Historic Crop Consumptive Use Analysis

South Platte Decision Support System

Final Report

March, 2010

Leonard Rice Engineers, Inc.

Acknowledgments

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1.0 Executive Summary

The South Platte River Basin historic crop consumptive use analysis was performed on a monthly basis for the period from 1950 through 2006 as part of the South Platte Decision Support System (SPDSS). The SPDSS project was developed jointly by the State of Colorado Water Conservation Board and the Division of Water Resources. The objective of the historic crop consumptive use portion was to quantify 100 percent of the basin's historic crop consumptive use. Other, non-agricultural water use is described in the separate Consumptive Uses and Losses Summary Report.

This report documents the input and results of the historic crop consumptive use analysis completed in March 2010.

1.1 Background

The South Platte Basin is located in northeastern Colorado and encompasses approximately 19,300 square miles (**Section 2.1, Figure 8**). The South Platte main stem rises in the Rocky Mountains in the vicinity of Fairplay, Colorado and flows easterly where it is joined by the South Fork of the South Platte at Hartsel, Colorado. The main stem continues northeast to the Eastern Plains until it reaches the state line near Julesburg, Colorado. Major tributaries to the South Platte include Clear Creek, Saint Vrain River, Big Thompson River, and the Cache la Poudre River. Most stream flow originates from snowmelt in the surrounding mountains. Average annual precipitation in the basin ranges from 13 inches at Ft. Morgan to 38 inches at Berthoud Pass.

1.2 Approach

The South Platte historic crop consumptive use analysis was performed using StateCU, a generic, data driven consumptive use model and graphical user interface. The objective of the model is to develop monthly consumptive use estimates for the assessment of historical and future water management policies. Key information used by the model to assess historic consumptive use include irrigated acreage, crop types, monthly climate data, diversion records, and well information.

A number of subtasks were performed in support of the historic crop consumptive use analysis. Individual technical memoranda describing the approach and results of these subtasks have been included as appendices to this report. In addition, information provided by other SPDSS Contractors was used in the preparation of the historic crop consumptive use estimates, and is referenced herein.

1.3 Results

Table 1 presents the average annual acreage and historic crop consumptive use analyses results, by water district, for the 1950 to 2006 study period. As shown, the irrigation water requirement averages 1,544,000 acre-feet per year while water supply-limited consumptive use averages 1,171,000 acre-feet per year. The average annual shortage in the basin is 24 percent.

Table 1
Average Annual Acreage and Consumptive Use Results - 1950 through 2006

Water District	Acres	Irrigation Water Requirement (acre-feet)	Supply-Limited CU (acre-feet)	Percent Short
1	241,369	367,967	324,040	12%
2	172,486	281,739	201,376	29%
3	215,810	328,082	246,166	25%
4	77,915	127,088	86,886	32%
5	62,925	106,686	60,980	43%
6	50,999	89,284	48,367	46%
7	13,213	25,202	21,036	17%
8	6,600	9,967	8,949	10%
9	2,135	4,027	3,053	24%
23	18,133	28,318	15,315	46%
48 & 76	4,226	6,530	4,619	29%
64	98,226	167,862	148,954	11%
80	1,060	1,558	1,253	20%
Total	**965,097**	**1,544,310**	**1,170,994**	**24%**

Figure 1 presents historic acreage with and without a ground water source. Note that acreage with a ground water source may use ground water to supplement a surface water source; however the surface water acreage category only receives surface water. As shown, total irrigated acreage has decreased over time, reflecting municipal development.

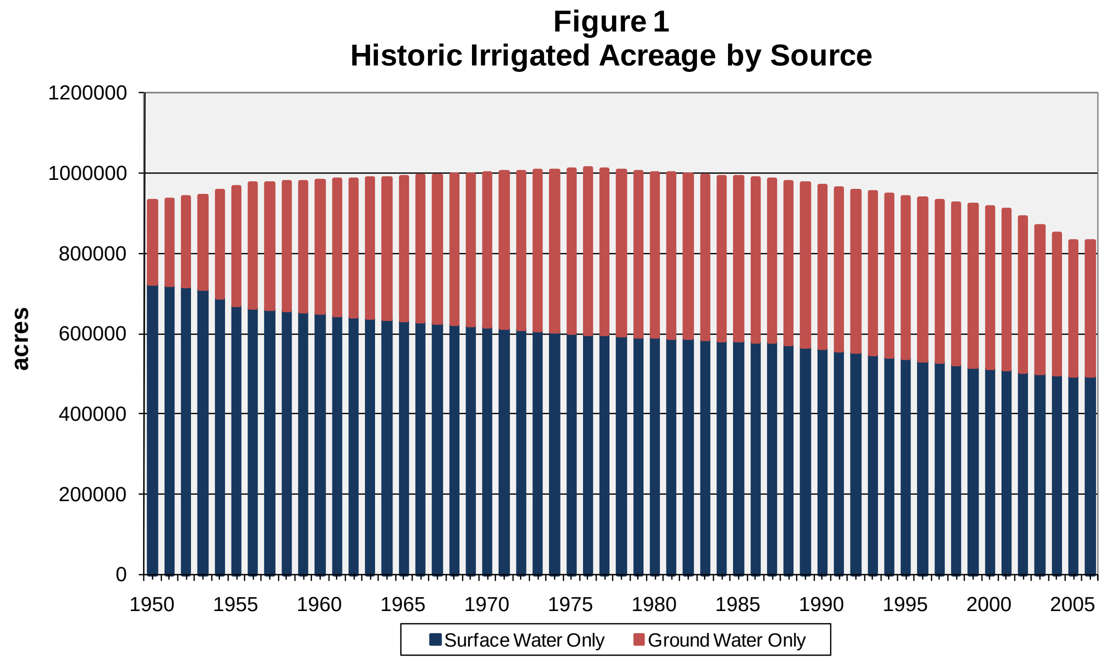


Figure 2 presents historic acreage by crop type. As shown, corn is grown on the majority of irrigated land in the basin. Alfalfa acreage increased until the 2002 drought. Other crops generally showed a decrease over time.

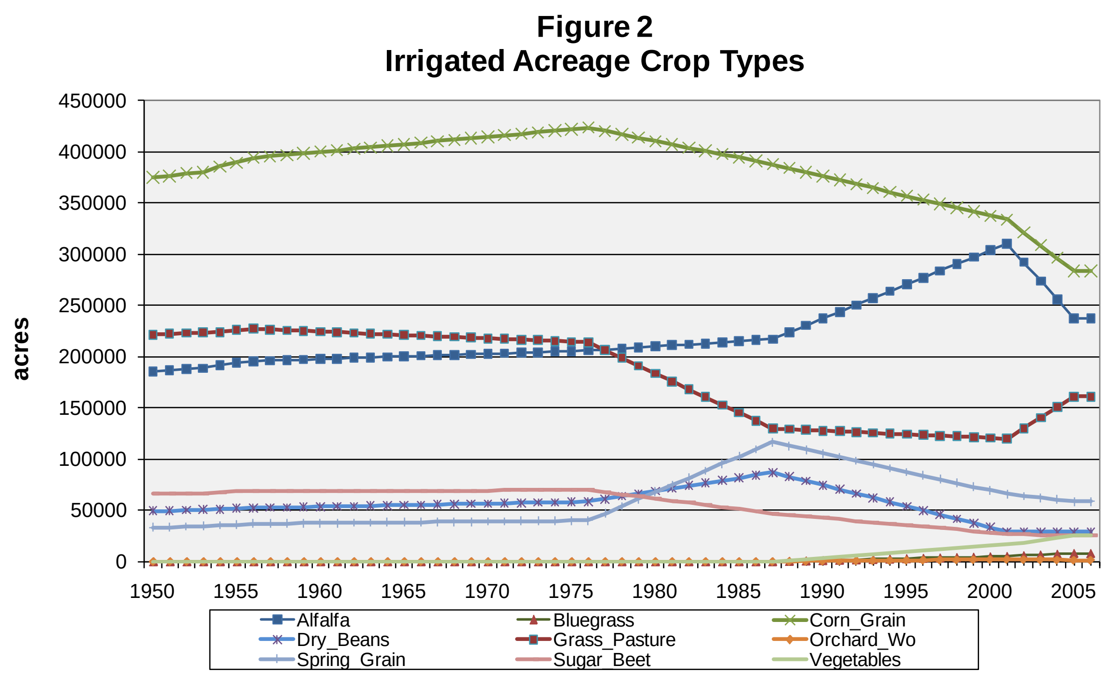


Figure 3 presents the modeled historic acreage and irrigation water requirement for the study period. The irrigated acreage from 1950 to 2006 averaged approximately 965,097 acres. Average annual irrigation water requirement was approximately 1,544,000 acre-feet. As shown, irrigation water requirement in the basin followed a general increasing trend from 1950 through the mid-1970s that corresponded with the increase in irrigated

acreage. Because irrigated acreage and crop type do not vary significantly from year to year, the pronounced yearly variations in irrigation water requirement are attributed to climate (temperature and precipitation).

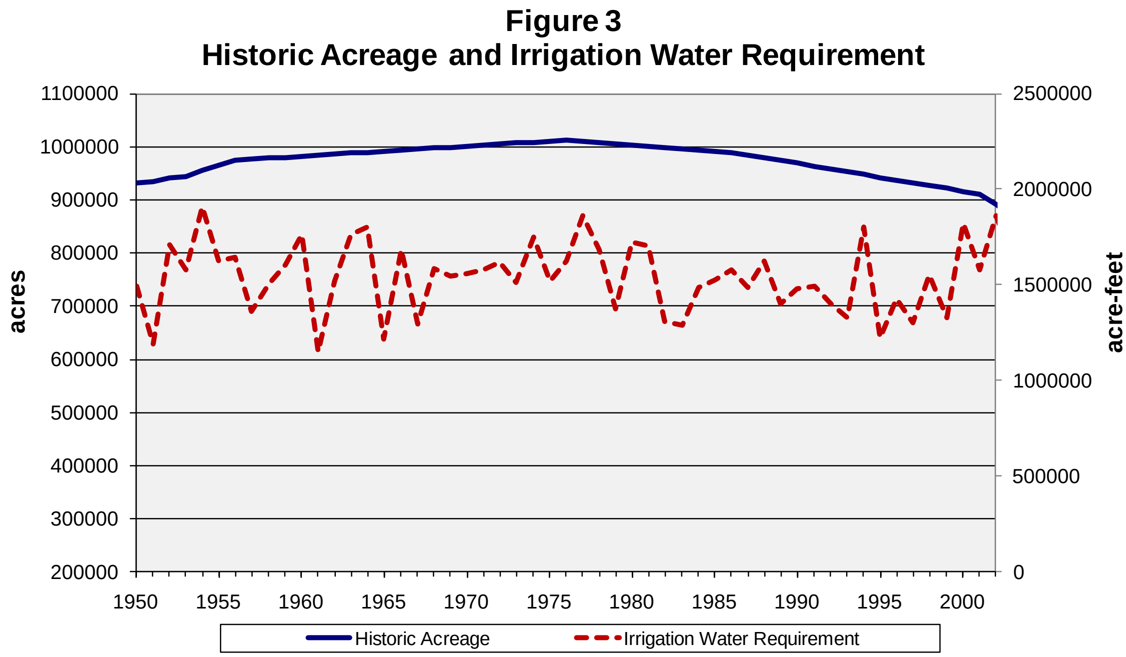
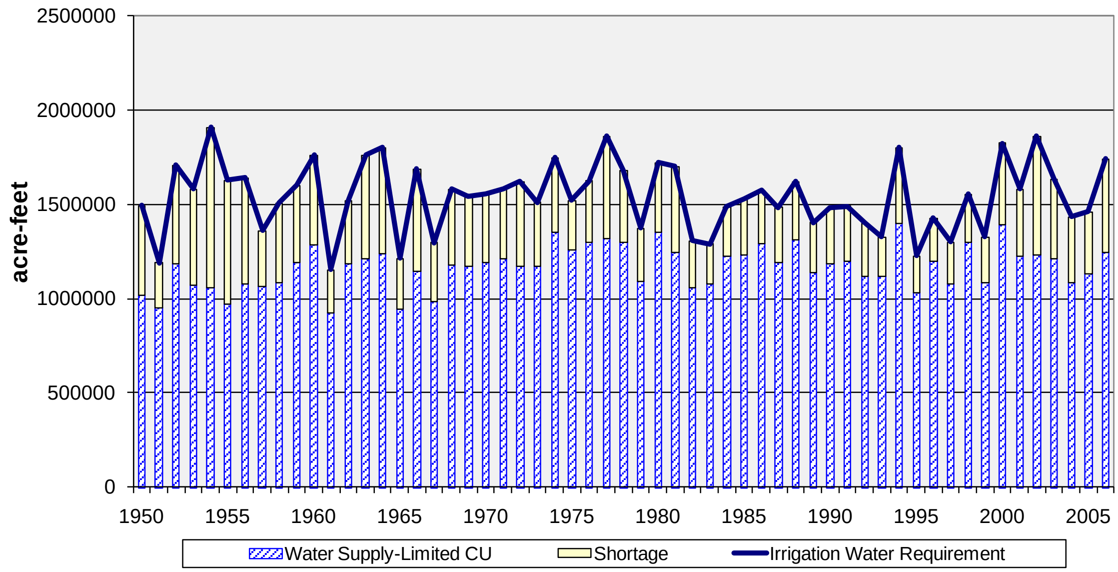


Figure 4 presents the historic irrigation water requirement and the actual consumptive use, limited by supply. The average annual irrigation water requirement from 1950 through 2006 was approximately 1,544,000 acre-feet while the average annual water supply limited consumptive use was approximately 1,171,000 acre-feet. As shown, the percent of irrigation water requirement not satisfied has decreased slightly over time, averaging 24 percent over the study period. Greater shortages from 1950 through 1956, averaging 33 percent, represent limited water supply due to well development levels and below average stream flows. Shortages averaging 18 percent from 1990 through 1999 are consistent with well development and normal to above average stream flows. Shortages increased in the early 2000s due to drought conditions and restrictions on well pumping.

Figure 4
Irrigation Water Requirements and Water Supply-Limited CU



The use of ground water to meet irrigation water requirements has been common practice during the study period. Based on the 2001 well to irrigated parcel associations determined in the SPDSS Irrigated Acreage Assessment, approximately 44 percent of the irrigated acreage in the basin had the ability to either meet their entire demand, or help reduce surface water shortages, with ground water. The average annual consumptive use of surface water from 1950 through 2006 was approximately 858,000 acre-feet while the average annual consumptive use of ground water was approximately 312,000 acre-feet. **Figure 5** demonstrates that the supply from ground water has increased slightly from 1950 to 2006 as new wells were developed. Also, the supply from ground water increases when surface water supplies decrease. Note that 1955, 1977, and had high pumping estimates, corresponding to years of reduced surface water availability. Also, note the reduction in ground water consumptive use after 2002 is the result of strict administration of augmentation plans and restriction of pumping with the implementation of pumping quotas.

Figure 5
Consumptive Use from Surface Water and Ground Water

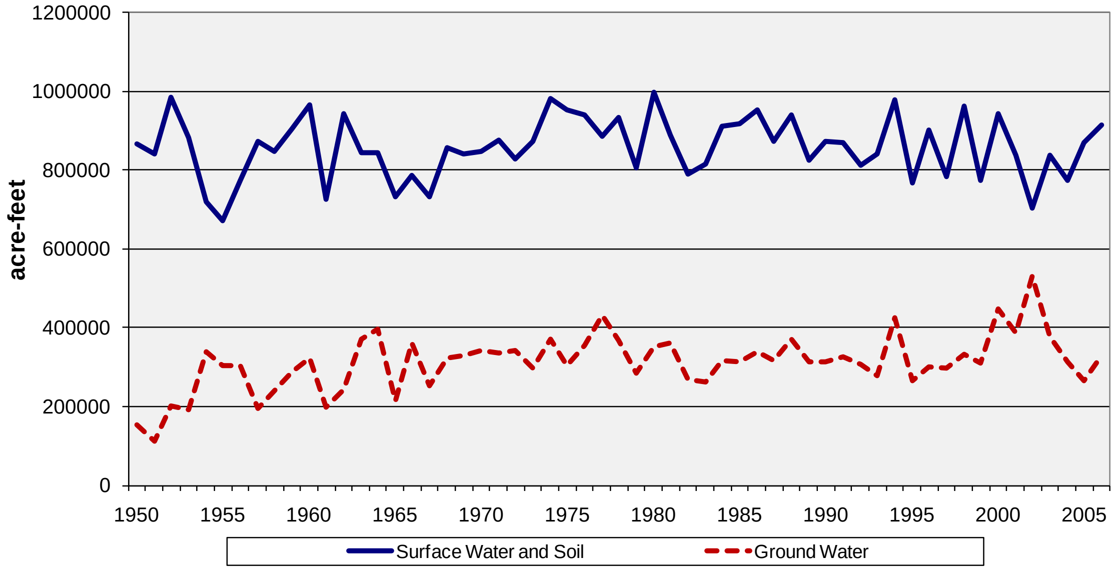


Figure 6 shows the annual estimated diversions from surface water and ground water to meet crop irrigation requirements. The average annual surface water diversions from 1950 through 2006 were 2,425,000 acre-feet while the average annual estimated ground water diversions (pumping) were 487,000 acre-feet. Note that increases in pumping tend to occur when surface water supplies are relatively low.

Figure 6
Diversions from Surface Water and Ground Water

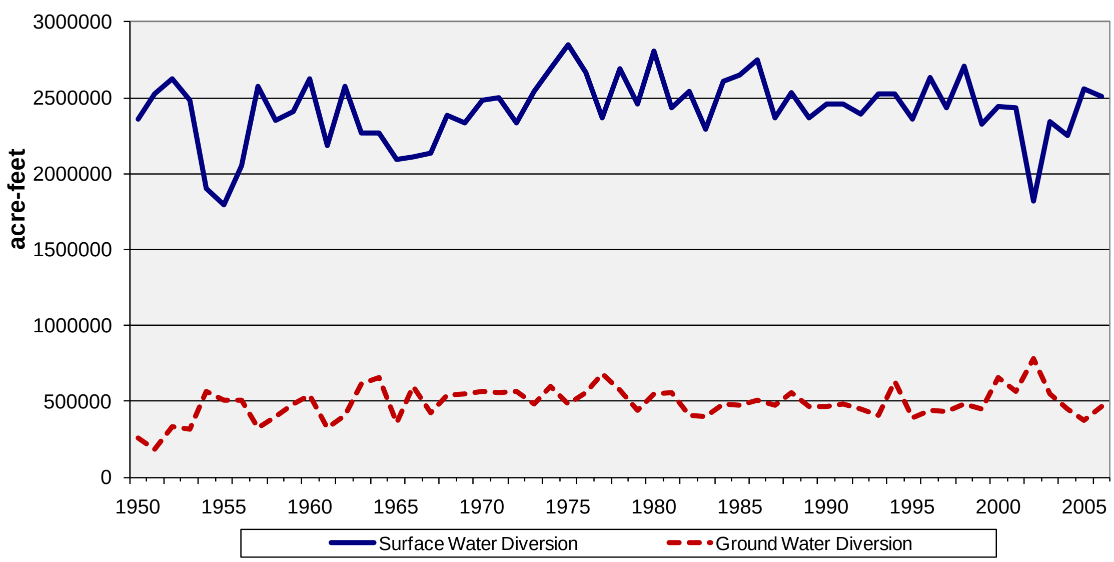
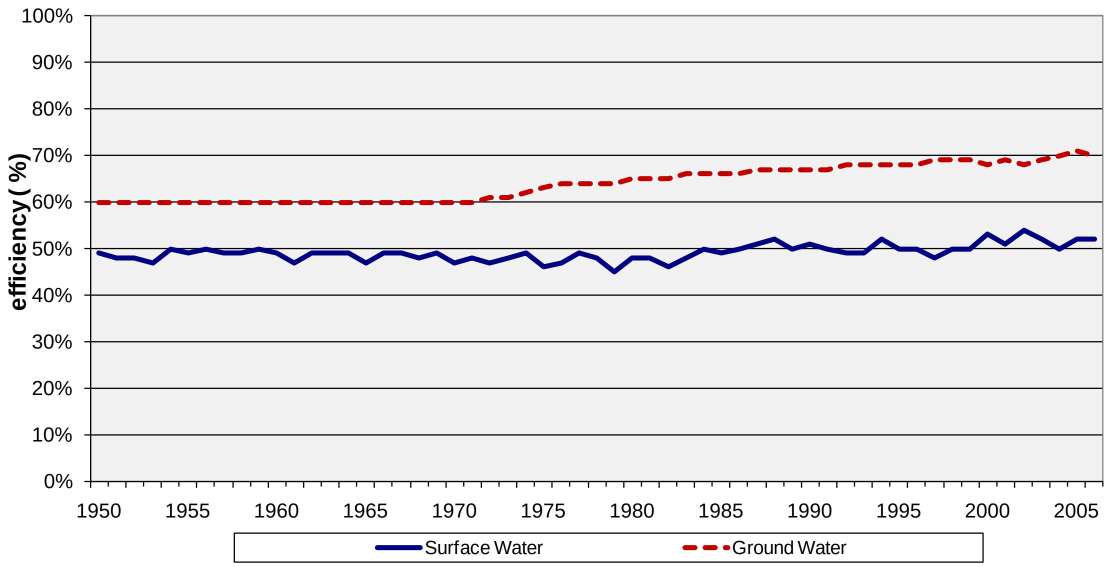


Figure 7 shows the average annual calculated on-farm application efficiencies for surface and ground water supplies. The average annual surface water application efficiency from 1950 through 2006 was approximately 49 percent while the average annual ground water efficiency (pumping) was approximately 64 percent. Note that surface water application efficiencies generally reflect significant flood irrigation practices and the practice of taking water when in priority, while ground water efficiencies reflect a combination of flood and sprinkler irrigation practices. As shown in **Figure 7**, ground water efficiencies have increased with the increased use of sprinkler application methods, beginning in the early 1970s. Surface water application efficiencies generally remaining constant, even through some surface water lands installed sprinklers, indicating surface water application efficiencies are influenced more by water availability.

Figure 7
On-Farm Efficiency



2.0 Introduction

The estimation of historic consumptive uses and losses in the South Platte Basin and the tool used to perform the analysis are documented in four major reports as follows:

1. The Irrigated Lands Assessment Report describes the development of the 1956, 1976, 1987, 2001, and 2005 irrigated lands coverages, including the process used to determine irrigated acreage, associated crop type, irrigation method (sprinkler or flood), and surface water source.

2. The Historic Crop Consumptive Use Analysis Report is the main document associated with estimating agricultural consumptive uses in the South Platte Basin. It describes the approach and results of the crop consumptive use analysis.

3. The Consumptive Uses and Losses Summary Report describes the approach and results used to develop the estimate of total basin water use (agricultural and non-agricultural) for 1950 through 2006.

4. The StateCU Documentation describes the consumptive use model and graphical user interface used to perform all consumptive use analyses conducted as part of the South Platte Decision Support System.

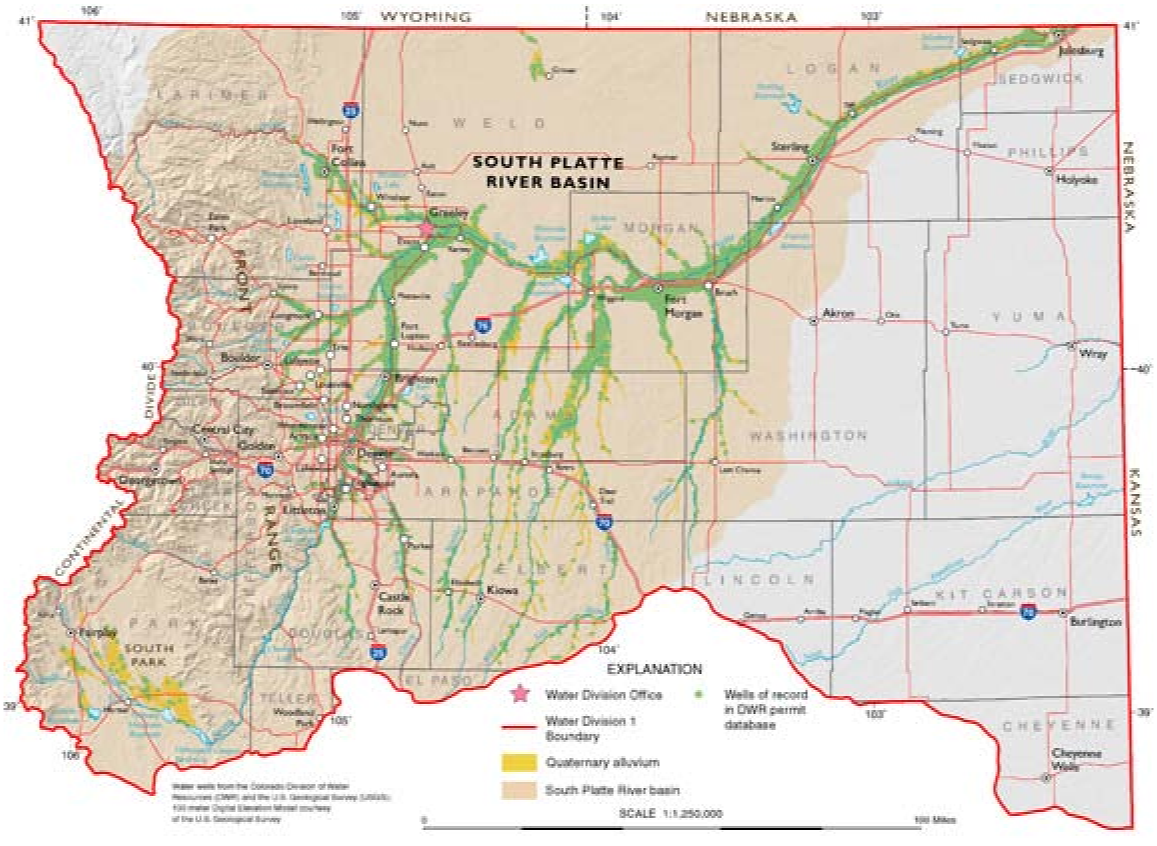
This Historic Crop Consumptive Use Analysis Report has not attempted to reiterate the detailed analyses and results of each subtask performed in support of the final historic crop consumptive use analysis. Instead, it summarizes the major results of each technical memorandum, which are then referenced and attached as appendices. The technical memoranda developed by other SPDSS Contractors that were used to support the consumptive use analysis are also referenced as appropriate.

2.1 Basin Description

The South Platte Basin **(Figure 8)** is located in northeastern Colorado and encompasses approximately 19,300 square miles. The South Platte main stem rises in the Rocky Mountains in the vicinity of Fairplay, Colorado at an elevation of 14,270 feet and flows easterly where it is joined by the South Fork of the South Platte at Hartsel. The main stem continues northeast through Greeley and the eastern plains until it reaches the Colorado-Nebraska state line near Julesburg at an elevation 3,420 feet. Major tributaries to the South Platte include Clear Creek, Saint Vrain River, Big Thompson River, and the Poudre River. Most stream flow originates from snowmelt in the surrounding mountains. Average annual precipitation in the basin ranges from 14 inches in Denver to 38 inches at Berthoud Pass.

There is approximately 3,000 square miles in Designated Basins in the South Platte River basin. The complex subsurface geology of the valley is generally comprised of a shallow unconfined alluvial aquifer and a deeper Denver Basin confined aquifer. The alluvial aquifer system is in hydrologic connection with the surface water system. There is approximately 3,000 square miles in Designated Basins that are not hydraulically connected to the South Platte River.

Figure 8
South Platte River Basin



2.2 Support to other SPDSS Modeling Efforts

As part of estimating historic consumptive use, the following information was developed and provided to other SPDSS Contractors to support their modeling efforts:

- Surface Water Modeling Effort
  - Historic surface water diversions
  - Historic irrigation water requirements
  - Historic ground water pumping
  - Average monthly ditch system and well pumping efficiencies
- Ground Water Modeling Effort
  - Historic surface water diversions
  - Historic ground water pumping
  - Ditch system conveyance losses
  - Surface water and ground water application losses

A subset of the historical crop consumptive use analysis was developed to estimate consumptive uses and pumping within the alluvial aquifer. This StateCU scenario termed the Ground Water Model Area Water Budget scenario, estimates the amount of irrigation-related recharge and pumping that occurs from ditches that irrigated within the active ground water model boundary, documented in **Appendix M**. The results of this scenario can be used to generally compare with the ground water model active cell input, and is the basis for the crop consumptive use component of the Ground Water Model Area Water Budget, documented in a separate report.

The historical crop consumptive use analysis presented herein only considers diversion for irrigation uses. The information provided for surface water and ground water modeling efforts are from input and results of a separate StateCU scenario termed the Ground Water Total River Division scenario, documented in **Appendix N**. This StateCU scenario was developed to include historical diversions to reservoir storage, recharge, municipal, and industrial uses. The results of this scenario provide the input required for the ground water modeling effort, including conveyance loss associated with total diversions.

The SPDSS alluvial ground water model covers the area overlying the alluvial aquifer in the South Platte basin and considers the effects of pumping and irrigation-related recharge adjacent to the model boundary as lateral input. The data-centered ground water modeling process reads the results of the Ground Water Total River Diversion scenario and spatially determines the portion of pumping, non-consumed irrigation water, and ditch conveyance losses to input directly to active model cells; input to the model via surface drainages; or input as lateral boundary inflow.

2.3 Supporting Subtasks

The following subtasks were performed under the Consumptive Use and Water Budget Component to determine monthly crop consumptive use in the South Platte basin for the period 1950 through 2006:

- Key Structure Identification. Although 100 percent of the recent irrigated acreage is included in the model, some of the acreage on smaller tributaries may not be represented explicitly. The approach and results of the selection of explicit key structures represented in the CDSS models are provided in a memorandum attached as **Appendix A**.
- Non-Key Structure Aggregation. Although 100 percent of the recent irrigated acreage is included in the model, some of the acreage on smaller tributaries may not be represented explicitly. The approach and results of the selection of explicit key structures represented in the CDSS models are provided in a memorandum attached as **Appendix B**.
- Soil Moisture Capacity Assignments to Parcels and Structures. Soil moisture capacity estimates were determined for each ditch system or aggregated ditch system based on Colorado STATSGO mapping and irrigated acreage parcel locations. The CDSS Toolbox "Soil Parameters by SW Structure" tool was used to assign individual available water capacities to each structure. The approach and results are provided in a memorandum attached as **Appendix C**.
- Key Climate Stations Selection and Data Filling. Key climate stations were selected for the South Platte River basin based on their period of record and location. Precipitation, temperature, and frost data were filled as needed to create monthly data for the study period. The approach and results are provided in a memorandum attached as **Appendix D**.
- Climate Stations to Irrigated Parcel Assignments. Climate station weights were assigned to each structure based on climate station weight grids for each station and the location of irrigated acreage. The CDSS Toolbox "Climate Weights by Structure" tool combines the station grids based on irrigated area and calculates a weight for each modeled structure. The approach and results are provided in a memorandum attached as **Appendix E**.
- Irrigated Acreage and Crop Type Time Series Generation. Historic irrigated acreage by crop type was estimated based on the 1956, 1976, 1987, 2001, and 2005 Irrigated Lands Assessment. A linear interpolation approach was taken to create a time series of irrigated acreage from 1950 through 2006. The investigation, approach, and results are provided in a memorandum attached as **Appendix F**.
- Ditch System Efficiency Estimates. Conveyance efficiencies were calculated or recorded for surface water structures in the South Platte basin. Available information based on water user interviews and previous studies were incorporated. Conveyance efficiencies were calculated based on SCS curves for different soil types. The SCS curves reflect the relationship between total ditch length and permeability to calculate conveyance efficiencies. The CDSS Toolbox "Soil Parameters by User-Specified Polygon ID" and "Aggregate Canal Segments" tools were used to determine the individual parameters needed to calculate the conveyance

efficiency for each structure. Maximum sprinkler and flood application efficiencies were estimated based on knowledge of irrigation practices in the basin. The approach and results are provided in a memorandum attached as **Appendix G**.

- Annual Irrigation Parameter Time Series Generation. Irrigation source and application methods were determined in the 1956, 1976, 1987, 2001, and 2005 Irrigated Lands Assessment. A time series of acreage with access to ground water supply, and the associated pumping capacity, was estimated based on well to parcel assignments and well permit and well right information. A linear interpolation approach was taken to create a time series of acreage by source and irrigation method. The approach and results are provided in a memorandum attached as **Appendix H**.
- Surface Water Diversion Estimates. Diversion records are generally available for ditches in the South Platte River basin. Irrigation demands for some structures are met both by headgate direct water right diversions and by water released from on-ditch reservoirs. Data filling and estimation techniques are used to generate a time-series of surface water irrigation supply. The approach and results are provided in a memorandum attached as **Appendix I**.
- Blaney-Criddle Coefficient Calibration. South Platte Basin calibrated crop coefficients for the Blaney-Criddle method were developed through comparisons of potential ET estimated using the ASCE Standardized Penman method to better match local data. Potential ET for grass pasture above 6,500 feet is estimated using original Blaney-Criddle high altitude coefficients developed for Denver Water. The approach and results are provided in a memorandum attached as **Appendix J**.
- Calibrated Coefficients - Unit Irrigation Water Requirements. StateCU was exercised with calibrated crop coefficients and parameters to develop unit irrigation water requirements at climate stations in the basin for the major crops grown in the basin. The approach and results are provided in a memorandum attached as **Appendix K**.
- Deficit Irrigation Investigation. An investigation was made to determine the extent of intentional deficit irrigation in the South Platte based on available data; surveys and discussion with water users; and review of previous studies. The approach and results are provided in a memorandum attached as **Appendix L**.
- Ground Water Model Area Water Budget Scenario. A subset of the historical consumptive use analysis was prepared that includes surface and ground water structures with at least a portion of their irrigated acreage within the active ground water model boundary. This scenario was specifically developed to estimate crop consumptive use for the Ground Water Model Area Water Budget analysis and to provide results to generally compare with the ground water model active cell input. The approach and results are provided in a memorandum attached as **Appendix M**.
- Ground Water Total River Diversion Scenario. A separate consumptive use analysis was prepared that includes headgate diversions, and their associated ditch losses, for uses other than irrigation. This scenario was specifically developed so total recharge associated with ditch losses would be estimated for the ground water modeling effort. The approach and results are provided in a memorandum attached as **Appendix N**.

- Development of Historical Pumping Estimates. StateCU estimates historical ground water pumped based on acreage served by wells, decreed capacity (alluvial wells) and permitted capacity (designated basin wells). To represent current pumping estimates for irrigation structures associated with Central Colorado Water Conservancy District WAS and GMS augmentation plans, pumping quotas were applied in 2005 and 2006. The approach and results are provided in a memorandum attached as **Appendix O.**

2.4 Definitions

Several terms used in this report have been broadly used in other studies. The following definitions are consistent with the American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 70 - Evapotranspiration and Irrigation Water Requirements.

Potential Evapotranspiration (ET) The total amount of water that would be used for crop growth if provided with an ample water supply, also called potential consumptive use.

Effective Precipitation The portion of precipitation falling during the crop-growing season that is available to meet the evapotranspiration requirements of the crop.

Winter Effective Precipitation The portion of precipitation falling during the non-growing season that is available for storage in the soil reservoir, and subsequently available to crops during the next growing season.

Irrigation Water Requirement The amount of water required from surface or ground water diversions to meet crop consumptive needs. Calculated as potential evapotranspiration less effective precipitation and stored winter precipitation.

Water Supply-Limited Consumptive Use The amount of water actually used by the crop, limited by water availability. Also called actual consumptive use.

The following terms are commonly used in the CDSS efforts:

Irrigated Parcel An irrigated "field" having the same crop type, irrigation method (sprinkler or flood), and water source - not divided by a large feature, such as river or highway.

Ditch Service Area The area of land that a ditch system has either the physical ability or the legal right to irrigate. Note that a ditch service area often includes farmhouses, roads, ditches, fallow fields and undeveloped lands. Therefore a ditch service area is typically greater than the land irrigated under that ditch.

Key Diversion Structure A ditch system that is modeled explicitly in both the StateCU historic consumptive use model efforts and the StateMod water resources planning model. Ditch systems are generally defined as key if they have relatively large diversions, have senior water rights, or are important for administration.

Diversion System Structure A group of diversion structures on the same tributary that operate in a similar fashion to satisfy a common demand.

Aggregated Diversion Structure A group of non-key structures. Aggregated diversions are typically aggregated based on location; e.g. diverting from the same river reach or tributary.

Demand Stucture A defined demand (agricultural or municipal) that can be met from several surface water sources not diverted from the same point on the river. For instance, irrigation demand under Riverside Canal (Riverside "Demand Structure") can be met from a direct flow right through the Riverside Canal and, if necessary, from water released from Riverside Reservoir.

Ground Water Only Structure A group of irrigated parcels without a surface water source. Ground water only lands are typically aggregated based on location; e.g. ground water parcels that fall between two surface water gages on the same side of the river.

HydroBase The State of Colorado's relational database used in the CDSS efforts. HydroBase contains historic, real-time, and administrative water resources data.

Data Management Interface (DMI) A CDSS program that allows data to flow from HydroBase to the CDSS models using an automated data-centered approach.

StateMod The CDSS water allocation model used to analyze historic and future water management policies.

Natural Sub-irrigation Ground water supplied to meet a crop evapotranspiration demands due to a high ground water table.

3.0 Model Development

The South Platte historic crop consumptive use analysis was performed using StateCU, a generic data driven consumptive use model and graphical user interface. The objective of the model is to develop monthly consumptive use estimates for the assessment of historic and future water management policies.

The model originated at the USBR and has undergone substantial enhancements while being applied to the Colorado River Decision Support System and the South Platte Decision Support System. The StateCU Documentation provides a complete description of the model and its capabilities.

3.1 Modeling Approach

To perform the historic crop consumptive use analysis, irrigated acreage and their associated crop types were assigned to three types of structures; key, aggregated and ground water only. As presented in **Table 2**, key diversion structures and ground water only parcels represent 99 percent of the 2001 irrigated acreage assigned to a surface water source. Aggregated structures, which are a geographical grouping of non-key surface water structures, represent one percent of the basin irrigated acreage. Ground water only structures, which are a geographical grouping of lands without a surface water supply, represent approximately eighteen percent of the basin irrigated acreage.

Table 2
2001 Irrigated Acreage by Structure Type

Structure Type	**2001 Acres**	**Percent of Total**
Key	733,844	81 %
Aggregated	9,427	1 %
Ground Water Only	167,247	18 %
Total All Structures	**910,518**	**100 %**

The general methodology used to estimate historic consumptive use for the South Platte Basin is as follows (See the StateCU Documentation for a more complete description of the calculation methods):

1. A South Platte Basin scenario was developed that includes 100% of the recent irrigated acreage in the South Platte using the key, aggregated and ground water only structures and their associated acreage and crop patterns.
2. Climate stations were assigned to each structure based on the use of the CDSS Toolbox "Climate Station Weights by Structure" tool.
3. Potential ET was determined using the SCS Modified Blaney-Criddle consumptive use methodology with locally calibrated crop parameters for acreage below 6500 feet and the Original Blaney-Criddle consumptive use methodology with high-altitude crop coefficients developed for Denver Water for acreage above 6500 feet. The SCS effective rainfall method outlined in the SCS publication Irrigation Water Requirements Technical Release No. 21 (TR-21) was used to determine the amount of water available from precipitation, resulting in irrigation water requirement.
4. Water supply-limited consumptive use was determined by including diversion records, conveyance efficiencies, application efficiencies, soil moisture interactions, and supplemental ground water supplies. Historic pumping in the basin is not generally known, therefore, pumping was estimated through the model analysis. The model determined water supply-limited consumptive use and ground water pumping in the following general sequence, termed the "mutual ditch" approach:
   - Surface water was applied to meet irrigation water requirements for land under the ditch system. If excess surface water still remained, it was stored in the soil moisture reservoir.

- If the irrigation water requirement was not satisfied, surface water stored in the soil moisture reservoir was used to meet remaining irrigation water requirements.
- If the irrigation water requirement was still not satisfied, ground water was first pumped to meet remaining irrigation water requirements for sprinkler irrigated lands identified as having a ground water source, up to the maximum permitted or decreed pumping capacity. If pumping capacity was not exceeded, ground water was then pumped to meet remaining irrigation water requirements for flood irrigated lands identified as having a ground water source, up to the remaining pumping capacity.

3.2 File Directory Convention

To assist in the file organization and maintenance of official State data, the files associated with a historic consumptive use analysis will install to the default subdirectory \cdss\data\ *Analysis_description* \statecu. *Analysis_description* is **SP2008_crop** for the South Platte crop consumptive use analysis, completed in 2008. Other official State historic consumptive use data *Analysis_descriptions* include rg2004 for the Rio Grande River, cm2005 for the Upper Colorado River Basin, etc. Note that these directory conventions are not a requirement of the model, simply a data management convention for official State data.

3.3 File Naming Convention

Specific file names or extensions are not a requirement of the model except for the StateCU response file (*.rcu). Standard extensions have been adopted by the State for data management purposes, and are outlined in **Section 4.0 Data Development**.

3.4 Data Centered Model Development

Nearly all SPDSS StateCU input files have been generated from HydroBase using the data management interfaces StateDMI (Version 03.09.01, 2009-02-18) and TSTool (Version 09.05.03, 2009-11-17). A description of these tools as applied to StateCU is included in **Section 4 Data Description,** where applicable.

3.5 Product Distribution

The StateCU model and SPDSS input files can be downloaded from the State of Colorado's CDSS web page at http://cdss.state.co.us.

4.0 Data Description

The following sections provide a description of each input file, the source of the data contained in the input file, and the procedure for generating the input file. More detailed information regarding the file contents and formats can be found in the StateCU Documentation.

1. Simulation information files
   - StateCU Response File ***Section 4.1***
   - StateCU Control File ***Section 4.2***
2. Structure specific files
   - StateCU Structure File ***Section 4.3***
   - Crop Distribution File ***Section 4.4***
   - Annual Irrigation Parameter File ***Section 4.5***
   - Historical Diversion File ***Section 4.6***
   - Historical Pumping File ***Section 4.7***
   - Surface Water Reuse File ***Section 4.8***
3. Climate data related files
   - Climate Station Information File ***Section 4.9***
   - Climate Data Files ***Section 4.10***
4. Blaney-Criddle specific files
   - Blaney-Criddle Crop Coefficient File ***Section 4.11***
   - Crop Characteristics File ***Section 4.12***

4.1 StateCU Response File (SP2008_crop.rcu)

The StateCU response file contains the names of input files used for a StateCU analysis. The StateCU response file was created using a text editor for the South Platte Basin. Input file names in the response file can be revised through the StateCU Interface.

4.2 StateCU Model Control File (SP2008.ccu)

The StateCU Model control file contains the following information used in the historic consumptive use analysis:

- Beginning and ending year for simulation – The simulation period for the analysis was 1950 through 2006.
- Consumptive use analysis method – Both the SCS Modified Blaney-Criddle, described in TR-21, and the Original Blaney-Criddle analysis were used.
- Effective precipitation method – The SCS Effective Precipitation method, defined in TR-21 was used.
- Scenario type – The analysis was defined as a “structure” scenario.

- Water supply/rights consideration – The water supply/rights consideration switch was set to "4" which specifies that water supply-limited consumptive use was calculated considering both surface and ground water sources, but consumptive use was not accounted for by water rights.
- Soil moisture consideration – The soil moisture switch was set to "2" indicating the analysis should include soil moisture accounting and run a 'pre-simulation" to set initial soil content to simulated ending soil content for each structure.
- Initial soil moisture information – This parameter was not used, as the 'pre-simulation' option for initializing soil content was selected.
- Winter carry-over precipitation percent – The winter carry-over precipitation defines the amount of non-irrigation season precipitation that is available for storage in the soil moisture reservoir. Winter carry-over precipitation percent was set to 38 percent for the South Platte analysis, based on the published study <u>Snowfall and its Potential Management in the Semiarid Central Great Plains</u>, U.S. Department of Agriculture, December 1980 (sometimes referred to as the Greb Study)
- Surface water reuse consideration – The surface water reuse switch was set to "1" indicating the analysis should consider drain/return flow information in the supply-limited calculation. The surface water reuse file was used to offset diversions to storage and recharge specifically to provide conveyance loss from those diversions to the ground water model. No specific drains were identified for inclusion in the South Platte.
- Output options – The output summary switch was set to "3" indicating a detailed water budget output should be generated. The switch for additional reporting for the ground water modeling effort was set to "1". Additional reporting includes ground water pumping by irrigation method (flood and sprinkler), consumptive use shortage, and irrigation water requirements for irrigated pasture and alfalfa.

The StateCU model control file was created using a text editor for the South Platte Basin. Options in the model control file can be revised through the StateCU Interface.

4.3 StateCU Structure File (SP2008_crop.str)

A structure file defines the structures to be use in the analysis. The structure file contains physical information and structure-specific information that does not vary over time including location information; available soil capacity; and assignments of climate stations to use in the analysis. Location information includes the latitude, elevation, and county for each structure. The latitude is used in the Blaney-Criddle method to determine the hours of daylight during the growing season. The elevation is used to incorporate an orographic adjustment for structures assigned to a single nearby climate station.

The structure file used in the historic consumptive use analysis was created using **StateDMI** to extract diversion structure location information stored in HydroBase. Soil capacity information and climate weights were assigned from list files generated by the CDSS Toolbox "Climate Weights by Structure" and "Soil Parameters by SW Structure" tools. Structures were classified as key (including diversions systems), surface water aggregates, or ground water aggregates. As presented in **Table 3**, 81 percent of acreage with a surface water source was assigned to key structures. The approach and results are outlined in the Task 3 Summary – Key Diversion Structures memorandum included in **Appendix A** and the Subtask 3- Aggregate Non-Key Agricultural Diversion Structures memorandum included in **Appendix B**.

Table 3
Historic Consumptive Use Structure Scenario

Structure Type	2001 Acres	Number of Structures [1)]	Percent of Total Acreage
Key/Diversion System Structures	733,843	317	81 %
Aggregated Surface Water Structures	9,427	13	1 %
Aggregated Ground Water Structures	167,248	83	18 %
Total Structures	**910,518**	**413**	**100 %**

1) Number of total structure IDs included in the model. Aggregates and diversion systems represent more than one physical structure.

In general, the following criteria were used in determining whether structures would be modeled explicitly or in an aggregated fashion:

Key Diversion Structures: Ditch systems, totaling 733,843 acres in 2001, with relatively large diversions, senior water rights, or important in administration of the South Platte were defined as key. Key structures include diversion systems. In addition, twenty-five key structures are represented as "Demand Structures". They are agricultural users that receive water from several sources to meet a common irrigation demand. For instance, Riverside Irrigation System meets their irrigation demand from a direct flow right through the Riverside Canal and, if necessary, from water released from Riverside Reservoir. Riverside Reservoir is an "on-ditch" reservoir; therefore releases are not carried through the headgate of Riverside Canal. A "demand" structure is recommended if:

- Demand can be met through more than one river headgate. For instance, North Poudre Irrigation Company can meet their irrigation demand from headgates on both the North Poudre and the mainstem Cache la Poudre Rivers.
- An off-channel reservoir delivers water directly to demand. The demand may also be met from direct diversions, as with the Riverside example above, or the demand can be met only from reservoir releases, as is the case with the FRICO-Milton demand.
- Demand can be met through a single headgate, but water sources have different delivery losses. For instance, deliveries from an upstream reservoir may experience both river losses and canal losses whereas direct diversions only experience canal losses.
- River headgate delivers water to more than one demand, and at least one of those demands is irrigation. For example, Evans #2 Ditch delivers water to both Milton Reservoir (for FRICO-Milton use) and to lands

irigated under Evans #2 Ditch. In this case, irrigation under Evans #2 is modeled as a separate “demand” structure, because Evans #2 delivers water to two separate demands.

Aggregated Surface Water Structures: Ditch systems, totaling 9,427 acres (~1 percent of 2001 basin total acreage), not defined as key diversion structures were grouped together into aggregated diversion structures. Non-key structures are defined as structures with little or no diversion records located within a common area.

Aggregated Ground Water Structures: Irrigated parcels, totaling 167,248 acres (~18 percent of 2001 basin total acreage), do not fall within a ditch system service area and were determined to have ground water as the only supply source. These parcels were combined into aggregated groups based on location.

Available soil moisture capacities are assigned to individual structures in the structure file. Available soil moisture capacities were determined using Colorado STATSGO mapping and irrigated acreage parcel locations, as described in the Task 57- Assign Soil Moisture Water Holding Capacities to Structures memorandum, included in **Appendix C**. Soil moisture capacities for each structure, in inches of holding capacity per inch of soil depth, were provided for key and aggregate structures from comma separated output generated using the CDSS Toolbox. Structure soil moisture capacity by structure ranges from 0.0850 to 0.1800 inches per inch.

Table 4 summarizes the range of soil moisture capacities used in the consumptive use analysis by Water District.

Table 4
Average Soil Moisture Capacity (inches/inch)

Water District	Average Soil Moisture Capacity (inches/inch)
1	0.1302
2	0.1312
3	0.1216
4	0.1214
5	0.1258
6	0.1302
7	0.1412
8	0.1379
9	0.1308
23	0.0786
48 & 76	0.0961
64	0.1281
80	0.0658

Climate stations were selected for use in the consumptive use calculation based on their period of records and location with respect to irrigated land. The selection of these key climate stations and methods used to fill missing data is discussed in the South Platte Historic Crop Consumptive Use – Collect and Fill Missing Monthly Climate Data memorandum, included in **Appendix D**.

Climate station assignments were assigned using the in the CDSS Toolbox "Climate Weights by Structure" tool. Climate weights were assigned based on the proximity of irrigated lands to climate stations for each structure. The CDSS Toolbox provided a comma separated file that defines the link between structures (diversion, and aggregates) and the climate stations to be used when determining the structure's irrigation water requirements. The assignment of climate stations and associated weights is discussed in the South Platte Historic Crop Consumptive Use - Climate Station Assignments memorandum, included in **Appendix E**.

Table 5 summarizes the key climate stations used in the analysis, their period of record, and their percent complete for temperature and precipitation data. Some climate stations have moved over time and assigned a new station identifier. Often these stations can be combined, as noted, to create a long-term record.

Table 5
Key Climate Station Information

Station ID	Station Name	WD	Period of Record	Elevation (feet)	Percent Complete (1950 – 2003)	
					Temperature	Precipitation
0109	Akron 4 E (combined) [1]	65	1918 - 2003	4540	98.9%	99.1%
0185	Allenspark 1 NW (combined)	5	1948 - 2003	8500	63.6%	86.6%
0263	Antero Reservoir	23	1961 - 2003	8920	75.8%	77.0%
0454	Bailey	80	1948 - 2003	7730	86.1%	97.4%
0848	Boulder	6	1948 - 2003	5484	94.0%	95.4%
0945	Briggsdale	1	1963 - 2003	4834	54.3%	67.0%
1179	Byers 5 ENE	1	1948 - 2003	5100	90.9%	97.8%
1401	Castle Rock	8	1948 - 2003	6352	61.6%	69.6%
1528	Cheesman	80	1948 - 2003	6880	97.5%	97.5%
2220	Denver WSFO AP (Stapleton)	2	1948 - 2003	5286	98.9%	99.4%
2494	Eastonville 2 NNW [2]	1	1956 - 2003	7210	-	87.2%
2761	Estes Park 1 SSE (combined)	4	1948 - 2003	7785	82.7%	86.9%
2790	Evergreen (combined) [3]	9	1948 - 2003	7000	70.1%	75.2%
3005	Fort Collins	3	1900 - 2003	5004	99.1%	99.2%
3038	Fort Morgan	1	1948 - 2002	4332	93.7%	92.9%
3261	Georgetown	7	1948 - 2003	8520	45.7%	68.8%
3553	Greeley UNC (combined)	3	1948 - 2003	4715	91.4%	97.4%
4413	Julesburg	64	1918 - 2003	3469	75.2%	86.3%
4762	Lakewood (combined)	8	1948 - 2003	5640	82.1%	93.8%
5116	Longmont 2 ESE	5	1948 - 2003	4950	94.3%	96.5%
5922	New Raymer	64	1948 - 2003	4783	65.1%	71.3%
5934	New Raymer 21 N (combined)	64	1948 - 2003	5180	94.8%	97.1%
6323	Parker 2 N (combined)	8	1948 - 2003	5904	92.9%	94.8%
6921	Red Feather Lakes (combined)	3	1948 - 1997	8300	63.9%	78.9%
7515	Sedgwick 5 S (combined)	64	1948 - 2003	3990	96.5%	99.1%
7950	Sterling	64	1948 - 2003	3938	92.7%	95.5%

Notes: [1]Akron 4 E (combined) is located outside the SPDSS study area, but was selected as key due its proximity.
[2]Eastonville 2 NNW qualifies as a key climate station with precipitation data only.
[3]Evergreen station records are only combined for precipitation.

4.4 Crop Distribution File (SP2008.cds)

The crop distribution file contains acreage and associated crop percentages for each key, diversion system, and aggregate ground water and surface water structure for every year in the analysis period (1950 through 2006).

The SPDSS Historical Crop Consumptive Use Analysis is based on the 1956, 1976, 1987, 2001, and 2005 irrigated acreage coverage developed by Riverside Technology, inc (RTi) for SPDSS. The coverages include acreage and crop, as described in the SPDSS Task 93 Memorandum – Mapping Historic Land Use, RTi. Each parcel receiving surface water was assigned to a ditch system structure identifier based on service area locations. Parcels receiving only ground water or supplemented by ground water were assigned to wells, as described in the SPDSS Task 91 Memorandum – Map

Wells, Irrigation Systems and Irrigation Service Areas, RTi. **Table 6** summarizes the 2001 acreage by crop type. **Table 7** shows the total 2001 acreage by water district.

Table 6
2001 Irrigated Acreage by Crop Type

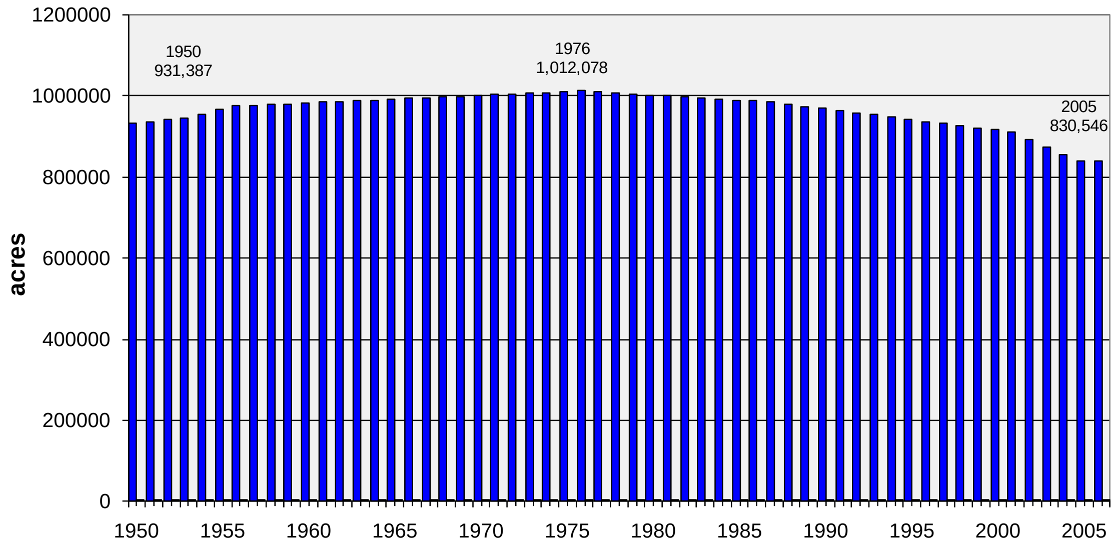
Crop	Acreage
Corn	333,942
Alfalfa	310,520
Pasture Grass	120,074
Spring Grains	65,848
Dry Beans	29,401
Sugar Beets	26,904
Vegetables	16,343
Orchard	2,239
Blue Grass	5,246
Total Acreage	**910,518**

Table 7
2001 Irrigated Acreage by Water District

Water District	Acreage
01	254,331
02	166,853
03	199,795
04	68,586
05	54,329
06	40,455
07	6,212
08	3,743
09	2,031
23	7,604
48 & 76	3,738
64	101,915
80	926
Total Basin	**910,518**

Historic (1950 through 2006) acreage and corresponding crop types were estimated for each structure based on the 1956, 1976, 1987, 2001, and 2005 irrigated acreage coverages, as described in the **Appendix F**, Task 71 – Estimate Historical Acreage memorandum. Irrigated acreage parcels and crop types for 2001 and historic (1950 through 2006) county acreage by crop type were stored in HydroBase. As shown in **Figure 9** irrigated acreage was estimated to change from approximately 931,387 in 1950 to a high of 1,012,078 acres in 1976 and a low of 830,546 in 2005.

Figure 9
Estimated Irrigated Acreage in the South Platte Basin



The crop distribution file used in the historic consumptive use analysis was created using **StateDMI. StateDMI** was used to extract the acreage and crop type information from HydroBase, perform the historic estimation calculation described in the **Appendix F** memorandum, and develop the crop distribution file.

4.5 Annual Irrigation Parameter File (SP2008_crop.ipy)

The annual irrigation parameter file contains yearly (time series) structure information required to run consumptive use simulations, including the following:

- conveyance efficiencies
- maximum flood irrigation efficiencies
- maximum sprinkler irrigation efficiencies
- acreage flood irrigated with surface water only
- acreage sprinkler irrigated with surface water only
- acreage flood irrigated with ground water only or supplemental to surface water
- acreage sprinkler irrigated with ground water only or supplemental to surface water
- maximum permitted or decreed monthly pumping capacity
- ground water use mode (ground water primary or secondary source)

The conveyance efficiency accounts for losses between the river headgate and the farm headgate, including losses through canals, ditches and laterals. The maximum flood irrigation and sprinkler efficiencies account for application losses between the farm headgate or well and the crops. Note that conveyance and maximum application efficiency data input data were not adjusted by year. However, a structure's overall, system efficiency may change by year due to changes in the percent of land served by sprinkler or flood application methods, or due to surface water supply in excess of crop requirements.

The development of efficiency estimates is described in the memorandum titled Task 56 – Conveyance and Application Efficiencies included in **Appendix G**. Conveyance efficiencies provided by water administrators, ditch companies, water rights decrees and published literature were available for 69 structures in the SPDSS study area (listed in **Appendix G**). Conveyance efficiencies for other ditch systems are based on a relationship between conveyance efficiency, soil type, and the overall ditch and lateral length, described in **Appendix G**. **Table 8** shows the results of this analysis and the number of ditches that are represented in each efficiency bracket. Structures assigned 100% efficiency include municipal pipelines, aggregate ground water structures, and some irrigation demand structures where losses are accounted for with their carrier structures. The maximum flood irrigation and sprinkler irrigation efficiencies were estimated to be 60 percent and 80 percent respectively.

Table 8
Conveyance Efficiencies and Corresponding Number of Ditches

Efficiency	Number of Ditches
100%	105 [1]
>90%	32
80 to 90 %	114
70 to 80 %	142
60 to 70 %	13
< 60%	7
Total	413

Notes: [1]Structures with ground water source only

The acreage with ground water supply is the total acreage of parcels under a structure that have an active well for each year. The acreage irrigated by sprinklers is the total acreage of parcels under a structure that are irrigated with sprinklers for each year. The maximum monthly pumping volume is the decreed rate for alluvial wells or the permitted capacity for designated basin wells associated with irrigated parcels under a structure. Acreage with ground water supply and the corresponding well pumping volume was developed based on the priority of the well associated with each parcel.

The procedures for estimating irrigated acreage by source (surface water, ground water); irrigation method (flood, sprinkler); and maximum monthly pumping volumes by structure are described in South Platte Historic Consumptive Use - Annual Irrigation Parameter Time Series (Ground Water Acreage and Sprinkler Acreage) memorandum, included in **Appendix H. Figure 10** shows the time-series of the modeled surface water-only acreage and acreage irrigated with ground water only or to supplement surface water. Also shown is the corresponding decreed capacity (alluvial wells) or permitted capacity (designated basin wells) for the ground water use.

Figure 10 shows that well development increased from 1950 through the mid-1970s then remained relatively constant until around 2003. Surface water-only acreage decreased over time, as wells began to supplement surface water supplies and ditches were transferred to municipal use. Decreed pumping capacity followed the same general trend as ground water acreage.

Figure 10
Estimated Acreage by Source and Decreed Pumping Capacity

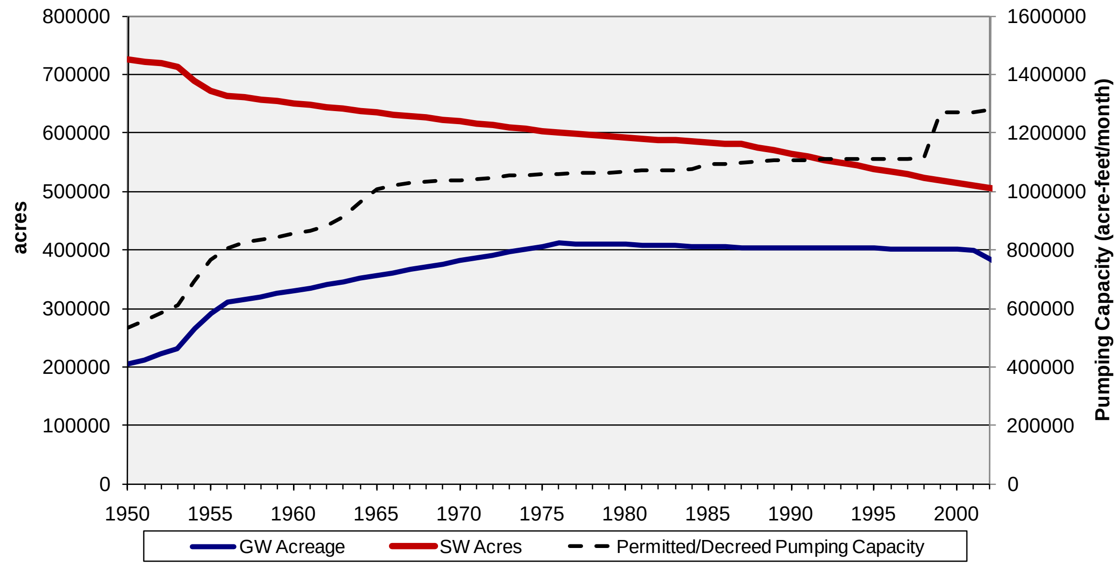
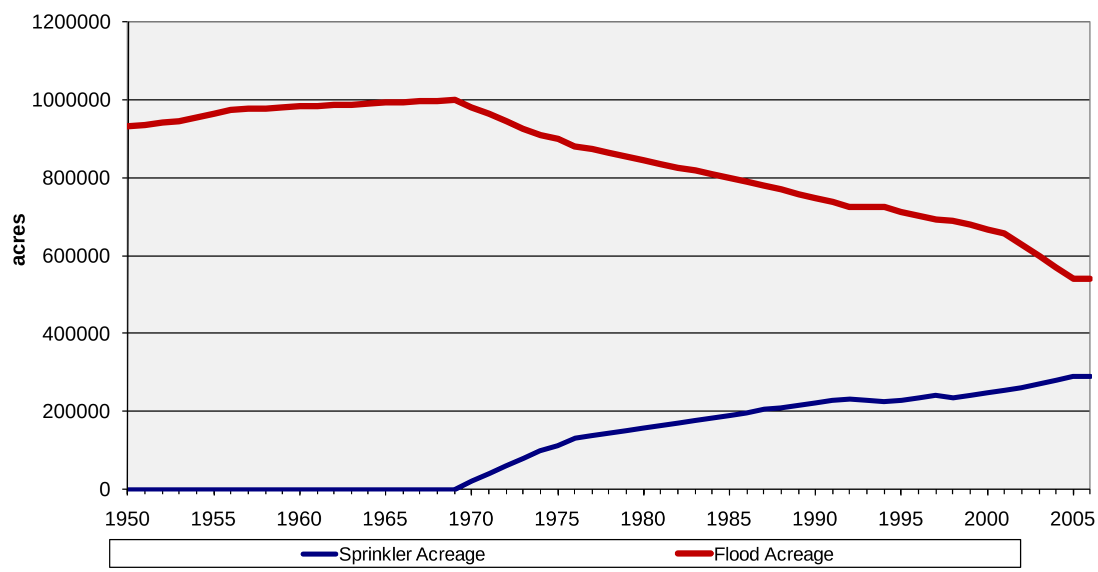


Figure 11 shows how acreage irrigated by sprinkler and flood methods has changed over time, trending towards more efficient use sprinkler application of both surface water and ground water.

Figure 11
Estimated Acreage by Irrigation Method



The ground water use mode determines how surface water and ground water are used to meet irrigation water requirements. The "mutual ditch" (GWMODE = 2) approach applies surface water to lands equally, as in a mutual ditch system, and ground water is then pumped to meet the deficit on lands with a ground water supply as follows:

1. Surface water is applied evenly to all acreage under a ditch system to meet the total irrigation water requirement.
2. Ground water is pumped to meet any remaining irrigation water requirement on sprinkler irrigated acreage identified as having a ground water source, up to the maximum decreed capacity (alluvial wells) or permitted capacity (designated basin wells). Total (gross) pumping is estimated for sprinkler acreage using a maximum efficiency of 80%.
3. Ground water is pumped to meet any remaining irrigation water requirement on flood irrigated acreage identified as having a ground water source, up to the remaining pumping volume. Total (gross) pumping is estimated for flood irrigated acreage using a maximum efficiency of 60%.

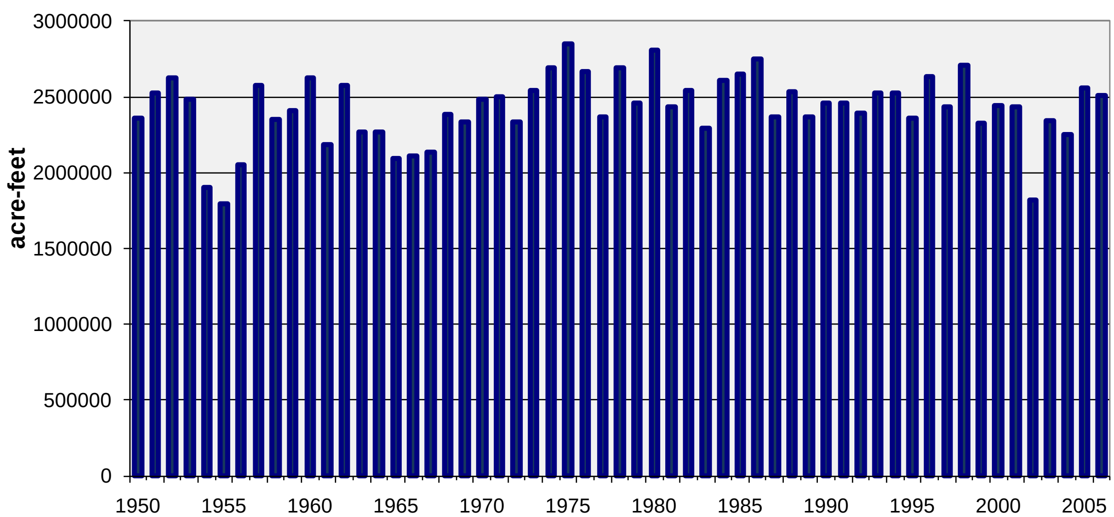
For the South Platte Basin historic consumptive use analysis, the "mutual" approach was used to best represent irrigation practices in the basin.

As described in **Appendix H**, HydroBase stores decreed well water rights and designated basin permits and associated location information, plus time series information defining irrigation methods for each parcel. Efficiency numbers are derived, as described in **Appendix G**, and are not stored in HydroBase. **StateDMI** was used to extract the time series information from HydroBase, perform the necessary calculations, include derived efficiency values, and create the annual irrigation parameter file.

4.6 Historical Irrigation Diversion File (SP2008_crop.ddh)

The historical diversion file provides surface water supply information required to estimate supply-limited consumptive use, as described in **Appendix I**, South Platte Historic Consumptive Use - Development of Historical Diversions. Irrigation diversions are provided for each modeled key and aggregate surface water diversion structure. Appendix I also describes the historical diversion file (SP2008.ddh) developed in support of the Ground Water Total River Diversion scenario that includes diversions for carriers, municipal and industrial structures, transbasin structures, and other structures that have no irrigation demands. **Figure 12** shows how surface water diversions for irrigation in the basin have changed over time. Surface water diversions for irrigation averaged approximately 2,425,000 acre-feet over the 1950 through 2006 study period. The variation seen in **Figure 12** is due to water supply limitations, highlighted by the decreased diversions in the drought years of 1954, 1955, and 2002 and the increased diversions during the wet years of 1975, 1980, and 1998.

Figure 12
Surface Water Irrigation Diversions



Appendix I describes how **StateDMI** was used extract diversion records from HydroBase, fill missing diversion record, and estimate surface water supplies available to demand structures**.**

If available, StateCU will also read historic ground water supply information to use in the estimation of water supply-limited consumptive use. Historic ground water supply information is not available for structures in the South Platte Basin.

4.7 Historical Pumping File (SP2008_Restricted.gwp)

The historical pumping file provides the ground water supply information required to estimate supply limited consumptive use. The development of historical pumping estimates for SPDSS is a two step process.

First, the complete StateCU analysis is run to estimate the ground water pumping (diversion) required to satisfy crop consumptive demands not met by surface water (SP2008.gwp). These pumping estimates include inefficiencies associated with ground water application (flood or sprinkler) and are limited by decreed capacity (alluvial wells) or permitted capacity (designated basin wells).

Second, pumping estimates were reduced in 2005 and 2006 for irrigation structures associated with Central Colorado Water Conservancy District WAS and GMS augmentation plans based on quotas. Quotas were applied to the pumping estimates from StateCU (SP2008.gwp) using TSTool, resulting in restricted historical pumping (SP2008_Restricted.gwp) as discussed in **Appendix O**.

4.8 Surface Water Reuse File (SP2008.dra)

The storage diversion file is used in SPDSS to offset diversions to recharge sites that are included in the historical diversion (*.ddh) file. Including the negative of these non-irrigation diversions (after conveyance loss) in the storage diversion file makes sure these non-irrigation diversions are not available to meet crop consumptive use directly or to be stored in the soil zone and available to meet crop consumptive use in subsequent months. This use of the storage diversion file is necessary because, until recently, diversions to recharge were not been coded separately from diversions to irrigation.

Diversions to recharge were provided by Division 1 for the period 1979 through 2007, and are estimated to be zero prior to that time. The storage diversion file contains approximately 77,000 acre-feet on average (over the 1979 to 2007 period) of diversions to recharge sites delivered through 52 structures, as documented in Appendix R of the Lower South Platte Surface Water Model User's Manual. These diversions to recharge are "offset" using the storage diversion file, assuring they are not included in the crop consumptive use analysis as an irrigation supply. The file was created using TSTool.

4.9 Climate Station Information File (SPclim2006.cli)

The climate station information file provides climate station location information for climate stations used in the analysis, including latitude, elevation, county and HUC. **Table 5**, shown in Section 4.3, lists the climate stations included in the climate station information file. The climate station information file was created using **StateDMI** to extract location information stored in HydroBase based on the list of climate stations to be used in the analysis.

4.10 Climate Data Files (SPclim2006.tmp, SPclim2006.prc, SPclim2006.fd)

StateCU requires historical time series data, in calendar year, for temperature, frost dates, and precipitation. The SPDSS climate data files, developed using the **TSTool** DMI, contain monthly data for twenty-seven stations. **Table 9** summarizes the 1950 through 2006 average annual temperature, frost dates and precipitation for each station.

Table 9
Average Annual Filled Climate Values 1950 through 2006

Climate Station					Frost Dates – Degrees F			
No.	Name	Station ID	Temperature (Degrees F)	Precip (Inches)	Spring 28 Deg	Spring 32 Deg	Fall 32 Deg	Fall 28 Deg
1	Akron 4 E (combined)	0109	48.9	16.03	30-Apr	12-May	28-Sep	10-Oct
2	Allenspark 1 NW (combined)	0185	40.1	21.77	25-May	10-Jun	28-Aug	20-Sep
3	Antero Reservoir	0263	36.0	10.06	10-Jun	22-Jun	4-Aug	1-Sep
4	Bailey	0454	41.5	16.60	1-Jun	14-Jun	22-Aug	12-Sep
5	Boulder	0848	51.8	19.31	21-Apr	4-May	6-Oct	16-Oct
6	Briggsdale	0945	48.2	12.88	4-May	14-May	25-Sep	6-Oct
7	Byers 5 ENE	1179	49.4	15.05	2-May	12-May	27-Sep	5-Oct
8	Castle Rock	1401	47.9	17.37	5-May	20-May	25-Sep	6-Oct
9	Cheesman	1528	44.9	16.36	19-May	2-Jun	10-Sep	25-Sep
10	Denver WSFO AP (Stapleton)	2220	50.6	15.49	22-Apr	3-May	6-Oct	18-Oct
11	Eastonville 2 NNW	2494	NA	18.54	NA	NA	NA	NA
12	Estes Park	2759	43.5	14.58	16-May	2-Jun	11-Sep	22-Sep
13	Evergreen (combined)	2790	43.9	18.68	16-May	1-Jun	14-Sep	25-Sep
14	Fort Collins	3005	49.1	15.23	22-Apr	5-May	2-Oct	10-Oct
15	Fort Morgan	3038	49.8	12.93	21-Apr	2-May	4-Oct	14-Oct
16	Georgetown	3261	42.3	16.30	14-May	27-May	19-Sep	1-Oct
17	Greeley UNC (combined)	3553	49.9	13.28	21-Apr	6-May	1-Oct	11-Oct
18	Julesburg	4413	50.9	17.16	23-Apr	6-May	2-Oct	12-Oct
19	Lakewood (combined)	4762	50.2	16.17	28-Apr	10-May	30-Sep	12-Oct
20	Longmont 2 ESE	5116	49.0	13.40	26-Apr	6-May	29-Sep	9-Oct
21	New Raymer	5922	48.2	14.91	2-May	14-May	27-Sep	6-Oct
22	New Raymer 21 N (combined)	5934	46.8	14.22	9-May	20-May	19-Sep	28-Sep
23	Parker 2 N (combined) [3]	6323	48.7	14.71	5-May	18-May	25-Sep	4-Oct
24	Red Feather Lakes (combined)	6921	40.6	16.92	27-May	10-Jun	30-Aug	15-Sep
25	Sedgwick 5 S (combined)	7515	50.6	17.78	23-Apr	4-May	4-Oct	13-Oct
26	Sterling	7950	49.5	15.21	23-Apr	7-May	30-Sep	10-Oct

Figures 13 and 14 show the 1950 through 2006 average monthly precipitation and temperature for the Greeley UNC climate station, located in the north centeral portion of the South Platte Basin. Historic missing data for these climate stations were filled from 1950 through 2006 using the **TSTool** DMI, as described in the Task 53.2 – Collect and Fill Missing Monthly Climate Data memorandum, included in **Appendix D.**

Figure 13
Average Mean Monthly Temperature
Greeley UNC Climate Station 1950 through 2006

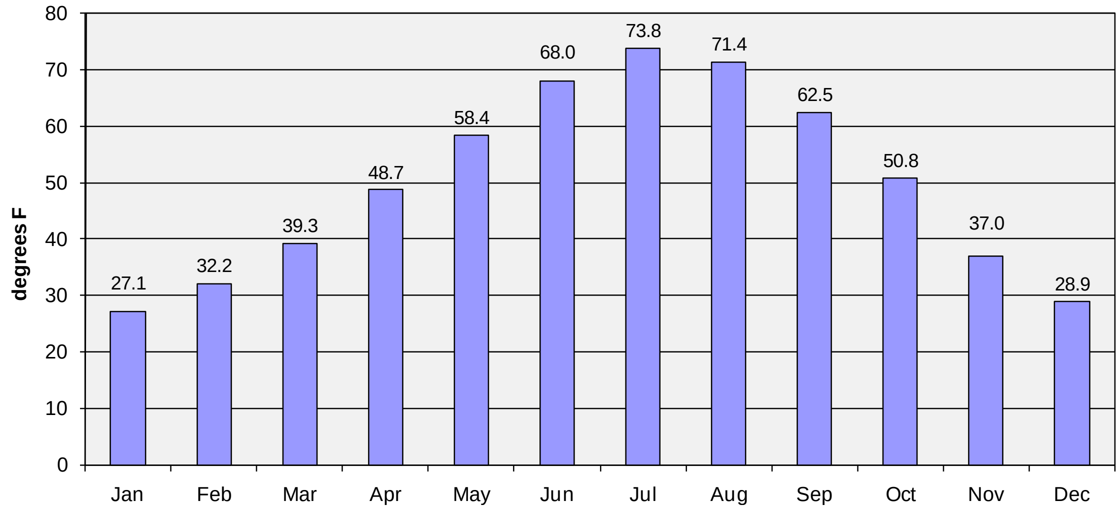
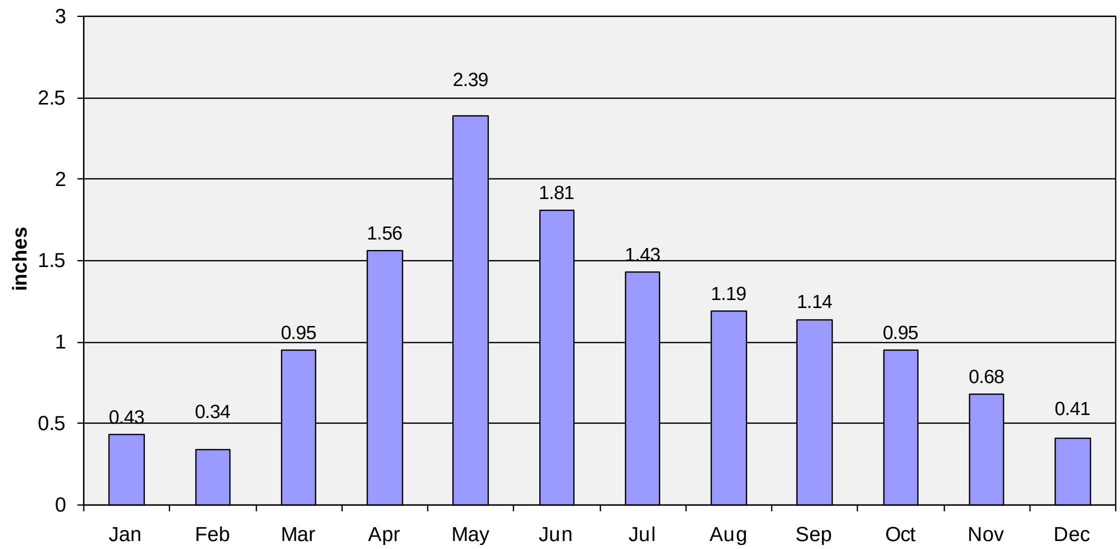


Figure 14
Average Monthly Precipitation
Greeley UNC Climate Station 1950 through 2006



4.11 Blaney-Criddle Crop Coefficient File (CDSS.kbc)

The Blaney-Criddle crop coefficient file contains locally calibrated crop coefficient data used in the SPDSS historic consumptive use analysis. Standard TR-21 Blaney-Criddle crop coefficients were revised to yield average evapotranspiration results more consistent with results obtained using the ASCE Standardized Penman-Monteith method over an eleven year period for the plains region of the model area. The more data-intensive ASCE Standardized daily method for estimating crop ET has been shown to better represent measured crop ET than the monthly SCS Modified Blaney-Criddle method. The analysis resulted in crop coefficients representing two regions – the upper plains area and the lower plains area (Water District 64). The standard procedure, whereby monthly Blaney-Criddle coefficients are adjusted until the average monthly Blaney-Criddle results match ASCE Standardized results, is documented in the Task 59.1 – Develop Locally Calibrated Blaney-Criddle Crop Coefficients memorandum, included in **Appendix J**.

Several high-altitude crop studies, performed by Leonard Rice Engineers, Inc. and others, were reviewed to determine appropriate coefficients to represent grass pasture grown in the high elevation meadows of the SDPSS study area. The calibrated crop coefficients recommended in the comprehensive study sponsored by Denver Water were selected for use in the analysis, also documented in **Appendix J**. These coefficients were developed for use with the Original Blaney-Criddle methodology.

Table 10 shows original TR-21 and locally calibrated crop coefficients for selected days developed for pasture and alfalfa, both perennial crops. As discussed in **Appendix J**, TR-21 coefficients do not accurately represent variations in daily minimum and maximum temperatures seen throughout Colorado, as they were developed at sites closer to sea level. In the early and late growing season, when day and night temperature variations are the greatest, calibrated coefficients provide the necessary temperature-based correction to match the ASCE Penman estimates and the measured lysimeter data. Calibrated coefficients also include the effects of other climate data used in the ASCE Penman calculation to provide more accurate potential consumptive use estimates, including wind, vapor pressure, and solar radiation.

Table 10
TR-21 and Calibrated Crop Coefficients for Pasture and Alfalfa

Day of Year	Pasture				Alfalfa		
	TR-21	Upper Plains	Lower Plains	High Altitude	TR-21	Upper Plains	Lower Plains
1	0.48	0.480	0.480	0.000	0.600	0.600	0.600
15	0.47	0.470	0.470	0.000	0.630	0.630	0.630
32	0.525	0.525	0.525	0.000	0.680	0.680	0.680
46	0.575	0.575	0.575	0.000	0.730	0.730	0.730
60	0.64	1.280	0.640	0.000	0.790	0.790	0.790
74	0.74	1.480	0.740	0.000	0.850	0.850	0.850
91	0.815	1.643	1.946	0.000	0.920	1.415	1.506
105	0.855	1.723	2.041	0.000	0.990	1.522	1.621
121	0.88	1.278	1.396	1.180	1.045	1.477	1.644
135	0.90	1.307	1.428	1.180	1.090	1.540	1.715
152	0.915	1.104	1.240	1.400	1.120	1.360	1.540
166	0.92	1.110	1.247	1.400	1.135	1.379	1.561
182	0.925	0.947	1.039	1.220	1.130	0.951	1.005
196	0.925	0.947	1.039	1.220	1.115	0.939	0.992
213	0.915	0.908	1.012	0.810	1.090	0.949	1.022
227	0.905	0.898	1.001	0.810	1.065	0.927	0.998
244	0.89	1.150	1.303	0.860	1.030	0.885	0.970
258	0.87	1.124	1.274	0.860	0.990	0.850	0.932
274	0.84	1.557	1.753	0.750	0.950	1.042	1.195
288	0.795	1.474	1.659	0.750	0.905	0.993	1.139
305	0.735	0.735	0.735	0.000	0.850	0.850	0.850
319	0.67	0.670	0.670	0.000	0.790	0.790	0.790
335	0.605	0.605	0.605	0.000	0.720	0.720	0.720
349	0.55	0.550	0.550	0.000	0.640	0.640	0.640
366	0.48	0.480	0.480	0.000	0.600	0.600	0.600

Table 11 shows original TR-21 and locally calibrated crop coefficients for selected days developed for Corn Grain, an annual crop.

Table 11
TR-21 and Calibrated Crop Coefficients for Corn Grain

Percent of Growing Season	TR-21	Upper Plains	Lower Plains
0	0.440	0.283	0.338
5	0.460	0.295	0.354
10	0.490	0.335	0.377
15	0.530	0.436	0.462
20	0.580	0.478	0.545
25	0.640	0.527	0.601
30	0.710	0.585	0.667
35	0.820	0.725	0.796
40	0.920	0.891	1.006
45	1.010	0.978	1.105
50	1.050	1.017	1.148
55	1.080	1.046	1.181
60	1.080	1.105	1.226
65	1.080	1.105	1.237
70	1.060	1.085	1.214
75	1.040	1.065	1.191
80	1.000	1.069	1.247
85	0.970	1.220	1.358
90	0.930	1.169	1.302
95	0.890	1.119	1.246
100	0.850	1.069	1.190

The calibrated Blaney-Criddle crop coefficients were provided to the Relational Database Contractor and are stored in HydroBase. The crop coefficient file used in the historic consumptive use analysis was created using StateDMI to extracting the representative crop coefficients from HydroBase.

4.12 Crop Characteristic File (CDSS.cch)

The crop characteristic file contains information on planting, harvesting, and root depth. Standard TR-21 Blaney-Criddle crop characteristics are representative of both the upper and lower plains regional South Platte crop characteristics and were used in the analysis. Crop characteristics from the Denver Water study were used for grass pasture above 6,500 feet. The beginning temperature and ending calibrated temperature used to define the growing season high altitude grass pasture is 42 degrees Fahrenheit. Because grass pasture is a perennial crop, the length of season is set to 365 days.

Table 12 presents the crop characteristics representative of growing patterns in the South Platte Basin for alfalfa, corn grain, dry beans, pasture grass, small grains, and sugar beets. More detail is provided in the Task 59.1 – Develop Locally Calibrated Blaney-Criddle Crop Coefficients memorandum, included in **Appendix J**.

Table 12
TR-21 and Calibrated Season Begin Temperature, End Temperature and Length

Crop	Beginning Temperature (Degrees Fahrenheit)	Ending Temperature (Degrees Fahrenheit)	Length of Season (days)
Alfalfa	50	28	365
Corn Grain	55	32	140
Dry Beans	60	32	112
Grass Pasture	45	45	365
Small Grains	45	32	137
Sugar Beets	28	28	184

The representative Blaney-Criddle crop characteristics were provided to the Relational Database Contractor and are stored in HydroBase. The crop characteristic file used in the historic consumptive use analysis was created using StateDMI by extracting the representative crop characteristics from HydroBase and develop the crop characteristics input file.

StateCU was exercised with calibrated crop coefficients and parameters to develop unit irrigation water requirements at climate stations in the basin for the major cops shown. The approach and results are provided in Task 59.2 – Irrigation Water Requirements at Climate Stations memorandum, included in **Appendix K**.

5.0 Results

5.1 StateCU Model Result Presentation

The South Platte Basin historic crop consumptive use results are a product of the input files described in **Section 4**. This section provides a summary of historic crop consumptive use, ground water pumping estimates, and system efficiencies. Results for individual key, aggregated, and ground water only structures can be easily viewed and printed by obtaining the StateCU input files and StateCU model from the CDSS web site (see **Section 3.5**).

Tables 13a and **13b** show the average annual basin consumptive use water budget accounting for the period 1950 through 2006. The individual component results are discussed in detail in the following sections.

Table 13a
Basin Average Annual Results 1950 through 2006 (acre-feet)

Irrigation Water Required	Surface Water Diversion Accounting							
	River Headgate Diversion	Conv Loss	Diversion to Recharge	Diversion to Farm	Surface Water Diversion To:			Calculated Application Efficiency
					CU	Soil	Non-Consumed	
1,544,302	2,425,410	652,412	26,172	1,746,826	749,505	109,564	887,758	49%

Table 13b
Basin Average Annual Results 1950 through 2006 (acre-feet) - Continued

Ground Water Diversion Accounting				Estimated Crop CU			Total Non-Consumed
Diversion (Pumping)	Application Efficiency	To CU	Non-Consumed	From SW and GW	From Soil	Total	
487,295	64%	312,332	174,947	1,061,837	108,873	1,170,710	1,062,705

Note that *Irrigation Water Requirement* is potential consumptive use less the amount of precipitation effective in meeting crop demands directly during the irrigation season and the amount of precipitation during the winter months that is stored in the soil zone and subsequently used to meet crop demands.

5.2 Historic Crop Consumptive Use

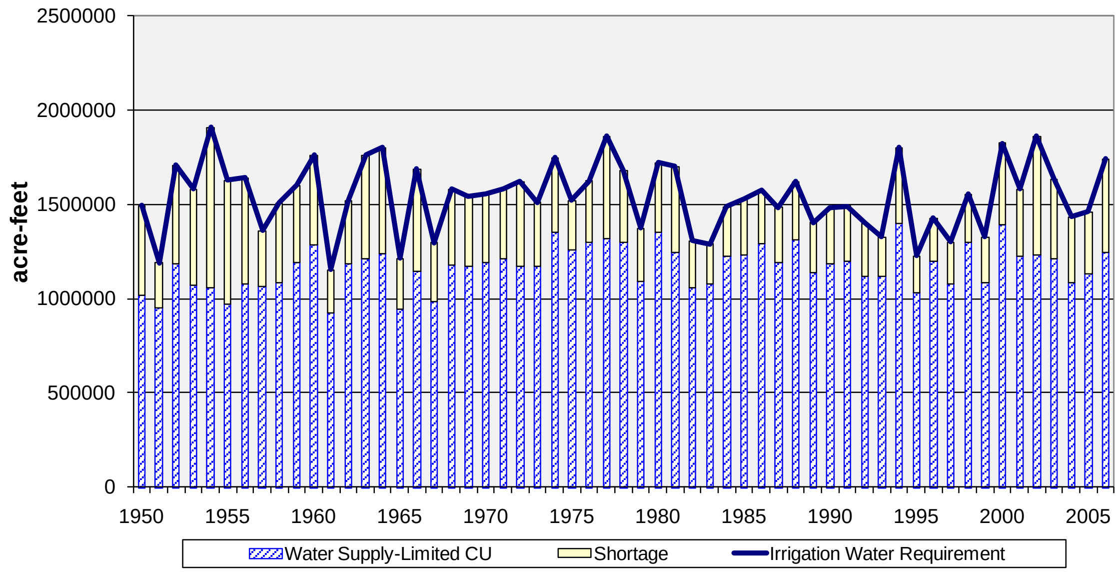
Table 14 presents the historic crop consumptive use analysis results, by water district, for the 1950 to 2006 study period. As shown, water supply-limited consumptive use averages 1,170,994 acre-feet per year. The average annual shortage in the basin is 24 percent.

Table 14
Average Annual Consumptive Use Results - 1950 through 2006

Water District	Acres	Irrigation Water Requirement (acre-feet)	Supply-Limited CU (acre-feet)	Percent Short
1	241,369	367,967	324,040	12%
2	172,486	281,739	201,376	29%
3	215,810	328,082	246,166	25%
4	77,915	127,088	86,886	32%
5	62,925	106,686	60,980	43%
6	50,999	89,284	48,367	46%
7	13,213	25,202	21,036	17%
8	6,600	9,967	8,949	10%
9	2,135	4,027	3,053	24%
23	18,133	28,318	15,315	46%
48 & 76	4,226	6,530	4,619	29%
64	98,226	167,862	148,954	11%
80	1,060	1,558	1,253	20%
Total	**965,097**	**1,544,310**	**1,170,994**	**24%**

Figure 15 presents basin crop consumptive use results by year. As shown, the percent of irrigation water requirement not satisfied has decreased slightly over time, averaging 24 percent. Greater shortages from 1950 through 1956, averaging 33 percent, represent limited water supply due to well development levels and below average stream flows. Shortages averaging 18 percent from 1990 through 1999 are consistent with well development and normal to above average stream flows.

Figure 15
Irrigation Water Requirements and Water Supply-Limited CU

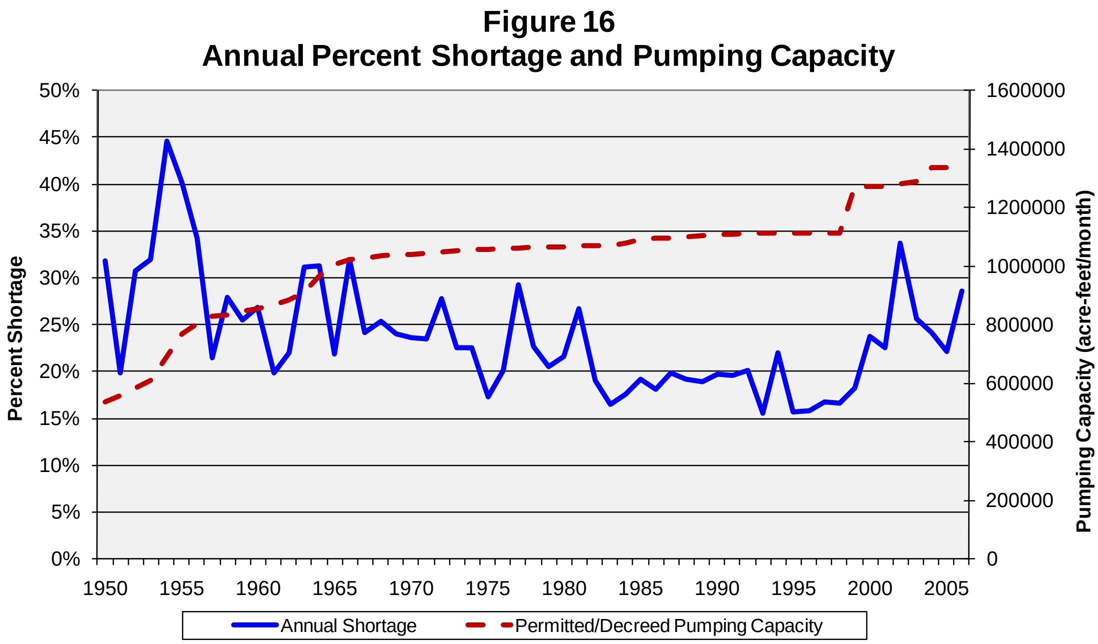


Average monthly shortages for the study period vary from a low of 19 percent in May to a high of 41 percent in October, as shown in **Table 15**.

Table 15
Average Monthly Shortage - 1950 through 2006

Month	Apr	May	Jun	Jul	Aug	Sep	Oct
Average Shortage	29%	19%	21%	23%	24%	31%	41%

Figure 16 presents shortage by year as well as decreed capacity (alluvial wells) or permitted capacity (designated basin wells) in the basin. As shown, shortages vary from year to year based on water supply; however, shortages appear to have decreased over time as more wells have been permitted and decreed.

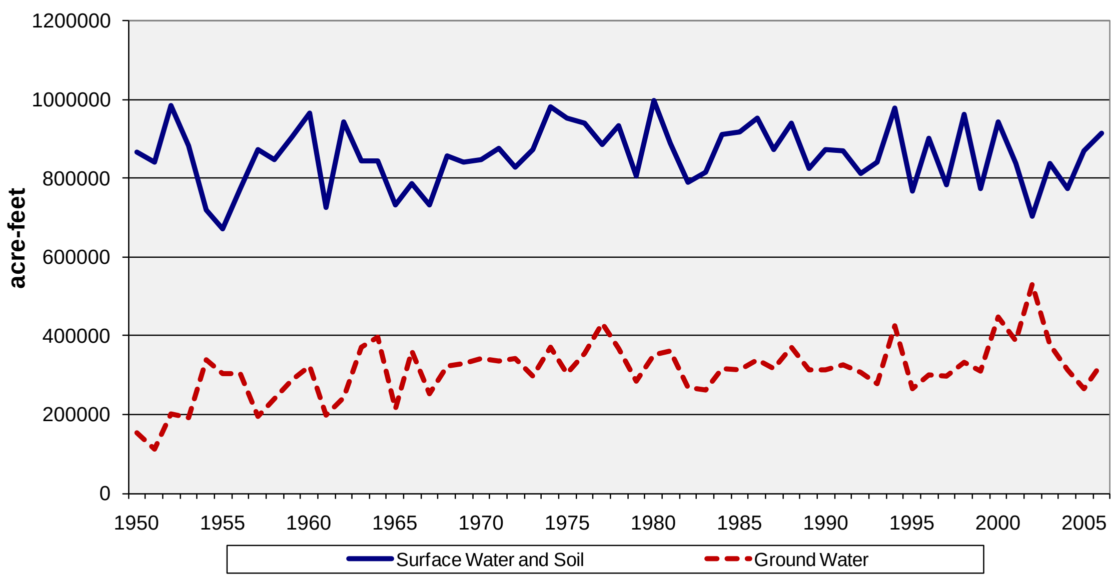


Irrigation water requirements are satisfied from both surface water and ground water. **Table 16** shows the average water supply-limited consumptive use for each Water District by source for the study period. **Figure 17** shows the overall basin information by year. As shown, consumptive use from ground water tends to be higher in years when consumptive use from surface water is less (i.e. in years of short surface water supply). Note the consumptive use from surface water includes excess surface water stored in the soil moisture and then subsequently used by crops. Ground water, as modeled, does not contribute to soil moisture storage.

Table 16
Average Annual Consumptive Use by Source - 1950 through 2006

Water District	Consumptive Use from Surface Water	Consumptive Use from Ground Water	Total CU	Surface Water as % of Total
1	168,498	155,542	324,040	52%
2	153,777	47,599	201,376	76%
3	217,022	29,144	246,166	88%
4	85,722	1,164	86,886	99%
5	60,058	922	60,980	98%
6	47,353	1,014	48,367	98%
7	20,719	317	21,036	98%
8	3,102	5,847	8,949	35%
9	3,053	0	3,053	100%
23	15,315	0	15,315	100%
48 & 76	4,619	0	4,619	100%
64	78,092	70,862	148,954	52%
80	1,252	0	1,252	100%
Total	**858,582**	**312,411**	**1,170,993**	**73%**

Figure 17
Consumptive Use from Surface Water and Ground Water



As presented in **Table 16**, approximately 73 percent of the crop consumptive use is satisfied from surface water over the study period. **Figure 18** shows annual percent of consumptive use from surface water plus the yearly acreage with available ground water supply. As shown, surface water tended to be a higher percent of the total consumptive use in the early part of the study period prior to the prevalent use of ground water.

However, since the early 1970s, surface water use as a percent of total consumptive use is driven by hydrology (surface water availability).

Figure 18
Percent Consumptive Use Met by Surface Water and Acreage with Available Ground Water Supply

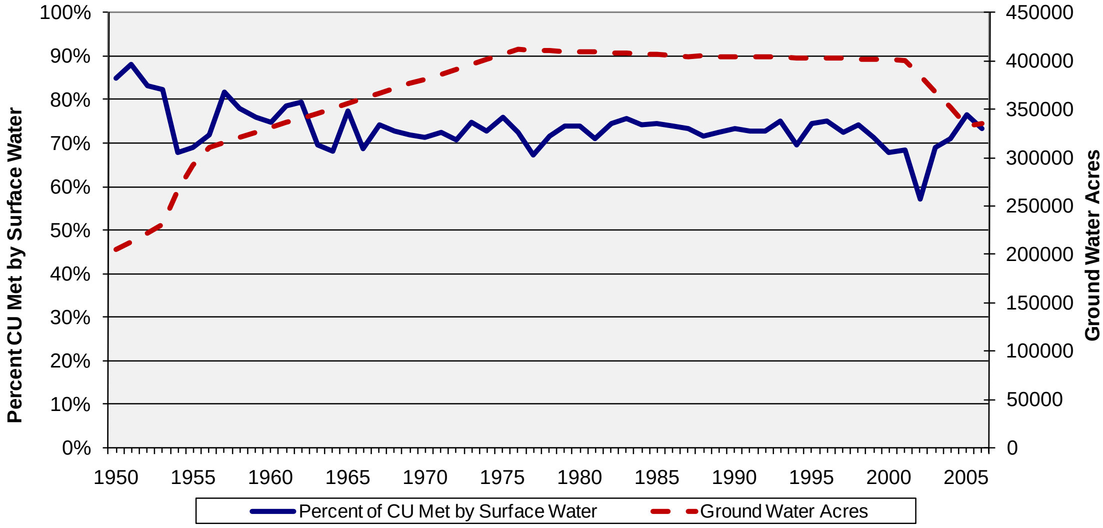
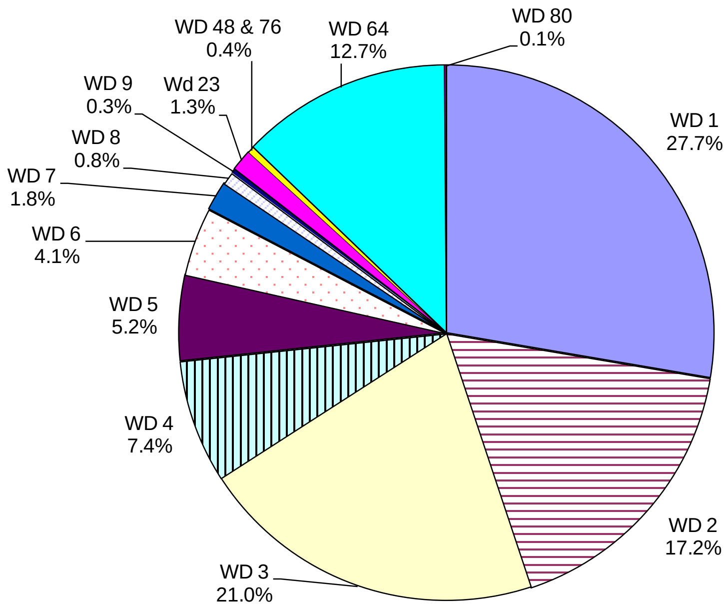


Figure 19 graphically displays the distribution of South Platte Basin consumptive use by water district. As shown, most of the crop consumptive use is in the lower South Platte basin (Water District 1, 2, and 64) and the Cache la Poudre basin (Water District 3).

Figure 19
Percent Historic Consumptive Use by Water District
Average 1950 through 2006



5.3 Ground Water Pumping Estimates

The historical pumping file was developed using a two step process to represent historical and more recent pumping estimates (**Section 4.7**).To represent historic pumping estimates StateCU estimates ground water pumping (diversion) required to satisfy crop consumptive demands not met by surface water. These pumping estimates include water pumped to offset the inefficiencies associated with ground water application (flood or sprinkler). Also, the amount of ground water pumped is limited by the acres served by wells and the decreed capacity (alluvial wells) or permitted capacity (designated basin wells) for each month.

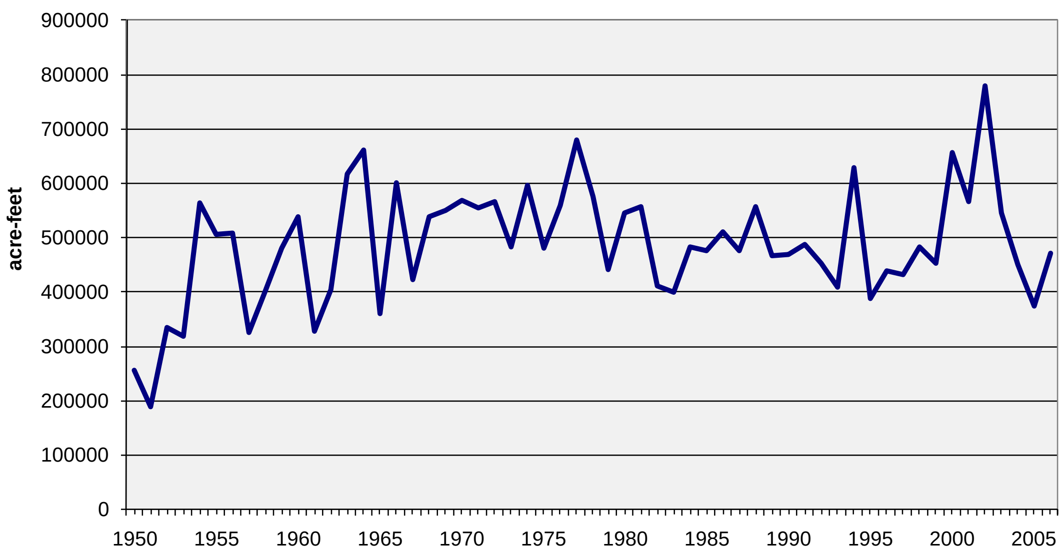
To represent more recent pumping estimates, fifty-three irrigation structures associated with Central Colorado Water Conservancy District augmentation plans; WAS and GMS; were revised to incorperate pumping quotas in 2005 and 2006. The result is a reduction in basin-wide pumping estimate of 49,190 acre-feet (12%) in 2005 and 72,610 acre-feet (13%) in 2006. As shown in **Table 17**, the average estimated ground water pumping from 1950 through 2006 is 487,294 acre-feet per year. For more information see **Appendix O**.

Table 17
Estimated Ground Water Diversion - 1950 through 2006

Water District	Estimated Ground Water Diversion
1	237,650
2	75,491
3	48,190
4	1,943
5	1,374
6	1,701
7	531
8	9,747
9	0
23	0
48 & 76	0
64	110,667
80	0
Total	487,294

Figure 20 presents ground water diversions (pumping) by year. Note that 1964, 1977, and the 2002 had high pumping estimates, corresponding to years of reduced surface water availability. In recent years, 1993 and 1995 had low pumping estimates, corresponding to wet hydrologic years.

Figure 20
Ground Water Pumping



If measured or estimated ground water pumping information is available for specific structures, StateCU will apply the ground water diversions provided in the historic pumping volume file to meet consumptive use demands.

5.4 Estimated Actual Efficiencies

As described in the StateCU Documentation, the amount of surface water available to meet the crop demand is the river headgate diversion less conveyance losses and application losses. If the surface water supply exceeds the irrigation water requirement, water can be stored in the soil moisture up to its water holding capacity. Note that ground water is only pumped to meet the irrigation water requirement and associated application losses. Therefore, ground water does not contribute to soil moisture storage.

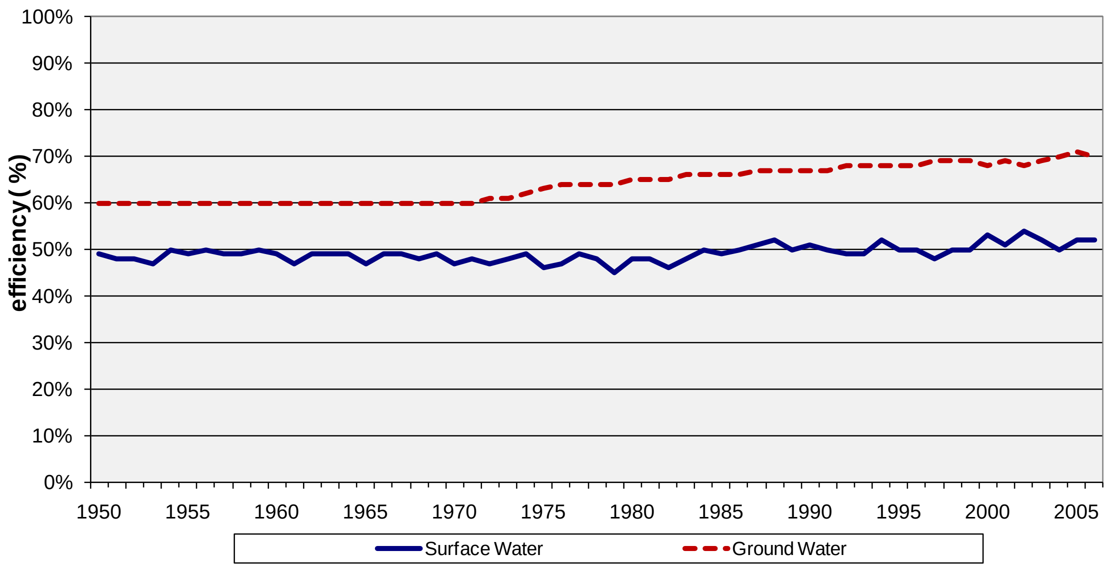
Maximum efficiencies for surface water and ground water diversions are provided as input to StateCU, as described in **Section 4.5**. Actual efficiencies are calculated based on the amount of water available to meet crop demands and the application method (e.g. flood or sprinkler).

Table 18 provides the average monthly calculated application efficiencies for surface water and ground water supplies. Note that surface water efficiencies generally reflect flood irrigation practices while ground water efficiencies include a combination of flood and sprinkler irrigation practices. **Figure 21** shows the same data by year. Ground water efficiencies have increased with the increased use of sprinkler application methods, beginning in the early 1970s. Surface water application efficiencies have remained relatively constant throughout the study period, with the slight variations due to water availability. As shown in **Table 18**, April efficiencies are generally low, indicating water is diverted in excess of crop needs (i.e. to fill the soil reservoir). During the typically high runoff months of May and June, application efficiencies are lower than in mid to late summer when less surface water is available for diversion.

Table 18
Average Monthly Calculated Application Efficiencies - 1950 through 2006

Diversion Type	Apr	May	Jun	Jul	Aug	Sep	Oct
Surface Water	39%	47%	49%	52%	53%	50%	41%
Ground Water	65%	65%	65%	64%	64%	64%	63%

Figure 21
On-Farm Efficiency



6.0 Model Sensitivity

As described in Section 4.0 Data Description, some of the input data and modeling procedures are estimated based on accepted engineering techniques. It is important to understand how sensitive the consumptive use model results are to these estimates. The following input estimates and procedures were varied:

- Acreage filling techniques
- Conveyance efficiency estimates
- Maximum application efficiency estimates
- Pumping estimate procedure

The model sensitivity was accessed by comparing supply-limited consumptive use and the results used as input to the ground water modeling effort: conveyance loss, pumping, and non-consumed applied irrigation water.

6.1 Sensitivity to Irrigated Acreage Filling Techniques

Appendix F describes the procedures used to estimate irrigated acreage, by ditch system, between the detailed acreage assessment years. As noted, a straight-line interpolation approach was adopted to estimate irrigated acreage and crop type by ditch. In addition, a straight-line approach was also used to fill irrigation method (sprinkler versus flood) between acreage assessment years. A sensitivity scenario was developed that used a fill-forward approach to filling acreage and irrigation method between years.

The resulting crop consumptive use, pumping, conveyance loss, and non-consumed applied water varied by less than 1 percent during the recent period from 1988 through 2006. The model was more sensitive during the period between the 1956 acreage assessment and the 1987 acreage assessment, when a fill-forward approach does not reflect the gradual conversion to sprinkler irrigation. The sensitivity analysis reinforced that the acreage filling method selected is appropriate for the SPDSS consumptive use analysis because it recognizes that changes in irrigated acreage and, especially, irrigation methods occur gradually.

6.2 Sensitivity to Conveyance Efficiency Estimates

Appendix G describes the investigation and resulting estimates of conveyance efficiency by ditch. Where available, conveyance efficiencies estimated in support of water court applications were used. For the remaining structures included in the consumptive use analysis, conveyance efficiency was estimated based on soil properties and ditch lengths. Sensitivity analyses were developed that considered the results if estimated conveyance efficiencies were over-estimated by 10 percent or under-estimated by 10 percent. Note that conveyance efficiencies from water court applications were not revised as part of the sensitivity analyses.

When conveyance efficiency estimates were increased by 10 percent, historical consumptive use increased by 2 percent; pumping estimates decreased by 3 percent; and there was a 12 percent increase in non-consumed applied water. As expected, basin-wide conveyance loss decreased significantly, by 42 percent, when conveyance efficiencies were increased. The sum of potential recharge components (ditch loss plus non-consumed applied water) decreased by 2 percent, indicating that when less water is “lost” en route to the farm, more water is delivered to the farm and non-consumed applied water increases accordingly.

When conveyance efficiencies estimates were decreased by 10 percent, historical consumptive use decreased by 3 percent; pumping estimates increased by 4 percent; and there was a 12 percent decrease in non-consumed applied water. As expected, basin-wide conveyance loss increased significantly, by 42 percent, when conveyance efficiencies were decreased. The sum of potential recharge components (ditch loss plus non-consumed applied water) increased by only 2 percent, indicating that when more water is “lost” en route to the farm, less water is delivered to the farm and non-consumed applied water decreases accordingly.

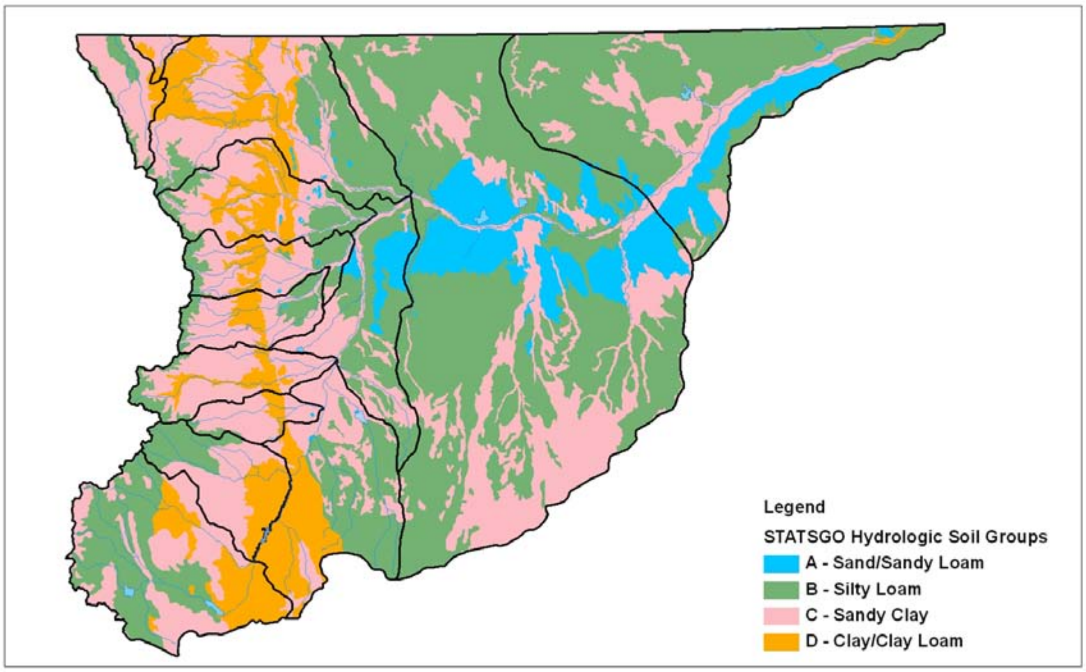
The larger ditches, accounting for the majority of diversions and associated ditch loss in the basin, conveyance efficiencies based on water court applications were used. Conveyance efficiencies for the remaining ditches are estimated based on an accepted method. Therefore, although the consumptive use model estimates of ditch loss and non-consumed water are sensitive to the conveyance efficiencies used, no revisions were recommended based on the sensitivity analysis. In the future, as the SPDSS is updated, new conveyance efficiency information should be incorporated.

6.3 Sensitivity to Maximum Application Efficiency Estimates

Maximum application efficiencies were estimated to be 60 percent for flood irrigated acreage and 80 percent for sprinkler irrigated acreage. Note that actual application efficiency of surface water estimated by StateCU varies with water supply, reaching maximum efficiency when water-supply is limited. When historical pumping records are not available and pumping is estimated by StateCU, as in SPDSS efforts, maximum efficiency is used in the calculation.

Maximum efficiency for sandy soils may be lower than maximum efficiency for other soil types, because the soil is unable to store water as efficiently. Approximately 17 percent of the soil in the South Platte has been characterized as "sandy loam" by the Natural Resources Conservation Service, as shown in **Figure 22**.

Figure 22
South Platte Hydrologic Soil Groups



A sensitivity analyses was developed that considered the results if maximum application efficiency was set to 50 percent for flood irrigated lands and 70 percent for sprinkler irrigated lands overlying sand and sandy loam soil groups. Basin-wide historical consumptive use estimates varied by less than one-half percent. Pumping estimates increased by 5 percent. The increase in pumping estimates was offset by a 5 percent increase in the amount of non-consumed applied water.

The 60 percent and 80 percent maximum application efficiencies are commonly used to estimate historical crop consumptive use in the South Platte basin for change cases and augmentation plans, even when the water court application includes irrigated lands on sandy soils. Although basin-wide pumping estimates increased, the amount of non-consumed water available for recharge offsets the increased aquifer use in the ground water model. Because to data was found to support the lower maximum application efficiency values, no revisions were recommended based on the sensitivity analysis.

6.4 Sensitivity to Pumping Estimate Procedure

The historical estimates of pumping are based on the acreage assigned to ground water and surface water sources and the availability of surface water. Investigation into basin-wide, regional, and ditch level deficit irrigation was performed, as documented in the Task 77 – Perform Analysis of Deficit Irrigation memorandum, included in **Appendix L**. Based on the findings, no adjustment for deficit irrigation was recommended. Therefore, the historical crop consumptive use analysis estimated pumping using the consumptive use approach with a full supply.

A sensitivity analysis was performed to document the results if pumping was limited to meeting 90 percent of irrigation water requirement. Surface water was allowed to meet a full supply, if water was available, then if ground water was available, it could meet shortages up to 90 percent of the irrigation water requirement. For ground water only lands, pumping was estimated to meet 90 percent of irrigation water requirement.

On average from 1990 to 2000, when ground water acreage was relatively consistent, allowing deficit irrigation of 90 percent resulted in a 4 percent reduction in historical consumptive use estimates and a 13 percent decrease in estimated pumping. The sensitivity analysis resulted in a slight 1 percent decrease in non-consumed applied water.

The model results, especially pumping estimates, are sensitive to the procedure used to estimate pumping. As discussed in **Appendix L**, the investigation of deficit irrigation was unable to answer critical questions, such as does deficit irrigation occur? If so, does it occur basin-wide, regionally, or well by well? Therefore, no changes were recommended to the current procedure of estimating pumping using the consumptive use approach with a full supply.

6.5 Sensitivity Analysis Summary

The model sensitivity was accessed by comparing supply-limited consumptive use and the results used as input to the ground water modeling effort: conveyance loss, pumping, and non-consumed applied irrigation water. **Table 19** summarized the parameters varied and their impacts on key outputs, as detailed in the previous sections.

Table 19
Sensitivity Analysis Summary

Parameter Variation	Percent Difference from Recommended Scenario				
	Consumptive Use	**Conveyance Loss**	**Pumping Estimates**	**Non-consumed Applied Water**	**Total Non-consumed Water** [1)]
Fill-Forward Irrigated Acreage Approach	Decreased by 1.5%	No Change	Decreased by 5.6%	Decreased by 1%	Decreased by 1%
Conveyance Efficiency for estimated ditches Increased by 10%	Increased by 2%	Decreased 42%	Decreased by 3%	Increased by 12%	Decreased by 2%
Conveyance Efficiency for estimated ditches Decreased by 10%	Decreased by 3%	Increased by 42%	Increased by 4%	Decreased by 12%	Increased by 2%
Maximum Application Efficiency 50 and 70 for Sandy Soils	No Change	No Change	Increased by 5%	Increased by 2%	Increased by 1%
Pumping Estimated to meet 90% of IWR	Decreased by 4%	No Change	Decreased by 13%	Decreased by 1%	Decreased by 1%

1) Total Non-consumed Water is the portion of diversion (surface and ground water) that is not consumed by crops. It is the sum of conveyance loss and non-consumed applied water.

7.0 Comments and Concerns

The historic crop consumptive use estimates are based on measured and recorded data; information from other studies; information provided by local water commissioners and users; and engineering judgement. The results developed for this project are considered appropriate to use for SPDSS planning efforts. Areas of potential improvement or concern include:

- Historic Acreage. The irrigated acreage for the five assessment years (1956, 1976, 1987, 2001, and 2005) that serves as the basis for estimating historic acreage is considered very accurate. Acreage estimates in between the assessment years could be improved with additional historical assessments. Surface water service areas, which tie irrigated acreage to the surface diverting structure, are considered very accurate. Wells were assigned to irrigated parcels spatially, supplemented by user-supplied information. A more accurate well to parcel association, including more field verification, could improve consumptive use estimates and provide greater confidence in pumping estimates.
- Conveyance Efficiencies. As discussed in **Appendix G**, conveyance efficiency estimates for some larger ditches are based on user-supplied information and efficiencies used in support of water court applications. Little information exists for the other large ditch systems or the smaller systems. Future canal loss studies could improve the estimate of conveyance efficiencies used in the historic consumptive use estimate. Conveyance efficiency estimates used in the analysis are based on soil type and ditch length, determined by the GIS canal coverage. The canal coverage was digitized from previous mapping, and does not include all ditches or the entire

length of some ditch systems. More detailed mapping of ditch systems in the South Platte could improve the estimate of conveyance efficiencies.

- Application Efficiencies. The results presented herein include readily available data and engineering estimates for maximum flood irrigation and maximum sprinkler irrigation efficiencies. As discussed in Section 6.3, pumping estimates are sensitive to maximum efficiencies. Additional refinement could occur if additional data were developed to refine these estimates on a ditch by ditch basis.
- Natural Sub-Irrigation. The consumption of ground water by irrigated lands through natural subirrigation has not been included in the historic consumptive use analysis. Therefore it is possible that this analysis has over-estimated the amount of man controlled consumptive use. For example, if sub-irrigated lands are supplied by surface water only, too much of the diversion could be considered consumptive and attributed to a man induced activity. Similarly, if sub-irrigated lands have a ground water supply, pumping estimates may be overestimated and man controlled agricultural consumptive use may be overestimated. Future enhancements to the consumptive use analysis should consider quantifying the acres potentially served by natural sub-irrigation. Based on the results of such an analysis an appropriate methodology to estimate consumptive use by natural sub-irrigation may be developed.
- Water Use. The results presented are based on an approach that attempts to represent how water is actually applied to crops in the basin. The approach used is based on engineering judgement and informal discussions with water users. The effort did not include determining surface water shares for each owner under a ditch or determining different application rates based on crop types. Instead water was shared equally based on acreage. Therefore, this basin-wide historical crop consumptive use analysis is appropriate for SPDSS planning purposes. However, it should be used as a starting point only for a more detailed ditch level analysis.

The historical estimates of pumping are based on the acreage assigned to ground water and surface water sources and the availability of surface water. Investigation into basin-wide, regional, and ditch level deficit irrigation was performed, as documented in the Task 77 – Perform Analysis of Deficit Irrigation memorandum, included in **Appendix L**. Based on the findings, no adjustment for deficit irrigation is recommended. Therefore, the historical crop consumptive use analysis estimated pumping using the consumptive use approach with a full supply. As flow meter pumping data and power data with certified PCCs are collected under some of the newer decreed augmentation plans, a new source of information may become available for investigating deficit irrigation throughout the SPDSS study area.

Appendix A
Task 3 Summary – Key Diversion Structures

To: Ray Alvarado and Ray Bennett

From: LRE – Mark Mitisek and Erin Wilson

Subject: Task 3 Summary – Key Diversion Structures

Date: Apri1 5, 2008

Introduction

The objective of this Task 3 memorandum is as follows:

> *Identify key diversion structures accounting for approximately 85 percent of the net absolute decreed surface water rights in Water Division 1. Include additional structures, as appropriate, based on water rights and location and other structures that should be considered key based on interviews with Water Commissioners and Division Engineers.*

Background

Key diversion structures were initially identified as diversion structures representing the approximately 85 percent of net absolute decreed water rights within each Water District in the SPDSS study area. The preliminary list of key diversion structures was then revised during subsequent phases of the SPDSS effort based on interviews with Water Commissioners and Division 1 personnel. These interviews discussed diversion structures and/or diversion systems that should be included in potential future modeling efforts due to their impact on basin operations. Diversion systems are defined as a group of diversion structures on the same tributary and operated in a similar fashion to satisfy a common demand.

During Phases 1 and 2, fourteen meetings were held with Water Commissioners, Division Engineers, and Division of Water Resources personnel to discuss administrative practices in each Water District, particularly with regard to key diversion structures (SPDSS Task 3), transbasin diversions (SPDSS Task 4), and key storage structures (SPDSS Task 5). Meeting notes were prepared for each of the Task 3 meetings that summarize available information related to stream gages, diversion and storage structures, and the use of transbasin water in the Water Districts. Normal year river call sequences were discussed and summarized in the meeting notes along with information related to dry-up points on the river, return flow locations, and specific administrative practices.

During Phase 3, the key structure list was again reviewed and revised based on acreage assignments in the final SPDSS 2001 and historical irrigated acreage coverages as well as the availability of diversion records.

The approach and results associated with development of the initial and final list of key diversion structures are summarized below. The key structure list provided in this memorandum will be used to estimate agricultural consumptive use in the Phase 3 Historical Crop Consumptive Use Analysis (Task 74). The key structure lists also includes municipal diversions, reservoir carriers, and "demand" structures representing demands that receive water from more than one source. For consistency, the surface water and ground water modeling effort are expected to use these same structures.

Approach

Consumptive use modeling (StateCU), water budget modeling (StateWB), and surface water modeling (StateMod) for the 1950 to present study period will represent 100 percent of the consumptive uses within the SPDSS study area. Key diversion structures that make up approximately the top 85 percent of net absolute decreed surface water rights and diversions within specific Water Districts will be modeled explicitly. The remaining diversions will be modeled in an aggregate fashion. The final percentages of explicit (key) and aggregate structures to be modeled within each District are based on specific characteristics of the Water Districts.

Key diversion structures in the SPDSS study area were identified in each Water District based on the following approach:

- Identify and accumulate net absolute water rights per structure
- Identify recorded diversions per structure for 1950 to present period
- Rank structures according to net total absolute surface water rights
- Highlight the top 85 percent of net absolute water rights
- Identify preliminary average annual diversion threshold amounts associated with top 85 percent of water rights. This resulted in a threshold annual amount of 1,000 ac-ft for most Water Districts.
- Recognize and add structures with absolute water rights not included in the initial list that divert greater than the threshold amount.
- Remove structures with absolute water rights that will not be explicitly modeled, including:
    - Reservoir outlet structures
    - Duplicate structures used in coding for one Water District as FROM structures (CIU code = 'F') from another Water District
    - Structures identified as non-existent (CIU code = 'N'), historical (CIU code = 'H'), or inactive (CIU code = 'I') by the Water Commissionner
    - Structures receiving water from a non-river source (spring, seep, drainage, runoff, waste, salvaged water)
- Add structures integral to Water District operations, as recommended during the Task 3 Water District meetings. Generally these included:
    - Reservoir supply ditches and important carrier diversion structures
    - Smaller, very senior absolute direct flow water rights and calling ditches
    - Ditches integral to municipal operations
- Review percentage of total water rights and, if necessary, revise threshold amount to meet goal of explicitly modeling approximately 85 percent of diversions in the study area

- Review irrigated acreage assigned to structures in the SPDSS Irrigated Acreage Assessment and remove previously identified key irrigation structures that have not been assigned acreage. Remove key structures without consistently available diversion records.

In addition to key structures, represented by a single headgate structures with one demand, the modeling effort includes explicit representation of "demand structures" and "diversion systems".

Demand structures represent agricultural and/or municipal users that receive water from several sources to meet a single demand. For instance, Riverside Irrigation System meets their irrigation demand from a direct flow right through the Riverside Canal and, if necessary, from water released from Riverside Reservoir. Riverside Reservoir is an "on-ditch" reservoir; therefore releases are not carried through the headgate of Riverside Canal. Larger municipalities, such as Ft Collins, often have several treatment plants that can deliver water throughout the city. The river headgate diversions (or wells) that meet these demands will be modeled as carriers to a single "demand" structure.

Diversion systems are defined as a group of diversion structures on the same tributary and operated in a similar fashion to satisfy a common demand. Diversion systems represent the water rights, acreage, and historical diversions of each component diversion structure explicitly.

Results

Key Diversion Structures
Table 1 identifies the total number of key and diversion system structures, total decreed water rights, and total 2001 acreage by Water District. The general headgate locations of the key diversion structures are shown in the figures at the end of the memorandum. The headgate locations on the figures are based on the GIS coverage available on the CDSS web site. Note that some of these locations may not be on the stream or may overlap headgates from other structures. The figures are intended to provide a general understanding of the spatial distribution of key structures and diversion system structures that make up diversion systems. The Water District identifiers are included on the figures for reference. Names of structures were not included on the figures to ease readability.

As shown in **Table 1**, 359 structures were identified as key and recommended to be modeled explicitly in the South Platte River Basin. These structures include individual structures and the main identifier within diversion systems. 294 separate structures associated with diversion systems were also identified in the South Platte basin. The water rights, acreages, and demands associated with 653 total structures (key structures plus structures within diversion systems) will be modeled explicitly in the SPDSS efforts. This represents 99 percent of the irrigation demand in the basin.

Tables 2, included at the end of this memorandum, presents each key diversion structure and primary structure in diversion systems and the associated 2001 acreage for the South Platte basin. These key structures, as noted, include reservoir carriers, transbasin diversions, and municipal/industrial diversions in addition to irrigation diversions. Acreage listed under the primary structure of a diversion system includes acreage for all structures included. **Table 3**, also included at the end of the memorandum, lists the individual structures in each diversion system in the South Platte basin. The list of key structures is intended to be used in both the SPDSS consumptive use and water resource planning model efforts. Additional information about each key structure, including water source, total decree, diversion period of record, and average annual diversions are included in each individual Task 3 Water District memorandum.

Key Demand Structures

A "demand" structure is recommended if:

- Demand can be met through more than one river headgate. For instance, North Poudre Irrigation Company can meet their irrigation demand from headgates on both the North Poudre and the mainstem Cache la Poudre Rivers.
- An off-channel reservoir delivers water directly to demand. The demand may also be met from direct diversions, as with the Riverside example above, or the demand can be met only from reservoir releases, as is the case with the FRICO-Milton demand.
- Demand can be met through a single headgate, but water sources have different delivery losses. For instance, deliveries from an upstream reservoir may experience both river losses and canal losses whereas direct diversions only experience canal losses.
- River headgate delivers water to more than one demand, and at least one of those demands is irrigation. For example, Evans #2 Ditch delivers water to both Milton Reservoir (for FRICO-Milton use) and to lands irrigated under Evans #2 Ditch. In this case, irrigation under Evans #2 is modeled as a separate "demand" structure, because the Evans #2 headgate diverts water for two separate demands.

In the Task 66 memorandum (Collect and Develop Municipal and Industrial Consumptive Use Estimates) it was recommended to model key municipal demands that are served by several sources using indoor and outdoor demand nodes. For instance, the City of Greeley has a single indoor demand, but has diversion points both on the Cache la Poudre River and the Big Thompson River that meet that demand.

Key demand structures are included in **Tables 2 and 3**. As discussed above, the individual diversions and water rights that will be modeled as carriers to these demands are shown **Table 1** and noted as such in the comment section column. Ten (10) municipalities and nine (9) industrial structures will be modeled explicitly as demand structures – the remaining municipal and rural demands will be modeled in aggregates. Twenty-five (25) irrigation systems will be modeled explicitly with demand structures. Note that for modeling efforts, acreage assigned to the river headgate structure is re-assigned to the demand structure.

The naming convention adopted for modeling demand structures is as follows:

- Municipal demand nodes include water district, abbreviated municipal name, and "I" or "O" representing indoor or outdoor demand. Demand structure names are limited to 12 characters. For instance, Thornton demand structures are 02THORTON_I and 02THORTON_O. As discussed in the Task 66 memorandum, splitting demand into indoor and outdoor allows outdoor demands to be given a lower use priority in times of limited supply.
- Demand structures are given a unique identifier that includes the primary source identifier with a '_I' extension. For example, the North Poudre Irrigation Company

demand structure is assigned the unique identifier '0300994_I' to designate that the primary source is North Poudre Canal (0300994). Similarly, the demand structure associated with FRICO-Milton is assigned the unique identifier '0203876_I' to designate that the primary source as Milton Reservoir (0203876).

Key Diversions Systems

Diversion systems are defined as a group of diversion structures on the same tributary and operated in a similar fashion to satisfy a common demand. Diversion systems represent the water rights, acreage, and historical diversions of each component diversion structure explicitly. Example diversion systems are as follows:

- Berger Ditch Diversion System (8000774_D) has four separate ditches that commingle and irrigated lands for a single ranch. The ditches operate conjunctively to meet a common demand.
- The City of Aurora has transferred many irrigation ditches in Water District 23 to municipal use. Per decree, these ditches are logically grouped and administered at stream gages in the basin. The water rights and operations associated with the "administrative gages" are represented as diversion systems.
- Water rights associated with Riverside Ditch (0100710) and Illinois Ditch (0100504) are taken through Riverside Canal (0100503). They are represented, along with Riverside Canal water rights, under Riverside Diversion System (0100503_D).

Diversion systems are generally given a unique identifier that includes the one of the structure WDIDs (usually the largest) with a '_D' extension. For example, Riverside Diversion System is assigned the unique identifier 0100503_D. In the specific case of the City of Aurora transfers, the unique identifiers have been given the abbreviation of the administrative gages used to measure the city's allowable transfer credit with a '23_' prefix to signify the diversion system is in Water District 23 (for example 23_TARCOMCO).

Table 1
Summary of Key Structures

Water District	Numbers of Diversion Structures				Absolute Decreed Direct Rights (cfs)			2001 Diversion Structure Acreage		
	Total Structures	Key Structures	Key and DivSys Structures	Percentage of Total	Water District Total	Key and DivSys Total	Percentage of Total	Water District Total	Key and Divsys Total	Percentage of Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	33	21	29	88%	18,775	15,871	85%	147,036	146,270	99%
2	38	30	35	92%	9,087	8,377	92%	152,352	151,858	100%
3	66	28	35	53%	7,970	6,745	85%	191,911	188,968	98%
4	39	38	39	100%	11,868	11,741	99%	68,382	68,382	100%
5	62	43	54	87%	8,167	7,197	88%	54,193	53,547	99%
6	66	57	65	98%	10,348	6,491	63%	40,311	40,311	100%
7	44	24	41	93%	11,774	10,912	93%	6,066	5,870	97%
8	54	30	34	63%	1,203	1,030	86%	2,404	1,673	70%
9	17	8	14	82%	1,601	1,367	85%	2,031	2,008	99%
23	207	11	160	77%	1,458	308	21%	7,604	4,046	53%
48&76	67	21	67	100%	2,249	1,557	69%	3,738	3,738	100%
64	31	27	31	100%	3,813	2,709	71%	66,315	66,315	100%
80	61	21	49	80%	200	58	29%	926	858	93%
Total	**785**	**359**	**653**	**83%**	**88,513**	**74,364**	**84%**	**743,271**	**733,844**	**99%**

1. Total structures assigned acreage in any of the SPDSS Irrigated Acreage Assessment years, municipal carriers and structures, and reservoir carriers.
2. Key structures and primary structures of diversion systems. Note that this does not include “demand structures”.
3. Key structures plus all structures represented in diversion systems.
4. Percentage of structures with irrigated acreage, plus municipal diversions and reservoir carriers w/out acreage, that are explicitly represented.
5. Total absolute decreed direct water rights for active structures that are expected to be included in the model (excludes springs, seepage, and drainage rights).
6. Total absolute decreed direct water rights represented by key and diversion system structures.
7. Percentage of absolute decreed direct water rights that are explicitly represented.
8. Total acreage assigned to diversion structures in the SPDSS 2001 Irrigated Acreage Assessment.
9. Total acreage assigned to key and diversion system structures.
10. Percentage of total acreage assigned to diversions structures that is explicitly represented.

Operations within specific Districts determine the number of key structures and diversion systems. Most Districts have a relatively small number of diversion system structures. Exceptions to this general rule are discussed below:

- Water District 23 – Absolute water rights from many ditches within South Park have been aggregated and assigned to and administered at 20 stream gages within the District. SPDSS modeling will represent the water rights from the 149 individual structures at the 18 gages.
- Water District 48 – Many diversion systems within the Laramie River basin are recommended due to the number of large ranches that are irrigated by multiple ditch systems.
- Water District 80 – Similar to the Laramie River basin, several diversion systems are recommended due to the number of large ranches that are irrigated by multiple ditch systems.

More information regarding these Districts and others within the SPDSS study area can be found in the individual Water District meeting notes developed in Task 3.

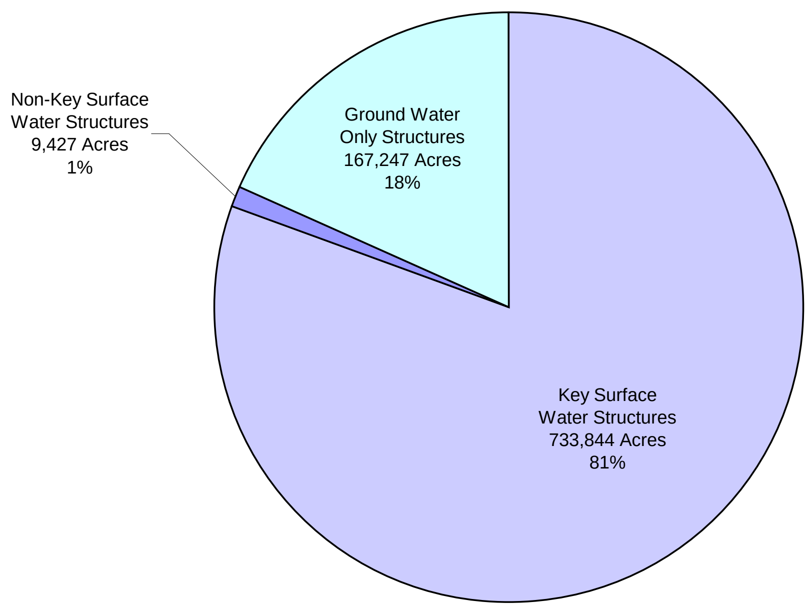
As presented in **Table 1**, the percentage of total decreed surface water rights associated with the key structures vary by tributary but, in total, account for approximately 84 percent of the total decreed surface rights anticipated to be included in the model (e.g., not including seeps, drains, reservoir outlets, etc.) in the South Platte. The percentages of total water rights associated with key structures within the Water Districts range from about 21 percent (District 23) to about 99 percent (District 4). Key structures and diversion systems account for about 99 percent of the total 2001 irrigated acreage assigned to structures in the South Platte basin.

The total irrigated acreage identified in the 2001 assessment for the South Platte is over 910,500 acres. Over 167,000 acres are assigned to ground water sources only. The associated well rights will be explicitly represented in both the consumptive use and surface water modeling efforts. The remaining acres are assigned to surface diversion structures and may also be supplemented with ground water. Figure 1 shows the breakdown of key surface water, non-key surface water, and ground water source only acreage for the South Platte River basin.

Where to find more information

- The Water District 3 Meeting Notes prepared for SPDSS Task 3 – Identify Key Diversion Structures contains additional information on the selection of key structures and the representation of diversion systems.
- The SPDSS Irrigated Acreage Assessment GIS coverages for 1956, 1976, 1987, 2001, and 2005 are available on the CDSS WEB site.
- Surface water irrigation structures not represented as “key” and parcels irrigated only with ground water are modeled in aggregate groups as documented in Task 3 – Aggregated Non-Key Agricultural Diversion Structures.

Figure 1
South Platte Acreage Categories



Recommendations

Structures identified as key will be used in the Phase 3 Historical Crop Consumptive Use analysis. However, additions and deletions to the list of key structures and diversion system structures may occur as more information is gathered during surface water modeling efforts. This document will be updated in the future if necessary.

Comments and Concerns

Eight-four percent of the absolute decreed direct water rights in the SPDSS study area are represented explicitly. This representation accounts for 99 percent of the acreage assigned to surface water diversions. Key structures, including irrigation, municipal, transbasin, and carrier structures, account for approximately 85 percent of decreed direct water rights. An additional 1 percent of the decreed direct water rights are represented in the aggregate structures. The decreed direct water rights not included in key or aggregate structures are generally associated with historic or inactive structures (CIU = H or I).

Table 2
List of South Platte Key Structures and Primary Structure in Diversion System

No.	Structure ID	Structure Name	Acreage	Comments
1	0100501	EMPIRE DITCH (INLET CANAL)	0	Carries to Empire Reservoir
2	0100503_D	RIVERSIDE CANAL	0	Carries water to 0100503_I and Riverside Reservoir System. Primary DivSys with 504 and 710
3	0100503_I	RIVERSIDE CANAL DEMAND	28,128	Receives water from Riverside Canal (01000503_D) and Riverside Reservoir
4	0100507_D	BIJOU CANAL	0	Carries water to 0100507_I and Bijou Reservoir No. 2. Primary DivSys with 506 and 509
5	0100507_I	BIJOU CANAL DEMAND	29,909	Receives water from Bijou Canal (0100507_D) and Empire Reservoir
6	0100511	WELDON VALLEY DITCH	7,462	
7	0100513	JACKSON LAKE INLET DITCH	0	Carries to Jackson Reservoir
8	0100514	FT MORGAN CANAL	10,383	
9	0100515	UPPER PLATTE BEAVER CNL	10,022	
10	0100517	DEUEL SNYDER CANAL	1,610	
11	0100518	LOWER PLATTE BEAVER D	12,355	
12	0100519_D	TREMONT DITCH	3,528	Primary DivSys with 521, 522, 523, and 713
13	0100520	GILL STEVENS DITCH	477	Alternate Point to Wells
14	0100524	TROWELL DITCH	514	Alternate Point to Wells
15	0100525	TETSEL DITCH	1,130	
16	0100526	JOHNSON EDWARDS DITCH	1,981	
17	0100687	NORTH STERLING CANAL	0	Carries water to 0100687_I and North Sterling Reservoir
18	0100687_I	NORTH STERLING DEMAND	36,680	Receives water from North Sterling Canal and North Sterling Reservoir
19	0100688	UNION DITCH	1,067	
20	0100829	PREWITT INLET CANAL	0	Carries to Prewitt Reservoir
21	0100565	MAGUIRE DITCH	239	Structure located in Upper Kiowa Bijou Designated Basin.
22	0100570	EAST GULCH DITCH	200	Structure located in Upper Kiowa Bijou Designated Basin.
23	0100620	CONSOLIDATED LARSON D	375	Structure located in Upper Crow Creek Designated Basin.
24	0103576	PIERCE RES 3	126	Structure located in Upper Crow Creek Designated Basin.
25	01_PAWNPP	PAWNEE POWER PLANT		Industrial Demand Node, No acreage assigned. Receives water from Upper Platte and Beaver (515).
26	0103817_I	JACKSON RESERVOIR DEMAND	82	Receives water from only Jackson Reservoir
27	0200800	FARMER AND GARDNERS DITCH	0	Owned by Denver, some irrigation. No acreage identified so model with reasonable efficiency for historical

No.	Structure ID	Structure Name	Acreage	Comments
28	0200802	BURLINGTON D RIVER HG	0	Headgate diversion to Little Burlington, Henrylyn, FRICO-Barr Carriers
29	0200805	DENVER-HUDSON CNL	0	Carrier from Burlington Headgate to 0200805_I, Prospect Res, and Horse Creek Res. Includes water rights for 902.
30	0200805_I	DENVER-HUDSON CNL	31,021	Supply carried through 805. Includes 902 water rights.
31	0200806	GARDNERS DITCH	0	Serves Cherokee Power Plant - had historical irrigation. No acreage identified so model historical with reasonable efficiency for irrigation
32	0200808	FULTON DITCH	8,639	
33	0200809	BRANTNER DITCH	4,332	
34	0200810	BRIGHTON DITCH	1,811	
35	0200812	LUPTON BOTTOM DITCH	3,717	
36	0200813	PLATTEVILLE DITCH	3,860	
37	0200817	EVANS NO 2 DITCH	0	Carries water to 0200817_I and to Milton Reservoir
38	0200817_I	EVANS NO 2 DEMAND	15,059	Receives water from Evans No 2
39	0200821	MEADOW ISLAND 1 DITCH	1,194	
40	0200822	MEADOW ISLAND DITCH	2,991	
41	0200824	FARMERSINDEPENDENT D	6,751	
42	0200825	HEWES COOK DITCH	7,642	
43	0200826	JAY THOMAS DITCH	207	
44	0200828	UNION DITCH	0	Carries water to 0200828_I and Lower Latham Reservoir
45	0200828_I	UNION IRRIGATION DEMAND	4,591	Receives water from Union Ditch, includes 0200886 seepage water
46	0200830	SECTION NO 3 DITCH	1,222	
47	0200834	LOWER LATHAM DITCH	0	Carries water to 0200834_I
48	0200834_I	LOWER LATHAM DEMAND	10,837	Receives water from Lower Latham Ditch and Lower Latham Reservoir
49	0200836	PATTERSON DITCH	656	
50	0200837	HIGHLAND DITCH	494	
51	0200871	WHIPPLE DITCH	6,343	
52	0200872	GERMAN DITCH	678	
53	0200873	BIG DRY CREEK DITCH	685	
54	0200874	YOXALL DITCH	356	
55	0200915	LITTLE BURLINGTON CNL	5,543	Water Carried through Burlington Canal
56	0200922	GOOSEQUILL PUMP STATION	0	Primary DivSys for Public Service use at Fort St. Vrain Power Plant with 0200923 (Jay Thomas Pump Station)
57	0200991	STANDLEY/WESTMINSTER PL1	0	Carrier to Westminster Demand Nodes
58	0200992	STANDLEY/WESTMINSTER PL2	0	Model with 0200991

No.	Structure ID	Structure Name	Acreage	Comments
59	0200993	STANDLEY/NORTHGLENN PL	0	Carrier from Thornton PL to Northglenn Demand NodeS
60	0200994	STANDLEY/THORNTON PL	0	Carrier to Thornton Demand Nodes
61	0203837_C	FRICO-BARR CARRIER	0	Carrier from Burlington Headgate to FRICO-BARR Demand and Barr Res.
62	0203837_I	FRICO-BARR LAKE DEMAND	20,669	Receives water from Burlington (0203837_C) and Barr Lake
63	0203876_I	FRICO-MILTON LAKE DEMAND	12,560	Receives water from Milton Reservoir
64	02NORTHGL_I	NORTHGLENN INDOOR DEMAND		Indoor Demand for Northglenn, receives water from Standley Lake and other sources
65	02NORTHGL_O	NORTHGLENN OUTDOOR DEMAND		Outdoor Demand for Northglenn, receives water from Standley Lake and other sources
66	02THORNTON_I	THORNTON INDOOR DEMAND		Indoor Demand for Thorton, receives water from Standley Lake and other sources
67	02THORNTON_O	THORNTON OUTDOOR DEMAND		Outdoor Demand for Thornton, receives water from Standley Lake and other sources
68	02WESTMIN_I	WESTMINSTER INDOOR DEMAND		Indoor Demand for Westminster, receives water from Standley Lake and other sources
69	02WESTMIN_O	WESTMINSTER OUTDOOR DEMAND		Outdoor Demand for Westminster, receives water from Standley Lake and other sources
70	02_CHRKPP	CHEROKEE POWER PLANT		Industrial Demand Node, No acreage assigned. Receives water from Fisher Ditch.
71	02_VRNPP	FORT ST. VRAIN POWER PLANT		Industrial Demand Node, No acreage assigned. Receives water from Jay Thomas Ditch (826) and Goosequill Pump Station (922).
72	0300909	HANSEN SUPPLY CANAL	0	Delivers water from Horsetooth Reservoir to the Poudre
73	0300905	NORTH POUDRE SUPPLY CANAL	0	Carries water to 0300994_I and North Poudre Reservoir System
74	0300906	FORT COLLINS PIPELINE	0	Carries water to Ft. Collins Demand Nodes
75	0300907	POUDRE VALLEY CANAL	0	Carries water to reservoirs
76	0300908	GREELEY FLTRS PL	0	Carries water to Greeley Demand Nodes
77	0300910	PLEASANT VALLEY LAKE CNL	2,279	
78	0300911	LARIMER COUNTY DITCH	0	Carries water to 0300911_I and WSSC Reservoirs
79	0300911_I	LARIMER COUNTY DEMAND	43,199	Receives water from Larimer County Ditch and reservoirs
80	0300912	DRY CREEK DITCH	1,577	
81	0300915	CACHE LA POUDRE DITCH	0	Carries water to 0300915_I and Terry Lake
82	0300915_I	CACHE LA POUDRE DEMAND	649	Receives water from Cache La Poudre Ditch
83	0300919	LARIMER WELD IRR CANAL	0	Carries water to 0300919_I and Windsor Reservoir
84	0300919_I	LARIMER WELD IRR DEMAND	61,695	Receives water from 0300919 and reservoirs
85	0300921	JOSH AMES DITCH	70	
86	0300922	LAKE CANAL DITCH	6,173	
87	0300924	CACHE LA POUDRE RES IN CNL	0	Carries water to Timnath Reservoir

No.	Structure ID	Structure Name	Acreage	Comments
88	0300925	CHAFFEE DITCH	0	Alternate Point to Ft. Collins M&I Demand
89	0300926	BOXELDER DITCH	937	
90	0300929	NEW CACHE LA POUDRE CO D	0	Carries water to 0300292_I.
91	0300929_I	NEW CACHE LA POUDRE DEMAND	35,947	Receives water from 0300929 and reservoirs. Primary DivSys with 3770
92	0300930	WHITNEY IRR DITCH	2,290	
93	0300931	B H EATON DITCH	422	
94	0300932	WILLIAM R JONES DITCH	334	
95	0300934	CANAL 3 DITCH	984	
96	0300935	BOYD FREEMAN DITCH	21	
97	0300937	OGILVY DITCH	2,247	
98	0300994_D	NORTH POUDRE CANAL	0	Carries water to 0300944_I and reservoirs. Primary DivSys with 995 and 996
99	0300994_I	NORTH POUDRE DEMAND	26,856	Receives water from 0300994_D, 0300905, and reservoirs
100	0301029	TAYLOR GILL DITCH	247	
101	0301203	PLATTE R PWR PMG DIVR	0	Delivers water to Rawhide Power Plant
102	0304608	DEADMAN DITCH	0	Exports water from WD48 to WD 3
103	03FTCOLLIN_I	FT COLLINS INDOOR DEMAND		Receives water from Ft Collins Pipeline and other sources
104	03FTCOLLIN_O	FT COLLINS OUTDOOR DEMAND		Receives water from Ft Collins Pipeline and other sources
105	03GREELEY_I	GREELEY INDOOR DEMAND		Receives water from Greeley Fltr Plnt, Greeley Fltr Plnt/Boyd Lake and other sources
106	03GREELEY_O	GREELEY OUTDOOR DEMAND		Receives water from Greeley Fltr Plnt, Greeley Fltr Plnt/Boyd Lake and other sources
107	0301321	GRAHAM SEEP DITCH	288	
108	0300923	JOHN G COY	0	Delivers water to Lincoln Greens Golf Course
109	03_RAWHPP	RAWHIDE POWER PLANT		Industrial Demand Node, No acreage assigned. Receives water from City of Fort Collins WWTP #2, and Platte R PWR PMG DIVR (1203)
110	0300913_D	NEW MERCER DIVSYS	2,753	Primary DivSys with 914, 918, 1142, and 5381
111	0400502_D	BIG T PLATTE R DITCH	1,740	Primary DivSys with 502, 918, 587
112	0400503	BIG THOMPSON D MFG	801	
113	0400511	LOVELAND PIPELINE	0	Carries to water Loveland Demand Nodes
114	0400517	EVANSTOWN DITCH	236	
115	0400518	ESTES PARK, CITY OF	0	Carries water to Upper WD 4 Muncipal Demand Node
116	0400519	FARMERS IRR CANAL	2,198	
117	0400520	GEORGE RIST DITCH	404	
118	0400521	HANDY DITCH	8,595	
119	0400522	HILL BRUSH DITCH	428	
120	0400523	HILLSBOROUGH DITCH	7,087	
121	0400524	HOME SUPPLY DITCH	0	Carries water to 0400524_I and reservoirs

No.	Structure ID	Structure Name	Acreage	Comments
122	0400524_I	HOME SUPPLY DEMAND	17,299	Receives water from 0400524 and reservoirs
123	0400530	LOUDEN DITCH	2,545	
124	0400532	LOVELAND GREELEY CANAL	0	Carries water to 0400532_I and reservoirs. Primary DivSys - includes lands under 501
125	0400532_I	LOVELAND GREELEY DEMAND	18,490	Receives water from 0400532, 0400501, and reservoirs
126	0400540	DILLE TUNNEL	0	Delivers water from Lake Estes to the Big Thompson to generate HydroPower
127	0400541	RIST GOSS DITCH	28	
128	0400543	SOUTH SIDE DITCH	973	
129	0400545	BERTHOUD WATER WORKS	0	Carries water to Lower WD 4 Municipal Demand Node
130	0400546	JOHNSTOWN FILTER PLANT	0	Carries water to Lower WD 4 Municipal Demand Node
131	0400587	BEELINE DITCH	0	Carries water to lands that are included with Big T & Platte Ditch (0400502)
132	0400588	BOULD LARIM CO IRR MFG D	0	Carries water to 0400588_I and reservoirs.
133	0400588_I	BOULD LARIM CO IRR MFG DEMAND	2,645	Receives water from 0400588 and reservoirs. Primary DivSys with 4156
134	0400592	EAGLE DITCH	68	
135	0400596	JIM EGLIN DITCH	172	
136	0400599	MINER LONGAN DITCH	206	
137	0400600	OSBORNE CAYWOOD DITCH	131	
138	0400601	ROCKWELL D ROCKWELL P P	248	
139	0400602	SUPPLY LATERAL DITCH	1,024	
140	0400603	W R BLOWER DITCH 1	238	
141	0400691	HANSEN FEEDER CNL FLOW N	0	Carries CBT water to Horsetooth Reservoir, the Poudre, and 0400691_I
142	0400691_I	HANSEN FEEDER DEMAND	1,943	Receives water from 0400691
143	0400692	ST VRAIN SUPPLY CANAL	0	Carrier CBT water to St. Vrain and Boulder Creeks and to 0400692_I
144	0400692_I	ST VRAIN SUPPLY DEMAND	437	Receives water form 0400692
145	0400702	GREELEY FLTR PLNT/BOYD L	0	Carries water to Greeley Demand Nodes
146	04LOVELAND_I	LOVELAND INDOOR DEMAND		Receives water from Loveland Pipeline and other sources
147	04LOVELAND_O	LOVELAND OUTDOOR DEMAND		Receives water from Loveland Pipeline and other sources
148	0400534	MARIANA DITCH	31	
149	0400561	BLACK CANNON DITCH	87	
150	0400574	BUCKHORN HIGHLINE DITCH	8	
151	0400578	KIRCHNER DITCH	30	
152	0400580	PERKINS DITCH	158	
153	0400582	UNION DITCH	21	
154	0400583	VICTORY IRR CNL	111	

No.	Structure ID	Structure Name	Acreage	Comments
155	0400501	BARNES DITCH	0	Carries water to Loveland Greeley Demand (0400532_I)
156	0500511	LONGMONT PIPELINE NORTH	24	Also carrier of water to Longmont Municipal Demand Nodes
157	0500512	LYONS PIPELINE	0	Carries water to Upper WD 5 Demand Node
158	0500519	REESE STILES DITCH	9	
159	0500520	SOUTH LEDGE DITCH	82	
160	0500522	LONGMONT PIPELINE SOUTH	0	Carries water to Longmont Demand Nodes
161	0500523	SUPPLY DITCH	4,568	
162	0500526	HIGHLAND DITCH	0	Carries water to 0500256_I and reservoirs
163	0500526_I	HIGHLAND DITCH DEMAND	30,172	Receives water from 0500526
164	0500527	ROUGH READY DITCH	1,719	
165	0500528	ST VRAIN PALMERTON DITCH	854	
166	0500529	SWEDE DITCH	1,571	
167	0500530	SMEAD DITCH	236	
168	0500531	MONTGOMERY PRIVATE DITCH	0	Transferred to other uses, diversions through ditch ended 1994
169	0500532	FOOTHILLS INLET	0	Carries water to Foothills Reservoir (owned by Highland Ditch)
170	0500534	GOSS PRIVATE DITCH 1	133	
171	0500535	CLOUGH/TRUE DITCH	15	
172	0500536	CLOUGH PRIVATE DITCH	50	
173	0500537	WEBSTER MCCASLIN DITCH	143	
174	0500538	TRUE WEBSTER DITCH	72	
175	0500539	JAMES DITCH	651	
176	0500542	DAVIS DOWNING DITCH	496	
177	0500545	LONGMONT SUPPLY DITCH	205	Carries water to Longmont Municipal Demands
178	0500546	CHAPMAN MCCASLIN DITCH	157	
179	0500547	OLIGARCHY DITCH	0	Carries water to 0500527_I and Union Reservoir
180	0500547_I	OLIGARCHY DITCH DEMAND	1,661	Receives water from 0500547
181	0500548	DENIO TAYLOR DITCH	84	
182	0500549	RUNYAN DITCH	39	
183	0500550	PECK DITCH	260	
184	0500551	PELLA DITCH	131	
185	0500552	CLOVER BASIN DITCH	75	
186	0500553	HAGERS MEADOW DITCH	44	
187	0500554	NIWOT DITCH	300	
188	0500557	NORTHWEST MUT INS CO D	50	
189	0500558	SOUTH FLAT DITCH	228	
190	0500559	CUSHMAN DITCH	31	
191	0500560	BECKWITH DITCH	140	
192	0500563	BONUS DITCH	584	
193	0500589	LAST CHANCE DITCH	1,600	

No.	Structure ID	Structure Name	Acreage	Comments
194	0500601	ZWECK TURNER DITCH	260	
195	0500602	JAMES MASON DITCH	24	
196	0500603_D	LEFT HAND DITCH	0	Carries water to 0500603_I and reservoirs. Primary DivSys with others in District
197	0500603_I	LEFT HAND DITCH DEMAND	6,698	Receives water from 0500603_D and reservoirs. Primary DivSys with others in District
198	05LONGMONT_I	LONGMONT INDOOR DEMAND		Receives water from Longmont Pipeline North, Longmont Pipeline South, Longmont Supply Ditch, and other sources
199	05LONGMONT_O	LONGMONT OUTDOOR DEMAND		Receives water from Longmont Pipeline North, Longmont Pipeline South, Longmont Supply Ditch, and other sources
200	0500513	DAVE MILLER DITCH	9	
201	0500561	ISLAND DITCH	29	
202	0500938	CARL HOLCOMB DITCH	2	
203	0500942	COLE SEEPAGE DITCH	143	
204	0600501	ANDERSON DITCH	60	
205	0600513	BOULDER LEFT HAND DITCH	1,360	
206	0600515_D	BOULDER WELD CTY DITCH	1,950	Primary DivSys with 540, 533
207	0600516	BOULDER WHITE ROCK DITCH	5,764	
208	0600518	BUTTE MILL DITCH	292	
209	0600520_D	CARR TYLER DITCH	0	Primary DivSys with 545, historical acreage, 0 in 2001
210	0600523	DELEHANT DITCH	70	
211	0600525	FARMERS DITCH	1,501	
212	0600527	GODDING DAILEY PLUMB D	562	
213	0600528	GREEN DITCH	327	
214	0600532	HIGHLAND S SIDE DITCH	1,124	
215	0600534	HOUCK 2 DITCH	93	
216	0600536	HOWELL DITCH	104	
217	0600537	LEGGETT DITCH	3,011	
218	0600538_D	LOWER BOULDER DITCH	6,808	Primary DivSys with 562 and 0200552
219	0600543	N BOULD FARMER DITCH	480	
220	0600551	RURAL DITCH	639	
221	0600553	SMITH EMMONS DITCH	393	
222	0600554	SMITH GOSS DITCH	7	
223	0600560	ANDREWS FARWELL DITCH	128	
224	0600564_D	COMMUNITY DITCH	0	Carries water to 0600564_I and Marshall Reservoir. Primary DivSys with 589
225	0600564_I	COMMUNITY DITCH DEMAND	4,115	Receives water from 0600564_D and reservoirs.
226	0600565	LEYNER COTTONWOOD DITCH	1,361	
227	0600566	COTTONWOOD DITCH 2	599	
228	0600567	DAVIDSON DITCH	699	

No.	Structure ID	Structure Name	Acreage	Comments
229	0600569_D	DRY CREEK DAVIDSON DITCH	644	Primary DivSys with 735 - 735 water rights diverted here.
230	0600570	DRY CREEK NO 2 DITCH	359	
231	0600575	EAST BOULDER DITCH	44	Carry water to Valmont Power Plant
232	0600576	ENTERPRISE DITCH	148	
233	0600580	HOWARD DITCH	143	
234	0600582	JONES DONNELLY DITCH	292	
235	0600585	MARSHALVILLE DITCH	1,045	
236	0600586	MCGINN DITCH	1,095	
237	0600588	S BOULDER BEAR CR DITCH	218	
238	0600590	S BOULDER DIVR CONDUIT	0	Carries water to Ralston Reservoir and Denver Demand Nodes
239	0600592	SCHEARER DITCH	386	
240	0600593	S BOULDER CANON DITCH	1,230	
241	0600597	LAFAYETTE PL	0	Carries water to Lower Water District 6 Municipal Demand Node
242	0600598	LOUISEVILLE PL	0	Carries water to Lower Water District 6 Municipal Demand Node
243	0600599	BOULDER CITY PL	0	Carries water to Boulder Demand Nodes
244	0600603	SILVER LAKE DITCH	516	
245	0600606	CHURCH DITCH (UPPER)	0	Carries water to Upper Church Reservoir for Lower Water District 6 Municipal Demand Node
246	0600608_D	EGGLESTON NO 1 DITCH	91	Primary DivSys with 605 and 609
247	0600610	ERIE COAL CR DITCH	426	
248	0600611	HARRIS DITCH	56	
249	0600612	KERR DITCH NO 1	136	
250	0600613	KERR DITCH NO 2	10	
251	0600615	LAST CHANCE DITCH	0	Carries water to Standley Lake
252	0600621	WILLIAM C HAKE DITCH	71	
253	0600622	T N WILLIS DITCH	37	
254	0600650	GOODHUE DITCH	1,904	
255	0600767	LOUISVILLE CCGC PL 2	0	Carries water to Lower Water District 6 Municipal Demand Node
256	0600800	BOULDER RES MUN INTAKE	0	Carries CBT water to Boulder Demand Nodes from Boulder Reservoir
257	0600878	LAFAYETTE BOULDER C PL 1	0	Carries water to Lower Water District 6 Municipal Demand Node
258	0600889	LAFAYETTE DIVERISON PT 4	0	Carries water to Lower Water District 6 Municipal Demand Node
259	0600902	NEW DRY CR CARRIER DITCH	0	Carries water to 576, 889, 566, 569, 560, 565
260	0600943	BOULDER PL 3 AT BARKER R	0	Carries water to Boulder Demand Nodes
261	06BOULDER_I	BOULDER INDOOR DEMAND		Receives water from Boulder City PL, Boulder Res Mun Intake, Boulder PL 3, and other sources

No.	Structure ID	Structure Name	Acreage	Comments
262	06BOULDER_O	BOULDER OUTDOOR DEMAND		Receives water from Boulder City PL, Boulder Res Mun Intake, Boulder PL 3, and other sources
263	0600542	MC CARTY DITCH	12	
264	06_VALMPP	VALMONT POWER PLANT		Industrial Demand Node, No acreage assigned. Receives water from East Boulder Ditch (575) and Enterprise Ditch (576).
265	06_ELDORA	ELDORA SKI AREA		Industrial Demand Node, No acreage assigned. Receives water from South Boulder and Middle Boulder Creek.
266	0700502	AGRICULTURAL DITCH	631	Also carrier to reservoirs
267	0700527_D	SLOUGH OR BIJOU ASS"N D	166	Primary DivSys for Slough Ditches, diversions recorded here
268	0700540	CHURCH DITCH	474	
269	0700542	GOLDEN CITY DITCH	0	Carries water to Lower Water District 7 Municipal Demand Node
270	0700547	CLEAR CR PLATTE RIVER D	950	
271	0700549	COLO AGRICULTURAL D	69	
272	0700551	CORT GRAVES HUGHES DITCH	2	
273	0700553	CROKE CANAL	0	Delivers water to Standley Lake
274	0700569	FARMERS HIGHLINE CNL	2,861	
275	0700570	FISHER DITCH	43	
276	0700597	KERSHAW DITCH	16	
277	0700601	LEE STEWART ESKINS DITCH	67	
278	0700614	MANHART DITCH	37	
279	0700632	OUELETTE DITCH	1	
280	0700647	RENO JUCHEM DITCH	235	
281	0700652_D	ROCKY MOUNTAIN DITCH	19	Primary DivSys with 620
282	0700681	GEORGETOWN DITCH	0	Carries water to Upper Water District 7 Municipal Demand Node
283	0700698	WANNEMAKER DITCH	212	
284	0700699	WELCH DITCH	86	
285	0700725	COORS IND DITCH	0	Delivers water to Coors Industrial Demand
286	0700728	CROKE CANAL RALSTON CR	0	Carries water from Ralston Creek to 553 Demand
287	0700872	FARMERS HIGHLINE RALSTON	0	Carries water from Ralston Creek to 569 Demand
288	0700873	FARMERS HIGHLINE LEYDEN	0	Carries water from Leyden Creek to 569 Demand
289	0700942	CHURCH DITCH RALSTON CR	0	Carries water from Ralston Creek to 540 Demand
290	07_LSA	LOVELAND SKI AREA		Industrial Demand Node, No acreage assigned. Receives water from Upper Clear Creek.
291	07_COORS	COORS BREWERY		Industrial Demand Node, No acreage assigned. Receives water from Coors Industrial Ditch (725) and Wannemaker Ditch (698).

No.	Structure ID	Structure Name	Acreage	Comments
292	0801001	AURORA INTAKE	0	Carries water to Aurora Reservoir and Aurora Demand Nodes, Primary DivSys with 0801000
293	0801002_D	DENVER CONDUIT NO 20	0	Primary DivSys with 1005. Carriers to Marston Reservoir and Marston WTP for Denver Demand Nodes
294	0801004_D	HIGHLINE CNL	589	Primary DivSys with 1007
295	0801008	CITY DITCH PL	55	Also carries to Englewood Demand Node (or WD 8 Municipal Demand Node)
296	0801009_D	NEVADA DITCH	93	Primary DivSys with 1011 and 1462, plus carries to municipal demand
297	0801013	ENGLEWOOD INTAKE	0	Carries water to Engelwood Demand (or WD 8 Municipal Demand)
298	0801014	ARAPAHOE POWER PLANT	0	Industrial water for power plant
299	0801015	EPPERSON DITCH/PUMP	0	Alternate point to Denver (Harriman Ditch) - Irrigates outside golf course demand
300	0801016	LACOMBE POWER PLANT	0	Industrial water for Zuni power plant
301	0801017	DENVER FOOTHILLS PL 26	0	Carries to Foothills WTP - Denver Demand Nodes
302	0801124	HAYLAND DITCH	15	
303	0801125	FAIRVIEW DITCH	145	
304	0801127	OLD TIME DITCH	15	
305	0801128	GARDEN DITCH	15	
306	0801235	RED ROCK DITCH	16	
307	0801237	SPRING CREEK DITCH	70	
308	0801240	RATCLIFF DILLON DITCH	70	
309	0801241	DAKAN DITCH	70	
310	0801362	JOHN JONES DITCH	71	
311	0801400	ALDERMAN DITCH	27	
312	0801403	HEISER DITCH	77	
313	0801404	MCCRACKEN DITCH	103	
314	0801405	SMITH DITCH	33	
315	0801406	SCHREIBER DITCH	11	
316	0801412	SIXTY SEVEN DITCH	94	
317	0801413	CRAWFORD DITCH	27	
318	0801414	BIRMINGHAM DITCH	7	
319	0801416	GOODRICH DITCH	46	
320	0801417	ROCKY RIDGE DITCH	0	Historical acreage, 0 in 2001
321	0801492	IZZARD DITCH	23	
322	08AURORA_I	AURORA INDOOR DEMAND		Receives water from Aurora Intake and other sources
323	08AURORA_O	AURORA OUTDOOR DEMAND		Receives water from Aurora Intake and other sources
324	08DENVER_I	DENVER INDOOR DEMAND		Receives water from S. Boulder Divr Conduit, Denver Conduit 20, Denver Foothills Pipeline 26, and other sources

No.	Structure ID	Structure Name	Acreage	Comments
325	08DENVER_O	DENVER OUTDOOR DEMAND		Receives water from S. Boulder Divr Conduit, Denver Conduit 20, Denver Foothills Pipeline 26, and other sources
326	0900731_D	ARNETT/HARRIMAN DITCH	1,078	Primary DivSys with 522, 862,and 880
327	0900752	HODGSON DITCH	24	
328	0900816	MCBROOM DITCH	0	Carries water to outdoor municipal use, Primary DivSys with 962 and 964
329	0900903	WARRIER/HARRIMAN D TK CR	0	Carries water from Turkey Creek to Warrior/Harriman Ditch, Primary DivSys with 961
330	0900958	WARD DITCH	768	
331	0900963_D	WARRIOR/HARRIMAN DITCH	0	Carries water to outdoor municipal use, Primary DivSys with 896, 962 and 964
332	0900535	BERGEN DITCH	32	
333	0900767	INDEPENDENT HIGHLINE D	107	
334	2300500	PLATTE STATION DITCH	151	
335	2300760	SACRAMENTO DITCH	299	
336	2300902	PETRIE DITCH	458	
337	2300904	LINK DITCH	601	
338	2300922	HOLST DITCH 2	60	
339	2300923	HOLST PACKER D	90	
340	2300924	HOLST DITCH 1	60	
341	2300926	PACKER BONIS DITCH	37	
342	2300991	TAYLOR DITCH	155	
343	2300993	GIBSON DITCH	160	
344	2300994	CROSIER TAYLOR DITCH	286	
345	23_DIXCOMCO	DIXON FLUME ON HOLTHUSEN GULCH	0	Administrative Gage for South Park Transferred Rights
346	23_FOUHARCO	FOUR MILE CREEK NEAR HARTSEL	0	Administrative Gage for South Park Transferred Rights
347	23_FOUHIGCO	FOUR MILE CREEK AT HIGH CREEK	0	Administrative Gage for South Park Transferred Rights
348	23_FRNCRKCO	FRENCH CREEK ABOVE MICHIGAN CREEK	0	Administrative Gage for South Park Transferred Rights
349	23_JEFJEFCO	JEFFERSON CREEK NEAR JEFFERSON	412	Administrative Gage for South Park Transferred Rights
350	23_JEFSNYCO	JEFFERSON CREEK BELOW SNYDER CREEK	80	Administrative Gage for South Park Transferred Rights
351	23_MCHJEFCO	MICHIGAN CREEK ABOVE JEFFERSON	231	Administrative Gage for South Park Transferred Rights
352	23_MFKPRICO	MIDDLE FORK SOUTH PLATTE AT PRINCE	0	Administrative Gage for South Park Transferred Rights
353	23_MFKSTMCO	MIDDLE FORK SOUTH PLATTE AT SANTA MARIA	0	Administrative Gage for South Park Transferred Rights
354	23_OHGJEFCO	OHLER GULCH NEAR JEFFERSON	0	Administrative Gage for South Park Transferred Rights

No.	Structure ID	Structure Name	Acreage	Comments
355	23_PLASPICO	SOUTH PLATTE RIVER ABOVE SPINNEY RESERVOIR	0	Administrative Gage for South Park Transferred Rights
356	23_RCKTARCO	ROCK CREEK ABOVE TARRYALLCREEK	0	Administrative Gage for South Park Transferred Rights
357	23_SCHFLMCO	SCHATTINGER FLUME ABOVE MICHIGAN CREEK	0	Administrative Gage for South Park Transferred Rights
358	23_SFKANTCO	SOUTH FORK OF SOUTH PLATTE ABOVE ANTERO	11	Administrative Gage for South Park Transferred Rights
359	23_SFKHARCO	SOUTH FORK RIVER NEAR HARTSEL	0	Administrative Gage for South Park Transferred Rights
360	23_SPRBRNCO	SPRING BRANCH ABOVE MIDDLE FORK SOUTH PLATTE	0	Administrative Gage for South Park Transferred Rights
361	23_TARBORCO	TARRYALL CREEK AT BORDEN DITCH	0	Administrative Gage for South Park Transferred Rights
362	23_TARCOMCO	TARRYALL CREEK AT UPPER STATION NEAR COMO, CO	955	Administrative Gage for South Park Transferred Rights
363	4800506	PARKER DITCH	137	
364	4800514_D	YELTON DITCH	1,186	Primary DivSys with 507,508,509,535,510,511,512,513, 584
365	4800519_D	MANSFIELD DITCH 2	274	Primary DivSys with 518
366	4800520_D	WARREN DITCH	297	Primary DivSys with 568, 521
367	4800527_D	LINK DITCH 2	160	Primary DivSys with 501,505,522,523,582
368	4800531_D	DAVY DITCH	48	Primary DivSys with 524,528,529,530
369	4800532_D	STUBB CREEK DITCH	12	Primary DivSys with 533
370	4800534	FORRESTER DITCH	50	
371	4800538_D	MCINTYRE DITCH	77	Primary DivSys with 536, 537, 544
372	4800541_D	HOMESTEAD DITCH	231	Primary DivSys with 539,526,540,569,545,546,542,548, 579
373	4800552_D	OLLIE DITCH	259	Primary DivSys with 556,549,551,554,550
374	4800553_D	JIMMY CREEK DITCH	76	Primary DivSys with 515 - water rights here
375	4800558_D	LA GARDE DITCH 1	380	Primary DivSys with 560,557,562,561
376	4800559	LA GARDE DITCH	68	
377	4800563	FORRESTER CREEK DITCH	20	
378	4800564	DETRO DITCH 1	25	
379	4800565_D	GRACE CREEK DITCH	438	Primary DivSys with 567, 566
380	4800573	BOB CREEK DITCH DIVR	0	Exports water from WD 48 to WD 3
381	4800576	LARAMIE RIVER TUNNEL SYS	0	Exports water from WD 48 to WD 3, Primary Divsys with 4800500
382	4800577	SKLYLINE DITCH	0	Exports water from WD 48 to WD 3
383	6400501	CARLSON DITCH	107	
384	6400502	LIDDLE DITCH	902	
385	6400503	SOUTH RESERVATION DITCH	896	
386	6400504	PETERSON DITCH	6,477	
387	6400506	RED LION SUPPLY DITCH	239	
388	6400507	LONG ISLAND DITCH	1,738	Alternate Point to Wells

No.	Structure ID	Structure Name	Acreage	Comments
389	6400508	SETTLERS DITCH	4,656	
390	6400511_D	HARMONY DITCH 1	0	Carries water to 6400511_I and Jumbo Reservoir. Primary DivSys with 515, 510
391	6400511_I	HARMONY DITCH 1 DEMAND	11,094	Receives water from 6400511_D and Jumbo Reservoir (3906).
392	6400513	CHAMBERS DITCH	406	Note does not take water from the river - pumps and augments with wells
393	6400514	RAMSEY DITCH	291	
394	6400516	POWELL BLAIR DITCH	1,780	
395	6400518	LONE TREE DITCH	696	
396	6400519	JUD BRUSH DITCH	0	Alternate Point to Wells - acreage not assigned. Should be further investigated
397	6400520	ILIFF PLATTE VALLEY D	6,332	
398	6400522_D	BRAVO DITCH	1,814	Primary DivSys with 521
399	6400524	LOWLINE DITCH	1,774	
400	6400525	HENDERSON SMITH DITCH	335	
401	6400526	STERLING IRR CO DITCH 2	0	Changed to alternate Point to municipal wells, has historical acreage
402	6400528	STERLING IRR CO DITCH 1	7,505	
403	6400530	SPRINGDALE DITCH	3,267	
404	6400531	SCHNEIDER DITCH	2,335	
405	6400532	DAVIS BROS DITCH	1,923	
406	6400533	PAWNEE DITCH	7,202	
407	6400535	SOUTH PLATTE DITCH	4,000	
408	6400542	MCWILLIAMS CANAL	41	
409	6400584	I O JONES DITCH	64	
410	6400599	RICE DITCH	441	
411	7600600	WILSON SUPPLY DITCH	0	Exports water delivered from WD48 through Deadman Ditch and Sand Creek water to WD 3
412	8000650	WANITA DITCH	11	
413	8000651	HALL VALLEY DITCH	4	
414	8000657_D	HEPBURN DITCH 2	69	Primary DivSys for Hepburn Ranch with 739, 740
415	8000662_D	MACK DITCH 1	74	Primary DivSys for Fitzsimmons Ranch with 893, 661, 659, 660, 889
416	8000667	SOUTH SIDE DITCH	33	
417	8000673_D	BOND DITCH 2	53	Primary DivSys for Herford Ranch with 674
418	8000706	BEAVER CREEK DITCH	129	
419	8000713	KENOSHA DITCH	18	
420	8000732_D	CRAIG PARK GULCH DITCH	27	Primary DivSys for Camp Santa Maria includes 728, 729, 730, 732
421	8000759	MCARTHUR DITCH	26	
422	8000760	WINKLER DITCH 1	11	
423	8000761	WINKLER DITCH 3	20	

No.	Structure ID	Structure Name	Acreage	Comments
424	8000774_D	BERGER DITCH	25	Primary DivSys for Berger Ranch with 777, 776, 773
425	8000784	JEFFRIES CRAWFORD DITCH	55	
426	8000785	WONDER DITCH	9	
427	8000792	PARMALEE DITCH 2 & 3	65	
428	8000794	FLUME DITCH	34	
429	8000799_D	ALKIRE DITCH	21	DivSys for Deer Creek Ranch with 801, 845, 800
430	8000812	CLIFFORD GULCH DITCH	18	
431	8000829_D	ROCKY MTN FUEL DITCH 1	86	Primary DivSys for Magnus Ranch with 843,842,826,827,825,828
432	8000831_D	DAVIS DITCH 1	72	Primary DivSys for State Parks Ranch includes 848, 854, 858, 849, 847
Total			**733,844**	

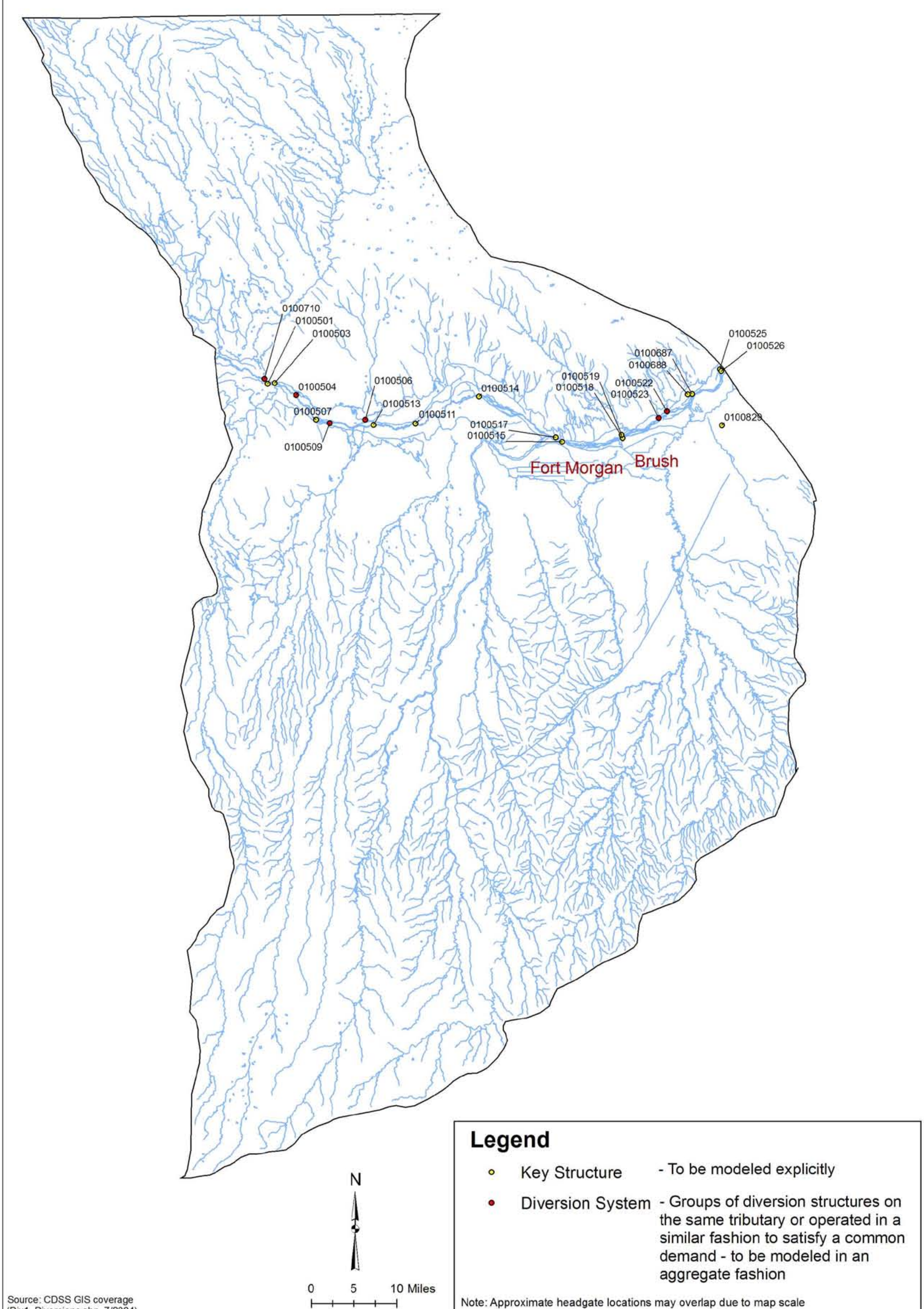
Table 3
List of South Platte Structures in Diversion Systems

No.	Diversion System Primary ID	Diversion System Name	Additional Structures Included in Diversion System
1	0100503_D	RIVERSIDE DIVSYS	0100503, 0100504, 0100710
2	0100503_I	RIVERSIDE CANAL DEMAND	0100503, 0100504, 0100710
3	0100507_D	BIJOUCANAL DIVSYS	0100507, 0100506, 0100509
4	0100507_I	BIJOU CANAL DEMAND	0100507, 0100506, 0100509
5	0100519_D	TREMONT DITCH DIVSYS	0100519, 0100521, 0100522, 0100523,0100713
6	0100687_I	NORTH STERLING DEMAND	0100687
7	0103817_I	JACKSON RESERVOIR DEMAND	0103817
8	0200805_I	DENVER-HUDSON CNL DEMAND	0200805, 0200902
9	0200817_I	EVANS NO 2 DEMAND	0200817
10	0200828_I	UNION IRRIGATION DEMAND	0200828, 0200886
11	0200834_I	LOWER LATHAM DEMAND	0200834
12	0203837_I	FRICO-BARR LAKE DEMAND	0203837
13	0203876_I	FRICO-MILTON LAKE DEMAND	0203876
14	0300911_I	LARIMER COUNTY DEMAND	0300911
15	0300913_D	NEW MERCER DIVSYS	0300913, 0300914, 0300918, 0301142, 0305381
16	0300915_I	CACHE LA POUDRE DEMAND	0300915
17	0300919_I	LARIMER WELD IRR DEMAND	0300919
18	0300929_I	NEW CACHE LA POUDRE DEMAND	0300929, 0303770
19	0300994_D	NORTH POUDRE DIVSYS	0300994, 0300995, 0300996
20	0300994_I	NORTH POUDRE DEMAND	0300994, 0300905, 0300995, 0300996
21	0400502_D	BIG T PLATTE R DITCH DIVSYS	0400502, 0400587
22	0400524_I	HOME SUPPLY DEMAND	0400524
23	0400532_I	LOVELAND GREELEY DEMAND	0400532, 0400501
24	0400588_I	BOULD LARIM CO IRR MFG DEMAND	0400588, 0404156
25	0400691_I	HANSEN FEEDER DEMAND	0400691
26	0400692_I	ST VRAIN SUPPLY DEMAND	0400692
27	0500526_I	HIGHLAND DITCH DEMAND	0500526
28	0500547_I	OLIGARCHY DITCH DEMAND	0500547
29	0500603_D	LEFT HAND DITCH DIVSYS	0500603, 0500564, 0500565, 0500568, 0500569, 0500570, 0500571, 0500572, 0500573, 0500574, 0500575, 0500648
30	0500603_I	LEFT HAND DITCH DEMAND	0500603, 0500564, 0500565, 0500568, 0500569, 0500570, 0500571, 0500572, 0500573, 0500574, 0500575, 0500648
31	0600515_D	BOULDER WELD CTY DIVSYS	0600515, 0600540, 0600533
32	0600520_D	CARRTYLER DITCH DIVSYS	0600520, 0600545
33	0600538_D	LOWER BOULDER DIVSYS	0600538, 0600562, 0200552
34	0600564_D	COMMUNITY DITCH DIVSYS	0600564, 0600589
35	0600564_I	COMMUNITY DITCH DEMAND	0600564, 0600589
36	0600569_D	DRY CREEK DAVIDSON DIVSYS	0600569, 0600735
37	0600608_D	EGGLESTON 1 DITCH DIVSYS	0600608, 0600605, 0600609

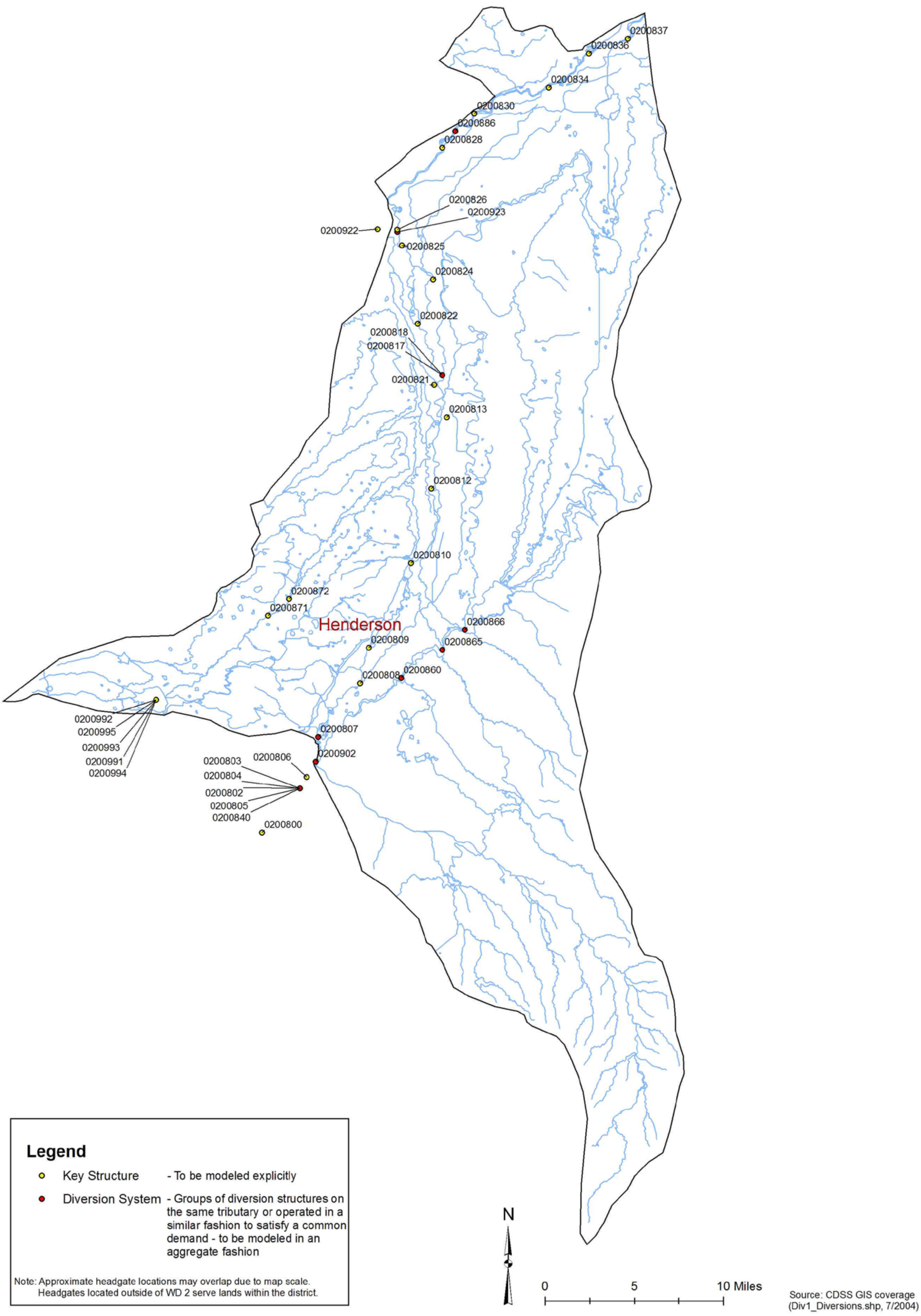
No.	Diversion System Primary ID	Diversion System Name	Additional Structures Included in Diversion System
38	0700527_D	SLOUGH DIVSYS	0700527, 0700523, 0700528, 0700550, 0700581, 0700595, 0700599, 0700649, 0700650, 0700654, 0700655, 0700663, 0700666, 0700677, 0700694, 0700705, 0700706
39	0700652_D	ROCKYMOUNTAIN DIVSYS	0700652, 0700620
40	0801002_D	CONDUIT 20 DIVSYS	0801002, 0801005
41	0801004_D	HIGHLINE CNL DIVSYS	0801004, 0801007
42	0801009_D	NEVADA DITCH DIVSYS	0801009, 0801011, 0801462
43	0900731_D	ARNETT/HARRIMAN DIVSYS	0900731, 0900522, 0900862, 0900880
44	0900963_D	WARRIOR/HARRIMAN DITCH	0900896, 0900963, 0900962, 0900964
45	23_DIXCOMCO	DIXCOMCO DIVSYS	2300952, 2300878, 2300951, 2300954
46	23_FOUHARCO	FOUHARCO DIVSYS	2300628, 2300623, 2300626, 2300627, 2300624, 2300622, 2300645
47	23_FOUHIGCO	FOUHIGCO DIVSYS	2300616, 2300617, 2300612, 2300610, 2300609, 2300601, 2300541, 2300611
48	23_FRNCRKCO	FRNCRKCO DIVSYS	2300961
49	23_JEFJEFCO	JEFJEFCO DIVSYS	2301011, 2301003, 2301006, 2301009, 2301013, 2301004, 2301008, 2301001
50	23_JEFSNYCO	JEFSNYCO DIVSYS	2301020, 2301019, 2301014, 2301029
51	23_MCHJEFCO	MCHJEFCO DIVSYS	2300963, 2300966, 2300977, 2300986, 2300984, 2300976, 2300967, 2300978, , , ,
52	23_MFKPRICO	MFKPRICO DIVSYS	2300680, 2300661, 2300673, 2300659, 2300683, 2300675, 2300654, 2300663, 2300665, 2300664, 2300672, 2300678, 2300676, 2300677, 2300620
53	23_MFKSTMCO	MFKSTMCO DIVSYS	2300689, 2300686, 2300687, 2300694, 2300695, 2300691, 2300698, 2300699, 2300803, 2301078, 2300807
54	23_OHGJEFCO	OHGJEFCO DIVSYS	2301024
55	23_PLASPICO	PLASPICO DIVSYS	2300814, 2300712, 2300816, 2300710, 2300562, 2300708, 2300703, 2300714, 2300702, 2300706, 2300709, 2300707, 2300700, 2300827, 2300829, 2300830, ,
56	23_RCKTARCO	RCKTARCO DIVSYS	2301055, 2301046, 2301044, 2301042, 2301036, 2301037, 2301047, 2301045, 2301043, 2301040, 2301041, 2301039, 2301038, 2301031, 2301032, , ,
57	23_SCHFLMCO	SCHFLMCO DIVSYS	2300974, 2300802, 2300983, 2300962
58	23_SFKANTCO	SFKANTCO DIVSYS	2300551, 2300525, 2300520, 2300538, 2300515, 2300546, 2300550, 2300542, 2300530, 2300575, 2300510, 2300580, 2300529, 2300552, 2300507, 2300519, 2300514, 2300574, 2300634, 2300513, 2300566, 2300511, 2300523, 2300553
59	23_SFKHARCO	SFKHARCO DIVSYS	2300561
60	23_SPRBRNCO	SPRBRNCO DIVSYS	2300667

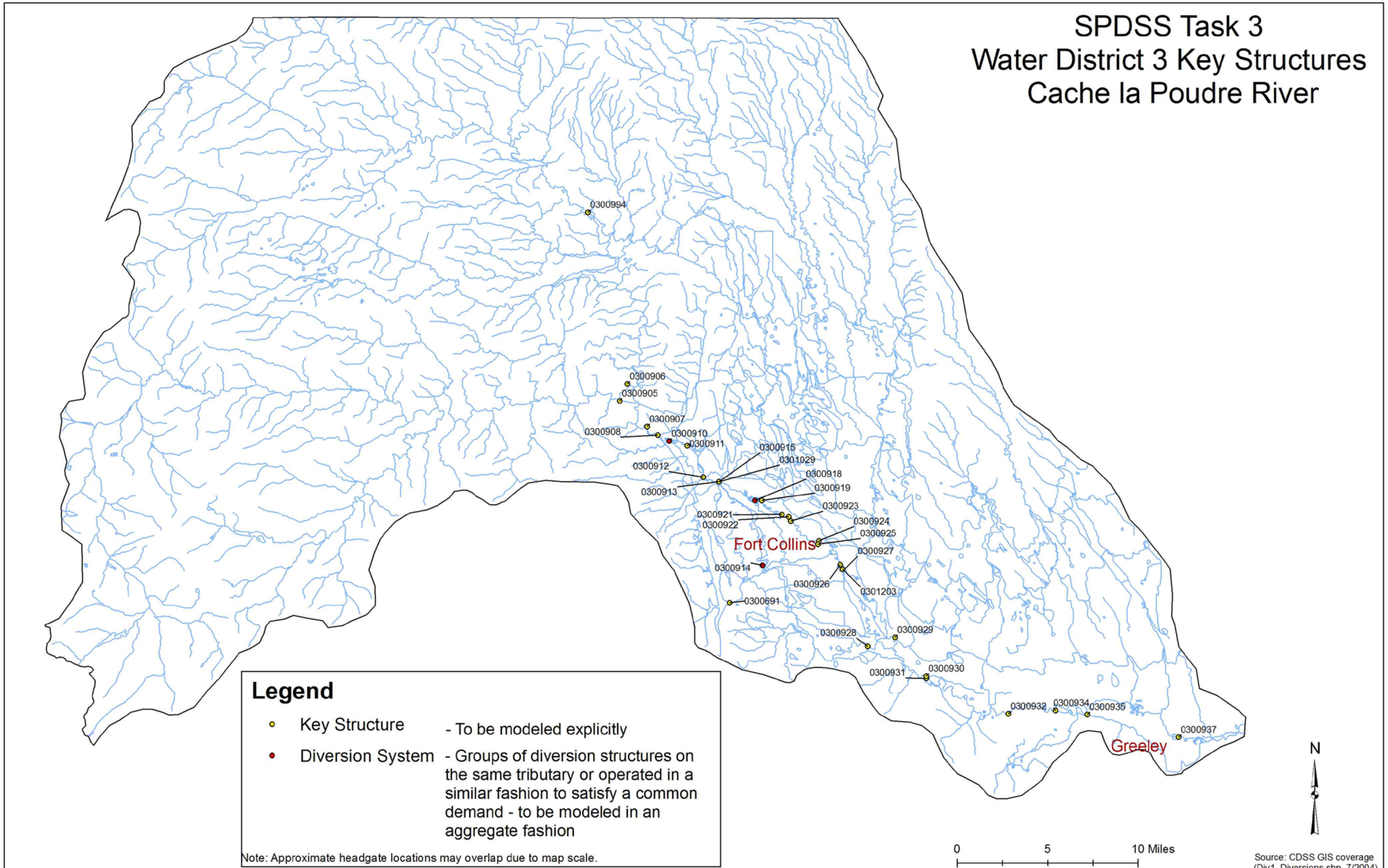
No.	Diversion System Primary ID	Diversion System Name	Additional Structures Included in Diversion System
61	23_TARBORCO	TARBORCO DIVSYS	2300928, 2300920, 2300921, 2300910, 2301087, 2300911, 2300909
62	23_TARCOMCO	TARCOMCO DIVSYS	2300895, 2300903, 2300879, 2300884, 2300892, 2300890, 2300885, 2300894, 2300887, 2300889, 2300888, 2300882, 2300886, 2301089
63	4800514_D	YELTON DITCH DIVSYS	4800514, 4800507, 4800508, 4800509, 4800510, 4800511, 4800512, 4800513, 4800535, 4800584
64	4800519_D	MANSFIELD DITCH 2 DIVSYS	4800519, 4800518
65	4800520_D	WARREN DITCH DIVSYS	4800520, 4800521, 4800568
66	4800527_D	LINK DITCH 2 DIVSYS	4800527, 4800501, 4800505, 4800522, 4800523, 4800582
67	4800531_D	DAVY DITCH DIVSYS	4800531, 4800524, 4800528, 4800529, 4800530
68	4800532_D	STUBB CREEK DITCH DIVSYS	4800532, 4800533
69	4800538_D	MCINTYRE DITCH DIVSYS	4800538, 4800536, 4800537, 4800544
70	4800541_D	HOMESTEAD DITCH DIVSYS	4800541, 4800526, 4800539, 4800540, 4800542, 4800545, 4800546, 4800548, 4800569, 4800579
71	4800552_D	OLLIE DITCH DIVSYS	4800552, 4800549, 4800550, 4800551, 4800554, 4800556
72	4800553_D	JIMMY CREEK DITCH DIVSYS	4800553, 4800515
73	4800558_D	LAGARDE DITCH 1 DIVSYS	4800558, 4800557, 4800560, 4800561, 4800562
74	4800565_D	GRACE CREEK DITCH DIVSYS	4800565, 4800566, 4800567
75	6400511_I	HARMONY DITCH 1 DEMAND	6400511, 6400510, 6400515, 6403906
76	6400522_D	BRAVO DITCH DIVSYS	6400522, 6400521
77	8000657_D	HEPBURN DITCH 2 DIVSYS	8000657, 8000739, 8000740
78	8000662_D	MACK DITCH 1 DIVSYS	8000662, 8000659, 8000660, 8000661, 8000889, 8000893
79	8000673_D	BOND DITCH 2 DIVSYS	8000673, 8000674
80	8000732_D	CRAIG PARK GULCH DIVSYS	8000732, 8000728, 8000729, 8000730
81	8000774_D	BERGER DITCH DIVSYS	8000774, 8000773, 8000776, 8000777
82	8000799_D	ALKIRE DITCH DIVSYS	8000799, 8000800, 8000801, 8000845
83	8000829_D	ROCKY MTN FUEL 1 DIVSYS	8000829, 8000825, 8000826, 8000827, 8000828, 8000842, 8000843
84	8000831_D	DAVIS DITCH 1 DIVSYS	8000831, 8000847, 8000848, 8000849, 8000854, 8000858

SPDSS Task 3
Water District 1 Key Structures
South Platte River



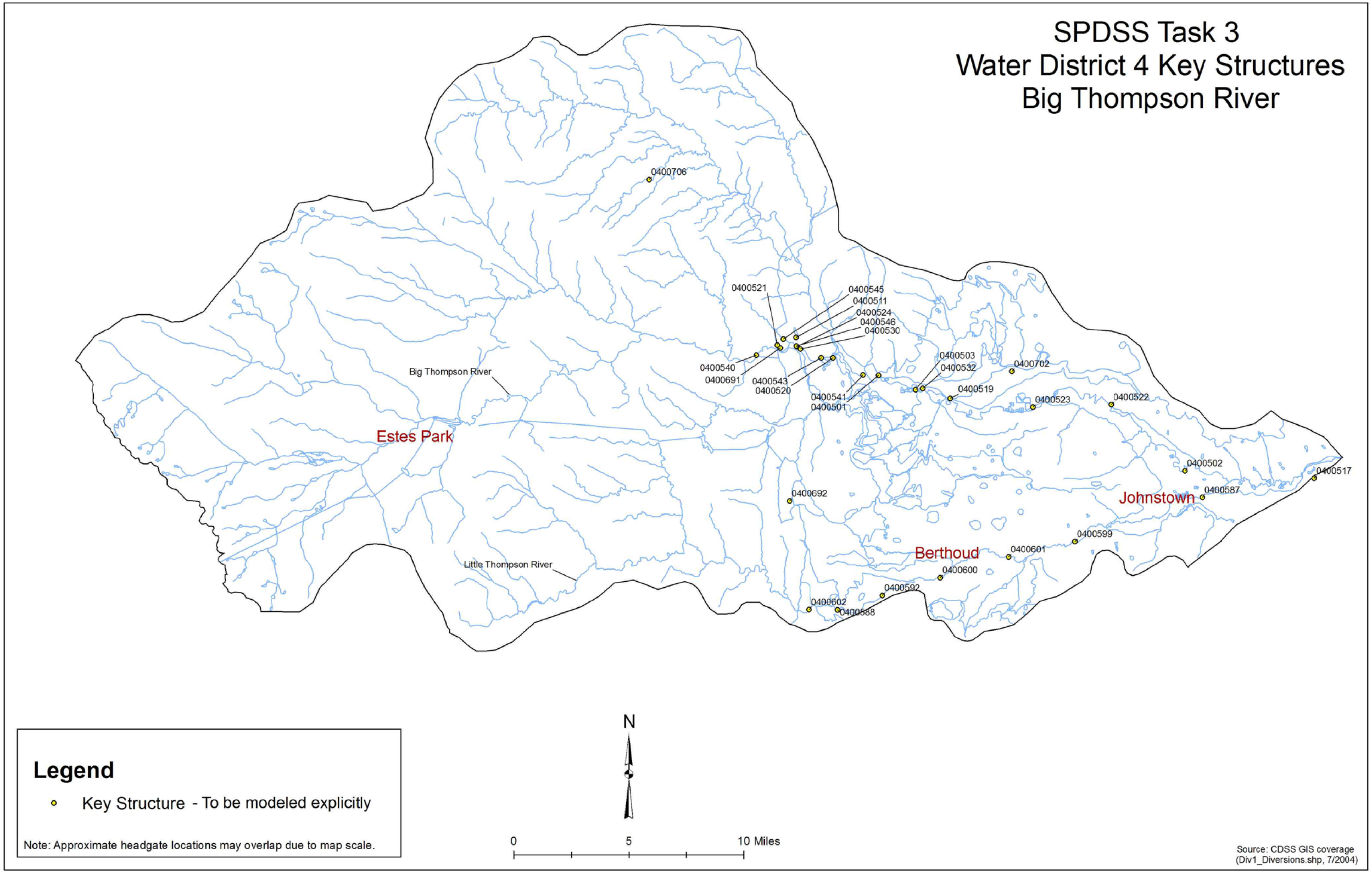
SPDSS Task 3
Water District 2 Key Structures
South Platte River



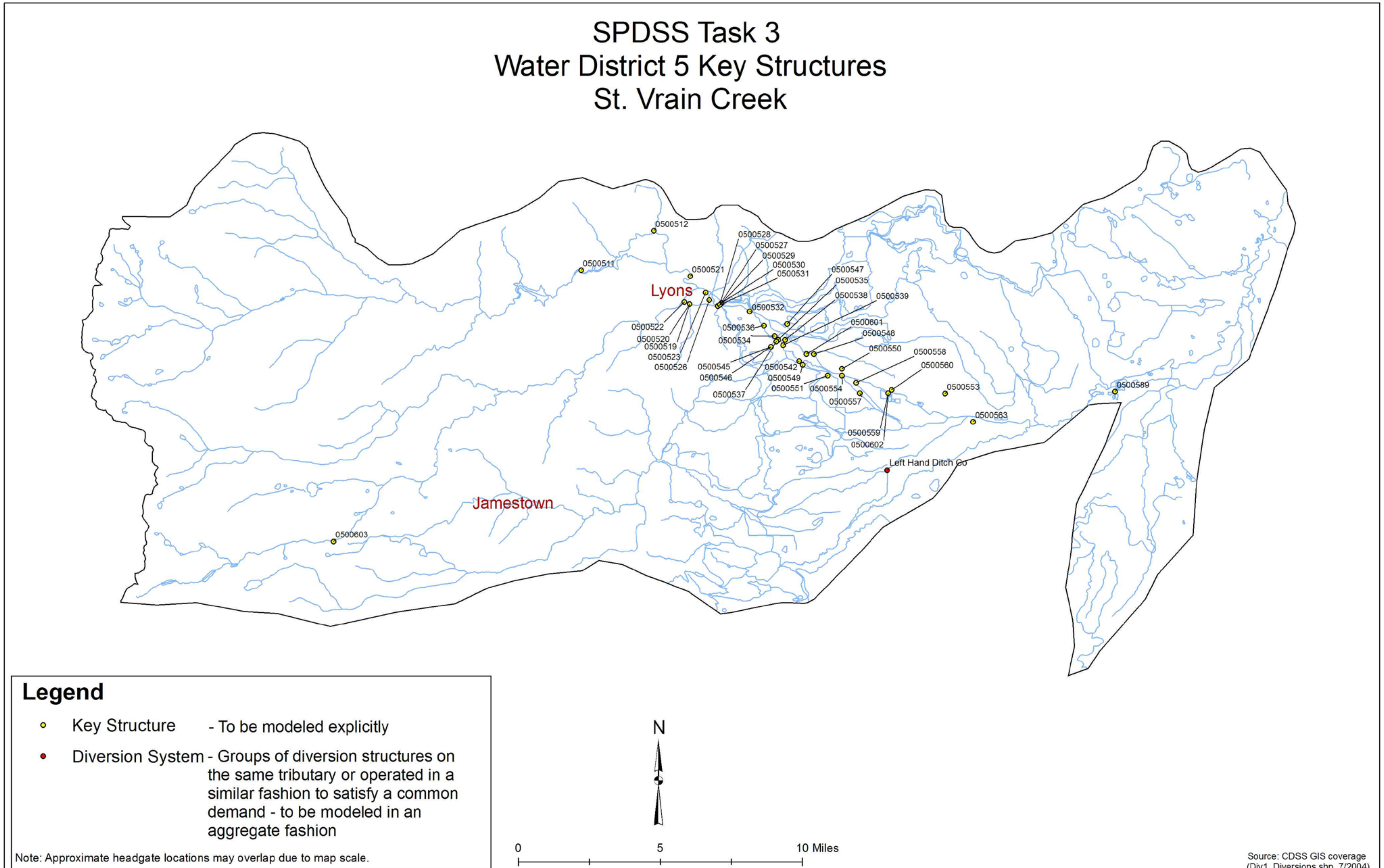


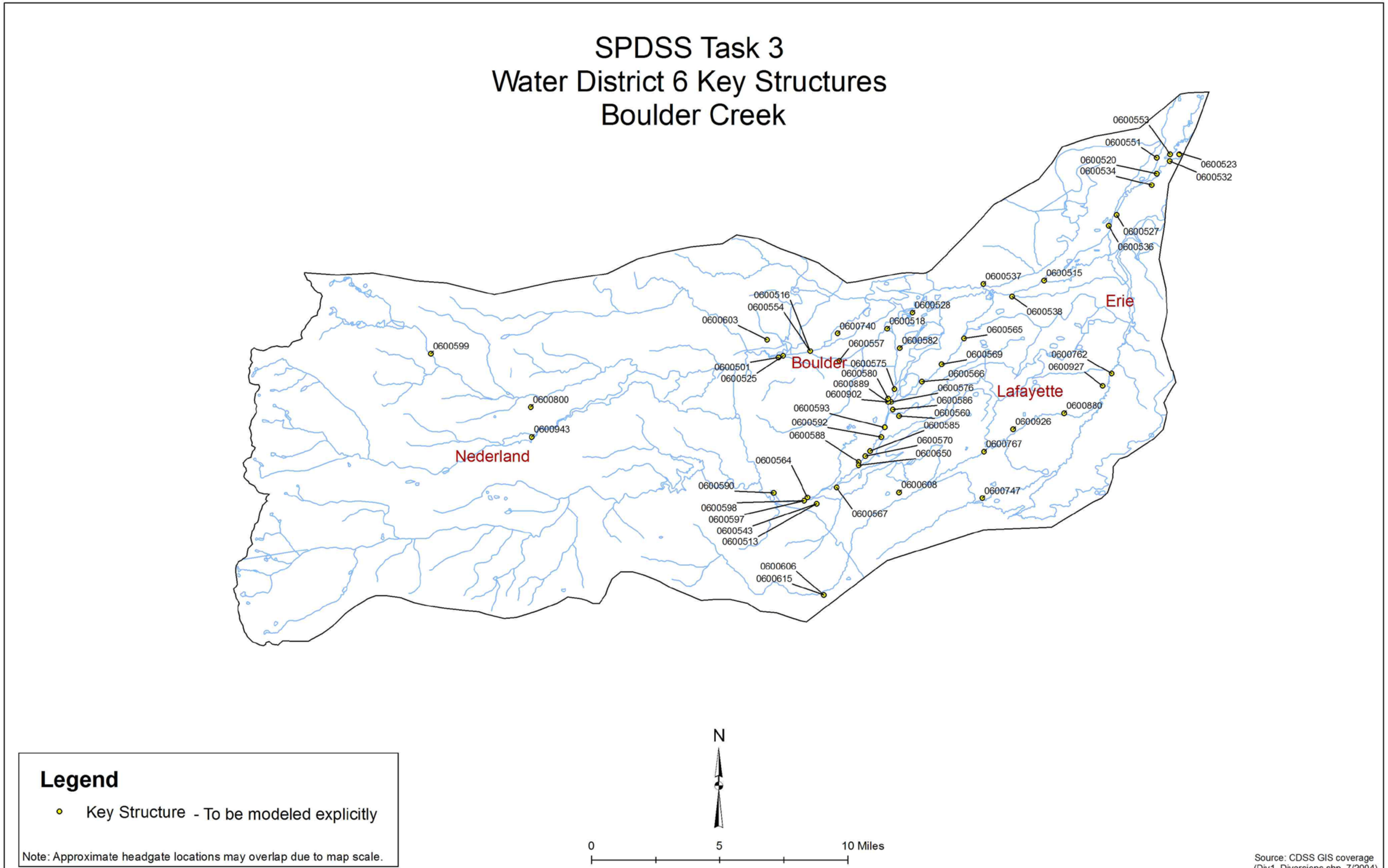
SPDSS Task 3
Water District 3 Key Structures
Cache la Poudre River
0300994
0300906
0300905
0300907
0300908
0300910
0300911
0300915
0301029
0300912
0300913
0300918
0300919
0300923
0300921
0300922
0300924
0300925
Fort Collins
0300927
0300914
0300926
0301203
0300691
0300928
0300929
0300931
0300930
0300932
0300934
0300935
0300937
Greeley
N
Legend
Key Structure
- To be modeled explicitly
Diversion System
- Groups of diversion structures on the same tributary or operated in a similar fashion to satisfy a common demand - to be modeled in an aggregate fashion
Note: Approximate headgate locations may overlap due to map scale.
0
5
10 Miles
Source: CDSS GIS coverage (Div1_Diversions.shp, 7/2004)

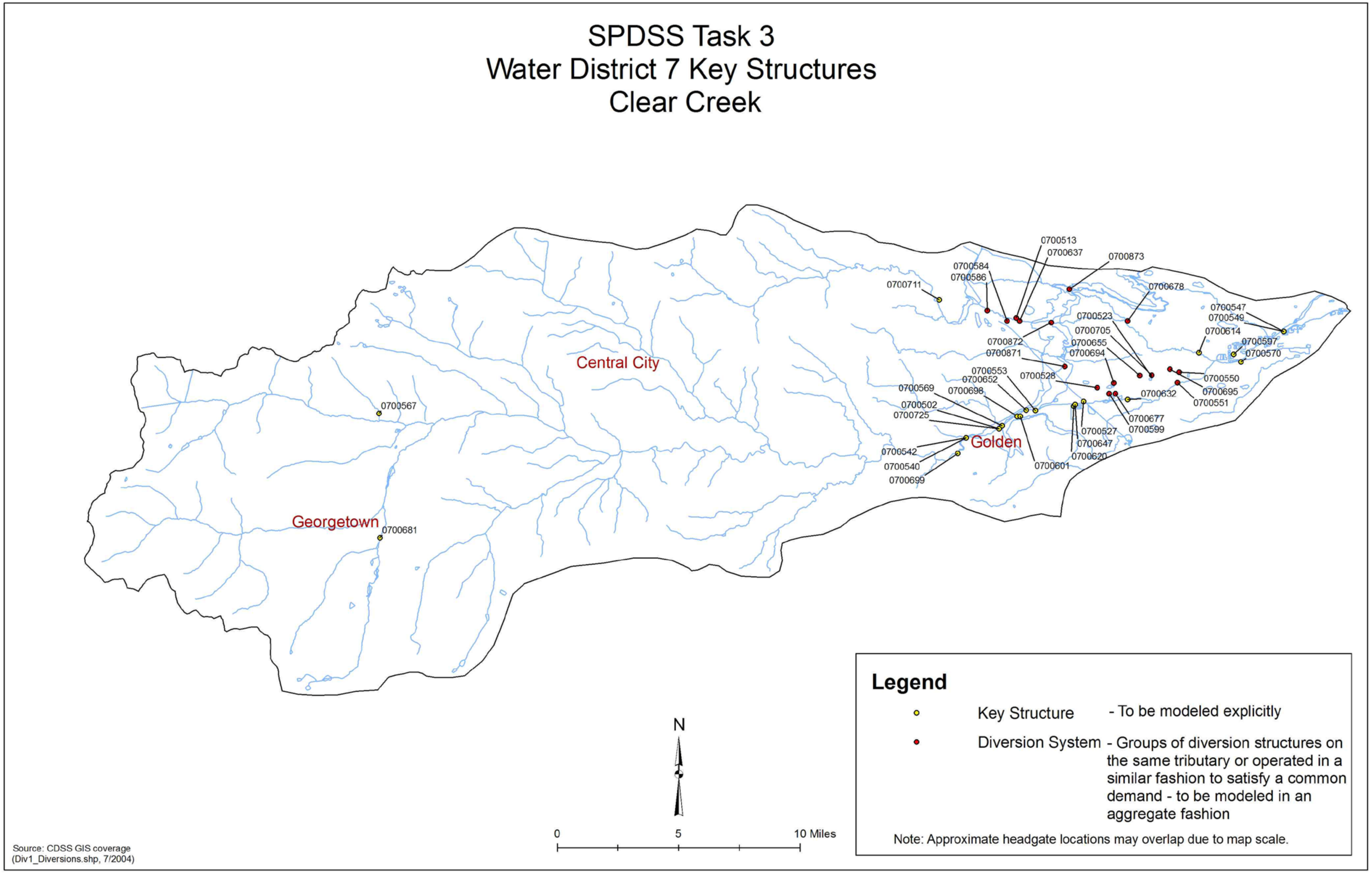
3

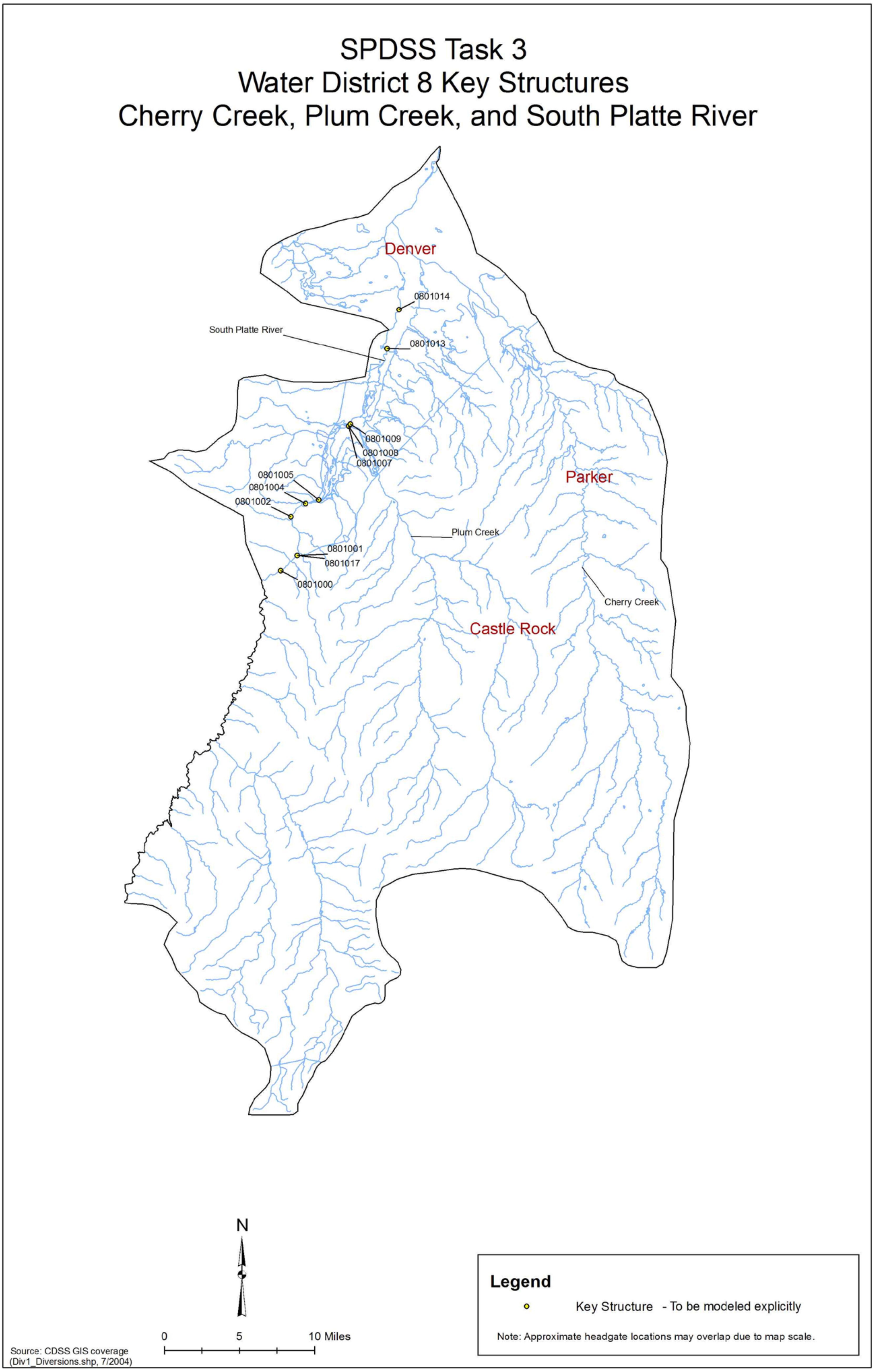


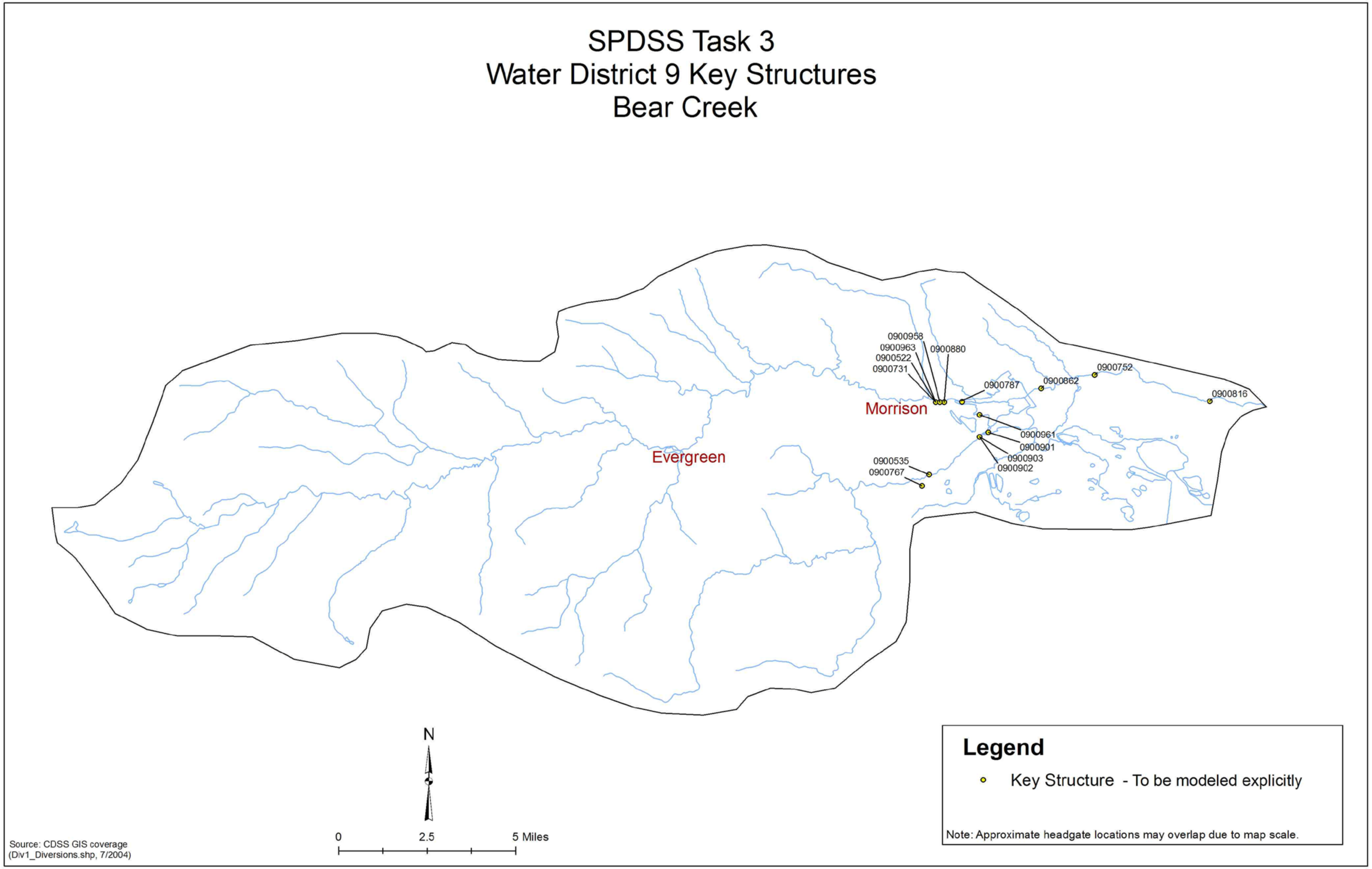
SPDSS Task 3
Water District 4 Key Structures
Big Thompson River
0400706
0400521
0400545
0400511
0400524
0400546
0400530
0400540
0400691
0400543
0400520
0400503
0400532
0400702
0400519
0400541
0400501
0400523
0400522
Big Thompson River
Estes Park
0400502
0400517
0400692
0400587
Johnstown
0400599
Berthoud
0400601
0400600
Little Thompson River
0400592
0400602
0400588
Legend
Key Structure - To be modeled explicitly
Note: Approximate headgate locations may overlap due to map scale.
N
0
5
10 Miles
Source: CDSS GIS coverage
(Div1_Diversions.shp, 7/2004)


SPDSS Task 3
Water District 5 Key Structures
St. Vrain Creek
0500512
0500511
0500528
0500527
0500529
0500530
0500531
0500521
Lyons
0500547
0500535
0500538
0500539
0500532
0500522
0500520
0500519
0500523
0500526
0500536
0500534
0500601
0500548
0500550
0500558
0500560
0500545
0500546
0500542
0500549
0500551
0500554
0500537
0500557
0500553
0500589
0500563
0500559
0500602
Left Hand Ditch Co
Jamestown
0500603
Legend
Key Structure - To be modeled explicitly
Diversion System - Groups of diversion structures on the same tributary or operated in a similar fashion to satisfy a common demand - to be modeled in an aggregate fashion
Note: Approximate headgate locations may overlap due to map scale.
N
0
5
10 Miles
Source: CDSS GIS coverage
(Div1_Diversions.shp, 7/2004)

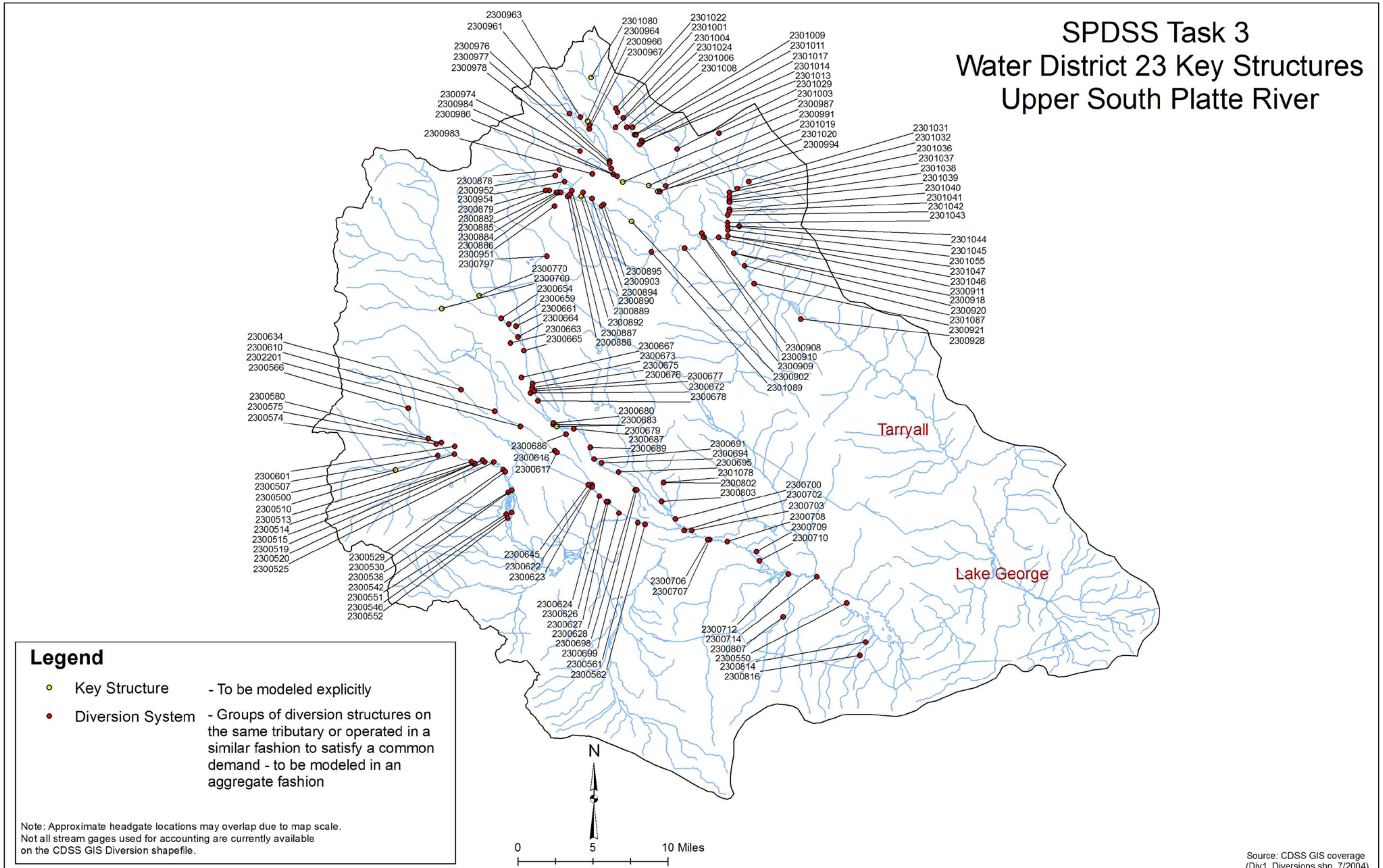

SPDSS Task 3
Water District 6 Key Structures
Boulder Creek
Nederland
Boulder
Lafayette
Erie
0600553
0600551
0600520
0600534
0600523
0600532
0600527
0600536
0600537
0600515
0600538
0600516
0600554
0600603
0600528
0600740
0600518
0600565
0600557
0600582
0600599
0600501
0600525
0600575
0600580
0600569
0600762
0600927
0600889
0600902
0600566
0600576
0600586
0600560
0600800
0600593
0600592
0600588
0600585
0600570
0600650
0600880
0600926
0600767
0600943
0600564
0600590
0600598
0600597
0600543
0600513
0600608
0600747
0600567
0600606
0600615
Legend
Key Structure - To be modeled explicitly
Note: Approximate headgate locations may overlap due to map scale.
N
0
5
10 Miles
Source: CDSS GIS coverage
(Div1_Diversions.shp, 7/2004)

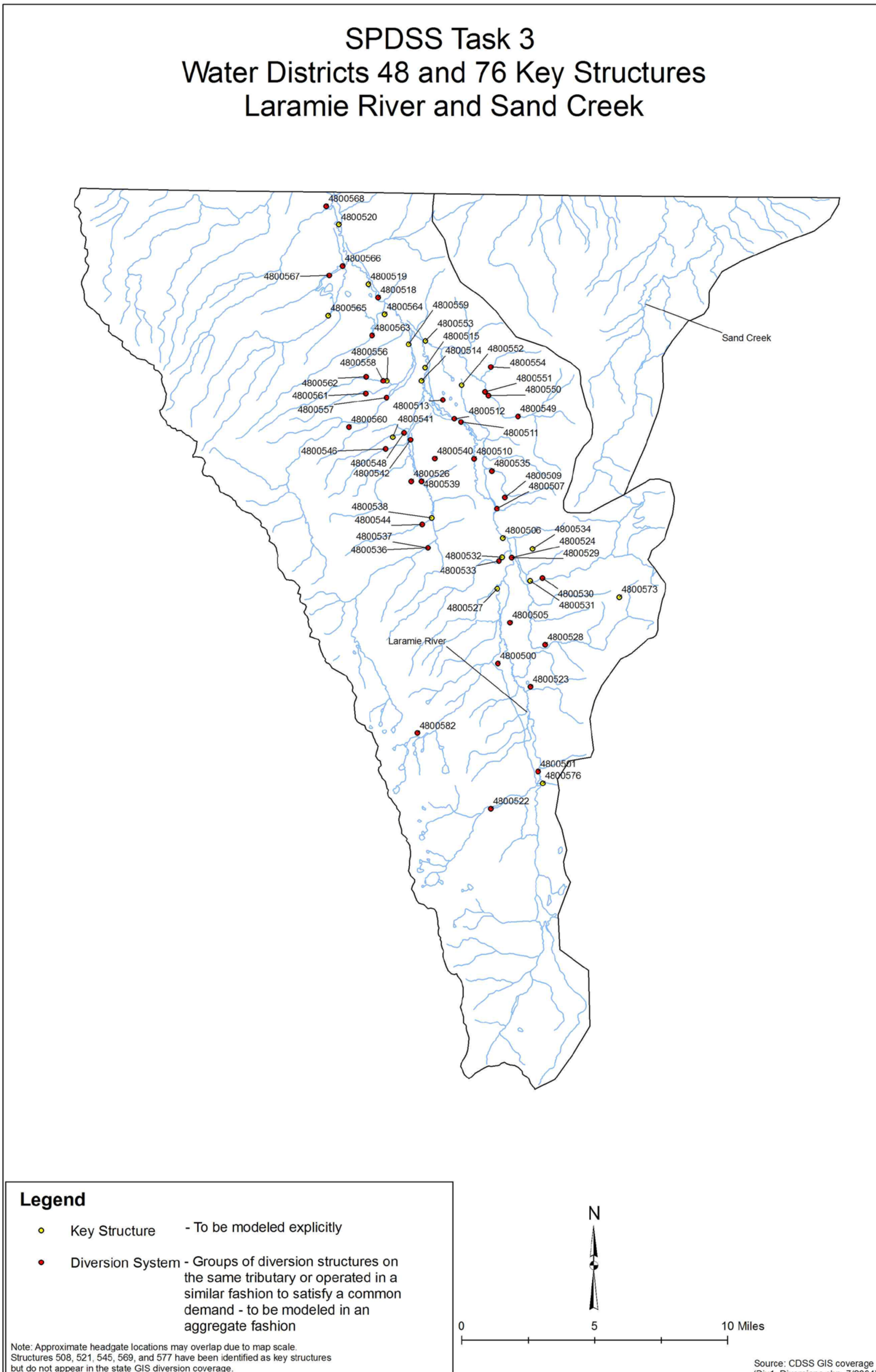

SPDSS Task 3
Water District 7 Key Structures
Clear Creek
Central City
Georgetown
Golden
0700567
0700681
0700711
0700584
0700586
0700513
0700637
0700873
0700678
0700523
0700705
0700655
0700694
0700872
0700871
0700553
0700652
0700528
0700569
0700698
0700502
0700725
0700542
0700540
0700699
0700601
0700527
0700647
0700620
0700677
0700599
0700632
0700550
0700695
0700551
0700547
0700549
0700614
0700597
0700570
Legend
Key Structure - To be modeled explicitly
Diversion System - Groups of diversion structures on the same tributary or operated in a similar fashion to satisfy a common demand - to be modeled in an aggregate fashion
Note: Approximate headgate locations may overlap due to map scale.
N
0
5
10 Miles
Source: CDSS GIS coverage
(Div1_Diversions.shp, 7/2004)

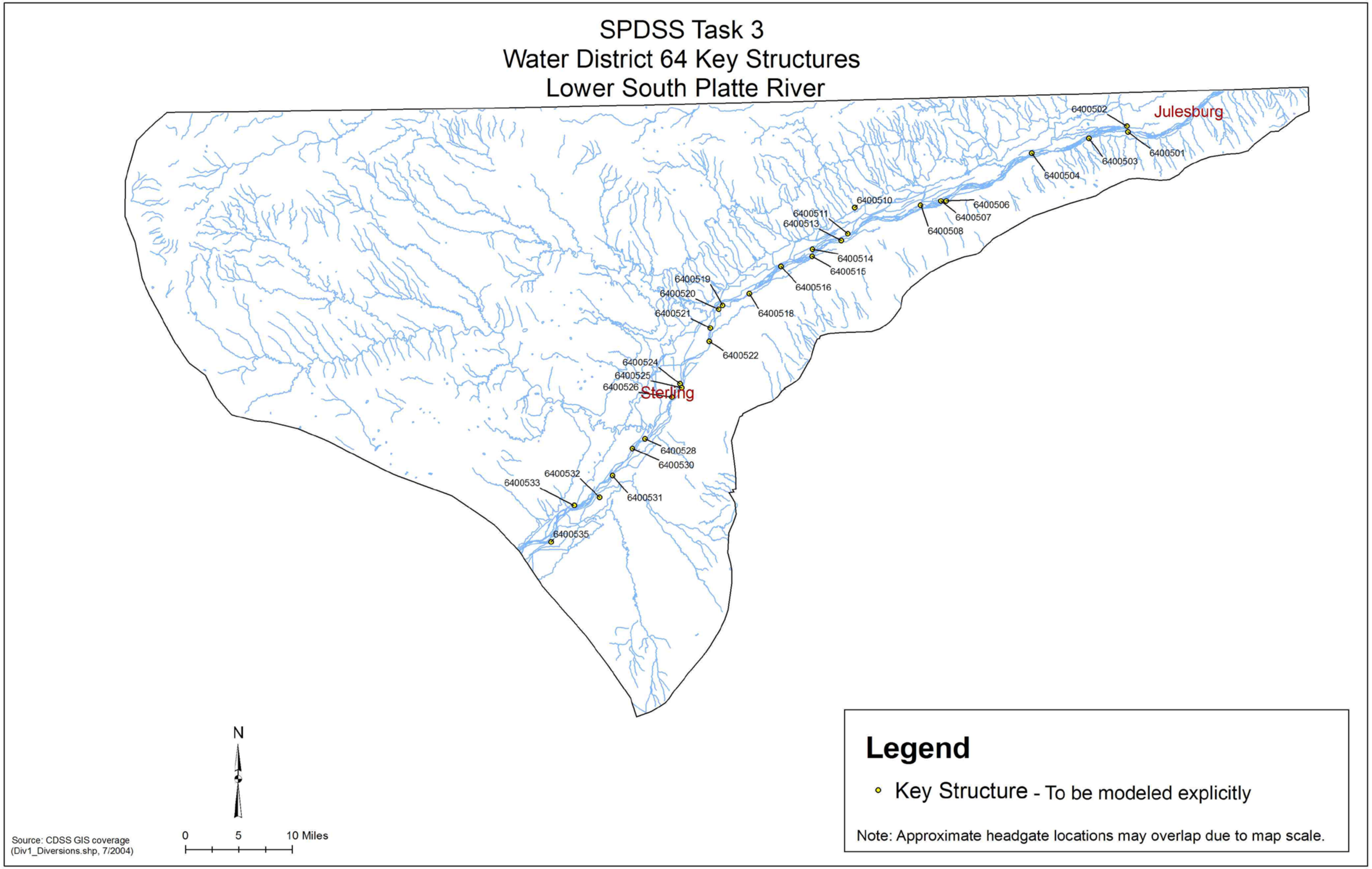

SPDSS Task 3
Water District 8 Key Structures
Cherry Creek, Plum Creek, and South Platte River
Denver
0801014
South Platte River
0801013
0801009
0801008
0801007
Parker
0801005
0801004
0801002
Plum Creek
0801001
0801017
0801000
Cherry Creek
Castle Rock
N
0
5
10 Miles
Source: CDSS GIS coverage
(Div1_Diversions.shp, 7/2004)
Legend
Key Structure - To be modeled explicitly
Note: Approximate headgate locations may overlap due to map scale.

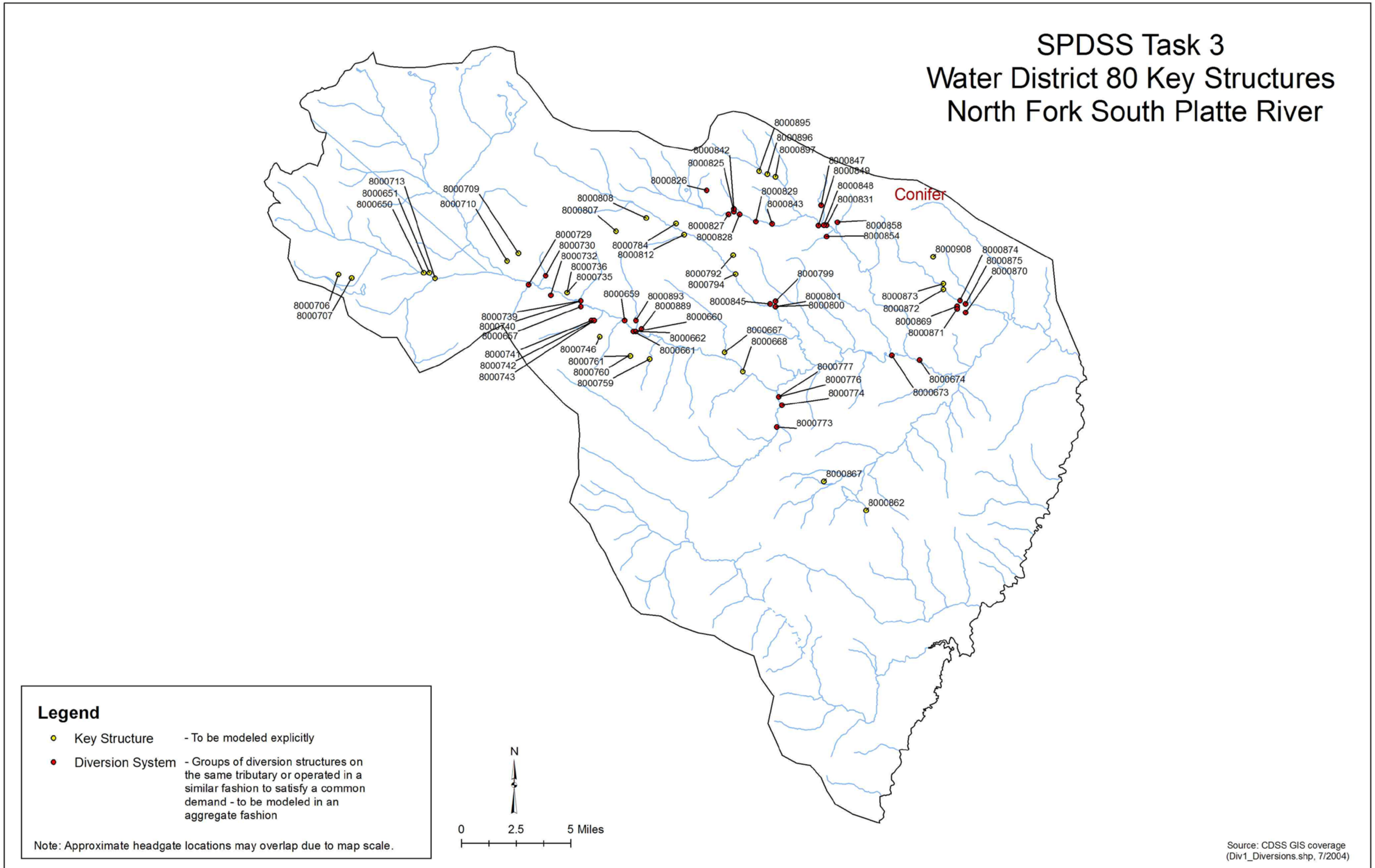


SPDSS Task 3
Water District 9 Key Structures
Bear Creek
0900958
0900963
0900522
0900731
0900880
0900787
0900862
0900752
0900816
Morrison
Evergreen
0900961
0900901
0900903
0900902
0900535
0900767
N
0
2.5
5 Miles
Source: CDSS GIS coverage
(Div1_Diversions.shp, 7/2004)
Legend
Key Structure - To be modeled explicitly
Note: Approximate headgate locations may overlap due to map scale.


SPDSS Task 3
Water District 23 Key Structures
Upper South Platte River
Tarryall
Lake George
2300963
2300961
2300976
2300977
2300978
2300974
2300984
2300986
2300983
2301080
2300964
2300966
2300967
2301022
2301001
2301004
2301024
2301006
2301008
2301009
2301011
2301017
2301014
2301013
2301029
2301003
2300987
2300991
2301019
2301020
2300994
2301031
2301032
2301036
2301037
2301038
2301039
2301040
2301041
2301042
2301043
2301044
2301045
2301055
2301047
2301046
2300911
2300918
2300920
2301087
2300921
2300928
2300878
2300952
2300954
2300879
2300882
2300885
2300884
2300886
2300951
2300797
2300770
2300760
2300654
2300659
2300661
2300664
2300663
2300665
2300895
2300903
2300894
2300890
2300889
2300892
2300887
2300888
2300908
2300910
2300909
2300902
2301089
2300634
2300610
2302201
2300566
2300667
2300673
2300675
2300676
2300677
2300672
2300678
2300580
2300575
2300574
2300680
2300683
2300679
2300687
2300689
2300686
2300616
2300617
2300691
2300694
2300695
2301078
2300802
2300803
2300700
2300702
2300703
2300708
2300709
2300710
2300601
2300507
2300500
2300510
2300513
2300514
2300515
2300519
2300520
2300525
2300529
2300530
2300538
2300542
2300551
2300546
2300552
2300645
2300622
2300623
2300706
2300707
2300624
2300626
2300627
2300628
2300698
2300699
2300561
2300562
2300712
2300714
2300807
2300550
2300814
2300816
Legend
Key Structure - To be modeled explicitly
Diversion System - Groups of diversion structures on the same tributary or operated in a similar fashion to satisfy a common demand - to be modeled in an aggregate fashion
Note: Approximate headgate locations may overlap due to map scale.
Not all stream gages used for accounting are currently available
on the CDSS GIS Diversion shapefile.
N
0
5
10 Miles
Source: CDSS GIS coverage
(Div1_Diversions.shp, 7/2004)


SPDSS Task 3
Water Districts 48 and 76 Key Structures
Laramie River and Sand Creek
4800568
4800520
4800566
4800567
4800519
4800518
4800565
4800564
4800559
4800563
4800553
4800515
4800556
4800558
4800514
4800552
4800554
4800562
4800551
4800550
4800561
4800557
4800513
4800512
4800549
4800560
4800541
4800511
4800546
4800540
4800510
4800548
4800535
4800542
4800526
4800509
4800539
4800507
4800538
4800544
4800506
4800534
4800537
4800524
4800536
4800532
4800529
4800533
4800530
4800573
4800531
4800527
4800505
4800528
Laramie River
4800500
4800523
4800582
4800501
4800576
4800522
Sand Creek
Legend
Key Structure - To be modeled explicitly
Diversion System - Groups of diversion structures on the same tributary or operated in a similar fashion to satisfy a common demand - to be modeled in an aggregate fashion
Note: Approximate headgate locations may overlap due to map scale.
Structures 508, 521, 545, 569, and 577 have been identified as key structures but do not appear in the state GIS diversion coverage.
N
0
5
10 Miles
Source: CDSS GIS coverage
(Div1_Diversions.shp, 7/2004)


SPDSS Task 3
Water District 64 Key Structures
Lower South Platte River
Julesburg
Sterling
6400501
6400502
6400503
6400504
6400506
6400507
6400508
6400510
6400511
6400513
6400514
6400515
6400516
6400518
6400519
6400520
6400521
6400522
6400524
6400525
6400526
6400528
6400530
6400531
6400532
6400533
6400535
N
0
5
10 Miles
Source: CDSS GIS coverage
(Div1_Diversions.shp, 7/2004)
Legend
Key Structure - To be modeled explicitly
Note: Approximate headgate locations may overlap due to map scale.


SPDSS Task 3
Water District 80 Key Structures
North Fork South Platte River
Conifer
8000895
8000896
8000897
8000842
8000825
8000826
8000847
8000849
8000848
8000831
8000829
8000843
8000713
8000651
8000650
8000709
8000710
8000808
8000807
8000827
8000828
8000858
8000854
8000729
8000730
8000732
8000736
8000735
8000784
8000812
8000908
8000874
8000875
8000870
8000792
8000794
8000799
8000706
8000707
8000659
8000893
8000889
8000845
8000801
8000800
8000873
8000872
8000739
8000740
8000657
8000660
8000869
8000871
8000667
8000668
8000662
8000661
8000741
8000742
8000743
8000746
8000761
8000760
8000759
8000777
8000776
8000774
8000674
8000673
8000773
8000867
8000862
Legend
Key Structure - To be modeled explicitly
Diversion System - Groups of diversion structures on the same tributary or operated in a similar fashion to satisfy a common demand - to be modeled in an aggregate fashion
Note: Approximate headgate locations may overlap due to map scale.
N
0
2.5
5 Miles
Source: CDSS GIS coverage
(Div1_Diversions.shp, 7/2004)

Appendix B
Non-Key Structure Aggregation

To: Ray Alvarado and Ray Bennett

From: LRE, Erin Wilson and Mark Mitisek

Subject: Task 3- Aggregate Non-Key Agricultural Diversion Structures

Date: March 20, 2008

Introduction

This memo describes the approach and results of Phase 3 Task 3, Aggregate Non-Key Agricultural Diversion Structures. The objective of this task was as follows:

> *Determine which non-key diversion and groundwater only structures should be grouped together (aggregated) and decide where the node representing each group's aggregate operations should fit into the river network*

The SPDSS Historical Crop Consumptive Use analysis is based on the 1956, 1976, 1987, 2001, and 2005 Irrigated Acreage coverages developed by Riverside Technology, inc. (RTi) for SPDSS. Key surface water structures were determined and documented in Subtask 3.1 (Task 3 Summary – Key Diversion Structures May 2007, revised March 2008). The spatial aggregation of non-key surface water or conjunctive use structures and aggregation of ground water only parcels was completed using tools in the CDSS GIS Toolbox developed in Task 18. Note that throughout this memorandum, "surface water structures" means structures receiving surface water. Surface water structures may or may not also use supplemental ground water. Ground water only parcels only have a ground water source.

Background

The SPDSS Historical Crop Consumptive Use analysis (using StateCU) and subsequent water resources planning model efforts (using StateMod) represents 100 percent of the crop consumptive use in the South Platte and North Platte River basins in current years (both 2001 and 2005 acreage coverages). Both models will be used for planning purposes, therefore accurate representation of current water use, operations, and administration is important.

Key diversion structures were initially identified as diversion structures representing the approximately upper 85 percent of net absolute decreed water rights within each Water District in the SPDSS study area. The preliminary list of key diversion structures was then revised during Phase 1 and Phase 2 of the SPDSS effort based on interviews with Water Commissioners and Division 1 and 6 Engineer office personnel. These interviews discussed diversion structures and/or diversion systems that should be included in potential future modeling efforts due to their impact on basin operations. Diversion systems are defined as a group of key diversion structures on the same tributary and operated in a similar fashion to satisfy a common demand.

In general, non-key structures that are currently active are included in aggregates and exhibit one or more of the following characteristics:

- Active structures (CIU indicates active) that currently (in the period since 2001) divert for irrigation
- Sparse or no diversion records during the 1950 to current digitized (2006) year SPDSS study period
- Diversion source is a small tributary that will not be included in the water resources planning model
- Relatively small acreage, generally less than 100 acres

Each water right associated with a well assigned to irrigated acreage will be specifically included in the StateCU and StateMod analyses. However, for modeling purposes, it is appropriate to group well only lands regionally. This effectively reduces the number of individual acreage groups served only by ground water only from greater than 4,500 to around 85, and allows more efficient simulation of both the StateCU and StateMod models.

Approach

The following approach was used to determine aggregated irrigated structures and aggregated ground water only parcels in the South Platte River basin.

1. A single coverage for both surface and ground water aggregates was created by dividing water districts into subsets that were based on the location of non-key irrigated lands, confluences, designated basins, stream gage locations, and the alluvial ground water boundary.
2. The coverage was assigned a unique SW and GW only ID. The non-key surface water aggregates and ground water only aggregates were assigned nine character identifiers that are made up of the Water District, ADP (Aggregate Diversion Platte) or AWP (Aggregate Well Platte), and a unique Aggregation ID. For example 01_ADP001 indicates a surface water aggregate located in Water District 1, while 01_AWP001 indicates a ground water only structure located in Water District 1.
3. The ArcMap CDSS Tools toolbox was used to spatially aggregate irrigated land using the "Aggregate by GW Parcel" and "Aggregate by SW Structure" tools under the Aggregate Menu.
   - The "Aggregate by GW Parcel" was used to combine irrigated lands with ground water as the only source within each Aggregate ID. The irrigated land coverage for each year (1956, 1976, 1987, 2001, and 2005) was run independently and resulted in four output tables of Aggregate ID, Parcel ID, and Parcel acreage. These tables are in a comma

separated format and can be used directly by StateDMI in creating StateCU and StateMod input files.

- The “Aggregate by SW Structure” was used to combine active non-key surface water structures within each Aggregate ID. The irrigated land coverages for recent years (2001 and 2005) were run independently and resulted in two output tables of Aggregate ID, WDID, and total acreage.

4. The Aggregate shapefile polygons were revised, and steps 2 through 3 repeated as necessary, until acreage included in each surface or ground water aggregate was less than approximately 5,000 acres.
5. Non-key surface water structure tables for the 2001 and 2005 irrigate acreage snapshot were combined to create a single list of active non-key diversion structures for each Aggregate ID without duplicates.
6. Finally, there are 39 parcels (2005) that do not have a surface or ground water source that receive “multi-use” water from Budweiser. These parcels are grouped into an aggregate called 03_BUDUSE.

Results

Table 1 lists the aggregated surface water structures and associated acreage assigned to Aggregates IDs for each year. As presented, there are 13 surface water aggregates that include 132 individual structures. There is a total of 9,427 acres include in surface water aggregates 2001. This represents approximately 1 percent of the total 2001 surface water acreage in the South Platte Basin.

Table 2 lists 83 ground water aggregates and associated acreage assigned for each year. There is a total of 167,247 acres include in ground water aggregates 2001. This represents 100 percent of the total acreage with ground water as the only source in the South Platte Basin.

Figure 1 shows the acreage assigned to surface water and ground water aggregates for the five acreage coverage years. As shown, ground water only acreage increased significantly between the 1956 and 1976 coverages, likely because of improvements in technology. Ground water only acreage remained relatively stable after South Platte Rules and Regulations were introduced in 1974 and decreased between the 1987 and 2001 coverages possibly due to competition for augmentation sources. As shown in **Figure 1**, aggregate surface water structure acreage declines over time, partly due to municipal development. **Table 3** summarizes both key and aggregated structure information by Water District for 2001.

Figure 2 and Figure 3 show the spatial boundaries used for surface and ground water aggregation of the South Platte River basin. **Exhibit A**, attached, lists the surface water diversion structures represented in each aggregate and their acreage by year. The ground water parcels represented in each aggregate and the total acreage associated with each parcel by year may be found by looking at the comma separated value files associated with this task. (1956GW_Agg.csv, 1976GW_Agg.csv, 1987GW_Agg.csv, 2001GW_Agg.csv, 2005GW_Agg.csv)

Comments and Concerns

- Key and aggregate structures represent 100 percent of the acreage and associated crop consumptive use in the South Platte and North Platte river basins in current years (2001 and 2005). The procedure used to aggregate non-key structures is automated, therefore can be easily updated if key structures are redefined, new coverages are added, or additional information becomes available and existing coverages are enhanced.
- Aggregation allows the development of a planning tool to focus on key structures likely to be important in future planning efforts, yet provides basin wide totals of current diversions and consumptive use. The data centered modeling approach, including the CDSS GIS toolbox, allows revisions or refinements to the aggregation process to occur relatively efficiently.
- Aggregated acreage for years when irrigated acreage mapping does not exist will be estimated using the approach described in the Task 71 – Estimate Historical Acreage memorandum.
- Non-key surface water structures that have no acreage in 2001 or 2005 (but had acreage in earlier years) generally have a historical or inactive CIU code; have no recent diversion records; and/or have no active water rights and are not included in the aggregates. The historical use associated with these structures will be included in the Water Resources Planning Model in the baseflow gain/loss term.
- There are 167 structures being excluded that have historical acreage but no current acreage, therefore inaccuracies are introduced to the historic consumptive use estimates. This is considered reasonable because the acreage and associated consumptive use are small compared to the amount represented. The historic structures not included make up approximately 0.4 percent of the total basin acreage in 1976, which underestimates basin-wide consumptive use in 1976 by approximately 5,000 acre-feet.

Table 1
Surface Water Aggregation Summary

#	Aggregate ID	Aggregate Name	# of Structures	Total Acreage				
				1956	1976	1987	2001	2005
1	01_ADP037	South Platte River below Kersey, Co North 2	4	507	667	800	766	768
2	02_ADP003	South Platte River below Ft Lupton West	3	425	469	517	494	441
3	03_ADP003	N Fork Cache la Poudre River above Confluence	21	1,861	1,942	1,376	1,479	1,482
4	03_ADP002	Cache la Poudre River Above Greeley, Co	10	2,375	2,057	1,712	1,465	1,809
5	05_ADP002	Left Hand Creek above Saint Vrain Confluence	9	809	658	638	646	530
6	07_ADP001	Clear Creek below Golden, Co	3	913	160	268	196	122
7	08_ADP003	South Platte River above Chatfield Reservior	3	36	36	44	44	44
8	08_ADP004	Plum Creek above South Platte Confluence	12	303	325	779	273	230
9	08_ADP002	Cherry Creek above Franktown, Co	5	446	445	493	415	447
10	09_ADP003	Bear Creek above Morrison, Co	3	30	30	30	23	23
11	23_ADP001	SF South Platte River above Tarryall Confluence	28	1,182	1,180	1,083	1,108	883
12	23_ADP002	Tarryall Creek above SF South Platte Confluence	19	2,430	2,530	2,934	2,451	1,083
13	80_ADP001	Water District 80, NF South Platte River	12	89	78	79	69	94
Total			**132**	**11,407**	**10,578**	**10,752**	**9,427**	**7,954**

Table 2
Ground Water Aggregation Summary

#	Aggregate ID	Aggregate Name	1956		1976		1987		2001		2005	
			# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage
1	01_AWP001	Camp Creek Designated Basin	0	0	10	1,044	19	1,938	19	2,113	18	1,803
2	01_AWP002	South Platte River below Weldona, CO North	32	2042.524	55	2,510	77	2,957	48	2,402	56	1,840
3	01_AWP003	WD 1, Upper Beaver Creek	90	3489.329	127	5,335	133	4,952	85	3,698	75	3,078
4	01_AWP004	WD 1, Main Stem Beaver Creek	150	5984.122	135	5,028	159	5,032	68	2,828	37	1,701
5	01_AWP005	WD 1, Washington County	50	1946.423	56	2,415	60	2,380	23	1,559	2	208
6	01_AWP006	South Platte River below Weldona, CO South 1	16	731.637	30	1,651	45	1,789	20	1,038	16	1,023
7	01_AWP007	South Platte River below Weldona, CO South 2	38	1967.338	45	2,256	67	2,938	47	2,739	24	1,604
8	01_AWP008	Upper Kiowa Bijou Designated Basin, Wolf Creek	5	198.085	9	390	21	907	16	907	11	808
9	01_AWP009	Upper Kiowa Bijou Designated Basin, West Bijou	2	275.752	19	760	23	1,016	18	1,017	20	1,093
10	01_AWP010	Lower Kiowa Bijou Designated Basin East 1	14	1194.565	29	1,776	36	2,148	17	1,923	21	1,720
11	01_AWP011	Lower Kiowa Bijou Designated Basin East 2	27	1885.74	67	3,166	84	3,549	40	3,039	30	2,347
12	01_AWP012	Lower Kiowa Bijou Designated Basin East 4	82	6832.299	110	5,830	153	5,827	78	4,539	98	4,204
13	01_AWP013	Lower Kiowa Bijou Designated Basin East 5	14	1380.263	63	3,175	66	2,654	37	2,476	44	2,425
14	01_AWP014	Lower Kiowa Bijou Designated Basin East 6	77	3563.523	135	4,962	132	4,798	62	3,670	52	3,439

#	Aggregate ID	Aggregate Name	1956		1976		1987		2001		2005	
			# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage
15	01_AWP015	Lower Kiowa Bijou Designated Basin East 7	46	2817.546	81	3,555	124	3,605	57	3,068	56	2,753
16	01_AWP016	Lower Kiowa Bijou Designated Basin East 8	59	3847.911	96	4,975	103	3,795	66	3,588	57	3,096
17	01_AWP017	Lower Kiowa Bijou Designated Basin East 9	23	1183.289	50	2,860	62	2,860	47	2,722	44	2,663
18	01_AWP018	Lower Kiowa Bijou Designated Basin East 10	36	1995.44	100	5,201	101	4,466	67	4,576	77	5,019
19	01_AWP019	Lower Kiowa Bijou Designated Basin West 1	66	3133.678	76	3,408	103	4,114	65	3,621	66	3,635
20	01_AWP020	Lower Kiowa Bijou Designated Basin West 2	25	1808.633	44	2,740	48	2,540	34	2,412	37	2,134
21	01_AWP021	Lower Kiowa Bijou Designated Basin West 3	42	1125.412	55	1,412	59	1,383	36	1,233	45	1,252
22	01_AWP022	Lower Lost Creek Designated Basin 1	0	0	10	1,350	9	1,052	18	2,748	21	2,850
23	01_AWP023	Lower Lost Creek Designated Basin 2	13	793.296	44	4,000	62	4,297	52	4,424	48	4,473
24	01_AWP024	Lower Lost Creek Designated Basin 3	36	1828.99	36	1,719	50	1,399	37	1,910	35	1,794
25	01_AWP025	Upper Lost Creek Designated Basin	6	518.74	27	1,495	12	1,113	22	2,066	21	2,066
26	01_AWP026	South Platte River Above Weldona, Co, South 1	7	631.217	19	2,321	19	2,189	18	2,409	12	1,434
27	01_AWP027	South Platte River Above Weldona, Co, South 2	12	1580.115	29	3,116	39	3,249	34	3,249	33	2,617
28	01_AWP028	South Platte River Above Weldona, Co, South 3	51	4460.286	102	4,767	120	4,676	76	5,027	50	3,633
29	01_AWP029	South Platte River Above Weldona, Co, South 4	40	2140.891	55	2,651	63	2,855	48	3,067	36	2,227

#	Aggregate ID	Aggregate Name	1956		1976		1987		2001		2005	
			# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage
30	01_AWP030	South Platte River Above Weldona, Co, South 5	43	2874.88	69	3,307	87	3,025	51	3,161	29	2,045
31	01_AWP031	South Platte River below Riverside Canal, South	20	1594.158	51	4,252	59	3,252	59	4,411	53	4,325
32	01_AWP032	WD 1, Lower Boxelder Creek	46	1566.234	59	2,087	91	2,478	71	2,561	67	2,492
33	01_AWP033	South Platte River Above Weldona, Co, North	30	1500.296	45	2,947	71	2,813	51	2,925	37	1,908
34	01_AWP034	Boxelder Creek below Horse Creek Reservoir West	0	0	0	0	0	0	0	0	1	8
35	01_AWP035	WD 1, Upper Boxelder Creek	37	1758.357	44	1,867	46	1,688	30	1,112	16	804
36	01_AWP036	South Platte River below Kersey, Co North 1	2	35.376	3	383	2	93	3	441	4	502
37	01_AWP037	South Platte River below Kersey, Co North 2	7	482.2	15	507	20	1,287	10	348	1	73
38	01_AWP038	Upper Crow Creek Designated Basin	23	1369.141	71	4,625	62	3,939	59	4,455	64	4,501
39	01_AWP039	Upper Kiowa Bijou Designated Basin, Kiowa Creek	13	268.235	53	1,366	50	1,570	33	1,244	45	1,423
40	01_AWP040	Upper Kiowa Bijou Designated Basin, East Bijou	12	221.193	35	889	26	870	19	948	15	617
41	01_AWP041	WD 1, Lower Boxelder Creek East	0	0	3	251	5	434	3	184	3	184
42	01_AWP042	Boxelder Creek below Horse Creek Reservoir East	64	3094.248	95	4,755	133	4,965	94	4,934	87	4,474
43	01_AWP043	WD 1, Running Creek	24	708.333	37	944	69	1,007	12	400	19	461
44	01_AWP044	WD 1, Lower Boxelder Creek West	2	49.723	3	54	3	45	4	103	4	90

#	Aggregate ID	Aggregate Name	1956		1976		1987		2001		2005	
			# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage
45	02_AWP001	WD 2, Beebe Draw 1	37	1892.538	63	3,718	75	3,784	66	3,805	52	3,573
46	02_AWP002	WD 2, Beebe Draw 2	33	3274.413	64	4,720	85	5,113	61	5,099	54	4,681
47	02_AWP003	South Platte River below Ft Lupton West	38	1218.587	42	1,321	60	1,309	56	1,361	37	1,157
48	02_AWP004	Sand Creek Basin and Burlington System	95	3593.238	134	4,506	163	4,930	119	3,871	98	3,768
49	02_AWP005	South Platte River below Clr Crk Confluence West	13	355.801	13	355	27	677	18	366	18	335
50	03_AWP001	Cache la Poudre River Above Greeley, Co	97	2354.139	91	3,384	124	3,296	87	2,971	74	2,523
51	03_AWP002	Cache la Poudre River Above Fort Collins, Co	117	3275.318	123	3,279	155	3,751	116	3,403	95	3,056
52	03_BUDUSE	Budweiser Fields. Get multi use water from plant	0	0	0	0	23	827	36	1,510	39	1,783
53	04_AWP002	Little Thompson above Berthoud, Co	2	51.274	2	51	7	222	2	73	4	63
54	04_AWP004	Big Thompson River above Loveland, Co	0	0	0	0	4	49	1	21	2	35
55	04_AWP005	Little Thompson above Big Thompson Confluence	5	110.823	6	133	6	133	5	111	6	132
56	05_AWP001	Saint Vrain Creek below Longmont, Co South	1	7.987	0	0	9	190	0	0	1	39
57	05_AWP002	Left Hand Creek above Saint Vrain Confluence	0	0	0	0	3	60	0	0	0	0
58	05_AWP004	Saint Vrain Creek below Lyons, Co North	2	150.069	2	92	4	167	1	135	1	135
59	06_AWP001	Boulder Creek above Eldorado Springs, Co	5	213.35	5	213	7	340	2	143	0	0
60	06_AWP003	Boulder Creek below Eldorado Springs, Co	0	0	0	0	1	30	0	0	0	0

#	Aggregate ID	Aggregate Name	1956		1976		1987		2001		2005	
			# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage
61	07_AWP001	Clear Creek below Golden, Co	7	146.04	7	146	8	147	7	146	0	0
62	08_AWP001	South Platte River below Chatfield Reservoir	6	104.648	4	54	4	54	4	54	3	31
63	08_AWP002	Cherry Creek above Franktown, Co	69	1546.736	67	1,685	94	1,539	29	448	19	315
64	08_AWP003	South Platte River above Chatfield Reservior	2	11.278	2	11	2	11	2	11	2	13
65	08_AWP004	Plum Creek above South Platte Confluence	5	73.656	5	74	39	678	4	71	3	55
66	08_AWP005	Cherry Creek above Chatfield Reservoir	89	3265.157	93	3,356	104	2,391	31	755	19	427
67	64_AWP001	Water District 64, Sedgwick County North	3	45.079	5	148	4	156	4	154	3	135
68	64_AWP002	Water District 64, Sedgwick County South	2	78.147	11	458	14	243	6	142	6	130
69	64_AWP003	Water District 64, Sedgwick County South East	0	0	24	1,342	15	1,441	20	1,621	21	1,611
70	64_AWP004	Water District 64, Sedgwick County GW 1	50	1621.953	70	2,865	80	2,679	65	2,969	69	2,876
71	64_AWP005	Water District 64, Sedgwick County GW 2	39	1353.52	63	2,312	69	2,245	52	2,574	64	2,623
72	64_AWP006	Water District 64, Lower Logan County North	5	188.098	8	318	35	1,073	26	776	19	701
73	64_AWP007	Water District 64, Lower Logan County South 1	17	570.334	28	1,958	35	1,933	19	1,922	22	1,923
74	64_AWP008	Water District 64, Lower Logan County South 2	0	0	40	4,881	40	4,944	33	4,799	36	5,019
75	64_AWP009	Water District 64, Lower Logan County South 3	6	951.829	29	3,940	39	3,891	35	3,891	35	3,878

#	Aggregate ID	Aggregate Name	1956		1976		1987		2001		2005	
			# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage	# of Parcels	Total Acreage
76	64_AWP010	WD 64, Logan County North Blw Tetsel North	2	123.323	7	344	8	846	6	846	6	846
77	64_AWP011	Water District 64, Logan County North Central	14	950.548	30	1,763	36	1,464	29	1,317	30	1,484
78	64_AWP012	WD 64, Logan County S of Pawnee Canal	39	2354.835	47	2,738	80	2,815	53	2,841	61	2,739
79	64_AWP013	WD 64, Logan County N of Pawnee Canal	48	2452.779	75	4,525	109	4,514	70	4,234	76	4,369
80	64_AWP014	WD 64, Logan County North Blw Sterling No 1	74	3842.665	87	5,008	152	5,586	77	4,699	86	4,599
81	64_AWP015	Water District 64, Logan County South	2	109.352	18	1,198	30	1,138	11	660	0	0
82	64_AWP016	Water District 64, Weld County	2	26.94	15	928	11	738	11	1,268	0	0
83	64_AWP017	WD 64, Logan County North Below Tetsel	14	479.97	17	678	23	865	13	889	13	662
Total			**2,322**	**111,674**	**3,594**	**176,598**	**4,557**	**180,209**	**2,931**	**167,247**	**2,819**	**156,188**

Figure 1
Total Aggregate Acreage by GIS Coverage

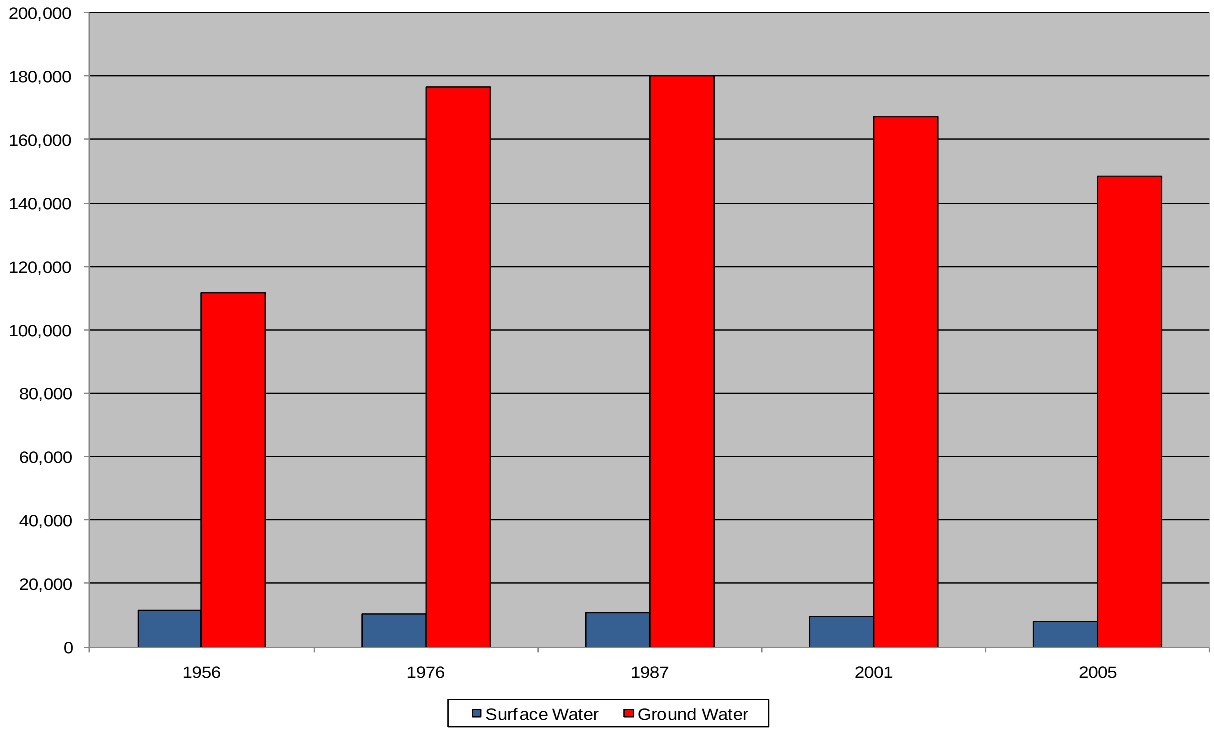


Table 3
2001 Surface Water Structure Summary

Water District	2001 Surface Diversion Structure Acreage			
	Aggregate Total	Key Total	Water District Total	Aggregate % of Total
1	766	146,270	147,036	1%
2	494	151,858	152,352	0%
3	2,943	188,968	191,911	2%
4	0	68,382	68,382	0%
5	646	53,547	54,193	1%
6	0	40,311	40,311	0%
7	196	5,870	6,066	3%
8	732	1,673	2,404	30%
9	23	2,008	2,031	1%
23	3,559	4,046	7,604	47%
48&76	0	3,738	3,738	0%
64	0	66,315	66,315	0%
80	69	858	927	7%
Total	**9,427**	**733,844**	**743,271**	**1%**

Figure 2 – SPDSS Surface Water Aggregate Boundaries

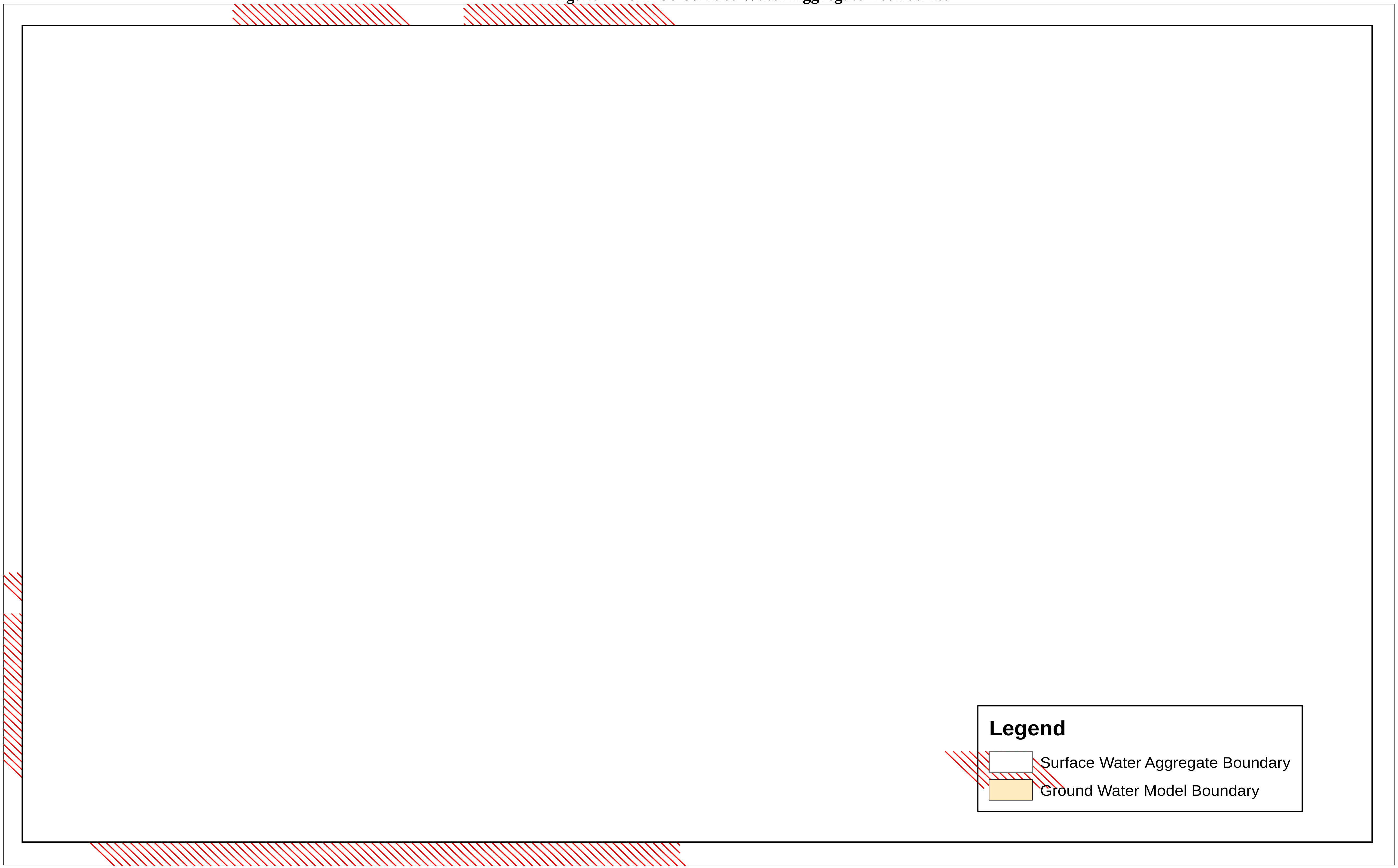


Figure 3 – SPDSS Ground Water Aggregate Boundaries

Exhibit A
Surface Water Structures in Aggregates

#	Aggregate ID	Aggregate Name	WDID	Total Acreage				
				1956	1976	1987	2001	2005
1	01_ADP037	South Platte River below Kersey, Co North 2	0100643	385.47	513.75	596.92	562.99	562.99
2	01_ADP037	South Platte River below Kersey, Co North 2	0100644	28.37	28.31	28.31	28.31	33.34
3	01_ADP037	South Platte River below Kersey, Co North 2	0100835	24.79	32.13	32.13	32.13	28.94
4	01_ADP037	South Platte River below Kersey, Co North 2	0104486	68.22	93.00	142.60	142.60	142.40
5	02_ADP003	South Platte River below Ft Lupton West	0200885	301.58	282.35	318.08	307.65	258.16
6	02_ADP003	South Platte River below Ft Lupton West	0200887	95.35	95.17	95.18	95.18	95.18
7	02_ADP003	South Platte River below Ft Lupton West	0200888	28.09	91.41	103.73	91.42	87.70
8	03_ADP002	Cache la Poudre River Above Greeley, Co	0301067	90.90	90.73	90.73	90.73	90.73
9	03_ADP002	Cache la Poudre River Above Greeley, Co	0301076	42.17	42.09	0.00	11.88	11.88
10	03_ADP002	Cache la Poudre River Above Greeley, Co	0301106	5.92	5.91	5.91	5.91	5.91
11	03_ADP002	Cache la Poudre River Above Greeley, Co	0301108	82.13	81.98	81.98	81.98	81.98
12	03_ADP002	Cache la Poudre River Above Greeley, Co	0301109	36.11	62.65	47.63	62.65	62.65
13	03_ADP002	Cache la Poudre River Above Greeley, Co	0301111	21.36	21.32	18.85	21.33	19.51
14	03_ADP002	Cache la Poudre River Above Greeley, Co	0301115	7.35	7.34	26.89	7.34	11.11
15	03_ADP002	Cache la Poudre River Above Greeley, Co	0301191	15.75	15.72	15.72	15.72	15.72
16	03_ADP002	Cache la Poudre River Above Greeley, Co	0301260	34.47	34.40	34.41	34.41	34.41
17	03_ADP002	Cache la Poudre River Above Greeley, Co	0303731	152.22	207.60	181.10	193.34	193.34
18	03_ADP003	N Fork Cache la Poudre River above Confluence	0300766	781.34	779.87	263.19	326.79	265.06
19	03_ADP003	N Fork Cache la Poudre River above Confluence	0300797	271.91	271.40	185.97	122.37	185.97
20	03_ADP003	N Fork Cache la Poudre River above Confluence	0300814	6.18	8.45	8.45	8.45	8.45
21	03_ADP003	N Fork Cache la Poudre River above Confluence	0300991	169.00	168.68	159.94	163.12	163.12
22	03_ADP003	N Fork Cache la Poudre River above Confluence	0300997	14.11	14.09	14.09	14.09	14.09
23	03_ADP003	N Fork Cache la Poudre River above Confluence	0301017	14.11	14.09	14.09	14.09	14.09
24	03_ADP003	N Fork Cache la Poudre River above Confluence	0301021	23.40	23.36	13.45	23.36	23.36
25	03_ADP003	N Fork Cache la Poudre River above Confluence	0301022	0.00	0.00	79.26	104.81	104.81
26	03_ADP003	N Fork Cache la Poudre River above Confluence	0301023	178.48	178.15	71.45	71.45	71.45

#	Aggregate ID	Aggregate Name	WDID	Total Acreage				
				1956	1976	1987	2001	2005
27	03_ADP003	N Fork Cache la Poudre River above Confluence	0301030	95.38	95.20	95.21	95.20	95.20
28	03_ADP003	N Fork Cache la Poudre River above Confluence	0301038	74.93	74.79	92.73	74.79	74.79
29	03_ADP003	N Fork Cache la Poudre River above Confluence	0301039	19.38	19.34	0.00	19.34	36.76
30	03_ADP003	N Fork Cache la Poudre River above Confluence	0301040	123.84	123.61	123.61	123.61	123.61
31	03_ADP003	N Fork Cache la Poudre River above Confluence	0301041	879.12	877.46	880.49	732.24	1,099.33
32	03_ADP003	N Fork Cache la Poudre River above Confluence	0301050	50.66	50.57	37.75	75.50	37.75
33	03_ADP003	N Fork Cache la Poudre River above Confluence	0301051	122.22	121.99	46.35	34.98	34.98
34	03_ADP003	N Fork Cache la Poudre River above Confluence	0301056	38.13	38.06	22.57	38.07	38.06
35	03_ADP003	N Fork Cache la Poudre River above Confluence	0301059	54.83	54.73	54.73	54.73	54.73
36	03_ADP003	N Fork Cache la Poudre River above Confluence	0301204	0.00	0.00	57.13	83.48	83.48
37	03_ADP003	N Fork Cache la Poudre River above Confluence	0301206	29.00	28.95	28.95	28.95	28.95
38	03_ADP003	N Fork Cache la Poudre River above Confluence	0301229	801.85	486.68	335.10	208.46	206.14
39	05_ADP002	Left Hand Creek above Saint Vrain Confluence	0500555	0.00	0.00	0.00	19.21	19.21
40	05_ADP002	Left Hand Creek above Saint Vrain Confluence	0500556	4.90	4.89	4.89	17.27	17.27
41	05_ADP002	Left Hand Creek above Saint Vrain Confluence	0500583	274.05	249.65	246.55	228.19	112.32
42	05_ADP002	Left Hand Creek above Saint Vrain Confluence	0500584	168.70	114.95	114.95	114.95	114.95
43	05_ADP002	Left Hand Creek above Saint Vrain Confluence	0500587	42.87	42.80	39.84	39.84	25.98
44	05_ADP002	Left Hand Creek above Saint Vrain Confluence	0500588	109.91	109.71	116.52	116.52	122.09
45	05_ADP002	Left Hand Creek above Saint Vrain Confluence	0500829	106.65	34.53	17.06	17.06	17.06
46	05_ADP002	Left Hand Creek above Saint Vrain Confluence	0500831	86.49	86.33	76.65	49.84	57.66
47	05_ADP002	Left Hand Creek above Saint Vrain Confluence	0600732	15.37	15.35	21.55	43.10	43.10
48	07_ADP001	Clear Creek below Golden, Co	0700526	817.91	64.54	136.37	64.54	13.58
49	07_ADP001	Clear Creek below Golden, Co	0700711	36.38	36.31	72.62	72.62	72.62
50	07_ADP001	Clear Creek below Golden, Co	0700720	58.81	58.70	58.70	58.70	35.46
51	08_ADP002	Cherry Creek above Franktown, Co	0801360	18.75	18.75	18.75	18.75	18.75
52	08_ADP002	Cherry Creek above Franktown, Co	0801418	16.83	16.83	16.83	16.83	16.83
53	08_ADP002	Cherry Creek above Franktown, Co	0801421	0.00	0.00	0.00	0.00	8.83
54	08_ADP002	Cherry Creek above Franktown, Co	0801426	0.00	0.00	59.01	8.86	8.86
55	08_ADP002	Cherry Creek above Franktown, Co	0801427	0.00	0.00	0.00	0.00	16.18

#	Aggregate ID	Aggregate Name	WDID	Total Acreage				
				1956	1976	1987	2001	2005
56	08_ADP003	South Platte River above Chatfield Reservior	0800909	145.86	145.59	291.18	126.73	108.78
57	08_ADP003	South Platte River above Chatfield Reservior	0800910	79.62	96.57	122.41	79.06	79.06
58	08_ADP003	South Platte River above Chatfield Reservior	0801483	19.22	19.19	19.19	0.00	0.00
59	08_ADP004	Plum Creek above South Platte Confluence	0801215	5.26	10.50	28.55	0.00	0.00
60	08_ADP004	Plum Creek above South Platte Confluence	0801216	8.96	8.94	113.62	19.75	8.26
61	08_ADP004	Plum Creek above South Platte Confluence	0801217	0.00	0.00	35.97	0.00	0.00
62	08_ADP004	Plum Creek above South Platte Confluence	0801230	0.00	0.00	37.38	0.00	0.00
63	08_ADP004	Plum Creek above South Platte Confluence	0801250	44.36	44.28	72.01	0.00	0.00
64	08_ADP004	Plum Creek above South Platte Confluence	0801252	0.00	0.00	0.00	38.96	0.00
65	08_ADP004	Plum Creek above South Platte Confluence	0801254	139.86	139.59	131.03	101.29	89.25
66	08_ADP004	Plum Creek above South Platte Confluence	0801264	58.10	58.00	57.95	56.44	56.44
67	08_ADP004	Plum Creek above South Platte Confluence	0801266	65.79	65.67	70.42	47.13	47.13
68	08_ADP004	Plum Creek above South Platte Confluence	0801267	111.86	111.65	160.66	116.41	116.41
69	08_ADP004	Plum Creek above South Platte Confluence	0801278	70.46	70.33	72.97	93.42	138.06
70	08_ADP004	Plum Creek above South Platte Confluence	0801279	0.00	0.00	7.97	7.97	7.97
71	09_ADP003	Bear Creek above Morrison, Co	0900739	21.87	21.82	21.83	14.30	14.30
72	09_ADP003	Bear Creek above Morrison, Co	0900740	4.66	4.65	4.65	4.65	4.65
73	09_ADP003	Bear Creek above Morrison, Co	0900741	3.74	3.73	3.73	3.73	3.73
74	23_ADP001	SF South Platte River above Tarryall Confluence	2300502	0.00	0.00	0.00	0.00	3.60
75	23_ADP001	SF South Platte River above Tarryall Confluence	2300503	11.06	11.04	11.04	11.04	11.04
76	23_ADP001	SF South Platte River above Tarryall Confluence	2300504	20.53	20.49	20.49	20.49	20.49
77	23_ADP001	SF South Platte River above Tarryall Confluence	2300505	13.28	13.26	13.26	13.26	13.26
78	23_ADP001	SF South Platte River above Tarryall Confluence	2300506	3.81	3.80	3.80	3.80	3.80
79	23_ADP001	SF South Platte River above Tarryall Confluence	2300516	43.19	43.11	24.78	24.78	19.74
80	23_ADP001	SF South Platte River above Tarryall Confluence	2300564	95.58	95.40	95.40	95.40	95.40
81	23_ADP001	SF South Platte River above Tarryall Confluence	2300568	42.31	42.23	42.23	42.23	42.23
82	23_ADP001	SF South Platte River above Tarryall Confluence	2300569	42.31	42.23	42.23	42.23	42.23
83	23_ADP001	SF South Platte River above Tarryall Confluence	2300573	42.31	42.23	42.23	42.23	42.23
84	23_ADP001	SF South Platte River above Tarryall Confluence	2300579	42.31	42.23	42.23	42.23	42.23

#	Aggregate ID	Aggregate Name	WDID	Total Acreage				
				1956	1976	1987	2001	2005
85	23_ADP001	SF South Platte River above Tarryall Confluence	2300583	6.48	6.47	6.47	6.47	0.00
86	23_ADP001	SF South Platte River above Tarryall Confluence	2300585	31.89	31.83	0.00	6.46	0.00
87	23_ADP001	SF South Platte River above Tarryall Confluence	2300586	169.82	169.51	169.51	169.51	0.00
88	23_ADP001	SF South Platte River above Tarryall Confluence	2300587	104.85	104.65	104.65	104.65	92.39
89	23_ADP001	SF South Platte River above Tarryall Confluence	2300631	155.13	154.84	154.84	154.84	134.07
90	23_ADP001	SF South Platte River above Tarryall Confluence	2300763	4.22	4.21	4.21	4.21	4.21
91	23_ADP001	SF South Platte River above Tarryall Confluence	2300774	52.83	52.73	42.46	109.89	94.00
92	23_ADP001	SF South Platte River above Tarryall Confluence	2300787	15.48	15.45	15.45	15.45	15.45
93	23_ADP001	SF South Platte River above Tarryall Confluence	2300788	25.86	25.81	25.81	25.81	25.81
94	23_ADP001	SF South Platte River above Tarryall Confluence	2300789	10.38	10.36	10.36	10.36	10.36
95	23_ADP001	SF South Platte River above Tarryall Confluence	2300797	59.85	59.74	59.74	59.74	59.74
96	23_ADP001	SF South Platte River above Tarryall Confluence	2300866	70.51	70.38	38.93	0.00	4.14
97	23_ADP001	SF South Platte River above Tarryall Confluence	2300867	35.29	35.23	29.87	35.23	37.83
98	23_ADP001	SF South Platte River above Tarryall Confluence	2300868	17.59	17.56	17.56	17.56	24.18
99	23_ADP001	SF South Platte River above Tarryall Confluence	2300869	17.59	17.56	17.56	17.56	24.18
100	23_ADP001	SF South Platte River above Tarryall Confluence	2301138	18.16	18.13	18.13	10.45	0.00
101	23_ADP001	SF South Platte River above Tarryall Confluence	2301140	29.63	29.57	29.57	22.26	20.59
102	23_ADP002	Tarryall Creek above SF South Platte Confluence	2300908	25.07	25.02	33.66	33.66	0.00
103	23_ADP002	Tarryall Creek above SF South Platte Confluence	2300931	50.99	50.90	50.90	50.90	51.33
104	23_ADP002	Tarryall Creek above SF South Platte Confluence	2300932	13.07	13.05	13.05	13.05	13.05
105	23_ADP002	Tarryall Creek above SF South Platte Confluence	2300933	14.21	14.19	14.19	14.19	14.19
106	23_ADP002	Tarryall Creek above SF South Platte Confluence	2300936	12.11	12.09	12.09	12.09	0.00
107	23_ADP002	Tarryall Creek above SF South Platte Confluence	2300937	41.09	41.01	41.01	41.01	35.44
108	23_ADP002	Tarryall Creek above SF South Platte Confluence	2300940	7.34	7.32	7.32	7.32	0.00
109	23_ADP002	Tarryall Creek above SF South Platte Confluence	2300948	19.72	19.68	15.20	19.68	19.68
110	23_ADP002	Tarryall Creek above SF South Platte Confluence	2300968	34.03	33.97	50.40	50.40	50.40
111	23_ADP002	Tarryall Creek above SF South Platte Confluence	2300975	50.14	50.05	50.05	50.05	50.05
112	23_ADP002	Tarryall Creek above SF South Platte Confluence	2300987	1,126.02	1,123.91	1,123.93	1,082.15	0.00
113	23_ADP002	Tarryall Creek above SF South Platte Confluence	2301002	46.16	46.08	92.15	92.15	0.00

#	Aggregate ID	Aggregate Name	WDID	Total Acreage				
				1956	1976	1987	2001	2005
114	23_ADP002	Tarryall Creek above SF South Platte Confluence	2301005	344.82	242.22	489.51	240.57	284.12
115	23_ADP002	Tarryall Creek above SF South Platte Confluence	2301018	62.94	62.82	62.82	62.82	62.82
116	23_ADP002	Tarryall Creek above SF South Platte Confluence	2301022	92.21	65.81	153.71	153.71	125.75
117	23_ADP002	Tarryall Creek above SF South Platte Confluence	2301025	147.75	99.48	218.47	128.68	104.41
118	23_ADP002	Tarryall Creek above SF South Platte Confluence	2301075	49.76	49.67	49.67	49.67	43.68
119	23_ADP002	Tarryall Creek above SF South Platte Confluence	2301083	10.70	10.68	7.54	10.68	10.68
120	23_ADP002	Tarryall Creek above SF South Platte Confluence	2302910	281.59	562.12	448.50	337.73	217.18
121	80_ADP001	Water District 80, NF South Platte River	8000668	0.00	0.00	0.00	1.81	0.00
122	80_ADP001	Water District 80, NF South Platte River	8000708	10.72	0.00	0.00	0.00	0.00
123	80_ADP001	Water District 80, NF South Platte River	8000709	4.78	4.78	4.78	4.78	4.78
124	80_ADP001	Water District 80, NF South Platte River	8000710	13.55	13.55	13.55	13.55	13.55
125	80_ADP001	Water District 80, NF South Platte River	8000763	0.00	0.00	0.00	4.56	4.56
126	80_ADP001	Water District 80, NF South Platte River	8000764	0.00	0.00	0.00	4.56	4.56
127	80_ADP001	Water District 80, NF South Platte River	8000867	0.00	0.00	0.00	5.90	4.36
128	80_ADP001	Water District 80, NF South Platte River	8000895	13.67	13.65	13.65	7.43	19.08
129	80_ADP001	Water District 80, NF South Platte River	8000896	9.64	9.63	9.63	6.28	5.42
130	80_ADP001	Water District 80, NF South Platte River	8000897	1.52	1.52	1.52	2.42	3.52
131	80_ADP001	Water District 80, NF South Platte River	8000921	9.81	9.79	9.79	8.26	8.26
132	80_ADP001	Water District 80, NF South Platte River	8001014	25.61	25.56	25.84	8.95	25.48
Total			132	11,406.61	10,577.68	10,752.17	9,426.70	7,954.44

Appendix C
Task 57 – Assign Soil Moisture Water Holding Capacities to Structures

To: Ray Alvarado and Ray Bennett

From: LRE, Erin Wilson and Mark Mitisek

Subject: Task 57- Assign Soil Moisture Water Holding Capacities to Structures

Date: May 29, 2007, revised March 2008 (to represent finalized structure list)

Introduction

This memo describes the approach and results of Phase 3 Task 57, Assign Soil Moisture Water Holding Capacities to Agricultural Structures. The objective of this task was as follows:

> *Determine the soil moisture holding capacity for agricultural structures (key, diversion systems, and aggregate structures).*

Irrigation structures were determined as Key, Aggregate (non-key), or part of a Diversion System. Key surface water structures and diversion systems were determined and documented in Task 3 Summary – Key Diversion Structures, March 2008. Aggregate surface water structures and ground water only structures were identified in Task 3 - Aggregate Non-Key Agricultural Diversion Structures, March 2008. The spatial assignment of soil moisture capacity to agricultural structures was completed using the CDSS Toolbox and GIS coverages developed in previous tasks.

The SPDSS Historical Crop Consumptive Use Analysis uses soil moisture capacity information, along with crop root depth and crop acreage, to represent the volume of soil reservoir available to "store" excess diversions. Available water holding capacity for each irrigation structure is an input to the StateCU model, included in the StateCU structure file.

Approach

The following approach was used to assign soil moisture capacity or Available Water Capacity (AWC) values to each key structure, diversion system, and aggregate structure modeled in the historic consumptive use analysis.

7. The ArcMap CDSS Tools toolbox was used to spatially assign AWC to irrigated land using the "Soil Parameter by SW Structure" and "Soil Parameter by User-Specified Polygon ID" tools under the Soil Assignments Menu (see CDSS GIS Tools User Documentation, March 2008).
8. Soil characteristics and area determine the soil moisture information for each structure. The Statewide Soils coverage derived from the NRCS STATSGO database provide available water capacity (AWC) information for the South Platte and North Platte River basins based

on a 60 inch rooting depth. The 2001 Irrigated Land coverages for the South Platte provide the irrigated area for each structure. The “Soil Parameter by SW Structure” tool was used to assign an area weighted AWC for each key structure and diversion system. A relatively few key structures irrigated early in the study period, but not in 2001. Those structures were assigned average AWC based on the Aggregate structure approach listed below.

9. Diversion System structures were assigned a weighted AWC based on their primary Key structure association.
10. Aggregate structures were assigned an average area-weighted AWC based for the polygons that define the aggregate areas as developed in Subtask 3.3. The CDSS toolbox “Soil Parameter by User-Specified Polygon ID” tool was used.
11. The CDSS Toolbox Soil Assignment tools provided out put files in a comma separated format that will be used directly by StateDMI in creating StateCU and StateMod input files.

Results

Table 1 summarizes the AWC values estimated for the South Platte River Basin. As presented, AWC estimates range from 0.02 to 0.18. AWC values for individual structures are assigned in the StateCU structure (*.str) input file.

Table 1
AWC Summary for the South Platte

Irrigation Structure Type	# of Structures	Minimum AWC	Maximum AWC	Average AWC
Key and Diversion System	342	0.02	0.18	0.12
Aggregate Systems	96	0.06	0.17	0.13
Municipal or Carrier	62	N/A	N/A	N/A
Total Structures	500	0.02	0.18	0.12

Comments and Concerns

Following are comments and concerns related to the assignment of AWC values to irrigation structures:

- Only irrigation structures are assigned AWC values – it is not necessary to provide values for municipal, industrial, and carrier structures. Therefore, they are not represented in the structure count in Table 1.
- The few key structures irrigating early in the study period, but not in 2001, were assigned average AWC based on the Aggregate structure approach described above.
- The Statewide Soils coverage used NRCS STATSGO data to estimate AWC values based on a 60 inch rooting depth. Although 60 inches is relatively deep when compared to the rooting depth of many crops grown in the SPDSS study area, this readily available GIS coverage is considered appropriate for a basin-wide analysis.

Appendix D
South Platte Historic Crop Consumptive Use – Collect and Fill Missing Monthly Climate Data

To: Ray Alvarado and Ray Bennett

From: LRE – Erin Wilson, Beorn Courtney, and Kara Sobieski

Subject: Task 53.2 – Collect and Fill Missing Monthly Climate Data

Date: February 7, 2005

Introduction

Monthly temperature and precipitation data will be used to estimate historic crop consumptive use throughout the South Platte, North Platte, and Laramie River basins (SPDSS study area). Precipitation data will be used as an inflow component of water budget modeling efforts and to estimate recharge to ground water aquifers for ground water modeling efforts. In addition, climate data may be used, in conjunction with other information, to estimate native vegetation ET required for ground water modeling efforts.

This memorandum presents the general approach and results for the following Task 53 subtasks:

1. *Identify key long-term NOAA climate stations that adequately represent variations in climate seen throughout the SPDSS study area.*
2. *Investigate and determine appropriate methods for filling missing monthly data.*
3. *Fill missing monthly climate data to support the estimation of historic crop consumptive use using the Blaney-Criddle methodology.*

Daily data were also collected under Task 53 from entities other than NOAA. A summary of the collected data, including percent complete and descriptions of the methods required to extract data from each resource, is presented in the "Task 53.1 – Daily Climate Data Collection for HydroBase" memo. Climate stations from these other sources will not be considered "key" in this memorandum nor will daily climate data be filled for this task.

Approach and Results

1. Identify Key Long Term NOAA Climate Stations

A "key climate station" will be defined as follows:

Key Climate Station – Climate Station located within the SPDSS study area with records available from HydroBase and:

- At least 70 percent complete in either monthly average temperature or total precipitation throughout the SPDSS study period (1950-2003), or

- At a location that adequately represents irrigated acreage and variations in climate throughout the SPDSS study area.

Key climate stations were selected based on long-term periods of record and location within the basin using the following approach:

1. Monthly total precipitation and average temperature data for NOAA climate stations stored in HydroBase were extracted using the **TSTool** Data Management Interface (DMI). There are approximately 126 NOAA stations within the SPDSS study area.
2. The percent complete for the 1950 through 2003 SPDSS study period was determined for each climate station using the **TSTool** "Data Limits Summary" report.
3. The draft SPDSS irrigated acreage GIS coverage and CDSS Climate Station GIS coverages were reviewed to verify that the subset of climate stations provided adequate spatial coverage to represent agricultural areas for the crop consumptive use analysis. In addition, a basin-wide spatial review was conducted to verify overall basin coverage for water budget and ground water modeling efforts. There were several sets of climate stations meeting key criteria from Steps 1 and 2 above that were in close proximity. The number of key climate stations was reduced in those areas where adequate spatial coverage could be maintained.

The 27 key climate station names and associated data are summarized below in **Table 1** (sorted alphabetically). The locations of the key temperature and precipitation climate stations are shown in **Figures 1** and **2**, respectively. As depicted in the figure legend, the stations are color coded to indicate the percent missing data for each station from 1950 through 2003. The figure also labels each key climate station with its name, ID and percent missing.

Table 1
Key Climate Station Information

No.	Station ID	Station Name	WD	Period of Record	Elevation (feet)	Percent Complete (1950 – 2003)		Frost Data Percent Complete (1950 – 2003)			
						Temperature	Precipitation	Spring 28˚ F	Spring 32˚ F	Fall 32˚ F	Fall 32˚ F
1	109	Akron 4 E (combined)	65 [1]	1918 - 2003	4540	98.9%	99.1%	98.1%	100.0%	94.4%	94.4%
2	185	Allenspark 1 NW (combined)	5	1948 - 2003	8500	63.6%	86.6%	53.7%	64.8%	59.3%	55.6%
3	263	Antero Reservoir	23	1961 - 2003	8920	75.8%	77.0%	77.8%	79.6%	75.9%	75.9%
4	454	Bailey	80	1948 - 2003	7730	86.1%	97.4%	77.8%	88.9%	88.9%	88.9%
5	848	Boulder	6	1948 - 2003	5484	94.0%	95.4%	88.9%	88.9%	92.6%	90.7%
6	945	Briggsdale	1	1963 - 2003	4834	54.3%	67.0%	53.7%	53.7%	53.7%	51.9%
7	1179	Byers 5 ENE	1	1948 - 2003	5100	90.9%	97.8%	79.6%	79.6%	83.3%	83.3%
8	1401	Castle Rock	8	1948 - 2003	6352	61.6%	69.6%	61.1%	61.1%	55.6%	55.6%
9	1528	Cheesman	80	1948 - 2003	6880	97.5%	97.5%	96.3%	96.3%	100.0%	98.1%
10	2220	Denver WSFO AP (Stapleton)	2	1948 - 2003	5286	98.9%	99.4%	98.1%	98.1%	92.6%	92.6%
11	2494	Eastonville 2 NNW [2]	1	1956 - 2003	7210	-	87.2%	-	-	-	-
12	2761	Estes Park 1 SSE (combined)	4	1948 - 2003	7785	82.7%	86.9%	72.2%	74.1%	70.4%	68.5%
13	2790	Evergreen (combined) [3]	9	1948 - 2003	7000	70.1%	75.2%	68.5%	74.1%	70.4%	68.5%
14	3005	Fort Collins	3	1900 - 2003	5004	99.1%	99.2%	96.3%	98.1%	100.0%	100.0%
15	3038	Fort Morgan	1	1948 - 2002	4332	93.7%	92.9%	92.6%	92.6%	94.4%	90.7%
16	3261	Georgetown	7	1948 - 2003	8520	45.7%	68.8%	46.3%	50.0%	38.9%	35.2%
17	3553	Greeley UNC (combined)	3	1948 - 2003	4715	91.4%	97.4%	94.4%	96.3%	87.0%	85.2%
18	4413	Julesburg	64	1918 - 2003	3469	75.2%	86.3%	61.1%	66.7%	63.0%	59.3%
19	4762	Lakewood (combined)	8	1948 - 2003	5640	82.1%	93.8%	68.5%	72.2%	64.8%	61.1%
20	5116	Longmont 2 ESE	5	1948 - 2003	4950	94.3%	96.5%	90.7%	92.6%	87.0%	85.2%
21	5922	New Raymer	64	1948 - 2003	4783	65.1%	71.3%	59.3%	59.3%	68.5%	68.5%
22	5934	New Raymer 21 N (combined)	64	1948 - 2003	5180	94.8%	97.1%	90.7%	92.6%	88.9%	88.9%
23	6323	Parker 2 N (combined)	8	1948 - 2003	5904	92.9%	94.8%	90.7%	94.4%	92.6%	92.6%
24	6921	Red Feather Lakes (combined)	3	1948 - 1997	8300	63.9%	78.9%	64.8%	68.5%	59.3%	57.4%
25	7515	Sedgwick 5 S (combined)	64	1948 - 2003	3990	96.5%	99.1%	90.1%	90.1%	88.9%	88.9%
26	7950	Sterling	64	1948 - 2003	3938	92.7%	95.5%	88.9%	88.9%	83.3%	83.3%
27	8756	Walden	47	1948 - 2003	8120	94.1%	97.4%	90.7%	92.6%	94.4%	92.6%

Notes:
[1] Akron 4 E (combined) is located outside the SPDSS study area, but was selected as key due its close proximity.
[2] Eastonville 2 NNW qualifies as a key climate station with precipitation data only.
[3] Evergreen station records are only combined for precipitation.

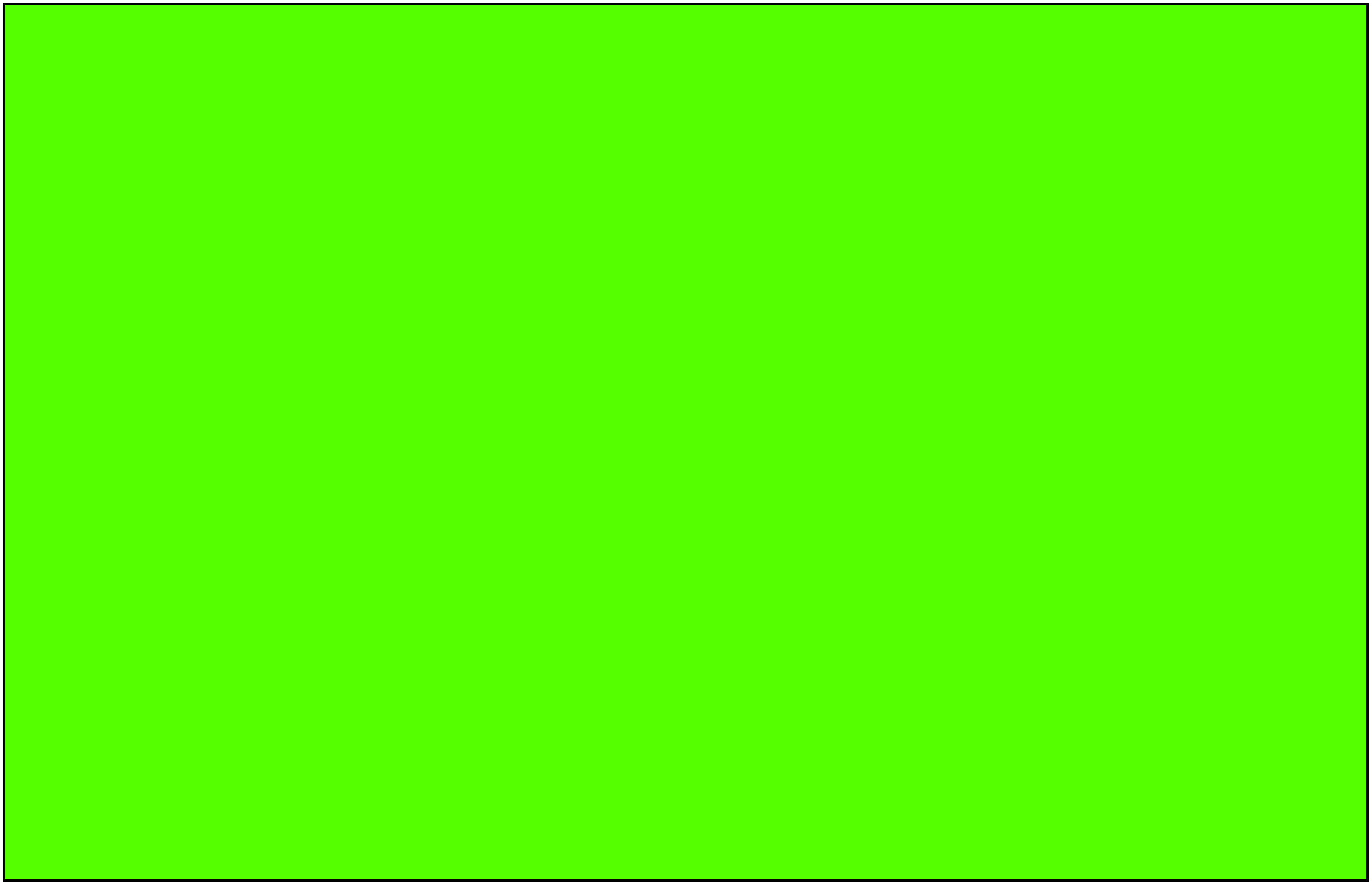


Figure 1 – Key Temperature Climate Station Locations

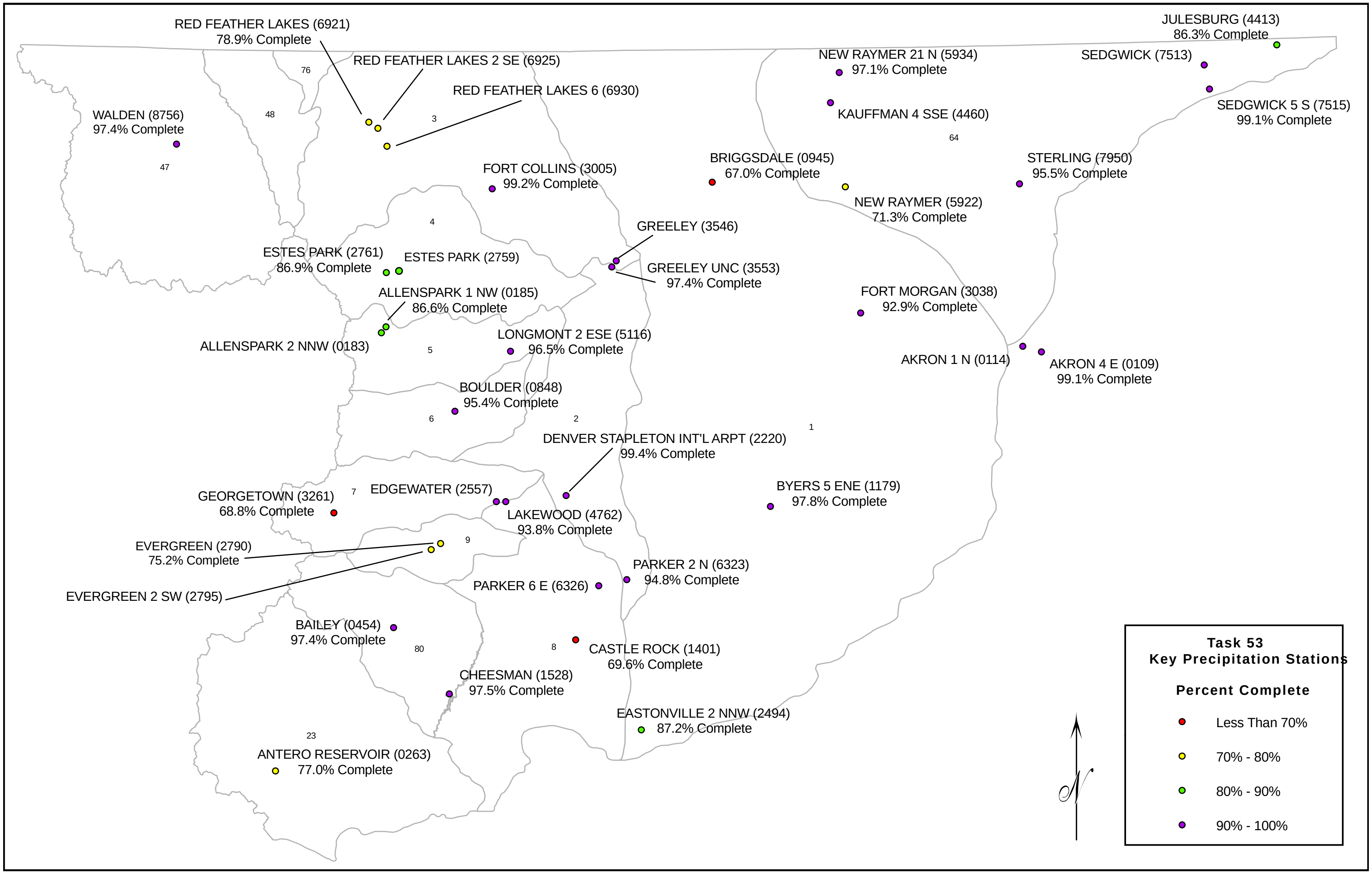


Figure 2 – Key Precipitation Climate Station Locations

1.1 Combine Climate Stations

There are ten sets of key climate stations listed in Table 1 for which the physical station location moved during the SPDSS study period and/or combining the data for the two stations was determined to be appropriate. The two station locations were compared in terms of distance and elevation differences. The combined stations, with the difference in elevation and distances, are listed below in **Table 2**.

Table 2
Combined Key Climate Stations

Independent Time Series (Old Station)		Dependent Time Series (New Station)		Distance [1]	Elevation Differences [2]
Station Name and ID	Period of Record	Station Name and ID	Period of Record		
Akron 1 N (114)	1937 - 1999	Akron 4 E (109)	1918 - 2003	3.7 miles	120 feet
Allenspark 2 NNW (183)	1948 - 1993	Allenspark 1 NW (185)	1994 - 2003	1.4 miles	180 feet
Estes Park (2759)	1948 – 2001	Estes Park 1 SSE (2761)	2001 - 2003	n/a [3]	305 feet
Evergreen 2 SW (2795) (No Temperature Data)	1948 - 1951	Evergreen (2790)	1961 - 2003	2.1 miles	310 feet
Greeley (3546)	1948 - 1967	Greeley UNC (3553)	1967 - 2003	1.4 miles	60 feet
Edgewater (2557)	1948 - 1962	Lakewood (4762)	1962 - 2003	1.8 miles	190 feet
Kauffman 4 SSE (4460)	1948 - 1987	New Raymer 21 N (5934)	1987 - 2003	9.1 miles	70 feet
Parker 6 E (6326)	1948 - 1997	Parker 2 N (6323)	1997 - 2003	5.4 miles	400 feet
Red Feather Lakes 2 SE (6925) Red Feather Lakes 6 (6930)	1948 - 1990 1959 - 1962	Red Feather Lakes (6921)	1991 - 1997	2.1 miles 3.9 miles	135 feet 560 feet
Sedgwick (7513)	1948 - 2003	Sedgwick 5 S (7515)	1958 - 2003	4.7 miles	400 feet

Notes: [1] Distances based on CDSS Climate Station GIS coverage
[2] Elevation differences based on data from HydroBase
[3] No GIS coverage of Estes Park 1 SSE

Data from the combined stations were graphed using cumulative mass diagrams to check for consistency and to verify that combining the stations was a valid approach (**Attachment A**). The fitted lines show no break in the slope of the cumulative precipitation, indicating that there are no major differences between data collected from the two locations. This confirms it is appropriate to combine these stations.

The combined data sets were created using the following **TSTool** commands:

1. **setOutputPeriod –** Extends the dependent time series (new station) to include the period of the independent time series (old station).
2. **fillFromTS –** Copies data from the independent time series to replace missing values in the dependent time series.

With this method, data from the dependent time series (new station) are used during any period where the two stations have overlapping data. **TSTool** assigns the name and ID of the dependent time series to the combined station. The combined stations are indicated as such in the **TSTool** input command files provided in **Attachment D-2**.

1. Investigate and Determine Appropriate Methods for Filling Missing Monthly Data

Daily climate data stored in HydroBase are obtained from NOAA. Consistent with NOAA's approach, monthly average temperature and total precipitation values in HydroBase are calculated from daily data. If there are nine days or less missing within a particular month, a monthly value is calculated based on the available daily data. If more than nine days of data are missing in a particular month, no monthly value is calculated (the monthly value is missing). Frost dates in HydroBase are calculated using NOAA's method of determining frost dates from minimum daily temperature data. NOAA utilizes the date of June 30th as the end of spring, and July 1st as the beginning of fall for frost date analysis. There may be climate stations located in the higher altitudes where a detailed investigation of local irrigation practices, growing seasons, and minimum daily temperature data show that a different date may be more appropriate in determining the last spring and first fall dates. However, it is our recommendation that the June 30th and July 1st dates be used for the basin-wide SPDSS analyses.

Missing monthly climate data were filled using techniques adopted in previous DSS modeling efforts, which generally involved filling missing data using regression with stations located in close proximity. Prior to filling, a cursory review of daily climate data was performed. During this review, we encountered some extreme values, e.g. 900.0˚ F and –60.0˚ F daily temperature values. These extreme values were removed from the analysis and considered as missing data.

2.1 Temperature and Precipitation

The following four regression techniques can be easily applied in **TSTool** for temperature and precipitation data:

- **Annual** regression (one equation) with **linear** data transformation
- **Annual** regression (one equation) with **logarithmic** data transformation
- **Monthly** regression (twelve equations) with **linear** data transformation
- **Monthly** regression (twelve equations) with **logarithmic** data transformation

Each regression technique was tested to determine which predicted data that best matched historical data (minimized the residual). As described when filling streamflow data in the SPDSS memo, "Task 2 – Identify Key Streamflow Gages and Estimate Streamflows for Missing Records", the correlation coefficient (R) was not used as the factor for deciding the best regression technique because the coefficients from twelve monthly equations cannot be compared directly to the coefficient resulting from one annual equation.

The monthly linear regression technique provided for the smallest residuals between predicted and historical data for both temperature and precipitation data. The R-values were generally high with respect to temperature data but significantly lower with precipitation data. An example of the accuracy of predicted data using monthly linear regression can be seen in **Figures 3** and **4**.

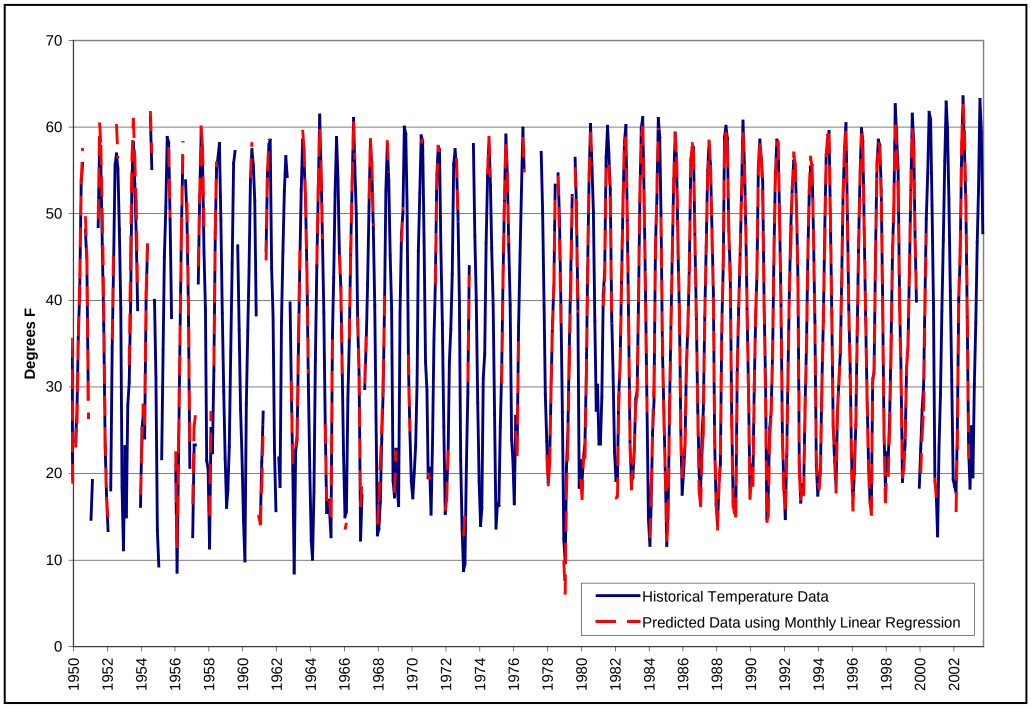


Figure 3 – Walden Temperature Historical Data versus Predicted Data from Monthly Linear Regression with Spicer

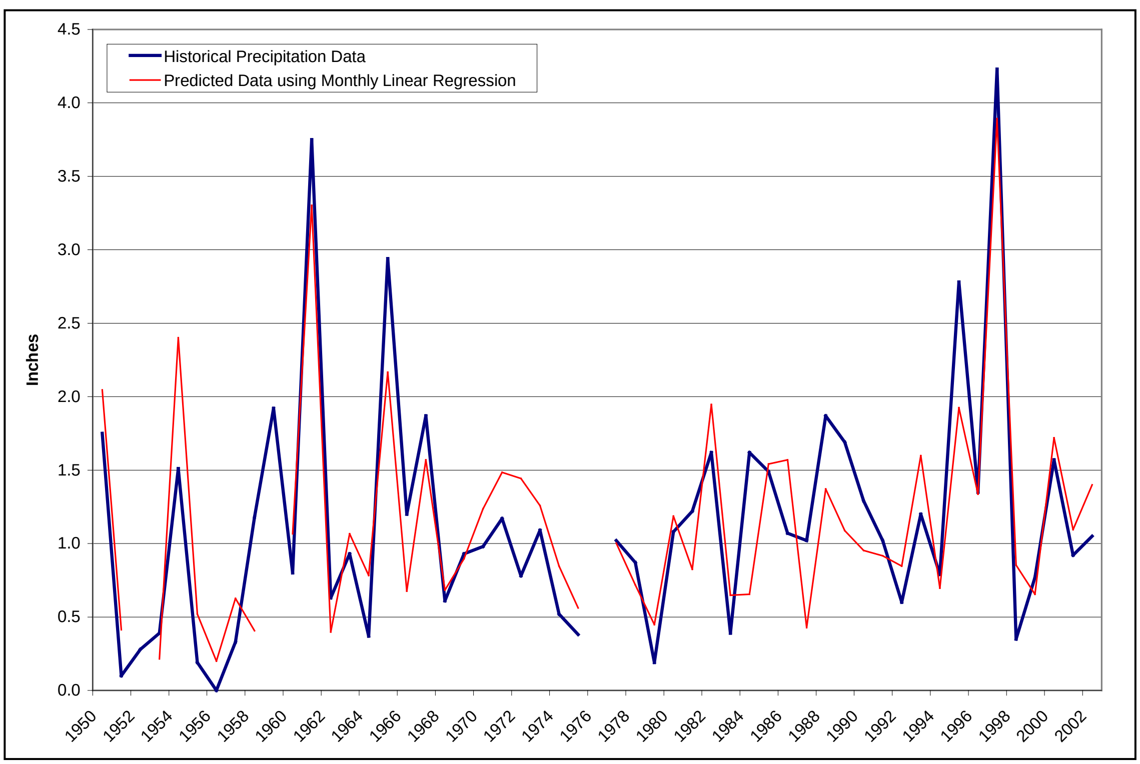


Figure 4 – Walden Precipitation Historical Data versus Predicted Data from Monthly Linear Regression with Spicer

2.2 Frost Dates

Regression of annual frost dates with data from a nearby climate station provided moderate to poor correlations. Generally, a portion of the data from a dependent station would correlate very well to the concurrent independent data. Several outlying data points, however, would skew the trend line producing filled results that are not consistent with the original data. An example of this is shown in **Figure 5**.

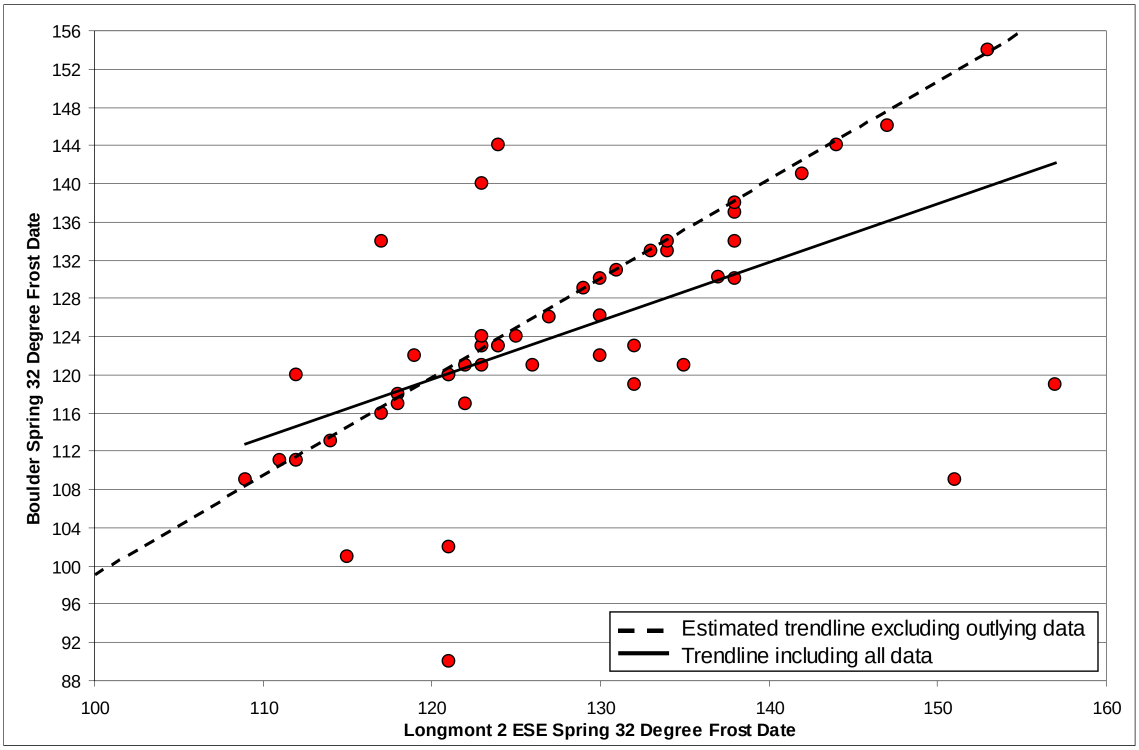


Figure 5 – Boulder vs. Longmont 2 ESE Scatterplot – Frost Dates

Based on this assessment, an alternate approach was developed using monthly linear regression with nearby climate stations to fill daily minimum temperature data. Annual frost dates were then calculated from the filled minimum daily temperature data using June 30 as the last spring frost date and July 1 as the first fall frost date. As described further in the Recommendations section, we recommend that an algorithm be added to **TSTool** to allow calculation of frost dates from daily data.

3. Fill Missing Monthly Climate Data

3.1 Temperature and Precipitation

The first step in filling missing monthly temperature and precipitation data was to select an independent station to fill the missing data. Close proximity and the highest correlation coefficients (R) using monthly linear regression were the main criteria for selecting an independent station. Preference was also given to an independent station with historical data that provided a complete record for the dependent station (as opposed to first filling the independent station and then using it to fill the dependent station). **Table 3** and **Table 4** provide the temperature and precipitation regression analysis results, respectively. If the dependent station was filled with an independent station that had already been filled, then the independent station name is followed by the word “filled”.

Monthly linear regression generally produced high correlations for most of the dependent stations being filled with temperature data. Correlations were not as high for precipitation data filling. It is important to note that if a dependent station had only a few months to fill, the independent station was selected based on the R-value for only the months being filled. This may produce an overall lower range of R-values, however does allow for the best correlations for the data that is actually filled. Instances of this, which take place in the precipitation regression, are indicated in Table 4 by showing the overall R-value range along with R-values for specific months being filled.

The filled average monthly temperature and precipitation values are summarized in **Table 5** and **Table 6**, respectively. The **TSTool** input command files, which include the regression commands for the monthly temperature and precipitation data are provided in **Attachment B.**

Table 3
Temperature Regression Analysis Results

Dependent Station			Independent Station		
No.	Station ID	Station Name	Station ID	Station Name	Range of Monthly Correlation Coefficients (R)
1	109	Akron 4 E (combined)	4945	Leroy 5 WSW	0.919 - 0.981
2	185	Allenspark 1 NW (combined)	2761	Estes Park 1 SSE (combined) (filled)	0.693 - 0.861
3	263	Antero Reservoir	454	Bailey	0.597 - 0.883
4	454	Bailey	3530	Grant	0.789 - 0.938
5	848	Boulder	5116	Longmont 2 ESE	0.593 - 0.944
6	945	Briggsdale	3038	Fort Morgan	0.838 - 0.965
7	1179	Byers 5 ENE	2220	Denver WSFO AP (Stapleton)	0.833 - 0.961
8	1401	Castle Rock	2220	Denver WSFO AP (Stapleton)	0.827 - 0.950
9	1528	Cheesman	454	Bailey	0.563 - 0.904
10	2220	Denver WSFO AP (Stapleton)	6323	Parker 2 N (combined)	0.822 - 0.961
11	2494	Eastonville 2 NNW [1]	No temperature data.		
12	2761	Estes Park 1 SSE (combined)	3005	Fort Collins	0.794 - 0.955
13	2790	Evergreen (combined) [2]	2220	Denver WSFO AP (Stapleton)	0.834 - 0.936
14	3005	Fort Collins	Complete record/regression not needed.		
15	3038	Fort Morgan	945	Briggsdale	0.838 - 0.965
16	3261	Georgetown	454	Bailey (filled)	0.799 - 0.966
17	3553	Greeley UNC (combined)	3005	Fort Collins	0.922 - 0.973
18	4413	Julesburg	7515	Sedgwick 5 S (combined) (filled)	0.874 - 0.977
19	4762	Lakewood (combined)	2220	Denver WSFO AP (Stapleton)	0.844 - 0.935
20	5116	Longmont 2 ESE	3005	Fort Collins	0.876 - 0.953
21	5922	New Raymer	7950	Sterling	0.790 - 0.978
22	5934	New Raymer 21 N (combined)	7950	Sterling	0.678 - 0.905
23	6323	Parker 2 N (combined)	2220	Denver WSFO AP (Stapleton)	0.822 – 0.961

Dependent Station			Independent Station		
No.	Station ID	Station Name	Station ID	Station Name	Range of Monthly Correlation Coefficients (R)
24	6921	Red Feather Lakes (combined)	3005	Fort Collins	0.748 - 0.923
25	7515	Sedgwick 5 S (combined)	4082	Holyoke	0.899 - 0.975
26	7950	Sterling	4945	Leroy 5 WSW	0.755 - 0.976
27	8756	Walden	7848	Spicer	0.770 - 0.957

Notes: [1] Eastonville 2 NNW has precipitation data only.
[2] Evergreen station records are only combined for precipitation.

Table 4
Precipitation Regression Analysis Results

Dependent Station			Independent Station		
No.	Station ID	Station Name	Station ID	Station Name	Range of Monthly Correlation Coefficients (R)
1	109	Akron 4 E (combined)	4945	Leroy 5 WSW	0.287 - 0.839 (Dec R=0.714)
2	185	Allenspark 1 NW (combined)	2761	Estes Park 1 SSE (combined) (filled)	0.461 - 0.876
3	263	Antero Reservoir	454	Bailey	0.444 - 0.825
4	454	Bailey	3530	Grant	0.590 - 0.897
5	848	Boulder	5116	Longmont 2 ESE	0.533 - 0.896
6	945	Briggsdale	3553	Greeley UNC (combined)	0.426 - 0.869
7	1179	Byers 5 ENE	2220	Denver WSFO AP (Stapleton)	0.547 - 0.903 (Aug R=0.664, Dec R=0.903)
8	1401	Castle Rock	2220	Denver WSFO AP (Stapleton)	0.499 - 0.895
9	1528	Cheesman	4452	Kassler	0.439 - 0.919 (Feb R = 0.870)
10	2220	Denver WSFO AP (Stapleton)	1547	Cherry Creek Dam	0.675 - 0.941 (June R=0.781, Aug R=0.738)
11	2494	Eastonville 2 NNW [1]	6323	Parker 2 N (combined)	0.437 - 0.876
12	2761	Estes Park 1 SSE (combined)	3005	Fort Collins	0.400 - 0.841
13	2790	Evergreen (combined) [2]	4762	Lakewood (combined)	0.527 – 0.912
14	3005	Fort Collins	Complete record/regression not needed.		
15	3038	Fort Morgan	5922	New Raymer	0.494 - 0.941
16	3261	Georgetown	454	Bailey	0.407 - 0.902
17	3553	Greeley UNC (combined)	Complete record/regression not needed.		
18	4413	Julesburg	7515	Sedgwick 5 S (combined) (filled)	0.496 - 0.944
19	4762	Lakewood (combined)	2790	Evergreen (combined)	0.527 - 0.912 (June R=0.704, July R=0.670)
20	5116	Longmont 2 ESE	3005	Fort Collins	0.214 - 0.941 (Feb R = 0.834)
21	5922	New Raymer	3038	Fort Morgan	0.494 – 0.941
22	5934	New Raymer 21 N (combined)	7950	Sterling	0.545 - 0.768
23	6323	Parker 2 N (combined)	2220	Denver WSFO AP (Stapleton)	0.555 - 0.905
24	6921	Red Feather Lakes (combined)	2761	Estes Park 1 SSE (combined) (filled)	0.478 - 0.849
25	7515	Sedgwick 5 S (combined)	2947	Fleming 3 SW (combined)	0.487 - 0.928 (June R=0.806 Oct R=0.928 Nov R = 0.809)
26	7950	Sterling	109	Akron 4 E (combined)	0.404 - 0.809
27	8756	Walden	7848	Spicer	0.481 - 0.870

Notes: [1] Eastonville 2 NNW has precipitation data only.
[2] Evergreen station records are only combined for precipitation.

Table 5
Filled Average Monthly Temperatures
(1950 – 2003)

No.	Station ID	Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1	109	Akron 4 E (combined)	26.3	30.7	36.6	46.3	56.3	66.7	73.4	71.5	62.3	50.4	36.3	28.4	48.8
2	185	Allenspark 1 NW (combined)	23.7	25.6	29.0	36.3	45.4	54.0	60.1	58.2	51.2	42.3	31.4	25.6	40.2
3	263	Antero Reservoir	15.3	17.8	24.9	33.9	43.7	52.5	58.2	56.4	49.2	38.5	25.4	16.4	36.0
4	454	Bailey	24.3	26.5	31.3	38.8	47.5	56.3	61.7	59.8	52.6	43.0	31.5	25.1	41.5
5	848	Boulder	33.3	36.1	40.8	49.0	58.0	67.4	73.2	71.4	63.1	53.1	40.7	34.7	51.7
6	945	Briggsdale	26.0	30.9	37.3	46.6	56.2	65.9	72.1	70.3	60.9	49.2	35.3	26.9	48.1
7	1179	Byers 5 ENE	27.6	31.9	38.0	47.1	56.9	66.9	73.1	71.2	62.3	50.8	36.9	29.4	49.3
8	1401	Castle Rock	29.1	31.8	36.6	44.8	54.2	63.6	69.5	67.5	59.5	49.4	37.1	30.7	47.8
9	1528	Cheesman	26.8	28.8	33.9	41.6	50.5	60.1	65.3	63.4	56.4	46.6	35.2	28.6	44.8
10	2220	Denver WSFO AP (Stapleton)	30.6	33.8	39.1	47.9	57.4	67.4	73.6	71.7	62.8	51.6	38.7	31.9	50.5
11	2494	Eastonville 2 NNW	No temperature data.												
12	2759	Estes Park	28.0	29.2	33.0	40.3	48.5	57.1	62.7	60.8	53.9	45.1	34.5	28.9	43.5
13	2790	Evergreen (combined) [1]	27.2	29.0	33.4	40.7	49.3	58.3	63.9	62.5	54.7	44.9	34.2	28.2	43.9
14	3005	Fort Collins	28.4	32.5	38.4	47.3	56.6	65.8	71.5	69.4	60.7	49.9	37.3	30.3	49.0
15	3038	Fort Morgan	25.2	30.9	38.3	48.3	58.6	68.9	75.0	72.8	63.2	51.0	36.6	27.8	49.7
16	3261	Georgetown	26.0	27.7	31.2	38.1	47.3	56.4	62.7	60.8	53.4	44.8	33.3	26.8	42.3
17	3553	Greeley UNC (combined)	26.8	32.1	39.0	48.5	58.2	67.8	73.7	71.4	62.3	50.6	36.8	28.8	49.7
18	4413	Julesburg	27.2	32.5	38.7	49.1	59.2	69.7	76.1	74.0	64.3	52.2	38.0	29.6	50.9
19	4762	Lakewood (combined)	31.4	34.2	38.9	47.0	56.2	66.1	72.3	70.4	61.8	51.4	39.0	32.9	50.1
20	5116	Longmont 2 ESE	27.3	31.6	37.8	47.1	56.9	66.4	72.2	70.0	61.1	50.0	36.8	29.5	48.9
21	5922	New Raymer	26.0	30.6	36.7	45.9	55.8	65.6	72.5	70.5	61.4	49.7	35.2	27.7	48.1
22	5934	New Raymer 21 N (combined)	26.3	29.9	34.8	44.4	54.2	63.8	70.3	68.6	59.2	48.0	34.9	28.2	46.9
23	6323	Parker 2 N (combined) [3]	29.5	32.3	37.1	45.7	54.8	64.6	70.9	69.0	61.1	50.6	37.4	31.0	48.7
24	6921	Red Feather Lakes (combined)	24.2	25.8	29.0	36.2	45.5	54.6	60.8	59.1	51.9	42.5	31.0	25.9	40.5
25	7515	Sedgwick 5 S (combined)	27.0	32.1	38.4	48.6	58.6	68.6	75.1	73.5	64.3	52.4	37.6	29.3	50.5
26	7950	Sterling	25.4	31.0	37.7	47.9	58.2	68.6	74.8	72.6	62.5	50.3	36.3	27.6	49.4
27	8756	Walden	16.7	19.4	25.9	35.3	44.6	53.7	59.0	56.7	48.9	38.9	26.3	18.4	37.0

Notes: [1] Evergreen station records are only combined for precipitation.

Table 6

Filled Average Monthly Precipitation

(1950 – 2003)

No.	Station ID	Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	109	Akron 4 E (combined)	0.36	0.35	0.94	1.30	3.02	2.41	2.63	2.12	1.10	0.83	0.62	0.37	16.03
2	185	Allenspark 1 NW (combined)	1.15	1.09	2.08	2.49	2.78	1.93	2.36	2.29	1.70	1.18	1.40	1.08	21.52
3	263	Antero Reservoir	0.18	0.25	0.50	0.66	0.98	1.08	1.92	2.17	0.94	0.65	0.33	0.27	9.95
4	454	Bailey	0.38	0.55	1.24	1.78	2.09	1.62	2.58	2.55	1.33	1.10	0.74	0.53	16.50
5	848	Boulder	0.65	0.79	1.80	2.44	3.15	2.04	1.82	1.67	1.66	1.25	1.23	0.70	19.20
6	945	Briggsdale	0.23	0.18	0.73	1.12	2.09	2.10	2.31	1.82	1.23	0.69	0.38	0.24	13.13
7	1179	Byers 5 ENE	0.42	0.40	1.04	1.42	2.62	1.97	2.29	1.76	1.25	0.83	0.67	0.39	15.06
8	1401	Castle Rock	0.56	0.67	1.52	1.79	2.51	1.96	2.33	2.11	1.27	1.06	0.89	0.62	17.28
9	1528	Cheesman	0.42	0.60	1.32	1.61	2.00	1.66	2.52	2.59	1.21	1.03	0.78	0.56	16.31
10	2220	Denver WSFO AP (Stapleton)	0.50	0.60	1.29	1.78	2.46	1.67	2.02	1.64	1.19	0.96	0.87	0.55	15.54
11	2494	Eastonville 2 NNW [1]	0.42	0.43	1.26	1.93	2.63	2.24	2.90	2.96	1.38	1.00	0.76	0.46	18.38
12	2761	Estes Park 1SSE (combined)	0.36	0.49	0.99	1.40	2.08	1.66	2.19	1.96	1.25	0.80	0.64	0.45	14.28
13	2790	Evergreen (combined) [2]	0.53	0.81	1.65	2.14	2.72	2.07	2.25	2.29	1.45	1.20	0.96	0.67	18.74
14	3005	Fort Collins	0.42	0.40	1.35	1.88	2.73	1.91	1.65	1.48	1.25	1.00	0.71	0.42	15.19
15	3038	Fort Morgan	0.25	0.21	0.69	1.23	2.45	2.01	1.99	1.48	1.17	0.78	0.43	0.25	12.95
16	3261	Georgetown	0.61	0.65	1.34	1.73	1.86	1.44	2.14	2.38	1.37	0.96	0.86	0.76	16.11
17	3553	Greeley UNC (combined)	0.42	0.34	0.98	1.58	2.47	1.79	1.45	1.19	1.16	0.88	0.69	0.38	13.33
18	4413	Julesburg	0.39	0.37	1.19	1.59	3.27	2.93	2.48	1.96	1.34	0.91	0.55	0.32	17.29
19	4762	Lakewood (combined)	0.50	0.56	1.36	1.91	2.63	1.93	1.75	1.62	1.35	0.97	0.94	0.52	16.05
20	5116	Longmont 2 ESE	0.40	0.39	1.14	1.72	2.45	1.64	1.09	1.26	1.26	0.84	0.70	0.46	13.34
21	5922	New Raymer	0.28	0.23	0.77	1.29	2.48	2.63	2.49	1.87	1.40	0.80	0.44	0.24	14.92
22	5934	New Raymer 21 N (combined)	0.29	0.22	0.80	1.34	2.58	2.27	2.26	1.64	1.24	0.80	0.45	0.28	14.18
23	6323	Parker 2 N (combined) [3]	0.31	0.34	0.94	1.46	2.43	1.88	2.26	2.04	1.10	0.80	0.68	0.33	14.55
24	6921	Red Feather Lakes (combined)	0.58	0.69	1.52	1.99	2.29	1.76	2.20	1.82	1.40	0.96	0.96	0.56	16.72
25	7515	Sedgwick 5 S (combined)	0.43	0.50	1.12	1.76	3.24	3.01	2.54	1.96	1.32	0.95	0.65	0.39	17.86
26	7950	Sterling	0.31	0.29	0.83	1.26	2.80	2.66	2.58	1.77	1.12	0.90	0.50	0.30	15.33
27	8756	Walden	0.57	0.54	0.68	0.90	1.30	1.07	1.32	1.26	1.14	0.82	0.73	0.58	10.92

Notes: [1] Evergreen station records are only combined for precipitation.

3.2 Frost Dates

The first step in filling missing frost dates was to fill the daily minimum temperature data. Generally, the same independent stations selected for filling mean monthly temperature data were used in the regression of daily minimum temperature. In a few instances, the stations used to fill the monthly temperature data could not completely fill the missing daily data. In these instances, the next closest station was used to fill the daily data. The resulting range of R-values was very similar to those produced from the monthly temperature regression, presented in Table 3. The frost dates were then calculated from the filled minimum daily temperature records.

Table 7 shows the average annual frost dates resulting from frost date selection using minimum temperature regression. The **TSTool** input command file used to fill minimum temperature data and to compile the frost dates from all the stations is provided in **Attachment B.**

Table 7
Filled Average Annual Frost Dates
(1950 – 2003)

No.	Station ID	Station Name	Spring 28˚ Frost Date	Spring 32˚ Frost Date	Fall 32˚ Frost Date	Fall 28˚ Frost Date
1	109	Akron 4 E (combined)	04/30	05/12	09/28	10/09
2	185	Allenspark 1 NW (combined)	05/26	06/11	08/27	09/19
3	263	Antero Reservoir	06/10	06/22	08/04	09/01
4	454	Bailey	06/01	06/15	08/23	09/13
5	848	Boulder	04/21	05/04	10/05	10/16
6	945	Briggsdale	05/03	05/14	09/25	10/06
7	1179	Byers 5 ENE	05/01	05/12	09/27	10/05
8	1401	Castle Rock	05/05	05/20	09/25	10/04
9	1528	Cheesman	05/19	06/02	09/09	09/24
10	2220	Denver WSFO AP (Stapleton)	04/22	05/03	10/06	10/18
11	2494	Eastonville 2 NNW	No Temperature Data			
12	2761	Estes Park 1SSE (combined)	05/17	06/02	09/12	09/22
13	2790	Evergreen (combined) [1]	05/16	06/01	09/14	09/25
14	3005	Fort Collins	04/21	05/06	10/01	10/09
15	3038	Fort Morgan	04/21	05/02	10/03	10/14
16	3261	Georgetown	05/14	05/26	09/20	10/01
17	3553	Greeley UNC (combined)	04/21	05/06	09/30	10/10
18	4413	Julesburg	04/23	05/06	10/02	10/12
19	4762	Lakewood (combined)	04/28	05/10	09/30	10/11
20	5116	Longmont 2 ESE	04/26	05/07	09/29	10/09
21	5922	New Raymer	05/02	05/14	09/27	10/06
22	5934	New Raymer 21 N (combined)	05/08	05/20	09/18	09/27
23	6323	Parker 2 N (combined)	05/05	05/18	09/25	10/04
24	6921	Red Feather Lakes (combined)	05/28	06/11	08/30	09/14
25	7515	Sedgwick 5 S (combined)	04/23	05/04	10/04	10/13
26	7950	Sterling	04/23	05/07	09/29	10/09
27	8756	Walden	06/08	06/22	07/21	08/16

Notes: [1] Evergreen station records are only combined for precipitation.

Recommendations

Several potential enhancements to **TSTool** were identified under Task 2 with respect to regression analyses that would have also been useful under this task. The following additional potential **TSTool** enhancements were identified with respect to filling climate data.

- Replicate the NOAA method of calculating monthly average temperature and total precipitation from daily data by ignoring missing data if less than or equal to 9 days are missing (10 or more missing days would produce an "NC"). The number of missing days could be a user-specified variable, with the default set to the NOAA criterion of 9 days.

- Add a flag in HydroBase that can be viewed through TSTool that designates when calculated monthly average temperature and total precipitation values are based off of missing daily data (1 to 9 days within a particular month). Note that NOAA uses a designation of "X" to flag these cases.

- Add an option to calculate frost dates from daily minimum temperature data, using the NOAA criteria of June 30 as the last spring date and July 1 as the first fall date. The last spring and first fall dates could be user-specified variables, with the default set to the NOAA criteria. A user-specified number of sequential missing daily data should be allowed in a given month. When missing data are encountered, the algorithm should continue looking if a user-specified number of surrounding days are not less than 28/32 degrees Fahrenheit. This enhancement would reduce the need for supplemental data files containing frost dates calculated from regressed daily minimum temperature data, as used in this task.

- Currently the State loads climate data from the past two years into HydroBase. NOAA climate data is constantly under review and changes are periodically made to improve available data. Due to these periodic updates of NOAA climate data throughout the SPDSS study period, we recommend a full refresh of all climate data every five years.

- Check the stations that are downloaded from NOAA to ensure that any new stations are added to HydroBase (e.g. Estes Park 1 SSE (2761) installed in 2001).

Comments and Concerns

The selected study period is 1950 through the most current year available. The **TSTool** input command files were provided for the period of 1950 through 2003, the most recent data available at this time. In the future, these command files can be modified to include additional years of data as it becomes available. As more data become available, the results from filling missing data through regression may change slightly, however it is unlikely to significantly affect the correlations and filled results.

Where to find more information

- The South Platte Decision Support System Feasibility Study Final Report, October 2001 is available on the State's website (http://cdss.state.co.us).

- The Task 53.4 – Distribution of Climate Station memo provides additional information on the spatial coverage of the climate stations.

Attachment A – Cumulative Mass Diagrams for Combined Stations

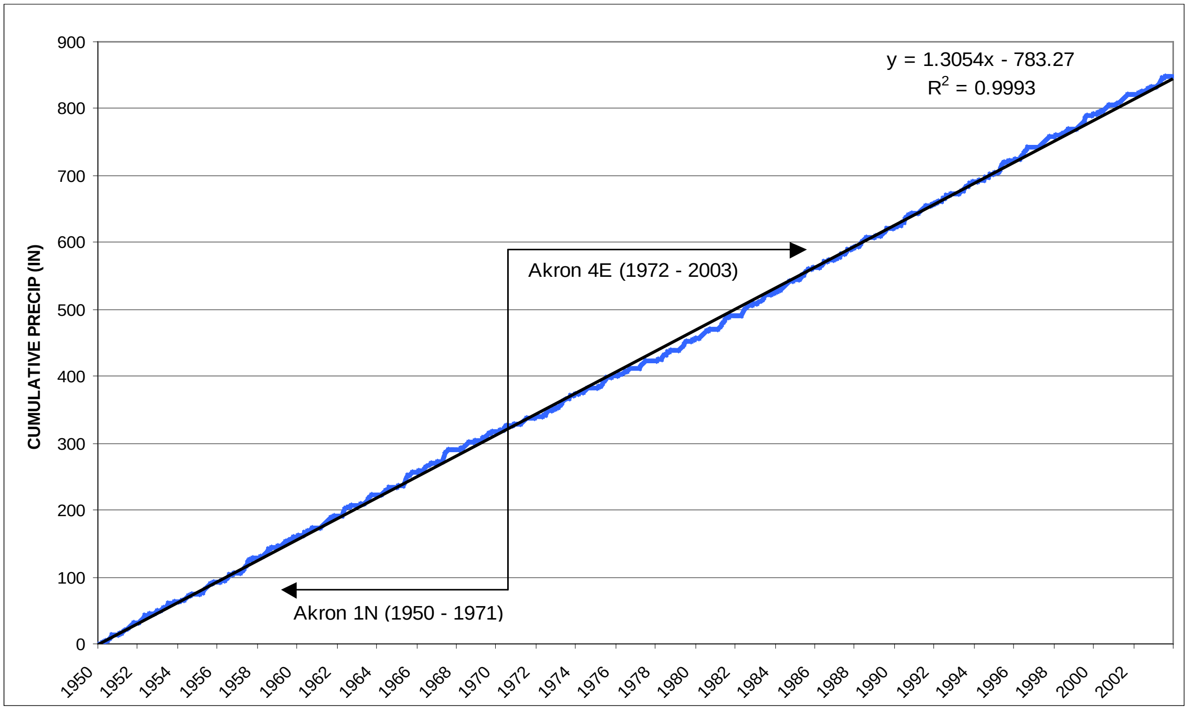


Figure A.1 - Precipitation Mass Diagram
Akron 4 E combined with Akron 1 N

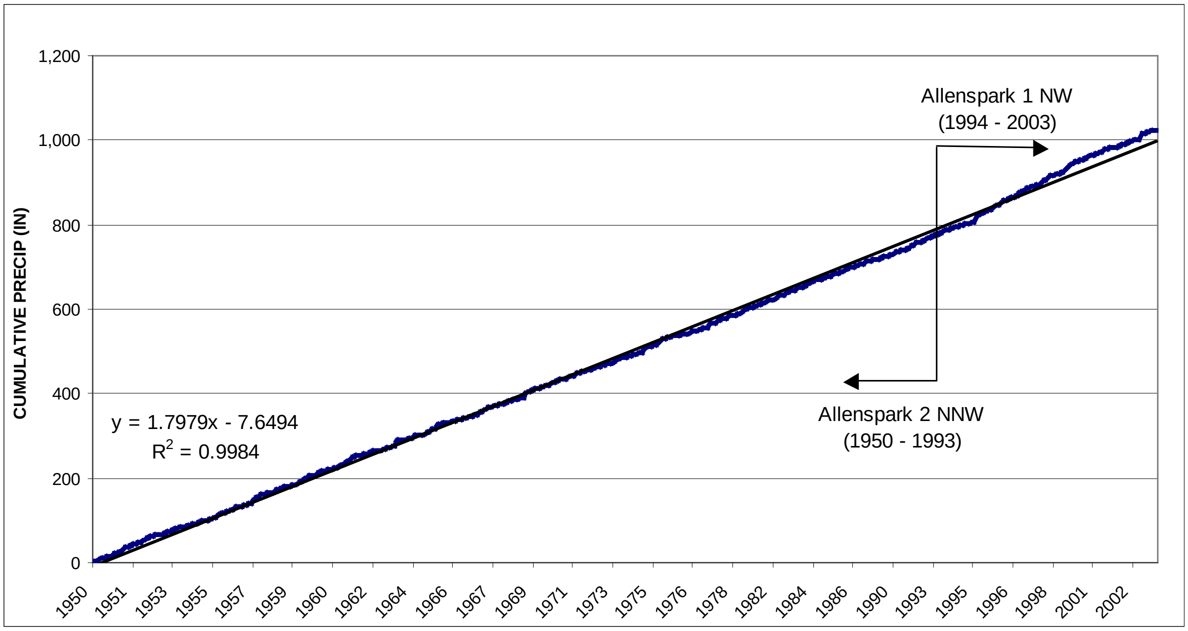


Figure A.2 - Precipitation Mass Diagram
Allenspark 1 NW combined with Allenspark 2 NNW

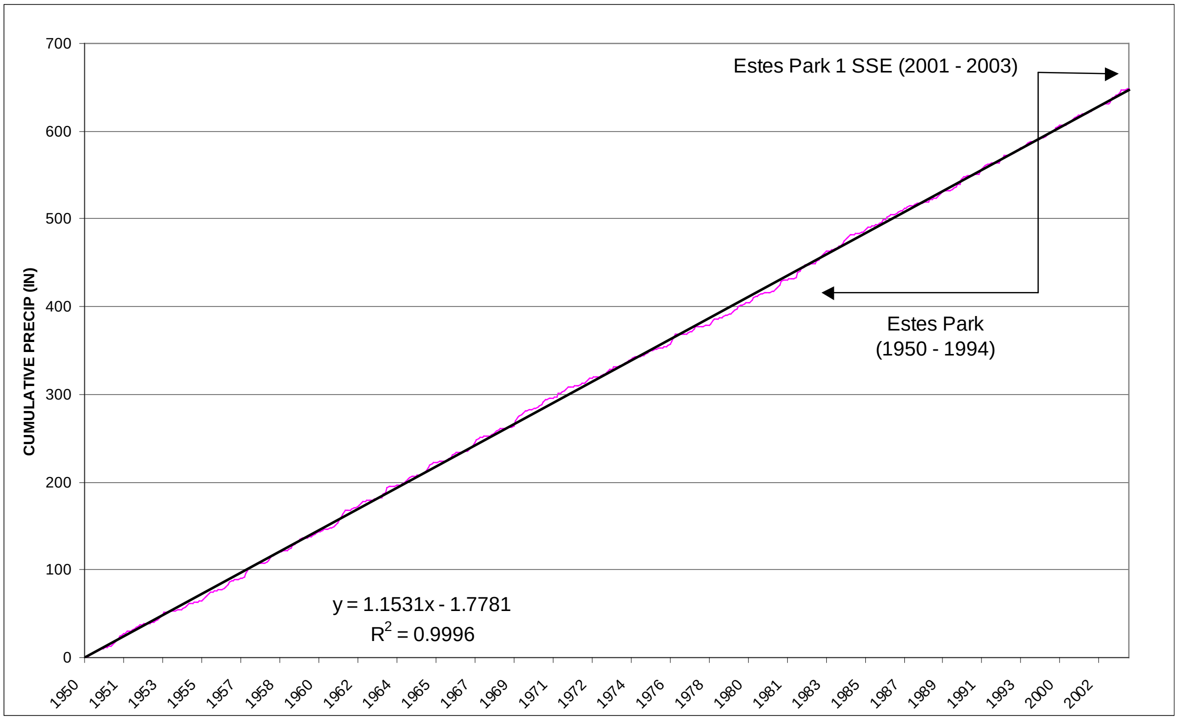


Figure A.3 - Precipitation Mass Diagram
Estes Park 1 SSE combined with Estes Park

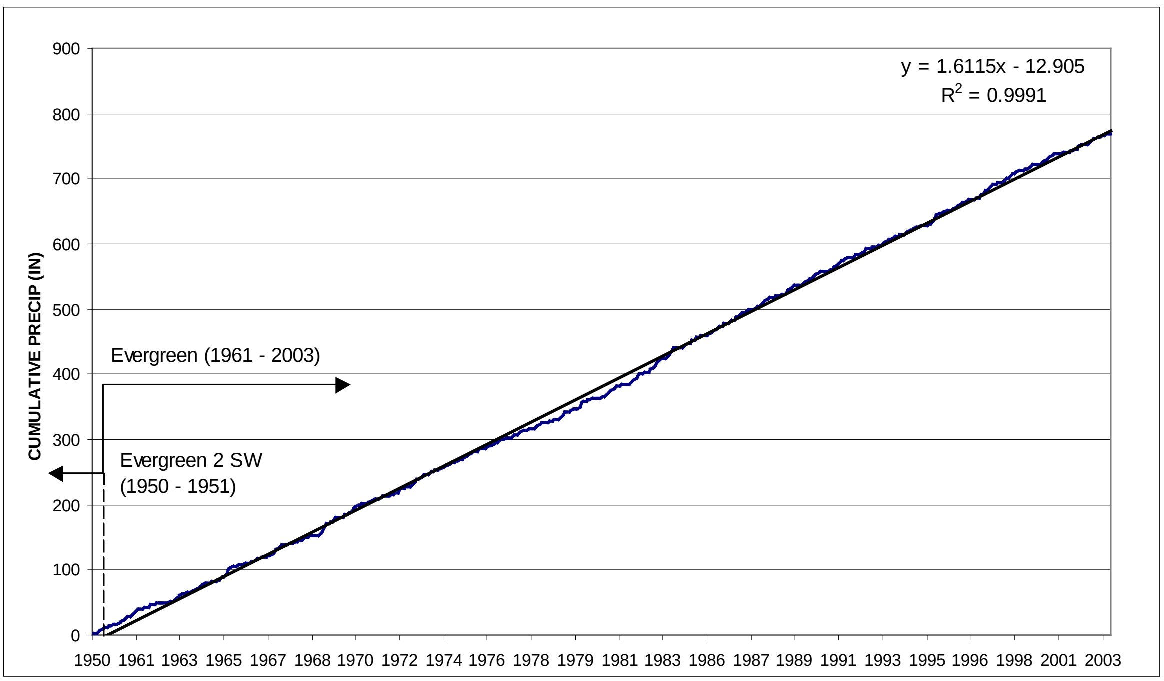


Figure A.4 - Precipitation Mass Diagram
Evergreen combined with Evergreen 2 SW

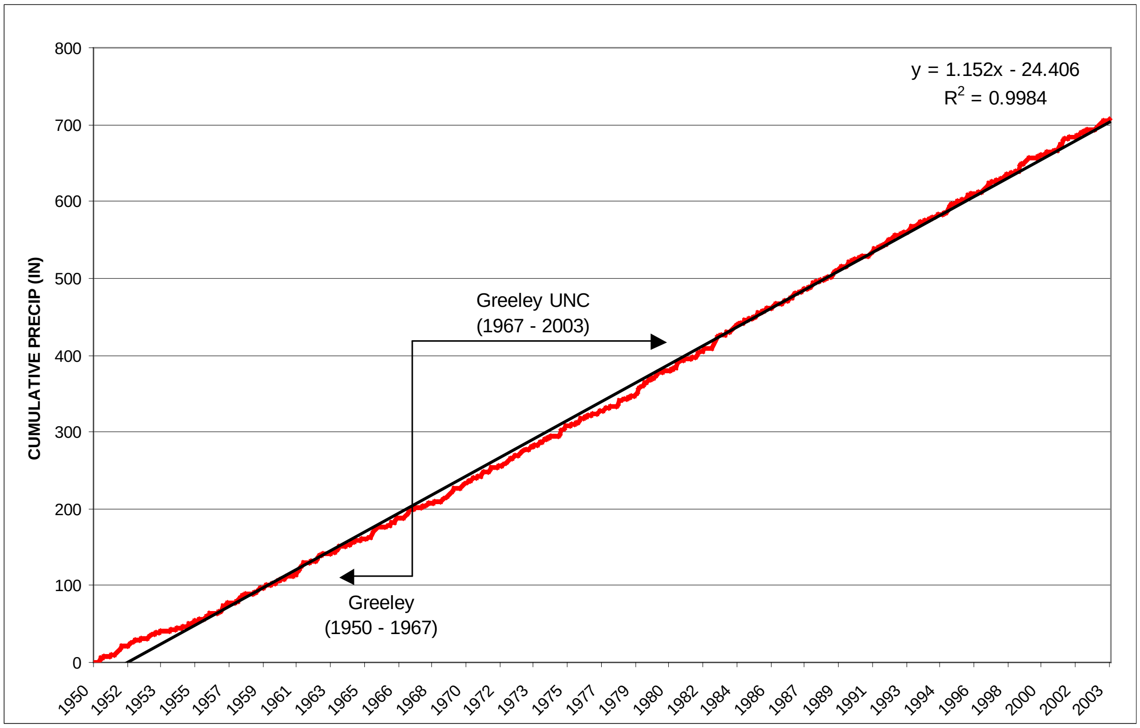


Figure A.5 - Precipitation Mass Diagram
Greeley UNC combined with Greeley

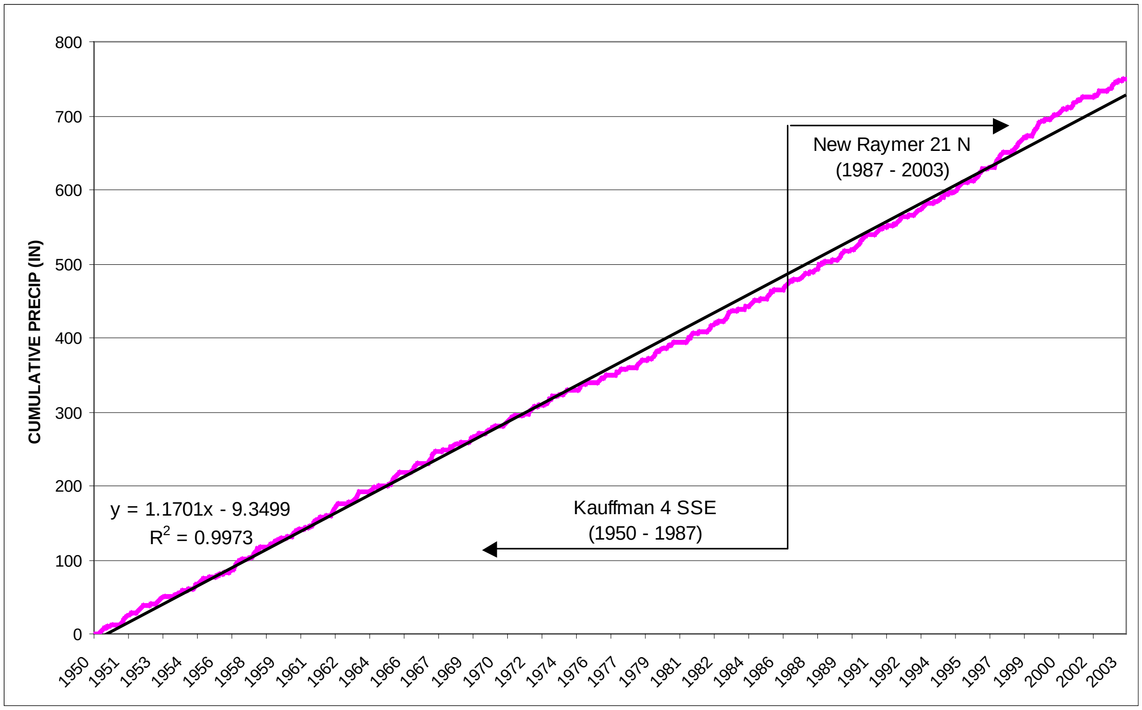


Figure A.6 - Precipitation Mass Diagram
New Raymer 21 N combined with Kauffman 4 SSE

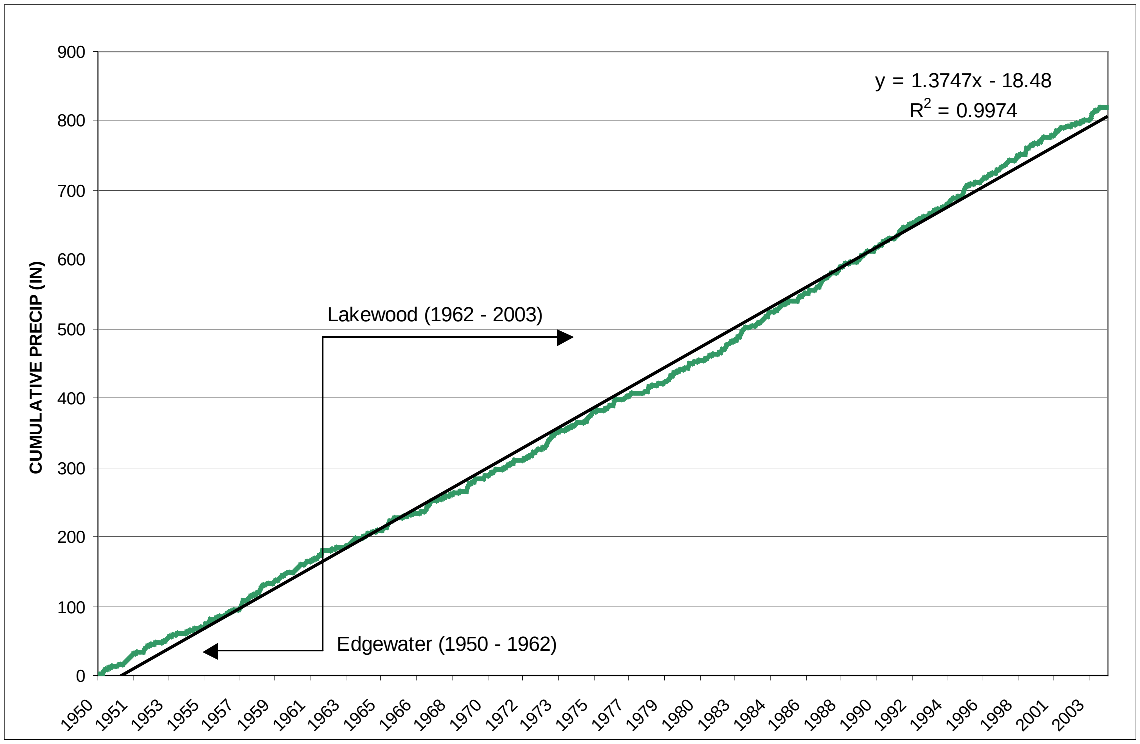


Figure A.7 - Precipitation Mass Diagram
Lakewood combined with Edgewater

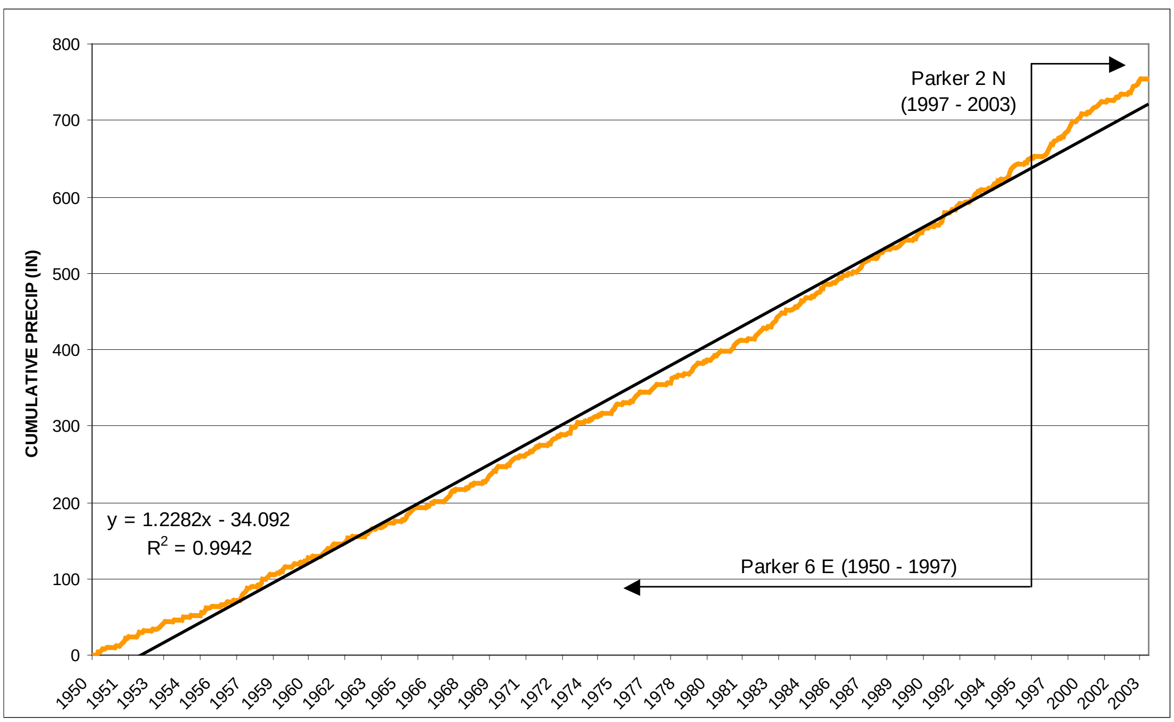


Figure A.8 - Precipitation Mass Diagram
Parker 2 N combined with Parker 6 E

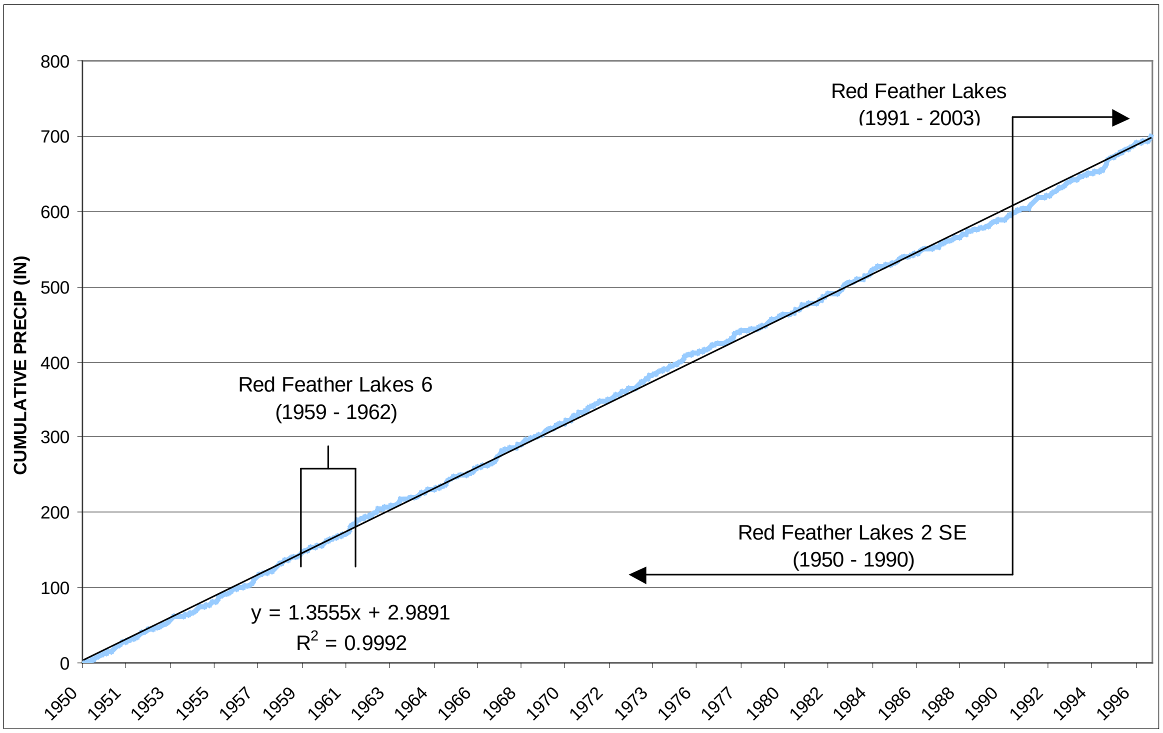


Figure A.9 - Precipitation Mass Diagram
Red Feather Lakes combined with Red Feather Lakes 2 SE and Red Feather Lakes 6

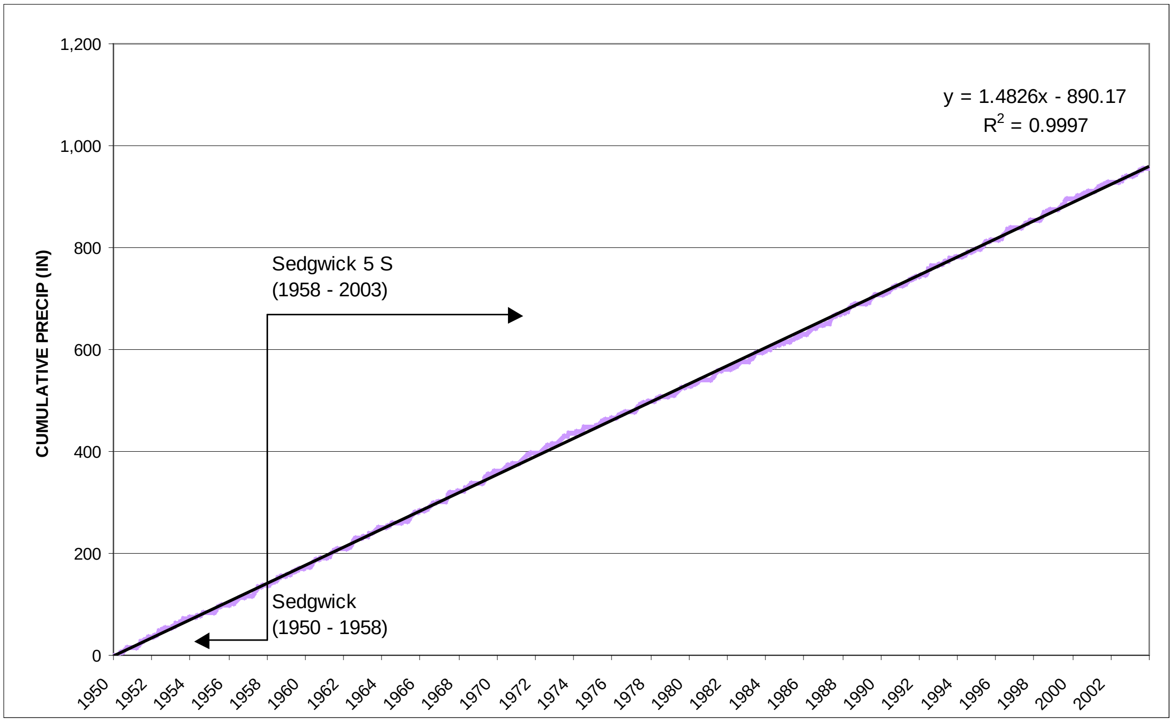


Figure A.10 - Precipitation Mass Diagram
Sedgwick 5 S combined with Sedgwick

Attachment B– TSTool Command Files

Final Key NCDC Climate Station Command File (Includes Regressed Stations)
– must be run using a HydroBase that includes both Division 1 & 6

Monthly Precipitation Command File:

```
setOutputPeriod(01/1950,12/2003)
setOutputYearType(Calendar)
#
# 3038 - Fort Morgan filled with stm, then regressed with New Raymer
3038.NOAA.Precip.Month~HydroBase
ftmo_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\ftmo_p.stm
fillFromTS(3038.NOAA.Precip.Month,ftmo_p...MONTH,*,*)
free(TSID="ftmo_p...MONTH")
5922.NOAA.Precip.Month~HydroBase
newr_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\newr_p.stm
fillFromTS(5922.NOAA.Precip.Month,newr_p...MONTH,*,*)
free(TSID="newr_p...MONTH")
fillRegression(3038.NOAA.Precip.Month,5922.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="5922.NOAA.Precip.Month")
#
# 0109 - Akron 4 E combined with Akron 1 N, filled with stm, then regressed with Leroy
0109.NOAA.Precip.Month~HydroBase
0114.NOAA.Precip.Month~HydroBase
akro_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\akro_p.stm
fillFromTS(0109.NOAA.Precip.Month,0114.NOAA.Precip.Month,*,*)
fillFromTS(0109.NOAA.Precip.Month,akro_p...MONTH,*,*)
free(TSID="0114.NOAA.Precip.Month")
free(TSID="akro_p...MONTH")
4945.NOAA.Precip.Month~HydroBase
fillRegression(0109.NOAA.Precip.Month,4945.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="4945.NOAA.Precip.Month")
#
# 3005 - Fort Collins filled with stm
3005.NOAA.Precip.Month~HydroBase
ftco_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\ftco_p.stm
fillFromTS(3005.NOAA.Precip.Month,ftco_p...MONTH,*,*)
free(TSID="ftco_p...MONTH")
#
# 3553 - Greeley UNC combined with Greeley, filled with stm
3553.NOAA.Precip.Month~HydroBase
3546.NOAA.Precip.Month~HydroBase
fillFromTS(3553.NOAA.Precip.Month,3546.NOAA.Precip.Month,*,*)
free(TSID="3546.NOAA.Precip.Month")
gree_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\gree_p.stm
fillFromTS(3553.NOAA.Precip.Month,gree_p...MONTH,*,*)
free(TSID="gree_p...MONTH")
#
# 0945 - Briggsdale filled with stm, then regressed with Greeley
0945.NOAA.Precip.Month~HydroBase
brig_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\brig_p.stm
fillFromTS(0945.NOAA.Precip.Month,brig_p...MONTH,*,*)
free(TSID="brig_p...MONTH")
fillRegression(0945.NOAA.Precip.Month,3553.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 0263 - Antero Reservoir filled with stm, then regressed with Bailey
0263.NOAA.Precip.Month~HydroBase
ante_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\ante_p.stm
fillFromTS(0263.NOAA.Precip.Month,ante_p...MONTH,*,*)
free(TSID="ante_p...MONTH")
0454.NOAA.Precip.Month~HydroBase
bail_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\bail_p.stm
fillFromTS(0454.NOAA.Precip.Month,bail_p...MONTH,*,*)
free(TSID="bail_p...MONTH")
fillRegression(0263.NOAA.Precip.Month,0454.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 3261 - Georgetown filled with stm, then regressed with Bailey
3261.NOAA.Precip.Month~HydroBase
geor_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\geor_p.stm
fillFromTS(3261.NOAA.Precip.Month,geor_p...MONTH,*,*)
free(TSID="geor_p...MONTH")
fillRegression(3261.NOAA.Precip.Month,0454.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 0454 - Bailey filled with stm, then regressed with Grant
3530.NOAA.Precip.Month~HydroBase
fillRegression(0454.NOAA.Precip.Month,3530.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
```

```
free(TSID="3530.NOAA.Precip.Month")
#
# 1528 - Cheesman filled with stm, then regressed with Kassler
1528.NOAA.Precip.Month~HydroBase
chee_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\chee_p.stm
fillFromTS(1528.NOAA.Precip.Month,chee_p...MONTH,*,*)
free(TSID="chee_p...MONTH")
4452.NOAA.Precip.Month~HydroBase
fillRegression(1528.NOAA.Precip.Month,4452.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="4452.NOAA.Precip.Month")
#
# 0848 - Boulder filled with stm, then regressed with Longmont 2 ESE
0848.NOAA.Precip.Month~HydroBase
boul_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\boul_p.stm
fillFromTS(0848.NOAA.Precip.Month,boul_p...MONTH,*,*)
free(TSID="boul_p...MONTH")
5116.NOAA.Precip.Month~HydroBase
long_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\long_p.stm
fillFromTS(5116.NOAA.Precip.Month,long_p...MONTH,*,*)
free(TSID="long_p...MONTH")
fillRegression(0848.NOAA.Precip.Month,5116.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 5116 - Longmont 2 ESE filled with stm, then regressed with Fort Collins
fillRegression(5116.NOAA.Precip.Month,3005.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 2494 - Eastonville 2 NNW filled with stm, then regressed with Parker 2 N combined with Parker 6 E
2494.NOAA.Precip.Month~HydroBase
east_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\east_p.stm
fillFromTS(2494.NOAA.Precip.Month,east_p...MONTH,*,*)
free(TSID="east_p...MONTH")
6323.NOAA.Precip.Month~HydroBase
6326.NOAA.Precip.Month~HydroBase
fillFromTS(6323.NOAA.Precip.Month,6326.NOAA.Precip.Month,*,*)
free(TSID="6326.NOAA.Precip.Month")
park_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\park_p.stm
fillFromTS(6323.NOAA.Precip.Month,park_p...MONTH,*,*)
free(TSID="park_p...MONTH")
fillRegression(2494.NOAA.Precip.Month,6323.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 6323 - Parker 2 N combined with Parker 6 E, filled with stm, then regressed with Denver
2220.NOAA.Precip.Month~HydroBase
denv_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\denv_p.stm
fillFromTS(2220.NOAA.Precip.Month,denv_p...MONTH,*,*)
free(TSID="denv_p...MONTH")
fillRegression(6323.NOAA.Precip.Month,2220.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 1179 - Byers 5 ENE filled with stm, then regressed with Denver
1179.NOAA.Precip.Month~HydroBase
byer_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\byer_p.stm
fillFromTS(1179.NOAA.Precip.Month,byer_p...MONTH,*,*)
free(TSID="byer_p...MONTH")
fillRegression(1179.NOAA.Precip.Month,2220.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 1401 - Castle Rock filled with stm, then regressed with Denver
1401.NOAA.Precip.Month~HydroBase
cast_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\cast_p.stm
fillFromTS(1401.NOAA.Precip.Month,cast_p...MONTH,*,*)
free(TSID="cast_p...MONTH")
fillRegression(1401.NOAA.Precip.Month,2220.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 2220 - Denver filled with stm, then regressed with Cherry Creek Dam
1547.NOAA.Precip.Month~HydroBase
fillRegression(2220.NOAA.Precip.Month,1547.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="1547.NOAA.Precip.Month")
#
# 4762 - Lakewood combined with Edgewater, filled with stm, regressed with Evergreen combined with Evergreen 2
SW
4762.NOAA.Precip.Month~HydroBase
2557.NOAA.Precip.Month~HydroBase
lake_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\lake_p.stm
fillFromTS(4762.NOAA.Precip.Month,2557.NOAA.Precip.Month,*,*)
fillFromTS(4762.NOAA.Precip.Month,lake_p...MONTH,*,*)
free(TSID="lake_p...MONTH")
free(TSID="2557.NOAA.Precip.Month")
2790.NOAA.Precip.Month~HydroBase
2795.NOAA.Precip.Month~HydroBase
ever_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\ever_p.stm
fillFromTS(2790.NOAA.Precip.Month,2795.NOAA.Precip.Month,*,*)
fillFromTS(2790.NOAA.Precip.Month,ever_p...MONTH,*,*)
free(TSID="ever_p...MONTH")
free(TSID="2795.NOAA.Precip.Month")
```

```
fillRegression(4762.NOAA.Precip.Month,2790.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="2790.NOAA.Precip.Month")
#
# 2761 - Estes Park 1 SSE combined with Estes Park, filled with stm, then regressed with Fort Collins
2761.NOAA.Precip.Month~HydroBase
2759.NOAA.Precip.Month~HydroBase
este_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\este_p.stm
fillFromTS(2761.NOAA.Precip.Month,2759.NOAA.Precip.Month,*,*)
fillFromTS(2761.NOAA.Precip.Month,este_p...MONTH,*,*)
free(TSID="2759.NOAA.Precip.Month")
free(TSID="este_p...MONTH")
fillRegression(2761.NOAA.Precip.Month,3005.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 0185 - Allenspark 1 NW combined with Allenspark 2 NNW, filled with stm, then regressed with Estes Park filled
0185.NOAA.Precip.Month~HydroBase
0183.NOAA.Precip.Month~HydroBase
fillFromTS(0185.NOAA.Precip.Month,0183.NOAA.Precip.Month,*,*)
alle_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\alle_p.stm
fillFromTS(0185.NOAA.Precip.Month,alle_p...MONTH,*,*)
free(TSID="0183.NOAA.Precip.Month")
free(TSID="alle_p...MONTH")
fillRegression(0185.NOAA.Precip.Month,2761.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 6925 - Red Feather Lakes, combined with Red Feather Lakes 2 SE, combined with Red Feather Lakes 6, filled
with stm,
#        then regressed with Estes Park filled
6925.NOAA.Precip.Month~HydroBase
6930.NOAA.Precip.Month~HydroBase
fillFromTS(6925.NOAA.Precip.Month,6930.NOAA.Precip.Month,*,*)
free(TSID="6930.NOAA.Precip.Month")
6921.NOAA.Precip.Month~HydroBase
fillFromTS(6921.NOAA.Precip.Month,6925.NOAA.Precip.Month,*,*)
free(TSID="6925.NOAA.Precip.Month")
redf_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\redf_p.stm
fillFromTS(6921.NOAA.Precip.Month,redf_p...MONTH,*,*)
free(TSID="redf_p...MONTH")
fillRegression(6921.NOAA.Precip.Month,2761.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 7515 - Sedgwick 5 S combined with Sedgwick, filled with stm, then regressed wtih Fleming 3 SW combined with
Fleming
7515.NOAA.Precip.Month~HydroBase
7513.NOAA.Precip.Month~HydroBase
fillFromTS(7515.NOAA.Precip.Month,7513.NOAA.Precip.Month,*,*)
sedg_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\sedg_p.stm
fillFromTS(7515.NOAA.Precip.Month,sedg_p...MONTH,*,*)
free(TSID="7513.NOAA.Precip.Month")
free(TSID="sedg_p...MONTH")
2947.NOAA.Precip.Month~HydroBase
2944.NOAA.Precip.Month~HydroBase
fillFromTS(2947.NOAA.Precip.Month,2944.NOAA.Precip.Month,*,*)
free(TSID="2944.NOAA.Precip.Month")
fillRegression(7515.NOAA.Precip.Month,2947.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="2947.NOAA.Precip.Month")
#
# 4413 - Julesburg filled with stm, then regressed with Sedgwick 5 S combined with Sedgwick filled
4413.NOAA.Precip.Month~HydroBase
jule_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\jule_p.stm
fillFromTS(4413.NOAA.Precip.Month,jule_p...MONTH,*,*)
free(TSID="jule_p...MONTH")
fillRegression(4413.NOAA.Precip.Month,7515.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 5934 - New Raymer 21 N combined with Kauffman 4 SSE filled with stm, then regressed with Sterling
5934.NOAA.Precip.Month~HydroBase
4460.NOAA.Precip.Month~HydroBase
fillFromTS(5934.NOAA.Precip.Month,4460.NOAA.Precip.Month,*,*)
free(TSID="4460.NOAA.Precip.Month")
nr21_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\nr21_p.stm
fillFromTS(5934.NOAA.Precip.Month,nr21_p...MONTH,*,*)
free(TSID="nr21_p...MONTH")
7950.NOAA.Precip.Month~HydroBase
ster_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\ster_p.stm
fillFromTS(7950.NOAA.Precip.Month,ster_p...MONTH,*,*)
free(TSID="ster_p...MONTH")
fillRegression(5934.NOAA.Precip.Month,7950.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 7950 - Sterling filled with stm, then regressed with Akron 4 E combined with Akron 1 N
0109.NOAA.Precip.Month~HydroBase
0114.NOAA.Precip.Month~HydroBase
akro_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\akro_p.stm
fillFromTS(0109.NOAA.Precip.Month,0114.NOAA.Precip.Month,*,*)
fillFromTS(0109.NOAA.Precip.Month,akro_p...MONTH,*,*)
```

```
free(TSID="0114.NOAA.Precip.Month")
free(TSID="akro_p...MONTH")
fillRegression(7950.NOAA.Precip.Month,0109.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="0109.NOAA.Precip.Month")
#
# 5922 - New Raymer filled with stm, then regressed with Fort Morgan
5922.NOAA.Precip.Month~HydroBase
newr_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\newr_p.stm
fillFromTS(5922.NOAA.Precip.Month,newr_p...MONTH,*,*)
free(TSID="newr_p...MONTH")
3038.NOAA.Precip.Month~HydroBase
ftmo_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\ftmo_p.stm
fillFromTS(3038.NOAA.Precip.Month,ftmo_p...MONTH,*,*)
free(TSID="ftmo_p...MONTH")
fillRegression(5922.NOAA.Precip.Month,3038.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="3038.NOAA.Precip.Month")
#
# 2790 - Evergreen combined with Evergreen 2 SW filled with stm, then regressed with Lakewood combined with
Edgewater
2790.NOAA.Precip.Month~HydroBase
2795.NOAA.Precip.Month~HydroBase
ever_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\ever_p.stm
fillFromTS(2790.NOAA.Precip.Month,2795.NOAA.Precip.Month,*,*)
fillFromTS(2790.NOAA.Precip.Month,ever_p...MONTH,*,*)
free(TSID="ever_p...MONTH")
free(TSID="2795.NOAA.Precip.Month")
4762.NOAA.Precip.Month~HydroBase
2557.NOAA.Precip.Month~HydroBase
lake_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\lake_p.stm
fillFromTS(4762.NOAA.Precip.Month,2557.NOAA.Precip.Month,*,*)
fillFromTS(4762.NOAA.Precip.Month,lake_p...MONTH,*,*)
free(TSID="lake_p...MONTH")
free(TSID="2557.NOAA.Precip.Month")
fillRegression(2790.NOAA.Precip.Month,4762.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="4762.NOAA.Precip.Month")
#
# Water District 47 - Division 6 - West Hydrobase commmands
# 8756 - Walden filled with stm, then regressed with Spicer filled with stm
# 8756.NOAA.Precip.Month~HydroBase
# wald_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\wald_p.stm
# fillFromTS(8756.NOAA.Precip.Month,wald_p...MONTH,*,*)
# 7848.NOAA.Precip.Month~HydroBase
# spic_p...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\spic_p.stm
# fillFromTS(7848.NOAA.Precip.Month,spic_p...MONTH,*,*)
#
fillRegression(8756.NOAA.Precip.Month,7848.NOAA.Precip.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
# free(TSID="wald_p...MONTH")
# free(TSID="spic_p...MONTH")
# free(TSID="7848.NOAA.Precip.Month")
#
8756...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Precip\waldencomp_p.stm
#
writeStateMod("Precip_Out.stm",*)
```

Monthly Temperature Command File:

```
setOutputPeriod(01/1950,12/2003)
setOutputYearType(Calendar)
#
# 0109 - Akron 4 E combined with Akron 1 N, filled with stm, then regressed with Leroy
0109.NOAA.TempMean.Month~HydroBase
0114.NOAA.TempMean.Month~HydroBase
fillFromTS(0109.NOAA.TempMean.Month,0114.NOAA.TempMean.Month,*,*)
free(TSID="0114.NOAA.TempMean.Month")
akro_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\akro_t.stm
fillFromTS(0109.NOAA.TempMean.Month,akro_t...MONTH,*,*)
free(TSID="akro_t...MONTH")
4945.NOAA.TempMean.Month~HydroBase
fillRegression(0109.NOAA.TempMean.Month,4945.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 0945 - Briggsdale filled with stm, then regressed with Fort Morgan
0945.NOAA.TempMean.Month~HydroBase
brig_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\brig_t.stm
fillFromTS(0945.NOAA.TempMean.Month,brig_t...MONTH,*,*)
free(TSID="brig_t...MONTH")
3038.NOAA.TempMean.Month~HydroBase
ftmo_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\ftmo_t.stm
fillFromTS(3038.NOAA.TempMean.Month,ftmo_t...MONTH,*,*)
free(TSID="ftmo_t...MONTH")
fillRegression(0945.NOAA.TempMean.Month,3038.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 5922 - New Raymer filled with stm, then regressed with Sterling
7950.NOAA.TempMean.Month~HydroBase
ster_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\ster_t.stm
fillFromTS(7950.NOAA.TempMean.Month,ster_t...MONTH,*,*)
free(TSID="ster_t...MONTH")
5922.NOAA.TempMean.Month~HydroBase
newr_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\newr_t.stm
fillFromTS(5922.NOAA.TempMean.Month,newr_t...MONTH,*,*)
free(TSID="newr_t...MONTH")
fillRegression(5922.NOAA.TempMean.Month,7950.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 5934 - New Raymer 21 N combined with Kauffman filled with stm, then regressed with Sterling
5934.NOAA.TempMean.Month~HydroBase
4460.NOAA.TempMean.Month~HydroBase
fillFromTS(5934.NOAA.TempMean.Month,4460.NOAA.TempMean.Month,*,*)
free(TSID="4460.NOAA.TempMean.Month")
nr21_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\nr21_t.stm
fillFromTS(5934.NOAA.TempMean.Month,nr21_t...MONTH,*,*)
free(TSID="nr21_t...MONTH")
fillRegression(5934.NOAA.TempMean.Month,7950.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 7950 - Sterling filled with stm, then regressed with Leroy
fillRegression(7950.NOAA.TempMean.Month,4945.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
free(TSID="4945.NOAA.TempMean.Month")
#
# 1528 - Cheesman filled with stm, then regressed with Bailey
1528.NOAA.TempMean.Month~HydroBase
chee_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\chee_t.stm
fillFromTS(1528.NOAA.TempMean.Month,chee_t...MONTH,*,*)
free(TSID="chee_t...MONTH")
0454.NOAA.TempMean.Month~HydroBase
bail_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\bail_t.stm
fillFromTS(0454.NOAA.TempMean.Month,bail_t...MONTH,*,*)
free(TSID="bail_t...MONTH")
fillRegression(1528.NOAA.TempMean.Month,0454.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 0263 - Antero Reservoir filled with stm, then regressed with Bailey
0263.NOAA.TempMean.Month~HydroBase
ante_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\ante_t.stm
fillFromTS(0263.NOAA.TempMean.Month,ante_t...MONTH,*,*)
free(TSID="ante_t...MONTH")
fillRegression(0263.NOAA.TempMean.Month,0454.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 0454 - Bailey filled with stm, then regressed with Grant
3530.NOAA.TempMean.Month~HydroBase
fillRegression(0454.NOAA.TempMean.Month,3530.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
```

```
free(TSID="3530.NOAA.TempMean.Month")
#
# 3261 - Georgetown filled with stm, then regressed with Bailey filled
3261.NOAA.TempMean.Month~HydroBase
geor_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\geor_t.stm
fillFromTS(3261.NOAA.TempMean.Month,geor_t...MONTH,*,*)
free(TSID="geor_t...MONTH")
fillRegression(3261.NOAA.TempMean.Month,0454.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 3005 - Fort Collins filled with stm
3005.NOAA.TempMean.Month~HydroBase
ftco_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\ftco_t.stm
fillFromTS(3005.NOAA.TempMean.Month,ftco_t...MONTH,*,*)
free(TSID="ftco_t...MONTH")
#
# 3553 - Greeley UNC combined with Greeley, filled with stm, then regressed with Fort Collins
3553.NOAA.TempMean.Month~HydroBase
3546.NOAA.TempMean.Month~HydroBase
fillFromTS(3553.NOAA.TempMean.Month,3546.NOAA.TempMean.Month,*,*)
gree_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\gree_t.stm
fillFromTS(3553.NOAA.TempMean.Month,gree_t...MONTH,*,*)
free(TSID="3546.NOAA.TempMean.Month")
free(TSID="gree_t...MONTH")
fillRegression(3553.NOAA.TempMean.Month,3005.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 6921 - RF Lakes combined with RD Lakes 2 SE combined with RF Lakes 6, filled with stm, then regressed with Ft
Collins
6925.NOAA.TempMean.Month~HydroBase
6930.NOAA.TempMean.Month~HydroBase
fillFromTS(6925.NOAA.TempMean.Month,6930.NOAA.TempMean.Month,*,*)
free(TSID="6930.NOAA.TempMean.Month")
6921.NOAA.TempMean.Month~HydroBase
fillFromTS(6921.NOAA.TempMean.Month,6925.NOAA.TempMean.Month,*,*)
free(TSID="6925.NOAA.TempMean.Month")
redf_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\redf_t.stm
fillFromTS(6921.NOAA.TempMean.Month,redf_t...MONTH,*,*)
free(TSID="redf_t...MONTH")
fillRegression(6921.NOAA.TempMean.Month,3005.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 2761 - Estes Park 1 SSE combined with Estes Park, filled with stm, then regressed with Fort Collins
2761.NOAA.TempMean.Month~HydroBase
2759.NOAA.TempMean.Month~HydroBase
fillFromTS(2761.NOAA.TempMean.Month,2759.NOAA.TempMean.Month,*,*)
free(TSID="2759.NOAA.TempMean.Month")
este_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\este_t.stm
fillFromTS(2761.NOAA.TempMean.Month,este_t...MONTH,*,*)
free(TSID="este_t...MONTH")
fillRegression(2761.NOAA.TempMean.Month,3005.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 0185 - Allenspark 1 NW combined with Allenspark 2 NNW, filled with stm, the regressed with Estes Park filled
# Note SetDate commands so as not to include low or neg. data points in regression
0185.NOAA.TempMean.Month~HydroBase
0183.NOAA.TempMean.Month~HydroBase
fillFromTS(0185.NOAA.TempMean.Month,0183.NOAA.TempMean.Month,*,*)
free(TSID="0183.NOAA.TempMean.Month")
alle_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\alle_t.stm
fillFromTS(0185.NOAA.TempMean.Month,alle_t...MONTH,*,*)
free(TSID="alle_t...MONTH")
setDataValue(0185.NOAA.TempMean.Month,01/1985,-999)
setDataValue(0185.NOAA.TempMean.Month,01/1988,-999)
fillRegression(0185.NOAA.TempMean.Month,2761.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
setDataValue(0185.NOAA.TempMean.Month,01/1985,7.2)
setDataValue(0185.NOAA.TempMean.Month,01/1988,-6.3)
#
# 7515 - Sedgwick 5 S combined with Sedgwick, filled with stm, then regressed with Holyoke
7515.NOAA.TempMean.Month~HydroBase
7513.NOAA.TempMean.Month~HydroBase
fillFromTS(7515.NOAA.TempMean.Month,7513.NOAA.TempMean.Month,*,*)
free(TSID="7513.NOAA.TempMean.Month")
sedg_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\sedg_t.stm
fillFromTS(7515.NOAA.TempMean.Month,sedg_t...MONTH,*,*)
free(TSID="sedg_t...MONTH")
4082.NOAA.TempMean.Month~HydroBase
fillRegression(7515.NOAA.TempMean.Month,4082.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
free(TSID="4082.NOAA.TempMean.Month")
```

```
#
# 4413 - Julesburg filled with stm, then regressed with Sedgwick 5 S combined with Sedgwick filled
4413.NOAA.TempMean.Month~HydroBase
jule_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\jule_t.stm
fillFromTS(4413.NOAA.TempMean.Month,jule_t...MONTH,*,*)
free(TSID="jule_t...MONTH")
fillRegression(4413.NOAA.TempMean.Month,7515.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 0848 - Boulder filled with stm, then regressed with Longmont
0848.NOAA.TempMean.Month~HydroBase
boul_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\boul_t.stm
fillFromTS(0848.NOAA.TempMean.Month,boul_t...MONTH,*,*)
free(TSID="boul_t...MONTH")
5116.NOAA.TempMean.Month~HydroBase
long_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\long_t.stm
fillFromTS(5116.NOAA.TempMean.Month,long_t...MONTH,*,*)
free(TSID="long_t...MONTH")
fillRegression(0848.NOAA.TempMean.Month,5116.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 5116 - Longmont 2 ESE filled with stm, then regressed with Fort Collins
fillRegression(5116.NOAA.TempMean.Month,3005.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 6323 - Parker 2 N combined with Parker 6 E, filled with stm, then regressed with Denver
6323.NOAA.TempMean.Month~HydroBase
6326.NOAA.TempMean.Month~HydroBase
park_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\park_t.stm
fillFromTS(6323.NOAA.TempMean.Month,6326.NOAA.TempMean.Month,*,*)
fillFromTS(6323.NOAA.TempMean.Month,park_t...MONTH,*,*)
free(TSID="6326.NOAA.TempMean.Month")
free(TSID="park_t...MONTH")
2220.NOAA.TempMean.Month~HydroBase
denv_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\denv_t.stm
fillFromTS(2220.NOAA.TempMean.Month,denv_t...MONTH,*,*)
free(TSID="denv_t...MONTH")
fillRegression(6323.NOAA.TempMean.Month,2220.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 1401 - Castle Rock filled with stm, then regressed with Denver
1401.NOAA.TempMean.Month~HydroBase
cast_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\cast_t.stm
fillFromTS(1401.NOAA.TempMean.Month,cast_t...MONTH,*,*)
free(TSID="cast_t...MONTH")
fillRegression(1401.NOAA.TempMean.Month,2220.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 1179 - Byers 5 ENE filled with stm, then regressed with Denver
1179.NOAA.TempMean.Month~HydroBase
byer_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\byer_t.stm
fillFromTS(1179.NOAA.TempMean.Month,byer_t...MONTH,*,*)
free(TSID="byer_t...MONTH")
fillRegression(1179.NOAA.TempMean.Month,2220.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 4762 - Lakewood combined with Edgewater, filled with stm, then regressed with Denver
4762.NOAA.TempMean.Month~HydroBase
2557.NOAA.TempMean.Month~HydroBase
lake_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\lake_t.stm
fillFromTS(4762.NOAA.TempMean.Month,2557.NOAA.TempMean.Month,*,*)
fillFromTS(4762.NOAA.TempMean.Month,lake_t...MONTH,*,*)
free(TSID="2557.NOAA.TempMean.Month")
free(TSID="lake_t...MONTH")
fillRegression(4762.NOAA.TempMean.Month,2220.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
# 2790 - Evergreen filled stm, then regressed with Denver
2790.NOAA.TempMean.Month~HydroBase
ever_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\ever_t.stm
fillFromTS(2790.NOAA.TempMean.Month,ever_t...MONTH,*,*)
free(TSID="ever_t...MONTH")
fillRegression(2790.NOAA.TempMean.Month,2220.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
#
#2220 - Denver Stapleton Intl AP filled with stm, then regressed with Parker 2 N combined with Parker 6 E
6323.NOAA.TempMean.Month~HydroBase
6326.NOAA.TempMean.Month~HydroBase
park_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\park_t.stm
fillFromTS(6323.NOAA.TempMean.Month,6326.NOAA.TempMean.Month,*,*)
fillFromTS(6323.NOAA.TempMean.Month,park_t...MONTH,*,*)
```

```
free(TSID="6326.NOAA.TempMean.Month")
free(TSID="park_t...MONTH")
fillRegression(2220.NOAA.TempMean.Month,6323.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
free(TSID="6323.NOAA.TempMean.Month")
#
# 3038 - Fort Morgan filled with stm, then regressed with Briggsdale
0945.NOAA.TempMean.Month~HydroBase
brig_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\brig_t.stm
fillFromTS(0945.NOAA.TempMean.Month,brig_t...MONTH,*,*)
free(TSID="brig_t...MONTH")
fillRegression(3038.NOAA.TempMean.Month,0945.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
free(TSID="0945.NOAA.TempMean.Month")
#
#
# Water District 47 - Division 6 - West Hydrobase Commands
# 8756 - Walden filled with stm, then regressed with Spicer filled with stm
# 8756.NOAA.TempMean.Month~HydroBase
# wald_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\wald_t.stm
# fillFromTS(8756.NOAA.TempMean.Month,wald_t...MONTH,*,*)
# free(TSID="wald_t...MONTH")
# 7848.NOAA.TempMean.Month~HydroBase
# spic_t...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\spic_t.stm
# fillFromTS(7848.NOAA.TempMean.Month,spic_t...MONTH,*,*)
# free(TSID="spic_t...MONTH")
#
fillRegression(8756.NOAA.TempMean.Month,7848.NOAA.TempMean.Month,MonthlyEquations,Linear,*,12/2003,01/1950,12/2
003)
# free(TSID="7848.NOAA.TempMean.Month")
#
8756...MONTH~StateMod~C:\Projects\SPDSS\Task 53\STM Files\Temperature\waldencomp_t.stm
#
writeStateMod("Temp_Out.stm",*)
```

Daily Minimum Temperature Command File:

```
# It is anticipated that in the future, TSTool will have the capability of calculating frost dates from filled minimum temperatures
# When that capability becomes available, new commands will need to be added to this file.
#
setOutputPeriod(01/01/1950,12/31/2003)
setOutputYearType(Calendar)
#
# 0945 - Briggsdale regressed with Fort Morgan
0945.NOAA.TempMin.Day~HydroBase
3038.NOAA.TempMin.Day~HydroBase
fillRegression(0945.NOAA.TempMin.Day,3038.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 3038 - Fort Morgan regressed with Sterling
7950.NOAA.TempMin.Day~HydroBase
fillRegression(3038.NOAA.TempMin.Day,7950.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 5922 - New Raymer regressed with Sterling
5922.NOAA.TempMin.Day~HydroBase
fillRegression(5922.NOAA.TempMin.Day,7950.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 5934 - New Raymer 21 filled with Kauffman regressed with Sterling
5934.NOAA.TempMin.Day~HydroBase
4460.NOAA.TempMin.Day~HydroBase
fillFromTS(5934.NOAA.TempMin.Day,4460.NOAA.TempMin.Day,*,*)
free(TSID="4460.NOAA.TempMin.Day")
fillRegression(5934.NOAA.TempMin.Day,7950.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 0454 - Bailey regressed with Cheesman
0454.NOAA.TempMin.Day~HydroBase
1528.NOAA.TempMin.Day~HydroBase
fillRegression(0454.NOAA.TempMin.Day,1528.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 3261 - Georgetown regressed with Bailey filled
# Note ReplaceValue commands so as not to include extreme high temp. data points in regression
3261.NOAA.TempMin.Day~HydroBase
replaceValue(3261.NOAA.TempMin.Day,100,1000,-999,*,*)
fillRegression(3261.NOAA.TempMin.Day,0454.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 0263 - Antero Reservoir regressed with Bailey filled
0263.NOAA.TempMin.Day~HydroBase
fillRegression(0263.NOAA.TempMin.Day,0454.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 6921 - RF Lakes combined with RF Lakes 2 SE combined with RF Lakes 6 regressed with Ft Collins
3005.NOAA.TempMin.Day~HydroBase
6925.NOAA.TempMin.Day~HydroBase
6930.NOAA.TempMin.Day~HydroBase
fillFromTS(6925.NOAA.TempMin.Day,6930.NOAA.TempMin.Day,*,*)
free(TSID="6930.NOAA.TempMin.Day")
6921.NOAA.TempMin.Day~HydroBase
fillFromTS(6921.NOAA.TempMin.Day,6925.NOAA.TempMin.Day,*,*)
free(TSID="6925.NOAA.TempMin.Day")
fillRegression(6921.NOAA.TempMin.Day,3005.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 2761 - Estes Park 1 SSE combined with Estes Park, regressed with Fort Collins
2761.NOAA.TempMin.Day~HydroBase
2759.NOAA.TempMin.Day~HydroBase
fillFromTS(2761.NOAA.TempMin.Day,2759.NOAA.TempMin.Day,*,*)
free(TSID="2759.NOAA.TempMin.Day")
fillRegression(2761.NOAA.TempMin.Day,3005.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 0185 - Allenspark 1 NW combined with Allenspark 2 NNW regressed with Estes Park 1 SSE combined with Estes Park filled
# Note ReplaceValue commands so as not to include extreme low temp. data points in regression
0185.NOAA.TempMin.Day~HydroBase
0183.NOAA.TempMin.Day~HydroBase
fillFromTS(0185.NOAA.TempMin.Day,0183.NOAA.TempMin.Day,*,*)
free(TSID="0183.NOAA.TempMin.Day")
replaceValue(0185.NOAA.TempMin.Day,-60,-50,-999,*,*)
fillRegression(0185.NOAA.TempMin.Day,2761.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 7515 - Sedgwick 5 S combined with Sedgwick regressed with Holyoke
7515.NOAA.TempMin.Day~HydroBase
7513.NOAA.TempMin.Day~HydroBase
fillFromTS(7515.NOAA.TempMin.Day,7513.NOAA.TempMin.Day,*,*)
free(TSID="7513.NOAA.TempMin.Day")
4082.NOAA.TempMin.Day~HydroBase
fillRegression(7515.NOAA.TempMin.Day,4082.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="4082.NOAA.TempMin.Day")
#
```

```
# 4413 - Julesburg regressed with Sedgwick 5 S combined with Sedgwick filled
4413.NOAA.TempMin.Day~HydroBase
fillRegression(4413.NOAA.TempMin.Day,7515.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 0848 - Boulder regressed with Longmont
0848.NOAA.TempMin.Day~HydroBase
5116.NOAA.TempMin.Day~HydroBase
fillRegression(0848.NOAA.TempMin.Day,5116.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 5116 - Longmont 2 ESE regressed with Fort Collins
fillRegression(5116.NOAA.TempMin.Day,3005.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 6323 - Parker 2 N combined with Parker 6 E regressed with Denver
6323.NOAA.TempMin.Day~HydroBase
6326.NOAA.TempMin.Day~HydroBase
fillFromTS(6323.NOAA.TempMin.Day,6326.NOAA.TempMin.Day,*,*)
free(TSID="6326.NOAA.TempMin.Day")
2220.NOAA.TempMin.Day~HydroBase
fillRegression(6323.NOAA.TempMin.Day,2220.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 1401 - Castle Rock regressed with Denver
1401.NOAA.TempMin.Day~HydroBase
fillRegression(1401.NOAA.TempMin.Day,2220.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 1179 - Byers 5 ENE regressed with Denver
1179.NOAA.TempMin.Day~HydroBase
fillRegression(1179.NOAA.TempMin.Day,2220.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 4762 - Lakewood combined with Edgewater regressed with Denver
4762.NOAA.TempMin.Day~HydroBase
2557.NOAA.TempMin.Day~HydroBase
fillFromTS(4762.NOAA.TempMin.Day,2557.NOAA.TempMin.Day,*,*)
free(TSID="2557.NOAA.TempMin.Day")
fillRegression(4762.NOAA.TempMin.Day,2220.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
#
# 2790 - Evergreen regressed with Denver
2790.NOAA.TempMin.Day~HydroBase
fillRegression(2790.NOAA.TempMin.Day,2220.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="2220.NOAA.TempMin.Day")
#
# 1528 - Cheesman regressed with Bailey
0454.NOAA.TempMin.Day~HydroBase
fillRegression(1528.NOAA.TempMin.Day,0454.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="0454.NOAA.TempMin.Day")
#
# 3005 - Fort Collins regressed with Longmont
5116.NOAA.TempMin.Day~HydroBase
fillRegression(3005.NOAA.TempMin.Day,5116.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="5116.NOAA.TempMin.Day")
#
# 7950 - Sterling regressed with Fort Morgan
3038.NOAA.TempMin.Day~HydroBase
fillRegression(7950.NOAA.TempMin.Day,3038.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="3038.NOAA.TempMin.Day")
#
# Following commands require a HydroBase that includes Division 6!
# 8756 - Walden regressed with Spicer
8756.NOAA.TempMin.Day~HydroBase
7848.NOAA.TempMin.Day~HydroBase
fillRegression(8756.NOAA.TempMin.Day,7848.NOAA.TempMin.Day,MonthlyEquations,Linear,*,12/2003,01/1950,12/2003)
free(TSID="7848.NOAA.TempMin.Day")
#
# selectTimeSeries(Pos="10")
# writeDateValue(OutputFile="3261.in",TSList="SelectedTS")
```

Frost Date Command File:

```
setOutputPeriod(01/1950,12/2003)
# 0109 - Akron combo, combined with paper records
0109.NOAA.FrostDateF28F.Year~HydroBase
0109.NOAA.FrostDateF32F.Year~HydroBase
0109.NOAA.FrostDateL28S.Year~HydroBase
0109.NOAA.FrostDateL32S.Year~HydroBase
0114.NOAA.FrostDateF28F.Year~HydroBase
0114.NOAA.FrostDateF32F.Year~HydroBase
0114.NOAA.FrostDateL28S.Year~HydroBase
0114.NOAA.FrostDateL32S.Year~HydroBase
fillFromTS(0109.NOAA.FrostDateF28F.Year,0114.NOAA.FrostDateF28F.Year,*,*)
fillFromTS(0109.NOAA.FrostDateF32F.Year,0114.NOAA.FrostDateF32F.Year,*,*)
```

```
fillFromTS(0109.NOAA.FrostDateL28S.Year,0114.NOAA.FrostDateL28S.Year,*,*)
fillFromTS(0109.NOAA.FrostDateL32S.Year,0114.NOAA.FrostDateL32S.Year,*,*)
free(TSID="0114.NOAA.FrostDateF28F.Year")
free(TSID="0114.NOAA.FrostDateF32F.Year")
free(TSID="0114.NOAA.FrostDateL32S.Year")
free(TSID="0114.NOAA.FrostDateL28S.Year")
akro_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\akro_fd.stm
akro_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\akro_fd.stm
akro_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\akro_fd.stm
akro_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\akro_fd.stm
fillFromTS(0109.NOAA.FrostDateF28F.Year,akro_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(0109.NOAA.FrostDateF32F.Year,akro_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(0109.NOAA.FrostDateL28S.Year,akro_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(0109.NOAA.FrostDateL32S.Year,akro_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="akro_fd.StateCU.FrostDateL28S.Year")
free(TSID="akro_fd.StateCU.FrostDateL32S.Year")
free(TSID="akro_fd.StateCU.FrostDateF32F.Year")
free(TSID="akro_fd.StateCU.FrostDateF28F.Year")
#
# 0185 - Allenspark combo, combined with frost.exe output
0185.NOAA.FrostDateF28F.Year~HydroBase
0185.NOAA.FrostDateF32F.Year~HydroBase
0185.NOAA.FrostDateL28S.Year~HydroBase
0185.NOAA.FrostDateL32S.Year~HydroBase
0183.NOAA.FrostDateF28F.Year~HydroBase
0183.NOAA.FrostDateF32F.Year~HydroBase
0183.NOAA.FrostDateL28S.Year~HydroBase
0183.NOAA.FrostDateL32S.Year~HydroBase
fillFromTS(0185.NOAA.FrostDateF28F.Year,0183.NOAA.FrostDateF28F.Year,*,*)
fillFromTS(0185.NOAA.FrostDateF32F.Year,0183.NOAA.FrostDateF32F.Year,*,*)
fillFromTS(0185.NOAA.FrostDateL28S.Year,0183.NOAA.FrostDateL28S.Year,*,*)
fillFromTS(0185.NOAA.FrostDateL32S.Year,0183.NOAA.FrostDateL32S.Year,*,*)
free(TSID="0183.NOAA.FrostDateF28F.Year")
free(TSID="0183.NOAA.FrostDateF32F.Year")
free(TSID="0183.NOAA.FrostDateL32S.Year")
free(TSID="0183.NOAA.FrostDateL28S.Year")
0185.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0185.stm
0185.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0185.stm
0185.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0185.stm
0185.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0185.stm
fillFromTS(0185.NOAA.FrostDateF28F.Year,0185.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(0185.NOAA.FrostDateF32F.Year,0185.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(0185.NOAA.FrostDateL28S.Year,0185.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(0185.NOAA.FrostDateL32S.Year,0185.StateCU.FrostDateL32S.Year,*,*)
free(TSID="0185.StateCU.FrostDateL28S.Year")
free(TSID="0185.StateCU.FrostDateL32S.Year")
free(TSID="0185.StateCU.FrostDateF32F.Year")
free(TSID="0185.StateCU.FrostDateF28F.Year")
#
# 0263 - Antero, combined with frost.exe output
0263.NOAA.FrostDateF28F.Year~HydroBase
0263.NOAA.FrostDateF32F.Year~HydroBase
0263.NOAA.FrostDateL28S.Year~HydroBase
0263.NOAA.FrostDateL32S.Year~HydroBase
0263.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0263.stm
0263.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0263.stm
0263.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0263.stm
0263.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0263.stm
fillFromTS(0263.NOAA.FrostDateF28F.Year,0263.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(0263.NOAA.FrostDateF32F.Year,0263.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(0263.NOAA.FrostDateL28S.Year,0263.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(0263.NOAA.FrostDateL32S.Year,0263.StateCU.FrostDateL32S.Year,*,*)
free(TSID="0263.StateCU.FrostDateL28S.Year")
free(TSID="0263.StateCU.FrostDateL32S.Year")
free(TSID="0263.StateCU.FrostDateF32F.Year")
free(TSID="0263.StateCU.FrostDateF28F.Year")
#
# 0454 - Bailey, combined with frost.exe output
0454.NOAA.FrostDateF28F.Year~HydroBase
0454.NOAA.FrostDateF32F.Year~HydroBase
0454.NOAA.FrostDateL28S.Year~HydroBase
0454.NOAA.FrostDateL32S.Year~HydroBase
0454.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0454.stm
0454.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0454.stm
0454.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0454.stm
0454.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0454.stm
fillFromTS(0454.NOAA.FrostDateF28F.Year,0454.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(0454.NOAA.FrostDateF32F.Year,0454.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(0454.NOAA.FrostDateL28S.Year,0454.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(0454.NOAA.FrostDateL32S.Year,0454.StateCU.FrostDateL32S.Year,*,*)
free(TSID="0454.StateCU.FrostDateL28S.Year")
```

```
free(TSID="0454.StateCU.FrostDateL32S.Year")
free(TSID="0454.StateCU.FrostDateF32F.Year")
free(TSID="0454.StateCU.FrostDateF28F.Year")
#
# 0848 - Boulder combined with paper records, combined with frost.exe output
0848.NOAA.FrostDateF28F.Year~HydroBase
0848.NOAA.FrostDateF32F.Year~HydroBase
0848.NOAA.FrostDateL28S.Year~HydroBase
0848.NOAA.FrostDateL32S.Year~HydroBase
boul_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\boul_fd.stm
boul_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\boul_fd.stm
boul_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\boul_fd.stm
boul_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\boul_fd.stm
fillFromTS(0848.NOAA.FrostDateF28F.Year,boul_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(0848.NOAA.FrostDateF32F.Year,boul_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(0848.NOAA.FrostDateL28S.Year,boul_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(0848.NOAA.FrostDateL32S.Year,boul_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="boul_fd.StateCU.FrostDateL28S.Year")
free(TSID="boul_fd.StateCU.FrostDateL32S.Year")
free(TSID="boul_fd.StateCU.FrostDateF32F.Year")
free(TSID="boul_fd.StateCU.FrostDateF28F.Year")
0848.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0848.stm
0848.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0848.stm
0848.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0848.stm
0848.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0848.stm
fillFromTS(0848.NOAA.FrostDateF28F.Year,0848.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(0848.NOAA.FrostDateF32F.Year,0848.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(0848.NOAA.FrostDateL28S.Year,0848.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(0848.NOAA.FrostDateL32S.Year,0848.StateCU.FrostDateL32S.Year,*,*)
free(TSID="0848.StateCU.FrostDateL28S.Year")
free(TSID="0848.StateCU.FrostDateL32S.Year")
free(TSID="0848.StateCU.FrostDateF32F.Year")
free(TSID="0848.StateCU.FrostDateF28F.Year")
#
# 0945 - Briggsdale combined with paper records, combined with frost.exe output
0945.NOAA.FrostDateF28F.Year~HydroBase
0945.NOAA.FrostDateF32F.Year~HydroBase
0945.NOAA.FrostDateL28S.Year~HydroBase
0945.NOAA.FrostDateL32S.Year~HydroBase
brig_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\brig_fd.stm
brig_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\brig_fd.stm
brig_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\brig_fd.stm
brig_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\brig_fd.stm
fillFromTS(0945.NOAA.FrostDateF28F.Year,brig_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(0945.NOAA.FrostDateF32F.Year,brig_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(0945.NOAA.FrostDateL28S.Year,brig_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(0945.NOAA.FrostDateL32S.Year,brig_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="brig_fd.StateCU.FrostDateL28S.Year")
free(TSID="brig_fd.StateCU.FrostDateL32S.Year")
free(TSID="brig_fd.StateCU.FrostDateF32F.Year")
free(TSID="brig_fd.StateCU.FrostDateF28F.Year")
0945.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0945.stm
0945.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0945.stm
0945.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0945.stm
0945.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\0945.stm
fillFromTS(0945.NOAA.FrostDateF28F.Year,0945.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(0945.NOAA.FrostDateF32F.Year,0945.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(0945.NOAA.FrostDateL28S.Year,0945.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(0945.NOAA.FrostDateL32S.Year,0945.StateCU.FrostDateL32S.Year,*,*)
free(TSID="0945.StateCU.FrostDateL28S.Year")
free(TSID="0945.StateCU.FrostDateL32S.Year")
free(TSID="0945.StateCU.FrostDateF32F.Year")
free(TSID="0945.StateCU.FrostDateF28F.Year")
#
# 1179 - Byers combined with paper records, combined with frost.exe output
1179.NOAA.FrostDateF28F.Year~HydroBase
1179.NOAA.FrostDateF32F.Year~HydroBase
1179.NOAA.FrostDateL28S.Year~HydroBase
1179.NOAA.FrostDateL32S.Year~HydroBase
byer_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\byer_fd.stm
byer_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\byer_fd.stm
byer_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\byer_fd.stm
byer_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\byer_fd.stm
fillFromTS(1179.NOAA.FrostDateF28F.Year,byer_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(1179.NOAA.FrostDateF32F.Year,byer_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(1179.NOAA.FrostDateL28S.Year,byer_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(1179.NOAA.FrostDateL32S.Year,byer_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="byer_fd.StateCU.FrostDateL28S.Year")
free(TSID="byer_fd.StateCU.FrostDateL32S.Year")
free(TSID="byer_fd.StateCU.FrostDateF32F.Year")
free(TSID="byer_fd.StateCU.FrostDateF28F.Year")
```

```
1179.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1179.stm
1179.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1179.stm
1179.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1179.stm
1179.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1179.stm
fillFromTS(1179.NOAA.FrostDateF28F.Year,1179.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(1179.NOAA.FrostDateF32F.Year,1179.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(1179.NOAA.FrostDateL28S.Year,1179.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(1179.NOAA.FrostDateL32S.Year,1179.StateCU.FrostDateL32S.Year,*,*)
free(TSID="1179.StateCU.FrostDateL28S.Year")
free(TSID="1179.StateCU.FrostDateL32S.Year")
free(TSID="1179.StateCU.FrostDateF32F.Year")
free(TSID="1179.StateCU.FrostDateF28F.Year")
#
# 1401 - Castle Rock combined with paper records, combined with frost.exe output
1401.NOAA.FrostDateF28F.Year~HydroBase
1401.NOAA.FrostDateF32F.Year~HydroBase
1401.NOAA.FrostDateL28S.Year~HydroBase
1401.NOAA.FrostDateL32S.Year~HydroBase
cast_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\cast_fd.stm
cast_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\cast_fd.stm
cast_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\cast_fd.stm
cast_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\cast_fd.stm
fillFromTS(1401.NOAA.FrostDateF28F.Year,cast_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(1401.NOAA.FrostDateF32F.Year,cast_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(1401.NOAA.FrostDateL28S.Year,cast_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(1401.NOAA.FrostDateL32S.Year,cast_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="cast_fd.StateCU.FrostDateL28S.Year")
free(TSID="cast_fd.StateCU.FrostDateL32S.Year")
free(TSID="cast_fd.StateCU.FrostDateF32F.Year")
free(TSID="cast_fd.StateCU.FrostDateF28F.Year")
1401.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1401.stm
1401.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1401.stm
1401.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1401.stm
1401.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1401.stm
fillFromTS(1401.NOAA.FrostDateF28F.Year,1401.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(1401.NOAA.FrostDateF32F.Year,1401.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(1401.NOAA.FrostDateL28S.Year,1401.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(1401.NOAA.FrostDateL32S.Year,1401.StateCU.FrostDateL32S.Year,*,*)
free(TSID="1401.StateCU.FrostDateL28S.Year")
free(TSID="1401.StateCU.FrostDateL32S.Year")
free(TSID="1401.StateCU.FrostDateF32F.Year")
free(TSID="1401.StateCU.FrostDateF28F.Year")
#
# 1528 - Cheesman combined with frost.exe output
1528.NOAA.FrostDateF28F.Year~HydroBase
1528.NOAA.FrostDateF32F.Year~HydroBase
1528.NOAA.FrostDateL28S.Year~HydroBase
1528.NOAA.FrostDateL32S.Year~HydroBase
1528.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1528.stm
1528.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1528.stm
1528.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1528.stm
1528.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\1528.stm
fillFromTS(1528.NOAA.FrostDateF28F.Year,1528.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(1528.NOAA.FrostDateF32F.Year,1528.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(1528.NOAA.FrostDateL28S.Year,1528.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(1528.NOAA.FrostDateL32S.Year,1528.StateCU.FrostDateL32S.Year,*,*)
free(TSID="1528.StateCU.FrostDateL28S.Year")
free(TSID="1528.StateCU.FrostDateL32S.Year")
free(TSID="1528.StateCU.FrostDateF32F.Year")
free(TSID="1528.StateCU.FrostDateF28F.Year")
#
# 2220 - Denver combined with paper records
2220.NOAA.FrostDateF28F.Year~HydroBase
2220.NOAA.FrostDateF32F.Year~HydroBase
2220.NOAA.FrostDateL28S.Year~HydroBase
2220.NOAA.FrostDateL32S.Year~HydroBase
denv_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\denv_fd.stm
denv_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\denv_fd.stm
denv_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\denv_fd.stm
denv_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\denv_fd.stm
fillFromTS(2220.NOAA.FrostDateF28F.Year,denv_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(2220.NOAA.FrostDateF32F.Year,denv_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(2220.NOAA.FrostDateL28S.Year,denv_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(2220.NOAA.FrostDateL32S.Year,denv_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="denv_fd.StateCU.FrostDateL28S.Year")
free(TSID="denv_fd.StateCU.FrostDateL32S.Year")
free(TSID="denv_fd.StateCU.FrostDateF32F.Year")
free(TSID="denv_fd.StateCU.FrostDateF28F.Year")
#
# 2761 - Estes Park combo combined with paper records, combined with frost.exe output
# The 2761 frost dates do not have a source listed in HB, thus the "2761..FrostDate." command.
```

```
2761..FrostDateF28F.Year~HydroBase
2761..FrostDateF32F.Year~HydroBase
2761..FrostDateL32S.Year~HydroBase
2761..FrostDateL28S.Year~HydroBase
2759.NOAA.FrostDateF28F.Year~HydroBase
2759.NOAA.FrostDateF32F.Year~HydroBase
2759.NOAA.FrostDateL28S.Year~HydroBase
2759.NOAA.FrostDateL32S.Year~HydroBase
fillFromTS(2761..FrostDateF28F.Year,2759.NOAA.FrostDateF28F.Year,*,*)
fillFromTS(2761..FrostDateF32F.Year,2759.NOAA.FrostDateF32F.Year,*,*)
fillFromTS(2761..FrostDateL28S.Year,2759.NOAA.FrostDateL28S.Year,*,*)
fillFromTS(2761..FrostDateL32S.Year,2759.NOAA.FrostDateL32S.Year,*,*)
free(TSID="2759.NOAA.FrostDateF28F.Year")
free(TSID="2759.NOAA.FrostDateF32F.Year")
free(TSID="2759.NOAA.FrostDateL32S.Year")
free(TSID="2759.NOAA.FrostDateL28S.Year")
este_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\este_fd.stm
este_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\este_fd.stm
este_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\este_fd.stm
este_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\este_fd.stm
fillFromTS(2761..FrostDateF28F.Year,este_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(2761..FrostDateF32F.Year,este_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(2761..FrostDateL28S.Year,este_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(2761..FrostDateL32S.Year,este_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="este_fd.StateCU.FrostDateL28S.Year")
free(TSID="este_fd.StateCU.FrostDateL32S.Year")
free(TSID="este_fd.StateCU.FrostDateF32F.Year")
free(TSID="este_fd.StateCU.FrostDateF28F.Year")
2761.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\2761.stm
2761.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\2761.stm
2761.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\2761.stm
2761.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\2761.stm
fillFromTS(2761..FrostDateF28F.Year,2761.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(2761..FrostDateF32F.Year,2761.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(2761..FrostDateL28S.Year,2761.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(2761..FrostDateL32S.Year,2761.StateCU.FrostDateL32S.Year,*,*)
free(TSID="2761.StateCU.FrostDateL28S.Year")
free(TSID="2761.StateCU.FrostDateL32S.Year")
free(TSID="2761.StateCU.FrostDateF32F.Year")
free(TSID="2761.StateCU.FrostDateF28F.Year")
#
# 2790 - Evergreen (don't need to combo it b/c Evergreen 2 SW doesn't have temp data) combine with frost.exe
output
2790.NOAA.FrostDateF28F.Year~HydroBase
2790.NOAA.FrostDateF32F.Year~HydroBase
2790.NOAA.FrostDateL28S.Year~HydroBase
2790.NOAA.FrostDateL32S.Year~HydroBase
2790.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\2790.stm
2790.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\2790.stm
2790.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\2790.stm
2790.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\2790.stm
fillFromTS(2790.NOAA.FrostDateF28F.Year,2790.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(2790.NOAA.FrostDateF32F.Year,2790.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(2790.NOAA.FrostDateL28S.Year,2790.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(2790.NOAA.FrostDateL32S.Year,2790.StateCU.FrostDateL32S.Year,*,*)
free(TSID="2790.StateCU.FrostDateL28S.Year")
free(TSID="2790.StateCU.FrostDateL32S.Year")
free(TSID="2790.StateCU.FrostDateF32F.Year")
free(TSID="2790.StateCU.FrostDateF28F.Year")
#
# 3005 - Ft. Collins combine with paper records, combine with frost.exe output
3005.NOAA.FrostDateF28F.Year~HydroBase
3005.NOAA.FrostDateF32F.Year~HydroBase
3005.NOAA.FrostDateL28S.Year~HydroBase
3005.NOAA.FrostDateL32S.Year~HydroBase
ftco_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\ftco_fd.stm
ftco_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\ftco_fd.stm
ftco_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\ftco_fd.stm
ftco_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\ftco_fd.stm
fillFromTS(3005.NOAA.FrostDateF28F.Year,ftco_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(3005.NOAA.FrostDateF32F.Year,ftco_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(3005.NOAA.FrostDateL28S.Year,ftco_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(3005.NOAA.FrostDateL32S.Year,ftco_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="ftco_fd.StateCU.FrostDateL28S.Year")
free(TSID="ftco_fd.StateCU.FrostDateL32S.Year")
free(TSID="ftco_fd.StateCU.FrostDateF32F.Year")
free(TSID="ftco_fd.StateCU.FrostDateF28F.Year")
3005.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3005.stm
3005.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3005.stm
3005.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3005.stm
3005.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3005.stm
```

```
fillFromTS(3005.NOAA.FrostDateF28F.Year,3005.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(3005.NOAA.FrostDateF32F.Year,3005.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(3005.NOAA.FrostDateL28S.Year,3005.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(3005.NOAA.FrostDateL32S.Year,3005.StateCU.FrostDateL32S.Year,*,*)
free(TSID="3005.StateCU.FrostDateL28S.Year")
free(TSID="3005.StateCU.FrostDateL32S.Year")
free(TSID="3005.StateCU.FrostDateF32F.Year")
free(TSID="3005.StateCU.FrostDateF28F.Year")
#
# 3038 - Ft. Morgan combine with paper records, combine with frost.exe output
3038.NOAA.FrostDateF28F.Year~HydroBase
3038.NOAA.FrostDateF32F.Year~HydroBase
3038.NOAA.FrostDateL28S.Year~HydroBase
3038.NOAA.FrostDateL32S.Year~HydroBase
ftmo_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\ftmo_fd.stm
ftmo_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\ftmo_fd.stm
ftmo_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\ftmo_fd.stm
ftmo_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\ftmo_fd.stm
fillFromTS(3038.NOAA.FrostDateF28F.Year,ftmo_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(3038.NOAA.FrostDateF32F.Year,ftmo_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(3038.NOAA.FrostDateL28S.Year,ftmo_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(3038.NOAA.FrostDateL32S.Year,ftmo_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="ftmo_fd.StateCU.FrostDateL28S.Year")
free(TSID="ftmo_fd.StateCU.FrostDateL32S.Year")
free(TSID="ftmo_fd.StateCU.FrostDateF32F.Year")
free(TSID="ftmo_fd.StateCU.FrostDateF28F.Year")
3038.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3038.stm
3038.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3038.stm
3038.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3038.stm
3038.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3038.stm
fillFromTS(3038.NOAA.FrostDateF28F.Year,3038.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(3038.NOAA.FrostDateF32F.Year,3038.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(3038.NOAA.FrostDateL28S.Year,3038.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(3038.NOAA.FrostDateL32S.Year,3038.StateCU.FrostDateL32S.Year,*,*)
free(TSID="3038.StateCU.FrostDateL28S.Year")
free(TSID="3038.StateCU.FrostDateL32S.Year")
free(TSID="3038.StateCU.FrostDateF32F.Year")
free(TSID="3038.StateCU.FrostDateF28F.Year")
#
# 3261 - Georgetown combine with frost.exe output
3261.NOAA.FrostDateF28F.Year~HydroBase
3261.NOAA.FrostDateF32F.Year~HydroBase
3261.NOAA.FrostDateL28S.Year~HydroBase
3261.NOAA.FrostDateL32S.Year~HydroBase
3261.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3261.stm
3261.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3261.stm
3261.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3261.stm
3261.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\3261.stm
fillFromTS(3261.NOAA.FrostDateF28F.Year,3261.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(3261.NOAA.FrostDateF32F.Year,3261.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(3261.NOAA.FrostDateL28S.Year,3261.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(3261.NOAA.FrostDateL32S.Year,3261.StateCU.FrostDateL32S.Year,*,*)
free(TSID="3261.StateCU.FrostDateL28S.Year")
free(TSID="3261.StateCU.FrostDateL32S.Year")
free(TSID="3261.StateCU.FrostDateF32F.Year")
free(TSID="3261.StateCU.FrostDateF28F.Year")
#
# 3553 - Greeley combo combine with paper records
3553.NOAA.FrostDateF28F.Year~HydroBase
3553.NOAA.FrostDateF32F.Year~HydroBase
3553.NOAA.FrostDateL28S.Year~HydroBase
3553.NOAA.FrostDateL32S.Year~HydroBase
3546.NOAA.FrostDateF28F.Year~HydroBase
3546.NOAA.FrostDateF32F.Year~HydroBase
3546.NOAA.FrostDateL28S.Year~HydroBase
3546.NOAA.FrostDateL32S.Year~HydroBase
fillFromTS(3553.NOAA.FrostDateF28F.Year,3546.NOAA.FrostDateF28F.Year,*,*)
fillFromTS(3553.NOAA.FrostDateF32F.Year,3546.NOAA.FrostDateF32F.Year,*,*)
fillFromTS(3553.NOAA.FrostDateL28S.Year,3546.NOAA.FrostDateL28S.Year,*,*)
fillFromTS(3553.NOAA.FrostDateL32S.Year,3546.NOAA.FrostDateL32S.Year,*,*)
free(TSID="3546.NOAA.FrostDateF28F.Year")
free(TSID="3546.NOAA.FrostDateF32F.Year")
free(TSID="3546.NOAA.FrostDateL32S.Year")
free(TSID="3546.NOAA.FrostDateL28S.Year")
gree_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\gree_fd.stm
gree_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\gree_fd.stm
gree_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\gree_fd.stm
gree_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\gree_fd.stm
fillFromTS(3553.NOAA.FrostDateF28F.Year,gree_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(3553.NOAA.FrostDateF32F.Year,gree_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(3553.NOAA.FrostDateL28S.Year,gree_fd.StateCU.FrostDateL28S.Year,*,*)
```

```
fillFromTS(3553.NOAA.FrostDateL32S.Year,gree_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="gree_fd.StateCU.FrostDateL28S.Year")
free(TSID="gree_fd.StateCU.FrostDateL32S.Year")
free(TSID="gree_fd.StateCU.FrostDateF32F.Year")
free(TSID="gree_fd.StateCU.FrostDateF28F.Year")
#
# 4413 - Julesburg combine with paper records combine with frost.exe output
4413.NOAA.FrostDateF28F.Year~HydroBase
4413.NOAA.FrostDateF32F.Year~HydroBase
4413.NOAA.FrostDateL28S.Year~HydroBase
4413.NOAA.FrostDateL32S.Year~HydroBase
jule_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\jule_fd.stm
jule_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\jule_fd.stm
jule_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\jule_fd.stm
jule_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\jule_fd.stm
fillFromTS(4413.NOAA.FrostDateF28F.Year,jule_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(4413.NOAA.FrostDateF32F.Year,jule_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(4413.NOAA.FrostDateL28S.Year,jule_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(4413.NOAA.FrostDateL32S.Year,jule_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="jule_fd.StateCU.FrostDateL28S.Year")
free(TSID="jule_fd.StateCU.FrostDateL32S.Year")
free(TSID="jule_fd.StateCU.FrostDateF32F.Year")
free(TSID="jule_fd.StateCU.FrostDateF28F.Year")
4413.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\4413.stm
4413.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\4413.stm
4413.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\4413.stm
4413.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\4413.stm
fillFromTS(4413.NOAA.FrostDateF28F.Year,4413.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(4413.NOAA.FrostDateF32F.Year,4413.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(4413.NOAA.FrostDateL28S.Year,4413.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(4413.NOAA.FrostDateL32S.Year,4413.StateCU.FrostDateL32S.Year,*,*)
free(TSID="4413.StateCU.FrostDateL28S.Year")
free(TSID="4413.StateCU.FrostDateL32S.Year")
free(TSID="4413.StateCU.FrostDateF32F.Year")
free(TSID="4413.StateCU.FrostDateF28F.Year")
#
# 4762 - Lakewood combo combine with paper records combine with frost.exe output
4762.NOAA.FrostDateF28F.Year~HydroBase
4762.NOAA.FrostDateF32F.Year~HydroBase
4762.NOAA.FrostDateL28S.Year~HydroBase
4762.NOAA.FrostDateL32S.Year~HydroBase
2557.NOAA.FrostDateF28F.Year~HydroBase
2557.NOAA.FrostDateF32F.Year~HydroBase
2557.NOAA.FrostDateL28S.Year~HydroBase
2557.NOAA.FrostDateL32S.Year~HydroBase
fillFromTS(4762.NOAA.FrostDateF28F.Year,2557.NOAA.FrostDateF28F.Year,*,*)
fillFromTS(4762.NOAA.FrostDateF32F.Year,2557.NOAA.FrostDateF32F.Year,*,*)
fillFromTS(4762.NOAA.FrostDateL28S.Year,2557.NOAA.FrostDateL28S.Year,*,*)
fillFromTS(4762.NOAA.FrostDateL32S.Year,2557.NOAA.FrostDateL32S.Year,*,*)
free(TSID="2557.NOAA.FrostDateF28F.Year")
free(TSID="2557.NOAA.FrostDateF32F.Year")
free(TSID="2557.NOAA.FrostDateL32S.Year")
free(TSID="2557.NOAA.FrostDateL28S.Year")
lake_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\lake_fd.stm
lake_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\lake_fd.stm
lake_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\lake_fd.stm
lake_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\lake_fd.stm
fillFromTS(4762.NOAA.FrostDateF28F.Year,lake_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(4762.NOAA.FrostDateF32F.Year,lake_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(4762.NOAA.FrostDateL28S.Year,lake_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(4762.NOAA.FrostDateL32S.Year,lake_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="lake_fd.StateCU.FrostDateL28S.Year")
free(TSID="lake_fd.StateCU.FrostDateL32S.Year")
free(TSID="lake_fd.StateCU.FrostDateF32F.Year")
free(TSID="lake_fd.StateCU.FrostDateF28F.Year")
4762.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\4762.stm
4762.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\4762.stm
4762.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\4762.stm
4762.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\4762.stm
fillFromTS(4762.NOAA.FrostDateF28F.Year,4762.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(4762.NOAA.FrostDateF32F.Year,4762.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(4762.NOAA.FrostDateL28S.Year,4762.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(4762.NOAA.FrostDateL32S.Year,4762.StateCU.FrostDateL32S.Year,*,*)
free(TSID="4762.StateCU.FrostDateL28S.Year")
free(TSID="4762.StateCU.FrostDateL32S.Year")
free(TSID="4762.StateCU.FrostDateF32F.Year")
free(TSID="4762.StateCU.FrostDateF28F.Year")
#
# 5116 - Longmont combine with paper records combine with frost.exe output
5116.NOAA.FrostDateF28F.Year~HydroBase
5116.NOAA.FrostDateF32F.Year~HydroBase
```

```
5116.NOAA.FrostDateL28S.Year~HydroBase
5116.NOAA.FrostDateL32S.Year~HydroBase
long_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\long_fd.stm
long_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\long_fd.stm
long_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\long_fd.stm
long_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\long_fd.stm
fillFromTS(5116.NOAA.FrostDateF28F.Year,long_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(5116.NOAA.FrostDateF32F.Year,long_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(5116.NOAA.FrostDateL28S.Year,long_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(5116.NOAA.FrostDateL32S.Year,long_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="long_fd.StateCU.FrostDateL28S.Year")
free(TSID="long_fd.StateCU.FrostDateL32S.Year")
free(TSID="long_fd.StateCU.FrostDateF32F.Year")
free(TSID="long_fd.StateCU.FrostDateF28F.Year")
5116.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5116.stm
5116.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5116.stm
5116.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5116.stm
5116.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5116.stm
fillFromTS(5116.NOAA.FrostDateF28F.Year,5116.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(5116.NOAA.FrostDateF32F.Year,5116.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(5116.NOAA.FrostDateL28S.Year,5116.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(5116.NOAA.FrostDateL32S.Year,5116.StateCU.FrostDateL32S.Year,*,*)
free(TSID="5116.StateCU.FrostDateL28S.Year")
free(TSID="5116.StateCU.FrostDateL32S.Year")
free(TSID="5116.StateCU.FrostDateF32F.Year")
free(TSID="5116.StateCU.FrostDateF28F.Year")
#
# 5922 - New Raymer combine with paper records combine with frost.exe output
5922.NOAA.FrostDateF28F.Year~HydroBase
5922.NOAA.FrostDateF32F.Year~HydroBase
5922.NOAA.FrostDateL28S.Year~HydroBase
5922.NOAA.FrostDateL32S.Year~HydroBase
newr_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\newr_fd.stm
newr_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\newr_fd.stm
newr_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\newr_fd.stm
newr_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\newr_fd.stm
fillFromTS(5922.NOAA.FrostDateF28F.Year,newr_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(5922.NOAA.FrostDateF32F.Year,newr_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(5922.NOAA.FrostDateL28S.Year,newr_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(5922.NOAA.FrostDateL32S.Year,newr_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="newr_fd.StateCU.FrostDateL28S.Year")
free(TSID="newr_fd.StateCU.FrostDateL32S.Year")
free(TSID="newr_fd.StateCU.FrostDateF32F.Year")
free(TSID="newr_fd.StateCU.FrostDateF28F.Year")
5922.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5922.stm
5922.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5922.stm
5922.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5922.stm
5922.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5922.stm
fillFromTS(5922.NOAA.FrostDateF28F.Year,5922.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(5922.NOAA.FrostDateF32F.Year,5922.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(5922.NOAA.FrostDateL28S.Year,5922.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(5922.NOAA.FrostDateL32S.Year,5922.StateCU.FrostDateL32S.Year,*,*)
free(TSID="5922.StateCU.FrostDateL28S.Year")
free(TSID="5922.StateCU.FrostDateL32S.Year")
free(TSID="5922.StateCU.FrostDateF32F.Year")
free(TSID="5922.StateCU.FrostDateF28F.Year")
#
# 5934 - New Raymer 21 combo combine with paper records combine with frost.exe output
5934.NOAA.FrostDateF28F.Year~HydroBase
5934.NOAA.FrostDateF32F.Year~HydroBase
5934.NOAA.FrostDateL28S.Year~HydroBase
5934.NOAA.FrostDateL32S.Year~HydroBase
4460.NOAA.FrostDateF28F.Year~HydroBase
4460.NOAA.FrostDateF32F.Year~HydroBase
4460.NOAA.FrostDateL28S.Year~HydroBase
4460.NOAA.FrostDateL32S.Year~HydroBase
fillFromTS(5934.NOAA.FrostDateF28F.Year,4460.NOAA.FrostDateF28F.Year,*,*)
fillFromTS(5934.NOAA.FrostDateF32F.Year,4460.NOAA.FrostDateF32F.Year,*,*)
fillFromTS(5934.NOAA.FrostDateL28S.Year,4460.NOAA.FrostDateL28S.Year,*,*)
fillFromTS(5934.NOAA.FrostDateL32S.Year,4460.NOAA.FrostDateL32S.Year,*,*)
free(TSID="4460.NOAA.FrostDateF28F.Year")
free(TSID="4460.NOAA.FrostDateF32F.Year")
free(TSID="4460.NOAA.FrostDateL32S.Year")
free(TSID="4460.NOAA.FrostDateL28S.Year")
nr21_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\nr21_fd.stm
nr21_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\nr21_fd.stm
nr21_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\nr21_fd.stm
nr21_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\nr21_fd.stm
fillFromTS(5934.NOAA.FrostDateF28F.Year,nr21_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(5934.NOAA.FrostDateF32F.Year,nr21_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(5934.NOAA.FrostDateL28S.Year,nr21_fd.StateCU.FrostDateL28S.Year,*,*)
```

```
fillFromTS(5934.NOAA.FrostDateL32S.Year,nr21_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="nr21_fd.StateCU.FrostDateL28S.Year")
free(TSID="nr21_fd.StateCU.FrostDateL32S.Year")
free(TSID="nr21_fd.StateCU.FrostDateF32F.Year")
free(TSID="nr21_fd.StateCU.FrostDateF28F.Year")
5934.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5934.stm
5934.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5934.stm
5934.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5934.stm
5934.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\5934.stm
fillFromTS(5934.NOAA.FrostDateF28F.Year,5934.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(5934.NOAA.FrostDateF32F.Year,5934.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(5934.NOAA.FrostDateL28S.Year,5934.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(5934.NOAA.FrostDateL32S.Year,5934.StateCU.FrostDateL32S.Year,*,*)
free(TSID="5934.StateCU.FrostDateL28S.Year")
free(TSID="5934.StateCU.FrostDateL32S.Year")
free(TSID="5934.StateCU.FrostDateF32F.Year")
free(TSID="5934.StateCU.FrostDateF28F.Year")
#
# 6323 - Parker combo combine with paper records combine with frost.exe output
# The 6323 frost dates do not have a source listed in HB, thus the "6323..FrostDate." command.
6323..FrostDateF28F.Year~HydroBase
6323..FrostDateF32F.Year~HydroBase
6323..FrostDateL28S.Year~HydroBase
6323..FrostDateL32S.Year~HydroBase
6326.NOAA.FrostDateF28F.Year~HydroBase
6326.NOAA.FrostDateF32F.Year~HydroBase
6326.NOAA.FrostDateL28S.Year~HydroBase
6326.NOAA.FrostDateL32S.Year~HydroBase
fillFromTS(6323..FrostDateF28F.Year,6326.NOAA.FrostDateF28F.Year,*,*)
fillFromTS(6323..FrostDateF32F.Year,6326.NOAA.FrostDateF32F.Year,*,*)
fillFromTS(6323..FrostDateL28S.Year,6326.NOAA.FrostDateL28S.Year,*,*)
fillFromTS(6323..FrostDateL32S.Year,6326.NOAA.FrostDateL32S.Year,*,*)
free(TSID="6326.NOAA.FrostDateF28F.Year")
free(TSID="6326.NOAA.FrostDateF32F.Year")
free(TSID="6326.NOAA.FrostDateL28S.Year")
free(TSID="6326.NOAA.FrostDateL32S.Year")
park_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\park_fd.stm
park_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\park_fd.stm
park_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\park_fd.stm
park_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\park_fd.stm
fillFromTS(6323..FrostDateF28F.Year,park_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(6323..FrostDateF32F.Year,park_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(6323..FrostDateL28S.Year,park_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(6323..FrostDateL32S.Year,park_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="park_fd.StateCU.FrostDateL28S.Year")
free(TSID="park_fd.StateCU.FrostDateL32S.Year")
free(TSID="park_fd.StateCU.FrostDateF32F.Year")
free(TSID="park_fd.StateCU.FrostDateF28F.Year")
6323.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\6323.stm
6323.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\6323.stm
6323.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\6323.stm
6323.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\6323.stm
fillFromTS(6323..FrostDateF28F.Year,6323.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(6323..FrostDateF32F.Year,6323.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(6323..FrostDateL28S.Year,6323.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(6323..FrostDateL32S.Year,6323.StateCU.FrostDateL32S.Year,*,*)
free(TSID="6323.StateCU.FrostDateL28S.Year")
free(TSID="6323.StateCU.FrostDateL32S.Year")
free(TSID="6323.StateCU.FrostDateF32F.Year")
free(TSID="6323.StateCU.FrostDateF28F.Year")
#
# 6921 - Red Feathers Combo combine with frost.exe output
6925.NOAA.FrostDateF28F.Year~HydroBase
6925.NOAA.FrostDateF32F.Year~HydroBase
6925.NOAA.FrostDateL28S.Year~HydroBase
6925.NOAA.FrostDateL32S.Year~HydroBase
6930.NOAA.FrostDateF28F.Year~HydroBase
6930.NOAA.FrostDateF32F.Year~HydroBase
6930.NOAA.FrostDateL28S.Year~HydroBase
6930.NOAA.FrostDateL32S.Year~HydroBase
fillFromTS(6925.NOAA.FrostDateF28F.Year,6930.NOAA.FrostDateF28F.Year,*,*)
fillFromTS(6925.NOAA.FrostDateF32F.Year,6930.NOAA.FrostDateF32F.Year,*,*)
fillFromTS(6925.NOAA.FrostDateL28S.Year,6930.NOAA.FrostDateL28S.Year,*,*)
fillFromTS(6925.NOAA.FrostDateL32S.Year,6930.NOAA.FrostDateL32S.Year,*,*)
free(TSID="6930.NOAA.FrostDateF28F.Year")
free(TSID="6930.NOAA.FrostDateF32F.Year")
free(TSID="6930.NOAA.FrostDateL32S.Year")
free(TSID="6930.NOAA.FrostDateL28S.Year")
6921.NOAA.FrostDateF28F.Year~HydroBase
6921.NOAA.FrostDateF32F.Year~HydroBase
6921.NOAA.FrostDateL28S.Year~HydroBase
```

```
6921.NOAA.FrostDateL32S.Year~HydroBase
fillFromTS(6921.NOAA.FrostDateF28F.Year,6925.NOAA.FrostDateF28F.Year,*,*)
fillFromTS(6921.NOAA.FrostDateF32F.Year,6925.NOAA.FrostDateF32F.Year,*,*)
fillFromTS(6921.NOAA.FrostDateL28S.Year,6925.NOAA.FrostDateL28S.Year,*,*)
fillFromTS(6921.NOAA.FrostDateL32S.Year,6925.NOAA.FrostDateL32S.Year,*,*)
free(TSID="6925.NOAA.FrostDateF28F.Year")
free(TSID="6925.NOAA.FrostDateF32F.Year")
free(TSID="6925.NOAA.FrostDateL32S.Year")
free(TSID="6925.NOAA.FrostDateL28S.Year")
6921.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\6921.stm
6921.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\6921.stm
6921.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\6921.stm
6921.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\6921.stm
fillFromTS(6921.NOAA.FrostDateF28F.Year,6921.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(6921.NOAA.FrostDateF32F.Year,6921.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(6921.NOAA.FrostDateL28S.Year,6921.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(6921.NOAA.FrostDateL32S.Year,6921.StateCU.FrostDateL32S.Year,*,*)
free(TSID="6921.StateCU.FrostDateL28S.Year")
free(TSID="6921.StateCU.FrostDateL32S.Year")
free(TSID="6921.StateCU.FrostDateF32F.Year")
free(TSID="6921.StateCU.FrostDateF28F.Year")
#
# 7515 - Sedgwick Combo combine with paper records combine with frost.exe output
7515.NOAA.FrostDateF28F.Year~HydroBase
7515.NOAA.FrostDateF32F.Year~HydroBase
7515.NOAA.FrostDateL28S.Year~HydroBase
7515.NOAA.FrostDateL32S.Year~HydroBase
7513.NOAA.FrostDateF28F.Year~HydroBase
7513.NOAA.FrostDateF32F.Year~HydroBase
7513.NOAA.FrostDateL28S.Year~HydroBase
7513.NOAA.FrostDateL32S.Year~HydroBase
fillFromTS(7515.NOAA.FrostDateF28F.Year,7513.NOAA.FrostDateF28F.Year,*,*)
fillFromTS(7515.NOAA.FrostDateF32F.Year,7513.NOAA.FrostDateF32F.Year,*,*)
fillFromTS(7515.NOAA.FrostDateL28S.Year,7513.NOAA.FrostDateL28S.Year,*,*)
fillFromTS(7515.NOAA.FrostDateL32S.Year,7513.NOAA.FrostDateL32S.Year,*,*)
free(TSID="7513.NOAA.FrostDateF28F.Year")
free(TSID="7513.NOAA.FrostDateF32F.Year")
free(TSID="7513.NOAA.FrostDateL32S.Year")
free(TSID="7513.NOAA.FrostDateL28S.Year")
sedg_fd.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\sedg_fd.stm
sedg_fd.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\sedg_fd.stm
sedg_fd.StateCU.FrostDateL32S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\sedg_fd.stm
sedg_fd.StateCU.FrostDateL28S.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\sedg_fd.stm
fillFromTS(7515.NOAA.FrostDateF28F.Year,sedg_fd.StateCU.FrostDateF28F.Year,*,*)
fillFromTS(7515.NOAA.FrostDateF32F.Year,sedg_fd.StateCU.FrostDateF32F.Year,*,*)
fillFromTS(7515.NOAA.FrostDateL28S.Year,sedg_fd.StateCU.FrostDateL28S.Year,*,*)
fillFromTS(7515.NOAA.FrostDateL32S.Year,sedg_fd.StateCU.FrostDateL32S.Year,*,*)
free(TSID="sedg_fd.StateCU.FrostDateL28S.Year")
free(TSID="sedg_fd.StateCU.FrostDateL32S.Year")
free(TSID="sedg_fd.StateCU.FrostDateF32F.Year")
free(TSID="sedg_fd.StateCU.FrostDateF28F.Year")
7515.StateCU.FrostDateF28F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\7515.stm
7515.StateCU.FrostDateF32F.Year~StateCU~C:\Projects\SPDSS\Task 53\STM Files\FrostDates\7515.stm
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#
# 7950 - Sterling combine with paper records combine with frost.exe output
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```
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# Water District 47, Division 6 commands - MUST BE RUN WITH A WEST SLOPE HYDROBASE
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8756.NOAA.FrostDateL28S.Year~HydroBase
8756.NOAA.FrostDateL32S.Year~HydroBase
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#
#
writeStateCU("FrostDates_Out.stm")
```

Appendix E
South Platte Historic Crop Consumptive Use - Climate Station Assignments

To: Ray Alvarado and Ray Bennett

From: LRE – Bruce Rindahl, Erin Wilson, and Beorn Courtney

Subject: Task 53.3 – Assign Key Climate Information to Irrigated Acreage and Reservoirs

Date: September 1, 2005 (Revised February 1, 2006)

Introduction

This memorandum presents the general approach for the following Task 53 subtasks:

1. *Assign key climate stations to geographic areas for the SPDSS modeling efforts.*
2. *Estimate average monthly reservoir evaporation rates for geographic areas.*

Temperature and/or precipitation climate data will be used in the SPDSS in four model efforts:

- Consumptive Use (CU) Model
- Ground Water (GW) Model
- Surface Water (SW) Model
- Water Budget (WB) Model

Consumptive Use Model. Monthly temperature and precipitation climate data will be used to estimate historic crop consumptive use in the CU model throughout the South Platte, North Platte and Laramie River Basins (SPDSS study area). Key climate stations were selected and monthly data were filled under the SPDSS "Task 53.2 – Collect and Fill Missing Monthly Climate Data." By assigning key climate stations to geographic areas (irrigated lands) within the SPDSS study area, consumptive use can be estimated at any location.

Ground Water Model. Monthly precipitation data will be used to estimate recharge for the GW model. As with the CU model efforts, by assigning key climate stations to geographic areas (ground water model cells) within the GW model area, recharge from precipitation can be estimated at any location.

Surface Water Model. Average annual precipitation data will be used in the baseflow calculations in the SW model to distribute flow at gages to ungaged locations. The average annual precipitation GIS coverage, developed by the Colorado Climate Center, will be used to estimate average annual precipitation within a defined sub-basin.

Water Budget Model. Two water budgets will be developed to represent the SPDSS area; a monthly water budget representing the ground water model area, and an average annual water budget representing the entire South Platte drainage. For the monthly water budget, monthly precipitation data will be used to estimate precipitation inflow over the ground water model area. By assigning key climate stations to geographic areas within the ground water model area, precipitation inflow can be estimated at any location. For the average annual basin-wide water budget, the average annual precipitation GIS coverage, developed by the Colorado Climate Center, will be used to estimate the basin-wide average annual precipitation.

Reservoir evaporation rates and water surface areas will be used in preparing the Consumptive Use and Losses Summary, the water budget, and for the potential future surface water modeling efforts. Reservoir evaporation data exist at only a few reservoirs in the SPDSS study area and only for a short period during the 1950 through current year study period.

Approach and Results

1. Assign Key Climate Stations to Geographic Areas

Several interpolation methodologies commonly used to spatially distribute data to a subset of a given area were investigated including: Thiessen polygon weighting, linear interpolation, and kriging. The advantages and limitations of each method were investigated and are summarized below. The criteria used to evaluate the methods were as follows:

1. Data Centered Approach – The method must be able to respond to changes in the input data sets. For example, if the irrigated area associated with a structure is adjusted, the method must be able to adjust the associated climate stations and weights in a straight forward manner, preferably by just rerunning a procedure with a new input data set.

2. Applicability – The method must be applicable for the use intended. For example, the climate station weights should be applied for those portions of the models where the elevation of the respective stations is similar to the data set.

3. Engineering Judgment – The method must be able to be adjusted based on an engineering review of the results. For example, the automated procedure may develop climate station weights for a structure from six or seven climate stations while the practical limit may be to use only the highest three or four stations.

4. Compatibility with Existing Models – The method must be developed with the existing CDSS models in mind. For example, StateCU requires that each structure have a fixed number of climate stations and fixed weights throughout the study period. Variable weights by year would not be practical nor needed for SPDSS.

5. Standard Tools – The method should be developed with existing software currently in use in the CDSS. This includes the ArcView GIS software package with standard extensions.

Thiessen Polygon Weighting

A Thiessen polygon weighting procedure can be used to assign weights associated with defined point climate station locations. This procedure is straightforward in the standard GIS software packages used in the SPDSS. The method works well for regions larger than the individual Thiessen polygons. However, discontinuities can arise from this method when areas are relatively small and near the boundaries of the computed polygons. The climate station weights could differ enough to result in abrupt changes in the climate station data used to estimate consumptive use (or evaporation, recharge, etc.) across a short distance.

Linear Interpolation of Climate Station Weights

An alternate method is to use varying weights based on the distance from each station, ranging from 1.0 at the station itself to 0.0 at each adjacent station. A Triangular Irregular Network (TIN) is created by joining the location of each climate station into a series of triangles that cover the entire region of interest. The triangular network defined around each climate station can be adjusted, if necessary, to reflect engineering judgment (elevation consideration, topographic influences, extrapolation, etc.) At the selected climate station, each triangle vertex is assigned a value of one while all other vertices are assigned a value of zero.

A grid is then created for each climate station as a linear interpolation of each triangle in the TIN. This automated process is then repeated for each climate station. The final product is a spline interpolation with linear basis functions. This assures that the sum of the weights at any point equal one and that at a particular climate station, the weight for that climate station is equal to one. It also assures that all weights are greater than zero, which is not always guaranteed in the kriging method described below. By using ArcView's spatial analyst extension, the weights are stored as separate grids and can be combined easily for a point location or summarized for any polygon area. Note that weights can be automatically extended between the edge of the study area and climate stations within the study area based on user-input criteria or climate stations outside the study area (for instance climate stations in the Republican Basin).

Once the grids are created for each climate station, they can be used for weighting any region in the study area from large areas such as water districts to small areas including ditch structures or individual farm parcels.

Kriging

Kriging is another method for spatially interpolating point values to a continuous surface and is available in the ArcView GIS program. A major disadvantage of the kriging method in existing GIS software is that it is necessary to define the point or area at which the weights are being determined before developing the weights as opposed to the Thiessen polygon or linear interpolation method which defines a grid around each climate station. Another disadvantage is that the kriging method does not ensure that all weights are greater than zero.

<u>Results – GW Model and CU Model</u>

After reviewing the Thiessen polygon weighting, linear interpolation, and kriging methods, it was determined that the linear interpolation method was most appropriate for the SPDSS ground water and consumptive use models. This method is data centered, compatible with the existing models in the SPDSS, and provides a more continuous interpolation of the point values available for the climate station data than the Thiessen polygon method. Once the grid network is developed, it can be applied to any point location or summarized for a polygon area whereas with kriging, the locations must be determined beforehand. Note that both the linear interpolation and kriging methods may require an orographic adjustment, applied to the actual climate data, if used over areas with elevations outside the range of the climate station coverage.

The linear interpolation method was applied to develop a grid network for key climate stations east of the foothills that include the entire GW model area and the majority of irrigated acreage. For the irrigated acreage in the SPDSS, the vast majority of lands are at an elevation of less than 6,500 feet and have adequate coverage of climate stations without the need for elevation adjustment. Higher areas of the groundwater model may require an orographic precipitation adjustment to the climate station data to accurately estimate precipitation recharge. This orographic adjustment to precipitation data is described below. This network of climate station grids was then used to create a uniform coverage of climate station weights. The coverage will be used to automate the assignment of appropriate key climate stations and weights for estimating consumptive use at any point or area (parcels, groups of parcels, grid cells, etc) located in their respective study areas.

In order to extrapolate climate station weights to the limits of the study area and to those areas up to 6,500 feet, the locations of climate stations from outside the state and above 6,500 feet were utilized to create a network of grids. After this analysis, the weights from climate stations outside the state or above 6,500 feet were set to zero and the remaining weights prorated upward to assure a total value of 1.0. This maintains the requirement of insuring the sum of the climate station weights equal to one, and also avoids utilizing climate station data outside the state not currently stored in HydroBase.

In the foothills and higher elevations, climate stations were assigned to reflect climate conditions by sub-water district. **Figure 1** shows the division of water districts along the foothills with the upper and lower designations. Figure 1 was developed using digital elevations obtained from the State, originally derived from data obtained from the USGS. **Table 1** presents the upper water district climate stations that should be used in the consumptive use model.

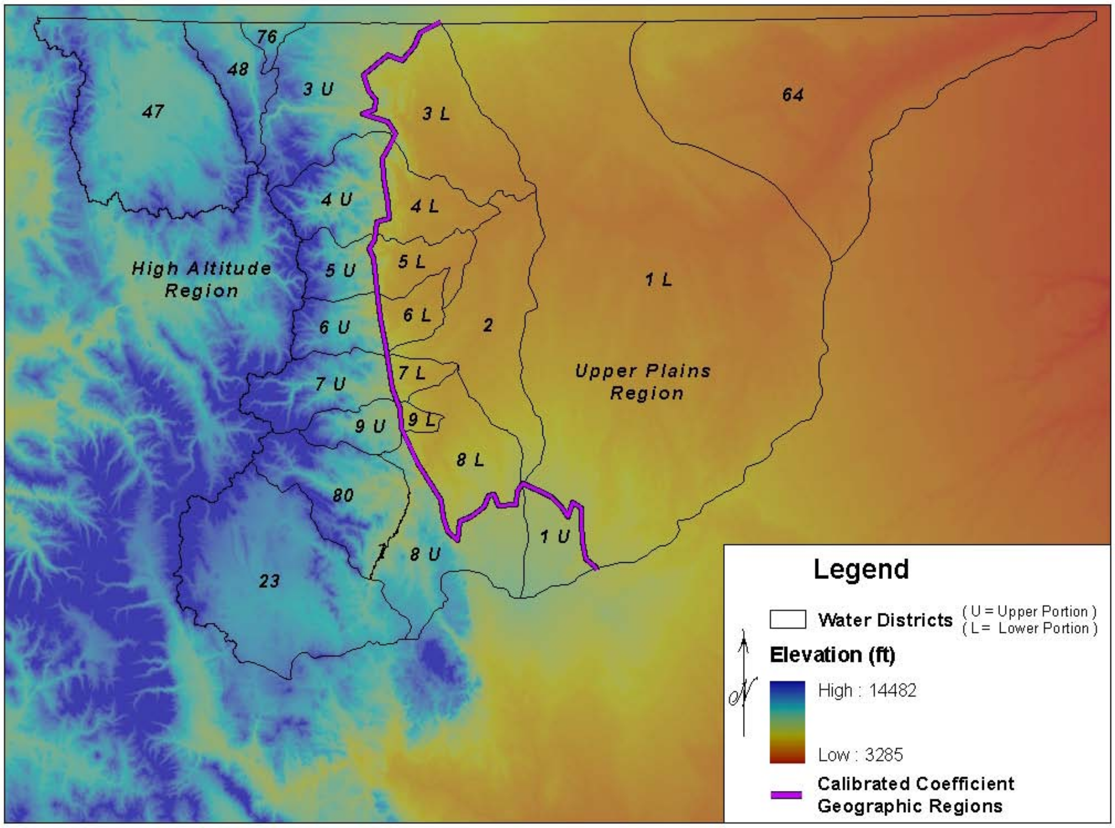


Figure 1 – Division of Water Districts along the Foothills

Table 1
Key Climate Stations Assignments for Crop Consumptive Use Estimates

Station ID	Station Names	Representative WD
0185	Allenspark 1 NW (combined)	5U
0263	Antero Reservoir	23
0454	Bailey	80
1528	Castle Rock	8U
2494	Eastonville 2 NNW	1U
2761	Estes Park 1 SSE (combined)	4U
2790	Evergreen (combined)	7U, 9U
0185	Allenspark 1 NW (combined)	6U
6921	Red Feather Lakes (combined)	3U, 48, 76
8756	Walden	47

The assignments shown in Table 1 are based on the location of climate stations compared to irrigate lands identified in the preliminary SPDSS Irrigated Acreage Assessment. Note that in the preliminary acreage assessment, no lands were identified in the upper portions of water districts 3, 5, 6, and 7; however according to the water commissioners there are minor diversions for irrigation in these water districts above 6,500 feet.

Orographic adjustment

The ground water model requires monthly precipitation estimates for recharge values. Since some areas of the proposed ground water model are at elevations not represented by nearby climate stations, an orographic adjustment will be applied to precipitation values from climate stations. This basis of the adjustments will the Colorado Average Annual Precipitation Map (1951 – 1980) published by the Colorado Climate Center. At each climate station, the average annual precipitation value will be estimated from the map. Other locations in the vicinity of each climate station will then be assigned a value equal to the estimated annual precipitation at the location of interest divided by the annual precipitation value at the nearby climate station. For example, if the average annual precipitation value at a climate station is 15 inches, then every location affected by that station with a precipitation value of 14 inches will be assigned a value of 15/14 or 0.93. This process will create a continuous grid of weights for each station. The product of the spatial grid weights and the orographic weights can then be used to automate the estimate of precipitation values throughout the groundwater model area. It is important to note that using this method, the total weights can be greater than or less than 1.0.

Results – SW Model and WB Model

As noted above, average annual precipitation data is required for the SW model and the basin-wide WB model. An automated approach will be developed within ArcGIS, as part of SPDSS Task 18, to determine the annual precipitation for a defined area using the GIS average annual precipitation coverage developed by the Colorado Climate Center. For the basin-wide average annual WB model, the defined area will be the entire basin. For the SW model, defined areas will represent drainage areas.

2. Estimate Average Monthly Reservoir Evaporation Rates for Geographic Areas

There are no continuous reservoir evaporation stations located in the SPDSS study area. The Denver Water Department and Northern Colorado Water Conservancy District (NCWCD) have developed average monthly reservoir evaporation rates for their respective models, which they provided to SPDSS for review. Denver Water also provided a memorandum documenting their evaporation rates (“Estimation of Net Evaporation Rates”, December 11, 2003). Documentation of the development of evaporation rates for NCWCD was not available and there were discrepancies between Denver Water and NCWCD evaporation rates used in near proximity. A review of the data used in these models shows that the methods used to estimate net evaporation rates (net evaporation = gross evaporation – effective precipitation) are inconsistent. For example, some of the average monthly rates were based on State Engineer’s Office data, which has applied a 70 percent factor when calculating effective precipitation (net evaporation = gross evaporation – 0.70 x total precipitation) while others were based on Denver Water Department and Bureau of Reclamation data which consider 100 percent of precipitation to be effective. In addition, Denver Water estimates winter evaporation rates at upper reservoirs to be zero, whereas our analysis shows that reservoirs in these areas can experience net winter evaporation.

The State Engineer’s Office is calculating evaporation for a different purpose than Denver Water and the Bureau of Reclamation. The State Engineer’s Office administers reservoir storage based on decreed storage rights, regardless of evaporation. However, when reservoirs are required to replace evaporation of water that was stored out of priority, for example water stored in an un-lined gravel pit, then 70 percent of the total precipitation is considered effective and applied as a credit. According to the State Engineer's Office, this assumes that 70 percent of precipitation on the reservoir site was previously consumed by native vegetation, and 30 percent contributed to stream flow. (Note that this 70 percent factor should not be confused with the 0.70 pan coefficient generally applied to pan evaporation estimates to get gross evaporation estimates.)

Denver Water and the Bureau of Reclamation, however, are calculating a mass-balance of reservoir inflows and outflows; therefore they consider the full precipitation in their net reservoir evaporation calculation. Similarly for the SPDSS Water Budget and Surface Water modeling efforts, the full precipitation should be considered in the net evaporation calculation. Due to inconsistencies noted, the reservoir evaporation rates from the Denver Water and NCWCD models were not used.

In the absence of site-specific data, the following consistent method was adopted for the entire basin, as explained in detail below:

1. Determine average annual gross evaporation based on NOAA publications
2. Determine average annual precipitation based on Colorado Climate Center publications
3. Distribute annual gross evaporation to monthly using State Engineer's Office procedure
4. Distribute annual precipitation to monthly using local climate station data
5. Estimate average net monthly evaporation rates by subtracting precipitation from gross evaporation

Steps 1 and 2: Determine average annual gross evaporation and average annual precipitation

The CDSS GIS coverage includes the following gross evaporation and precipitation shape files based on average annual estimates:

- NOAA Free Water Surface Evaporation published in June 1982, based on a 1956 through 1970 study period.
- Precipitation Isohyetal Map published by the Colorado Climate Center, based on a report titled "Analysis of Colorado Average Annual Precipitation for the 1951-1980 Period".

These files were used to develop average annual gross reservoir evaporation and total precipitation estimates for each water district or sub-district shown in Figure 1 above.

Step 3: Distribute annual gross evaporation to monthly

Average annual gross reservoir evaporation estimates developed in Step 1 above were distributed monthly with the percentages used by the State Engineer's Office (presented by Wolfe and Stenzel at a 1995 ET and Irrigation Efficiency Seminar and summarized in a paper titled "Evaporation"). There are two average monthly distributions; one for below 6,500 feet and one for above 6,500 feet above mean sea level (**Table 2**). The below 6,500 feet distribution was used for Water Districts 2, 64, and the lower portions of Water Districts 1, 3, 4, 5, 6, 7, 8, and 9. The above 6,500 feet distribution was used for the upper portions of Water Districts 1, 3, 4, 5, 6, 7, 8, 9 and Water Districts 23, 47, 48, 76, and 80. The resulting average monthly gross reservoir evaporation estimates are provided in **Table 3**.

Table 2
Average Monthly Gross Evaporation Distribution

Elevation (ft)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Below 6,500	3.0%	3.5%	5.5%	9.0%	12.0%	14.5%	15.0%	13.5%	10.0%	7.0%	4.0%	3.0%
Above 6,500	1.0%	3.0%	6.0%	9.0%	12.5%	15.5%	16.0%	13.0%	11.0%	7.5%	4.0%	1.5%

Table 3
Estimated Average Monthly Gross Reservoir Evaporation
(Inches)

Water District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1-Upper	0.43	1.30	2.61	3.91	5.43	6.74	6.95	5.65	4.78	3.26	1.74	0.65	43.46
1-Lower	1.41	1.65	2.59	4.24	5.65	6.83	7.07	6.36	4.71	3.30	1.88	1.41	47.11
2	1.31	1.53	2.40	3.93	5.24	6.34	6.55	5.90	4.37	3.06	1.75	1.31	43.70
3-Upper	0.37	1.11	2.22	3.34	4.63	5.75	5.93	4.82	4.08	2.78	1.48	0.56	37.07
3-Lower	1.19	1.39	2.19	3.58	4.78	5.77	5.97	5.37	3.98	2.79	1.59	1.19	39.79
4-Upper	0.36	1.07	2.14	3.22	4.47	5.54	5.72	4.65	3.93	2.68	1.43	0.54	35.75
4-Lower	1.16	1.35	2.12	3.47	4.62	5.58	5.78	5.20	3.85	2.70	1.54	1.16	38.52
5-Upper	0.35	1.06	2.13	3.19	4.43	5.49	5.67	4.61	3.90	2.66	1.42	0.53	35.43
5-Lower	1.15	1.35	2.12	3.46	4.62	5.58	5.77	5.20	3.85	2.69	1.54	1.15	38.49
6-Upper	0.36	1.07	2.14	3.20	4.45	5.52	5.69	4.63	3.91	2.67	1.42	0.53	35.58
6-Lower	1.15	1.35	2.11	3.46	4.61	5.57	5.77	5.19	3.84	2.69	1.54	1.15	38.44
7-Upper	0.36	1.07	2.14	3.22	4.47	5.54	5.72	4.65	3.93	2.68	1.43	0.54	35.73
7-Lower	1.19	1.39	2.19	3.58	4.77	5.77	5.97	5.37	3.98	2.78	1.59	1.19	39.78
8-Upper	0.38	1.15	2.31	3.46	4.81	5.96	6.15	5.00	4.23	2.88	1.54	0.58	38.45
8-Lower	1.25	1.45	2.28	3.74	4.98	6.02	6.23	5.61	4.15	2.91	1.66	1.25	41.52
9-Upper	0.37	1.10	2.19	3.29	4.57	5.66	5.85	4.75	4.02	2.74	1.46	0.55	36.54
9-Lower	1.20	1.40	2.21	3.61	4.82	5.82	6.02	5.42	4.01	2.81	1.61	1.20	40.13
23	0.39	1.16	2.32	3.49	4.84	6.00	6.20	5.03	4.26	2.90	1.55	0.58	38.72
47	0.38	1.13	2.27	3.40	4.73	5.86	6.05	4.91	4.16	2.84	1.51	0.57	37.80
48	0.37	1.11	2.23	3.34	4.64	5.76	5.94	4.83	4.09	2.79	1.49	0.56	37.15
64	1.46	1.71	2.68	4.38	5.85	7.06	7.31	6.58	4.87	3.41	1.95	1.46	48.72
76	0.40	1.19	2.37	3.56	4.95	6.13	6.33	5.14	4.35	2.97	1.58	0.59	39.56
80	0.36	1.07	2.13	3.20	4.44	5.51	5.69	4.62	3.91	2.67	1.42	0.53	35.54

Step 4: Distribute annual precipitation to monthly

Monthly precipitation data for key climate stations were collected and filled under Task 53.2. Average annual precipitation (100% effective) estimates developed in Step 2 above were distributed monthly based on data from designated key climate stations. The key climate stations selected to represent each water district or portion of a water district are shown in **Table 4**. These representative key climate stations were selected based on existing reservoir locations. The resulting average monthly total precipitation estimates are provided in **Table 5**.

Table 4
Key Climate Stations Assignments for Net Reservoir Evaporation Estimates

Station ID	Station Name	Representative WD
0185	Allenspark 1 NW (combined)	5U
0263	Antero Reservoir	23
0454	Bailey	80
0848	Boulder	6L
0945	Briggsdale	1L
1401	Castle Rock	8L
1528	Cheesman	8U
2494	Eastonville 2 NNW	1U
2761	Estes Park 1 SSE (combined)	4U
2790	Evergreen (combined)	9U
3261	Georgetown	6U, 7U
3553	Greeley UNC (combined)	2, 3L
4762	Lakewood (combined)	7L, 9L
5116	Longmont 2 ESE	4L, 5L
6921	Red Feather Lakes (combined)	3U, 48, 76
7950	Sterling	64
8756	Walden	47

Table 5
Estimated Average Monthly Total Precipitation
(Inches)

Water District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1-Upper	0.36	0.37	1.08	1.66	2.26	1.92	2.49	2.54	1.19	0.86	0.65	0.40	15.79
1-Lower	0.23	0.18	0.73	1.12	2.09	2.10	2.31	1.82	1.23	0.69	0.38	0.24	13.15
2	0.41	0.34	0.97	1.56	2.44	1.76	1.43	1.17	1.14	0.87	0.68	0.37	13.14
3-Upper	0.68	0.81	1.78	2.33	2.68	2.06	2.58	2.13	1.64	1.12	1.12	0.66	19.61
3-Lower	0.44	0.36	1.03	1.66	2.60	1.88	1.52	1.25	1.22	0.92	0.73	0.40	14.01
4-Upper	0.55	0.75	1.51	2.13	3.17	2.53	3.33	2.98	1.90	1.22	0.97	0.69	21.73
4-Lower	0.43	0.42	1.22	1.84	2.62	1.76	1.17	1.35	1.35	0.90	0.75	0.49	14.30
5-Upper	1.32	1.25	2.38	2.85	3.18	2.21	2.70	2.62	1.94	1.35	1.60	1.24	24.63
5-Lower	0.44	0.43	1.25	1.88	2.68	1.79	1.19	1.38	1.38	0.92	0.77	0.50	14.60
6-Upper	0.90	0.96	1.98	2.55	2.74	2.12	3.16	3.51	2.02	1.42	1.27	1.12	23.74
6-Lower	0.55	0.67	1.52	2.07	2.67	1.73	1.54	1.41	1.41	1.06	1.04	0.59	16.27
7-Upper	0.83	0.89	1.83	2.37	2.54	1.97	2.93	3.25	1.87	1.31	1.18	1.04	22.02
7-Lower	0.49	0.55	1.33	1.87	2.58	1.89	1.71	1.59	1.32	0.95	0.92	0.51	15.72
8-Upper	0.41	0.58	1.28	1.56	1.94	1.61	2.44	2.51	1.17	1.00	0.76	0.54	15.81
8-Lower	0.50	0.60	1.35	1.59	2.24	1.75	2.07	1.88	1.13	0.94	0.79	0.55	15.40
9-Upper	0.59	0.91	1.85	2.40	3.04	2.32	2.52	2.56	1.62	1.34	1.07	0.75	20.97
9-Lower	0.49	0.55	1.34	1.89	2.60	1.91	1.73	1.60	1.33	0.96	0.93	0.51	15.86
23	0.28	0.39	0.78	1.02	1.52	1.67	2.98	3.36	1.46	1.01	0.51	0.42	15.39
47	1.02	0.96	1.21	1.60	2.32	1.91	2.35	2.25	2.03	1.46	1.30	1.03	19.45
48	0.78	0.93	2.06	2.69	3.10	2.38	2.98	2.46	1.89	1.30	1.30	0.76	22.64
64	0.30	0.28	0.80	1.22	2.70	2.57	2.49	1.71	1.08	0.87	0.48	0.29	14.79
76	0.64	0.76	1.67	2.19	2.52	1.94	2.42	2.00	1.54	1.06	1.06	0.62	18.41
80	0.45	0.65	1.46	2.09	2.45	1.90	3.03	2.99	1.56	1.29	0.87	0.62	19.35

Step 5: Estimate average net monthly evaporation rates

Average monthly net reservoir evaporation was calculated as the difference between gross reservoir evaporation and total precipitation (**Table 6**). Total precipitation can exceed gross reservoir evaporation, resulting in a negative net reservoir evaporation (a net addition to the reservoir). When this occurs under water rights applications, the net evaporation is estimated to be zero (a credit is not given for negative net evaporation). However, because these estimates are being used in the SPDSS to represent physical conditions for modeling purposes, negative net evaporation values are used.

Table 6
Estimated Average Monthly Net Reservoir Evaporation
(Inches)

Water District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1-Upper	0.07	0.93	1.52	2.25	3.17	4.81	4.46	3.11	3.59	2.40	1.09	0.26	27.67
1-Lower	1.18	1.47	1.86	3.12	3.56	4.73	4.75	4.54	3.48	2.61	1.50	1.17	33.96
2	0.90	1.19	1.44	2.37	2.81	4.57	5.12	4.73	3.23	2.19	1.07	0.94	30.55
3-Upper	-0.31	0.30	0.44	1.00	1.95	3.68	3.35	2.69	2.44	1.65	0.36	-0.10	17.46
3-Lower	0.75	1.04	1.16	1.92	2.18	3.89	4.44	4.12	2.76	1.86	0.87	0.79	25.78
4-Upper	-0.19	0.33	0.64	1.09	1.30	3.01	2.38	1.66	2.03	1.46	0.46	-0.15	14.02
4-Lower	0.73	0.93	0.90	1.62	2.00	3.83	4.61	3.85	2.50	1.80	0.79	0.66	24.22
5-Upper	-0.96	-0.18	-0.25	0.34	1.25	3.28	2.97	1.99	1.95	1.31	-0.18	-0.70	10.79
5-Lower	0.72	0.92	0.87	1.58	1.94	3.79	4.58	3.82	2.47	1.78	0.77	0.65	23.89
6-Upper	-0.54	0.11	0.16	0.65	1.71	3.39	2.54	1.12	1.89	1.25	0.16	-0.59	11.85
6-Lower	0.60	0.68	0.59	1.39	1.94	3.85	4.22	3.77	2.44	1.63	0.50	0.56	22.17
7-Upper	-0.48	0.18	0.31	0.85	1.92	3.57	2.79	1.39	2.06	1.37	0.25	-0.50	13.72
7-Lower	0.70	0.84	0.86	1.71	2.20	3.88	4.25	3.78	2.66	1.83	0.67	0.68	24.06
8-Upper	-0.02	0.57	1.03	1.90	2.87	4.35	3.71	2.49	3.06	1.88	0.78	0.03	22.63
8-Lower	0.75	0.86	0.93	2.14	2.75	4.28	4.15	3.73	3.02	1.96	0.87	0.69	26.13
9-Upper	-0.23	0.19	0.35	0.89	1.52	3.35	3.33	2.19	2.40	1.40	0.39	-0.20	15.57
9-Lower	0.71	0.85	0.86	1.72	2.21	3.91	4.29	3.82	2.68	1.85	0.68	0.69	24.27
23	0.11	0.77	1.55	2.46	3.32	4.33	3.22	1.67	2.80	1.90	1.04	0.16	23.33
47	-0.64	0.17	1.06	1.80	2.41	3.95	3.69	2.67	2.13	1.37	0.21	-0.47	18.35
48	-0.41	0.18	0.17	0.65	1.54	3.38	2.97	2.37	2.19	1.49	0.19	-0.20	14.51
64	1.16	1.43	1.88	3.17	3.14	4.50	4.82	4.87	3.79	2.54	1.47	1.17	33.93
76	-0.24	0.43	0.70	1.37	2.42	4.19	3.91	3.14	2.81	1.91	0.53	-0.02	21.15
80	-0.09	0.42	0.68	1.11	1.99	3.61	2.66	1.63	2.35	1.37	0.55	-0.09	16.19

Comments and Concerns

Recommended average monthly evaporation rates vary from the rates used by Denver Water and NCWCD in their surface water modeling efforts. A comparison between SPDSS recommended average monthly evaporation rates and Denver Water rates for the same regions show they vary between 1 percent and 35 percent. The largest variations are for upper reservoirs where Denver Water sets winter evaporation rates to zero, whereas our analysis shows that reservoirs in these areas should experience winter evaporation.

Appendix F
Task 71 – Estimate Historical Acreage

To: Ray Bennett and Ray Alvarado

From: LRE - Erin Wilson and Greg Espegren

Subject: Task 71 – Estimate Historical Acreage

Date: October 31, 2006, revised March 21, 2007

Introduction

Irrigated acreage and crop types are key data components used to estimate crop consumptive use in the SPDSS study area. GIS coverages were developed for SPDSS (RTi, 2006) that represent acreage and crop types by ditch or water source for 2001, 1987, and 1976 using thermal signatures from satellite imagery, aerial photos, and field interviews. In addition, a coverage was developed that represents irrigated acreage by ditch or water source for 1956 using aerial photography. Crop types were not able to be assigned to irrigated acreage for 1956 using aerial photos.

Colorado Agricultural Statistics (CAS) and National Agricultural Statistics (NAS) report user-provided acreage and yield by crop at the county level on an annual and a 5-year basis, respectively[1]. This data was collected, digitized as necessary, and incorporated into HydroBase during Phase 1.

This memorandum presents the general approach and results from the completion of the following:

> *Determine an appropriate method for using agricultural statistics, water rights, water availability, and other data to estimate historic irrigated acreage and crop types by ditch or other water source for the entire SPDSS study period (e.g. time periods before and between GIS irrigated acreage coverages).*

Approach and Results – Agricultural Statistics (AgStats) Analysis

AgStats data was evaluated from 1950 through 2005 to determine whether observed changes in crop type over time at the basin wide and county levels could be used to help fill data gaps in the GIS irrigated acreage coverages at the ditch level.

A summary of AgStats over the entire South Platte River basin reveals that the total number of irrigated acres declined from approximately 1.4 million acres in 1965 to around 1 million acres

[1] CAS and NAS data are collectively referred to as "AgStats" data throughout this report.

in 2005 (Figure 1)[2, 3]. A closer look at individual counties shows that the decline was most pronounced in "urbanized" counties like Jefferson (Figure 2). Irrigated acres in rural counties varied between years but either remained relatively constant over this time period, as in Logan County (Figure 3), or increased slightly over time, as in Sedgewick County (Figure 4).

Figure 1. Irrigated Acres - South Platte River Basin

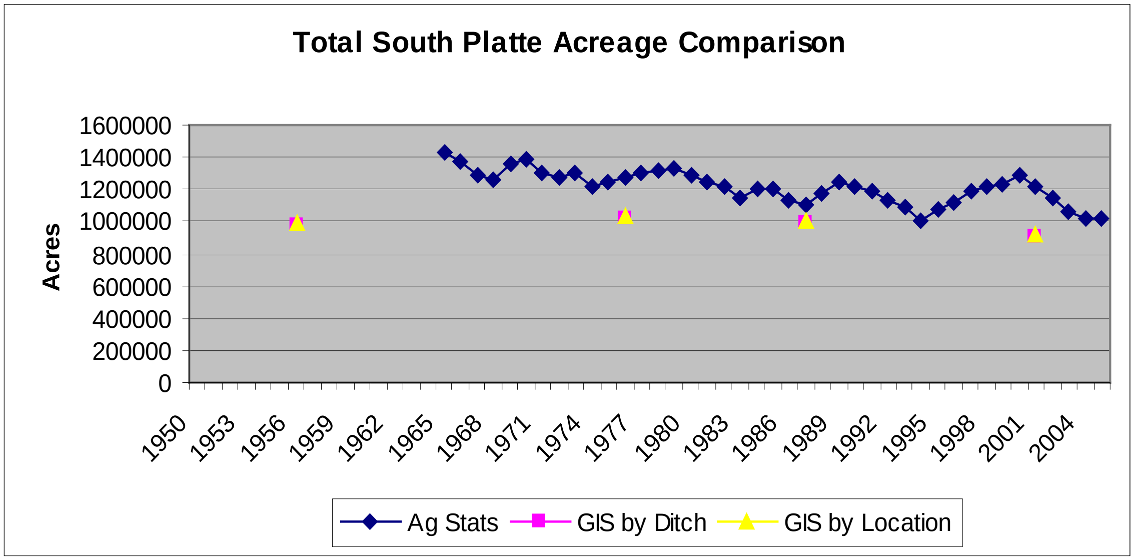
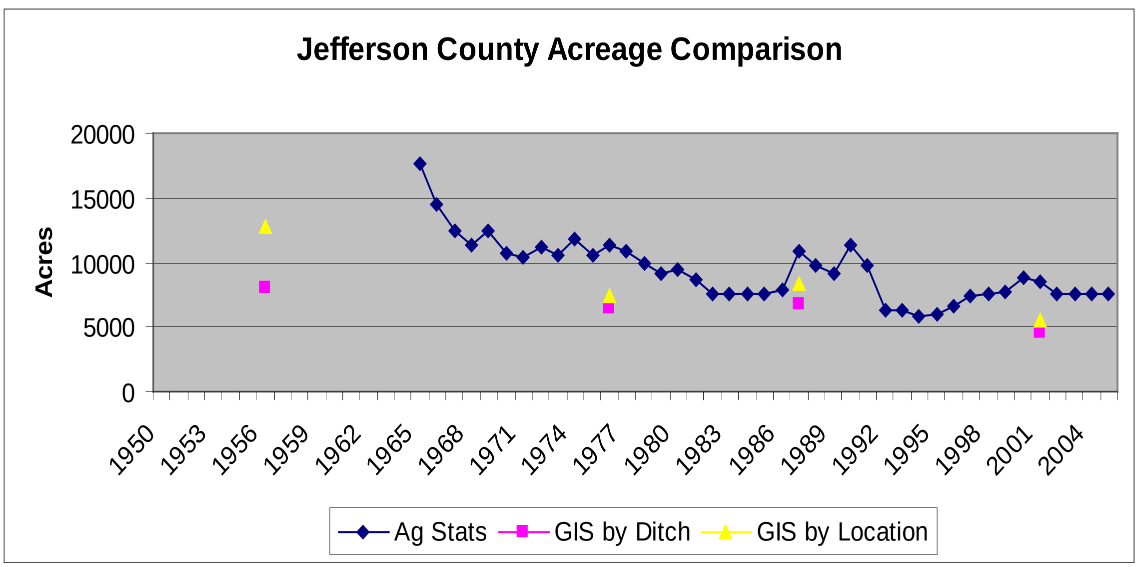


Figure 2. Irrigated Acres - Jefferson County



[2] AgStat data is depicted by lines on Figures 1 through 8 while GIS irrigated acreage data, which is discussed later in this memorandum, is depicted by individual points.
[3] Note that AgStats does not provide information on alfalfa and pasture prior to 1967 or on irrigated corn prior to 1964.

Figure 3. Irrigated Acres - Logan County

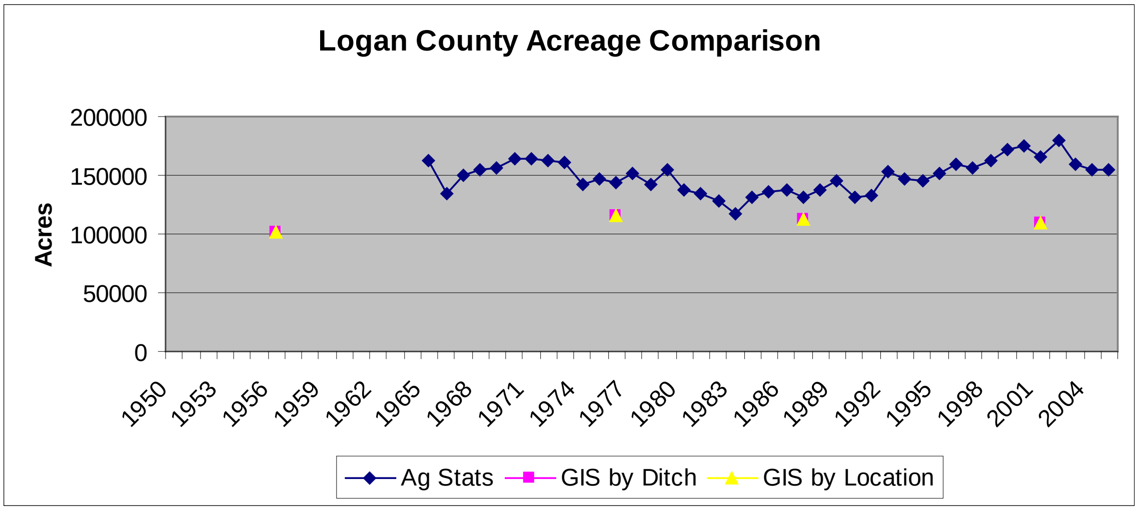
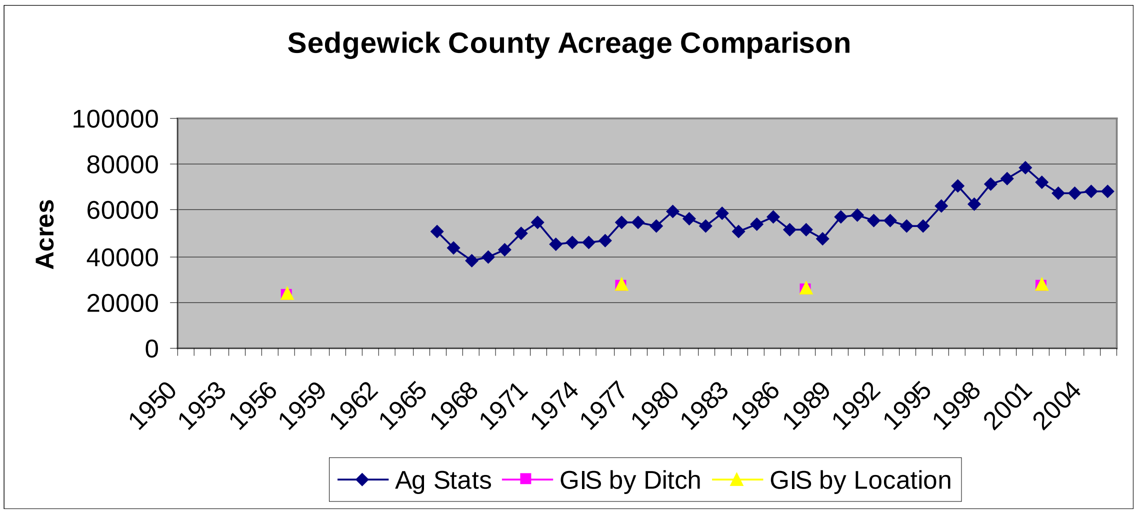


Figure 4. Irrigated Acres - Sedgewick County



AgStats also provides an opportunity to look at changes in irrigated acreage by crop type at the county level over the 1950 to 2005 time period. Figure 5 shows AgStat trends in irrigated acres of corn, beans, grains, sugar beets, alfalfa and pasture. Basin wide, irrigated acres of corn can vary greatly between years while most of the other crop types remain relatively constant over time. Some counties, like Weld (Figure 6), are similar to the basin wide trends in crop type variability while other counties, like Boulder (Figure 7) and Adams (Figure 8), exhibit a great deal of variability in all crop types between years. There does not appear to be consistent crop type patterns between counties.

Figure 5. Irrigated Acres by Crop Type - South Platte River Basin wide

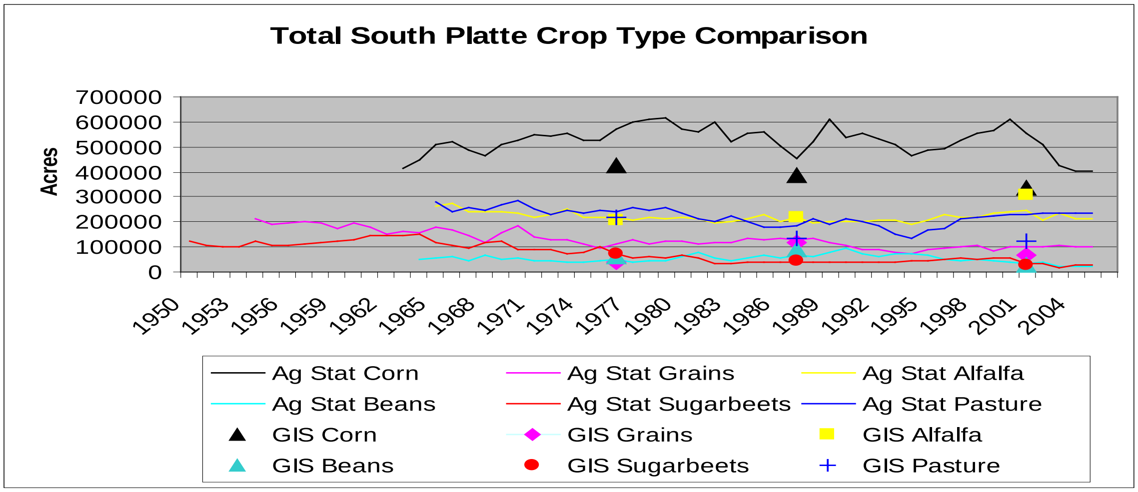


Figure 6. Irrigated Acres by Crop Type - Weld County

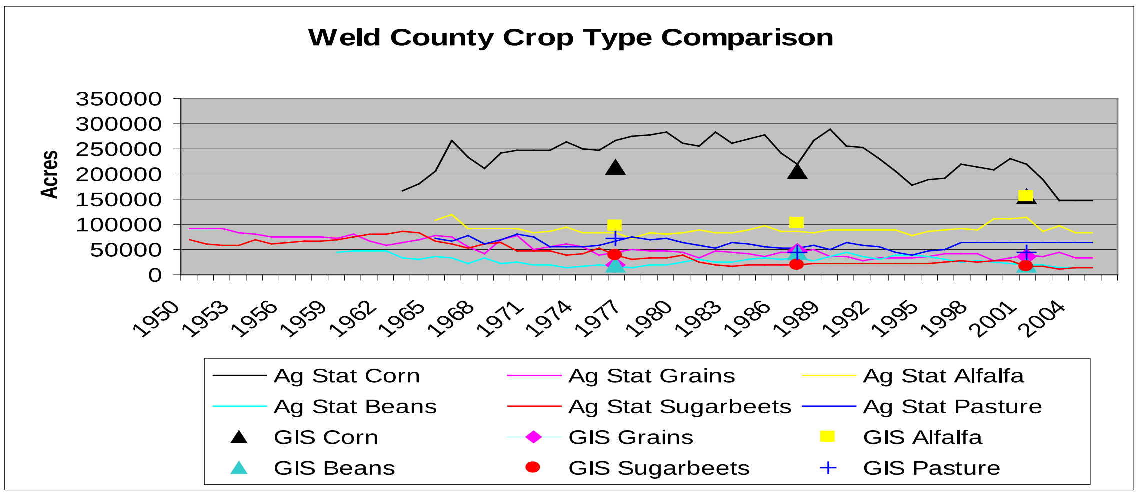


Figure 7. Irrigated Acres by Crop Type - Boulder County

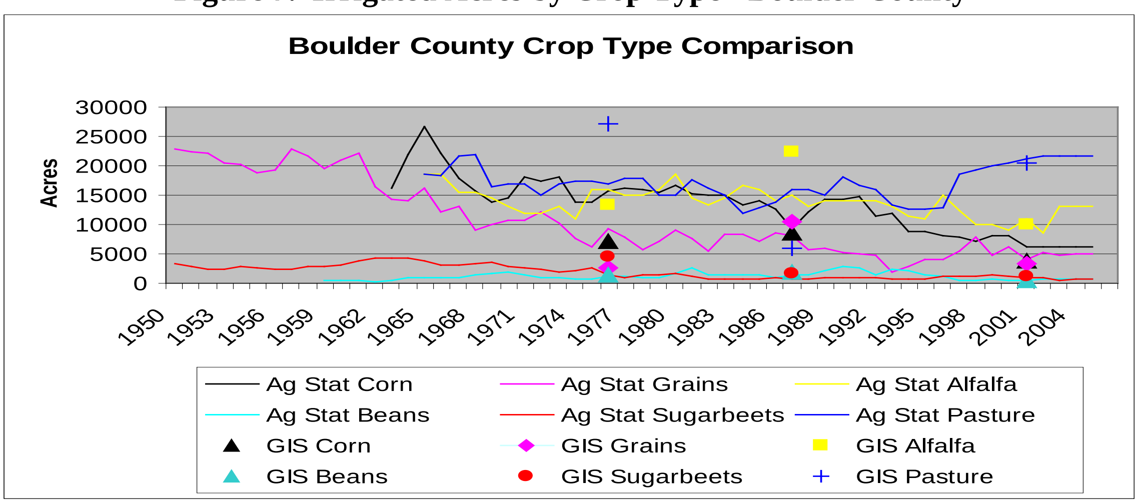
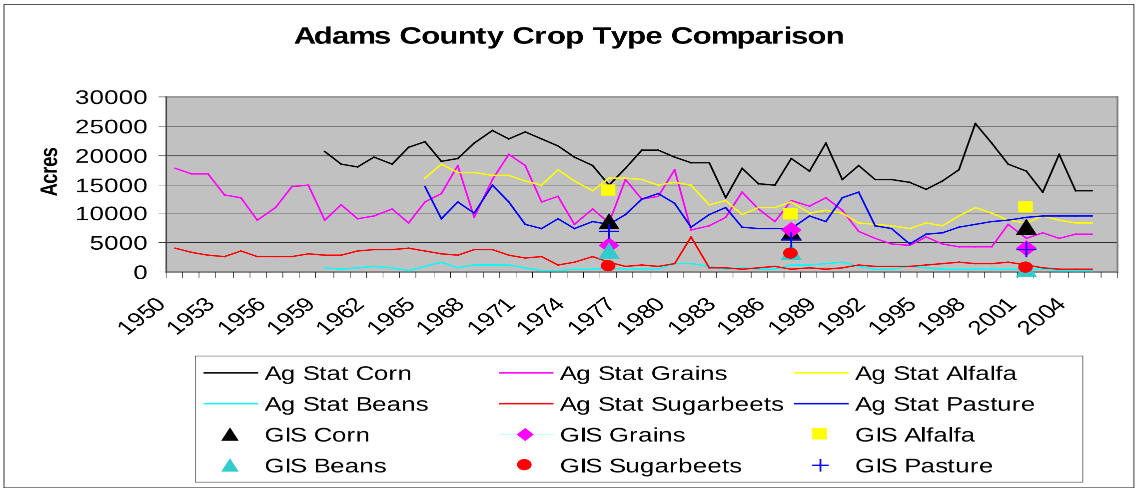


Figure 8. Irrigated Acres by Crop Type - Adams County



Approach and Results – GIS Irrigated Acreage Coverages

In order to determine how AgStats could be used to estimate acreage for years with no GIS coverages, trends in the GIS irrigated acreage were compared to the changes and trends in the AgStats. As noted above, GIS irrigated acreage coverages were provided for 1956, 1976, 1987, and 2001. Coverages from 1976, 1987, and 2001 contained information on crop type and irrigated acres. The 1956 coverage originally only contained information on irrigated acres.

Some ditches span several counties. Therefore, two techniques were used to assign the GIS irrigated acreage to a county[4]. "GIS by Ditch" assigned the ditch to the county that contained the majority of the irrigated acreage under that ditch. "GIS by Location" assigned irrigated acreages to a county based on the spatial location of the irrigated parcel of land, in which case parts of ditches may be represented in more than one county.

Figures 1 through 8 also contain information on the four GIS irrigated acreage coverages. GIS coverages indicate that basin-wide, irrigated acreage remained relatively constant at around 1 million acres from 1956 to 1987 (Figure 1) and that between 1987 and 2001, irrigated acres dropped to around 910,000 acres.

Figures 1 through 4 and Table 1 also indicate that GIS estimates of total irrigated acres at both the basin and county levels are significantly less than AgStat estimates of irrigated acres. Figures 5 through 8 provide an opportunity to take a closer look at changes in crop type over time. These figures suggest that the largest discrepancy between the GIS coverages and AgStats occurs in estimates of irrigated acres of corn.

AgStat and GIS estimates of acres of beans, grains, sugar beets, alfalfa and pasture are relatively consistent. Note that although most crops have both "irrigated" and "non-irrigated" categories, AgStat corn statistics are only available for "total". Therefore, it is likely that some of the

[4] According to AgStats, there is an attempt to have large users split their acreage up by county, however, it is recognized that most users report their acreage under one county regardless.

discrepancy between the GIS coverages and AgStat estimates in irrigated acres of the corn crop type may be due to the inclusion of non-irrigated corn acreages in AgStats.

The GIS irrigated acreage coverages do not include irrigated parks, golf courses, open spaces, or small hobby farms less than 3 acres (see RTi documentation) within the overall boundaries of cities; this information is included in AgStats. This likely contributes to the large discrepancies in counties encompassing municipalities, such as Arapahoe, Douglas, and Jefferson.

Table 1. GIS Acreage as a Percent of AgStat Acreage by County by GIS Year

	Year		
County	**1976**	**1987**	**2001**
Adams	80%	81%	71%
Arapahoe	23%	20%	17%
Boulder	92%	100%	90%
Clear Creek	38%	31%	3%
Elbert	50%	61%	24%
Douglas	43%	63%	17%
Jefferson	58%	62%	54%
Larimer	73%	84%	84%
Logan	81%	86%	66%
Morgan	90%	116%	87%
Park	77%	62%	52%
Sedgwick	49%	50%	37%
Washington	20%	25%	13%
Weld	88%	99%	91%
Basin Total	**80%**	**90%**	**75%**

Water Rights Analysis – Approach and Results

Changes in crop type and irrigated acres based on the relative priorities of several ditches were evaluated. Using information from HydroBase, senior and junior water rights were reviewed to determine whether changes in irrigated acres of individual crop types from the GIS irrigated acreage assessment were dependent on water rights priority. In Figures 9 and 10, the general trends for Boulder County Agstats (left axis) are compared to the percentage changes in crop type at the ditch level (right axis) for two senior and two junior water rights, respectively. In Figure 9, the senior Howell Ditch (WDID 0600536) changed from a mix of 62% alfalfa and 38% pasture in 1976 to 100% alfalfa in 1987 to 100% pasture in 2001. The total acreage under this ditch remained constant at 103.5 acres. Over this same time period, the senior Chapman McCaslin Ditch (WDID 0500546) changed from a mix of 85% pasture, 8% corn and 7% alfalfa in 1976 to 7% pasture, 3% corn, 85% alfalfa, and 6% small grains in 1987 to 75% pasture, 11% corn, and 14% alfalfa in 2001. The total acreage under this ditch remained constant at 258 acres in 1956 and 1976 but dropped to 175 acres in 1987 and to 157 acres in 2001 as parcels portions of the ditch were transferred to municipal use.

In Figure 10, the junior Reese Stiles Ditch (WDID 0500519) went from 100% pasture in 1976 to 28% pasture and 72% alfalfa in 1987 back to 100% pasture in 2001. The total acreage under this ditch remained constant at 29 acres until 2001 when it dropped to 9 acres. User-supplied acreage reported annually in HydroBase indicates acreage under this ditch has both increased and decreased several times over the last 20 years, even though water rights have not been transferred.

During this same time period, the junior Harris Ditch (WDID 0600611) went from 40% alfalfa, 55% pasture, and 5% small grains in 1976 to 28% alfalfa, 62% corn, 5% dry beans, and 5% pasture in 1987 to 28% alfalfa, 25% pasture, and 47% small grains in 2001. The total acreage under this ditch stayed relatively consistent at 59 acres in 1956 and 1976 and 56 acres in 1987 and 2001.

Figure 9. Crop Type Changes Over Time for Representative Senior Ditches

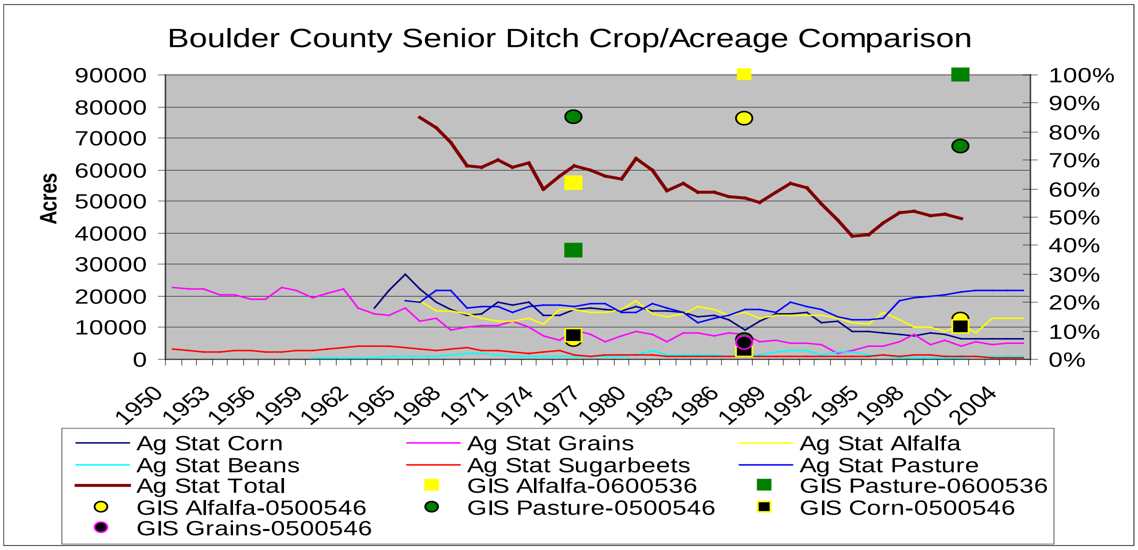
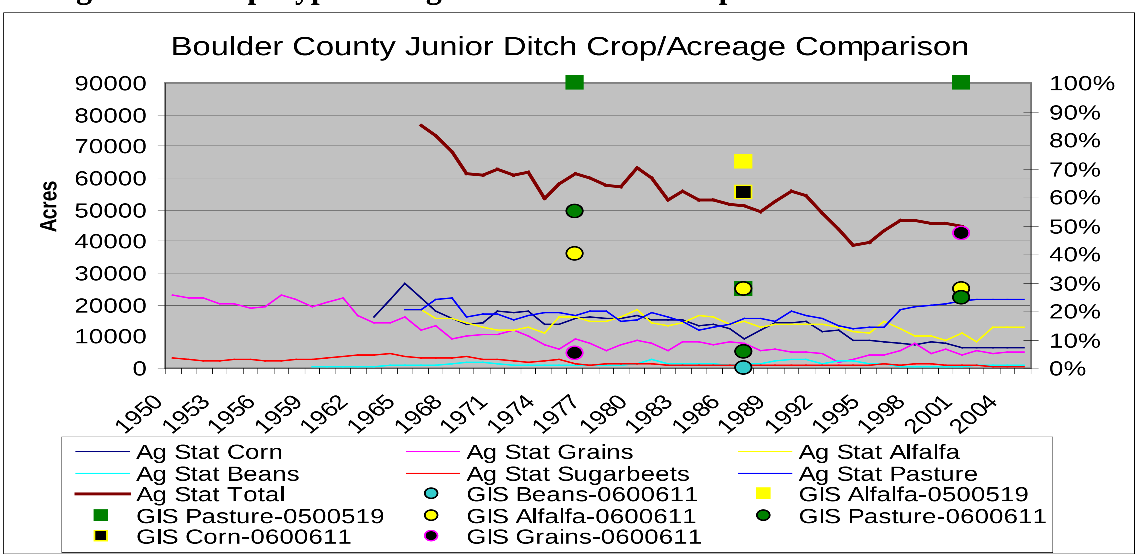


Figure 10. Crop Type Changes Over Time for Representative Junior Ditches



Based on this comparison, it does not appear that the relative priority of a water right can be used to predict changes in crop type in conjunction with AgStats. Figures 9 and 10 also show that changes in crop type over time at the county level, as represented by AgStats, are not good predictors of changes in crop type at the ditch level.

Approach and Results – Hydrologic Analysis

Hydrologic conditions were evaluated to determine if hydrology could help predict acreages and/or crop type at the ditch level. Using the South Platte at Julesburg (06764000) and South Platte River at Kersey (06754000) streamflow gages and the Analyze Pattern option in TSTool, "dry", "average", and "wet" years were defined based on the 25% and 75% mean monthly flows between 1950 to 2005 (Table 2).

Table 2. Hydrologic Conditions during GIS Coverage years

Year	Gage ID	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1956	06754000_pat	DRY	DRY	DRY	DRY	DRY	DRY	DRY	AVG	DRY	DRY	AVG	DRY
1956	06764000_pat	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	AVG	DRY
1976	06754000_pat	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	DRY	AVG	AVG	WET
1976	06764000_pat	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	DRY	DRY	DRY	AVG
1987	06754000_pat	WET	WET	WET	WET	WET	WET	WET	WET	AVG	AVG	AVG	AVG
1987	06764000_pat	WET	WET	WET	WET	AVG	WET	WET	WET	WET	AVG	AVG	WET
2001	06754000_pat	AVG	AVG	AVG	AVG	WET	AVG	AVG	AVG	AVG	AVG	AVG	AVG
2001	06764000_pat	AVG	DRY	DRY	AVG	AVG	DRY	AVG	AVG	AVG	AVG	AVG	AVG

As shown, 1956 was a dry, 1976 and 2001 were relatively average years, and 1987 was a wet year. Changes in acreage and crop type at the county level (Figures 6 through 8) and at the ditch level (Figures 9 and 10) do not appear to be related to the hydrologic conditions that were present in these years.

Observations

The following observations can be made based on the evaluation of AgStats, water rights, hydrology and GIS coverages:

- There is a general trend towards reduced crop acreage over time in most counties (both AgStats and GIS).
- For most counties and basin-wide, total GIS acreage is less than AgStat acreage.
- CAS does not differentiate between irrigated and non-irrigated acres of corn and therefore CAS estimates of corn appear to be higher than GIS coverage estimates of corn in every county.
- AgStat surveys attempt to have larger users split their acreage by county, however, it is recognized that most users report their acreage under one county instead.
- Ditches may irrigate lands that span many counties. Irrigated acreage under a single ditch may be represented in AgStats in more than one county making it difficult to fill data at the ditch level with county-based AgStats data.
- There does not appear to be consistent crop type patterns between counties.

- CAS and NAS do not contain information on acres of alfalfa or pasture prior to 1967 or on irrigated corn prior to 1964.
- Neither senior nor junior ditches appear to follow general AgStat patterns.
- Unless transferred, acreage under both senior and junior ditches did not change significantly in the four historical coverage years.
- Total irrigated acreage assigned to specific ditch systems in the GIS coverages tends to be relatively consistent over time, even as wells were added. This indicates that wells were added as a supplemental to surface water, not to increase acreage. Lands served only by ground water generally were not irrigated prior to well development, therefore as new sole-source wells were added, irrigated acreage increased. Therefore, the recommended method to fill data gaps needs to consider acreage under ditch systems separately from acreage irrigated only by ground water.

Recommendation for Filling Data Gaps in GIS Irrigated Acreage Coverage

Opportunities for using agricultural statistics, diversion records, water rights, and hydrology to fill data gaps in the GIS irrigated acreage coverage at the ditch level were evaluated.

Agricultural statistics are most useful for evaluating general trends in crop rotation. The county-specific statistical summaries provided in CAS and NAS are based on census information that is provided voluntarily by farmers; consequently, the accuracy and precision of variation in crop type and irrigated acreage may be somewhat masked by the amount of user participation in a particular year. In addition, user-supplied estimates of irrigated acreage are probably not as accurate as estimates based on GIS, aerial photos or other scientific means. While the CAS and NAS data are useful for identifying general trends at the county level, they do not seem to provide useful information for filling data gaps between GIS coverage years at the ditch-specific level of resolution as desired under Task 71.

Relative priority of irrigation water rights were also reviewed to determined if they could be used to help predict crop type or acres of irrigated land at the ditch or well level. The analysis indicated that total acres of irrigated land remained relatively constant over time for acreage irrigated with surface water only or irrigated with surface water and supplemented with ground water, regardless of the irrigation right priority, unless rights were transferred to municipalities. In contrast, irrigated acreage increased over time for lands served only by ground water. The analysis also indicated that changes in crop type could not be determined by the priority of an irrigation right.

Hydrologic conditions during the four GIS coverage years were evaluated and it was determined that they could not be used to predict changes in crop type or irrigated acres.

Based on the evaluation, we recommend the following procedure for filling crop type data at the ditch or well level:

Lands Irrigated with Surface Water Only or Supplemented with Ground Water

1. Fill Crop Type for 1956 Coverage: Use 1976 GIS coverage to fill crop type for 1956 coverage. In instances where parcels from the 1976 GIS coverage are spatially identical or overlap parcels in the 1956 coverage, use the 1976 crop type to fill the 1956 parcel. Parcels that existed in 1956 but do not overlap with parcels in 1976 should be filled with the crop type of the 1976 parcel that is located nearest to the 1956 parcel.
2. Back Fill Acreage and Crop Type from 1955 to 1950: Use acreage and crop types from the completed 1956 GIS coverage to back fill to 1950.
3. Linear Interpolate Acreage and Crop Types from 1957 to 1975: Use acreage and crop types from the completed 1956 and 1975 GIS coverages. Use a straight-line interpolation between individual crop acreage, add individual crop acreage to get total.
4. Linear Interpolate Acreage and Crop Types from 1977 to 1986: Use a straight-line interpolation between individual crop acreage, add individual crop acreage to get total.
5. Linear Interpolate Acreage and Crop Types from 1988 to 2000: Use a straight-line interpolation between individual crop acreage, add individual crop acreage to get total.
6. Forward Fill Acreage and Crop Types from 2002 to 2005: Use acreage and crop types from 2001 GIS coverage to forward fill to 2005.

Lands Irrigated with Ground Water Only

1. Fill Crop Type for 1956 Coverage: Use 1976 GIS coverage to fill crop type for 1956 coverage. In instances where parcels from the 1976 GIS coverage are spatially identical or overlap parcels in the 1956 coverage, use the 1976 crop type to fill the 1956 parcel. Parcels that existed in 1956 but do not overlap with parcels in 1976 should be filled with the crop type of the 1976 parcel that is located nearest to the 1956 parcel.
2. Back Fill Acreage and Crop Type from 1955 to 1950: Use acreage and crop types from the completed 1956 GIS coverage. Include 1956 acreage only for years after wells assigned to 1956 coverage were permitted or adjudicated. For instance, if an irrigated parcel had a well assigned in the 1956 coverage that was permitted or adjudicated in 1953, that parcel would be included as irrigated acreage in 1953 through 1955, but would be not be included as irrigated in 1950 through 1952.
3. Linear Interpolate Acreage and Crop Types from 1957 to 1975: Use acreage and crop types from the completed 1956 and 1975 GIS coverages. Use a straight-line interpolation between individual crop acreage, add individual crop acreage to get total.
4. Linear Interpolate Acreage and Crop Types from 1977 to 1986: Use a straight-line interpolation between individual crop acreage, add individual crop acreage to get total.
5. Linear Interpolate Acreage and Crop Types from 1988 to 2000: Use a straight-line interpolation between individual crop acreage, add individual crop acreage to get total.
6. Forward Fill Acreage and Crop Types from 2002 to 2005: Use acreage and crop types from 2001 GIS coverage to forward fill to 2005.

Comments and Concerns

LRE has evaluated various methods to use statistics, water rights, hydrology, and other data to estimate historic irrigated acreage and crop types by water source for time periods before and between GIS irrigated acreage coverages. Note of the methods evaluated provided reasonable estimates. Therefore, the recommended approach varies for ditch systems and lands that have only ground water sources but, in general, uses back filling or forward filling. The following are noted:

- The historical crop consumptive use analysis requires time series of ground water and sprinkler acreage in addition to time series of total acreage and crop types discussed in this memorandum. Recommendations for developing sprinkler and ground water acreage time series are addressed in a separate memorandum.

Appendix G
Task 56 – Conveyance and Application Efficiencies

To: Ray Bennett and Ray Alvarado

From: LRE, Erin Wilson and Mark Mitisek

Subject: Task 56 – Conveyance and Application Efficiencies

Date: August 25, 2006, revised March 2008 (to represent finalized structure list)

Introduction

This memorandum describes the approach and results obtained under Task 56 – Conveyance and Application Efficiencies. This task includes an estimation of both ditch system conveyance and maximum application (on-farm) efficiencies likely to be experienced in the South Platte basin, plus a recommendation on efficiencies to use for the historic consumptive use analyses. The conveyance loss estimates are to be used for ditches of variable size including key structures identified in Task 3 and medium and small ditch systems throughout the basin. All estimates are based on available data or developed from sources using a data-centered approach.

Conveyance Efficiencies

The StateCU model uses estimated conveyance efficiencies to determine the quantity of river diversions delivered to the farm for application on the crops.

Factors that affect conveyance efficiencies typically include:

- Frequency and duration of diversions (i.e., the beginning of diversion season versus late summer diversions)
- Soil properties such as hydraulic conductivity and permeability
- Canal geometry (e.g. wetted perimeter)
- Canal length
- Location of water table relative to the depth of flow in the canal
- Flow rate in the canal

Approach-Conveyance System Efficiencies

In an effort to acquire the best available information regarding conveyance efficiencies for irrigation ditches in the South Platte basin, the following steps were performed:

- A literature search of published studies on conveyance losses in the South Platte basin was completed,
- Summaries of water rights decrees and published loss estimates were reviewed (most notably, summaries of decreed ditch losses and application efficiencies compiled by LRE, Martin & Wood Water Consultants, Inc., and Bishop-Brogden Associates, Inc., and Water Resources Investigation reports developed for the Colorado Division of Water Resources),

- Efficiencies provided through interviews with water administrators and ditch companies were compiled (SPDSS Task 5), and
- Numerous governmental agencies were contacted, including county offices of the Natural Resources Conservation Service and the Farm Services Agency.

These inquiries yielded estimates of ditch efficiencies for 69 of the 404 explicitly modeled surface water structures identified for the South Platte in SPDSS Task 3, which represents approximately 40 percent of surface water-source acreage. These ditch efficiencies are recommended for use in StateCU and StateMod modeling efforts. **Attachment A** shows the ditch conveyance efficiencies found during the search. For the remaining key structures in the study area, there is limited information regarding conveyance losses. Consequently, a search of empirical methods that have been developed to estimate ditch efficiencies was completed, and an appropriate method selected, as outlined in **Attachment B**.

Recommendations - Conveyance Efficiencies

The following is the recommended sequence for estimating conveyance efficiencies:

1. Use ditch efficiencies provided by water administrators, ditch companies, water rights decrees, and published literature (listed in **Attachment A**, provides efficiencies for 69 structures).
2. Estimate conveyance efficiencies for key structures based on canal length and soil type, using the NRCS approach outlined in **Attachment B**, using the following procedure. Note that this procedure was also used to estimate conveyance efficiencies for the RGDSS consumptive use analysis.
    - Determine canal lengths using the GIS CDSS Toolbox “Aggregated Canal Segments” tool. The required input file is the SPDSS Canal coverage. The comma-separated output file lists WDID and canal length in feet.
    - Determine average weighted ditch permeability using the GIS CDSS Toolbox “Soil Parameter by User Supplied Polyline ID” tool. The required input files include the StateWide STATSGO Permeability coverage and the SPDSS Canal coverage. The comma-separated output file lists WDID and average canal permeability.
    - Based on soil permeability, determine soil classification by canal (see relationship in **Table B-3, Attachment B**).
    - Based on the soil classification and canal length, select corresponding efficiency as described in the approach section.
3. Estimate conveyance efficiency for aggregate structures and key structures without canal length information using the NRCS approach outlined above, based average conveyance loss determined by aggregate area as follows:
    - Estimate ditch length to be the median length of ditches with values estimated in step 2 above.
    - Determine average weighted ditch permeability using the GIS CDSS Toolbox “Soil Parameter by User Supplied Polygon ID” tool. The required input files include the StateWide STATSGO Permeability coverage and

the SPDSS Aggregate polygon coverage developed in Task 3 – Aggregate Non-Key Structures. The comma-separated output file lists Aggregate ID and average permeability.

- Based on soil permeability, determine soil classification by canal (see relationship in **Table B-3, Attachment B**).
- Based on the soil classification and canal length, select corresponding efficiency as described in the approach section

Maximum Application Efficiencies

The StateCU model uses e maximum application efficiency to estimate the maximum water available to meet crop consumptive use demands. StateCU calculates the actual application efficiency by dividing the water delivered to the farm by the crop consumptive use met with input river diversions.

Factors that affect maximum application efficiencies include:

- Irrigation practice (i.e., sprinkler versus flood irrigation)
- Crop types
- Soil types

Approach – Maximum Application Efficiencies

1. Review interviews with water administrators and ditch companies and extract the following information from the resulting Key Structure Operating Memoranda as well as from other available sources including summaries of water rights decrees, SPDSS GIS irrigated acreage coverages, or published literature:
   – Irrigation application method
   – Application efficiency for each irrigation method
2. Review other published data for on-farm irrigation efficiencies in the South Platte basin and adjacent areas.
3. Suggest appropriate maximum application efficiencies to use based on irrigation methods.

Results – Maximum Application Efficiencies

As mentioned in the introduction, application efficiencies are dependent on irrigation methods, which may vary with crop type and soils. In addition, irrigation methods and planting practices have changed during the period considered in the SPDSS project. The review of application efficiencies for the South Platte basin has largely consisted of a review of efficiencies contained in water rights decrees. This review indicated efficiencies range from 45 percent to 85 percent. Klamm and Brenner (1995) have developed a list of recommended potential efficiency estimates by type of irrigation system. A summary of the recommendations are shown in **Table 1**. Boesch (1995) also reported a variety of application efficiencies that are dependent upon the irrigation system type from a study done by the NRCS in Rocky Ford, Colorado. The findings of the study encompass the values listed in **Table 1**.

Table 1
Potential Efficiencies by Irrigation Systems

Irrigation System Type	**Potential Efficiency**	**Irrigation System Type**	**Potential Efficiency**
Borders	(%)	Flood Irrigation	(%)
Level or Basin	90	Controlled	60
Graded	80	Uncontrolled	50
Guide	70	Contour Ditch	60
Contour – level		Sprinkler	
Field Crop	70	Big gun or boom	60
Rice	80	Hand or wheel line	70
Border Ditch	60	Solid set (above canopy)	75
Furrow		Solid set (below canopy)	80
Level or Basin	90	Center-pivot	80
Graded	75	Center-pivot (LEPA)	85
Contour	75	Trickle	
Corrugations	75	Point Source	90
Surge	85	Spray emitters	85
Sub-irrigated	75	Continuous tape	90

Source: Klamm and Brenner (1995)

Recommendations – Maximum Application Efficiencies

The StateCU model uses maximum application efficiencies to estimate the amount of irrigation water delivered to the farm that is available to meet crop consumptive use demands. The flood irrigated and sprinkler irrigated acreage under each ditch system, by year, and maximum flood and sprinkler efficiencies are input to the StateCU model. The actual application efficiency is calculated within the model based on historic water supply and may be considerably less than the input maximum application efficiency.

Although actual application efficiency can vary with crop type and soil type, a consistent maximum application efficiency is recommended throughout the basin based on irrigation method. **Table 2** shows the recommended maximum application efficiencies for use in the consumptive use analysis. These efficiencies are consistent with published data reviewed for Task 56 including user information and efficiencies published in engineering reports supporting water court applications and adjudications.

Table 2
Recommended Maximum Application Efficiencies

Flood Irrigation	Sprinkler Irrigation
60 %	80 %

Comments and Concerns

The recommended conveyance efficiencies are appropriate for use in analyses performed as part of the SPDSS project. However, ditch loss data were only available for large ditch systems. In addition, the GIS canal coverage may not include all the ditch systems, and some ditches may include main canal plus laterals while others may only include the main canal. If more information becomes available through further investigations, ditch-specific conveyance efficiencies may be more accurately determined.

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Worstell, R.V. 1976. “Estimating Seepage Losses from Canal Systems,” *Journal of the Irrigation and Drainage Division*, 102(1), 137-147.

Attachment A
Ditch Conveyance Efficiencies from Literature Search

No.	WDID	NAME	Conveyance Efficiency %	Structure Type
1	0100503_D	RIVERSIDE INLET CANAL	0.75	DivSys
2	0100507_D	BIJOU CANAL	0.67	DivSys
3	0100511	WELDON VALLEY DITCH	0.77	Key
4	0100514	FORT MORGAN CANAL	0.65	Key
5	0100515	UPPER PLATTE AND BEAVER CANAL	0.80	Key
6	0100525	TETSEL DITCH	0.75	Key
7	0100687	NORTH STERLING INLET CANAL	0.50	Key
8	0200802	BURLINGTON - O'BRIEN CANAL[1]	0.72	Key
9	0200805	DENVER HUDSON CANAL[2]	0.50	Key
10	0200806	GARDENERS DITCH	0.95	Key
11	0200808	FULTON DITCH	0.85	Key
12	0200809	BRANTNER DITCH	0.78	Key
13	0200810	BRIGHTON DITCH	0.75	Key
14	0200812	LUPTON BOTTOM DITCH	0.67	Key
15	0200821	MEADOWS ISLAND NO. 1 DITCH	0.75	Key
16	0200825	HEWES COOK DITCH	0.95	Key
17	0200826	JAY THOMAS DITCH	0.90	Key
18	0200834	LOWER LATHAM DITCH	0.88	Key
19	0200915	LITTLE BURLINGTON CANAL[3]	0.74	Key
20	0203837_C	FRICO-BARR IRRIGATION[4]	0.72	Key
21	0300905	NORTH POUDRE SUPPLY CANAL	0.84	Key
22	0300911	LARIMER COUNTY CANAL	0.86	Key
23	0300929	GREELEY NO. 2 DITCH	0.85	Key
24	0300934	CANAL NO. 3 DITCH	0.90	Key
25	0300994_D	NORTH POUDRE CANAL	0.84	DivSys
26	0400501	BIG BARNES DITCH	0.78	Key
27	0400524	HOME SUPPLY DITCH	0.90	Key
28	0400532	LOVELAND GREELEY CANAL	0.78	Key
29	0400588	BOULDER LARIMER DITCH	0.90	Key
30	0500526	HIGHLAND DITCH	0.90	Key
31	0500603_D	LEFT HAND DITCH COMPANY	0.70	DivSys
32	0600501	ANDERSON DITCH	0.95	Key
33	0600570	DRY CREEK DITCH NO. 2	0.90	Key
34	0600576	ENTERPRISE DITCH	0.90	Key
35	0600538_D	LOWER BOULDER DITCH	0.80	DivSys
36	0600564_D	COMMUNITY DITCH	0.70	DivSys
37	0600615	LAST CHANCE DITCH	0.87	Key
38	0700502	AGRICULTURAL DITCH	0.80	Key
39	0700540	CHURCH DITCH	0.75	Key
40	0700547	LOWER CLEAR CREEK DITCH	0.80	Key
41	0700549	COLORADO AGRICULTURAL DITCH	0.77	Key
42	0700551	CORT, GRAVES AND HUGHES DITCH	0.90	Key
43	0700553	CROKE CANAL	0.85	Key
44	0700569	FARMERS HIGHLINE DITCH	0.75	Key

No.	WDID	NAME	Conveyance Efficiency %	Structure Type
45	0700570	FISHER DITCH	0.90	Key
46	0700597	KERSHAW DITCH	0.92	Key
47	0700601	LEE, STEWART, & ESKINS DITCH	0.85	Key
48	0700614	MANHART DITCH	0.80	Key
49	0700647	RENO-JUCHEM DITCH	0.80	Key
50	0700698	WANNEMAKER DITCH	0.90	Key
51	0801009_D	NEVADA DITCH	0.90	DivSys
52	0801015	EPPERSON DITCH	0.90	Key
53	0900731_D	HARRIMAN DITCH	0.82	DivSys
54	0900752	HODGSON DITCH	0.85	Key
55	0900816	MCBROOM DITCH	0.90	Key
56	0900963_D	WARRIOR DITCH	0.80	DivSys
57	6400501	CARLSON DITCH	0.75	Key
58	6400502	LIDDLE DITCH	0.75	Key
59	6400503	SOUTH RESERVATION DITCH	0.95	Key
60	6400504	PETERSON DITCH	0.70	Key
61	6400508	SETTLERS DITCH	0.75	Key
62	6400514	RAMSEY DITCH	0.75	Key
63	6400518	LONE TREE DITCH	0.75	Key
64	6400520	ILIFF AND PLATTE VALLEY DITCH	0.80	Key
65	6400524	LOWLINE DITCH	0.80	Key
66	6400530	SPRINGDALE DITCH	0.55	Key
67	6400531	SCHNEIDER DITCH	0.70	Key
68	6400532	DAVIS BROS DITCH	0.90	Key
69	6400535	SOUTH PLATTE DITCH	0.67	Key

Notes:
1. BURLINGTON DITCH-O'BRIEN CANAL (Headgate to Denver Hudson bifurcation)
2. DENVER HUDSON CANAL (Burlington headgate to Henrylyn irrigation)
3. LITTLE BURLINGTON CANAL (Burlington headgate to irrigated land)
4. FRICO-BARR IRRIGATION (Burlington headgate to reservoir)

Attachment B
Review and Recommendation of Analytical Methods for Estimating Ditch Efficiency

The following summarizes the results and recommendations for estimating ditch efficiency based on a review of analytical methods, the data required for each method, and the data readily available for the SPDSS basin-wide requirement. Several methods were identified that have been developed use the same basic parameters. The following parameters are used estimate conveyance efficiency:

- Seepage loss
- Canal length
- Canal geometry such as wetted perimeter or cross-sectional area
- Number of days water is in the ditch
- Diversion flow rate.

These methods generally use the same parameters but estimate seepage loss differently. A commonly used methodology for estimating conveyance efficiency was published by the SCS in the *National Engineering Handbook* (1993). The method estimates seepage losses as a function of material type, flow, and incidental vegetation losses.

Worstell (1976) developed an empirical estimate of seepage rates or conveyance losses that was dependent upon the predominant soil type of the canal as well as the longitudinal area of the canal (i.e., the product of the wetted perimeter and canal length). The seepage rate estimates were based on numerous studies that utilized ponding tests as the predominant method for determining seepage losses.

Swamee et al. (2000) developed a method to estimate seepage loss based upon the hydraulic conductivity of the soil and the width-to-depth ratio of the canal. The premise of the analysis is that the depth to the water table is large and that the soils are homogenous and isotropic.

The SCS, Worstell (1976), and Swamee et al. (2000) are all appropriate for estimating efficiencies for an individual ditch system when the parameters listed above are known. However, they are not recommended for use in the SPDSS basin-wide analysis because the canal geometry, required for wetted perimeter or width-to-depth ratio, is generally not known and cannot be easily estimated. The data-centered approach used for the historic crop consumptive use analysis requires information to be developed or estimated basin-wide using available data, GIS coverages, or HydroBase.

Since there is limited information available pertaining to conveyance efficiency for most of the key structures within the South Platte basin, the existing information that was available was used to develop a simplified approach. Nineteen major ditch systems throughout the South Platte Basin were selected for further analysis based on the availability of:

- Estimating average available soil moisture content (AWC) and soil type based on permeability to represent each main canal from the soil AWC and soil permeability
-
- Conveyance loss information from the user interviews, published reports, and/or summaries of water rights decrees
  - Corresponding main canal lengths from user interviews or the GIS canal coverage developed for the SPDSS project
  - Corresponding canal capacities from user interviews or HydroBase (v. 20051115)

Results – Conveyance Efficiencies

Conveyance loss information for the 19 structures identified is shown in **Table B-1**. The table includes structures with information gathered from user interviews, HydroBase, and SPDSS GIS river and canal coverage. In some cases, the contact for the ditch company was able to indicate a percentage of flow loss experienced along the main canal, portions of the main canal, or throughout the ditch system. The loss data and other information related to ditch system operations is included in the memoranda developed as part of the SPDSS Task 5.

The lengths of the main canals in **Table B-1** were either provided by the ditch company or were extracted from the SPDSS GIS river and canal coverage, with preference given to the GIS coverage. Canal lengths provided in the Key Structure Operating Memoranda were verified from the SPDSS GIS canal coverage, which was primarily developed from USGS maps. Main canal capacities are those provided by ditch companies or the maximum daily diversions reported in HydroBase. The percent conveyance loss per mile is the quotient of the estimated conveyance loss and the main canal length.

The average soil available water content beneath the main canal was determined from the SPDSS Soil AWC GIS mapping, which was developed from STATSGO data obtained from the NRCS. Canals in the South Platte basin are believed to flow through the lower soil layer. Permeability for the layer beneath the main canal was determined from the SPDSS Soil Permeability GIS mapping also developed from STATSGO.

Table B-1
Available Key Structure Conveyance Loss Information

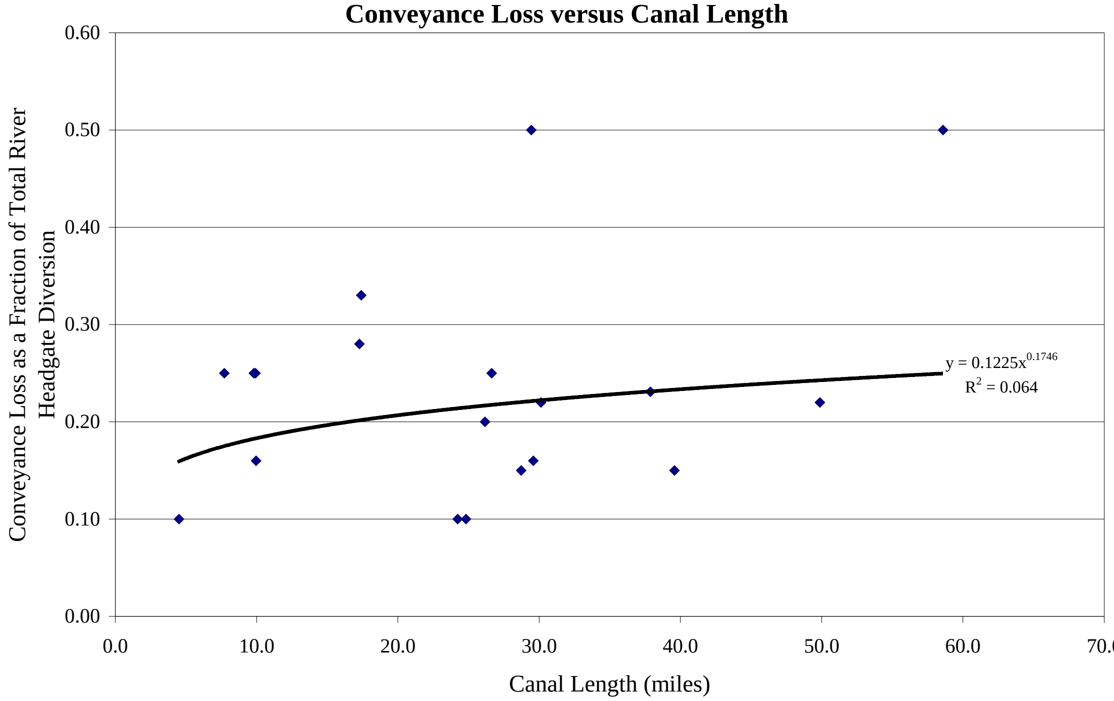
WDID	Ditch System	Main Canal Length (mi)	Main Canal Capacity (cfs)	Estimated Losses (Pct. Of Diversion)	Percent Loss per Mile	Average Permeability (in./hr.)	Soil Available Water Content (AWC)	Soil Type
0200810	Brighton Ditch	9.8	60	0.25	2.5	5	0.150	Sandy Loam
0200802	Burlington Ditch	17.3	1000	0.28	1.6	9	0.120	Sand
0700540	Church Ditch	26.6	120	0.25	0.9	4	0.155	Sand
0600564	Community Ditch	37.9	175	0.23	0.6	2	0.151	Sandy Loam
0200805	Denver Hudson Canal	49.9	350	0.22	0.4	2	0.149	Sand
0100514	Fort Morgan Canal	29.4	285	0.50	1.7	10	0.124	Sand
0200818	Fulton Ditch	28.7	238	0.15	0.5	6	0.115	Sandy Loam
0300929	Greeley No 2 Canal	39.6	650	0.15	0.4	5	0.126	Sand
0500526	Highland Ditch	24.8	325	0.10	0.4	3	0.122	Sandy Loam
0400524	Home Supply Ditch	24.2	325	0.10	0.4	3	0.143	Sandy Loam
0400532	Loveland and Greeley Canal	30.1	220	0.22	0.7	4	0.129	Sand
0200812	Lupton Bottom Ditch	17.4	155	0.33	1.9	11	0.115	Sand
0200821	Meadow Island Ditch No 1	7.7	66	0.25	3.2	12	0.112	Sand
0801009	Nevada Ditch	4.5	36	0.10	2.2	10	0.127	Sand
0300994	North Poudre Canal	29.6	175	0.16	0.5	8	0.141	Sand
0300905	North Poudre Supply Canal	10.0	250	0.16	1.6	7	0.100	Sand
0100687	North Sterling Canal	58.6	600	0.50	0.9	6	0.144	Sand
0200818	Platte Valley Canal	26.2	500	0.20	0.8	7	0.116	Sand
0100503	Riverside Intake Canal	9.9	1000	0.25	2.5	12	0.110	Sand

Notes: 1) Main canal length is the length reported by the ditch company or extracted from SPDSS GIS canal coverage.
2) Main canal capacities obtained from ditch company interview or HydroBase (maximum daily discharge).
3) Estimated losses obtained from ditch company interview, engineering report, or water right decree.
4) Percent Loss per Mile is the quotient of estimated losses and main canal length.
5) Average permeability and soil available water content were extracted from NRCS STATSGO GIS mapping.

Conveyance Loss versus Main Canal Length

Most of the ditch company representatives provided loss percentages for the irrigation season. As shown in **Table B-1**, reported conveyance losses for the large ditch systems range from 10 to 50 percent, with an average of 23 percent. **Figure B-1** shows the estimated ditch losses as a fraction of the total river head gate diversion versus the length of the main canal. An attempted relationship between ditch loss and main canal length resulted in a low coefficient of determination (r^2), which indicates minimal correlation between the data. However, the data indicates that, in general, as canal length increases, ditch losses increase.

Figure B-1
Conveyance Loss versus Canal Length

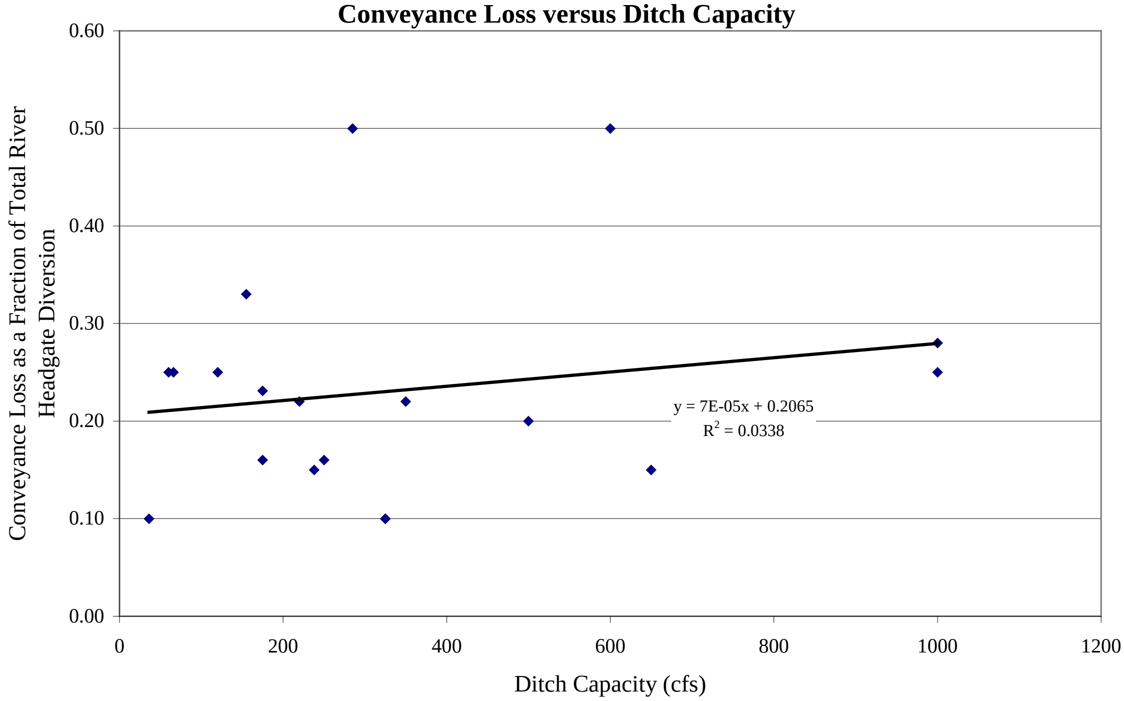


In some instances, it was unclear whether the ditch system losses provided by the ditch companies were for the main canal only, or included parts of the lateral delivery system. In addition, some of the main canals become laterals and, therefore, there was uncertainty involved with measuring the main canal lengths.

Conveyance Loss versus Canal Capacity

Canal capacity often provides a good basis for estimating conveyance loss, since it can be representative of overall system size as well as the wetted perimeter. **Figure B-2** illustrates conveyance loss versus the flow capacity of the ditch. The data illustrated in **Figure B-2** indicate, that, in general, irrigation ditches with greater flow capacities may have greater ditch losses. However, the coefficient of determination (r^2) indicates that there is minimal correlation between the two variables. In addition, many of the flow capacities for the canals used in the analysis were obtained from HydroBase, which reports capacities based on total decreed water rights or historic maximum daily discharges, either of which may not accurately represent the current ditch configuration.

Figure B-2
Conveyance Loss versus Ditch Capacity



Conveyance Loss versus Soil Moisture Parameters

Average soil moisture holding capacities (AWC) for each ditch system were estimated based on the Soil AWC GIS layer prepared for the SPDSS project. **Figure B-3** indicates no apparent correlation between canal loss per mile and AWC. Therefore, relationships between canal loss and average AWC should not be used to predict canal losses by water district in the South Platte basin.

Average permeability of the lower soil layer (i.e., the soil layer greater than 3 feet below the ground surface) for each ditch system was estimated based on the soil permeability layer prepared for the SPDSS project. **Figure B-4** indicates that there is a correlation between canal loss per mile and lower soil layer permeability. The figure also indicates that ditches flowing through soil with higher permeability have greater losses.

Figure B-3
Conveyance Loss versus Soil Available Water Content

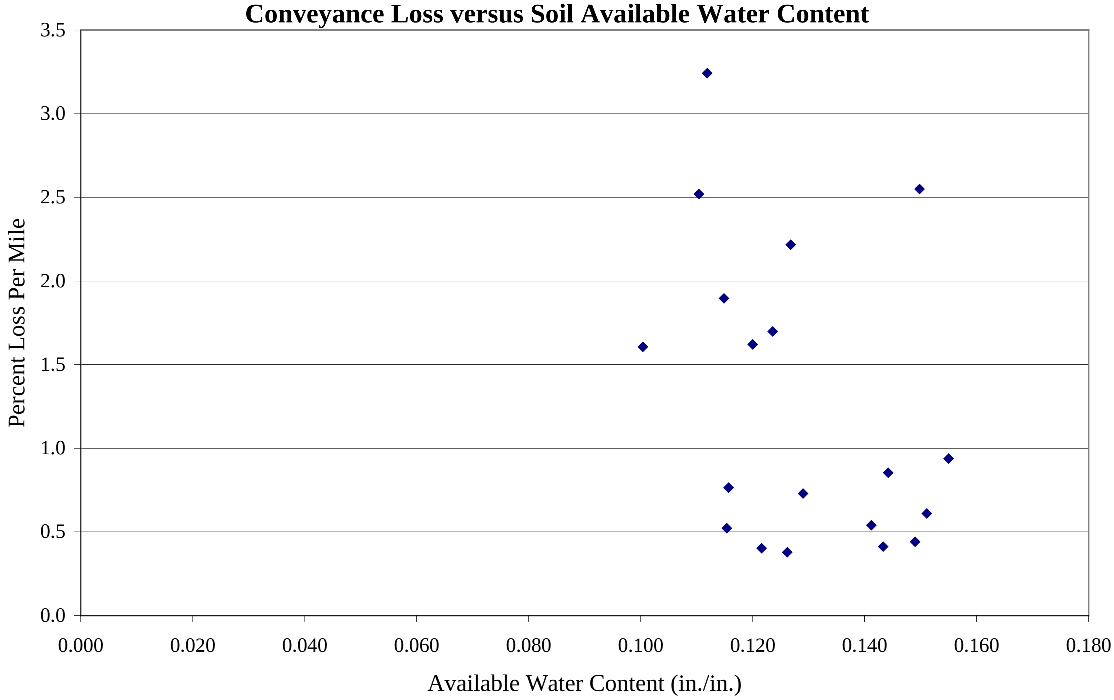
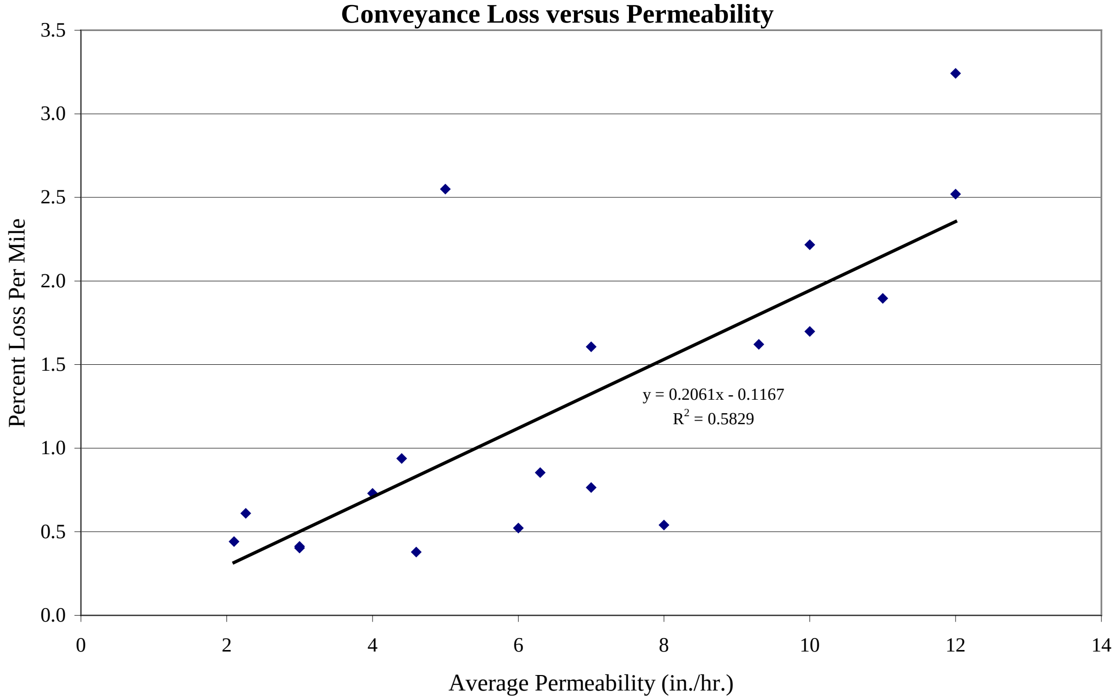
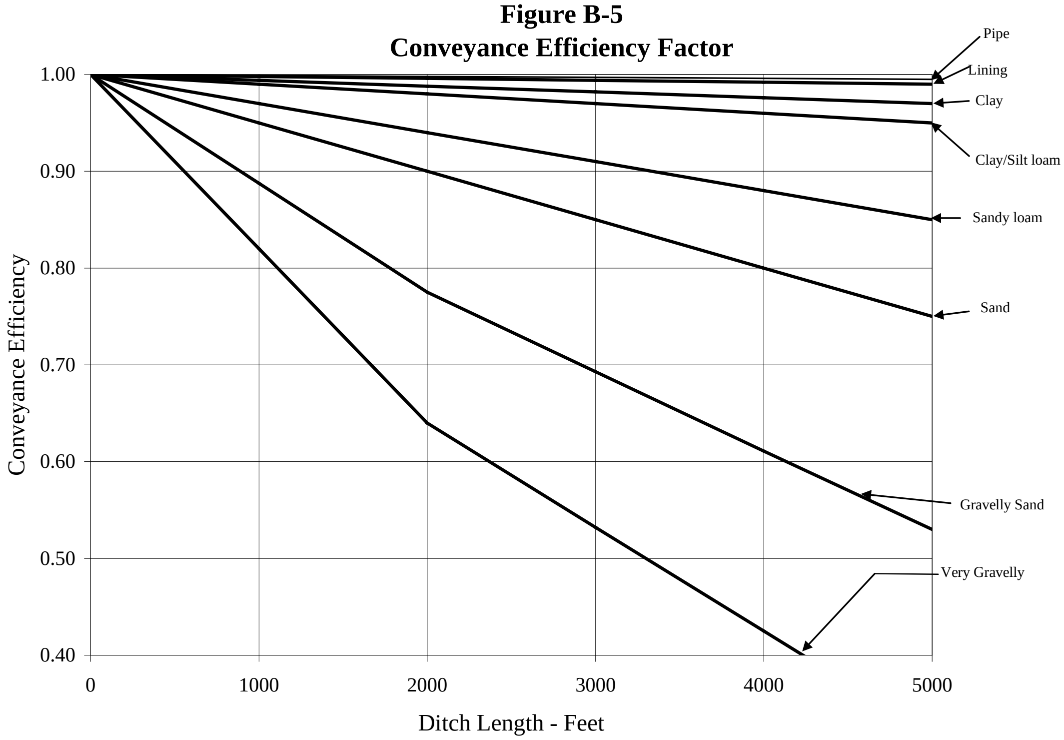


Figure B-4
Conveyance Loss versus Permeability



The NRCS has developed conveyance efficiency curves that can be used to estimate ditch efficiency as a function of soil type, which is based on the permeability of the soil, and ditch length for ditches less than one mile in length. This information can be readily developed from GIS coverages for the study area. Based on the apparent correlation of ditch loss per mile and permeability in **Figure B-4** and the data restrictions that preclude the use of the other methodologies described previously, this method was investigated for use in the South Platte basin. Note this method was previously used for the Rio Grande Decision Support System (RGDSS) analysis. **Figure B-5** shows the curves, published by the NRCS in the *Farm Irrigation Rating Index (FIRI) – A method for planning, evaluating, and improving irrigation management*, June 1991.

Figure B-5
Conveyance Efficiency Factor



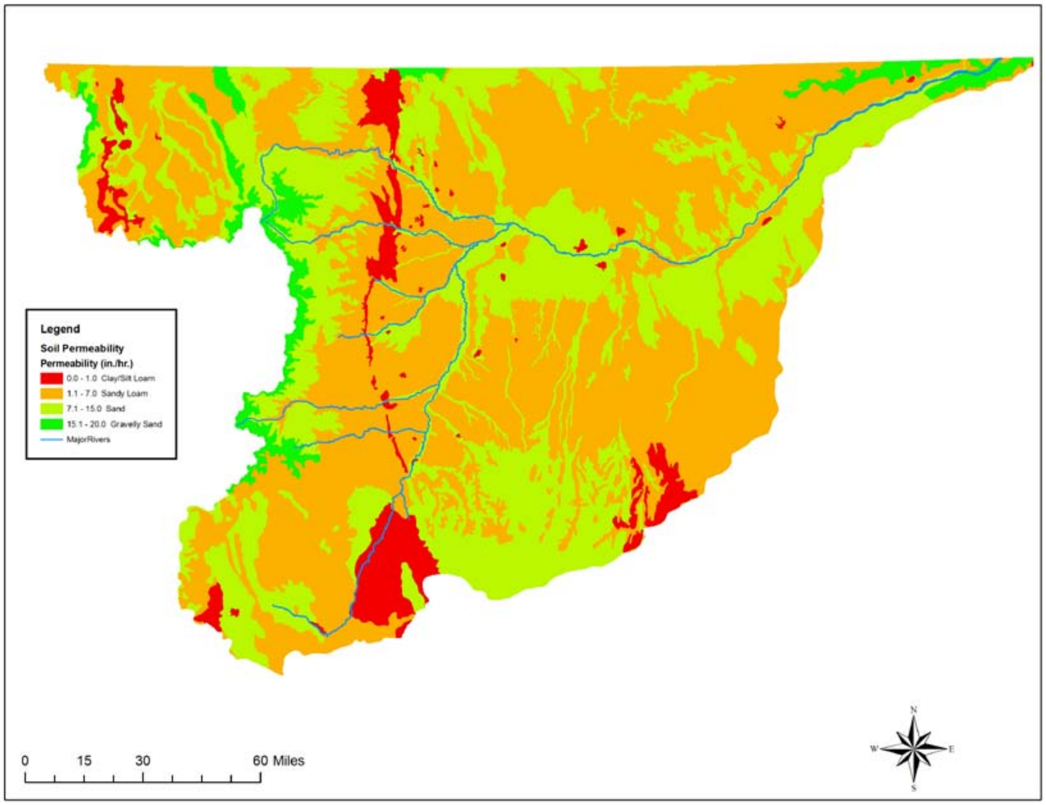
The NRCS STATSGO soil mapping was reviewed to determine the relationship between permeability in the lower soil layer and soil description so the curves shown in **Figure B-5** could be used to develop soil type-weighted conveyance loss estimates. **Table B-3** shows the general relationship for the South Platte basin between soil description and permeability. Other soil types are not present in the irrigated portion of the basin.

Table B-3
Relationship between Soil Classification and Permeability

Soil Description	Permeability (inches/hour)
Clay/Silt Loam	0.2 – 1.0
Sandy Loam	1.0 – 7.0
Sand	7.0 – 15.0
Gravelly-Sand	15.0 – 20.0

Figure B-6 shows the soil permeability and soil descriptions in the SPDSS study area. As shown, most of the South Platte ditches flow through soil described either as sand or sandy loam.

Figure B-6
Permeability and Soil Type in the South Platte Basin



The curves shown in **Figure B-5** were developed for ditch systems less than one mile in length. However, that only represents a portion of the total ditch systems in the basin. Therefore, the curves were extended based on the canal loss information for the larger ditches discussed previously. **Figures B-7** and **B-8** show the NRCS conveyance efficiency curves for ditch lengths up to one mile in sandy loam and sand, respectively, and extrapolated curves based on the estimated ditch loss data from **Table B-1**. Note that the extrapolated curves developed from the South Platte data are similar to the extrapolated curves developed for the RGDSS effort. Conveyance efficiencies were estimated for all key structures not listed in **Table B-1** based on ditch length, permeability, and the extrapolated NRCS conveyance efficiency curves shown in **Figures B-7** and **B-8** using the CDSS GIS data management tool developed by LRE, which determines a length-weighted permeability for each structure.

There has not been a trend towards improving or lining canals and laterals in an attempt to decrease conveyance losses in the South Platte basin. Therefore, the recommended conveyance efficiencies are appropriate for the 1950 to present study period. In addition, the range of conveyance efficiencies is consistent with our knowledge of conveyance efficiencies in areas outside of the South Platte basin with similar soils.

Figure B-7
Conveyance Efficiency Curves for Sandy Loam

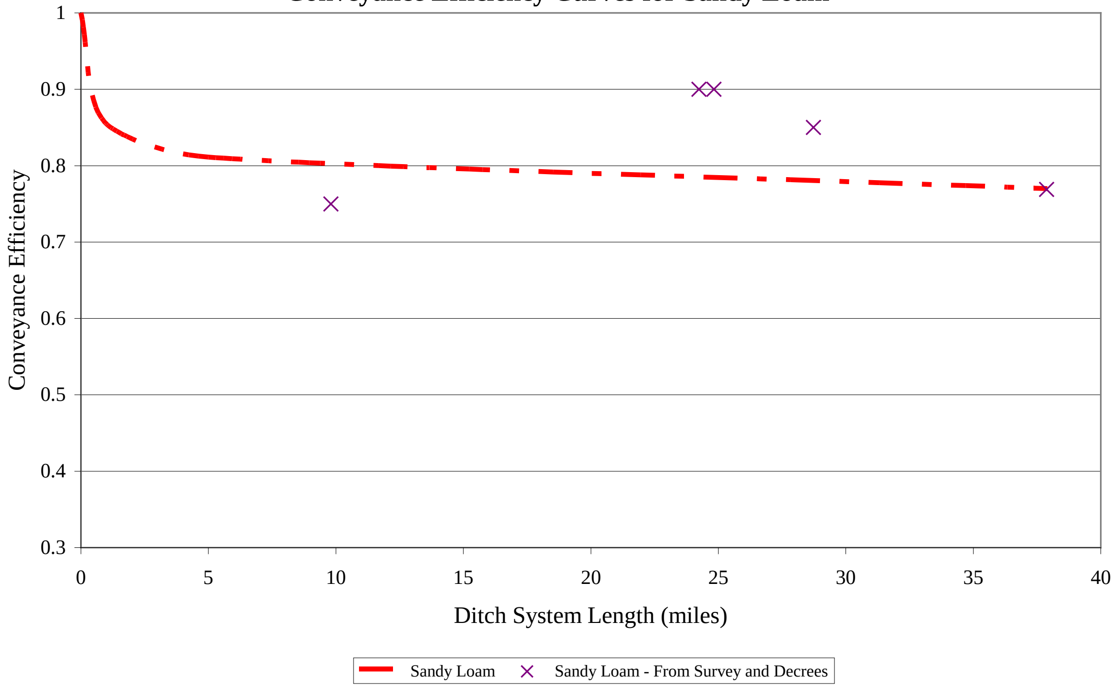
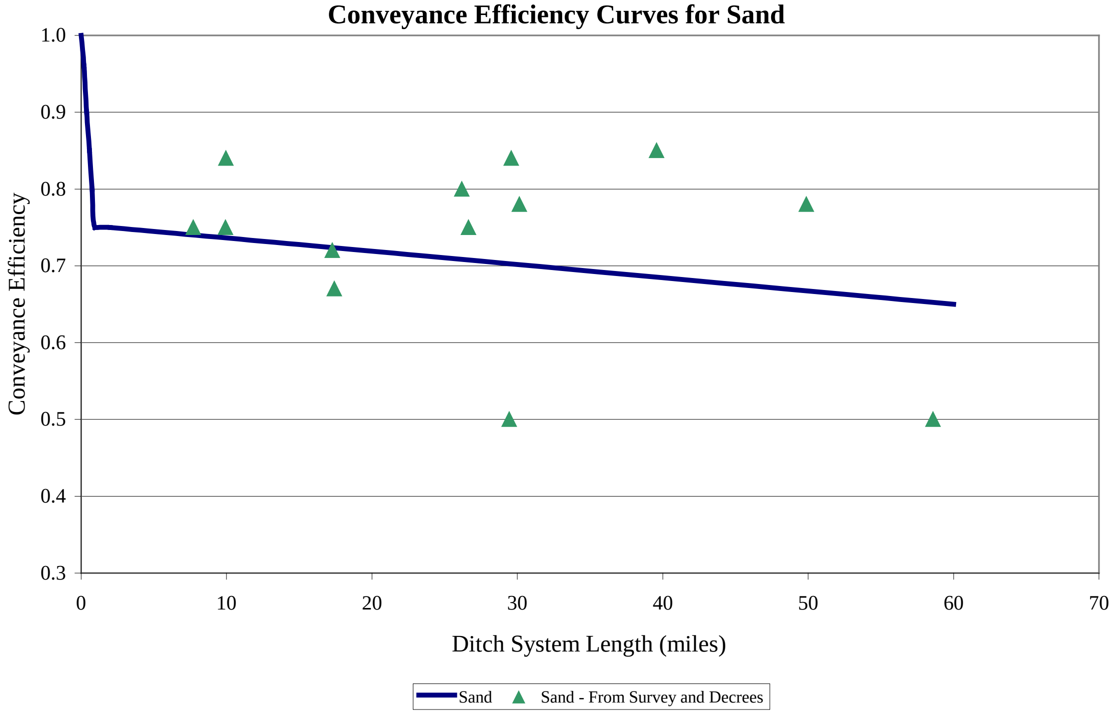


Figure B-8
Conveyance Efficiency Curves for Sand



Appendix H
South Platte Historic Consumptive Use Analysis – Annual Irrigation Parameter Time Series (Ground Water Acreage and Sprinkler Acreage)

To: Ray Bennett and Ray Alvarado

From: LRE, Erin Wilson and Mark Mitisek

Subject: South Platte Historic Consumptive Use - Annual Irrigation Parameter Time Series (Ground Water Acreage and Sprinkler Acreage)

Date: March 20, 2006, Updated March 2008 to Include 2005 Acreage

Introduction

Irrigated acreage and crop types are key data components used to estimate crop consumptive use in the SPDSS study area. GIS coverages were developed for SPDSS (RTi, 2006) that represent acreage and crop types by ditch or water source for 2005, 2001, 1987, and 1976 using thermal signatures from satellite imagery, aerial photos, and field interviews. In addition, a coverage was developed that represents irrigated acreage by ditch or water source for 1956 using aerial photography. The Task 71 memorandum included a recommendation for filling crop acreage between GIS coverages.

This memorandum presents the general approach to fill missing irrigated acreage data for the following:

> *Determine an appropriate method for estimating supplemental ground water acreage and sprinkler acreage, by ditch or other water source, for the entire SPDSS study period (time periods before, after, and between GIS irrigated acreage coverages). The method must be able to be added as a feature to StateDMI and utilize data stored in HydroBase directly from the GIS coverages plus information stored in HydroBase that match wells assigned to acreage in the GIS coverages with their permit or adjudication dates.*

Each modeled surface water structure, group of surface water structures, or group of wells are assigned a total acreage and crop type in the crop distribution file (*.cds). In addition, total acreage is split by application method and source and assigned in the yearly irrigation parameter file (*.ipy). The acronym assigned below is used to describe the "type" of acreage (acreage subsets) in the remainder of this memorandum.

- Acreage receiving surface water only, irrigated by sprinkler application (SS)
- Acreage receiving surface water only, irrigated by flood application (SF)
- Acreage receiving ground water (and surface water if assigned to ditch) irrigated by sprinkler application (GS)
- Acreage receiving ground water (and surface water if assigned to ditch) irrigated by flood application (GF)

Approach – Acreage Subset Filling

Two different methods were considered for filling acreage subsets between GIS coverages. Two methods were also investigated for estimating well capacity over the SPDSS study period. Representative diversion structures with irrigated land receiving both surface and ground water use were chosen to evaluate both methods – Fort Morgan Canal, Riverside Canal, and Greeley-Loveland Irrigation Company Canal (GLIC). One aggregated ground water grouping representing Sedgwick County was also evaluated. These structures were chosen for evaluation because of their varying levels of ground water and sprinkler acreage.

The acreage filling methods were based on the following premises:

- Total irrigated acreage assigned to specific surface water ditch systems in the GIS coverages tends to be relatively consistent over time, even as wells were added. In other words, wells were added as supplemental ground water, not to increase acreage.
- Conversely, lands served only by ground water generally were not irrigated prior to well development, therefore as new sole-source wells were added, irrigated acreage increased.

As a consequence, the methods investigated to fill ground water and sprinkler acreage data gaps were different for ditch systems and lands irrigated only by ground water. In both cases, the filling occurs at the parcel level, then is summed and reported by structure or aggregation.

Acreage Filling A

The first approach, **Acreage Filling A**, uses ground water well decreed dates as a basis to estimate acreage between coverages.

Lands Irrigated with Surface Water Only or Supplemented with Ground Water
Through interviews with water commissioners and users, it was determined that ditches in the South Platte generally operate as mutual ditches. Based on review of the GIS coverages and interviews with water users, it is generally believed that under mutual ditch systems, wells were added to supplement surface water supplies, not to increase acreage. In addition, sprinklers were added on previously flood irrigated lands to improve the use of supplies, not to increase acreage. Based on this information, the procedure used for filling in the ground water and sprinkler acreage subsets under lands irrigated with surface water only or supplemented with ground water recognizes that total acreage does not change between GIS coverages as follows:

- As acreage receiving supplemental ground water increases between GIS coverages, acreage receiving only surface water decreases by the same amount.
- As sprinkler acreage increases between coverages, flood acreage decreases by the same amount.

The following serves as an example of how the acreage subsets under a specific ditch would change for the year 1977, based on both the 1976 and 1987 GIS acreage, and well information:

1977 GF = 1976 total GF + 1987 GF parcels assigned to wells permitted in 1977
1977 SF = 1976 total SF - 1987 GF parcels assigned to wells permitted in 1977
1977 GS = 1976 total GS + 1987 GS parcels assigned to wells permitted in 1977
1977 SS = 1976 total SS - 1987 SS parcels assigned to wells permitted in 1977

If 1977 SS < 0, SF= 1977 SF + 1977 SS, and 1977 SS = 0

Acreage subsets for 1978 would follow the same algorithm, starting with the acreage subsets determined for 1977, and so on through 1986. This procedure was used for filling acreage forward between each of the coverages (1957 through 1975, 1977 through 1986, 1988 through 2000, and 2002 through 2004).

A similar procedure was used to fill back to 1950 through 1955 acreage under each subset based on 1956, as demonstrated in the following example:

1955 GF = 1956 total GF - 1956 GF parcels assigned to wells permitted in 1956
1955 SF = 1956 total SF + 1956 GF parcels assigned to wells permitted in 1956

Acreage subsets for 1954 would follow the same algorithm, starting with the acreage categories determined for 1955, and so on back to 1950.

Acreage under each subset from after 2005 will estimated to be the same as in the 2005 coverage.

Lands Irrigated with Ground Water Only
Lands served only by ground water generally were not irrigated prior to well development, therefore as new sole-source wells were added, irrigated acreage increased. As a result, the total acreage for ground water may change year to year.

The following serves as an example of how the categorized acreage served by wells would change for the year 1977, based on both the 1976 and 1987 GIS acreage, and well information:

1977 GF = 1976 total GF + 1987 GF parcels assigned to wells permitted in 1977
1977 GS = 1976 total GS + 1987 GS parcels assigned to wells permitted in 1977

Note that total ground water only acreage in 1977 does not equal total acreage in 1976, instead total 1977 acreage is the sum of 1977 flood irrigated acreage and 1977 sprinkler irrigated acreage. Acreage subsets for 1978 would follow the same algorithm, starting with the acreage subsets determined for 1977, and so on through 1986. This procedure was used for filling acreage forward between each of the coverages (1957 through 1975, 1977 through 1986, 1988 through 2000, and 2002 through 2004).

A similar procedure was used to fill ground water only lands back between 1950 and 1955 under each subset based on 1956, as demonstrated in the following example. It is estimated that earliest sprinklers were installed in the South Platte River basin around 1969, based on discussions with water users and review of historical water use studies. The first snapshot to include sprinkler acreage is 1976 – parcels prior to that time have been assigned as flood. To reflect the change in technology, SS and GS acreage is set to zero prior to 1969.

1955 GF = 1956 total GF - 1956 GF parcels assigned to wells permitted in 1956

Acreage subsets for 1954 would follow the same algorithm, starting with the acreage subsets determined for 1955, and so on back to 1950.

Ground water only acreage under each subset for years after 2005 was estimated to be the same as in the 2005 coverage.

Acreage Filling B

The second approach, **Acreage Filling B**, was simplified to recognize that there is minimal information available to infer acreage subset changes between GIS coverages. Therefore, a linear interpolation approach was used to connect the known data points.

This method to fill ground water and sprinkler acreage data gaps considers the same filling method for surface water structures and lands irrigated only by ground water with a minor difference only for filling 1950 through 1955.

Again, to reflect the earliest use of sprinkler in the basin, SS and GS acreage is set to zero prior to 1969.

1. Linear interpolation was used between GIS coverages for total acreage and acreage subset data for both surface water structures and ground water only structures.
2. Fill forward for total acreage and acreage subset data points is recommended for both surface water structures and ground water only structures when data is required beyond the most recent GIS coverage.
3. For structures with a surface water supply (and potentially supplemental ground water) a procedure similar to Acreage Filling A was used to create a 1950 data point. Total acreage from the 1956 snapshot was held constant and acreage subsets were allowed to adjust depending on well permit dates, as demonstrated in the following example:

   1950 GF = 1956 total GF - 1956 GF parcels assigned to wells permitted from 1951 through 1956
   1950 SF = 1956 total SF + 1956 GF parcels assigned to wells permitted from 1951 through 1956

   The years 1951 through 1955 were filled linearly between the known 1956 snapshot and the developed 1950 data point.
4. For ground water only structures, a procedure similar to Acreage Filling A was used to create a 1950 data point. Total acreage and acreage subsets were allowed to adjust depending on well permit dates, as demonstrated in the following example:

1950 GF = 1956 total GF - 1956 GF parcels assigned to wells permitted from 1951 through 1956

Total acreage is the sum of the two acreage subsets.

Approach – Well Capacity Filling

Two approaches were investigated for filling well capacity between snapshots. The first approach, **Well Capacity Filling A**, was based on well permit or appropriation date and all wells that were historically used by a structure. The second approach, **Well Capacity Filling B**, was based on well capacity at each snapshot and filled linearly between known points.

Well Capacity Filling A - Approach

1. A list was generated of all wells used historically from snapshots and limited to unique wells.
2. The capacity for any given year was determined by adding the capacities of all wells permitted or appropriated at that time.

Well Capacity Filling B - Approach

1. A list of wells in use was generated for each snapshot.
2. The capacity for any given snapshot was determined by adding the capacities of all wells used for that snapshot.
3. For non-snapshot years capacity was linearly interpreted between snapshots.
4. The capacity for 1956 was used for years 1950 through 1955.
5. The capacity for 2005 was used for years after 2005.

Results showed that total well capacity estimated by Well Capacity Filling B was lower than Well Capacity Filling A for some years between acreage snapshots. These results prompted a sensitivity investigation using StateCU to analyze the affects of the lower total well capacity generated by Well Capacity Filling B. Two StateCU runs were created to analyze the affects of the differences in total well capacity between Well Capacity Filling A and B. Acreage Filling B was used to generate irrigated acreage and its distribution between the four acreage subsets and did not very between analyses – only total well capacity varied.

Results

Figure 1 through 4 present the acreage distribution by acreage subset over time for the Acreage Filling A and the Acreage Filling B. Figures 5 through 8 present the total well capacity per structure estimates, using both filling procedures.

Observed differences between the two filling approaches are:

Subject	Acreage Filling A	Acreage Filling B
Acreage Transition	Total acreage remains constant for structures with surface water. Abrupt changes at acreage snapshots.	Total acreage changes between acreage snapshots; smooth transitions.
Acreage Subset Transition	Controlled by well appropriation date and snapshot distributions; abrupt changes at snapshots.	Controlled by snapshot distributions only; smooth transitions.
Subject	**Well Capacity Filling A**	**Well Capacity Filling B**
Total Well Capacity	Controlled by wells assigned to the structure and well appropriation date.	Controlled by wells assigned to acreage in each snapshot and linearly connecting the capacities.

The consumptive use analyses performed showed that the differences in total well capacity did not limit pumping in any year between 1950 and 2005.

Recommendations

We recommend using Acreage Filling B (Linear Interpolation) with sprinkler acreage set to zero in 1969 and Well Capacity Filling A (Decreed based on when wells became active), as described in the approach section.

1. The Acreage Filling A uses well appropriation date as the basis for acreage subset changes between snapshots. However, there are some inconsistencies in the well assignment process that causes abrupt changes at the year representing the snapshots. For instance, there are structures that have wells assigned in the 1987 and 1956 snapshots that have an appropriation date of 1955. However, these wells were NOT assigned to acreage in the 1976 snapshot.
2. The Acreage Filling A is complex and will be difficult to code in StateDMI, therefore difficult to test. More importantly, the approach will be difficult to explain to water users and other interested parties.
3. A more complex approach may signify to users that we have more confidence in the filled data than a simpler approach would indicate.

Comments and Concerns

The filling procedures recommended in this memorandum assure consistency with total acreage and crop type filling algorithm recommended in the Task 71 memorandum.

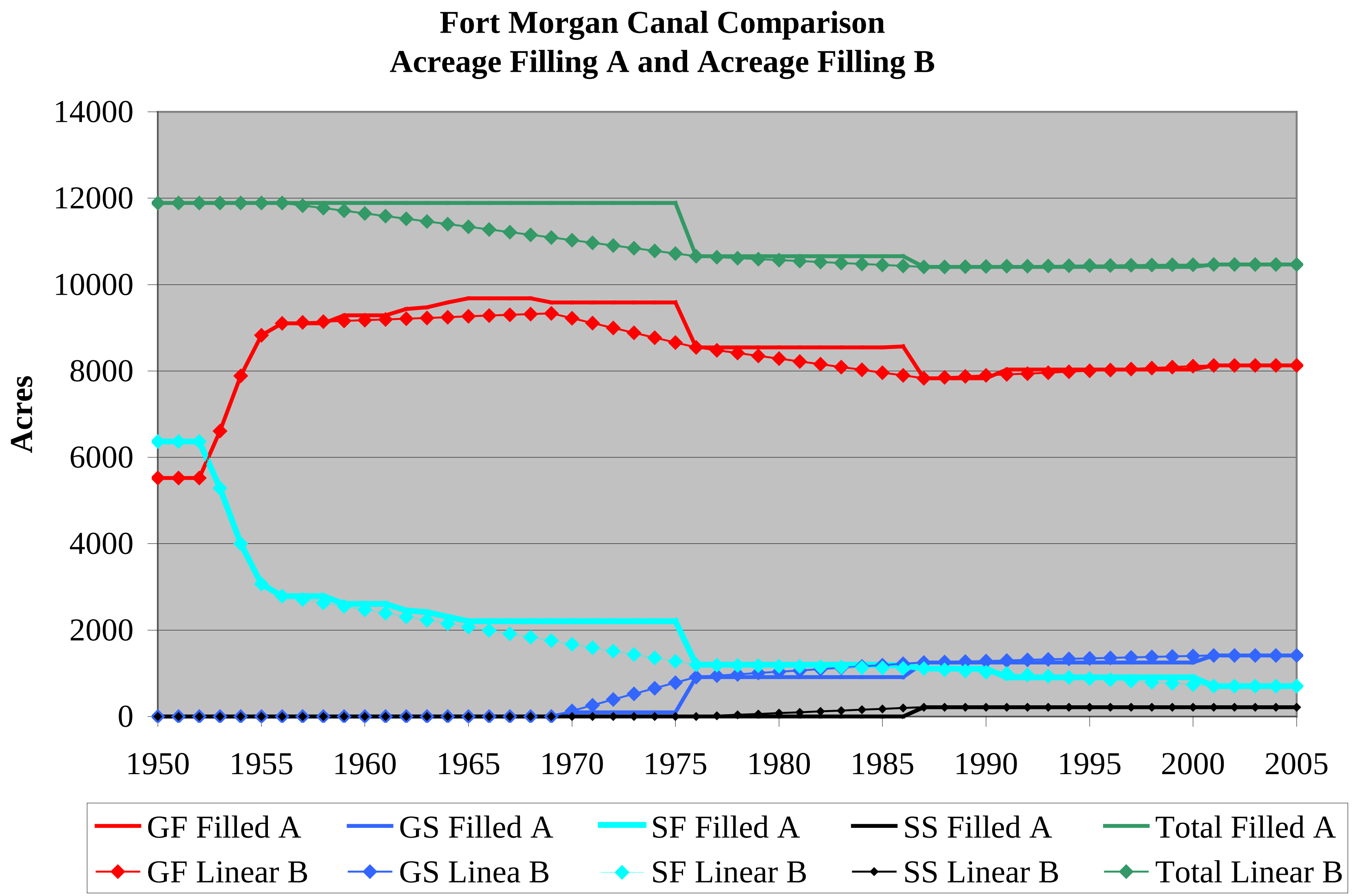

Fort Morgan Canal Comparison
Acreage Filling A and Acreage Filling B
Acres
14000
12000
10000
8000
6000
4000
2000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
GF Filled A
GS Filled A
SF Filled A
SS Filled A
Total Filled A
GF Linear B
GS Linea B
SF Linear B
SS Linear B
Total Linear B

Figure 1

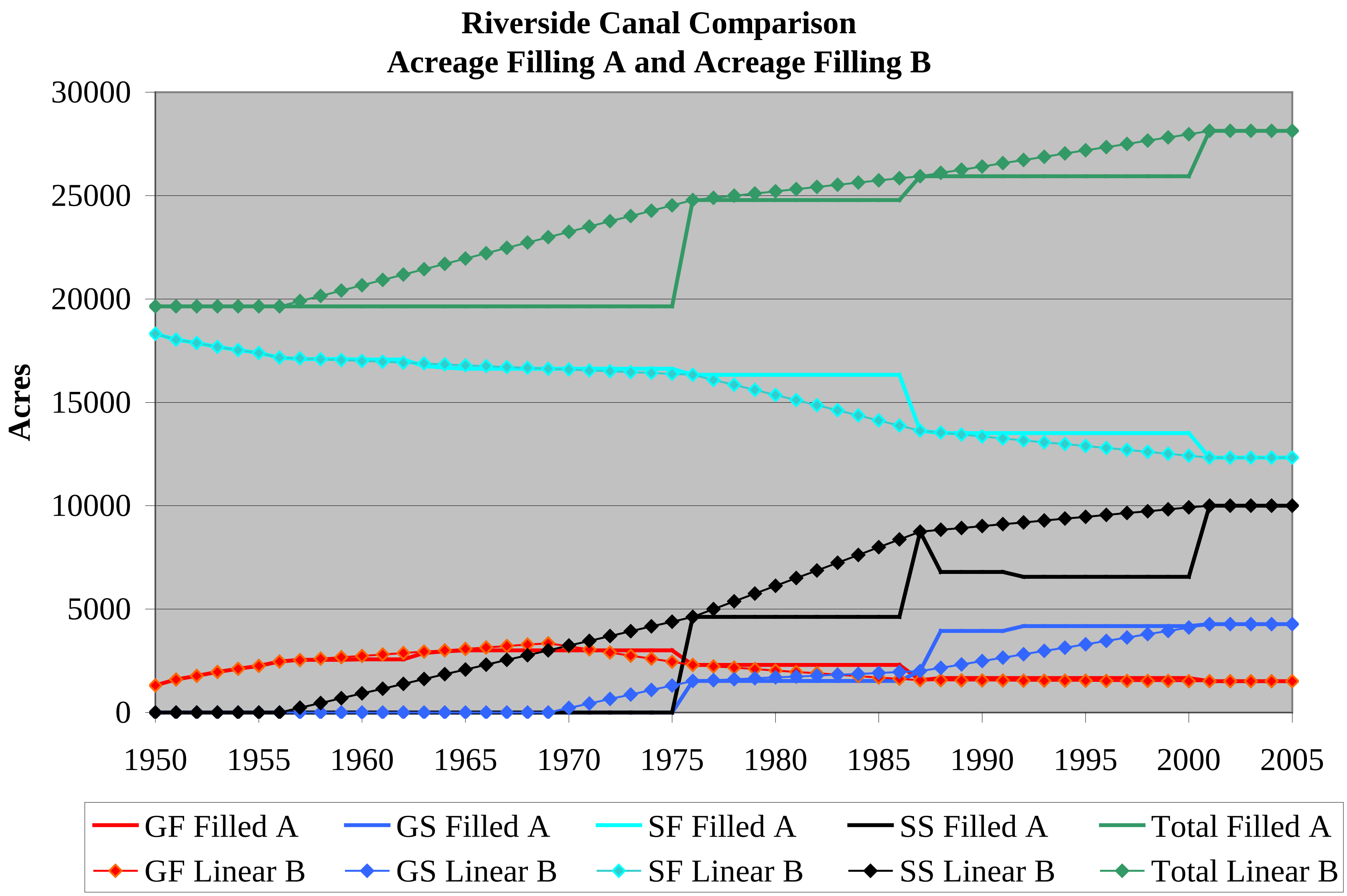

Riverside Canal Comparison
Acreage Filling A and Acreage Filling B
Acres
30000
25000
20000
15000
10000
5000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
GF Filled A
GS Filled A
SF Filled A
SS Filled A
Total Filled A
GF Linear B
GS Linear B
SF Linear B
SS Linear B
Total Linear B

Figure 2

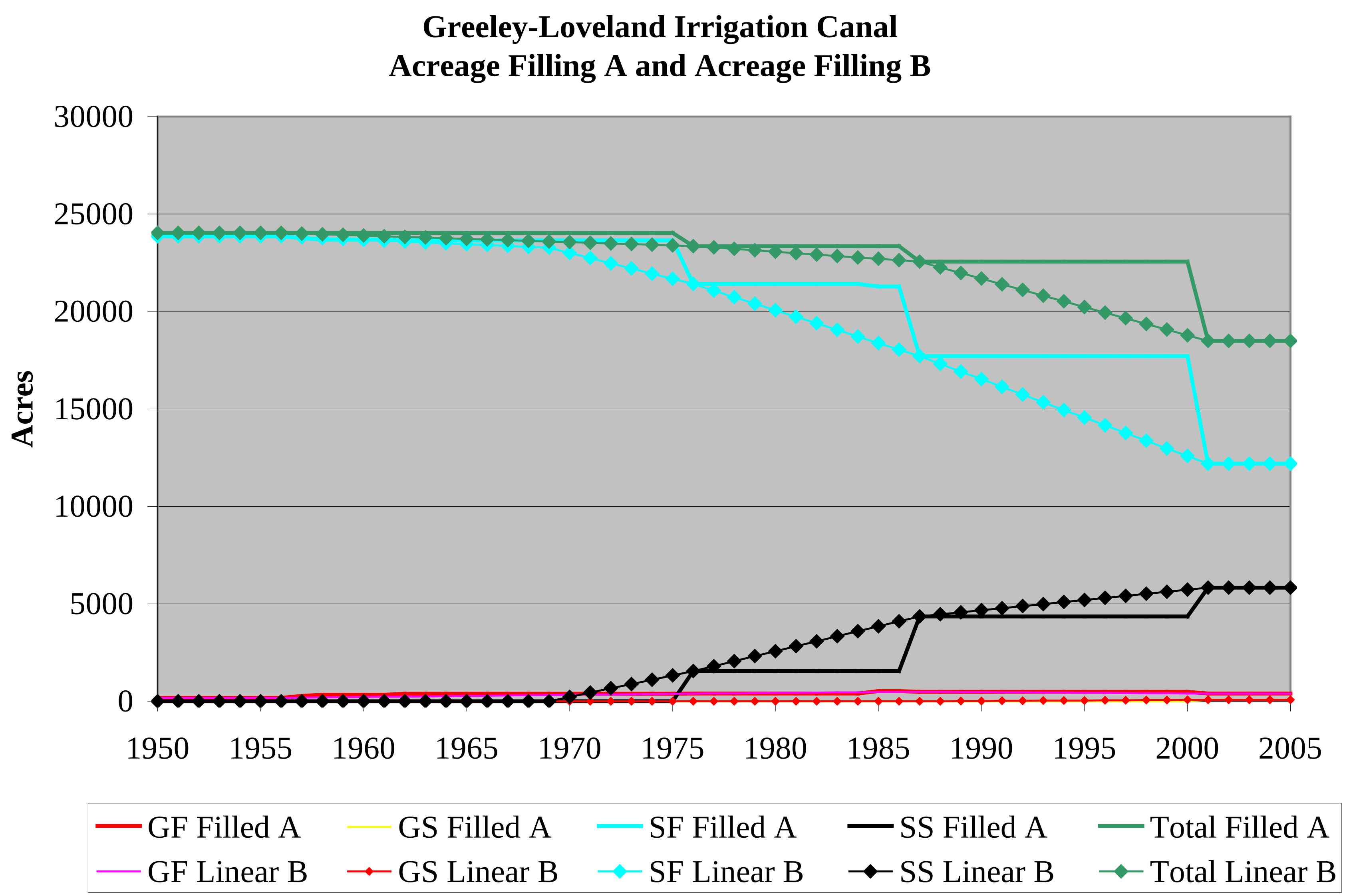

Greeley-Loveland Irrigation Canal
Acreage Filling A and Acreage Filling B
Acres
30000
25000
20000
15000
10000
5000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
GF Filled A
GS Filled A
SF Filled A
SS Filled A
Total Filled A
GF Linear B
GS Linear B
SF Linear B
SS Linear B
Total Linear B

Figure 3

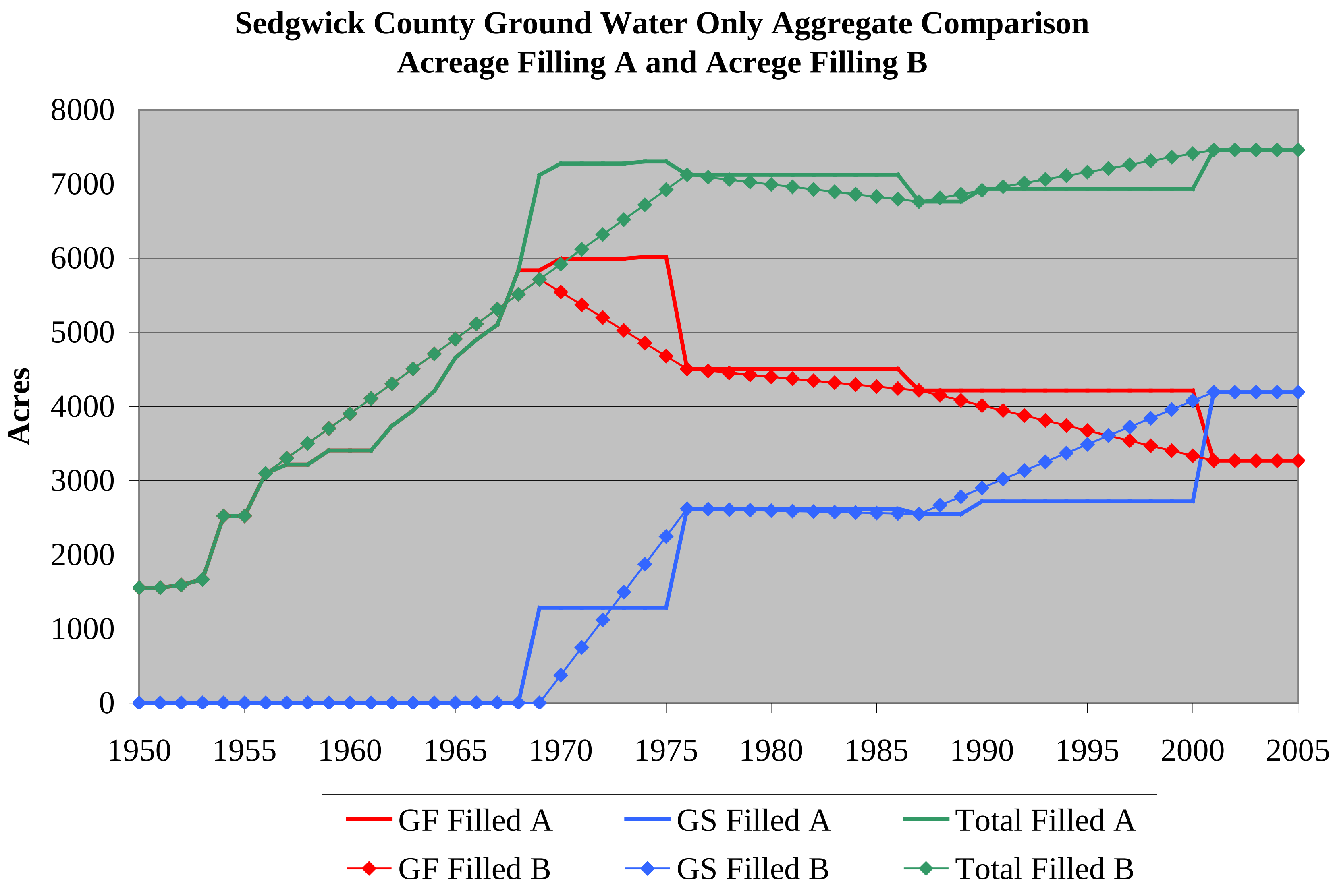
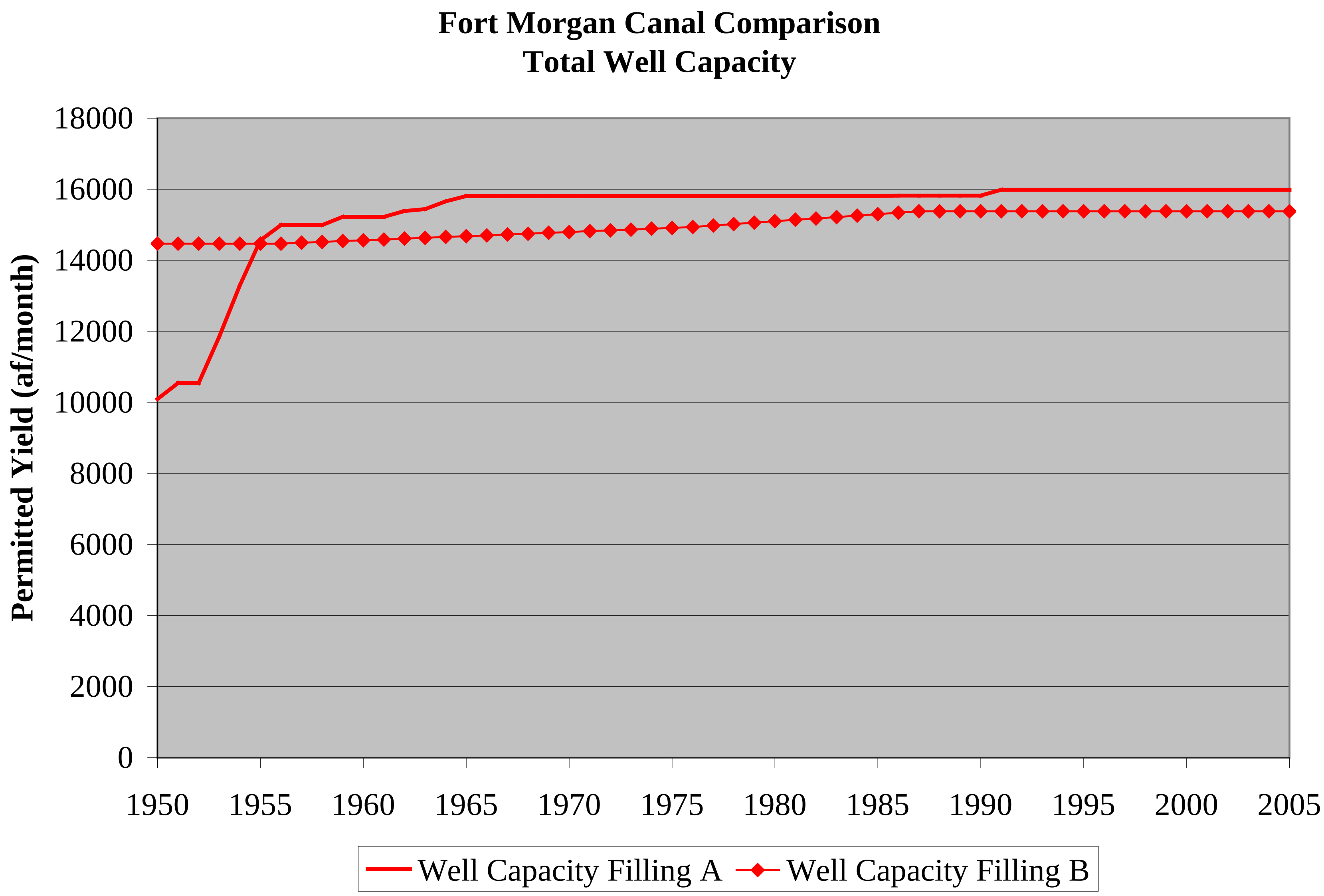

Sedgwick County Ground Water Only Aggregate Comparison
Acreage Filling A and Acrege Filling B
Acres
8000
7000
6000
5000
4000
3000
2000
1000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
GF Filled A
GS Filled A
Total Filled A
GF Filled B
GS Filled B
Total Filled B

Figure 4



Fort Morgan Canal Comparison
Total Well Capacity
Permitted Yield (af/month)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Well Capacity Filling A
Well Capacity Filling B

Figure 5

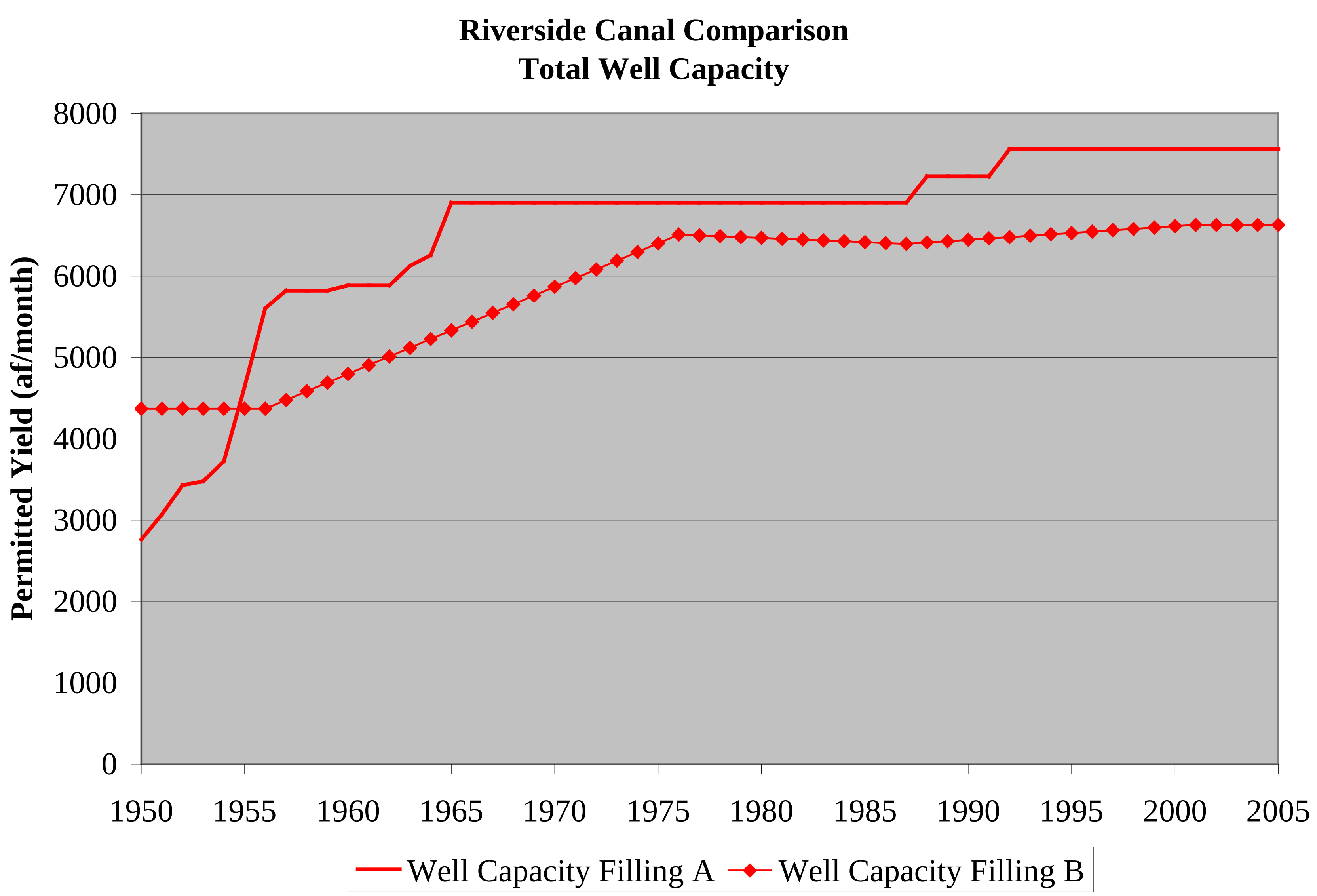
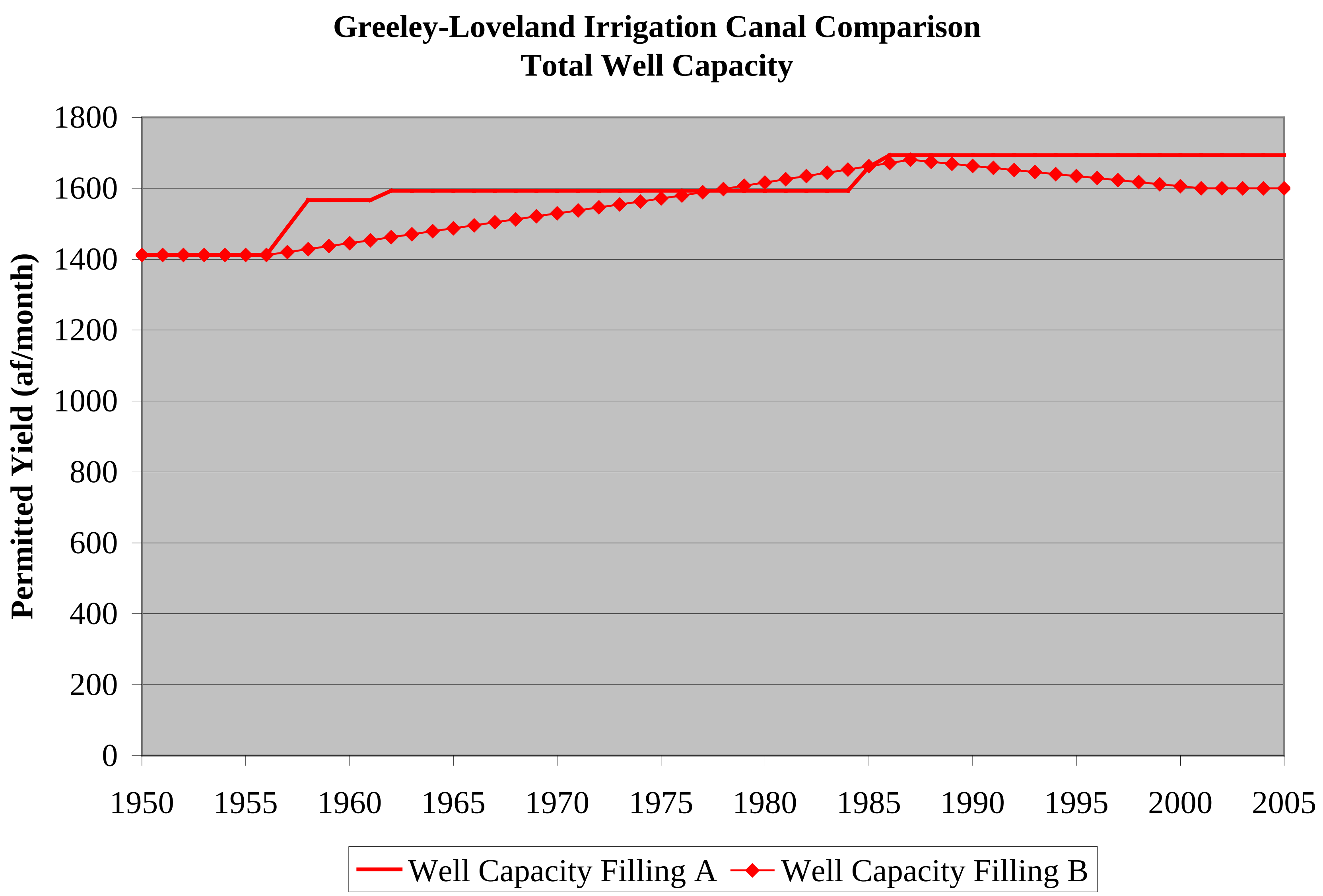

Riverside Canal Comparison
Total Well Capacity
Permitted Yield (af/month)
8000
7000
6000
5000
4000
3000
2000
1000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Well Capacity Filling A
Well Capacity Filling B

Figure 6



Greeley-Loveland Irrigation Canal Comparison
Total Well Capacity
Permitted Yield (af/month)
1800
1600
1400
1200
1000
800
600
400
200
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Well Capacity Filling A
Well Capacity Filling B

Figure 7

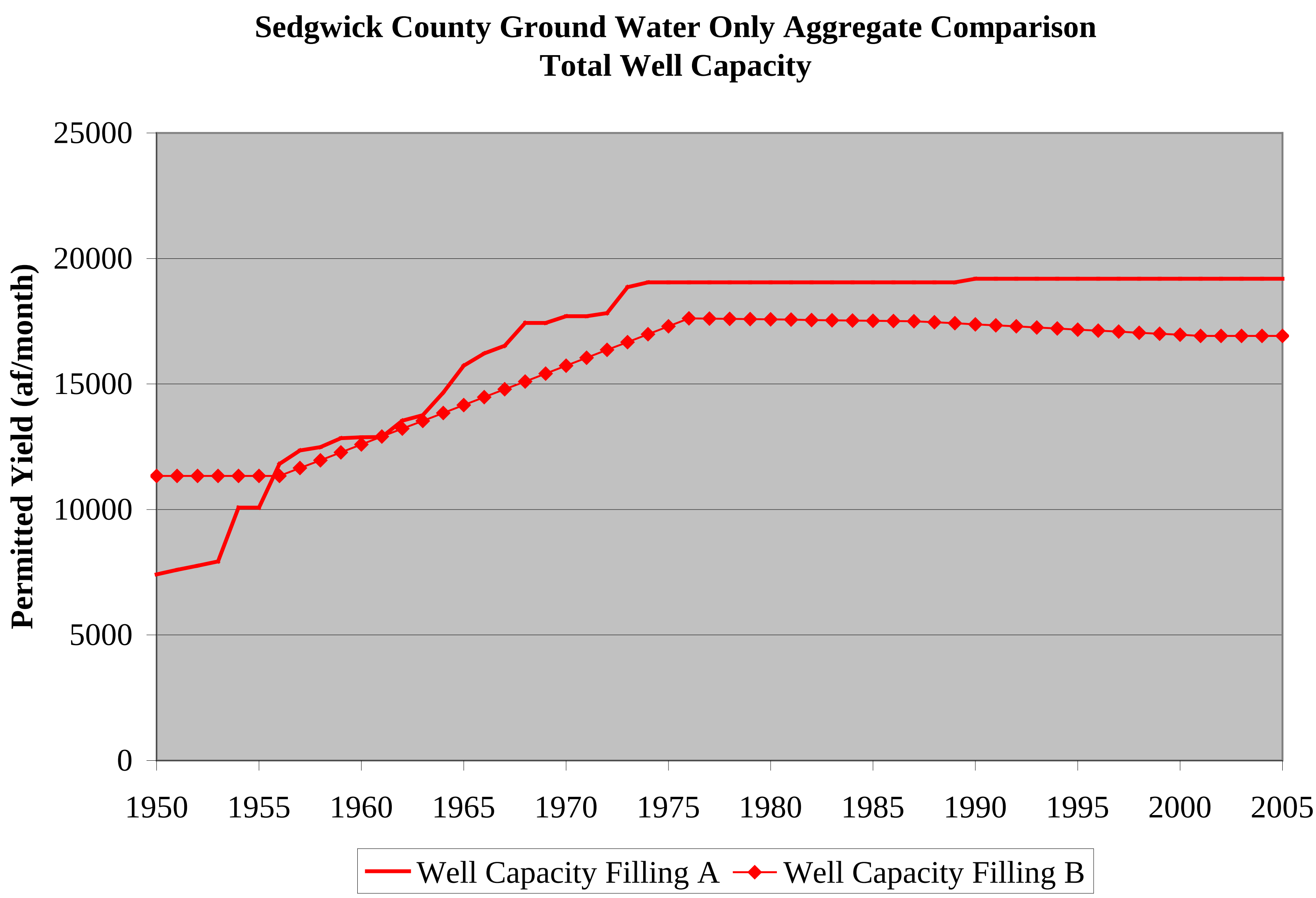

Sedgwick County Ground Water Only Aggregate Comparison
Total Well Capacity
Permitted Yield (af/month)
25000
20000
15000
10000
5000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Well Capacity Filling A
Well Capacity Filling B

Figure 8

Appendix I
South Platte Historic Consumptive Use – Development of Historical Diversions

To: Ray Bennett and Ray Alvarado

From: LRE – Erin Wilson, Rick Parsons

Subject: Development of Historical Diversions

Date: June 15, 2008

Introduction

The majority of key structures consist of a single headgate structure diverting to meet one demand. Available diversion records were used directly from HydroBase, with missing values filled as described below. Diversion records for diversions systems, defined as structures on the same tributary that are operated in a similar fashion to meet a common demand, were extracted from HydroBase and added with the StateDMI tool. Similarly, diversion records for aggregated structures were extracted from HydroBase and added with the StateDMI tool.

In addition to these relatively simple structures, the modeling effort includes explicit representation of more complicated systems where a headgate structure diverts and carries water to meet more than one demand (Carrier Structure in **Figure 1**). Irrigation demand structures represent agricultural and/or municipal users that receive water from several sources to meet a single demand (**Figure 1**). For example, Riverside Canal irrigated acreage demand is supplied from a direct flow right through the Riverside Canal and, if necessary, from water released from Riverside Reservoir. Riverside Reservoir is an “on-ditch” reservoir; therefore, releases are not carried through the headgate of Riverside Canal. The river headgate or well structures that meet these demands are modeled as carriers to a single “demand” structure.

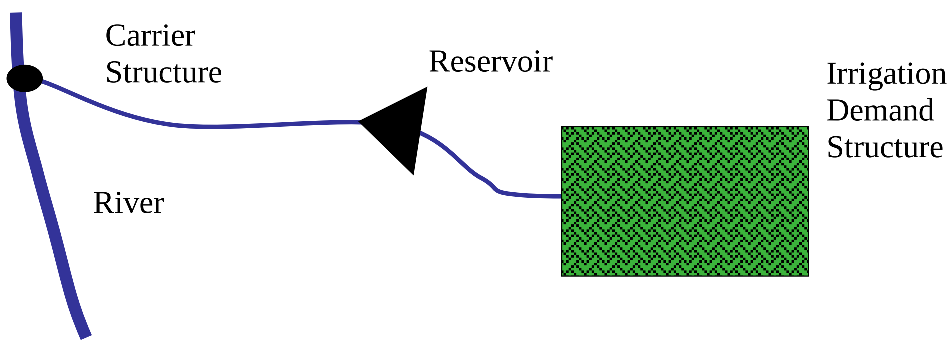


Figure 1 – Carrier/Irrigation Demand Example

In early years during the 1950 through present study period, generally prior to 1974; diversions through structures for off-channel storage were not recorded, likely because water commissioners were seasonal employees. Therefore, diversions through both carrier structures to more than one demand and structures diverting water only for an off-channel reservoir need to be estimated for the SPDSS modeling efforts. These complex carrier structures and their associated demands are summarized in **Table 1**.

Total headgate diversions can include non-irrigation supplies, such as reservoir supplies in the Figure 1 example or supplies to recharge sites. It is important that these supplied are not considered as available supply to meet crop demands in the consumptive use analysis. Therefore, the SPDSS approach is to use total headgate diversions, determine conveyance loss en route to reservoirs or recharge sites, and then “remove” the delivered storage/recharge water prior to applying the water on-farm to meet crop demands. The water is “removed" by including the negative of the deliveries in the surface water reuse (*.dra) file. With the approach, the canal losses associated with diversion to reservoirs or ditch sites are accounted for, and available for inclusion in the SPDSS ground water modeling effort.

Table 1
Key Demand Structures and Diversion Systems

#	Model ID	Structure Name	Irrigation Demand Structure	Reservoir Demand Structure
1	0100501	Empire Inlet Canal	N/A	01003816 - Empire Reservoir
2	0100503_D	Riverside Canal	0100503_I - Riverside Irrigation	01003651 - Riverside Reservoir
3	0100507_D	Bijou Canal	0100507_I - Bijou Irrigation	01003570 - Bijou Reservoir 2
4	0100513	Jackson Lake Inlet Ditch	N/A	0103817 - Jackson Lake Reservoir[1)]
5	0100687	North Sterling Canal	0100687_I - North Sterling Irrigation	6403551 - North Sterling Reservoir
6	0100829	Prewitt Inlet Canal	N/A	6403552 - Prewitt Reservoir
7	0200805	Denver-Hudson Canal	0200805_I - Henrylyn Irrigation	Various
8	0200817	Evans No 2 Ditch	0200817_I - Evans No 2 Irrigation	0203876 - Milton Reservoir[2)]
9	0200828	Union Ditch	0200828_I - Union Irrigation	0203858 - Lower Lathan Reservoir
10	0200834	Lower Latham Ditch	0200834_I - Lower Latham Irrigation	N/A
11	0203837_C	FRICO-Barr Lake Carrier	0203837_I - FRICO-Barr Irrigation	0203837 - Barr Lake
12	0300905	North Poudre Supply Canal	N/A	Various
13	0300994_D	North Poudre Canal Div System	0300944_I - North Poudre Irrigation	Various
14	0300907	Poudre Valley Canal	N/A	Various
15	0300911	Larimer County Ditch	0300911_I - Larimer County Irr	Various
16	0300915	Cache la Poudre Ditch	0300915_I - Cache la Poudre Irr	0300805 - Terry Lake Reservoir
17	0300919	Larimer Weld Irr Canal	0300919_I - Larimer Weld Irrigation	0303738 - Big Windsor Reservoir
18	0300929	New Cache la Poudre Demand	0300929_I - New Cache la Poudre Irr	0303770 - Windsor Lake
19	0300924	Cache la Poudre Res In Cnl	N/A	0303775 - Timnath Reservoir
20	0400501	Barnes Ditch	N/A	Various
21	0400524	Home Supply Ditch	04000524 - Home Supply Irrigation	Various
22	0400532	Loveland Greeley Canal	0400532_I - Loveland Greeley Irr	N/A
23	0400588	Bould Larim Co Irr Mfg D	0400588_I - Boulder Larimer Irr	0404158 - Boulder Larimer Res
24	0400691	Hanser Feeder Ditch	0400691_I - Hansen Feeder Irr[3)]	0303732 - Carter Reservoir
25	0500603_D	Left Hand Ditch Div System	0500603_I - Left Hand Irrigation	Various
26	0500526	Highland Ditch	0500526_I - Higland Irrigation	Various
27	0500532	Foothills Inlet	N/A	0504071 - Foothills Reservoir
28	0500547	Oligarchy Ditch	0500547_I - Oligarchy Irrigation	Various

29	0600564_D	Community Ditch Div System	0600454_I - Community Ditch Irr	Various
30	0700553	Croke Canal	N/A	0203903 - Standley Lake
31	6400511_D	Harmony Ditch 1 Div System	6400511_I - Harmony Ditch 1 Irr	6403906 - Julesburg Reservoir

1) Jackson Reservoir releases to the river for downstream structures and directly to structure 0103817_I for minor irrigation.

2) Milton Reservoir releases directly to 0203876_I for FRICO-Milton Irrigation.

3) Hanson Feeder Canal carriers CBT water to Carter Lake and also releases directly to structure 0400691_I for minor irrigation.

Background

Historical diversions were estimated for modeled structures based on data available in HydroBase (Version 20080301).

The primary diversion data includes the following:

- Total Diversion at Ditch. DivTotal for Ditch ID representing total water diverted through structure. Diversions are generally measured near the river headgate, but in some cases are measured a significant distance down the ditch from the river headgate (e.g., Riverside Canal, Prewitt Reservoir), which requires adding in conveyance losses to represent diversions at the river.
- Total Diversion at Reservoir – DivTotal to storage, generally measured at the river headgate, but included in HydroBase under the Reservoir ID.
- Diversion Classes. DivClass for Ditch ID or Reservoir ID representing different "colors" of water diverted through structure. DivClasses include a Source code (e.g., from river, from storage, from transbasin, from seepage) and a Use code (e.g., irrigation, storage, recharge, municipal). DivClasses may include a From code, representing the Source of water (e.g., Source: Storage From: Union Reservoir; Source: Transbasin From: Horsetooth Reservoir). DivClasses may also include a Type code (e.g., trade, exchange, carrier). The sum of the DivClass records (excluding Source 6 combined) equals DivTotal.

The coding protocol for DivClasses is described in the *Water Commissioner Manual* (Colorado Division of Water Resources, 1996). The approach outlined in the Manual is currently followed in most of the Water Districts, with Water District 3 being the primary exception. Coding variations over time and between Water Districts have resulted in inconsistent data sources that require interpretation. This adds uncertainty to the analyses.

Approach – Historical Diversion File (SP2008.ddh)

The historical diversion file was developed primarily for the StateCU Ground Water Total River Diversion scenario and surface water modeling efforts. It includes diversions for irrigation, off-channel reservoir storage, recharge, and municipal and industrial uses. A subset of this file that only includes diversions to irrigation, described below, was developed for the historical crop consumptive use analysis.

Structures with One Demand

A general approach was developed to estimate the historical diversions associated with structures represented by a single headgate structure with one demand in previous CDSS modeling efforts. DivTotal records for the majority of structures are available in HydroBase and directly accessible through DMIs. This approach applies to key structures, diversion systems, and aggregate structures that divert to meet a single demand. Missing data, if any, were filled with wet-, dry-, and average-year monthly DivTotal averages. The determination of month type was based on flow conditions at "pattern" streamflow gages, assigned to structures based on proximity. **Table 2** shows the "pattern" streamflow gages and their assignments to Water Districts.

Table 2
Pattern Gage Assignments for Diversion Record Filling Algorithm

Water District	Streamflow Pattern Gage
1	06754000 - SOUTH PLATTE RIVER NEAR KERSEY
2	06720500 - SOUTH PLATTE RIVER AT HENDERSON
3	06752000 - CACHE LA POUDRE AT CANYON MOUTH NEAR FT COLLINS
4	06738000 - BIG THOMPSON RIVER AT MOUTH OF CANYON NEAR DRAKE
5	06724000 - SAINT VRAIN CREEK AT LYONS, CO
6	06727000 - BOULDER CREEK NEAR ORODELL
7	06719500 - CLEAR CREEK NEAR GOLDEN, CO.
8	06714000 - SOUTH PLATTE RIVER AT DENVER
9	06710500 - BEAR CREEK AT MORRISON
23 & 80	06695000 - SOUTH PLATTE RIVER ABOVE ELEVENMILE RESERVOIR
64	06764000 - SOUTH PLATTE RIVER AT JULESBURG (COMBINED)

Carrier and Demand Structures
The more complicated structures that divert to meet more than one demand or divert to fill reservoirs require additional effort to estimate historical diversions. Separate TSTool commands files were developed for each system. The self-documenting TSTool commands files used to develop historical diversion data in StateMod format include comments summarizing the approach used and specific issues that may have been identified with the HydroBase data for the particular system. The steps in the general approach vary by Water District and over certain parts of the 1950 to present study period within each Water District as described below.

Available diversion data associated with the filler ditches and off-channel reservoirs were identified through a review of HydroBase records associated with the ditches and reservoirs. Water Commissioners typically recorded diversions only during the irrigation season until the early-1970s.

- Prior to the early 1970s, irrigation diversions were recorded and assigned to the ditch ID. Although not coded as such, in some cases the records appear to include diversions to storage during the irrigation season. Generally, no diversions were record during the non-irrigation season.
- Diversions to storage were recorded and assigned to the reservoir ID during most of the 1970s and 1980s in Water Districts 1, 2, 5, 6, and 64. Total diversions recorded at the ditch during this period represent irrigation diversions.
- Diversions to irrigation and diversions to storage were typically recorded and coded separately under the ditch ID starting in the late 1980s.

The following general approach was used to estimate river headgate diversions to storage and irrigation and to estimate total supply to irrigation demand structures. Ditch system specific modifications, for instance if the ditch measurement device is not close to the river headgate or if additional supply from seepage is included, are detailed in the headers of each self-documenting TSTool command file.

1. Estimate river diversions to storage and storage releases for irrigation.

   The approach used to estimate diversions to storage and storage releases for irrigation is consistent for all SPDSS Water Districts.

   Records of available reservoir contents were used to develop time series of reservoir end-of-month contents over the 1950 to present study period. Missing data were filled to develop complete time series based on the approach outlined in the Task 5 Summary – Key Reservoirs memorandum.

   Monthly net reservoir evaporation was calculated based on monthly storage contents, area-capacity curves, and average monthly net evaporation estimated in Task 53.3 – Assign Key Climate Information to Irrigated Acreage and Reservoirs. For the early period when diversions to storage were not recorded, increases in storage contents between months, accounting for net evaporation, were represented as river diversions to storage by adding in conveyance loss estimates from the river to the reservoir, based on conveyance efficiencies recommended in Task 56 – Conveyance and Application Efficiencies. Decreases in storage contents between months represent storage releases to supply irrigation demand structures, as discussed further below.

2. Estimate irrigation supply for irrigation demand structures.

The approach used to estimate irrigation supply for irrigation demand structures is consistent for all SPDSS Water Districts with the exception of Water District 3.

The following general approach was used for structures in all Water Districts except Water District 3.

DivClass records of diversions for irrigation use through the river headgate are available for the entire study period. These irrigation use diversions were extracted from HydroBase and filled, if necessary, using the pattern gage filling approach. In recent years, diversions to recharge are also included with irrigation diversions to provide a mechanism for recharged water to be included in the ground water and surface water modeling efforts.

Recorded diversions to irrigation/recharge were reduced by conveyance loss to estimate diversions from direct rights at the outlet of off-channel reservoirs (where exist) or at the irrigated lands themselves. Where applicable, reservoir releases from Step 1 above were added to estimate total supply to each irrigation demand structure.

The following general approach was used for structures in Water District 3.

Prior to 1974, only irrigation diversions were recorded for Water District 3 ditches. Therefore, irrigation supply for irrigation demand structures were estimated as DivTotal less conveyance loss plus calculated storage releases from Step 1 above.

Since 1974, the direct irrigation diversions and storage releases for irrigation were recorded in aggregate as Source 6 Use 1. According to the Water Commissioner, these records represent some or all of the following:

- River diversions to irrigation
- On-ditch reservoir storage releases to irrigation
- Up gradient storage releases to irrigation (e.g., Long Pond under Larimer County Ditch directly releases to Larimer Weld Canal for irrigation)
- Seepage to irrigation (reported to be return flows from up gradient ditch systems)

Closer review of the District 3 diversion records and estimate storage releases yielded slightly different approaches for each of the big four ditches (North Poudre, Larimer County, Larimer & Weld, and New Cache), as documented in the individual command files. In general, from 1974 to present, irrigation supplies for irrigation demand structure are estimates as DivClass Source 6 Use 1 less conveyance loss, since on-ditch reservoir releases are included.

3. Estimate total ditch diversion (DivTotal) from the river.

The approach used to estimate total ditch diversions from the river varies by Water District as described below. Note that Water Districts not specifically discussed do not have carriers to demand structures.

The following general approach was used for Water Districts 1, 2, 7, and 64 due to consistency in diversion record coding during the study period.

Total ditch diversions (DivTotal) from the river were generally calculated as follows:

a) 1950 to early-1970s. Recorded irrigation diversions at ditch plus calculated storage diversions from Step 1, increased to reflect conveyance loss from the river.
b) Early-1970s to late-1980s. Recorded irrigation diversions at ditch plus storage diversions recorded at reservoir.
c) Late-1980s to present. Total diversions recorded at ditch.

Notable exceptions to the general approach include:

- Croke Canal. Standley Reservoir is filled by a number of ditches on Clear Creek and the Last Chance Ditch on Coal Creek. The Last Chance Ditch fills several small reservoirs, in addition to Standley Reservoir. These diversions to storage records are not separated by reservoir. Since the amount of water Standley Reservoir receives from Last Chance Ditch is small compared to the diversions from Clear Creek, these diversions are ignored. Total storage diversions from Clear Creek are represented at the Croke Canal.
- Burlington Ditch. Three systems are supplied by the Burlington Ditch river headgate. These three systems (Little Burlington Ditch, Barr Lake system, and

Henrylyn system) are modeled separately because they each incur different conveyance losses en route to their storage and irrigation demands. The Burlington Ditch is modeled as a carrier for the three systems.

There is no complete set of data or much consistency from the various sources reviewed from the Farmers Reservoir and Irrigation Company (FRICO), HydroBase, and previous change case analyses of Little Burlington Ditch system operations. The general approach used for the Burlington Ditch systems was:

- o 1950 to 1968. FRICO-provided data, except for Little Burlington Ditch, which relied on previous change case analyses.
- o 1969 to 2000. FRICO-provided data for all three systems.
- o 2002. HydroBase data for all three systems.
- o 2001, 2003 to 2006. Filled ditch diversions using the standard fill pattern method plus calculated storage diversions from Step 1.

The following general approach was used for Water Districts 4, 5, and 6 due to consistency in diversion record coding during the study period.

Total ditch diversions (DivTotal) from the river were generally calculated as follows:

a) 1950 to late 1960s. Recorded irrigation diversions at ditch plus calculated storage diversions from Step 1.
b) Late 1960s to late 1980s/early 1990s. Total diversions recorded at ditch.
c) Late 1980s/early 1990s to present. Recorded irrigation diversions at ditch plus total diversions recorded at reservoir.

Notable exceptions to the general approach include:

- South Boulder Ditch. Total diversions provided by Denver Water Board for 1950 to present.

The following general approach was used for Water District 3.

Total ditch diversions (DivTotal) from the river were generally calculated as follows:

a) 1950 to 1973. Recorded irrigation diversions at ditch plus calculated storage diversions from Step 1.
b) Late 1974 to present. Total diversions recorded at the ditch.

Approach – Historical Irrigation Diversion File (SP2008_crop.ddh)

The Historical Irrigation Diversion File was developed to represent historical diversions for crop use only. The Historical Diversion File, described above, was revised using a TSTool command file to create this subset diversion file as follows:

- Transbasin structures, municipal and industrial structures, structures that only carry water to reservoirs, and structures that carry water to both reservoir and irrigation demands structures were removed.
- Historical diversion for irrigation demand structures (estimated to be irrigation diversions available at the on-ditch reservoir outlets) were revised to represent river headgate diversions by dividing the SP2008 estimated diversion values by the carrier structure efficiency.

Approach – Surface Water Reuse File (*.dra)

The estimate of diversions to storage at the reservoir (after conveyance loss), required to develop the historical diversions for both carrier and demands structures discussed above, are “scaled” by a factor of “-1” then written directly in the surface water reuse file using TSTool commands. In addition, in support of the Lower South Platte Surface Water Modeling effort, diversions to recharge at the recharge sites (after conveyance loss) were determined as documented in Appendix R of the Lower South Platte Surface Water Model User’s Manual. These diversions to recharge were also scaled by a factor of “-1” and written directly to the surface water reuse file using TSTool commands.

Results

Monthly estimates of total river diversions, associated conveyance losses (for input to the ground water model), diverted water to non-irrigation supplies, and irrigation diversions were output to individual StateMod format files (*.stm). These output files were used to develop the basin-wide historical direct diversion (*.ddh) StateCU and StateMod input file and the surface water reuse file (*.dra). Other output from the commands include date value (*.dv) files of columnar input data and calculated data that can be used by modelers and reviewers to independently check that the complicated TSTool commands are operating as expected.

Comments and Concerns

The following comments and concerns are noted:

- Variations in diversion coding methods exist for Water Districts over time and between Water Districts. Interpretation of diversion coding is necessary to estimate what data indicate what uses, which may be different or mean more than what is explained in the general approach to coding outlined in the Water Commissioner Manual. General interpretation of the coding for each ditch system analyzed herein is included in the commands files and can be revisited, as necessary, during the StateMod planning effort.
- Use of a fixed conveyance loss for an individual system does not represent the monthly and seasonal variability of system losses. This may become evident during simulations with the StateMod planning model, and it is recommended that input file development be re-visited at that time.
- The Burlington system represents an important component of water use in Water District 2. Beebe Seep flows occurring from operation of the Burlington system components represent major storage inflows to Lower Latham Reservoirs and Milton Reservoir that are represented in the historical end-of-month contents but are not represented in river diversions to storage from these systems. The uncertainty within the developed input data should be closely examined during StateMod model development.
- The complexity of data available after 1973 in Water District 3 made it difficult to identify storage versus irrigation diversions from the river. The estimates of irrigation diversions described above, specifically the addition of calculated storage releases for the Larimer and Weld Ditch and the Larimer County Ditch, may over estimate the amount of storage releases to irrigation since some of the off-channel storage releases (amount unknown) are implicitly included in the Source 6 records to irrigation.

Appendix J
Task 59.1 – Develop Locally Calibrated Blaney-Criddle Crop Coefficients

To: Ray Bennett and Ray Alvarado

From: LRE – Erin Wilson, Ross Bethel, and Beorn Courtney

Subject: Task 59.1 – Develop Locally Calibrated Blaney-Criddle Crop Coefficients

Date: March 18, 2005 (updated January 11, 2008)

Introduction

The modified SCS Blaney-Criddle consumptive use methodology estimates potential consumptive use (PCU) on a monthly basis using monthly average temperature and daylight hours estimated from latitude. Because this data is readily available for long study periods, the methodology is widely used and recommended for use in the SPDSS. However, the modified Blaney-Criddle crop coefficients available from the SCS publication Irrigation Water Requirements Technical Release No. 21 (TR-21) were developed to represent general conditions around the west and may not represent local conditions in the South Platte, North Platte, and Laramie River basins (SPDSS study area). Therefore locally calibrated Blaney-Criddle crop coefficients were developed for SPDSS. The SPDSS *Task 58 – Review Previous Estimates of Potential CU* memo discusses the methods used throughout Colorado for calculating potential crop consumptive use. As summarized in Task 58, local coefficients can be developed based on lysimeter data or results of a more detailed evapotranspiration equation. Due to the relatively large expanse and varying elevations of the SPDSS study area, three different crop coefficients were developed for three different geographical regions of the study area.

This memorandum presents the general approach and results from the completion of the following Task 59 subtasks:

1. *Gather and review appropriate data and literature from previous lysimeter studies used to develop Blaney-Criddle crop coefficients in high altitude areas of Colorado.*
2. *Review the ASCE Standardized Penman-Monteith methodology and determine its appropriateness for use in the calibration of Blaney-Criddle crop coefficients by comparing results to lysimeter studies.*
3. *Recommend methodology for the development of locally calibrated crop coefficients by geographic regions*
4. *Develop locally calibrated crop coefficients using the recommended methodology. Approach and Results*

The locally calibrated crop coefficients developed under this task will be used to estimate potential crop consumptive use under conditions of a full water supply. The potential crop consumptive use will then be compared to historical water supply, using a soil moisture balance, to estimate supply-limited crop evapotranspiration.

Information in this memorandum is believed to be accurate. However, information should not be relied upon in any legal proceeding.

Approach and Results

1. Gather and Review Appropriate Data and Literature from Previous Lysimeter Studies to Develop Local Blaney-Criddle Crop Coefficients

As described in Task 58, the most common means of calculating PCU at high elevations throughout Colorado is by use of lysimeter-derived crop coefficients with the original Blaney-Criddle method (temperature coefficient $K_t = 1$). Several lysimeter studies for high altitude irrigated grasses/meadow were identified under Task 58. It was originally anticipated that some of the lysimeter studies of interest might present data but not actually provide calibrated coefficients. As described below, calibrated coefficients were developed as part of each study. Therefore, it was not necessary to develop any calibrated coefficients for this task.

The following lysimeter studies were investigated for this task:

1. **South Park –** Leonard Rice Consulting Water Engineers, Inc. (1993) and other consultants have used a pattern of derived crop coefficients for water rights changes cases in South Park. These coefficients are based on a simple averaging of reported coefficients from a number of lysimeter studies. The individual studies evaluated data collected from 1968 through 1970, 1973 through 1974, and 1977 through 1979.
2. **South Park –** In a report prepared for the Denver Water Board, Walter, Siemer, Quinlan and Burman (1990) evaluated a number of previous lysimeter studies conducted around South Park. Walter et al. developed a set of recommended crop coefficients and compared PCU with those coefficients against measured lysimeter results. The individual studies evaluated data collected from 1968 through 1970, 1974, 1975, 1977, and 1978 through 1979 (note that a number of these studies were also used by LRCWE, 1993).
3. **Division 6 Lysimeter Program –** This ongoing lysimeter data collection program was initiated in 1978 by Energy Fuels Corporation and subsequently taken over by personnel in Division VI (Division of Water Resources, 2003) in 1983. Lysimeters are principally located in the Yampa River drainage, however a lysimeter was installed in year 2000 in the SPDSS study area near Walden, Colorado.
4. **Grand County –** Denver Water commissioned lysimeter studies of consumptive use of mountain meadows at high altitudes in Grand County from 1987 through 1990. Results from these studies are reported by Carlson, Pollara, and Le (1991).
5. **South Park and Gunnison River Basin –** Lysimeter studies were conducted near South Park from 1968 through 1970 and Gunnison from 1969 through 1971 (Kruse and Haise, 1974). Note that the South Park component of this study was reviewed by Walter, et al. (1990).
6. **Gunnison River Basin –** The Upper Gunnison Water Conservancy District sponsored lysimeter-based investigations of irrigated meadow grass consumptive use from 1999 through 2003 at ten sites in the Gunnison River Basin. This investigation was conducted by Colorado State University (Smith, 2004).

Because the principal crop grown at high elevations in Colorado is pasture or meadow grasses, these studies focused on the PCU of high altitude grasses (**Table 1** and **Figure 1**).

Table 1
Lysimeter-Derived Grass Crop Coefficients [1]
(for use with the Original Blaney-Criddle Method)

Lysimeter Study	Apr	May	Jun	Jul	Aug	Sep	Oct	Elevation
South Park – LRCWE	0.58	1.11	1.28	1.26	1.07	1.14	0.78	~ 9500'
South Park – Walter	**-**	**1.18**	**1.40**	**1.22**	**0.81**	**0.86**	**0.75**	~ 8900' - 9420'
So Park – Kruse	-	0.996	1.163	0.983	0.729	0.890	-	~ 9100'
Div 6 – CYCC	-	0.93	0.96	1.02	0.92	0.79	0.86	~ 6670'
Div 6 – Catamount	-	0.74	0.93	0.84	0.73	0.71	0.78	~ 7000'
Div 6 – No Park (Walden)	-	0.87	1.13	1.12	0.97	0.86	-	~ 8220'
Grand County	-	1.05	1.08	1.01	0.83	0.98	-	~ 7500' - 7850'
Gunnison – Kruse	-	1.253	1.095	0.959	0.908	0.988	-	~ 8000' - 9100'
Gunnison – Smith	-	1.24	1.42	1.13	0.82	0.87	-	~ 7774' - 8685'

[1] Lysimeter-derived crop coefficients used to estimate potential crop consumptive use under full water supply conditions.

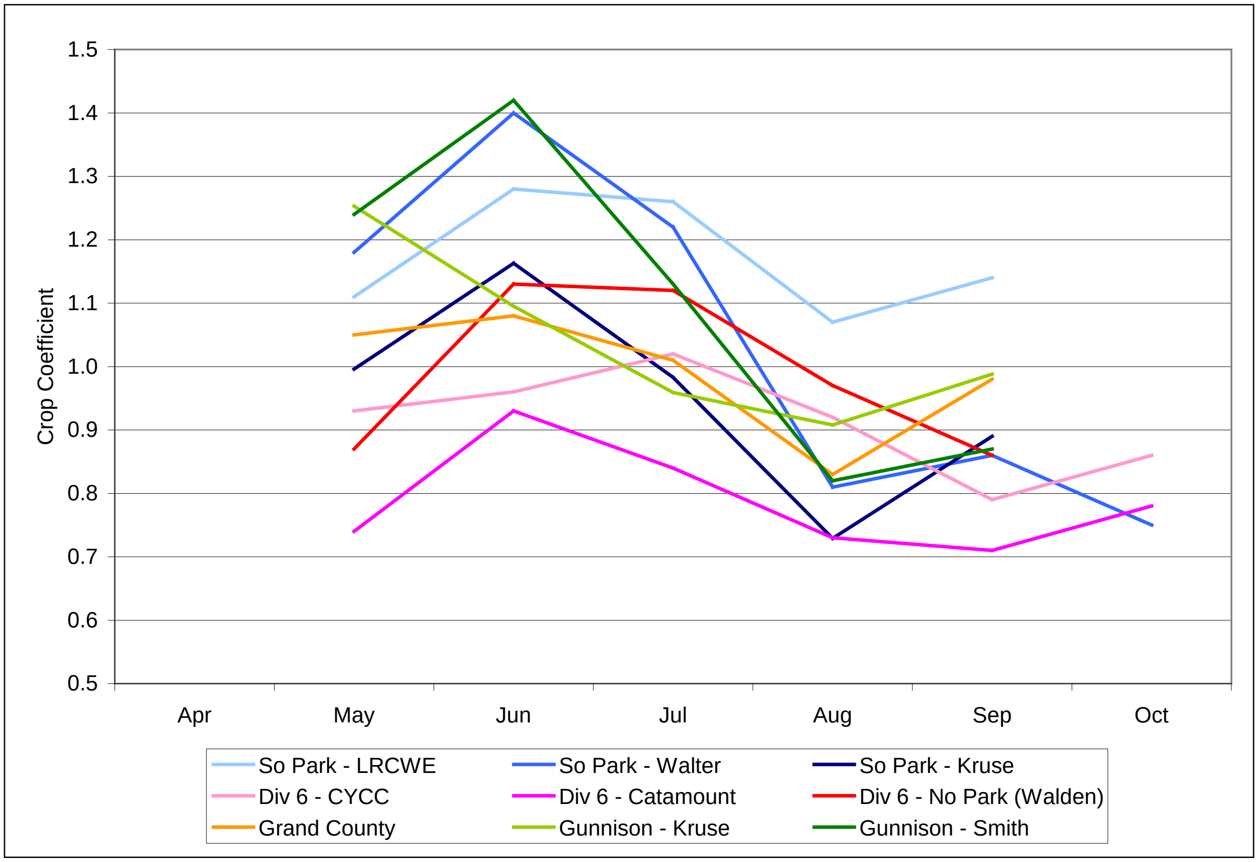


Figure 1 – Lysimeter-Derived Grass Crop Coefficients

It is important when evaluating data from different lysimeters to recognize differences between haying practices, irrigated environment around the lysimeters, means of filling the lysimeter, changes of vegetative matter, operational problems, etc. Examples of inconsistencies found include:

- The Division VI lysimeters are filled manually rather than automatically filling from a reservoir controlled by a float. According to Division VI staff, the sites were flooded at least once a month or when necessary to prevent drought stress to the plants (an attempt is made to irrigate before wilting occurs). These lysimeters are also surrounded by large non-irrigated pasture that may make them unrepresentative of irrigated meadows. While one would typically believe that the location of the lysimeter sites in non-irrigated meadows would increase the measured consumptive use, we believe that the manual filling of the lysimeters based on visual observation produces measured consumptive use more similar to an actual consumptive use value (with limited irrigation) rather than potential consumptive use.

- The South Park lysimeter data used by LRCWE (1993) was not adjusted to reflect haying practices. Adjustment for haying (which usually occurs in early August in South Park) would reduce the averaged coefficients for August and September. The derivation of the crop coefficients also appears to have included less detailed review for consistency and adjustment when compared to the Walter 1990 study. While the Walter Study considered some of the same lysimeter data, Walter discarded from further consideration a number of the sites that were not considered representative of high altitude irrigated meadows and adjusted the crop coefficients of other sites to be consistent with a hayed meadow.

- The Gunnison – Kruse crop coefficient pattern has a different shape than most of the crop coefficient curves derived from high altitude lysimeter studies which tend to peak in June, bottom out in August (with harvest) and then recover some after harvest in September. The Kruse study did not provide an explanation for the Gunnison bowl-shaped coefficient curve.

Both the Walter study for the South Park area and the Smith study for the Upper Gunnison River Basin appear to have made a reasonable effort to identify and exclude lysimeter data that was not reflective of irrigated meadows, and adjust data for consistency (i.e. haying practices). The Walter and Smith crop coefficient curves shown in Figure 1 each represent an average of lysimeter results from several different sites. A summary of the individual lysimeter studies reviewed by Walter are shown below in **Figure 2** and the individual site results from the Smith study are shown in **Figure 3**. So while the Walter and Smith curves shown in Figure 1 appear to be at the upper extent of the studies reviewed, they are actually the average of a subset of studies and individual site curves. These are the two most comprehensive and complete lysimeter studies reviewed and while producing independent derivations of crop coefficients, the resulting average monthly crop coefficients are very similar. Application of either set of coefficients with the original Blaney-Criddle method would be reasonable for SPDSS, however, due to the level of documentation provided with the Walter study we recommend the South Park – Walter coefficients be used for SPDSS (Table 1 shown in bold). The South Park – Walter study showed that the season of significant plant growth was well-approximated by using a five-day temperature threshold of 42 degrees, as opposed to the 45 degrees mean temperature outlined in TR-21. When applying the South Park – Walter coefficients for SPDSS, the growing season will be defined by a mean temperature of 42 degrees for both spring and fall.

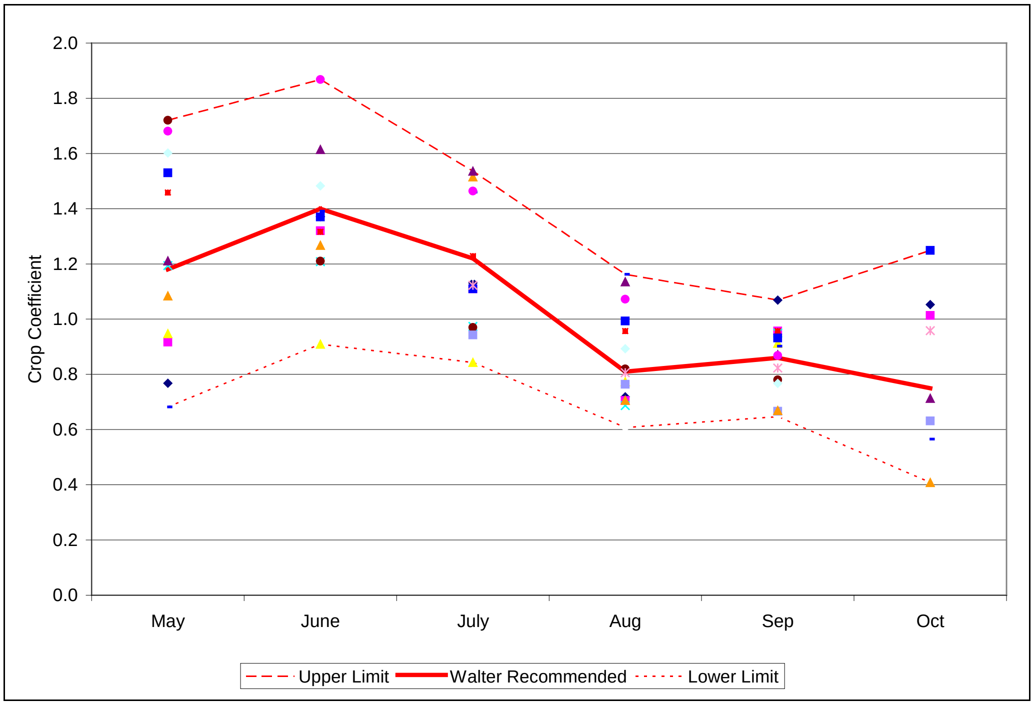


Figure 2 – Lysimeter-Derived Grass Crop Coefficients Evaluated by Walter et al.

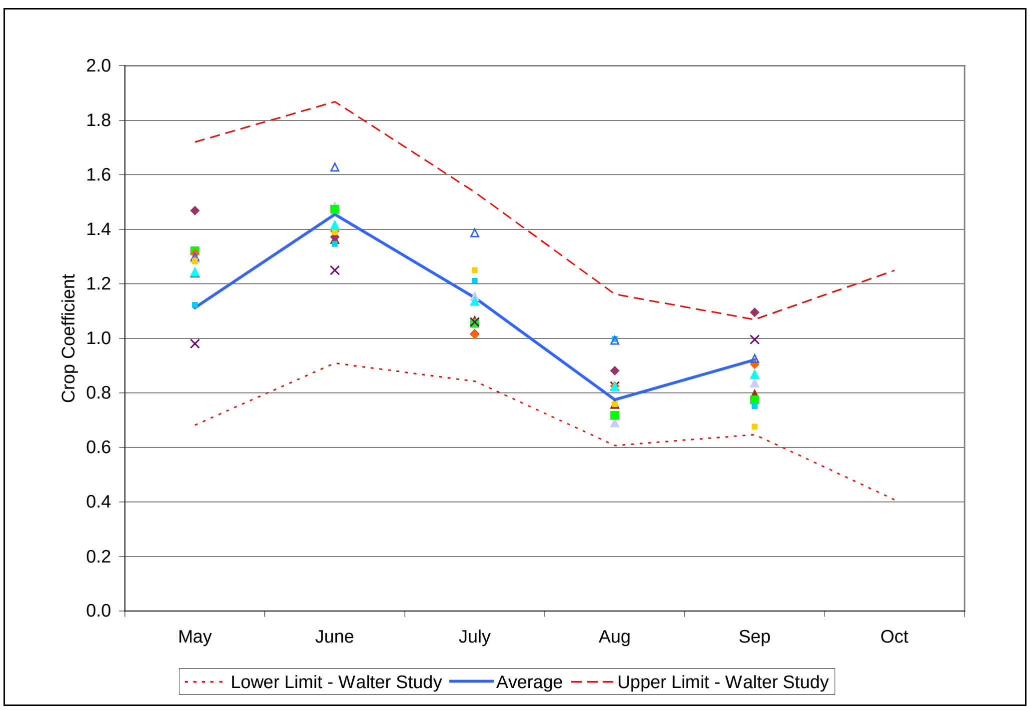


Figure 3 – Lysimeter-Derived Grass Crop Coefficients from the Smith Study

2. Review the ASCE Standardized Penman-Monteith Methodology and Determine its Appropriateness for Use in the Calibration of Blaney-Criddle Crop Coefficients

Under Task 58, it was recommended that the ASCE Standardized Penman-Monteith equation be used to develop locally calibrated coefficients for the modified Blaney-Criddle method in areas where lysimeter data are not available. Similar to the original Penman-Monteith equation, the ASCE Standardized method can be applied using a set of short reference crop (grass) or tall reference crop (alfalfa) coefficients. Alfalfa has been suggested as the preferable reference crop for arid climates (ASCE, 1990) and therefore, the ASCE Standardized equation for tall reference crop was added to the State's consumptive use model, StateCU.

ASCE provides a set of mean crop coefficients and basal crop coefficients for a tall reference crop (ASCE, 1990). The mean coefficients include ET from both the crop and the soil whereas the basal coefficients require an additional set of coefficients to account for ET from the soil. Site-specific information is needed to develop the basal coefficients and while this may be appropriate for a farm-level analysis, the mean coefficients were determined to be more appropriate for the SPDSS basin-scale analyses. The mean crop coefficients for tall reference crop provided by ASCE were originally developed by J.L. Wright in 1982 for the 1982 Kimberly Penman equation (see ASCE, 1990, Table 6.9 **–** "Mean *Et* Crop Coefficients, *Kcm*, for Normal Irrigation and Precipitation Conditions, for Use with Alfalfa Reference *Et*, *Etr*"). According to the ASCE Environmental and Water Resources Research Institute, these coefficients can be used in the ASCE Standardized method without any adjustment.

The growing season parameters outlined in TR-21 and typically used with the modified Blaney-Criddle method are commonly applied in water rights analyses throughout the SPDSS study area. These parameters define the beginning and ending of the growing season, maximum root zone depth, maximum application depth, and cutting parameters for each crop type. While more site-specific information might be applied for a specific parcel analysis, these parameters are believed to sufficiently represent the SPDSS area for this basin wide analysis. Therefore, the TR-21 growing season parameters were used with the Standardized ASCE method.

3. Recommend Methodology for the Development of Locally Calibrated Crop Coefficients by Geographic Regions

Consistent with the recommendations made under Task 58, locally calibrated crop coefficients for irrigated grasses at high altitude will be based on lysimeter data. Locally calibrated coefficients for the major crop types irrigated throughout the plains (from the foothills east) of the SPDSS study area will be developed through calibration with the ASCE Standardized method, due to the unavailability of lysimeter data. This calibration will be performed by comparing PCU (gross potential consumptive use prior to reducing for effective precipitation) estimates between the modified Blaney-Criddle and ASCE Standardized methods.

For this task and other SPDSS tasks, the high altitude portion of the SPDSS study area is defined as areas west of the foothills (generally above 6,500 feet) including Water Districts 23, 47, 48, 76, and 80 and the upper portions of Water Districts 3, 4, 5, 6, 7, 8, 9 as depicted in **Figure 4**. Figure 4 and the division between upper and lower portions of water districts were developed using digital elevations obtained from the State, originally derived from data obtained from the USGS.

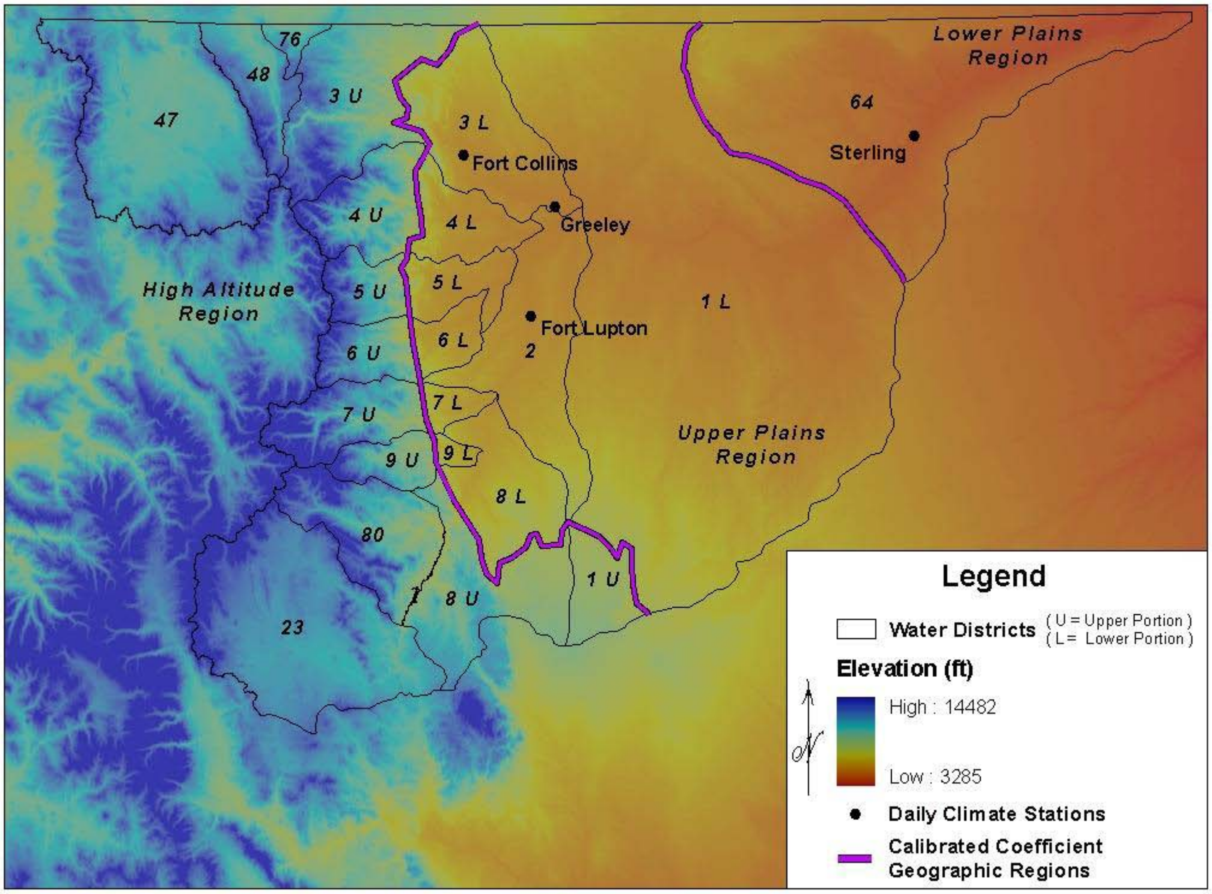


Figure 4 – Calibrated Coefficient Geographic Boundaries

4. Develop Locally Calibrated Crop Coefficients

4.1 High Altitude Portions of the SPDSS Study Area

Lysimeter-derived crop coefficients, because they represent actual field experiments, produce more accurate results than using a generalized consumptive use method with standardized crop coefficients. Even if an adjustment for elevation is made to the generalized method and standardized coefficients, consumptive use results are not typically as accurate as those based on local lysimeter data. As an example, the original Blaney-Criddle consumptive use method was analyzed using the lysimeter-derived coefficients from the Walter study (Table 1) and compared to the modified Blaney-Criddle method run with the TR-21 crop coefficients and an upward elevation adjustment of 10% for each 1,000 meters increase in elevation above sea level (as recommended in ASCE, 1990). While PCU is a linear function of the crop coefficients with the original Blaney-Criddle method, the relationship is not linear with the modified Blaney-Criddle method due to the additional temperature adjustment. Therefore, crop coefficients for the two methods cannot be compared directly. However, the resulting PCU of pasture/meadow grass can be compared and are provided in **Table 2** at two high altitude climate stations, Antero Reservoir and Bailey.

Table 2
Average Annual (1950 – 2003) PCU for Pasture Grass using Lysimeter-Derived Crop Coefficients vs. Standardized Coefficients with Elevation Adjustment

Climate Station	Lysimeter-Derived Coefficients	Modified Blaney-Criddle w/Elev Adj	Ratio (Elev Adj/Lysimeter)
Antero	2.17 feet	1.33 feet	61%
Bailey	2.52 feet	1.66 feet	66%

As presented above, even with an elevation adjustment, use of the modified Blaney-Criddle method and standard TR-21 coefficients significantly understates (by over 30%) the estimated potential consumptive use of grass pasture when compared to lysimeter data. This is also shown in Figure 7.49 of Manual No. 70 where South Park lysimeter results are compared to several temperature-based ET methods (ASCE, 1990). It is recommended that lysimeter-derived coefficients from the South Park study by Walter et al. (Table 1 and Table 8 below) be used with the original Blaney-Criddle method for high altitude areas of the SPDSS, using the growing season trigger of 42 degrees mean temperature.

4.2 Plains Portion of the SPDSS Study Area

The following approach was used to develop locally calibrated modified Blaney-Criddle crop coefficients for the plains area.

- Identify and obtain available climate data.
- Identify irrigated crop types throughout the SPDSS study area.
- Compare the ASCE Standardized method and modified Blaney-Criddle method PCU estimates.
- Adjust the modified Blaney-Criddle crop coefficients to represent the PCU results predicted using the ASCE Standardized method.

Identify and Obtain Available Climate Data

The average monthly temperature data and frost dates required for the modified Blaney-Criddle consumptive use method are readily available for long study periods from the National Climate Data Center through the National Oceanic and Atmospheric Administration (NOAA), who is responsible for operation of the stations, and are included in the State's central database, **HydroBase**.

Daily maximum temperature, minimum temperature, wind speed, solar radiation, and vapor pressure data required for the ASCE Standardized calculations are primarily available from two sources throughout the SPDSS study area, the Northern Colorado Water Conservancy District (NCWCD) and the Colorado Agricultural Meteorological Network (CoAgMet). Longer periods of record are available for CoAgMet climate data. Three CoAgMet climate stations and one NCWCD climate station were selected for use in the calibration of modified Blaney-Criddle crop coefficients (**Figure 4** and **Table 3**).

Table 3
CoAgMet and NCWCD Climate Stations

Station Name	Source	Identifier	Water District	Elevation (feet)	Period of Record [1]
Fort Collins	CoAgMet	FTC01	3	5,120	1993-2003
Fort Lupton [2]	CoAgMet	FTL01	2	5,055	1993-2003
Greeley	CoAgMet	GLY03	3	4,680	1993-2003
Sterling [3]	NCWCD	Sterling	64	3,938	1996-2006

[1] Calibration at the Fort Collins, Fort Lupton, and Greeley stations was performed in 2004, based on 1993-2003 period of record. Calibration at the Sterling station was performed in 2007, based on 1996-2006 period of record.
[2] The Fort Collins climate station was
[3] Elevation information not available from NCWCD website; estimated based on NOAA climate station location.

The analyses were based on the full available period of record. The daily climate data were inspected and, based on discussions with CoAgMet, negative values of solar radiation and vapor pressure were removed. There were also instances where the wind data had a value of 15.45 km/day for multiple days in a row. This is an unreasonably low wind value and because of the repeated days in a row with the same value and based on discussions with CoAgMet personnel, these data were also removed. Guidelines from "The ASCE Standardized Reference Evapotranspiration Equation" (ASCE, 2005) were used to inspect and adjust the daily climate data.

The daily climate data were generally very complete during the growing season of April through October throughout the analysis period. The Fort Collins station was over 97% complete for all parameters, Fort Lupton was over 99% complete for all parameters, Greeley was over 98% complete for all parameters except wind which was around 79% complete, and Sterling was 100% complete for all parameters. Missing daily data were filled using linear regression techniques described in the SPDSS *Task 53.2 – Collect and Fill Monthly Climate Data* memo. Following is a summary of that analysis for the four comparison stations:

- Selection of climate stations providing the raw data to fill another climate station data set was based on proximity of the stations resulting in similar climatic conditions, amount of data that could be filled, and the relative correlations between the two data sets.
- The unfilled Greeley climate station data was used to fill both the Fort Collins and Fort Lupton climate data and the unfilled Fort Lupton climate station was used to fill Greeley.

The monthly correlation coefficients (R) generally fell in the range of 0.70 to 0.99. There was a small amount (around 0.5% or less for each parameter at each climate station) of missing data that could not be filled using regression because concurrent data were not available at both climate stations. Therefore, the remaining missing data were filled using linear interpolation.

The calibrated coefficients resulting from this task will be applied to the SPDSS key climate stations using the monthly NOAA data stored in HydroBase. However, for consistency with the data used in developing the calibrated coefficients with the ASCE Standardized and modified

Blaney-Criddle methods, the average monthly temperature data used with the modified Blaney-Criddle method were calculated from the daily maximum and minimum temperature CoAgMet/NCWCD data used with the ASCE Standardized method. Likewise, frost dates were selected from the CoAgMet/NCWCD daily minimum temperature data set.

Identify Irrigated Crop Types

The SPDSS irrigated acreage assessment shows that common crops in the SPDSS study area can generally be classified into the following categories:

- Alfalfa
- Corn Grain
- Dry Beans
- Pasture Grass
- Small Grains
- Sugar Beets

There are also relatively minor percentages of orchard and vegetables grown throughout the SPDSS study area. Because the amount of acreage planted is relatively small, and based on our research, mean crop coefficients that can be used with the ASCE Standardized method are not available for orchard or vegetables, calibrated crop coefficients could not be developed for either of these crops. Therefore, unadjusted TR-21 modified Blaney-Criddle crop coefficients will be used to represent these crops in the historical consumptive use analyses.

Compare the ASCE Standardized and Modified Blaney-Criddle PCU Estimates

StateCU was run using the ASCE Standardized option with daily climate data and the modified Blaney-Criddle option with monthly climate data and the TR-21 crop coefficients. **Table 4** summarizes the average annual PCU results derived from the two methods and the percentage difference as the (ASCE Standardized results – Modified Blaney-Criddle results) / ASCE Standardized results.

Table 4
Average Annual PCU Estimates Using the ASCE Standardized Method and the Modified Blaney-Criddle Method with TR-21 Crop Coefficients

Crop Type	ASCE	BC	Difference	% Difference
Fort Collins (1993-2003 Average)				
Alfalfa	2.27	2.26	0.01	0%
Corn Grain	1.57	1.66	-0.09	-6%
Dry Beans	1.20	1.48	-0.28	-23%
Grass Pasture	2.50	2.10	0.40	16%
Small Grains	1.59	1.56	0.03	2%
Sugar Beets	1.69	2.00	-0.31	-18%
Fort Lupton (1993-2003 Average)				
Alfalfa	2.66	2.58	0.08	3%
Corn Grain	1.86	1.86	0.00	0%
Dry Beans	1.39	1.65	-0.26	-19%
Grass Pasture	2.88	2.32	0.56	19%
Small Grains	1.74	1.64	0.10	6%
Sugar Beets	2.17	2.32	-0.15	-7%
Greeley (1993-2003 Average)				
Alfalfa	2.67	2.53	0.14	5%
Corn Grain	1.83	1.84	-0.01	-1%
Dry Beans	1.35	1.65	-0.30	-22%
Grass Pasture	2.85	2.27	0.58	20%
Small Grains	1.80	1.66	0.14	8%
Sugar Beets	2.10	2.27	-0.17	-8%
Sterling (1996-2006)				
Alfalfa	2.93	2.59	0.34	12%
Corn Grain	2.08	1.89	0.19	9%
Dry Beans	1.53	1.66	-0.13	-8%
Grass Pasture	3.22	2.32	0.9	28%
Small Grains	1.94	1.55	0.39	20%
Sugar Beets	2.18	2.18	0.00	0%

As indicated in Table 4, the ASCE Standardized method produces greater seasonal PCU estimates for certain crops at certain locations while the modified Blaney-Criddle method (with TR-21 coefficients) produces greater seasonal PCU at other locations. **Figures 6** through **28**, depicting these results on a monthly basis, are provided at the end of the memo.

<u>Adjust the Modified Blaney-Criddle Crop Coefficients to Represent the PCU Results Predicted Using the ASCE Standardized Method</u>

In previous DSS efforts, calibration of modified Blaney-Criddle crop parameters was accomplished in two steps; first adjustment of growing seasons and next adjustment of crop coefficients. As noted above, the crop growing seasons are based on frost dates or average temperatures reported in TR-21 for both the ASCE Standardized and the modified Blaney-Criddle methods. Because the source of the climate data was the same for both the ASCE Standardized and Modified Blaney-Criddle runs, growing season adjustment was not necessary under this task and only adjustment of the modified Blaney-Criddle crop coefficients was required in developing calibrated coefficients.

Calibrated coefficients for alfalfa, corn grain, dry beans, grass pasture, small grains and sugar beets were developed at the Fort Collins, Fort Lupton, and Greeley climate stations for the available period of record. Because PCU is not a linear function of the crop coefficients, developing the coefficients was an iterative process. The following steps describe the process used to develop calibrated coefficients for each crop type at each of the four climate stations:

1. The ASCE Standardized option in StateCU was run with daily climate data.
2. The modified Blaney-Criddle option in StateCU was run with monthly climate data using the TR-21 crop coefficients.
3. The average monthly ASCE Standardized PCU estimates (Step 1) were divided by the average monthly modified Blaney-Criddle PCU estimates (Step 2).
4. The resulting monthly factors (Step 3) were applied to the modified Blaney-Criddle crop coefficients in deriving calibrated crop coefficients. For crop coefficients based on day of year (perennial crops including alfalfa and pasture grass), the monthly factors were applied to the monthly TR-21 crop coefficients. For crop coefficients based on percentage of growing season (annual crops including corn grain, dry beans, small grains, and sugar beets), the monthly factors were applied to the crop coefficients during the average growing season for each crop type at each climate station.
5. The modified Blaney-Criddle option in StateCU was run using the calibrated crop coefficients.
6. The monthly ASCE Standardized PCU estimates (Step 1) were divided by the monthly modified Blaney-Criddle PCU estimates based on the calibrated crop coefficients (Step 5).
7. Steps 4 through 6 were repeated until the monthly factors calculated in Step 6 were 1.0 for each month, generally taking around three to four iterations.

As compared to the Sterling climate station, the Fort Collins, Fort Lupton, and Greeley stations are located relatively close to each other and have similar elevations. The modified Blaney-Criddle method was run using the calibrated crop coefficients for the Fort Collins, Fort Lupton, Greeley, and Sterling climate stations at the Greeley station. An example is shown in **Figure 5** for alfalfa. A comparison showed that the seasonal PCU using the Fort Collins, Fort Lupton, and Greeley calibrated crop coefficients was typically within a few percentages of each other while the seasonal PCU using the Sterling coefficients was on the order of ten percent different. Therefore, the Fort Collins, Fort Lupton, and Greeley coefficients were averaged and will be used to represent the Upper Plains (Water District 1, 2, and the lower portions of Water Districts 3, 4, 5, 6, 7, 8, and 9). The Sterling calibrated coefficients will be used to represent the Lower Plains (Water District 64).

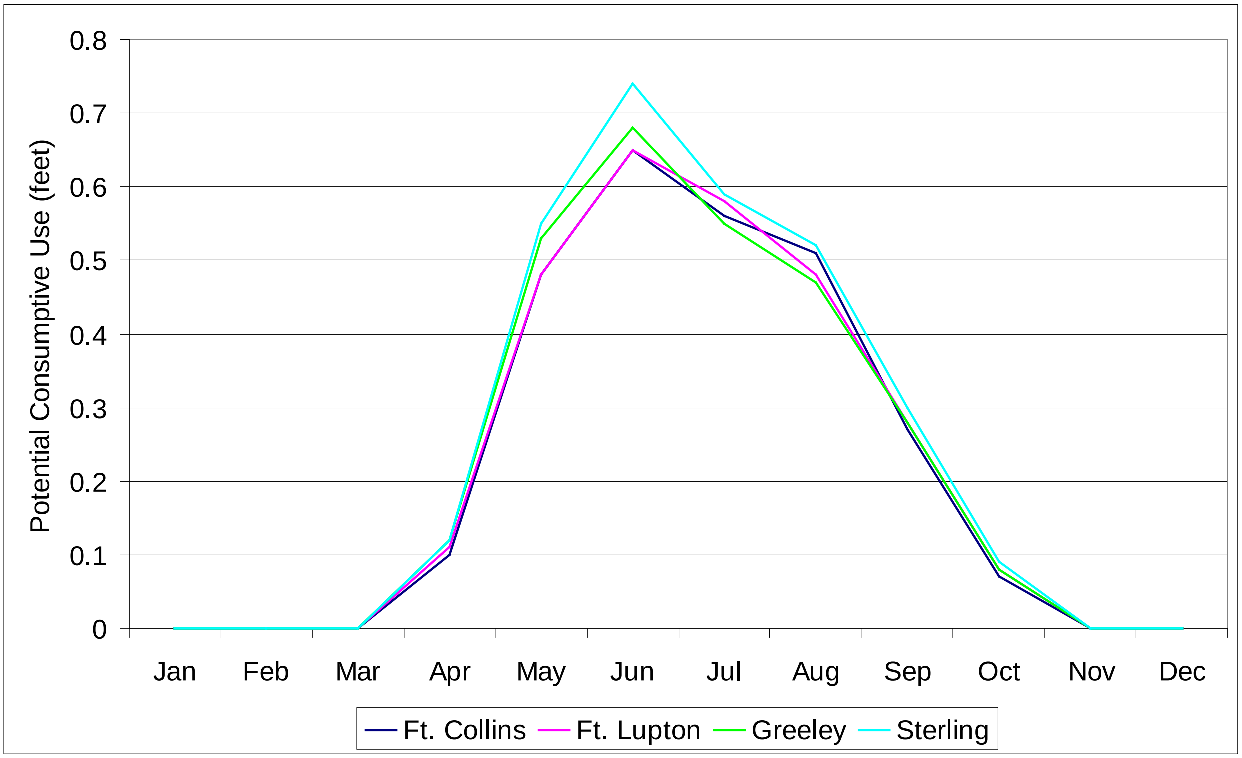


Figure 5 – Potential Consumptive Use for Alfalfa at the Fort Lupton Climate Station Using the Fort Collins, Fort Lupton, Greeley, and Sterling Calibrated Coefficients

Tables 5 through **10** show the TR-21 modified Blaney-Criddle crop coefficients compared to the calibrated crop coefficients. Note that the alfalfa calibrated coefficients shown in Table 5 were calibrated to the ASCE Standardized method of three cuttings with 45 days between the first and second cutting and 45 days between the second and third cutting.

Table 5
TR-21 and Calibrated Crop Coefficients for Alfalfa [1]

Day of Year	TR-21	Calibrated Coefficients	
		Upper Plains	Lower Plains
1	0.600	0.600	0.600
15	0.630	0.630	0.630
32	0.680	0.680	0.680
46	0.730	0.730	0.730
60	0.790	0.790	0.790
74	0.850	0.850	0.850
91	0.920	1.415	1.506
105	0.990	1.522	1.621
121	1.045	1.477	1.644
135	1.090	1.540	1.715
152	1.120	1.360	1.540
166	1.135	1.379	1.561
182	1.130	0.951	1.005
196	1.115	0.939	0.992
213	1.090	0.949	1.022
227	1.065	0.927	0.998
244	1.030	0.885	0.970
258	0.990	0.850	0.932
274	0.950	1.042	1.195
288	0.905	0.993	1.139
305	0.850	0.850	0.850
319	0.790	0.790	0.790
335	0.720	0.720	0.720
349	0.640	0.640	0.640
366	0.600	0.600	0.600

[1] Calibrated crop coefficients can be used to estimate potential crop consumptive use under full water supply conditions.

Table 6
TR-21 and Calibrated Crop Coefficients for Corn Grain [1]

Percent of Growing Season	TR-21	Calibrated Coefficients	
		Upper Plains	Lower Plains
0	0.440	0.283	0.338
5	0.460	0.295	0.354
10	0.490	0.335	0.377
15	0.530	0.436	0.462
20	0.580	0.478	0.545
25	0.640	0.527	0.601
30	0.710	0.585	0.667
35	0.820	0.725	0.796
40	0.920	0.891	1.006
45	1.010	0.978	1.105
50	1.050	1.017	1.148
55	1.080	1.046	1.181
60	1.080	1.105	1.226
65	1.080	1.105	1.237
70	1.060	1.085	1.214
75	1.040	1.065	1.191
80	1.000	1.069	1.247
85	0.970	1.220	1.358
90	0.930	1.169	1.302
95	0.890	1.119	1.246
100	0.850	1.069	1.190

[1] Calibrated crop coefficients can be used to estimate potential crop consumptive use under full water supply conditions.

Table 7
TR-21 and Calibrated Crop Coefficients for Dry Beans [1]

Percent of Growing Season	TR-21	Calibrated Coefficients	
		Upper Plains	Lower Plains
0	0.500	0.235	0.267
5	0.540	0.317	0.325
10	0.590	0.482	0.541
15	0.650	0.531	0.596
20	0.720	0.589	0.660
25	0.810	0.662	0.743
30	0.900	0.760	0.825
35	0.970	0.901	0.999
40	1.040	0.987	1.101
45	1.080	1.025	1.144
50	1.110	1.054	1.175
55	1.120	1.063	1.186
60	1.120	1.019	1.186
65	1.080	0.824	0.900
70	1.030	0.785	0.858
75	0.960	0.732	0.800
80	0.890	0.679	0.742
85	0.820	0.625	0.683
90	0.750	0.310	0.504
95	0.670	0.200	0.287
100	0.600	0.179	0.257

[1] Calibrated crop coefficients can be used to estimate potential crop consumptive use under full water supply conditions.

Table 8
TR-21 and Calibrated Crop Coefficients for Grass Pasture [1]

Day of Year	TR-21	Calibrated Coefficients		
		High Altitude [2]	Upper Plains	Lower Plains
1	0.480	0.00	0.480	0.480
15	0.470	0.00	0.470	0.470
32	0.525	0.00	0.525	0.525
46	0.575	0.00	0.575	0.575
60	0.640	0.00	1.280	0.640
74	0.740	0.00	1.480	0.740
91	0.815	0.00	1.643	1.946
105	0.855	0.00	1.723	2.041
121	0.880	1.18	1.278	1.396
135	0.900	1.18	1.307	1.428
152	0.915	1.40	1.104	1.240
166	0.920	1.40	1.110	1.247
182	0.925	1.22	0.947	1.039
196	0.925	1.22	0.947	1.039
213	0.915	0.81	0.908	1.012
227	0.905	0.81	0.898	1.001
244	0.890	0.86	1.150	1.303
258	0.870	0.86	1.124	1.274
274	0.840	0.75	1.557	1.753
288	0.795	0.75	1.474	1.659
305	0.735	0.00	0.735	0.735
319	0.670	0.00	0.670	0.670
335	0.605	0.00	0.605	0.605
349	0.550	0.00	0.550	0.550
366	0.480	0.00	0.480	0.480

[1] Calibrated crop coefficients can be used to estimate potential crop consumptive use under full water supply conditions.
[2] High Altitude Coefficients to be used with original Blaney-Criddle methods; all others to be used with modified Blaney-Criddle.

Table 9
Calibrated Crop Coefficients for Small Grains [1]

Percent of Growing Season	TR-21	Calibrated Coefficients	
		Upper Plains	Lower Plains
0	0.280	0.462	0.560
5	0.350	0.578	0.700
10	0.460	0.754	0.920
15	0.580	0.921	1.160
20	0.710	1.127	1.325
25	0.830	1.318	1.384
30	0.940	1.493	1.567
35	1.040	1.632	1.734
40	1.150	1.290	1.917
45	1.250	1.403	1.728
50	1.310	1.470	1.566
55	1.310	1.469	1.566
60	1.270	1.011	1.518
65	1.180	0.940	1.411
70	1.040	0.828	0.957
75	0.870	0.693	0.800
80	0.690	0.470	0.635
85	0.500	0.273	0.460
90	0.300	0.164	0.281
95	0.130	0.071	0.130
100	0.000	0.000	0.000

[1] Calibrated crop coefficients can be used to estimate potential crop consumptive use under full water supply conditions.

Table 10
Calibrated Crop Coefficients for Sugar Beets [1]

Percent of Growing Season	TR-21	Calibrated Coefficients	
		Upper Plains	Lower Plains
0	0.450	0.529	0.363
5	0.460	0.345	0.371
10	0.490	0.368	0.395
15	0.540	0.406	0.420
20	0.610	0.453	0.407
25	0.690	0.470	0.460
30	0.790	0.511	0.527
35	0.870	0.562	0.659
40	0.950	0.745	0.848
45	1.030	0.941	0.919
50	1.100	1.010	0.982
55	1.160	1.061	1.132
60	1.210	1.084	1.240
65	1.240	1.136	1.271
70	1.250	1.149	1.281
75	1.250	1.196	1.437
80	1.220	1.284	1.505
85	1.180	1.292	1.456
90	1.140	1.281	1.407
95	1.100	1.548	1.734
100	1.040	1.500	1.733

[1] Calibrated crop coefficients can be used to estimate potential crop consumptive use under full water supply conditions.

Table 11 shows average annual PCU estimates using the Upper Plains calibrated coefficients at the Fort Lupton Climate Station and the Lower Plains calibrated coefficients at the Sterling climate station.

Table 11
Average Annual PCU Estimates Using
Upper Plains Calibrated Coefficients at Fort Lupton and
Lower Plains Calibrated Coefficients at Sterling

Crop Type	Ft. Lupton (1993-2003)	Sterling (1996-2006)
Alfalfa	2.66	2.93
Corn Grain	1.81	2.08
Dry Beans	1.36	1.53
Grass Pasture	2.86	3.21
Small Grains	1.73	1.95
Sugar Beets	2.09	2.17

Monthly time series plots (**Figures 29** through **40** provided at the end of this memo) for the six crops at Fort Lupton using the Upper Plains coefficients and at Sterling using the Lower Plains coefficients for the available period of record show that the PCU estimates using the calibrated coefficients closely approximate the ASCE Standardized method with the Wright crop coefficients.

Comments and Concerns

The recommended calibrated coefficients (Tables 5 through 10) will be added to the SPDSS StateCU input dataset and HydroBase. Following is a summary of the results from the locally calibrated Blaney-Criddle crop coefficients created under this task:

- For high altitude pasture grass, the recommended coefficient adjustments result in over 30% more PCU than unadjusted values (Table 2).
- For alfalfa, grass pasture, and small grains, the recommended coefficient adjustments result in approximately 0% to 28% more PCU than the unadjusted values (Table 4).
- For dry beans and sugar beets the recommended coefficient adjustments result in approximately 0% to 23% less PCU than the unadjusted values (Table 4).
- For corn grain, the recommended coefficient adjustments result in approximately the same PCU (ranging from 9% more to 6% less PCU) as the unadjusted values (Table 4).

This memorandum has been updated to reflect comments and questions raised at an SPDSS Consumptive Use and Water Budget Technical Peer Review meeting and additional analyses conducted in response to that meeting. Following are comments and concerns that reflect this additional review:

- The South Park-Walter study showed that the season of significant plant growth was well-approximated by using a five-day temperature threshold of 42 degrees. For SPDSS, the South Park-Walter coefficients will be used with a growing season defined by a *mean* temperature of 42 degrees for both spring and fall as an approximation.
- Different PCU estimates above and below an elevation of 6,500 feet may result if the South Park – Walter study lysimeter-derived crop coefficients are used for the high

altitude portion above 6,500 feet and the Upper Plains calibrated coefficients are used below.

- As with monthly data, daily climate data used for the ASCE Standardized method need to be reviewed for reasonableness. Based on inspection and discussions with CoAgMet, negative solar radiation and vapor pressure values, as well as unreasonably low wind values, were removed prior to using the daily data. Inspecting data graphically helps identify such extreme values. Methods described in "The ASCE Standardized Reference Evapotranspiration Equation" (ASCE, 2005) provide comprehensive data inspection and adjustment guidelines.
- While the Upper Plains and Lower Plains calibrated coefficients closely approximate the ASCE Standardized method, it is recognized that use of the modified Blaney-Criddle method will produce results that are somewhat smoothed and not fully reflective of the differences between years seen with the application of the ASCE Standardized method.
- The Upper Plains and Lower Plains locally calibrated coefficient were created using daily data from climate stations located in agricultural settings. For SPDSS modeling efforts, these crop coefficients will be applied with monthly NOAA data from stations located in both agricultural and urban settings. Based on further investigation described in the Task 81.2 memorandum, this is reasonable for the SPDSS modeling efforts.

Where to find more information

- The Task 53.2 – Collect and Fill Missing Monthly Climate Data memo provides additional information on selected key climate stations.
- The Task 58 – Review Previous Estimates of Potential CU memo provides additional information on several potential consumptive use equations.
- The Task 81.2 – Consumptive Use and Water Budget Technical Peer Review Meeting Follow-Up memo provides additional information based on technical peer review of this task.

References

ASCE Manuals and Reports on Engineering Practice No. 70, Evapotranspiration and Irrigation Water Requirements, Edited by Jensen, M.E., Burman, R.D., and Allen, R.G., 1990.

Carlson, N. C., Pollara, J.R., and Le, T. (1991). "Evapotranspiration in High Altitude Mountain Meadows, in Grand County", Report for the Board of Water Commissioners, City and County of Denver, CO. November, 1991.

Division of Water Resources (2003), "CUSUM, Summary Report, Irrigation Consumptive Use and Data Collection Program, 1983-2003", Division of Water Resources, Water Division VI. Also relied on were miscellaneous communications with Andy Schaffner, Water Commissioner for Districts 57 and 58, about the nature of the program.

Kruse, E.G. and H.R. Haise (1974). "Water Use by Native Grasses in High Altitude Colorado Meadows", Agricultural Research Service, U.S. Dept. of Agriculture, ARS-W-6, Feb.

LRCWE (1993). "Change of Water Rights of the Ralph Johnson Ranch", Leonard Rice Consulting Water Engineers, Prepared for City of Aurora, August, 1993.

Smith, D. H. (2004). "Special Report to: Statewide Water Supply Initiative (on Upper Gunnison River Basin Irrigation Water Consumptive Use Studies)", May 19, 2004. Numerous data and spreadsheets were also provided by Mr. Smith related to the Upper Gunnison Basin lysimeter studies.

The ASCE Standardize Reference Evapotranspiration Equation, Edited by Allen, R.G., Walter, I.A., Elliott, R., Howell, T., Itenfisu, D., and Jensen, M., 2005.

Walter, I.A., Siemer, J.P., Quinlan and Burman, R.D. (1990). "Evapotranspiration and Agronomic Responses in Formerly Irrigated Mountain Meadows, South Park, Colorado", Report for the Board of Water Commissioners, City and County of Denver, CO. March 1, 1990.

Comparison of Average Monthly (1993-2003) PCU Estimates Using the ASCE Standardized Method and the Modified Blaney-Criddle Method with TR-21 Crop Coefficients:

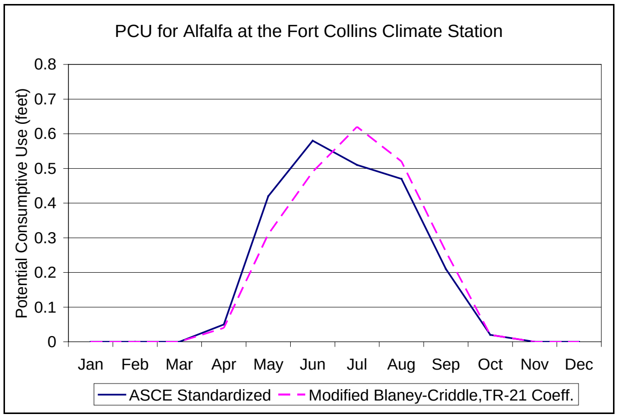


Figure 6 – Avg PCU for Alfalfa at Fort Collins

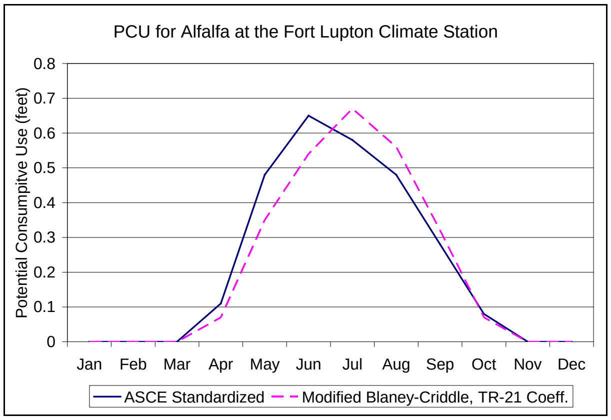


Figure 6 – Avg PCU for Alfalfa at Fort Lupton

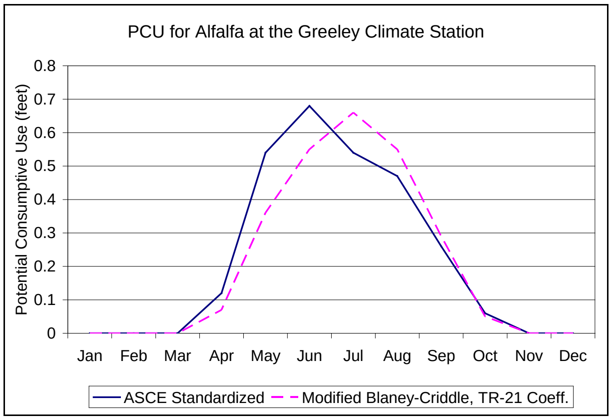


Figure 7 – Avg PCU for Alfalfa at Greeley

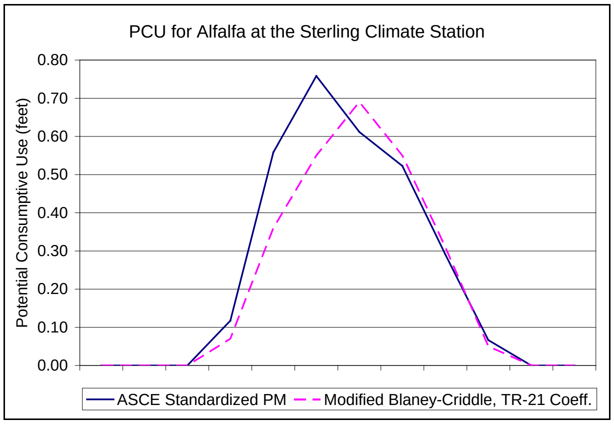


Figure 8 – Avg PCU for Alfalfa at Sterling

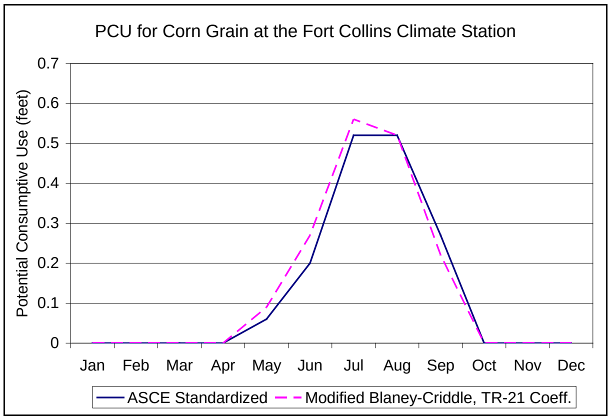


Figure 9 – Avg PCU for Corn Grain at Fort Collins

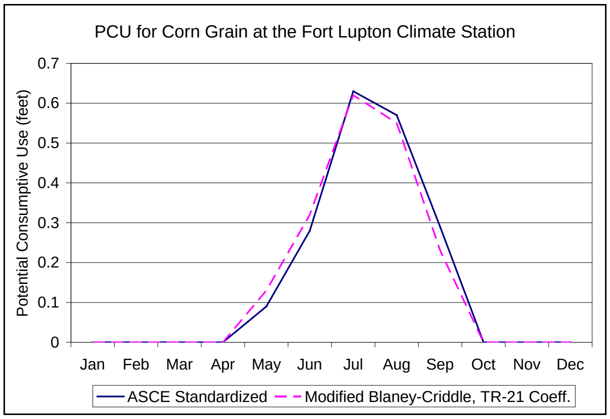


Figure 10 – Avg PCU for Corn Grain at Fort Lupton

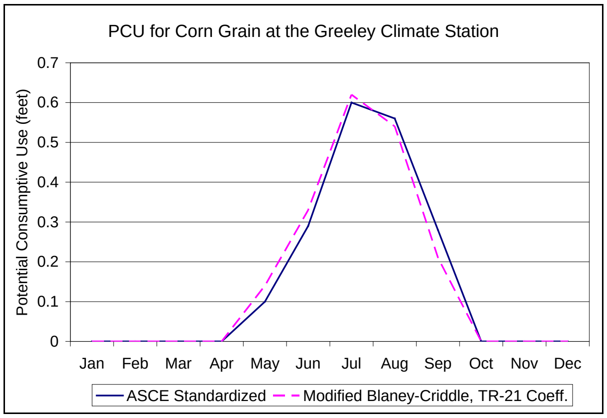


Figure 11 – Avg PCU for Corn Grain at Greeley

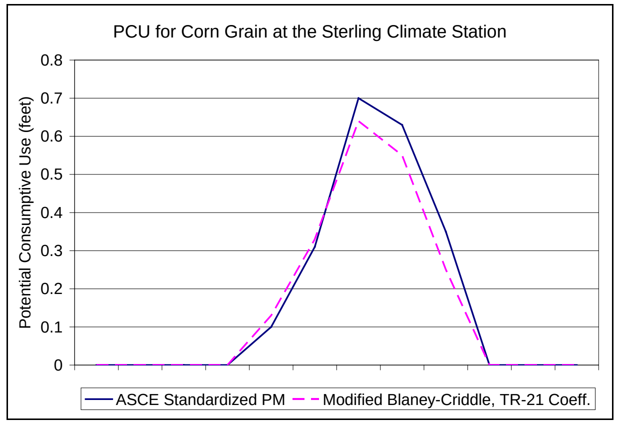


Figure 12 – Avg PCU for Corn Grain at Sterling

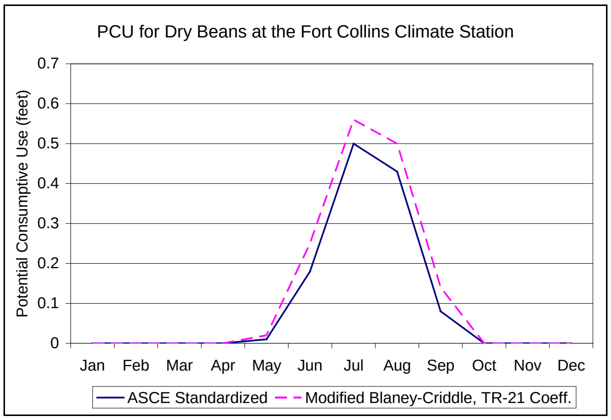


Figure 13 – Avg PCU for Dry Beans at Fort Collins

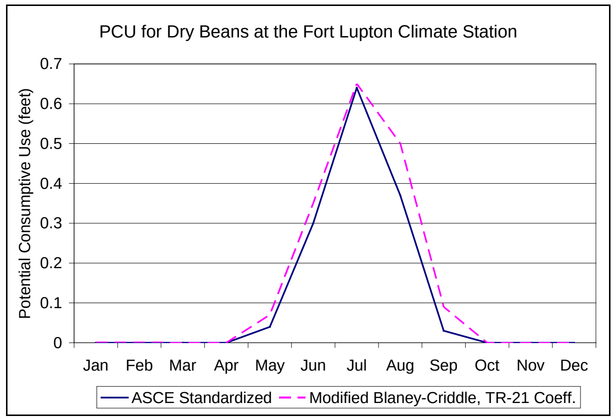


Figure 14 – Avg PCU for Dry Beans at Fort Lupton

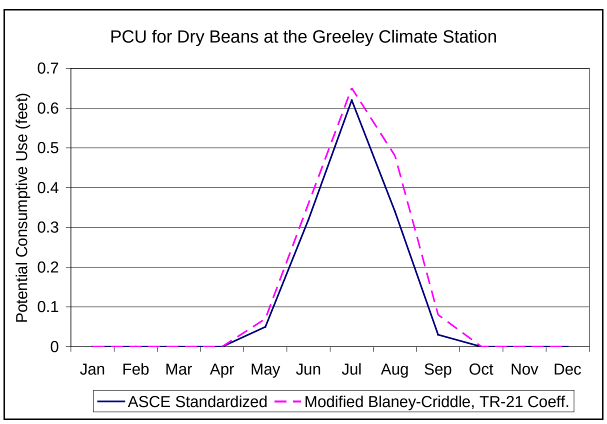


Figure 15 – Avg PCU for Dry Beans at Greeley

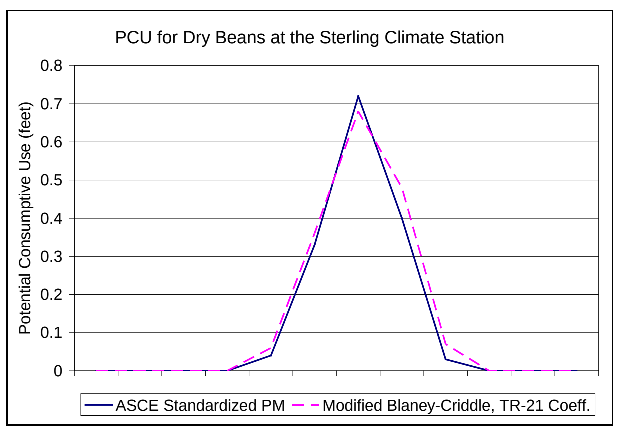


Figure 16 – Avg PCU for Dry Beans at Sterling

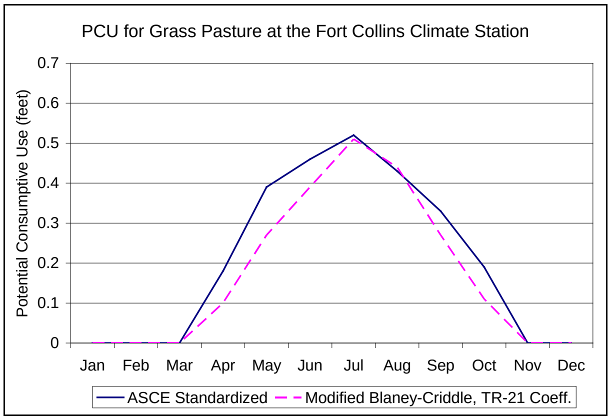


Figure 17 – Avg PCU for Pasture at Fort Collins

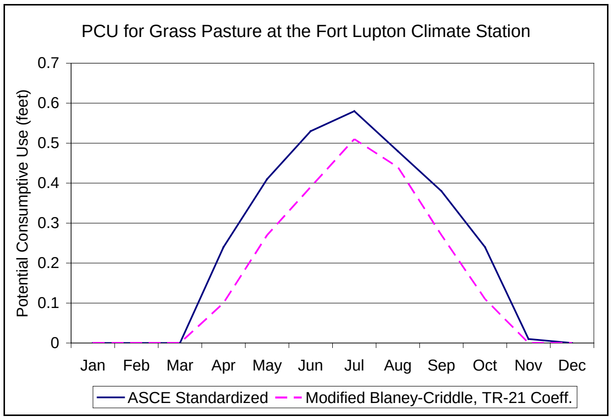


Figure 18 – Avg PCU for Pasture at Fort Lupton

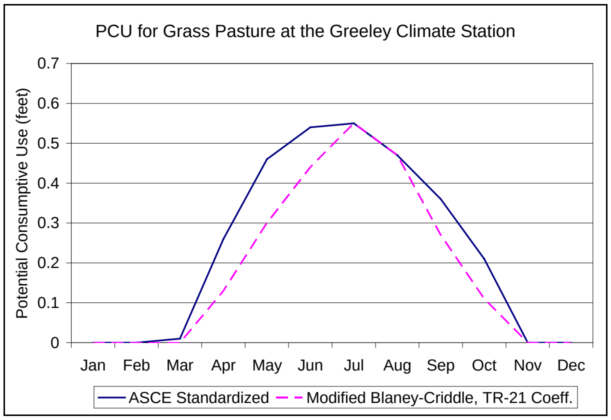


Figure 19 – Avg PCU for Pasture at Fort Collins

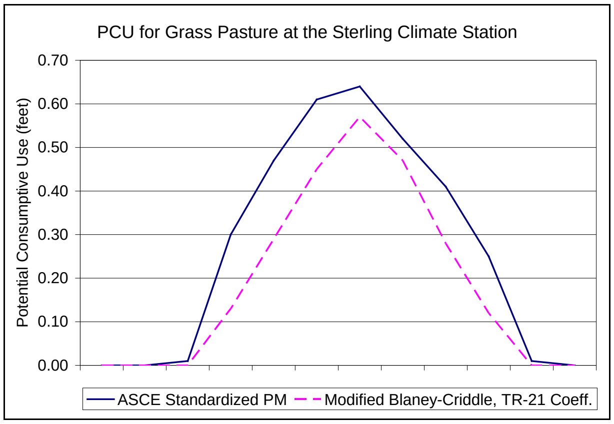


Figure 20 – Avg PCU for Pasture at Sterling

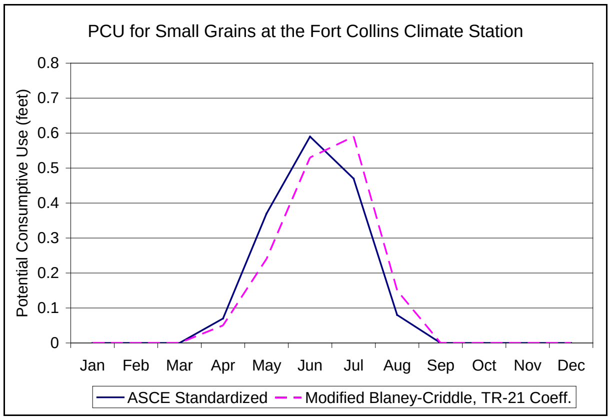


Figure 21 – Avg PCU for Grains at Fort Collins

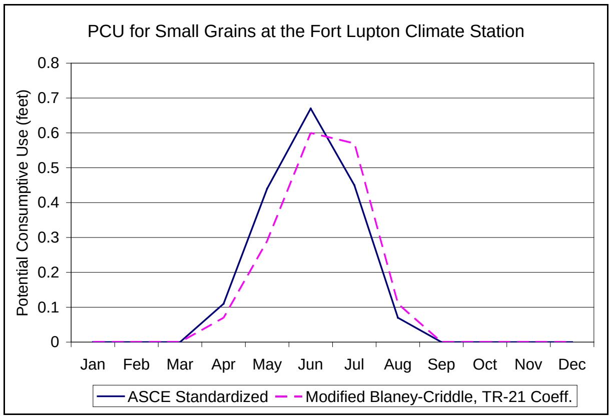


Figure 22 – Avg PCU for Grains at Fort Lupton

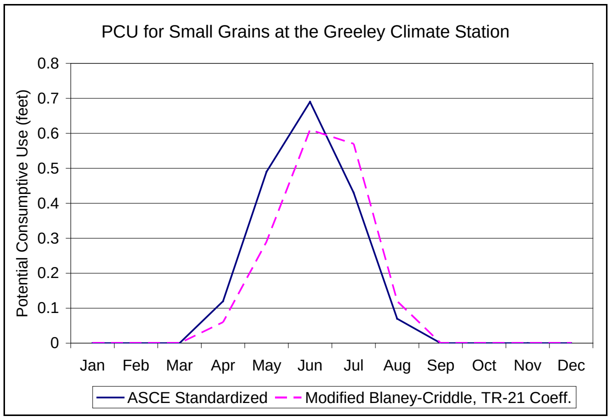


Figure 23 – Avg PCU for Small Grains at Greeley

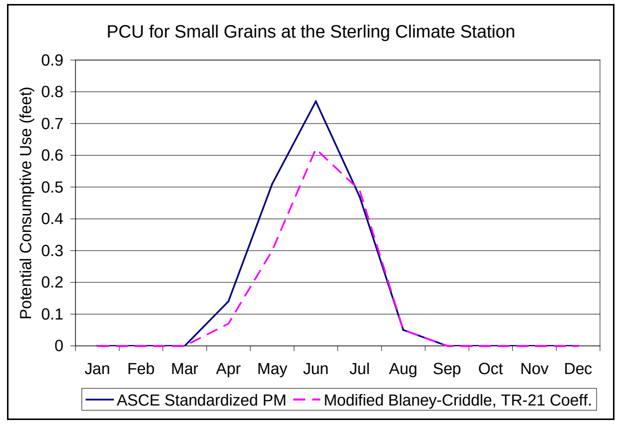


Figure 24 – Avg PCU for Small Grains at Sterling

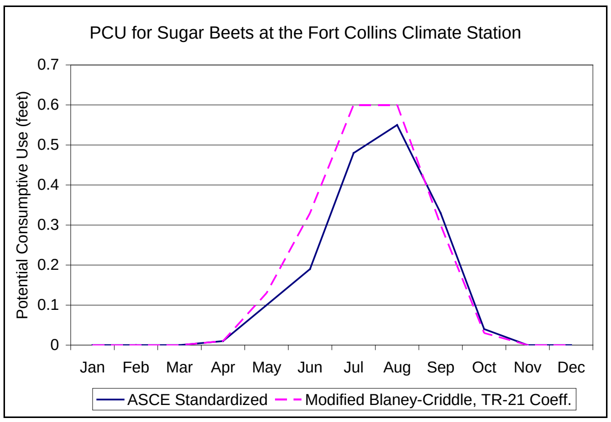


Figure 25 – Avg PCU for Sugar Beets at Fort Collins

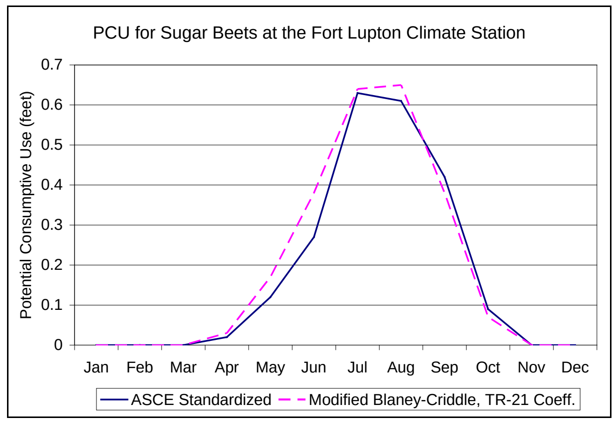


Figure 26 – Avg PCU for Sugar Beets at Fort Lupton

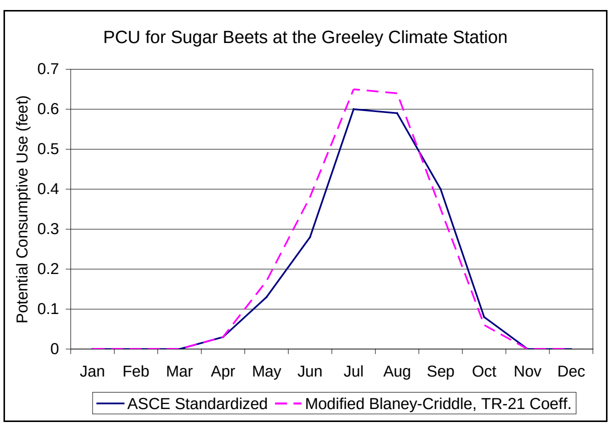


Figure 27 – Avg PCU for Sugar Beets at Greeley

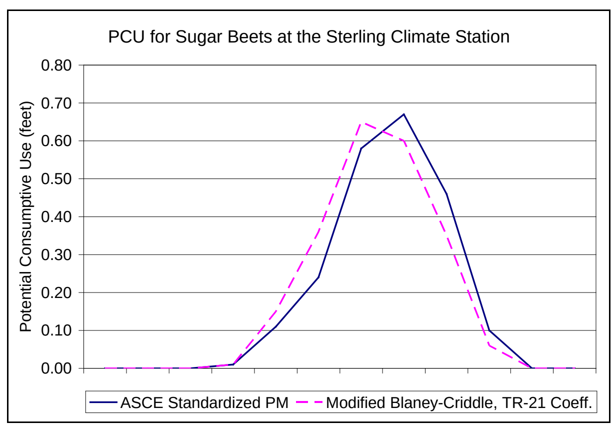


Figure 28 – Avg PCU for Sugar Beets at Sterling

Comparison of Monthly PCU Estimates Using the ASCE Standardized Method and the Modified Blaney-Criddle Method with Calibrated Crop Coefficients:

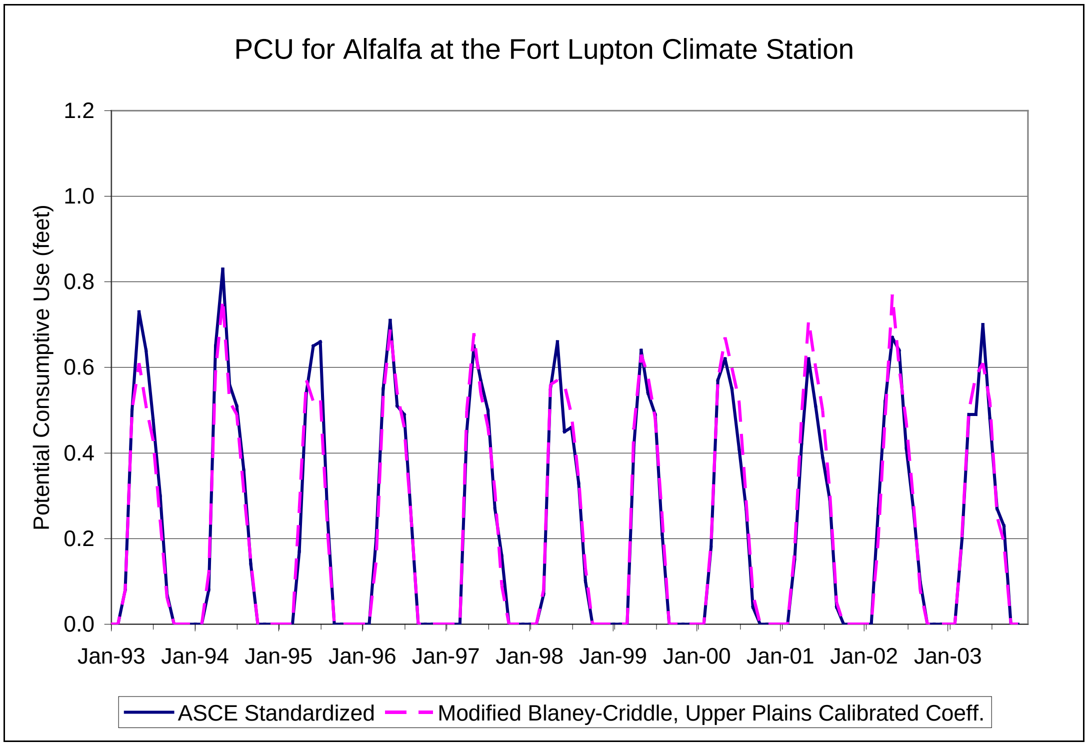


Figure 29 – PCU for Alfalfa at Fort Lupton

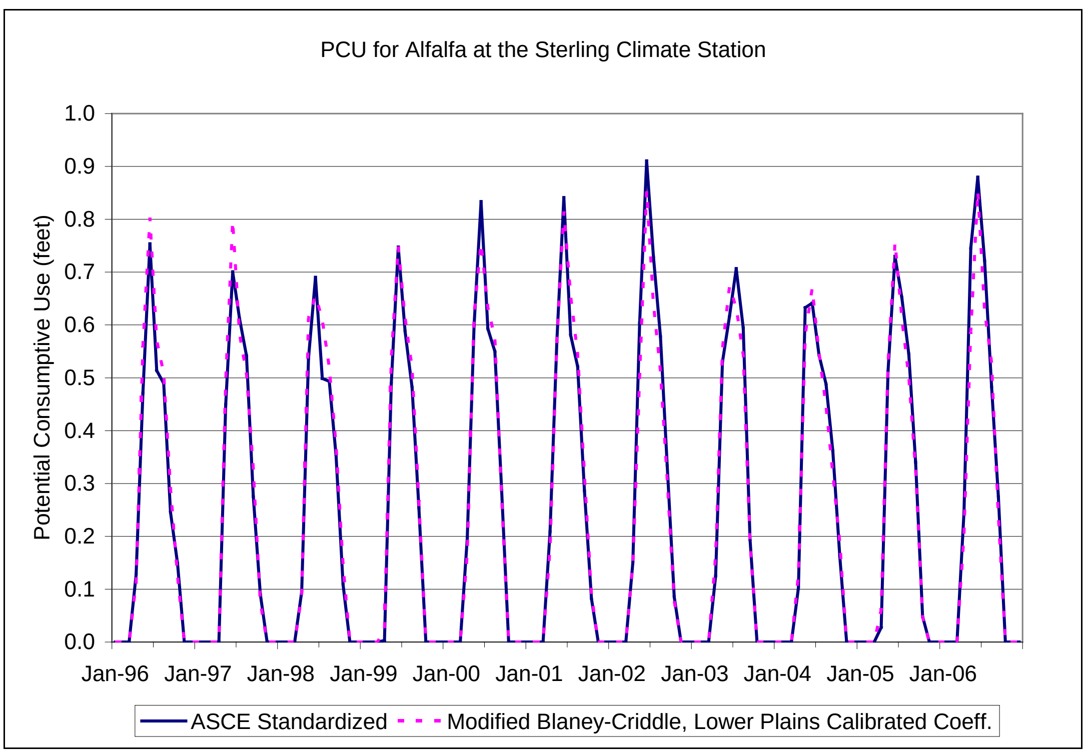


Figure 30 – PCU for Alfalfa at Sterling

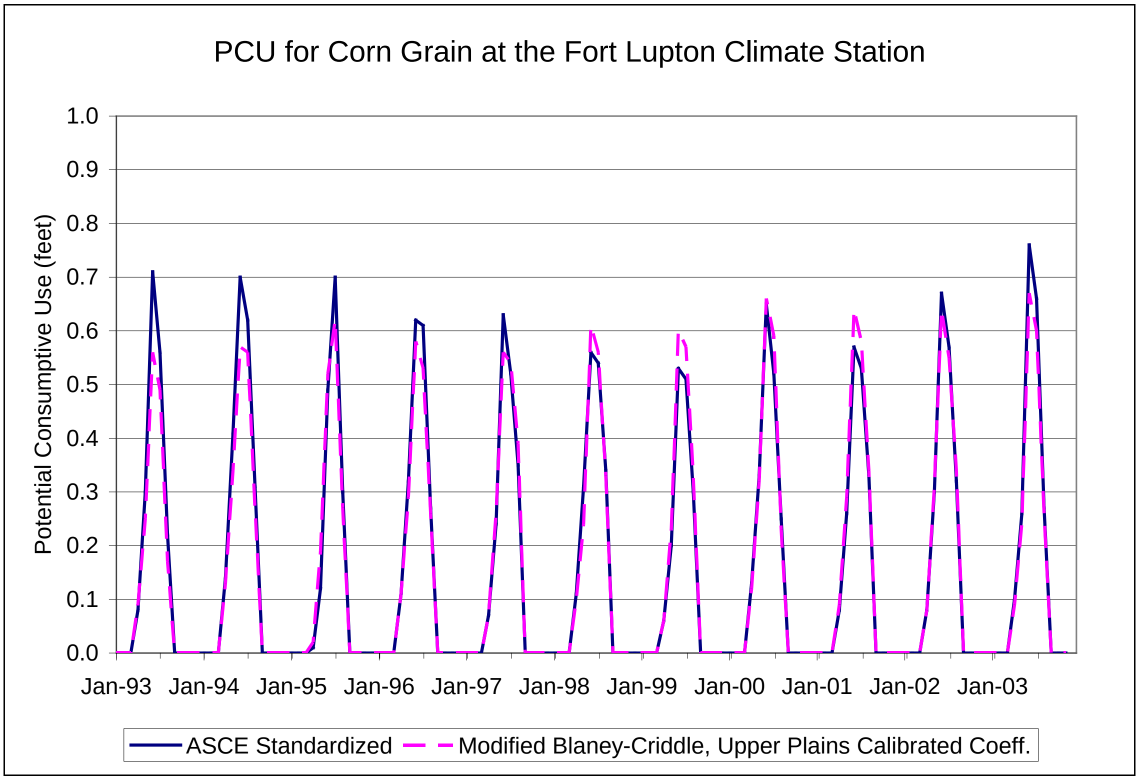


Figure 31 – PCU for Corn Grain at Fort Lupton

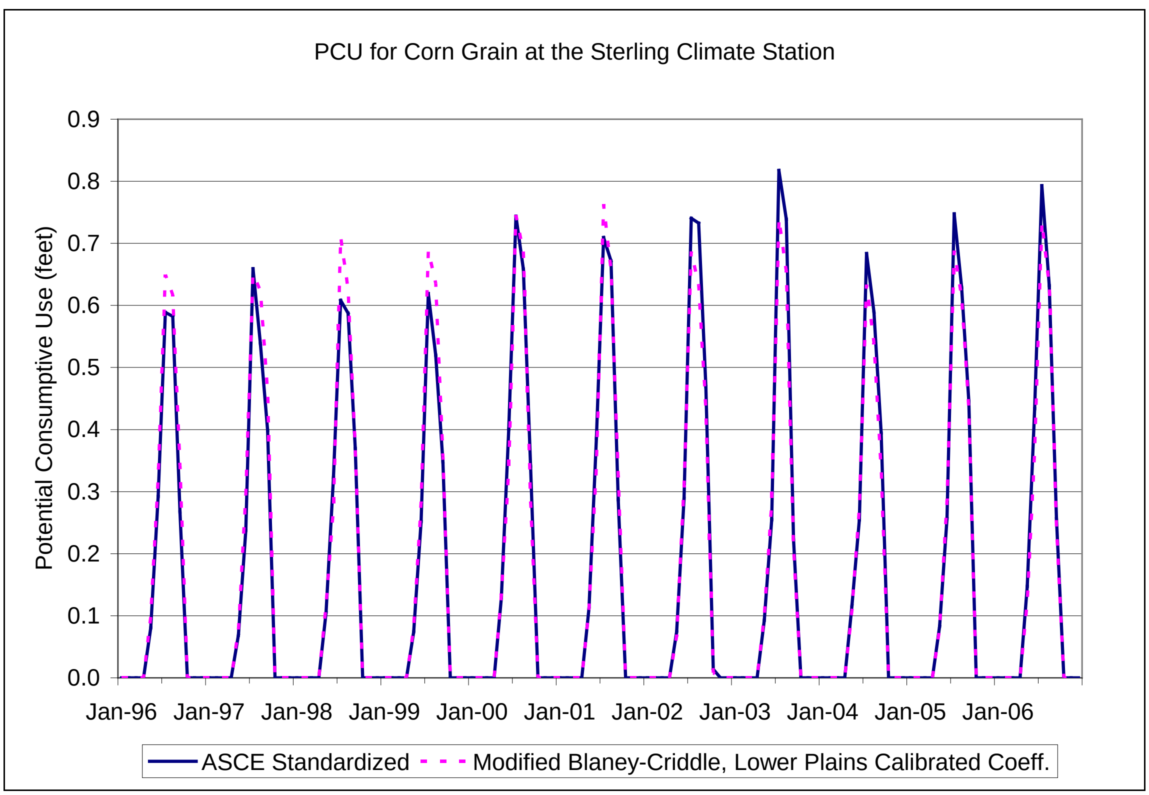


Figure 32 – PCU for Corn Grain at Sterling

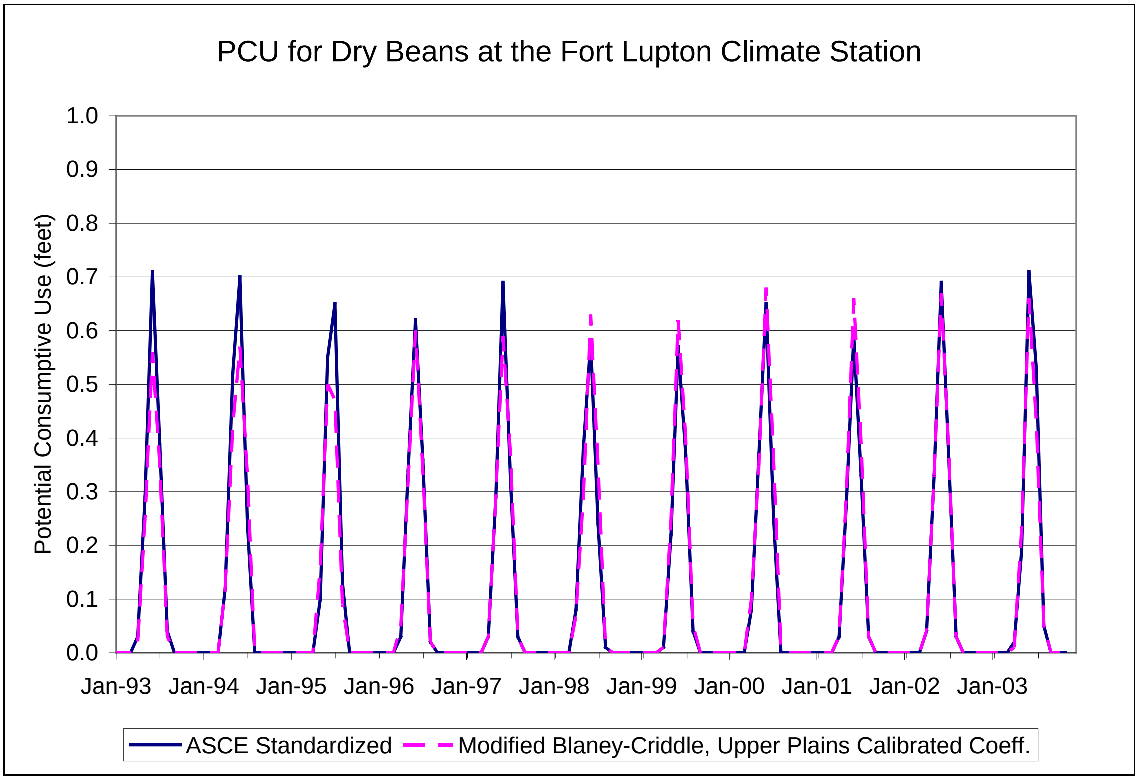


Figure 33 – PCU for Dry Beans at Fort Lupton

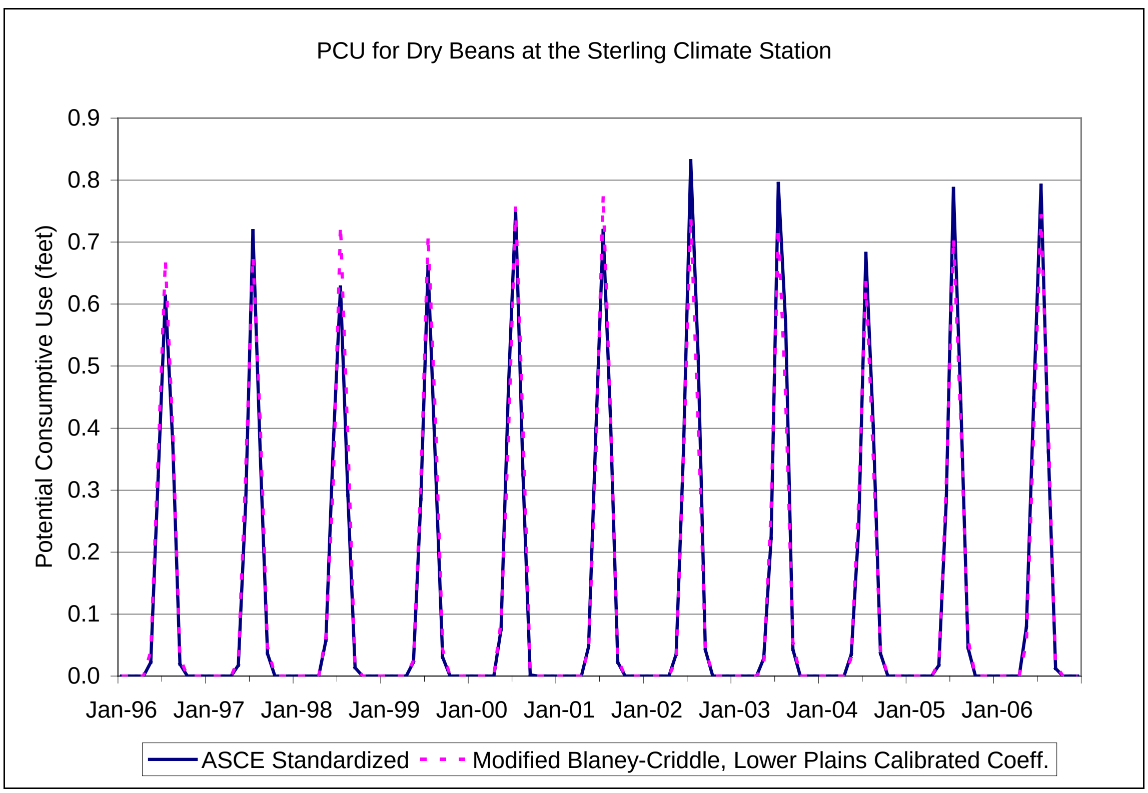


Figure 34 – PCU for Dry Beans at Sterling

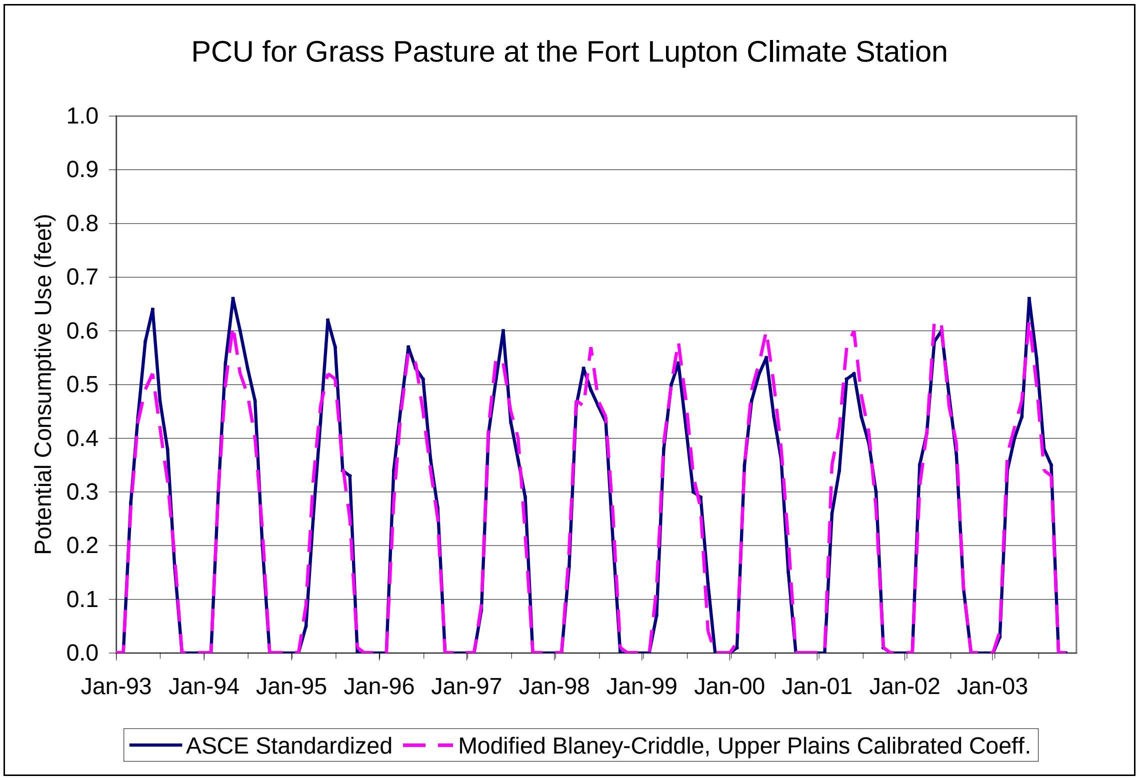


Figure 35 – PCU for Grass Pasture at Fort Lupton

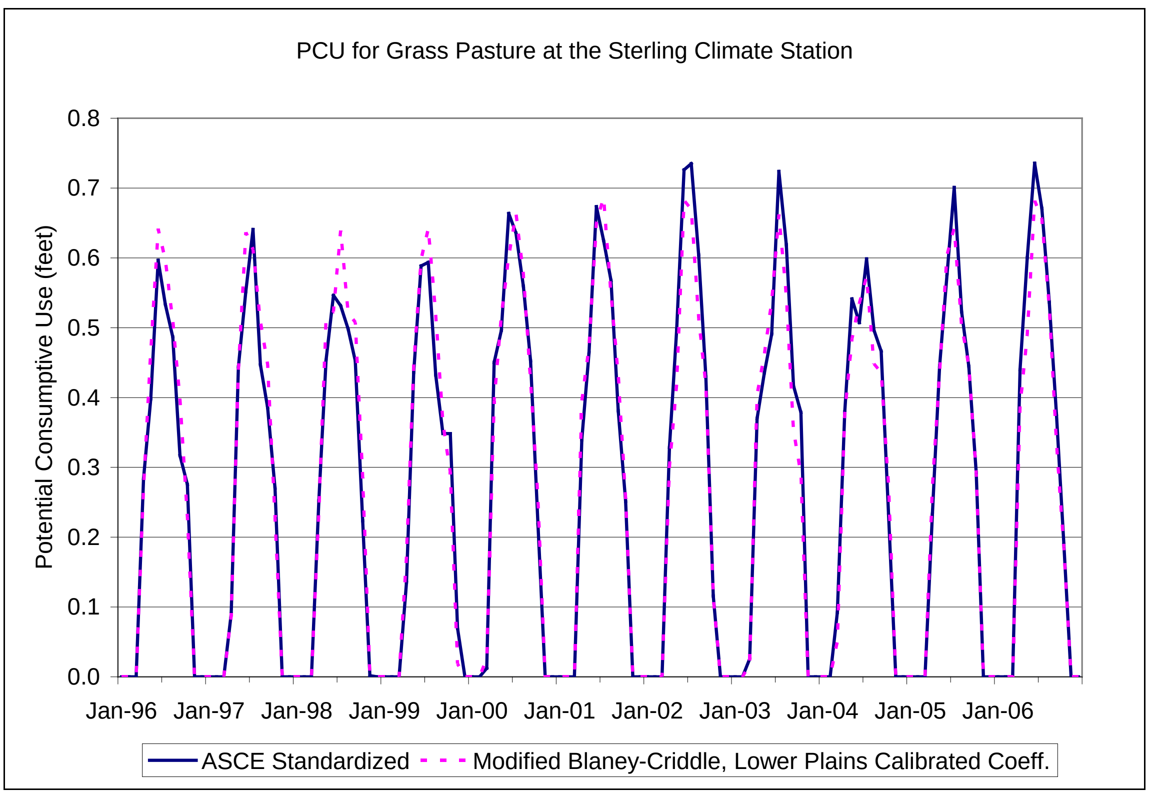


Figure 36 – PCU for Grass Pasture at Sterling

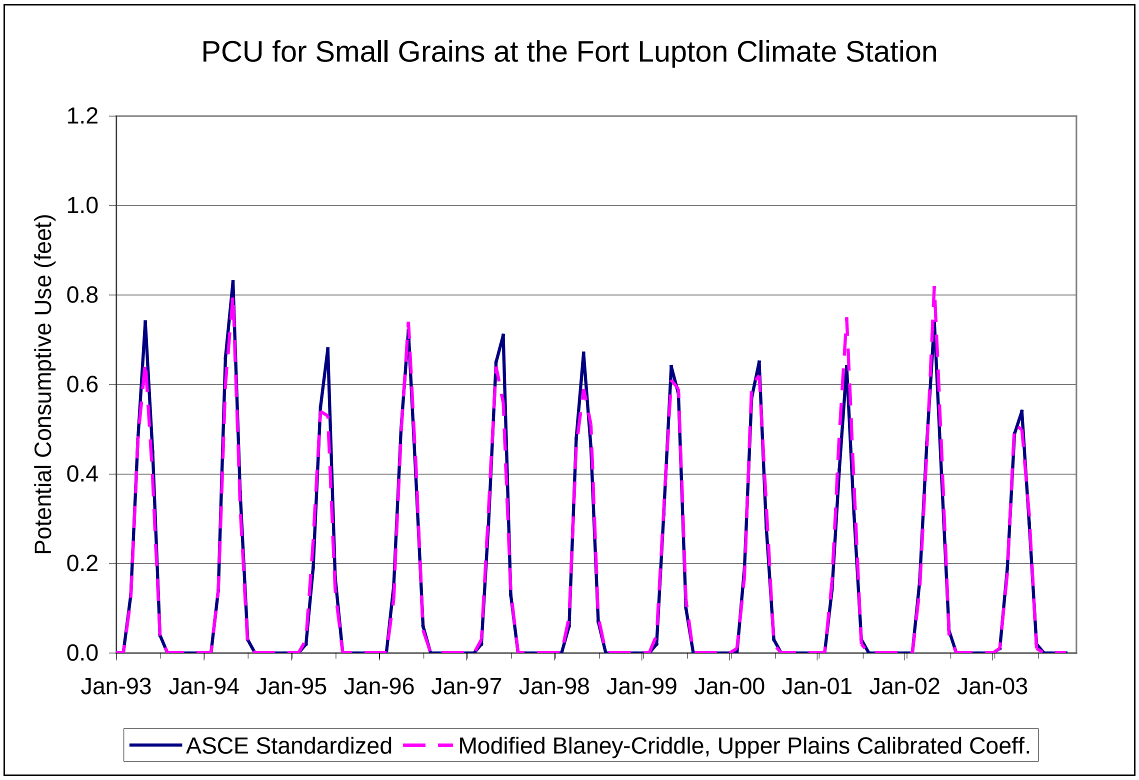


Figure 37 – PCU for Small Grains at Fort Lupton

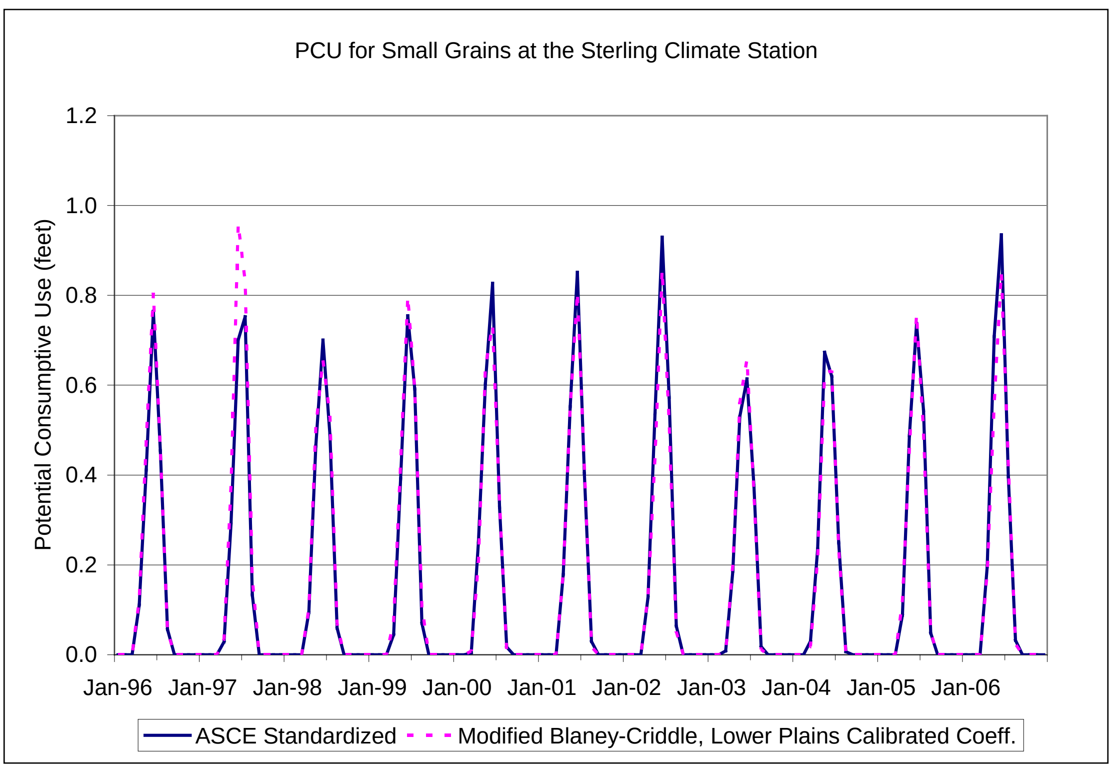


Figure 38 – PCU for Small Grains at Sterling

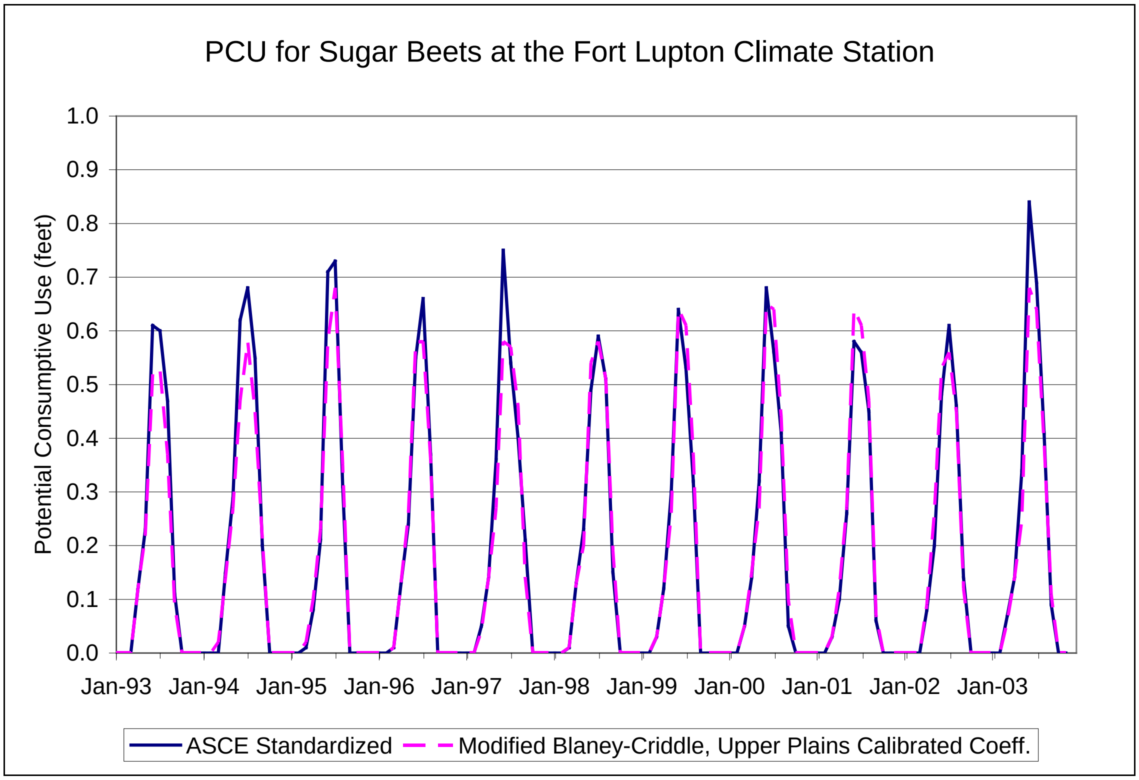


Figure 39 – PCU for Sugar Beets at Fort Lupton

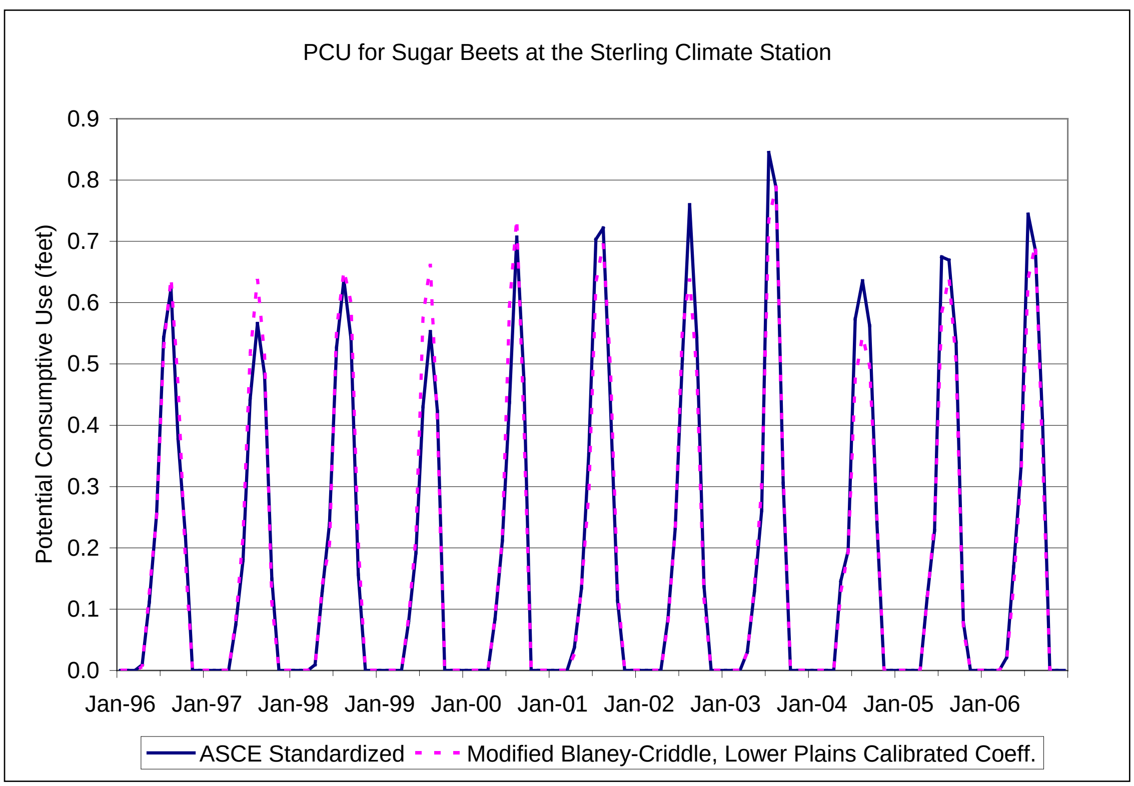


Figure 40 – PCU for Sugar Beets at Sterling

Appendix K
Task 59.2 – Irrigation Water Requirements at Climate Stations

To: Ray Bennett and Ray Alvarado

From: LRE – Erin Wilson, Beorn Courtney, and Kara Sobieski

Subject: Task 59.2 – Irrigation Water Requirements at Climate Stations

Date: March 24, 2005

Introduction

This memorandum presents the approach and results from the completion of the following Task 59 subtask:

- *Using calibrated crop coefficients, estimate the irrigation water requirement for common crops grown at the key climate stations identified in Task 53.*

The SPDSS Task 53.2 – Collect and Fill Missing Monthly Climate Data memo discusses the identification of and filling techniques for the key climate stations selected to represent climatic conditions throughout the South Platte, North Platte and Laramie River basins (SPDSS study area). **Figure 1** shows the locations of the 26 key climate stations. The SPDSS Task 59.1 – Develop Locally Calibrated Blaney-Criddle Coefficients memo describes the process of developing the three sets of calibrated coefficients that will be applied to the SPDSS study area:

- High Altitude Region – Water Districts 23, 47, 48, 80, and the upper portions of Water Districts 1, 3, 4, 5, 6, 7, 8, and 9
- Upper Plains Region – Water District 2, and the lower portions of Water Districts 1, 3, 4, 5, 6, 7, 8, and 9
- Lower Plains Region – Water District 64

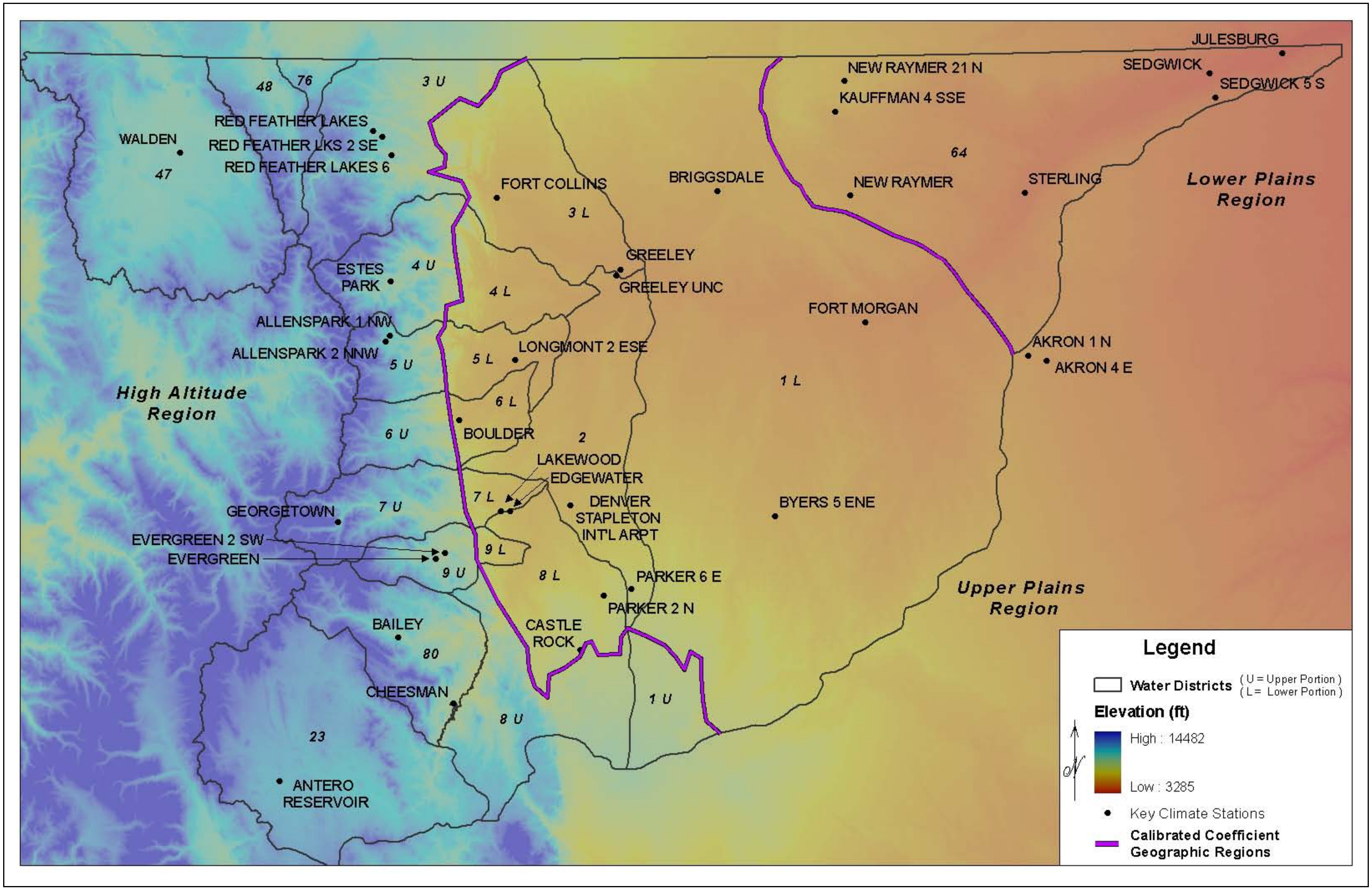


Figure 1: Key Climate Station Locations

Approach

The SPDSS irrigated acreage assessment for 2001 shows the crop types listed in **Table 1** as being prominent throughout the SPDSS study area, and grown specifically in the Water Districts shown.

Table 1
Irrigated Crop Types throughout the SPDSS Study Area

Crop Type	Water District													
	1	2	3	4	5	6	7	8	9	23	47	48	64	80
Alfalfa	X	X	X	X	X	X	X	X					X	
Corn Grain	X	X	X	X	X	X	X						X	
Dry Beans	X	X	X	X	X	X							X	
Grass Pasture	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Small Grains	X	X	X	X	X	X		X					X	
Sugar Beets	X	X	X	X	X	X							X	

In addition, there are also relatively minor amounts of orchard and vegetables grown throughout the SPDSS study area. Based on our research, crop coefficients for the ASCE Standardized method are not available for orchard or vegetables. Therefore calibrated coefficients were not developed for these crop types and unadjusted TR-21 modified Blaney-Criddle crop coefficients will be used to represent these crops in the historical consumptive use analyses.

Crop irrigation water requirement (IWR), the potential consumptive use less effective precipitation, was determined using the calibrated crop coefficients at the locations of the key climate stations for the crop types identified in Table 1. The original Blaney-Criddle method was used with the calibrated crop coefficients for the High Altitude Region and the modified Blaney-Criddle method was used with the calibrated coefficients for the Upper Plains and Lower Plains Regions to estimate potential consumptive use. Effective precipitation was estimated using the SCS effective rainfall method outlined in TR-21. The following StateCU input files were used for the climate station scenario:

- Filled climate data sets generated in Task 53.2
- Calibrated crop characteristic file generated in Task 59.1
- Calibrated crop coefficient file generated in Task 59.1
- Crop pattern files with 1 acre of each crop type

Results

The average annual irrigation water requirement estimated by crop type at associated key climate stations is shown in **Table 2** for the period 1950 through 2003.

Table 2
Average Annual Irrigation Water Requirement in Feet
1950 through 2003

Climate Station	Station ID	Water District	Alfalfa	Corn Grain	Dry Beans	Grass Pasture	Small Grains	Sugar Beets
High Altitude Region								
Allenspark 1 NW (combined)	185	5	-	-	-	1.69	-	-
Antero Reservoir	263	23	-	-	-	1.74	-	-
Bailey	454	80	-	-	-	1.86	-	-
Cheesman	1528	80	-	-	-	2.07	-	-
Estes Park (combined)	2761	4	-	-	-	1.99	-	-
Evergreen (combined)	2790	9	-	-	-	1.92	-	-
Georgetown	3261	7	-	-	-	1.94	-	-
Red Feather Lakes (combined)	6921	3	-	-	-	1.80	-	-
Walden	8756	47	-	-	-	1.88	-	-
High Altitude Region Average			-	-	-	1.88	-	-
High Altitude Region Maximum % Difference			-	-	-	10%	-	-
Upper Plains Region								
Boulder	848	6	2.07	1.35	0.97	2.23	1.07	1.55
Briggsdale	945	1	1.87	1.23	0.88	2.04	1.18	1.35
Byers 5 ENE	1179	1	1.94	1.30	0.94	2.13	1.19	1.44
Castle Rock	1401	8	1.60	-	-	1.76	1.05	-
Denver WSFO AP (Stapleton)	2220	2	2.12	1.38	1.00	2.26	1.20	1.60
Fort Collins	3005	3	1.93	1.29	0.93	2.07	1.15	1.49
Fort Morgan	3038	1	2.23	1.45	1.06	2.36	1.28	1.69
Greeley UNC (combined)	3553	3	2.18	1.45	1.07	2.34	1.24	1.66
Lakewood (combined)	4762	8	1.95	-	-	2.12	1.17	-
Longmont 2 ESE	5116	5	2.05	1.38	1.02	2.19	1.26	1.56
Parker 2 N (combined)	6323	8	1.75	-	-	1.95	1.11	-
Upper Plains Region Average			1.97	1.35	0.98	2.13	1.17	1.54
Upper Plains Region Maximum % Difference			19%	9%	11%	17%	10%	12%
Lower Plains Region								
Akron 4 E (combined)	109	65 [1]	2.06	1.36	0.95	2.27	1.26	1.56
Julesburg	4413	64	2.35	1.51	1.05	2.60	1.29	1.76
New Raymer	5922	64	1.97	1.29	0.90	2.19	1.23	1.46
New Raymer 21 N (combined)	5934	64	1.76	1.18	0.84	1.99	1.20	1.32
Sedgwick 5 S (combined)	7515	64	2.28	1.48	1.02	2.51	1.24	1.73
Sterling	7950	64	2.25	1.45	1.03	2.46	1.30	1.69
Lower Plains Region Average			2.11	1.38	0.97	2.34	1.25	1.59
Lower Plains Region Maximum % Difference			17%	14%	13%	15%	4%	17%

Note: [1] Akron 4 E (combined) is located in Water District 65, and will use the Lower Plains Calibrated Coefficients.

Figures 2 through **7** at the end of this memo show the average annual IWR over the 1950 through 2003 period for each crop type. The maximum percent difference for a given crop type across climate stations within the same regions ranges from 4% to 19%. The largest percent difference was found with alfalfa in the Upper Plains Region where a 19% difference equates to approximately .37 feet on an average annual basis. As shown, IWR is generally highest in the Lower Plains Region for all crop types and lowest in the High Altitude Region for grass pasture.

Figures 8 through **32** at the end of this memo show the total annual IWR for the crops at each climate station from 1950 through 2003. As shown, IWR varies from year to year based on temperature, which determines both length of growing season and potential consumptive use during the growing season. IWR also varies from year to year based on precipitation, as less irrigation water is required when more of the potential demand is met from rainfall.

Comments and Concerns

None.

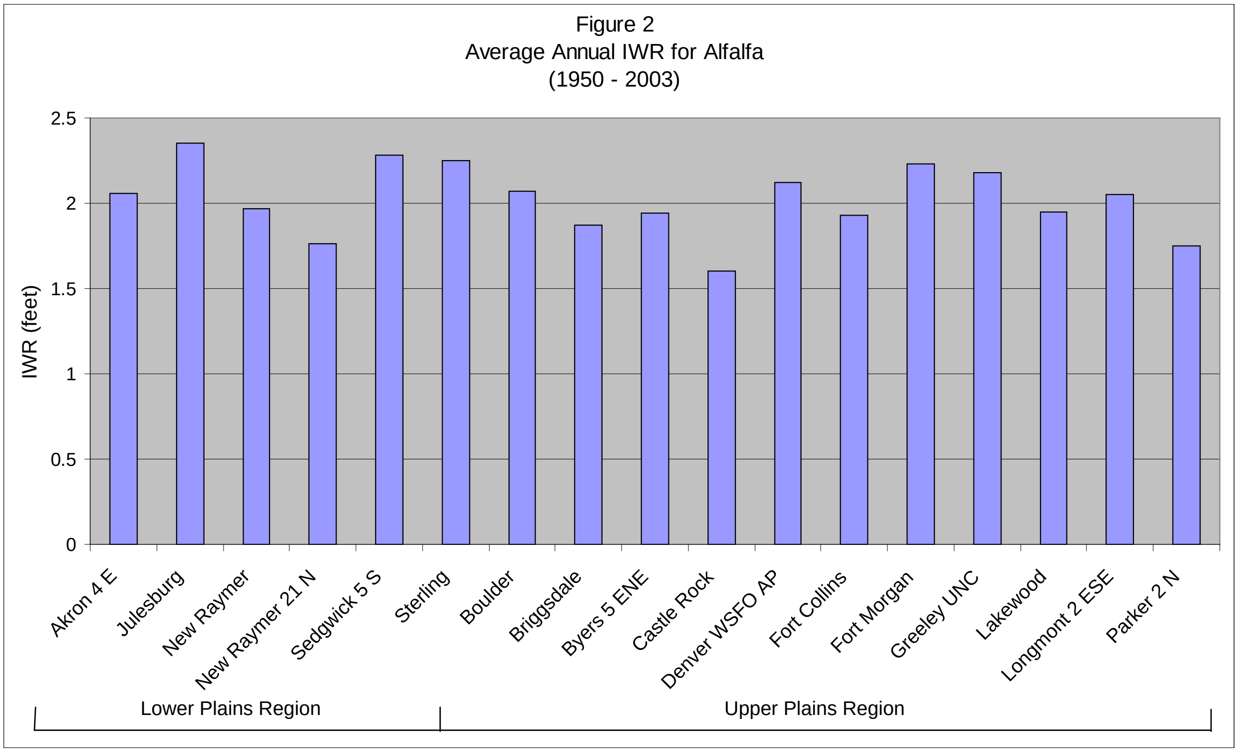


Figure 2
Average Annual IWR for Alfalfa
(1950 - 2003)
IWR (feet)
2.5
2
1.5
1
0.5
0
Akron 4 E
Julesburg
New Raymer
New Raymer 21 N
Sedgwick 5 S
Sterling
Boulder
Briggsdale
Byers 5 ENE
Castle Rock
Denver WSFO AP
Fort Collins
Fort Morgan
Greeley UNC
Lakewood
Longmont 2 ESE
Parker 2 N
Lower Plains Region
Upper Plains Region

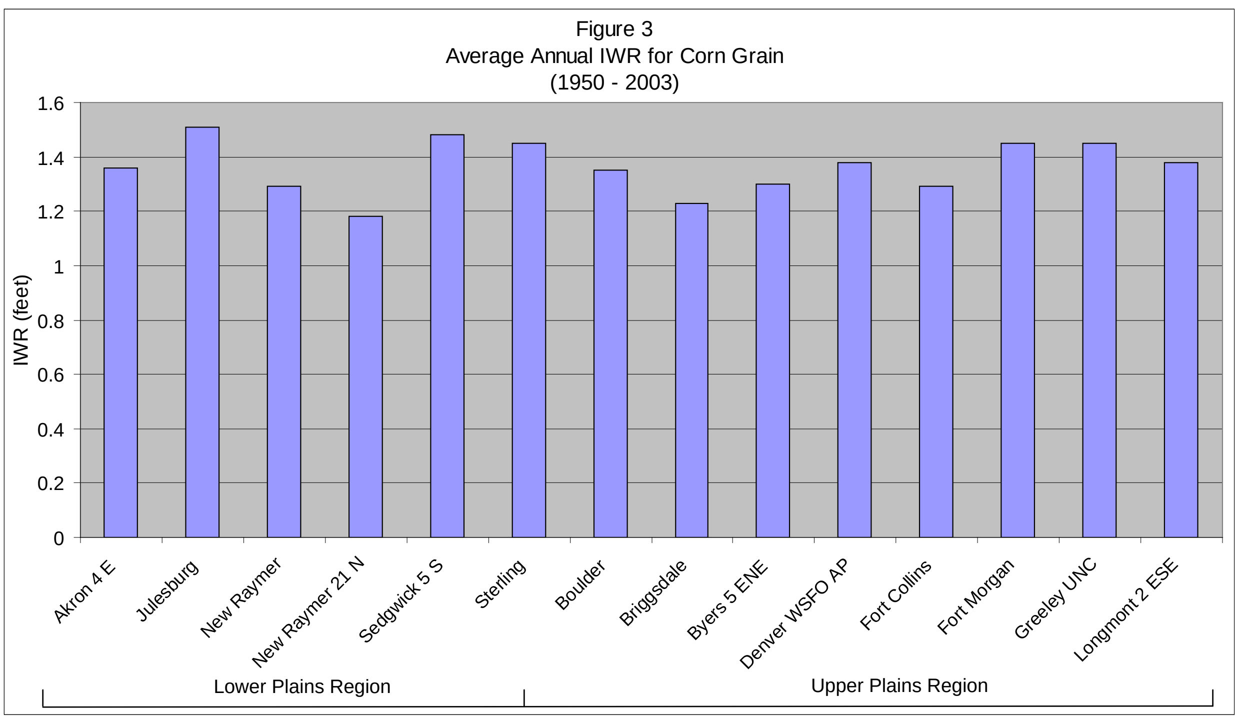


Figure 3
Average Annual IWR for Corn Grain
(1950 - 2003)
IWR (feet)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Akron 4 E
Julesburg
New Raymer
New Raymer 21 N
Sedgwick 5 S
Sterling
Boulder
Briggsdale
Byers 5 ENE
Denver WSFO AP
Fort Collins
Fort Morgan
Greeley UNC
Longmont 2 ESE
Lower Plains Region
Upper Plains Region

Figure 4
Average Annual IWR for Dry Beans
(1950 - 2003)

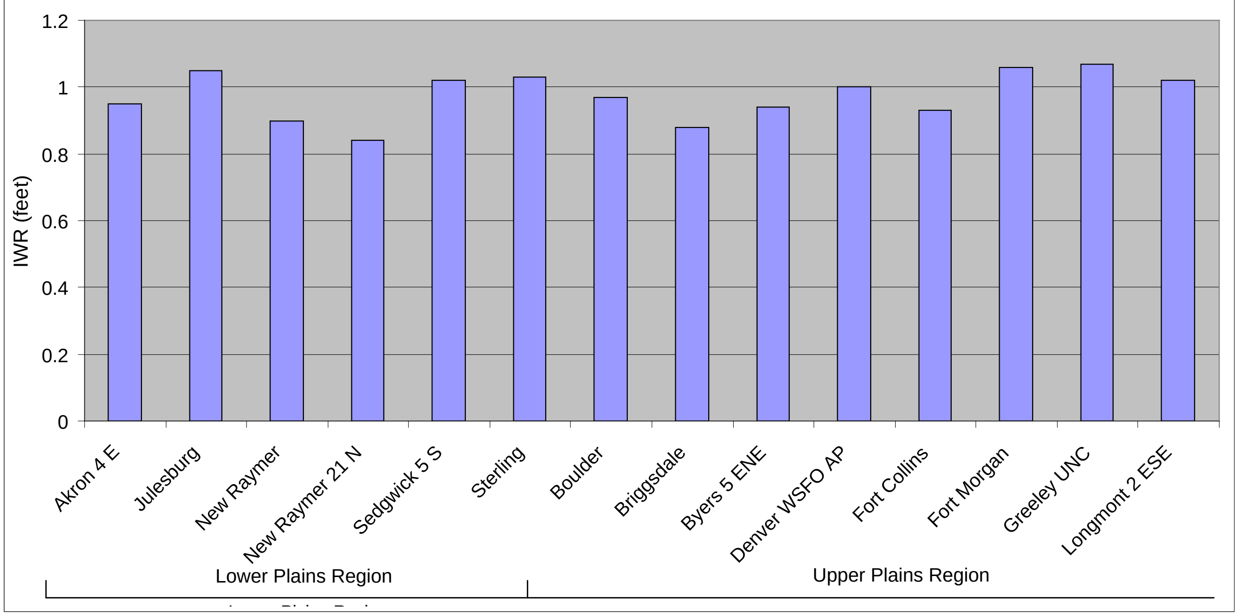
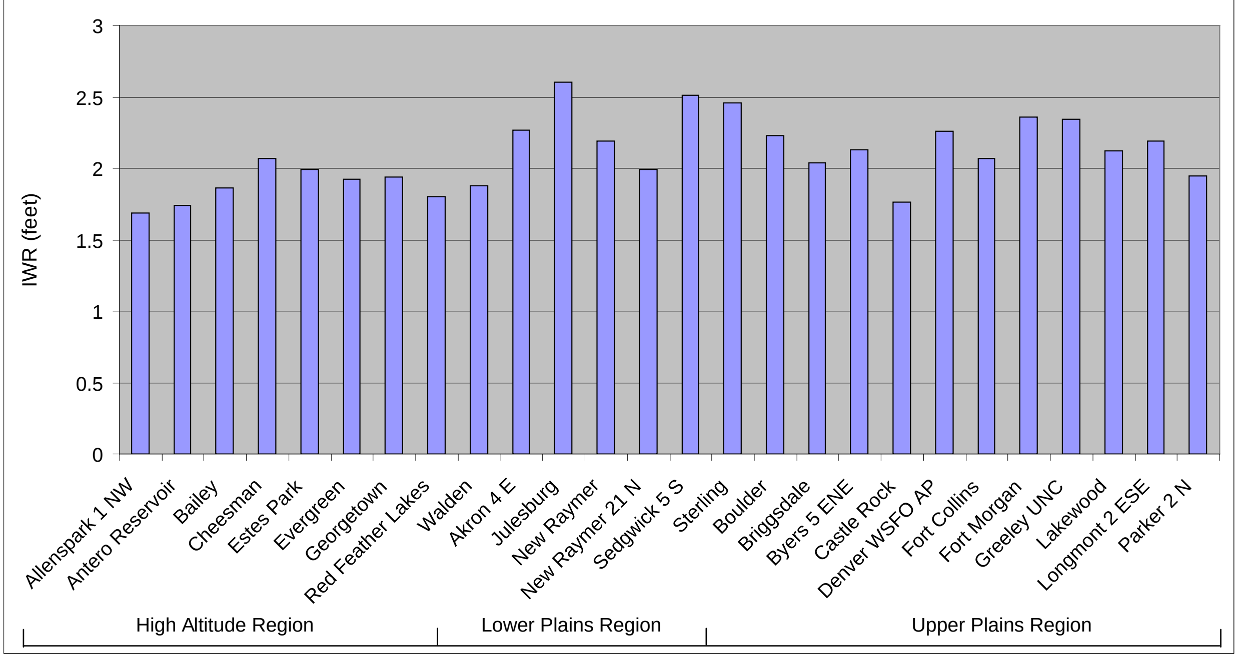


Figure 5
Average Annual IWR for Grass Pasture
(1950 - 2003)



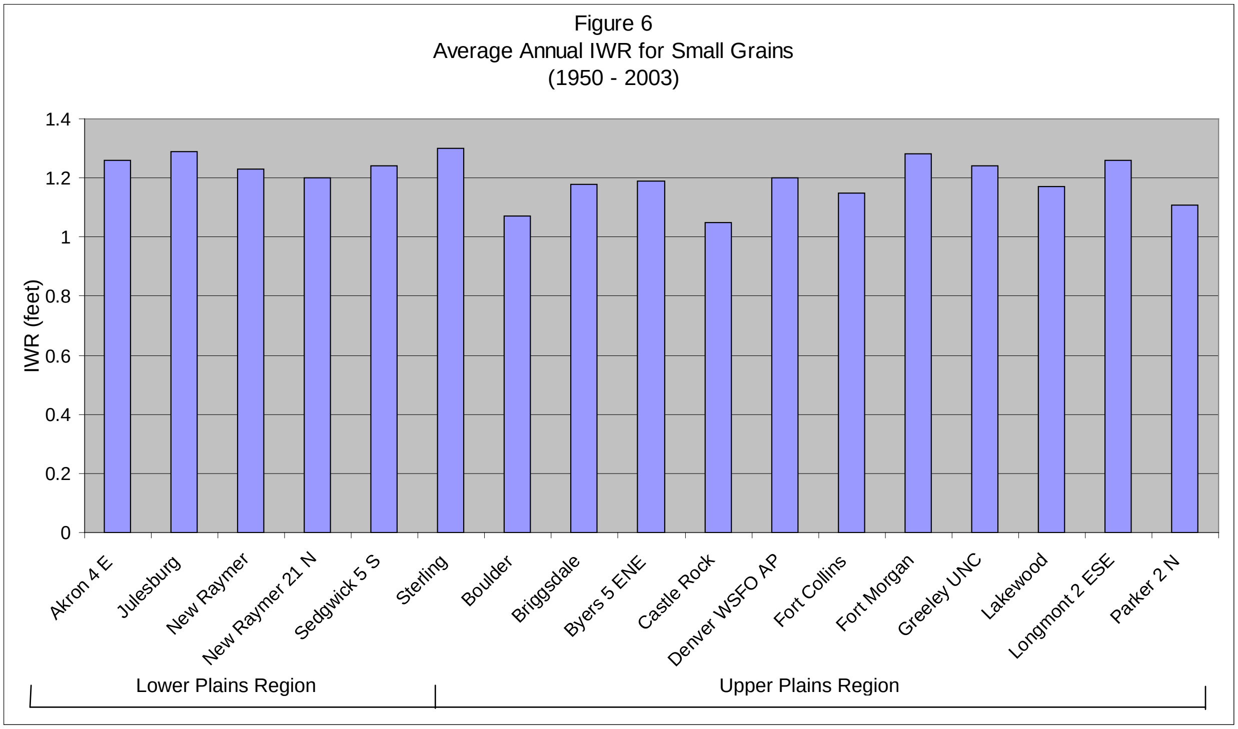


Figure 6
Average Annual IWR for Small Grains
(1950 - 2003)
IWR (feet)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Akron 4 E
Julesburg
New Raymer
New Raymer 21 N
Sedgwick 5 S
Sterling
Boulder
Briggsdale
Byers 5 ENE
Castle Rock
Denver WSFO AP
Fort Collins
Fort Morgan
Greeley UNC
Lakewood
Longmont 2 ESE
Parker 2 N
Lower Plains Region
Upper Plains Region

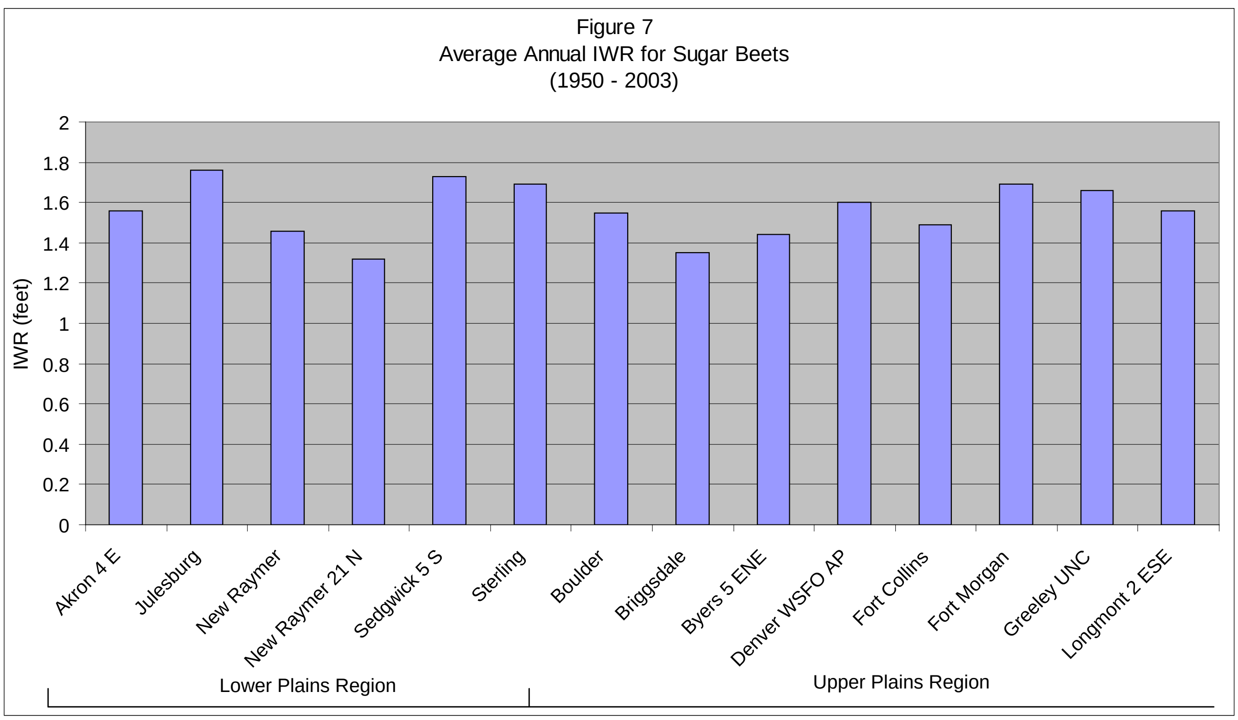


Figure 7
Average Annual IWR for Sugar Beets
(1950 - 2003)
IWR (feet)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Akron 4 E
Julesburg
New Raymer
New Raymer 21 N
Sedgwick 5 S
Sterling
Boulder
Briggsdale
Byers 5 ENE
Denver WSFO AP
Fort Collins
Fort Morgan
Greeley UNC
Longmont 2 ESE
Lower Plains Region
Upper Plains Region

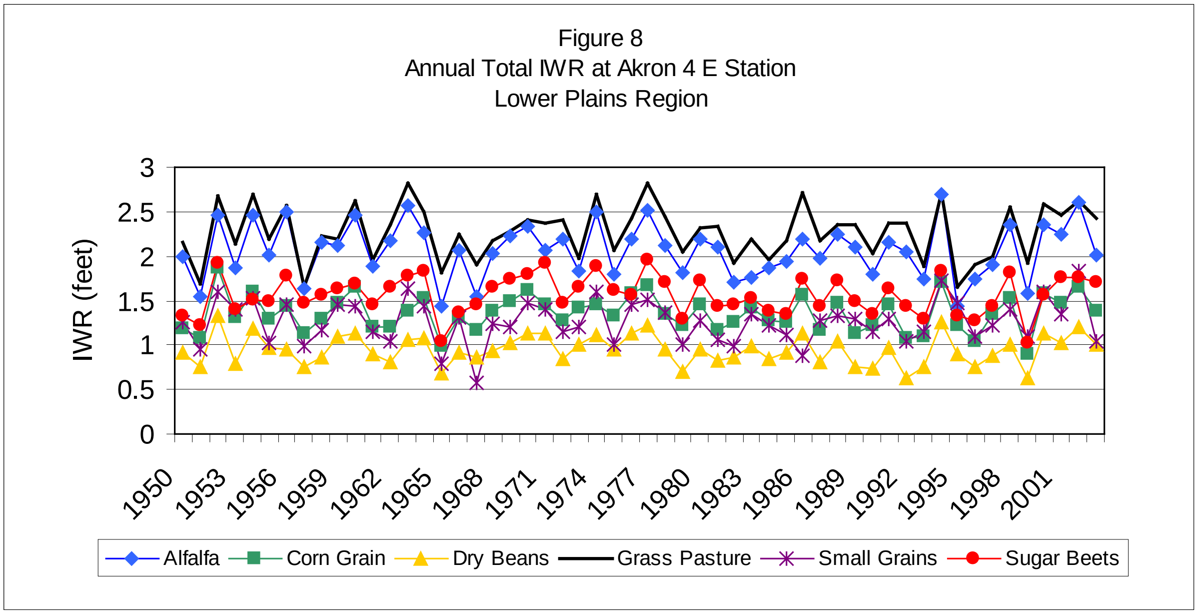


Figure 8
Annual Total IWR at Akron 4 E Station
Lower Plains Region
IWR (feet)
3
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

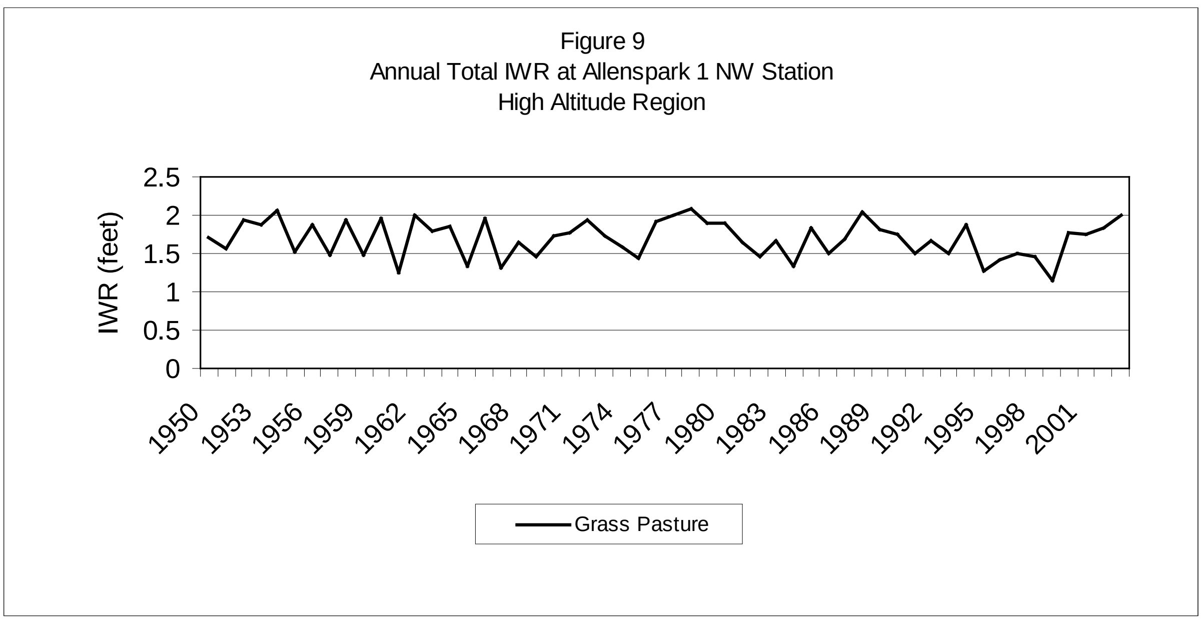


Figure 9
Annual Total IWR at Allenspark 1 NW Station
High Altitude Region
IWR (feet)
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Grass Pasture

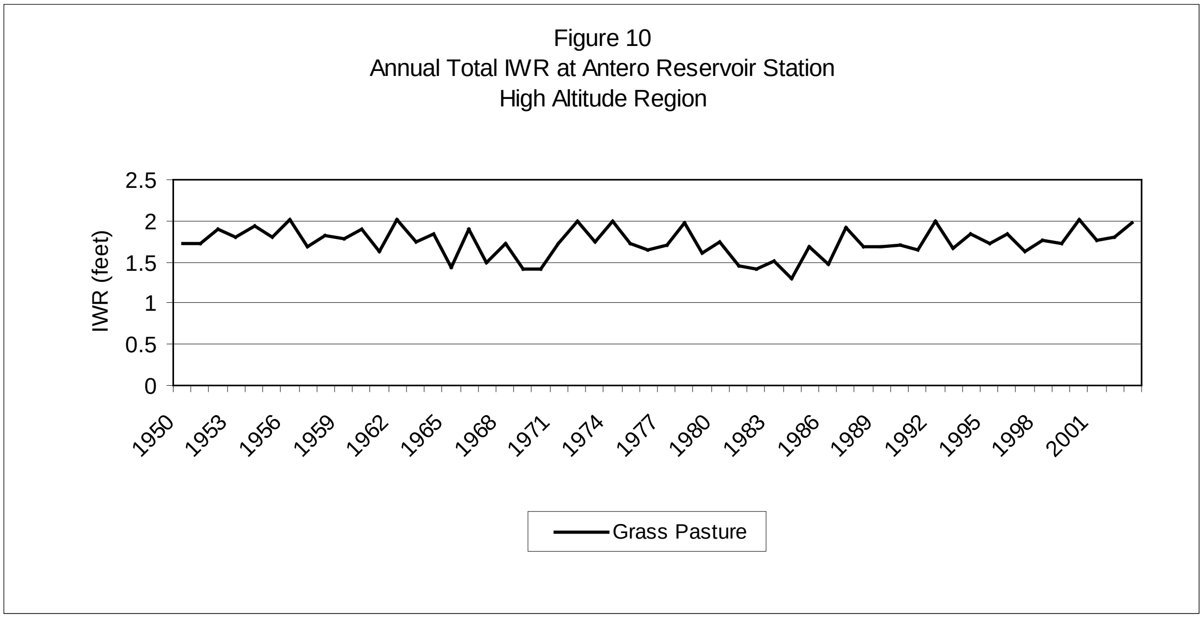


Figure 10
Annual Total IWR at Antero Reservoir Station
High Altitude Region
IWR (feet)
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Grass Pasture

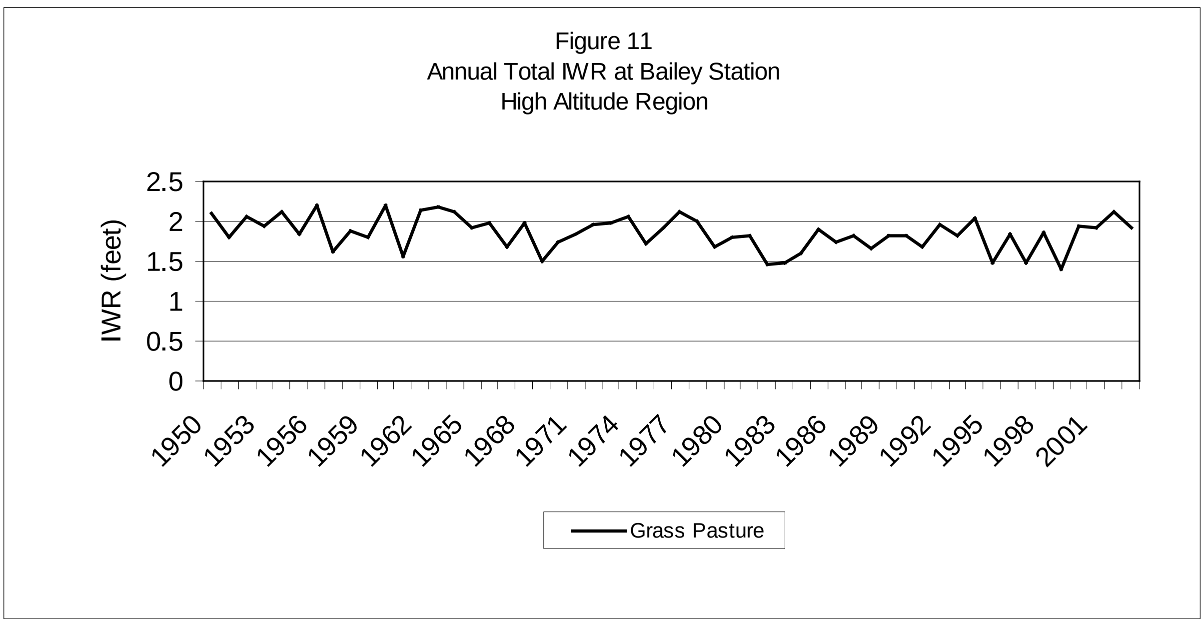


Figure 11
Annual Total IWR at Bailey Station
High Altitude Region
IWR (feet)
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Grass Pasture

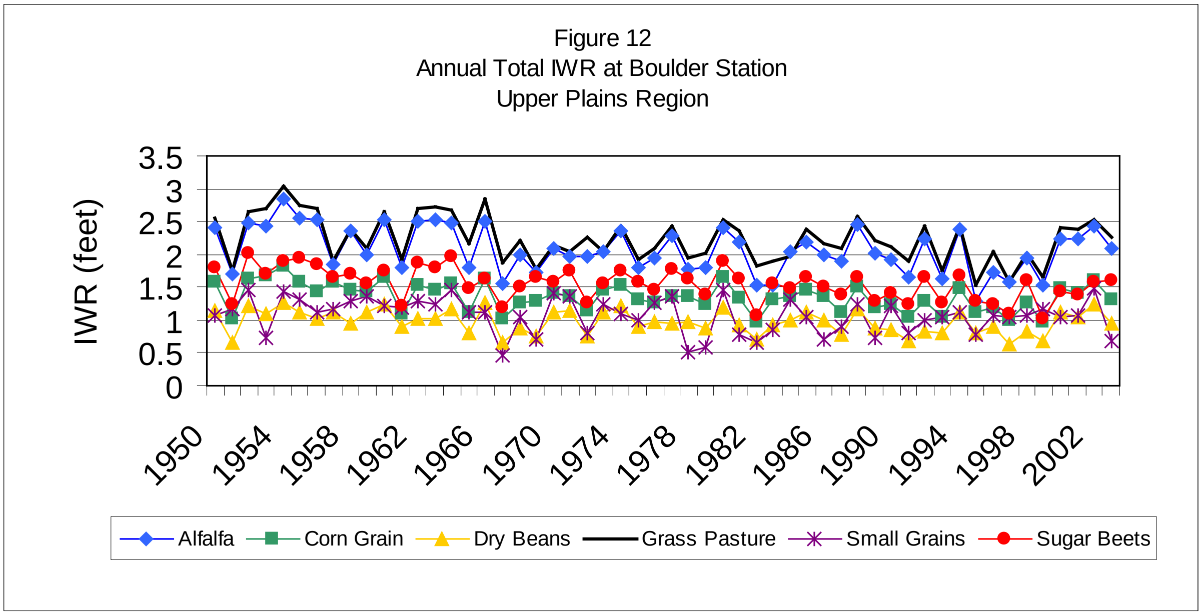


Figure 12
Annual Total IWR at Boulder Station
Upper Plains Region
IWR (feet)
3.5
3
2.5
2
1.5
1
0.5
0
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

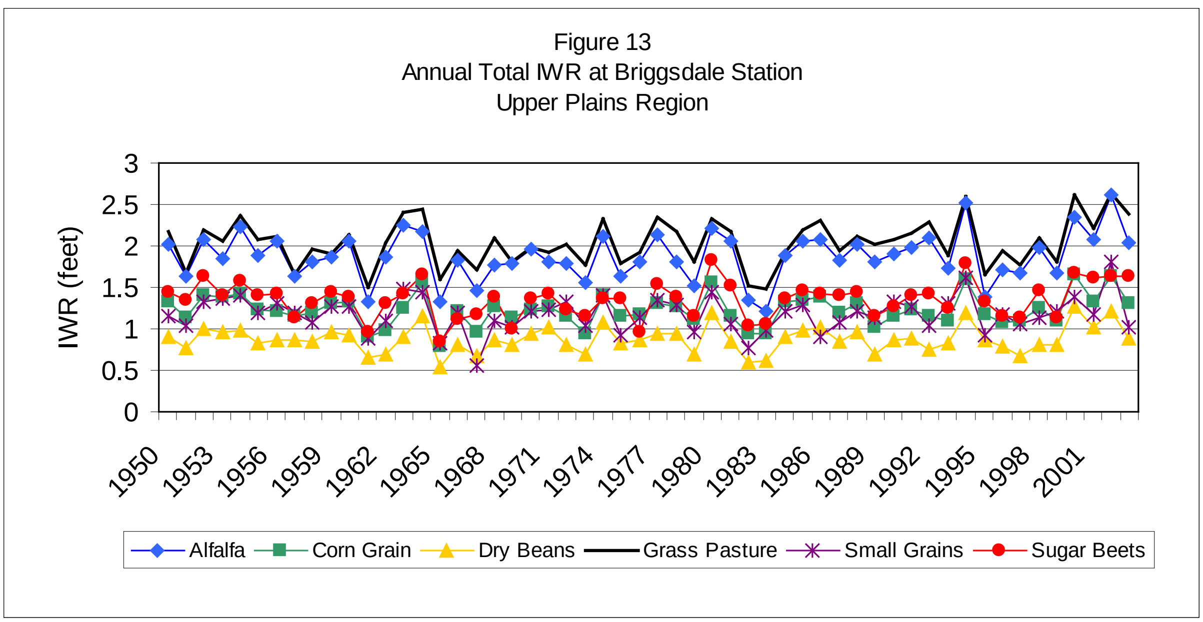


Figure 13
Annual Total IWR at Briggsdale Station
Upper Plains Region
IWR (feet)
3
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

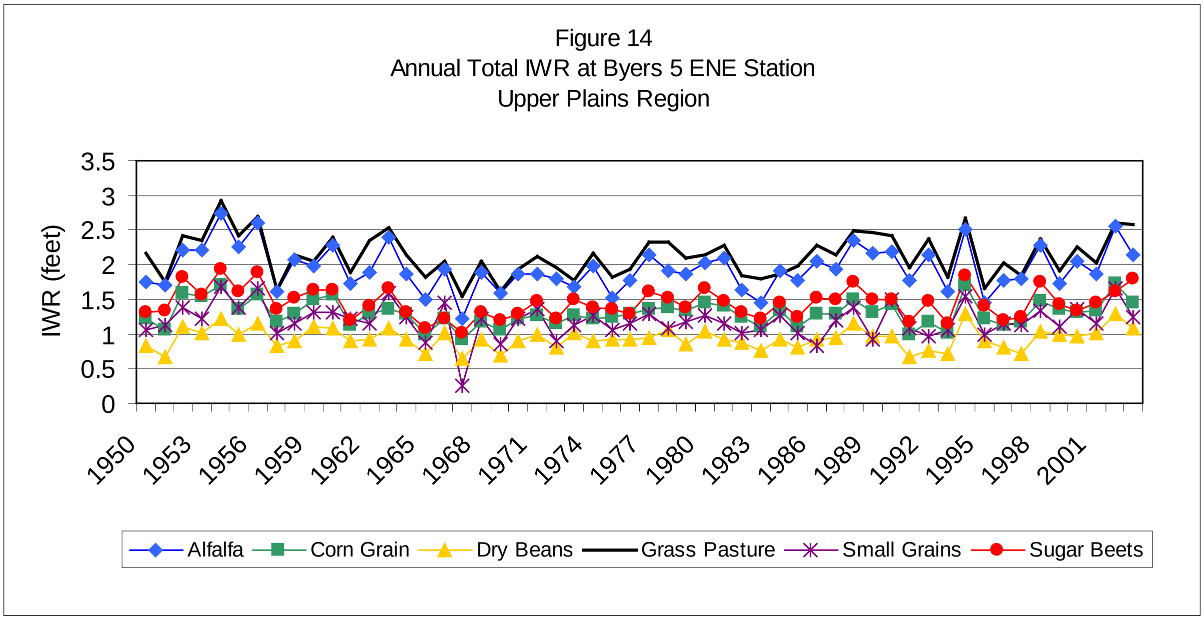


Figure 14
Annual Total IWR at Byers 5 ENE Station
Upper Plains Region
IWR (feet)
3.5
3
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

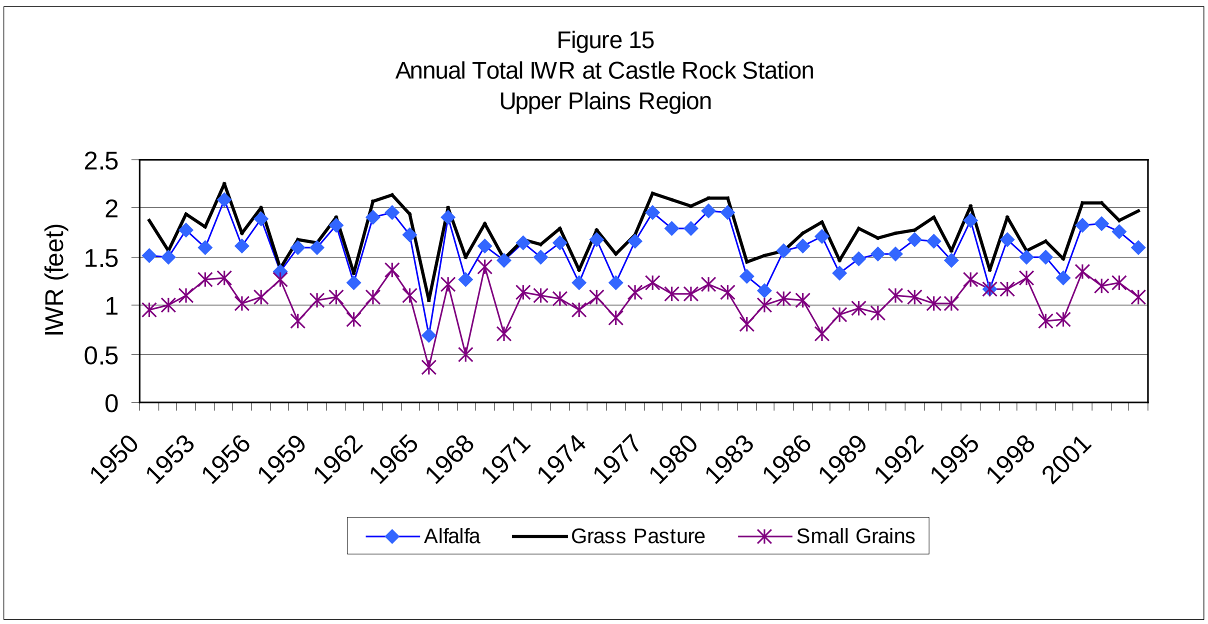


Figure 15
Annual Total IWR at Castle Rock Station
Upper Plains Region
IWR (feet)
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Grass Pasture
Small Grains

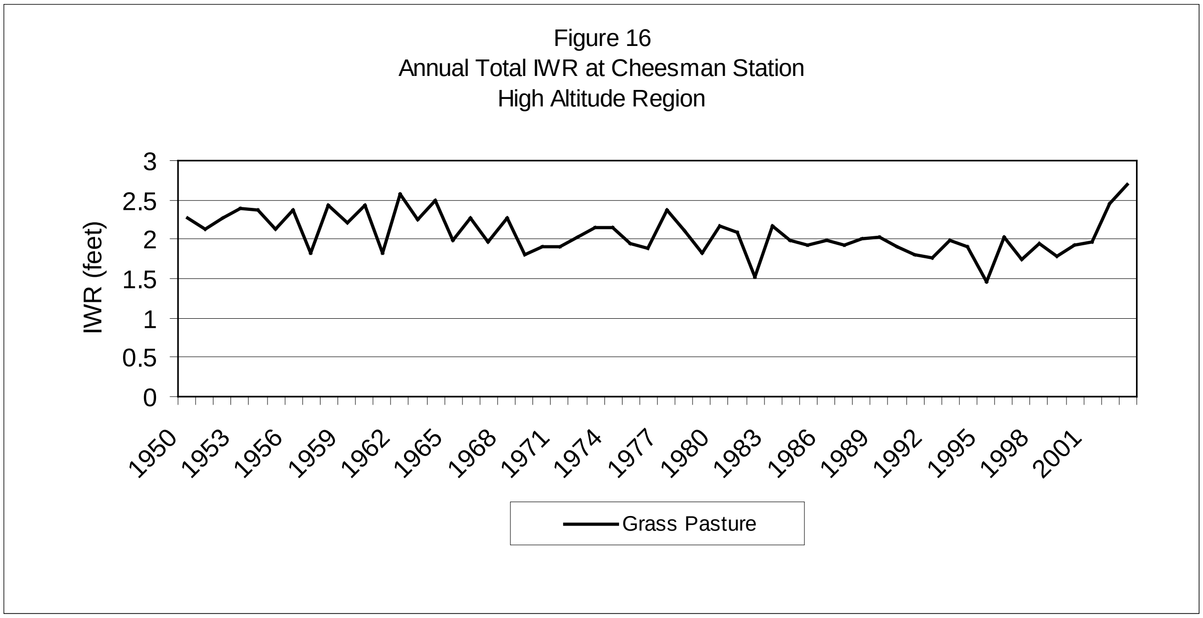


Figure 16
Annual Total IWR at Cheesman Station
High Altitude Region
IWR (feet)
Grass Pasture

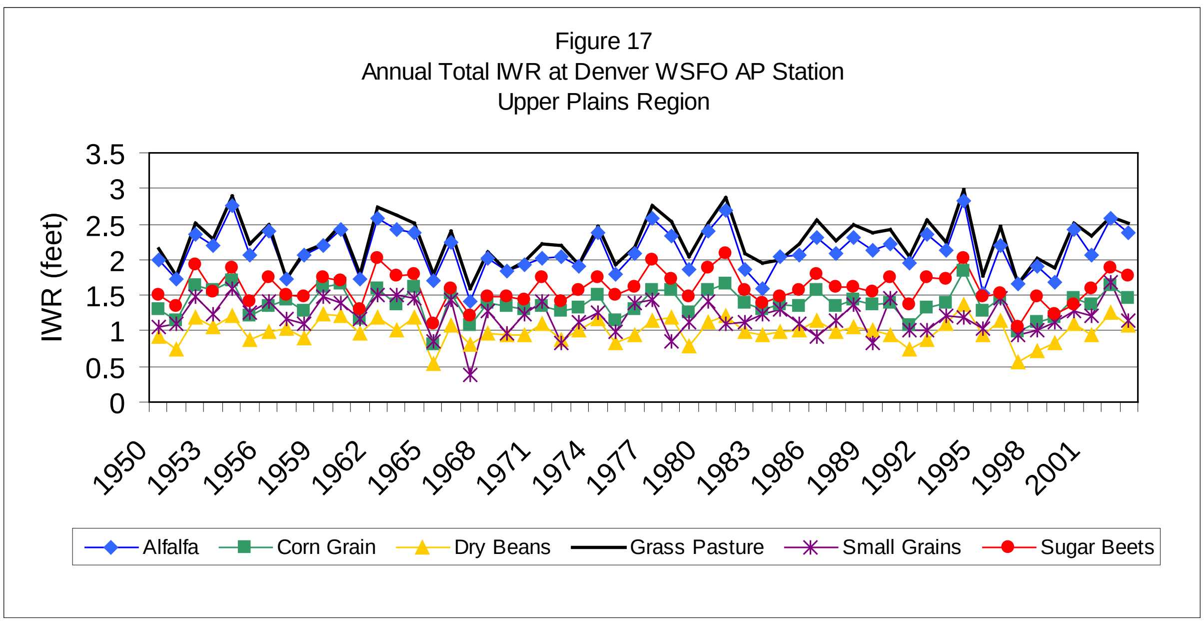


Figure 17
Annual Total IWR at Denver WSFO AP Station
Upper Plains Region
IWR (feet)
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

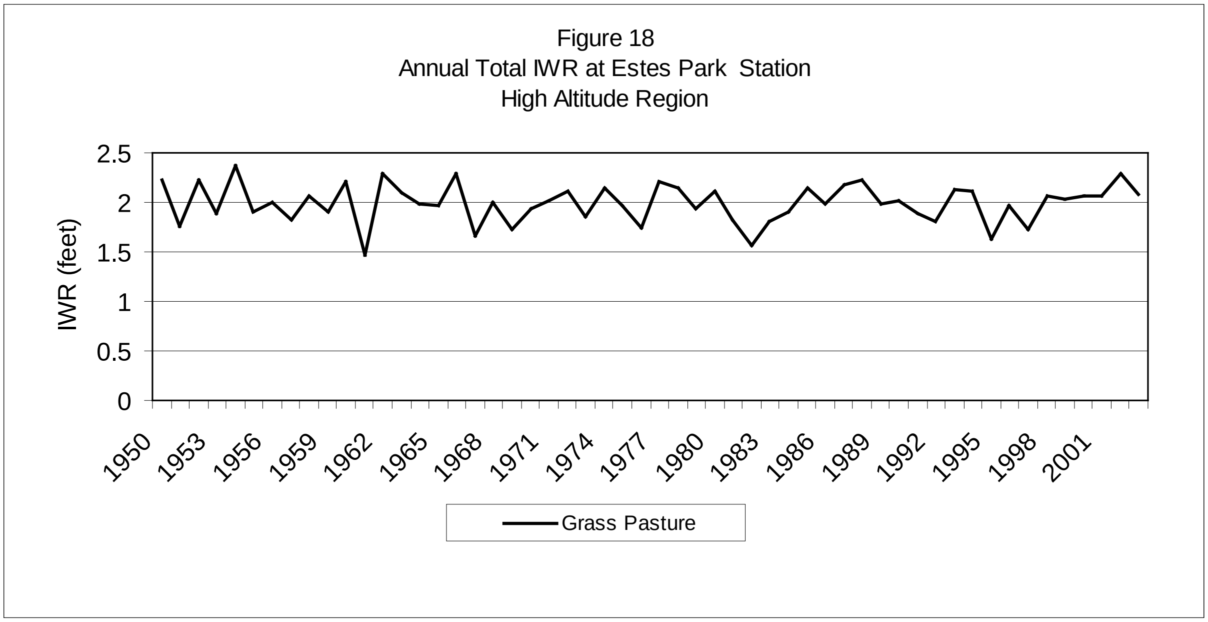


Figure 18
Annual Total IWR at Estes Park Station
High Altitude Region
IWR (feet)
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Grass Pasture

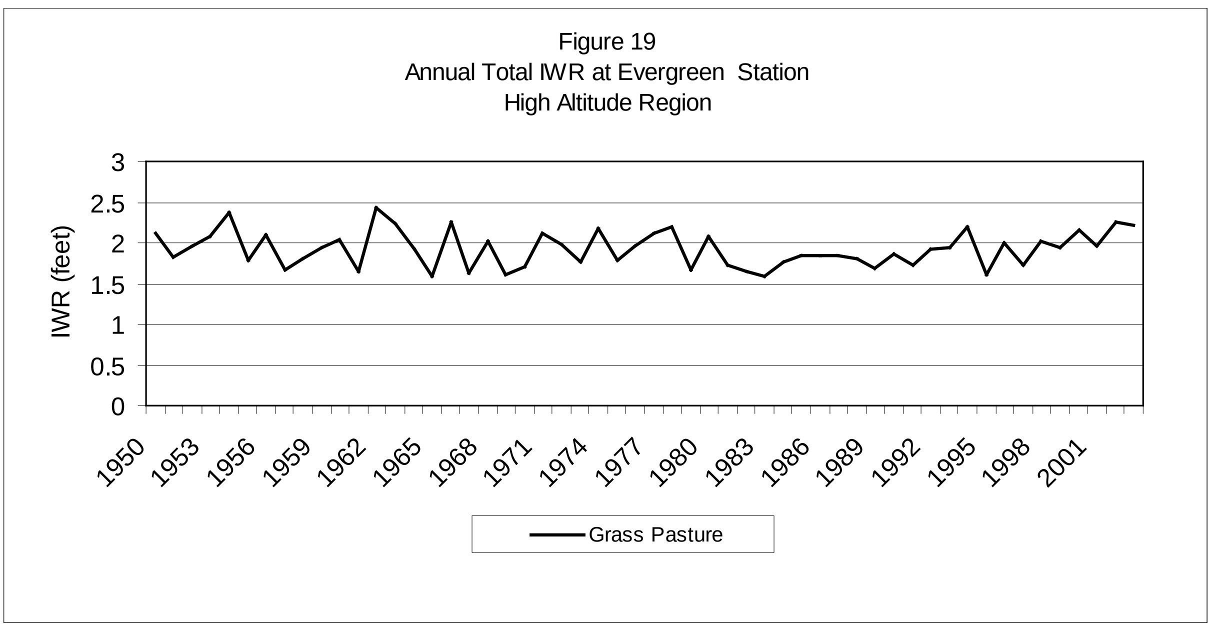


Figure 19
Annual Total IWR at Evergreen Station
High Altitude Region
IWR (feet)
3
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Grass Pasture

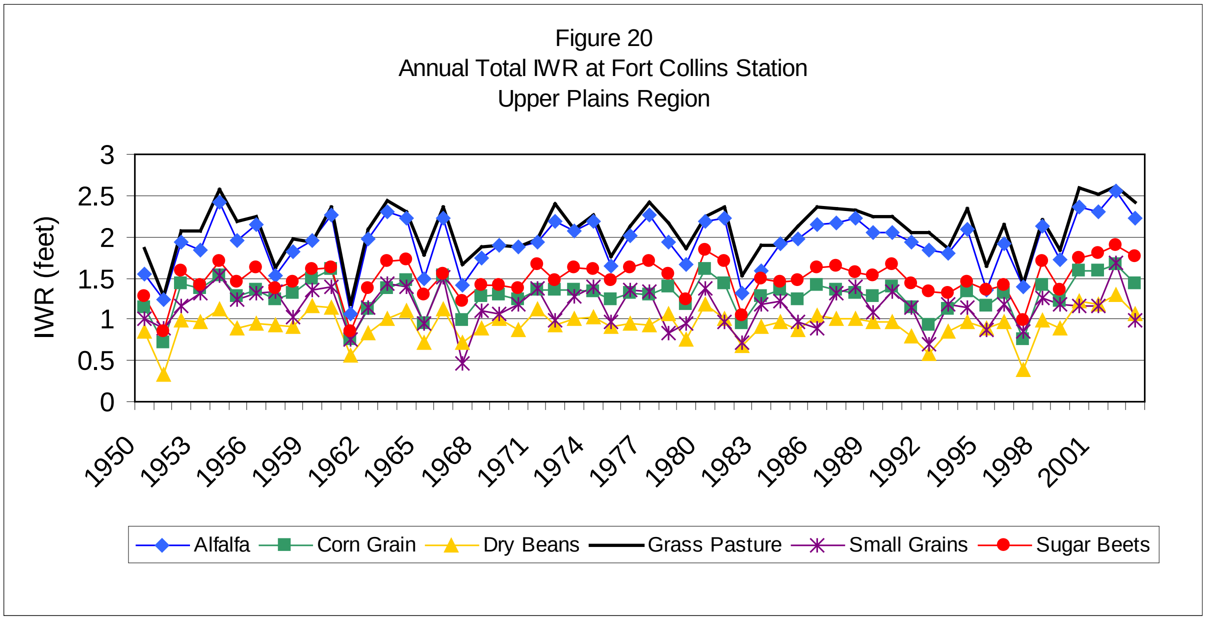


Figure 20
Annual Total IWR at Fort Collins Station
Upper Plains Region
IWR (feet)
0
0.5
1
1.5
2
2.5
3
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

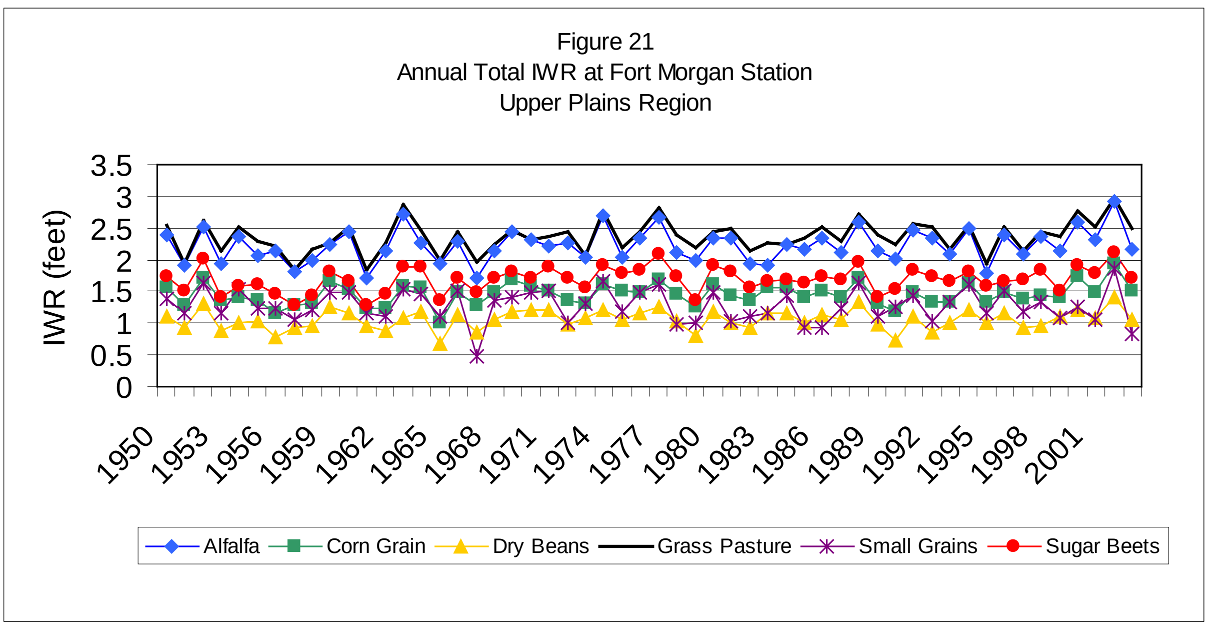


Figure 21
Annual Total IWR at Fort Morgan Station
Upper Plains Region
IWR (feet)
0
0.5
1
1.5
2
2.5
3
3.5
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

Figure 22
Annual Total IWR at Georgetown Station
High Altitude Region

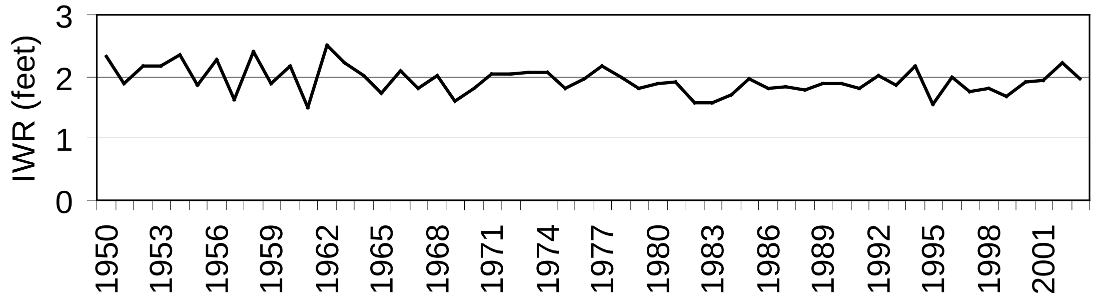
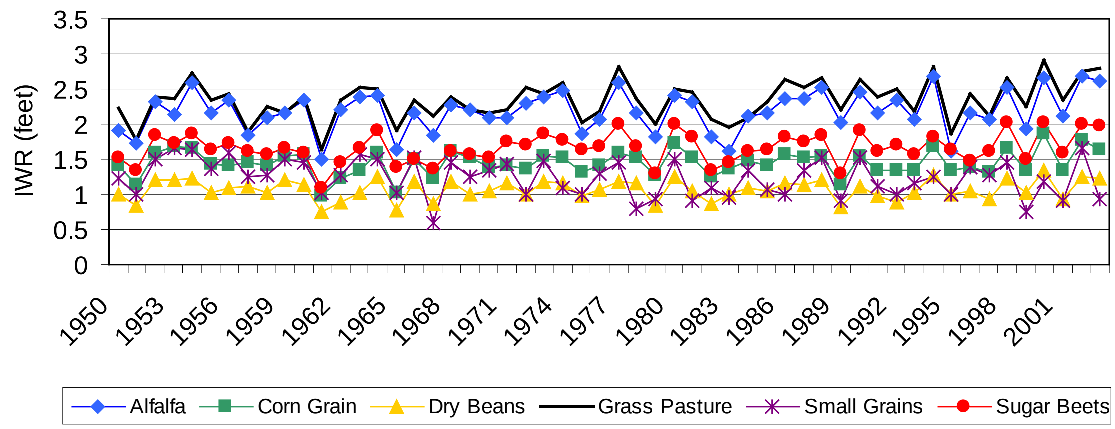


Figure 23
Annual Total IWR at Greeley UNC Station
Upper Plains Region



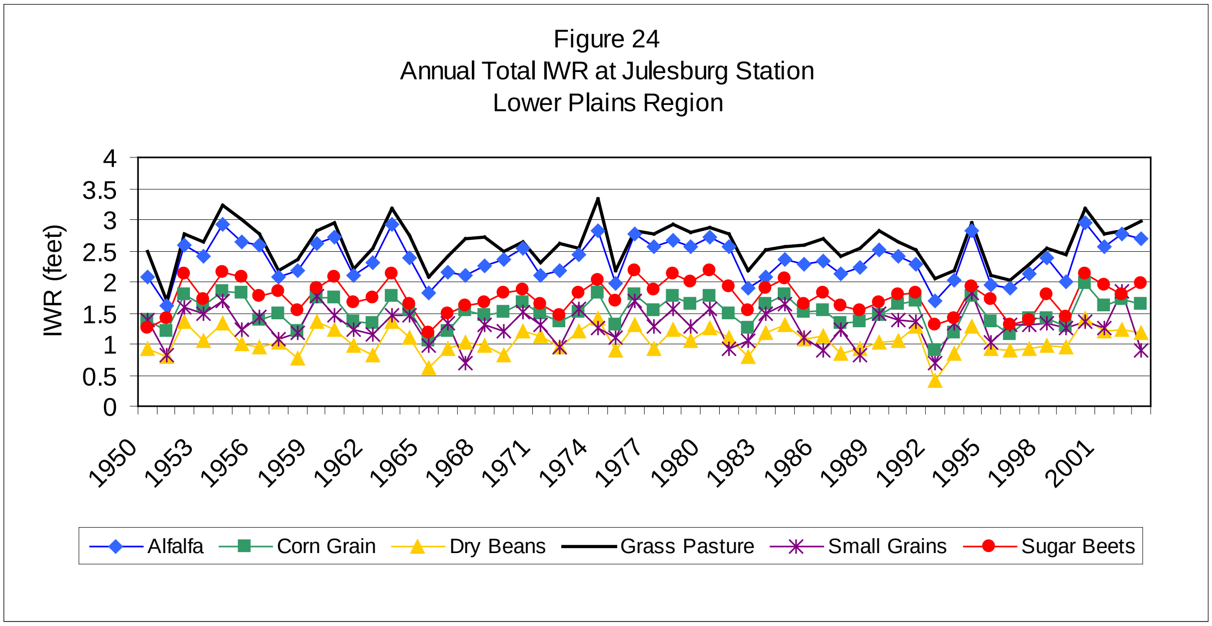


Figure 24
Annual Total IWR at Julesburg Station
Lower Plains Region
IWR (feet)
0
0.5
1
1.5
2
2.5
3
3.5
4
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

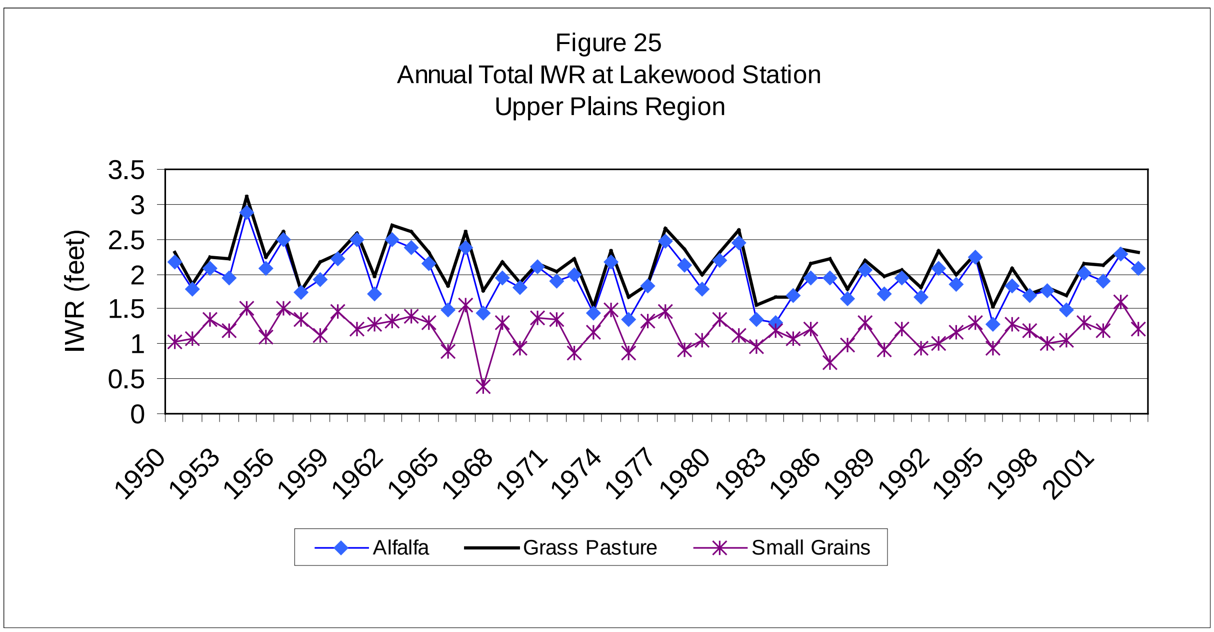


Figure 25
Annual Total IWR at Lakewood Station
Upper Plains Region
IWR (feet)
0
0.5
1
1.5
2
2.5
3
3.5
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Grass Pasture
Small Grains

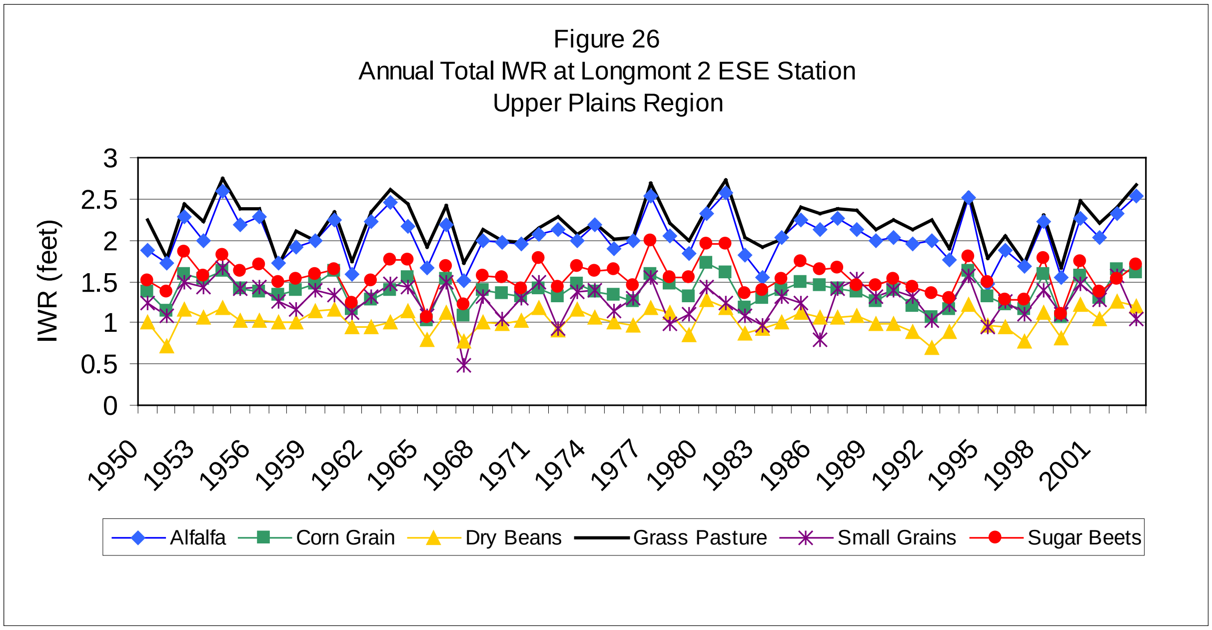


Figure 26
Annual Total IWR at Longmont 2 ESE Station
Upper Plains Region
IWR (feet)
0
0.5
1
1.5
2
2.5
3
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

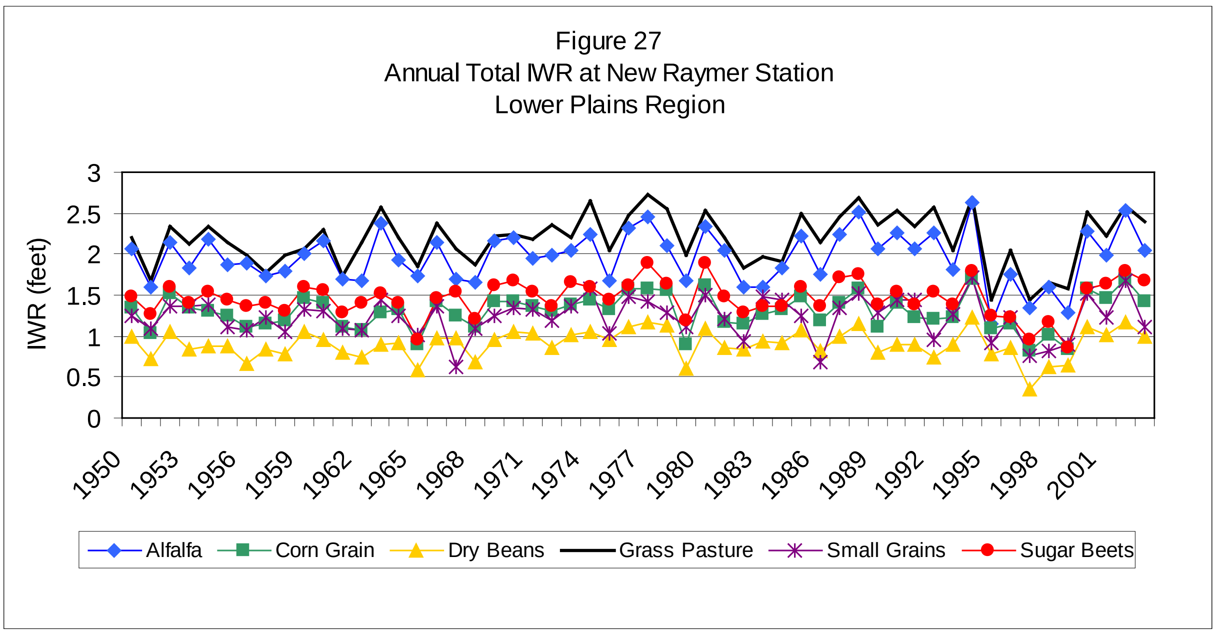


Figure 27
Annual Total IWR at New Raymer Station
Lower Plains Region
IWR (feet)
0
0.5
1
1.5
2
2.5
3
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

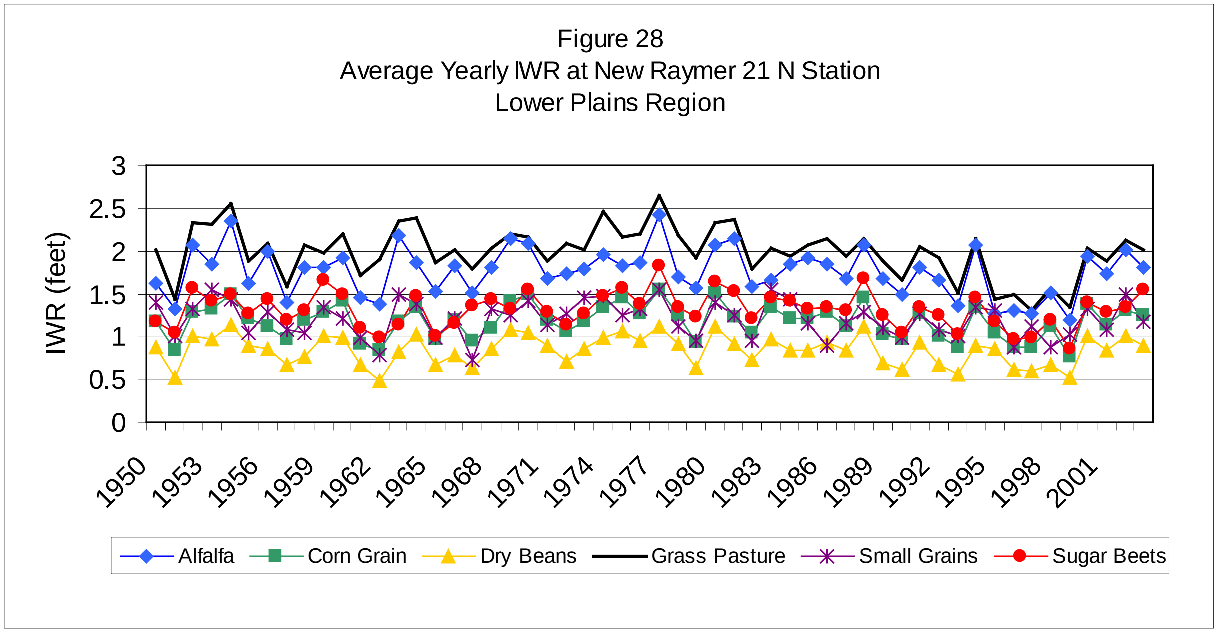


Figure 28
Average Yearly IWR at New Raymer 21 N Station
Lower Plains Region
IWR (feet)
3
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

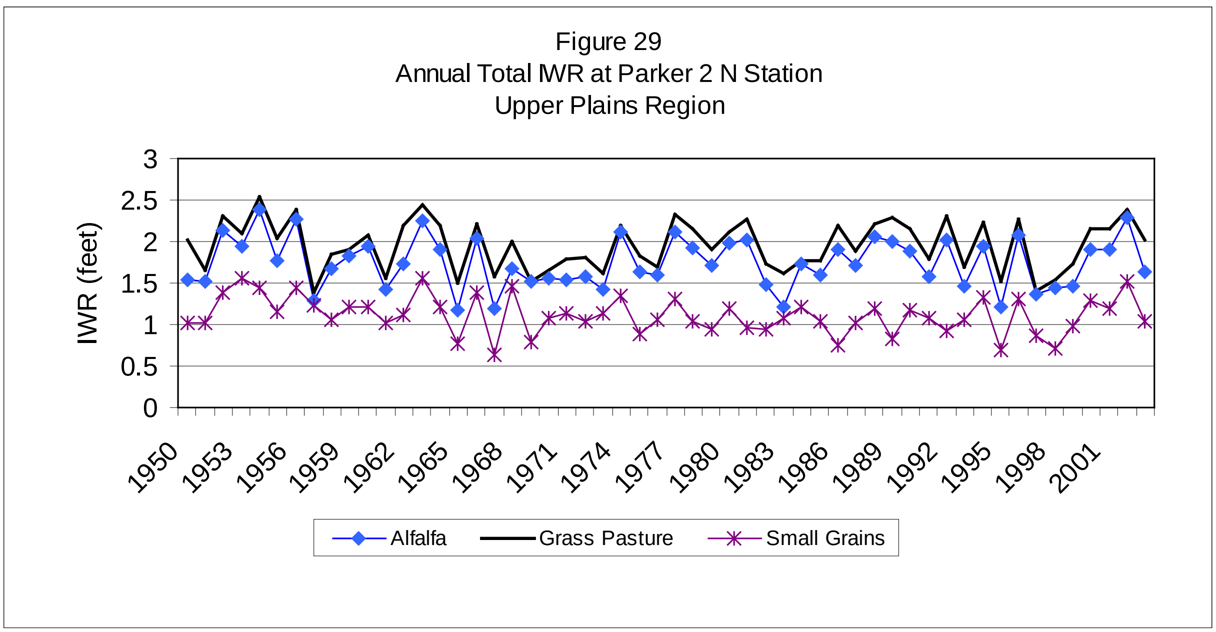


Figure 29
Annual Total IWR at Parker 2 N Station
Upper Plains Region
IWR (feet)
3
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Grass Pasture
Small Grains

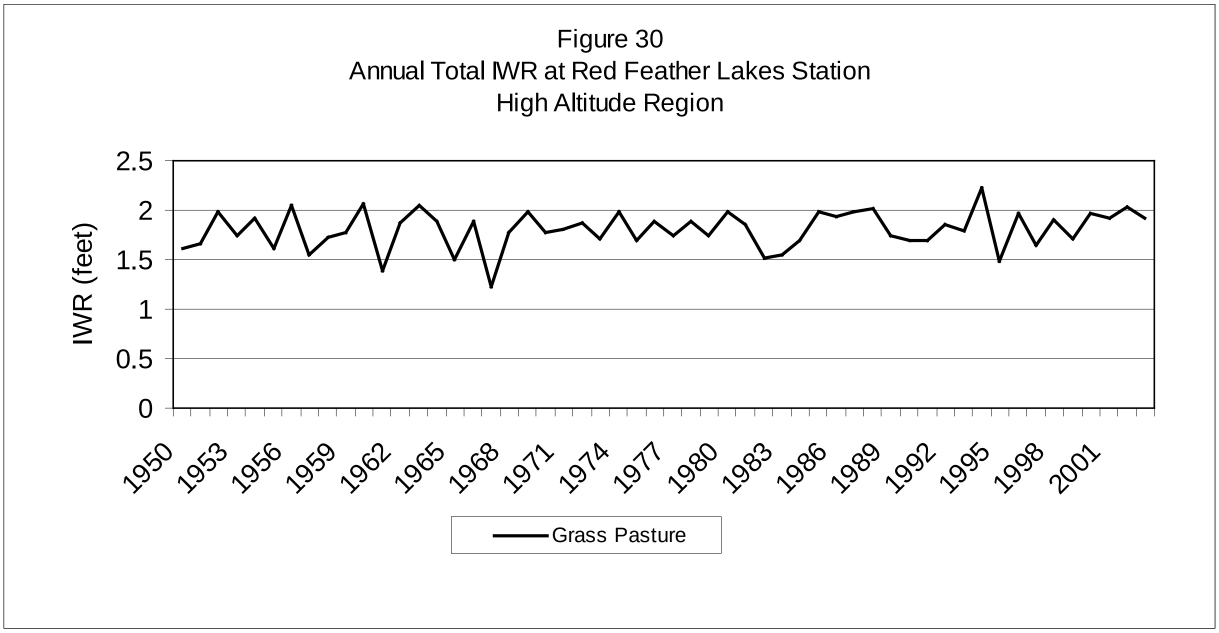


Figure 30
Annual Total IWR at Red Feather Lakes Station
High Altitude Region
IWR (feet)
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Grass Pasture

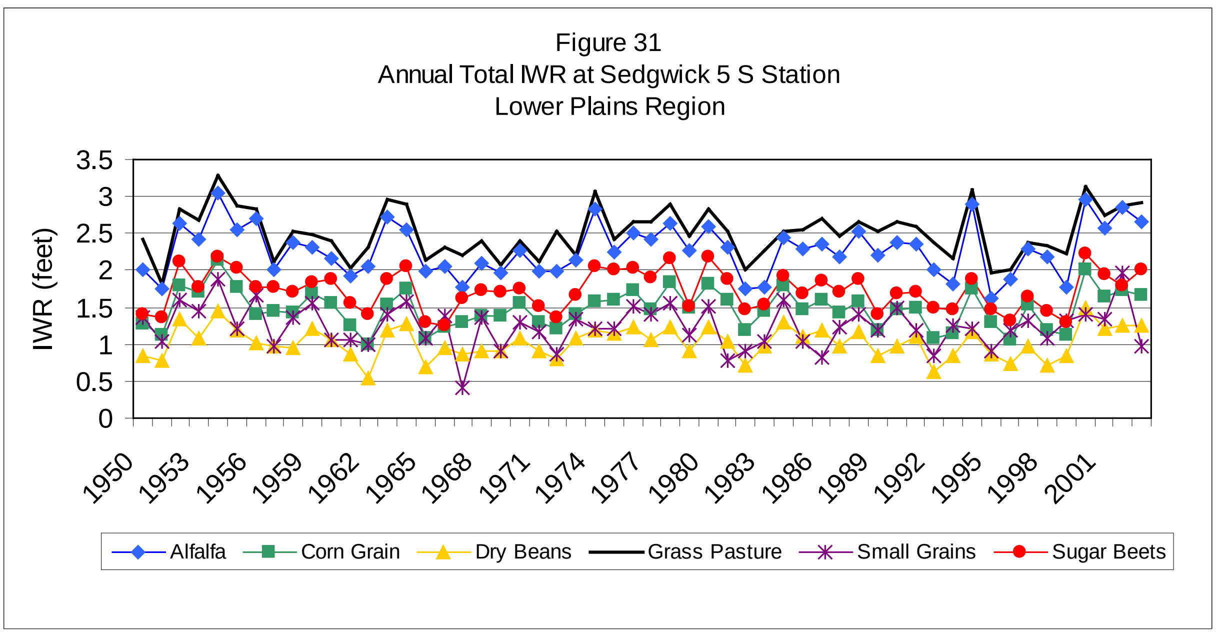


Figure 31
Annual Total IWR at Sedgwick 5 S Station
Lower Plains Region
IWR (feet)
3.5
3
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

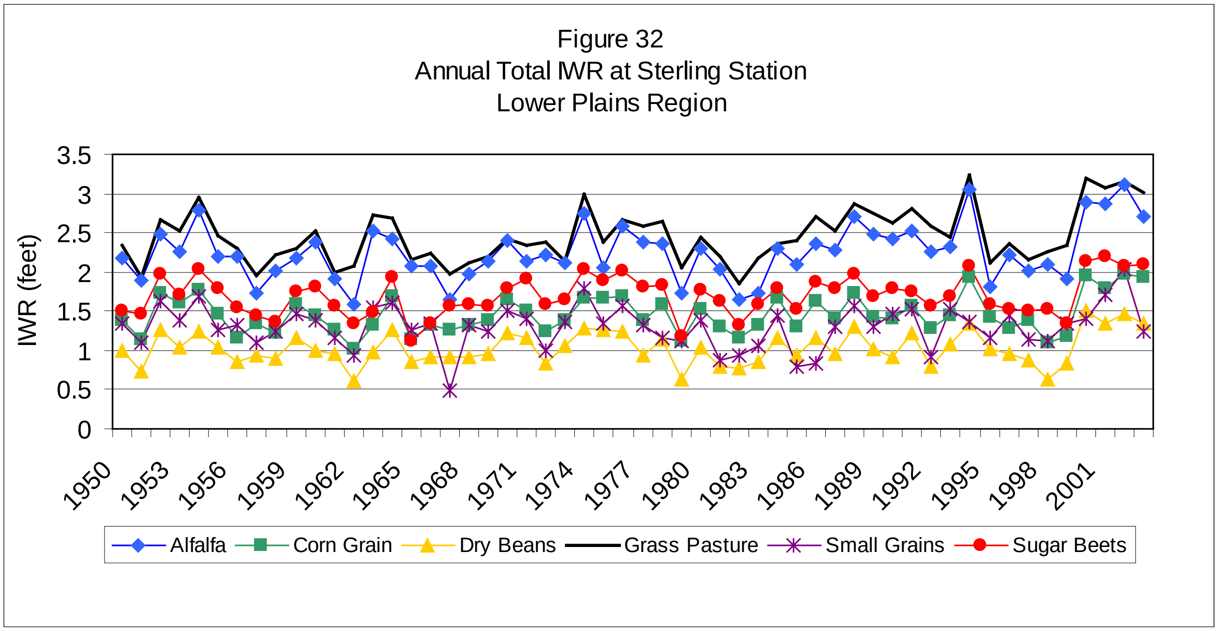


Figure 32
Annual Total IWR at Sterling Station
Lower Plains Region
IWR (feet)
3.5
3
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Alfalfa
Corn Grain
Dry Beans
Grass Pasture
Small Grains
Sugar Beets

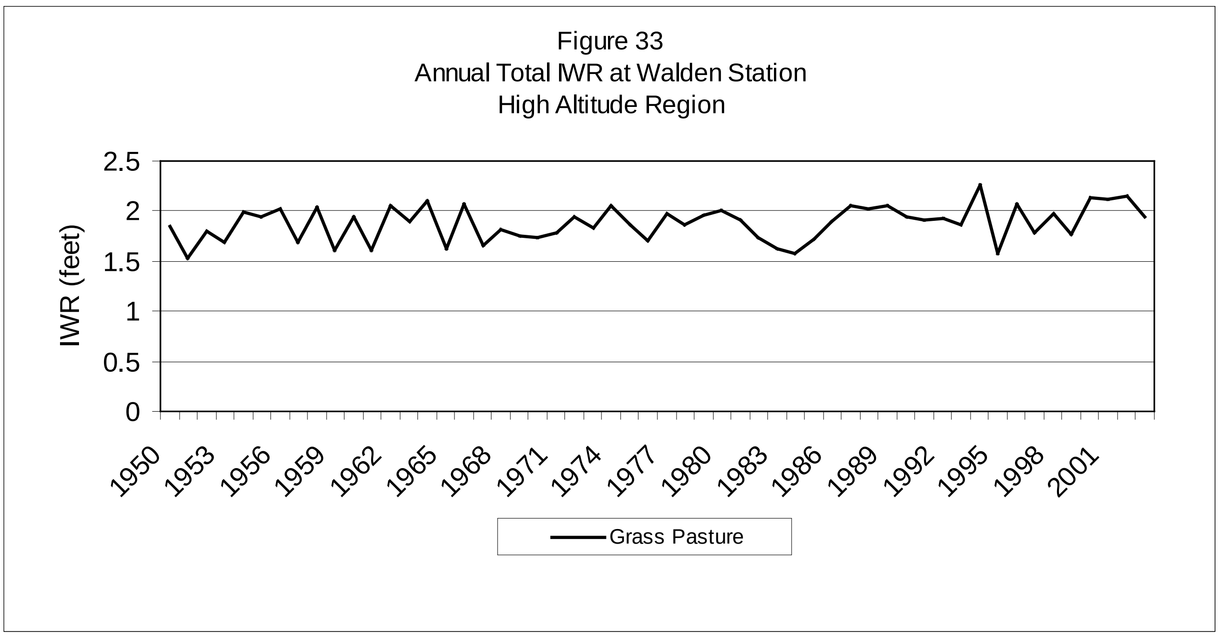


Figure 33
Annual Total IWR at Walden Station
High Altitude Region
IWR (feet)
2.5
2
1.5
1
0.5
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
Grass Pasture

Appendix L
Task 77 – Perform Analysis of Deficit Irrigation

To: Ray Alvarado and Ray Bennett

From: LRE – Erin Wilson and Beorn Courtney

Subject: Task 77 – Perform Analysis of Deficit Irrigation

Date: July 13, 2006

Introduction

Consumptive use methods, such as the modified Blaney-Criddle formula, can be used to estimate crop consumptive use. These methods estimate the crop consumptive water requirement under a full water supply. In the case of lands irrigated solely by surface water supplies, historical diversion records, less losses, are used to estimate the portion of the full demand that was actually met. For lands supplied by ground water or on-ditch reservoir releases, for which historical records are generally unavailable, consumptive use methods can be used to estimate pumping and on-ditch reservoir releases. Pumping and reservoir releases can be estimated as the irrigation water requirement (IWR) divided by an estimated application efficiency (IWR is potential CU less the effective precipitation).

During the SPDSS feasibility study, some water users indicated the consumptive use approach may overestimate the irrigation water requirement, and associated pumping and on-ditch reservoir releases, in the water-short South Platte River basin. Deficit irrigation, defined here as the method of applying less water than the amount that would be estimated using a consumptive use method, was again reported to occur in the South Platte River basin by users interviewed in Phase 1 and Phase 2.

This memorandum presents the general approach for Task 77:

> *Perform an analysis to determine whether estimating the use of supplemental supplies (i.e. ground water and reservoir releases) to meet full or partial potential use is appropriate for regions within the South Platte.*

The findings summarized in this memorandum pertain to deficit irrigation on lands served by ground water or on-ditch reservoir releases. To the extent that deficit irrigation occurs on lands served solely by surface water diversions, the deficit can be characterized through the historical diversion records.

Approach and Results

The following individuals familiar with ground water and irrigation practices throughout the SPDSS study area and other river basins in Colorado were interviewed in search of data and to research opinions on deficit irrigation in the SPDSS study area:

- Bob Longenbaugh – Consultant Water Engineer
- CDM – Gordon McCurry
- Central Colorado Water Conservancy District – Tom Cech and Randy Ray
- Colorado State University – Luis Garcia
- DWR – Dave Nettles, Susanne Sellers, Brent Schantz, and Chris Lytle
- Helton & Williamsen – Jim Slattery and Tom Williamsen
- Leonard Rice Engineers – Jon Ford and Greg Roush
- Lower South Platte Water Conservancy District – Joe Frank
- Nation Engineering – Heath Kuntz
- Northern Colorado Water Conservancy District – Jon Altenhofen and Mark Crookston

State rules governing groundwater use and measurement requirements and historical augmentation plans were reviewed. In addition, data sources found through the literature search or provided by individuals interviewed were investigated. The information obtained through the literature reviews and provided in the interviews is summarized in the sections below, which are organized under the following categories:

- ***General Information*** **–** this section describes the factors that influence deficit irrigation and opinions on whether deficit irrigation occurs and why.
- ***Power Conversion Coefficient Method*** **–** this section describes background on the power conversion coefficient method and power data that may be available through the CSU archives.
- ***Historical Augmentation Plans*** **–** this section describes the method used to estimate pumping under historical augmentation plans and actual pumping data that may become available from augmentation plans in the future.
- ***Pumping Data Review*** **–** this section presents conclusions related to deficit irrigation associated with two different datasets of pumping data.

General Information

There is consensus that deficit irrigation might occur throughout the SPDSS study area, supported by observations of visible crop stress, particularly during warmer months. While some of the individuals interviewed believe there is economic incentive to deficit irrigate, the majority indicated that irrigators are not "intentionally" deficit irrigating. Rather, it is a result of the physical system (well and pump capacity, declining aquifer levels, pivot rate, etc.) not being able to meet crop demand during periods of high IWR (due to climatic conditions). For example, there are times when a center pivot cannot make a full rotation prior to a portion of the irrigated area becoming stressed. Deficit irrigation may also be more likely to occur on lands served by ground water and/or reservoir water because pumping and reservoir releases can be scheduled as opposed to direct flow surface water supplies.

The Integrated Decision Support (IDS) Group at Colorado State University is studying how satellite imagery can be used to investigate crop consumptive use, crop stress, and effects of salinity. This research is mainly focused on studies in the Arkansas River Basin. Based on a review of information developed for a limited area and time period of the lower South Platte River basin, this type of research may be useful in the future for investigating deficit irrigation through identifying crop stress. The IDS Group has identified crop stress under parcels using sole source wells as the supply, particularly for lands on the south side of the South Platte River in areas with sandy soils.

Information from studies in the Arkansas and Republican River Basins regarding irrigation pumping versus consumptive use studies indicates that the level of deficit irrigation is not consistent. For example, in the Arkansas, it is not unusual to pump more than would be predicted by the consumptive use methods because of water quality issues. In the Republican, where greater aquifer depths drive pumping costs up, pumping is consistently less than estimated by the consumptive use methods. The South Platte does not have the same water quality issues as the Arkansas so "over" pumping is not expected to the extent found in the Arkansas. Nor does the South Platte have the aquifer depths of the Republican River Basin, so the economic incentive to deficit irrigate is not expected to be as strong. To characterize deficit irrigation over an expansive area, a representative sample of wells need to be investigated. For example, soil properties vary greatly throughout the South Platte River basin. Several people interviewed indicated they would expect deficit irrigation to occur more in areas with sandy soils because the soils cannot retain moisture as effectively.

In summary, the primary factors identified by individuals interviewed that influence deficit irrigation include:

- Soil type
- Climatic conditions
- Time of growing season
- Crop type
- Whether the well serves as a sole source or supplemental supply
- Irrigation system capacity (well, pump, sprinkler)
- Aquifer level

Power Conversion Coefficient Method

The most direct way to investigate the extent of deficit irrigation occurring throughout the SPDSS study area is to compare monthly pumping records to IWR estimates divided by an application efficiency. For this comparison, the acreage and crop type associated with the pumping records are needed to calculate the IWR. In the absence of flow meter records, electric power records could be used with power conversion coefficients (PCCs) to estimate pumping. The development of PCCs requires several parameters to be estimated including depth to ground water, pumping capacity, and pump efficiency. These parameters are site specific and can change over time.

In the mid 1990's DWR adopted Rules Governing the Measurement of Tributary Ground Water Diversions Located in the Arkansas River Basin. Under these rules, the PCC approach can be used to estimate pumping as an alternative to using a totalizing flowmeter (TFM) to directly measure pumping. PCCs must be determined utilizing rating procedures approved by the State Engineer and conducted under supervision of an individual/entity annually approved by the State Engineer to conduct such tests. The PCC rating must be updated at least every four years.

Research conducted by the USGS (Troutmann, et al) on the Lower Arkansas River Basin showed that PCCs developed in year one tend to overestimate pumping when applied to future years' power consumption (as compared to pumping measured using totalizing flowmeters). The USGS found a potential difference in pumping amounts calculated using the PCC approach and those measured with a TFM to vary by 2.2 percent per year, without considering variability due to pumping water level changes. An additional 1.6 percent per year difference was observed due to the lag between the year the PCC measurement was made and the year pumping was estimated. The USGS study estimated total network pumping for 1,000 wells using both approaches and found the calculated PCC pumping to be 8.4 to 11.3 percent greater than the measured TFM pumping for a four-year lag time and from 3.9 to 6.4 percent greater for a two-year lag time.

The proposed Rules Governing the Measurement of Ground Water Diversions Located in Water Division No. 3, The Rio Grande Basin are recommending more strict requirements with the PCC approach than outline under the Arkansas Rules: 1) the PCC approach must produce results within +/- 5 percent of the actual volume pumped over the calendar year, 2) PCC ratings must be determined by at least two ratings during the course of a single irrigation season with a minimum interval of 90 calendar days between each rating, and 3) PCCs must be updated at least every two years.

Over the past twenty years, the State has found that the PCC approach does not have long-term accuracy and additional conditions are needed to ensure pumping estimates made using the PCC approach remain accurate. Given these findings and the scope of the SPDSS, it was determined that power data would only be used to estimate pumping if PCCs associated with the specific dataset are provided.

Power records available through the Colorado State University archives were considered. Based on information provided by Bob Longenbaugh, two potential sources of information were identified:

1. Annual power records from the 1930's through the mid- 1970's, as reported by individual power companies. These records are not associated with individual wells but rather provide the annual power records on a regional county basis. There is no simple way to associate the regions with specific acreages and crop types. The records are reported in kilowatt-hours and do not include PCCs. Further, the records are annual and do not provide monthly distributions.
2. Monthly power records from around 1945 through 1965 for Morgan County associated with unique identifiers that correspond to individual wells. The records are reported in kilowatt-hours and do not include PCCs or associated acreages and crop types.

These sources were not complete enough to be analyzed. Specifically, both sources are limited by not having associated PCCs and the first source is limited because it only provides annual totals.

Historical Augmentation Plans

Prior to the early 2000's, there were no decreed augmentation plans or approved substitute water supply plans within the SPDSS study area that were based on pumping records. The standard practice was to base augmentation requirements on pumping demand predicted using an IWR method, typically modified Blaney-Criddle. As discussed in the *Task 58 – Review Previous Estimates of Potential CU* memorandum, the Colorado Revised Statues direct applicants to use the modified Blaney-Criddle method to calculate depletions associated with wells for diversions that are not actually measured. Some irrigators did maintain pumping recorded by flow meters or estimated pumping using power records and PCCs. Within the SPDSS study area, irrigators were not required to certify flow meters and PCCs, which are both very sensitive and without proper calibration, can result in records that are not representative of actual pumping.

Several recently decreed lower South Platte augmentation plans have augmentation requirements based on actual pumping records multiplied by an application efficiency (generally 80% for sprinklers, 60% for flood). Under some of the larger augmentation plans, users will maintain both flow meter readings and power data that can be used with a certified PCC to estimate pumping. Meters are in the process of being installed and certified. In the coming years, records associated with these new decrees will be valuable for investigating deficit irrigation.

Pumping Data Review

The GASP (Groundwater Appropriators of the South Platte) database was developed primarily from user-supplied information. Most of the information in this database was derived from power records that were not certified and included estimated pumping and application efficiencies. Based on discussions with individuals who have reviewed and worked with this database, while it may have been sufficient for other uses, its error range is too large to estimate deficit irrigation.

Central Colorado Water Conservancy District and other districts are in the process of installing (and certifying) flow meters on individual wells. While Central has some metered flow records available from the past several years, a quota has been applied during this period. The quota limits pumping to a percentage of the estimated demand. With restricted pumping, the records may not be representative of the entire SPDSS study period and therefore were not considered appropriate for characterizing deficit irrigation.

Pumping records were requested from several other ditch companies and water districts. The majority of the contacts indicated that pumping records were not available or that they could not obtain the individual users' permission to release the data. Two potential data sets were provided: (1) monthly pumping records associated with several wells located on the eastern plains of the South Platte River Basin, and (2) annual pumping estimates associated with the Northern High Plains area.

South Platte River Basin Dataset
Three years of monthly pumping records (2003 through 2005) associated with numerous wells located in the vicinity of Julesburg were reviewed. Using the WDID's and the 3/15/2006 version of the 2001 Irrigated Lands Assessment provided by the SPDSS GIS contractor (RTi), six wells that use ground water as the sole source were identified. The other wells provide a supplemental supply to lands that are also irrigated with surface water supplies. These wells were not considered because additional information regarding surface water supplies, which is required for this analysis, was not provided.

Historical pumping records were compared to estimated pumping, which was based on IWR from a modified Blaney-Criddle analysis using the SPDSS calibrated coefficients for Julesburg. The IWR was divided by an estimated application efficiency of 80% for sprinklers to estimate pumping. The results are shown below in **Figure 1**. For a given year, the peak monthly percent deficit irrigation varies between wells from around thirty percent to over 250 percent. For a given well, the pattern was not consistent across the three years of data.

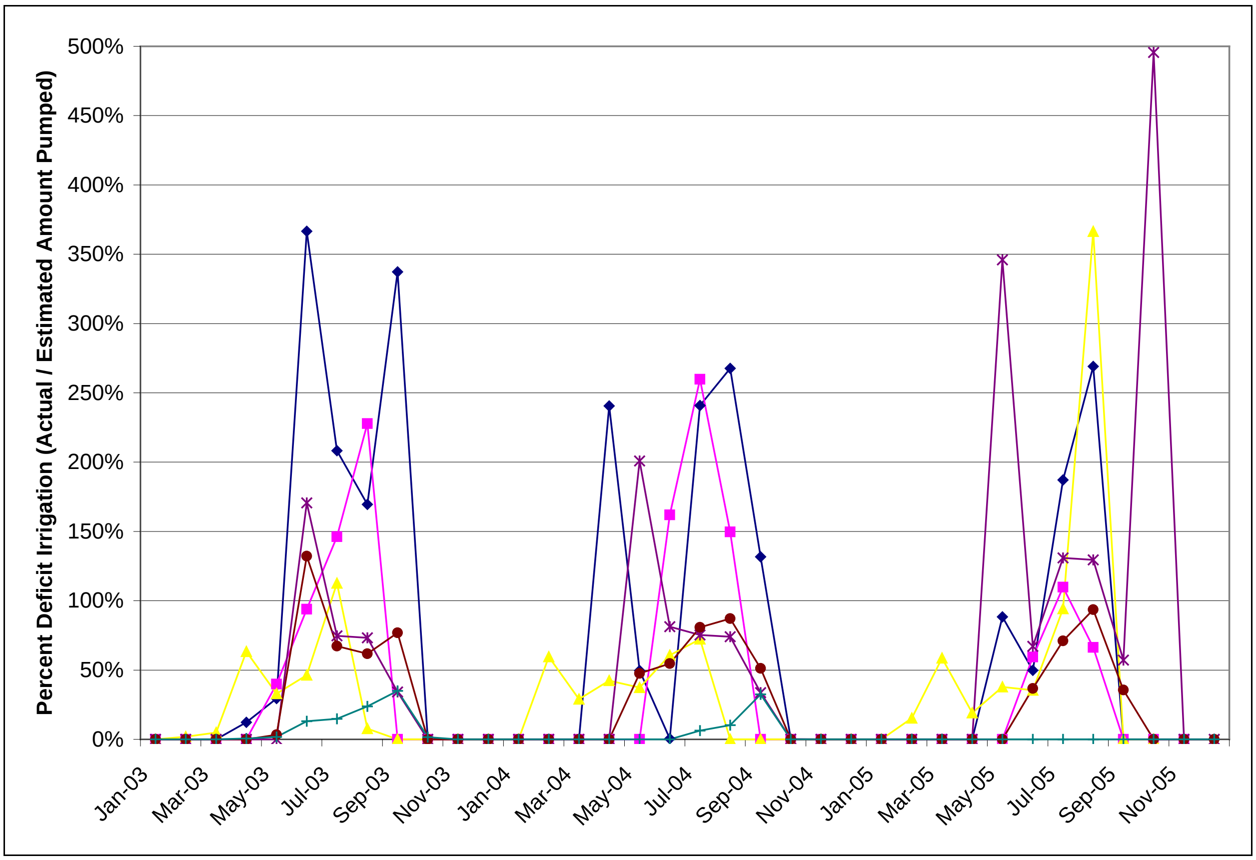


Figure 1. Deficit Irrigation Estimates Using Monthly Data for Wells near Julesburg

Northern High Plains Dataset
Several years of annual pumping estimates associated with fourteen sole source wells located in the Northern High Plains area were reviewed. The period of record spanned

from 1979 through 2003, with around ten to fifteen years of data for any given well. The SEO provided datasets in the form of:

- Estimated historical pumping which had been converted from power records using the PCC method with assigned PCCs, and
- Theoretical pumping which had been based on a consumptive use analysis (IWR) with acreages and crop types assigned to each well, divided by application efficiencies ranging from 60% to 70%.

The historical estimated pumping was divided by the estimated pumping to determine the percent deficit irrigation. A sample of the results is provided in **Figure 2** below, with each time series representing results from an individual well (well permit ID's were omitted for confidentiality). These data provided a representative sample of the twenty-one wells that were investigated. As shown, the results did not reveal consistent patterns across years for a given well or by comparing a given year among different wells.

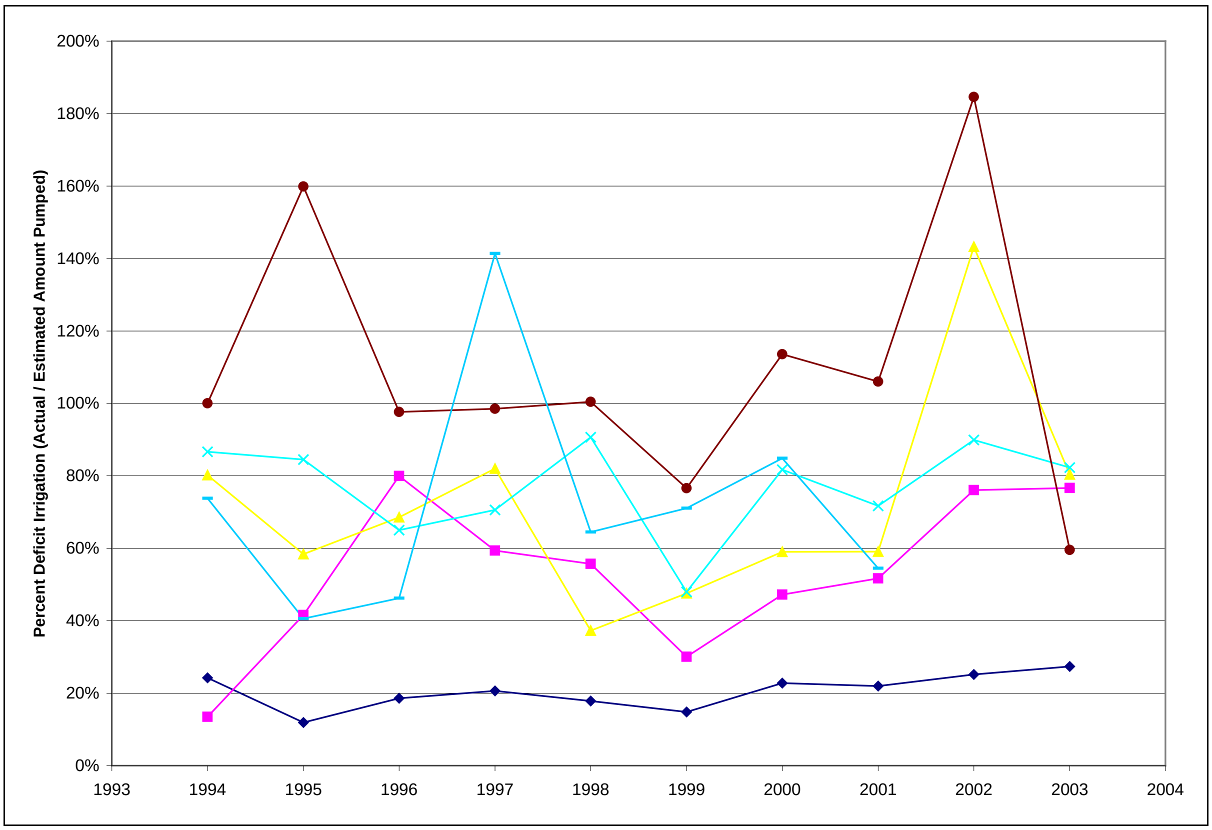


Figure 2. Deficit Irrigation Estimates Using Annual Data Provided by the SEO

Conclusions

An appropriate data set that could be used to quantify deficit irrigation was not identified. The comparison of pumping records to estimated IWR is sensitive to the crop type, acreage, and application efficiency. While there is consensus that deficit irrigation likely occurs, there is also consensus that it is likely to occur at different levels depending on soil type, climatic conditions, time of growing season, crop type, and whether the well serves as a sole source or supplemental supply. Data is not available at this time to provide a thorough investigation that is representative of large portions of the SPDSS study area. The specific data needed to complete a thorough analysis include the following:

- Monthly pumping data (metered records or power records with certified PCCs)
- Acreage and crop type information directly corresponding to the pumping data
- Estimated application efficiencies
- Multiple years of data covering wet/dry/average periods with unrestricted pumping (no quotas)

Until such time that more comprehensive data is available, no adjustment for deficit irrigation is recommended. For the SPDSS, pumping should be estimated using the consumptive use approach with a full supply.

Comments and Concerns

As flow meter pumping data and power data with certified PCCs are collected under some of the newer decreed augmentation plans, a new source of information may become available for investigating deficit irrigation throughout the SPDSS study area. Based on the analyses performed for this task, we recommend a minimum of 5 years of monthly data be collected prior to reconsidering. We also recommend a representative sample of the study area be analyzed, e.g. wells located on the north and south side of the South Platte River, wells irrigating different crop types, wells serving as the sole source versus supplemental supply, etc.

References

Troutman, Brent M., Edelmann, Patrick, and Russell G. Dash. Variability of Differences between Two Approaches for Determining Ground-Water Discharge and Pumpage, Including Effects of Time Trends, Lower Arkansas River Basin, Southeastern Colorado, 1998-2002. Available online at http://pubs.usgs.gov/sir/2005/5063.

Appendix M
Ground Water Model Area Scenario

To: Ray Bennett and Ray Alvarado

From: LRE – Erin Wilson, Mark Mitisek

Subject: Ground Water Model Area Scenario

Date: November 25, 2008

Introduction

A subset of the basin historic consumptive use analysis was developed to estimate consumptive use and pumping within the alluvial aquifer. This analysis, defined by the scenario response file **SP2008GW.rcu**, only includes ditches that have a portion of their irrigated land within the ground water model area. Note that although some of the ditches included irrigate lands completely within the ground water model area, many of the ditch systems have irrigated lands that extend beyond the boundary of active ground water model cells. Results of this scenario are used directly in the Ground Water Model Area Water Budget. In addition, the results provide a general check of pumping and recharge input to active cells within the alluvial ground water model from the Ground Water Total River Diversion scenario results.

Approach

Only the input structure file (**SP2008GW.str**) that defines the structures used in the analysis is different from the Ground Water Total River Diversion consumptive use analysis. Table 1 shows the acreage and structures represented in the Ground Water Model Area scenario.

Table 1
Ground Water Model Area Scenario

Structure Type	2001 Acres	Number of Structures 1)	Percent of Total Acreage
Key/Diversion System Structures	637,590	172	81 %
Aggregated Surface Water Structures	690	2	0 %
Aggregated Ground Water Structures	145,354	54	19 %
Total Structures	**783,634**	**228**	**100 %**

1) Number of total structure IDs included in the model. Aggregates and diversion systems represent more than one physical structure. Includes non-irrigation structures, such as reservoir carriers and municipal and industrial structures.

The Ground Water Model Area scenario includes 86 percent of the total irrigated acreage in the basin, and 87 percent of the acreage with only a ground water source.

Results

Table 2 shows the results of the Ground Water Model Area scenario consumptive use analysis.

Table 2a

Ground Water Model Area Scenario Results 1950 through 2006 (acre-feet)

Irrigation Water Required	Surface Water Diversion Accounting							
	River Headgate Irr Divert	Irr. Conv Loss	Diversion to Recharge	Diversion to Farm	Surface Water Diversion To: CU	Soil	Non-Consumed	Calculated Application Efficiency
1,288,435	1,974,325	577,118	26,172	1,371,035	643,900	92,207	634,929	54%

Table 2b

Ground Water Model Area Scenario Results 1950 through 2006 (acre-feet) - Continued

Ground Water Diversion Accounting				Estimated Crop CU			Total Non-Consumed
Diversion (Pumping)	Application Efficiency	To CU	Non-Consumed	From SW and GW	From Soil	Total	
446,063	66%	292,756	153,298	936,655	91,637	1,028,292	788,227

Table 3 compares crop consumptive use and pumping estimates for the Ground Water Model Area Scenario compared to the basin-wide crop consumptive use analysis. As shown, approximately 88 percent of the basin crop consumptive use and 92 percent of the basin pumping occurs in the ground water model scenario. The ground water model scenario does not include pumping that occurs outside the model boundary, even though it may influence the ground water model through lateral boundary conditions. The calculated application efficiency is higher for the ground water model scenario than for the basin scenario (54% compared to 49%). In general, the ditches on the tributaries to the South Platte have more senior water rights than the lower South Platte structures; therefore they divert more water and operate at a lower efficiency. Many of these tributary ditches are not included in the ground water model scenario.

Table 3

Crop Consumptive Use and Pumping Comparison

1950 through 2006 (acre-feet)

Total Basin Wide CU	Ground Water Area CU	Ground Water Area % of Total	Total Basin Wide Pumping	Ground Water Area Pumping	Ground Water Area % of Total
1,170,710	1,028,292	88%	487,294	446,063	92%

To allow a general comparison with direct inputs to active model cells, **Table 4** presents conveyance loss associated with diversions within the ground water model area for uses other than irrigation.

Table 4
Total Conveyance Loss within the Ground Water Model Area
1950 through 2006 (acre-feet)

Irrigation Conveyance Loss	Other Uses Conveyance Loss	Total Conveyance Loss
577,118	11,739	588,857

Comments and Concerns

None.

Appendix N
Ground Water Total River Diversion Scenario

To: Ray Bennett and Ray Alvarado

From: LRE – Erin Wilson, Mark Mitisek

Subject: Ground Water Total River Diversion Scenario

Date: November 25, 2008

Introduction

The SPDSS alluvial ground water model covers the area overlying the alluvial aquifer in the South Platte basin and considers the effects of pumping and irrigation-related recharge adjacent to the model boundary as lateral input. The data-centered ground water modeling process reads the results of the Ground Water Total River Diversion scenario and spatially determines the portion of pumping, non-consumed irrigation water, and ditch conveyance losses to input directly to active model cells; input to the model via surface drainages; or input as lateral boundary inflow.

Approach

The Ground Water Total River Diversion scenario includes diversions, and associated conveyance loss, for structures in the basin diverting for uses other than irrigation, including diversions to storage and recharge, municipal diversions, and industrial diversions. Only the input structure file (**SP2008.str**) that defines the structures used in the analysis and the historical diversion file (**SP2008.ddh**) are different from the basin historic consumptive use analysis. **Appendix I**, South Platte Historic Consumptive Use - Development of Historical Diversions describes the development of the historical diversion file. **Table 1** shows the acreage and structures represented in the Ground Water Total River Diversion scenario.

Table 1
Ground Water Total River Diversions Scenario

Structure Type	2001 Acres	Number of Structures 1)	Percent of Total Acreage
Key/Diversion System IrrigationStructures	733,843	317	81 %
Carrier, Municipal, Industrial Structures	0	87	0 %
Aggregated Surface Water Irrigation Structures	9,427	13	1 %
Aggregated Ground Water Structures	167,248	83	18 %
Total Structures	**910,518**	**500**	**100 %**

1) Number of total structure IDs included in the model. Aggregates and diversion systems represent more than one physical structure.

As with the basin historic consumptive use analysis, the storage diversion file (SP2008.dra) is used to offset diversions to recharge sites that are included in the historical diversion file (SP2008.ddh). The storage diversion file is also used to offset diversions to off-channel reservoir. Including the negative of these non-irrigation diversions (after conveyance loss) in the storage diversion file makes sure these non-irrigation diversions are not available to meet crop consumptive use directly or to be stored in the soil zone and available to meet crop consumptive use in subsequent months. With this approach, the canal losses associated with diversions to reservoirs or ditch sites are accounted for, and available for inclusion in the SPDSS ground water modeling effort.

The storage diversion file contains negative reservoir deliveries for diversions to 29 off-channel reservoirs, as discussed in **Appendix I**, South Platte Historic Consumptive Use - Development of Historical Diversions. In addition, approximately 77,000 acre-feet on average (over the 1979 to 2007 period) was diverted to recharge sites delivered through 52 structures, as documented in Appendix R of the Lower South Platte Surface Water Model User's Manual. These diversions to recharge are also "offset" using the storage diversion file, assuring they are not included in the crop consumptive use analysis as an irrigation supply.

Results

Table 2 shows the results of the Ground Water Total River Diversion scenario consumptive use analysis.

Table 2a
Ground Water Total River Diversion Results 1950 through 2006 (acre-feet)

Irrigation Water Required	Surface Water Diversion Accounting								
	Total River Headgate Diversion	Irr. Conv Loss	M&I, Storage, Recharge Conv Loss	Diversion to M&I, Storage and Recharge	Diversion to Farm	Surface Water Diversion To: CU	Surface Water Diversion To: Soil	Surface Water Diversion To: Non-Consumed	Calculated Application Efficiency
1,544,306	3,736,209	652,412	18,300	974,723	2,090,774	749,023	109,439	1,232,312	41%

Table 2b
Ground Water Total River Diversion Results 1950 through 2006 (acre-feet) - Continued

Ground Water Diversion Accounting				Estimated Crop CU			Total Non-Consumed
Diversion (Pumping)	Application Efficiency	To CU	Non-Consumed	From SW and GW	From Soil	Total	
487,294	64%	312,408	174,871	1,061,432	108,749	1,170,180	1,407,184

The Ground Water Total River Diversion Scenario estimates the same historical consumptive use, pumping, and non-consumed applied water as the historic crop consumptive use analysis. Only conveyance loss estimates vary, since they include losses associated with diversions to storage, recharge, municipal, and industrial uses. Basin-wide average (1950 through 2006) conveyance loss associated resulting from all uses is 670,712 acre-feet per year compared to 652,412 acre-feet per year associated with irrigation uses only.

Comments and Concerns

None.

Appendix O
Develop Historical Pumping Estimates

To: Ray Alvarado

From: LRE – Erin Wilson, Mark Mitisek

Subject: Develop Historical Pumping Estimates

Date: March 16, 2010

Introduction

The historical pumping file provides ground water supply information required to estimate supply-limited consumptive use. Historical pumping estimates are provided for each modeled irrigation structure that is assigned ground water acreage.

Approach

The historical pumping file was developed using a two step process to represent historical and more recent pumping estimates limited by Central Colorado Water Conservancy District (CCWCD) quota restrictions. To represent historic pumping estimates StateCU estimates ground water pumping (diversion) required to satisfy crop consumptive demands not met by surface water. These pumping estimates include water pumped to offset the inefficiencies associated with ground water application (flood or sprinkler). Also, the amount of ground water pumped is limited by the acres served by wells and the decreed capacity (alluvial wells) or permitted capacity (designated basin wells) for each month.

To represent more recent pumping estimates associated with the two CCWCD augmentation plans a quotas were applied to the StateCU estimated historical pumping in 2005 and 2006. Pumping was restricted for 53 irrigation structures associated with WAS and GMS augmentation plans. **Table 1** shows the total acreage, and percentage of acreage associated with the CCWCD augmentation plans by structure. The pumping estimates from StateCU for these structures were reduced based on GMS and WAS acreage assigned to each structure and their quotas for 2005 and 2006. **Table 2** summarizes the total number of CCWCD wells assigned to irrigated acreage in 2005 and their quotas for 2005 and 2006.

Table 1
Central Colorado Water Conservancy District WAS and GMS Acreage Assignments

WDID	Structure Name	2005 Irrigated Acreage	Percent of Acreage WAS	GMS	Non - CCWCD
01_AWP002	South Platte River Below Weldona Co North	1840.20	5%	0%	95%
01_AWP017	Lower Kiowa Bijou Designated Basin East 9	2663.00	2%	0%	98%
01_AWP026	South Platte River Above Weldona Co South 1	1434.20	28%	0%	72%
01_AWP027	South Platte River Above Weldona Co South 2	2617.10	34%	21%	45%
01_AWP028	South Platte River Above Weldona Co South 3	3632.80	19%	79%	1%
01_AWP029	South Platte River Above Weldona Co South 4	2227.40	16%	59%	26%
01_AWP030	South Platte River Above Weldona Co South 5	2045.10	0%	82%	18%
01_AWP031	South Platte River Below Riverside Canal South	4324.60	0%	2%	98%
01_AWP032	Wd 1 Lower Boxelder Creek	2492.30	21%	60%	19%
01_AWP033	South Platte River Above Weldona Co North	1908.50	12%	0%	88%
01_AWP034	Boxelder Creek Below Horse Creek Reservoir West	7.60	0%	100%	0%
01_AWP035	Wd 1 Upper Boxelder Creek	803.40	0%	82%	18%
01_AWP037	South Platte River Below Kersey Co North 2	73.30	0%	100%	0%
01_AWP041	Wd 1 Lower Boxelder Creek	183.80	0%	100%	0%
01_AWP042	South Platte River Below Kersey Co South	4474.00	37%	61%	3%
01_AWP044	Wd 1 Lower Boxelder Creek	89.60	0%	100%	0%
0100507_I	Bijou Canal Demand	28145.30	2%	0%	98%
02_ADP003	South Platte River Below Ft Lupton West	441.00	0%	100%	0%
02_AWP001	Wd 2 Beebe Draw 1	3573.40	23%	72%	5%
02_AWP002	Wd 2 Beebe Draw 2	4680.70	26%	74%	0%
02_AWP003	South Platte River Below Ft Lupton West	1157.40	46%	52%	3%
02_AWP004	Sand Creek Basin And Burlington System	3768.00	1%	97%	2%
02_AWP005	South Platte River Below Clr Crk Confluence West	335.10	0%	100%	0%
0200805_I	Denver-Hudson Cnl	29469.00	0%	38%	62%
0200808	Fulton Ditch	7988.30	6%	90%	4%
0200809	Brantner Ditch	3972.30	0%	100%	0%
0200810	Brighton Ditch	1753.20	3%	97%	0%
0200812	Lupton Bottom Ditch	3261.60	52%	44%	4%
0200813	Platteville Ditch	3554.30	70%	25%	5%
0200817_I	Evans No 2 Demand	14185.80	37%	61%	1%
0200821	Meadow Island 1 Ditch	902.30	32%	68%	0%
0200822	Meadow Island Ditch	2491.00	53%	47%	0%
0200824	Farmers Independent D	6454.30	22%	71%	7%
0200825	Hewes Cook Ditch	7068.40	22%	55%	23%
0200828_I	Union Irrigation Demand	4365.30	4%	30%	66%
0200830	Section No 3 Ditch	1204.20	7%	83%	10%
0200834_I	Lower Latham Demand	10068.70	0%	54%	47%
0200836	Patterson Ditch	644.50	0%	23%	77%
0200871	Whipple Ditch	4783.90	0%	100%	0%
0200915	Little Burlington Cnl	4402.50	5%	84%	11%
0203837_I	Frico-Barr Lake Demand	18927.90	11%	89%	0%
0203876_I	Frico-Milton Lake Demand	12167.70	29%	68%	4%
03_AWP001	Cache La Poudre River Above Greeley Co	2523.00	1%	0%	99%
0300929_I	New Cache La Poudre Demand	32498.20	3%	0%	97%
0300934	Canal 3 Ditch	777.60	0%	26%	75%
04_AWP002	Little Thompson Above Big Thompson Confluence	63.10	0%	61%	39%
04_AWP005	Little Thompson Above Big Thompson Confluence	131.80	0%	16%	84%
0400502_D	Big T Platte R Ditch	1463.70	18%	82%	0%
0400522	Hill Brush Ditch	457.00	0%	100%	0%
0400523	Hillsborough Ditch	5613.00	50%	31%	19%
05_AWP004	Saint Vrain Creek Below Lyons Co	135.20	50%	50%	0%
0500523	Supply Ditch	4387.80	0%	100%	0%
0500589	Last Chance Ditch	1398.10	100%	0%	0%

Table 2
Central Colorado Water Conservancy District WAS and GMS Wells Assigned in the 2005 Irrigated Acreage Coverage and Pumping Quotas for 2005 and 2006

Decree	Wells	Quota 2005	Quota 2006
WAS	766	40%	0%
GMS	194	50%	50%

Results

The application of a quota, by ditch, for WAS and GMS pumping resulted in a basin-wide reduction of 49,190 acre-feet (12%) in 2005 and 72,610 acre-feet (13%) in 2006.

Comments and Concerns

None.