6. SURFACE WATER MODEL

This section describes the role, development, and calibration of the surface water operations model using the STELLA software package

6.1 Model Purpose

The purpose of the surface water model is to simulate the operations of present day surface water components within the Central Platte Valley (reservoirs, river, and canals) and calculate the water budget terms of these components of the surface water system.

Operating rules have been developed through model calibration based on historic operations for each surface water component. These rules approximate the operational/water management decisions that are made on a regular basis and significantly affect flow conditions in the Platte River; routing flows through the modeled reach, appropriately storing, diverting, or discharging flows through the surface water network. The calibration of these rules has been evaluated against known reservoir, diversion and Platte River flow data to avoid systemic errors in the simulation results.

6.2 Stella Model Description

The surface water system is represented using the modeling software STELLA Version 10.1.2 by isee systems. A core concept of the surface water model is the use of logic-based rules to simulate management decisions in routing flows through the system. Specific elements such as irrigation demands, anticipated gains, storage levels in a particular reservoir, time of year, and more are all factors in management or operational decisions in routing water through the system. For each of these decision points, a logic based rule has been developed to represent and to simulate those decisions. The development of these rules for each type of surface water element is described in further detail in Section 6.7. The calibration of the surface water model then focused on refinements to these rules to match historic observations and avoid systemic errors in simulation results.

In its final form (for the integrated modeling sequence), the surface water model is completely 'rules-driven'; that is, the only historic inputs are the daily South Platte and North Platte River inflows at the upstream end of the modeled reach. These rules were developed during calibration, using historic data for water budget terms for calibration. Once these flows have entered the model domain, their path and fate through the system is dictated solely by the operating rules. This model construction allows use of the model in forecasting system responses to future management changes, operational changes, physical changes (due to new projects) or hydrologic changes (such as increased or decreased river flows and change in natural gain/loss rates).

6.3 STELLA Model Components

Physical elements of the surface water model system represented in the STELLA model include: main stem river reaches of the South Platte, North Platte, and Platte Rivers; gaged tributaries; diversion and returns for irrigation and hydropower; and hydropower generation.

Figure 6.3-1 spatially illustrates the key Platte River gages, canal diversions and returns, and reservoirs represented in the STELLA model. STELLA nodes were included at each gage location along the North Platte, South Platte and Platte River main stems. STELLA nodes were also included in the model to represent points of surface water diversion for irrigation and hydropower canals, as well as intermediate locations along the canals and the canal return discharges to the Platte River main stem. The physical attributes of each canal are incorporated into the STELLA node descriptions. For the reservoirs, elevation-area-volume data are incorporated into the STELLA node to represent the physical attributes of the reservoir. The locations of the nodes were selected for a variety of reasons. Some nodes were selected to represent flow changes or physical changes in the system; for example at locations where water is added to or diverted from the mainstem. Some nodes were selected to represent decision points and operation points that play a role in routing the water through the system. Some nodes were selected at gage locations where water is tracked through the system.

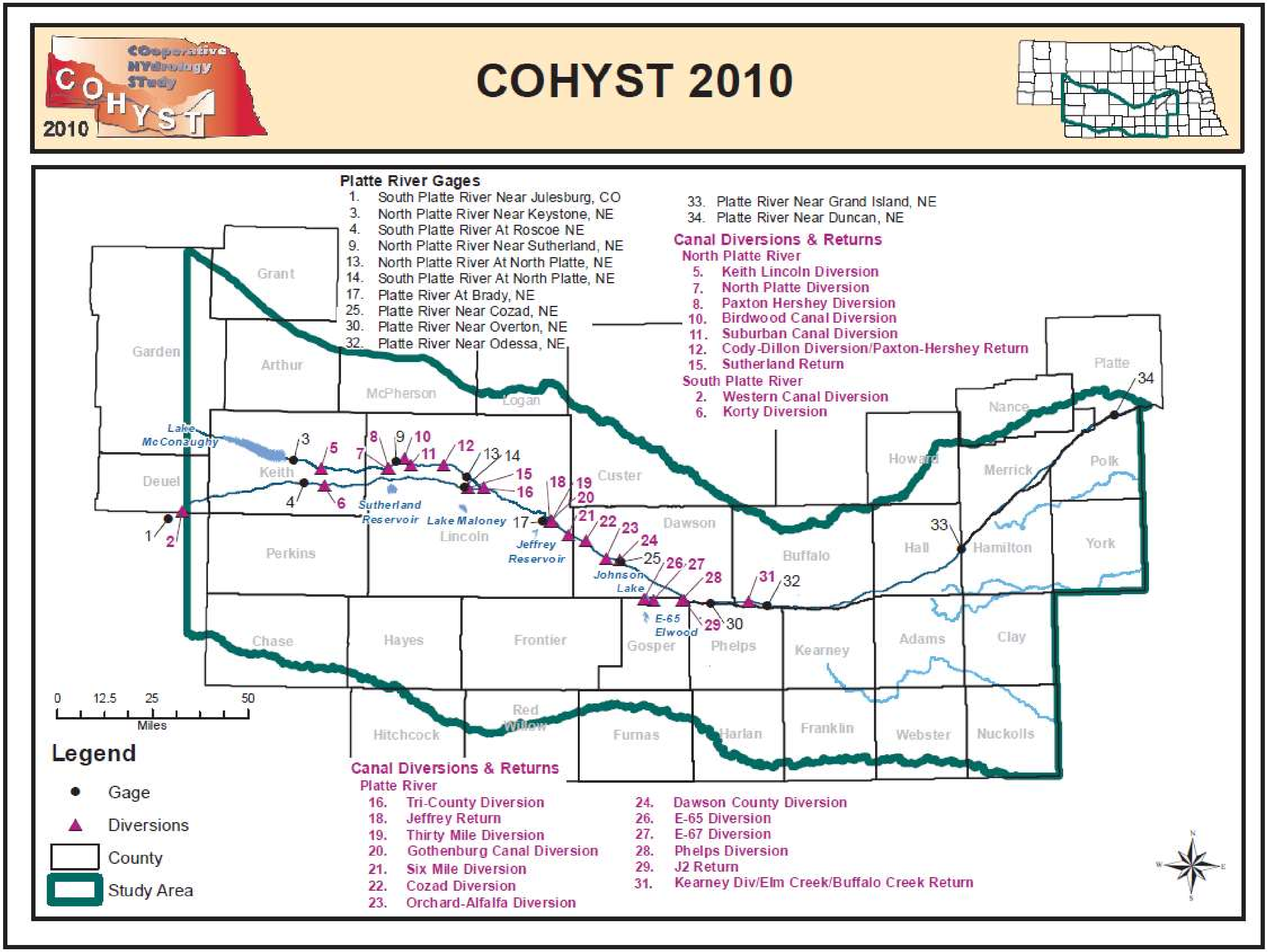


Figure 6.3-1.Platte River STELLA nodes.

Appendix 6-A contains aerial photographic mapping of the Platte River valley with STELLA node locations identified.'

6.3.1 Reservoirs

Nodes for the following reservoirs where operations can affect the system have been included in the STELLA model:

- Lake McConaughy
- Sutherland Reservoir
- Lake Maloney
- Jeffrey Reservoir
- Johnson Lake
- Elwood Reservoir

6.3.2 Stream Gages

Nodes for the following stream gages where water is tracked throughout the system have been included in the STELLA model:

- South Platte River near Julesburg, CO
- North Platte River near Keystone, NE
- North Platte River near Sutherland, NE
- North Platte River at North Platte, NE
- South Platte River at Roscoe, NE
- South Platte River at North Platte, NE
- Platte River at North Platte, NE
- Platte River at Brady, NE
- Platte River near Cozad, NE
- Platte River near Overton, NE
- Platte River near Odessa, NE
- Platte River near Grand Island, NE
- Platte River near Duncan, NE

6.3.3 Diversions and Returns

Nodes for the following diversions and returns where water is added to or diverted from the mainstem have been included in the STELLA model:

- Keystone Diversion
- North Platte Canals (Total)
- Keith Lincoln Diversion
- North Platte Diversion
- Paxton Hershey Diversion
- Suburban Diversion
- Cody Dillon Diversion
- Birdwood Diversion
- Western Diversion
- Korty Diversion
- Tri County Diversion
- Gothenburg Diversion
- Thirty Mile Diversion
- Six Mile Diversion
- Cozad Diversion
- Dawson Diversion
- Orchard Alfalfa Diversion
- Kearney Diversion
- E-65 Diversion
- E-67 Diversion
- Phelps Diversion
- Jeffrey Return
- Johnson Return
- Sutherland Return

6.3.4 Hydropower Facilities

Nodes for the following hydropower facilities have been included in the STELLA model:

- Kingsley Hydropower (North Platte River)
- North Platte Hydropower (Sutherland Canal)
- Jeffrey Hydropower (Tri-County Canal)
- J1 & J2 Hydropower (Tri-County Canal)
- Kearney Hydropower (Kearney Canal)

Currently, only the discharge capacity of these facilities has been incorporated into the model. When using the modeling tools to evaluate water management scenarios in the future, power generation curves can be incorporated into the STELLA model nodes for each of the hydropower facilities to estimate scenario impacts to power generation.

6.3.5 Water Priority System

Priority rules were created and implemented into the surface water model logic. The priority logic enables the model to “color” the water throughout the system and quantify the amount of natural flow and storage water at nodes along the river. More details and assumptions on the priority rules are located in Section 6.7.6.

6.4 STELLA Model Software

The surface water system is represented using the modeling software STELLA Version 10.1.2 by isee systems. STELLA is an object oriented, dynamic modeling software with built-in functions to facilitate mathematical, statistical, and logical operations. STELLA ‘nodes’ are used to represent key elements of the surface water system (diversions, returns, gages, reservoirs, etc.) and linked to form the model framework. Model nodes are characterized as one of three types of components within STELLA:

1. Stock – combines inflows and outflows and calculates a net outflow.
2. Flow – fills and drains accumulations.
3. Converter – holds values for constants, defines external inputs into the model, calculates algebraic relationships, and serves as the repository for graphical functions. In general, converts inputs to outputs.

In general, stocks are used to represent reservoirs; flows are used to represent streams, canals, and drains; and converters are used to represent model inputs (i.e. historical gage data, historical reservoir data) and to define logical functions.

An illustrative example of the STELLA model components is shown in **Figure 6.4-1** for the Lake McConaughy area.

Knobs, sliders and switches allow for user adjustments to model parameters either before or during simulations. Knobs, sliders and switches can be used to adjust values for constants and to override logical functions with numerical inputs (see **Figure 6.4-2**).

Model results can be displayed as graphs, tables, animations, QuickTime movies, and files within the STELLA software or exported to Microsoft Excel or CSV files. Export (and import) of data can be performed dynamically or manually. **Appendix 6-B** contains the STELLA schematic representation of the surface water elements of the Platte River valley.

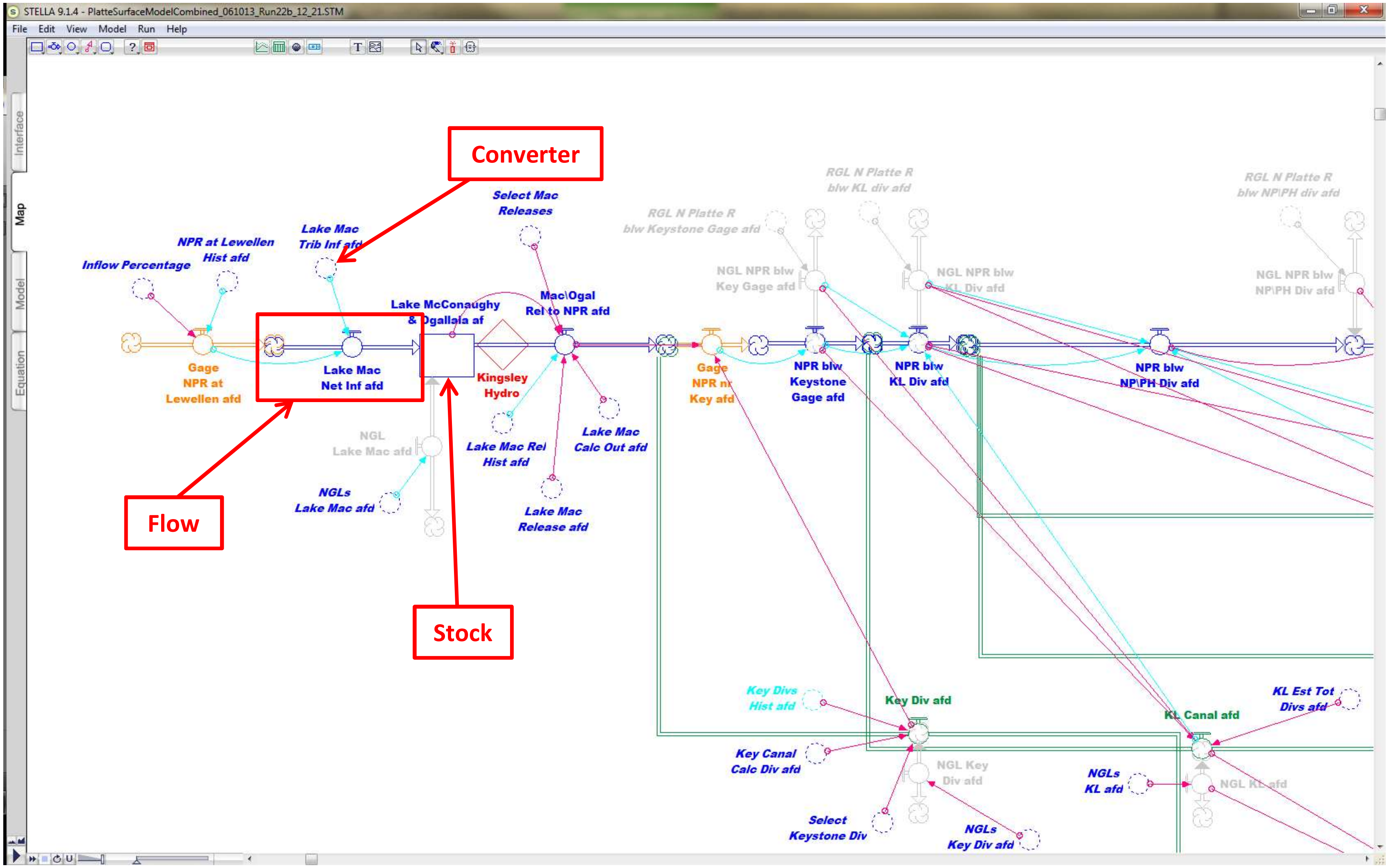
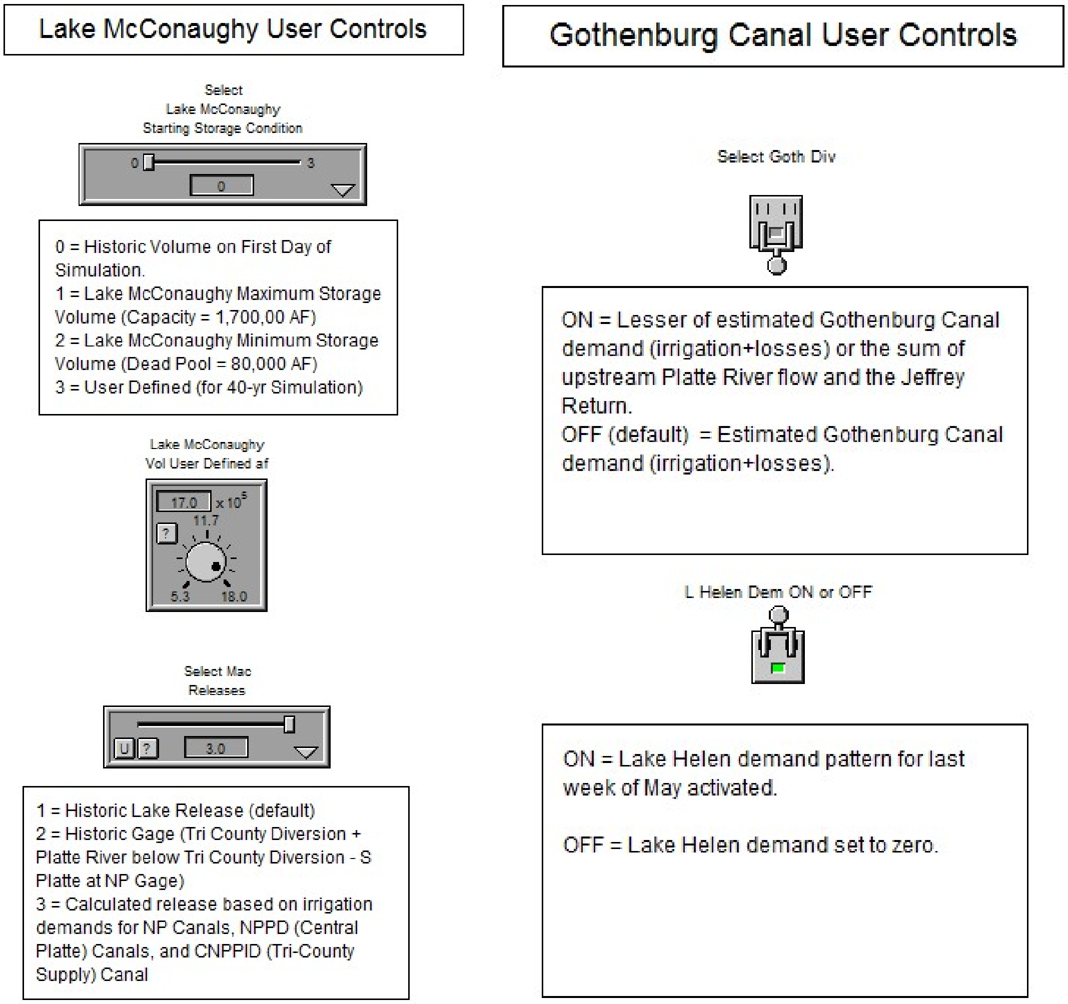


Figure 6.4-1. STELLA Schematic for Lake McConaughy Area.



0 = Historic Volume on First Day of Simulation.
1 = Lake McConaughy Maximum Storage Volume (Capacity = 1,700,00 AF)
2 = Lake McConaughy Minimum Storage Volume (Dead Pool = 80,000 AF)
3 = User Defined (for 40-yr Simulation)

1 = Historic Lake Release (default)
2 = Historic Gage (Tri County Diversion + Platte River below Tri County Diversion - S Platte at NP Gage)
3 = Calculated release based on irrigation demands for NP Canals, NPPD (Central Platte) Canals, and CNPPID (Tri-County Supply) Canal

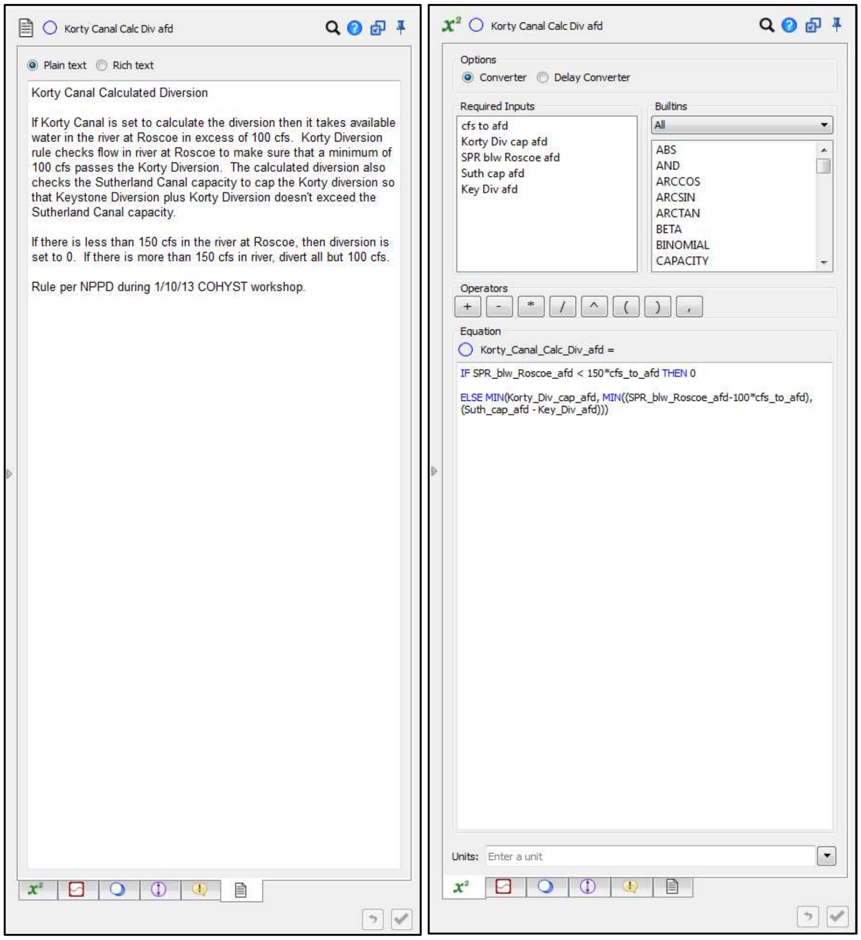
ON = Lesser of estimated Gothenburg Canal demand (irrigation+losses) or the sum of upstream Platte River flow and the Jeffrey Return.
OFF (default) = Estimated Gothenburg Canal demand (irrigation+losses).

ON = Lake Helen demand pattern for last week of May activated.

OFF = Lake Helen demand set to zero.

Figure 6.4-2. Example of STELLA Knobs and Sliders.

A core concept of the surface water model is the use of logic-based rules to simulate management decisions in routing flows through the system. Section 6.7 further describes the development of these rules. An example of the logic-based rules and documentation incorporated into the model is illustrated in **Figure 6.4-3.**



Korty Canal Calc Div afd

● Plain text ○ Rich text

Korty Canal Calculated Diversion

If Korty Canal is set to calculate the diversion then it takes available water in the river at Roscoe in excess of 100 cfs. Korty Diversion rule checks flow in river at Roscoe to make sure that a minimum of 100 cfs passes the Korty Diversion. The calculated diversion also checks the Sutherland Canal capacity to cap the Korty diversion so that Keystone Diversion plus Korty Diversion doesn't exceed the Sutherland Canal capacity.

If there is less than 150 cfs in the river at Roscoe, then diversion is set to 0. If there is more than 150 cfs in river, divert all but 100 cfs.

Rule per NPPD during 1/10/13 COHYST workshop.

Korty Canal Calc Div afd

Options: ● Converter ○ Delay Converter

Required Inputs:
- cfs to afd
- Korty Div cap afd
- SPR blw Roscoe afd
- Suth cap afd
- Key Div afd

Builtins: All

Equation:

```
Korty_Canal_Calc_Div_afd =
IF SPR_blw_Roscoe_afd < 150*cfs_to_afd THEN 0

ELSE MIN(Korty_Div_cap_afd, MIN((SPR_blw_Roscoe_afd-100*cfs_to_afd),
(Suth_cap_afd - Key_Div_afd)))
```

Figure 6.4-3. Example of STELLA Operating Rule for Canal Diversion.

The example logic-based rule in **Figure 6.4-3** is for the Korty Canal diversion from the South Platte River. The Korty Canal Diversion is a function of the simulated flow in the South Platte River at Roscoe, the Korty Diversion capacity, Sutherland Canal capacity, and simulated Keystone Diversion flow. The logic in the lower box of **Figure 6.4-3** states the following:

> If flow in the South Platte River is less than 150 cfs, then the Korty Canal Diversion is equal to 0; otherwise the Korty Canal Diversion is the minimum of the following

quantities: (1) Korty Canal Diversion Capacity, (2) Flow in the South Platte River at Roscoe minus 100 cfs, or (3) Sutherland Canal Capacity minus the Keystone Diversion.

The upper dialog box in **Figure 6.4-3** describes the logic behind the rule and references the source for the rule as well as any modifications made during calibration or based on Sponsor input. Further background on the Korty Canal Diversion rule is provided in Section 6.7.3.1.

6.5 Water Budget Elements

This section describes the STELLA model's simulation of the water budget elements relevant to the surface water system. It is important to identify the necessary water budget elements in order to account for the ultimate fate of water in the surface water system. Stella was designed to track these components through the simulated Platte River system to determine how operational changes would impact each water budget element as the water moves downstream.

6.5.1 Precipitation/Evaporation

Precipitation (additions to water supply) and evaporation (deductions from water supply) were summed to develop a net evaporation term. Net evaporation volumes were computed for canals, reservoirs, and the main stem reaches of the Platte River. Surface areas for canals and river reaches were computed based on reach lengths and constant, typical top widths estimated from aerial mapping and operator input. Reservoir surface areas are dependent on stage and are based on the stage-area-elevation data for each reservoir. According to a report by John Cassidy prepared for NPPD, the Sutherland Reservoir serves as a heat sink for the Gerald Gentleman Station and therefore includes a heat induced evaporation rate as well.

6.5.2 Reach Gain/Loss

For the development and calibration of the surface water model, historic daily reach gains/losses were computed for each reach utilizing available historic stream, diversion, and return gage data, as described in Section 4.4.2. The calculated daily reach gain/loss values are a lumped quantity that represents the river evaporation and transpiration losses, watershed runoff, canal returns, and baseflow gains occurring within the reach. The calculated historic daily reach gain/loss values were used to represent these water budget elements in the calibration of the surface water operations model to isolate the surface water system and allow refinement of system operational rules during calibration.

6.5.3 Seepage

Seepage rate estimates for each irrigation canal reach were developed based on data summarized in Section 4.4.2, anecdotal estimates from operators, and analysis of historic pre-irrigation diversion data. An example of this analysis is described in **Appendix 6-C**. A summary of the seepage rates for each canal is also included in Appendix 6-C. Because the canals are head-based systems, the estimated seepage rate is assumed to be a constant once canals are filled. In addition to the constant seepage rate approach, a toggle was added to the STELLA model which allows the user to use a seepage estimate based on percentage of diversion. This option was not used during model calibration.

The seepage for the Sutherland Canal system reaches (including Sutherland Reservoir and Lake Maloney) were determined in a previous study conducted by HDR on the Republican River for NDNR. The Republican River study conducted a reach by reach water balance of the Sutherland system using historic observations to estimate seepage rates and produced results that best matched historic observations. Toggles were added to the STELLA model so that the user may select canal seepage rate estimates based on the December 1993 Study performed by Harza Engineering Company and reservoir seepage estimates based on the NPPD stage-dependent seepage equation. These options were not used during model calibration.

The Tri-County supply canal has flow dependent seepage rates derived from analysis of CNPPID canal data along the Tri-County supply canal. In addition to the constant seepage rate approach used in model calibration, the STELLA model does include a toggle that the user may use a seepage estimate based on percentage of diversion. This option was not used during model calibration

Computed seepage volumes for the canals and reservoirs are assumed to be distributed evenly over the area of the reservoir/length of the canal reach, respectively.

6.5.4 Crop Deliveries

Crop deliveries for surface water canals were computed based on crop demands of surface water on irrigated lands served by each canal, as described in Section 5.0, and the available surface water supply in the canal, limited to the canal capacity and adjusted for canal losses (seepage and net evaporation) during conveyance.

6.5.5 Canal Returns

Canal returns are a major part of the water supply system as one progresses downstream through the system. Flows diverted and not used return to the river as canal returns and can provide a large portion of the water supply for downstream diversions. Canal returns for irrigation canals were computed as a residual of the diverted volume less the seepage, crop deliveries, and net evaporation. Canal returns in the integrated model are added to the main stem flows and routed downstream. Direct measurement of canal returns could improve this procedure.

6.6 Model Parameters and Inputs

6.6.1 Simulation Period and Computational Time Step

The 1985-2010 time period was used in developing the model, while the truncated 1990-2005 period was used for model calibration. The time period 2006-2010 was considered model validation. The Stella model was also configured structurally to have the ability to extend back to 1947 and forward to 2050. A daily computation time step was used in the simulations. Daily results were aggregated to monthly values for consistency with the groundwater and watershed models during integration. Daily, monthly, annual, and cumulative results were used in evaluating the surface water model performance during calibration.

6.6.2 Initial and Boundary Conditions

Historic observations were used to set reservoir initial conditions for the simulation. The boundary conditions consist of inflows on the South and North Platte Rivers. The Julesburg gage historic daily flows were used for the South Platte River inflow boundary conditions. North Platte River inflow boundary conditions consist of the Lewellen gage historic daily flows in addition to daily tributary inflows that occur between the Lewellen gage and Lake McConaughy. Estimates of long-term daily average tributary inflows were provided by the NDNR Bridgeport field office and summarized in **Table 6.6-1**. These estimates are based on periodic stream measurement data collected by NDNR.

Table 6.6-1. Lake McConaughy Tributary Inflows below Lewellen.

Month	Estimated Daily Inflow (cfs)
January	38
February	38
March	39
April	37
May	34
June	30
July	31
August	30
September	34
October	36
November	36
December	34

6.6.3 Travel Time

Time lags were included in the STELLA model to represent travel time as flows are routed through the system. Estimates of travel time were provided by the NDNR Bridgeport field office and are summarized in **Table 6.6-2**.

Table 6.6-2. Travel Time Estimates.

Location	Travel Time (Days) (from McConaughy/Julesburg)
North Platte River @ Keystone Canal Diversion	0
North Platte River, Downstream of Keystone Canal Diversion	0
North Platte River, Downstream of Birdwood Creek	1
Western Canal Diversion – South Platte River	0
Korty Canal Diversion – South Platte River	1
Platte River @ Tri-County Diversion	2
Platte River @ Gothenburg Canal Diversion	3
Platte River @ Cozad Canal Diversion	4
Platte River @ Dawson County Canal Diversion	4
Platte River @ Overton	5
Platte River @ Kearney Canal Diversion	6
Platte River @ Odessa	6
Platte River @ Grand Island	7
Platte River @ Duncan	8

6.6.4 Anecdotal Reach Gains

The operational rules for many elements of the system, as described later in Section 6.7, are based on downstream demands that are adjusted for anticipated reach gains. The use of anticipated gains is consistent with the ‘forecasting’ approach and intent of the model and the operational rules of the surface water system. The estimates for the anticipated reach gains used in the operational rules are anecdotal and were developed through discussions with NDNR Bridgeport and CNPPID staff about observations from their experience of managing the river over the last several decades. The anecdotal reach gain estimates are summarized in **Table 6.6-3**.

It is important to note that the translation of demands upstream for use in the operational rules are adjusted based on the anecdotal reach gains, while the computed historic reach gain/loss is used during calibration in routing flows downstream through the model extents and to quantify flows at each main stem node. Historic reach gains/losses change seasonally and even day by day. Similar to operational practices employed by water managers on the Platte River system, the rules within STELLA utilize the anticipated gains that represent more of an average conditions and not the computed reach gains/losses containing daily fluctuations for making simulating operations.

Table 6.6-3. Anecdotal Reach Gain Daily Estimates.

Reach	Daily Anecdotal Reach Gain Estimate (cfs)
South Platte River – Julesburg to Roscoe	20
South Platte River – Roscoe to North Platte	180
North Platte River – Keystone to Sutherland	100*
North Platte River – Sutherland to North Platte	200*
Platte River – North Platte to Brady	120*
Platte River – Brady to Cozad	100*
Platte River – Cozad to Overton	100
Platte River – Overton to Odessa	100

* Anecdotal Reach Gain during July is 0 cfs for these reaches

These values are used for the irrigation season and are based on estimates from CNPPID and DNR staff. As an example, when determining the amount of water that needs to be bypassed at the Tri County Diversion to serve the Gothenburg Canal in May, you would calculate the demand and anticipate that 120 cfs of gains would be occurring to determine the actual amount required to be bypassed.

6.7 System Operational Rules

Logic-based operational rules for each component of the surface water system are the engine that drives the STELLA surface water model. These operational rules were developed through an iterative process involving:

- obtaining general operational descriptions from the owners/operators;
- development of logic-based operating rules to represent general operational descriptions;
- evaluation of results and adjustment of triggers/criteria/rules to better reflect historic observations;

- review of operating rules and evaluation of simulation results with owners/operators;
- refinements to the operating rules.

The current final operating rules contained in the model are based on input from the COHYST 2010 Sponsor group during a series of meetings and technical working sessions throughout model development and calibration. The operational rules were defined to represent operational characteristics of reservoirs, canal diversions, and canal returns. Rules are intended to approximately represent present day operations. Some historic operations known to vary from current operational protocols or model rules have been identified. In many of these cases, the variations are noted, but specific rules to reflect historic operations have not been developed

6.7.1 Lake McConaughy

Lake McConaughy is near the upstream end of the model domain on the North Platte/Platte River system and is the largest reservoir in the modeled system. The storage releases from Lake McConaughy dictate much of the downstream streamflow conditions.

The release rules for Lake McConaughy are governed by irrigation demands, hydropower demands, and FERC regulations for maximum reservoir levels and minimum river flows. The downstream irrigation and hydropower demands are aggregated and adjusted for anticipated reach gains based on anecdotal estimates (section 6.6.4) to account for system gains between Lake McConaughy and the demand's diversion points. Once the Lake McConaughy release is computed based on demands and operational mode, flows are routed through the Platte River system accounting for diversions and returns as one progresses downstream.

General operating rules for Lake McConaughy and the Tri-County System were provided by CNPPID and are included in **Appendix 6-D**. These general rules served as an initial operational framework for the model and were modified through the development and calibration of the surface water model, resulting in three modes, or "conditions", that are specific to Lake McConaughy for operations: Wet, Dry or Transitional. It should be noted that these are not the same as USFWS classifications that go by similar names. The operational mode is determined by the model based on the simulated reservoir storage on October 1st of each year. Each of these three conditions, as well as the FERC rules, are described further in the subsequent sections. Tests were done to consider additional conditions to capture operations in years where conditions changed prior to the irrigation system, but no such additions were adopted.

The model has the ability to calculate Environmental Account storage (EA) within the Lake McConaughy reservoir, but the calculation is done in parallel to the operations currently with no specific release rules to manage the Environmental Account. Limits on storage demands by downstream users are not currently represented in the model. The model generally reflects operations during calibration but may need to be modified going forward.

6.7.1.1 Operational Modes

Wet Conditions

The Wet condition is triggered when the October 1st Lake McConaughy reservoir storage is at or above 1,500,000 acre-feet and maximizes hydropower generation while also meeting irrigation demands. During the irrigation season, releases are made to meet full irrigation demands for the North Platte Canals, CNPPID irrigation canals, and the Central Platte Canals, as well as maximizing hydropower generation, year-round, for the CNPPID Tri-County system. A full capacity diversion [set at 2,175 cfs consistent with long-term records] was assumed for CNPPID Tri-County Diversion for the wet condition.

Dry Conditions

The Dry condition is triggered when the October 1st Lake McConaughy reservoir storage is at or below 1,056,000 acre-feet and releases are limited to those required for irrigation demands No releases are made for hydropower demands in order to maximize reservoir storage.

Transitional Conditions

The Transitional condition is triggered when the October 1st Lake McConaughy reservoir storage is between 1,056,000 acre-feet and 1,500,000 acre-feet. During the irrigation season, releases are operated for full irrigation demands for the North Platte Canals, CNPPID irrigation canals, and the Central Platte Canals, as well as for full hydropower demands. Outside of the irrigation season the transitional mode has two different release rules for hydropower demands. The pre-irrigation (January 1st to June 15th) CNPPID hydropower demand is 50% of the diversion capacity at the Tri-County diversion and the post-irrigation (September 11 to December 31st) demand is a full diversion at the Tri-County diversion.

Lake McConaughy releases during the irrigation season for full hydropower demands is a good example of a model rule that is used to provide a decent match to historic operations, but might not reflect the current operational mindset. Currently, when Lake McConaughy reservoir storage levels fall within the transitional condition, operators may not make releases for full hydropower.

6.7.1.2 FERC Operating Limits and Minimum Releases

The FERC operating limits and minimum releases are also included in the Lake McConaughy release rules. The maximum operating level for the reservoir was provided by CNPPID based on their current FERC operating license requirements and is noted in **Table 6.7-1**.

Table 6.7-1. Lake McConaughy FERC Operating Limits.

Date	Maximum Operating Elevation (ft)
January 1 – February 29	3,265.0
March 1 – April 24	3,260.0
April 25 – April 29	3,260.5
April 30 – May 3	3,261.0
May 4 – May 7	3,261.5
May 8 – May 11	3,262.0
May 12 – May 15	3,263.0
May 16 – May 20	3,264.0
May 21 – September 30	3,265.0
October 1 – December 31	3,260.0

To match historic operations, the January through February maximum operating level in Lake McConaughy was set at 3,260 ft instead of 3,265 ft. Similarly, the maximum operating level near the end of the water year was modified to provide a smooth transition from the late September to early October target elevation and avoid spikes in releases. Intermediate target elevations between August 1 and September 15 were set within the STELLA operating rules as follows:

- August 1 – 3,263.0 ft
- August 15 – 3,262.0 ft
- September 1 – 3,260.5 ft
- September 15 – 3,260.0 ft

The surface water model compares the simulated Lake McConaughy reservoir elevation to the target maximum elevations on a daily basis. If the simulated reservoir level exceeds the target maximum level, then reservoir outflow is set equal to the inflow (up to the capacity of the dam’s outlet works) until the reservoir level drops below the target maximum elevation which may result in some daily oscillations of releases but would not affect results on a monthly basis.

The minimum FERC releases, which are documented in the description of the Nebraska Environmental Account Document (Attachment 5, Section 5, PRRIP, 2006), are also included in the Lake McConaughy release rules. The minimum releases are based on the operational mode (i.e. wet, dry, and transitional) and are triggered only when the calculated release demand is less than the FERC minimum release.

6.7.2 Individual Irrigation Canals

The operational rules for the irrigation canals were developed based on historical diversion patterns, seepage rates, evaporation, crop demands, canal returns, physical diversion capacity, and flow available for diversion. The computation methodology for the diversions is based on assumed efficiencies for each canal and crop demands of the lands served by the canal. The assumed efficiency was determined from estimates of seepage, evaporation, and returns from synoptic studies (referenced in Section 4.4.2) and operator input. Once flow is diverted into the canal it is partitioned to seepage, evaporation, and crop deliveries (during the irrigation season) and the residual is returned to the river as return flow. Irrigation season demands for the individual irrigation canals were developed using CROPSIM rather than using historic diversion records. This approach was utilized to allow application of the modeling tools to evaluate changes in climatic conditions, irrigation efficiency, physical improvements to the canal, water source, and land use changes.

6.7.2.1 Historical Diversion Patterns

Based on review of the average historic diversion patterns and discussions with NPPD, CNPPID, NDNR and canal operator staff, variations in system operations were identified over the calibration period. The variations were primarily a trend in later years to delay the start of the diversion season, with rate of diversions remaining fairly constant. To represent these changes in operations, average historic diversion patterns were developed for subsets of the calibration period for each irrigation canal. The three subsets used are 1985-1990 (mid-April typical start of diversions), 1991-2000 (mid-May typical start of diversions), and 2001-2005 (early June start of diversions). The 2001-2005 subset was used for the 2006-2010 period as well.

6.7.2.2 Diversion Seasons

The irrigation canal rules are defined by two seasons; the non-irrigation season and the irrigation season. The non-irrigation season is pre-June 15th and diversion rates are based on the average historic diversion pattern during the calibration period. The initial canal filling and pre-irrigation season diversions occur during the non-irrigation season. The irrigation season runs between June 15th and September 10th and diversion rates during this period are based on crop demands (developed by CROPSIM) and estimated canal efficiencies. During both periods, the diversion amount is capped by the physical diversion capacity and available flow in the river at the point of diversion.

Non-Irrigation Season (Initial Canal Filling and Pre-irrigation season)

The start date for initial canal filling is based on the average first day of the historic diversion. The diversion amount for the first 14 days is based on the average of the first 14 days from each year in the study period, regardless of actual starting date. Each irrigation canal operates under this rule for the first 14 days of the irrigation season.

The pre-irrigation season is the period between the end of the initial canal filling and the start of the irrigation season and begins 15 days after the start of diversions (initial canal filling). A constant rate of diversion during the pre-irrigation period was determined for each canal based on the average diversion rate from historic diversion records.

Irrigation Season

The irrigation season begins on June 15th and ends on September 10th. Canal diversions during this period are based on crop demands and estimated canal efficiency. The crop demand is provided by the CROPSim model in the form of a monthly demand for each canal. The irrigation season demands (June, July, August and September) are summed to create an annual irrigation demand (demands outside of this period are neglected and will be passed back to the watershed model as unmet demands). This calculated annual demand is distributed monthly through the irrigation season and discretized into a daily demand. The monthly distribution was further refined during calibration based on historic diversion patterns and is noted below.

- June 16th – 30th: 7.4%
- July: 50%
- August: 35.9%
- September: 6.7%

The reason for the further refinement is to represent the human factor or operational element that appeared through analyses of historic diversion patterns. The temporal distribution based on CROPSIM theoretical demand does not replicate these human factors based on climatic conditions. A technical memorandum is included in **Appendix 6-E** that further describes the crop demand representation in the surface water model and how it has been updated from the 2013 model.

6.7.2.3 Predicted and Calculated Canal Returns

The predicted canal returns are required to develop the total net demand at the canal diversion. The predicted canal return is a percentage of the seepage and crop demands, resulting in a total canal diversion demand. The predicted return percentages currently in the model for each canal are noted below.

- Keith-Lincoln Canal: 15%
- North Platte Canal: 20%
- Paxton-Hershey Canal: 20%
- Suburban Canal: 30%
- Cody-Dillon Canal: 5%
- Gothenburg Canal: 21%
- Thirty-Mile Canal: 23%
- Six-Mile Canal: 5%
- Cozad Canal: 23%
- Orchard-Alfalfa Canal: 6%
- Dawson County Canal: 35%
- E-65/E-67/Phelps: 0%

Limited gage data are available for the irrigation canal returns. The return percentages used in the model were developed through the calibration effort to match historic diversions. Input from canal operators was solicited throughout out the calibration process to ensure return percentages were within valid ranges for each individual canal. NDNR is currently collecting return data for select canals during the irrigation season that may be used to refine these return estimates.

The calculated canal returns are computed within the Stella model and are a residual from the partitioning of diverted water to seepage, evaporation and crop delivery.

6.7.3 Sutherland System

The Sutherland System is represented in the surface water model by the following four components: Korty Canal, Keystone Canal, Sutherland Reservoir and Lake Maloney. Details of each component are described in the subsequent sections. General operating rules were provided by NPPD and are provided in **Appendix 6-F.** These general rules served as an initial operational framework for the model and were iteratively refined during model calibration.

6.7.3.1 Korty Diversion

The Korty Canal Diversion is located downstream of the South Platte River gage at Roscoe. Based on correspondence with NPPD, Korty Canal is operated to maintain a minimum of 100 cfs in the South Platte River below the Korty Canal Diversion. In order to replicate this condition in the surface water model, the rule for the Korty Canal diversion is associated with the model predicted flow in the South Platte River at Roscoe. If the modeled flow in the river (at Roscoe) is less than 150 cfs, then no flow is diverted into the Korty Canal. If flow in the river exceeds 150 cfs, then 100 cfs is allowed to bypass the diversion with the remainder being diverted into the Korty Canal. The diversion rule uses 150 cfs, instead of 100 cfs, essentially making the minimum Korty Diversion 50 cfs in order to always maintain at least 100 cfs bypassing the diversion. The Korty Diversion rule also checks to ensure that the diversion, both at the Korty Canal headgate and at the Sutherland Canal (where the Korty and Keystone Canals converge), does not exceed the headgate or canal capacity.

6.7.3.2 Keystone Diversion

The Keystone Canal Diversion is located just downstream of Lake McConaughy and upstream of the North Platte River gage at Keystone. The rule for the Keystone Canal diversion is associated with the Lake McConaughy release (described in **Section 6.7.1Error! Reference source not found.**) and the irrigation demand for the North Platte Canals. Lake McConaughy releases in excess of those needed for the North Platte Canals (accounting for anecdotal reach gains) is diverted into the Keystone Canal. The rule also checks to ensure that the calculated diversion does not exceed the Keystone Canal capacity. In the event flows are available at both the Keystone and Korty diversions, maximum diversion is made at Keystone and supplemented with Korty diversions up to the Sutherland Canal capacity.

6.7.3.3 Sutherland Reservoir

Korty Canal and Keystone Canal come together to form the Sutherland Canal, which provides inflow to the Sutherland Reservoir. The surface water model is setup to toggle between two different operating rules for the Sutherland Reservoir. A memorandum summarizing the Sutherland Reservoir operating rules in more detail is included in **Appendix 6-F**.

The model uses the operating rule with the set minimum and target operating curve provided by NPPD in October 2013. It is recognized that this rule may not reflect historic operations, but better represents recent and future planned operations. **Figure 6.7-1** compares the October 2013 target operating curve to the historic reservoir elevations for 1990-1995. The figure shows the target operating curve provides a good estimate and matches the trends pretty well, but does not reach the historic minimums and maximums, as expected when using a target curve based on normal operating conditions.

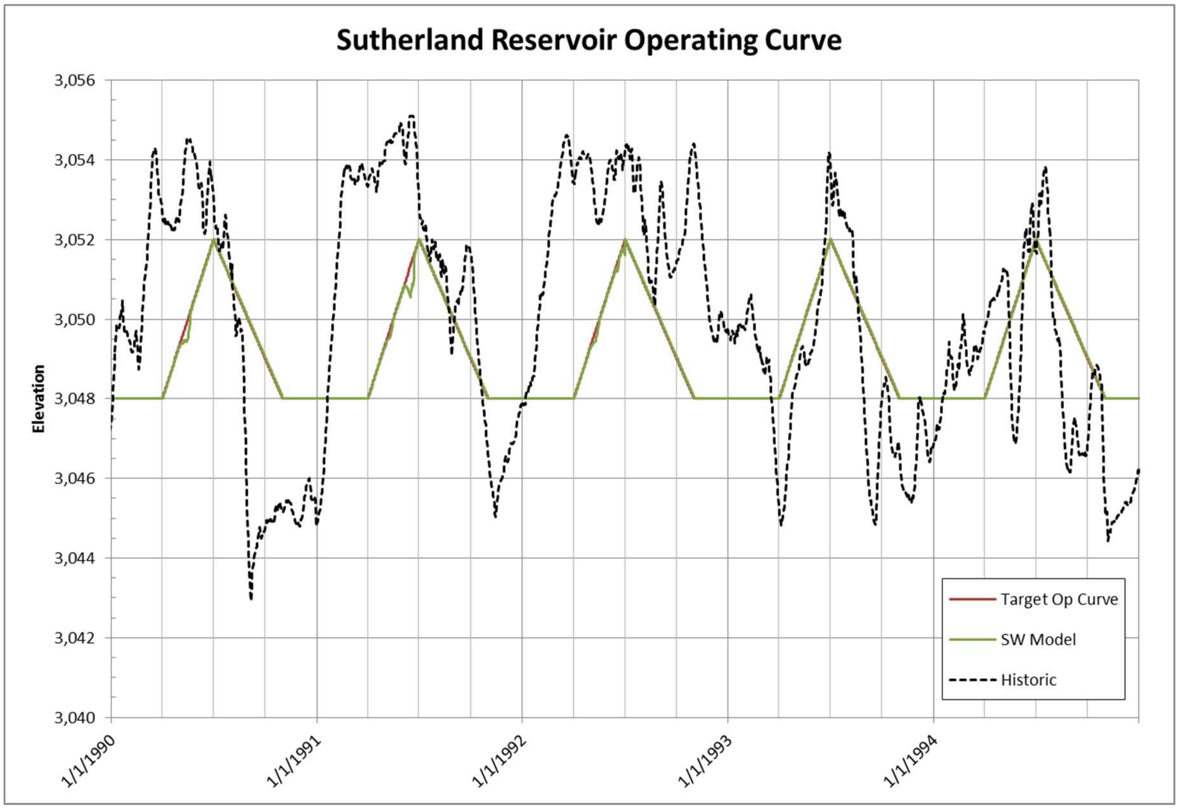


Figure 6.7-1.Sutherland Reservoir Target Operating vs. Historic Reservoir Elevations.

6.7.3.4 Lake Maloney

Lake Maloney is a regulating reservoir for NPPD's North Platte hydropower facility Lake Maloney is simulated as a pass-through reservoir with a minimum pool elevation criteria.

6.7.4 Tri-County System

The CNPPID Tri-County System is represented by a series of canals (irrigation and supply), reservoirs, hydropower facilities, and canal returns.

6.7.4.1 Tri-County Diversion

The CNPPID Tri-County Diversion is located downstream of the North Platte River and South Platte River confluence. The diversion rule at Tri-County is to divert all available flow in the river at the confluence, up to the Tri-County Diversion capacity; based on historical data this was set at 2,175 cfs. Diversions are conveyed through the CNIPPID supply canal which has two segments: Segment 1 - Tri-County Diversion to Jeffrey Lake; and Segment 2 - Jeffrey Lake to Johnson Lake.

6.7.4.2 Jeffrey Lake

Jeffrey Lake is located downstream of the Tri-County Diversion at the end of first segment of the supply canal. It is operated as a regulating reservoir for the Jeffrey Hydropower facility, which is one of three hydropower facilities within the CNPPID Tri-County System. The surface water model operates Jeffrey Lake as a pass-through to the Jeffrey Return (Section 6.7.4.3) with minimum pool elevation criteria.

6.7.4.3 Jeffrey Return

Jeffrey Return is located downstream of Jeffrey Lake and returns flows to the Platte River. Jeffrey Return is operated as needed to meet the irrigation demands for the Central Platte Canals. The rule for the Jeffrey Return checks the model predicted flow in the Platte River at Brady, which is located just upstream of the return, to see if the river flow along with anecdotal reach gains will satisfy the irrigation demand for the Central Platte Canals. If the river flow and anecdotal gains will meet the demand, then the return is set to zero and the water remains in the CNPPID system in the second segment of the supply canal. If there is a deficit between the river flow with anecdotal gains and the Central Platte Canals demand, then that deficit is supplied by the Jeffrey Return. The Jeffrey Return rule also verifies that the calculated return does not exceed the physical capacity of the return canal or the flows remaining in the Tri-County supply canal do not exceed the capacity of the second segment of the supply canal.

6.7.4.4 Johnson Lake

Flows bypassing the Jeffrey Return remain in Segment 2 of the supply canal and are available for diversion into E-65 Canal (see Section 6.7.4.5) or inflow into Johnson Lake. Similar to Jeffrey Lake, Johnson Lake serves as a regulating reservoir to regulate flows to E-67 Canal (see Section 6.7.4.7) and Johnson Hydro #1 and Johnson Hydro #2. Johnson Lake is operated as a pass-through in the surface water model with minimum pool elevation criteria.

6.7.4.5 E-65 Diversion

The E-65 Diversion supplies flow from the supply canal to Elwood Reservoir and E-65 Canal. The E-65 Diversion rule sums the Elwood Reservoir Inflow and the irrigation demand for E-65 Canal below Elwood Reservoir (see Section 6.7.4.6), with the upper limit being the E-65 Plum Creek siphon capacity (365 cfs per CNPPID). If that quantity is available in the supply canal upstream of the E-65 diversion, then it is diverted into the E-65 Diversion with any residual going to Johnson Lake.

6.7.4.6 Elwood Reservoir and E-65 below Elwood Reservoir

Elwood Reservoir is filled via pumping from the E-65 Canal during the non-irrigation season and is operated to supplement irrigation demands to the E-65 Canal (downstream of Elwood Reservoir) during the peak irrigation season. The reservoir filling takes place each year in late spring and late fall. The target operating curve for the reservoir was provided by CNPPID and is shown in **Figure 6.7-2**.

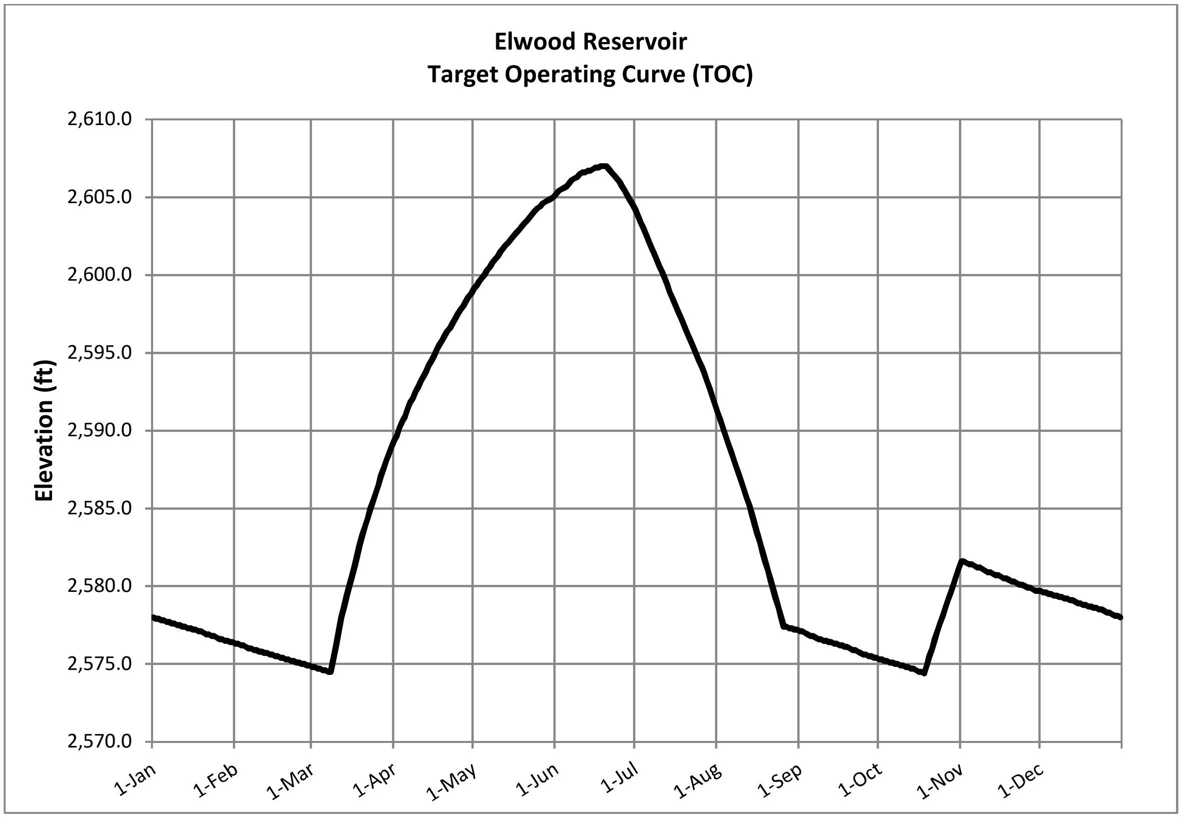


Figure 6.7-2 Elwood Reservoir Target Operating Curve

The late spring, or Early Season Fill, begins on March 8th and ends on June 15th. According to the target operating curve, the late fall, or Late Season Fill, begins on October 15th and ends on October 31st. Based on discussion with CNPPID, the purpose of the late season fill is to get the reservoir level high enough to offset the anticipated seepage and evaporation losses over the winter months and to have the reservoir level be at least 2,575 ft in early March. The reservoir is filled at the end of the irrigation season while the E-65 Canal is already charged. Because the modeled irrigation season ends on September 10th, the surface water model uses a starting date of September 11th for the late season fill and ends on October 31st. The Elwood Reservoir outflow supplements the E-65 Canal irrigation demands which cannot be met due to capacity limitations of the E-65 Plum Creek Siphon (365 cfs per CNPPID). The Elwood Reservoir outflow rule checks the E-65 irrigation requirement compared to the E-65 Diversion and delivers the supplemental volume (if necessary) up to the Elwood outflow capacity (310 cfs per CNPPID).

6.7.4.7 E-65 below Elwood Reservoir/E-67/Phelps Canal

E-65 Canal, E-67 Canal and Phelps Canal serve the irrigation lands on the CNPPID System. E-65 canal is downstream of Elwood Reservoir and is served through the E-65 Diversion and supplemented with Elwood Reservoir during the peak irrigation season. E-67 Canal Diversion is located downstream of Johnson Lake between Johnson Hydro #1 and Johnson Hydro #2. Phelps Canal Diversion is located between Johnson Hydro #2 and the J-2 Return (see Section 6.7.4.8). The diversion rules for E-65 below Elwood Reservoir, E-67 and Phelps are similar to the irrigation canal rules previously described in Section 6.7.2 and account for crop demands as well as predicted canal efficiencies.

6.7.4.8 J-2 Return

The J-2 Return is located downstream of the Johnson Hydro #2 and returns flows to the Platte River, upstream of the Kearney Canal Diversion. The rule for the J-2 Return is configured to return all of the flow in the canal except for what is needed to meet Phelps Canal demands.

6.7.5 Kearney Canal

Kearney Canal operates for both hydropower and irrigation demands. Flows are typically diverted in the spring and fall for hydropower and during the irrigation season for both hydropower and irrigation. Historically, approximately 70-80% of the canal diversions are returned to the Platte River

The surface water model is setup to toggle between four different diversion rules for the Kearney Canal; (1) Historic Daily Diversion, (2) Average Historic Diversion, (3) Calculated Diversion based on irrigation demand, and (4) Hydro Power Use Only. The default setting in the model is Historic Daily Diversion due to the highly variable operational patterns during the calibration period. The hydro power use only rule was added since the 2013 model. This rule is based on email correspondence with NPPD in February 2015 and may be helpful in looking at future operational patterns. For this option, the beginning diversion date is April 15 and the end diversion date is November 1. The rule uses a run up rate of 50 cfs/day, a shut down rate of 100 cfs /day, a maximum diversion rate of 325 cfs, and a minimum diversion rate of 50 cfs.

Similar to the other irrigation canals, the Kearney Canal returns are the calculated residual from the assumed canal efficiency and the crop deliveries (see Section 6.7.2.3).

6.7.6 Water Priority System

Because the canals are operated based on natural flow rights, priority rules were created and implemented into the surface water model logic. The priority logic enables the model to “color” the water throughout the system and quantify the amount of natural flow and storage water at nodes along the river. The natural flow diversion is limited to the natural flow appropriation, assuming a canal will not take more than their appropriation. Further underlying assumptions are listed below.

- Reach losses are assigned to the natural flow, unless there is no natural flow in the river. This is a simplifying assumption in the accounting logic. The river as a whole gains on average 80% of the time, so this simplification has a minor effect on the results.
- Rules incorporate priority dates and appropriated natural flow right.
- Coloring of water is dependent on simulated available natural/storage upstream of diversion.
- Anecdotal reach gain/loss used in rules (used when there is a senior appropriation downstream).
- Coloring of water in Stella is done on a daily time-step unlike PWAP, which is ‘hindcasted’.

- It is noted that the intention of the priority logic within the STELLA model is to evaluate the impacts on natural flows/storage water in the river of alternative scenarios, not to serve as an accounting tool for administration.

The Stella model is not currently set up to have the priority rules affect diversion volumes or ‘shut-off’ canals, which is generally consistent with typical 1985-2005 operations (the 2002-2005 drought being the exception).

Appendix 6-G is a technical memorandum on the priority accounting that further explains the logic in the model, discusses simulated storage and natural flow diversion results, and contains a schematic with calculations at each node.

6.8 Model Calibration

Calibration of the surface water model was accomplished through comparison of simulated and historical observations for the 1990-2005 period. The primary calibration targets consisted of main stem stream gages, canal diversions (and gaged returns), reservoir stages, and mini-water budgets of the North Platte River at the Keystone Diversion, North Platte River at North Platte, the Platte River at the confluence of the North and South Platte Rivers, and the Sutherland and Tri-County systems.

Daily, monthly, seasonal, annual, wet/dry/normal hydrologic conditions, and cumulative values were evaluated. In addition, cumulative difference analyses were included to determine if systemic errors were present in the model simulations.

6.8.1 Calibration Process

Results of model simulations were reviewed with the modeling team, the Sponsor Technical Committee and operators with a focus on possible adjustments to parameters and operating rules that would improve model performance while still remaining within the system constraints. The focus of calibration adjustments centered on those elements that have the greatest uncertainty, as summarized below.

- Irrigation canal return estimates used in computing diversion demands.
- Lake McConaughy threshold elevations that determine wet/dry/transitional conditions.
- Targeted diversion at Tri-County Canal used in determining Lake McConaughy release rates.

- Anecdotal reach gains used in determining Lake McConaughy release rates.
- Temporal distribution of the annual irrigation demand over the irrigation season.
- Logic of operational rules.

Appendix 6-H is a catalog of STELLA model versions and descriptions of major adjustments made during calibration, ending with the current version (version number 15).

6.8.2 Calibration Results

The calibration results discussed herein are based on Run 28b_15_HIST where '28b' designates the watershed model run that provides the crop irrigation demands; '15' designates the STELLA model version; and 'HIST' designates calculated historic reach gain/loss values which were used to simulate those water budget elements not represented in the STELLA model, as discussed in Section 6.5.2.

6.8.2.1 Stream Gages

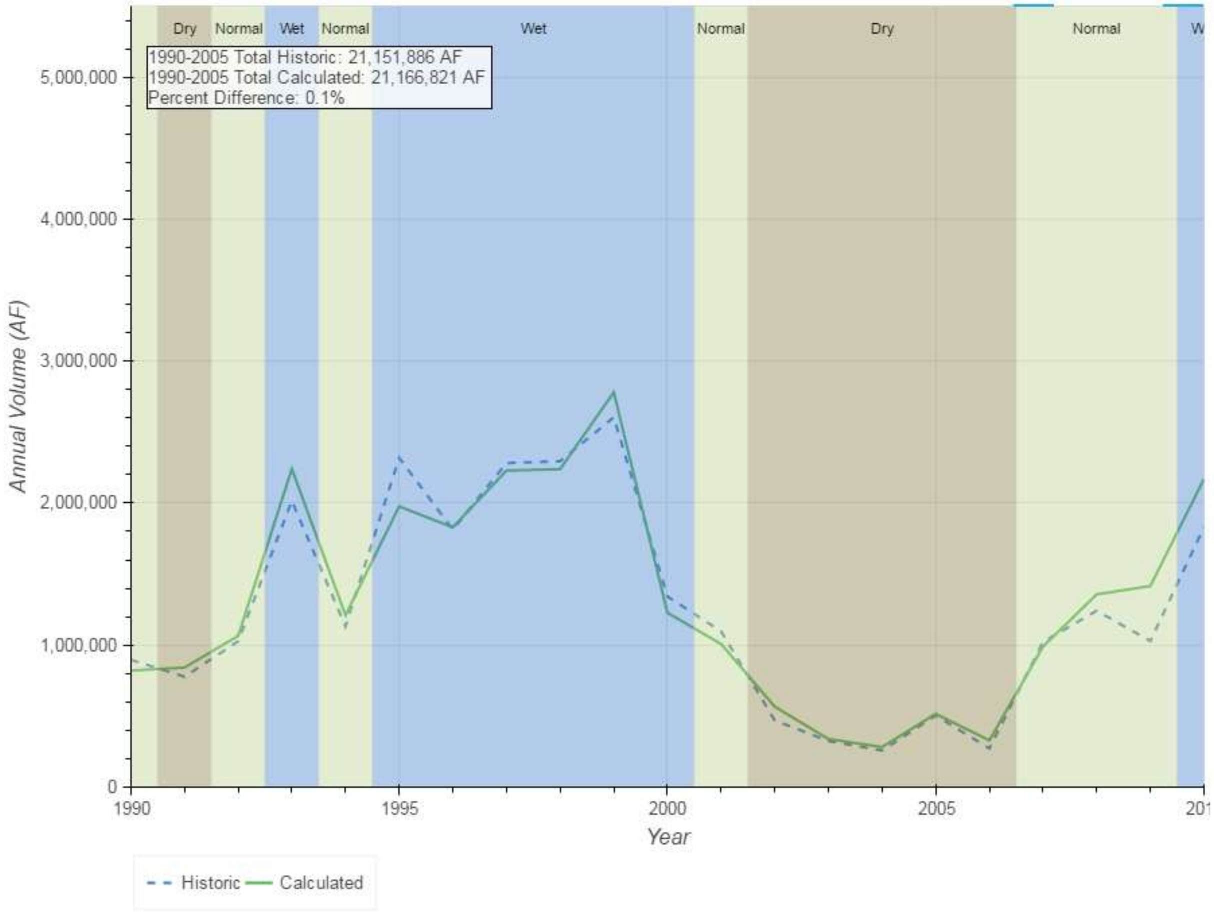
Table 6.8-1 summarizes the cumulative differences between model predictions and historic observations at the main stem gage locations. The 1985-2010 time period was used in developing the model, while the truncated 1990-2005 period was used for model calibration. The time period 2006-2010 was considered model validation. The results presented in **Table 6.8-1** represent the calibrated time frame 1990-2005. The figures in this section show the 1990-2010 time period.

Table 6.8-1. Stream Gage Cumulative Volume (1990-2005) Calibration Results.

		South Platte River		North Platte River		
		Roscoe	NPlatte	Mac Rls	Keystone	NPlatte
Total Historic Volume (AF)		6,723,090	4,918,060	13,409,810	3,865,960	6,149,400
AvgHistoric Daily Flow (cfs)		580	430	1,160	330	530
Cumulative Difference from Historic at End of Simulation(2005)	**Acre-Feet**	126,980	318,340	-468,252	-1,008,370	-799,760
	CFS (avg/day)	8	21	-31	-66	-53
	% of Total Volume	2%	6%	-3%	-26%	-13%

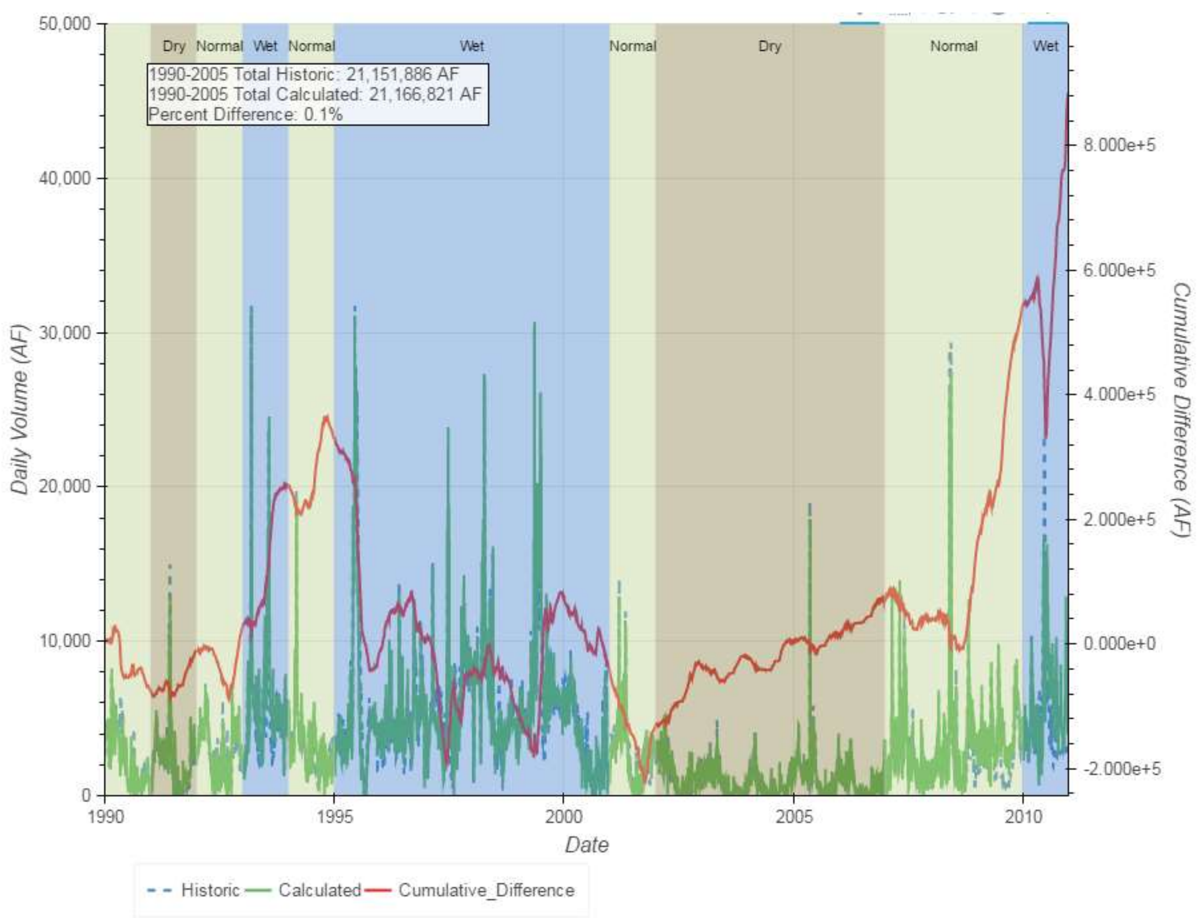
		Platte River						
		NPlatte	Brady	Cozad	Overton	Odessa	Grand Island	Duncan
Total Historic Volume (AF)		20,929,700	6,886,070	5,440,260	15,885,220	16,077,940	17,486,930	21,151,890
AvgHistoric Daily Flow (cfs)		1,810	600	470	1,370	1,390	1,510	1,830
Cumulative Difference from Historic at End of Simulation (2005)	**Acre-Feet**	-275,390	-344,780	104,759	-123,300	393,250	-26,870	14,935
	CFS (avg/day)	-18	-23	7	-8	30	-2	1
	% of Total Volume	-1%	-5%	2%	0.4%	2%	0.2%	0.1%

The cumulative percent difference between modeled and historic volumes for the calibrated time frame 1990-2005 ranges from -26 % to +6 %, with the cumulative difference for the majority of gage locations within +/- 2%. The largest cumulative difference on a percentage basis (-26%) occurs at the North Platte at Keystone gage and reflects a combination of under prediction in Lake McConaughy releases, and an over prediction of Keystone Diversion flows. **Figure 6.8-1 and Figure 6.8-2** illustrate comparisons of simulated and historic flows both on a cumulative annual volume and daily flow volume basis with the cumulative difference for the Platte River at Duncan gage for the 1990-2010 time period.



NOTE: The table values provide a summary of the 1990-2005 calibration while the figure includes the 2006-2010 validation period.

Figure 6.8-1. Platte River near Duncan Gage Annual Data.



NOTE: The table values provide a summary of the 1990-2005 calibration while the figure includes the 2006-2010 validation period.

Figure 6.8-2. Platte River near Duncan Gage Daily Data.

The colored shading in the figures denoting wet, dry, and normal correspond to hydrologic conditions in the Platte River basin as determined by the US Fish & Wildlife Service. The Platte River at Duncan gage is representative of the typical calibration results; similar plots for each gage are included in **Appendix 6-I**. Items of note are provided below.

- The model results generally match Platte River historic flows very well, both on an annual and seasonal basis under varying hydrologic conditions. This indicates appropriate and robust operating rules of the surface water components.
- The lower reaches of the Platte River illustrate a bias that occurs when using historic reach gain/loss. Historically in 2004 and 2005, the gage flow has reached zero, which in essence limits the reach losses in the historic reach gain/loss calculation during drought periods.

- At several gages ‘spikes’ in the cumulative difference curves, indicating a short-term significant difference between simulated and historic flows, can be observed (1995, 1997, and 1999, for example). These variations were discussed at length with the Sponsor technical group and upon inspection of Lake McConaughy rules and releases, Keystone Diversion flows, and the river gages, each of these spikes was determined to be driven primarily by trigger elevations used in Lake McConaughy operating rules and operational changes that the model as currently configured will not be able to capture. As such, it should be noted as a model limitation.

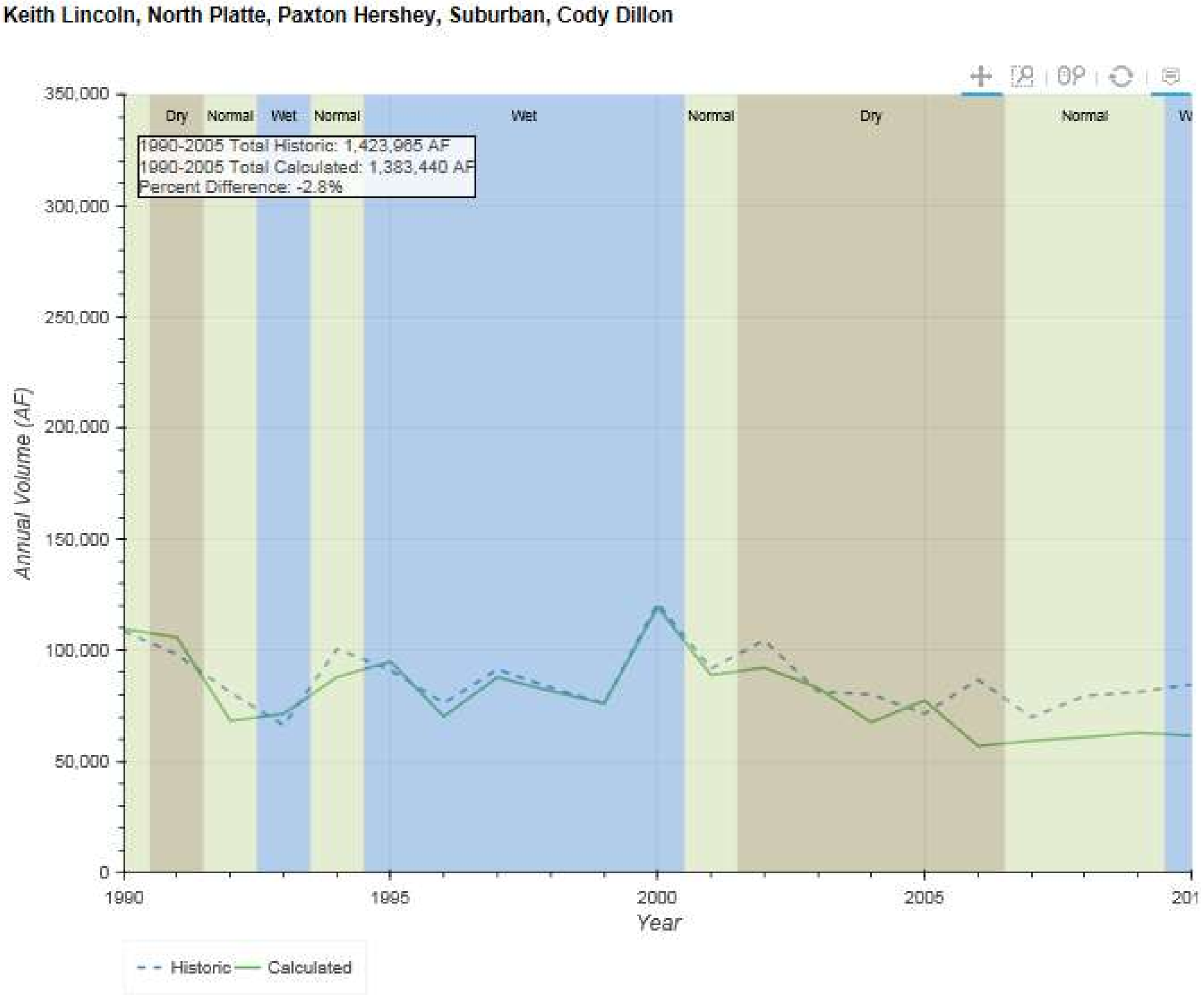
  An example of this occurs in 1997. On October 1 of 1996, the model determines a transitional year operation based on current storage volume in Lake McConaughy and the appropriate constant winter releases are set. Simulation results track well through January 1 when initial snow pack forecasts become available. By March 1, historic releases have increased from Lake McConaughy and Keystone Diversion flows have increased as well. In the model, because the adjustment to increase releases based on intermediate snowpack forecasts was not made, the simulated reservoir elevation reaches the FERC limits on Lake McConaughy in May, resulting in forced releases out of Lake McConaughy. Because these forced releases exceed the available capacity of the Keystone Diversion, the flows are sent down the North Platte River resulting in ‘spikes’ at the downstream gages.

  This is one example of the model’s limitation to representing day-to-day operational decisions which are made based on human influences of past experience, history, and future forecasts.

6.8.2.2 Canal Diversions

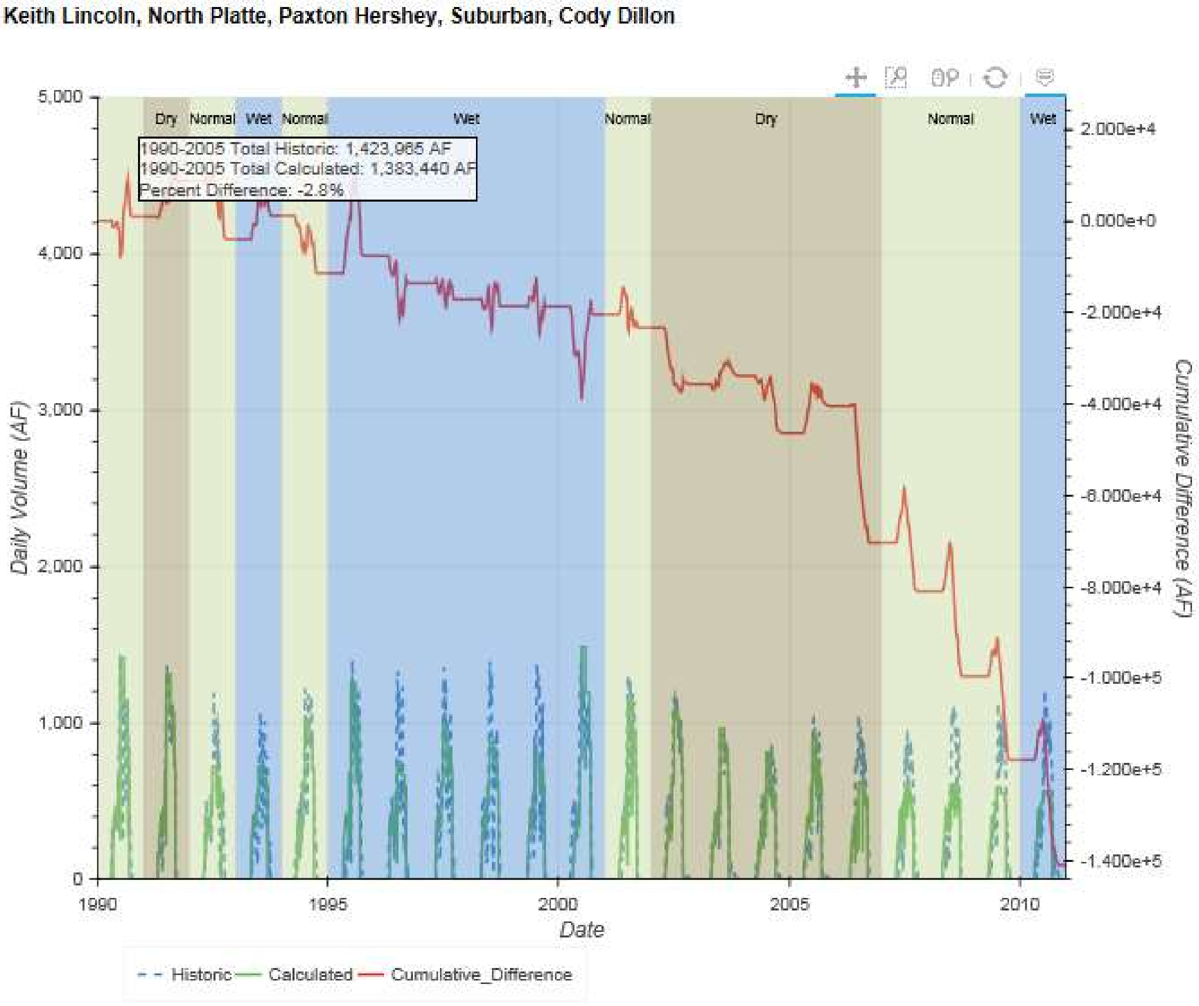
Plots of modeled and historic annual diversions, and daily diversions (and returns for those gaged returns) as well as cumulative differences for each diversion are included in **Appendix 6-J**. The cumulative percent difference between simulated and historic diversion volumes during 1990-2005 are within +/- 5%, with the cumulative difference for the majority of diversions within +/- 3%.

Figure 6.8-3 illustrates the annual simulated and historic diversion volumes of the North Platte canals and **Figure 6.8-4** illustrates the daily simulated and historic diversion volumes, as well as the cumulative difference. As noted, because of the complexity and coordination of the North Platte canals' system (Keith-Lincoln, North Platte, Paxton-Hershey, Suburban, and Cody-Dillon), the total sum of these diversions served as the primary calibration target and individual canals as a secondary calibration target.



NOTE: The table values provide a summary of the 1990-2005 calibration while the figure includes the 2006-2010 validation period.

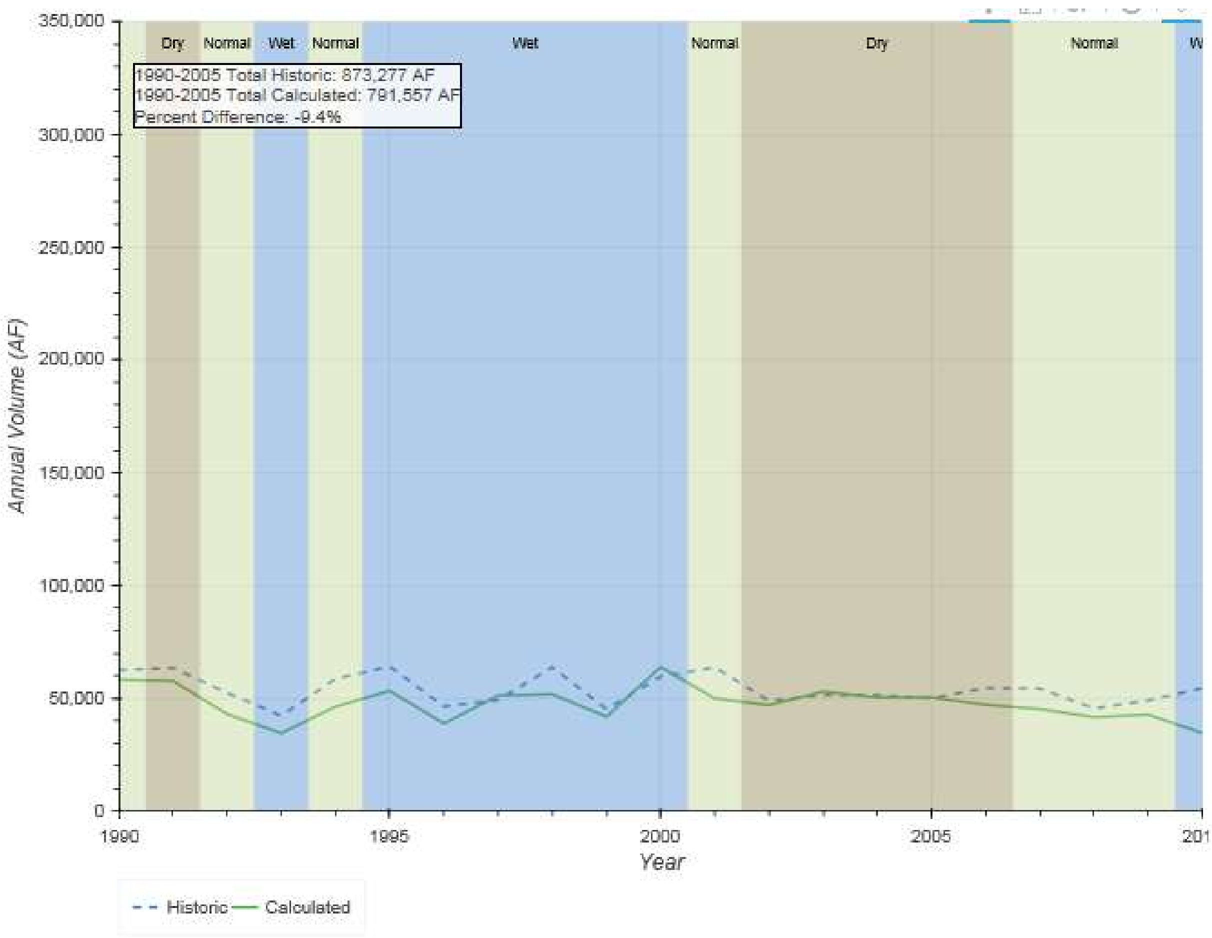
Figure 6.8-3. North Platte Canals Annual Diversion Data.



NOTE: The table values provide a summary of the 1990-2005 calibration while the figure includes the 2006-2010 validation period.

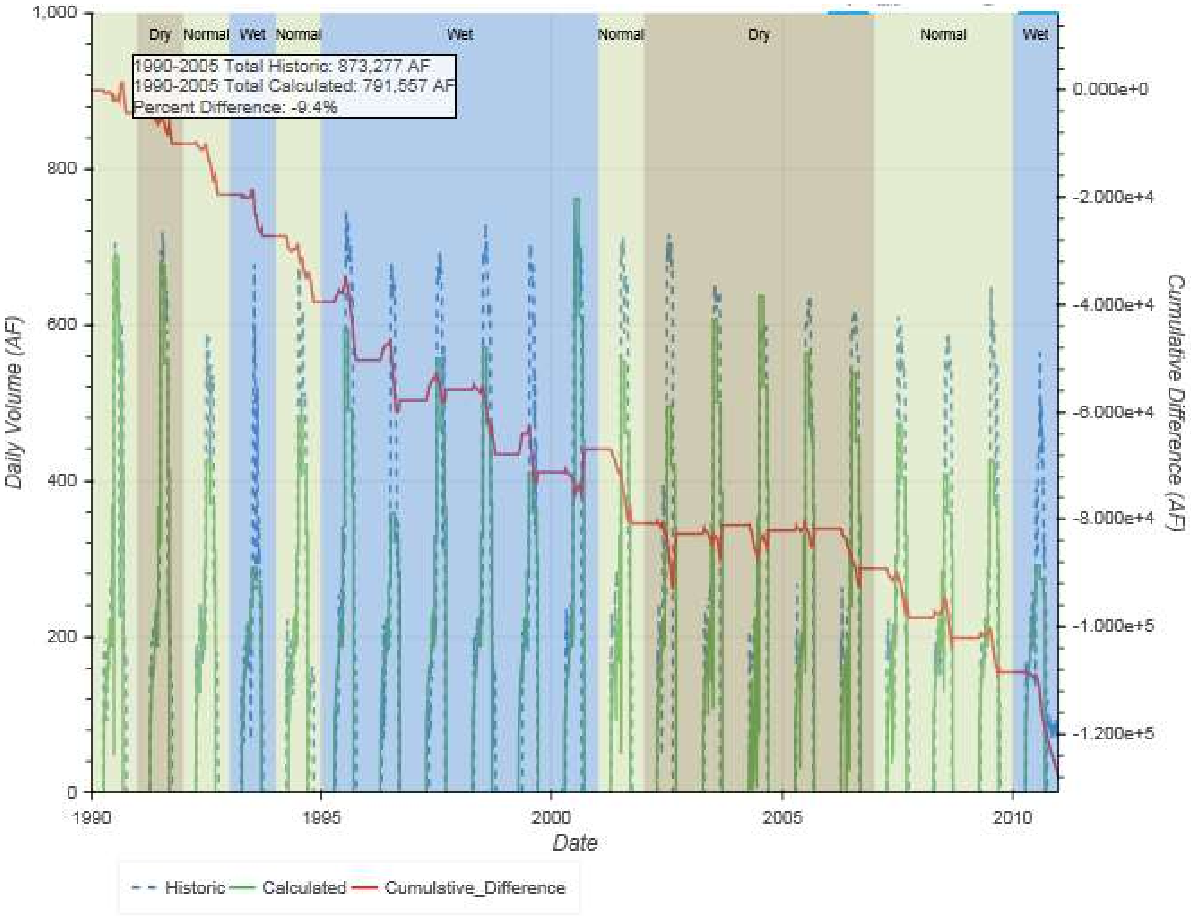
Figure 6.8-4. North Platte Canals Daily Diversion Data.

Figure 6.8-5 illustrates the annual simulated and historic diversion volumes of the Gothenburg Canal and **Figure 6.8-6** illustrates the daily simulated and historic diversion volumes, as well as the cumulative difference.



NOTE: The table values provide a summary of the 1990-2005 calibration while the figure includes the 2006-2010 validation period.

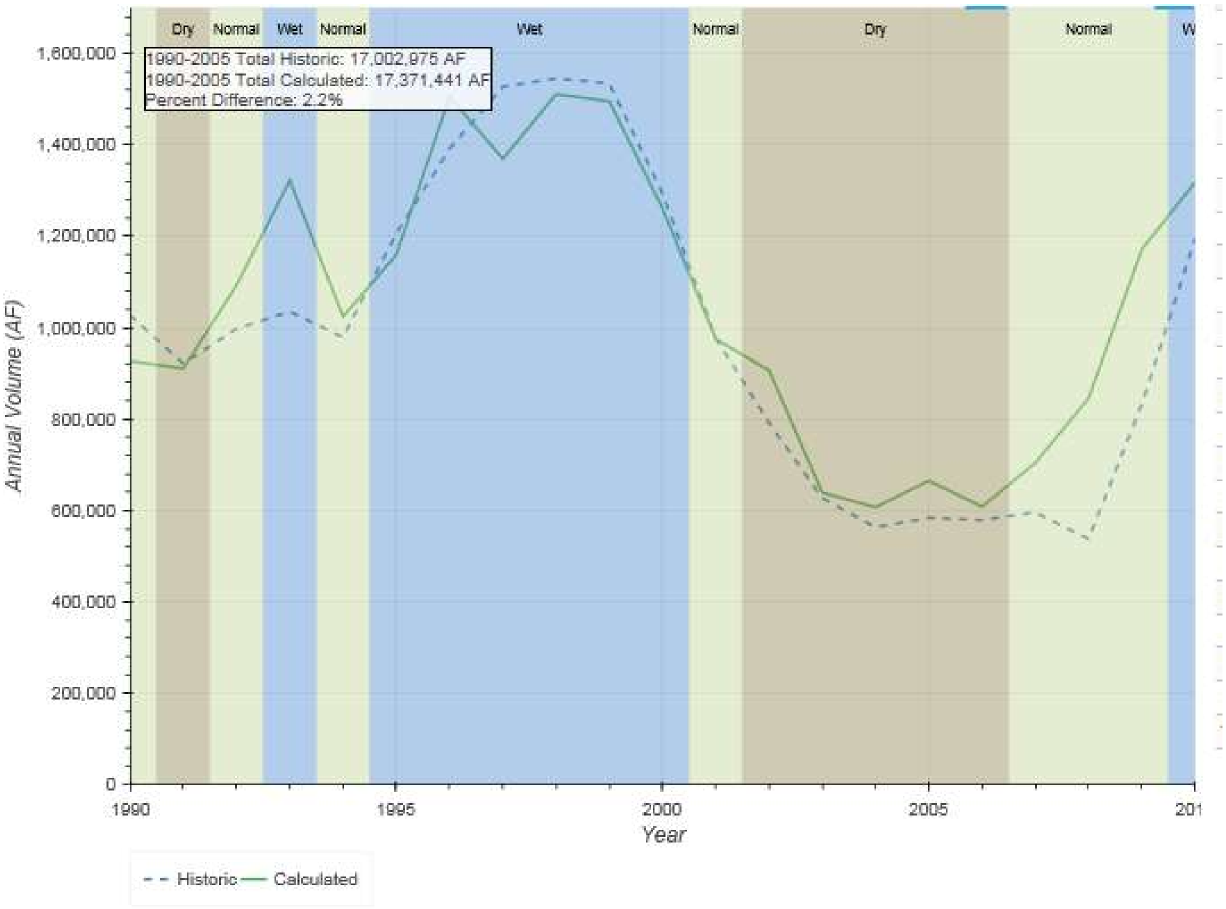
Figure 6.8-5. Gothenburg Canal Annual Diversion Data.



NOTE: The table values provide a summary of the 1990-2005 calibration while the figure includes the 2006-2010 validation period.

Figure 6.8-6. Gothenburg Canal Daily Diversion Data.

Figure 6.8-7 illustrates the annual simulated and historic diversion volumes of the Tri-County Supply Canal and **Figure 6.8-8** illustrates the daily simulated and historic diversion volumes, as well as the cumulative difference.



NOTE: The table values provide a summary of the 1990-2005 calibration while the figure includes the 2006-2010 validation period.

Figure 6.8-7. Tri-County Supply Canal Annual Diversion Data.

NOTE: The table values provide a summary of the 1990-2005 calibration while the figure includes the 2006-2010 validation period.

Figure 6.8-8.Tri-County Supply Canal Daily Diversion Data.

Items of note regarding the diversion and return calibration results.

- The model results generally match historic diversions very well, both on an annual and seasonal basis under varying hydrologic conditions. This indicates appropriate and robust operating rules of the surface water components.
- The simulated annual diversion volumes for irrigation canals generally do not vary to the extremes found in the historic record. This is likely due in part to the approach used in determining crop irrigation demands and should be noted by the user in future applications of the model.

- Within the irrigation and non-irrigation seasons, slight differences between simulated results and historic observations can be found. These are largely due to the use of average values from the calibration period, in whole or part, for factors such as diversion start dates, pre-irrigation season diversion rates, and seepage rates. This also reinforces that the model is not currently capable of serving as a daily systems operations model. For example, the model does not have the ability to reflect daily canal operator response to rainfall events.
- The distribution of crop irrigation demand on a monthly basis generally does not capture the full magnitude of the 4 to 7 day peak demand that typically occurs in late June/early July. In order to capture this magnitude, the crop irrigation demand would require further discretization.

6.8.2.3 Reservoirs

Reservoir calibration focused on the three reservoirs that have substantive operational fluctuations: Lake McConaughy, Sutherland Reservoir, and Elwood Reservoir. **Figure 6.8-9**, **Figure 6.8-10**, and **Figure 6.8-11** illustrate results of the daily simulated and historic storage volumes, as well as the percent difference between simulated and observed storage volumes.

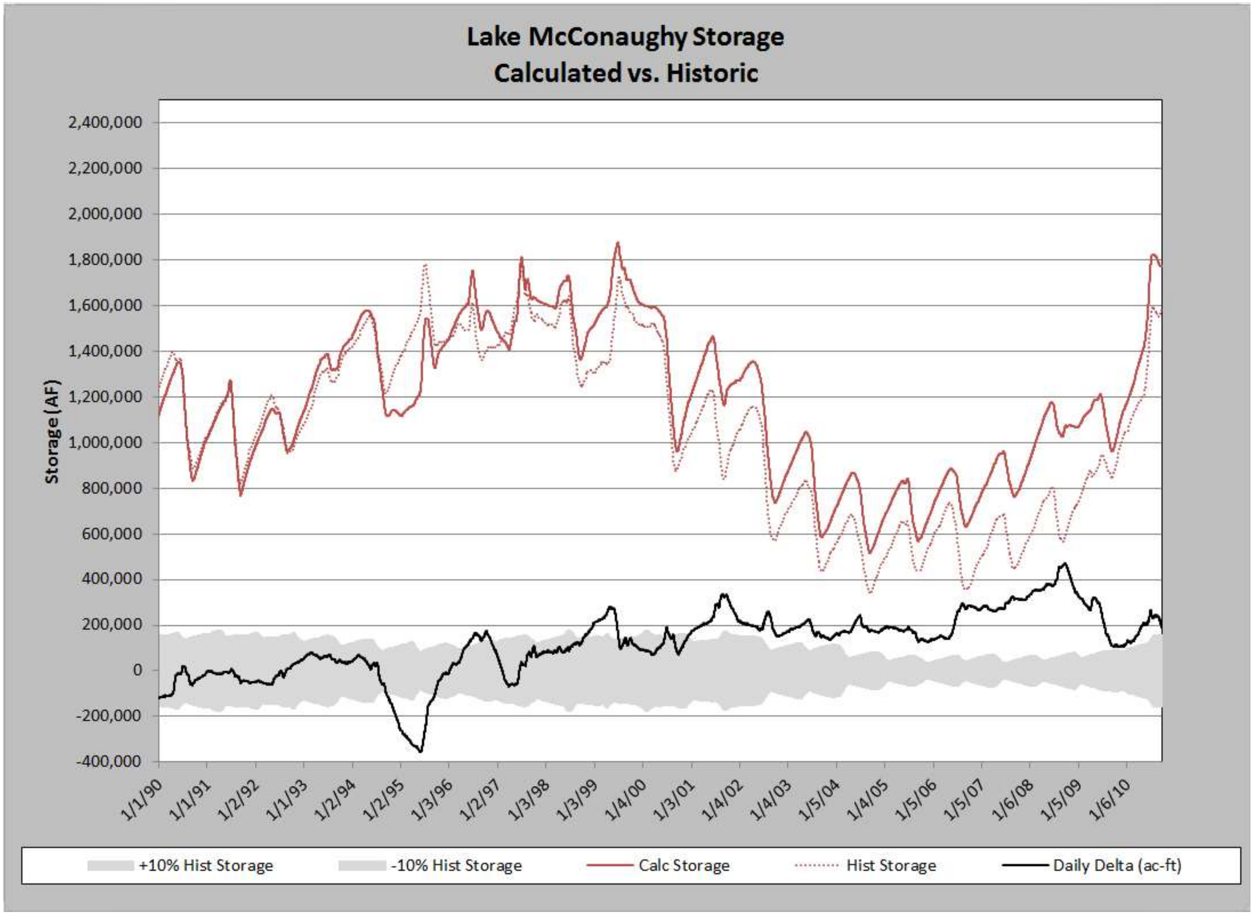


Figure 6.8-9. Lake McConaughy Simulated and Historic Daily Storage.

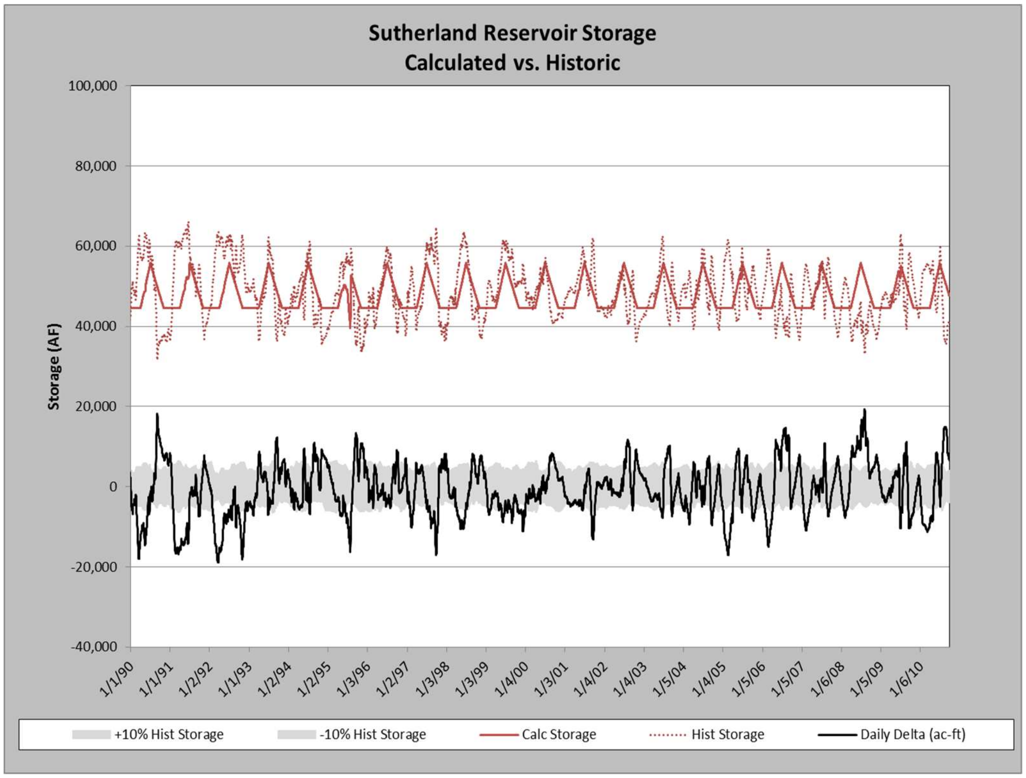


Figure 6.8-10. Sutherland Reservoir Simulated and Historic Daily Storage.

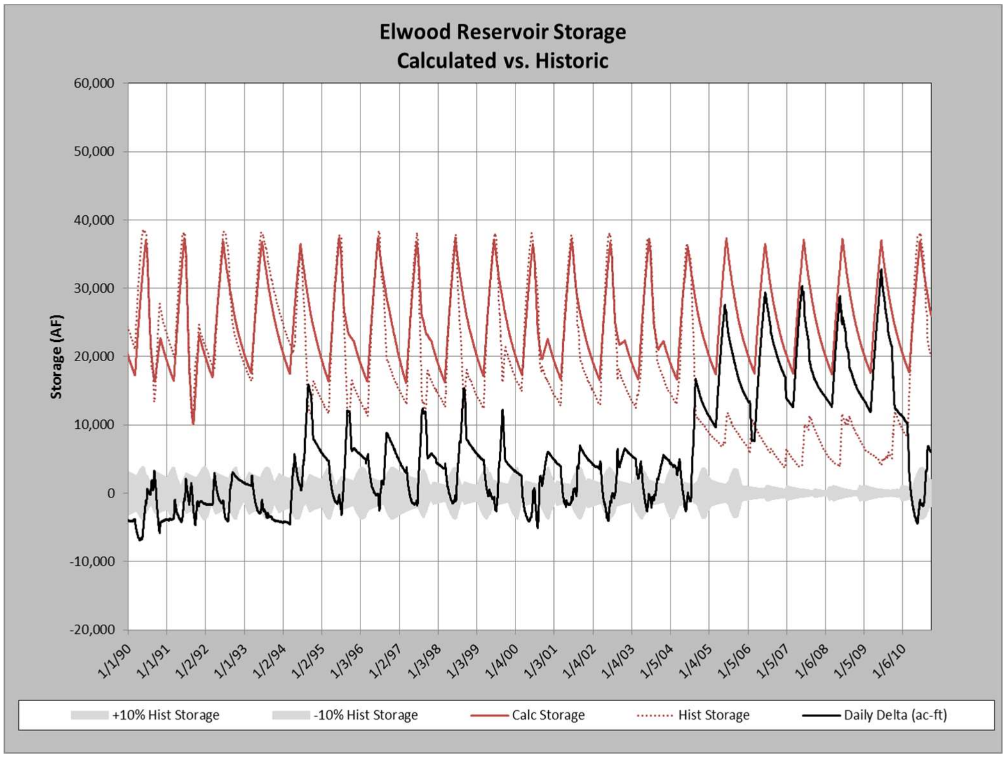


Figure 6.8-11. Elwood Reservoir Simulated and Historic Daily Storage.

The following are items of note regarding the reservoir calibration results.

Lake McConaughy

- Model results are very sensitive to threshold elevations used to determine wet/dry/transitional operations. Adjustments of as little as 20,000 acre-feet in storage thresholds can trigger a mismatched annual operating mode (between historic and simulated) that has ripple effects that can extend for several years.
- The model currently does not have the capability to make mid-year adjustments to operations. During wetter than normal years (such as 1997 and 1999), above average snow pack over the winter resulted in operators increasing releases from Lake McConaughy in early spring to avoid forced releases required by FERC maximum reservoir stage limits. That mid-year adjustment to operations is not simulated in the model, resulting in predicted lower releases in early spring and forced releases later in the year when FERC maximums come into play. This phenomenon impacts not only Lake McConaughy levels, but predicted flows in both the Sutherland Supply Canal and the North Platte River downstream of Lake McConaughy, as can be observed in the Keystone Diversion and North Platte River at Keystone plots.

Sutherland Reservoir

- A set minimum and maximum target operating curve were provided by NPPD in October 2013 for Sutherland Reservoir operations. These replace the previous minimum and maximum bounds with a flat target minimum elevation (EL 3,045) and a variable target operating curve. The target operating curve operates between the previous (pre October 2013) minimum and maximum curves. Model results based on the target operating curve do not necessarily improve the calibrated model results compared to historic observations, but are more representative of current and anticipated operational procedures and are useful in evaluating management scenarios.

Elwood Reservoir

- The simulated reservoir storage volumes during the late irrigation season typically do not decline at the rate or the extent of historical observations. This may be a reflection of underestimating late season crop irrigation demands on E-65 or historic operations within CNPPID's delivery system not currently captured in the operating rule (such as bypassing Tri-County Supply Canal flows past E-65 to serve Phelps and serving E-65 demands to a greater extent from Elwood Reservoir storage).
- The simulation results in 2005 (and beyond) do not include the allocation limits CNPPID placed on irrigation deliveries to surface water irrigators. These allocation limits eliminated the need for supplemental irrigation deliveries from Elwood Storage and therefore historically limited the filling of Elwood Reservoir that occurred in late fall 2004/early spring 2005 (and beyond).

6.8.2.4 Reach-Scale Water Budgets

Several reach-scale annual water budgets were developed where adequate gage data were available to assess model performance. These water budgets were used to compare modeled results with historic observations, as well as inform parameter adjustments necessary for better overall model performance. These reach-scale water budgets included the following:

- North Platte River (Lake McConaughy Release/Keystone Diversion/North Platte River at Keystone).
- North Platte River – Keystone to North Platte reach.
- Sutherland System.
- North Platte River at North Platte.
- Tri-County Canal System.

Results for these reach-scale water budgets are included in **Appendix 6-K** and include annual tabular data as well as plots of annual data for the simulation period. **Figure 6.8-12** illustrates results of the annual simulated and historic volumes for the Sutherland System. **Figure 6.8-13** illustrates results of the annual simulated and historic volumes for the Tri-County Canal System.

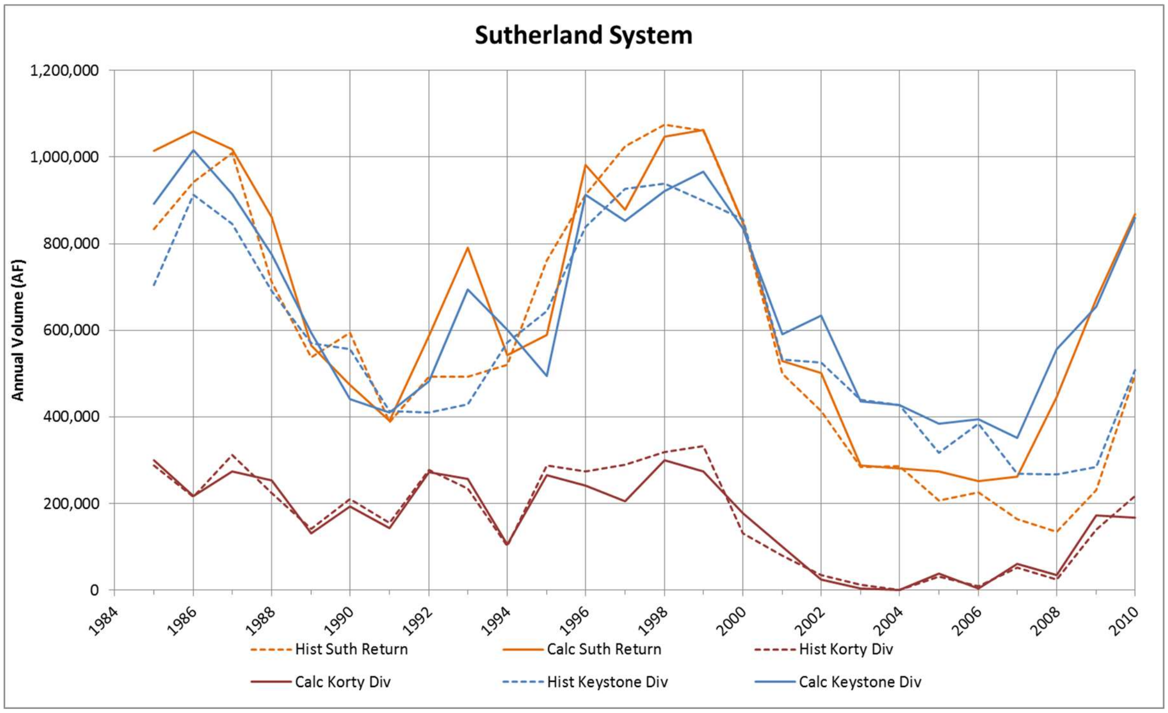


Figure 6.8-12 Reach-scale Annual Water Budget for Sutherland Canal System.

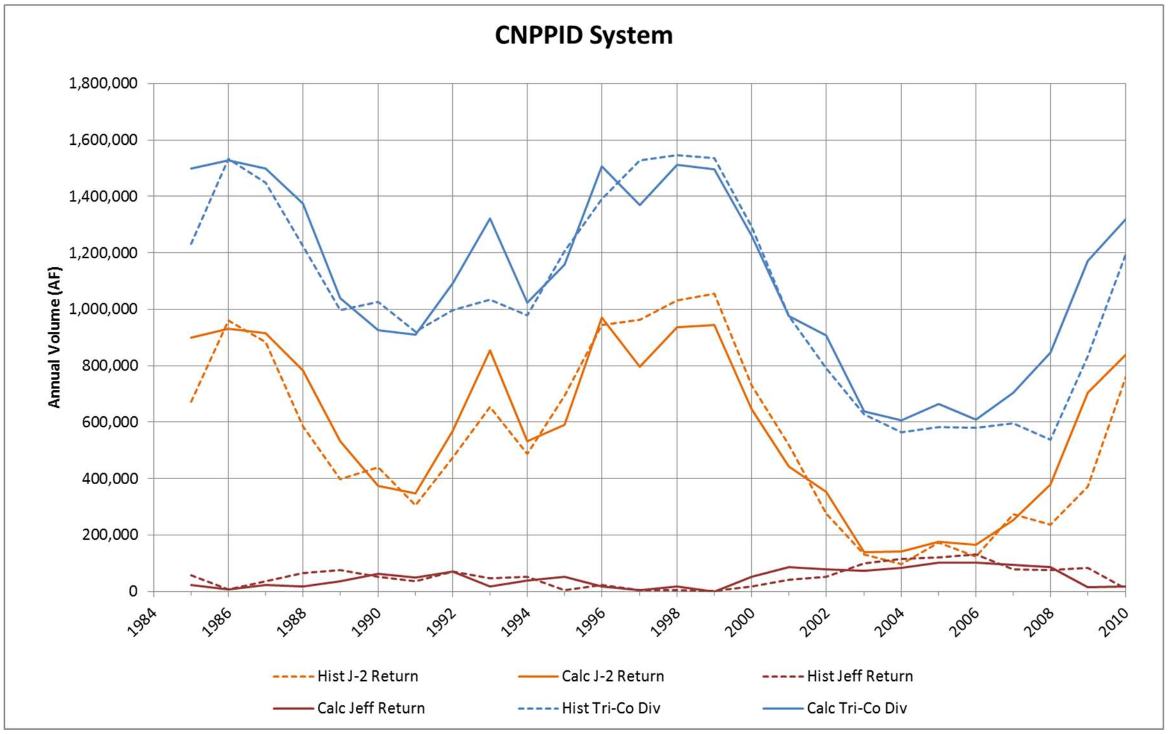


Figure 6.8-13 Reach-scale Annual Water Budget for Tri-County Supply Canal System.

Items of note regarding the reach-scale water budgets include the following:

- The model captures annual trends very well under varying hydrologic conditions. This indicates appropriate and robust operating rules of the surface water components.
- The reach-scale water budgets balance, indicating that water is appropriately accounted for in each of the reaches and the water balance is not compromised.
- The model currently underestimates surface water losses to the Platte River system (via seepage, evaporation, or irrigation delivery) on the Sutherland System (183,000 AF total, approximately 1% of the cumulative diversion volume) and overestimates the surface water losses to the Platte River System on the Tri-County canal (747,000 AF total, approximately 3% of the cumulative diversion volume) systems.

6.8.2.5 North Platte Focus Study

The irrigational canal system of the North Platte River is highly interdependent, both physically and operationally. Returns and drains of one canal may directly and immediately affect adjacent diversions, or may be used to more efficiently convey water to the downstream diversion. Operations of the canals are closely coordinated to maximize beneficial use of flows in the North Platte River. Because of the complexity of this network of canals and their sometimes coordinated operation, a focus study effort was conducted with the intent to: (1) diagnose the model and data to determine what is not being represented and simulated in a realistic, technically sound manner, and (2) formulate revisions to the model that will achieve a suitable calibration. This focus study effort was concentrated on the North Platte River below Lake McConaughy, but the results and concepts determined from the focus study effort informed calibration efforts in the remaining model domain. Some of the key findings from this study that were incorporated into the modeling effort include adjusting runoff parameters, informing return percentages, and setting three distinct canal diversion patterns to reflect changes in operations.

A memorandum summarizing the North Platte Focus Area study in more detail is included in **Appendix 6-L**.

6.8.2.6 Water Priority System

The priority logic enables the model to “color” the water throughout the system and quantify the amount of natural flow and storage water at nodes along the river. **Figure 6.8-14** shows the historic and calculated natural flow, storage water and total diversions for Gothenburg Canal.

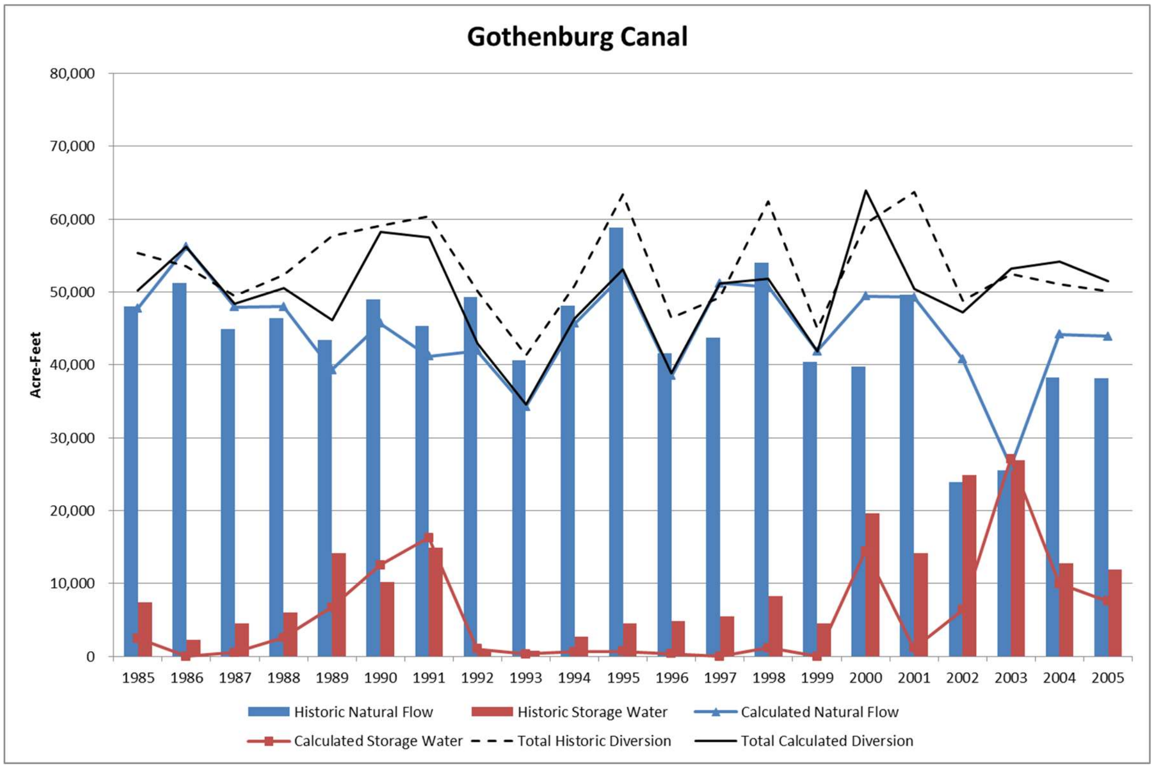


Figure 6.8-14 Gothenburg Canal – Historic and Calculated Natural Flow, Storage Water and Total Diversions.

The total calculated diversions are typically less than the total historic diversions, which also partially explains the discrepancy in historic and simulated storage and natural flow diversion volumes. In general the simulated storage and natural storage diversion model match the historic pattern.

6.8.2.7 PRRIP Effort

A separate task was authorized by the COHYST Sponsor Group concurrent with the model development, partially as a test of the model capabilities and limitations. This task primarily focused on the inclusion and analyses of two proposed Platte River Recovery Implementation

Program (PRRIP) projects using the STELLA surface water operations model: 1) J2 regulating reservoir; and 2) Phelps Canal recharge project. The surface water operations model was extended in this effort to include the 1947-2010 time period. The ultimate goals of this effort were to test overall model functionality and to compute project scoring of the proposed projects based on the reduction in target flow shortages in the central Platte River reach.

Appendix 6-M is a technical memorandum that documents the modeling efforts and results completed for this effort.

6.9 Summary

The purpose of the surface water model is to simulate the operations of present day surface water components within the Central Platte Valley (reservoirs, river, and canals) and calculate the water budget terms of these components of the surface water system. The 1985-2010 time period was used in developing the model, while the truncated 1990-2005 period was used for model calibration. The time period 2006-2010 was considered model validation.

Operating rules have been developed through model calibration based on historic operations for each surface water component. These rules approximate the operational/water management decisions that are made on a regular basis and significantly affect flow conditions in the Platte River; routing flows through the modeled reach, appropriately storing, releasing, diverting, returning or discharging flows through the surface water network. The calibration of these rules has been evaluated against observed reservoir, diversion and Platte River flow data to evaluate model function and avoid systemic errors in the simulation results.

Calibration of the surface water model was accomplished through comparison of simulated and historical observations for the 1990-2005 period. The primary calibration targets consisted of main stem stream gages, canal diversions (and gaged returns), reservoir stages, and ‘mini-water’ budgets of the North Platte River at the Keystone Diversion, North Platte River at North Platte, the Platte River at the confluence of the North and South Platte Rivers, and the Sutherland and Tri-County systems.

Daily, monthly, seasonal, annual, wet/dry/normal hydrologic conditions, and cumulative values were evaluated. In addition, cumulative difference analyses were included to determine if systemic errors were present in the model simulations.

The cumulative percent difference between modeled and historic stream gage observations for the calibrated time frame 1990-2005 ranges from -26 % to +6 %, with the cumulative difference for the majority of gage locations within +/- 2%. The cumulative percent difference between simulated and historic diversion volumes during 1990-2005 are within +/- 5%, with the cumulative difference for the majority of diversions within +/- 3%.

The results of the reach-scale water budgets show the model captures annual trends very well under varying hydrologic conditions. This indicates appropriate and robust operating rules of the surface water components. The reach-scale water budgets balance, indicating that water is appropriately accounted for in each of the reaches and the water balance is not compromised.

Overall, the surface water model, and the operational rules contained therein, is producing results that are considered reasonable. The model is capable of accurately reflecting the key water budget components of the Central Platte River system, both in magnitude and trend, under a range of flow and climatic conditions. The model construction and calibration provides the Sponsors a useful tool that can be used to determine effects of future changes (hydrologic, operational, and physical) in the system on the water budget components of the Central Platte River.

Future recommendations for the surface water model include:

- Irrigation Canal Returns – Evaluate the effects for temporal variation in canal returns.
- Lake McConaughy Operations – Improve operating modes during transitional periods to allow mid-year changes in operational patterns.
- Priority Accounting – Allocate losses to surface water and natural flows and limit diversions based on priorities (as has been done in the Conjunctive Management model).

- PRRIP Environmental Account – Represent EA (accounting and releases) in Lake McConaughy.
- Integrated Model Performance During Wet Periods – Significant improvements have been made during the drought years, but as a result, the results in wet years are worse– Improve the wet years' performance while maintaining the dry years' performance – if deemed necessary.