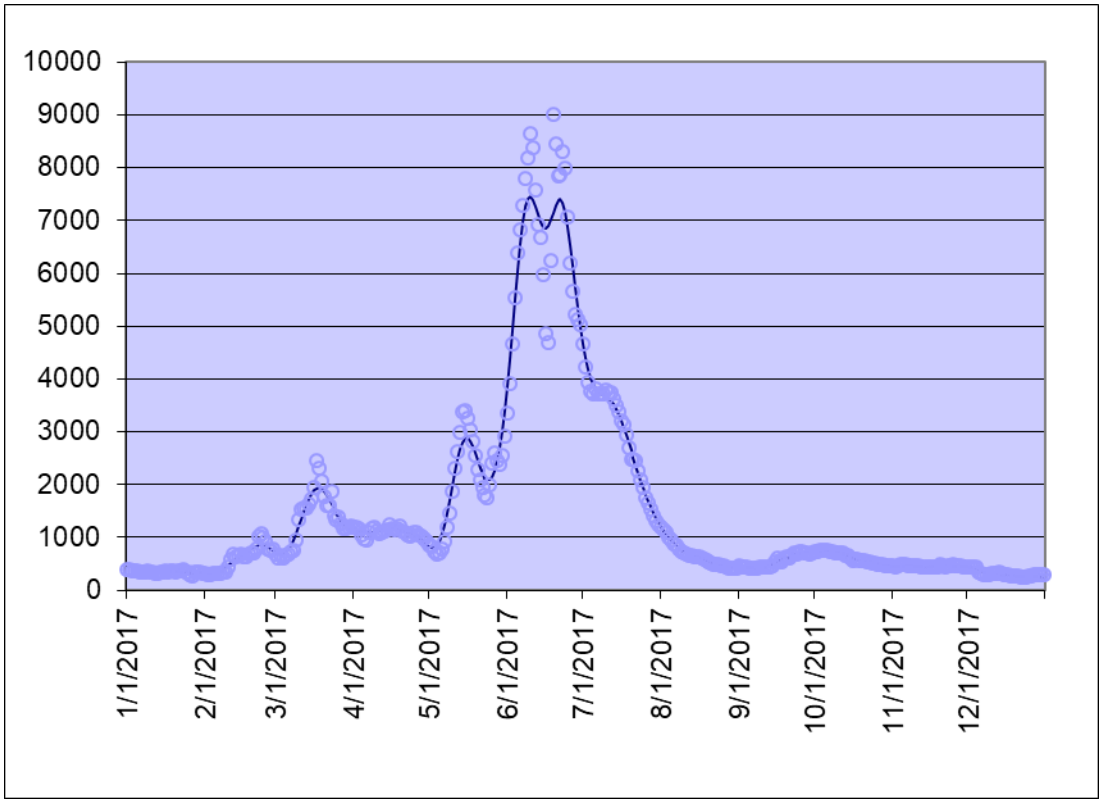

Figure 13. 2017 Flow hydrograph for USGS Stream Gage 09205000, New Fork River near Big Piney, WY

Final ET volume (AF) for each county/HUC8 is calculated by multiplying the calculated ET depths for shorted and full-supply crops by their respective acreages. Shorted pasture/hay and alfalfa acreage for each county/HUC8 is calculated by multiplying the total irrigated acreage for the county/HUC8 by the shortage percentage values listed in Table 1. These acreages are multiplied by ET estimates for the abbreviated growing season defined by calculated irrigation shutoff dates. Total pasture/hay and alfalfa acreage minus shorted acreage yields the full supply acreage, which is multiplied by ET estimates calculated for the entire growing season.

Separate XCONS model runs are made for pasture/hay and alfalfa: one assuming a full water supply for all irrigated lands and the other using the specified cutoff dates. Subtracting the estimated depletion (ET volume) from the shortage run from that from the full supply run produces a volume estimate of shortage.

Table 1: Current Reclamation database of USGS gages, cutoff flows, and shortage percentages for county/HUC8s within the Upper Colorado River Basin.

State	County	HUC8	USGS Gage	Cutoff Flow (cfs)		Shorted Acreage Percentage	
				Pasture	Alfalfa	Pasture	Alfalfa
Colorado	ARCHULETA	14080101	09342500	1100	N/A	5%	0%
Colorado	ARCHULETA	14080102	09349800	190	160	5%	8%
Colorado	DELTA	14020005	09147500	650	N/A	5%	0%
Colorado	DOLORES	14030002	09165000	89	N/A	5%	0%
Colorado	EAGLE	14010001	09070500	2510	N/A	5%	0%
Colorado	EAGLE	14010003	09070000	740	N/A	5%	0%

State	County	HUC8	USGS Gage	Cutoff Flow (cfs)		Shorted Acreage Percentage	
				Pasture	Alfalfa	Pasture	Alfalfa
Colorado	EAGLE	14010004	09085000	1140	N/A	5%	0%
Colorado	GARFIELD	14010004	09085000	900	N/A	5%	0%
Colorado	GARFIELD	14010005	09089500	13	N/A	5%	0%
Colorado	GARFIELD	14010006	09081600	95	N/A	5%	0%
Colorado	GARFIELD	14050007	09306290	N/A	N/A	0%	0%
Colorado	GRAND	14010001	09034250	N/A	N/A	0%	0%
Colorado	GUNNISON	14020001	09111000	870	N/A	5%	0%
Colorado	GUNNISON	14020002	09114500	870	N/A	5%	0%
Colorado	GUNNISON	14020003	09114500	870	N/A	5%	0%
Colorado	LA PLATA	14080101	09354500	220	N/A	5%	0%
Colorado	LA PLATA	14080104	09361500	630	N/A	5%	0%
Colorado	LA PLATA	14080105	09366500	20	18	5%	8%
Colorado	MESA	14010005	09097500	13	N/A	5%	0%
Colorado	MESA	14010006	09089500	13	N/A	5%	0%
Colorado	MESA	14020005	09147500	650	320	5%	8%
Colorado	MESA	14030001	09165000	89	78	5%	8%
Colorado	MINERAL	14080101	09165000	89	N/A	5%	0%
Colorado	MOFFAT	14040106	09251000	970	N/A	5%	0%
Colorado	MOFFAT	14040109	09251000	970	N/A	5%	0%
Colorado	MOFFAT	14050001	09251000	970	720	5%	8%
Colorado	MOFFAT	14050002	09251000	970	720	5%	8%
Colorado	MOFFAT	14050003	09260000	96	30	5%	8%
Colorado	MOFFAT	14050007	09306290	720	N/A	30%	0%
Colorado	MONTEZUMA	14080107	09372000	55	N/A	5%	0%
Colorado	MONTEZUMA	14080202	09372000	55	N/A	5%	0%
Colorado	MONTROSE	14030002	09165000	89	N/A	5%	0%
Colorado	OURAY	14020006	09147500	650	N/A	5%	0%
Colorado	PITKIN	14010004	09306500	750	N/A	5%	0%
Colorado	RIO BLANCO	14050001	09251000	970	N/A	5%	0%
Colorado	RIO BLANCO	14050002	09251000	970	N/A	5%	0%
Colorado	RIO BLANCO	14050005	09304500	660	570	5%	8%
Colorado	RIO BLANCO	14050006	09304500	660	N/A	5%	0%
Colorado	ROUTT	14010001	09239500	220	N/A	5%	0%
Colorado	ROUTT	14050001	09239500	220	125	10%	5%
Colorado	ROUTT	14050003	09260000	130	N/A	9%	0%
Colorado	SAN MIGUEL	14030002	09165000	89	N/A	9%	0%
Colorado	SAN MIGUEL	14030003	09172500	192	N/A	1%	0%
Utah	CARBON	14060005	09295000	540	450	12%	33%
Utah	CARBON	14060007	09314500	40	35	25%	25%
Utah	DAGGETT	14040106	09210500	44	39	50%	50%
Utah	DUCHESNE	14060003	09292500	146	128	40%	50%
Utah	DUCHESNE	14060004	09292500	146	128	40%	50%
Utah	DUCHESNE	14060005	09295000	540	450	13%	33%
Utah	EMERY	14060005	09295000	N/A	N/A	0%	0%

State	County	HUC8	USGS Gage	Cutoff Flow (cfs)		Shorted Acreage Percentage	
				Pasture	Alfalfa	Pasture	Alfalfa
Utah	EMERY	14060007	09314500	40	35	75%	25%
Utah	EMERY	14060008	09330230	90	N/A	60%	0%
Utah	EMERY	14060009	09330230	90	82	55%	35%
Utah	EMERY	14070002	09330500	68	62	55%	50%
Utah	GARFIELD	14070003	09329050	14	13	45%	44%
Utah	GARFIELD	14070005	09330230	90	82	45%	67%
Utah	GARFIELD	14070007	09337000	4.5	N/A	45%	0%
Utah	GRAND	14030001	09165000	89	78	53%	65%
Utah	GRAND	14030004	09165000	89	78	53%	53%
Utah	GRAND	14030005	09165000	89	78	53%	65%
Utah	GRAND	14060008	09165000	89	N/A	53%	0%
Utah	SAN JUAN	14030002	09165000	89	78	75%	53%
Utah	SAN JUAN	14030005	09165000	89	78	77%	65%
Utah	SAN JUAN	14080201	09371500	41	37	77%	75%
Utah	SEVIER	14070002	09330500	68	62	54%	50%
Utah	UINTAH	14040106	09210500	44	N/A	50%	0%
Utah	UINTAH	14050007	09306290	N/A	650	0%	50%
Utah	UINTAH	14060001	09266500	96	89	56%	50%
Utah	UINTAH	14060002	09266500	96	89	76%	50%
Utah	UINTAH	14060003	09292500	146	128	43%	47%
Utah	UINTAH	14060005	09295000	N/A	450	0%	50%
Utah	UINTAH	14060006	09295000	540	N/A	73%	0%
Utah	WAYNE	14070003	09329050	14	13	40%	40%
Utah	WAYNE	14070004	09329050	14	N/A	50%	0%
Wyoming	CARBON	14050004	09257000	30	N/A	33%	0%
Wyoming	LINCOLN	14040101	09205000	570	N/A	62%	0%
Wyoming	LINCOLN	14040103	09217900	39	N/A	62%	0%
Wyoming	LINCOLN	14040107	09223000	380	N/A	62%	0%
Wyoming	SUBLETTE	14040101	09205000	570	N/A	58%	0%
Wyoming	SUBLETTE	14040102	09205000	570	N/A	58%	0%
Wyoming	SWEETWATER	14040104	09213500	45	N/A	65%	0%
Wyoming	SWEETWATER	14040106	09217900	39	N/A	65%	0%
Wyoming	UINTA	14040106	09217900	39	N/A	65%	0%
Wyoming	UINTA	14040107	09217900	39	N/A	62%	0%
Wyoming	UINTA	14040108	09217900	39	N/A	62%	0%

References

Upper Colorado Region State-Federal lnter-Agency Group I Pacific Southwest Inter -Agency Committee I Water Resources Council (1971), Upper Colorado Region Comprehensive Framework Study, 112 pp.