RECLAMATION

Managing Water in the West

CITY OF AURORA

Proposed Excess Capacity Contracts
Fryingpan-Arkansas Project

Draft Water Resources TECHNICAL REPORT

Prepared for:

Bureau of Reclamation
Eastern Colorado Area Office
Loveland, Colorado

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Denver, Colorado

In Association With
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PREFACE

This technical report was prepared to provide the hydrology information necessary to assess the effects of proposed contracts between Reclamation and Aurora for the use of excess capacity in the Fryingpan-Arkansas Project. As such, it has been prepared to fulfill reporting requirements of the Water Resources Studies Task of Professional Services Agreement No. 02PO783 (dated November 26, 2003) between the City of Aurora and MWH Americas, Inc.

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ac-ft	acre-feet
bgs	below ground surface
AHRA	Arkansas Headwaters Recreation Area
CDPHE	Colorado Department of Public Health and Environment
CDSS	Colorado Decision Support System
CDWR	Colorado Division of Water Resources
cfs	cubic feet per second
CWCB	Colorado Water Conservation Board
DOQQ	Digital orthophoto quarter quadrangle
DRG	Digital raster graphics
EA	Environmental Assessment
FEMA	Federal Emergency Management Agency
FMP	Flow Management Program
Fry-Ark	Fryingpan -Arkansas Project
FVA	Fountain Valley Authority
gpm	gallons per minute
HARP	Historic Arkansas Riverwalk of Pueblo
IGA	Intergovernmental Agreement
IHA	Indicators of Hydrologic Alteration
LVSWWTF	Colorado Springs Utilities' Las Vegas Street Wastewater Treatment Facility
M&I	Municipal and Industrial
mgd	million gallons per day
NEPA	National Environmental Policy Act
NRCS	U.S. Department of Agriculture Natural Resources Conservation Service
NWIS	USGS National Water Information System
PBWW	Pueblo Board of Water Works
PFMP	Pueblo Flow Management Program
RICD	Recreational In-Channel Diversion
ROY	Restoration of Yield
SECWCD	Southeastern Colorado Water Conservancy District

TSWSP	Temporary Substitute Water Supply Plan
UAVFMP	Upper Arkansas Voluntary Flow Management Program
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WTP	Water Treatment Plant
WWSP	Winter Water Storage Program
WWTP	Wastewater Treatment Plant

1.0 INTRODUCTION

The Bureau of Reclamation (Reclamation) is considering a request from the City of Aurora, Colorado, for a long-term excess capacity contract and a long-term exchange contract. The purpose of the proposed contract(s) is to establish a long-term agreement that allows Aurora to efficiently manage and use its decreed Arkansas River water rights and leased Arkansas River water. Aurora's water rights and leased water from the Arkansas River provide about 25 percent to 40 percent of its water supply (depending on hydrologic conditions in a particular year) and are needed to meet the City's existing and future municipal and industrial water demands. Use of excess capacity in the Fryingpan-Arkansas (Fry-Ark) Project would eliminate the need for construction of a new reservoir and other facilities to facilitate the movement of this water from the Arkansas Basin to the South Platte Basin where it can be used by Aurora.

The Fry-Ark Project is a Reclamation project that delivers water from the West Slope of Colorado to the upper Arkansas River Basin near Leadville. Turquoise Reservoir and Twin Lakes Reservoir are Reclamation facilities in the upper Arkansas River Basin that store Fry-Ark Project water before it is delivered to downstream users. From Turquoise Reservoir and Twin Lakes Reservoir, Fry-Ark Project water is delivered via the Arkansas River to Pueblo Reservoir where this water is further distributed to Fry-Ark Project users.

Reclamation has the authority to decide whether to enter into these long-term (40-year) contracts with Aurora. Because this decision involves a federal action, the proposal is subject to compliance with the National Environmental Policy Act (NEPA) of 1969, amendments, and other regulatory laws. Reclamation is preparing an Environmental Assessment (EA) to analyze and disclose the potential effects associated with the Proposed Action, as well as the No Action Alternative if Reclamation denies the request for storage and exchange. To assist in the preparation of the EA, Reclamation has requested that the third-party consultant team prepare technical reports for resources of concern. The technical reports provide information on the affected environment and the environmental consequences of the Proposed Action and No Action Alternative. Information from the technical reports will be used in preparation of the EA.

1.1 Water Resources Technical Report

The Water Resources Technical Report is being prepared to provide the hydrology information necessary to assess the effects of proposed contracts between Reclamation and Aurora for the use of excess capacity in the Fryingpan-Arkansas Project. The technical report covers proposed study methods and descriptions of the existing surface water hydrology, stream hydraulics and geomorphology, and ground water (the affected environment). This document also summarizes hydrologic modeling results for Existing Conditions, the Proposed Action, and the No Action Alternative and the related effects on stream hydraulics, geomorphology, and ground water. The methodology and criteria for hydrologic modeling are described in the Excess Capacity Contract Environmental Assessment Hydrologic Model

Documentation (Hydrosphere, 2005), which is provided under separate cover. In addition, the Water Quality Technical Report (MWH, 2005b) addresses the water quality analysis.

1.2 Relationship to Other Resource Studies

Output from the water resources analysis, and specifically the quarter-monthly hydrologic modeling conducted by Hydrosphere, will be used by several other resource areas. The relationships with each of these resource areas are further described below. This Water Resources Technical Report is used to convey information on existing water resources conditions and results of the hydrologic analyses to the other resource teams.

Aquatic habitat studies required water resources data of various kinds (e.g., minimum flows, average flows, water levels, hydraulic properties, and water quality) in channels and reservoirs. The Aquatic Resources Technical Report used the Indicators of Hydrologic Alteration (IHA) method for analysis of aquatic habitat effects. IHA relies on statistical analyses of daily streamflow data for native or Existing Conditions and any project alternatives.

Wetland and vegetation specialists required seasonal water levels in streams and reservoirs, and overbank flow conditions in floodplains.

Studies of aesthetics, socioeconomics, and land use require flow rates, water levels and erosion conditions for Existing Conditions, the Proposed Action, and the No Action Alternative.

Recreation studies required channel hydrology data and reservoir water levels.

The water resources team coordinated with other resource specialists to provide required information needed to address any important new issues that were raised during the EA study process.

1.3 Description of Alternative

Aurora currently owns Arkansas River Basin water rights, and has relied upon temporary (one-year) “if-and-when” storage and exchange contracts with Reclamation to store and exchange Arkansas River Basin water into Pueblo Reservoir. An “if-and-when” contract permits an entity to store non-Fry-Ark Project water in Pueblo Reservoir if-and-when Reclamation determines that conditions are appropriate. An exchange contract, obtained from the Colorado Department of Water Resources, authorizes an entity to exchange water between locations, i.e., Aurora exchanges Colorado Canal streamflow diversions upstream to for storage into Pueblo Reservoir.

The Proposed Action is to enter into a long-term contract with Aurora to allow the use of excess capacity in Pueblo Reservoir of the Fry-Ark Project for storage of Aurora’s non-Fry-Ark Project water and contract exchange of Aurora’s water with Fry-Ark Project water. Under the No Action Alternative, Reclamation would no longer contract with Aurora for the storage and exchange of Aurora’s water rights, and Aurora would develop other means of storage in the Arkansas River Basin. The Proposed Action and the No Action Alternative are described in more detail below.

1.3.1 Proposed Action

Under the Proposed Action, Reclamation would execute a long-term (40-year) storage contract with Aurora for the use of up to 10,000 acre-feet of available excess capacity in Pueblo Reservoir. The storage space could be filled and emptied multiple times each year to accommodate water exchanges to Twin Lakes Reservoir, Turquoise Reservoir, and the Otero Pump Station. Additionally, Aurora has requested that Reclamation enter into a separate contract that would allow annual contract exchanges of up to 10,000 acre-feet of Aurora's water rights stored in Pueblo Reservoir for Fry-Ark Project water stored in Twin Lakes Reservoir and Turquoise Reservoir. Contract exchanges could take place multiple times in one year, as long as the total amount exchanged in one year does not exceed 10,000 acre-feet. The Proposed Action does not require construction of new facilities.

1.3.2 No Action Alternative

Under the No Action Alternative, Reclamation would not enter into an excess capacity storage contract with Aurora. Additionally, Reclamation would not enter into a contract with Aurora for exchanges of up to 10,000 acre-feet of Aurora's Arkansas River water for Fry-Ark Project water in Twin Lakes Reservoir or Turquoise Reservoir. In the absence of these contracts with Reclamation, Aurora would look to other ways to use its decreed Arkansas River water rights. Aurora would pursue both short-term and long-term actions to store and exchange existing Arkansas River water rights. In the short-term, this would include filings with Colorado Water Court to modify existing decrees to allow additional alternate points of diversion for use of those water rights to upstream locations. In the long-term, new infrastructure, primarily gravel pit conversion to reservoir storage would need to be constructed.

To provide for the long-term use of its water rights and to develop their full available yield, Aurora would develop 10,000 acre-feet of water storage within a future gravel pit. Aurora currently has an option on the purchase of an active gravel mining site that could provide water storage following gravel excavation. The site is located adjacent to the Arkansas River about 6 miles downstream of the City of Pueblo. Depending on final site development, it is anticipated that about 500 acres of land would be needed to provide sufficient storage for 10,000 acre-feet of water.

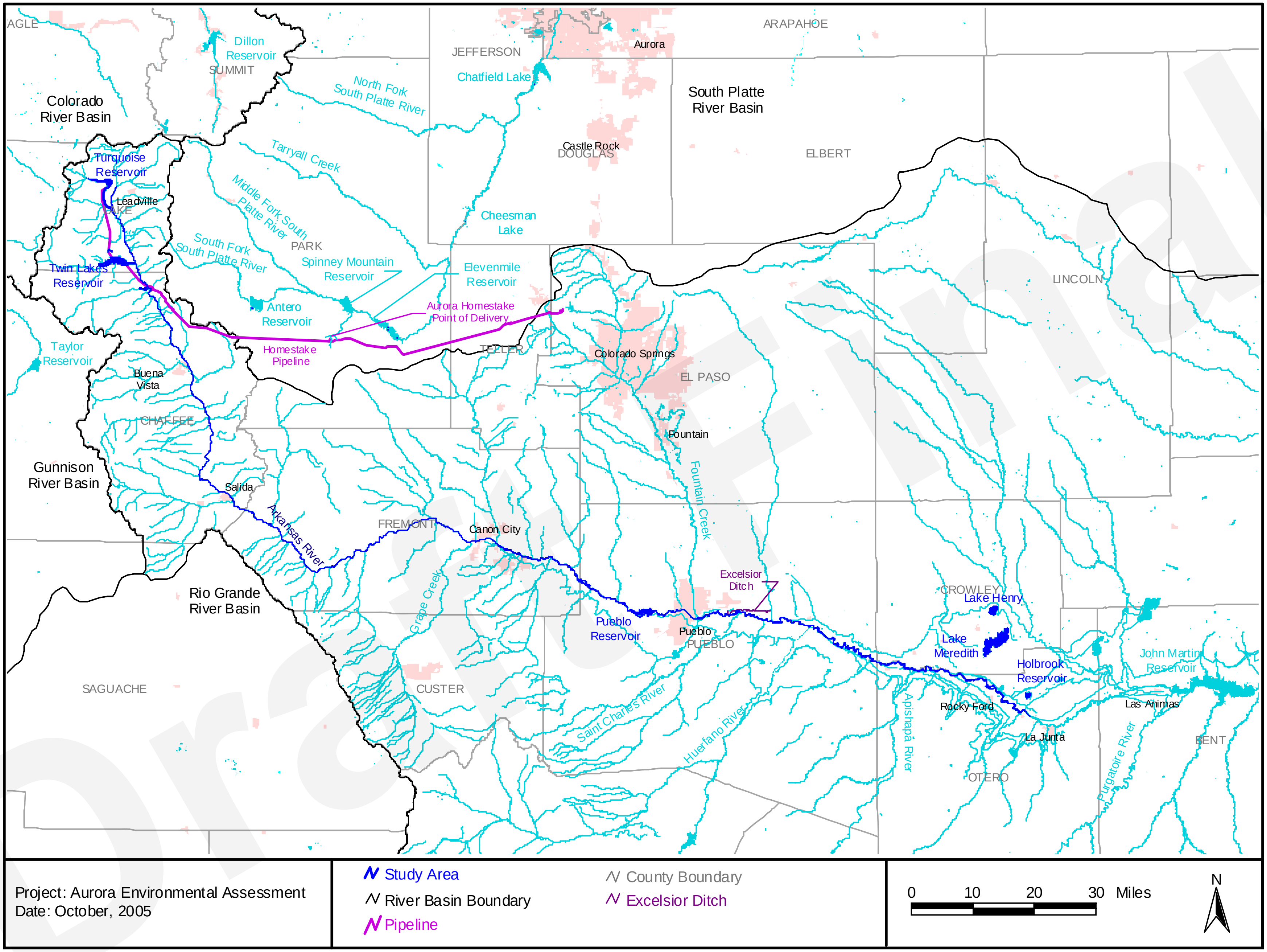
Water would be diverted to the site via the existing Excelsior Ditch located about 2 miles upstream of the site. The Excelsior Ditch headgate on the Arkansas River is estimated to have adequate capacity, but some improvements to the ditch may be necessary to convey Aurora's Arkansas River water rights. Water from this gravel pit storage would be returned to the Arkansas River using a new outlet structure and pumping facilities as necessary. Development of the gravel pit site, including mining operations and the associated improvements that would be needed to make this site suitable for water storage, is expected to take about 10 years.

1.4 Study Area

The water resources study area encompasses Lake Fork below Turquoise Reservoir, Lake Creek below Twin Lakes Reservoir, and the Arkansas River from the Lake Fork confluence to the outlet of Holbrook Reservoir. Five existing reservoirs, including Turquoise Reservoir, Twin Lakes Reservoir, Pueblo Reservoir, Lake Meredith, Lake Henry, and Holbrook Reservoir could potentially be affected by the Proposed Action. In addition, new gravel pit storage under the No Action Alternative would be located adjacent to the Arkansas River east of the City of Pueblo. These streams and reservoirs are collectively referred to as the study area and are shown in shown in **Figure 1-1**.

The effects of Aurora's actions on Twin Lakes Reservoir were not considered for two reasons: there are daily fluctuations in the top two feet of the reservoir due to power operations conducted by Reclamation as part of the Fry-Ark Project, and Aurora only owns 5 percent of the storage capacity in Twin Lakes Reservoir. As a result, Reclamation has determined that Aurora's actions will have minimal effects on storage contents and reservoir pool elevations when compared with historical fluctuations.

Figure 1-1. Study Area Methods



Project: Aurora Environmental Assessment
Date: October, 2005

2.0 METHODS

Section 2 provides a description of the methods used for describing the hydrologic characteristics of the affected environment and analysis of the Proposed Action and No Action Alternative.

2.1 Surface Water Quantity Studies

Documentation was gathered and summarized for surface water quantity data in the study area, including: streamflow, reservoir levels, irrigation diversions, water use, and flood flows.

2.1.1 Existing Data Sources and Review

Data and analyses for daily and monthly streamflow were collected from U.S. Geological Survey (USGS) gage records, Reclamation data, previous water resources planning reports for the area (e.g., Arkansas Basin Technical and Environmental Studies (MWH, 2000)), and previous model databases. Hourly data was collected for a limited number of USGS gages to document typical diurnal flow fluctuations. Historical flood data and flood-frequency analyses were collected from USGS gage records and previous flood studies by USGS, Federal Emergency Management Agency (FEMA), the U.S. Army Corps of Engineers (USACE) and Colorado Water Conservation Board (CWCB).

2.1.2 Supplemental Data Collection

No new stream gage or reservoir level measurements were collected for the analysis.

2.1.3 Data Analysis

Historical data is presented in **Section 3.0** of this report. A simulation model was used to estimate existing and future streamflow conditions for purposes of analyzing the effects of the Proposed Action and No Action Alternative. The simulation model itself is not discussed in this technical report - only the results from the model are presented and discussed. A more thorough discussion of the model is presented in the model documentation report (Hydrosphere, 2005).

Tabular and graphical summaries were prepared for mean monthly discharges, minimum daily discharges, chronological streamflows, and other parameters requested by the various EA resource areas for historical conditions and the Proposed Action and No Action Alternative. Summaries were prepared for key gage locations on the Arkansas River. Historical and simulated reservoir level data was summarized for Pueblo Reservoir, Turquoise Reservoir, Twin Lakes Reservoir, Lake Meredith and Lake Henry.

2.1.3.1 Simulated Streamflows and Reservoir Levels

Streamflows and reservoir levels under Existing Conditions, and the Proposed Action and No Action Alternative were determined using the results of the Hydrosphere hydrologic modeling analysis described in the hydrologic modeling work plan. Changes in monthly and quarter-monthly flows at gage stations were summarized. Quarter-Monthly Model results were provided to the resource teams, including the percent difference between the Proposed Action and No Action Alternative.

Quarter-Monthly Model results are presented from October through September. This time period was chosen in accordance with common hydrologic practice, with the designation of a water year starting in October and ending in September of the following calendar year. The water year accounts for the typical annual cycle of precipitation and runoff that occurs in the basin.

For reservoir contents, the model results were reported as quarter-monthly volumes. Daily values between the given results were pro-rated to distribute the quarter-monthly change in storage throughout the days in the quarter-month period.

Colorado Canal System Reservoir Contents

Due to the complexity of the operations of the Colorado Canal system, the Quarter-Monthly Model simulates storage in Colorado Canal system reservoirs (Lake Henry and Lake Meredith) as one reservoir. However, simulated Colorado Canal System reservoir contents are subsequently distributed to Lake Henry and Lake Meredith storage outside of the Quarter-Monthly Model using the following assumptions:

- Water available to the Colorado Canal system is first stored in Lake Meredith, up to the maximum storage and down to the minimum storage of Lake Meredith.
- If more water is available than storage available in Lake Meredith, excess is stored in Lake Henry, up to the maximum storage and down to the minimum storage of Lake Henry.
- Any additional available water is stored in Lake Meredith, which allows storage above the maximum Lake Meredith contents, similar to historical operations of the Colorado Canal system.

The methodology used to distribute Colorado Canal system storage assumes that all effects on storage associated with municipal operations occur at Lake Meredith before they occur at Lake Henry. In reality, municipal effects are seen at Lake Meredith first for two reasons:

- Lake Meredith is larger than Lake Henry, encouraging more municipal exchanges from Lake Meredith than from Lake Henry.
- A majority of agricultural demands from the Colorado Canal system are met with water stored in Lake Henry, because it is higher in elevation than Lake

Meredith, and water released from Lake Henry is physically capable of supplying more agricultural demands than Lake Meredith.

2.1.3.2 Peak Flow Analysis

Peak flow discharge values were determined using a frequency analysis for streamgage locations in select stream sections in the study area. The select stream sections were chosen based on the results of the stream geomorphology described in **Section 3.5**. A frequency analysis was completed for stream segments that were determined to be geomorphically sensitive to hydrologic changes. Annual maximum instantaneous peak streamflows obtained from the USGS National Water Information System database were used in the frequency analyses. A lognormal distribution was assumed for the frequency analyses (Bedient et. al, 2002).

2.1.4 Threshold Determination

The Arkansas River is a highly managed river, in which storage facilities are operated for a variety of purposes including agricultural and municipal supplies, recreation benefits and environmental values. Under these conditions, timing and variability of flows have been highly altered from native hydrology. No specific thresholds were established for significant changes in flow conditions; rather, all results were forwarded to the various resource disciplines for assessment of potential impacts.

2.2 Stream Hydraulics and Geomorphology

The Proposed Action and No Action Alternative may affect stream hydraulics (stream depth) and geomorphology (erosion, deposition and sediment transport) for stream reaches in which the alternative alters existing hydrology. In addition, impacts to other resources depend on these parameters. Potential impacts of the Proposed Action and No Action Alternative were determined for those stream reaches in which surface hydrology is modified by the alternative. No impact analysis was performed for stream reaches in which no significant hydrologic impacts were predicted by the Quarter-Monthly model simulation.

2.2.1 Existing Data Sources and Review

Topographic data was needed to determine channel geometry (width, depth, and slope) in potentially impacted reaches. Data sources included the USGS, USACE Fountain Creek Watershed Study (USACE 2005), cities and counties, and other agencies. In most areas the best available mapping is USGS 7.5-minute quadrangle maps. Historical aerial photography for the channel corridors in the potentially impacted reaches was collected from the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS).

2.2.2 Supplemental Data Collection

MWH personnel performed field reconnaissance activities to assess stream channel conditions in the study area. In April of 2004, field investigations were performed for stream gages along the Arkansas River. The investigations were performed to determine whether streamgage locations in the study area are representative of natural stream channel characteristics. Field notes and photographs were used to interpret channel geomorphology conditions. The following gages were visited to assess channel conditions:

- Lake Fork below Sugarloaf Dam
- Lake Creek below Twin Lakes Reservoir
- Arkansas River at Granite
- Arkansas River near Wellsville
- Arkansas River at Portland
- Arkansas River above Pueblo
- Arkansas River at Moffat Street
- Arkansas River at Avondale
- Arkansas River at Nepesta
- Arkansas River at Catlin Dam
- Arkansas River at La Junta

New field observations were made at the streamgage locations listed above to supplement existing channel condition data and assess the channel erodibility potential. The information from the observations was used in the stream classification described in the geomorphology sub-section. Approximate channel depths and widths at representative cross sections were estimated and correlated to best available topographic mapping and aerial photography.

2.2.3 Hydraulics Data Analysis

Stream stage and reservoir elevation values were determined based on Quarter-Monthly Model simulated streamflow and reservoir contents. Quarter-Monthly stream stage was calculated using Quarter-Monthly streamflow data and stage-discharge curves provided by the State Engineer's office. Quarter-Monthly reservoir elevation and surface area were calculated using elevation-area-capacity curves for each reservoir and the Quarter-Monthly reservoir content data. It should be noted that monthly averages for reservoir elevation and surface area given in **Sections 4.0** and **5.0** are the averages of Quarter-Monthly reservoir elevations and surface areas, and are not equal to the reservoir elevation and surface area that corresponds to the monthly average reservoir contents. This difference is a result of the non-linear relationship between elevation, surface area, and reservoir contents.

2.2.4 Geomorphology Data Analysis

The potentially impacted area of the Arkansas River was subdivided into relatively homogenous reaches that are representative of existing hydraulic and geomorphic conditions. A cross-section location was selected to be representative of each subreach. Cross section geometry was determined based on the best available topographic mapping for the site or on previous hydraulic analysis data if available. At each cross section the following data was calculated:

- Flow stage for range of discharges
- Historical channel erosion and deposition (representative of the subreach)
- Channel vegetation and channel bed material conditions (representative of the subreach)

Stages at each cross section were calculated based on rating curves at each section. Erosion and deposition, channel vegetation and bed material conditions were determined based on review of aerial photography, and field observations.

Changes in flow at each cross section (based on the Hydrosphere modeling) for the Proposed Action and No Action Alternative were translated into changes in stage using the hydraulic tools described above (i.e., single cross section normal depth calculations or existing hydraulic models). Changes in stage were summarized in the same manner as flow and were summarized using flow duration curves.

The geomorphology of uniform stream segments was determined using procedures described in Applied River Morphology (Rosgen, 1996), and each uniform stream segment was given a geomorphic classification. The geomorphic classifications were used to determine the sensitivity of each stream segment to hydrologic changes (including streamflow magnitude and timing and sediment increases). Rosgen stream classification was performed using topographic mapping, aerial photographs, field observations, and results of the hydraulic analysis.

Flow duration curves (plots of magnitude of streamflow versus percent of time the streamflow value is not exceeded) were developed for reaches that were determined to be geomorphically unstable using the Rosgen methodology described in the previous paragraph.

The bankfull discharge (the 1.5-year discharge (Dunne and Leopold, 1978)) was plotted with the flow duration curves. Bankfull discharge is defined as "the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels" (Rosgen, 1996). The bankfull discharge was used as one of the threshold criteria to evaluate the significance of impacts on stream geomorphology.

In addition to streamflow, the hydraulics sections also contain summaries of simulated reservoir surface area and water surface elevation. Simulated storage volumes were translated into areas and elevations using the most recent elevation-area-capacity curves available for each reservoir.

2.2.5 Threshold Determination

Hydraulic impacts were evaluated using the flow duration curves described above for stream reaches that were determined to be sensitive to hydrologic changes. Hydraulic and geomorphic changes were analyzed in further detail if the following threshold criteria were satisfied:

1. Differences between streamflows for the Proposed Action and No Action Alternative flow duration curves occur for non-exceedance values that correspond to streamflow greater than bankfull discharge.
2. Differences described in the previous criterion are greater than 10 percent.

2.3 Ground Water Studies

The Proposed Action and No Action Alternative may affect ground water conditions for aquifers adjacent to stream reaches in which the Proposed Action or No Action Alternative alter existing hydrology. Existing ground water conditions in the study area were described. Impacts on ground water conditions as a result of the Proposed Action and No Action Alternative were characterized.

2.3.1 Existing Data Sources and Review

Existing data was collected primarily from USGS technical reports, with supplemental data from the Colorado Division of Water Resources (CDWR) and the CDPHE.

2.3.2 Supplemental Data Collection

No new ground water levels or other measurements were collected for the analysis.

2.3.3 Data Analysis

Existing reports were used to prepare a summary of existing ground water resources in the study area. This included a description of primary aquifers, ground water levels, ground water quality, aquifer uses, recharge areas, and factors that affect ground water conditions. Ground water beneficial uses and regulations were summarized.

Ground water modeling was not proposed and was not used as an approach to determine potential impacts of alternatives on water levels. Therefore, surrogate measures, as discussed in **Section 2.3.4** were used to perform a qualitative ground water impact analysis.

2.3.4 Threshold Determination

Because ground water modeling was not used for the ground water analysis, surrogate measures were required to determine the impacts on ground water. Ground water impacts in the basin are related to streamflow stage, irrigation application and ground water use, each of which are measurable within the scope of the study. If any of the following conditions occurred as a result of the Proposed Action and No Action Alternative, then changes in ground water conditions were identified for impact analysis:

- If differences in mean flow depth for the Proposed Action at selected locations on the Arkansas River vary from the No Action Alternative mean depth by more than 10 percent
- If differences in projected irrigation application for the Proposed Action vary from No Action Alternative irrigation application by more than 5 percent
- If differences in projected ground water use for the Proposed Action vary from No Action Alternative ground water use by more than 5 percent

3.0 AFFECTED ENVIRONMENT

This section contains a description of the affected environment. The extent of the affected environment is defined by the City of Aurora's Proposed Action and No Action Alternative covered under this EA. The affected water resources environment extends along the Arkansas River from its confluence with Lake Fork downstream to the outlet of Holbrook Reservoir near La Junta. The affected environment also includes the tributaries of Lake Fork and Lake Creek downstream of Turquoise Reservoir and Twin Lakes, respectively.

The following is a description of the affected environment as related to surface water quantity. This includes a general description of the affected environment from a water resources perspective, a description of water rights in the basin, water use in the basin and historical streamflow, stage and reservoir levels at selected locations, geomorphic and hydraulic conditions, and ground water conditions.

3.1 Study Period

The description of Existing Conditions within the basin requires a defined study period. The hydrologic models used in this analysis superimpose existing and future conditions on historical hydrology. The selected study period would ideally be the longest possible period-of-record for the basin, which in the Arkansas, is approximately 110 years. However, streamflow data is only available at a few selected sites for this entire record, and the computational time required for this length of simulation would be extensive. Therefore, it is common practice to run the model on a subset of the entire dataset population.

The selection of the study period for the hydrologic analysis is dependent upon several conditions, including the purposes of the model, the extent of available data, and changes in river operating conditions. Reclamation's NEPA guidance suggests a minimum 20-year dataset (Reclamation, 2000). In selection of a study period for NEPA purposes, the following considerations were given:

- The primary purpose of the Quarter-Monthly Model is to determine effects of the Proposed Action and No Action Alternative, and assist in making a selection between alternatives. Because extreme events (either extremely high or low flows) have the greatest effect on the hydrologic environment, they are the most important events to include in the simulation model, and the dataset should include the range of events that are representative of the overall hydrologic record.
- Construction of East Slope Fryingpan-Arkansas Project (Fry-Ark) facilities began in 1965 with Turquoise Reservoir and continued through the 1980s. Fry-Ark operations have significant effects on river operations within the basin. The following milestones have had an effect on operations within the Arkansas River, including (Reclamation, 2001):
    - May 1972 - Initial diversions through Boustead Tunnel
    - January 1974 - Began storing in Pueblo Reservoir

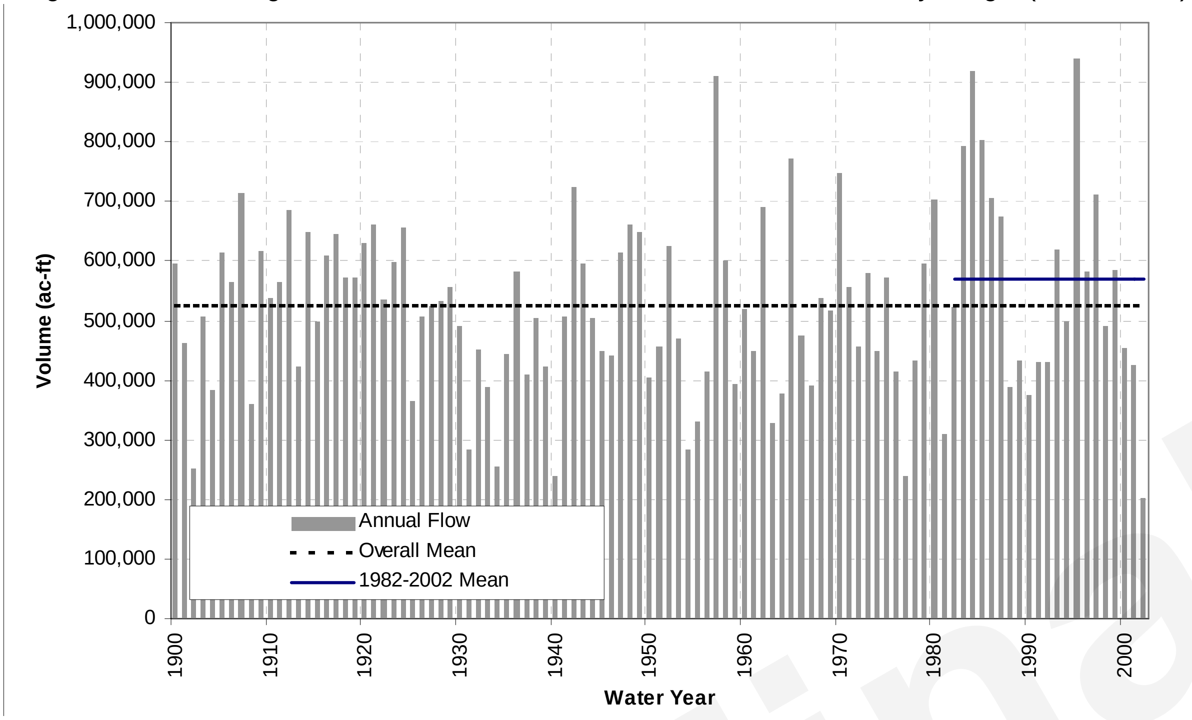
    - May 1981 - Substantial completion of the West Slope diversion facilities
    - June 1981 - Reclamation assumes operations of Twin Lakes Dam
    - October 1981 - Completion of Mount Elbert Powerplant Unit #1
    - June 1982 - Turquoise Reservoir filled for first time
    - July 1985 - Initial diversion through Fountain Valley Conduit
    - November 1985 - Began operations of Twin Lakes pipeline
    - July 1990 - Initial releases from Twin Lakes for recreational flows on Arkansas River
    - September 1990 - Completion of Pueblo Fish Hatchery
- The Winter Water Storage Program (WWSP) was developed to allow direct flow agricultural water rights to be stored in Pueblo reservoir from November 15 through March 15. This program began in 1977.
- Colorado Canal transfers to municipal uses were completed during the late 1980s.

Based on the information above, a study period of water years 1982 through 2002 was selected. A statistical summary of the study period as compared to the long-range statistics for the Arkansas River at Cañon City gage is presented in **Table 3-1**, while the annual flows as compared with the mean flows for the full period-of-record and the proposed study period are shown in **Figure 3-1**. As shown, the mean of the study period is approximately 9 percent higher than the overall statistics. However, the median is only one percent higher. This indicates that the mean of the study period is being exaggerated by a few extremely high flows. In addition, the study period contains operations of the Fry-Ark Project, which from 1972 through 2005 diverted an average of approximately 49,000 ac-ft per year (Hopkins, 2005) through the Boustead Tunnel. This accounts for a large majority of the difference between the period-of-record and the study period. Of more importance for many of the required statistical values for the environmental resource analyses is the inclusion of both the absolute minimum and absolute maximum flow years within the study period.

Table 3-1. Statistical Comparison of Annual Flow, Arkansas River at Cañon City Gage (07096000)

Statistic	Value (ac-ft)	
	Overall 1900-2002	Study Period 1982-2002
Absolute Minimum	202,440	202,440
80% Exceedance	411,564	430,362
Median	516,678	523,109
Mean	524,134	570,699
20% Exceedance	639,922	712,204
Absolute Maximum	940,328	940,328

Figure 3-1. Average Annual Flow, Arkansas River at Cañon City Gage (07096000)



3.2 General Description of Study Area

The Arkansas Basin in Colorado encompasses approximately the southeastern quarter of Colorado. The Arkansas River headwaters are located in the Mosquito and Sawatch ranges of the Southern Rocky Mountains. The river generally flows south to Salida, then east to the Kansas State line. The City of Pueblo is the largest municipality located on the river. There are several smaller communities from the headwaters to the state line that are also located along the river. Currently, agriculture, primarily located downstream of the City of Pueblo, is the major user of water in the basin. However, municipal water use is increasing as populations increase. Native water supplies in the basin are supplemented by several transmountain diversion projects. In addition, several storage facilities in the basin store peak runoff for use later in the year.

The following sub-sections discuss the native hydrologic setting, water supplies and water uses in the study area in more detail, especially as they pertain to the actions and alternatives analyzed in the EA.

3.2.1 Hydrologic Setting

Natural streamflow in the Arkansas River occurs primarily as a result of snowmelt runoff. Mean annual precipitation ranges from less than 10 inches in the plains to more than 40 inches in the high mountains (Abbot, 1985). Precipitation in the mountains occurs primarily as snowfall, resulting in the accumulation of snowpack during the winter and early spring months, which results in high intensity short duration runoff events in the late spring and early summer months. Precipitation in the plains occurs slightly more evenly throughout the year, with frequent isolated intense summer storms. Except for the high mountain areas that define the drainage basin, most of the basin is considered a semi-arid environment (Abbot, 1985).

The majority of streamflow in the Arkansas River originates upstream of Salida as runoff from the Collegiate Peaks of the Sawatch Range, where mean annual runoff exceeds 30 inches. Major tributaries to the Arkansas River upstream of Salida include Lake Fork, Lake Creek, Clear Creek, Cottonwood Creek and the South Fork of the Arkansas River. Between Salida and Pueblo, tributary inflows originate from the Sangre de Cristo Range and Wet Mountains in the south and the South Slope of Pike's Peak in the north, where runoff is approximately 5 inches per year. Major tributaries in this area include Fourmile Creek, Beaver Creek, and Grape Creek. Tributaries between Pueblo and John Martin Reservoir originate in the Culebra Range in the south, where runoff is between 2 and 5 inches per year, and the Colorado Piedmont on the north, where runoff is 0.2 to 0.1 inches per year. Major southern tributaries include the Huerfano River, Apishapa River and the Purgatoire River. Horse Creek is the major tributary from the north (Abbot, 1985).

In addition to precipitation and snowmelt runoff, streamflow in the Arkansas River is influenced by the operations of several transmountain diversion projects, exchanges and existing exports out of the basin. These systems and their impact on streamflow are discussed in later subsections of this document.

A summary of average annual flow for the Arkansas River within the study area is shown in **Table 3-2**. As shown, tributary inflows and incidental ungaged surface and ground water inflows (the increase in flow not attributable to a gaged inflow shown in the table) contribute a portion of the Arkansas River streamflow from the Leadville gage to the Salida gage. From the Salida gage to Pueblo Reservoir, tributary inflows contribute a lesser amount of flow, however, there are some minor ungaged tributary inflows.

A transit loss of 0.07 percent per mile was established for the Upper Arkansas River from Twin Lakes to Pueblo Reservoir (Sunnyside Park Ditch vs. M.S. Hindelider, State Engineer; Court Case No. 3345; 1944-45) (Crouch, 1984). The length of river between Twin Lakes and Pueblo Reservoir is approximately 139 miles, resulting in a total transit loss of approximately 10 percent. Between Pueblo Reservoir and Fountain Creek, the river loses flow both to transit losses and diversions. Fountain Creek flows increase Arkansas River streamflows above the Avondale gage. From the Avondale gage, agricultural diversions and return flows take place, and the overall consumptive use of the agricultural diversions reduces streamflow. Specific details regarding the data for these gages are discussed in later sections of this technical report.

Table 3-2. Summary of Average Annual Flow for Arkansas River and Tributary Inflows

Station	Mainstem Streamflow(1) (ac-ft)	Tributary Inflow(1)(2) (ac-ft)
Arkansas River Near Leadville, Co. (7081200)	56,414	
Lake Fork Creek Below Sugar Loaf Dam Near Leadville (7082500)		15,475
Halfmoon Creek Near Malta, Co. (7083000)		23,033
Lake Creek Below Twin Lakes Reservoir (LAKBTLCO)		164,884
Arkansas River At Granite (7086000)	314,122	
Clear Creek Below Clear Creek Reservoir (CCBCCRCO)		49,686
Chalk Creek At Nathrop (7091000)		35,643
Cottonwood C Bl Hot Springs, Nr Buena Vista, Co. (7089000)		45,190
Arkansas River At Salida (7091500)	481,790	
Arkansas River Near Wellsville (7093700)	544,853	
Arkansas River At Canyon City (7096000)	570,699	
Fourmile Creek Near Cañon City (7096500)		28,074
Arkansas River At Portland (7097000)	611,484	
Beaver Creek Near Portland (7099100)		30,045
Pueblo Reservoir		
Arkansas River Above Pueblo (7099400)	553,939	
Fountain Creek At Pueblo (7106500)		121,499
Saint Charles River At Vineland (7108900)		31,036
Arkansas River Near Avondale (7109500)	754,522	
Huerfano River Near Boone (7116500)		27,418
Arkansas River Near Nepesta (7117000)	601,534	
Apishapa River Near Fowler (7119500)		13,324
Arkansas River At Catlin Dam Near Fowler (7119700)	541,574	
Timpas Creek At Mouth Near Swink, Co. (7121500)		47,477
Arkansas River At La Junta (7123000)	229,962	
Arkansas River At Las Animas (7124000)	240,494	

Notes:

(1) Study Period: 1982-2002

(2) Tributary inflows presented for major gaged tributaries only

3.2.2 Water Use

Water is used for many purposes within the Arkansas River Basin, including, agricultural, municipal, industrial, recreation, fisheries and augmentation (CWCB, 2002). Irrigation is the single largest use of water within the Arkansas Basin, followed by M&I use. The average annual diversions from the river for the major diversions in the Arkansas Basin are shown in **Table 3-3**. Because M&I uses are the primary consumptive uses, and because other water uses will be covered by other resource areas, only M&I uses are further discussed in this report.

Table 3-3. Summary of Selected Major Diversions from Arkansas River within Study Area

Diversion	Primary Purpose	Average Annual Diversion (ac-ft)(1)
Otero Pump Station (River Intake)(2)	Municipal	6,500
Otero Pump Station (Twin Lakes Pipeline)(2)	Municipal	52,400
South Cañon Ditch	Agriculture	16,000
Cañon City Hydraulic Ditch	Municipal/Agriculture	30,200
Cañon City Water Works	Municipal	4,600
Cañon and Oil Creek Ditch	Agriculture	15,100
Fremont County Ditch	Agriculture	7,100
Minnequa/Union Ditch	Industrial/Agriculture	67,000
Bessemer Ditch	Agriculture	65,500
Pueblo West Metropolitan District	Municipal	1,000
Fountain Valley Conduit	Municipal	4,700
West Pueblo Ditch	Municipal	400
Comanche Power Plant Pump Station	Industrial	8,200
Pueblo Northside Diversions	Municipal	26,700
Pueblo Southside Diversions	Municipal	3,300
Riverside Dairy Ditch	Agriculture	300
Public Service (Aquila Energy)	Industrial	14,500
St. Charles Mesa Ditch	Municipal	1,000
Excelsior Ditch	Agriculture	1,200
Collier Ditch	Agriculture	300
Colorado Canal	Municipal	101,400
Rocky Ford Highline Canal	Agriculture	97,600
Oxford Canal	Agriculture	30,400
Otero Ditch	Agriculture	8,500
Catlin Canal	Agriculture	104,100
Holbrook Canal	Agriculture	57,600
Rocky Ford Ditch	Municipal	37,900
Fort Lyon Storage Canal	Agriculture	91,500
Fort Lyon Canal	Agriculture	277,400
Las Animas Consolidated	Agriculture	31,300
TOTAL		**1,163,700**

Notes:

(1) 1982-2002 Historical Diversions

(2) Otero Pump Station diversion were taken through the river intake from water year 1982 to March 1986 and through the Twin Lakes Pipeline from May 1986 to water year 2002.

It should be noted that most of the agricultural diversions shown in **Table 3-3** have at least some ownership of shares by municipal and industrial entities. Two of the diversions, the Colorado Canal and the Rocky Ford Ditch, are owned mostly by municipal and industrial entities, and are further discussed in separate sub-sections of this document.

3.2.2.1 Agricultural

Agricultural water use is the major water use in the study area. The CWCB estimates that annual diversions for irrigation within the Arkansas Basin as a whole, which includes many counties outside of the study area, is about 2 million acre-feet. The next highest diversion category, other than water diverted for storage, is municipal use, estimated to be about 173,000 acre-feet (CWCB, 2002). The USGS estimated that annual diversions from the Arkansas River for irrigation between Pueblo Reservoir and the Kansas state line for the period 1940-1981, when most ditch companies were agricultural use only, generally ranged between 500,000 and 1,100,000 acre-feet per year (Abbott, 1985).

Total irrigated acreage and net irrigation requirements for crops are shown in **Table 3-4**. Net irrigation requirements are equal to consumptive use if a full water supply is available and applied. Factors that account for transit losses and on-farm application losses must be applied to estimate total diversion requirements at the canal headgate.

A majority of the land irrigated for crops other than pastures is in the counties between Pueblo and John Martin Reservoir. Crops grown in this area primarily consist of alfalfa, corn (for both silage and grain), other hay crops, and other row crops. In counties upstream of Pueblo Reservoir and El Paso County, irrigation is primarily used for forage crops, such as alfalfa, other hays and pastures. It should be noted that although the net irrigation requirement shown for pastures in Lake County is relatively high, this amount of water is rarely available and therefore, seldom applied. It should also be noted that although the majority of Bent County is outside of the study area, irrigation requirements for the county are included in the total irrigation requirements for the study area. Bent County irrigation requirements are included in the study area total because most of the diversions for Bent County occur within the study area.

Table 3-4. Irrigated Acreage and Net Irrigation Requirements in Study Area

County	Total Irrigated Acres (1995)	Net Irrigation Requirement by Crop (ac-ft) (2)								
		Alfalfa	Corn (Grain)	Pastures and Other Lands	Other Hay	Corn (Silage)	Dry Beans	Grain Crops	Other Crops	Total
Bent(1)	63,276	125,446	15,208	4,842	5,162	3,870	0	9,411	0	163,939
Chaffee	16,655	7,155	0	11,111	9,190	0	0	0	5	27,461
Crowley	12,818	20,113	4,067	3,304	2,377	1,104	0	0	499	31,464
El Paso	12,049	11,618	0	4,544	3,560	522	0	272	1,301	21,817
Fremont	12,639	13,308	0	6,740	9,035	886	0	0	1,159	31,128
Lake	53,555	0	0	88,813	668	0	0	0	0	89,481
Otero	64,539	74,934	35,448	14,514	6,732	2,837	1,955	3,760	3,561	143,741
Pueblo	29,142	28,171	11,837	6,934	6,982	1,106	3,582	1,247	2,699	62,558
Total	**264,673**	**280,745**	**66,560**	**140,802**	**43,706**	**10,325**	**5,537**	**14,690**	**9,224**	**571,589**

Notes:

(1) Bent County is mostly outside of the study area, but is largely irrigated by canals that divert from inside the study area.

(2) Net Irrigation Requirement is equal to consumptive use if a full supply is available and applied.

(3) Source: (Frank and Carlson, 1999).

Major agricultural diversions on the Arkansas River (those with an average annual diversion greater than 50,000 ac-ft) include the Fort Lyon Canal (including the Fort-Lyon Storage Canal), the Catlin Canal, the Rocky Ford Highline Canal, the Bessemer Ditch, the Minnequa/Union Ditch diversion, and the Holbrook Canal. The Minnequa/Union ditch diverts water from the Arkansas River near Florence, and then bifurcates to separate canal systems. The Bessemer Ditch diverts water directly from Pueblo Reservoir through its own outlet structure and delivers water to agricultural users near Pueblo and east of Pueblo. The ditch also conveys water for municipal use to the St. Charles Mesa Water District. The remaining major diversions all divert water downstream of Pueblo Reservoir within the study area. Irrigation water from the Catlin Canal, the Rocky Ford Highline Canal and the Holbrook Canal are primarily used within the study area. The Fort Lyon Canal serves some water users within the study area upstream of John Martin Reservoir, but primarily serves water users downstream of John Martin Reservoir. These major agricultural divisions comprise approximately two-thirds of the total historical diversions from the Arkansas River.

3.2.2.2 Municipal and Industrial

The two largest M&I water users in the Arkansas Basin are Colorado Springs Utilities and the Pueblo Board of Water Works (PBWW). However, due to their location within the basin and their water rights portfolios, their use of Arkansas Basin water is different.

Colorado Spring Utilities

Colorado Springs Utilities' water use can generally be described in two categories: the local collection system and the non-local collection systems. The local collection system primarily includes those systems that divert runoff from Pikes's Peak, while the non-local systems include transmountain collection systems and some native Arkansas River rights through ownership in storage and canal companies. An important aspect to Colorado Springs Utilities' water rights portfolio is that all waters originating from non-tributary sources, primarily transmountain diversions but also that derived from non-tributary ground water and from transfers of agricultural consumptive use water, can be reused to extinction according to their decrees. This water can be and is currently used for local exchanges and augmentation, the non-potable reuse system and Arkansas River exchanges. The average annual yield available from these sources is shown in **Table 3-5**.

Table 3-5. Colorado Springs Utilities Existing Collection System Yields (MWH 2005)

System	Firm Yield (1978) (5)		Average Yield	
	(ac-ft/yr)	(mgd)	(ac-ft/yr)	(mgd)
Local System - Direct Flow Water Rights	18,800	16.8	38,000	33.9
Local System - Water From Storage	17,200	15.4	100	0.1
Blue River Pipeline	7,800	7.0	8,100	7.2
Otero Pump Station	64,700	57.8	71,500	63.8
Fountain Valley Conduit	8,300	7.4	12,600	11.3
Groundwater	2,200	2.0	1,900	1.7
Total	**119,000**	**106.4**	**132,200**	**118.0**

Notes:

(1) System yield is the yield from each system based on hydrology, physical system constraints and storage.

(2) Firm System yield is higher than hydrologic yield due to the benefits of storage.

(3) Yield calculations were determined assuming local system improvements were implemented, such as Bear Creek, Pikeview (10 mgd) and the Highline to Northfield Transfer Pipe.

(4) Average yield numbers are based on the total average for each system under 2046 demands.

(5) Firm yield numbers are based on the critical year for the firm yield run, which was 1978.

The average annual yield available from the local collection system is approximately 38,000 acre-feet, while the yield available from non-local water supplies is approximately 94,200 acre-feet (MWH, 2005). Storage, delivery system, water quality and other constraints substantially reduce the amount of local system inflows that are actually diverted by Colorado Springs Utilities.

Colorado Springs takes delivery of its transmountain and Arkansas River water through three separate delivery systems. Twin Lakes Project yield, Homestake project yield, exchanged reusable return flows (as described below) and other Arkansas Basin water is delivered through the Otero Pump Station and Homestake Pipeline. Fry-Ark Project water is delivered through the Fountain Valley Conduit, while Blue River water is delivered through the Blue River Pipeline.

Return flows from water use within Colorado Springs Utilities' service area accrues to both surface water, including sewered and a small volume of non-sewered return flows, and ground water through non-sewered return flows. The return flows accrue as both reusable return flows and non-reusable return flows. Reusable return flows are then used for local exchange and augmentation purposes or flow down Fountain Creek and are made available for exchanges on the Arkansas River.

Sewered return flows are quantified by the amount of wastewater effluent leaving the Las Vegas Street Wastewater Treatment Facility (LVSWWTF). Non-sewered return flows account for return flows that do not accrue to a wastewater treatment facility, and are primarily from landscape irrigation and other outdoor uses. As required by their reusable return flow decrees, Colorado Springs Utilities maintains daily accounting forms that quantify return flows to determine the amount that is available for local exchange and augmentation and Arkansas River exchanges. These spreadsheets are presented to Reclamation annually in the Blue River Report.

Reusable return flows available for exchange at the Fountain Creek confluence with the Arkansas River have averaged approximately 18,000 acre-feet since 1985, and have approached 24,000 acre-feet during several years since 1995. An average of 15,000 acre-feet have actually been exchanged since 1985, with exchanges approaching the entire 24,000 acre-feet of reusable return flows during several years since 1995. Water is exchanged from the mouth of Fountain Creek to Pueblo Reservoir through river exchange and water is exchanged from Pueblo Reservoir to Twin Lakes primarily through river exchanges and occasional contract exchanges. Exchanges are also made directly from Lake Meredith releases to Twin Lakes.

Pueblo Board of Water Works

The PBWW has a broad range of water rights in its portfolio, including senior direct flow water rights, ownership of and storage rights for Clear Creek Reservoir and shares in several transmountain diversion projects. The transmountain diversion projects are discussed in later sections of this report. The direct flow water rights provide the PBWW with their base water supply. The PBWW owns approximately 83 cfs of direct flow water rights, including two of the most senior water rights on the river. Historically, these water rights have comprised a significant portion of the PBWW water use. In addition to the direct flow water rights, the PBWW diverts and stores native water in Clear Creek Reservoir, as well as exchanging some transmountain water rights into the reservoir. The PBWW typically leases water to several entities within the basin, including the Comanche Power Plant and the City of Aurora (GEI, 1998).

The PBWW diverts water primarily through the recently completed Joint Use Pipeline (JUP) from Pueblo Dam to the Whitlock Water Treatment Plant (WTP). The PBWW can also make diversions from the river, through the Northside and Southside diversion structures to the WTP, which was the only means of division prior to the completion of the JUP in 2002. Treated wastewater is discharged from the Pueblo Wastewater Treatment Plant (WWTP) back to Arkansas River just downstream of Fountain Creek.

Aurora

The City of Aurora owns shares in the Twin Lakes Reservoir and Canal Company, the Colorado Canal Company (including the Lake Henry and Lake Meredith Companies) and the Rocky Ford Ditch. In addition, the City of Aurora has signed agreements for dry-year leases of Rocky Ford Highline Canal water. Aurora moves water from the Lower Basin to Twin Lakes and Turquoise Reservoir either by river exchange or contract exchange, and takes delivery of the water through the Homestake pipeline. Aurora's operations in the Arkansas Basin are discussed in more detail in **Section 3.2.5**.

Other Municipal Water Users

In addition to the larger entities, there are other smaller municipal entities in the basin, including the City of Fountain, the Security Water District, and the Pueblo West Metropolitan District, that own direct flow water rights.

The City of Fountain has historically relied upon two sources of supply. The primary source of supply is Fry-Ark Project water available through the Fountain Valley Conduit. The secondary source of supply is from wells owned by the City. The Fry-Ark Project can supply approximately 1,900 acre-feet while wells can supply a firm capacity of 2,500 acre-feet per year. Existing demands are approximately 2,240 acre-feet per year (B&V, 2004). Sewered return flows accrue to Fountain Creek through the Fountain Sanitation District wastewater treatment facilities, which outfalls to the creek just downstream of the City of Fountain. Non-sewered return flows accrue to Fountain Creek and shallow ground water.

The Security Water and Sanitation District provides potable water supplies to those entities within the District boundaries. The District has two primary sources of supply: Widefield aquifer wells owned by the District that supply approximately 2,000 acre-feet of water, and deliveries from Fountain Valley Authority, which supplies approximately 1,600 acre-feet of water. The District also has a contract in place with Colorado Springs Utilities for deliveries of 300 to 600 acre-feet per year (GMS 2001). Sewered return flows accrue to Fountain Creek through the District's wastewater treatment facility, which outfalls to the creek on the southern edge of the District's boundaries.

Pueblo West Metropolitan District (Pueblo West) provides potable water supplies to entities within the District boundaries immediately north of Pueblo Reservoir. Pueblo West's current water supplies consist of ownership in the Twin Lakes Reservoir and Canal Company, ownership in the Colorado Canal Company and Lake Meredith Company, Wheel Ranch Ditch water rights and non-tributary ground water from the Dakota and Purgatoire formations. Pueblo West can reuse sewered and non-sewered return flows that originate from the Twin Lakes Project ownership (WRC 1998). Surface water is pumped from Pueblo

Reservoir through the existing South Outlet Works. The District currently serves a residential population of approximately 22,000, as well as numerous commercial and industrial entities (Pueblo West 2004).

Many other smaller entities have purchased ownership in transmountain diversion projects and canal companies. Water supplies for these entities are not detailed herein. Additional information on these water users is provided in the Arkansas Basin Water and Storage Needs Assessment document (GEI, 1998).

Industrial Water Users

The primary industrial water use in the study area is for cooling at power plants and the old CF&I steel mill, which has a relatively low consumptive use. Xcel Energy's Comanche Power Plant diverts water out of the Arkansas River downstream of Pueblo Reservoir through a pump station. Typical diversions range from 14 to 16 cfs, and utilize water leased from the PBWW. Return flows from the diversions accrue to the Arkansas River downstream of the Fountain Creek confluence. Aquila Energy diverts water upstream of the Moffat Street gage, while the return flows accrue to the Arkansas River downstream of the Moffat Street gage and upstream of the Fountain Creek confluence. Return flows from this plant flow through the channels along the Historic Arkansas Riverwalk (also referred to as HARP) before accruing back to the Arkansas River downstream of the Moffat Street gage and upstream of the Fountain Creek confluence. The diversion volume historically has not been measured. Periodic data available from CDPHE shows return flows ranged from 0 cfs to in excess of 100 cfs, with values typically ranging from 20 to 50 cfs (Mars and Fleming, 2001). The old CF&I steel mill obtains its cooling water from the Minnequa Canal, which diverts water from the Arkansas River near Cañon City. Return flows accrue downstream of Fountain Creek.

3.2.3 Water Supplies

Water supplies for water users in the Arkansas Basin are primarily made up of native supplies from Arkansas River surface flows, ground water and transmountain diversions. As previously mentioned, exchanges are an important means to recapture reusable return flows for the water users. Ground water supplies and uses are discussed in detail in later chapters of this technical report. The following sub-sections describe the supply and use of native Arkansas River water, transmountain diversion projects, exchanges and changed water uses, the Arkansas River water bank and the existing flow management programs and instream flow water rights.

3.2.3.1 *Native Water Rights*

As with the rest of Colorado, native water in the Arkansas Basin is administered according to the prior appropriation doctrine. Direct flow water users own rights to use water from the stream according to availability. When there is not enough water in the river to meet all water rights, a call is placed on the river, and diversions are satisfied in priority based upon the date of appropriation of the water right. Water in the Arkansas River is highly appropriated. Only in extremely wet periods is there a “free river” (when there is no call on the river).

Table 3-6 presents a summary of the major water rights on the Arkansas River. The earliest appropriation date (or priority date) on the river within the study period is owned by the PBWW for 7 cfs. Historically, those water rights with priority dates earlier than 1874 are in priority nearly 100 percent of the time. There are a large number of diversions with priority dates between 1874 and 1890. Subsequently, any water right later than 1890 has historically been in priority only 30 percent of the time. Most of these more junior water rights are storage rights that only divert during the peak-runoff season.

As discussed later in this section, the WWSP is from November 15 through March 15. During this time, the WWSP participants (which includes most of the major agricultural diversions) store their water in various reservoirs rather than take a direct-flow diversion. Therefore, these water rights are not administered in priority, and the total WWSP diversions are divided among the participants. Non-participants retain the right to divert water according to their priority date. The WWSP is administered with a priority date of 3/1/1910.

Table 3-6. Major Direct Flow and Storage Water Rights on Arkansas River in Study Area

Priority Date	Entity (rate or volume) (1)	Percent of Time in Priority (2,3)
4/1/1861	PBWW (7 cfs)	100.0%
12/31/1861	Bessemer Ditch (20 cfs), Highline Canal (40 cfs)	100.0%
7/01/1869	Highline Canal (16.6 cfs)	100.0%
4/1/1874	PBWW (45 cfs)	99.7%
5/15/1874	Rocky Ford Ditch (111.76 cfs)	99.4%
4/10/1875	Catlin Canal (22 cfs), Las Animas Consolidated (22 cfs)	98.6%
3/7/1884	Highline Canal (32.5 cfs)	98.6%
4/15/1884	Fort Lyon Canal (164.64 cfs)	98.2%
12/03/1884	Catlin Canal (226 cfs), Las Animas Consolidated (22 cfs)	96.0%
6/30/1885	Highline Canal (30 cfs)	82.9%
2/25/1887	Oxford Farmers (116 cfs)	82.8%
3/1/1887	Fort Lyon Canal (597.16 cfs)	70.2%
5/01/1887	Bessemer Ditch (322 cfs), Collier Ditch (22 cfs), Excelsior Ditch (20 cfs)	43.9%
11/14/1887	Catlin Canal (97 cfs)	41.3%
3/13/1888	Las Animas Consolidated (80 cfs)	40.8%
9/25/1889	Holbrook Canal (155 cfs)	40.5%
12/31/1889	Lake Henry (6,353 ac-ft)	35.7%
1/06/1890	Excelsior Ditch (40 cfs), Highline Canal (380.5 cfs)	35.7%
3/3/1890	Otero Canal (123 cfs)	31.6%
5/5/1890	Rocky Ford Ditch (97 cfs)	30.8%
6/8/1890	Colorado Canal (756.28 cfs)	30.8%
3/2/1892	Holbrook Reservoir (4,247 ac-ft)	25.5%

Table 3-6. Major Direct Flow and Storage Water Rights on Arkansas River in Study Area

Priority Date	Entity (rate or volume) (1)	Percent of Time in Priority (2,3)
8/30/1893	Holbrook Canal (445 cfs)	24.8%
8/31/1893	Fort Lyon Canal (171.2 cfs)	22.8%
8/1/1896	Great Plains Reservoir System (265,552 ac-ft)	22.8%
3/9/1898	Lake Meredith (26,028 ac-ft)	16.2%
2/2/1903	Otero Canal (334.92 cfs)	15.0%
10/10/1903	Dye Reservoir (4,500 ac-ft)	15.0%
1/25/1906	Adobe Creek Reservoir (61575 ac-ft), Horse Creek Reservoir (26,887 ac-ft)	15.0%
11/30/1907	Baldwin-Stubbs (22 cfs)	12.8%
6/12/1908	Horse Creek Reservoir (1,113 ac-ft)	12.5%
12/29/1908	Adobe Creek Reservoir (25,452 ac-ft)	12.5%
4/15/1909	Las Animas Consolidated Extension (44.8 cfs)	12.5%
5/15/1909	Lake Henry (3,561 ac-ft)	12.5%
9/3/1909	Dye Reservoir (3,486 ac-ft)	12.5%
9/15/1909	Holbrook Reservoir (3,196 ac-ft)	12.5%
12/14/1948	John Martin Reservoir	12.5%
6/25/1962	Pueblo Reservoir (357,678 ac-ft)	5.4%
	Free River	5.2%

Notes:

(1) Generally includes water rights greater than 50 cfs or greater than 5000 ac-ft only, or of importance to analysis. Entities may have additional water rights to those shown in this table. USGS (1985) and CDSS water rights database (2003).

(2) Non-WWSP Season Only. Includes days when the water right is the calling water right.

(3) Based on State Engineer's Office Division 2 call records, 10/1/1982 - 8/7/2002.

3.2.3.2 Arkansas River Compact

Native streamflows in the Arkansas River are administered according to the requirements of the Arkansas River Compact (Colorado Statutes, Title 37, Article 69, and Section 37-69-101). The Arkansas River Compact was ratified by the states of Colorado and Kansas in 1948. The Compact divides and apportions waters of the Arkansas River between the states of Colorado and Kansas and sets forth operating criteria for John Martin Reservoir, which was constructed by the U.S. Army Corps of Engineers in 1943. The following is a summary of provisions set forth in the following sub-section of Article V.

A. During the John Martin Reservoir winter storage season (November 1 through March 31), all water entering the reservoir up to its conservation capacity shall be stored, except that Colorado may demand releases up to 100 cfs.
B. During the John Martin Reservoir summer storage season (April 1 through October 31), all water entering the reservoir up to its conservation capacity shall be stored, except that Colorado may demand releases up to the river flow or 500 cfs, whichever is less, and Kansas may demand releases up to the river flow between 500 cfs and 750 cfs, irrespective of Colorado's releases.
C. During the summer storage season, Colorado may demand releases up to 750 cfs and Kansas may demand releases up to 500 cfs. If the conservation pool is less than 20,000 ac-ft, then these values shall be reduced to 600 cfs and 400 cfs, respectively.

D. Reservoir releases under (A), (B) and (C) shall not impose a call on water users diverting upstream of John Martin Reservoir.
E. Releases may be made simultaneously, shall be put to beneficial use, shall be measured by gaging stations downstream of the dam and shall be timed to meet demands required at the state line. Neither state will be allowed to accumulate credits or debits for or against either state.
F. If the conservation pool is nearly exhausted, then Colorado must administer water rights in district 67 (downstream of John Martin) in priority relative to all water rights in the Arkansas River Basin until a time when the conservation pool is replenished to allow administration according to provisions (A) through (E).
G. When Colorado is administering decreed priorities for district 67, Kansas shall not be entitled to any portion of the river flow entering John Martin Reservoir.
H. The decreed priorities in district 67 and in Kansas between the state line and Garden City shall not be increased if they will cause a depletion to flows.

Administration of the Compact using John Martin Reservoir was further clarified by the Arkansas River Compact Association (ARCA) through the 1976 Permanent Pool Criteria (ARCA, 1976), the 1980 Operating Plan (ARCA 1980) and the subsequent 1984 update to the Operating Plan (ARCA, 1984). These documents defined storage accounts in John Martin Reservoir for Kansas, for District 67 ditches and for selected District 17 ditches, as well as established spill priorities for these ditches.

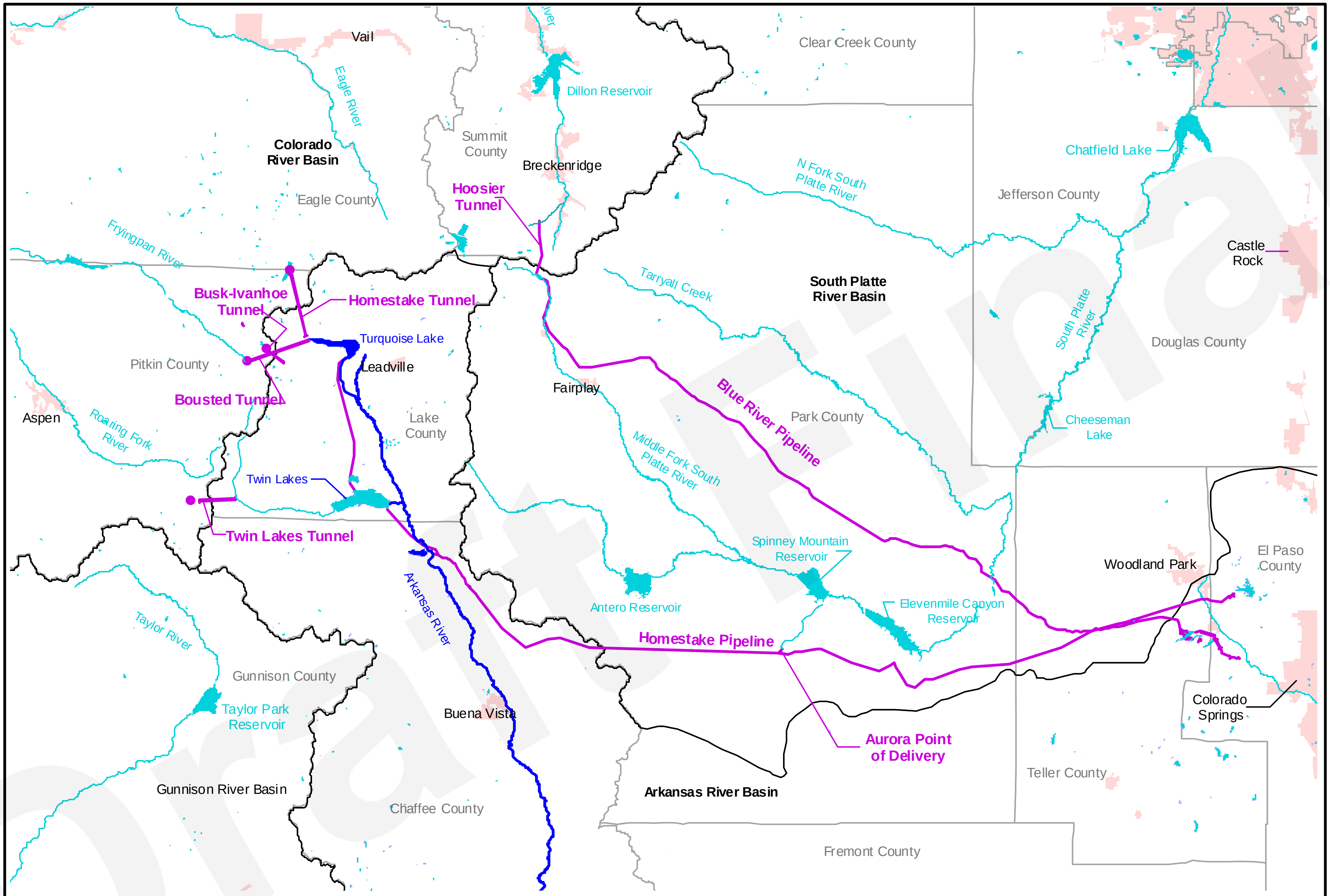
In response to the 1995 ruling by the United States Supreme Court that Colorado violated the compact by causing material depletions in useable Stateline flows via well pumping (Kansas vs. Colorado, 115 S.Ct 1733, 1995), an Offset Account was established in John Martin Reservoir. This 20,000 acre-foot account allows ground water pumping by Colorado in excess of the pre-Compact entitlement of 15,000 acre-feet per year by releasing water from storage to replace depletions in excess of the pre-Compact entitlements. Colorado must fill the Offset Account using fully consumable water as approved by the Colorado State Engineer (ARCA, 1998).

The effect of the Compact and subsequent agreements within the study area is a December 14, 1948 priority date for storage of water in John Martin Reservoir. The decree includes a provision that the Fry-Ark Project facilities can only store under their decreed east slope water rights when the conservation pool at John Martin Reservoir is spilling (SECWCD, 2003). The Compact also requires that well pumping be augmented as to not cause a depletion to useable Stateline flows and that all water rights change case decrees be structured so that only consumptive use is transferred and historical return flow patterns remain the same.

3.2.3.3 Transmountain Diversion Projects

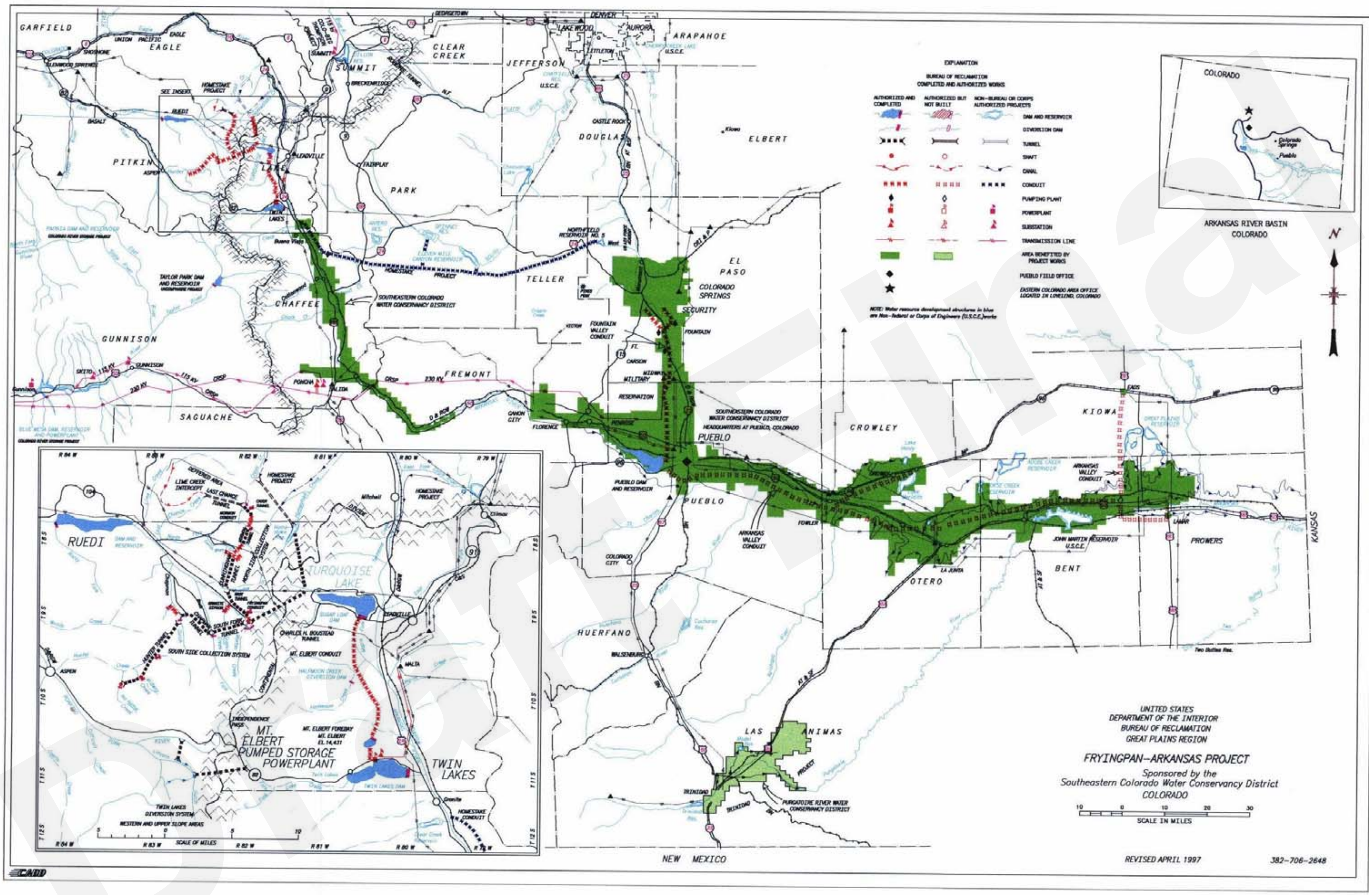
Several transmountain diversion projects import water from the Colorado River Basin into the Arkansas Basin to supplement native supplies. These projects are described in the following subs-sections. A map showing the major transmountain imports to the Arkansas Basin is presented in **Figure 3-2**.

Figure 3-2. Major Transmountain Imports to the Arkansas River Basin



Project: Aurora Environmental Assessment
Date: August, 2005

Figure 3-3. Fryingpan-Arkansas Project Location and Boundaries of SECWCD



Fryingpan-Arkansas Project

The Fryingpan-Arkansas Project is a transmountain diversion project constructed by Reclamation to supplement municipal and agricultural demands within the Arkansas Valley of Colorado. The Fry-Ark Project consists of five reservoirs and one transmountain diversion tunnel. The Boustead Tunnel diverts water from the Roaring Fork River Basin on the western slope of the Continental Divide in the Sawatch Range. Ruedi Reservoir stores and releases water back to the Roaring Fork River Basin for replacement and conservation of water for Western Slope water users. Boustead Tunnel average annual yield was about 55,300 acre-feet for the study period (CDSS 2004). Turquoise Reservoir receives the Boustead Tunnel imports on the East Slope.

Water from Turquoise Reservoir is stored and released through the Mount Elbert Conduit to the Mount Elbert Forebay. Water from the forebay is then used to generate power at the Mount Elbert Pumped-Storage Powerplant. Twin Lakes is the receiving reservoir for water used at the power plant, and water is released from Twin Lakes to the Arkansas River via Lake Creek. Pueblo Reservoir is a direct-flow storage reservoir on the Front Range which stores and delivers water to municipal and agricultural entities in the Lower Arkansas Valley. **Figure 3-3** shows the location of the components of the Fry-Ark Project.

The Fry-Ark Project owns water rights on both the East Slope and the West Slope of the Continental Divide. The West Slope water rights are held on tributaries to the Fryingpan River and imported through the Boustead Tunnel. The East Slope water rights are native Arkansas River water rights with a 1962 priority date, and thus are rarely in priority. Previous studies found that between 1966 and 1995, the water rights were in priority during 9 of the 360 months. Future Fry-Ark diversions on both the West Slope and East Slope will likely be different than they have in the past because increased Fry-Ark demands may increase available Fry-Ark storage space on the East Slope. The storage capacities for each of the Fry-Ark reservoirs are shown in **Table 3-7**.

Table 3-7. Fryingpan-Arkansas Project Reservoir Storage Volumes

Reservoir	Reservoir Storage (ac-ft)					
	Dead	Inactive(1)	Active Conservation	Joint Use(2)	Flood Control	Total Capacity
Ruedi	63	1,095	101,278	0	0	102,373
Turquoise	2,810	8,920	120,478	0	0	129,398
Pueblo	2,329	28,121	228,828	66,000	26,991	349,940
Twin Lakes	63,324	72,938	67,917	0	0	140,855
Mount Elbert Forebay	561	3,825	7,318	0	0	11,143

Notes:

(1) The volume shown for inactive includes the volume shown for dead storage. Dead storage is storage below the outlet works that physically cannot be drained. Inactive storage is storage that by operational principals is reserved for in-reservoir use and never evacuated from storage.

(2) The Joint Use pool is reserved for flood control space from April 15 through November 1. At other times, it can be used for conservation storage.

(3) From (USBR, 2001).

The Southeastern Colorado Water Conservancy District (SECWCD) was established in the 1950s as the local sponsoring agency for the Fry-Ark Project. The SECWCD is responsible for repayment to the United States and allocation of Fry-Ark water to its constituents. Through their allocation principals, the SECWCD has categorized Fry-Ark Project municipal water users into four groupings: municipal entities west of Pueblo, the PBWW, municipal entities east of Pueblo and Fountain Valley Authority (FVA) entities. Each entity is allocated a certain percentage of Fry-Ark Project yield and Fry-Ark Project storage. Original estimates of Fry-Ark Project yield were approximately 80,400 acre-feet (Reclamation, 1990). A total of 159,000 acre-feet of Project storage is set aside for municipal storage and municipal carryover storage (Reclamation, 1990). A summary of Fry-Ark Project yield and storage allocations for each of the entities is presented in **Table 3-8**. It should be noted that the entities are not guaranteed the yield as shown in **Table 3-8**. The actual yield available to an entity for any given year is their percentage of the allocated Project yield for any individual year.

Table 3-8. Summary of Fry-Ark Municipal Yield and Storage Allocations

Entity	Allocation Percentage	Average Annual Yield Allocation(1) (ac-ft)	Storage Space Allocation (ac-ft)
Municipal West of Pueblo	4%	3,216	12,400
Pueblo Board of Water Works	10%	8,040	31,200
Municipal East of Pueblo	12%	9,648	37,400
Fountain Valley Pipeline	25%	20,100	78,000
Total	**51%**	**41,004**	**159,000**

Notes:

(1) Based on average annual Fry-Ark Project yield of 80,400 acre-feet

(2) From SECWCD Allocation Principles (SECWCD, 1979). However, in the Allocation Policies (SECWCD, 2004), the municipal carryover storage space was stated to be 163,100 ac-ft. Reclamation considers the additional 4,100 ac-ft to be used for non-Fry-Ark Project Purposes only (Musgrove, 2005).

In addition to firm account space, Reclamation has historically allowed storage of non-Fry-Ark Project water in Fry-Ark Project storage space through programs such as the WWSP and if-and-when (Temporary Excess Capacity) accounts. These non-Fry-Ark Project accounts are allowed to store as long as storage space is available. The largest users of these contracts have historically been Colorado Springs Utilities and the City of Aurora and amounts have been about 10,000 acre-feet. These contracts are now referred to as "Short-term Excess Capacity Contracts" (Short-Term Contracts). Historical contract amounts are shown in **Table 3-10**.

When storage space is unavailable to accommodate both Fry-Ark Project and non-Fry-Ark Project accounts, non-Fry-Ark Project water is "spilled" from the reservoirs. The current spill priorities shown in **Table 3-9** have been established by Reclamation (Reclamation, 1990). As shown, Aurora's proposed Long-Term Excess Capacity account would be in the first group of storage accounts to spill.

Table 3-9. Fryingpan-Arkansas Project Reservoir Spill Priorities

Spill Order (1)	Storage Account
1	Entities Outside of District (Including Aurora)
2	if-and-when Storage
3	WWSP water in Excess of 70,000 ac-ft
4	Municipal non-Fry-Ark Project water
5	WWSP water less than 70,000 ac-ft
6	Native Arkansas River Basin Fry-Ark Project water

Notes:

(1) First to spill is the first account in the list.

Table 3-10. Historical Pueblo Reservoir Excess Capacity Contracts

Entity	Year																	
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Aurora	1,000	1,000	1,000	10,000	10,000	10,000	1,000	1,000	1,700	3,500	3,000	3,000	1,000	3,000	3,000	3,000	5,000	5,000
Beaver Park									1,000	1,000								
Bessemer Ditch								1,250		10,000								
Brewer, Robert							283		400	400								
Carter, Alvin							281	220	335									
Catlin Canal Co.			250	250	250	300	300	300	1,000	1,000	1,000	1,000						200
Cesar Dairy									150	250								
Colorado Springs	500		1,000		2,500	6,000	6,000	10,000	10,000	10,000			10,000	10,000	2,500	5,000	5,000	10,000
Colorado Department of Corrections									75	220								
CWPDA									1,000	2,100								1,000
Dept. of Parks and Outdoor Recreation									7,200	3,500								
City of Fountain																		1,300
Holbrook Mutual Company										3,403								
Jordan, Gerald									500	500								
LAWMA										165								
Orville Tomky							58		250									
Public Service Company											1,000							
Pueblo Board of Water Works		250	2,000	2,000	2,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	5,000	5,000	5,000	
Pueblo West Metropolitan District														1,000	1,000	1,000	2,000	2,000
Salida																		350
Security Water District																		400
SEWAE																		100
Southwest Ready Mix									50									
St. Charles Mesa Water District																		150
Upper Arkansas Water C D									120	150			50	50				
Widefield Water and Sanitation D																		400
Totals	**1,500**	**1,250**	**4,250**	**12,250**	**14,750**	**19,300**	**10,922**	**14,770**	**26,780**	**39,188**	**8,000**	**7,000**	**14,050**	**17,050**	**11,500**	**14,000**	**17,000**	**20,900**

Notes:

(1) Source: Reclamation Eastern Colorado Area Office

(2) 1986-1988 volumes for Aurora are estimated.

(3) Pueblo Board of Water Works was issued a 25-year long-term contract in 2001.

The WWSP was developed to allow agricultural water users to store in-priority water rights during the winter in Pueblo Reservoir. Prior to completion of Pueblo Dam, agricultural entities would divert their water rights in-priority through their normal conveyance systems to maintain soil moisture levels. However, problems associated with winter operations were frequently experienced. Therefore, beginning in 1975, a program was developed to allow these entities to divert water into storage for use during the following irrigation season. The following information is used by the division engineer in administration of the WWSP:

- River flows in excess of the amount necessary to supply senior priorities not participating in the program may be stored in Pueblo Reservoir, John Martin Reservoir, or participants' off-stream storage facilities from November 15 to March 15.
- Such water is apportioned by the Division Engineer according to pre-defined percentages.
- The WWSP water stored in Pueblo Reservoir is subject to be spilled if the storage space occupied within the conservation pool is required for the storage of Fry-Ark Project water or if the storage space it occupies is within the joint-use pool which must be evacuated pursuant to the Fry-Ark Project flood control criteria by April 15 of each year.
- All WWSP water is released from storage within 18 months from the commencement of the winter storage period but not later than May 1 of the year following the end of the winter storage period in which it was stored.

Homestake Project

The Homestake Project is a municipal transmountain diversion project owned jointly by Colorado Springs Utilities and the City of Aurora. The West Slope diversion system diverts water from the Homestake Creek watershed, a tributary of the Eagle River, into Homestake Reservoir. From Homestake Reservoir, this water is diverted to Turquoise Reservoir through the Homestake Tunnel. From Turquoise Reservoir, water is conveyed to Twin Lakes Reservoir via administrative processes. From Twin Lakes, water is diverted through the Twin Lakes pipeline to the Otero Pump Station, where it is pumped into the Homestake pipeline and distributed to Spinney Mountain Reservoir in the South Platte Basin for Aurora and to the Catamount Reservoir system for Colorado Springs Utilities.

Colorado Springs Utilities and Aurora split ownership in the Homestake Project. Aurora sold 2,500 acre-feet of Homestake water to the PBWW. Typically, this water is leased back to Aurora as part of a long-term lease arrangement for 5,000 acre-feet of transmountain water from PBWW to Aurora. Both Colorado Springs Utilities and Aurora have 15,000 acre-foot long-term storage contracts in Turquoise Reservoir for storage of Homestake water. By contract, this storage space can only be used for storage of Homestake water and cannot be used for storage of any other types of water. Historical yield of the Homestake System is about 25,400 acre-feet (CDSS, 2004).

Twin Lakes Project

The Twin Lakes Project is a transmountain diversion and storage system constructed in the 1930's to serve lands under the Colorado Canal system (USGS, 1985). The Independence Pass Transmountain Diversion System diverts water from several streams located in Pitkin County on the West Slope into Grizzly Reservoir. From Grizzly Reservoir, this water is diverted into the Twin Lakes (or Independence Pass) tunnel into Lake Creek above Twin Lakes. In addition, the Twin Lakes Project also possesses East Slope water rights with 1896 and 1897 priority dates. The average annual total Twin Lakes Project yield is about 48,200 acre-feet, with about 36,500 acre-feet coming from West Slope water rights and 11,700 acre-feet from East Slope water rights (Ringle, 2004). **Table 3-11** summarizes ownership of the Twin Lakes Project. Aurora does not export native Twin Lakes Project water out of the Arkansas River Basin, but does use the native water in other ways, such as augmentation.

Table 3-11. Twin Lakes Project Ownership Distribution (check #s with model)

Entity	Shares	Percent	Storage (ac-ft)
Aurora	2,478.475	5.00%	2,722
Colorado Springs Utilities	27,103.693	54.66%	29,762
Pueblo Board of Water Works	11,476.157	23.14%	12,602
Pueblo West	5,766.410	11.63%	6,332
Augmentation	472.822	0.95%	519
Other M&I	1,697.341	3.42%	1,863
Other Ag and Inactive	594.070	1.20%	652
Sub-Total	**49,588.968**	**100.00%**	**54,452**

Notes:
(1) From Ringle (2004).

Busk-Ivanhoe System

The Busk-Ivanhoe System is a transmountain diversion project that diverts water from the upper reaches of Ivanhoe Creek in the Colorado River Basin to Turquoise Reservoir. Diversions were originally made through the Carlton Tunnel, which is a converted railroad tunnel. However, due to the condition of the tunnel, it cannot carry the full transmountain supply. In recent years, at least a portion of the supply is carried through the Boustead Tunnel. Historical average annual yield of the Busk-Ivanhoe System was about 5,200 acre-feet for the study period (CDSS 2004).

Aurora and the PBWW each own 5,000 acre-feet of Busk-Ivanhoe agricultural storage space in Turquoise Reservoir. The 10,000 acre-feet of Busk-Ivanhoe storage space in Turquoise Reservoir is firm storage space with agricultural type and place of use requirements and thus, cannot be used by Aurora or PBWW. In addition, both Aurora and PBWW each own 5,000 acre-feet of storage space in Turquoise Reservoir through their purchase of CF&I shares, which can be used to store Busk-Ivanhoe water. The City of Aurora takes delivery of their water through the Homestake pipeline via the Mount Elbert Conduit, Twin Lakes and the Otero Pump Station. The PBWW typically leases most of their Busk-Ivanhoe yield to Aurora (2,500 acre-feet per year). Any remaining yield is either stored in CF&I storage space or leased to other entities in the Arkansas Basin.

Columbine, Ewing, and Wurtz Ditches

Columbine, Ewing and Wurtz Ditches are smaller transmountain diversion ditches that divert water from the Colorado River Basin to the Arkansas River Basin near Tennessee and Fremont Passes north of Leadville. The PBWW owns the diversion structures and their associated yields. Because of their relatively small diversion amount and small influence on overall flows in the Arkansas Basin, future diversions through these ditches are assumed to be the same as historical. Historical average annual yield for the Columbine, Ewing, and Wurtz Ditches was about 5,800 acre-feet for the study period (CDSS 2004).

Blue River Project

The Blue River Project is a transmountain project that diverts water from the upper reaches of the Blue River into Colorado Springs Utilities' local system. Water is diverted out of several tributary streams to the Blue River and the Blue River headwaters through a series of pipelines and tunnels to the Hoosier Tunnel. The Hoosier Tunnel conveys water beneath the Continental Divide to Montgomery Reservoir in the South Platte Basin. From Montgomery Reservoir, water flows by gravity through the Montgomery Pipeline to North Catamount Reservoir on the north slope of Pike's Peak where it is then conveyed to Colorado Springs Utilities water treatment plants.

By decree, water diverted through the Blue River system must be reused to extinction by Colorado Springs. Therefore, although its direct imports do not directly affect the study area, the reusable return flows resulting from its use do impact the study area.

3.2.3.4 Multiple Use Diversion Projects

The multiple use diversion projects in the Arkansas River Basin primarily consist of projects that were formerly used entirely for agriculture, but are now used as agricultural, municipal and industrial water supplies. Although most of the canal companies have at least a small amount of their shares owned by municipal or industrial entities, there are two systems in the Arkansas Basin that have a majority of their shares owned by non-agricultural entities: the Colorado Canal System and the Rocky Ford Ditch. Each of these systems is discussed in more detail in the following sub-sections.

Colorado Canal System

The Colorado Canal System is comprised of the Colorado Canal Company, the Lake Meredith Company and the Lake Henry Company. The Colorado Canal diverts water from the Arkansas River near Boone, downstream of Pueblo. The Colorado Canal conveys water either directly to agricultural water users or to storage in Lake Meredith and Lake Henry. Water can then be released from Lake Meredith and Lake Henry to be exchanged upstream for use by municipal and industrial shareholders. In addition, releases can be made from the reservoirs and exchanged back to the Colorado Canal headgate for use by the agricultural shareholders. All shareholders must physically divert water through the Colorado Canal and then exchange the water upstream (84CW62, 84CW63 and 84CW64). There is no alternate point-of-diversion located in upstream facilities as with other change cases. A map of the Colorado Canal system is shown in **Figure 3-4**.

As stated, shares of the Colorado Canal system are mostly owned by municipal and agricultural entities, with Colorado Springs Utilities being the majority shareholder. A breakdown of the ownership within each company is shown in **Table 3-12**. Aurora's use of their Colorado Canal system water rights is further discussed in **Section 3.2.5**.

Table 3-12. Ownership of Colorado Canal System Companies

Entity	Company Shares			Percent Ownership		
	Colorado Canal(3)	Lake Meredith	Lake Henry	Colorado Canal	Lake Meredith	Lake Henry
Colorado Springs Utilities	28,012.760	21,084.750	6,923.150	56.4%	51.9%	77.2%
City of Aurora	14,225.380	13,061.800	1,163.580	28.7%	32.2%	13.0%
City of Fountain	512.500	512.500	0.000	1.0%	1.3%	0.0%
Pueblo West	360.330	360.330	0.000	0.7%	0.9%	0.0%
Woodland Park	583.250	336.000	247.250	1.2%	0.8%	2.8%
Other Uses(2)	1,108.584	946.184	123.000	2.2%	2.3%	1.4%
Agricultural	4,836.171	4,319.821	510.600	9.7%	10.6%	5.7%
Total	**49,638.975**	**40,621.385**	**8,967.580**	**100.0%**	**100.0%**	**100.0%**

Notes:

(1) Source: Ringle (2004).
(2) Includes municipal and industrial use and uses for augmentation.
(3) Total Colorado Canal shares are typically the sum of Lake Meredith and Lake Henry shares, but this is not always true. Data reported is most accurate available.

Rocky Ford Ditch

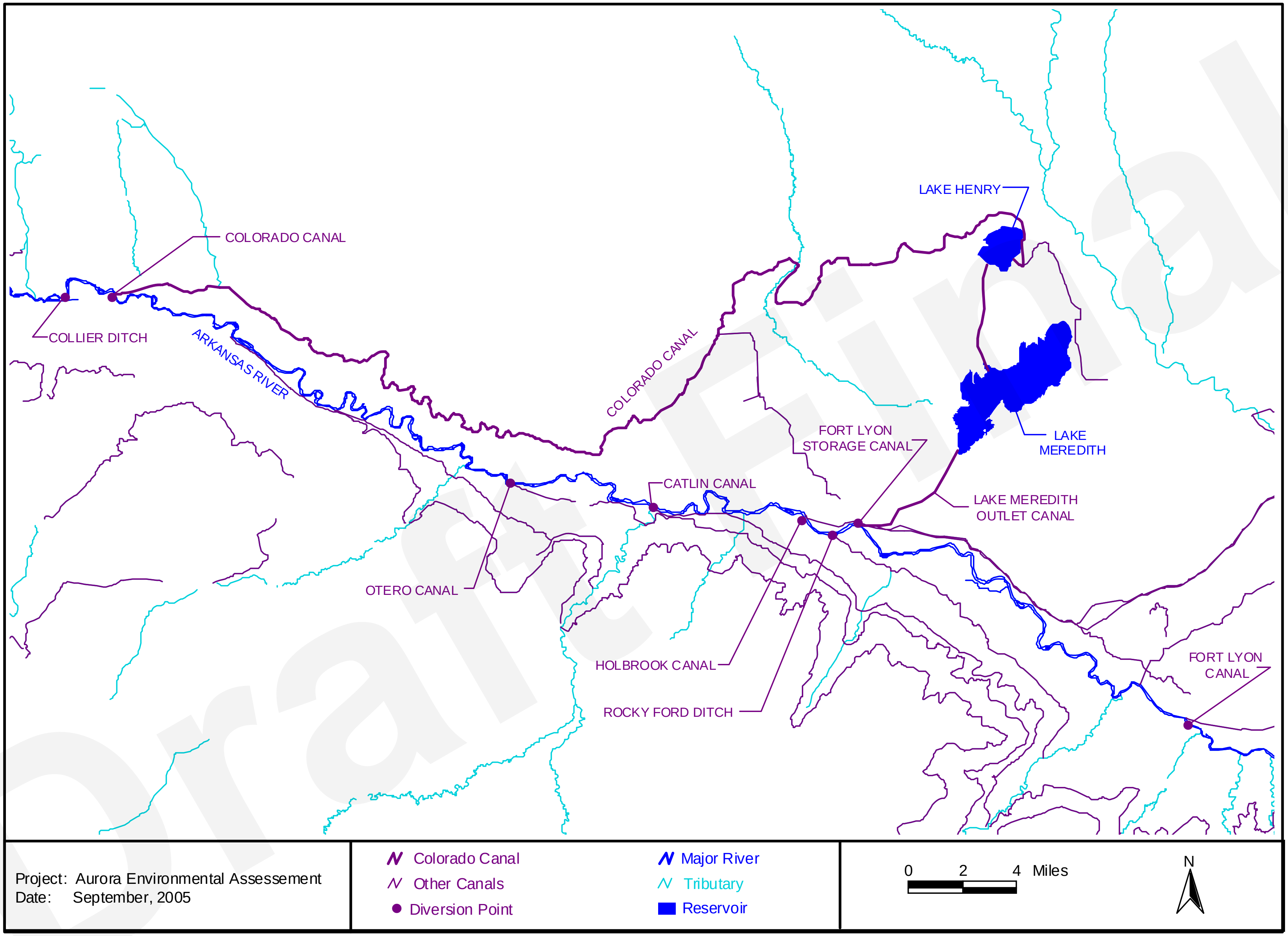
The Rocky Ford Ditch diverts water from the Arkansas River between Manzanola and Rocky Ford and formerly irrigated approximately 8,000 acres of land surrounding the town of Rocky Ford (Simpson, 2005). The ditch still supplies water to the town of Rocky Ford, the Colorado State Research station, and a limited amount of irrigated land. The Rocky Ford Ditch has a priority date of May 15, 1874, making it one of the most senior water rights in the Arkansas River system. In recent years, the City of Aurora has purchased a majority of water rights in the Rocky Ford Ditch. These purchases were completed at two different times and are categorized as the Rocky Ford I purchase and the Rocky Ford II purchase. Further discussion of Aurora's use of their Rocky Ford water rights is discussed in **Section 3.2.5**.

3.2.3.5 Exchanges and Alternate Points-of-Diversion

Exchanges and alternate points-of-diversion are the primary means for moving water into Pueblo Reservoir and from Pueblo Reservoir to upstream storage and conveyance facilities. In addition, the change in point-of-diversion for Rocky Ford Ditch water relies upon exchange-type accounting for storage in Pueblo Reservoir by Aurora. There are several decreed and pending exchanges on the Arkansas River. . The exchanges are summarized in **Table 3-13**.

As shown, the decreed exchanges in the table (priorities 1-11) are administered in a rather complex priority system and often have monthly and annual limitations. Several exchanges are dependent upon using Fry-Ark Project storage space to facilitate the exchanges.

Figure 3-4. Colorado Canal System



Project: Aurora Environmental Assessement
Date: September, 2005

The exchanges and alternate points-of-diversion listed in **Table 3-13** include the City of Aurora Rocky Ford II application, City of Fountain exchange application, the SECWCD exchange application for non-sewered municipal and agricultural Fry-Ark Project return flows, the Pueblo West exchange application, and the City of Pueblo Recreational In-Channel Diversion (RICD) application. All water rights applications submitted in 2001 are grouped as priority 13 because their appropriation dates have yet to be decreed by water court, and thus priority of operations has yet to be determined.

As part of the Winter Water Storage Program decree (84CW170, Division2) and stipulation between Colorado Springs and the Winter Water Storage Program applicants (December 28, 1984), Colorado Springs and the Winter Water Storage Program share storage of native Pueblo Reservoir inflows during the Winter Water season (November 15-March 15). Colorado Springs is limited to 17,000 acre-feet of annual diversions during the Winter Water season. As a result of the Winter Water Storage Program decree and priority date (March 1, 1910) no other exchanges are made into Pueblo Reservoir during the Winter Water season. Therefore, the decrees as shown in **Table 3-13** primarily apply only during the non-Winter Water season. However, the PBWW is allowed to exchange to its river intakes below Pueblo Dam during the Winter Water season up to its decreed rate.

Table 3-13. Arkansas River Exchange Priorities

Priority	Beneficiary	Amount	Case	Priority Date
1	SECWCD	(1)	B42135, 88CW143, 84CW56	2/10/1939
2	PBWW	27 cfs	83CW18, 84CW62, 84CW63, 84CW64, 84CW35, 84CW202, 84CW203, 84CW177, 84CW178	4/14/81, 5/31/84
3	Colorado Canal Company Agricultural Entities	100 cfs		
4	PBWW	50 cfs		
	Colorado Canal Companies	50 cfs		
5	Colorado Canal Companies	50 cfs		
6	Colorado Springs	77 cfs minus PBWW 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 CSU Exchange under #6		
	Colorado Canal Companies	½ or remaining exchange potential up to 756 cfs		
9	Colorado Springs	½ of remaining exchange potential minus Rocky Ford I under #9		
	City of Aurora	Up to 40 cfs of ½, but not to exceed 500 ac-ft annually; thereafter 25% of ½ up to an additional 500 ac-ft annually.		
10	Colorado Springs	164 cfs/1000 acre-feet	86CW118	3/20/1985
11	Public Service Company	14 cfs		
12	City of Aurora	Applicable Maximum Rate of Flow Allowed by Decree in 99CW169	99CW169	12/28/1999
13	City of Fountain	60 cfs	01CW108, 01CW146	(3)
	SECWCD	(2)	01CW151	(3)
	Pueblo West	100 cfs	01CW152	(3)
	City of Pueblo	(4)	01CW160	(3)

Notes:

(1) Measured Municipal Fry-Ark Project Return Flows generated and re-purchased by the same entity.
(2) Non-measured Municipal and Agricultural Fry-Ark Project Return Flows.
(3) Priority yet to be determined.
(4) See discussion on Pueblo Flow Management Program.

3.2.3.6 Arkansas Basin Water Bank

On June 5, 2001, Colorado Governor Bill Owens signed into law House Bill 01-1354 which created the Arkansas River Water Bank Pilot Program (Arkansas River Water Bank Program, 2004). During its first two years of operations, the Arkansas River Water Bank saw no transactions, even in the relatively dry years of 2002 and 2003. As of the date of this document, there is no agency that sponsors the pilot program, and there are no potential water transactions in the near future (Witte, 2005).

3.2.3.7 Flow Management Programs and Minimum Flows

There are several legally binding flow programs and decreed minimum flow requirements within the study area, especially along the Arkansas River. Decrees for minimum flows are held by the CWCB on numerous tributaries to the Arkansas River, including Lake Fork and Lake Creek. However, most of the minimum flow rights are fairly junior and do not affect major diversions within the basin. However, the decreed minimum flows do affect many of the exchange decrees (which are often junior to the instream flow decrees). There are also minimum flow rates tied to several of the exchange decrees, including those held by Aurora. These are discussed in more detail in **Section 3.2.5**.

There are two flow management programs currently in operation that have an effect on flows in the Arkansas River: the Upper Arkansas Voluntary Flow Management Program (UAVFMP) and the Pueblo Flow Management Program (PFMP). Each of these is discussed in more detail in the following subsections.

Upper Arkansas Voluntary Flow Management Program

The Upper Arkansas Voluntary Flow Management Program (UAVFMP) is designed to provide water for fisheries and recreation in the Upper Arkansas River. The program is primarily aimed at providing target flows for releases of Fry-Ark Project water from Twin Lakes and Turquoise Reservoir to Pueblo Reservoir. However, many other entities have voluntarily agreed to the program as well, including Colorado Springs Utilities, the PBWW and the City of Aurora. The flow recommendations are “intended to provide an annual flow regime that helps the state maintain the brown trout fishery, meet the demand for boating recreation, support the region’s tourism industry, and allow managers of the Arkansas Headwaters Recreation Area (AHRA) to meet their obligation to manage recreation and natural resources within the area’s boundaries” (Walcher, 2003).

Recommended flows for the program are defined at the Wellsville gage. Components of the recommended flows include (Walcher, 2003):

1. The highest priority is the maintenance of a minimum year-round flow of at least 250 cfs to protect the fishery.
2. Winter incubation flows (mid November through April) should be maintained at a level of not more than 5 inches below river height during the spawning period (October 15 to November 15). The optimum flow range is from 250 to 400 cfs, depending on spawning flows:

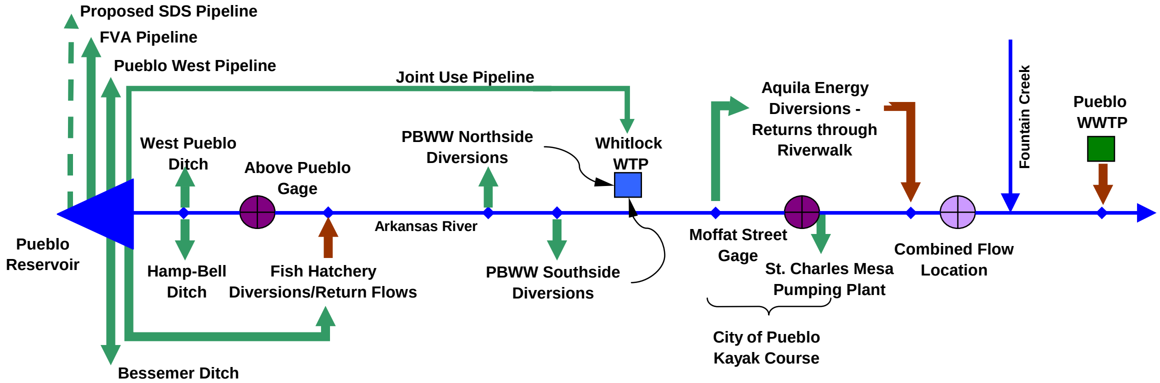
Minimum Incubation Flow ***Nov. 16 - Apr. 30***		***Spawning Flow*** ***Oct. 15 - Nov. 15***
250 cfs	*IF*	*300-500 cfs*
325 cfs	*IF*	*500-600 cfs*
400 cfs	*IF*	*600-700 cfs*

3. To the extent possible, between April 1 and May 15, Reclamation should maintain flows within the range of 250 cfs to 400 cfs in order to provide conditions favorable to egg hatching and fry emergence.
4. Deliveries in excess of 10,000 acre-feet should be subject to review and consideration, prior to such deliveries, by Reclamation and the SECWCD.
5. Subject to water and storage availability, Reclamation should augment flows during the July 1 to August 15 period at 700 cfs through releases from the Fry-Ark Project. The 700 cfs is a target; when augmentation occurs, every effort should be made to ensure that flows are as little above, or as little below, 700 cfs as possible. The Division of Parks and Outdoor Recreation, using funds collected from commercial outfitters, shall be responsible for replacing evaporative losses caused by summer augmentation.
6. Reclamation should avoid dramatic fluctuations on the river as much as possible throughout the year. When it is necessary to alter flow rates, Reclamation should limit the daily change to 10 to 15 percent.
7. It may be possible to improve feeding conditions for brown trout by reducing flows between Labor Day and October 15 in years when flows would otherwise be higher than those recommended by the Division of Wildlife. If potential benefits warrant the effort, AHRA managers, the Division of Wildlife, Reclamation and the Division 2 Engineer should work with water users to seek opportunities for reducing flows after Labor Day.

City of Pueblo Flow Management Program and RICD Application

Of particular interest in the NEPA analysis is the PFMP and Recreational In-Channel Diversion (RICD) water rights application. A schematic of the Arkansas River through the City of Pueblo is shown in **Figure 3-5**.

Figure 3-5. Schematic of Arkansas River through the City of Pueblo



In 2001, the City of Pueblo filed an RICD water right application in Division 2 water court (01CW160). Shortly after this application, Colorado Springs Utilities, PBWW, City of Aurora, SECWCD, and other entities began negotiating with the City of Pueblo regarding potential subordination of existing decreed exchanges to meet all or a portion of the RICD flows. The result of these negotiations is two intergovernmental agreements between these parties for a target flow program on the Arkansas River through the City of Pueblo. The components of the program that are directly related to hydrology include (February IGA, 2004; May IGA, 2004):

- **Year-round Flows -** Exchanges (or changes of water rights) will be reduced or curtailed as necessary to attain a minimum average daily flow of 100 cfs at the Above Pueblo gage (including Pueblo Fish Hatchery return flows and an amount equal to any below dam diversions by or for the benefit of the parties to the agreement). Likewise, exchanges will be reduced or curtailed to attain a minimum average daily flow of 85 cfs at the combined flow location (downstream of the inflow from Runyon Lake, and above the confluence with Fountain Creek).
- **Recreational Flows -** During the period of March 16 through November 14 of each year, exchanges (or changes of water rights) will be reduced or curtailed as necessary to maintain the average flows specified in **Figure 3-6**. The "Above Average" flows shown on the graph shall apply when the NRCS "most probable" forecast for the Arkansas River at Salida (Forecast) is 100 percent or more, and the "Below Average" flow shall apply when the Forecast is less than 100 percent.
- **Equitable Allocation of Operational Hours -** The original IGA contained a clause "to generally achieve on a monthly basis a 50/50 balance of time between periods of reduction of the Subject Exchanges and periods of no reduction of the Subject Exchanges." The recreational target flows "shall be in effect during the day, and reduction requirements [associated with recreational target flows] shall not be required during the night" (February IGA 2004). The Pueblo Flow Management Committee modified the clause in 2005, with the concurrence of Reclamation and the Colorado Division of Wildlife, by

recommending that the recreational flow targets be operated on a weekly basis instead of the diurnal basis described in the original IGA. The committee agreed that "the exchanges would be curtailed to the extent necessary to meet flow targets on Thursdays at 3:00 p.m. to accommodate recreational uses over the weekend period. The exchanges would cease to be curtailed at 12:00 p.m. on Mondays" to allow entities party to the IGA to realize their exchange potential (Gracely, 2005).

- **Dry-Year Exception -** No obligation to reduce or curtail exchanges when the "Most Probable Flow" forecast by the NRCS is below 70 percent.
- **Cooperative Flow Management Program -** Development of a program to manage storage in and release storage from Pueblo Reservoir to meet a recreation flow target of 600 cfs to 1,000 cfs during an unspecified number of weekend periods during the summer.
- **Storage Restoration -** The IGA contains a provision for storage restoration following excessively dry years. During the year following a year where the Forecast is less than 70 percent, the Flow Management Committee will decide how the program will operate with regards to both the intent of the agreement and the need to restore storage levels. **Section 3.2.3.8** provides more information regarding Restoration of yield storage.

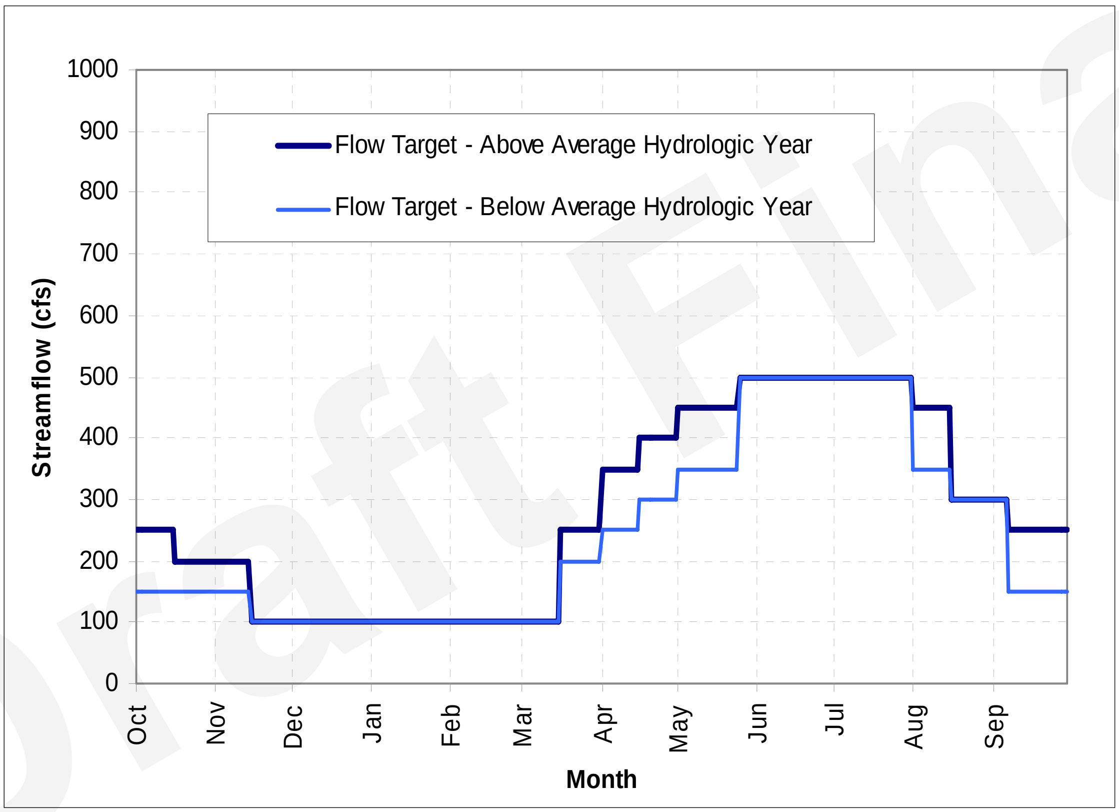
There are several provisions within the IGA regarding termination of the agreement and other matters. Three of the more important provisions are as follows:

- **Section II.A Stipulated Decree** (February IGA, 2004). Colorado Springs and the Board (Pueblo Board of Water Works) shall stipulate to entry of a decree in Case No. 01CW160 (Water Division 2) that provides for the same flows and restrictions specified in paragraphs I.B, C., E. and H., except that the Stipulated Decree shall provide for the decreed flows to be measured at the Moffat Street Gage…
- **Section VIII.D Colorado Springs' Support for Flow Management** (February IGA, 2004). If, at any time, Colorado Springs is unable to reasonably construct the SDS from Pueblo Dam due to terms, conditions or requirements contained in any federal, state or local permit, permission, or license including Reclamation's Record of Decision or Pueblo County's 1041 permit, then Colorado Springs may terminate this Agreement by providing written notice of such termination to the other Parties…
- **Section XIII.B.3 Effective Date and Related Matters, Interim Agreement on Recreation Flows, Aurora** (May IGA, 2004). As to Aurora, the Recreation Flow Provisions shall become permanently effective upon final approval by Reclamation of Aurora's request for a Long-Term Excess Capacity Contract. If such has not occurred prior to the end of the five-year period identified above, the Recreation Flow Provisions shall remain in effect so long as Aurora's request for a Long-Term Excess Capacity Contract remains pending. Upon denial by Reclamation of Aurora's request for a Long-Term Excess Capacity Contract, Aurora shall be relieved of all obligations to comply with the Recreation Flow Provisions; provided, however, that such

obligations shall be revived if Aurora reapplies for approval of a Long-Term Excess Capacity Contract, and shall remain in effect for so long as such reapplication remains pending.

From the language contained in the above sub-sections of the IGAs, it is clear that there remains two distinct parts of the flow program: (1) the agreed-to flow targets that could curtail exchanges by any participant and (2) the RICD water right that, if decreed and depending on adjudication date, could be senior to any new water rights on the Arkansas River. The provisions also state that Colorado Springs Utilities and Fountain may terminate their participation if the SDS Project is abandoned or is constructed without the diversion point located at Pueblo Dam, and Aurora may terminate its participation if a long-term excess capacity contract is not granted by Reclamation.

Figure 3-6. Proposed Recreational Flow Targets at Above Pueblo Gage for Pueblo Flow Management Program



3.2.3.8 Restoration of Yield (ROY) Storage

Restoration of Yield (ROY) was developed in principle as part of the PFMP Intergovernmental Agreements (February IGA, 2004; May IGA, 2004). The intent of ROY is to develop operations and facilities that would allow the signatory parties to recover a portion of the yield lost as part of their participation in the FMP. Recently, the City of Aurora has signed a temporary agreement with the Holbrook Irrigating Company to use excess capacity in the Holbrook system as part of the ROY program (Holbrook and Aurora, 2005). The City of Aurora then signed agreements with other ROY participants to divide the available excess capacity between the participants (Aurora et al., 2005).

The agreement between Aurora and Holbrook allows use of the entire Holbrook system by Aurora, including both Holbrook Reservoir and Dye Reservoir. The Temporary Substitute Water Supply Plan (TSWSP) that was obtained by Aurora to administer the program includes the ability to divert unexchanged reusable return flows in the Colorado Canal system as well (Wolfe, 2005).

The active storage capacity for Holbrook Reservoir is approximately 6,200 acre-feet (Simpson, 2005). The agreements state the ROY participants may use "Excess Capacity" in the reservoirs. Thus, the ROY participants can only store water in Holbrook Reservoir when space is available beyond Holbrook's normal operations. Based on agreements signed between the ROY participants, **Table 3-14** shows a breakdown of ROY storage in Holbrook Reservoir.

Table 3-14. Division of ROY Storage in Holbrook Reservoir

Entity	Percent of ROY Storage	Maximum Potential Holbrook Storage (ac-ft)
Aurora	46%	2,852
Colorado Springs Utilities	46%	2,852
Fountain	5%	310
PBWW	2%	124
SECWCD	1%	62
Total	100%	6,200

Notes:

(1) Assumes 6,200 acre-feet of potential ROY storage in Holbrook Reservoir. Storage available as "Excess Capacity" only.

Water used to fill Holbrook Reservoir can be diverted by several means: the Holbrook Reservoir native flow storage rights (priority dates of 3/2/1892 and 9/15/1909), by exchange from lower portions of the system and through the Winter Water Storage Program (Division 2 diversion and water rights records). Because the native water rights' priority dates are relatively junior, the reservoirs are only able to divert water during times of high flow on the river and do not always fill under their native flow right. The reservoirs do often fill during the Winter Water season. However, as part of the agreements, Holbrook will operate so that Winter Water does not spill ROY participant water from the Holbrook system if storage space is available in Pueblo Reservoir (Holbrook and Aurora, 2005).

3.2.4 Storage Facilities

Because of the highly variable annual streamflow hydrograph, water users have a heavy reliance on storage reservoirs at times when natural streamflows are inadequate to meet demands. Therefore, reservoir storage and releases have impacts on the environment within the basin.

3.2.4.1 Fry-Ark Project Reservoirs

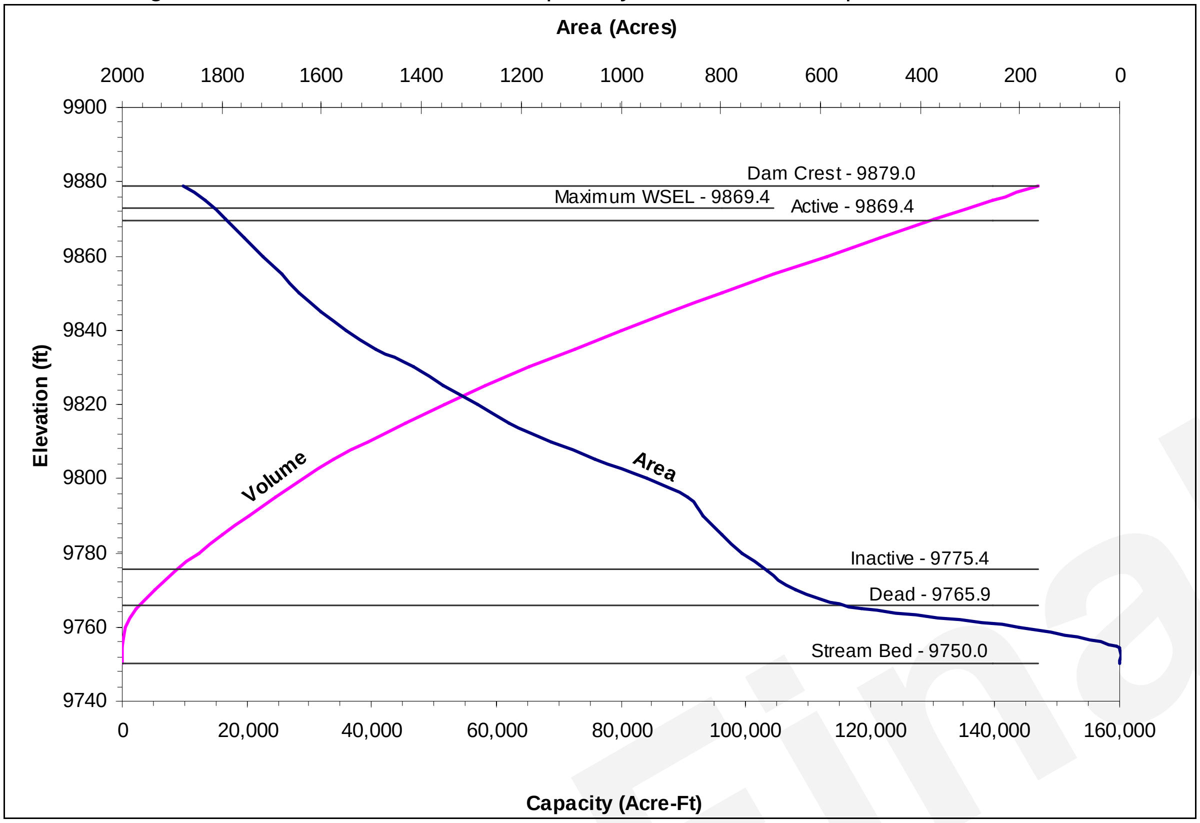
Through the Fry-Ark Project, Reclamation increased the capacity of Turquoise Reservoir from its original capacity of 17,416 acre-feet (Reclamation 1975) to its current capacity of 129,398 acre-feet. The original reservoir contained accounts for the original CF&I storage system. During enlargement, additional storage space was added for the Fry-Ark Project and the Homestake Project. **Table 3-15** presents the storage accounts in Turquoise Reservoir. Aurora and the Pueblo Board of Water Works each own 5,000 acre-feet of CF&I storage space, which can be used to store Busk-Ivanhoe water. The elevation-area-capacity curve for Turqoise Reservoir is presented in **Figure 3-7**.

Table 3-15. Turquoise Reservoir Accounts

Account	Storage (ac-ft)
Dead/Inactive	**8,920**
Active	
CF&I	
Colorado Springs Utilities	17,416
Aurora	5,000
Pueblo Board of Water Works	5,000
Sub-Total	**27,416**
Homestake	
Aurora	15,000
Colorado Springs Utilities	15,000
Sub-Total	**30,000**
Fry-Ark Project	**63,062**
Sub-Total	**120,478**
TOTAL	**129,398**

Notes:
(1) Source: Fry-Ark AOP (Reclamation, 2004)

Figure 3-7. Elevation-Area-Capacity Curve for Turquoise Reservoir



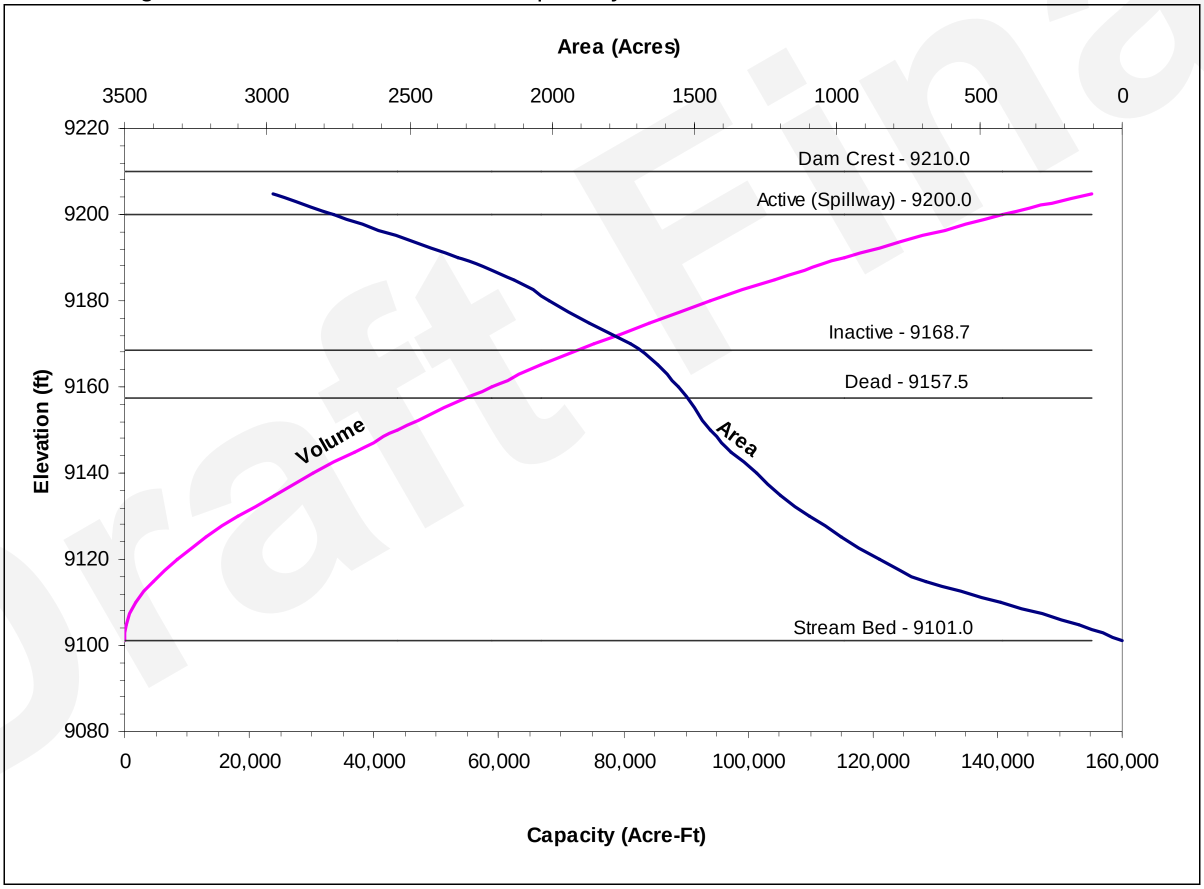
Like Turquoise Reservoir, Twin Lakes Reservoir was enlarged by Reclamation during construction of the Fry-Ark Project. The original owner of the reservoir was the Twin Lakes Reservoir and Canal Company, during which time the reservoir had approximately 54,452 acre-feet of active storage (Reclamation 1975). Reclamation added additional 13,465 acre-feet of active storage to bring the total active storage to 67,917 acre-feet and the total storage to 140,855 acre-feet. The accounts in Twin Lakes Reservoir are presented in **Table 3-16**, while an elevation-area-capacity curve is presented in **Figure 3-8**.

Table 3-16. Twin Lakes Reservoir Accounts

Account	Storage (ac-ft)
Dead/Inactive	72,938
Active	
Twin Lakes Project	
Colorado Springs Utilities	29,762
Aurora	2,722
Pueblo Board of Water Works	12,602
Pueblo West	6,332
Augmentation	519
Other M&I	1,863
Other Agriculture and Inactive Shares	652
Sub-Total	**54,452**
Fry-Ark Project	**13,465**
Sub-Total	**67.917**
TOTAL	**140,855**

Notes:
(1) Twin Lakes Project storage accounts based on share information provided by Alan Ringle (2004).

Figure 3-8. Elevation-Area-Capacity Curve for Twin Lakes Reservoir

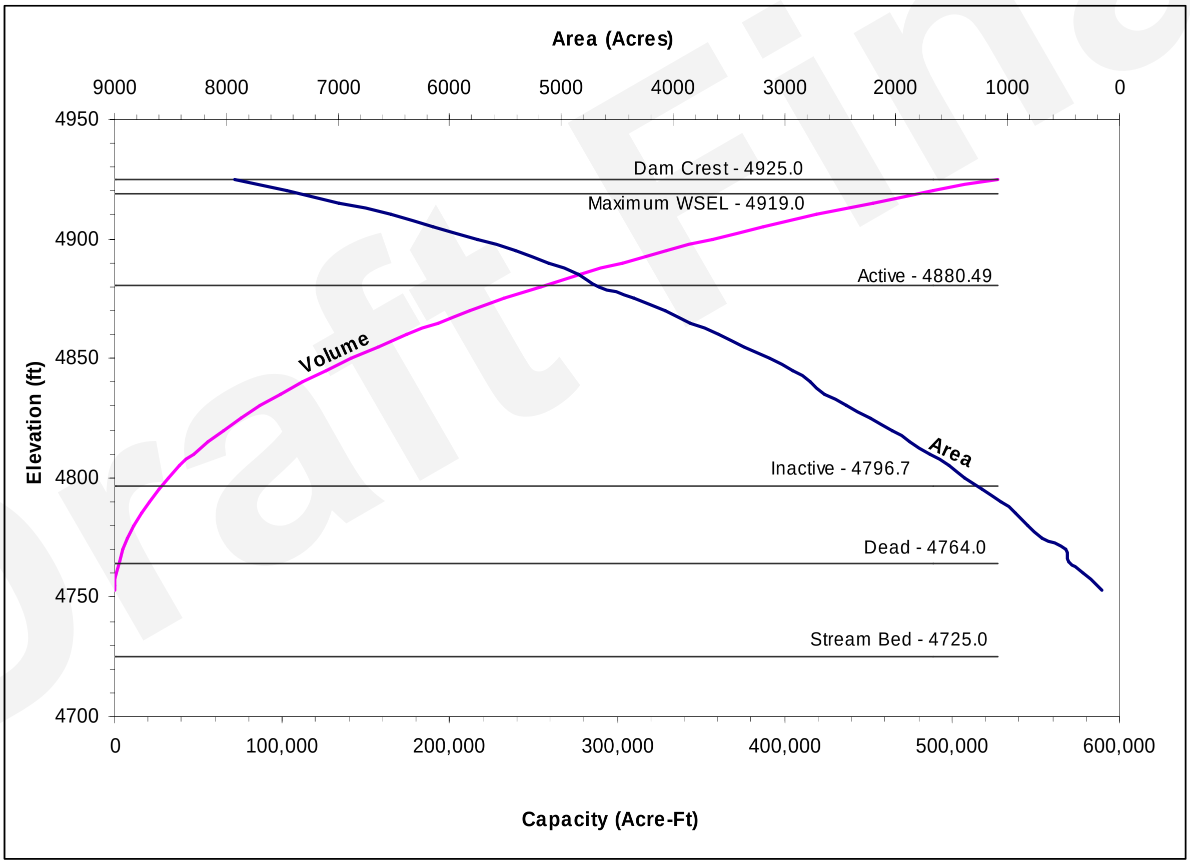


Pueblo Reservoir was newly constructed as part of the Fry-Ark Project and had no additional non-Fry-Ark Project space added to the Fry-Ark Project volume requirements. Therefore, Fry-Ark Project space is the only account in the reservoir. Total active capacity of Pueblo Reservoir is 256,949 acre-feet. In addition to the active capacity, Pueblo Reservoir has dedicated flood control space of 26,991 acre-feet and a Joint Use pool of 66,000 acre-feet. The Joint Use pool must be evacuated between April 15 and November 1 for flood control use. Outside of this period, the Joint Use pool can be used for conservation storage. An elevation-area-capacity curve for Pueblo Reservoir is presented in **Figure 3-9**.

Table 3-17. Pueblo Reservoir Accounts

Account	Storage (ac-ft)
Dead/Inactive	**28,121**
Active	
Fry-Ark Project	228,828
Joint Use	66,000
Flood Control	26,991
Subtotal	**321,819**
Total Capacity	**349,940**

Figure 3-9. Elevation-Area-Capacity Curve for Pueblo Reservoir.



3.2.4.2 Colorado Canal System Reservoirs

The other two major reservoirs within the study area, Lake Henry and Lake Meredith, are located within the Colorado Canal system. Both facilities are off-channel reservoirs. Water is diverted to the reservoirs from the Arkansas River through the Colorado Canal. Colorado Canal can deliver water directly to either Lake Henry or Lake Meredith. However, Lake Henry is upstream of Lake Meredith, so water from Lake Henry can be delivered to Lake Meredith, but not vice-versa. Lake Henry is able to serve a portion of the irrigated lands under the system by gravity, but Lake Meredith cannot. Releases are made from the reservoirs to the Arkansas River and either exchanged to the Colorado Canal headgate for use by the agricultural shareholders, or exchanged to Pueblo Reservoir for use by the municipal shareholders. The active capacity of Lake Henry is 8,961 acre-feet, while the active capacity of Lake Meredith is 39,804 acre-feet. The accounts for Lake Meredith and Lake Henry are presented in **Table 3-18** and **Table 3-19**. Elevation-area-capacity curves are presented in **Figure** 3-10 and **Figure 3-11**.

Table 3-18. Lake Meredith Accounts

Account	Storage (ac-ft)
Dead/Inactive	**1,196**
Active	
Colorado Springs Utilities	20,661
City of Aurora	12,799
City of Fountain	502
Pueblo West	353
Woodland Park	329
Other M&I	927
Agricultural	4,233
Sub-Total	**39,804**
Total	**41,000**

Table 3-19. Lake Henry Accounts

Account	Storage (ac-ft)
Dead/Inactive	**1,039**
Active	
Colorado Springs Utilities	6,918
City of Aurora	1,163
City of Fountain	0
Pueblo West	0
Woodland Park	247
Other M&I	123
Agricultural	510
Sub-Total	**8,961**
Total	**10,000**

Figure 3-10. Elevation-Area-Capacity Curve for Lake Meredith

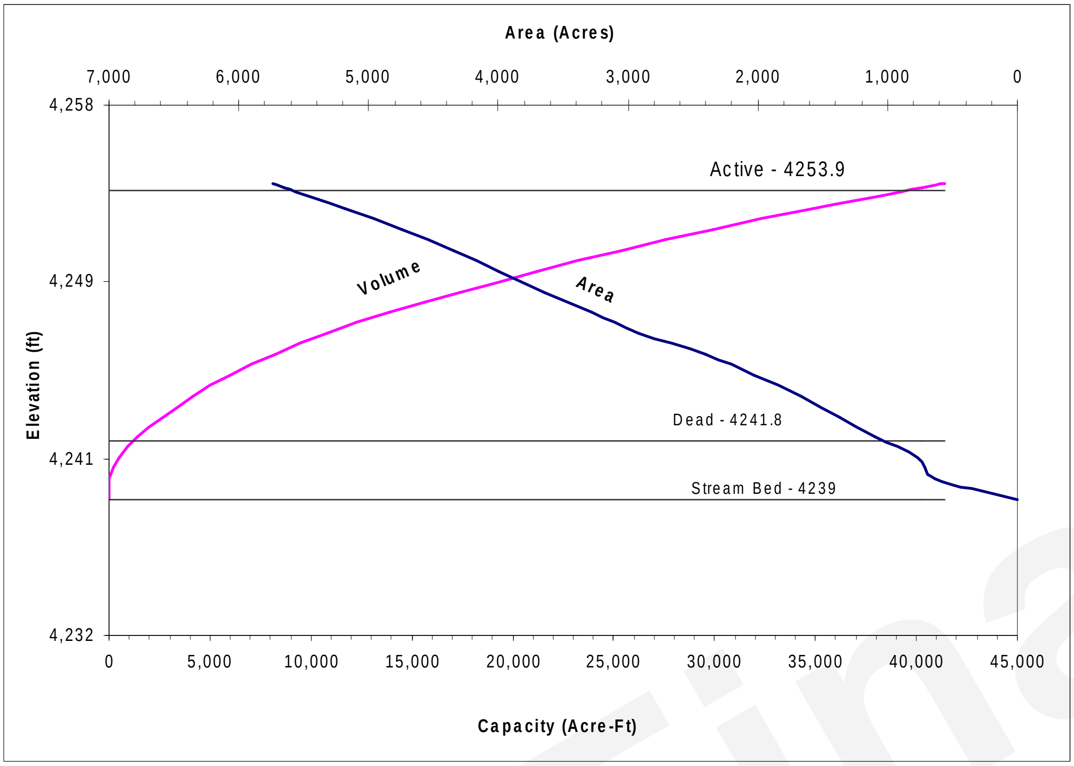
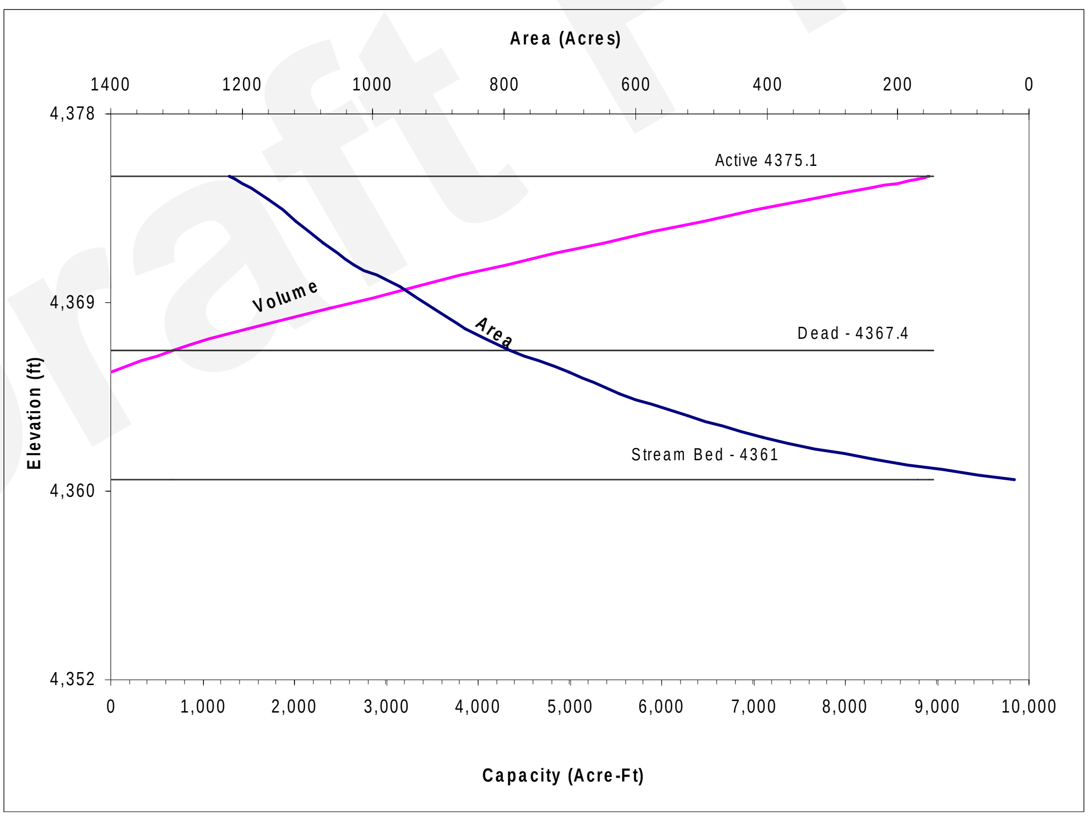


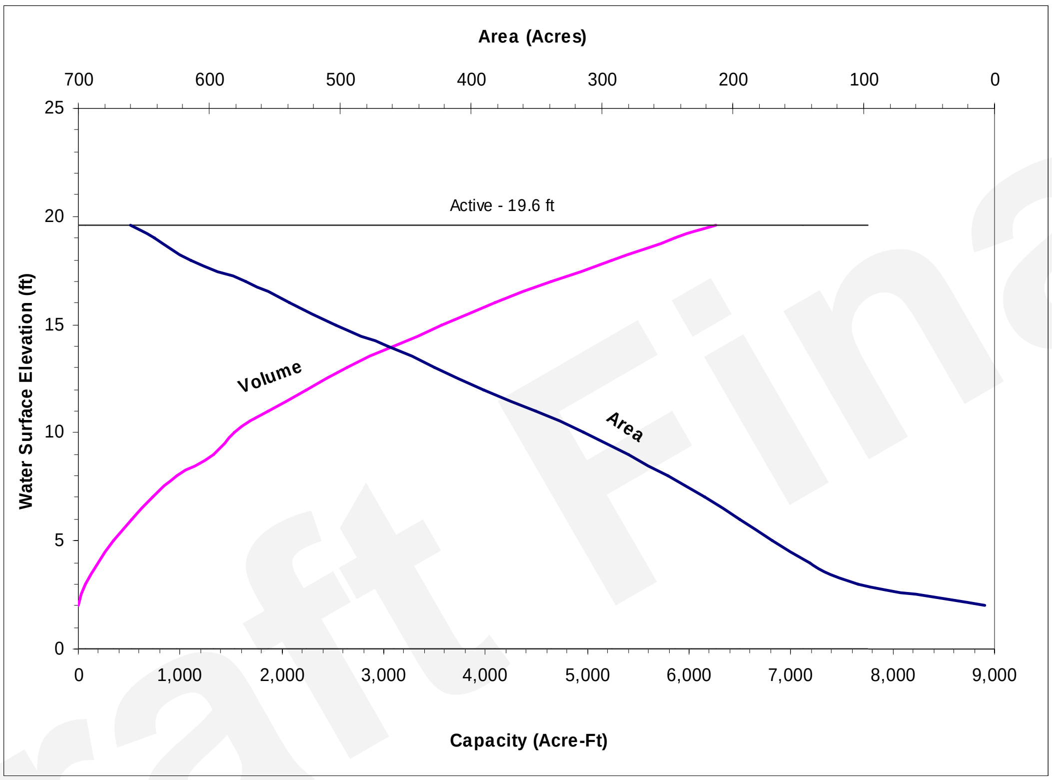
Figure 3-11. Elevation Area Capacity Curve for Lake Henry



3.2.4.3 Holbrook Reservoir

Holbrook Reservoir is part of the Holbrook System, which is used for ROY storage previously discussed. Holbrook Reservoir is filled via the Holbrook Canal, which has a capacity of approximately 700 cfs. Recreational access to Holbrook Reservoir is leased by the Colorado Division of Wildlife as a State Wildlife Area (SWA). The active storage capacity of Holbrook Reservoir is about 6,200 acre-feet, and the surface area of the reservoir is slightly more than 600 acres. An elevation-area-capacity curve for the reservoir is shown in **Figure 3-12**.

Figure 3-12. Elevation-Area-Capacity Curve for Holbrook Reservoir



3.2.5 Aurora Water Operations in the Arkansas Basin

This section provides a detailed summary of the City of Aurora's existing water rights and water operations in the Arkansas Basin, including Aurora's Arkansas River Basin water sources and transmountain water sources. Although only a portion of these sources are affected by the Proposed Action, all sources that affect Arkansas River Basin operations are discussed herein to provide the setting for coordinated operations of the systems.

3.2.5.1 General Description

Aurora's operations in the Arkansas Basin can generally be grouped into three categories: Lower Arkansas Basin supplies, Upper Arkansas Basin (or Ranch) supplies and Colorado River Basin supplies. These operations are all linked because they store water in Twin Lakes and Turquoise Reservoir and are all diverted into the South Platte River Basin to Aurora through the Otero Pump Station and Homestake Pipeline.

The Lower Arkansas Basin water supplies consist of the purchase or lease of shares and transfer of consumptive use in larger irrigation companies. The Upper Arkansas Basin water supplies consist of the purchase of water rights from ranches located in Lake County. Water supplies for both the Lower Arkansas and Upper Arkansas supplies originate from water that is native to the Arkansas River. Transmountain (or Colorado River) supplies consist of participation in projects that import water from the Colorado River Basin for storage and subsequent conveyance to the South Platte Basin. With the exception of the Twin Lakes Project, Aurora's transmountain projects do not divert native Arkansas River water. The Twin Lakes Project diverts approximately two-thirds of its water from the Colorado River Basin and one-third of its water from the Arkansas River Basin. A summary of these systems and their average annual yield is shown in **Table 3-20**.

Table 3-20. Summary of Aurora Arkansas and Colorado River Basin Water Supplies

Source	Source	Estimated Annual Yield (acre-feet)
Lower Arkansas River	Rocky Ford I	8,100
	Rocky Ford II	5,100
	Colorado Canal	7,900
	Interruptible and short term leases (Including Highline Canal Lease)	8,200
Upper Arkansas River(1)	Buffalo Park	1,600
	Burrows	
	Hayden	
	Spurlin-Shaw	
Transmountain(1)	Homestake	12,900
	Twin Lakes Project	2,700
	Busk-Ivanhoe	2,500
	PBWW Leases	5,000
TOTAL		**54,000**

Notes:

(1) Operations of the Upper Arkansas River and transmountain water supply systems are unaffected by the Proposed Action and No Action Alternative.

(2) Includes all interruptible and short term leases. Projected from pending Water Court actions.

(3) Source of data: (October IGA 2003).

All water delivered to Aurora from both the Arkansas River Basin and the Colorado River Basin is conveyed from Twin Lakes through the Otero Pump Station and Homestake Pipeline. Storage accounts in the Upper Basin reservoirs of Twin Lakes and Turquoise reservoirs are typically reduced to a minimum prior to the beginning of runoff. This allows for Twin Lakes yield along with exchanges from the Lower Basin water rights to be pumped through Otero during the summer and early fall period. Waters stored from the Colorado basin are available for transport during the remainder of the year.

The Otero Pump Station, located 10 miles north of Buena Vista, transports water from Twin Lakes through the Homestake pipeline and outlet channel to Spinney Mountain Reservoir. Aurora owns 78 cfs of capacity in the Homestake pipeline, or half of the original 156 cfs capacity of the system. Aurora and Colorado Springs have occasionally used more than half of the pipeline's capacity when it was not in use by the other entity.. Colorado Springs Utilities has recently expanded their portion of the Otero Pump Station so that their capacity in the system is 105 cfs.

Moving the Colorado Canal and Rocky Ford Ditch water rights upstream to Twin Lakes is accomplished using either river or contract exchanges. Since the river exchanges are dependent on streamflow conditions, they are primarily operated during the runoff season. This is especially true for the Rocky Ford I & II exchanges, which are junior exchanges. The Colorado Canal exchange is more flexible due to it being the senior exchange on the river. Contract exchanges are currently operated primarily with the PBWW, but have also been executed with other municipal entities and Reclamation.

The actions proposed by Aurora in the Environmental Assessment involve the storage of diversions made under the Rocky Ford Ditch decrees, exchanges made under the Colorado Canal decrees and water diverted as part of leasing programs. Therefore, the only systems affected by the Proposed Action are the Lower Arkansas Basin supplies. However, all operations by the City of Aurora that affect operations in the Arkansas Basin are discussed herein to provide the setting for coordinated operations of the systems.

3.2.5.2 Rocky Ford Ditch

Aurora owns a majority of the Rocky Ford Ditch shares. These shares have been purchased and converted to municipal use under two separate cases: Rocky Ford I, also referred to as RIG (83CW18, Division 2) and Rocky Ford II, also referred to as RFSG (99CW169, Division 2). The Rocky Ford I shares were purchased and adjudicated in the mid 1980's while the Rocky Ford II shares were purchased in the late 1990's and adjudicated in 2003. These change cases change the use of the water to include municipal uses and allow alternate points-of-diversion at Pueblo Reservoir and other locations. In addition, exchanges from the point-of-diversion to the Upper Arkansas Basin are adjudicated under separate exchange cases. The change cases and exchange cases are discussed in the following sub-sections.

Rocky Ford Change Cases

Aurora's Rocky Ford I water rights are derived from a purchase of 466.48 shares of the 800 total shares (58.31 percent) in the Rocky Ford Ditch from Resource Investment Group (RIG) during 1986. The transfer of these shares from agricultural to municipal use in 83CW18 allows for an alternate point of diversion at Pueblo Reservoir. After diversion for storage at Pueblo Reservoir the water must be exchanged upstream to Twin Lakes for delivery through the Otero pump station. The Rocky Ford I water rights are diverted beginning March 15 through October 31, according to a set diversion pattern. Total annual diversions are limited to a maximum of 9,270 acre-feet. From this total diversion, 1,000 acre-feet is held for winter return flow release. A summary of the monthly diversion rates and monthly maximum volumes for the Rocky Ford I water right is shown in **Table 3-21**.

Table 3-21. Summary of Rocky Ford I Diversion Rates

	Mar 15-31	Apr	May	Jun	Jul	Aug	Sep 1-15	Sep 16-30	Oct.
Daily Rate (cfs)	11	19	23	32	32	30	20	25	13
Monthly Total (ac-ft)	370	1129	1412	1901	1964	1841	594	743	798

Notes:

(1) Monthly volumetric limits do not equal annual volumetric limit.

Aurora has more recently pursued and decreed additional Rocky Ford II water rights. The city purchased and transferred 290 shares of the 333.52 remaining Rocky Ford shares. The transfer of these shares from agricultural to municipal use in 99CW169 allows an alternate point of diversion at Pueblo Reservoir, as well as several other locations, including the proposed gravel lake location in the No Action Alternative. After diversion in Pueblo Reservoir or similar location, the water can be exchanged upstream to Twin Lakes for delivery through the Otero pump station under 99CW170. The Rocky Ford II water rights are diverted beginning March 15 through October 31, according to a set diversion pattern. Total annual diversions are limited to a maximum of 6,386 acre-feet. From this total diversion 619 acre-feet is held for winter return flow release. A summary of the monthly diversion rates and maximum monthly volumes for the Rocky Ford II water right is shown in **Table 3-22**.

Table 3-22. Summary of Rocky Ford II Diversion Rates and Volumes

	Mar 15-31	Apr	May	Jun	Jul	Aug	Sep 1-15	Sep 16-30	Oct.
Daily Rate (cfs)	7	13	15	21	21	20	13	17	9
Monthly Total (ac-ft)	236	774	863	1166	1208	1150	387	506	553

Presently, all of the Rocky Ford I water can be diverted to storage but only a portion of the Rocky Ford II water can be diverted to storage. As more lands associated with the Rocky Ford II water rights are revegetated, more water will be available for diversion. Aurora expects that they will be able to divert their full Rocky Ford II water rights (5,100 acre-feet) by 2010.

As part of the change cases for Rocky Ford I and Rocky Ford II, Aurora has agreed to the restrictions described below.

- Pursuant to the decrees (83-CW-18, 99-CW-169, and the Highline lease), Aurora may not divert at Pueblo Reservoir when native inflows drop below 155 cfs when senior water rights are fully diverting.
- Aurora would operate to provide a minimum flow of 100 cfs at the Pueblo gage, which is located approximately 0.4 miles downstream of Pueblo Dam (Decrees 83-CW-18, 99-CW-169, and the Highline lease). This flow provides protection for Colorado Division of Wildlife fish hatchery.

- The combined flow location is located below the outlet from Runyon Lake (HARP return flows) and above Fountain Creek (The exact location is yet to be determined.) There must be at least 85 cfs at the combined location or 57 cfs at the Moffat Street gage before Aurora can divert at Pueblo Reservoir (Decree 99-CW-169 and extended to 83-CW-18).
- Aurora would curtail exchanges and diversions when winter flows are less than 50 cfs at the Moffat Street gage between November 15 and March 15 for the St. Charles Mesa Water District (Decree 99-CW-170 and extended to 87-CW-63).
- Aurora would curtail exchanges from the Colorado Canal if the flows in the Arkansas River at the Avondale gage drop below 500 cfs, if requested by the Arkansas Valley Ditch Company (Decrees 84-CW-62, 83-CW-63, and 84-CW-64).
- Exchanges from Lake Meredith to Pueblo Reservoir at the Colorado Canal headgate would be curtailed if the flow in the Arkansas River at the Avondale gage were less than 500 cfs (Decrees 84-CW-62, 83-CW-63, and 84-CW-64).
- Aurora would operate the Highline Canal lease water or future lease water pursuant to an annual Temporary Substitute Supply Plan approved by the State Engineer's Office or through future decrees obtained in Water Court.

All Rocky Ford diversions at Pueblo Reservoir are subject to the provisions of the Pueblo Flow Management Program. Because the Pueblo Whitewater Park was completed during the spring of 2005, the full provisions of the Pueblo FMP are currently being implemented. These provisions will become permanent for the City of Aurora upon receipt of a Long-Term Excess Capacity Contract in Pueblo Reservoir. If Aurora does not receive the contract, Aurora has the option to discontinue its participation in the program.

Rocky Ford Exchanges

Water diverted and stored at Pueblo Reservoir under Aurora's Rocky Ford Ditch rights and exchange decrees is exchanged to upstream storage in Twin Lakes Reservoir or Turquoise Reservoir. Water can also be exchanged directly to the diversion at the Otero Pump Station. A river exchange allows an entity to divert water out of priority at one location in the basin and replace the diversion with water at another point of diversion as long as senior appropriators are not injured. During a river exchange, streamflow in the reach between the exchanging reservoirs is decreased by the amount of the exchange. In this case, it would be the reach between Twin Lakes Reservoir and Pueblo Reservoir. Aurora would divert water at one or more of the upstream storage sites, and would replace a like amount of water to the Arkansas River below Pueblo Reservoir to ensure that senior water right holders downstream of Pueblo Reservoir are not injured. Physical exchange of flowing water must be approved by the Colorado State Engineer's Office or Colorado water court to ensure that no senior water rights in the intervening reach of the stream are harmed because of the exchange.

The exchange decree for Rocky Ford I water (87-CW-63) was approved in Colorado water court in 1987. The exchange decree for Rocky Ford II water (99-CW-170) was approved in 2005. All of the provisions contained in the Rocky Ford I decree are part of the Rocky Ford II decree. The Rocky Ford II decree has established additional limitations that further protect flows in the Upper Arkansas River. These conditions include:

- The maximum flow rates for the exchange vary with receiving facility; Twin Lakes at 500 cfs, Turquoise Reservoir at 350 cfs, Clear Creek Reservoir at 250 cfs, and Otero pump station intake at 165 cfs.
- The exchanges may not operate such that the native flow at the Fremont County Wastewater Treatment Plant (Cañon City Portland gage) is less than 190 cfs, or the native flow at the Salida Wastewater Treatment Plant is less than 240 cfs, except in July and August when the flow restriction is 260 cfs.
- Because they have a senior priority, Colorado Water Conservation Board (CWCB) minimum streamflow requirements of 15 cfs in Lake Fork Creek below Turquoise Reservoir and Lake Creek below Twin Lakes Reservoir would be maintained.
- Rocky Ford exchange decrees (87-CW-63 and 99-CW-170) include minimum flow commitments at the Wellsville gage and at the Portland gage as shown in **Table 3-23**.

Table 3-23. Summary of Upper Arkansas River Minimum Flow Commitments

Location	Minimum Flow (cfs)
Lake Fork Creek below Turquoise	15
Lake Creek below Twin Lakes	15
Wellsville Gage	240/260
Portland Gage	190
Arkansas River Flow Management Program Rafting flows July 1-August 15 (Wellsville)	700

- Aurora has agreed it would not exchange against any releases made by Reclamation to augment streamflows and meet Colorado's recommended flows in the Arkansas River (Decrees 87-CW-63 and 99-CW-170).
- Aurora has agreed to a stipulation in the Rocky Ford II decree (99-CW-170) with the Arkansas River Outfitters Association. This stipulation limits the rate at which Aurora may operate its Rocky Ford Ditch exchanges. In accordance with the stipulation, the rate of exchange shall not exceed the maximum exchange rate when the flows of the Arkansas River at the Wellsville gage are at the levels shown in **Table 3-34**. This stipulation was extended to the Rocky Ford I decree (87-CW-63) and any future leases from the lower Arkansas Basin. Aurora's typical exchange rates would range from 50 to 100 cfs.

Table 3-24. Aurora's Maximum Exchange Rates for Rocky Ford Water Rights on the Arkansas River Based on Flows at the Wellsville Gage

Gage Flow (cfs)	Maximum Exchange Rate (cfs)
0 - 249	0
250 - 499	50
500 - 999	75
1,000 - 1,499	125
1,500 - 1,999	175
2,000 - 2,999	250
3,000 and above	500

- Per Rocky Ford exchange decrees (87-CW-63 and 99-CW-170), physical exchanges from Pueblo Reservoir to Turquoise Reservoir, Twin Lakes Reservoir and Clear Creek Reservoir would not be allowed during the Winter Water Storage Program (November 15 through March 15).

As stated, Rocky Ford I and II exchange decrees would be operated in a manner so as not to adversely affect the amount of water that Reclamation would use to support the Upper Arkansas River Voluntary Flow Program. The Voluntary Flow Program is designed to provide augmentation flows for the benefit of the Arkansas River fishery and recreational uses. Recommendations are provided to Reclamation annually from the Colorado Department of Natural Resources and include flow recommendations for fisheries and recreation. Colorado has provided these recommendations to Reclamation annually since 1990 and generally includes recommended minimum rafting flows of 700 cfs between July 1 and August 15 at the Wellsville gage. Aurora would not make exchanges against releases made for instream flow purposes, and it would not exchange against native flows when the exchange would cause the Arkansas River flow to be reduced below the amounts agreed to in the Voluntary Flow Program.

Contract Exchanges

In addition to river exchanges, Aurora maintains a long-term contract with PBWW for the purpose of moving water from Pueblo Reservoir upstream to Twin Lakes or Turquoise Reservoir. This contract requires a minimum of 4,000 ac-ft and a maximum of 10,000 ac-ft of exchanges annually and can be scheduled during any time of the year. Aurora provides water to the PBWW in Pueblo Reservoir while receiving a like amount of water in either Twin Lakes or Turquoise Reservoir. This exchange is scheduled to allow for exchanges of up to 1,000-acre-feet per month and is generally operated late in the year.

In addition to contract exchanges with PBWW, Aurora has historically used contract exchanges with other entities in the basin to move water from Pueblo Reservoir to upstream locations. Aurora has executed annual contracts on an as-needed basis with Reclamation to move water from Pueblo Reservoir to Twin Lakes and Turquoise Reservoir. There are some farmers under the Colorado Canal system that own or lease shares of Twin Lakes water. Arrangements can be made to exchange water stored in Lake Henry upstream for waters they have in Twin Lakes. In addition, Aurora has historically executed contract exchanges with other municipal entities within the basin. These are operated on an informal basis as the opportunity arises.

3.2.5.3 Colorado Canal Operations

Aurora owns 14,225.38 shares, or 28.7 percent, of the Colorado Canal. Of the total 13,061.8 shares are Lake Meredith (32.2 percent of company) and 1,163.58 are Lake Henry shares (13.0 percent). This total results in 13,962 acre-feet of storage in Lake Meredith and Lake Henry. Colorado Springs is the majority stockholder in the Colorado Canal and each reservoir company. Colorado Canal system water rights are diverted from the Arkansas River at the Boone diversion and transported through the canal and placed into storage in the associated reservoir. After deduction for seepage and return flows, the consumptive use portion is available for Aurora's use. During the irrigation season when the Colorado Canal System is in priority (typically during the spring run-off and some summer precipitation events), Aurora would accumulate additional storage amounts. System storage also includes water stored during the Winter Water Storage Program (November 15 through March 15).

Aurora's Colorado Canal transfer and exchange decrees (84-CW-62, 84-CW-63, and 84-CW-64) allow water to be exchanged directly from the Lake Meredith Outlet upstream to Pueblo Reservoir, Twin Lakes Reservoir, and/or Turquoise Reservoir. Aurora's storage space in the Colorado Canal System could be depleted and restored several times during the year. Typically, all water would be evacuated from storage by November 15 of each year. However, Aurora could retain some water in storage for exchange and use the following year if it cannot exchange water due to river conditions.

Pursuant to the Colorado Canal exchange decrees, Aurora can operate this exchange in two ways.

1. Aurora can divert water at Twin Lakes Reservoir or Turquoise Reservoir and replace it with a like amount of water to the Arkansas River at the Lake Meredith Outlet Canal. The exchange would be operated in a manner that would prevent injury to senior diverters in the intervening stream reach between the Lake Meredith Outlet Canal and the upstream exchange site.
2. Alternatively, water can be exchanged from the Lake Meredith Outlet structure to Pueblo Reservoir first and then exchanged upstream to Aurora's space in either Twin Lake Reservoir or Turquoise Reservoir.

Aurora's exchange decree includes a stipulation that requires that the Colorado Canal Company to notify the Arkansas Valley Ditch Association when the upstream exchanges are operating and when the Arkansas River at the Avondale gage is less than 500 cfs. If Arkansas Valley Ditch operations were affected, the Colorado Canal Company would reduce exchanges.

As with the Rocky Ford Ditch diversions, all of Aurora's Colorado Canal exchanges are subject to the provisions of the Pueblo FMP.

3.2.5.4 Leased Water

Aurora has signed agreements with the SECWCD that allows negotiations of short-term leases with Arkansas Valley ditches in the reach between the Rocky Ford Ditch and Pueblo Reservoir (October IGA 2003). The lease program limits the leases to no more than 3 years out of every ten-year period beginning in 2006, with a maximum annual lease of no more than 10,000 acre-feet.

Aurora proposes to use contract exchanges to move leased water stored in Pueblo Reservoir to upstream storage in Twin Lakes Reservoir or Turquoise Reservoir. Aurora would provide stored water to Reclamation at Pueblo Reservoir in exchange for a like amount of stored water from Reclamation at Twin Lakes Reservoir or Turquoise Reservoir.

Aurora recently entered into a lease contract with shareholders of the Highline Canal Company for water that can be stored at Pueblo Reservoir under the proposed excess capacity contract in 2004 and 2005. The lease would allow Aurora to divert up to a maximum of 12,500 acre-feet of Highline Canal water throughout the growing season (March 15 through November 14) at a rate commensurate with the historical irrigation consumptive use. The water could be diverted at Pueblo Reservoir pursuant to annual approval of a Temporary Substitute Supply Plan by the Colorado State Engineer.

All exchanges and alternate points-of-diversion made as part of the leasing programs are subject to the provisions of the Pueblo FMP (March IGA, 2004; May IGA, 2004).

3.2.5.5 Other Water Operations in the Arkansas Valley

In addition to the Lower Arkansas Basin water supplies, the City of Aurora owns water supplies in the Upper Arkansas River Basin and in the Colorado River Basin that affect overall operations in the Arkansas River. However, because these water supplies are not stored in Pueblo Reservoir, these operations are not affected by the Proposed Action. However, these water supplies are discussed herein to provide a comprehensive description of Aurora's Arkansas Basin operations.

Upper Arkansas Water Rights

Aurora has purchased water rights from several ranches in the Upper Arkansas basin. These rights yield above the confluence of Lake Creek and the Arkansas River. The rights are diverted at Twin Lakes and Turquoise Reservoirs as alternate points of diversion. These operations are junior to the CWCB minimum stream flows on Lake Creek and Lake Fork Creek. These diversions are made during the May through August period. These rights are operated simultaneously with the lower Arkansas River water exchanges, and are junior to exchanges with a senior adjudication date. A second option is to exchange the water upstream through Reclamation's conduit into Turquoise Reservoir. This section briefly describes each of these rights.

Buffalo Park (89CW42)

The Buffalo Park water rights were transferred to Aurora from a ranch in Lake County. These water rights are diverted by exchange into Twin Lakes, with an alternate point of Turquoise Reservoir. The water rights consist of three ditches with a combined diversion rate of 3.3 cfs. The ditches all have an adjudication date of 6/19/1890. The Upper Ditch has an appropriation date of 5/7/1882, the Abbot and Loper #1 an appropriation date of 4/25/1882, and the Abbot and Loper #2 an appropriation date of 5/7/1887. The yield from Buffalo Park includes monthly diversion caps and an annual cap of 324 ac-ft annually. Additionally, a ten-year period maximum of 2,820 acre-feet may be diverted. A summary of the water rights is shown in Table 3-25. When diverting into Twin Lakes, the yield incurs a 0.75 percent transit loss as administered by the Division Engineer.

Table 3-25. Summary of Buffalo Park Water Right

Ditch	Diversion (cfs)	Maximum Diversion (ac-ft)				
		May	June	July	August	Annual
Upper	1.4	19	76	64	35	179
Abbot and Loper 1	0.4					
Abbot and Loper 2	1.5	17	76	53	26	159
Annual Total						**324**

Notes:

(1) These rights are diverted by exchange into Twin Lakes. When diverting into Twin Lakes, a 0.75 percent transit loss (as administered by the Division Engineer) is incurred.

Burrows (W4799, 82CW182)

The Burrows ranch water rights originate in Lake County in the upper Arkansas Basin. The water rights consist of three diversion ditches, which combine to a diversion rate of 1.7 cfs. All three ditches - the Younger #1, Younger #2, and the Beaver Ditch - have an adjudication date of 6/19/1890 with appropriation dates of: Youger #1 & #2 5/15/1879 and Beaver ditch 5/15/1881. The diversion season runs from May 15 through August 15. The yield from the Burrows water right is capped at 260 ac-ft annually with no monthly diversion caps. These rights are diverted by exchange into Twin Lakes. When diverting into Twin Lakes, the yield incurs a 0.87 percent transit loss as administered by the Division Engineer.

Hayden (98CW137(A))

The Hayden Ranch water rights are a collection of four ditch rights that historically diverted from the Arkansas River, and irrigated 889 acres west of the river between Lake Creek and Lake Fork Creek. The priority dates for the ditches range from 1877 to 1880 and have a total decreed diversion rate of 42 cfs, with a maximum municipal diversion rate of 4.01 cfs. The Hayden Ranch rights decree allows Aurora to annually divert up to a total of 1,091 acre-feet. Of this amount, 828 acre-feet can be consumptively used by Aurora, and 263 acre-feet is to be stored and released at a later time to replace delayed return flows that occurred historically. The delayed return flows are to be released to the Arkansas River from September through March after the water was diverted.

Water for the Hayden Ranch was originally conveyed through the Upper River Ditch, Pioneer Ditch, Champ Ditch and Wheel Ditch, all of which divert from the Arkansas River upstream of Lake Creek. Through the water court case, Aurora has alternate points-of-diversion at Twin Lakes, Turquoise Reservoir, Otero Pump Station intake, Clear Creek

Reservoir, Ski Cooper, Mt. Massive Golf Course, Hallenbeck Ranch, Hayden Meadows Reservoir, and at various points in Lake County for use as augmentation water. Aurora's decree also allows for the continued diversion and use of the water on the Hayden Ranch for irrigation, if Aurora so chooses. All diversions under this right will be charged evaporation and transit losses as determined by the Division Engineer.

Spurlin-Shaw (98CW137(A))

The Spurlin-Shaw water rights were transferred in the same decree as the Hayden Ranch rights. The Spurlin-Shaw rights are a collection of four ditch rights that historically diverted from the Arkansas River and Lake Fork Creek, and irrigated 314 acres on both sides of Lake Fork below Turquoise Reservoir. The priority dates for the ditches range from 1878 to 1887 and have a total decreed diversion rate of 26.44 cfs, with a maximum municipal diversion rate of 3.14 cfs. Aurora changed 22.44 cfs of this amount, with the remaining 4 cfs remaining with a partial owner. The Spurlin-Shaw decree allows Aurora to annually divert a total of 478 acre-feet. Of this amount, 247 acre-feet can be consumptively used by Aurora, and 231 acre-feet is to be stored and released at a later time to replace delayed return flows that occurred historically. The delayed return flows are to be released to the Arkansas River from August through April following the diversion of the consumptive use water.

Water for the Spurlin-Shaw Ranch was originally conveyed through the Henderson-Delappe Ditch, which diverts from Lake Fork downstream of Turquoise Reservoir, and the Delappe Ditch and Wells and Star Ditch, which divert from the Arkansas River upstream of Lake Fork. Through the water court case, Aurora has alternate points-of-diversion at Twin Lakes, Turquoise Reservoir, Otero Pump Station intake, Clear Creek Reservoir, Ski Cooper, Mt. Massive Golf Course, Hallenbeck Ranch, Hayden Meadows Reservoir, or at various points in Lake County for use as augmentation water. All diversions under this right will be charged evaporation and transit losses as determined by the Division Engineer.

Colorado River Water Sources

Transmountain diversion projects were discussed in previous sections of this document. The following paragraphs describe operations of these systems that are unique to Aurora. With the exception of the Twin Lakes system, the Colorado River Basin water rights are delivered into Turquoise Reservoir for storage prior to being released to Otero Pump station. The Colorado River waters are generally moved to Twin Lakes and ultimately pumped through Otero Pump Station during the non-peak runoff period of fall through winter. This storage and routing provides flexibility in the timing of movement of these waters to the Otero Pump Station. Aurora's water is moved from Turquoise to Twin Lakes and subsequently the Otero Pump Station by administrative processes. The only operational consideration of concern occurs when Reclamation may be moving maximum amounts of Fry-Ark Project water through the Mt. Elbert Conduit with no additional available space for others' use. This would occur generally during the peak of a large runoff when a large amount of imports and native inflow into Turquoise Reservoir needs to be routed into Twin Lakes.

Busk-Ivanhoe

The Pueblo Board of Water Works (PBWW) and the City of Aurora each own 5,000 acre-feet of Busk-Ivanhoe agricultural storage space in Turquoise Reservoir. The 10,000 acre-feet of Busk-Ivanhoe storage space in Turquoise Reservoir is firm storage space but can only be used to store agricultural water and thus, cannot be used by Aurora or PBWW. However, both Aurora and PBWW each own 5,000 acre-feet of storage space in Turquoise Reservoir through their purchase of CF&I shares, which can be used to store Busk-Ivanhoe water. The City of Aurora takes delivery of its water through the Homestake Pipeline via the Mt. Elbert Conduit, Twin Lakes, and the Otero Pump Station. The PBWW typically leases approximately 2,500 acre-feet of their Busk-Ivanhoe water and leases any remaining water to other Arkansas Basin entities.

Homestake

Aurora owns half of the Homestake Project. As part of their ownership, 2,500 acre-feet annually are owed to PBWW under agreements made between Aurora and the PBWW. Currently, a long-term contract is in place by which Aurora purchases 5,000 ac-ft annually from PBWW. Typically, the first 2,500 ac-ft of this lease is taken from PBWW's portion of the Homestake Project.

Twin Lakes

Aurora owns 2,478.475 shares or 5 percent of the Twin Lakes Reservoir and Canal Company. In addition to the water rights associated with the Twin Lakes Company, 2,722 acre-feet of storage space is available to the City of Aurora in Twin Lakes Reservoir for storage of any waters. The Twin Lakes Pipeline, an intake pipeline from Twin Lakes to the Otero pump station, makes the reservoir an integral part of the delivery system for Aurora's raw water supply.

Pueblo Board of Water Works Lease

As previously discussed, Aurora has a 15-25 year lease with the PBWW for 5,000 acre-feet of transmountain water annually. The lease agreement is a 15 year agreement begun in 1999 with up to a 10 year extension. The first 2,500 ac-ft delivery to Aurora is made on July 15, with the second delivery made during any other time of the year. This water is deliverable in Twin Lakes or Turquoise Reservoir. As a matter of convenience, the first 2,500 ac-ft can be foregone in exchange for the 2,500 acre-feet of Homestake water that is due to the PBWW annually. This water can be delivered to Aurora after July 15th.

3.3 Historical Streamflow Data

The USGS and the Colorado Department of Natural Resources maintain streamflow gaging stations throughout the basin. As previously discussed, Reclamation has selected several of these gaging stations to analyze as being indicative of overall conditions in the Arkansas River Basin. Other streamflow gages within the study area were also included in the analysis as needed for specific reasons. The following sub-sections provide a brief review of monthly, daily, and sub-daily records for selected gages in the study area. Complete records for each gage during the study period can be found in the appendices.

3.3.1 Historical Monthly Streamflow

Historical monthly streamflow values were developed from daily data by averaging the daily streamflow for each day during the month. The monthly streamflows for each year throughout the study period were then averaged to calculate the historical average monthly streamflow provided in this section. The following sub-sections provide a brief description of the hydrologic nodes and a summary of the average monthly streamflow for those nodes. The reaches of river have generally been divided according to the State Engineer's Office water district classification system for Division 2.

3.3.1.1 Arkansas River - Headwaters to Salida

The Arkansas River from its headwaters to Salida generally corresponds to Water District 11. The list of nodes originally proposed by Reclamation includes five streamflow gages between the headwaters and the Wellsville gage. Two additional nodes are summarized: the Leadville gage and the Salida gage. The Leadville gage provides documentation of river flows immediately above the affected reach. The Salida gage is commonly used for river administration and forecasting. The following provides a brief summary of each site. The average monthly flow for the 1982-2002 study period is shown in **Table 3-26** and **Table 3-27**.

- **Arkansas River Near Leadville, CO (07081200):** The Leadville gage essentially provides native Arkansas River flows upstream of the Lake Fork confluence and will be used as the headwaters gage in the simulation model. There is small amount of transbasin water from the Columbine, Ewing and Wurtz ditches and a small amount of water diversion and use in the Leadville area that must be adjusted to get true native flows. The period-of-record for this gage is 1967 through present. However, the CDSS dataset is missing data for the gage for water years 1984-1989 and part of 1990.
- **Lake Fork Creek below Sugar Loaf Dam near Leadville (07082500):** The Lake Fork below Sugar Loaf Dam gage essentially measures releases from Turquoise Reservoir through its river outlet to Lake Fork. The gage is located upstream of tributary inflows, including Halfmoon Creek. The period-of-record for this gage is 1970 through present. However, the CDSS dataset is missing data for the gage in 1991.

- **Arkansas River Near Malta, CO (07083700):** The Malta gage is located between Lake Fork (the river outlet for Turquoise Reservoir) and Lake Creek (the river outlet for Twin Lakes). Therefore, the streamflow values contain native Arkansas River flows plus Turquoise Reservoir releases and some tributary inflows. The overall period-of-record for the gage is 1965-1984, with missing data from 1968-1974. There are only 3 years of data at the gage within the study period.
- **Lake Creek below Twin Lakes Reservoir (LAKBTLCO):** The Lake Creek below Twin Lakes gage essentially measures releases from Twin Lakes through its river outlet to Lake Creek. The gage is located upstream of tributary inflows. The period-of-record for this gage is 1954 through present, with several years of missing data. The CDSS dataset is missing data for the gage in 1985, 1991 and 1992.
- **Arkansas River at Granite (07086000):** The Granite gage is located downstream of the confluence of Lake Creek and the Arkansas River, but upstream of the confluence with Clear Creek. Therefore, the Granite gage is influenced by any transmountain water released from Twin Lakes and Turquoise Reservoir downstream, as well as the storage and releases of native Arkansas River flows. The period-of-record for this gage is 1910 through present, with missing data only in the first year of record. Therefore, there is no missing data in the study period.
- **Arkansas River near Nathrop (07091200):** The Nathrop gage is located on the Arkansas River near the town of Nathrop, immediately upstream of Brown's Canyon. Readings at the Nathrop gage are currently only made during the summer months. There are two periods of continuous measurements at the Nathrop gage: from 1965 through 1982 and 1989 through 1993. Therefore, streamflow data is incomplete from 1983 to 1989 and 1994 to 2002 at the Nathrop gage.
- **Arkansas River at Salida (07091500):** The Salida gage is located adjacent to the town of Salida, upstream of the town's wastewater treatment facilities. The Salida gage has a long, continuous period-of-record (1910 through present) and its projected streamflow by the NRCS is used as a basis for determining target flows for the Pueblo Flow Management Program.
- **Arkansas River near Wellsville (07093700):** The Wellsville gage is located downstream of the Salida gage, and includes discharges from the Salida wastewater treatment facility. The Wellsville gage is of significant importance in the Arkansas Basin because it is used to administer the Upper Arkansas Flow Management Program. The period-of-record for this gage is 1961 through present, with missing data for a short period in September, 1989. Therefore, the data is virtually complete for the study period.

Table 3-26. Historical Mean Monthly Flow - Arkansas River from Headwaters to Granite

Month	Historical Mean Monthly Streamflow (cfs), 1982 - 2002			
	Arkansas River Near Leadville, Co. (07081200)(1)	Lake Fork Creek Below Sugar Loaf Dam Near Leadville (07082500)(2)	Arkansas River Near Malta, Co. (07083700)(3)	Lake Creek Below Twin Lakes Reservoir (LAKBTLCO)(4)
Oct	30	5	104	52
Nov	23	5	80	54
Dec	18	4	67	90
Jan	16	4	70	110
Feb	16	4	76	120
Mar	16	5	70	125
Apr	32	9	79	111
May	176	24	297	420
Jun	354	65	793	729
Jul	145	91	785	540
Aug	68	30	413	290
Sep	39	8	159	84
Avg	79	21	249	227

Notes:
(1) Data missing for water years 1984-1989 and a portion of 1990.
(2) Data missing for water year 1991.
(3) Period-of-Record: 1982-1984.
(4) Data missing for water years 1985 and 1991-1992.

Table 3-27. Historical Mean Monthly Flow - Arkansas River from Granite to Salida

Month	Historical Mean Monthly Streamflow (cfs), 1982 - 2002			
	Arkansas River At Granite (07086000)	Arkansas River Near Nathrop (07091200)(1)	Arkansas River At Salida (07091500)	Arkansas River Near Wellsville (07093700)
Oct	169	338	361	425
Nov	159	315	353	445
Dec	177	280	334	426
Jan	198	329	337	416
Feb	220	365	337	416
Mar	230	349	337	407
Apr	253	367	347	408
May	769	977	971	1,089
Jun	1,374	1,932	2,021	2,192
Jul	944	1,271	1,377	1,455
Aug	494	777	787	862
Sep	207	399	407	471
Avg	433	759	664	751

Notes:
(1) No data 1983-1989. March through October data only 1994-2002.

3.3.1.2 Arkansas River - Salida to Pueblo Reservoir

The reach of river from Salida to Pueblo Reservoir corresponds to Water District 12. The original Reclamation node list included 1 streamflow gaging station in this reach. The Cañon City gage was added due to its long period-of-record. The following provides a brief description of each site. The average monthly flow for the 1982-2002 study period is shown in **Table 3-28**.

Arkansas River at Canyon [Cañon] City (07096000): The Cañon City gage has the longest period-of-record on the Arkansas River Basin, dating back to 1889 with some missing data between 1890 and 1896. Although flows at the gage are influenced by transmountain diversions and storage, there are relatively few consumptive use diversions upstream of the gage. Therefore, as shown in **Table 3-1** and **Figure 3-1** of **Section 3.1**, it can be used to investigate long-term streamflow trends in the basin.

Arkansas River at Portland (07097000): The Arkansas River at Portland gage is located about 4 miles upstream of Pueblo Reservoir, and is the closest gage to the upstream end of the reservoir. Essentially, the gage measures streamflow into the reservoir, as there is virtually no tributary inflow between the gage and the reservoir. The overall period-of-record for this gage is from 1939 to 1952 and 1975 to present. There is no missing data for the study period.

Table 3-28. Historical Mean Monthly Flow -
Arkansas River from Salida to Pueblo Reservoir

Month	Historical Mean Monthly Streamflow (cfs), 1982 - 2002	
	Arkansas River At Canyon City (07096000)	Arkansas River At Portland (07097000)
Oct	388	455
Nov	433	481
Dec	447	447
Jan	445	436
Feb	450	434
Mar	466	453
Apr	449	494
May	1,152	1,302
Jun	2,389	2,529
Jul	1,523	1,619
Aug	871	977
Sep	430	485
Avg	787	843

3.3.1.3 Arkansas River - Pueblo Reservoir to Fowler

The Arkansas River from Pueblo Reservoir to Fowler primarily encompasses Water District 14. Reclamation included only the Above Pueblo gage between Pueblo Reservoir and Fountain Creek on the original list of nodes. However, based upon public comments and initial resources studies made since the original list was assembled, the Moffat Street gage was added to the summary in order to evaluate flows and potential changes in flows in that portion of the river. The following provides a brief description of each site. The average monthly flow for the 1982-2002 study period is shown in **Table 3-29**.

- **Arkansas River above Pueblo (07099400):** The above Pueblo gage is located immediately downstream of Pueblo Reservoir. This gage generally represents river releases from Pueblo Reservoir. However, there are return flows from the Pueblo Fish Hatchery that enter the river downstream of the gage, and in many instances, when a target flow at the Above Pueblo gage is mentioned, it is assumed to include the Fish Hatchery return flows. The gage is the basis for both year round flows and recreational flows in the Pueblo Flow Management Program. The period-of-record for this gage is 1966 to present.
- **Arkansas River At Moffat Street At Pueblo (07099970):** The Moffat Street gage is located immediately upstream of the St. Charles Mesa pumping plant, just downstream of the Interstate 25 crossing of the Arkansas River in Pueblo. This gage represents the amount of flow through the City of Pueblo's kayak course. Aquila Energy/HARP diverts water upstream of this gage and returns downstream of the gage. The period-of-record for the gage is 1989 to present.
- **Arkansas River near Avondale (07109500):** The Avondale gage is located downstream of the confluence with Fountain Creek, and upstream of the major agricultural diversions. Because the gage includes flows from Fountain Creek and most of the major agricultural deliveries, this gage has the highest average annual flow of any gage on the Arkansas River in Colorado. The period-of-record for this gage is 1939 to present, with data missing from 1952 to 1965.

Table 3-29. Historical Mean Monthly Flow -
Arkansas River from Pueblo Reservoir to Fowler

Month	Historical Mean Monthly Streamflow (cfs), 1982 - 2002		
	Arkansas River Above Pueblo (07099400)	Arkansas River At Moffat Street At Pueblo (07099970)(1)	Arkansas River Near Avondale (07109500)
Oct	387	244	588
Nov	268	213	520
Dec	173	112	390
Jan	193	104	417
Feb	235	136	457
Mar	363	307	604
Apr	669	556	973
May	1,251	1,097	1,747
Jun	2,360	2,092	2,741
Jul	1,677	1,435	1,938
Aug	1,092	892	1,411
Sep	481	335	683
Avg	763	627	1039

Notes:
(1) Period-of-Record: 1989-2002.

3.3.1.4 Arkansas River - Fowler to La Junta

The Arkansas River from Fowler to La Junta is within Water District 17. This reach shows the effects of agricultural diversions and return flows in the Arkansas River. The original Reclamation node list included an unspecified gage near Rocky Ford and the Las Animas gage. However, the La Junta gage is the last gage in the study reach. This list has been expanded to include three gages in the reach, although the Rocky Ford gage is relatively new and provides limited value when comparing to historical streamflows. **Table 3-30** presents a summary of the historical mean monthly flow.

- **Arkansas River at Catlin Dam near Fowler (07119700):** The Catlin Dam gage is located on the Arkansas River. The gage is physically located below the Catlin Canal diversion dam. However, the reported data includes Catlin Canal diversions (CDWR, 2000). Therefore, the reported flows from the gage, and thus the flows shown herein, are flows immediately above the Catlin Canal diversion. The period-of-record for the gage is 1965 to present.
- **Arkansas River near Rocky Ford (ARKROCCO):** The Rocky Ford gage is a recently installed gage located just upstream of the confluence with Timpas Creek. The station was installed in 1999, so there are only three years of data in the study period.
- **Arkansas River at La Junta (07123000):** The La Junta gage is located downstream of the Fort Lyon Canal and downstream of Crooked Arroyo. The La Junta gage is downstream of most of the major diversions except for the Las Animas Consolidated Ditch. Flows at the La Junta gage are often the lowest flows on the river. The period-of-record for the La Junta gage is 1912 to present.

Table 3-30. Historical Mean Monthly Flow - Fowler to La Junta

Month	Historical Mean Monthly Streamflow (cfs), 1982 - 2002		
	Arkansas River At Catlin Dam Near Fowler (07119700)	Arkansas River Near Rocky Ford (ARKROCCO)(1)	Arkansas River At La Junta (07123000)
Oct	377	176	193
Nov	459	244	152
Dec	431	143	143
Jan	452	173	189
Feb	415	122	185
Mar	390	183	134
Apr	559	360	158
May	1,301	548	623
Jun	2,003	513	969
Jul	1,266	375	563
Aug	921	352	360
Sep	381	117	131
Avg	746	275	317

Notes:
(1) Period-of-Record: 1989-2002.

3.3.2 Historical Daily Streamflow

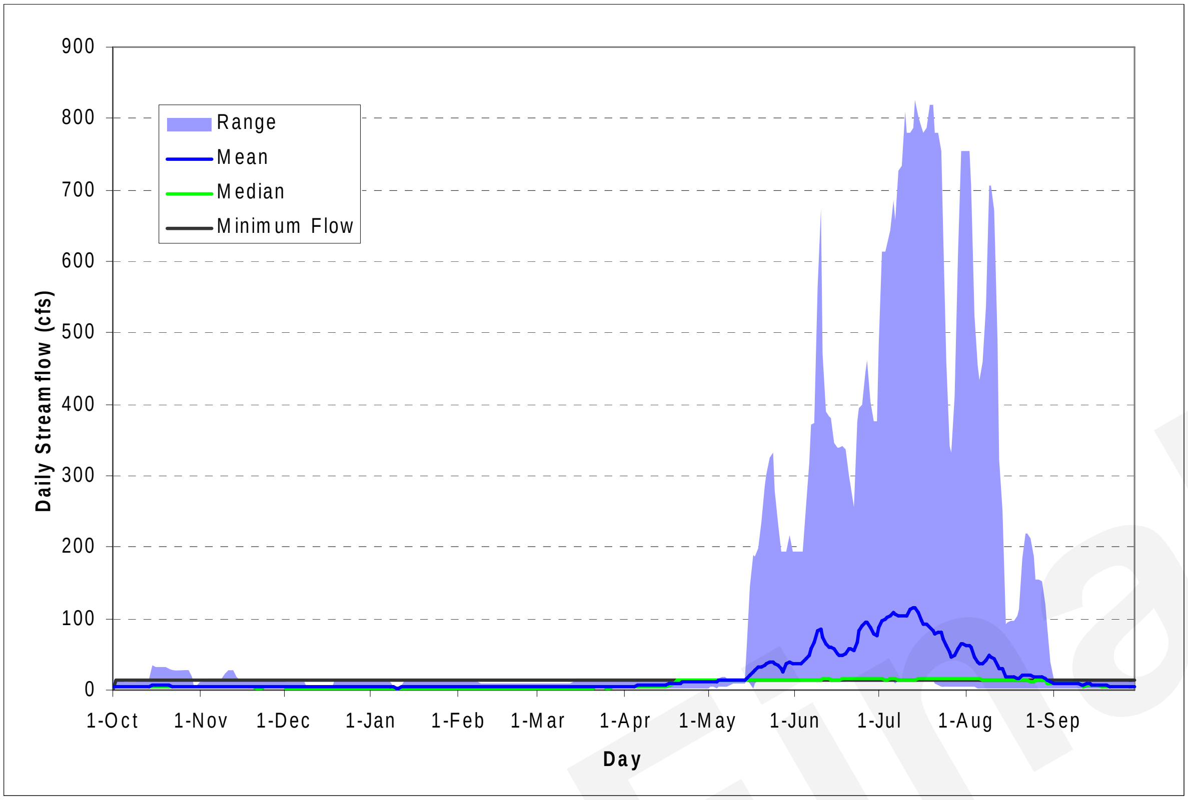
As previously stated, the original data collected for the streamflow gaging stations are daily data. Therefore, daily records have been obtained and are available for all streamflow gaging stations shown in this document and in its appendices. For purposes of brevity, graphs showing means and median daily streamflows for selected gaging stations are presented in the text portion of this section.

3.3.2.1 Lake Fork Gage Daily Streamflow

A daily flow summary for Lake Fork below Turquoise Reservoir is shown in **Figure 3-13**. Flows at the gage are completely controlled by river releases from Turquoise Reservoir. Typically, flows are only released from the reservoir to meet the minimum flow requirements at the gage, which is the minimum of 15 cfs and the native inflow (decreed). There are two decreed CWCB water rights that make up the minimum flow requirements on Lake Fork: 15 cfs from Sugarloaf Dam to Willow Creek (water Division 2, case number 77W4654), and 20 cfs from Willow Creek to the Arkansas River confluence (water Division 2, case number 77W4655). The appropriation date for the two water rights is January 19, 1977. Native inflows are normally less than 15 cfs during the winter, and releases from Turquoise Reservoir are made to maintain 3 to 4 cfs at the gage. During the summer, releases are made to meet the 15 cfs minimum flow. During a majority of the years in the study period, no further releases were made to Lake Fork (this is evidenced by the median streamflow values corresponding to the minimum flow line in **Figure 3-13**). However, during peak flow events or when releases required from Turquoise Reservoir are greater than the capacity of the Mount Elbert Conduit, releases are made to Lake Fork. Therefore, there can be a wide range of flows experienced in the river from year to year during peak flow months.

The two CWCB minimum flow requirements discussed above are junior to Fry-Ark Project water rights on Lake Fork. As a result, minimum flows on Lake Fork are associated with Reclamation's operation of Turquoise Reservoir for the Fry-Ark Project. The junior CWCB minimum flow requirements are not necessarily met, except during the summer as noted above. The minimum flows shown in **Figure 3-13** are minimum flows resulting from Reclamation's Fry-Ark Project operations.

Figure 3-13. Lake Fork Gage Daily Flow Summary for Study Period

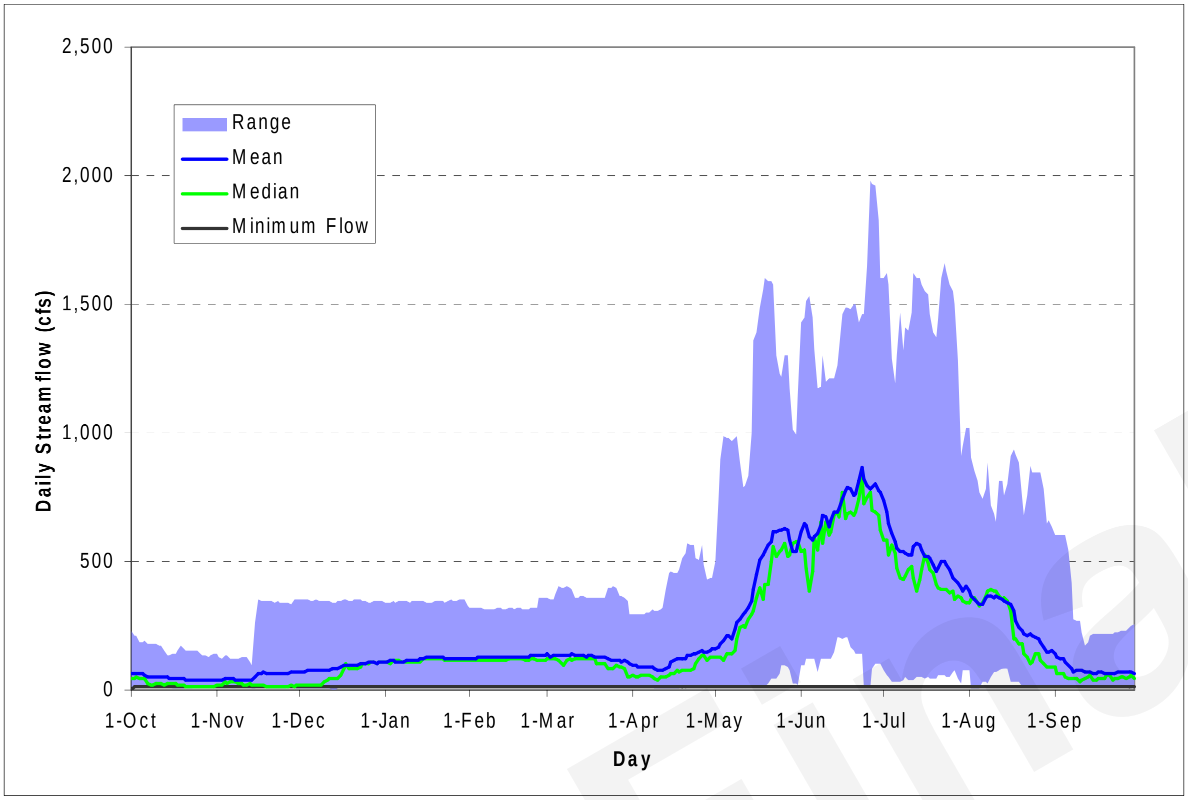


3.3.2.2 Lake Creek Gage Daily Streamflow

A summary of daily flows at the Lake Creek gage below Twin Lakes is shown in **Figure 3-14**. Flows at the Lake Creek gage are entirely due to reservoir releases from Twin Lakes. As shown, flows in Lake Creek are substantially higher than those in Lake Fork and have a much higher range of flows during the winter. This is due to several reasons: (1) the native flows in Lake Creek above Twin Lakes are greater than the Lake Fork inflows above Turquoise Reservoir; (2) Lake Fork flows and Halfmoon Creek flows not needed to satisfy minimum flows in those creeks are typically diverted through the Mount Elbert Conduit to generate power before being released to the Arkansas River; (3) all Fry-Ark Project water is routed through the Mount Elbert Conduit before being released to the Arkansas River.

There is a CWCB minimum instream flow requirement for Lake Creek of 15 cfs, with an appropriation date of May 1, 1975 (water Division 2, case number 75W4271) that is shown in **Figure 3-14**. As shown, the minimum flow requirement in Lake Creek is always met due to releases from Twin Lakes.

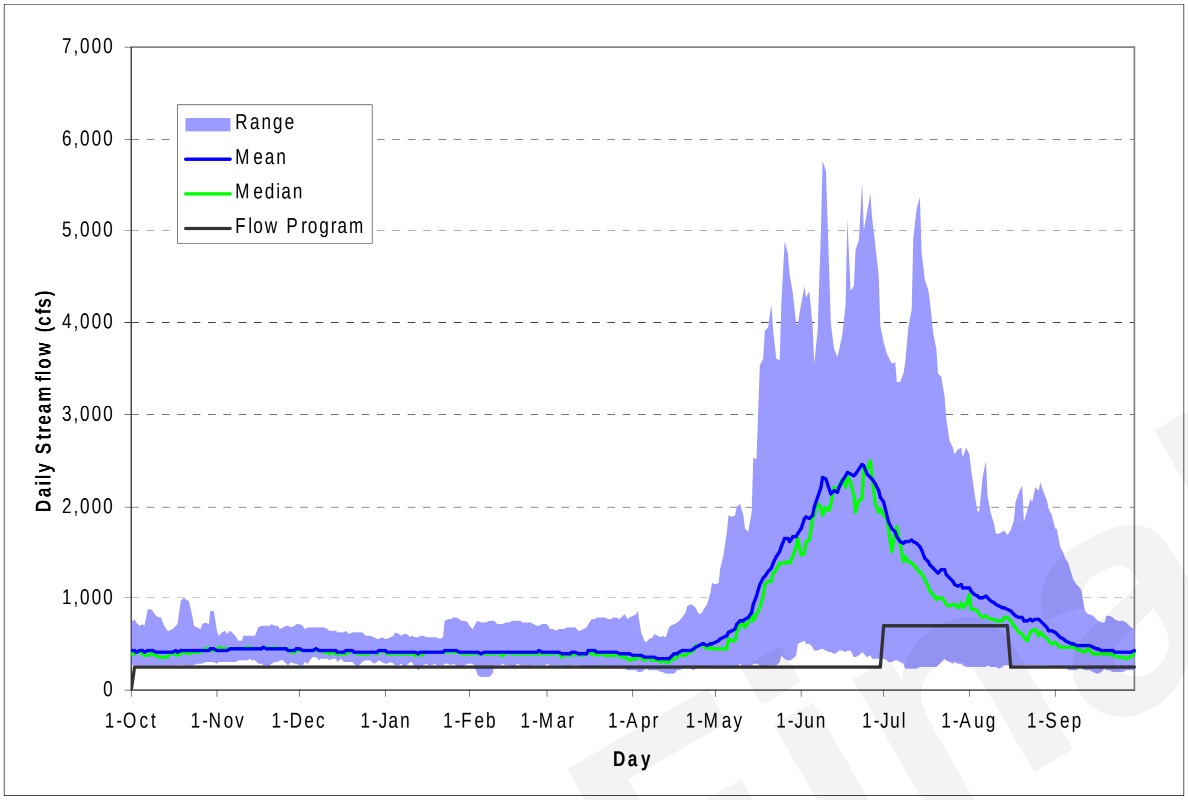
Figure 3-14. Lake Creek Gage Daily Flow Summary for Study Period



3.3.2.3 *Wellsville Gage Daily Streamflow*

Mean and median daily flows, the range of daily flows and the minimum flows associated with the Wellsville flow program, are shown in **Figure 3-15**. As shown, flows have a fairly narrow range between 250 cfs and 700 cfs from mid-September through mid-April. Annual peak flows at the gage occur anytime from mid-May through mid-July. As shown in **Figure 3-15**, flows during the summer have ranged between 250 cfs and 5,800 cfs. The target flows shown are those for the Upper Arkansas Voluntary Flow Management Program and are the minimum of the possible target flows in the agreement (700 cfs from July 1 to August 15, and 250 cfs for the remainder of the year). Target flows could be higher (250 to 400 cfs) during the winter incubation period (November 16 to April 30), depending on flows during the previous spawning period (October 15 to November 15). Reclamation makes releases from Fry-Ark Project storage to meet the target flows. In general, other water providers do not make releases to meet the target flows. The mean and median flows show that the flow program targets are generally met. However, there have been years when the 700 cfs flow target was not met. Most of these low flows occurred in 2002 when native flows were extremely low and inadequate Fry-Ark Project water was available in Twin Lakes and Turquoise Reservoir to make releases to meet the targets. During the remaining years in the study period, the target flows were met or very nearly met.

Figure 3-15. Wellsville Daily Flow Summary for Study Period

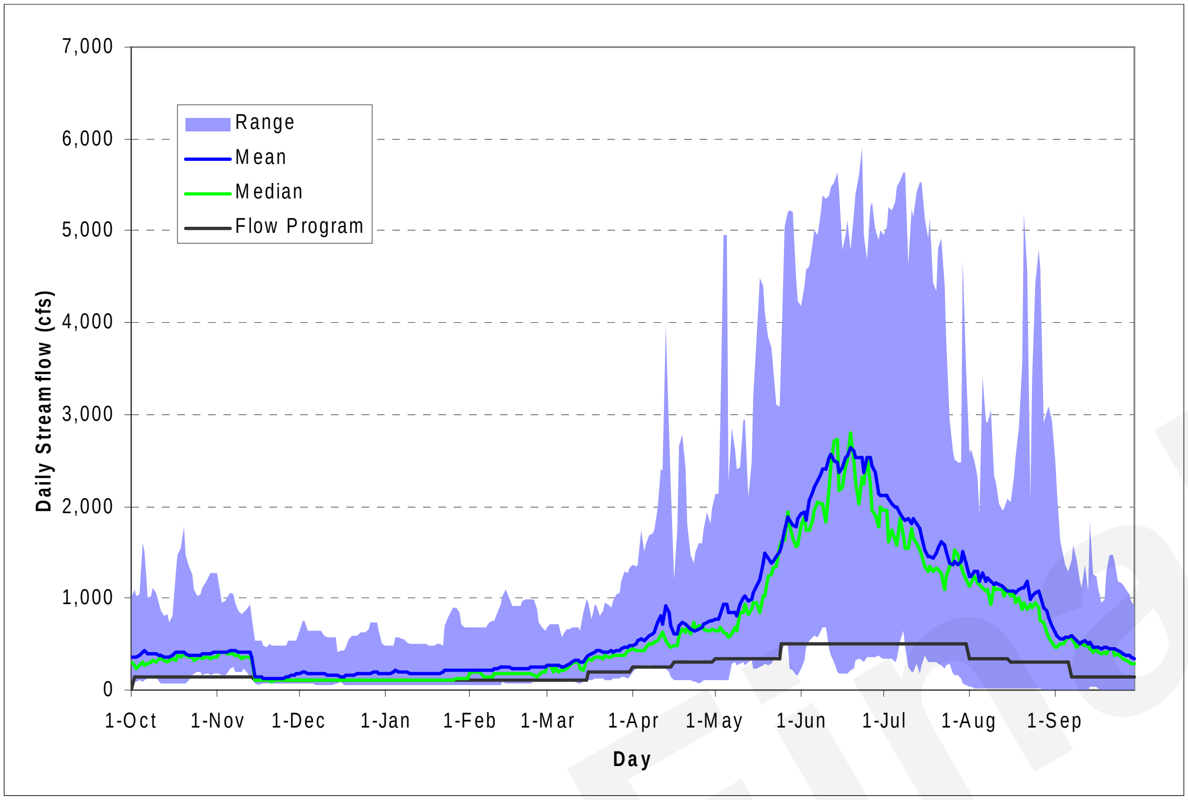


3.3.2.4 Above Pueblo Gage Daily Streamflow

A summary of daily streamflow for the Above Pueblo gage is shown in **Figure 3-16**. Streamflow at the Above Pueblo gage is completely controlled by releases from Pueblo Reservoir. This is evident in the hydrograph as minimum daily flows during the spring and summer months are higher than those at the Wellsville gage. In addition, the mean and median flows in the later summer are much higher and last for several weeks longer than those at the Wellsville gage. There are also some high peak flow events at the Above Pueblo gage that are reservoir releases made for irrigation.

The Flow Program flow line shown in **Figure 3-16** represents the “above average” target flows for the Pueblo Flow Management Program, stipulated in the intergovernmental agreement (May IGA, 2004). Streamflows shown in **Figure 3-16** are flows at the Above Pueblo gage. However, the target flows are administered at the combined flow location downstream of the Above Pueblo gage. Return flows from Runyon Lake, including return flows from the Aquila Energy Diversion Dam, return to the Arkansas River between the Above Pueblo gage and the combined flow location. For purposes of presentation in the graph, only the “Above Average” hydrologic condition target flows are shown, because the “Above Average” target flows are more restrictive than the “Below Average” target flows. Releases from storage are not made to meet IGA target flows. The target flows only curtail exchanges by entities that are party to the IGA.

Figure 3-16. Above Pueblo Gage Daily Flow Summary for Study Period

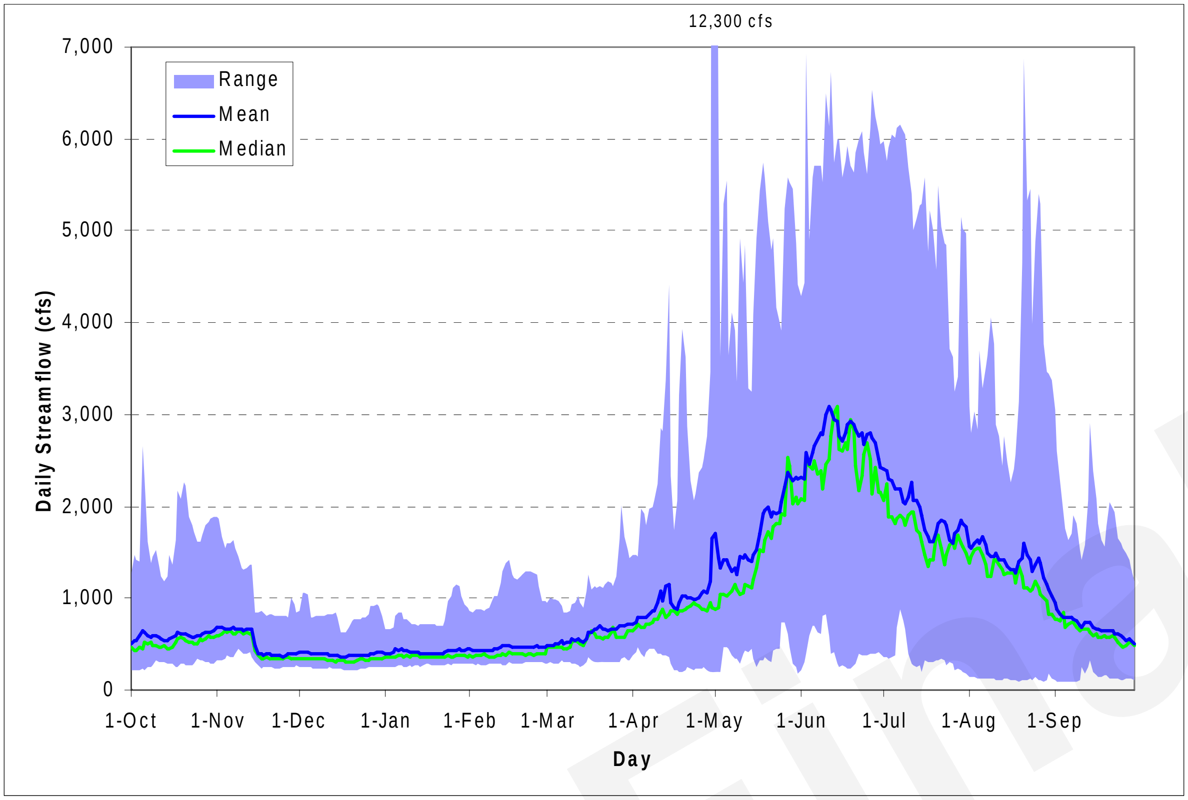


3.3.2.5 Avondale Gage Daily Streamflow

The daily flow summary for the Avondale gage is shown in **Figure 3-17**. As with the Above Pueblo gage, flows at the Avondale gage are heavily influenced by releases from Pueblo Reservoir for irrigation purposes that can total several thousand cubic feet per second.

The other flow event that is clearly evident in the Avondale gage flow summary is the extremely high flow event that lasted from April 30 to May 1 in 1999. When compared with flows at the Fountain Creek gage and the La Junta gage, it is clearly evident that this peak flow event increased in flow rate as it progressed downstream, indicating the true regional magnitude of the storm event.

Figure 3-17. Avondale Gage Daily Flow Summary for Study Period

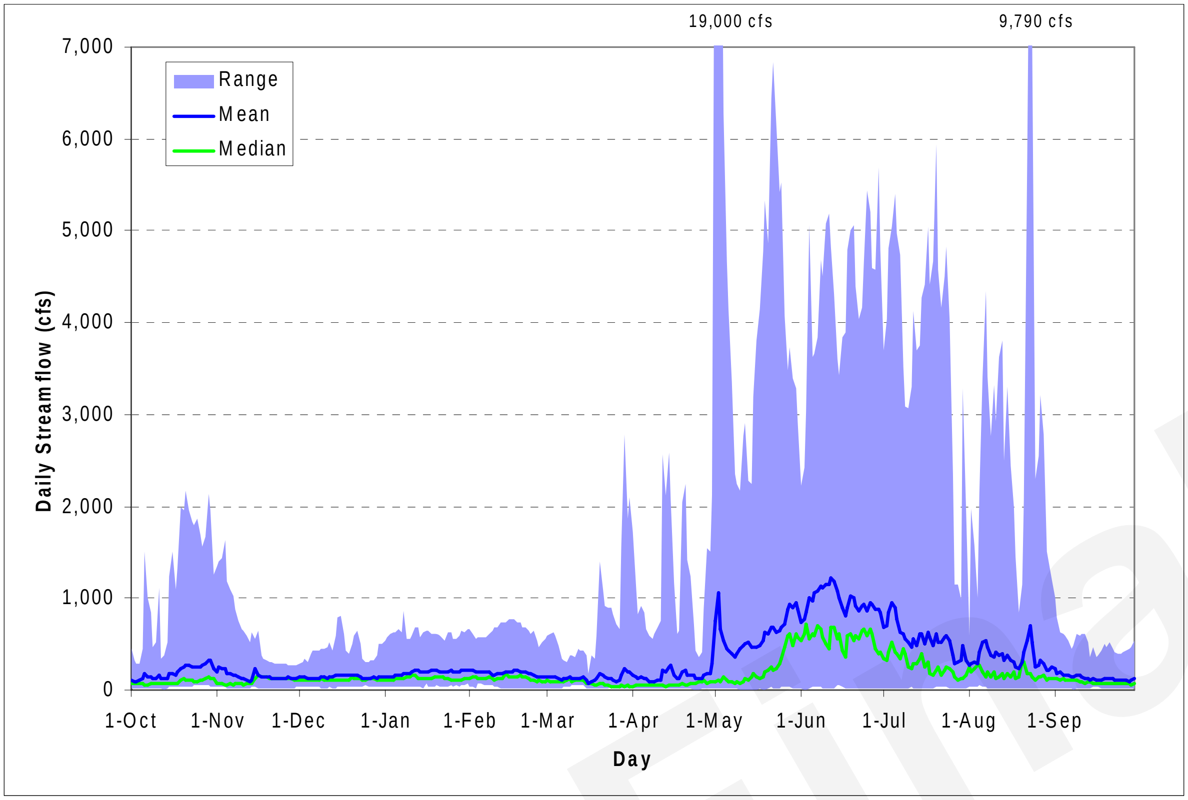


3.3.2.6 La Junta Gage Daily Streamflow

Daily summaries of flows at the La Junta gage are shown in **Figure 3-18**. As expected, flows at the La Junta gage are substantially less than flows at the Avondale gage. This is due to the amount of diversions that take place in the intervening reach. Wintertime flows are less due to the WWSP off-channel diversions to the Colorado Canal System reservoirs and the Great Plains system reservoirs through the Fort Lyon Storage Canal.

As with the Avondale gage, the April 30 to May 1 peak flow event in 1999 is clearly evident in the graph. When comparing peak discharge at the La Junta gage with peak discharge at the Avondale gage, there was an increase of approximately 6,700 cfs.

Figure 3-18. La Junta Gage Daily Flow Summary for Study Period



3.3.3 Historical Diurnal Streamflow Data

Historical diurnal flow fluctuations were examined at locations downstream of Pueblo Reservoir. **Figure 3-19** presents a hydrograph showing monthly, daily, and 15-minute streamflow for USGS Gage 7099970 (Arkansas River at Moffat Street at Pueblo), while **Figure 3-20** presents a hydrograph showing monthly, daily, and 30-minute streamflow for USGS Gage 7109500 (Arkansas River near Avondale). Daily streamflow values were obtained from the Colorado Division of Water Resource's Colorado Decision Support System (CDSS) historic daily average database. Monthly streamflow data was calculated from the CDSS daily data. The USGS Pueblo area office provided 15 and 30-minute streamflow data in electronic format.

The hydrographs for the Arkansas River at the Moffat Street at Pueblo gage and the Arkansas River near Avondale gage show a low mean streamflow for the September through March period. Spring and summer snowmelt dominates streamflow in the Arkansas River, causing higher streamflow for the May through August period for all three time scales plotted. The large fluctuations between monthly, daily, and 15- or 30-minute streamflow seen in **Figure 3-19** and **Figure 3-20** during the spring and summer are a result of either precipitation events or releases from Pueblo Reservoir. The latter can vary on an hourly time scale, depending on downstream water demands associated with agricultural water rights.

Figure 3-19. Hydrograph for USGS Gage 07099970 (Arkansas River at Moffat Street at Pueblo) for Water Year 2001

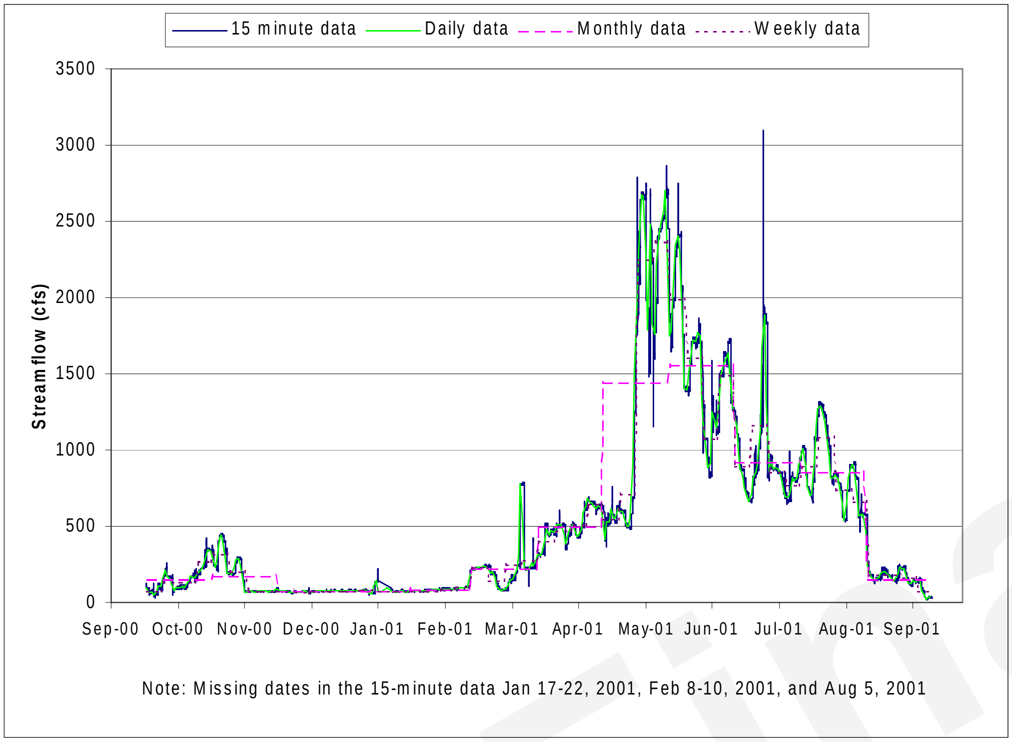
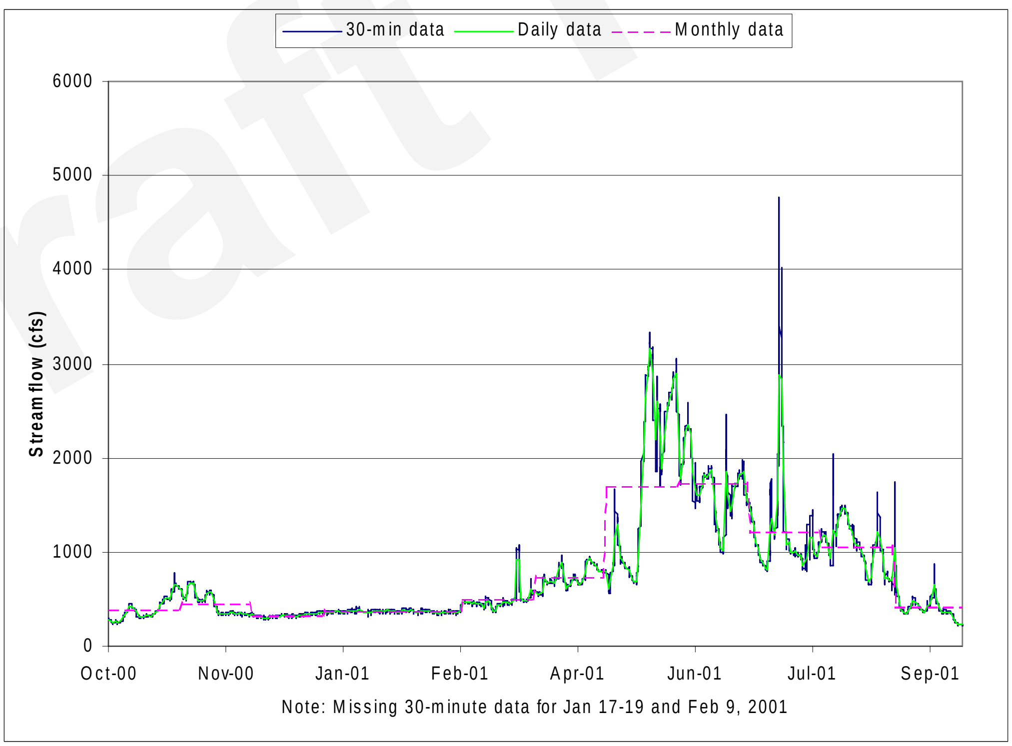


Figure 3-20. Hydrograph for USGS Gage 07109500 (Arkansas River near Avondale) for Water Year 2001



3.3.4 Historical Peak Flow Discharge

Peak discharge data were calculated using historical instantaneous peak discharge data obtained from the USGS National Water Information System. A frequency analysis was completed for streamgage locations associated with stream reaches that were determined to be geomorphically unstable as described in **Section 3.5.2**.

Figure 3-31 summarizes peak discharge data available for the study area. The peak discharge data in this section are instantaneous peak flows, and are not daily or 15-minute averages. The peak flow discharge values shown are given for the 2-, 10-, 50-, 100-, and 500-year recurrence interval flows. The chance of occurrence in any given year for the 2-, 10-, 50-, 100-, and 500-year flows is 50, 10, 2, 1, and 0.2 percent, respectively. The discharge locations are shown in **Figure 3-21**. The maximum recorded instantaneous peak flows are summarized in **Table 3-32**.

Table 3-31. Summary of Peak Discharges

Gage (Gage Number)	Drainage Area (sq. mi.)	Period of Record (1)	Peak Flow Discharge (cfs)					
			1.5-Year	2-year	10-year	50-year	100-year	500-year
Arkansas River at Portland (07097000)	4,024	1975 - 2004	4,500	5,400	8,700	11,600	12,900	15,800
Arkansas River Above Pueblo gage (0709940)	4,670	1974 - 2004	3,000	3,800	6,700	9,500	10,700	13,700
Arkansas River at Moffat Street gage (07099970)	4,778	1989 - 2004	3,100	4,000	8,300	12,800	14,900	20,300
Arkansas River near Avondale (07109500)	6,327	1974 - 2004	4,400	5,700	11,700	18,000	20,900	28,500
Arkansas River at La Junta (071023000)	12,210	1974 - 2004	2,700	4,200	14,200	29,600	38,300	64,800

Notes:

(1) Period of record used in the frequency analysis. The entire period of record available was used for streamgage locations upstream of Pueblo Reservoir. The period of record after Pueblo Reservoir began operations (1974) was used for locations downstream of Pueblo Reservoir.

Table 3-32. Maximum Recorded Instantaneous Peak Discharge

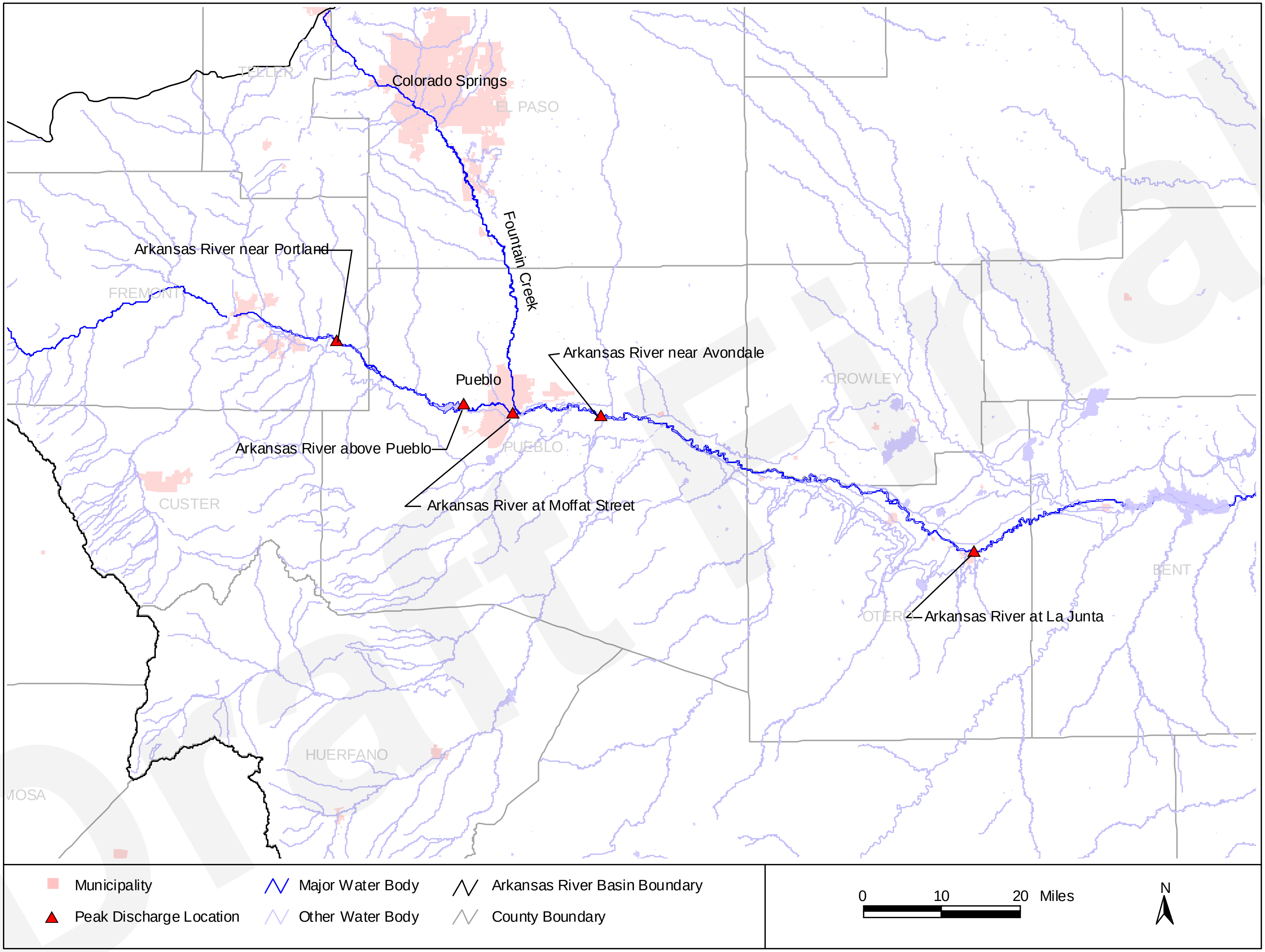
Gage (Gage Number)	Instantaneous Peak Flow Period of Record	Date of Recorded Peak Flow	Maximum Recorded Instantaneous Flow(1) (cfs)
Arkansas River at Cañon City (07097000)	1975-2004	August 2, 1976	10,200 (2)
Arkansas River Above Pueblo gage (0709940)	1966-2004	August 1, 1966	10,100 (2)
Arkansas River at Moffat Street gage (07099970)	1989-2004	June 3, 1994	10,400 (2)
Arkansas River near Avondale (07109500)	1939-2004	June 18, 1965	50,000 (2)
Arkansas River at La Junta (071023000)	1912-2004	June 4, 1921	200,000 (2)

Notes:

(1) Data Source: USGS National Water Information System (NWIS) database.

(2) Discharge affected by regulation or diversion.

Figure 3-21. Peak Flow Stations on the Arkansas River



3.4 Historical Reservoir Data

Historical reservoir data was collected for each of the East Slope Fryingpan-Arkansas Storage facilities, the two Colorado Canal system reservoirs, and Holbrook Reservoir. These reservoirs constitute the existing storage facilities that lie within the study area and would be affected by either the Proposed Action or the No Action Alternative. Monthly and daily summaries are presented in the following subsections, while actual historical data is shown in the appendices.

3.4.1 Historical Monthly Reservoir Contents

Historical mean monthly reservoir contents were developed from daily data by averaging the mean daily reservoir contents for each day during the month. The monthly storage amounts for each year throughout the study period were then averaged to calculate the historical monthly storage provided in this section (e.g., one average storage for each month of the year). The following sub-sections provide a brief description of the reservoirs and a summary of the average monthly storage contents for those reservoirs. The reservoirs were divided into three groups based upon their ownership: Fryingpan-Arkansas Project Reservoirs, Colorado Canal system reservoirs, and Holbrook Canal reservoirs.

3.4.1.1 Fryingpan-Arkansas Project Reservoirs

East Slope Fryingpan-Arkansas Project Reservoirs include Turquoise Reservoir, Twin Lakes Reservoir and Pueblo Reservoir. Pueblo Reservoir was the only reservoir that was included on Reclamation's original list of nodes for cumulative effects. However, due to the exchanges into and out of Twin Lakes and Turquoise Reservoir and potential impacts to these reservoirs from the Proposed Action and the No Action Alternative, summaries for all three reservoirs have been included herein. Historical monthly reservoir contents are shown in **Table 3-33**, while a brief summary of each reservoir is discussed in the following paragraphs.

- **Turquoise Reservoir -** Turquoise Reservoir was completed in 1982 (Reclamation, 2001). Therefore, data prior to this date for Turquoise Reservoir occurred before the reservoir was operational under its existing configuration. No adjustments were made to the historical data to account for this. All data except January 1983 through September 1984 and March through July of 1988 was available as daily data from Reclamation's Hydromet data system (Reclamation, 2004). For the missing periods, end-of-month storage contents were taken from the Reclamation Annual Operating Plans. The capacity of Turquoise Reservoir (top of conservation pool) is 129,398 acre-feet.
- **Twin Lakes Reservoir -** Reclamation assumed operations at Twin Lakes Reservoir in October 1981, which is the same date as the beginning of the study period. Therefore, Twin Lakes was fully operational throughout the study period. Daily data for Twin Lakes Reservoir from water year 1987 through 2002 was obtained from Reclamation's Hydromet data system

(Reclamation, 2004). Prior to water year 1987, end-of-month storage contents were taken from the Reclamation Annual Operating Plans. The capacity of Twin Lakes (top of conservation pool) is 140,855 acre-feet. Although commonly reported together, the Twin Lakes contents shown herein do not include storage in the Mount Elbert Forebay.

- **Pueblo Reservoir -** Construction on Pueblo Reservoir was completed in 1975. Therefore, its full capacity was available for filling during the entire study period. Pueblo Reservoir filled for the first time during 1983, so the Reservoir has been fully operational for nearly the entire study period. Daily data was available from Reclamation's Hydromet system from water year 1983 through 2002. Monthly data was taken from the 1982-1983 AOP for water year 1982. The capacity of Pueblo Reservoir (top of conservation pool) is 256,949 acre-feet not including the dead pool, and 259,279 acre-feet including the dead pool.

Table 3-33. Historical Reservoir Contents - Fry-Ark Project Reservoirs

Month	Historical Mean Monthly Contents (ac-ft), 1982-2002		
	Turquoise Reservoir	Twin Lakes	Pueblo Reservoir
Capacity (1)	129,398	140,855	256,949
Oct	118,893	115,082	157,680
Nov	114,622	114,358	161,250
Dec	107,895	114,223	178,904
Jan	101,029	115,236	196,349
Feb	92,646	112,911	210,882
Mar	85,035	110,436	220,896
Apr	81,397	110,161	213,245
May	80,989	110,714	203,657
Jun	105,247	120,555	203,249
Jul	121,989	128,180	194,082
Aug	121,952	122,900	176,551
Sep	119,940	119,560	163,959
Average	104,303	116,193	190,059

Notes:

(1) Capacity is at the top of the conservation pool.

3.4.1.2 Colorado Canal System Reservoirs

Colorado Canal System reservoirs include Lake Henry and Lake Meredith. Both of these reservoirs are supplied by the Colorado Canal. The reservoirs contain separate water rights. However, water can be delivered from Lake Henry to Lake Meredith for release to the Arkansas River for exchanges. Therefore, these two reservoirs are commonly discussed as one reservoir. However, for the affected environment section of this report, their contents will be discussed separately in order to show physical contents in each reservoir. Historical monthly reservoir contents are shown in **Table 3-34**, while a brief summary of each reservoir is discussed in the following paragraphs.

- **Lake Henry -** Lake Henry is higher in elevation that Lake Meredith, but much smaller. Lake Henry also has a more senior water right than Lake Meredith, but limitations in canal capacity limit deliveries to the reservoir.

Periodic daily data from water year 1995 through 2002 is available from Reclamation's Hydromet system. Monthly data was available from the Colorado Canal system manager for the entire study period. To maintain consistency in the dataset, the Colorado Canal system data was used for the entire study period.

- **Lake Meredith -** Lake Meredith is lower in elevation, but much larger. All water released from the Colorado Canal system for exchanges flows through Lake Meredith. Periodic daily data from water year 1995 through 2002 is available from Reclamation's Hydromet system. Monthly data was available from the Colorado Canal system manager for the entire study period. To maintain consistency in the dataset, the Colorado Canal system data was used for the entire study period.

Table 3-34. Historical Reservoir Contents - Colorado Canal System Reservoirs

Month	Historical Mean Monthly Contents (ac-ft), 1982-2002	
	Lake Henry	Lake Meredith
Capacity (1)	8,961	39,804
Oct	3,795	18,376
Nov	3,492	19,328
Dec	3,518	21,240
Jan	3,636	23,512
Feb	4,853	26,248
Mar	6,540	28,726
Apr	6,910	29,004
May	6,605	28,197
Jun	6,316	28,047
Jul	5,864	26,120
Aug	5,225	22,670
Sep	4,487	19,711
Average	5,103	24,265

Notes:

(1) Capacity is at the top of the active conservation pool.

3.4.1.3 Holbrook Canal Reservoirs

The Holbrook Canal System reservoirs include Holbrook Reservoir and Dye Reservoir, which are part of the Holbrook agricultural irrigation system owned and operated by the Holbrook Irrigating Company (HIC). Water stored in the Holbrook system reservoirs is surface water originating from the Arkansas River that is diverted north of Manzanola into the Holbrook Canal. Historical contents are provided for Holbrook Reservoir and not for Dye Reservoir, because only Holbrook Reservoir has been used to date as part of the Restoration of Yield program described in **Section 3.2.3.8**.

Historical contents for Holbrook Reservoir were obtained from the NRCS National Water and Climate Center. Data from the NRCS was provided on a quarter-monthly to monthly basis for the period from 1987 to 2002. Estimates of daily and monthly contents were made for this report. Historical monthly contents for Holbrook Reservoir are provided in **Table 3-35**.

Table 3-35. Historical Reservoir Contents - Holbrook Reservoir

Month	Historical Monthly Contents (ac-ft) 1987-2002 (1)
	Holbrook Reservoir
Capacity (2)	6,200
Oct	1,372
Nov	1,627
Dec	2,387
Jan	3,807
Feb	4,910
Mar	5,732
Apr	5,563
May	4,864
Jun	4,614
Jul	3,141
Aug	2,081
Sep	1,486
Average	3,465

Notes

(1) Period of record used was 1987 to 2002 because data was unavailable from 1982 to 1986.

(2) Active capacity.

3.4.2 Historical Daily Reservoir Contents

As previously stated, when available, the original data collected for the reservoirs are daily data. Therefore, daily records were obtained and are available for the reservoirs discussed in the previous sub-sections. For purposes of brevity, two graphs are presented in the text of this report to summarize daily reservoir contents data: time series plot showing available historical data in the study period and a plot showing mean and median daily storage for the study period.

3.4.2.1 Turquoise Reservoir

A time series plot showing historical storage for Turquoise Reservoir is shown in **Figure 3-22**. Storage contents in Turquoise Reservoir had an annual variability, but the reservoir filled for most of the years in the study period. There was one year (water year 1998) when storage in Turquoise Reservoir exceeded conservation storage. Mean and median daily reservoir contents through the study period for Turquoise Reservoir are shown in **Figure 3-23**. Fry-Ark Project contents are generally drawn down through the winter months for two reasons: (1) to meet flow requirements at the Wellsville gage and (2) to make room for the following summer's transmountain imports through the Boustead Tunnel. In addition, water from non-Fry-Ark Project space, including Homestake space and CF&I space, is released for delivery through the Homestake pipeline. This is evident in the figure as storage space in Turquoise Reservoir is drawn down by about 40,000 acre-feet during the winter. Because the call on the Arkansas River is set to March 1, 1910, during the WWSP season, the CWCB in-stream flow rights are out of priority from November 15 through March 15 each year. However, past Reclamation operations have typically released 3 to 4 cfs in Lake Fork and 15 cfs in Lake Creek from Fry-Ark Project storage for piscatorial purposes. All native inflows during the WWSP season are stored in Turquoise and Twin Lakes reservoirs for the benefit of WWSP participants.

Figure 3-22. Historical Contents for Turquoise Reservoir for the Study Period

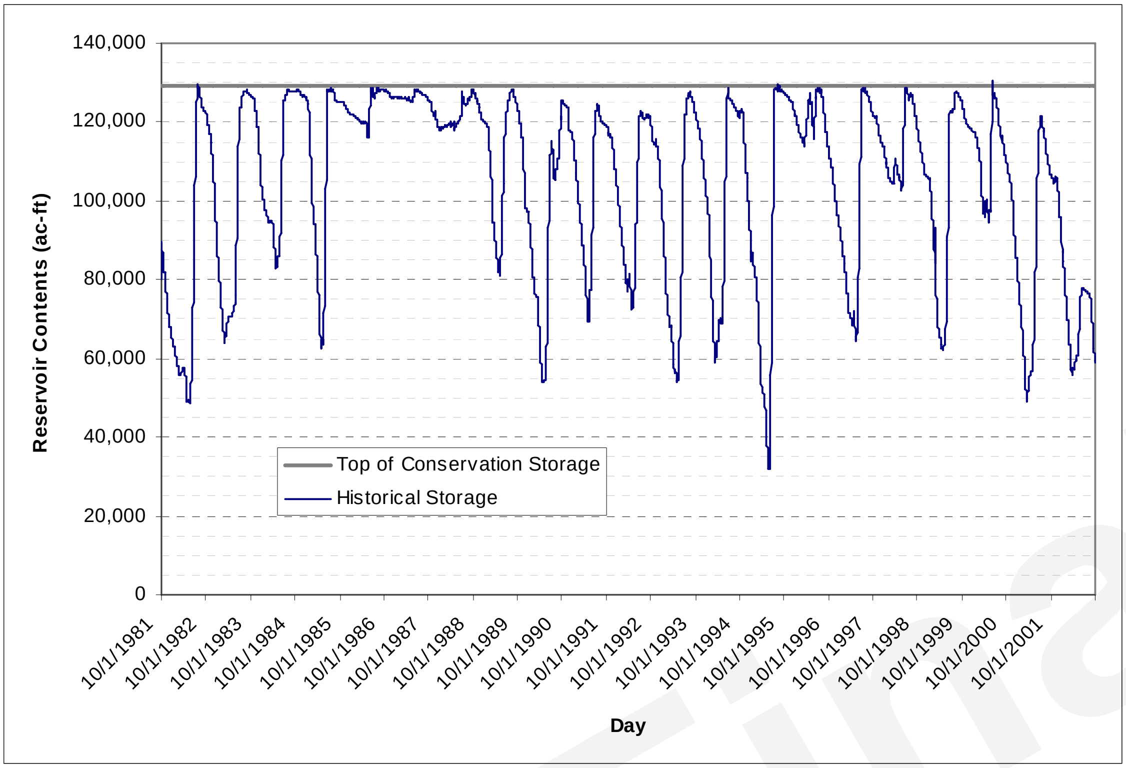
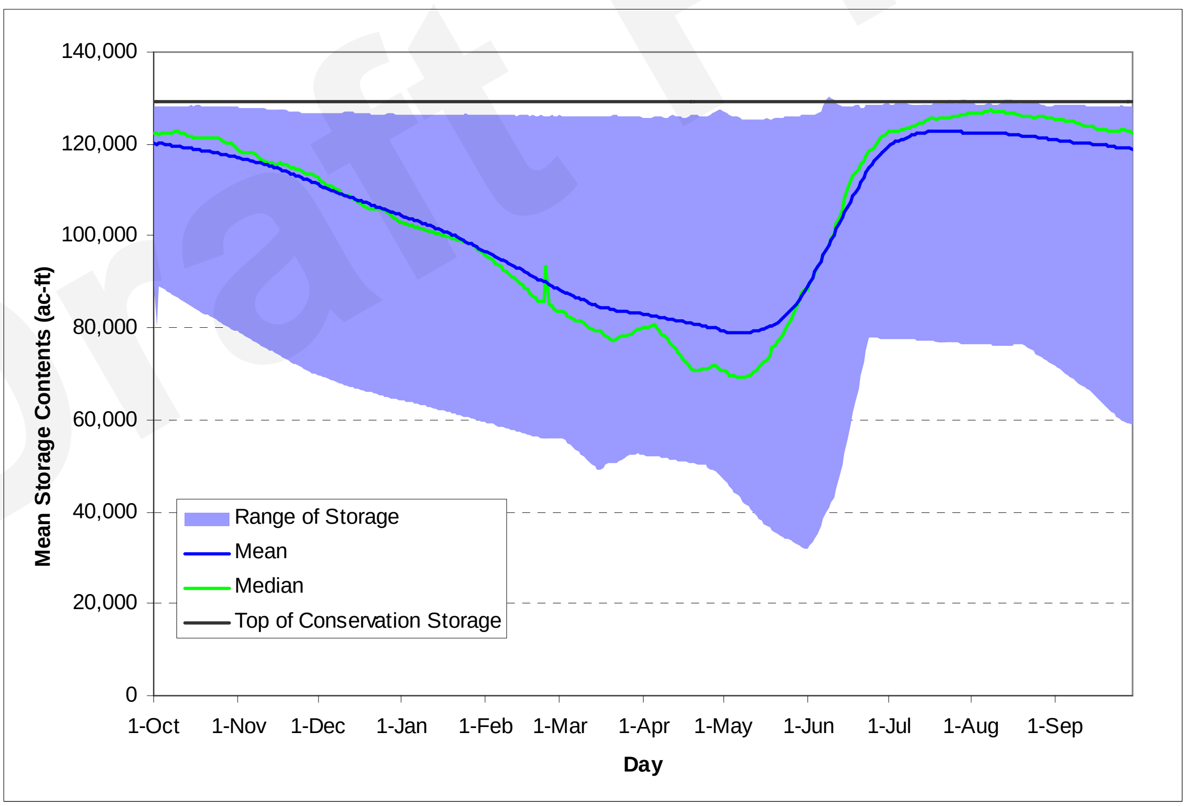


Figure 3-23. Turquoise Reservoir Daily Storage Summary for Study Period



3.4.2.2 *Twin Lakes Reservoir*

A time series plot showing historical storage for Twin Lakes Reservoir is shown in **Figure 3-24**. Storage contents in Twin Lakes Reservoir had an annual variability, but on average the reservoir contents ranged between about 75,000 acre-feet and the top of conservation storage throughout the study period. Twin Lakes Reservoir filled to within about 25,000 acre-feet of active capacity throughout the study period. Mean and median daily reservoir contents for Twin Lakes Reservoir are shown in **Figure 3-25**. As previously mentioned, although commonly reported together, the Twin Lakes contents shown herein do not include storage in the Mount Elbert Forebay. As shown, average daily contents at Twin Lakes are less variable than those for Turquoise Reservoir. However, Twin Lakes is the tailwater reservoir for the Mount Elbert Pump-Storage Project. Therefore, from day-to-day, there can be changes in reservoir contents of several thousand acre-feet.

Figure 3-24. Historical Contents for Twin Lakes Reservoir during the Study Period

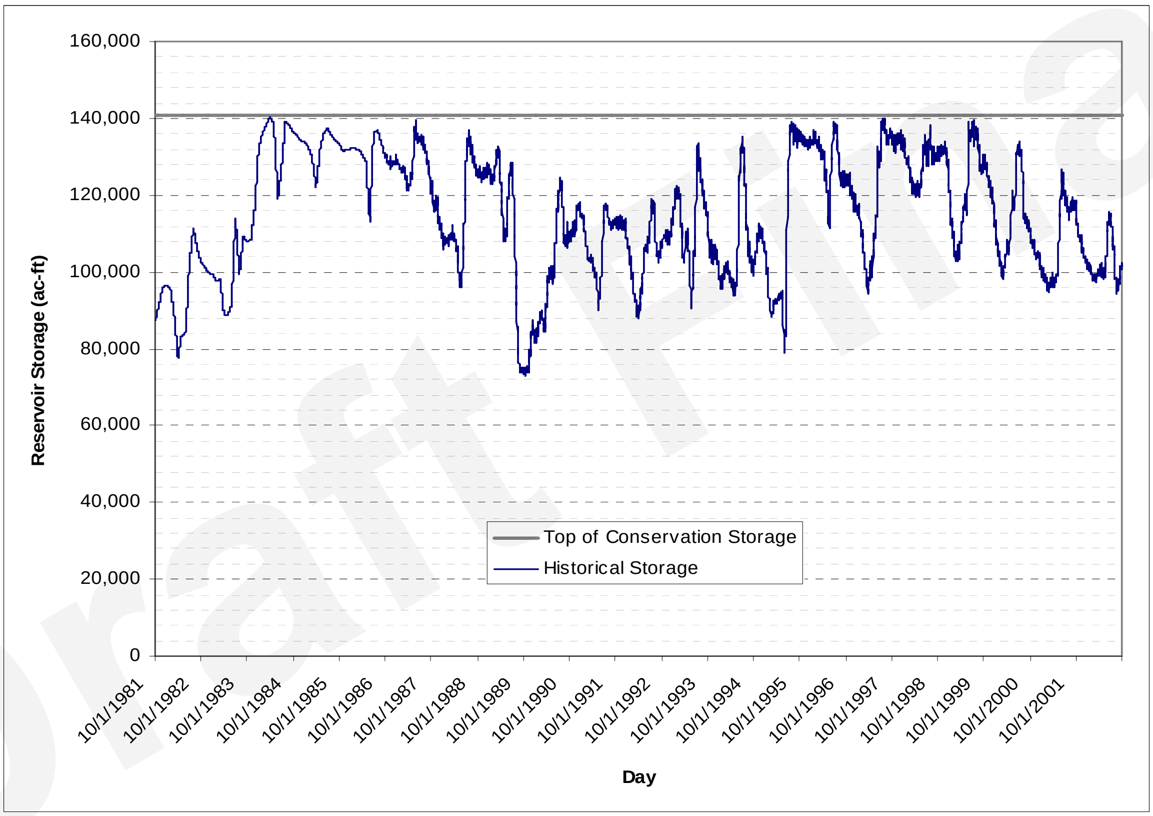
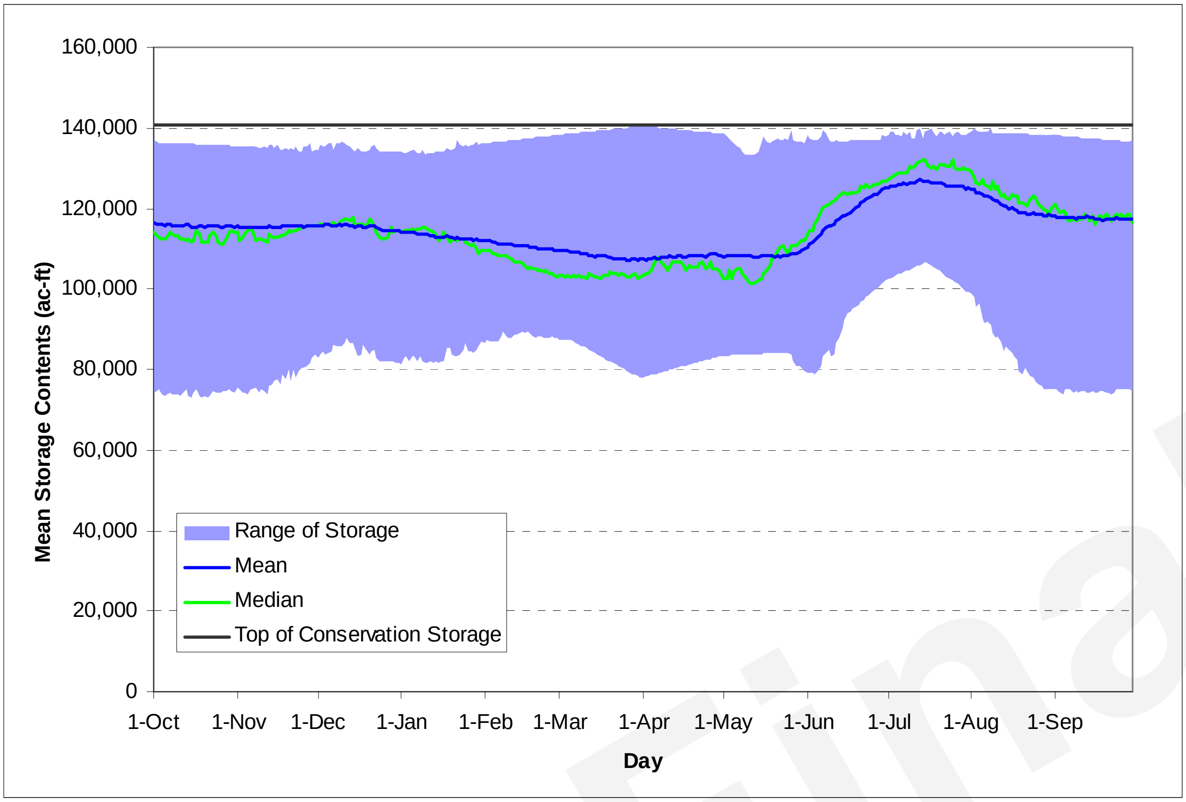


Figure 3-25. Twin Lakes Daily Storage Summary for Study Period



As shown, there are times when storage is above the top of the conservation pool. This typically occurs when water is stored for flood control reasons.

3.4.2.3 Pueblo Reservoir

A time series plot showing historical storage for Pueblo Reservoir is shown in **Figure 3-26**. Pueblo Reservoir contents were relatively high in the 1980s and for some years from 1995 to 1999. The effects of drought on Pueblo Reservoir contents are seen in the figure as contents declined starting in 2000. Storage in Pueblo Reservoir's joint use pool occurred for several years during the study period. Mean and median daily reservoir contents through the study period for Pueblo Reservoir are shown in **Figure 3-27**. Pueblo Reservoir stores water during the winter months as part of the WWSP. Typically, Pueblo Reservoir stores between 30,000 and 50,000 acre-feet per year of WWSP water, with a few years outside of this range (GEI, 1998). A decline in reservoir contents through the summer months reflects the delivery of both Fry-Ark Project water and WWSP water from the reservoir to meet late season agricultural and municipal demands.

Figure 3-26. Historical Contents for Pueblo Reservoir during the Study Period

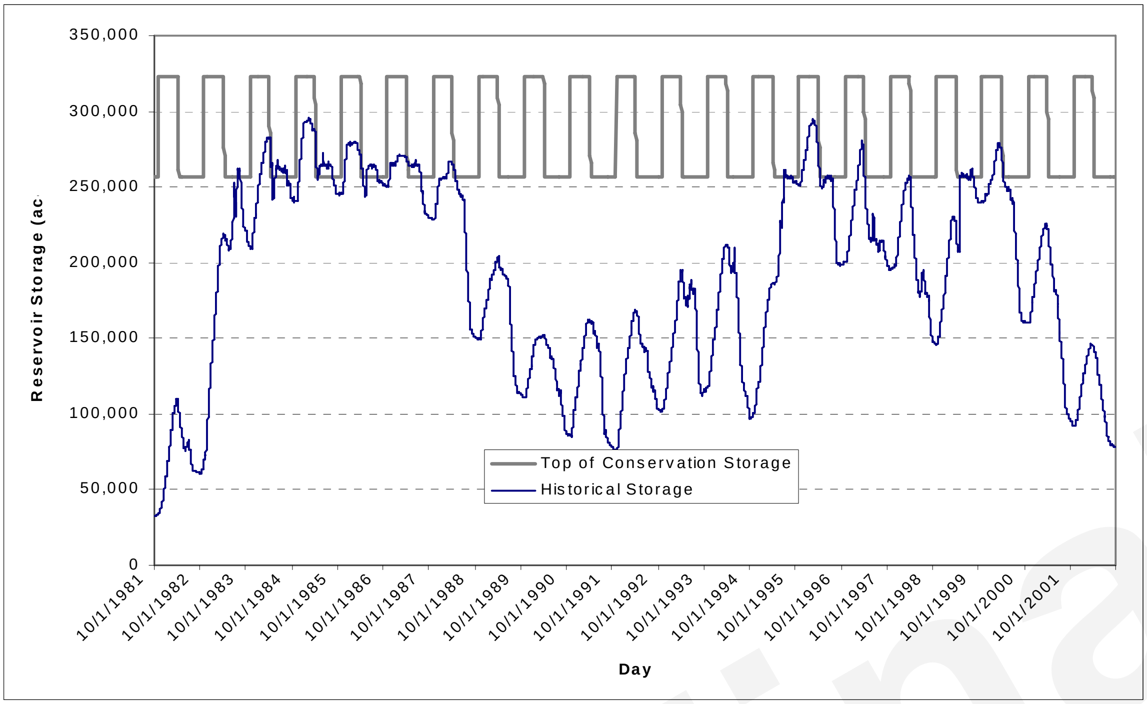
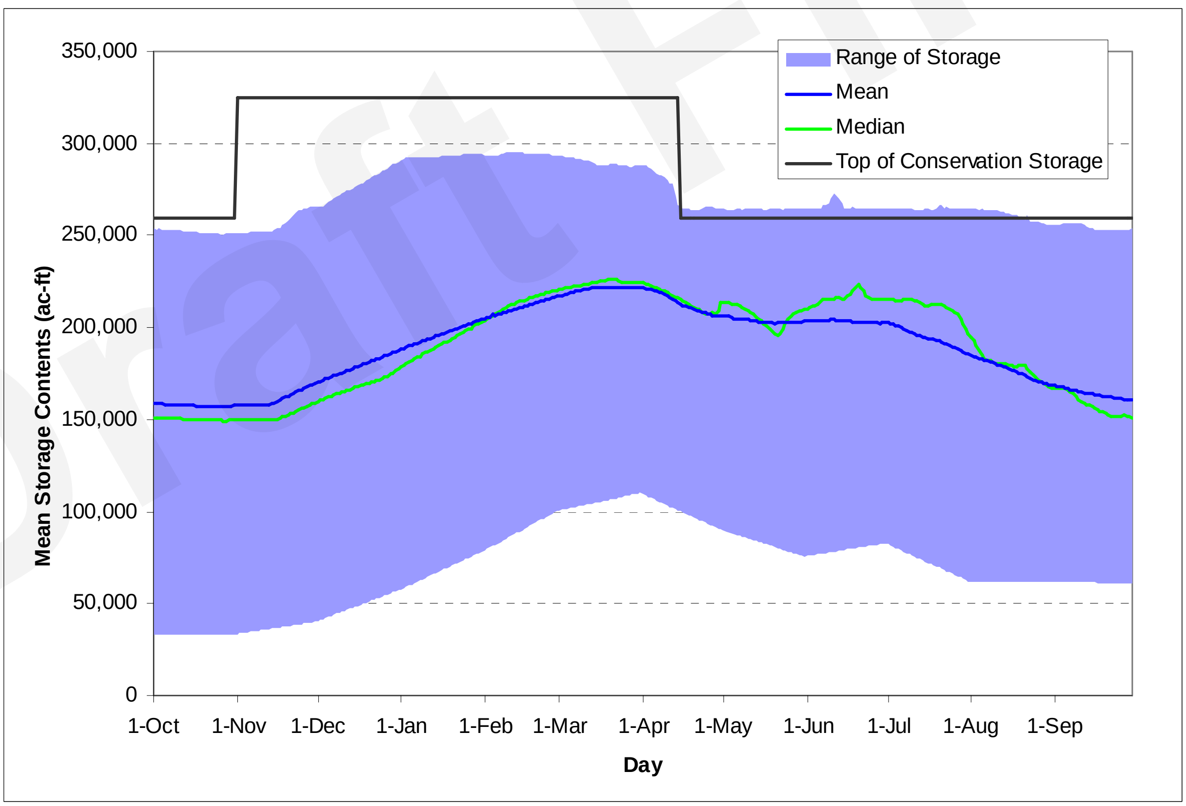


Figure 3-27. Pueblo Reservoir Daily Storage Summary for Study Period

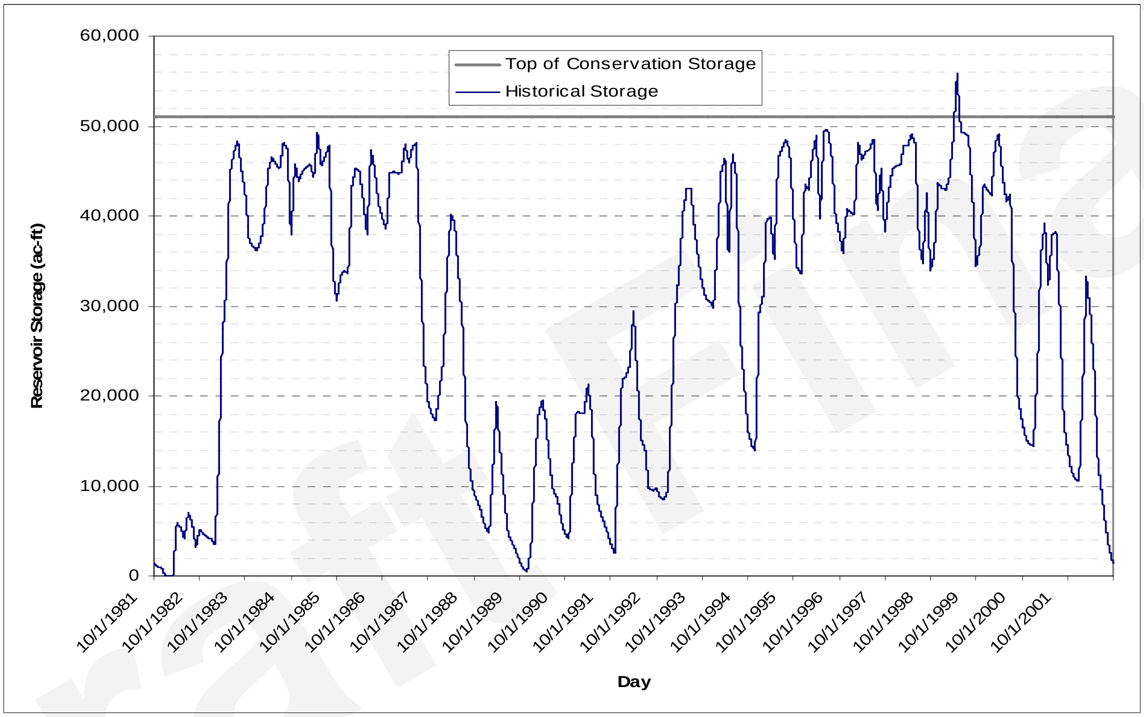


As shown, there are times when storage is above the top of the conservation pool. This typically occurs when water is stored for flood control reasons.

3.4.2.4 Lake Henry and Lake Meredith

A time series plot showing historical storage for the sum of Lake Henry and Lake Meredith contents is shown in **Figure 3-28**. Annual variations are seen in the Lake Henry and Lake Meredith contents plot. Total Lake Henry and Lake Meredith contents were near the top of the conservation storage during the study period, except for the dry periods in the early 1990s and the drought beginning in 2002.

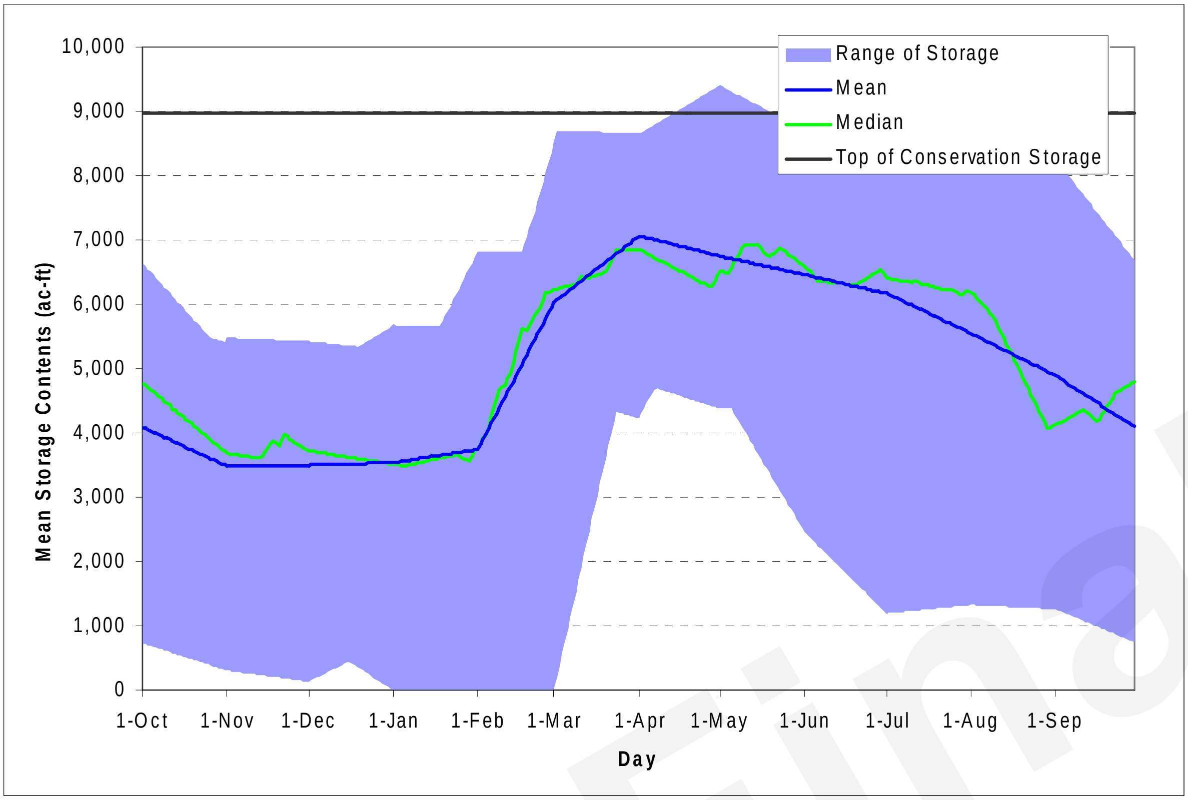
Figure 3-28. Historical Contents for Lake Henry and Lake Meredith for the Study Period



Lake Henry

Figure 3-29 presents daily summary information for Lake Henry. As shown, annual patterns for filling and drawing down Lake Henry are much more consistent than those for Lake Meredith, as shown in the following sub-section. Most filling of Lake Henry comes in the early spring months, partially as part of the WWSP and partially due to the water rights being in priority before most of the major water rights in the basin are diverting.

Figure 3-29. Lake Henry Daily Storage Summary for Study Period

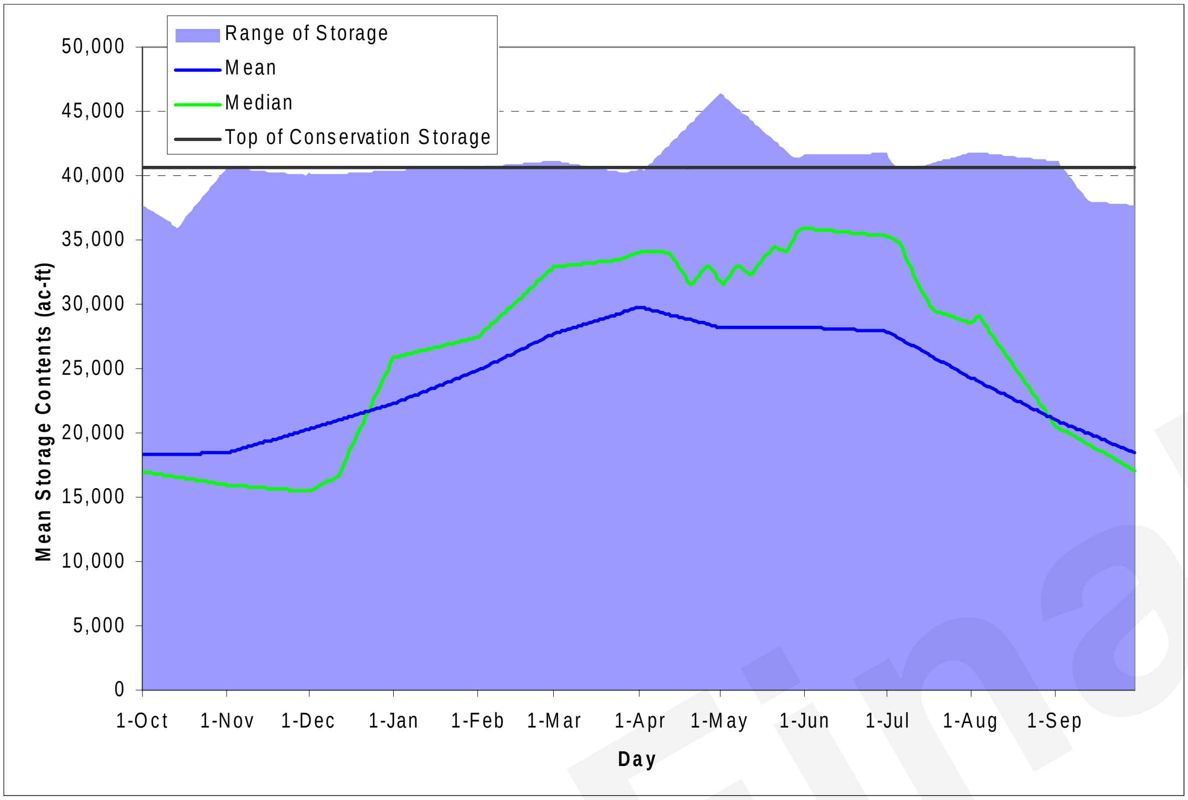


As shown, there are times when storage is above the top of the conservation pool. This typically occurs when water is stored for flood control reasons.

Lake Meredith

Mean and median daily reservoir contents through the study period for Lake Meredith are shown in **Figure 3-30**. As shown, storage contents in Lake Meredith have historically varied over its entire range of available storage space nearly every day during the year. The median values are higher than the mean values during the spring and summer months, indicating that a few years with very little storage in the reservoir are reducing the calculated average storage contents.

Figure 3-30. Lake Meredith Daily Storage Summary for Study Period



As shown, there are times when storage is above the top of the conservation pool. This typically occurs when water is stored for flood control reasons.

3.4.2.5 Holbrook Reservoir

A time series plot showing historical storage for Holbrook Reservoir contents for water years 1988 to 2002 is shown in **Figure 3-31**. Storage contents data for Holbrook Reservoir prior to water year 1988 were not available. Holbrook Reservoir typically fills with Winter Water during the winter, and during wet years, native streamflow contributes to Holbrook Reservoir contents throughout the winter and spring. The reservoir typically empties each year in the later summer or fall. Mean and median daily reservoir contents for the period from 1987 to 2002 for Holbrook Reservoir are shown in **Figure 3-32**. As previously described, the 1987 to 2002 period was used, because data was unavailable from the NRCS for the 1982 to 1986 period. As shown, storage contents in Holbrook Reservoir have historically varied during the fall and winter, with less variation during the spring and summer months. Mean storage contents are higher than median contents during the fall, indicating that a few years with higher storage result in high mean storage contents.

Figure 3-31. Historical Contents for Holbrook Reservoir during the Study Period

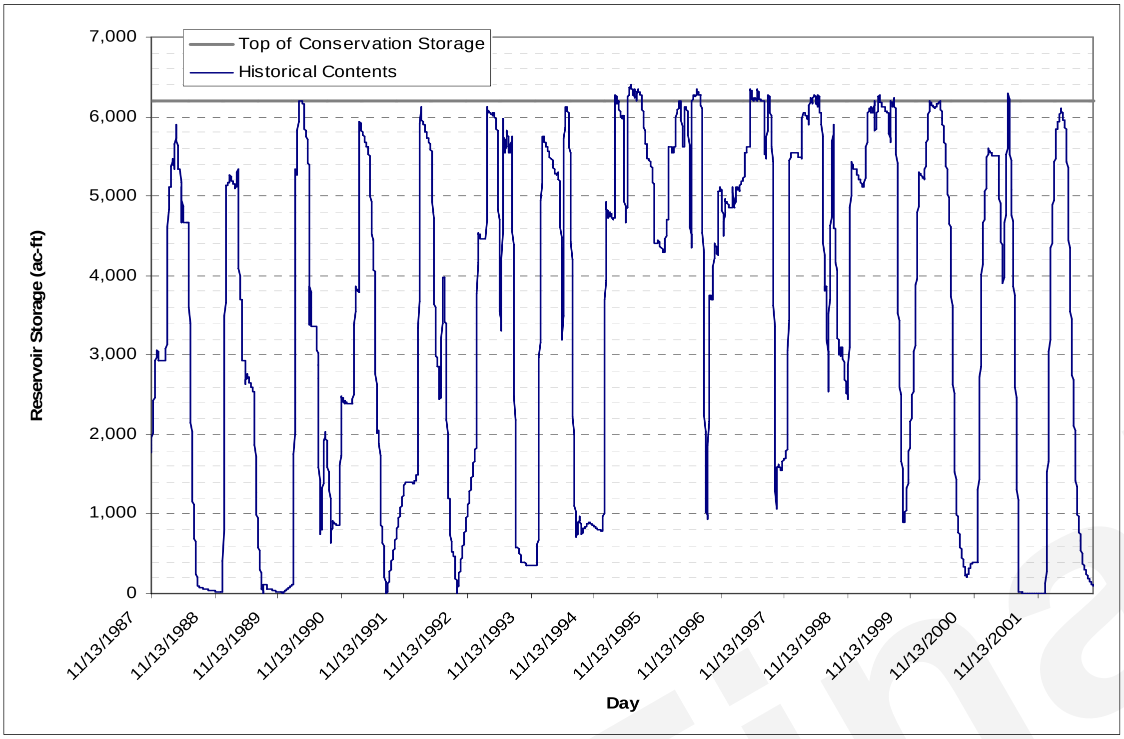
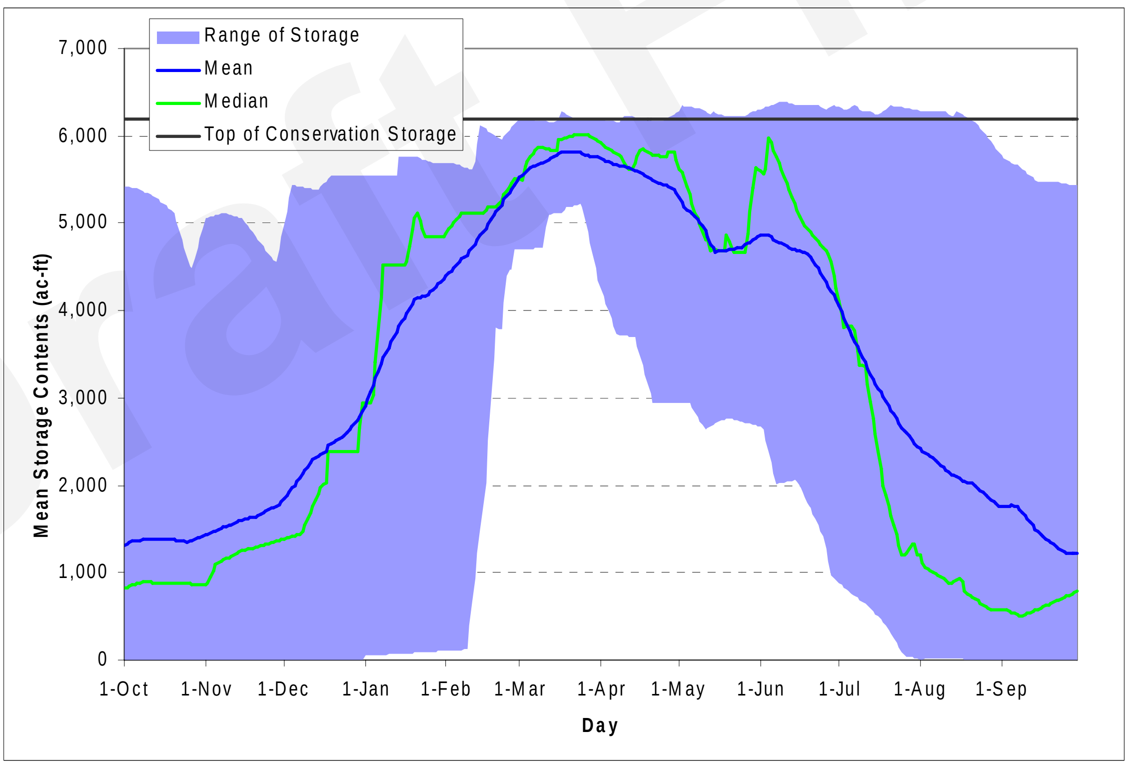


Figure 3-32. Holbrook Reservoir Daily Storage Summary for Study Period



3.5 Stream Hydraulics and Geomorphology

Any effects on streamflows would also have an effect on channel hydraulics and geomorphology. Geomorphology is a branch of geology that explains features found and processes operating on the surface of the Earth. Hydraulics and geomorphology are closely related, as changes in hydraulic parameters such as flow distribution can have impacts on overall stream geomorphology. This section presents a summary of existing hydraulic parameters and geomorphologic parameters in the study area.

3.5.1 Hydraulics

Historical river stages were determined based on historical streamflow data presented in **Section 3.3** and stream gage rating curves provided by the USGS and CDWR. Hydraulic conditions were assessed at streamgage locations throughout the study area, except for Lake Fork Creek. Hydraulic conditions for Lake Fork Creek were reported for a location about 7,800 feet downstream of Sugarloaf Dam, because the Lake Fork below Sugarloaf dam streamgage is located in a Parshall flume and does not represent natural stream conditions.

Stream gage rating curves were provided by the USGS and Colorado DWR for locations throughout the study area, except for Lake Fork Creek. The rating curve for Lake Fork Creek was developed from channel properties determined during field observations and cross-section data based on USGS 1:24,000 topographic maps.

Daily mean streamflow was used to interpolate daily mean river stage from the rating curves. Daily river stages for each month were averaged to calculate monthly mean stage. Monthly stages are provided in tabular form in **Section 3.5.1.1**, and daily stages are provided in graphical format in **Section 3.5.1.2**.

River stages are reported on a relative basis in relation to an arbitrary datum and are not necessarily equal to flow depth. Stages are based on channel cross section data collected by the USGS and Colorado DWR, which do not provide the elevation of the datum used. Stages presented in this report will be used to estimate changes in flow depth from the Proposed Action and No Action Alternative and are not absolute flow depth or water surface elevations.

3.5.1.1 Historical Monthly River Stages

Historical monthly river stages were developed from daily data by averaging the daily stage for each day during the month. Monthly stages are presented by region along the Arkansas River: the Headwaters to Salida, Salida to Pueblo Reservoir, Pueblo Reservoir to Fowler, and Fowler to the La Junta gage regions.

Arkansas River - Headwaters to Salida

The average monthly stage for the Arkansas River at USGS stream gages from the headwaters to Salida for the 1982-2002 study period is shown in **Table 3-36** and **Table 3-37**.

Table 3-36. Historical Mean Monthly River Stage - Arkansas River from Headwaters to Granite

Month	Historical Mean River Stage (ft), 1982 - 2002		
	Lake Fork Creek, 7,800' Downstream of Sugar Loaf Dam (1)	Arkansas River Near Malta, Co. (07083700) (2)	Lake Creek Below Twin Lakes Reservoir (LAKBTLCO) (3)
Oct	1.29	2.18	0.53
Nov	1.25	2.04	0.54
Dec	1.21	1.95	0.76
Jan	1.21	1.97	0.93
Feb	1.22	2.01	0.98
Mar	1.25	1.97	0.96
Apr	1.43	2.03	0.89
May	1.78	2.64	2.06
Jun	2.11	3.61	3.02
Jul	2.17	3.58	2.45
Aug	1.73	3.02	1.63
Sep	1.38	2.45	0.71
Avg	1.50	1.47	1.29

Notes:
(1) Data missing for water year 1991.
(2) Period-of-Record: 1982-1984.
(3) Data missing for water years 1985 and 1991-1992.

Table 3-37. Historical Mean Monthly River Stage - Arkansas River from Granite to Salida

Month	Historical Mean Monthly Streamflow (cfs), 1982 - 2002			
	Arkansas River At Granite (07086000)	Arkansas River Near Nathrop (07091200) (1)	Arkansas River At Salida (07091500)	Arkansas River Near Wellsville (07093700) (2)
Oct	2.57	3.78	2.99	3.49
Nov	2.54	3.72	2.98	3.56
Dec	2.59	3.61	2.94	3.51
Jan	2.65	3.76	2.94	3.48
Feb	2.70	3.85	2.92	3.47
Mar	2.72	3.72	2.92	3.44
Apr	2.80	3.82	2.93	3.42
May	3.72	4.84	3.75	4.50
Jun	4.54	6.02	4.65	5.77
Jul	3.98	5.26	4.13	4.99
Aug	3.31	4.60	3.57	4.26
Sep	2.67	3.90	3.05	3.57
Avg	3.07	4.43	3.32	3.96

Notes:
(1) No data 1983-1989. March through October data only 1994-2002.
(2) No data for a short period in September of 1989.

Arkansas River - Salida to Pueblo Reservoir

The average monthly stage for the Canyon City and Portland gages for the 1982-2002 study period is shown in **Table 3-38**.

Table 3-38. Historical Mean Monthly River Stage - Arkansas River from Salida to Pueblo Reservoir

Month	Historical Mean Monthly River Stage (ft), 1982 - 2002	
	Arkansas River At Canyon City (07096000)	Arkansas River At Portland (07097000)
Oct	5.57	1.93
Nov	5.67	2.01
Dec	5.70	1.94
Jan	5.70	1.92
Feb	5.70	1.91
Mar	5.73	1.95
Apr	5.67	1.98
May	6.56	3.16
Jun	7.83	4.51
Jul	7.00	3.57
Aug	6.29	2.77
Sep	5.63	1.97
Avg	6.09	2.47

Arkansas River - Pueblo Reservoir to Fowler

The average monthly stage for the gages from Pueblo Reservoir to Avondale for the 1982-2002 study period is shown in **Table 3-39**.

Table 3-39. Historical Mean Monthly River Stage - Arkansas River from Pueblo Reservoir to Fowler

Month	Historical Mean Monthly River Stage (ft), 1982 - 2002		
	Arkansas River Above Pueblo (07099400)	Arkansas River At Moffat Street At Pueblo (07099970) (1)	Arkansas River Near Avondale (07109500)
Oct	2.74	8.42	1.66
Nov	2.39	8.24	1.55
Dec	2.08	7.83	1.32
Jan	2.16	7.84	1.38
Feb	2.29	8.04	1.45
Mar	2.67	8.55	1.70
Apr	3.29	9.08	2.10
May	4.10	9.73	2.09
Jun	5.35	10.53	1.69
Jul	4.66	10.09	2.48
Aug	3.91	9.51	2.45
Sep	2.89	8.55	1.79
Avg	3.22	8.87	1.81

Notes:

(1) Period-of-Record: 1989-2002

Arkansas River - Fowler to La Junta

The average monthly stage for the gages from Fowler to La Junta for the 1982-2002 study period is shown in **Table 3-40**.

Table 3-40. Historical Mean Monthly River Stage - Fowler to La Junta

Month	Historical Mean Monthly River Stage (ft), 1982 - 2002		
	Arkansas River At Catlin Dam Near Fowler (07119700)	Arkansas River Near Rocky Ford (ARKROCCO) (1)	Arkansas River At La Junta (07123000)
Oct	2.32	1.74	6.18
Nov	2.50	1.86	6.10
Dec	2.45	1.58	6.15
Jan	2.48	1.57	6.26
Feb	2.40	1.47	6.24
Mar	2.35	1.68	6.03
Apr	2.59	2.04	6.02
May	3.44	2.25	6.72
Jun	4.23	2.21	7.31
Jul	3.45	1.95	6.75
Aug	3.07	1.90	6.46
Sep	2.32	1.49	6.06
Avg	2.80	1.81	6.36

Notes:

(1) Period-of-Record: 2000-2002.

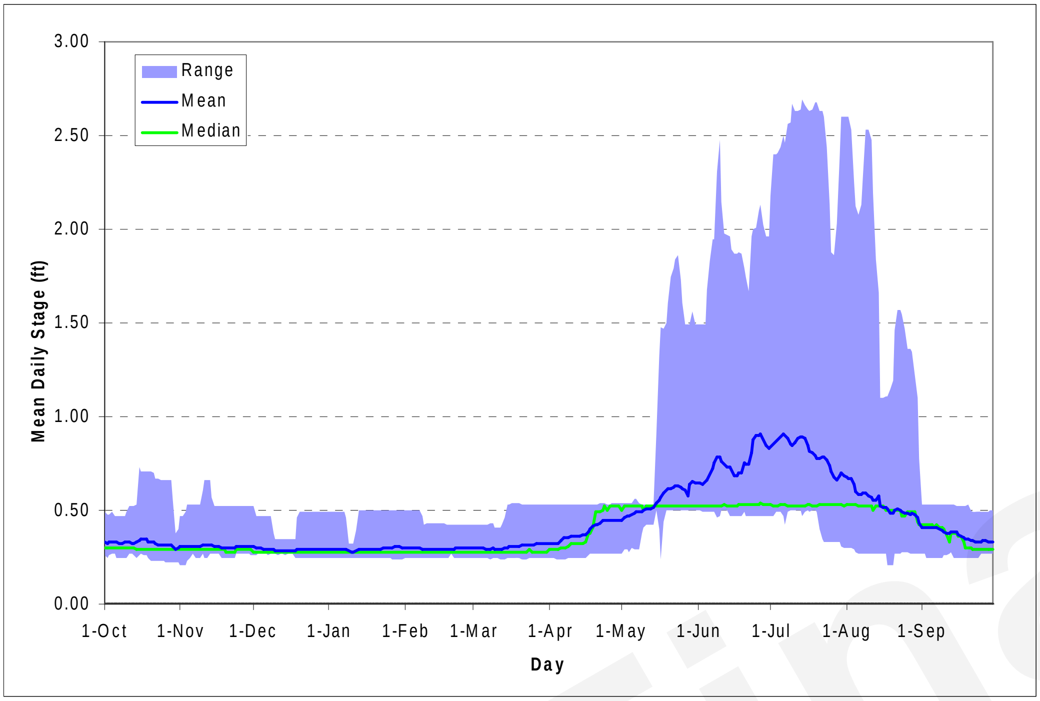
3.5.1.2 Historical Daily River Stage

Daily mean streamflows, presented in **Section 3.3**, were used to interpolate daily mean river stage from the rating curves obtained from the USGS and CDWR, except for the Lake Fork Creek location as noted above. Daily stages are graphically presented for the location on Lake Fork Creek as discussed above, and for the following gages: Lake Creek below Twin Lakes, Arkansas River near Wellsville, Arkansas River above Pueblo, Arkansas River near Avondale, Arkansas River at La Junta.

Lake Fork Gage Daily River Stage

The average daily stage for the location on Lake Fork about 7,800 feet downstream of the Sugarloaf Dam is shown in **Figure 3-33**.

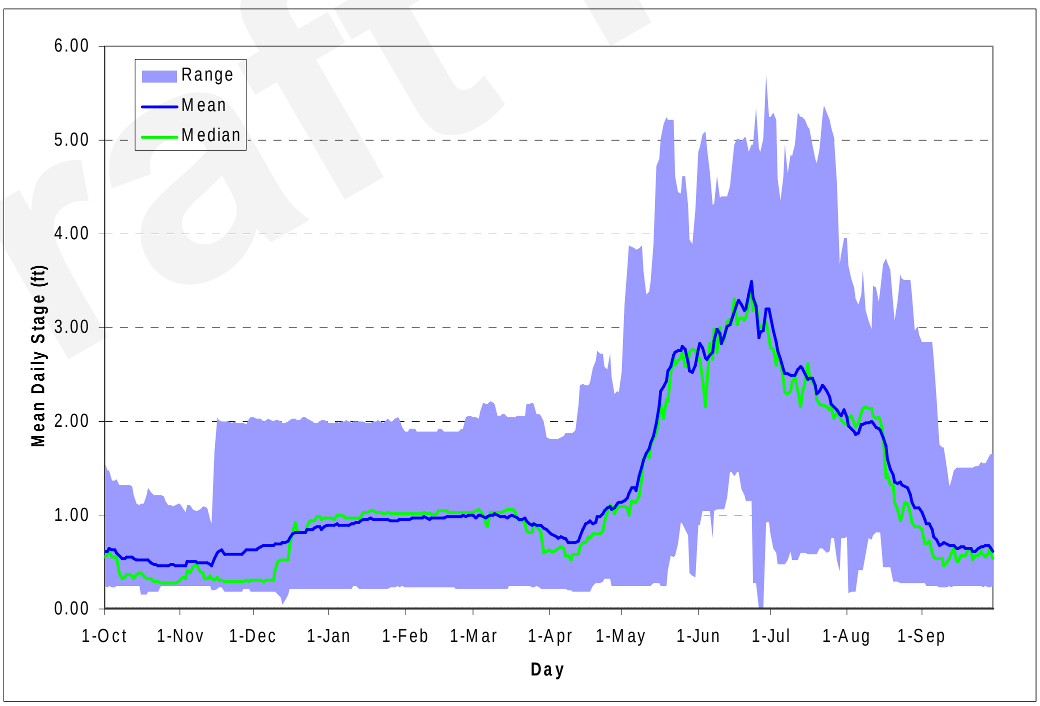
Figure 3-33. Lake Fork Gage Daily River Stage Summary for Study Period (7,800 feet downstream of Sugarloaf Dam)



Lake Creek Gage Daily River Stage

The average daily stage for the Lake Creek below Twin Lakes gage is shown in **Figure 3-34**.

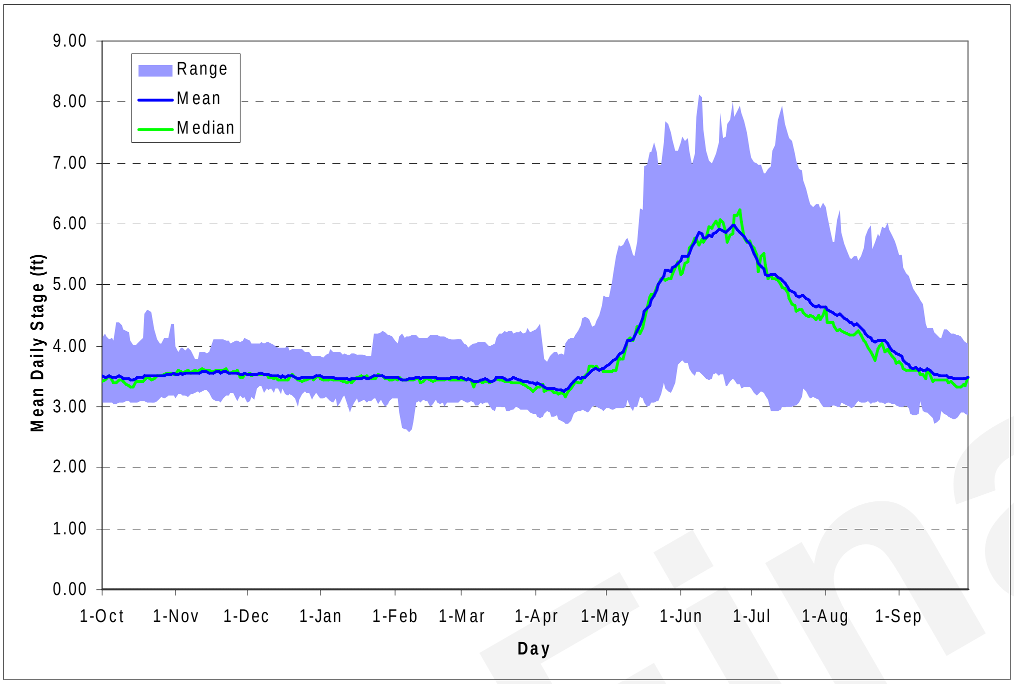
Figure 3-34. Lake Creek Gage Daily River Stage Summary for Study Period



Wellsville Gage Daily River Stage

The average daily stage for the Arkansas River near Wellsville gage is shown in **Figure 3-35**.

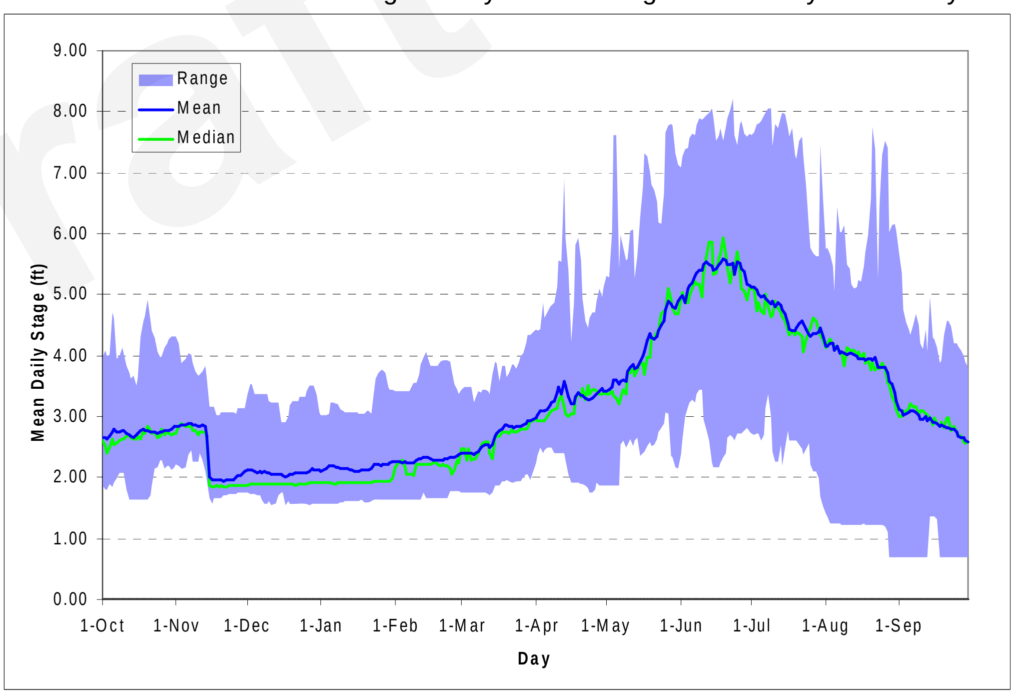
Figure 3-35. Wellsville Daily River Stage Summary for Study Period



Above Pueblo Gage Daily River Stage

The average daily stage for the Arkansas River Above Pueblo gage is shown in **Figure 3-36**.

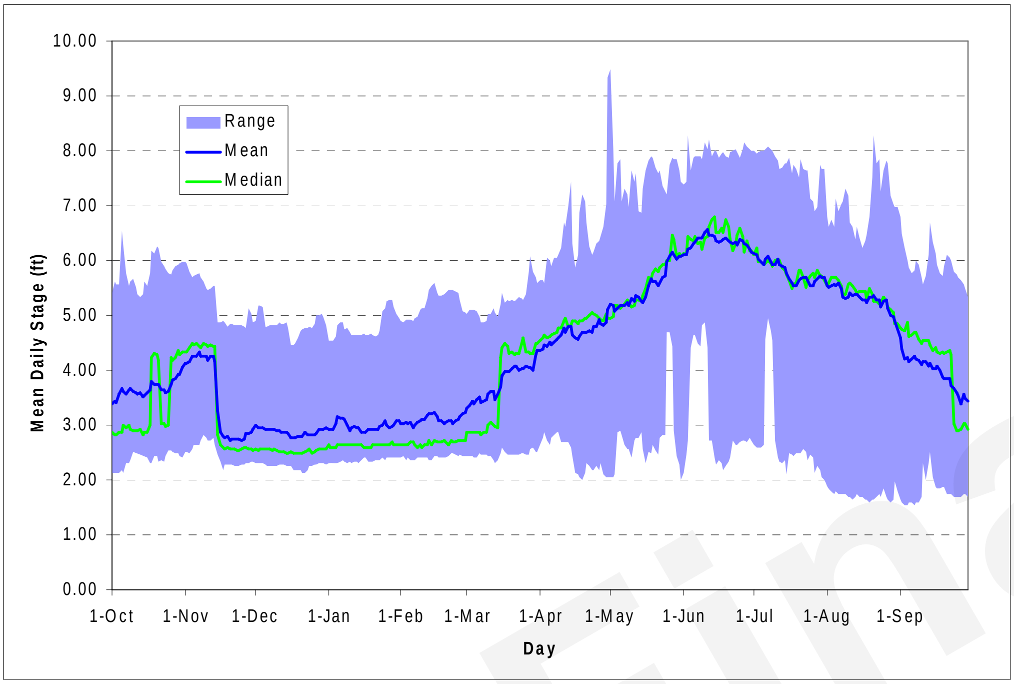
Figure 3-36. Above Pueblo Gage Daily River Stage Summary for Study Period



Avondale Gage Daily River Stage

The average daily stage for the Arkansas River near Avondale gage is shown in **Figure 3-37**.

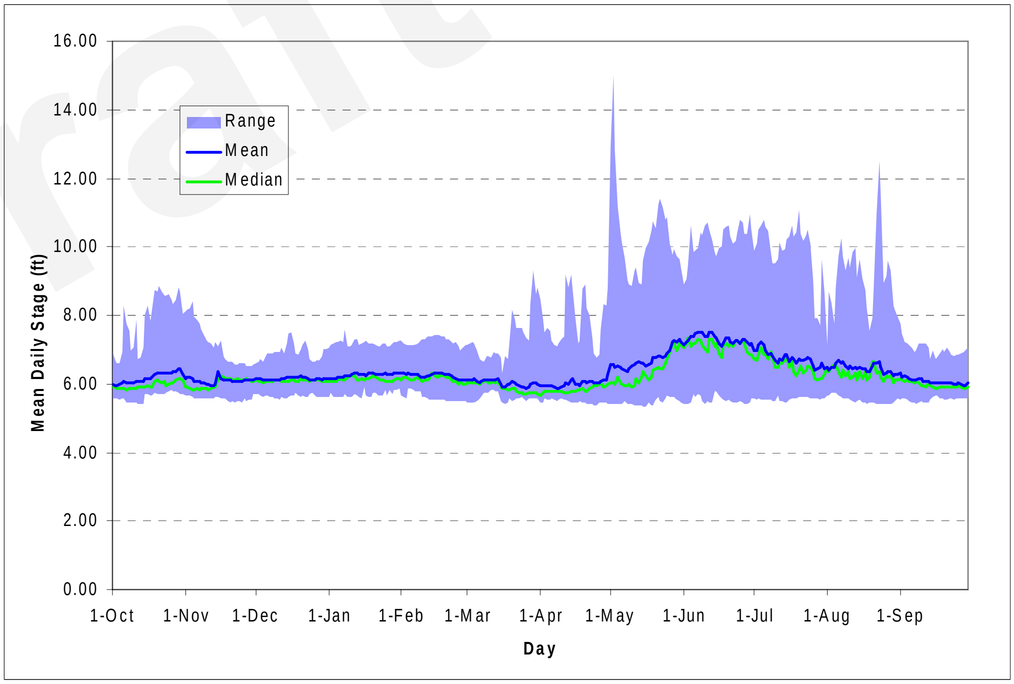
Figure 3-37. Avondale Gage Daily River Stage Summary for Study Period



La Junta Gage Daily River Stage

The average daily stage for the Arkansas River at La Junta gage is shown in **Figure 3-38**.

Figure 3-38. La Junta Gage Daily River Stage Summary for Study Period



3.5.2 Geomorphology

An analysis was conducted to document the existing stream morphology of Lake Fork Creek and the Arkansas River in the potentially affected area for the project. Stream classification and a comparison of historical versus recent aerial photographs provided a means for assessing and summarizing the river morphology in the study area.

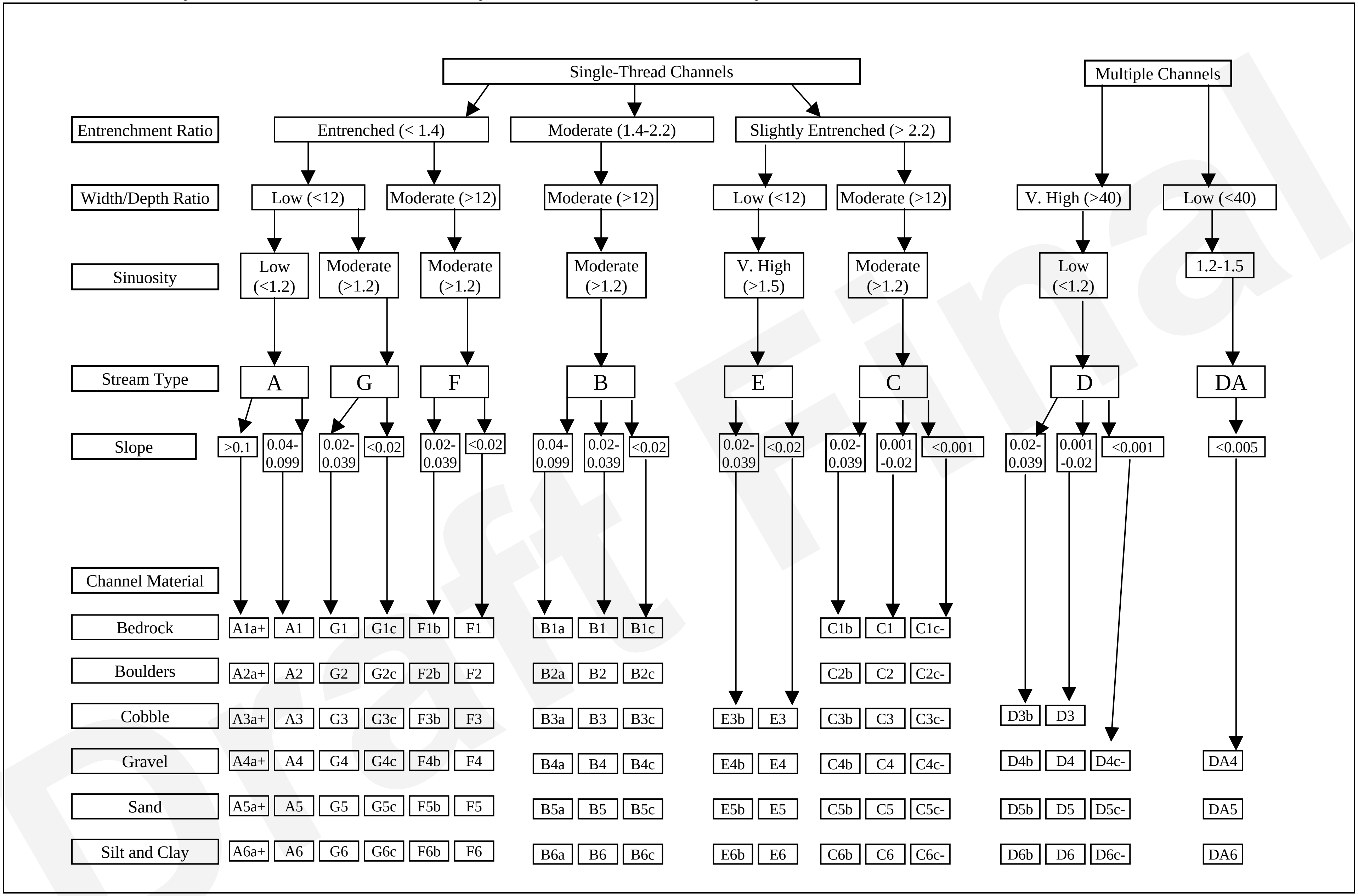
3.5.2.1 Stream Classification

Stream classification for the Arkansas River was completed using a classification scheme developed by Rosgen (1996). The hierarchical river classification scheme developed by Rosgen is comprised of four inventory levels starting with a broad geomorphic characterization and becoming more complex with each level down to detailed site-specific description. Level I and Level II of the Rosgen classification system were used for this cursory investigation into the morphology of the Arkansas River. In Level I of the classification scheme - “geomorphic characterization” - stream segments are grouped into eight stream types based on channel slope, channel shape, and channel patterns. These eight stream types are described briefly as follows.

- Type A: Single-thread, entrenched channels with low width/depth ratio and low sinuosity.
- Type B: Single-thread, moderately entrenched channels with moderate width/depth ratio and moderate sinuosity.
- Type C: Single-thread, slightly entrenched channels with moderate width/depth ratio and moderate sinuosity.
- Type D: Multiple-channels with very high width/depth ratio and low sinuosity.
- Type DA: Multiple-channels with low width/depth ratio and moderate sinuosity.
- Type E: Single-thread, slightly entrenched channels with low width/depth ratio and very high sinuosity.
- Type F: Single-thread, entrenched channels with moderate width/depth ratio and moderate sinuosity.
- Type G: Single-thread, entrenched channels with low width/depth ratio and moderate sinuosity.

Level II classification is based on morphological descriptions of stream segments considering factors such as entrenchment ratio, width/depth ratio, sinuosity, channel slope, and channel materials. **Figure 3-39** provides details on parameters and stream types used in Level I and Level II of the Rosgen classification scheme (Rosgen, 1996).

Figure 3-39. Flowchart Showing Levels I and II of the Rosgen Stream Classification of Natural Rivers



The parameters used in the Rosgen classification scheme were estimated for the affected stream segments using topographic maps, aerial photographs, and field reconnaissance. Digital orthophoto quarter quadrangle (DOQQ) county mosaic aerial photographs, taken between 1988 and present, were obtained from the National Resources Conservation Service (NRCS). United States Geological Survey digital raster graphics (DRG) topographic maps (scale 1:24,000) were acquired from the CDWR. Stream characteristics were determined by analyzing the aerial photographs and topographic maps using ArcView GIS. The type of channel materials in stream segments used for Level II classification was based on field observations taken during the spring of 2004.

The potential response and recovery potential of each classified stream segment resulting from disturbances such as changes in streamflow were estimated using methods in Rosgen (1996). Five factors from the Rosgen classification scheme were considered in the analysis of the response and recovery of each segment: sensitivity to disturbance, recovery potential, streambank erosion potential, sediment supply, and vegetation controlling influence. Disturbances considered include changes in streamflow magnitude and timing and sediment increases. Recovery potential assumes natural recovery once the cause of instability is corrected. Sediment supply includes suspended load and bedload from channel derived sources and from stream adjacent slopes. Vegetation controlling influence is vegetation that influences the stability of the width to depth ratio.

The possible effects of changes in streamflow as a result of project alternatives were evaluated based on the classification of each stream segment. The stream classification and the response and recovery potential of the Arkansas River are discussed by reach below.

Lake Fork Creek

Stream classification of Lake Fork Creek between Turquoise Reservoir and the Arkansas River confluence resulted in two distinct geomorphic reaches. The reaches were both single-thread, slightly entrenched sections with high sinuosity and low to moderate channel slope. The upstream reach LF-1 has a low width to depth ratio and cobble streambed material (E3). The downstream reach LF-2 has a moderate width to depth ratio with cobble streambed material (C3). Reach locations are shown in **Figure 3-40**. Representative aerial photographs for each section are shown in **Figure 3-41** and **Figure 3-42**. Flows in Lake Fork Creek are highly regulated by releases from Turquoise Reservoir.

Lake Creek

Stream classification of Lake Creek between Twin Lakes Reservoir and the Arkansas River confluence resulted in one geomorphic reach. The reach was a single-thread, moderately entrenched section with moderate sinuosity and low channel slope. The reach has a moderate width to depth ratio and cobble streambed material and was classified as a B3c stream using the Rosgen classification. A representative aerial photograph of the reach is shown in **Figure 3-43**. Flows in Lake Creek are highly regulated by releases from Twin Lakes Reservoir.

Upper Arkansas River (Leadville to Pueblo Reservoir)

Stream classification analysis of the upper Arkansas River from Leadville to Pueblo Reservoir resulted in six distinct geomorphic reaches. The unique reaches ranged from multiple channels with gravel streambed material (DA4) to single thread channels with bedrock streambed material (B1c). **Figure 3-40** shows the location and class of the stream sections.

The six classified sections of the Upper Arkansas River have unique potential responses based on the stream type of each section. Representative aerial photographs for each section are shown in **Figure 3-44** through **Figure 3-49**.

Table 3-41 provides predictions of responses and recovery potential for both of the Lake Fork Creek sections and each of the Upper Arkansas River sections based on stream type.

Table 3-41. Response of Upper Arkansas River, Lake Fork (LF), and Lake Creek (LC) to Potential Disturbances

Section	Stream Type	Sensitivity to Disturbance	Recovery Potential	Streambank Erosion Potential	Sediment Supply	Vegetation Controlling Influence
LF-1	E3	High	Good	Moderate	Low	Very High
LF-2	C3	Moderate	Good	Moderate	Moderate	Very High
LC	B3c	Low	Excellent	Low	Low	Moderate
1	DA4	Moderate	Good	Low	Very Low	Very High
2	B3c	Low	Excellent	Low	Low	Moderate
3	B2c	Very Low	Excellent	Very Low	Very Low	Negligible
4	B3c	Low	Excellent	Low	Low	Moderate
5	B1c	Very Low	Excellent	Very Low	Very Low	Negligible
6	B4c	Moderate	Excellent	Low	Moderate	Moderate

The two Lake Fork Creek segments in the study area have moderate to high sensitivity to changes in streamflow, with good recovery potential. The Lake Creek segment in the study area has low sensitivity to hydrologic disturbances and excellent recovery potential. The six segments in the Upper Arkansas River Basin have very low to moderate sensitivity to changes in streamflow, with good to excellent recovery potential.

Figure 3-40. Rosgen Stream Classification for the Upper Arkansas River

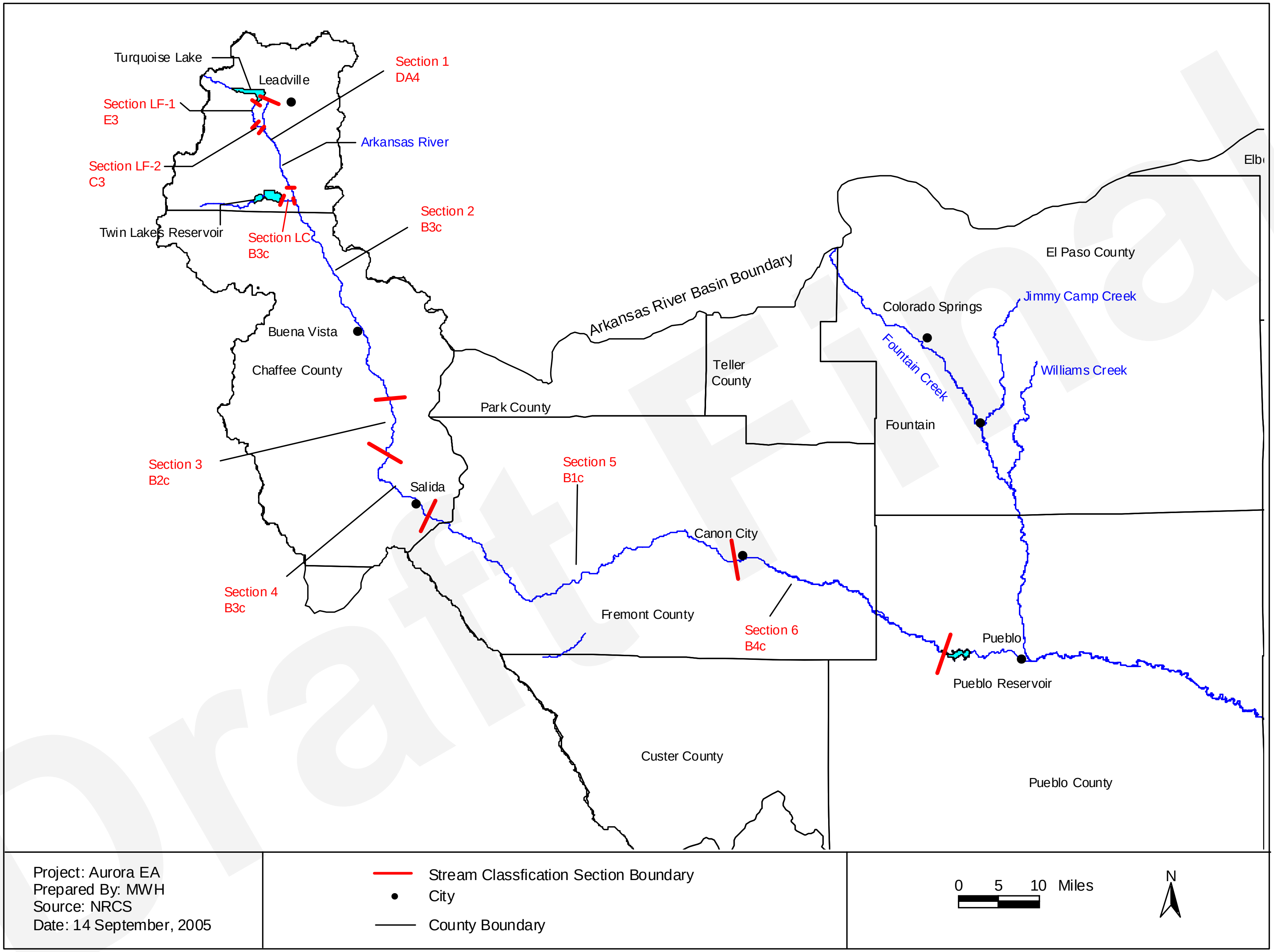
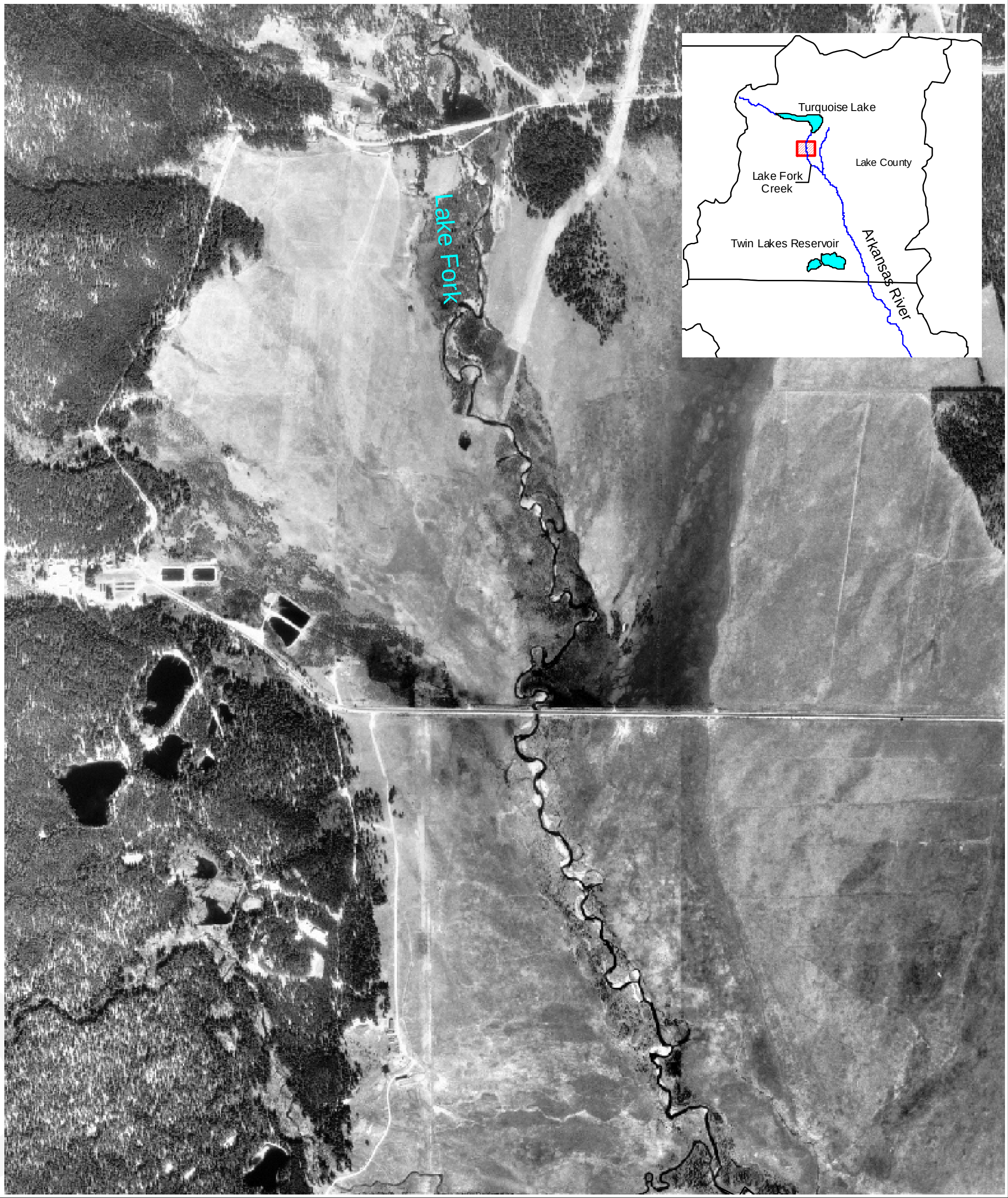


Figure 3-41. Lake Fork Aerial Photograph, Section LF-1

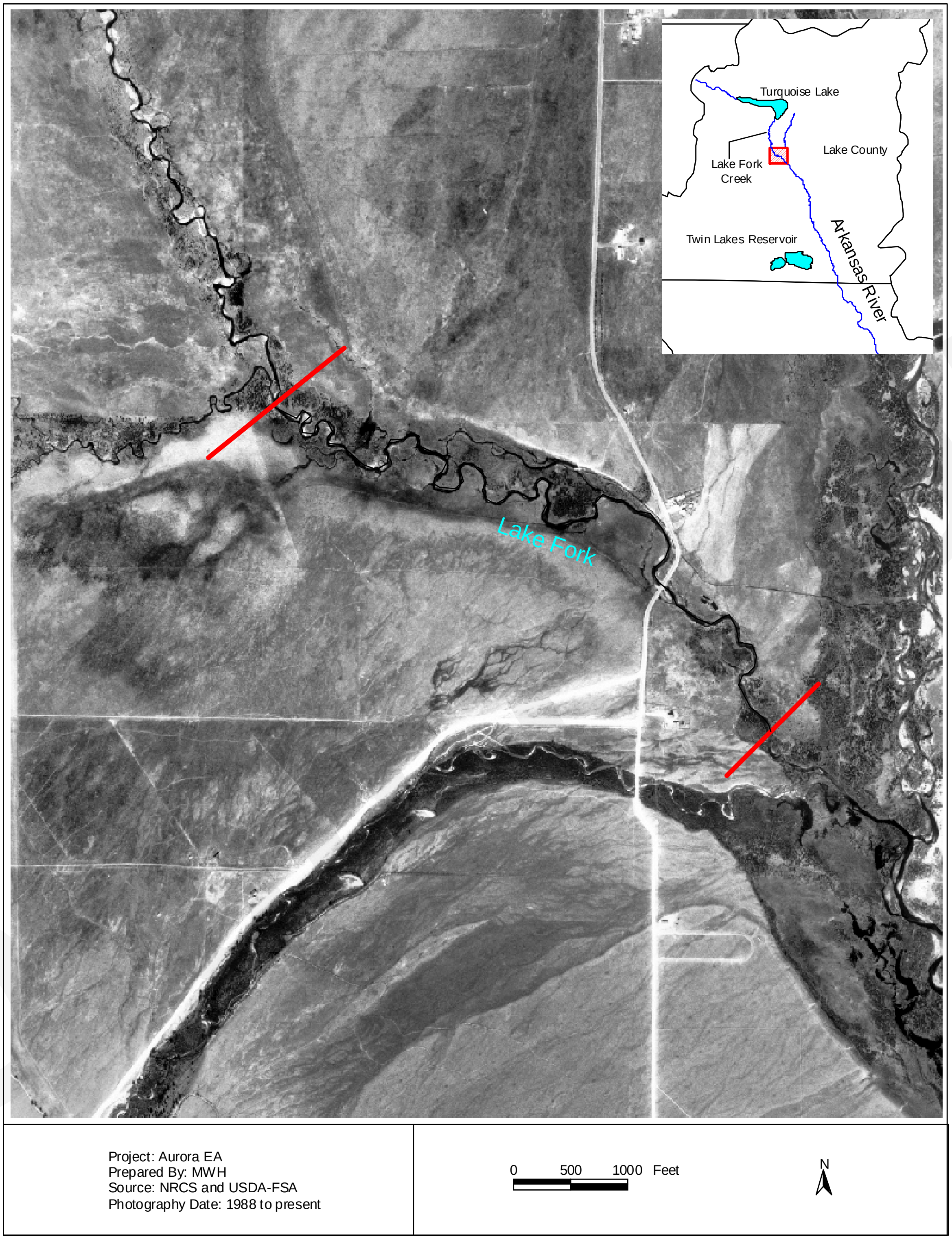


Project: Aurora EA
Prepared By: MWH
Source: NRCS and USDA-FSA
Photography Date: 1988 to present

0 500 1000 Feet

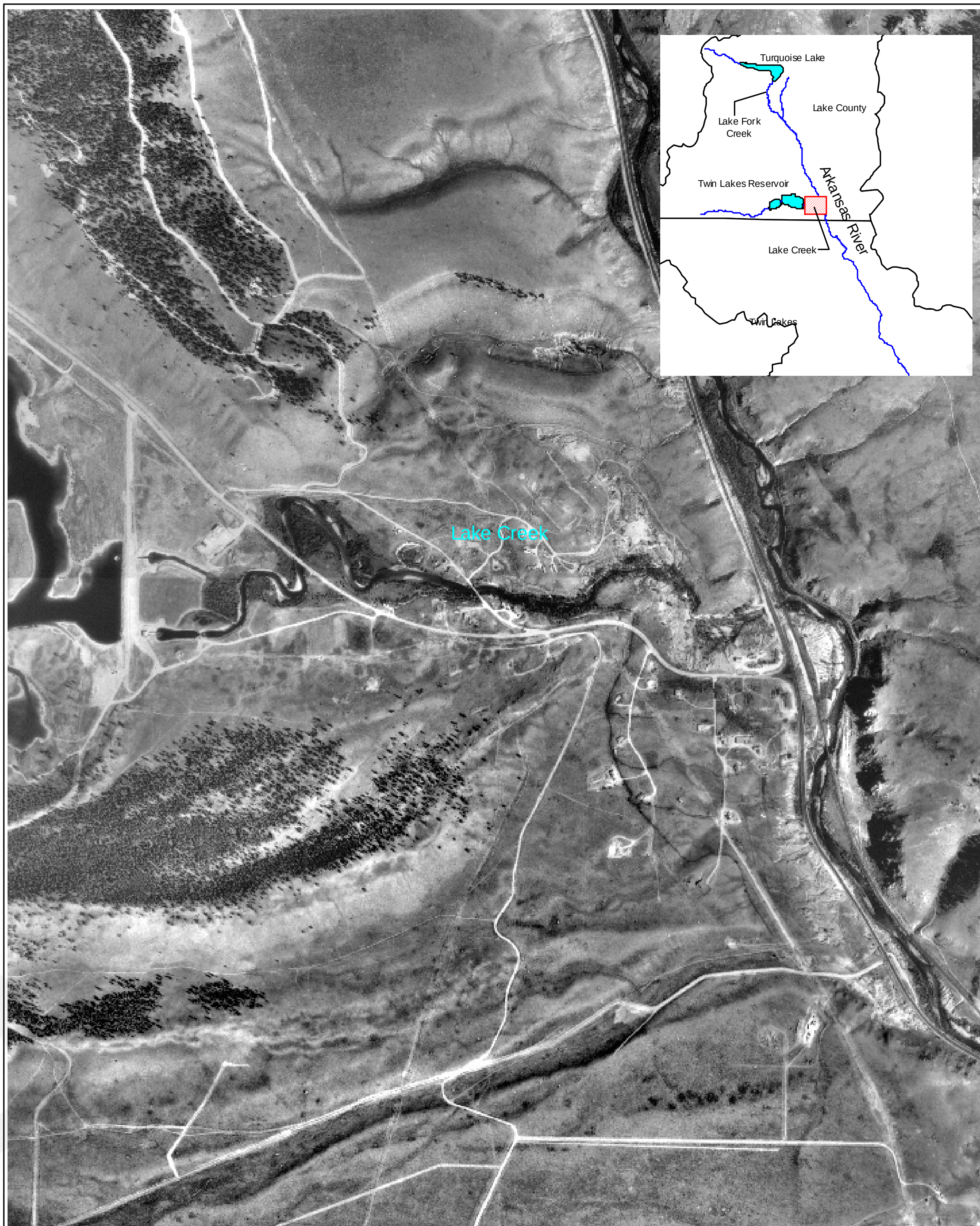
N

Figure 3-42. Lake Fork Aerial Photograph, Section LF-2



Project: Aurora EA
Prepared By: MWH
Source: NRCS and USDA-FSA
Photography Date: 1988 to present

Figure 3-43. Lake Creek Aerial Photograph (B3c Stream Classification)

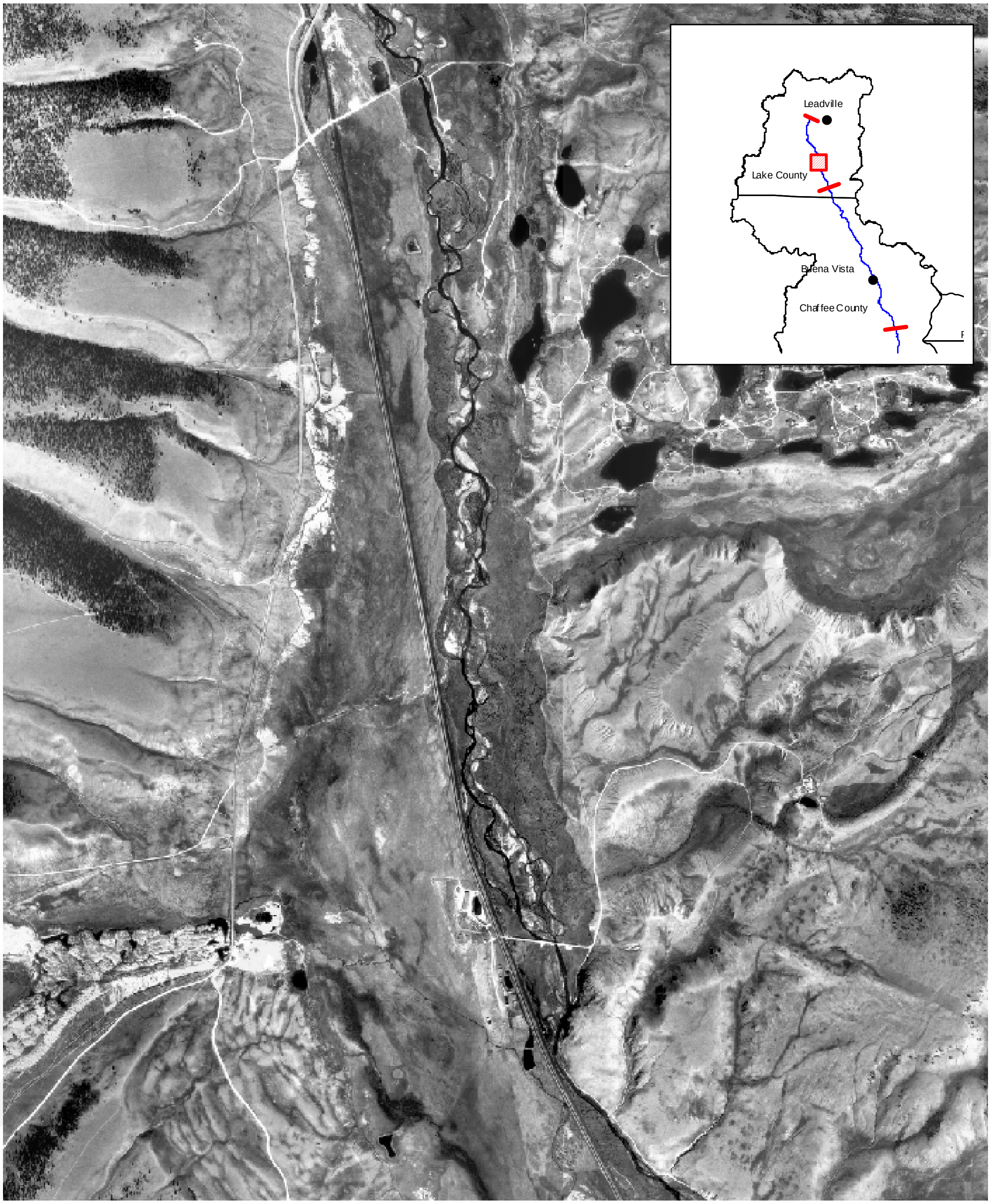


Project: Aurora EA
Prepared By: MWH
Source: NRCS
Photography Date: 1988 to present

0 500 1000 Feet

N

Figure 3-44. Section 1 Representative Aerial Photograph
(DA4 Stream Classification)

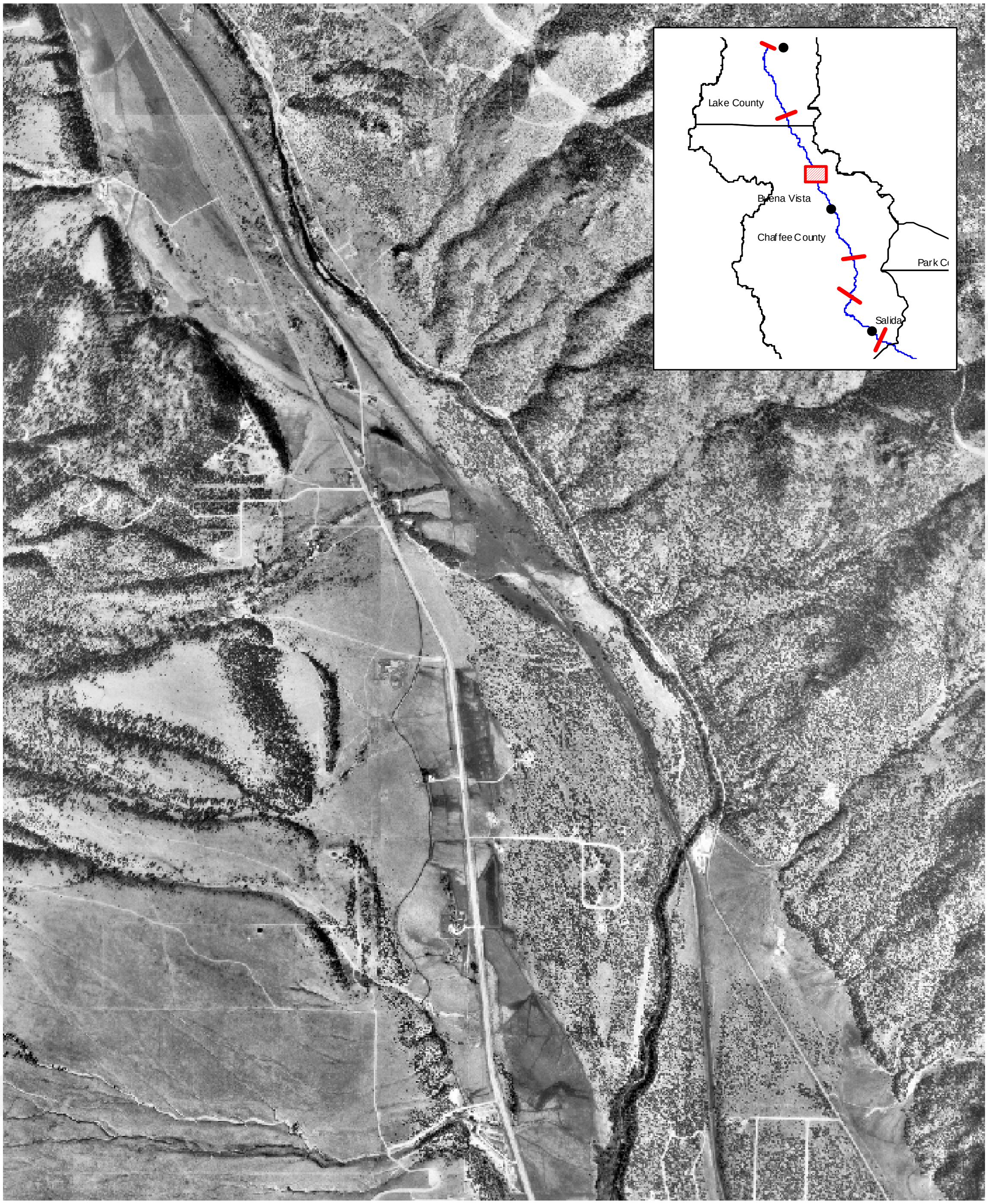


Project: Aurora EA
Prepared By: MWH
Source: NRCS and USDA-FSA
Photography Date: 1988 to present

0 1000 2000 Feet

N

Figure 3-45. Section 2 Representative Aerial Photograph
(B3c Stream Classification)

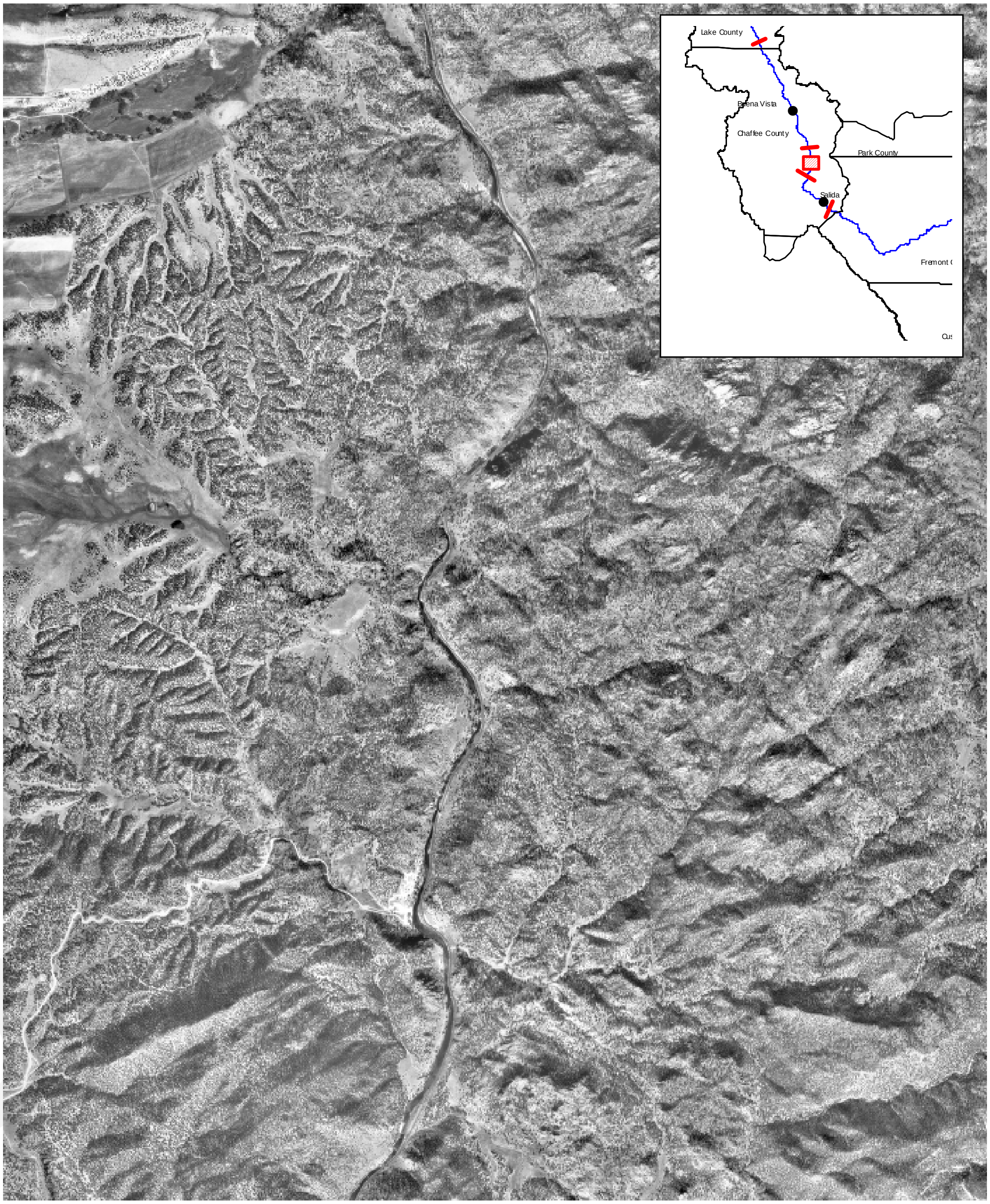


Project: Aurora EA
Prepared By: MWH
Source: NRCS and USDA-FSA
Photography Date: 1988 to present

0 1000 2000 Feet

N

Figure 3-46. Section 3 Representative Aerial Photograph
(B2c Stream Classification)

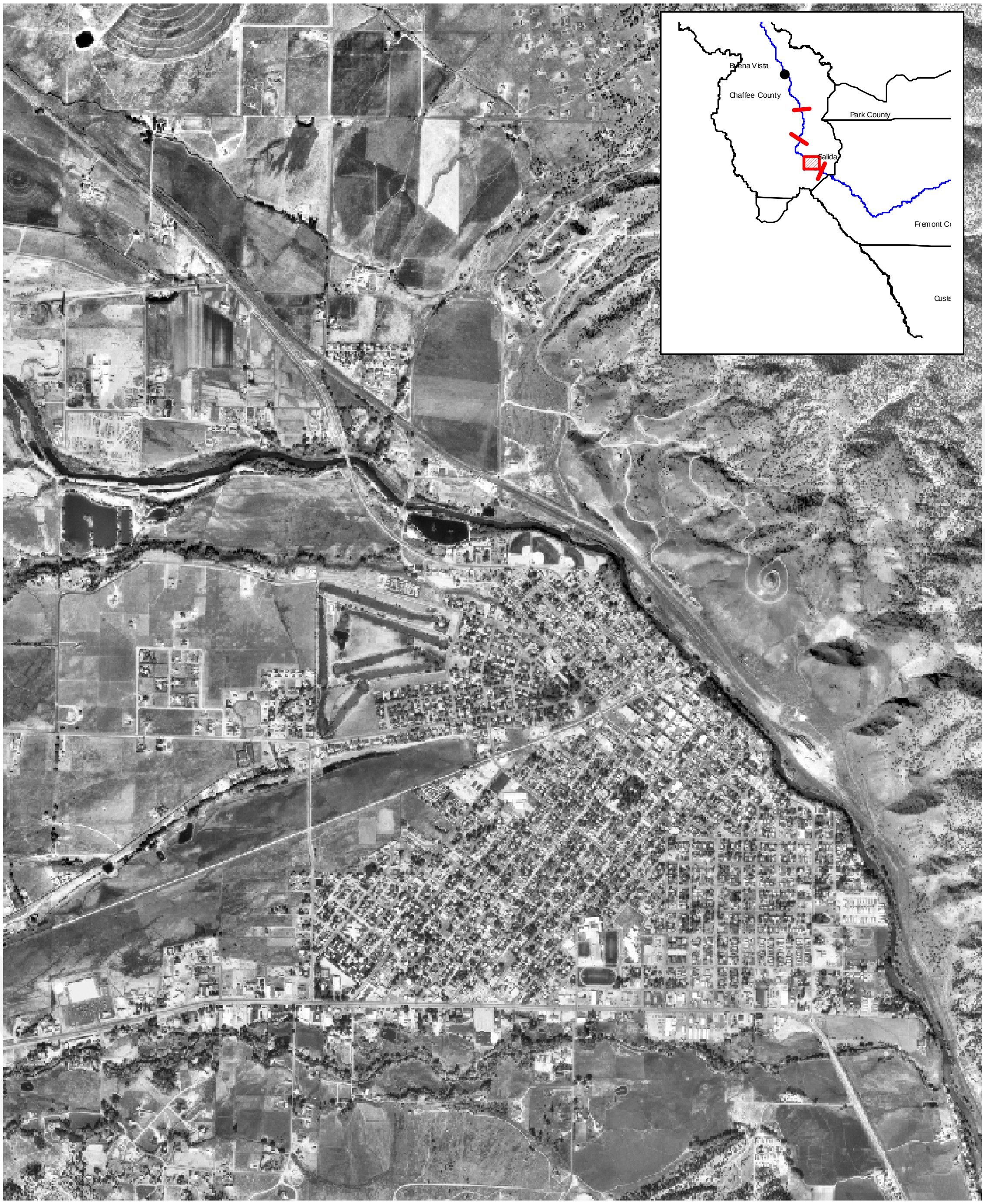


Project: Aurora EA
Prepared By: MWH
Source: NRCS and USDA-FSA
Photography Date: 1988 to present

0 1000 2000 Feet

N

Figure 3-47. Section 4 Representative Aerial Photograph
(B3c Stream Classification)

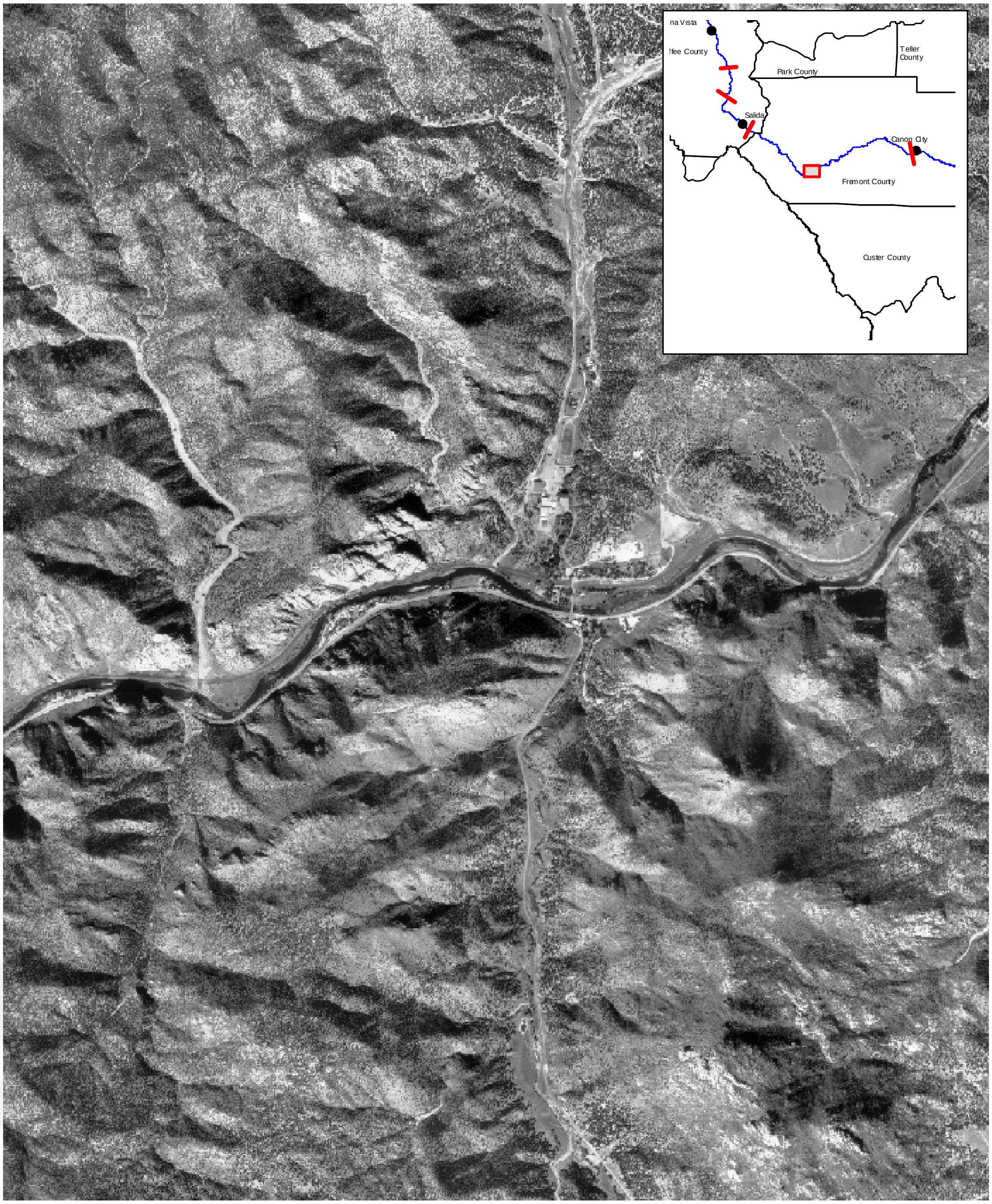


Project: Aurora EA
Prepared By: MWH
Source: NRCS and USDA-FSA
Photography Date: 1988 to present

0 1000 2000 Feet

N

Figure 3-48. Section 5 Representative Aerial Photograph
(B1c Stream Classification)

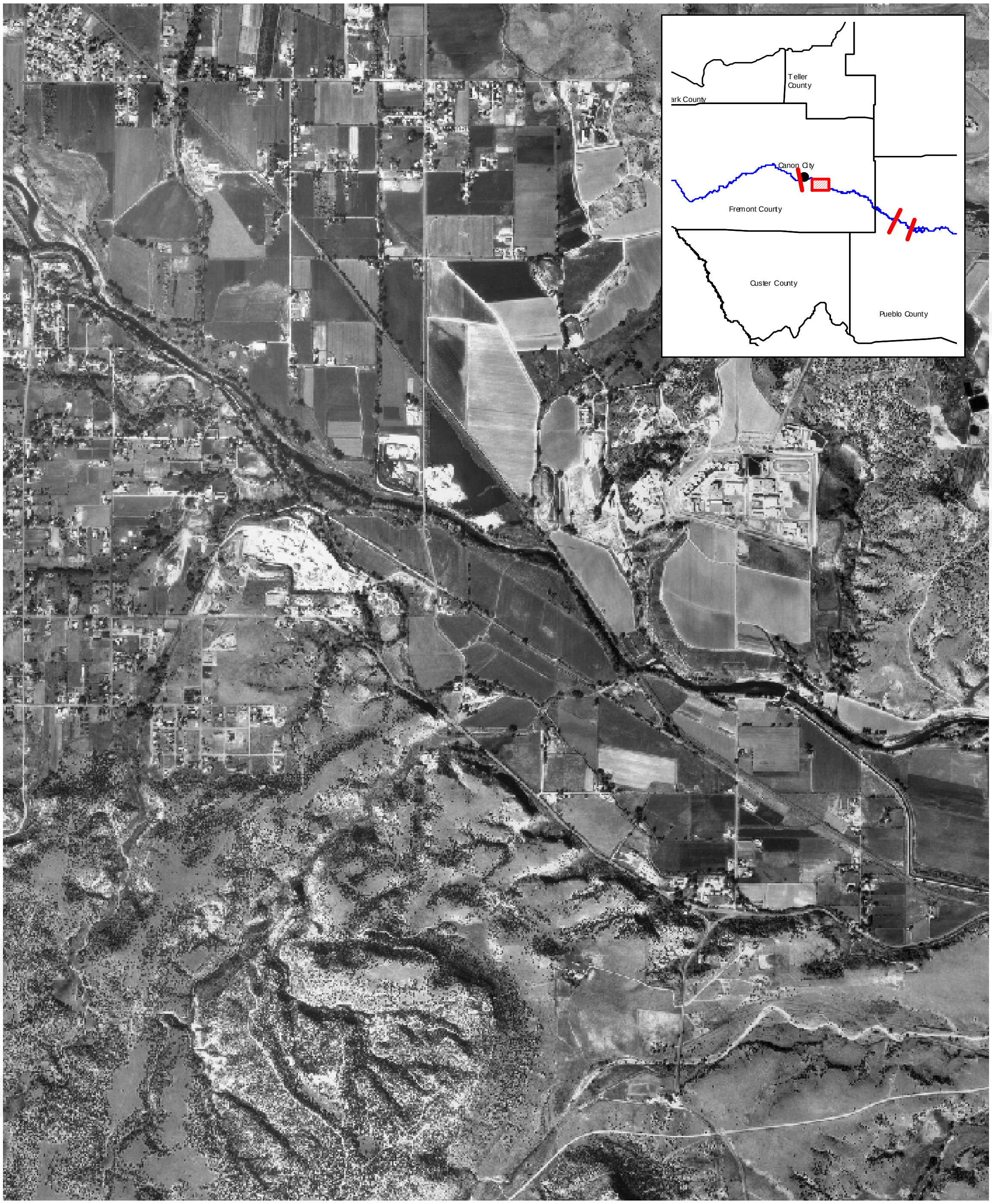


Project: Aurora EA
Prepared By: MWH
Source: NRCS and USDA-FSA
Photography Date: 1988 to present

0 1000 2000 Feet

N

Figure 3-49. Section 6 Representative Aerial Photograph)
B4c Stream Classification)



Project: Aurora EA
Prepared By: MWH
Source: NRCS and USDA-FSA
Photography Date: 1988 to present

Lower Arkansas River (Pueblo Reservoir to the La Junta Gage)

Stream classification of the lower Arkansas River from Pueblo Reservoir to the La Junta gage resulted in five distinct reaches shown in **Figure 3-50**. The four sections between the Fountain Creek confluence and John Martin Reservoir were classified using the Rosgen method for natural streams.

The geomorphology of the section from Pueblo Dam to the Fountain Creek confluence (Section 7) was summarized based on an Arkansas River fisheries habitat restoration report (U.S. Army Corps of Engineers, 2001). The Rosgen stream classification for natural streams was not used for this section as a result of man-made influences on the channel. **Figure 3-51** shows the location of each sub-reach of Section 7.

As part of the Legacy Project, the U.S. Army Corps of Engineers is currently completing work on the Arkansas River channel corridor through Pueblo (U.S. Army Corps of Engineers 2001). The objective of the Legacy Project is to convert the altered river corridor through Pueblo into a more natural and stable corridor. Channel realignments for this section are being considered in order to reduce channelization and reverse the reduction in habitat diversity that has occurred following anthropogenic influences.

The Corps divided the reach between Pueblo Reservoir and the Fountain Creek confluence into the three distinct reaches shown in **Figure 3-51** based on geomorphic differences, i.e. bed slope, planform configuration, hydrologic inputs, and anthropogenic influences. Anthropogenic influences considered include levee construction, channelization, and bank stabilization. Section 7a extends from approximately 1,500 feet downstream of the Pueblo Dam to the Wild Horse Creek confluence, and has been moderately affected by man-made geomorphic alterations. This reach has some meanders but also has channelized lengths with hardened banks and levees. Section 7a has no tributaries and receives little sediment supply as a result. Sediment is being removed from this section and not being replaced. Section 7b extends from the Wild Horse Creek confluence downstream through the City of Pueblo to the end of the concrete levee where Interstate-25 crosses the Arkansas River. This reach has been constrained by a concrete levee for flood protection. Bedrock has been exposed in parts of Section 7b, and the reach could continue to scour to the bedrock level. Section 7c extends from the end of the concrete levee to the Fountain Creek confluence and is influenced by backwater effects as a result of sediment deposition in the Arkansas River from Fountain Creek.

Figure 3-50. Stream Classification for the Lower Arkansas River

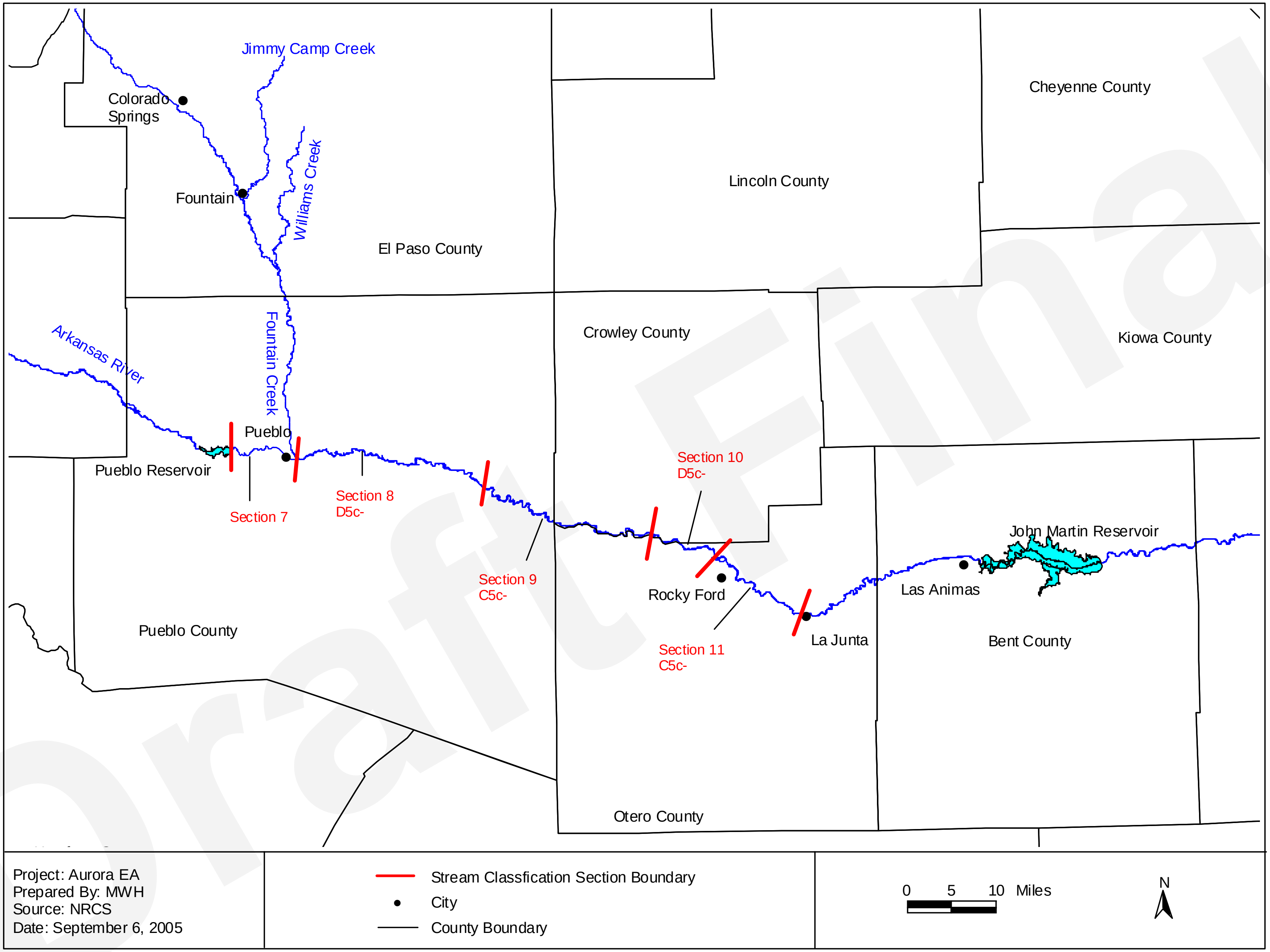
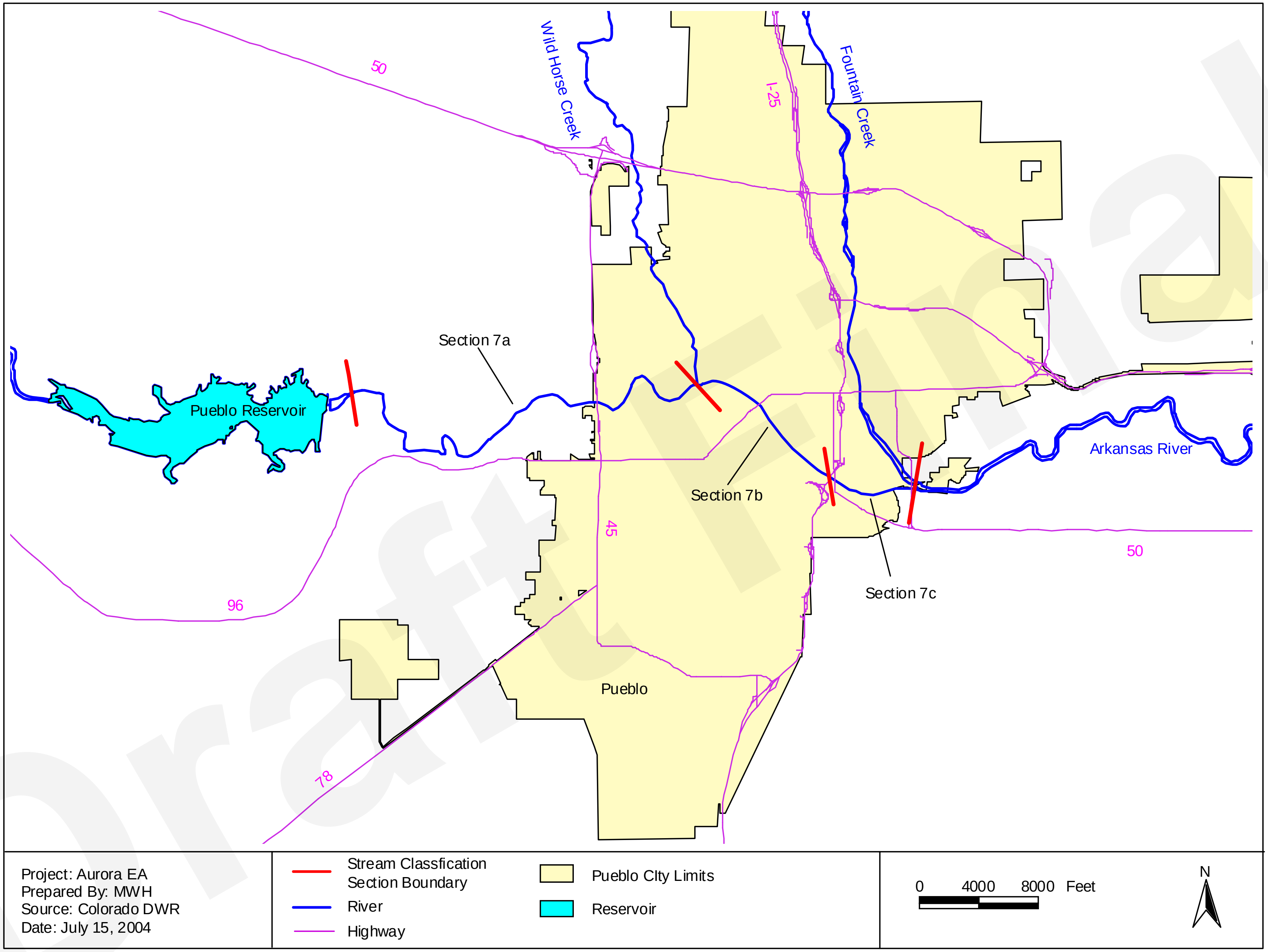


Figure 3-51. Sub-reach Locations for Section 7 Between Pueblo Reservoir and Fountain Creek Confluence



The four natural stream sections downstream of the Fountain Creek confluence ranged from multiple channels with high width to depth ratios (D5c-) to single thread channels with slight entrenchment and moderate width to depth ratios (C5c-). Streambed material for the lower Arkansas River is sand. Based on the stream type of each of five natural stream sections in the Lower Arkansas River, **Table 3-42** provides predictions of responses and recovery.

Table 3-42. Response of Lower Arkansas River to Potential Disturbances

Section	Stream Type	Sensitivity to Disturbance	Recovery Potential	Streambank Erosion Potential	Sediment Supply	Vegetation Controlling Influence
8	D5c-	Very High	Poor	Very High	Very High	Moderate
9	C5c-	Very High	Fair	Very High	Very High	Very High
10	D5c-	Very High	Poor	Very High	Very High	Moderate
11	C5c-	Very High	Fair	Very High	Very High	Very High

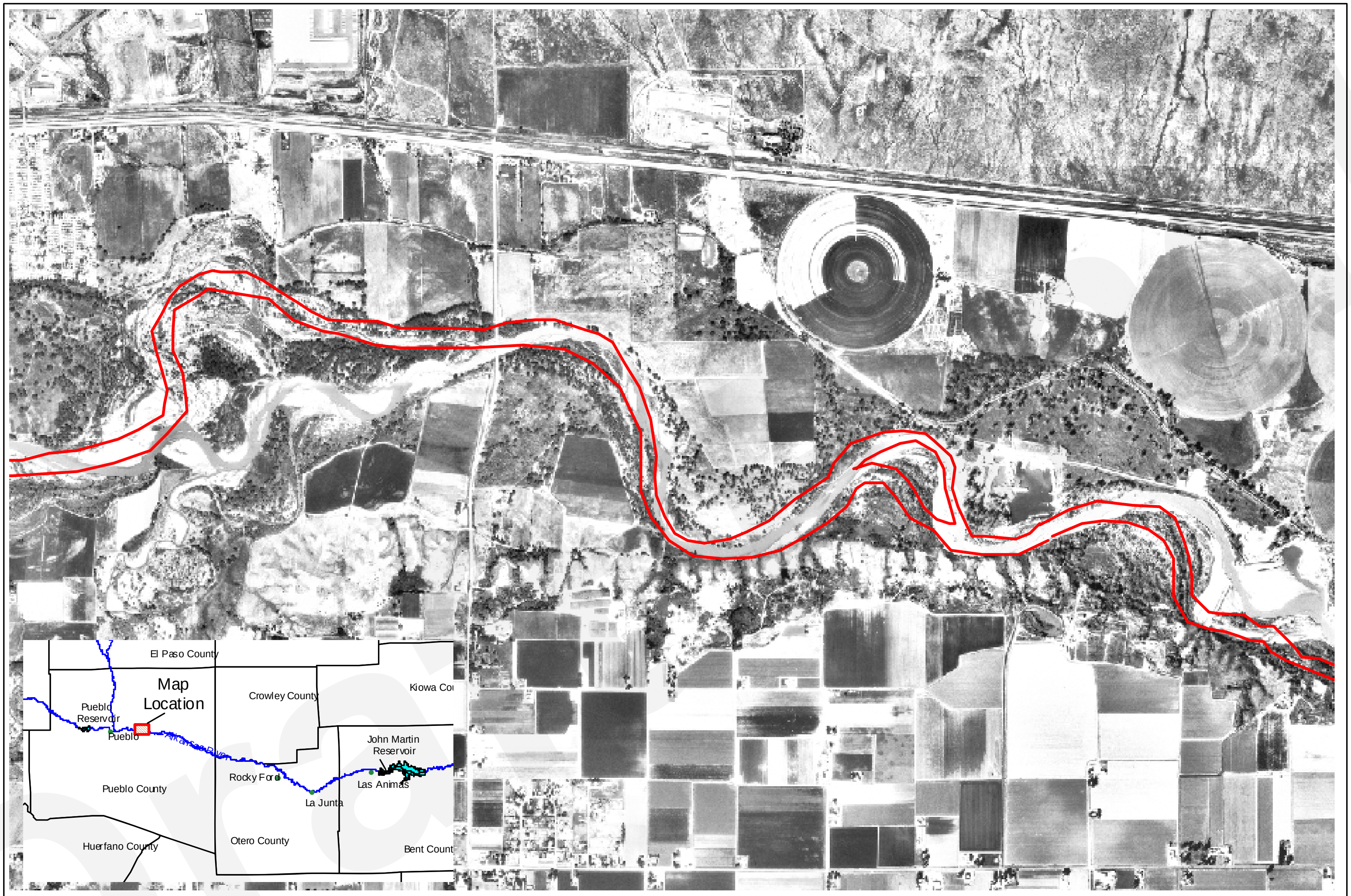
The sensitivity of these sections to disturbances is discussed further in the next sub-section, where historical aerial photos were compared with current photos to determine the effects of development along Fountain Creek and in the City of Pueblo on Arkansas River geomorphology. The section of the Arkansas River that runs through Pueblo will be affected by the potential channel realignments proposed by the U.S. Army Corps of Engineers, but will not be sensitive to changes in the streamflow regime. This section is controlled by man-made structures such as levees and bank stabilization rather than changes in streamflow regime.

3.5.2.2 Aerial Photograph Analysis

Historical (1960s) and current (1993 to 2001) aerial photographs were compared to determine changes in stream segments for the lower Arkansas River. Stream segments that have shown changes in morphology over the span of a few decades may be sensitive to changes in the rate and timing of streamflow. Historical aerial photographs from the 1960s were obtained from the United States Department of Agriculture Aerial Photography Field Office (USDA-FSA). Current DOQQs that were taken between 1993 and 2001 were obtained from the NRCS. The scale of the DOQQs was manipulated in ArcView GIS to match the scale of the historical photographs as closely as possible. The historical streamline was drawn in the GIS project over the current DOQQs.

Approximately three-quarters of the Lower Arkansas River exhibited slight to major change in morphology over a 35-year period. Examples of the morphologic changes along the lower Arkansas River are shown in **Figure 3-52** and **Figure 3-53**.

Figure 3-52. Lower Arkansas River Historical Channel (1964) versus Recent DOQQ (1993-2001)

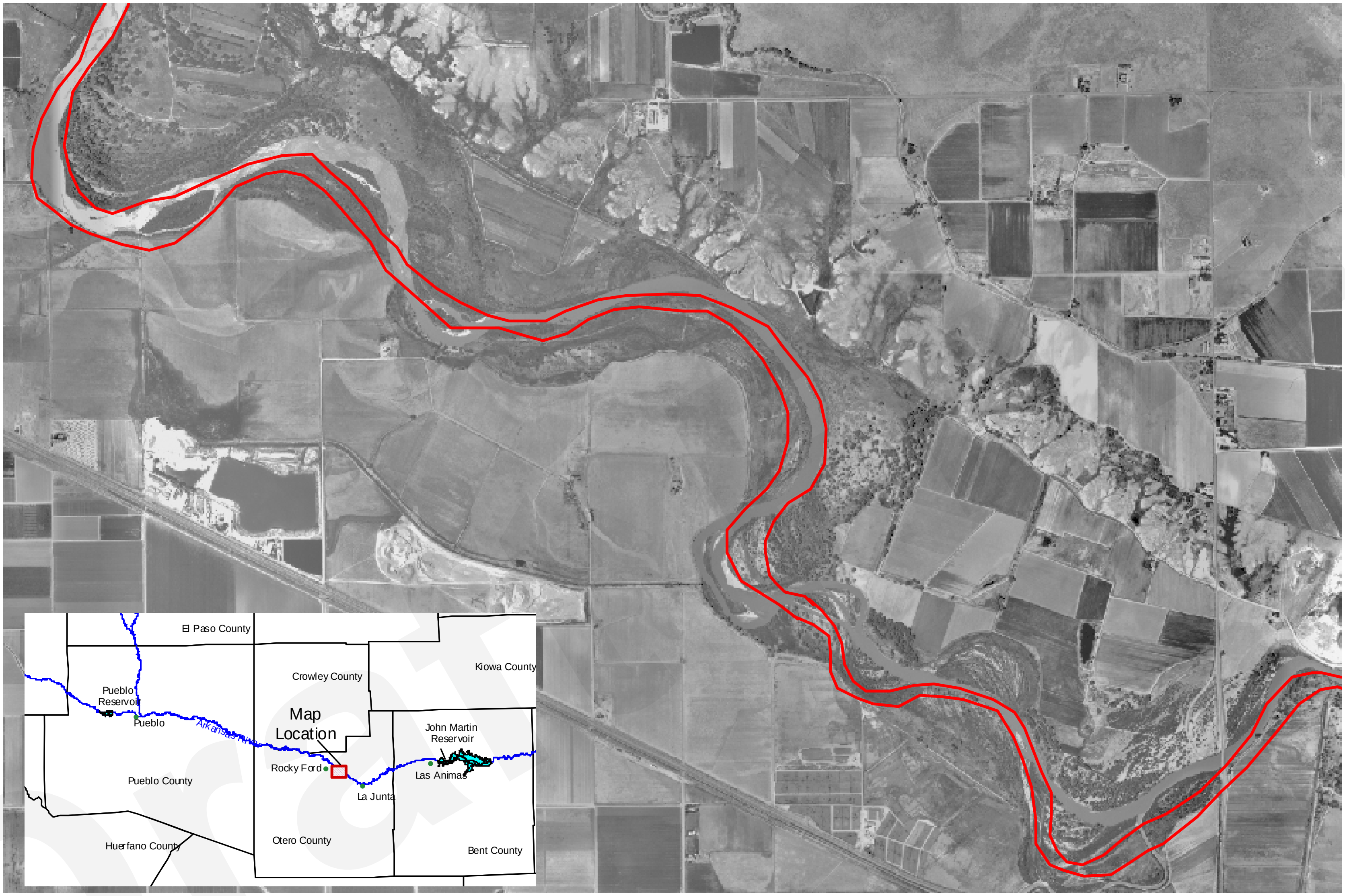


Project: Aurora EA
Prepared By: MWH
Source: NRCS and USDA-FSA
Date: July 15, 2004

Main Channel - 1964

Note: Aerial photograph in background taken between 1993 and 2001

Figure 3-53. Lower Arkansas River Historical Channel (1964) versus Recent DOQQ (1993-2001)



Project: Aurora EA
Prepared By: MWH
Source: NRCS and USDA-FSA
Date: July 15, 2004

Main Channel - 1964

Note: Aerial photograph in background taken between 1993 and 2001

0 1000 2000 Feet

N

The current Arkansas River seen in the DOQQ in **Figure 3-52** shows a smaller meander belt width and a meander that has been cut off since 1960. **Figure 3-53** shows meander migration. The channel migration seen between 1964 and 1993 is likely a result of increased streamflow to the Upper Arkansas River Basin as a result of transbasin diversions to the Arkansas River Basin. Construction of the Fryingpan-Arkansas project began in 1964, and diversions to the Arkansas River Basin commenced in 1972 (SECWCD 2004). The increase in streamflow as a result of transbasin diversions like the Fryingpan-Arkansas project has resulted in channel migration like that seen in **Figure 3-52** and **Figure 3-53**. These figures confirm that the Arkansas River downstream of Pueblo Reservoir is sensitive to changes in streamflow as was predicted from the stream classification discussed in previous sub-sections.

3.6 Ground Water

Any effects on streamflows or stream hydraulics could also have an effect on ground water conditions. This section presents a summary of ground water conditions for the study area. Historical water levels and fluctuations were determined based on existing reports.

Ground water is a major resource in the Arkansas River Basin in Colorado, providing 9 percent of total water supply basinwide in 2000. Within the basin, ground water withdrawals by county in 2000 ranged from lows in Chaffee and Lake Counties of 1,030 ac-ft and 720 ac-ft, respectively, to a high of 108,000 ac-ft in Prowers County (USGS, 2000). Ground water occurs in unconsolidated sediments, consolidated sedimentary bedrock formations, and fractured crystalline igneous and metamorphic rocks. Alluvial aquifers are more prevalent in the Lower Arkansas Basin and are an important water resource used primarily for agricultural purposes.

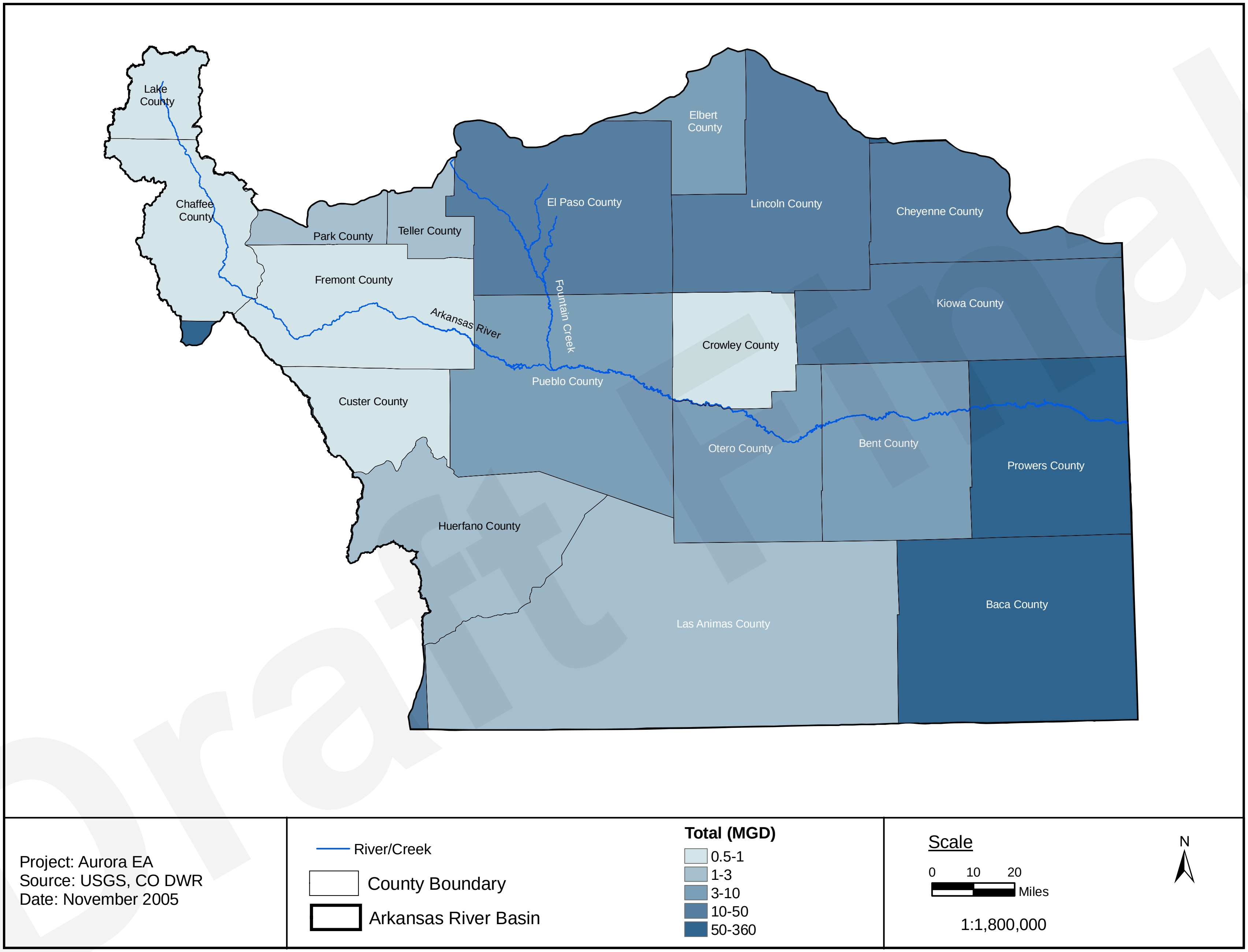
3.6.1 Existing Ground Water Conditions

Existing ground water conditions in the project study area were assessed by review of existing data and reports from the USGS, Colorado Geological Survey, CDWR, and private companies. Existing physical ground water conditions and applicable Colorado ground water law and beneficial uses are summarized. Primary aquifers, ground water levels, aquifer uses, recharge areas, and factors that affect ground water conditions are described. Water use statistics are available by county for the year 2000.

Ground water use in specific portions of the study area is described in the following subsections. Several figures shown on the following pages are referenced throughout this section. These figures are described as follows:

- **Figure 3-54** through **Figure 3-56** show map-based ground water use statistics.
- **Figure 3-57** through **Figure 3-59** show map-based physical ground water characteristics.
- **Figure 3-60** through **Figure 3-62** show chart-based ground water use.

Figure 3-54. Total Ground Water Use in 2000



Project: Aurora EA
Source: USGS, CO DWR
Date: November 2005

Figure 3-55. Agricultural Ground Water Use in 2000

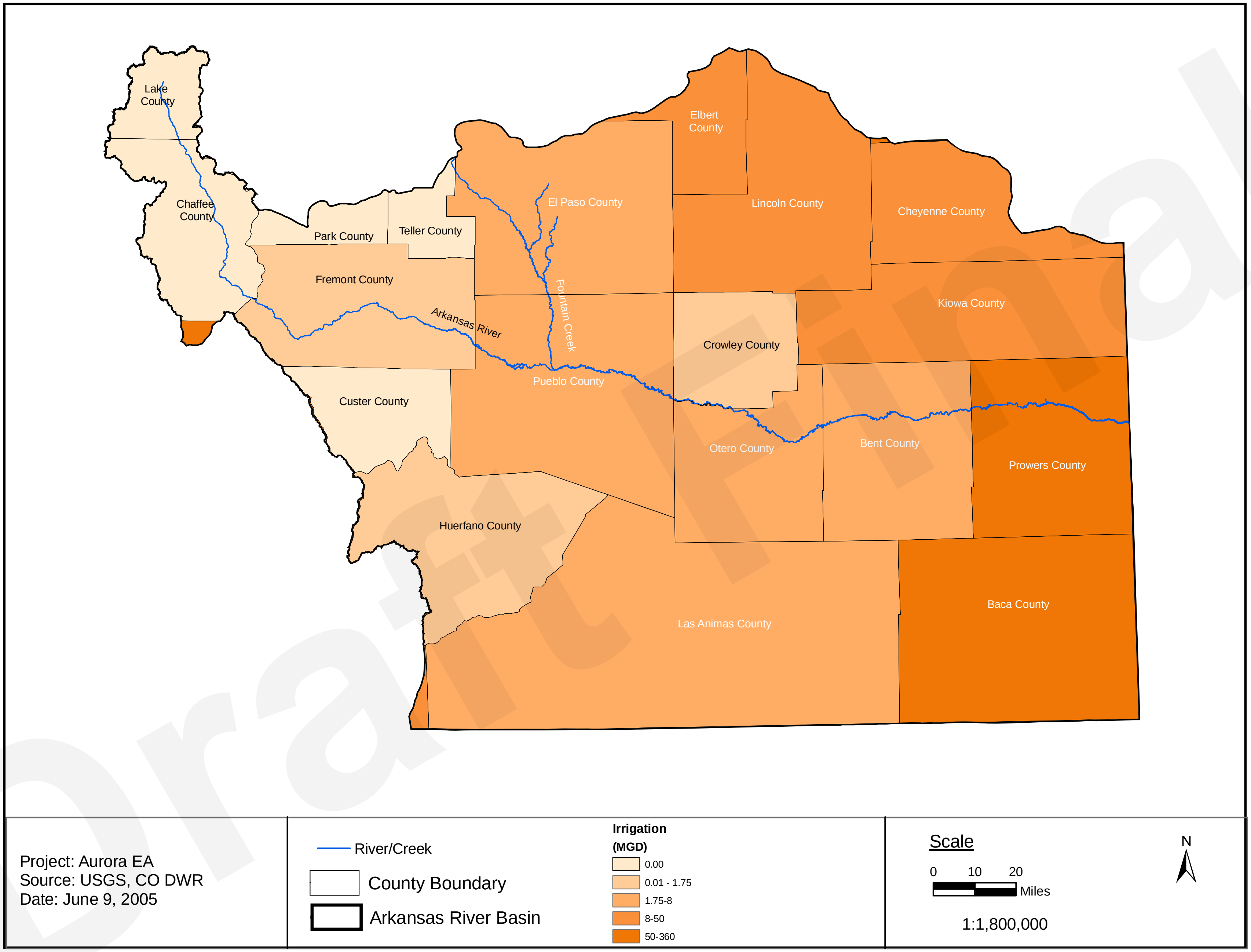


Figure 3-56. Municipal and Industrial Ground Water Use in 2000

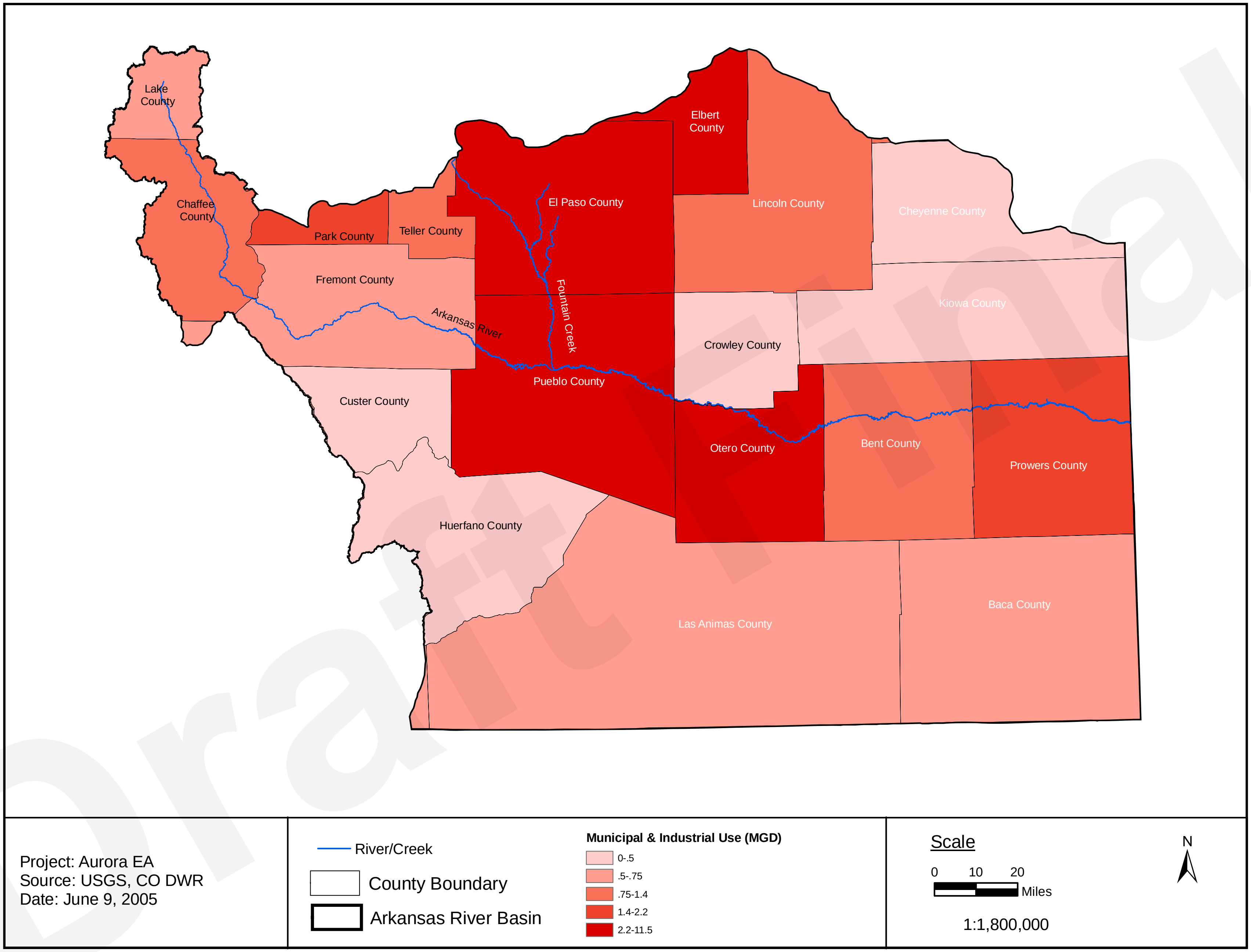


Figure 3-57. Designated Ground Water Basins and Extent of Alluvium in the Arkansas River Basin

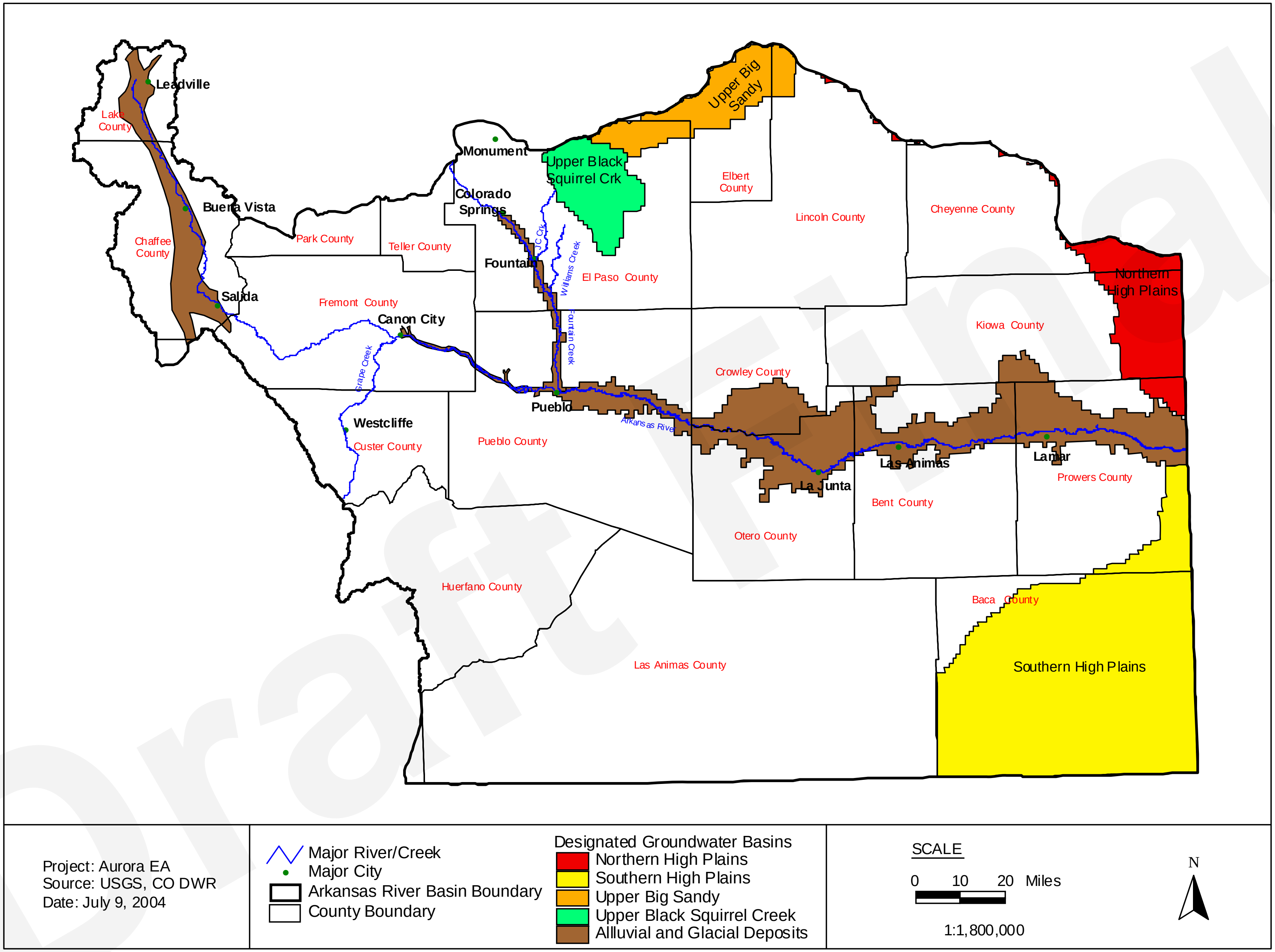


Figure 3-58. Extent and Location of Denver Basin Aquifers within the Arkansas River Basin

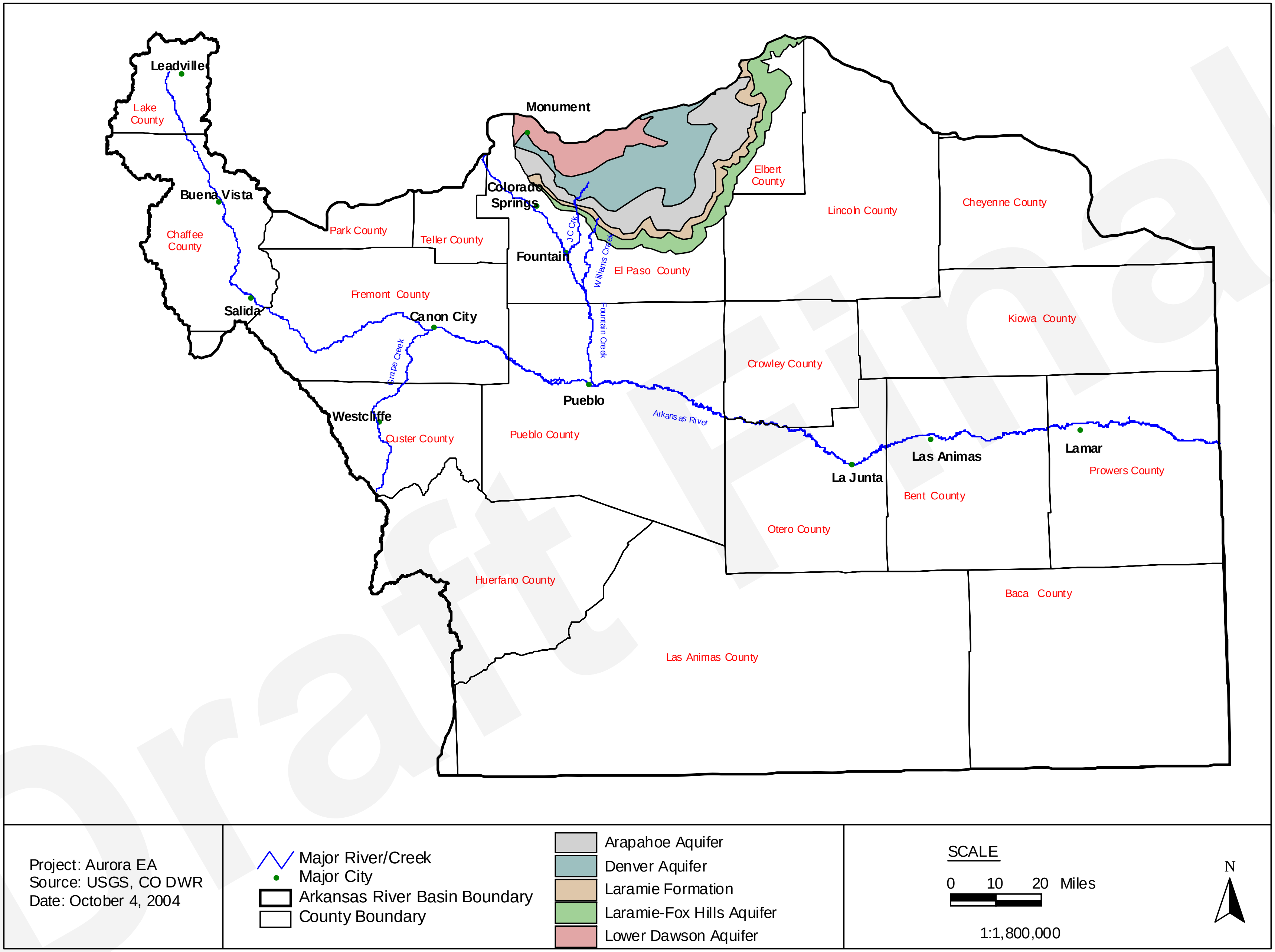


Figure 3-59. Structural Basins within the Upper Arkansas River Basin

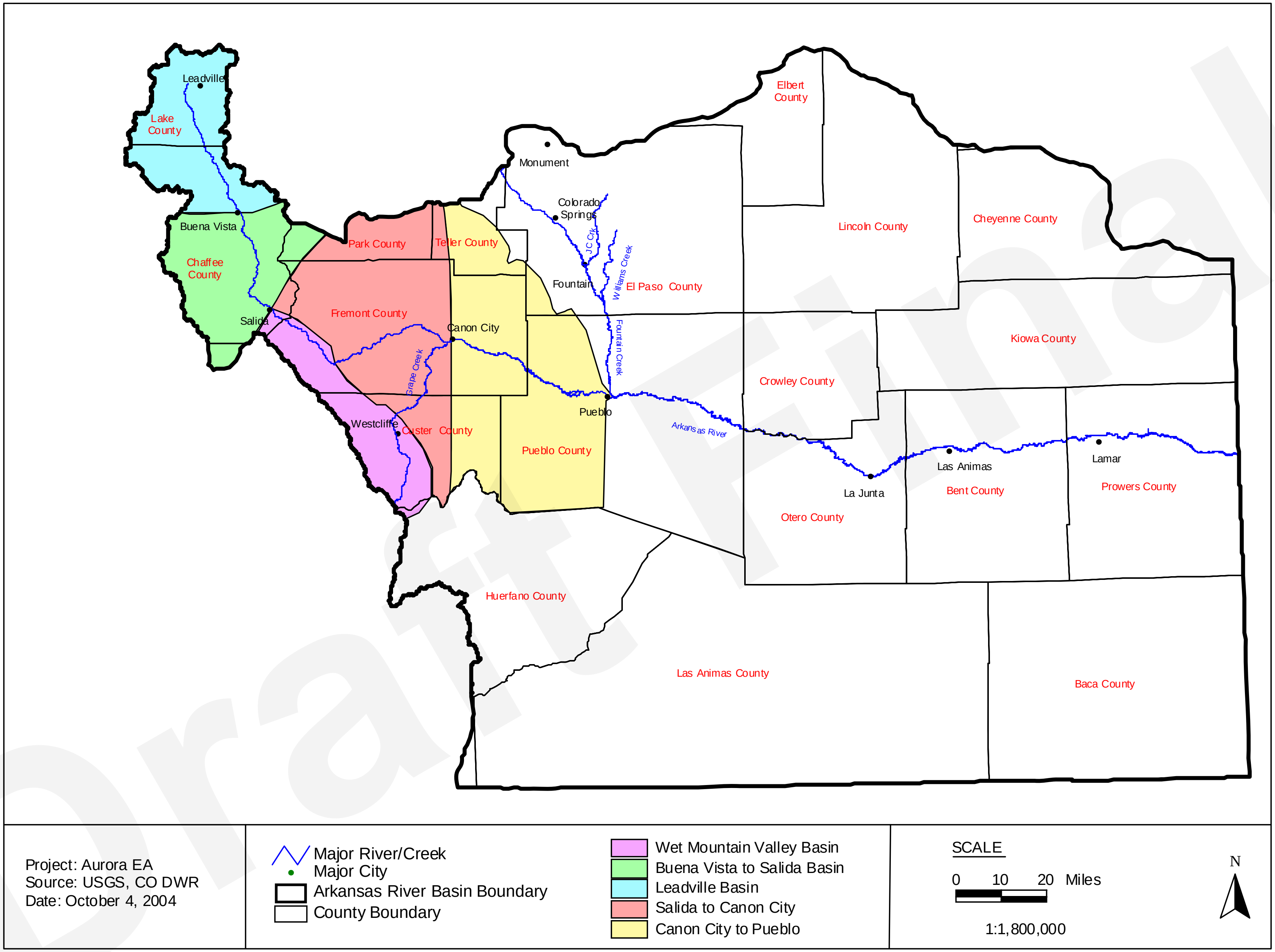


Figure 3-60. Total 2000 Ground Water Use by County (USGS, 2000)

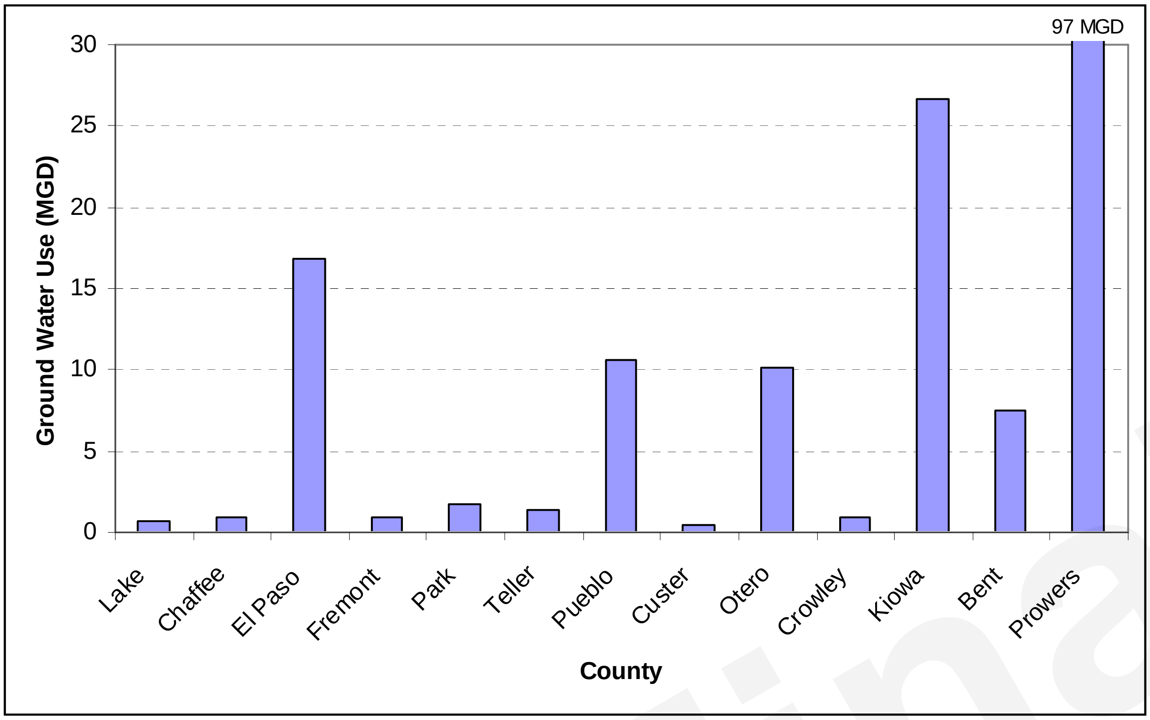


Figure 3-61. Percentage of 2000 Total Water Use Originating from Ground Water (USGS, 2000)

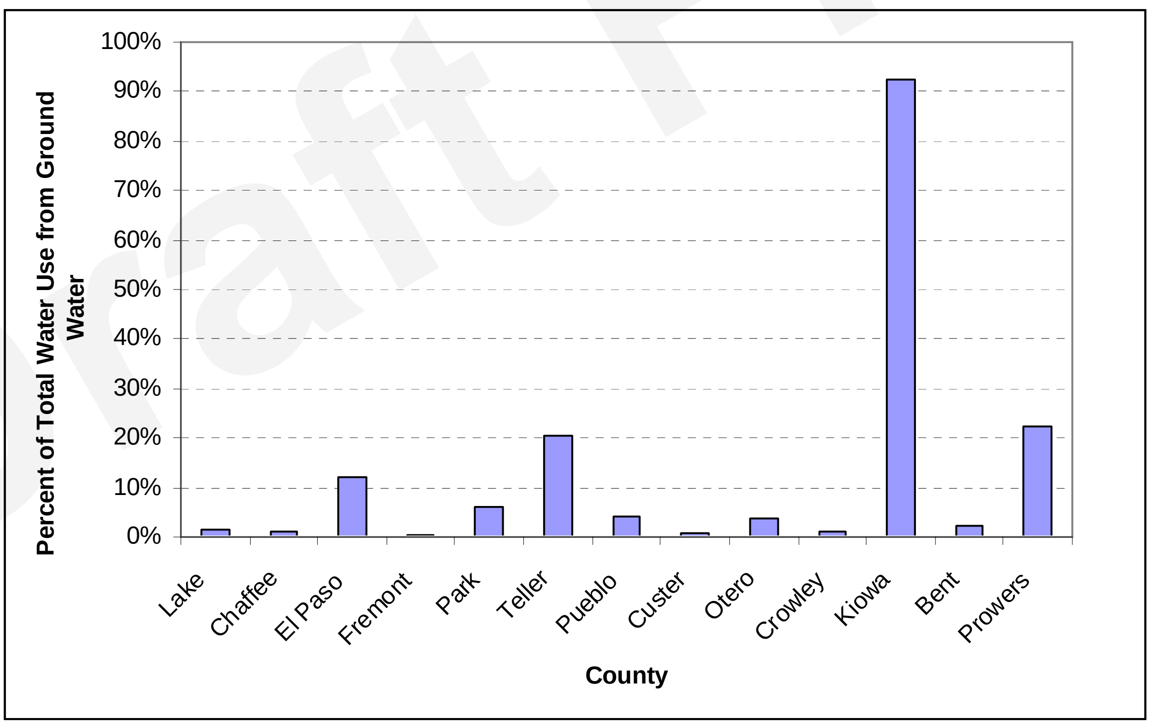
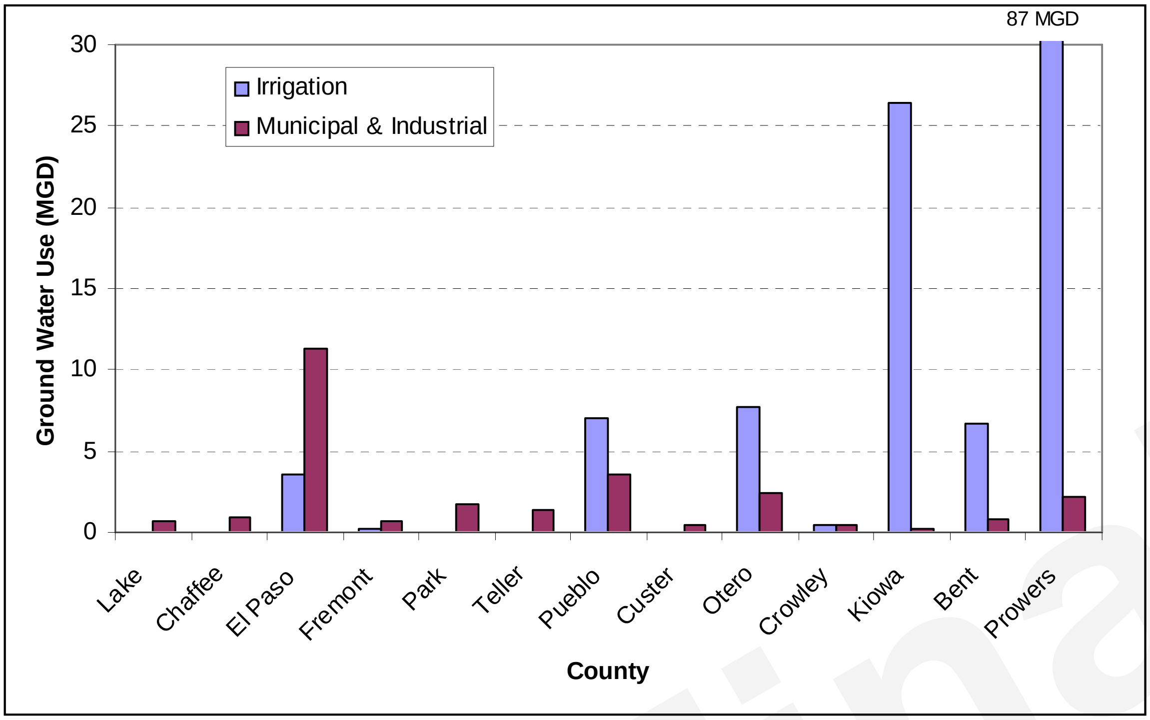


Figure 3-62. 2000 Ground Water Use, M&I and Irrigation Use (USGS, 2000)



3.6.1.1 *Upper Arkansas Basin*

Two types of aquifers are present in the Upper Arkansas Basin: unconsolidated sediment aquifers and consolidated rock aquifers. The unconsolidated aquifers, which are the most productive aquifers in the basin, are comprised of valley-fill alluvium, glacial deposits, and basin-fill deposits. The only consolidated rock aquifer in the Upper Arkansas Basin that provides significant water resources is the Dakota-Purgatoire sandstone formation (USGS, 1984), which is discussed below.

Alluvium in the Upper Arkansas Basin is not continuous due to the outcropping of consolidated rock material in mountainous regions. Because of the high velocity of streamflow in the Upper Basin, sediments that make up the alluvial aquifer vary in size from glacial silts to large boulders. Low mean well yield in the Upper Basin does not necessarily correlate with low hydraulic conductivity of the alluvial material. The high frequency of domestic and stock watering small capacity wells, which are legally required to yield less than 15 gpm, impart a low bias to mean upper Arkansas well yield. Sources of recharge to the Upper Basin alluvium include surface runoff via streamflow from the surrounding mountains, underflow from adjacent consolidated rock aquifers, and direct precipitation. Seepage loss measurements indicate that within the Upper Arkansas Basin, the Arkansas River is a gaining stream as a result of ground water inflow, except for a short reach between Salida and Wellsville (USGS 1984). Ground water in Upper and Lower Arkansas Basin alluvium interacts solely through the Arkansas River, as the two regions of alluvium are not physically connected.

In the Upper Arkansas Basin, there are five structural basins with unique aquifer characteristics and ground water storage: Leadville, Buena Vista-Salida, the Wet Mountain Valley, Salida to Cañon City, and Cañon City to Pueblo basins. The Leadville basin includes the area along the Arkansas River between Leadville and Buena Vista. The Wet Mountain Valley is approximately 60 miles southwest of Pueblo with runoff draining into Grape Creek, a major tributary of the Arkansas River (see **Figure 3-59** for location and extent of structural basins).

Alluvial aquifer material is present along the Arkansas River and its major tributaries except in the Salida - Cañon City basin. Alluvium is up to 100 feet thick, and well yields are reported up to 500 gpm, with a median yield of 15 gpm. The Leadville, Buena Vista-Salida, and Wet Mountain Valley basins contain significant ground water storage volumes in the unconsolidated sediment aquifers. The Leadville basin has about 100 square miles of unconsolidated sediments, which contain about 1.9 million ac-ft of storage. The Buena Vista-Salida basin has about 200 square miles of unconsolidated deposits and 3.8 million ac-ft of storage. The Wet Mountain Valley has about 233 square miles of unconsolidated sediments and 4.5 million ac-ft of storage (USGS, 1984). The Salida-Cañon City basin has no unconsolidated sediments, and the Cañon City-Pueblo basin has thin alluvial aquifer material along the Arkansas River. Although ground water makes up less than 5 percent of total water use in the Upper Basin, ground water use for small capacity domestic and stock watering wells is common.

Although alluvial aquifer ground water use is predominant in the Upper Basin, consolidated deposits and glacial deposits also provide ground water. The top of the Dakota-Purgatoire aquifer outcrops along the Arkansas River in locations near Cañon City and is up to 4,500 feet below ground surface in other locations. Thickness of glacial deposits ranges from 0 to 500 feet, with well yields of 10 to 1,500 gpm. Basin-fill deposit aquifers are up to 4,000 feet thick, with well yields of 10 to 1,200 gpm (USGS, 1984). A summary of ground water use in the Upper Basin is shown in **Table 3-43**.

Table 3-43. Summary of Ground Water Use in the Upper Arkansas Basin (USGS 2000)

Upper Basin County	Total Ground Water Use (MGD)	M&I Ground Water Use (MGD)	Agricultural Ground Water Use (MGD)	Other Use (MGD)
Lake	0.64	0.64	0	0
Chaffee	0.92	0.92	0	0
Fremont	0.88	0.68	0.2	0

Water levels in the Upper Basin alluvium ranged from 5 to 58 feet below ground surface (bgs) during the 1990s (USGS, 1997). Strong seasonal fluctuations in ground water levels are common in the Upper Basin, and are positively correlated with spring snowmelt runoff. There are over 1,600 ground water wells in the alluvial aquifer of the Upper Basin, with a median depth of 50 feet bgs (CDWR, 2001). Depth to water in the Leadville basin is less than 20 feet bgs in three-quarters of the wells in alluvial sediments, 2 to 40 feet bgs in glacial deposits, and 20 to 200 feet bgs in basin-fill deposits. Depth to water in the Buena Vista-Salida basin is less than 100 feet bgs in alluvial deposits and 100 to 200 feet bgs in basin fill aquifers.

In 2000, the highest ground water use in Fremont County was for industrial supply, which is water supplied for industrial operations such as manufacturing and mining (0.38 MGD). In Chaffee County, the highest use was for domestic supply, which is ground water supplied by private wells (0.63 MGD), and in Lake County it was domestic supply (0.42 MGD) (USGS, 2000). Public supply, which is water supplied by municipalities, was the second largest ground water use in 2000 in Lake County. Wells in alluvium of the Buena Vista-Salida basin are mostly used for domestic and stock-watering use and are completed to depths of less than 100 feet. Wells in the northern part of the Wet Mountain Valley are primarily domestic and stock-watering wells screened in the glacial deposits and are 20 to 90 feet deep (USGS, 1984). Wells in the southern part of the valley take ground water from the underlying basin-fill deposits. The shallow nature of the Dakota Purgatoire aquifer between Cañon City and Pueblo provides economically feasible ground water supply to domestic and stock watering wells in the area. For most of the wells in the plains east of the mountains and west of the City of Pueblo, the Dakota Sandstone is the source of ground water. Although domestic and stock watering wells are most common in the Dakota Purgatoire aquifer, public supply and irrigation ground water uses by the City of Pueblo are also significant. The Pueblo West well field is one of the largest producers of ground water from the Dakota Purgatoire aquifer. (USGS, 1984).

3.6.1.2 Lower Arkansas Basin

Arkansas River Alluvial Aquifers

Alluvial aquifers in the lower Arkansas River Basin are more reliable as a source of ground water, because they are more extensive and continuous than alluvium in the Upper Arkansas Basin. Quaternary age alluvium along the Arkansas River extends 150 miles from Pueblo Reservoir to the Kansas state line, is up to 250 feet thick, and is underlain by impermeable Cretaceous bedrock (Barkmann et al., 2003). As a result of lower river velocity, Lower Basin alluvial sediments are more uniform in size than in the Upper Basin, and are mostly sand, gravel, silts, and clays. There is little to no tributary alluvium along the southern tributaries of the lower Arkansas River. Northern tributaries of Fountain, Big Sandy, and Black Squirrel Creeks have significant alluvial aquifers along the creeks. There are six alluvial terraces in the Lower Basin, which are remnants of historical drainage patterns and are often hydraulically connected to present day alluvium.

Aquifer characteristics such as transmissivity, hydraulic conductivity, well yield, specific capacity, and specific yield vary widely for the lower Arkansas alluvium, depending on variations in soil type and saturated thickness, and are presented in **Table 3-44**.

Table 3-44. Alluvial Aquifer Characteristics for the Lower Arkansas River Basin from Pueblo to Kansas State Line

Transmissivity (ft2/d)	Hydraulic Conductivity (ft/d)	Well Yield (gpm)	Specific Capacity (gpm/foot of drawdown)	Specific Yield
2,000-60,000	70-1,200 (mean=530)	10-4,000	7-54	0.13-0.20

CDWR records show over 3,400 wells screened in the lower Arkansas alluvium, assuming an alluvial aquifer thickness of 250 feet, with a median depth of 42 feet bgs (Barkmann et al., 2003). Ground water use in the lower Arkansas basin is primarily for agricultural irrigation, especially in the region downstream from the City of Pueblo. Approximately 12 percent of wells have yields greater than 1,000 gpm. Domestic and stock wells with yields of less than 50 gpm make up about 50 percent of wells in the Lower Basin.

Ground water is an important resource in the lower Arkansas River Basin as shown by estimated 2000 ground water use from the USGS. Ground water consumption and beneficial uses varied geographically throughout the lower Arkansas River Basin. Ground water use ranged from a high of 96.6 MGD for Prowers County, to a low of 0.97 MGD for Crowley County (**Figure 3-54** through **Figure 3-56**, and **Figure 3-60**). Crowley County derived 0.99 percent of its total water supply from ground water, while Pueblo and Prowers counties derived 4.31 and 22.5 percent, respectively, of total water supply originate from ground water (**Figure 3-61**). El Paso County was the only county in the Lower Arkansas River Basin with domestic supply as the largest ground water use, and the remaining counties had irrigation as the largest ground water use (USGS 2000).

Water levels in alluvium along the lower Arkansas River and its tributaries are generally 5 to 30 feet bgs, with a shallower water table closer to the Arkansas River and its tributaries. In Pueblo County, USGS identified a group of wells with depth to water of 7 to 10 feet bgs and another group with depth to water of 13 to 19 feet bgs (USGS, 2002). Variation in water table depth is likely a function of proximity to the Arkansas River or variation in agricultural practices. Wells closer to the river have a shallower water table and less variation in depth to water from year to year for the 1971 to 2000 period. In Crowley and Otero Counties, depth to water for wells close to the Arkansas River ranged from 6 to 25 feet bgs, and for wells further from the river from 21 to 44 feet bgs. Depth to water in wells from the area in Bent County upstream from John Martin Reservoir ranged from 2 to 17 feet bgs, and depth to water for wells downstream of the reservoir ranged from 5 to 11 feet bgs. Depth to water in Prowers County wells ranged from 2 to 38 feet bgs (USGS, 2002). Greater than average precipitation during the period of 1982 to 1999 is a potential cause of increased water table elevation in lower Arkansas basin alluvial wells for the same period (USGS, 2002). Ground water withdrawals are lower during wet years and infiltration is higher, resulting in a higher water table.

Recharge to the Arkansas River alluvium mostly occurs through river discharge to the aquifer, with localized recharge from irrigation canals and surface application of irrigation downstream of the Pueblo and Crowley County line. Water development projects that import water to the basin (e.g., Fryingpan-Arkansas Project) and increase streamflow in the lower Arkansas Basin have enhanced recharge to the alluvium. The WWSP permits irrigation canal companies to store winter surface flow in Pueblo Reservoir to be used the following spring and summer for agricultural purposes. The resulting increased spring surface flow has a short-term effect on recharge to the alluvium immediately adjacent to the Arkansas River.

La Junta Region

The primary aquifer in the immediate area of the City of La Junta is the alluvial aquifer adjacent to the Arkansas River and Fort Lyon Canal (see **Figure 3-57**). The aquifer is comprised of mostly porous sand and gravel, overlain by silty-clay loam to sandy loam, and underlain by primarily shale bedrock (Gates et al., Personal communication). Aquifer thickness ranges from 3 to 100 feet, with an average of 30 feet. Hydraulic conductivity estimates range from 3.3x10-3 ft/day in the upper silty-clay loam to 1.7x103 ft/day in the lower layers of coarser sand and gravel, and an overall mean of 3.5 feet/day. Estimates for specific yield and ground water storage are 0.20 and 40,000 ac-ft, respectively (Bossong, 2000).

Watts et al. described the alluvial aquifer in a 5 mile long, 1.5 mile wide, and 7.6 square miles study area around La Junta in 1992. The highly transmissive, unconfined aquifer had a saturated thickness of less than 35 feet in 1966. The aquifer consists of Holocene and Pleistocene alluvial deposits of clay, silt, sand, and gravel. Average hydraulic conductivity was 670 ft/day, and specific yield estimates ranged from 0.17 to 0.25 (Watts et al., 1992).

Alluvial ground water is generally shallow in the La Junta area, with higher levels between the Fort Lyon Canal and the Arkansas River. In the area from the Fort Lyon Canal headgate east to the Otero County line, agricultural land and personal property is occasionally impaired by the unusually high water table. Depth to water is deeper closer to the Fort Lyon Canal and shallower near the Arkansas River. Ground water gradient is approximately 6 feet per mile in the La Junta area. The USGS measured water levels in 49 wells during the spring of 1999 to assess current water table depth, and the statistics are presented in **Table 3-45** (Bossong, 2000).

Table 3-45. Depth to Water Statistics for 49 Wells in the Vicinity of La Junta, Spring 1999

Mean (feet)	Minimum (feet)	Median (feet)	Maximum (feet)
12.30	-0.44	11.35	35.31

Notes:
(1) Source: (Bossong, 2000)

Both the Arkansas River and Fort Lyon Canal supply recharge to alluvial ground water in the La Junta area.

Total ground water withdrawals in 2000 for Otero County were 10.2 MGD (USGS, 2000b). Municipal wells near La Junta are clustered on the north side of the Arkansas River, and irrigation wells are uniformly distributed. In 1992, there were 41 irrigation wells, 3 municipal well fields, and 1 industrial well in the La Junta area (Watts et al., 1992). Combined irrigation and industrial ground water pumpage in the La Junta area was approximately 7,000 ac-ft per year in 1960 to 1971 (Watts et al., 1992). The City of La Junta pumped 2,500 to 3,000 ac-ft per year of alluvial ground water over the period from 1999 to 2003 for municipal supply (La Junta Water and Wastewater Department, 2004).

Surface water applications for irrigation, ground water withdrawals, and stages of the Fort Lyon Canal and Arkansas River affect ground water levels in the La Junta area. Forth Lyon Canal is unlined and has a direct relation to ground water levels. Conveyance losses of up to 15 ac-ft per day per canal mile have been reported (Bossong, 2000). Increased application of surface water for irrigation leads to decreased depth to ground water. The long-term mean for ground water withdrawals for 1972 to 1994 in the La Junta area was 1.64 feet per year for municipal and irrigation use (Bossong, 2000). Short term increases in Arkansas River stage lead to short term increases in water table elevation in wells near the river.

Watts et al. identified components of recharge and discharge to the alluvial aquifer in the La Junta vicinity through an average annual ground water budget for the period from 1960 to 1979, which is summarized in **Table 3-46**.

Table 3-46. Approximate Annual Ground Water Budget for the Alluvial Aquifer near La Junta, 1960-1979

Recharge Component	Recharge Amount (ac-ft/year)	Discharge Component	Discharge Amount (ac-ft/year)
Arkansas River Leakage	5,710	Municipal Pumpage	2,800
Fort Lyon Canal Leakage	3,910	Irrigation & Industrial Pumpage	7,055
Infiltration	3,185	Evapotranspiration	2,940
Underflow	1,320	Underflow	1,330
Total Recharge	**14,125**	**Total Discharge**	**14,125**

Notes:
(1) Source: (Watts, et. al., 1992)

The amount of irrigation water infiltrating to the water table on irrigated land was estimated to be 29 percent of the annual 5 feet per year of applied water over 2,100 acres, for a total of 3,045 ac-ft per year in the La Junta area. The amount of precipitation infiltrating to the water table on non-irrigated land was estimated to be 5 percent of the annual 11 inches of precipitation, for a total of 0.05 ft per year or about 140 ac-ft per year (Watts et al., 1992).

Ranges of hydrologic properties that describe the hydrologic connection between the alluvial aquifer and the Arkansas River were given by Watts et al. and are presented in
Table 3-47.

Table 3-47. Properties that Define the Extent of Hydrologic Connection between the Arkansas River and the Alluvial Aquifer in the La Junta Area

Hydrologic Property	Range
Arkansas River Leakage	0.5-2.5 cfs per mile
Maximum Infiltration Rate (Q/A)	1-3 feet per day
Streambed Conductance (Q/delta h)	94,000-282,000 ft2 per day
Streambed Leakance (K/L, L=streambed thickness)	2.9 1/d

Notes:
(1) Source: (Watts, et. al., 1992)

Streambed conductance can be used to predict the amount of leakage from the river to the aquifer given a change in river stage. For example, using a value of 188,000 ft2 per day, if the river stage rose by one foot the increased leakage would be 188,000 ft^2 per day × 1 foot = 188,000 ft^3 per day.

Flood irrigation is the dominant type of irrigation in the area, with some spray and drip irrigation. Irrigation water is taken as surface water from the Fort Lyon Canal and as ground water from the local alluvial aquifer. Ground water supply can make up 40 to 60 percent of irrigation water during periods of low surface flow. Of the 4,874 acre study area defined by Watts et al., 2,100 acres were irrigated with surface and ground water.

3.6.2 Ground Water Regulations

Colorado ground water is classified as tributary, non-tributary, not non-tributary, designated, or geothermal. Non-tributary ground water is ground water that the withdrawal of which will not deplete stream flow to an extent of 0.1 percent of the annual pumping rate within 100 years of pumping. Tributary ground water is ground water outside the Denver Basin aquifers that does not meet the definition of non-tributary ground water (i.e., ground water withdrawals do affect stream flows). See **Figure 3-58** for the location and extent of the Denver Basin aquifers. Not non-tributary ground water is any ground water inside the Denver Basin aquifers that does not meet the definition of non-tributary ground water.

The Colorado Groundwater Management Act, ch. 319, 1965 Colo. Sess. Laws 1246 (codified at COLO. REV. STAT. § 37-90-101 to -143 (1997)) was the first act to specifically address ground water rights unique from surface water rights. The 1965 Act defined designated ground water, created the Colorado Groundwater Commission to regulate designated ground water, delineated eight designated ground water basins in Colorado, and defined the judicial setting for arbitrating designated ground water disputes.

The 1965 Act defines designated ground water in two ways. Designated ground water is ground water that would not be available to fulfill decreed surface water rights, and that is hydrologically disconnected from surface water bodies. A second definition defines designated ground water as that which is not adjacent to a stream, given that ground water withdrawals have been the principal use of that water for at least 15 years before the first legal proceeding regarding the designation of the ground water. Each definition requires the ground water to be within the geographic regions of a designated basin. The second definition potentially could include water that may be considered tributary to surface water.

The Colorado Groundwater Commission was created to regulate the use of designated ground water. The commission can and has established ground water management districts to locally enforce its policies. There are eight designated basins in Colorado. The Upper Black Squirrel Creek and Upper Big Sandy designated basins are located in the northern part of the lower Arkansas basin. The Northern High Plains and Southern High Plains designated basins are in the eastern lower Arkansas basin. See **Figure 3-57** for the location of designated basins in the Arkansas River Basin. Ground water in Upper Black Squirrel Creek basin is overappropriated, which requires augmentations for any new appropriations in the basin.

New appropriations in the Upper Big Sandy, Northern High Plains, and Southern High Plains basins are allowed, with the requirement that existing water rights not be impaired.

The Colorado Water Rights Determination and Administration Act of 1969 (1969 Act) integrated aquifers which are in direct hydrologic connection with surface waters into the prior appropriation doctrine used for surface water rights (Colo. Rev. Stat. §§ 37-92-101 to -602). Wells pumping tributary ground water became subject to restrictions that would preserve decreed surface water rights that were part of the priority system of senior surface water rights. Wells outside of a platted subdivision, pumping less than 15 gpm for residential and domestic animal use are exempt from the prior appropriation rules.

Disputes over designated ground water are taken before the district court in the county where the dispute occurs, where a single district judge is designated for each basin. Wells permitted for less than 50 gpm are exempt from designated basin rules if the total annual pumped volume is less than 5 ac-ft. Disputes over ground water not classified as designated are heard in the Water Courts.

Senate Bill 213, passed in 1973, amended the 1965 Act by basing non-tributary ground water rights on land ownership. Rights to non-tributary ground water are given to overlying landowners, which are also required to pump the ground water at a rate that will preserve a 100-year life for the ground water. Wells that were pumping prior to passage of Senate Bill 213 are exempt from Senate Bill 213 rules.

Senate Bill 5, passed in 1985, established the legal definition of non-tributary ground water, rules for allocation of Denver Basin aquifer ground water, and rules for ground water augmentations. The legal definition for non-tributary ground water requires depletions smaller than 0.1 percent of the annual pumping rate over 100 years of pumping. Ground water in the Denver Basin aquifers is allocated on the basis of overlying land ownership and a 100-year life of the aquifer, including ground water that fails to meet the non-tributary legal definition. Senate Bill 5 gave the Water Court the responsibility of determining the amount of augmentation required to replace depletions in tributary ground water throughout Colorado and not non-tributary Denver Basin ground water. Depletions to wells within a mile of a stream require augmentation. Four percent of annual pumping must be augmented for depletions to wells that are greater than a mile from a stream.

The CDWR promulgated rules specific to the Arkansas River Basin in 1996 called "Amendments to Rules Governing the Measurement of Tributary Ground Water Diversions Located in the Arkansas River Basin." The 1996 rules cease pumping of ground water for irrigation with rights junior to the Arkansas River Compact of 1948, unless the pumped ground water is replaced with an approved augmentation plan. The rules also restrict ground water pumped for irrigation purposes with priorities senior to the 1948 compact to 15,000 ac-ft per year, unless the pumping is augmented. Ground water diversions affecting senior surface water rights are also banned without an approved augmentation plan.

4.0 EFFECTS ANALYSIS

The effects analysis estimates the effects of the Proposed Action and No Action Alternative due to these actions alone. The purpose of this analysis is to “isolate” the effects of the actions. This section presents the effects analysis for water quantity, hydraulics and geomorphology, and ground water.

4.1 General Description of Hydrologic Analysis

The primary tool used to estimate the effects of the Proposed Action and No Action Alternative on hydrology of the Arkansas River Basin was the Arkansas River Basin Quarter-Monthly Model developed by Hydrosphere Resource Consultants. This model superimposes existing and future demands on 1982 through 2002 historical hydrology using a quarter-monthly (approximately weekly) time-step, and is constructed to simulate anticipated operations of the Proposed Action and No Action Alternative. A detailed description of the Quarter-Monthly Model construction is provided under separate cover (Hydrosphere, 2005). The objective of the Quarter-Monthly Model is to allow comparisons between the simulated alternatives.

Pertinent assumptions and Quarter-Monthly Model variables for Existing Conditions, the Proposed Action, and No Action Alternative effects are shown in **Table 4-1**. As shown, most of the model assumptions for those variables not directly associated with Aurora are held constant in each of the simulations. Each of the scenarios is discussed in the following sub-sections.

4.1.1 Existing Conditions

The primary goal of Existing Conditions was to simulate 2004 operational conditions in the river for the modeled period. Existing Conditions differ from historical conditions in that Existing Conditions assume existing (2004) operations on the river for the entire study period (1982-2002). The historical conditions, on the other hand, reflect varied river operations and demands on the river during the 1982 through 2002 study period. The Existing Conditions provide a basis of comparison to the Proposed Action and No Action Alternative.

Existing Conditions assume 2004 demands (unconstrained by drought-related conservation programs that were in effect), current levels of excess storage capacity contracts (if-and-when contracts) in Pueblo Reservoir, and facilities and decreed water rights as of the beginning of the year. The Aurora Rocky Ford I transfer, Rocky Ford II transfer, and Highline Canal lease are included in this condition. Fifty percent of the total decreed yield of the Rocky Ford II transfer was modeled for this condition, because by decree, water cannot be changed from a tract of land until revegetation is complete. Although the conditions of the Pueblo FMP are currently being administered, the Pueblo FMP is not included in this condition because Aurora’s future participation in the Pueblo FMP is dependent on the adoption of the Proposed Action. The City of Aurora’s existing “if-and-when” excess capacity contract was in place in 2004 and as a result was assumed for the Existing Conditions simulation.

Table 4-1. Summary of Simulation Model Variable Settings for Effects Analysis

Model Variable	Effect Scenario		
	Existing Condition	No Action	Proposed Action
General Settings			
Municipal Demands	2004	2004	2004
Other Demand by Others	No	No	No
Agricultural Demands (1)	Historical	Historical	Historical
Otero Pump Station Capacity	118.5 mgd	118.5 mgd	118.5 mgd
Aurora Settings			
Excess Capacity in Pueblo Res.	10,000 ac-ft	0 ac-ft	10,000 ac-ft
Gravel Lakes Storage	0 ac-ft	10,000 ac-ft	0 ac-ft
USBR Contract Exchanges	0 ac-ft	0 ac-ft	10,000 ac-ft
Transmountain Diversions	Yes	Yes	Yes
Upper Arkansas Ranch water Rights	Yes	Yes	Yes
Rocky Ford I Transfer	Yes	Yes (junior to RICD)	Yes
Colorado Canal	Yes	Yes	Yes
Rocky Ford II Transfer (2) (3)	Yes (50%)	Yes (100%)	Yes (100%)
Highline Lease	Yes	Yes	Yes
Pueblo FMP/RICD - Aurora	None	None	Full
ROY Storage - Aurora	No	No	Yes
Other Municipal Settings			
Pueblo Board of Water Works Excess Capacity Storage in Pueblo Reservoir	3,000 ac-ft	3,000 ac-ft	3,000 ac-ft
Pueblo West Excess Capacity Storage in Pueblo Reservoir	1,000 ac-ft	1,000 ac-ft	1,000 ac-ft
Colorado Springs Utilities Excess Capacity in Pueblo Reservoir	10,000 ac-ft	10,000 ac-ft	10,000 ac-ft
Pueblo FMP/RICD - Others(4)	None	None	None
ROY Storage - Others	No	No	No
Colorado Springs' Future Operations(5)	No	No	No

Notes:

(1) Agricultural demands are assumed to be the same as historical except for those systems that have been converted to municipal use, such as the Colorado Canal system, Rocky Ford Ditch and Highline Canal lease.

(2) The percentage value indicates the percent of the total decreed yield that is changed and diverted by Aurora. By decree, water cannot be changed from a tract of land until revegetation is complete.

(3) During actual 2004 operations, because Aurora's Upper Basin exchange application (99CW170) was not finalized, Rocky Ford II water was diverted into the PBWW Excess Capacity account in Pueblo Reservoir, then moved to Twin Lakes by contract exchange with the PBWW (Simpson, 2005). The Upper Basin exchange was decreed in 2005. Therefore, the Quarter-Monthly Model operates per the decree. The differences in storage and streamflow between actual and simulated operations during 2004 are negligible.

(4) Due to limitations in the Quarter-Monthly Model, all Colorado Canal exchanges (including those by Colorado Springs Utilities, Pueblo West and the City of Fountain) are subject to the same Pueblo FMP conditions as other Aurora exchanges

(5) Colorado Springs Utilities future operations assumed to consist of increased ground water pumping and increased non-potable and potable reuse.

4.1.2 Proposed Action Alternative

The Proposed Action simulates operations of the Arkansas River assuming that the Proposed Action is implemented under existing operations. In-basin municipal demands were set to equal demands in the year 2004. As in-basin municipal demands increase, Aurora's effects on the Arkansas River Basin hydrology become relatively smaller. That is to say later in the contract period (closer to 2045), Aurora's effects would be dampened due to the exercise of senior exchanges made by other entities in the basin. The following operational differences are unique to the Proposed Action when compared with the Existing Conditions run:

- The City of Aurora would be permitted to exchange up to 10,000 ac-ft via contract exchanges from Pueblo Reservoir with Reclamation's Fry-Ark Project water in Twin Lakes and Turquoise Reservoir.
- The percent of the total decreed yield of the Rocky Ford II transfer that is simulated increases from 50 to 100 percent.
- The Pueblo FMP is simulated.
- Restoration of yield (ROY) Storage is simulated.

Additionally, under the Proposed Action, the City of Aurora's current annual "if-and-when" excess capacity contracts for 10,000 acre-feet of storage in Pueblo Reservoir would become a long-term (40-year) excess capacity contract. In the Quarter-Monthly Model, however, the excess capacity contracts are simulated in the same manner for the Existing Conditions and Proposed Action. Settings for all other operations in the Arkansas River Basin are assumed to be the same as for Existing Conditions.

4.1.3 No Action Alternative

The No Action Alternative simulates the future operations of the Arkansas River assuming that the No Action Alternative is implemented. For the purposes of this alternative, it was assumed that Aurora would not have an annual excess capacity contract with Reclamation. Municipal demands were set to equal demands in the year 2004 for the same reasons discussed for the Proposed Action. The following operational differences are unique to the No Action Alternative when compared with the Existing Conditions run:

- 10,000 acre-feet of gravel lakes storage by the City of Aurora is generally located adjacent to the Arkansas River east of the Fountain Creek confluence.
- The Rocky Ford I transfer is assumed to be junior to the City of Pueblo RICD, because its current decree does not allow an alternate point of diversion at any location other than Pueblo Reservoir.
- The percent of the total decreed yield of the Rocky Ford II transfer that is simulated increases from 50 to 100 percent.

Settings for all other operations in the Arkansas River Basin are the same as for Existing Conditions.

4.2 Surface Water Quantity Analysis

This section provides the effects surface water quantity analysis. Surface water quantity studies include the analysis of streamflow and reservoir storage. Most of the analyses performed for surface water quantity studies are directly or indirectly based on the Quarter-Monthly Model results. Analyses include direct examination of Quarter-Monthly Model results, summary model results, and a peak flow analysis.

4.2.1 Hydrologic Year Summary

Use of hydrologic year classification allows the Quarter-Monthly Model results to be summarized on a mean, dry, and wet year basis. Based on this, the three summary conditions are stated as follows:

- **Overall Mean -** Mean of all years in the 1982-2002 study period
- **Mean Dry-** Mean of the driest 30 percent of years in the study period
- **Mean Wet -** Mean of the wettest 30 percent of years in the study period

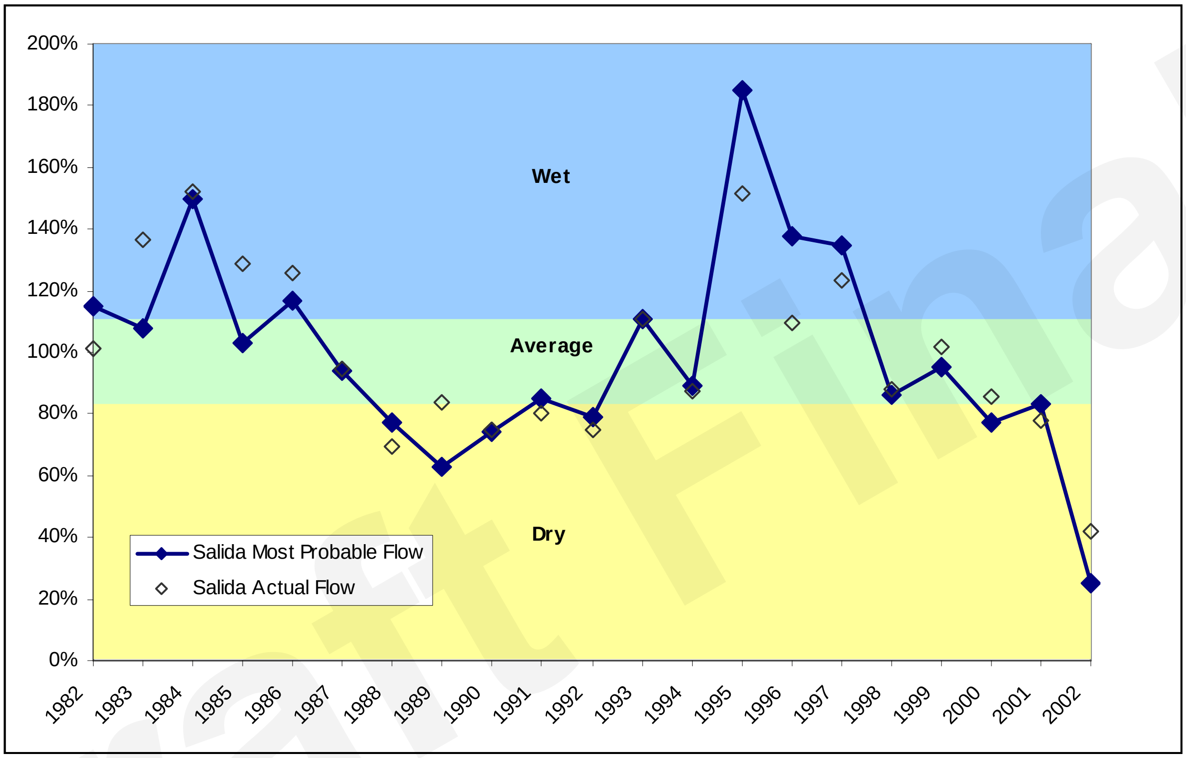
Based upon historical most probable flow forecasts available from the NRCS, the years within the 1982-2002 study period were classified as dry, average or wet. NRCS estimates of most probable flows are made between January and June of each year and do not reflect actual flow in the river. However, decisions within the river basin are typically made using forecasts because they represent the most real-time information available (i.e. it is unknown from real-time streamflow whether the overall hydrologic condition for the year will be wet or dry), justifying its use as a hydrologic indicator. **Table 4-2** presents a summary of the hydrologic classification.

Table 4-2. Hydrologic Year Classification for Salida Gage

Water Year	Salida Most Probable Flow		Rank (ni)	Non-Exceedance Probability (Pi)	Hydrologic Classification
	(% of Average)	(ac-ft)			
1982	115%	356,500	16	0.727	Wet
1983	108%	334,800	14	0.636	Avg
1984	150%	465,000	20	0.909	Wet
1985	103%	319,300	13	0.591	Avg
1986	117%	362,700	17	0.773	Wet
1987	94%	291,400	11	0.500	Avg
1988	77%	238,700	4	0.182	Dry
1989	63%	195,300	2	0.091	Dry
1990	74%	229,400	3	0.136	Dry
1991	85%	263,500	8	0.364	Avg
1992	79%	244,900	6	0.273	Dry
1993	111%	344,100	15	0.682	Avg
1994	89%	275,900	10	0.455	Avg
1995	185%	573,500	21	0.955	Wet
1996	138%	427,800	19	0.864	Wet
1997	135%	418,500	18	0.818	Wet
1998	86%	266,600	9	0.409	Avg
1999	95%	294,500	12	0.545	Avg
2000	77%	238,700	4	0.182	Dry
2001	83%	257,300	7	0.318	Avg
2002	25%	77,500	1	0.045	Dry
Dry	83%	257,300			
Wet	111%	344,100			

In order to compare differences between forecasted flow and actual flow, a graph showing the annual flow forecast (as percent of average) and actual flows at the Salida gage is shown **Figure 4-1**. The NRCS most probable flows are forecasts of natural flow. Actual flows in the Arkansas River are typically greater due to transmountain imports. For purposes of the information shown, the actual flow at the gage has been divided by the mean annual flow to obtain a percent of average estimate. As shown in **Figure 4-1**, typically actual percent of average is within the same hydrologic classification as the forecasted percent of average. Therefore, the use of the NRCS flow predictions to estimate actual streamflows is shown to be a reliable prediction method.

Figure 4-1. Hydrologic Year Classification and Actual Flow at the Salida Gage



4.2.2 Simulated Exchanges and Project Yield

Both the Proposed Action and the No Action Alternative transfer water available from Aurora's existing Lower Arkansas River water rights from the lower portion of the basin to storage in the Upper Basin via alternate points of diversion, river exchanges and contract exchanges. Because of differing alternate point-of-delivery and exchange priorities assumed under the two actions, the resulting exchanges and yields differ.

Table 4-3 presents a summary of the simulated exchanges under the Existing Condition, No Action Alternative and Proposed Action. Exchanges under the No Action Alternative are less than for Existing Conditions and the Proposed Action due to the following:

1. Exchanges from the Rocky Ford I and Colorado Canal are less because of their junior priority in the No Action Alternative.
2. The inability to move water stored in the No Action Alternative gravel lake to the Upper Basin by contract exchange in the No Action Alternative.

Exchanges under the Proposed Action are generally greater than under Existing Conditions for the following reasons:

1. Exchanges that are part of the full Rocky Ford II Transfer are part of the Proposed Action.
2. Contract exchanges unique to the Proposed Action allow more efficient use of Aurora's water rights.

Table 4-3. Summary of Simulated Annual Exchanges for Effects Analysis

Exchange	Source	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)
River Exchanges to Pueblo Reservoir or Gravel Pit	Rocky Ford I	7,344	5,198	4,743
	Rocky Ford II	2,151	2,568	3,313
	Colorado Canal	5,876	1,615	5,519
	Highline Lease	2,990	839	2,042
	Holbrook Reservoir Release	0	0	2,323
Contract Exchange to Pueblo Reservoir or gravel lakes	Holbrook Contract	0	0	2,578
	Total to Pueblo Reservoir or Gravel Pit	18,361	10,221	20,519
River Exchanges to Upper Basin	From Pueblo Reservoir Storage	3,315	6,778	3,764
	Colorado Canal	5,597	3,488	5,704
Contract Exchanges to Upper Basin	via PBWW	8,952	0	8,952

Notes:

(1) Total exchanges to the Upper Arkansas River Basin are the total Lower Arkansas River Basin water rights yield at the Upper Arkansas River Basin Storage.

Table 4-4and **Table 4-5** present the annual exchange to the Upper Arkansas River Basin (Turquoise Reservoir and Twin Lakes Reservoir) and the Lower Arkansas River Basin (Pueblo Reservoir or gravel lakes), respectively, under each scenario. All of the simulated scenarios include 10,000 acre-feet of storage in either Pueblo Reservoir or gravel lakes. The primary benefit of storage in Pueblo Reservoir is that all decrees can be diverted or exchanged to Pueblo Reservoir. Under the No Action Alternative (gravel lakes), a portion of the decrees would need to be changed to allow diversion and exchange to gravel lakes. It was assumed that these changes would result in decrees that would be junior to a number of existing decrees. In addition, contract exchanges can be made out of Pueblo Reservoir but not out of gravel lakes storage. Contract exchanges shown in **Table 4-4** are higher under the Proposed Action than under Existing Conditions and the No Action Alternative, because contract exchanges are unique to the Proposed Action (see **Table 4-1**).

River exchanges are higher for the Proposed Action than under Existing Conditions, because the percent of the total Rocky Ford II Transfer decreed yield that is diverted by Aurora increases from 50 to 100 percent from Existing Conditions to the Proposed Action. The additional Rocky Ford II Transfer yield increases Aurora's river exchange potential. During dry years (e.g., 1989 and 2002), river exchanges are higher for the Proposed Action than under Existing Conditions as a result of ROY storage in Holbrook Reservoir. Aurora's ROY storage in Holbrook Reservoir is unique to the Proposed Action, and the additional storage in Holbrook Reservoir is available for river exchanges into Pueblo Reservoir.

The primary benefit of gravel lakes storage is that storage in this vessel would be firm storage, while storage in Pueblo Reservoir excess capacity storage space is not firm, and can be spilled by Project water, WWSP water and other in-District excess capacity accounts. However, as shown in the tables, even with the benefit of firm storage in the gravel lakes, exchanges are lower for the No Action Alternative than for the Proposed Action. Aurora's Arkansas River Basin yield is also less for the No Action Alternative, because exchanges to the Upper Arkansas River Basin from the Lower Arkansas River Basin make up a large portion of Aurora's yield from the basin.

Table 4-4. Simulated Annual Exchange into Pueblo Reservoir or Gravel Lake from Lower Arkansas River Water Supplies for Effects Analysis

Year	Existing Conditions			No Action Alternative			Proposed Action		
	River	Contract (1)	Total	River	Contract (1)	Total	River	Contract	Total
1982	27,891	0	27,891	13,663	0	13,663	28,300	1,157	29,457
1983	27,865	0	27,865	11,231	0	11,231	27,248	3,529	30,777
1984	27,699	0	27,699	21,313	0	21,313	25,921	283	26,204
1985	24,914	0	24,914	15,311	0	15,311	22,988	3,149	26,137
1986	26,841	0	26,841	15,152	0	15,152	23,090	3,516	26,606
1987	29,607	0	29,607	13,797	0	13,797	22,332	5,348	27,680
1988	21,724	0	21,724	11,604	0	11,604	17,880	2,675	20,555
1989	15,358	0	15,358	14,574	0	14,574	19,452	1,708	21,160
1990	23,635	0	23,635	11,370	0	11,370	26,205	1,721	27,926
1991	23,886	0	23,886	15,522	0	15,522	25,671	1,818	27,489
1992	23,905	0	23,905	14,185	0	14,185	27,195	667	27,862
1993	20,717	0	20,717	15,830	0	15,830	23,514	701	24,215
1994	20,819	0	20,819	9,629	0	9,629	21,406	2,780	24,186
1995	26,402	0	26,402	13,497	0	13,497	29,649	1,713	31,362
1996	27,383	0	27,383	14,697	0	14,697	28,780	2,701	31,481
1997	21,751	0	21,751	18,955	0	18,955	24,159	640	24,799
1998	22,646	0	22,646	14,359	0	14,359	23,041	4,037	27,078
1999	30,783	0	30,783	13,545	0	13,545	31,774	2,193	33,967
2000	26,217	0	26,217	9,462	0	9,462	12,362	5,807	18,169
2001	21,616	0	21,616	13,700	0	13,700	20,826	3,740	24,566
2002	11,454	0	11,454	6,493	0	6,493	14,741	4,260	19,001
Avg	23,958	0	23,958	13,709	0	13,709	23,644	2,578	26,223

Notes:

(1) Historically there have been sporadic contract exchanges from Lake Henry and Lake Meredith to Pueblo Reservoir. However, contract exchanges were set to zero for purposes of defining Existing Conditions and the No Action Alternative.

Table 4-5. Simulated Annual Exchange into Upper Arkansas River Basin Storage for Effects Analysis

Year	Existing Conditions			No Action Alternative			Proposed Action		
	River	Contract (1)	Total	River	Contract (1)	Total	River	Contract	Total
1982	16,605	9,000	25,605	10,241	0	10,241	11,829	17,000	28,829
1983	17,572	8,000	25,572	13,110	0	13,110	9,972	17,000	26,972
1984	15,505	9,000	24,505	15,002	0	15,002	15,346	9,000	24,346
1985	12,975	10,000	22,975	9,600	0	9,600	12,975	10,000	22,975
1986	17,306	9,000	26,306	11,898	0	11,898	17,306	9,000	26,306
1987	15,258	9,000	24,258	10,098	0	10,098	14,283	9,000	23,283
1988	10,494	9,000	19,494	8,107	0	8,107	9,303	9,000	18,303
1989	11,852	9,000	20,852	11,109	0	11,109	12,595	14,000	26,595
1990	8,312	9,000	17,312	7,872	0	7,872	8,400	18,000	26,400
1991	13,251	9,000	22,251	12,049	0	12,049	9,561	17,000	26,561
1992	12,293	9,000	21,293	11,949	0	11,949	9,892	16,000	25,892
1993	12,070	9,000	21,070	11,163	0	11,163	10,707	12,000	22,707
1994	10,020	9,000	19,020	6,159	0	6,159	6,164	16,000	22,164
1995	17,503	9,000	26,503	10,760	0	10,760	17,460	9,000	26,460
1996	15,026	9,000	24,026	10,619	0	10,619	14,817	10,000	24,817
1997	16,760	7,000	23,760	17,632	0	17,632	22,341	8,000	30,341
1998	9,714	11,000	20,714	8,942	0	8,942	12,506	10,000	22,506
1999	17,095	8,000	25,095	10,139	0	10,139	18,359	9,000	27,359
2000	10,725	9,000	19,725	5,961	0	5,961	6,521	9,000	15,521
2001	11,131	9,000	20,131	10,215	0	10,215	13,415	13,000	26,415
2002	1,626	9,000	10,626	2,964	0	2,964	3,897	18,000	21,897
Avg	13,004	8,952	21,957	10,266	0	10,266	12,269	12,333	24,602

Notes:

(1) Exchanges include river and contract exchanges from Pueblo Reservoir plus river exchanges from the Colorado Canal system.

Simulated storage in the existing if-and-when account in Pueblo Reservoir for Existing Conditions is shown in **Figure 4-2**. As shown, the storage space fills during slightly more than half of the years in the simulation and is drawn down within 5,000 acre-feet during about half of the years in the simulation.

Figure 4-3 shows simulated storage in gravel lakes storage for the No Action Alternative. The results show the reduced yield of Aurora's water rights in the basin. Because it was assumed that Reclamation would not own any storage space in the gravel lakes, contract exchanges are not executed. Therefore, all water must be moved to the Upper Basin using junior river exchanges, which reduces yield. Minimum storage never drops below 4,300 acre-feet. This indicates that the same yield would be available from a gravel lake reservoir of only 5,700 ac-ft. However, daily fluctuations in exchange potential that are not captured by the Quarter-Monthly Model may result in more utilization of the 10,000 acre-feet of storage on a daily basis.

Figure 4-2. Simulated Aurora Storage in Pueblo Reservoir - Existing Conditions

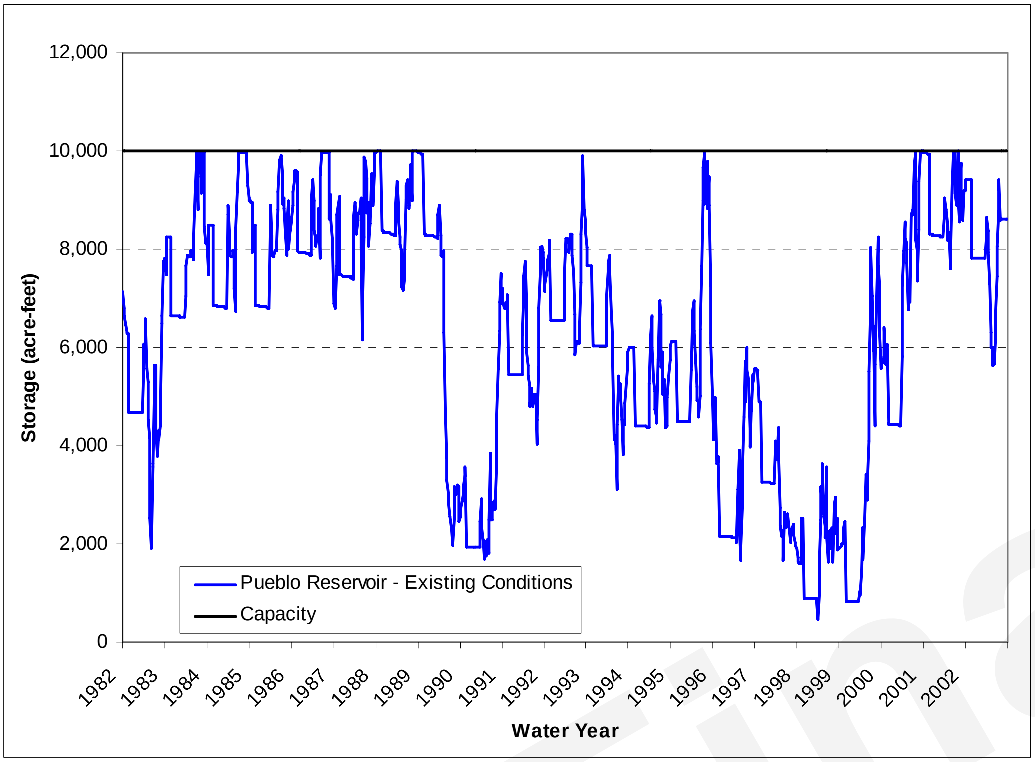


Figure 4-3. Simulated Aurora Storage in gravel lakes - No Action Alternative Effects

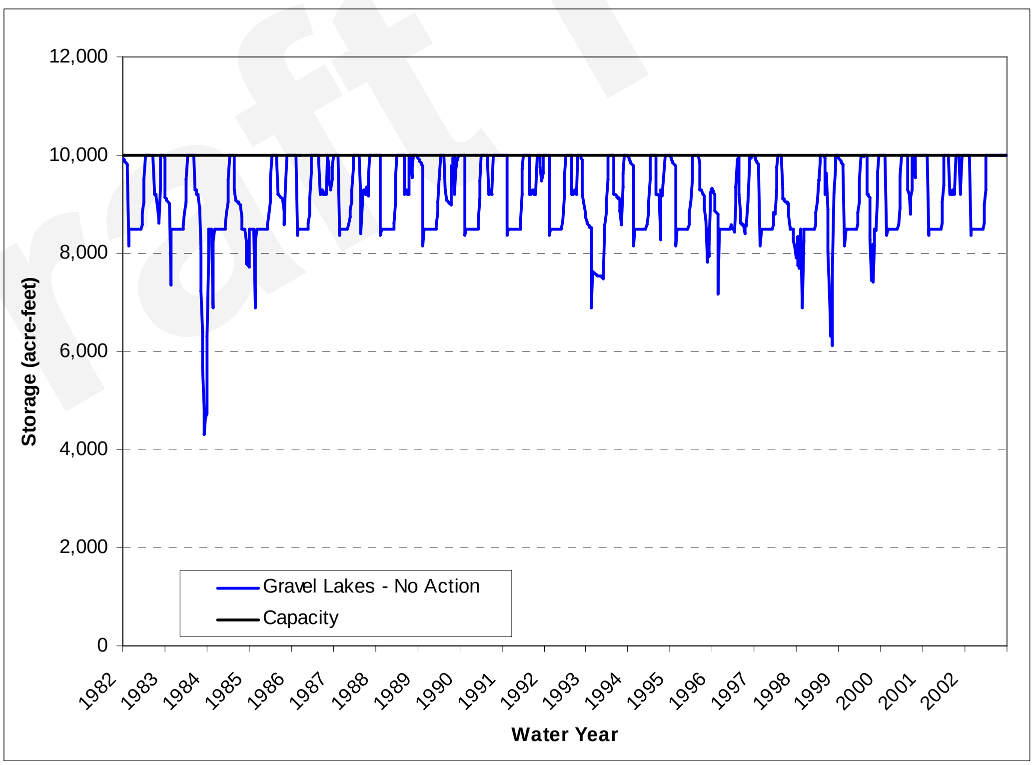
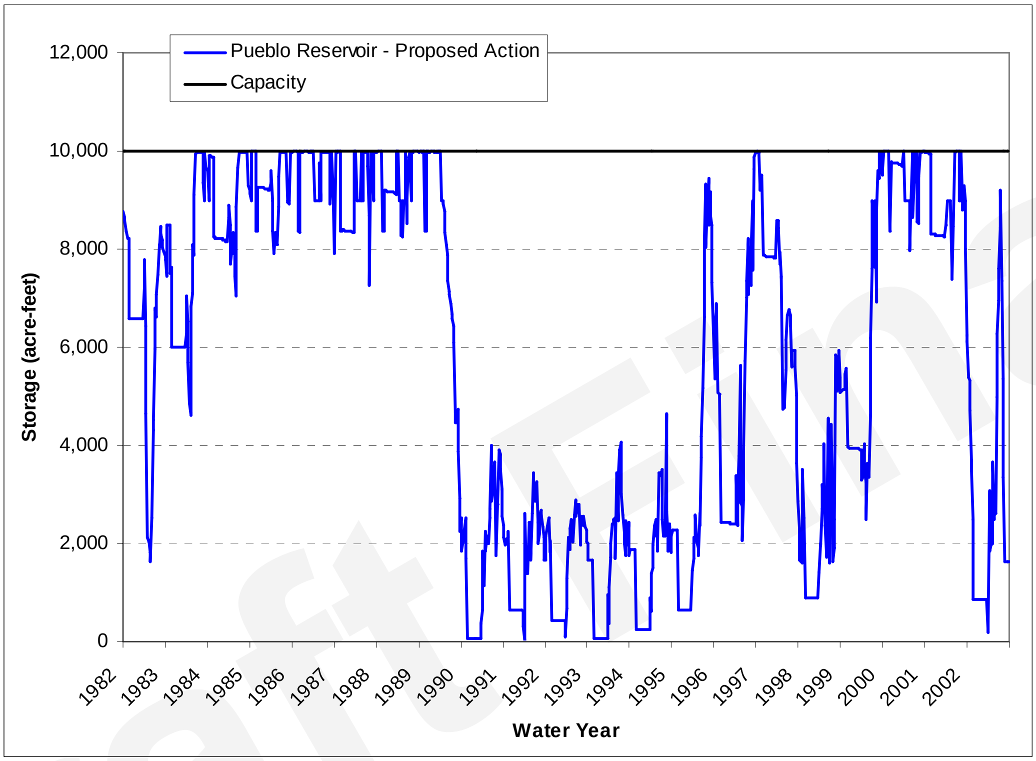


Figure 4-4 shows simulated storage in the Long Term Excess Capacity account in Pueblo Reservoir as part of the Proposed Action. Storage in this account is less than for Existing Conditions because of the ability to execute contract exchanges with Reclamation under the Proposed Action, which moves water more quickly to Upper Arkansas River Basin storage.

More detail on reservoir storage levels is provided for select major reservoirs in subsequent sections.

Figure 4-4. Simulated Aurora Storage in Pueblo Reservoir - Proposed Action Effects



4.2.3 Comparison of Flows Within Reaches

The Quarter-Monthly Model simulates flows at several locations within the Study Area. As previously stated, Reclamation requested that effects of the Proposed Action be analyzed at several nodes in the river. Output from the Quarter-Monthly Model for all of the nodes is contained in the appendix. However, for purposes of describing the effects in the river within this document and for other resource studies, it was appropriate to narrow the number of locations that are specifically addressed. This sub-section compares flows between gages in similar reaches and makes a selection of key gages within the river for specific analysis in this report.

Table 4-6 presents a summary of the simulated Proposed Action monthly average streamflow minus No Action monthly average streamflow for the originally requested streamflow gages on the Arkansas River above Pueblo Reservoir. As expected, there are similarities in several of the mainstem gages between Lake Creek and Pueblo Reservoir because there are no differences in operations within this reach for the Proposed Action or for the No Action Alternative. Therefore, the analysis for these gages was consolidated into a single gage. Because the Wellsville gage is the point of measurement for the Upper Arkansas Flow Management Program, the Wellsville gage was selected from this group. Similarly, effects at the Lake Fork gage and the Malta gage are identical because there are no differences in operations between the Lake Fork and Malta gages for the Proposed Action or for the No Action Alternative. Therefore, for purposes of discussion, the Lake Fork gage was selected. Although the Lake Creek gage effects are similar to those in the mainstem, it is discussed separately because it is a tributary stream. Therefore, within this document, hydrologic effects are discussed at the following gages above Pueblo Reservoir:

- Lake Fork gage
- Lake Creek gage
- Wellsville gage

Table 4-6. Comparison of Effects for Proposed Action at Gage Locations Above Pueblo Reservoir

Month	Proposed Action minus No Action Monthly Average Streamflow (cfs)						
	Lake Fork	Malta	Lake Creek	Granite	Nathrop	Wellsville	Portland
Oct	0	0	-2	-5	-5	-5	-5
Nov	0	0	0	-10	-10	-10	-10
Dec	-2	-2	-6	-15	-15	-15	-15
Jan	4	4	-5	-10	-10	-10	-10
Feb	-3	-3	-10	-26	-26	-26	-26
Mar	-3	-3	-13	-41	-41	-41	-41
Apr	-3	-3	-14	-1	-1	-1	-1
May	0	0	-23	-3	-3	-3	-3
Jun	0	0	-39	-6	-6	-6	-6
Jul	0	0	2	-2	-2	-2	-2
Aug	0	0	-3	0	0	0	0
Sep	0	0	-6	-6	-6	-6	-6
Average	0	0	-10	-10	-10	-10	-10

Table 4-7 presents a summary of the simulated Proposed Action monthly average streamflow minus No Action monthly average streamflow for the originally requested streamflow gages on the Arkansas River below Pueblo Reservoir. There are three distinct reaches below Pueblo Reservoir: from Pueblo Reservoir to the No Action Alternative gravel pit location (below the Fountain Creek confluence), from the gravel lake to the Colorado Canal outlet channel, and downstream of the outlet channel. A gage was selected as representative for each of these reaches. In addition, because of the importance of both the Above Pueblo gage and the Moffat Street gage in the analysis, both of these gages were also included. Based on this, the hydrologic effects of the following gages below Pueblo Reservoir are discussed in this document:

- Above Pueblo gage
- Moffat Street gage
- Avondale gage
- La Junta gage

Table 4-7. Comparison of Effects for Proposed Action at Gage Locations Below Pueblo Reservoir

Month	Proposed Action minus No Action Monthly Average Streamflow (cfs)			
	Above Pueblo	Moffat Street	Avondale	La Junta
Oct	1	1	1	0
Nov	0	0	2	0
Dec	-2	-3	12	2
Jan	-35	-35	-9	-2
Feb	-67	-68	-52	-7
Mar	-38	-38	-28	18
Apr	0	0	11	-1
May	-18	-18	-2	-6
Jun	-6	-6	4	-2
Jul	1	1	7	1
Aug	-8	-8	4	-7
Sep	19	19	21	19
Average	-13	-13	-3	1

All of the major reservoirs are included in the discussion with the exception of Twin Lakes. Effects are not shown at Twin Lakes because all effects of the proposed project occur within the normal operating pool of the reservoir and because Twin Lakes is part of the Mount Elbert Pump-Storage Project, its reservoir levels are highly variable. The Quarter-Monthly Model lumps the Colorado Canal System reservoirs (Lake Henry and Lake Meredith) into one single reservoir. However, simulated Colorado Canal System reservoir contents are subsequently distributed to Lake Henry and Lake Meredith contents outside of the Quarter-Monthly Model. The methodology used to distribute Colorado Canal storage contents among Lake Henry and Lake Meredith is described in **Section 2.1.3.1**. Based on this, the hydrologic effects of the following reservoirs are discussed in this analysis.

- Turquoise Reservoir
- Pueblo Reservoir
- Lake Henry
- Lake Meredith
- Holbrook Reservoir

4.2.4 Discussion of Selected Quarter-Monthly Results

This section presents a discussion of the Quarter-Monthly Model results. Raw model results for each streamflow location in the simulation are presented in Appendix A. Quarter-Monthly Model results are provided for the Existing Conditions, Proposed Action, and No Action Alternative scenarios. The effects of the Proposed Action are measured relative to the No Action Alternative results.

4.2.4.1 Arkansas River Above Pueblo Reservoir

This section summarizes model results and net effects for key locations above Pueblo Reservoir, including Turquoise Reservoir, Lake Fork, Lake Creek and the Wellsville gage.

Turquoise Reservoir

Summary data for the effects analysis at Turquoise Reservoir is shown in **Table 4-8**, **Figure 4-5**, and **Figure 4-6**. Proposed Action simulated storage is generally greater than No Action Alternative storage, except for winter and spring months during mean dry years when it is slightly less. The effects are greatest during mean wet years. Proposed Action storage is less than storage under the No Action Alternative during winter and spring months of mean dry years, because more water is exchanged into Twin Lakes Reservoir than Turquoise Reservoir during dry years as a result of contract exchanges to Twin Lakes Reservoir. The increased storage under Proposed Action occurs because Aurora is able to contract exchange more water into Twin Lakes and Turquoise Reservoirs under the Proposed Action. Because the Quarter-Monthly Model always diverts water stored in Twin Lakes through the Otero Pump Station before water stored in Turquoise Reservoir, Aurora's Turquoise Reservoir accounts generally remain more full under the Proposed Action than for the No Action Alternative.

Table 4-8. Turquoise Reservoir - Summary of Effects

Month	Simulated Storage			Effects (1)	
	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)	(ac-ft)	(%)
Overall Mean					
Oct	111,058	107,317	111,552	4,234	4%
Nov	107,661	104,046	108,095	4,049	4%
Dec	102,788	99,567	103,015	3,449	3%
Jan	99,172	96,051	98,788	2,737	3%
Feb	94,259	91,709	94,127	2,418	3%
Mar	84,543	82,799	84,672	1,873	2%
Apr	66,915	66,758	67,803	1,046	2%
May	62,867	61,626	63,734	2,108	3%
Jun	98,629	96,162	99,000	2,838	3%
Jul	116,825	114,377	116,743	2,366	2%
Aug	115,669	113,072	115,562	2,491	2%
Sep	112,949	109,928	112,994	3,066	3%
Average	97,778	95,284	98,007	2,723	3%
Mean Wet					
Oct	112,921	108,850	113,220	4,369	4%
Nov	110,753	106,094	110,575	4,481	4%
Dec	106,821	100,416	106,041	5,625	6%
Jan	104,940	96,780	103,891	7,111	7%
Feb	101,921	94,479	101,185	6,706	7%
Mar	91,786	85,758	91,473	5,714	7%
Apr	67,639	65,389	68,439	3,050	5%
May	63,861	60,992	65,053	4,061	7%
Jun	105,552	101,581	106,067	4,486	4%
Jul	128,658	126,048	128,919	2,872	2%
Aug	129,032	126,752	129,192	2,439	2%
Sep	127,596	125,027	128,062	3,036	2%
Average	104,290	99,847	104,343	4,496	5%

Table 4-8. Turquoise Reservoir - Summary of Effects

Month	Simulated Storage: Existing Conditions (ac-ft)	Simulated Storage: No Action (ac-ft)	Simulated Storage: Proposed Action (ac-ft)	Effects (1) (ac-ft)	Effects (1) (%)
Mean Dry					
Oct	104,638	100,249	105,580	5,331	5%
Nov	100,147	97,267	101,318	4,051	4%
Dec	95,463	94,392	96,321	1,929	2%
Jan	91,555	92,065	90,978	-1,087	-1%
Feb	86,791	88,009	85,581	-2,429	-3%
Mar	79,405	81,034	78,610	-2,424	-3%
Apr	65,304	67,418	65,264	-2,154	-3%
May	59,397	60,344	58,848	-1,495	-2%
Jun	87,204	86,506	86,127	-379	0%
Jul	98,742	97,108	97,472	364	0%
Aug	95,388	93,288	93,842	555	1%
Sep	91,446	89,586	89,528	-58	0%
Average	87,957	87,272	87,456	184	0%

Notes:

(1) Effects (ac-ft) = Proposed Action - No Action simulated storage. Effects (%) = (Proposed Action - No Action simulated storage)/No Action simulated storage.

Figure 4-5. Turquoise Reservoir Effects Time Series Plot

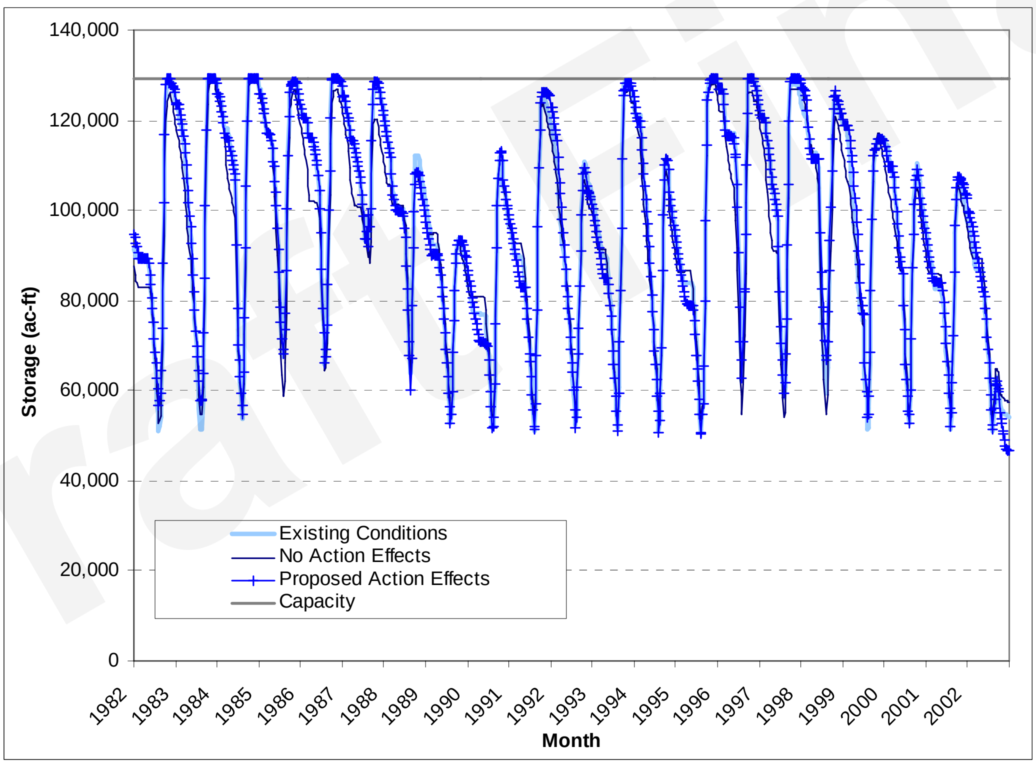
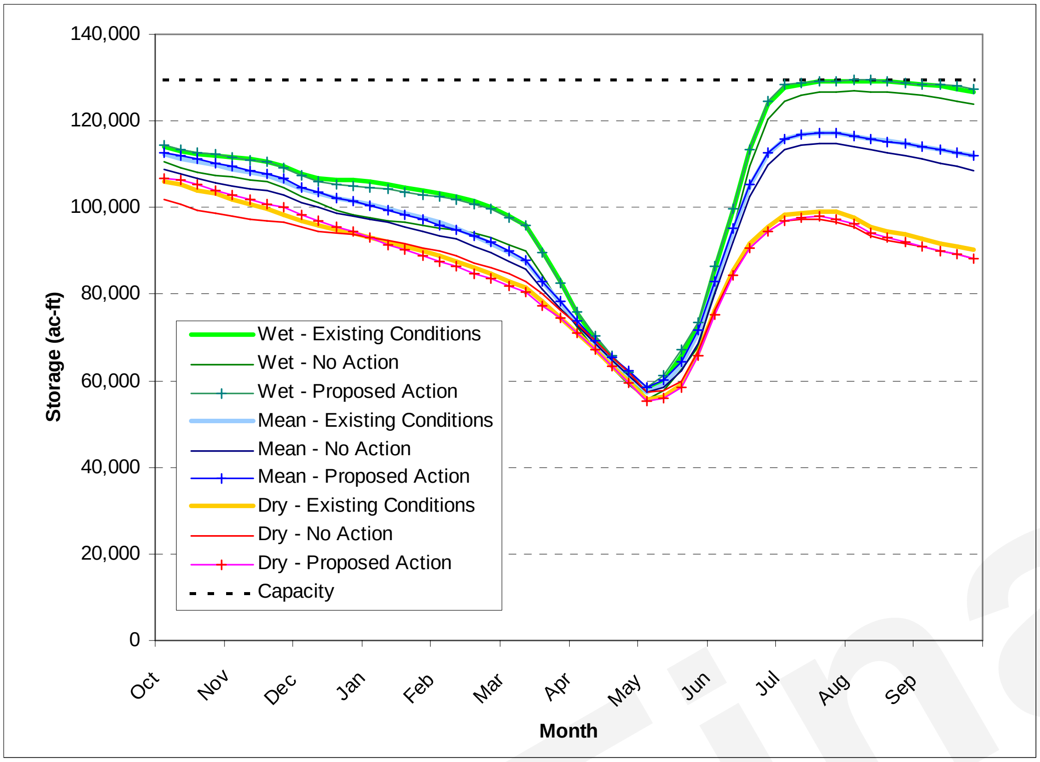


Figure 4-6. Turquoise Reservoir - Simulated Effects Storage



Lake Fork

Summary information for the Lake Fork gage is presented in **Table 4-9** and **Figure 4-7**. Lake Fork streamflow is mostly a result of releases from Turquoise Reservoir. Effects associated with the No Action Alternative and the Proposed Action are minimal, because releases from Turquoise Reservoir will maintain streamflow patterns in Lake Fork.

Specific operations of Turquoise Reservoir releases to Lake Fork are difficult to simulate in the Quarter-Monthly Model because releases depend on available capacity for native flows in the Mt. Elbert Conduit, deliveries made from non-Fry-Ark Project accounts in Turquoise Reservoir, and other operational decisions made on a daily basis that are outside of the scope of the Quarter-Monthly Model. Therefore, although the analysis of model results shows some effects on Lake Fork streamflows due to both the Proposed Action and No Action Alternative, it is unlikely that actual effects would be as great as those shown by the model on a monthly basis.

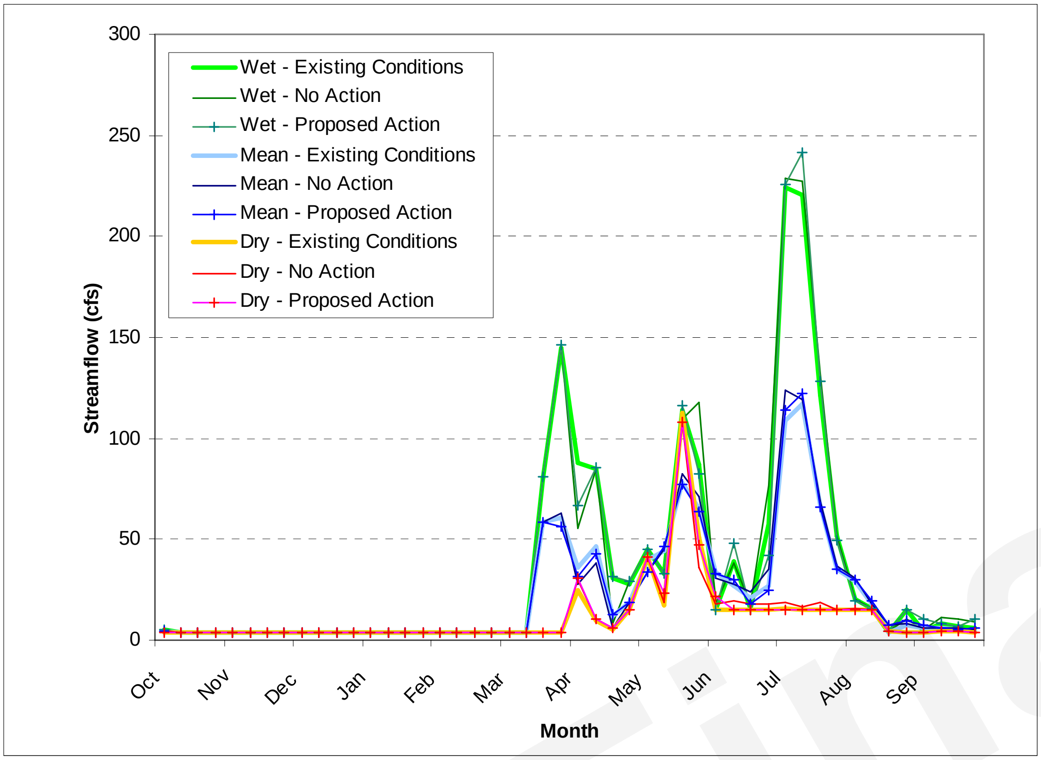
Table 4-9. Lake Fork Gage - Summary of Effects

Month	Simulated Streamflow Existing Conditions (cfs)	Simulated Streamflow No Action (cfs)	Simulated Streamflow Proposed Action (cfs)	Effects (1) (cfs)	Effects (1) (%)
Overall Mean					
Oct	4	4	4	0	-1%
Nov	4	4	4	0	0%
Dec	4	4	4	0	0%
Jan	4	4	4	0	0%
Feb	4	4	4	0	0%
Mar	31	31	30	-2	-5%
Apr	29	23	27	4	16%
May	57	58	55	-3	-5%
Jun	27	29	27	-3	-9%
Jul	83	89	86	-3	-3%
Aug	15	16	17	0	3%
Sep	6	6	6	0	4%
Average	22	23	22	0	-2%
Mean Wet					
Oct	4	4	4	0	0%
Nov	4	4	4	0	0%
Dec	4	4	4	0	0%
Jan	4	4	4	0	0%
Feb	4	4	4	0	0%
Mar	56	56	56	0	0%
Apr	60	46	55	8	18%
May	69	75	69	-6	-8%
Jun	32	37	30	-7	-19%
Jul	158	163	165	2	1%
Aug	14	13	14	1	7%
Sep	7	9	9	0	0%
Average	35	35	35	0	-1%
Mean Dry					
Oct	4	4	4	0	-2%
Nov	4	4	4	0	0%
Dec	4	4	4	0	0%
Jan	4	4	4	0	0%
Feb	4	4	4	0	0%
Mar	4	4	4	0	0%
Apr	14	16	16	0	2%
May	56	52	55	4	7%
Jun	15	19	17	-2	-10%
Jul	15	17	15	-2	-12%
Aug	10	10	10	0	-2%
Sep	4	4	4	0	0%
Average	11	12	12	0	0%

Notes:

(1) Effects (cfs) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 4-7. Lake Fork Gage - Simulated Effect Streamflow



Lake Creek

Summary information for the Lake Creek gage is shown in **Table 4-10** and **Figure 4-8**. As with the Lake Fork gage, streamflows are affected by reservoir releases, and Lake Creek streamflow is often a result of native and transmountain releases from Twin Lakes Reservoir. Releases from Twin Lakes Reservoir have historically been made to ensure a streamflow of 15 cfs in Lake Creek (Reclamation, 1975).

Proposed Action streamflows are less than Existing Conditions and the No Action Alternative streamflows, especially during the fall, winter, and early spring months. This is because Reclamation typically moves much of the Fry-Ark Project account in Turquoise Reservoir to Pueblo Reservoir during these months to make room for the Boustead Tunnel imports. Under the Proposed Action, the contract exchanges result in less water released to Lake Creek from the Fry-Ark account during the winter. Because contract exchanges are not part of Existing Conditions or the No Action Alternative, releases to Lake Creek are higher under Existing Conditions and the No Action Alternative than in the Proposed Action. The reduction in streamflow corresponds to increased yields of the Proposed Action compared to the No Action Alternative.

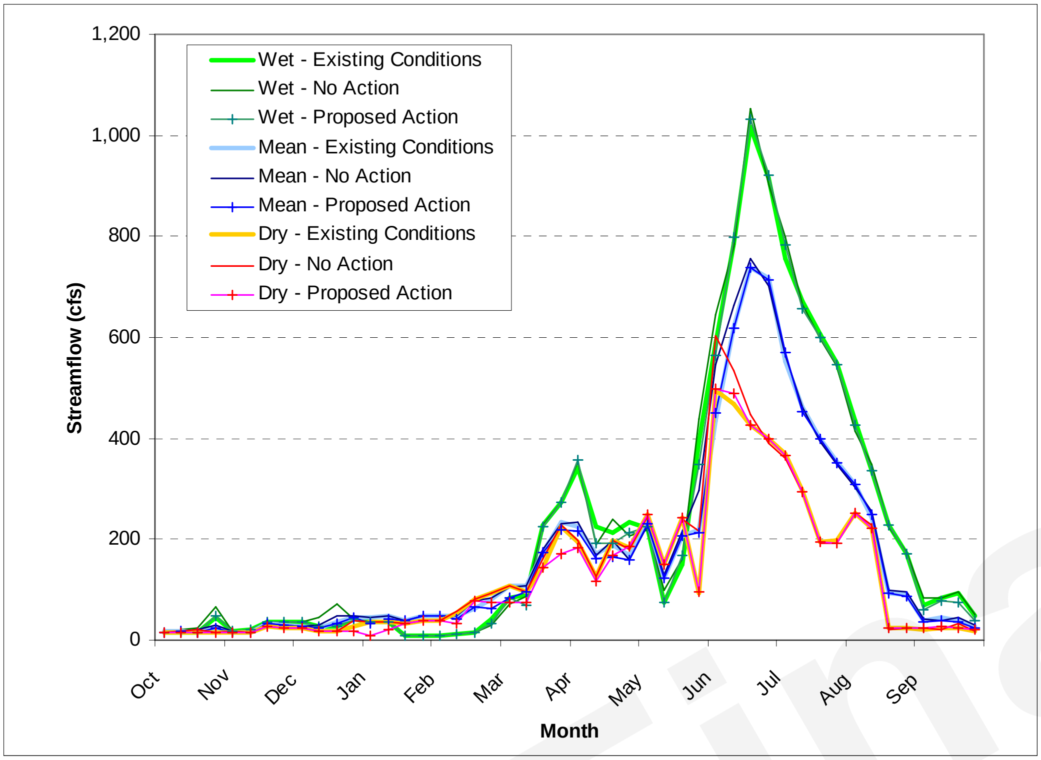
Table 4-10. Lake Creek Gage - Summary of Effects

Month	Simulated Streamflow			Effects (1)	
	Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	(cfs)	(%)
Overall Mean					
Oct	19	21	18	-2	-11%
Nov	23	23	23	0	-1%
Dec	33	38	32	-6	-15%
Jan	45	45	40	-5	-11%
Feb	60	65	55	-10	-15%
Mar	154	154	141	-13	-9%
Apr	189	191	177	-14	-7%
May	195	215	192	-23	-11%
Jun	621	662	624	-39	-6%
Jul	445	445	446	2	0%
Aug	187	190	187	-3	-2%
Sep	38	40	33	-6	-15%
Average	167	174	164	-10	-6%
Mean Wet					
Oct	22	30	23	-7	-24%
Nov	27	27	27	0	-1%
Dec	33	49	33	-16	-33%
Jan	23	23	23	0	0%
Feb	19	17	17	1	4%
Mar	165	162	159	-2	-1%
Apr	256	249	241	-8	-3%
May	204	222	199	-23	-10%
Jun	817	837	818	-19	-2%
Jul	649	654	649	-5	-1%
Aug	297	294	294	-1	0%
Sep	74	79	63	-15	-19%
Average	216	220	212	-8	-4%
Mean Dry					
Oct	15	18	15	-2	-12%
Nov	20	20	20	-1	-3%
Dec	21	24	19	-5	-21%
Jan	35	35	25	-11	-30%
Feb	66	67	56	-11	-16%
Mar	140	146	115	-31	-21%
Apr	175	174	163	-10	-6%
May	187	214	187	-27	-12%
Jun	450	498	455	-43	-9%
Jul	267	262	264	2	1%
Aug	133	134	134	-1	0%
Sep	22	24	24	0	1%
Average	128	135	123	-12	-9%

Notes:

(1) Effects (cfs) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 4-8. Lake Creek Gage - Simulated Effect Streamflow



Wellsville Gage

Summary information for the Wellsville gage is presented in **Table 4-12** and **Figure 4-9**. Magnitudes of streamflow effects at the Wellsville gage are nearly the same as those at the Lake Creek gage because most of the exchanges that take place are exchanged through Twin Lakes. However, the effects as a percentage of the streamflow are much smaller at the Wellsville gage because of its much larger flow.

Streamflows for the Proposed Action are generally lower than the No Action Alternative. This is due to the same changes in Fry-Ark Project releases as described for the Lake Creek gage. As with the Lake Creek gage, the reduction in streamflow corresponds to increased yields of the Proposed Action compared to Existing Conditions and the No Action Alternative.

Figure 4-9 shows minimum flows under the Upper Arkansas Voluntary Flow Management Program. The ability of Reclamation to make releases to meet the flow program is about the same under each of the alternatives. **Figure 4-9** shows that target flows are not met during some dry years. However, the Proposed Action does not reduce Reclamation's ability to meet the target flows. **Table 4-11**shows the percent of time that the target flows for the UAVFMP are met or exceeded.

Table 4-11. UAVFMP - Percent of Time Target Values are Met or Exceeded for Effects Analysis

Percent of Time Target Flows are Met or Exceeded		
Existing Conditions	No Action Effects	Proposed Action Effects
97.5	97.4	97.0

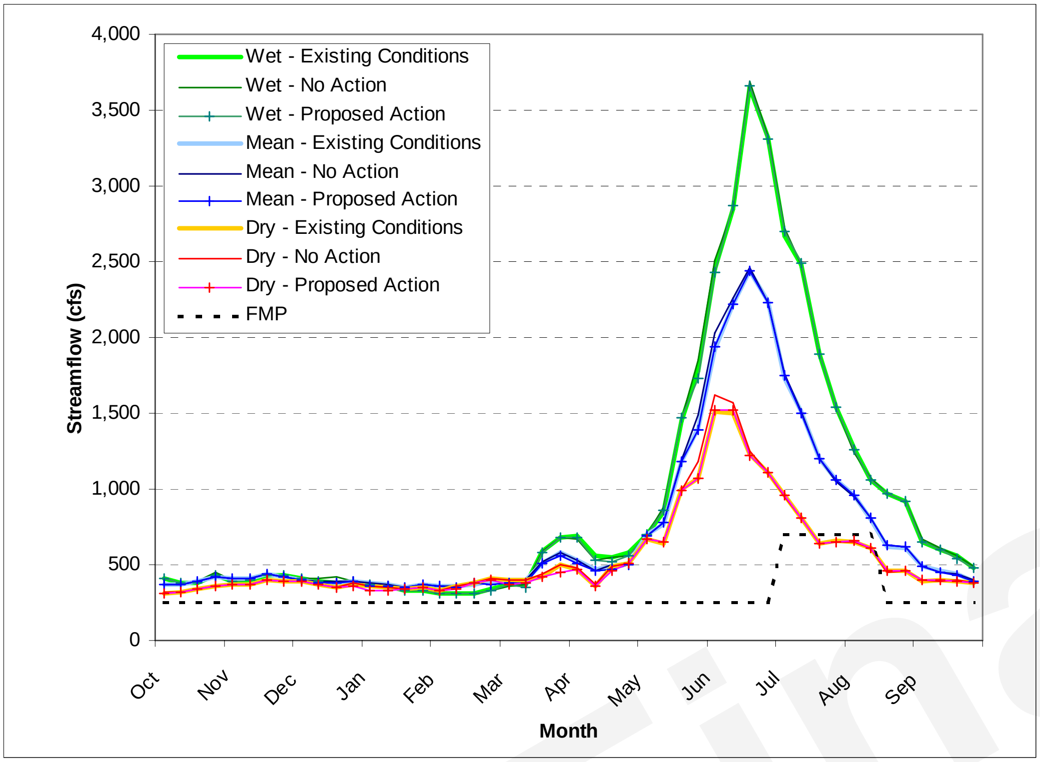
Table 4-12. Wellsville Gage - Summary of Effects

Month	Simulated Streamflow			Effects (1)	
	Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	(cfs)	(%)
Overall Mean					
Oct	386	389	386	-2	-1%
Nov	420	420	420	0	0%
Dec	388	393	388	-6	-1%
Jan	367	367	362	-5	-1%
Feb	372	376	366	-10	-3%
Mar	470	471	456	-15	-3%
Apr	499	496	486	-10	-2%
May	1,002	1,023	997	-26	-3%
Jun	2,197	2,240	2,199	-41	-2%
Jul	1,386	1,391	1,389	-1	0%
Aug	754	759	756	-3	0%
Sep	446	448	442	-6	-1%
Average	724	731	721	-10	-1%
Mean Wet					
Oct	399	407	400	-7	-2%
Nov	411	411	411	0	0%
Dec	393	410	393	-16	-4%
Jan	350	350	350	0	0%
Feb	319	316	317	1	0%
Mar	497	494	491	-2	0%
Apr	597	576	577	1	0%
May	1,176	1,200	1,171	-29	-2%
Jun	3,040	3,066	3,040	-26	-1%
Jul	2,166	2,177	2,173	-3	0%
Aug	1,059	1,055	1,055	0	0%
Sep	578	585	570	-15	-3%
Average	915	921	912	-8	-1%
Mean Dry					
Oct	330	332	330	-2	-1%
Nov	383	384	383	-1	0%
Dec	369	372	367	-5	-1%
Jan	347	347	337	-11	-3%
Feb	371	372	361	-11	-3%
Mar	428	434	403	-31	-7%
Apr	457	458	448	-10	-2%
May	839	861	839	-23	-3%
Jun	1,349	1,401	1,356	-45	-3%
Jul	772	769	769	0	0%
Aug	546	547	546	-1	0%
Sep	390	392	393	0	0%
Average	548	556	544	-12	-2%

Notes:

(1) Effects (ac-ft) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 4-9. Wellsville Gage - Simulated Effects Streamflow



4.2.4.2 Arkansas River below Pueblo Reservoir

This section summarizes net effects for key locations below Pueblo Reservoir, including Pueblo Reservoir, the Above Pueblo gage, the Moffat Street gage, the Avondale gage, the La Junta gage, Lake Meredith, Lake Henry, and Holbrook Reservoir.

Pueblo Reservoir

A summary of simulated storage contents in Pueblo Reservoir is shown in **Table 3-1**, **Figure 4-10**, and **Figure 4-11**. Storage in Pueblo Reservoir under the Proposed Action and the No Action Alternative is less than storage under the Existing Conditions.

Effects are positive for simulated Pueblo Reservoir storage, indicating that storage contents under the Proposed Action are consistently higher than under the No Action Alternative. Storage of water by Aurora in Pueblo Reservoir is part of the Proposed Action but not part of the No Action Alternative, resulting in greater Pueblo Reservoir storage under the Proposed Action when compared with the No Action Alternative.

Table 4-13. Pueblo Reservoir - Summary of Effects

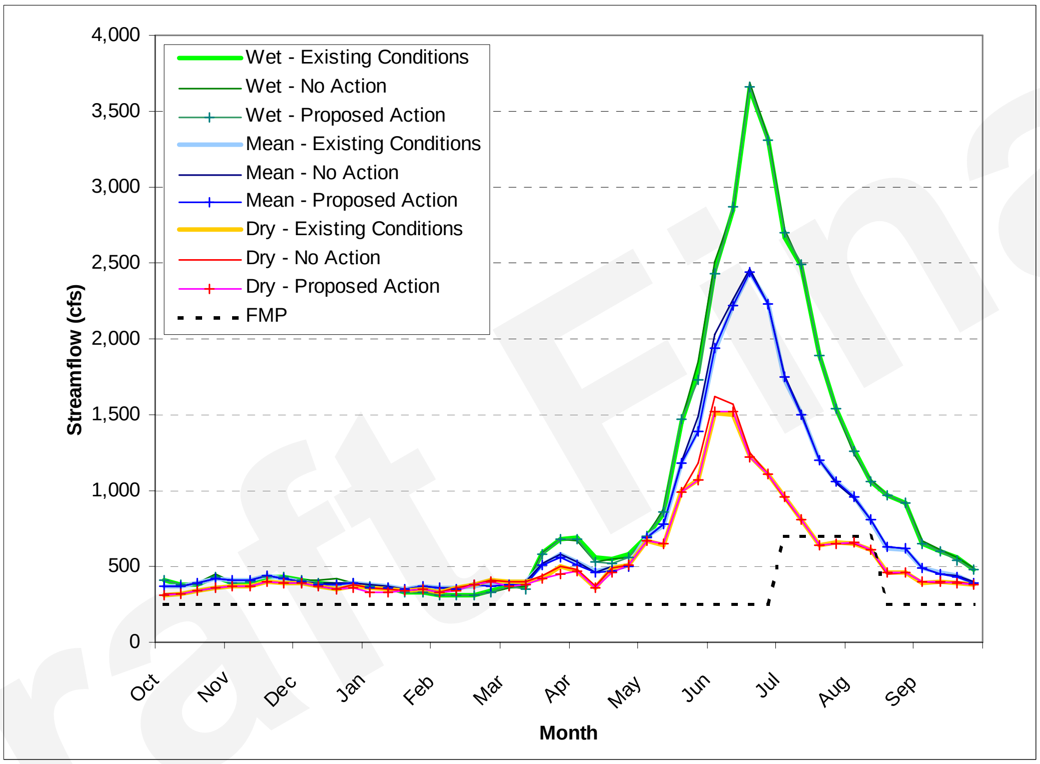
Month	Simulated Storage			Effects (1)	
	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)	(ac-ft)	(%)
Overall Mean					
Oct	164,006	149,977	157,408	7,431	5%
Nov	169,249	156,277	162,896	6,619	4%
Dec	178,549	167,616	172,798	5,182	3%
Jan	187,764	177,529	181,813	4,284	2%
Feb	194,024	183,999	188,007	4,008	2%
Mar	200,903	191,157	194,233	3,076	2%
Apr	197,039	185,382	189,411	4,029	2%
May	189,120	175,810	181,388	5,578	3%
Jun	185,729	171,740	178,152	6,412	4%
Jul	178,473	164,587	170,830	6,243	4%
Aug	172,148	157,608	164,726	7,118	5%
Sep	165,275	150,589	157,895	7,306	5%
Average	181,857	169,356	174,963	5,607	3%
Mean Wet					
Oct	179,314	160,274	173,183	12,909	8%
Nov	184,275	167,135	179,008	11,873	7%
Dec	190,591	179,318	187,182	7,864	4%
Jan	197,059	188,184	193,601	5,417	3%
Feb	200,866	191,999	197,339	5,340	3%
Mar	204,933	195,783	201,126	5,343	3%
Apr	201,858	190,729	196,971	6,242	3%
May	196,754	184,704	191,632	6,928	4%
Jun	205,178	194,125	201,007	6,883	4%
Jul	207,776	197,987	203,942	5,955	3%
Aug	207,276	197,424	203,678	6,254	3%
Sep	206,995	196,415	202,896	6,482	3%
Average	198,573	187,006	194,297	7,291	4%
Mean Dry					
Oct	156,718	147,799	151,028	3,229	2%
Nov	158,732	150,391	153,035	2,644	2%
Dec	167,391	159,494	161,672	2,178	1%
Jan	176,748	169,001	170,356	1,355	1%
Feb	182,245	174,551	175,501	950	1%
Mar	189,954	182,461	182,052	-409	0%
Apr	186,522	177,376	177,232	-144	0%
May	185,549	173,851	175,747	1,896	1%
Jun	177,873	164,445	167,880	3,435	2%
Jul	151,474	137,119	141,309	4,190	3%
Aug	127,084	110,937	116,395	5,458	5%
Sep	116,296	99,573	105,244	5,671	6%
Average	164,716	153,917	156,454	2,538	2%

Notes:

(1) Effects (ac-ft) = Proposed Action - No Action simulated storage. Effects (%) = (Proposed Action - No Action simulated storage)/No Action simulated storage.

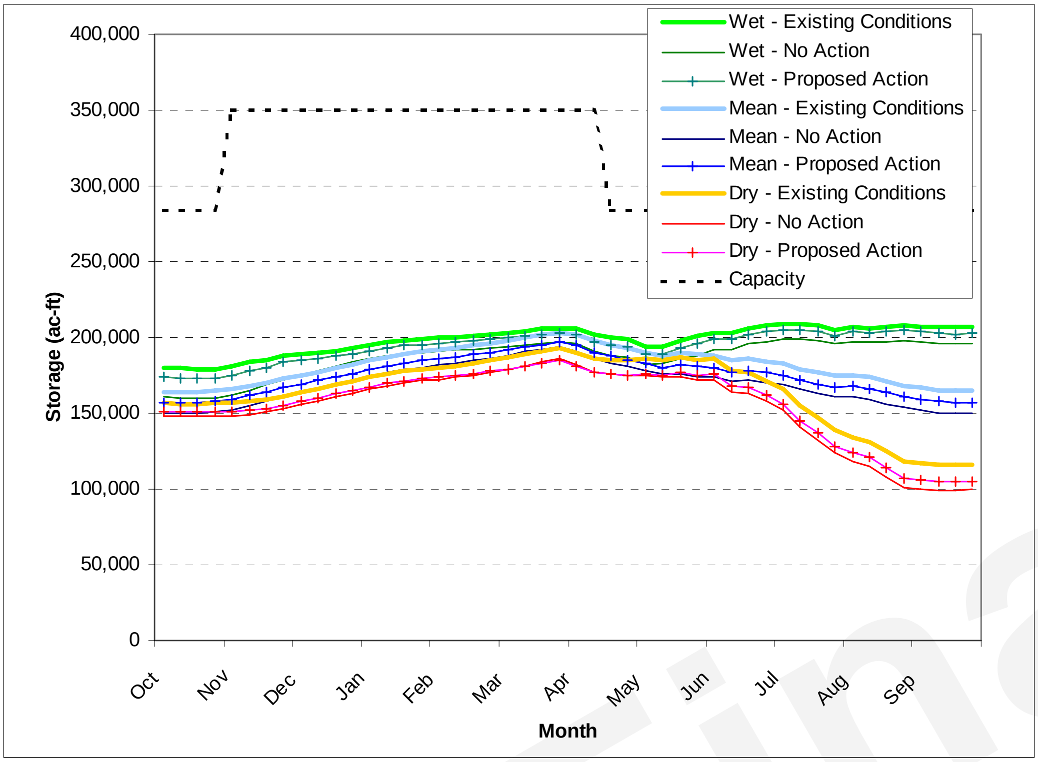
The Proposed Action results in less storage in Pueblo Reservoir than the Existing Conditions primarily due to the effects of the Pueblo Flow Management Program (FMP) and ROY storage in Holbrook Reservoir. Under the Proposed Action, Aurora's exchanges are limited due to the Pueblo FMP while they are not in Existing Conditions. Water that is not stored in Pueblo Reservoir due to the Pueblo FMP restrictions is stored in Holbrook Reservoir first, and when this space is full, in Lake Meredith. Typically, when water is released from Holbrook Reservoir and Lake Meredith, the water is quickly exchanged through Pueblo Reservoir via contract and river exchanges to Upper Basin reservoirs and spends little time in Pueblo Reservoir, causing a decrease in contents under the Proposed Action. As shown in **Figure 4-10**, effects at Pueblo Reservoir are highest when storage contents in the reservoir are low.

Figure 4-10. Pueblo Reservoir Effects Time Series



Pueblo Reservoir effects for October and November during mean wet years are high as a result of how the Quarter-Monthly model is programmed to release stored water from reservoirs in the study area. The model uses a predefined storage target to force releases from Turquoise and Twin Lakes reservoirs during the fall and winter months. The targets are based on the historical tendency for Turquoise and Twin Lakes reservoirs to be drawn down to make room for the next year's spring runoff and West Slope imports. The increase in Pueblo Reservoir storage in October and November is a result of releases from Turquoise and Twin Lakes reservoirs made during the fall of two wet years (1984 and 1996) to meet the priorities. A portion of the water released from Turquoise and Twin Lakes reservoirs is stored in Pueblo Reservoir, resulting in higher effects during these months. The remaining unstored releases flow downstream.

Figure 4-11. Pueblo Reservoir - Simulated Effects Storage



Above Pueblo Gage

A summary of simulated streamflow at the Above Pueblo gage is shown in **Table 4-15** and **Figure 4-31**. Streamflows at the Above Pueblo gage are higher for the No Action Alternative than under Existing Conditions, except during mean wet years. Proposed Action streamflows are lower than under Existing Conditions, except during mean dry years. Proposed Action streamflows are higher than under Existing Conditions during mean dry years because the PFMP is in effect under the Proposed Action but not under Existing Conditions. The PFMP target flows have the largest effect on streamflows during mean dry years when Proposed Action streamflows are maintained at the target flow levels, while Existing Conditions streamflows are reduced below target flow levels as a result of exchanges.

None of Aurora's existing decrees in the Arkansas Basin allow diversions or exchanges of water during the Winter Water Storage Program, which operates between November 15 and March 15. Therefore, during most years in the simulation, Aurora's actions do not have an effect on streamflow during this time. Proposed Action streamflows are less than Existing Conditions streamflows as a result of winter water storage in Pueblo Reservoir. ROY Storage in Holbrook Reservoir results in Holbrook Company's storage of winter water in Pueblo Reservoir, reducing streamflows at the Above Pueblo gage. Additionally, because of the predefined storage target described in the Pueblo Reservoir effects section, releases frm Turquoise and Twin Lakes reservoirs made in the fall and winter months result in increased storage contents in Pueblo Reservoir. Spills from Pueblo Reservoir occur to make room for water diverted into Pueblo Reservoir through the Winter Water Storage Program, and streamflow at the Above Pueblo gage increase as a result. During actual operations, it is unlikely that Aurora would divert water into Pueblo Reservoir storage during times when there is a high likelihood of spill by the Winter Water Storage Program, and thus the spills would not occur and there would be no effect on streamflows.

Changes in flow during the summer months are due to higher yields of the Rocky Ford water rights under the Proposed Action, as well as a general decrease in yield under the No Action as a result of the junior exchange status for moving water out of gravel lakes storage to Upper Arkansas River Basin storage.

As mentioned in **Section 3.0**, the City of Pueblo and several entities with exchange water rights on the Arkansas River have recently signed an Intergovernmental Agreement regarding a flow management program on the Arkansas River through the City of Pueblo (May IGA, 2004). The flow management program defines flow targets at the Above Pueblo gage. **Table 4-14** shows the percent of time that these flow targets are met or exceeded during each simulation. As shown, the percentage is similar under each of the alternatives. **Figure 4-12** shows that target flows are not met during some years. However, the Proposed Action does not have a direct effect on the percent of time that flow targets are met or exceeded.

Table 4-14. Pueblo Flow Management Program - Percent of Time Flow Targets Met or Exceeded at Above Pueblo Gage for Effects Analysis

Percent of Time Target Flows are Met or Exceeded		
Existing Conditions	**No Action Effects**	**Proposed Action Effects**
63.4	63.3	63.0

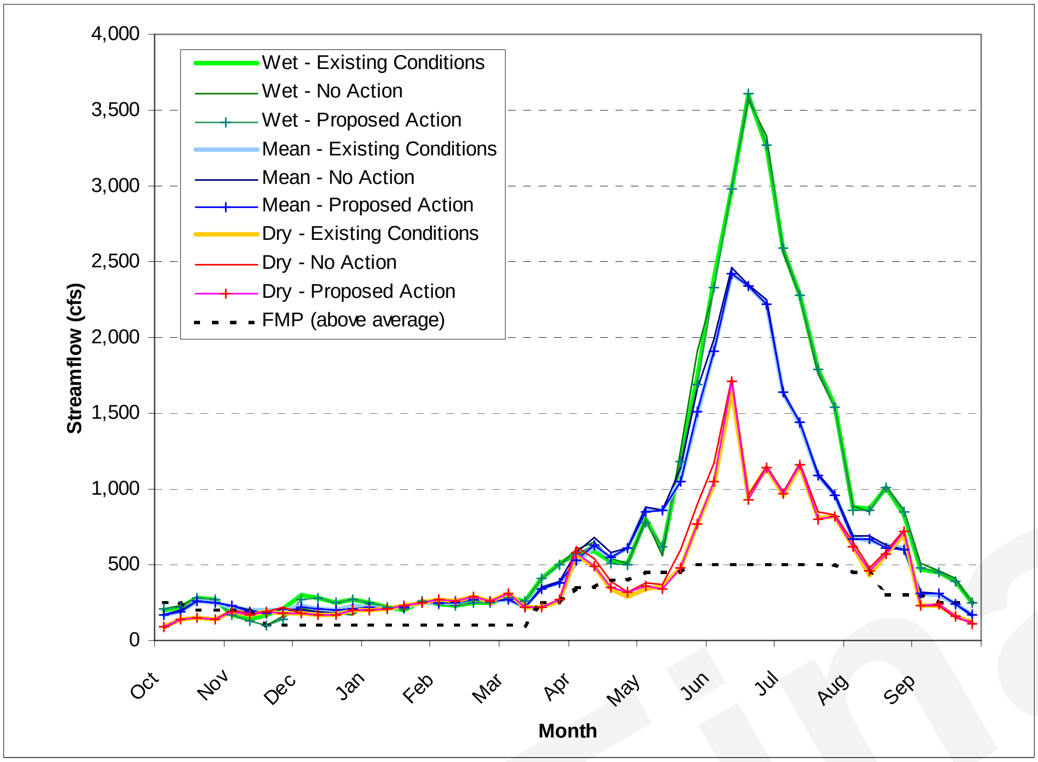
Table 4-15. Above Pueblo Gage - Summary of Effects

Month	Simulated Streamflow			Effects (1)	
	Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	(cfs)	(%)
Overall Mean					
Oct	216	216	217	1	0%
Nov	207	203	195	-8	-4%
Dec	215	191	210	19	10%
Jan	225	225	226	1	0%
Feb	260	257	257	0	0%
Mar	304	304	302	-2	-1%
Apr	573	614	579	-35	-6%
May	1,056	1,118	1,051	-67	-6%
Jun	2,221	2,259	2,221	-38	-2%
Jul	1,289	1,296	1,296	0	0%
Aug	645	657	640	-18	-3%
Sep	257	264	258	-6	-2%
Average	622	634	621	-13	-2%
Mean Wet					
Oct	242	248	245	-3	-1%
Nov	171	140	135	-5	-3%
Dec	277	191	267	77	40%
Jan	233	231	234	3	1%
Feb	244	244	244	0	0%
Mar	363	361	360	-1	0%
Apr	548	576	556	-20	-3%
May	1,059	1,109	1,049	-61	-5%
Jun	3,034	3,027	3,022	-5	0%
Jul	2,064	2,049	2,066	17	1%
Aug	900	909	897	-13	-1%
Sep	395	413	397	-16	-4%
Average	794	792	789	-2	0%
Mean Dry					
Oct	131	128	128	0	0%
Nov	181	194	182	-12	-6%
Dec	181	181	181	0	0%
Jan	222	222	222	0	0%
Feb	268	268	268	0	0%
Mar	251	251	251	0	0%
Apr	428	474	440	-35	-7%
May	481	554	482	-71	-13%
Jun	1,204	1,268	1,215	-53	-4%
Jul	939	961	943	-18	-2%
Aug	574	607	587	-20	-3%
Sep	188	187	190	4	2%
Average	421	441	424	-17	-4%

Notes:

(1) Effects (ac-ft) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 4-12. Above Pueblo Gage - Simulated Effects Streamflow



Moffat Street Gage

A summary of simulated streamflow at the Moffat Street gage is shown in **Table 4-16** and . Streamflows under the No Action Alternative are greater than under Existing Conditions except during mean wet years. Streamflows under the Proposed Action are less than under Existing Conditions, except during mean dry years. Effects are generally close to zero, or small negative values, indicating that No Action Alternative streamflows are slightly greater than for the Proposed Action. Changes in flow are for the same reason as those described for the Above Pueblo gage.

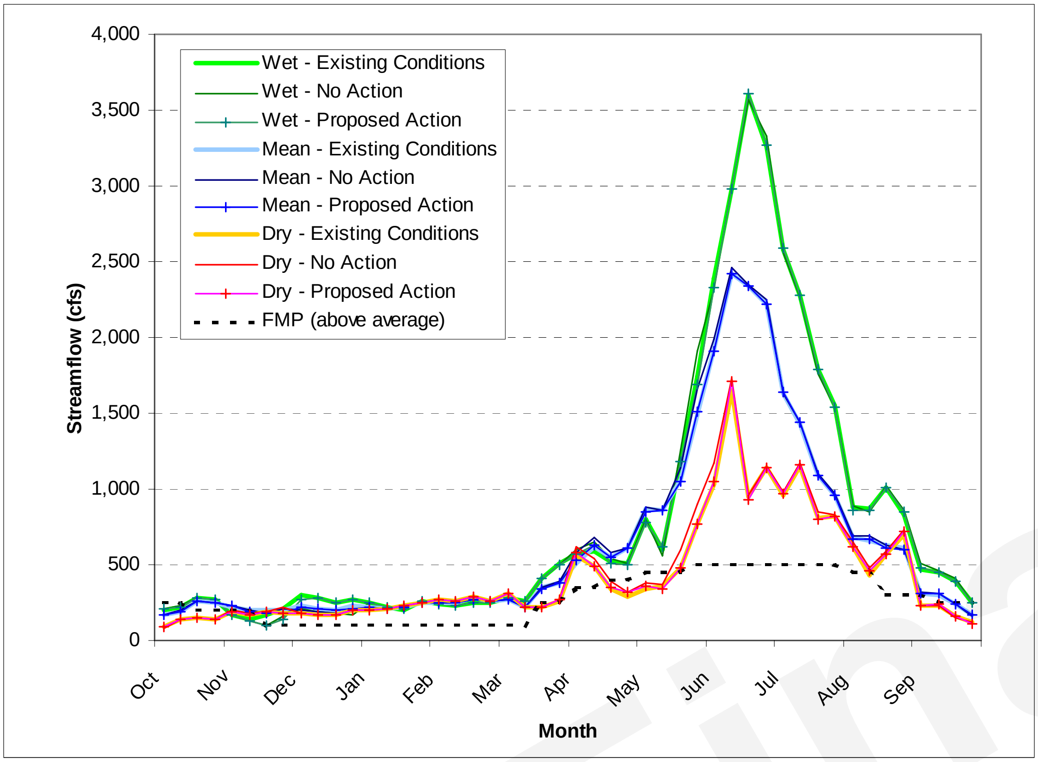
Table 4-16. Moffat Street Gage - Summary of Effects

Month	Simulated Streamflow			Effects (1)	
	Existing Conditions	No Action	Proposed Action		
	(cfs)	(cfs)	(cfs)	(cfs)	(%)
Overall Mean					
Oct	207	208	209	1	0%
Nov	198	194	186	-8	-4%
Dec	203	178	198	19	11%
Jan	214	215	216	1	0%
Feb	252	250	250	0	0%
Mar	294	296	293	-3	-1%
Apr	564	606	571	-35	-6%
May	1,043	1,106	1,038	-68	-6%
Jun	2,207	2,244	2,206	-38	-2%
Jul	1,281	1,287	1,287	0	0%
Aug	636	647	630	-18	-3%
Sep	248	256	250	-6	-2%
Average	612	624	611	-13	-2%
Mean Wet					
Oct	231	238	235	-3	-1%
Nov	160	129	124	-5	-4%
Dec	264	177	254	77	43%
Jan	222	220	223	3	1%
Feb	235	235	235	0	0%
Mar	354	352	351	-1	0%
Apr	540	569	549	-20	-4%
May	1,048	1,099	1,037	-62	-6%
Jun	3,020	3,013	3,008	-5	0%
Jul	2,070	2,053	2,071	18	1%
Aug	889	899	886	-13	-1%
Sep	384	401	385	-16	-4%
Average	785	782	780	-2	0%
Mean Dry					
Oct	126	123	123	0	0%
Nov	172	185	174	-12	-6%
Dec	168	168	168	0	0%
Jan	211	211	211	0	0%
Feb	259	259	259	0	0%
Mar	242	242	243	0	0%
Apr	419	466	431	-35	-8%
May	467	540	468	-71	-13%
Jun	1,190	1,255	1,201	-54	-4%
Jul	927	948	929	-19	-2%
Aug	566	599	580	-20	-3%
Sep	183	182	185	4	2%
Average	411	432	414	-17	-4%

Notes:

(1) Effects (ac-ft) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 4-13. Moffat Street Gage - Simulated Effect Streamflow



Avondale Gage

Simulated Quarter-Monthly Model results for the Avondale gage are shown in **Table 4-17** and **Figure 4-14**. The Avondale gage is downstream of the gravel lakes storage site contemplated in the No Action Alternative. The greatest changes in flow between the Proposed Action and No Action Alternative occur during May and June when Aurora's Rocky Ford yields are not divertible at gravel lakes storage because the storage capacity is full. Releases made from Turquoise Reservoir during 1984 and 1996, when Pueblo Reservoir was full, are also evident in the wet year flows during December. Overall, average flow at the Avondale gage is nearly identical under all scenarios.

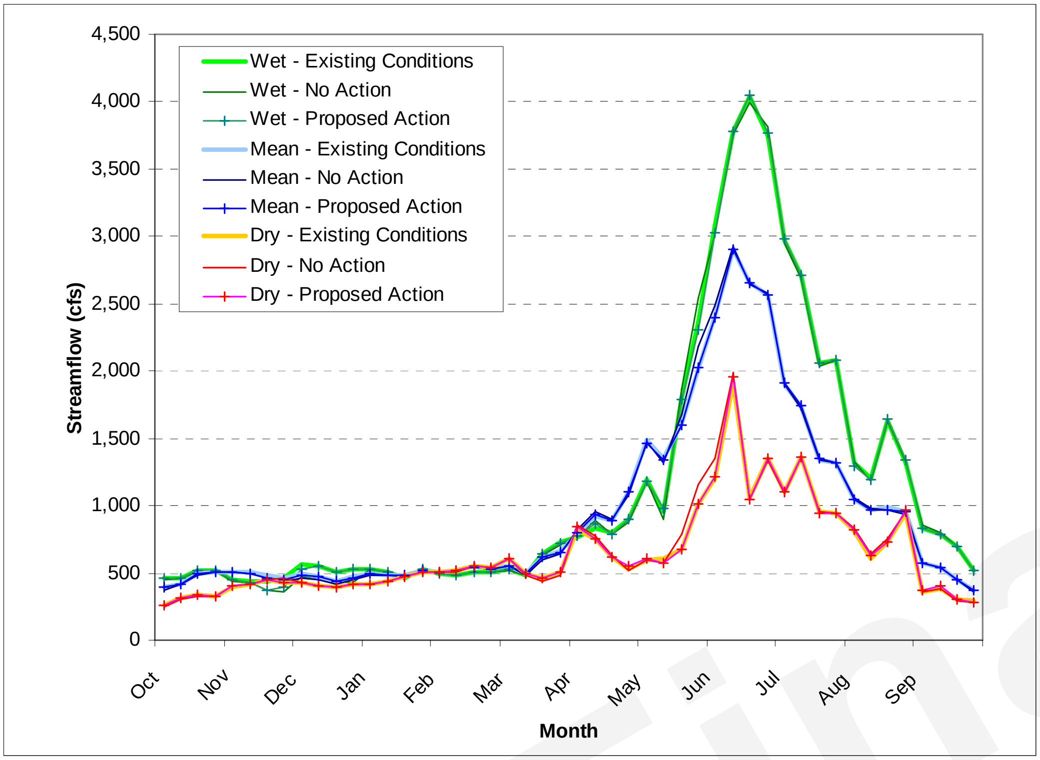
Table 4-17. Avondale Gage - Summary of Effects

Month	Simulated Streamflow			Effects (1)	
	Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	(cfs)	(%)
Overall Mean					
Oct	450	442	450	7	2%
Nov	491	477	480	4	1%
Dec	468	442	463	21	5%
Jan	491	490	491	1	0%
Feb	527	523	525	2	0%
Mar	579	566	578	12	2%
Apr	920	936	927	-9	-1%
May	1,599	1,645	1,593	-52	-3%
Jun	2,632	2,661	2,633	-28	-1%
Jul	1,583	1,578	1,589	11	1%
Aug	991	989	987	-2	0%
Sep	487	486	490	4	1%
Average	935	936	934	-3	0%
Mean Wet					
Oct	488	483	489	7	1%
Nov	445	403	410	7	2%
Dec	538	450	528	79	17%
Jan	506	504	507	3	1%
Feb	500	498	500	1	0%
Mar	592	580	590	10	2%
Apr	821	831	831	0	0%
May	1,553	1,591	1,542	-49	-3%
Jun	3,647	3,627	3,638	11	0%
Jul	2,469	2,449	2,472	23	1%
Aug	1,369	1,367	1,365	-2	0%
Sep	715	724	717	-7	-1%
Average	1,137	1,125	1,132	7	1%
Mean Dry					
Oct	312	301	309	8	3%
Nov	423	430	424	-6	-1%
Dec	410	409	410	1	0%
Jan	456	456	456	0	0%
Feb	529	528	529	1	0%
Mar	518	502	519	17	3%
Apr	689	702	701	-1	0%
May	711	766	710	-56	-7%
Jun	1,392	1,444	1,405	-39	-3%
Jul	1,095	1,094	1,097	3	0%
Aug	769	789	780	-9	-1%
Sep	338	332	341	9	3%
Average	637	646	640	-6	-1%

Notes:

(1) Effects (ac-ft) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 4-14. Avondale Gage - Simulated Effects Streamflow



Lake Meredith

Simulated reservoir contents at Lake Meredith are shown in, **Table 4-18**, **Figure 4-15**, and **Figure 4-16**. Reservoir contents are slightly higher under the Proposed Action than Existing Conditions, and much higher under the No Action Alternative when compared with Existing Conditions. Effects are negative, indicating that No Action Alternative storage contents are greater than contents under the Proposed Action.

Reservoir contents at Lake Meredith are affected by both the No Action Alternative and Proposed Action not only because of the ability to exchange Colorado Canal yields upstream, but also because Lake Meredith can serve as an alternate point of diversion for Rocky Ford and other leased water. Lake Meredith storage contents are greater under the No Action Alternative because of limits on exchanges from gravel lakes storage to the Upper Arkansas River Basin. Under the No Action Alternative, Aurora's Rocky Ford and other leased water rights that cannot be diverted into gravel lakes storage is diverted into Lake Meredith.

Table 4-18. Lake Meredith - Summary of Effects

Month	Simulated Storage			Effects (1)	
	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)	(ac-ft)	(%)
Overall Mean					
Oct	8,817	11,868	9,167	-2,701	-23%
Nov	8,413	11,307	8,921	-2,386	-21%
Dec	9,568	12,540	10,210	-2,329	-19%
Jan	11,110	14,423	11,833	-2,590	-18%
Feb	11,275	14,836	12,051	-2,785	-19%
Mar	16,021	19,506	16,636	-2,870	-15%
Apr	14,990	19,195	15,637	-3,558	-19%
May	11,039	14,241	11,535	-2,706	-19%
Jun	6,347	11,127	6,828	-4,298	-39%
Jul	9,416	13,773	9,593	-4,180	-30%
Aug	9,561	13,661	9,803	-3,858	-28%
Sep	9,496	12,953	9,806	-3,147	-24%
Average	10,504	14,119	11,002	-3,117	-22%
Mean Wet					
Oct	12,982	16,225	12,940	-3,285	-20%
Nov	12,920	15,853	12,965	-2,888	-18%
Dec	14,404	17,143	14,415	-2,728	-16%
Jan	16,161	19,025	16,160	-2,865	-15%
Feb	16,183	19,313	16,227	-3,086	-16%
Mar	18,854	22,526	18,834	-3,692	-16%
Apr	17,206	21,699	17,267	-4,432	-20%
May	12,648	15,994	12,949	-3,044	-19%
Jun	9,008	13,724	9,072	-4,651	-34%
Jul	14,736	19,119	14,928	-4,192	-22%
Aug	16,062	19,940	16,522	-3,417	-17%
Sep	18,088	21,069	18,817	-2,252	-11%
Average	14,938	18,469	15,091	-3,378	-18%
Mean Dry					
Oct	4,900	9,063	4,783	-4,280	-47%
Nov	4,815	8,796	4,709	-4,087	-46%
Dec	6,170	10,312	6,351	-3,960	-38%
Jan	7,552	12,118	8,027	-4,091	-34%
Feb	7,472	12,493	8,093	-4,400	-35%
Mar	13,989	18,262	14,468	-3,794	-21%
Apr	13,619	17,606	14,362	-3,243	-18%
May	8,460	11,468	9,357	-2,112	-18%
Jun	2,842	7,956	3,913	-4,043	-51%
Jul	3,096	7,590	3,810	-3,780	-50%
Aug	2,426	6,599	2,998	-3,601	-55%
Sep	1,983	5,617	2,452	-3,165	-56%
Average	6,444	10,657	6,944	-3,713	-35%

Notes:

(1) Effects (ac-ft) = Proposed Action - No Action simulated storage. Effects (%) = (Proposed Action - No Action simulated storage)/No Action simulated storage.

Figure 4-15. Lake Meredith Effects Time Series Plot

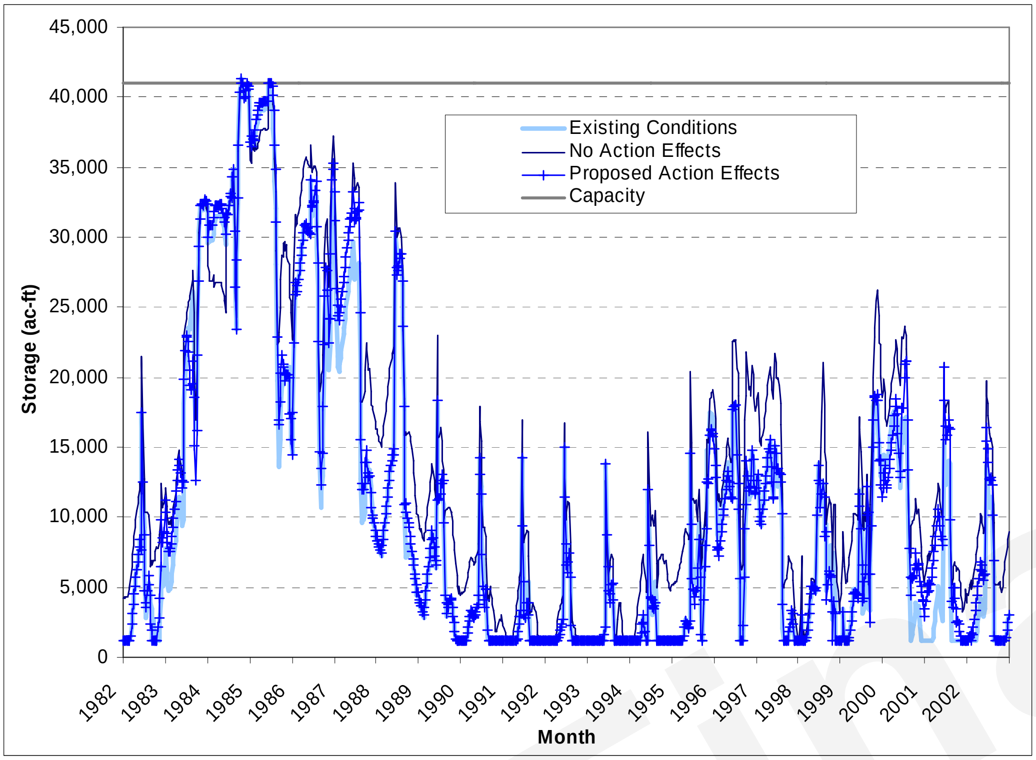
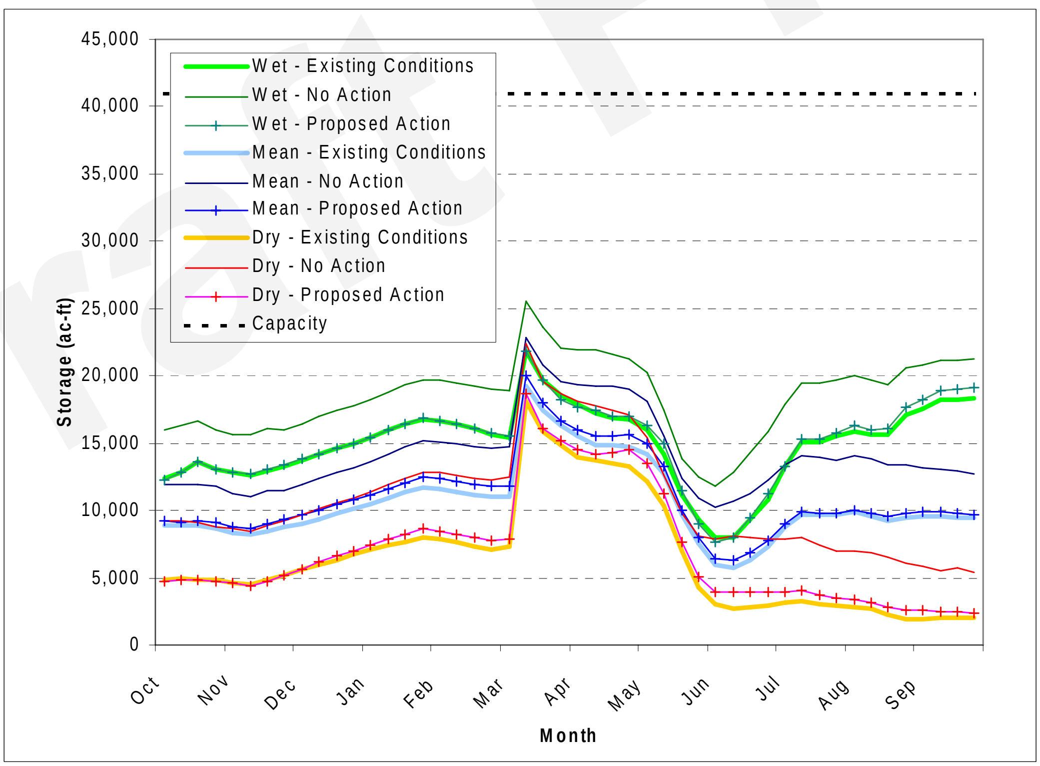


Figure 4-16. Lake Meredith - Simulated Effects Storage



Lake Henry

Simulated reservoir contents at Lake Henry are shown in **Table 4-19**, **Figure 4-17** and **Figure 4-18**. Storage contents under the No Action Alternative and the Proposed Action are greater than contents under Existing Conditions. Effects are generally negative, indicating that contents under the No Action Alternative are greater than contents under the Proposed Action. As with Lake Meredith, Lake Henry is part of the Colorado Canal system and effects at the reservoir occur for the same reasons as the effects at Lake Meredith.

Table 4-19. Lake Henry - Summary of Effects

Month	Simulated Storage			Effects (1)	
	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)	(ac-ft)	(%)
Overall Mean					
Oct	2,925	3,599	3,066	-533	-15%
Nov	2,855	3,370	2,910	-460	-14%
Dec	3,293	3,502	3,293	-209	-6%
Jan	3,672	3,691	3,672	-19	-1%
Feb	5,139	5,137	5,139	1	0%
Mar	6,674	6,693	6,699	5	0%
Apr	6,870	6,874	6,876	2	0%
May	6,278	6,550	6,248	-302	-5%
Jun	5,412	6,280	5,439	-841	-13%
Jul	5,177	5,794	5,261	-534	-9%
Aug	4,372	5,103	4,507	-596	-12%
Sep	3,353	4,258	3,550	-708	-17%
Average	4,668	5,071	4,721	-350	-7%
Mean Wet					
Oct	3,676	3,942	3,676	-266	-7%
Nov	3,507	3,678	3,499	-178	-5%
Dec	3,663	3,670	3,658	-12	0%
Jan	3,741	3,741	3,741	0	0%
Feb	5,015	5,015	5,015	0	0%
Mar	6,622	6,622	6,622	0	0%
Apr	6,907	6,907	6,907	0	0%
May	6,671	6,934	6,749	-186	-3%
Jun	6,562	7,196	6,425	-771	-11%
Jul	6,997	7,137	7,049	-88	-1%
Aug	6,662	6,662	6,662	0	0%
Sep	5,622	5,969	5,649	-319	-5%
Average	5,470	5,623	5,471	-152	-3%
Mean Dry					
Oct	2,125	2,529	2,396	-134	-5%
Nov	1,889	2,341	2,046	-294	-13%
Dec	2,186	2,452	2,186	-266	-11%
Jan	2,710	2,729	2,710	-18	-1%
Feb	4,508	4,508	4,508	0	0%
Mar	6,097	6,097	6,097	0	0%
Apr	5,920	5,920	5,920	0	0%
May	4,801	5,101	4,801	-299	-6%
Jun	3,432	4,507	3,426	-1,080	-24%
Jul	2,734	3,736	2,730	-1,005	-27%
Aug	1,928	2,836	1,925	-911	-32%
Sep	1,410	2,211	1,638	-574	-26%
Average	3,312	3,747	3,365	-382	-10%

Notes: Effects (ac-ft) = Proposed Action - No Action simulated storage. Effects (%) = (Proposed Action - No Action simulated storage)/No Action simulated storage.

Figure 4-17. Lake Henry Effects Time Series Plot

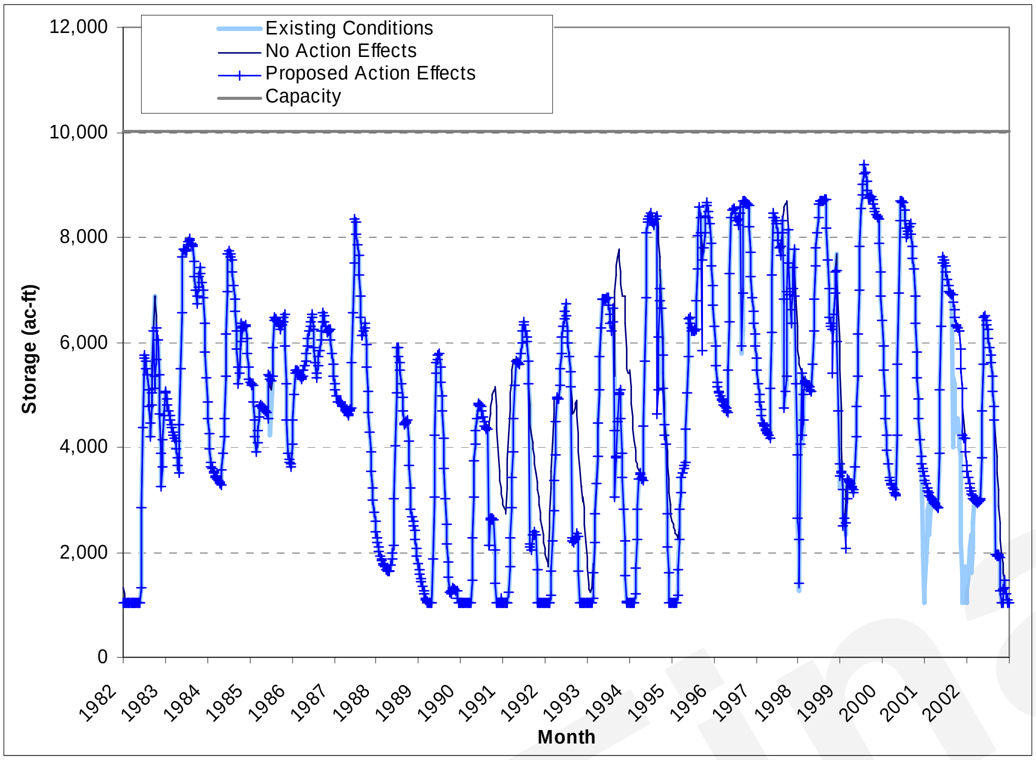
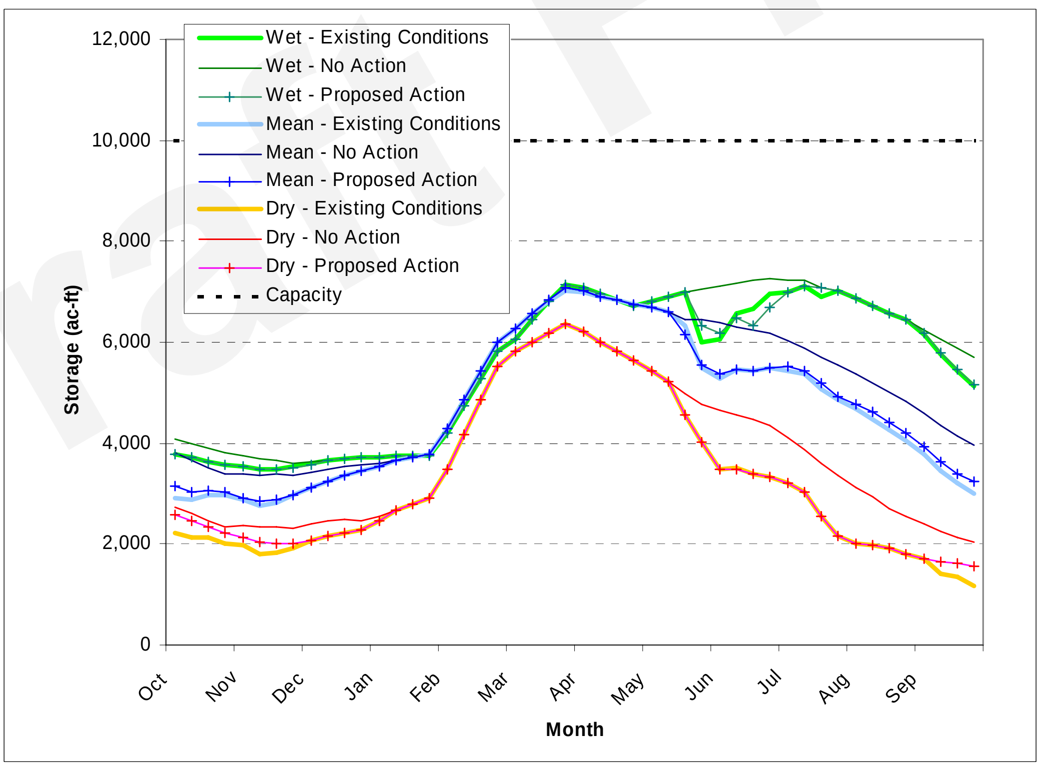


Figure 4-18. Lake Henry - Simulated Effects Storage



Holbrook Reservoir

Simulated Quarter-Monthly Model results for Holbrook Reservoir are shown in **Table 4-20**, **Figure 4-19** and **Figure 4-20**. Holbrook Reservoir simulated storage under the No Action Alternative is equal to storage under the Existing Conditions, reflecting the model assumption that Aurora does not utilize ROY storage under the Existing Conditions or the No Action Alternative. The increase in storage seen under the Proposed Action is indicative of ROY storage in Holbrook Reservoir that is unique to the Proposed Action. Effects are positive because ROY storage under the Proposed Action increases storage contents in Holbrook Reservoir.

The capacities given in **Table 4-20**, **Figure 4-19** and **Figure 4-20** are equal to Aurora's simulated storage in Holbrook Reservoir in addition to the historical storage in the reservoir. Because the model does not restrict storage in Aurora's ROY account based on historical storage in Holbrook Reservoir, the storage contents shown in the table and figures exceed the actual capacity of Holbrook Reservoir (6,200 acre-feet) for some months. Contents in **Figure 4-20** are not provided prior to 1988, because historical Holbrook Reservoir contents are only available for 1989 to present.

Table 4-20. Holbrook Reservoir - Summary of Effects

Month	Simulated Storage			Effects (1)	
	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)	(ac-ft)	(%)
Overall Mean					
Oct	974	974	1,594	620	64%
Nov	1,160	1,160	1,789	628	54%
Dec	1,713	1,713	2,155	442	26%
Jan	2,730	2,730	3,169	439	16%
Feb	3,502	3,502	3,939	437	12%
Mar	4,096	4,096	4,691	596	15%
Apr	3,969	3,969	4,482	513	13%
May	3,473	3,473	3,765	292	8%
Jun	3,287	3,287	3,614	327	10%
Jul	2,230	2,230	2,766	536	24%
Aug	1,481	1,481	1,964	483	33%
Sep	1,052	1,052	1,599	546	52%
Average	2,472	2,472	2,960	488	20%
Mean Wet					
Oct	1,719	1,719	1,774	54	3%
Nov	1,690	1,690	1,690	0	0%
Dec	1,672	1,672	1,672	0	0%
Jan	2,242	2,242	2,242	0	0%
Feb	2,577	2,577	2,577	0	0%
Mar	2,820	2,820	2,905	85	3%
Apr	2,927	2,927	3,099	172	6%
May	2,833	2,833	2,833	0	0%
Jun	3,144	3,144	3,144	0	0%
Jul	3,048	3,048	3,099	51	2%
Aug	2,353	2,353	2,464	110	5%
Sep	2,082	2,082	2,194	112	5%
Average	2,426	2,426	2,475	49	2%

Table 4-20. Holbrook Reservoir - Summary of Effects

Month	Simulated Storage			Effects (1)	
	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)	(ac-ft)	(%)
Mean Dry					
Oct	580	580	2,200	1,620	279%
Nov	910	910	2,615	1,705	187%
Dec	1,411	1,411	2,469	1,058	75%
Jan	2,680	2,680	3,729	1,049	39%
Feb	4,597	4,597	5,642	1,045	23%
Mar	5,731	5,731	7,040	1,310	23%
Apr	5,369	5,369	6,525	1,156	22%
May	4,187	4,187	4,822	635	15%
Jun	3,327	3,327	3,940	613	18%
Jul	1,496	1,496	2,430	934	62%
Aug	614	614	1,649	1,036	169%
Sep	299	299	1,442	1,143	382%
Average	2,600	2,600	3,709	1,109	43%

Notes:

(1) Simulated storage for Holbrook Reservoir is the sum of Aurora's simulated storage and the historical contents of the reservoir.

(2) Effects (ac-ft) = Proposed Action - No Action simulated storage. Effects (%) = (Proposed Action - No Action simulated storage)/No Action simulated storage.

(3) Period-of-Record: 1982 to 2002.

Figure 4-19. Holbrook Reservoir - Simulated Effects Storage

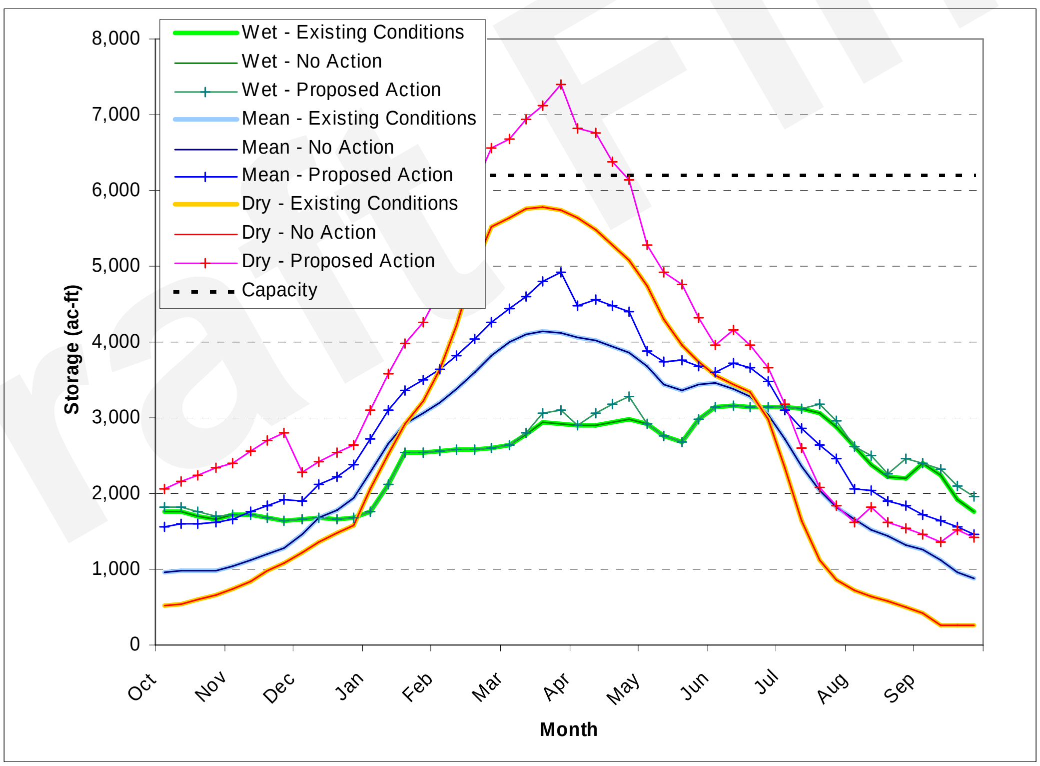
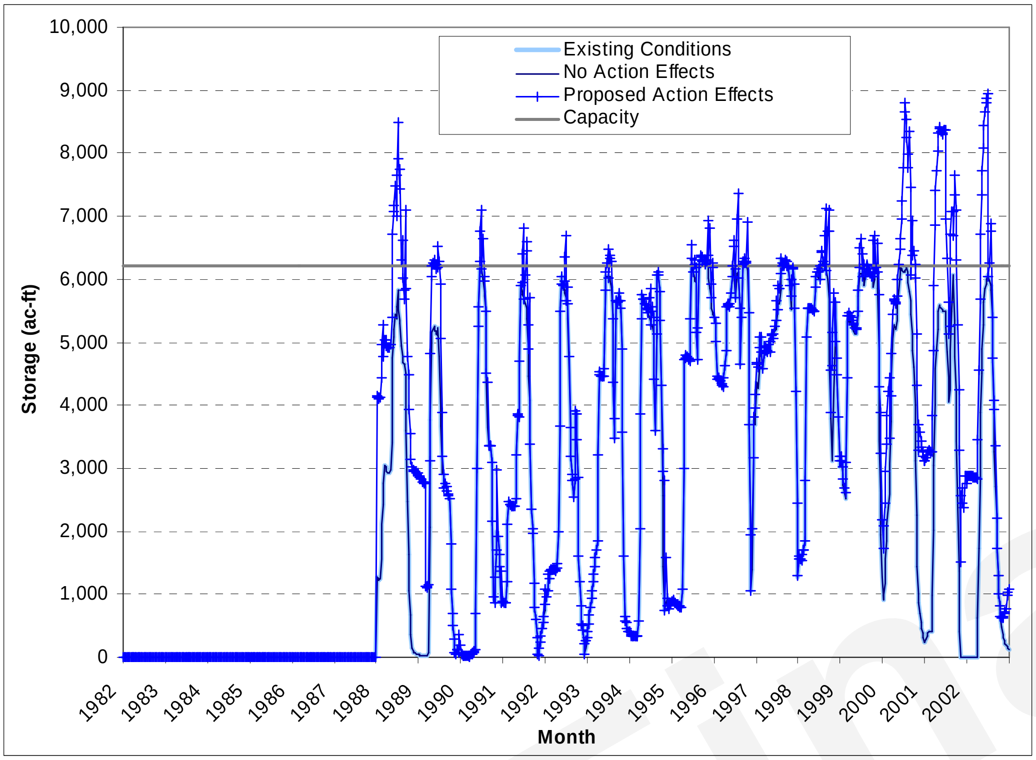


Figure 4-20. Holbrook Reservoir - Simulated Effects Storage Time Series



La Junta Gage

Simulated streamflow at the La Junta gage is shown in Table 4-21 and **Figure 4-21**. The La Junta gage is downstream of the exchange reaches and diversion points for all of Aurora's water rights in both the No Action Alternative and the Proposed Action. As a result, the Quarter-Monthly Model typically shows little change in flow at the La Junta gage for both alternatives. Streamflows are slightly less under the No Action Alternative and the Proposed Action than under Existing Conditions, except for mean dry years.

Differences in flow between the Proposed Action and No Action Alternative are due to increased diversions of Rocky Ford water under the Proposed Action due to the increased ability to move water from Pueblo Reservoir to Upper Arkansas River Basin storage. La Junta flows for all scenarios are greater than observed historical flows, indicating that all water rights and Arkansas River Compact deliveries downstream of the La Junta gage would be met as they were historically.

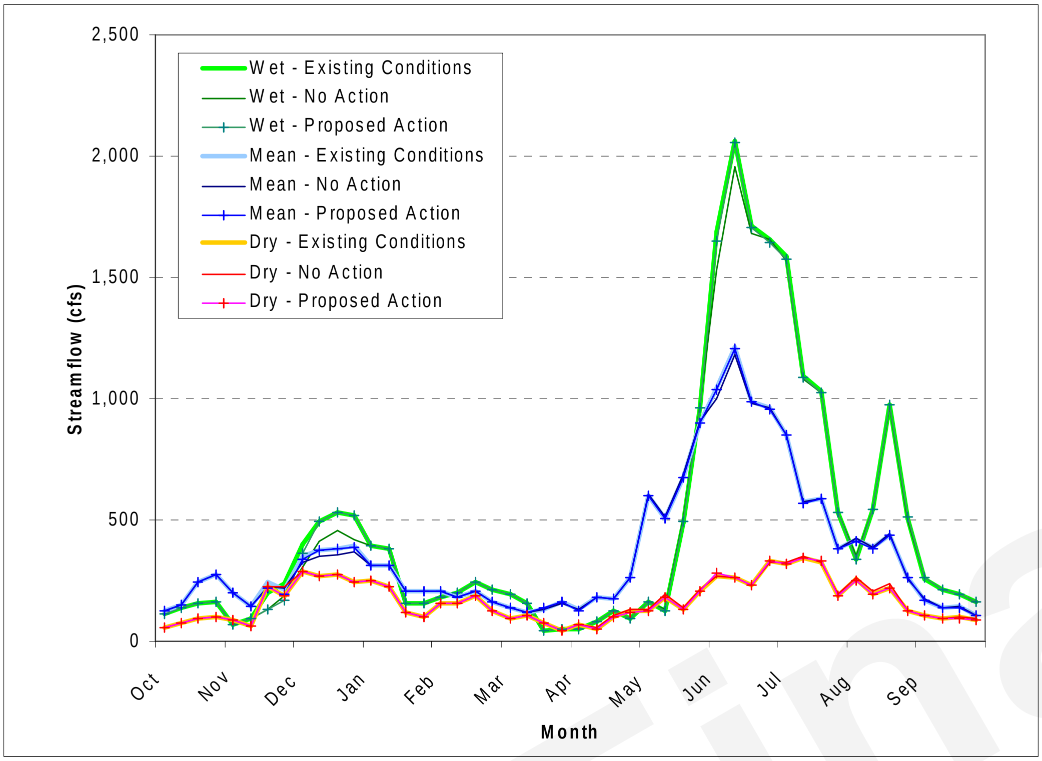
Table 4-21. La Junta Gage - Summary of Effects

Month	Simulated Streamflow			Effects (1)	
	Existing Conditions	No Action	Proposed Action		
	(cfs)	(cfs)	(cfs)	(cfs)	(%)
Overall Mean					
Oct	195	195	196	1	0%
Nov	197	194	187	-7	-4%
Dec	374	349	368	19	6%
Jan	262	262	262	0	0%
Feb	188	188	188	0	0%
Mar	138	136	138	2	1%
Apr	184	186	183	-2	-1%
May	664	672	665	-7	-1%
Jun	1,057	1,033	1,051	18	2%
Jul	606	606	604	-1	0%
Aug	379	383	377	-6	-1%
Sep	140	141	139	-2	-1%
Average	365	362	363	1	0%
Mean Wet					
Oct	141	141	141	0	0%
Nov	146	117	113	-4	-4%
Dec	485	398	475	77	19%
Jan	275	275	275	0	0%
Feb	210	210	210	0	0%
Mar	112	112	112	0	0%
Apr	86	86	86	-1	-1%
May	419	426	419	-7	-2%
Jun	1,784	1,709	1,769	60	4%
Jul	1,078	1,069	1,070	1	0%
Aug	594	594	595	1	0%
Sep	208	209	209	0	0%
Average	461	446	456	11	2%
Mean Dry					
Oct	80	80	80	0	0%
Nov	137	146	136	-9	-6%
Dec	268	268	268	0	0%
Jan	176	176	176	0	0%
Feb	155	155	155	0	0%
Mar	81	81	81	0	0%
Apr	83	88	83	-5	-6%
May	161	168	160	-8	-5%
Jun	273	272	275	3	1%
Jul	297	302	298	-5	-2%
Aug	201	209	200	-9	-4%
Sep	98	98	96	-2	-2%
Average	167	170	167	-3	-2%

Notes:

(1) Effects (ac-ft) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 4-21. La Junta Gage - Simulated Effects Streamflow



4.2.5 Peak Flow Analysis

As previously discussed, the Quarter-Monthly Model simulates streamflow on a quarter-monthly (approximately weekly) time-step. Therefore, the streamflows produced by the Quarter-Monthly Model represent the average streamflow for the time-step. Actual peak-flow events occur on a much shorter time-step. Peak flow is the maximum instantaneous discharge, which typically occurs on an hourly, or even sub-hourly, basis. Because of the difference between the Quarter-Monthly Model time-step and the occurrences of peak discharge, the Quarter-Monthly Model cannot be used to infer changes in peak-discharge.

Both the Proposed Action and No Action Alternative consider exchanges of water from downstream locations to upstream locations. By nature of this operation, streamflows are reduced within the exchange reach by the amount of the exchange. Therefore, the Proposed Action could potentially slightly decrease peak flows within the exchange reaches.

There will not be an appreciable change in peak flows in the Upper Arkansas River Basin as a result of the proposed exchanges, because of the nature of peak flows in the upper basin. The majority of peak flows in the Upper Arkansas River Basin occur as a result of precipitation runoff that accrues to the Arkansas River between the upper basin reservoirs and Pueblo Reservoir. A portion of the streamflow contributing to peak flows accrues upstream of Turqoise Reservoir and Twin Lakes. Although the reservoirs provide some incidental flood control, since there is no dedicated flood control space in either reservoir, the amount of impact these reservoirs have on peak flow is small. As shown in **Table 3-31**, the 100-year peak flow in the Upper Arkansas River is approximately 12,900 at the Portland gage, while maximum exchange rates by Aurora are approximately 300 cfs. Therefore, the proposed exchanges will not result in an appreciable reduction in peak flows in the Arkansas River above Pueblo Reservoir.

Similarly, the Proposed Action will not result in an appreciable change in peak flows in the Lower Arkansas River Basin. Pueblo Reservoir contains dedicated flood control storage space of 26,991 acre-feet. In addition, the 66,000 acre-feet joint use pool is used for flood control purposes from April 15 to November 1. Aurora would not store water in either the dedicated flood control space or in the joint use pool between April 15 and November 1 in Pueblo Reservoir. Thus operations of the flood control pool are not affected by the Proposed Action or No Action Alternative. Additionally, the majority of peak flows in the lower basin occur as a result of precipitation runoff that accrues to the Arkansas River from Fountain Creek and from overland flow directly to the Arkansas River downstream of the Fountain Creek confluence. As shown in **Table 3-31**, the 100-year peak flow in the Lower Arkansas River is approximately 20,900 at the Avondale gage, while maximum exchange rates by Aurora are approximately 300 cfs. Therefore, the proposed exchanges will not result in an appreciable reduction in peak flows in the Arkansas River below Pueblo Reservoir.

4.3 Stream Hydraulics and Geomorphology Analysis

As presented in **Section 4.2**, both the Proposed Action and No Action Alternative affect streamflows within the study area. Therefore, there are changes in both stream hydraulics and stream geomorphology. Hydraulics and geomorphology are closely related, as changes in hydraulic parameters such as flow distribution can have effects on overall stream geomorphology. This section presents a summary of pertinent hydraulic parameters, as well as a summary of how changes in those parameters could affect geomorphology.

4.3.1 Hydraulic Analysis

The simulated streamflow and reservoir storage contents, along with existing rating curves available at those locations, were used to estimate river stage at streamgage locations and reservoir water surface elevation and surface area for those reservoirs in the study area. In addition, flow duration curves were developed at streamflow locations where cross-section information was available.

4.3.1.1 Arkansas River above Pueblo Reservoir

This section summarizes the effects for key locations above Pueblo Reservoir, including Turquoise Reservoir, Lake Fork, Lake Creek and the Wellsville gage. Effects are not shown at Twin Lakes because all effects of the proposed project occur within the normal operating pool of the reservoir, and because Twin Lakes is part of the Mount Elbert Pump-Storage Project, its reservoir levels are highly variable.

Turquoise Reservoir

Summary data for the effects on Turquoise Reservoir pool elevation are shown in **Table 4-22** and **Figure 4-22**. There is generally a decrease in reservoir pool elevation seen as a result of the No Action Alternative. Elevations for the Proposed Action are less than elevations under the Existing Conditions, except during mean dry years. Effects are generally positive except during the winter and spring months during mean dry years. Simulated elevations under the Proposed Action and the No Action Alternative are within the range of elevation for the Turquoise Reservoir normal operating pool (9,775.4 to 9,869.4 feet).

Data showing effects on Turquoise Reservoir surface area are shown in **Table 4-23**, **Figure 4-23** and **Figure 4-24**. Surface area under the No Action Alternative is lower than area under Existing Conditions, except during mean dry years. Surface area under the Proposed Action is higher than area under Existing Conditions, except during mean dry years. Effects are generally positive except during the winter and spring months during mean dry years. However, as with Turquoise Reservoir simulated elevations, simulated water surface areas are within the range of the normal operating pool.

Table 4-22. Turquoise Reservoir Elevation- Summary of Effects

Month	Simulated Streamflow			Effects (1)	
	Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	(cfs)	(%)
Overall Mean					
Oct	9,858.27	9,856.05	9,858.62	2.57	2%
Nov	9,856.25	9,854.15	9,856.48	2.32	2%
Dec	9,853.36	9,851.48	9,853.45	1.98	2%
Jan	9,851.19	9,849.36	9,850.96	1.61	2%
Feb	9,848.18	9,846.70	9,848.14	1.44	2%
Mar	9,842.15	9,841.12	9,842.24	1.12	1%
Apr	9,830.48	9,830.42	9,831.08	0.67	1%
May	9,827.51	9,826.70	9,828.18	1.48	2%
Jun	9,850.77	9,849.26	9,851.00	1.74	2%
Jul	9,861.51	9,860.15	9,861.44	1.29	1%
Aug	9,860.80	9,859.31	9,860.65	1.35	1%
Sep	9,859.25	9,857.50	9,859.19	1.69	2%
Average	**9,849.98**	**9,848.52**	**9,850.12**	**1.60**	**2%**
Mean Wet					
Oct	9,859.33	9,856.92	9,859.58	2.67	3%
Nov	9,858.00	9,855.25	9,857.88	2.63	3%
Dec	9,855.54	9,851.92	9,855.13	3.21	3%
Jan	9,854.50	9,849.83	9,853.92	4.08	4%
Feb	9,852.88	9,848.38	9,852.46	4.08	4%
Mar	9,846.63	9,843.00	9,846.38	3.38	4%
Apr	9,831.04	9,829.54	9,831.63	2.08	3%
May	9,828.29	9,826.29	9,829.17	2.88	4%
Jun	9,855.00	9,852.50	9,855.17	2.67	3%
Jul	9,868.54	9,867.04	9,868.71	1.67	1%
Aug	9,868.75	9,867.42	9,868.88	1.46	1%
Sep	9,868.00	9,866.54	9,868.25	1.71	1%
Average	**9,853.88**	**9,851.22**	**9,853.93**	**2.71**	**3%**

Table 4-22. Turquoise Reservoir Elevation- Summary of Effects

Month	Simulated Streamflow			Effects (1)	
	Existing Conditions	No Action	Proposed Action		
	(cfs)	(cfs)	(cfs)	(cfs)	(%)
Mean Dry					
Oct	9,854.50	9,851.92	9,855.17	3.25	3%
Nov	9,851.83	9,850.08	9,852.50	2.42	2%
Dec	9,849.08	9,848.38	9,849.54	1.17	1%
Jan	9,846.67	9,847.00	9,846.25	-0.75	-1%
Feb	9,843.58	9,844.46	9,842.83	-1.63	-2%
Mar	9,838.96	9,840.04	9,838.42	-1.63	-2%
Apr	9,829.38	9,830.83	9,829.33	-1.50	-2%
May	9,825.25	9,825.88	9,824.83	-1.04	-1%
Jun	9,843.83	9,843.38	9,843.13	-0.25	0%
Jul	9,850.58	9,849.75	9,849.83	0.08	0%
Aug	9,848.54	9,847.33	9,847.54	0.21	0%
Sep	9,846.17	9,845.13	9,844.88	-0.25	0%
Average	**9,844.03**	**9,843.68**	**9,843.69**	**0.01**	**0%**

Notes:

(1) Effects (feet) = Proposed Action - No Action simulated elevation. Effects (%) = (Proposed Action - No Action simulated elevation)/No Action simulated depth.

Table 4-23. Turquoise Reservoir Area- Summary of Effects

Month	Simulated Area			Effects (1)	
	Existing Conditions	No Action	Proposed Action		
	(acres)	(acres)	(acres)	(acres)	(%)
Overall Mean					
Oct	1,707.4	1,690.1	1,709.7	19.6	1%
Nov	1,691.0	1,675.0	1,692.9	17.9	1%
Dec	1,668.6	1,655.6	1,669.0	13.4	1%
Jan	1,652.4	1,639.6	1,648.6	9.0	1%
Feb	1,627.1	1,616.7	1,625.2	8.6	1%
Mar	1,567.3	1,560.1	1,567.3	7.2	0%
Apr	1,428.9	1,428.3	1,437.0	8.7	1%
May	1,391.1	1,381.7	1,399.7	18.0	1%
Jun	1,642.5	1,631.0	1,644.6	13.6	1%
Jul	1,727.8	1,717.7	1,726.8	9.1	1%
Aug	1,722.0	1,711.5	1,720.1	8.7	1%
Sep	1,709.7	1,697.0	1,708.0	11.0	1%
Average	**1,628.0**	**1,617.0**	**1,629.1**	**12.1**	**1%**
Mean Wet					
Oct	1,715.2	1,695.4	1,716.9	21.6	1%
Nov	1,704.5	1,682.6	1,703.6	21.0	1%
Dec	1,686.9	1,658.1	1,682.8	24.7	1%
Jan	1,678.9	1,642.0	1,672.5	30.5	2%
Feb	1,664.9	1,631.0	1,660.0	29.0	2%
Mar	1,610.1	1,578.9	1,607.3	28.4	2%
Apr	1,438.0	1,418.9	1,445.5	26.6	2%
May	1,402.8	1,377.8	1,414.3	36.5	3%
Jun	1,677.0	1,657.5	1,680.0	22.5	1%
Jul	1,785.3	1,773.7	1,786.4	12.6	1%
Aug	1,787.0	1,776.9	1,787.7	10.8	1%
Sep	1,780.7	1,769.3	1,782.8	13.5	1%
Average	**1,660.9**	**1,638.5**	**1,661.6**	**23.1**	**1%**

Table 4-23. Turquoise Reservoir Area- Summary of Effects

Month	Simulated Area			Effects (1)	
	Existing Conditions (acres)	No Action (acres)	Proposed Action (acres)	(acres)	(%)
Mean Dry					
Oct	1,678.2	1,658.6	1,682.8	24.2	1%
Nov	1,656.0	1,644.5	1,661.9	17.4	1%
Dec	1,633.5	1,631.9	1,637.0	5.0	0%
Jan	1,615.6	1,620.6	1,609.5	-11.1	-1%
Feb	1,589.0	1,597.7	1,579.3	-18.4	-1%
Mar	1,536.1	1,549.0	1,529.7	-19.3	-1%
Apr	1,413.6	1,433.2	1,413.8	-19.4	-1%
May	1,362.2	1,371.9	1,357.1	-14.8	-1%
Jun	1,579.0	1,577.1	1,572.8	-4.3	0%
Jul	1,633.6	1,628.8	1,626.0	-2.9	0%
Aug	1,616.5	1,610.2	1,604.7	-5.5	0%
Sep	1,597.8	1,591.8	1,582.6	-9.2	-1%
Average	**1,575.9**	**1,576.3**	**1,571.4**	**-4.8**	**0%**

Notes:

(1) Effects (acres) = Proposed Action - No Action simulated area. Effects (%) = (Proposed Action - No Action simulated area)/No Action simulated area.

Figure 4-22. Turquoise Reservoir - Simulated Effect Elevation

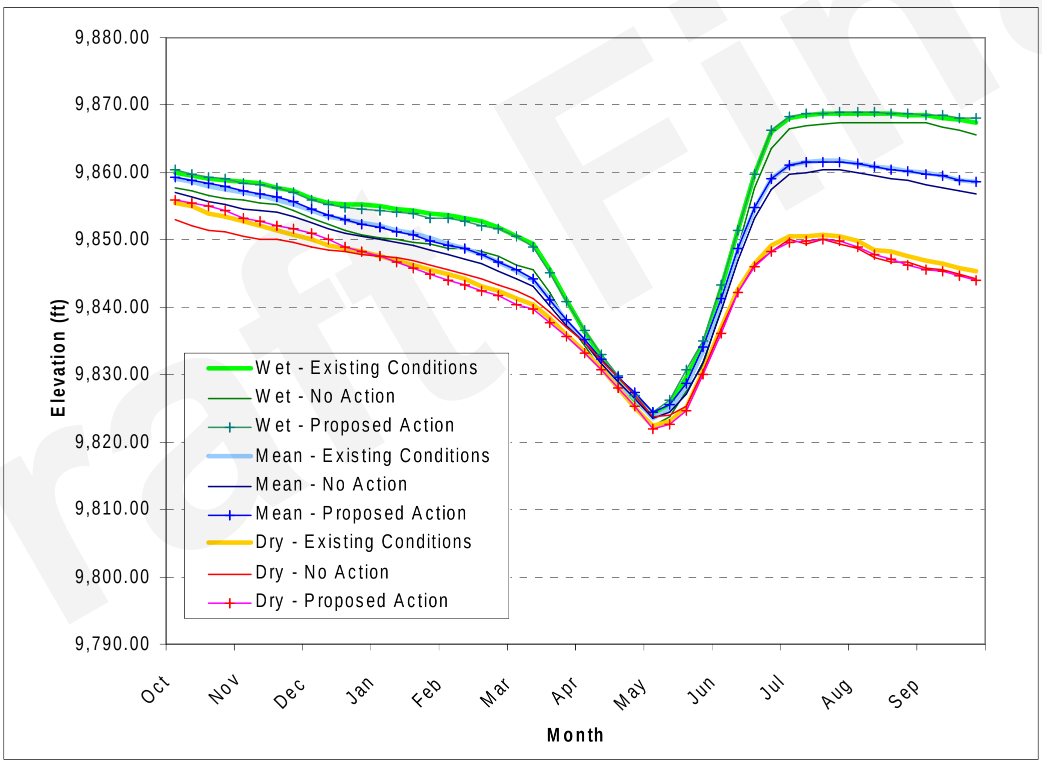


Figure 4-23. Turquoise Reservoir - Simulated Effect Surface Area

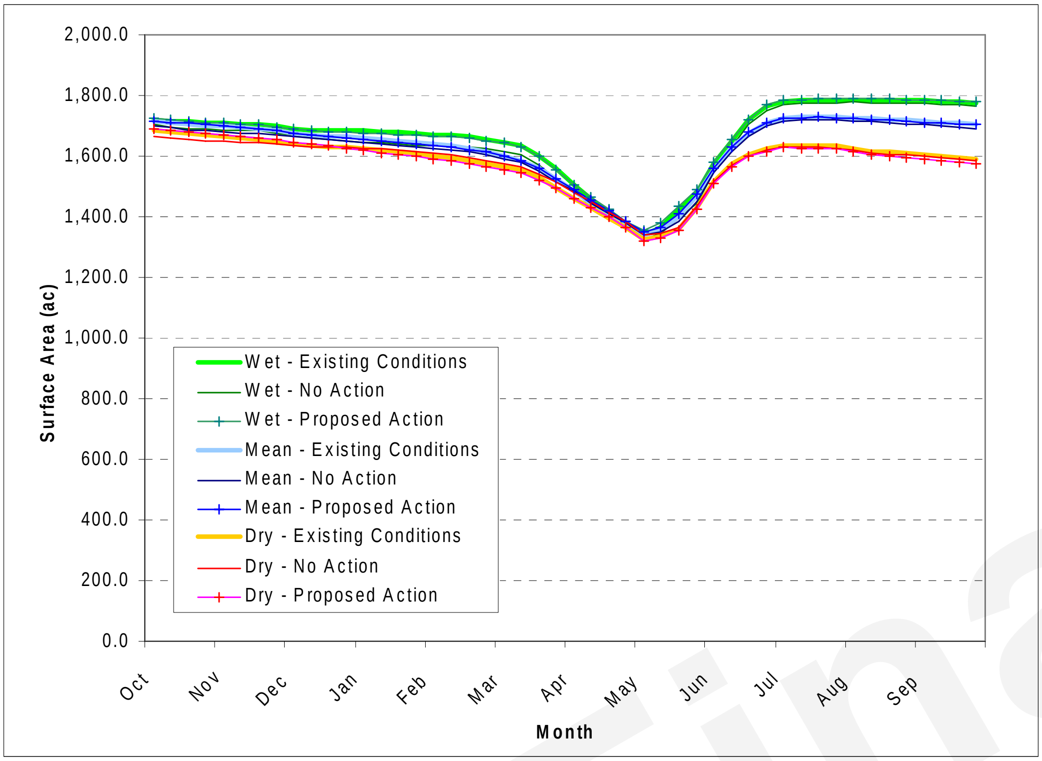
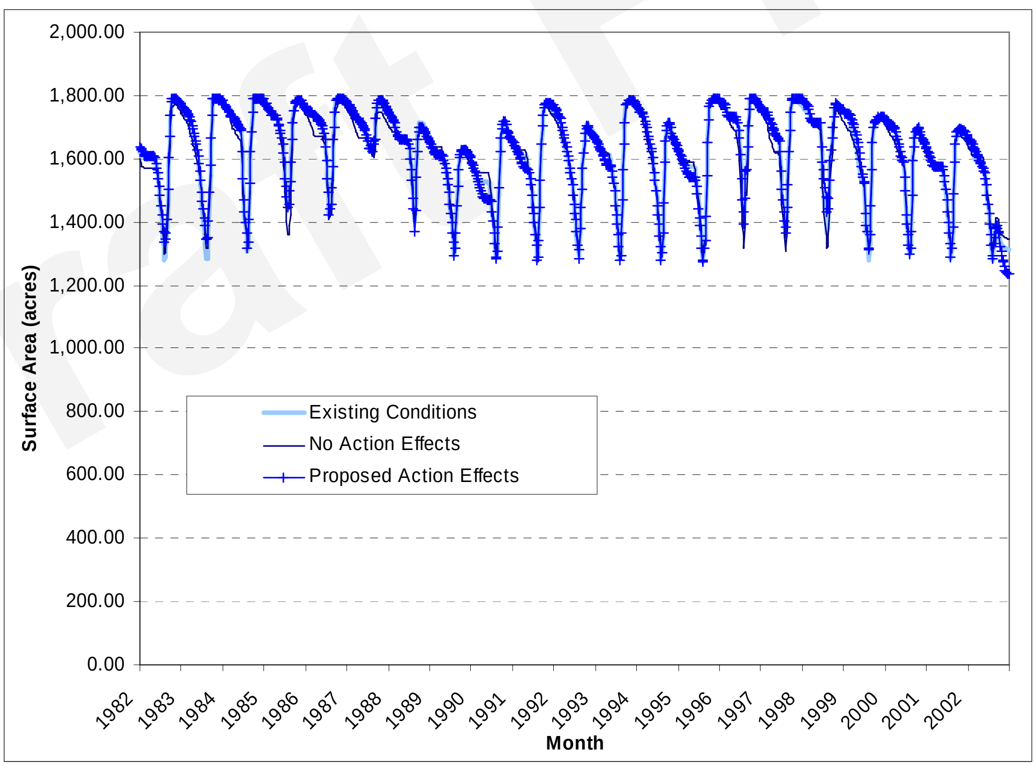


Figure 4-24. Turquoise Reservoir - Simulated Effects Surface Area Time Series



Lake Fork

Summary data for the effects on the stage of the Lake Fork gage are shown in **Table 4-24**, and **Figure 4-25**. Simulated stages under the No Action Alternative and Proposed Action are generally higher than stages under Existing Conditions. Effects are generally negative during summer months and close to zero for the remainder of the year.

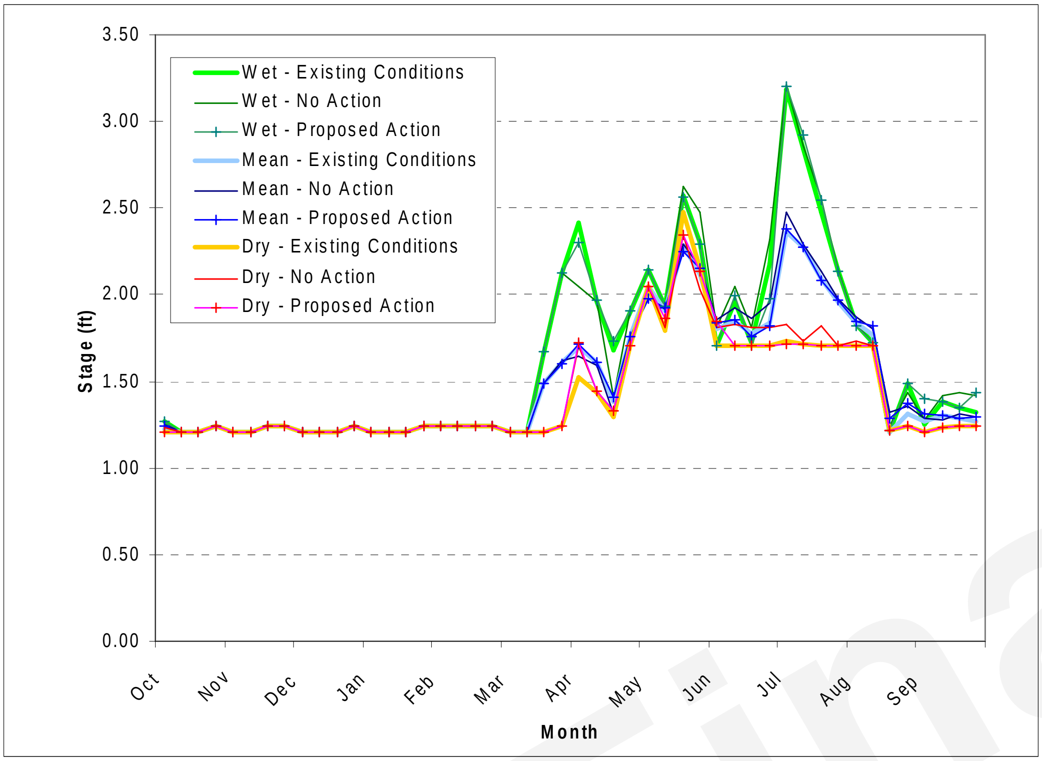
Table 4-24. Lake Fork Gage Stage - Summary of Effects

Month	Simulated Stage			Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	1.22	1.23	1.22	0.00	0%
Nov	1.22	1.22	1.22	0.00	0%
Dec	1.21	1.21	1.21	0.00	0%
Jan	1.21	1.21	1.21	0.00	0%
Feb	1.24	1.24	1.24	0.00	0%
Mar	1.38	1.38	1.38	0.00	0%
Apr	1.61	1.58	1.62	0.05	4%
May	2.09	2.09	2.08	-0.01	-1%
Jun	1.82	1.90	1.82	-0.08	-6%
Jul	2.17	2.22	2.18	-0.04	-3%
Aug	1.53	1.59	1.58	-0.01	-1%
Sep	1.28	1.29	1.30	0.01	1%
Average	**1.50**	**1.51**	**1.51**	**-0.01**	**-1%**
Mean Wet					
Oct	1.23	1.23	1.23	0.00	0%
Nov	1.22	1.22	1.22	0.00	0%
Dec	1.21	1.21	1.21	0.00	0%
Jan	1.21	1.21	1.21	0.00	0%
Feb	1.24	1.24	1.24	0.00	0%
Mar	1.55	1.55	1.55	0.00	0%
Apr	1.99	1.83	1.98	0.15	11%
May	2.24	2.29	2.23	-0.06	-3%
Jun	1.89	2.00	1.85	-0.15	-10%
Jul	2.66	2.69	2.70	0.01	0%
Aug	1.56	1.56	1.56	0.01	1%
Sep	1.32	1.39	1.39	0.00	0%
Average	**1.61**	**1.62**	**1.62**	**0.00**	**0%**
Mean Dry					
Oct	1.21	1.22	1.21	-0.01	-1%
Nov	1.22	1.22	1.22	0.00	0%
Dec	1.21	1.21	1.21	0.00	0%
Jan	1.21	1.21	1.21	0.00	0%
Feb	1.24	1.24	1.24	0.00	0%
Mar	1.21	1.21	1.21	0.00	0%
Apr	1.49	1.55	1.55	0.00	0%
May	2.12	2.06	2.10	0.04	3%
Jun	1.70	1.81	1.74	-0.08	-6%
Jul	1.71	1.77	1.71	-0.06	-5%
Aug	1.47	1.47	1.47	-0.01	-1%
Sep	1.23	1.23	1.23	0.00	0%
Average	**1.42**	**1.44**	**1.43**	**-0.01**	**-1%**

Notes:

(1) Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 4-25. Lake Fork Gage - Simulated Effect Stage



Lake Creek

Summary data for the effects on the stage for the Lake Creek gage are shown in **Table 4-25** and **Figure 4-26**. Simulated stages under the No Action Alternative are greater than stages under Existing Conditions. Simulated stages under the Proposed Action are less than stages under Existing Conditions. Effects are generally negative, indicating that stages under the No Action Alternative are greater than stages under the Proposed Action.

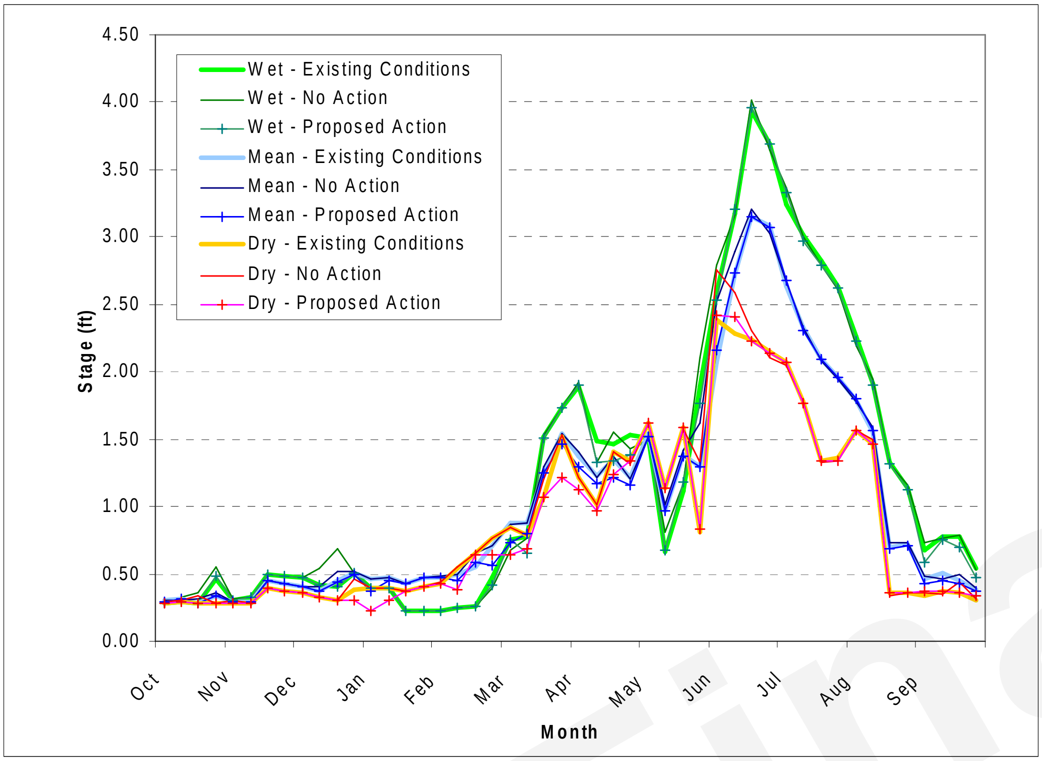
Table 4-25. Lake Creek Gage Stage - Summary of Effects

Month	Simulated Stage			Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	0.31	0.32	0.31	-0.02	-5%
Nov	0.36	0.37	0.36	0.00	-1%
Dec	0.43	0.46	0.43	-0.04	-8%
Jan	0.46	0.46	0.43	-0.03	-7%
Feb	0.56	0.59	0.52	-0.07	-11%
Mar	1.13	1.14	1.06	-0.08	-7%
Apr	1.29	1.30	1.21	-0.09	-7%
May	1.30	1.39	1.29	-0.10	-8%
Jun	2.75	2.91	2.78	-0.13	-5%
Jul	2.26	2.25	2.26	0.00	0%
Aug	1.19	1.21	1.19	-0.02	-2%
Sep	0.45	0.46	0.42	-0.04	-8%
Average	**1.04**	**1.07**	**1.02**	**-0.05**	**-5%**
Mean Wet					
Oct	0.33	0.38	0.33	-0.05	-12%
Nov	0.40	0.40	0.40	0.00	-1%
Dec	0.45	0.55	0.45	-0.10	-19%
Jan	0.31	0.31	0.31	0.00	0%
Feb	0.30	0.28	0.29	0.01	2%
Mar	1.19	1.18	1.16	-0.02	-1%
Apr	1.59	1.56	1.49	-0.07	-5%
May	1.29	1.40	1.28	-0.11	-8%
Jun	3.35	3.41	3.35	-0.06	-2%
Jul	2.93	2.94	2.93	-0.02	-1%
Aug	1.66	1.65	1.65	-0.01	0%
Sep	0.69	0.70	0.63	-0.08	-11%
Average	**1.21**	**1.23**	**1.19**	**-0.04**	**-3%**
Mean Dry					
Oct	0.28	0.30	0.28	-0.02	-6%
Nov	0.33	0.34	0.33	-0.01	-2%
Dec	0.34	0.36	0.32	-0.04	-10%
Jan	0.39	0.39	0.33	-0.07	-17%
Feb	0.60	0.60	0.52	-0.08	-13%
Mar	1.05	1.09	0.90	-0.19	-17%
Apr	1.24	1.24	1.17	-0.07	-6%
May	1.29	1.42	1.29	-0.12	-9%
Jun	2.26	2.44	2.30	-0.14	-6%
Jul	1.64	1.62	1.63	0.01	0%
Aug	0.94	0.94	0.94	0.00	0%
Sep	0.35	0.36	0.36	0.00	0%
Average	**0.89**	**0.93**	**0.86**	**-0.06**	**-7%**

Notes:

(1) Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 4-26. Lake Creek Gage - Simulated Effect Stage



Wellsville Gage

Summary data for the effects on the stage for the Wellsville gage are shown in **Table 4-26** and **Figure 4-27**. Simulated stages under the No Action Alternative are greater than stages under Existing Conditions. Simulated stages under the Proposed Action are less than stages under Existing Conditions. Effects are generally negative, indicating that stages under the No Action Alternative are greater than stages under the Proposed Action.

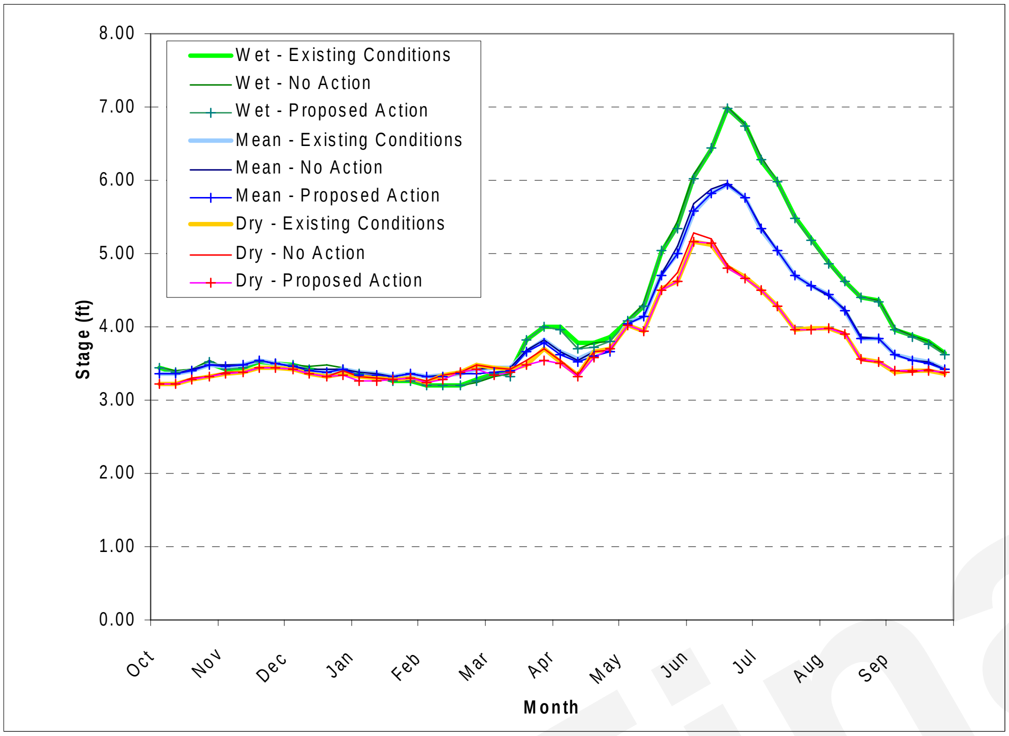
Table 4-26. Wellsville Gage Stage - Summary of Effects

Month	Simulated Stage			Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	3.40	3.41	3.40	-0.01	0%
Nov	3.50	3.50	3.50	0.00	0%
Dec	3.42	3.43	3.41	-0.01	-1%
Jan	3.35	3.35	3.34	-0.01	-1%
Feb	3.36	3.37	3.34	-0.03	-1%
Mar	3.59	3.60	3.56	-0.04	-2%
Apr	3.64	3.64	3.60	-0.03	-2%
May	4.48	4.51	4.47	-0.03	-1%
Jun	5.78	5.82	5.78	-0.04	-1%
Jul	4.91	4.91	4.91	0.00	0%
Aug	4.08	4.09	4.09	-0.01	0%
Sep	3.53	3.53	3.52	-0.01	-1%
Average	**3.92**	**3.93**	**3.91**	**-0.02**	**-1%**
Mean Wet					
Oct	3.43	3.45	3.43	-0.02	-1%
Nov	3.47	3.47	3.47	0.00	0%
Dec	3.43	3.46	3.43	-0.04	-2%
Jan	3.31	3.31	3.31	0.00	0%
Feb	3.22	3.21	3.21	0.00	0%
Mar	3.64	3.63	3.63	-0.01	0%
Apr	3.85	3.81	3.80	-0.02	-1%
May	4.69	4.72	4.68	-0.03	-1%
Jun	6.55	6.56	6.54	-0.02	0%
Jul	5.73	5.74	5.74	-0.01	0%
Aug	4.57	4.56	4.56	0.00	0%
Sep	3.82	3.83	3.80	-0.03	-1%
Average	**4.14**	**4.15**	**4.13**	**-0.01**	**0%**
Mean Dry					
Oct	3.26	3.26	3.26	-0.01	0%
Nov	3.41	3.41	3.41	0.00	0%
Dec	3.37	3.38	3.36	-0.01	-1%
Jan	3.30	3.30	3.28	-0.03	-1%
Feb	3.36	3.36	3.33	-0.03	-2%
Mar	3.51	3.53	3.44	-0.09	-4%
Apr	3.55	3.55	3.52	-0.03	-2%
May	4.27	4.30	4.27	-0.03	-1%
Jun	4.94	5.00	4.95	-0.05	-1%
Jul	4.18	4.18	4.18	0.00	0%
Aug	3.74	3.74	3.74	0.00	0%
Sep	3.39	3.39	3.39	0.00	0%
Average	**3.69**	**3.70**	**3.68**	**-0.02**	**-1%**

Notes:

(1) Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 4-27. Wellsville Gage - Simulated Effects Stage



4.3.1.2 Arkansas River Below Pueblo Reservoir

This section summarizes effects for key locations below Pueblo Reservoir, including Pueblo Reservoir, the Above Pueblo gage, the Moffat Street gage, the Avondale gage, the La Junta gage, Lake Meredith, Lake Henry, and Holbrook Reservoir.

Pueblo Reservoir

Summary data for the effects on Pueblo Reservoir pool elevation are shown in and . Simulated reservoir pool elevations are lower for the No Action Alternative and the Proposed Action when compared with elevations for Existing Conditions. Effects are generally positive, indicating that reservoir pool elevations are higher for the Proposed Action than under the No Action Alternative. However, simulated reservoir pool elevations for both scenarios are within the elevation range of the Pueblo Reservoir normal operating pool (4,796.7 to 4,880.49 feet).

Summary data for the effects on Pueblo Reservoir surface area are shown in **Table 4-27**, **Table 4-28** and **Figure 4-28**, **Figure 4-29**, and **Figure 4-30**. Simulated reservoir surface area is less for the No Action Alternative and the Proposed Action when compared with surface area for Existing Conditions. Effects are generally positive, indicating that reservoir surface area is higher for the Proposed Action than under the No Action Alternative. However, the Pueblo Reservoir water surface would remain within the normal operating pool as discussed in the previous paragraph.

Table 4-27. Pueblo Reservoir Elevation - Summary of Effects

Month	Simulated Elevation			Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	4,852.33	4,845.50	4,849.47	3.97	4%
Nov	4,854.08	4,848.05	4,851.39	3.34	4%
Dec	4,857.43	4,852.62	4,855.10	2.48	2%
Jan	4,860.68	4,856.52	4,858.44	1.92	2%
Feb	4,862.79	4,858.98	4,860.65	1.67	2%
Mar	4,865.18	4,861.66	4,862.92	1.26	1%
Apr	4,864.31	4,860.14	4,861.73	1.59	1%
May	4,861.88	4,856.92	4,859.11	2.18	2%
Jun	4,860.86	4,855.53	4,858.14	2.61	3%
Jul	4,858.26	4,852.59	4,855.33	2.74	3%
Aug	4,855.67	4,849.25	4,852.51	3.26	3%
Sep	4,853.30	4,846.28	4,849.92	3.63	4%
Average	**4,858.90**	**4,853.67**	**4,856.23**	**2.56**	**3%**
Mean Wet					
Oct	4,855.14	4,846.25	4,852.56	6.31	7%
Nov	4,856.39	4,848.57	4,854.07	5.50	6%
Dec	4,858.68	4,853.02	4,856.93	3.92	4%
Jan	4,861.28	4,856.80	4,859.70	2.90	3%
Feb	4,862.96	4,858.86	4,861.47	2.61	2%
Mar	4,864.93	4,860.90	4,863.45	2.56	2%
Apr	4,864.12	4,859.33	4,862.21	2.88	3%
May	4,861.77	4,856.05	4,859.39	3.35	3%
Jun	4,864.62	4,859.24	4,862.86	3.62	3%
Jul	4,865.34	4,860.29	4,863.86	3.57	3%
Aug	4,865.20	4,860.16	4,863.76	3.59	3%
Sep	4,865.91	4,861.12	4,864.44	3.31	3%
Average	**4,862.19**	**4,856.72**	**4,860.39**	**3.68**	**4%**
Mean Dry					
Oct	4,850.64	4,846.15	4,847.89	1.74	2%
Nov	4,851.46	4,847.26	4,848.74	1.48	2%
Dec	4,854.79	4,851.30	4,852.40	1.09	1%
Jan	4,858.15	4,855.07	4,855.65	0.58	1%
Feb	4,859.95	4,857.03	4,857.47	0.43	0%
Mar	4,862.42	4,859.78	4,859.67	-0.11	0%
Apr	4,861.90	4,858.77	4,858.74	-0.03	0%
May	4,861.62	4,857.64	4,858.21	0.57	1%
Jun	4,859.39	4,854.70	4,855.84	1.14	1%
Jul	4,851.40	4,845.75	4,847.39	1.64	2%
Aug	4,843.42	4,836.06	4,838.63	2.57	3%
Sep	4,839.16	4,830.54	4,833.71	3.17	4%
Average	**4,854.53**	**4,850.00**	**4,851.20**	**1.19**	**1%**

Notes:

(1) Effects (feet) = Proposed Action - No Action simulated elevation. Effects (%) = (Proposed Action - No Action simulated elevation)/No Action simulated depth.

Table 4-28. Pueblo Reservoir Surface Area - Summary of Effects

Month	Simulated Area			Effects (1)	
	Existing Conditions	No Action	Proposed Action		
	(acres)	(acres)	(acres)	(acres)	(%)
Overall Mean					
Oct	3,406.8	3,153.1	3,294.5	141.5	4%
Nov	3,484.4	3,256.0	3,378.6	122.6	4%
Dec	3,618.2	3,436.2	3,529.4	93.2	3%
Jan	3,742.4	3,595.1	3,663.7	68.6	2%
Feb	3,824.5	3,691.9	3,745.1	53.1	1%
Mar	3,918.8	3,788.2	3,830.3	42.1	1%
Apr	3,869.3	3,712.1	3,764.0	51.9	1%
May	3,759.5	3,575.9	3,649.4	73.5	2%
Jun	3,723.1	3,514.1	3,614.3	100.2	3%
Jul	3,625.4	3,405.0	3,510.1	105.1	3%
Aug	3,531.7	3,290.2	3,413.1	122.9	4%
Sep	3,440.1	3,177.7	3,310.5	132.7	4%
Average	**3,662.0**	**3,466.3**	**3,558.6**	**92.3**	**3%**
Mean Wet					
Oct	3,570.7	3,227.3	3,467.7	240.3	7%
Nov	3,638.5	3,335.8	3,548.6	212.7	6%
Dec	3,731.4	3,529.7	3,675.3	145.5	4%
Jan	3,826.4	3,680.4	3,780.5	100.0	3%
Feb	3,884.6	3,755.5	3,834.9	79.3	2%
Mar	3,955.8	3,818.4	3,899.8	81.4	2%
Apr	3,915.4	3,747.9	3,839.6	91.7	2%
May	3,824.7	3,630.9	3,739.6	108.7	3%
Jun	3,950.2	3,759.2	3,881.9	122.6	3%
Jul	3,987.6	3,806.9	3,925.2	118.2	3%
Aug	3,975.5	3,796.2	3,919.5	123.3	3%
Sep	3,988.0	3,804.1	3,922.6	118.5	3%
Average	**3,854.1**	**3,657.7**	**3,786.2**	**128.5**	**4%**
Mean Dry					
Oct	3,322.1	3,159.8	3,217.6	57.7	2%
Nov	3,349.1	3,199.1	3,249.2	50.0	2%
Dec	3,480.0	3,343.2	3,381.9	38.7	1%
Jan	3,620.3	3,494.4	3,518.2	23.8	1%
Feb	3,692.3	3,580.6	3,597.2	16.7	0%
Mar	3,782.5	3,694.2	3,686.5	-7.7	0%
Apr	3,740.0	3,625.4	3,618.5	-6.9	0%
May	3,733.0	3,569.5	3,590.2	20.6	1%
Jun	3,626.8	3,435.2	3,480.8	45.6	1%
Jul	3,278.0	3,067.7	3,129.9	62.2	2%
Aug	2,948.5	2,682.7	2,776.4	93.7	3%
Sep	2,792.0	2,481.0	2,592.2	111.3	4%
Average	**3,447.0**	**3,277.7**	**3,319.9**	**42.1**	**1%**

Notes:

(1) Effects (acres) = Proposed Action - No Action simulated area. Effects (%) = (Proposed Action - No Action simulated area)/No Action simulated area.

Figure 4-28. Pueblo Reservoir - Simulated Effects Elevation

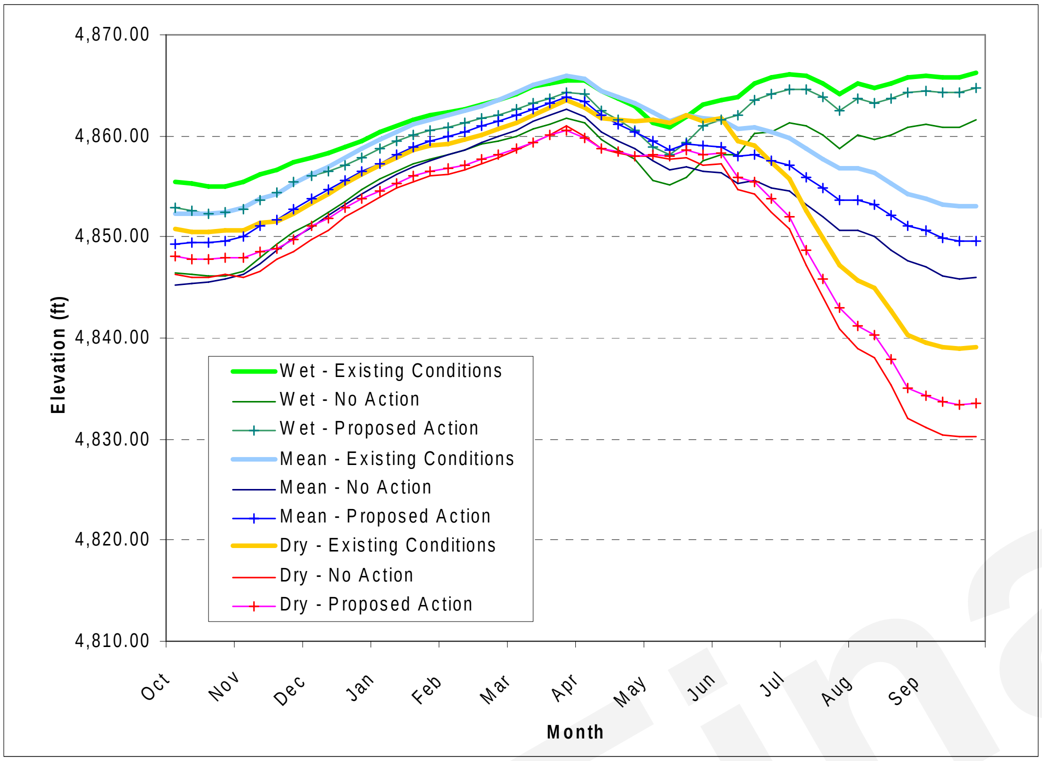


Figure 4-29. Pueblo Reservoir - Simulated Effects Surface Area

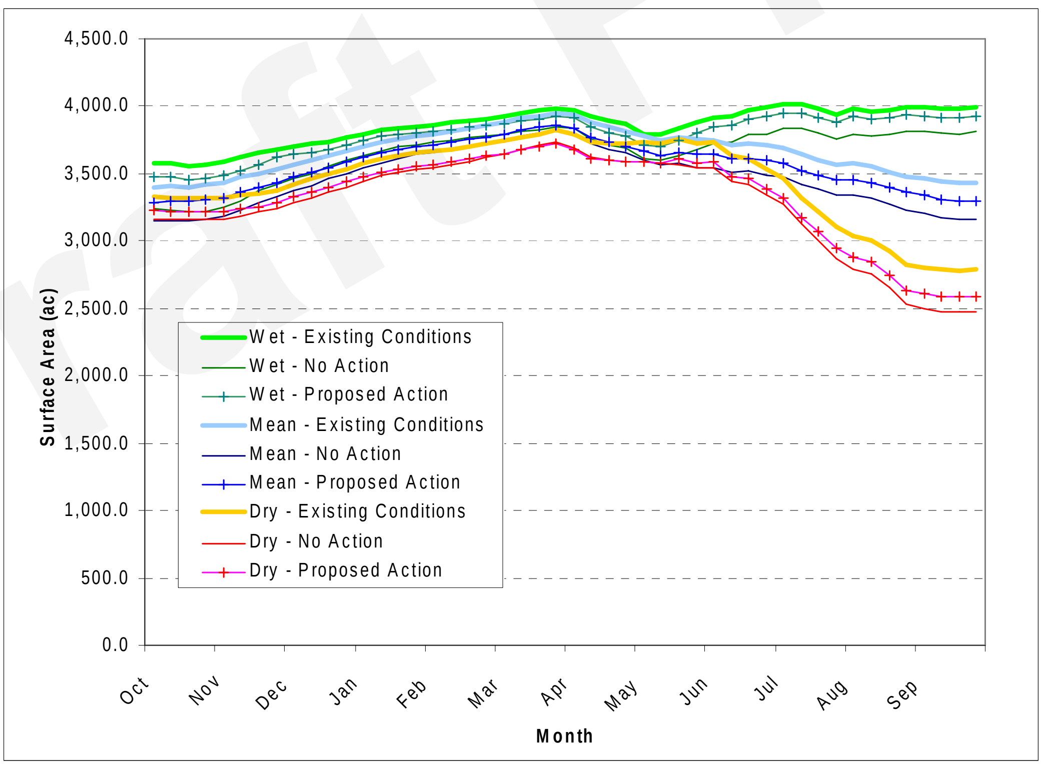
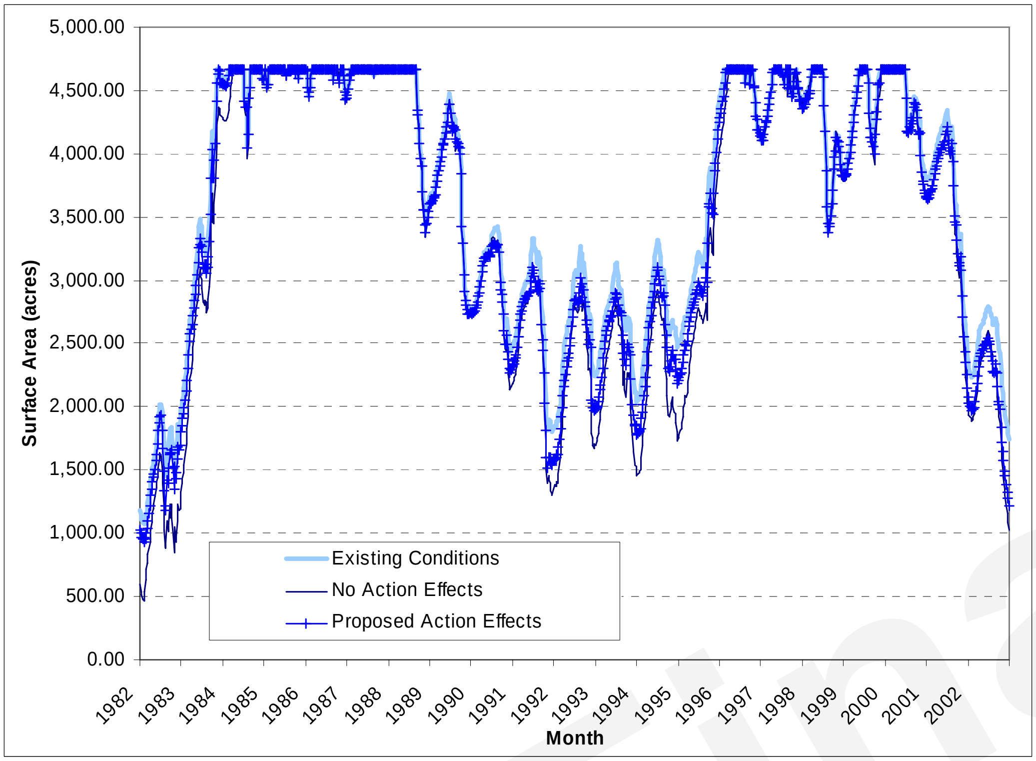


Figure 4-30. Pueblo Reservoir - Simulated Effects Surface Area Time Series



Above Pueblo Gage

Summary data for the effects on the stage for the Above Pueblo gage are shown in **Table 4-29** and **Figure 4-31**. Stages under the No Action Alternative and Proposed Action are similar to stages under Existing Conditions.

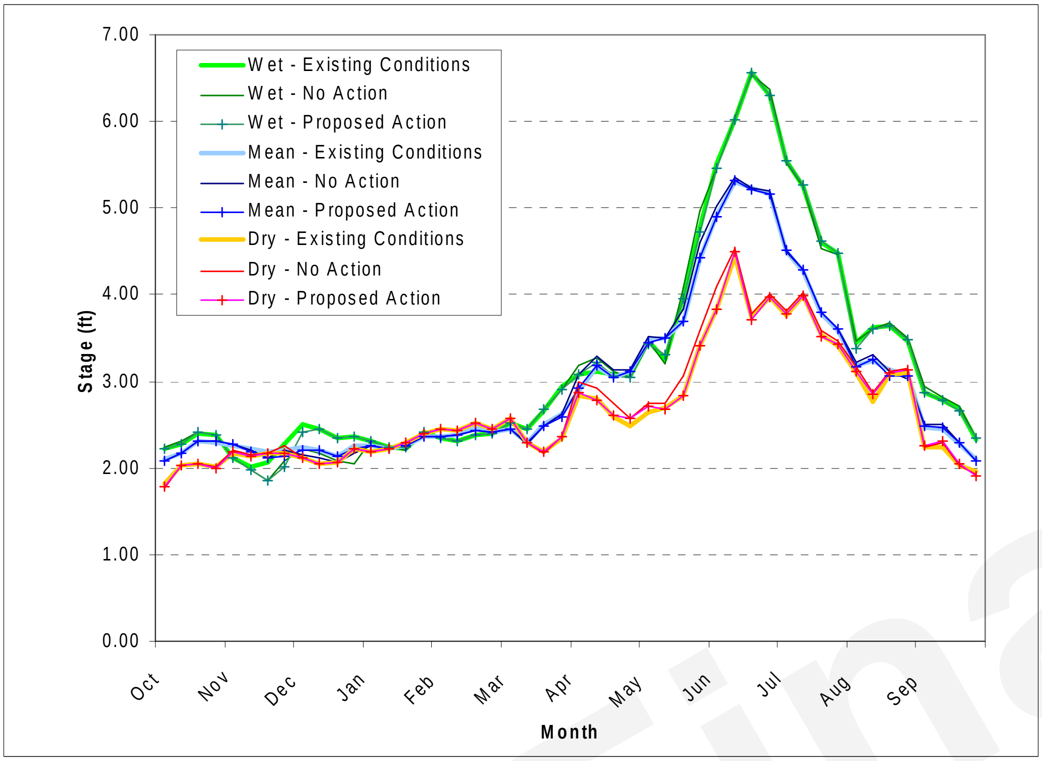
Table 4-29. Above Pueblo Gage Stage - Summary of Effects

	Simulated Stage				
	Existing Conditions	No Action	Proposed Action	Effects (1)	
Month	(feet)	(feet)	(feet)	(feet)	(%)
Overall Mean					
Oct	2.22	2.22	2.22	0.00	0%
Nov	2.22	2.20	2.18	-0.02	-1%
Dec	2.21	2.13	2.19	0.07	3%
Jan	2.28	2.27	2.28	0.00	0%
Feb	2.40	2.39	2.40	0.00	0%
Mar	2.46	2.46	2.45	-0.01	0%
Apr	3.05	3.15	3.07	-0.08	-3%
May	3.77	3.86	3.77	-0.10	-3%
Jun	5.15	5.20	5.15	-0.05	-1%
Jul	4.03	4.05	4.05	0.00	0%
Aug	3.15	3.17	3.14	-0.03	-1%
Sep	2.32	2.34	2.33	-0.01	-1%
Average	**2.94**	**2.95**	**2.94**	**-0.02**	**-1%**
Mean Wet					
Oct	2.32	2.33	2.33	-0.01	0%
Nov	2.12	2.01	1.99	-0.02	-1%
Dec	2.42	2.13	2.40	0.27	13%
Jan	2.30	2.29	2.31	0.01	0%
Feb	2.36	2.36	2.36	0.00	0%
Mar	2.64	2.64	2.63	0.00	0%
Apr	3.08	3.15	3.10	-0.05	-2%
May	3.87	3.92	3.85	-0.07	-2%
Jun	6.10	6.10	6.09	-0.01	0%
Jul	4.97	4.95	4.98	0.03	1%
Aug	3.54	3.56	3.53	-0.04	-1%
Sep	2.67	2.70	2.67	-0.04	-1%
Average	**3.20**	**3.18**	**3.19**	**0.01**	**0%**
Mean Dry					
Oct	1.98	1.97	1.97	0.00	0%
Nov	2.16	2.20	2.17	-0.03	-2%
Dec	2.11	2.11	2.11	0.00	0%
Jan	2.28	2.28	2.28	0.00	0%
Feb	2.47	2.47	2.47	0.00	0%
Mar	2.35	2.35	2.35	0.00	0%
Apr	2.68	2.81	2.71	-0.10	-4%
May	2.90	3.04	2.91	-0.13	-4%
Jun	4.00	4.10	4.00	-0.10	-2%
Jul	3.67	3.72	3.69	-0.03	-1%
Aug	3.01	3.08	3.05	-0.03	-1%
Sep	2.12	2.12	2.13	0.01	0%
Average	**2.64**	**2.69**	**2.65**	**-0.03**	**-1%**

Notes:

(1) Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 4-31. Above Pueblo Gage - Simulated Effects Stage



Moffat Street Gage

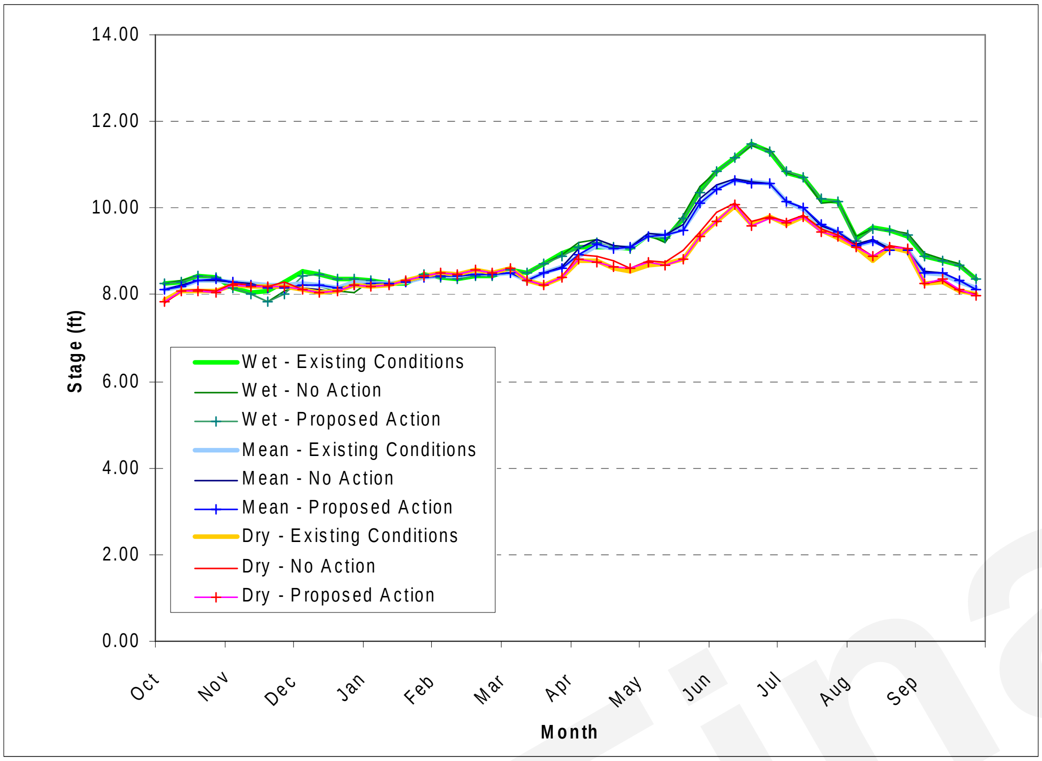
Summary data for the effects on the stage for the Moffat Street gage are shown in **Table 4-29** and **Figure 4-32**. Stages under the No Action Alternative and Proposed Action are similar to stages under Existing Conditions.

Table 4-30. Moffat Street Gage Stage - Summary of Effects

Month	Simulated Stage			Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	8.25	8.25	8.25	0.00	0%
Nov	8.25	8.23	8.21	-0.02	-1%
Dec	8.22	8.14	8.21	0.07	5%
Jan	8.30	8.31	8.31	0.00	0%
Feb	8.45	8.44	8.44	0.00	0%
Mar	8.49	8.50	8.49	-0.01	-1%
Apr	9.04	9.14	9.06	-0.08	-3%
May	9.59	9.66	9.58	-0.08	-3%
Jun	10.56	10.60	10.56	-0.04	-1%
Jul	9.79	9.80	9.80	0.00	0%
Aug	9.12	9.13	9.10	-0.03	-1%
Sep	8.36	8.38	8.36	-0.01	-1%
Average	**8.87**	**8.88**	**8.86**	**-0.02**	**-1%**
Mean Wet					
Oct	8.35	8.36	8.35	-0.01	0%
Nov	8.14	8.02	8.01	-0.02	-1%
Dec	8.44	8.13	8.42	0.28	20%
Jan	8.33	8.33	8.34	0.01	1%
Feb	8.41	8.41	8.41	0.00	0%
Mar	8.68	8.67	8.67	0.00	0%
Apr	9.10	9.16	9.12	-0.05	-2%
May	9.71	9.74	9.69	-0.05	-2%
Jun	11.20	11.20	11.19	-0.01	0%
Jul	10.47	10.45	10.48	0.03	1%
Aug	9.42	9.44	9.41	-0.04	-1%
Sep	8.67	8.71	8.67	-0.03	-2%
Average	**9.08**	**9.05**	**9.06**	**0.01**	**0%**
Mean Dry					
Oct	8.03	8.02	8.02	0.00	0%
Nov	8.20	8.24	8.20	-0.03	-2%
Dec	8.12	8.12	8.12	0.00	0%
Jan	8.30	8.30	8.30	0.00	0%
Feb	8.51	8.51	8.51	0.00	0%
Mar	8.40	8.39	8.39	0.00	0%
Apr	8.68	8.81	8.70	-0.11	-5%
May	8.88	9.01	8.90	-0.11	-5%
Jun	9.79	9.88	9.78	-0.09	-3%
Jul	9.56	9.61	9.57	-0.03	-1%
Aug	9.00	9.06	9.04	-0.03	-1%
Sep	8.17	8.17	8.18	0.01	1%
Average	8.64	8.68	8.64	-0.03	-2%

Notes:
(1) Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 4-32. Moffat Street Gage - Simulated Effects Stage



Avondale Gage

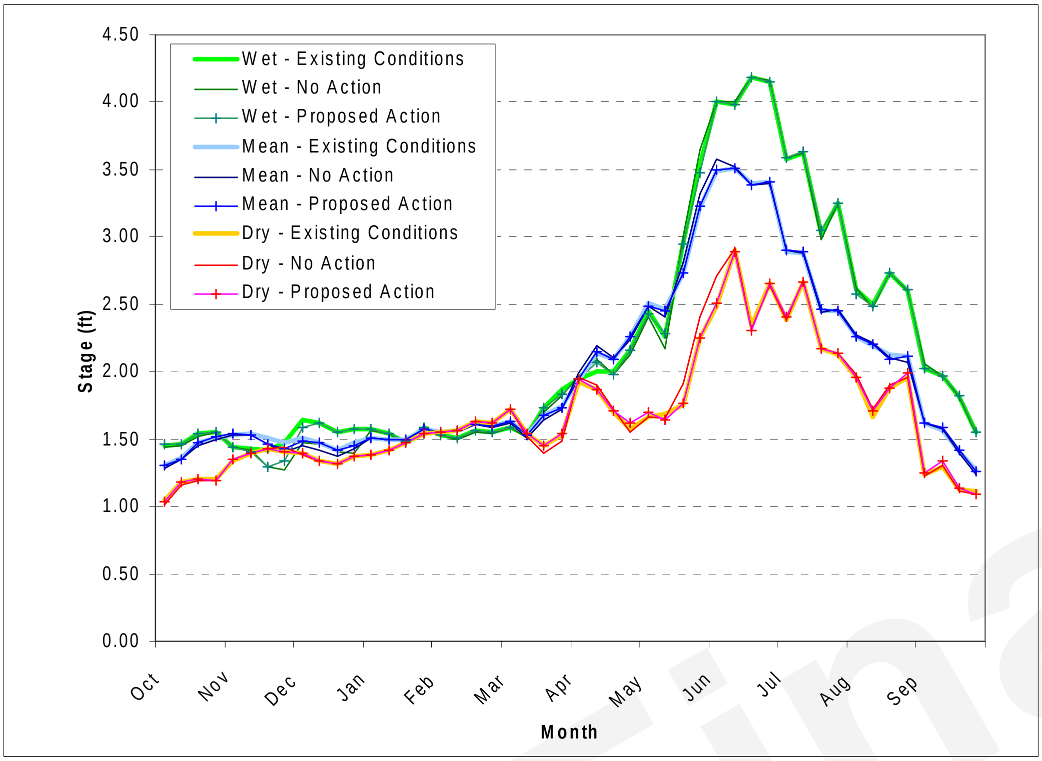
Summary data for the effects on the stage for the Avondale gage are shown in **Table 4-31** and **Figure 4-33**. Stages under the No Action Alternative and Proposed Action are similar to stages under Existing Conditions.

Table 4-31. Avondale Gage Stage - Summary of Effects

	Simulated Stage				
	Existing Conditions	No Action	Proposed Action	Effects (1)	
Month	(feet)	(feet)	(feet)	(feet)	(%)
Overall Mean					
Oct	1.41	1.40	1.41	0.02	1%
Nov	1.51	1.48	1.49	0.01	1%
Dec	1.47	1.42	1.46	0.04	3%
Jan	1.52	1.52	1.52	0.00	0%
Feb	1.58	1.58	1.58	0.00	0%
Mar	1.65	1.62	1.64	0.02	2%
Apr	2.10	2.13	2.12	-0.01	-1%
May	2.73	2.76	2.72	-0.03	-1%
Jun	3.45	3.47	3.45	-0.02	-1%
Jul	2.67	2.67	2.68	0.01	0%
Aug	2.17	2.17	2.17	0.00	0%
Sep	1.47	1.46	1.47	0.01	1%
Average	**1.98**	**1.97**	**1.98**	**0.00**	**0%**
Mean Wet					
Oct	1.50	1.49	1.51	0.01	1%
Nov	1.44	1.35	1.37	0.02	2%
Dec	1.60	1.44	1.58	0.14	12%
Jan	1.54	1.54	1.55	0.01	1%
Feb	1.54	1.53	1.54	0.00	0%
Mar	1.68	1.65	1.67	0.02	1%
Apr	2.03	2.04	2.04	0.00	0%
May	2.80	2.81	2.79	-0.02	-1%
Jun	4.08	4.09	4.08	-0.01	0%
Jul	3.37	3.36	3.38	0.02	1%
Aug	2.61	2.61	2.60	0.00	0%
Sep	1.84	1.85	1.84	-0.01	0%
Average	**2.17**	**2.15**	**2.16**	**0.02**	**1%**
Mean Dry					
Oct	1.16	1.14	1.16	0.02	2%
Nov	1.39	1.40	1.39	-0.01	-1%
Dec	1.36	1.35	1.36	0.00	0%
Jan	1.45	1.45	1.45	0.00	0%
Feb	1.59	1.59	1.59	0.00	0%
Mar	1.56	1.53	1.56	0.03	3%
Apr	1.77	1.79	1.78	0.00	0%
May	1.84	1.91	1.84	-0.07	-4%
Jun	2.59	2.65	2.59	-0.06	-2%
Jul	2.34	2.34	2.35	0.00	0%
Aug	1.87	1.89	1.89	-0.01	0%
Sep	1.19	1.18	1.20	0.02	2%
Average	**1.68**	**1.69**	**1.68**	**-0.01**	**0%**

Notes:
(1) Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 4-33. Avondale Gage - Simulated Effects Stage



Lake Meredith

Summary data for the effects on Lake Meredith pool elevation are shown in **Table 4-32** and Figure 4-34. Reservoir pool elevations for the No Action Alternative and the Proposed Action are higher than for Existing Conditions. Effects are negative, indicating that simulated elevations for the No Action Alternative are higher than elevations under the Proposed Action. Simulated Lake Meredith pool elevations are within the elevation range of the normal operating pool for Lake Meredith (4,241.8 to 4,253.9 feet).

Data showing effects on Lake Meredith surface area are shown in **Table 4-33**, **Figure 4-35**, and **Figure 4-36**. Reservoir surface area for the No Action Alternative and the Proposed Action is higher than for Existing Conditions. Effects are negative, indicating that simulated surface area for the No Action Alternative is higher than surface area under the Proposed Action. However, as discussed in the previous paragraph, the simulated surface area under the No Action Alternative would be within the normal operating pool of Lake Meredith.

Table 4-32. Lake Meredith Elevation- Summary of Effects

Month	Simulated Elevation			Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	4,245.90	4,247.16	4,246.05	-1.11	-22%
Nov	4,245.75	4,247.00	4,245.96	-1.04	-22%
Dec	4,246.18	4,247.45	4,246.45	-0.99	-19%
Jan	4,246.83	4,248.10	4,247.08	-1.02	-17%
Feb	4,246.94	4,248.27	4,247.21	-1.07	-17%
Mar	4,248.67	4,249.68	4,248.83	-0.86	-11%
Apr	4,248.26	4,249.61	4,248.40	-1.20	-16%
May	4,246.93	4,248.16	4,247.10	-1.06	-18%
Jun	4,245.24	4,247.22	4,245.46	-1.77	-35%
Jul	4,246.16	4,247.86	4,246.24	-1.62	-28%
Aug	4,246.17	4,247.72	4,246.29	-1.43	-26%
Sep	4,246.06	4,247.41	4,246.21	-1.20	-23%
Average	**4,246.59**	**4,247.97**	**4,246.77**	**-1.20**	**-21%**
Mean Wet					
Oct	4,247.46	4,248.70	4,247.43	-1.27	-19%
Nov	4,247.36	4,248.58	4,247.34	-1.24	-19%
Dec	4,247.85	4,249.01	4,247.84	-1.17	-17%
Jan	4,248.49	4,249.58	4,248.48	-1.10	-15%
Feb	4,248.58	4,249.69	4,248.58	-1.11	-15%
Mar	4,249.50	4,250.54	4,249.47	-1.07	-13%
Apr	4,248.84	4,250.27	4,248.83	-1.44	-18%
May	4,247.40	4,248.72	4,247.47	-1.24	-19%
Jun	4,246.03	4,248.03	4,245.99	-2.04	-35%
Jul	4,247.75	4,249.40	4,247.78	-1.61	-22%
Aug	4,248.35	4,249.65	4,248.54	-1.11	-15%
Sep	4,248.82	4,249.73	4,249.07	-0.67	-9%
Average	**4,248.03**	**4,249.32**	**4,248.07**	**-1.26**	**-18%**
Mean Dry					
Oct	4,244.82	4,246.52	4,244.81	-1.71	-39%
Nov	4,244.78	4,246.47	4,244.79	-1.68	-39%
Dec	4,245.37	4,246.99	4,245.54	-1.44	-30%
Jan	4,245.95	4,247.60	4,246.18	-1.42	-26%
Feb	4,245.99	4,247.77	4,246.26	-1.51	-27%
Mar	4,248.25	4,249.48	4,248.40	-1.08	-15%
Apr	4,248.12	4,249.32	4,248.29	-1.03	-14%
May	4,246.13	4,247.40	4,246.48	-0.91	-17%
Jun	4,243.98	4,246.25	4,244.48	-1.78	-43%
Jul	4,244.14	4,246.05	4,244.46	-1.59	-41%
Aug	4,243.78	4,245.69	4,244.07	-1.62	-46%
Sep	4,243.56	4,245.36	4,243.83	-1.53	-48%
Average	**4,245.40**	**4,247.07**	**4,245.63**	**-1.44**	**-29%**

Notes:
(1) Effects (feet) = Proposed Action - No Action simulated elevation. Effects (%) = (Proposed Action - No Action simulated elevation)/No Action simulated depth.

Table 4-33. Lake Meredith Area- Summary of Effects

Month	Simulated Area			Effects (1)	
	Existing Conditions (acres)	No Action (acres)	Proposed Action (acres)	(acres)	(%)
Overall Mean					
Oct	2,456.4	2,914.9	2,514.1	-400.8	-14%
Nov	2,399.4	2,856.6	2,474.2	-382.4	-13%
Dec	2,560.5	3,028.6	2,662.6	-366.0	-12%
Jan	2,793.7	3,287.1	2,895.8	-391.4	-12%
Feb	2,831.1	3,351.3	2,938.6	-412.6	-12%
Mar	3,510.6	3,896.3	3,569.5	-326.8	-8%
Apr	3,331.5	3,878.1	3,385.7	-492.4	-13%
May	2,827.9	3,298.6	2,892.4	-406.3	-12%
Jun	2,195.3	2,925.0	2,275.7	-649.3	-22%
Jul	2,550.1	3,177.4	2,577.7	-599.7	-19%
Aug	2,557.9	3,129.6	2,599.2	-530.4	-17%
Sep	2,524.9	3,014.7	2,581.8	-432.8	-14%
Average	**2,711.6**	**3,229.9**	**2,780.6**	**-449.2**	**-14%**
Mean Wet					
Oct	3,055.4	3,480.9	3,044.2	-436.7	-13%
Nov	3,013.7	3,447.0	3,003.1	-443.9	-13%
Dec	3,198.4	3,613.4	3,195.7	-417.8	-12%
Jan	3,428.2	3,860.7	3,424.8	-435.9	-11%
Feb	3,467.7	3,906.7	3,468.3	-438.4	-11%
Mar	3,827.2	4,220.1	3,816.8	-403.3	-10%
Apr	3,554.9	4,131.4	3,552.4	-579.0	-14%
May	3,001.2	3,517.6	3,026.9	-490.6	-14%
Jun	2,501.7	3,222.9	2,489.1	-733.8	-23%
Jul	3,171.7	3,784.4	3,178.7	-605.7	-16%
Aug	3,391.0	3,884.0	3,464.8	-419.2	-11%
Sep	3,577.7	3,940.4	3,696.2	-244.2	-6%
Average	**3,265.7**	**3,750.8**	**3,280.1**	**-470.7**	**-13%**
Mean Dry					
Oct	2,039.7	2,670.5	2,035.1	-635.4	-24%
Nov	2,021.8	2,650.4	2,023.0	-627.4	-24%
Dec	2,237.4	2,850.4	2,293.5	-556.9	-20%
Jan	2,452.7	3,079.8	2,537.6	-542.1	-18%
Feb	2,459.5	3,144.6	2,557.9	-586.7	-19%
Mar	3,347.2	3,810.6	3,401.2	-409.4	-11%
Apr	3,286.4	3,763.1	3,336.6	-426.5	-11%
May	2,522.3	3,003.8	2,651.1	-352.7	-12%
Jun	1,708.5	2,571.6	1,899.3	-672.3	-26%
Jul	1,761.6	2,501.1	1,891.3	-609.8	-24%
Aug	1,631.7	2,355.0	1,736.6	-618.4	-26%
Sep	1,552.0	2,217.6	1,641.7	-575.9	-26%
Average	**2,251.7**	**2,884.9**	**2,333.7**	**-551.1**	**-19%**

Notes:
(1) Effects (acres) = Proposed Action - No Action simulated area. Effects (%) = (Proposed Action - No Action simulated area)/No Action simulated area.

Figure 4-34. Lake Meredith Gage - Simulated Effects Elevation

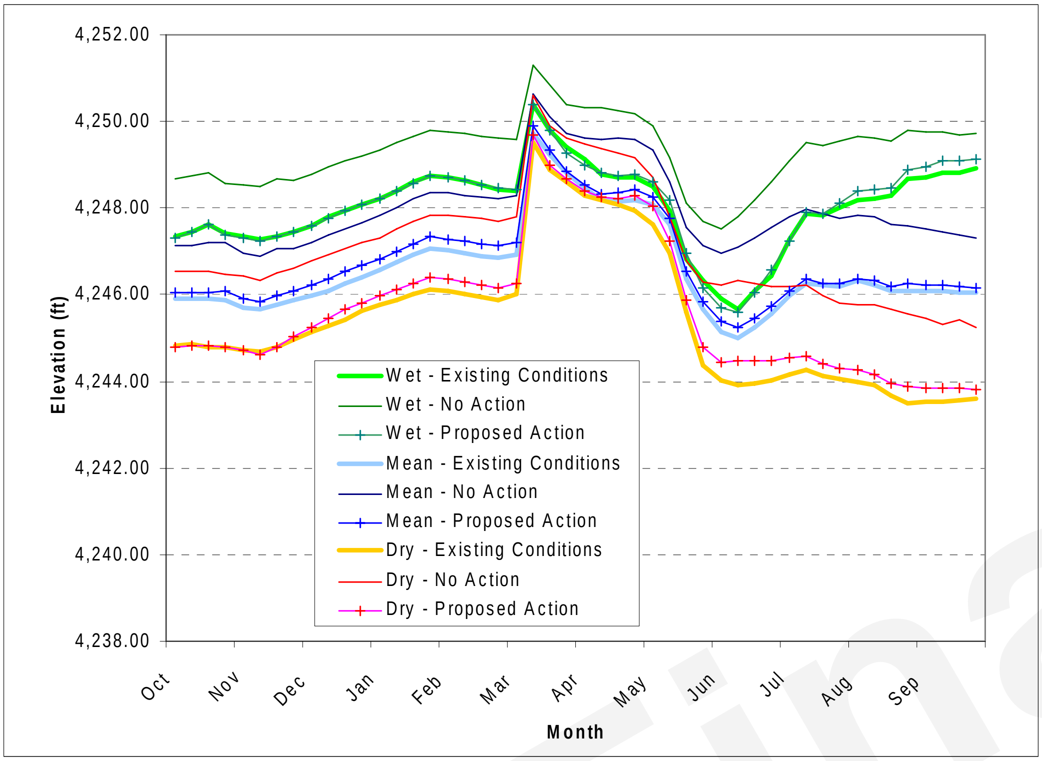


Figure 4-35. Lake Meredith Gage - Simulated Effects Surface Area

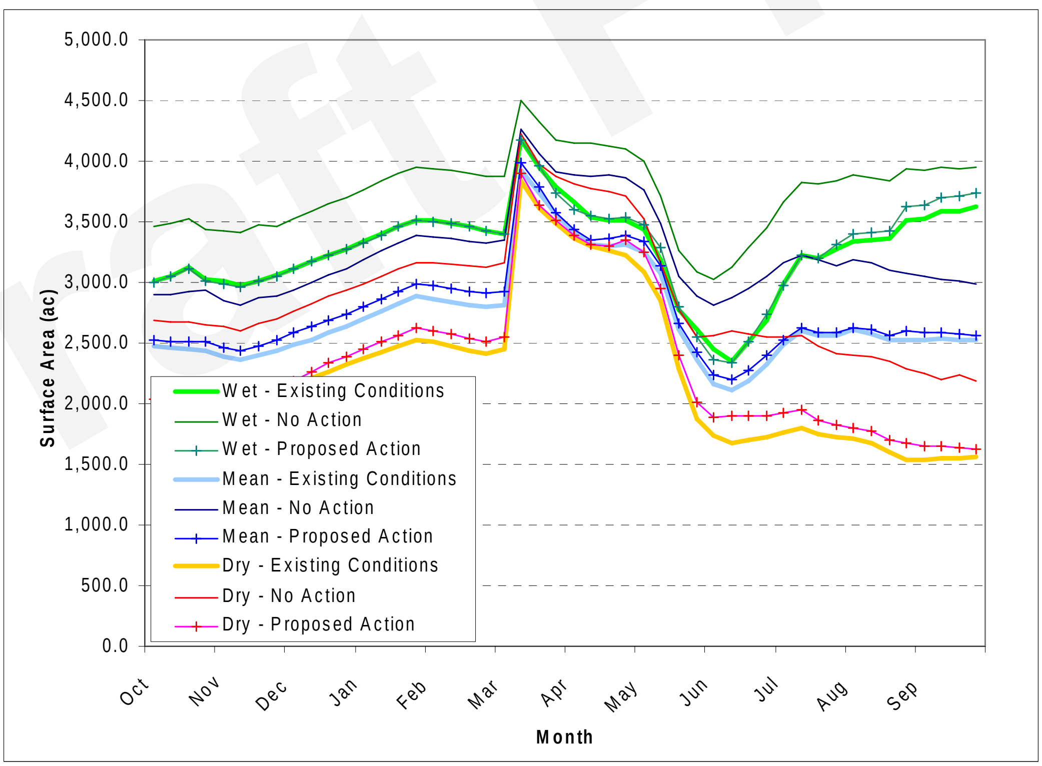
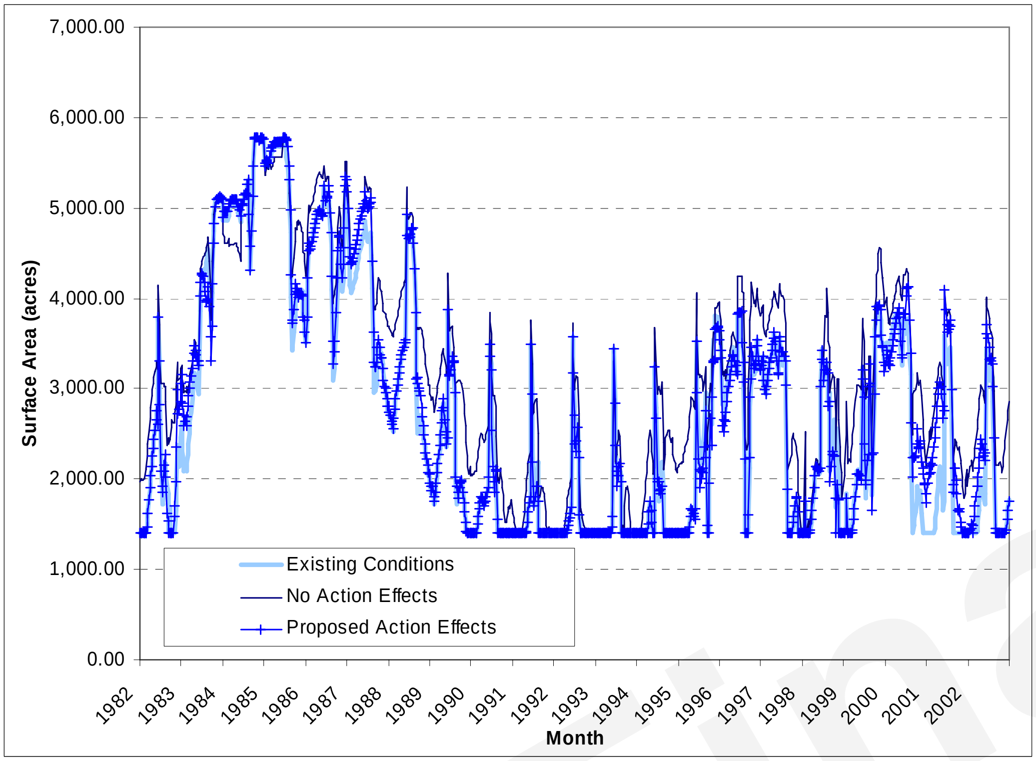


Figure 4-36. Lake Meredith - Simulated Effects Surface Area Time Series



Lake Henry

Summary data for the effects on Lake Henry pool elevation are shown in **Table 4-34** and **Figure 4-37**. Reservoir pool elevations are generally higher under the No Action Alternative and the Proposed Action than for Existing Conditions. Effects are generally negative, indicating that No Action Alternative elevations are higher than Proposed Action elevations. The magnitude of effects is the greatest during the summer months. However, reservoir pool elevations under each of the scenarios are within the elevation range of the normal operating pool (4367.4 to 4375.1 feet).

Data showing effects on Lake Henry surface area are shown in **Table 4-35**, **Figure 4-38** and **Figure 4-39**. Similar to reservoir pool elevations, simulated Lake Henry surface area is greater for the No Action Alternative and the Proposed Action when compared with surface area under Existing Conditions. Additionally, as with reservoir pool elevations, surface area under each of the scenarios is within the range of the normal operating pool.

Table 4-34. Lake Henry Elevation - Summary of Effects

Month	Simulated Elevation			Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	4,369.46	4,370.19	4,369.61	-0.58	-14%
Nov	4,369.41	4,369.97	4,369.47	-0.50	-13%
Dec	4,369.90	4,370.11	4,369.90	-0.21	-5%
Jan	4,370.29	4,370.31	4,370.29	-0.02	0%
Feb	4,371.71	4,371.70	4,371.71	0.00	0%
Mar	4,373.13	4,373.15	4,373.16	0.01	0%
Apr	4,373.31	4,373.32	4,373.32	0.00	0%
May	4,372.75	4,373.02	4,372.72	-0.29	-4%
Jun	4,371.92	4,372.76	4,371.95	-0.81	-12%
Jul	4,371.68	4,372.30	4,371.76	-0.54	-9%
Aug	4,370.87	4,371.64	4,371.01	-0.63	-11%
Sep	4,369.86	4,370.83	4,370.08	-0.75	-16%
Average	**4,371.19**	**4,371.61**	**4,371.25**	**-0.36**	**-7%**
Mean Wet					
Oct	4,370.23	4,370.53	4,370.23	-0.31	-7%
Nov	4,370.08	4,370.27	4,370.07	-0.21	-5%
Dec	4,370.27	4,370.28	4,370.27	-0.01	0%
Jan	4,370.35	4,370.35	4,370.35	0.00	0%
Feb	4,371.54	4,371.54	4,371.54	0.00	0%
Mar	4,373.07	4,373.07	4,373.07	0.00	0%
Apr	4,373.36	4,373.36	4,373.36	0.00	0%
May	4,373.14	4,373.37	4,373.21	-0.16	-2%
Jun	4,373.05	4,373.61	4,372.93	-0.68	-9%
Jul	4,373.44	4,373.57	4,373.49	-0.08	-1%
Aug	4,373.13	4,373.13	4,373.13	0.00	0%
Sep	4,372.19	4,372.52	4,372.22	-0.30	-5%
Average	**4,371.99**	**4,372.13**	**4,371.99**	**-0.15**	**-2%**
Mean Dry					
Oct	4,368.62	4,369.08	4,368.92	-0.16	-5%
Nov	4,368.40	4,368.90	4,368.57	-0.33	-12%
Dec	4,368.73	4,369.00	4,368.73	-0.27	-9%
Jan	4,369.29	4,369.30	4,369.29	-0.02	-1%
Feb	4,371.10	4,371.10	4,371.10	0.00	0%
Mar	4,372.62	4,372.62	4,372.62	0.00	0%
Apr	4,372.47	4,372.47	4,372.47	0.00	0%
May	4,371.39	4,371.70	4,371.39	-0.31	-6%
Jun	4,369.98	4,371.09	4,369.97	-1.12	-22%
Jul	4,369.27	4,370.33	4,369.27	-1.06	-25%
Aug	4,368.42	4,369.43	4,368.42	-1.01	-30%
Sep	4,367.86	4,368.76	4,368.11	-0.65	-25%
Average	**4,369.85**	**4,370.31**	**4,369.90**	**-0.41**	**-10%**

Notes:
(1) Effects (feet) = Proposed Action - No Action simulated elevation. Effects (%) = (Proposed Action - No Action simulated elevation)/No Action simulated depth.

Table 4-35. Lake Henry Area - Summary of Effects

Month	Simulated Area: Existing Conditions (acres)	Simulated Area: No Action (acres)	Simulated Area: Proposed Action (acres)	Effects (1) (acres)	Effects (1) (%)
Overall Mean					
Oct	937.0	977.4	944.9	-32.5	-3%
Nov	935.1	965.6	938.1	-27.5	-3%
Dec	960.7	972.8	960.6	-12.1	-1%
Jan	982.4	983.2	982.4	-0.8	0%
Feb	1,056.2	1,056.2	1,056.2	0.0	0%
Mar	1,123.7	1,124.6	1,124.9	0.2	0%
Apr	1,133.6	1,133.8	1,133.9	0.1	0%
May	1,105.7	1,119.3	1,103.9	-15.5	-1%
Jun	1,063.1	1,105.5	1,064.2	-41.3	-4%
Jul	1,050.7	1,082.3	1,054.2	-28.0	-3%
Aug	1,006.4	1,048.1	1,014.1	-34.1	-3%
Sep	955.1	1,007.1	967.0	-40.1	-4%
Average	**1,025.8**	**1,048.0**	**1,028.7**	**-19.3**	**-2%**
Mean Wet					
Oct	979.2	996.2	979.2	-17.0	-2%
Nov	971.7	982.2	971.2	-11.0	-1%
Dec	982.0	982.4	981.7	-0.7	0%
Jan	986.3	986.3	986.3	0.0	0%
Feb	1,045.1	1,045.1	1,045.1	0.0	0%
Mar	1,119.2	1,119.2	1,119.2	0.0	0%
Apr	1,135.0	1,135.0	1,135.0	0.0	0%
May	1,125.5	1,135.8	1,128.4	-7.4	-1%
Jun	1,121.9	1,146.9	1,116.6	-30.3	-3%
Jul	1,139.1	1,144.2	1,141.0	-3.2	0%
Aug	1,122.9	1,122.9	1,122.9	0.0	0%
Sep	1,080.5	1,097.0	1,081.9	-15.1	-1%
Average	**1,067.4**	**1,074.4**	**1,067.4**	**-7.1**	**-1%**
Mean Dry					
Oct	891.2	915.7	906.4	-9.3	-1%
Nov	878.3	904.3	886.9	-17.5	-2%
Dec	894.5	910.5	894.4	-16.1	-2%
Jan	926.7	927.5	926.7	-0.8	0%
Feb	1,025.9	1,025.9	1,025.9	0.0	0%
Mar	1,101.6	1,101.6	1,101.6	0.0	0%
Apr	1,097.0	1,097.0	1,097.0	0.0	0%
May	1,040.7	1,058.7	1,040.7	-18.0	-2%
Jun	962.4	1,026.1	962.1	-64.0	-6%
Jul	924.7	983.8	924.5	-59.3	-6%
Aug	879.7	935.4	879.4	-56.0	-6%
Sep	847.8	896.1	860.9	-35.2	-4%
Average	**955.9**	**981.9**	**958.9**	**-23.0**	**-2%**

Notes:
(1) Effects (acres) = Proposed Action - No Action simulated area. Effects (%) = (Proposed Action - No Action simulated area)/No Action simulated area.

Figure 4-37. Lake Henry - Simulated Effects Elevation

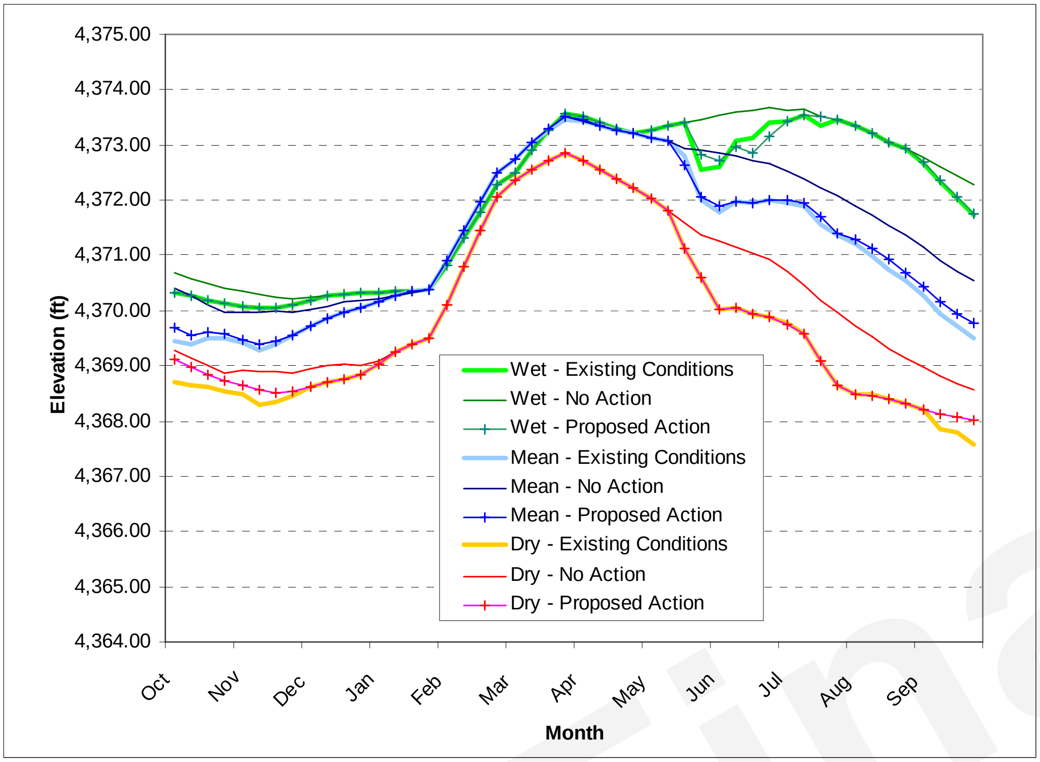


Figure 4-38. Lake Henry - Simulated Effects Surface Area

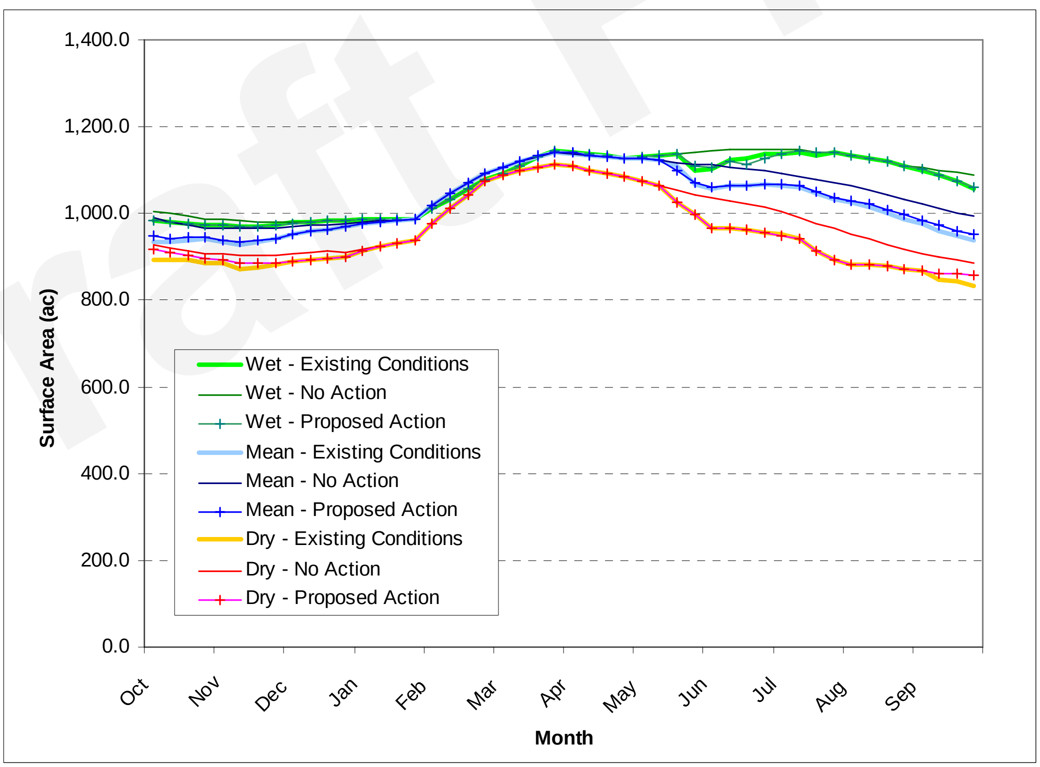
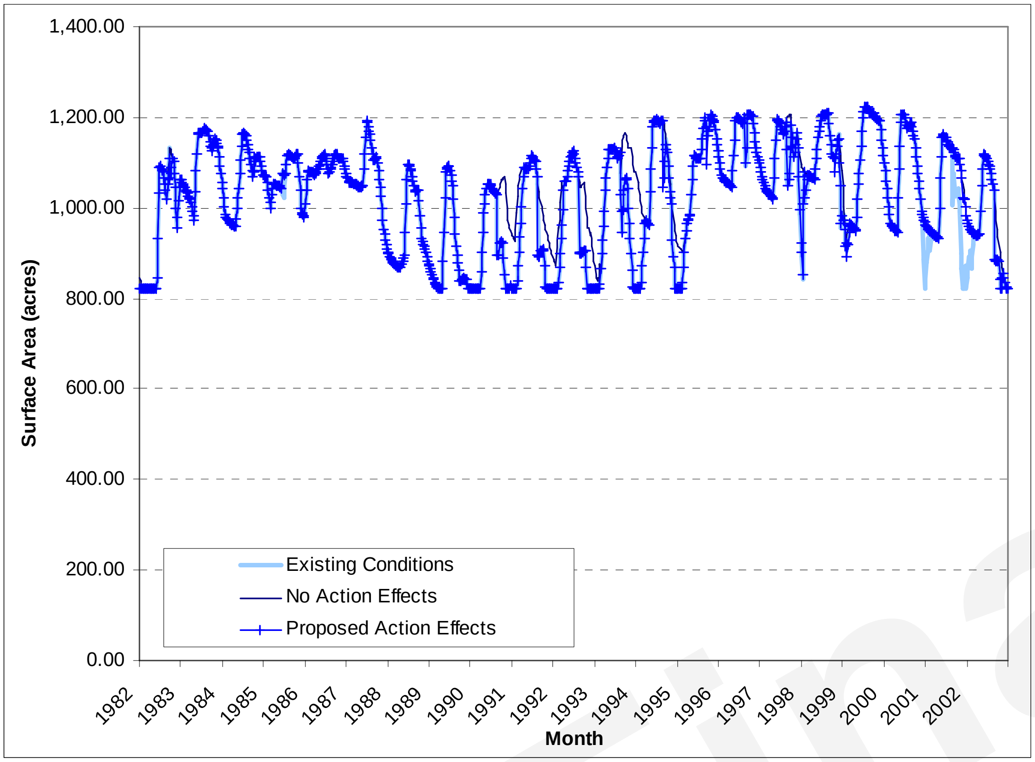


Figure 4-39. Lake Henry - Simulated Effects Surface Area Time Series



Holbrook Reservoir

Summary data for the effects on Holbrook Reservoir pool elevation are shown in **Table 4-36** and **Figure 4-40**. Simulated elevations are identical under Existing Conditions and the No Action Alternative. Elevations are higher for the Proposed Action than for the No Action Alternative and Existing Conditions. Effects are positive, reflecting the higher elevations under the Proposed Action when compared with the No Action Alternative.

Summary data for the effects on Holbrook Reservoir surface area are shown in **Table 4-37**, **Figure 4-41**, **Figure 4-42**. Simulated surface area is identical under Existing Conditions and the No Action Alternative. Surface area is higher for the Proposed Action than for the No Action Alternative and Existing Conditions. Effects are positive, reflecting the higher surface area under the Proposed Action when compared with the No Action Alternative.

Table 4-36. Holbrook Reservoir - Simulated Effects Elevation

Month	Simulated Elevation			Effects (1)	
	Existing Conditions	No Action	Proposed Action		
	(feet)	(feet)	(feet)	(feet)	(%)
Overall Mean					
Oct	6.36	6.36	8.43	2.08	48%
Nov	6.97	6.97	8.96	1.99	40%
Dec	8.37	8.37	9.70	1.33	21%
Jan	11.14	11.14	11.94	0.81	9%
Feb	12.87	12.87	13.51	0.64	6%
Mar	13.98	13.98	14.80	0.82	7%
Apr	13.75	13.75	14.51	0.75	6%
May	12.88	12.88	13.34	0.46	4%
Jun	12.41	12.41	12.96	0.55	5%
Jul	9.78	9.78	11.03	1.24	16%
Aug	7.42	7.42	9.05	1.62	30%
Sep	6.36	6.36	8.33	1.98	46%
Average	**10.19**	**10.19**	**11.38**	**1.19**	**15%**
Mean Wet					
Oct	7.96	7.96	8.06	0.10	2%
Nov	7.89	7.89	7.89	0.00	0%
Dec	7.85	7.85	7.85	0.00	0%
Jan	9.22	9.22	9.22	0.00	0%
Feb	9.92	9.92	9.92	0.00	0%
Mar	10.31	10.31	10.45	0.14	2%
Apr	10.48	10.48	10.75	0.27	3%
May	10.33	10.33	10.33	0.00	0%
Jun	10.82	10.82	10.82	0.00	0%
Jul	10.67	10.67	10.75	0.08	1%
Aug	9.26	9.26	9.48	0.22	3%
Sep	8.91	8.91	9.10	0.19	3%
Average	**9.47**	**9.47**	**9.55**	**0.08**	**1%**
Mean Dry					
Oct	5.39	5.39	10.94	5.55	164%
Nov	6.41	6.41	11.84	5.43	123%
Dec	7.61	7.61	11.27	3.66	66%
Jan	11.93	11.93	14.03	2.09	21%
Feb	16.44	16.44	18.08	1.65	11%
Mar	18.76	18.76	20.57	1.81	11%
Apr	18.11	18.11	19.73	1.61	10%
May	16.01	16.01	16.99	0.99	7%
Jun	14.27	14.27	15.33	1.06	9%
Jul	9.33	9.33	11.56	2.23	30%
Aug	5.88	5.88	9.36	3.48	90%
Sep	4.32	4.32	8.68	4.36	191%
Average	**11.21**	**11.21**	**14.03**	**2.83**	**31%**

Notes:
(1) Effects (feet) = Proposed Action - No Action simulated elevation. Effects (%) = (Proposed Action - No Action simulated elevation)/No Action simulated depth.

Table 4-37. Holbrook Reservoir - Simulated Effects Surface Area

Month	Simulated Area Existing Conditions (acres)	Simulated Area No Action (acres)	Simulated Area Proposed Action (acres)	Effects (1) (acres)	Effects (1) (%)
Overall Mean					
Oct	185.0	185.0	259.3	74.3	40%
Nov	204.6	204.6	276.9	72.3	35%
Dec	254.2	254.2	302.6	48.4	19%
Jan	356.3	356.3	380.3	24.0	7%
Feb	418.2	418.2	431.0	12.8	3%
Mar	455.9	455.9	466.6	10.8	2%
Apr	447.7	447.7	461.6	13.9	3%
May	416.4	416.4	426.1	9.7	2%
Jun	398.6	398.6	412.3	13.7	3%
Jul	306.8	306.8	349.7	42.9	14%
Aug	226.5	226.5	281.4	54.9	24%
Sep	190.0	190.0	258.3	68.3	36%
Average	**321.7**	**321.7**	**358.8**	**37.2**	**12%**
Mean Wet					
Oct	235.9	235.9	239.3	3.3	1%
Nov	233.6	233.6	233.6	0.0	0%
Dec	232.1	232.1	232.1	0.0	0%
Jan	280.4	280.4	280.4	0.0	0%
Feb	305.8	305.8	305.8	0.0	0%
Mar	318.9	318.9	321.1	2.2	1%
Apr	324.4	324.4	328.9	4.5	1%
May	319.0	319.0	319.0	0.0	0%
Jun	333.8	333.8	333.8	0.0	0%
Jul	329.9	329.9	331.0	1.1	0%
Aug	279.6	279.6	284.1	4.5	2%
Sep	269.4	269.4	275.3	6.0	2%
Average	**288.6**	**288.6**	**290.4**	**1.8**	**1%**
Mean Dry					
Oct	150.9	150.9	355.0	204.0	135%
Nov	183.7	183.7	385.5	201.8	110%
Dec	228.9	228.9	364.1	135.2	59%
Jan	395.4	395.4	468.1	72.7	18%
Feb	555.4	555.4	593.6	38.2	7%
Mar	634.8	634.8	657.4	22.6	4%
Apr	611.4	611.4	635.5	24.2	4%
May	536.8	536.8	556.4	19.6	4%
Jun	473.9	473.9	506.1	32.2	7%
Jul	299.8	299.8	378.6	78.9	26%
Aug	191.8	191.8	306.6	114.8	60%
Sep	139.8	139.8	283.9	144.1	103%
Average	**366.9**	**366.9**	**457.6**	**90.7**	**25%**

Notes:
(1) Effects (acres) = Proposed Action - No Action simulated area. Effects (%) = (Proposed Action - No Action simulated area)/No Action simulated area.

Figure 4-40. Holbrook Reservoir - Simulated Effects Elevation

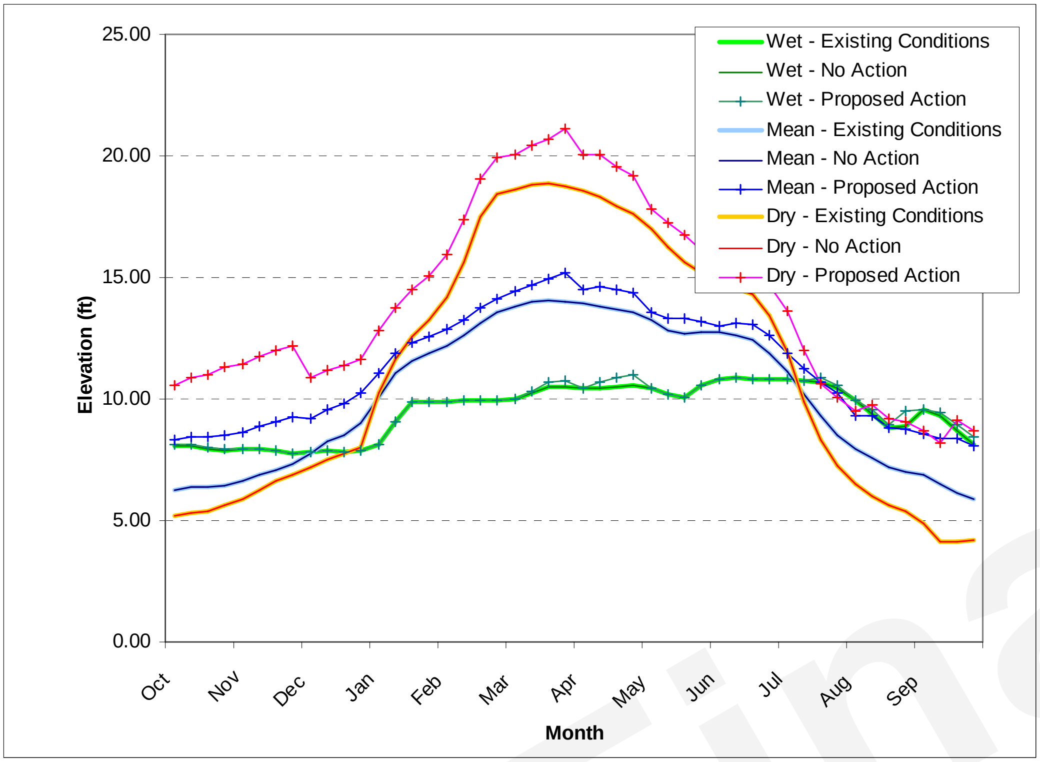


Figure 4-41. Holbrook Reservoir - Simulated Effects Surface Area

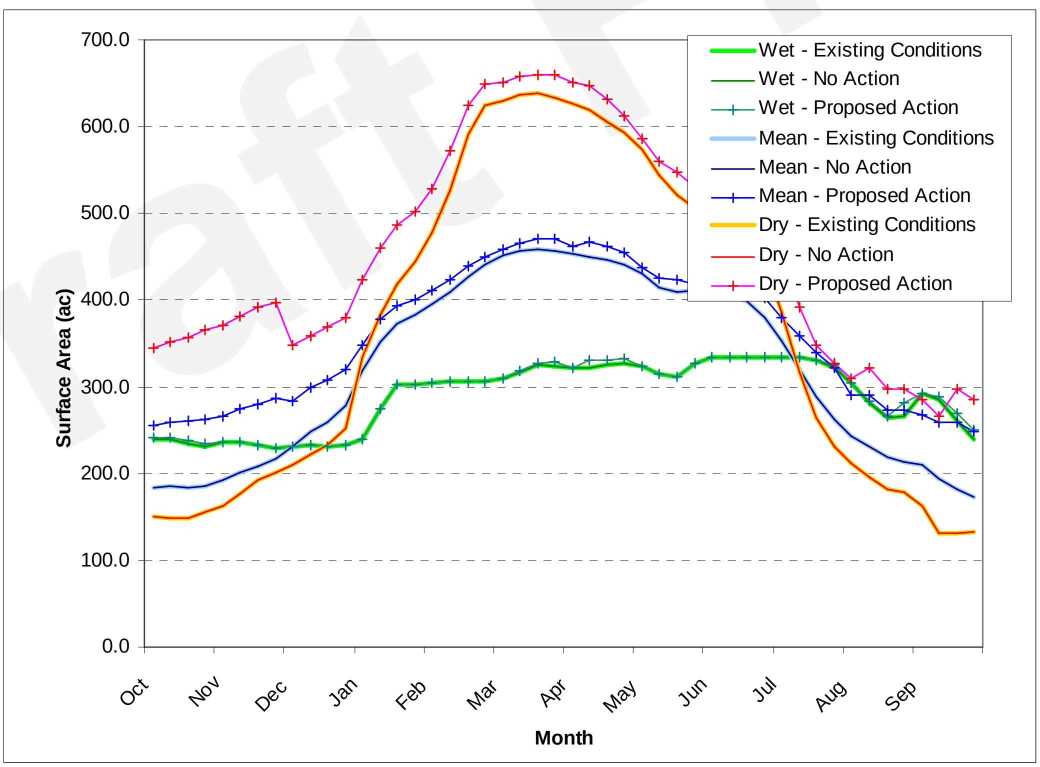
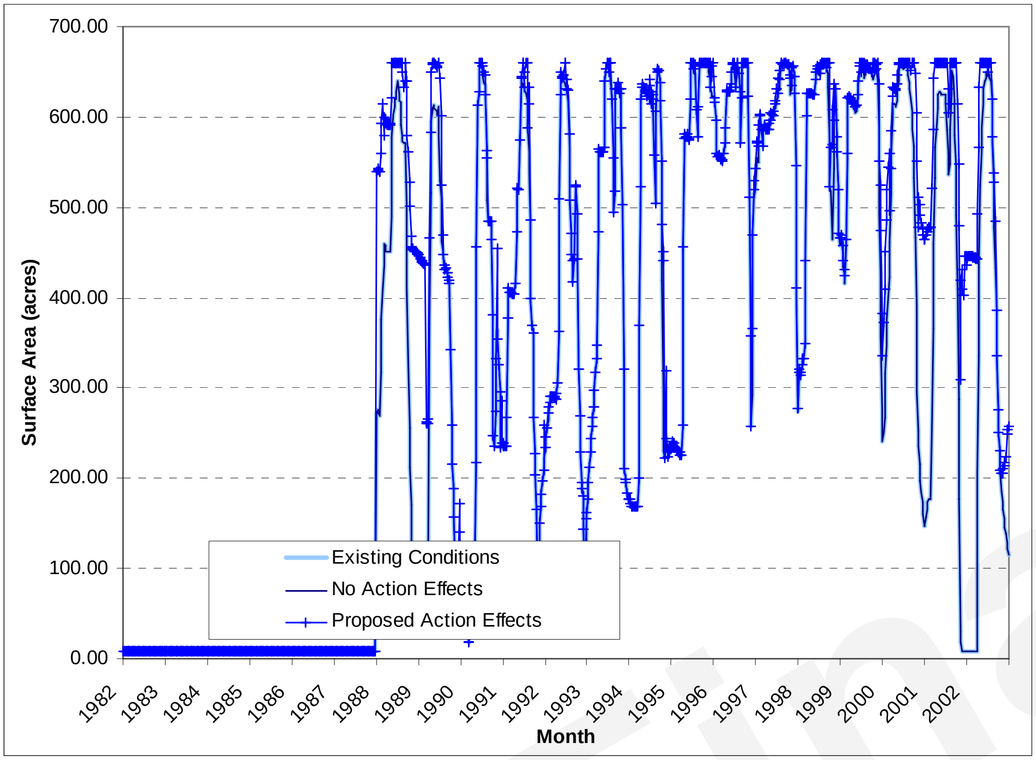


Figure 4-42. Holbrook Reservoir - Simulated Effects Surface Area Time Series



La Junta Gage

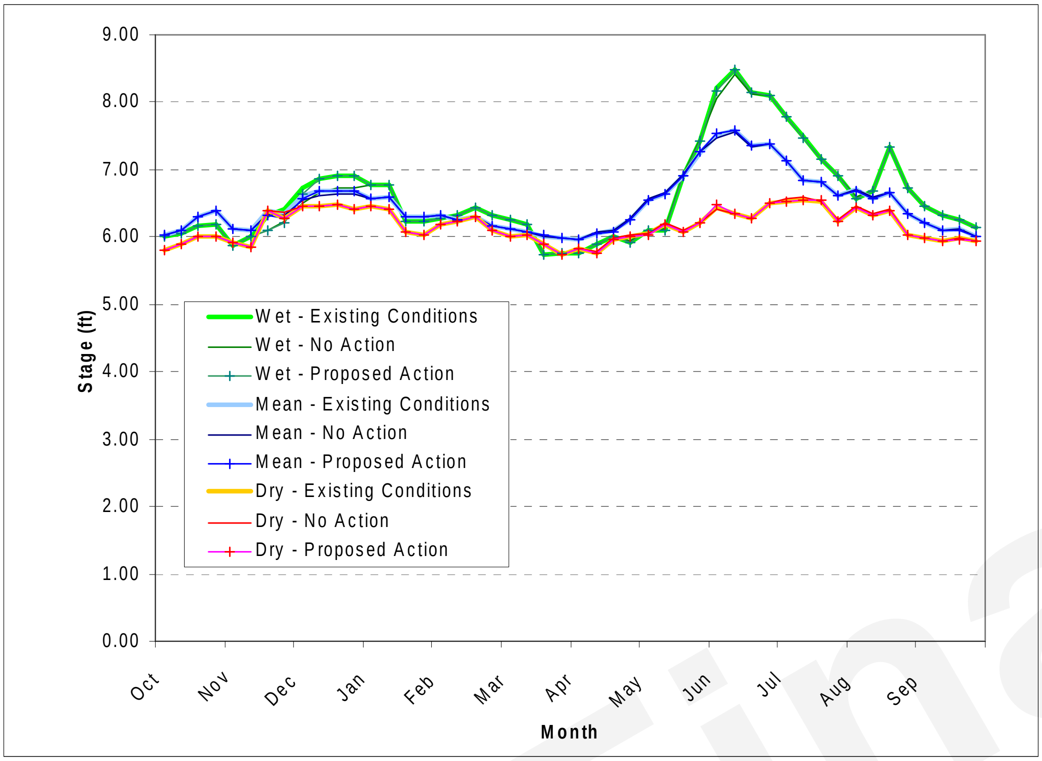
Summary data for the effects on the stage for the La Junta Gage are shown in **Table 4-36** and **Figure 4-43**. Simulated Proposed Action and No Action Alternative stages are similar to Existing Conditions stages. Effects range from small negative values to small positive values, reflecting the similarities between simulated stages under the No Action Alternative and the Proposed Action.

Table 4-38. La Junta Gage Stage - Summary of Effects

Month	Simulated Stage			Effects (1)	
	Existing Conditions	No Action	Proposed Action		
	(feet)	(feet)	(feet)	(feet)	(%)
Overall Mean					
Oct	6.20	6.20	6.20	0.00	0%
Nov	6.24	6.22	6.21	-0.01	-1%
Dec	6.67	6.61	6.66	0.05	3%
Jan	6.45	6.45	6.45	0.00	0%
Feb	6.26	6.26	6.26	0.00	0%
Mar	6.05	6.05	6.05	0.00	0%
Apr	6.09	6.10	6.09	-0.01	-1%
May	6.84	6.86	6.84	-0.02	-1%
Jun	7.46	7.44	7.46	0.02	1%
Jul	6.85	6.86	6.85	-0.01	0%
Aug	6.57	6.58	6.56	-0.01	-1%
Sep	6.10	6.11	6.10	0.00	-1%
Average	**6.48**	**6.48**	**6.48**	**0.00**	**0%**
Mean Wet					
Oct	6.11	6.11	6.10	0.00	0%
Nov	6.15	6.05	6.04	-0.01	-1%
Dec	6.85	6.65	6.83	0.17	12%
Jan	6.49	6.49	6.49	0.00	0%
Feb	6.34	6.34	6.34	0.00	0%
Mar	5.99	5.99	5.99	0.00	0%
Apr	5.89	5.89	5.89	0.00	0%
May	6.63	6.64	6.63	-0.01	-1%
Jun	8.24	8.18	8.23	0.05	2%
Jul	7.33	7.33	7.33	0.00	0%
Aug	6.83	6.83	6.83	0.00	0%
Sep	6.30	6.30	6.30	0.00	0%
Average	**6.60**	**6.57**	**6.58**	**0.02**	**1%**
Mean Dry					
Oct	5.93	5.93	5.93	0.00	0%
Nov	6.11	6.13	6.11	-0.02	-2%
Dec	6.45	6.45	6.45	0.00	0%
Jan	6.24	6.24	6.24	0.00	0%
Feb	6.21	6.21	6.21	0.00	0%
Mar	5.92	5.92	5.92	0.00	0%
Apr	5.88	5.90	5.88	-0.02	-3%
May	6.13	6.15	6.13	-0.02	-2%
Jun	6.39	6.39	6.40	0.02	1%
Jul	6.46	6.49	6.46	-0.03	-2%
Aug	6.30	6.32	6.29	-0.02	-2%
Sep	5.96	5.96	5.96	-0.01	-1%
Average	**6.17**	**6.17**	**6.17**	**-0.01**	**-1%**

Notes:
(1) Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 4-43. La Junta Gage - Simulated Effects Stage



4.3.2 Stream Geomorphology

Potential changes to stream geomorphology due to the effects of the Proposed Action were evaluated by comparison of changes in flow duration curves to bankfull discharge. Through comparison of the flow duration curves, the maximum difference between the Proposed Action and No Action Alternative flow duration curves for a given non-exceedance percentage was determined. Geomorphic changes were analyzed in more detail if this maximum difference was greater than 10 percent and occurred at streamflow values that exceed the bankfull discharge. Because the average morphologic characteristics of a channel are formed as a result of bankfull discharge (Rosgen, 1996), differences between Proposed Action and No Action Alternative flow duration curves that are lower than the bankfull discharge will have minimal effects on channel geomorphology for the potentially affected stream channels.

Comparison of flow duration curves was only completed for reaches that were determined to be moderately to very highly sensitive to hydrologic changes using the Rosgen classification technique. The geomorphic stability of potentially affected stream reaches is described in **Section 3.5**. Locations where stream geomorphology analysis was completed are shown in **Figure 3-21**.

4.3.2.1 Upper Arkansas River Basin

There were only two reaches of the Arkansas River upstream of Pueblo Reservoir that were determined to be geomorphically sensitive to hydrologic changes: from the Lake Fork confluence to Lake Creek confluence, and from approximately Cañon City to Pueblo Reservoir. Operations associated with the Proposed Action and No Action Alternative would not affect hydrology of the Arkansas River between the Lake Fork confluence and the Lake Creek confluence, because the majority of Aurora's proposed exchanges would be made to Twin Lakes. As a result, effects on stream geomorphology for the Arkansas River between the Lake Fork confluence and the Lake Creek confluence were not analyzed. The effects on stream geomorphology of Lake Creek were not analyzed because the segment of Lake Creek in the study area was determined to have a low geomorphic sensitivity to hydrologic changes as discussed in **Section 3.5**.

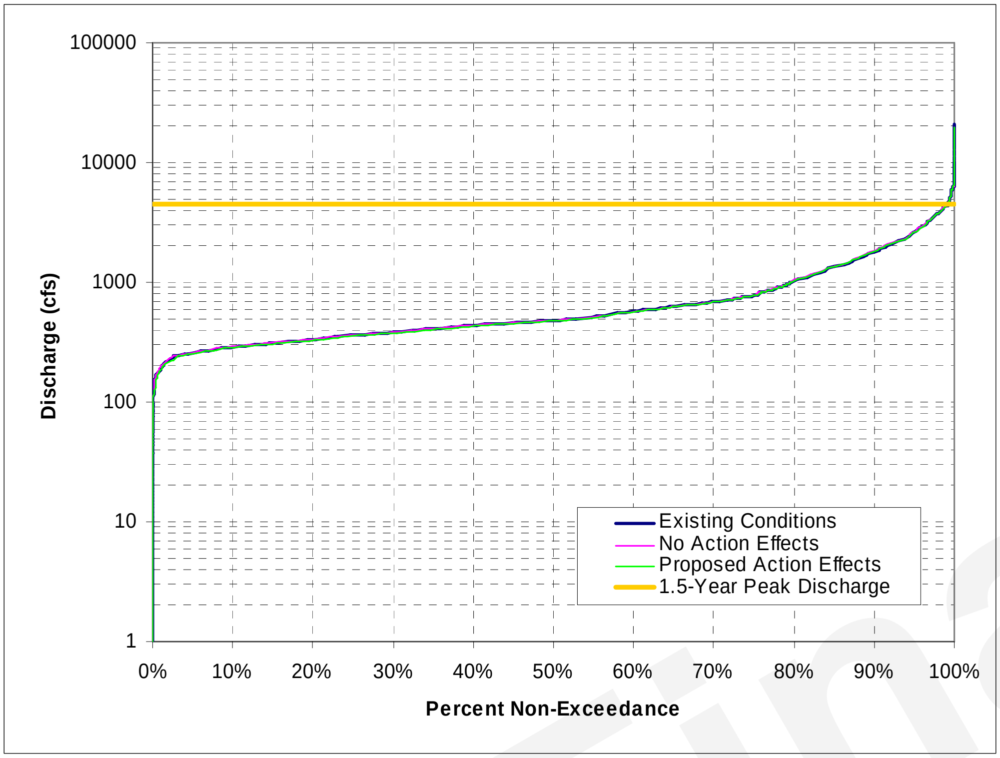
Portland

The flow duration curve for the Portland gage is presented in **Figure 4-44**. The maximum difference between Proposed Action and No Action Alternative flow duration curves showed that Proposed Action flows were 11 percent less than No Action Alternative flows for the 1 percent non-exceedance (approximately 160 cfs). The 1.5-year peak flow discharge for the Portland gage (4,500 cfs) is also plotted in **Figure 4-44**.

As discussed in **Section 3.5.2**, the Portland gage is located in a section of the Arkansas River that is moderately sensitive to hydrologic disturbance.

Although the section of the Arkansas River at Portland gage is sensitive to hydrologic disturbances, there are no changes in streamflow greater than 10 percent that occur at streamflow values that exceed the bankfull discharge at the Portland gage. As a result, minimal differences in stream morphology near the Portland gage are expected.

Figure 4-44. Portland Gage - Effects Flow Duration Curve



4.3.2.2 Lower Arkansas River Basin

All reaches of the Arkansas River downstream of Pueblo Reservoir were determined to be geomorphically sensitive to hydrologic changes. Therefore, analysis was performed at the Above Pueblo, Moffat Street, Avondale, and La Junta gages.

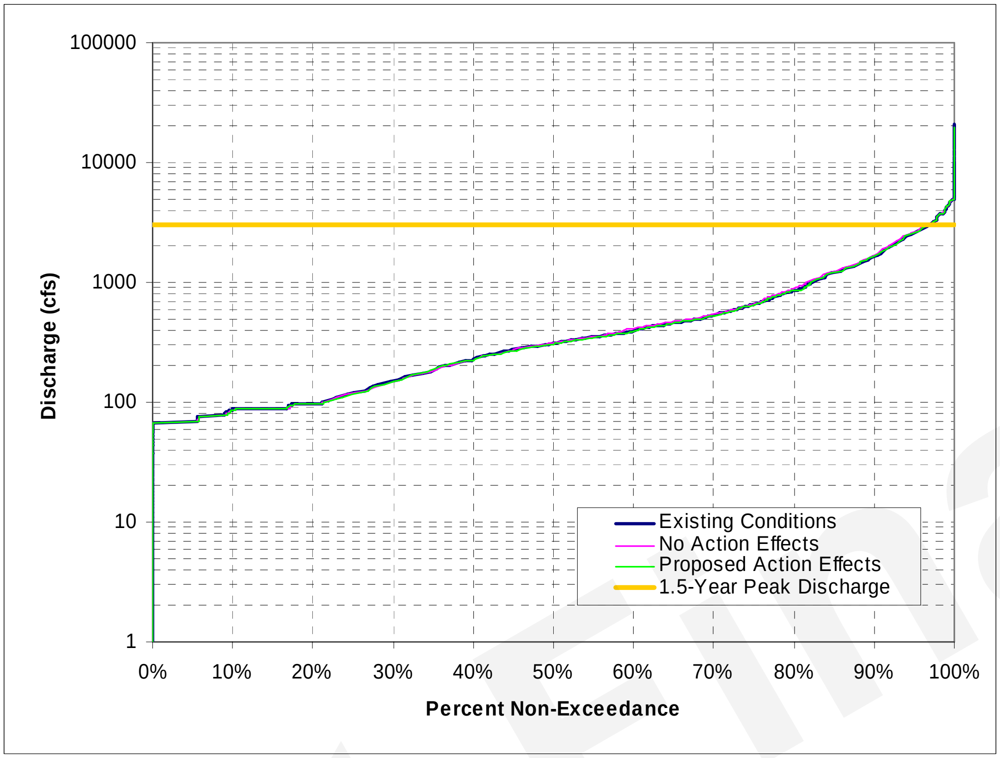
Above Pueblo

The flow duration curve presented in **Figure 4-45** shows no differences between existing and future conditions at the Above Pueblo gage greater than 10 percent. The maximum difference between Proposed Action and No Action Alternative flow duration curves showed that Proposed Action flows were 8 percent less than No Action Alternative flows at the 81 percent non-exceedance level (approximately 880 cfs). The 1.5-year peak flow discharge for the Above Pueblo gage (3,000 cfs) is also plotted in **Figure 4-45**.

As discussed in **Section 3.5.2**, the Above Pueblo gage is located in a section of the Arkansas River that is part of the Legacy Project, which has the objective of stabilizing the Arkansas River channel through the City of Pueblo. The Rosgen stream classification was not applied to this reach of the Arkansas River because sections of the reach have been stabilized with man-made structures and will be addressed as part of the Legacy Project.

The greatest difference between the flow duration curves occurred well below the bankfull discharge. Additionally, sections of the reach of the Arkansas River near the Above Pueblo gage are geomorphically stable because of the existing structures and future structures associated with the Legacy Project. As a result, no significant differences in stream morphology near the Above Pueblo gage are expected.

Figure 4-45. Above Pueblo Gage - Effects Flow Duration Curve



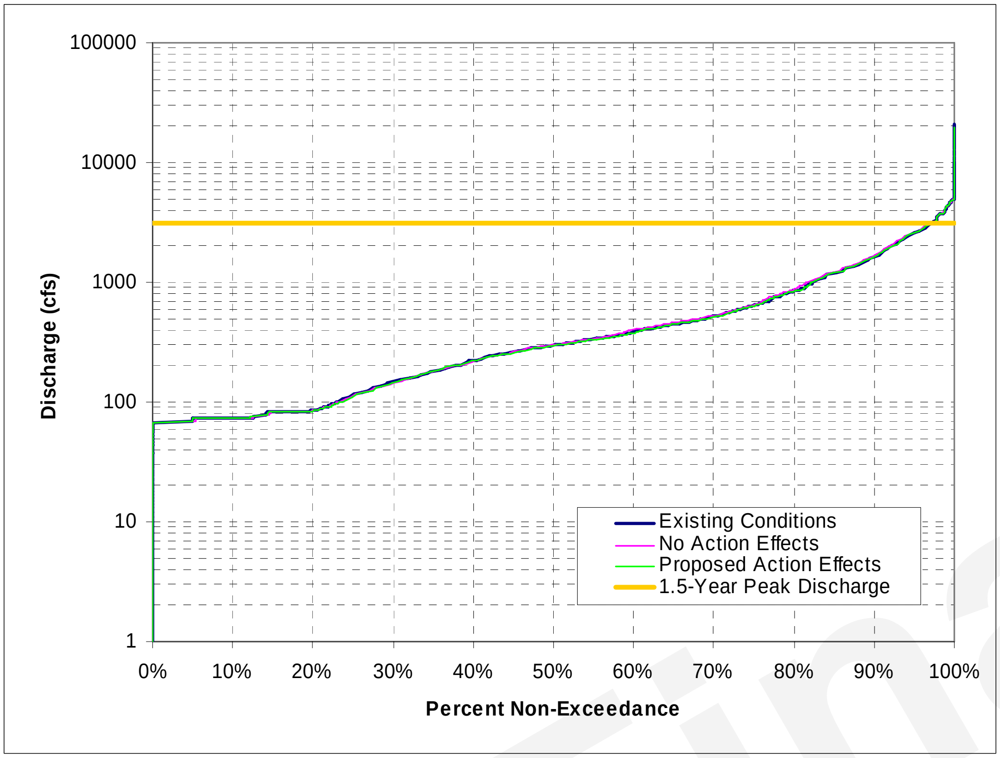
Moffat Street

The flow duration curve for the Moffat Street gage is presented in **Figure 4-46**. The flat portion of the curve at approximately 80 cfs reflects the effects from operations of the Pueblo FMP. The maximum difference between Proposed Action and No Action Alternative flow duration curves showed that Proposed Action flows were 8 percent less than No Action Alternative flows at the 81 percent non-exceedance level (approximately 880 cfs). The 1.5-year peak flow discharge for the Moffat Street gage (3,100 cfs) is also plotted in **Figure 4-46**.

As discussed in **Section 3.5.2**, the Moffat Street gage is located in a section of the Arkansas River that is part of the Legacy Project, which has the objective of stabilizing the Arkansas River channel through the City of Pueblo. Additionally, the Moffat Street gage is directly downstream of a concrete lined section of the Arkansas River, which provides geomorphic stability to the stream channel near the Moffat Street gage.

There are no differences greater than 10 percent between the Proposed Action and No Action Alternative flow duration curves for the range of flows at the Moffat Street gage. The greatest difference between the flow duration curves occurred well below the bankfull discharge. Additionally, the effects indicate that the Proposed Action streamflows would be less than the No Action Alternative streamflows. The Proposed Action streamflows would result in fewer effects on channel geomorphology than the No Action Alternative streamflows.

Figure 4-46. Moffat Street Gage - Effects Flow Duration Curve



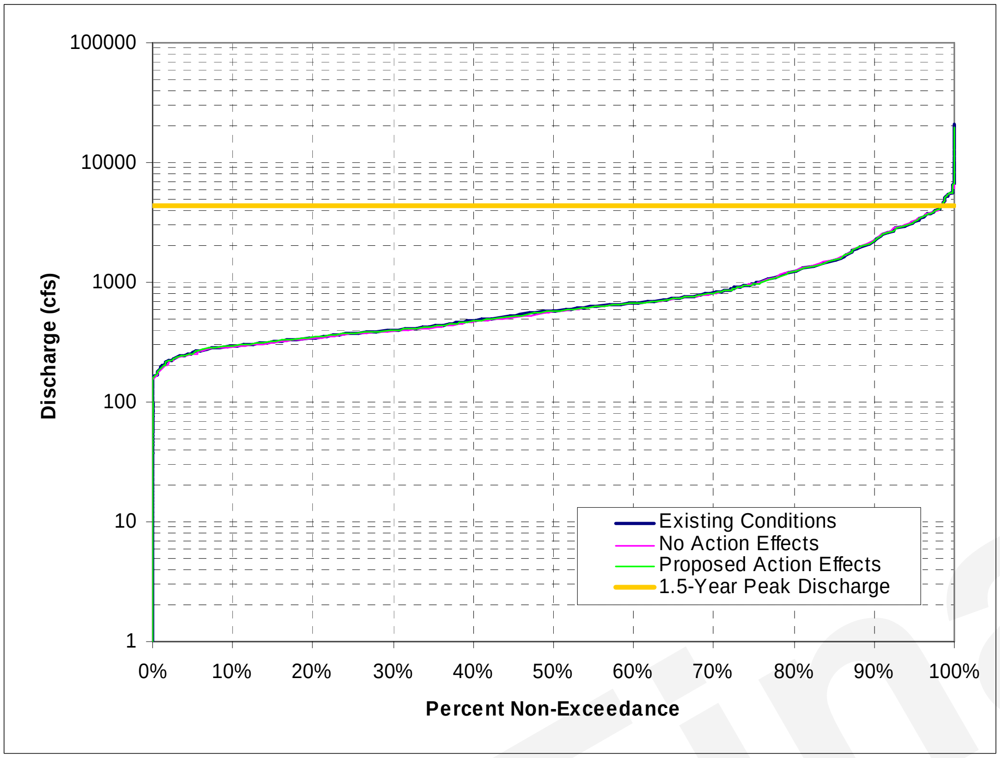
Avondale

The flow duration curve for the Avondale gage is presented in **Figure 4-47**. Flow duration curves for existing and future conditions are similar. The maximum difference between Proposed Action and No Action Alternative flow duration curves showed that Proposed Action flows were 8 percent more than No Action Alternative flows for the 99 percent non-exceedance (approximately 6,700 cfs). The 1.5-year peak flow discharge for the Avondale gage (4,400 cfs) is also plotted in **Figure 4-47**.

As discussed in **Section 3.5.2**, the Avondale gage is located in a section of the Arkansas River that is highly sensitive to hydrologic disturbance.

Although the section of the Arkansas River near the Avondale gage is sensitive to hydrologic disturbances, there are no changes in streamflow greater than 10 percent for the range of flows at the Avondale gage. As a result, minimal differences in stream morphology near the Avondale gage are expected.

Figure 4-47. Avondale Gage - Effects Flow Duration Curve

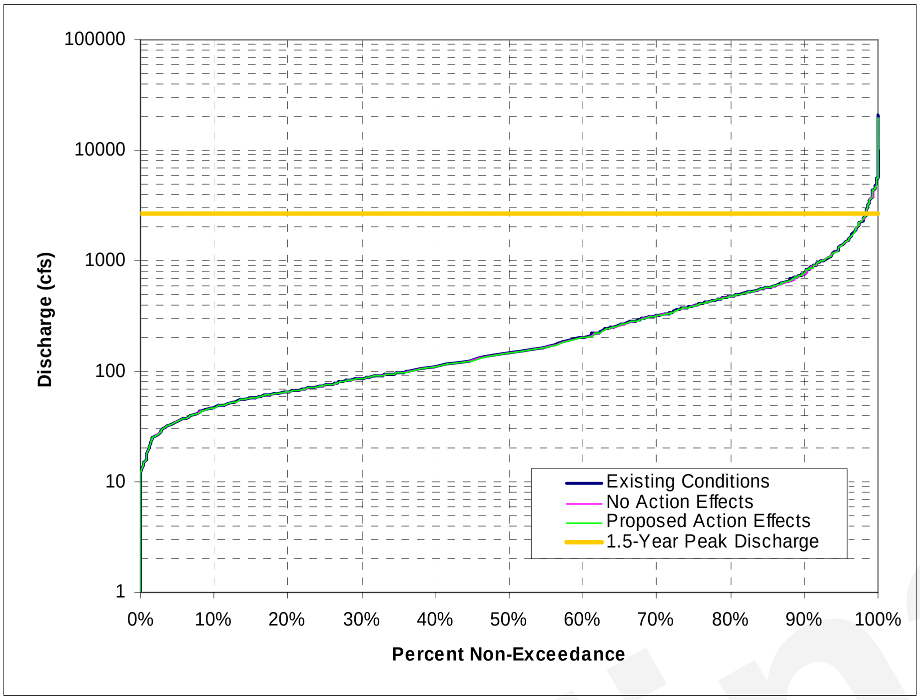


La Junta

The flow duration curves for the effects at the La Junta gage are shown in **Figure 4-48**. The maximum difference between Proposed Action and No Action Alternative flow duration curves showed that Proposed Action flows were 12 percent higher than No Action Alternative flows at the 98 percent non-exceedance level (approximately 2,900 cfs). The 1.5-year peak flow discharge for the La Junta gage (2,700 cfs) is also plotted in **Figure 4-48**. Although Proposed Action flows at the 98 percent non-exceedance level are more than 10 percent higher than No Action flows, Proposed Action flows are closer to Existing Conditions flows than under the No Action Alternative. At the 98 percent non-exceedance level, Proposed Action streamflow is 2,900 cfs, No Action streamflow is 2,600 cfs, and Existing Conditions streamflow is 2,900 cfs. Proposed Action streamflows would result in less effects on stream geomorphology than No Action Alternative streamflows, because Proposed Action streamflows are approximately equal to Existing Conditions streamflows at the 98 percent non-exceedance level. No Action Alternative streamflows are less than Existing Conditions and Proposed Action streamflows and may result in more sedimentation near the La Junta gage than under the Proposed Action.

The La Junta gage is located in a section of the Arkansas River classified as a C5c- stream, as described in the geomorphic characterization in **Section 3.5.2**. According to the Rosgen stream classification, this type of stream has a very high sensitivity to changes in streamflow. Effects associated with the Proposed Action are expected to be less than effects associated with the No Action Alternative, because Proposed Action streamflows are closer to Existing Conditions streamflows than No Action Alternative streamflows at high non-exceedance levels.

Figure 4-48. La Junta Gage Effects Flow Duration Curve



4.4 Ground Water

The primary causes for changes in ground water levels in the study area would be changes in river stage or changes in irrigation and ground water pumping practices. As described in **Section 2.3**, three threshold criteria were evaluated to determine effects on ground water in the study area. Results of the evaluation of each of the threshold criteria are described below.

- As described in **Section 4.3.1**, difference between mean flow depth for the Proposed Action and the No Action Alternative were less than 10 percent for locations on the Arkansas River, except for one month at the Avondale and La Junta gages. The differences in mean flow depth at the Avondale and La Junta gages during the one wet month will not result in effects on ground water. The differences are a result of an artifact in the Quarter-Monthly Model and are short-term increases that would not be sustained long enough to translate into effects on ground water.
- Assumptions for irrigation practices are the same under the Proposed Action and No Action Alternative. As a result, differences in projected irrigation practices do not vary by more than 5 percent between the Proposed Action and No Action Alternative.
- Assumptions for ground water pumping practices are the same under the Proposed Action and No Action Alternative. As a result, differences in projected ground water pumping practices do not vary by more than 5 percent between the Proposed Action and No Action Alternative.

Based on these criteria, there would be no significant effects on ground water due to the Proposed Action.

5.0 CUMULATIVE EFFECTS ANALYSIS

The cumulative effects analysis estimates the effects of the Proposed Action or No Action Alternative when combined with other reasonably foreseeable actions in the basin. The purpose of this analysis is to show the effects of the Proposed Action coupled with other projects in the basin to simulate expected future conditions. This section presents the cumulative effects analysis for water quantity, hydraulics and geomorphology, and ground water. Cumulative effects resulting in greater than 10 percent difference between the Proposed Action and No Action Alternative Quarter-Monthly Model results will be analyzed further by the resource experts (e.g., socioeconomic, fisheries, and cultural resource experts).

5.1 General Description of Hydrologic Analysis

Cumulative effects are the potential effects of the Proposed Action or No Action Alternative in combination with past, present, and future actions. NEPA regulations define cumulative effects "as the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor, but collectively significant actions taking place over time" (40 CFS 1508.7).

The cumulative effects analysis for this project is based on reasonably foreseeable future actions that, if implemented, would contribute to the effects of the Proposed Action or No Action Alternative. The year 2045 was used as the time period for the assessment of cumulative effects because this is the approximate end of the proposed 40-year contract period for the storage and exchange contracts between Aurora and Reclamation under the Proposed Action.

Reclamation has defined reasonably foreseeable projects involving federal action as those for which NEPA permitting has been successfully completed and are awaiting completion of implementation (i.e. construction or operational implementation). Consequently, there are no reasonably foreseeable projects at this time. Never-the-less, Reclamation has determined for purposes of this analysis that the reasonably foreseeable actions for the cumulative effects analysis are to be based on anticipated changes in water demand, use, and storage in the year 2045. Anticipated reasonably foreseeable actions include:

- Municipal entities would increase use of Fry-Ark and native water.
- Consistent with the PBWW Excess Capacity Contract, storage in Pueblo Reservoir would increase from 3,000 acre-feet to 15,000 acre-feet.
- Colorado Springs Utilities' Excess Capacity Contract for storage in Pueblo Reservoir would be reduced from 10,000 acre-feet to 1,000 acre-feet.
- Colorado Springs Utilities would increase ground water pumping and potable reuse to meet future demands.

- Colorado Springs Utilities would construct a 25,000 acre-foot reservoir in the Fountain Creek Basin as part of the reuse plan.
- All entities currently participating in restoration of yield (ROY) storage (Aurora, Colorado Springs, Fountain, SECWCD, and PBWW) would continue their participation.

Because the No Action Alternative includes the development of gravel pit water storage, reasonably foreseeable actions in the vicinity of the gravel pit storage site were assessed. No reasonably foreseeable actions or activities were identified near the potential area of gravel pit storage.

In addition to reasonably foreseeable actions, there were other model variables that required definition. A summary of these variables for the Existing Conditions, Proposed Action and No Action Alternative is presented in **Table 5-1**. The cumulative effects Existing Conditions is identical to the Effects Existing Conditions.

Other than the items mentioned above, the definitions for No Action and Proposed Action are the same as described in the Effects section.

Table 5-1. Summary of Simulation Model Variable Settings for Cumulative Effects Analysis

Model Variable	Cumulative Effects Scenario		
	Existing Condition	No Action	Proposed Action
General Settings			
Municipal Demands	2004	2045	2045
Other Demand by Others	No	Yes	Yes
Agricultural Demands (1)	Historical	Historical	Historical
Otero Pump Station Capacity	118.5 mgd	118.5 mgd	118.5 mgd
Aurora Settings			
Excess Capacity in Pueblo Reservoir	10,000 ac-ft	0 ac-ft	10,000 ac-ft
Gravel Lakes Storage	0 ac-ft	10,000 ac-ft	0 ac-ft
USBR Contract Exchanges	0 ac-ft	0 ac-ft	10,000 ac-ft
Transmountain Diversions	Yes	Yes	Yes
Upper Arkansas Ranch water rights	Yes	Yes	Yes
Rocky Ford I Transfer	Yes	Yes (junior to RICD)	Yes
Colorado Canal	Yes	Yes	Yes
Rocky Ford II Transfer (2) (3)	Yes (50%)	Yes (100%)	Yes (100%)
Highline Lease	Yes	Yes	Yes
Pueblo FMP/RICD - Aurora	None	None	Full
ROY Storage - Aurora	No	No	Yes

Table 5-1. Summary of Simulation Model Variable Settings for Cumulative Effects Analysis

Model Variable	Cumulative Effects Scenario		
	Existing Condition	No Action	Proposed Action
Other Municipal Settings			
Pueblo Board of Water Works Excess Capacity Storage in Pueblo Reservoir	3,000 ac-ft	15,000 ac-ft	15,000 ac-ft
Pueblo West Excess Capacity Storage in Pueblo Reservoir	1,000 ac-ft	1,000 ac-ft	1,000 ac-ft
Colorado Springs Utilities Excess Capacity in Pueblo Reservoir	10,000 ac-ft	1,000 ac-ft	1,000 ac-ft
Pueblo FMP/RICD - Others (4)	None	None	None
ROY Storage - Others	No	Yes	Yes
Colorado Springs Future Operations (5)	No	Yes	Yes

Notes:

(1) Agricultural demands are assumed to be the same as historical except for those systems that have been converted to municipal use, such as the Colorado Canal system, Rocky Ford Ditch and Highline Canal lease.

(2) The percentage value indicates the percent of the total decreed yield that is changed and diverted by Aurora. By decree, water cannot be changed from a tract of land until revegetation is complete.

(3) During actual 2004 operations, because Aurora's Upper Basin exchange application (99CW170) was not finalized, Rocky Ford II water was diverted into the PBWW Excess Capacity account in Pueblo Reservoir, then moved to Twin Lakes by contract exchange with the PBWW (Simpson, 2005). It is reasonably expected that the Upper Basin exchange application will be decreed in 2005. Therefore, the model will operate per the decree. The differences in storage and streamflow between actual and simulated operations during 2004 are negligible.

(4) Due to limitations in the model, all Colorado Canal exchanges (including those by Colorado Springs Utilities, Pueblo West and the City of Fountain) are subject to the same Pueblo FMP conditions as other Aurora exchanges

(5) Colorado Springs Utilities future operations were assumed to consist of increased ground water pumping and increased non-potable and potable reuse.

5.2 Surface Water Quantity

This section provides the cumulative effects surface water quantity analysis. Surface water quantity studies include the analysis of streamflow and reservoir storage. As previously mentioned, all of the analyses performed for surface water quantity studies are based on the simulation model results. Analyses include direct examination of Quarter-Monthly Model results, summary model results, and a peak flow analysis.

5.2.1 Hydrologic Year Summary

The hydrologic year classifications used for the cumulative effects analysis are identical to those used in the Effects analysis.

5.2.2 Simulated Exchanges and Project Yield

Table 5-2 presents a summary of the simulated exchanges under Existing Conditions, the Proposed Action and No Action Alternative for the cumulative effects analysis. **Table 5-3** and **Table 5-4** present the annual exchange under each scenario for the Upper Arkansas River Basin and the Lower Arkansas River Basin, respectively. As with the Effects Analysis, the results show reduced exchanges under the No Action Alternative because of a lack of contract exchanges and junior river exchanges under the alternative. Aurora's Arkansas River

Basin exchanges are less for the No Action Alternative, because exchanges to the Upper Arkansas River Basin from the Lower Arkansas River Basin make up a large portion of Aurora's yield from the basin. Contract exchanges shown in **Table 5-3** are higher under the Proposed Action than under Existing Conditions and the No Action Alternative, because contract exchanges are unique to the Proposed Action (see **Table 5-1**).

River exchanges are higher for the Proposed Action than under Existing Conditions, because the percent of the total Rocky Ford II Transfer decreed yield that is diverted by Aurora increases from 50 to 100 percent from Existing Conditions to Proposed Action. The additional Rocky Ford II Transfer yield increases Aurora's river exchange potential. During dry years (e.g., 1989 and 2002), river exchanges are higher for the Proposed Action than under Existing Conditions as a result of ROY storage in Holbrook Reservoir. Aurora's ROY storage in Holbrook Reservoir is unique to the Proposed Action, and the additional storage in Holbrook Reservoir is available for river exchanges into Pueblo Reservoir.

Table 5-2. Summary of Simulated Annual Exchanges for the Cumulative Effects Analysis

Exchange	Source	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)
River Exchanges to Pueblo Reservoir or Gravel Pit	Rocky Ford I	7,344	5,631	5,050
	Rocky Ford II	2,151	2,967	3,698
	Colorado Canal	5,876	2,347	5,310
	Highline Lease	2,990	1,065	2,415
	Holbrook Reservoir Release	0	0	2,408
Contract Exchange to Pueblo Reservoir or gravel lakes	Holbrook Contract	0	0	2,359
	Total to Pueblo Reservoir or Gravel Pit	18,361	12,010	21,242
River Exchanges to Upper Basin	From Pueblo Reservoir Storage	3,315	8,593	4,576
	Colorado Canal	5,597	4,867	5,536
Contract Exchanges to Upper Basin	via PBWW	8,952	0	8,667
	via USBR	0	0	3,048
	Total to Upper Basin (1)	17,865	13,460	21,826

Notes:

(1) Total exchanges to the Upper Arkansas River Basin are the total Lower Arkansas River Basin water rights yield at the Upper Arkansas River Basin Storage.

Table 5-3. Simulated Annual Exchange to Lower Arkansas River Basin Storage for Cumulative Effects Analysis

Year	Existing Conditions			No Action Alternative			Proposed Action		
	River	Contract(1)	Total	River	Contract(1)	Total	River	Contract	Total
1982	27,891	0	27,891	18,837	0	18,837	29,900	446	30,346
1983	27,865	0	27,865	15,748	0	15,748	32,537	3,446	35,983
1984	27,699	0	27,699	23,763	0	23,763	29,842	283	30,125
1985	24,914	0	24,914	21,634	0	21,634	25,899	3,342	29,241
1986	26,841	0	26,841	18,602	0	18,602	26,828	4,472	31,300
1987	29,607	0	29,607	18,752	0	18,752	25,235	3,430	28,665
1988	21,724	0	21,724	13,492	0	13,492	18,197	3,154	21,351
1989	15,358	0	15,358	14,395	0	14,395	18,199	1,416	19,615
1990	23,635	0	23,635	12,121	0	12,121	27,509	846	28,355
1991	23,886	0	23,886	13,671	0	13,671	25,325	283	25,608
1992	23,905	0	23,905	14,729	0	14,729	25,322	774	26,096
1993	20,717	0	20,717	16,674	0	16,674	24,178	283	24,461
1994	20,819	0	20,819	14,311	0	14,311	21,423	2,806	24,229
1995	26,402	0	26,402	15,931	0	15,931	29,156	1,784	30,940
1996	27,383	0	27,383	18,251	0	18,251	28,232	2,467	30,699
1997	21,751	0	21,751	23,268	0	23,268	24,047	641	24,688
1998	22,646	0	22,646	17,491	0	17,491	16,832	4,037	20,869
1999	30,783	0	30,783	20,365	0	20,365	31,282	2,629	33,911
2000	26,217	0	26,217	16,002	0	16,002	19,913	5,045	24,958
2001	21,616	0	21,616	17,248	0	17,248	20,122	4,000	24,122
2002	11,454	0	11,454	9,134	0	9,134	12,809	3,962	16,771
Avg	**23,958**	**0**	**23,958**	**16,877**	**0**	**16,877**	**24,418**	**2,359**	**26,778**

Notes: (1) Historically there have been sporadic contract exchanges from Lake Henry and Lake Meredith to Pueblo Reservoir. However, contract exchanges were set to zero for purposes of defining Existing Conditions and the No Action Alternative.

Table 5-4. Simulated Annual Exchange to Upper Arkansas River Basin Storage for Cumulative Effects Analysis

Year	Existing Conditions			No Action Alternative			Proposed Action		
	River	Contract	Total	River	Contract	Total	River	Contract	Total
1982	16,605	9,000	25,605	17,822	0	17,822	17,637	11,000	28,637
1983	17,572	8,000	25,572	15,767	0	15,767	17,051	16,000	33,051
1984	15,505	9,000	24,505	18,824	0	18,824	17,869	9,000	26,869
1985	12,975	10,000	22,975	14,202	0	14,202	15,137	10,000	25,137
1986	17,306	9,000	26,306	16,937	0	16,937	22,730	8,000	30,730
1987	15,258	9,000	24,258	13,536	0	13,536	14,360	9,000	23,360
1988	10,494	9,000	19,494	10,002	0	10,002	10,082	9,000	19,082
1989	11,852	9,000	20,852	10,955	0	10,955	9,430	16,000	25,430
1990	8,312	9,000	17,312	8,627	0	8,627	7,642	19,000	26,642
1991	13,251	9,000	22,251	10,193	0	10,193	7,227	17,000	24,227
1992	12,293	9,000	21,293	11,242	0	11,242	8,509	16,000	24,509
1993	12,070	9,000	21,070	13,267	0	13,267	11,849	11,000	22,849
1994	10,020	9,000	19,020	10,894	0	10,894	8,340	14,000	22,340
1995	17,503	9,000	26,503	13,218	0	13,218	16,504	10,000	26,504
1996	15,026	9,000	24,026	14,174	0	14,174	14,738	10,000	24,738
1997	16,760	7,000	23,760	22,210	0	22,210	24,745	5,000	29,745
1998	9,714	11,000	20,714	11,883	0	11,883	9,760	9,000	18,760
1999	17,095	8,000	25,095	17,168	0	17,168	18,859	8,000	26,859
2000	10,725	9,000	19,725	12,359	0	12,359	11,069	9,000	20,069
2001	11,131	9,000	20,131	13,774	0	13,774	13,674	14,000	27,674
2002	1,626	9,000	10,626	5,616	0	5,616	1,491	16,000	17,491
Avg	**13,004**	**8,952**	**21,957**	**13,460**	**0**	**13,460**	**13,272**	**11,714**	**24,986**

Notes: (1) Exchanges include river and contract exchanges from Pueblo Reservoir plus river exchanges from the Colorado Canal system.

Figure 5-1 shows simulated storage in gravel lakes storage in the No Action Alternative cumulative effects analysis. Minimum storage never drops below 3,950 acre-feet. This indicates that the same yield would be available from a gravel lake reservoir of 6,050 acre-feet.

Figure 5-1. Simulated Aurora Storage in gravel lakes - No Action Alternative Cumulative Effects Analysis

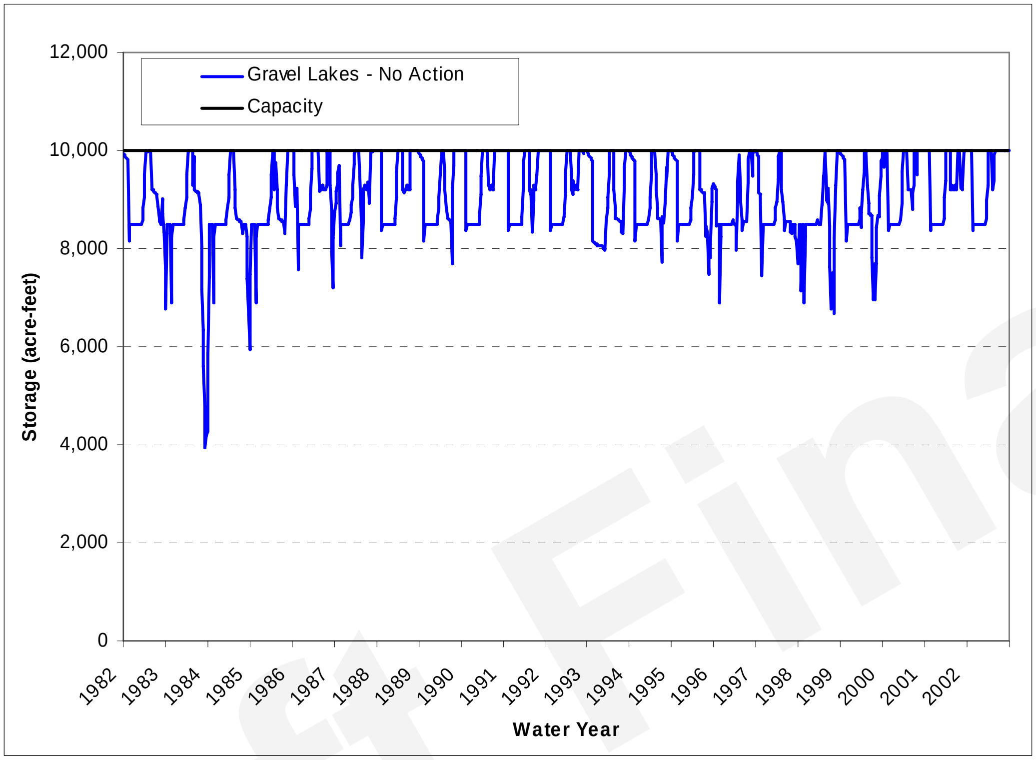
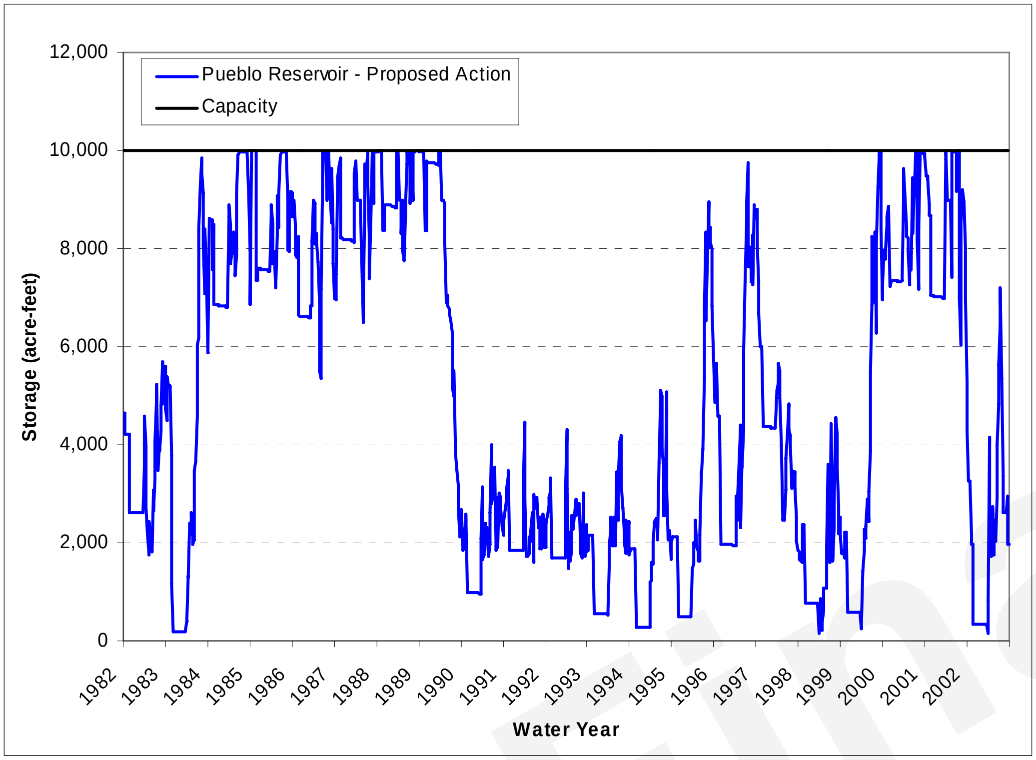


Figure 5-2 shows simulated storage in the Long Term Excess Capacity account in Pueblo Reservoir as part of the Proposed Action. Storage in this account is less than under Existing Conditions because of the ability to execute contract exchanges with Reclamation under the Proposed Action.

More detail on reservoir storage levels is provided for select major reservoirs in subsequent sections.

Figure 5-2. Simulated Aurora Storage in Pueblo Reservoir - Proposed Action Cumulative Effects



5.2.3 Comparison of Flows Within Reaches

The Quarter-Monthly model simulates flows at several locations within the Study Area. As previously stated, Reclamation requested that effects of the Proposed Action be analyzed at several gage locations. Output from the model for all of the gages is contained in Appendix A. However, for purposes of describing the effects in the river in this document and in other resource studies, it was appropriate to narrow the number of locations that are specifically addressed. This sub-section compares flows between gages in similar reaches and makes a selection of key gages within the river for specific analysis in this report.

Table 5-5 presents a summary of the simulated Proposed Action monthly average streamflows minus the No Action Alternative monthly average streamflows for the originally requested streamflow gages on the Arkansas River above Pueblo Reservoir. As expected, there are similarities in several of the mainstem gages between Lake Creek and Pueblo Reservoir because there are no differences in operations in this reach for the Proposed Action or for the No Action Alternative. Therefore, the analysis for these gages was consolidated into a single gage. Because the Wellsville gage is the point of measurement for the Upper Arkansas Flow Management Program, the Wellsville gage was selected from this group. Similarly, effects at the Lake Fork gage and the Malta gage are nearly identical because there are no differences in operations between the Lake Fork and Malta gages for the Proposed Action or for the No Action Alternative. Therefore, for purposes of discussion, the Lake Fork gage was selected. Although the Lake Creek gage effects are similar to those in the mainstem, it is discussed separately because it is a tributary stream. Therefore, within this document, hydrologic effects will be discussed at the following gages above Pueblo Reservoir:

- Lake Fork gage
- Lake Creek gage
- Wellsville gage

Table 5-5. Cumulative Effects Comparison for Gaged Flows Above Pueblo Reservoir

Month	Proposed Action minus No Action Alternative Monthly Average Streamflow (cfs)						
	Lake Fork	Malta	Lake Creek	Granite	Nathrop	Wellsville	Portland
Oct	0	0	-9	-9	-9	-9	-9
Nov	0	0	-19	-19	-19	-19	-19
Dec	3	3	-21	-18	-18	-18	-18
Jan	1	1	6	7	6	6	6
Feb	-3	-3	-3	-6	-6	-6	-6
Mar	-2	-2	-14	-16	-16	-16	-16
Apr	-8	-8	0	-7	-7	-7	-7
May	0	0	-4	-4	-4	-4	-4
Jun	0	0	-9	-9	-9	-9	-9
Jul	0	0	-6	-5	-5	-5	-5
Aug	0	0	0	0	0	0	0
Sep	0	0	-2	-2	-2	-2	-2
Average	**-1**	**-1**	**-7**	**-7**	**-7**	**-7**	**-7**

Table 5-6 presents a summary of the simulated Proposed Action monthly average streamflows minus No Action Alternative monthly average streamflows for the originally requested streamflow gages on the Arkansas River below Pueblo Reservoir. The cumulative effects for each of the four gages are relatively unique, and as a result, the cumulative effects for each of the gages are discussed in this document. Based on this, the hydrologic effects at the following gages below Pueblo Reservoir are discussed in this document:

- Above Pueblo gage
- Moffat Street gage
- Avondale gage
- La Junta gage

Table 5-6. Cumulative Effects Comparison for Gaged Flows Below Pueblo Reservoir

Month	Proposed Action minus No Action Alternative Monthly Average Streamflow (cfs)			
	Above Pueblo	Moffat Street	Avondale	La Junta
Oct	7	7	8	1
Nov	4	4	6	0
Dec	-14	-14	-2	1
Jan	-23	-24	-1	-2
Feb	-11	-11	-13	-4
Mar	-37	-38	-35	5
Apr	-10	-12	-2	-3
May	-8	-8	2	2
Jun	-5	-5	2	-3
Jul	-6	-6	7	0
Aug	-11	-11	4	-6
Sep	0	0	2	0
Average	**-10**	**-10**	**-2**	**-1**

As for the Effects analysis, all of the reservoirs are included in the discussion with the exception of Twin Lakes. The Quarter-Monthly model lumps the Colorado Canal System reservoirs (Lake Henry and Lake Meredith) into one single reservoir. However, simulated Colorado Canal System reservoir contents are subsequently distributed to Lake Henry and Lake Meredith contents outside of the Quarter-Monthly Model. The methodology used to distribute Colorado Canal storage contents among Lake Henry and Lake Meredith is described in **Section 2.1.3.1**. Based on this, the hydrologic effects of the following reservoirs are discussed in this analysis.

- Turquoise Reservoir
- Pueblo Reservoir
- Lake Henry
- Lake Meredith
- Holbrook Reservoir

5.2.4 Discussion of Selected Quarter-Monthly Results

This section presents a discussion of the Quarter-Monthly Model results. Raw model results for each streamflow location in the simulation are presented in Appendix A. Quarter-Monthly Model results are provided for the Existing Conditions, the Proposed Action, and No Action Alternative. The effects of the Proposed Action are measured relative to the No Action Alternative results.

5.2.4.1 Arkansas River above Pueblo Reservoir

This subsection summarizes net effects for key locations above Pueblo Reservoir, including Turquoise Reservoir, Lake Fork, Lake Creek and the Wellsville gages.

Turquoise Reservoir

Summary data for the cumulative effects analysis at Turquoise Reservoir is shown in **Table 5-7**, **Figure 5-3** and **Figure 5-4**. The general effect of both the Proposed Action and the No Action Alternative is a slight reduction in Turquoise Reservoir storage contents. Simulated storage under the Proposed Action is greater than under the No Action Alternative, except during winter and spring months for the mean dry years. Cumulative effects at Turquoise Reservoir are generally an increase in storage as a result of the Proposed Action.

The effects are due to the same factors as described in the Effects analysis. However, under the cumulative effects analysis, increased water use from other users in the basin contributes to additional decreases in reservoir contents when compared with Existing Conditions. This includes additional use from Colorado Springs Utilities, Pueblo Board of Water Works and Fry-Ark Project accounts, which are anticipated to use more water from storage on an annual basis than they have in the past.

Table 5-7. Turquoise Reservoir - Summary of Cumulative Effects

Month	Simulated Storage			Cumulative Effects (1)	
	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)	(ac-ft)	(%)
Overall Mean					
Oct	111,058	107,217	109,620	2,403	2%
Nov	107,661	103,831	106,124	2,293	2%
Dec	102,788	99,232	100,647	1,415	1%
Jan	99,172	95,178	96,217	1,038	1%
Feb	94,259	89,762	92,007	2,245	3%
Mar	84,543	81,136	83,736	2,600	3%
Apr	66,915	66,886	68,828	1,943	3%
May	62,867	61,382	63,300	1,919	3%
Jun	98,629	97,022	97,575	553	1%
Jul	116,825	115,074	115,665	591	1%
Aug	115,669	113,432	114,524	1,092	1%
Sep	112,949	110,528	111,882	1,354	1%
Average	**97,778**	**95,057**	**96,677**	**1,620**	**2%**
Mean Wet					
Oct	112,921	106,960	109,356	2,395	2%
Nov	110,753	103,947	105,490	1,543	1%
Dec	106,821	98,536	99,764	1,227	1%
Jan	104,940	92,949	95,958	3,010	3%
Feb	101,921	87,267	93,316	6,049	7%
Mar	91,786	78,384	85,999	7,615	10%
Apr	67,639	63,637	68,657	5,020	8%
May	63,861	57,821	62,868	5,047	9%
Jun	105,552	99,794	100,822	1,028	1%
Jul	128,658	124,671	125,389	717	1%
Aug	129,032	124,639	125,796	1,157	1%
Sep	127,596	123,811	125,036	1,225	1%
Average	**104,290**	**96,868**	**99,871**	**3,003**	**3%**

Table 5-7. Turquoise Reservoir - Summary of Cumulative Effects

Month	Simulated Storage			Cumulative Effects (1)	
	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)	(ac-ft)	(%)
Mean Dry					
Oct	104,638	101,555	104,402	2,847	3%
Nov	100,147	98,225	100,861	2,636	3%
Dec	95,463	95,014	96,574	1,560	2%
Jan	91,555	92,348	91,892	-456	0%
Feb	86,791	87,887	86,332	-1,554	-2%
Mar	79,405	80,905	78,913	-1,992	-2%
Apr	65,304	67,085	65,435	-1,650	-2%
May	59,397	60,919	59,511	-1,408	-2%
Jun	87,204	88,335	87,346	-989	-1%
Jul	98,742	99,022	98,813	-209	0%
Aug	95,388	94,913	95,411	498	1%
Sep	91,446	90,493	90,645	152	0%
Average	**87,957**	**88,058**	**88,011**	**-47**	**0%**

Notes:
(1) Cumulative Effects (ac-ft) = Proposed Action - No Action simulated storage. Effects (%) = (Proposed Action - No Action simulated storage)/No Action simulated storage.

Figure 5-3. Turquoise Reservoir - Simulated Cumulative Effects Storage

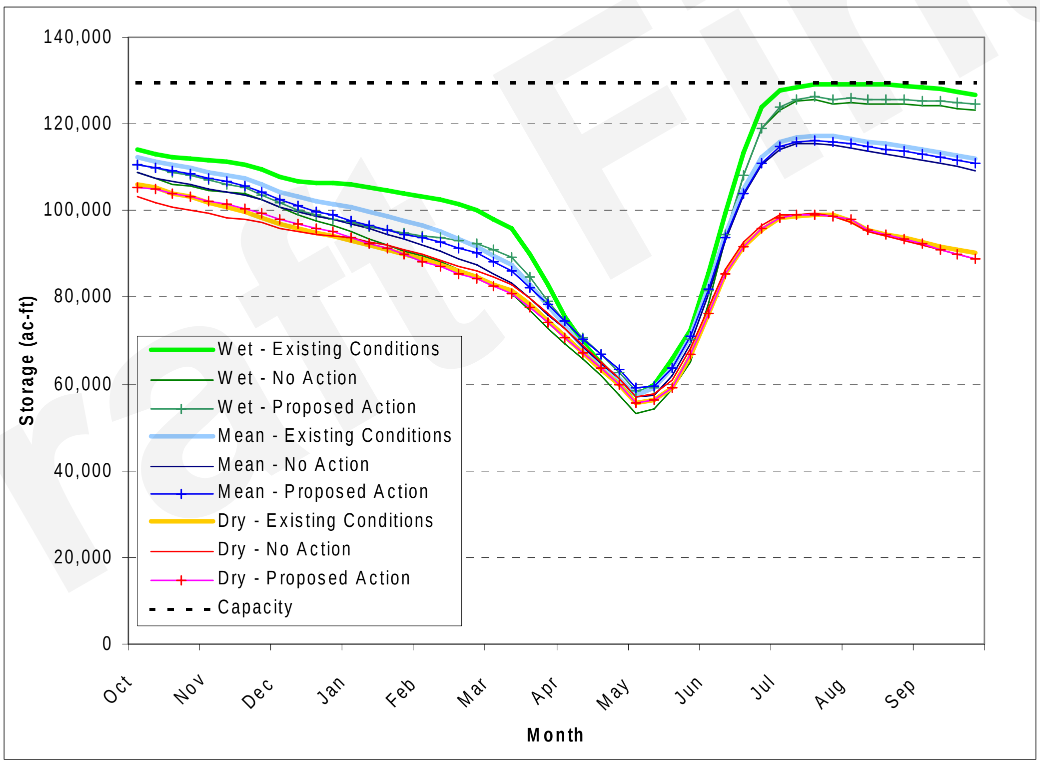
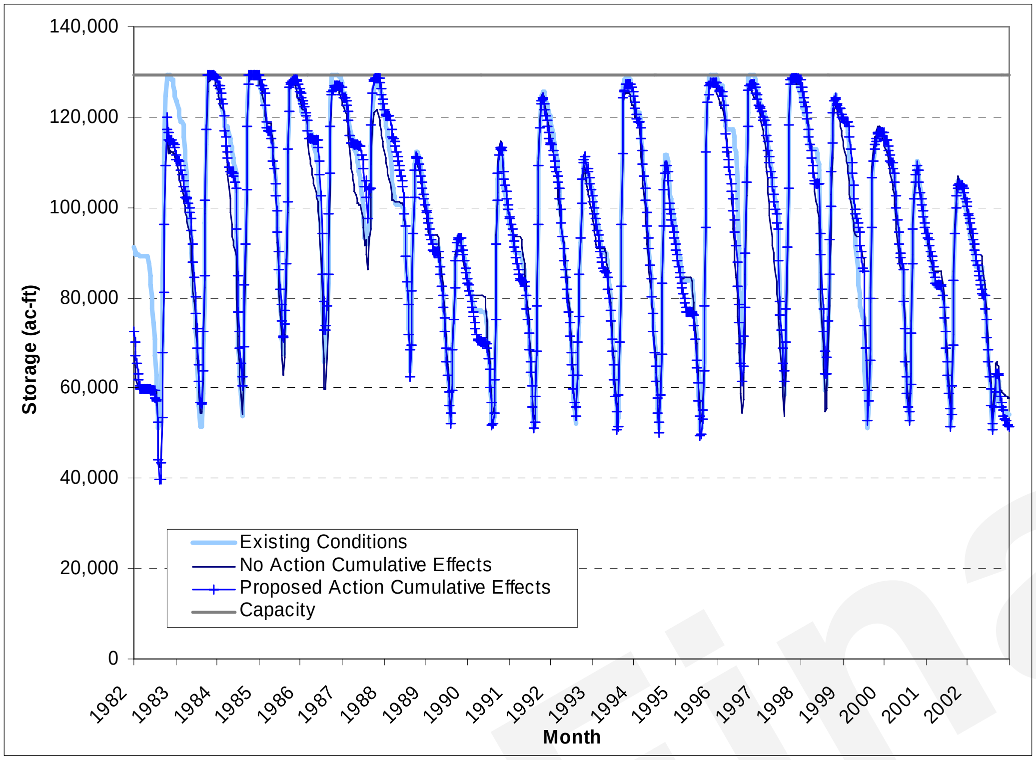


Figure 5-4. Turquoise Reservoir - Simulated Cumulative Effects Storage Time Series



Lake Fork

Summary data for the cumulative effects analysis at the Lake Fork gage are shown in **Table 5-8** and **Figure 5-5**. Because dry, average and wet year conditions are defined at the Salida gage, the Lake Fork flows are generally not consistent with the hydrologic classification due to the effects of Turquoise Reservoir storage releases on streamflow. There are differences between the Proposed Action, the No Action Alternative, and Existing Conditions streamflow, with the largest differences seen during wet years.

Specific operations of Turquoise Reservoir releases to Lake Fork are difficult to simulate in the Quarter-Monthly Model because releases depend on available capacity for native flows in the Mt. Elbert Conduit, deliveries made from non-Fry-Ark Project accounts in Turquoise Reservoir, and other operational decisions made on a daily basis that are outside of the scope of the Quarter-Monthly Model. Therefore, although the analysis of model results shows some effects on Lake Fork streamflows due to both the Proposed Action and No Action Alternative, it is unlikely that actual effects would be as great as those shown by the model on a monthly basis.

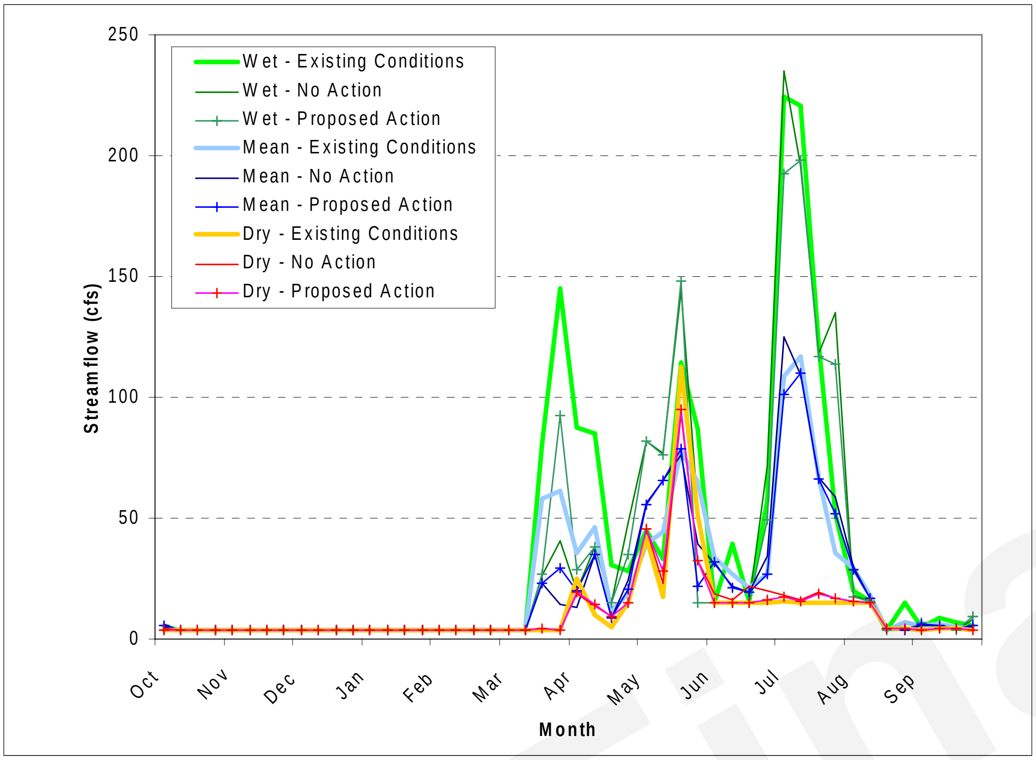
Table 5-8. Lake Fork - Summary of Cumulative Effects

Month	Simulated Streamflow			Cumulative Effects (1)	
	Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	(cfs)	(%)
Overall Mean					
Oct	4	4	4	0	2%
Nov	4	4	4	0	0%
Dec	4	4	4	0	0%
Jan	4	4	4	0	0%
Feb	4	4	4	0	0%
Mar	31	11	15	3	30%
Apr	29	21	22	1	5%
May	57	60	57	-3	-5%
Jun	27	27	25	-2	-7%
Jul	83	91	83	-8	-9%
Aug	15	14	14	0	-2%
Sep	6	5	5	0	5%
Average	**22**	**21**	**20**	**-1**	**-3%**
Mean Wet					
Oct	4	5	4	-1	-13%
Nov	4	4	4	0	0%
Dec	4	4	4	0	0%
Jan	4	4	4	0	0%
Feb	4	4	4	0	0%
Mar	56	18	30	12	66%
Apr	60	30	30	-1	-3%
May	69	90	83	-8	-9%
Jun	32	28	23	-5	-19%
Jul	158	172	157	-15	-9%
Aug	14	11	11	0	-1%
Sep	7	5	6	1	19%
Average	**35**	**31**	**30**	**-1**	**-5%**
Mean Dry					
Oct	4	4	4	0	-2%
Nov	4	4	4	0	0%
Dec	4	4	4	0	0%
Jan	4	4	4	0	0%
Feb	4	4	4	0	0%
Mar	4	4	4	0	0%
Apr	14	15	15	0	1%
May	56	49	51	2	4%
Jun	15	19	15	-4	-20%
Jul	15	18	17	-1	-3%
Aug	10	10	10	0	0%
Sep	4	4	4	0	0%
Average	**11**	**12**	**11**	**0**	**-2%**

Notes:

(1) Cumulative Effects (cfs) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 5-5. Lake Fork Gage - Simulated Cumulative Effect Streamflow



Lake Creek

Simulated streamflows and net effects for the Lake Creek gage are shown in **Table 5-9** and **Figure 5-6**. Lake Creek flows are also highly regulated by storage, although they are much more consistent with the hydrologic year classification due to the higher native flow component than Lake Fork streamflows.

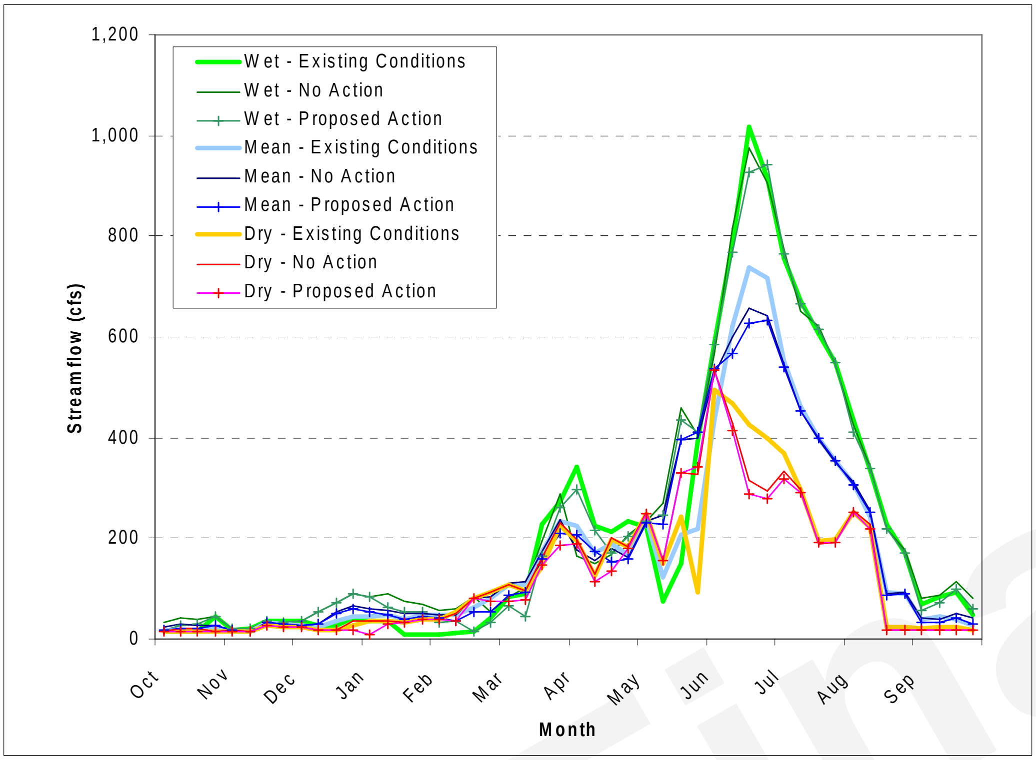
Proposed Action streamflows are less than No Action Alternative streamflows, especially during the fall, winter, and early spring months. This is because Reclamation typically moves much of the Fry-Ark Project account in Turquoise Reservoir to Pueblo Reservoir during these months to make room for the Boustead Tunnel imports. Under the Proposed Action, the contract exchanges result in less water released to Lake Creek from the Fry-Ark account during the winter. Because contract exchanges are not part of the No Action Alternative, releases to Lake Creek are higher in the No Action Alternative than in the Proposed Action. The reduction in streamflow corresponds to increased yields of the Proposed Action compared to the No Action Alternative.

Table 5-9. Lake Creek - Summary of Cumulative Effects

Month	Simulated Streamflow			Cumulative Effects (1)	
	Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	(cfs)	(%)
Overall Mean					
Oct	19	27	22	-6	-20%
Nov	23	23	23	0	-1%
Dec	33	44	42	-2	-5%
Jan	45	55	46	-9	-16%
Feb	60	65	46	-19	-28%
Mar	154	157	135	-21	-14%
Apr	189	169	174	6	3%
May	195	316	314	-3	-1%
Jun	621	603	589	-14	-2%
Jul	445	439	439	0	0%
Aug	187	190	186	-4	-2%
Sep	38	43	34	-9	-21%
Average	**167**	**178**	**171**	**-7**	**-4%**
Mean Wet					
Oct	22	39	30	-9	-24%
Nov	27	28	28	0	0%
Dec	33	62	62	0	0%
Jan	23	80	64	-16	-20%
Feb	19	64	30	-34	-54%
Mar	165	163	130	-33	-20%
Apr	256	172	225	53	31%
May	204	340	329	-11	-3%
Jun	817	809	797	-11	-1%
Jul	649	651	652	1	0%
Aug	297	295	289	-6	-2%
Sep	74	90	71	-19	-21%
Average	**216**	**233**	**226**	**-7**	**-3%**
Mean Dry					
Oct	15	18	15	-3	-15%
Nov	20	20	20	-1	-3%
Dec	21	24	19	-4	-19%
Jan	35	35	27	-8	-22%
Feb	66	65	58	-8	-12%
Mar	140	147	120	-27	-18%
Apr	175	177	154	-23	-13%
May	187	264	267	3	1%
Jun	450	399	385	-14	-3%
Jul	267	254	249	-5	-2%
Aug	133	133	130	-3	-2%
Sep	22	18	18	0	-1%
Average	**128**	**130**	**122**	**-8**	**-6%**

Notes:
(1) Cumulative Effects (cfs) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 5-6. Lake Creek Gage - Simulated Cumulative Effects Streamflow



Wellsville

Summary information for the Wellsville gage is presented in **Table 5-12** and **Figure 5-7**. Magnitudes of streamflow effects at the Wellsville gage are nearly the same as those at the Lake Creek gage because most of the exchanges that take place are exchanged through Twin Lakes. However, the effects as a percentage of the streamflow are much smaller at the Wellsville gage because of its much larger flow. Differences in streamflow are due to the same reasons as described for Lake Creek.

Streamflows for the Proposed Action and No Action Alternative are generally higher than under Existing Conditions, except during mean dry years when Proposed Action streamflows are less than under Existing Conditions. Cumulative effects are negative for almost all months, indicating that No Action Alternative streamflows are higher than those under the Proposed Action. Streamflows are higher for the Proposed Action and No Action Alternative than under Existing Conditions because Colorado Springs Utilities exchanges less water to the Upper Arkansas River Basin from Pueblo Reservoir under Existing Conditions. Less water is exchanged due to Colorado Springs' reduced ability to exchange reusable return flows under Existing Conditions.

Effects by other water users in the basin are the difference between the cumulative effects described in this section and the direct effects described in **Section 4.0**. The distribution of cumulative effects from Aurora and from other entities is shown in **Table 5-10**.

Table 5-10. Distribution of Cumulative Effects for Wellsville Gage

Entity	Cumulative Effects (cfs) by Hydrologic Condition		
	Overall Mean	**Mean Wet**	**Mean Dry**
Aurora	-10	-8	-12
Other Entities	3	-1	4
Total Cumulative Effects	**-7**	**-9**	**-8**

Notes:
(1) Distribution of cumulative effects of other entities was calculated by subtracting Effects flows from Cumulative Effects flows. However, there could be slight changes in Aurora's operations in 2045 that are due to others' operations. Therefore, actual distribution of effects may vary slightly from those shown.

Figure 5-7 shows minimum flows under the UAVFMP. The ability of Reclamation to make releases to meet or exceed the flow program is about the same under each of the alternatives. **Figure 5-7** shows that the target flows are not met during parts of July and August during dry years. However, the Proposed Action does not reduce Reclamation's ability to meet or exceed the target flows. **Table 5-11** shows the percent of time that the target flows for the UAVFMP are met or exceeded.

Figure 5-7. Wellsville Gage - Simulated Cumulative Effects Streamflow

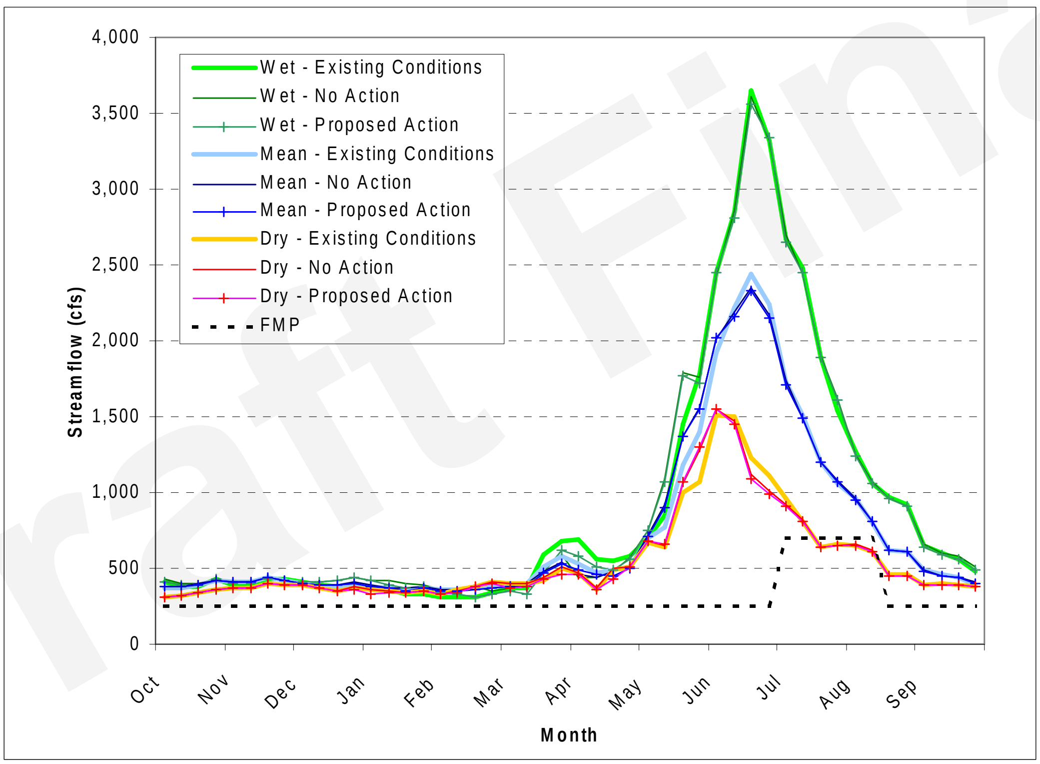


Table 5-11. UAVFMP - Percent of Time Target Values are Met or Exceeded

Percent of Time Target Flows are Met or Exceeded		
Existing Conditions	**No Action Cumulative Effects**	**Proposed Action Cumulative Effects**
97.5	97.2	96.8

Table 5-12. Wellsville - Summary of Cumulative Effects

Month	Simulated Streamflow Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	Cumulative Effects (1) (cfs)	(%)
Overall Mean					
Oct	386	395	390	-5	-1%
Nov	420	420	420	0	0%
Dec	388	399	397	-2	0%
Jan	367	377	368	-9	-2%
Feb	372	376	358	-19	-5%
Mar	470	454	436	-18	-4%
Apr	499	471	477	6	1%
May	1,002	1,125	1,119	-6	-1%
Jun	2,197	2,175	2,159	-16	-1%
Jul	1,386	1,387	1,379	-7	-1%
Aug	754	756	752	-4	-1%
Sep	446	451	442	-9	-2%
Average	**724**	**732**	**725**	**-7**	**-1%**
Mean Wet					
Oct	399	416	406	-10	-2%
Nov	411	411	411	0	0%
Dec	393	421	421	0	0%
Jan	350	407	391	-16	-4%
Feb	319	363	328	-34	-10%
Mar	497	457	436	-21	-5%
Apr	597	482	534	52	11%
May	1,176	1,332	1,314	-19	-1%
Jun	3,040	3,027	3,011	-16	-1%
Jul	2,166	2,182	2,167	-15	-1%
Aug	1,059	1,053	1,047	-6	-1%
Sep	578	592	574	-18	-3%
Average	**915**	**929**	**920**	**-9**	**-1%**
Mean Dry					
Oct	330	333	330	-3	-1%
Nov	383	384	383	-1	0%
Dec	369	372	367	-4	-1%
Jan	347	347	340	-8	-2%
Feb	371	370	362	-8	-2%
Mar	428	435	407	-27	-6%
Apr	457	460	437	-23	-5%
May	839	909	914	5	1%
Jun	1,349	1,302	1,284	-18	-1%
Jul	772	762	757	-5	-1%
Aug	546	546	543	-3	-1%
Sep	390	387	387	0	0%
Average	**548**	**550**	**543**	**-8**	**-1%**

Notes:
(1) Cumulative Effects (cfs) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

5.2.4.2 Arkansas River below Pueblo Reservoir

This section summarizes net effects for key locations below Pueblo Reservoir, including the Above Pueblo Gage, the Moffat Street Gage, the Avondale Gage, the Rocky Ford Gage, the La Junta Gage, Lake Meredith, Lake Henry, and Holbrook Reservoir.

Pueblo Reservoir

Simulated cumulative effects reservoir contents for Pueblo Reservoir are shown in **Table 5-14**, **Figure 5-8**, and **Figure 5-9**. Storage in Pueblo Reservoir under the Proposed Action and the No Action Alternative is less than storage under the Existing Conditions. Storage of water by Aurora in Pueblo Reservoir is part of the Proposed Action but not part of the No Action Alternative, resulting in greater Pueblo Reservoir storage under the Proposed Action when compared with the No Action Alternative. Cumulative effects are positive for all months because of the effects of Aurora's storage of water in Pueblo Reservoir under the Proposed Action.

Storage effects at Pueblo Reservoir are a result of a combination of Aurora's actions as described in the previous section and changes in use of stored water by other water users in the basin, including Colorado Springs Utilities, the Fry-Ark Project, and the PBWW. These changes result in lower storage in Pueblo Reservoir when compared with Existing Conditions.

Pueblo Reservoir cumulative effects for October and November during mean wet years are high as a result of how the Quarter-Monthly model is programmed to release stored water from reservoirs in the study area. The model uses a predefined storage target to force releases from Turquoise and Twin Lakes reservoirs during the fall and winter months. The targets are based on the historical tendency for Turquoise and Twin Lakes reservoirs to be drawn down to make room for the next year's spring runoff and West Slope imports. The increase in Pueblo Reservoir storage in October and November is a result of releases from Turquoise and Twin Lakes reservoirs made during the fall of two wet years (1984 and 1996) to meet the priorities. A portion of the water released from Turquoise and Twin Lakes reservoirs is stored in Pueblo Reservoir, resulting in higher cumulative effects during these months.

Effects by other water users in the basin are the difference between the cumulative effects described in this section and the direct effects described in **Section 4.0**. The distribution of cumulative effects from Aurora and from other entities is shown in **Table 5-13**.

Table 5-13. Distribution of Cumulative Effects for Pueblo Reservoir

Entity	Cumulative Effects (ac-ft) by Hydrologic Condition		
	Overall Mean	**Mean Wet**	**Mean Dry**
Aurora	5,607	7,291	2,538
Other Entities	-462	-2,221	-1,242
Total Cumulative Effects	**5,145**	**9,512**	**1,296**

Notes:
(1) Distribution of cumulative effects of other entities was calculated by subtracting Effects flows from Cumulative Effects flows. However, there could be slight changes in Aurora's operations in 2045 that are due to others' operations. Therefore, actual distribution of effects may vary slightly from those shown.

Table 5-14. Pueblo Reservoir - Summary of Cumulative Effects

Month	Simulated Storage			Cumulative Effects (1)	
	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)	(ac-ft)	(%)
Overall Mean					
Oct	164,006	148,130	154,640	6,510	4%
Nov	169,249	152,929	158,783	5,854	4%
Dec	178,549	163,399	168,711	5,313	3%
Jan	187,764	174,830	179,536	4,706	3%
Feb	194,024	181,465	185,056	3,591	2%
Mar	200,903	187,120	189,579	2,458	1%
Apr	197,039	179,188	183,482	4,293	2%
May	189,120	173,201	177,839	4,638	3%
Jun	185,729	170,365	176,017	5,652	3%
Jul	178,473	162,169	168,190	6,021	4%
Aug	172,148	154,985	161,318	6,333	4%
Sep	165,275	148,418	154,788	6,369	4%
Average	**181,857**	**166,350**	**171,495**	**5,145**	**3%**
Mean Wet					
Oct	179,314	143,502	156,340	12,838	9%
Nov	184,275	149,492	161,351	11,859	8%
Dec	190,591	160,068	171,365	11,298	7%
Jan	197,059	174,801	185,108	10,307	6%
Feb	200,866	183,959	191,489	7,530	4%
Mar	204,933	187,794	193,006	5,212	3%
Apr	201,858	175,948	185,105	9,157	5%
May	196,754	173,647	182,769	9,122	5%
Jun	205,178	181,445	190,310	8,865	5%
Jul	207,776	182,719	192,330	9,611	5%
Aug	207,276	182,803	192,607	9,804	5%
Sep	206,995	184,402	192,946	8,544	5%
Average	**198,573**	**173,382**	**182,894**	**9,512**	**5%**
Mean Dry					
Oct	156,718	154,175	156,611	2,436	2%
Nov	158,732	155,833	157,683	1,850	1%
Dec	167,391	164,455	165,851	1,396	1%
Jan	176,748	173,539	174,277	738	0%
Feb	182,245	178,615	179,139	525	0%
Mar	189,954	184,546	184,249	-297	0%
Apr	186,522	178,575	178,548	-27	0%
May	185,549	176,083	175,945	-139	0%
Jun	177,873	170,491	171,496	1,005	1%
Jul	151,474	144,487	146,026	1,539	1%
Aug	127,084	118,778	121,514	2,736	2%
Sep	116,296	107,784	111,571	3,787	4%
Average	**164,716**	**158,947**	**160,242**	**1,296**	**1%**

Notes:
(1) Cumulative Effects (ac-ft) = Proposed Action - No Action simulated storage. Effects (%) = (Proposed Action - No Action simulated storage)/No Action simulated storage.

Figure 5-8. Pueblo Reservoir - Simulated Cumulative Effects Storage

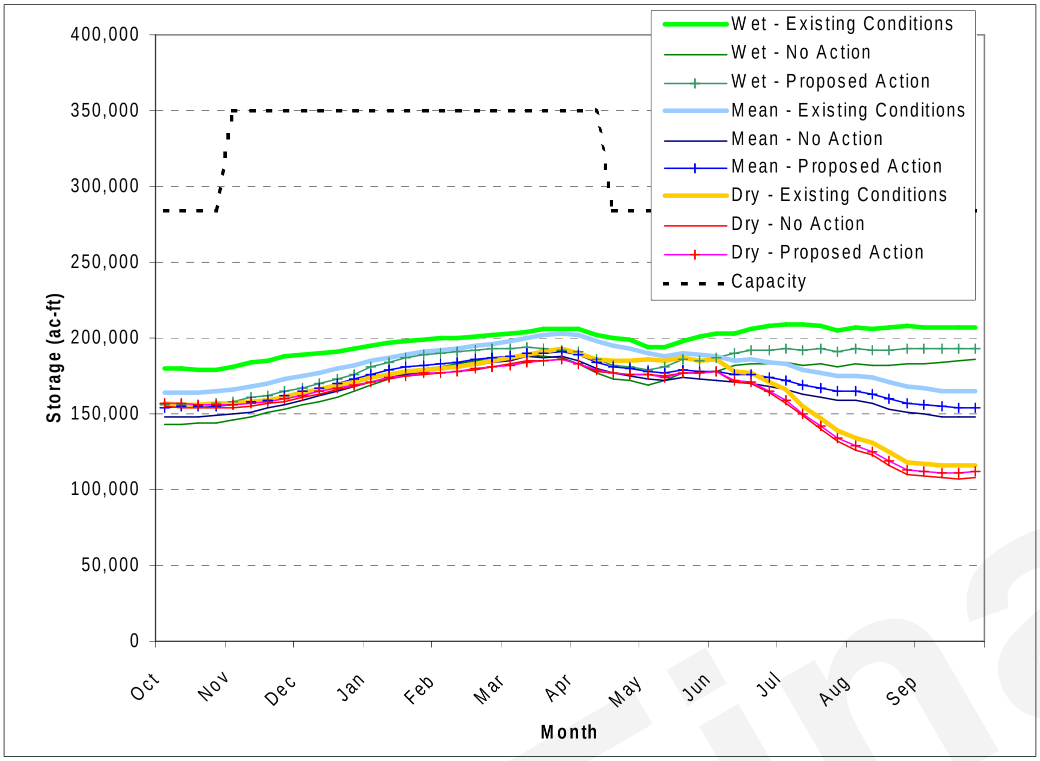
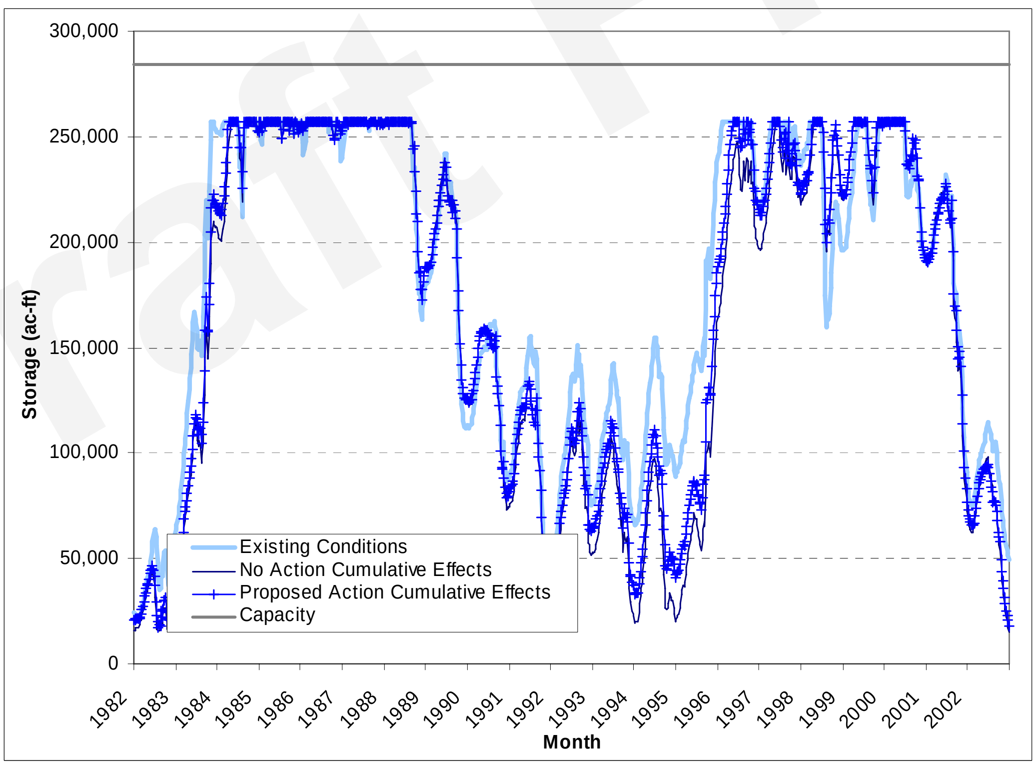


Figure 5-9. Pueblo Reservoir - Simulated Cumulative Effects Storage Time Series



Above Pueblo Gage

Simulated streamflow at the Above Pueblo gage is shown in **Table 5-17** and **Figure 5-10**. The Above Pueblo gage essentially represents releases to the Arkansas River from Pueblo Reservoir. For both the Proposed Action and the No Action Alternative, simulated streamflows are less than Existing Conditions streamflows for nearly all months in the year. This is primarily a result of two changes in future operations: (1) the conversion of Fry-Ark Project water from predominantly agricultural use for Existing Conditions to a 51/49 percent municipal to agricultural use ratio (see Quarter-Monthly Model Documentation (Hydrosphere, 2005)), and (2) future exchanges by Aurora, Pueblo Board of Water Works, Colorado Springs Utilities, and others. The No Action Alternative shows slightly higher streamflows than the Proposed Action.

None of Aurora's existing decrees in the Arkansas Basin allow diversions or exchanges of water during the Winter Water Storage Program, which operates between November 15 and March 15. Therefore, during most years in the simulation, Aurora's actions do not have an effect on streamflow during this time. Proposed Action streamflows are less than under Existing Conditions streamflows as a result of winter water storage in Pueblor Reservoir. ROY Storage in Holbrook Reservoir results in Holbrook Company's storage of winter water in Pueblo Reservoir, reducing streamflows at the Above Pueblo gage. Additionally, during wet years when Pueblo Reservoir is full, there are occasions when the Quarter-Monthly Model shows Aurora diverting water into storage prior to November 15 which is later spilled from the reservoir by Winter Water diversions, causing an increase in flow during those quarter-months with the spill. During actual operations, it is unlikely that Aurora would divert water into Pueblo Reservoir storage during times when there is a high likelihood of spill by the Winter Water Storage Program, and thus the spills would not occur and there would be no effect on streamflows.

Changes in flow during the summer months are due to higher yields of the Rocky Ford water rights under the Proposed Action, as well as a general decrease in yield under the No Action as a result of the junior exchange status for moving water out of gravel lakes storage to Upper Arkansas River Basin storage.

Effects by other water users in the basin are the difference between the cumulative effects described in this section and the direct effects described in **Section 4.0**. The distribution of cumulative effects from Aurora and from other entities is shown in **Table 5-15**.

Table 5-15. Distribution of Cumulative Effects for Above Pueblo Gage

Entity	Cumulative Effects (cfs) by Hydrologic Condition		
	Overall Mean	Mean Wet	Mean Dry
Aurora	-13	-2	-17
Other Entities	3	-2	5
Total Cumulative Effects	**-10**	**-4**	**-12**

Notes:
(1) Distribution of cumulative effects of other entities was calculated by subtracting Effects flows from Cumulative Effects flows. However, there could be slight changes in Aurora's operations in 2045 that are due to others' operations. Therefore, actual distribution of effects may vary slightly from those shown.

As mentioned in **Section 3.2.3**, the City of Pueblo and several entities with exchange water rights on the Arkansas River have recently signed an Intergovernmental Agreement regarding a flow management program on the Arkansas through the City of Pueblo (May IGA, 2004). The flow management program defines flow targets at the Above Pueblo gage. **Table 5-16** shows the percent of time that these flow targets are met or exceeded during each simulation. As shown, the percentage is similar under each of the alternatives. **Figure 5-10** shows that target flows are not met during some years. However, Aurora's Proposed Action would not reduce Reclamation's ability to meet or exceed the target flows.

Table 5-16. Pueblo Flow Management Program - Percent of Time Flow Targets Met or Exceeded at Above Pueblo Gage

Percent of Time Flow Targets are Met or Exceeded		
Existing Conditions	No Action Cumulative Effects	Proposed Action Cumulative Effects
63.4	64.0	62.9

Table 5-17. Above Pueblo Gage - Summary of Cumulative Effects

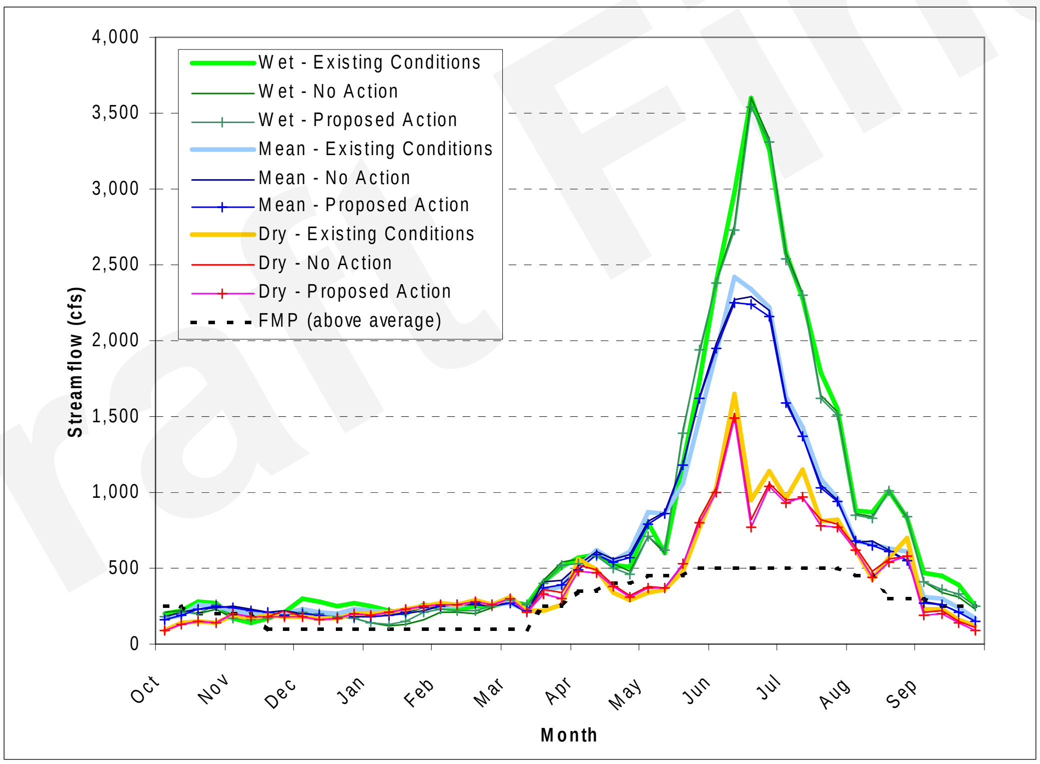
	Simulated Streamflow				
	Existing Conditions	No Action	Proposed Action	Cumulative Effects (1)	
Month	(cfs)	(cfs)	(cfs)	(cfs)	(%)
Overall Mean					
Oct	216	213	207	-6	-3%
Nov	207	227	216	-11	-5%
Dec	215	186	186	0	0%
Jan	225	195	203	7	4%
Feb	260	254	258	4	2%
Mar	304	324	310	-14	-4%
Apr	573	569	545	-23	-4%
May	1,056	1,107	1,096	-11	-1%
Jun	2,221	2,182	2,145	-37	-2%
Jul	1,289	1,254	1,244	-10	-1%
Aug	645	634	626	-8	-1%
Sep	257	230	226	-5	-2%
Average	**622**	**615**	**605**	**-10**	**-2%**
Mean Wet					
Oct	242	213	211	-2	-1%
Nov	171	180	170	-11	-6%
Dec	277	190	190	0	0%
Jan	233	138	156	18	13%
Feb	244	215	230	15	7%
Mar	363	365	362	-3	-1%
Apr	548	544	520	-24	-4%
May	1,059	1,137	1,138	1	0%
Jun	3,034	2,991	2,963	-29	-1%
Jul	2,064	2,029	2,007	-21	-1%
Aug	900	890	884	-6	-1%
Sep	395	326	339	13	4%
Average	**794**	**768**	**764**	**-4**	**-1%**

Table 5-17. Above Pueblo Gage - Summary of Cumulative Effects

Month	Simulated Streamflow			Cumulative Effects (1)	
	Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	(cfs)	(%)
Mean Dry					
Oct	131	128	124	-3	-3%
Nov	181	195	185	-11	-6%
Dec	181	178	178	0	0%
Jan	222	219	219	0	0%
Feb	268	265	265	0	0%
Mar	251	303	286	-17	-6%
Apr	428	435	413	-22	-5%
May	481	516	510	-6	-1%
Jun	1,204	1,118	1,085	-33	-3%
Jul	939	882	864	-18	-2%
Aug	574	564	543	-21	-4%
Sep	188	176	158	-17	-10%
Average	**421**	**415**	**403**	**-12**	**-3%**

Notes:
(1) Cumulative Effects (cfs) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 5-10. Above Pueblo Gage - Simulated Cumulative Effects Streamflow



Moffat Street Gage

A summary of simulated streamflow at the Moffat Street gage is shown in **Table 5-18** and **Figure** 5-11. Effects at the Moffat Street gage are nearly identical to the effects on streamflows at the Above Pueblo gage and are for the same reasons described for the Above Pueblo gage. However, because base streamflow at the Moffat Street gage is less than that at the Above Pueblo gage, percent effects are slightly greater.

As with the Above Pueblo gage, the Proposed Action streamflows are less than for Existing Conditions and for the No Action Alternative. On average, cumulative effects are negative, indicating that No Action streamflows are greater than Proposed Action streamflows.

Table 5-18. Moffat Street Gage - Summary of Cumulative Effects

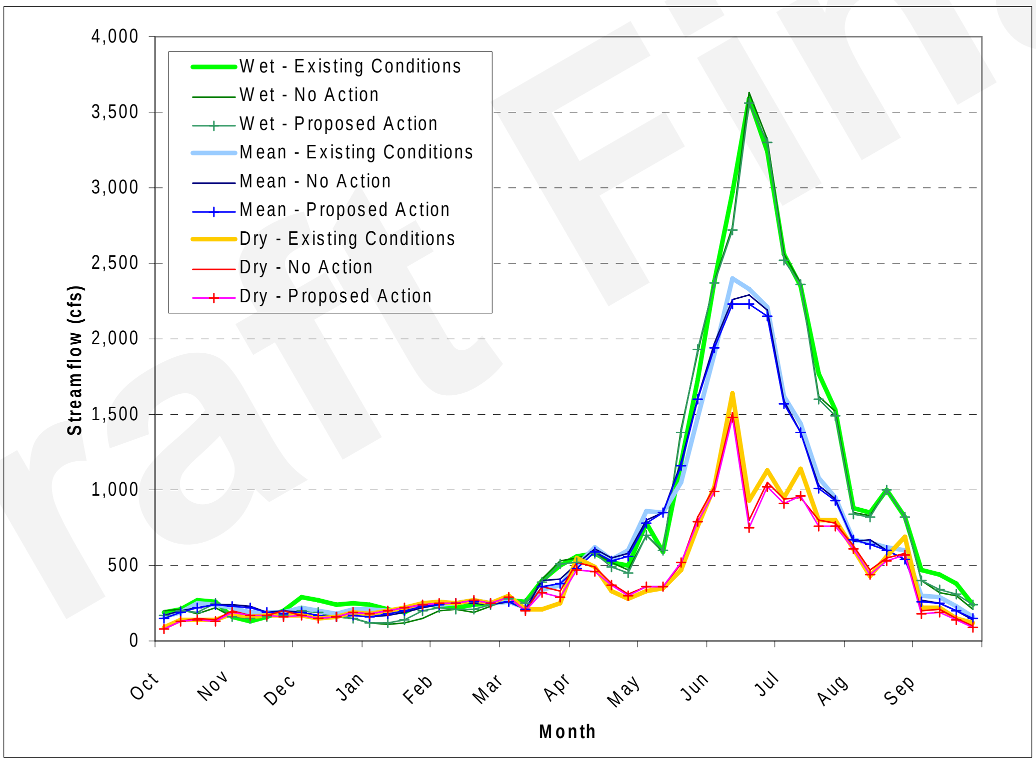
	Simulated Streamflow			Cumulative Effects (1)	
	Existing Conditions	No Action	Proposed Action		
Month	(cfs)	(cfs)	(cfs)	(cfs)	(%)
Overall Mean					
Oct	207	205	199	-6	-3%
Nov	198	218	207	-11	-5%
Dec	203	174	174	0	0%
Jan	214	185	193	7	4%
Feb	252	246	251	4	2%
Mar	294	316	302	-14	-5%
Apr	564	561	537	-24	-4%
May	1,043	1,093	1,083	-11	-1%
Jun	2,207	2,171	2,132	-38	-2%
Jul	1,281	1,246	1,234	-12	-1%
Aug	636	623	615	-8	-1%
Sep	248	221	216	-5	-2%
Average	**612**	**605**	**595**	**-10**	**-2%**
Mean Wet					
Oct	231	203	201	-2	-1%
Nov	160	170	159	-11	-6%
Dec	264	177	177	0	0%
Jan	222	127	145	18	14%
Feb	235	207	222	15	7%
Mar	354	356	352	-3	-1%
Apr	540	537	513	-24	-4%
May	1,048	1,126	1,127	1	0%
Jun	3,020	2,987	2,955	-32	-1%
Jul	2,070	2,035	2,009	-26	-1%
Aug	889	878	871	-6	-1%
Sep	384	313	326	13	4%
Average	**785**	**760**	**755**	**-5**	**-1%**

Table 5-18. Moffat Street Gage - Summary of Cumulative Effects

Month	Simulated Streamflow Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	Cumulative Effects (1) (cfs)	(%)
Mean Dry					
Oct	126	123	119	-3	-3%
Nov	172	186	175	-11	-6%
Dec	168	165	165	0	0%
Jan	211	208	208	0	0%
Feb	259	255	255	0	0%
Mar	242	295	278	-17	-6%
Apr	419	427	405	-22	-5%
May	467	502	496	-6	-1%
Jun	1,190	1,105	1,071	-34	-3%
Jul	927	869	850	-19	-2%
Aug	566	555	534	-21	-4%
Sep	183	171	153	-17	-10%
Average	**411**	**405**	**392**	**-13**	**-3%**

Notes:
(1) Cumulative Effects (cfs) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 5-11. Moffat Street Gage - Simulated Cumulative Effects Streamflow



Avondale Gage

Simulated streamflow at the Avondale Gage is shown in **Table 5-19** and **Figure 5-12**. For most months in the simulation, simulated flow at the Avondale gage is greater under both the Proposed Action and No Action Alternative than for Existing Conditions. This is due to an increase in unused reusable return flows for Colorado Springs Utilities and PBWW under future operations that are either flowing to ROY storage or Lake Meredith. The greatest changes in flow between the Proposed Action and No Action Alternative occur during May and June when Aurora's Rocky Ford yields are not divertible at gravel lakes storage because the storage capacity is full. Releases made from Turquoise Reservoir during 1984 and 1996, when Pueblo Reservoir was full, are also evident in the wet year flows during December.

Simulated Proposed Action and No Action Alternative streamflows are generally higher than those under Existing Conditions. Cumulative Effects are 1 cfs less than Effects at the Avondale gage.

Table 5-19. Avondale Gage - Summary of Cumulative Effects

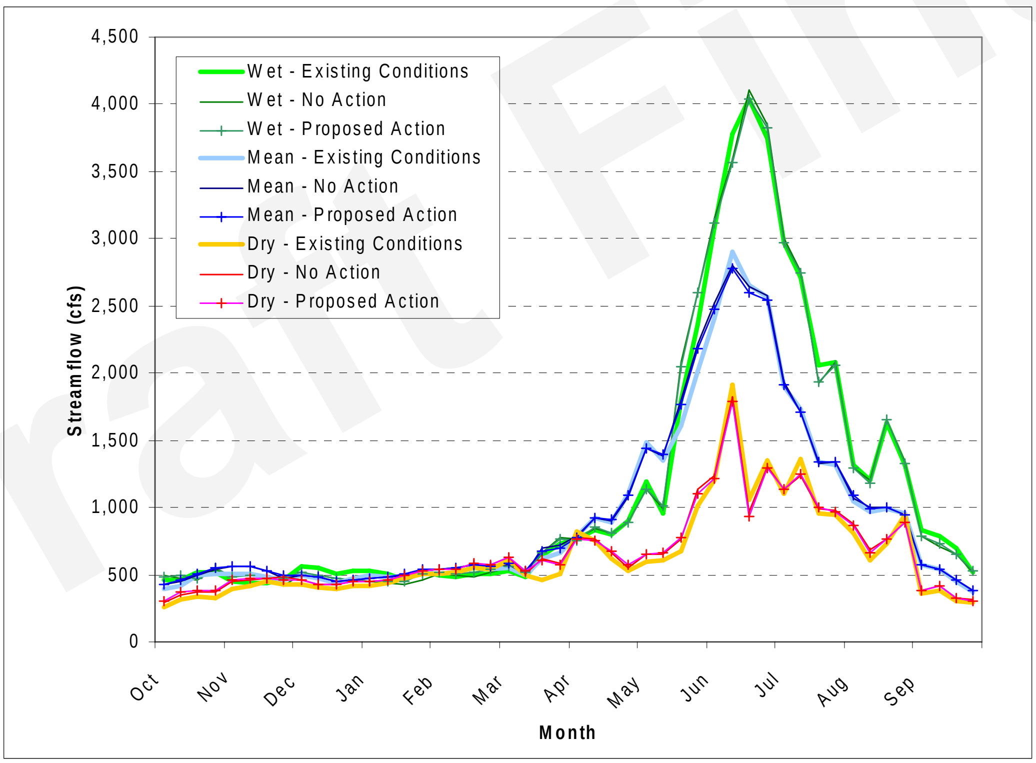
	Simulated Streamflow			Cumulative Effects (1)	
	Existing Conditions	No Action	Proposed Action		
Month	(cfs)	(cfs)	(cfs)	(cfs)	(%)
Overall Mean					
Oct	450	476	482	7	1%
Nov	491	535	539	4	1%
Dec	468	472	474	2	0%
Jan	491	493	501	8	2%
Feb	527	554	560	6	1%
Mar	579	620	618	-2	0%
Apr	920	919	918	-1	0%
May	1,599	1,693	1,680	-13	-1%
Jun	2,632	2,637	2,602	-35	-1%
Jul	1,583	1,585	1,583	-2	0%
Aug	991	1,006	1,007	2	0%
Sep	487	491	493	2	0%
Average	**935**	**957**	**955**	**-2**	**0%**
Mean Wet					
Oct	488	490	498	8	2%
Nov	445	474	482	8	2%
Dec	538	483	487	4	1%
Jan	506	443	461	18	4%
Feb	500	504	520	17	3%
Mar	592	615	622	6	1%
Apr	821	825	824	-1	0%
May	1,553	1,671	1,669	-3	0%
Jun	3,647	3,650	3,616	-34	-1%
Jul	2,469	2,452	2,437	-15	-1%
Aug	1,369	1,372	1,366	-7	-1%
Sep	715	672	681	9	1%
Average	**1,137**	**1,138**	**1,138**	**1**	**0%**

Table 5-19. Avondale Gage - Summary of Cumulative Effects

Month	Simulated Streamflow			Cumulative Effects (1)	
	Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	(cfs)	(%)
Mean Dry					
Oct	312	344	358	13	4%
Nov	423	470	468	-2	0%
Dec	410	440	441	1	0%
Jan	456	485	485	0	0%
Feb	529	559	560	1	0%
Mar	518	586	586	0	0%
Apr	689	695	694	-1	0%
May	711	791	790	-1	0%
Jun	1,392	1,346	1,322	-24	-2%
Jul	1,095	1,091	1,094	2	0%
Aug	769	801	793	-8	-1%
Sep	338	364	360	-4	-1%
Average	**637**	**664**	**663**	**-2**	**0%**

Notes:
(1) Cumulative Effects (cfs) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 5-12. Avondale Gage - Simulated Cumulative Effects Streamflow



Lake Meredith

Simulated reservoir contents at Lake Meredith are shown in **Table 5-20**, **Figure 5-13** and **Figure 5-14**. Reservoir contents at Lake Meredith are affected by both the No Action Alternative and Proposed Action not only because of the ability to exchange Colorado Canal yields upstream, but also because Lake Meredith can serve as an alternate point of diversion for Rocky Ford water and store unused reusable return flows for other entities. Lake Meredith storage is higher in the cumulative effects runs than in the Effects runs, because of the operations of other entities (primarily Colorado Springs Utilities).

Lake Meredith contents are consistently higher under the No Action Alternative than for the Proposed Action. Reservoir contents are higher than Existing Conditions for the Proposed Action alternative and higher than Existing Conditions for the No Action Alternative. Storage is higher for the No Action Alternative than under the Proposed Action because exchanges typically cannot be fully made out of the gravel lakes causing the gravel lakes to remain at full capacity for a significant portion of the year. Therefore, because there is no room to store Rocky Ford water in the gravel lakes, it is diverted and stored at Lake Meredith. In addition, Colorado Canal water cannot be exchanged upstream as early in the year under the No Action Alternative as it can under the both the Existing Conditions and Proposed Action. Therefore, it remains in the system longer and results in higher average reservoir contents. Contract exchanges under Existing Conditions also result in more room in Pueblo Reservoir to receive exchanges from the Colorado Canal system.

Figure 5-13. Lake Meredith - Simulated Cumulative Effects Storage

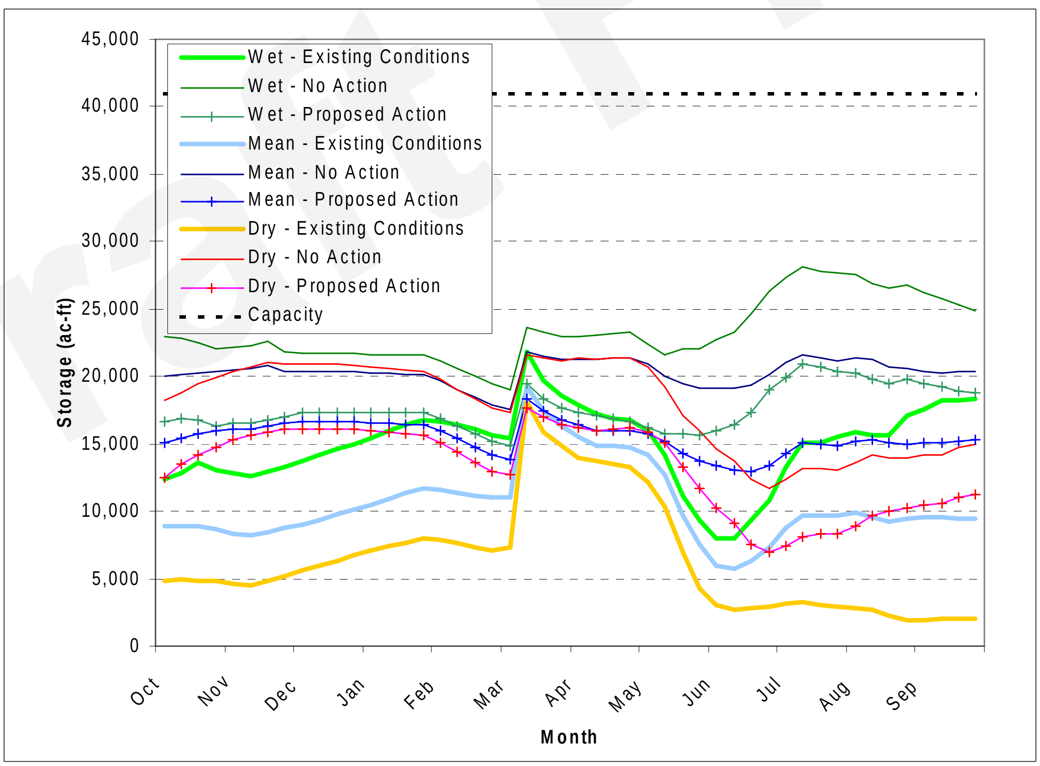
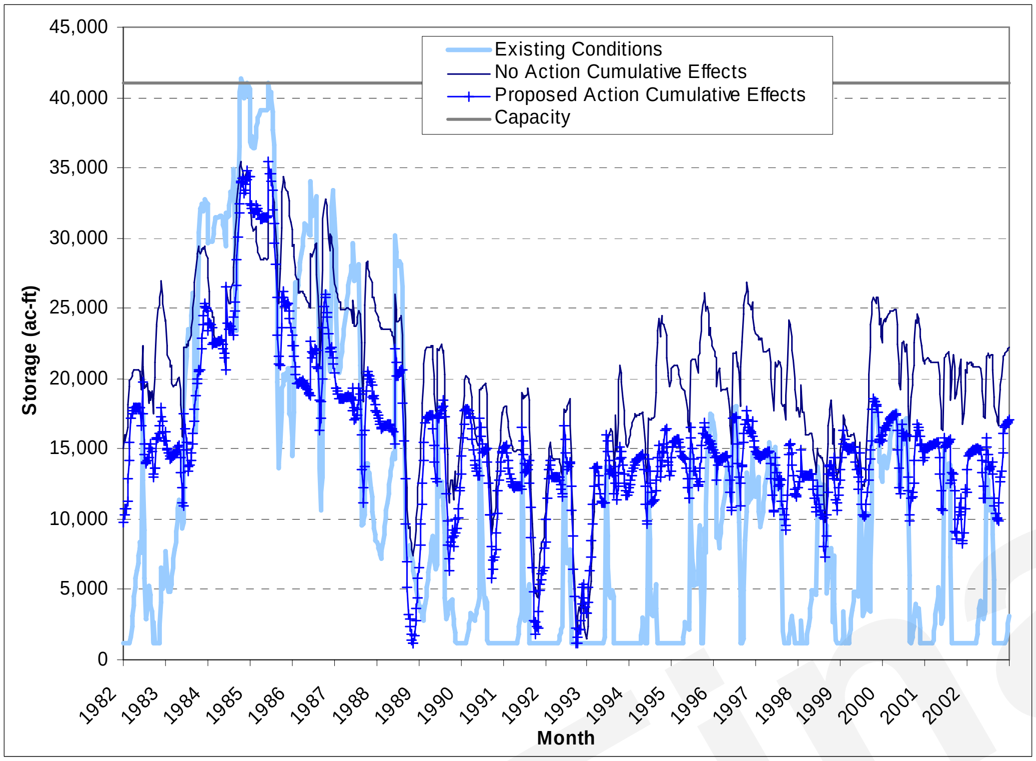


Table 5-20. Lake Meredith - Summary of Cumulative Effects

Month	Simulated Storage			Cumulative Effects (1)	
	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)	(ac-ft)	(%)
Overall Mean					
Oct	8,817	20,185	15,558	-4,627	-23%
Nov	8,413	20,578	16,260	-4,318	-21%
Dec	9,568	20,380	16,645	-3,735	-18%
Jan	11,110	20,209	16,504	-3,705	-18%
Feb	11,275	18,747	15,072	-3,674	-20%
Mar	16,021	20,512	16,604	-3,909	-19%
Apr	14,990	21,320	16,083	-5,237	-25%
May	11,039	19,866	14,722	-5,144	-26%
Jun	6,347	19,445	13,219	-6,226	-32%
Jul	9,416	21,275	14,813	-6,462	-30%
Aug	9,561	20,947	15,127	-5,820	-28%
Sep	9,496	20,339	15,140	-5,199	-26%
Average	**10,504**	**20,317**	**15,479**	**-4,838**	**-24%**
Mean Wet					
Oct	12,982	22,567	16,676	-5,891	-26%
Nov	12,920	22,218	16,715	-5,503	-25%
Dec	14,404	21,710	17,325	-4,385	-20%
Jan	16,161	21,639	17,308	-4,331	-20%
Feb	16,183	20,328	16,030	-4,297	-21%
Mar	18,854	22,226	17,581	-4,645	-21%
Apr	17,206	23,121	16,981	-6,140	-27%
May	12,648	22,020	15,823	-6,197	-28%
Jun	9,008	24,261	17,205	-7,055	-29%
Jul	14,736	27,735	20,467	-7,268	-26%
Aug	16,062	26,947	19,821	-7,126	-26%
Sep	18,088	25,560	19,101	-6,459	-25%
Average	**14,938**	**23,361**	**17,586**	**-5,775**	**-25%**
Mean Dry					
Oct	4,900	19,082	13,753	-5,329	-28%
Nov	4,815	20,761	15,741	-5,020	-24%
Dec	6,170	20,898	16,100	-4,798	-23%
Jan	7,552	20,549	15,804	-4,746	-23%
Feb	7,472	18,715	14,004	-4,711	-25%
Mar	13,989	20,359	15,930	-4,429	-22%
Apr	13,619	21,359	16,114	-5,245	-25%
May	8,460	18,261	13,975	-4,286	-23%
Jun	2,842	13,124	8,459	-4,665	-36%
Jul	3,096	12,936	8,061	-4,876	-38%
Aug	2,426	13,944	9,683	-4,261	-31%
Sep	1,983	14,523	10,830	-3,693	-25%
Average	**6,444**	**17,876**	**13,204**	**-4,671**	**-26%**

Notes:
(1) Cumulative Effects (ac-ft) = Proposed Action - No Action simulated storage. Effects (%) = (Proposed Action - No Action simulated storage)/No Action simulated storage.

Figure 5-14. Lake Meredith - Simulated Cumulative Effects Storage Time Series



Lake Henry

Simulated reservoir contents at Lake Henry are shown in **Table 5-21**, **Figure 5-15**, and **Figure 5-16**. Storage contents for the Proposed Action and No Action Alternative are higher than under Existing Conditions. As with Lake Meredith, Lake Henry is part of the Colorado Canal system and effects at the reservoir are for the same reasons as the effects at Lake Meredith. The modeling methodology assumes that all effects on reservoir contents in the Colorado Canal system occur at Lake Meredith before they occur at Lake Henry. As described in **Section 2.1**, the Quarter-Monthly Model reports the combined storage at Lake Henry and Lake Meredith. Effects on Lake Henry storage contents will only occur when Lake Meredith is full, due to the algorithm used to distribute the contents to Lake Henry and to Lake Meredith. Lake Meredith never fills for the Proposed Action, and as a result, there are no cumulative effects for Lake Henry.

Table 5-21. Lake Henry - Summary of Cumulative Effects

Month	Simulated Storage			Cumulative Effects (1)	
	Existing Conditions (ac-ft)	No Action (ac-ft)	Proposed Action (ac-ft)	(ac-ft)	(%)
Overall Mean					
Oct	2,925	3,750	3,750	0	0%
Nov	2,855	3,540	3,540	0	0%
Dec	3,293	3,581	3,581	0	0%
Jan	3,672	3,716	3,716	0	0%
Feb	5,139	5,139	5,139	0	0%
Mar	6,674	6,663	6,663	0	0%
Apr	6,870	6,870	6,870	0	0%
May	6,278	6,570	6,570	0	0%
Jun	5,412	6,280	6,280	0	0%
Jul	5,177	5,789	5,789	0	0%
Aug	4,372	5,146	5,146	0	0%
Sep	3,353	4,393	4,393	0	0%
Average	**4,668**	**5,120**	**5,120**	**0**	**0%**
Mean Wet					
Oct	3,676	3,942	3,942	0	0%
Nov	3,507	3,678	3,678	0	0%
Dec	3,663	3,670	3,670	0	0%
Jan	3,741	3,741	3,741	0	0%
Feb	5,015	5,015	5,015	0	0%
Mar	6,622	6,622	6,622	0	0%
Apr	6,907	6,907	6,907	0	0%
May	6,671	6,934	6,934	0	0%
Jun	6,562	7,196	7,196	0	0%
Jul	6,997	7,116	7,116	0	0%
Aug	6,662	6,662	6,662	0	0%
Sep	5,622	5,969	5,969	0	0%
Average	**5,470**	**5,621**	**5,621**	**0**	**0%**
Mean Dry					
Oct	2,125	2,529	2,529	0	0%
Nov	1,889	2,456	2,456	0	0%
Dec	2,186	2,501	2,501	0	0%
Jan	2,710	2,729	2,729	0	0%
Feb	4,508	4,508	4,508	0	0%
Mar	6,097	6,097	6,097	0	0%
Apr	5,920	5,920	5,920	0	0%
May	4,801	5,101	5,101	0	0%
Jun	3,432	4,507	4,507	0	0%
Jul	2,734	3,736	3,736	0	0%
Aug	1,928	2,966	2,966	0	0%
Sep	1,410	2,578	2,578	0	0%
Average	**3,312**	**3,802**	**3,802**	**0**	**0%**

Notes:
(1) Cumulative Effects (ac-ft) = Proposed Action - No Action simulated storage. Effects (%) = (Proposed Action - No Action simulated storage)/No Action simulated storage.

Figure 5-15. Lake Henry - Simulated Cumulative Effects Storage

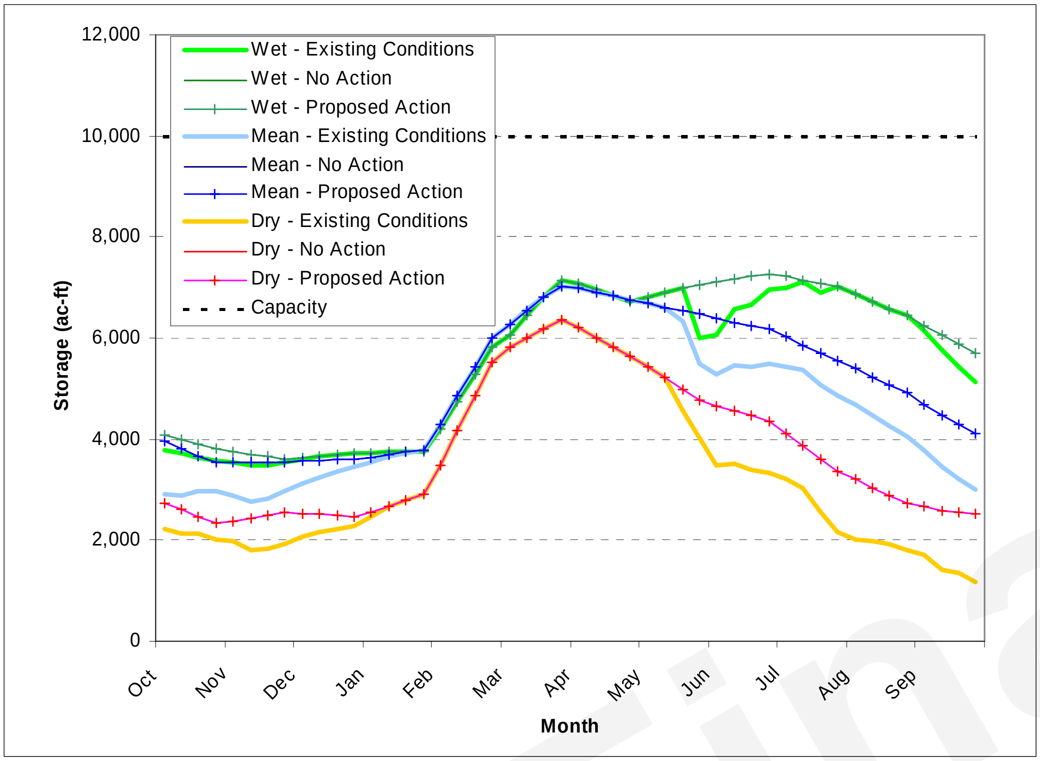
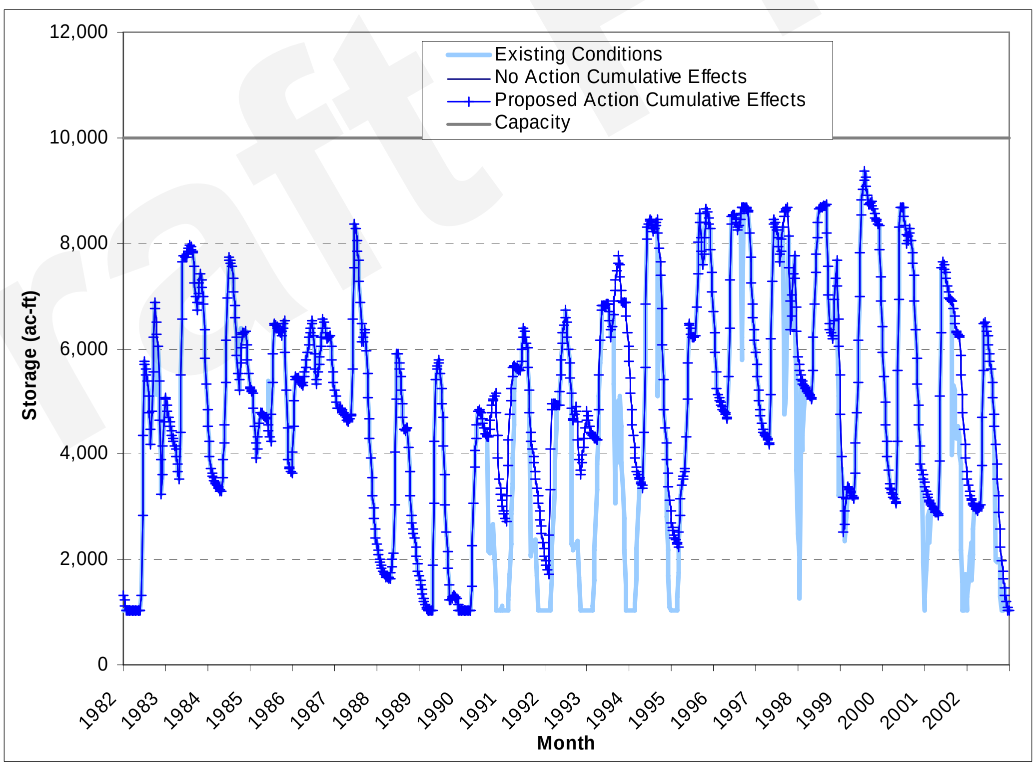


Figure 5-16. Lake Henry - Simulated Cumulative Effects Storage Time Series



Holbrook Reservoir

Simulated Quarter-Monthly Model results for Holbrook Reservoir are shown in **Table 5-22**, **Figure 5-17**, and **Figure 5-18**. The increase in storage seen under the Proposed Action is indicative of Restoration of yield (ROY) storage in Holbrook Reservoir that is unique to the Proposed Action. Simulated storage under the No Action Alternative is identical to storage under Existing Conditions, because Aurora would not use ROY storage under the Existing Conditions or the Proposed Action.

The capacities given in **Table 5-22**, **Figure 5-17**, and **Figure 5-18** are equal to Aurora's and Colorado Springs Utilities' simulated storage in Holbrook Reservoir in addition to the historical storage in the reservoir. Because the model does not restrict storage in Aurora's ROY account based on historical storage in Holbrook Reservoir, the storage contents shown in the table and figures exceed the actual capacity of Holbrook Reservoir (6,200 acre-feet) for some months. Contents in **Figure 5-18** are not provided prior to 1988, because historical Holbrook Reservoir contents are only available for 1989 to present.

Figure 5-17. Holbrook Reservoir - Simulated Cumulative Effects Storage

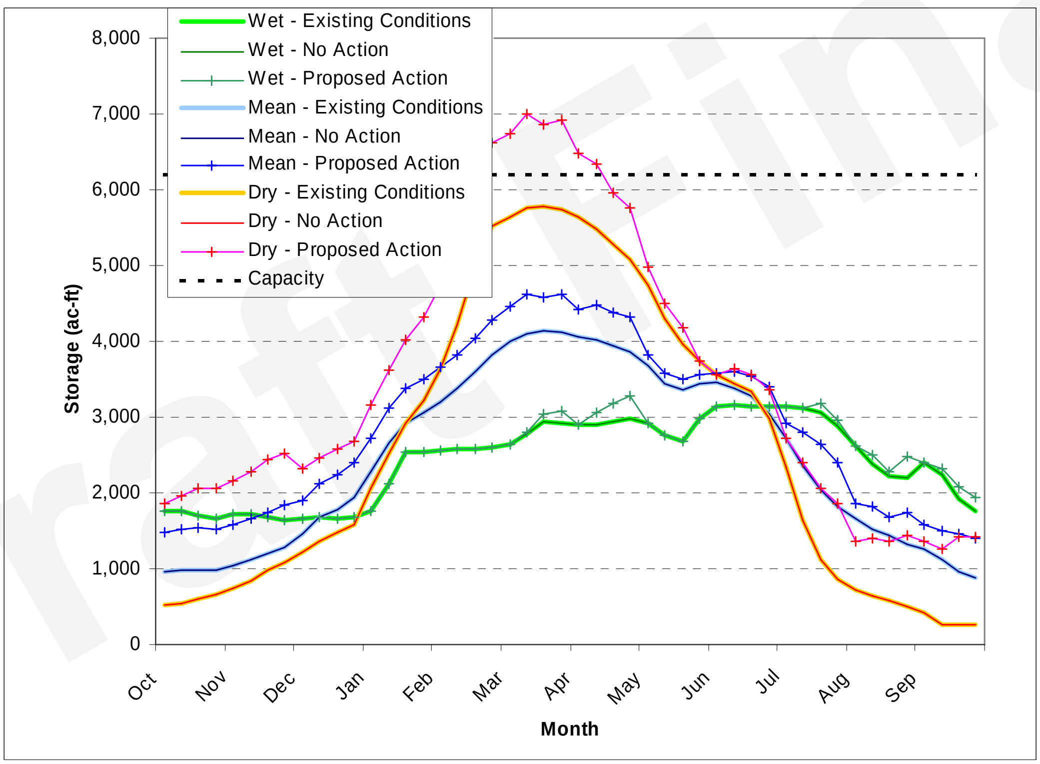


Table 5-22. Holbrook Reservoir - Summary of Cumulative Effects

	Simulated Storage (1)				
	Existing Conditions	No Action	Proposed Action	Cumulative Effects (2)	
Month	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(%)
Overall Mean					
Oct	974	974	1,517	543	56%
Nov	1,160	1,160	1,708	548	47%
Dec	1,713	1,713	2,164	451	26%
Jan	2,730	2,730	3,181	451	17%
Feb	3,502	3,502	3,953	451	13%
Mar	4,096	4,096	4,571	476	12%
Apr	3,969	3,969	4,396	427	11%
May	3,473	3,473	3,619	146	4%
Jun	3,287	3,287	3,532	245	7%
Jul	2,230	2,230	2,688	458	21%
Aug	1,481	1,481	1,773	292	20%
Sep	1,052	1,052	1,491	439	42%
Average	**2,472**	**2,472**	**2,883**	**411**	**17%**
Mean Wet					
Oct	1,719	1,719	1,719	0	0%
Nov	1,690	1,690	1,690	0	0%
Dec	1,672	1,672	1,672	0	0%
Jan	2,242	2,242	2,242	0	0%
Feb	2,577	2,577	2,577	0	0%
Mar	2,820	2,820	2,896	75	3%
Apr	2,927	2,927	3,099	172	6%
May	2,833	2,833	2,833	0	0%
Jun	3,144	3,144	3,144	0	0%
Jul	3,048	3,048	3,099	51	2%
Aug	2,353	2,353	2,469	116	5%
Sep	2,082	2,082	2,184	102	5%
Average	**2,426**	**2,426**	**2,469**	**43**	**2%**
Mean Dry					
Oct	580	580	1,985	1,405	242%
Nov	910	910	2,348	1,438	158%
Dec	1,411	1,411	2,511	1,099	78%
Jan	2,680	2,680	3,780	1,099	41%
Feb	4,597	4,597	5,697	1,099	24%
Mar	5,731	5,731	6,878	1,147	20%
Apr	5,369	5,369	6,137	768	14%
May	4,187	4,187	4,350	163	4%
Jun	3,327	3,327	3,527	200	6%
Jul	1,496	1,496	2,257	761	51%
Aug	614	614	1,392	778	127%
Sep	299	299	1,368	1,069	358%
Average	**2,600**	**2,600**	**3,519**	**919**	**35%**

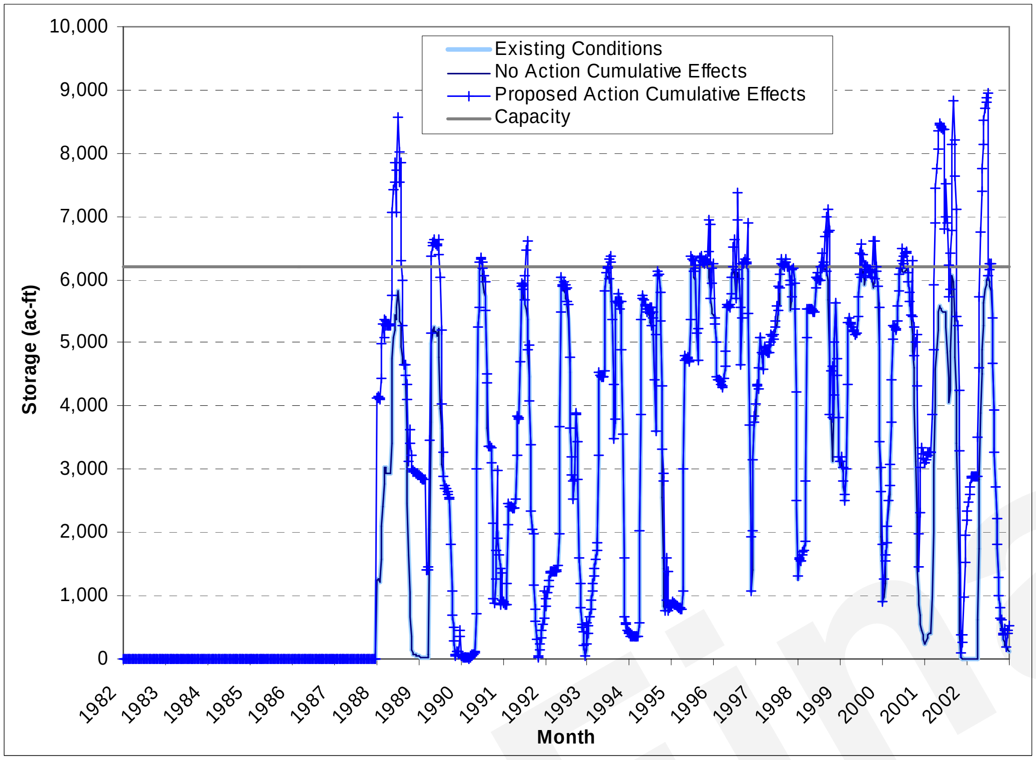
Notes:

(1) Simulated storage for Holbrook Reservoir is the sum of Aurora's simulated storage and the historical contents of the reservoir.

(2) Cumulative Effects (ac-ft) = Proposed Action - No Action simulated storage. Effects (%) = (Proposed Action - No Action simulated storage)/No Action simulated storage.

(3) Period-of-Record: 1988 to 2002.

Figure 5-18. Holbrook Reservoir - Simulated Cumulative Effects Storage Time Series



La Junta

Simulated streamflow at the La Junta Gage is shown in **Table 5-23** and **Figure 5-19**. The La Junta gage is downstream of the exchange reaches and diversion points for all of Aurora's water rights in both the No Action Alternative and Proposed Action. As a result, the Quarter-Monthly Model typically shows little change in flow at the La Junta gage for both alternatives. Streamflows are slightly less under the No Action Alternative and the Proposed Action than under Existing Conditions, except for mean dry years. Effects range from small negative values to small positive values.

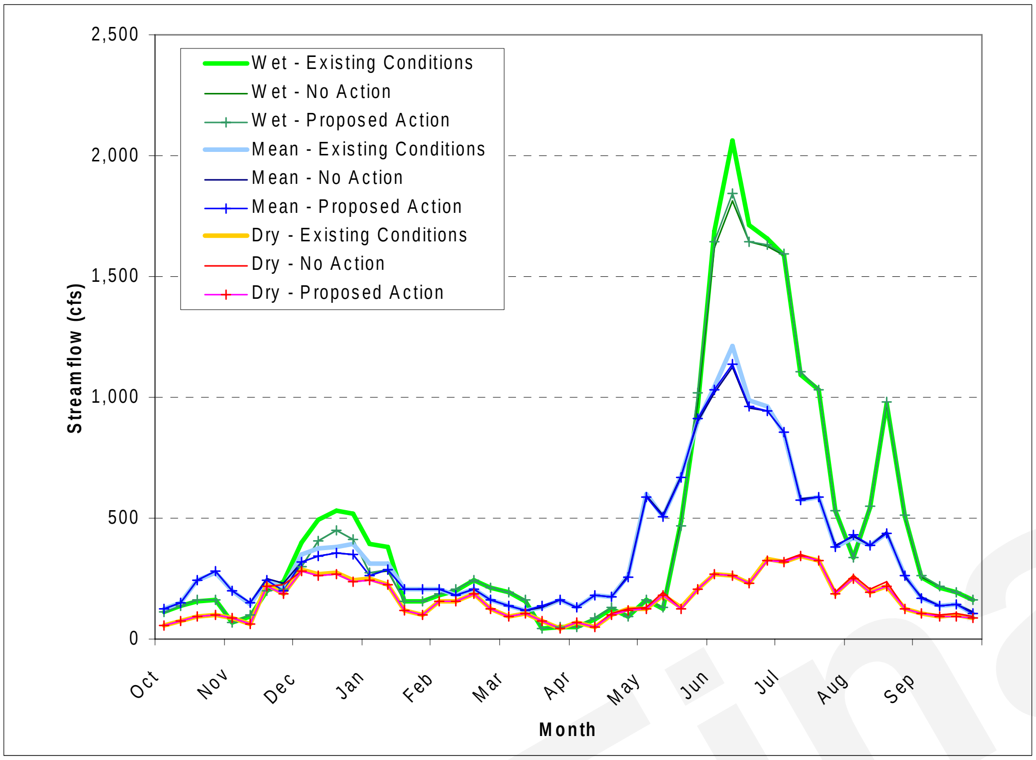
Differences in flow between the Proposed Action and No Action Alternative are due to increased diversions of Rocky Ford water under the Proposed Action due to the increased ability to move water from Pueblo Reservoir to Upper Arkansas River Basin storage. On average, Cumulative Effects are 2 cfs greater than Effects at the La Junta gage.

Table 5-23. La Junta Gage - Summary of Cumulative Effects

	Simulated Streamflow				
Month	Existing Conditions (cfs)	No Action (cfs)	Proposed Action (cfs)	Cumulative Effects (1) (cfs)	(%)
Overall Mean					
Oct	195	196	196	0	0%
Nov	197	205	198	-6	-3%
Dec	374	342	342	0	0%
Jan	262	242	243	1	0%
Feb	188	189	189	0	0%
Mar	138	137	139	1	1%
Apr	184	185	184	-2	-1%
May	664	663	659	-4	-1%
Jun	1,057	1,017	1,022	5	1%
Jul	606	610	607	-3	-1%
Aug	379	382	384	2	0%
Sep	140	143	140	-3	-2%
Average	**365**	**359**	**359**	**-1**	**0%**
Mean Wet					
Oct	141	142	142	0	0%
Nov	146	143	139	-5	-3%
Dec	485	393	393	0	0%
Jan	275	220	221	1	1%
Feb	210	212	212	0	0%
Mar	112	115	115	0	0%
Apr	86	89	89	-1	-1%
May	419	423	426	4	1%
Jun	1,784	1,677	1,693	17	1%
Jul	1,078	1,081	1,083	2	0%
Aug	594	594	597	3	1%
Sep	208	211	211	0	0%
Average	**461**	**442**	**443**	**2**	**0%**
Mean Dry					
Oct	80	81	80	0	0%
Nov	137	144	134	-9	-7%
Dec	268	265	265	0	0%
Jan	176	174	174	0	0%
Feb	155	155	155	0	0%
Mar	81	81	81	0	0%
Apr	83	85	83	-3	-3%
May	161	164	158	-6	-4%
Jun	273	272	272	0	0%
Jul	297	303	296	-7	-2%
Aug	201	209	200	-9	-4%
Sep	98	100	96	-4	-4%
Average	**167**	**169**	**166**	**-3**	**-2%**

Notes:
(1) Cumulative Effects (cfs) = Proposed Action - No Action simulated streamflow. Effects (%) = (Proposed Action - No Action simulated streamflow)/No Action simulated streamflow.

Figure 5-19. La Junta Gage - Simulated Cumulative Effects Streamflow



5.3 Peak Flow Analysis

As previously discussed, the Quarter-Monthly Model simulates streamflow on a quarter-monthly (approximately weekly) time-step. Therefore, the streamflows produced by the Quarter-Monthly Model represent the average streamflow for the time-step. Actual peak-flow events occur on a much shorter time-step. Peak flow is the maximum instantaneous discharge, which typically occurs on an hourly, or even sub-hourly, basis. Because of the difference between the Quarter-Monthly Model time-step and the occurrences of peak discharge, the Quarter-Monthly Model cannot be used to infer changes in peak-discharge.

Both the Proposed Action and No Action Alternative consider exchanges of water from downstream locations to upstream locations. By nature of this operation, streamflows are reduced within the exchange reach by the amount of the exchange. Therefore, the Proposed Action could potentially slightly decrease peak flows within the exchange reaches.

There will not be an appreciable change in peak flows in the Upper Arkansas River Basin as a result of the proposed exchanges, because of the nature of peak flows in the upper basin. The majority of peak flows in the Upper Arkansas River Basin occur as a result of precipitation runoff that accrues to the Arkansas River between the upper basin reservoirs and Pueblo Reservoir. A portion of the streamflow contributing to peak flows accrues upstream of Turquoise Reservoir and Twin Lakes. Although the reservoirs do provide some incidental flood control, since there is no dedicated flood control space in either reservoir, the amount of impact these reservoirs have on peak flow is small. As shown in **Table 3-31**, the 100-year peak flow in the Upper Arkansas River is approximately 12,900 at the Portland gage, while maximum exchange rates by Aurora are approximately 300 cfs. Therefore, the proposed exchanges will not result in an appreciable reduction in peak flows in the Arkansas River above Pueblo Reservoir.

Similarly, the Proposed Action will not result in an appreciable change in peak flows in the Lower Arkansas River Basin. Pueblo Reservoir contains dedicated flood control storage space of 26,991 acre-feet. In addition, the 66,000 acre-feet joint use pool is used for flood control purposes from April 15 to November 1. Aurora would not store water in either the dedicated flood control space or in the joint use pool between April 15 to November 1 in Pueblo Reservoir, thus operations of the flood control pool are not affected by the Proposed Action or No Action Alternative. Additionally, the majority of peak flows in the lower basin occur as a result of precipitation runoff that accrues to the Arkansas River from Fountain Creek and from overland flow directly to the Arkansas River downstream of the Fountain Creek confluence. As shown in **Table 3-31**, the 100-year peak flow in the Lower Arkansas River is approximately 20,900 at the Avondale gage, while maximum exchange rates by Aurora are approximately 300 cfs. Therefore, the proposed exchanges will not result in an appreciable reduction in peak flows in the Arkansas River below Pueblo Reservoir.

5.4 Stream Hydraulics and Geomorphology

Both the Proposed Action and No Action Alternative affect streamflows within the study area. Changes in streamflow result in changes to both stream hydraulics and stream geomorphology. Hydraulics and geomorphology are closely related, as changes in hydraulic parameters such as flow velocity and flow distribution can have effects on overall stream geomorphology. This section presents a summary of pertinent hydraulic parameters, as well as a summary of how changes in those parameters could affect geomorphology.

5.4.1 Stream Hydraulics

The simulated streamflow and reservoir storage contents, along with existing rating curves available at those locations, were used to estimate river stage at streamgage locations and reservoir water surface elevation and surface area for those reservoirs in the study area. In addition, flow duration curves and velocity duration curves were developed at streamflow locations where cross-section information was available.

5.4.1.1 Arkansas River Above Pueblo Reservoir

This section summarizes net effects for key locations above Pueblo Reservoir, including Turquoise Reservoir, Lake Fork, Lake Creek and the Wellsville gage.

Turquoise Reservoir

Summary data for the cumulative effects on Turquoise Reservoir pool elevation are shown in **Table 5-24** and **Figure 5-20**. There is generally a decrease in reservoir pool elevation as a result of the Proposed Action and No Action Alternative, with a larger effect on elevation resulting from the No Action Alternative. Cumulative effects are positive except for mean dry years when cumulative effects range from slightly negative to slightly positive differences. Simulated elevations under the Proposed Action and the No Action Alternative are within the range of elevation for the Turquoise Reservoir normal operating pool (9,775.4 to 9,869.4 feet).

Data showing cumulative effects on Turquoise Reservoir surface area are shown in **Table 5-25**, **Figure 5-21**, and **Figure 5-22**. There is generally a decrease in reservoir surface area for the No Action Alternative and the Proposed Action except during mean dry years. As with Turquoise Reservoir simulated elevations, simulated water surface areas are within the range of the normal operating pool.

Table 5-24. Turquoise Reservoir Elevation - Cumulative Effects

	Simulated Elevation			Cumulative Effects (1)	
	Existing Conditions	No Action	Proposed Action		
Month	(feet)	(feet)	(feet)	(feet)	(%)
Overall Mean					
Oct	9,858.27	9,855.90	9,857.35	1.44	1%
Nov	9,856.25	9,853.92	9,855.26	1.35	1%
Dec	9,853.36	9,851.26	9,851.94	0.68	1%
Jan	9,851.19	9,848.86	9,849.31	0.45	0%
Feb	9,848.18	9,845.51	9,846.76	1.25	1%
Mar	9,842.15	9,840.08	9,841.51	1.43	2%
Apr	9,830.48	9,830.51	9,831.76	1.25	2%
May	9,827.51	9,826.52	9,827.75	1.23	2%
Jun	9,850.77	9,849.82	9,850.04	0.21	0%
Jul	9,861.51	9,860.58	9,860.86	0.27	0%
Aug	9,860.80	9,859.56	9,860.20	0.64	1%
Sep	9,859.25	9,857.85	9,858.57	0.73	1%
Average	**9,849.98**	**9,848.37**	**9,849.28**	**0.91**	**1%**
Mean Wet					
Oct	9,859.33	9,855.50	9,857.04	1.54	1%
Nov	9,858.00	9,853.75	9,854.63	0.88	1%
Dec	9,855.54	9,850.54	9,851.21	0.67	1%
Jan	9,854.50	9,847.21	9,849.04	1.83	2%
Feb	9,852.88	9,843.83	9,847.33	3.50	4%
Mar	9,846.63	9,838.17	9,842.79	4.63	5%
Apr	9,831.04	9,828.33	9,831.79	3.46	4%
May	9,828.29	9,823.83	9,827.42	3.58	5%
Jun	9,855.00	9,851.33	9,851.83	0.50	0%
Jul	9,868.54	9,866.33	9,866.63	0.29	0%
Aug	9,868.75	9,866.29	9,866.92	0.63	1%
Sep	9,868.00	9,865.83	9,866.33	0.50	0%
Average	**9,853.88**	**9,849.25**	**9,851.08**	**1.83**	**2%**
Mean Dry					
Oct	9,854.50	9,852.67	9,854.38	1.71	2%
Nov	9,851.83	9,850.71	9,852.25	1.54	2%
Dec	9,849.08	9,848.92	9,849.58	0.67	1%
Jan	9,846.67	9,847.29	9,846.71	-0.58	-1%
Feb	9,843.58	9,844.46	9,843.38	-1.08	-1%
Mar	9,838.96	9,840.04	9,838.50	-1.54	-2%
Apr	9,829.38	9,830.63	9,829.46	-1.17	-1%
May	9,825.25	9,826.42	9,825.33	-1.08	-1%
Jun	9,843.83	9,844.54	9,843.79	-0.75	-1%
Jul	9,850.58	9,850.83	9,850.71	-0.13	0%
Aug	9,848.54	9,848.46	9,848.63	0.17	0%
Sep	9,846.17	9,845.67	9,845.63	-0.04	0%
Average	**9,844.03**	**9,844.22**	**9,844.03**	**-0.19**	**0%**

Notes:
(1) Cumulative Effects (feet) = Proposed Action - No Action simulated elevation. Effects (%) = (Proposed Action - No Action simulated elevation)/No Action simulated depth.

Table 5-25. Turquoise Reservoir Area - Proposed Action Cumulative Effects

Month	Simulated Area: Existing Conditions (acres)	Simulated Area: No Action (acres)	Simulated Area: Proposed Action (acres)	Cumulative Effects (1) (acres)	Cumulative Effects (1) (%)
Overall Mean					
Oct	1,707.4	1,686.0	1,697.9	11.9	1%
Nov	1,691.0	1,669.3	1,679.1	9.7	1%
Dec	1,668.6	1,649.2	1,652.6	3.4	0%
Jan	1,652.4	1,631.0	1,631.0	0.0	0%
Feb	1,627.1	1,603.1	1,609.9	6.8	0%
Mar	1,567.3	1,548.1	1,558.3	10.3	1%
Apr	1,428.9	1,429.7	1,443.5	13.8	1%
May	1,391.1	1,378.7	1,392.8	14.0	1%
Jun	1,642.5	1,634.2	1,636.2	2.0	0%
Jul	1,727.8	1,721.0	1,723.0	2.0	0%
Aug	1,722.0	1,713.2	1,716.7	3.4	0%
Sep	1,709.7	1,699.9	1,704.1	4.3	0%
Average	**1,628.0**	**1,613.6**	**1,620.4**	**6.8**	**0%**
Mean Wet					
Oct	1,715.2	1,673.2	1,688.1	14.9	1%
Nov	1,704.5	1,656.2	1,663.3	7.1	0%
Dec	1,686.9	1,632.9	1,635.9	3.0	0%
Jan	1,678.9	1,608.3	1,618.1	9.8	1%
Feb	1,664.9	1,580.8	1,606.4	25.5	2%
Mar	1,610.1	1,525.9	1,567.2	41.3	3%
Apr	1,438.0	1,403.1	1,447.0	43.9	3%
May	1,402.8	1,345.7	1,389.5	43.9	3%
Jun	1,677.0	1,643.6	1,648.0	4.4	0%
Jul	1,785.3	1,768.1	1,771.1	3.1	0%
Aug	1,787.0	1,768.0	1,772.9	4.9	0%
Sep	1,780.7	1,764.3	1,769.6	5.3	0%
Average	**1,660.9**	**1,614.2**	**1,631.4**	**17.3**	**1%**
Mean Dry					
Oct	1,678.2	1,664.3	1,677.0	12.7	1%
Nov	1,656.0	1,648.8	1,658.5	9.7	1%
Dec	1,633.5	1,634.3	1,635.8	1.5	0%
Jan	1,615.6	1,621.8	1,611.3	-10.5	-1%
Feb	1,589.0	1,596.8	1,580.8	-16.0	-1%
Mar	1,536.1	1,548.2	1,528.8	-19.4	-1%
Apr	1,413.6	1,430.7	1,414.6	-16.1	-1%
May	1,362.2	1,377.6	1,363.5	-14.1	-1%
Jun	1,579.0	1,587.4	1,580.4	-6.9	0%
Jul	1,633.6	1,637.6	1,634.7	-2.9	0%
Aug	1,616.5	1,617.7	1,615.3	-2.4	0%
Sep	1,597.8	1,596.3	1,591.3	-5.0	0%
Average	**1,575.9**	**1,580.1**	**1,574.3**	**-5.8**	**0%**

Notes:

(1) Cumulative Effects (acres) = Proposed Action - No Action simulated area. Effects (%) = (Proposed Action - No Action simulated area)/No Action simulated area.

Figure 5-20. Turquoise Reservoir - Simulated Cumulative Effects Elevation

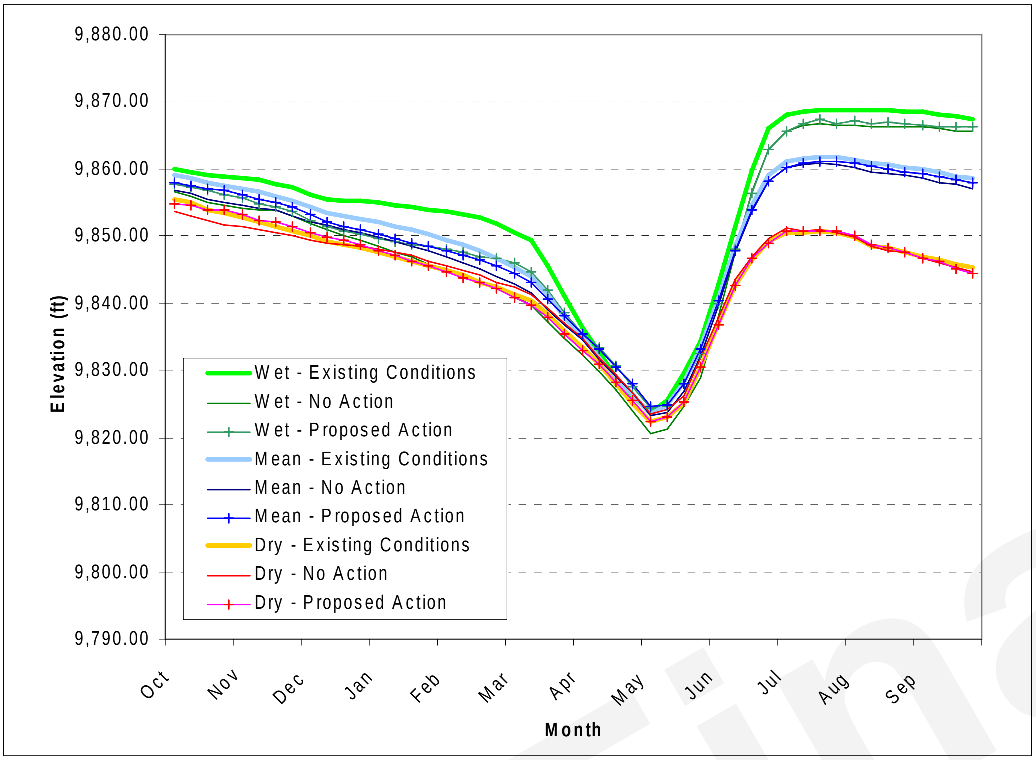


Figure 5-21. Turquoise Reservoir - Simulated Cumulative Effects Surface Area

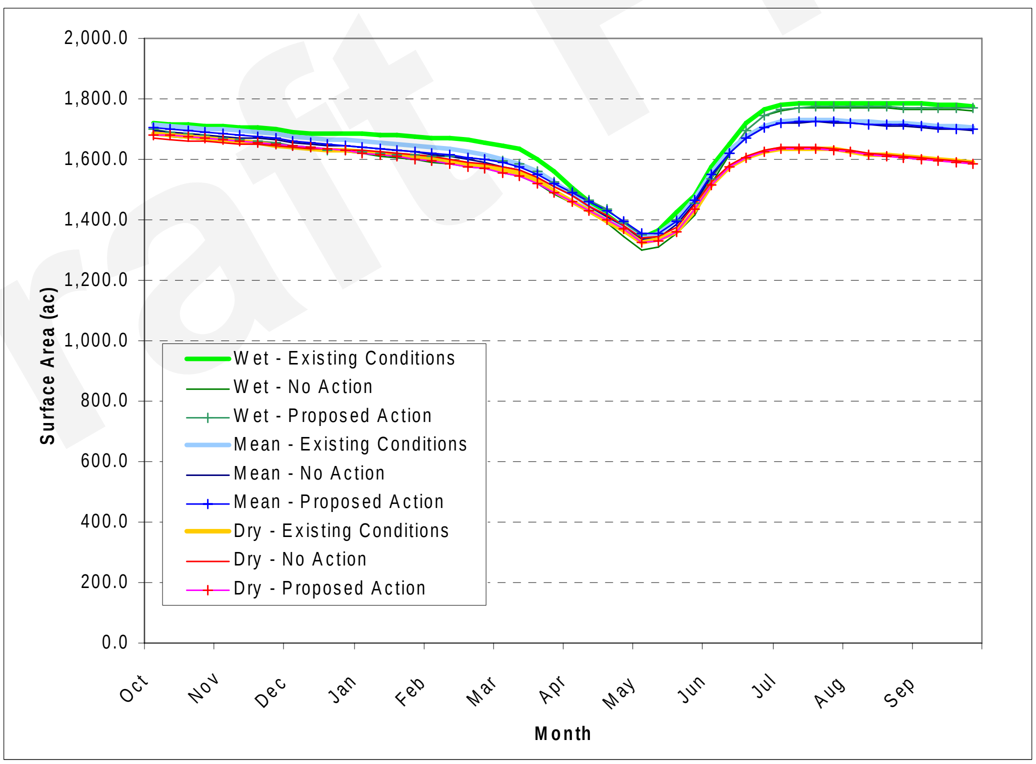
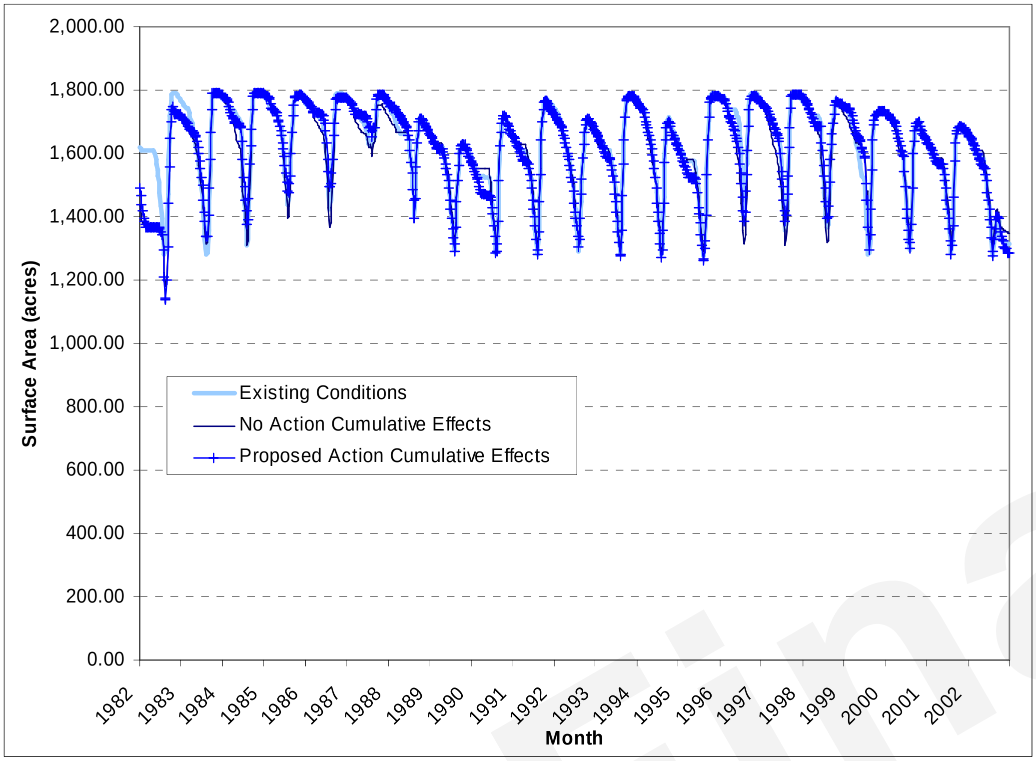


Figure 5-22. Turquoise Reservoir - Simulated Cumulative Effects Surface Area Time Series



Lake Fork

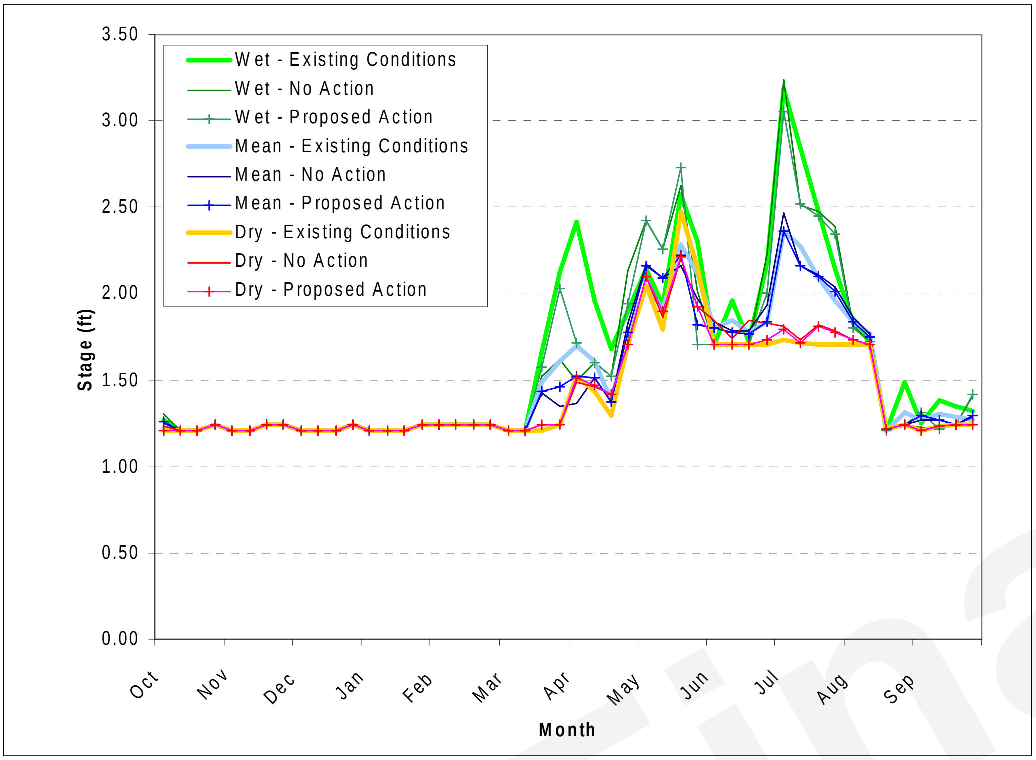
Summary data for the cumulative effects on stage for the Lake Fork gage are shown in **Table 5-26** and **Figure 5-23**. Stages under the No Action Alternative and Proposed Action are generally lower than stages under Existing Conditions, except during mean dry years.

Table 5-26. Lake Fork Gage Stage - Summary of Cumulative Effects

Month	Simulated Stage			Cumulative Effects (1)	
	Existing Conditions	No Action	Proposed Action		
	(feet)	(feet)	(feet)	(feet)	(%)
Overall Mean					
Oct	1.22	1.23	1.23	0.00	0%
Nov	1.22	1.22	1.22	0.00	0%
Dec	1.21	1.21	1.21	0.00	0%
Jan	1.21	1.21	1.21	0.00	0%
Feb	1.24	1.24	1.24	0.00	0%
Mar	1.38	1.29	1.33	0.03	4%
Apr	1.61	1.52	1.55	0.02	2%
May	2.09	2.10	2.07	-0.02	-2%
Jun	1.82	1.84	1.80	-0.04	-3%
Jul	2.17	2.19	2.16	-0.03	-2%
Aug	1.53	1.52	1.51	-0.01	-1%
Sep	1.28	1.27	1.27	0.01	1%
Average	**1.50**	**1.49**	**1.48**	**0.00**	**0%**
Mean Wet					
Oct	1.23	1.24	1.21	-0.02	-3%
Nov	1.22	1.22	1.22	0.00	0%
Dec	1.21	1.21	1.21	0.00	0%
Jan	1.21	1.21	1.21	0.00	0%
Feb	1.24	1.24	1.24	0.00	0%
Mar	1.55	1.39	1.50	0.11	13%
Apr	1.99	1.69	1.69	0.01	1%
May	2.24	2.33	2.28	-0.05	-3%
Jun	1.89	1.84	1.78	-0.06	-4%
Jul	2.66	2.65	2.59	-0.06	-3%
Aug	1.56	1.50	1.49	0.00	0%
Sep	1.32	1.27	1.30	0.03	3%
Average	**1.61**	**1.57**	**1.56**	**0.00**	**0%**
Mean Dry					
Oct	1.21	1.22	1.21	-0.01	-1%
Nov	1.22	1.22	1.22	0.00	0%
Dec	1.21	1.21	1.21	0.00	0%
Jan	1.21	1.21	1.21	0.00	0%
Feb	1.24	1.24	1.24	0.00	0%
Mar	1.21	1.22	1.22	0.00	0%
Apr	1.49	1.52	1.53	0.01	1%
May	2.12	2.02	2.03	0.01	1%
Jun	1.70	1.82	1.71	-0.10	-8%
Jul	1.71	1.79	1.77	-0.01	-1%
Aug	1.47	1.47	1.47	0.00	0%
Sep	1.23	1.23	1.23	0.00	0%
Average	**1.42**	**1.43**	**1.42**	**-0.01**	**-1%**

Notes:
(1) Cumulative Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 5-23. Lake Fork Gage - Simulated Cumulative Effects Stage



Lake Creek

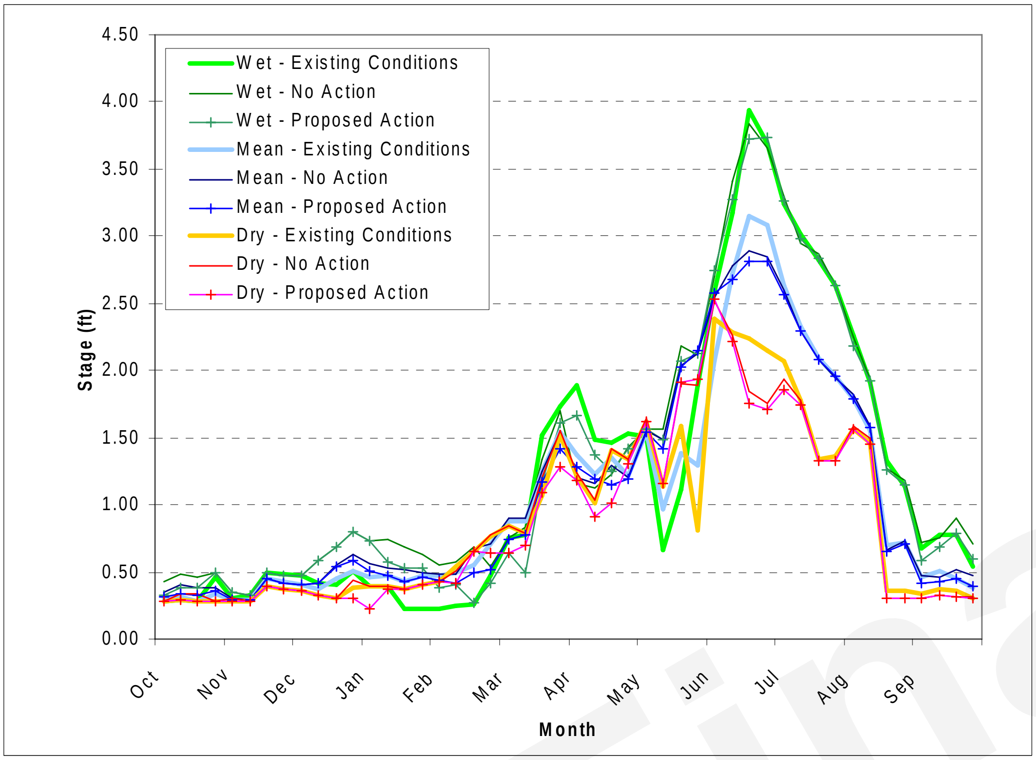
Summary data for the cumulative effects on stage for the Lake Creek Gage are shown in **Table 5-27** and **Figure 5-24**. No Action Alternative and Proposed Action streamflows are generally less than streamflows under Existing Conditions, except during mean dry years. Cumulative effects are negative, indicating that stages are higher for the No Action Alternative than for the Proposed Action.

Table 5-27. Lake Creek Gage Stage - Summary of Cumulative Effects

Month	Simulated Stage			Cumulative Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	0.31	0.38	0.34	-0.04	-12%
Nov	0.36	0.37	0.37	0.00	0%
Dec	0.43	0.50	0.49	-0.01	-3%
Jan	0.46	0.53	0.47	-0.06	-11%
Feb	0.56	0.59	0.47	-0.12	-21%
Mar	1.13	1.15	1.03	-0.12	-11%
Apr	1.29	1.22	1.20	-0.01	-1%
May	1.30	1.80	1.78	-0.01	-1%
Jun	2.75	2.76	2.72	-0.04	-2%
Jul	2.26	2.23	2.23	-0.01	0%
Aug	1.19	1.20	1.18	-0.02	-2%
Sep	0.45	0.48	0.42	-0.06	-13%
Average	**1.04**	**1.10**	**1.06**	**-0.04**	**-4%**
Mean Wet					
Oct	0.33	0.47	0.40	-0.07	-15%
Nov	0.40	0.41	0.41	0.00	0%
Dec	0.45	0.63	0.63	0.00	0%
Jan	0.31	0.70	0.59	-0.11	-16%
Feb	0.30	0.59	0.37	-0.22	-38%
Mar	1.19	1.15	0.98	-0.18	-15%
Apr	1.59	1.24	1.43	0.19	15%
May	1.29	1.86	1.81	-0.04	-2%
Jun	3.35	3.40	3.37	-0.03	-1%
Jul	2.93	2.94	2.93	-0.01	0%
Aug	1.66	1.66	1.63	-0.03	-2%
Sep	0.69	0.77	0.66	-0.11	-14%
Average	**1.21**	**1.32**	**1.27**	**-0.05**	**-4%**
Mean Dry					
Oct	0.28	0.31	0.28	-0.03	-8%
Nov	0.33	0.34	0.33	-0.01	-2%
Dec	0.34	0.36	0.32	-0.03	-10%
Jan	0.39	0.39	0.34	-0.05	-13%
Feb	0.60	0.59	0.53	-0.06	-9%
Mar	1.05	1.10	0.93	-0.17	-16%
Apr	1.24	1.26	1.10	-0.15	-12%
May	1.29	1.65	1.66	0.01	1%
Jun	2.26	2.10	2.05	-0.04	-2%
Jul	1.64	1.59	1.56	-0.03	-2%
Aug	0.94	0.92	0.91	-0.02	-2%
Sep	0.35	0.31	0.31	0.00	-1%
Average	**0.89**	**0.91**	**0.86**	**-0.05**	**-5%**

Notes:
(1) Cumulative Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 5-24. Lake Creek Gage - Simulated Cumulative Effects Stage



Wellsville

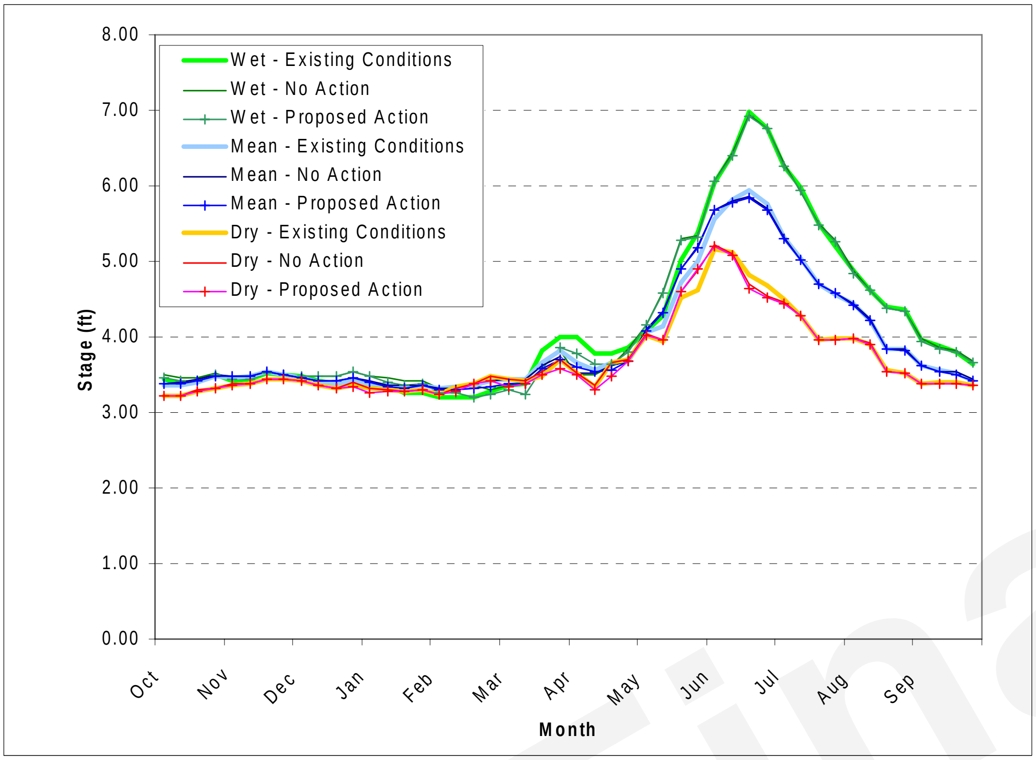
Summary data for the cumulative effects on stage for the Wellsville Gage are shown in **Table 5-28** and **Figure 5-25**. Cumulative Effects are generally negative, indicating that stages under the No Action Alternative are greater than stages under the Proposed Action.

Table 5-28. Wellsville Gage Stage - Summary of Cumulative Effects

Month	Simulated Stage: Existing Conditions (feet)	Simulated Stage: No Action (feet)	Simulated Stage: Proposed Action (feet)	Cumulative Effects (1) (feet)	Cumulative Effects (1) (%)
Overall Mean					
Oct	3.40	3.43	3.41	-0.02	-1%
Nov	3.50	3.50	3.50	0.00	0%
Dec	3.42	3.44	3.44	-0.01	0%
Jan	3.35	3.37	3.35	-0.02	-1%
Feb	3.36	3.37	3.32	-0.05	-3%
Mar	3.59	3.56	3.51	-0.05	-2%
Apr	3.64	3.59	3.59	0.00	0%
May	4.48	4.63	4.62	-0.01	0%
Jun	5.78	5.76	5.74	-0.02	0%
Jul	4.91	4.91	4.90	-0.01	0%
Aug	4.08	4.09	4.08	-0.01	0%
Sep	3.53	3.54	3.52	-0.02	-1%
Average	**3.92**	**3.93**	**3.92**	**-0.02**	**-1%**
Mean Wet					
Oct	3.43	3.48	3.45	-0.03	-1%
Nov	3.47	3.47	3.47	0.00	0%
Dec	3.43	3.50	3.50	0.00	0%
Jan	3.31	3.45	3.41	-0.04	-2%
Feb	3.22	3.33	3.24	-0.09	-5%
Mar	3.64	3.55	3.50	-0.06	-3%
Apr	3.85	3.62	3.72	0.10	5%
May	4.69	4.85	4.83	-0.02	-1%
Jun	6.55	6.55	6.54	-0.01	0%
Jul	5.73	5.75	5.74	-0.02	0%
Aug	4.57	4.56	4.55	-0.01	0%
Sep	3.82	3.84	3.81	-0.03	-1%
Average	**4.14**	**4.16**	**4.15**	**-0.02**	**-1%**
Mean Dry					
Oct	3.26	3.27	3.26	-0.01	0%
Nov	3.41	3.41	3.41	0.00	0%
Dec	3.37	3.37	3.36	-0.01	-1%
Jan	3.30	3.30	3.28	-0.02	-1%
Feb	3.36	3.36	3.34	-0.02	-1%
Mar	3.51	3.53	3.45	-0.08	-4%
Apr	3.55	3.56	3.49	-0.07	-3%
May	4.27	4.37	4.37	0.00	0%
Jun	4.94	4.89	4.86	-0.02	-1%
Jul	4.18	4.17	4.16	-0.01	0%
Aug	3.74	3.74	3.73	-0.01	0%
Sep	3.39	3.38	3.38	0.00	0%
Average	**3.69**	**3.69**	**3.67**	**-0.02**	**-1%**

Notes:
(1) Cumulative Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 5-25. Wellsville Gage - Simulated Cumulative Effects Stage



5.4.1.2 Arkansas River Below Pueblo Reservoir

This section summarizes net effects for key locations below Pueblo Reservoir, including Pueblo Reservoir, the Above Pueblo gage, the Moffat Street gage, the Avondale gage, the La Junta gage, Lake Meredith, Lake Henry, and Holbrook Reservoir.

Pueblo Reservoir

Summary data for the cumulative effects on Pueblo Reservoir pool elevation are shown in **Table 5-29** and **Figure 5-26**. Reservoir pool elevations decrease for both the No Action Alternative and the Proposed Action when compared to Existing Conditions elevations. Elevations for the No Action Alternative are lower than elevations for the Proposed Action for all months, resulting in positive cumulative effects. Simulated reservoir pool elevations for both the Proposed Action and the No Action Alternative are within the elevation range of the Pueblo Reservoir normal operating pool (4,796.7 to 4,880.49 feet).

Data showing cumulative effects on Pueblo Reservoir surface area are shown in **Table 5-30**, **Figure 5-27**, and **Figure 5-28**. Simulated cumulative effects for reservoir surface area for the Proposed Action and No Action Alternative are less than under Existing Conditions. However, reservoir surface area cumulative effects are positive, indicating that surface area is greater under the Proposed Action than for the No Action Alternative. Additionally, the Pueblo Reservoir water surface would remain within the normal operating pool as discussed in the previous paragraph.

Table 5-29. Pueblo Reservoir Elevation - Proposed Action Cumulative Effects

Month	Simulated Elevation			Cumulative Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	4,852.33	4,844.62	4,847.98	3.36	4%
Nov	4,854.08	4,846.90	4,849.73	2.83	3%
Dec	4,857.43	4,851.33	4,853.57	2.24	2%
Jan	4,860.68	4,855.57	4,857.34	1.78	2%
Feb	4,862.79	4,858.04	4,859.41	1.37	1%
Mar	4,865.18	4,860.11	4,861.08	0.97	1%
Apr	4,864.31	4,857.41	4,859.02	1.61	2%
May	4,861.88	4,855.37	4,857.10	1.73	2%
Jun	4,860.86	4,854.43	4,856.61	2.17	2%
Jul	4,858.26	4,851.03	4,853.58	2.55	3%
Aug	4,855.67	4,847.86	4,850.62	2.76	3%
Sep	4,853.30	4,844.90	4,848.08	3.18	3%
Average	**4,858.90**	**4,852.30**	**4,854.51**	**2.21**	**2%**
Mean Wet					
Oct	4,855.14	4,841.51	4,847.28	5.77	7%
Nov	4,856.39	4,844.14	4,849.06	4.92	5%
Dec	4,858.68	4,848.18	4,852.44	4.26	4%
Jan	4,861.28	4,853.36	4,856.92	3.56	4%
Feb	4,862.96	4,856.65	4,859.31	2.66	3%
Mar	4,864.93	4,858.00	4,860.03	2.03	2%
Apr	4,864.12	4,853.11	4,856.53	3.42	3%
May	4,861.77	4,851.87	4,855.11	3.23	3%
Jun	4,864.62	4,855.23	4,858.36	3.13	3%
Jul	4,865.34	4,855.80	4,859.21	3.41	3%
Aug	4,865.20	4,855.97	4,859.40	3.44	3%
Sep	4,865.91	4,857.51	4,860.49	2.97	3%
Average	**4,862.19**	**4,852.61**	**4,856.18**	**3.57**	**4%**
Mean Dry					
Oct	4,850.64	4,848.49	4,849.92	1.43	1%
Nov	4,851.46	4,849.18	4,850.34	1.17	1%
Dec	4,854.79	4,852.97	4,853.76	0.79	1%
Jan	4,858.15	4,856.48	4,856.85	0.37	0%
Feb	4,859.95	4,858.26	4,858.54	0.28	0%
Mar	4,862.42	4,860.37	4,860.30	-0.06	0%
Apr	4,861.90	4,858.82	4,858.86	0.05	0%
May	4,861.62	4,857.99	4,857.98	-0.02	0%
Jun	4,859.39	4,856.13	4,856.50	0.38	0%
Jul	4,851.40	4,847.66	4,848.44	0.79	1%
Aug	4,843.42	4,838.33	4,839.67	1.34	2%
Sep	4,839.16	4,833.01	4,835.06	2.05	3%
Average	**4,854.53**	**4,851.47**	**4,852.19**	**0.71**	**1%**

Notes:
(1) Cumulative Effects (feet) = Proposed Action - No Action simulated elevation. Effects (%) = (Proposed Action - No Action simulated elevation)/No Action simulated depth.

Table 5-30. Pueblo Reservoir Area - Proposed Action Cumulative Effects

Month	Simulated Area			Cumulative Effects (1)	
	Existing Conditions (acres)	No Action (acres)	Proposed Action (acres)	(acres)	(%)
Overall Mean					
Oct	3,406.8	3,120.2	3,239.0	118.8	4%
Nov	3,484.4	3,203.1	3,308.2	105.1	3%
Dec	3,618.2	3,373.7	3,462.1	88.4	3%
Jan	3,742.4	3,552.9	3,625.7	72.8	2%
Feb	3,824.5	3,657.3	3,712.7	55.4	2%
Mar	3,918.8	3,736.9	3,771.7	34.8	1%
Apr	3,869.3	3,620.6	3,682.5	62.0	2%
May	3,759.5	3,531.3	3,601.4	70.0	2%
Jun	3,723.1	3,485.0	3,571.6	86.6	2%
Jul	3,625.4	3,358.9	3,452.6	93.7	3%
Aug	3,531.7	3,240.4	3,344.0	103.6	3%
Sep	3,440.1	3,130.1	3,244.7	114.6	4%
Average	**3,662.0**	**3,417.5**	**3,501.3**	**83.8**	**2%**
Mean Wet					
Oct	3,570.7	3,009.2	3,223.7	214.5	7%
Nov	3,638.5	3,108.1	3,301.6	193.5	6%
Dec	3,731.4	3,273.1	3,453.5	180.4	6%
Jan	3,826.4	3,501.1	3,656.3	155.1	4%
Feb	3,884.6	3,640.7	3,759.9	119.2	3%
Mar	3,955.8	3,699.3	3,786.1	86.9	2%
Apr	3,915.4	3,502.6	3,647.5	144.9	4%
May	3,824.7	3,459.3	3,600.9	141.6	4%
Jun	3,950.2	3,592.0	3,722.5	130.5	4%
Jul	3,987.6	3,611.1	3,738.4	127.3	4%
Aug	3,975.5	3,604.2	3,744.0	139.9	4%
Sep	3,988.0	3,641.9	3,769.3	127.4	3%
Average	**3,854.1**	**3,470.2**	**3,617.0**	**146.8**	**4%**
Mean Dry					
Oct	3,322.1	3,246.2	3,292.7	46.5	1%
Nov	3,349.1	3,269.7	3,308.3	38.7	1%
Dec	3,480.0	3,412.8	3,439.7	26.9	1%
Jan	3,620.3	3,559.5	3,573.3	13.8	0%
Feb	3,692.3	3,639.2	3,649.0	9.8	0%
Mar	3,782.5	3,725.5	3,720.1	-5.4	0%
Apr	3,740.0	3,647.4	3,641.6	-5.9	0%
May	3,733.0	3,602.8	3,596.4	-6.4	0%
Jun	3,626.8	3,513.3	3,524.2	10.9	0%
Jul	3,278.0	3,162.3	3,188.4	26.1	1%
Aug	2,948.5	2,779.2	2,829.5	50.3	2%
Sep	2,792.0	2,585.0	2,653.5	68.5	3%
Average	**3,447.0**	**3,345.2**	**3,368.1**	**22.8**	**1%**

Notes:
(1) Cumulative Effects (acres) = Proposed Action - No Action simulated area. Effects (%) = (Proposed Action - No Action simulated area)/No Action simulated area.

Figure 5-26. Pueblo Reservoir - Simulated Cumulative Effects Elevation

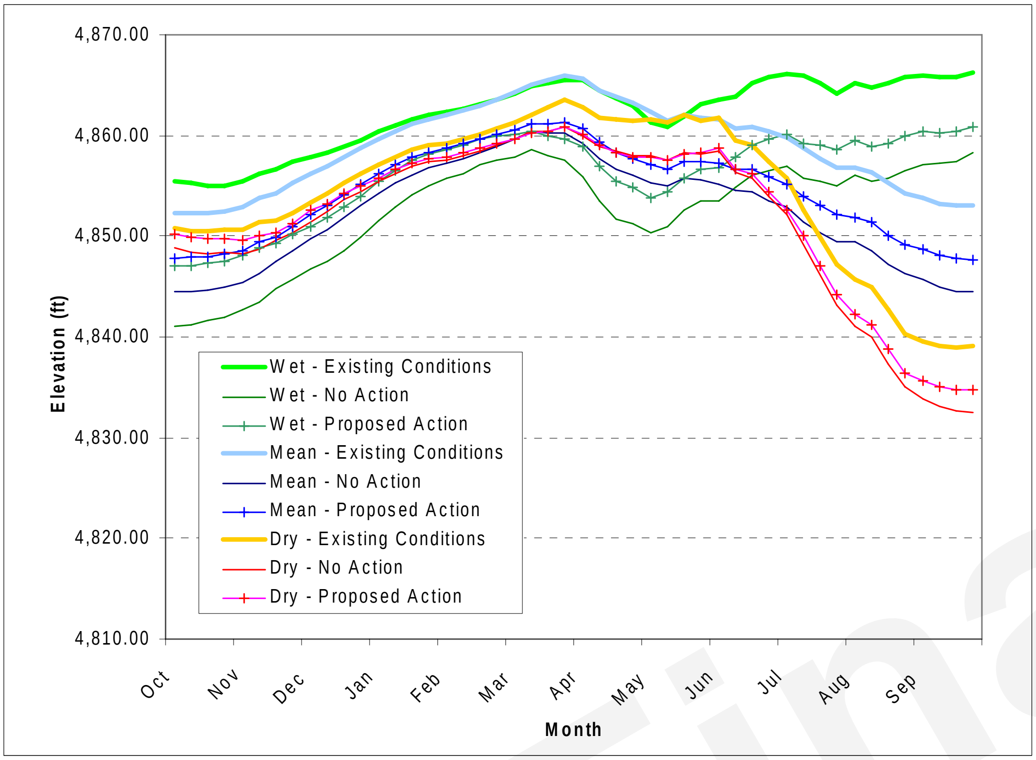


Figure 5-27. Pueblo Reservoir - Simulated Cumulative Effects Surface Area

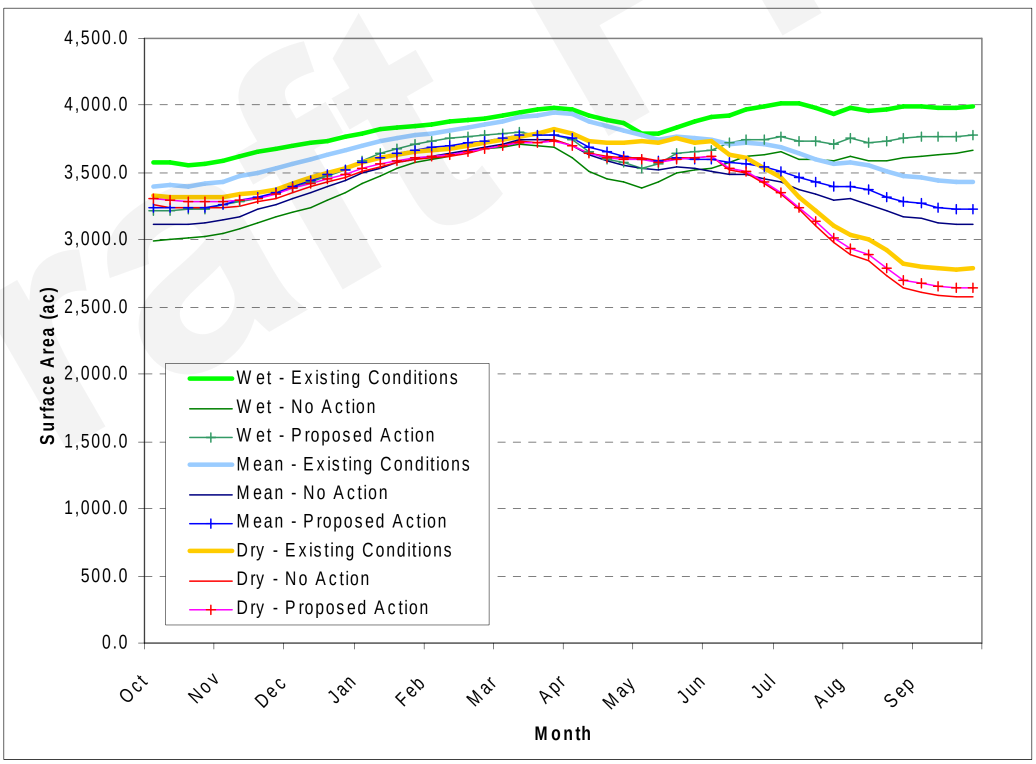
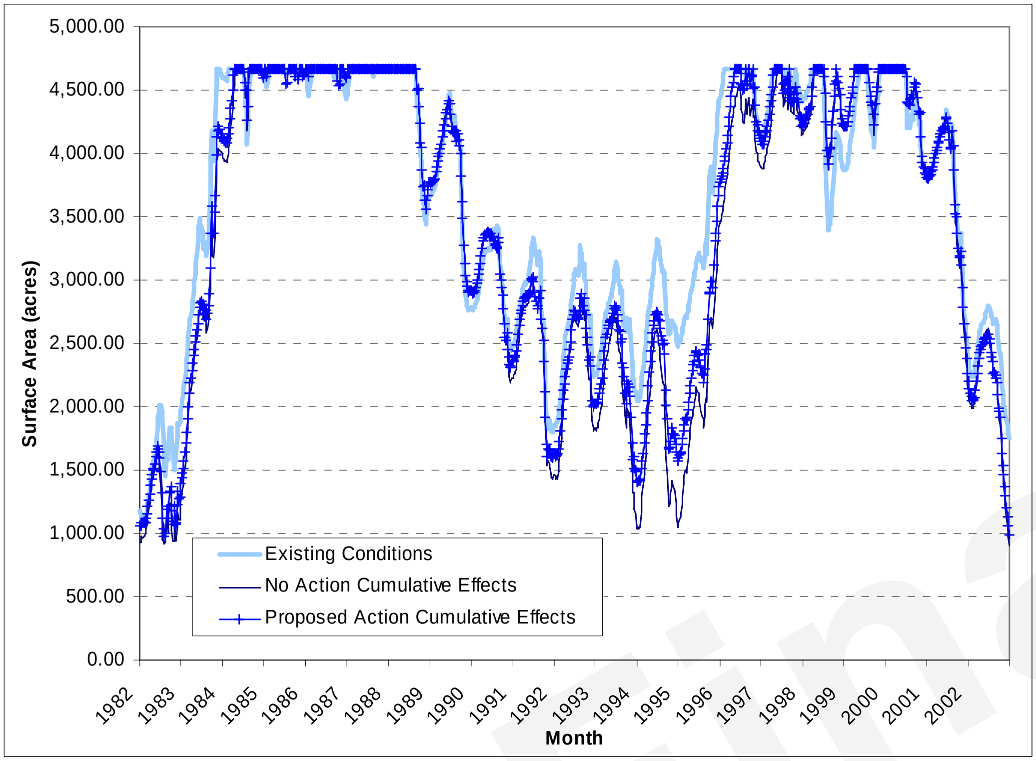


Figure 5-28. Pueblo Reservoir - Simulated Cumulative Effects
Surface Area Time Series



Above Pueblo Gage

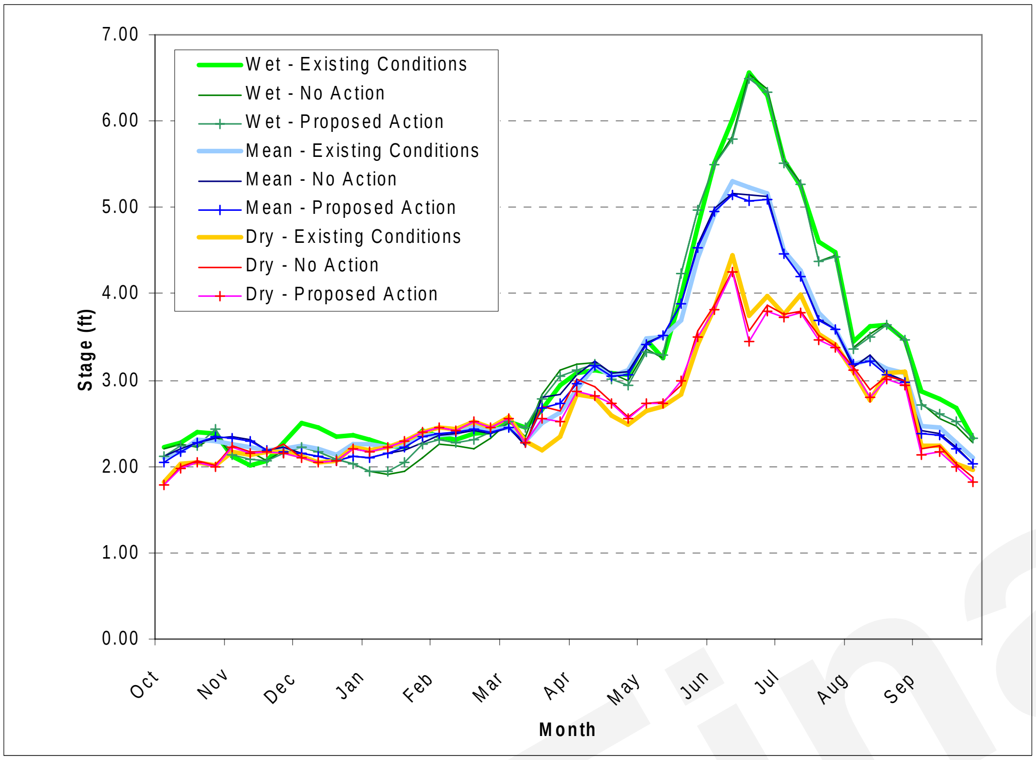
Summary data for the cumulative effects on stage for the Above Pueblo Gage are shown in **Table 5-31** and **Figure 5-29**. Stage is generally reduced as a result of the No Action and Proposed Action alternatives, except for mean dry years.

Table 5-31. Above Pueblo Gage Stage - Summary of Cumulative Effects

	Simulated Stage				
	Existing Conditions	No Action	Proposed Action	Cumulative Effects (1)	
Month	(feet)	(feet)	(feet)	(feet)	(%)
Overall Mean					
Oct	2.22	2.23	2.21	-0.02	-1%
Nov	2.22	2.27	2.24	-0.03	-1%
Dec	2.21	2.11	2.11	0.00	0%
Jan	2.28	2.18	2.20	0.03	1%
Feb	2.40	2.39	2.41	0.02	1%
Mar	2.46	2.58	2.54	-0.04	-2%
Apr	3.05	3.11	3.06	-0.06	-2%
May	3.77	3.85	3.84	-0.01	0%
Jun	5.15	5.11	5.07	-0.04	-1%
Jul	4.03	3.99	3.98	0.00	0%
Aug	3.15	3.13	3.11	-0.02	-1%
Sep	2.32	2.26	2.24	-0.02	-1%
Average	**2.94**	**2.93**	**2.92**	**-0.02**	**-1%**
Mean Wet					
Oct	2.32	2.26	2.26	0.00	0%
Nov	2.12	2.14	2.11	-0.03	-1%
Dec	2.42	2.13	2.13	0.00	0%
Jan	2.30	1.97	2.04	0.07	4%
Feb	2.36	2.26	2.32	0.06	3%
Mar	2.64	2.70	2.70	0.00	0%
Apr	3.08	3.12	3.06	-0.06	-2%
May	3.87	3.96	3.96	0.00	0%
Jun	6.10	6.06	6.03	-0.02	0%
Jul	4.97	4.92	4.90	-0.02	0%
Aug	3.54	3.50	3.49	-0.01	0%
Sep	2.67	2.51	2.55	0.04	1%
Average	**3.20**	**3.13**	**3.13**	**0.00**	**0%**
Mean Dry					
Oct	1.98	1.97	1.95	-0.01	-1%
Nov	2.16	2.21	2.18	-0.03	-1%
Dec	2.11	2.10	2.10	0.00	0%
Jan	2.28	2.27	2.27	0.00	0%
Feb	2.47	2.46	2.46	0.00	0%
Mar	2.35	2.54	2.48	-0.06	-2%
Apr	2.68	2.81	2.74	-0.07	-2%
May	2.90	2.99	2.99	-0.01	0%
Jun	4.00	3.89	3.83	-0.06	-2%
Jul	3.67	3.62	3.59	-0.03	-1%
Aug	3.01	3.02	2.97	-0.05	-2%
Sep	2.12	2.09	2.03	-0.06	-3%
Average	**2.64**	**2.66**	**2.63**	**-0.03**	**-1%**

Notes:
(1) Cumulative Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 5-29. Above Pueblo Gage - Simulated Cumulative Effects Elevation



Moffat Street Gage

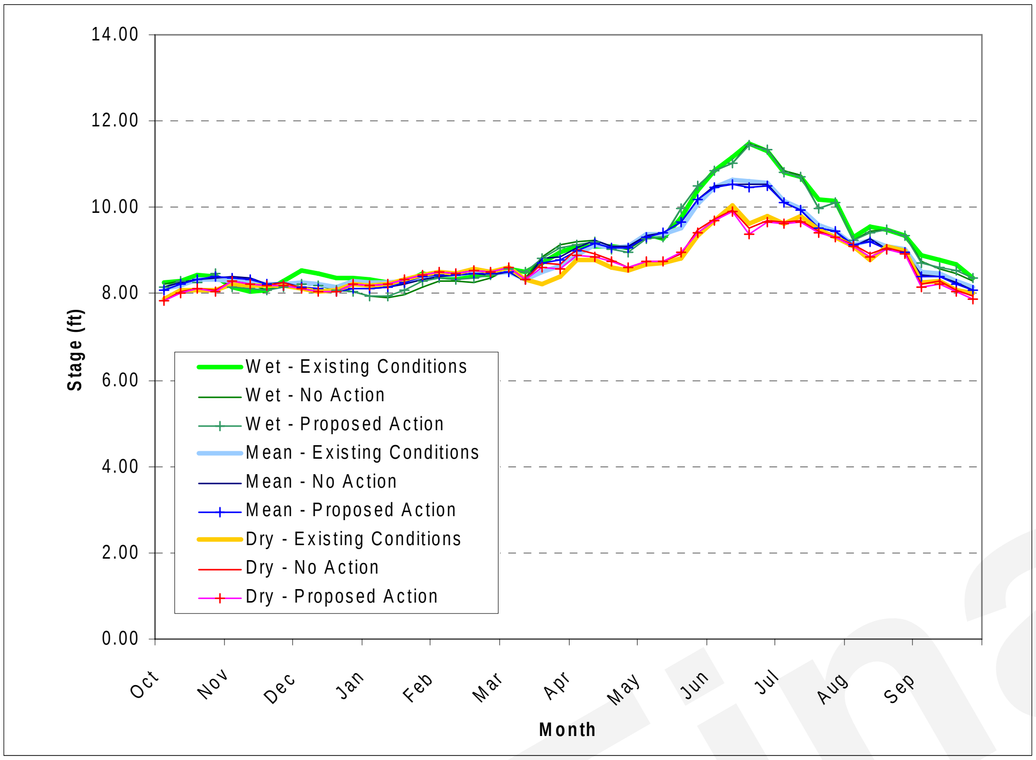
Summary data for the cumulative effects on stage for the Moffat Street Gage are shown in **Table 5-32** and **Figure 5-30**. Small positive and negative changes in stage are seen as a result of the No Action Alternative and Proposed Action, except for mean dry years when, on average, No Action Alternative stages are higher than under Existing Conditions and the Proposed Action.

Table 5-32. Moffat Street Gage Stage - Summary of Cumulative Effects

Month	Simulated Stage			Cumulative Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	8.25	8.27	8.25	-0.02	-1%
Nov	8.25	8.30	8.27	-0.03	-2%
Dec	8.22	8.12	8.12	0.00	0%
Jan	8.30	8.20	8.23	0.03	2%
Feb	8.45	8.44	8.45	0.02	1%
Mar	8.49	8.62	8.58	-0.04	-2%
Apr	9.04	9.12	9.06	-0.06	-2%
May	9.59	9.65	9.64	-0.01	0%
Jun	10.56	10.53	10.50	-0.03	-1%
Jul	9.79	9.75	9.75	0.00	0%
Aug	9.12	9.09	9.07	-0.02	-1%
Sep	8.36	8.29	8.28	-0.02	-1%
Average	**8.87**	**8.87**	**8.85**	**-0.01**	**-1%**
Mean Wet					
Oct	8.35	8.30	8.30	0.00	0%
Nov	8.14	8.16	8.13	-0.03	-2%
Dec	8.44	8.13	8.13	0.00	0%
Jan	8.33	7.99	8.06	0.07	6%
Feb	8.41	8.30	8.37	0.07	4%
Mar	8.68	8.74	8.74	0.00	0%
Apr	9.10	9.14	9.08	-0.06	-2%
May	9.71	9.76	9.76	0.00	0%
Jun	11.20	11.18	11.16	-0.02	0%
Jul	10.47	10.42	10.41	-0.01	0%
Aug	9.42	9.38	9.37	-0.01	0%
Sep	8.67	8.52	8.56	0.04	2%
Average	**9.08**	**9.00**	**9.01**	**0.00**	**0%**
Mean Dry					
Oct	8.03	8.02	8.00	-0.02	-1%
Nov	8.20	8.24	8.21	-0.03	-2%
Dec	8.12	8.11	8.11	0.00	0%
Jan	8.30	8.29	8.29	0.00	0%
Feb	8.51	8.50	8.50	0.00	0%
Mar	8.40	8.59	8.53	-0.06	-3%
Apr	8.68	8.84	8.77	-0.07	-3%
May	8.88	8.98	8.98	0.00	0%
Jun	9.79	9.72	9.66	-0.06	-2%
Jul	9.56	9.53	9.50	-0.03	-1%
Aug	9.00	9.02	8.97	-0.05	-2%
Sep	8.17	8.14	8.08	-0.06	-4%
Average	**8.64**	**8.67**	**8.63**	**-0.03**	**-2%**

Notes:
(1) Cumulative Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 5-30. Moffat Street Gage - Simulated Cumulative Effects Elevation



Avondale Gage

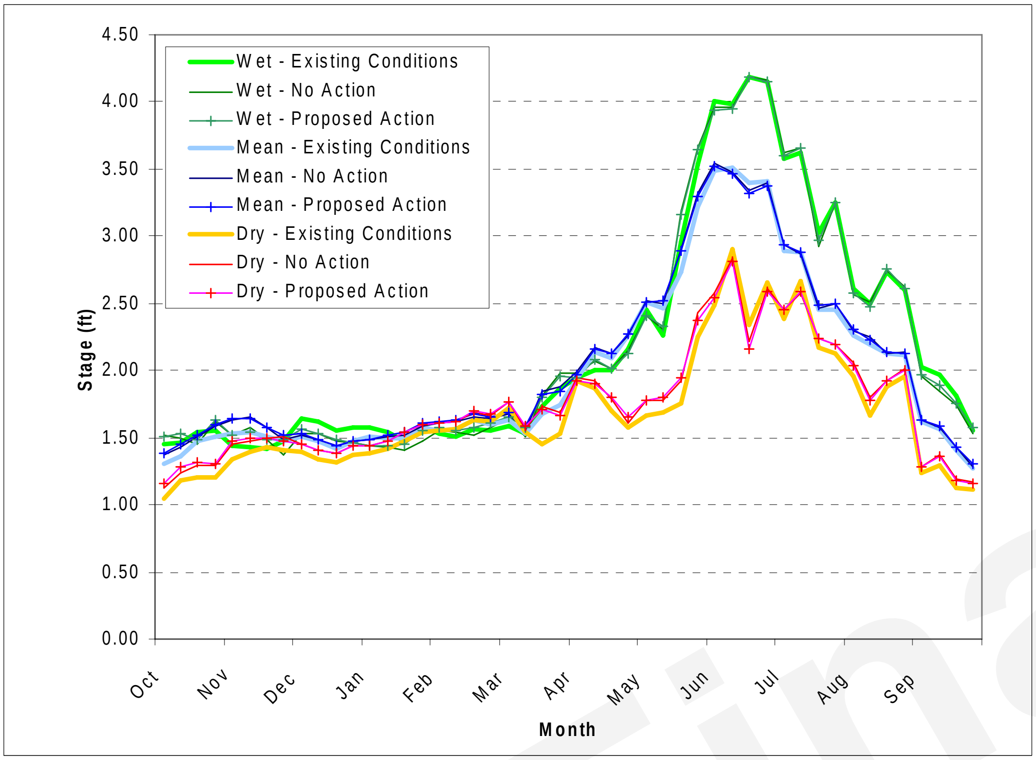
Summary data for the cumulative effects on stage for the Avondale Gage are shown in **Table 5-33** and **Figure 5-31**. Changes in stage are positive as a result of the No Action Alternative and Proposed Action, except during mean wet years, when stages under the No Action Alternative are less than those under Existing Conditions and the Proposed Action.

Table 5-33. Avondale Gage Stage - Summary of Cumulative Effects

Month	Simulated Stage			Cumulative Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	1.41	1.47	1.49	0.01	1%
Nov	1.51	1.58	1.59	0.01	1%
Dec	1.47	1.48	1.48	0.00	0%
Jan	1.52	1.53	1.54	0.01	1%
Feb	1.58	1.63	1.64	0.01	1%
Mar	1.65	1.74	1.73	0.00	0%
Apr	2.10	2.13	2.13	0.00	0%
May	2.73	2.81	2.80	-0.01	0%
Jun	3.45	3.44	3.42	-0.02	0%
Jul	2.67	2.69	2.70	0.01	0%
Aug	2.17	2.20	2.20	0.00	0%
Sep	1.47	1.48	1.49	0.01	1%
Average	**1.98**	**2.02**	**2.02**	**0.00**	**0%**
Mean Wet					
Oct	1.50	1.52	1.54	0.01	1%
Nov	1.44	1.49	1.51	0.02	2%
Dec	1.60	1.50	1.51	0.01	1%
Jan	1.54	1.44	1.47	0.03	3%
Feb	1.54	1.55	1.58	0.03	2%
Mar	1.68	1.74	1.75	0.01	1%
Apr	2.03	2.05	2.04	-0.01	0%
May	2.80	2.89	2.89	0.00	0%
Jun	4.08	4.07	4.06	-0.01	0%
Jul	3.37	3.36	3.37	0.01	0%
Aug	2.61	2.61	2.60	-0.01	0%
Sep	1.84	1.77	1.79	0.02	2%
Average	**2.17**	**2.16**	**2.18**	**0.01**	**1%**
Mean Dry					
Oct	1.16	1.24	1.27	0.03	3%
Nov	1.39	1.48	1.48	0.00	0%
Dec	1.36	1.42	1.42	0.00	0%
Jan	1.45	1.51	1.51	0.00	0%
Feb	1.59	1.65	1.65	0.00	0%
Mar	1.56	1.69	1.69	0.00	0%
Apr	1.77	1.82	1.82	0.00	0%
May	1.84	1.97	1.98	0.00	0%
Jun	2.59	2.56	2.53	-0.03	-1%
Jul	2.34	2.36	2.37	0.00	0%
Aug	1.87	1.95	1.94	-0.01	-1%
Sep	1.19	1.25	1.25	-0.01	-1%
Average	**1.68**	**1.74**	**1.74**	**0.00**	**0%**

Notes:
(1) Cumulative Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 5-31. Avondale Gage - Simulated Cumulative Effects Stage



Lake Meredith

Summary data for the cumulative effects on Lake Meredith pool elevation are shown in **Table 5-34** and **Figure 5-32**. Simulated stages are higher for the No Action Alternative and Proposed Action than for the Existing Conditions. Cumulative effects are negative, indicating that stages for the No Action Alternative are higher than under the Proposed Action. However, simulated Lake Meredith pool elevations are within the elevation range of the normal operating pool for Lake Meredith (4,241.8 to 4,253.9 feet).

Data showing cumulative effects on Lake Meredith surface area are shown in **Table 5-35**, **Figure 5-33**, and **Figure 5-34**. The surface area under the No Action Alternative and Proposed Action is consistently greater than the surface area for Existing Conditions. Cumulative effects are negative, indicating that surface area under the No Action Alternative is greater than surface area under the Proposed Action. However, as discussed in the previous paragraph, the simulated surface area under the No Action Alternative would be within the normal operating pool of Lake Meredith.

Table 5-34. Lake Meredith Elevation - Proposed Action Cumulative Effects

Month	Simulated Elevation			Cumulative Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	4,245.90	4,250.01	4,248.82	-1.19	-15%
Nov	4,245.75	4,250.17	4,249.06	-1.11	-14%
Dec	4,246.18	4,250.14	4,249.18	-0.97	-12%
Jan	4,246.83	4,250.10	4,249.14	-0.96	-12%
Feb	4,246.94	4,249.72	4,248.72	-1.00	-13%
Mar	4,248.67	4,250.16	4,249.14	-1.02	-13%
Apr	4,248.26	4,250.36	4,249.00	-1.37	-17%
May	4,246.93	4,250.00	4,248.62	-1.38	-18%
Jun	4,245.24	4,249.78	4,248.08	-1.70	-22%
Jul	4,246.16	4,250.13	4,248.39	-1.74	-22%
Aug	4,246.17	4,250.10	4,248.54	-1.56	-20%
Sep	4,246.06	4,249.96	4,248.60	-1.35	-17%
Average	**4,246.59**	**4,250.05**	**4,248.77**	**-1.28**	**-16%**
Mean Wet					
Oct	4,247.46	4,250.67	4,249.16	-1.51	-18%
Nov	4,247.36	4,250.61	4,249.21	-1.40	-17%
Dec	4,247.85	4,250.50	4,249.38	-1.12	-13%
Jan	4,248.49	4,250.48	4,249.37	-1.11	-13%
Feb	4,248.58	4,250.15	4,249.00	-1.14	-14%
Mar	4,249.50	4,250.60	4,249.42	-1.18	-14%
Apr	4,248.84	4,250.81	4,249.26	-1.56	-18%
May	4,247.40	4,250.55	4,248.93	-1.62	-19%
Jun	4,246.03	4,251.05	4,249.26	-1.79	-20%
Jul	4,247.75	4,251.83	4,250.09	-1.74	-18%
Aug	4,248.35	4,251.66	4,249.93	-1.73	-18%
Sep	4,248.82	4,251.34	4,249.72	-1.62	-18%
Average	**4,248.03**	**4,250.85**	**4,249.39**	**-1.46**	**-17%**
Mean Dry					
Oct	4,244.82	4,249.80	4,248.36	-1.44	-19%
Nov	4,244.78	4,250.25	4,248.97	-1.28	-16%
Dec	4,245.37	4,250.28	4,249.07	-1.21	-15%
Jan	4,245.95	4,250.19	4,248.99	-1.20	-15%
Feb	4,245.99	4,249.73	4,248.48	-1.25	-17%
Mar	4,248.25	4,250.15	4,249.01	-1.15	-14%
Apr	4,248.12	4,250.41	4,249.06	-1.35	-16%
May	4,246.13	4,249.62	4,248.44	-1.18	-16%
Jun	4,243.98	4,248.05	4,246.58	-1.47	-25%
Jul	4,244.14	4,247.90	4,246.24	-1.66	-29%
Aug	4,243.78	4,248.21	4,246.81	-1.41	-23%
Sep	4,243.56	4,248.31	4,247.27	-1.04	-17%
Average	**4,245.40**	**4,249.41**	**4,248.11**	**-1.30**	**-18%**

Notes:

(1) Cumulative Effects (feet) = Proposed Action - No Action simulated elevation. Effects (%) = (Proposed Action - No Action simulated elevation)/No Action simulated depth.

Table 5-35. Lake Meredith Area - Proposed Action Cumulative Effects

Month	Simulated Area Existing Conditions (acres)	Simulated Area No Action (acres)	Simulated Area Proposed Action (acres)	Cumulative Effects (1) (acres)	Cumulative Effects (1) (%)
Overall Mean					
Oct	2,456.4	3,996.8	3,569.1	-427.7	-11%
Nov	2,399.4	4,057.1	3,668.7	-388.4	-10%
Dec	2,560.5	4,048.7	3,709.5	-339.2	-8%
Jan	2,793.7	4,031.9	3,695.1	-336.8	-8%
Feb	2,831.1	3,898.9	3,545.0	-354.0	-9%
Mar	3,510.6	4,058.0	3,696.2	-361.9	-9%
Apr	3,331.5	4,130.4	3,643.7	-486.7	-12%
May	2,827.9	3,999.5	3,502.6	-496.8	-12%
Jun	2,195.3	3,914.1	3,287.8	-626.2	-16%
Jul	2,550.1	4,043.9	3,397.7	-646.1	-16%
Aug	2,557.9	4,028.3	3,456.6	-571.7	-14%
Sep	2,524.9	3,985.4	3,481.0	-504.4	-13%
Average	**2,711.6**	**4,016.1**	**3,554.4**	**-461.7**	**-11%**
Mean Wet					
Oct	3,055.4	4,240.7	3,695.9	-544.8	-13%
Nov	3,013.7	4,213.2	3,714.5	-498.7	-12%
Dec	3,198.4	4,171.0	3,775.7	-395.4	-9%
Jan	3,428.2	4,164.6	3,773.2	-391.5	-9%
Feb	3,467.7	4,048.9	3,640.0	-408.9	-10%
Mar	3,827.2	4,213.8	3,788.8	-425.1	-10%
Apr	3,554.9	4,293.2	3,730.3	-562.9	-13%
May	3,001.2	4,197.9	3,613.4	-584.5	-14%
Jun	2,501.7	4,390.0	3,740.8	-649.2	-15%
Jul	3,171.7	4,689.4	4,054.1	-635.3	-14%
Aug	3,391.0	4,622.3	3,993.9	-628.3	-14%
Sep	3,577.7	4,502.4	3,922.5	-579.9	-13%
Average	**3,265.7**	**4,312.3**	**3,786.9**	**-525.4**	**-12%**
Mean Dry					
Oct	2,039.7	3,922.4	3,402.9	-519.5	-13%
Nov	2,021.8	4,083.3	3,633.8	-449.5	-11%
Dec	2,237.4	4,092.5	3,668.2	-424.4	-10%
Jan	2,452.7	4,060.9	3,639.4	-421.5	-10%
Feb	2,459.5	3,900.0	3,457.3	-442.8	-11%
Mar	3,347.2	4,048.5	3,645.6	-402.9	-10%
Apr	3,286.4	4,138.6	3,665.1	-473.5	-11%
May	2,522.3	3,859.9	3,439.2	-420.7	-11%
Jun	1,708.5	3,273.6	2,706.2	-567.4	-17%
Jul	1,761.6	3,207.7	2,570.8	-636.9	-20%
Aug	1,631.7	3,308.8	2,802.8	-506.1	-15%
Sep	1,552.0	3,366.7	2,963.4	-403.3	-12%
Average	**2,251.7**	**3,771.9**	**3,299.5**	**-472.4**	**-13%**

Notes:
(1) Cumulative Effects (acres) = Proposed Action - No Action simulated area. Effects (%) = (Proposed Action - No Action simulated area)/No Action simulated area.

Figure 5-32. Lake Meredith - Simulated Cumulative Effects Elevation,

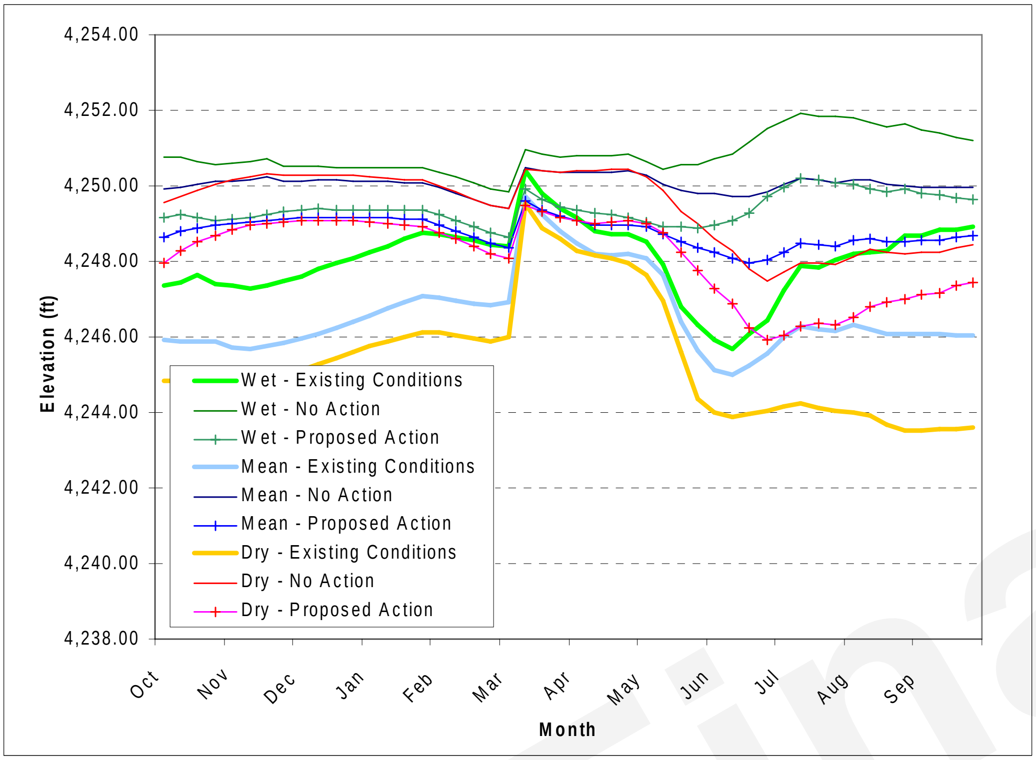


Figure 5-33. Lake Meredith Gage - Simulated Cumulative Effects Surface Area

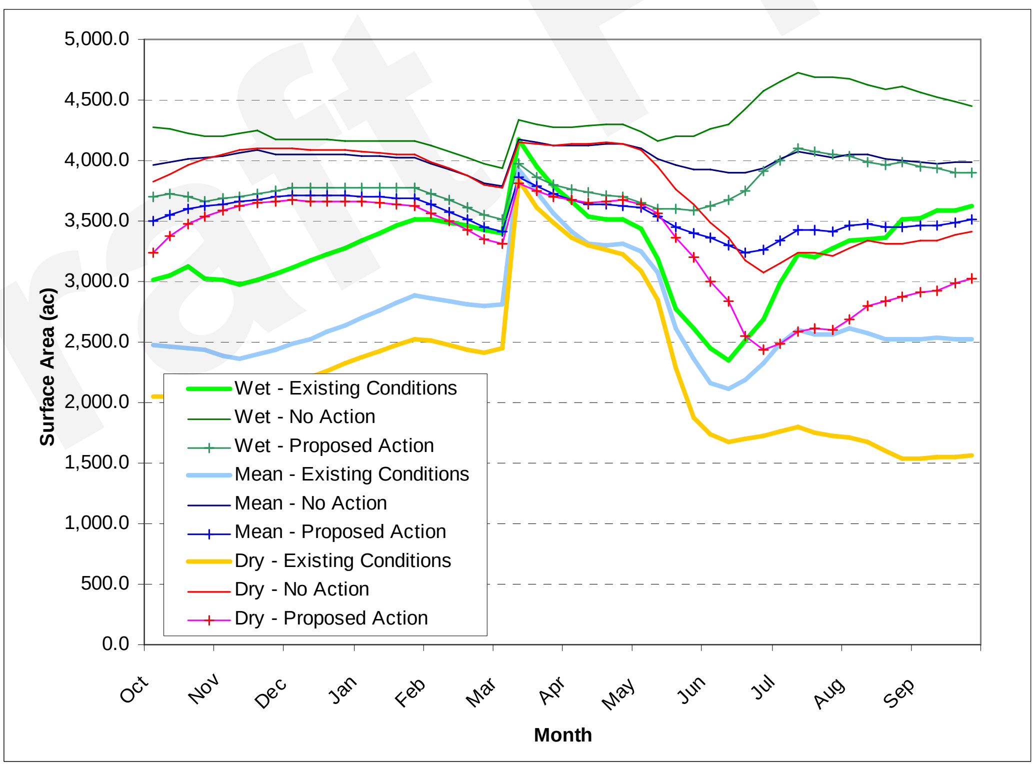
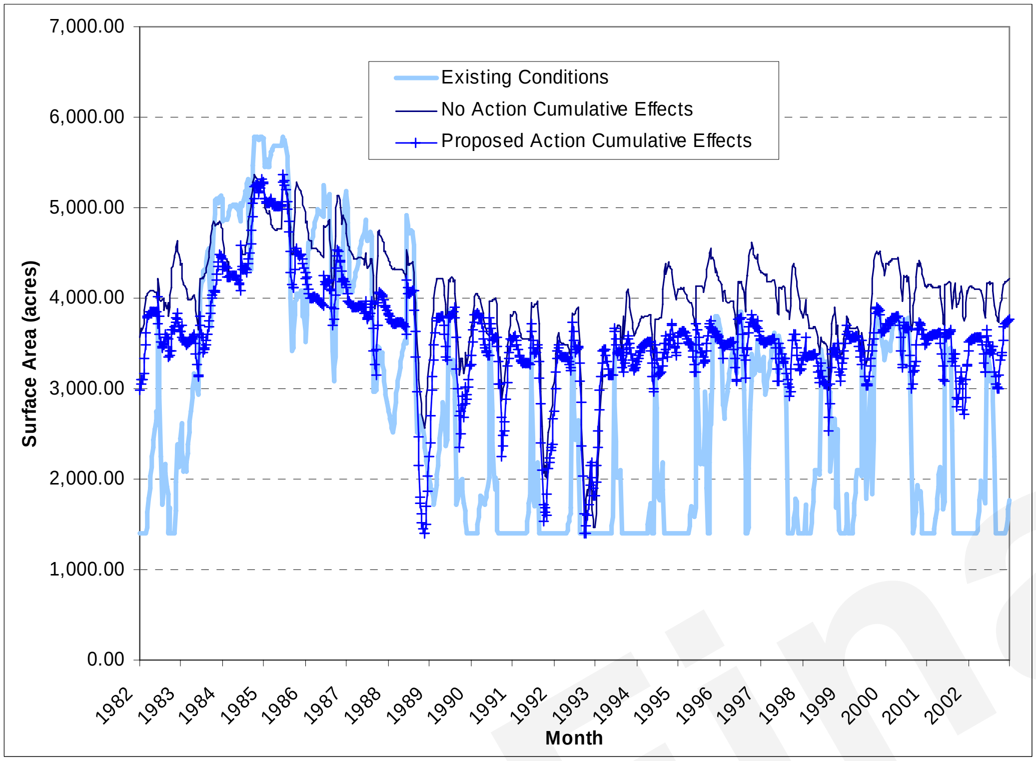


Figure 5-34. Lake Meredith - Simulated Cumulative Effects Surface Area Time Series



Lake Henry

Summary data for the cumulative effects on Lake Henry pool elevation are shown in **Table 5-36** and **Figure 5-35**. Simulated elevations are slightly higher for the No Action Alternative and the Proposed Action than under Existing Conditions. Cumulative effects are zero for all months, indicating that elevations are the same for the Proposed Action and No Action Alternative. Additionally, simulated Lake Henry pool elevations are within the elevation range of the normal operating pool for Lake Henry (4,367.4 to 4,375.1 feet).

Lake Henry surface area is shown in **Table 5-37**, **Figure 5-35**, and **Figure 5-36**. Simulated surface area for the Proposed Action and the No Action Alternative is greater than under Existing Conditions. Cumulative effects are zero for all months, indicating that surface area under the Proposed Action is equal to the surface area under the No Action Alternative. Additionally, as discussed for the Lake Henry pool elevations, simulated surface areas are within the range of areas corresponding to the normal operating pool for Lake Henry.

Table 5-36. Lake Henry Elevation - Proposed Action Cumulative Effects

Month	Simulated Elevation			Cumulative Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	4,369.46	4,370.35	4,370.35	0.00	0%
Nov	4,369.41	4,370.15	4,370.15	0.00	0%
Dec	4,369.90	4,370.19	4,370.19	0.00	0%
Jan	4,370.29	4,370.33	4,370.33	0.00	0%
Feb	4,371.71	4,371.71	4,371.71	0.00	0%
Mar	4,373.13	4,373.12	4,373.12	0.00	0%
Apr	4,373.31	4,373.31	4,373.31	0.00	0%
May	4,372.75	4,373.03	4,373.03	0.00	0%
Jun	4,371.92	4,372.76	4,372.76	0.00	0%
Jul	4,371.68	4,372.30	4,372.30	0.00	0%
Aug	4,370.87	4,371.68	4,371.68	0.00	0%
Sep	4,369.86	4,370.96	4,370.96	0.00	0%
Average	**4,371.19**	**4,371.66**	**4,371.66**	**0.00**	**0%**
Mean Wet					
Oct	4,370.23	4,370.53	4,370.53	0.00	0%
Nov	4,370.08	4,370.27	4,370.27	0.00	0%
Dec	4,370.27	4,370.28	4,370.28	0.00	0%
Jan	4,370.35	4,370.35	4,370.35	0.00	0%
Feb	4,371.54	4,371.54	4,371.54	0.00	0%
Mar	4,373.07	4,373.07	4,373.07	0.00	0%
Apr	4,373.36	4,373.36	4,373.36	0.00	0%
May	4,373.14	4,373.37	4,373.37	0.00	0%
Jun	4,373.05	4,373.61	4,373.61	0.00	0%
Jul	4,373.44	4,373.55	4,373.55	0.00	0%
Aug	4,373.13	4,373.13	4,373.13	0.00	0%
Sep	4,372.19	4,372.52	4,372.52	0.00	0%
Average	**4,371.99**	**4,372.13**	**4,372.13**	**0.00**	**0%**
Mean Dry					
Oct	4,368.62	4,369.08	4,369.08	0.00	0%
Nov	4,368.40	4,369.01	4,369.01	0.00	0%
Dec	4,368.73	4,369.04	4,369.04	0.00	0%
Jan	4,369.29	4,369.30	4,369.30	0.00	0%
Feb	4,371.10	4,371.10	4,371.10	0.00	0%
Mar	4,372.62	4,372.62	4,372.62	0.00	0%
Apr	4,372.47	4,372.47	4,372.47	0.00	0%
May	4,371.39	4,371.70	4,371.70	0.00	0%
Jun	4,369.98	4,371.09	4,371.09	0.00	0%
Jul	4,369.27	4,370.33	4,370.33	0.00	0%
Aug	4,368.42	4,369.56	4,369.56	0.00	0%
Sep	4,367.86	4,369.14	4,369.14	0.00	0%
Average	**4,369.85**	**4,370.37**	**4,370.37**	**0.00**	**0%**

Notes:

(1) Cumulative Effects (feet) = Proposed Action - No Action simulated elevation. Effects (%) = (Proposed Action - No Action simulated elevation)/No Action simulated depth.

Table 5-37. Lake Henry Area - Proposed Action Cumulative Effects

Month	Simulated Area: Existing Conditions (acres)	Simulated Area: No Action (acres)	Simulated Area: Proposed Action (acres)	Cumulative Effects (1) (acres)	Cumulative Effects (1) (%)
Overall Mean					
Oct	937.0	986.5	986.5	0.0	0%
Nov	935.1	976.0	976.0	0.0	0%
Dec	960.7	977.6	977.6	0.0	0%
Jan	982.4	984.2	984.2	0.0	0%
Feb	1,056.2	1,056.3	1,056.3	0.0	0%
Mar	1,123.7	1,123.3	1,123.3	0.0	0%
Apr	1,133.6	1,133.6	1,133.6	0.0	0%
May	1,105.7	1,120.1	1,120.1	0.0	0%
Jun	1,063.1	1,105.5	1,105.5	0.0	0%
Jul	1,050.7	1,082.1	1,082.1	0.0	0%
Aug	1,006.4	1,050.8	1,050.8	0.0	0%
Sep	955.1	1,014.5	1,014.5	0.0	0%
Average	**1,025.8**	**1,050.9**	**1,050.9**	**0.0**	**0%**
Mean Wet					
Oct	979.2	996.2	996.2	0.0	0%
Nov	971.7	982.2	982.2	0.0	0%
Dec	982.0	982.4	982.4	0.0	0%
Jan	986.3	986.3	986.3	0.0	0%
Feb	1,045.1	1,045.1	1,045.1	0.0	0%
Mar	1,119.2	1,119.2	1,119.2	0.0	0%
Apr	1,135.0	1,135.0	1,135.0	0.0	0%
May	1,125.5	1,135.8	1,135.8	0.0	0%
Jun	1,121.9	1,146.9	1,146.9	0.0	0%
Jul	1,139.1	1,143.5	1,143.5	0.0	0%
Aug	1,122.9	1,122.9	1,122.9	0.0	0%
Sep	1,080.5	1,097.0	1,097.0	0.0	0%
Average	**1,067.4**	**1,074.4**	**1,074.4**	**0.0**	**0%**
Mean Dry					
Oct	891.2	915.7	915.7	0.0	0%
Nov	878.3	911.5	911.5	0.0	0%
Dec	894.5	913.0	913.0	0.0	0%
Jan	926.7	927.5	927.5	0.0	0%
Feb	1,025.9	1,025.9	1,025.9	0.0	0%
Mar	1,101.6	1,101.6	1,101.6	0.0	0%
Apr	1,097.0	1,097.0	1,097.0	0.0	0%
May	1,040.7	1,058.7	1,058.7	0.0	0%
Jun	962.4	1,026.1	1,026.1	0.0	0%
Jul	924.7	983.8	983.8	0.0	0%
Aug	879.7	943.9	943.9	0.0	0%
Sep	847.8	918.4	918.4	0.0	0%
Average	**955.9**	**985.2**	**985.2**	**0.0**	**0%**

Notes:
(1) Cumulative Effects (acres) = Proposed Action - No Action simulated area. Effects (%) = (Proposed Action - No Action simulated area)/No Action simulated area.

Figure 5-35. Lake Henry - Simulated Cumulative Effects Elevation

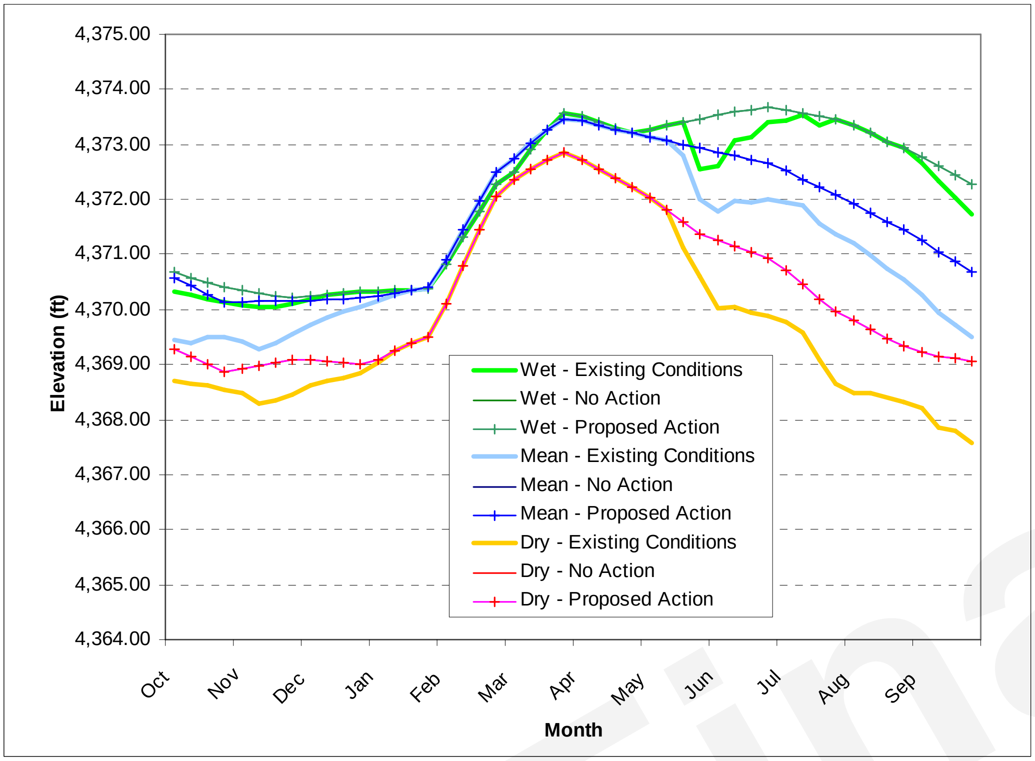


Figure 5-36. Lake Henry - Simulated Cumulative Effects Surface Area

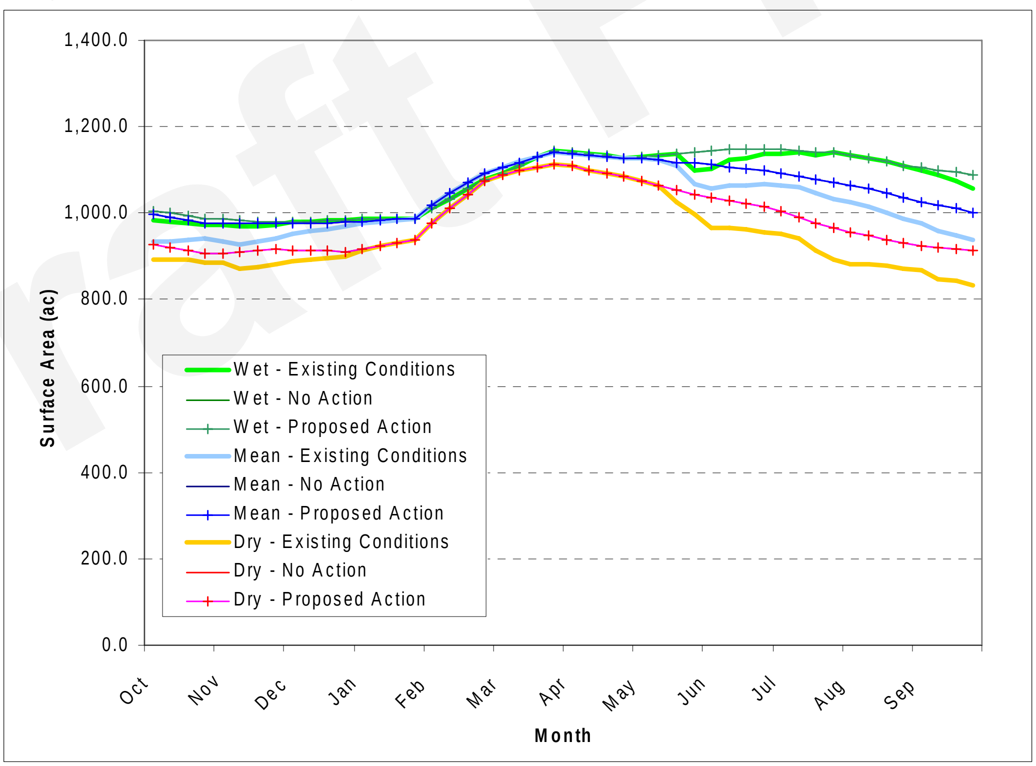
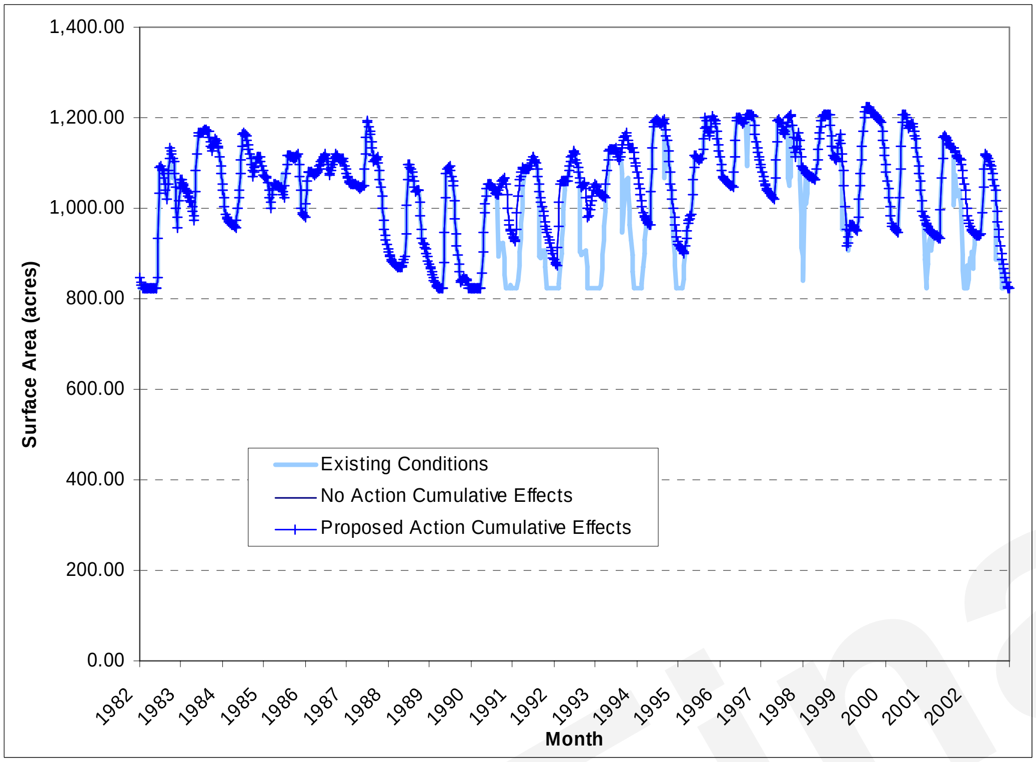


Figure 5-37. Lake Henry - Simulated Cumulative Effects Surface Area Time Series



Holbrook Reservoir

Summary data for the cumulative effects on Holbrook Reservoir pool elevation are shown in **Table 5-38** and **Figure 5-38**. Simulated reservoir pool elevations are identical for the Existing Conditions and the No Action Alternative. Elevations are greater for the Proposed Action than for the No Action Alternative, resulting in positive cumulative effects. The highest cumulative effects occur during mean dry years.

Summary data for the cumulative effects on Holbrook Reservoir surface area are shown in **Table 5-39**, **Figure 5-39**, and **Figure 5-40**. Cumulative effects for surface area are similar to the effects seen for reservoir pool elevations. Simulated reservoir surface area is identical for the Existing Conditions and the No Action Alternative. Surface area is greater for the Proposed Action than for the No Action Alternative, resulting in positive cumulative effects. The highest cumulative effects occur during mean dry years.

Table 5-38. Holbrook Reservoir - Simulated Cumulative Effects Elevation

Month	Simulated Elevation: Existing Conditions (feet)	Simulated Elevation: No Action (feet)	Simulated Elevation: Proposed Action (feet)	Cumulative Effects (1) (feet)	Cumulative Effects (1) (%)
Overall Mean					
Oct	6.36	6.36	8.23	1.87	43%
Nov	6.97	6.97	8.78	1.82	37%
Dec	8.37	8.37	9.74	1.37	22%
Jan	11.14	11.14	11.97	0.83	9%
Feb	12.87	12.87	13.53	0.66	6%
Mar	13.98	13.98	14.63	0.65	5%
Apr	13.75	13.75	14.43	0.67	6%
May	12.88	12.88	13.11	0.23	2%
Jun	12.41	12.41	12.79	0.38	4%
Jul	9.78	9.78	10.89	1.11	14%
Aug	7.42	7.42	8.46	1.04	19%
Sep	6.36	6.36	8.03	1.67	39%
Average	**10.19**	**10.19**	**11.21**	**1.03**	**13%**
Mean Wet					
Oct	7.96	7.96	7.96	0.00	0%
Nov	7.89	7.89	7.89	0.00	0%
Dec	7.85	7.85	7.85	0.00	0%
Jan	9.22	9.22	9.22	0.00	0%
Feb	9.92	9.92	9.92	0.00	0%
Mar	10.31	10.31	10.43	0.12	1%
Apr	10.48	10.48	10.76	0.27	3%
May	10.33	10.33	10.33	0.00	0%
Jun	10.82	10.82	10.82	0.00	0%
Jul	10.67	10.67	10.75	0.08	1%
Aug	9.26	9.26	9.49	0.23	3%
Sep	8.91	8.91	9.08	0.17	2%
Average	**9.47**	**9.47**	**9.54**	**0.07**	**1%**
Mean Dry					
Oct	5.39	5.39	10.33	4.94	146%
Nov	6.41	6.41	11.26	4.85	110%
Dec	7.61	7.61	11.42	3.81	68%
Jan	11.93	11.93	14.13	2.19	22%
Feb	16.44	16.44	18.17	1.73	12%
Mar	18.76	18.76	20.30	1.54	9%
Apr	18.11	18.11	19.30	1.19	7%
May	16.01	16.01	16.28	0.27	2%
Jun	14.27	14.27	14.64	0.37	3%
Jul	9.33	9.33	11.26	1.93	26%
Aug	5.88	5.88	8.64	2.76	71%
Sep	4.32	4.32	8.35	4.02	176%
Average	**11.21**	**11.21**	**13.67**	**2.47**	**27%**

Notes:
(1) Cumulative Effects (feet) = Proposed Action - No Action simulated elevation. Effects (%) = (Proposed Action - No Action simulated elevation)/No Action simulated depth.

Table 5-39. Holbrook Reservoir - Simulated Cumulative Effects Surface Area

Month	Simulated Area Existing Conditions (acres)	Simulated Area No Action (acres)	Simulated Area Proposed Action (acres)	Cumulative Effects (1) (acres)	Cumulative Effects (1) (%)
Overall Mean					
Oct	185.0	185.0	252.1	67.1	36%
Nov	204.6	204.6	270.4	65.9	32%
Dec	254.2	254.2	303.9	49.6	20%
Jan	356.3	356.3	381.2	24.9	7%
Feb	418.2	418.2	430.4	12.2	3%
Mar	455.9	455.9	465.1	9.3	2%
Apr	447.7	447.7	462.5	14.8	3%
May	416.4	416.4	422.1	5.7	1%
Jun	398.6	398.6	406.9	8.3	2%
Jul	306.8	306.8	345.2	38.4	13%
Aug	226.5	226.5	262.2	35.7	16%
Sep	190.0	190.0	247.8	57.7	30%
Average	**321.7**	**321.7**	**354.2**	**32.5**	**10%**
Mean Wet					
Oct	235.9	235.9	235.9	0.0	0%
Nov	233.6	233.6	233.6	0.0	0%
Dec	232.1	232.1	232.1	0.0	0%
Jan	280.4	280.4	280.4	0.0	0%
Feb	305.8	305.8	305.8	0.0	0%
Mar	318.9	318.9	321.0	2.1	1%
Apr	324.4	324.4	328.9	4.5	1%
May	319.0	319.0	319.0	0.0	0%
Jun	333.8	333.8	333.8	0.0	0%
Jul	329.9	329.9	331.0	1.1	0%
Aug	279.6	279.6	284.1	4.5	2%
Sep	269.4	269.4	274.7	5.3	2%
Average	**288.6**	**288.6**	**290.0**	**1.5**	**1%**
Mean Dry					
Oct	150.9	150.9	333.0	182.1	121%
Nov	183.7	183.7	363.9	180.2	98%
Dec	228.9	228.9	369.0	140.1	61%
Jan	395.4	395.4	472.0	76.6	19%
Feb	555.4	555.4	592.6	37.2	7%
Mar	634.8	634.8	656.1	21.3	3%
Apr	611.4	611.4	636.7	25.3	4%
May	536.8	536.8	546.2	9.4	2%
Jun	473.9	473.9	487.3	13.4	3%
Jul	299.8	299.8	368.3	68.5	23%
Aug	191.8	191.8	281.9	90.1	47%
Sep	139.8	139.8	274.1	134.3	96%
Average	**366.9**	**366.9**	**448.4**	**81.5**	**22%**

Notes:
(1) Cumulative Effects (acres) = Proposed Action - No Action simulated area. Cumulative Effects (%) = (Proposed Action - No Action simulated area)/No Action simulated area.

Figure 5-38. Holbrook Reservoir - Simulated Cumulative Effects Elevation

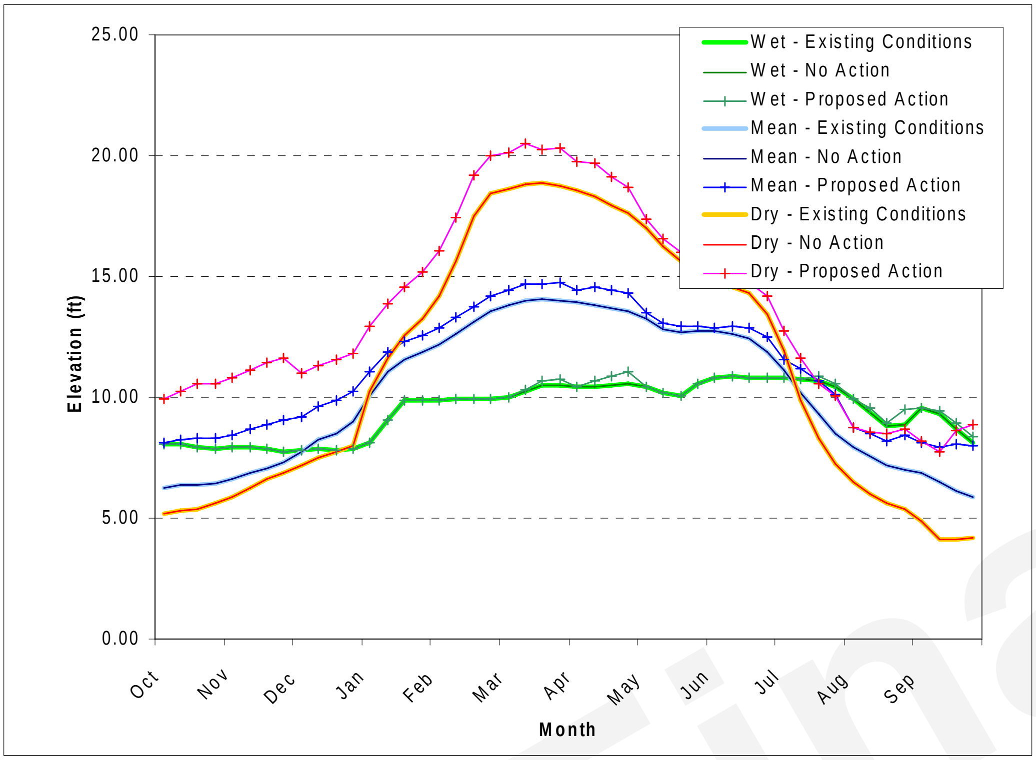


Figure 5-39. Holbrook Reservoir - Simulated Cumulative Effects Surface Area

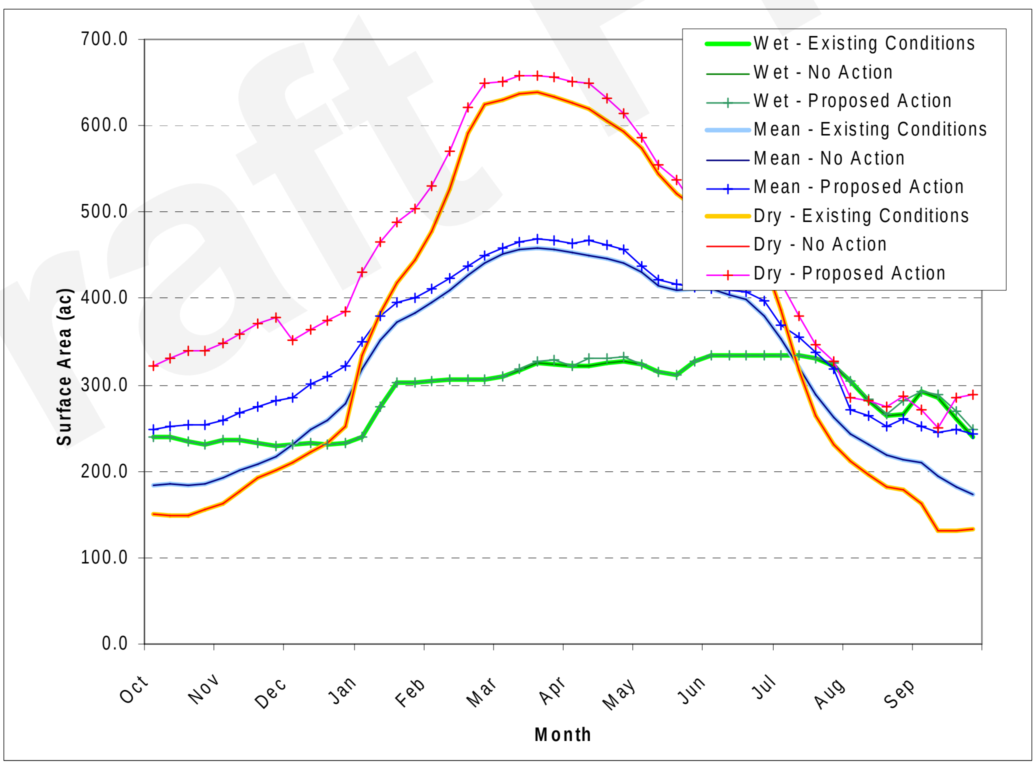
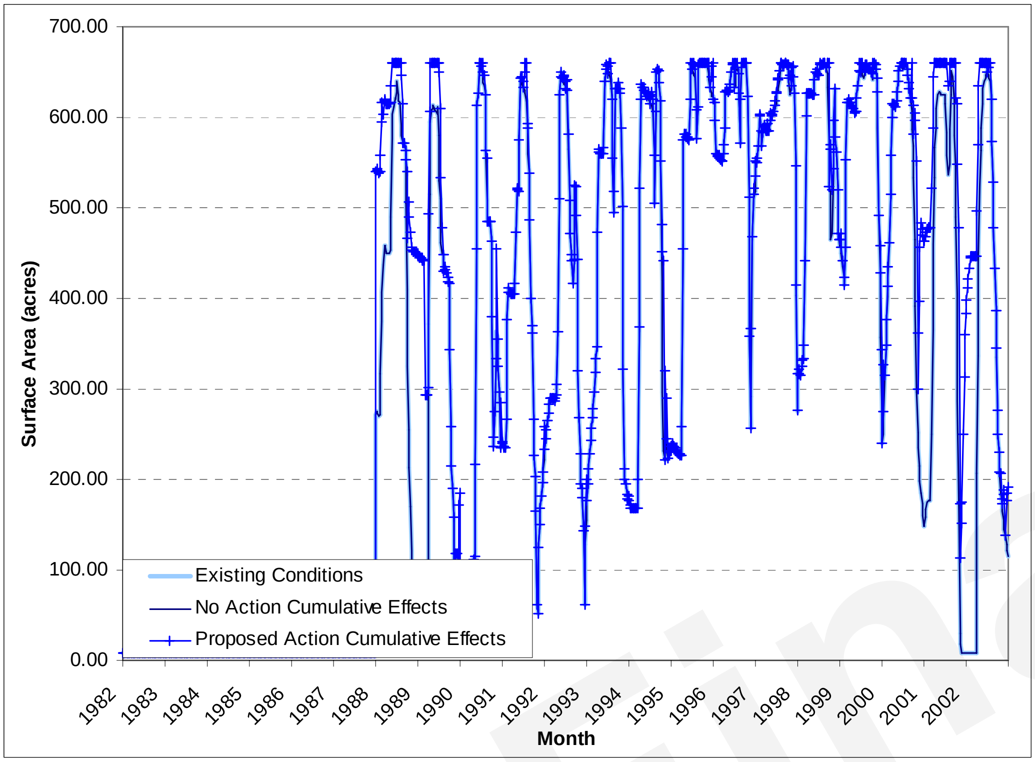


Figure 5-40. Holbrook Reservoir - Simulated Cumulative Effects Surface Area Time Series



La Junta Gage

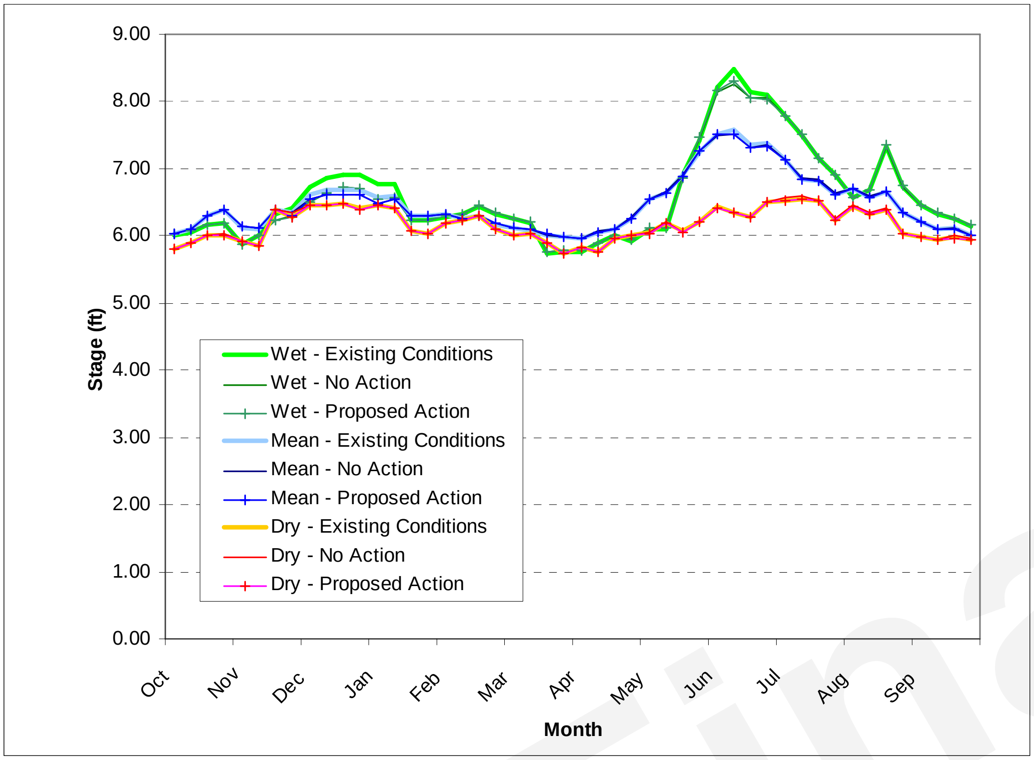
Summary data for the cumulative effects on stage for the La Junta Gage are shown in **Table 5-40** and **Figure 5-41**. There are small positive and negative differences between stages under the Existing Conditions and the No Action Alternative and the Proposed Action.

Table 5-40. La Junta Gage Stage - Summary of Cumulative Effects

Month	Simulated Stage			Cumulative Effects (1)	
	Existing Conditions (feet)	No Action (feet)	Proposed Action (feet)	(feet)	(%)
Overall Mean					
Oct	6.20	6.20	6.20	0.00	0%
Nov	6.24	6.25	6.23	-0.01	-1%
Dec	6.67	6.60	6.60	0.00	0%
Jan	6.45	6.41	6.41	0.00	0%
Feb	6.26	6.27	6.27	0.00	0%
Mar	6.05	6.05	6.06	0.00	0%
Apr	6.09	6.10	6.10	-0.01	-1%
May	6.84	6.85	6.83	-0.01	-1%
Jun	7.46	7.42	7.42	0.00	0%
Jul	6.85	6.87	6.85	-0.01	-1%
Aug	6.57	6.58	6.57	-0.01	-1%
Sep	6.10	6.11	6.11	-0.01	-1%
Average	**6.48**	**6.48**	**6.47**	**0.00**	**0%**
Mean Wet					
Oct	6.11	6.11	6.11	0.00	0%
Nov	6.15	6.11	6.10	-0.01	-1%
Dec	6.85	6.65	6.65	0.00	0%
Jan	6.49	6.39	6.40	0.00	0%
Feb	6.34	6.35	6.35	0.00	0%
Mar	5.99	6.00	6.00	0.00	0%
Apr	5.89	5.91	5.91	0.00	0%
May	6.63	6.65	6.64	0.00	0%
Jun	8.24	8.13	8.14	0.02	1%
Jul	7.33	7.34	7.34	0.00	0%
Aug	6.83	6.84	6.84	0.00	0%
Sep	6.30	6.31	6.31	0.00	0%
Average	**6.60**	**6.57**	**6.57**	**0.00**	**0%**
Mean Dry					
Oct	5.93	5.93	5.93	0.00	0%
Nov	6.11	6.13	6.11	-0.02	-2%
Dec	6.45	6.45	6.45	0.00	0%
Jan	6.24	6.24	6.24	0.00	0%
Feb	6.21	6.21	6.21	0.00	0%
Mar	5.92	5.92	5.92	0.00	0%
Apr	5.88	5.89	5.88	-0.01	-2%
May	6.13	6.13	6.12	-0.02	-2%
Jun	6.39	6.39	6.39	0.00	0%
Jul	6.46	6.49	6.46	-0.03	-3%
Aug	6.30	6.32	6.29	-0.02	-2%
Sep	5.96	5.97	5.95	-0.01	-2%
Average	**6.17**	**6.17**	**6.16**	**-0.01**	**-1%**

Notes:
(1) Cumulative Effects (feet) = Proposed Action - No Action simulated stage. Effects (%) = (Proposed Action - No Action simulated stage)/No Action simulated stage.

Figure 5-41. La Junta Gage - Simulated Cumulative Effects Stage



5.4.2 Stream Geomorphology

Potential changes to stream geomorphology due to the cumulative effects of the Proposed Action were evaluated by comparison of changes in flow duration curves to bankfull discharge. Through comparison of the flow duration curves, the maximum difference between the Proposed Action and No Action Alternative flow duration curves for a given non-exceedance percentage was determined. Geomorphic changes were analyzed in more detail if this maximum difference was greater than 10 percent and occurred at streamflow values that exceed the bankfull discharge. Because the average morphologic characteristics of a channel are formed as a result of bankfull discharge (Rosgen, 1996), differences between Proposed Action and No Action Alternative flow duration curves that are lower than the bankfull discharge will have minimal effects on channel geomorphology for the potentially affected stream channels.

Comparison of flow duration curves was only completed for reaches that were determined to be moderately to very highly sensitive to hydrologic changes using the Rosgen classification technique. The geomorphic stability of potentially affected stream reaches is described in **Section 3.5**. Locations where stream geomorphology analysis was completed are shown in **Figure 3-21**.

5.4.2.1 Upper Arkansas River Basin

For the Upper Arkansas River Basin, the geomorphic analysis was conducted for the same reaches as in the effects analysis.

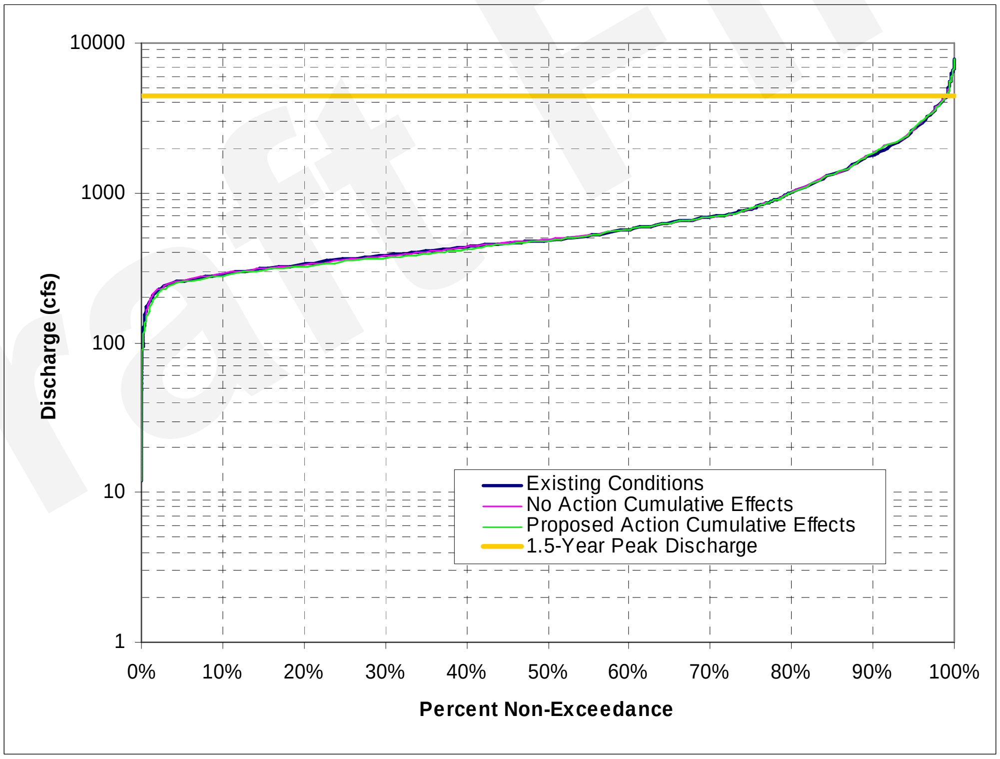
Portland

The flow duration curve for the Portland gage is presented in **Figure 5-42**. The maximum difference between Proposed Action and No Action Alternative flow duration curves showed that Proposed Action flows were 11 percent less than No Action Alternative flows for the 1 percent non-exceedance (approximately 155 cfs). The 1.5-year peak flow discharge for the Portland gage (4,500 cfs) is also plotted in **Figure 5-42**.

As discussed in **Section 3.5.2**, the Portland gage is located in a section of the Arkansas River that is moderately sensitive to hydrologic disturbance.

Although the section of the Arkansas River at Portland gage is sensitive to hydrologic disturbances, there are no changes in streamflow greater than 10 percent that occur at streamflow values that exceed the bankfull discharge at the Portland gage. As a result, minimal differences in stream morphology near the Portland gage are expected.

Figure 5-42. Portland Gage - Cumulative Effects Flow Duration Curve



5.4.2.2 *Lower Arkansas River Basin*

As with the effects analysis, the geomorphology analysis was conducted at the Above Pueblo, Moffat Street, Avondale, and La Junta gages.

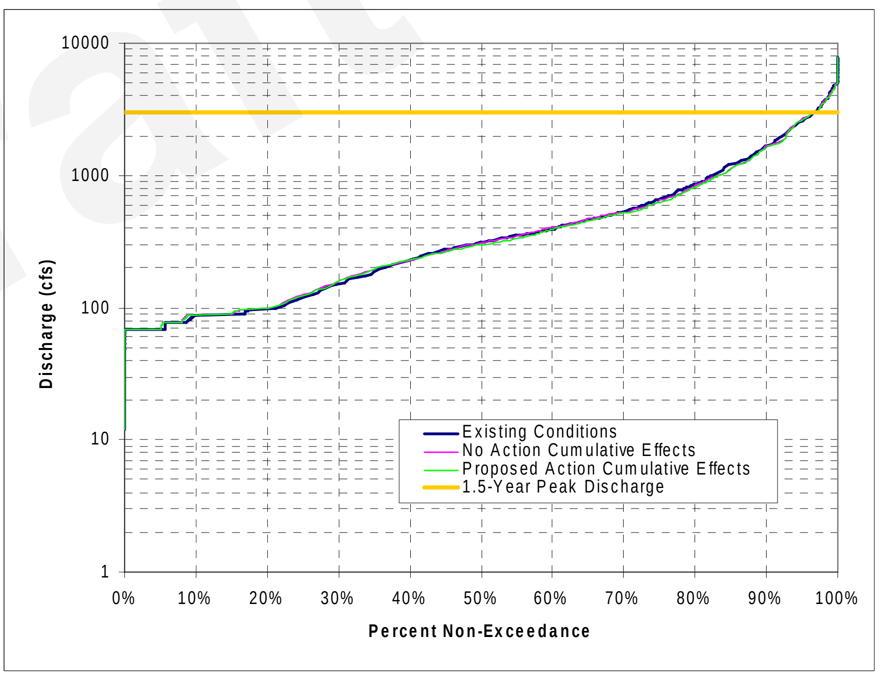
Above Pueblo

The flow duration curve for the Above Pueblo gage is presented in **Figure 5-43**. The flat portion of the curve near the flow value of 100 cfs reflects the effects of the Pueblo RICD. The maximum difference between Proposed Action and No Action Alternative flow duration curves showed that Proposed Action flows were 5 percent less than No Action Alternative flows at the 99 percent non-exceedance level (approximately 3,000 cfs). The 1.5-year peak flow discharge for the Above Pueblo gage (4,100 cfs) is also plotted in **Figure 5-43**. There are no changes greater than 10 percent for the entire range of streamflow values.

As discussed in **Section 3.5.2**, the Above Pueblo gage is located in a section of the Arkansas River that is part of the Legacy Project, which has the objective of stabilizing the Arkansas River channel through the City of Pueblo. The Rosgen stream classification was not applied to this reach of the Arkansas River because the reach has been stabilized with man-made structures and will be addressed as part of the Legacy Project.

Effects on stream morphology near the Above Pueblo gage are expected to be minimal, because differences between Proposed Action and No Action Alternative flow duration curves are less than 10 percent for the range of flows. Additionally, existing and future man-made structures in this reach will reduce impacts on geomorphology caused by potential hydrologic changes.

Figure 5-43. Above Pueblo Gage Cumulative Effects Flow Duration Curve



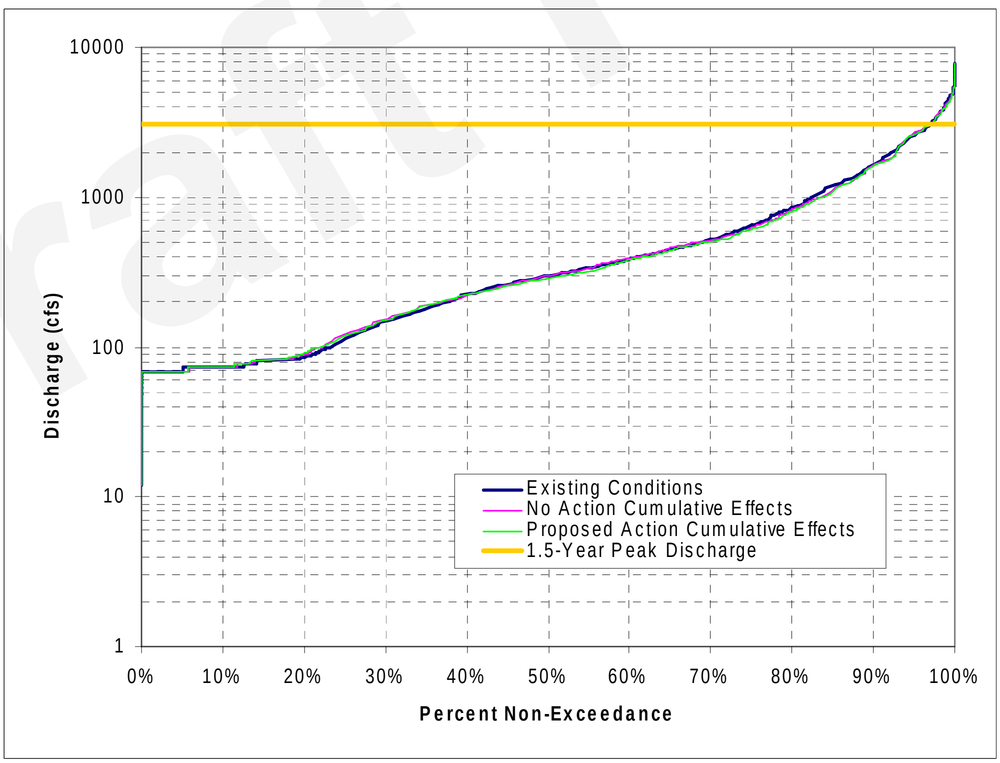
Moffat Street

The Moffat Street gage cumulative effects flow duration curve is presented in **Figure 5-44**. The flat portion of the flow duration curve near the flow value of 80 cfs reflects the effects of the Pueblo FMP. The maximum difference between Proposed Action and No Action Alternative flow duration curves showed that Proposed Action flows were 5 percent less than No Action Alternative flows at the 58 percent non-exceedance level (approximately 350 cfs). The 1.5-year peak flow discharge for the Moffat Street gage (3,100 cfs) is also plotted in **Figure 5-44**. There are differences between the Proposed Action and No Action Alternative flow duration curves, however the differences are less than 10 percent and are well below the bankfull discharge.

As discussed in **Section 3.5.2**, the Moffat Street gage is located in a section of the Arkansas River that is directly downstream of the Legacy Project, which has the objective of stabilizing the Arkansas River channel through the City of Pueblo. Additionally, the Moffat Street gage is located directly downstream of a concrete lined section of the Arkansas River. The Rosgen stream classification was not applied to this reach of the Arkansas River, because the reach is lined with concrete, and is not a natural stream channel as a result.

Effects on geomorphology at the Moffat Street gage are expected to be minimal because differences in the flow duration curves are less than 10 percent for the range of flows and occur at streamflow values less than the bankfull discharge. Additionally, the concrete lining of the Arkansas River near the Moffat Street gage will stabilize the geomorphology near the Moffat Street gage.

Figure 5-44. Moffat Street Gage Cumulative Effects Flow Duration Curve

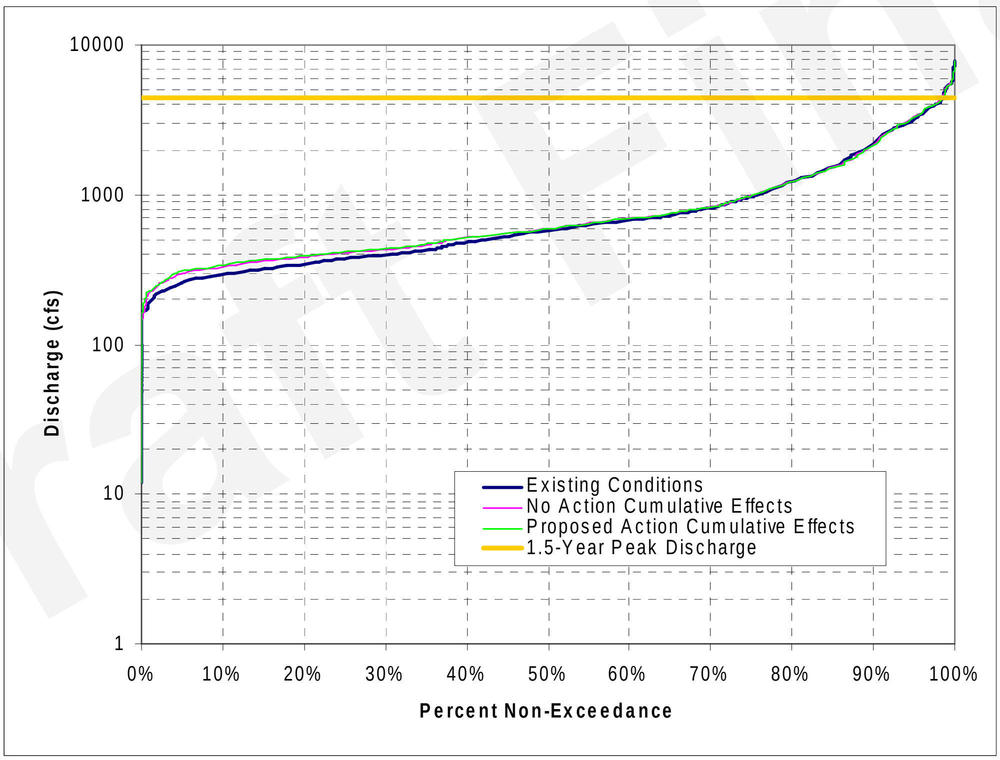


Avondale

The flow duration curves for the cumulative effects at the Avondale gage are shown in **Figure 5-45**. The maximum difference between Proposed Action and No Action Alternative flow duration curves showed that Proposed Action flows were 15 percent higher than No Action Alternative flows at the 1 percent non-exceedance flow level (approximately 190 cfs). There are no differences greater than 10 percent between the Proposed Action and No Action Alternative flow duration curves for flows above the 1 percent non-exceedance level. The 1.5-year peak flow discharge for the Avondale gage (4,400 cfs) is also plotted in **Figure 5-45**.

The Avondale gage is located in a section of the Arkansas River classified as a D5c- stream, as described in the geomorphic characterization in **Section 3.5.2**. According to the Rosgen stream classification, this type of stream has a very high sensitivity to changes in streamflow. However, as discussed in the previous paragraph, there are no differences between the Proposed Action and No Action Alternative flow duration curves greater than 10 percent that occur for streamflow values greater than the bankfull discharge. As a result, effects on channel geomorphology are expected to be minimal near the Avondale gage.

Figure 5-45. Cumulative Effects Avondale Gage Flow Duration Curve

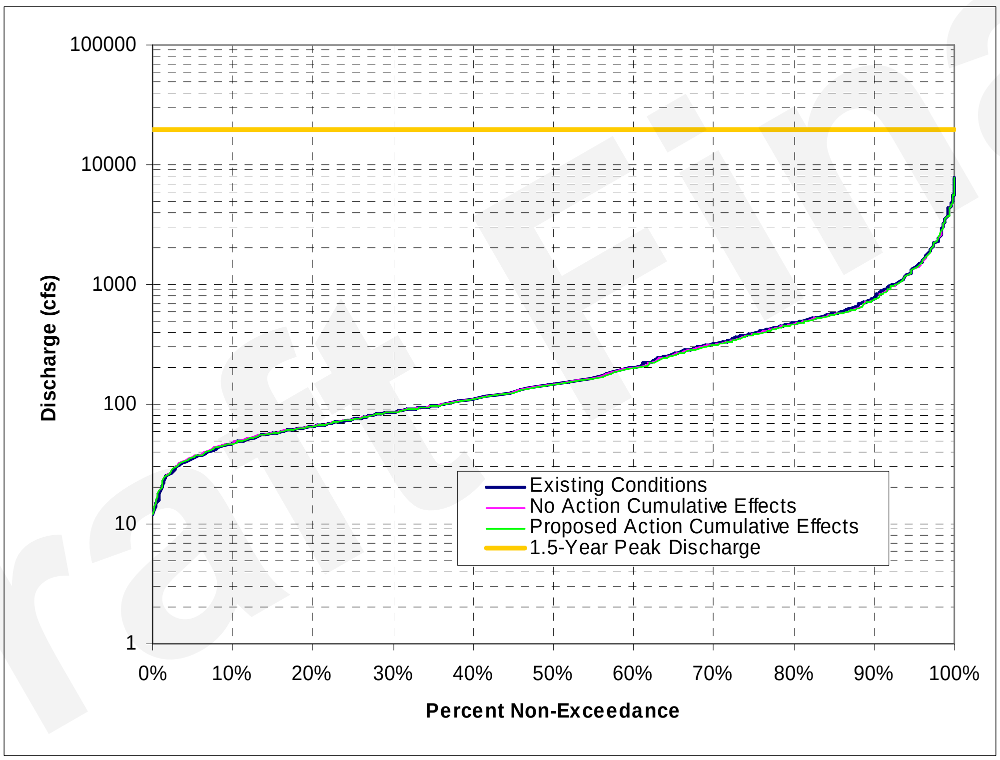


La Junta

The flow duration curves for the cumulative effects at the La Junta gage are shown in **Figure 5-46**. The maximum difference between Proposed Action and No Action Alternative flow duration curves showed that Proposed Action flows were 8 percent higher than No Action Alternative flows at the 98 percent non-exceedance level (approximately 2,800 cfs). The 1.5-year peak flow discharge for the La Junta gage (2,700 cfs) is also plotted in **Figure 5-46**.

The La Junta gage is located in a section of the Arkansas River classified as a C5c- stream, as described in the geomorphic characterization in **Section 3.5.2**. According to the Rosgen stream classification, this type of stream has a very high sensitivity to changes in streamflow. However, minimal effects on channel geomorphology near the La Junta gage are expected because differences between Proposed Action and No Action Alternative flow duration curves are less than 10 percent for the entire range of streamflows.

Figure 5-46. Cumulative Effects La Junta Gage Flow Duration Curve



5.5 Ground Water

The primary causes for changes in ground water levels in the study area would be changes in river stage or changes in irrigation and ground water pumping practices. As described in **Section 2.3**, three threshold criteria were evaluated to determine cumulative effects on ground water in the study area. Results of the evaluation of each of the threshold criteria are described below.

- As described in **Section 4.3.1**, difference between mean flow depth for the Proposed Action and the No Action Alternative were less than 10 percent for locations on the Arkansas River, except for one month at the Avondale and La Junta gages. The differences in mean flow depth at the Avondale and La Junta gages during the one wet month will not result in cumulative effects on ground water. The differences are short-term increases that would not be sustained long enough to translate into cumulative effects on ground water.
- Assumptions for irrigation practices are the same under the Proposed Action and No Action Alternative. As a result, differences in projected irrigation practices do not vary by more than 5 percent between the Proposed Action and No Action Alternative.
- Assumptions for ground water pumping practices are the same under the Proposed Action and No Action Alternative. As a result, differences in projected ground water pumping practices do not vary by more than 5 percent between the Proposed Action and No Action Alternative.

Based on these criteria, there would be no significant cumulative effects on ground water due to the Proposed Action.

6.0 REFERENCES

Abbott, P.O. 1985. Description of Water-Systems Operations in the Arkansas River Basin, Colorado. U.S. Geological Survey Report 85-4092. Lakewood, Colorado.

Arkansas River Compact Association (ARCA). 1976. Exhibit 1 to 1976 ARCA Resolution Approving a Permanent Pool at John Martin Reservoir - John Martin Permanent Pool Operating Criteria.

Arkansas River Compact Association (ARCA). 1980. Resolution Concerning an Operating Plan for John Martin Reservoir. April 24.

Arkansas River Compact Association (ARCA). 1984. Resolution Concerning an Operating Plan for John Martin Reservoir. Revisions approved May 10, 1984 and December 11, 1984.

Arkansas River Compact Association (ARCA). 1998. Resolution Concerning an Offset Account in John Martin Reservoir for Colorado Pumping as Amended March 30, 1998. March 30.

Aurora et al. 2005. “Agreement between Aurora and ROY Participants for use of the Holbrook System Facilities.” Agreement between the City of Aurora, the Southeastern Colorado Water Activity Enterprise, the City of Fountain, the City of Colorado Springs, and the Pueblo Board of Water Works.

Barkmann, P.E., Bellis, W.H., Hamilton, J.L., Spray, K.L., and Topper, R., 2003, Ground Water Atlas of Colorado, Colorado Geological Survey Special Publication 53.

Bedient, P.B., Huber, W. C. Hydrology and Floodplain Analysis. Third ed. Upper Saddle River, New Jersey. Prentice Hall

Black & Veatch. 2004. Water Resource Study for Fountain, Colorado. B&V Project No. 134962. February.

Bossong, C.R., 2000, Analysis of Hydrologic Factors That Affect Ground-Water Levels in the Arkansas River Alluvial Aquifer Near La Junta, Colorado, 1959-99, Water-Resources Investigations Report 00-4047.

Colorado Decision Support System (CDSS). 2004. HydroBase database [cited 2004]. Available from World Wide Web: http://cdss.state.co.us/db/index.asp.

Colorado Department of Public Health and Environment, 2001, Regulation 21 - The Basic Standards for Ground Water, December 30, 2001, http://www.cdphe.state.co.us/op/regs/waterqualityregs.asp, accessed February 9, 2004.

Colorado Department of Public Health and Environment, 2002, Status of Water Quality in Colorado 2002, http://www.cdphe.state.co.us/op/wqcc/waterstatus2002/305(b)tableofcontents.pdf, accessed January 19, 2004.

Colorado Division of Water Resources (CDWR) water well database, 2001.

Colorado Springs Utilities, 2003, Colorado Springs Utilities 2003 Water Quality Report, http://www.csu.org/files/general/2190.pdf, accessed March 10, 2004.

Colorado Water Conservation Board (CWCB). 2002. Findings of Fact and Final Recommendation of the Colorado Water Conservation Board to the Water Court. Case Number 01CW160, Concerning the Application for Water Rights of Pueblo. District Court, Water Division No. 2, Colorado. August.

Colorado Water Conservation Board (CWCB). 2003. Colorado Decision Support System (CDSS). http://cdss.state.co.us.

Crouch, Thomas M., Doug Cain, P.O. Abbot, Robert D. Penley, and R. Theodore Hurr. 1984. Water-Resources Appraisal of the Upper Arkansas River Basin from Leadville to Pueblo, Colorado. U.S. Geological Survey Water-Resources Investigations Report 82-4114. Lakewood Colorado.

Dunne, T. and Leopold, L.B. 1978. Water in Environmental Planning. W.H. Freeman and Co., San Francisco, CA.

Federal Emergency Management Agency (FEMA). 1985. Otero County Flood Insurance Study.

Federal Emergency Management Agency (FEMA). 1989. Flood Insurance Studies for Colorado Springs, and El Paso County, Colorado.

Federal Emergency Management Agency (FEMA), 2002. Fremont County Flood Insurance Study. March.

Gates, T.K., Burkhalter, J.P., Labadie, J.W., Valliant, J.C., and Broner, I., 2002, Monitoring and Modeling Flow and Salt Transport in a Salinity-Threatened Irrigated Valley, Journal of Irrigation and Drainage Engineering, March/April, 2002.

Gates, T.K., Burkhalter, J.P., 2004, Colorado State University Civil Engineering Department, personal communication.

GEI, Inc. 1998. SECWCD/Arkansas River Basin Future Water and Storage Needs Assessment. Prepared for: SECWCD/Arkansas River Basin Future Water and Storage Needs Assessment. In Association with: Helton & Williamsen, P.C., David Bamberger & Associates. GEI Project 97411. Englewood, Colorado. December 10.

Gracely, Brett. 2003. Personal communication via e-mail and meetings. Colorado Springs Utilities, Planning and Engineering Division, Regional Projects. July.

Gracely, Brett. 2005. "Re: Pueblo IGA, Equitable Allocation of Hours." E-mail to Gerald Gibbens. July 18.

Holbrook Mutual Irrigating Company and the City of Aurora (Holbrook and Aurora). 2005. "Agreement for Use of Excess Capacity." Agreement between the Holbrook Mutual Irrigating Company and the City of Aurora. March 1.

Hopkins, Linda. 2005. U.S. Bureau of Reclamation. Personal communication with Tom Simpson of Aurora Utilities Department. September.

Hydrosphere Resource Consultants, Inc. 2005. Excess Capacity Contract Environmental Assessment Arkansas River Quarter-Monthly Model Documentation. Prepared for the Bureau of Reclamation and the City of Aurora. September.

"Intergovernmental Agreement Among the City of Pueblo, The City of Colorado Springs, And The Board of Water Works of Pueblo, Colorado." (February IGA). March, 2004.

"Intergovernmental Agreement Among the City of Pueblo, The City of Aurora, The Southeastern Colorado Water Conservancy District, The City of Fountain, The City of Colorado Springs, and The Board of Water Works of Pueblo, Colorado." (May IGA). May, 2004.

"Intergovernmental Agreement Between the Southeastern Colorado Water Conservancy District and the City of Aurora." (October IGA). October, 2003.

Kiowa Engineering Corp. and HRS Water Consultants, Inc., 1996, Groundwater and Wastewater Reuse Development Study, prepared for Colorado Springs Utilities Water Resources Department, June 1966.

Kuhn, Gerhard. 1988. Methods to Determine Transit Losses for Return Flows of Transmountain Water in Fountain Creek Between Colorado Springs and the Arkansas River, Colorado. USGS Water Resources Investigations Report 87-4119. Denver, Colorado.

La Junta Water and Wastewater Department, 2004, Personal communication with Joe Kelley, Director of Water and Wastewater Department.

Labadie, John W., Marc L. Baldo and Roger Larson. 2000. MODSIM: Decision Support System for River Basin Management Documentation and User Manual. Colorado State University and Bureau of Reclamation. May.

Livingston, Russell K. 1978. Transit Losses and Traveltimes of Reservoir Releases Along the Arkansas River from Pueblo Reservoir to John Martin Reservoir, Southeastern Colorado. U.S. Geological Survey Water Resources Investigations 78-75. Prepared in cooperation with the Southeastern Colorado Water Conservancy District. September.

Mars, Scott and Peter Fleming. 2001. Personal communication via facsimile and phone call. Colorado Springs Utilities staff. July 19 and July 24.

Montgomery Watson (MW). 1998. Operations and Yield Model Report. Prepared for Colorado Springs Utilities. September 30.

Montgomery Watson (MW). 2001. Hydrologic Analysis - Technical and Environmental Analysis of Storage Alternatives. Prepared for: Colorado Springs Utilities and the Arkansas River Basin Future Water and Storage Needs Assessment Enterprise. Denver, Colorado.

Montgomery Watson Harza (MWH). 2002. Report to the Colorado Water Conservation Board from Gerald A. Gibbens regarding "Colorado Springs Utilities Water Resources Planning Models Description and Results." June 5.

Montgomery Watson Harza (MWH). 2005a. DRAFT Raw Water Yield Study, Monthly Model Documentation and Results. Prepared for Colorado Springs Utilities. July.

Montgomery Watson Harza (MWH). 2005b. DRAFT Water Quality Technical Report. Prepared for Bureau of Reclamation. August.

Musgrove, Tom. 2005. Personal communication, phone call with Gerald Gibbens, MWH, and Bob Hamilton, SECWCD. Reclamation Pueblo Field Office. October 28.

National Weather Service (NWS). 1982. NOAA Technical Report NWS 33, Evaporation Atlas for the Contiguous 48 United States. Washington D.C.

The Nature Conservancy. 2001. Indicators of Hydrologic Alteration User's Manual. Prepared with Smythe Scientific Software, Boulder, Colorado. July.

Oppelt, Eric. 2004. CDPHE WQCD, Personal conversation with Tracy Wilcox on June 30, 2004.

Ramirez, Jorge A. 2004. Class Notes, CE522 - Engineering Hydrology. Colorado State University. http://www.engr.colostate.edu/~ramirez/ce_old/classes/ce522_ramirez/

Richter, Brian. 2005. Personal communication with Steve Smith at the Indicators of Hydrologic Alteration (IHA) Workshop: Software for Understanding the Ecological Consequences of Hydrologic Change. Ecologist, The Natural Conservancy. June 27-28.

Rosgen, Dave, 1996, Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Simpson, Tom. 2005. Personal communication via phone call with Jerry Gibbens and John Winchester. Senior Water Resources Engineer, Arkansas Valley Range Project. May 3 and May 20.

Southeastern Colorado Water Conservancy District (SECWCD). 1979. Allocation Principals, Findings, Determinations and Resolutions. November 29.

Southeastern Colorado Water Conservancy District (SECWCD). 2001. 2001 Annual Report.

Southeastern Colorado Water Conservancy District (SECWCD). 2004. Water Allocation Fryingpan-Arkansas Project Water. April15.

Thompson, Gary B., 2004, W.W. Wheeler and Associates, Inc., Personal communication.

United States Army Corps of Engineers (USACE). 2001, Draft Ecosystem Restoration Report and Environmental Assessment, Technical Appendices. April.

United States Army Corps of Engineers (USACE). 2003. Draft Fountain Creek - El Paso, Pueblo, and Teller Counties, CO. Hydrologic Watershed Analysis.

United States Bureau of Reclamation (Reclamation). 1975. Fryingpan-Arkansas Project Colorado, Final Environmental Statement, Vol. 1. April 16.

United States Bureau of Reclamation (Reclamation). 1979. Contract Between the United States and the Southeastern Colorado Water Conservancy District for Conveyance Service From the Fountain Valley Conduit. Fryingpan-Arkansas Project, Colorado. July 10.

United States Bureau of Reclamation (Reclamation). 1990. Review of Operations: Fryingpan-Arkansas Project, Colorado. In cooperation with the Southeastern Colorado Water Conservancy District, September.

United States Bureau of Reclamation (Reclamation). 2001. Annual Operating Plans Fryingpan-Arkansas Project Summary of Actual Operations Water Year 2001. http://www.usbr.gov/gp/aop/fa/01/toc.cfm.

United States Bureau of Reclamation (Reclamation). 2003. Southern Delivery System Project, Fryingpan-Arkansas Project, Colorado Notice of Intent to Prepare an Environmental Impact Statement. No. 4310-MN-P.

United States Bureau of Reclamation (Reclamation). 2004. Annual Operation Plan Fryingpan-Arkansas Project Water Year 2004 Summary of Actual Operations.

United States Bureau of Reclamation (Reclamation). 2003. Great Plains Region Hydromet Data System. http://www.usbr.gov/gp/hydromet.cfm.

United States Bureau of Reclamation (Reclamation). Date Unknown. Review Draft - National Environmental Policy Act Guidelines.

United States Environmental Protection Agency (USEPA). 2003. Superfund Sites National Priority List, http://www.epa.gov/superfund/sites/npl/co.htm, accessed January 7, 2004.

United States Geological Survey (USGS). 1984. Water Resources Appraisal of the Upper Arkansas River Basin from Leadville to Pueblo, Colorado, Water Resources Investigations Report 82-4114.

United States Geological Survey (USGS). 1987. Hydrologic Unit Maps, http://water.usgs.gov/GIS/huc.html, Adapted from Seaber, P.R., Kapinos, F.P., and Knapp, G.L., 1987, Hydrologic Unit Maps: U.S. Geological Survey Water-Supply Paper 2294, 63 p.

United States Geological Survey (USGS). USGS, 1995b. Quality of Water in the Alluvial Aquifer and Tributary Alluvium of the Fountain Creek Valley, Southwestern El Paso County, Colorado, 1991-92, Water Resources Investigations Report 94-4118.

United States Geological Survey (USGS). - Pueblo Subdistrict, 1997. Report on ground-water levels in USGS-monitored wells in the upper Arkansas River valley: Presented to the Southeastern Colorado Water Conservancy District, January 16, 1997.

United States Geological Survey (USGS). 2000. Estimated Water Use in the United States in 2000 [Cited January 17, 2005]. Available from World Wide Web: http://water.usgs.gov/watuse/.

United States Geological Survey (USGS). 2002. Changes in Ground-Water Levels in Selected Wells in the Arkansas River Alluvial Aquifer Downstream from Pueblo Reservoir, Southeastern Colorado, 1965-2001, USGS Fact Sheet 023-02.

United States Geological Survey (USGS). 2005. National Water Information System Database [online, cited June 20, 1997]. Available from World Wide Web: http://water.usgs.gov

Walton-Day, K., Rossi, F.J., Gerner, L.J., Evans, J.B., Yager, T.J., Ranville, J.F., and Smith, K.S., Effects of Fluvial Tailings Deposits on Soils and Surface- and Ground-Water Quality, and Implications for Remediation-Upper Arkansas River, Colorado, 1992-96, USGS Water-Resources Investigations Report 99-4273.

Watts, K.R. and Lindner-Lunsford, J.B., 1992, Evaluation of Proposed Water-Management Alternatives to Lower the High Water Table in the Arkansas River Valley Near La Junta, Colorado, USGS Water-Resources Investigations Report 91-4046.

Witte, Steve. 2005. Colorado Division of Water Resources, Division 2 Engineer. Phone conversation with Steve Smith, July 13.

Wolfe, D. 2005. Letter to Austin Hamre, Duncan, Ostrander & Dingess, P.C. regarding "Holbrook Substitute Supply Plan, a.k.a. Restoration of Yield (ROY) Program, Water Division 2, Water Districts 14 and 17." Assistant State Engineer. March 21.