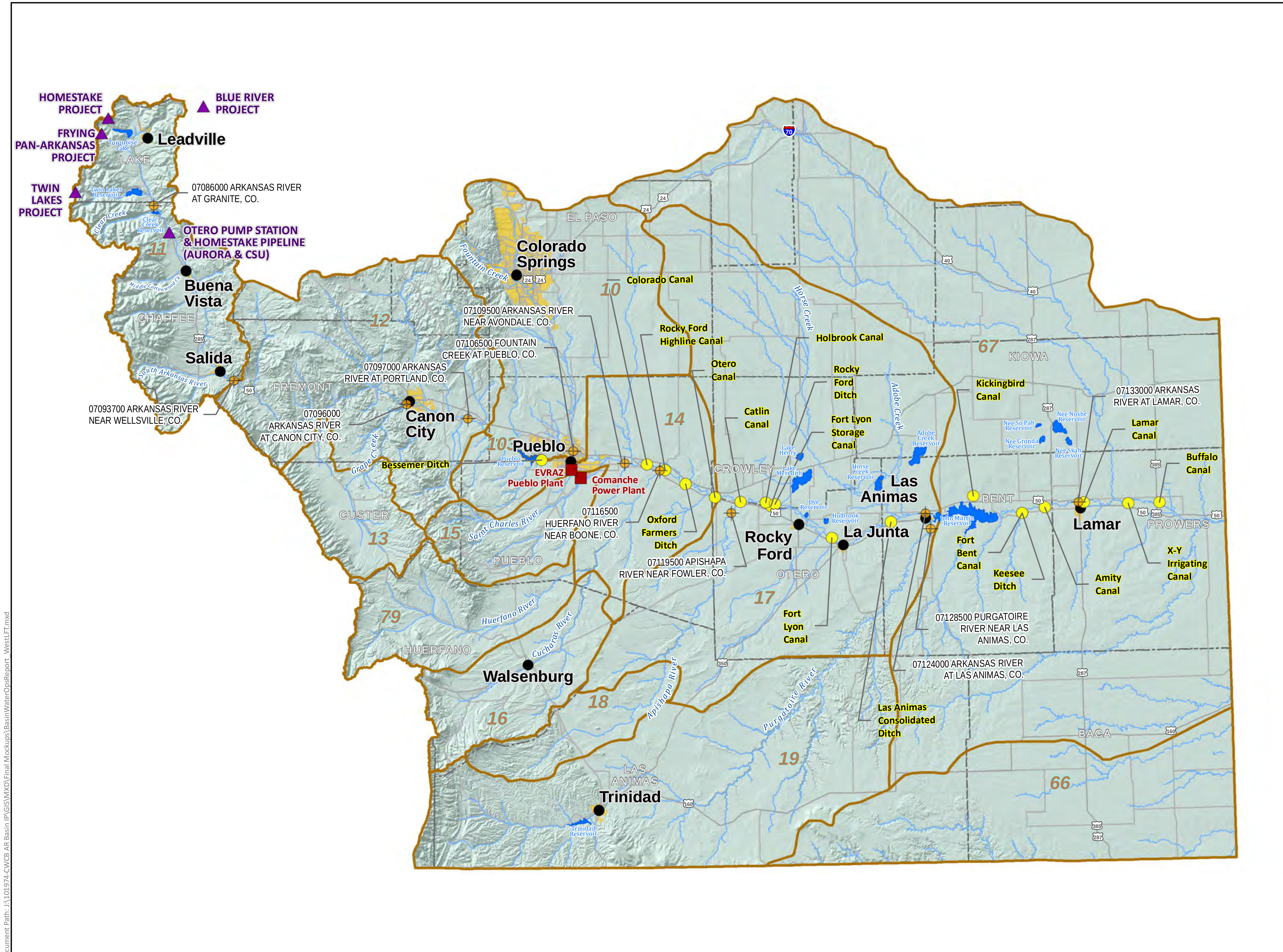
Figure 1
Location Map

Arkansas River Basin Implementation Plan



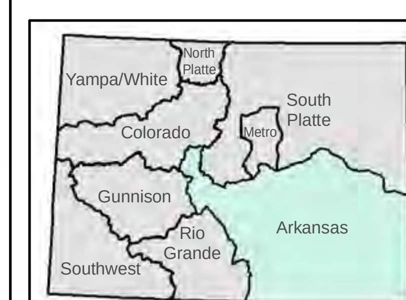
Legend:
- Water District
- Major Stream Gage
- Major Irrigation System Headgate
- Major Industrial Water User
- Major Transmountain System

0 20 40 Miles

N W E S

CDM Smith

COLORADO Colorado Water Conservation Board Department of Natural Resources



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Document Path: J:\101974-CWCB AR Basin IP\GIS\MXD\Final Mockups\BasinWaterOpsReport_WestLFT.mxd

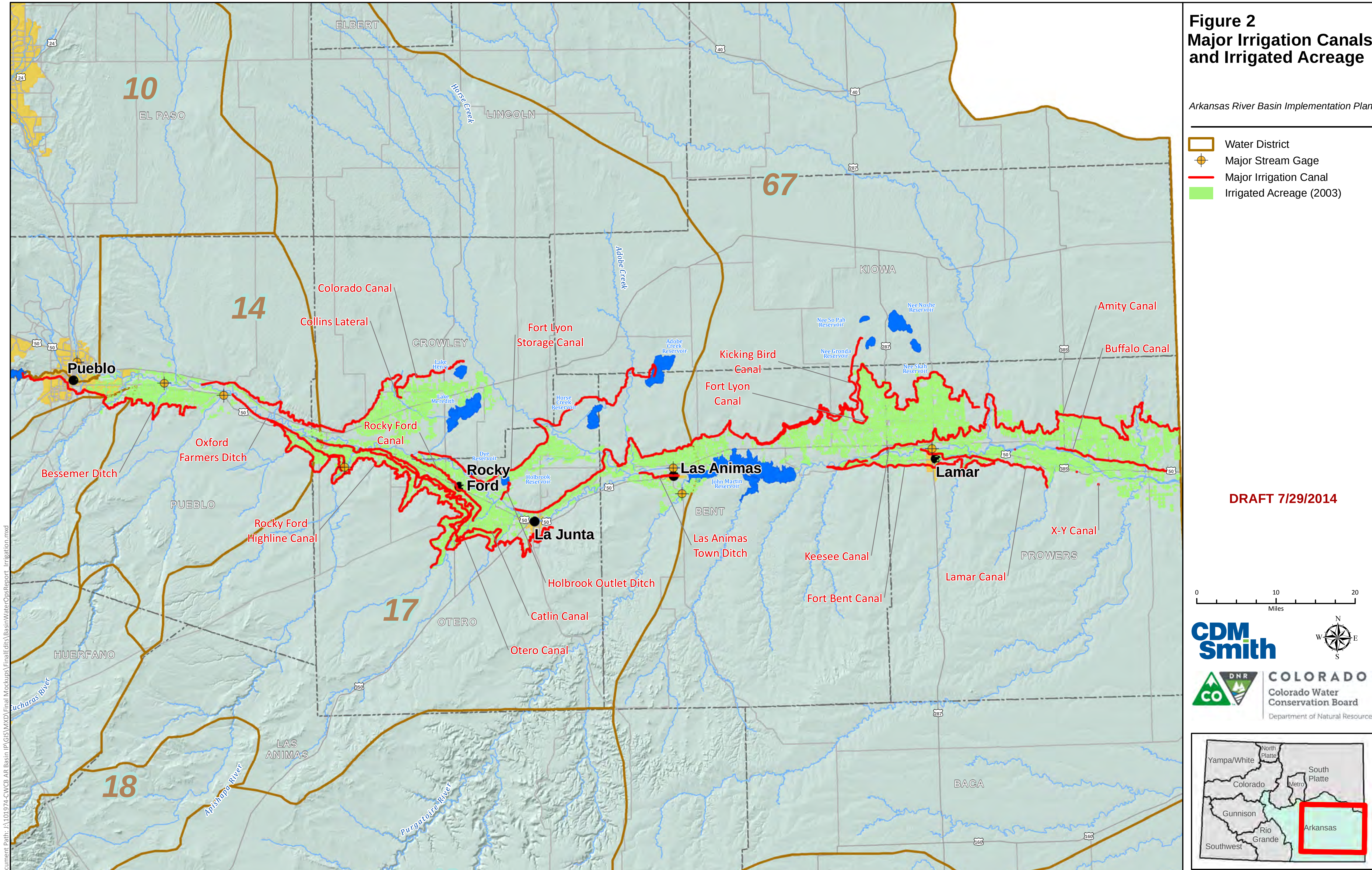


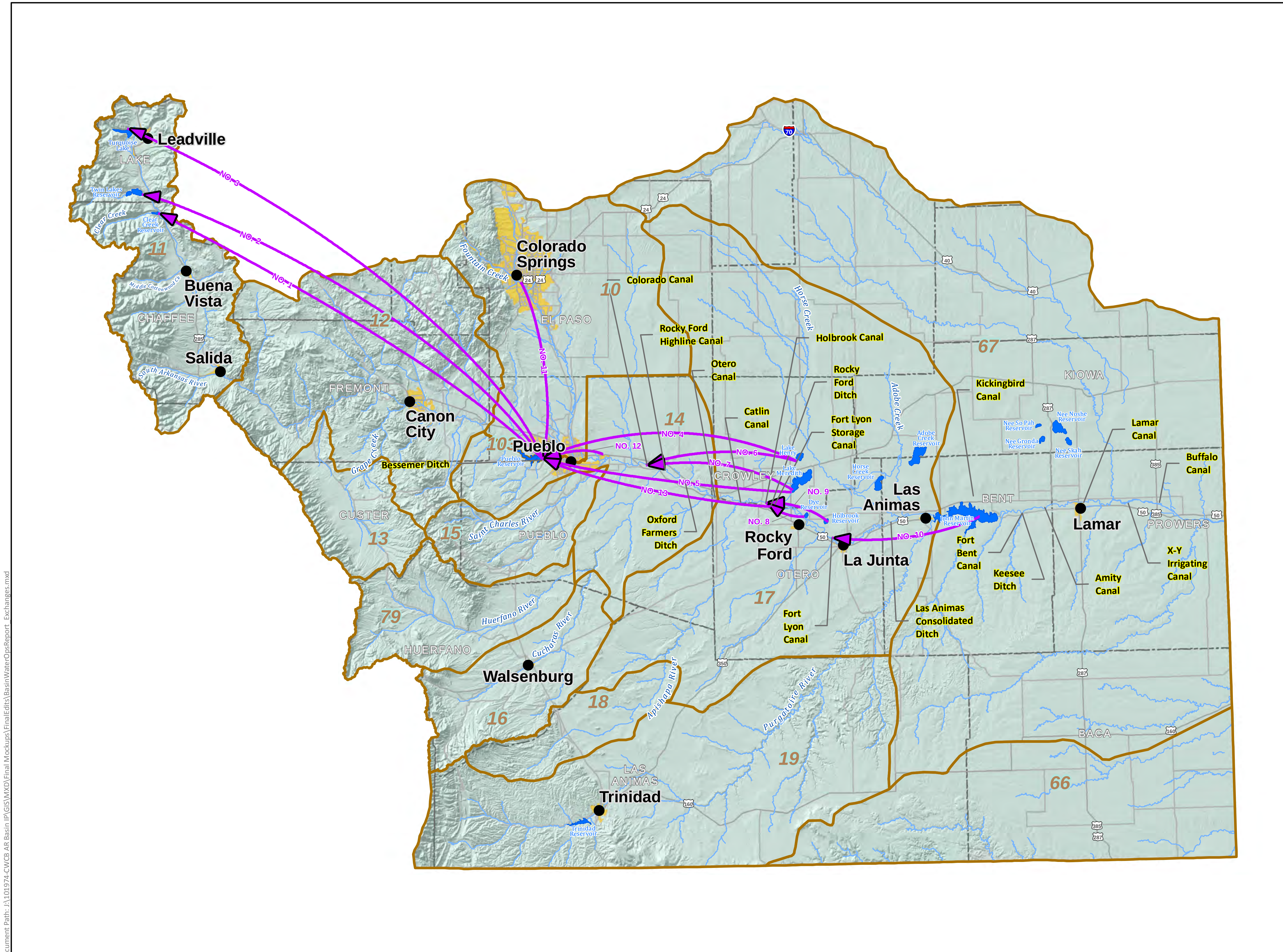
Figure 2
Major Irrigation Canals and Irrigated Acreage

Arkansas River Basin Implementation Plan

Document Path: J:\101974-CWCB AR Basin IP\GIS\MXD\Final Mockups\FinalEdits\BasinWaterOpsReport_Irrigation.mxd

Figure 3
Exchanges

Arkansas River Basin Implementation Plan



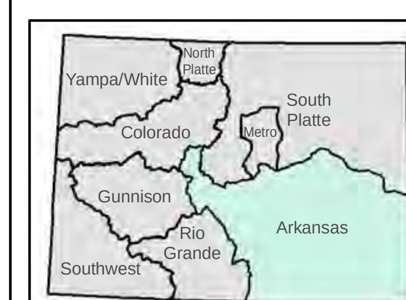
Water District
Major Exchange
Major Irrigation System Headgate

DRAFT 7/29/2014

0 20 40
Miles

CDM Smith

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

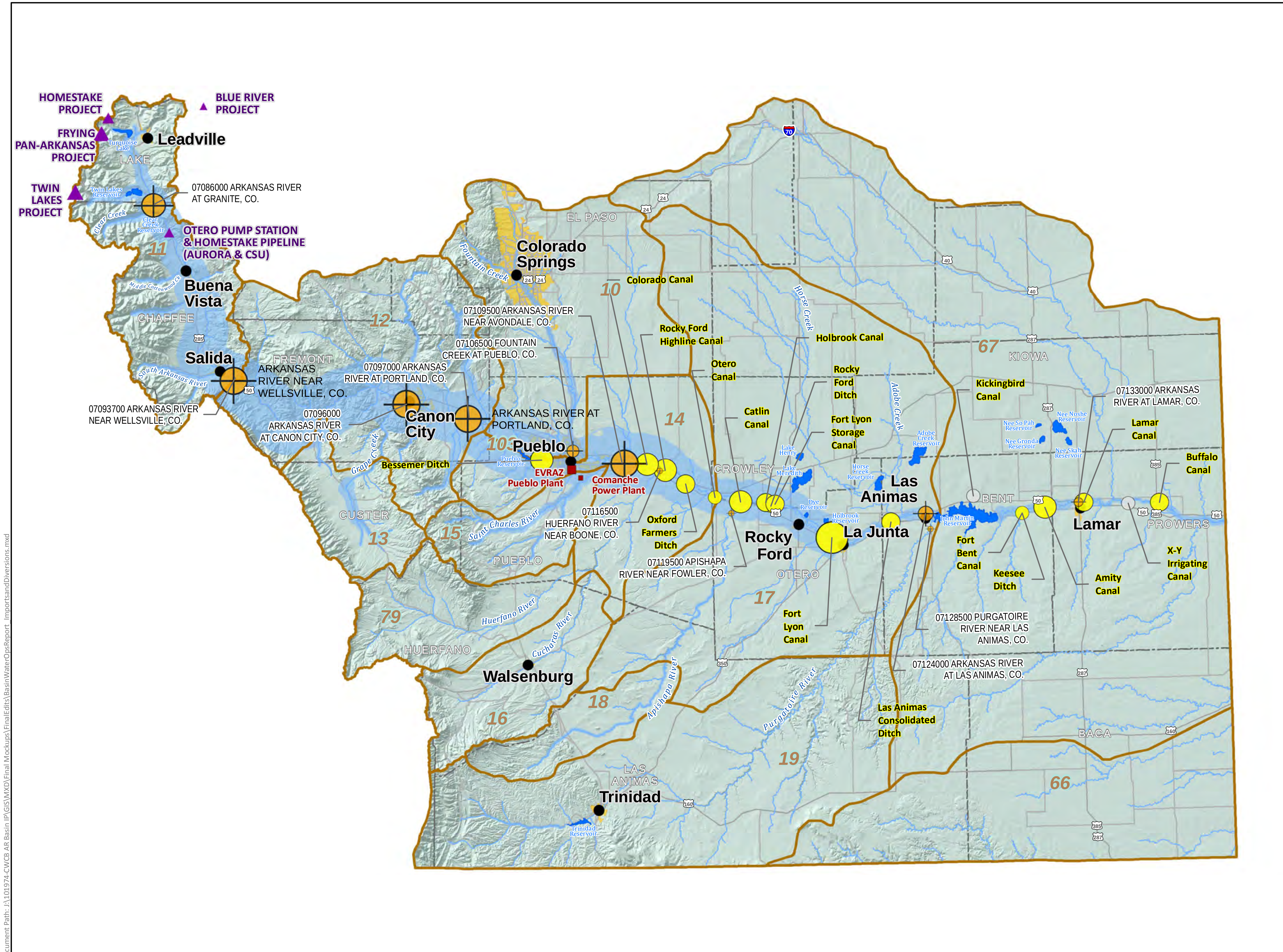


Document Path: J:\101974-CWCB AR Basin IP\GIS\MXD\Final Mockups\FinalEdits\BasinWaterOpsReport_Exchanges.mxd

Figure 4
Imports and Diversions

WET YEAR [WR 2011]

Arkansas River Basin Implementation Plan



Streamflow - Width is proportional to annual flow volume

Water District

Major Imports and Diversions
Symbol size is proportional to annual flow (AFY)

< 1 000 — > 500 000

Symbol Types

- Major Stream Gage
- Major Irrigation System Headgate
- Major Industrial Water User
- Major Transmountain System
- Major Irrigation System Headgate - No Data Available for this year

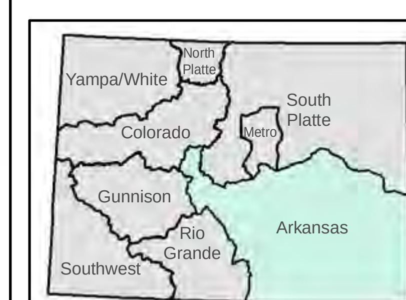
DRAFT 7/29/2014

Headgate diversions and gages: Historical Records (Hydrobase)
Streamflow widths: National Hydrography Dataset, USGS and Gage Records

0 20 40
Miles

CDM Smith

COLORADO
Colorado Water Conservation Board
Department of Natural Resources



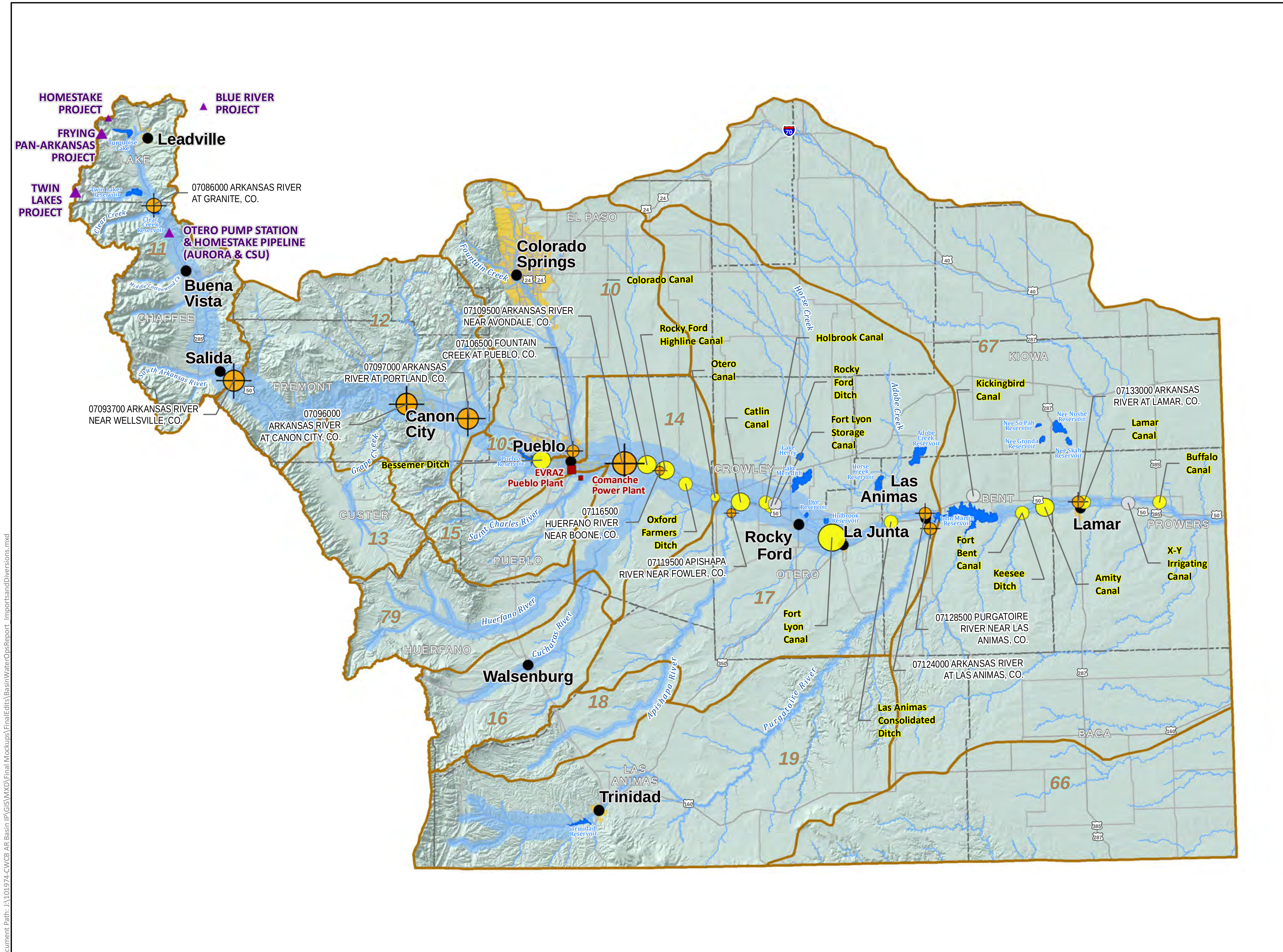


Figure 5
Imports and Diversions

DRY YEAR [WR 2005]

Arkansas River Basin Implementation Plan

Streamflow - Width is proportional to annual flow volume

Water District

Major Imports and Diversions
Symbol size is proportional to annual flow (AFY)

< 1 000 — > 500 000

Symbol Types

- Major Stream Gage
- Major Irrigation System Headgate
- Major Industrial Water User
- Major Transmountain System
- Major Irrigation System Headgate - No Data Available for this year

DRAFT 7/29/2014

Headgate diversions and gages: Historical Records (Hydrobase)
Streamflow widths: National Hydrography Dataset, USGS and Gage Records

0 20 40
Miles

CDM Smith

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Yampa/White, North Platte, South Platte, Colorado, Metro, Gunnison, Rio Grande, Southwest, Arkansas

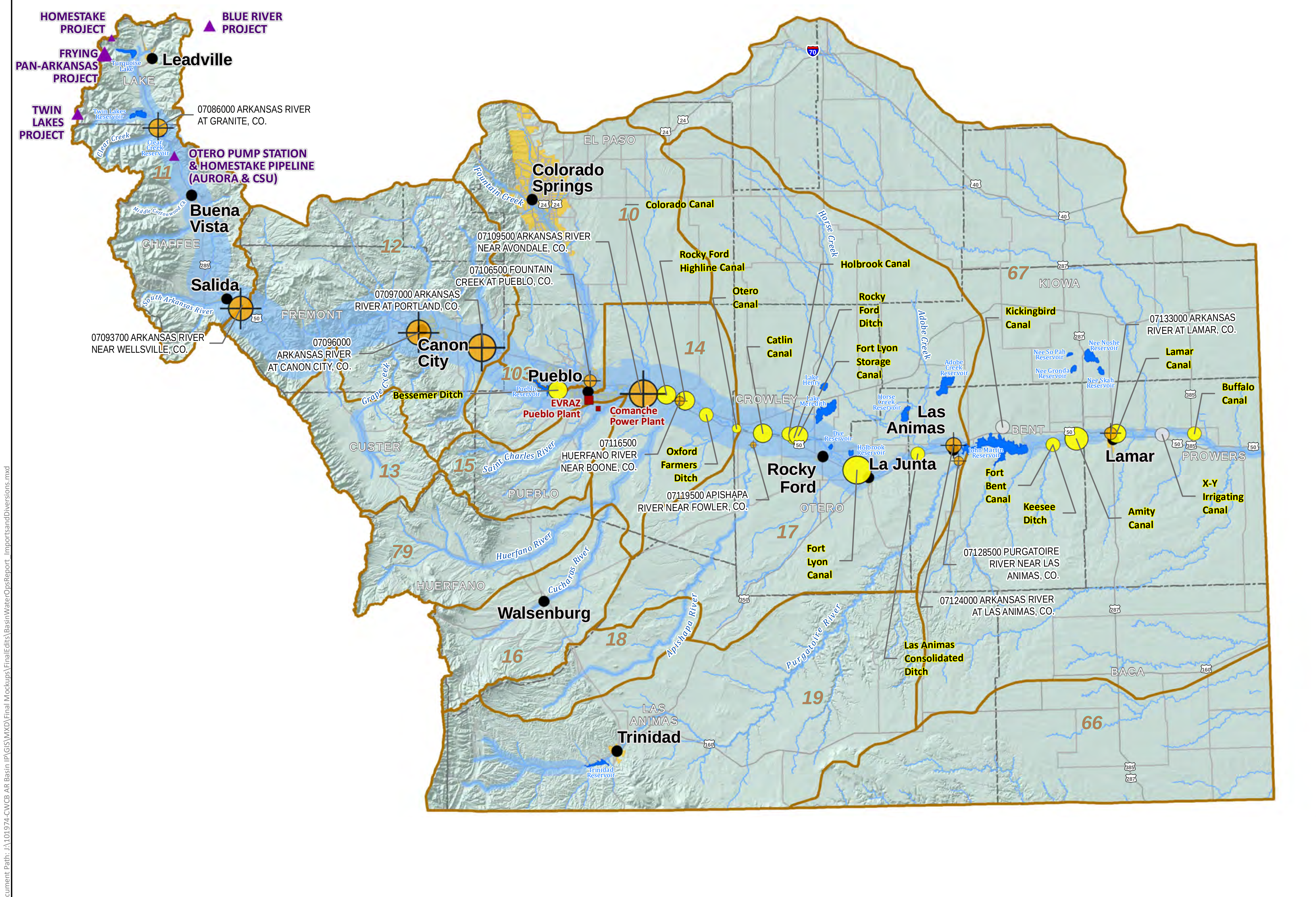


Figure 6
Imports and Diversions

AVERAGE YEAR [WR 2010]

Arkansas River Basin Implementation Plan

Streamflow - Width is proportional to annual flow volume

Water District

Major Imports and Diversions
Symbol size is proportional to annual flow (AFY)

< 1 000 ---- > 500 000

Symbol Types

- Major Stream Gage
- Major Irrigation System Headgate
- Major Industrial Water User
- Major Transmountain System
- Major Irrigation System Headgate - No Data Available for this year

DRAFT 7/29/2014

Headgate diversions and gages: Historical Records (Hydrobase)
Streamflow widths: National Hydrography Dataset, USGS and Gage Records

0 20 40
Miles

N W E S

CDM Smith

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

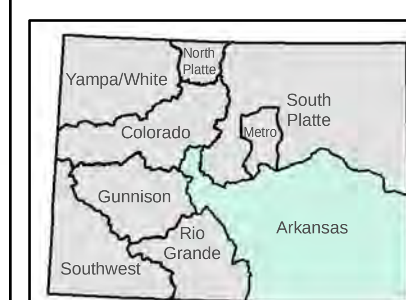
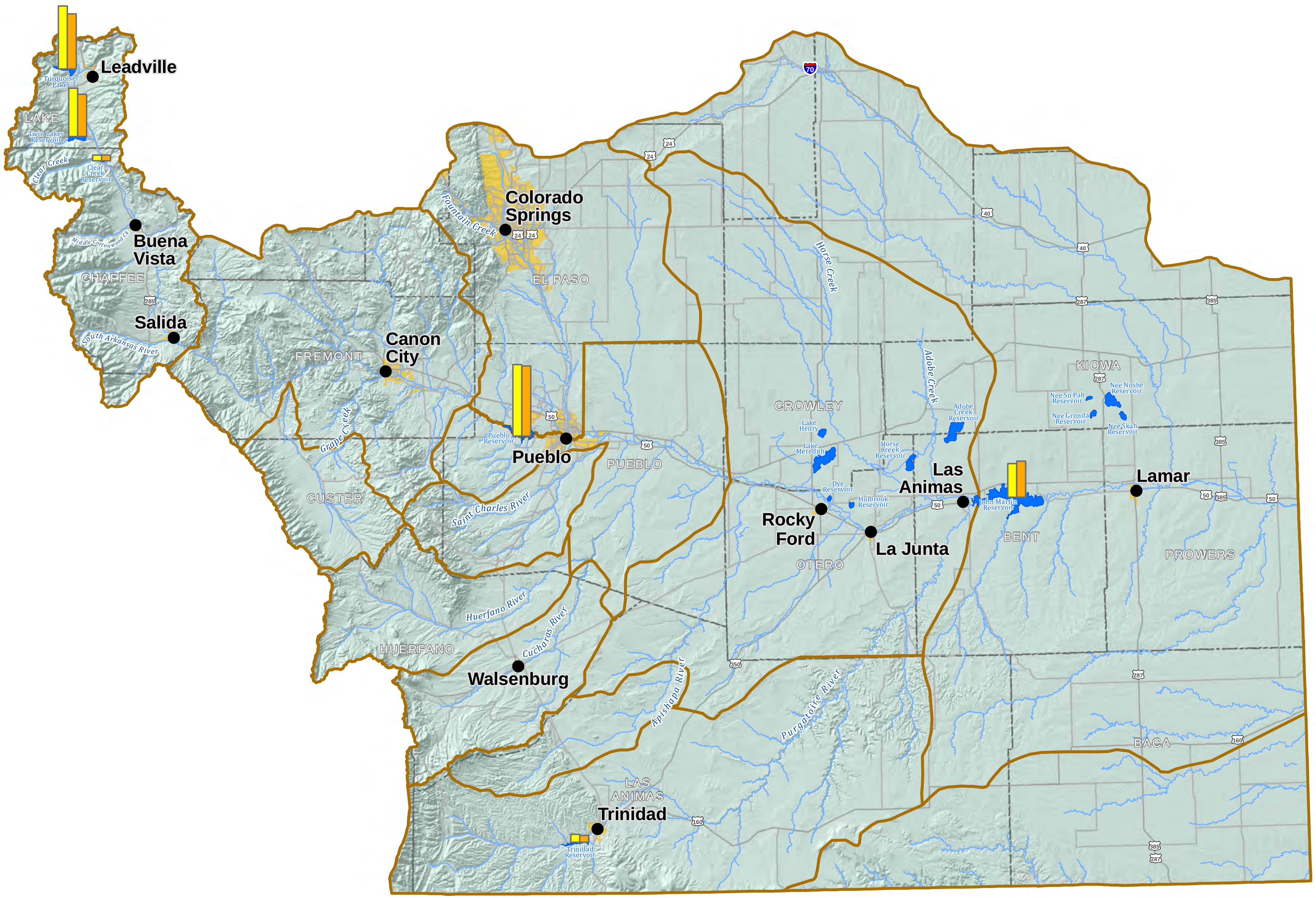


Figure 7
Reservoir Storage and Release

WET YEAR [WR 2011]

Arkansas River Basin Implementation Plan



Water District

Reservoir Annual Flow (AFY)

49,000

Capture

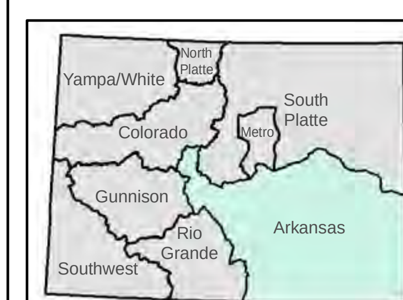
Release

DRAFT 7/29/2014

0 20 40
Miles

CDM Smith

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

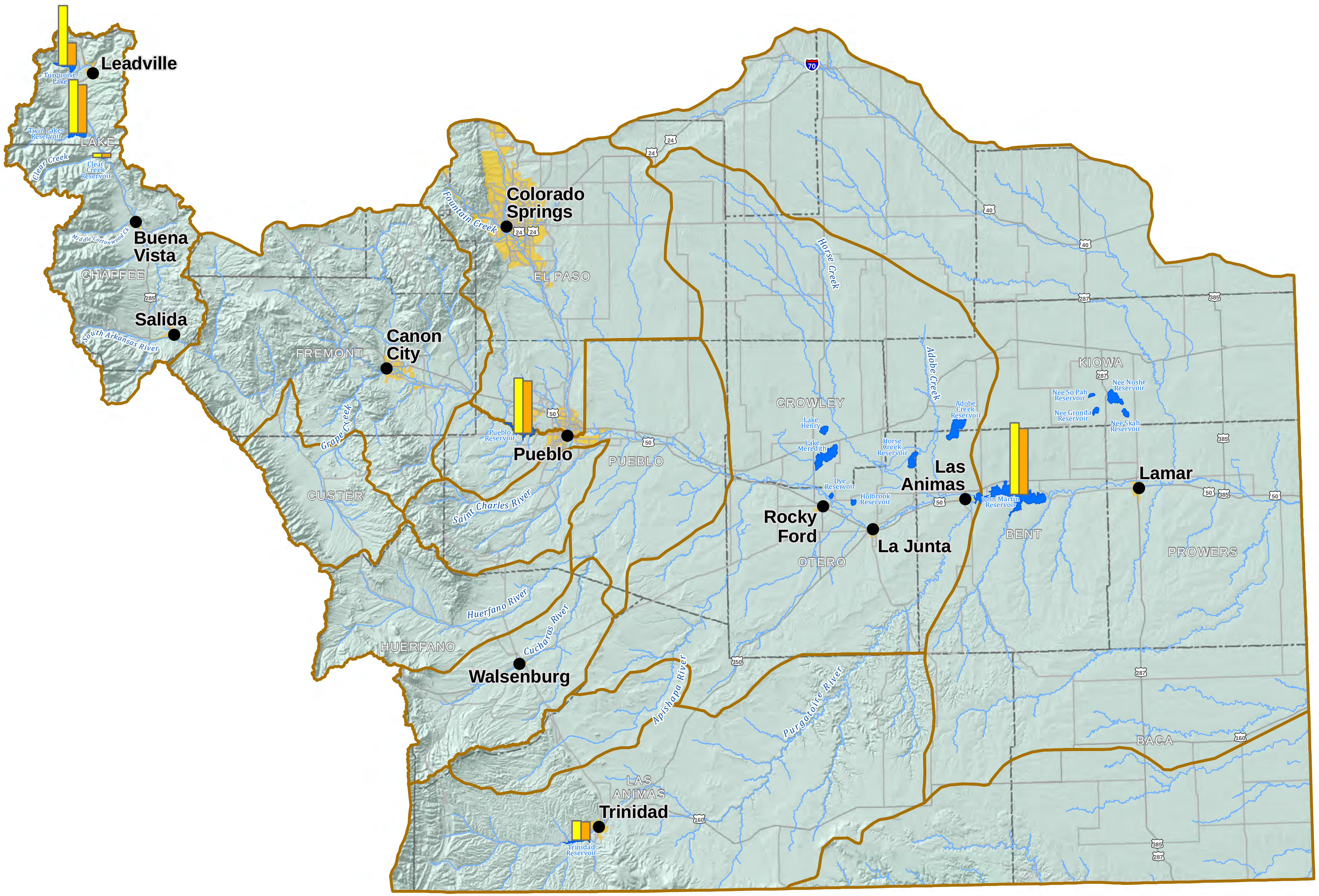


Document Path: J:\101974-CWCB AR Basin IP\GIS\MXD\Final Mockups\FinalEdits\BasinWaterOpsReport_Reservoir.mxd

Figure 8
Reservoir Storage and Release

DRY YEAR [WR 2005]

Arkansas River Basin Implementation Plan



Water District

Reservoir Annual Flow (AFY)

39,000

Capture

Release

DRAFT 7/29/2014

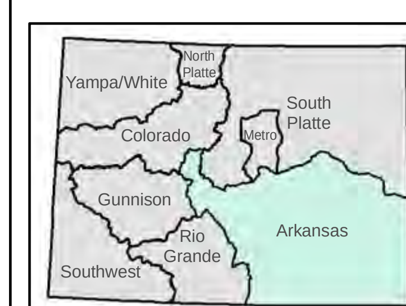
0 20 40

Miles

N W E S

CDM Smith

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

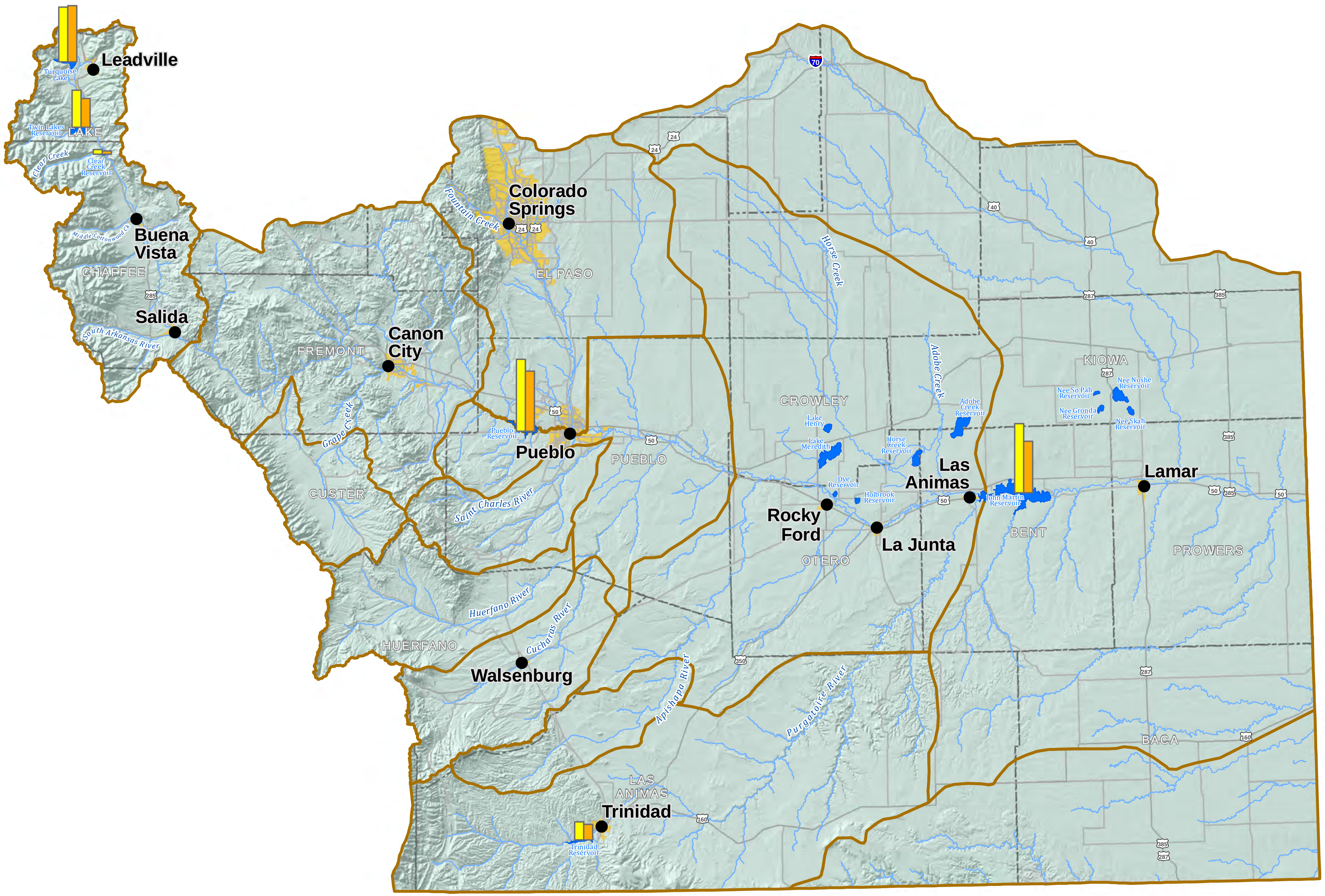


Document Path: J:\101974-CWCB AR Basin IP\GIS\MXD\Final Mockups\FinalEdits\BasinWaterOpsReport_Reservoir.mxd

Figure 9
Reservoir Storage and Release

AVERAGE YEAR [WR 2010]

Arkansas River Basin Implementation Plan



Water District

Reservoir Annual Flow (AFY)

45,000

Capture

Release

DRAFT 7/29/2014

0 20 40
Miles

CDM Smith

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

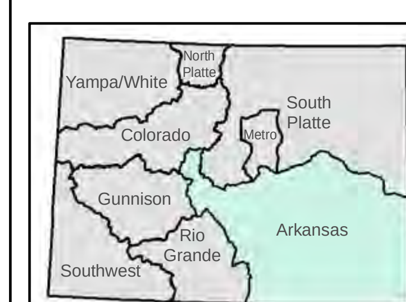
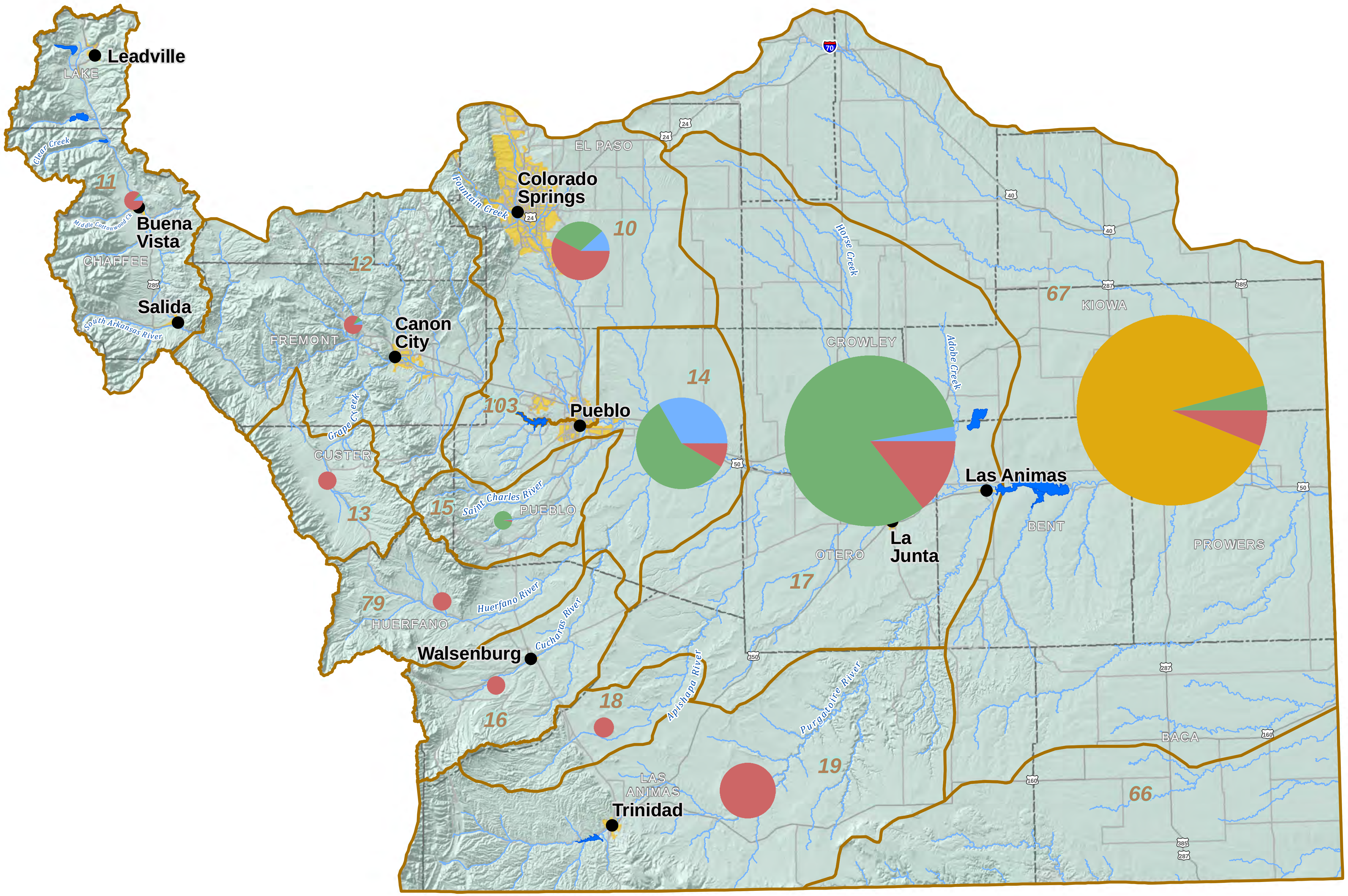


Figure 10
Groundwater Pumping
WET YEAR [WR 2011]

Arkansas River Basin Implementation Plan



Water District

Major Well Assocation

- AGUA
- CWPDA
- LAWMA
- Other

<u>Groundwater Pumping</u>
[by well association and water district]
Symbol size is proportional to
sum use by all users (AFY)

< 100
1000
>= 5 000

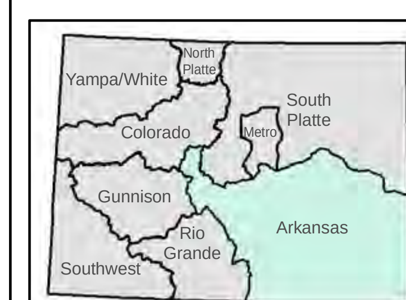
DRAFT 7/29/2014

Pumping Data: Department of Natural Resources records

0 20 40
Miles

CDM Smith

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

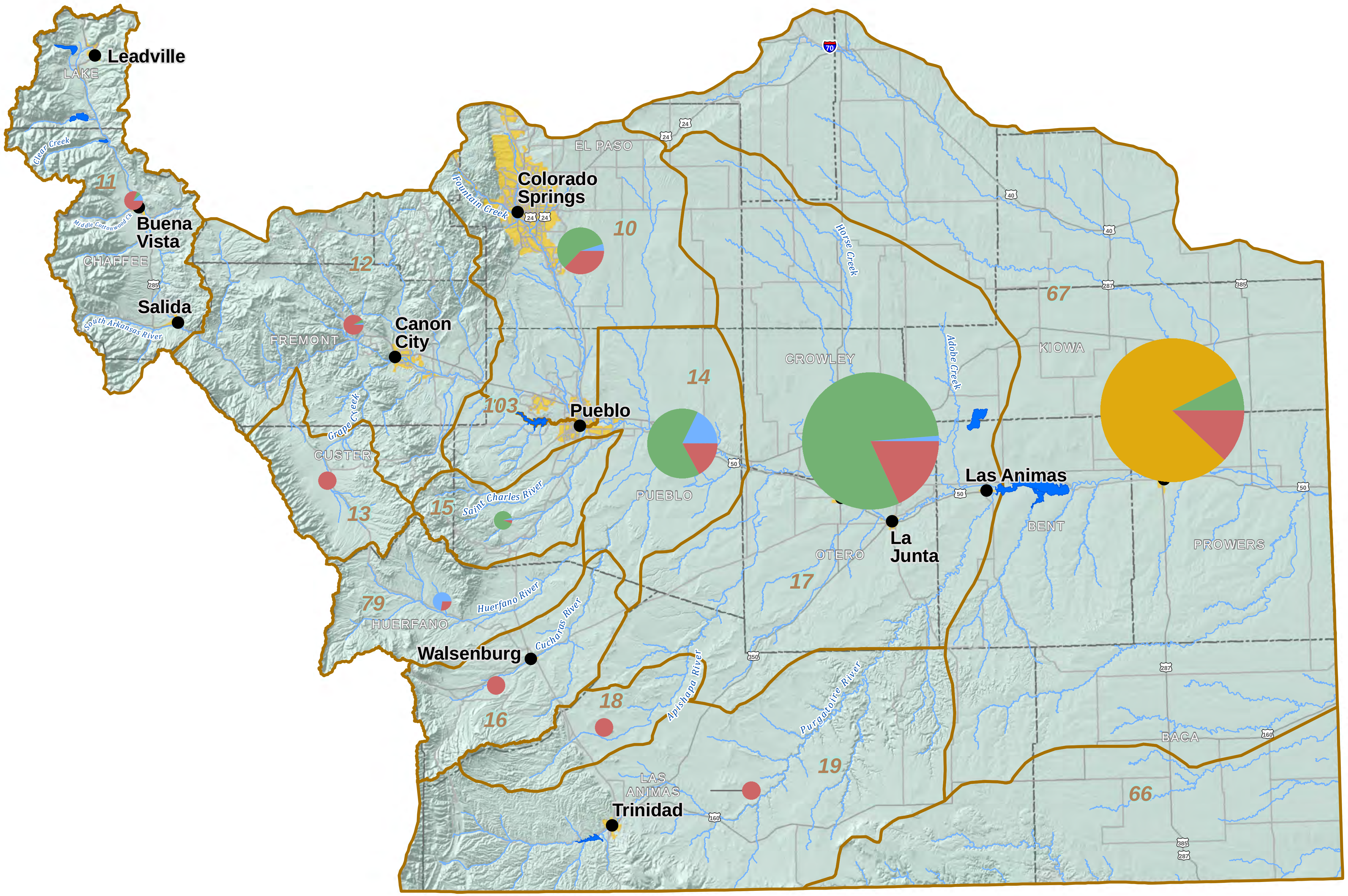


Document Path: J:\101974-CWCB AR Basin IP\GIS\MXD\Final Mockups\FinalEdits\BasinWaterOpsReport_Groundwater.mxd

Figure 11
Groundwater Pumping

DRY YEAR [WR 2005]

Arkansas River Basin Implementation Plan



Water District

Major Well Assocation

- AGUA
- CWPDA
- LAWMA
- Other

Groundwater Pumping
[by well association and water district]
Symbol size is proportional to
sum use by all users (AFY)

< 100
1000
>= 5 000

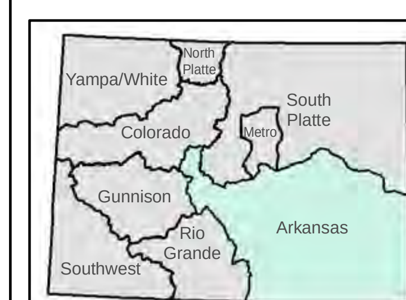
DRAFT 7/29/2014

Pumping Data: Department of Natural Resources records

0 20 40
Miles

CDM Smith

COLORADO
Colorado Water Conservation Board
Department of Natural Resources



Document Path: J:\101974-CWCB AR Basin IP\GIS\MXD\Final Mockups\FinalEdits\BasinWaterOpsReport_Groundwater.mxd

Figure 12
Groundwater Pumping

AVERAGE YEAR [WR 2010]

Arkansas River Basin Implementation Plan

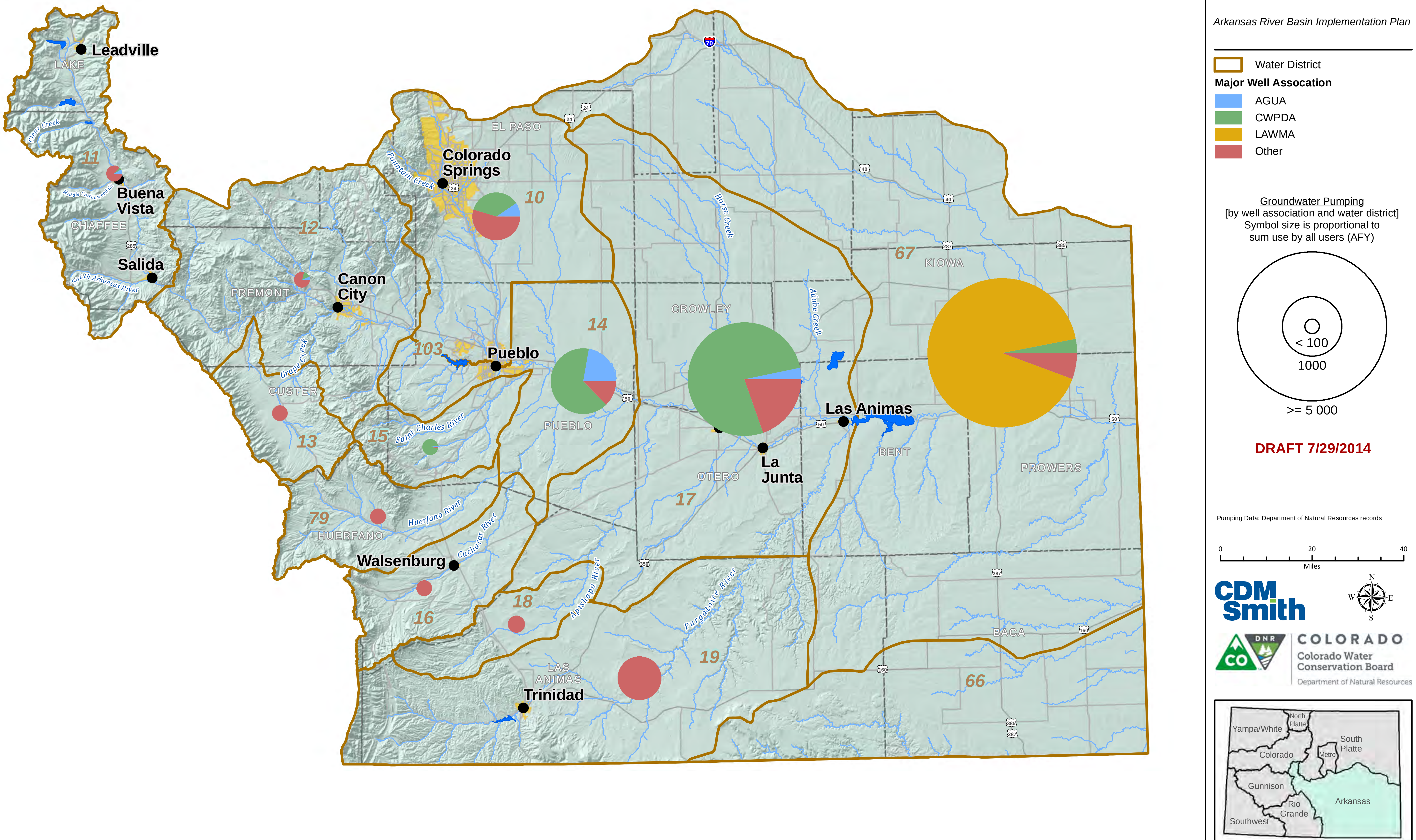


Table of Contents

Figures

Tables

3.2. Water Management and Administration in the Arkansas BIP

This report is an overview of the water administration in the Arkansas River Basin (Basin) and is intended to be part of the Basin Implementation Plan (BIP) currently under development by the Arkansas Basin Roundtable (Roundtable). This report will become or be integrated into Section 3 of the Arkansas Basin Implementation Plan (BIP).

3.2.1 Introduction

The purpose of this task is to provide a common understanding of water administration and Arkansas River Compact administration policies. This will aid the Roundtable with a better understanding how these policies impact water use in the Basin.

Water administration in the Basin can be grouped into the following topics:

- Arkansas River Compact Administration
- Surface Water Administration
- Groundwater Administration

This document is not intended to provide legal guidance or advice but to rather summarize the statutes, policies, and rules and regulations that impact water administration and use as it relates to water resource operations in the Basin.

3.2.2 Arkansas River Compact

Background

The history of litigation between Kansas and Colorado with respect to the flows of the Arkansas River extends back to early 1900s when Kansas sued Colorado in the U.S. Supreme Court in the case referred to as **Kansas v. Colorado** (1907). Kansas sought to have Supreme Court apportion the waters of the Arkansas River. The Supreme Court ruled that Kansas did not show that there was any economic damage to Kansas but did state that "there will come a time when Kansas may justly say there is no longer an equitable division of benefits and may rightfully call for relief." This decision did provide important guidance to all states sharing a river basin that there should be an equitable apportionment of the water supplies of that river.

In 1928 Colorado filed a complaint with the U.S. Supreme Court in a case referred to as **Colorado v. Kansas** (1943). This litigation was intended to settle a series of lawsuit filed by Kansas irrigators beginning in 1910 to attempt to adjudicate interstate priorities for waters of the Arkansas River. There were negotiations among the states with respect to a compact but no success was reached. The Special Master assigned to the case submitted his report to the Supreme Court in May of 1943 with recommendations. The Supreme Court did not adopt the Special Master's recommendations and found that:

- Colorado should not be subject to future litigation from Kansas irrigators.
- It denied Kansas demand for an apportionment of the water of the Arkansas River.
- The Supreme Court strongly advised the states to settle future disputes through negotiations of an interstate compact.

The states agreed to initiate compact negotiations in 1945 and appointed commissioners to represent each state. Congress in 1945 passed legislation granting both states the right to negotiate compact including the operations of John Martin Reservoir that was nearing completion. The reservoir was constructed by the Army Corps of Engineers and construction began on the dam in August of 1940. Hans Kramer, retired Brigadier General, was appointed as the federal representative. After intensive negotiations, the compact was signed on December 14, 1948. It was approved by both state legislatures and the U.S. Congress in 1949.

Arkansas River Compact Features and Administration

The Arkansas River Compact does not have a quantifiable allocation of water to either state unlike other compacts that Colorado entered into and have one of the following quantifiable features:

- A delivery obligation at the Stateline such as in the Rio Grande Compact or the La Plata River Compact.
- An allocation of consumptive use among the states as in the Colorado River Compacts and the Republican River Compact.
- The operation of a common water rights administration system across the Stateline such as the Costilla Creek compact and the South Platte River Compact.

Instead the Arkansas River Compact limited the future development (post compact) in Colorado and Kansas so as to not deplete the usable flow of the river above the Stateline to the detriment of precompact water rights in each state. The key provision is Article IV D. which states:

> This compact is not intended to impede or prevent future beneficial development of the Arkansas River basin in Colorado and Kansas by federal or state agencies, by private enterprise, or by combinations thereof, which may involve construction of dams, reservoirs and other works for the purposes of water utilization and control as well as the improved or prolonged functioning of existing works: Provided, that the waters of the Arkansas River shall not be materially depleted in usable quantity or availability for use to the water users in Colorado and Kansas under this compact by such future development or construction.

Thus, the compact is basically protecting existing development as of 1948 including John Martin Reservoir from any material depletion by post compact activities or development. At times of high flow when all precompact water rights and John Martin Reservoir are satisfied, it may be possible to divert under a post compact water right. This has only occurred five times since 1954.

The compact provides for the storage of water in John Martin Reservoir commencing on November 1 and continuing to March 31 of the following year and is referred to as winter storage. The water can be released at the rate of up to 750 cfs for Colorado users and up to 500 cfs for Kansas water users which is a 60/40 division of the water stored. The compact allows either state to call for water from storage beginning April 1. If the content of John Martin Reservoir is less than 20,000 ac-ft, the release rates are reduced to 600 cfs for Colorado water users and 400 cfs for Kansas water users.

Summer storage is also allowed in John Martin Reservoir provided Colorado is not administering water rights below John Martin Reservoir. Any summer stored water is to be released on the same 60/40 ratio as for winter stored water.

The compact is administered by a seven member compact administration with a non-voting federal representative appointed by the President acting as chair person and with three members appointed by the Governor of each respective state. Each state has only one vote on any compact action and thus to approve any action requires unanimous approval of the compact administration.

The states often would call for releases of winter stored water shortly after April 1 and the reservoir was often drawn down before the irrigation season was very far along. This "race" to use the water at the rate of releases set forth in the compact led to the compact administration amending the operations in 1980 by allocating the water stored in John Martin Reservoir based on volume with Colorado receiving 60 percent and Kansas 40 percent. The water could be released when any state desired and can be carried over if desired. Colorado ditches are allocated a fixed percentage of the Colorado allocation and have separate accounts in the reservoir. The amendment of the operations was accomplished by the compact administration approving the "Resolution Concerning an Operating Plan for John Martin Reservoir" on April 24, 1980 and is referred to as the 1980 Operating Plan. This change in operation allowed for better management and use of the waters stored in the reservoir. The Division Engineer for Water Division 2 is required to give an accounting of the operations under the plan no later than December 1 of each year.

The compact administration also approved a resolution in 1976 creating a permanent pool of 10,000 ac-ft for the purposes of fish, wildlife, and recreation in John Martin Reservoir. The pool is to be filled by Colorado water rights owned by the Colorado Division of Parks and Wildlife. The pool will be charged its prorata share of evaporation from the reservoir.

Post Compact Water Development

After the compact was signed, there was post compact development related to the construction of large capacity tributary wells along the Arkansas River as described in the Tributary Groundwater Section below. At that time, especially during the drought of the 1950s, it was not recognized that the construction of these wells would impact the flow of the Arkansas River. The number of wells constructed increased until the 1965 Ground Water Management Act as discussed in the Tributary Groundwater Section below. Unfortunately, the number of post compact wells in operation along the

Arkansas River was around 3000. The pumping of these wells were subject to the 1973 use rules until the 1996 amended use rules were adopted.

The Fry-Ark Project including Pueblo Reservoir became operational in 1975 with the completion of Pueblo Dam. The project was authorized to store water imported from the Colorado River Basin and to store water in the enlarged Turquoise Reservoir and the enlarged Twin Lakes Reservoir as well as Pueblo Reservoir. As described in the Winter Water Storage Section below, the Fry-Ark Project authorizing legislation included the Winter Water Storage Program, which involves the storage of precompact water rights in Pueblo Reservoir and other existing off-channel reservoirs.

Trinidad Reservoir was completed in 1977 and its primary purposes as set forth in the authorizing federal legislation were:

1. Control of floods originating above the reservoir for the benefit of the City of Trinidad and downstream reaches.
2. Optimum beneficial use of available water for irrigation and municipal and industrial use through:
   a) Transfer of the storage decree in the Model Reservoir for 20,000 ac-ft annually.
   b) Storage of flood flows which would otherwise spill from John Martin Reservoir
   c) Storage of winter flows that were historically diverted for winter irrigation of project lands.
3. Maintenance of a minimum pool for fishery and wildlife enhancement values.

Litigation with Kansas over Post Compact Development

In 1985, Kansas filed a request with the U.S. Supreme Court for permission to file a lawsuit against Colorado over compliance with the Arkansas River Compact and specifically the post compact development described previously. Kansas alleged that the operation of post compact wells, the Winter Water Storage Program, and the operation of Trinidad Reservoir had violated the compact. The Supreme Court granted Kansas' motion to file a complaint in March of 1986.

The trial was bifurcated into a liability phase and a remedy phase. The liability phase of the trial commenced on September 17, 1990 in front of Special Master Arthur Littleworth and concluded on December 16, 1992. The Special Master issued his report with recommendations to the Supreme Court in July of 1994. He recommended a finding that the increase of groundwater pumping in Colorado had caused serious depletions of usable Stateline flow in violation of Article IV-D of the compact. He also recommended a finding that Kansas did not prove that the operation of the Winter Water Storage Program had caused material depletions of Stateline flow. He also recommended dismissal of the claim concerning Trinidad Reservoir. Both states filed exceptions to the report and a hearing was held in front of the Supreme Court. The Supreme Court overruled the exceptions on May 15, 1995.

Subsequent hearings in front of the Special Master resulted in a final determination that the depletions to usable Stateline flow from 1950 through 1996 were 428,005 ac-ft. The economic damages to Kansas based on these depletions was also determined and found to be $34,615,146, which Colorado paid to Kansas on April 29, 2005.

As a result of the first report of the Special Master in July of 1994, the State Engineer adopted amended groundwater use rules in 1996 as described in the previous section. The Special Master was impressed with Colorado's efforts to come into compliance with the compact and so stated in his second report to the Supreme Court in 1997. Based on the opinions of Colorado's experts, the Special Master also recommended that compact compliance be determined using the H-I Model over a 10-year moving period to smooth out annual variations in the model's operation. The Supreme Court agreed with this recommendation and the first 10-year period was 1997 to 2006. The results of the model run for this period showed a credit for Colorado and each subsequent 10-year period has shown a credit and no depletions. For the period 2003 to 2012, the credit had grown to 58,708 ac-ft indicating that the amended use rules are in fact working as intended and that Colorado is in compliance with the compact.

Continuing to Comply with the Compact

Colorado has been vigilant in efforts to comply with the compact after the finding about post compact well development and the fiscal impact as a result of the damages awarded Kansas. The Irrigation Improvement Rules discussed in the section below are an example of this effort to not allow irrigation system improvements to cause an additional depletion to Stateline flows.

The storage of water in post compact reservoirs using post compact water rights continues to be closely monitored and prohibited by the Division Engineer. New reservoirs can only store water from transbasin sources or from changed precompact water rights that allow the water from these water rights to be fully consumed including return flows from a previous use such as municipal sewage effluent. Water from nontributary groundwater sources can also be stored in a new reservoir or an existing post compact reservoir.

3.2.3 Surface Water Administration

Surface water in the Basin is administered separately but in conjunction with groundwater to be in accordance with Colorado water law and compact administration. Colorado administers water rights according to the Doctrine of Prior Appropriation, first in time, first in right, which gives older senior water rights priority over newer junior water rights when water is not available to the senior water right.

Doctrine of Prior Administration

A water right in Colorado is a right to use, in accordance with its priority, a certain portion of the waters of the state by reason of appropriation. Appropriation is the application of a specified portion of the waters of the state to a beneficial use. A water right in Colorado arises by application of water to beneficial use and is confirmed by a Water Court decree, which determines the amount and priority of the water right for the purposes of administration by state water officials. The appropriation date (date of first use) of each water right generally establishes the "rank" or priority of the right, the first right (the senior right) having priority over those rights that are later in time (junior rights). There is an exception to this general principle if a water right was not adjudicated in the first possible adjudication, it will have a lower priority than any water right adjudicated in the prior adjudication even if its appropriation date is older than any other water right in the prior adjudication. Therefore, the priority of a water right is based on the date of first use and the date of adjudication. Decrees for diversions for direct use are approved as a rate in cubic feet per second (cfs); decrees for storage rights are approved as a volume in acre-feet (ac-ft). Water rights are administered by the State Engineer, division engineers, and water commissioners based on the priority of each water right in accordance with the decrees of the Colorado courts and applicable laws, including interstate compacts.

Streamflow Data

In order to administer surface water in Colorado and the Basin, data on streamflow is required in order to make administrative decisions regarding specific surface water diversions that are allowed to divert water according to their priority.

Data on water availability is obtained via several different methods and stored in a centralized water resources database, HydroBase. Streamflows are obtained and recorded at numerous locations within the Basin to assist the water commissioners and division engineer in administering water rights within the Basin. The Hydrography and Satellite Monitoring branch of the Division of Water Resources (DWR) operates and maintains many key stream gages that are at specific locations to support water rights administration. In addition, the U.S. Geological Survey (USGS) operates and maintains other stream gages in conjunction with cooperators that are also used by the DWR to monitor streamflow at other locations within the Basin.

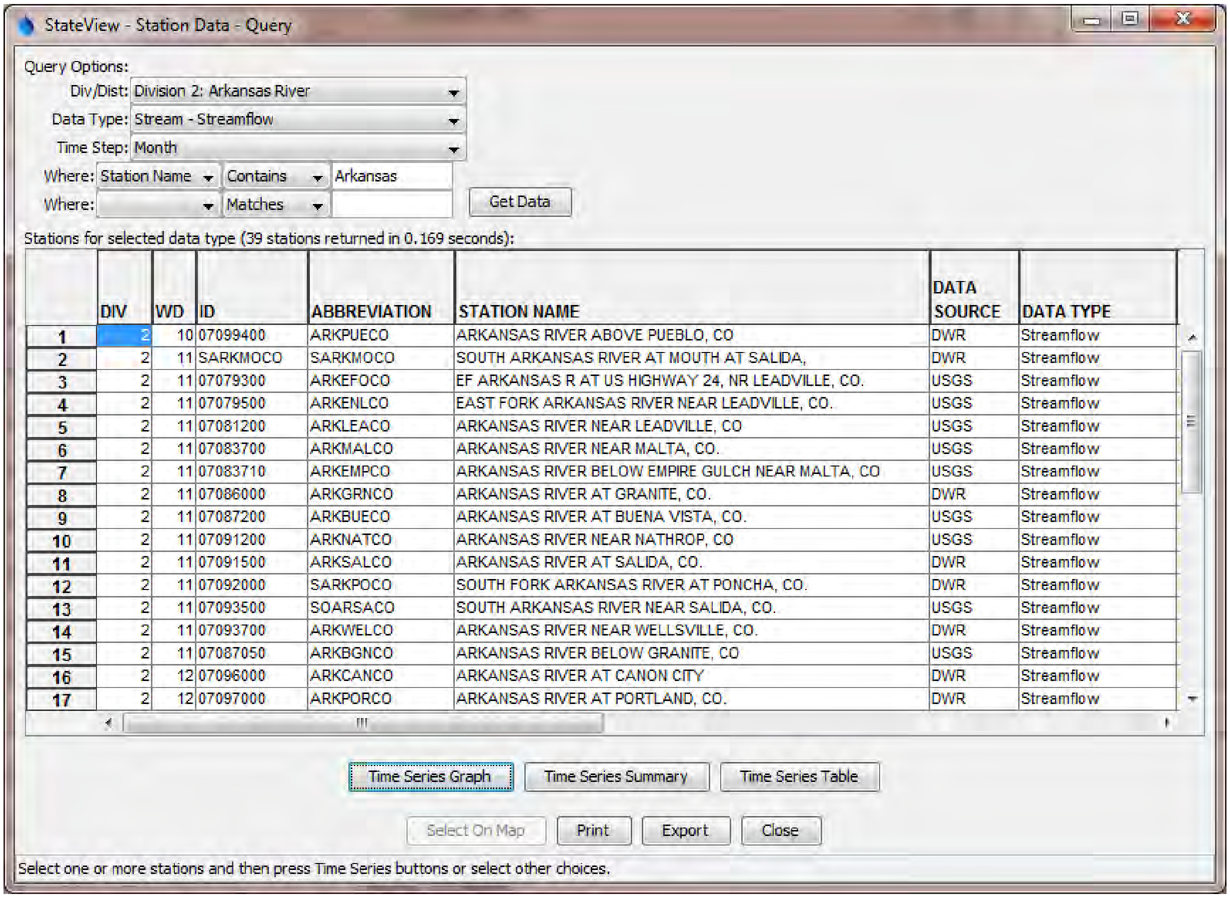
Colorado is the only state in the U.S. that operates its own hydrographic program in order to have the stream gages it needs for water rights administration and also to not have to rely on the USGS Stream gaging program for data. This saves the DWR funds by not having to pay the USGS for operating the gages since the USGS costs would be higher than what it costs the state to operate its stream gaging program.

HydroBase

The DWR and Colorado Water Conservation Board (CWCB) maintain a central database of water resources data within the State of Colorado called HydroBase. HydroBase contains data on streamflow, diversions, storage, and water rights. It is maintained by DWR and is publically available on the state website. HydroBase is updated annually after the irrigation season ends on October 31.

HydroBase also contains conditional and decreed water rights that can be queried using several various parameters to identify water rights.

Figure 3.2.1 - Screenshot of HydroBase Streamflows (via StateView)

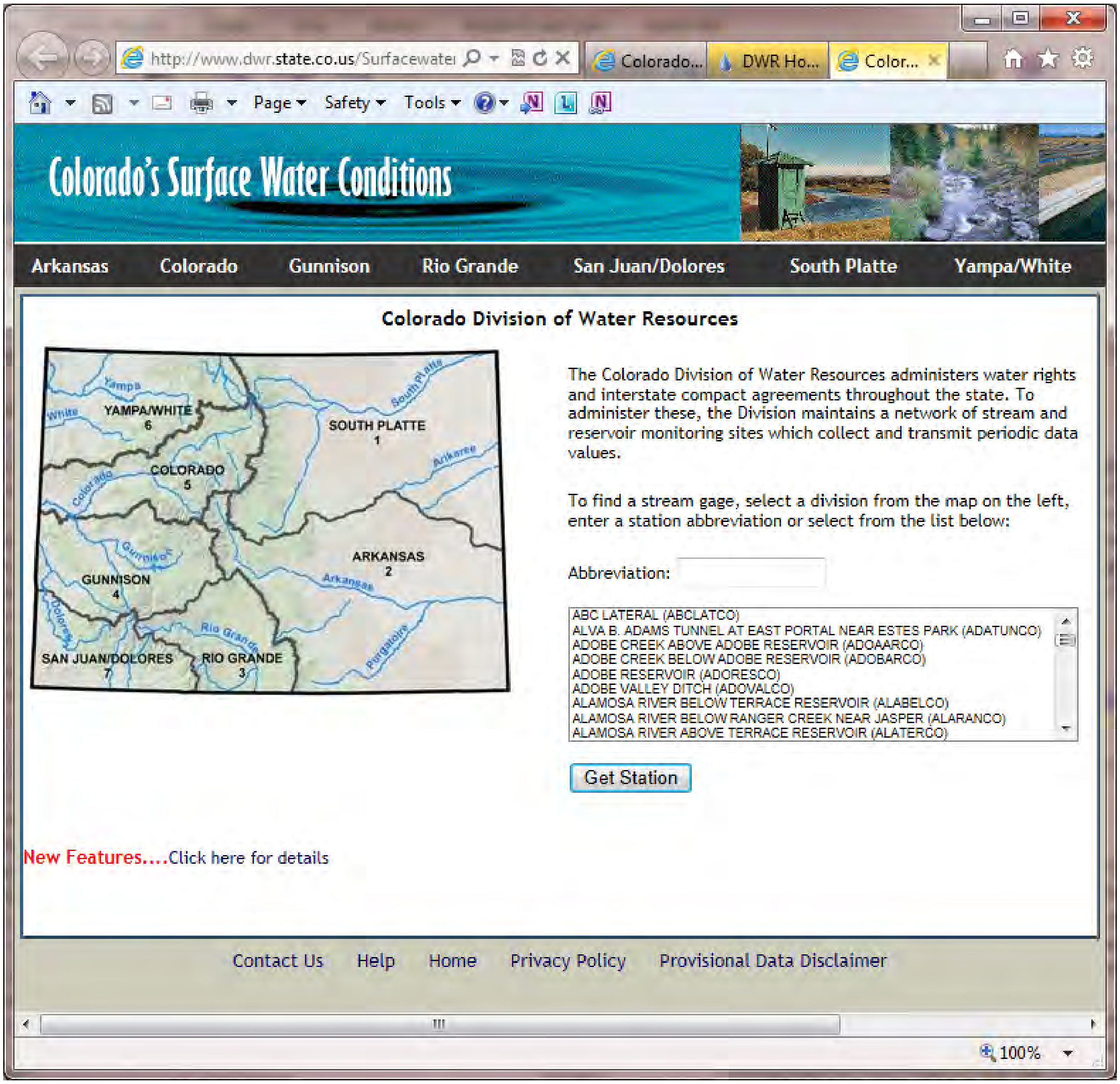


	DIV	WD	ID	ABBREVIATION	STATION NAME	DATA SOURCE	DATA TYPE
1	2	10	07099400	ARKPUECO	ARKANSAS RIVER ABOVE PUEBLO, CO	DWR	Streamflow
2	2	11	SARKMOCO	SARKMOCO	SOUTH ARKANSAS RIVER AT MOUTH AT SALIDA,	DWR	Streamflow
3	2	11	07079300	ARKEFOCO	EF ARKANSAS R AT US HIGHWAY 24, NR LEADVILLE, CO.	USGS	Streamflow
4	2	11	07079500	ARKENLCO	EAST FORK ARKANSAS RIVER NEAR LEADVILLE, CO.	USGS	Streamflow
5	2	11	07081200	ARKLEACO	ARKANSAS RIVER NEAR LEADVILLE, CO	USGS	Streamflow
6	2	11	07083700	ARKMALCO	ARKANSAS RIVER NEAR MALTA, CO.	USGS	Streamflow
7	2	11	07083710	ARKEMPCO	ARKANSAS RIVER BELOW EMPIRE GULCH NEAR MALTA, CO	USGS	Streamflow
8	2	11	07086000	ARKGRNCO	ARKANSAS RIVER AT GRANITE, CO.	DWR	Streamflow
9	2	11	07087200	ARKBUECO	ARKANSAS RIVER AT BUENA VISTA, CO.	USGS	Streamflow
10	2	11	07091200	ARKNATCO	ARKANSAS RIVER NEAR NATHROP, CO	USGS	Streamflow
11	2	11	07091500	ARKSALCO	ARKANSAS RIVER AT SALIDA, CO.	DWR	Streamflow
12	2	11	07092000	SARKPOCO	SOUTH FORK ARKANSAS RIVER AT PONCHA, CO.	DWR	Streamflow
13	2	11	07093500	SOARSACO	SOUTH ARKANSAS RIVER NEAR SALIDA, CO.	USGS	Streamflow
14	2	11	07093700	ARKWELCO	ARKANSAS RIVER NEAR WELLSVILLE, CO.	DWR	Streamflow
15	2	11	07087050	ARKBGNCO	ARKANSAS RIVER BELOW GRANITE, CO	USGS	Streamflow
16	2	12	07096000	ARKCANCO	ARKANSAS RIVER AT CANON CITY	DWR	Streamflow
17	2	12	07097000	ARKPORCO	ARKANSAS RIVER AT PORTLAND, CO.	DWR	Streamflow

Satellite Monitoring System

Another important function of administration is having accurate, timely and reliable data on streamflow. The Satellite Monitoring System (SMS), operated by the Hydrography and Satellite Monitoring branch, provides near real-time gaging station data on streamflow, reservoirs and selected canal diversions at approximately 240 locations in the Basin. Most of this data is reported every hour so it is truly near real time. This near real-time data can be retrieved via the DWR's Surface Water Conditions page (http://www.dwr.state.co.us/Surfacewater/default.aspx), Figure 3.2.2.

Figure 3.2.2 - Screenshot of DWR's Surface Water Conditions



<u>*Water Rights Administration*</u>

The primary utility of the Colorado's SMS is for water rights administration. The availability of real-time data from a network of key gaging stations in each major river basin in Colorado provides an overview of the hydrologic conditions of the basin that was previously not available. By evaluating real-time data for upstream stations, downstream flow conditions can typically be predicted 24 to 48 hours in advance. This becomes an essential planning tool in the hands of the Division Engineers and Water Commissioners. The "river call" can be adjusted more precisely to satisfy as many water rights as possible, even if just for short duration flow peaks caused by precipitation events. Access to real-time data makes it possible to adjust the "river call" to match dynamic hydrologic conditions. If additional water supplies are available in a basin, more junior rights can be satisfied. On the other hand, if water supplies decrease, then water use can be curtailed to protect senior rights.

The administration of water rights in Colorado is becoming increasingly more complex due to increased demands, implementation of augmentation plans, water exchanges, transbasin diversions, and minimum stream flow requirements. For example, the number of water rights in Colorado has increased from 102,028 in 1982 to over 173,000 in 2007. Increasing numbers of water rights has continued to the present. Water rights transfers approved by the water courts are becoming increasingly complex. This is especially evident where agricultural water rights are transferred to municipal use.

There is considerable interest in monitoring transbasin diversions, both by western slope water users and the eastern slope entities diverting the water. Transbasin diversion water is administered differently than water originating in the basin. In general, this water may be claimed for reuse by the diverter until it is totally consumed. Forty transbasin diversions are monitored by the SMS.

Water exchanges between water users or between specific locations are becoming increasingly frequent. These exchanges can provide for more effective utilization of available water resources in high demand river basins, but can be difficult to administer. The satellite-linked monitoring system has proven to be an integral component in monitoring and accounting of these exchanges.

Many municipalities and major irrigation companies have reservoir storage rights. Generally, these entities can call for release of stored water on demand. The Division Engineer must be able to delineate the natural flow from the storage release while in the stream. He/she then must track the release and ensure that the proper delivery is made. The SMS has demonstrated to be effective in this area.

The utility of the SMS in the administration of interstate compacts is an especially important application. Data collected from over 20 gage stations operated by both the Colorado DWR and the USGS are incorporated in the statewide monitoring network and utilized for the effective administration of interstate compacts.

The majority of the large, senior water rights in Colorado belong to irrigation companies. These rights are often the calling right in the administration of a water district. The direct diversion rights exercised can affect significantly the hydrology of the river. Dozens of major irrigation diversions are monitored by the system.

Instream flow water rights have been appropriated by the CWCB to provide minimum instream flows (ISF) in critical stream reaches around the state. These ISF water rights are junior water rights and cannot prevent a senior water right from reducing the flow below the minimum amount appropriated; however, these ISF water rights can protect a stream reach from diversions by junior water rights or from a reach being impacted by a change in use of a senior water right. The availability of real-time data is essential in ensuring that these minimum stream flows are protected to the extent of the law.

Hydrologic Records Development

Specialized software programs provide for the processing of raw hydrologic data on a real-time basis. Conversions such as stage-discharge relationships and shift applications are performed on a real-time basis as the data transmissions are received. Mean daily values are computed automatically each day for the previous day. Data values that fall outside of user defined normal or expected ranges are flagged appropriately. Flagged data values are not utilized in computing mean daily values. Missing values can be added and invalid data values corrected by the respective hydrographer for that station using data editing functions.

Data can be retrieved and displayed in various formats including the standardized USGS-Water Resources Division annual report format adopted by the Colorado DWR for publication purposes. An advantage of real-time hydrologic data collection is in being able to monitor the station for ongoing valid data collection. If a sensor or recorder fails, the hydrographer is immediately aware of the problem and can take corrective action before losing a significant amount of data.

It is essential to understand that real-time records can be different from the final record for a given station. This can be the result of editing raw data values because of sensor calibration errors, sensor malfunctions, analog-to-digital conversion errors, or parity errors. The entering of more current rating tables and shifts can modify discharge conversions. Corrections to the data are sometimes necessary to compensate for hydrologic effects such as icing. Human error can also result in invalid data. The final record for those gaging stations operated by nonstate entities, such as the USGS-Water Resources Division, is the responsibility of that entity. Modifications to the real-time records for these stations are accepted by the State of Colorado.

The Hydrography Branch develops historic streamflow records in coordination with other state and federal entities and the water user community. At the conclusion of each water year, the State Engineer's Office compiles streamflow information and measurements conducted throughout the year for publication. Published streamflow records describe the mean daily discharge, the instantaneous maximum, lowest mean discharge, and monthly/ annual volumetric totals for a specific location on a river or stream. These annual streamflow records are computed using two critical sources of information: streamflow measurements made throughout the water year to calibrate the stage-discharge relationship at a specific site, and the electronic record of stream stage collected by the satellite monitoring system. Using these data, a continuous record of streamflow for the water year is computed. Streamflow records undergo a rigorous data quality control/quality assurance program to ensure the product is accurate. The DWR Hydrographic program computes and publishes over 240 streamflow, reservoir, and canal diversion records annually in the Basin. Published historical streamflow data are extremely valuable in support of water resources planning and management decision-making, assessment of current conditions and comparisons with historical flow data, and hydrologic modeling.

Water Resources Accounting

Currently, the satellite-linked monitoring system is being utilized for accounting for the Colorado River Decision Support System (CRDSS), the Colorado-Big Thompson Project, the Dolores Project, and the Fryingpan-Arkansas (Fry-Ark) Project Winter Water Storage Program among others around the state. The ability to input real-time data into these accounting programs allows for current and ongoing tabulations.

Dam Safety

Dam safety monitoring has developed in recent years into a major issue. Numerous onsite parameters are of interest to the State Engineer in assessing stability of a dam. At this time, the system monitors reservoir inflow, water surface elevation, and reservoir release or outflow at more than 50 reservoirs in Colorado. These data provide a basis for evaluating current operating conditions as compared to specific operating instructions. The installation and operation of additional sensor types could provide essential data on internal hydraulic pressure, vertical and horizontal movement, and seepage rates.

Exchanges

Water exchanges (exchanges) are an important component of surface water administration and water management. Exchanges allow a water user/provider to move water upstream to a point of diversion or reservoir. A water exchange is accomplished by diverting water at one point in a river basin and replacing that water with a like quantity released from a reservoir or from a source that can legally be used for this purpose, which could include transbasin diversions, transbasin diversion return flows, or fully consumable water from a change in use of senior irrigation water rights.

An exchange has a priority among other exchanges based on the date it was first implemented and can be adjudicated by the water court to establish a priority for administration with other exchanges that may be occurring in a reach of the river. Exchanges cannot operate if injury to other water rights would occur and the Division Engineer and water commissioners must carefully administer exchanges to prevent injury.

An example of a simple exchange would be the operations under the Holbrook Canal located on the north side of the Arkansas River near Manzanola. The Holbrook Canal has two reservoirs—Dye and Holbrook Reservoir—that are filled with water from the canal and are located downgradient from the canal so water cannot be released to serve lands under the canal. The reservoir water is released to the Arkansas River to meet the demands of senior downstream water rights and a like amount of water is diverted (exchanged) upstream at the Holbrook Canal headgate to irrigate lands under the canal. The Colorado Canal also has exchanged water from Lake Meredith to its headgate to allow the stored water to be used to serve the lands under the canal.

An example of a more complex exchange is where transbasin return flows from the Colorado Springs wastewater treatment plant in Fountain Creek at the confluence of the Arkansas River are exchanged upstream to Pueblo Reservoir. This water is not native water to the Basin and can be legally reused to complete extinction so it becomes the source of water for the exchange by having this quantity of water flow downstream to meet a senior demand and a like amount of water is stored in Pueblo Reservoir by exchange. Again the Division Engineer and water commissioners must carefully administer the exchange to prevent injury to other water rights.

There are several exchanges of water from the Arkansas River below Pueblo Reservoir upstream to storage in Pueblo Reservoir or even higher upstream to Twin Lakes Reservoir, Turquoise Reservoir, Clear Creek Reservoir, or to the Otero Pumping Plant near Buena Vista for diversion from the Arkansas River by Aurora or Colorado Springs. These exchanges are all decreed by the water court and are operated by Colorado Springs Utility, the Pueblo Board of Water Works, Aurora Water as well as other utilities to a smaller degree. Table 3.2.1 (Table 2, AVC FEIS, Appendix D.1) provides an example of the number and priorities of exchanges from the Arkansas River below Pueblo Reservoir to the reservoir.

Table 3.2.1 - Major Arkansas River Exchange Priorities into Pueblo Reservoir

Priority	Beneficiary	Amount	Case	Priority Date
1	Southeastern	(1)	B42135, 88CW143, 84CW56	2/10/1939
2	Board of Water Works Pueblo	27 cfs	83CW18, 84CW62, 84CW63, 84CW64, 84CW35, 84CW202, 84CW203, 84CW177, 84CW178	6/5/1985
3	Colorado Canal Company Agricultural Entities	100 cfs		
4	Board of Water Works Pueblo	50 cfs		
	Colorado Canal Companies	50 cfs		
5	Colorado Canal Companies	50 cfs		
6	Colorado Springs	77 cfs minus Board of Water Works of Pueblo Exchange under #2 and #4		
7	City of Aurora	Applicable Maximum Rate of Flow Allowed by Decree in 83CW18		
8	Colorado Springs	100 cfs minus Colorado Springs Exchange under #6		
9	Colorado Canal Companies	1/2 of remaining exchange potential up to 756 cfs		
	Colorado Springs	1/2 of remaining exchange potential minus Rocky Ford I under #9		

Priority	Beneficiary	Amount	Case	Priority Date
	City of Aurora	Up to 40 cfs of 1/2, but not to exceed 500 ac-ft annually; thereafter 25% of 1/2 up to an additional 500 ac-ft annually		
10	Colorado Springs	William Creek Reservoir		
11	Pueblo West	6.0 cfs (measured return flows)	85CW134A	12/31/1985
12	City of Aurora (Rocky Ford II)	Applicable Maximum Rate of Flow Allowed by Decree in 99CW169)	99CW169	12/28/1999
13	City of Pueblo	(2)	01CW160	5/15/2000
	City of Fountain	60 cfs	01CW108, 01CW146	(4)
	Southeastern	50 cfs (3)	01CW151	(4)
	Pueblo West	100 cfs	01CW152	(4)
14	Aurora – Rocky Ford Highline	500 cfs	05CW105	(4)
15	Southeastern	Varies	06CW8	(4)
	Restoration of Yield Storage – Holbrook Reservoir	2,000 cfs	06CW120	(4)
16	Super Ditch	Varies	10CW4	(4)
17	Other currently undecreed exchanges, including return flows originating from nontributary groundwater	(5)	(5)	(5)

Notes:
(1) Measured Municipal Fry-Ark Return Flows generated and re-purchased by the same entity.
(2) See discussion on Pueblo Flow Management Program in below sections.
(3) Non-measured Municipal and Agricultural Fry-Ark Return Flows.
(4) Priority yet to be determined.
(5) No water rights application or decree.

Reservoir Storage

Reservoir storage plays an important role in meeting Colorado's water supply needs. Colorado is a headwaters state, meaning that all the water supplies Colorado has falls in the form of precipitation (rain or snow). The timing of runoff plays a key role in water resources planning. To mitigate the runoff pattern (70 percent of annual runoff volume occurring in 3 months) to better match water supply needs both within a year and inter year, many reservoirs have been constructed within the state. Reservoirs have been constructed by various entities and for a variety of purposes including water supply, power generation, recreation, and flood protection.

Pursuant to section 37-87-101, C.R.S., the right to store water for later use is recognized as a beneficial use of water under the Colorado statutes. The structure must be operated in such a manner as to not cause material injury to other water users. Water in Colorado at a time of demand can only be stored when there is a water right to store the water. Storage water rights are obtained in a similar process to direct flow rights and assigned a priority so that they can be administered according to the prior appropriation system.

One Fill Rule

Water may either be stored under a water right under the priority system or in some situations contractually—for instance a user may be able to store reusable water in a reservoir. The one fill rule concerns the storage of water under the priority system. Under Colorado law, a water user may store water whenever the water is physically available, its water right is in-priority, and the decree for the water right has not been filled. Under Colorado Supreme Court decisions, a user is entitled to only one filling of a reservoir water right in any one year unless a user has a water right that provides for a refill and/or additional storage or free river conditions exist (i.e., no downstream shortage of water to meet the demands of all users for their decreed water rights including storage in John Martin Reservoir pursuant to the Arkansas River compact).

Carryover

Generally, any water remaining in a reservoir at the end of the seasonal year is called "carryover water," and is credited to the next year's fill. This will limit the amount of new water to be put into storage during next year's seasonal year. For example, if a reservoir's decreed and physical capacity is 100,000 ac-ft and at the end of seasonal year 1 it contains 60,000 ac-ft, then the carryover would be 60,000 ac-ft for the next year, seasonal year 2. In this situation, the Division Engineer or Water Commissioner would limit the amount the owner could divert and store in seasonal year 2 to 40,000 ac-ft because the 100,000 ac-ft water right is filled once the 40,000 ac-ft is stored. The 40,000 ac-ft limit would exist even if the owner released water from storage during seasonal year 2 and created additional capacity. In this situation, this additional capacity can only be refilled under free river conditions since no other storage rights exist.

Decreed versus Physical Capacity

Given the large investment required for reservoir construction, a potential reservoir owner generally receives a decree for a conditional water right to store an amount of water prior to construction. Upon completion of the reservoir, the actual physical capacity of the reservoir may be different from the decreed capacity. This raises the question of whether the physical capacity or the decreed capacity controls the administration of the amount of water that can be stored. If the physical capacity is less than the decreed capacity, then the allowed amount of fill will be based upon the physical capacity rather than the decreed capacity. For example, when a reservoir is physically full at 50,000 ac-ft and has a decreed capacity of 60,000 ac-ft, then the reservoir has reached its one fill and cannot come back in later in the season when space becomes available to fill the additional 10,000 ac-ft. The difference between the decreed capacity and the lower physical capacity is subject to abandonment (or if conditional[1], to cancellation for failure to prove diligence)[2] unless the reservoir owner shows intent to make subsequent modifications to enlarge the reservoir to the originally decreed capacity [3].

When physical capacity is greater than decreed capacity, a fill is based upon the decreed capacity. To use the additional capacity, the reservoir owner must adjudicate a new water right for the difference, use other foreign water legally available for storage in the reservoir, or hope to fill the difference under free river conditions.

Storable Inflow

Storable inflow is the amount of water that is physically and legally available for storage in a reservoir under a particular water right. After the beginning of the seasonal year, all storable inflow must be accounted against the storage right in order to protect other water users, whether or not the reservoir owner actually stores the water. This assures junior water right users that they will be able to divert water in the amount and time that they could have if the senior storage right had filled with all water available to it under its storage priority. For example, if a reservoir operator with a decree to store 20,000 ac-ft of water chooses to bypass 5,000 ac-ft of water that they would otherwise have been able to store in-priority; the Division Engineer considers the bypassed water "storable inflow." Accordingly, the Division Engineer would credit the bypassed water toward the fill of the reservoir and would consider the storage right to be filled when the reservoir physically contains 15,000 ac-ft of water stored under the storage right.

Refill Rights

Some reservoirs in the Basin operate under decrees that provide for refill rights. A refill right typically has a later priority than the original storage right. However, if the reservoir owner applied for a refill right in the original application, the owner may have been given a right to store under the same priority of the original appropriation after the reservoir achieves its first fill and capacity becomes available. Available capacity for a refill right in a reservoir is created by evaporative and seepage losses in addition to actual storage releases.

Paper Fill, Including Bookover

As discussed below, a paper fill is an accounting mechanism whereby storable inflow is charged against a storage water right either because the reservoir owner elected not to physically divert or store water

[1] A conditional water right is one in which the amount claimed in the decree has not been put to a beneficial use.
[2] Diligence is the process of showing progress towards putting the conditional water right to beneficial use. Evidence is presented to the Water Court on the progress made during the current diligence period.
[3] Decreed capacity is the specified storage capacity in the water court decree.

under that right or a junior upstream reservoir diverted the storable inflow out of priority. Some examples of paper fill are described below, followed by a discussion of some of the exceptions to the general rule. These are not meant to be exhaustive on this issue, but should provide an understanding of the most typical situations.

1. A reservoir may have multiple rights. For example, it may have a senior storage right and a junior storage right for additional decreed uses. If water is stored under the junior right before the senior right is filled, then a paper fill for the amount stored and credited under the junior right will also be charged against the senior storage water right, to the extent that it remains unfilled. Once the senior right is filled (either physically or on paper), the junior right may continue to store under its own priority unless it is (or until it becomes) filled.
2. A paper fill is charged against a water storage right when a reservoir cannot be filled to its decreed capacity because of a flood control limitation on storage (unless flood control is a decreed beneficial use) or because of a State Engineer storage restriction on the dam[4].
3. A paper fill is charged if sedimentation has occurred limiting the reservoir's physical capacity.
4. A paper fill is charged when actual storage in the reservoir includes foreign water that limits the capacity of the reservoir to fill under a senior priority unless the owner of the senior priority books over the foreign water in the reservoir to the senior right at the rate that the senior right would have filled the space taken up by the foreign water.
5. A paper fill is charged for any exchange on natural flow into the reservoir for foreign water. For example, assume an on-stream reservoir user exchanges 20 cfs of foreign water into the reservoir by making release of a substitute supply downstream at the same time the user is entitled to fill the reservoir in priority. In this example, the reservoir would be paper filled for the 20 cfs or approximately 40 ac-ft each day the exchange occurred.

Evaporation

Reservoirs are categorized based on their location from a natural stream as either on-channel or off-channel. When a reservoir is constructed on a natural stream bed (on-channel) it causes an increase in losses to the stream system due to the increase in free water surface area of the stream. When an on-channel reservoir is in-priority and filling, the operator does not have to pay back the stream for this increased loss. However when the reservoir is not filling in priority, the operator is required to release stored water to offset the amount of this increased loss to assure that the total natural flow is passed through the reservoir as if the reservoir did not exist. Usually, the release for this loss is accomplished by lowering the reservoir stage to correspond to the calculated net depletion amount. If daily administration is not practical because of the limited size of a reservoir surface, releases for this loss are often aggregated and made on a monthly rather than daily basis. If more than one water right is in a reservoir or the reservoir contains foreign water, the reservoir owner may specify which type(s) of water to release to account for evaporation.

[4] According to the 2012 State Engineers Dam Safety Report, there are 20 dams in the Basin with restrictions.

When predicting the amount of future evaporation to be replaced for an on-channel reservoir, the average gross evaporation (free water surface) must be calculated based upon average evaporation atlases in National Oceanic and Atmospheric Association (NOAA) Technical Report NWS 33 and the maximum surface area of the reservoir (unless otherwise decreed). The total gross evaporation estimate from NOAA shall be distributed to all months. The monthly distributions for elevations are shown in Table 3.2.2.

Table 3.2.2 - Monthly Distribution of Gross Evaporation.

Month	Gross Evaporation as Percent (below 6500 feet)	Gross Evaporation as Percent (above 6500 feet)
Jan	3.0%	1.0%
Feb	3.5%	3.0%
Mar	5.5%	6.0%
Apr	9.0%	9.0%
May	12.0%	12.5%
Jun	14.5%	15.5%
Jul	15.0%	16.0%
Aug	13.5%	13.0%
Sep	10.0%	11.0%
Oct	7.0%	7.5%
Nov	4.0%	4.0%
Dec	3.0%	1.5%

For some reservoirs, the Division Engineer may require that the owner install a weather station with an evaporation pan in order to obtain more accurate estimates of evaporation. The reservoir evaporation may be reduced by the amount of effective precipitation occurring on that day. The effective precipitation is the precipitation that would not have contributed to streamflow had the reservoir not been constructed. This reduction of gross evaporation reduces the amount of water released to compensate for the evaporation from the on-channel reservoir.

Seepage

As soon as water stored in a reservoir or in the process of being delivered by a ditch seeps through the bottom or sides of the structure, it is considered waters of the state subject to the prior appropriation doctrine. This applies to water that cannot be "re-used" as well as fully-consumable water that is no longer under the dominion and control of the user. A reservoir owner may not recapture seepage water from a reservoir as part of the original storage right unless specifically allowed by decree and may not recapture fully consumable water without dominion and control accounting approved by the division engineer. An appropriator of seepage water cannot require or demand that the seepage continue as the reservoir or ditch owner is generally allowed to make improvements that may eliminate or reduce the seepage.

Winter Water Storage Program

The Winter Water Storage Program became a reality as a result of the completion of Pueblo Reservoir in 1975. The program had been in the conceptual stage since the 1930s when the Fryingpan – Arkansas Project was envisioned.

The agricultural users have some of the most senior rights on the river. In the wintertime, they were able to continue diverting water to their fields as long as there was water in the river available to their water rights in priority. The concept was that although crops needed little or no irrigation during winter months water could be stored in the soil underlying fields. This soil moisture content was important for spring planting and winter wheat. This concept was in place from the 1880s to 1976 when Pueblo Reservoir became available for storing inflows to the reservoir outside the irrigation season. Winter irrigation also prevented junior off-channel reservoirs from diverting in the winter by placing a call on the river.

The concept of Winter Water Storage Program is that there now is an on-channel reservoir to store water to be released later in the growing season allowing for better water management by the farming and ranching communities in the Lower Arkansas Valley. The need for a process of fairly diverting and dividing the amount of Winter Water Storage Program was negotiated among water users and resulted in the 1987 Decree (84CW179) officially recognizing the Winter Water Storage Program. The Winter Water Storage Program is administered by the Division 2 office of the Division of Water Resources.

The Winter Water Storage Program operates from 00 00:00 hours on November 15 of each year to 24:00 hours on March 14 the following spring. Currently, the Division Engineer requires 100 cfs to be passed through Pueblo Reservoir and down the river above the City of Pueblo when possible. Pursuant to the decree, the River Call is artificially set at March 1, 1910 during the Winter Water Storage Program allowing non-participants to divert water during the program period, provided they hold water rights senior to that date and they will not injure any other water users having senior priorities. There are also some further constraints and modifications in additional agreements and stipulations.

Storage is maintained at Pueblo Reservoir via an agreement with the United States Bureau of Reclamation. Additional, off-channel storage is allowed in reservoirs as agreed upon including water users above Pueblo Reservoir. This is also identified in the accounting in the section below. Overall, water is stored and released as prescribed by the decree entered in 84CW179.

The flow of the Arkansas River, including the Winter Water Storage Program, is subject to the Arkansas River Compact of 1948. The U.S. Army Corps of Engineers built John Martin Reservoir on the Arkansas River beginning in 1943 with completion in October 1948 for conservation and flood control purposes. The States of Colorado and Kansas agreed to a federally authorized compact regarding flows on the

Arkansas River in 1948. The Winter Water Storage Program allows storage of some water in John Martin Reservoir and the Compact Administration has approved resolutions permitting use of John Martin for this purpose. The Winter Water Storage Program is operated in compliance with these resolutions and the compact. The winter water allocation for the Winter Water Storage Program is shown in Tables 3.2.3-3.2.5.

Table 3.2.3 - Winter Water Storage Program First 100,000 ac-ft.

From 0:00 hours on Nov 15 to 24:00 hours on Mar 14
Direct Flow Participants
Receive 28.8% of the First 100,000 ac-ft stored

	Percent of the First 28.8% Stored	Percent of the Overall First 100,000 ac-ft
Bessemer	21.50%	6.19%
Highline	28.87%	8.31%
Oxford	6.96%	2.00%
Catlin	31.72%	9.14%
LA Consolidated	9.57%	2.76%
Riverside	0.46%	0.13%
West Pueblo	0.92%	0.26%
Total	100.00%	28.80%

Off Channel Storage Participants
Receive 71.2% of the First 100,000 ac-ft stored

	Percent of the First 71.2% Stored	Percent of the Overall First 100,000 ac-ft
Colorado Canal System	15.01%	10.69%
Holbrook	11.97%	8.52%
Fort Lyon	19.42%	13.83%
Amity	19.42%	13.83%
Total	100.00%	71.20%

Table 3.2.4 - Winter Water Storage Program Next 3,106 ac-ft.

Next 3,106 ac-ft Stored

Amity	2750 ac-ft
Holbrook	356 ac-ft

Table 3.2.5 - Winter Water Storage Program Water over 103,106 ac-ft.

Any Storage over 103,106 ac-ft
Direct Flow Participants
Receive 25.0% of any water over 103,106 ac-ft

	Percent of the First 25% Stored Over 103,106 ac-ft	Percent of the Overall Water Over 103,106 ac-ft
Bessemer	21.50%	5.38%
Highline	28.87%	7.22%
Oxford	6.96%	1.74%
Catlin	31.72%	7.93%
LA Consolidated	9.57%	2.39%
Riverside	0.46%	0.12%
West Pueblo	0.92%	0.23%
Total	100.00%	25.00%

Off Channel Storage Participants
Receive 75.0% of any water over 103,106 ac-ft

	Percent of the First 75% Stored Over 103,106 ac-ft	Percent of the Overall Water Over 103,106 ac-ft
Colorado Canal System	17.07%	12.80%
Holbrook	14.05%	10.54%
Fort Lyon	50.88%	38.16%
Amity	18.00%	13.50%
Total	100.00%	75.00%

Irrigation Improvement Rules

On September 30, 2009 the State Engineer filed the Compact Rules Governing Improvements to Surface Water Irrigation Systems in Basin ("Irrigation Improvement Rules" or "Rules") in the Division 2 Water Court. The Irrigation Improvement Rules are designed to allow improvements to the efficiency of irrigation systems in the Basin while ensuring compliance with the Arkansas River Compact ("Compact"),

§ 37-69-101, C.R.S. (2009). The Rules became effective on January 1, 2011. The rules apply to sprinkler and drip systems installed on or after October 1, 1999.

The State Engineer determined that the improvements to surface water irrigation systems, such as sprinklers and drip systems that replace flood and furrow irrigation, or canal-lining that reduce seepage, have the potential to materially deplete the usable waters of the Arkansas River in violation of the Compact and specifically Article IV-D. The Rules provide a process, referred to as a Compact Compliance Plan, for water users who have or will improve their irrigation systems that will deplete the usable waters of the Arkansas River to maintain historical seepage and return flows using other water sources. The Compact Compliance Plan must be approved annually by the Division Engineer.

3.2.4 Groundwater Administration

Groundwater is a key component of water supplies in Colorado and the Basin. Groundwater is used for municipal, agricultural, industrial, and other uses. Groundwater in Colorado is presumed to be tributary unless shown to be otherwise. Groundwater that is nontributary is water from aquifers that have minimal or no connection with surface waters as described below.

Colorado's' prior appropriation system regulates tributary groundwater. Groundwater other than tributary is defined by Colorado statutes for three additional categories— designated, nontributary, and Denver Basin groundwater.

Groundwater administration in the Basin can be grouped into the following topics:

- Tributary Groundwater
- Nontributary Groundwater
- Denver Basin Groundwater
- Designated Groundwater Basins

Tributary Groundwater

Tributary groundwater is hydraulically connected to a surface stream or alluvium and cannot be appropriated without a well permit from the State Engineer who must find that water is available for appropriation without causing injury to other water rights. If there will be injury to other water rights, the applicant must obtain approval from the water court of a plan for augmentation to replace out-of-priority depletions resulting from the pumping of a well. Since the Arkansas River is over appropriated, no tributary well permits can be issued for non-exempt uses without a plan for augmentation. Exempt uses include household use only wells in a single family dwelling or domestic wells on parcels of land greater than 35 acres and both types of wells must have pumps with a capacity of 15 gallons per minute (gpm) or less.

Tributary well development began in the early 1900s and the number of irrigation wells increased dramatically during the drought of the early 1950s when turbine pump technology along with the availability of electrical power from Rural Electric Associations. The number of large capacity wells increased until the 1965 Ground Water Management Act was approved by the legislature. This legislation focused primarily on the authority of the Colorado Ground Water Commission but did have a provision in section 37-90-137 CRS addressing permits to construct wells outside of designated groundwater basins. This section required that the State Engineer issue a well permit before construction of a well and that there had to be a finding that the use of well would not materially injure vested water rights. This State Engineer began restricting the issuance of well permits in over appropriated basins including the Basin.

In 1969 the legislature approved the Water Right and Determination Act dealing with all water rights including tributary groundwater. The 1969 Act came about in part from the complaints by senior surface water rights in both the Arkansas and South Platte River basins that tributary irrigation wells were reducing stream flow and that the water supply in the streams were declining. The Legislature in 1968 authorized two studies by engineering firms to evaluate the impact of the rapid development of wells. Both studies found that there was a correlation with declining stream flow and well development. The 1969 Act required all tributary large capacity wells to file for adjudication by July 1, 1972 with the new Division Water Courts created by the act. The 1969 Act further required the State Engineer to administer the wells once adjudicated in the priority system. Furthermore, the State Engineer could promulgate rules to assist in the administration of tributary wells.

In1973, the State Engineer promulgated rules for the Basin governing the use of tributary wells. These rules limited pumping to three days per week; Monday, Tuesday, and Wednesday. The 3/7 operational period could modified for different days of pumping if approved by the Division Engineer so long as the pumping was restricted to 3 days. The 1973 Rules were not opposed by the water users. They were not supported by increased staffing and were not effectively enforced.

In 1974, the State Engineer attempted to amend the rules to provide for curtailing wells 5 days per week in 1974, 6 days in 1975, and completely in 1976. These rules were challenged and a trial was held in the Division 2 water court. The outcome was that the court decided that the new rules should not be implemented because there had not been sufficient time to evaluate the effectiveness of the 1973 rules. The decision was appealed by the State Engineer to the Supreme Court which sustained the water court disapproval (Kuiper v. Atchison, Topeka, and Santa Fe, June, 1978). The 1973 rules remained in effect until they were amended in 1996 as discussed below.

1994 Measurement Rules and Regulations

As a result of the litigation with Kansas over the Arkansas River Compact that began in 1985 (Kansas v. Colorado, No. 105 original) when the U. S. Supreme Court granted Kansas the right to sue Colorado over the administration of the compact, Colorado had to begin a more stringent administration of tributary wells in the Basin. There was a need to have accurate well pumping records so that depletions by the tributary wells could be computed using computer models.

In March 1994, the Colorado State Engineers Office (SEO) adopted "Rules Governing the Measurement of Tributary Ground Water Diversions Located in the Arkansas River Basin" (Office of the State Engineer, 1994); these initial rules were amended in February 1996 (Office of the State Engineer, 1996) and again in November 2005 (Office of the State Engineer, 2005). The amended rules require users of wells that divert tributary ground water to annually report the water pumped monthly by each well.

The 1994 measurement rules require all tributary wells (except exempt wells) to be measured by a totalizing flow meter, the power conversion coefficient method or report as inactive (not being used). Exempt wells are wells that are exempt from water rights administration and are not administered under the priority system. In most cases, exempt well permits limit the pumping rates to less than 15 gpm (Guide to Colorado Well Permits, Water Rights and Water Administration; DWR September 2012). Examples of exempt wells include: household use only, domestic and livestock wells, pre-1972 domestic and livestock wells, monitoring and observation wells, and fire protection wells.

Annual Reporting of the monthly water amounts pumped for the period November 1 to October 31 from wells within the Basin meeting the criteria must be reported to the Division Engineer no later than January 31 of the following year.

Totalizing flow meters are required to be re-verified in the field to be in accurate working condition under the supervision of state certified well tester every 4 years. The power conversion coefficient must be re-verified every 2 years. The legislature supported the implementation of these rules by authorizing 4.5 FTEs to enforce the rules.

1996 Ground Water Use Rules and Regulations

In 1996, the original 1973 Rules were amended, and are referred to as the 1996 Ground Water Use Rules. These rules apply to all wells except:

- Exempt wells permitted under 37-92-602 C.R.S.
- Wells located within a designated groundwater basin
- Decreed or permitted non-tributary wells
- Exposure of groundwater in gravel mining operations
- Wells withdrawing from the Denver Basin, Dakota or Cheyenne aquifers

These rules were opposed and a trial was held in 1996 in the Division 2 water court. The outcome was that Judge Anderson upheld the rules and they were promulgated and effective in 1996. The legislature also supported the rulemaking by authorizing 9.5 FTE (Full Time Employees) to enforce the rules.

All wells subject to the rules are required to replace depletions to senior water rights and to Stateline flow. The rules have standard well head depletion factors based on the irrigation method so that the stream depletion can be computed using a computer model jointly developed by both states which is referred to as the H-I Model.

The rules require monthly reporting of well pumping so that the depletions associated with the previous month's pumping as well as the pumping for the prior 240 months can be computed and replaced in the current month. There are few if any river basins anywhere in the world that have tributary groundwater administered on such a near real time basis. When combined with the real time administration of surface water using the SMS, the Basin may be the only basin of this size so administered anywhere.

The rules in Rule 14 allow the State Engineer to approve annual replacement plans for well users that do not have permanent water rights that can be included in a plan for augmentation approved by the water court. The three main well augmentation associations in the Basin—Colorado Water Protective and Development Association (CWPDA), Arkansas Groundwater Users Association (AGUA) and Lower Arkansas Water Management Association (LAWMA)—all operate to some extent with leased water for replacing well depletions and therefore have a need to use the replacement plan rather than water court approved augmentation plans. Although LAWMA does have decreed augmentation plans using changed senior irrigation rights it purchased. In 2013, the State Engineer approved 12 replacement plans under Rule 14. In 2014, 11 replacement plans were approved.

Augmentation Plans

Augmentation plans are a key part of managing Colorado's water resources. In the 1969 act, the General Assembly created the concept of an augmentation plan. An augmentation plan is a court-approved plan designed to protect senior water rights, while allowing junior water rights to divert water out-of-priority and avoid State Engineer curtailment orders.

Augmentation plans allow for out-of-priority diversions by replacing water that junior water right users consume (stream depletions). The replacement water must meet the needs of senior water rights holders at the time, place, quantity and suitable quality they would expect absent the out-of-priority diversions. For example, this would allow a junior water user to pump a tributary groundwater well, even when a river call exists on the stream by providing augmentation or replacement water to the calling water right. The depletions impacting the stream at a time of call, even if from pumping effects in prior years, must be replaced and this often requires complex accounting of pumping, consumptive use of the pumped water, and the computation of the amount and time of stream depletions.

Augmentation water can come from a variety of legally available sources and is provided in a variety of means. An augmentation plan identifies structures, diversions, beneficial uses, timing, and amount of depletions to be replaced. It also identifies how and when the replacement water will be supplied and how the augmentation plan will be operated. Some augmentation plans use stored water to replace diversions. Others use senior water rights whose use is changed to include augmentation. This has been done in the Lower Arkansas River basin below John Martin Reservoir by LAWMA.

Substitute Water Supply Plans

The State Engineer is allowed to approve substitute water supply plans, under certain circumstances, while an augmentation plan application is pending in water court. A notice of a request to approve the substitute water supply plan needs to be provided to all interested parties, so they can provide comments to the SEO.

Substitute water supply plans allow temporary out-of-priority diversions if sufficient replacement water can be provided to senior water rights to offset depletions. Substitute water Supply Plans are approved by the State Engineer for a defined period. Substitute water supply plans differ from Augmentation plans, which are long-term and must be approved by the water courts. In the Basin approximately 50 to 100 are approved per year.

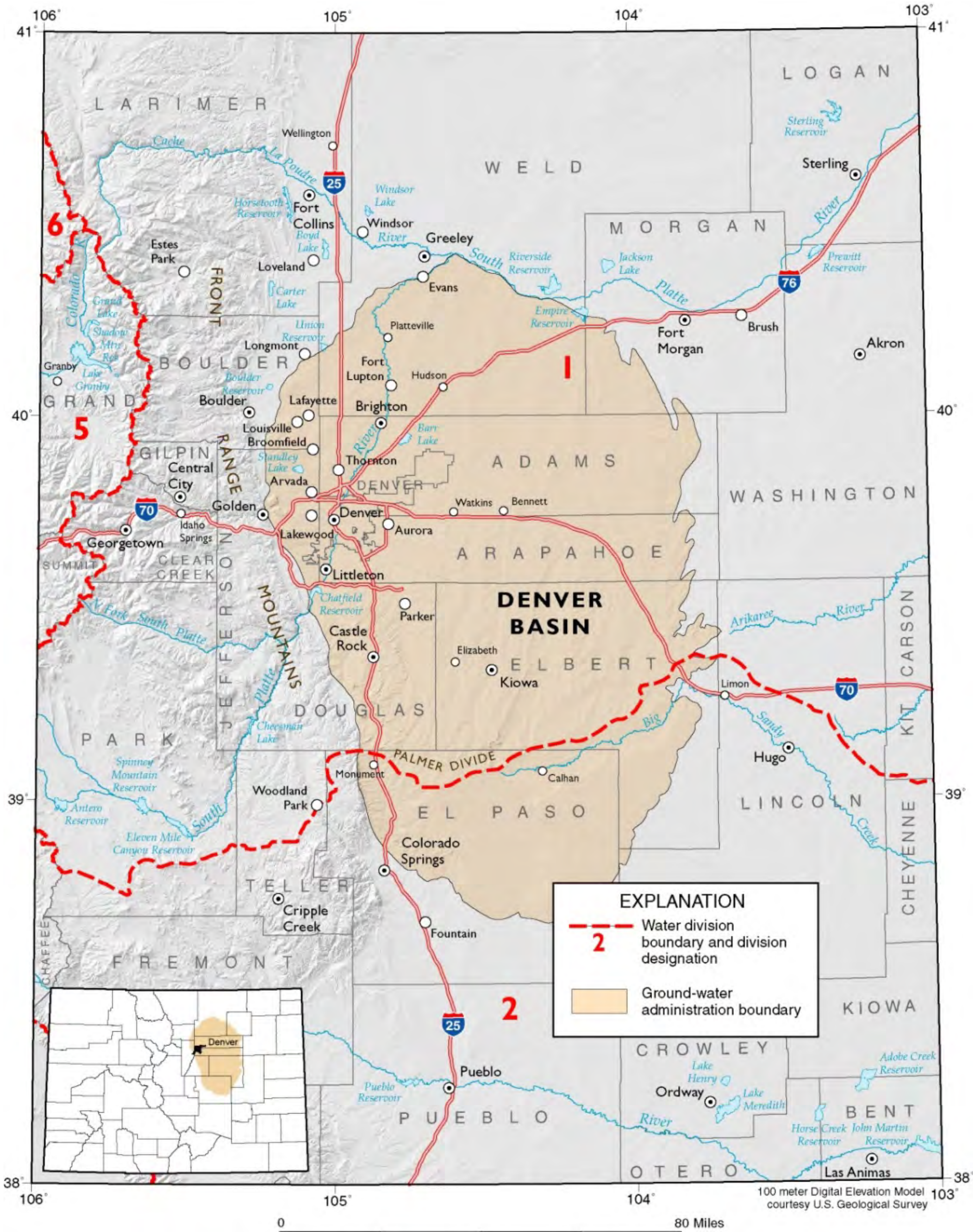
After review, the State Engineer will define the term and conditions of the plan to assure that the operation of the plan will replace all the out-of-priority depletions in time, location, and amount to prevent injury to other water rights.

Nontributary Groundwater including the Denver Basin

The northern portion of the Basin overlies the southern portion of the Denver Basin aquifers in northern El Paso and southern Elbert Counties, Figure 3.2.3. Some water providers in this area rely on the Denver Basin aquifers for their water supplies. These aquifers contain both nontributary and not nontributary[5] groundwater. Withdrawing groundwater from the Denver Basin must comply with the Denver Basin Rules as discussed below and the Denver Basin is shown on Figure 3.2.3.

[5] Not nontributary aquifers in the Denver Basin are those that do not meet the definition of nontributary and that are more than one mile from the point of contact with the stream its alluvium.

Figure 3.2.3 - Denver Basin Extent (Source: CGS – Water Atlas image download)



In 1985, complex legislation commonly known as Senate Bill 5 was enacted to address the allocation and use of the Denver Basin aquifers, as well as other nontributary groundwater aquifers statewide. The rules for the groundwater withdrawal from the Denver Basin aquifers are commonly referred to as the "Denver Basin Rules."

By enacting this legislation, the General Assembly established a policy that it was acceptable to mine the Denver Basin aquifers by withdrawing more water than was being recharged by precipitation. These statutes clarified that nontributary groundwater is groundwater "the withdrawal of which will not, within 100 years, deplete the flow of a natural stream at an annual rate greater than 1/10th of one percent of the annual rate of withdrawal." This definition applies to all nontributary aquifers, including the Denver Basin. For parts of the Denver Basin not within a designated groundwater basin, the water court has the jurisdiction to enter decrees for the use of groundwater. Groundwater withdrawals from the Denver Basin and all nontributary aquifers are limited so as to provide for a 100 year aquifer life, allowing the annual pumping of 1/100th of the available water in the aquifer by the overlying land owner, municipality, or service district.

The Denver Basin rules implement the provisions of section 37-90-137 CRS pertaining to the Denver Basin. The Rules include maps of the four aquifers in the basin: Laramie- Fox Hills, Arapahoe, Denver, and Dawson depicting the areas that are nontributary. In these areas, well permits can be granted by the State Engineer without the need for an augmentation plan. The nontributary water can be reused but 2 percent of the water pumped must not be consumed by the user.

For portions of the Denver basin aquifers that are not nontributary and more than one mile from the point of contact of the aquifer with a stream or its alluvium, the statutes require that a water court approved plan for augmentation be in place to replace 4 percent of the amount of water annual withdrawn before the well permit is approved.

For portions of the Denver Basin aquifers within one mile of the contact of the aquifer with a stream or its alluvium, the augmentation plan must replace actual depletions with the assumption that the hydrostatic pressure in the aquifer has been lowered to the top of the aquifer.

In parts of the Basin, the Dakota formation underlies some areas and depending on the conditions, some of the Dakota formation contains groundwater that meets the definition of nontributary groundwater. The remainder of the formation would contain tributary groundwater and new appropriations would not be approved without a water court approved plan for augmentation.

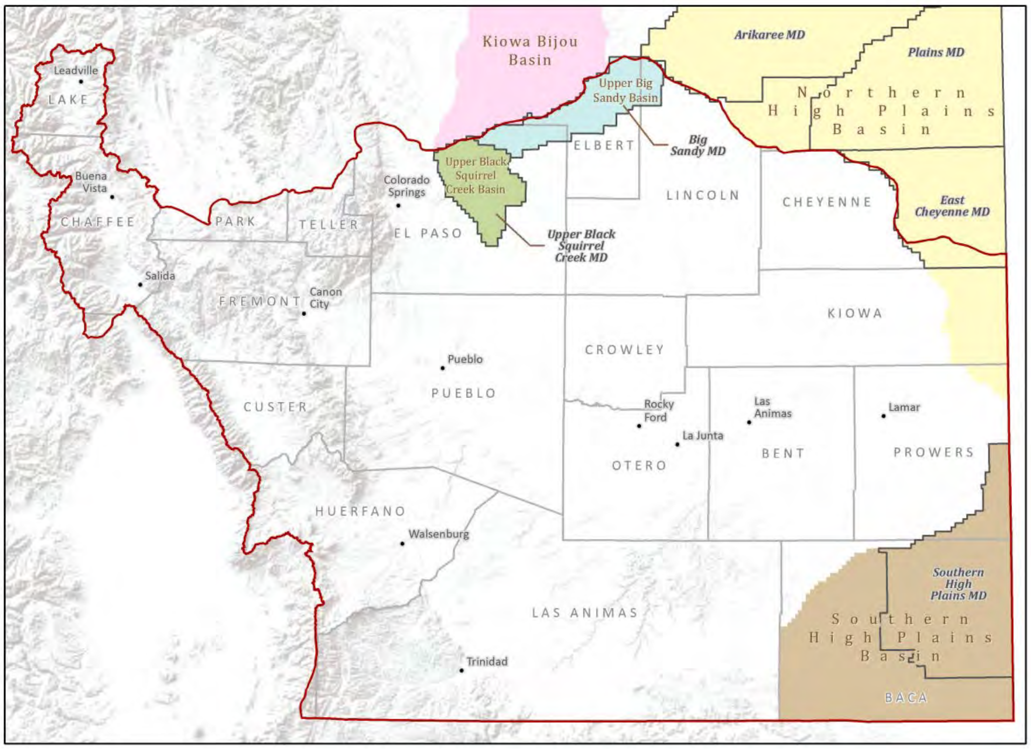
Designated Groundwater Basins

In the Basin there are four designated groundwater basins, Figure 3.2.4.

The designated groundwater basins in the Basin are:

- Upper Big Sandy
- Upper Black Squirrel Creek
- Southern High Plans
- Northern High Plans (small portion)

Figure 3.2.4 - Designated Basins



Administration of the designated groundwater basins is under the jurisdiction of the Colorado Ground Water Commission and is not administered by the State Engineer. The State Engineer provides technical and staff support to the Ground Water Commission. The General Assembly has granted the Ground Water Commission authority under Title 37, Article 90 of the Colorado Revised Statues (Ground Water Management Act) to grant water rights and issue large capacity well permits. Small capacity wells are administered by the State Engineer. Small capacity wells are intended for domestic use, livestock, and small commercial operations. These wells are limited to a maximum pumping rate of 15 gpm and no more than one acre of lawn and garden irrigation (Guide to Colorado Well Permits, Water Rights and Water Administration, Sept 2012).

Designated groundwater is groundwater that in its natural course would not be available to and required for the fulfillment of decreed surface rights, or groundwater in areas not adjacent to a continuously flowing natural steam wherein groundwater withdrawals have constituted the principal water usage for at least 15 years. It is applicable to the groundwater underlying the eight "designated basin" areas created by the Colorado Groundwater Commission, located on Colorado's eastern plains. See Figure 3.2.4.

Thirteen Ground Water Management Districts (GWMDs) have been created pursuant to local elections and state statutes. The GWMDs are authorized to adopt additional rules and regulations to assist in administration and management of groundwater within their district.

The GWMD rules for GWMDs in the Basin can be found on the Colorado DWR website:

- Upper Big Sandy - http://water.state.co.us/DWRIPub/Documents/UpperBigSandy.pdf
- Upper Black Squirrel Creek - http://water.state.co.us/DWRIPub/Documents/UBSCRules.pdf
- Southern High Plains - http://water.state.co.us/DWRIPub/Documents/SouthernHighPlains.pdf
- Northern High Plains - http://water.state.co.us/DWRIPub/Documents/EastCheyenne.pdf

These rules and regulations approved by the specific GWMDs include items such as: rules for the removal of groundwater from the district, well spacing, annual appropriations, land to be irrigated and compliance.

Produced Nontributary Groundwater from Oil & Gas Operations

The Colorado DWR has recently promulgated rules for produced nontributary groundwater from oil and gas operations. These rules were made final in the "Produced Nontributary Ground Water Rules (2 CCR 402-17). The purpose of these rules is to assist the State Engineer with the administration of dewatering of geologic formations by withdrawing nontributary groundwater to facilitate mining of oil and natural gas.

Groundwater in the State of Colorado is legally presumed to be "tributary or hydrologically connected to the surface water system requiring administration within the prior appropriation system in conjunction with surface rights, unless it is demonstrated to be nontributary groundwater in accordance with the law. As part of these rules, Rule 17.7.D. identifies geographically delineated areas under which groundwater in specified formations is nontributary for the limited purpose of the Rule. These maps are available on the DWR website (water.state.co.us).

One can submit a petition for a Determination of Nontributary Groundwater if the area and formation has not been previously determined to be nontributary. This requires the demonstration by the use of a numerical groundwater model or alternate methodology that the groundwater being produced is nontributary.

These rules do not apply to any aquifer or portion thereof that contains designated groundwater and is located within the boundaries of a designated groundwater basin.

In addition, tributary produced groundwater from oil and gas operations are required to have a well permit and operate in accordance with a plan for augmentation or substitute water supply plan that replaces depletions to affected streams.

3.2.5 Summary and Challenges

Water rights administration is complex, but particularly so in the Basin, where the interstate compact with the State of Kansas, and subsequent lawsuits, have put additional requirements on both water users and the Division of Water Resources. The level of scrutiny for changes in any attribute of a historic water rights, including timing, replacement of return flows, and place of use, make water rights administration particularly difficult, and represent a challenge to meeting the needs of the basin for both consumptive and nonconsumptive uses.

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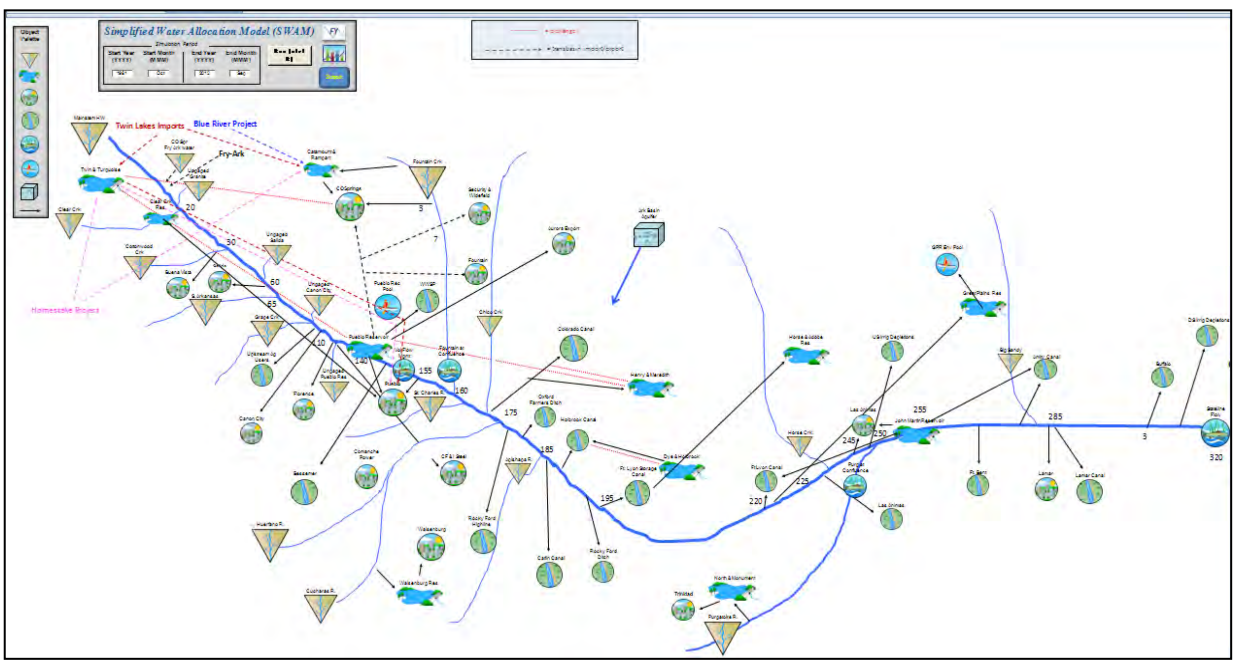
3.3 Water Allocation Planning Model Documentation

3.3.1 Overview

A water allocation model has been developed for the Arkansas River Basin (Figure 3.3.1) to support the Basin Implementation Plan (BIP). The model spatial domain extends from the Arkansas River at Leadville flow gage in the western headwaters to the Colorado-Kansas state line in the east. It includes all major tributaries, agricultural ditch diversions, M&I water users, and transbasin water imports. All other significant inflows and withdrawals in the basin have been represented implicitly in the model in aggregated form. The model is designed for large-scale planning studies and, more specifically, the quantification of water shortages in the basin as a result of increasing future demands. It is not designed to be a river administration or operational support tool, nor is it intended to replicate the Arkansas Basin Decision Support System (ArkDSS) that has recently completed a Feasibility Study. Consequently, there are intentional simplifications in the model, compared to the ArkDSS, to maintain its ease of use and transparency for coarser resolution planning. These simplifications include: a monthly timestep, aggregated agricultural diversions, simplified reservoir operations and accounting, and simplified representation and inclusion of water exchange and augmentation plans. That being said, the key drivers of water availability in the basin, including native hydrology, major water uses and return flows, the water rights priority system, groundwater pumping with surface returns and stream depletions, and transbasin imports, are all explicitly represented in the model. Lastly, the model is well supported by a calibration/verification exercise based on recent (1982 – 2012) river gage data.

Figure 3.3.1 - Arkansas River BIP Water Allocation Model



3.3.2 Modeling Platform

The Arkansas Basin planning model was developed using CDM Smith's Simplified Water Allocation Model (SWAM). SWAM was originally developed in 2009 to address an identified need for a networked, generalized water allocation modeling tool that could be easily and simply applied for planning studies by a wide range of end users. It has been extensively modified and enhanced since that inception. SWAM is designed to be intuitive in its use and streamlined in functionality and data requirements, while still maintaining the key elements of water allocation modeling.

SWAM is not intended to replace more complex water allocation modeling software. It is not well-suited for either operational support or water rights administration modeling. There are key constraints in the model with respect to the number of simulated water user nodes and the level of complexity available for simulating reservoir operations. Rather, SWAM was designed to complement these more complex tools by providing for efficient planning-level analyses of water supply systems. It is best suited for either analysis of focused networks or coarser resolution basin-level studies.

Like most water allocation models, SWAM calculates physically and legally available water, diversions, storage, consumption, and return flows at user-defined nodes in a networked river system. Both municipal and agricultural demands can be specified and/or calculated in the model. Legal availability of water is calculated based on prioritized water rights, downstream physical availability, and specified return flow percentages. Additional features in SWAM include easily-parameterized M&I conservation and reuse programs, agricultural land transfers, groundwater pumping, water user exchange agreements, and transbasin diversion projects. Multiple layers of complexity are available as options in SWAM to allow for easy development of a range of systems, from the very simple to the more complex.

SWAM operates on a monthly timestep over an extended continuous simulation period intended to capture a range of hydrologic conditions. The program is coded in Visual Basic object-oriented code with a Microsoft *Excel*-based interface.

3.3.3 Model Construction

Model Simulation Period

The Arkansas Basin model simulates the water years 1982 – 2012. This historical period is known to include all of the current major basin operations, storage and diversion structures, and transbasin imports and is inclusive of the critical drought of the early 2000s. It is also consistent with the simulation period utilized for the SDS modeling performed as part of that project's EIS (MWH 2007).

Tributary Objects

Tributary objects are used in SWAM to establish native flows throughout the basin. In addition to a mainstem headwater flow, multiple tributaries are included in the model in a dendritic network. These model objects are parameterized with a monthly flow time series and spatial location identifiers (e.g., confluence location). Gaged flow records were used, to the extent possible, to quantify native flows in the basin. Gages used for this purpose in the model are located above major basin operations and generally represent unimpaired flows. As described below, flow contributions from a number of ungaged sub-basins were also included in the model developed using statistical estimation techniques and adjusted as part of the model calibration process. Standard hydrologic statistical methods were also employed to extend or augment gaged records, as necessary.

The following tributaries, with full or partial gaged flow records, are explicitly included in the model:

- Mainstem Headwater;
- Clear Creek;
- Cottonwood Creek;
- S. Arkansas River;
- Grape Creek;
- Fountain Creek and local runoff;
- St. Charles River;
- Chico Creek;
- Huerfano River;
- Cucharas River;
- Apishapa River;
- Horse Creek;
- Purgatoire River;
- Big Sandy Creek.

In some cases, tributary reaches are explicitly simulated in the model and include surface water user nodes along the extent of the reach. These tributary objects are parameterized with upstream (headwater) gaged flows and, in some cases, reach gains and losses (quantified as part of the calibration process) (Table 3.3.1). In other cases, the tributaries merely serve as point inflows to the mainstem river and are therefore parameterized using flow rates measured near the mainstem confluence. For both types of tributary objects, monthly flow records for the simulation period were either obtained directly from USGS gage records or were estimated using well-known statistical techniques, including area-weighting with a surrogate gage and the MOVE.2 record-filling method.

Table 3.3.1 - Summary of Model Tributary Objects

Tributary Object	Representative USGS Flow Gage	Drainage Area (mi^2)	Available Period of Gage Record	Statistical Extension or Record-Filling Method	Calibration Gain/Loss Factor (unitless)[1]	Mean Annual Flow (AFY) [2]
Mainstem Headwater	Arkansas River nr Leadville (07081200)	99	Oct '81 – Sep '83; May '90 – Sep '12	MOVE.2 (with 07086000 reference gage)	1	55,000
Clear Creek at Clear Crk Reservoir	Clear Creek ab Clear Crk Reservoir (07086500)	67	Oct '81 – Sep '12	none	1	49,000
S. Arkansas River at Mouth	Grape Creek nr Westcliffe (07095000) (surrogate)	201	Oct '81 – Sep '12	area-weighting, surrogate gage	1	16,000
Grape Creek at Mouth	Grape Creek nr Westcliffe (07095000)	541	Oct '81 – Sep '12	area-weighting, down to confluence	1	43,000
Fountain Crk & Local Runoff	Fountain Creek nr CO Springs (07103700) + Estimated Local Runoff[3]	102 (+ local runoff drainage)	Oct '81 – Sep '12	none	1	77,000
St. Charles River at Mouth	St. Charles River at Vineland (07108900)	474	Oct '81 – Sep '12	none	1	28,000
Chico Creek at Mouth	Chico Creek nr Avondale (07110500)	864	Mar '39 – Sep '46	mean monthly flows	30	2,500
Huerfano River Headwater	Huerfano River at Manzanola (07111000)	73	Oct '81 – Sep '87; Oct '94 – Sep '12	MOVE.2 (with 07124200 reference gage)	3.5	52,000
Cucharas River Headwater	Cucharas River ab Walsenburg (07114000)	56	Oct '81 – Sep '87; Oct '94 – Sep '12	MOVE.2 (with 07124200 reference gage)	1	16,000
Apishapa River at Mouth	Apishapa at Fowler (07119500)	1074	Oct '81 – Sep '12	none	1	12,000
Horse Creek at Mouth	Horse Creek nr Las Animas (07123675)	1403	Oct '79 – Sep '93	mean monthly flows	1	9,000
Purgatoire River Headwater	Purgatoire ab Madrid (07124200)	505	Oct '81 – Sep '12	none	0.85	52,000
Big Sandy Creek at Mouth	Big Sandy nr Lamar (07134100)	65	Jul '95 – Sep '12	mean monthly flows	0.75	12,000
Ungaged Above Granite	NA	350	NA	area-weighting (with 07086500 reference gage)	0.75	253,000
Ungaged Below Granite, Above Salida	NA	600	NA	area-weighting (with 07091015 reference gage)	0.75	240,000
Ungaged Below Salida, Above Canon	NA	1120	NA	area-weighting (with 07095000 reference gage)	0.75	88,000

Tributary Object	Representative USGS Flow Gage	Drainage Area (mi^2)	Available Period of Gage Record	Statistical Extension or Record-Filling Method	Calibration Gain/Loss Factor (unitless)[1]	Mean Annual Flow (AFY) [2]
City						
Ungaged Below Canon City, Above Pueblo Reservoir	NA	1400	NA	area-weighting (with 07099060 reference gage)	0.75	110,000

[1] Factor applied to estimated flow to represent reach gains or losses down to the confluence, quantified as part of calibration process

[2] Flow at initial point of application in model, prior to gains or losses

[3] Estimated as part of calibration process

For the Fountain Creek sub-basin, upstream of Colorado Springs, stream gage data were augmented with estimates of additional flow into Colorado Springs local reservoir system. This runoff is known to be a significant source of supply for the city and is not captured in the Fountain Creek gage data. The flow augmentation was achieved by applying a uniform factor to the Fountain Creek near Colorado Springs gage data, quantified as part of the calibration process. This process was guided by downstream Fountain Creek gaged flows (Fountain Creek at Pueblo, see Section 3.3.4) and independent estimates of local runoff for Colorado Springs (Colorado Springs Water Tour document).

In addition to the individual tributaries listed above, a number of ungaged tributaries were included in the model in aggregate form. Flows for these ungaged areas were estimated using area-weighting techniques applied to surrogate gages. Adjustments were made to the flow estimates as part of the calibration process (described in Section 3.3.4). The focus of this analysis was on the ungaged headwater regions of the basin where contributions from snowmelt are likely significant. As can be seen in Table 3.3.1, these ungaged headwater tributaries constitute well over half of the total native flow in the basin as simulated in the model.

Reservoirs

The following major reservoirs are included in the model:

- Twin and Turquoise Aggregate Reservoir (offline);
- Clear Creek Reservoir (online);
- Pueblo Reservoir (online);
- Catamount and Rampart Aggregate Reservoir (offline);
- Walsenburg Reservoir (offline);
- Henry and Meredith Aggregate Reservoir (offline);
- Dye and Holbrook Aggregate Reservoir (offline);
- Horse and Adobe Aggregate Reservoir (offline);
- North and Monument Aggregate Reservoir (offline);
- John Martin Reservoir (online);

- Great Plains Aggregate Reservoir (offline).

Reservoirs are parameterized according to total storage capacity, user accounts, simplified release and operational rules, and evaporation rates (Table 3.3.2). Inflows and withdrawals from the reservoirs are dictated by activity associated with the individual water user accounts in each reservoir. Offline reservoirs divert water for storage according to physical and legal availability for individual user accounts. Online reservoirs hold inflow only to the extent legally allowed according to user account water rights and downstream senior calls. For online reservoirs, excess water not held in individual accounts, and not called by downstream users, is stored in flood control pools. The storage capacity of these pools is calculated as the difference between total user account storage and the total physical storage of the reservoir. Releases from flood control pools are defined by user-input outflow-capacity tables.

Table 3.3.2 - Modeled Reservoirs

Reservoir Name	Total Storage Capacity (AF)	Sources of Water	User Accounts	Evaporation Losses (Apr – Sep)	Prescribed Release Rules
Twin & Turquoise Aggregate	269,000	Transbasin imports	Colorado Springs, City of Pueblo	0.14 – 0.28 in d^{-1}	none
Clear Creek Reservoir	11,400	Clear Creek	City of Pueblo	1% per month	none
Pueblo Reservoir	330,000	Arkansas R. mainstem	City of Pueblo, Colorado Springs, City of Fountain, Lamar, Security & Widefield, Bessemer Ditch, Aggregate Upstream Ag Users, Aurora Export	0.14 – 0.28 in d^{-1}	flood control pool: 0 – 5000 AFM (0 – 100% capacity)
Catamount and Rampart Aggregate	60,000	Fountain Creek, transbasin imports	Colorado Springs	1% per month	none
Walsenburg Reservoir	843	Cucharas River	Walsenburg	1% per month	none
Henry and Meredith Aggregate	49,000	Arkansas R. mainstem	CO Canal	1% per month	none
Dye and Holbrook Aggregate	50,000	Arkansas R. mainstem	Holbrook Aggregate Canal	1% per month	none
Horse and Adobe Aggregate	200,000	Arkansas R. mainstem	Fort Lyon Storage Canal	1% per month	none
North and Monument Aggregate	5700	Purgatoire R.	City of Trinidad	1% per month	none
John Martin Reservoir	450,000	Arkansas R. mainstem	Las Animas Ditch, Ft. Lyon Canal, Ft. Bent Canal	0.1 – 0.3 in d^{-1}	flood control pool: 0 – 70,000 AFM (0 – 100% capacity)
Aggregate Great Plains Reservoir	70,000	Arkansas R. mainstem	GPR environmental pool	1% per month	none

In the current model, reservoir bathymetry is defined by simplified area-capacity curves where such information is available. Monthly mean evaporation rates (inches per day) have been specified in the model based on regional values reported in the literature. In the absence of reservoir bathymetric information (smaller reservoirs only), 1 percent volumetric evaporative losses are assumed for the months of April – October, with no evaporation during the winter months.

Two nonconsumptive environmental pools are also included in the model, associated with Pueblo and the Aggregate Great Plains Reservoir. These model objects designate minimum storage levels that are maintained, to the extent possible, given physical and legal availability of water. Environmental pools are assigned a water right appropriation date in the same manner as consumptive users. This water right determines the ability of the object to divert and store water. The only losses from the environmental pools are evaporative. The Pueblo environmental pool is set at 30,000 AF with a relatively senior appropriation date of 1/1/1900. The Great Plains Reservoir environmental pool is set at 21,000 AF with a largely junior appropriation date of 1/1/1990 (i.e., it only fills during wet years).

M&I Users

The following M&I water users are explicitly included in the Arkansas Basin SWAM model:

- Colorado Springs;
- Pueblo;
- Buena Vista;
- Salida;
- Canon City;
- Florence;
- Security and Widefield;
- Fountain;
- CF&I Steel;
- Walsenburg;
- Trinidad;
- Las Animas;
- Lamar;
- Aurora Export.

Each M&I user is parameterized according to spatial location (diversions and return flows), current demand estimates, representative water rights appropriation dates, diversion rights, and source water portfolio details (including direct diversions, storage accounts, transbasin imports, and groundwater pumping) (Table 3.3.3). M&I users in SWAM can have multiple sources of supply used to satisfy a single set of demands, in order of user-defined preferences. Sources of supply can include: direct surface diversions, surface diversions via storage accounts, and groundwater pumping.

Table 3.3.3 - Summary of M&I Water User Objects

Name	Total Demand (AFY)	Modeled Sources of Supply	Modeled Storage Accounts
Colorado Springs	116,000	• Groundwater (implicit in model) • Direct Fountain Creek + local runoff, • Storage Fountain Creek + local runoff • Transbasin with Pueblo Res. storage (Fry-Ark) • Transbasin with Catamount & Rampart storage (Blue River, Twin Lakes, and Homestake) • Exchange of transbasin return flows (to Pueblo Res.) • Exchange of Colorado Canal and Lake Meredith water (to Pueblo Res.)	• Catamount & Rampart (60,000 AF) • Twin & Turquoise (47,000 AF) • Pueblo (17,000 AF) • Henry & Meredith (27,000 AF)
City of Pueblo	40,000	• Direct mainstem • Storage Clear Creek • Transbasin with Twin & Turquoise storage (Twin Lakes and Homestake) • Transbasin with Pueblo Res. storage (Fry Ark) • Exchange of transbasin return flows (to Pueblo Res.)	• Clear Creek Res. (11,400 AF) • Twin & Turquois (17,600 AF) • Pueblo Res. (10,000 AF)
Buena Vista	900	• Direct Cottonwood Creek • Groundwater	none
Salida	3000	• Direct mainstem • Groundwater	none
Canon City	7200	• Direct mainstem	none
Florence	2800	• Direct mainstem	none
Security and Widefield	9000	• Groundwater • Transbasin with Pueblo Res. storage (Fry-Ark)	• Pueblo (1000 AF)
Fountain	5200	• Groundwater • Transbasin with Pueblo Res. storage (Fry-Ark)	• Pueblo (5000 AF)
CF&I Steel	4100	• Direct mainstem	none
Walsenburg	1000	• Storage Cucharas Riv.	• Walsenburg Res. (840 AF)
Trinidad	5100	• Storage Purgatoire Riv.	• North & Monument (5700 AF)
Las Animas	1000	• Groundwater	none
Lamar	2750	• Groundwater • Transbasin with Pueblo Res. storage (Fry-Ark)	• Pueblo (1400 AF)
Aurora Export	17,500	• Storage mainstem	• Pueblo (10,000 AF)

The model calculates both legally and physically available flow at each surface water diversion point associated with M&I water user objects. Legal availability is calculated in SWAM using the same algorithm (Modified Direct Solution Algorithm) utilized in the State of Colorado DSS and considers downstream senior calls, return flows, and diversion rights. In SWAM, the actual diverted amount is calculated as a function of physical and legal availability and demand. Monthly M&I demands are set in the model, based on the best available information, to approximately represent current demands. Monthly demand patterns are defined in the model based on model default values that follow patterns typical of M&I usage in Colorado. Water user storage accounts are assigned a "parent" reservoir, a total account capacity, and water rights (diversion and storage rights). The model attempts to maintain a full storage account, to the extent physically and legally allowable, by imparting a diversion demand on the source river in the same way that direct diversion demands are imparted. For all M&I users in the model, a uniform return flow monthly pattern is assumed based on typical indoor vs. outdoor usage patterns and consumptive use portions associated with each. No time lags have been included for return flows in this monthly timestep model.

Note that neither stream depletions nor surface water augmentation plans are explicitly included in the model M&I object portfolios, as the combination of the two represents a zero net change in the surface water budget. Also note that exchange agreements allowing the Cities of Colorado Springs and Pueblo to use their transbasin import water to extinction are included in the portfolios for these two model objects, parameterized with appropriate decree priority dates. An exchange agreement between Colorado Springs and Colorado Canal, with storage in Henry & Meredith Aggregate Reservoir, is also included as part of the water supply portfolio for the city. See *Exchanges and Flow Management Programs* for further details on modeled exchanges.

Agricultural Users

The following irrigation ditches are explicitly included in the model:

- Colorado Canal;
- Bessemer Ditch;
- Las Animas Ditch;
- Fort Lyon Canal;
- Rocky Ford Highline;
- Catlin Canal;
- Lamar Canal;
- Buffalo Canal;
- Holbrook Canal;
- Amity Canal;
- Ft. Lyon Storage Canal;
- Oxford Farmers Ditch;
- Ft. Bent Canal;
- Rocky Ford Ditch;
- Upstream Aggregate Ditch (aggregation of all ditches upstream of Pueblo Res.).

The major ditches listed above comprise approximately two-thirds of the total agricultural diversion in the basin. The remaining diversions, achieved with smaller ditches and canals, were assigned, in aggregate, to the major users in the model based on relative proximity to the major diversion location.

In this way, approximately 100 percent of the reported total agricultural water use is included in the model but at a coarser spatial resolution than in actual operation.

As with M&I users, agricultural users are parameterized in the model according to spatial location, demands, water rights, and source water details (Table 3.3.4). In the current model, agricultural user demands are set based on reported historical headgate diversions averaged over the simulation period (1982 – 2012). Monthly-varying average diversion volumes, calculated using the full dataset, are used to characterize the seasonality in water use. Diversions are assumed to all occur from the mainstem of the Arkansas River. Aggregate storage accounts are included, where appropriate, based on available information (e.g., HydroBase diversion records, see *Data Sources*. For aggregate diversions where a significant portion of the diverted water is transmitted to storage prior to use, a single storage account was assigned to one of the simulated reservoirs (Table 3.3.4). Storage account capacities were initially roughly estimated based on available data with subsequent minor adjustments as part of the calibration process. These accounts are intended to represent lumped storage available to the various diversions, and are used to overcome seasonal constraints associated with available river diversion water.

Table 3.3.4 - Summary of Aggregate Agricultural Water User Objects

Name	Total Demand (AFY)	Representative Priority Date	Storage Accounts
Colorado Canal	147,000	6/9/1890	Henry & Meredith (49,000 AF)
Bessemer Ditch	124,000	5/1/1887	Pueblo (10,000 AF)
Las Animas Ditch	124,000	3/13/1888	John Martin (5000 AF)
Fort Lyon Canal	240,000	3/1/1887	John Martin (20,000 AF)
Rocky Ford Highline	81,000	3/7/1884	none
Catlin Canal	102,000	12/3/1884	none
Lamar Canal	60,000	7/16/1890	none
Buffalo Canal	53,000	10/1/1895	none
Holbrook Canal	48,000	10/10/1903	Dye & Holbrook (30,000 AF)
Amity Canal	91,000	4/1/1893	none
Ft. Lyon Storage Canal	75,000	3/1/1910	Horse & Adobe (200,000)
Oxford Farmers Ditch	55,000	2/26/1887	none
Ft. Bent Canal	40,000	12/31/1900	John Martin (20,000 AF)
Rocky Ford Ditch	31,000	5/15/1874	none
Upstream Aggregate Ditch	303,000	5/2/1887	Pueblo (10,000 AF)

Representative water rights appropriation dates are assigned to each of the major users listed above based on the date listed for the largest diversion right associated with the ditch or canal. A uniform return flow percentage (43 percent) is assumed for all agricultural users based on average historical efficiencies reported for the basin (SDS report). Return flows are not lagged and are assumed to return to the river at single specified downstream locations, assigned based on visual assessment of the mapped irrigation areas associated with each major ditch.

Transbasin Imports

Imported transbasin water is included in the model as a major source of supply for many of the M&I water users described above. Transbasin imports are simulated in the model as steady monthly inflows to the river basin. Imports are made available to their corresponding water users by either direct transmittal to water user storage accounts or via mainstem conveyance. As an example of the latter, Fry-Ark water utilized by Colorado Springs, Pueblo, and downstream agricultural users is modeled as a steady point inflow to the mainstem river at the top of the system (above Clear Creek confluence). This water flows down the mainstem and a portion is captured and stored in accounts in Pueblo Reservoir, where it is available for use by Colorado Springs and Pueblo. The Fry-Ark water owned by downstream agricultural water users is transported further downstream to aggregate agricultural diversions, as dictated by downstream water rights. In other cases, transbasin imports are simulated with a direct transmittal to a specified water user storage account (e.g., Colorado Springs Homestake, Twin Lakes, and Blue River imports).

Major transbasin imports explicitly represented in the model, and their associated water users, are listed below (and summarized in Table 3.3.5):

- Homestake (Colorado Springs, Pueblo);
- Blue River (Colorado Springs);
- Twin Lakes (Colorado Springs, Pueblo);
- Fry-Ark (Colorado Springs, Pueblo, City of Fountain, Security & Widefield, Lamar, downstream agricultural users).

Table 3.3.5 - Summary of Modeled Transbasin Import Water.

Name	End Users	Modeled Storage	Modeled Yield (AFY)
Homestake	Colorado Springs, Pueblo	Catamount & Rampart (CO Springs), Twin & Turquoise (Pueblo)	15,500 (CO Springs) 12,000 (Pueblo)
Blue River	Colorado Springs	Catamount & Rampart (CO Springs)	8,000 (CO Springs)
Twin Lakes	Colorado Springs, Pueblo	Catamount & Rampart (CO Springs), Twin & Turquoise (Pueblo)	29,000 (CO Springs) 12,000 (Pueblo)
Fry-Ark	Colorado Springs, Pueblo, Fountain, Security & Widefield, Lamar, downstream ag users	Pueblo Reservoir (CO Springs, Pueblo, Fountain, Security & Widefield, Lamar)	14,500 (CO Springs) 5000 (Pueblo) 10,000 (Fountain) 10,000 (Security & Widefield) 1400 (Lamar) 32,000 (downstream ag users)

Exchanges and Flow Management Programs

Water exchanges in the Arkansas River Basin involve diversion and water use at one location offset by a simultaneous release of an equivalent volume at a different location. For the basin as a whole, a zero net change in river flows is realized. However, exchanges do impact the spatial distribution and timing of flows within the basin. Exchanges can also represent an important element of individual water supply portfolios in the basin. For this planning-level model, only a select number of key exchanges were explicitly included in the model (Table 3.3.6):

- Colorado Springs transbasin return flows;
- City of Pueblo transbasin return flows;
- Colorado Springs – Colorado Canal exchange;
- Aurora – Rocky Ford exchange;
- Winter Water Storage Program (WWSP).

Table 3.3.6 - Summary of Modeled Exchanges

Name	Water Users Involved	Storage	Exchange Quantity (AFY)[1]	Water Right Priority Date
CO Springs transbasin return flows	CO Springs	Twin & Turquoise	37,000	6/5/1985
Pueblo transbasin return flows	City of Pueblo	Pueblo Res.	17,000	6/5/1985
CO Springs – Colorado Canal	CO Springs, Colorado Canal	Henry & Meredith, Pueblo Res.	1200	6/5/1985 (CO Springs), 6/10/1890 (CO Canal)
Aurora-Rocky Ford	Aurora Export	Pueblo Res.	5500	6/5/1985
Winter Water Storage Program	Multiple downstream ag users	Pueblo Res.	50,000	1/1/1885

[1] Average annual volume exchanged in current model, as calculated as a function of demand and physical and legal availability

The first two listed exchanges capture the ability of these cities to use their transbasin import water (excluding Fry-Ark) to extinction. Both are represented in the model with additional senior diversion rights set equal to their modeled, monthly-variable return flows from transbasin project water yields. For the Colorado Springs model object, water is diverted under this exchange from the mainstem headwaters and stored in Twin & Turquoise Aggregate Reservoir for as-needed use. For the Pueblo object, return flow exchange water is diverted at Pueblo Reservoir and stored in a Pueblo account for as-needed use.

The Colorado Springs – Colorado Canal exchange involves the use of Colorado Springs shares in Colorado Canal diversion water and Henry & Meredith Aggregate Reservoir storage. In the model, SWAM's water exchange functionality is utilized, within the Colorado Springs water supply portfolio (see Table 3.3.3), to divert and store downstream mainstem water in Henry & Meredith. This water is released, as needed, to offset upstream city diversions at Pueblo Reservoir.

The Aurora – Rocky Ford exchange is represented in the model using the Aurora Export M&I water user noted above (Table 3.3.6). This model object includes a seasonal diversion of water just above Pueblo Reservoir with diversion rights set according to the Rocky Ford Exchange agreement (Mar – Oct water rights). Water is diverted to a storage account in Pueblo Reservoir (10,000 AF) and then utilized with typical M&I seasonal usage patterns with zero return flows (i.e., an export from the basin). While the exchange with Rocky Ford ditch is not explicitly simulated in this model, it is assumed that ample flow is available at the Rock Ford diversion point to allow for the upstream diversion.

The WWSP is represented in the model with a winter-only diversion (Nov – Mar) just upstream of Pueblo Reservoir and storage in the reservoir. The stored water is then fully released during the growing season months (Apr – Sep) for use by downstream agricultural users. In other words, downstream agricultural users are able to divert additional water during the growing season equal to the amount of WWSP stored water released from Pueblo Reservoir. The total annual WWSP diversion is set in the model at 50,000 AFY based on recent historical recorded totals (Reclamation, 2013).

Lastly, the Arkansas River Flow Management program is represented in the model with an instream flow object located on the mainstem just downstream of Pueblo Reservoir. Target flows for this object vary monthly, ranging from 100 cfs (Dec – Feb) to 500 cfs (Jun and Jul), based on recreation and fishery needs during low flow years (Flow Management Program May 2004 Exhibit 1, commonly known as the "6-party IGA."). These instream flow targets are prioritized with a decree date of 6/4/1985, which makes them just senior to the municipal exchange programs described above. In other words, if minimum downstream flow requirements are not met then the municipal exchanges described above are not allowed. The Arkansas River Flow Management object does not impact the ability of more senior water user objects to divert water.

Groundwater Pumping

A single groundwater aquifer is included in the model to provide water for M&I user pumping. Pumping in the model is currently unconstrained by groundwater hydrology (high recharge rate, no aquifer depletion). M&I groundwater supplies are included in the water user supply portfolios as appropriate. Agricultural (irrigation) groundwater pumping is not included in the model, as only surface water agricultural demands and diversions are simulated. Return flows from irrigation groundwater pumping are assumed to be negligible for the planning analysis performed here.

Groundwater pumping in the basin is known to result in significant depletions of river flow. In the model, stream depletions are represented with fully consumptive agricultural diversion objects at two different lumped locations, upstream and downstream of John Martin Reservoir. The total depletion amount is set in the model as 41,500 AFY (29,600 upstream, 11,900 downstream) based on 2014 Rule 14 plans for LAWMA for the downstream of John Martin Reservoir and from AGWUA and CWPDA above John Martin Reservoir. Water rights priority dates for the two lumped depletion objects are set such that they are junior to all other agricultural diversions.

Data Sources

Data sources used to parameterize the model elements described above are summarized in Table 3.3.7. Detailed descriptions of these data sources are provided elsewhere.

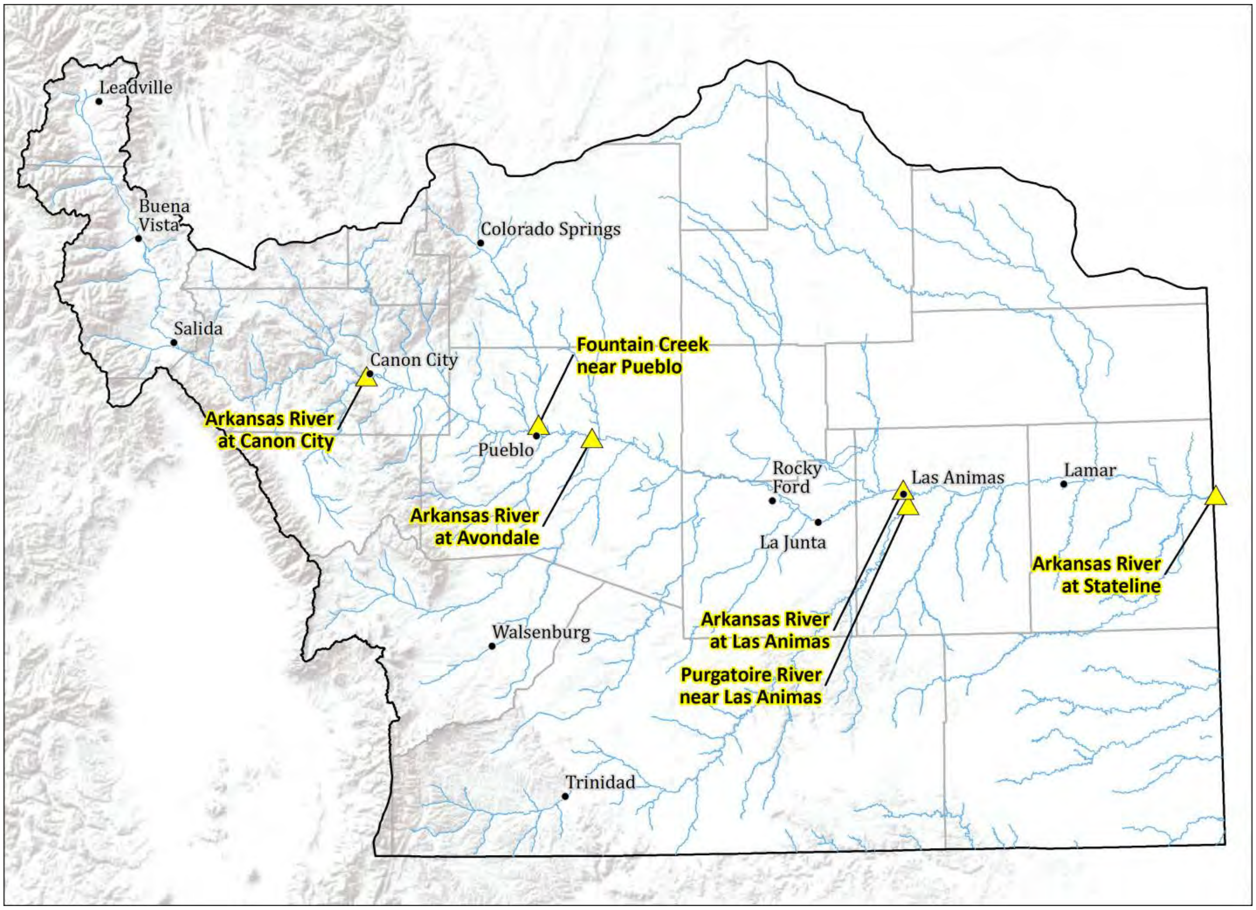
Table 3.3.7 - Summary of Data Sources.

Model Parameter	Data Sources
Tributary object monthly flows	USGS flow gages, statistical extension methods, GIS drainage area calculations
Reservoir bathymetry	AVC EIS Report (Reclamation 2013)
Reservoir capacities	Abbott Report (USGS 1985)
Reservoir evaporation rates	Western Regional Climate Center (http://www.wrcc.dri.edu/)
Online reservoir outflow curves	calibration
M&I water user demands	Abbott Report (USGS 1985); CO Springs SDS Report (MWH 2007)
M&I source water details	Abbott Report (USGS 1985); ArkDSS Feasibility Study (Brown and Caldwell 2011); CO Springs Water Tour Document, Fry Ark Return Flows and Exchanges Report (MWH 2008); City of Fountain Online Bulletin (www.fountaincolorado.org); City of Security Conservation Plan (WaterMatters 2011); Buena Vista – Salida Groundwater report (USGS 2005); Aurora Water Supply Fact Book (Aurora Water 2011); phone interviews (small cities)
M&I water rights and appropriation dates	Division 2 Line Diagrams (SE CO Water Conservancy District); Abbott Report (USGS 1985); AVC EIS Report (Reclamation 2013)
Ag canal aggregation	GIS mapping of diversion location, HydroBase data: lat/long location, historical annual diversion amounts
Ag user demands	HydroBase diversion records (1982 – 2012)
Ag user storage details	HydroBase (storage flags)
Ag user diversion appropriation dates	HydroBase (assigned based on appropriation date of largest individual diversion within aggregation)
Transbasin project details (yields, storage, ownership)	HydroBase, Abbott Report (USGS 1985); Fry Ark Report (MWH 2008); CO Springs Water Tour Document; CO Springs SDS Report (MWH 2007)
Major exchange program details	AVC EIS Report, Appendix D (Reclamation 2013); Division 2 Line Diagrams (SE CO Water Conservancy District); ArkDSS Feasibility Study (Brown and Caldwell 2011)

3.3.4 Model Calibration

The objective of any model calibration process is to lend confidence to model predictions of future conditions by demonstrating, and refining, the model's ability to replicate past conditions. For this study, the calibration exercise sought to achieve adequate model representation of mainstem flow at selected key downstream locations (Figure 3.3.2), as a function of upstream headwater and tributary inputs and basin operations and water use. Calibration points were selected based on available flow gage records and to achieve sufficient spatial coverage to allow for a spatial assessment of model performance. Calibration performance metrics include: annual average flow, monthly average flow, monthly flow percentiles, major reservoir storage, and water user shortages. These metrics provide insight into the model's ability to simulate, respectively: the overall basin water budget, seasonality in flow and water use, flow variability (including extreme events), reservoir flow regulation and operations, and individual water user supply and demand characterization. Calibration adjustment parameters were primarily ungaged flow gains/losses and online reservoir outflow-capacity curves. Uncertainty associated with both sets of parameters is considered relatively high, and, therefore, calibration adjustments are deemed appropriate. The calibration exercise was supported by USGS flow gage records and reported monthly reservoir storage levels for the simulation period (1982 – 2013).

Figure 3.3.2 - Arkansas River Model Flow Calibration Locations



Calibration results are summarized in Table 3.3.8 and Figures 3.3.3 – 3.3.6. As shown, a good agreement between modeled and measured metrics is achieved. Differences between modeled and measured annual flows are all less than 5 percent. Monthly patterns of simulated stream flow generally match the patterns observed in the gage data. Similarly, percentile plots indicate that the model does an excellent job of capturing the range of monthly flow variability observed at multiple locations throughout the basin. Monthly storage values in the two major reservoirs, Pueblo and John Martin, are also well-represented by the model. Lastly, model predictions of agricultural shortages for the simulation period meet expectation. Since agricultural diversions in the model are parameterized based on average recorded diversion volumes for the period of record (but with variable hydrology), the predicted small, and infrequent, shortages (0 – 12 percent of the average demand) appear appropriate. For M&I water users, the model predicts that current demands are able to be met with the modeled supply portfolios throughout the simulation period (minor exception in Buena Vista).

Results of this exercise lend confidence to the use of the model for simulating future scenarios.

Table 3.3.8 - Preliminary Calibration Results

Gage Location	Mean Measured Flow (AFY)	Mean Modeled Flow (AFY)	Percent Difference
Arkansas River at Canon City	535,000	528,000	-1%
Arkansas River at Avondale	680,000	692,000	2%
Arkansas River at Las Animas	205,000	199,000	-3%
Arkansas River at Stateline	171,000	175,000	2%
Fountain Creek nr Pueblo	111,000	111,000	0%
Purgatoire River nr Las Animas	43,000	42,000	-2%

Figure 3.3.3 - Model Calibration Results, Mean Monthly Flows

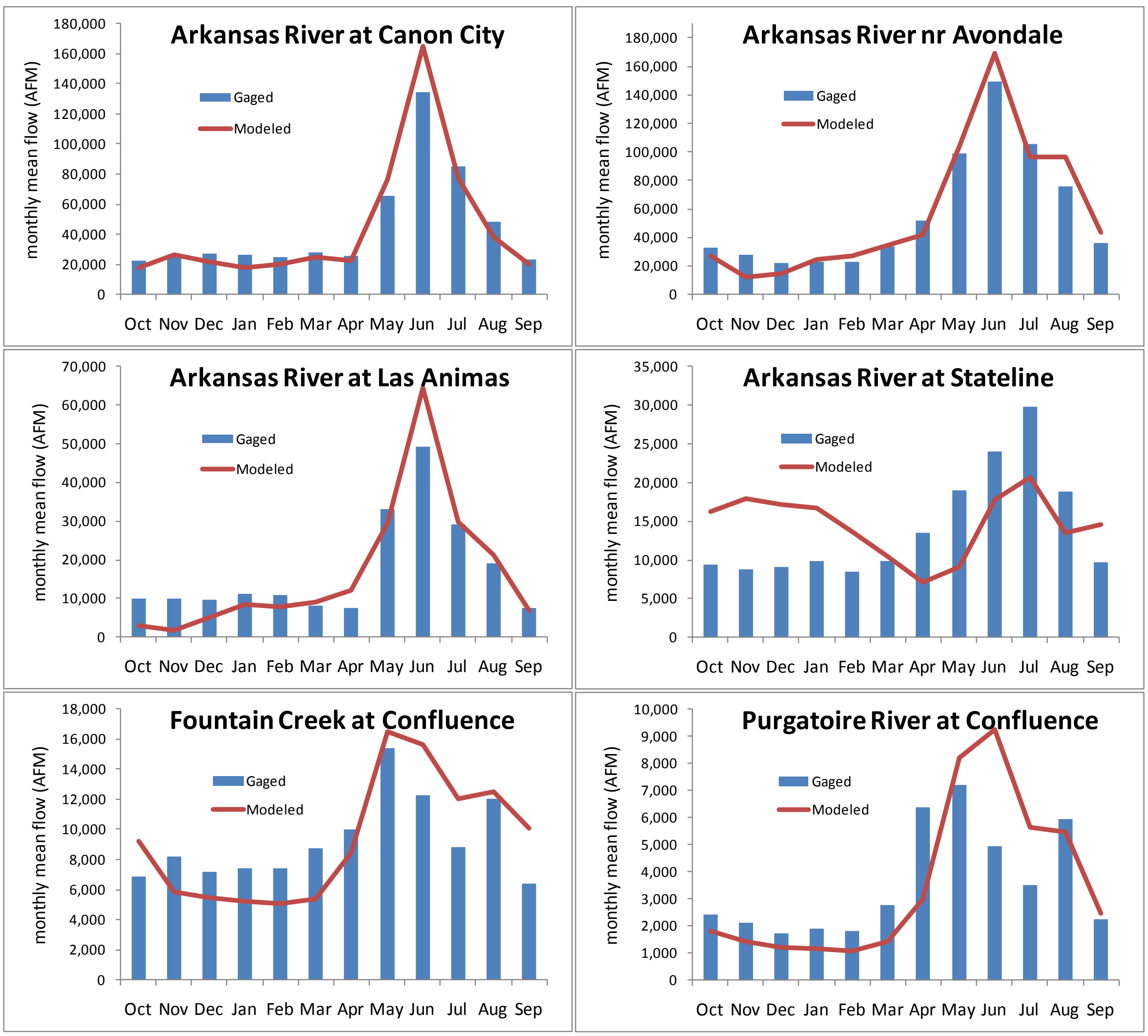


Figure 3.3.4 - Model Calibration Results, Monthly Flow Percentiles

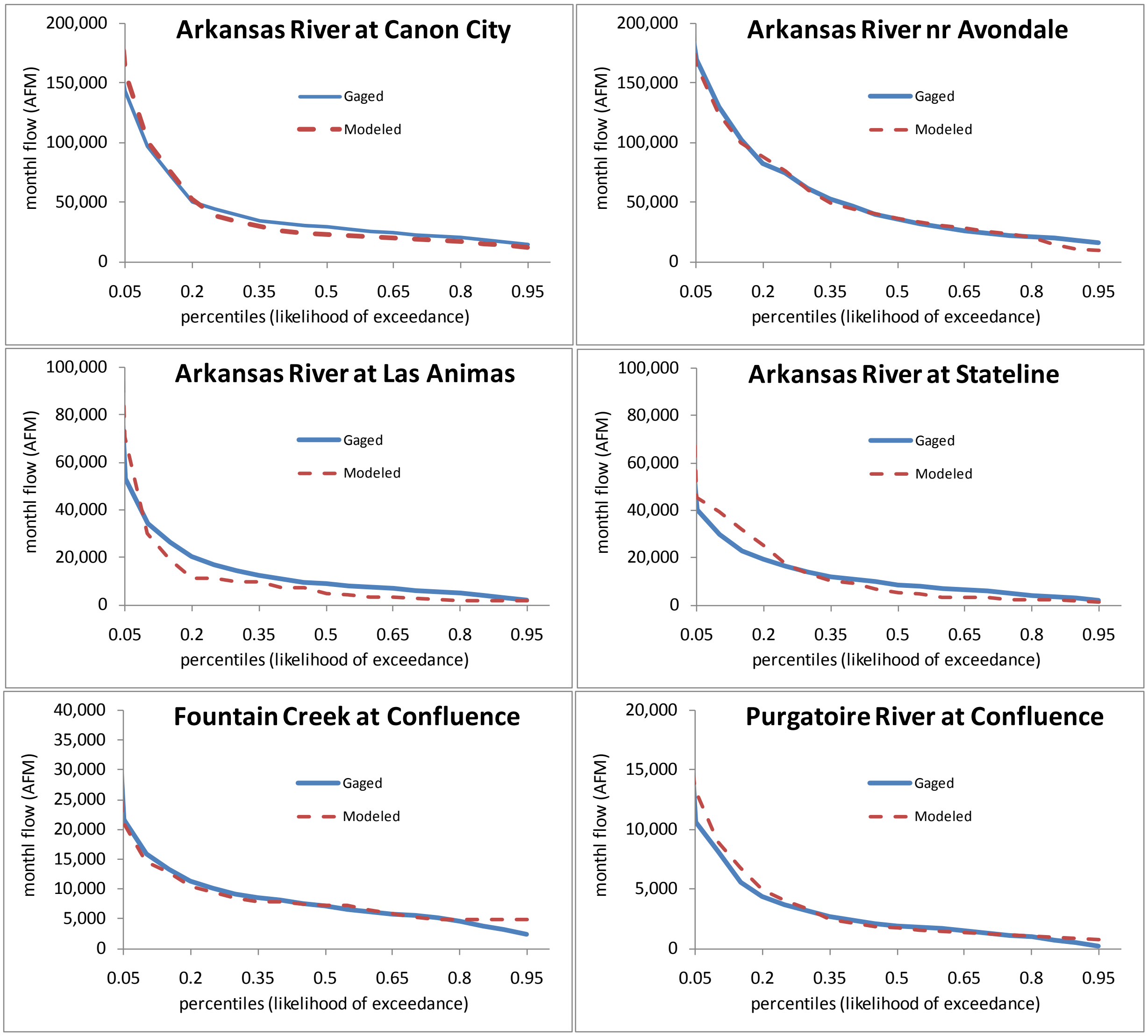


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Figure 3.3.5 - Model Calibration Results, Reservoir Storage

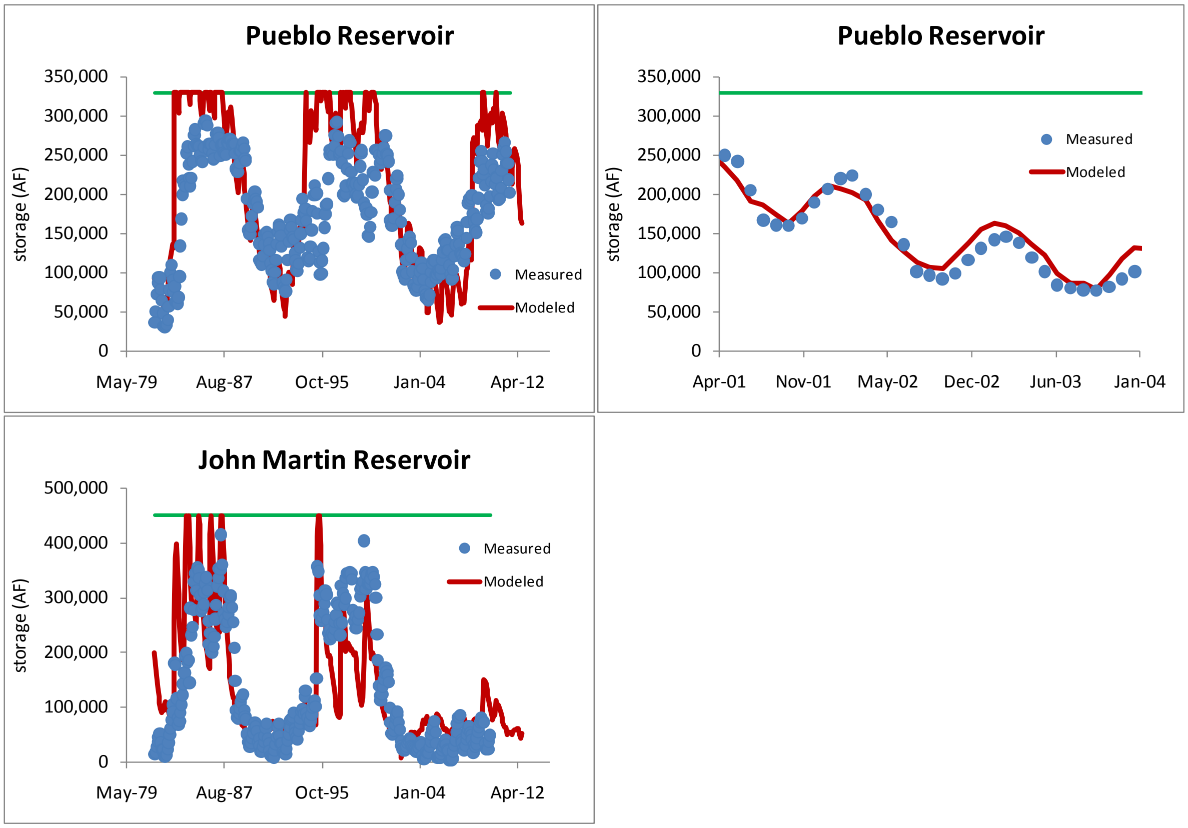
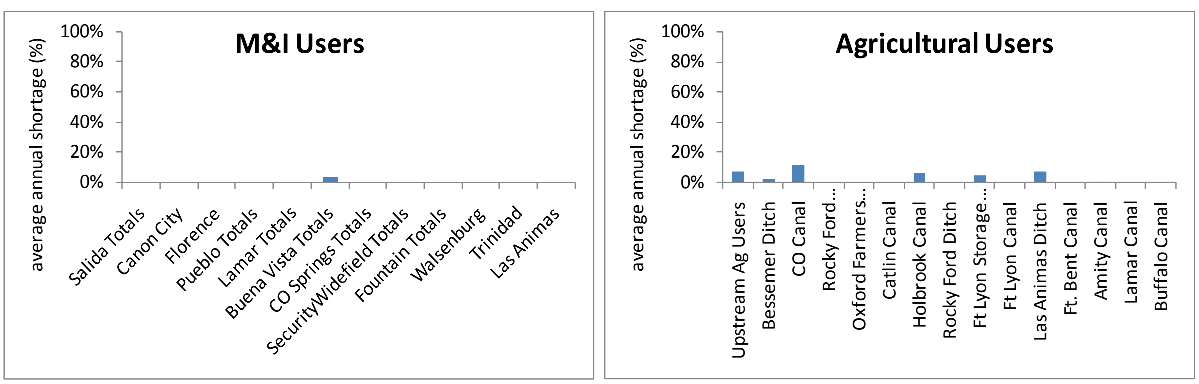


Figure 3.3.6 - Model Calibration Results, Water User Shortages



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3.4 Current and Future Shortage Analysis (Work in Progress)

3.4.1 Overview

The primary goal of this analysis is to assess water supply availability for a future planning horizon (2050) in the Arkansas River Basin. The Arkansas River Basin Model (discussed in Section 3.3) will be modified and used to analyze basin water availability and water user shortages.

The shortage analysis model will be based on the Arkansas River Basin Model and will simulate native flows, reservoir storage, water user demands, return flows, exchange agreements, and transbasin projects across a network of key locations, or nodes, in the basin. The model will be modified to simulate a range of hydrologic conditions subject to future demands. Model output will include physical availability of water (streamflows), legal availability of water (to identify legal constraints), reservoir storage levels, diversions, return flows, and water supply shortfalls. Output will be provided for locations throughout the basin on a monthly timestep.

As noted in Section 3.3, model simplifications are required to provide useful and practical simulations of basin water resources within constraints imposed by data, budget, and schedule limitations. These simplifications include aggregation of water use nodes and/or simplified representation of legal exchange agreements or operating rules. Simplifications made for the calibrated model will be carried forward into the shortage analysis model.

Note, it is anticipated that this current and future shortage analysis will be completed after the submission of the DRAFT Arkansas BIP to the CWCB. As a result, the following sections describe in further detail the shortage analysis approach, key assumptions, and data sources concerning hydrology, demands, and basin operations. This approach describes a single scenario; however, additional scenarios may be evaluated per the direction of the Arkansas Basin Roundtable.

3.4.2 Hydrology

A historical hydrology from 1982 – 2012 will be utilized for the shortage analysis. This 30-year hydrology data set will be the same as the calibrated model described in Section 3.3. The period between 1982 and 2012 includes a range of both wet and dry hydrologic conditions. Additional detail on the selected study period's variability can be found in Section 3.1.

3.4.3 Demands

M&I Demand

Future demand conditions will based on a "high growth" scenario developed as part of SWSI 2010 and will include passive conservation (see Section 4.2 and Appendix H of SWSI 2010). The SWSI 2010 projections were made at the county level; however, the Arkansas Basin Model explicitly includes individual M&I users represented as model objects (see Section 3.3 for more detail). The discrepancy in spatial representation of M&I water use requires a more generalized approach to future demand allocation. Specifically, each M&I water user model object will be assigned to a single county. For those M&I water user model objects that have representative service areas in multiple counties, a dominant county will be assigned based on the county with the largest proportion of water use for that M&I water user. The increase in county level M&I water demand from existing levels to 2050 (i.e., "delta demand") will be assigned to each existing M&I water user model object based on the proportion of existing water use represented by the M&I water user in that county. In other words, existing demands (as described in Section 3.3) will be increased so that total water demand represented in the model will be equal to that projected in the 2050 High Growth with passive conservation scenario described in SWSI 2010. This approach, while general, maintains an approximation of the spatial distribution of the projected growth. This results in an increase of basin-wide M&I demand from 215,550 AFY to 352,000 AFY, or an increase of 63 percent.

Crop Irrigation Demand

Similar to M&I demand, agricultural demands will be based on a 2050 planning horizon as projected by SWSI 2010. The SWSI 2010 crop irrigation demand projections were made at the DWR administrative water district level. Future agriculture water demand will be based on existing irrigation water requirement (IWR) estimates from SWSI 2010 except reduced to reflect estimates of planned agricultural to municipal water right transfers identified on the Identified Project and Processes list (approximately 7,000 acres) and estimates of land use conversion resulting from urbanization (approximately 2,500 acres). The SWSI 2010 agricultural projections also included unidentified agricultural to municipal transfers as a means to meet the projected 2050 M&I gap. In the Arkansas Basin "meeting the gap" through unplanned agricultural to M&I transfers resulted in an additional loss of approximately 45,000 irrigated acres by 2050. These unidentified transfers will not be included in the BIP shortage analysis. The above approach results in a reduction of acreage from 428,000 acres to 418,500; or 2.2 percent.

Agricultural demand projections in SWSI 2010 for crop irrigation are based on an IWR application rate of 2.32 AF/acre, which results in an estimated IWR in 2050 of just under 970,000 AFY (not including unplanned transfers). This represents a decrease in demand of 25,000 AFY compared to existing IWR levels of 995,000 AFY.

The Arkansas Basin Model requires input of headgate demand (or diversions). To convert SWSI 2010 estimates of IWR to estimated future headgate demand for the purposes of this shortage analysis a historical return flow factor (i.e., 43 percent) and historical canal loss factor (i.e., 20 percent) will be used. The equation for headgate demand is shown below.

$$\boldsymbol{Agricultural\ Headgate\ Demand} = \frac{\boldsymbol{Irrigation\ Water\ Requirement}}{(\mathbf{1} - \boldsymbol{Return\ Flow\ Factor}) * (\mathbf{1} - \boldsymbol{Canal\ Loss\ Factor})}$$

Similar to M&I demands, agricultural demands will be aggregated to the associated water user model objects. Specifically, aggregated water user model objects (as described in Section 3.3) will be assigned to a specific DWR administrative water district. For those aggregated model objects that have representative irrigated lands in multiple water districts, a dominant water district will be assigned based on the water district with the largest proportion of water use for the aggregated agricultural water user. Existing headgate demands will be modified so that total water demand represented in the model will be equal to that projected in SWSI 2010 for 2050 (not including unplanned transfer from agricultural to municipal). This approach will maintain an approximation of the spatial distribution of the projected agriculture water demand. The above approach results in a decrease of basin-wide headgate demand of 2,182,000 AFY to 2,120,000 AFY.

Return Flows

Return flows will be modeled based on typical return flow factors associated with each demand sector. For agricultural demands, the same return flow factor that is utilized to determine headgate demand will be input into the model to maintain consistency with the irrigation water requirement projections from SWSI 2010.

3.4.4 Basin Operations and Identified Projects and Processes

Basin Operations will remain largely unchanged in the shortage analysis model. Existing transbasin imports and exports will be assumed to remain constant, as described in Section 3.3. In addition, the four explicitly modeled exchanges will remain unchanged. Basin operations will be modified as needed to incorporate two large water supply projects currently under development and planning in the Arkansas Basin. These two projects are the Southern Delivery System (SDS) and the Arkansas Valley Conduit (AVC).

3.4.5 Shortage Analysis

Section to be completed after shortage analysis, which is currently ongoing.

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4.5. Municipal and Industrial Projects and Methods

The earliest projects to meet the municipal and industrial gaps in the Arkansas Basin focused primarily on infrastructure solutions: New raw water conveyance systems like the Southern Delivery System, serving urban El Paso County, and the Arkansas Valley Conduit serving the Lower Valley, or; Development of additional storage capacity, like the Preferred Storage Option Plan (PSOP). Methods, on the other hand, have explored the frontier of water resource allocation in Colorado, focusing on concepts like rotating fallowing of farm land to serve municipal needs, or alluvial aquifer storage and recovery and other non-evaporative, underground storage approaches. Over the decade since the SWSI process began, many of these earliest projects and methods have advanced significantly.

To fully understand the potential for municipal project and methods throughout the basin, the Roundtable has initiated a public outreach program. As that information is collected and reviewed by the Roundtable, the concept of localized needs and local and/or regional solutions to those needs is gaining greater validity. A shift in viewpoint from the aggregate needs of the basin to increased understanding of local needs builds on the experience gained in SWSI 2010.

This section will update the status of Identified Projects and Process (IPP's) from SWSI 2010, discuss projects and methods supported by the Roundtable since SWSI 2010, and chronicle efforts that are currently underway.

4.5.1. Definitions and Glossary

These definitions and a glossary are provided for edification of the section contents and to provide clarity to the reader.

- **Alluvial Water:** Ground water that is hydrologically part of a natural surface stream system.
- **Aquifer:** An underground layer of sand, gravel or rock through which water can pass and is stored. Aquifers supply the water for wells and springs. They may be alluvial or nontributary in nature.
- **Conjunctive Use:** Coordinated use of surface and ground water supplies to meet demand so that both sources are used more efficiently.
- **Designated Basin:** An area in which the use of ground water is assumed not to impact the major surface river basin to which the designated basin would otherwise be tributary. Much of eastern Colorado is in designated basins.
- **Environmental Impact Statement (EIS):** Detailed analysis of the impacts of a project on all aspects of the natural environment required by federal National Environmental Policy Act for federal permitting or use of federal funds.
- **National Environmental Policy Act (NEPA):** The federal law enacted to ensure the integration of natural and social sciences and environmental design in planning and in decision making that may impact the quality of the human environment.
- **Nontributary Ground Water:** Underground water in an aquifer that neither draws from nor contributes to a natural surface stream in any measurable degree.

- **Record of Decision:** The final approval of an Environmental Impact Statement which will be issued by Federal Agency review in the EIS. It is a public document that explains the reasons for a project decision and summarizes any mitigation measures that will be incorporated in the project.

4.5.2. Projects to Meet the Municipal Gap

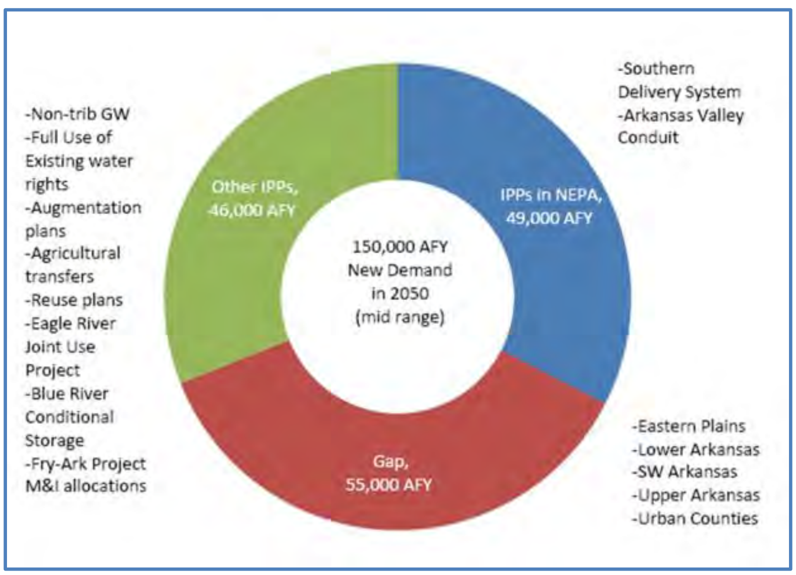
The Statewide Water Supply Initiative (SWSI) 2010 Executive Summary provided three primary recommendations to address the Municipal and Industrial (M&I) supply gap in the Arkansas Basin:

- The Arkansas Basin Roundtable acknowledges a limited number of Identified Projects and Process (IPP's) were able to meet the majority of the gap – the Southern Delivery System, the Arkansas Valley Conduit, and the Preferred Storage Option Plan;
- Storage is essential to meeting all of the basin's consumptive and nonconsumptive needs. In addition to traditional storage, aquifer storage and recovery must be considered and investigated as a future storage option;
- The Roundtable identified a critical gap as the need to replace nonrenewable groundwater and augment the sustainability of designated basins.

4.5.2.1. SWSI 2010 Identified Projects and Processes

A graphic from SWSI 2010 illustrates the role of the earliest identified projects to address the gap. Since SWSI 2010, the Arkansas Basin Roundtable has made progress on its recommendations. The three projects have all completed National Environmental Policy Act compliance and are in the implementation phase,:

Figure 1 - 2050 New Demand



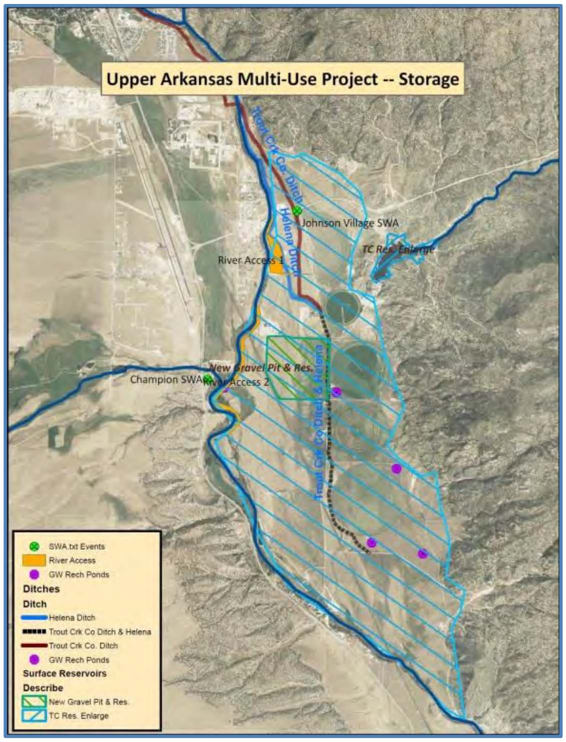
1. The Southern Delivery System is currently under construction, with anticipated deliveries commencing in 2016.
2. The Arkansas Valley Conduit has a Record of Decision approving the final Environmental Impact Statement. The Bureau of Reclamation Record of Decision for the Arkansas Valley Conduit selected the Comanche North Alternative.[1]
3. The Preferred Storage Option Plan was modified to become SWCWCD Long-Term Storage Contracts (40 years), which now has a Record of Decision for its Environmental Assessment.

[1] Bureau of Reclamation – February 27, 2014: http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=46104

4.5.2.2. Storage Projects and Processes

The concept of underground water storage, particularly Alluvial Aquifer and Storage and Recovery (ASR), is employed in many Western states as a means to retain water for future needs. The Colorado General Assembly promulgated Senate Bill 06-193, which funded a study of underground storage in the Arkansas and South Platte basins. Some of the earliest Arkansas Basin Roundtable initiatives continued to build on the potential of this form of storage within the Arkansas basin.

Figure 2 - Multi-Use Storage Project Map



In 2007, the Roundtable supported both an investigation of the alluvial aquifer storage potential of the Upper Black Squirrel Designated Basin and a two-day ASR conference in collaboration with the American Ground Water Trust on the subject (See appendix xxx and xxx). Since SWSI 2010, the Roundtable has supported investigations in the Upper Arkansas and continued investigations into the viability of alluvial aquifer storage.

Upper Arkansas Basin Multi-Use Project builds on earlier work with the United State Geological Survey concluded in 2005.[2] The following is a brief summary provided by the Upper Arkansas Water Conservancy District:

Upper Arkansas Water Conservancy District Multi-Use Project

The Upper Arkansas Water Conservancy District (UAWCD) Multi-Use Project is a collaborative approach to address multiple needs and issues, while providing a high level of benefit throughout the basin. This

[2] U.S. Geologic Survey, Scientific Investigative Report 2005-5179, Kenneth Watts

project will have a multi-purpose focus that will strive to address needs associated with municipal, industrial, agricultural, recreational and environmental demands. The Multi-Use project has the ability to integrate all of these demands and create win- win situations for all parties. The focus of this project will be presented through 5 key topics:

1. **Storage**: address future water supply demands through the effective use of existing storage, creation of new storage, and integration of surface and groundwater for storage.
2. **ATM and IPP**: produce a reliable water source through interruptible water supply and rotational lease fallowing and implement planned projects by using the Lease Fallowing Tool.
3. **Recreation & Environment**: effectively enhance and provide recreational opportunities and environmental benefits.
4. **Hydro-Power**: promote cost effectiveness through the development of a low-impact hydropower system to generate revenue.
5. **Storage Authority and Cooperation between Water Users**: promote collaboration and cooperation between private, government and public entities and create a basin wide Water Storage Authority.

Pikes Peak Regional Water Authority Black Squirrel Water Quality Monitoring Study

Applicant: El Paso County Board of County Commissioners
Completion: December 26, 2013
Status: Complete
Funds: Basin: $35,000; State: $0

The Pikes Peak Regional Water Authority (PPRWA) Black Squirrel Water Quality Monitoring Study is currently in a data collection phase. The project is to monitor water quality for potential aquifer recharge uses. The project is on-going with periodic meetings of the Groundwater Quality Study Committee, with technical advice provided by the United States Geological Survey.

4.5.3. Projects in support of Municipal Operations

This section provides information for projects in progress subsequent to SWSI 2010 which were supported by the Roundtable for ongoing municipal operations.

North Lake Dam Rehabilitation Project

Applicant: City of Trinidad
Completion: June 30, 2014
Status: In Progress
Funds: Basin: $36,962; State: $702,273

The City of Trinidad is rehabilitating North Lake Dam. North Lake Reservoir is located approximately 40 miles west of Trinidad and is the primary source of municipal water for the City. Due to safety concerns, the Office of the State Engineer imposed a restriction on the dam. To avoid further restrictions, the City is addressing the dam safety concerns by constructing a new stability berm and replacing the spillway.

Hale Reservoir Renovation

Applicant: Cross Creek Metropolitan District
Completion: June 30, 2014
Status: In Progress
Funds: Basin: $20,000; State: $100,000

Cross Creek Metropolitan District is renovating the reservoir in order to meet multiple needs, including stormwater management and nonconsumptive aesthetic and recreational demands. The nonconsumptive renovations include environmental restoration of surrounding wetlands and development of wildlife habitat and birding opportunities. In addition, the reservoir will be considered a non-potable well and will provide irrigation water to Cross Creek Regional Park and surrounding landscapes.

Water Tank Replacement

Applicant: McClave Water Association Inc.
Completion: December 31, 2014
Status: In Progress
Funds: Basin: $64,300; State: $0

The tank is one of two 50,000 gallon water tanks constructed in 1974 that has undergone regular maintenance and cleaning during their service life, and remains in good condition, if not for the failure of the cement retainer ring. The cement retainer ring around the base of the tank failed, allowing the soil under the west portion of the tank to compact and settle, causing the drain line to snap in June, 2013 and resulting in the draining of the tank. Together, the two tanks provide water to approximately 25 homes, and the fill/supply for a 150,000 gallon tank that supplies water to the system's remaining customers. Without the storage tank the supply wells and pumps are being stressed, creating an untenable and unsustainable situation. The request was by a small Water Association with few cash reserves to fund this emergency project. In addition, the urgent nature of the project precludes funding sources that would take additional time to secure and obtain a notice to proceed.

Lamar Raw Water Transmission Line Replacement Project

Applicant: City of Lamar Wastewater Department
Completion: June 30, 2015
Status: In Progress, Contracting
Funds: Basin: $50,000; State: $150,000

4.5.4. Anticipated Future Projects

Current and future water supply gaps in the Arkansas Basin demand adaptability to develop and implement new projects going forward. There are two primary drivers behind anticipating future projects and needs:

- The Public Education and Outreach efforts will generate new projects in the short to medium term. The Arkansas Basin Roundtable will need to address these potential projects through its existing processes and determine those with sufficient and appropriate cost-benefits. The outreach effort is critical in understanding stakeholder concerns and generating future projects; and,
- Data used in the Applegate 2008 report and SWSI 2010 were aggregated to the basin level, leaving the potential for significant regional or local gaps. Future projects need to address localized supply gaps at the county level. To do this, data need to be disaggregated to the county level and analyses need to provide local insights into future supply and demand.[3]

Additionally, House Bill 1284 allows pilot projects to examine new and viable ways to providing water to users. These include Super Ditch[4] and technology projects. New IPP's are anticipated in the future in order to make further use of the pilot project concept.

Finally, SWSI 2010 assumed that water supplies which were available in 2008 would remain available in 2050. This assumption needs to be revisited in future projects to account for changing watershed health, nonrenewable groundwater yields, and localized supply and demand information. New projects need to address these concerns.[5]

4.5.5. Summary and Challenges

SWSI 2010 clearly articulated that the Arkansas Basin faces a substantial municipal supply gap 40 years hence in 2050, between 36,000 and 110,000 AF depending on the success rate for IPP's,. Through regular dialogue since SWSI 2010, and particularly in the Portfolio Tool process conducted by all basin roundtables in 2012, the Arkansas Basin Roundtable has come to the realization that the timing for a municipal gap is right now.

Municipal dependence on nonrenewable hard-rock aquifers and designated groundwater sources become significant liabilities as these aquifers reach the end of their useful life. That terminal date, when the economics of continued pumping increase exponentially, is here. Alternatively, the storage potential and non-evaporative nature of these same groundwater sources indicates these liabilities can become assets in addressing the gap. Municipal projects and methods which attempt to address the immediacy of the civic supply gap will continue to be supported by the Arkansas Basin Roundtable.

[3] For more information see Sections 2.2 and 3.0

[4] A pilot program to release water to Fowler by the Arkansas Valley Super Ditch was terminated in early March when irrigators/farmers who were providing the water removed their support.

[5] See Section 2.2

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4.6. Agricultural Projects and Methods

Agriculture plays a critical role in the economy and culture of the Arkansas Basin. The transfer of agricultural water resources to the growing municipalities is a historic fact of the post-World War II era. Maintaining reliable water supplies within the basin has been a priority of the Arkansas Basin Roundtable since its inception. The 2004 Statewide Water Supply Initiative (SWSI 2004) stated:

> *"Colorado will see a significantly greater reduction in agricultural lands as municipal and industrial water providers seek additional permanent transfers of agricultural water to provide for increased urban demand." – SWSI 2004.*

The Governor's Executive Order echo's this concern about the future of irrigated agriculture when it states: *Coloradans find that the current rate of purchase and transfer of water rights from irrigated agriculture (also known as "buy-and-dry") is unacceptable."*[1] This section will describe the Arkansas Basin Roundtable's funding of projects and methods to address the needs of agriculture. The earliest efforts focused on methods. Since SWSI 2010, projects and methods have centered on three focus areas: Alternative Transfer Methods (ATM), projects which improve agricultural operations, and most recently, the need for augmentation water to support increased efficiency on the farm.

Considerations for Agriculture to Urban Water Transfers

Some of the Roundtable's earliest funded work resulted in the 2008 report *Considerations for Agriculture to Urban Water Transfers*. Arkansas Basin water stakeholders made significant efforts to answer the question: "If water is going to be transferred from agriculture, how can it be done right – with full awareness of the issues to be resolved?" The 2008 report was specifically referenced in SWSI 2010's executive summary recommendations, which reaffirmed the Basin Roundtable's support for the framework and its application to future agricultural to urban transfers. The Basin's 2009 *Meeting the Needs* Report was included in SWSI 2010 as an appendix. The 2009 Report proposed rotating fallowing of agriculture as the primary method to reduce permanent dry-up of farm land.

Considerations for Agricultural to Urban Water Transfers, 2008

FRAMEWORK CRITERIA

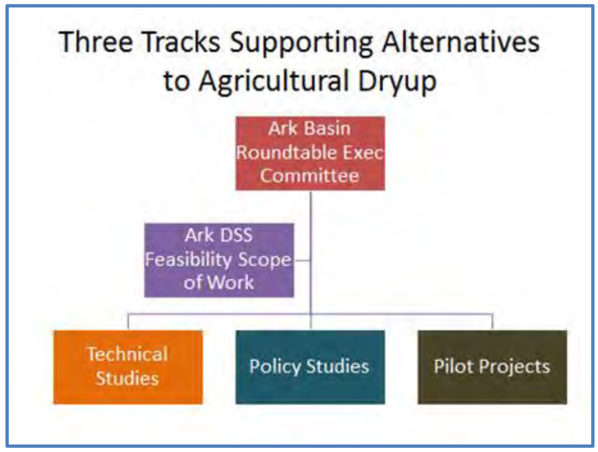
- Size of the transfer relative to the affected areas;
- Location of the transfer relative to the affected areas;
- Period of time to implement the transfer;
- Point of diversion;
- Time of diversion;
- Means of conveyance;
- Storage issues;
- Water quality impacts;
- Impact on environment;
- Impact on recreation;
- Economic impact to affected communities;
- Non-economic social impacts (psychological, health, cultural, historical, aesthetic, etc…); and,
- Local government interests.

[1] Executive Order 2013-005, Section II Purpose and Need, para. C.

Three Tracks for Rotating Fallowing

Subsequent to SWSI 2010, the Basin Roundtable has approved funding to establish rotating fallowing as an "alternative agricultural transfer method." The roundtable continues to build on the three-track program[2] developed in 2009, now conducted in conjunction with the CWCB's Alternative Agricultural Transfer Grant program. The three tracks, Technical Studies, Policy Studies and Pilot Projects, are pursued with oversight by the Roundtable's Executive Committee, and in support of a future Arkansas Decision Support System.

Figure 1 - Three tracks supporting ATM



As these three tracts developed, one of the unique constraints of the Arkansas Compact emerged. Increased farm efficiency, for example a change from flood irrigation to center-pivot sprinklers, requires increased supplemental volumes of water (augmentation)[3]. There is now a recognition that the development of alternatives to permanent dry-up will also support agriculture as it becomes more efficient in the future.

4.6.1. Definitions and Glossary

Agricultural definitions and a glossary are provided for edification of the section contents and to provide clarity to the reader.

- **Agricultural Gap**: the difference between what the basin indicates it wants to achieve with regard to agriculture, as defined in its goals and measurable outcomes, and what projects and methods it has determined could be implemented to meet those needs (from SWSI 2016 Glossary, Colorado Water Conservation Board). This definition is significantly different than that provided by SWSI 2010, which defined the gap as the difference between full irrigation water requirement consumptive use and water-supply-limited consumptive use.
- **Alternative Agricultural Transfer Methods**: methods to prevent the permanent transfer of water away from agriculture (typically to meet urban demands). They include rotational fallowing, water banks, purchase and leasebacks, deficit irrigation, and alternative crops.
- **Augmentation Water**: Augmentation water provides replacement of out-of-priority depletions to prevent injury to other water rights, and is required under Rule 10 and Rule 14 Plans, approved by Colorado Division of Water Resources Division 2 Engineer. Augmentation water

[2] See Section 2.2.4.1

[3] The Arkansas River Compact of 1948 apportions the waters of the Arkansas River between Colorado and Kansas, while providing for the operation of John Martin Reservoir. The Compact is "not intended to impede or prevent future beneficial development… as well as the improved or prolonged functioning of existing works: Provided, that the waters of the Arkansas River… shall not be materially depleted in usable quantity or availability…" (Article IV, para. D.).

sources include fully consumable irrigation water that has been through a water court change case, municipal effluent from transbasin sources and effluent from non-tributary groundwater.

- **Decision Support System**: water management system developed by the Colorado Water Conservation Board and the Colorado Division of Water Resources for each of the State's major water basins. It provides water resource data, modeling, geographic information systems, and documentation to support basin and statewide water decision making. At this time, there is not a fully articulated Decision Support System in place, however, funding continues on elements identified in a Feasibility Scope of Work.
- **Rule 10 plans**: The Colorado State Engineer, in order to comply with the Compact, developed "Compact Rules Governing Improvements to Surface Water irrigation System in the Arkansas River Basin in Colorado." Rule 10 allows ditch systems to collaborate on a Compact Compliance Plan to cover multiple irrigators. Plans must be filed by irrigators within the relevant regions (above and below John Martin Reservoir) detailing their acquisition of augmentation water to preclude depletion of flows within the Arkansas River.
- **Rule 14 plans**: Developed in accordance with Rule 14: Applications for Approval of Plans to Divert Tributary Ground Water. These rules were promulgated in response to the Kansas v. Colorado U.S. Supreme Court decision in 1996 requiring augmentation of groundwater wells constructed after 1948.

4.6.2. Projects to Support Alternatives to Permanent Dry-up

Studies to develop projects and method supported by the Arkansas Roundtable came from both the Water Supply Reserve Account program and a separate ATM grant program. Both grant programs are approved by the Colorado Water Conservation Board and administered by the CWCB staff, however, only WSRA grants are subject to approval by the Roundtable. Following are summaries derived from various CWCB memoranda describing the individual programs, organized in time periods since SWSI 2010. Studies conducted under the separate ATM program are included in Appendix XXX.

4.6.2.1. SWSI 2010 through July, 2012

The following are the WSRA grant summaries maintained by the Colorado Water Conservation Board for the programs and studies initiated:

Accounting and Administrative Tool for Lease Fallow

Applicant: Upper Arkansas Water Conservancy District
Approved: March 2013
Status: In Progress
WSRA Funds: $59,215

The Accounting and Administrative Tool project will build, assess, and document accounting and administration tools for lease fallowing as part of a "Super Ditch" style plan, in which several ditches come together, among seven Arkansas River ditches located between Pueblo Reservoir and John Martin Reservoir. The objectives of the tool are to:

1. Quantify the transferrable consumptive use derived from fallowed land parcels;

2. Quantify the associated changes in the amount, timing, and location of:
    a. Surface runoff to drains and to the Arkansas River;
    b. Recharge to the alluvial aquifer; and
    c. Groundwater return flows to the Arkansas River.
3. Support the development of plans to maintain return flows at or above historical levels and to quantify transferrable consumptive use at or below historical levels in a manner that complies with Colorado water law and the Arkansas River Compact; and,
4. Develop data interfaces that will complement the Arkansas River Decision Support System (ArkDSS) and build a common technical platform for the transfer of data to and from Hydrobase.

The Accounting and Administrative Tool is scheduled to be completed by January, 2015. For further information regarding the Accounting and Administrative Tool contact Terry Scanga, Upper Arkansas Conservancy District, at manager@uawcd.com.

Super Ditch Delivery Engineering

Applicant: Lower Arkansas Valley Water Conservancy District
Approved: November, 2011
Status: In Progress
WSRA Funds: $225,837

The Super Ditch Delivery Engineering project is an extension of the previous work performed by and for the Lower Arkansas Valley Water Conservancy District (LACWCD) to advance the Super Ditch fallowing project. The LAVWCD and the Super Ditch Company seek to preserve irrigated agriculture in the Lower Arkansas Basin with temporary water transfers and other methods than can benefit both the municipal interests and those of the local agricultural based economy. This additional engineering analysis is intended to enhance the understanding of the water resources in the Lower Arkansas Basin and improve the modeling of the operations. The key objectives of the project include:

- Analysis of reservoir operations in the lower Arkansas basin;
- Analysis of Pueblo Reservoir operations;
- Analysis of the Winter Water Storage Program;
- Recovery of non-exchangeable supplies;
- System calibration and optimization; and,
- Engineering and economic integration.

For further information on the Super Ditch Delivery Engineering project, contact Jay Winner, General Manager, Lower Arkansas Valley Water Conservancy District, at jwinner@centurytel.net; or Carla Quezada, Office Manager, LAVWCD, at cquezada@centurytel.net, (719) 254-5115.

4.6.2.2. 2012 to the Present

The dialogue between Arkansas Roundtable members revealed additional areas appropriate for investigation. The economic contribution of agricultural water supplies to the environment (species habitat and open space) and recreation (rafting, fishing, etc.) was examined[4]. Senior agricultural water rights in the Lower Arkansas Valley call water downstream, providing sustainable river flows in the Upper Arkansas. An understanding of the economic benefits of the current condition was deemed useful to better evaluate the economic impact of potential permanent dry-up. Legislative initiatives taken in good faith to support agriculture during this period, also prompted the Roundtable to convene a conference for water policy makers, to better understand the economics of agricultural water usage.

Legal challenges were raised to the first pilot project efforts. In the 2013 session of the Colorado General Assembly, legislation was passed known as House Bill 13 1248, *CONCERNING THE AUTHORIZATION OF PILOT PROJECTS FOR THE LEASING OF WATER FOR MUNIPAL US*E (Appendix XXX). This legislative solution was preceded by a public policy working group to coordinate with other basin roundtables on state law that might impact other basins. Following are summaries of the programs:

Study of Economic Contribution of Agriculture to Arkansas Basin

Applicant: Colorado State University
Approved: 2013
Status: Completed

A study was conducted in 2013 by Prof. James Pritchett and M.S. Candidate Jake Salcone (Dept. of Agricultural and Resource Economics, Colorado State University) to better understand the implications of water transfers out of agricultural uses. Methods were summarized for calculating a comprehensive value of the water used in agriculture by considering irrigated crop sales, economic spillovers from direct agriculture sales and additional non-consumptive water use benefits accrued to recreational activity through agricultural water deliveries. In a specific application, the direct, indirect and induced economic activity from the Arkansas River basin's irrigated agriculture is estimated using a generalized input-output model (IMPLAN) and recreation values are estimated using benefit transfer methods. Limitations of this study include a reliance on secondary data rather than primary data collection, and the accounting stance does not include all potential water values such as the provision of non-market ecosystem services and dynamic effects found in multiple years of impact adaptation. Results estimate a collective economic activity totaling more than $1.5 billion, employing over 12,000 people from industries intertwined with Arkansas Basin agricultural water use.

[4] At the request of the Arkansas Roundtable, this study was funded by a Task Order directly from CWCB to the Colorado State University Water Institute. A "Value of Agriculture" committee was formed within the Roundtable, which provided oversight and regular updates on the progress of the study.

***Pilot Project**: Agricultural Municipal Conservation Easement Demonstration*

Applicant: Lower Arkansas Valley Water Conservancy District
Approved: December, 2012
Status: Completed
WSRA Funds: $270,000

The purpose of the Agricultural Municipal Conservation Easement Demonstration is to demonstrate the use of conservation easements on irrigated agricultural land to both preserve long-term agricultural irrigation and provide secure long-term water supplies to a municipality. The concept would create an additional new alternative to the historical "buy- and-dry" of irrigation water rights for Municipal and Industrial uses. An Agricultural Municipal Conservation Easement would perpetually preserve the irrigated land and give the municipality a secure, legally enforceable permanent source of additional water supplies.

Subsequent to the demonstration project, three additional projects have been completed, with one in progress along the High Line Canal. The project area includes 400 acres with the option for municipalities to lease the water during three out of ten years. Additionally, the project ties the water to the land permanently and facilitates intergenerational transfer. Finally, the Lower Arkansas Valley Water Conservancy District is operating or commencing similar (although not intergenerational) projects on both the Holbrook and Catlin Canals. Funding for several projects is coming from the Gates Family Foundation (Colorado) and the Palmer Foundation.

Public Policy: Rotating Agricultural Fallowing Public Policy Work Group

Applicant: Pikes Peak Regional Water Authority
Approved: July, 2011
Status: Completed
WSRA Funds: $20,000

This grant helped fund a facilitated dialogue with interested stakeholders regarding the need for legislation to facilitate alternative agricultural water transfers (e.g. agricultural fallowing) based on research into existing statutes. The Work Group was a response to the proposed yet unsuccessful legislation (HB11 1068) of the 2011 legislative session. The goals of the working group are listed below:

- Review existing statutory law concerning agricultural transfers;
- Identify pertinent citations that might be modified for expediting agricultural transfers;
- Conduct a facilitated dialogue with the stakeholders; and
- Produce a summary report of the process.

Public Policy: *Agricultural Economics and Water Resources: Methods, Metrics and Models A Speciality Workshop*

Applicant: Colorado State University
Approved: June 2013
Status: Completed
WSRA Funds: $9,746
Other Funds: Provided by a working partnership with the Colorado Ag Water Alliance (CAWA).

The project convened workshop in Colorado Springs, CO that included experts in the field of agricultural and water resource economics. The objective of the workshop was to examine current methods and modeling techniques to estimate the value of water for various uses including agriculture and other nonconsumptive uses. The Draft Report, dated February 18, 2014, is still under review, and is included here as Appendix XXX.

4.6.3. Agricultural Projects Directly in Support of Agriculture

The Arkansas Roundtable approved grants that were directly in support of current agricultural operations, including:

Ordway Cattle Feeders Water Line Extension, Phase II

Applicant: Crowley County Board of Commissioners
Approved: April, 2013
Status: Completed
WSRA Funds: $72,500

The purpose of the Line Extension Project was to complete a raw water system to provide a consistent, viable water supply, enabling Ordway Cattle Feeders to sustain its operations and improve economic stability within Crowley County. The total cost of the Project was estimated to be $3.38 million. Crowley County was approved for a $275,000 WSRA grant by the Arkansas Basin Roundtable. The Company also obtained a loan from the CWCB to cover the remaining 90 percent of Project Costs.

Project: A Multi-Media Program for Reporting Crop and Turf Water Use Estimates from the Colorado Agricultural Meteorological Network (CoAgMet).

Applicant: Sangre de Cristo RC&D Council Inc.
Approved: September, 2011
Status: Completed
WSRA Funds: $9,000

This project employs a multi-media approach to communicate crop and turf water use reports to irrigators in the Arkansas Basin, particularly the areas served by the Colorado Agricultural Meteorological Network (CoAgMet). It consists of a multi-media approach over a three year period to expand the CoAgMet with improvements to allow other types of devices (such as cellular phones) to be used in place of computers. An additional project component developed a telemetric system for daily or weekly distribution of evapotranspiration reports through cellular telephone text messaging.

4.6.4. Anticipated Future Projects

The Basin Implementation Plan Outreach[5] program is currently seeking input from regional and local stakeholders. This process will reveal or generate additional projects potentially eligible for WSRA funding through the Arkansas Basin Roundtable. In addition, expanding the pilot programs into fully operational, basin-wide projects and methods is critical to future success in meeting the needs of agriculture in the Arkansas Basin. The pilot projects, many of which are in-progress, demonstrate successes and opportunities for improvement before full expansion or investment.

4.6.5. Summary and Challenges

The Arkansas Basin Roundtable fully recognizes the challenges facing irrigated agriculture within the Basin; the primary concern of agricultural stakeholders is the permanent drying of irrigated land. The Roundtable has sought to develop projects and methods to promote rotating fallowing using projects such as conservation easements, accounting and administrative tools, along with supportive changes in public policy. In addition, the Roundtable has focused on specific economic needs, such as the Ordway Cattle Feeders project and modern delivery of CoAgMet data. These projects underpin the ability of local producers to maximize their resources and encourage economic development.

To further understanding of agriculture's contribution to the Arkansas Basin economy, the Roundtable commissioned an economic study by the Water Institute and convened a conference for policy makers in partnership with the Colorado Agricultural Water Alliance. While rotating fallowing projects are being undertaken, as of this date, their outcomes are uncertain. The Roundtable is using pilot projects to study the efficacy of fallowing projects. However, the group acknowledges that the strong economic forces driving water toward municipal users from agriculture will continue.

The Arkansas Basin Roundtable has identified a primary goal of "sustaining an annual $1.5 billion agricultural economy within the basin." By selecting an economic goal, as opposed to a gross acreage goal, the Roundtable's projects and methods may allow water to be removed from the most marginally productive lands, while encouraging projects and methods that move the basin toward high-value crops and production. At the same time, support for collaborative solutions between and municipal and agricultural will continue. This approach addresses the need for additional augmentation water for agriculture, while acknowledging the important role agricultural water plays in the entire economy of the Arkansas River Basin.

[5] See Section 4.1 Outreach, Participation and Education

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4.8. Interbasin Projects and Methods

Interbasin projects and methods focus on those projects where multiple basin roundtables may have a common interest. The Arkansas Basin is an importing and exporting basin, receiving water transfers from several watersheds in the Colorado basin, and delivering native water to the South Platte basin. Imported water can be used to extinction within the Arkansas Basin, which, when combined with storage in the Upper and Lower Arkansas Valley, becomes the corner stone for all types of uses, recreation, environmental, agricultural and municipal.

Section 4.8 was deemed optional by the Colorado Water Conservation Board; however, the Arkansas Basin Roundtable included it for three reasons:

1. As an importing and exporting basin, the future of the State's Colorado River Compact Entitlement directly affects all water uses in the Arkansas Basin; in particular, a future without New Supply, as that term is understood in the lexicon of SWSI 2010, is detrimental to the future of agriculture in the Arkansas Basin;
2. There are opportunities for collaboration across the Continental Divide in both directions. Collaboration at that scale might only be possible through vigorous dialogue between basin roundtables with support from the Interbasin Compact Committee, and;
3. Storage in all forms— both restoration of existing structures and construction of new storage vessels— is impacted by the regulatory regime that governs dam design. Practical and realistic design of dam structure using the latest in technological advances will benefit every basin in Colorado.

Previous reports and documents have described agricultural dry-up as a medium to long-term issue; however, the Arkansas Basin Roundtable sees the issue as critical in the near-term. Discussions concerning new supplies need to include all potential alternatives. New, interbasin supplies are a potential alternative to long-term permanent agricultural dry-up, as identified in the Governor's Executive Order D 2013-005.

Cooperation in the storage and release of water in the Upper basin creates the recreation that underpins the economy of several counties. Because the bedrock of the Voluntary Flow Agreement is appropriate hydrology for fish species in the Spring and Fall, the management of storage releases is fundamental to a robust environment. New storage vessels are needed to meet all demands, yet the high cost of construction for new storage is exacerbated by current design requirements. Improved analysis, for example, the Extreme Precipitation Assessment Tool ("EPAT"), could potentially reduce those future costs, but needs support from water users in all basins.

4.8.1. Definitions and Glossary

Interbasin Compact Committee (CRS 37-75-101 et seq.)**:** The Interbasin Compact Committee (IBCC) was established by the Colorado Water for the 21st Century Act to facilitate conversations among Colorado's river basins and to address statewide water issues. A 27-member committee, the IBCC encourages dialogue on water, broadens the range of stakeholders actively participating in the state's water decisions, and creates a locally driven process where the decision-making power rests with those living in the state's river basins.[1]

Interbasin Compact Charter: Foundational legal principles for the Interbasin Compact Committee.[2]

4.8.2. Background on New Supply Initiatives

The 2009 Needs Report acknowledged the Arkansas Basin's dependence on the Colorado River. At that time, two efforts—a private effort known as the Million Resource Group and a public effort by the Colorado-Wyoming Coalition—were exploring construction of a pipeline from Flaming Gorge Reservoir. What impact might development of new supplies from Flaming Gorge mean to the Arkansas Basin; and, given the scale of the municipal supply gap identified by the Metro and South Platte Roundtables, would any new supply from the Flaming Gorge ever reach the Arkansas Basin?

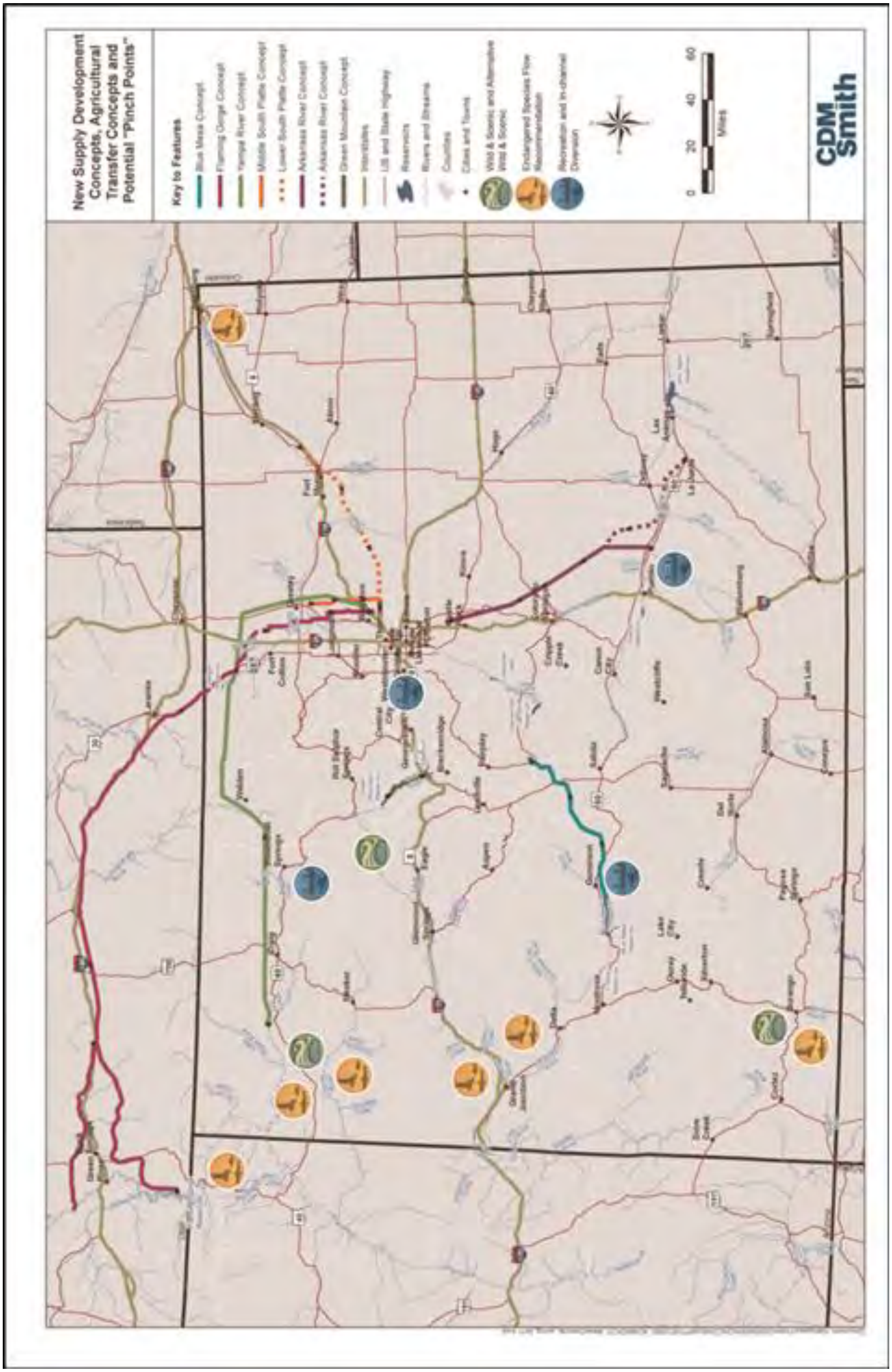
The Arkansas Basin Roundtable, in collaboration with the South Platte Roundtable, commenced work in 2010 on an evaluation of the merits of a basin-to-basin working group. The Assessment was conceived in order to determine the viability of dialogue on new water supplies from the Colorado River Basin. The Flaming Gorge Project Task Force Assessment is detailed below.

Flaming Gorge Project Task Force Assessment

Applicant: El Paso County Water Authority
Approved: May, 2010
Status: Completed
Funds: Basin: $20,000 each, total Arkansas and South Platte Roundtables, total $40,000

The Flaming Gorge Project Task Force Assessment determined the viability of forming a task force, similar to the Fountain Creek Vision Task Force, to inform a Flaming Gorge Project. The Assessment reviewed constituent agendas, supply alternatives, demand management, environmental impacts, and project development strategies to determine if a collaborative task force model is viable. Keystone Center prepared a written Assessment Summary, including a recommendation on whether to proceed to the convening of a task force or not. The Assessment recommended proceeding with a full task force with an invitation for all nine basin roundtables to participate. Concurrently, the Colorado Water Conservation Board, in drafting SWSI 2010, produced a Pinch Points map. The Assessment Summary is included as Appendix XXX.

[1] For further information: http://cwcb.state.co.us/about-us/about-the-ibcc-brts/Pages/main.aspx
[2] For further information: http://cwcbweblink.state.co.us/weblink/0/doc/114181/Page1.aspx?searchid=c38d2e6b-e19e-4b70-9c88-89fd819136e6


New Supply Development Concepts, Agricultural Transfer Concepts and Potential "Pinch Points"
Key to Features
CDM Smith

4.8.3. Background: Statewide Water Supply Initiative 2010

The Arkansas Basin's edition of the Statewide Water Supply Initiative of 2010 included the recommendation that all 4 legs of the stool, including New Supply, were critical to the future, and included a discussion of the Flaming Gorge Task Force Assessment.

4.8.4. Post SWSI 2010: Projects In-Progress

The Flaming Task Force convened as recommended in the Assessment. In approving the program, the CWCB divided the effort into two phases. Phase One was completed in the Fall of 2012, a summary is included below:

Project Exploration Committee: Flaming Gorge

Applicant: Pikes Peak Regional Water Authority
Approved: December 2011
Status: Completed
Funds[3]: Statewide: $50,000, Arkansas WSRA Basin: $5,300, Metro: $8,700, South Platte, Gunnison & Colorado: $2,000 each, Rio Grande & Southwest: $1,000 each.

This grant established the Basin Roundtable Project Exploration Committee to serve as a venue for roundtable to roundtable discussions of potential water supply projects, with the Flaming Gorge Pipeline project serving as a test case or starting point. The Basin Roundtable discussions did not seek consensus on whether or not to build a Flaming Gorge project, but rather examined the issues involved in the project, the challenges or barriers to such a project, and potential benefits of such a project. This grant built on the Flaming Gorge Task Force Situation Assessment WSRA grant approved by the Board in May 2010. The Assessment grant asked independent facilitators to assess the timeliness and merits of a discussion on the topic of a Flaming Gorge project.

The Task Force Report is included in Appendix xxx, and includes a Process Flow Chart and a list of elements that would constitute a "Good" Project. In January, 2013, the CWCB board declined to proceed with Phase Two of the Task Force, perhaps in anticipation of the Colorado Water Plan.

Subsequently, the Roundtable has continued its interest in the New Supply dialogue, with discussion of a more environmentally-centered approach to a pipeline from the Green River as described below:

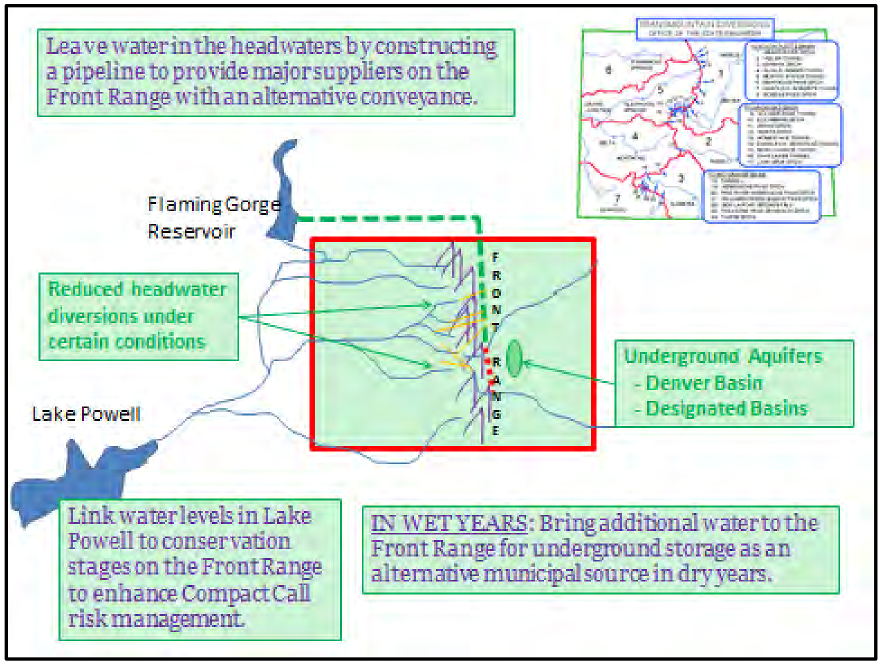
Green River Riparian Restoration Project

The New Supply conversation is proceeding at the IBCC under the heading "preserving options" or "conceptual agreement." On a parallel track, a discussion among roundtable chairs in early 2014 reviewed the following approach for further dialogue between roundtables.

[3] SUMMARY MINUTES AND RECORD OF DECISIONS, September 13-14, 2011,Final and Approved November 15, 2011

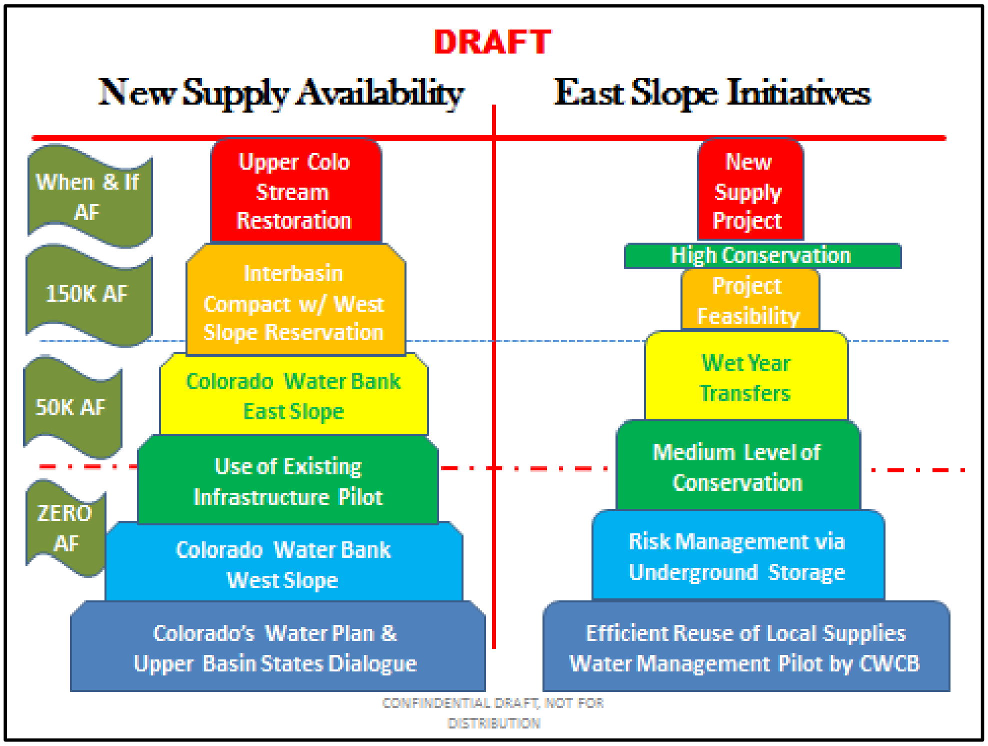
Objectives of a Project Proposal

The Project Exploration Committee asked its members to articulate perspectives on the advantages and disadvantages of a potential pipeline project. One of these, as shown in the graphic, was framed as an alternative conveyance for existing Colorado River Compact water rights, which would then allow reduced diversions in Colorado River headwater streams for restoration of the riparian habitat. With an alternative delivery mechanism, those entities with entitlements to divert at the headwaters would convey an equivalent amount of water through a new pipeline. The pipeline then becomes a tool for greater flexibility in management of Colorado's entitlement under the Colorado River Compact.



In the summer of 2013, in the wake of the Governor's Executive Order calling for a State Water Plan, the three East Slope roundtables began development of a White Paper as a means to align approaches to the various topics under discussion. The draft White Paper was specific as to New Supply, including the Pinch Points map from SWSI 2010 identifying potential pipeline configurations. Of the six (6) identified projects, only the one sourced in the Green River appeared as a viable alternative to move Colorado River water to the East Slope without excessive energy costs. When an alternative delivery mechanism is in place, headwaters restoration becomes possible.

The White Paper also agreed with many West Slope concepts for elements precedent to any project development, such as risk management. The proposed Section 4.8 draft would proffer specific actions establishing milestones along the path of project development—a "stack strategy." The graphic below is intended to describe the milestones, which are then linked to availability of new water supplies. The strategy takes on Risk Management, Conservation, and a reservation of water for future growth on the West Slope. Such an "intrabasin compact" is an integral component of the *Water for the 21st Century Act.*



Next Steps

In a conversation between roundtable chairs on March 8, 2014, there was a willingness to respond to this approach within basin implementation plans if proposed by the Arkansas roundtable, hence its inclusion here.

4.8.5. Continuing Interbasin Dialogue

The July 8, 2014 Arkansas Basin Roundtable included a brief discussion of the Draft Conceptual Agreement by the IBCC. A summary memorandum by Jacob Bornstein, IBCC, and Roundtable Program Manager of CWCB staff, is included as Appendix XXX.

4.8.6. Design and Construction of New Storage

The State of Colorado needs to support the continual improvement of the design criteria and parameters for new storage. This support is important for the all Basin Implementation Plans. As technology changes, the State should provide funding to support updating technical programs and activities which will help meet the gap. Better management tools will optimize projects to meet multiple needs, minimize cost, and protect public health and safety.

4.8.7. Summary and Challenges

Although an "optional" section, a discussion of Interbasin Projects and Methods is fundamental to an Arkansas Basin Implementation Plan. The Arkansas Roundtable has consistently taken the initiative to foster basin-to-basin initiatives. The motivation is derived from what the Basin stands to lose—not only continued and increasing transfers from agriculture to municipal uses—but also significant recreational and environmental benefits derived from Colorado River basin imports. Hundreds of thousands of tourists enjoy rafting the Arkansas River each year, with no awareness (nor is one needed) that they are rafting on imported Colorado River water. Water is stored in the headwaters, retimed to support native flows ,and recaptured in Pueblo Reservoir where it serves agriculture and municipal needs. When managed through the Voluntary Flow Agreement, the supplemental flow supports the Gold Medal fishery of the Upper Arkansas River and the economy thereof. All water interests present at the Arkansas Roundtable are therefore stakeholders in the future of the Colorado River. This subject is important to our collective future.

Section 5 Implementation Strategies for Projects and Methods

Table of Contents

5.1 Introduction

This section identifies water management challenges and opportunities within the basin and outlines a framework for addressing them. The Arkansas Basin Implementation Plan continually emphasizes the need to develop sustainable and reliable water supplies for the future. This implies focusing on quality and quantity through standardized decision making processes, stakeholder engagement, public outreach, and thorough research.

The Arkansas Basin Roundtable has focused on water as an economic asset while incorporating its cultural, social, and environmental aspects in decision making. The Roundtable intends to continue using this framework for grant decision making. In addition, the Basin Implementation Plan has provided the Roundtable the opportunity to deepen community and stakeholder engagement, outreach and education. Stakeholders and water constituents are critical to developing a well-rounded and complete needs assessment of the Basin going forward. While the Basin Implementation Plan provides significant needs assessments (see Section 2), it is critical that the Basin continue to develop needs assessments, as changing public attitudes, regional demographics and economics demand attention.

Fundamental to the outreach and education process are the Roundtable's goals of integrating water planning across the Arkansas Basin. Providing Water Supply Research Account (WSRA) grants to a broad variety of users and water uses is important to the future of the Basin in addressing all water needs and concerns, from developing sustainable municipal water supplies for at-risk regions to maintaining and growing water based tourism, the Arkansas Basin Roundtable seeks equal input from all stakeholders in order to create an integrated plan.

Finally, the Arkansas Basin Roundtable finds research to be critical to its understanding of the roles water plays in the Arkansas Basin. Recently, the Roundtable funded a Colorado Water Institute (Colorado State University) study of the economic role of water in the Basin, conducted an infrastructure study, and established exploratory committees to review opportunities. These projects demonstrate the ongoing commitment by the Roundtable to developing greater knowledge and understanding of the roles water plays in the lives of Arkansas Basin Residents.

5.2 Meeting the Challenges and Implementing the Identified Projects and Processes (IPP's)

The Arkansas Basin Roundtable has a strong history of stakeholder engagement and methodical planning. In developing the Basin Implementation Plan, the Roundtable used a two tiered approach:

1. Water planning is conducted through an economic perspective, an initiative supported directly through the Governor's Executive Order 2013-005. The Executive Order requests that the Statewide Water Plan, and by extension the Basin Implementation Plans, incorporate *"a productive economy that supports vibrant and sustainable cities, viable and productive agriculture, and a robust skiing, recreation, and tourism industry."*
2. Water planning incorporates public outreach and education in order to elicit stakeholder responses, generate broad coverage of water issues, and detail the totality of the Arkansas

Basin's needs. This process has revealed the sub-regional nature of the projects and processes identified by the Basin Implementation Plan, and the importance for those projects and processes to have local support in the future.

The Arkansas Basin Roundtable, through the previous reports, came to consensus through the SWSI 2010 process on the critical needs and paths forward for the Basin. A subset of the SWSI 2010 recommendations includes:

- Implementing all "four legs of the stool[1]";
  - Active and passive conservation;
  - Implementation of all identified projects and processes;
  - Alternatives to agricultural transfers;
  - Development of Colorado River supplies;
- Addressing the critical gap that exists in nonrenewable groundwater supplies and the sustainability of designated groundwater basins;
- Acknowledging that storage, including alluvial storage and recovery, is critical to meeting the Basin's consumptive and nonconsumptive needs, and is essential to all solutions;
- Generating greater stakeholder input and participation for environmental, recreational, and agricultural water users and advocates; and,
- Acknowledging the importance of agriculture as a key cultural and social component of the Basin, beyond its economic importance.

The Arkansas Basin Roundtable continues to view the SWSI 2010 recommendations as critical components of water strategy and planning going forward. The SWSI 2010 document and recommendations built on dialogue generated by the preceding reports produced by the Roundtable.

5.3 Finalizing the Basin Implementation Plan

In order to process the input received, bring clarity to identified projects and processes (IPP's) and understand potential projects and methods, the Arkansas Basin Roundtable will follow three steps:

1. Review and determine status of all input received, sorting into categories:
   A. Meets the IPP criteria, or;
   B. Qualifies as a Project or Method, or;
   C. Requires more information, or;
   D. No project identified—expression of sentiment or general commentary on the process
2. Convert the input into a project sheet format organized by sub-regions
3. Establish a protocol for setting priorities
   A. How the project meets the basin needs and goals

[1] This euphemism was articulate by the Interbasin Compact Committee in a Portfolio Tool Exercise (2012) that explored various combinations of these elements at the basin-wide level. The Arkansas Roundtable adopted recommendations that emphasized that all four elements were critical to meeting the Arkansas Basin's gaps. For a complete list of the recommendations see SWSI 2010 page ES-

B. Tier 1, 2 & 3 methodology

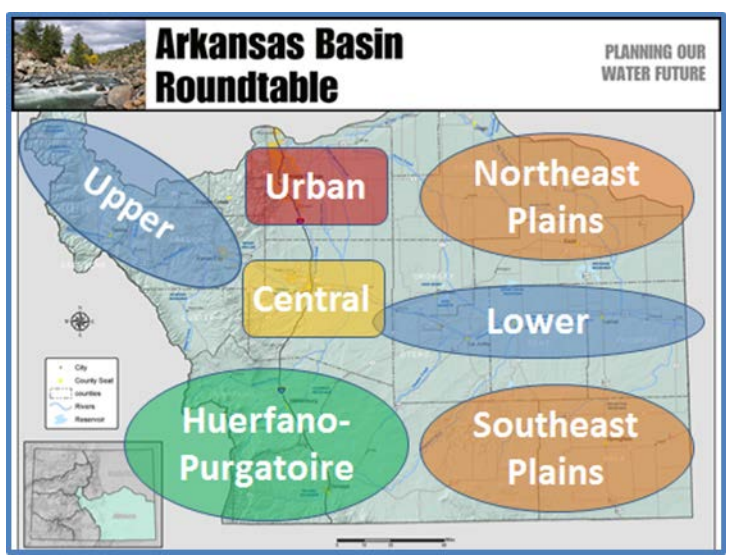
The historic approach by the Arkansas Basin Roundtable, as documented in SWSI 2010, took a basin-wide viewpoint. Seeking to address local and regional issues through collaboration is recommended as the guiding principal for the Arkansas Basin Roundtable and its constituents for future water planning.

<u>*Decision Mechanisms*</u>

Prior to SWSI 2010, the Arkansas Basin Roundtable produced the document *Meeting the Needs of the Arkansas Basin 2009*, which used a sustainability model to rank and prioritize projects and methods. The sub-regional nature of water supply gaps in all topic areas, agriculture, environment, recreation and municipal, was identified as a critical issue during the planning process. Therefore, the information derived from the Roundtable's outreach effort should be organized along the same lines. Since the bulk of Roundtable members are identified in the *Water for the 21st Century Act* by County, the Input Forms included a similar designation. Grouping these County identifiers into sub-regions provides an organizing protocol for processing the suggestions garnered from Basin stakeholders.

Table 1 – Counties as Sub-Regions, Arkansas Basin.

Subregion	County					
Central	Pueblo					
Huerfano-Purgatoire	Huerfano	Las Animas				
Lower	Bent	Crowley	Otero	Prowers		
Northeast Plains	Cheyenne	Elbert	Lincoln			
Southeast Plains	Baca					
Upper	Chaffee	Custer	Fremont	Lake	Teller	Saguache
Urban	El Paso					



Processing the input received, and continuing to identify projects and methods that are underway in various sub-regions of the Basin, will be the primary task of the Arkansas Roundtable during the period of August 1, 2014 through the end of the year. In parallel with the sorting and processing, the Roundtable will develop a Project Summary Sheet and a protocol for establishing priorities among the suggestions received. Excellent examples of both a Project Summary Sheet and a set of Tiered Criteria were presented by other Basin Roundtables to the Colorado Water Conservation Board at its July, 2014 meeting. Modified versions of these tools will be adapted by the Arkansas Roundtable for its internal use and for input to Colorado's Water Plan and SWSI 2016.

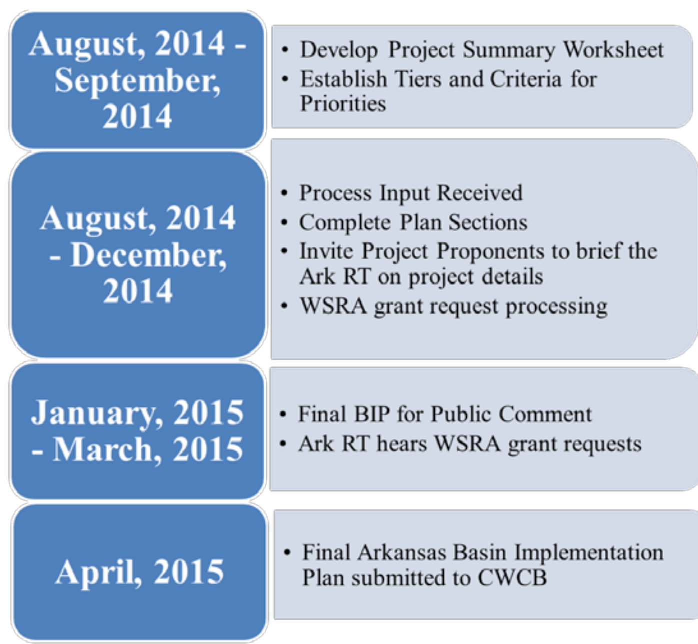
5.4 Timeline for Activities

The Arkansas Basin Roundtable will move forward over the next year to build a solid foundation of projects, processes, and methods for the SWSI 2016 initiative. The identified timeline involves spending the remainder of 2014 reviewing Basin Implementation Plan results, input forms, presentations, and project proposals. Beginning in January 2015, the Roundtable intends to invite public comment both at Basin Roundtable meetings and on the Roundtable's website (arkansasbasin.com). Comment and feedback on projects and processes going forward has always been welcomed.

5.5 Processing Input and Regional Initiatives

Beginning in August, through December 2014, the Roundtable will develop and complete its own Project Summary Sheets, organize these on a sub-regional basis, and establish internal criteria for setting priorities. Factors in the criteria might include whether the project is multi-purpose, brings partnerships together, provides creative and multi-source funding and the extent to which the project or method addresses specific Basin Goals.

Many sound concepts appear to have merit, as proposed, but will need to be understood in greater depth. Therefore, project proponents may be asked to present their project to the Roundtable at a regular, monthly meeting. This provides an opportunity for feedback and suggestions from Roundtable members to strengthen the project's potential for implementation.



Finally, the projects can be measured against the criteria developed, the standards for qualifying as an IPP and the Basin's Goals. The tables below present an example based on a recent request for WSRA funding approved by CWCB in May, 2014. The first table shows that the Red Wing Augmentation Facility meets the standards of an IPP[2], is a Tier 1 project (criteria to be developed, shown here for illustrative purposes) and addresses several of the Basin's categories of need. The second table highlights specific Basin Implementation Plan goals that are met by the project proposal.

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[2] See SWSI 2016 Glossary for details of standards for IPP classification.

Tables 2 – Example of How a Project Meets Basin Needs

Project SubRegion	Project or Method	IPP?	Proponent	Tier	Needs Meet				
	Name	Y/N	Name	1,2 or 3	Storage	M & I	Ag	Enviro	Rec
H-P	Red Wing Aug Facility	Y	HCWCD	1	X	X	X	X	

Project or Method	Basin Goals Met																			
Name	S1	S2	S3	S4	M1	M2	M3	M4	A1	A2	A3	A4	NC1	NC2	NC3	NC4	NC5	NC6	NC7	NC8
Red Wing Aug Facility	X		X					X		X							X		X	

5.6 Receiving Public Comment

The Arkansas Basin Implementation Plan process included a series of town meetings, allowing the Roundtable to directly hear the suggestions, concerns and questions of its constituents. The Arkansas Basin Roundtable will commence a final review of the Basin Implementation Plan documentation from October through December 2014 in anticipation of receiving public comment on the final draft document. This preparation includes finalizing or refining Sections 2.1 Nonconsumptive Needs, Section 4.2 Watershed Health, and Section 4.7, Nonconsumptive Projects and Methods. These sections were completed just in time for the July 31, 2014 deadline for submission of a Draft Plan, and will be reviewed by the Roundtable over the next few months.

Beginning in January, 2015, the Arkansas Basin Implementation Plan will be available in a final draft form for public comment. The Roundtable needs to determine the process for soliciting and reviewing public comment. Suggestions include formal presentations to the conservancy district and water utility boards of directors, public presentation to non-governmental organizations with specific areas of interest (conservation, stream flow restoration, boating, wildlife viewing, etc.), regional public meetings hosted by Roundtable members throughout the Basin, and perhaps a custom input form available on the website. Through this process, the Basin Roundtable will engage the public to elicit feedback which may refine the project selection process, and finalize the Basin Implementation Plan for inclusion in the State Water Plan. This process sets the Arkansas Basin on the path to compile all of its IPP's in support of the SWSI 2016 initiative.

5.7 Cross Basin Recommendations and Collaborations

The Arkansas Basin Roundtable has encouraged collaboration between basins within Colorado. The process used for Section 4.2 of the Basin Implementation Plan, Watershed Health, is one the Roundtable feels has application in other basins. During development of the Watershed Health section of the plan, the Arkansas Basin Roundtable invited other basins to participate. The Rio Grande and South

Platte/Metro Basins actively participated, while Gunnison River Basin observed the process. Going forward, the Arkansas Basin Roundtable seeks continued collaboration with all Colorado Basins.

Discussions with Basin Roundtable Chairs at the March, 2014 Roundtable Summit, led to the inclusion by the Arkansas Basin of the Green River Riparian Restoration Project (GRRRP) in Section 4.8 of the Basin Implementation Plan.[3] Between 2009 and 2012, the Arkansas Basin Roundtable organized and funded a project exploration committee that included all nine basin roundtables. The committee was funded in two phases: Phase One produced a report and process flowchart; Phase Two was not funded. During the process, the committee defined a "good" project that anticipated basin-to-basin dialogue, including creating roles for the Interbasin Compact Committee (IBCC), Colorado Water Conservation Board (CWCB), and the State of Colorado. This approach may be replicated in similar contexts and for future projects.

Section 4.8 stresses the need for continued interbasin dialogue. As interbasin water imports and exports are critical to meeting gaps across the state, basin roundtables and stakeholders are encouraged to find collaborative solutions within Colorado's Water Plan. The Arkansas Basin both imports and exports water. Therefore, the Roundtable places a high value on basin-to-basin collaboration in meeting its needs. Of particular note is the recently completed Interbasin Compact Committee (IBCC) Draft Conceptual Agreement.

The IBCC Draft Conceptual Agreement is the fruit of many years of Interbasin dialogue. At its June 24, 2014 meeting, the IBCC unanimously agreed that: "*the Draft Conceptual Agreement is ready to go the Board [CWCB] for consideration while we continue to get feedback from our roundtables, our constituencies, and the public.*[4]" The document embodies seven principles for a possible Trans-Mountain Diversion ("TMD"):

IBCC Summary Points

1) The East Slope is not looking for firm yield from a new TMD project and would accept hydrologic risk for that project.
2) A new TMD project would be used conjunctively with East Slope interruptible supply agreements, Denver Basin Aquifer resources, carry-over storage, terminal storage, drought restriction savings, and other non-West Slope water sources.
3) In order to manage when a new TMD will be able to divert, triggers are needed.
4) An insurance policy that protects against involuntary curtailment is needed for existing uses and some reasonable increment of future development in the Colorado River system, but it will not cover a new TMD.
5) Future West Slope needs should be accommodated as part of a new TMD project.
6) Colorado will continue its commitment to improve conservation and reuse.
7) Environmental resiliency and recreational needs must be addressed both before and

[3] See Section 4.8.

[4] Memorandum by Jacob Bornstein, IBCC and Basin Roundtable Program Manager to the Colorado Water Conservation Board Members dated July 16, 2014

conjunctively with a new TMD.

Discussion at the July 9, 2014 Arkansas Roundtable meeting on this topic was favorable.

Finally, the Arkansas Basin Roundtable has recognized the need for advanced techniques and technology to measure extreme rainfall for scaling safe spillways for dams in Colorado. As the Arkansas Basin Roundtable has identified storage as critical to all solutions within the Basin, reservoir renovation, design, and construction costs are critical to the Basin's future. Spillway construction or refurbishment adds significantly to the cost of reservoirs. By developing a modern, effective tool for assessing extreme rainfall events, the costs of spillway construction may be reduced and increased storage made more viable for all Colorado water basins. A viable extreme precipitation assessment tool, shaped by participation and collaboration across basins, could significantly improve development of storage across Colorado, aiding most basins in meeting their water supply gaps in the future.

Collaboration is seen as critical by the Arkansas Basin Roundtable, both within the Arkansas Basin and between basins. Through interbasin collaboration, the State of Colorado may address its needs, new tools tested and shared, and perhaps water resources better coordinated.

5.8 Funding Mechanisms

The Roundtable is presented with more opportunities than it is able to fund at current levels. The Water Supply Reserve Account funding has been the primary funding mechanism. However, the fund is not sufficient to satisfy all of the potential projects. This highlights the need for a decision model to be used by the Roundtable in allocating limited funds to address the needs of the Basin, fill current and future water supply gaps, and develop sustainable and renewable water supplies.

Exploration of new and existing funding mechanisms could improve the efficacy of the Arkansas Basin Implementation plan while also informing the Colorado Water Plan and its capacity to address all of the Arkansas Basin's needs. The Arkansas Basin has several examples that support this exploration. The potential use of conservation easements as a method to support rotational fallowing concepts is a demonstration project in the Lower Valley. Transition to an active program of coordinated land and water conservation through the State of Colorado's tax credit program could support both agriculture and the environment, the latter through protection of high biodiversity species habitat.

Similarly, the Great Outdoors Colorado website describes the types of projects it funds[5]. These include whitewater parks, fishing piers, non-game wildlife habitat preservation, land acquisition for future outdoor recreation facilities, land protection along river corridors and agricultural land. These categories align with many of the Arkansas Basin's goals. Finally, Water Supply Reserve Account grant recipients in the Arkansas Basin have leveraged the WSRA funds as a match for grants from state and federal agencies. Examples include the Colorado Division of Local Affairs ("DOLA") and the National Resource Conservation Service. Clearly, this form of collaboration in seeking funding partners not only

[5] http://www.goco.org/grants/about/what-we-fund

increases the efficiency of WSRA funds, it substantially strengthens the dialogue within the Arkansas Basin. Expanding the tools for Roundtable funding provides a fulcrum for implementation of solutions and an extension of the Roundtable's collaborative model.

5.9 Meeting the Gap

Previous documents and reports have identified the existing and anticipated supply gaps in the Arkansas Basin, as well as identifying various challenges, opportunities, and projects. Those reports include:

- *Meeting Colorado's Future Water Supply Needs, 2008*
- *Considerations for Agriculture to Urban Water Transfer, 2008*
- *Projects and Methods to Meet the Needs of the Arkansas Basin, 2009*
- *Statewide Water Supply Initiative 2010*
- *Projects and Methods to Meet the Needs of the Arkansas Basin Update, 2012*

For the past decade, the Arkansas Basin Roundtable has identified methods, projects and processes to meet the water supply gaps identified through research, education, outreach, and assessment. Many of the projects and processes have been successful, but much of that work was conducted with a larger, basin-wide view. In order to secure the Arkansas Basin's water future, identifying local and regional challenges that can be addressed through local and regional solutions becomes the new perspective, coupled with continued diligence to understand the multi-purpose importance of sustaining agriculture.

The interdependence of agriculture with environmental and recreational water uses needs greater definition and study. Through the Basin Implementation Plan, a better understanding of the knowledge gaps has been developed. Further review of environmental needs is necessary in order to identify projects and processes for implementation. Recreational water use plays a significant economic and cultural role within the Arkansas Basin. The Roundtable explicitly supports projects and processes to increase and all types of water-based recreation, and to improve fish and wildlife habitat. Critical to maintaining all of these is the Voluntary Flow Agreement[6].

Agricultural water security is a continuing objective for Colorado and the Arkansas Basin. The Governor's executive order specifically addresses the rate of agricultural dry-up, and implores water planners and responsible stakeholders to find alternatives to agricultural to urban transfers. Projects such as rotational fallowing have met with implementation challenges. The Roundtable is working to identify and implement more projects and processes focused on rotational fallowing, not only for agricultural to urban water transfers, but also for increased agricultural efficiency. The Roundtable explicitly acknowledges that agriculture is part of the social, historic, and cultural fabric of the Arkansas Basin, and is focused on maintaining and increasing the $1.5 billion agricultural economy within the Basin.

[6] See Section 4.4 for details. The Voluntary Flow Agreement stores in headwaters reservoirs, then releases flow from storage that supports species habitat and rafting, with recapture in Pueblo Reservoir.

Storage is a critical component of water management within the Arkansas Basin. The Roundtable, through various reports and studies, including SWSI 2010 and *Projects and Methods to Meet the Needs of the Arkansas Basin, 2009*, has identified storage as critical to all water solutions within the Arkansas Basin. At present, increasing storage options and improving storage requires further assistance from stakeholders and the State.

Municipal projects and processes have focused on providing secure and reliable water supplies for growing urban populations. While strides have been made, significant work remains in freeing some municipalities from reliance on nonrenewable groundwater sources. Several sub-regions within the Arkansas Basin face the need to replace existing public water supplies. The challenges inherent in acquiring and funding a replacement water supply for any community are daunting.

The Arkansas Basin faces many dynamic challenges as it grapples with growth in some regions and the decline of available water resources in others. Roundtable members are pursuing a number of initiatives to improve the understanding of localized needs and gaps. Perhaps it is too soon to tell whether all needs can be met to the satisfaction of stakeholders. However, through dialogue, collaboration, and transparency, the Arkansas Basin Roundtable will continue to provide leadership, engage stakeholders, identify opportunities, and encourage projects and processes to meet all future water needs.