North Platte 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

COLORADO DIVISION OF WATER RESOURCES
DEPARTMENT OF NATURAL RESOURCES

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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 North Platte River Basin Water Resources Planning Model (North Platte 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. The models are created and analyzed through StateMod, an application developed by the State of Colorado for use in the CDSS project. The North Platte River Model Baseline dataset, which this document describes, extends from 1956 to 2007. It simulates current demands, current infrastructure and projects, and the current administrative environment as though they were in place throughout the modeled period.

The North Platte River Model was developed as a tool to test the impacts of proposed diversions, instream flows, reservoirs, water rights and/or changes in operations and management strategies. The model can simulate proposed changes using a highly variable physical water supply constrained by administrative water rights. The Baseline dataset can serve as a starting point, demonstrating stream conditions absent the proposed change but including current conditions. It is recommended the user compare the Baseline simulation results to results from a model to which they have added the proposed features, to determine the performance and effects of the proposed changes.

1.2 Development of the North Platte River Basin Water Resources Planning Model

The South Platte Decision Support System (SPDSS) included the development of a surface water resources planning model for the North Platte River basin. The model, as outlined in the SPDSS Feasibility Study, was to be developed using the StateMod program, similar to other DSS models. Efforts to support the development of the North Platte River Model were completed during early phases of the SPDSS. These efforts included the irrigated acreage assessment, user interviews, evaporative and climate data collection, and review of available streamflow and diversion data.

Continued efforts to develop the North Platte River Model built upon the work performed through SPDSS. Additional information and data was collected by coordinating with local water users and administrators to develop the consumptive use analysis and the framework for the StateMod model. Once the modeling framework was developed, operational information for special operations in the basin were understood and incorporated into the model. Finally, the model underwent calibration and the Baseline dataset was developed.

1.3 Results

The key results of the North Platte River Model efforts are as follows:

- A water resources planning model was developed that can make comparative analyses of historical and future water management policies in the North Platte River Basin. The model includes 100 percent of the basin's surface water use.
- An irrigated acreage assessment was completed for the basin, allowing for a comparison between historic and currently irrigated acreage and the total irrigated acreage as defined in the Equitable Apportionment Decree between Colorado and Wyoming.
- The calibration in the Historical simulation is considered very good, based on a comparison of historical to simulated streamflows, reservoir contents, and diversions. The model was calibrated for a study period extending from 1975 through 2007. This is a sufficient calibration period including wet, dry and averages years and reflects the best available data, specifically diversion data, in the basin.
- The model established hydrology for several tributaries in the model that historically have very little or no streamflow information.
- Calculated demands were developed which represent the amount of water crops would have used if given a full supply. These demands are the basis for the Baseline dataset demands.
- A Baseline dataset was prepared which, unlike the Historical dataset, simulates existing water resources systems on-line and operational for the period of 1956 through 2007. The Baseline dataset is an appropriate starting point for evaluating various "what if" scenarios over a long hydrologic time period containing dry, average, and wet hydrologic cycles.

1.4 Future Enhancements

The North Platte River Model was developed to include 100 percent of the basin's consumptive use through a combination of explicit and aggregated structures. The North Platte River Model could be enhanced in the future by incorporating additional streamflow information gained from new or re-activated streamflow gages; through incorporating additional information through consultation with the major water users on historical and future irrigation practices; and through the development of a daily model.

1.5 Acknowledgements

The work described in this report was funded by the State of Colorado, Colorado Water Conservation Board (CWCB) as part of the South Platte River Decision Support System (SPDSS). The project was directed by Ray Alvarado with the Colorado Water Conservation Board. The Leonard Rice Engineers, Inc. project team included Erin Wilson P.E., Kara Sobieski P.E., and Adam Kremers. The Jackson County Water Conservancy District Board and other basin water users were instrumental in the development of the supporting analysis. The project team would especially like to recognize and remember Dave Meyring (1941-2009) whose assistance in organizing water user interviews was invaluable.

2. What's in This Document

2.1 Scope of this Manual

This reference manual describes the CDSS North Platte 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 North Platte River Basin development or management scenario,
- Is interested in estimated conditions in the North Platte River Basin under current development over a range of hydrologic conditions, as simulated by this model, and in understanding the modeling estimates.

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

The manual describes the model input files, implementation issues encountered, approaches used to estimate parameters, and results of both calibrating and simulating the model. Limited general information is provided on the mechanics of assembling datasets and using various CDSS tools.

2.2 Manual Contents

This manual is divided into the following sections:

Section 3: The North Platte River Basin – describes the physical setting for the model, provides general review of water resources development, and issues in the basin.

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

- Aerial extent and spatial detail, including the model network diagram
- Study period
- Co-mingled irrigation systems
- Data filling methods

- Simulation of processes related to irrigation use, such as delivery loss, soil moisture storage, crop consumptive use, and return of excess diversions
- Development of natural flows (baseflows)
- Calibration methods

Section 5: Baseline Dataset – refers to the Monthly Baseline dataset 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 dataset 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 is advised to become fully aware of 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 the 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 Monthly Baseline simulation. It shows the state of the basin as the North Platte 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.

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

2.3 What's in other CDSS documentation

The user may well 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 North Platte River Model to implement specific future operations or extend the modeled period,
- Introduce changes that require regenerating the baseflow data file,
- Regenerate input files using the Data Management Interface (DMI) tools and HydroBase, or
- Develop a StateMod model for a different basin.

An ample body of documentation exists for CDSS and is available on the CDSS website (cdss.state.co.us). A user's biggest challenge may be in efficiently finding the information they need. This list of descriptions is intended to help in selecting the most relevant data source:

DMI user documentation – user documentation for **StateDMI** and **TSTool** is currently available, and covers aspects of executing these codes against the HydroBase database. Note that creating datasets for StateMod is only one aspect of their capabilities. The DMIs pre-process some of the StateMod input data. For example, StateDMI computed coefficients for distributing baseflow gains throughout the model and calculated irrigation demands, and TSTool filled missing time series data. Thus the documentation, which explains algorithms for these processes, is helpful in understanding the planning model estimates. In addition, the documentation is essential for the user who is modifying and regenerating input files using the DMIs.

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 user's understanding of North Platte River Model results. If the user is modifying input files, they should consult Section 4: Input Description to determine how to format files. To analyze model results in detail, they should review Section 5: Output Description, which describes the wide variety of reports available to the user.

Self-documented input files – an important aspect of the StateMod input files is that their genesis was documented in the files themselves. Command files that directed the DMIs creation of the files were 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 Memoranda – 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:

- CDSS Memorandum "South Platte Decision Support System Feasibility Study"
- Task Memorandum 3 – Identify Key Diversion Structures, Notes from Water District 47 Meeting with Water Users in the Basin
- Task Memorandum 5 – Key Structure, Cameron Pass Ditch and Michigan Ditch
- Task Memorandum 53.2 – Collect and Fill Monthly Climate Data
- Task Memorandum 53.3 – Assign Key Climate Information to Irrigated Acreage and Reservoirs
- CDSS Memorandum "North Platte Historical Crop Consumptive Use Analysis Report

3. The North Platte River Basin

The North Park basin lies in Jackson County in north-central Colorado and is comprised of the headwaters of the North Platte River and several major tributaries, including the Michigan River, Illinois River, and Canadian River. The basin opens northward into Wyoming, following the flow of the North Platte River. It is confined on the east by the Medicine Bow Range, on the west by the Park Range, on the south by the Rabbit Ears Range, and on the north by the Wyoming state line. The basin covers all of Jackson County in Colorado as shown in **Figure 3.1**.

3.1 Physical Geography

North Park basin covers approximately 2,050 square miles. North Park ranges in elevation between 8,000 and 9,000 feet. The North Platte River is the primary stream in the basin, with major tributaries including the Michigan River, Illinois River, and Canadian River. The North Park region includes the Routt National Forest which covers 1.1 million acres of federal lands from north-central Colorado up to central Wyoming. The region is covered with 46 percent of forested area including the Routt National Forest.

Figure 3.1 – North Platte River Basin

3.2 Human and Economic Factors

The area remains sparsely populated, with the 2000 census estimating the population at 1,686. Walden is the only major population center in the basin with approximately 725 people. The major water use in the basin is irrigation, with over 400 irrigation ditches diverting from the mainstem and the numerous tributary streams throughout the basin. Total irrigated acreage in the basin, based on 2001 estimates, is approximately 116,000 acres. A portion of the North Platte water is exported to the Front Range via Michigan Ditch and Cameron Pass, which combined divert approximately 4,500 acre-feet per year out of the basin.

The North Platte River Basin is expected to see an increase in municipal and industrial water demand due to interest in the natural resources in the basin, including fossil fuels. The North Park basin has a history of logging, lumber mills and coal mines, but now is reliant on ranching, hunting and outdoor recreation as its main industries. The Arapaho National Wildlife Refuge, as well as other federal and state owned land, provide for excellent hunting and wildlife viewing areas. These lands, rich in wildlife, attract visitors from all over, bolstering tourism in the basin. The predominant wildlife that can be found in the basin includes moose, mule deer, elk, sage grouse, trout, waterfowl, and bald eagles.

3.3 Water Resources Development

The North Platte River basin has seen water resources development in the form of private irrigation systems, transbasin diversions, and reservoir projects. Table 3.1 summarizes key development and agreements within the basin over time.

Table 3.1 – Key Water Resources Developments

Date	Description
1902	Cameron Pass Ditch
1908	Michigan Ditch
1945	North Platte Equitable Apportionment Decree (Amended 1953)
1954	Walden Reservoir
1955	Lake John
1980	Meadow Creek Reservoir
2001	Modified North Platte Decree

3.4 Water Rights Administration and Operations

Many of the basin's administrative calls occur on the tributaries to the North Platte River and not on the mainstream. The major tributaries generally are under administration in dry years and often under administration. The priority and location of calling rights vary throughout the year. Newport Ditch on Pinkham Creek and the Wolfer Creek Ditch on the Roaring Fork are two examples of the frequently calling rights on the tributaries.

3.5 Section 3 References

1. North Platte River Basin Facts, Colorado Water Conservation Board, available at http://cwcb.state.co.us

2. Census and Population Estimate Data, Colorado Demography Office, available at http://dola.colorado.gov/demog/Demog.cfm

3. Task 3 – Identify Key Diversion Structures, Notes from Water District 47 Meeting Memorandum, available at http://cdss.state.co.us

4. Modeling Approach

This section describes the approach taken in modeling the North Platte 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 North Platte 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 dataset is a representation of current water use, demand, and administrative conditions, which can serve as the comparative 'base' in paired simulations comparing river conditions with and without proposed future changes. By modifying the Baseline dataset to incorporate the proposed features to be analyzed, the user can create the second input dataset of the pair.

The model estimates the basin's current 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 some small structures at 'aggregated' nodes. Structures that operated together to serve a single demand were combined and represented at a 'multi-structure system' node or 'diversion system' node. The model was developed for the period from 1956 through 2007 creating a long-term dataset reflecting a wide variety of hydrologic subsequences and 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

Figure 4.1 shows the network diagram for the North Platte River model. The network diagram includes over 580 nodes, representing diversion structures, reservoirs, trans-basin diversions, and instream flow reaches on 90 tributaries to represent the basin. The network begins with the headwaters of the North Platte River and ends at the Colorado-Wyoming border.

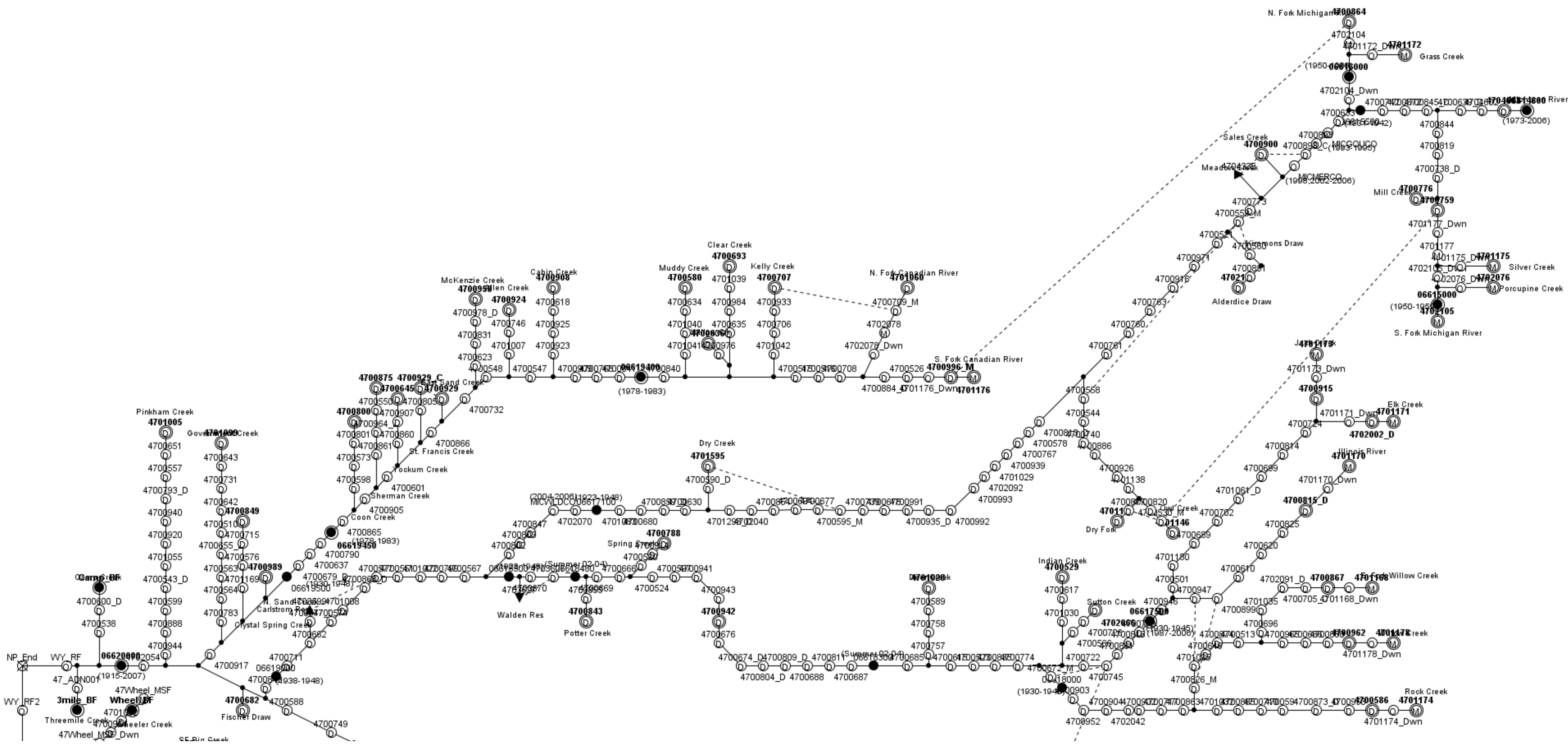


Figure 4.1a Network Diagram – North Platte River Planning Model

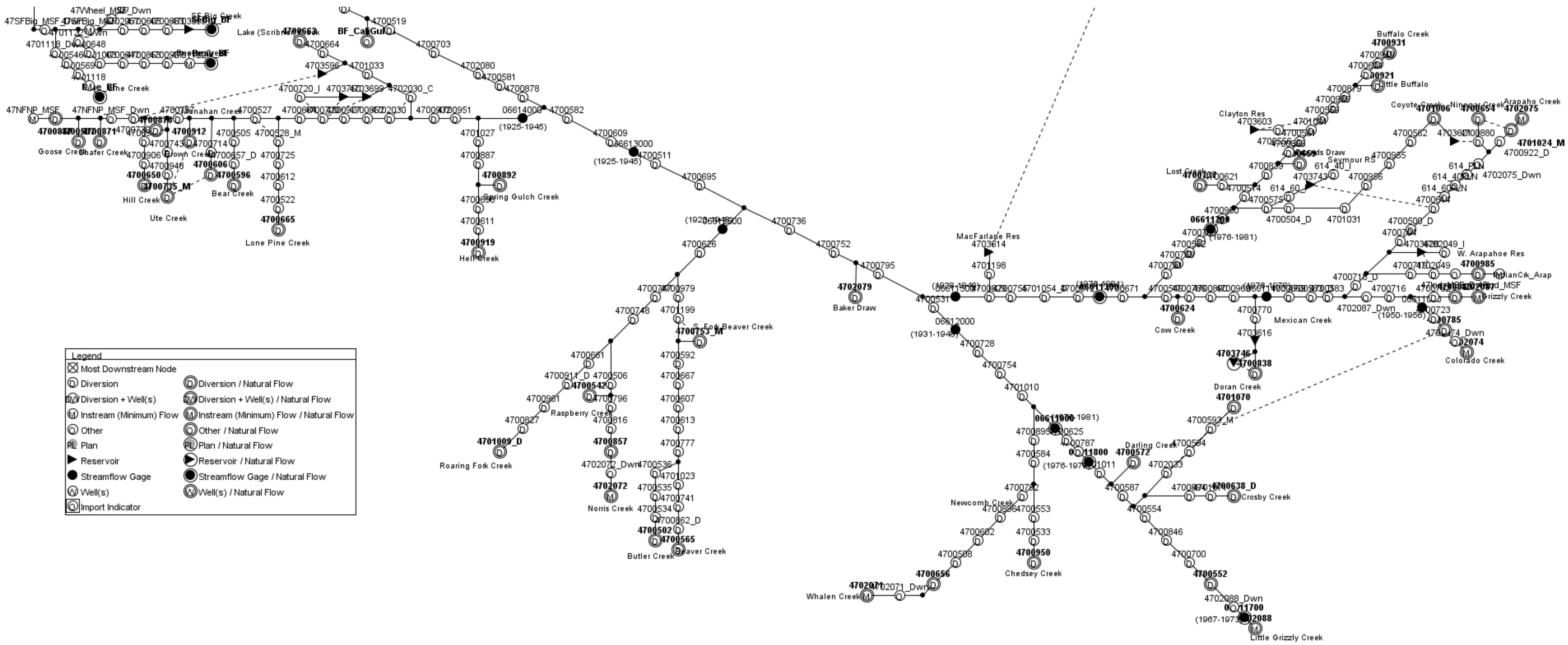


Figure 4.1b Network Diagram – North Platte River Planning Model

4.2.2. Diversion Structures

4.2.2.1 Key Diversion Structures

Due to the extent that was taken to include several North Platte tributaries in the model and the prevalence of diversion data for most structures, a goal of this model was to represent all possible structures 'explicitly'. This enabled the model to represent all the consumptive use while identifying more exact controlling or constraining points in the model. By predominately modeling structures as 'explicit', it also allows the user to have more options during future simulations to turn explicit demands on or off, or analyze which demands would be affected by a future change.

The ability to 'aggregate' structures was utilized to a small extent in this model, with one aggregate diversion node currently modeled. The operating practice whereby two or more diversion structures serve the same irrigation demand is prevalent in the North Platte basin, due to several large ranching operations in the basin. Groups of diversion structures on the same tributary that operate in a similar fashion to satisfy a common demand are sometimes combined into 'diversion systems'. 'Multi-structure systems' are the same as diversion systems, except that diverting structures in a multi-structure system are located on different tributaries. The North Platte explicitly models over 440 key structures, including diversion and multi-structure systems.

4.2.2.2 Aggregate Structures, Diversion Systems and Multi-Structure Systems

The ability to aggregate irrigation structures was utilized in the Threemile Creek basin because a small amount of irrigated acreage existed on multiple tributaries in the creek's headwaters. Modeling the small tributaries with little irrigable land was not practical, and the irrigation structures were aggregated into a single Threemile Creek aggregate node. It represents the combined historical diversions, demand, and water rights of the small structures within the Threemile Creek sub-basin. The structures included in the Threemile Creek aggregate node (47_ADN001) are:

- Spring Creek Ditch (4700891)
- Three Mile Ditch (4700918)
- Valley Ditch (4700930)
- Six Mile Ditch (4700877)

The decision to create diversion systems and multi-structure systems was based on Water Commissioner and/or water user input, or supplemental water rights information found in the State's HydroBase database. If a water right was decreed as an alternate point of diversion to another structure, these structures were often combined into diversion or multi-structure systems. Water Commissioner notes in HydroBase also indicated the presence of multiple structures serving the same irrigation demand. For example, the diversion comments may indicate several structures serving the same ranch, or irrigated acreage for a specific structure may have been included in the irrigated acreage survey of another structure (i.e. co-mingled irrigation practices). Water user input was crucial in the modeling of this basin, and the irrigators provided insight into each diversion or multi-structure system that was proposed for the model.

Diversion system and multi-structure nodes are designated in the model by the primary structure WDID followed by a '_D' or '_M' suffix, respectively. The primary structure is typically the structure where the actual demand is located, or if multiple structures have demands, the structure with the most senior water right is the primary structure. Other structures included in the diversion or multi-structure node are called secondary structures and are often simply carrier structures to the primary demand. Nodes for secondary structures in diversion system nodes are not included in the model, however secondary structures in multi-structure systems remain in the model as 'place-holders' for diversions and water rights. Thirty-seven diversion systems are modeled in North Platte basin, representing over 90 individual structures. Likewise, fifteen multi-structure systems are modeled in the basin, representing over 40 individual structures. Table 4.1 lists the diversion system nodes in the North Platte model, while Table 4.2 lists the multi-structure system nodes.

Aggregate and diversion system node data is based on data of the individual structures in each combined node. Historical diversions were developed by summing the historical diversions of the individual structures, and their irrigation water requirements were developed from the combined acreage associated with all structures in the aggregate or system. Aggregate and diversion system node water rights include the individual water rights assigned to each structure in the aggregate or system.

Multi-structure system historical diversion data and irrigation water requirement was developed in the same fashion as diversion system node data, by summing the data for each individual structure. However since secondary structures in multi-structure systems remain in the model, the water rights remain at the individual structures and operating rules are used to carry the water to the multi-structure demand through the original structures.

Table 4.1
North Platte Diversion Systems

Node	Diversion System Name	Primary Structure	Secondary Structures
4700500_D	Arapahoe DivSys	4700500	4700616
4700504_D	Badger State DivSys	4700504	4701004
4700543_D	Capron DivSys	4700543	4702056
4700583_D	Damfino DivSys	4700583	4700712, 4700870
4700590_D	Dike DivSys	4700590	4701056
4700600_D	Dwinell DivSys	4700600	4700968
4700638_D	Glendale DivSys	4700638	4700503, 4700509, 4701048
4700639_D	Gould DivSys	4700639	4700641, 4701318, 4701319, 4701320
4700655_D	Oxford DivSys	4700655	4700823
4700657_D	Haworth DivSys	4700657	4700658
4700674_D	Hubbard DivSys	4700674	4700675, 4701012
4700679_D	Hunter DivSys	4700679	4700540
4700705_D	Sutton DivSys	4700705	4700727, 4701026
4700718_D	Lawrence DivSys	4700718	4700959
4700738_D	Lost Treasure DivSys	4700738	4700631
4700793_D	Newport DivSys	4700793	4700780
4700804_D	North Park DivSys	4700804	4700798
4700809_D	Oklahoma DivSys	4700809	4700810
4700813_D	Old SC DivSys	4700813	4702010, 4702059, 4702028, 4702027, 4701192, 4701193, 4701194
4700815_D	Olive DivSys	4700815	4700824
4700845_D	Poverty DivSys	4700845	4700934, 4700734
4700859_D	Ruction DivSys	4700859	4700681
4700862_D	Saint Joseph DivSys	4700862	4700701
4700868_D	Seneca DivSys	4700868	4700627
4700873_D	Shearer DivSys	4700873	4701021
4700884_D	Smith DivSys	4700884	4700622, 4700858
4700911_D	Sunday DivSys	4700911	4700660
4700922_D	Titanic DivSys	4700922	4702046
4700935_D	Walden Ditch DivSys	4700935	4700936, 4702050
4700964_D	Yocum DivSys	4700964	4700963
4700978_D	Kenny DivSys	4700978	4700808
4701009_D	Norell DivSys	4701009	4700782
4701054_D	Big Grizzly DivSys	4701054	4700830
4701061_D	Garland DivSys	4701061	4700628
4701298_D	Smith Diversion DivSys	4701298	4701297
4702002_D	Elk Creek DivSys	4702002	4702003
4702091_D	Roslyn DivSys	4702091	4702017

Table 4.2
North Platte Multi-Structure Systems

Node	Diversion System Name	Primary Structure	Secondary Structures
4700528_M	Briggs Bohn Ditch MS	4700528	4700527
4700530_M	Brocker Endomile MS	4700530	4700759, 4700817, 4700820
4700559_M	Cleveland Ditch MS	4700559	4700558, 4700560
4700593_M	Doran Ditch MS	4700593	4700785, 4700594, 4701070, 4702033
4700595_M	Dry Creek Ditch MS	4700595	4701595
4700672_M	Howard Ranch MS	4700672	4700745
4700709_M	Kermode MS	4700709	4700707, 4701060
4700735_M	Lookout Ditch MS	4700735	4700606, 4700912
4700753_M	Manville Ditch 2 MS	4700753	4701199
4700826_M	Peabody Ditch MS	4700826	4700947, 4700899
4700929	Ute Pass Creek MS [1]	4700929	4700929_C
4700996_M	Sales Ditch 2 MS	4700996	4700864
4701024_M	Cochrane MS	4701024	4700654

[1] Ute Pass Creek is decreed to divert water from two tributaries, however serves a single irrigation demand. The primary structure was modeled in its historic location on East Sand Creek and a 'carrier' node (4700929_C) was created and placed on St. Francis Creek. The two nodes were then combined in the multi-structure.

4.2.2.3 Irrigation Demand Structures

Irrigation demand structures are used to represent a common irrigation demand that receives water from several sources. An irrigation demand structure is recommended if:

- The irrigation demand can be met through more than one river headgate.
- An off-channel reservoir delivers water directly to the demand. The demand may also be met from direct diversions.
- The irrigation demand can be met through a single headgate, but water sources have different delivery losses. For example, deliveries from an upstream reservoir may experience both river losses and canal losses whereas direct diversions only experience canal losses.
- River headgate delivers water to more than one demand, and at least one of those demands is irrigation.

The irrigation demand is isolated and represented by an irrigation demand structure, designated with a '_I' suffix. Operating rules are then used to carry direct flow diversions from the primary structure or reservoir releases using the appropriate water rights. Table 4.3 lists the irrigation demand structure nodes in the North Platte model.

Irrigation demand structure node data is based on the data associated with irrigation uses of the primary structure. Historical diversions were developed by separating out headgate direct flow diversions from diversions to storage, then adding in off-channel reservoir releases to irrigation if applicable. Their irrigation water requirements were developed from the acreage associated with the primary structure. Irrigation demand structures do not inherently have water rights, water rights used for irrigation remain at the headgate structure and operating rules are used to carry the diverted irrigation water and reservoir releases.

Table 4.3
North Platte Irrigation Demand Structures

Node	Diversion System Name	Primary Structure
4700556_I	Clayton Ditch IRR	4700556
4700577_I	Cumberland Ditch IRR	4700577
4700720_I	Legal Tender IRR	4700720
4702049_I	West Arapahoe Feeder No 2 IRR	4702049
614_60_I 614_40_I	Eureka Ditch IRR [1]	4700614

[1] Eureka Ditch Irrigation Demand was divided (60% / 40%) into two irrigation demands based on operational differences as indicated by the water user.

4.2.2.4 Municipal and Industrial Uses

The Town of Walden is the only major municipality in the basin. The Town of Walden is served by two high capacity wells, which are currently not included in the model. The town also has a senior river diversion (Walden Michigan River Diversion, 4701083), included in the model just upstream of the Michigan River at Walden streamgage, that is used when low aquifer levels limits the use of the wells. The Walden Michigan River Diversion node water rights and historical diversions are included in the model, primarily to model Walden municipal demand for future scenarios.

4.2.3. Reservoirs

4.2.3.1 Key Reservoirs

Reservoirs in the basin used primarily for irrigation are considered key reservoirs, and are explicitly modeled. There are twelve key reservoirs with a combined total capacity of approximately 24,200 acre-feet. For reservoirs that operate for both irrigation and recreational/piscatorial uses, separate accounts were created in the reservoirs. The irrigation account experiences evaporative consumptive use and can release to specific irrigation demands, set through operating rules. Recreational and piscatorial accounts, generally owned by the Colorado Department of Wildlife (CDOW), are maintained as full reservoir accounts, resulting in only evaporative consumptive use. The storage volume lost to evaporation is filled, based on physical and legally available water. Other reservoirs in the basin used solely for recreation or piscatorial uses were not included in the model.

Limited information detailing the area-capacity surveys of the key reservoirs was available during these modeling efforts. Each reservoir was estimated to be 10 feet deep and was assigned a 3 point area-capacity curve. The first point is zero capacity and zero area. The second point is total capacity with the area equal to the total capacity divided by 10. The third point is a very large capacity with the area equal to the total capacity divided by 10.

4.2.3.2 Reservoir Systems

Two of the reservoir nodes in the model represent reservoir systems. Each reservoir system represents two or more reservoirs that operate in a similar fashion or share water rights. The reservoir system is represented in the model under the primary reservoir WDID. The following list summarizes each reservoir system.

- **Seymour Reservoir System** includes Seymour Reservoir (4703743) and Hecla Reservoir (4703608). The reservoirs are both located on and filled from Eureka Ditch (4700614), and are operated in tandem to serve Eureka Ditch irrigation demands.

- **Slack Weiss Reservoir System** includes Slack & Weiss Reservoir (4703621) and Ninegar Reservoir (4703777). The reservoirs are both located on Ninegar Creek and are filled from Slack Weiss Ditch (4700880). The reservoir operator noted that the reservoirs could also be filled using Harrison Ditch (4700654), however the diversions to storage are minimal and Harrison Ditch is not modeled explicitly (part of 4701024_M), therefore this filling operation is not modeled. According to the reservoir operator, approximately two-thirds of the releases serve irrigation demands under Allard Ditch (4701006) and one-third of the releases serve irrigation demands under Cochrane Ditch (4701024_M). Separate reservoir accounts were used to accomplish these release operations.

With reservoir systems, the water rights from secondary reservoirs are assigned to the primary reservoir in the model, therefore all storage under the reservoir system will be filled using the combined water rights. The same method for estimating area-capacity tables used for key reservoirs was also used with reservoir systems, based on the total volume summed from the reservoirs included in each reservoir system. The evaporation for the system is based on the combined surface area of all the reservoirs in the system.

4.2.4. Instream Flow Structures

The model includes 26 instream flow reaches; 22 represent existing instream flow rights held by the CWCB and 4 represent proposed CWCB instream flow reaches at the time of the model completion. These are a subset of the total CWCB tabulation of rights for the Water District because a portion of instream flow decrees are for stream reaches high in the basin, above the upper extent of the model network.

4.3 Modeling Period

The North Platte River Model dataset extends from 1956 through 2007 and operates on a calendar year basis. The calibration period was 1975 through 2007, a period selected because reliable historical diversion data were readily available for key structures. In addition, the period reflects most recent operations in the basin, and includes both drought (1977, 1989-1992, 2000-2003) and wet cycles (1983-1985).

4.4 Data Filling

In order to extend the dataset to 1956, a substantial amount of reservoir content, diversion, demand, and natural flow time series data needed to be estimated. In many areas of the North Platte basin, HydroBase data begins in 1974, although for some structures there is additional historical data. A data-centered approach to filling missing data was taken, utilizing CDSS tools, specifically StateDMI and TSTool, to automate the filling of missing data. This section describes the data filling methods for the North Platte River Model.

4.4.1. Historical Data Review

Review of historical diversion records identified two periods during which diversions appeared to be inaccurate based on trends over the entire period of record. The diversion records in the early 1970s throughout the basin are much higher than diversions recorded for remaining historical period. The opposite is true during the mid-1950s, where daily diversion records in HydroBase appear not to have been filled forward using the SEO standard algorithm, resulting in diversion records that are much lower than would be expected even during that dry period. Based on review of Water Commissioner Field books and discussions with current and past Division 6 personnel, diversion records for these time periods were determined to be unreliable and were replaced with filled data as described below.

4.4.2. Automated Time Series Filling

A data-centered approach was taken to fill time series data (i.e. historical diversions, demand, historical reservoir contents, and reservoir targets) input to the model. 'Data-centered' implies that the data input into the model is maintained in an accessible database, specifically HydroBase, and is accessed and manipulated through data management interfaces (DMIs), including StateDMI and TSTool. The approach allows the user to easily make changes to input data through the DMIs and allows for a consistent and reproducible approach to creating the input data. The DMIs operate using command files, which can be 'run' to create the time series data. These command files are included with the final dataset deliverable.

The first attempt at filling missing data is to fill with a pattern according to an 'indicator' gage. A pattern file was created for the only long-term gage in the North Platte basin, North Platte near Northgate, CO gage (06620000). Each month of the streamflow at this indicator gage was categorized as an Average, Wet, or Dry month through a process referred to as 'streamflow characterization'. Months with gage flows at or below the 25^{th} percentile for that month are characterized as ‘Dry’, while months at or above the 75th percentile are characterized as ‘Wet’, and months with flows in the middle are characterized as ‘Average’. Using this characterization, missing data points were filled based on the Wet, Dry, or Average pattern. For example, a data point missing for a Wet March was filled with the average of other Wet Marches in the partial time series, rather than all Marches. The North Platte near Northgate, CO characterization was used for data in Water District 47. If missing data still existed after filling with a pattern file, historical monthly averages were used to fill the remaining data.

4.4.2.1 Historical Reservoir Contents

Storage records for the key reservoirs were generally available from the State’s HydroBase database starting in 1974. From 1974 to present, first linear interpolation over a maximum of six missing months, then historic month averages were used to fill missing end-of-month storage data. Due to lack of data, the storage records prior to 1974 were filled using the reservoirs capacity.

With the reservoir systems, the individual reservoir storage records were filled first, using the techniques discussed above, then the storage records were combined to create a single storage record the system.

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 collected in the CDSS Technical Papers:

  -Data Extension Feasibility

  -Evaluate Extension of Historical Data

  -Characterize Streamflow Data

  -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. Natural Flow 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 stream flow time series are complete, diversions, return flows, changes in storage, and so forth are added to or subtracted from the gage value to produce an estimated natural flow.

The typical approach was deemed inadequate for general CDSS efforts for study periods that extend 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 occurred at the earlier time. The CDSS approach is therefore to estimate natural flows at points where actual gage records are available, and then correlate between naturalized flows, as permitted by availability of data. Ideally, since natural flows do not reflect human activity, the relationship between two sets of natural flows is independent of the resource use and can be applied to any period.

Natural flow 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 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 eligible correlations.

There is limited gaged streamflow data in the North Platte Basin that can be used to develop natural flows. This means that not only is a large percentage of natural flow data filled using the methods above, it also means that with only one long-term gage, the North Platte River at Northgate, CO gage, most of the natural flow data is filled using the natural flows generated at this gage location. Approximately 95 percent of the gage site natural flows are filled using the methods discussed above.

The filling approach discussed above could not be used for the natural flow estimates in Grizzly Creek due to its unique streamflow pattern. Specifically in Grizzly Creek, runoff peaks earlier in the year compared to other runoff patterns in the basin, therefore the approach of filling natural flow using other natural flow estimates within the North Platte River basin was not used. Instead, the streamflow information for Grizzly Creek was first filled using regression techniques with a streamflow gage outside of the North Platte basin that more closely mimicked Grizzly Creek streamflow patterns. Then natural flows were estimated using the process discussed in Section 4.7 – Natural Flow Estimation.

Where to find more information

- The task memorandum documenting application of the Mixed Station Model to CDSS natural flows is entitled 'Subtask 11.10 Fill Missing Baseflows' and is in the CDSS Technical Papers. It describes a sensitivity investigation of the use of historical gage data in lieu of natural flow estimates when the latter is unavailable.

4.5 Consumptive Use and Return Flow Amounts

The consumptive use and return flow data are key components of both natural flow estimation and simulation in water resources modeling. StateMod's natural flow 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 natural flow, 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 North Platte 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 multiplied by maximum efficiency, and the balance of the diversion returns to the stream.

The model is supplied with a time series of irrigation water requirements for each structure, based on its crop type and irrigated acreage. This information was generated using the CDSS StateCU model. Maximum efficiency is also input to the model. For the North Platte River basin, maximum efficiency is estimated to be 60 percent.

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 dataset, 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 potential ET 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')

$TR = SR$ (Non-consumed equals 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')

$TR = SR$ (Non-consumed equals total return flow)

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

$\mathbf{CU_w}$ is water supply limited consumptive use;

$\mathbf{SS_m}$ is the maximum soil moisture reservoir storage;

$\mathbf{SS_i}$ is the initial soil moisture reservoir storage;

$\mathbf{SS_f}$ 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, the maximum system efficiency is 60 percent; therefore a maximum of 60 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. In this case, the crop needs are completely satisfied, and the water supply-limited consumptive use equals the irrigation water requirement.

When 60 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 60 percent of the diversion deemed unable to reach the field (non-consumed).

With respect to consumptive use and return flows, aggregated irrigation structures, diversion system and multi-structure systems are treated as described above, where the irrigation water requirement is based on total acreage for the aggregate or system.

4.5.2. Constant Efficiency for Other Uses and Special Cases

In specific cases, the North Platte River Model applies an assumed, specified annual or monthly efficiency to a diversion in order to determine consumptive use and return flows. This approach is applied to transbasin diversions and irrigation carrier canals used in multi-structure systems. The transbasin diversions in the North Platte River Model were assigned a diversion efficiency of 100 percent in all months. During both natural flow estimation and simulation, the entire amount of the diversion is estimated to be removed from the hydrologic system.

In multi-structure systems, both the primary and secondary structures in the system are modeled, as it is important to reflect diversions on the tributaries from which they actually divert. The demand, however, is only modeled at the primary structure location, and the secondary structures 'carry' irrigation diversions to the primary structure's demand. Irrigation carrier canals and other carriers that do not irrigate lands were assigned a diversion efficiency of zero in all months, reflecting that 100 percent of the diversions 'return' to the primary structure demand. See Table 4.2 for a list of the secondary structures in each multi-structure system.

As with multi-structure systems, the primary structures associated with the irrigation demand structures 'carry' irrigation diversions to the irrigation demand structure. These irrigation carrier canals were assigned a diversion efficiency of zero in all months, reflecting that 100 percent of the diversions 'return' to the irrigation demand. See Table 4.3 for a list of the primary structures for each irrigation demand structure.

Each 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 through 2007. 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 CU Irrigation Parameter Yearly file (Section 5.5.2)
  - Soil moisture capacity in the StateCU Structure file (Section 5.5.1)
  - Loss to the hydrologic system in the Return Flow Delay Table file (Section 5.4.2)

4.6 Disposition of Return Flows

4.6.1. Return Flow Timing

Return flow timing is simulated in 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. Due to the fact that a great majority of the diversions in the basin are for the same use, namely irrigation, and the irrigated meadows are generally close to the point of diversions, a single return flow pattern is used for the entire basin. The return flow pattern is a generalized pattern derived through conversations with ranchers and farmers throughout the basin. Per these conversations, approximately 85 percent of the non-consumed surface water returns in the same month that the diversion took place. The remaining non-consumed water, 15 percent, returns in the following month. Sensitivity of this return flow pattern compared to patterns developed through Glover equations in other basins was tested during calibration, with this return flow pattern yielding the most accurate calibration.

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 water users in the basin. Some return flow locations were modified during calibration.

4.7 Natural Flow Estimation

In order to simulate river basin operations, the model must have 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 ‘natural flow‘. The term is used in favor of ‘virgin flow’ or ‘baseflow’ because it recognizes that some historical operations can be left ‘in the gage’, with the estimation 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 natural flow time series at specified discrete inflow nodes. This process was executed prior to executing simulations, and the resulting natural flow file became part of the input dataset for subsequent simulations. Natural flow estimation requires three steps: 1) adjust USGS stream gage flows using historical records of operations to get natural flow time series at gaged points, for the gage period of record; 2) fill the natural flow time series by regression against other natural flow time series; 3) distribute natural flow gains above and between gages to user-specified, ungaged inflow nodes. These three steps are described below.

4.7.1. Natural Flow Computations at Gages

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

$$Q_{natural\ flow} = Q_{gage} + Diversions - Returns - Imports +/- \Delta Storage + Evap +/- \Delta Soil\ Moisture$$

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 and soil storage 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

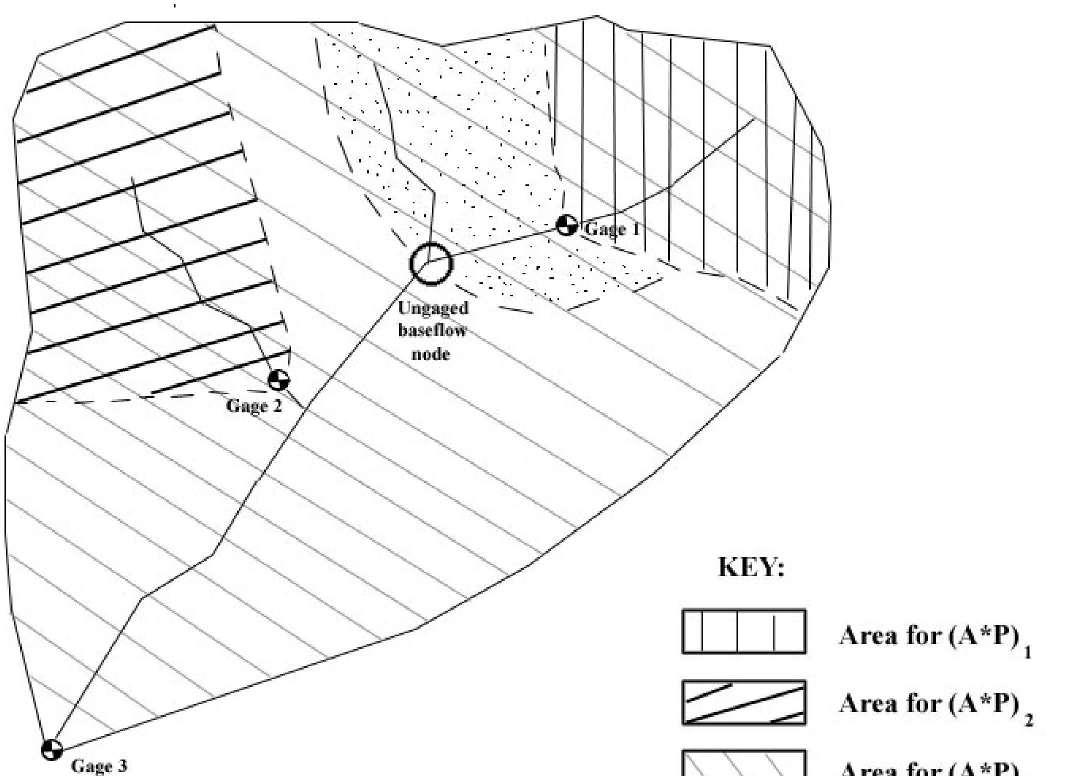
- When StateMod is executed to estimate natural flows at gages, it creates a Baseflow Information file *(*.xbi*) that shows this computation for each gage and each month of the time step.

4.7.2. Natural Flow Filling

Wherever gage records are missing, natural flows are estimated as described in Section 4.4.3 - Natural Flow Filling.

4.7.3. Distribution of Natural Flow to Ungaged Points

In order for StateMod to have a water supply to allocate in tributary headwaters, natural flow must be estimated at all ungaged headwater nodes. In addition, natural flow gains between gages are modeled as entering the system at ungaged points, to better simulate the river's growth due to generalized groundwater contributions and unmodeled tributaries. During calibration, other ungaged nodes were sometimes made natural flow nodes to better simulate a water supply that would support historical operations.



$$BFungaged = BF_1 + \frac{(A*P)ungaged}{(A*P)_3 - (A*P)_2 - (A*P)_1} *(BF_3 - BF_2 - BF_1)$$

Figure 4.2 Hypothetical Basin Illustration

StateMod has an operating mode in which, given natural flows at gaged sites and physical parameters of the gaged and ungaged sub-basins, it distributes natural flow gains spatially. The default method ('gain approach') for assigning natural flow to ungaged locations pro-rates natural flow gain above or between gages according to the product of drainage area and average annual precipitation. That is, each gage is assigned an 'Area * Precipitation' (A * P) term, equal to the product of total area above the gage, and average annual precipitation over the gage's entire drainage area. Ungaged natural flow points are assigned an incremental 'A * P', the product of the incremental drainage area above the ungaged natural flow point and below upstream gages, and the average annual precipitation over that area. Figure 4.2 illustrates a hypothetical basin and the areas associated with each of three gages and an ungaged location.

The portion of the natural flow gain below Gages 1 and 2 and above Gage 3, at the Ungaged location between the gages, is the gage-to-gage natural flow gain (BF_3 minus ($BF_2 + BF_1$)) times the ratio $(A^* P)_{ungaged}/[(A^* P)_{downstream\ gage} - \Sigma (A^* P)_{upstream\ gage(s)}]$. Total natural flow at the ungaged location is equal to this term, plus the sum of natural flows at upstream gages. In the example there is only one upstream gage, having natural flow BF_1.

A second option for estimating headwater natural flows was sometimes invoked if the default method created results that did not seem credible. This method, referred to as the 'neighboring gage approach', created a natural flow time series by multiplying the natural flow series at a specified gage by the ratio $(A^*P)_{headwater}/(A^*P)_{gage}$. This approach was effective, for example, for an ungaged tributary parallel and close to a gaged tributary.

The approaches discussed above were used to estimate natural flow at a majority of the ungaged locations in the model. There are six natural flow locations on streams that are tributary to the North Platte River downstream of the North Platte near Northgate, CO gage, therefore a portion of the natural gains seen at the North Platte gage could not be distributed to those locations using the approaches discussed above. Instead the drainage A* P factors for these natural flow locations were used to estimate natural flow as a percentage of natural flow estimated at other locations in the basin.

For example, the characteristics of Beaver Creek are similar to those of North Fork of the North Platte River, therefore the natural flow of Beaver Creek was estimated by scaling the natural flow estimated for the upper reaches of the North Fork of the North Platte River based on a comparison of their respective A* P factors. This approach, executed through TSTool commands, was used for the natural flow nodes listed below in Table 4.4.

Table 4.4
North Platte Ungaged Natural Flow Nodes Downstream of the Northgate Gage

Node	Natural Flow Node Name	Comparative Natural Flow Node
Line_BF.	Line Creek	Pleasant Valley Ditch (4700837)
Wheel_BF	Wheeler Creek	Dry Creek Ditch – Riley Creek (4701595)
SFBig_BF	South Fork Big Creek	Hillside Ditch (4700665)
Beav_BF.	Beaver Creek	Pleasant Valley Ditch (4700837)
Camp_BF	Camp Creek	Rarus Ditch (4700849)
3mile_BF	Threemile Creek	California Gulch (CaliGulch_BF)

Where to find more information

- Documentation for **StateDMI** describes computation of natural flow 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 streamflow gages, reservoir levels, and diversions. The North Platte River Model was calibrated in a two-step process described below. The issues encountered and results obtained are described in Section 7.

4.8.1. First Step Calibration

In the first calibration run, the model was executed with relatively little freedom with respect to operating rules. Headgate demand was simulated by historical diversions, and historical reservoir contents served as operational targets. The reservoirs would not fill beyond the historical content even if water was legally and physically available. Operating rules caused the reservoir to release to satisfy beneficiaries' demands, but if simulated reservoir content was higher than historical after all demand was satisfied, the reservoir released water to the river to achieve the historical end-of-month content. In addition, multi-structure systems would feature the historical diversion as the demand at each diversion point.

The objective of the first calibration run was to refine natural flow hydrology and return flow locations before introducing uncertainties related to rule-based operations. Diversion shortages, that is, the inability of a water right to divert what it diverted historically, indicated possible problems with the way natural flows were represented or with the location assigned to return flows back to the river. Natural flow issues were also evidenced by poor simulation of the historical gages. Generally, the parameters that were adjusted related to the distribution of natural flows (i.e., A* P parameters or the method for distributing natural flows to ungaged locations), and locations of return flows.

4.8.2. Second Step Calibration

In the second calibration run, constraints on reservoir operations were relaxed. As in the first calibration run, reservoirs were simulated for the period in which they were on-line historically. Reservoir storage was limited by water right and availability, and generally, reservoir releases were controlled by downstream demands. Exceptions were made for reservoirs known to operate by power or flood control curves, or other unmodeled considerations. In these cases, targets were developed to express the operation. For multi-structure systems in the North Platte River Model, the centralized demand was placed at the final destination nodes, and priorities and legal availability govern diversions from the various headgates.

The objective of the second calibration step was to refine operational parameters. For example, poor calibration at a reservoir might indicate poor representation of administration or operating objectives. Calibration was evaluated by comparing simulated gage flows, reservoir contents, and diversions with historical observations of these parameters.

Where to find more information

- Section 7 of this document describes calibration of the North Platte River Model

4.9 Baseline Dataset

The Baseline dataset is intended as a generic representation of current conditions on the North Platte River and tributaries, 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. Existing water resources systems are online and operational in the model from 1956 forward, as are junior rights and current levels of demand. The dataset 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.

4.9.1. Calculated Irrigation Demand

In the Baseline dataset, 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 1956 through 2007 is generated directly, by taking the maximum of crop irrigation water requirement divided by average monthly irrigation efficiency, and historic diversions. The irrigation efficiency may not exceed the defined maximum efficiency (60 percent), however, which represents a practical upper limit on efficiency for flood irrigation systems. Thus calculated demand for a perennially shorted diversion (irrigation water requirement divided by diversions is, on average, greater than 0.60) will 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

The Town of Walden municipal surface water demand reflects the pattern-filled monthly diversions over the 1956 to 2007 period.

4.9.3. Transbasin Demand

The two transbasin diversion demands were set to the historic pattern-filled monthly diversions over the period 1956 through 2007 period.

4.9.4. Reservoirs

Reservoirs are represented as being on-line throughout the study period, at their current capacities. Initial reservoir contents were set to max capacity. During simulation, StateMod allows reservoir releases to satisfy unmet headgate demand, based on the reservoir being a supplemental supply to direct flow rights.

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 North Platte 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. For instance, they may want to look at the effect of conditional water rights on available flow. 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 simply 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 natural flow 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 characteristics of plan structures in the model: type, efficiency, return flow location, and failure criteria. The plan structures work in conjunction with operating rules
- Section 5.9 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 all 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 natural flows 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 natural flow generation.

5.1.1. For Baseline Simulation

The listing below shows the file names in *np2008B.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
np2008.ctl	Control file – specifies execution parameters, such as run title, modeling period, options switches	Section 5.2
np2008.rin	River Network file – lists every model node and specifies connectivity of network	Section 5.3.1
np2008.ris	River Station file – lists model nodes, both gaged and ungaged, where hydrologic inflow enters the system	Section 5.3.2
np2008.rib	Natural Flow Parameter file – gives coefficients and related gage ID’s for each natural flow node, with which StateMod computes natural flow gain at the node	Section 5.3.3
np2008.rih	Historical Streamflow file – Monthly time series of streamflows at modeled gages	Section 5.3.4
np2008x.xbm	Natural Flow Data file – time series of undepleted flows at nodes listed in NP2008.ris	Section 5.3.5
np2008.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
np2008.dly	Delay Table file – 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 extinguished	Section 5.4.2

File Name	Description	Reference
np2008.ddh	Historical Diversions file – Monthly time series of historical diversions	Section 5.4.3
np2008B.ddm	Monthly Demand file – monthly time series of headgate demands for each direct diversion structure	Section 5.4.4
np2008.ddr	Direct Diversion Rights file – lists water rights for direct diversion	Section 5.4.5
np2008.str	StateCU Structure file – soil moisture capacity by structure, for variable efficiency structures	Section 5.5.1
np2008.ipy	CU Irrigation Parameter Yearly file – maximum efficiency and irrigated acreage by year and by structure, for variable efficiency structures	Section 5.5.2
np2008.ddc	Irrigation Water Requirement file – monthly time series of crop water requirement by structure, for variable efficiency structures	Section 5.5.3
np2008.res	Reservoir Station file – lists physical reservoir characteristics such as volume, area-capacity table, and some administration parameters	Section 5.6.1
np2008.eva	Evaporation file – gives monthly rates for net evaporation from free water surface	Section 5.6.2
np2008.eom	Reservoir End-of-Month Contents file – Monthly time series of historical reservoir contents	Section 5.6.3
np2008B.tam	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
np2008.rer	Reservoir Rights file – lists storage rights for reservoirs	Section 5.6.5
np2008.ifs	Instream Flow Station file – lists instream flow reaches	Section 5.7.1
np2008.ifa	Instream Flow Annual Demand file – gives the decreed monthly instream flow demand rates	Section 5.7.2
np2008.ifr	Instream Flow Right file – gives decreed amount and administration number of instream flow rights associated with instream flow reaches	Section 5.7.3
np2008.pln	Plan Data file – contains parameters for plan structures	Section 5.8
np2008.opr	Operational Rights file – specifies many different kinds of operations that were more complex than a direct diversion or an on-stream storage right. Operational rights could 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 was not downstream, or a direct diversion to fill a reservoir via a feeder	Section 5.9

5.1.2. For Generating Natural Flow

The natural flow file (*.xbm) that is part of the Baseline data set was created by StateMod and the Mixed Station Model in four steps, which are described in Sections 4.7.1 through 4.7.3. In the first step, StateMod estimates natural flows at gaged locations, using the files listed in the response file np2008_BF.rsp. The natural flow time series created in this first step are all partial series, because gage data is missing some of the time for all gages.

In the second step, Mixed Station Model is used to fill the series, creating a complete series of natural flows at gages in a file named np2008_BF.xbf. The response file for the third step, in which StateMod distributes natural flow to ungaged points, is named np2008_BFx.rsp. As discussed in Section 4.7.3, external filling for select gaged locations was necessary. This is accomplished in the fourth step through the BF_XBM.TSTool commands, resulting in the final natural flow file NP2008_BF_rev.xbm used in the Historical and Baseline scenarios.

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 North Platte Model. Control file switches are all specifically described in the StateMod documentation. The simulation period parameters (starting and ending year) are the ones that users most typically adjust.

5.3 River System Files

5.3.1. River Network File (*.rin)

The river network file was created by StateDMI from the graphical network representation file created within StateDMI – StateMod Network interface (np2008.net) as shown in Figure 4.1 in Section 4.2.1. The river network file describes the location and connectivity of each node in the model. Specifically, it is 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 generally labeled with United States Geological Survey (USGS) stream gaging station numbers (i.e., 06600000). As noted above, there are six ungaged tributaries that flow into the North Platte River downstream of the last USGS stream gage. These tributaries are also represented by river gage nodes designated by the river name and BF for natural flow; for example Camp Creek inflow node identifier is Camp_BF.

In general, diversion and reservoir structure identification numbers are composed of Water District number followed by the State Engineer's four-digit structure ID. Instream flow water rights are also identified by the Water District number followed by the assigned State Engineer's four-digit identifier. Other nodes are locations in the basin where information is desired, such as return flow locations. Table 5.1 shows how many nodes of each type are in the North Platte Model.

Table 5.1
River Network Elements

Type	Number
Diversion	448
Instream Flow	26
Reservoirs	14
Plans	3
Stream Gages	18
Other	48
Total	**557**

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 was created by StateDMI. It lists the model's natural flow nodes, both gaged and ungaged. These are the discrete locations where streamflow is added to the modeled system.

There are 18 streamflow gage locations used for natural flow in the model and 97 ungaged natural flow locations, for a total of 115 hydrologic inflows to the North Platte Model. Ungaged natural flow nodes include all ungaged headwater nodes, one key reservoir node, one transbasin diversion node, and any other nodes where calibration revealed a need for it. 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. Natural Flow Parameter File (*.rib)

The natural flow parameter file contains an entry for each ungaged natural flow node in the model, specifying coefficients, or "proration factors", used to calculate the natural flow gain at that point. StateDMI computed proration factors based on the network structure and *area* multiplied by *precipitation* values supplied for both gages and ungaged natural flow nodes. This information is in the network file, which was input to StateDMI. Under the default "gain approach", described in Section 4.7.3, the factors reflect the ratio of the product of incremental area and local average precipitation above the ungaged point to the product of incremental area and local average precipitation for the entire gage-to-gage reach.

Where to find more information

- Section 4.7.3 describes how natural flows are distributed spatially.

5.3.4. Historical Streamflow File (*.rih)

Created by TSTool, the historical streamflow file contains historical gage records for 1956 through 2007 for the modeled gages. These are used for natural flow stream generation and to create comparison output that is useful during model calibration. Records for gaged locations are taken directly from USGS tables in HydroBase. Missing values, when the gage was not in operation, are denoted as such, using the value "-999." Table 5.2 lists the USGS gages used, their periods of record, and their average annual flows over the period of record. Note that the historical streamflow file also includes the six gage locations that required external processing to develop natural flows.

- Camp Creek
- Three Mile Creek
- Wheeler Creek
- Beaver Creek
- Line Creek
- Big Creek

The historical records for these gage locations are unknown and were set to missing in the historical streamflow file.

Table 5.2
Historical Average Annual Flows for Modeled USGS North Platte Stream Gages

Gage ID	Gage Name	Period of Record	Historical Flow (acre-feet/year)
06611200	Buffalo Creek Near Hebron	1977 - 1980	3,233
06611300	Grizzly Creek Near Hebron	1977 - 1980	39,765
06611700	Little Grizzly Creek Near Coalmont	1968 - 1973	14,837
06611800	Little Grizzly Creek Above Coalmont	1977 - 1979	17,762
06611900	Little Grizzly Creek Above Hebron	1977 - 1980	15,680
06614800	Michigan River Near Cameron Pass	1973 - 2008	2,162
06615000	South Fork Michigan River Near Gould	1951 - 1958	12,386
06616000	North Fork Michigan River Near Gould	1951 - 1982	12,210
06617500	Illinois Creek Near Rand	1931 - 1940 1994 - 1998 2002 - 2008	23,966
06619400	Canadian River Near Lindland	1978 - 1983	13,376
06619450	Canadian River Near Brownlee	1978 - 1983	20,813
06620000	North Platte River Near Northgate	1916 - 2008	307,210

5.3.5. Natural Flow Files (*.xbm)

The natural flow file contains estimates of base streamflows throughout the modeling period, at the locations listed in the river station file. Natural flows represent the conditions upon which simulated diversion, reservoir, and minimum streamflow demands are superimposed. StateMod estimates natural flows 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 natural flow at gage sites to ungaged locations using proration factors representing the fraction of the reach gain estimated to be tributary to a natural flow point.

Table 5.3 compares historical gage flows with simulated natural flows for the gage that operated continuously throughout the calibration period (1975-2007). The difference between historical gage flows and simulated natural flows represents estimated historical consumptive use over this period upstream of the gages.

Table 5.3
Natural Flow Comparison
1975-2007 Average (af/yr)

Gage ID	Gage Name	Natural Flow	Historical	Difference
06620000	North Platte River Near Northgate	413,024	291,962	121,062

Where to find more information

- Sections 4.7.1 through 4.7.3 explain how StateMod and the Mixed Station Model were used to create natural flows.
- When StateMod is executed to estimate natural flows 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 natural flows, it creates two reports, np2008.*sum* and np2008.*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)

The direct diversion station file describes the physical properties of each diversion simulated in the North Platte Model. Table 5.4 is a summary of the North Platte Model's diversion station file contents, including each structure's diversion capacity, irrigated acreage served in 2001, and average annual system efficiency. The table also includes average annual headgate demand. This 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, the file also specifies return flow nodes and average monthly efficiencies.

Generally, the diversion station ID, name, diversion capacity, and irrigated acreage were gathered from HydroBase, by StateDMI. Return flow locations were specified to StateDMI in a hand-edited file NP2008.rtn. The return flow locations and distribution were based on physical location of irrigated lands, discussions with Division 6 personnel, as well as calibration efforts. StateCU computed monthly system efficiency for irrigation structures from historical diversions and historical crop irrigation requirements, and StateDMI wrote them into the *.dds file.

For non-irrigation structures, monthly efficiency was specified by the user as input to StateDMI. Baseline irrigation demand was assigned to primary structures of multi-structure systems, therefore primary and secondary structures of multi-structure systems were assigned the average monthly efficiencies calculated for the irrigation system based on irrigation water requirements and water delivered from all sources. If efficiency was constant for each month, it could be specified in the hand-edited file np2008.rtn. Note that unknown capacity was set to 999 by StateDMI. This number was significantly large so as not to limit diversions.

Table 5.4
Direct Flow Diversion Summary Average (1975-2007)

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
1	4700500_D	Arapahoe DivSys	80	1646	44	2,542
2	4700501	ARNOLD DITCH	17	395	44	836
3	4700502	ASPIN DITCH	3	36	50	132
4	4700504_D	Badger State DivSys	17	457	43	968
5	4700505	BEAR CREEK DITCH	9	131	47	590
6	4700506	BEAVER DITCH	15	399	44	1,386
7	4700507	BEAVERDALE DITCH	12	198	44	592
8	4700508	BENNETT & LESHURE D	27	248	44	1,695
9	4700510	BERN DITCH	10	74	51	59
10	4700511	BERNARD DITCH	5	49	43	101
11	4700512	BIG GRIZZLY DITCH	67	878	42	3,522
12	4700513	BIG WILLOW DITCH	37	291	49	877
13	4700514	BOCK DITCH	3	43	51	139

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
14	4700515	BONA FIDE DITCH	47	372	44	1,100
15	4700516	BONA FIDE DITCH 2	9	114	43	524
16	4700519	BOONE DITCH	19	250	43	1,019
17	4700520	BOSTON DITCH 1	4	15	45	15
18	4700521	BOSTWICK DITCH	82	2060	42	4,709
19	4700522	BOULDER DITCH	26	418	44	1,529
20	4700523	BOWEN DITCH	12	94	50	126
21	4700524	BOYCE BROS DITCH NO 1	30	515	44	1,183
22	4700526	BRADFIELD DITCH	8	62	46	245
23	4700527	BRIGGS BOHN DITCH [1]	44	0	41	0
24	4700528_M	Briggs Bohn Ditch MS	69	774	41	4,836
25	4700529	BROCKER DITCH	3	23	48	51
26	4700530_M	Brocker Endomile MS	53	765	46	2,438
27	4700531	BUCKEYE DITCH	21	406	50	1,187
28	4700532	BURKE DITCH	14	181	45	321
29	4700533	BURNS DITCH	18	67	49	299
30	4700534	BUTLER DITCH	3	96	53	173
31	4700535	BUTLER DITCH 3	4	181	57	176
32	4700536	BUTLER DITCH 2	4	124	43	182
33	4700538	CAMP CREEK DITCH	20	51	47	319
34	4700542	CANON DITCH	15	235	50	439
35	4700543_D	Capron DivSys	15	728	45	840
36	4700544	CARDEN-DAGLE DITCH	8	201	44	482
37	4700546	CARNEY DITCH	12	30	43	522
38	4700547	CARPENTER DITCH	11	71	43	170
39	4700548	CARPENTER DITCH 2	2	37	48	134
40	4700549	CASTLE DITCH	17	210	47	740
41	4700550	CHACE DITCH	10	231	51	635
42	4700551	CHAMPION DITCH	6	164	56	69
43	4700552	CHAPMAN DITCH	67	905	48	3,570
44	4700553	CHEDSEY DITCH 1	4	179	50	261
45	4700554	CHEDSEY DITCH 2	30	435	47	1,487
46	4700556	CLAYTON DITCH [3]	18	0	47	0
47	4700556_I	Clayton D Irr [2]	18	76	47	227
48	4700557	CLAYTON RICH DITCH	4	0	51	51
49	4700558	CLEVELAND D OWL CK EXT [1]	5	0	42	0
50	4700559_M	Cleveland Ditch MS	64	1078	42	4,047
51	4700560	CLEVELAND D KIMMONS EXT[1]	5	0	42	0
52	4700561	CLIFTON DITCH	5	57	54	140
53	4700562	COCHRANE DITCH	3	63	53	155

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
54	4700563	COE DITCH NO 1	8	57	49	234
55	4700564	COE DITCH NO 2	5	220	54	281
56	4700565	COLUMBINE DITCH	20	60	46	392
57	4700566	COLUMBUS DITCH	6	45	39	94
58	4700567	COL DAVIS DITCH	23	421	44	1,336
59	4700569	CONTINENTAL DITCH	11	34	43	406
60	4700572	COOK DITCH	3	46	45	199
61	4700573	COON CREEK DITCH	8	170	49	452
62	4700574	COWDREY DITCH	19	78	40	725
63	4700575	COYOTE DITCH	7	45	40	402
64	4700576	CRYSTAL SPRING DITCH	1	63	51	76
65	4700577	CUMBERLAND DITCH 3)	74	0	0	0
66	4700577_I	Cumberland D Irr 2)	74	1113	48	5,951
67	4700578	CURTIN DITCH	59	1305	43	4,119
68	4700580	DALE DITCH 1	14	154	48	483
69	4700581	DALOM DITCH	29	164	41	1,057
70	4700582	DAM DITCH	37	133	41	1,970
71	4700583	DAMFINO DITCH	30	45	43	219
72	4700583_D	Damfino DivSys	44	783	44	1,965
73	4700584	DARBY DITCH	104	2615	42	6,793
74	4700586	DARCY DITCH	43	5	35	166
75	4700587	DARLING DITCH	8	68	43	326
76	4700588	DAVIS DITCH	18	275	44	705
77	4700589	DEER DITCH	7	15	48	15
78	4700590_D	Dike DivSys	8	52	40	408
79	4700591	DONELSON DITCH	16	358	43	686
80	4700592	DORA DITCH	5	82	55	101
81	4700593_M	Doran Ditch MS	62	257	52	1,250
82	4700594	DORAN DITCH 2 1)	15	0	0	0
83	4700595_M	Dry Creek Ditch MS	47	414	43	1,937
84	4700596	DRY RUN DITCH	23	581	45	1,463
85	4700597	DRYER DITCH	18	324	45	536
86	4700598	DULANEY DITCH	4	68	54	175
87	4700599	DURGIN DITCH	6	127	44	304
88	4700600_D	Dwinell DivSys	14	138	51	147
89	4700601	DWINELL DITCH	52	732	44	2,430
90	4700602	EASSOM DITCH	18	214	47	783
91	4700604	EAST BUFFALO DITCH	12	92	51	86
92	4700605	EAST LYNNE DITCH	20	328	50	1,183
93	4700606	EBER DITCH 1)	8	0	0	0

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
94	4700607	EDITH DITCH	8	24	50	42
95	4700609	ELLEN DITCH	11	70	43	512
96	4700610	ENDOMILE DITCH	4	51	44	190
97	4700611	ERICKSON D BOHN ENL	11	82	40	555
98	4700612	ERIKA DITCH	14	425	53	736
99	4700613	ERNEST DITCH	2	26	42	64
100	4700614	EUREKA DITCH 3)	70	0	0	0
101	4700615	EVERHARD BALDWIN DITCH	50	1442	44	2,960
102	4700617	FAULKNER DITCH	6	52	50	32
103	4700618	FERANDO DITCH	13	260	50	601
104	4700620	FLYING DUTCHMAN DITCH	12	169	40	888
105	4700621	FORREST DITCH	6	83	46	141
106	4700623	FREEMAN DITCH	2	58	57	65
107	4700624	FULLER DITCH	3	28	50	33
108	4700625	GAMBER BRINKER DITCH	35	174	43	778
109	4700626	GARDEN DITCH	10	73	41	573
110	4700630	GEORGE WARD DITCH	12	93	46	384
111	4700633	GIBBS DITCH	18	274	45	295
112	4700634	GILLETTE DITCH 1	5	99	49	288
113	4700635	GILLETTE DITCH 2	8	282	41	401
114	4700636	GILLETTE DITCH 3	8	292	45	590
115	4700637	GIVEADAM JONES DITCH	5	28	41	198
116	4700638_D	Glendale DivSys	18	358	49	836
117	4700639_D	Gould DivSys	28	271	43	1,326
118	4700642	GOVERNMENT DITCH NO 1	7	66	54	219
119	4700643	GOVERNMENT DITCH NO 2	8	309	51	112
120	4700645	HAMILTON DITCH	22	29	50	352
121	4700646	HANOVER DITCH	26	247	42	1,337
122	4700647	HANS CLAUSON D NO 1	6	62	50	176
123	4700648	HANS CLAUSON D NO 2	8	102	50	278
124	4700650	HARD TO FIND DITCH	8	132	49	440
125	4700651	HARDWORK DITCH	11	255	50	438
126	4700654	COCHRANE DITCH 1)	11	0	37	0
127	4700655_D	Oxford DivSys	3	26	53	84
128	4700656	HARTZELL DITCH	11	87	50	284
129	4700657_D	Haworth DivSys	22	418	50	563
130	4700659	HEADACHE DITCH	14	70	44	204
131	4700661	HIGO DITCH	4	86	43	256
132	4700662	HIHO DITCH	55	692	44	2,388
133	4700663	HILL DITCH NO 1	25	649	50	1,413

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
134	4700664	HILL DITCH NO 2	18	245	50	896
135	4700665	HILLSIDE DITCH	75	954	43	3,865
136	4700666	HILL, CROUTER DITCH	9	130	40	289
137	4700667	HODGSON DITCH	8	91	43	378
138	4700669	HOME NO 1 & UPLAND D	23	297	44	729
139	4700670	HOME DITCH NO 2	8	92	41	494
140	4700671	HOMESTEAD DITCH	18	166	44	1,013
141	4700672_M	Howard Ranch MS	189	991	45	3,800
142	4700674_D	Hubbard DivSys	110	2033	46	4,121
143	4700676	HUBBARD DITCH 1	17	278	43	729
144	4700677	HUGH GRIFFITH DITCH	5	0	51	82
145	4700678	HUGH GRIFFITH DITCH 2	7	23	49	286
146	4700679_D	Hunter DivSys	65	565	42	2,711
147	4700680	HUNTER DITCH 1	6	48	52	150
148	4700682	HUNTINGTON DITCH	6	138	53	25
149	4700683	INDEPENDENCE DITCH	95	617	32	2,814
150	4700684	INDEPENDENT DITCH	113	1232	43	5,000
151	4700685	ISH & BALDWIN DITCH	5	30	46	89
152	4700686	ISH DITCH	17	101	41	622
153	4700687	ISH EVERHARD DITCH	6	86	47	240
154	4700688	ISLAND DITCH	2	90	50	126
155	4700689	IVEY DITCH	6	101	50	103
156	4700693	JACKSON DITCH	40	5	43	713
157	4700694	JAKEY DITCH	12	67	41	391
158	4700695	JAMES D DITCH	4	64	45	249
159	4700696	JAMES SUTTON DITCH 2	9	98	48	261
160	4700698	JAP DAVISON DITCH	7	72	43	353
161	4700699	JAY DITCH	32	132	43	533
162	4700700	JENNIE DITCH	17	570	52	1,246
163	4700702	JOHN S SUTTON DITCH	30	709	47	1,265
164	4700703	JOHNSON DITCH	6	59	47	347
165	4700704	JORDAN DITCH	10	61	44	152
166	4700705_D	Sutton DivSys	48	696	44	1,850
167	4700706	KELLY DITCH	10	116	45	440
168	4700707	KELLY HIGHLINE DITCH [1)]	6	0	44	0
169	4700708	KERMODE DITCH	7	68	41	431
170	4700709_M	Kermode MS	22	192	43	661
171	4700710	KERR DITCH	14	159	51	292
172	4700711	KIWA DITCH	54	574	40	3,509
173	4700714	LAKE CREEK DITCH	19	365	55	776

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
174	4700715	LANDHURST DITCH	2	52	52	57
175	4700716	LARSEN DITCH	24	119	45	692
176	4700717	LAST CHANCE DITCH	2	56	52	95
177	4700718_D	Lawrence DivSys	18	191	48	858
178	4700719	LAWRENCE DITCH 1	10	232	45	467
179	4700720	LEGAL TENDER DITCH 3)	64	0	0	0
180	4700720_I	Legal Tender D Irr 2)	64	470	44	3,190
181	4700722	LEONARD DITCH	8	128	51	480
182	4700723	LEWIS DITCH	80	991	54	1,730
183	4700724	LIEUALLEN DITCH	5	0	46	120
184	4700725	LILLIE DITCH	22	130	42	837
185	4700726	LITTLE CHIEF DITCH	6	0	40	67
186	4700728	LITTLE GRIZZLY DITCH	25	261	42	1,236
187	4700730	LITTLE NELLIE DITCH	89	1105	41	5,439
188	4700731	LIVINGSTONE DITCH	3	50	47	122
189	4700732	LIZZIE DITCH	5	130	55	143
190	4700735_M	Lookout Ditch MS	23	691	54	1,630
191	4700736	LORENA DITCH	8	74	50	300
192	4700737	LOST CREEK DITCH	9	15	42	69
193	4700738_D	Lost Treasure DivSys	65	550	35	5,839
194	4700739	LOWER WALDEN DITCH	10	211	44	636
195	4700740	LOWLAND DITCH	31	553	49	1,494
196	4700741	LUCKPENNY DITCH	24	1197	49	2,019
197	4700742	LYNCH DITCH	7	49	53	169
198	4700743	MABEL DOW DITCH	34	527	50	1,424
199	4700745	MACFARLANE EXT D 1)	53	0	0	0
200	4700746	MAGGIE DITCH	10	176	49	524
201	4700747	MALLON DITCH	38	954	51	1,312
202	4700748	MALLON DITCH NO 2	80	1182	42	6,289
203	4700749	MAMMOUTH DITCH	20	482	47	1,349
204	4700752	MANVILLE DITCH	20	59	41	471
205	4700753_M	Manville Ditch 2 MS	96	668	38	5,511
206	4700754	MARR DITCH 1	18	289	44	573
207	4700755	MARR DITCH 2	56	141	35	1,859
208	4700757	MARY ISH DITCH	4	17	42	125
209	4700758	MARY ISH DITCH NO 2	2	10	41	84
210	4700759	MASON DITCH 1)	33	0	0	0
211	4700760	MATHEWS DITCH	26	606	48	1,736
212	4700761	MATHEWS, EASTERN DITCH	20	277	43	873
213	4700762	MAY GRAY DITCH	5	164	51	294

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
214	4700763	MACFARLANE MEADOWS D	11	96	52	278
215	4700767	MEADOW CREEK DITCH	4	32	41	126
216	4700768	MEDICINE BOW DITCH	33	617	42	2,179
217	4700769	MELLON DITCH	3	39	49	160
218	4700770	MEXICAN DITCH	8	64	45	297
219	4700773	MICHIGAN HIGHLINE DITCH	60	682	49	3,020
220	4700774	MIDLAND DITCH	214	3099	42	9,387
221	4700776	MILL CREEK DITCH	16	85	50	166
222	4700777	MITCHELL DITCH	45	1413	45	2,951
223	4700779	MONROE DITCH	7	173	44	463
224	4700783	MOORE NO 1 DITCH	4	68	45	232
225	4700785	MORAINE DITCH [1)]	16	0	0	0
226	4700786	MUTUAL DITCH	158	3649	42	10,881
227	4700787	NAIRN DITCH	35	463	43	1,994
228	4700788	NELLIE E DITCH	6	92	50	249
229	4700789	NEW BURKE DITCH	12	10	44	82
230	4700790	NEW PIONEER DITCH	50	307	41	2,357
231	4700791	NEW ROSS DITCH	20	462	44	886
232	4700792	NEWCOMB DITCH	16	108	48	1,089
233	4700793_D	Newport DivSys	55	440	45	830
234	4700795	NILE DITCH	17	150	43	753
235	4700796	NORRIS DITCH	18	220	55	790
236	4700797	NORTH FORK DITCH	6	90	43	291
237	4700799	NORTH PARK DITCH NO 7	21	201	42	1,036
238	4700800	NORTH PARK DITCH NO 2	3	41	50	136
239	4700801	NORTH PARK DITCH NO 3	3	44	52	127
240	4700802	NORTH PARK DITCH NO 4	24	118	42	1,070
241	4700803	NORTH PARK DITCH NO 5	35	667	45	1,144
242	4700804_D	North Park DivSys	27	362	44	800
243	4700805	NOVELTY DITCH	8	77	46	234
244	4700809_D	Oklahoma DivSys	61	1048	44	1,553
245	4700811	OKLAHOMA DITCH NO 2	15	258	42	613
246	4700813_D	Old SC DivSys	64	758	42	3,060
247	4700814	OLDENBERG DITCH	9	75	46	396
248	4700815_D	Olive DivSys	19	77	50	514
249	4700816	OPEN A DIAMOND DITCH	40	251	41	1,800
250	4700817	ORB DITCH [1)]	4	0	0	0
251	4700818	OTTAWA DITCH	5	16	42	272
252	4700819	OVERLAND DITCH	108	1528	42	3,079
253	4700820	OWL DITCH [1)]	999	0	0	0

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
254	4700825	PARK VIEW DITCH	6	42	55	99
255	4700826_M	Peabody Ditch MS	89	1592	44	3,966
256	4700827	PEARL DITCH	6	24	51	95
257	4700829	PETERSON DITCH 1	15	270	43	920
258	4700831	PHELAN DITCH	2	24	55	41
259	4700835	PIONEER DITCH	20	406	42	1,031
260	4700837	PLEASANT VALLEY DITCH	36	107	50	821
261	4700838	POLE MTN RES FEEDER D 3)	45	0	0	0
262	4700839	POLED ANGUS DITCH	10	326	45	561
263	4700840	POMROY DITCH 1	51	577	43	2,380
264	4700841	POMROY DITCH NO 2	14	0	42	110
265	4700842	POQUETTE DITCH	31	147	44	1,238
266	4700843	POTTER DITCH NO 2	5	34	38	122
267	4700844	POVERTY FLAT D NO 2	53	518	44	1,572
268	4700845_D	Poverty DivSys	93	784	43	2,772
269	4700846	POWELL DITCH	10	357	55	278
270	4700847	QUEEN DITCH	23	182	39	,1477
271	4700849	RARUS DITCH	2	21	47	68
272	4700850	RATTLER DITCH	7	99	49	231
273	4700851	RAVINE DITCH	15	28	38	251
274	4700852	REITHMEYER D	4	90	44	253
275	4700853	RHEA DITCH	22	314	48	1,296
276	4700854	RICHMOND DITCH	10	206	45	627
277	4700855	RIDDLE DITCH	17	273	39	481
278	4700857	ROARING DITCH	38	475	43	2,467
279	4700859_D	Ruction DivSys	24	371	43	1,537
280	4700860	SAINT FRANCES NO 1 D	8	169	51	289
281	4700861	SAINT FRANCES DITCH 7	6	7	42	247
282	4700862_D	Saint Joseph DivSys	22	213	56	598
283	4700863	SALEM DITCH	47	574	45	1,158
284	4700864	SALES DITCH 1)	22	0	51	0
285	4700865	SANBORN DITCH	45	225	41	1,519
286	4700866	SAND CREEK DITCH	18	238	48	777
287	4700867	SCHOOL SECTION DITCH	30	31	49	208
288	4700868_D	Seneca DivSys	84	1146	43	5,269
289	4700869	SEYMOUR DITCH 1	10	159	42	577
290	4700871	SHAFER DITCH	48	379	44	1,217
291	4700872	SHAFTO DITCH	5	10	46	63
292	4700873_D	Shearer DivSys	16	314	44	848
293	4700874	SHEARER DITCH NO 2	5	18	45	125

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
294	4700875	SHERMAN DITCH	17	313	54	764
295	4700876	SHORT RUN DITCH	14	152	46	619
296	4700878	SIXTEEN DITCH	10	254	46	564
297	4700879	SLACK DITCH	20	312	49	728
298	4700880	SLACK WEISS DITCH	14	63	38	317
299	4700881	SLEW DITCH	9	56	48	335
300	4700883	SMEED DITCH	10	143	50	394
301	4700884_D	Smith DivSys	30	756	49	1,207
302	4700885	SNIDE DITCH	6	40	49	122
303	4700886	SOLDIERS HOME DITCH	22	138	47	604
304	4700887	SORENSON DITCH	11	87	43	544
305	4700888	SPAULDING DITCH	8	107	50	294
306	4700890	SPICER DITCH	22	604	44	1,471
307	4700892	SPRING GULCH DITCH	18	107	43	466
308	4700893	SQUIBOB DITCH	106	611	38	3,217
309	4700893_C	Squibob Storage Carrier 3)	106	0	0	0
310	4700894	STAMBAUGH DITCH	15	10	44	157
311	4700895	STAPLES DITCH 1	100	2260	44	6,107
312	4700896	STAPLES DITCH NO 2	62	712	45	2,855
313	4700898	STEELE DITCH	4	39	49	124
314	4700899	STELLA DITCH 1)	31	0	0	0
315	4700900	STEMLER DITCH	25	175	48	201
316	4700902	STEVENSON DITCH 4	14	224	45	508
317	4700903	STEVENSON DITCH NO 3	3	26	48	55
318	4700904	STEVENSON NO 2 DITCH	19	156	44	448
319	4700905	STILLWATER DITCH	27	203	42	1,216
320	4700906	STORMY DITCH	27	495	50	1,417
321	4700907	SAINT FRANCES NO 2	4	11	48	189
322	4700908	SUDDITH NO 1 DITCH	9	293	50	442
323	4700909	SUDDUTH DITCH NO 5	16	170	46	544
324	4700911_D	Sunday DivSys	30	628	53	1,879
325	4700912	SUNRISE DITCH 1)	5	0	55	0
326	4700914	TAYLOR DITCH	5	100	48	99
327	4700915	TELLER DITCH	4	586	50	54
328	4700916	TERRELL DITCH	28	87	42	413
329	4700917	THIRTY SIX DITCH	15	189	48	768
330	4700919	TIMBER DITCH	6	10	32	296
331	4700920	TIMOTHY DITCH	2	17	46	87
332	4700921	TIMOTHY HILL DITCH	38	28	51	134
333	4700922_D	Titanic DivSys	28	133	50	299

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
334	4700923	TOGO DITCH NO 2	13	113	49	352
335	4700924	TOLEDO DITCH	8	88	50	300
336	4700925	TROUBLESOME DITCH	3	40	54	123
337	4700926	TROY DITCH	6	170	49	391
338	4700927	ULRICH DITCH	2	30	41	146
339	4700929	Ute Pass Creek MS	42	81	45	330
340	4700929_C	Ute Pass Creek Carrier [1)]	42	0	0	0
341	4700931	VAN PATTEN DITCH	18	76	47	373
342	4700932	VICTOR DITCH	67	604	40	5,288
343	4700933	VITA DITCH	6	0	44	87
344	4700935_D	Walden Ditch DivSys	24	170	47	950
345	4700939	WALES DITCH	23	514	43	1,528
346	4700940	WALKER DITCH	4	23	46	129
347	4700941	WARD DITCH 2	15	16	42	201
348	4700942	WARD DITCH 1	36	494	41	1,975
349	4700943	WARD DITCH 3	29	54	39	466
350	4700944	WATSON DITCH	3	216	52	152
351	4700946	WEED DITCH	6	20	41	264
352	4700947	WELCH DITCH [1)]	18	0	0	0
353	4700948	WEST BOETTCHER DITCH	27	25	39	617
354	4700949	WEST BUFFALO DITCH	10	237	50	493
355	4700950	WEST DITCH	25	186	51	560
356	4700951	WEST FORK DITCH	35	426	41	2,999
357	4700952	WEST SIDE DITCH	19	0	49	22
358	4700953	WESTFIELD DITCH	36	312	49	408
359	4700954	WHEELER DITCH	6	95	57	34
360	4700955	WHEELER DITCH 1	8	113	50	234
361	4700956	WHEELER DITCH 2	6	21	45	147
362	4700957	WILLFORD DITCH	20	27	41	414
363	4700958	WILLIAM KERR DITCH	8	22	49	190
364	4700960	WISCONSIN DITCH	11	198	31	506
365	4700961	WOLFER DITCH	218	2865	44	13,086
366	4700962	WYCOFF DITCH	28	74	40	177
367	4700964_D	Yocum DivSys	9	92	48	379
368	4700965	ZELMA DARCY DITCH	7	70	52	241
369	4700966	ZIRKEL DITCH	7	192	46	416
370	4700969	NINE SIX NINE DITCH	48	364	43	2552
371	4700971	EDITH DITCH	8	105	49	349
372	4700976	JACKSON DITCH NO 2	18	92	47	534
373	4700978_D	Kenny DivSys	6	89	52	208

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
374	4700979	LAST CHANCE DITCH	23	114	40	530
375	4700984	MACE BULL PASTURE D	999	72	49	204
376	4700985	MCISAAC DITCH	8	78	51	88
377	4700986	MCISAAC DITCH NO 2	5	11	51	50
378	4700989	NEW SAND CREEK D	27	367	51	405
379	4700991	PAUL DITCH NO 1	11	11	37	268
380	4700992	PAUL DITCH NO 2	10	11	41	195
381	4700993	PAUL DITCH NO 3	10	26	46	204
382	4700996_M	Sales Ditch 2 MS	27	144	51	351
383	4701001	ADDISON DITCH	19	280	44	942
384	4701002	AKERS DITCH	6	14	56	35
385	4701003	ALBERT CLAUSON DITCH	7	89	52	184
386	4701005	ALLARD DITCH	6	25	44	188
387	4701006	ALLARD DITCH	9	63	53	219
388	4701007	ALLEN DITCH	3	62	48	158
389	4701008	ALMA DITCH	15	23	45	349
390	4701009_D	Norell DivSys	28	356	41	1,806
391	4701010	ANDERSON DITCH	26	291	49	277
392	4701011	ANTELOPE DITCH	39	605	43	2,111
393	4701022	BUCKEYE DITCH	20	419	44	1,330
394	4701023	BUTLER DITCH 4	6	44	44	172
395	4701024_M	Cochrane MS	41	400	37	2,090
396	4701025	COCHRANE DITCH	6	41	48	178
397	4701027	HOMESTEAD DITCH	8	233	45	535
398	4701028	DUGAN DITCH	3	0	47	39
399	4701029	MARTIN DITCH	10	66	46	347
400	4701030	LITTLE CHIEF D HG NO 2	5	0	0	160
401	4701031	MONROE DITCH	5	54	46	229
402	4701032	OLLIVER DITCH	18	41	50	437
403	4701033	PARK DITCH	11	55	44	226
404	4701035	VICTOR DITCH	8	98	54	134
405	4701039	JACKSON DITCH NO. 3	14	113	44	645
406	4701040	UPPER LITTLE MUDDY DITCH	12	13	43	176
407	4701041	LOWER LITTLE MUDDY D	14	22	45	170
408	4701042	LYNN DITCH	20	86	47	499
409	4701054_D	Big Grizzly DivSys	50	450	45	1,404
410	4701055	ALMEDA DITCH	8	155	49	228
411	4701060	KERMODE DITCH 2 ALT PT [1)]	999	0	44	0
412	4701061_D	Garland DivSys	38	450	50	1,108
413	4701070	DORAN DITCH 3 [1)]	12	0	0	0

#	Model ID #	Name	Cap (cfs)	2001 Area (acres)	Average System Efficiency (percent)	Average Annual Demand (af)
414	4701071	ANDREW NORRELL DITCH	8	161	55	416
415	4701083	WALDEN MICHIGAN R DIV 4)	2	0	0	84
416	4701099	LATTER DITCH	1	3	44	39
417	4701137	DRY FORK DITCH	5	25	49	68
418	4701138	OIL WELL DITCH	5	33	48	176
419	4701146	COOK DITCH	10	17	46	78
420	4701169	ROUGH AND READY DITCH	2	0	49	62
421	4701180	EMCO DITCH NO 1	2	6	37	118
422	4701198	HOWARD D MACFARLANE ACT	999	1043	49	2,207
423	4701199	SWIFT DITCH 1)	25	0	37	0
424	4701298_D	Smith Diversion DivSys	2	6	48	32
425	4701595	DRY CRK DITCH RILEY CRK 1)	5	0	43	0
426	4702002_D	Elk Creek DivSys	1	0	44	53
427	4702030	WATTENBERG DITCH	4	43	43	148
428	4702030_C	Wattenburg Lake Crk Carr 3)	999	0	0	0
429	4702033	DORAN DITCH 4 1)	8	0	0	0
430	4702040	NANCY JANE DITCH	2	22	52	92
431	4702042	STEVENSEN NO 1 DITCH	10	22	44	250
432	4702049	WEST ARAPAHOE FEEDER 2 3)	60	0	0	0
433	4702049_I	West Arapahoe Fdr IRR 2)	60	55	44	198
434	4702054	A BAR A DITCH	12	181	51	83
435	4702057	PLAINWELL DITCH	9	87	51	497
436	4702066	WILHELM EXTENSION	10	63	49	151
437	4702070	CEMETARY PUMP STA	0	3	40	16
438	4702079	BAKER DRAW DITCH	5	76	45	285
439	4702080	BARBER DITCH	8	48	48	436
440	4702091_D	Roslyn DivSys	10	54	46	352
441	4702092	PAUL DITCH NO 4	3	41	50	92
442	4702103	RAVINE DITCH NO 2	15	28	45	249
443	4703627_C	Walden Storage Carrier 3)	999	0	0	0
444	4704602	CAMERON PASS DITCH 5)	28	0	100	98
445	4704603	MICHIGAN DITCH 5)	295	0	100	2,351
446	47_ADN001	Threemile Creek Agg	32	428	51	645
447	614_40_I	Eureka D Irr 40 perc 6)	70	452	47	1,480
448	614_60_I	Eureka D Irr 60 perc 6)	70	679	46	2,607

1) Secondary Structure of a Multi-structure System, Acreage/Demand Assigned to Primary Structure
2) Irrigation demand node
3) Reservoir Feeder or Carrier Ditch, Demand Assigned to Destination
4) Municipal/Industrial Diversion
5) Basin Export
6) Split-Share Demand Node

5.4.1.1 Key Structures

Key diversion structures and diversion systems are modeled explicitly, that is, the node associated with those structures represents a single demand. 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 the diversions in the North Platte basin are for irrigation. Exceptions are noted in Table 5.4 above.

Average historical monthly efficiencies for each 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, industrial and transbasin diverters, StateMod uses the efficiencies in the diversion station file directly during simulation to compute consumptive use and return flows. Diversion efficiency is set to values consistent with the type of use based on engineering judgment, or, if available, user information. For example, Walden Michigan River diversions municipal use is assigned monthly efficiencies that do not vary by year. Reservoir feeders and other carriers are assigned an efficiency of 0 percent, meaning their diversions are delivered without loss. Exports from the basin, such as the Cameron Pass Ditch, are assigned an efficiency of 100 percent because there are no return flows to the basin.

Diversion capacity is stored in HydroBase for most structures and was generally taken directly from the database. In preparing the direct diversion station file, however, the DMIs determine whether historical records of diversion indicate diversions greater than the database capacity. If so, the diversion capacity was modified to reflect the recorded diversion.

Return flow parameters in the diversions station file specify the nodes at which return flows will re-enter the stream, and divide the returns among several locations as appropriate. The locations were determined primarily case-by-case based on topography, locations of irrigated acreage, and conversations with water commissioners and users.

Both the primary and secondary structures associated with multi-structure systems are considered key structures, as discussed in Section 4.2.2. Only one structure is used to represent each diversion system. Both the irrigation demand structure and their associated carrier/primary structures are also considered key structures.

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 tables gives the return flow locations and percent of return flow to each location, for every diversion structure in the model. Another table provides the information shown in Table 5.4
- Section 4.2.2.1 describes how key structures were selected.
- Section 4.2.2.2 lists the components of each multi-structure and diversion system. Irrigation demand structures are listed in Section 4.2.2.3.
- 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 on tributaries to Threemile Creek were combined and represented as an aggregated node. The aggregated irrigation structure was given the identifier 47_ADN001, where "ADN" stands for Aggregated Diversion North Platte.

Where to find more information

- Section 4.2.2.2 describes how small irrigation structures were aggregated into larger structures

5.4.1.3 Special Structures

5.4.1.3.1 Cumberland Ditch Irrigation Demand Structure

Cumberland Ditch diverts water to meet irrigation demands and for storage in Carlstrom Reservoir. In addition, irrigated lands under Cumberland Ditch are downstream of Carlstrom Reservoir and irrigation demands are supplemented with releases from Carlstrom Reservoir and Walden Reservoir. Because there are multiple demands (irrigation and storage) and multiple sources (direct diversions and reservoir releases), an "irrigation demand structure" was used in the model (4700557_I). Cumberland Ditch functions as a carrier, diverting water both to storage and to the irrigation demand structure.

5.4.1.3.2 Clayton Ditch Irrigation Demand Structure

Clayton Ditch diverts water to meet irrigation demands and for storage in Clayton Reservoir. In addition, irrigated lands under Clayton Ditch are downstream of Clayton Reservoir and irrigation demands are supplemented with releases from Clayton Reservoir. Because there are multiple demands (irrigation and storage) and multiple sources (direct diversions and reservoir releases), an "irrigation demand structure" was used in the model (4700556_I). ClaytonDitch functions as a carrier, diverting water both to storage and to the irrigation demand structure.

5.4.1.3.3 Legal Tender Ditch Irrigation Demand Structure

Legal Tender Ditch diverts water to meet irrigation demands and for storage in Lake John Reservoir. In addition, Legal Tender Ditch can also divert out-of-priority to meet irrigation demands, with replacements made from Lake John Annex and Boettcher Reservoir. Because there are multiple demands (irrigation and storage) and multiple sources (direct diversions and reservoir releases), an "irrigation demand structure" was used in the model (4700720_I). Legal Tender Ditch functions as a carrier, diverting water both to storage and to the irrigation demand structure.

5.4.1.3.4 West Arapahoe Feeder Ditch Irrigation Demand Structure

West Arapahoe Feeder No 2 Ditch diverts water to meet irrigation demands and for storage in West Arapahoe Reservoir. Because there are multiple demands (irrigation and storage), an "irrigation demand structure" was used in the model (4702049_I). West Arapahoe Feeder No 2 Ditch functions as a carrier, diverting water both to storage and to the irrigation demand structure.

5.4.1.3.5 Squibob Ditch Carrier Structure

Squibob Ditch diverts water to meet irrigation demands and for storage in Meadow Creek Reservoir. Because there are multiple demands (irrigation and storage), a carrier structure was used in the model (4700893_C) to represent historical and model simulated diversions to storage in Meadow Creek Reservoir. A carrier structure was chosen over an "irrigation demands structure" to facilitate natural flow estimates, since the Squibob Ditch point of diversion is above a modeled stream gage and the subsequent irrigation return flows are downstream of the same modeled stream gage. Note that the irrigation demand associated with Squibob Ditch (4700893) is represented at the ditch headgate. Squibob Ditch diversions to storage are released to Sales Creek and re-diverted and, according to the water commissioner, re-measured in Stemler Ditch.

5.4.1.3.6 Walden Reservoir Carrier Structure

Walden Reservoir is filled from the Old SC Ditch on the Michigan River. The portion of the canal system that continues to Walden Reservoir can also divert additional water from the Illinois River. There is not an official structure WDID for the Illinois River diversion, therefore the Walden Reservoir Carrier Structure (4703627_C) represents the carrier ditch point of diversion on the Illinois River.

5.4.1.3.7 Eureka Ditch Irrigation Demands

Eureka Ditch (4700614) diverts water to meet irrigation demands and for storage in Seymour Reservoir. Approximately 40 percent of the irrigated acreage served by the ditch is above Seymour Reservoir, therefore cannot receive supplemental storage water. The remaining 60 percent of the irrigated acreage is downstream of the reservoir and can receive supplemental storage water. Based on information provided by water users, a Plan structure was created that diverts the water, in priority, from the river then "splits" the direct diversion water into two accounts available to meet the demands upstream and downstream of the reservoir. The demands are placed at two irrigation demand structures; 60 percent at structure 614_60_I and 40 percent at structure 614_40_I. Irrigation demand structure 614_60_I also receives supplemental water from Seymour Reservoir.

5.4.1.3.8 Damfino Ditch

Damfino Ditch (4700583) diverts water to meet irrigation demands that are, in part, also met by Koping Ditch and Seymour Ditches. A portion of the irrigated land, approximately 32 percent, can be served only by the Damfino Ditch water rights. The remaining lands get commingled water from Damfino, Koping, and Seymour ditches. The irrigated acreage and associated demands are represented at two structures, Damfino Ditch (4700583) and Damfino Diversion System (4700583_D).

5.4.2. Return Flow Delay Tables (*.dly)

The np2008.dly file, which is created with a text editor, describes the estimated re-entry of return flows into the river system. The return flow pattern accounts for both immediate surface water returns, and lagged ground water returns.

Two patterns are used in the North Platte Model, as shown in Table 5.5. Pattern 1 represents estimated return flows for irrigation use in the basin. As shown, much of the non-consumed water returns within the same month of diversion, either via surface returns or short-term lagged ground water returns. The remaining non-consumed water is estimated to return the second month. This pattern was estimated based on aquifer parameters, the general location of irrigated land compared to rivers and drainages, and revised slightly during model calibration. Pattern 2 represents immediate returns, for municipal and industrial uses.

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

Pattern	Month 1	Month 2
Pattern 1	85.0	15.0
Pattern 2	100.0	0.0
Note: Month 1 is the same month as diversion		

5.4.3. Historical Diversion File (*.ddh)

The historical diversion file contains time series of diversions for each structure. The file was created by StateDMI, which filled missing records as described in Section 4.4.2. StateMod uses the file for natural flow estimations at stream gage locations and for comparison output during calibration. As discussed in Section 4.4.1, review of historical diversion records identified two periods with diversions appeared to be inaccurate based on trends over the entire period of record. Based on this review, diversion records for pre-1977 were determined to be unreliable and were replaced with filled data.

This historical diversion file was also referenced by StateDMI when developing the headgate demand time series for the diversion demand file.

5.4.3.1 Key Structures

For most explicitly modeled irrigation and M&I structures, StateDMI accessed HydroBase for historical diversion records. Total historical diversions through the headgate were accumulated by StateDMI for defined diversion systems.

For certain structures, diversions to specific uses were required, for instance diversion to storage for a ditch that diverts to both storage and irrigation. In other instances, only diversions to irrigation were recorded, and early season diversion to storage needed to be estimated based on reservoir content. Two structures (Gillette Ditch and Wolfer Ditch) had errant data in HydroBase that needed to be replaced. Historical diversions for the following structures required additional manipulation and time-series files were created and read by StateDMI:

WDID	Name
4700556_I	Clayton Ditch Irrigation Demand Structure
4700577_I	Cumberland Ditch Irrigation Demand Structure
4700634	Gillette Ditch
4700672_M	Howard Ditch Multi-Structure
4700720_I	Legal Tender Ditch Irrigation Demand Structure
4700745	MacFarlane Extension Ditch
4700583	Damfino Ditch

4700583_D	Damfino Ditch Diversion System
4700893	Squibob Ditch
4700893_C	Squibob Ditch Carrier
4700900	Stemler Ditch
4700961	Wolfer Ditch
4702049_I	West Arapahoe Feeder Irrigation Demand Structure
614_60_I	Eureka Ditch Demand Downstream of Seymour Reservoir
614_40_I	Eureka Ditch Demand Upstream Seymour Reservoir

5.4.3.1 Aggregate Structures

As with diversion systems, the aggregated irrigation structure is assigned the sum of the constituent structures' historical diversion records from HydroBase.

5.4.4. Direct Diversion Demand File (*.ddm)

Created by StateDMI, this file contains time series of demands 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 in Section 5.4.1 lists average annual demand for each diversion structure. Note that the Baseline demands do not include demands associated with conditional water rights.

5.4.4.1 Key Structures

Irrigation demand was computed as the maximum of crop irrigation water requirement divided by monthly efficiency for the structure or historical diversions, as described in Section 4.9.1. Irrigation water requirement is based on actual climate data beginning in 1956. Monthly system efficiency is the average system efficiency over the study period (1956 through 2007) but capped at the maximum efficiency defined by structure.

The single municipal demand was set to historical diversions. The demand for carrier structures was set to zero, as these structures carry to meet demand at other key structures.

5.4.4.2 Aggregate Structures, Diversion Systems and Multi-Structure Systems

The irrigation demand for aggregated structures and diversion systems is computed the same as for key irrigation structures. The irrigation demand for multi-structure systems is associated with the primary structure based on the crop irrigation water requirement for land under both the primary and secondary structures in the system.

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 created the diversion right file based on the structure list in the diversion station file. Note that the Baseline direct diversion right file does not include conditional water rights. It is recommended for future updates that the StateDMI commands be run initially without the "set" commands. This allows the modeler to view any changes to water rights (transfers, conditional to absolute, abandonment, etc.) reflected in updated versions of HydroBase and modify the "set" commands as necessary. 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.

All diversion rights were set "on" in the North Platte Model. Operating rules and/or demands are used to limit direct diversion rights for some structures, for example structures that only carry water to demands at other structures.

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, many structures have been assigned a "free water 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 water rights under free river conditions, provided their demand is unsatisfied and water is legally available.

Irrigation demand structures, by definition, are demand structures only and do not have associated water rights. The water rights remain at the primary/carrier structures associated with the demand structures.

5.4.5.2 Aggregate Structures, Diversion Systems

In the North Platte Model, the single aggregated structure includes four individual ditches. The water rights associated with these ditches are assigned to the aggregate structure. Water rights associated with the primary and secondary structures in a diversion system are assigned to the diversion system structure.

5.4.5.3 Special Diversion Rights

5.4.5.3.9 Ute Pass Ditch

Ute Pass Ditch has one water right in HydroBase assigned to its Sand Creek identifier. The water right decree allows a portion of the water right to be diverted from St. Francis Creek. The water right was split and 27.983 cfs was assigned to Ute Pass Ditch (4700929) with the original administration number of 23016.22177. The remaining 14.43 was assigned to Ute Pass Ditch Carrier on Sand Creek (4700929_C), with a slightly junior administration number of 23016.2178.

5.4.5.3.10 Mace Bull Pasture Ditch

Mace Bull Ditch (4700984) has current irrigated acreage and diversion records, but no water rights in HydroBase. Based on discussions with the water user and historical diversions, a junior water right for 8 cfs was assigned with a junior administration number of 30200.00000.

5.4.5.3.11 Squibob Storage Carrier

Squibob Storage Carrier (4700793_C) was assigned the storage water right for 46.00 cfs with the associated administration number of 47481.46505.

5.4.5.3.12 Damfino Diversion System

Damfino Ditch (4700583) water right decreed amounts were split, with 32 percent assigned to Damfino Ditch, and 68 percent assigned to the Damfino Diversion System (470483_D). Damfino Ditch was assigned the following water rights: 0.8 cfs with administration number 12919.0000, 0.8 cfs with administration number 13330.0000, and 8.00 cfs with administration number 21366.20964. Damfino Diversion System was assigned the remaining water rights: 1.70 cfs with administration number 12919.0000, 1.70 cfs with administration number 13330.00000, and 17.0 cfs with administration number 21366.20964. The water rights for Seymour Ditch and Kopin Ditch are represented in the Damfino Diversion System.

5.4.5.3.13 Cochrane Ditch

Cochrane Ditch, the primary structure in multi-structure system (4701024_M), has water rights junior to Eureka Ditch; however, according to water user input, they are owned by the same rancher. Accordingly, the Eureka Ditch has not historically placed a call that would limit the ability for Cochrane Ditch to divert. Therefore, the Cochrane Ditch water right for 30 cfs was assigned an administration number of 13764.99999 just senior to the Eureka Ditch senior water right.

5.4.5.3.14 Multi-Structure Systems

To easily distinguish primary structures in the multi-structure systems, their WDIDs were modified to include a '_M' extension. Therefore, because the model ID did not exactly match the WDID designation in HydroBase, their water rights had to be set. The water rights and administration numbers set correspond to the decreed water rights in HydroBase.

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 diversions.

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 natural flow and simulation modes. Soil moisture capacity values were gathered from Natural Resources Conservation Service (NRCS) mapping. The file was created by StateDMI.

5.5.2. Irrigation Parameter Yearly (*.ipy)

This file contains conveyance efficiency and maximum application efficiency by irrigation type for each irrigation structure for which efficiency varies, and each year of the study period. The file also contains acreage by irrigation type – either flood or sprinkler. In the North Platte basin, all acreage has been assigned flood irrigation type. Maximum application efficiency has been set to 60 percent for all structures, representing a reasonable upper limit to flood irrigation efficiency. Conveyance efficiencies have been estimated for each ditch, taking into account soil type and ditch length. This file was created by StateDMI.

5.5.3. Irrigation Water Requirement File (*.ddc)

Data for the irrigation water requirement file was generated by StateCU for the period 1956 through 2007. 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. Acreage for each structure was set to the acreage defined in SPDSS Irrigated Acreage Assessment completed for 1956, 1977, 1986, 2001, and 2005. Linear interpolation was used to estimate by-ditch changes in acreage between the GIS coverages. The differences in acreage between GIS coverages were minimal over the model study period. The irrigation water requirement file contains the time series of monthly irrigation water requirements for irrigation structures for the study period.

5.6 Reservoir Files

5.6.1. Reservoir Station File (*.res)

This file describes physical properties and some administrative characteristics of each reservoir simulated in the North Platte Model. It was assembled by StateDMI, using considerable amount of information provided in the commands file. Fourteen key reservoirs were modeled explicitly.

The modeled reservoirs are shown below in Table 5.6 with their capacity and their number of accounts or pools.

Table 5.6
Reservoirs in the North Platte River Model

#	WDID	Name	Capacity (af)	# of Owners
1	4703595	BIG CREEK RESERVOIR	1,434	1
2	4703596	BOETTCHER RESERVOIR	658	1
3	4703599	CARLSTROM RESERVOIR	530	1
4	4703603	CLAYTON RESERVOIR	213	1
5	4703614	MACFARLANE RESERVOIR	6,507	2
6	4703616	MEXICAN RESERVOIR	154	1
7	4703621	SLACK WEISS RESERVOIR	182	2
8	4703627	WALDEN RESERVOIR	5,100	3
9	4703628	WEST ARAPAHOE RESERVOIR	498	1
10	4703699	ANNEX RESERVOIR	900	1
11	4703743	SEYMOUR RESERVOIR	780	1
12	4703746	POLE MOUNTAIN RESERVOIR	1,805	1
13	4703750	LAKE JOHN RESERVOIR	7,092	1
14	4704335	MEADOW CREEK RESERVOIR	4,750	3

Parameters related to the physical attributes of key reservoirs include inactive storage where applicable, total storage, area-capacity data, applicable evaporation/precipitation stations, and initial reservoir contents. For explicitly modeled reservoirs, storage information was obtained from either the Division Engineer or the reservoir owners. Area/capacity tables were not available, therefore the reservoir were estimated to be 10 feet deep for purposes of estimating evaporation. Initial contents for all reservoirs are set to the December 1955 content, if available. After filling dead pools, initial contents are prorated to reservoir accounts based on account size.

Administrative information includes reservoir account ownership, administrative fill date, and evaporation charge specifications. This information was obtained from interview with the Division Engineer, local water commissioners, and in most cases, the owner/operator of the individual reservoirs.

5.6.1.1 Reservoir Accounts

5.6.1.1.15 Big Creek Reservoir

Big Creek Reservoir (4703595) is an on-channel reservoir filled from Big Creek. Although the decreed capacity is 6,900 acre-feet, the estimated actual capacity is 1,434 acre-feet. It has a single irrigation account to deliver supplemental irrigation supply to the downstream Independence Ditch (4700683).

5.6.1.1.16 Boettcher Reservoir

Boettcher Reservoir (4703596) is an off-channel reservoir located in the Lake Creek drainage. It is filled from the North Fork North Platte River via Little Nellie Ditch (4700730). It has a single irrigation account with 658 acre-feet capacity used to release general replacement water to Lake Creek and downstream North Fork North Platte River diverters, thereby keeping the downstream senior user ditches (Victor Ditch 4700932 and West Fork Ditch 4700951) from placing a call.

5.6.1.1.17 Carlstrom Reservoir

Carlstrom Reservoir (4703599) is an off-channel reservoir located in the Michigan River drainage. It is filled from the Michigan River by Cumberland Ditch (4700577). It has a single irrigation account with 530 acre-feet capacity used to deliver supplemental water to Cumberland Ditch Irrigation Demand (4700577_I).

5.6.1.1.18 Clayton Reservoir

Clayton Reservoir (4703603) is an off-channel reservoir located in the Buffalo Creek drainage. It is filled from Buffalo Creek by Clayton Ditch (4700556). It has a single irrigation account with 213 acre-feet capacity used to deliver supplemental water to Clayton Ditch Irrigation Demand (47005556_I), Bock Ditch (4700514), Clifton Ditch (4700561), Poled Angus Ditch (4700839) and Steele Ditch (4700898).

5.6.1.1.19 MacFarlane Reservoir

MacFarlane Reservoir (4703614) is an off-channel reservoir located in the Grizzly Creek Drainage. It is filled from the Illinois River and Willow Creek via the MacFarlane Extension Ditch (4700745) and the Howard Ranch Ditch (4700672_M). MacFarlane is modeled with two accounts; a 3,254 acre-feet irrigation account and a 3,253 acre-feet U.S. Fish and Wildlife Service (USFWS) account. Water is released to the river from the irrigation account in exchange for diversions through the following upstream structures: Midland Ditch (4700774), New Ross Ditch (4700791), and Howard Ranch Ditch (4700672_M). Water is releases from the USFWS account to irrigated meadowlands directly downstream of the reservoir (Howard D MacFarlane Acct 4701198).

5.6.1.1.20 Mexican Reservoir

Mexican Reservoir (4703616) is an on-channel reservoir filled from Mexican Creek. It can be refilled by releases from upstream Pole Mountain Creek. It has a single irrigation account with 154 acre-feet capacity used to deliver supplemental water to Mexican Ditch (4700770).

5.6.1.1.21 Slack Weiss Reservoir System

Slack Weiss Reservoir System (4703621) includes combined storage and uses of Slack Weiss Reservoir (4703621) and Ninegar Reservoir (4703777). It is an off-channel reservoir system filled from Ninegar Creek via Slack Weiss Ditch (4700880). It is modeled with two irrigation accounts with 121 acre-feet of reservoir storage reserved in Account 1 for supplemental deliveries to Allard Ditch (4701006) located in the Coyote Creek drainage and 61 acre-feet of reservoir storage reserved in Account 2 for supplemental deliveries to Cochrane Ditch MS (4701024_M).

5.6.1.1.22 Walden Reservoir

Walden Reservoir (4703627) is an off-channel reservoir modeled with three accounts; a 4,148 acre-feet irrigation account, a 102 acre-feet municipal account, and an 850 acre-feet CDOW account. It is filled from the Michigan River via Old SC diversion system (4700813_D), plus picks up Illinois River water via Walden Storage Carrier (4703627_C). Releases from the irrigation account are made to the following downstream structures:

- Col Davis Ditch (4700567)
- Cumberland Ditch Irrigation Demand (4700577_I)
- Hiho Ditch (4700662)
- Kiwa Ditch (4700711)
- North Park Ditch No 7 (4700799)
- Seneca Diversion System (4700868_D)
- Alma Ditch (4701008)
- Buckeye Ditch (4701022)
- Poquette Ditch (4700842)

In addition, releases are made, by exchange, to the following upstream ditch demands:

- George Ward Ditch (4700630)
- North Park Ditch No 4 (4700802)
- North Park Ditch No 5 (4700803)
- Queen Ditch (4700847)
- Ruction Diversion System (4700859_D)

5.6.1.1.23 West Arapahoe Reservoir

West Arapahoe Reservoir (4703628) is an off-channel reservoir filled from Arapahoe Creek via the West Arapahoe Feeder Ditch (4702049). Diversions from the single 498 acre-feet irrigation account are released, by exchange, to Eureka Ditch for irrigation use and to be carried to storage in Seymour Reservoir.

5.6.1.1.24 Annex Reservoir

Annex Reservoir (4703699, aka Lake John Annex) is an off-channel reservoir located in the Lake Creek drainage. It is filled from Lake Creek via Hill Ditch 1 (4700663), Hill Ditch 2 (4700664), and can also be filled from the North Fork North Platte River via Little Nellie Ditch (4700730). It has a single irrigation account with 900 acre-feet capacity used to release general replacement water to Lake Creek and downstream North Fork North Platte River diverters, thereby keeping the downstream senior user ditches (Victor Ditch 4700932 and West Fork Ditch 4700951) from placing a call. It also releases water, by exchange, to Legal Tender Irrigation Demand (4700720_I).

5.6.1.1.25 Seymour Reservoir System

Seymour Reservoir System (4703743) includes combined storage and uses of Seymour Reservoir and Heckla Reservoir (4703608). It is an off-channel reservoir filled from Arapahoe Creek via the Eureka Ditch (4700614) and from storage exchanged from West Arapahoe Reservoir to Eureka Ditch. Water is released from the single 780 acre-feet irrigation account to the 60 percent of Eureka Ditch demand (614_60_I) located downstream of the reservoir.

5.6.1.1.26 Pole Mountain Reservoir

Pole Mountain Reservoir (4703746) is located on Middle Fork Mexican Creek and fills from both tributary inflow and from Mexican Creek via Pole Moutain Reservoir Feeder Ditch (4700838). Water is released from the single 1,805 acre-feet irrigation account to refill Mexican Reservoir and to meet supplemental demands of Nine Six Nine Ditch (4700969).

5.6.1.1.27 Lake John Reservoir

Lake John Reservoir (4703750) is an off-channel reservoir located in the Lake Creek drainage. It is filled from the North Fork North Platte River via Legal Tender Ditch (4700720). The reservoir is owned and operated by CDOW, with a single 7,092 acre-feet account. There is no demand for reservoir releases; therefore Legal Tender Ditch diversions are to replace evaporation losses.

5.6.1.1.28 Meadow Creek Reservoir

Meadow Creek Reservoir (4704335) is located on Meadow Creek and can fill from tributary inflow, but is mostly filled from the Michigan River via Squibob Ditch (4700893_C). Meadow Creek is modeled with three accounts, Fort Collins 1 account for 500 acre-feet, an irrigation account for 3,550 acre-feet, and Fort Collins 2 account for 700 acre-feet. Water from the two Fort Collins' accounts is released by exchange for diversions through the Michigan Ditch transbasin diversion (4704603). Releases from the irrigation account are made to the following downstream structures:

- Cleveland Ditch (4700559_M)
- George Water Ditch (4700630)
- Michigan Highline Ditch (4700773)
- Wales Ditch (4700939)
- North Park Ditch No 5 (4700803)
- Queen Ditch (4700847)
- Ruction Diversion System (4700859_D)
- Bostwick Ditch (4700521)
- North Park Ditch No 4 (4700802)

In addition, releases are made, by exchange, to the following ditch demands:

- Gibbs Ditch (4700633)
- Poverty Diversion System (4700845_D)
- Poverty Flat Ditch No 2 (4700844)
- Gould Diversion System (4700639_D)
- Overland Ditch (4700819)
- Squibob Ditch (4700893)
- Brocker Endomile Ditch (4700530_M)
- Mill Creek Ditch (4700776)

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 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 based on elevation through the distributions listed in Table 5.7. These monthly distributions are used by the State Engineer's Office.

Table 5.7
Monthly Distribution of Evaporation (percent)

Month	Distribution
Jan	3.0
Feb	3.5
Mar	5.5
Apr	9.0
May	12.0
Jun	14.5
Jul	15.0
Aug	13.5
Sep	10.0
Oct	7.0
Nov	4.0
Dec	3.0

The resulting net monthly free water surface evaporation estimates used in the North Platte model, in feet, are as follows, resulting in an annual free surface evaporation of 1.532 feet.

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.114	0.018	-0.038	-0.053	0.014	0.088	0.150	0.201	0.329	0.308	0.223	0.178

Where to find more information

- SPDSS Task 53.3 Technical Memorandum describes the procedure for determining the appropriate net evaporation to use in the North Park Model.

5.6.3. End-Of-Month 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 natural flow to reverse the effects of reservoir storage and evaporation on gaged streamflows, and to produce comparison output useful for calibration. The file was created by TSTool, which reads data from HydroBase and filled missing data with a variety of user-specified algorithms.

Data for the North Platte Model key reservoirs was generated by converting sporadic daily observations stored in HydroBase to month-end data. Missing end-of-month contents were filled using linear interpolation between observed data over a 6 month maximum period, then with the average of available values for months with the same hydrologic condition. Most of the reservoirs in the North Platte Model were on-line prior to 1956. Table 5.8 presents the on-line date for reservoirs that were not operating during the full study period. Historical contents in the *.eom file are set to zero prior to the on-line date.

Table 5.8
Reservoir On-line Dates

WDID	Reservoir Name	On-Line Date
4703746	Pole Mountain	1962
4704335	Meadow Creek	1980

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 were set to zero and the maximum targets were set to capacity for all reservoirs. Targets allow maximum control of reservoir levels by storage rights and releases to meet demands. The file was created by TSTool.

5.6.5. Reservoir Right File (*.rer)

The reservoir right file contains 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 was used as a first or second fill. It is recommended for future updates that the StateDMI commands be run initially without the "set" commands. This allows the modeler to view any changes to water rights (transfers, conditional to absolute, abandonment, etc.) reflected in updated versions of HydroBase and modify the "set" commands as necessary.

In general, water rights for explicitly modeled reservoirs were taken from HydroBase and correspond to the State Engineer's official water rights tabulation.

5.6.5.1 Special Reservoir Rights

5.6.5.1.1 Annex Reservoir

Annex Reservoir (4703699 aka Lake John Annex) does not have a decreed water right in HydroBase, pending current court action. A "free river" water right was set to fill the reservoir with an administration number of 99999.99999.

5.6.5.1.2 Reservoir Refill Water Rights

StateDMI automatically extracts reservoir storage rights in HydroBase and assigns them a "first fill" flag. Many of the reservoirs have refill rights. The refill flag was set using StateDMI set commands for the refill rights decreed for the following reservoirs:

- Carlstrom Reservoir (4703599)
- Clayton Reservoir (4703603)
- MacFarlane Reservoir (4703614)
- Walden Reservoir (4703627)
- Seymour Reservoir System (4703743)
- Meadow Creek Reservoir (4704335)

5.7 Instream Flow Files

5.7.1. Instream Flow Station File (*.ifs)

Twenty-six instream flow reaches are defined in this file, which was created in 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 5.9 lists each instream flow station included in the North Platte Model along with their location and average annual demand. These rights represent decrees acquired by CWCB, with the exception of four proposed instream flows included in the model for analysis purposes.

5.7.2. Instream Flow Annual Demand File (*.ifa)

Instream flow demands were developed from decreed amounts and comments in the State Engineer's water rights tabulation. Twelve monthly instream flow demands were used for each year of the simulation. The file contains monthly demands for each instream flow structure included in the North Platte Model.

5.7.3. Instream Right File (*.ifr)

Water rights for each instream flow reach modeled in the North Platte Model are contained in the instream flow right file, and shown in Table 5.9. This information was obtained from the CWCB instream flow database. The instream flow rights associated with the proposed reaches were "turned off" for the simulation.

Table 5.9
Instream Flow Summary

#	WDID	Name	Location	Decree (cfs)
1	4701118	Line Creek MSF	Headwaters to Confluence of Davis Creek to CO/WY Border	3.00
2	4701122	Beaver Creek MSF	Headwaters to USFS Boundary	5.00
3	4701168	East Branch Willow Creek MSF	Headwaters to School Section Ditch	2.50
4	4701170	Illinois River MSF	Headwaters to Park Ditch	3.00
5	4701171	Elk Creek MSF	Headwaters to Jack Creek	0.75
6	4701172	Grass Creek MSF	Headwaters to North Michigan Creek Reservoir	0.50
7	4701173	Jack Creek MSF	Headwaters to Teller Ditch	8.50
8	4701174	Rock Creek MSF	Headwaters to Darcy Ditch	1.00
9	4701175	Silver Creek MSF	Headwaters to South Fork Michigan River	3.00
10	4701176	South Fork Canadian River MSF	Headwater to Bradfield Ditch	2.00
11	4701177	South Fork Michigan River MSF-Lower	Silver Creek to Mason Ditch	18.00
12	4701178	Willow Creek MSF	Headwaters to Wycoff Ditch	5.00
13	4702071	Whalen Creek MSF	Headwaters at Lake to Newcomb Creek	3.00
14	4702072	Norris Creek MSF	Headwaters to Roaring Ditch	7.00

15	4702074	Colorado Creek MSF	Headwaters to Morraine Ditch	3.00
16	4702075	Arapahoe Creek MSF	Confluence of Middle Fork and South Fork to Eureka Ditch	8.00
17	4702076	Porcupine Creek MSF	Headwaters to South Fork Michigan River	2.00
18	4702078	North Fork Canadian River MSF	Headwaters to South Fork Canadian River	3.00
19	4702087	Grizzly Creek MSF	Headwaters to Arapahoe Creek	2.00
20	4702088	Little Grizzly Creek MSF	Headwaters to Jennie Ditch	4.00
21	4702104	North Fork Michigan River MSF	Headwaters to Michigan River	5.00
22	4702105	South Fork Michigan River MSF	Headwaters to Silver Creek	15.00
23	47Ind_MSF	Prop Indian Creek MSF	Headwaters to Araphoe Feeder Ditch 2	4.00
24	47NFNP_MSF	Prop NF North Platte MSF	Headwaters to Little Nellie Ditch	7.10
25	47SFBig_MSF	Prop SF Big Creek MSF	Confluence with Wheeler Creek to CO/WY Border	10.20
26	47Wheel_MSF	Prop Wheeler Creek MSF	Headwaters toSouth Fork Big Creek	0.80

5.8 Plan Data File (*.pln)

The plan data file can contain information related to operating terms and conditions, well augmentation, water reuse, recharge, and out-of-priority plans. Plan structures are accounting tools used in coordination with operating rights to model complicated systems. In the North Platte Model, accounting plan structures are used to split in-priority diversions through Eureka Ditch into two “accounts” for use on lands irrigated upstream and downstream of Seymour Reservoir. The use of an accounting plan structure assures when water supply is limited, all land under the ditch share in the shortages.

When Eureka is legally entitled to water, it is diverted into the Eureka Full Plan (614_PLN). The diverted water is then split into two plans; 60 percent is moved into plan 614_60PLN, and 40 percent is moved into plan 614_40PLN. The water is then available to the split irrigation demands under Eureka Ditch (614_40_I and 614_60_I). Any unused water is released back to the river during the same time step.

5.9 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 reservoir 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 North Platte model, seven different types of operating rights are used:

- **Type 2** – a release from storage to the stream, for shepherded delivery to a downstream diversion or carrier. Typically, the reservoir supply is supplemental, and its release is given an administration number junior to direct flow rights at the destination structure. A release is made only if demand at the diversion structure is not satisfied after direct flow rights have diverted.

- **Type 3** – a release from storage directly to a carrier (a ditch or canal as opposed to the river), for delivery to a diversion station. Typically, the reservoir supply is supplemental, and its release is given an administration number junior to direct flow rights at the destination structure. A release is made only if demand at the diversion structure is not satisfied after direct flow rights have diverted.
- **Type 4** – a release from storage in exchange for a direct diversion elsewhere in the system. The release can occur only to the extent that legally available water occurs in the exchange reach. Typically, the storage water is supplemental, and is give an administration number junior to direct flow rights at the diverting structure.
- **Type 7** – a release from storage in exchange for diversion by a carrier elsewhere in the system. The release can occur only to the extent that there is legally available water in the exchange reach. Typically, the storage water is supplemental, and is given an administration number junior to carrier's operating right. Releases to irrigation structures are made only if there is remaining crop irrigation requirement.
- **Type 10** – a general replacement release from storage for a diversion by river direct or by exchange elsewhere in the system.
- **Type 11** – a direct flow diversion to another diversion or reservoir through an intervening carrier. It uses the administration number and decreed amount of the direct flow right associated with the carrier, regardless of the administration number assigned to the operating right itself. In the North Platte model, the Type 11 operating right is used both as a direct flow diversion to another diversion and as a direct flow diversion to a reservoir.
- **Type 22** – 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. The depth of the soil zone is defined in the control file (*.ctl). For the North Platte River Model, the effective soil depth or root zone was set to 3.3 feet. As discussed in section 5.5.1, the available water content, in inches per inch, was defined for each irrigating structure in the StateCU structure file (*.str).
- **Type 24** – a direct flow diversion's water right exchanged to another direct flow structure, reservoir or plan structure. The exchange can occur from the river or by a carrier. In the North Platte River Model, this operating rule is used in association with the Eureka Ditch water rights exchanged to the Eureka Ditch plan structures.
- **Type 27** – a release from storage tied to a reuse plan to a diversion or reservoir and corresponding plan structure directly via the river or a carrier. This rule type is used to release water from the Eureka Ditch plan structures to the Eureka Ditch irrigation demand.
- **Type 29** – provides a method to spill water from a reuse plan or accounting plan back to the river. Water that is stored in a plan structure that is not released to meet a demand in the same time step must be released by the river and available to meet demands elsewhere in the basin.
- **Type 46** – provides a method to distribute water from one accounting plan to multiple accounting plans at the same priority. It is typically used along with a Type 24 or 25 operating rule when diverted water is used by more than one owner. This rule allows for shortages to be shared amongst the multiple receiving plans and their associated users.

For all type 2, 3, 4, and 11 operating rules where water is released from a reservoir directly to irrigation (i.e. not via the river), the variable iopsou(4,1) in the operating file has been set to "1". This directs StateMod to release water only when an irrigation water requirement exists. When an irrigation water requirement exists, the operating rule will attempt to release the full amount required to satisfy the headgate demand defined in the *.ddm file. The variable efficiency algorithm will then determine the actual efficiency of the released water.

The presentation of operating rights for the North Platte Model is generally organized according to the projects/reservoirs involved:

Section	**Description**
5.9.1	Big Creek Reservoir
5.9.2	Boettcher Reservoir
5.9.3	Carlstrom Reservoir and Irrigation
5.9.4	Clayton Reservoir and Irrigation
5.9.5	MacFarlane Reservoir and Irrigation
5.9.6	Mexican Reservoir
5.9.7	Slack Weiss Reservoir
5.9.8	Walden Reservoir
5.9.9	West Arapahoe Reservoir and Irrigation
5.9.10	Eureka Ditch and Seymour Reservoir
5.9.11	Lake John, Annex Reservoir, and Legal Tender Irrigation
5.9.12	Pole Mountain Reservoir
5.9.13	Meadow Creek Reservoir
5.9.14	Multi-structures Irrigating the Same Acreage
5.9.15	Soil Moisture Operations

Where to find more information

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

5.9.1. Big Creek Reservoir

Big Creek Reservoir (4703595) in an on-channel reservoir located on the South Fork of Big Creek near the Colorado-Wyoming stateline. The reservoir delivers supplemental water for irrigation under Independence Ditch, located downstream of the reservoir, from the single irrigation account. The priority of the operating rule to release water is set to be just junior to the direct flow right on the ditch.

One operating rule is used to specify Big Creek Reservoir operations:

Right #	Destination	Reservoir Account	Admin #	Right Type	Description
1	Independence Ditch	1	16750.00001	2	Release to direct diversion

5.9.2. Boettcher Reservoir

Boettcher Reservoir (4703596) is located in the Lake (Scribner) Creek basin, tributary of the North Fork of the North Platte River. The single irrigation account in the reservoir is filled via Little Nellie Ditch (4700730) and provides supplemental water to junior diverters on the North Fork of the North Platte River. In lieu of including several reservoir release operating rules, releases from Boettcher Reservoir is modeled using a General Replacement operating rules.

Three operating rules are used to simulate Boettcher Reservoir operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	Boettcher Reservoir	Little Nellie Ditch	30280.13696	11	Carrier to reservoir
2	Multiple Structures	1	54880.00000	10	General replacement
3	Legal Tender Irrig.	1	54880.00000	4	Exchange to direct diversion

Operating rule 1 diverts water for storage in Boettcher Reservoir (4703596) via Little Nellie Ditch (4700730). The administration number for this operating rule corresponds to the reservoir right. The amount of water delivered is limited to water physically and legally available under the reservoir right, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rule 2 allows for water to be released from the reservoir to multiple structures, either by direct release or exchange, as indicted by the replacement option (*ireptyp*) in the direct diversion station file (*.dds). The following structures were set to receive supplemental supply from Boettcher Reservoir.

WDID	Name	WDID	Name
4702030	Wattenburg Ditch	4700606	Eber Ditch
4700852	Reithmeyer Ditch	4700912	Sunrise Ditch
4700927	Ulrich Ditch	4700797	North Fork Ditch
4700684	Independent Ditch	4700876	Short Run Ditch
4700527	Briggs Bohn Ditch	4700743	Mabel Dow Ditch
4700528_M	Briggs Bohn MS	4700948	West Boettcher Ditch
4700725	Lillie Ditch	4700735_M	Lookout Ditch MS
4700612	Erika Ditch	4700966	Zirkel Ditch
4700522	Boulder Ditch	4700906	Stormy Ditchi

4700665	Hillside Ditch	4700650	Hard to Find Ditch
4700505	Bear Creek Ditch	4700730	Little Nellie Ditch
4700657_D	Haworth Ditch DS	4700871	Shafer Ditch
4700596	Dry Run Ditch	4700507	Beaverdale Ditch
4700714	Lake Creek Ditch	4700837	Pleasant Valley Ditch

The General Replacement operating rule does not automatically trigger a reservoir release for off-channel demands; therefore Operating Rule 3 allows the reservoir to release to Legal Tender Irrigation Demand. The priority for both the Operating Rules 2 and 3 was set such that it was junior to the direct diversion rights associated with structures on the North Fork of the North Platte River.

5.9.3. Carlstrom Reservoir and Irrigation

Carlstrom Reservoir (4703599) is an off-channel reservoir located in the Michigan River basin. The single irrigation account is filled via Cumberland Ditch (4700577) and provides supplemental water to irrigated lands located downstream of the reservoir. The irrigation demand associated with these lands is modeled under the Cumberland Ditch irrigation demand structure (4700577_I).

Eight operating rules are used to simulate Carlstrom Reservoir operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	Cumberland Ditch Irrig. Demand	Cumberland Ditch	13605.00000	11	Carrier to demand
2	Cumberland Ditch Irrig. Demand	Cumberland Ditch	14323.00000	11	Carrier to demand
3	Cumberland Ditch Irrig. Demand	Cumberland Ditch	17420.00000	11	Carrier to demand
4	Cumberland Ditch Irrig. Demand	Cumberland Ditch	23016.21807	11	Carrier to demand
5	Cumberland Ditch Irrig. Demand	Cumberland Ditch	48212.32293	11	Carrier to demand
6	Carlstrom Reservoir	Cumberland Ditch	36354.00000	11	Carrier to reservoir
7	Carlstrom Reservoir	Cumberland Ditch	49673.36354	11	Carrier to reservoir
8	Cumberland Ditch Irrig. Demand	1	48212.32294	3	Release to carrier

Operating rules 1 through 5 carry direct diversions to Cumberland Ditch irrigation demand (4700577_I) via Cumberland Ditch (4700577). The administration numbers for these operating rules correspond to Cumberland Ditch direct water rights. The amount of water delivered is limited to water physically and legally available under the ditch right, capacity in the carrier ditch, and irrigation demand.

Operating rules 6 and 7 divert water for storage in Carlstrom Reservoir (4703599) via Cumberland Ditch (4700577). The administration numbers for these operating rules correspond to the two reservoir rights. The amount of water delivered is limited to water physically and legally available under the reservoir right, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rule 8 releases Carlstrom Reservoir storage water from the single irrigation account directly to the Cumberland Ditch irrigation demand (4700577_I). The administration number for this operating right is just junior to the direct flow rights for Cumberland Ditch. The amount of water released is limited by the amount currently in the irrigation account and the unsatisfied irrigation demand.

5.9.4. Clayton Reservoir and Irrigation

Clayton Reservoir (4703603) is an off-channel reservoir located in the Buffalo Creek basin. The single irrigation account is filled via Clayton Ditch (4700556) and provides supplemental water to irrigated lands located downstream of the reservoir, as well as irrigated lands further downstream of the reservoir in the Buffalo Creek basin.

Ten operating rules are used to simulate Clayton Reservoir operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	Clayton Ditch Irrig. Demand	Clayton Ditch	14769.00000	11	Carrier to demand
2	Clayton Ditch Irrig. Demand	Clayton Ditch	14769.00000	11	Carrier to demand
3	Clayton Reservoir	Clayton Ditch	21366.19981	11	Carrier to reservoir
4	Clayton Reservoir	Clayton Ditch	33534.32772	11	Carrier to reservoir
5	Clayton Reservoir	Clayton Ditch	50403.38902	11	Carrier to reservoir
6	Clayton Ditch Irrig. Demand	1	21366.19578	3	Release to carrier
7	Bock Ditch	1	30280.16955	2	Release to direct diversion
8	Clifton Ditch	1	21366.19579	2	Release to direct diversion
9	Poled Angus Ditch	1	33534.24258	2	Release to direct diversion
10	Steele Ditch	1	30280.16924	2	Release to direct diversion

Operating rules 1 and 2 carry direct diversions to Clayton Ditch irrigation demand (4700556_I) via Clayton Ditch (4700556). The administration numbers for these operating rules correspond to Clayton Ditch direct water rights. The amount of water delivered is limited to water physically and legally available under the ditch right, capacity in the carrier ditch, and irrigation demand.

Operating rules 3 through 5 diverts water for storage in Clayton Reservoir (4703603) via Clayton Ditch (4700556). The administration numbers for these operating rules correspond to the three reservoir rights. The amount of water delivered is limited to water physically and legally available under the reservoir right, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rule 6 releases Clayton Reservoir storage water from the single irrigation account directly to the Clayton Ditch irrigation demand (4700556_I). The administration number for this operating right is just junior to the direct flow rights for Clayton Ditch. The amount of water released is limited by the amount currently in the irrigation account and the unsatisfied irrigation demand.

Operating rules 7 through 10 release Clayton Reservoir storage water from the single irrigation account to four ditches downstream of the reservoir via the river. The administration numbers for these operating rights is just junior to the most junior direct flow right for the ditches. The amount of water released is limited by the amount currently in the irrigation account and the unsatisfied demand at the ditch.

5.9.5. MacFarlane Reservoir and Irrigation

MacFarlane Reservoir (4703614) is an off-channel reservoir located in the Illinois Creek basin. The dual-purpose reservoir is used for irrigation and by the U.S. Fish and Wildlife Service (USFWS) in the Arapaho National Wildlife Refuge (ANWR). The reservoir can store both Willow Creek and Illinois River diversions via Howard Ditch (4700672_M) and the MacFarlane Extension Ditch (4700745), respectively. MacFarlane Extension Ditch diverts from the Illinois River, conveys the storage water to Willow Creek where the water is rediverted by Howard Ditch and conveyed to the reservoir. Releases via exchange from the irrigation account provide supplemental water to irrigated lands located in the Willow Creek and Buffalo Creek basins. Releases from the USFWS account provide supplemental water to irrigated meadowlands and ponds located downstream of the reservoir in ANWR.

Ten operating rules are used to simulate MacFarlane Reservoir operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	MacFarlane Ditch	MacFarlane Ext. Ditch	21366.18780	11	Carrier to demand
2	MacFarlane Ditch	MacFarlane Ext. Ditch	22455.00001	11	Carrier to demand
3	MacFarlane Reservoir	Howard Ditch	22207.00000	11	Carrier to reservoir
4	MacFarlane Reservoir	MacFarlane Ext. Ditch	22207.00000	11	Carrier to reservoir
5	MacFarlane Reservoir	Howard Ditch	49102.00000	11	Carrier to reservoir
6	MacFarlane Reservoir	MacFarlane Ext. Ditch	49102.00000	11	Carrier to reservoir
7	USFWS Demand	2	50402.00000	3	Release to carrier
8	Midland Ditch	1	50403.32719	4	Exchange to direct diversion
9	New Ross Ditch	1	50403.36060	4	Exchange to direct diversion
10	Howard Ditch MS	1	50403.32769	4	Exchange to direct diversion

Operating rules 1 and 2 carry direct diversions to MacFarlane Ditch irrigation demand (4701198) via MacFarlane Extension Ditch (4700745). The administration numbers for these operating rules are one junior to Howard Ditch's direct water rights. The amount of water delivered is limited to water physically and legally available under the ditch right, capacity in the carrier ditch, and irrigation demand.

Operating rules 3 through 6 divert water for storage in MacFarlane Reservoir (4703603) via Howard Ditch (4700672_M) and MacFarlane Extension Ditch (4700745). As noted above, the MacFarlane Extension Ditch diversions to storage are rediverted by Howard Ditch, therefore the Howard Ditch structure is modeled as a carrier for the operating rules. The administration numbers for these operating rules correspond to the two reservoir rights; the reservoir rights can be diverted from both locations therefore four operating rules were necessary. The amount of water delivered is limited to water physically and legally available under the reservoir right, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rule 7 releases MacFarlane Reservoir storage water from the USFWS account directly to the USFWS (Howard Ditch MacFarlane Acct, 4701198) irrigation demand. The USFWS irrigation demand structure does not have decreed direct flow rights, therefore the administration number for this operating right was modeled based on the administration numbers associated with other reservoir releases. The amount of water released is limited by the amount currently in the reservoir account and the unsatisfied irrigation demand.

Operating rules 8 through 10 release MacFarlane Reservoir storage water from the irrigation account to Midland Ditch (4700774), New Ross Ditch (4700791), and Howard Ditch MS (4700672_M) via an exchange. The administration numbers for these operating rights are just junior to the most junior direct flow right for the ditches. The amount of water released is limited by the amount currently in the irrigation account, the unsatisfied demand at each ditch, and legally available water at the point of diversion.

5.9.6. Mexican Reservoir and Irrigation

Mexican Reservoir (4703616) is an on-channel reservoir located on Mexican Creek, tributary to Grizzly Creek. The single irrigation account provides supplemental water to Mexican Ditch (4700770), located downstream of the reservoir. In addition to storing under reservoir rights, Pole Mountain Creek Reservoir releases can be stored in Mexican Reservoir.

Two operating rules are used to simulate Mexican Reservoir operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	Mexican Ditch	1	30280.23892	2	Release to direct diversion
2	Mexican Reservoir	Pole Mtn. Creek Reservoir	33534.23893	2	Release to reservoir

Operating rule 1 releases Mexican Reservoir storage water from the single irrigation account to Mexican Ditch (4700770). The administration number for this operating right is just junior to the most junior direct flow right. The amount of water released is limited by the amount currently in the irrigation account and the unsatisfied demand at the ditch.

Operating rule 2 releases Pole Mountain Creek Reservoir storage water to Mexican Reservoir. The administration number for this operating right is just junior to the Mexican Reservoir right. The amount of water released is limited by the amount currently in both the Mexican Pole Mountain Creek Reservoir and Mexican Reservoir accounts.

5.9.7. Slack Weiss Reservoir System

Slack Weiss Reservoir System (4703621) includes combined storage and uses of Slack Weiss Reservoir (4703621) and Ninegar Reservoir (4703777). It is an off-channel reservoir system filled from Ninegar Creek via Slack Weiss Ditch (4700880) located in the Arapaho Creek basin. The reservoir is modeled with two irrigation accounts; 121 acre-feet stored in Account 1 for supplemental water to Allard Ditch (4701006) and 61 acre-feet stored in Account 2 for supplemental deliveries to Cochrane Ditch (4701024_M).

Five operating rules are used to simulate Slack Weiss Reservoir operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	Slack Weiss Res. System	Slack Weiss Ditch	26727.14764	11	Carrier to reservoir
2	Slack Weiss Res. System	Slack Weiss Ditch	43829.14853	11	Carrier to reservoir
3	Slack Weiss Res. System	Slack Weiss Ditch	50769.30315	11	Carrier to reservoir
4	Allard Ditch	1	30280.14612	3	Release to carrier
5	Cochrane Ditch MS	2	26727.15142	3	Release to carrier

Operating rules 1 through 3 divert water for storage in both accounts in Slack Weiss Reservoir (4703621) via Slack Weiss Ditch (4700880). The administration numbers for these operating rules correspond to the three reservoir rights. The amount of water delivered is limited to water physically and legally available under the reservoir right, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rule 4 releases Slack Weiss Reservoir storage water from Account 1 to Allard Ditch (4701006). The administration number for this operating right is just junior to the direct flow rights for Allard Ditch. The amount of water released is limited by the amount currently in Account 1 and the unsatisfied irrigation demand.

Operating rule 5 releases Slack Weiss Reservoir storage water from Account 2 to Slack Weiss Ditch MS (4701024_M). The administration number for this operating right is just junior to the direct flow rights for Slack Weiss Ditch. The amount of water released is limited by the amount currently in Account 2 and the unsatisfied irrigation demand.

5.9.8. Walden Reservoir

Walden Reservoir (4703627) is an off-channel reservoir located in the Michigan Creek basin. The multi-purpose reservoir is used for irrigation, municipal, and by the Colorado Department of Wildlife (CDOW) as a conservation pool. The reservoir can store both Illinois River and Michigan River diversions via Walden Storage Carrier (4703627_C) and Old SC Ditch (4700813_D), respectively. Old SC Ditch diverts from the Michigan River, conveys the storage water to Illinois Creek where the water is rediverted by the Walden Storage Carrier and conveyed to the reservoir. Direct releases and releases via exchange from the irrigation account provide supplemental water to irrigated lands located in the Michigan River and Illinois River basins. No releases are modeled from the CDOW conservation pool, only evaporation depletes this account. The municipal account currently serves as a placeholder; the majority of the municipal demand is met by ground water and demands not included in the model.

Twenty operating rules are used to simulate Walden Reservoir operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	Walden Reservoir	Walden Storage Carrier	38187.00000	11	Carrier to reservoir
2	Walden Reservoir	Walden Storage Carrier	43829.40365	11	Carrier to reservoir
3	Walden Reservoir	Walden Storage Carrier	47100.00000	11	Carrier to reservoir
4	Walden Reservoir	Old SC Ditch	47938.00000	11	Carrier to reservoir
5	Walden Reservoir	Walden Storage Carrier	49673.38187	11	Carrier to reservoir
6	Walden Reservoir	Walden Storage Carrier	52595.38187	11	Carrier to reservoir
7	Col. Davis Ditch	1	50403.32708	2	Release to direct diversion
8	Hiho Ditch	1	50403.29016	2	Release to direct diversion
9	Kiwa Ditch	1	50403.35590	2	Release to direct diversion
10	North Park Ditch No 7	1	50403.32780	2	Release to direct diversion
11	Seneca Ditch DS	1	50403.35590	2	Release to direct diversion
12	Alma Ditch	1	33534.29067	2	Release to direct diversion
13	Buckeye Ditch	1	50664.00001	2	Release to direct diversion
14	Poquette Ditch	1	50403.28642	2	Release to direct diversion
15	Cumberland Ditch Irrig. Demand	1	48212.32295	4	Exchange to direct diversion
16	George Ward Ditch	1	21366.13424	4	Exchange to direct diversion
17	North Park Ditch No 4	1	50403.32660	4	Exchange to direct diversion
18	North Park Ditch No 5	1	50610.00001	4	Exchange to direct diversion

19	Queen Ditch	1	50403.32780	4	Exchange to direct diversion
20	Runction Ditch DS	1	50403.45425	4	Exchange to direct diversion

Operating rules 1 through 6 divert water for storage in Walden Reservoir (4703627) via Walden Storage Carrier (4703627_C) and Old SC Ditch (4700813_D). As noted above, the Old SC Ditch diversions to storage are rediverted by Walden Storage Carrier, therefore the Walden Storage Carrier structure is modeled as a carrier for these operating rules. The administration numbers for these operating rules correspond to the five reservoir rights from the Illinois River and one reservoir right from the Michigan River. The reservoir rights are modeled to fill all three accounts. The amount of water delivered is limited to water physically and legally available under the reservoir right, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rules 7 through 14 release Walden Reservoir storage water from the irrigation account to multiple structures downstream of the reservoir. The administration numbers for these operating rights are just junior to the most junior direct flow rights for each structure. The amount of water released is limited by the amount currently in the irrigation account and the unsatisfied demand at the ditch.

Operating rules 15 through 20 release Walden Reservoir storage water from the irrigation account to multiple structures upstream of the reservoir via an exchange. The administration numbers for these operating rights are just junior to the most junior direct flow rights for each structure. The amount of water released is limited by the amount currently in the irrigation account, the unsatisfied demand at each ditch, and legally available water at the point of diversion.

5.9.9. West Arapahoe Reservoir and Irrigation

West Arapahoe Reservoir (4703628) is an off-channel reservoir located in the Arapahoe Creek basin. The single irrigation account is filled via West Arapahoe Feeder Ditch (4702049) and provides supplemental water by exchange to Eureka Ditch (4700614), as well as for storage in Seymour Reservoir.

Four operating rules are used to simulate West Arapahoe Reservoir operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	W. Arapahoe Ditch Irrig. Demand	W. Arapahoe Feeder Ditch	47574.00000	11	Carrier to demand
2	W. Arapahoe Reservoir	W. Arapahoe Feeder Ditch	37115.00000	11	Carrier to reservoir
3	W. Arapahoe Reservoir	W. Arapahoe Feeder Ditch	47116.41447	11	Carrier to reservoir
4	Seymour Reservoir	1, Eureka Ditch	13765.00006	7	Exchange to carrier

Operating rule 1 carries direct diversions to West Arapahoe Ditch irrigation demand (4702049_I) via West Araphoe Feeder Ditch (4702049). The administration number for this operating rule corresponds to West Araphoe Feeder Ditch direct water right. The amount of water delivered is limited to water physically and legally available under the ditch right, capacity in the carrier ditch, and irrigation demand.

Operating rules 2 and 3 divert water for storage in West Arapahoe Reservoir (4703628) via West Araphoe Feeder Ditch (4702049). The administration numbers for these operating rules correspond to the two reservoir rights. The amount of water delivered is limited to water physically and legally available under the reservoir right, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rule 4 releases water from West Arapahoe Reservoir in exchange for diversions at Eureka Ditch for storage in Seymour Reservoir. This operating right reflects a simplification to the system. Releases from the West Arapahoe Reservoir are generally made to the Lawrence Ditch DS (4700718_D) in exchange for diversions through Eureka Ditch. The simplification was made in that the reservoir makes releases via exchange to Eureka Ditch for storage in Seymour Reservoir. The releases from West Arapahoe Reservoir are then available for diversion to meet Lawrence Ditch DS demand. This operating rule is directly related to the Seymour Reservoir operating right 1 discussed in Section 5.9.10.

5.9.10. Eureka Ditch and Seymour Reservoir

Seymour Reservoir (4703743) is an off-channel reservoir located in the Buffalo Creek basin. The single irrigation account is filled via Eureka Ditch (4700614) and provides supplemental water to approximately 60 percent of the total Eureka Ditch irrigation demand (614_60_I). The remaining 40 percent of the irrigation demand (614_40_I) is met from direct flow supplies only. An accounting plan structure was used to represent the Eureka Ditch operations, as discussed in Section 5.8 above, to split in-priority diversions through Eureka Ditch into two accounts. Operating rules are used to “release” the direct flow water from the plan structure (614_PLN) to the two irrigation demands, and release water from Seymour Reservoir to provide supplemental irrigation water.

Twelve operating rules are used to simulate Eureka Ditch and Seymour Reservoir operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	Seymour Reservoir	Eureka Ditch	33534.21040	11	Carrier to reservoir
2	Seymour Reservoir	Eureka Ditch	43829.36046	11	Carrier to reservoir
3	Seymour Reservoir	Eureka Ditch	50403.21411	11	Carrier to reservoir
4	Seymour Reservoir	Eureka Ditch	50403.36386	11	Carrier to reservoir
5	Eureka Ditch Accounting Plan (614_PLN)	Eureka Ditch	13765.00000	24	Carrier to acct. plan
6	60% & 40% Eureka Ditch Irrig. Plans (614_40PLN, 614_60PLN)	Eureka Ditch Accounting Plan	13765.00002	46	Split acct. plan

7	60% Eureka Irrig. Demand (614_60_I)	60% Eureka Ditch Irrig. Plan	13765.00003	27	Release from plan
8	40% Eureka Irrig. Demand (614_40_I)	40% Eureka Ditch Irrig. Plan	13765.00004	27	Release from plan
9	60% Eureka Irrig. Demand (614_60_I)	Seymour Reservoir	13765.00009	3	Release to carrier
10	N/A	Eureka Ditch Accounting Plan	13766.00000	29	Plan spill
11	N/A	60% Eureka Ditch Irrig. Plan	13766.00000	29	Plan spill
12	N/A	40% Eureka Ditch Irrig. Plan	13766.00000	29	Plan spill

Operating rules 1 through 4 divert water for storage in Seymour Reservoir (4703628) via Eureka Ditch (4700614). The administration numbers for these operating rules correspond to the four reservoir rights. The amount of water delivered is limited to water physically and legally available under the reservoir rights, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rules 5 and 6 allow for water that Eureka Ditch is legally entitled to be diverted into the Eureka Ditch Accounting Plan (614_PLN). The administration number for this operating rule corresponds to the Eureka Ditch direct flow right. Water diverted in priority to the full Eureka Ditch Accounting Plan is then split into two irrigation plans; 60 percent is moved into plan 614_60PLN, and 40 percent is moved into plan 614_40PLN. The use of accounting plan structures assures when direct flow supplies are limited, all land under the ditch share in the shortages. The administration number for this operating rule is just junior to the Eureka Ditch Accounting Plan operating rule. The amount of water carried to the Eureka Ditch Accounting Plan, and subsequently split to the two irrigation plans, is limited to the water physically and legally available under the direct flow rights and capacity of the carrier ditch. Note that the volumetric plan limitation was set large enough so as not to be a limiting factor.

Operating rules 7 and 8 directs water diverted into the Eureka Ditch Irrigation Plans (614_40PLN and 614_60PLN) to their respective Eureka Ditch Irrigation Demands (614_40_I and 614_60_I). The administration numbers for these operating rules is just junior to the Eureka Ditch split plan operating rule. The amount of water released to the Eureka Ditch Irrigation Demands is limited by the water available in the Irrigation Plans and the irrigation demand.

Operating rule 9 releases Seymour Reservoir storage water from the irrigation account to the 60 percent Eureka Ditch Irrigation Demand. The administration number for this operating right is just junior to the “release” from Eureka Ditch Irrigation Plans to the demands. The amount of water released is limited by the amount currently in the irrigation account and the unsatisfied irrigation demand.

Operating rules 10 through 12 allow for the Eureka Ditch Accounting and Irrigation Plan structures to “spill” any unused water back to the river in the same timestep, allowing for other users in the basin to divert the water. The administration numbers for these operating rules is just junior to the release from Seymour Reservoir storage water, and is the final operation associated with the Eureka Ditch and Seymour Reservoir operations.

5.9.11. Lake John, Annex Reservoir, and Legal Tender Irrigation

Lake John (4703750) and Annex Reservoir (4703699) are located in the Lake (Scribner) Creek basin, tributary of the North Fork of the North Platte River. Lake John is owned by CDOW for fish and wildlife protection purposes; the single CDOW account in the reservoir is filled via Legal Tender Ditch (4700720) from the North Fork of the North Platte River. Due to the use of the reservoir, no releases from Lake John are currently represented in the model.

The Annex provides supplemental water to junior diverters on the North Fork of the North Platte River, and the single irrigation account is filled via Hill Ditch No 1 (4700663), Hill Ditch No 2 (4700664), and, if needed, Little Nellie Ditch (4700730). In lieu of including several reservoir release operating rules, releases from Annex Reservoir is modeled using a General Replacement operating rule.

Ten operating rules are used to simulate Lake John and Annex operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	Legal Tender Ditch Irrig. Demand	Legal Tender Ditch	14397.00000	11	Carrier to demand
2	Legal Tender Ditch Irrig. Demand	Legal Tender Ditch	14762.00000	11	Carrier to demand
3	Legal Tender Ditch Irrig. Demand	Legal Tender Ditch	30280.14397	11	Carrier to demand
4	Lake John Reservoir	Legal Tender Ditch	47116.38615	11	Carrier to reservoir
5	Lake John Reservoir	Legal Tender Ditch	48212.39202	11	Carrier to reservoir
6	Annex Reservoir	Hill Ditch No. 1	99999.99999	11	Carrier to reservoir
7	Annex Reservoir	Hill Ditch No. 2	99999.99999	11	Carrier to reservoir
8	Annex Reservoir	Little Nellie Ditch	99999.99999	11	Carrier to reservoir
9	Multiple Structures	1, Annex Res.	54880.00000	10	General replacement
10	Legal Tender Irrig. Demand	1, Annex Res.	54880.00000	4	Exchange to direct diversion

Operating rules 1 through 3 carry direct diversions to Legal Tender Ditch irrigation demand (4700720_I) via Legal Tender Ditch (4700720). The administration numbers for these operating rules correspond to Legal Tender Ditch direct water rights. The amount of water delivered is limited to water physically and legally available under the ditch right, capacity in the carrier ditch, and irrigation demand.

Operating rules 4 and 5 divert water for storage in Lake John Reservoir (4703750) via Legal Tender Ditch (4700720). The administration numbers for these operating rules correspond to the two reservoir rights. The amount of water delivered is limited to water physically and legally available under the reservoir rights, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rules 6 and 7 divert water for storage in Annex Reservoir (4703699) via Hill Ditch No 1 (4700663) and Hill Ditch No 2 (4700664). Operating rule 8 diverts additional water for storage via Little Nellie Ditch (4700730), although the reservoir generally benefits from return flows from the Little Nellie Ditch irrigation demand as opposed to direct diversions through the Little Nellie Ditch. The storage rights for the reservoir are currently in dispute; therefore the administration numbers for these operating rules were set to 99999.99999 to signify diversions to storage only after all other users in the basin have been satisfied. The amount of water delivered is limited to water physically and legally available under the reservoir rights, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rule 9 allows for water to be released from the reservoir to multiple structures, either by direct release or exchange, as indicted by the replacement option (*ireptyp*) in the direct diversion station file (*.dds). The following structures were set to receive supplemental supply from Annex Reservoir. Note that these are the same list of structures that can receive supplemental supply from Boettcher Reservoir as well.

WDID	Name	WDID	Name
4702030	Wattenburg Ditch	4700606	Eber Ditch
4700852	Reithmeyer Ditch	4700912	Sunrise Ditch
4700927	Ulrich Ditch	4700797	North Fork Ditch
4700684	Independent Ditch	4700876	Short Run Ditch
4700527	Briggs Bohn Ditch	4700743	Mabel Dow Ditch
4700528_M	Briggs Bohn MS	4700948	West Boettcher Ditch
4700725	Lillie Ditch	4700735_M	Lookout Ditch MS
4700612	Erika Ditch	4700966	Zirkel Ditch
4700522	Boulder Ditch	4700906	Stormy Ditchi
4700665	Hillside Ditch	4700650	Hard to Find Ditch
4700505	Bear Creek Ditch	4700730	Little Nellie Ditch
4700657_D	Haworth Ditch DS	4700871	Shafer Ditch
4700596	Dry Run Ditch	4700507	Beaverdale Ditch
4700714	Lake Creek Ditch	4700837	Pleasant Valley Ditch

The General Replacement operating rule does not automatically trigger a reservoir release for off-channel demands; therefore Operating Rule 10 allows the reservoir to release to Legal Tender Irrigation Demand (4700720_I). The priority for both the Operating Rules 6 and 7 was set such that it was junior to the direct diversion rights associated with structures on the North Fork of the North Platte River.

5.9.12. Pole Mountain Reservoir

Pole Mountain Reservoir (4703746) is an on-channel reservoir located on the North Fork of Mexican Creek, tributary to Mexican Creek. The single irrigation account is filled with North Fork of Mexican Creek inflow and via Pole Mountain Reservoir Feeder (4700838). The reservoir provides supplemental water to Nine-Six-Nine Ditch (4700969), located downstream of the reservoir on Grizzly Creek, and can release for storage in Mexican Reservoir.

Three operating rules are used to simulate Pole Mountain Reservoir operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	Pole Mtn. Reservoir	Pole Mtn. Res. Feeder	43829.41069	11	Carrier to reservoir
2	Mexican Reservoir	Pole Mtn. Creek Reservoir	33534.23893	2	Release to reservoir
3	Nine-Six-Nine Ditch	1	50769.35138	2	Release to direct diversion

Operating rule 1 diverts water for storage in Pole Mountain Reservoir (4703746) via Pole Mountain Reservoir Feeder Ditch (4700838). The administration number for this operating rule corresponds to the reservoir right. The amount of water delivered is limited to water physically and legally available under the reservoir right, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rule 2 releases Pole Mountain Creek Reservoir storage water to storage in Mexican Reservoir (4703616). The administration number for this operating right is just junior to the Mexican Reservoir right. The amount of water released is limited by the amount currently in both the Mexican Pole Mountain Creek Reservoir and Mexican Reservoir accounts.

Operating rule 3 releases Mexican Reservoir storage water from the single irrigation account to Nine-Six-Nine Ditch (4700969). The administration number for this operating right is just junior to the most junior direct flow right. The amount of water released is limited by the amount currently in the irrigation account and the unsatisfied demand at the ditch.

5.9.13. Meadow Creek Reservoir

Meadow Creek Reservoir (4704335) is an on-channel reservoir located on Meadow Creek, tributary to Michigan River. The multi-purpose reservoir has three accounts; account 2 for irrigation, and accounts 1 and 3 for Fort Collins municipal use. All three accounts are filled with Meadow Creek inflow and from Squibob Ditch Carrier (4700893_C), which diverts from the Michigan River. Direct releases and releases via exchange from the irrigation account provide supplemental water to irrigated lands located in the Michigan River basin. Releases from accounts 1 and 3 are exchanged for diversions through the Michigan Ditch transbasin diversion (4704603) destined for Fort Collins municipal use.

Twenty-three operating rules are used to simulate Meadow Creek Reservoir operations:

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	Meadow Creek Reservoir	Squibob Ditch Carrier	45701.00000	11	Carrier to reservoir
2	Meadow Creek Reservoir	Squibob Ditch Carrier	46505.00000	11	Carrier to reservoir
3	Meadow Creek Reservoir	Squibob Ditch Carrier	50403.48797	11	Carrier to reservoir
4	Cleveland Ditch	2	50769.50312	2	Release to direct diversion
5	George Water Ditch	2	21366.13424	2	Release to direct diversion
6	Michigan Highline Ditch	2	22468.00001	2	Release to direct diversion
7	Wales Ditch	2	21366.19237	2	Release to direct diversion
8	North Park Ditch No 5	2	50610.00001	2	Release to direct diversion
9	Queen Ditch	2	50403.32780	2	Release to direct diversion
10	Ruction Ditch DS	2	50403.45425	2	Release to direct diversion
11	Bostwick Ditch	2	50769.50313	2	Release to direct diversion
12	North Park Ditch No 4	2	50403.32660	2	Release to direct diversion
13	Michigan Ditch	1	50584.00001	4	Exchange to direct diversion
14	Michigan Ditch	3	50584.00002	4	Exchange to direct diversion
15	Gibbs Ditch	2	18762.00001	4	Exchange to direct diversion
16	Poverty Diversion System	2	50403.32354	4	Exchange to direct diversion
17	Poverty Flat Ditch No 2	2	50403.32354	4	Exchange to direct diversion
18	Gould Diversion System	2	54421.19723	4	Exchange to direct diversion
19	Overland Ditch	2	50403.32354	4	Exchange to direct diversion
20	Squibob Ditch	2	50403.32354	4	Exchange to direct diversion
21	Brocker Endomile Ditch	2	50403.39705	4	Exchange to direct diversion
22	Mason Ditch	2	50403.28017	4	Exchange to direct diversion
23	Mill Creek Ditch	2	50403.31624	4	Exchange to direct diversion

Operating rules 1 through 3 diverts water for storage in Meadow Creek Reservoir (4704335) via Squibob Ditch Carrier (4700893_C). The administration numbers for these operating rules correspond to the three reservoir rights; the reservoir rights are modeled to fill all three accounts. The amount of water delivered is limited to water physically and legally available under the reservoir right, capacity in the carrier ditch, and storage capacity in the reservoir.

Operating rules 4 through 12 release Meadow Creek Reservoir storage water from the irrigation account to multiple structures downstream of the reservoir. The administration numbers for these operating rights are just junior to the most junior direct flow rights for each structure. The amount of water released is limited by the amount currently in the irrigation account and the unsatisfied demand at the ditch.

Operating rule 13 and 14 release Meadow Creek Reservoir storage water from the municipal accounts 1 and 3 to Michigan Ditch (4704603) via an exchange. The administration numbers for these operating rights are just junior to the most junior direct flow rights for Michigan Ditch. The amount of water released is limited by the amount currently in the municipal accounts, the unsatisfied demand at each ditch, and legally available water at the point of diversion.

Operating rules 15 through 23 release Meadow Creek Reservoir storage water from the irrigation account to multiple structures upstream of the reservoir via an exchange. The administration numbers for these operating rights are just junior to the most junior direct flow rights for each structure. The amount of water released is limited by the amount currently in the irrigation account, the unsatisfied demand at each ditch, and legally available water at the point of diversion.

5.9.14. Multi-structures Irrigating the Same Acreage

Several parcels of irrigated land in the North Platte River basin receive irrigation water from multiple diversion structures on different tributaries. The historical diversions at these multiple structures are modeled at their respective historical headgate locations for baseflow generation and the Historical calibration (see Section 7). In the Baseline data set, total demand for these lands are assigned to a primary structure and diversions from the secondary structure headgates are driven by operating rules. The sources for each operating rule are the direct flow rights at each secondary structure. Thirty-three type 11 operating rules are used to simulate multi-structure operations. Multi-structures in the North Platte Model are as follows:

Primary Structure	Secondary Structures
4700528_M - Briggs Bohn Ditch	4700527 – Briggs Bohn Ditch
4700530_M - Brocker Endomile	4700759 – Mason Ditch 4700817 – Orb Ditch 4700820 – Owl Ditch
4700559_M - Cleveland Ditch	4700558 – Cleveland D Owl Ck Ext 4700560 – Cleveland D Kimmons Ext
4700593_M - Doran Ditch	4700785 – Moraine Ditch 4700594 – Doran Ditch 2 4701070 – Doran Ditch 3 4702033 – Doran Ditch 4
4700595_M - Dry Creek Ditch	4701595 – Dry Crk Ditch Riley Creek
4700672_M - Howard Ranch	4700745 – MacFarlane Ext Ditch
4700709_M - Kermode	4700707 – Kelly Highline Ditch 4701060 – Kermode Ditch 2 Alt Pt
4700735_M - Lookout Ditch	4700606 – Eber Ditch 4700912 – Sunrise Ditch
4700753_M - Manville Ditch 2	4701199 – Swift Ditch

Primary Structure	Secondary Structures
4700826_M - Peabody Ditch	4700947 – Welch Ditch 4700899 – Stella Ditch
4700929 - Ute Pass Creek Ditch	4700929_C – Ute Pass Sand Creek Carrier
4700996_M - Sales Ditch 2	4700864 – Sales Ditch
4701024_M - Cochrane	4700654 – Cochrane Ditch

5.9.15. Soil Moisture Operations

A type 22 operating rule is also used to allow soil moisture accounts for irrigation structures.

Right #	Destination	Account or Carrier	Admin #	Right Type	Description
1	Operate Soil Moisture	N/A	90000.00000	22	Soil moisture reservoir accounting

Operating rule 1 directs StateMod to consider soil moisture in the variable efficiency accounting. The administration number was set junior to allow for most operations at irrigation structures to occur. This operating rule allows structures with crop irrigation water requirements to store excess diverted water not required by the crops during the month of diversion in the soil reservoir zone. It also allows releases from the soil reservoir to meet unsatisfied demands if diversions are not adequate to meet crop irrigation water requirements during the month of diversion.

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 North Platte River Model characterizes it, under these assumptions.

6.1 Baseline Streamflows

Table 6.1 shows the average annual flow from the Baseline simulation for each gage, based on the entire simulation period (1956 – 2007). 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 than the total simulated flow.

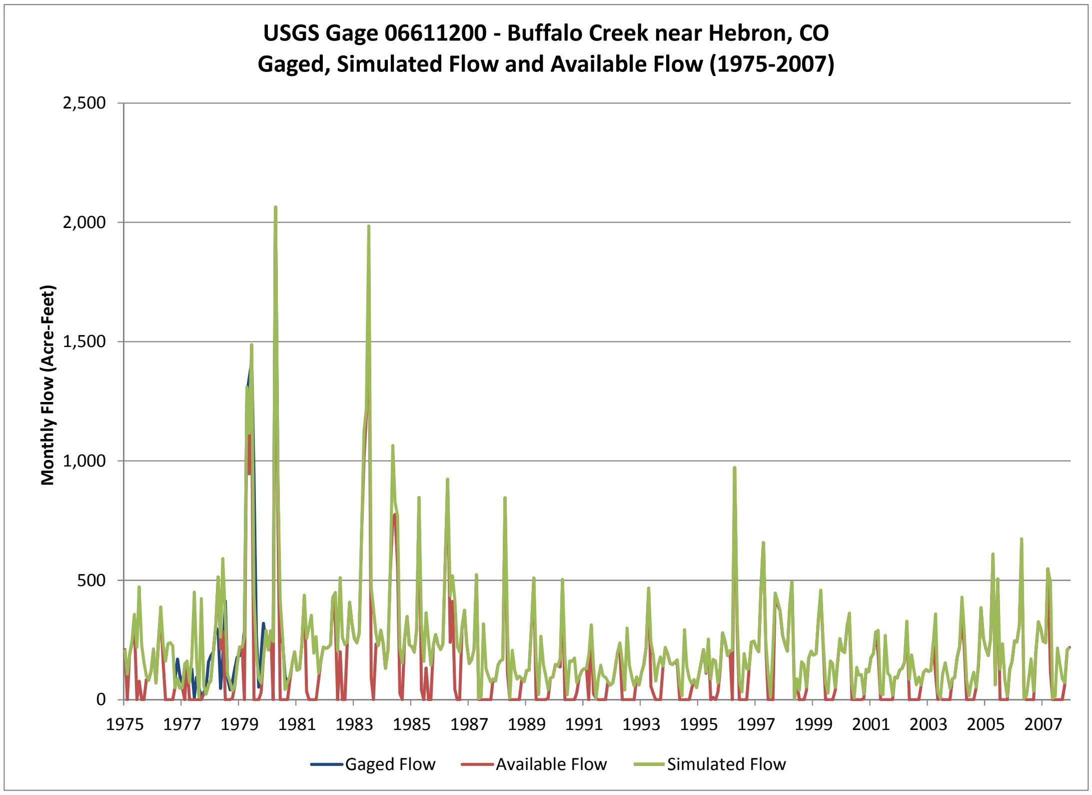
The Baseline data set, and corresponding results, does not include any conditional water rights represented in the Baseline data set. Variations of the Baseline data set could include conditional rights within the North Platte River basin, and would likely result in less available flow than presented here.

Temporal variability of the historical and Baseline simulated flows is illustrated in Figures 6.1 through 6.10 for selected gages. Each figure shows two graphs: overlain hydrographs of historical gage flow, simulated gage flow, and simulated available flow for 1975 through 2007; and an average annual hydrograph of modeled results based on the entire modeling period. The annual hydrograph is a plot of monthly average flow values for simulated and available flow. The gages selected for these figures have at least some gaged data between 1975 and 2007; however many of the gages were not online for the entire study period and a significant number of the gages have less than five years of data. Therefore, available historical data is not included in the average monthly hydrographs for gages without historical record over the full study period.

Note that at times, the flow amounts closely match and one or more time series may not be visible on the graphs.

Table 6.1
Simulated and Available Baseline Average Annual Flows for the North Platte River Model Gages (1956-2007)

Gage ID	Gage Name	Simulated Flow (af)	Simulated Available Flow (af)
06611200	BUFFALO CREEK NEAR HEBRON, CO.	2,837	1,949
06611300	GRIZZLY CREEK NEAR HEBRON, CO.	36,746	31,965
06611700	LITTLE GRIZZLY CREEK NEAR COALMONT, CO.	12,053	6,592
06611800	LITTLE GRIZZLY CREEK ABOVE COALMONT, CO.	15,755	15317
06611900	LITTLE GRIZZLY CREEK ABOVE HEBRON, CO.	18,668	18,661
06614800	MICHIGAN RIVER NEAR CAMERON PASS, CO	2,298	1,286
06615000	SOUTH FORK MICHIGAN RIVER NEAR GOULD, CO.	10,564	5,108
06616000	NORTH FORK MICHIGAN RIVER NEAR GOULD, CO.	12,300	7,082
06617500	ILLINOIS RIVER NEAR RAND, CO.	23,683	3,930
06619400	CANADIAN RIVER NEAR LINDLAND, CO.	13,021	11,013
06619450	CANADIAN RIVER NEAR BROWNLEE, CO.	18,357	17,997
06620000	NORTH PLATTE RIVER NEAR NORTHGATE, CO	272,479	272,479



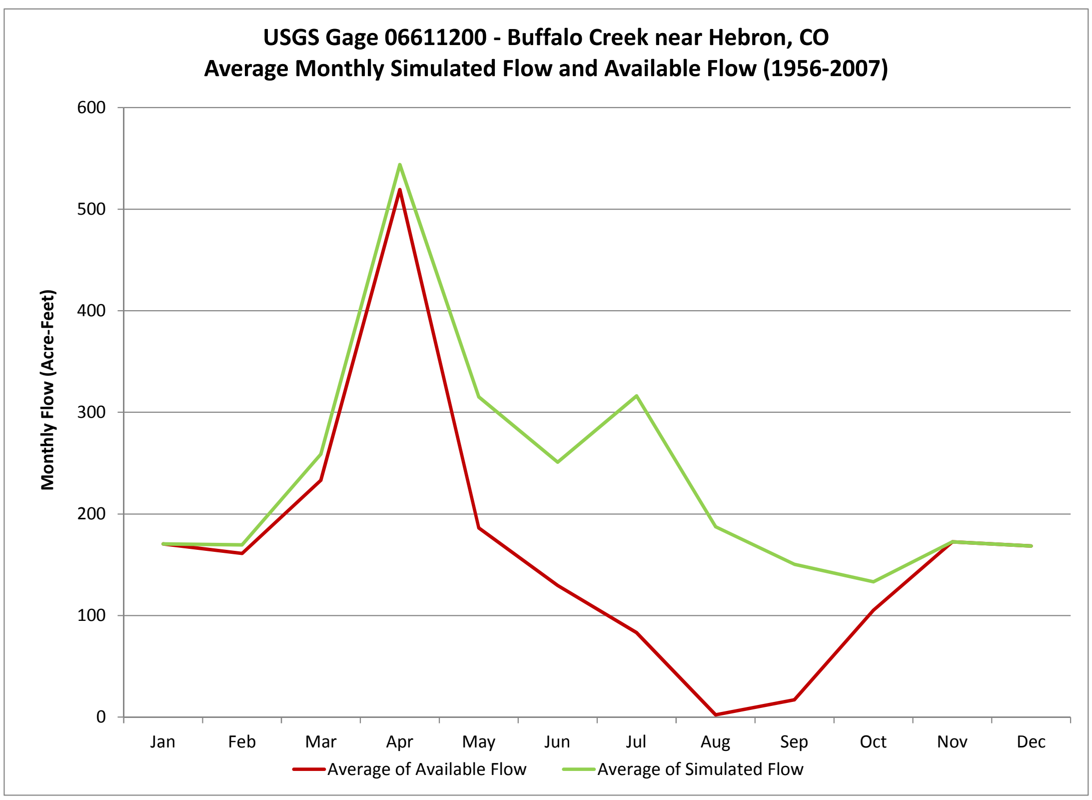
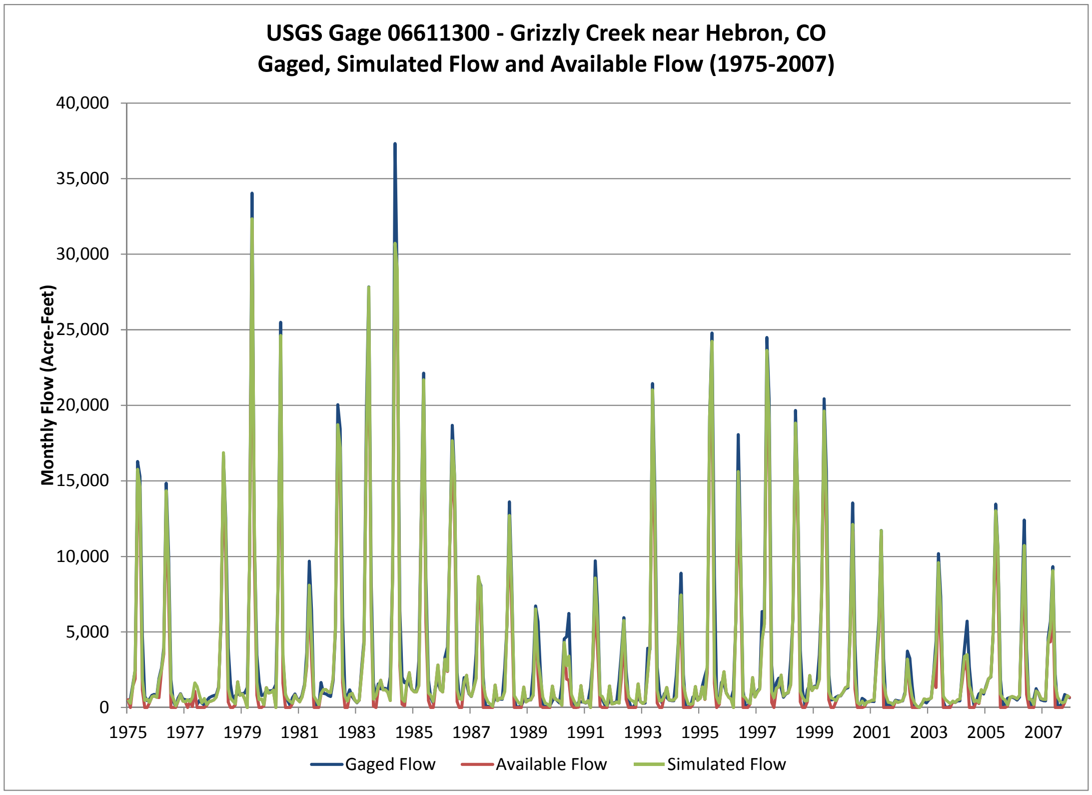


Figure 6.1 Baseline Results – Buffalo Creek near Hebron, CO



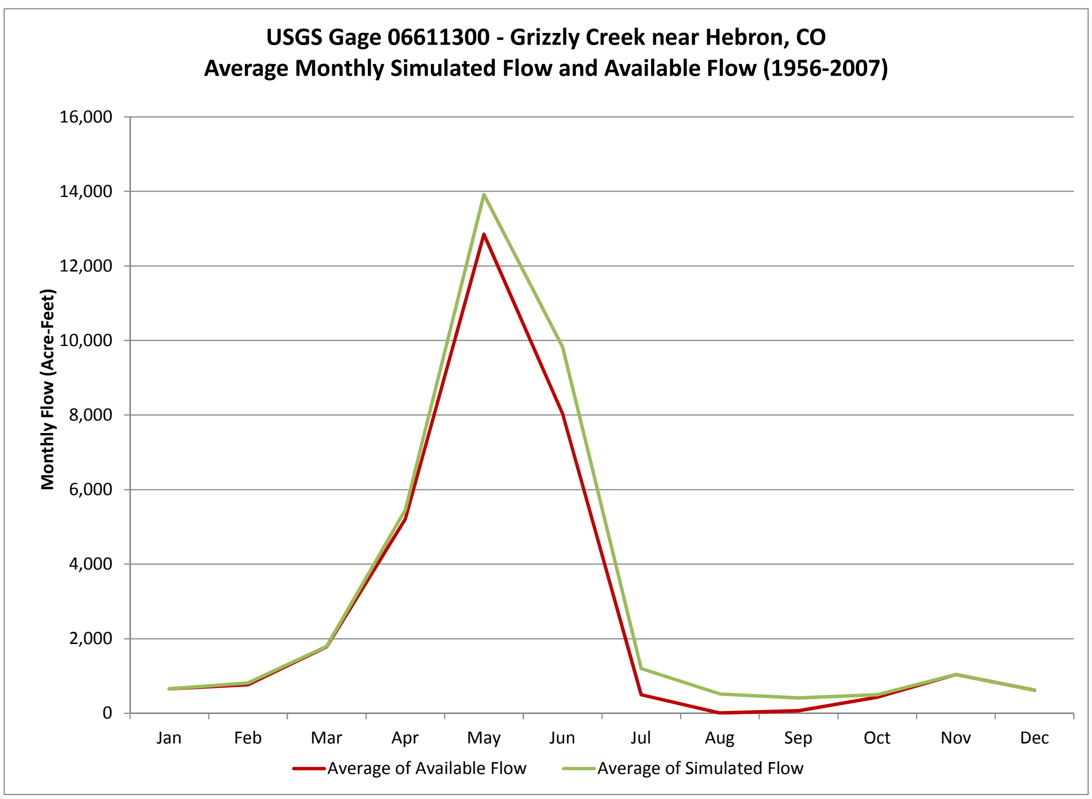
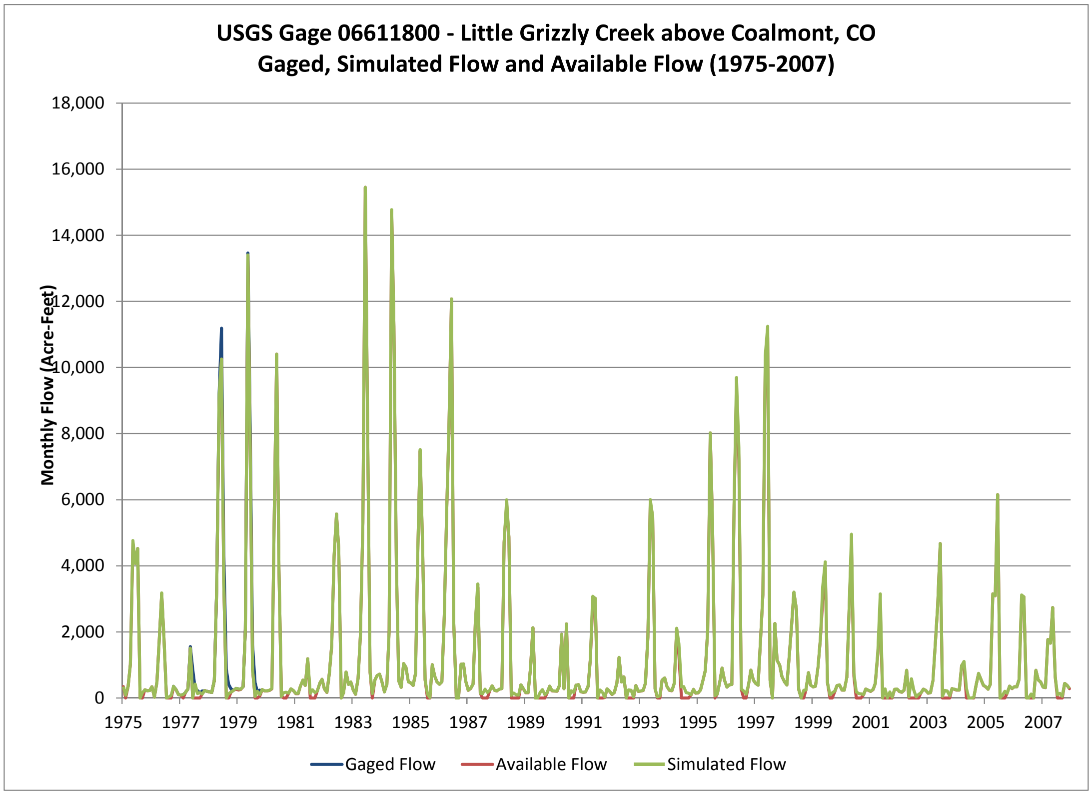


Figure 6.2 Baseline Results – Grizzly Creek near Hebron, CO



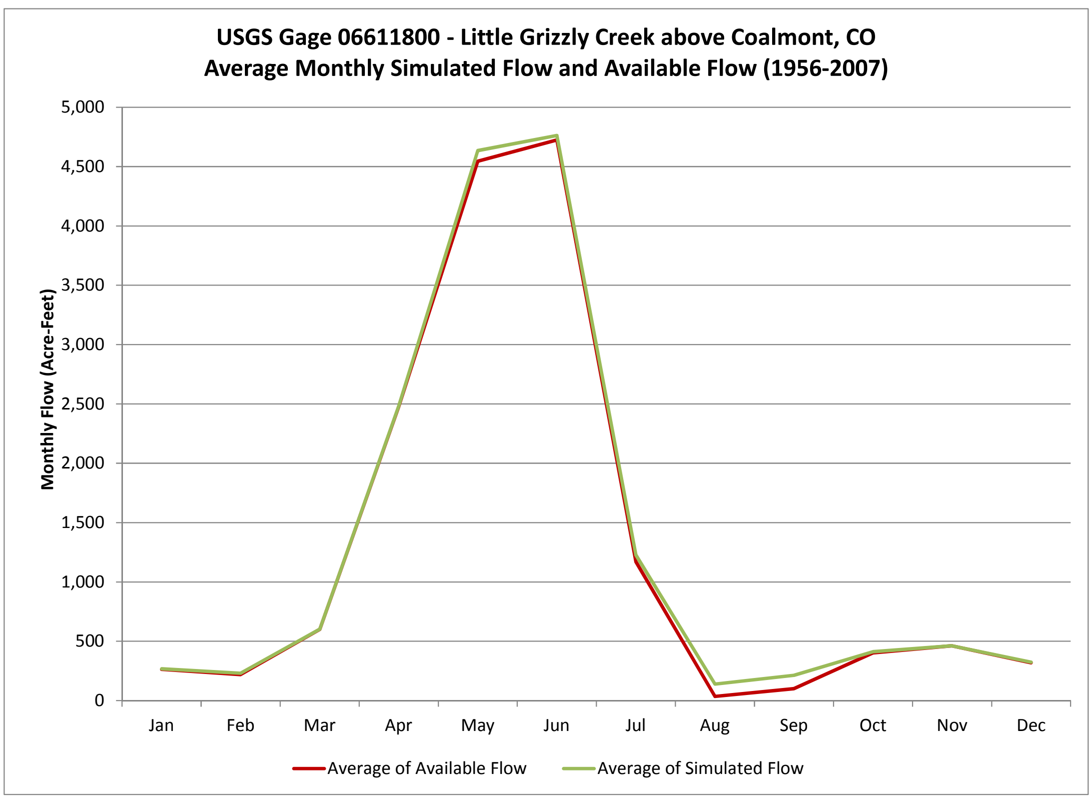
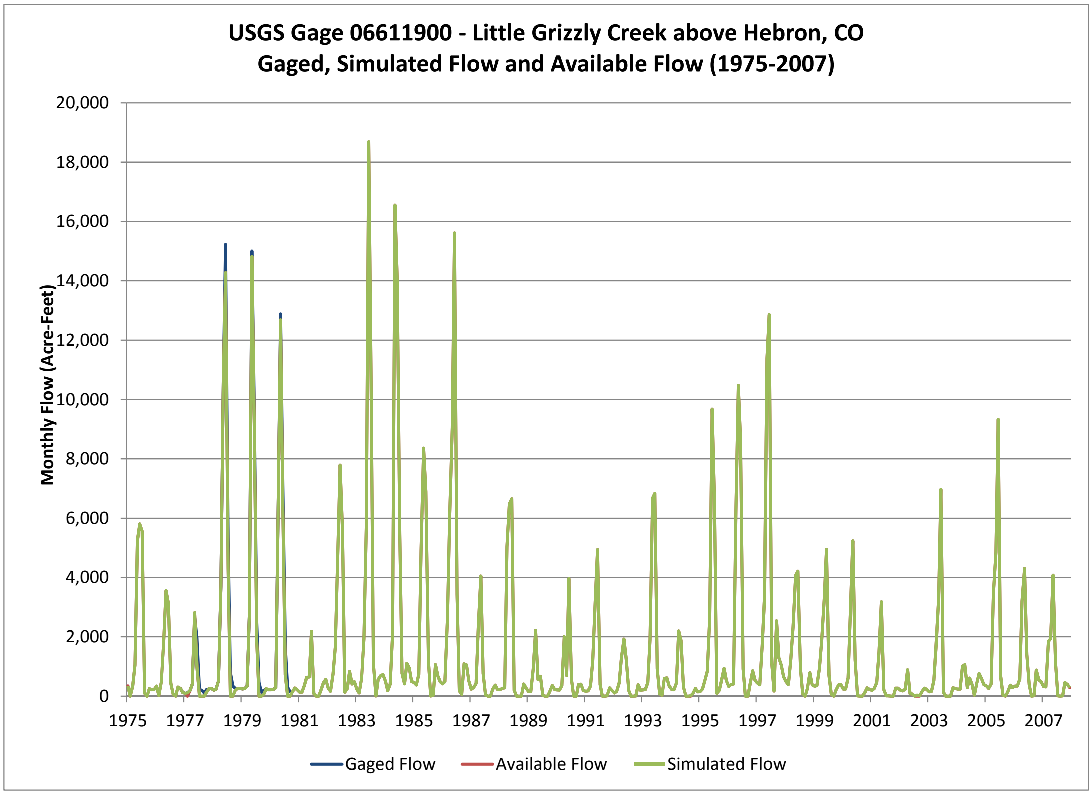


Figure 6.3 Baseline Results – Little Grizzly Creek above Coalmont, CO



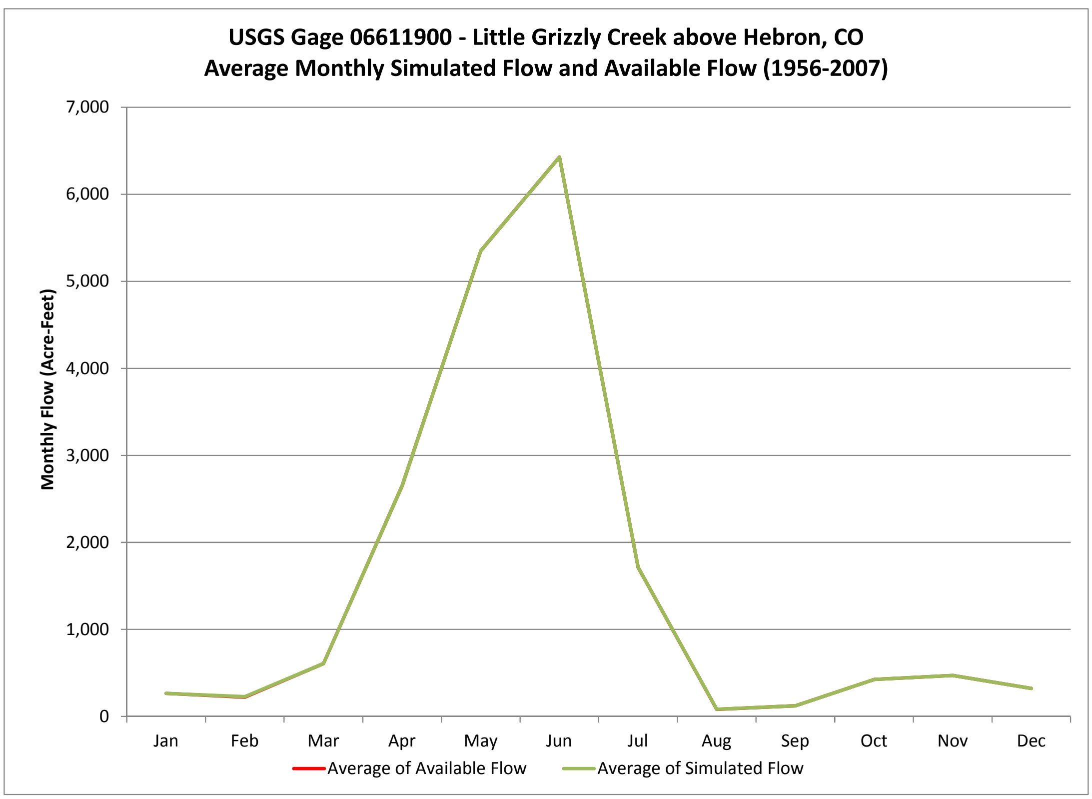
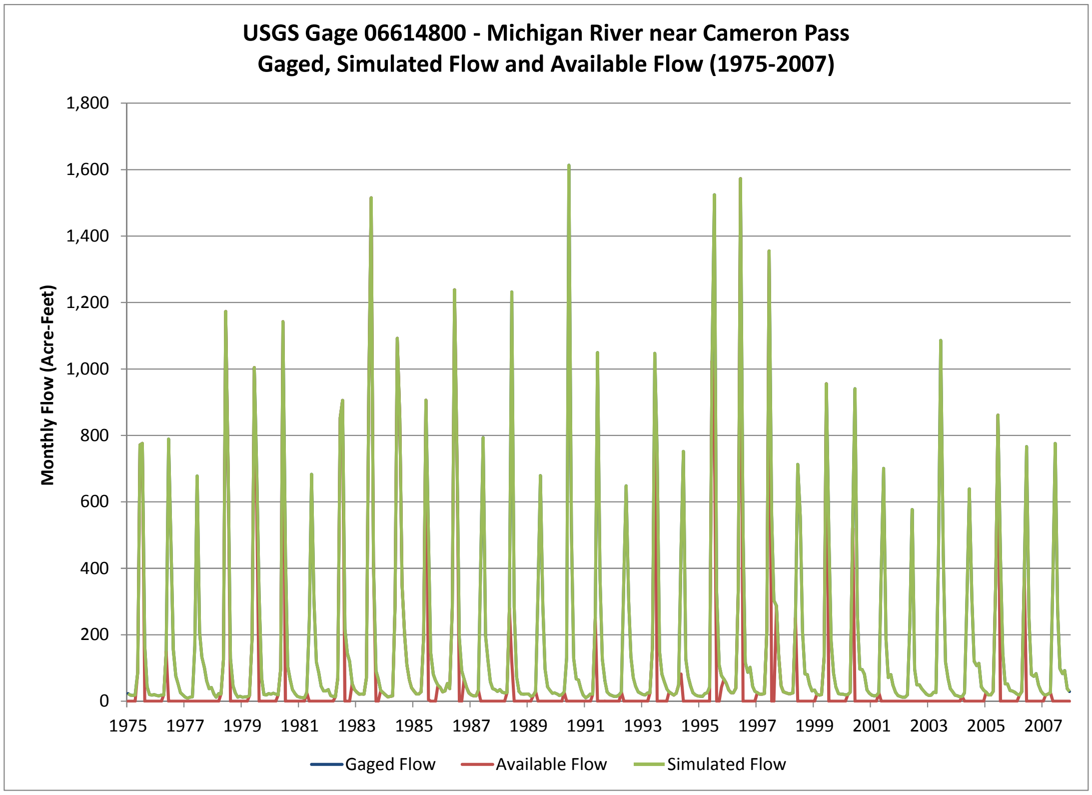


Figure 6.4 Baseline Results – Little Grizzly Creek above Hebron, CO



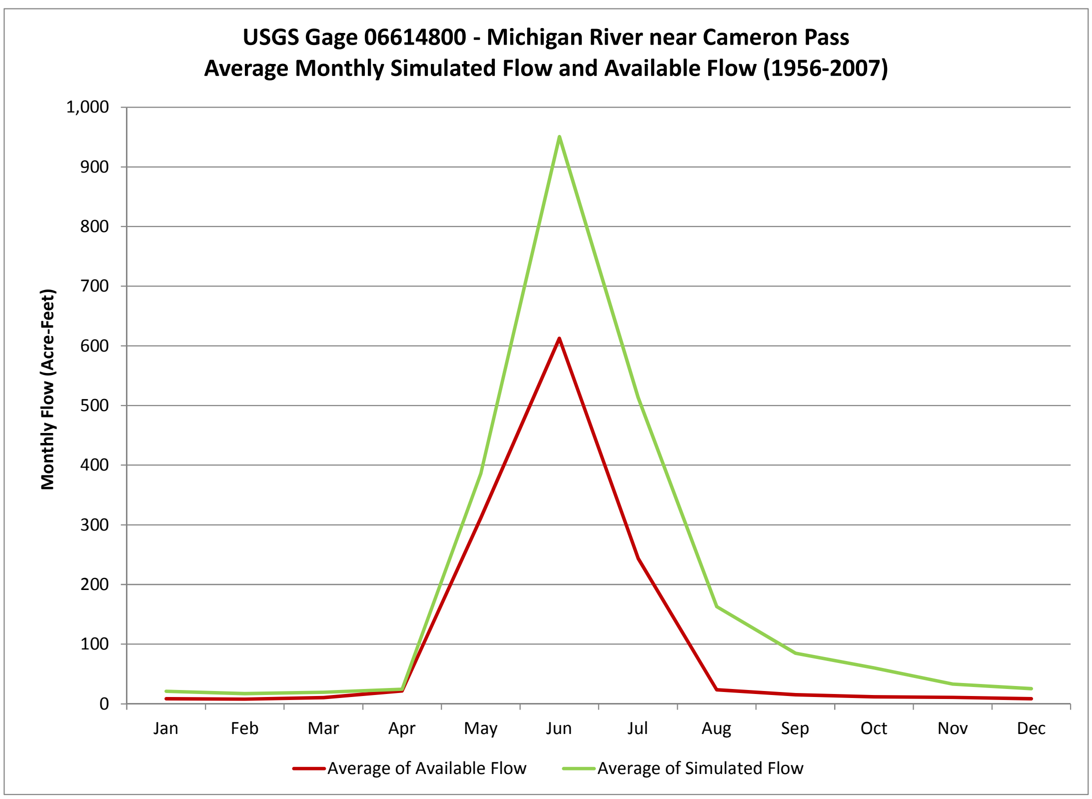
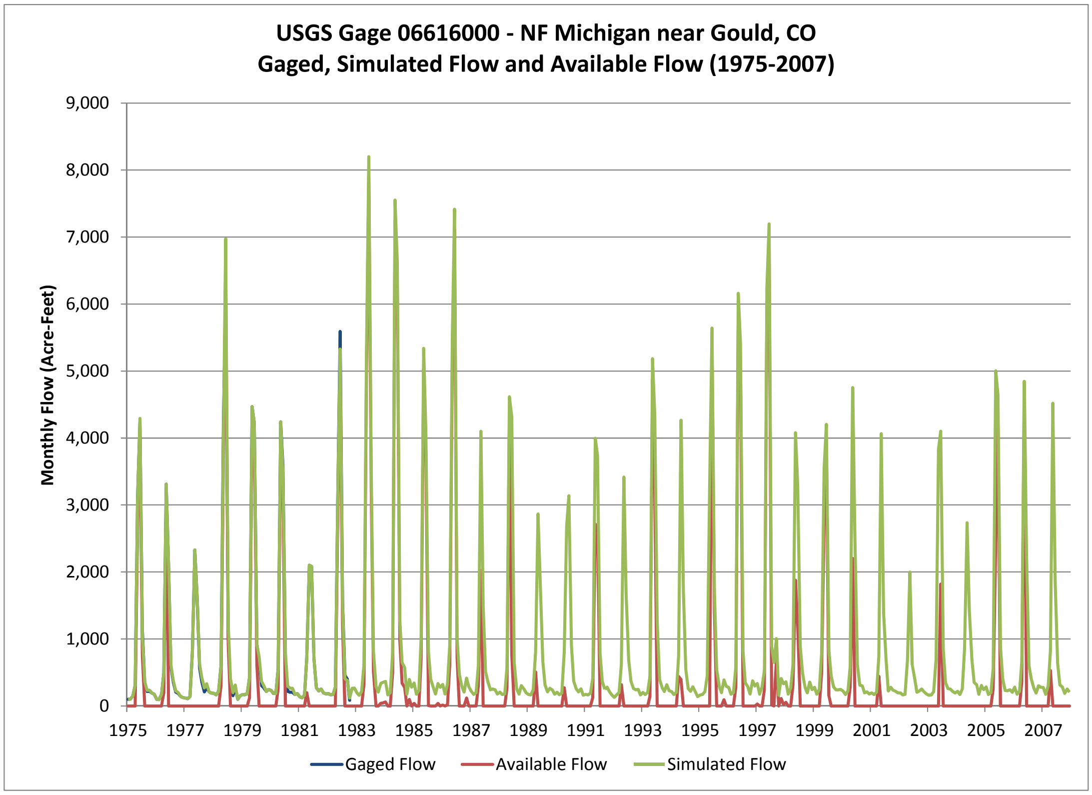


Figure 6.5 Baseline Results – Michigan River near Cameron Pass



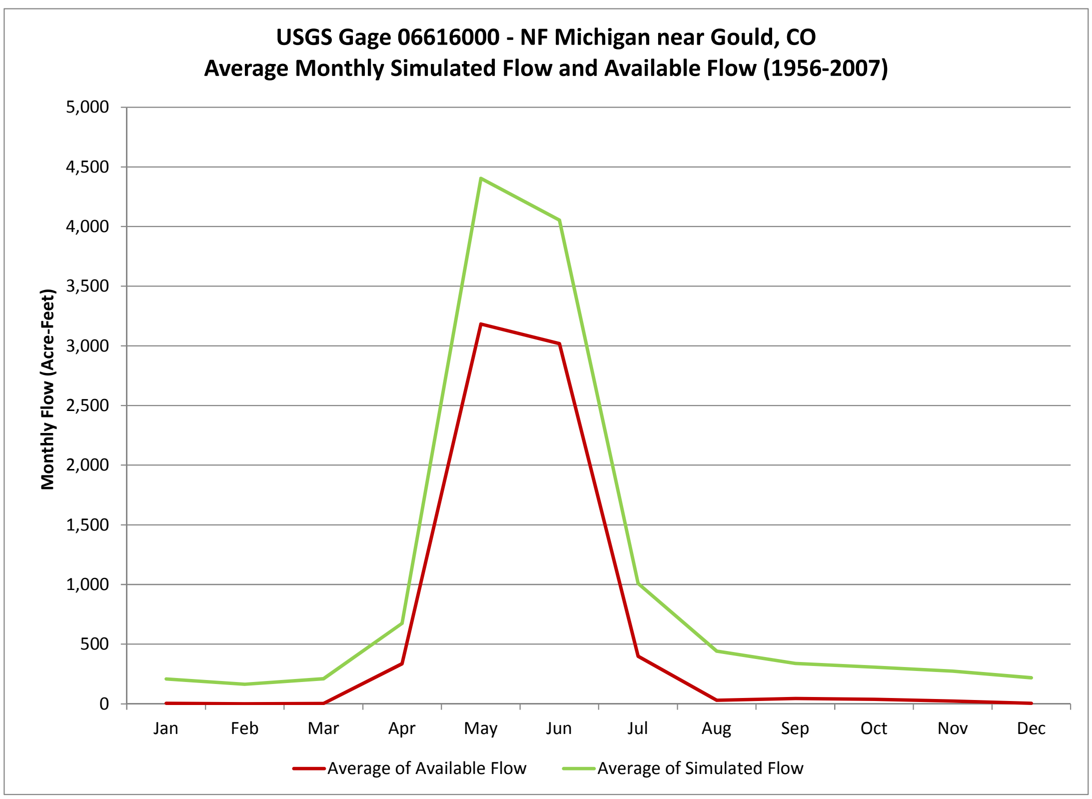
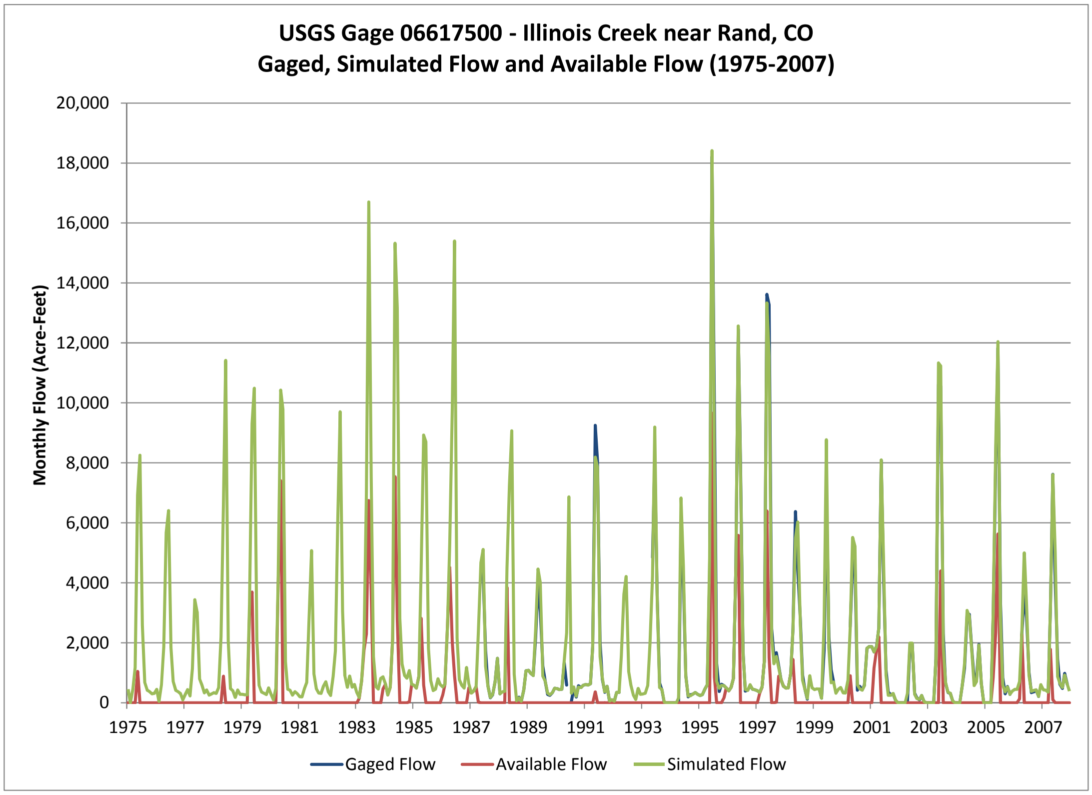


Figure 6.6 Baseline Results – North Fork Michigan River near Gould, CO



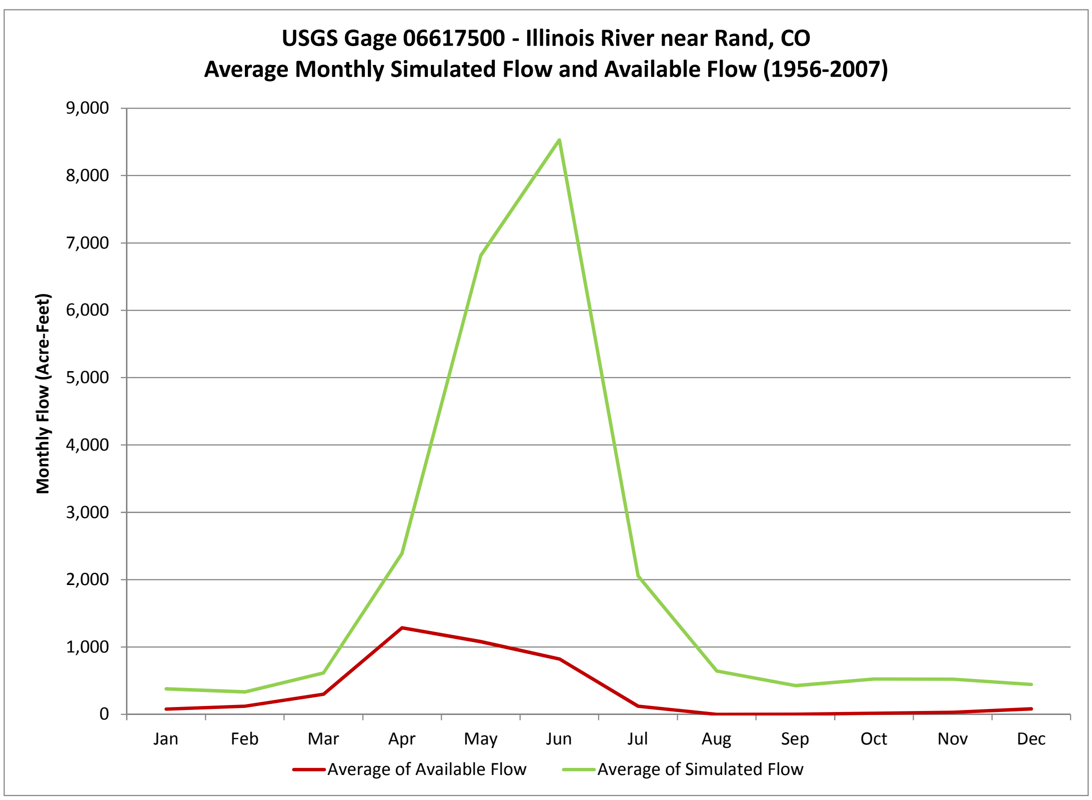
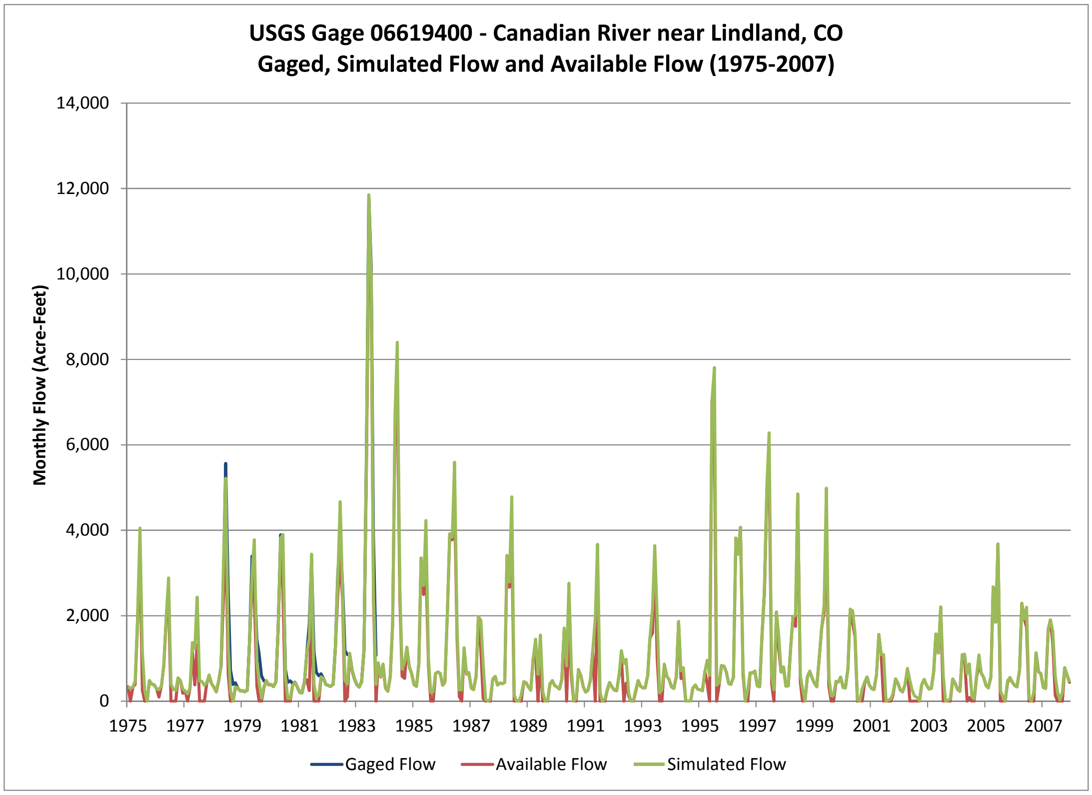


Figure 6.7 Baseline Results – Illinois River near Rand, CO



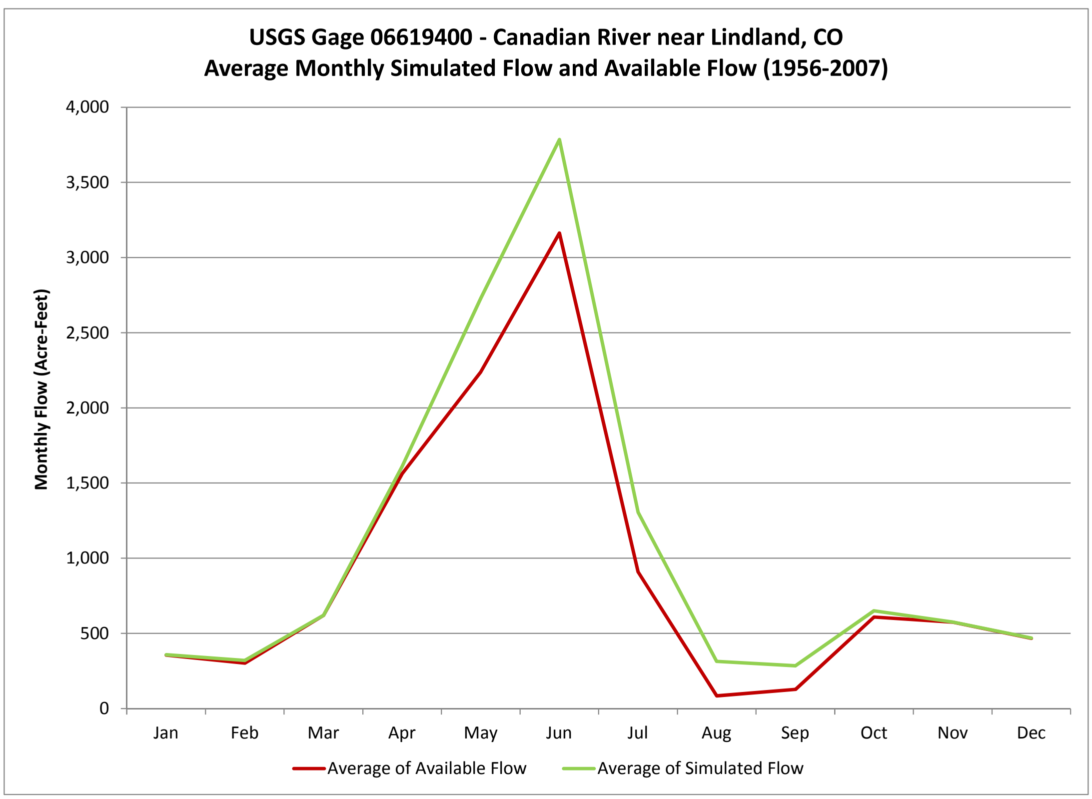
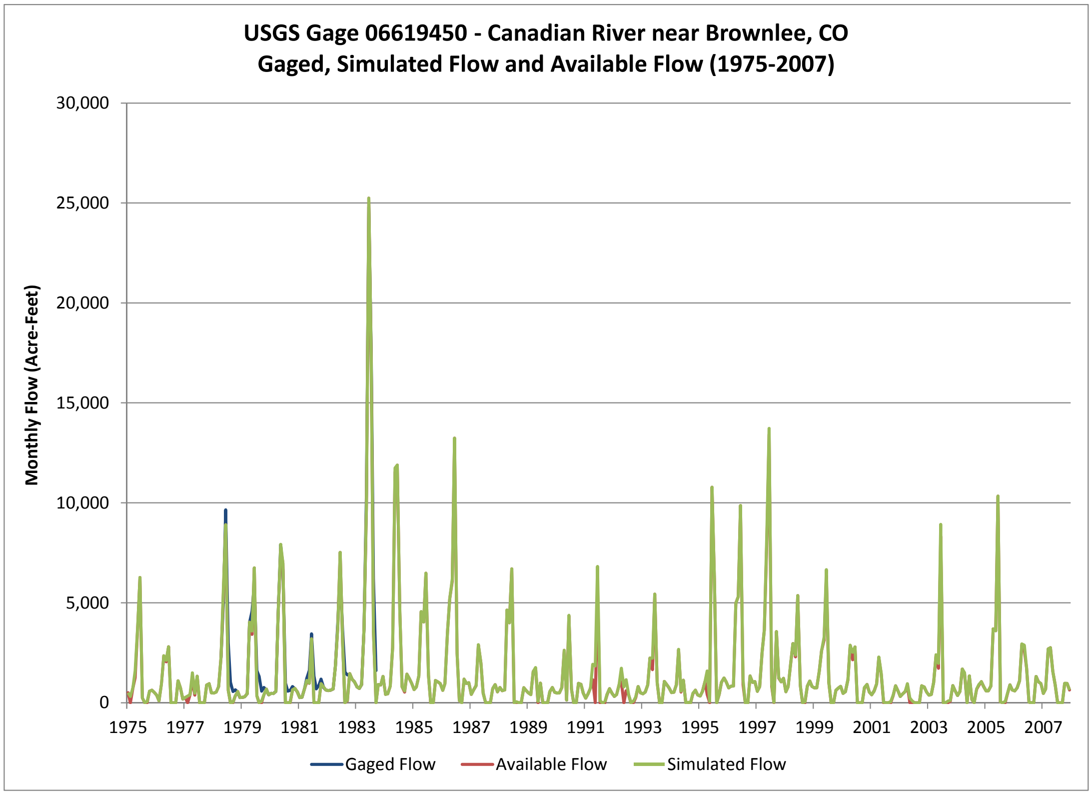


Figure 6.8 Baseline Results – Canadian River near Lindland, CO



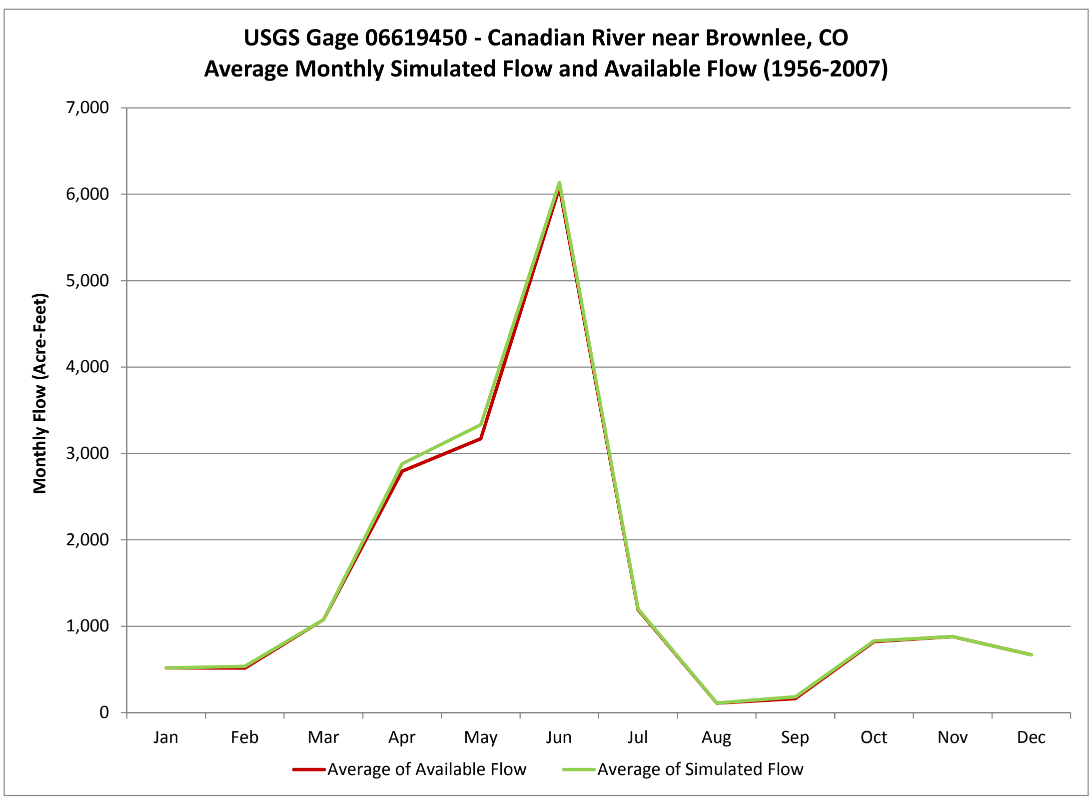
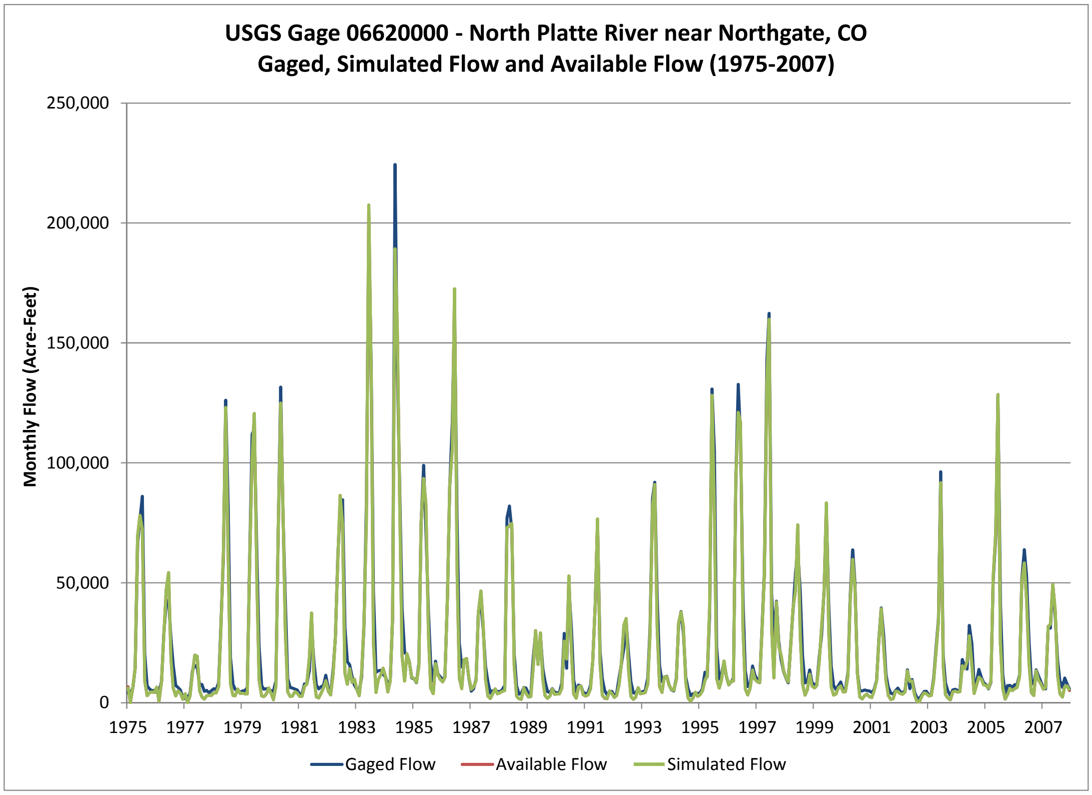


Figure 6.9 Baseline Results – Canadian River near Brownlee, CO



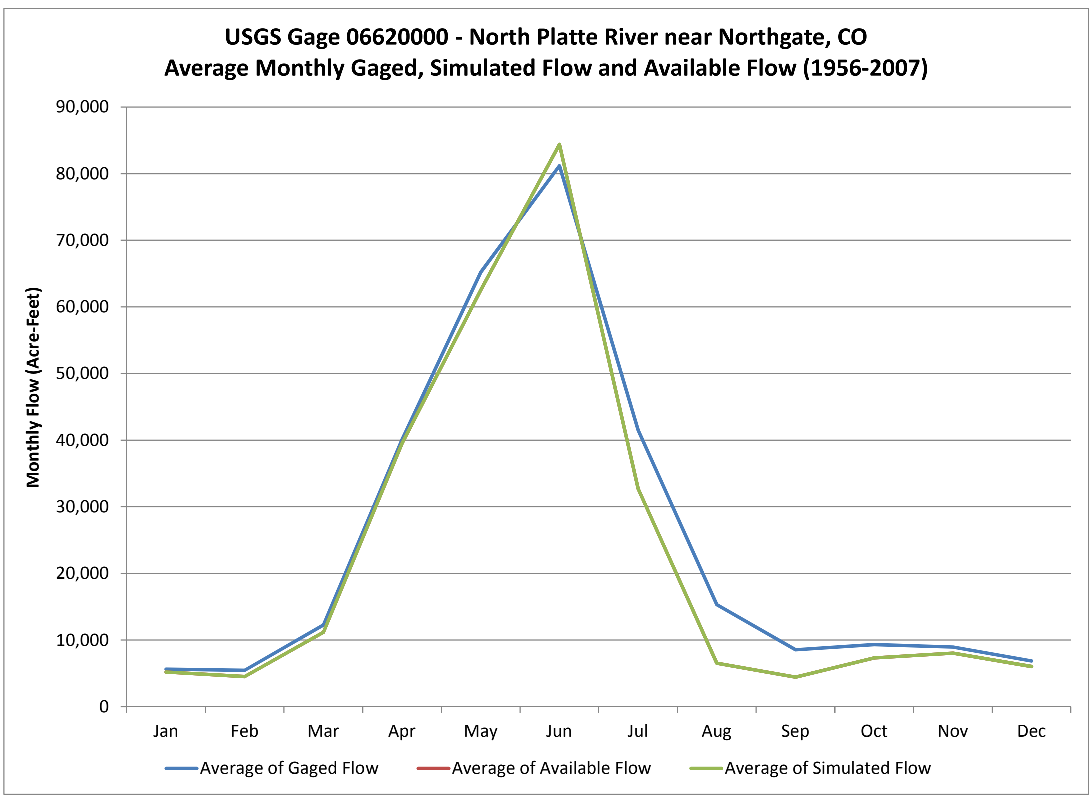


Figure 6.10 Baseline Results – North Platte River near Northgate, CO

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 North Platte River Model. It describes specific areas of the basin that were revised during calibration, and it presents summaries comparing modeled results for 1975 through 2007 with historical values for the period.

7.1 Calibration Process

The North Platte River Model was calibrated in a two-step process, based on the period 1975 through 2007. In the first step, 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 upon demand, but if the demand-driven operations left more water in a reservoir than it had historically, the model released enough water to the stream to achieve its historical end-of-month contents. In this step, the basic hydrology was assessed and 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 occurred. For example, a shortage might occur because a user’s water right was 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. Gains may not be modeled as entering the system until the next downstream gage, bypassing the shorted structures. Because the historical diversion and consumption did not occur, the model then overestimates flow at the downstream gage. Baseflow distribution parameters can be adjusted such that more water entered the system within the tributary, and typically, incremental inflow below the tributary is then reduced. The first step of calibration might also expose errors such as incorrect placement of a gage or a diversion structure.

In the second step, reservoirs responded to demands and were permitted to seek the level required to meet the demands. Model results were again reviewed, this time focusing on the operations. For example, where reservoir history revealed that annual administration was not strictly observed, the annual administration feature was removed.

The model at the conclusion of the second step is considered the calibrated model, as represented by the historical scenario. Note that the model is calibrated on a basin-wide level, concentrating on gage and reservoir locations. When using this model for future analyses involving smaller areas of the basin, it is recommended that further stream flow evaluations be conducted. A refined calibration will improve results of local analyses.

7.2 Historical Data Set

Calibration is based on supplying input that represents historical conditions, so that resulting gage and diversion values can be compared with historical records. 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. Direct Flow 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 the vagaries of operations that cannot be predicted – headgate maintenance, dry-up periods, and so on.

Demands for irrigation multi-structures and multiple node projects were placed at the point of diversion. In the Baseline data set, the combined demands are placed at the summary node, and operating rules drive the diversions from the individual headgates.

7.2.2. Irrigation Water Requirement File

Irrigation water requirement file (*.ddc) for the Historical data set is based on historical irrigated acreage. Because acreage has varied little in the North Platte River basin over the study period, the same irrigation water requirement is used for both Baseline and Historical simulations.

7.2.3. Reservoir Station File, Reservoir Right File, and Reservoir Target File

In the Historical data set, reservoirs are inactive prior to commencement of their historical operations; which applies to two reservoirs in the North Platte River model. Initial contents in the reservoir file (*.res) were set to their historical end-of-month content in September, 1955, and storage targets (*.tar file) were set to zero until the reservoir historically began to fill. Reservoir rights (*.rer) are on for the entire study period, as the target of zero prevents the reservoir from storing.

In the first calibration step, maximum storage targets were set to historical end-of-month contents. In the second calibration step, maximum reservoir storage targets were set to capacity for reservoirs that operated primarily for agricultural and municipal purposes. If capacity of a reservoir changed midway through the study period, the Historical data set accounts for the enlargement (not applicable in the North Platte River Model).

In the Baseline data set, reservoir rights are on the entire study period, and maximum targets were set to capacity for the entire study period.

7.2.4. Operational Rights File

The reservoir storage target file (*.tar) and the operating rules file (*.opr) work together to constrain reservoir operations in the first calibration step. During the first calibration step, the operational rights file includes rules to release water that remains in the reservoir above historical levels (specified in the target file) after demand-driven releases are made. In the second calibration step, release-to-target rules in the *.opr file are removed, and the reservoir is allowed to store and release water based on water availability, capacity, targets and irrigation demand associated with release operating rules. In both calibration runs, when water is released to a downstream irrigation diversion, enough water is released to meet the diverter's historical diverted amount, regardless of the efficiency of that operation or whether crop irrigation water requirements are satisfied. Section 5.9 describes each operating rule used in the Baseline and Historical simulations.

Differences between the Baseline data set and the Historical data set are summarized in Table 7.1.

Table 7.1
Comparison of Baseline and Historical (Calibration) Files

Input File	Baseline Data Set	Historical data Set
Diversion demand (*.ddm)	▪ Irrigation structures – "Calculated" demand for full supply, based on crop requirements and historical efficiency ▪ Non-irrigation structures – estimated current demand or historical average ▪ Demands placed on primary structures of multi-structure systems and demands placed at use location for carrier systems	▪ Historical diversions ▪ Historical diversions for multi-structures and irrigation demand structures were set at individual diversion headgates
Reservoir target (*.tar)	▪ Current maximum capacity	▪ First step – historical EOM contents, 0 prior to construction ▪ Second step – historical maximum capacity, 0 prior to construction
Operational right (*.opr)	▪ Operating rules drive diversions to demand destination through multi-structure and carrier structures ▪ Reservoir releases were made to irrigation structures to satisfy headgate demands only if crop irrigation water requirements were not met by other sources.	▪ First step - release-to-target operations allowed reservoirs to release to target contents ▪ First step - reservoir releases were made to irrigation structures to satisfy headgate demands regardless if crop irrigation water requirements were met.

7.3 Calibration Issues

This section describes areas of the model that were investigated in the calibration efforts of the North Platte River Model.

7.3.1. General Natural Flow Estimates

Historical streamflow records in the North Platte River model were limited, both spatially and in longevity. This impacted the understanding of contributing flows from tributaries, and ultimately, the distribution of the natural flow estimates throughout the model. Often times, calibration on a particular tributary was limited to the review of less than five years of streamflow data. Calibration on these tributaries relied more heavily on the review and comparison of historical diversion records, and the amount of natural flow and return flows accruing to a particular tributary to satisfy the historical demands. When adjustments were necessary, calibration was performed through the refinement of return flow locations and the distribution of natural flow to ungaged locations.

7.3.2. Grizzly Creek Natural Flow Estimate

As discussed in Section 4.4.3, Grizzly Creek experiences a different runoff pattern than other tributaries in the basin. Therefore, instead of filling Grizzly Creek natural flow with natural flow from other gages in the model, the historical records were filled using regression techniques and records from the Little Snake near Lily, CO gage. Review during calibration indicated that this approach resulted in better calibration on the tributary.

7.3.3. Lower Tributary Natural Flow Estimates

As discussed in Section 4.7.3, the automated process for estimating natural flow at gaged locations could not be simulated for streams that are tributary to the North Platte River below the Northgate gage. Therefore it was necessary to estimate natural flows for those tributaries using an external process. The tributaries, including Big Creek, Camp Creek, Three Mile Creek, Wheeler Creek, Beaver Creek, and Line Creek, do not have historical or currently active streamflow gages, and the natural flow estimates were based on a comparison of drainage area and precipitation of the lower tributaries to other tributaries in the model. Calibration on these tributaries relied on the comparison of historical diversion records, and the amount of natural flow estimated to meet the historical diversion records.

7.3.4. Reservoir and Irrigation Operations

The understanding of reservoir operations in the North Platte River basin were initially based on interviews with the two water commissioners, as part of the original SPDSS data collection phase. During model development, two full-day meetings were hosted by the Jackson County Water Conservancy District. Water users reviewed the modeled reservoir operations and the combining of structures into diversions systems and multi-structure systems. Based on their review and input, basin operations were refined, resulting in better reservoir, diversion and streamgage calibration.

7.3.5. Free Water Rights

Several irrigation structures have historical demands greater than their associated water rights. To allow these structures to divert in times of free-river conditions, they were assigned a junior water right ("free river right). Assigning free river rights to irrigation structures resulted in less shortages and better historical calibration.

7.4 Calibration Results

Calibration of the North Platte River Model is considered good, with most streamflow gages deviating less than 3 percent from historical values on an average annual basis. Nearly half the diversion structures' shortages are at or below 2 percent on an annual basis, and the basin wide shortage is around 3 percent per year, on average. Simulated reservoir contents are representative of historical values.

7.4.1. Water Balance

Table 7.2 summarizes the water balance for the North Platte River Model, for the calibration period (1975-2007). The following are observations based on the summary table:

- Stream water inflow to the basin averages 435 thousand acre-feet per year, and stream water outflow averages 315 thousand acre-feet per year.
- Annual diversions amount to approximately 392 thousand acre-feet on average, indicating that there is re-diversion of return flows in the basin.
- Approximately 120 thousand acre-feet per year reflects crop consumption and reservoir evaporation.
- 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), and indicates that the model correctly conserves mass.

Table 7.2
Average Annual Water Balance for Calibrated North Platte River Model 1975-2007 (af/yr)

Month	Stream Inflow	Return	From Soil Moisture	From Plan	Total Inflow	Diversions	Reservoir Evap	Stream Outflow	Reservoir Change	To Soil Moisture	Soil Moisture Change	Total Outflow	Inflow - Outflow	CU
JAN	6,731	413	0	330	7,474	773	-99	6,400	400	17	-17	7,474	0	23
FEB	5,687	514	0	440	6,640	1,010	32	5,421	178	38	-38	6,640	0	50
MAR	14,127	954	0	787	15,867	1,881	204	13,532	250	108	-108	15,867	0	221
APR	45,381	8,155	24	3,400	56,959	15,524	357	40,220	834	2,853	-2,829	56,959	0	681
MAY	109,024	52,801	883	4,252	166,961	93,790	493	71,393	402	8,741	-7,858	166,961	0	21,700
JUN	152,100	130,762	2,159	3,588	288,609	204,049	787	83,351	-1,736	9,471	-7,313	288,609	0	50,411
JUL	49,926	54,276	12,128	688	117,019	61,372	696	43,680	-858	173	11,955	117,019	0	34,191
AUG	11,463	7,941	6,495	114	26,013	4,552	492	14,597	-122	69	6,426	26,013	0	8,797
SEP	10,651	1,841	1,071	121	13,683	3,134	390	9,153	-65	134	936	13,683	0	2,615
OCT	10,898	1,687	69	309	12,962	2,883	250	9,537	223	518	-449	12,962	0	722
NOV	10,643	1,232	0	738	12,613	2,077	40	9,976	520	204	-204	12,613	0	93
DEC	8,279	493	0	315	9,086	863	-74	7,893	404	50	-50	9,086	0	35
AVG	434,909	261,069	22,829	15,080	733,887	391,909	3,568	315,152	429	22,376	453	733,887	0	119,539

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

7.4.2. Streamflow Calibration Results

Table 7.3 summarizes the annual average streamflow for water years 1975 through 2007, 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. Figures 7.1 through 7.10 (at the end of this section) graphically present monthly streamflow estimated by the model compared to historical observations at key streamflow gages, in both time-series format and as scatter graphs. When only one line appears on the time-series graph, it indicates that the simulated and historical results are the same at the scale presented. The "goodness of fit" is indicated by the R^2 value shown on each scatter graph.

Calibration based on streamflow simulation for gages is generally very good in terms of both annual volume and monthly pattern. As discussed above, the amount of historical streamflow data to calibrate to is very limited, in some cases, less than five years. Gages with a longer period of record are generally those on the mainstem or large tributaries, and the comparison at those locations indicates good calibration.

Table 7.3
Historical and Simulated Average Annual Streamflow Volumes (1975-2007)
Calibration Run (acre-feet/year)

Gage ID	Historical	Simulated	Historical -Simulated		Gage Name
			Volume	Percent	
06611200	3,233	3,656	423	13%	Buffalo Creek near Hebron, CO
06611300	39,644	40,428	-784	-2%	Grizzly Creek near Hebron, CO
06611700	No Historical Data in Calibration Period				Little Grizzly Creek near Coalmont, CO
06611800	17,762	17,363	399	2%	Little Grizzly Creek above Coalmont, CO
06611900	25,605	24,952	653	3%	Little Grizzly Creek above Hebron, CO
06614800	2,154	2,154	0	0%	Michigan River near Cameron Pass, CO
06615000	No Historical Data in Calibration Period				South Fork Michigan River near Gould, CO
06616000	9,812	9,749	63	1%	North Fork Michigan River near Gould, CO
06617500	22,510	22,657	-147	-1%	Illinois River near Rand, CO
06619400	13,376	13,950	- 574	- 4%	Canadian River near Lindland, CO
06619450	20,813	21,514	- 701	- 3%	Canadian River near Brownlee, CO
06620000	291,962	297,917	-5955	-2%	North Platte River near Northgate, CO

7.4.3. Diversion Calibration Results

Table 7.5 (at the end of this section) shows the average annual shortages for water years 1975 through 2007 by structure. On a basin-wide basis, average annual diversions differ from historical diversions by around 7 percent in the calibration run. Note that total diversions shown in Table 7.5 are not the same as total diversions shown in Table 7.2. Diversions in Table 7.2 include diverted amounts both at carriers and their destination.

- Structures that operate by operating rules rather than by historical demand may have simulated diversions different than historical diversions. In the North Platte Model, this most often occurs for primary and secondary structures represented as multi-system structures.
- Reservoir feeder canals are driven by the destination reservoir's end-of-month contents target. As noted below, the reservoirs generally stay fuller than historical; therefore less water is diverted through feeder canals.
- A significant amount of the basin shortages occur on the North Fork of the North Platte River. The only historical streamgage on the North Fork was decommissioned prior to the model study period. Although significant effort was made to understand and accurately represent the natural flow hydrograph, this tributary could benefit from additional gage records and refinement.

7.4.4. Reservoir Calibration Results

Figures 7.11 through 7.17 (located at the end of this section) present reservoir EOM contents estimated by the model compared to historical observations at selected reservoirs. The following can be observed:

- The simulated EOM contents generally follow the same pattern as historical measured EOM contents.

7.4.5. Consumptive Use Calibration Results

Crop consumptive use is estimated by StateMod and reported in the consumptive use summary file (*.xcu) for each diversion structure in the simulation. The crop consumptive use estimated by StateCU, based on historical recorded diversions, is reported in the water supply-limited summary file (*.wsl) for each agricultural diversion structure in the basin.

Table 7.4 shows the StateCU estimated crop consumptive use compared to StateMod estimate of crop consumptive use for structures in the basin. Historical diversions are used by StateCU to estimate supply-limited (actual) consumptive use. The approximately 3 percent difference reflects the shortages in diversions simulated in the calibration model.

Table 7.4
Average Annual Crop Consumptive Use Comparison (1975-2007)

Comparison	StateCU Results (af/yr)	Calibration Run Results (af/yr)	% Difference
Basin Total	119,756	115,971	3%

Table 7.5
Historical and Simulated Average Annual Diversions (1975-2007)
Calibration Run (acre-feet/year)

WDID	Historical	Simulated	Historical - Simulated Volume	Historical - Simulated Percent	Name
4700501	836	608	228	27	ARNOLD DITCH
4700502	132	106	26	20	ASPIN DITCH
4700505	590	561	29	5	BEAR CREEK DITCH
4700506	1386	1275	111	8	BEAVER DITCH
4700507	592	422	170	29	BEAVERDALE DITCH
4700508	1695	1554	141	8	BENNETT & LESHURE D
4700510	59	59	0	1	BERN DITCH
4700511	101	101	0	0	Bernard Ditch
4700512	3522	3520	2	0	BIG GRIZZLY DITCH
4700513	877	782	94	11	BIG WILLOW DITCH
4700514	139	133	6	4	BOCK DITCH
4700515	1100	1072	28	3	BONA FIDE DITCH
4700516	524	523	1	0	BONA FIDE DITCH 2
4700519	1019	1019	0	0	BOONE DITCH
4700520	15	15	0	0	BOSTON DITCH 1
4700521	4709	4682	27	1	BOSTWICK DITCH
4700522	1529	1168	362	24	BOULDER DITCH
4700523	126	114	12	10	BOWEN DITCH
4700524	1183	1082	101	9	BOYCE BROS DITCH NO 1
4700526	245	177	68	28	BRADFIELD DITCH
4700529	51	17	34	67	BROCKER DITCH
4700531	1187	1187	0	0	BUCKEYE DITCH
4700532	321	316	5	2	BURKE DITCH
4700533	299	248	50	17	BURNS DITCH
4700534	173	172	1	1	BUTLER DITCH
4700535	176	171	5	3	BUTLER DITCH 3
4700536	182	179	3	2	BUTLER DITCH 2
4700538	319	273	45	14	CAMP CREEK DITCH
4700542	439	399	40	9	CANON DITCH
4700544	482	460	21	4	CARDEN-DAGLE DITCH
4700546	522	515	7	1	CARNEY DITCH
4700547	170	170	0	0	CARPENTER DITCH
4700548	134	134	0	0	CARPENTER DITCH 2
4700549	740	740	0	0	CASTLE DITCH
4700550	635	574	62	10	CHACE DITCH
4700551	69	69	0	0	CHAMPION DITCH

WDID	Historical	Simulated	Historical - Simulated Volume	Historical - Simulated Percent	Name
4700552	3570	3449	121	3	CHAPMAN DITCH
4700553	261	261	0	0	CHEDSEY DITCH 1
4700554	1487	1454	33	2	CHEDSEY DITCH 2
4700556	235	299	-64	-27	CLAYTON DITCH
4700557	51	41	11	21	CLAYTON RICH DITCH
4700561	140	134	6	4	CLIFTON DITCH
4700562	155	144	12	8	COCHRANE DITCH
4700563	234	230	3	1	COE DITCH NO 1
4700564	281	280	1	0	COE DITCH NO 2
4700565	392	257	135	34	COLUMBINE DITCH
4700566	94	80	14	15	COLUMBUS DITCH
4700567	1336	1336	0	0	COL DAVIS DITCH
4700569	406	375	32	8	CONTINENTAL DITCH
4700572	199	184	15	8	COOK DITCH
4700573	452	426	25	6	COON CREEK DITCH
4700574	725	725	0	0	COWDREY DITCH
4700575	402	386	15	4	COYOTE DITCH
4700576	76	74	2	2	CRYSTAL SPRING DITCH
4700577	6029	5911	118	2	CUMBERLAND DITCH
4700578	4119	4051	68	2	CURTIN DITCH
4700580	483	480	3	1	DALE DITCH
4700581	1057	1057	0	0	DALOM DITCH
4700582	1970	1970	0	0	DAM DITCH
4700583	219	218	1	0	DAMFINO DITCH
4700584	6793	5935	858	13	DARBY DITCH
4700586	166	112	54	33	DARCY DITCH
4700587	326	323	4	1	DARLING DITCH
4700588	705	701	4	1	DAVIS DITCH
4700589	15	11	5	30	DEER DITCH
4700591	686	630	56	8	DONELSON DITCH
4700592	101	101	0	0	DORA DITCH
4700596	1463	1373	90	6	DRY RUN DITCH
4700597	536	534	2	0	DRYER DITCH
4700598	175	139	35	20	DULANEY DITCH
4700599	304	300	4	1	DURGIN DITCH
4700601	2430	2429	1	0	DWINELL DITCH
4700602	783	645	138	18	EASSOM DITCH
4700604	86	85	1	1	EAST BUFFALO DITCH
4700605	1183	899	284	24	EAST LYNNE DITCH
4700607	42	42	0	0	EDITH DITCH
4700609	512	512	0	0	ELLEN DITCH
4700610	190	185	5	3	ENDOMILE DITCH
4700611	555	504	51	9	ERICKSON D BOHN ENL
4700612	736	516	221	30	ERIKA DITCH
4700613	64	64	0	0	ERNEST DITCH
4700614	4112	3722	391	9	EUREKA DITCH
4700615	2960	2861	99	3	EVERHARD BALDWIN DITCH
4700617	32	21	12	37	FAULKNER DITCH

WDID	Historical	Simulated	Historical - Simulated		Name
			Volume	Percent	
4700618	601	580	21	3	FERANDO DITCH
4700620	888	859	30	3	FLYING DUTCHMAN DITCH
4700621	141	123	18	13	FORREST DITCH
4700623	65	61	3	5	FREEMAN DITCH
4700624	33	32	0	1	FULLER DITCH
4700625	778	778	0	0	GAMBER BRINKER DITCH
4700626	573	570	3	1	GARDEN DITCH
4700630	384	384	0	0	GEORGE WARD DITCH
4700633	295	294	2	1	GIBBS DITCH
4700634	288	288	0	0	GILLETTE DITCH 1
4700635	401	398	2	1	GILLETTE DITCH 2
4700636	590	576	14	2	GILLETTE DITCH 3
4700637	198	195	4	2	GIVEADAM JONES DITCH
4700642	219	219	0	0	GOVERNMENT DITCH NO 1
4700643	112	111	0	0	GOVERNMENT DITCH NO 2
4700645	352	299	53	15	HAMILTON DITCH
4700646	1337	1118	218	16	HANOVER DITCH
4700647	176	151	25	14	HANS CLAUSON D NO 1
4700648	278	266	12	4	HANS CLAUSON D NO 2
4700650	440	409	31	7	HARD TO FIND DITCH
4700651	438	436	2	0	HARDWORK DITCH
4700656	284	214	69	24	HARTZELL DITCH
4700659	204	174	31	15	HEADACHE DITCH
4700661	256	247	10	4	HIGO DITCH
4700662	2388	2388	0	0	HIHO DITCH
4700663	1413	1393	20	1	HILL DITCH NO 1
4700664	896	737	159	18	HILL DITCH NO 2
4700665	3865	2671	1194	31	HILLSIDE DITCH
4700666	289	284	5	2	HILL,CROUTER DITCH
4700667	378	363	15	4	HODGSON DITCH
4700669	729	729	0	0	HOME NO 1 & UPLAND D
4700670	494	486	8	2	HOME DITCH NO 2
4700671	1013	1013	0	0	HOMESTEAD DITCH
4700676	729	708	21	3	HUBBARD DITCH 1
4700677	82	78	4	5	HUGH GRIFFITH DITCH
4700678	286	286	0	0	HUGH GRIFFITH DITCH 2
4700680	150	147	3	2	HUNTER DITCH 1
4700682	25	25	0	2	HUNTINGTON DITCH
4700683	2814	2723	91	3	INDEPENDENCE DITCH
4700684	5000	4862	137	3	INDEPENDENT DITCH
4700685	89	70	19	22	ISH & BALDWIN DITCH
4700686	622	442	180	29	ISH DITCH
4700687	240	240	0	0	ISH EVERHARD DITCH
4700688	126	125	1	1	ISLAND DITCH
4700689	103	103	0	0	IVEY DITCH
4700693	713	635	79	11	JACKSON DITCH
4700694	391	389	3	1	JAKEY DITCH
4700695	249	249	0	0	JAMES D DITCH

WDID	Historical	Simulated	Historical - Simulated Volume	Percent	Name
4700696	261	240	21	8	JAMES SUTTON DITCH 2
4700698	353	341	12	3	JAP DAVISON DITCH
4700699	533	522	11	2	JAY DITCH
4700700	1246	1222	24	2	JENNIE DITCH
4700702	1265	1225	39	3	JOHN S SUTTON DITCH
4700703	347	347	0	0	JOHNSON DITCH
4700704	152	130	23	15	JORDAN DITCH
4700706	440	434	6	1	KELLY DITCH
4700708	431	431	0	0	KERMODE DITCH
4700710	292	292	0	0	KERR DITCH
4700711	3509	3509	0	0	KIWA DITCH
4700714	776	679	98	13	LAKE CREEK DITCH
4700715	57	56	1	1	LANDHURST DITCH
4700716	692	680	11	2	LARSEN DITCH
4700717	95	83	11	12	LAST CHANCE DITCH
4700719	467	459	7	2	LAWRENCE DITCH 1
4700720	4065	4057	8	0	LEGAL TENDER DITCH
4700722	480	474	6	1	LEONARD DITCH
4700723	1730	1599	131	8	LEWIS DITCH
4700724	120	110	10	9	LIEUALLEN DITCH
4700725	837	446	391	47	LILLIE DITCH
4700726	67	46	21	32	LITTLE CHIEF DITCH
4700728	1236	1236	0	0	LITTLE GRIZZLY DITCH
4700730	5439	4632	807	15	LITTLE NELLIE DITCH
4700731	122	120	1	1	LIVINGSTONE DITCH
4700732	143	143	0	0	LIZZIE DITCH
4700736	300	300	0	0	LORENA DITCH
4700737	69	54	15	22	LOST CREEK DITCH
4700739	636	636	0	0	LOWER WALDEN DITCH
4700740	1494	1280	214	14	LOWLAND DITCH
4700741	2019	1752	267	13	LUCKPENNY DITCH
4700742	169	156	13	8	LYNCH DITCH
4700743	1424	1166	258	18	MABEL DOW DITCH
4700745	0	2335	-2335	0	MACFARLANE EXT D
4700746	524	481	43	8	MAGGIE DITCH
4700747	1312	1256	57	4	MALLON DITCH
4700748	6289	5772	517	8	MALLON DITCH NO 2
4700749	1349	1349	0	0	MAMMOUTH DITCH
4700752	471	471	0	0	MANVILLE DITCH
4700754	573	573	0	0	MARR DITCH 1
4700755	1859	1858	1	0	MARR DITCH 2
4700757	125	85	40	32	MARY ISH DITCH
4700758	84	55	29	35	MARY ISH DITCH NO 2
4700760	1736	1714	22	1	MATHEWS DITCH
4700761	873	837	36	4	MATHEWS, EASTERN DITCH
4700762	294	291	3	1	MAY GRAY DITCH
4700763	278	276	2	1	MACFARLANE MEADOWS D
4700767	126	120	7	5	MEADOW CREEK DITCH

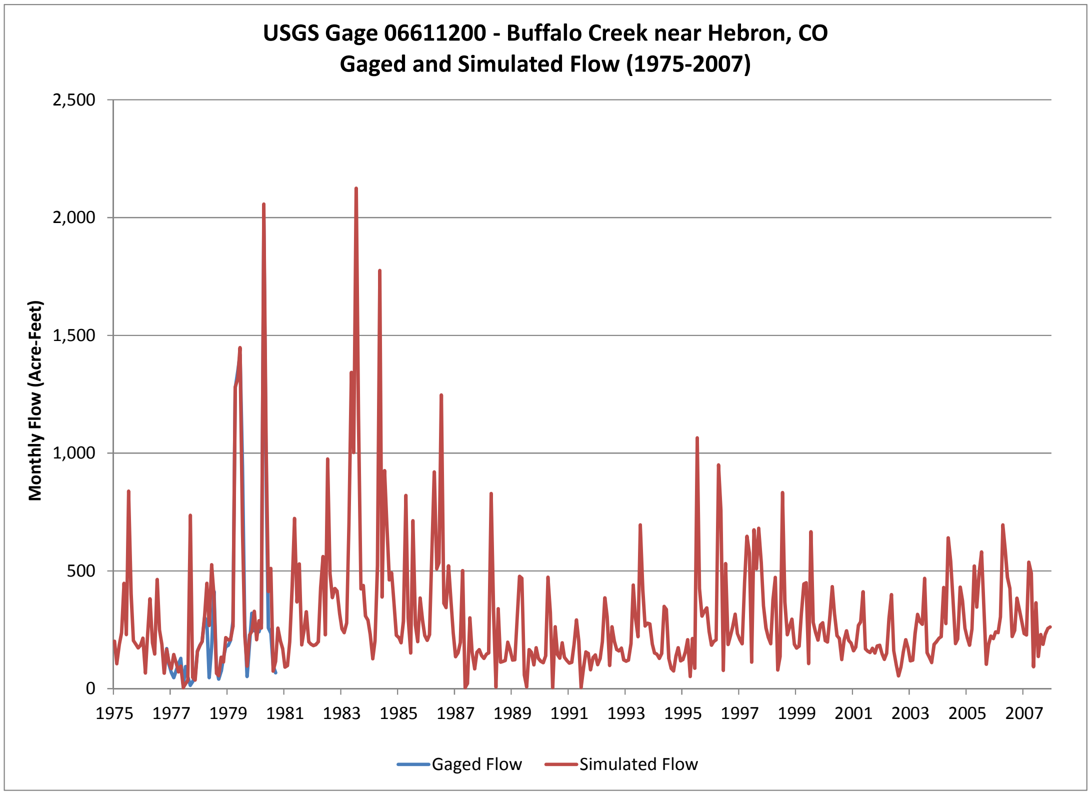
WDID	Historical	Simulated	Historical - Simulated Volume	Historical - Simulated Percent	Name
4700768	2179	2179	0	0	MEDICINE BOW DITCH
4700769	160	160	0	0	MELLON DITCH
4700770	297	295	2	1	MEXICAN DITCH
4700773	3020	2962	57	2	MICHIGAN HIGHLINE DITCH
4700774	9387	8427	960	10	MIDLAND DITCH
4700776	166	129	36	22	MILL CREEK DITCH
4700777	2951	2778	172	6	MITCHELL DITCH
4700779	463	458	4	1	MONROE DITCH
4700783	232	231	1	0	MOORE NO 1 DITCH
4700786	10881	10872	9	0	MUTUAL DITCH
4700787	1994	1980	14	1	NAIRN DITCH
4700788	249	236	14	5	NELLIE E DITCH
4700789	82	82	0	0	NEW BURKE DITCH
4700790	2357	2349	8	0	NEW PIONEER DITCH
4700791	886	883	3	0	NEW ROSS DITCH
4700792	1089	1086	3	0	NEWCOMB DITCH
4700795	753	753	0	0	NILE DITCH
4700796	790	635	154	20	NORRIS DITCH
4700797	291	269	22	8	NORTH FORK DITCH
4700799	1036	1036	0	0	NORTH PARK DITCH NO 7
4700800	136	132	4	3	NORTH PARK DITCH NO 2
4700801	127	115	13	10	NORTH PARK DITCH NO 3
4700802	1070	1070	0	0	NORTH PARK DITCH NO 4
4700803	1144	1144	0	0	NORTH PARK DITCH NO 5
4700805	234	223	11	5	NOVELTY DITCH
4700811	613	550	63	10	OKLAHOMA DITCH NO 2
4700814	396	297	98	25	OLDENBERG DITCH
4700816	1800	1725	74	4	OPEN A DIAMOND DITCH
4700818	272	268	4	1	OTTAWA DITCH
4700819	3079	2747	332	11	OVERLAND DITCH
4700825	99	84	15	15	PARK VIEW DITCH
4700827	95	16	78	83	PEARL DITCH
4700829	920	919	1	0	PETERSON DITCH 1
4700831	41	41	0	0	PHELAN DITCH
4700835	1031	986	45	4	PIONEER DITCH
4700837	821	739	83	10	PLEASANT VALLEY DITCH
4700838	202	154	48	24	POLE MTN RES FEEDER D
4700839	561	515	46	8	POLED ANGUS DITCH
4700840	2380	2380	0	0	POMROY DITCH 1
4700841	110	102	8	7	POMROY DITCH NO 2
4700842	1238	1238	0	0	POQUETTE DITCH
4700843	122	119	3	3	POTTER DITCH NO 2
4700844	1572	1451	121	8	POVERTY FLAT D NO 2
4700846	278	245	34	12	POWELL DITCH
4700847	1477	1477	0	0	QUEEN DITCH
4700849	68	60	9	13	RARUS DITCH
4700850	231	200	31	14	RATTLER DITCH
4700851	251	236	15	6	RAVINE DITCH

WDID	Historical	Simulated	Historical - Simulated Volume	Percent	Name
4700852	253	251	2	1	REITHMEYER D
4700853	1296	1230	65	5	RHEA DITCH
4700854	627	618	9	1	RICHMOND DITCH
4700855	481	472	9	2	RIDDLE DITCH
4700857	2467	2101	366	15	ROARING DITCH
4700860	289	289	0	0	SAINT FRANCES NO 1 D
4700861	247	213	34	14	SAINT FRANCES DITCH 7
4700863	1158	1034	124	11	SALEM DITCH
4700864	179	162	17	9	SALES DITCH
4700865	1519	1519	0	0	SANBORN DITCH
4700866	777	777	0	0	SAND CREEK DITCH
4700867	208	208	0	0	SCHOOL SECTION DITCH
4700869	577	572	5	1	SEYMOUR DITCH 1
4700871	1217	774	443	36	SHAFER DITCH
4700872	63	53	9	15	SHAFTO DITCH
4700874	125	110	15	12	SHEARER DITCH NO 2
4700875	764	720	44	6	SHERMAN DITCH
4700876	619	526	93	15	SHORT RUN DITCH
4700878	564	564	0	0	SIXTEEN DITCH
4700879	728	632	96	13	SLACK DITCH
4700880	317	266	51	16	SLACK WEISS DITCH
4700881	335	312	23	7	SLEW DITCH
4700883	394	388	6	1	SMEED DITCH
4700885	122	102	20	17	SNIDE DITCH
4700886	604	569	35	6	SOLDIERS HOME DITCH
4700887	544	543	1	0	SORENSON DITCH
4700888	294	294	0	0	SPAULDING DITCH
4700890	1471	1471	0	0	SPICER DITCH
4700892	466	461	5	1	SPRING GULCH DITCH
4700893	3217	3215	3	0	SQUIBOB DITCH
4700894	157	148	8	5	STAMBAUGH DITCH
4700895	6107	5418	689	11	STAPLES DITCH 1
4700896	2855	2612	243	9	STAPLES DITCH NO 2
4700898	124	119	5	4	STEELE DITCH
4700900	201	187	14	7	STEMLER DITCH
4700902	508	498	10	2	STEVENSON DITCH 4
4700903	55	48	7	13	STEVENSON DITCH NO 3
4700904	448	439	10	2	STEVENSON NO 2 DITCH
4700905	1216	1216	0	0	STILLWATER DITCH
4700906	1417	1202	215	15	STORMY DITCH
4700907	189	189	0	0	SAINT FRANCES NO 2
4700908	442	429	12	3	SUDDITH NO 1 DITCH
4700909	544	541	2	0	SUDDUTH DITCH NO 5
4700914	99	94	5	5	TAYLOR DITCH
4700915	54	46	8	15	TELLER DITCH
4700916	413	409	5	1	TERRELL DITCH
4700917	768	768	0	0	THIRTY SIX DITCH
4700919	296	291	6	2	TIMBER DITCH

WDID	Historical	Simulated	Historical - Simulated Volume	Historical - Simulated Percent	Name
4700920	87	86	0	0	TIMOTHY DITCH
4700921	134	51	84	62	TIMOTHY HILL DITCH
4700923	352	339	13	4	TOGO DITCH NO 2
4700924	300	260	40	13	TOLEDO DITCH
4700925	123	123	0	0	TROUBLESOME DITCH
4700926	391	390	1	0	TROY DITCH
4700927	146	143	3	2	ULRICH DITCH
4700929	330	309	21	6	UTE PASS DITCH
4700931	373	278	95	25	VAN PATTEN DITCH
4700932	5288	4983	305	6	VICTOR DITCH
4700933	87	84	2	3	VITA DITCH
4700939	1528	1528	0	0	WALES DITCH
4700940	129	129	0	0	WALKER DITCH
4700941	201	91	110	55	WARD DITCH 2
4700942	1975	1867	108	5	WARD DITCH 1
4700943	466	336	130	28	WARD DITCH 3
4700944	152	152	0	0	WATSON DITCH
4700946	264	245	19	7	WEED DITCH
4700948	617	276	341	55	WEST BOETTCHER DITCH
4700949	493	447	46	9	WEST BUFFALO DITCH
4700950	560	357	203	36	WEST DITCH
4700951	2999	2963	36	1	WEST FORK DITCH
4700952	22	16	6	27	WEST SIDE DITCH
4700953	408	353	56	14	WESTFIELD DITCH
4700954	34	34	0	1	WHEELER DITCH
4700955	234	178	56	24	WHEELER DITCH 1
4700956	147	96	51	35	WHEELER DITCH 2
4700957	414	320	94	23	WILLFORD DITCH
4700958	190	188	2	1	WILLIAM KERR DITCH
4700960	506	499	6	1	WISCONSIN DITCH
4700961	13086	8371	4715	36	WOLFER DITCH
4700962	177	130	47	27	WYCOFF DITCH
4700965	241	116	125	52	ZELMA DARCY DITCH
4700966	416	286	131	31	ZIRKEL DITCH
4700969	2552	2552	0	0	NINE SIX NINE DITCH
4700971	349	334	15	4	EDITH DITCH
4700976	534	431	103	19	JACKSON DITCH NO 2
4700979	530	525	5	1	LAST CHANCE DITCH
4700984	204	204	0	0	MACE BULL PASTURE D
4700985	88	80	9	10	MCISAAC DITCH
4700986	50	19	31	63	MCISAAC DITCH NO 2
4700989	405	370	36	9	NEW SAND CREEK D
4700991	268	268	0	0	PAUL DITCH NO 1
4700992	195	181	15	7	PAUL DITCH NO 2
4700993	204	189	16	8	PAUL DITCH NO 3
4701001	942	785	157	17	ADDISON DITCH
4701002	35	30	4	13	AKERS DITCH
4701003	184	176	8	4	ALBERT CLAUSON DITCH

WDID	Historical	Simulated	Historical - Simulated Volume	Percent	Name
4701005	188	177	11	6	ALLARD DITCH
4701006	219	251	-32	-15	ALLARD DITCH
4701007	158	156	2	1	ALLEN DITCH
4701008	349	349	0	0	ALMA DITCH
4701010	277	277	0	0	ANDERSON DITCH
4701011	2111	2099	12	1	ANTELOPE DITCH
4701022	1330	1330	0	0	BUCKEYE DITCH
4701023	172	170	2	1	BUTLER DITCH 4
4701025	178	144	34	19	COCHRANE DITCH
4701027	535	531	4	1	HOMESTEAD DITCH
4701028	39	22	18	44	DUGAN DITCH
4701029	347	347	0	0	MARTIN DITCH
4701030	160	103	57	36	LITTLE CHIEF D HG NO 2
4701031	229	179	50	22	MONROE DITCH
4701032	437	287	150	34	OLLIVER DITCH
4701033	226	217	9	4	PARK DITCH
4701035	134	112	22	16	VICTOR DITCH
4701039	645	621	25	4	JACKSON DITCH NO. 3
4701040	176	165	11	6	UPPER LITTLE MUDDY DITCH
4701041	170	155	15	9	LOWER LITTLE MUDDY D
4701042	499	462	37	7	LYNN DITCH
4701055	228	203	25	11	ALMEDA DITCH
4701071	416	375	41	10	ANDREW NORRELL DITCH
4701083	84	84	0	0	WALDEN MICHIGAN R DIV
4701099	39	38	1	2	LATTER DITCH
4701137	68	61	7	11	DRY FORK DITCH
4701138	176	148	27	16	OIL WELL DITCH
4701146	78	61	17	22	COOK DITCH
4701169	62	62	0	0	ROUGH AND READY DITCH
4701180	118	90	28	24	EMCO DITCH NO 1
4701198	2207	2207	0	0	HOWARD D MACFARLANE ACCT
4702030	148	145	3	2	WATTENBERG DITCH
4702040	92	86	6	6	NANCY JANE DITCH
4702042	250	151	100	40	STEVENSEN NO 1 DITCH
4702049	380	578	-199	-52	WEST ARAPAHOE FEEDER D 2
4702054	83	83	0	0	A BAR A DITCH
4702057	497	374	123	25	PLAINWELL DITCH
4702066	151	65	87	57	WILHELM EXTENSION
4702070	16	15	1	7	CEMETARY PUMP STA
4702079	285	282	3	1	BAKER DRAW DITCH
4702080	436	436	0	0	BARBER DITCH
4702092	92	75	17	19	PAUL DITCH NO 4
4702103	249	217	32	13	RAVINE DITCH NO 2
4704602	103	103	0	0	CAMERON PASS DITCH
4704603	3035	2372	663	22	MICHIGAN DITCH
47_ADN001	645	549	96	15	Threemile Creek Agg
4700500_D	2542	2423	119	5	Arapahoe DivSys
4700504_D	968	945	23	2	Badger State DivSys

WDID	Historical	Simulated	Historical - Simulated Volume	Percent	Name
4700528_M	4836	4096	740	15	Briggs Bohn Ditch MS
4700530_M	2438	2327	111	5	Brocker Endomile MS
4700543_D	840	830	10	1	Capron DivSys
4700559_M	4047	4039	9	0	Cleveland Ditch MS
4700583_D	1965	1953	11	1	Damfino DivSys
4700590_D	408	378	30	7	Dike DivSys
4700593_M	1251	1088	163	13	Doran Ditch MS
4700595_M	1937	1911	26	1	Dry Creek Ditch MS
4700600_D	147	143	3	2	Dwinell DivSys
4700638_D	836	814	23	3	Glendale DivSys
4700639_D	1326	1282	44	3	Gould DivSys
4700655_D	84	84	0	0	Oxford DivSys
4700657_D	563	471	91	16	Haworth DivSys
4700672_M	4089	4154	-65	-2	Howard Ranch MS
4700674_D	4121	3683	437	11	Hubbard DivSys
4700679_D	2711	2663	48	2	Hunter DivSys
4700705_D	1850	1550	301	16	Sutton DivSys
4700709_M	661	632	30	4	Kermode MS
4700718_D	858	823	36	4	Lawrence DivSys
4700735_M	1630	1375	254	16	Lookout Ditch MS
4700738_D	5839	5449	390	7	Lost Treasure DivSys
4700753_M	5511	4491	1020	19	Manville Ditch 2 MS
4700793_D	830	820	10	1	Newport DivSys
4700804_D	800	694	106	13	North Park DivSys
4700809_D	1553	1538	15	1	Oklahoma DivSys
4700813_D	3060	3238	-178	-6	Old SC DivSys
4700815_D	514	459	55	11	Olive DivSys
4700826_M	3966	3544	422	11	Peabody Ditch MS
4700845_D	2772	2634	138	5	Poverty DivSys
4700859_D	1537	1537	0	0	Ruction DivSys
4700862_D	598	502	96	16	Saint Joseph DivSys
4700868_D	5269	5269	0	0	Seneca DivSys
4700873_D	848	826	21	2	Shearer DivSys
4700884_D	1207	1165	41	3	Smith DivSys
4700911_D	1879	1803	76	4	Sunday DivSys
4700922_D	299	196	102	34	Titanic DivSys
4700935_D	950	930	20	2	Walden Ditch DivSys
4700964_D	379	349	30	8	Yocum DivSys
4700978_D	208	181	27	13	Kenny DivSys
4700996_M	352	345	7	2	Sales Ditch 2 MS
4701009_D	1806	1095	711	39	Norell DivSys
4701024_M	2090	1712	378	18	Cochrane MS
4701054_D	1404	1404	0	0	Big Grizzly DivSys
4701061_D	1108	953	155	14	Garland DivSys
4701298_D	32	28	5	15	Smith Diversion DivSys
4702002_D	53	31	22	41	Elk Creek DivSys
4702091_D	352	156	196	56	Roslyn DivSys
Basin Total	**395,877**	**367,649**	**28,228**	**7%**	



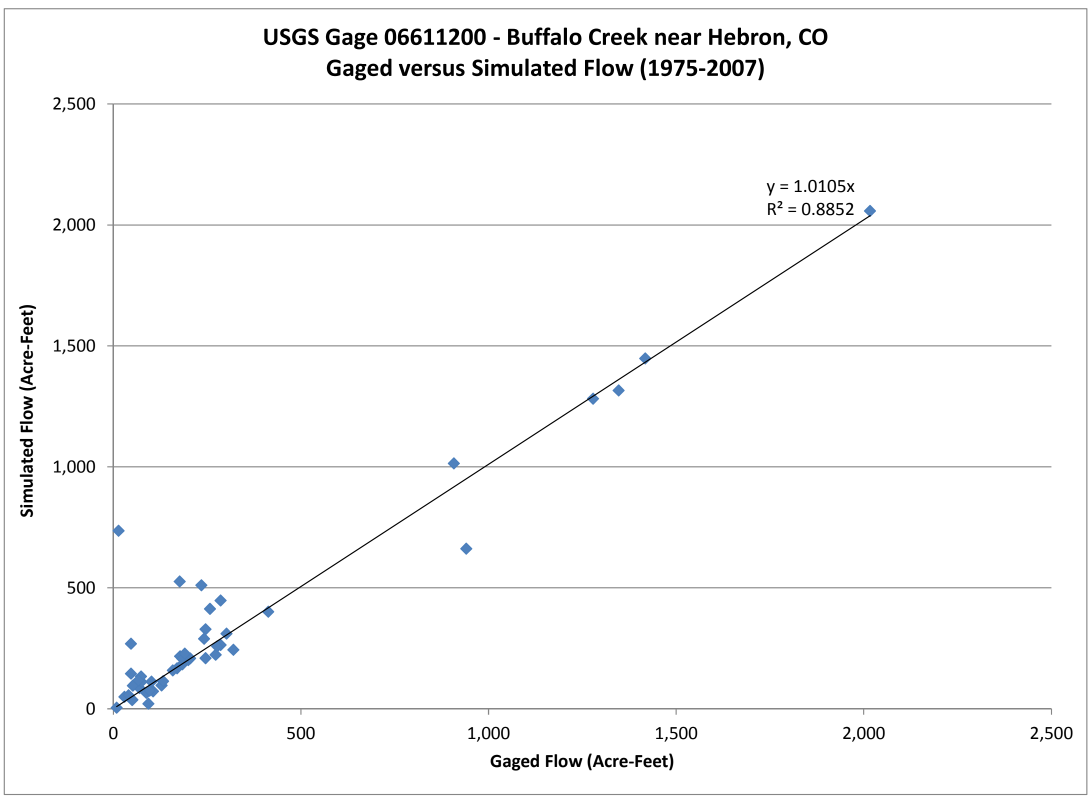
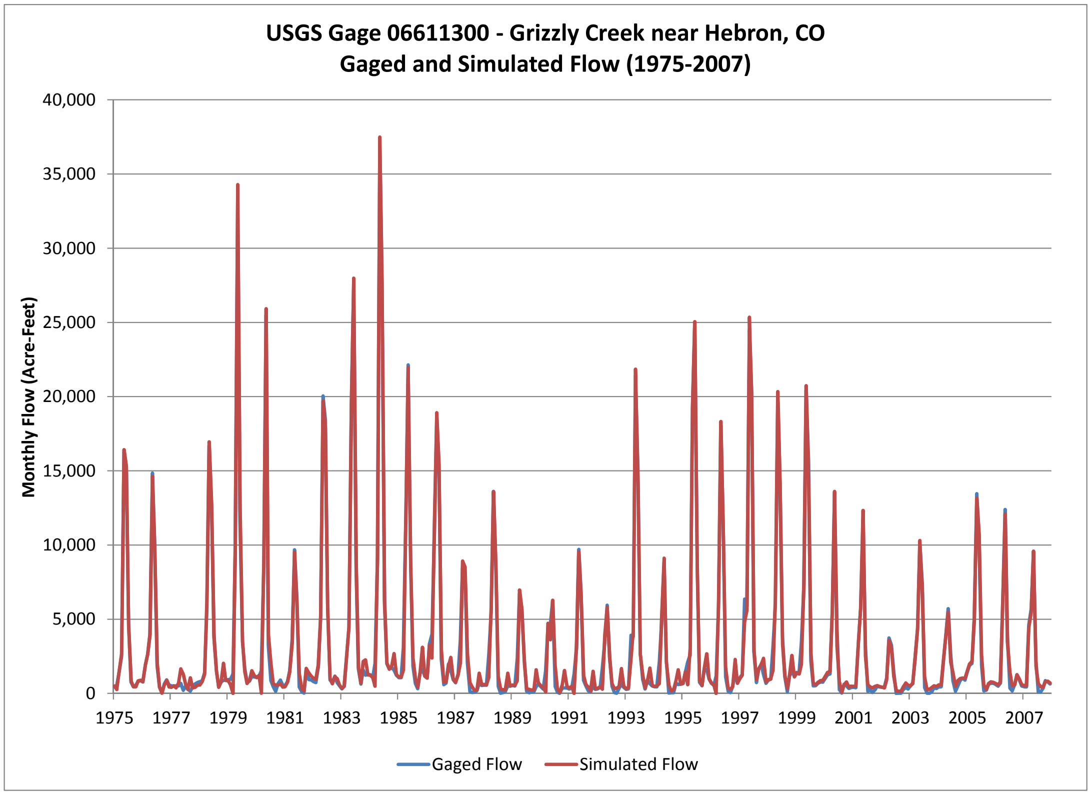


Figure 7.1 Streamflow Calibration – Buffalo Creek near Hebron, CO



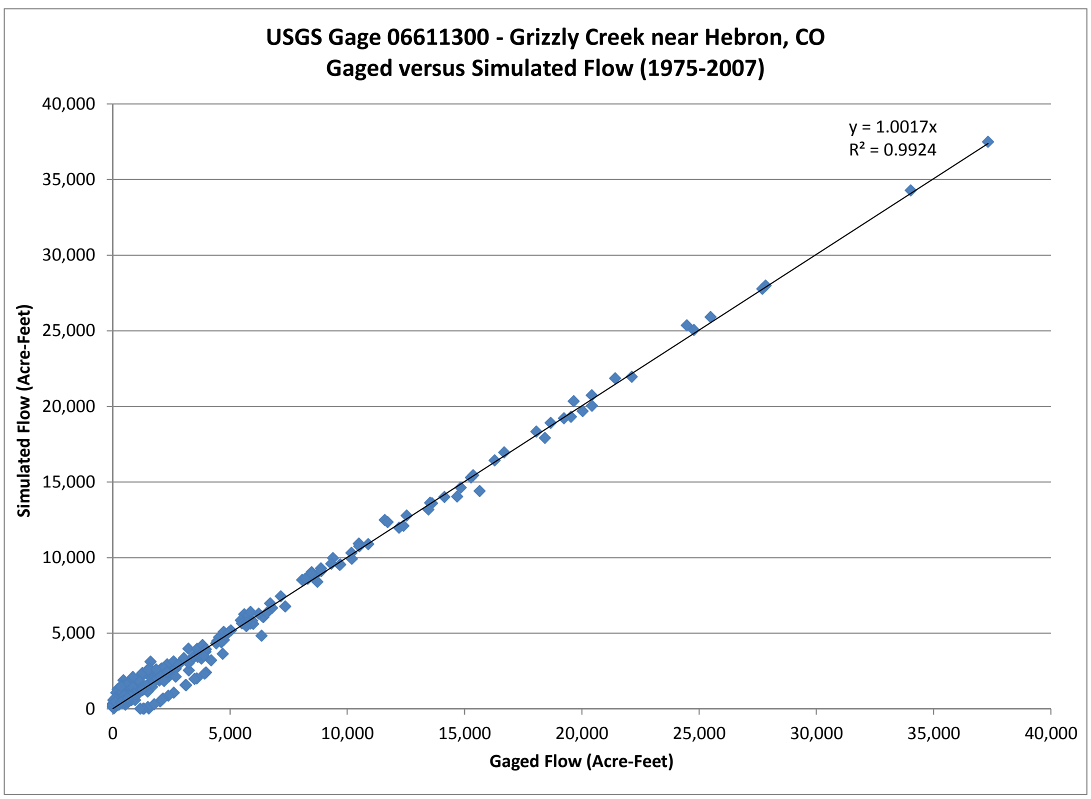
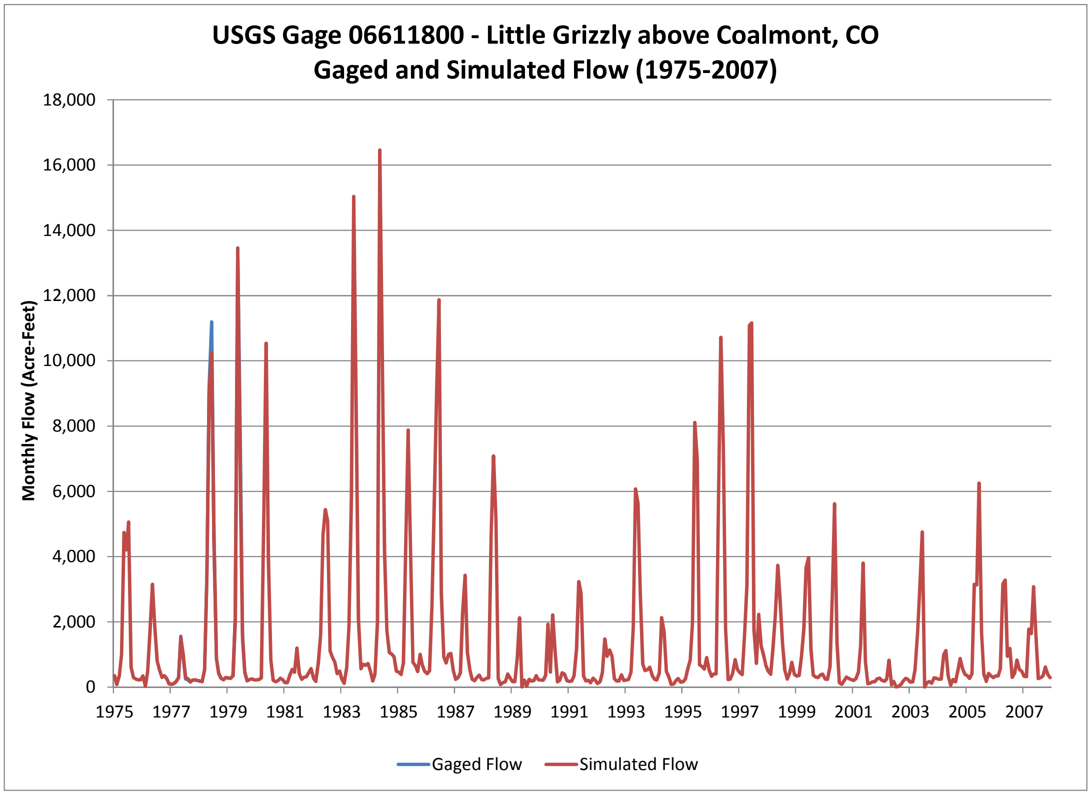


Figure 7.2 Streamflow Calibration – Grizzly Creek near Hebron, CO



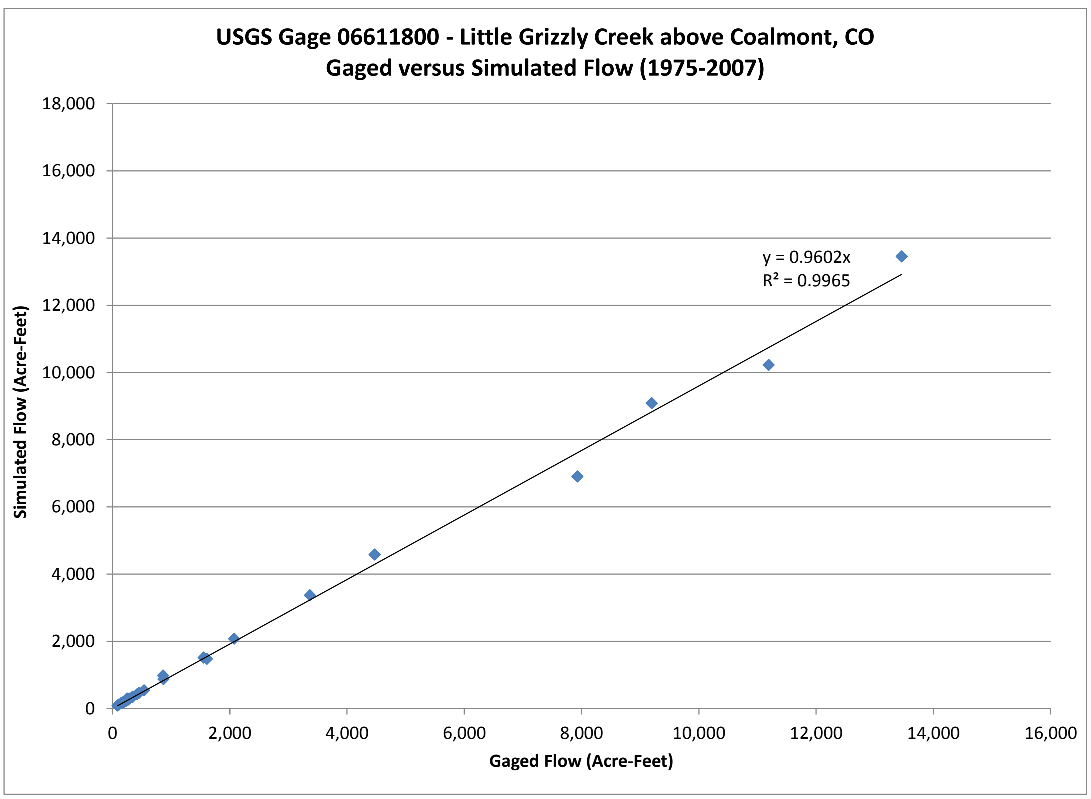
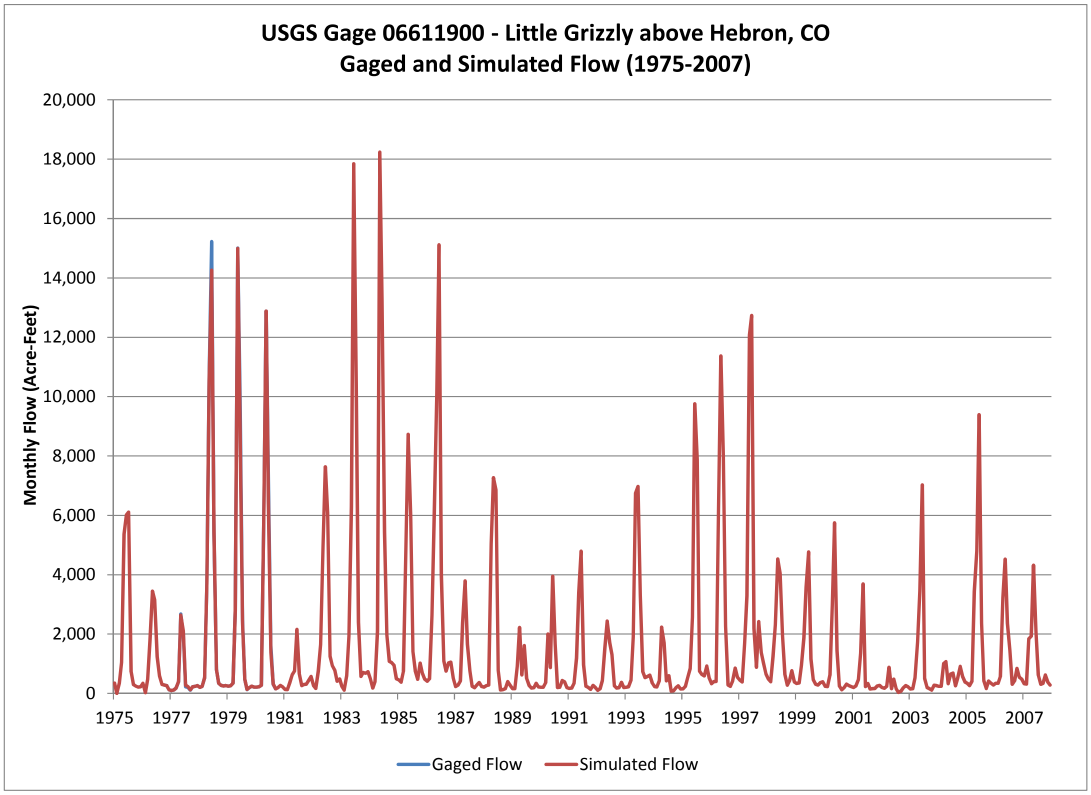


Figure 7.3 Streamflow Calibration – Little Grizzly Creek above Coalmont, CO



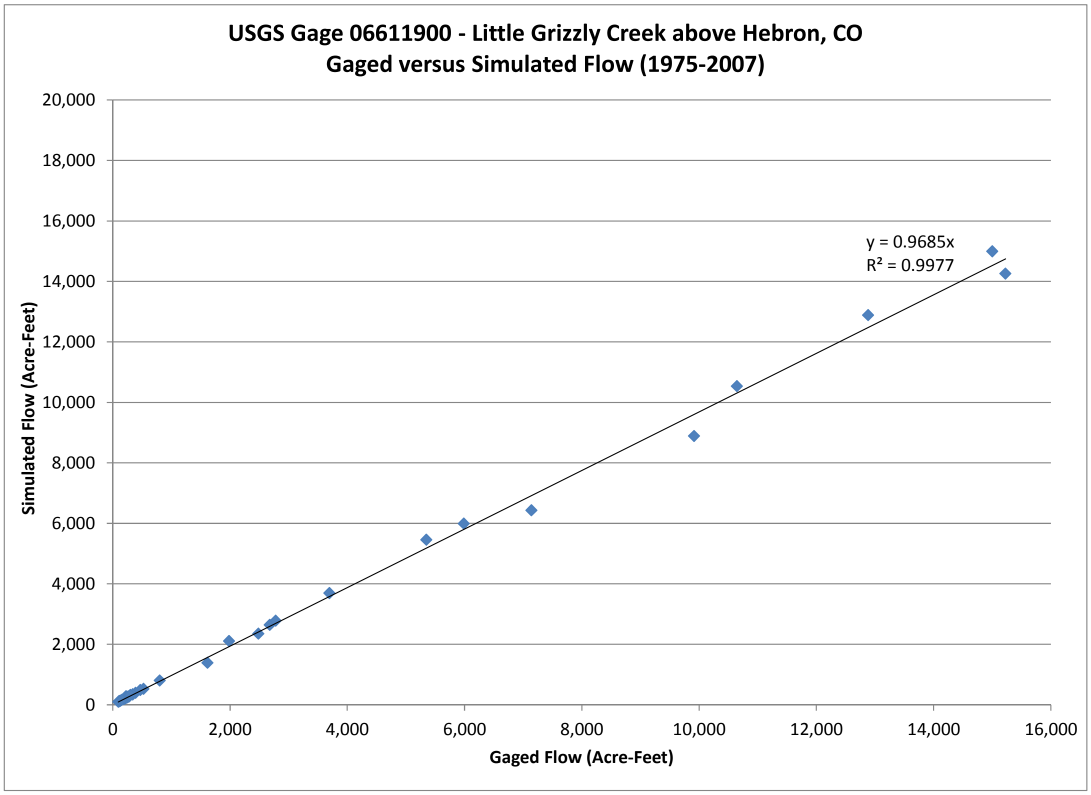
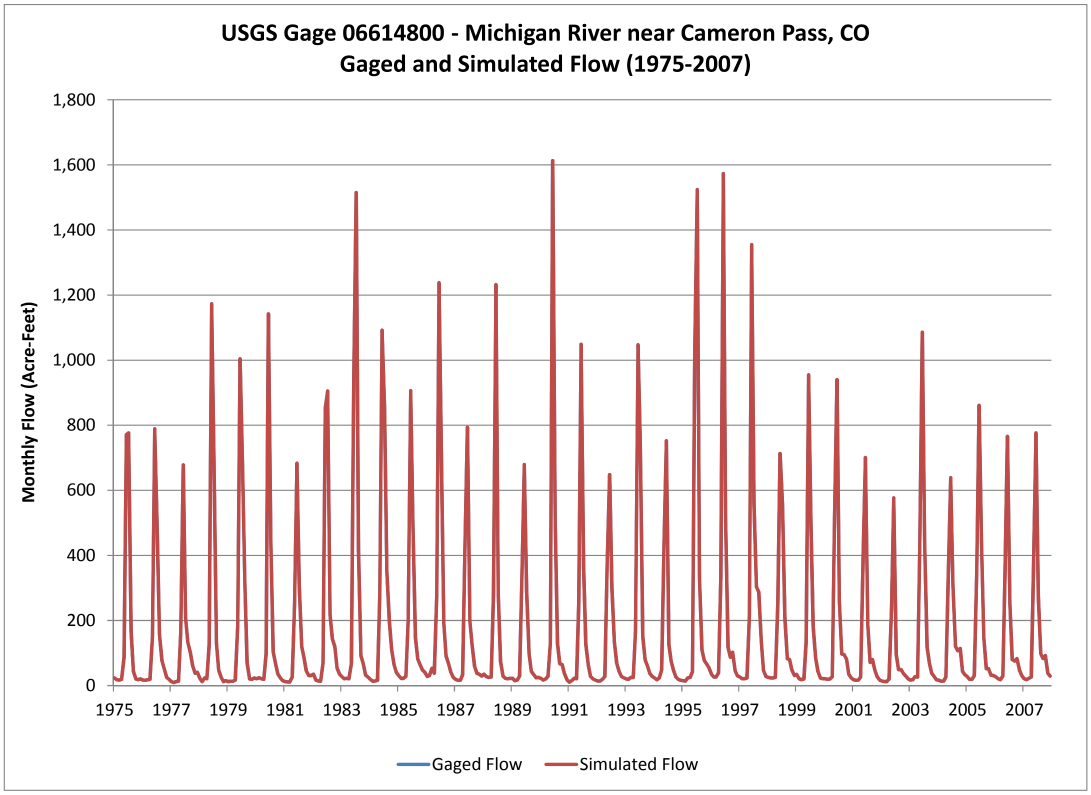


Figure 7.4 Streamflow Calibration – Little Grizzly Creek above Hebron, CO



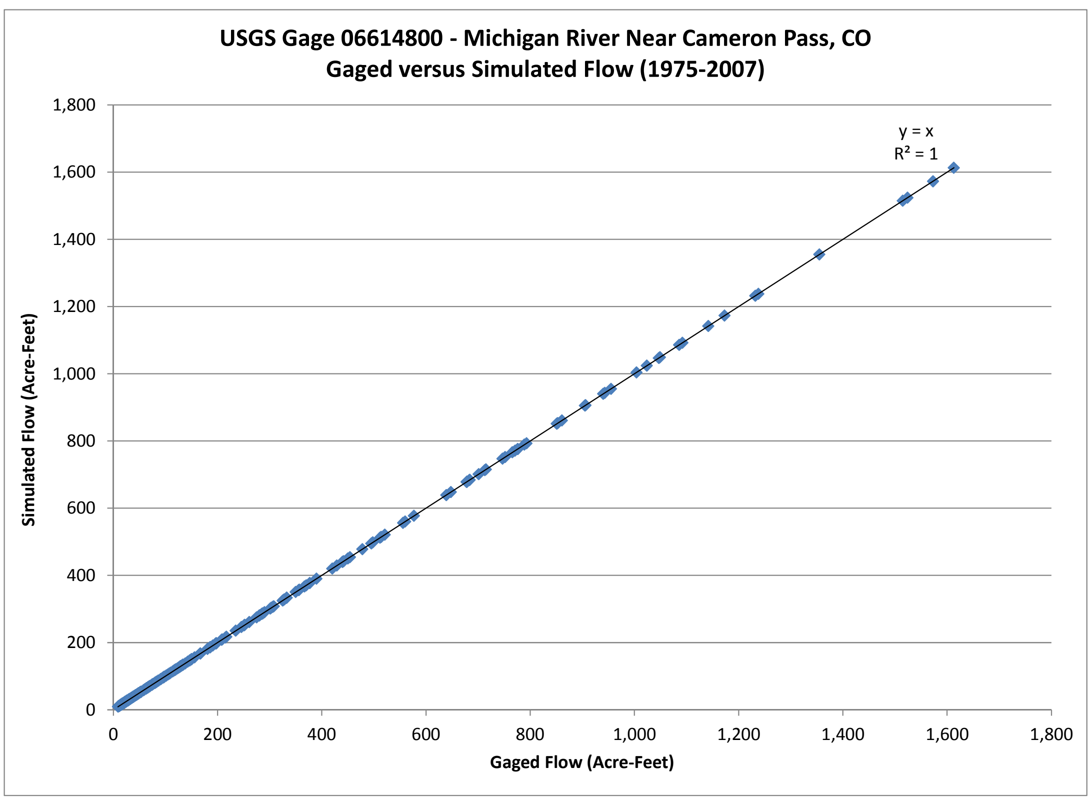
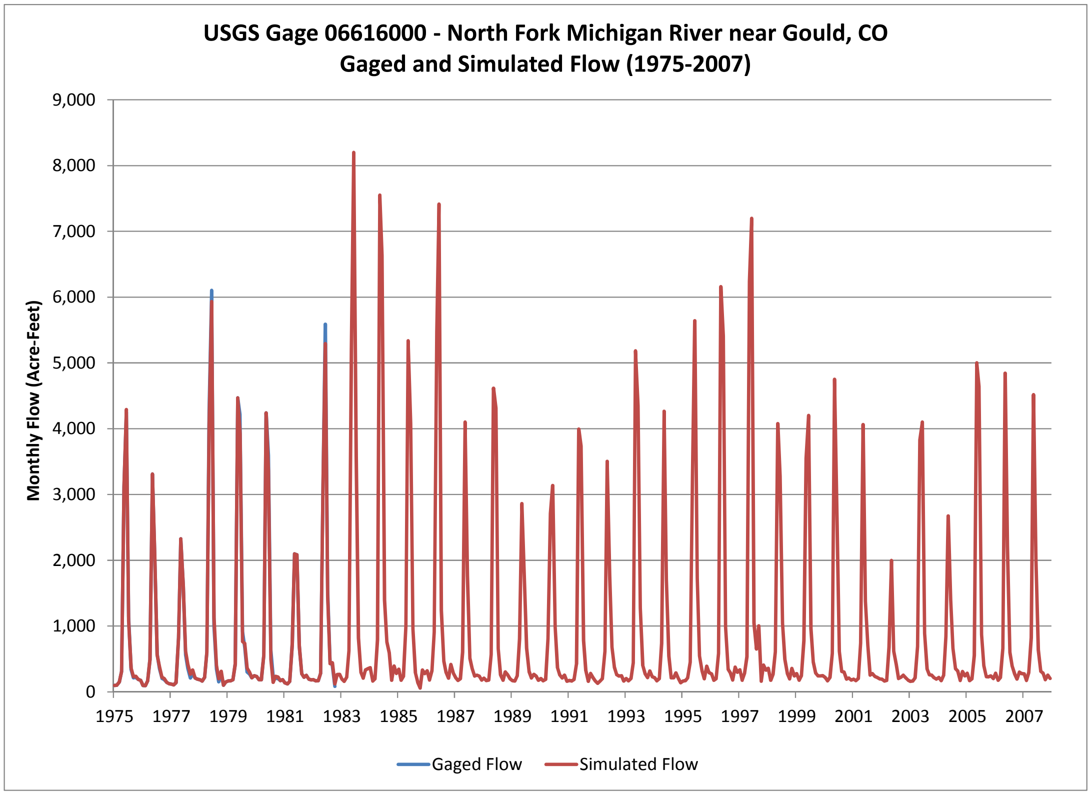


Figure 7.5 Streamflow Calibration – Michigan River near Cameron Pass, CO



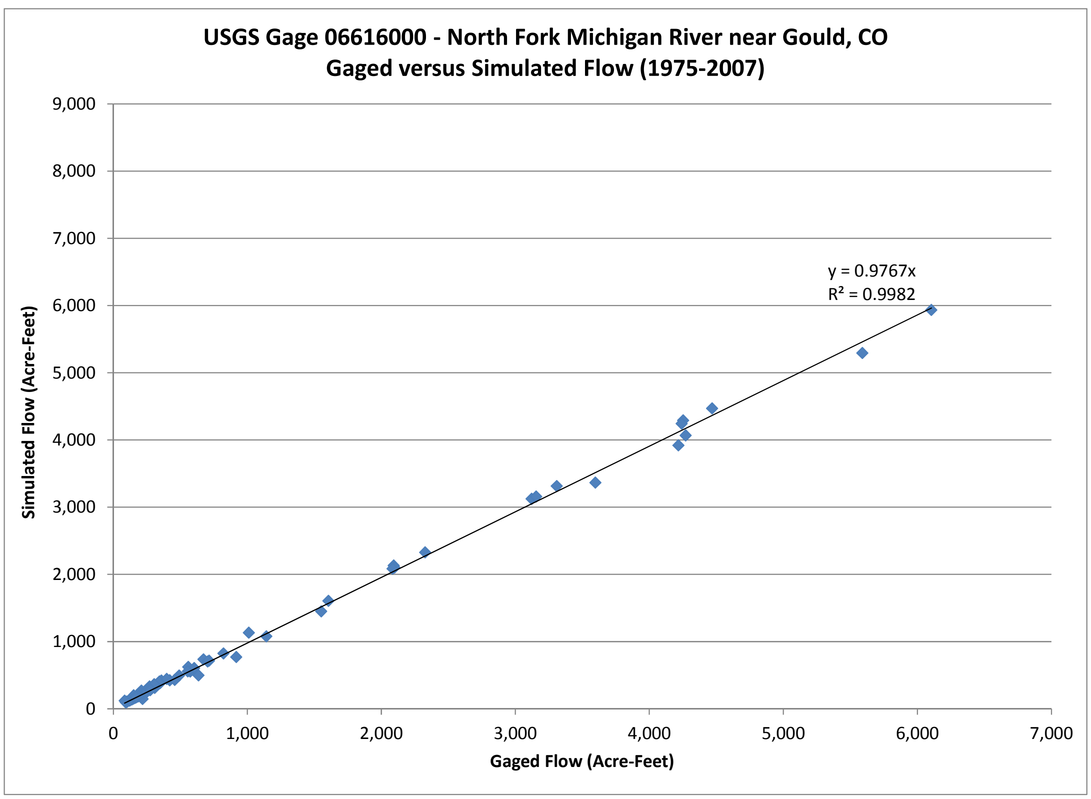
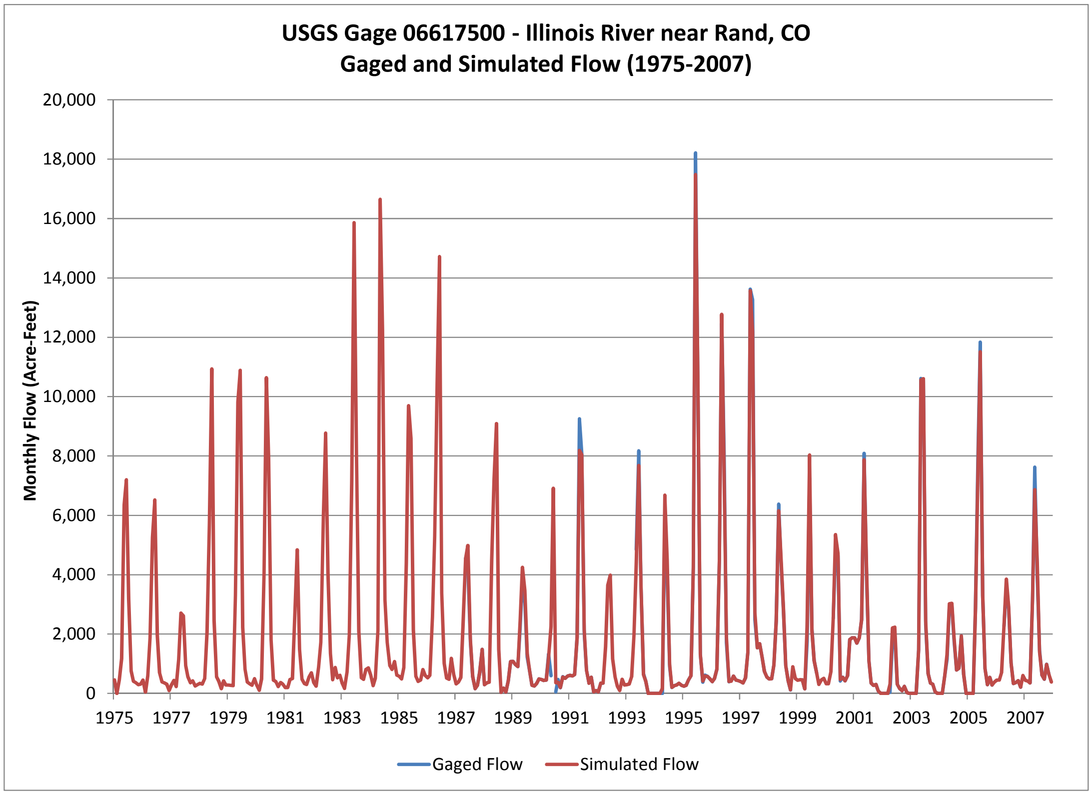


Figure 7.6 Streamflow Calibration – North Fork Michigan River near Gould, CO



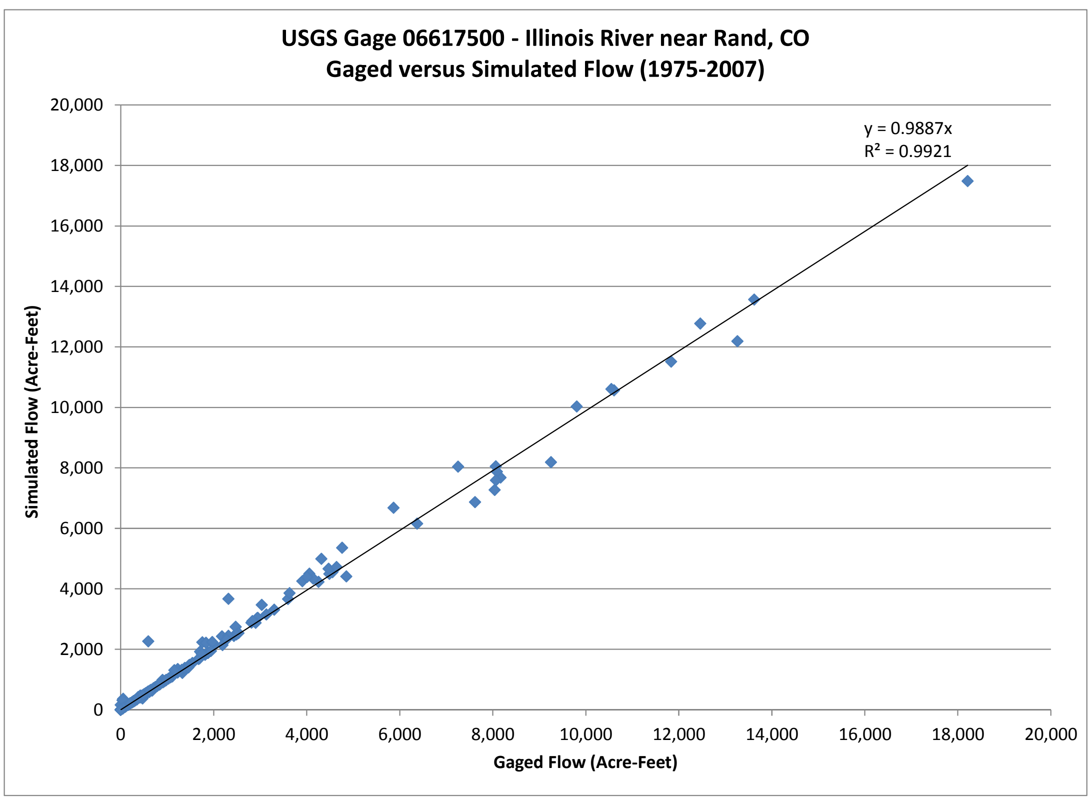
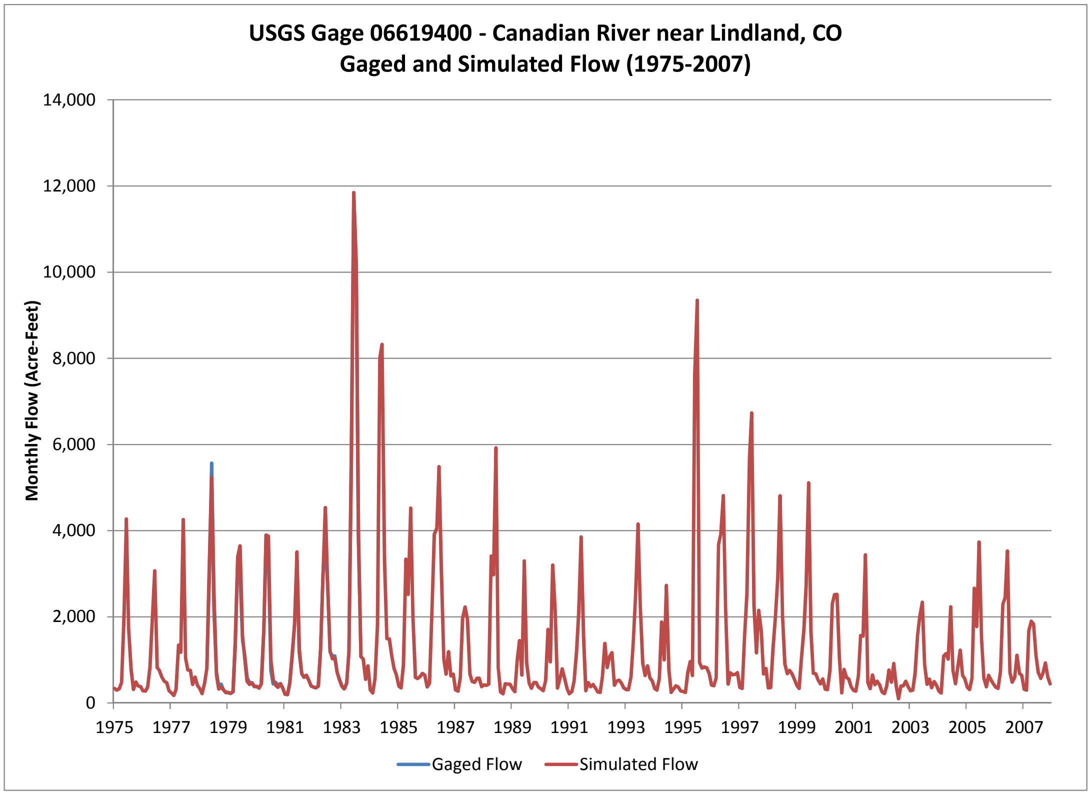


Figure 7.7 Streamflow Calibration – Illinois River near Rand, CO



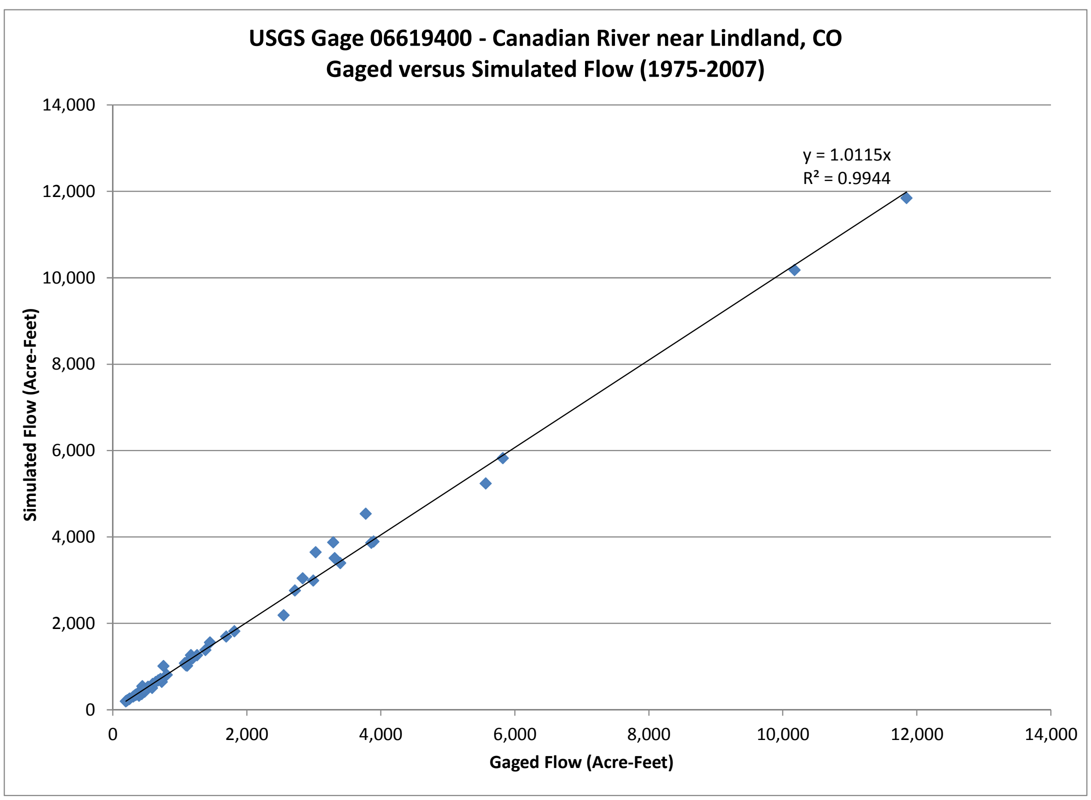
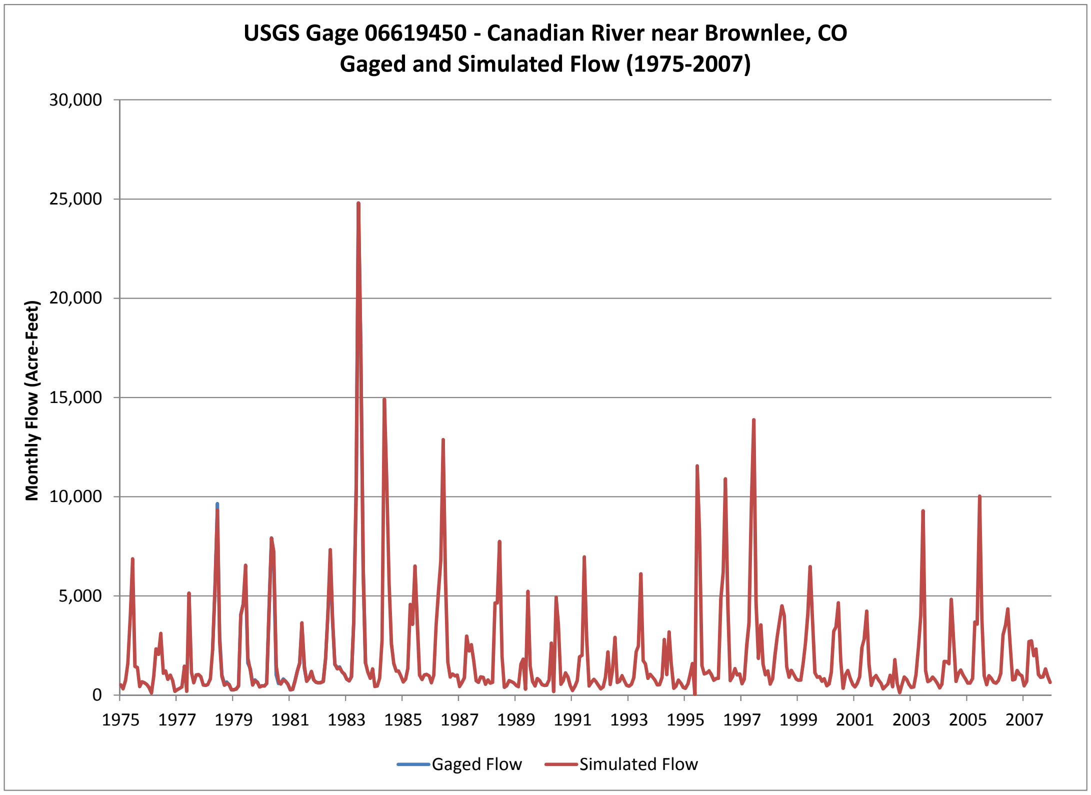


Figure 7.8 Streamflow Calibration – Canadian River near Lindland, CO



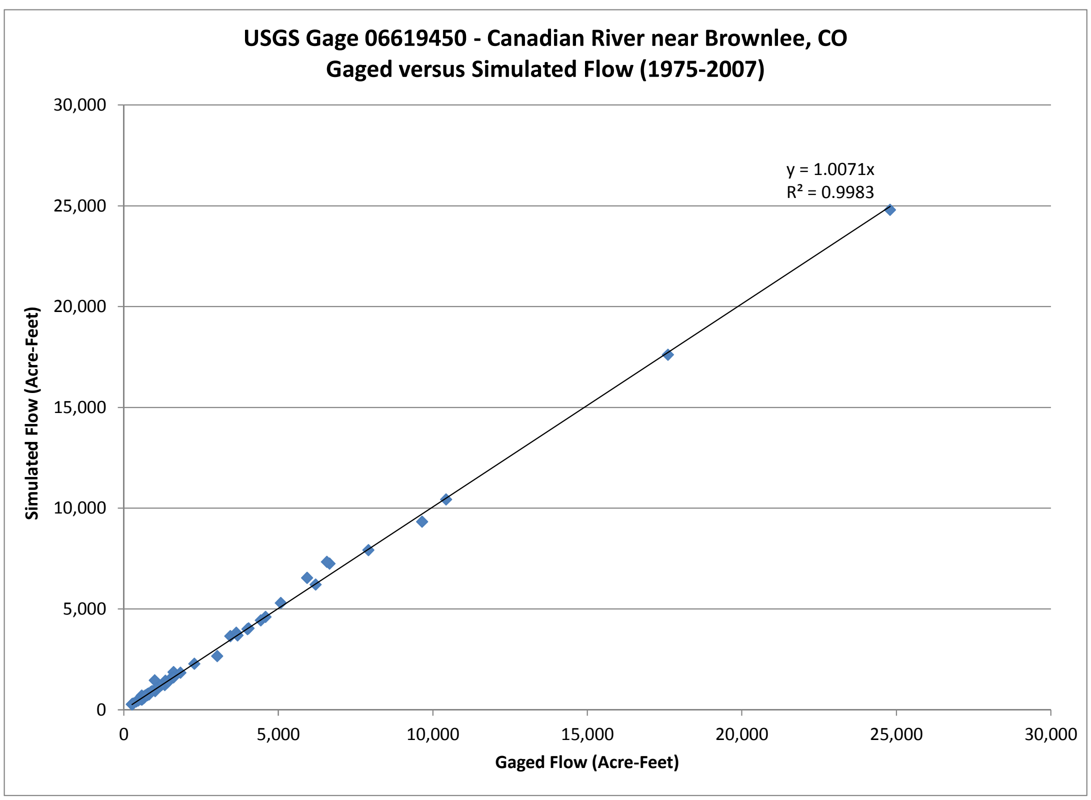
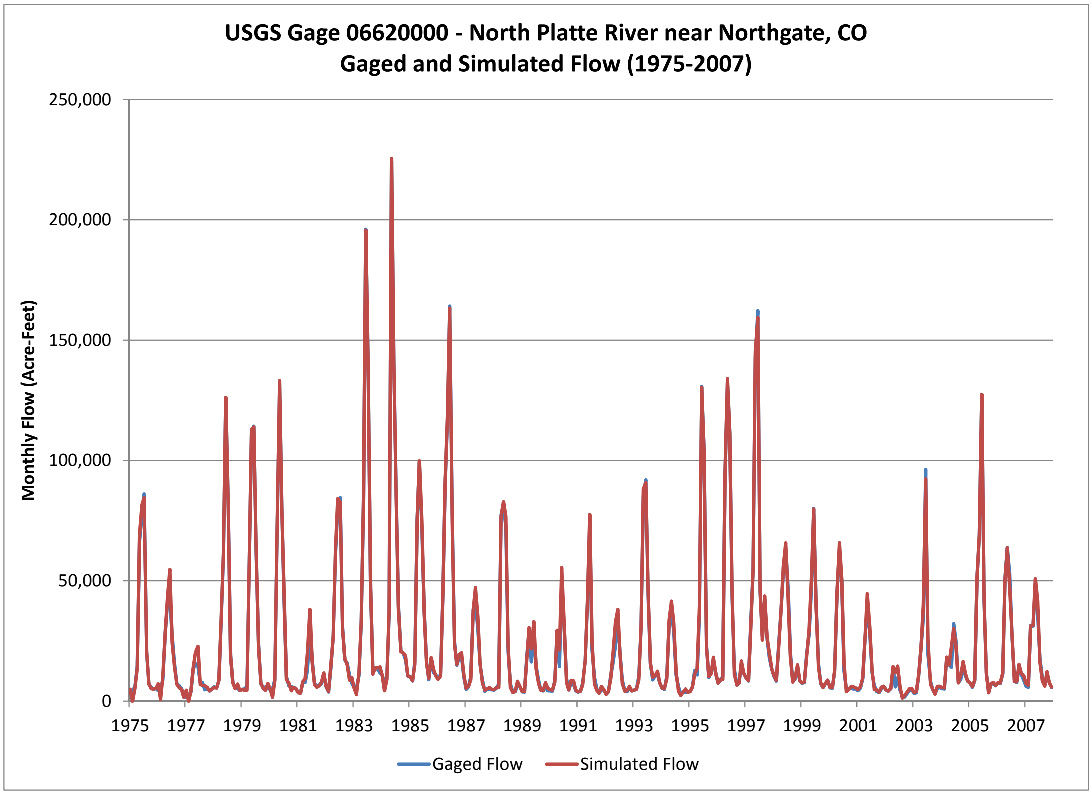


Figure 7.9 Streamflow Calibration – Canadian River near Brownlee, CO



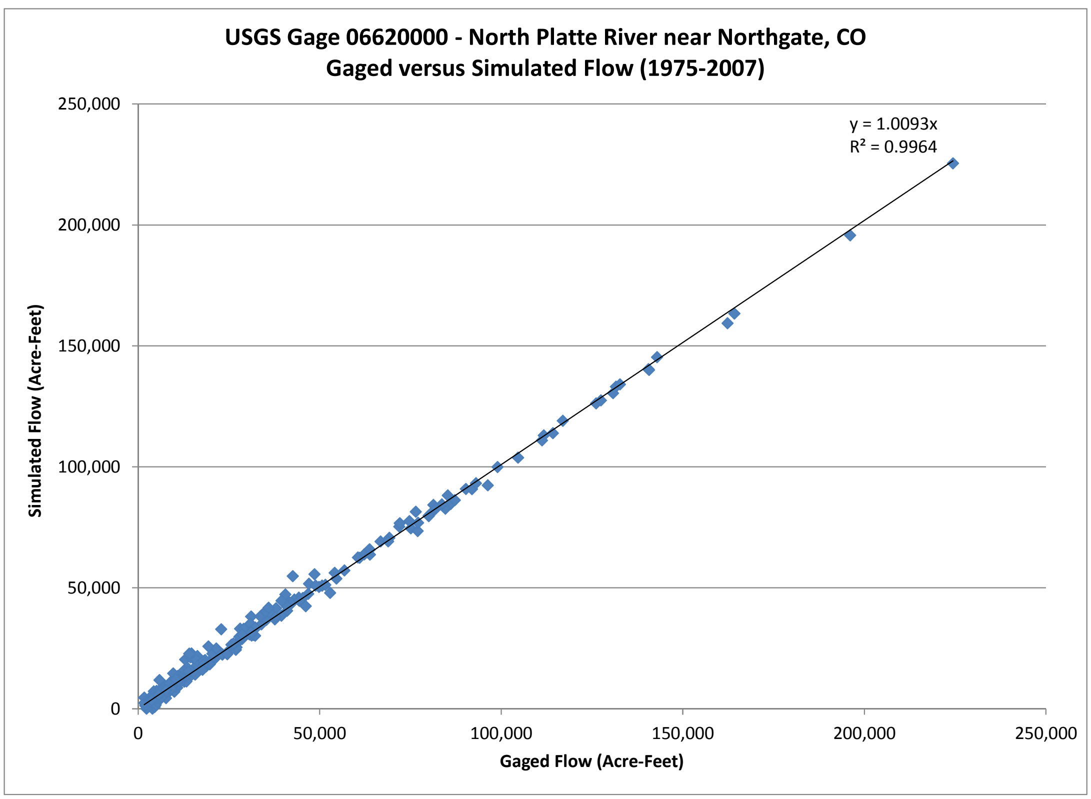


Figure 7.10 Streamflow Calibration – North Platte River near Northgate, CO

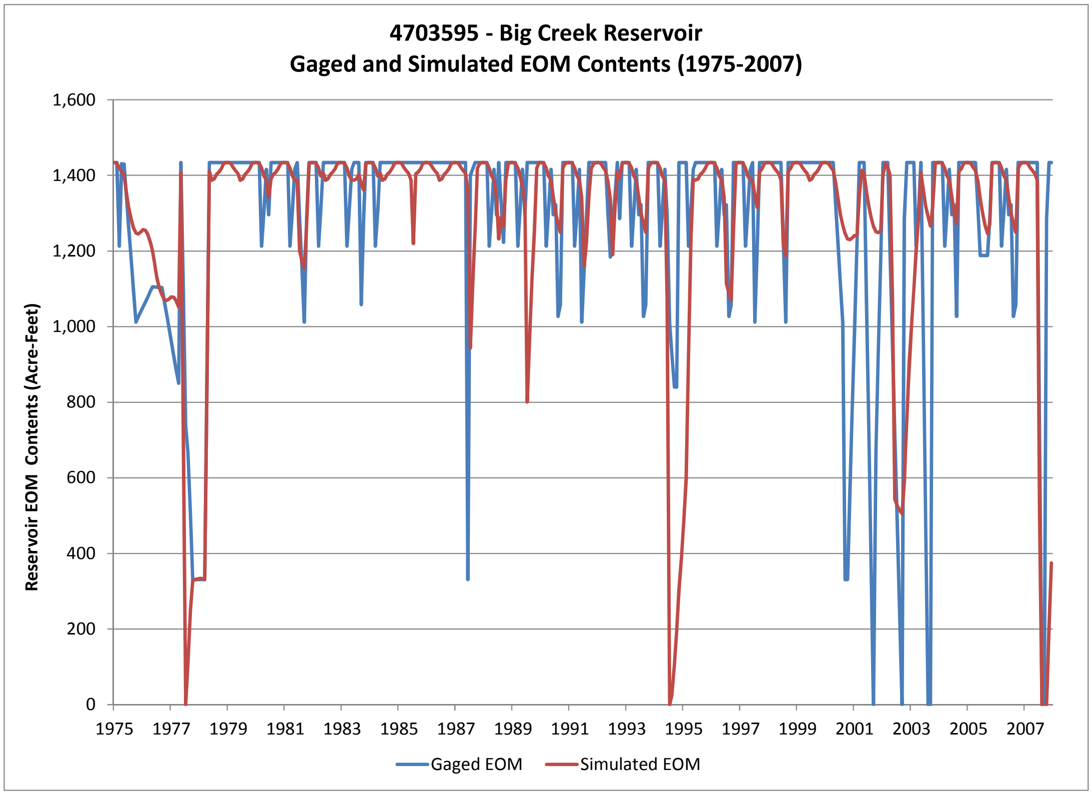


Figure 7.11 Reservoir Calibration – Big Creek Reservoir

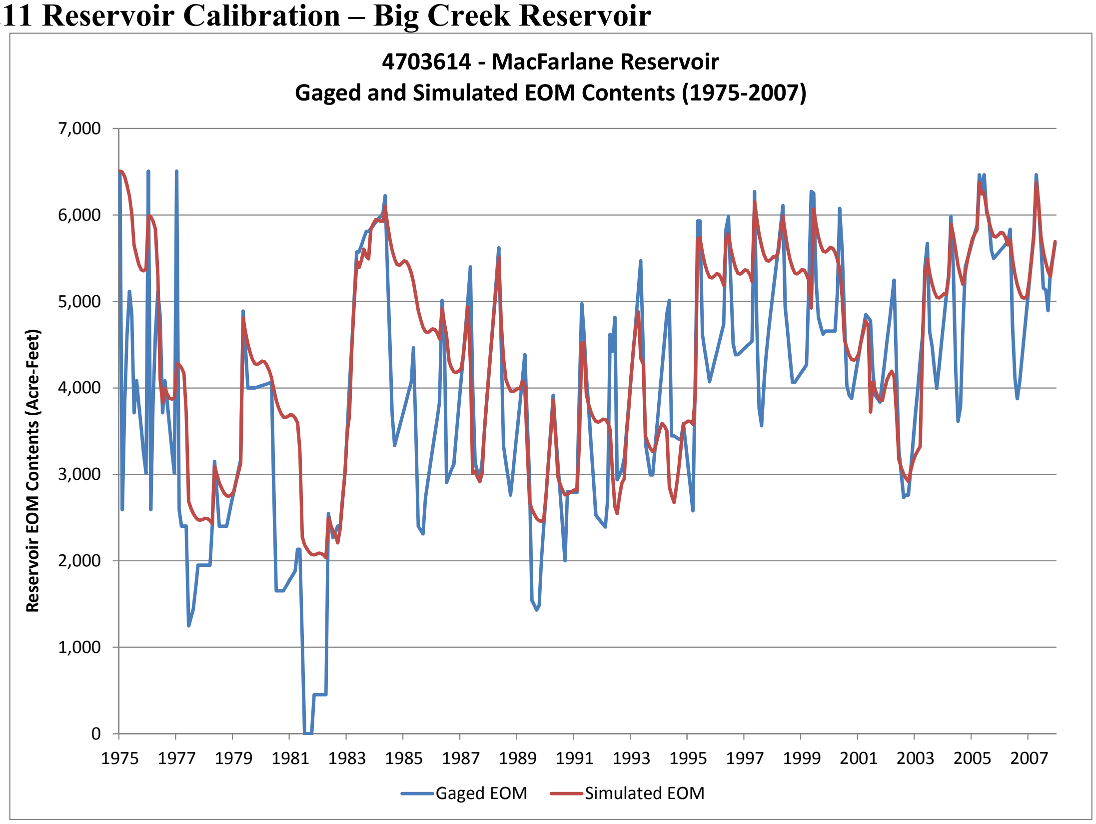


Figure 7.12 Reservoir Calibration – MacFarlane Reservoir

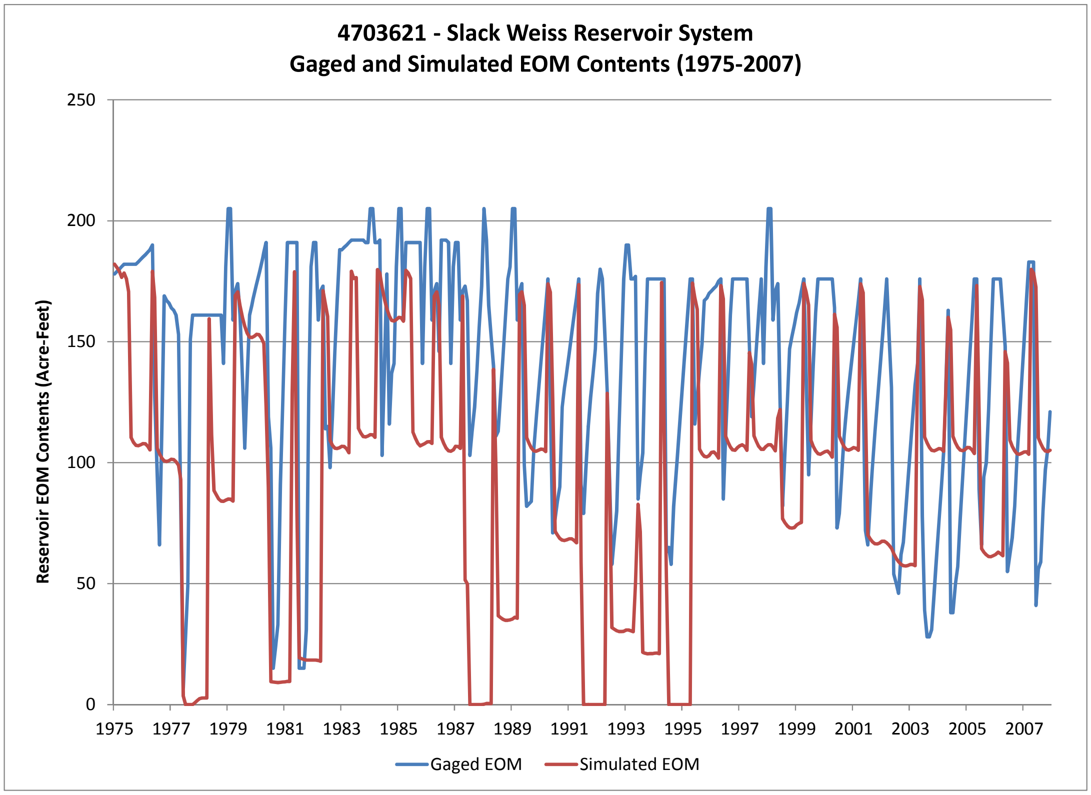


Figure 7.13 Reservoir Calibration – Slack Weiss Reservoir System

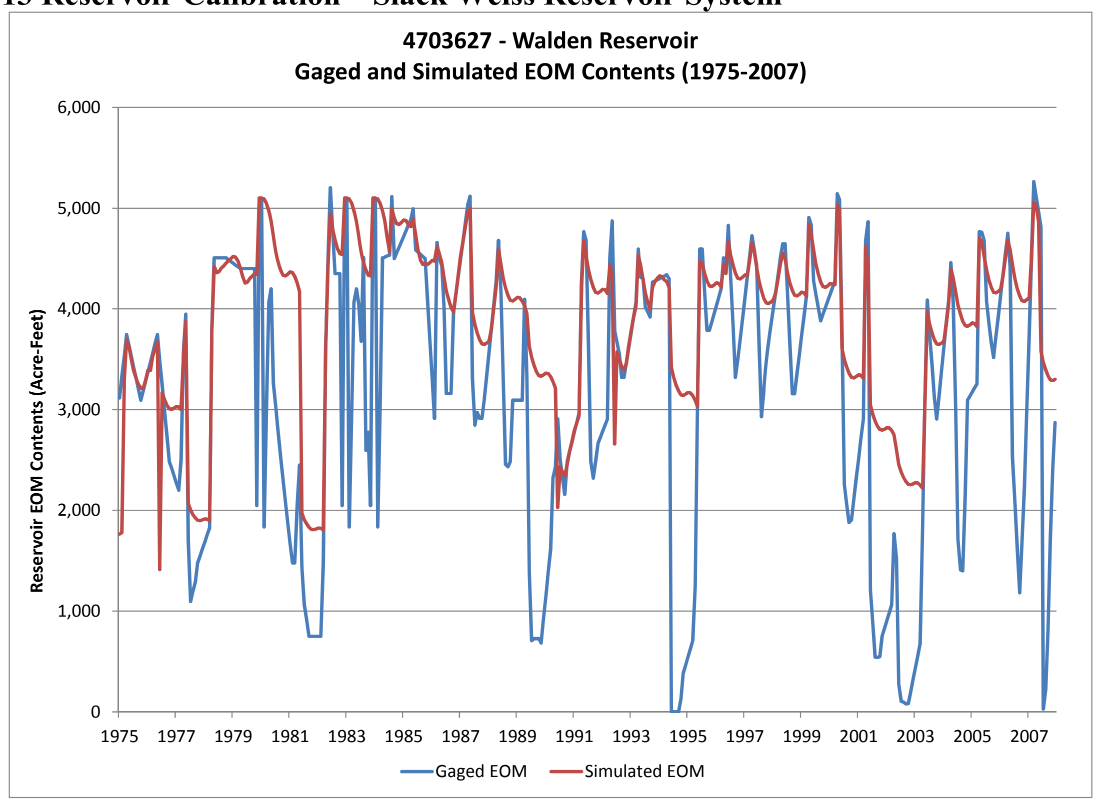


Figure 7.14 Reservoir Calibration – Walden Reservoir

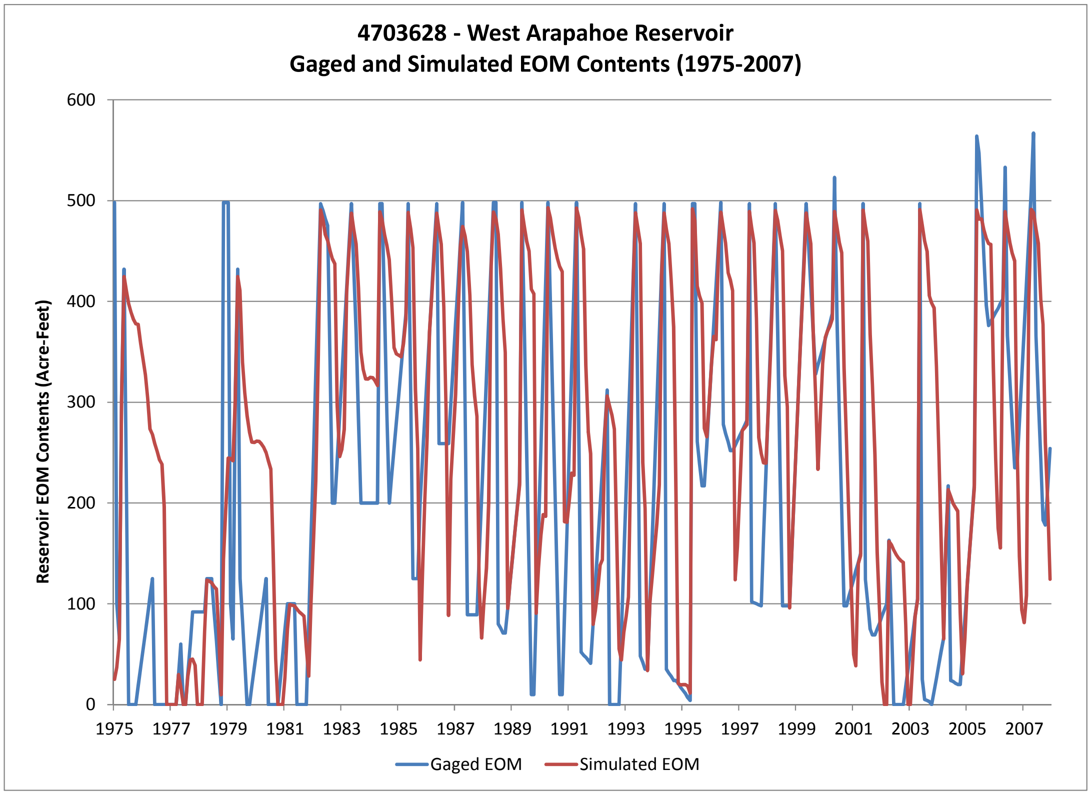


Figure 7.15 Reservoir Calibration – West Arapahoe Reservoir

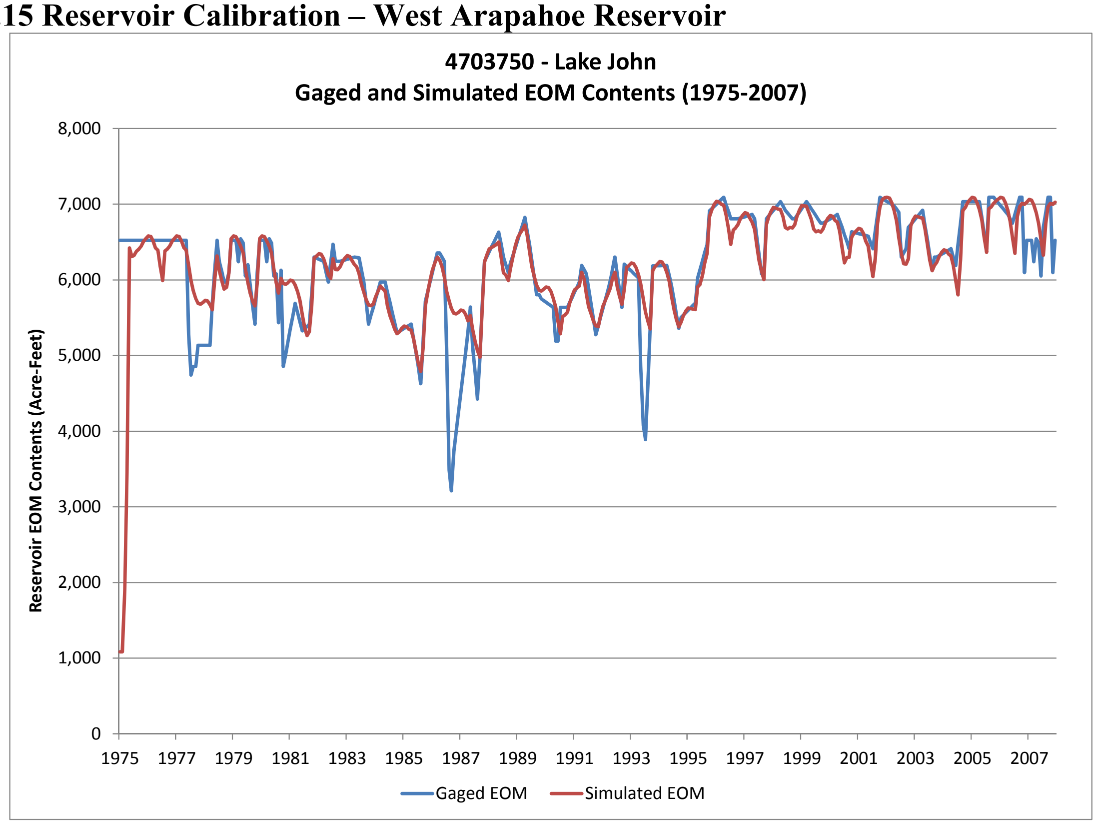


Figure 7.16 Reservoir Calibration – Lake John

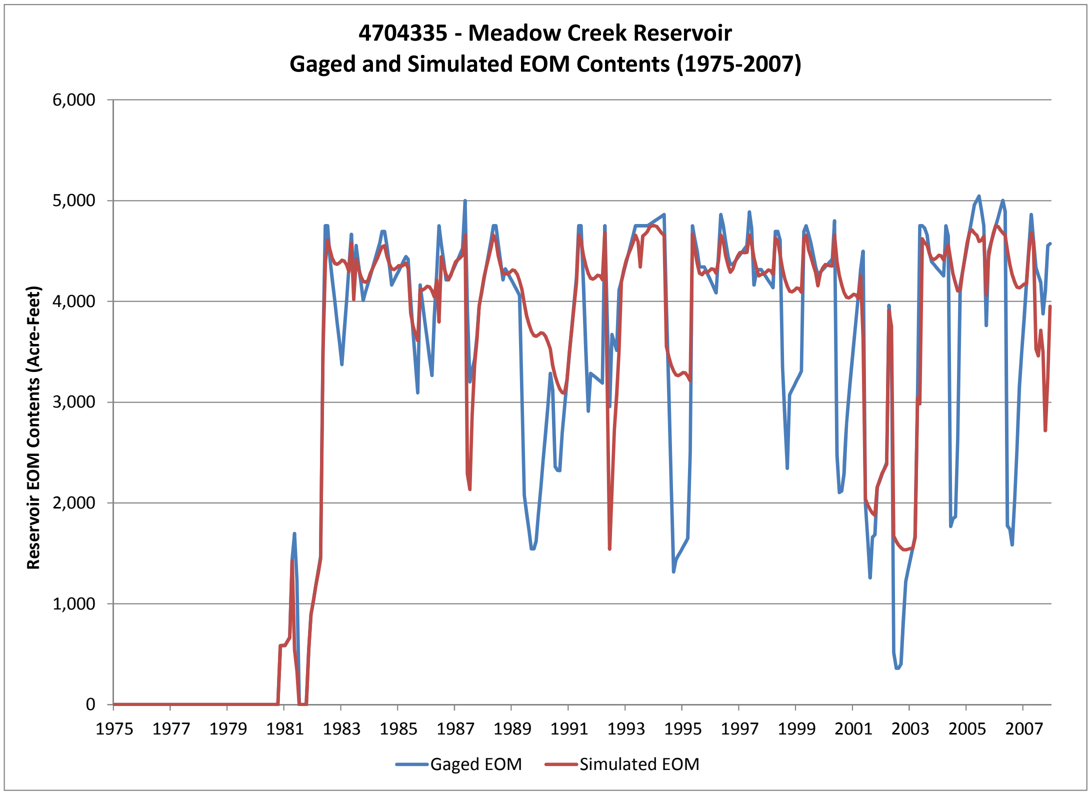


Figure 7.17 Reservoir Calibration – Meadow Creek Reservoir