Niobrara River Basin Study

Appendix C — Upper Niobrara-White Surface Water Operations Modeling

U.S. Department of the Interior

Nebraska
Department of Natural Resources
Lincoln, Nebraska

April 2015

Mission Statements

Department of the Interior

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Nebraska Department of Natural Resources

The Nebraska Department of Natural Resources is dedicated to the sustainable use and proper management of the State's natural resources.

On cover: Niobrara River channel in July 2006 near Mirage Flats. Photo by Nebraska Department of Natural Resources.

Niobrara River Basin Study

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Upper Niobrara-White Surface Water Operations Modeling

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Nebraska

U.S. Department of the Interior

Department of Natural Resources
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April 2015

Executive Summary

Purpose, Scope and Objectives

The Niobrara River Basin Study (Basin Study) is a collaborative effort by the Nebraska Department of Natural Resources (NDNR) and the US Bureau of Reclamation (Reclamation), which is authorized under the SECURE Water Act (Title IX, Subtitle F of Public Law 111-11). The purpose of Niobrara River Basin Study is to evaluate current and projected future water supply and demand and evaluate potential adaptation strategies which may reduce any identified gaps as part of the Water Sustain and Manage America's Resources for Tomorrow (WaterSMART) Program.

The purpose of this report is to describe the role, development, and calibration of the surface water operations model using the STELLA software package. The surface water operations model was developed for the Basin Study to be used as a part of the integrated modeling approach described in Appendix F, Integrated Water Management Model Report.

Model Purpose

The purpose of the surface water operations model is to simulate the present day surface water components of the Niobrara River surface water system from the Nebraska State Line to the Gordon gaging station (reservoirs, river, and canals) and calculate the water budget terms of these components for the surface water operations system.

Operating rules have been developed through model calibration based on historical operations for each surface water component. These rules represent the daily operational/water management decisions that are made on a daily basis and largely dictate flow conditions in the Niobrara 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 Niobrara River flow data.

Model Setup

Physical elements of the surface water operations model system represented in the STELLA model include: the main stem river reach of the Niobrara River; irrigation canal diversions, and reservoirs. Figure ES-1 spatially illustrates the key Niobrara River gages, canal diversions, and Box Butte reservoir represented in the STELLA model.

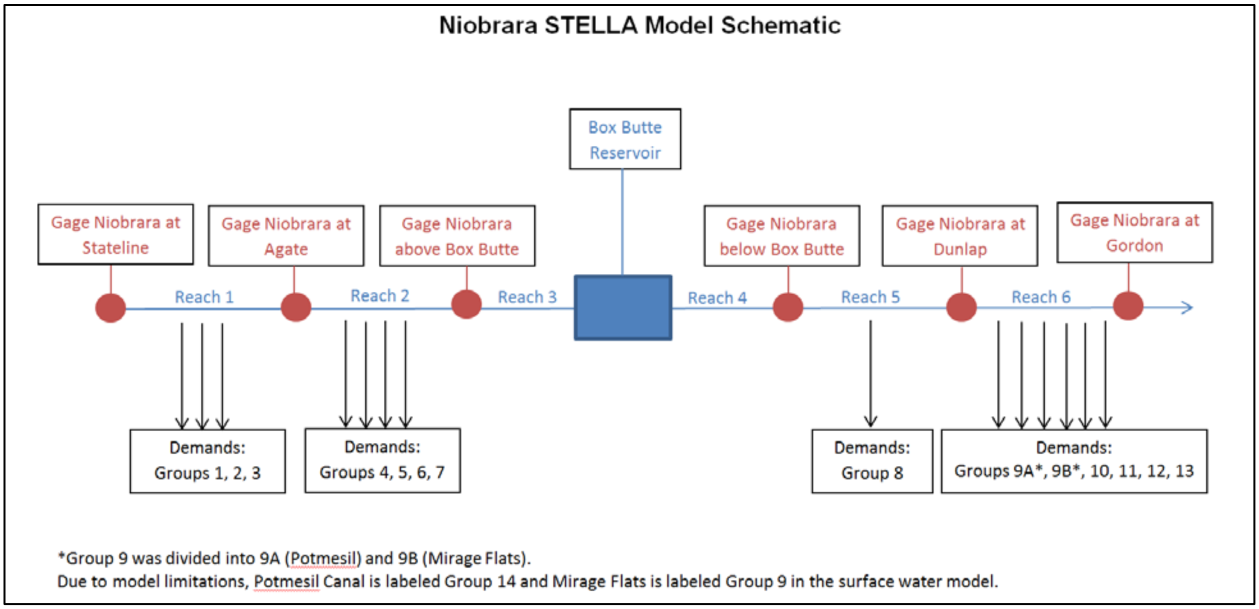

Figure ES-1. Niobrara River STELLA nodes.

Water Budget Elements

The STELLA model's simulation of the water budget elements relevant to the surface water system include reach gains/losses, seepage, precipitation/ evaporation, and crop deliveries.

For the development and calibration of the surface water operations model, historical daily reach gains/losses (RGL) were computed for each reach utilizing available historical stream and diversion gage data. The calculated daily reach gain/loss values are a lumped quantity that represents the river evaporation and transpiration losses, watershed runoff, canal returns (if any), and baseflow gains occurring within the reach. The calculated historical 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.

Computed seepage volumes for the major canals and the reservoir are assumed to be distributed evenly over the area of the reservoir/length of the canal reach, respectively, and communicated to the groundwater model by grid cell for developing a recharge file in the integrated model.

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, Box Butte reservoir, and the main stem reach of the Niobrara River.

Crop deliveries for surface water canals were computed based on crop demands of surface water on irrigated lands served by each canal 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.

Model Parameters and Input

The 1958-2010 time period was used in developing the model and 1980-1990 was used for model calibration. 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.

Historical observations were used to set reservoir initial conditions for the simulation. The boundary conditions consist of inflow to the Niobrara River. The Niobrara at Stateline gage historical daily flows were used for the Niobrara River inflow boundary conditions.

System Operational Rules

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

- obtaining general operational descriptions from the owner/operators
- development of a logic-based operating rule to represent general operational descriptions
- evaluation of results and adjustment of triggers/criteria/rules to better reflect historical observations
- review of operating rule and evaluation of simulation results with owner/operators
- refinements to the operating rule

The operational rules were defined to represent operational characteristics of reservoirs, diversions, and canal returns. Rules are intended to represent present day operations.

The operational rules for the irrigation canals were developed based on historical diversion patterns, estimated efficiencies (seepage rates, evaporation, crop demands, canal returns, etc.) physical diversion capacity, and flow available for diversion. The canal diversions were grouped by reach and the groups are shown in Figure ES-2. During calibration, the appropriation for each canal was used for the demand. A constant group demand based on each canal/diverter appropriation and demand adjustment is applied during June, July and August.

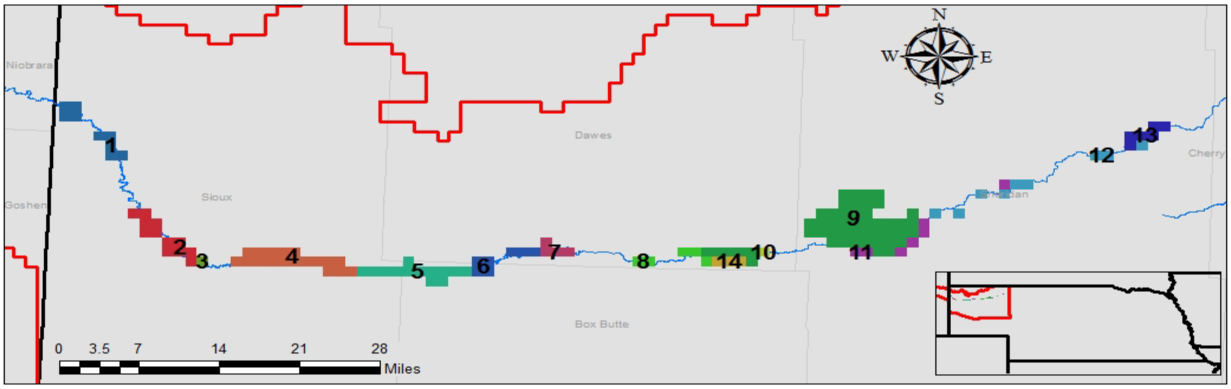

Figure ES-2. UNW surface water irrigation groups.

The authorized purposes of Box Butte Reservoir are to provide storage for irrigation, recreation, fish and wildlife, and sediment control. The primary purpose of the reservoir is the delivery of water from the storage space for irrigation purposes. Box Butte Reservoir is not a flood control reservoir.

Model Calibration

Calibration of the surface water operations model was accomplished through comparison of simulated and historical observations for the 1980-1990 period. The primary calibration targets consisted of main stem stream gages and gaged canal diversions.

The model has been calibrated first on a reach basis and then to specific canal group. Reach 1 (canal groups 1, 2, and 3) and Reaches 5 and 6 (groups 8 and 9) were calibrated this way because of the relatively complete diversion data for these two reaches. Figure ES-3 shows the calibration plots for Reach 1 including groups 1, 2, and 3. The reach calibration plot shows the historical diversion and the model calculated diversion data. The calibration plot for the Mirage Flats (Group 9B) is shown in Figures ES-4. In the group calibration plot, the full appropriation diversion rate is shown, as well as the historical diversion data, and model calculated diversion data. The model calculated diversion data mimics the historical diversion data and the lines are often indiscernible. More reach and group calibration plots are shown in Section 1.7.

Figure ES-5 is the calibration plot at the Niobrara River below Box Butte gage. Illustrated is the historical, calculated, and cumulative difference. Cumulative differences for all of the gages range from roughly 4% to 12%.

Systemic trends can be observed in the cumulative difference plots, largely in the non-irrigation season. This is largely due to the calculated reach gain losses used which includes canal diversion data in the computation of RGL and many of the historical datasets have diversion data in the non-irrigation season.

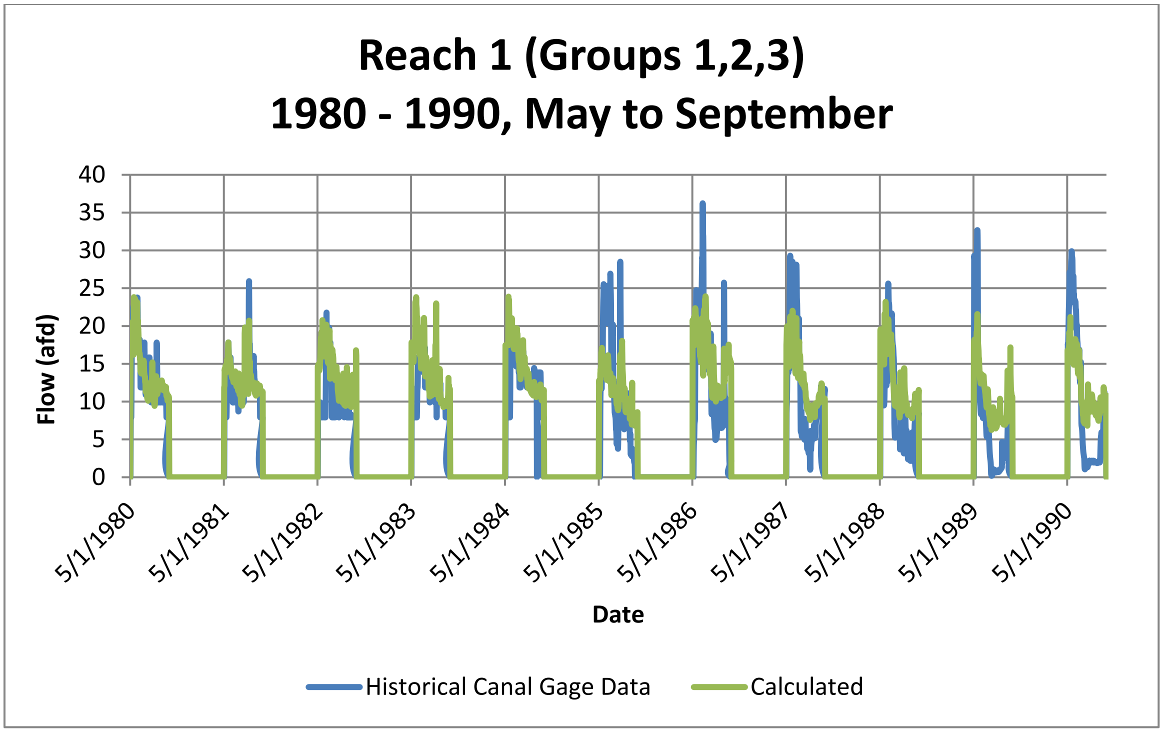

Figure ES-3. Reach 1 calibration plot.

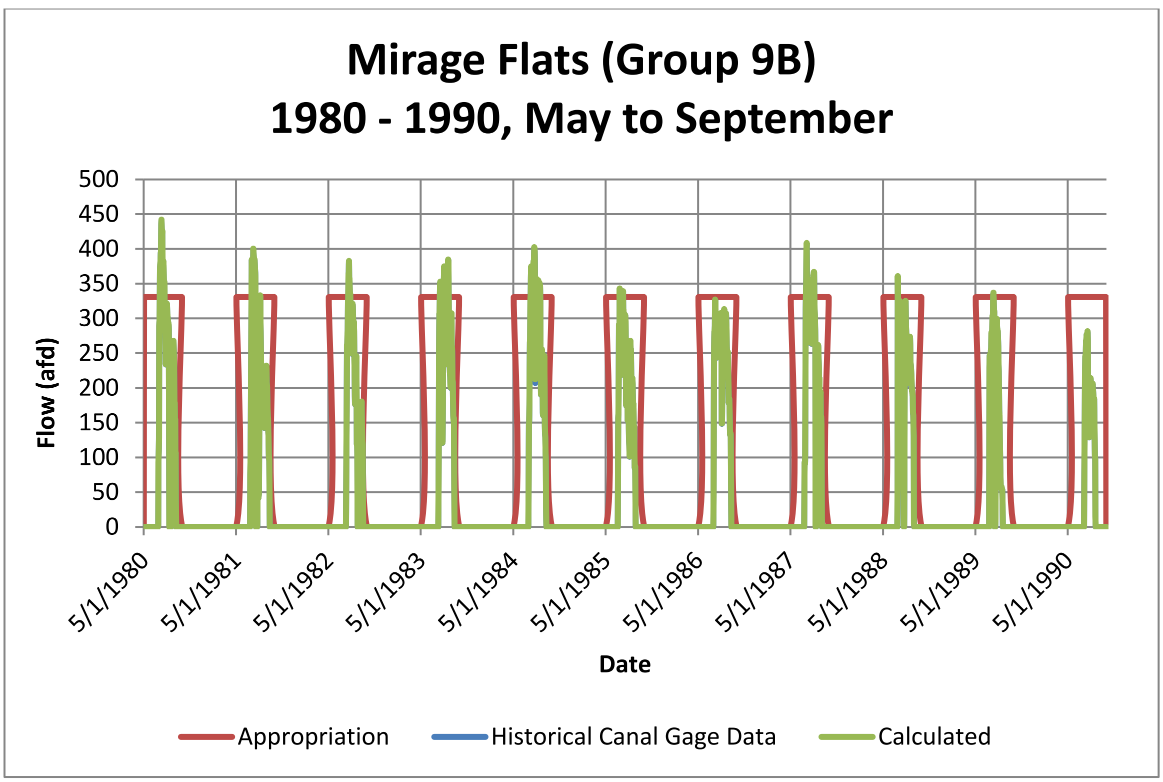

Figure ES-4. Mirage Flats (Group 9B) calibration plot.

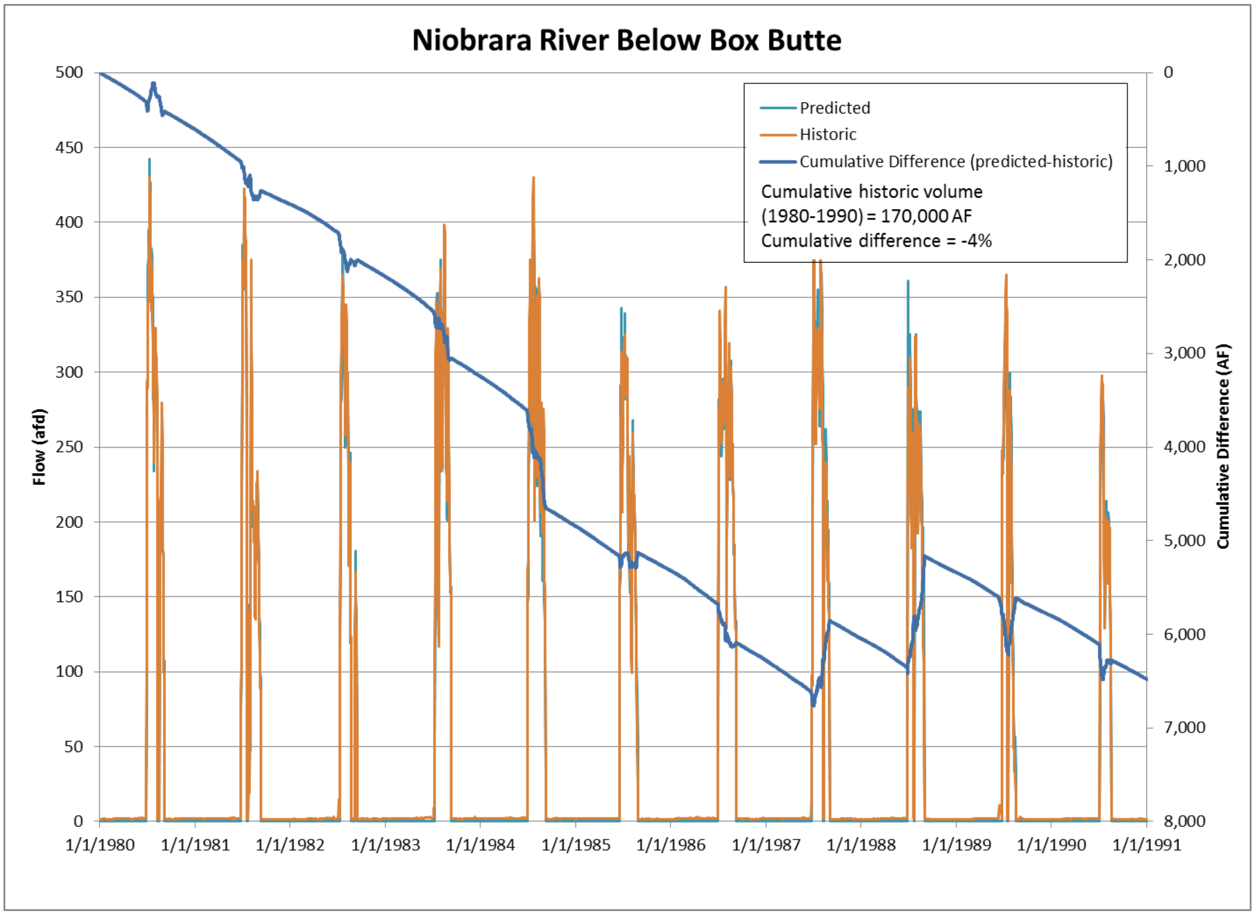

Figure ES-5. Niobrara River below Box Butte calibration plot.

The Niobrara River below Box Butte cumulative difference shows a consistent under prediction of flows during the non-irrigation season that result in the consistent downward trend in the cumulative difference. It is a very small amount, about 1-2 cfs a day (600 AF per year, 6000 AF over the calibration period – largely explains total cumulative difference). This could be gate leakage, reach gains over this short reach, or intentional release.

More calibration plots with the cumulative difference for other Niobrara River gages are shown in Section 1.7.

Contents

Figures

Tables

Acronyms

AFD	Acre-feet per day
NDNR	Nebraska Department of Natural Resources
RGL	Reach Gains/Losses
UNW	Upper Niobrara–White model region (includes Upper Niobrara-White Natural Resources Districts)
WaterSMART	Water Sustain and Manage America's Resources for Tomorrow

1 Introduction

The purpose of this report is to describe the role, development, and calibration of the surface water operations model using the STELLA software package. The surface water operations model was developed for the Niobrara River (from Nebraska State Line to the Gordon gage) to be used as a part of the integrated modeling approach described in Appendix F, Integrated Water Management Model Report.

2 Model Purpose

The purpose of the surface water operations model is to simulate the present day surface water components of the Niobrara River surface water system from the Nebraska State Line to the Gordon gaging station (reservoirs, river, and canals) and calculate the water budget terms of these components for the surface water system.

Operating rules have been developed through model calibration based on historical operations for each surface water component. These rules represent the daily operational/water management decisions that are made on a daily basis and largely dictate flow conditions in the Niobrara 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 Niobrara River flow data.

The surface water operations model is completely ‘rules-driven’, that is the only historical inputs are the daily Niobrara at Stateline inflows at the upstream end of the modeled reach. Once these flows have entered the modeled reach, their path 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 or operational changes.

3 STELLA Model Description

The surface water system is represented using the modeling software STELLA (Version 9.1.4) 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 inflow 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, calculated 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 define logical functions.

An illustrative example of the STELLA model components is shown in Figure 1 for the Box Butte area.

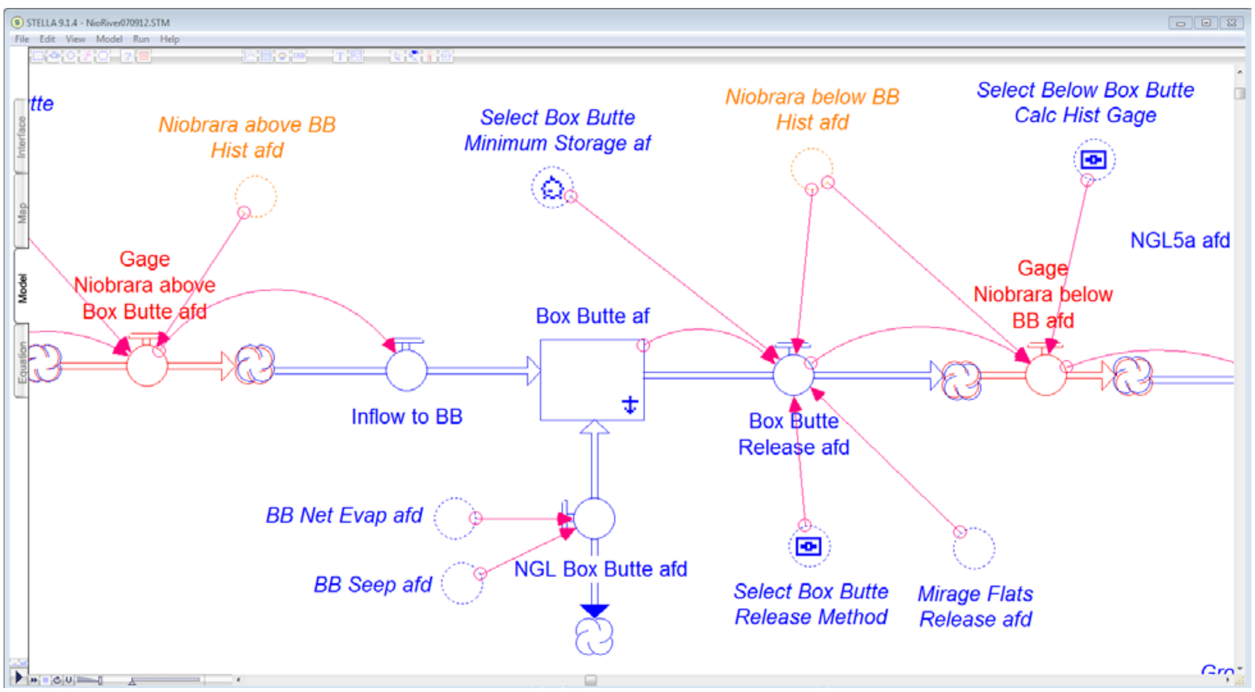

Figure 1. STELLA schematic for the Box Butte area.

Other model components, 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 equations logic with numerical inputs (see Figure 2).

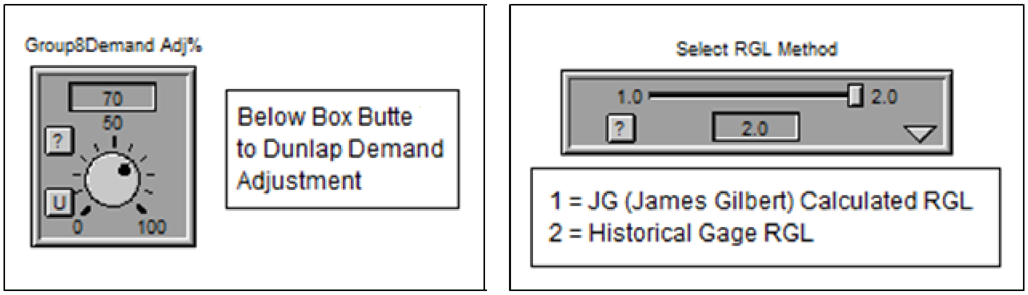

Figure 2. Example of STELLA knobs and sliders.

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. Attachment A contains topographic mapping of the modeled extent of the Niobrara River with STELLA node locations identified, and Attachment B contains the STELLA schematic representation of the surface water elements of the Niobrara River.

A core concept of the surface water operations model is the use of logic-based rules to simulate management decisions in routing flows through the system. The development of these rules for each type of surface water element is described in further detail in Section 1.6. The calibration of the surface water operations model then focused on refinements to these rules to match historical observations and avoid systemic errors in simulation results.

4 Physical Elements of the Niobrara River System

Physical elements of the surface water operations model system represented in the STELLA model include: the main stem river reach of the Niobrara River; irrigation canal diversions, and Box Butte reservoir.

Figure 3 spatially illustrates the key Niobrara River gages, canal diversions, and Box Butte reservoir represented in the STELLA model. STELLA nodes were included at each gage location along the Niobrara River main stem and include the following:

- USGS gage 6454000, Niobrara River at Wyo-Nebr State Line
- USGS gage 6454100, Niobrara River at Agate, NE
- USGS gage 6454500, Niobrara River above Box Butte Reservoir, NE
- USGS gage 6455500, Niobrara River below Box Butte Reservoir, NE
- USGS gage 6455900, Niobrara River at Dunlap, NE

- USGS gage 6457500, Niobrara River at Gordon, NE

STELLA nodes were also included in the model to represent points of surface water diversion for irrigation, as well as intermediate locations along the Niobrara River main stem where either flow changes may occur or specific information is desired from the model.

Because of the number of diversions and relatively small size of many of the diversions, multiple canals/appropriators were aggregated and applied at a single node along the main stem reach. Table 1 summarizes the grouping of the surface water irrigation diversions. Mirage Flats (Group 9) is the largest diversion. As shown in Table 1, the appropriation for Mirage Flats is 167 cfs, and the next biggest appropriation is 9.67 cfs for Harris/Neece (Group 4). For the Box Butte reservoir, elevation-area-volume data is incorporated into the STELLA node to represent the physical attributes of the reservoir.

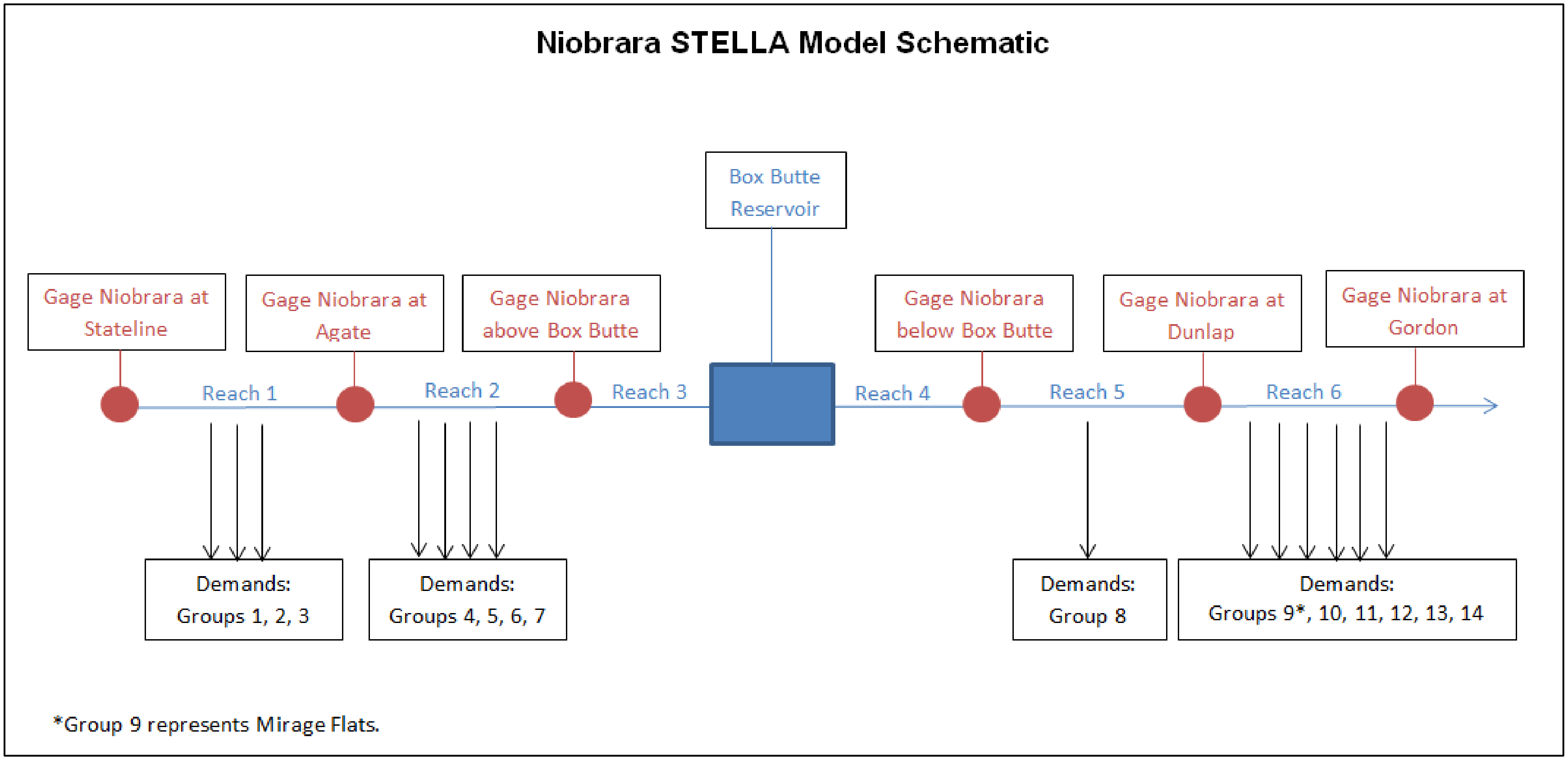

Figure 3. Niobrara River STELLA nodes.

Table 1. Grouping of Irrigation Canal Demands

Group	Demands	Appropriation (cfs)
Group 1	Dout Hoover	0.96
	Johnson	2.09
	Lakotah	5.76
Group 2	Earnest 1	2.86
	Earnest 2	3.6
	McGin N	5.06
	McGin S	1.34
	McGinCook	0.16
Group 3	Cook	2.31
	McGinPump	1.48
	Cook Pump	0.52
Group 4	ManningPump	0.39
	BennettKay	3.45
	HarrisNeece	9.67
	Labelle	3.67
	Mettlen	4.37
Group 5	Moore	5.71
	Geohitshew	2.76
	Hitshew	0.60
	McLaughlin	3.69
	Excelsor	4.78
	Hughes	0.57
Group 6	Hollibaugh	1.34
	Lees	4.93
	CrowButte	0.02
	Pioneer	3.82
Group 7	Klaes	2.2
	Campbell	1.63

Group	Demands	Appropriation (cfs)
Group 8	Desling	1.02
	Montague	2.15
	Lichte	4.03
	Iodence	0.42
Group 9	MirageFlats	167.0
Group 10	A18389	1.50
	A18168	2.16
	A12893	1.04
Group 11	A5531	2.64
	A17398	5.37
	Carlson	0.65
	Terrell	1.59
	A5854	1.46
	A10432	0.96
	A10490	0.66
	A8216	1.21
	A10761	0.17
	A4717	0.17
Group 12	A9018	0.77
	A2654	0.90
	A9017	1.16
	A9572	1.77
	A7871	1.05
	A7477	1.33
	A5467	0.30
	A9838	0.53
Group 13	A2555	0.96
	A4603	2.03
	A2623	0.34
Group 14	Potmesil	7.79

5 Water Budget Elements

This section describes the STELLA model's simulation of the water budget elements relevant to the surface water system.

5.1 Reach Gain/Loss

For the development and calibration of the surface water operations model, historical daily reach gains/losses (RGL) were computed for each reach utilizing available historical stream and diversion gage data. A toggle was added to the STELLA model which allows the user to use one of two RGL terms – one developed by NDNR to estimate baseflow, the other computed by HDR using historical gage information. The calculated daily reach gain/loss values are a lumped quantity that represents the river evaporation and transpiration losses, watershed runoff, canal returns (if any), and baseflow gains occurring within the reach. Minor canals are not explicitly represented in the model but are represented in the watershed runoff component of the reach gain/loss. The calculated historical reach gains/losses were split into four reaches for consistent period of record and were partitioned along the reaches, weighted by reach length. The calculated historical 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.

5.2 Seepage

Computed seepage volumes for the major canals and the reservoir are assumed to be distributed evenly over the area of the reservoir/length of the canal reach, respectively, and communicated to the groundwater model by grid cell for developing a recharge file in the integrated model.

5.3 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, Box Butte reservoir, and the main stem reach of the Niobrara River. Surface areas for major canals and river reaches were computed based on reach lengths and constant, typical top widths estimated from aerial mapping and operator input. The reservoir surface area is dependent on stage and is based on the stage-area-elevation data. Box Butte Net evaporation (afd) daily values were derived from monthly historical data for January 1979 to September 2009. For January 1958 to December 1978 and October 2009 to

December 2010, the monthly historical average of the period of record was used to obtain a daily net evaporation value.

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 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. As mentioned previously, surface water demands were aggregated to node locations. The model has group demand adjustment knobs for each group that allows the demands to be adjusted on a percent basis. The knob can be set to a percentage value and that percentage is multiplied by the demand to lower the demand. The adjustment knobs were used in the calibration effort.

6 Model Parameters and Inputs

6.1 Simulation Period and Computational Time Step

The 1958-2010 time period was used in developing the model and 1980-1990 was used for model calibration. 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 operations model performance during calibration.

6.2 Initial and Boundary Conditions

Historical observations were used to set reservoir initial conditions for the simulation. The boundary conditions consist of inflow to the Niobrara River. The Niobrara at Stateline gage historical daily flows were used for the Niobrara River inflow boundary conditions.

6.3 Travel Time

Time lags were included in the STELLA model to represent travel time as flows are routed through the system. There is a total of 3 days lag through the system, 1 day for between Stateline and Agate, 1 day for between Agate and above Box Butte, and 1 day for between Box Butte and Gordon. The modeled reach is partitioned into 6 reaches. The reaches are listed in Table 2.

Table 2. Stella Model Reach Locations and Group Demands

Reach	Location	Demands
Reach 1	Stateline to Agate	Groups 1, 2, 3
Reach 2	Agate to Above Box Butte	Groups 4, 5, 6, 7
Reach 3	Above Box Butte to Box Butte Reservoir	None
Reach 4	Box Butte Reservoir to Below Box Butte	None
Reach 5	Below Box Butte to Dunlap	Group 8
Reach 6	Dunlap to Gordon	Groups 9, 10, 11, 12, 13, 14

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 operations model. These operational rules were developed through an iterative process involving:

- obtaining general operational descriptions from the owner/operators
- development of a logic-based operating rule to represent general operational descriptions
- evaluation of results and adjustment of triggers/criteria/rules to better reflect historical observations
- review of operating rule and evaluation of simulation results with owner/operators
- refinements to the operating rule

The operational rules were defined to represent operational characteristics of reservoirs, diversions, and canal returns. Rules are intended to represent present day operations. If historical operations are known to vary from current operational protocols, identifying these will assist the calibration. These variations are noted and specific rules to reflect historical operations were not developed.

7.1 Irrigation Canals

The operational rules for the irrigation canals were developed based on historical diversion patterns, estimated efficiencies (seepage rates, evaporation, crop demands, canal returns, etc.) 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 and owner/operator input. Once flow is diverted into the canal it is partitioned to seepage, evaporation, and crop deliveries (during the irrigation season).

Diversion Season

The canal diversions were grouped by reach and the groups are shown in Figure 4. During calibration, the appropriation for each canal was used for the demand. A constant group demand based on each canal/diverter appropriation and demand adjustment is applied during June, July and August.

7.2 Box Butte Reservoir

The authorized purposes of Box Butte Reservoir are to provide storage for irrigation, recreation, fish and wildlife, and sediment control. The primary purpose of the reservoir is the delivery of water from the storage space for irrigation purposes. Box Butte Reservoir is not a flood control reservoir. Figure 5 from the Box Butte Reservoir Resource Management Plan depicts the reservoir capacity allocations (storage capacity in relation to water elevations).

A toggle was added to give options for the Box Butte releases. The toggle allows the user to use historical release or two calculated release options. The calculated release options are Mirage Flats Historical Diversion or the sum of Mirage Flats Appropriation, Potmesil Appropriation, Group 8 Appropriation and reach gains/losses. The calibration model run uses the sum of Mirage Flats Appropriation, Potmesil Appropriation, Group 8 Appropriation and reach gains/losses. Figure 5 summarizes the physical properties (storage and surface area) defined in the STELLA model. The “BOR Storage” data points shown in Figure 6 are the end of month elevation and storage data from BOR that were available for Box Butte Reservoir for October 1971 to September 2010.

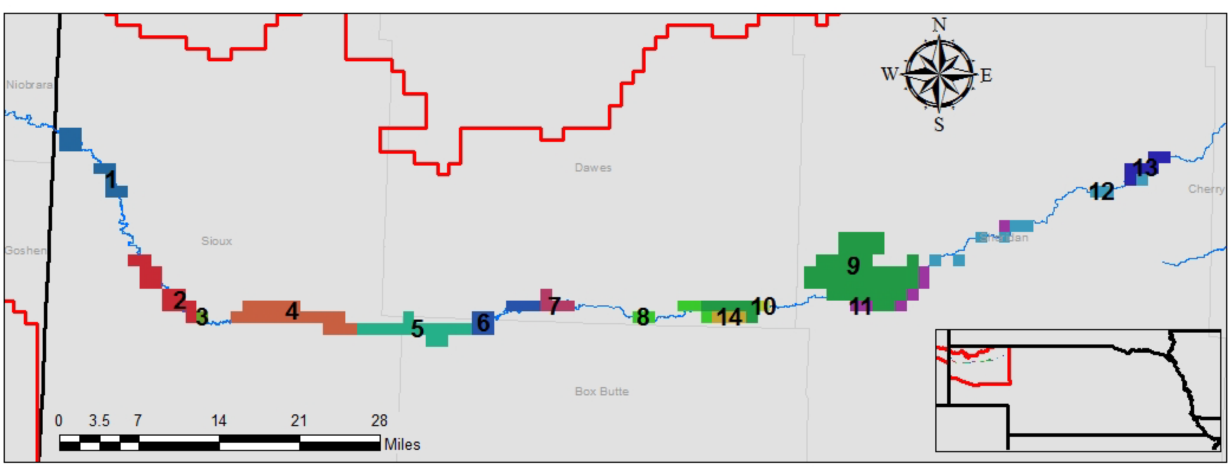

Figure 4. UNW surface-water irrigation groups.

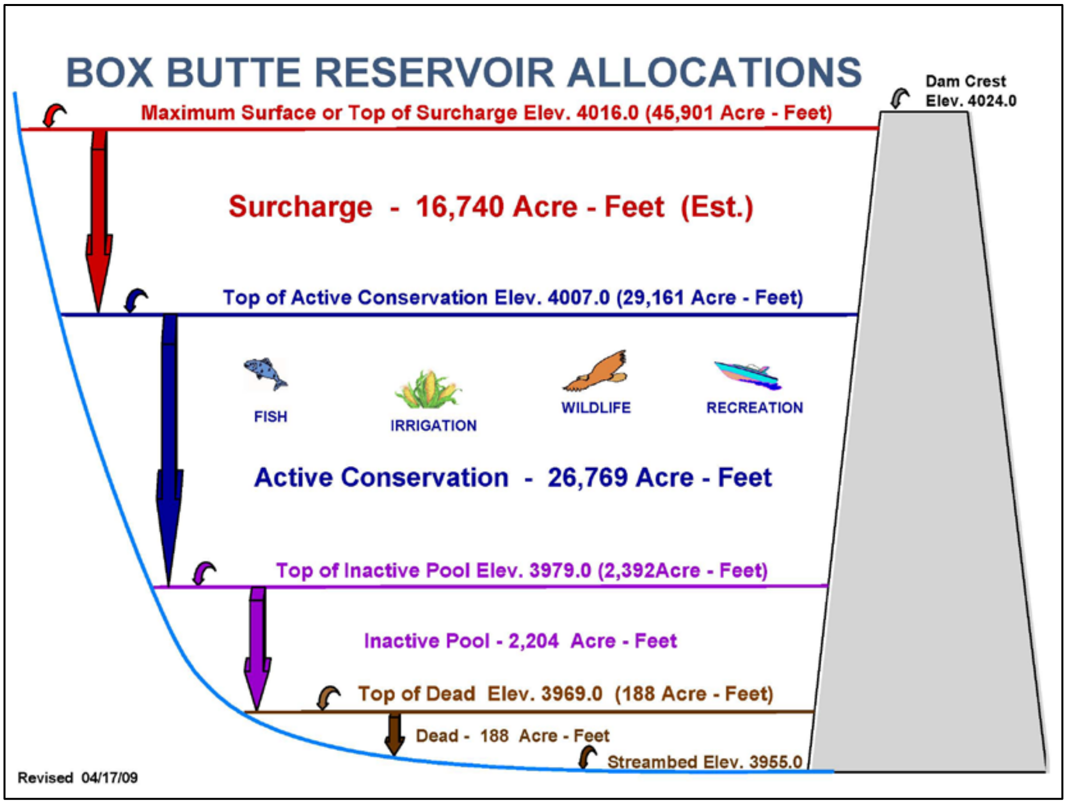

Figure 5. Box Butte Reservoir allocations. Source: BOR Box Butte Reservoir Resource Management Plan (RMP).

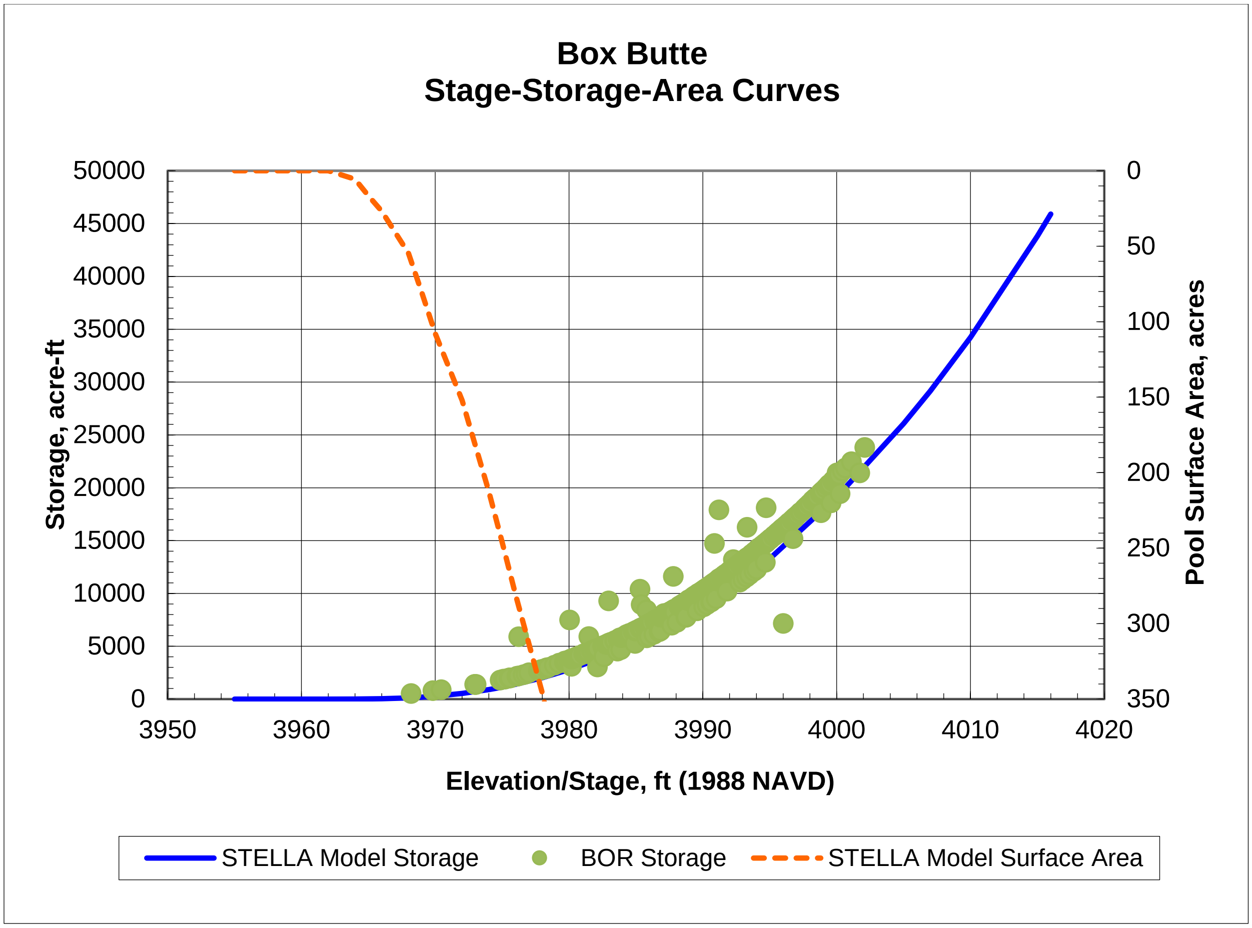

Figure 6. Box Butte attributes defined in STELLA model.

8 Model Calibration

Calibration of the surface water operations model was accomplished through comparison of simulated and historical observations for the 1980-1990 period. The primary calibration targets consisted of main stem stream gages and gaged canal diversions.

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 model has been calibrated first on a reach basis and then to specific canal group. Reach 1 (canal groups 1, 2, and 3) and Reaches 5 and 6 (canal groups 8, 9 and 14) were calibrated this way because of the relatively complete diversion data for these two reaches. The calibration plots for Reach 1 and Groups 1, 2, and 3 are shown in Figures 7 through 10. The calibration plots for Reaches 5 and 6 are shown in Figure 11. Groups 8, 9 and 14 are the only groups with historical data available for Reaches 5 and 6, so they are the only groups shown on Figure 11. Calibration plots for Group 8 and the Mirage Flats (Group 9) are shown in Figures 12 and 13 respectively. The reach calibration plots show the historical diversion and the model calculated diversion data. In the group calibration plots, the full appropriation diversion rate is shown, as well as the historical diversion data, and model calculated diversion data. The model calculated diversion data mimics the historical diversion data and the lines are often indiscernible.

The key knobs used for the diversion calibration are based on % of total demand, with the targets being reach total diversions and matching river gage flows.

Mirage Flats is the largest diversion in the reach. As shown in Table 1, the Mirage Flats (Group 9B) appropriation is 167 cfs and the next biggest appropriation is 9.67 cfs at Harris/Neece in Group 4.

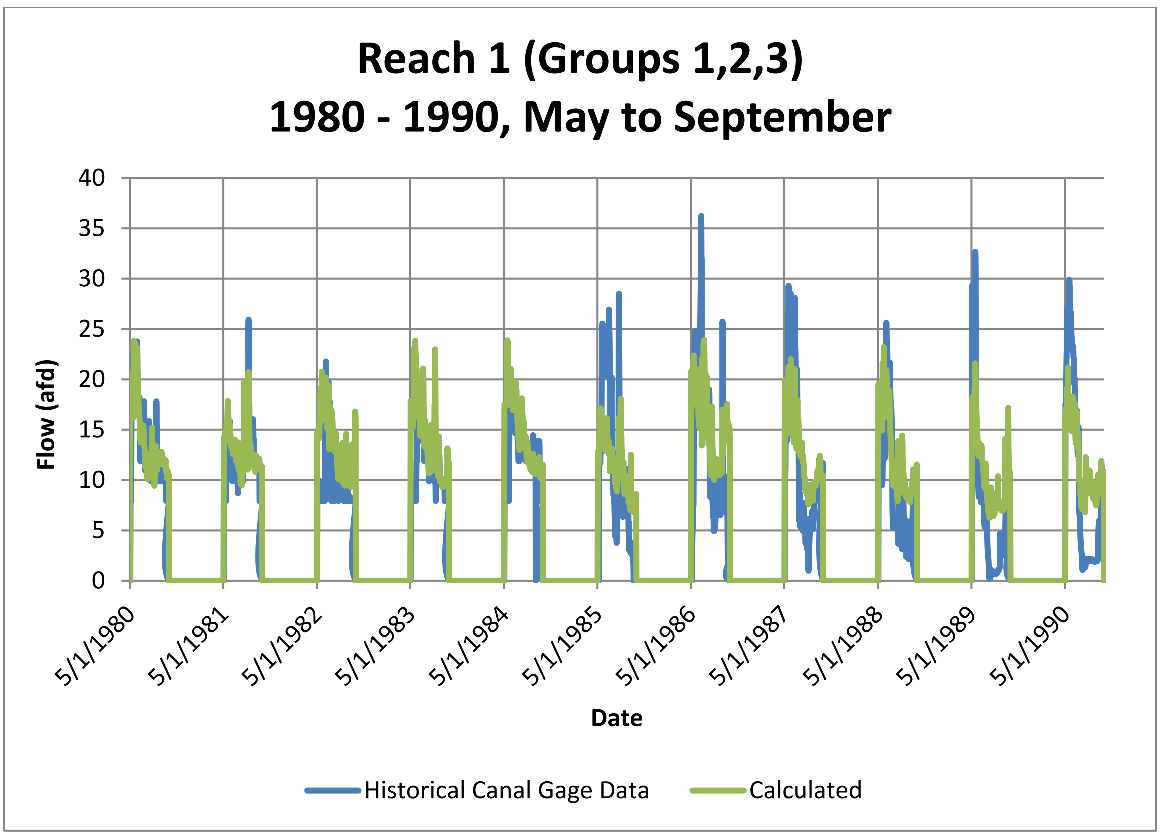

Figure 7. Reach 1 calibration plot.

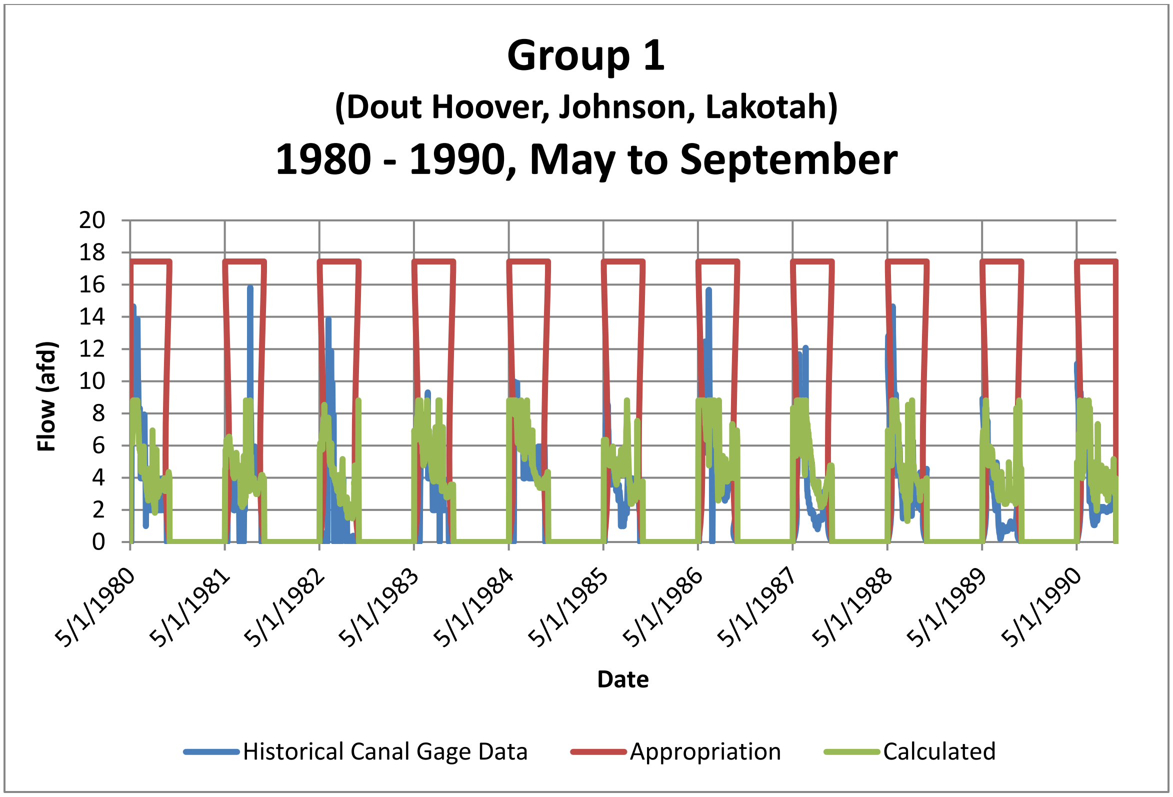

Figure 8. Group 1 calibration plot.

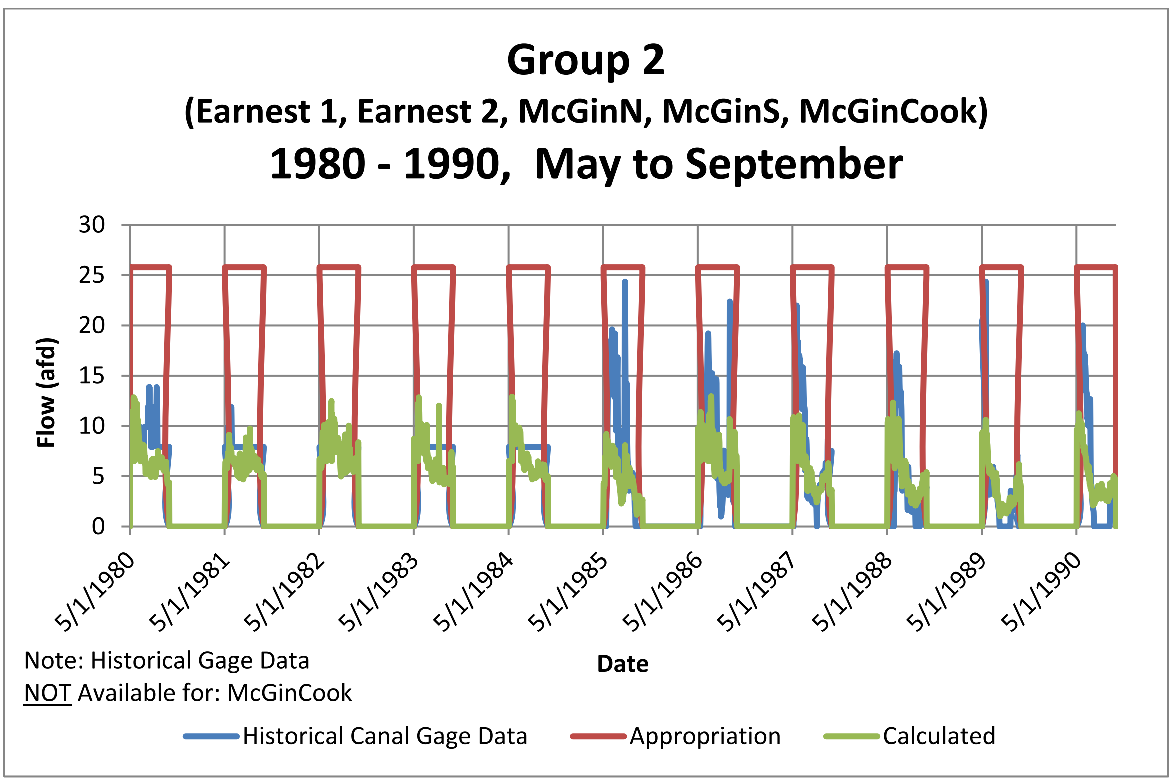

Figure 9. Group 2 Calibration Plot

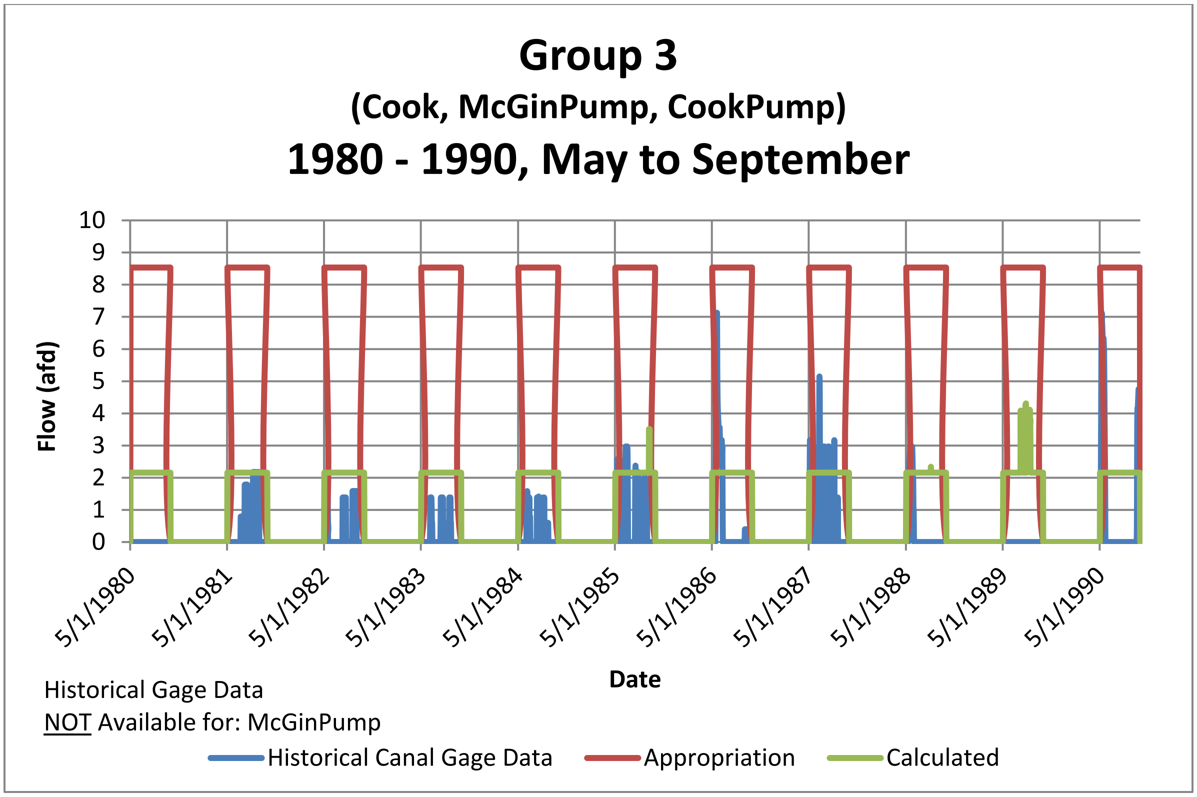

Figure 10. Group 3 calibration plot.

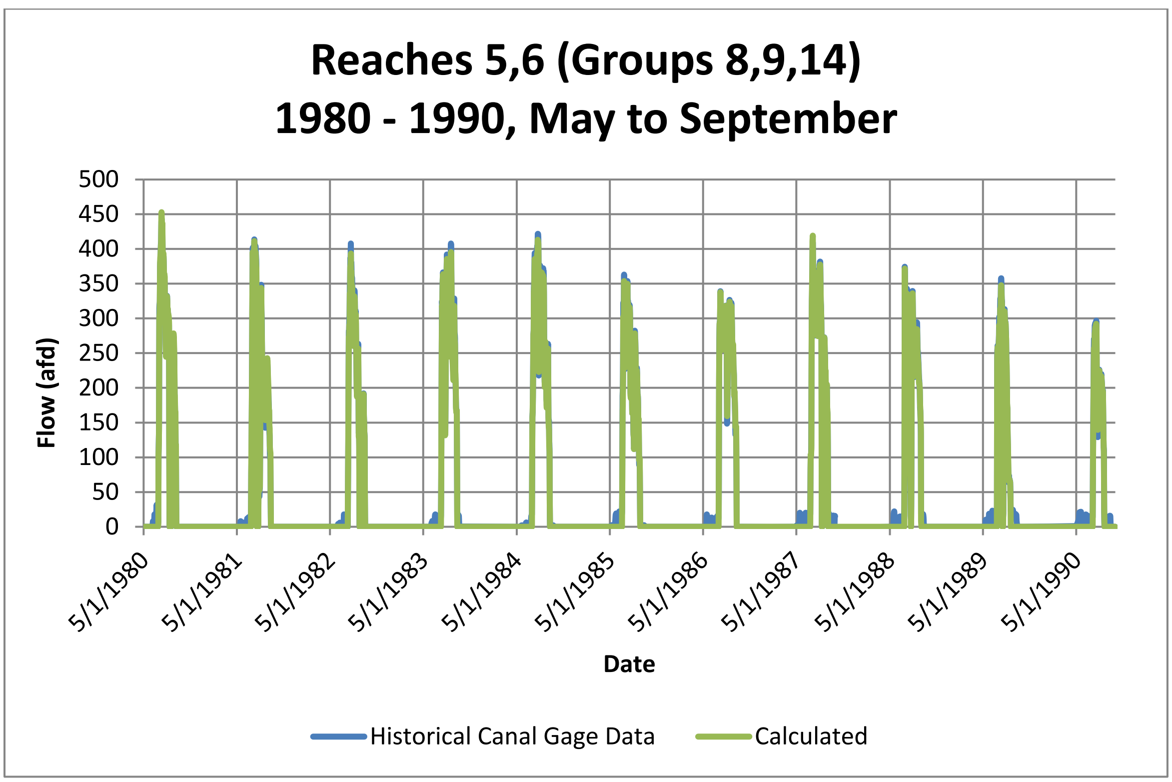

Figure 11. Reaches 5 and 6 calibration plot.

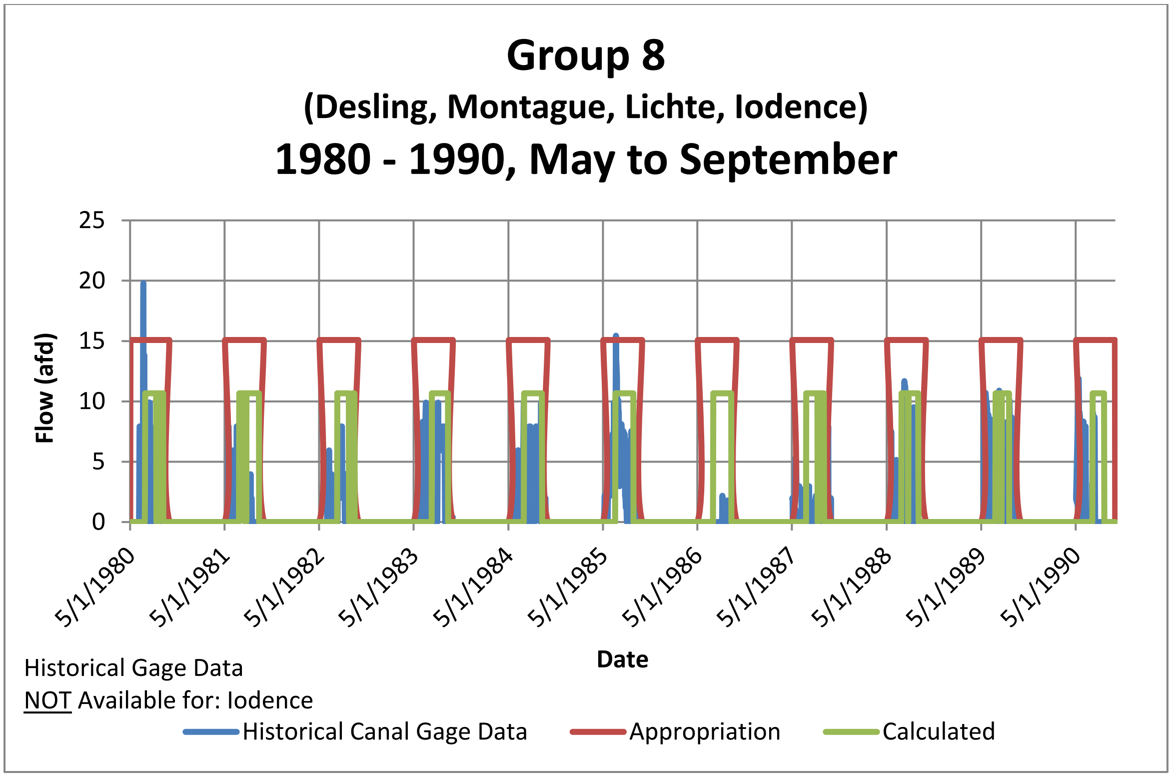

Figure 12. Group 8 calibration plot.

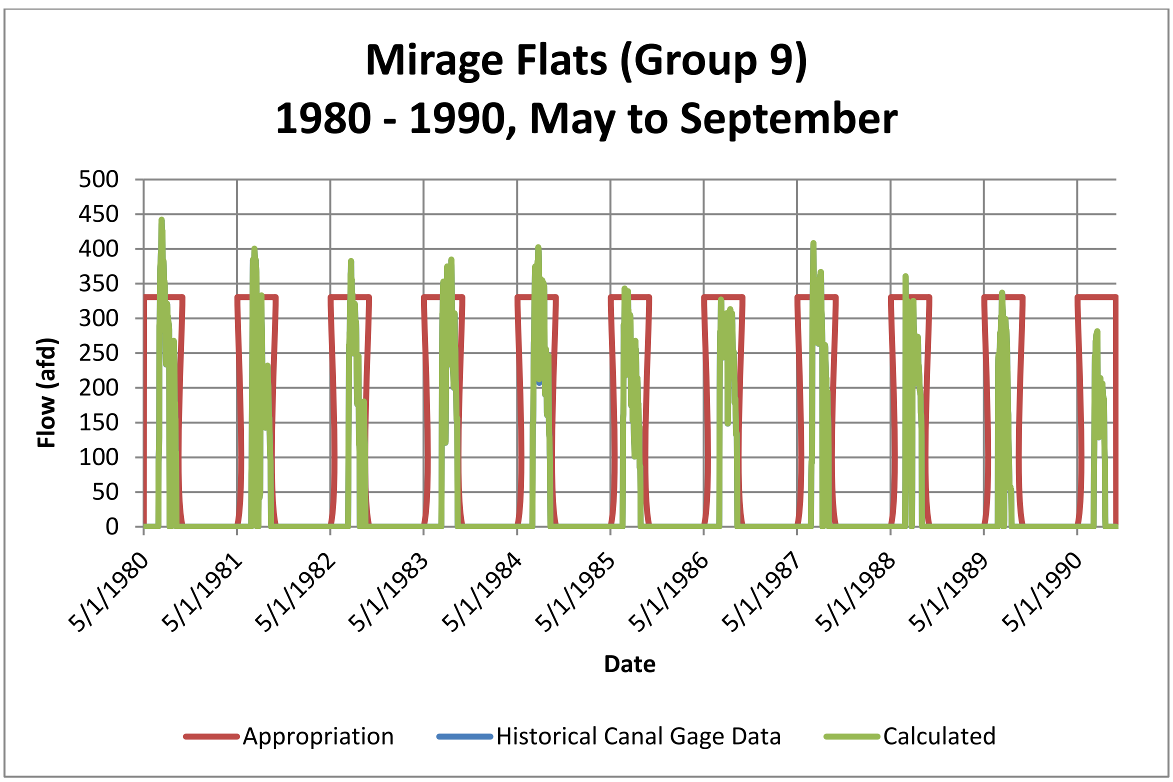

Figure 13. Mirage Flats (Group 9) calibration plot.

Figures 14 through 17 are calibration plots at the four Niobrara River gages. Illustrated is the historical, calculated and cumulative difference. Cumulative differences range from roughly 4% to 12%.

Systemic trends can be observed in the cumulative difference plots, largely in the non-irrigation season. This is largely due to the calculated RGL used, which include canal diversion data in the computation of RGL and many of the historical datasets have diversion data in the non-irrigation season. An example of this is clearly illustrated at the Agate gage. The historical diversion records from Group 2 canals in this reach have continuous diversions through 1985 – hence the overestimation of RGL and upward trend in the cumulative difference. Starting in September 1985, the historical diversion records for Group 2 in the non-irrigation season are zero as you would expect and the cumulative difference curve is much more appropriate as a result.

The Niobrara River below Box Butte cumulative difference shows a consistent under prediction of flows during the non-irrigation season that result in the consistent downward trend in the cumulative difference. It is a very small amount, about 1-2 cfs a day (600 AF per year, 6000 AF over the calibration period – largely explains total cumulative difference). This could be gate leakage, reach gains over this short reach, or intentional release.

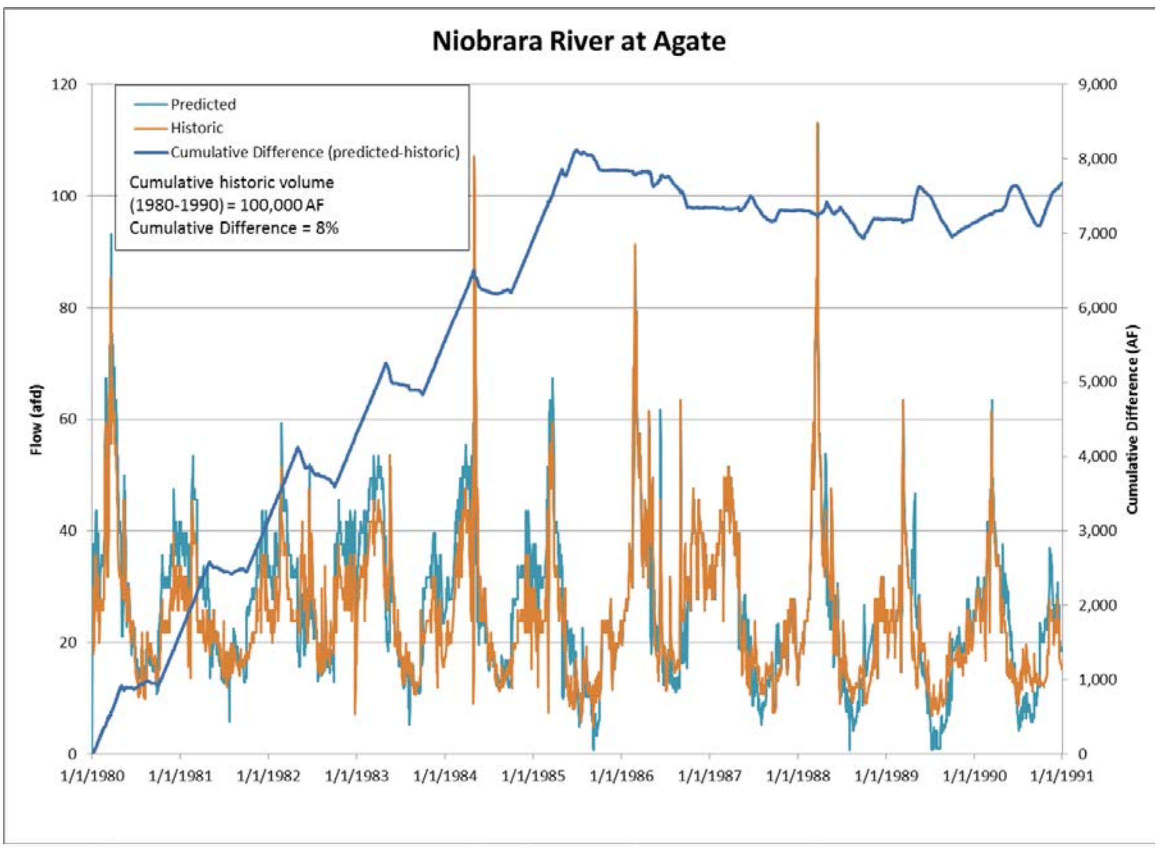

Figure 14. Niobrara River at Agate gage calibration plot.

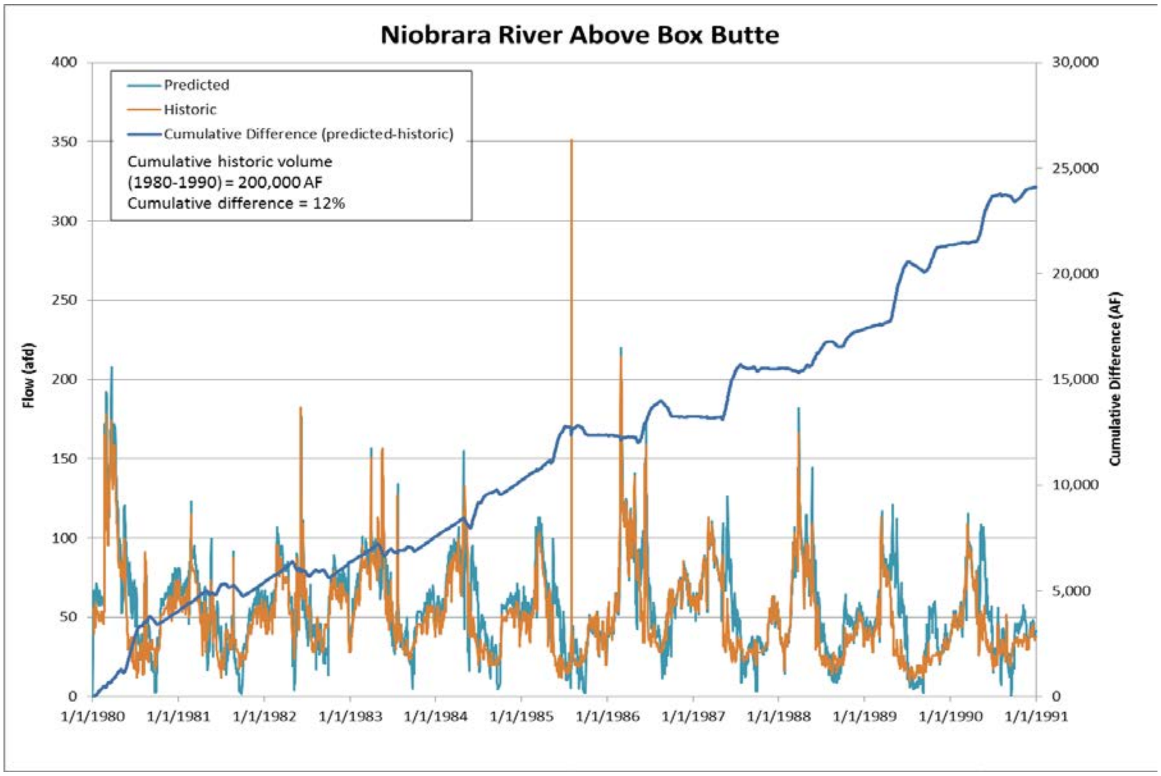

Figure 15. Niobrara River above Box Butte gage calibration plot.

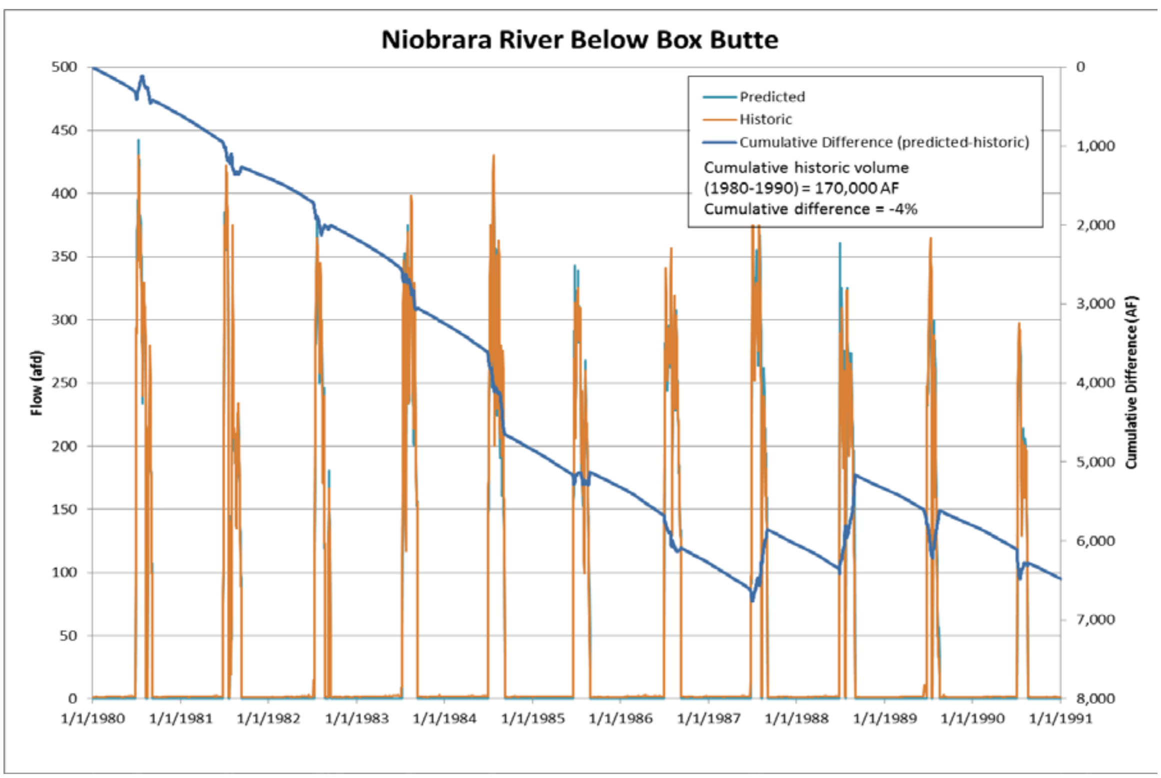

Figure 16. Niobrara River Below Box Butte gage calibration plot.

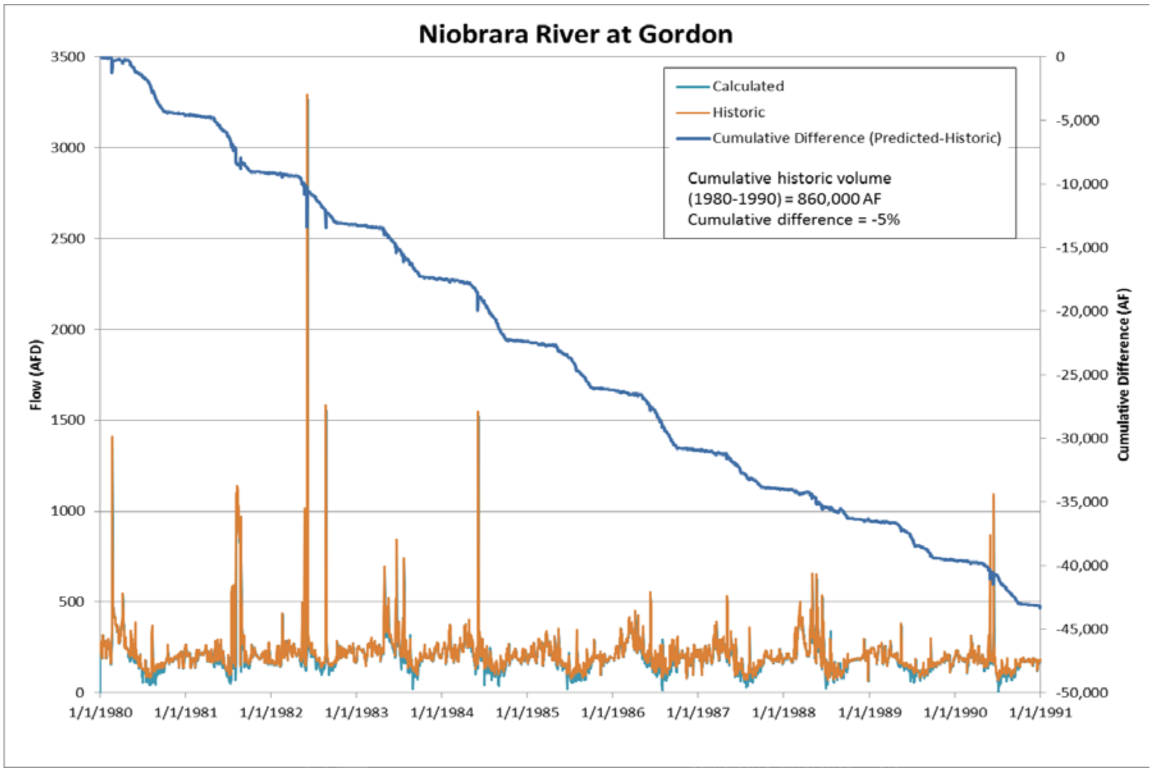

Figure 17. Niobrara River at Gordon gage calibration plot.

9 Summary

The surface water operations model was developed for the Basin Study to be used as a part of the integrated modeling approach described in Appendix F, Integrated Water Management Model Report. The purpose of the surface water operations model is to simulate the present day surface water components of the Niobrara River main stem system from the Nebraska State Line to the Gordon gaging station (Niobrara River, canals, and Box Butte Reservoir) and calculate the water budget terms of these components for the surface water operations system.

Operating rules have been developed through model calibration based on historical operations for each surface water component. These rules represent the operational/water management decisions that are made on a daily basis and largely dictate flow conditions in the Niobrara River; routing flows through the modeled reach, appropriately storing, diverting, or discharging flows through the surface water network.

Calibration of the surface water operations model was accomplished through comparison of simulated and historical observations for the 1980-1990 period. The primary calibration targets consisted of main stem stream gages, Box Butte

Reservoir storage, and gaged canal diversions. Daily, monthly, seasonal, annual, and cumulative values over the simulation period were evaluated during wet/dry/normal hydrologic conditions. The model calculated gage, storage, and diversion data matched the historical data within reason. Some small systematic errors were observed in the model results, but the causes were identified and could be attributed to the modeling approach and assumptions employed at the ungaged or discontinuous gage records of surface water canals. The model is considered suitable for evaluating changes in water budget elements of the Niobrara River main stem system under varying management scenarios.