CRWAS Phase I
Yampa River – StateMod Model Brief

1. Introduction

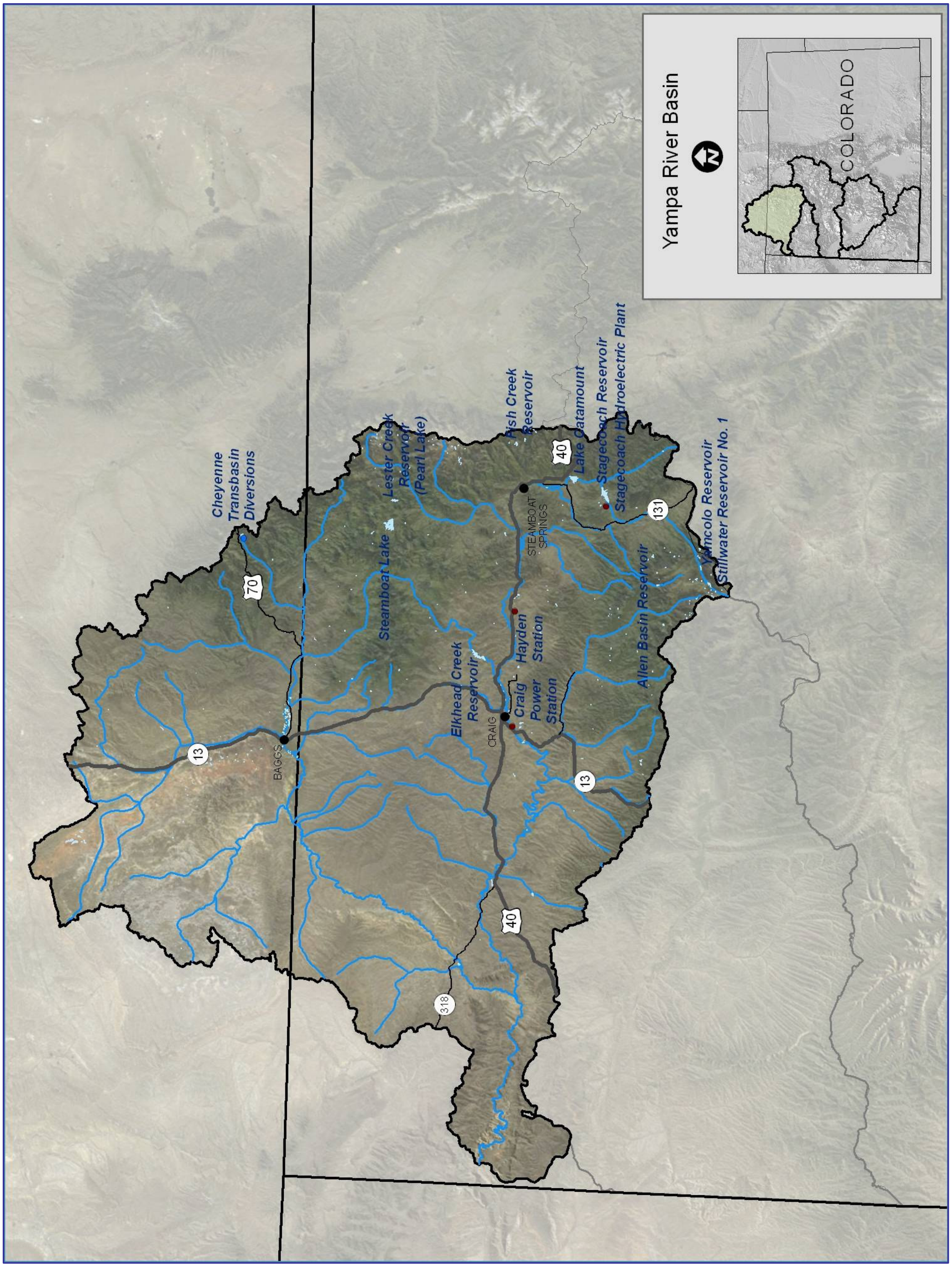
This document provides general descriptions of Yampa River Basin model development and calibration. It is a companion document to ***"Overview of the Colorado Decision Support System"***, which summarizes the integrated Colorado Decision Support System (CDSS) and its primary components (including StateMod, StateCU and HydroBase). The following sections describe:

- the four primary aspects of the Yampa River Basin StateMod model: 1) inflow hydrology; 2) physical infrastructure; 3) water demands; and 4) legal and administrative conditions (Section 2) and
- the process used for model calibration (Section 3).

Each section concludes with cross-references (denoted in gray boxes entitled "Where to find more detailed information:") that guide the reader to specific sections of existing CDSS documentation for further reading (e.g., Model User's Manual, Information Reports, and other CDSS documents). An Appendix describes primary water supply project operations.

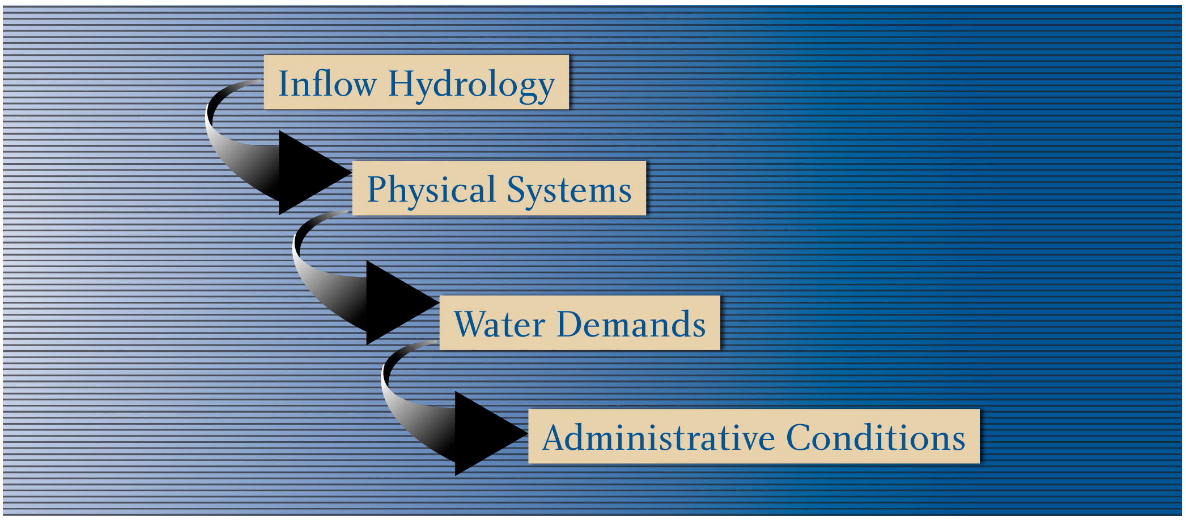
Figure 1 highlights the extent of the Yampa Basin Model and key rivers, streams, towns and water storage facilities. A significant portion of the basin's drainage area is in Wyoming, in the Little Snake River sub-basin, the most downstream major tributary to the Yampa River. The Wyoming portion is included in the Yampa River Basin model, although features, use, and hydrology in Wyoming are represented in much less detail than for the Colorado portion of the model.

Figure 1: Yampa River Basin Key Hydrography and Facilities



2. Model Components

The major components of the Yampa Model are input files representing the basin's unique hydrology, diversions, water demands, and legal and administrative conditions affecting project operations. The model consists of the following four major components:

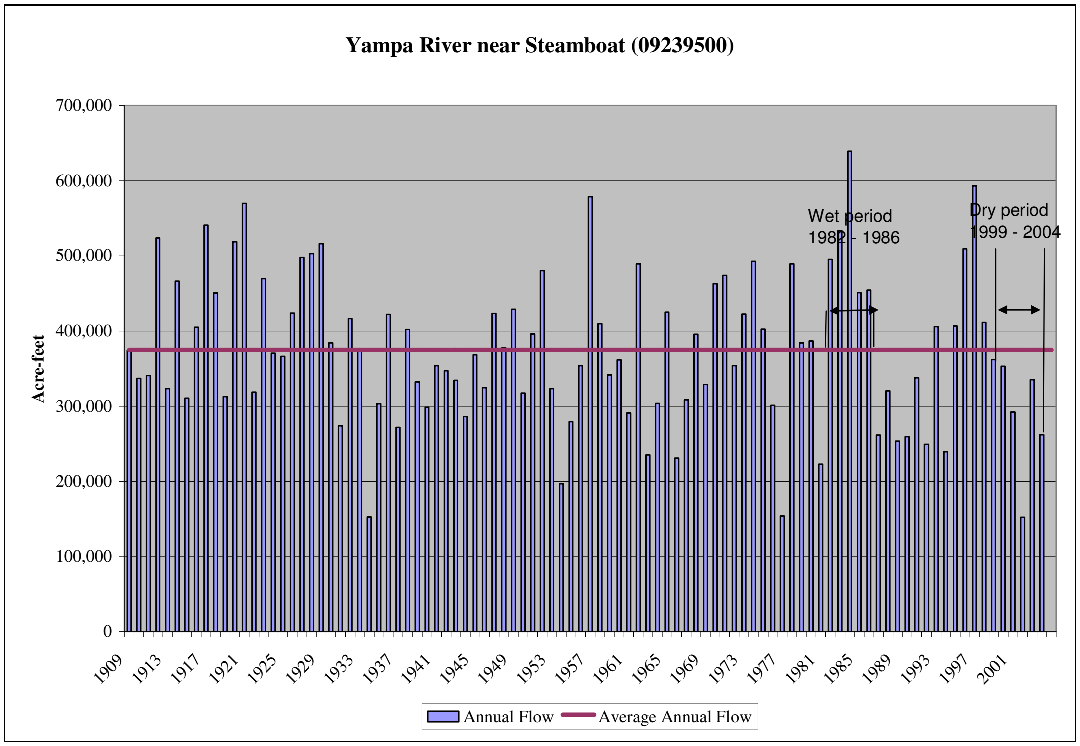


2.1 Inflow Hydrology

In order to simulate river basin operations, the model starts with the amount of water that would have been in the stream if none of the operations being modeled had taken place. These undepleted flows are called natural flows. Note that "natural flow" is synonymous with "baseflow", the term used in the Yampa River Basin Water Resources Planning Model User's Manual. Natural flows represent the conditions upon which simulated diversion, reservoir, and minimum streamflow demands were 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.

Given data on historical diversions, estimated timing and location of return flows, and reservoir operations, StateMod can estimate natural flow time series at specified discrete inflow nodes. Yampa River basin natural flows were estimated in three steps: 1) remove effects of human activity at USGS stream gage flows using historical records of operations to get natural flow time series for the gage period of record; 2) fill the gage location 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.

Monthly natural flows for the USGS water year period 1909 through 2005 were developed to allow a long hydrologic period to "drive" the model. Because measured data was limited in the early period, and the development of natural flows required significant data-filling, the period 1950 through 2005 was chosen as the model period for the purposes of the Colorado River Water Availability Study (CRWAS). Additional discussion on this chosen model period is provided in this Model Brief's companion document entitled "Overview of the Colorado Decision Support System". This period includes extended wet, dry, and average periods plus both extreme drought and high runoff years. The wide variation in hydrology provides the ability to check that the model adequately represents historical river administration and operations under differing flow regimes. The following natural flow graph, representing the Yampa River near Steamboat Springs gage, illustrates that wet, dry, and average years are all represented in the modeling period. Successive years with annual flows below the average (e.g.,1999-2004) constitute extended dry periods; conversely, successive years with flows above the average (e.g., 1982-1986) constitute extended wet periods.



Natural flows are introduced to the Yampa Model at 86 sites, including all modeled USGS gages, all tributary headwater locations, and selected intervening points. Extended hydrology based on tree-ring data and alternate hydrology based on climate change and forest modification scenarios will replace the natural flows at the 22 USGS stream gage locations, and the automated process developed as part of CDSS will allow the distribution of these new natural flows to the remaining ungaged inflow nodes. In addition to the main stem Yampa River, main tributaries represented include:

- Bear River
- Oak Creek
- Elk River
- Fortification Creek
- Little Snake River
- Hunt Creek
- Fish Creek
- Trout Creek
- Williams Fork
- Service Creek
- Soda Creek
- Elkhead Creek
- Milk Creek

Selection of streams to include in the model was generally based on the extent of acreage irrigated served by diversions or the presence of a transbasin diversion.

2.1.1 Data Sources and Filling Techniques

Data required to generate natural flows include historical streamflow data, diversion records, reservoir storage data, irrigation water requirements, and net evaporation rates.

Historical streamflow data used to generate natural flows were recorded by the USGS and by Division of Water Resources (DWR). Historical streamflow data from both sources (USGS and DWR) are stored in HydroBase. The natural flow algorithm does not require that historical streamflow records be complete. Gaps in the data are filled only for natural flows estimated at gage locations, after the effects of human activity have been removed, using the automated USGS Mixed Station Model. The name refers to its ability to use regression correlations to fill missing natural flows for many stations, using natural flows from available stations.

Historical diversions in Colorado are recorded by water commissioners and stored in HydroBase. For most water districts in the Yampa River basin, diversion records have been digitized from field notebooks and are generally complete from 1974 on. Many of the larger structures have diversion records in HydroBase back to the early 1950s. Diversion records are filled prior to being used in the natural flow calculation using a wet/dry/average month approach using an automated algorithm available in the CDSS DMIs. Each water district is associated with a long-term gage used to statistically assign each month in the study period a wet, dry, or average hydrologic designation. If diversion records for a ditch are missing in a designated "wet" month, then the average of diversion records for available "wet" months for that ditch will be used.

Historical diversions in Wyoming were based on the State of Wyoming's Green River Basin Plan spreadsheet models (available at http://waterplan.state.wy.us/plan/green/models/models.html). Because historical diversion records were not easily available, the Green River Basin Plan models generally represented only the depletive part of each diversion, which was based on irrigated lands mapping and estimates of consumptive use. The CDSS model's historical diversions in Wyoming were estimated as historical depletions per the Green River Basin Plan, divided by average monthly efficiencies typical of Colorado's Water District 54.

Historical reservoir end-of-month contents for the larger reservoirs are generally measured by the reservoir operators. This information is then provided to the water commissioners and stored in HydroBase. These historical records are sporadic for the reservoirs in the Yampa River model; missing records are filled based on linear interpolation if a limited number of consecutive months are missing. Otherwise, data are filled using the wet/dry/average approach described above. Again, this filling procedure has been automated using the CDSS DMIs.

Irrigation water requirements in Colorado are determined, by ditch, for the period 1950 through 2005 using StateCU. The calculation methods require mean monthly temperature and total monthly precipitation. Nine climate stations are used to represent temperature and precipitation in the Yampa River basin. The climate stations selected for the analysis are maintained by the

National Oceanic and Atmospheric Administration (NOAA). NOAA provides recorded data to DWR, and it is stored in HydroBase. Most of the climate stations used in the analysis have complete data for this period, therefore only minor filling was required. Mean monthly temperature was filled based on nearby climate station's data using monthly regression and monthly precipitation was filled based on monthly averages for the measured data, automated using the CDSS DMIs. Irrigation water requirements for the study period prior to 1950 are estimated using the automated wet/dry/average approach discussed above.

For Wyoming diversions, the irrigation water requirement came from the State's Green River Basin Plan. These were based on values developed at the University of Wyoming for specific climate stations and crops. Because the Green River Basin Plan modeling period does not coincide with the CDSS modeling period, the irrigation water requirement time series were filled according to the method described above for historical diversions,

The same set of average net monthly evaporation rates is used for all the reservoirs in the Yampa River model. It is based on annual gross free water surface evaporation per the National Oceanic and Atmospheric Administration (NOAA) Technical Report NWS 33. Annual net reservoir evaporation was estimated by subtracting a weighted average effective monthly precipitation based on records for Steamboat Springs and Yampa, from the estimated gross monthly free water surface evaporation. The annual estimates of evaporation were then distributed to monthly values using factors adopted by the State Engineer's Office.

Where to find more detailed information:

- Section 4.7 of the Yampa River Basin Water Resources Planning Model User's Manual, available on the CDSS website, provides details of the Baseflow (Natural Flow) Estimation process.
- Table 5.2 of the Yampa River Basin Water Resources Planning Model User's Manual lists the gaged locations where natural flows are introduced to the model.
- Section 4.4.1 of the Yampa River Basin Water Resources Planning Model User's Manual describes the automated time series filling algorithms.
- Section 4.4.2 of the Yampa River Basin Water Resources Planning Model User's Manual describes the natural flow filling using the Mixed Station Model.
- Section 5.6.2 of the Yampa River Basin Water Resources Planning Model User's Manual describes the evaporation rates and source used for each reservoir.
- Appendix C of the Yampa River Basin Water Resources Planning Model User's Manual is a technical memorandum detailing assumptions for modeling Wyoming reservoirs and stockponds.

2.2 Physical Systems

The Yampa Model includes active diversion structures, reservoirs, carrier systems, and instream flow reaches. Although every active diversion structure or reservoir is not explicitly included in the Yampa Model, 100 percent of the estimated irrigated acreage and storage in the basin is represented. Early in the CDSS process it was decided that, while all consumptive use should be represented in the models, it was not practical to model each and every water right or diversion structure individually. Explicit structures were selected based on a variety of criteria including amount and seniority of water rights, quantity of historical diversions, importance in administration, and participation in reservoir projects.

Seventy-five percent of Colorado's use in the basin is explicitly represented at correct river locations relative to other users, with correct priorities relative to other users. The remaining structures, and all but two of the Wyoming structures, are grouped into "aggregates" based generally on tributary boundaries, gage locations, critical administrative reaches, and instream flow reaches. The model includes approximately 240 explicit structures and 30 aggregates.

Similarly, not every reservoir and stock pond is explicitly included in the Yampa Model. Reservoirs with minimum decreed capacities of 4,000 acre-feet are considered key reservoirs, and are explicitly modeled. There are ten key reservoirs and ten aggregate reservoirs and stock ponds in the model. High Savery Reservoir (in Wyoming) is one of the key reservoirs, but there are no rights or rules in the current model to cause releases. The reservoir was completed in 2003, just before the Yampa River model was updated to incorporate the Wyoming sub-basin. The model reflects the evaporative losses from a full High Savery Reservoir. Aggregate reservoirs and stockponds allow accounting for evaporation consumptive use in the basin.

There are 17 CWCB instream flow segments modeled, accounting for instream flow segments decreed prior to 2005 that may affect basin operations. Headwater instream flow segments above the most upstream modeled diversions have, in some cases, been excluded. Instream flow segments on tributaries not specifically represented in the model are also not included.

The location of each structure or instream flow segment, in relationship to tributaries and other structures (upstream or downstream), is defined based on CDSS GIS coverages, available straight-line diagrams, discussions with water commissioners, and for Wyoming, the Green River Basin Plan. Physical information about diversion structures and reservoir capacities is required to constrain modeled water use – diversion structures are not allowed to divert more than canal capacity and reservoirs are not allowed to store more than reservoir storage capacity. In addition, the model will constrain controlled releases from reservoirs to downstream river channel capacity.

Physical information that represents the location of irrigated land, in terms of timing and location of return flows, is also incorporated into the model input files. Information required for reservoirs includes area/capacity curves, minimum reservoir pools, and user accounts within a reservoir.

2.2.1 Data Sources and Filling Techniques

Physical information regarding capacities (ditches and reservoirs) of Colorado structures is stored in HydroBase. Little information was available from original permits and decrees, therefore ditch capacities were often set in HydroBase as the sum of direct water rights under the ditch and reservoir capacity was often set as the sum of storage rights. As information continues to be gathered during the CDSS efforts, capacity information in HydroBase is updated to reflect user-provided information. Therefore, for the larger ditches that warranted user interviews, ditch capacities are set based on user-supplied information. For the remaining ditches, the data centered DMI approach allows ditch capacity to be set based on the maximum daily diversion recorded. Ditch capacities for Wyoming structures were set to large, non-limiting values, because capacities were not readily available. Generally, demand for water limits diversions by the Wyoming structures.

Reservoir capacity, area-capacity curves, dead pool and user-account information was collected based on interviews with the reservoir owners and operators. As noted above, much of that information has now been incorporated into HydroBase and is extracted directly for use in the modeling effort. Information for Wyoming reservoirs was provided by the Wyoming State Engineer's Office, and is documented in Appendix C of the Yampa River Basin Water Resources Planning Model User's Manual.

Irrigation return flow locations have been estimated based on the location of irrigated land and topography, using CDSS GIS available coverages. Each irrigation structure has been assigned a generic return flow delay pattern that recognizes the proximity of the irrigated acreage to a surface stream or drainage. Glover or other lagging analyses have not been performed for each irrigation structure.

Where to find more detailed information:

- Section 4.2.2 of the Yampa River Basin Water Resources Planning Model User's Manual provides details and criteria used to select explicit versus aggregate structures. Section 4.2.3 of the Yampa River Basin Water Resources Planning Model User's Manual provides details and criteria used to select explicit versus aggregate reservoir structures.

- Table 5.4 of the Yampa River Basin Water Resources Planning Model User's Manual lists each of the key structures represented in Yampa Model.

- Appendix A and Appendix B of the Yampa River Basin Water Resources Planning Model User's Manual describes the aggregation process for irrigation and non-irrigation structures and reservoirs.

- Section 5.6.1 of the Yampa River Basin Water Resources Planning Model User's Manual provides details on physical data and account information for the reservoirs included in the model.

2.3 Water Demands

The Yampa Baseline Model demands reflect current levels of irrigation, population, and reservoir capacity superimposed over historical natural flow hydrology from 1909 through 2005. Irrigation headgate demands are set to the irrigation water requirement for the specific time step and structure, divided by the historical efficiency for that month of the year. Irrigation water requirements allow demands to reflect full supply, and not be limited by water rights and administration. Historical system efficiencies reflect irrigation practices associated with application methods, conveyance losses, and other user choices such as early and late season diversions to fill the soil reservoir.

Municipal and industrial demands in the baseline data set are generally based on average monthly diversions over the recent period 1999 through 2004, for the entire model period of 1909 through 2005.

In general, transbasin diversion demands were set to average monthly diversions over the period 1999 through 2004 for the entire model period of 1909 through 2005.

Instream flow demands are set to the decreed monthly rates for the entire period of 1909 through 2005.

Minimum and maximum reservoir target storage limits are set as reservoir “demands”. Reservoirs may not store more than the maximum target, or release to the extent that storage falls below the minimum target. This feature is not used in the Yampa River model, except for Lake Catamount as described in the Appendix. All other reservoirs, which operate to supplement agricultural and municipal diversions, store when in priority to the limit of physical or decree capacity, and release to satisfy demands in accordance with operational rights, without target constraints.

2.3.1 Data Sources and Filling Techniques

Irrigation water requirements and average historical monthly efficiencies used to estimate irrigation demands for Colorado’s diversions are calculated by StateCU. Data sources and filling techniques used to determine Baseline irrigation water requirements are described in Section 4.9.1 of the Yampa River Basin Water Resources Planning Model User’s Manual. Average historical monthly efficiency is the average system efficiency (combined conveyance and application efficiency) over the period 1975 through 2004, capped at 60 percent. These efficiencies are calculated by StateCU based on historical acreage for the period and historical diversions. Historical diversion records are extracted from HydroBase and filled if needed, as described in Section 4.4.1 of the Yampa River Basin Water Resources Planning Model User’s Manual.

The same approach to irrigation demand was taken for Wyoming structures, but the data sources were different. Irrigation water requirements were obtained from the Green River Basin Plan models. The same monthly efficiency schedule, specifically, the average of District 54 structures' monthly efficiencies, was assumed to represent all Wyoming structures, and was used to calculate irrigation demand.

Monthly decreed demands for instream flow segments are extracted from the water rights tabulation stored in HydroBase.

Where to find more detailed information:

- Section 4.9.1 and Section 5.4.4 of the Yampa River Basin Water Resources Planning Model User's Manual provides details and criteria used to estimate calculated demands for diverting structures.

2.4 Legal and Administrative Conditions

Legal and administrative conditions include water rights (direct, storage, instream flow); policies and agreements such as minimum bypass flows; and reservoir operations. The method used to impose these conditions on the demands highlights why StateMod is an appropriate tool for representing Colorado's water rights system. Each water right and operational right is assigned an administration number. For water rights, the administration number is calculated from the appropriation and adjudication dates.

For bypass requirements, the administration number reflects the agreed upon "order" that the bypass requirement must be met. For instance, the administration number assigned to reservoir releases (operational rights) for supplemental irrigation supply are just junior to the direct flow rights of the destination structure. The structure diverts whatever it can under its direct flow rights first, after which the operational right causes a release from the reservoir if the structure's demand remains unsatisfied.

Primary project operations requiring operational rights in the model include the following which are further described in the Appendix:

- Stillwater Reservoir
- Yamcolo Reservoir
- Allen Basin Reservoir
- Stagecoach Reservoir
- Lake Catamount
- Fish Creek Reservoir
- Steamboat Lake Reservoir
- Lester Creek Reservoir
- Elkhead Creek Reservoir

2.4.1 Data Sources and Filling Techniques

Direct flow water rights are assigned to each diversion structure; storage rights are assigned to each reservoir; and instream flow rights are assigned to each instream flow segment. The CDSS DMIs automate the assignment of these rights directly from the water rights tabulation in HydroBase.

Most Wyoming rights were assigned an administration number making them senior to the direct flow rights in Colorado's District 54. In other words, it was assumed that the Wyoming diverters would not be subject to calls from Colorado. Several diverters on the Little Snake mainstem below Slater Creek were assigned a more junior priority so that they would not call out Colorado diverters on Slater Creek.

Six different operating rules types are used in the Yampa Model Baseline data set. The model required a total of 57 operational rights. Typically, these are operations involving two or more structures, such as a release from a reservoir to a diversion structure, a release from one reservoir to a second reservoir, or a diversion to an off-stream reservoir. The appropriate rules to apply to each operation were generally determined based on information from reservoir operators and water administrators.

3. Model Calibration

As noted above, the Yampa River Model study period for CRWAS from 1950 through 2005 was selected to include representative hydrologic periods. A subset of the study period, 1975 through 2005 was selected for model calibration. This calibration period was selected because historical diversion data were readily available (limited data filling required) and the period includes both drought (1977, 1999-2004) and wet cycles (1982-1986).

Calibration is the process of simulating the river basin under historical conditions, and judiciously adjusting parameter values to achieve agreement between observed and simulated values of streamflow gages, reservoir levels, and diversions. The Yampa Model was calibrated in a two-step process as follows:

3.1 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, multiple-headgate collection 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., the method for distributing natural flows to ungaged locations), and locations of return flows.

3.2 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 rights and availability and reservoir releases were controlled by downstream demands. 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. The model at the conclusion of the second step is considered the calibrated model. In some cases, reservoir operations have changed during our calibration period. Because we want our model to reflect current operations, calibration may be satisfied by explaining the differences in modeled versus measured condition.

The model is calibrated on a basin-wide level, meaning that major projects, diversions, and basin operations were specifically reviewed and modified, if necessary, so they are represented appropriately. Because calibration efforts concentrated on gage and reservoir locations, ungaged tributaries were not reviewed to the level of detail as gaged areas. The purpose of the Colorado River Water Availability Study is to determine the potential basin-wide effects of climate variability, therefore the calibrated model provides an appropriate prediction tool. When using this model for future analyses involving areas of the basin without historical stream gages that rely on derived hydrology, it is recommended that further stream flow evaluations be conducted. A refined calibration will improve results of local analyses. Average annual streamflow calibration results are presented in the **Table 3.1** for gages with complete records during the calibration period.

Table 3.1
Historical and Simulated Average Annual Streamflow Volumes (1975-2005)
Calibration Run (acre-feet/year)

Gage ID	Historical	Simulated	Historical minus Simulated		Gage Name
			Volume	Percent	
9236000	29,633	29,646	-13	0	Bear River Near Toponas
9237500	59,770	60,135	-365	-1	Yampa River Below Stagecoach Reservoir
9238900	44,492	44,616	-124	0	Fish Creek At Upper Station
9239500	322,547	323,107	-561	0	Yampa River At Steamboat Springs
9241000	231,396	231,225	172	0	Elk River At Clark
9244410	834,379	834,758	-379	0	Yampa River Below Diversion near Hayden
9245000	42,324	42,324	0	0	Elkhead Creek Near Elkhead
9245500	*No gage during calibration period*				North Fork Elkhead Creek
9246920	7,957	8,022	-65	-1	Fortification Creek near Fortification
9247600	893,891	894,257	-366	0	Yampa River Below Craig
9249000	*No gage during calibration period*				East Fork Of Williams Fork
9249200	28,073	28,073	0	0	South Fork Of Williams Fork
9249750	154,433	154,861	-427	0	Williams Fork At Mouth
9251000	1,126,118	1,126,864	-747	0	Yampa River Near Maybell
9253000	168,110	168,110	0	0	Little Snake River Near Slater
9255000	60,923	61,068	-144	0	Slater Fork Near Slater
9255500	39,077	39,077	0	0	Savery Creek at Upper Station
9256000	85,981	85,982	0	0	Savery Creek near Savery

9257000	378,895	379,145	-250	0	Little Snake River Near Dixon
9258000	7,930	7,982	-51	-1	Willow Creek Near Dixon
9260000	409,932	410,551	-619	0	Little Snake River Near Lily
9260050	1,531,326	1,531,984	-658	0	Yampa River At Deerlodge Park

As shown in the Table 3.1, calibration at each stream gage is within one percent on an average annual basis.

Where to find more detailed information:

- Section 7 of the Yampa River Basin Water Resources Planning Model User's Manual provides detailed calibration results, including time-series graphs and scatter plots of streamflow and reservoir calibrations.

Appendix: Yampa River Basin Primary Project Operations

1. Stillwater Reservoir

Stillwater Reservoir No. 1 is owned by the Bear River Reservoir Company and provides supplemental irrigation water supplies to several of the major direct flow structures in the upper Bear River. Separate storage accounts for the various owners were modeled in Stillwater Reservoir. Separate operational rights are used to release supplemental water, either directly or by exchange, to each owner. The rights release from the appropriate account and at a priority that is appropriate given the specific owner ditch's portfolio of water rights.

2. Yamcolo Reservoir

Yamcolo Reservoir is owned and operated by the Upper Yampa Water Conservancy District (UYWCD), and provides supplemental irrigation water to the critically water short reaches of the upper Yampa River (Bear River). It also has a relatively small pool allocated to municipal use, which serves the aggregated municipal demand in the upper basin. Separate modeled storage accounts and operational rights allow for simulation of releases to the various owners of the reservoir. The model also simulates the exchange of capacity in Stagecoach Reservoir, owned by UYWCD irrigators, with capacity in Yamcolo Reservoir, owned by Tri-State Power, the electrical utility. This arrangement is pursuant to a 1992 agreement, and allows the power company to release through the generating plant at Stagecoach Reservoir, and keeps irrigation supply higher in the basin.

3. Allen Basin Reservoir

Allen Basin Reservoir is a small irrigation reservoir located near the headwaters of Middle Hunt Creek. Although it is smaller than the minimum reservoir capacity (4,000 acre-feet) generally used for inclusion in the Yampa model, it is modeled explicitly because it plays a significant role in the irrigation water supply in this water-limited area of the Yampa River basin. An operational right is used to fill the reservoir via a feeder canal that imports water from South Hunt Creek. Operational rights also simulate releases of supplemental supply to the ditches that own storage in Allen Basin Reservoir.

4. Stagecoach Reservoir

Stagecoach Reservoir provides supplemental municipal and industrial water supplies, as well as a significantly sized conservation pool for recreational purposes. It is modeled to make three types of releases:

- Direct releases to the Craig Power Station
- Releases that allow diversions by exchange for the Town of Steamboat Springs, at its Fish Creek intake;
- Releases for power generation at the Stagecoach hydroelectric plant.

5. Lake Catamount

Lake Catamount Reservoir was built primarily for recreation for the planned residential and ski development near the lake. To date, that use has not developed. The reservoir is normally operated to keep it full except in October when the lake level is lowered to protect against frazil ice near the inlet during winter months. The model simulates this operation by releasing to a specified maximum target.

6. Fish Creek Reservoir

Fish Creek Reservoir is owned by the city of Steamboat Springs and is used as reserve raw water storage for the city and for the Mt. Werner Water & Sanitation District. It releases water to supplement Steamboat Springs' direct flow rights at the Fish Creek Municipal intake. The Fish Creek Reservoir supply is used before the Stagecoach exchange supply is used.

7. Steamboat Lake Reservoir

Steamboat Lake is used primarily for recreational purposes, and as back-up supply for the Hayden power station. Steamboat Lake makes releases to the Hayden Station when its direct flow rights are insufficient to meet demand.

8. Lester Creek Reservoir

Lester Creek Reservoir (aka Pearl Lake) is located on Lester Creek, a tributary of the Elk River downstream of Steamboat Lake. The reservoir is owned and operated by CDOW and used exclusively for recreational and fishery purposes. It does not make releases.

9. Elkhead Creek Reservoir

Elkhead Creek Reservoir is located on Elkhead Creek, a tributary of the Yampa River, just upstream of the city of Craig. The reservoir was originally constructed by the CDOW and the Yampa Project Participants, operators of the Craig Station power plant. In the early 1990's, the City of Craig acquired the reservoir, subject to the agreement that the dead pool would remain for the benefit of CDOW. The model reflects the status of the reservoir in approximately 2004, prior to its enlargement by the Colorado River Water Conservation District. In the model, the reservoir makes two types of releases: for supplemental supply to the Craig Station, and to the City of Craig, when their direct flow rights are insufficient to satisfy demand.

Where to find more detailed information:

- Section 5.8 of the Yampa River Basin Water Resources Planning Model User's Manual provides details regarding project operations and operating rules.

- Section 2 of the Yampa River Basin Information Report, available on the CDSS website, provides historical and overview information on Yampa River Projects and Special Operations.

- Section 3 of the Yampa River Basin Information Report provides Division 5 personnel recommendations on how to model basin project operations.

- Section 4.13 of the State of Colorado's Water Resources Model (StateMod) Documentation provides available operating rules, guidelines for selecting the appropriate rules based on water source and destination, and examples of how each operating rule has been applied to represent real Colorado operations.