Historical Crop Consumptive Use Analysis

White River Basin

Final Report
2015

Acknowledgments

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Historical Crop Consumptive Use

White River Basin

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1.0 Executive Summary

The White River Basin historical crop consumptive use analysis was performed on a monthly basis for the period from 1950 through 2013 to support the Colorado Decision Support System (CDSS). The CDSS project was developed jointly by the State of Colorado Water Conservation Board and the Division of Water Resources. The objective of the historical crop consumptive use portion was to quantify 100 percent of the basin's historical crop consumptive use. This report documents the input and results of the historical crop consumptive use analysis updated in 2015.

Information used in this model dataset is based on available data collected and developed through the CDSS, including information recorded by the State Engineer's Office. The model dataset and results are intended for basin-wide planning purposes. Individuals seeking to use the model dataset or results in any legal proceeding are responsible for verifying the accuracy of information included in the model.

1.1 Background

The White River Basin is located in northeastern Colorado and encompasses approximately 3,570 square miles. The North and South Forks of the White River originate in the highlands of the Flat Tops formation at about 11,000 feet and flows westerly into Utah through Rangely, Colorado at an elevation of 5,280 ft. Major tributaries in the White River basin include Big Beaver Creek, the North, and South Forks of the White River, Piceance Creek, Yellow Creek, and Douglas Creek. Most of the runoff is attributable to snowmelt from the higher elevation areas. Average annual rainfall varies from over 40 inches in the Flat Tops to approximately 10 inches at Rangely. The White River Basin supports a significant cattle ranching community. The primary use of water is pasture and alfalfa irrigation.

1.2 Approach

The White River historical crop consumptive use analysis was performed using StateCU, a generic, data driven consumptive use model and graphical user interface. The objective of the model is to develop monthly consumptive use estimates for the assessment of historical and future water management policies. Key information used by the model to assess historical consumptive use includes irrigated acreage, crop types, monthly climate data, and diversion records.

The historical crop consumptive use analysis also provides information and consumptive use estimates for the basin surface water model (StateMod) analysis of the White River Basin.

1.3 Results

Table 1 presents the average annual acreage and historical crop consumptive use analyses results for the 1950 to 2013 study period. As shown, the irrigation water requirement averages 43,319 acre-feet per year while water supply-limited consumptive use averages 40,887 acre-feet per year. The average annual shortage in the basin is 5 percent.

Table 1: Average Annual Acreage and Consumptive Use Results (1950 through 2013)

Water District	Average Acres	Irrigation Water Requirement (acre-feet)	Supply-Limited CU (acre-feet)	Percent Short
43	26,021	43,319	40,887	5%

Figure 1 presents historical acreage by crop type for 2010. The irrigated lands coverages for 1993, 2005, and 2010 were considered in the analysis. The total irrigated acreage from 1950 to 2013 averaged 26,021 acres. As shown, pasture grass is grown on the majority of irrigated land in the basin.

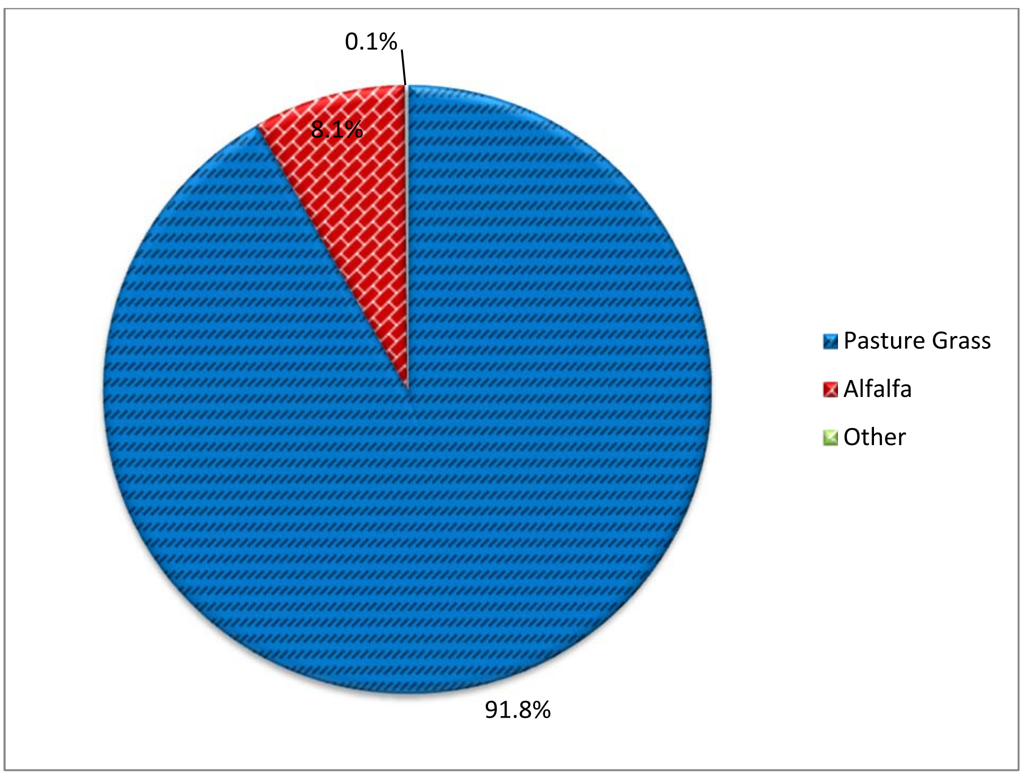


Figure 1: 2010 Irrigated Acreage by Crop Type

Figure 2 presents the annual historical acreage, irrigation water requirement and supply limited consumptive use for the study period. Although there are minor changes in irrigated acreage between 1993, 2005 and 2010, the pronounced yearly variations in irrigation water requirement are attributed to climate variability in the analysis (temperature and precipitation). The percent of irrigation water requirement not satisfied averaged 5 percent over the study period. Greater shortages from 2002 to 2007, averaging 10 percent, represented limited water supply due to below average stream flows. Shortages averaging 4 percent from 1996 through 2000 are consistent with normal to above average stream flows.

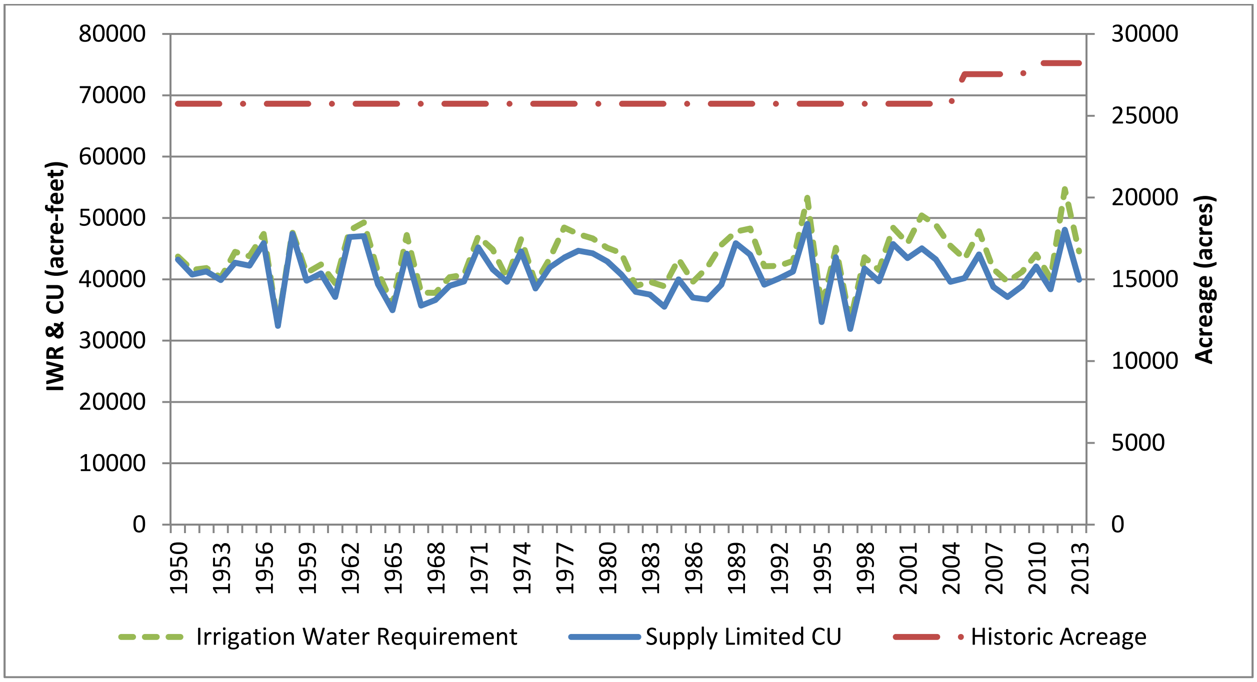


Figure 2: Historical Acreage, Irrigation Water Requirement and Supply Limited CU 1950 through 2013

Figure 3 shows the annual estimated diversions from surface water to meet crop irrigation requirement. The average annual surface water diversions from 1950 through 2013 were 287,932 acre-feet.

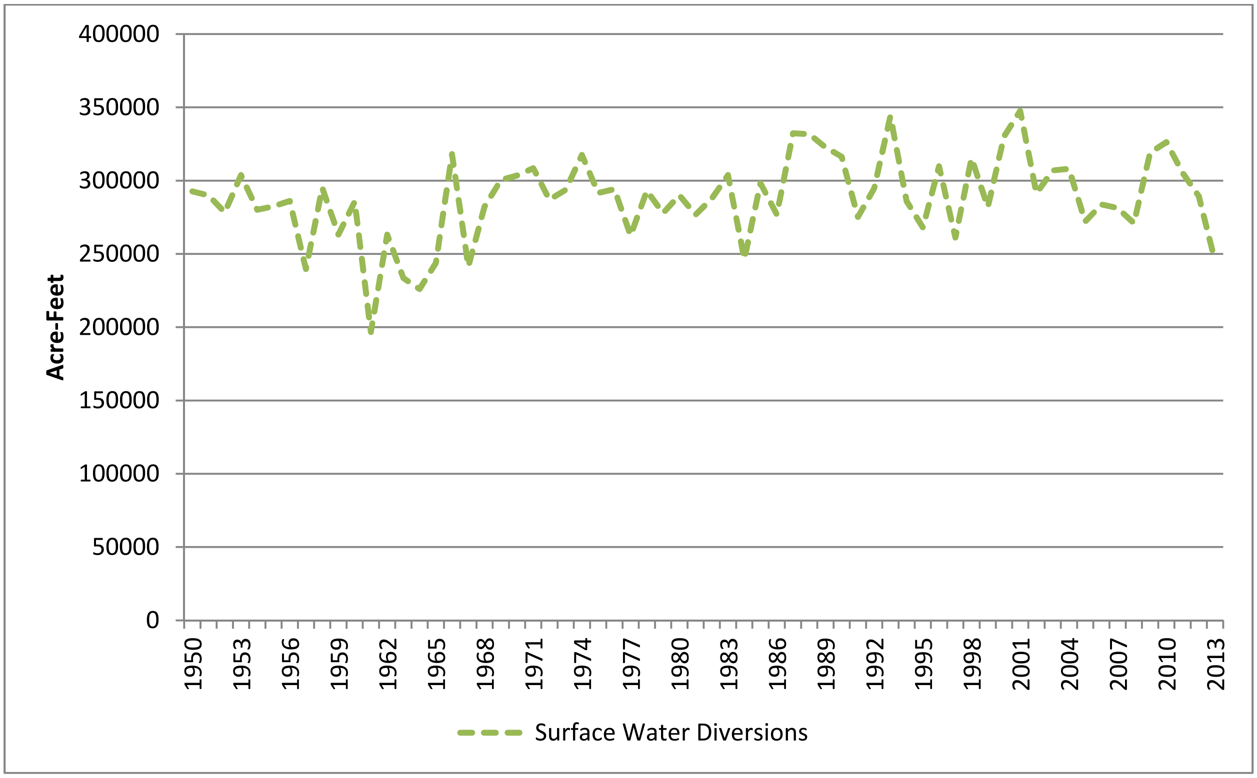


Figure 3: Annual Surface Water Diversions 1950 through 2013

2.0 Introduction

The estimation of historical crop consumptive use in the White River Basin and the tool used to perform the analysis are documented in three major reports as follows:

1. This report describes the climate and crop data from HydroBase used in the historical consumptive use analysis, and the parameters used in the analysis, including Blaney-Criddle crop coefficients and characteristics. This document summarizes the results of the analysis, total irrigation water requirement, and the supply-limited total consumptive use for the White River basin.

2. White River Basin Water Resources Planning Model User's Manual describes the development of the White River Basin StateMod surface water model. The document summarizes the process and results of developing the structure list of historical diversions for the historical consumptive use analysis.

3. The StateCU Documentation describes the consumptive use model and graphical user interface used to perform all consumptive use analyses conducted as part of the Colorado Decision Support System.

This Historical Crop Consumptive Use Analysis Report has not attempted to reiterate the detailed analyses and results of the previous efforts performed in support of the final historical crop consumptive use analysis. Instead, it summarizes the major results of each technical memorandum. Supporting memorandum and reports are available on the CDSS website.

2.1 Basin Description

The White River Basin, as shown in **Figure 4**, is located in northeastern Colorado and encompasses approximately 3,570 square miles. The North and South Forks of the White River originate in the highlands of the Flat Tops formation and flow generally west, meeting near Buford shortly outside the White River National Forest. The Grand Hogback forms the east boundary of the Piceance Creek basin, a major tributary of the White River that drains the Roan Plateau to the south, flowing north and entering the White River between Meeker and Rangely. The White River enters Utah about 20 miles west of Rangely.

Major tributaries in the White River basin include Big Beaver Creek, the North, and South Forks of the White River, Piceance Creek, Yellow Creek, and Douglas Creek. Most of the runoff is attributable to snowmelt from the higher elevation areas. Average annual rainfall varies from over 40 inches in the Flat Tops to approximately 10 inches at Rangely.

The basin economy is supported primarily by cattle ranching. Irrigated pasture and hay support this economic driver.

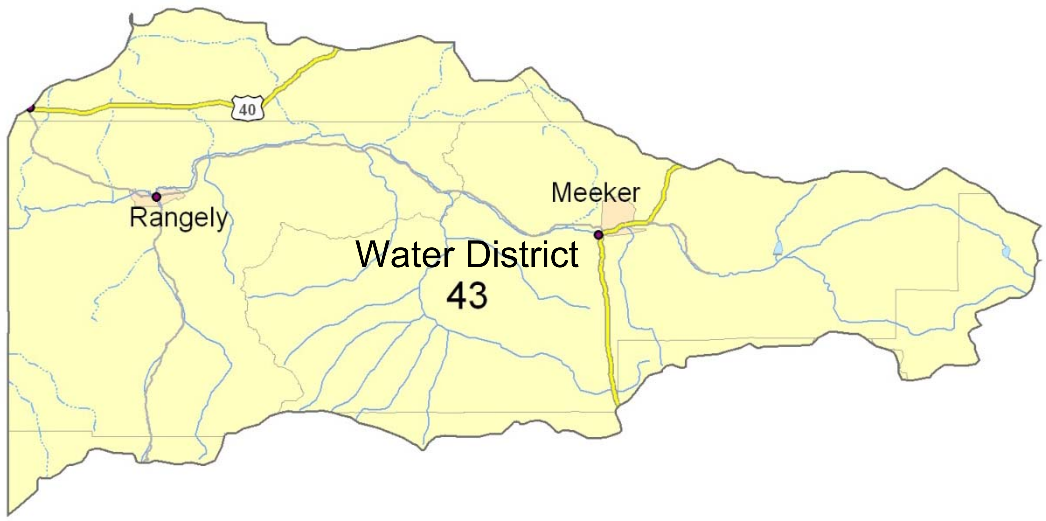


Figure 4: White River Basin

2.2 Definitions

Several terms used in this report have been broadly used in other studies. The following definitions are consistent with the American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 70 - Evapotranspiration and Irrigation Water Requirement.

Potential Evapotranspiration (ET) The total amount of water that would be used for crop growth if provided with an ample water supply, also called potential consumptive use.

Effective Precipitation The portion of precipitation falling during the crop-growing season that is available to meet the evapotranspiration requirement of the crop.

Winter Effective Precipitation The portion of precipitation falling during the non-growing season that is available for storage in the soil reservoir, and subsequently available to crops during the next growing season.

Irrigation Water Requirement The amount of water required from surface or ground water diversions to meet crop consumptive needs. Calculated as potential evapotranspiration less effective precipitation and stored winter precipitation.

Water Supply-Limited Consumptive Use The amount of water actually used by the crop, limited by water availability; also called actual consumptive use.

The following terms are commonly used in the CDSS efforts:

Irrigated Parcel An irrigated "field" having the same crop type, irrigation method (sprinkler or flood), and water source - not divided by a large feature, such as river or highway.

Ditch Service Area The area of land that a ditch system has either the physical ability or the legal right to irrigate. Note that a ditch service area often includes farmhouses, roads, ditches, fallow fields and undeveloped lands. Therefore a ditch service area is typically greater than the land irrigated under that ditch.

Key Diversion Structure A ditch system that is modeled explicitly in both the StateCU historical consumptive use model efforts and the StateMod water resources planning model. Ditch systems are generally defined as key if they have relatively large diversions, have senior water rights, or are important for administration.

Diversion System Structure A group of diversion structures on the same tributary that operate in a similar fashion to satisfy a common demand.

Aggregated Diversion Structure A group of non-key structures. Aggregated diversions are typically aggregated based on location; e.g. diverting from the same river reach or tributary.

HydroBase The State of Colorado's relational database used in the CDSS efforts. HydroBase contains historical, real-time, and administrative water resources data.

Data Management Interface (DMI) A CDSS program that allows data to flow from HydroBase to the CDSS models using an automated data-centered approach.

StateMod The CDSS water allocation model used to analyze historical and future water management policies.

3.0 Model Development

The White River Basin historical crop consumptive use analysis was performed using StateCU, a generic data driven consumptive use model and graphical user interface. The objective of the model is to develop consumptive use estimates for the assessment of historical and future water management policies.

The model originated at the USBR and has undergone substantial enhancements while being applied to the Colorado Decision Support System, the Rio Grande Decision Support System, and the South Platte Decision Support System. The *StateCU Documentation* provides a complete description of the model and its capabilities.

3.1 Modeling Approach

The general methodology used to estimate historical consumptive use for the White River Basin is as follows (See the *StateCU Documentation* for a more complete description of the calculation methods):

1. A White River Basin structure scenario was developed that includes 100 percent of the 2010 irrigated acreage in the White River Basin using the key and aggregated structures and their associated acreage and crop patterns.
2. Climate stations were assigned to each structure based on spatial determination of climate station weights by hydrologic unit code (HUC).
3. Potential ET was determined using the SCS Modified Blaney-Criddle consumptive use methodology with TR-21 crop characteristics for acreage below 6500 feet and the Original Blaney-Criddle consumptive use methodology with high-altitude crop coefficients developed for Denver Water for pasture above 6,500 feet. As recommended in the <u>ASCE Manuals and Reports on Engineering Practice No. 70, Evapotranspiration and Irrigation Water Requirements</u> (1990), an elevation adjustment of 10 percent adjustment upward for each 1,000 meters increase in elevation above sea level was applied to the Modified Blaney-Criddle method, i.e. for crops below 6,500 feet. The SCS effective rainfall method outlined in the SCS publication <u>Irrigation Water Requirement Technical Release No. 21</u> (TR-21) was used to determine the amount of water available from precipitation, resulting in irrigation water requirement.
4. Water supply-limited consumptive use was determined by including diversion records, conveyance efficiencies, application efficiencies, and soil moisture interactions. The model determined water supply-limited consumptive use by first applying surface water to meet irrigation water requirement for land under the ditch system. If excess surface water still remained, it was stored in the soil moisture reservoir. Then if the irrigation water requirement was not satisfied, surface water stored in the soil moisture reservoir was used to meet remaining irrigation water requirement.

3.2 File Directory Convention

To assist in the file organization and maintenance of official State data, the files associated with a historical consumptive use analysis will install to the default subdirectory \cdss\data\ *Analysis_description* \StateCU. *Analysis_description* is **wm2015** for the White River Basin crop consumptive use analysis, updated in 2015. Note that these directory conventions are not a requirement of the model, simply a data management convention for official State data.

3.3 File Naming Convention

Specific file names or extensions are not a requirement of the model except for the StateCU response file (*.rcu). Standard extensions have been adopted by the State for data management purposes, and are outlined in **Section 4.0 Data Development**.

3.4 Data Centered Model Development

Nearly all the StateCU input files have been generated from HydroBase using the data management interfaces StateDMI (Version 3.12.02, 4/17/2013) and TSTool (Version 10.20.00, 4/21/2013). A description of these tools as applied to StateCU is included in **Section 4 Data Description,** where applicable.

3.5 Product Distribution

The StateCU model, CDSS input files, and associated documentation can be downloaded from the State of Colorado's CDSS web page at http://cdss.state.co.us.

4.0 Data Description

The following sections provide a description of each input file, the source of the data contained in the input file, and the procedure for generating the input file. More detailed information regarding the file contents and formats can be found in the *StateCU Documentation*.

1. Simulation information files
   - StateCU Response File ***Section 4.1***
   - StateCU Control File ***Section 4.2***
2. Structure specific files
   - StateCU Structure File ***Section 4.3***
   - Crop Distribution File ***Section 4.4***
   - Annual Irrigation Parameter File ***Section 4.5***
   - Historical Diversion File ***Section 4.6***
3. Climate data related files
   - Climate Station Information File ***Section 4.7***
   - Climate Data Files ***Section 4.8***
4. Blaney-Criddle specific files
   - Blaney-Criddle Crop Coefficient File ***Section 4.9***
   - Crop Characteristics File ***Section 4.10***

4.1 StateCU Response File (wm2015.rcu)

The StateCU response file contains the names of input files used for a StateCU analysis. The StateCU response file was created using a text editor for the White River Basin. Input file names in the response file can be revised through the StateCU Interface.

4.2 StateCU Model Control File (wm2015.ccu)

The StateCU Model control file contains the following information used in the historical consumptive use analysis:

- Beginning and ending year for simulation – The simulation period for the analysis was 1950 through 2013.
- Consumptive use analysis method – Monthly SCS Modified Blaney-Criddle, described in TR-21, and the monthly Original Blaney-Criddle analysis were used.
- Effective precipitation method – The SCS Effective Precipitation method, defined in TR-21 was used.
- Scenario type – The analysis was defined as a “structure” scenario.
- Soil moisture consideration – The soil moisture switch was set to “1” indicating the analysis should include soil moisture accounting.
- Initial soil moisture information – The initial soil moisture was set to 50 percent of the capacity for each structure.

- Winter carry-over precipitation percent – The winter carry-over precipitation defines the amount of non-irrigation season precipitation that is available for storage in the soil moisture reservoir. Winter carry-over precipitation was not used for this scenario; set to zero.
- Output options – The output summary switch was set to "3" indicating a detailed water budget output should be generated.

The StateCU model control file was created using a text editor for the White River Basin. Options in the model control file can be revised through the StateCU Interface.

4.3 StateCU Structure File (wm2015.str)

A structure file defines the structures to be used in the analysis. The structure file contains physical information and structure-specific information that does not vary over time including location information; available soil capacity; and assignments of climate stations to use in the analysis. Location information includes the latitude, and county for each structure. The latitude is used in the Blaney-Criddle method to determine the hours of daylight during the growing season.

Key and Aggregate Structures

The structure file used in the historical consumptive use analysis was created using **StateDMI** to extract diversion structure location information stored in HydroBase. Early in the CDSS process it was decided that, while all consumptive use should be represented in the model, it was not practical to model each and every water right or diversion structure individually. Key structures to be "explicitly" modeled were determined by:

- Identifying net absolute water rights for each structure and accumulating each structure's decreed amounts
- Ranking structures according to net total absolute water rights
- Identifying the decreed amount at 75 percent of the basin-wide total decreed amount in the ranked list
- Generating a structures/water rights list consisting of structures at or above the threshold decreed amount
- Field verifying structures/water rights, or confirming their significance with basin water commissioners, and making adjustments

Based on this procedure, 4.8 cubic feet per second (cfs) was selected as the cutoff for explicit representation in the White River Basin; key diversion structures are those with total absolute water rights equal to or greater than 4.8 cfs. The White River Basin model includes 115 key diversion structures.

The use associated with irrigation diversions having total absolute rights less than 4.8 cfs were included in the StateCU and StateMod models at "aggregated nodes." These nodes represent the combined historical diversions, demand, and water rights of many small structures within a prescribed sub-basin. The aggregation boundaries were based generally on tributary boundaries; or if on the mainstem, gage location, critical administrative reaches, and instream flow reaches. To the extent possible, aggregations were devised so that they represented no more than 1,000 irrigated acres. In the White River Basin model, 22 aggregate nodes were identified, representing 6,633 acres of irrigated crops. Their historical diversions were developed by summing the historical diversions of the individual structures, and their irrigation water requirement is based on the total acreage associated with the aggregation.

As presented in **Table 3**, 76 percent of acreage with a surface water source in 2010 was assigned to key structures. The approach and results for selecting key structures and aggregations are outlined in more detail in **Appendix A**.

Table 2: Key and Aggregate Structure Summary

Structure Type	2005 Acres	Percent of Total Acreage	2010 Acres	Percent of Total Acreage	Number of Structures
Key/Diversion System	21,462	78%	21,575	76%	115
Aggregated	6,075	22%	6,633	24%	22(1) (295)
Total Structures	**27,537**	**100%**	**28,208**	**100%**	**137**

(1) There are a total of 22 aggregate structures representing 297 individual structures.

Available Soil Moisture Capacities

Available soil moisture capacities were estimated from Natural Resources Conservation Service (NRCS) digital mapping and assigned to individual structures in the structure file. Soil moisture capacities for each structure, in inches of holding capacity per inch of soil depth, were provided for key and aggregate structures from comma separated list files. Structure soil moisture capacity by structure ranges from 0.0560 to 0.1650 inches per inch. Structures that were not assigned capacities in the previous analysis and aggregate structures were assigned the water district average capacity of 0.109 inches per inch.

Climate Station Assignment

Climate stations were selected for use in the consumptive use calculation based on their period of records and location with respect to irrigated land (see **Section 4.7 Climate Station Information File** (COclim2015.cli) for more information on climate stations). Climate stations and respective weights were assigned to county/hydrologic unit code (HUC) combinations, originally based on USBR assignments. Climate station weights were then assigned to structures based on this county/HUC area combination method.

4.4 Crop Distribution File (wm2015.cds)

The crop distribution file contains acreage and associated crop types for each key and aggregate surface water structure for every year in the analysis period (1950 through 2013). The irrigated acreage assessment for 1993 was originally developed by the State Engineer's Office and the USBR. Each irrigated parcel was assigned a crop type and tied to a structure that provides water to the parcel. Acreage assessments representing 2005 and 2010 were also used in the analysis. The irrigated acreage, along with crop type identification, is available spatially through GIS shapefiles and is stored in HydroBase. **Table 4** summarizes the acreage by crop type.

Table 3: Irrigated Acreage by Crop Type

Crop	2005 Acreage	2010 Acreage
Alfalfa	2,534	2,284
Corn	0	0
Pasture Grass	24,933	25,883
Spring Grains	33	0
Other	37	40
Total Acreage	**27,537**	**28,208**

1993 acreage and crop type were assigned to years 1950 through 2004 reflecting the limited change in irrigated acreage in the White Basin. The year 2005 acreage and crop type were assigned to years 2005 through 2009. The year 2010 acreage and crop type were assigned to years 2010 through 2013. The crop distribution file used in the historical consumptive use analysis was created using **StateDMI** to extract the acreage and crop type information from HydroBase**.**

4.5 Annual Irrigation Parameter File (wm2015.ipy)

The annual irrigation parameter file contains yearly (time series) structure information required to run consumptive use simulations, including the following:

- conveyance efficiencies
- maximum flood irrigation efficiencies
- maximum sprinkler irrigation efficiencies
- acreage flood irrigated with surface water only
- acreage sprinkler irrigated with surface water only
- acreage flood irrigated with ground water only or supplemental to surface water
- acreage sprinkler irrigated with ground water only or supplemental to surface water
- maximum permitted or decreed monthly pumping capacity
- ground water use mode (ground water primary or secondary source)

The conveyance efficiency accounts for losses between the river headgate and the farm headgate, including losses through canals, ditches and laterals. The maximum flood irrigation and sprinkler efficiencies account for application losses between the farm headgate and the crops. Note that conveyance and maximum application efficiency data input data were not adjusted by year. However, a structure's overall, system efficiency may change by year due to changes in the percent of land served by sprinkler or flood application methods, or due to surface water supply in excess of crop requirement.

Ditch and lateral coverages for the White River Basin are not available to use in estimating individual structure ditch loss. Therefore, conveyance efficiency for all structures in the White River Basin is set at 100 percent. Maximum flood irrigation and sprinkler irrigation efficiencies represent maximum overall system efficiencies were estimated to be 54 percent and 72 percent respectively. The maximum flood irrigation system efficiency was derived based on a maximum application efficiency of 60 percent and 80 percent conveyance efficiency. Efficiency numbers are estimated and are not stored in HydroBase. Irrigation methods (flood vs sprinkler), however are stored in HydroBase. **StateDMI** was used to extract the time series information from HydroBase, set the estimated efficiency values, and create the annual irrigation parameter file.

In 2005, the irrigated acreage assessment identified about 1,800 acres (6.5%) as served by sprinklers. About the same amount is present in the 2010 assessment. The remaining acreage is irrigated with flood irrigation practices.

4.6 Historical Irrigation Diversion File (wm2015_cu.ddh)

The historical diversion file provides surface water supply information required to estimate supply-limited consumptive use. Irrigation diversions are provided for each modeled key and aggregate surface water diversion structure. **Figure 5** shows how surface water diversions for irrigation in the basin have changed over time. Surface water diversions for irrigation averaged approximately 287,932 acre-feet per year over the 1950 through 2013 study period. The variation seen in **Figure 5** is due to water supply limitations resulting from varying snowpack.

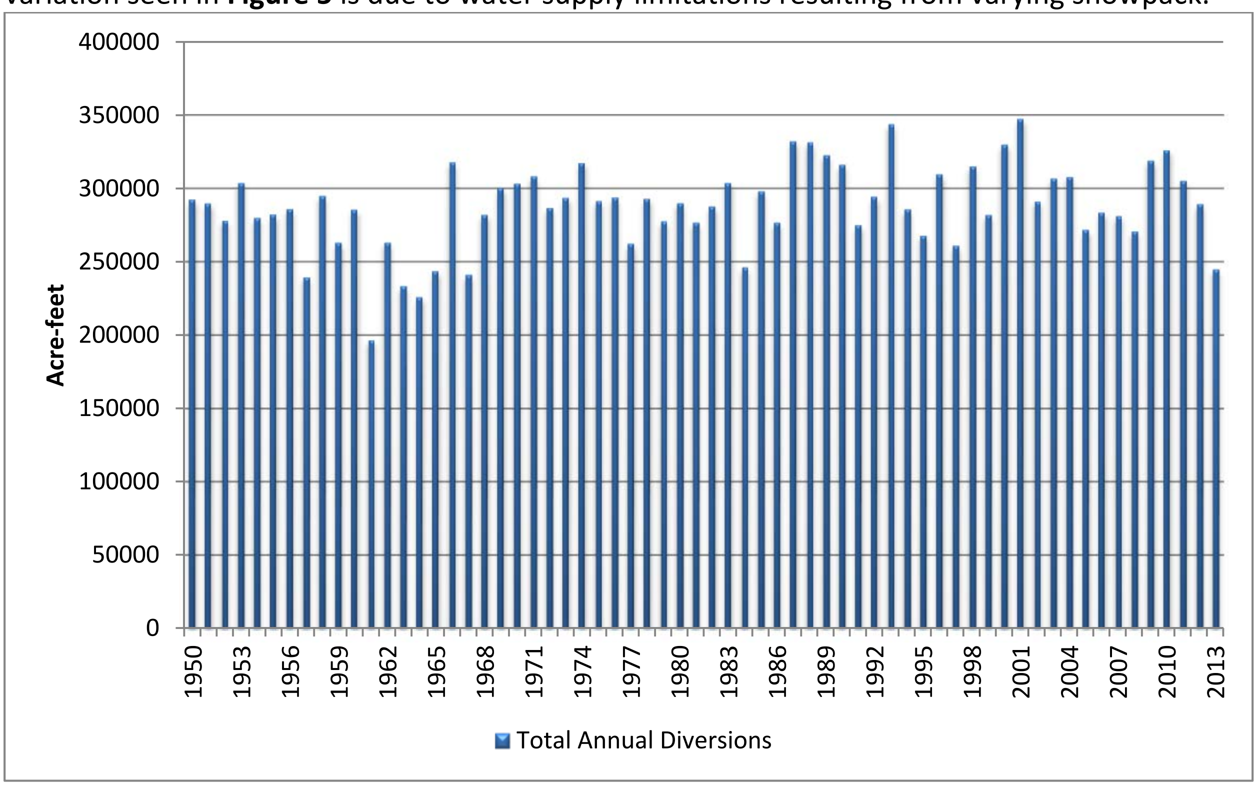


Figure 5: Total Annual Surface Water Irrigation Diversions

StateDMI was used to extract diversion records from HydroBase and fill missing diversion data**.** Diversion data for structures included in an aggregate structure are first extracted and filled, then combined with other structures' diversion data in the aggregate structure. Note that diversion comments were considered when extracting data from HydroBase; for instance, if the diversion comment for a specific structure indicated the structure was not usable for a specific year, that year of data for that structure was set to zero.

Missing data was filled using a wet/dry/average pattern according to an 'indicator' gage. Each month of streamflow at the indicator gage was categorized as a wet/dry/average month through a process referred to as 'streamflow characterization'. Months with gage flows at or below the 25th percentile for that month are characterized as 'dry', while months at or above the 75th percentile are characterized as 'wet', and remaining months are characterized as 'average'. Using this characterization, missing data points were filled based on the wet, dry, or average pattern. For example, a data point missing for a wet March was filled with the average of other wet Marches in the partial time series, rather than all Marches. The pattern streamflow gage used in the White River Basin is the White River near Meeker, CO (09304500). If missing data still existed after filling with a pattern file, historical monthly averages were used to fill the remaining data.

4.7 Climate Station Information File (COclim2015.cli)

The climate station information file provides climate station location information for climate stations used in the analysis, including latitude, elevation, county and HUC. A single climate station information file was developed for the entire western slope and therefore includes all key climate stations used in the Colorado River basin models (Gunnison, White, Yampa, Upper Colorado, San Juan/Dolores). **Table 5** lists the subset of climate stations used in the White River analysis, their period of record, and their percent complete for temperature and precipitation data. The climate station information file was created using **StateDMI** to extract location information stored in HydroBase based on a list of climate stations to be used in the analyses.

Table 4: Key Climate Station Information

Station ID	Station Name	WD	Period of Record	Elevation (feet)	Percent Complete (1950 – 2013)	
					Temperature	Precipitation
USC00055048	Little Hills	43	1946-1991	6140	60.81%	63.54%
USC00055414	Marvine Ranch	43	1972-1998	7800	40.49%	39.71%
USC00055484	Meeker 3 W *	43	1893-2014	6180	64.84%	64.71%
USC00056832	Rangely 1 E	43	1950-2015	5290	94.92%	95.96%

* Represents a combined climate station whereby the data from two or more stations has been combined to create a single key climate station.

4.8 Climate Data Files (COclim2015.tmp, COclim2015.prc, COclim2015.fd)

StateCU requires historical time series data, in calendar year, for temperature, frost dates, and precipitation. The CRDSS climate data files, developed using the **TSTool**, contain monthly data for fifty-four stations. Note that a single set of climate data files were developed for the entire western slope and therefore include data for all key climate stations used in the Colorado River basin models (Gunnison, White, Yampa, Upper Colorado, San Juan/Dolores). **Table 6** summarizes the average annual temperature, frost dates and precipitation based on filled data for the subset of stations used in the White River analysis.

Table 5: Average Annual Filled Climate Values 1950 through 2015

Station Name	Station ID	Average Annual		Frost Dates - Degrees F			
		Temperature (Degrees F)	Precipitation (Inches)	Spring 28 Deg	Spring 32 Deg	Fall 32 Deg	Fall 28 Deg
Little Hills	USC00055048	42.6	13.65	6/5	6/19	8/10	9/4
Marvine Ranch	USC00055414	36.8	26.11	6/17	6/23	7/12	8/8
Meeker 3 W *	USC00055484	44.3	15.73	5/22	6/7	9/8	9/24
Rangely 1 E	USC00056832	46.8	9.97	4/29	5/17	9/17	9/25

* Represents a combined climate station whereby the data from two or more stations has been combined to create a single key climate station.

Figures 6 and **7** show the 1950 through 2013 average monthly precipitation and temperature for the Rangley 1 E (USC00056832) climate station, located in the western portion of the White River Basin. Historical missing data for these climate stations were filled from 1950 through 2013 using **TSTool.** Historical month averages were used to fill missing precipitation data and linear regression techniques were used to fill missing temperature data**.**

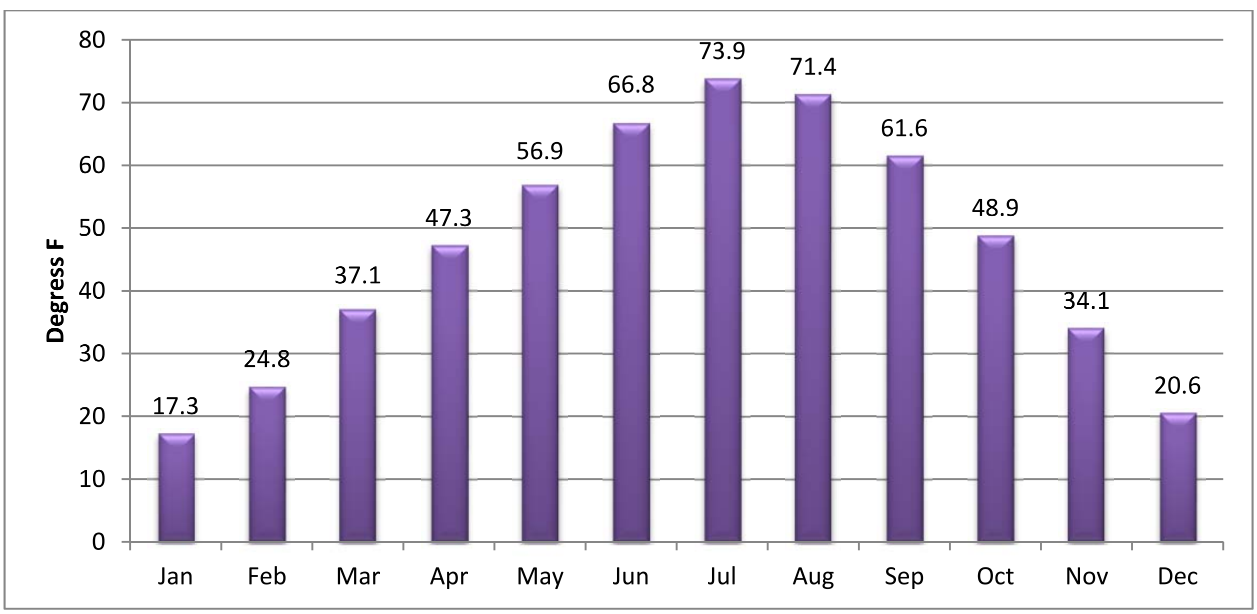


Figure 6: Average Mean Monthly Temperature for Rangley 1 E Climate Station 1950 through 2013

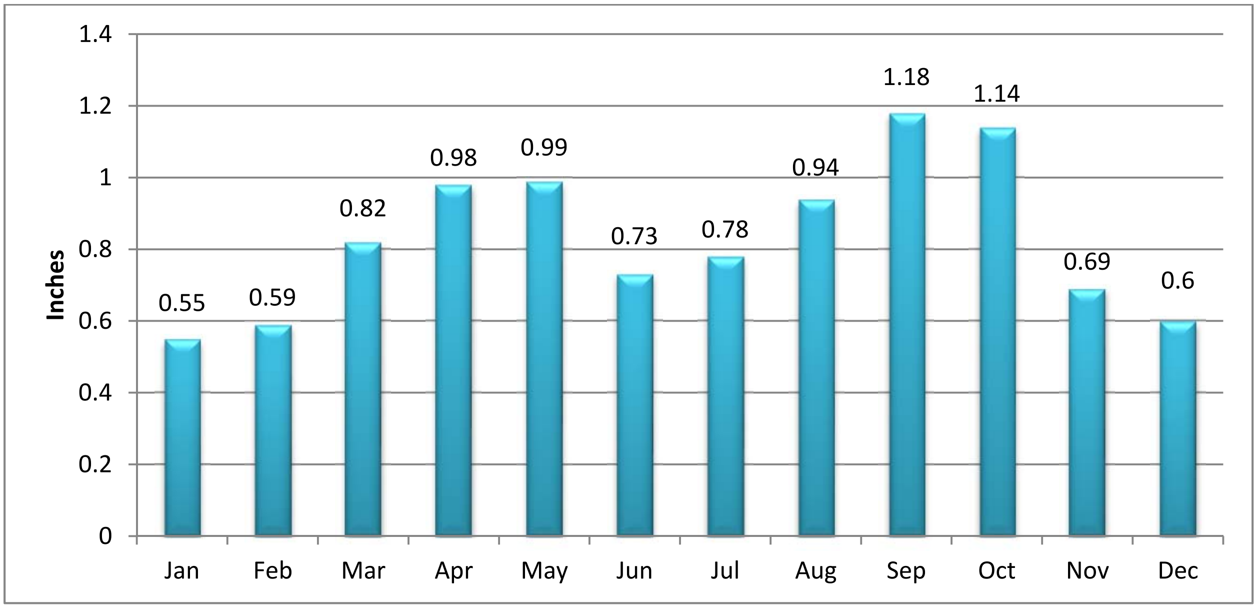


Figure 7: Average Mean Monthly Precipitation for Rangley 1 E Climate Station 1950 through 2013

4.9 Blaney-Criddle Crop Coefficient File (CDSS.kbc)

The Blaney-Criddle crop coefficient file contains crop coefficient data used in the CRDSS historical consumptive use analysis. Standard TR-21 Blaney-Criddle crop coefficient curve data is available for the Modified Blaney-Criddle method. The crop coefficient file contains TR-21 curve data for several crops, however only four TR-21 crops are modeled in the White River Basin; grass pasture, alfalfa, corn and spring grains.

Structures with irrigated grass pasture acreage located above 6500 feet in elevation were assigned the Denver Water High Altitude crop coefficients, included in the CDSS.kbc file, for use with the Original Blaney-Criddle methodology. Additional details on high altitude crop coefficients can be found the SPDSS Task 59.1 Technical Memorandum available on the CDSS website.

The flag to indicate an elevation adjustment to specific crops in the analysis is located in the crop coefficient file. It is recommended in the ASCE Manuals and Reports on Engineering Practice No. 70, Evapotranspiration and Irrigation Water Requirements (1990) that an elevation adjustment of 10 percent adjustment upward for each 1,000 meters increase in elevation above sea level be applied to the Modified Blaney-Criddle method when using TR-21 coefficients, i.e. for crops below 6500 feet. For this analysis, an elevation adjustment was applied for all Modified Blaney-Criddle crops. The elevation adjustment is applied based on the elevation of the structure, if provided in the structure file. However, in general, structure elevations are not available in HydroBase. If no structure elevation is provided, the elevation of the weighted climate station(s) is used for the elevation adjustment.

The crop coefficient file used in the historic consumptive use analysis was created using **StateDMI** to extract the crop coefficients stored in HydroBase.

4.10 Crop Characteristic File (CDSS.cch)

The crop characteristic file contains information on planting, harvesting, and root depth. Standard TR-21 Blaney-Criddle crop characteristics were adopted for the analysis. Crop characteristics from the Denver Water study were used for grass pasture above 6,500 feet in elevation. The beginning temperature and ending calibrated temperature used to define the growing season of high altitude grass pasture is 42 degrees Fahrenheit. Because grass pasture is a perennial crop, the length of season is set to 365 days. **Table 7** illustrates the crop characteristics for the crops grown in the White River Basin, including high altitude grass pasture.

The crop characteristic file used in the historic consumptive use analysis was created using **StateDMI** by extracting the representative crop characteristics from HydroBase and develop the crop characteristics input file.

Table 6: Characteristics of White River Basin Crops

Crop Type	Source	Length of Season	Beginning Temperature	End Temperature
Alfalfa	TR-21	365	50	28
Corn Grain	TR-21	140	55	32
Grass Pasture	TR-21	365	45	45
Spring Grains	TR-21	137	45	32
High Altitude Grass Pasture	Denver Water Study	365	42	42

5.0 Results

The White River Basin historical crop consumptive use results are a product of the input files described in **Section 4**. This section provides a summary of historical crop consumptive use and actual system efficiencies. Results for individual key and aggregated structures can be easily viewed and printed by downloading the StateCU input files and StateCU model from the CDSS web site (see **Section 3.5**).

5.1 StateCU Model Results

Tables 8 shows the average annual basin consumptive use water budget accounting for the period 1950 through 2013. The individual component results are discussed in detail in the following sections.

Table 7: Basin Average Annual Results 1950 through 2013 (acre-feet)

Irrigation Water Requirement	Surface Water Diversion Accounting					Estimated Crop CU		
	River Headgate Diversion	Surface Water Diversion To:			Calculated System Efficiency	From SW	From Soil	Total
		CU	Soil	Non-Consumed				
43,319	288,032	37,913	3,061	247,259	14%	37,913	2,974	40,887

Irrigation Water Requirement is potential consumptive use less the amount of precipitation effective in meeting crop demands directly during the irrigation season. Note that a conveyance loss of 10 percent is factored directly into the maximum system application efficiencies, as presented in Section 4.5. Therefore the *River Headgate Diversion* is adjusted for conveyance and application efficiency through the maximum application efficiency value. The *Non-Consumed* represents the total water not consumed by the crops; lost through canal conveyance or during application of the irrigation water. The non-consumed portion of diversions return to the river and are available for re-diversion downstream.

5.2 Historical Crop Consumptive Use

Table 9 presents the historical crop consumptive use analysis results for the 1950 to 2013 study period. Irrigation water requirement in the White River Basin is satisfied from surface water diversions, resulting in an estimate of water supply limited consumptive use. The White River Basin averages 40,887 acre-feet of water supply limited consumptive use annually. The average annual shortage in the basin is 5 percent. Note the consumptive use from surface water includes excess surface water stored in the soil moisture and then subsequently used by crops.

Table 8: Average Annual Consumptive Use Results 1950 through 2013

Average Acres	Irrigation Water Requirement (acre-feet)	Supply-Limited CU (acre-feet)	Percent Short
26,021	**43,319**	**40,887**	**5%**

Figure 8 presents basin crop consumptive use results by year. As shown, the percent of irrigation water requirement is directly related to water supply. Greater shortages from 2002 through 2007, averaging 10 percent, represent limited water supply due to below average stream flows. Shortages averaging 5 percent from 1991 through 2000 are consistent with normal to above average stream flows.

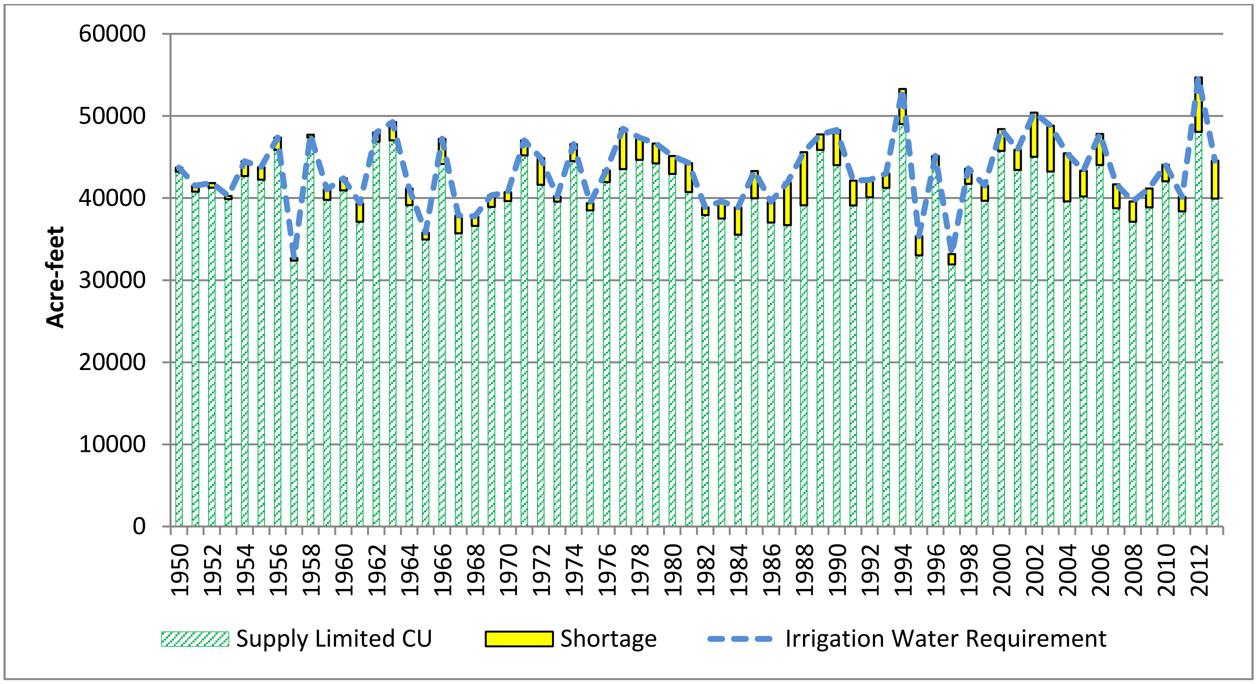


Figure 8: Irrigation Water Requirement and Supply Limited CU

Average monthly shortages for the study period vary from a low of 3.3 percent in June to a high of 11 percent in October, as shown in **Table 10**. In general the shortages throughout the basin are relatively low and occur later in the irrigation season after the runoff.

Table 9: Average Monthly Shortages 1950 through 2013

Apr	May	Jun	Jul	Aug	Sep	Oct
10.0%	4.5%	3.4%	4.9%	6.7%	9.3%	10.9%

Figure 9 present shortages by year. Shortages increased dramatically in the drought years in the early 2000s and again for 2012.

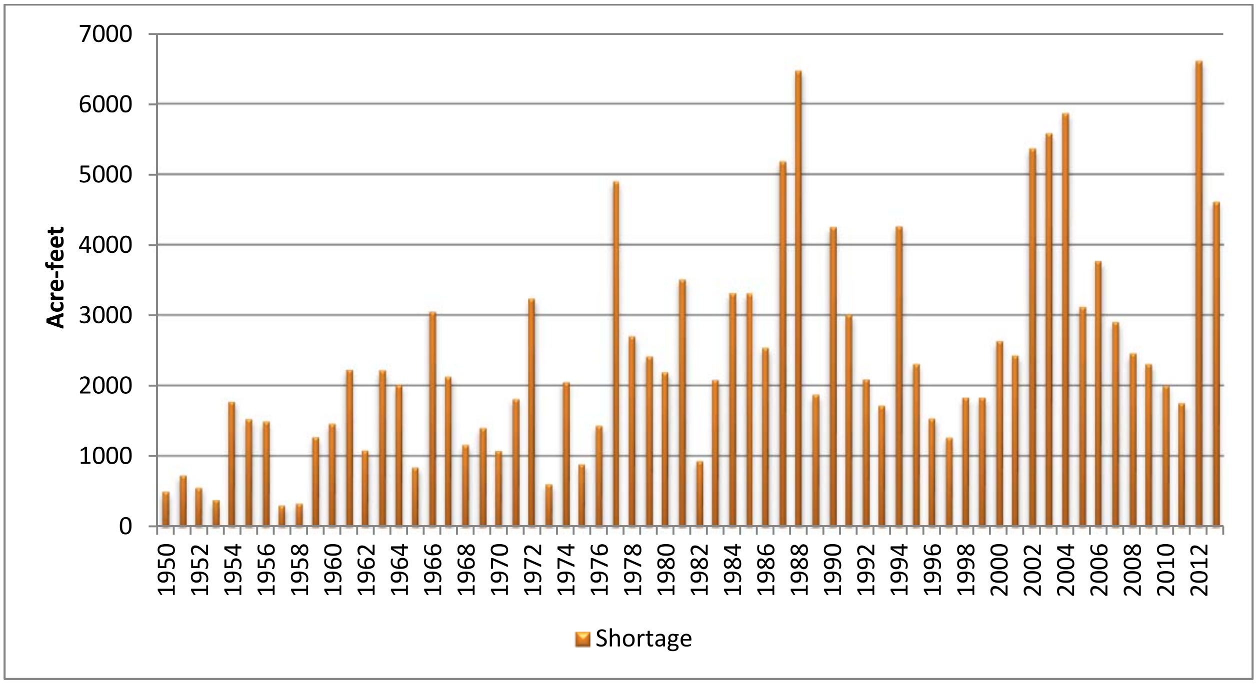


Figure 9: Annual Shortages

5.3 Estimated Actual Efficiencies

As described in the StateCU Documentation, the amount of surface water available to meet the crop demand is the river headgate diversion less conveyance and application losses. If the surface water supply exceeds the irrigation water requirement, water can be stored in the soil moisture up to its water holding capacity.

Maximum system efficiencies for surface water diversions are provided as input to StateCU, as described in **Section 4.5**. Actual system efficiencies are calculated based on the amount of water available to meet crop demands and the application method (e.g. flood or sprinkler).

Table 11 provides the average monthly calculated system efficiencies for surface water supplies. Surface water system efficiencies have remained relatively constant throughout the study period, with the slight variations due to water availability. As shown in **Table 11**, efficiencies tend to be lower during the peak runoff months of May and June.

Table 10: Average Monthly Calculated System Efficiencies 1950 through 2013

Apr	May	Jun	Jul	Aug	Sep	Oct
11%	15%	14%	17%	16%	12%	7%

6.0 Comments and Concerns

The historical crop consumptive use estimates are based on measured and recorded data; information from other studies; information provided by local water commissioners and users; and engineering judgement. The results developed for this project are considered appropriate to use for CDSS planning efforts. Areas of potential improvement or concern include:

- Historical Acreage. The irrigated acreage assessed for year 1993 serves as the basis for estimating historical acreage from 1950 to 2004 and is considered relatively accurate, as are irrigated acreage estimates for years 2005 and 2010. Diversion structures with irrigated acreage in either 2005 or 2010 were represented in the model. The model is not intended to represent all of the area that was historically irrigated.
- System Efficiencies. Maximum system efficiency estimates were set for the basin as a whole. Limited conveyance efficiency information based on actual canal loss studies exists. Canal loss studies, specifically for the larger systems, could improve the estimate of maximum system efficiencies used in the historical consumptive use estimate. Additionally, conveyance efficiency estimates based on soil type and ditch length, determined by the GIS soil type and canal coverages, could be used to also increase the accuracy of the maximum system efficiency estimates. Note that canal coverage does not exist for the White River Basin.
- Water Use. The results presented are based on an approach that attempts to represent how water is actually applied to crops in the basin. The approach used is based on engineering judgement and informal discussions with water users. The effort did not include determining surface water shares for each owner under a ditch or determining different application rates based on crop types. Instead water was shared equally based on acreage. Therefore, this basin-wide historical crop consumptive use analysis is appropriate for CDSS planning purposes. However, it should be used as a starting point only for a more detailed ditch level analysis.

Appendix A: Aggregation of Irrigation Diversion Structures

A-1: White River Basin Aggregated Irrigation Structures
A-2: Identification of Associated Structures (Diversion Systems and Multi-structures)

A-1: White River Basin Aggregated Irrigation Structures

Introduction

The original CDSS StateMod and StateCU modeling efforts were based on the 1993 irrigated acreage coverage developed during initial CRDSS efforts. Irrigated acreage assessments representing 2005 and 2010 have now been completed for the western slope basins. A portion of the 2005 and 2010 acreage was tied to structures that did not have identified acreage in the 1993 coverage, and, consequently, are not currently represented in the CDSS models. As part of this task, aggregate and diversion system structure lists for the western slope basins were revised to include 100 percent of the irrigated acreage based on both the 2005 and 2010 assessments. The update also included identification of associated structures and the development of "no diversion" aggregates—groups of structures that have been assigned acreage but do not have current diversion records.

The methodology for identifying associated structures is described more in-depth in Part 2 of this appendix. In general, associated structures—which divert to irrigate a common parcel of land—were updated to more accurately model combined acreage, diversions, and demands. These updates include the integration of the 2005 irrigated acreage, the 2010 irrigated acreage, as well as verification based on diversion comments and water right transaction comments.

"No diversion" aggregates were not included in the StateMod modeling effort. Because the individual structures included in these aggregates do not have current diversion records, their effect on the stream cannot be accounted for in the development of natural flows. Therefore, it is appropriate that their diversions also not be included in simulation. The individual structures in the "no diversion" aggregates generally irrigate minimal acreage, often with spring water as a source. Since the water use for these structures is included in the natural flow, there is an assumption that the use will not change in future "what-if" modeling scenarios.

Approach

The following approach was used to update the aggregated structures in the White River basin.

1. Identify structures assigned irrigated acreage in either the 2005 or 2010 CDSS acreage coverages.
2. Identify Key structures represented explicitly in the model. The process for determining key structures is outlined in Section 4.
3. Identify Key structures that should be represented as diversion systems, based on their association with other structures as outlined in Part 3 of this appendix.
4. Aggregate remaining irrigation structures identified in either the 2005 or 2010 irrigated acreage coverages based on the aggregate spatial boundaries shown in Figure 1. The boundaries were developed during previous White River Basin modeling effort to general group structures by tributaries with combined acreage less than 3,000.
5. Further split the aggregations based on structures with and without current diversions during the period 2000 through 2012.

Results

Table A-1 indicates the number of structures in the aggregation and the total the 2005 and 2010 aggregated acreage. All of the individual structures in the aggregates have recent diversion records.

Table A-1: White River Basin Aggregation Summary

Aggregation ID	Aggregation Name	Number of Structures	2005 Acres	2010 Acres
43_ADW001	WhiteNorthFork	21	231	292
43_ADW002	WhiteSouthFork	12	269	321
43_ADW003	WhiteAbColeCr	24	415	389
43_ADW004	WhiteNrMeeker	23	790	770
43_ADW005	WhiteNBLMeeker	32	527	659
43_ADW006	WhiteAbPiceanceC	4	63	71
43_ADW007	PiceanceUpper	17	193	236
43_ADW008	PiceanceBlRioBla	4	107	130
43_ADW009	PiceanceAbHunter	20	367	418
43_ADW010	PiceanceBlRyanGu	24	558	653
43_ADW012	WhiteBlBoiseCr	17	431	523
43_ADW013	WhiteBlDouglasCr	26	654	674
43_ADW014	WhiteNrStateLn	19	465	326
43_ADW015	EvacuationCr	11	25	189
43_ADW016	WhiteSBLMeeker	33	834	830

Table A-2 shows the number of structures in the aggregation and the total the 2005 and 2010 aggregated acreage. None of the individual structures in the aggregates have recent diversion records.

Table A-2: No Diversion Aggregation Summary

Aggregation ID	Aggregation Name	Number of Structures	2005 Acres	2010 Acres
43_AND001	WhiteNorthFork	1	8	8
43_AND005	WhiteNBLMeeker	1	1	1
43_AND007	PiceanceUpper	1	0	9
43_AND010	PiceanceBlRyanGu	1	65	65
43_AND012	WhiteBlBoiseCr	1	0	2
43_AND013	WhiteBlDouglasCr	1	0	1
43_AND016	WhiteSBLMeeker	2	70	66

Table A-3 indicates the structures in the diversion systems.

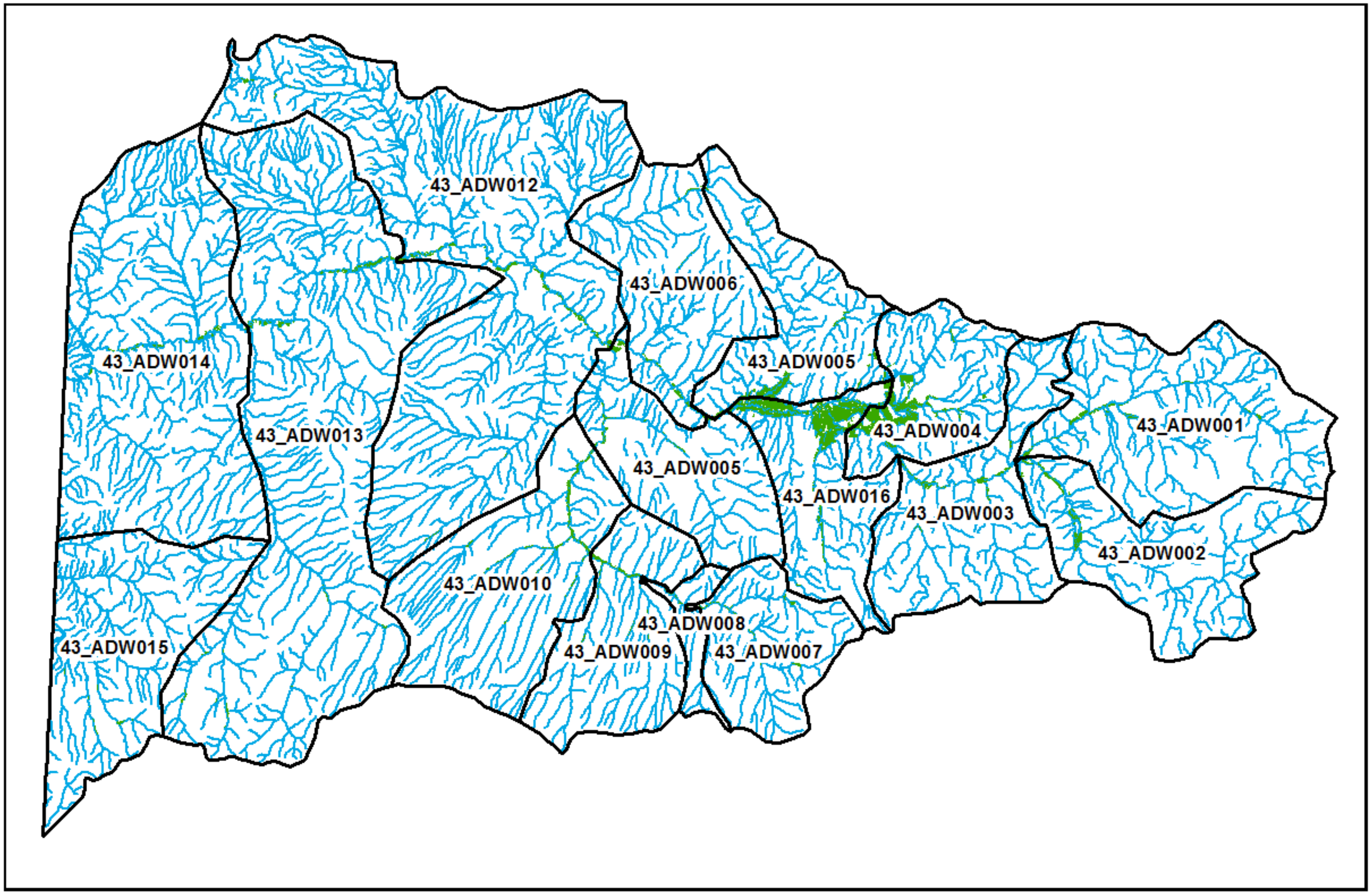
Table A-3: Diversion System Summary

Diversion System ID	Diversion System Name	WDID
4300527_D, Barbour S Side Ditch DivSys	BARBOUR SO SIDE D HG 1	4300527
	BARBOUR SO SIDE D HG 2	4300528
4300537_D, Beckman Ditch DivSys	BECKMAN DITCH	4300537

	PHILLIPS DITCH DIV 1	4300872
4300578_D, Coal Creek Mesa Ditch DivSys	COAL CREEK MESA DITCH	4300578
	BAR SEVEN DITCH	4300525
4300694_D, Thomas Ditch 2 DivSys	HIGHLAND DITCH	4300694
	WATT WASTEWATER DITCH	4302272
4300815_D, Metz & Reigan Ditch DivSys	METZ & REIGAN DITCH	4300815
	M REIGAN & P REIGAN D	4301085
4300819_D, Miller Creek Ditch DivSys	MILLER CREEK DITCH	4300819
	PIERCE WASTE DITCH	4300874

Figure A-1 shows the spatial boundaries of each aggregation. **Exhibit A**, attached, lists the diversion structures represented in each aggregate, while **Exhibit B** lists the diversion structures represented in each respective no diversion aggregate. Both Exhibit A and Exhibit B provide a comparison of the 2005 and 2010 irrigated acreage.

Figure A-1: Aggregate Structure Boundaries.



Recommendations

As part of this modeling update, various lists have been developed for review and reconciliation by the Water Commissioner. The lists include:

- Structures tied to irrigated acreage that do not have current diversion records
- Structures tied to irrigated acreage that do not have water rights for irrigation
- Structures that have current diversion records coded as irrigation use, but do not have irrigated acreage in either 2005 or 2010
- Structures that have irrigation water rights, but do not have irrigated acreage in either 2005 or 2010
- More than one structure is assigned to the same irrigated parcel, however there was no indication that the structures serve the same acreage in either diversion comments or water rights transaction comments.

Exhibit A: Diversion Structures in each Aggregate Structure

Aggregation ID	Structure Name	WDID	2005 Acres	2010 Acres
43_ADW001, WhiteNorthFork	Alta Vista Ditch No 1	4300503	14	14
	Alta Vista Ditch No 2	4300504	6	6
	Bear Creek Ditch	4300534	36	36
	Buford Ditch & Pond	4300557	10	10
	C Gentry D 1	4300562	23	23
	F M Taylor Ditch	4300635	5	5
	Gulliford Ditch 1	4300670	9	9
	Gulliford Ditch 2	4300671	3	3
	Herrell Ditch No 1	4300690	2	2
	Joe Fox Ditch & Pl	4300726	4	4
	Lava Ditch	4300757	16	16
	Lewis Sprinkler System	4300764	33	33
	Lynx Creek Ditch	4300780	0	56
	Ruehle Ditch 1	4300907	4	4
	Schneider Ck D 1	4300922	5	5
	Wakeman Ditch No 2	4300987	11	11
	Wakeman Ditch No 1	4300988	11	11
	West Marvine Ditch	4301003	28	28
	Halandras Ditch 1	4301102	2	2
	Missouri Cr Ditch	4301134	5	9
	Picket Pin Ditch	4301865	3	3
43_ADW002, WhiteSouthFork	Bailey Ditch No 1	4300518	27	49
	Bailey Ditch No 2	4300519	3	3
	Fowler Creek Ditch	4300643	61	61
	Frahm Ditch	4300644	13	13
	Gilly Ditch	4300655	6	7
	Hollman Ditch No 1	4300699	14	18
	Keil Ditch & Lake	4300743	8	8
	Kopje Ditch	4300750	61	61
	Mellinger Ditch	4300812	9	9
	Peltier Creek Ditch	4300869	10	13
	Sterry Ditch	4300951	57	57
	White Creek D 1	4301007	0	22
43_ADW003, WhiteAbColeCr	Arrington Ditch	4300510	4	4
	Coon Ditch	4300585	19	19
	Daum Ditch	4300596	43	38
	Daum Ditch 1	4300597	22	22
	Daum Ditch 2	4300598	11	0
	Daum Ditch 3	4300599	16	0
	Frank Myers Ditch	4300645	23	23

	Frank Smith Ditch	4300647	10	10
	La Kamp Ditch	4300752	46	44
	Lloyd Ditch 2	4300770	2	2
	Lynn Lee Ditch	4300779	4	4
	Merriweather Ditch	4300814	3	3
	Nelson Ditch	4300840	42	33
	Peterson & Coon Ditch	4300870	35	47
	Rector Springs No 1	4300890	7	9
	Rector Springs No 2	4300891	34	34
	Sandy Ditch	4300914	6	8
	Warren Smith Ditch	4300996	13	13
	West Fork Ditch 1	4301001	13	13
	West Fork Ditch 2	4301002	5	5
	Wise Ditch No 1	4301019	12	12
	Seven J 7 Spring D.	4301025	30	30
	Seven J 7 Westside D.	4301026	10	10
	Elk Creek Ditch No 3	4301101	7	7
43_ADW004, WhiteNrMeeker	Amick Seepage Ditch	4300505	0	29
	Coal Creek Valley Ditch	4300580	32	32
	Doughty Ditch	4300606	21	42
	E P Campbell Ditch	4300614	24	29
	Evans Gulch Ditch 1	4300634	13	13
	Hall Gulch Ditch	4300675	48	14
	Jasper M Burch Ditch	4300721	72	73
	Jasper M Burch D No 2	4300722	51	57
	John Quinton Ditch	4300728	47	47
	Kissinger Ditch	4300749	69	74
	Lone Tree Ditch	4300773	27	0
	Mary Murray Ditch	4300793	39	39
	Murr Ditch 1	4300834	45	49
	Murr Ditch 2	4300835	6	6
	Payson Ditch	4300866	52	114
	T B Scott Ditch	4300962	6	6
	Thomas Lunney Ditch	4300969	51	51
	Valverde Ditch No 1	4300981	32	30
	Valverde Ditch No 5	4300982	92	0
	Williams Ditch	4301013	30	30
	Valverde Ditch No 4	4301037	27	28
	Nine Mile Spring 2	4301264	4	4
	Mchatten Reservoir	4303652	55	55
43_ADW005, WhiteNBLMeeker	Burch Ditch No 1	4300560	5	8
	Burch Ditch No 2	4300561	19	19

	Hughes Ditch 1	4300706	11	0
	Katie Ditch & Lat 1	4300735	0	31
	Keystone Ditch	4300738	76	75
	Keystone Ditch No 3	4300739	34	39
	Leroy A Cure Ditch No 2	4300760	9	16
	Leroy A Cure Ditch No 1	4300761	13	13
	Loring Ditch	4300774	16	16
	M S L Ditch	4300783	17	17
	Mcwilliams & George D	4300796	21	56
	Pat Reigan Ditch	4300861	39	39
	Sayer Spring Ditch	4300920	15	42
	Sheridan Ditch No 3	4300927	54	40
	Sulphur Ditch No 2	4300958	13	14
	Sulphur Ditch No 3	4300959	16	18
	Sulphur Ditch No 4	4300960	4	5
	Toothe Ditch	4300971	46	46
	Hughes No 2 Ditch	4301092	0	15
	Strawberry L&C Ditch 1	4302515	12	12
	Strawberry L&C Ditch 2	4302516	17	17
	Strawberry L&C Ditch 3	4302517	7	9
	Strawberry L&C Ditch 4	4302518	9	9
	Little Hills Alt Hg 3	4302611	8	13
	Little Hills Alt Hg 4	4302612	11	12
	Little Hills Alt Hg 5	4302613	3	3
	Little Hills Alt Hg 6	4302614	5	5
	Little Hills Alt Hg 7	4302615	9	0
	Little Hills Alt Hg 8	4302616	17	17
	Dry Fork Ditch No. 1	4302658	0	16
	Dry Fork Ditch No. 2	4302659	0	17
	Little Hills Well 13	4305005	20	20
43_ADW006, WhiteAbPiceanceC	Indian Springs Ditch	4300712	3	5
	Keystone Ditch No 2	4300740	12	14
	Keystone Springs Ditch	4300741	12	14
	Tschudy Gulch Canal	4301747	37	38
43_ADW007, PiceanceUpper	Dog Town Ditch	4300603	31	31
	Engstrand Ditch	4300626	16	16
	Gordan Ditch	4300662	0	11
	Hanrahan Ditch No 2	4300679	16	16
	Home Supply Ditch	4300702	10	0
	Walsh & Spaulding D Hg 1	4300723	0	1
	Leonard Ditch	4300759	46	64
	Mooney Ditch 1 And 2 Hg	4300781	8	10

	Mooney Ditch 1	4300829	8	10
	Cow Creek Ditch	4301029	4	3
	Mooney Ditch 2	4301048	8	10
	Upper Wallace Ditch 2	4301089	7	7
	Walsh Ditch	4301203	0	1
	Piceance Ditch	4301482	2	10
	Private Spring	4302416	21	27
	Johnson Spring 5	4302421	8	8
	Wallace Ditch Hg Alt 2	4302618	9	9
43_ADW008, PiceanceBlRioBla	King Ditch 2	4300745	0	18
	Oldland Ditch 3	4300852	13	13
	Leonard Spg	4301081	87	87
	Spaulding D Hdg 2	4301107	7	12
43_ADW009, PiceanceAbHunter	Blue Grass Ditch	4300547	13	13
	Ebler Ditch	4300619	0	10
	Florence Ditch	4300637	10	10
	Jessup Ditch 1	4300724	15	15
	Jessup Ditch 2	4300725	5	5
	Limberg Spring Ditch	4300765	17	31
	Oldland Magor Ditch	4300853	42	42
	P & L Ditch	4300858	17	21
	Piggott Ditch No 1	4300875	20	20
	Pile Ditch	4300876	11	11
	Taylor Ditch	4300963	24	47
	Watson Thompson D No 1	4300999	15	18
	Willow Creek Ditch No 1	4301014	60	60
	Willow Creek Ditch No 2	4301015	15	9
	Willow Creek Ditch No 3	4301016	5	5
	Gardenheir Ditch	4301030	30	30
	Piggott Ditch No 2	4301046	15	15
	West Stewart Res Ditch	4301139	35	35
	Barnes Spg	4302412	0	2
	Limberg Ditch No 2	4302477	17	17
43_ADW010, PiceanceBlRyanGu	Bainbrick Mikkelsen 1&2	4300520	0	22
	Boies Ditch	4300548	25	25
	D D Taylor Ditch	4300594	53	49
	Duckett Ditch	4300611	32	32
	Gilmor Ditch	4300656	21	21
	Hillside Ditch	4300697	18	18
	Hutchinson Spring Ditch	4300708	23	32
	Last Chance Ditch	4300755	27	23
	Mckee Ditch	4300794	37	37

	Mcgee Ditch	4300801	0	24
	Miller Ditch	4300820	34	65
	N & L Ditch	4300836	18	41
	No Name Ditch	4300846	0	15
	Sawyer Ditch	4300916	9	9
	Schweizer Ditch	4300924	25	23
	Fawn Creek Ditch	4301087	0	13
	J W Bainbrick D No 1	4301099	0	25
	Greeno Ditch 1	4302473	0	9
	Greeno Ditch 2	4302474	2	0
	Greeno Ditch 3	4302475	28	2
	Greeno Ditch 4	4302476	28	2
	Schweizer Ditch Alt Pt	4302600	23	9
	Black Eagle Alt Pt 1	4302601	5	8
	Square S Cons D Alt Pt	4302633	151	151
43_ADW012, WhiteBlBoiseCr	Bassett Ditch	4300531	17	17
	Beard Ditch	4300536	78	49
	John Delaney Ditch	4300727	47	47
	Lathan Ditch	4300756	0	22
	Luxton Draw Ditch	4300778	0	10
	Mead Irrigation System	4300806	40	50
	Queen Ditch	4300886	77	88
	Thompson Ditch	4300970	11	11
	Hughes Ditch	4301492	0	67
	Davidson Ditch No 2	4302451	10	10
	Davidson Spg & Ditch	4302452	7	7
	Minford Ditch	4302454	14	12
	Karren Reeve Ditch	4302456	60	60
	Berry Spring	4302457	8	8
	Blue Mountain Ditch	4302458	60	60
	Wear Well 1	4305021	0	1
	Pitman Well 3	4305043	2	3
43_ADW013, WhiteBlDouglasCr	Adams & Owens Ditch	4300500	51	51
	Adams Ditch	4300501	0	17
	Banta Ditch	4300521	0	40
	Buckner Ditch	4300556	65	65
	Foundation Ditch 1	4300641	0	24
	J P White Ditch	4300715	10	10
	Middle Creek Ditch	4300817	83	83
	Red Rock Ditch	4300892	24	0
	Savage Ditch	4300915	55	23
	Storey Ditch 2	4300955	14	14

	Stroud Ditch	4300956	10	10
	West Creek Canal	4301000	24	24
	Lewis Ditch	4301041	2	2
	Noel Pump	4301078	42	42
	Mitchell Ditch	4301083	59	66
	Strain Surface Pump 31-1	4301130	0	1
	Gillam Draw Ditch	4301202	12	12
	Correll Pump	4301338	0	2
	Comstock Pump Pl	4301496	0	1
	Pepper Well Diversion D	4302149	15	15
	Cathedral Ck Diversion	4302480	3	3
	Ducey Pump	4302552	58	40
	Neilson Pump No 2	4302593	51	53
	Cox Pump No 2	4302594	50	52
	Cox Pump No 3	4302595	22	22
	Box Elder Ditch No 2	4302603	3	0
43_ADW014, WhiteNrStateLn	Pioneer Ditch	4300877	91	89
	Purdy Irrigation Pump	4300884	6	0
	George Menge D	4301105	6	2
	Shavetail Pump & Pl	4301244	4	0
	Robinson Wardell Pump 1	4301252	11	0
	Robinson Wardell Pump 3	4301254	47	10
	Robinson Wardell Pump 4	4301255	26	26
	Robinson Wardell Pump 5	4301256	30	39
	Robinson Wardell Pump 7	4301258	18	4
	Robinson Wardell Pump 13	4301260	16	0
	Robinson Wardell Pump 14	4301261	56	49
	Neiberger Pump Station 1	4301723	6	6
	Robinson Wardell Pump 12	4302160	15	15
	Little Colorow Pump	4302305	31	0
	Bell Pump Station 1	4302361	16	4
	Wright Pump Sta No 1	4302444	14	9
	Stinking Water P P Ditch	4302449	2	0
	Goff Ditch Pump No 2	4302624	58	58
	Blue Mountain Well No 2	4305031	14	14
43_ADW015, EvacuationCr	Daniels Ditch	4300595	0	24
	Essie Janes Ditch	4300627	0	14
	J F Roth Ditch	4300733	0	32
	Owens Ditch 2	4300854	0	10
	Owens Ditch	4300857	0	28
	Pleasant View Ditch	4300878	18	18
	Richard Owen Ditch	4300900	0	13

	Thomas J Janes Ditch	4300968	7	7
	Walker Ditch	4300989	0	14
	W G Hirons Ditch	4301022	0	9
	Howell Ditch	4301542	0	20
43_ADW016, WhiteSBLMeeker	B P Franklin Ditch 1	4300515	13	13
	B P Franklin Ditch 2	4300516	9	13
	Bawden Ditch	4300533	50	50
	Beard & Watson Ditch	4300535	34	34
	Chandler Ditch	4300571	54	54
	Dorrell Ditch 1	4300604	13	13
	E Chandler Ditch	4300612	61	61
	Halpen Pump Pipeline	4300673	26	26
	Hoback & Redpath D	4300698	47	47
	Howey Ditch	4300705	65	65
	Island Ditch	4300713	21	21
	Nichols Ditch	4300843	7	57
	Seely Ditch	4300925	12	12
	Sprod Ditch 3	4300945	20	19
	Thirteenmile Ranch Ditch	4300964	12	12
	Thirteenmile Ranch D Ap	4300995	13	0
	Yonch Ditch	4301024	89	89
	Meeker Bridge Ditch	4301042	26	26
	Otto Metzger Ditch	4301094	41	43
	Lagrange Ditch 2	4301415	28	0
	Lagrange Ditch 3	4301513	27	0
	Frank & Evalon Huff D 1	4302056	11	11
	John A Story D No 3	4302080	24	34
	L K Canal	4302106	31	35
	Lower Sprod Ditch	4302120	22	22
	Strehlke Spg & Ditch	4302184	4	4
	Upper Sprod Ditch	4302211	23	23
	Bissell Ditch	4302245	7	11
	Dorrell Ditch 3	4302281	14	14
	Dorrell Ditch 4	4302282	14	14
	Owens Ditch	4302481	8	0
	Strehlke Spg Ditch Ap 1	4302630	4	4
	Strehlke Spg Ditch Ap 2	4302631	4	4

Exhibit B: Diversion Structures in each "No Diversion" Aggregate Structure

Aggregation ID	Structure Name	WDID	2005 Acres	2010 Acres
43_AND001, White North Fork	Herrell Pipeline	4300692	1	1
43_AND005, White N Bl Meeker	Little Hills Spg No 5	4302113	0	9
43_AND007, Piceance Bl Ryan Gu	Mccarthy Spring Ditch	4300797	65	65
43_AND010, Piceance Bl Boise Cr	Ryan Ditch	4301043	0	2
43_AND012, White Bl Boise Cr	Wear Well 3	4305020	0	1
43_AND013, White Bl Douglas Cr	Smalec Pump Site	4302635	35	33
43_AND016, White S Bl Meeker	Mve Ii & Ii Well	4306155	35	33
	Mve Ii C Well	4306166	0	0

A-2: Identification of Associated Structures (Diversion Systems and Multi-structures)

Background

The previous CDSS Western Slope models include associated structures which divert to irrigate common parcels of land. These associations were primarily based on information provided directly during meetings with Water Commissioners, and were not based on information from the original 1993 irrigated acreage assessment. The original CDSS 1993 irrigated acreage assessment was based on the USBR identification of irrigated land enhanced with a water source (ditch identifier) that served that land. Many of the irrigated acreage parcels covered more than one ditch service area and, in lieu of spending significant time splitting the parcels by ditch service area, more than one ditch was assigned. For CDSS modeling purposes, the acreage was simply "split" and partially assigned to each ditch.

Introduction

For the recent 2005 and 2010 acreage assessments, there was significant effort spent trying to refine irrigated parcels based on the legal and physical ditch boundaries so, where possible, there was only one ditch assigned to each irrigated parcel in Divisions 5, 6, and 7. Division 4 efforts concentrated on a few areas, but not the entire basin. To model these ditches as accurately as possible, it is important to understand if the acreage that is still assigned to more than one ditch is actually irrigated by all assigned ditches in a comingled fashion or, alternatively, if the acreage should be "split" and the structures should be modeled as having no association. Ditches combined for modeling because the supplies are believed to be comingled are termed "associated structures" for the CDSS modeling effort.

Some associated structures can be identified based on the HydroBase water rights transaction table because they are decreed alternate points or exchange points, while others can be identified based on Water Commissioner accounting procedures, generally documented in their comments accessible through Hydrobase. In the models, associated structures are represented as diversion systems if the structures are located on the same tributary or multi-structure systems if they are located on different tributaries. As part of Task 3, the associated structures were updated to more accurately model the combined acreage, diversions, and demands. These updates include the integration of the 2005 irrigated acreage, the 2010 irrigated acreage, as well as verification of associated structures based on diversion comments and water right transaction comments.

Approach

The following steps were used to identify associated structures in Divisions 5, 6, and 7. Because the Division 4 parcels have not yet been refined to the ditch service level, no effort was made to determine additional associated structures. Note, however, the parcels that require additional refinement have been identified and provided to Division 4. These updates should be included with the next acreage assessment.

Updating the associated structures was a multi-step process that involved 1) identifying potential associated structures by integrating the 2005 and 2010 CDSS irrigated acreage, 2) verifying the associated structures using the diversion and water right transaction comments, and 3) making recommendations on how to best represent the associated structures in the CDSS Western Slope models.

1) *Develop an Associated Structure List Based on Revised 2005and 2010 CDSS Irrigated Acreage*

   An initial associated structure list was developed by combining the CDSS revised 2005 and 2010 irrigated acreage. During this process the overlapping similarities between the two irrigated acreage coverages were integrated, resulting in a list of associated structures containing unique IDs. An illustrative example is presented below. In this example, the 2005 irrigated acreage coverage contains parcel A assigned to structures 1, 2, and 3; while the 2010 irrigate acreage coverage contains parcel B assigned to structures 2 and 4. Parcel A and B are integrated, resulting in an association comprised of structures 1, 2, 3, and 4.

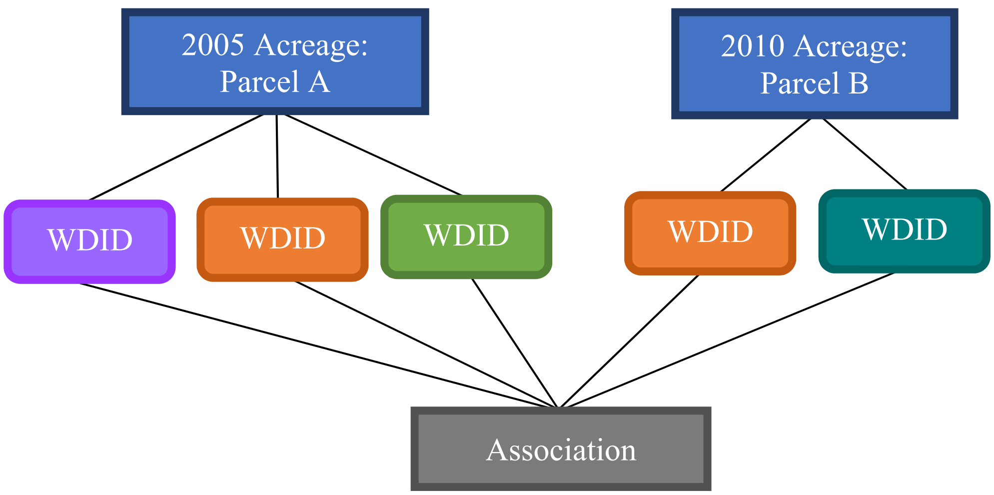


Figure A-2. Example of integrating the CDSS irrigated acreage coverage to identify associated structures.

2) *Verify the Associations Using Diversion and/or Water Right Transaction Comments*

   Once a unique list of associated structures was developed, each association was verified using diversion comments and/or water right transaction comments. If the diversion comments and/or water right transaction comments could not verify structure associations, then unverified structures were removed from the list of associated structures (i.e., their diversions will not be treated as commingled). Types of verification included comments identifying structures as alternate points of diversion, points of exchange, acreage reported under alternative structure, same points of diversion, and water right transfers.

   Below is an example of the verification methodology using the diversion and/or transaction comments for the association shown in step 1.

Table A-4. Example of Integrating the Diversion and Water Right Transaction Comments for Verification.

WDID	Verification Comment	Source	Verified?

1	Irrigates Y Ranch	Diversion Comment	N
2	Water right transferred to WDID 4	Transaction Comments	Y
3	Acreage is recorded under WDID 2	Diversion comments	Y
4	-	-	Y

Given this example, WDID 1 was not verified by the comments and, thus, not included in the final list of associated structures.

3) *Recommend a Modeling Approach for Representing Associated Structures in the CDSS Western Slope Models*

Using the refined associated structure list developed in step 2, recommendations on how to best represent the associated structures in the CDSS models were provided. These recommendations were based on the following criteria:

- If located on non-modeled tributaries, the associated structures were added to appropriate aggregates.
- Associated structures were explicitly modeled—either in diversion systems or multi-structure systems—if the net water rights for at least one structure in the association exceeded a specific threshold identified in previous modeling efforts. In general, the thresholds represent 75% of the net water rights and are listed in **Table A-5**.

Table A-5. Water Right Thresholds for Explicit Modeling.

CDSS Model	Water Right Threshold (CFS)
Yampa	5
White	4.8
Upper Colorado	11
San Juan/Dolores	5/6.5

Structures located on the same tributary were modeled as diversion systems, while structures located on different tributaries were modeled as a multi-structure system. Note, diversions systems combine acreage, headgate demands, and water rights; and the model treats them as a single structure. Contrastingly, multi-structure systems have the combined acreage and demand assigned to a primary structure; however, the water rights are represented at each individual structure, and the model meets the demand from each structure when their water right is in priority. **Figure A-3** illustrates how a diversion system is modeled, while **Figure A-4** illustrates how a multi-structure system is modeled.

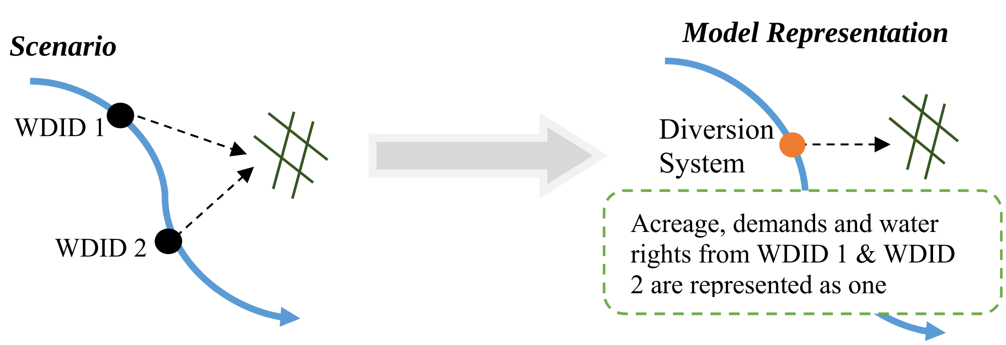


Figure A-3. Model Representation of a Diversion System.

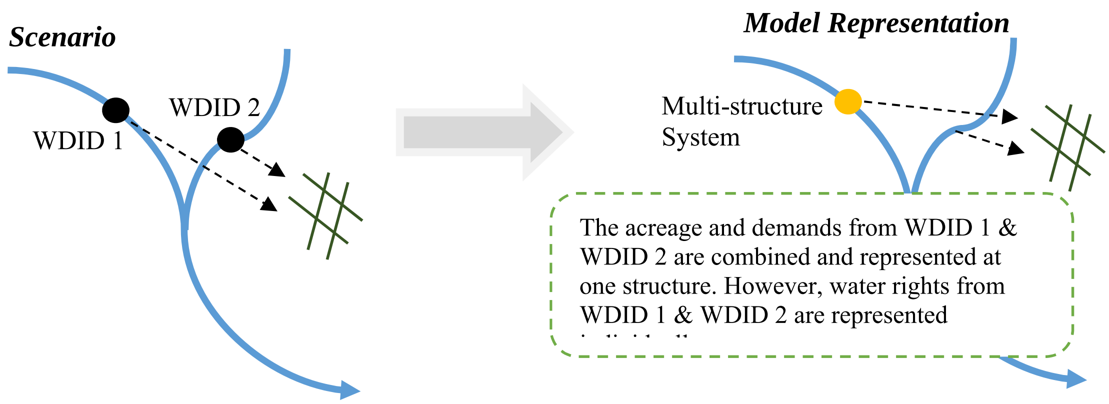


Figure A-4. Model Representation of a Multi-structure System.

  - o The structure with the most irrigated acreage—based on the 2005 and 2010 CDSS coverages—was selected as the modeled structure for each diversion system.
  - o The structure with the greatest net water rights was selected as the primary structure for multi-structure systems.
- If none of the structures in an association exceeded the water right threshold identified in Table A-5 and have contemporary diversion records, the structures were modeled in an aggregate.
- If all structures in an associated did not have diversion records, the structures were placed in a “no diversion” aggregate.