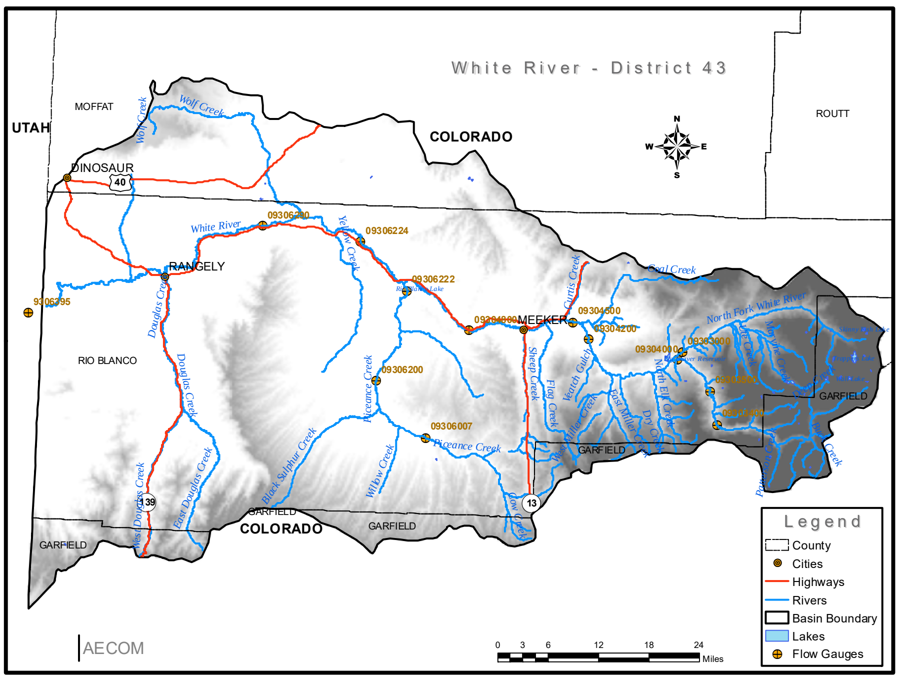
White River Basin
Water Resources Planning Model
User's Manual



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COLORADO'S DECISION SUPPORT SYSTEMS

COLORADO WATER CONSERVATION BOARD · STATE OF COLORADO · 1876 · 1937

Table of Contents

Table of Tables

Table of Figures

1. Introduction

1.1 Background

The Colorado Decision Support System (CDSS) consists of a database of hydrologic and administrative information related to water use in Colorado, and a variety of tools and models for reviewing, reporting, and analyzing the data. The CDSS water resources planning models, of which the White River Basin Water Resources Planning Model (White River model) is one, are water allocation models which determine availability of water to individual users and projects, based on hydrology, water rights, and operating rules and practices. They are implementations of "StateMod", a code developed by the State of Colorado for application in the CDSS project. The White River model "Baseline" data set, which this document describes, extends from the most currently available hydrologic year back to 1909. It simulates current demands, current infrastructure and projects, and the current administrative environment, as though they had been in place throughout the modeled period.

The White River model was developed as a tool to test the impacts of proposed diversions, reservoirs, water rights and/or changes in operations and management strategies. The model simulates proposed changes using a highly variable physical water supply constrained by administrative water rights. The Baseline data set can serve as the starting point for such analysis, demonstrating condition of the stream absent the proposed change but including current conditions. It is presumed that users will compare the Baseline simulation results to results from a model to which they have added the proposed features, to determine their performance and effects.

Information used in the model datasets are based on available data collected and developed through the CDSS, including information recorded by the State Engineer's Office. The model datasets 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.

1.2 Development of the White River Basin Water Resources Planning Model

The White River model was developed in steps that spanned 1994 through the present. The earliest effort designated Phase II following a Phase I scoping task, accomplished development of a calibrated model that simulated an estimated 75 percent of water use in the basin, leaving the remaining 25 percent of the use "in the gage". The original model study period was 1975 through 1991, which also served as the model's calibration period.

One objective of the CDSS endeavor was to represent all potential consumptive use within Colorado, and estimate actual consumptive use under water supply limitations. Thus in Phase IIIa, the previously unmodeled 25 percent use was added to the model as 16 aggregations of numerous small users. With the introduction of this demand, the calibration was reviewed and refined. The objective of Phase IIIb was to extend the model study period, using automated data filling techniques as well as research in the State's Records office to estimate or obtain historical gage and diversion information. The data set was extended back to 1909 and forward through 1996. The calibration was again reviewed, now using through the period 1975 through 1996.

The State continues to refine the White basin model. In 2005, the study period was extended through 2003, the "variable efficiency" method was added for determining irrigation consumptive use and return flows, and a daily version was created.

The most recent calibration effort extended the study period through 2013, included additional acreage assessments for 2005 and 2010, and re-evaluated the calibration. Additional nodes were added to represent future demands that can be turned on by users to explore "what-if" scenarios.

1.3 Acknowledgements

CDSS is a project of the Colorado Water Conservation Board (CWCB), with support from the Colorado Division of Water Resources (DWR). The White River model has been developed and enhanced at different stages by Riverside Technology, Inc., Boyle Engineering Corporation, Leonard Rice Engineers, CWCB, and DWR staff. The model update through 2013 was completed by Wilson Water Group.

2. What's In This Document

2.1 Scope of this Manual

This reference manual describes the CDSS White River Water Resources Planning Model, an application of the generic water allocation model StateMod and one component of the Colorado Decision Support System. It is intended for the reader who:

- Wants to understand basin operations and issues through review of the model
- Needs to evaluate the model's applicability to a particular planning or management issue
- Intends to use the model to analyze a particular White River development or management scenario
- Is interested in estimated conditions on the White River under current development, over a range of hydrologic conditions, as simulated by this model; and in understanding assumptions embedded in the modeling estimates.

For this manual to be most effective, the reader should have access to a complete set of data files for the White River model, as well as other CDSS documentation as needed (see below).

The manual describes content and assumptions in the model, implementation issues encountered, approaches used to estimate parameters, and results of both calibrating and simulating with the model. Limited general information is provided on the mechanics of assembling data sets using various CDSS tools.

2.2 Manual Contents

Specifically, the manual is divided into the following sections:

Section 3 White River Basin – describes the physical setting for the model, and reviews very generally water resources development and issues in the basin.

Section 4 Modeling Approach – provides an overview of methods and techniques used in the White River model, addressing an array of typical modeling issues such as:

- areal extent and spatial detail, including the model network diagram
- study period
- aggregation of small structures
- data filling methods

- simulation of processes related to irrigation use, such as delivery loss, soil moisture storage, crop consumptive use, and returns of excess diversions
- development of baseflows
- calibration methods

Much of Section 4 is common to the other CDSS models, although the section refers specifically to the White River model.

Section 5 Baseline Data Set – "Baseline data set" refers to the input files for simulating under current demands, current infrastructure and projects, and the current administrative environment, as though they were in place throughout the modeled period. The data set is generic with respect to future projects, and could be used as the basis against which to compare a simulation that includes a new use or operation. The user should understand how demands and operations are represented. Elements of these are subject to interpretation, and could legitimately be represented differently.

This section is organized by input file. The first is the response file, which lists all other files and therefore serves as a table of contents within the section. The content, source of data, and particular implementation issues are described for each file in specific detail.

Section 6 Baseline Results - presents summarized results of the Baseline simulation. It shows the state of the river as the White River model characterizes it under Baseline conditions. Both total flow and flow legally available to new development are presented for key sites.

Section 7 Calibration – describes the calibration process and demonstrates the model's ability to replicate historical conditions under historical demand and operations. Comparisons of streamflow, diversions, and reservoir levels are presented.

Appendix A Aggregation of Irrigation Diversion Structures – describes the methodology for creating aggregate structures, diversion systems and multi-structures systems. Tables of all structures included in aggregates and systems are presented. Includes technical memoranda describing how aggregate water rights classes were identified and implemented.

Appendix B Aggregation of Non-Irrigation Structures – historical technical memoranda specific to the White River model describing how municipal and industrial use, and aggregated reservoirs and stock ponds are represented.

There is some overlap of topics both within this manual and between this and other CDSS documentation. To help the user take advantage of all sources, pointers are included as applicable under the heading "**Where to find more information**" throughout the manual.

2.3 What's in Other CDSS Documentation

The user may find the need to supplement this manual with information from other CDSS documentation. This is particularly true for the reader who wants to:

- make significant changes to the White River model to implement specific future operations
- introduce changes that require regenerating the baseflow data file
- regenerate input files using the Data Management Interface (DMI) tools and Hydrobase
- develop a StateMod model for a different basin

An ample body of documentation exists for CDSS, and is still growing. A user's biggest challenge may be in efficiently finding the information. This list of descriptions is intended to help in selecting the most relevant data source:

Basin Information – the report "White River Basin Information" provides information on specific structures, operations, and practices within the basin. While the information was gathered in support of the planning model when it was first undertaken, it is widely useful to anyone doing any kind of water resources investigation or analysis.

Consumptive Use Report – the report "Historical Crop Consumptive Use Analysis: White River Basin 2015" provides information on the consumptive use analysis that was used as input to the Baseline Demand scenario.

DMI user documentation – user documentation for **StateDMI** and **TSTool** is currently available, and covers all aspects of executing these codes against the Hydrobase database. The DMI's preprocess some of the StateMod input data. For example, **StateDMI** computes coefficients for spatially distributing baseflow gains throughout the model, and aggregates water rights for numerous small structures; **TSTool** preprocesses time series input, and displays time series results. Thus the documentation, which explains algorithms for these processes, is helpful in understanding assumptions embedded in the planning models. In addition, the documentation is essential for the user who is modifying and regenerating input files using the DMI's.

StateMod documentation – the StateMod user manual describes the model in generic terms and specific detail. Section 3 Model Description and Section 7 Technical Notes offer the best descriptions of StateMod functionality, and would enhance the White River model user's understanding of results. Users who are modifying input files should consult Section 4 Input Description to determine how to format files. To analyze model results in detail, review Section 5 Output Description, which describes the wide variety of reports available to the user.

StateCU documentation – StateCU is the CDSS irrigation consumptive use analysis tool. It is used to generate structure-specific time series of irrigation water requirement, an input to

StateMod. A model change that involves modified irrigated acreage or crop-type would require re-execution of StateCU.

Self-documented input files – an important aspect of the StateMod input files is that their genesis is documented in the files themselves. Command files that directed the DMI's creation of the files are echoed in the file header. Generally, the model developers have incorporated comments in the command file that explain use of options, sources of data, etc.

Technical Memos – many aspects of the modeling methods adopted in CDSS were explored in feasibility or pilot studies before being implemented. Historical technical memoranda for these activities are available on the CDSS website.

- Phase IIIb Task Memorandum 10.1 – Data Extension Feasibility
- Phase IIIb Task Memorandum 10.2 – Evaluate Extension of Historical Data
- Phase IIIb Task Memorandum 11.5 – Characterize Streamflow Data
- Phase IIIb Task Memorandum 11.7 – Verify Diversion Estimates
- Phase IIIb Task Memorandum 11.10 – Fill Missing Baseflow data (include Mixed Station Model user instruction)
- Variable Efficiency Evaluation Task Memorandum 1.3 – Run StateMod to create baseflows using the Variable Efficiency and Soil Moisture Accounting Approach
- Variable Efficiency Evaluation Task Memorandum 1.5 – Compare StateMod Variable Efficiency and Soil Moisture Accounting Historical Model Results to Previous CDSS Model Results and Historical Measurements
- CDSS Memorandum "Colorado River Basin Representative Irrigation Return Flow Patterns"
- SPDSS Task 59.1 Memorandum – Develop Locally Calibrated Blaney-Criddle Crop Coefficients

3. The White River Basin

The White River basin lies between the Colorado River and Yampa River basins, in northwest Colorado. The White River is tributary to the Green River, but does not reach the Green until it has traveled into Utah. The basin within Colorado is approximately 3,750 square miles, and encompasses nearly all of Rio Blanco County as well as the southwestern fringe of Moffat County to the north, and portions of Garfield County to the south and east. Figure 3.1 is a map of the basin.

3.1 Physical Geography

The North and South Forks of the White River both begin in the highlands of the Flat Tops formation at about 11,000 feet. They flow generally west, meeting near Buford shortly outside the White River National Forest. The Flat Tops are a remnant of the White River Uplift, formed over 50 million years ago, and glaciated during the Pleistocene and possibly early Holocene. As a result, the landscape in the upper White River is characterized by many glacial lakes and U-shaped valleys. The uplift is bounded on the west by the Grand Hogback, a north-south trending, nearly vertical upturn of Mesa Verde sandstones and shales. This feature 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. At Rangely, the White River is on the edge of the Colorado Plateau physiographic province. Here the terrain is typical of that province, with impressive mesas, cliffs, and rims. The White River enters Utah about 20 miles west of Rangely.

Climate in the White River basin is similar to other western Colorado basins, varying with elevation. Average annual rainfall varies from over 40 inches in the Flat Tops to approximately 10 inches at Rangely. Temperatures vary inversely with elevation and variations in the growing season follow a similar trend. Winter brings snow and cold temperatures at the higher elevations but mild, sunny days in the west.

The various elevations in the basin define distinctive vegetation types and coverages. Lacking elevations over 12,500 feet, the White River basin has little land above treeline. At the upper, eastern end of the basin, Englemann spruce and sub-alpine fir are the dominant forest cover. Lodgepole pine, ponderosa pine, and spruce fir mingle with areas of high grasslands at slightly lower elevations. Below 9,000 feet, vegetation transitions to Gambel oak, pinion/juniper, and sagebrush-steppe communities. The western portion of the basin, at an elevation of approximately 5,500 feet, is dominated by sagebrush, grasslands, and salt desert shrublands.

Average annual streamflow in the White River at the Colorado-Utah state line is 596,000 acre-feet, based on operation of a USGS gage at the State Line from 1977 through 1985.

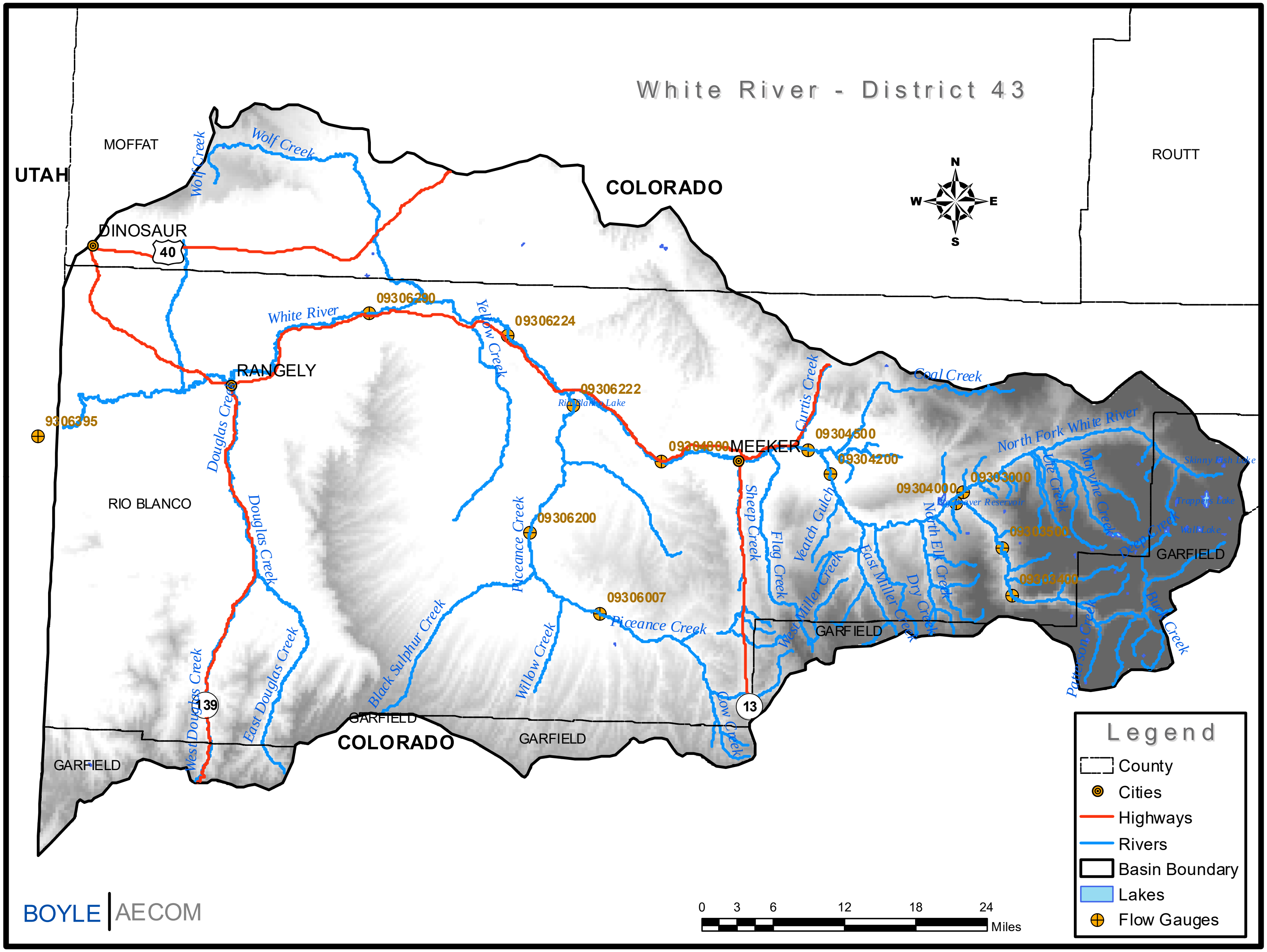


Figure 3.1 – White River Basin

Most of the runoff is attributable to snowmelt from the higher elevation areas. Sub-basins in the White River basin include Big Beaver Creek, Fawn Creek, Hahn Creek, the North and South Forks of the White River, Piceance Creek, Yellow Creek, and Douglas Creek.

3.2 Human and Economic Factors

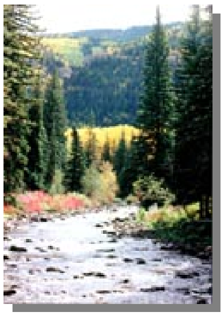


Figure 3.2 – Trapper's Lake

Public lands, primarily federally held, comprise the majority of the White River basin. The White River National Forest, including portions of the Flattop Wilderness Area, occupies the eastern headwater area. The central and western basin is nearly all under the Bureau of Land Management; of the White River basin in Rio Blanco County, approximately 60 percent is under BLM management. Private land is located between the National Forest and the BLM holdings, more or less in the vicinity of Meeker; and in narrow bands along the White River from Powell Park, west of Meeker, to the State Line, and along Piceance Creek.

The White River basin is sparsely populated. The US Census places Rio Blanco County's population at about 6,707 in 2014[1]. Meeker and Rangely are the only towns in the county, with populations of 2,475 and 2,433 respectively.

Farming and ranching are predominant economic activities in the eastern half of the basin. Irrigated acreage in the White River basin totals approximately 26,000 acres, of which approximately ninety percent is in pasture grass, and the remaining ten percent is in alfalfa. The greatest concentration of irrigated lands is in the river valley around Meeker. Irrigation is practiced on benches and lands adjacent to the stream, in the privately held corridors described above.

Mining and oil and gas extraction are major economic activities in the basin, particularly in the western portion. Traditional methods of extracting oil and gas have been used in the White River basin since Chevron Oil discovered the Weber Sandstone oil field there in the 1930's. The flagging economy of the day was responsible for low production there until World War II, after which Rangely became first a booming oil camp and then a town. The Roan Creek Plateau and Piceance Creek basin host some of the largest oil shale deposits and coal bed methane reservoirs known. Although oil extraction from oil shale is not practiced on a production scale, many conditional water rights have been filed in this area.

Recreational assets are abundant in the White River basin. Hunting and fishing are primary draws, as this area includes some of Colorado's best elk hunting. The Town of Meeker's website asserts that their population doubles during hunting season, and the Colorado Division

[1]United States Census Bureau. State & County QuickFacts, Rio Blanco County, Colorado. http://quickfacts.census.gov/qfd/states/08/08103.html. Accessed 5/11/2015

of Wildlife estimated that in 1996, out-of-state hunters and anglers brought $9.7 million dollars into Rio Blanco County.

3.3 Water Resources Development

The earliest rights in White River basin are irrigation rights bearing an appropriation date of 1880, and the first general adjudication was done in 1889. Although there is some municipal and industrial use of surface water, the primary use is agricultural. Irrigation is generally practiced by individual farmers or ranchers, and there are a small number of large organized, mutual ditch or irrigation companies, compared with other basins in the state.

The towns of Meeker and Rangely draw drinking water from the White River via alluvial wells. According to the Groundwater Atlas of Colorado, about 1,000 af/yr is pumped from alluvial aquifers, primarily for municipal, domestic, and stock watering purposes.

There are no known exports of water out of the White River basin.

Reservoir storage has not been significantly developed, and in fact, there are no federal storage projects in the basin. The three largest reservoirs in the basin are:

Figure 3.3 – Taylor Draw Reservoir

- Taylor Draw Reservoir (also known as Kenney Reservoir) has a storage volume of 13,800 acre-feet and is used primarily for recreation and hydropower generation. It is located just east of Rangely, was constructed by the Colorado River Water Conservation District, and is now owned and operated by Rio Blanco Water Conservancy District.
- Lake Avery Reservoir (also known as Big Beaver Reservoir) has a storage volume of 7,658 acre-feet and is used primarily for recreation. It is owned and operated by the Colorado Division of Wildlife and is located about 20 miles east of Meeker.
- Rio Blanco Reservoir (also known as Johnnie Johnson Reservoir), has a storage volume of 1,036 acre-feet. It is an off-channel reservoir located about 16 miles west of Meeker.

Industrial use of water in the basin remains minor at this time, amounting to less than 1,000 af/yr, according to estimates made during early CDSS development. The long-range potential for oil shale development in the area remains an open issue, however. Should such development occur the increased demand for water could potentially be high, depending on the technology used, the extent of the project, and the urban development required to accommodate an associated influx of the industrial workers and their families.

3.4 Water Rights Administration

There are few special water rights operations, exchanges, or water user agreements on the mainstream of the White River. The key ditch structures, which are located east of Meeker, include:

- Highland Ditch
- Miller Creek Ditch
- Oak Ridge Park Ditch
- Old Agency Ditch, and
- Lowland Ditch

Historical water rights have been administered in the White River basin on the basis of direct flow priorities where senior direct flow rights will call out junior diverts elsewhere on the river. The senior direct flow rights on the mainstream of the White River between Flat Creek and Miller Creek have only had to call out junior diverters twice, once in 1977 and once in 2002. Piceance Creek, a tributary to the White, is routinely subject to administrative regulation during the irrigation season.

3.5 Section 3 References

1. CDM Smith, (2014). *Projects and Methods Study*. Prepared for Yampa/White Basin Round Table. Retrieved from http://cwcb.state.co.us/water-management/basin-roundtables/Documents/YampaWhite/YampaWhiteProjectsMethodsStudy_DraftFinal02272014.pdf

2. Hydros Consulting and AMEC (2015). *Yampa/White/Green Basin Implementation Plan*. Prepared for Yampa/White/Green Basin Round Table. Retrieved from https://www.colorado.gov/pacific/sites/default/files/Yampa-WhiteBIP_Full.pdf

3. Yampa and White River Basin Facts, Colorado Water Conservation Board, available at http://cwcb.state.co.us

4. Modeling Approach

This section describes the approach taken in modeling the White River basin, from a general perspective. It addresses scope and level of detail of this model in both the space and time domains, and describes how certain hydrologic processes are parameterized.

4.1 Modeling Objectives

The objective of the White River modeling effort was to develop a water allocation and accounting model that water resources professionals can apply to evaluations of planning issues or management alternatives. The resulting “Baseline” input data set is one representation of current water use, demand, and administrative conditions, which can serve as the base in paired runs comparing river conditions without and with proposed future changes. By modifying the Baseline data set to incorporate the proposed features to be analyzed, the user can create the second input data set of the pair.

The model was used to estimate the basin’s consumptive use by simulating 100 percent of basin demand. This objective was accomplished by representing large or administratively significant structures at model nodes identified with individual structures, and representing many small structures at “aggregated” nodes. Although the model was first developed and calibrated for the period from 1975 forward, the data set was extended backward to 1909, creating a long-term data set reflecting a wide variety of hydrologic conditions.

Another objective of the CDSS modeling effort was to achieve good calibration, demonstrated by agreement between historical and simulated streamflows, reservoir contents, and diversions when the model was executed with historical demands and operating rules. This objective was achieved as demonstrated in Section 7.

4.2 Model Coverage and Extent

4.2.1 Network Diagram

The network diagram for the White River model can be viewed in StateDMI. It includes approximately 185 nodes, beginning at the headwaters of the North and South Forks and extending to the Colorado-Utah state line.

4.2.2 Diversion Structures

4.2.2.1 Key Diversion Structures

Early in the CDSS process it was decided that, while all consumptive use should be represented in the models, it was not practical to model each and every water right or diversion structure individually. Seventy-five percent of use in the basin, however, should be represented at strictly correct river locations relative to other users, with strictly correct priorities relative to other users. With this objective in mind, key structures to be "explicitly" modeled were identified 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 model includes 115 key diversion structures.

Where to find more information

- Section 3 of the CDSS document "White River Basin Information" lists candidate key structures and in some cases indicates why structures were or were not designated as "key". These decisions were often based on Water Commissioner input which is also documented in the White River Basin Information section "Division 6 Meeting".
- Appendix A: White River Aggregated Irrigation Structures describes how the irrigation structures were designated as "key" or included in aggregate structures.

4.2.2.2 Aggregation of Irrigation Structures

The use associated with irrigation diversions having total absolute rights less than 4.8 cfs were included in the model 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. The aggregations were devised so that each represented no more than 1,000 irrigated acres. In the White River model, 22 aggregated nodes were identified, representing about 6,600 acres of irrigated crops. Generally, these nodes were placed in the model at the most downstream position within the aggregated area.

Aggregated irrigation nodes were assigned all the water rights associated with their member structures. 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.

Where to find more information

- Appendix A: White River Aggregated Irrigation Structures describes how the irrigation structures were aggregated. It includes a table showing what diversion structures are included in each aggregation.

4.2.2.3 Aggregation of Municipal and Industrial Uses

One node in the model represents the combined small diversions for municipal, industrial, and livestock use in the basin. Total non-irrigation consumptive use in the White basin was estimated relatively early in CDSS development, as part of an effort to quantify total consumptive uses and losses in the Colorado River basin. Consumptive use of the key municipal and industrial diversions in the model was subtracted from this White River basin-wide M&I consumption, to derive the basin-wide consumptive use attributable to small M&I users.

The aggregated M&I node in the White River model represents approximately 1,100 af of consumptive use, a small percentage of the basin total use. These diversions have a priority of 1.0 (very senior) in the model, and a decreed amount that greatly exceeds their demands. In other words, these structures' diversions are not limited by their water right. The annual demand is distributed uniformly across the twelve months of the year.

Where to find more information

- Appendix B: White River Basin Aggregated Municipal and Industrial Use describes the task in which municipal and industrial uses were aggregated.

4.2.3   Reservoirs

4.2.3.1 Key Reservoirs

The two largest reservoirs, Big Beaver (aka Lake Avery) and Kenney Reservoir (aka Taylor Draw Reservoir), are considered key reservoirs and are explicitly modeled. Their physical capacities are 7,658 and 13,800 acre-feet, respectively.

4.2.3.2 Aggregation of Reservoirs

In keeping with CDSS's objective of representing all consumptive use in the basin, the evaporation losses associated with small reservoirs were incorporated using four aggregated reservoirs structures. Two structures represent all the adjudicated, absolute storage rights in the database that are otherwise unaccounted for. The basin-wide total storage of these rights amounted to approximately 4,200 acre-feet which were divided evenly between the two aggregations. One is located in the model above Piceance Creek in the middle of the basin, and the second is located near the Colorado-Utah state line gage. Surface area for the reservoirs was developed assuming they are straight-sided pits with a depth of 25 feet.

Table 4.1
Aggregated Reservoirs

ID	Name	Capacity(AF)	%
43_ARW001	Agg Res near COLO-UTAH State Line	2,117	50
43_ARW002	Agg Res above Piceance Cr - White River confluence	2,117	50
	Total	**4,234**	**100**

The two remaining reservoirs represent stockpond use, as documented in Appendix B. Total estimated storage for District 43 was divided in two and represented at two nodes. As with the decreed reservoir aggregates, one is located in the model in the middle of the basin above Piceance Creek, and the second is located near the state line. The stockponds were modeled as 10-foot deep, straight-sided pits.

Table 4.2
Aggregated Stockponds

ID	Name	Capacity(AF)	%
43_ASW001	Stock Pond near COLO-UTAH State Line	2,388	50
43_ASW002	Stock Pond above Piceance Cr - White River confluence	2,388	50
	Total	**4,776**	**100**

Neither the aggregated reservoirs nor the stockponds release to the river in the models. They evaporate, however, and fill to replace the evaporated amount. The effects of small reservoirs filling and releasing are left "in the gage" in the model, and are reflected in CDSS baseflow computations. The aggregated reservoirs are assigned storage rights with a priority of 1.0 (very senior) so that the evaporation use is not constrained by water rights.

> **Where to find more information**
>
> - Appendix B: White River Basin Aggregated Municipal and Industrial Use describes the task in which municipal and industrial uses were aggregated.

4.2.4 Instream Flow Structures

The model includes seven instream flow reaches representing instream flow rights held by CWCB. These are only a subset of the total CWCB tabulation of rights because many instream flow decrees are for stream reaches very high in the basin, above the model network. An additional instream flow structure is included to simulate a bypass requirement below Taylor Draw Reservoir. The purpose of the bypass is to meet flow needs of Colorado squawfish, as described in the Biological Opinion for the Taylor Draw Project, issued by the U.S. Fish and Wildlife Service in May, 1982.

4.3 Modeling Period

The White River model data set extends from 1909 through 2013 and operates on USGS water year (October 1 through September 30). The calibration period was 1975 through 2013; a period selected because historical diversion data were readily available in electronic format for key structures. In addition, the period reflects most recent operations in the basin, and includes both drought (1977, 1989-1992, 2000s) and wet cycles (1983-1985, 2011).

As one goes back in time within the data set, more and more data are estimated. Before extending the data set, a feasibility study was done which included a survey of available data and methods for data extension. The scope of the study included all five West Slope planning models.

> **Where to find more information**
>
> - The feasibility study for the data extension is documented in two task memos, which are available on the CDSS website:
>   - Task 10.1 - Data Extension Feasibility
>   - Task 10.2 - Evaluate Extension of Historical Data

4.4 Data Filling

In order to extend the data set to 1909, a substantial amount of reservoir content, diversion, demand, and baseflow time series data needed to be estimated. Generally, HydroBase data begins in 1975, although for some structures there is additional, earlier historical data.

Therefore, CDSS methods and tools had to be developed to automate the estimation process for the remaining structures. This section describes data filling and extension for the White River basin model.

4.4.1 Historical Data Extension for Major Structures

4.4.1.1 Historical Diversions

No additional data was collected outside of HydroBase records for historical diversions.

4.4.1.2 Historical Reservoir Contents

Two reservoirs are represented in the model. Both reservoirs are primarily operated to stay full year-round. Therefore, no additional data was collected. Missing data from the early period of operation is filled with constant reservoir capacity values.

Table 4.3
Major Reservoirs Structures

WDID	Reservoir Name	Capacity (af)	First Year of Operation
4303633	BIG BEAVER (LAKE AVERY)	7,658	1965
4304433	KENNEY (TAYLOR DRAW RESERVOIR)	13,800	1985

4.4.2 Automated Time Series Filling

An automated procedure was adopted to fill time series (i.e., historical diversions, demand, historical reservoir contents, reservoir targets, and irrigation water requirement) input to the model. It is a refinement over using an overall monthly average as the estimated value. Each month of the modeling period has been categorized as an Average, Wet, or Dry month based on the gage flow at a long-term "indicator" gage in the White basin. A data point missing for a Wet March, for example, is then filled with the average of only the Wet Marches in the partial time series, rather than all Marches.

The process of developing the Average, Wet, and Dry designation for each month is referred to as "streamflow characterization". The streamflow characterization in the White basin is based on the USGS gage White River near Meeker (09304500). 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 months with flows between these two cutoffs are characterized as "Average".

When historical diversion records are filled, a constraint is added to the estimation procedure. The estimated diversion may not exceed the water rights that were available to the diversion at the time. For example, if a ditch was enlarged and a junior right added to it in the 1950s, then a diversion estimate for 1935 cannot exceed the amount of the original right. The date of first use is derived from the administration number of the water right, which reflects the appropriation date.

Where to find more information

- A proof-of-concept effort with respect to the automated data filling process produced the following task memos, which are available on the CDSS website:
  - Task 10.1 - Data Extension Feasibility
  - Task 10.2 - Evaluate Extension of Historical Data
  - Task 11.5 - Characterize Streamflow Data
  - Task 11.7 - Verify Diversion Estimates
- These memos describe rationale for the data-filling approach, explore availability of basic gage data, explain the streamflow characterization procedure, and provide validation of the methods.
- StateDMI documentation describes the Streamflow Characterization Tool, a calculator for categorizing months as Average, Wet, or Dry
- TSTool documentation describes how to invoke the automated data filling procedure

4.4.3 Baseflow Filling

A typical approach to filling missing hydrologic sequences in the process of basin modeling is to develop regression models between historical stream gages. The best fitting model is then applied to estimate missing data points in the dependent gage's record. Once gage flow time series are complete; observed or estimated diversions, changes in storage, and so forth are added to or subtracted from the gage value to produce an estimated naturalized flow or baseflow.

The typical approach was deemed inadequate for a study period that extended over decades and greatly changed operating environments. Gage relationships derived from late-century gage records probably are not applicable to much earlier conditions, because the later gages reflect water use that may not have been occurring at the earlier time. The CDSS approach is therefore to estimate baseflows at all points where actual gage records are available, and then correlate between naturalized flows, as permitted by availability of data. Ideally, since baseflows do not reflect human activity, the relationship between two sets of baseflows is independent of the resource use and can be applied to any period. In the White River model, two historical gages were filled using regression prior to baseflow development, as shown in Table 5.2.

Baseflow filling is carried out more or less automatically using the USGS Mixed Station Model, enhanced for this application under the CDSS project. The name refers to its ability to fill many series, using data from all available stations. Many independent stations can be used to fill one time series, but only one station is used to fill each individual missing value. The Mixed Station Model fits each combination of dependent and independent variable with a linear regression relationship on log-transformed values, using the common period of record. For each point to be filled, the model then selects the regression that yields the least standard error of prediction (SEP) among all eligible correlations.

In reality, the further back in time records are researched, the fewer gage records exist to create baseflow series that can serve as independent variables. From 1909 to the 1960's, there were three or fewer USGS stations in the basin, depending on the year. Approximately 58 percent of the gage site baseflows are filled.

Where to find more information

- The task memorandum documenting application of the Mixed Station Model to CDSS baseflows is entitled "Subtask 11.10 Fill Missing Baseflows" and is available on the CDSS website. It describes a sensitivity investigation of the use of historical gage data in lieu of baseflow estimates.

4.5 Consumptive Use and Return Flow Amounts

The related values, consumptive use and return flow, are key components of both baseflow estimation and simulation in water resources modeling. StateMod's baseflow estimating equation includes a term for return flows. Imports and reservoir releases aside, water that was in the gage historically is either natural runoff or delayed return flow. To estimate the natural runoff, or more generally, the baseflow, one must estimate return flow. During simulation, return flows affect availability of water in the stream in both the month of the diversion and subsequent months.

For non-irrigation uses, consumptive use is the depletive portion of a diversion, the amount that is taken from the stream and removed from the hydrologic system by virtue of the beneficial use. The difference between the diversion and the consumptive use constitutes the return flow to the stream.

For irrigation uses, the relationship between crop consumptive use and return flow is complicated by interactions with the water supply stored in the soil, i.e., the soil moisture reservoir, and losses not attributable to crop use. This is explained in greater detail below.

4.5.1 Variable Efficiency of Irrigation Use

Generally, the efficiency of irrigation structures in the White River model is allowed to vary through time, up to a specified maximum efficiency. Setting aside soil moisture dynamics for the moment, the predetermined crop irrigation water requirement is met out of the simulated headgate diversion, and efficiency (the ratio of consumed water to diverted water) falls where it may – up to the specified maximum efficiency. If the diversion is too small to meet the irrigation requirement at the maximum efficiency, maximum efficiency becomes the controlling parameter. Crop consumption is limited to the diverted amount times maximum efficiency, and the balance of the diversion, less 3 percent loss, returns to the stream. The 3 percent loss represents water lost to the hydrologic system altogether through, for example, non-crop consumptive use, deep groundwater storage, or evaporation. This value is recommended as an appropriate estimate of incidental use for the White River basin.

The model is supplied with the time series of irrigation water requirements for each structure based on its crop type and irrigated acreage. This information is generated using the CDSS StateCU model. Maximum system efficiency is also input to the model. Maximum flood irrigation system efficiencies are estimated to be 54 percent (combined ditch efficiency and application efficiency) and sprinkler irrigation is estimated at 72 percent throughout the White River basin.

Headgate diversion is determined by the model, and is calculated in each time step as the minimum of 1) the water right, 2) available supply, 3) diversion capacity, and 4) headgate demand. Headgate demand is input as a time series for each structure. During calibration, headgate demand for each structure is simply its historical diversion time series. In the Baseline data set, headgate demand is set to the irrigation water requirement for the specific time step and structure, divided by the historical efficiency for that month of the year. Historical efficiency is defined as the smaller of 1) average historical diversion for the month, divided by average irrigation water requirement, and 2) maximum efficiency. In other words, if water supply is generally plentiful, the headgate demand reflects the water supply that has been typical in the past; and if water supply is generally limiting, it reflects the supply the crop needs in order to satisfy full crop irrigation requirement at the maximum efficiency.

StateMod also accounts for water supply available to the crop from the soil. Soil moisture capacity acts as a small reservoir, re-timing physical consumption of the water, and affecting the amount of return flow in any given month. Soil moisture capacity is input to the model for each irrigation structure, based on NRCS mapping. Formally, StateMod accounts for water supply to the crop as follows:

> Let **DIV** be defined as the river diversion, $\boldsymbol{\eta_{max}}$ be defined as the maximum system efficiency, and let $\mathbf{CU_i}$ be defined as the crop irrigation water requirement.
>
> Then, $SW = DIV * \eta_{max}$; (Max available water to crop)

when $SW \geq CU_i$: (Available water to crop is sufficient to meet crop demand)

$CU_w = CU_i$ (Water supply-limited CU = Crop irrigation water requirement)

$SS_f = SS_i + \min[(SS_m - SS_i),(SW - CU_w)]$ (Excess available water fills soil reservoir)

$SR = DIV - CU_w - (SS_f - SS_i)$ (Remaining diversion is “non-consumed”)

$TR = 0.97 * SR$ (Non-consumed less incidental loss is total return flow)

when $SW < CU_i$: (Available water to Crop is not sufficient to meet crop demand)

$CU_w = SW + \min[(CU_i - SW), SS_i]$ (Water supply-limited CU = available water to crop + available soil storage)

$SS_f = SS_i - \min[(CU_i - SW), SS_i]$ (Soil storage used to meet unsatisfied crop demand)

$SR = DIV - SW$ (Remaining diversion is “non-consumed”)

$TR = 0.97 * SR$ (Non-consumed less incidental loss is total return flow)

where **SW** is maximum water available to meet crop demand

CU_w is water supply limited consumptive use;

SS_m is the maximum soil moisture reservoir storage;

SS_i is the initial soil moisture reservoir storage;

SS_f is the final soil moisture reservoir storage;

SR is the diverted water in excess of crop requirement (non-consumed water);

TR is the total return to the stream attributable to this month’s diversion.

For the following example, assume the maximum system efficiency is 54 percent; therefore a maximum of 54 percent of the diverted amount can be delivered and available to the crop. When this amount exceeds the irrigation water requirement, the balance goes to the soil moisture reservoir, up to its capacity. Additional non-consumed water returns to the stream, subject to 3 percent incidental loss. In this case, the crop needs are completely satisfied, and the water supply-limited consumptive use equals the irrigation water requirement.

When 54 percent of the diverted amount (the water delivered and available to meet crop demands) is less than the irrigation water requirement, the crop pulls water out of soil moisture storage, limited by the available soil moisture and the unsatisfied irrigation water requirement. Water supply-limited consumptive use is the sum of diverted water available to the crop and supply taken from soil moisture, and may be less than the crop water requirement. Total return flow is the 46 percent of the diversion deemed unable to reach the field (non-consumed), less 3 percent incidental loss.

With respect to consumptive use and return flow, aggregated irrigation structures are treated as described above, where the irrigation water requirement is based on total acreage for the aggregate.

4.5.2 Efficiency for Other Uses and Special Cases

In specific cases, the White River model applies an assumed, specified annual or monthly efficiency to a diversion in order to determine consumptive use and return flows. In the case of monthly efficiencies, the efficiency varies by month, but the monthly pattern is the same in each simulation year. This approach is applied in the CDSS models to municipal, industrial, and transbasin users, as well as reservoir feeders and any irrigation diversion for which crop water requirement has not been developed.

The two explicitly modeled municipal systems in Colorado (Meeker and Rangely) have been given typical monthly efficiencies that reflect indoor use only in the winter, and combined indoor and outdoor use during the irrigation season. The California Company Pipeline use is reported to be 100 percent consumptive, so an annual efficiency of 100 percent was assigned to that structure. Finally, the Coal Creek Feeder Ditch has an efficiency of zero percent, because water diverted from Fawn Creek is delivered without loss to Coal Creek. (The diversions of record are measured at the Coal Creek end of the ditch, after any losses that would have occurred.)

Finally, every structure in the model, including irrigation structures operating by variable efficiency, has monthly efficiencies assigned to it in the model input files. For irrigation structures, these are average monthly efficiencies based on historical diversions and historical crop water requirement over the period 1975-2013, but may not exceed 0.60. These are used by DMI components of CDSS to create time series of headgate demands for input to the model, as described in Section 4.9.1.

Where to find more information

- StateCU documentation describes different methods for estimating irrigation water requirement for structures, for input to the StateMod model.
- Section 7 of the StateMod documentation has subsections that describe "Variable Efficiency Considerations" and "Soil Moisture Accounting"
- Section 5 of this manual describes the input files where the parameters for computing consumptive use and return flow amounts are specified:
    - Irrigation water requirement in the Irrigation Water Requirement file (Section 5.5.3)
    - Headgate demand in the Direct Diversion Demand file (Section 5.4.4)
    - Historical efficiency in the Direct Diversion Station file (Section 5.4.1)
    - Maximum efficiency in the Irrigation Parameter file (Section 5.5.2)
    - Soil moisture capacity in the StateCU Structure file (Section 5.5.1)
    - Loss to the hydrologic system in the Delay Table file (Section 5.4.2)

4.6 Return Flows

4.6.1 Return Flow Timing

Return flow timing is specified to the model by specifying what percentage of the return flow accruing from a diversion reaches the stream in the same month as the diversion, and in each month following the diversion month. Three return flow patterns are used in the White River model. One represents instantaneous (or within the same month as the diversion) returns and is applied to the municipal diversions and the Coal Creek Feeder Ditch. The other two patterns are generalized irrigation return patterns, applicable to irrigated lands "close" to the stream (center of acreage is less than 1,000 feet from the stream), and "further" from the stream (center of acreage is greater than 1,000 feet from the stream). They both assume incidental losses of 3 percent. The two patterns were developed using the Glover analytical solution for parallel drain systems. The State's Analytical Steam Depletion Model (September, 1978), which is widely used in determining return flows for water rights transfers and augmentation plans, permits this option for determining accretion factors.

The Glover analysis requires these input parameters:

T = Transmissivity in gallons per day per foot (gpd/ft). Transmissivity is the product of hydraulic conductivity (K) in feet per day, saturated thickness (b) in feet, and the appropriate conversion factor.

S = Specific Yield as a fraction

W = Distance from stream to impervious boundary in feet (ft)

x = Distance from point of recharge to stream in feet (ft)

Q = Recharge Rate in gallons per minute (gpm)

Regionalized values for the aquifer parameters were determined by selecting ten representative sites throughout the west slope, based partly on the ready availability of geologic data, and averaging them. The analysis estimated generalized transmissivity as 48,250 gpd/ft, specific yield as 0.13, and distance from the stream to the alluvial boundary as 3,500 ft. Two different values of x, representing lands "close to" and "further from" a live stream, were assumed in two Glover analyses that were otherwise the same, to produce the two return flow patterns.

It was assumed that the resulting pattern applies to only half of the return flow, and that the other half returns within the month via the surface (tailwater returns, headgate losses, etc.). Combining surface water returns with groundwater returns resulted in the two irrigation return patterns shown in Table 4.4 and graphed in Figure 4.1Error! Reference source not found.. Month 1 is the month in which the diversion takes place. Note that the sum of the monthly return fractions is 0.97, meaning that 3 percent of the non-consumed water is lost to the stream through processes such as evaporation or non-beneficial evapotranspiration.

Table 4.4 Percent of Return Flow Entering Stream in Month n after Diversion

Month n	For Lands "Close" to Stream (%)	For lands "Further" from Stream (%)
1	75.6	57.4
2	11.3	14.5
3	3.2	7.2
4	2.2	5.0
5	1.6	3.7
6	1.2	2.7
7	0.8	2.0
8	0.6	1.5
9	0.5	1.1
10	0	0.8
11	0	0.6
12	0	0.5
Total	97	97

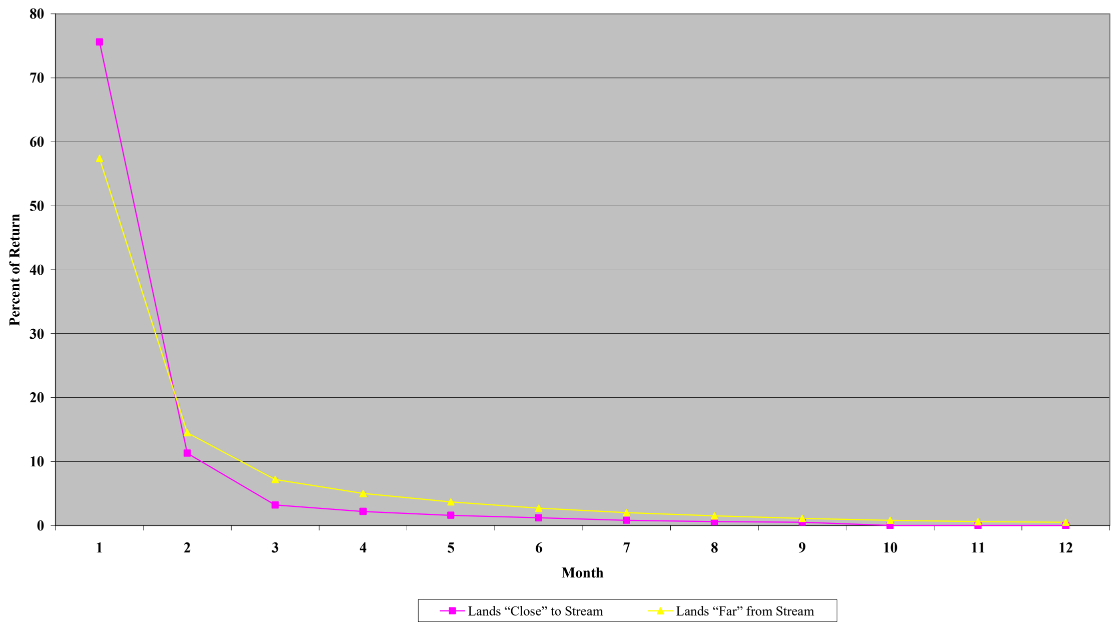


Figure 4.1 - Percent of Return in Months after Diversion

> **Where to find more information**
>
> - CDSS Memorandum "Colorado River Basin Representative Irrigation Return Flow Patterns", Leonard Rice Engineers, January, 2003, available on the CDSS website.

4.6.2 Return Flow Locations

Return flow locations were determined during the original data gathering, by examining irrigated lands mapping and USGS topographical maps, and confirming locations with Division 6 personnel. Some return flow locations and the percent of return flow that goes to multiple locations were modified during calibration.

4.7 Baseflow Estimation

In order to simulate river basin operations, the model starts with the amount of water that would have been in the stream if none of the operations being modeled had taken place. These undepleted flows are called "baseflows". The term is used in favor of "virgin flow" or "naturalized flow" because it recognizes that some historical operations can be left "in the gage", with the assumption that those operations and impacts will not change in the hypothetical situation being simulated.

Given data on historical depletions and reservoir operations, StateMod can estimate baseflow time series at specified discrete inflow nodes. This process was completed prior to executing any simulations, and the resulting baseflow file became part of the input data set for simulations. Baseflow estimation requires three steps: 1) adjust USGS stream gage flows using historical records of operations to get baseflow time series at gaged points, for the gage period of record; 2) fill the baseflow time series by regression against other baseflow time series; 3) distribute baseflow gains above and between gages to user-specified, ungaged inflow nodes. These three steps are described below.

4.7.1 Baseflow Computations at Gages

Baseflow at a site where historical gage data is available is computed by adding historical values of all upstream depletive effects to the gaged value, and subtracting historical values of all upstream augmenting effects from the gaged value:

$$Q_{baseflow} = Q_{gage} + Diversions - Returns - Imports +/- \Delta Storage + Evap$$

Historical diversions, imports, and reservoir contents are provided directly to StateMod to make this computation. Evaporation is computed by StateMod based on historical evaporation rates and reservoir contents. Return flows are similarly computed based on diversions, crop water requirements, and/or efficiencies as described in Section 4.5, and return flow parameters as described in Section 4.6.

Where to find more information

- When StateMod is executed to estimate baseflows at gages, it creates a Baseflow Information file (*.xbi) that shows this computation for each gage and each month of the time step.

4.7.2 Baseflow Filling

Wherever gage records are missing, baseflows are estimated as described in Section 4.4.2 Baseflow Filling.

4.7.3 Distribution of Baseflow to Ungaged Points

In order for StateMod to have flow on tributary headwaters, baseflow must be estimated at all ungaged headwater nodes. In addition, gains between gages are modeled as entering the system at locations to reflect increased flow due to unmodeled tributaries. Most key reservoirs were represented as baseflow nodes in order for the model to “see” all available water supply at the site. During calibration, other baseflow nodes were added to better simulate a water supply that would support historical operations.

StateMod has an operating mode that distributes a portion of baseflows at gaged locations to ungaged locations based on drainage area and average annual precipitation. The default method is the “gain approach”. In this approach, StateMod pro-rates baseflow gain above or between gages to ungaged locations using the product of drainage area and average annual precipitation.

Figure 4.2 illustrates a hypothetical basin and the areas associated with three gages and three ungaged baseflow nodes.

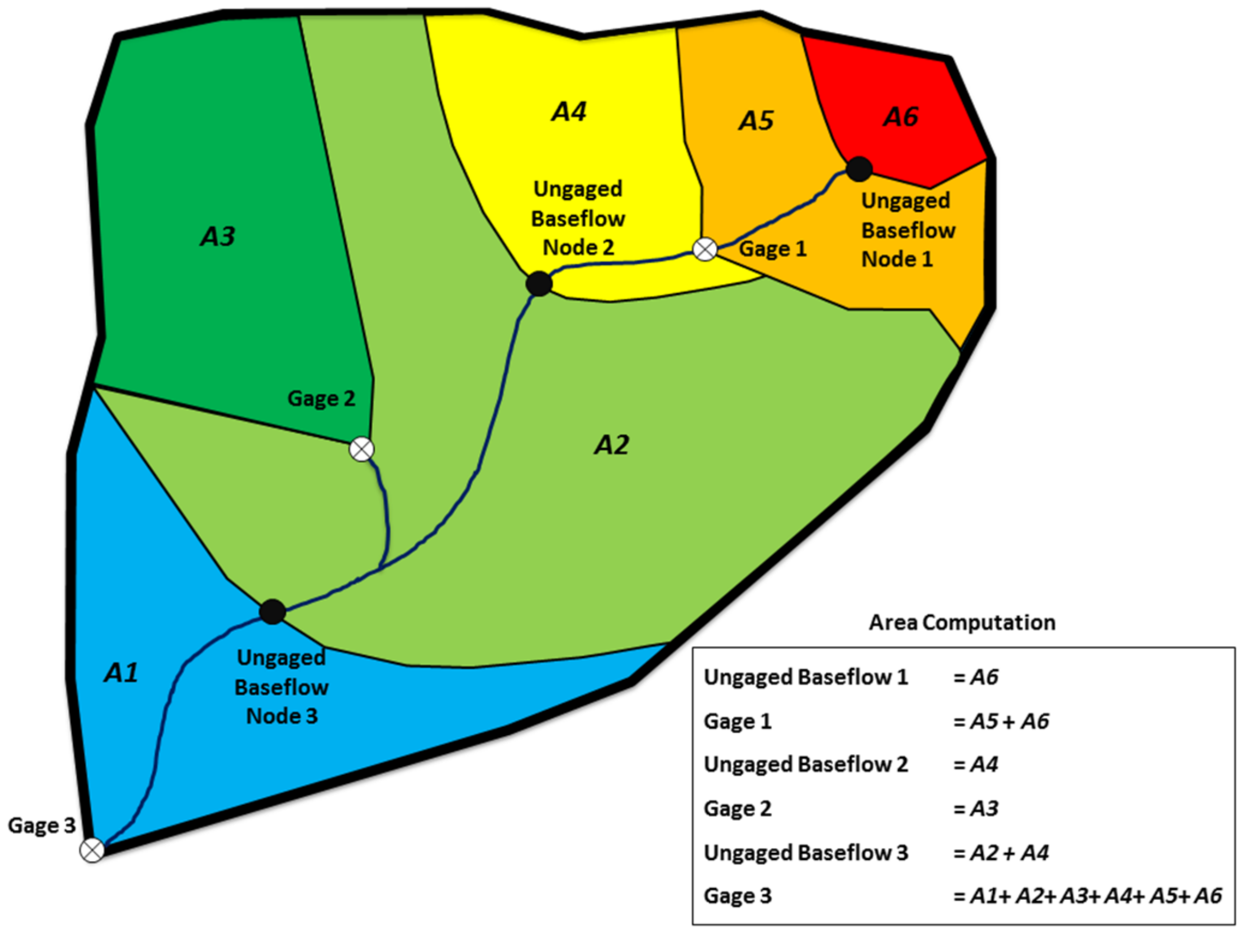


Figure 4.2 - Hypothetical Basin Illustration

The area associated with gages is the total upstream area. The area associated with ungaged nodes only includes the incremental area from the ungaged location to the next upstream gage or gages. For example, Gage 3 area includes the entire basin. Ungaged Baseflow Node 3 area (diagonal stripes) includes the upstream area between the Ungaged Baseflow Node 3 and Gage 2 and Gage 1.

In **Figure 4.2**, there are three ungaged baseflow nodes; the StateMod "gain approach" computes the total baseflow at each ungaged node based on the following:

The baseflow gain distributed to Ungaged Baseflow Node 1 is the baseflow gain above Gage 1 pro-rated on the A*P terms.

$$Gain_{ungaged,1} = \left(\frac{(A * P)_{ungaged,1}}{(A * P)_{gage,1}}\right)(BF_{gage,1})$$

Total baseflow at Ungaged Node 1 is equal to the $\text{Gain}_{\text{ungaged},1}$ term.

The baseflow gain distributed to Ungaged Baseflow Node 2 is the baseflow gain between Gage 1, 2, and 3 pro-rated on the A*P terms.

$$Gain_{ungaged,2} = \left(\frac{(A*P)_{ungaged,2}}{(A*P)_{gage,3} - (A*P)_{gage,2} - (A*P)_{gage,1}}\right)\left(BF_{gage,3} - BF_{gage,2} - BF_{gage,1}\right)$$

Total baseflow at Ungaged Node 2 is equal to the $Gain_{ungaged,2}$ term plus the baseflow at Gage 1.

$$BF_{ungaged,2} = Gain_{ungaged,2} + BF_{gage,1}$$

Ungaged Baseflow Node 3 calculations are very similar. The baseflow gain distributed to Ungaged Baseflow Node 3 is the baseflow gain between Gage 1, 2, and 3 pro-rated on the A*P term.

$$Gain_{ungaged,3} = \left(\frac{(A*P)_{ungaged,3}}{(A*P)_{gage,3} - (A*P)_{gage,2} - (A*P)_{gage,1}}\right)\left(BF_{gage,3} - BF_{gage,2} - BF_{gage,1}\right)$$

Total baseflow at Ungaged Node 3 is equal to the $Gain_{ungaged,3}$ term plus baseflow at Gage 1 and Gage 2.

$$BF_{ungaged,3} = Gain_{ungaged,3} + BF_{gage,1} + BF_{gage,2}$$

A second option for estimating headwater baseflows can be used if the default "gain approach" method created results that do not seem credible. This method, referred to as the "neighboring gage approach", creates a baseflow time series by multiplying the baseflows at a specified gage by the ratio $(A*P)_{headwater}/(A*P)_{gage}$. This approach is effective when the runoff at an ungaged location does not follow the same pattern as the gains along the main stem. For example, a small ungaged tributary that peaks much earlier or later than the main stem should use the neighboring gage approach with a streamgage in a similar watershed. The user is responsible for ensuring that the overall reach water balance is maintained when using the neighboring gage approach.

Where to find more information

- The **StateDMI** documentation in section 5.10 "Stream Estimate Data" for describes computation of baseflow distribution parameters based on A*P, incremental A*P, and the network configuration.

4.8 Calibration Approach

Calibration is the process of simulating the river basin under historical conditions, and judiciously adjusting parameter estimates to achieve agreement between observed and simulated values of stream gages, reservoir levels, and diversions. In other CDSS models, calibration was carried out in two steps. In the first, there is relatively little freedom in the model with respect to reservoir operations and multiple-headgated systems that serve a single demand location (multi-structure system) and the objective is to refine baseflow hydrology and return flow locations. In the second step, operations other than direct diversions from the stream are more rule-driven, and operational parameters for these rules are tested and refined.

In the White basin model, there was no need to calibrate in two steps, because neither of the modeled reservoirs release for downstream demands. Historical end-of-month contents reflect releases only for historical maintenance, which none of the CDSS models have included in their baseline models. Similarly, there are no collection systems in the White basin that divert from several sources simultaneously to satisfy a centralized demand. Thus there were no operations to calibrate.

The issues encountered and results obtained in calibration are described in Section 7.

Where to find more information

- Section 7 of this document describes calibration of the White River model.

4.9 Baseline Data Set

The Baseline data set is intended as a generic representation of recent conditions on the White River, to be used for "what if" analyses. It represents one interpretation of current use, operating, and administrative conditions, as though they prevailed throughout the modeling period. All existing water resources systems are on line and operational in the model from 1909 forward, as are junior rights and modern levels of demand. The data set is a starting point, which the user may choose to add to or adapt for a given application or interpretation of probable demands and near-term conditions. Additional information is found in Section 5.

4.9.1 Calculated Irrigation Demand

In the Baseline data set, irrigation demand is set to a time series determined from crop irrigation water requirement and average irrigation efficiency for the structure. This "Calculated Demand" is an estimate of the amount of water the structure would have diverted absent physical or legal availability constraints. Thus if more water was to become available to the diverter under a proposed new regime, the model would show the irrigator with sufficient water rights diverting more than he did historically.

Calculated demands must account for both crop needs and irrigation practices. Monthly calculated demand for 1975 through 2013 is generated directly, by taking the maximum of crop irrigation water requirement divided by average monthly irrigation efficiency, and historic diversions. The system irrigation efficiency may not exceed the defined maximum efficiency. Thus calculated demand for a perennially shorted diversion can be greater than the historical diversion for at least some months. By estimating demand to be the maximum of calculated demand and historical diversions, such irrigation practices as diverting to fill the soil moisture zone or diverting for stock watering can be mimicked more accurately.

4.9.2 Municipal and Industrial Demand

Municipal and industrial demands were set to recent values or averages of recent records.

4.9.3 Reservoirs

Reservoirs are represented as being on-line throughout the study period, at their current capacities. Initial reservoir contents were set to full.

5. Baseline Data Set

This section describes each StateMod input file in the Baseline Data Set. The data set, described in more general terms in Section 4.9, is expected to be a starting point for users who want to apply the White River water resources planning model to a particular management issue. Typically, the investigator wants to understand how the river regime would change under a new use or different operations. The change needs to be quantified relative to how the river would look today absent the new use or different operation, which may be quite different from the historical record. The Baseline data set provides a basis against which to compare future scenarios. Users may opt to modify the Baseline data set for their own interpretation of current or near-future conditions. The following detailed, file-by-file description is intended to provide enough detail that this can be done with confidence.

This section is divided into several subsections:

- Section 5.1 describes the response file, which lists names of the rest of the data files. The section tells briefly what is contained in each of the named files, so refer to it if you need to know where to find specific information.
- Section 5.2 describes the control file, which sets execution parameters for the run.
- Section 5.3 includes four files that together specify the river system. These files express the model network and baseflow hydrology.
- Section 5.4 includes files that define characteristics of the diversion structures in the model: physical characteristics, irrigation parameters, historical diversions, demand, and water rights.
- Section 5.5 includes files that further define irrigation parameters for diversion structures.
- Section 5.6 includes files that define characteristics of the reservoir structures in the model: physical characteristics, evaporation parameters, historical contents, operational targets, and water rights.
- Section 5.7 includes files that define characteristics of instream flow structures in the model: location, demand, and water rights.
- Section 5.8 describes the operating rights file, which specifies operations other than simple diversions, on-stream reservoir storage, and instream flow reservations. For example, the file specifies rules for reservoir releases to downstream users, diversions by exchange, and movement of water from one reservoir to another.

Where to find more information

- For generic information on every input file listed below, see the StateMod documentation. It describes how input parameters are used as well as format of the files.

5.1 Response File (*.rsp)

The response file is created by hand using a text editor, and lists the other files in the data set. StateMod reads the response file first, and then "knows" what files to open to get the rest of the input data. The list of input files is slightly different depending on whether StateMod is being run to generate baseflows or to simulate. Since the "Baseline data set" refers to a particular simulation scenario, the response file for the Baseline is presented first; it is followed by a description of the files used for baseflow generation.

5.1.1 For Baseline Simulation

The listing below shows the file names in wm2015B.rsp, describes contents of each file, and shows the subsection of this chapter where the file is described in more detail.

File Name	Description	Reference
wm2015.ctl	Control file – specifies execution parameters, such as run title, modeling period, options switches	Section 5.2
wm2015.rin	River network file – lists every model node and specifies connectivity of network	Section 5.3.1
wm2015.ris	River station file – lists model nodes, both gaged and ungaged, where hydrologic inflow enters the system	Section 5.3.2
wm2015.rib	Baseflow Parameter file – gives coefficients and related gage IDs for each baseflow node, with which StateMod computes baseflow gain at the node	Section 5.3.3
wm2015.rih	Historical streamflow file – Monthly time series of streamflows at modeled gages	Section 5.3.4
wm2015x.xbm	Baseflow data file – time series of undepleted flows at all nodes listed in *wm2015.ris*	Section 5.3.5
wm2015.dds	Direct diversion station file – contains parameters for each diversion structure in the model, such as diversion capacity, return flow characteristics, and irrigated acreage served	Section 5.4.1
wm2015.dly	Delay Table – contains several return flow patterns that express how much of the return flow accruing from diversions in one month reach the stream in each of the subsequent months, until the return is	Section 5.4.2

File Name	Description	Reference
	extinguished	
wm2015.ddh	Historical Diversions – Monthly time series of historical diversions	Section 5.4.3
wm2015B.ddm	Monthly demand file – monthly time series of headgate demands for each direct diversion structure	Section 5.4.4
wm2015.ddr	Direct diversion rights file – lists water rights for direct diversion	Section 5.4.5
wm2015.str	Soil Parameter file – soil moisture capacity by structure, for variable efficiency structures	Section 5.5.1
wm2015B.ipy	CU Time series file – maximum efficiency and irrigated acreage by year and by structure, for variable efficiency structures	Section 5.5.2
wm2015B.iwr	Irrigation Water Requirement file – monthly time series of crop water requirement by structure, for variable efficiency structures	Section 5.5.3
wm2015B.res	Reservoir station file – lists physical reservoir characteristics such as volume, area-capacity table, and some administration parameters	Section 5.6.1
wm2015.eva	Evaporation file – gives monthly rates for net evaporation from free water surface	Section 5.6.2
wm2015.eom	Reservoir End of month contents file – Monthly time series of historical reservoir contents	Section 5.6.3
wm2015B.tar	Reservoir target file – monthly time series of maximum and minimum targets for each reservoir. A reservoir may not store above its maximum target, and may not release below the minimum target	Section 5.6.4
wm2015.rer	Reservoir rights file – lists storage rights for all reservoirs	Section 5.6.5
wm2015.ifs	Instream flow station file – lists instream flow reaches	Section 5.7.1
wm2015.ifa	Instream flow demand file – gives the decreed monthly instream flow rates	Section 5.7.2
wm2015.ifr	Instream flow right file – gives decreed amount and administration number of instream flow rights	Section 5.7.3

File Name	Description	Reference
	associated with instream flow reaches	
wm2015B.opr	Operational rights file – specifies many different kinds of operations that are more complex than a direct diversion or an on-stream storage right. Operational rights can specify, for example, a reservoir release for delivery to a downstream diversion point, a reservoir release to allow diversion by exchange at a point which is not downstream, or a direct diversion to fill a reservoir via a feeder	Section 5.8

5.1.2 For Generating Baseflow

The baseflow file (*.xbm) that is part of the Baseline data set was created by StateMod and the Mixed Station Model in three steps which are described in Section 4.7. In the first step, StateMod estimates baseflows at gaged locations, using the files listed in the response file wm2015.rsp. The baseflow response file calls for different diversion demand and reservoir station file from the Baseline response file, to reflect strictly historical data.

The baseflow time series created in the first run are all partial series, because gage data is missing some of the time for all gages. The Mixed Station Model is used to fill the series, creating a complete series of baseflows at gages in a file named wm2015.xbf. The response file for the third step, in which StateMod distributes baseflow to ungaged points, is named wm2015x.rsp. The only difference between the first-step response file wm2015.rsp and third-step response file wm2015x.rsp is that the name wm2015.xbf is supplied for both the baseflow file and the historical gage file.

5.2 Control File (*.ctl)

The control file is hand-created using a text editor. It contains execution parameters for the model run, including starting and ending year for the simulation, the number of entries in certain files, conversion factors, and operational switches. Many of the switches relate to either debugging output, or to integrated simulation of groundwater and surface water supply sources. The latter was developed for the Rio Grande basin and is not a feature of the White River model. Control file switches are all specifically described in the StateMod documentation. Users most typically adjust the simulation period parameters (starting and ending year).

5.3 River System Files

5.3.1 River Network File (*.rin)

The river network file is created by StateDMI from the graphical network representation file created within the StateDMI – StateMod Network interface.

The river network file describes the location and connectivity of each node in the model. Specifically, it is simply a list of each structure ID and name, along with the ID of the next structure downstream. It is an inherent characteristic of the network that, with the exception of the downstream terminal node, each node has exactly one downstream node.

River gage nodes are labeled with United States Geological Survey (USGS) stream gaging station numbers (i.e., 09000000). Diversion and reservoir structure identification numbers are composed of Water District number followed by the State Engineer's four-digit structure ID. Table 5.1 shows how many nodes of each type are in the White River model.

Table 5.1 River Network Elements

Type	Number
Diversion	143
Reservoirs	7
Instream Flow	12
Stream Gages	14
Other	12
Total	188

Where to find more information

- StateDMI documentation gives the file layout and format for the .net file.

5.3.2 River Station File (*.ris)

The river station file is created by StateDMI. It lists the model's baseflow nodes, both gaged and ungaged. These are the discrete locations where streamflow is added to the modeled system.

There are 12 gages in the model and 31 ungaged baseflow locations, for a total of 43 hydrologic inflows to the White River model. Ungaged baseflow nodes include ungaged headwater nodes, key reservoir nodes, many of the aggregated diversion nodes, and any other nodes where calibration revealed a need for additional baseflow. In the last case, water that was simulated as entering the system further down (e.g., at the next gage) was moved up the system to the ungaged point.

5.3.3 Baseflow Parameter File (*.rib)

The baseflow parameter file has an entry for each ungaged baseflow node in the model, specifying coefficients, or "proration factors", used to calculate the baseflow gain at that point. StateDMI computes proration factors based on the network structure and drainage area multiplied by precipitation (A*P) values supplied for both gages and ungaged baseflow nodes. This information is in the network file which is input to StateDMI. Under the default "gain approach", described in Section 4.7, the factors reflect the ratio of the product of incremental area and local average precipitation above the ungaged point to the product of area and local average precipitation for the gage-to-gage reach.

At some locations, the hydrograph developed using the gain approach showed an attenuated shape that was not representative of a “natural” hydrograph. This occurred in headwater areas where runoff occurs earlier and quicker than on larger tributaries. In these situations, baseflow was determined as a function of baseflow at a nearby stream gage, specified by the user. Ideally, this “neighboring gage” was from drainage with similar physiographic characteristics. Baseflow at the ungaged site was assumed to be in the same proportion to baseflow at the nearby gage as the product of area and average precipitation at the two locations. This procedure, referred to as the “neighboring gage approach”, was applied to these tributaries:

Tributary Name	Baseflow WDID	Neighboring Gage
Coal Creek	4300578_D	09304000
Flag Creek	4300813	09306007
Evacuation Creek	43_ADW015	09306007

Where to find more information

- StateDMI documentation gives the file layout and format for the *.net file.
- Section 4.7.3 describes how baseflows are distributed spatially.

5.3.4 Historical Streamflow File (*.rih)

Created by TSTool, the historical streamflow file contains historical gage records for 1909-2013, for modeled gages. This file is used for baseflow generation and to create comparison output that is useful during model calibration. Records are taken directly from streamflow tables in the database, which include both USGS and DWR-operated gages. Missing values, when the gage was not in operation, are denoted as such, using the value “-999.”

Table 5.2 lists the gages used, their periods of record, and their average annual flows over the period of record.

Table 5.2 Historical Average Annual Flows for Modeled White River Basin Stream Gages

Gage ID	Gage Name	Period of Record	Historical Average Flow (af/yr)
09303000	North Fork White River at Buford	1911-1915,1920, 1952-2001	229,244
09303400	South Fork White River near Budge's Resort	1977-1995	143,418
09303500	South Fork White River near Buford	1911-1915,1943-1947,1968-1992	186,968
09304000	South Fork White River at Buford	1920, 1952-1997	185,176
09304200	White River above Coal Creek	1962-2013	400,186
09304500	White River near Meeker	1910-2013	447,805
09304800	White River below Meeker	1962-2013	468,841
09306007	Piceance Creek below Rio Blanco	1975-1998	15,199
09306200	Piceance Creek below Ryan Gulch	1965-2013	19,845
09306222	Piceance Creek at White River	1965-1966, 1971-2013	24,415
09306290	White River below Boise Creek near Rangely[1]	1983-2013	518,603
09306395	White River near Colorado State Line, Utah[2]	1977-1985	596,954

[1] Observed gage record was filled using a single regression equation with USGS gage 09304500. The regression equation is y = 1.0448x + 3926.76. The R^2 value is 0.98.

[2] Observed gage record was filled using a single regression equation with USGS gage 09304500. The regression equation is y = 1.0882x + 4635.60. The R^2 value is 0.97

5.3.5 Baseflow Files (*.xbm)

The baseflow file contains estimates of base streamflows throughout the modeling period, at the locations listed in the river station file. Baseflow represent the conditions upon which simulated diversion, reservoir, and minimum streamflow demands are superimposed. StateMod estimates baseflow at stream gages, during the gage's period of record, from historical streamflows, diversions, end-of-month contents of modeled reservoirs, and estimated consumption and return flow patterns. It then distributes baseflow at gage sites to ungaged locations using proration factors representing the fraction of the reach gain estimated to be tributary to a baseflow point.

Table 5.3 compares historical gage flows with simulated baseflow for the four gages with complete records throughout the calibration period (1975-2013). The difference between the two represents an estimate of historical consumption over this period.

Table 5.3 Streamflow Comparison
1975-2013 Average (af/yr)

Gage ID	Gage Name	Baseflow	Historical	Difference
09304200	White River above Coal Creek	487,128	398,582	88,545
09304500	White River near Meeker	509,882	442,688	67,194
09304800	White River below Meeker	512,353	473,427	38,926
09306222	Piceance Creek at White River	32,104	25,742	6,362

Where to find more information

- Sections 4.7.1 through 4.7.3 explain how StateMod and the Mixed Station Model are used to create baseflows.
- When StateMod is executed to estimate baseflows at gages, it creates a Baseflow Information file (*.xbi) that shows this computation for each gage and each month of the time step.
- When the Mixed Station Model is used to fill baseflows, it creates two reports, wm2015.sum and wm2015.sts. The first indicates which stations were used to estimate each missing data point, and the second compares statistics of the unfilled time series with statistics of the filled series for each gage.

5.4 Diversion Files

5.4.1 Direct Diversion Station File (*.dds)

StateDMI is used to create the direct diversion station file.

The direct diversion station file describes the physical properties of each diversion simulated in the White River model. Table 5.4 is a summary of the White River model's diversion station file contents, including each structure's diversion capacity, irrigated acreage served, average annual system efficiency, and average annual headgate demand. This last parameter is summarized from data in the diversion demand file rather than the diversion station file, but it is included here as an important characteristic of each diversion station. In addition to the tabulated parameters, the diversion station file also specifies return flow nodes, timing of returns, and average monthly efficiencies. Footnotes to Table 5.4 identify municipal and industrial diverters, carriers, and other non-irrigation structures.

Generally, the diversion station ID and name, diversion capacity, and irrigated acreage are gathered from Hydrobase by StateDMI. Return flow locations and timing are specified to the DMI in a hand-edited file wm2015.rtn. The return flow locations and spatial distribution are based on physical locations of irrigated lands and discussions with Division 6 personnel, as well as calibration efforts. Return flow timing is based on distance from the irrigated area to the stream, and generalized return patterns which are described more fully in Section 5.4.2. StateDMI computes monthly system efficiencies for each irrigation structure from historical diversions and historical crop irrigation requirements, and writes the efficiencies into the diversion station file. For non-irrigation structures, monthly efficiency is specified by the user as input to StateDMI. Diversion station parameters for different structures or structure types are described in more detail after Table 5.4.

Table 5.4 Direct Flow Diversion Summary Average 1975-2013

#	Model ID#	Name	Diversion Cap (cfs)	Irrigated Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
1	4300511	B A & B DITCH NO 1	20	177	16	1843
2	4300513	B M & H DITCH 1	21	161	24	1402
3	4300526	BARBOUR NORTH SIDE D	12	34	7	1572
4	4300527_D	Barbour S Side Ditch Div	47	77	2	9898
5	4300537_D	Beckman Ditch DivSys	44	267	20	4358
6	4300539	BIG BEAVER DITCH	10	55	12	1336
7	4300544	BLACK EAGLE D NO 2	6	49	48	225
8	4300546	BLAIR DITCH	15	230	31	1790
9	4300554	BRUCE BAKER DITCH	8	52	21	748
10	4300563	CALHOUN DITCH	8	36	36	269
11	4300564 [1]	CALIFORNIA CO WATER PL	11	0	100	449
12	4300565	CAMPBELL CREEK DITCH	8	42	16	966
13	4300570	CALVAT DITCH	10	14	7	802
14	4300572	CHARLIE SMITH DITCH	19	122	25	2382
15	4300573	CHASE & COLTHARP D	17	70	24	1126
16	4300575	CLOHERTY DITCH	8	68	27	1161
17	4300577 [2]	COAL CREEK FEEDER DITCH	25	83	0	0
18	4300578_D	Coal Creek Mesa Ditch Di	76	825	34	5054

#	Model ID#	Name	Diversion Cap (cfs)	Irrigated Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
19	4300605 [2]	DORRELL DITCH	3	14	8	416
20	4300607	DREIFUSS DITCH	18	93	16	2291
21	4300608	DREYFUSS DITCH	11	73	9	2003
22	4300623	ELK CREEK DITCH	13	119	16	2246
23	4300625	EMILY DITCH	7	93	16	1087
24	4300640	FORNEY CORCORAN DITCH	12	92	20	1191
25	4300652	G V DITCH	8	33	9	1435
26	4300653	GEORGE S WITTER DITCH	15	46	10	1693
27	4300665	GREENSTREET DITCH EXT	11	10	2	1458
28	4300678	HANRAHAN DITCH NO 1	2	8	40	102
29	4300681	HAY BRETHERTON DITCH	40	391	14	5357
30	4300684	HAY DITCH 2	6	77	20	792
31	4300687	HEFLEY PUMP PLANT NO 1	16	111	27	1422
32	4300688	HEFLEY PUMP PLANT NO 2	20	74	16	1423
33	4300693	HERWICK DITCH 1	5	11	15	323
34	4300694_D	Thomas Ditch 2 DivSys	264	2660	10	44,823
35	4300695	HILL CREEK NO 3 DITCH	10	61	38	846
36	4300696	HILL CREEK NO 2 DITCH	17	59	16	2049
37	4300701	HOME DITCH	6	39	15	783
38	4300710	IMES & REYNOLDS DITCH	26	124	9	2939
39	4300711	INDEPENDENT DITCH	21	98	35	696
40	4300714	IVO E SHULTS D & PUMP	5	32	26	362
41	4300718	JAMES HAYES DITCH	12	86	11	1291
42	4300719	JANES DITCH	3	11	48	90
43	4300729	JOHNSON DITCH	6	51	16	785
44	4300753	LAKE CREEK POOL DITCH	7	10	13	307
45	4300754 [3]	LARSON DITCH	2	0	25	102
46	4300758	LAWRENCE DITCH NO 1	6	76	37	751
47	4300762	LEWIS DITCH	7	27	17	509
48	4300769	LITTLE DITCH	17	163	14	2188
49	4300777	LOWLAND DITCH	46	107	11	2158
50	4300782	M H M GERMAN CONS D	18	174	27	1321
51	4300784	M SCHNEIDER DITCH	7	34	29	587

#	Model ID#	Name	Diversion Cap (cfs)	Irrigated Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
52	4300788	MARCOTT DITCH	31	111	8	4668
53	4300789	MARTIN DITCH	10	60	9	1450
54	4300790	MARVINE DITCH 1	10	37	8	1540
55	4300791	MARVINE NO 3 DITCH	8	16	6	856
56	4300808	MEEKER DITCH	30	236	8	5159
57	4300809	MEEKER POWER DITCH	182	10	8	257
58	4300810 [1,2]	MEEKER WATER SYS	10	0	36	0
59	4300813	MELVIN DITCH	19	60	30	567
60	4300815_D	Metz & Reigan Ditch DivS	12	58	8	1439
61	4300816	METZ DITCH	9	72	12	1028
62	4300818	MIKKELSON DITCH	3	5	32	79
63	4300819_D	Miller Creek Ditch DivSy	134	3312	16	32,065
64	4300823	MINER MARTIN DITCH	8	16	6	650
65	4300825	MISSOURI BOTTOM DITCH	7	45	56	257
66	4300828	MOONEY DITCH	11	50	20	1404
67	4300831	MORGAN DITCH 2	2	35	53	167
68	4300832	MORGAN DITCH 1	2	47	54	229
69	4300841	NEW ARCHER WARNER DITCH	10	60	27	1228
70	4300842	NIBLOCK DITCH	96	1433	16	16,494
71	4300848	OAK RIDGE PARK DITCH	133	2111	13	27,782
72	4300849	OLD AGENCY DITCH	59	795	15	9585
73	4300850	OLDLAND DITCH 1	14	138	23	1232
74	4300851	OLDLAND DITCH 2	19	20	6	834
75	4300862	PATTISON DITCH NO 1	6	87	45	676
76	4300867	PEASE DITCH	29	328	13	5013
77	4300868	PEDRICK DITCH	25	359	21	3328
78	4300873	PICEANCE CREEK DITCH	8	72	12	1044
79	4300881	POTHOLE DITCH	16	172	31	1977
80	4300883	POWELL PARK DITCH	101	1788	17	17,210
81	4300889 [1]	RANGELY WATER	31	0	36	1810
82	4300895	REDDIN DITCH	2	8	30	126
83	4300903	ROBERT MCKEE DITCH	15	109	13	1516
84	4300908	RYAN DITCH	10	95	39	492

#	Model ID#	Name	Diversion Cap (cfs)	Irrigated Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
85	4300909	RYE GRASS DITCH	12	80	17	1094
86	4300919	SAYER DITCH	6	17	11	353
87	4300923	SCHUTTE DITCH	15	40	17	792
88	4300926	SHERIDAN & MORTON D	10	38	11	1002
89	4300928	SIMPSON DITCH	7	41	14	1077
90	4300929	SIZEMORE DITCH 1	5	23	18	500
91	4300931	SKELTON DITCH	15	45	12	1353
92	4300934	SOLDIER CREEK DITCH	7	47	40	473
93	4300935	SOUTH SIDE HIGHLINE D	57	546	11	8559
94	430936	SPAULDING D	5	42	29	472
95	4300939	SPRING CREEK D PUMP 1	6	30	40	292
96	4300940	SPRING CREEK D PUMP STA	6	38	49	363
97	4300941	SPRING CREEK D PUMP 2	5	29	51	226
98	4300944	SPROD DITCH 1	6	11	2	992
99	4300948	SQUARE S CONS D SYS	21	139	12	2379
100	4300949	STADTMAN DITCH	12	110	52	815
101	4300954	STOREY DITCH 1	10	28	16	662
102	4300961	SWEEDE DITCH	22	138	18	3306
103	4300965	THOMAS DITCH	7	51	38	401
104	4300966	THOMAS DITCH 2	10	54	42	418
105	4300975	UPPER DITCH	2	13	46	75
106	4300980	UTE CREEK DITCH	14	60	7	2355
107	4301004	WHEELER DITCH	20	14	6	1858
108	4301010	WHITE RIVER MESA DITCH [1]	13	119	100	458
109	4301027	BELOT MOFFAT DITCH	17	126	18	1463
110	4301031	GORDON DITCH	3	10	25	209
111	4301033	LAWRENCE DITCH	6	75	41	757
112	4301047	LAGRANGE DITCH 1	5	14	25	318
113	4301108	JACOBS PUMP & PL	4	95	47	399
114	4301257 [3]	ROBINSON WARDELL PUMP 6	10	0	0	143
115	4301262	ROBINSON WARDELL PUMP 15	9	42	29	579
116	4301272	COX PUMP NO 1	17	90	25	1176
117	4301273	REIGAN PUMP NO 1	6	120	54	764

#	Model ID#	Name	Diversion Cap (cfs)	Irrigated Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
118	4301855	MCDOWELL NO 2 DITCH	12	131	20	1420
119	4302099	KENNEY PUMP NO 1	14	80	23	1216
120	4302571 [1]	TAYLOR RESERVOIR POWER P	1300	0	0	511,849
121	4303633_F [4]	Div_WhiteRiv_Avery	9999	0	0	0
122	4303633_O [4]	Lake Avery Enl Oil Shale	9999	0	100	0
123	4304313_O [4]	WCkResPipe_ToOilShale	9999	0	100	0
124	4306045 [1,2]	MEEKER WELLS	4	0	36	338
125	43_ADW001	Diversion Aggregate	40	292	17	4706
126	43_ADW002	Diversion Aggregate	52	321	37	3305
127	43_ADW003	Diversion Aggregate	44	389	15	6832
128	43_ADW004	Diversion Aggregate	100	770	45	4091
129	43_ADW005	Diversion Aggregate	29	659	36	3575
130	43_ADW006	Diversion Aggregate	7	71	25	585
131	43_ADW007	Diversion Aggregate	24	236	42	2074
132	43_ADW008	Diversion Aggregate	7	130	29	1348
133	43_ADW009	Diversion Aggregate	39	418	20	5579
134	43_ADW010	Diversion Aggregate	74	653	22	7799
135	43_ADW012	Diversion Aggregate	32	523	28	3150
136	43_ADW013	Diversion Aggregate	44	674	15	7125
137	43_ADW014	Diversion Aggregate	39	326	9	5358
138	43_ADW015	Diversion Aggregate	26	189	39	1342
139	43_ADW016	Diversion Aggregate	73	830	23	8139
140	43_AMW001 [1]	WHIT_AMW AggMuni&Ind	999	0	60	1104
141	43_OilDem [4]	Oil Shale Direct Right	9999	0	0	0
142	FUD001 [4]	Future Demand 1	0	0	60	0
143	FUD002 [4]	Future Demand 2	0	0	60	0
TOTAL			-----	28,181		880,387

[1] Municipal/industrial diversion
[2] Carrier ditch or feeder ditch to a reservoir
[3] Irrigated acreage assigned in 2005, but not in 2010
[4] Future demand node

5.4.1.1 Key Structures

Key diversion structures are those that are modeled explicitly; that is, the node associated with a key structure represents that single structure only. In the White basin, diversion structures with water rights totaling 4.8 cfs or more were designated key structures, except in the Piceance Creek basin, where structures with smaller water rights were represented explicitly in order to improve calibration. They are identified by a seven-digit number which is a combination of water district number and structure ID from the State Engineer's structure and water rights tabulations. The majority of diversion structures in the White basin are for irrigation, although several exceptions were noted above by footnote in Table 5.4.

Average historical monthly efficiencies for each irrigation structure appear in the diversion station file; however, StateMod operates in the "variable efficiency" mode for most irrigation structures, in which case, the values are not used during simulation. Efficiency in any given month of the simulation is a function of the amount diverted that month and the consumptive use, as limited by the water supply.

For municipal and industrial diverters, StateMod uses the efficiencies in the diversion station file directly during simulation to compute consumption and return flows. Municipal diversion efficiency is set to values that reflect indoor use in winter and a blend of indoor and outdoor use in the summer. The California Company Water Pipeline's diversions for oil extraction were assigned an efficiency of 100 percent, as there are no returns. The Coal Creek Feeder Ditch is zero percent efficient, meaning its diversions are delivered without loss. The Taylor Draw Power Conduit is zero percent efficient meaning power is generated without loss.

Diversion capacity is stored in Hydrobase for most structures and is generally taken directly from the database. In preparing this file, however, the DMI determines whether historical records of diversion indicate diversions greater than the database capacity. If so, the diversion capacity is modified to reflect the recorded diversion.

Return flow parameters in the diversion station file specify the nodes at which return flows will re-enter the stream system, and divide the returns among several locations as appropriate. The locations were determined primarily on a case-by-case basis from topography and from conversations with Water Commissioners and users.

Where to find more information

- When StateMod is executed in the “data check” mode, it generates an *.xtb file which contains summary tables of input. One of these gives the return flow locations and percent of return flow to each location, for every diversion structure in the model.
- Section 4.2.2 describes how key structures were selected.
- Section 4.5 describes the variable efficiency approach for irrigation structures, and describes how diversions, consumptive use, and efficiency interact in the model for different types of structures.

5.4.1.2 Aggregate Structures

Small structures within specific sub-basins were combined and represented at aggregated nodes. Aggregated irrigation structures were given the identifiers “wd_ADWxxx”, where “wd” is the Water District number, and “ADW” stands for Aggregated Diversion White; the “xxx” ranged from 001 to 016. Similarly, the aggregated municipal and industrial structures were named “WD_AMY001” for Aggregated Municipal White.

Efficiency for the aggregated M&I diversion was set to 100 percent because demands for this structure were modeled as depletions.

Where to find more information

- Section 4.2.2 describes how small irrigation structures were aggregated into larger structures.
- Appendix A – White River Aggregated Irrigation Structures describes the aggregation of irrigated lands under small structures

5.4.1.3 Special Structures

Town of Meeker

The Town of Meeker historically diverted at two surface water structures; 4300810 and 4300811, located very near the town. More recently, the town began taking its water supply at a wellfield approximately 5 miles upstream. Meeker has three alluvial wells, structures 4306045, 4306046, and 4306139, decreed as alternate points of diversion to the original water rights, and to each other.

The Town of Meeker is represented by two nodes in the model: 1) structure 4306045, representing the alluvial wellfield, and 2) structure 4300810 representing the historical location of diversions prior to development of the wellfield. Structure 4306045 was made a diversion system with structures 4306046 and 4306139 so that it represents the combined water rights, historical diversions, diversion capacity, and demand of three wells that compose the wellfield. Similarly, structure 4300810 represents the combined characteristics of structures 4300810 and 4300811, using the diversion system modeling option.

In the Baseline data set, Meeker's demand is located at structure 4306045. The historical structure 4300810 is has no demand in this scenario, therefore has no impact on the hydrologic system. Demands at the Meeker nodes are explained in more detail in subsections 5.4.4.

Monthly efficiencies for this municipal structure reflect indoor use in winter and a blend of indoor and outdoor use in summer:

Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
26%	0%	10%	10%	12%	14%	44%	55%	62%	61%	56%	44%

Return flows from Meeker's diversions are modeled as being "instantaneous", meaning they return in the same time step as the diversion.

Meeker Power Ditch

Despite its name, the Meeker Power Ditch (4300809) is an ordinary irrigation diversion structure. It is owned by the Town of Meeker and was originally decreed for a variety of uses including both irrigation and power generation. With four rights that total over 180 cfs, it appears to be one of the largest users in the basin; however, the power generation project envisioned has not yet been developed. The Town exercises only one right for 1.8 cfs to irrigate 15 acres at the town cemetery.

Town of Rangely

Rangely historically supplied its water works by a direct surface water diversion from the White River; recently, however, the Town developed alluvial wells and had them decreed as alternate points of diversions for their historical rights. The wells are in the vicinity of the original diversion site, and as a result, a single structure is used to model Rangely's water use. The structure (4300889) is made a diversion system in the model, with 4302622 and 4302623, the Town's two active wells. Using this approach, the modeled structure has the combined demand, historical diversions, and water rights of all three structures.

The monthly efficiencies shown above for Meeker are also used at the Rangely diversion station. Return flows are modeled as "instantaneous".

Coal Creek Feeder Ditch

The Coal Creek Feeder Ditch (4300577) is a trans-tributary diversion facility which delivers water from the headwaters of Fawn Creek (a tributary of the North Fork of the White River) into the headwaters of Coal Creek (a tributary of the White River). The diversion facility is located near the top of the drainage divide in a fairly remote area. The Water Commissioner reports that the recorded diversions are measured at the Coal Creek end of the ditch, and there may be a small amount of un-decreed use between Fawn Creek and the measurement. This use is not included in the model, partly because it is minor (40 acres), and partly because the records reflect the delivery to Coal Creek.

Water from the ditch is turned into Coal Creek, and is not shepherded to particular users. Amount of the diversion depends only on the physical and legal supply available. Accordingly, the structure is modeled as returning to Coal Creek Mesa Ditch, the most upstream modeled structure on Coal Creek, having zero percent efficiency and instantaneous returns.

California Company Water Pipeline

The California Company Water Pipeline (4300564) diverts water for use in oil extraction. The process is 100 percent consumptive. Use patterns changed dramatically in about 2000, with diversions dropping from several thousand acre-feet per year to several hundred acre-feet per year. The Water Commissioner believes the change was related to changes in technology or process. Modeled efficiency of the California Water Company Pipeline is 100 percent, meaning that none of the diversion returns to the stream.

Taylor Draw Reservoir Power Plant

Taylor Draw Reservoir Power Plant (4302571) is a run-of-the river power plant located at the Taylor Draw Reservoir outlet. Historical diversions are significantly less than the water right; however full demand is placed on the non-consumptive diversion in the

Baseline data set to better reflect its potential impact on upstream water availability. Efficiency is set to zero percent with instantaneous returns.

Future Use

Several diversion and reservoir stations were added to the network based on the Projects and Methods model that was developed for the Yampa/White Basin Round Table (2014). A brief description of the intended use of each node is included below. For additional information, the user is referred to the Projects and Method report. Water rights have been assigned to the nodes, but are turned off and their demand is set to zero. Related operating rules are included, but commented out.

- 4303633_F = Future diversion from White River to a pipeline to fill the future enlarged Lake Avery
- 4303633_O = Future oil and gas development demand. This node is located directly downstream from the future enlargement of Lake Avery on Beaver Creek. The demand node can be satisfied by releases from Lake Avery, releases from future Wolf Creek Reservoir, and direct diversions from the White River via a carrier.
- 4304313_O = Future oil and gas development demand. This node is located directly downstream from the future Wolf Creek Reservoir and can be satisfied by releases from the reservoir.
- 43_OilDem = Future oil and gas development demand. This node is located on the White River upstream of the confluence with Piceance Creek. This node represents the demand that can be satisfied by direct diversion rights from the White River. It carriers water to the 4303633_O node.

Two additional diversion stations in the network are “placeholders” for modeling future conditions. They are named FUD001 and FUD002, denoting “Future Use Diversion”. Both are located on Piceance Creek, and could be used, for example, to simulate rights which are conditional. For the Baseline data set, demands are set to zero.

5.4.2 Return Flow Delay Tables (*.dly)

The wm2015.dly file, which is hand-built with a text editor, describes the estimated re-entry of return flows into the river system. Each table gives the percent of the return flow generated by month n’s diversion, that reaches in the stream in month n, month n+1, month n+2, and so on until extinction of the return. The file contains 10 patterns, some of which are intended for use in other CDSS basins and are not referenced in the White River model.

Irrigation return patterns are based on Glover analysis for generalized characteristics of the alluvium, and have been applied to other West-slope basin models. The percent return flow in the first month for the Glover-derived patterns is adjusted to reflect "incidental loss", losses to the stream due to non-beneficial consumption or evaporation. The default amount of incidental loss in the White River model is 3 percent, based on a recommendation made in "Consumptive Uses and Losses Report, Comparison between StateCU CU & Losses Report and the USBR CU & Losses Report (1995-1998)" (Leonard Rice Engineers, October 1999). The lag times represent the combined impact of surface and subsurface returns.

Pattern 1 represents returns from irrigated lands relatively close to a live stream or drain (<1000 feet). Pattern 2 represents returns from irrigation further from a live stream (>1000 feet). Pattern 4 represents immediate returns, as for municipal and industrial uses, or feeder canals. Table 5.5 shows these three patterns.

Table 5.5 Percent of Return Flow Entering Stream in Months Following Diversion

Month n	Pattern 1	Pattern 2	Pattern 4
1	75.6	57.4	100
2	11.3	14.5	0
3	3.2	7.2	0
4	2.2	5.0	0
5	1.6	3.7	0
6	1.2	2.7	0
7	0.8	2.0	0
8	0.6	1.5	0
9	0.5	1.1	0
10	0	0.8	0
11	0	0.6	0
12	0	0.5	0
Total	97	97	100
Note: month 1 is the same month as the diversion			

Where to find more information

- Section 4.6.1 describes how irrigation return flow delay patterns were developed.

5.4.3 Historical Diversion File (*.ddh)

The historical diversion file contains time series of headgate diversions for each structure. It is not actually input to a Baseline simulation, but StateMod uses the file for estimating baseflows (*.xbm file) and developing irrigation demand (*B.ddm), both of which are required for a Baseline simulation. Furthermore, StateMod outputs comparisons of simulated diversions and the historical diversions in this file, which is useful during calibration.

StateDMI gathers historical diversions for most structures from Hydrobase, and then fills the resulting time series where data are missing. When StateDMI fills a historical diversion time series, it limits the estimated diversion to the structure's water rights at the time. Based on the appropriation date expressed in the administration number in the direct diversion rights (*.ddr) file, StateDMI determines the total amount of the water right during the time of the missing data, and constrains the diversion estimate accordingly. For example, suppose a ditch has two decrees, one for 2.5 cfs with an appropriation date of 1896, and the other for 6 cfs with an appropriation date of 1932. When StateDMI estimates diversions prior to 1932, it limits them to a constant rate of 2.5 cfs for the month, regardless of the average from available diversion records. This approach was adopted to better reflect historical use during the early part of the modeling period, for the purpose of both baseflow estimation and historical simulation.

5.4.3.1 Key Structures

In the White River model, StateDMI accesses Hydrobase to get historical diversion records for all key irrigation and M&I structures. That is, there are no instances of developing historical diversions independent of Hydrobase. StateDMI accumulates historical diversions across several structures for diversion systems.

5.4.3.2 Aggregate Structures

Aggregated irrigation diversion structures are assigned the sum of the member structures' historical diversion records from Hydrobase.

Historical diversions for the aggregated M&I node 43_AMW001 are modeled as the consumed or depletive portion of the diversion. The node represents non-irrigation consumptive use that is not modeled by key structures. Task Memorandum 2.09-11, "Non-Evaporation (Other Uses) Consumptive Uses and Losses in the White River Basin" (8/16/96) documents how basin-wide, total non-irrigation consumption was estimated. Consumptive use of the key municipal diverters, Rangely and Meeker, was subtracted from the basin-wide M&I consumption, to derive historical basin-wide consumptive use attributable to small M&I users. This number is assumed to be distributed uniformly across the year, and does not vary from year to year.

5.4.3.3 Special Structures

Town of Meeker

Modeled historical diversions for structure 4300810 are computed as the combined diversions recorded for structures 4300810 and 430811, which served the Town concurrently until 2003. Modeled historical diversions for structure 4306045 are a combination of the recorded historical diversions of 4306045, 4306046, and 4306139, three wells that Meeker now uses to supply the Town.

Town of Rangely

Modeled historical diversions for structure 4300889 are the sum of recorded historical diversions by structures 4300889, 4302622, and 4302623. The first is Rangely's historical surface water diversion, and the latter two are alluvial wells currently in use.

Future Use

The future use structures have historical diversions set to zero because they did not divert historically.

5.4.4 Direct Diversion Demand File (Baseline) (*.ddm)

Created by StateDMI, this file contains time series of demand for each structure in the model. Demand is the amount of water the structure "wants" to divert during simulation. Thus demand differs from historical diversions, as it represents what the structure would divert in order to get a full water supply. Table 5.4 lists average annual demand for each diversion structure.

5.4.4.1 Key Structures

Irrigation demand is computed as crop irrigation water requirement divided by average monthly efficiency for the structure, as described in Section 4.9.1. Note that the irrigation water requirement is based on actual climate data beginning in 1950. Prior to that, it is filled using the automatic data filling algorithm described in Section 4.4.1. Average monthly efficiency calculated over the period 1975 through 2013, but capped at 0.60. Exceptions are made when the historical diversion exceeds the calculated irrigation demand – in which case historical diversions are incorporated in the demand file. This approach addresses non-irrigation season diversions which may be for stock watering or wetting the soil, and typical wet year diversions when the ditch operates at lower-than-usual efficiency.

Demands for Rangely and the California Company Water Pipeline are set to monthly averages from the period 1998 through 2013. Demand for Meeker is set to monthly averages for 2003 through 2013 at the Baseline demand node 436045, to reflect that historical diversions for Meeker changed significantly in 2003. According to the Water Commissioner, the recent values are metered and are more accurate than the earlier values. The monthly demand for Taylor Draw Power Conduit is set to power plant capacity each month.

5.4.4.2 Aggregate Structures

Aggregated irrigation structure demand is computed as for key irrigation structures. The only difference is that the irrigated acreage, which is the basis of irrigation water requirement, is the sum of irrigated acreage for member structures. Similarly diversions are summed across all member structures, and average efficiency is based on efficiency of the aggregation in toto. Demand for the aggregated M&I structure is the same as it is in the historical diversion file.

5.4.4.3 Future Use

Demands of future depletion nodes are zeroed out, as they are not active in the baseline data set.

5.4.5 Direct Diversion Right File (*.ddr)

The direct diversion right file contains water rights information for each diversion structure in the model. StateDMI creates the diversion right file, based on the structure list in the diversion station file. The diversion right file contains absolute rights.

The information in this file is used during simulation to allocate water in the right sequence or priority and to limit the allocation by decreed amount. The file is also an input to StateDMI when it fills historical diversion time series, as described in Section 5.4.3.

5.4.5.1 Key Structures

Water rights for explicitly modeled structures were taken from Hydrobase and match the State Engineer's official water rights tabulation. In addition, structures that historically diverted more than their decreed water rights were assigned a "free river right", with an extremely junior administration number of 99999.99999 and a decreed amount of 999.0 cfs. These rights allow structures to divert more than their decreed amount under free river conditions, provided their demand is unsatisfied and water is legally available.

5.4.5.2 Aggregate Structures

Aggregated irrigation structures include many structures, each having multiple water rights. Therefore, aggregated irrigation structures were assigned up to eight water rights, one for each of eight water right classes. Appendix A describes the procedure and results for determining appropriate water right classes for the basin. The decreed amount for a given aggregate water right was the sum of all water rights that 1) were associated with the member structures included in the aggregate structure, and 2) had an administration number that fell within the water right class. The administration number for each aggregate right was calculated as the average administration number for the individual rights it represented, weighted by their decreed amounts.

The aggregated M&I structure was assigned a decreed amount equal to the uniform monthly demand for the structure, and assigned an administration number of 1.00000 (very senior).

5.4.5.3 Special Diversion Rights

Town of Meeker

Meeker's wellfield (4306045) was assigned the absolute junior rights of the three currently operating wells it represents (4306045, 4306046, and 4306139). In addition, it was given rights with the characteristics of water rights associated with Meeker's historical diversion structures (4300810 and 4300811), for which the wells are decreed alternate points. Structure 4300810 was assigned both its own absolute rights, and those associated with historical structure 4300811. The model is set up for the historical calibration run so that structures 4300810 and 4306045 never have a positive demand at the same time. Thus there is no risk of the historical structure's rights being exercised at two different places in the same model time step. For the Baseline data set, current demand is represented at 4306045.

Meeker Power Ditch

The Meeker Power Ditch's large rights for power generation are turned off in the direct diversion right file. The rights have absolute status in Hydrobase, but have apparently not been put to beneficial use. A right for 1.8 cfs is left on. Daily diversion records show a maximum and often recorded rate of 1.8 cfs for this structure.

Town of Rangely

The Town of Rangely diversion structure (4300889) was made a diversion system with structures 4302622 and 4302623, so that the structure's rights would include the wells' rights. At the current time, these wells have no absolute rights. If the well rights' status changes in Hydrobase, the command file will cause the additional, presumably junior, rights to be reflected in the direct diversion right file.

Future Use

Future use structures are listed in the direct diversion rights file, but the rights are turned off. This effectively disables the structure with regard to having an impact on the river.

Where to find more information

- Appendix A - Define Water Right Classes explains how water right classes for aggregated irrigation structures were established.

5.5 Irrigation Files

The irrigation files provide parameters used during simulation to compute on-farm consumptive use and return flow volumes related to a given month's diversion. For more information on the irrigation files, the user is referred to the Historical Crop Consumptive Use Analysis: White River Basin Final Report, 2015.

5.5.1 StateCU Structure File (*.str)

This file contains the soil moisture capacity of each irrigation structure in inches per inch of soil depth. It is required for StateMod's soil moisture accounting in both baseflow and simulation modes. Soil moisture capacity values were gathered from Natural Resources Conservation Service (NRCS) mapping. The file is assembled by StateDMI from hand-built files.

5.5.2 Irrigation Parameter Yearly File (*.ipy)

This file contains conveyance efficiency and maximum application efficiency by irrigation type, for each irrigation structure and each year of the study period. The file also contains acreage by irrigation type – either flood or sprinkler. Maximum flood irrigation system efficiency is assumed to be 54 percent and maximum sprinkler system irrigation efficiency is assumed to be 72 percent. The irrigated acreage is based on 2010 aerial imagery. Although this is an annual time-series file, StateMod will not simulate the White datasets if the irrigation parameter yearly file header is not changed from CYR to WYR. This change has to be done by hand in a text editor.

5.5.3 Irrigation Water Requirement File (*.iwr)

Data for the irrigation water requirement file is generated by StateCU for the period 1950 through 2013, then filled and formatted into StateMod file format by StateDMI. For lands below elevation 6,500 feet, StateCU was executed using the SCS modified Blaney-Criddle monthly evapotranspiration option with TR-21 crop coefficients and a standard elevation adjustment. For structures irrigating pasture grass above 6,500 feet, StateCU was executed using the original Blaney-Criddle method with high-altitude crop coefficients as described in the SPDSS 59.2 Task Memorandum *Develop Locally Calibrated Blaney-Criddle Crop Coefficients*, March 2005, available on the CDSS website. The irrigation water requirement for 1950 through 2013 is based on 2010 irrigated lands information stored in Hydrobase.

Where to find more information

- Historical Crop Consumptive Use Analysis: White River Basin 2015 provides details on the consumptive use analysis and associated input files.

5.6 Reservoir Files

5.6.1 Reservoir Station File (*.res)

This file describes physical properties and some administrative characteristics of the reservoirs in the White River basin. It is created by StateDMI, using information in Hydrobase supplemented with information provided in the command file. Two key reservoirs, two aggregated reservoirs, and two aggregated stockponds are included in the model. Two future reservoirs are included, but are not active. The aggregate structures account for evaporation from numerous small storage facilities. One aggregate reservoir and one aggregate stock pond were located on the White River above the state line gage; the other reservoir and stockpond were located on the White River above the Piceance Creek confluence. These general locations were selected based on reservoir locations and stock pond assignment to Hydrologic Units. The reservoir structures are listed below with their capacity and their number of accounts or pools:

ID #	Name	Capacity (af)	# of Owners
4303633	Big Beaver Creek Reservoir (aka Lake Avery)	7,658	1
4304433	Taylor Draw Reservoir	13,800	1
43_ARW001	Agg Res near Colo-Utah Stateline	2,117	1
43_ARW002	Agg Res above Piceance Creek	2,117	1
43_ASW001	Stock Pond near Colo-Utah Stateline	2,388	1
43_ASW002	Stock Pond above Piceance Creek	2,388	1
4304313	Future Wolf Creek Reservoir	162,400	1

Two reservoirs were included because they were investigated as part of the Yampa/White/Green Basin Roundtable's Basin Implementation Plan (BIP). The potential future enlargement of Lake Avery (48,274 af) was turned off and operated with current capacity. The potential future Wolf Creek Reservoir (4304313) are included in the reservoir station file, but are not operated in the model. Their water rights are turned off and their target storage is set to zero. Suggested operating rules are included in the wm2015B.opr file, but are turned off. It is the responsibility of the user to activate the reservoirs and verify that they are working as intended.

5.6.1.1 Key Reservoirs

Parameters related to the physical attributes of key reservoirs include inactive storage where applicable, total active storage, area-capacity data, applicable evaporation/precipitation stations, and initial contents. For the explicitly modeled reservoirs, storage and area-capacity information was obtained from Division personnel, the reservoir owners, or filing maps and construction drawings associated with the storage rights for the reservoirs. Initial contents for all reservoirs are set to full in the Baseline data set.

Administrative information includes reservoir account ownership, administrative fill date, and evaporation charge specifications. Annual administration is turned off at all reservoirs in the White River model, and evaporation is charged completely to the only account in each reservoir.

5.6.1.2 Aggregate Reservoirs

The amount of storage for aggregated reservoirs was based on storage decrees as related in the memorandum Subtask 2.11 White River Basin Aggregate Reservoirs and Stockponds (see Appendix B). Surface area for the reservoirs was developed assuming they are straight-sided pits with a depth of 25 feet. Initial contents were set to full.

5.6.1.3 Reservoir Accounts

Big Beaver Creek Reservoir (aka Lake Avery)

Big Beaver Creek Reservoir is named such in the State's database but is more commonly known as Lake Avery. The Colorado Division of Parks and Wildlife (CPW) owns the reservoir, which it keeps full for recreational and piscatorial uses. Construction drawings obtained from the State Engineer's Office indicate that the reservoir has no dead storage. It is therefore modeled as having a single account with no releases.

Taylor Draw Dam (aka Kenney Reservoir)

Taylor Draw was constructed by the Colorado River Water Conservation District in the mid-1980s, and ownership was transferred to the Rio Blanco Water Conservancy District in 1990. The reservoir is used for recreation and power generation, and for irrigation of a small amount of lawn at the marina. Early CDSS research cited a 1,735-af pool for the Town of Rangely and an 8,235-af pool for other water sales. However, recent operations do not reflect releases for Rangely or any other users. The reservoir is operated to maintain full pool and pass inflow through the hydropower plant. Accordingly, the reservoir is modeled as having a single account with no releases.

5.6.2 Net Evaporation File (*.eva)

The evaporation file contains monthly average evaporation data (12 values that are applied in every year). The annual net reservoir evaporation was estimated by subtracting the weighted average effective monthly precipitation at Meeker from the estimated gross monthly free water surface evaporation. Annual estimates of gross free water surface evaporation were taken from the National Oceanic and Atmospheric Administration (NOAA) Technical Report NWS 33. The annual estimates of evaporation were distributed to monthly values using the factors listed in Table 5.6. These monthly distributions are used by the State Engineer's Office.

Table 5.6 Monthly Distribution of Annual Evaporation as a Function of Elevation (percent)

Month	Greater than 6,500 ft	Less than 6,500 ft
Jan	3.0	1.0
Feb	3.5	3.0
Mar	5.5	6.0
Apr	9.0	9.0
May	12.0	12.5
Jun	14.5	15.5
Jul	15.0	16.0
Aug	13.5	13.0
Sep	10.0	11.0
Oct	7.0	7.5
Nov	4.0	4.0
Dec	3.0	1.5

The resulting net monthly free water surface evaporation estimates for the White River basin are shown below:

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
.13	.04	-.05	-.06	.02	.09	.16	.30	.41	.41	.27	.24

5.6.3 EOM Content File (*.eom)

The end-of-month content file contains historical end-of-month storage contents for all reservoirs in the reservoir station file. The historical EOM reservoir contents in this file are used by StateMod when estimating baseflow to reverse the effects of reservoir storage and evaporation on gaged streamflows, and to produce comparison output useful during calibration. The file is created by TSTool, which reads data from Hydrobase and fills it under a variety of user-specified algorithms.

5.6.3.1 Key Reservoirs

Data for the two key reservoirs was generated by converting sporadic observations from Hydrobase to month-end data. The user-specified tolerance for defining the end of the month was set to 14 days, because the observations were sparse. Short gaps were filled by linear interpolation, and longer gaps were filled with the average historical contents for the month (Big Beaver Creek Reservoir) or with reservoir capacity (Taylor Draw Reservoir).

Table 5.7 presents the on-line date for each reservoir. Historical contents in the *.eom file are set to zero prior to these dates

Table 5.7 Reservoir On-line Dates

Reservoir	On-Line Date
Big Beaver Creek	1964
Taylor Draw	1984

5.6.3.2 Aggregate Reservoirs

Aggregated reservoirs were assigned contents equal to their capacity, because there is no actual data. Aggregated reservoirs were modeled as though in operation throughout the study period.

5.6.4 Reservoir Target File (*.tar)

The reservoir target file contains minimum and maximum target storage limits for all reservoirs in the reservoir station file. The reservoir may not store more than the maximum target, or release to the extent that storage falls below the minimum target. In the Baseline data set, the minimum targets are set to zero and maximum targets are set to capacity for all reservoirs for the entire model period. These targets allow maximum control of reservoir levels by storage rights and releases to meet demands.

The two reservoirs investigated in the BIP have the maximum target set to zero. They do not store water.

5.6.5 Reservoir Right File (*.rer)

The reservoir right file contains the water rights associated with each reservoir in the reservoir station file. Specifically, the parameters for each storage right include the reservoir, administration number, decreed amount, the account(s) to which exercise of the right accrues, and whether the right is used as a first or second fill.

The BIP reservoirs are assigned hypothetical water rights but they are inactive.

5.6.5.1 Key Reservoirs

Water rights for explicitly modeled reservoirs were taken from the CDSS database and correspond to the State Engineer's official water rights tabulation.

5.6.5.2 Aggregate Reservoirs

Aggregated reservoirs and stock ponds were assigned a decreed amount equal to their capacity, and an administration number of 1.00000.

5.7 Instream Flow Files

5.7.1 Instream Station File (*.ifs)

Twelve instream flow reaches are defined in this file, which is created by StateDMI. The file specifies an instream flow station and downstream terminus node for each reach, through which instream flow rights can exert a demand in priority. Table 5.8 lists each instream flow station included in the White River model along with its maximum flow rate. With the exception of instream flow structure 434433_M, these rights represent decrees acquired by CWCB.

Structure 434433_M represents an minimum bypass requirement below Taylor Draw Reservoir. The Final Environmental Impact Statement (Army Corps of Engineers, June 1982) and biological opinion (Letter from U.S. Fish and Wildlife Service to Army Corps of Engineers, May 20, 1982) for the Taylor Draw Project indicate that the operation of the project would allow for bypassing water to meet temperature and flow requirements for the Colorado squawfish. The project operating criterion related to the squawfish is that 200 cfs (or reservoir inflow if it is less than 200 cfs) must be maintained below the dam. Water from storage is not required to be released if the inflow is less than 200 cfs.

Table 5.8 Instream Flow Summary

ID	Name	Demand (AF)
4301321	SOLDIER CREEK MSF	1086
4301325	LAKE CREEK MSF	1086
4301327	CATHEDRAL CK MSF	1086
4301845	WHITE RIVER MSF	144,795
4302321	FAWN CR MSF	2172
4302334	MARVINE CREEK MSF	28,959
4302337	MILLER CK MSF	7240
4302338	NORTH FK WHITE R MSF-L	86,877
4302339	NORTH FK WHITE R MSF-U	50,679
4302344	SOUTH FORK WHITE R MSF	57,918
4302372	UTE CREEK MSF	4344
4304433_M	TAYLOR DRAW BYPASS	144,795

5.7.2 Instream Demand File (*.ifa)

Instream flow demands were developed from decreed amounts and comments in the State Engineer’s water rights tabulation. The instream flow rights included in the White River model are all uniform. That is, the demands (decreed rates) do not vary from winter to summer as for many CWCB instream flow rights.

5.7.3 Instream Right File (*.ifr)

The instream flow right file contains the decreed flow rate and administration number for each modeled instream flow right. These data were obtained from Hydrobase, with the exception of instream flow structure 434433_M. This right is assigned an administration number just senior to the Taylor Draw Reservoir storage right.

5.8 Operating Rights File (*.opr)

The operating rights file specifies all operations that are more complicated than a direct diversion or storage in an on-stream reservoir. Typically, these are operations involving two or more structures, such as a release from a reservoir to a diversion structure, a release from one reservoir to a second reservoir, or a diversion to an off-stream reservoir. The file is created by hand, and the user is required to assign each operating right an administration number consistent with the structures' other rights and operations.

In the White River model, two different types of operating rights are used:

- **Type 9** – a release from storage to the river to meet a reservoir target. This operating rule type is used at both Big Beaver Creek and Taylor Draw Reservoirs because neither releases to downstream demand, and is the only type of rule used for reservoir releases in the White River model.

- **Type 22** – The type 22 operating right directs StateMod to consider soil moisture in the variable efficiency accounting. For structures with crop irrigation water requirements, excess diverted water not required by the crops during the month of diversion is stored in the soil reservoir zone, up to the soil reservoir's available capacity. If diversions are not adequate to meet crop irrigation water requirements during the month of diversion, water is withdrawn from the soil reservoir to meet unsatisfied demands.

Additionally, Type 3 and Type 11 operation rules have been added to support the future reservoir project operations identified in the BIP, but are not activated in the Baseline data set. Type 3 is a reservoir release to a diversion or reservoir by a carrier. Type 11 is a direct flow diversion to another diversion or reservoir through an intervening carrier.

Where to find more information

- StateMod documentation describes all the different types of operating rights that can be specified in this file, and describes format of the file.

5.8.1 Big Beaver Creek Reservoir

Big Beaver Reservoir, also known as Lake Avery, is located on Big Beaver Creek, a tributary of the White River just west of Buford. The Colorado Division of Parks and Wildlife (CPW) owns and operates Lake Avery. CPW does not release from Lake Avery to provide supplemental water supplies, but maintains the reservoir for recreational and piscatorial purposes. A single operating right is used to specify Lake Avery operations:

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	N/A	1	99999.99999	9	Release to target

Operating right 1 releases water when reservoir contents exceed the end-of-month maximum storage target. The administration number is set to a very high value so that the release occurs after all other operations in the time step are complete. In the Baseline data set, the target is set to the reservoir capacity, which effectively disables the operating rule. This is because the reservoir currently makes no releases for downstream flow maintenance or to downstream users. In the calibration run, maximum targets are set to historical end-of-month contents, and this rule allows the reservoir to mimic historical operations unrelated to downstream water supply.

5.8.2 Taylor Draw Reservoir

Taylor Draw Reservoir, or "Kenney Reservoir", is on the White River just east of Rangely. Kenney Reservoir is used only for hydropower and recreation, although it is decreed for irrigation, municipal, domestic, and stock use as well. The reservoir is operated for run-of-the-river power generation, under a FERC license requiring that they pass inflows through the reservoir.

A single operating right is used to simulate Kenney Reservoir operations:

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	N/A	1	99999.99999	9	Release to target

Operating right 1 releases water when reservoir contents exceed the end-of-month maximum storage target. The administration number is set to a very high value so that the release occurs after all other operations in the time step are complete. In the Baseline data set, the target is set to the reservoir capacity, which effectively disables the operating rule. This is because the reservoir currently makes no releases for downstream flow maintenance or to downstream users. In the calibration run, maximum targets are set to historical end-of-month contents, and this rule allows the reservoir to mimic historical operations unrelated to downstream water supply.

No operating right is required for the minimum bypass requirement, since water is not taken out of storage to satisfy the requirement. The administration number of the bypass requirement is just senior to the reservoir storage right, which causes the model to allocate water to the bypass before it allocates water to the reservoir. In this way, the bypass is maintained.

5.9 Basin Implementation Plan Reservoirs

Suggested operating rules are included in the wm2015B.opr file, but are turned off. It is the responsibility of the user to activate the reservoirs and verify the operations are working as intended.

6. Baseline Results

The “Baseline” data set simulates current demands, current infrastructure and projects, and the current administrative environment, as though they had been in place throughout the modeled period. This section summarizes the state of the river as the White River model characterizes it, under these assumptions.

6.1 Baseline Streamflows

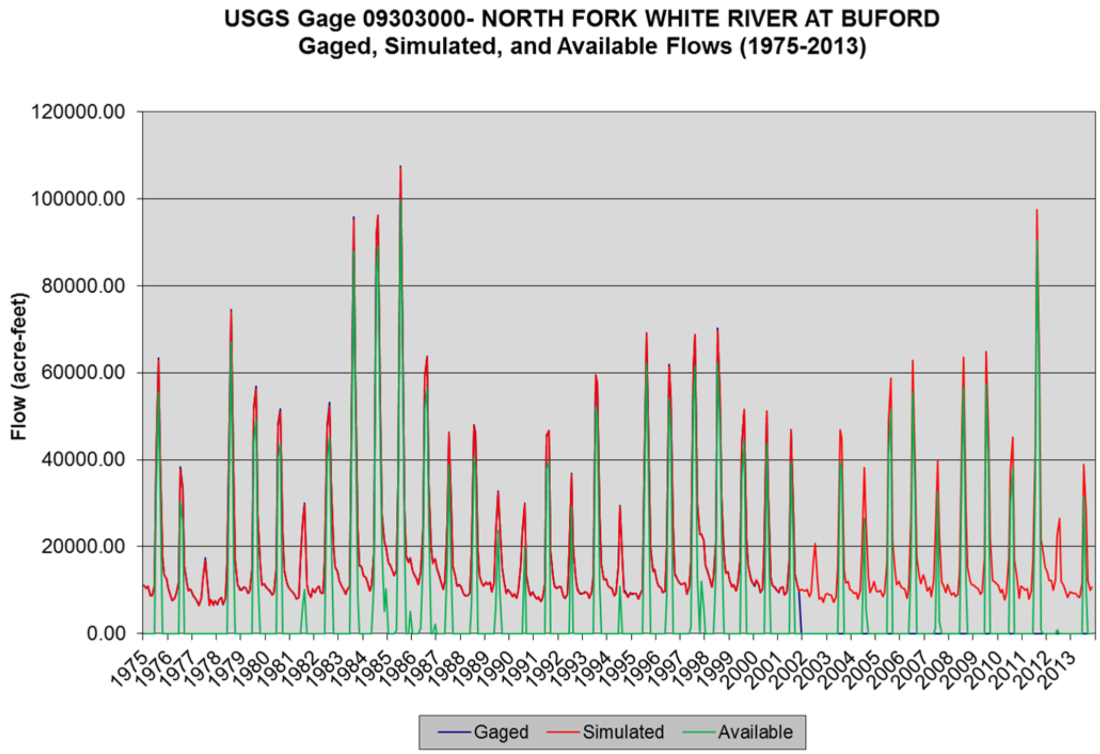
Table 6.1 shows, for each gage, the average annual flow from the Baseline simulation based on the entire simulation period (1909 – 2013). In general, this value is lower than the historical average, because demand has risen and the development of storage has re-timed the supply so that more of the demand can be met. The second value in the table is the average annual available flow, as identified by the model. Available flow at a point is water that is not needed to satisfy instream flows or downstream diversion demand; it represents the water that could be diverted by a new water right. The available flow is always less or the same as the total simulated flow.

Temporal variability of the historical and Baseline simulated flows for all the modeled gages is illustrated in **Error! Reference source not found.** through **Error! Reference source not found.**. Each figure shows two graphs: overlain hydrographs of historical gage flow, simulated gage flow, and simulated available flow for 1975 through 2013; and an average annual hydrograph for 1975 through 2013. The annual hydrograph is a plot of monthly average flow values, for the three parameters. The gages selected for these figures have a fairly complete record between 1975 and 2013.

Table 6.1 Simulated Baseline Average Annual Flows for White River Gages (1909-2013)

Gauged ID	Gage Name	Simulated Flow (af)	Simulated Available Flow (af)
09303000	North Fork White River At Buford	225,862	90,330
09303400	South Fork White River Nr Budges Resort	140,336	83,596
09303500	South Fork White River Near Buford	186,059	92,089
09304000	South Fork White River At Buford	184,061	94,413
09304200	White River Above Coal Creek	396,380	152,255
09304500	White River Near Meeker	436,755	152,580
09304800	White River Below Meeker	471,061	152,724
09306007	Piceance Creek Below Rio Blanco	9,604	3,163
09306200	Piceance Creek Below Ryan Gulch	17,702	5,771
09306222	Piceance Creek At White River	21,416	7,508
09306290	White River Bl Boise Creek Near Rangely	509,470	153,242

Gauged ID	Gage Name	Simulated Flow (af)	Simulated Available Flow (af)
09306395	White River Near Colorado State Line, UT	537,753	537,753



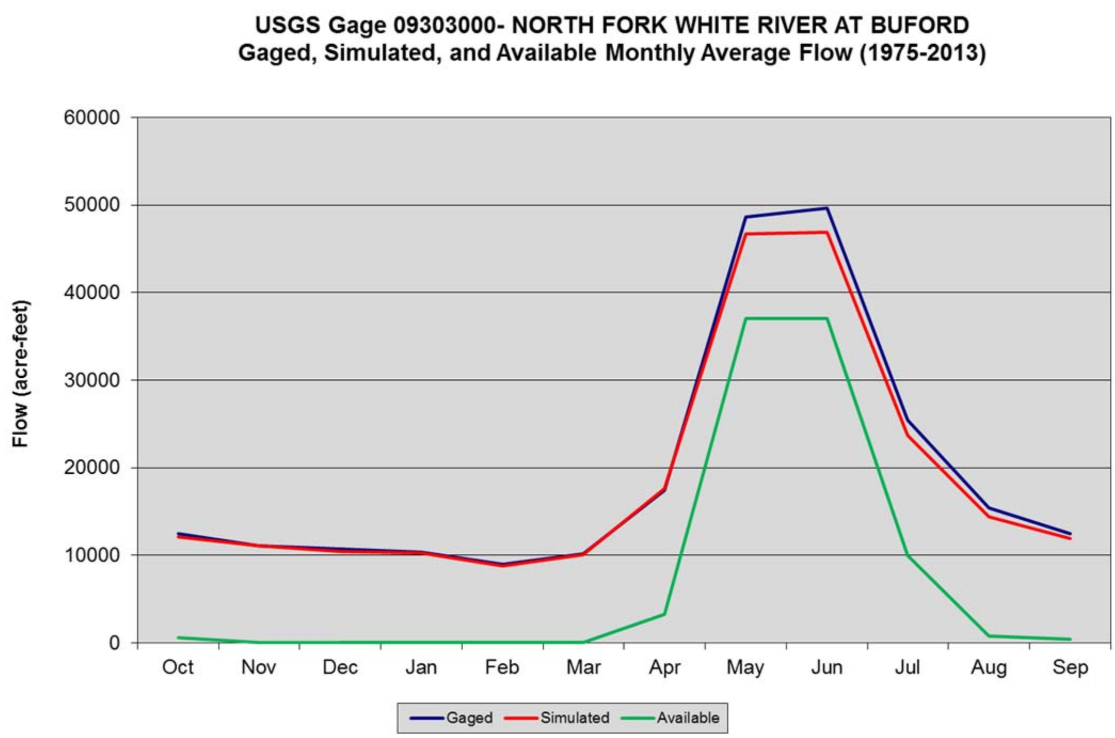
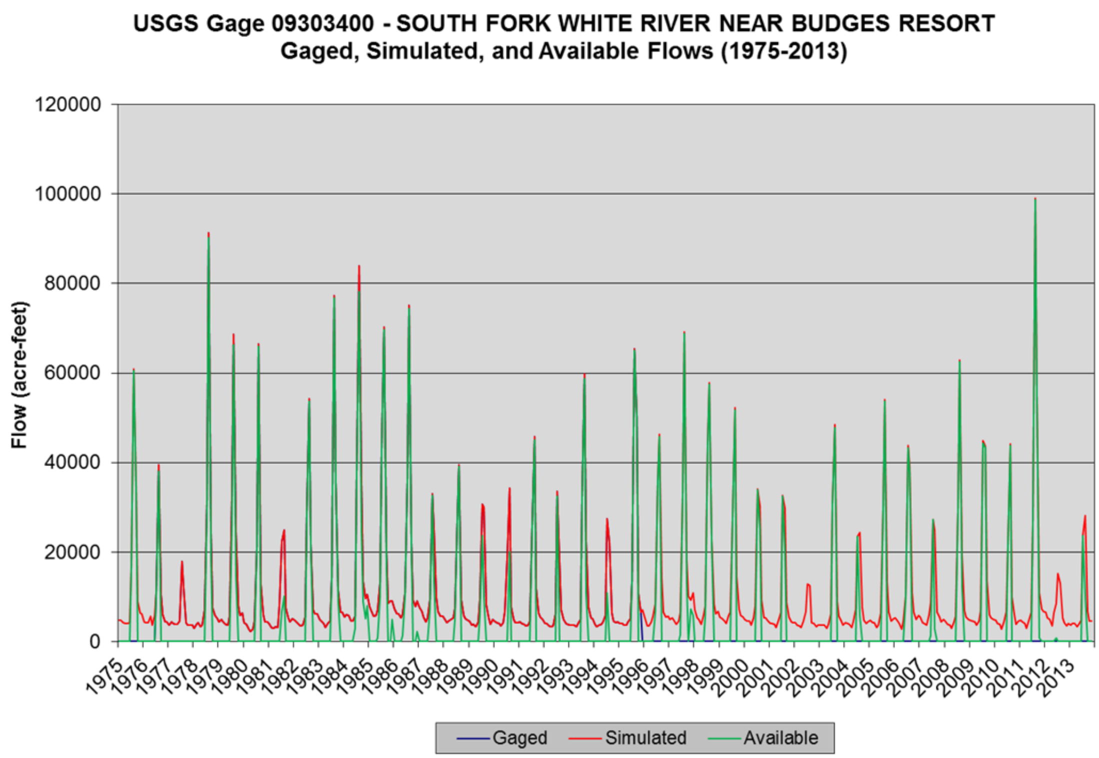


Figure 6.1 Gaged, Baseline Simulated, and Available Flows (USGS Gage 09303000 - North Fork White River at Buford)



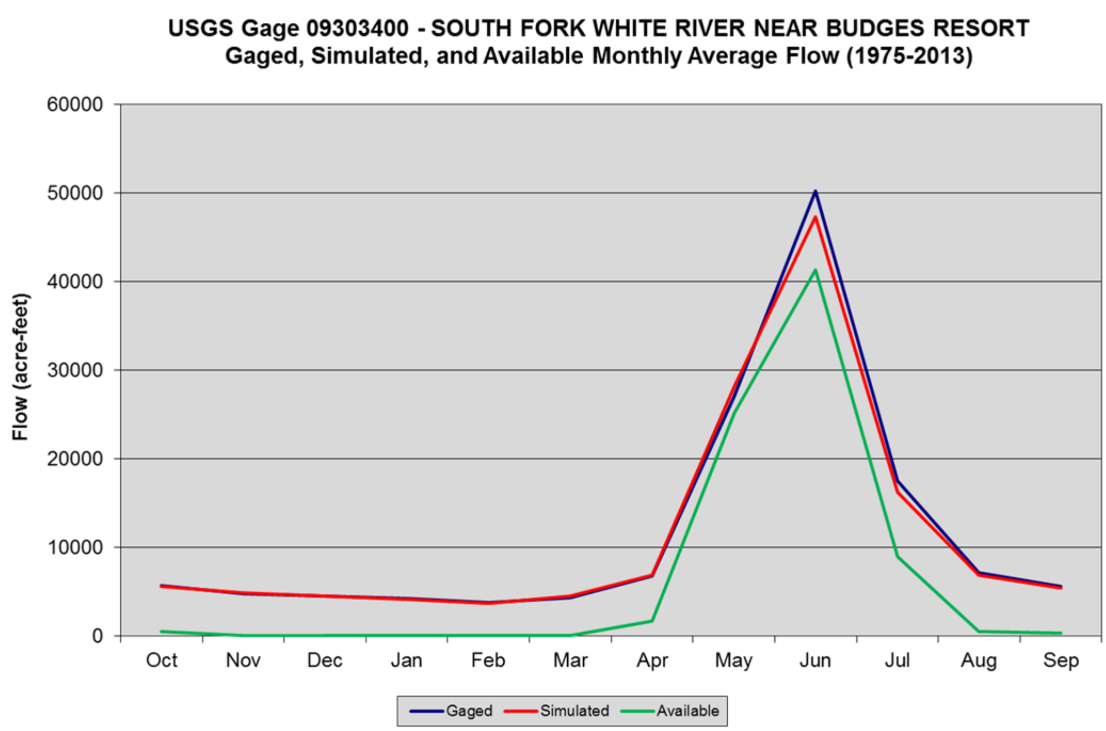
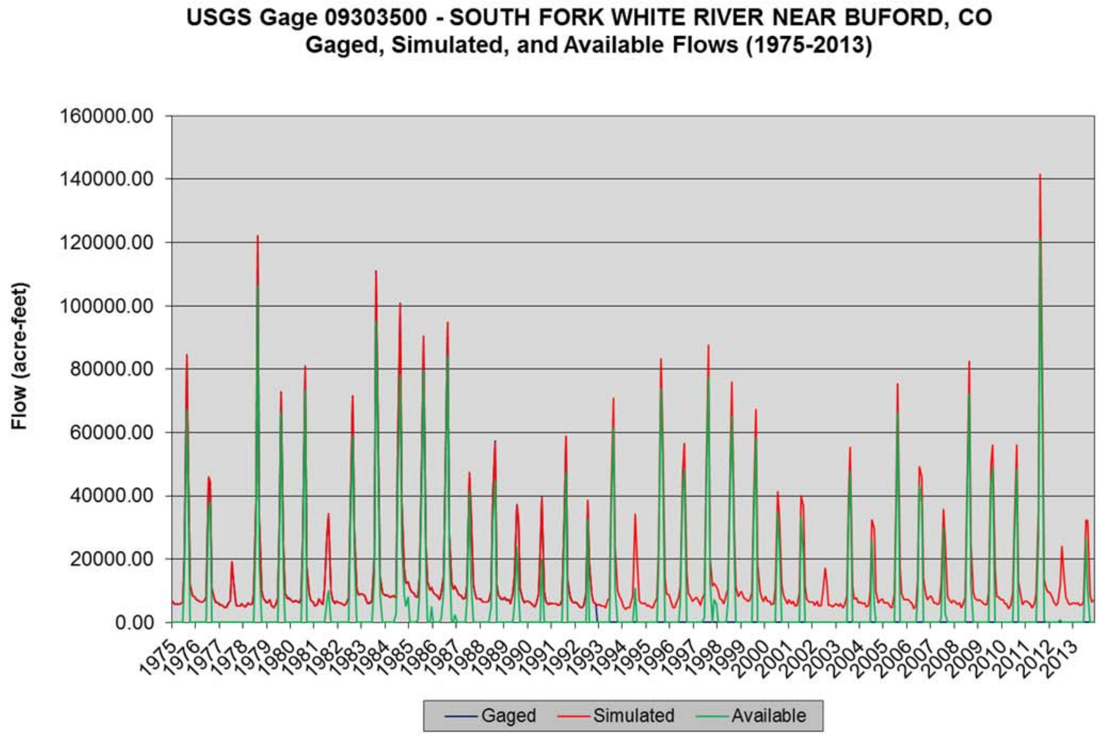


Figure 6.2 Gaged, Baseline Simulated, and Available Flows (USGS Gage 09303400 - South Fork White River near Budges Resort)



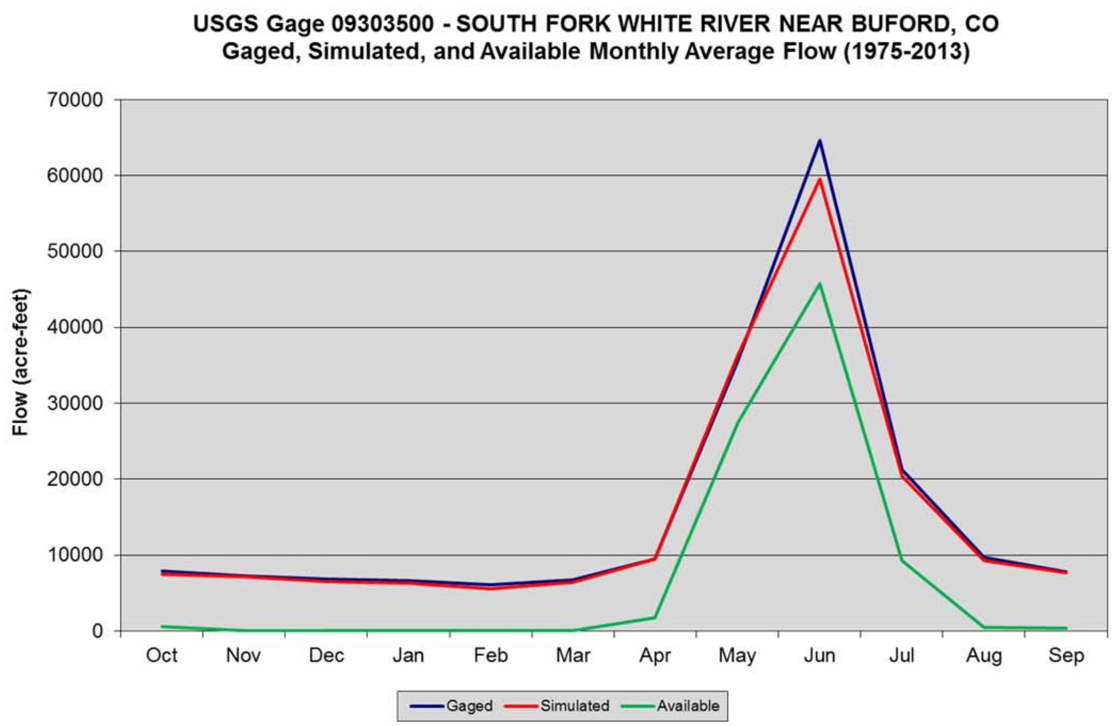
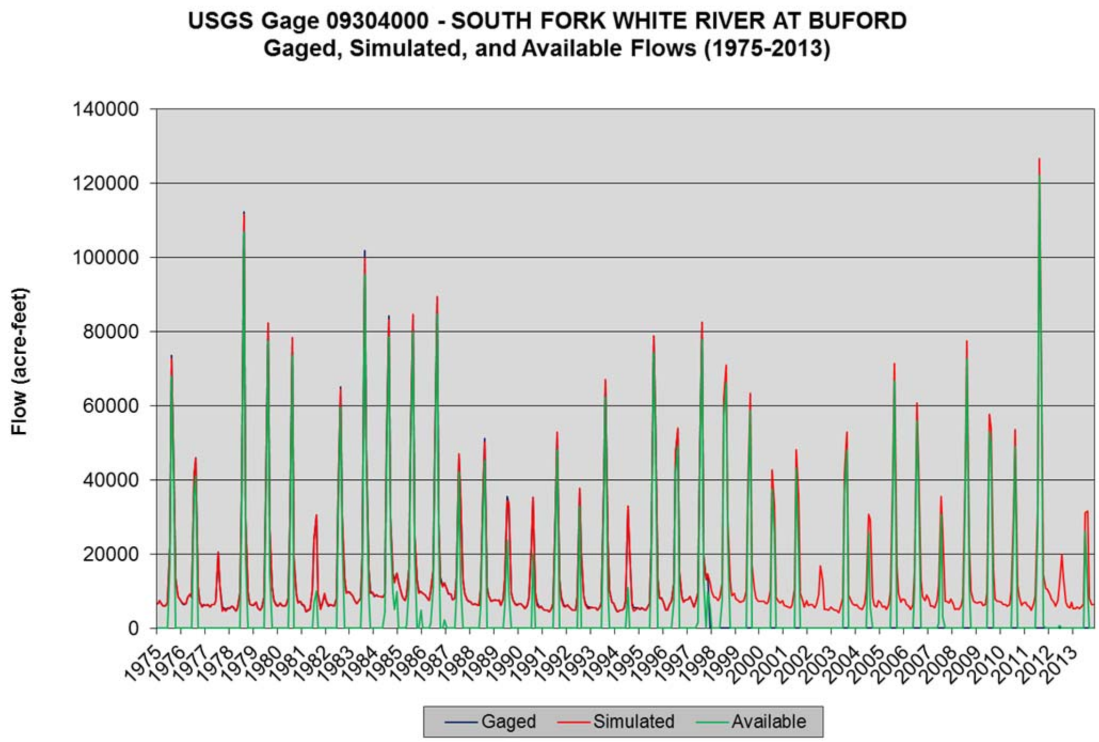


Figure 6.3 Gaged, Baseline Simulated, and Available Flows (USGS Gage 09303500 - South Fork White River Near Buford)



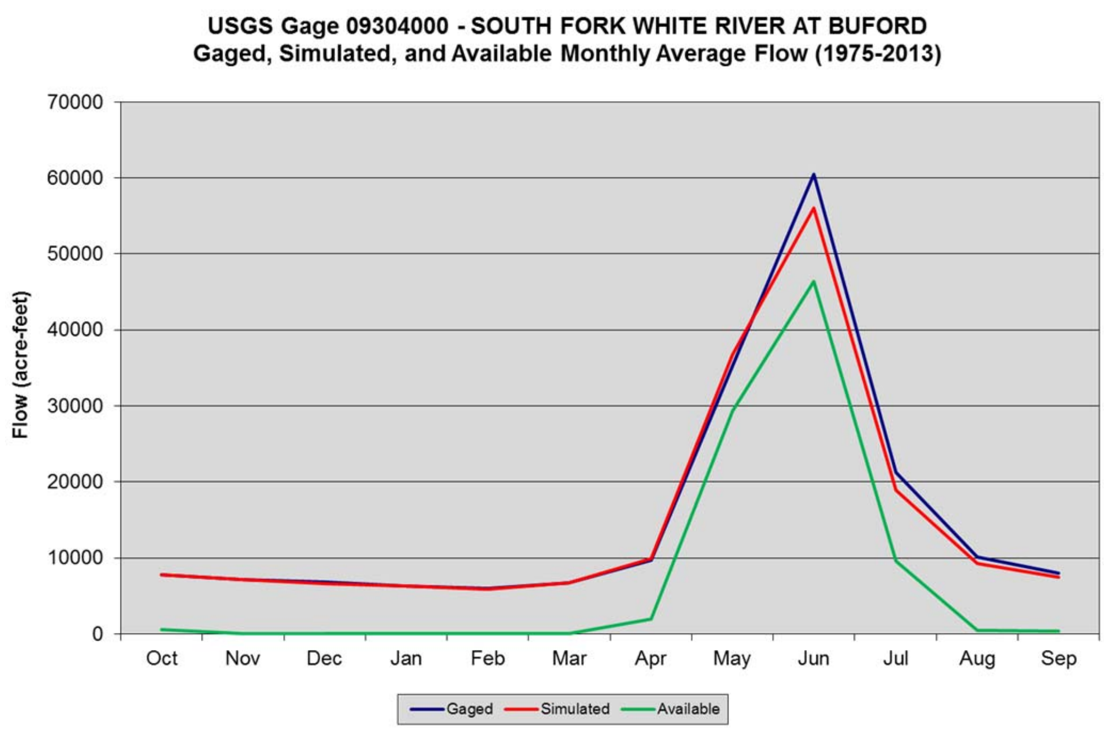
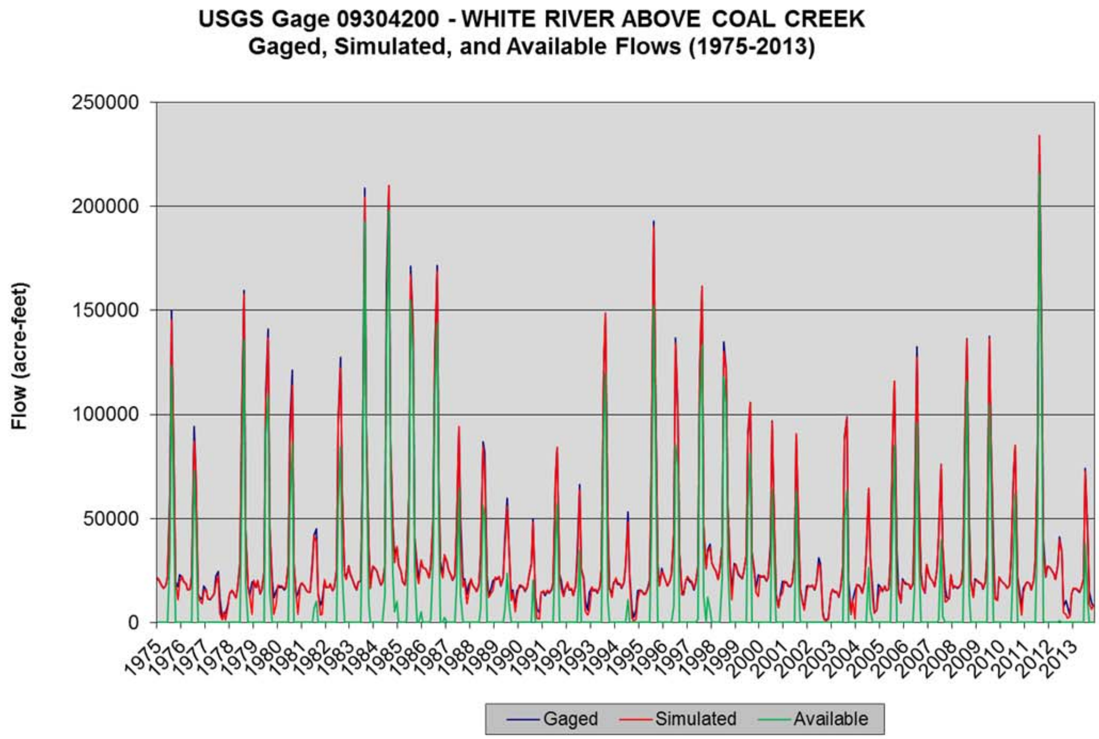


Figure 6.4 Gaged, Baseline Simulated, and Available Flows (USGS Gage 09304000 - South Fork White River at Buford)



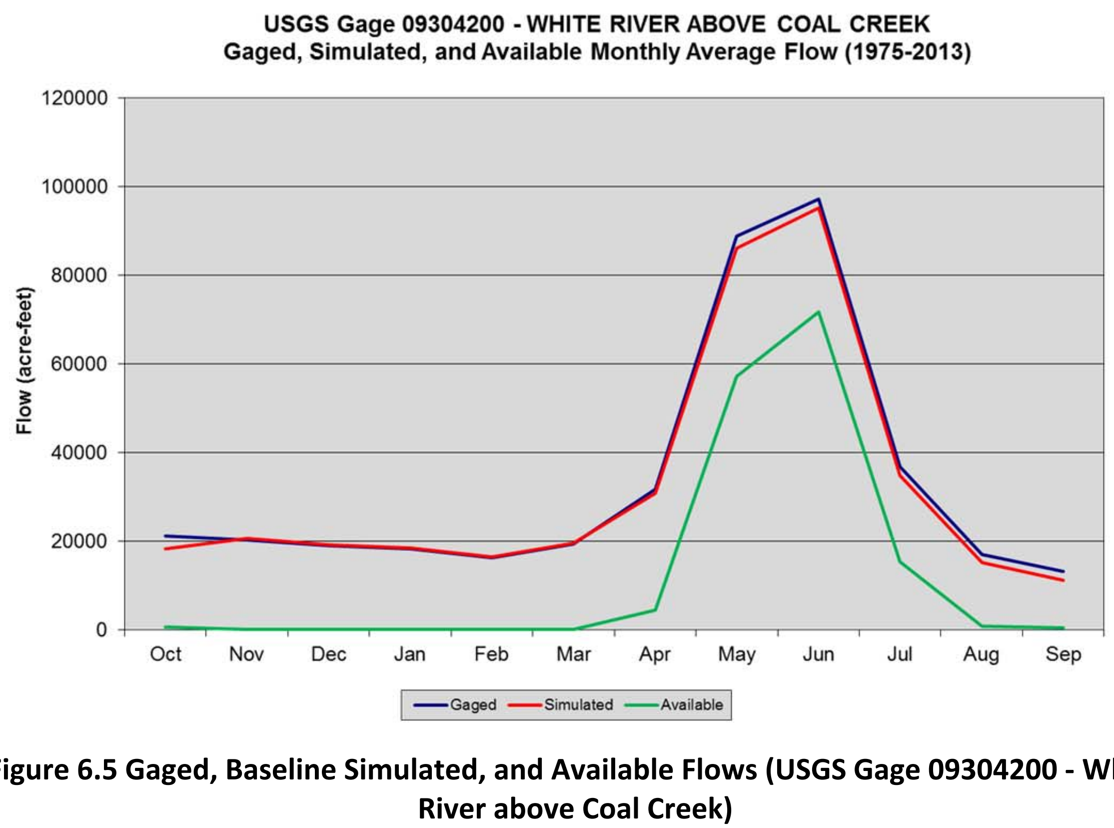
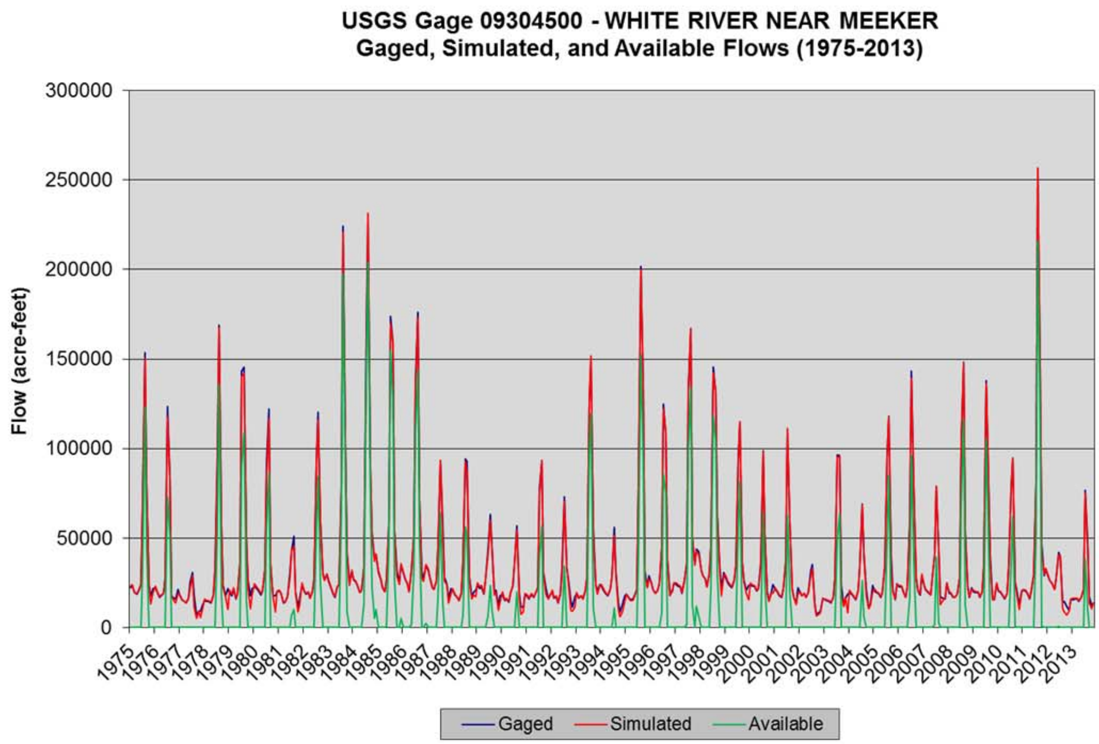


Figure 6.5 Gaged, Baseline Simulated, and Available Flows (USGS Gage 09304200 - White River above Coal Creek)



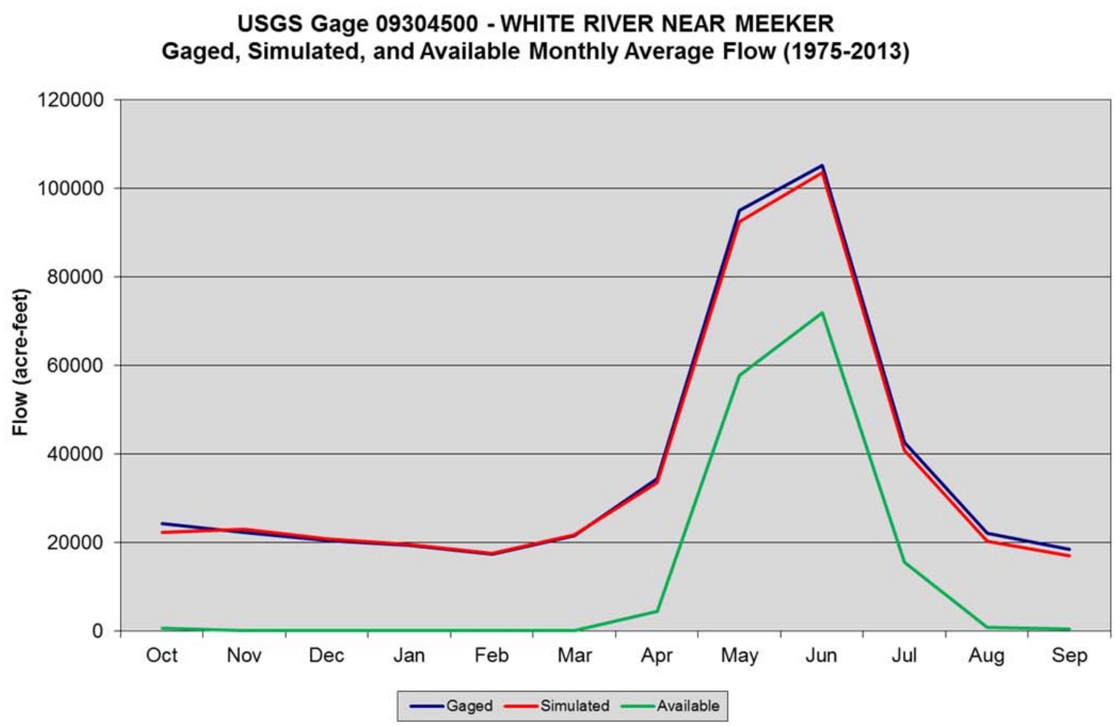
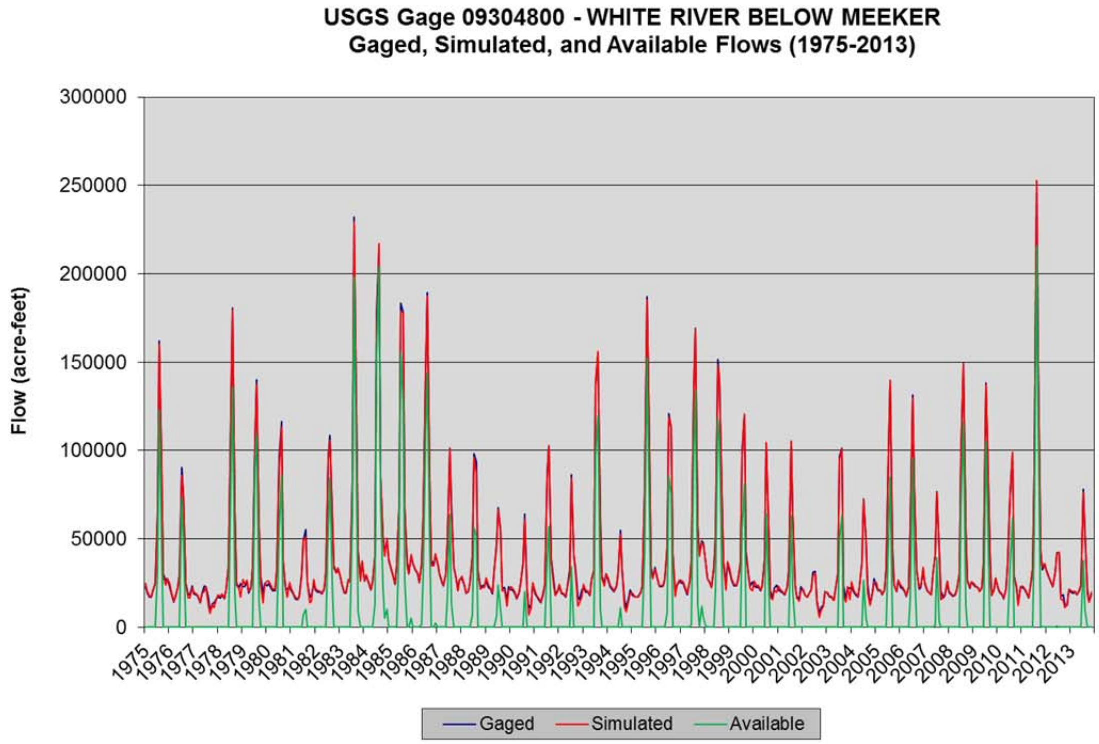


Figure 6.6 Gaged, Baseline Simulated, and Available Flows (USGS Gage 09304500 - White River near Meeker)



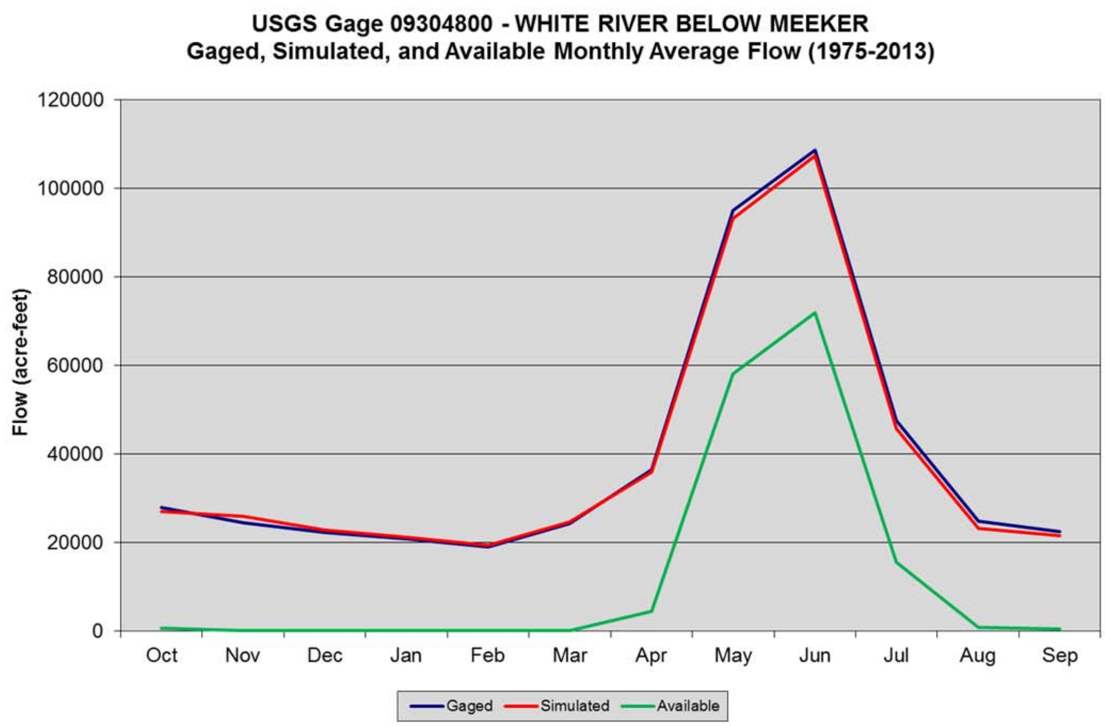
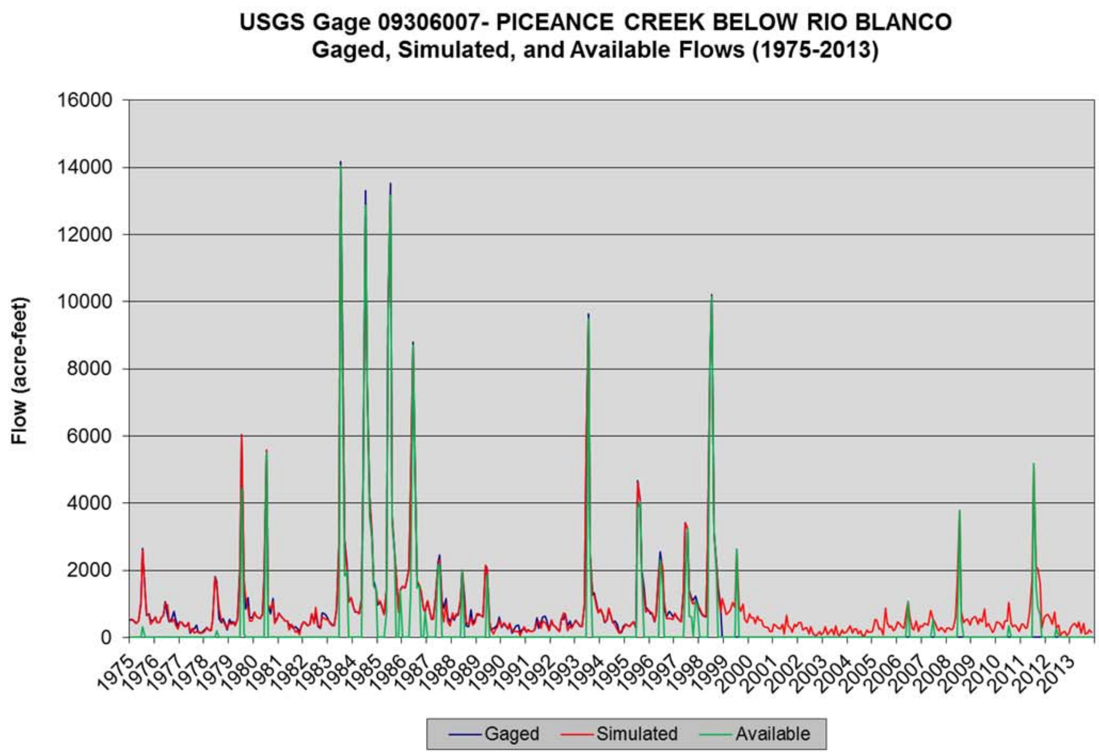


Figure 6.7 Gaged, Baseline Simulated, and Available Flows (USGS Gage 09304800 - White River below Meeker)



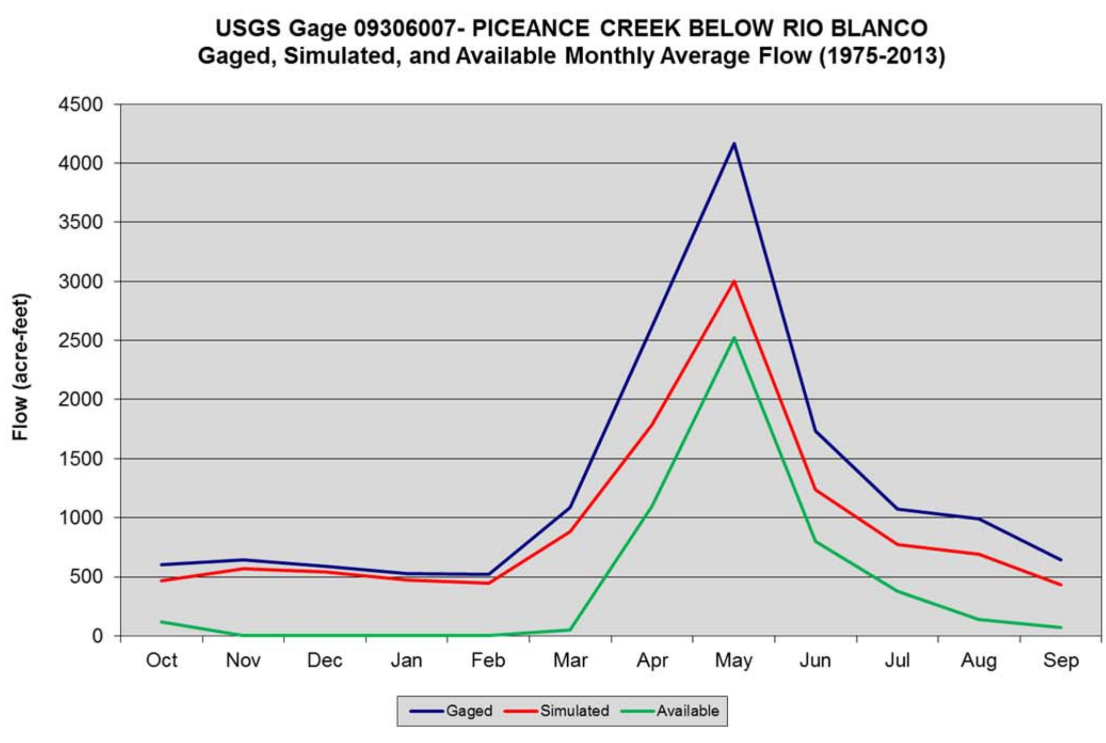
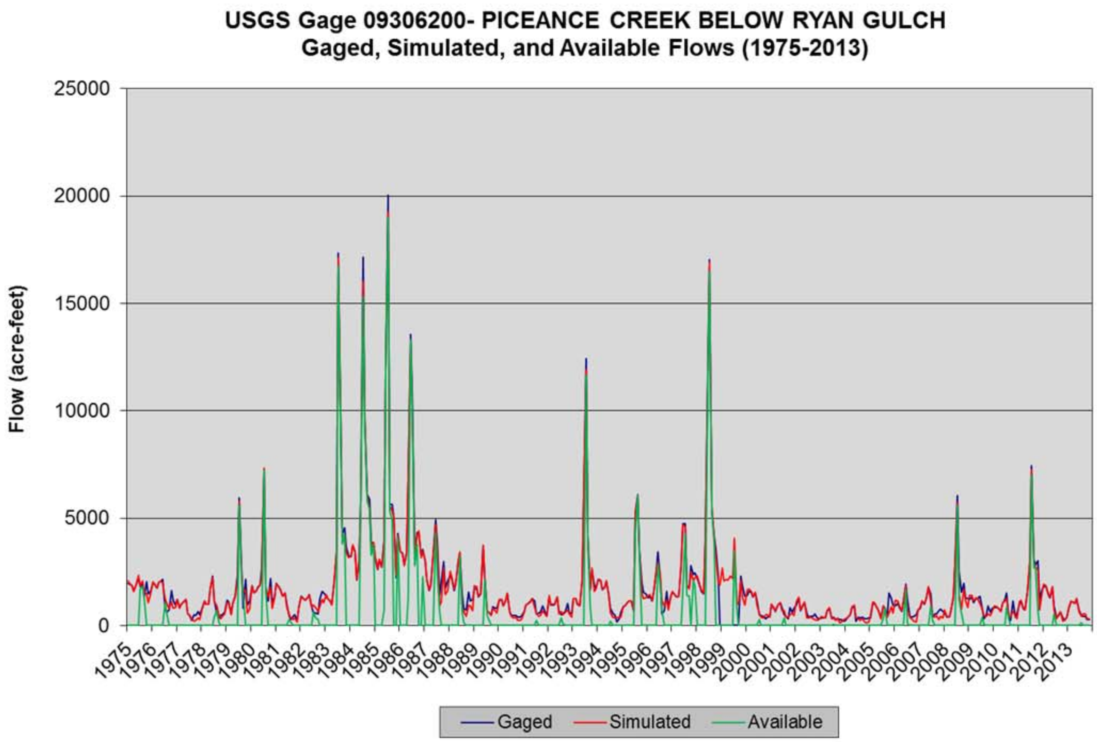


Figure 6.8 Gaged, Baseline Simulated, and Available Flows (USGS Gage 09306007 - Piceance Creek below Rio Blanco)



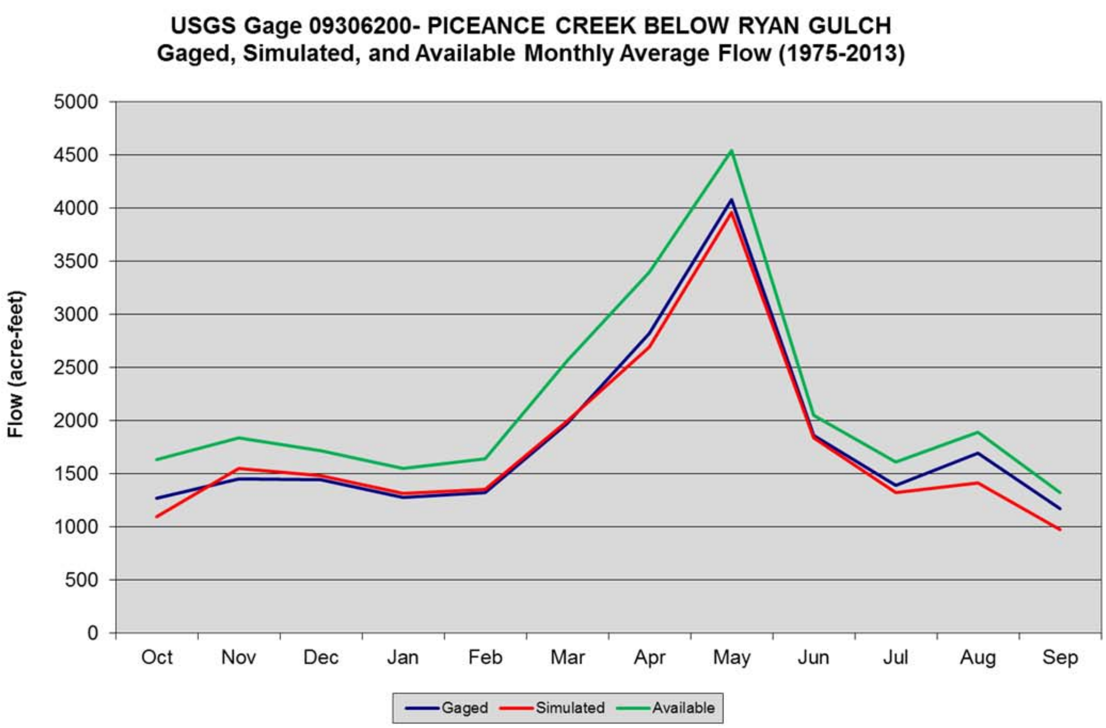
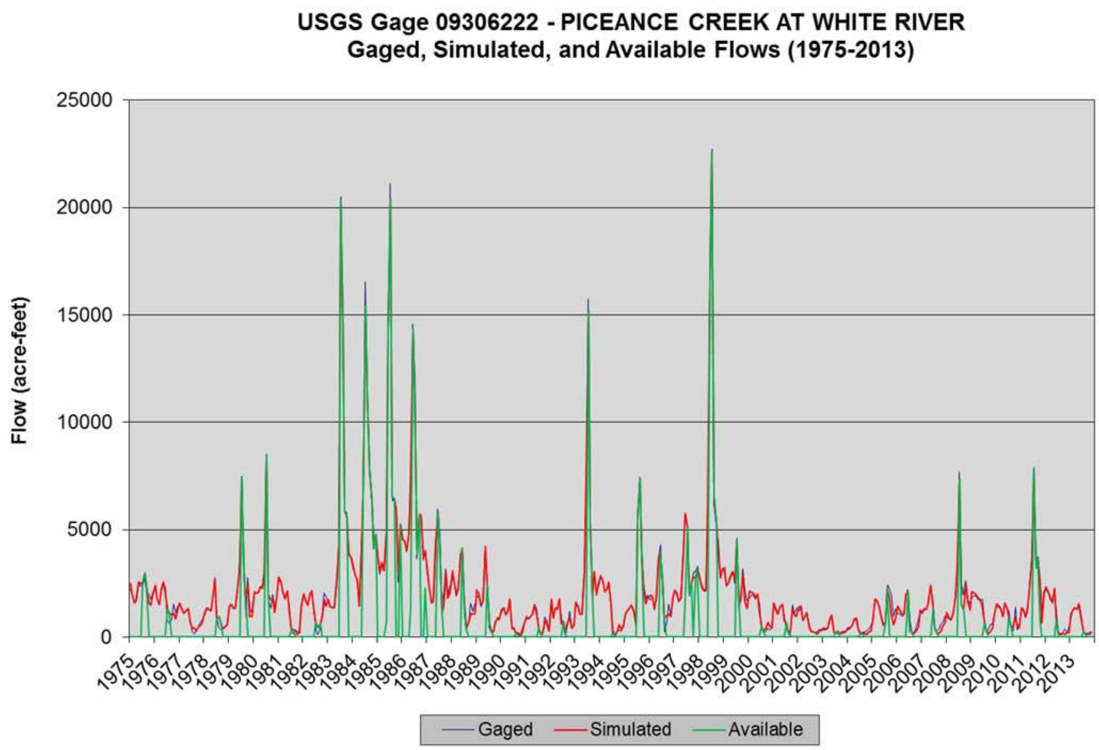


Figure 6.9 Gaged, Baseline Simulated, and Available Flows (USGS Gage 09306200 - Piceance Creek below Ryan Gulch)



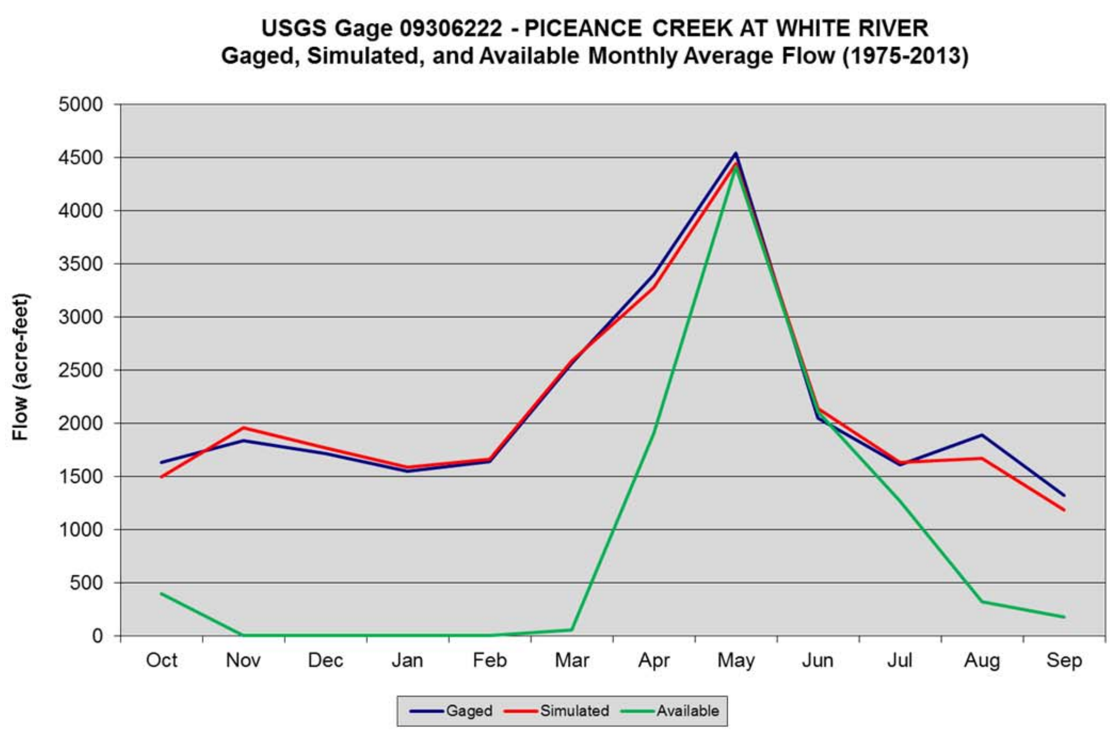
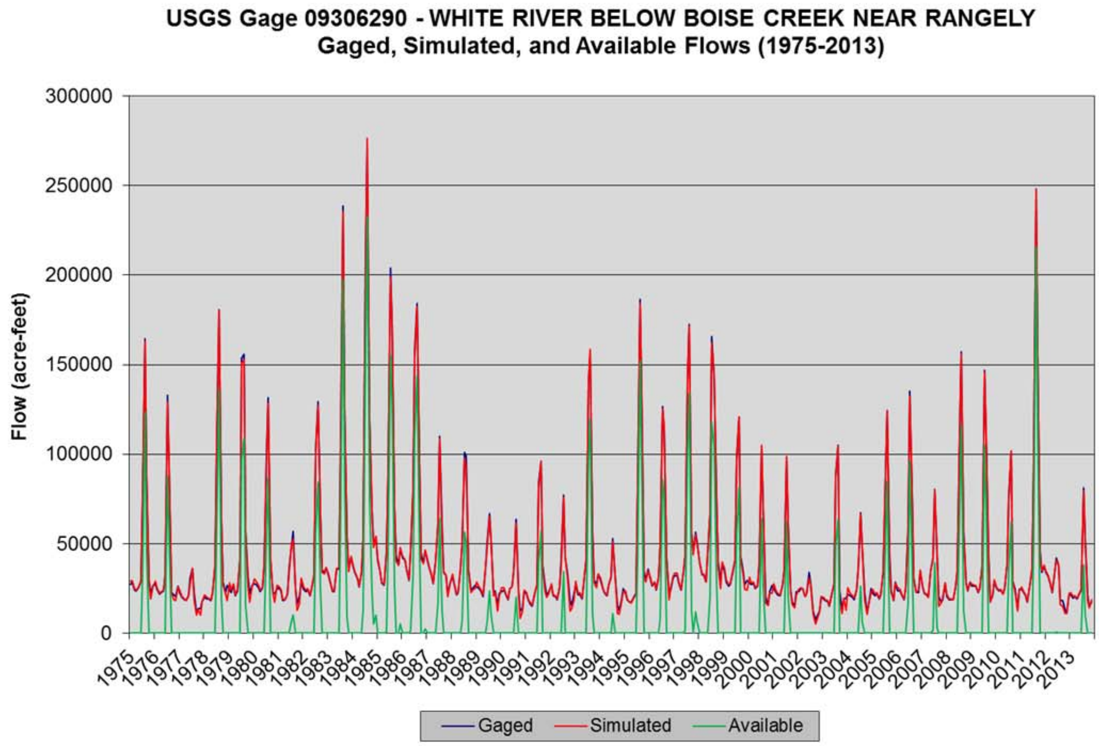


Figure 6.10 Gaged, Baseline Simulated, and Available Flows (USGS Gage 09306222 - Piceance Creek at White River)



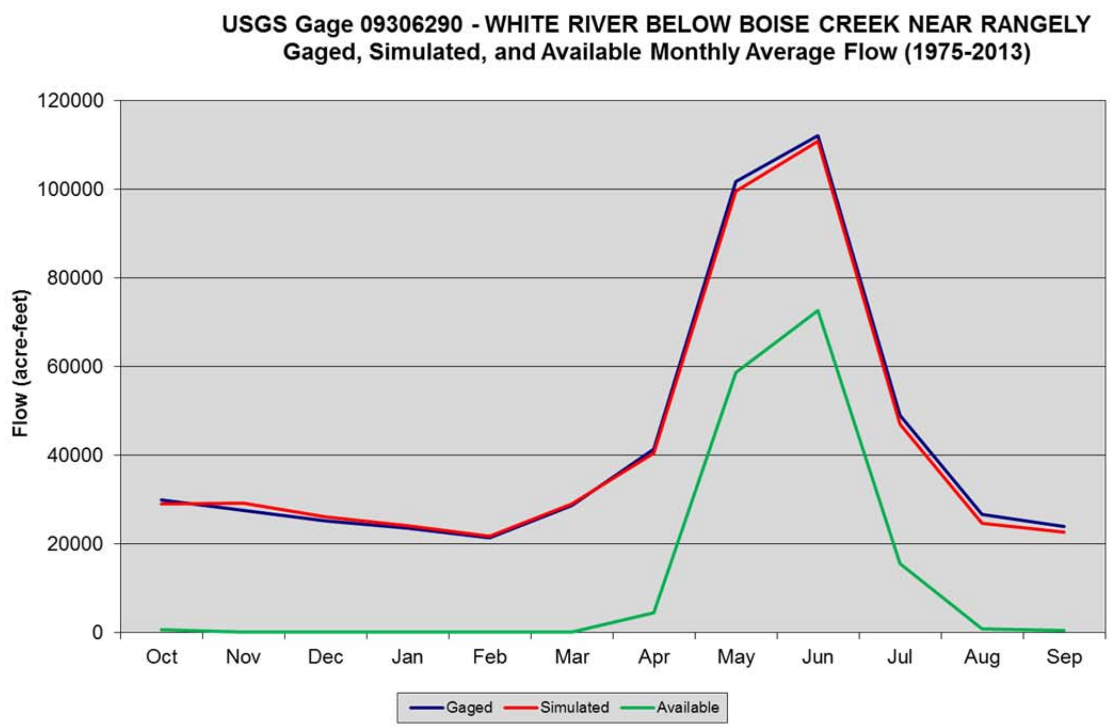


Figure 6.11 Gaged, Baseline Simulated, and Available Flows (USGS Gage 09306290 - White River below Boise Creek near Rangely)

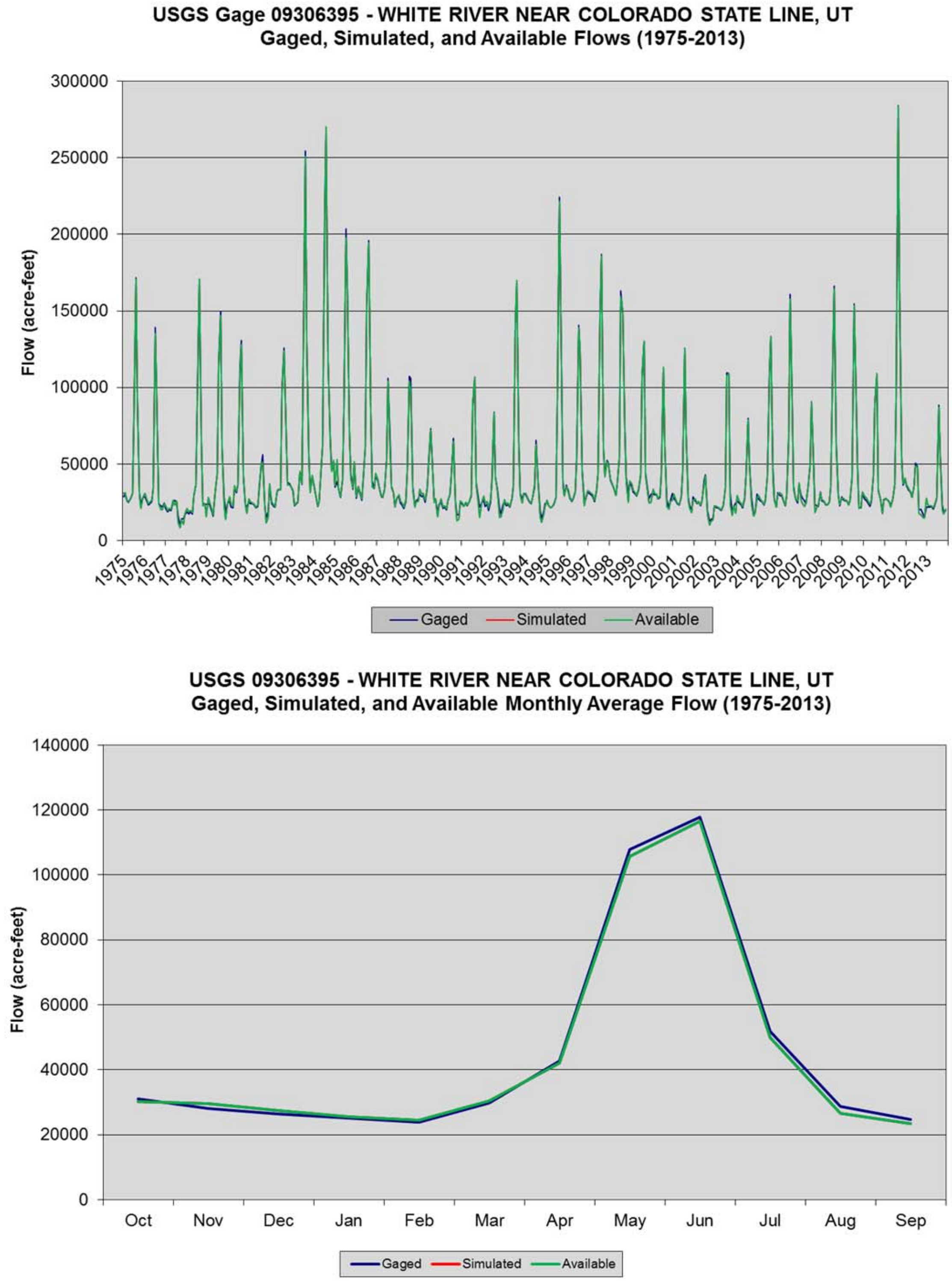


Figure 6.12 Gaged, Baseline Simulated, and Available Flows (USGS Gage 093063985 - White River near Colorado State Line, UT)

7. Calibration

Calibration is the process of executing the model under historical conditions, and modifying estimated parameters to improve agreement between the model results and the historical record. This section describes the general approach taken in calibrating the White River model. It describes specific areas of the basin that were worked on, and it presents summaries comparing modeled results for 1975 through 2013 with historical values for the period.

7.1 Calibration Process

The White River model was calibrated using the period 1975 through 2013. In the calibration data set (the Historical data set) demands were set to historical diversions, and reservoir levels were constrained to their historical levels. Reservoir storage was limited to the historical monthly content for each month. Reservoirs released water to the stream to achieve their historical end-of-month contents. The basic hydrology was assessed, and in general, baseflow distribution parameters and return flow characteristics were modified.

Reviewing the model run consisted of comparing simulated gage flows with historical flows, and determining where and why diversion shortages occur. For example, a shortage might occur because a user's water right is limiting. But it might also occur because water is physically unavailable or the water right is called out. In this typical calibration problem, there may be too little baseflow in a tributary reach to support historical levels of diversion in the model. Modeled gains may not occur in the system until the next downstream gage, bypassing the shorted structures. Because the historical diversion and consumption do not occur in the model, the model then overestimates flow at the downstream gage. Baseflow distribution parameters must be adjusted such that more water enters the system higher up, and typically, that type of change is accompanied by an offsetting reduction in incremental inflow lower in the system. Calibration might also expose errors such as incorrect placement of a gage or return flows.

7.2 Historical Data Set

Calibration is based on supplying input that represents historical conditions, so that resulting simulated gage and diversion values can be compared with the historical record. This data set is referred to as the "Historical data set", and it is helpful to understand how it differs from the Baseline data set described in Section 5.

7.2.1 Demand File

A primary difference in data sets is the representation of demands *(*.ddm* file). For calibration, both irrigation and non-irrigation demands were set to historical diversions, to the extent they were known. Gaps in the diversion records were filled using the automatic data filling algorithm described in Section 4.4.2. This demand reflects both limitations in the water supply and irrigation practices that cannot be predicted – headgate maintenance, dry-up periods, and so on.

7.2.2 Reservoir Station File and Reservoir Target File

In the Historical data set, reservoirs are inactive prior to onset of their historical operations. Initial contents in the reservoir file (*.res) are set to zero (as they were historically in 1909), and storage targets (*.tar file) are set to zero until the reservoir actually began to fill. Storage targets assume the value of the historical end-of-month contents.

7.2.3 Operational Rights File

Operational rights in the Historical simulation reflect the operations that were in place historically, and how they may have changed over time. In contrast, the Baseline operational rights file reflects our best estimate of how reservoirs and systems work now or in the near future. For instance, the Town of Meeker used one source of water through 2002, and a different source after 2002. Accordingly, the Historical operational rights file has two sets of rights governing the Town of Meeker, operating over the appropriate time periods. The Baseline operational rights file has only the post-2002 operational rights in it, and they are in force throughout the simulation.

Differences between the Baseline data set and the Historical data set are summarized in **Error! Reference source not found.**1.

Table 7.1 Comparison of Baseline and Historical (Calibration) Files

Input File	Baseline Data Set	Historical Data Set
Demand (*.ddm)	Irrigation structures – "Calculated" demand for full crop supply, based on historical efficiency Non-irrigation structures – estimated current demand	Historical diversions
Reservoir target (*.tar)	Current maximum capacity	Historical eom contents, 0 prior to historical operation
Operational right (*.opr)	Simulate current operations	Simulate historical operations

7.3 Calibration Issues

This section describes areas of the model that were investigated during calibration of the White River model.

7.3.1 Baseflow Calibration

Previous modeling efforts have focused on increasing baseflow at headwater tributaries and distributing enough water to mainstem baseflow nodes that shortages in historical diversions are minimized. This approach can result in StateMod oversimulating the gains between observed streamflow gages. StateMod compensates for excess water in the river by calculating a negative gain term. It is understood that the White River is a naturally gaining river and baseflow should increase from upstream to downstream. To address losing reaches, significant effort was spent on baseflows during calibration.

Reaches where the estimated combined upstream baseflow was larger than the downstream flow were identified and efforts made to improve the baseflow calibration. This included examining filled end-of-month reservoir contents and diversion records, and adjusting return flow locations. In previous modeling efforts, the approach was to include all available USGS streamgages were included in the model regardless of their measurement period. This was shown to cause problems in the baseflow filling algorithm when the streamgage had a short period of record that did not represent dry, average, and wet conditions. For the current effort, streamgages with limited period of records were removed when the filling techniques introduced either a positive or negative flow bias to the model.

7.3.2 Neighboring Gage Methodology for Selected Ungaged Tributaries

Some tributaries were in gage reaches that exhibited baseflow losses from time to time. In these months for these reaches, baseflows are positive at both the upstream gage(s) and the downstream gage, but the downstream baseflow is smaller than the upstream baseflow. Here the "neighboring gage" approach was used, in which baseflow for the ungaged tributary is estimated as a proportion of baseflow at a nearby gaged tributary, to alleviate shortages. The basis of the proportion is the Area*Precipitation term for each gage. The tributaries listed in Table 7.2 show where the "neighboring gage" methodology for baseflow estimation was implemented.

Table 7.2 Baseflow Nodes that Implement Neighboring Gage Methodology

Baseflow Node	Tributary	Neighboring Station	Proration Fraction
4300813	Flag Creek	Piceance Creek Below Rio Blanco (09306007)	0.284
4300578_D	Coal Creek	South Fork White River At Buford (09304000)	0.144
43_ADW015	Evacuation Creek	Piceance Creek Below Rio Blanco (09306007)	0.516

7.3.3 Baseflow Factor Adjustments

In the previous model updated, baseflow distribution factors were manipulated directly to reduce total shortages. The methodology attempted to redistribute baseflow, moving more baseflows to tributaries in the reach that presented the largest shortages in the basin. Selection of the factor took into consideration minimizing negative gains at the downstream baseflow nodes. However, the commands in StateDMI that implement this method are intended to distribute total flows, not gains. Therefore, the Area*Precipitation input to the network file was updated directly to maintain the calibration, but use the gains approach.

Additionally, aggregate nodes located immediately upstream of gages were assigned area and precipitation such that they received all remaining gains in the reach (baseflow factor = 1).

7.3.4 Other Calibration Issues

Piceance Creek basin, the upper part of the basin in particular, exhibited shortages in the calibrated model. Some of the difficulty in simulating this part of the basin may be because a section of the creek, indicated in Error! Reference source not found., regularly dries up in midsummer. When this condition occurs, the Division Engineer recognizes that a call would be futile, and does not administer. StateMod does not simulate a completely dry reach, and will permit a downstream senior below the dry reach to call out an upstream junior located above the dry reach. Additionally, the observed period of record for the creek is relatively short. This means that a significant percentage of baseflows are estimated by the Mixed Station Model, which introduces uncertainty.

The average baseflow "gain" in the reach between gage 09304500 White River near Meeker and 09304800 White River below Meeker is negative, due to several months exhibiting significant negative baseflow gains (that is, losses) on the order of 30,000 and 40,000 af. For instance, the baseflow loss for May 1979 is over 44,000 af, and for May 1976, approximately 33,000 af. Review of the baseflow computation for the gage sites shows that diversions of record for this reach are significantly less than 20 percent difference in historically gaged flow at the upstream and downstream gages; even if there were no return flows to this stream segment, the loss in gaged flow cannot be accounted for by the historical diversions. This suggests there may be error in either the gage record or diversion records in certain months. The Division 6 office has been notified of the discrepancy in the two months noted above.

Baseflow losses occur consistently in the reach between gage 09306224 White River above Crooked Wash near White River City and gage 09306290 White River below Boise Creek near Rangely. These two gages began operation in 1983, and the upstream gage was discontinued after Water Year 1989. Gage 09306224 was removed from the model, reducing the amount of negative gains but not totally eliminating them. There are still negative gains between downstream gage 09306290 White River below Boise Creek near Rangely and upstream gages 09306222 Piceance Creek at White River and 09304800 White River below Meeker.

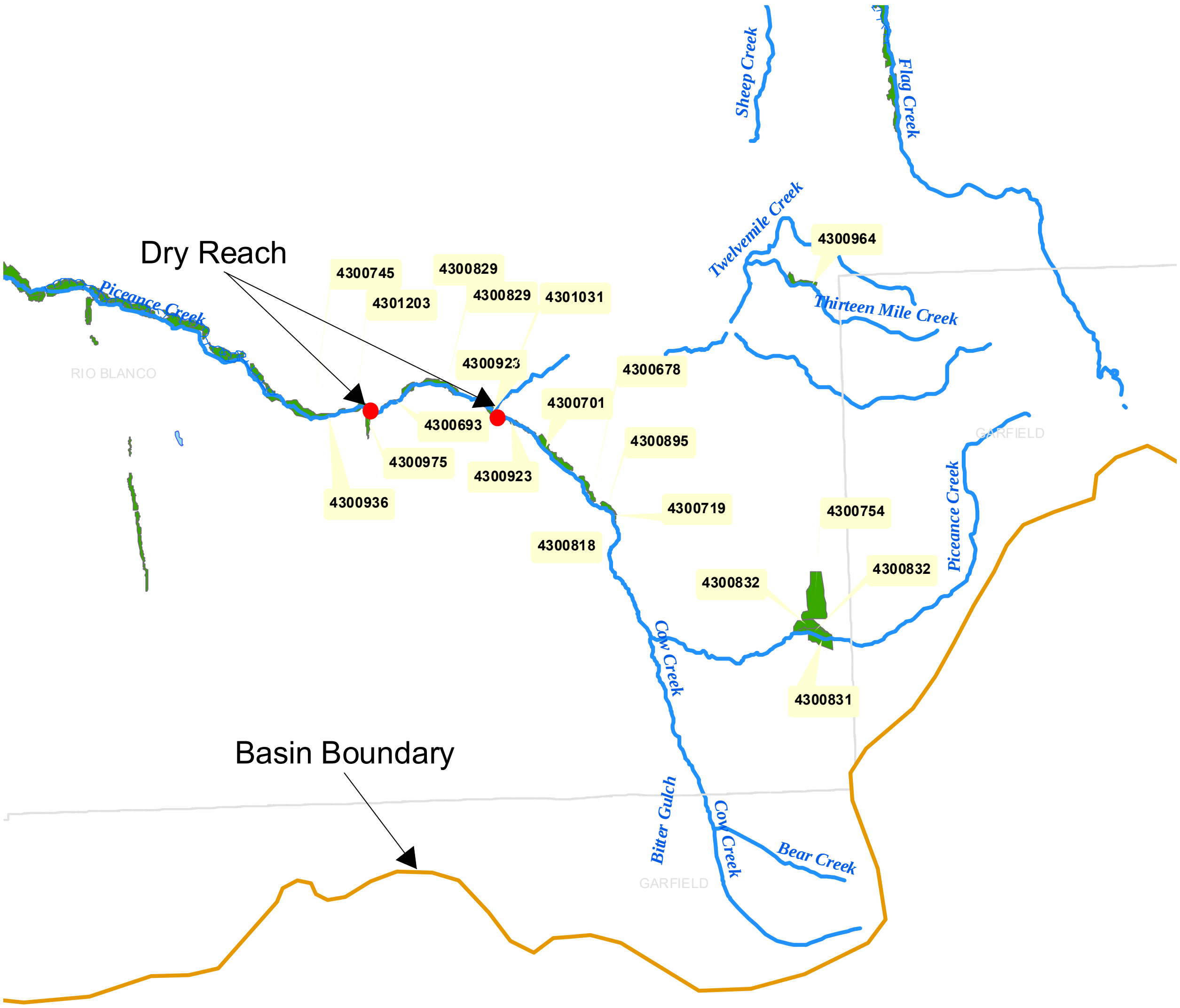


Figure 7.1 Futile Call Reach in the Upper Piceance Creek

Calibration of the White River model is considered very good, with all but one streamflow gage deviating less than one percent from historical values on an average annual basis. Approximately seventy percent of the diversion structures' shortages are at or below 1 percent on an annual basis, and the basin-wide shortage is about 1 percent per year, on average. Simulated reservoir contents are representative of historical values.

7.3.5 Water Balance

Table 7.3 summarizes the water balance for the White River model, for the calibration period (1975-2013. Following are observations based on the summary table:

- Surface water inflow to the basin averages 598,469 acre-feet per year, and surface water outflow averages 543,938 acre-feet per year.
- Annual diversions amount to approximately 297,117 acre-feet on average.

- Approximately 46,892 acre-feet per year are consumed.

- The column labeled "Inflow – Outflow" represents the net result of gain (inflow, return flows, and negative change in reservoir and soil moisture contents) less outflow terms (diversions, outflow, evaporation, and positive changes in storage). The small values are due to rounding on a monthly basis and indicate that the model correctly conserves mass.

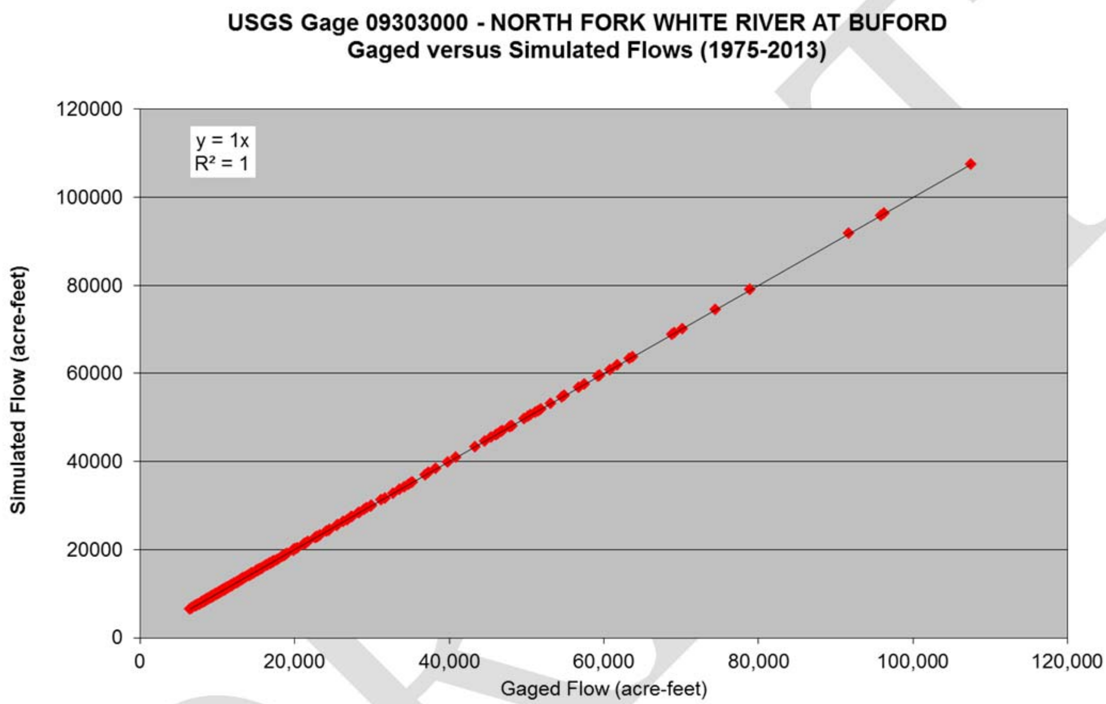
Table 7.3 Average Annual Water Balance for Calibrated White River Model (1975-2013) (af/yr)

Month	Inflow	Return	From Soil Moisture	Total Inflow	Diversions	Res Evap	Stream Outflow	Resvr Change	To Soil Moisture	Soil Moisture Change	Total Outflow	Inflow - Outflow	CU
OCT	OCT	29,725	21,336	224	51,285	19,532	162	31,020	346	235	-10	51,285	0
NOV	NOV	23,049	8,269	0	31,318	3,106	50	28,117	45	63	-63	31,318	0
DEC	DEC	23,615	5,246	0	28,862	2,109	-36	26,424	364	18	-18	28,862	0
JAN	JAN	23,033	4,170	0	27,203	2,050	-43	25,201	-5	10	-10	27,203	0
FEB	FEB	22,752	3,303	0	26,055	1,886	25	24,134	9	6	-6	26,055	0
MAR	MAR	29,834	2,868	1	32,703	2,283	114	30,353	-49	44	-42	32,703	0
APR	APR	45,807	5,874	287	51,968	7,482	203	43,896	100	377	-89	51,968	0
MAY	MAY	123,380	26,919	551	150,849	40,124	381	109,817	-23	860	-309	150,849	0
JUN	JUN	141,773	52,048	349	194,170	74,603	521	118,765	-68	828	-479	194,170	0
JUL	JUL	68,069	46,502	604	115,175	61,905	519	52,357	-210	206	399	115,175	0
AUG	AUG	37,958	36,831	665	75,454	45,516	340	28,918	15	238	428	75,454	0
SEP	SEP	29,475	32,121	433	62,028	36,522	302	24,935	-164	257	176	62,028	0
TOTAL	**598,469**	**245,485**	**3,115**	**847,069**	**297,117**	**2,540**	**543,938**	**359**	**3140**	**-24**	**847,069**	**0**	**46,892**

Note: Consumptive Use (CU) = Diversion (Divert) * Efficiency + Reservoir Evaporation (Evap)

7.3.6 Streamflow Calibration Results

Table 7.4 summarizes the annual average streamflow for water years 1975 through 2013, as estimated in the calibration run. It also shows average annual values of actual gage records for comparison. Both numbers are based only on years for which gage data are complete. Differences between gaged and simulated average annual streamflows are less than 1 percent for all stations, with the exception of Piceance Creek below Ryan Gulch.



through Error! Reference source not found. (at the end of this section) graphically present monthly streamflow estimated by the model compared to historical observations at key stream gages. The goodness of fit is indicated on the scatter plot by the equation for the "best fit" regression line relating simulated to gage values. A perfect fit would be indicated by an equation y = 1.000x.

Table 7.4 Historical and Simulated Average Annual Streamflow Volumes (1975-2013) Calibration Run (acre-feet/year)

Gage ID	Historical	Simulated	Historical minus Simulated		Gage Name
			Volume	Percent	
09303000	232,871	232,871	-1	0%	North Fork White River at Buford
09303400	143,418	143,418	0	0%	South Fork White River near Budges Resort,

					CO.
09303500	189,846	189,846	0	0%	South Fork White River Near Buford, CO.
09304000	185,578	185,578	0	0%	South Fork White River at Buford
09304200	398,667	398,658	8	0%	White River above Coal Creek
09304500	442,773	442,764	9	0%	White River near Meeker
09304800	473,551	473,544	7	0%	White River below Meeker
09306007	15,238	15,223	16	0%	Piceance Creek below Rio Blanco
09306200	21,727	22,609	-882	-4%	Piceance Creek below Ryan Gulch
09306222	25,762	25,650	112	0%	Piceance Creek at White River
09306290	510,886	510,845	41	0%	White River below Boise Creek near Rangely
09306395	537,572	537,496	76	0%	White River near Colorado State Line, UT

7.3.7 Diversion Calibration Results

Table 7.5 summarizes the average annual shortage for water years 1975 through 2013, for each ditch. Estimated diversions are generally within a few percent of recorded diversions or represent a relatively small volume of water. The greatest concentration of shortages is on Piceance Creek, as noted above under “Other Calibration Issues”. Other small tributaries have many of the ditches with shortages. This is to be expected given the difficulty of accurately estimating baseflow in ungaged basins.

On a basin-wide basis, average annual diversions differ from historical diversions by 1 percent in the calibration run.

Table 7.5 Historical and Simulated Average Annual Diversions by Sub-basin 1975-2013 (acre-feet/year)

Tributary or Sub-basin	Historical	Simulated	Historical minus Simulated	
			Volume	Percent
North Fork White River	24,929	23,476	1,452	5.8%
South Fork White River	18,798	18,416	382	2.0%
White River above Piceance Creek	197,708	196,588	1,120	0.6%
Piceance Creek	28,069	27,119	950	3.4%
White River below Piceance Creek	33,184	32,947	237	0.7%

Table 7.6 Historical and Simulated Average Annual Diversions 1975-2013 (acre-feet/year)

WDID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
4300511	1,489	1,421	68	5	B A & B DITCH NO 1
4300513	994	986	7	1	B M & H DITCH 1
4300526	1,251	1,238	12	1	BARBOUR NORTH SIDE D
4300527_D	8,740	7,607	1,133	15	Barbour S Side Ditch Div
4300537_D	3,310	3,009	301	10	Beckman Ditch DivSys
4300539	1,019	938	81	9	BIG BEAVER DITCH
4300544	122	121	1	0	BLACK EAGLE D NO 2
4300546	1,333	1,333	0	0	BLAIR DITCH
4300554	543	487	57	12	BRUCE BAKER DITCH
4300563	170	170	0	0	CALHOUN DITCH
4300564	2,240	2,200	40	2	CALIFORNIA CO WATER PL
4300565	704	702	2	0	CAMPBELL CREEK DITCH
4300570	581	581	0	0	CALVAT DITCH
4300572	1,774	1,773	1	0	CHARLIE SMITH DITCH
4300573	783	697	86	12	CHASE & COLTHARP D
4300575	889	889	0	0	CLOHERTY DITCH
4300577	494	494	0	0	COAL CREEK FEEDER DITCH
4300578_D	3,811	3,811	0	0	Coal Creek Mesa Ditch Di
4300605	320	320	0	0	DORRELL DITCH 2
4300607	1,819	1,819	0	0	DREIFUSS DITCH
4300608	1,618	1,460	159	11	DREYFUSS DITCH
4300623	1,780	1,622	158	10	ELK CREEK DITCH
4300625	817	781	36	5	EMILY DITCH
4300640	844	844	0	0	FORNEY CORCORAN DITCH
4300652	1,137	1,058	79	7	G V DITCH
4300653	1,180	1,180	0	0	GEORGE S WITTER DITCH
4300665	1,053	1,050	3	0	GREENSTREET DITCH EXT
4300678	60	55	5	8	HANRAHAN DITCH NO 1
4300681	4,510	4,510	0	0	HAY BRETHERTON DITCH
4300684	599	599	0	0	HAY DITCH 2
4300687	1,058	1,058	0	0	HEFLEY PUMP PLANT NO 1
4300688	1,055	1,055	0	0	HEFLEY PUMP PLANT NO 2
4300693	208	164	44	27	HERWICK DITCH 1
4300694_D	38,221	38,221	0	0	Thomas Ditch 2 DivSys

WDID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
4300695	590	555	35	6	HILL CREEK NO 3 DITCH
4300696	1,567	1,535	32	2	HILL CREEK NO 2 DITCH
4300701	620	586	33	6	HOME DITCH
4300710	2,243	2,243	0	0	IMES & REYNOLDS DITCH
4300711	491	491	0	0	INDEPENDENT DITCH
4300714	230	230	0	0	IVO E SHULTS D & PUMP
4300718	1,016	1,016	0	0	JAMES HAYES DITCH
4300719	44	42	2	5	JANES DITCH
4300729	559	521	38	7	JOHNSON DITCH
4300753	212	171	41	24	LAKE CREEK POOL DITCH
4300754	102	102	0	0	LARSON DITCH
4300758	537	534	2	0	LAWRENCE DITCH NO 1
4300762	355	353	2	1	LEWIS DITCH
4300769	1,683	1,683	0	0	LITTLE DITCH
4300777	1,651	1,623	28	2	LOWLAND DITCH
4300782	927	919	8	1	M H M GERMAN CONS D
4300784	392	392	0	0	M SCHNEIDER DITCH
4300788	3,887	3,878	9	0	MARCOTT DITCH
4300789	1,086	1,086	0	0	MARTIN DITCH
4300790	1,180	1,180	0	0	MARVINE DITCH 1
4300791	647	644	3	0	MARVINE NO 3 DITCH
4300808	4,340	4,339	1	0	MEEKER DITCH
4300809	205	205	0	0	MEEKER POWER DITCH
4300810	560	560	0	0	MEEKER WATER SYS
4300813	424	424	0	0	MELVIN DITCH
4300815_D	1,114	1,113	1	0	Metz & Reigan Ditch DivS
4300816	815	805	9	1	METZ DITCH
4300818	54	50	3	6	MIKKELSON DITCH
4300819_D	27,852	27,842	10	0	Miller Creek Ditch DivSy
4300823	452	452	0	0	MINER MARTIN DITCH
4300825	120	120	0	0	MISSOURI BOTTOM DITCH
4300828	1,086	1,086	0	0	MOONEY DITCH
4300831	70	65	5	8	MORGAN DITCH 2
4300832	118	117	0	0	MORGAN DITCH 1

WDID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
4300841	902	902	0	0	NEW ARCHER WARNER DITCH
4300842	14,016	14,014	2	0	NIBLOCK DITCH
4300848	23,418	23,418	0	0	OAK RIDGE PARK DITCH
4300849	7,884	7,833	51	1	OLD AGENCY DITCH
4300850	898	856	43	5	OLDLAND DITCH 1
4300851	553	449	103	23	OLDLAND DITCH 2
4300862	493	493	0	0	PATTISON DITCH NO 1
4300867	4,183	4,183	0	0	PEASE DITCH
4300868	2,494	2,494	0	0	PEDRICK DITCH
4300873	794	741	53	7	PICEANCE CREEK DITCH
4300881	1,495	1,282	213	17	POTHOLE DITCH
4300883	14,767	14,767	0	0	POWELL PARK DITCH
4300889	1,290	1,290	0	0	RANGELY WATER
4300895	78	71	6	9	REDDIN DITCH
4300903	1,113	1,056	57	5	ROBERT MCKEE DITCH
4300908	339	338	2	1	RYAN DITCH
4300909	750	682	68	10	RYE GRASS DITCH
4300919	228	228	0	0	SAYER DITCH
4300923	591	523	68	13	SCHUTTE DITCH
4300926	730	726	3	0	SHERIDAN & MORTON D
4300928	822	820	1	0	SIMPSON DITCH
4300929	341	265	76	29	SIZEMORE DITCH 1
4300931	1,024	1,024	0	0	SKELTON DITCH
4300934	339	289	50	17	SOLDIER CREEK DITCH
4300935	7,183	7,183	0	0	SOUTH SIDE HIGHLINE D
4300936	309	288	21	7	SPAULDING D
4300939	191	191	0	0	SPRING CREEK D PUMP 1
4300940	224	224	0	0	SPRING CREEK D PUMP STA
4300941	128	128	0	0	SPRING CREEK D PUMP 2
4300944	750	608	142	23	SPROD DITCH 1
4300948	1,785	1,785	0	0	SQUARE S CONS D SYS
4300949	524	524	0	0	STADTMAN DITCH
4300954	438	438	0	0	STOREY DITCH 1
4300961	2,613	2,613	0	0	SWEEDE DITCH

WDID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
4300965	246	246	0	0	THOMAS DITCH
4300966	267	267	0	0	THOMAS DITCH 2
4300975	37	37	0	1	UPPER DITCH
4300980	1,876	1,868	9	0	UTE CREEK DITCH
4301004	1,318	1,315	3	0	WHEELER DITCH
4301010	458	458	0	0	WHITE RIVER MESA DITCH
4301027	994	938	56	6	BELOT MOFFAT DITCH
4301031	130	117	13	11	GORDON DITCH
4301033	530	530	0	0	LAWRENCE DITCH
4301047	234	202	32	16	LAGRANGE DITCH 1
4301108	215	215	0	0	JACOBS PUMP & PL
4301257	143	143	0	0	ROBINSON WARDELL PUMP 6
4301262	414	414	0	0	ROBINSON WARDELL PUMP 15
4301272	893	893	0	0	COX PUMP NO 1
4301273	572	571	1	0	REIGAN PUMP NO 1
4301855	1,171	1,024	148	14	MCDOWELL NO 2 DITCH
4302099	871	871	0	0	KENNEY PUMP NO 1
4303633_F	0	0	0	0	Div_WhiteRiv_Avery
4303633_O	0	0	0	0	Lake Avery Enl Oil Shale
4304313_O	0	0	0	0	WCkResPipe_ToOilShale
4306045	98	98	0	0	MEEKER WELLS
43_ADW001	4,106	4,106	0	0	Diversion Aggregate
43_ADW002	2,652	2,652	0	0	Diversion Aggregate
43_ADW003	5,907	5,907	0	0	Diversion Aggregate
43_ADW004	2,601	2,601	0	0	Diversion Aggregate
43_ADW005	2,757	2,757	0	0	Diversion Aggregate
43_ADW006	434	434	0	0	Diversion Aggregate
43_ADW007	1,514	1,490	24	2	Diversion Aggregate
43_ADW008	1,065	1,029	36	4	Diversion Aggregate
43_ADW009	4,259	4,232	26	1	Diversion Aggregate
43_ADW010	6,111	5,895	216	4	Diversion Aggregate
43_ADW012	2,566	2,566	0	0	Diversion Aggregate
43_ADW013	5,825	5,825	0	0	Diversion Aggregate
43_ADW014	4,215	4,215	0	0	Diversion Aggregate

WDID	Historical	Simulated	Historical minus Simulated		Structure Name
			Volume	Percent	
43_ADW015	942	925	16	2	Diversion Aggregate
43_ADW016	7,231	7,231	0	0	Diversion Aggregate
43_AMW001	1,104	1,104	0	0	WHIT_AMW AggMuni&Ind
43_OilDem	0	0	0	0	Oil Shale Direct Right
FUD001	0	0	0	0	Future development on Piceance
FUD002	0	0	0	0	Future development on Piceance
Total*	301,198	297,118	4,081	1.4	

*The Total excludes historical diversions from Taylor Draw Power Plant.

7.3.8 Reservoir Calibration Results

Error! Reference source not found. and Error! Reference source not found. (located at the end of this chapter) present reservoir EOM contents estimated by the model compared to historical observations at selected reservoirs. The following can be observed:

- Big Beaver Creek (aka Lake Avery) Reservoir: most discrepancies between historical and simulated values occur because the historical observation exceeds the reported active storage capacity. It appears that freeboard storage may have been used occasionally, at least until the early 1990s, and the model does not replicate that operation.

- Taylor Draw Reservoir follows closely the estimated historical end-of-month content during the calibration. Small discrepancies in storage, caused by the reservoir evaporation computation, are observed.

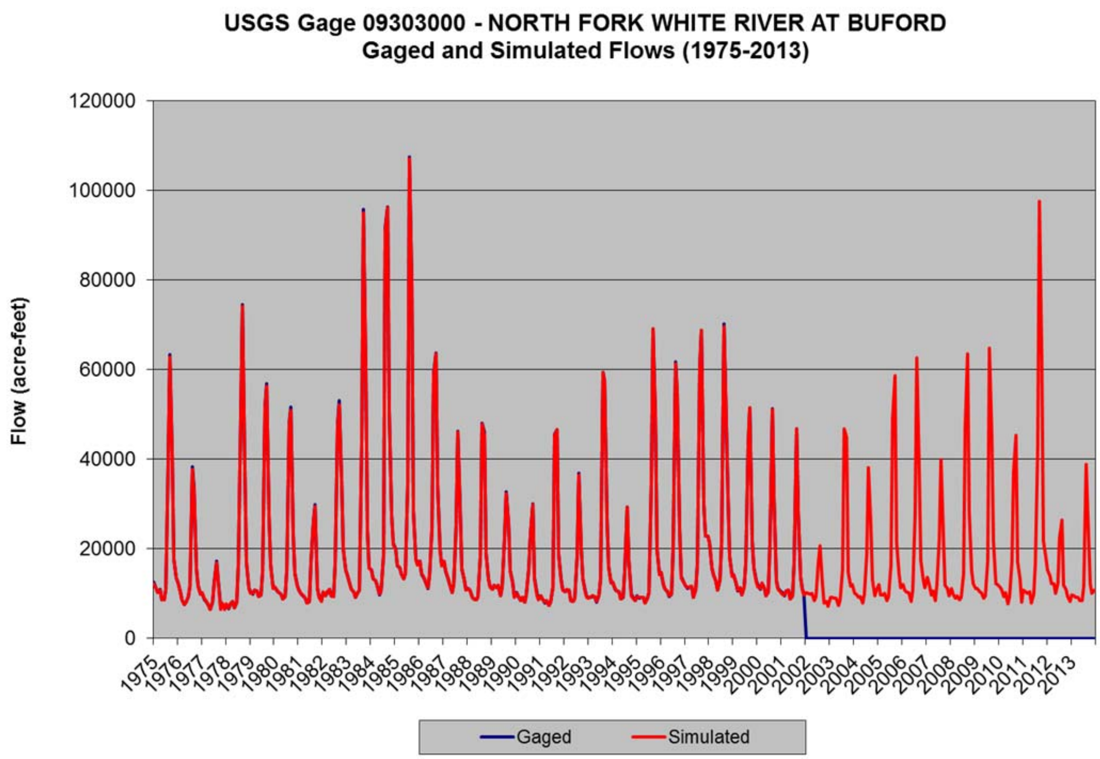
7.3.9 Irrigation Consumptive Use Calibration Results

Table 7.7 compares StateCU estimated crop consumptive use with StateMod estimated crop consumptive use for explicit structures, aggregate structures, and basin total. Note that only crop consumptive use is shown: consumptive use attributable to municipal, industrial, or transbasin diversions is not included. As shown, both explicit and aggregate structure consumptive use are less than StateCU results.

Table 7.7 Average Annual Crop Consumptive Use Comparison (1975-2013)

Comparison	StateCU Results (af/yr)	Calibration Run Results (af/yr)	% Difference
Explicit Structures	29,910	29,601	1%
Aggregate Structures	10,832	10,767	1%

Basin Total	40,742	40,368	1%



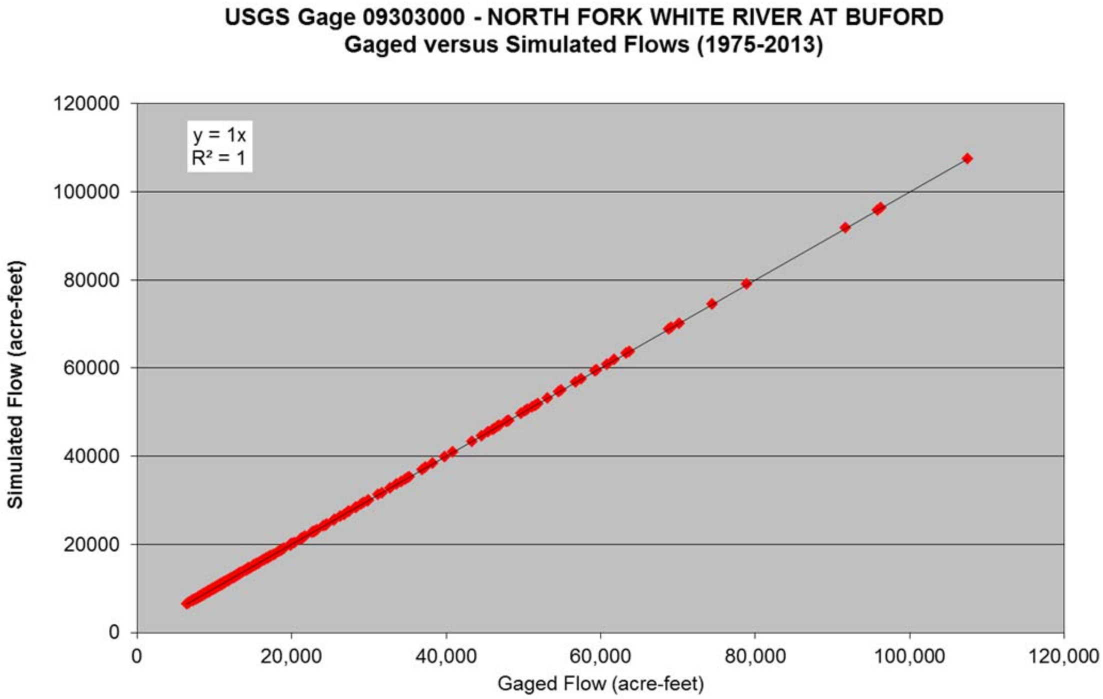


Figure 7.2 Stream Flow Calibration - North Fork White River at Buford

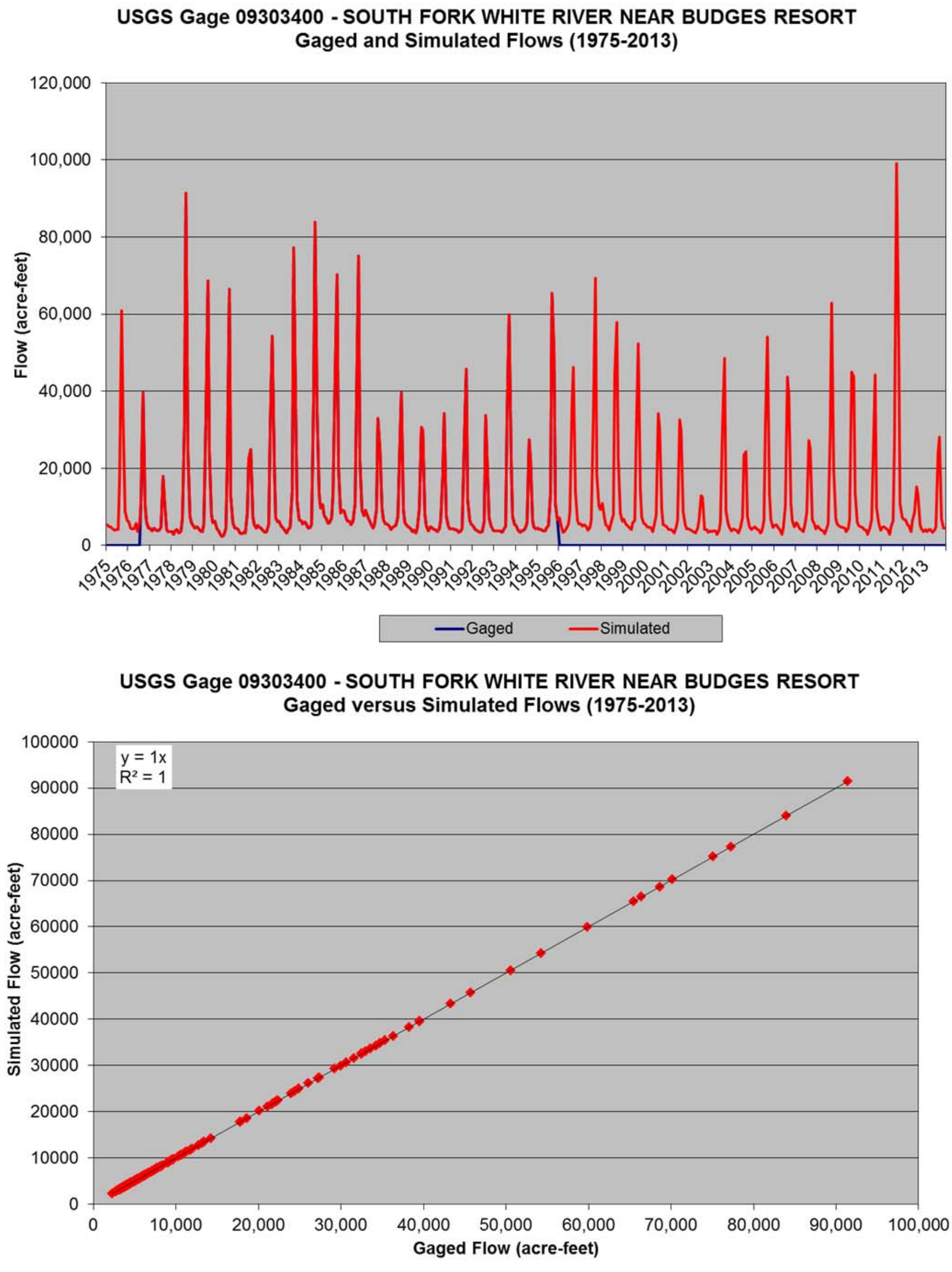
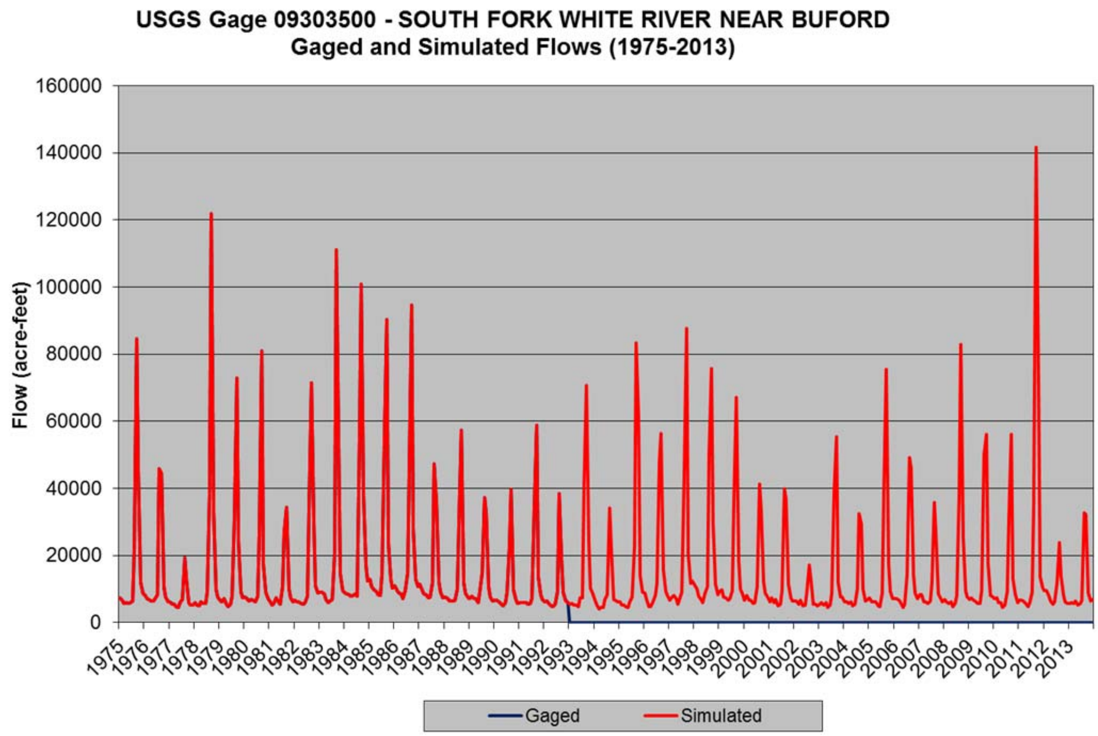


Figure 7.3 Stream Flow Calibration – South Fork White River near Budges Resort



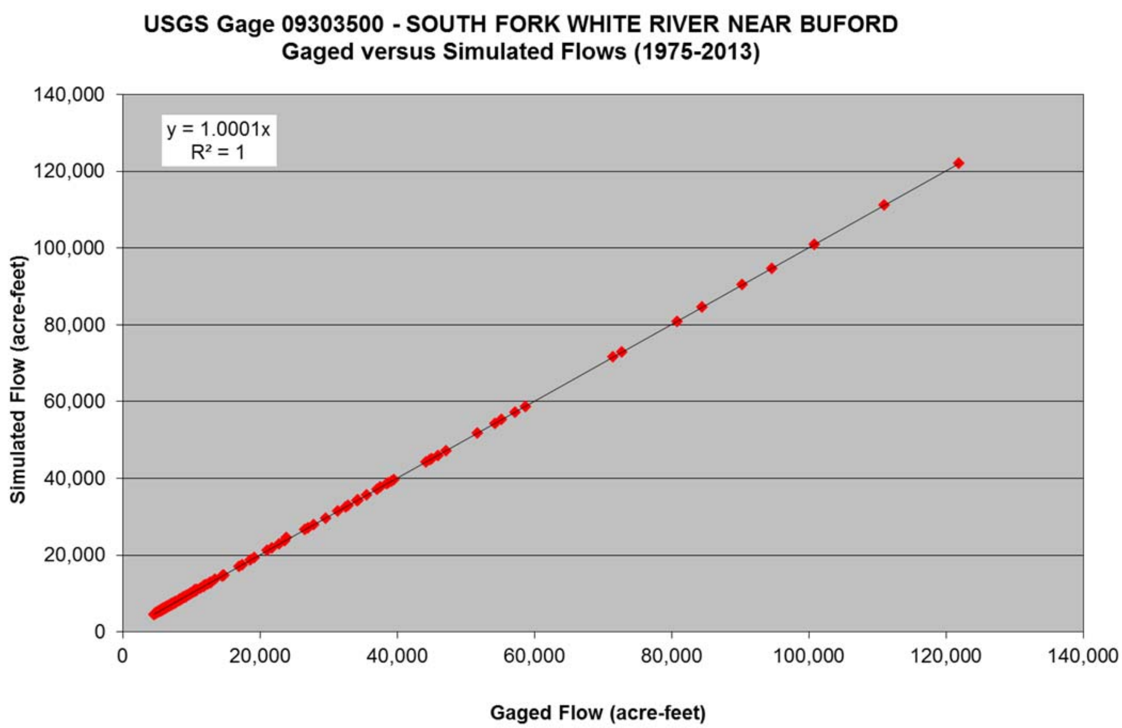
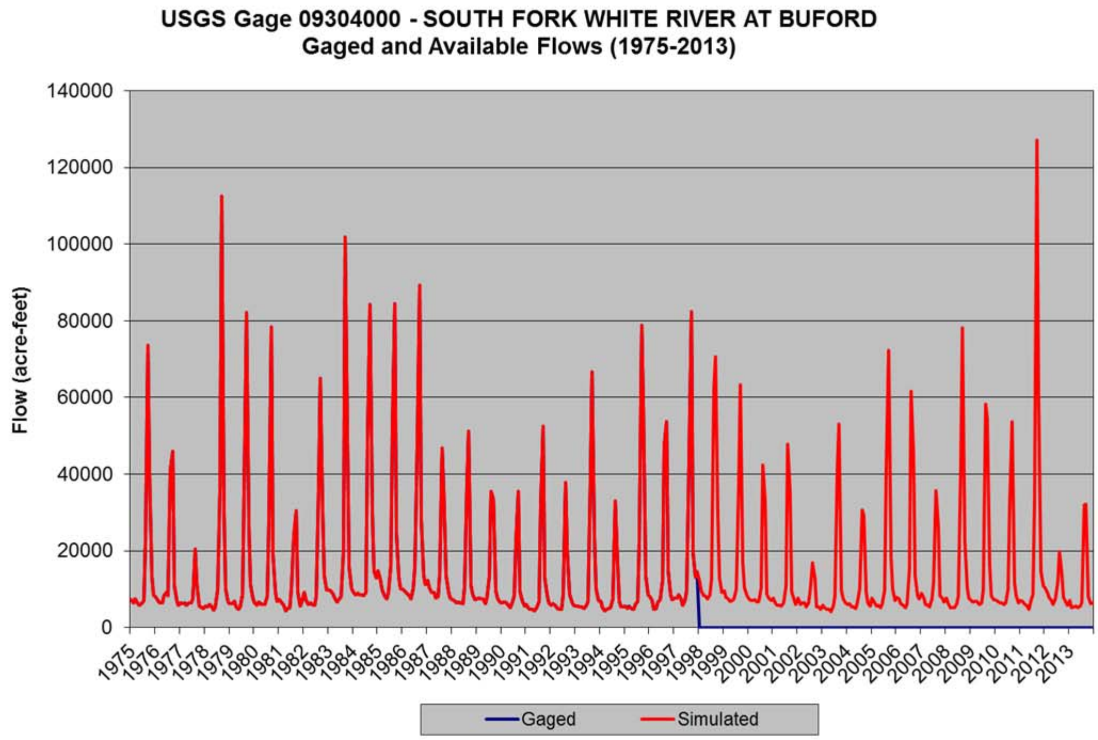


Figure 7.4 Stream Flow Calibration – South Fork White River near Buford



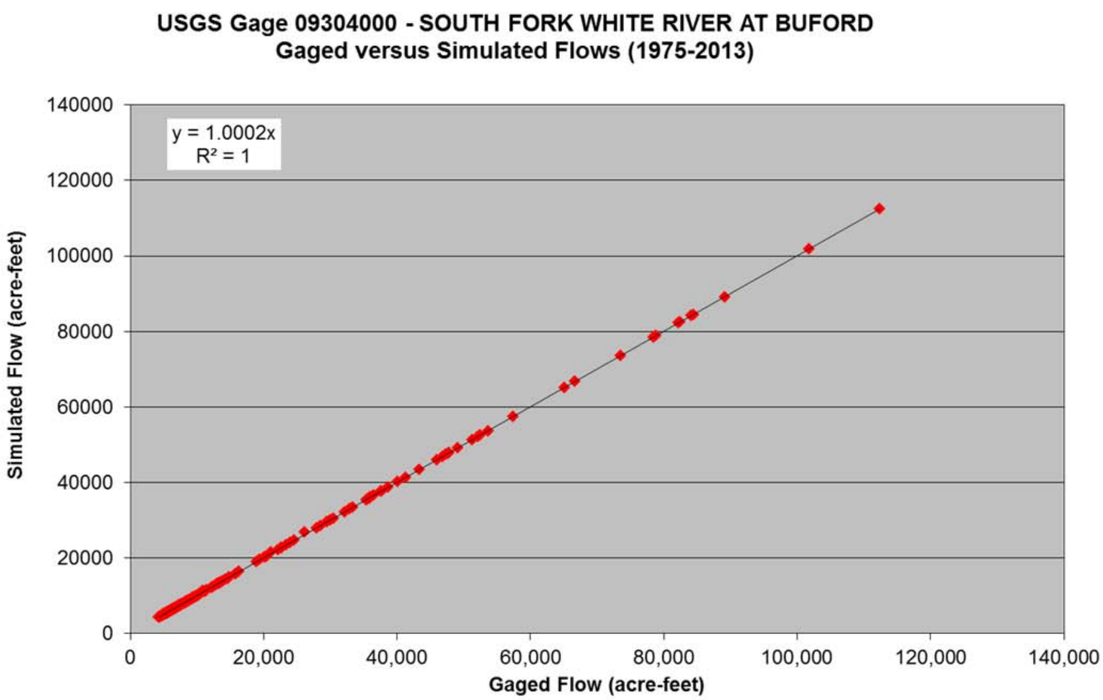
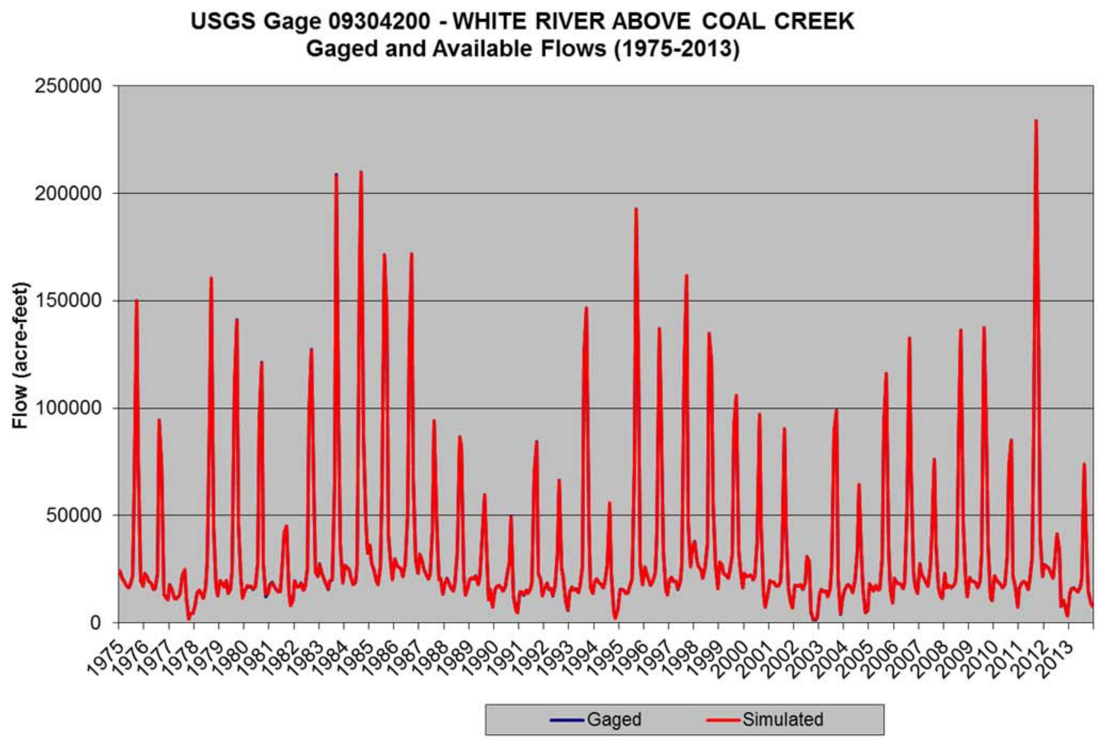


Figure 7.5 Stream Flow Calibration - South Fork White River at Buford



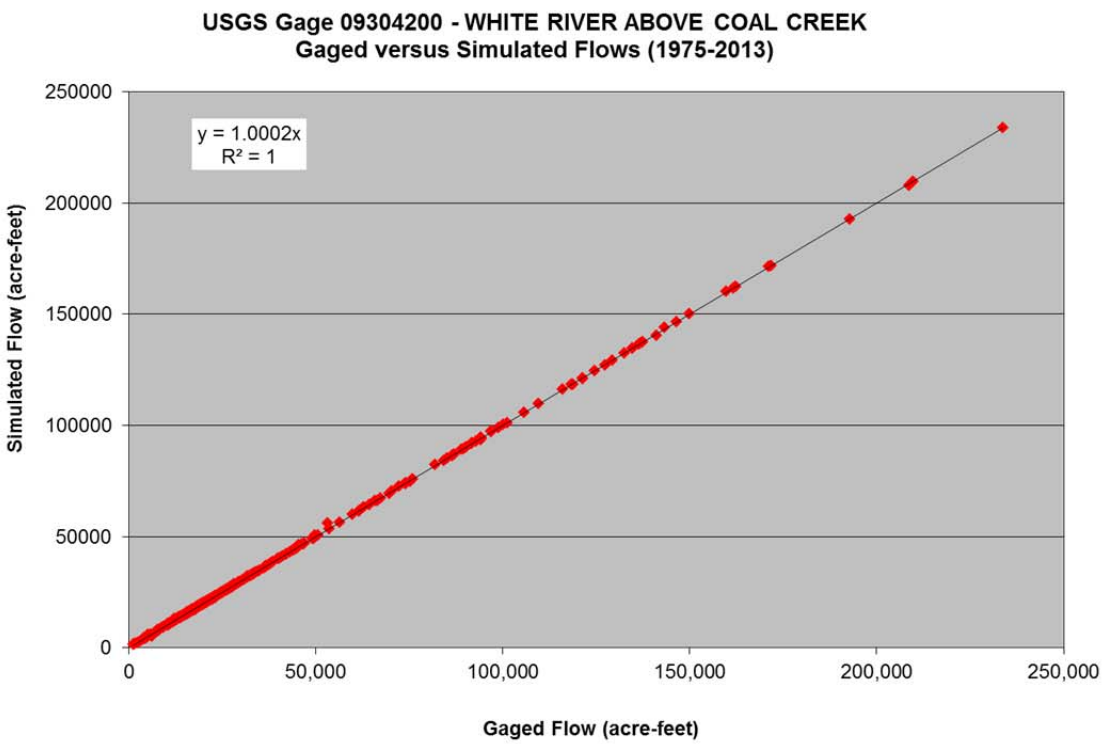
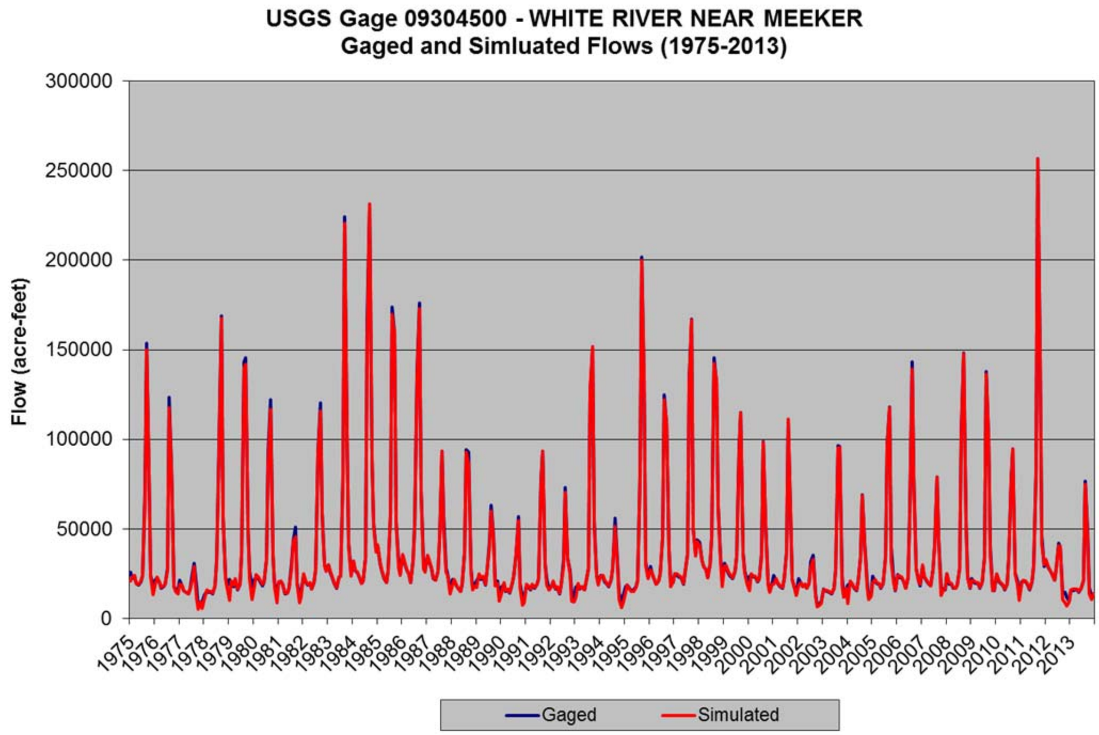


Figure 7.6 Stream Flow Calibration – White River above Coal Creek



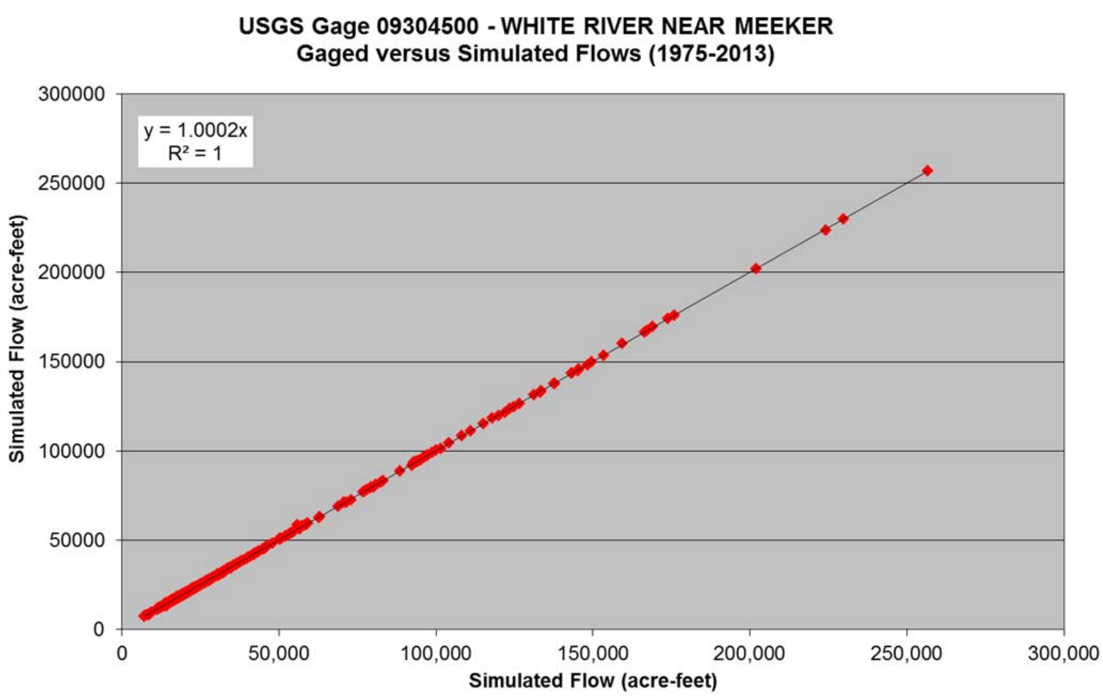
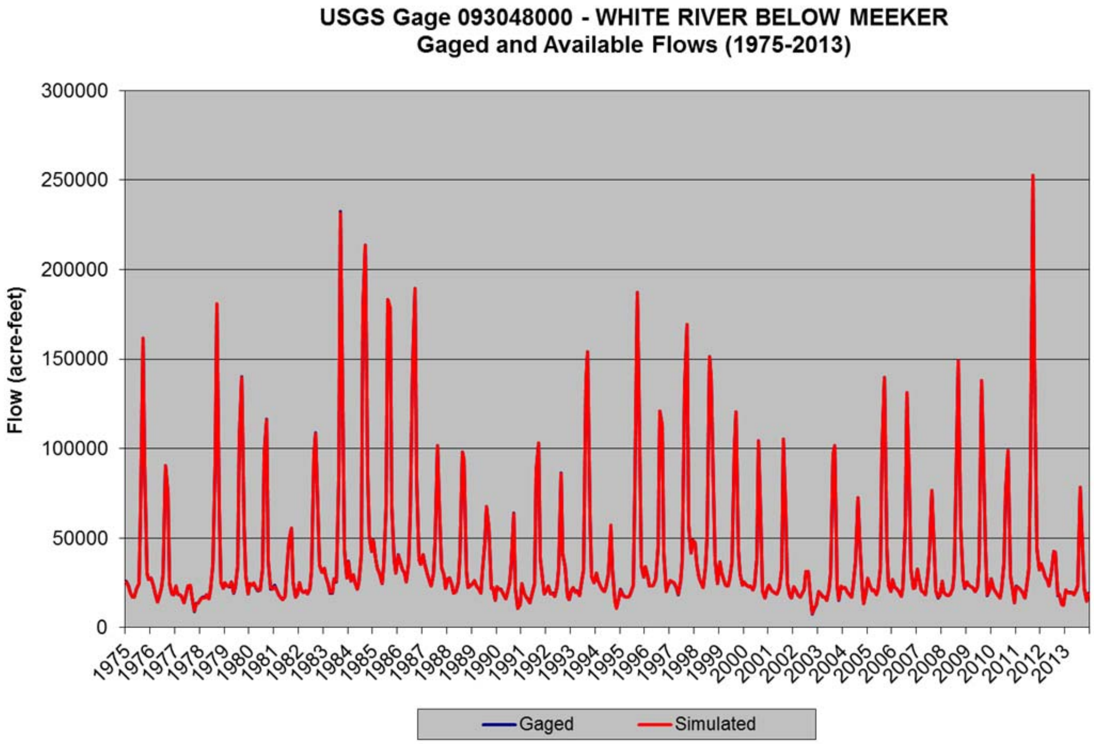


Figure 7.7 Stream Flow Calibration – White River near Meeker



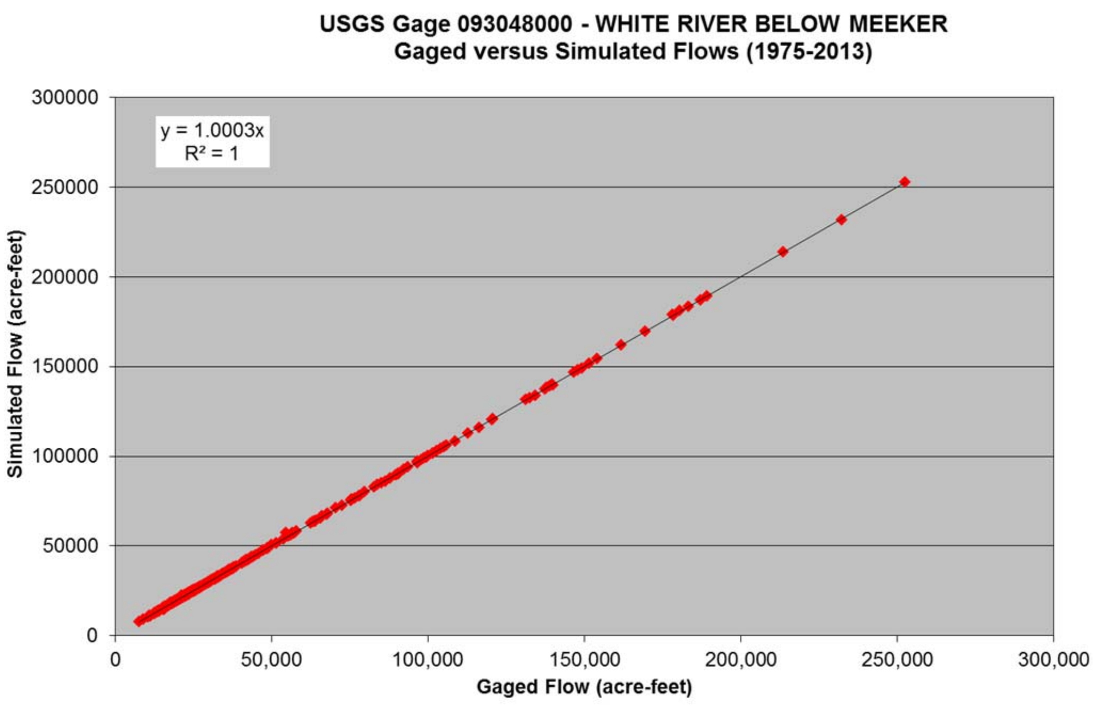
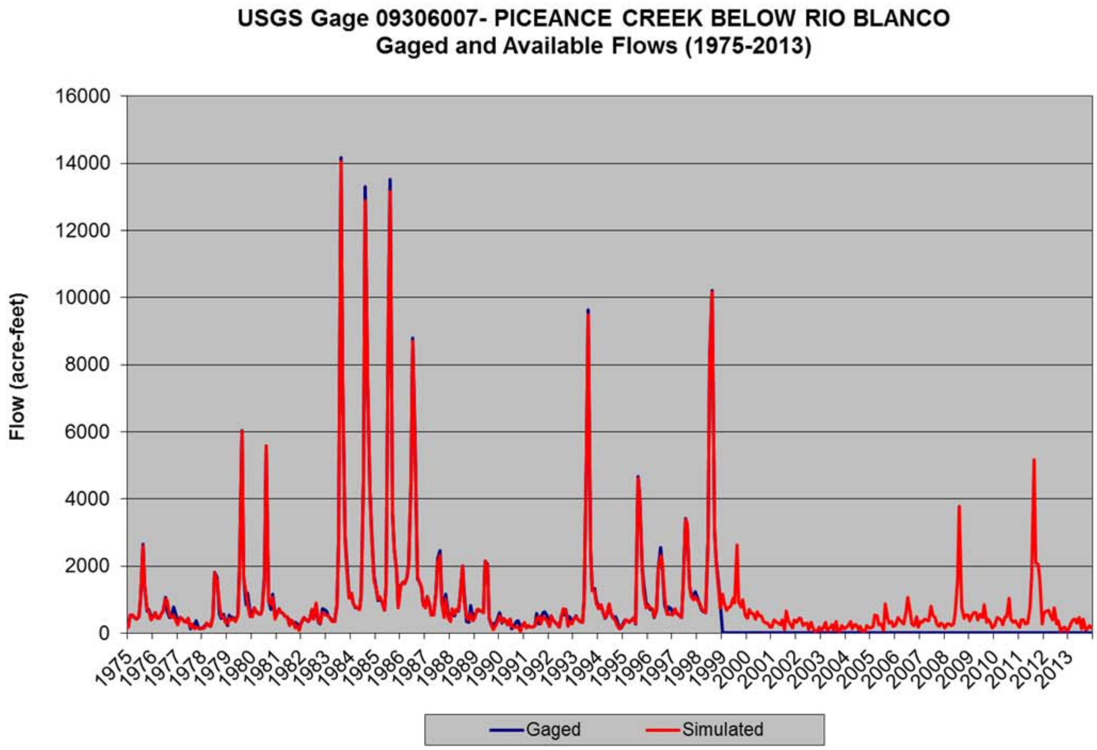


Figure 7.8 Stream Flow Calibration – White River below Meeker



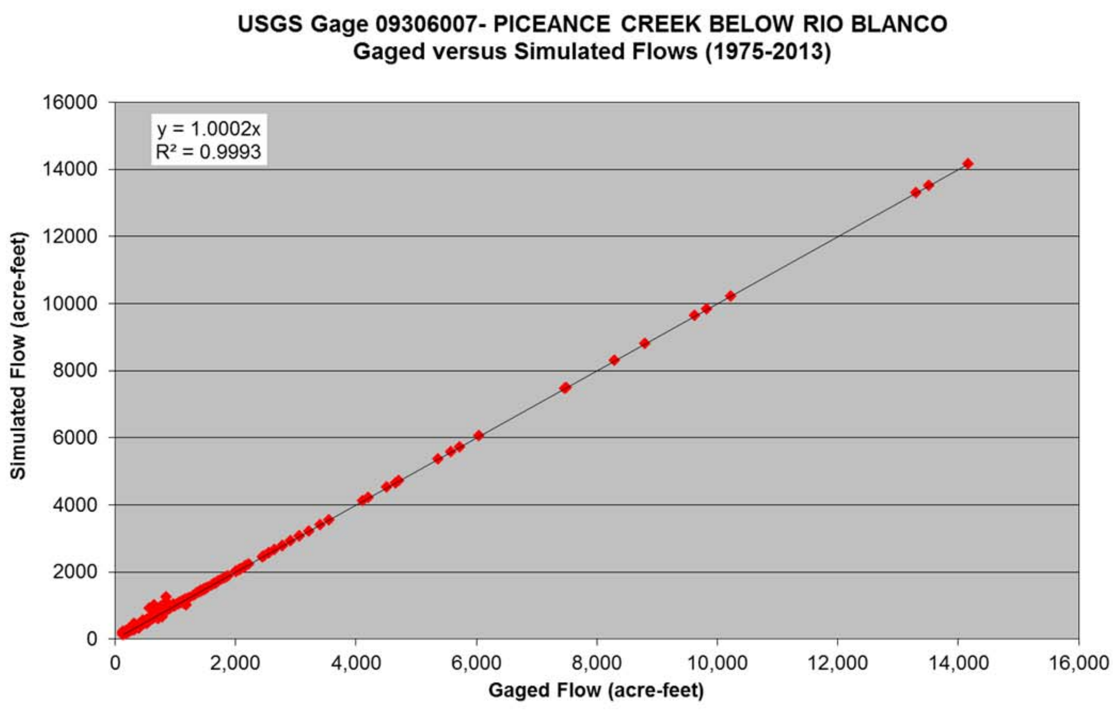
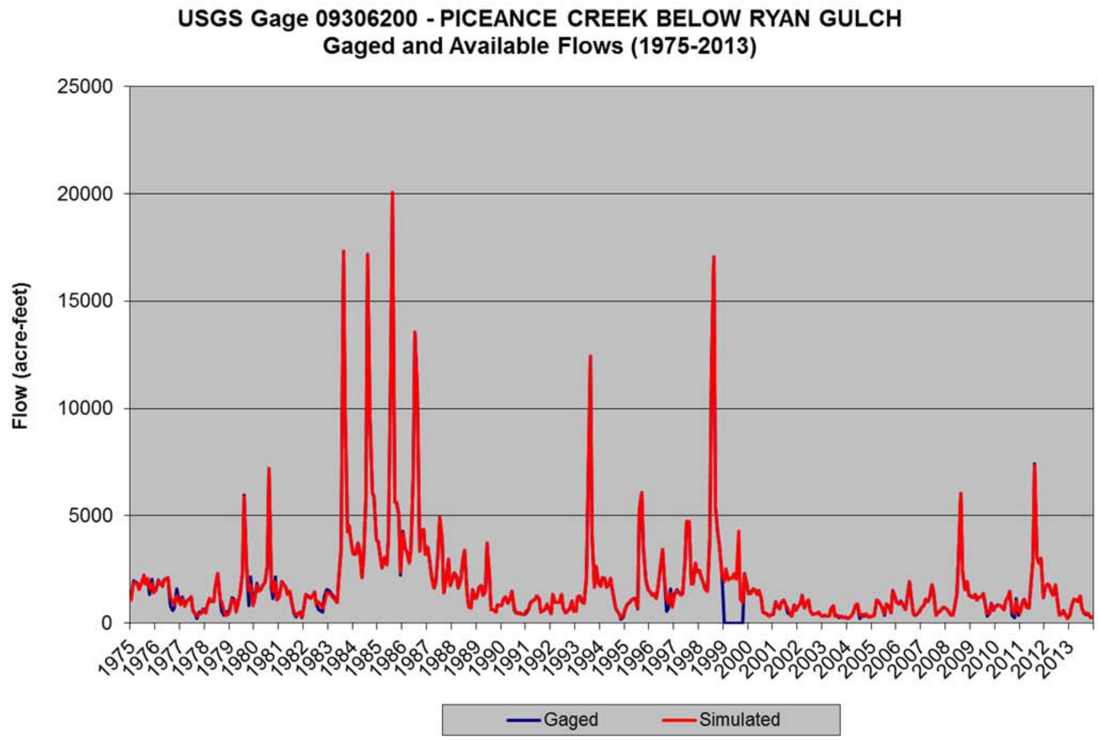


Figure 7.9 Stream Flow Calibration – Piceance Creek below Rio Blanco



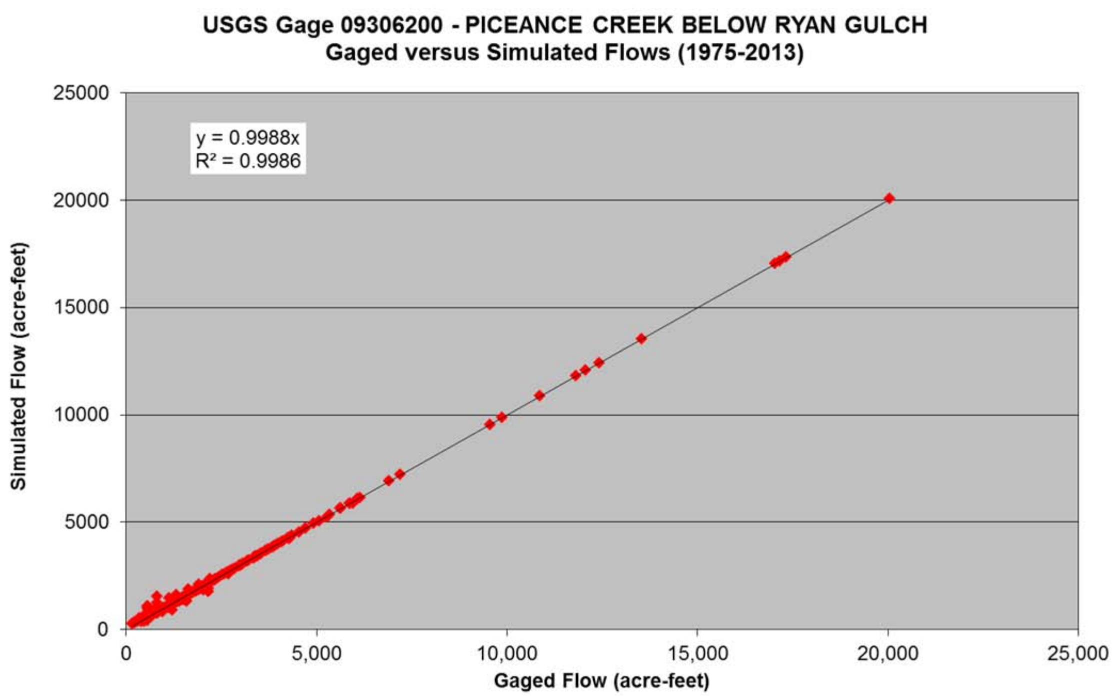
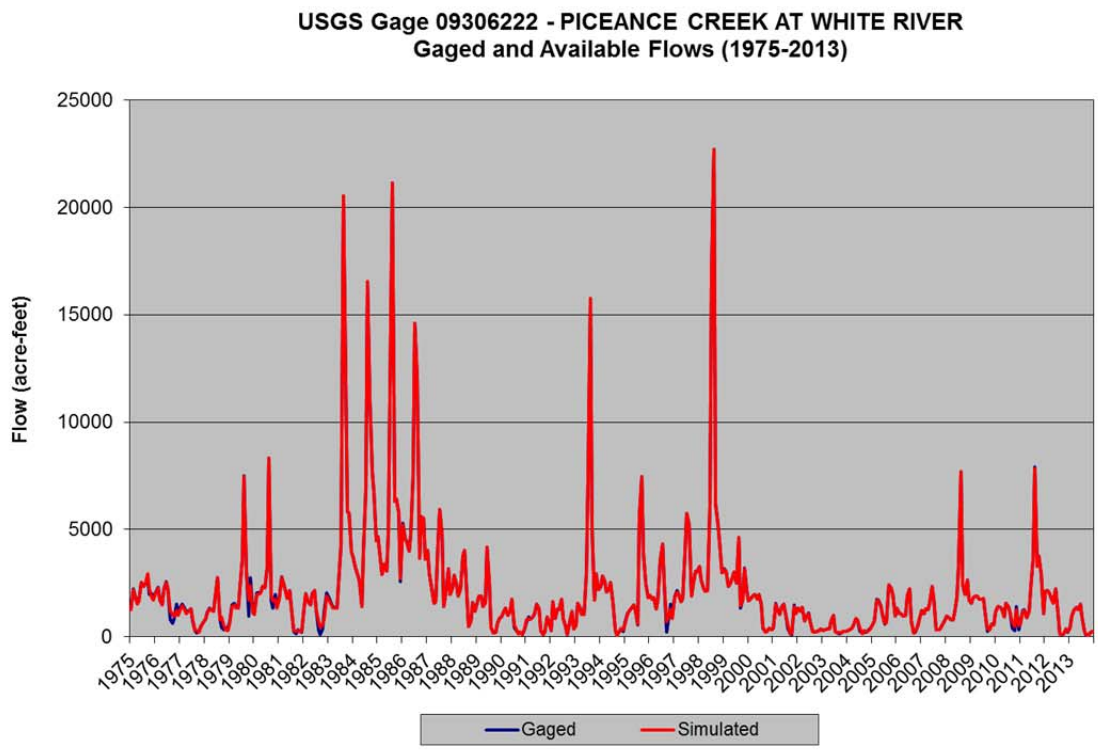


Figure 7.10 Stream Flow Calibration – Piceance Creek below Ryan Gulch



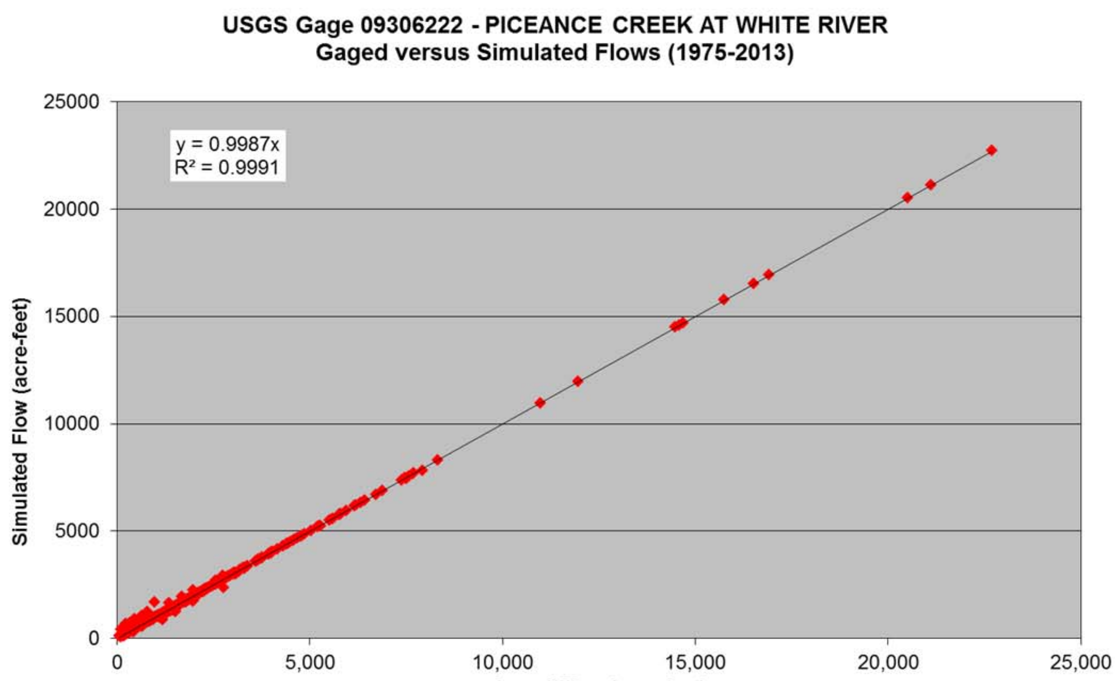
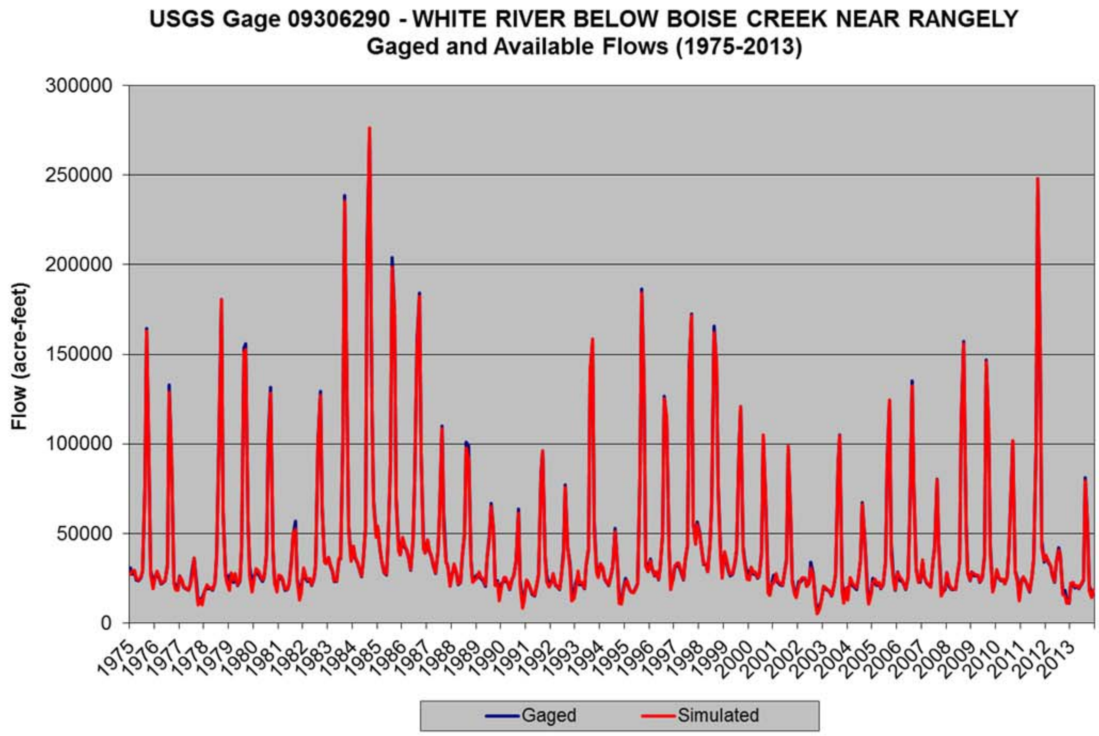


Figure 7.11 Stream Flow Calibration - Piceance Creek at White River



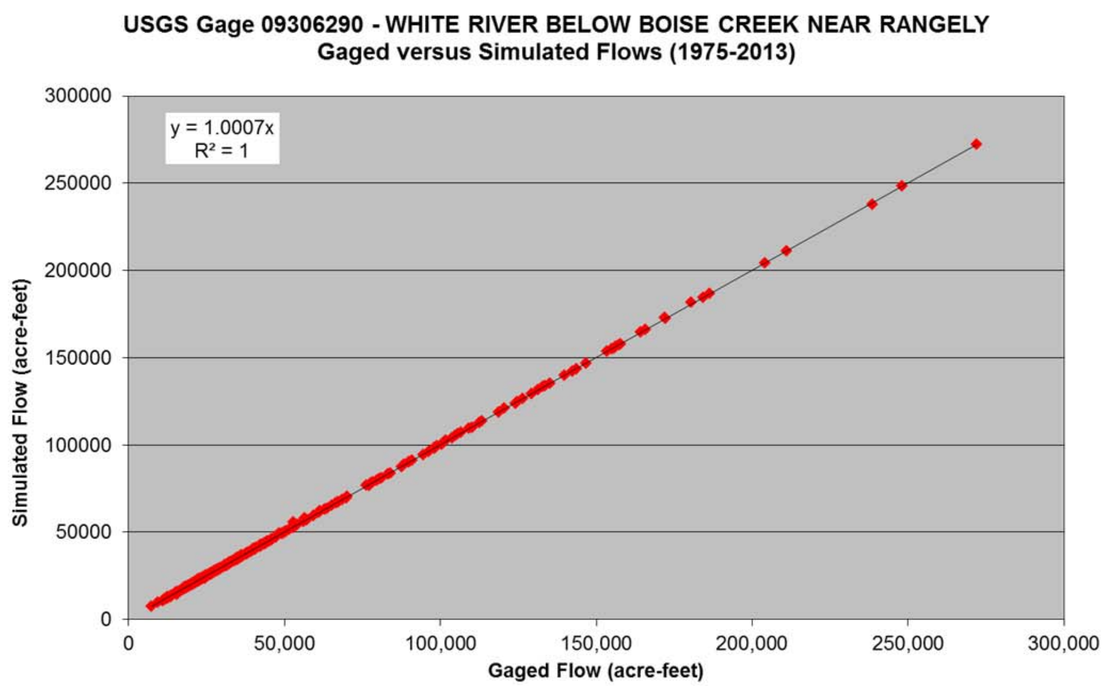
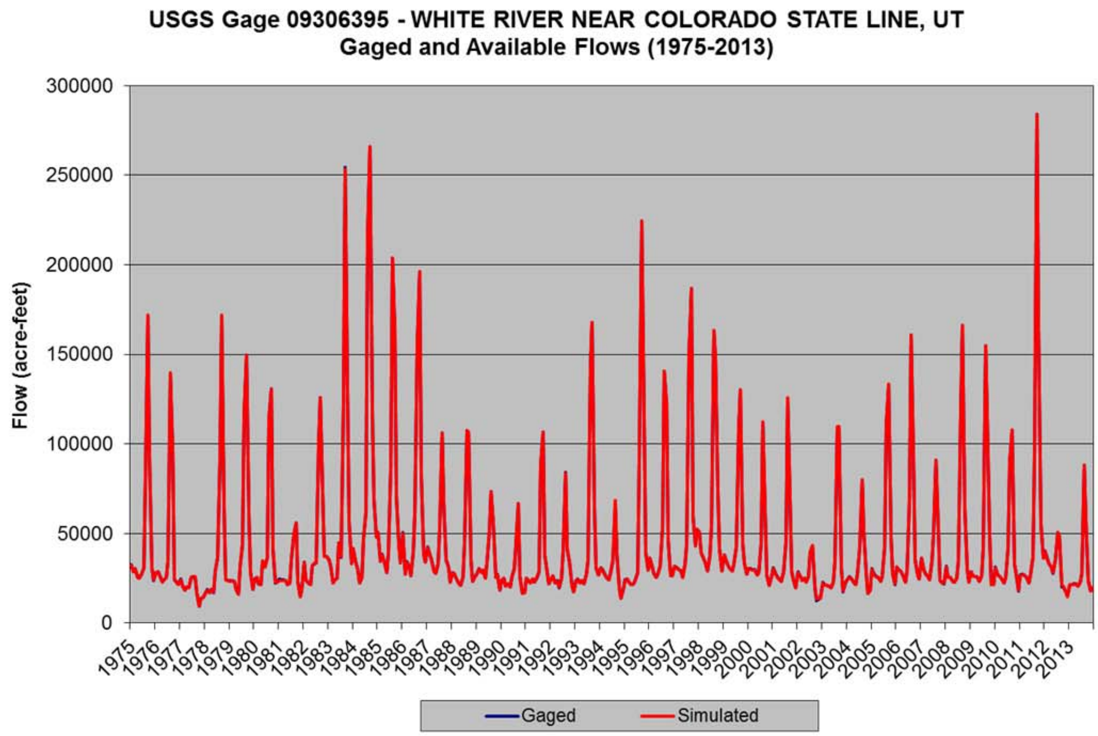


Figure 7.12 Stream Flow Calibration - White River below Boise Creek near Rangely



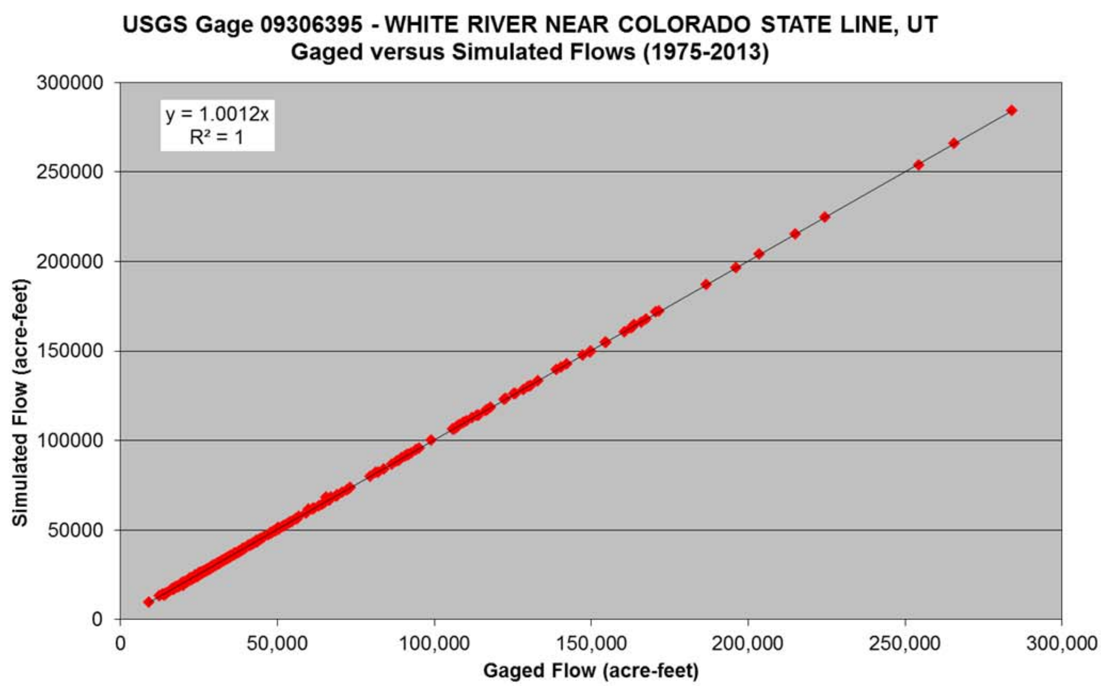


Figure 7.13 Stream Flow Calibration - White River near Colorado State Line, UT

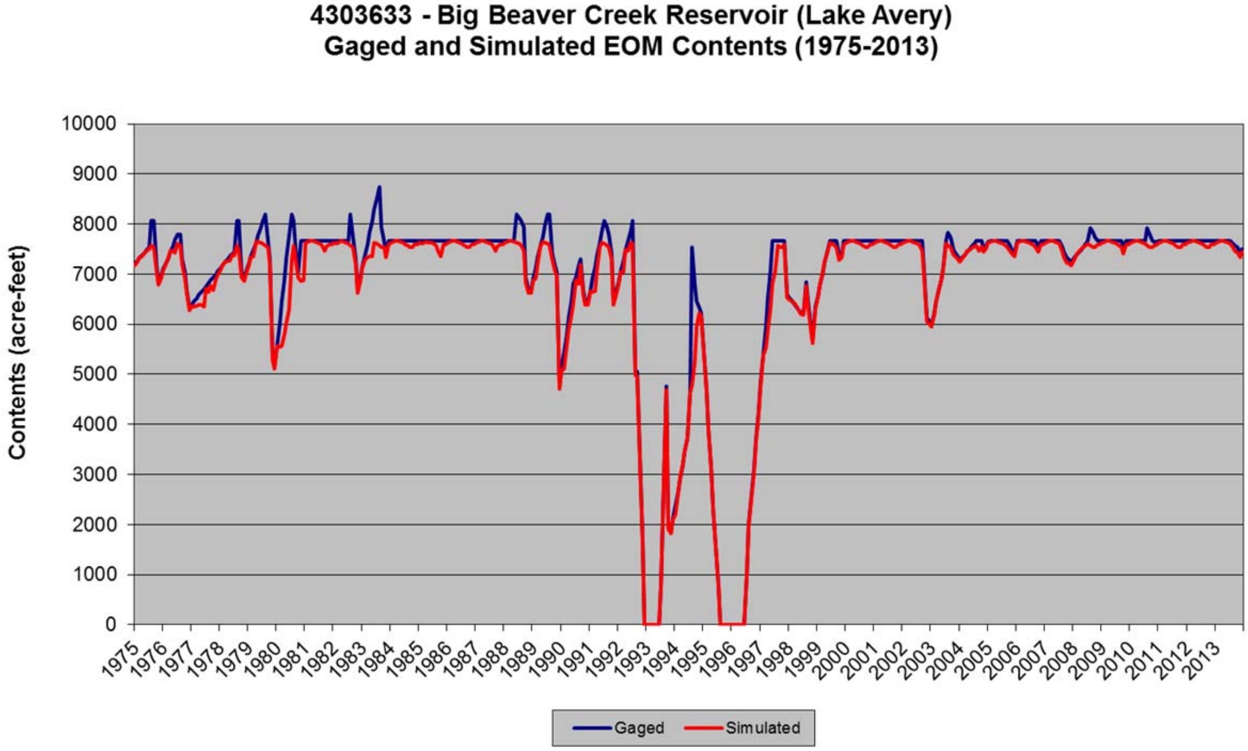


Figure 7.14 Reservoir Calibration - Big Beaver Creek (aka Lake Avery) Reservoir

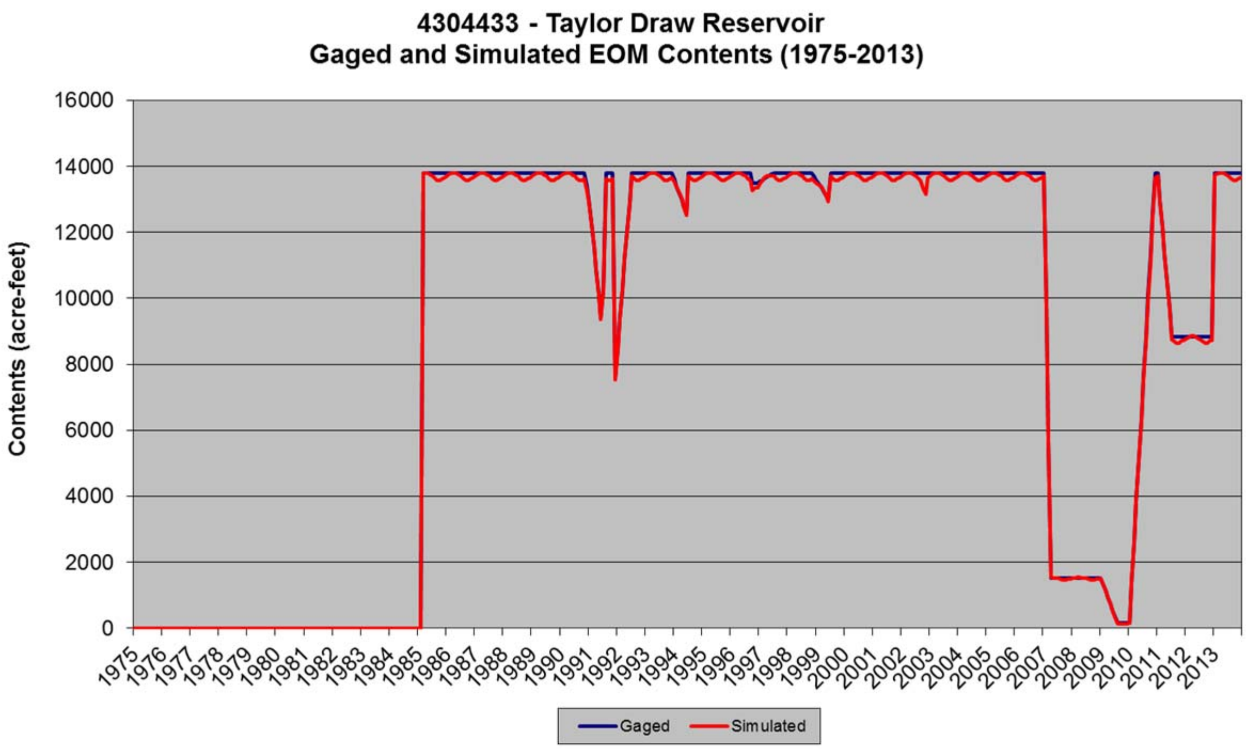


Figure 7.15 Reservoir Calibration – Taylor Draw Reservoir

Appendix A

Aggregation of Irrigation Diversion Structures

A1. 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.

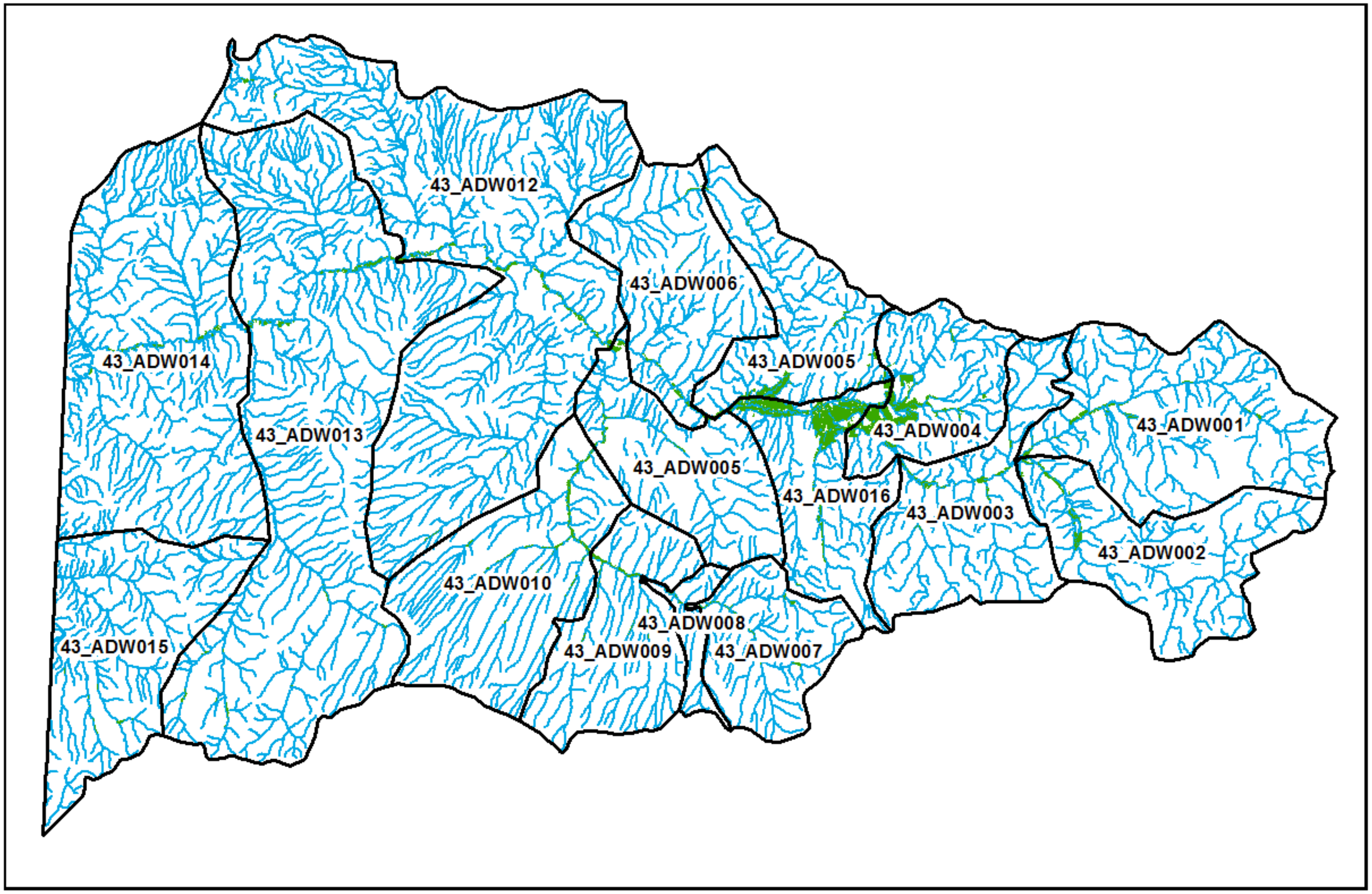


Figure A-1: Aggregate Structure Boundaries.

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.

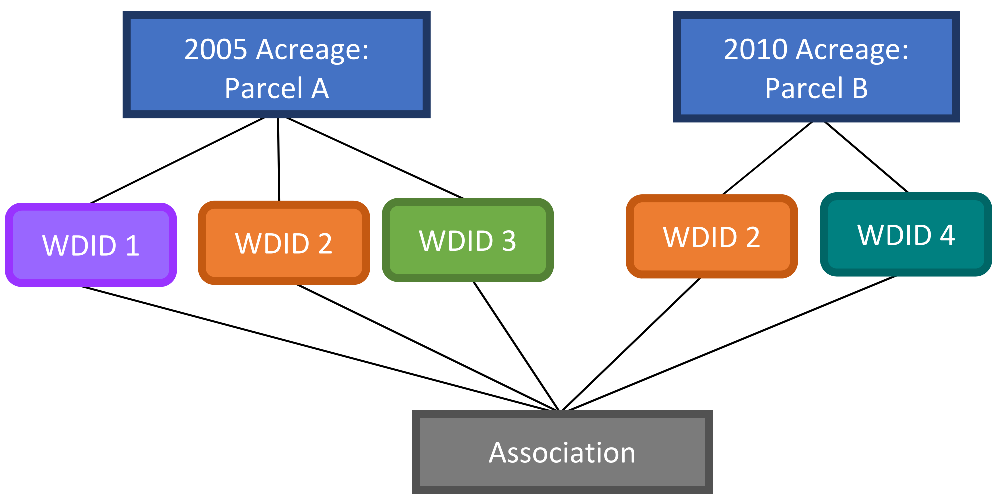


Figure A-2. Example of integrating the CDSS irrigated acreage coverage to identify associated structures.

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.

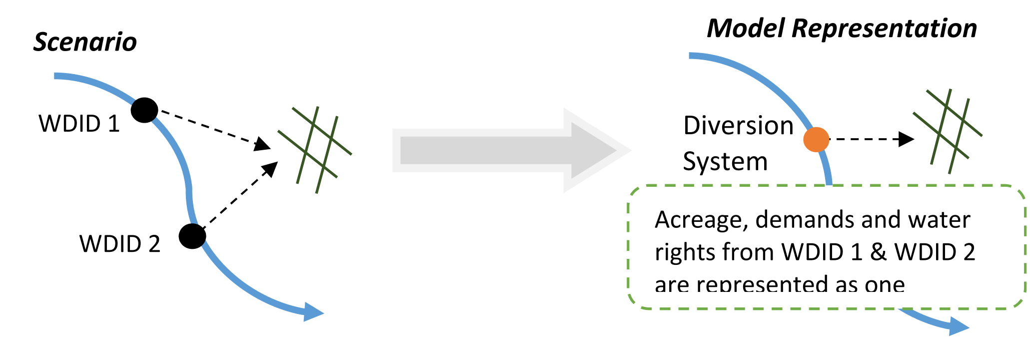


Figure A-3. Model Representation of a Diversion System.

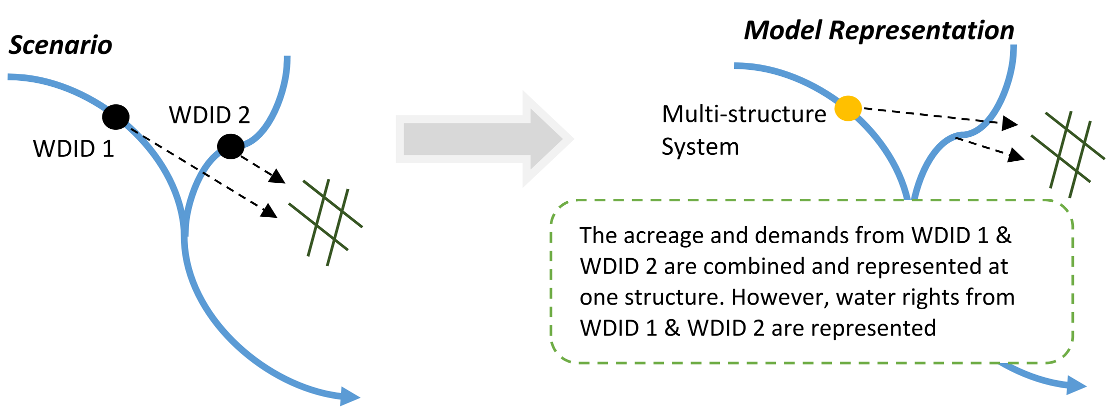


Figure A-4. Model Representation of a Multi-structure System.

- 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.
- 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.

3. CDSS Memorandum Subtask 2.05

November 19, 1996

MEMORANDUM

To: File

From: Ray R. Bennett

Subject: Subtask 2.05 Define Water Right Classes

Introduction

This memo describes the results of Subtask 2.05, Define Water Right Classes. The objective of this task was as follows:

> *Define approximately 10 water administration classes to be used to model the aggregated irrigation and reservoir groups in the White River Basin.*

Approach and Results

Plot Water Rights A plot was generated with the following data (**Exhibit 1** bottom to top):

- Line 1, All Absolute diversion water rights
- Line 2, Absolute water rights to be modeled in Phase IIIa
- Line 3, Absolute water rights associated with an irrigated parcel
- Line 4, Absolute water rights modeled in Phase II

Line 1, the list of all absolute water rights, was obtained by executing *Watright*, a Data Management Interface that extracts such information from the CRDSS database. Line 3, the list of absolute water rights associated with an irrigated parcel, was obtained by linking structures with irrigated land identified in the GIS coverage to the water rights presented in Line 1. Line 4, the list of absolute water rights modeled in Phase II, was obtained by linking structures modeled in Phase II to the water rights presented on Line 1. Line 2, the list of Absolute water rights to be modeled in Phase IIIa is a sum of the structures modeled in Phase II (Line 4) and those with irrigated acreage which had not yet been modeled.

Obtain Call Information Kent Holt of Division 6 was contacted by phone on July 26, 1996 regarding frequent calls in the White River Basin. Results were as follows:

River	Structure Name	ID	Right (cfs)	Admin. Number
Piceance Creek	Square S Consolidated	430948	2.2	13509.00000
Coal Creek	Coal Creek Mesa	430578	7.7	13940.00000
White River	Highland Ditch	430694	48.2	32172.16923

Note the White River call has only occurred one time, in 1977. Also, other small streams may have their own calls but are outside the intent of this study.

Water Right Groups Water Right aggregation groups were developed using the following data:

- District 43 call information,
- Incremental right group size (attempted to have incremental rights in each group of a similar size unless dictated by call information).

The resulting 8 categories are presented below:

#	Admin. Number From	Admin. Number To	Cumulative Right (cfs)	Incremental Right (cfs)
1	0	13509.00000	181	181
2	13509.00001	13940.00000	299	118
3	13940.00001	25767.16000	650	351
4	25767.16001	32172.16923	992	342
5	32172.16924	32172.24570	1273	281
6	32172.24571	38474.00000	1614	341
7	38474.00001	45504.00000	1959	345
8	45504.00001	Infinity	2132	173

Comments

Following are comments related to the execution of Subtask 2.05, Define Water Right Classes:

- Following is a break down of absolute direct flow decrees in the White River Basin:

Description	Decrees (cfs)	Percent (%))
Phase II tied to Irrigated land	1,559.60	54
Phase II not tied to Irrigated land	76.85	3
Phase III added	495.61	17
Subtotal (Phase III modeled)	**2132.06**	**73**
Other Rights	769.78	26
Total	**2,901.84**	**100**

- Regarding **Exhibit 1** and the above table, a spot check of the 'Other Right' (water rights that occur between Line 1 (All Absolute Water Rights) and Line 2, (Absolute Water Rights to be Modeled in Phase III), indicates they include rights which no longer operate, are associated with non consumptive activities, or are relatively small municipal and industrial rights. The following table identifies two of the larger rights within this group. In addition to those categories described above, the water rights that were not modeled are expected to include ditches which may currently divert but were not tied to irrigated land during the 1993 survey. They might be added if the irrigated acreage data is updated.

Ditch	Decree (cfs)	Comment
430809 Meeker Power Ditch	161.88	No longer operational
430888 Rainbow Lake Ditch	31.75	Non Consumptive

Appendix B

Aggregation of Non-Irrigation Structures

1. CDSS Memorandum Sub task 2.10
White River Basin Aggregated Municipal and Industrial Use

2. CDSS Memorandum Sub task 2.11
White River Basin Aggregated Reservoirs and Stock Ponds

September 19, 1996

MEMORANDUM

To: File

From: Ray R. Bennett

Subject: Sub task 2.10 White River Basin Aggregated Municipal and Industrial Use

Introduction

This memo describes the results of Sub task 2.10 White River Basin Aggregated Municipal and Industrial Use. The objective of this task was as follows:

> *Aggregate municipal and industrial uses not explicitly modeled in Phase II to simulate their depletive effects in the basin.*

Approach and Results

Phase II Modeled M&I Use The following table presents the 1975 to 1991 average annual Municipal and Industrial diversions and consumptive use modeled in Phase II. Note, the efficiency was revised from the 70% assigned in Phase II to the 30% recommended by WW Wheeler. Also, the California water company diversion is used for oil field near Rangely.

Ditch	Diversion (AF)	Depletion (AF)
Meeker (430810)	624	187
Rangely (430889)	1,083	325
Sub total	**1,707**	**512**
Cole Creek Feeder (430577)	726	0
Calif. Water Co. (430564)	3,831	3,831
Subtotal	**4,557**	**3,831**
Total	**6,264**	**4,343**

Phase II Consumptive Uses and Loss Estimates The following table presents the categories and values of M&I consumptive use presented in the task memorandum 2.09-11, Non-

Evapotranspiration (Other Uses) Consumptive Uses and Losses in the White River Basin (8/16/96).

Category	Depletion (AF)
Municipal	459
Mineral	728
Livestock	424
Total	**1,611**

Aggregated M&I Diversion Based on the above data and the relatively small amount of consumption, one aggregated M&I demand (AMW_001) was added to the model as one aggregated node (AMW_001) at the White River just above the state line gage (see Subtask 2.04 for a network diagram which includes the aggregated M&I demand). The structure was assigned a depletive demand (efficiency of 100%) of 1,099 AF/yr (1,611 AF - 512 AF) over 12 months evenly. Note this demand recognizes that the consumptive uses and losses estimates do not include the California water company demands which may be interpreted to be a depletion to the surface water system but not to the basin since the water is injected underground and held in storage. The aggregated M&I structure was assigned a water right of 2 cfs and a senior administration number of 1.

March, 1999

MEMORANDUM

To: File

From: Ray R. Bennett

Subject: Sub task 2.11 White River Basin Aggregate Reservoirs and Stock Ponds

Introduction

This memo describes the results of Sub task 2.11, Aggregate Reservoirs and Stock Ponds. The objective of this task was as follows:

> *Aggregate reservoirs and stock ponds not explicitly modeled in Phase II to allow simulation of effects of minor storage facilities in the White River Basin.*

Approach and Results

Reservoirs and Stock Ponds The following table presents the net absolute storage rights located the White River Basin that were modeled in Phase II along with those to be added in Phase III**. Exhibit 1** lists the individual structures associated with the reservoirs to be modeled in Phase III. **Exhibit 2** lists the SQL script used to obtain this data.

Phase	**Reservoir**	**Absolute Decree (AF)**	**Percent of Total**
Phase II	Taylor Draw	13,800	45
Phase II	Big Beaver	7,658	25
subtotal		**21,458**	**70**
Phase III	Reservoirs	4,234	14
Phase III	Stock ponds	4,776	16
subtotal		**9,010**	**30**
Total		**30,468**	**100**

Also presented on the above table is the storage associated with stock ponds which are to be modeled in Phase III. Stock pond capacity was obtained from the year 2 product, Task Memo

2.09, Non-Evapotranspiration (Other Uses) consumptive uses and Losses in the White River Basin (8/16/96).

Number of Structures and Location Based on a review of the Phase II reservoir coverage map and the location of stock ponds with regard to USGS hydrologic units, the Phase III reservoirs were incorporated into the model as two aggregated reservoirs; one on the White River above the state line gage (ARW_001) and another on the White River above the confluence with the Piceance Creek (ARW_002). Similarly, two reservoirs which represent stock ponds (ASW_001 and ASW_002) ponds were added at the same locations. Subtask 2.04 contains a network diagram which includes the aggregated reservoirs and stock ponds.

Accounts Each reservoir was assigned one account and an initial storage equal their capacity as follows:

Structure	**Capacity (AF)**	**Initial Contents(AF)**
Aggregated Reservoirs	2,117	2,117
Aggregated Stock Ponds	2,388	2,388

Area-Capacity and Evaporation Data Each aggregated reservoir was assigned a simple 2 point area capacity curve based on a 10 foot deep reservoir as follows:

Aggregated Reservoir Area-Capacity

Capacity (AF)	**Area (ac)**
0	0
2117	211.7

Aggregated Stock Pond Area-Capacity

Capacity (AF)	**Area (ac)**
0	0
2388	238.8

Evaporation The evaporation station assigned to each aggregated reservoir and stock pond is the same as that determined for Big Beaver Reservoir in Phase 2.

Operational Rules, Target Contents and End-of-Month Data No operating rules were implemented for aggregate reservoirs.

Comment

The following should be noted:

- ***Watright*** was scoped to develop one aggregated reservoir decree. In order to model two aggregated reservoirs it was necessary to hand edit the reservoir right file (*.rer).
- ***Statemod*** implements the one fill rule by priority. For example if a reservoir has 200 AF in storage at the administration date and two decrees as follows;

  100 AF at Priority 1 and

  400 AF at Priority 2

  then the first priority decree would not be allowed to divert for that year while the second priority decree would be limited to 300 af for the year. This approach required stock ponds and reservoir be modeled separated rather than combined as scoped.

wd	id	res_name	abs_af
43	3642	JOHNNY JOHNSON RES	1036.000
43	3769	BIG LICK RES	481.000
43	3659	SKINNEY FISH RESERVOIR	300.700
43	3644	KEYSTONE CR BEN PRICE RE	286.810
43	3643	KEYSTONE NO 2 RESERVOIR	151.000
43	3668	WATKIN RESERVOIR AND D	134.520
43	4287	PAGODA LAKE	120.000
43	3671	WILSON RES	103.000
43	3651	MC GINNIS MEADOW RES	87.000
43	3649	LUNNEY RESERVOIR	82.120
43	4504	TAYLOR RES	81.000
43	3669	WEST MILLER RESERVOIR	77.800
43	3717	BAXTER RES	64.600
43	3652	MC HATTEN RESERVOIR	64.200
43	4497	DESPERADO M SEDIMENT RP4	62.000
43	3647	LARSON RES	61.900
43	3632	BEAVER LAKE RESERVOIR	59.000
43	3893	MARK RES NO 1	54.800
43	3896	ALBRIGHT RES NO 2	52.200
43	4308	THEOS NO 1 RES	51.000
43	3639	GREGOR RESERVOIR	47.000
43	3634	BLACK GULCH RES	40.750
43	4284	NINE MI RANCH RES 1	40.710
43	4272	JACOBS RESERVOIR	38.300
43	4291	RAINBOW LAKE	36.700
43	4499	REEVES RES	34.000
43	3645	KEYSTONE RES NO 3	31.200
43	4280	MARK RES NO. 2	31.020
43	3717	BAXTER RES	30.000
43	3657	SEVENTH LAKE RESERVOIR	29.500
43	3897	MARK RES NO 3	28.300
43	3895	KIRBY RES NO 2/60	27.800
43	4463	VANDIVER POND	24.830
43	3894	BANTA RES NO 1	23.700
43	3630	BAILEY LAKE RETAIN POND	22.800
43	3769	BIG LICK RES	21.900
43	3671	WILSON RES	21.160
43	4320	JENSEN RES NO 1	19.000
43	3904	BALL LAKE RESERVOIR	18.000
43	3636	CABINE LAKE RESERVOIR	16.060
43	4249	DORTCH POND NO 1	13.600
43	3672	W STEWART GULCH RES	13.300
43	4327	SADDLE HORSE PARK RES	12.000
43	3660	STUMP LAKE RESERVOIR	10.230
43	4487	WILLIAMS POND	10.000
43	3661	TAWNEY HIRONS RESERVOIR	8.000
43	3631	BARBOUR POND	7.800
43	3632	BEAVER LAKE RESERVOIR	7.450
43	4461	KAWCAK POND NO 1	7.400
43	4385	DESPERADO POND RP-2 + 3	7.400
43	4383	DESPERADO MINE POND DP-1	7.036
43	3656	PROCTER RESERVOIR	6.660
43	4307	TERLEP POND	6.500

43	4285	NINE MILE RANCH RES NO 2	6.310
43	4497	DESPERADO M SEDIMENT RP4	6.000
43	3935	DIETZ SPG NO 1 POND	6.000
43	3716	JOY JOY AND WATSON RES	5.880
43	3638	GOOSMAN RESERVOIR	5.600
43	4351	JENSEN RES. NO. 2	5.000
43	4250	DORTCH POND NO 2	5.000
43	4318	YELLOW CREEK RES NO 1	5.000
43	4492	R R LOADOUT LOOP POND	4.930
43	3646	LADY LAKE	4.410
43	4262	FLAG CREEK RES NO 8	4.250
43	3934	FILENER RESERVOIR	4.000
43	3663	URRIOLA NO 1 RES	4.000
43	4386	DESPERADO MINE POND RP-1	3.530
43	4325	NORTHERN POND B	3.170
43	3670	WHITNER FISH POND	3.065
43	4253	FLAG CREEK RES NO 10	3.060
43	4326	NORTHERN POND C	3.000
43	3658	SHADOW LAKE RESERVOIR	2.600
43	3640	HERRELL FISHPOND	2.500
43	4488	SEVEN K RES	2.380
43	3657	SEVENTH LAKE RESERVOIR	2.120
43	4271	INDIAN SPG RESERVOIR	2.000
43	4260	FLAG CREEK RES NO 2	1.610
43	4276	LOVE RES NO 1	1.500
43	4493	STITT STOCK TANK + POND	1.500
43	4257	FLAG CREEK RES NO 16	1.380
43	4294	RAT MT POND NO 1	1.000
43	4446	JOHNSON POND NO 15	1.000
43	4445	JOHNSON POND NO 14	1.000
43	4440	JOHNSON POND NO 9	1.000
43	3667	VEACH GULCH STOCK POND 1	1.000
43	4322	JENSEN NO 3 RES	1.000
43	4242	BILL ALLEN RESERVOIR	1.000
43	3654	MONUMENT MT STKWTR PD	1.000
43	3655	NONAME STOCK WATER POND	1.000
43	3666	VEACH GULCH STKWTR PD 2	1.000
43	3635	BRADY GULCH STOCK POND	1.000
43	3641	JEAN URRUTY NO 2 RES	1.000
43	3901	JEAN URRUTY RES 1	1.000
43	3664	URRUTY RES 3	0.750
43	4273	JONES STOCK A FISH POND	0.750
43	3653	MC GINNIS MEADOW RES	0.700
43	3662	TRAPPERS LAKE RETAIN PD	0.690
43	4324	NORTHERN POND A	0.630
43	4437	JOHNSON POND NO 6	0.500
43	4459	JOHNSON POND NO 4	0.500
43	3899	ELK DRAW RES	0.500
43	3637	EVACUATION CR LAKE RES	0.500
43	4268	HARRY MANGUS SEEP POND	0.500
43	3665	URRUTY STOCK WATER TANK	0.500
43	4264	FLAG CK SPG NO 5	0.430
43	3886	GORDON RES NO 3	0.290
43	4265	FLAG CK SPG NO 6	0.290
43	4266	FRED SLIFKA SPG POND	0.250
43	4309	UPPER MOYER POND	0.250

43	4278 LOWER POND 2/67	0.250
43	4247 CRAWFORD POND	0.250
43	4277 LOWER MOYER POND	0.250
43	4255 FLAG CREEK RES NO 13	0.230
43	4261 FLAG CREEK RES NO 4	0.190
43	4297 ROAD POND	0.167
43	4311 WEST HUNTER CREEK POND	0.150
43	3892 GORDON SPG RES NO 2	0.140
43	4254 FLAG CREEK RES NO 12	0.140
43	4300 SADDLE POND 1/67	0.125
43	4289 POWER LINE POND 3/67	0.125
43	4267 GORDON SPG RES NO. 1	0.110
43	4259 FLAG CREEK RES NO 19	0.110
43	4448 JOHNSON POND NO 17	0.100
43	4279 MALCOLM POND	0.100
43	4256 FLAG CREEK RES NO 15	0.060
43	4423 HARP POND	0.050
43	4258 FLAG CREEK RES NO 18	0.040
43	4293 RANGELY RESERVOIR	0.000
43	4304 STOREY GULCH RES	
43	4305 STRAWBERRY CREEK RES	
43	4306 SUPERIOR OIL TERM RES	
43	4275 KENNY RESERVOIR NO 1	
43	4246 CATHEDRAL RES NO. 1	
43	4274 KELLOG GULCH RES	
43	4310 WALKER RESERVOIR	
43	4270 HUNTER CK RES	
43	4313 WOLF CK RES	
43	4313 WOLF CK RES	
43	4313 WOLF CK RES	
43	4314 WOLF RIDGE RES	
43	4315 WRAY GULCH RES	
43	4316 WRAY GULCH RES	
43	4317 YELLOW CREEK RES	
43	4290 R L BROWN RES	
43	4245 BUCKEYE RESERVOIR	
43	4269 HENRY RES	
43	4263 FOURTEEN MILE RES 1 ENL	
43	4244 BLACKS GULCH RES	
43	4243 BLACK SULPHUR RES	
43	4251 DUCK CREEK RES	
43	4348 E. NO NAME GULCH RES.	
43	4252 FIGURE FOUR RES	
43	4282 MILLER CK RES	
43	4727 DIETZ CABIN RES	
43	4288 POWELL PARK RES	
43	4384 DESPERADO MINE POND RP-4	
43	4286 NORTH ELK RES.	
43	4284 NINE MI RANCH RES 1	
43	4292 RALEY RESERVOIR	
43	4430 JOHNSON RES NO 2	
43	4431 JOHNSON RES NO 1	
43	3650 MARTIN VILLA RESERVOIR	
43	4433 TAYLOR DRAW RESERVOIR	
43	4434 JUMPS CABIN RES	
43	4435 HOWELLS CABIN RES	

43	4436 STAKE SPRINGS RESERVOIR
43	4283 MOELLER RES NO. 1
43	4438 JOHNSON POND NO 7
43	4439 JOHNSON POND NO 8
43	4293 RANGELY RESERVOIR
43	4441 JOHNSON POND NO 10
43	4442 JOHNSON POND NO 11
43	4443 JOHNSON POND NO 12
43	4444 JOHNSON POND NO 13
43	4282 MILLER CK RES
43	4295 RIO BLANCO RESERVOIR
43	4447 JOHNSON POND NO 16
43	4296 RIPPLE CREEK RESERVOIR
43	4449 CORRAL GULCH RES UPSTRM
43	4450 BOX ELDER GULCH RES ALT
43	4451 STAKE SPRING RES DWNSTRM
43	4453 CORRAL GULCH RESERVOIR
43	4454 WATER GULCH WATER FACIL
43	4455 STAKE SPGS RES H20 FACIL
43	4456 JOHNSON POND NO 1
43	4457 JOHNSON POND NO 2
43	4458 JOHNSON POND NO 3
43	4281 MEADOWS RES 1 ENL
43	4460 JOHNSON POND NO 5
43	3648 LOST PARK RESERVOIR
43	4462 HATCH GULCH RES
43	3647 LARSON RES
43	4464 WILLOW CR RES 1
43	4465 UPPER PICEANCE RES
43	4466 LOWER PICEANCE RES
43	4467 BEAR VALLEY RES + POND
43	4468 SPENCER DRAW POND =1
43	4469 SPENCER DRAW POND =2
43	4470 SPENCER DRAW POND =3
43	4471 SPENCER DRAW POND =4
43	4472 SPENCER DRAW POND =5
43	4473 UPPER WOLF CREEK POND
43	4474 UPPER WOLF CREEK LOWER P
43	4475 EAST TWIN WASH RESERVOIR
43	4476 TWIN WASH POND =1
43	4477 TWIN WASH POND =2
43	4478 TWIN WASH POND =4
43	4479 TWIN WASH POND =5
43	4480 TWIN WASH POND =6
43	4481 TWIN WASH POND =7
43	4482 TWIN WASH POND =8
43	4483 TWIN WASH POND =9
43	4484 TWIN WASH POND =10
43	4485 TWIN WASH POND =11
43	4486 TWIN WASH POND =13
43	4298 RYAN GULCH RESERVOIR
43	3907 BUCK CREEK RESERVOIR
43	4248 CROOKED WASH RES
43	4301 SAWMILL MOUNTAIN RES
43	4302 SOUTH FORK RESERVOIR
43	3902 BOIES RESERVOIR

43	4497 DESPERADO M SEDIMENT RP4
43	4498 JUDY BEARD RES
43	4303 STILLWATER RESERVOIR
43	4500 SPRING CR RES
43	4501 BOISE CR RES
43	4502 SMITH GULCH RESERVOIR
43	4503 P L RES NO 1
43	4304 STOREY GULCH RES
43	4504 TAYLOR RES