RAW WATER SUPPLY MASTER PLAN
ARAPAHOE COUNTY WATER AND WASTEWATER AUTHORITY

Prepared for:

Arapahoe County Water and Wastewater Authority

Prepared by:

Gregory K. Sullivan, P.E.

Spronk Water Engineers, Inc.

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Spronk Water Engineers, Inc.

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1.0 INTRODUCTION

The Arapahoe County Water and Wastewater Authority ("ACWWA") was formed in 1988 to continue to supply water and wastewater to an area previously served by the Arapahoe Water and Sanitation District ("AWSD"), which was dissolved and replaced by ACWWA. The primary ACWWA service area is located in southern Arapahoe County and a small portion of northern Douglas County along Cherry Creek east of Interstate 25 and south of Cherry Creek State Park as shown in Figure 1-1 ("Cherry Creek Service Area"). ACWWA also provides separate water service to the Elkhorn Ranch subdivision ("Elkhorn Ranch") in Elbert County approximately seven miles to the east.

ACWWA delivers water for office, commercial, light industrial, residential, and irrigation uses with in the Cherry Creek Service Area. Water historically has been provided from a combination of shallow wells in the Cherry Creek alluvial aquifer and deep bedrock wells in the Denver Basin aquifers. In 2010, ACWWA and its neighbor to the south, the Cottonwood Water and Sanitation District ("CWSD"), completed construction of a water treatment plant known as the Joint Water Purification Plant ("JWPP"). The JWPP provides advanced treatment of alluvial ground water delivered from ACWWA and CWSD wells.

In 2009, ACWWA entered into a contract with the United Water and Sanitation District ("United") to develop a renewable treated water supply from the South Platte River known as the ACWWA Flow Project. ACWWA Flow Project water is pumped from wells constructed in the Beebe Draw alluvial aquifer for treatment at the Northern Water Treatment Plant ("NWTP") and delivery to ACWWA through the Northern Pipeline developed in cooperation with United and the East Cherry Creek Valley Water and Sanitation District ("ECCV"). Deliveries of ACWWA Flow Project water commenced in 2013.

Wastewater from ACWWA, CWSD, and the Inverness Water and Sanitation District ("IWSD") is treated at ACWWA's Lone Tree Creek Water Reuse Facility ("LTCWRF") and discharged to Lone Tree Creek. By contract, a portion of ACWWA's treated effluent is delivered for golf course irrigation (land application) at the Valley Country Club. The IWSD's portion of the treated effluent is piped back for irrigation of the golf course at the Inverness Golf Club.

The last full master planning effort for ACWWA was completed in 2011 and covered ACWWA's potable, nonpotable, and wastewater treatment systems ("2011 Master Plan"). The 2011 Master Plan was a comprehensive effort that included projected development of raw water supplies, water treatment and water distribution facilities, wastewater collection and treatment, and capital development planning. The 2011 Master Plan was not formally adopted by the ACWWA Board of Directors and remains in draft form. Several refinements and updates to the 2011 Master Plan were made in 2013.

This Raw Water Supply Master Plan is intended to guide ACWWA's planning and development of raw water supplies to meet the future water demands of the Cherry Creek Service Area. ACWWA plans to initiate master planning efforts for its water treatment and distribution facilities and its wastewater collection and treatment facilities in the near future. It is expected that these efforts will include capital development plans for construction and financing of water and wastewater facilities.

This Raw Water Master Plan Report is organized in sections as follows:

- Section 2 is a narrative description of the development of the ACWWA water system.
- Section 3 presents ACWWA's current and future water requirements.
- Section 4 provides and overview of ACWWA's water sources and water supplies.
- Section 5 describes the ACWWA Water Supply Operations Model.
- Section 6 presents the results of several water supply scenarios that were simulated using the model.
- Section 7 discusses several factors that may affect ACWWA's water supply.
- Section 8 provides an overview of the Elkhorn Ranch water requirements and water supply.
- Section 9 summarizes the conclusions and recommendations from this study.
- Section 10 is a list of the documents relied upon in preparing this report.

Spronk Water Engineers, Inc. ("SWE") has provided water resources and water rights consulting to ACWWA and its predecessor since 1983. SWE's work has included assisting ACWWA in adjudicating its Denver Basin ground water rights, alluvial ground water rights, and augmentation plans in the Cherry Creek basin, assisting in the planning and development of the Upper Cherry Creek Water Association (of which ACWWA is a member) and its umbrella augmentation plan under which ACWWA currently operates, quantifying ACWWA's lawn irrigation return flows, preparing ACWWA's water rights accounting mechanisms and spreadsheets, development of a water supply and water operations model of the major Cherry Creek municipal water suppliers as part of the Cherry Creek Aquifer Modeling Project, and assisting ACWWA's legal counsel in efforts to protect ACWWA's water rights. This background and institutional knowledge have been invaluable in preparing this Raw Water Supply Master Plan.

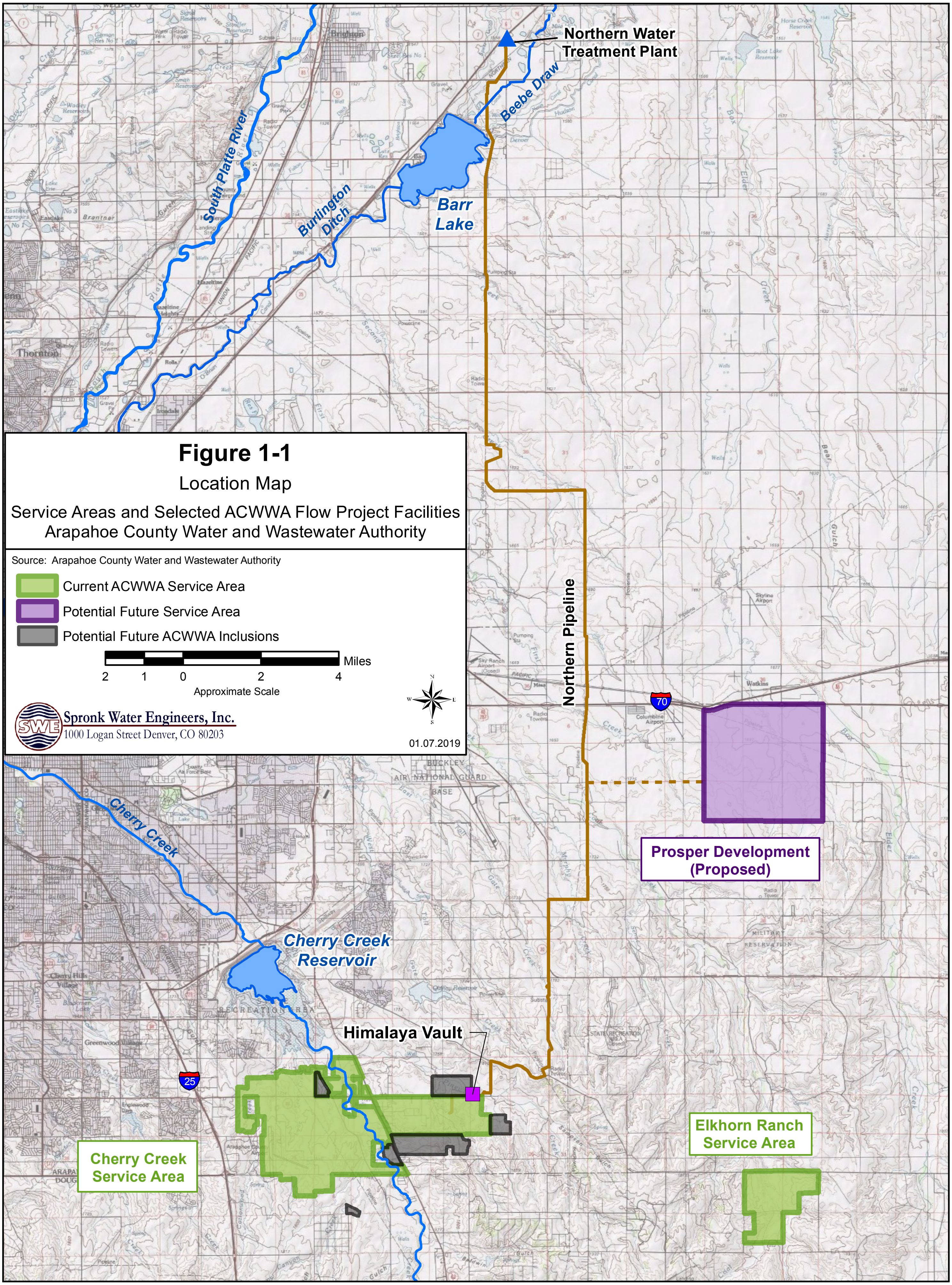


Figure 1-1

Location Map

Service Areas and Selected ACWWA Flow Project Facilities
Arapahoe County Water and Wastewater Authority

2.0 WATER SYSTEM DEVELOPMENT

2.1 Cherry Creek Service Area

ACWWA's predecessor, the AWSD, began serving water in approximately 1980 to a small service area west of Parker Road. The service area grew over time as developers included nearby parcels within the district for water service, including several inclusions that extended south into Douglas County. In the late-2000s, the service area was extended east of Parker Road to include the following existing developments that formerly were supplied by individual wells or small nontributary ground water systems:

- Chapparal Metropolitan District "(Chapparal")
- Antelope Subdivision ("Antelope")
- Estancia Subdivision ("Estancia")
- Town of Foxfield ("Foxfield")

As shown in Figure 2-1, the Cherry Creek Service Area is bounded by Cherry Creek State Park and ECCV to the north, the City of Aurora to the east, CWSD and the Stonegate Metropolitan District to the south, and the Inverness Water and Sanitation District ("IWSD") to the west. The service area presently encompasses approximately 7,300 acres.

2.2 Development of Water Systems and Water Sources

The original potable water supply for the Cherry Creek Service Area was provided from deep wells in the Denver Basin aquifers and shallow wells in the Cherry Creek alluvium. As the service area expanded, additional wells were constructed and connected to the distribution system. Water treatment was provided by chlorination at the wellhead. In 2010, ACWWA and CWSD began operation of the JWPP to provide advanced treatment of alluvial ground water. The JWPP is presently being reconfigured as a hybrid reverse osmosis and microfiltration treatment facility. Water pumped from the Denver Basin wells continues to be chlorinated at the well head.

In addition to the potable water system, ACWWA has also developed two nonpotable water systems for delivery of water for irrigation. One of these nonpotable systems is supplied from untreated alluvial wells and the other system is supplied by reclaimed effluent from the LTCWRF.

2.3 Land Use Mapping

During preparation of the 2011 Master Plan, detailed land use parcel mapping was developed for the Cherry Creek Service Area to assist in the planning efforts. This included mapping of existing land use types for developed areas and proposed land use types for undeveloped areas. SWE obtained the GIS shapefiles from ACWWA and performed and comprehensive review and update of the land use mapping. This included compiling updated information and data from ACWWA concerning actual development that has occurred since 2011 and updated projections of development of the undeveloped parcels. Among the data tabulated for each developed parcel were the gross parcel area, irrigated area, and square footage of commercial, industrial, and/or warehouse space. This information was compiled in a geospatial database of all of the parcels within the Cherry Creek Service Area for the following land use categories (developed and undeveloped):

- Commercial
- Industrial/Warehouse
- Office
- Single Family Residential
- Small Single Family Residential (not in subdivision)
- Multi-Family Residential
- Open space/farm
- Park/Golf Course/Greenbelt
- Special User
- Other

The updated land use map is shown in Figure 2-2. The land use mapping was used in the development of the potable and nonpotable water requirements that are described in Section 3.

2.4 Water Distribution Systems

ACWWA operates one potable water distribution system that extends to all portions of the Cherry Creek Service Area and two nonpotable water distribution systems that supply portions of the service area. A map showing the current and potential future extent of the nonpotable water distribution systems is provided as Figure 2-3. The current extent of these systems is depicted as the solid shading on the map and the potential future areas are cross-hatched. The areas of potential future expansion of the nonpotable distribution systems were identified by the ACWWA staff based on proximity to existing service lines and presence of existing or proposed irrigated parcels large enough to be economically served by a dual water system. It was assumed that there would be no retrofitting of existing single family or multi-family residential areas with nonpotable irrigation systems. Retrofitting of existing nonresidential properties that are currently served by potable water may be considered in the future, but is not planned at this time.

2.5 Wastewater Treatment

Wastewater service is provided to most of the Cherry Creek Service Area with the exception of the Antelope, Estancia, and Chapparal developments that are serviced by individual sewage disposal systems ("ISDS"). ACWWA's wastewater collection system delivers water for treatment at the Lone Tree Creek Water Reuse Facility located along Lone Tree Creek as shown in Figure 2-

1. The LTCWRF also treats wastewater from the CWSD and the IWSD. Additional discussion of the LTCWRF is provided in Section 4.4.

2.6 Elkhorn Ranch Service Area

The Elkhorn Ranch subdivision is comprised of 250 single family residential lots on approximately 1,500 acres in Elbert County about seven miles east of the Cherry Creek Service Area. Approximately 200 of the lots (80%) have been developed and are being served water. A map of the Elkhorn Ranch service area is provided in Figure 2.4. It is estimated that another ten accounts will be activated in 2019 and at the current rate of development buildout of the Elkhorn Ranch will occur by about 2023.

The water supply to the Elkhorn service area is currently provided from two Denver Basin wells, one in the Arapahoe aquifer and another in the Denver aquifer, and construction of another Arapahoe aquifer well is planned for 2019. Wastewater treatment is provided by individual sewage disposal systems.

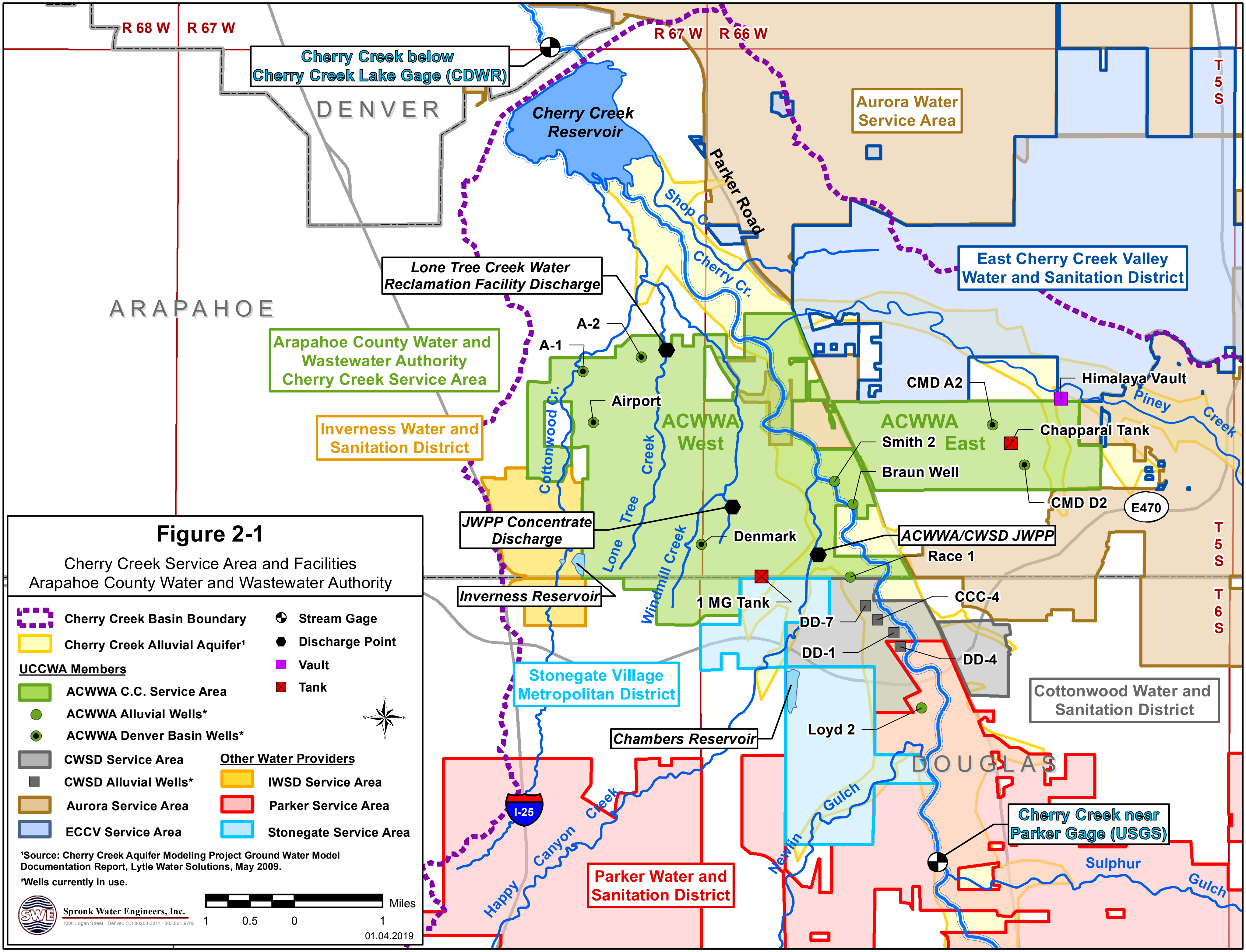


Figure 2-1

Cherry Creek Service Area and Facilities
Arapahoe County Water and Wastewater Authority

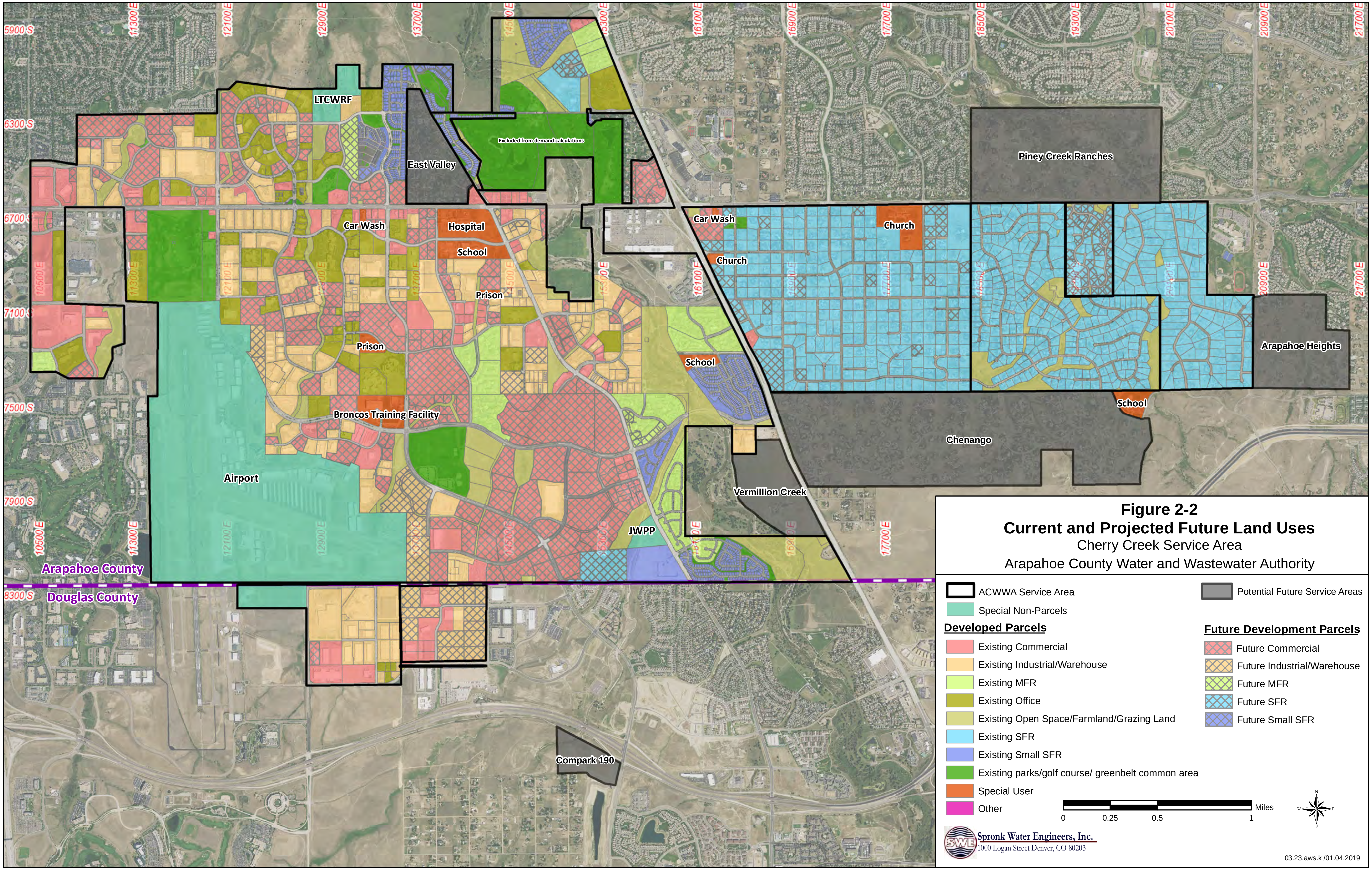


Figure 2-2
Current and Projected Future Land Uses
Cherry Creek Service Area
Arapahoe County Water and Wastewater Authority

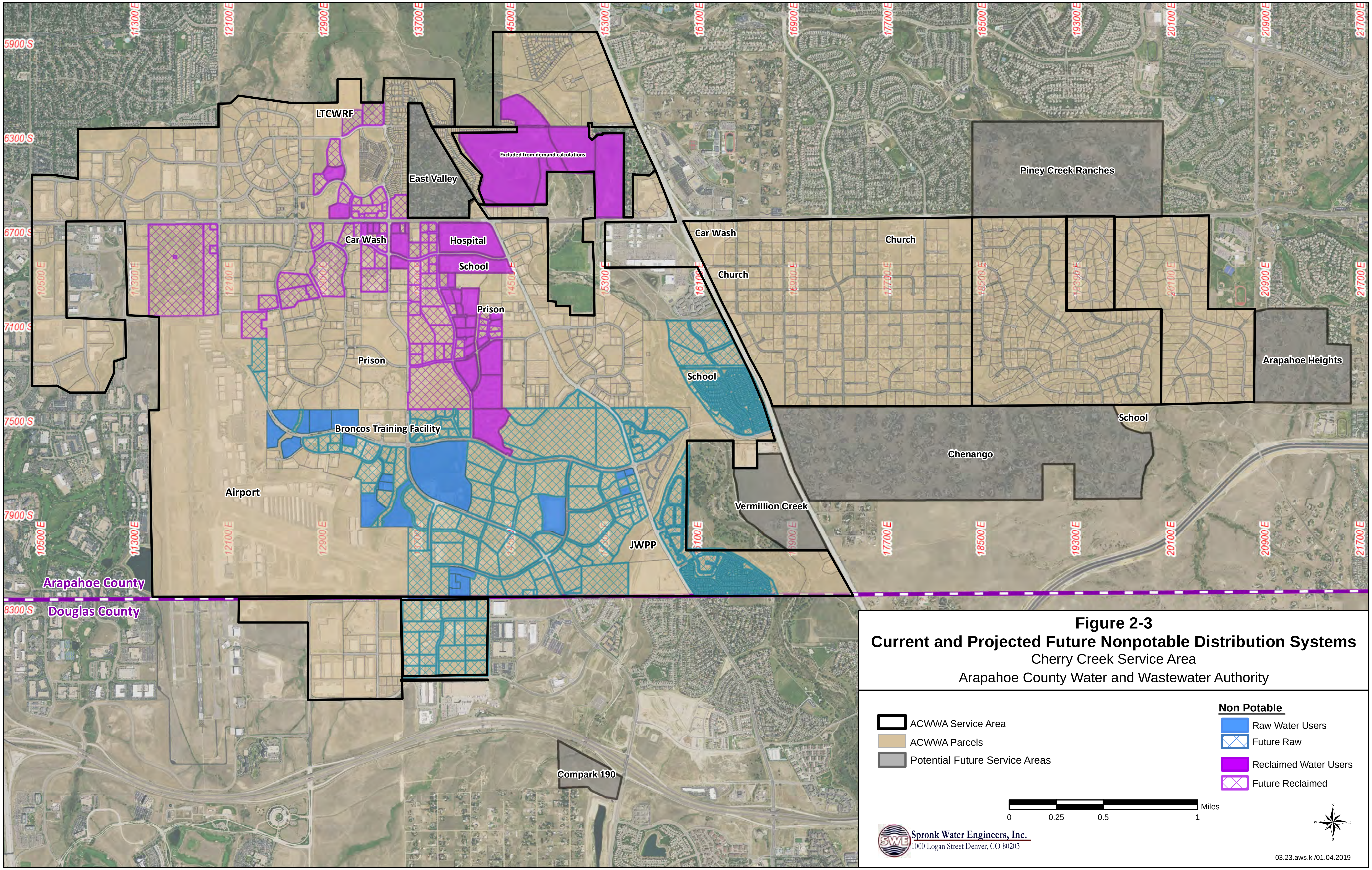
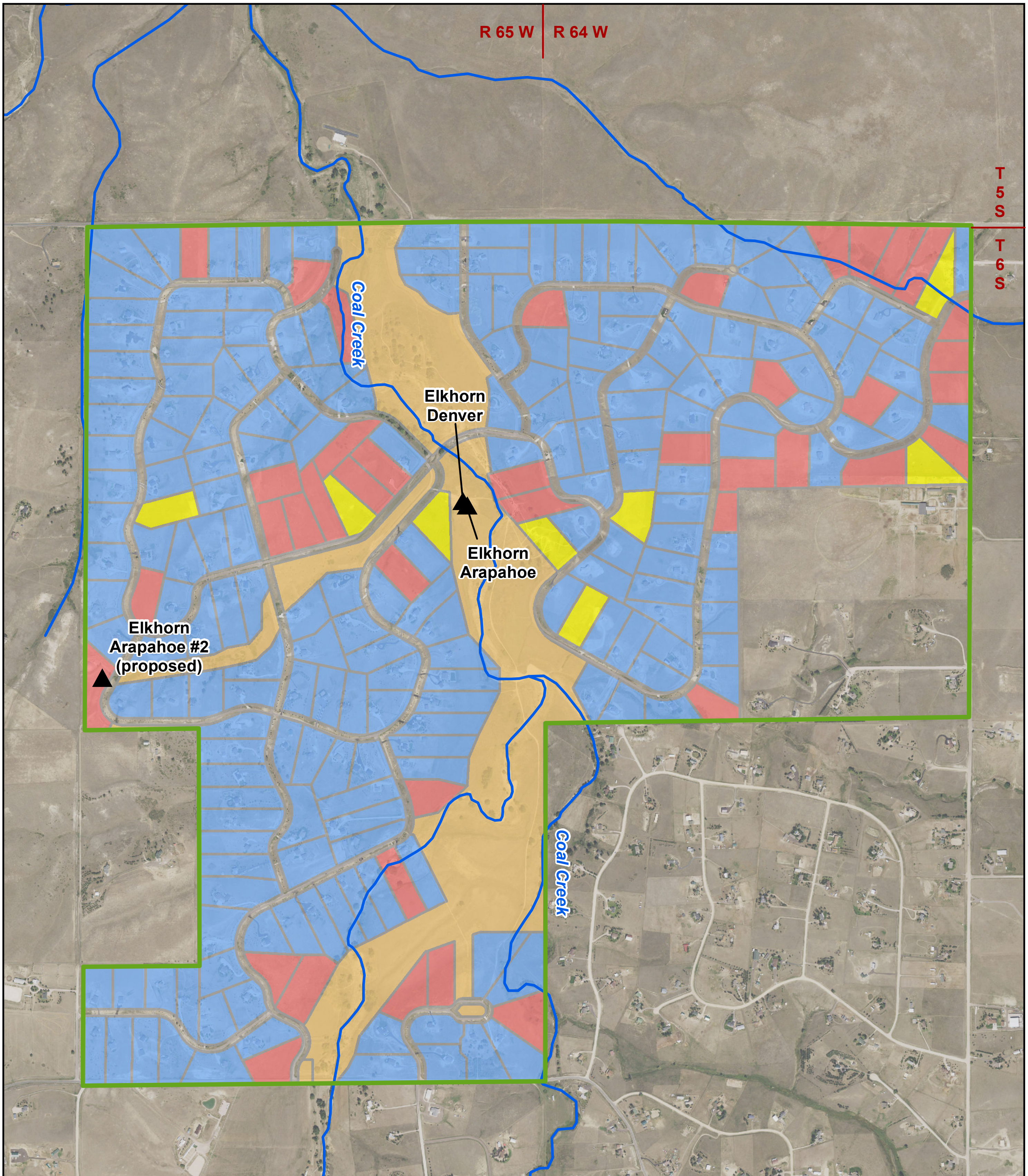


Figure 2-3
Current and Projected Future Nonpotable Distribution Systems
Cherry Creek Service Area
Arapahoe County Water and Wastewater Authority



Sources: ACWWA
USDA NAIP Elbert County 2017

Figure 2-4

Elkhorn Ranch Service Area and Facilities
Arapahoe County Water and Wastewater Authority

Wells
Existing SFR
Open Space
Under Construction
Undeveloped

Spronk Water Engineers, Inc.
1000 Logan Street Denver, CO 80203

Feet
1,100 550 0 1,100 2,200
Approximate Scale

03.23.aws.k/01.07.2019

3.0 WATER REQUIREMENTS

The water requirements for the Cherry Creek Service Area were estimated by developing water use figures for the various ACWWA land uses and applying these figures to the current and project land use mapping. The water use figures were developed from analysis of ACWWA's historical water use data and consideration of industry-standard water demand information.

For purposes of this report, water demand refers to the amount of water delivered to the customer for use, while water requirement refers to the amount of water that needs to be produced at the source to meet the customer demand allowing for water system losses.

3.1 Historical Water Use

ACWWA provides potable water service to commercial, office, industrial/warehouse, and residential water users. In addition, ACWWA delivers non-potable water for irrigation of parks, golf courses, and other open space areas. Records of ACWWA's historical water production were compiled from 1992 – 2017 including Denver Basin well pumping, alluvial well pumping, ACWWA Flow Project deliveries, and direct reuse of reclaimed effluent. These records were compiled largely from ACWWA's weekly water rights accounting and summed into monthly totals.[1]

Summaries of ACWWA's annual water production are provided in Table 3-1 and Figure 3-1[2]. Annual water production increased from approximately 1,200 acre-feet in 1992 to nearly 3,900 acre-feet in 2011. Despite the continued growth and development of the Cherry Creek Service Area, annual water production has declined slightly since 2011. The decline is likely due to a combination of weather conditions and more efficient irrigation water usage.

Also shown in Table 3-1 is the annual and cumulative potable and irrigation water tap sales from 1992 through 2017 expressed as tap equivalents. Tap sales averaged 224 TE per year from 1992 – 2017. Tap sales during the last 10 years averaged 132 TE and the highest 10-year averages was 417 TE. Annual water use per tap was computed by dividing the annual water use volume by the cumulative annual tap equivalents. The results, shown in Table 3-1 and Figure 3-1 indicate that water production per tap has declined from over 0.70 AF/TE in the 1990s to approximately 0.50 AF/TE in recent years.

Monthly average potable water production for the last five years (2013-2017) is summarized in Table 3-2. Water usage rises substantially during the summer months as a result of irrigation demand. Assuming that all water use during December through February is for indoor purposes,

[1] The monthly total values are approximate as they represent 4 week or 5 week total assigned to the nearest calendar month.
[2] Not including an average of 506 AF of alluvial well pumping to storage in Chambers Reservoir. This water was later released to Happy Canyon Creek unused to facilitate repairs to the Chambers Reservoir liner.

the average daily indoor use during the remainder of the year can be estimated by multiplying the average daily December-February water use (4.63 AF/day) by the number of days in each month. The resulting estimated indoor use is tabulated in Table 3-2 (red bars). The total potable water use in excess of the indoor use (blue bars), is assumed to be outdoor use, most of which is for irrigation. Based on the 2013-2017 average water use data, approximately 55% of ACWWA's present water use is for indoor uses and 45% is for outdoor uses.

3.2 System Losses

Like most municipal water suppliers, the amount of water that ACWWA delivers to its customers is less than the amount that it produces from its water sources. The difference between the amount diverted and the amount delivered is commonly termed the "system loss." The system losses are typically comprised of physical water losses due to leaks, hydrant flushing, unauthorized uses, etc., and paper losses due to measurement errors, billing system errors, etc. Water suppliers can take steps to reduce their system losses, but some system losses are unavoidable in a large water distribution system. For planning purposes, the system loss needs to be considered in evaluating the raw water supply that must be produced in order to deliver the water necessary to meet customer demands.

ACWWA staff compiled monthly records of potable water production and potable water deliveries from its billing system for the period from 2012 – 2017 and this information was analyzed to estimate ACWWA's system loss.

Direct comparison of water production and customer delivery records can be misleading due the time lag between the meter readings and the billing cycles. To consider this lag, the monthly billing volumes were advanced in time by trial and error until the monthly pattern of deliveries was reasonably centered and consistent with the monthly water production records. Graphs of these data are shown in Figure 3-2. The monthly potable water supply volumes are plotted as an orange line and the advanced monthly potable water delivery volumes are plotted as a blue line. The difference between the production volumes and the delivery volumes are shown as grey bars. The lower left chart shows the same information for the monthly average volumes over the 6-year data period, and the lower right chart shows the same information plotted as running two-month averages.

The average monthly system loss volumes are relatively consistent throughout the year indicating a systematic and non-random system loss. The ACWWA system loss during the 6-year data period averaged 12.2 percent. This figure is generally in line with system losses that have been reported by other water providers. For purposes of the water supply and demand analyses and projections described in Section 6.0, a system loss of 10 percent was assumed.

3.3 Future Water Demands

Approximately 75 percent of the Cherry Creek Service Area is developed, and future development is expected to be largely comprised of commercial, office, and industrial/warehouse uses. Additional residential development is projected to occur primarily through buildout of the Cherry Creek Service Area east of Parker Road.

Future ACWWA water requirements were estimated using the current and future development projections as reflected in the land use mapping described above in Section 2.3 and water requirements for the various land use types based on a combination of typical industry standard planning figures and water demands values derived from ACWWA's historical water use data. Separate projections were made for the indoor and outdoor components of the water demands. This allows potential changes in irrigation application rates and the portion of a parcel that is landscaped and irrigated to be considered.

The projected water demands are conservative "planning" estimates that reflect building occupancy that may be greater than existed during some historical years and irrigation water requirements that reflect water usage in hot and dry years. As a result, the planning water demand estimates for current development are somewhat greater than recent actual water usage.

3.3.1 Indoor Water Demands

Indoor water requirements were computed separately for residential and non-residential uses. For the non-residential uses, the current and projected future developed square footage for commercial, office, and industrial/warehouse uses were tabulated. These areas were multiplied by planning estimates of 80 gpd/1,000 square feet for commercial and office uses, and 30 gpd/1,000 square-feet for industrial/warehouse uses.

For the residential uses, the current and projected future single-family and multi-family residential units were tabulated based on parcel areas and actual or estimated density of residential development (units/acre). The resulting number of single and multi-family units were multiplied by assumed indoor water use figures of 169 gpd/structure for single-family units and 115 gpd/structure for multi-family units.

The resulting estimated current and future indoor water requirements are shown in Table 3-3 and total 1,945 AF/y for the developed portion of the Cherry Creek Service Area and an additional 976 AF/y for the undeveloped portion resulting in a projected total indoor demand of 2,921 AF/y at buildout.

3.3.2 Irrigation Water Demand

ACWWA's augmentation plan decrees (see Sections 4.2 and 4.5) require it to perform a detailed study of its irrigation operations every five years. Data from the most recent study was used to quantify the irrigated area within each developed parcel and to project the irrigated area for parcels to be developed in the future. A summary of the irrigated area for each major land use type and for certain distinct users is provided in Table 3-4. The current irrigated area totals 446 acres for the areas west of Parker Road ("ACWWA West") and 119 acres for the areas east of Parker Road ("ACWWA East"). Also shown in Table 3-4 are summaries of the average percentage of the gross parcel areas for each land use type that are irrigated (e.g., 8.7% of the gross area of the ACWWA West commercial parcels is irrigated).

The gross parcel areas for the undeveloped parcels were tabulated from the land use mapping and were multiplied by the appropriate percent irrigated figures from Table 3-2 to estimate the future irrigated area for the undeveloped parcels. This reasonably assumes that the irrigated portion of future developed parcels will be similar to the current developed parcels. The resulting estimates of future irrigated area in the ACWWA West and ACWWA East portions of the Cherry Creek Service Area are summarized in Table 3-5 and total 131 acres. Adding the current irrigated area of 446 acres results in a projected total irrigated area at buildout of 696 acres.

ACWWA's monthly irrigation water use is measured and estimated to compute lawn irrigation return flows that are claimed as a credit in ACWWA's water rights accounting. A tabulation of ACWWA's annual irrigation water use for the ACWWA West portion of the service area for the period from 1999 – 2017 is provided in Table 3-6 and summarized graphically in Figure 3-3.

Irrigation water use is typically higher in hot and dry years and lower in cool wet years as water users respond to varying weather conditions. Some water users are more responsive than others. The blue bars in Figure 3-3 show the computed annual average water application in acre-feet per acre in the ACWWA West area. The black line shows the computed annual irrigation application requirement for turfgrass. Comparison of the annual irrigation water use and application requirement shows that the ACWWA water users are generally responsive to varying irrigation demands.

Annual irrigation water deliveries during the last 19 years averaged 3.1 AF/ac and ranged from 2.3 AF/ac in 2013 to 4.1 AF/ac in 2001. Based on discussions with ACWWA staff, a maximum annual irrigation application rate of 4.0 AF/ac was selected for planning purposes.

Using the irrigated area projections and a 4.0 AF/ac annual irrigation application rate, planning estimates of ACWWA's irrigation water demand were computed as shown in Table 3-3. The current dry year irrigation application requirement is 2,261 AF/y, and this is projected to increase to 2,785 AF/y at build out. These irrigation demands will be met from a combination of potable water, raw alluvial ground water, and direct use of reclaimed effluent.

3.3.3 Total Water Demand and Water Requirements

The total water requirements for the current Cherry Creek Service Area were computed by summing the planning water demands for indoor uses and irrigation uses described above. The results, summarized in Table 3-3, show a current dry year water demand of 4,205 AF/y and a buildout water demand of 5,706 AF/y. Assuming a 10 percent system loss, these translate into production water requirements of 4,673 AF/y for the current development and 6,340 AF/y at buildout of the present service area.

3.4 Time to Buildout of Cherry Creek Service Area

The timing of the projected increase in ACWWA's water requirements will depend on the rate of growth and continued development of the Cherry Creek Service Area. Based on review of annual water tap sales data, ACWWA staff have recommend projected growth rates for planning purposes ranging from a low growth rate of 170 TE/year to a high growth rate of 250 TE/year. Based on the recent average water production rate of approximately 0.50 AF/TE (including system losses), the projected growth in the annual water requirement would range from 85 AF/y for low growth to 125 AF/y for high growth. These water use growth rates were applied to the current annual planning water requirement of 4,673 AF/y to estimate the number of years to buildout of the Cherry Creek Service Area. The result is a projected buildout of the Cherry Creek Service Area in about 20 years (2037) for the low growth projection and 14 years (2031) for the high growth projection. The projected increases in annual water use for the low growth and high growth rates are plotted in Figure 3-4.

3.5 Monthly Water Requirements

The current and projected annual planning water requirements were distributed monthly using the monthly indoor and outdoor distribution percentages in Table 3-2. These monthly distribution percentages were applied to the annual indoor and outdoor water use volumes for ACWWA's current and projected future development. The resulting total monthly water requirements for the current development and buildout of the Cherry Creek Service Area are shown in Figure 3-5.

3.6 Peak-day Water Requirements

Based on discussions with ACWWA staff, ACWWA's raw water delivery facilities are sized to meet peak-day water demands. Greater peak demands of shorter duration (e.g., peak hour) for the potable water system will be met from ACWWA's potable water storage tanks. Short-term peak demands for the nonpotable irrigation systems will be met through nonpotable water storage and through demand management and scheduling.

The peak day potable water requirements for current and future development were computed by deriving peak day water use factors from ACWWA's historical potable water production data. ACWWA's water rights accounting is performed on a weekly time-step and weekly potable water production data for the period from 2009 – 2017 were tabulated and analyzed. For each year during 2009 – 2017, the average water use and peak week water use were tabulated and summarized in Figure 3-6. The peak week / average factors ranged from 1.77 in 2012 to 2.06 in 2010.

Daily water use data were compiled by ACWWA staff from the SCADA reporting system for ACWWA's potable water sources for 2016 and 2017. The daily data from these two years are plotted in in the upper graph Figure 3-7 along with 7-day running averages. The daily values from 2016 and 2017 were divided by the 7-day running averages to compute peak day/week factors for each day and the results are summarized in the lower chart in Figure 3-7. The highest peak day/week values in the graph approach 1.2 and this figure was adopted for planning purposes. In other words, it was assumed that the peak day water use within each week could be estimated by increasing the average daily water use in each week by 20 percent. Using this approach, the peak week/average values for each year in Figure 3-6 were increased by 20 percent to estimate the peak day/average factor. The resulting peak day/average factors ranged from 2.12 in 2012 to 2.47 in 2010, and a current peak day/average factor of 2.5 for ACWWA's potable water system was adopted for planning purposes.

The current peak day/average factor of 2.5 reflects the present approximately 50%/50% mix of indoor and irrigation water uses from the potable water system. The mix of potable water use is projected to shift to approximately 65% indoor and 35% outdoor at buildout and this should result in a decline in the peak day/average factor. The effect of the shift toward relatively more indoor water use was factored into the demand analysis by deriving a peak day/month factor of 1.33 that when applied to the current monthly water demand estimates resulted in a peak day/average factor of 2.5 for the current potable water demands. When the 1.33 peak day/month factor is applied to the projected monthly buildout water demands, the result is peak day/average factor of approximately 2.2.

The current peak day/average factor of 2.5 was applied to the current average potable water requirement to compute a current peak-day potable water requirement of 9.7 MGD for the Cherry Creek Service Area as shown in Table 3.3. The buildout peak day/average factor of 2.2 was applied to the average potable requirement at buildout to compute a peak-day potable water requirement at buildout of 10.0 MGD. Because of the shift in water demand towards more relatively more indoor use, the peak day requirement at buildout is projected to be only 0.3 MGD greater than it is today.

3.7 Water Requirements for Potential Inclusions of Nearby Areas

There are several areas adjacent to and near the current Cherry Creek Service Area that have been identified by ACWWA staff as areas that potentially could be included in ACWWA for water and wastewater service. These areas are shaded in grey in Figure 2-2 and include the following:

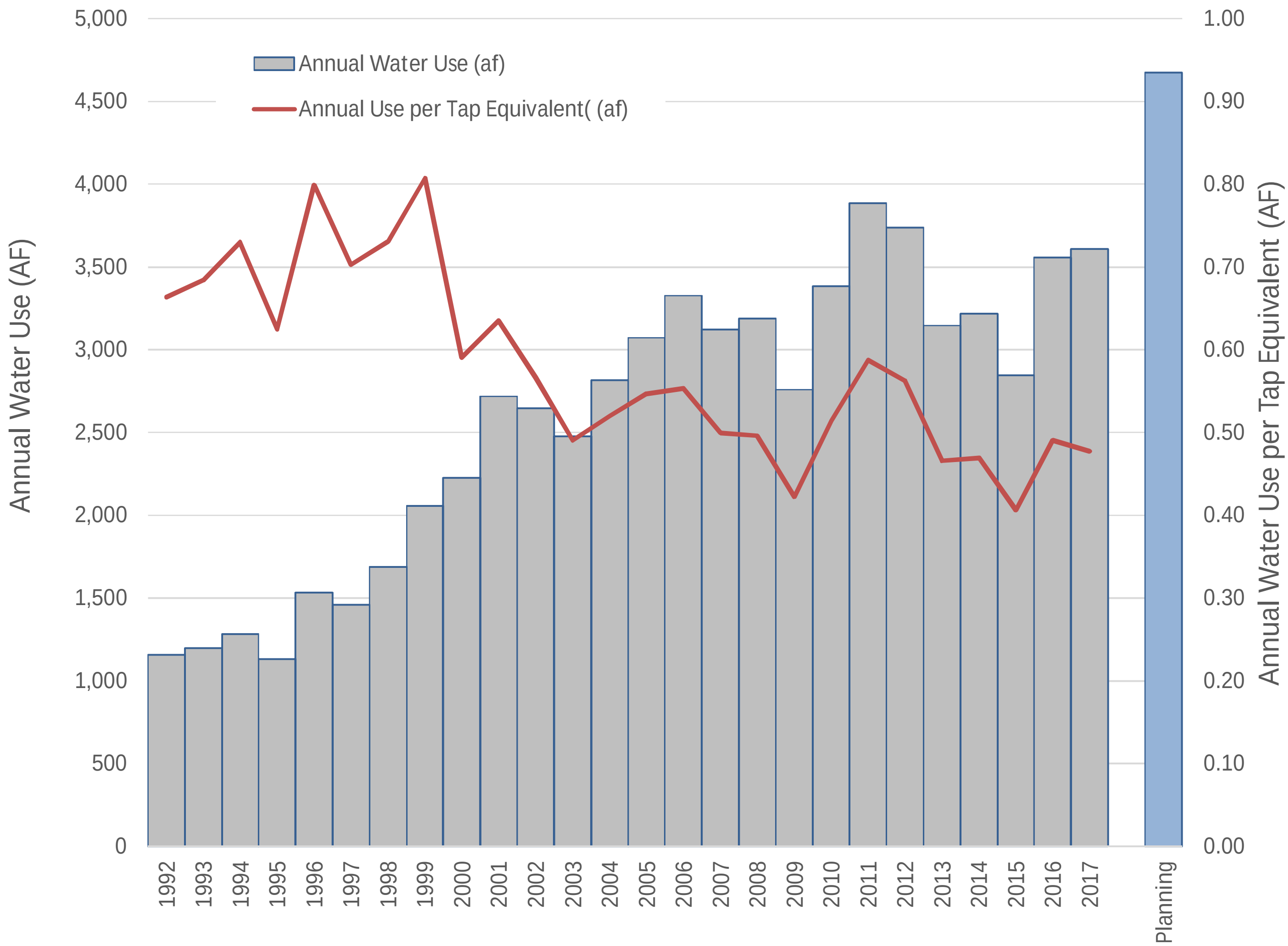
- Arapahoe Heights
- Chenango
- Piney Creek Ranches
- Vermillion Creek
- Compark 190
- East Valley[3]

The demands for the potential future inclusions would likely all be supplied as potable water. The combined annual demands total 1,074 AF/y as shown in Table 3-7. Assuming a 10 percent system loss results in a total annual water requirement of 1,193 AF/y. Application of a 2.5 peak day/average factor results in peak day potable demand of 2.7 MGD for the potential inclusion areas. Note that ACWWA's Rules and Regulations require that any area that is included in the ACWWA service area must come with water rights that are sufficient to supply the anticipated demands for the development. Alternatively, the developer or entity may pay a cash in-lieu fee for the water needed to serve the development.

[3] East Valley is fully developed residential subdivision currently served by Denver Basin ground water. They potentially could look to ACWWA for renewable water service in the future.

Figure 3-1

Annual Water Use (1992 - 2017)
and 2017 Planning Water Requirement
Arapahoe County Water and Wastewater Authority



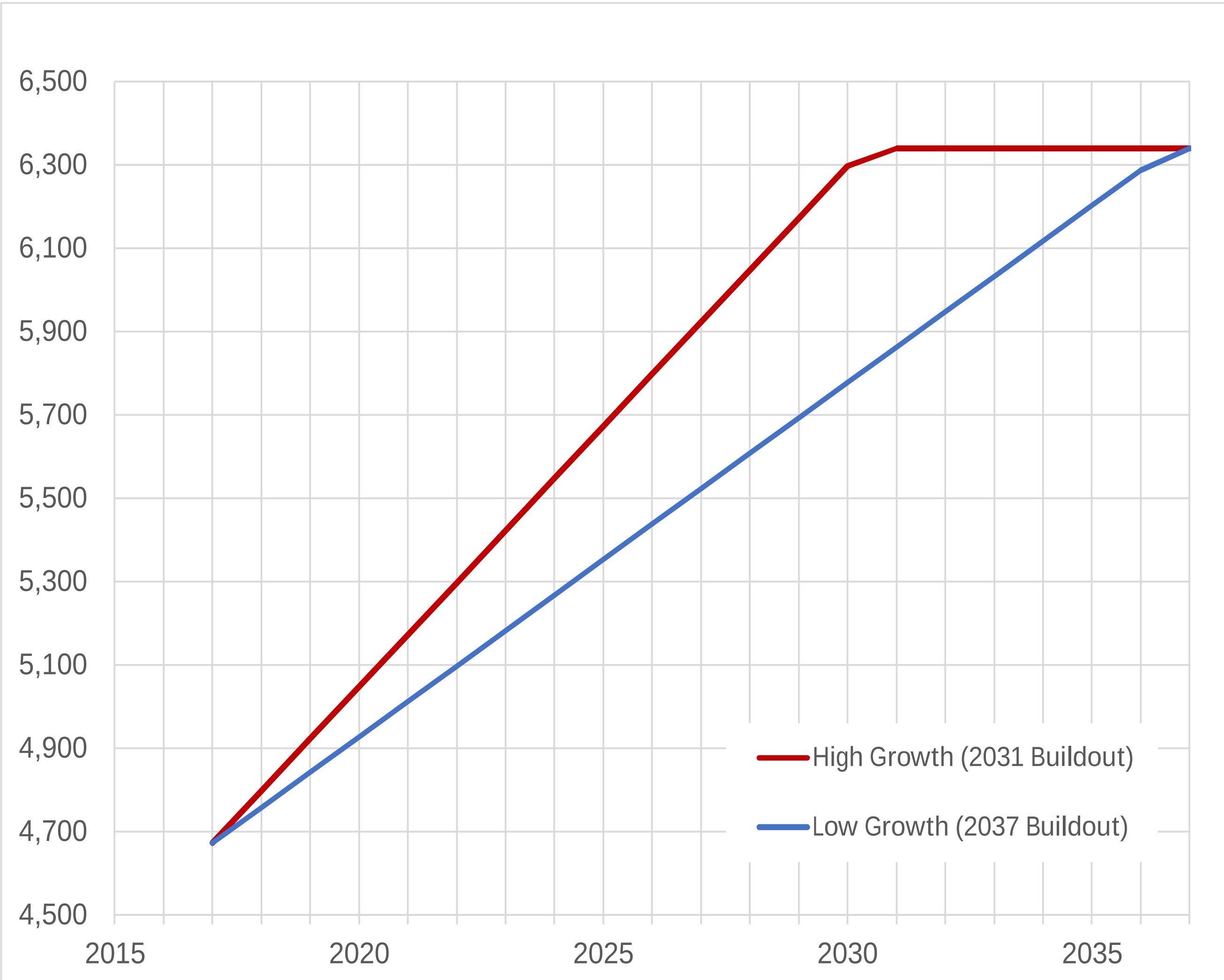
Notes:

(1) Total municipal water production computed as the of potable alluvial wells, Denver Basin wells, ACWWA Flow deliveries nonpotable alluvial wells, and direct effluent reuse (not including alluvial pumping to Chambers Reservoir).

(2) Dry year planning demand for 2017 (includes 10% system loss)

Figure 3-2

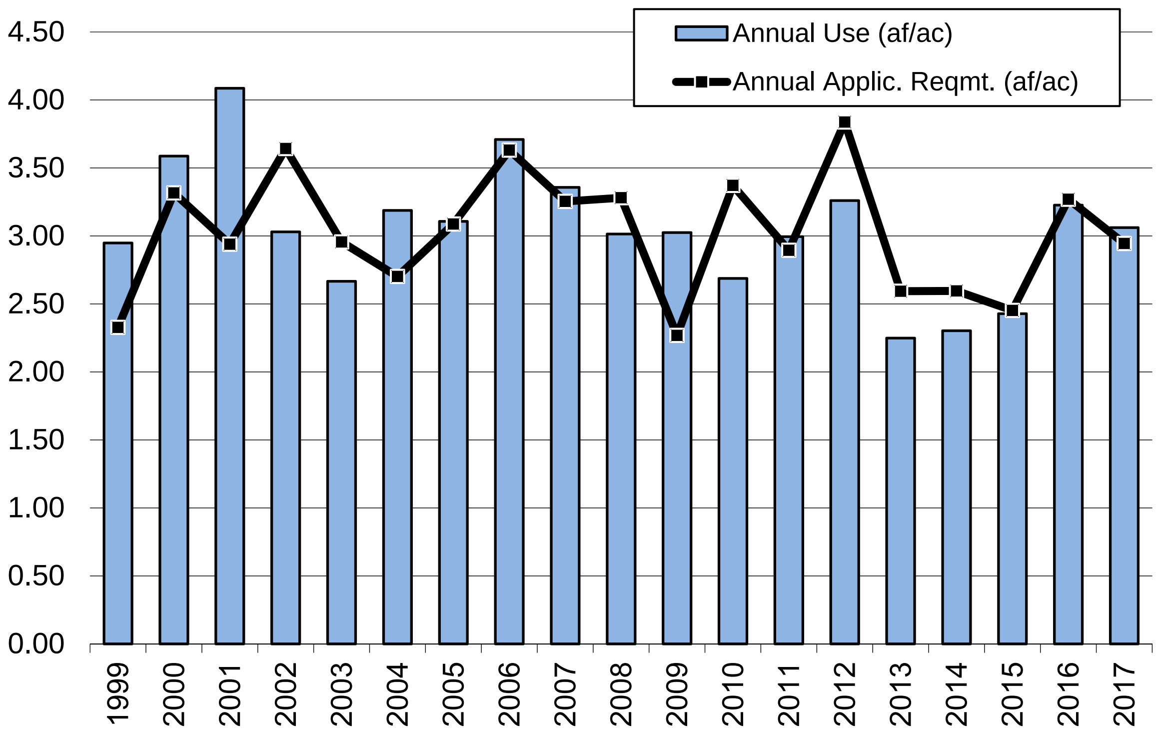
Projected Dry Year Water Requirements (2017 - Buildout)
Arapahoe County Water and Wastewater Authority
(acre-feet)



Notes: Low Growth at 170 tap equivalents per year (85 AF/y).
High Growth at 250 tap equivalents per year (125 AF/y).

Figure 3-3

Annual Irrigation Water Use and Irrigation Requirement (1999-2017)
ACWWA West Area
Arapahoe County Water and Wastewater Authority
(acre-feet per acre)

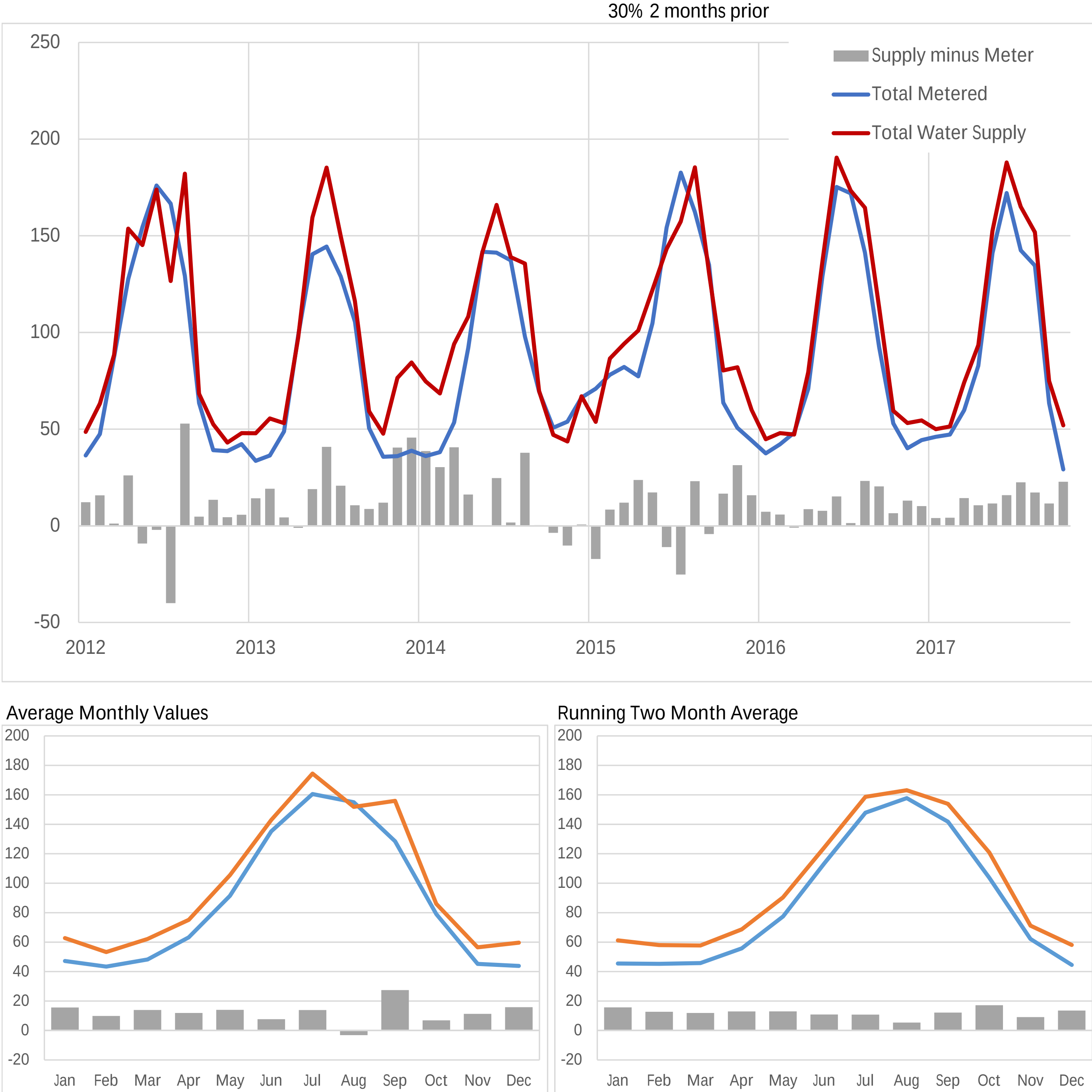


Note:
See Table 3-6 for description of data.

Figure 3-4

Monthly Water Supply vs Metered Water Use (2012-2017)
Arapahoe County Water and Wastewater Authority
(million gallons)

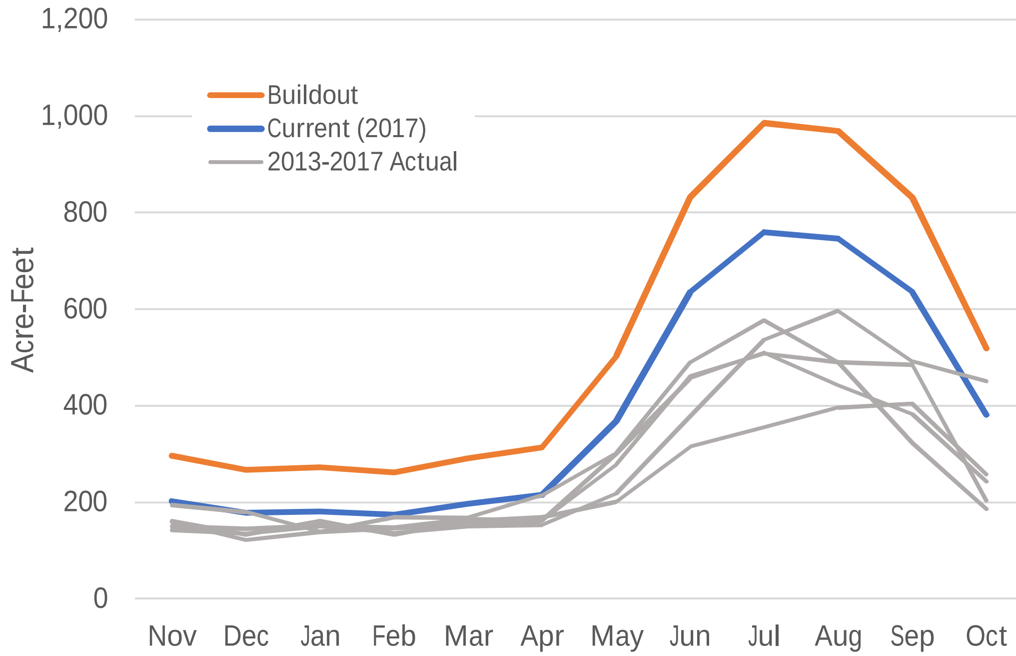
Advance Of Metered Use 70% 1 month prior
30% 2 months prior



Note:
From ACWWA pumping and billing data.

Figure 3-5

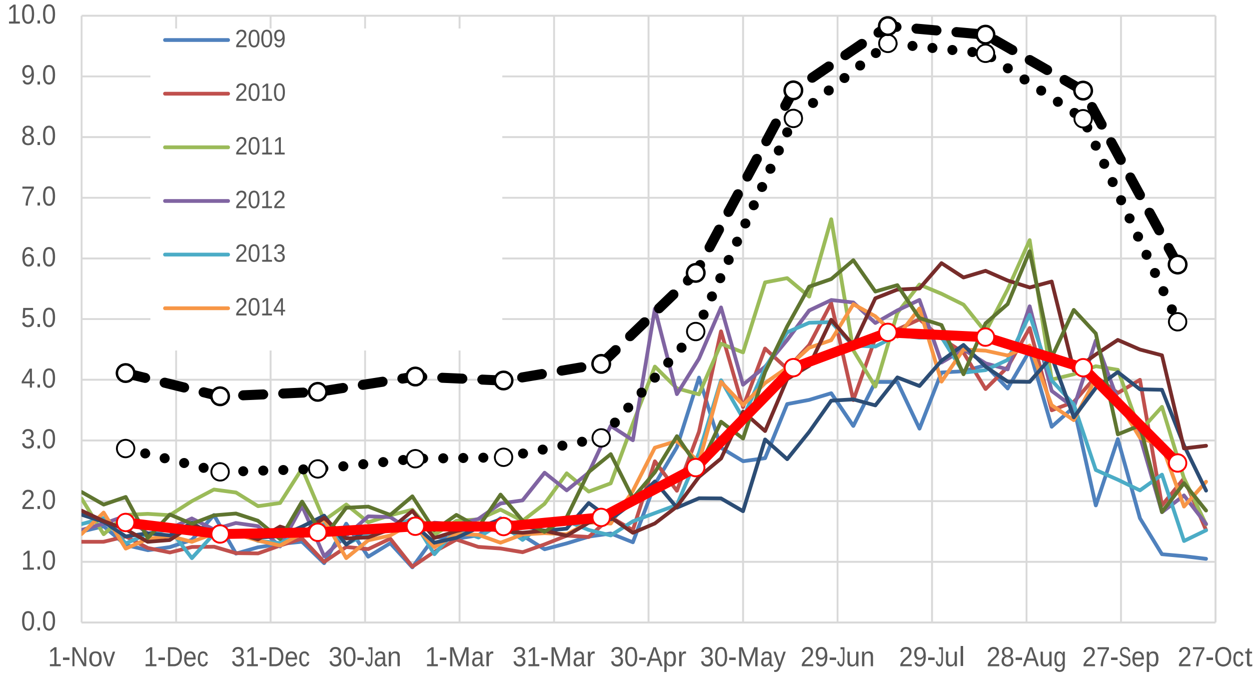
Projected Dry Year Monthly Water Requirements
Cherry Creek Service Area
Arapahoe County Water and Wastewater Authority



Note:
Includes potable system and nonpotable irrigation uses with 10% system loss.

Figure 3-6

Weekly Potable System Water Production (2009-2017) and Dry-Year Peak Day Potable Water Requirements
(million gallons per day)



(1) Potable System Peaks	2009	2010	2011	2012	2013	2014	2015	2016	2017
Average (mgd)	2.22	2.56	3.24	3.01	2.54	2.66	2.46	2.91	3.01
Peak Week (mgd)	4.48	5.26	6.65	5.32	5.07	5.25	4.57	5.92	6.12
Peak Week/ Avg	2.02	2.06	2.05	1.77	2.00	1.97	1.86	2.03	2.04
(2) Est. Peak Day (mgd)	5.37	6.32	7.98	6.38	6.09	6.29	5.49	7.11	7.34
Est. Peak Day / Avg *	2.42	2.47	2.46	2.12	2.40	2.37	2.23	2.44	2.44

Notes:

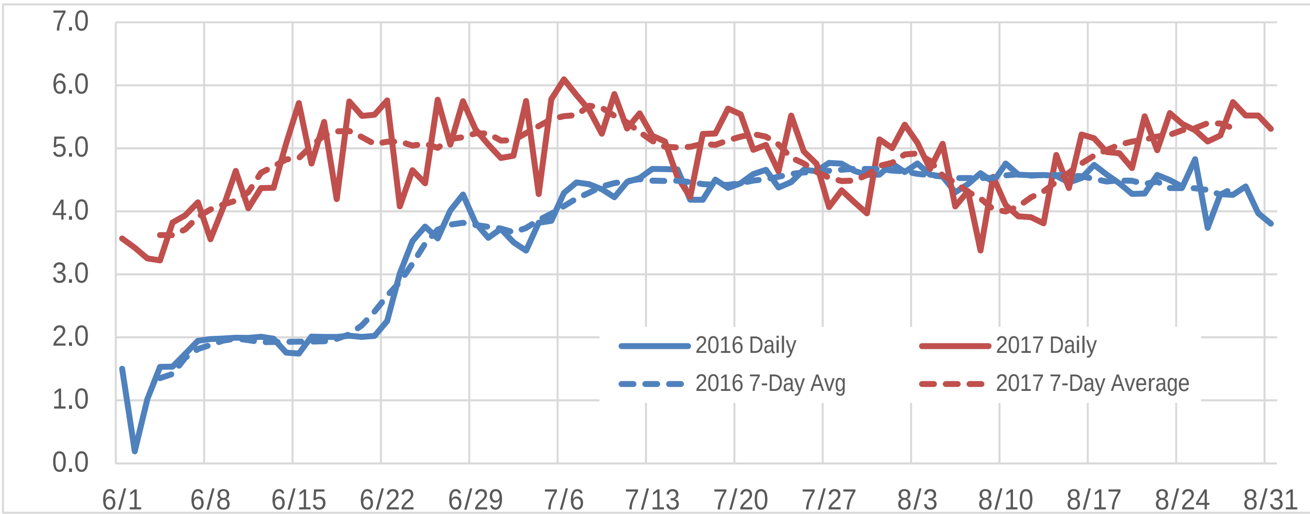
(1) Includes potable supplies only (wells and ACWWA Flow)

(2) Peak week x 1.2 factor derived from daily SCADA data for 2016 and 2017.

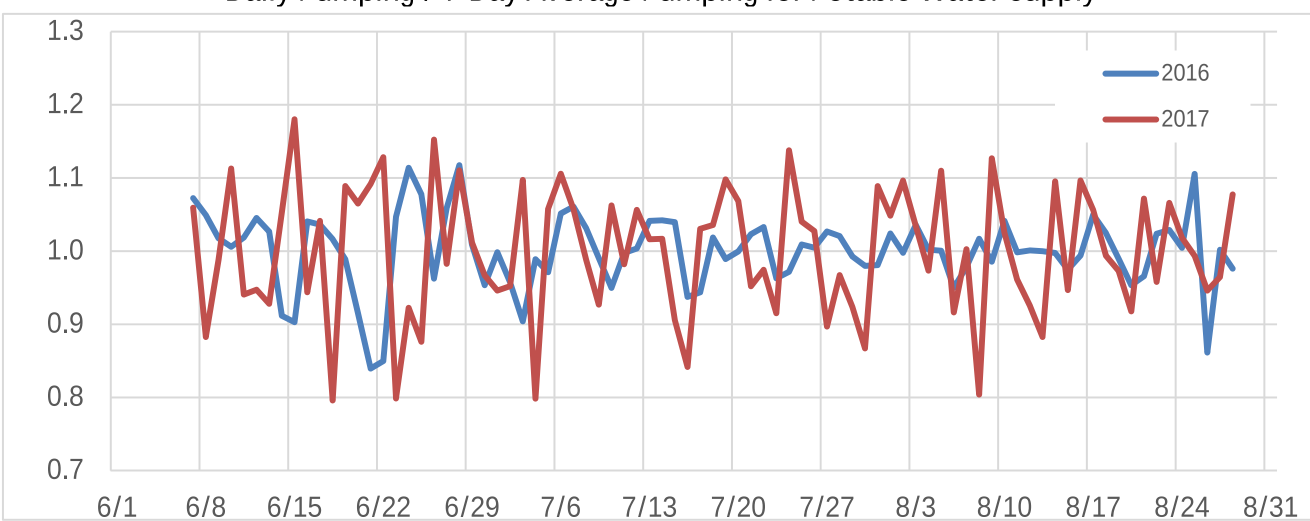
(3) Current and buildout peak-day potable water demands simulated in the ACWWA Water Supply Operations Model.

Figure 3-7

Daily Pumping and 7-Day Centered Average Pumping for Potable Water Supply
Arapahoe County Water and Wastewater Authority
(million gallons per day)



Daily Pumping / 7-Day Average Pumping for Potable Water Supply



Note:
Includes all sources for the potable water system (alluvial wells, Denver Basin wells, and ACWWA Flow deliveries) excluding the Chapparral Wells that are not yet part of the SCADA System

Table 3-1

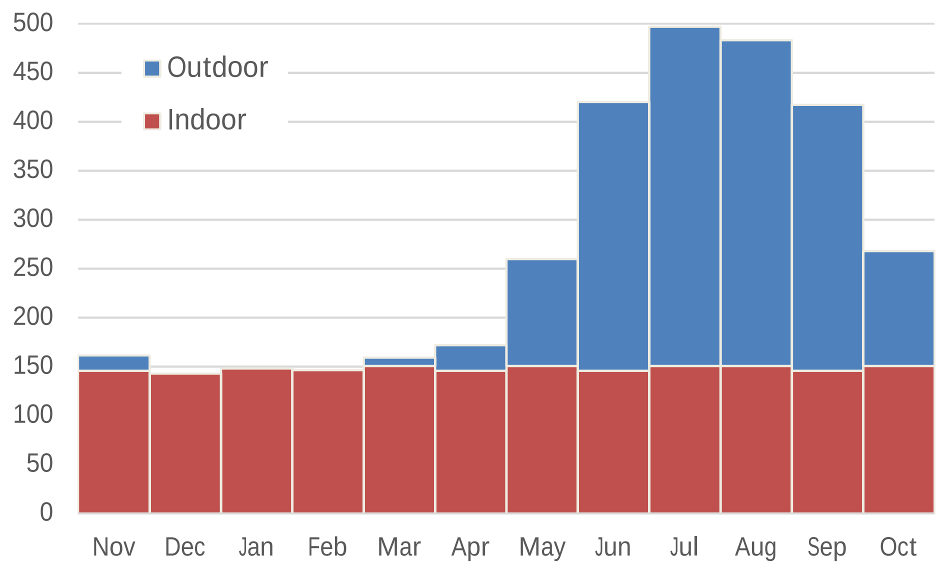
Annual Water Use (1992-2017)
Arapahoe County Water and Wastewater Authority
(acre-feet)

Water Year	(1) Alluvial Ground Water	Denver Basin Ground Water	ACWWA Flow	Treated Effluent Direct Reuse	Total	(2) Total Taps Sold	Water Use per Tap (AF/tap)
1992	767	389	0	0	1,156	1,742	0.66
1993	742	456	0	0	1,198	1,750	0.68
1994	824	460	0	0	1,284	1,760	0.73
1995	622	510	0	0	1,133	1,812	0.63
1996	1,040	493	0	0	1,533	1,919	0.80
1997	876	582	0	0	1,458	2,075	0.70
1998	928	759	0	0	1,687	2,309	0.73
1999	1,285	773	0	0	2,058	2,550	0.81
2000	1,361	866	0	0	2,227	3,772	0.59
2001	1,395	1,323	0	0	2,718	4,282	0.63
2002	1,283	1,365	0	0	2,648	4,677	0.57
2003	1,579	897	0	0	2,477	5,047	0.49
2004	1,706	1,109	0	0	2,814	5,413	0.52
2005	2,050	1,022	0	0	3,072	5,617	0.55
2006	2,363	964	0	0	3,327	6,011	0.55
2007	2,198	923	0	0	3,120	6,241	0.50
2008	2,106	1,080	0	0	3,186	6,423	0.50
2009	1,814	946	0	0	2,759	6,535	0.42
2010	2,479	906	0	0	3,384	6,583	0.51
2011	3,169	716	0	0	3,885	6,617	0.59
2012	2,578	1,056	0	104	3,634	6,646	0.55
2013	1,732	855	482	78	3,069	6,757	0.45
2014	1,170	1,007	958	81	3,135	6,848	0.46
2015	687	795	1,279	84	2,761	7,001	0.39
2016	1,169	1,023	1,272	91	3,465	7,245	0.48
2017	1,354	1,158	999	96	3,511	7,556	0.46

Notes:
(1) Not including pumping of alluvial ground water to Chambers Reservoir that occurred in 2014 - 2016.
(2) Cumulative tap equivalents for potable and irrigation taps.

Table 3-2

Monthly Average Potable Water Use (2013-2017)
and Estimated Indoor and Outdoor Portions
Arapahoe County Water and Wastewater Authority



Month	2013 - 2017 Average Monthly Water Use Avg	% Ann	Estimated Indoor and Outdoor Water Use Indoor (af)	Outdoor (af)	Total (af)	Indoor % Ann	Irrig % Ann
Nov	152	5.0%	139	13	152	8.2%	1.0%
Dec	139	4.6%	139	0	139	8.2%	0.0%
Jan	141	4.6%	141	0	141	8.4%	0.0%
Feb	136	4.5%	136	0	136	8.1%	0.0%
Mar	150	4.9%	143	7	150	8.5%	0.5%
Apr	159	5.2%	139	21	159	8.2%	1.5%
May	243	8.0%	143	99	243	8.5%	7.3%
Jun	387	12.7%	139	248	387	8.2%	18.3%
Jul	455	14.9%	143	311	455	8.5%	22.9%
Aug	448	14.7%	143	304	448	8.5%	22.4%
Sep	387	12.7%	139	248	387	8.2%	18.2%
Oct	250	8.2%	143	107	250	8.5%	7.9%
Total	3,047	100%	1,689	1,358	3,047	55.4%	44.6%
Dec-Feb avg	4.63	af/d					

Notes:

(1) Indoor use based on actual use during Dec - Feb, and average daily Dec-Feb use multiplied by the number of days per month in other months.

(2) Outdoor use based on total use minus indoor use.

Table 3-3

Current and Projected Future Dry Year Water Requirements
Cherry Creek Service Area
Arapahoe County Water and Wastewater Authority

		Current (2017)		Buildout	
	Municipal Use	(acres)	(AF/y)	(acres)	(AF/y)
	Indoor	n/a	1,945	n/a	2,921
(1)	Irrigation Use (Dry Year)				
(2)	Potable System	489.6	1,958	419.2	1,677
	Untreated Alluvial Wells	49.4	198	185.5	742
(3)	Reclaimed Effluent	26.2	105	91.5	366
	Total Irrigation	565.1	2,261	696.2	2,785
(4)	Total Water Demand		4,205		5,706
	Total Requirement (with 10% system loss)		4,673		6,340
	Potable Water System Demand Summary				
(5)	Potable Water Demand		3,903		4,598
	Total Requirement (with 10% system loss)		4,337		5,109
			MGD		MGD
(6)	Average Potable Requirement		3.9		4.6
(7)	Peak Day/Average Factor		2.5		2.2
(8)	Peak Day Potable Water Requirement*		9.7		10.0

Notes:

(1) Dry year irrigation demand of 4.0 AF/y per acre.
(2) Some potable system lands are projected convert to nonpotable sources.
(3) Not including reclaimed effluent provided to by contract to Valley Country Club (358 AF/y).
(4) Sum of indoor demands and all irrigation demands. Divide by 0.9 to add 10% system loss.
(5) Sum of indoor demand and potable irrigation demand. Divide by 0.9 to add 10% system loss.
(6) Annual potable water demand with system loss converted to average MGD
(7) Peak Day/Average factor projected to declined from current 2.5 to 2.2 at buildout due to less irrigation for future development.
(8) Average Potable Demand multiplied by 2.5 peaking factor.

Table 3-4

2017 Irrigated Area
Arapahoe County Water and Wastewater Authority

Current Irrigated Area (Measured) - ACWWA West

Land Use	(1) Parcel Acres	(2) % Irrigated	(3) Irrigated Acres	
Existing Commercial	360.0	8.7%	31.3	
Existing Industrial/Warehouse	741.1	11.8%	87.7	
Existing Office	391.4	15.9%	62.3	
Existing Small SFR	214.4	29.1%	62.4	
Existing MFR	214.2	25.0%	53.5	
Existing SFR	19.6	7.7%	1.5	
Existing Open Space/Farmland/Grazing Land	412.8	3.5%	14.6	
Existing parks/ golf course/ greenbelt common area	244.7	39.8%	97.4	
Special User- Airport	-	-	14.2	
Special User- Broncos Training Facility	25.4	33.8%	8.6	
Special User- Hospital	31.9	9.1%	2.9	
Special User- Prison	9.9	9.4%	0.9	
Special User- School	28.9	12.2%	3.5	
Special User- Car Wash	2.1	30.8%	0.7	
Road Median	-	-	4.6	
Valley Country Club Golf Course	177.2	75.7%	134.0	
Total without VCC Golf Course	2696.6	16.5%	446.1	79%
Total with VCC Golf Course	2873.8	20.2%	580.1	

Current Irrigated Area (Measured and Estimated) - ACWWA East

	Land Use	Parcel Acres	% Irrigated	Irrigated Acres	
(4)	Existing Commercial	5.3	0.7%	0.03	
	Existing SFR	1269.5	8.7%	109.8	
	Existing parks/ golf course/ greenbelt common area	3.3	0.0%	0.0	
	Existing Open Space/Farmland/Grazing Land	81.8	0.3%	0.2	
	Special User- Car Wash	1.0	0.0%	0.0	
	Special User- Church	30.5	9.1%	2.8	
	Special User-School	13.8	44.9%	6.2	
	Total Irrigated Area East of Parker Road	1405.2	8.5%	119.1	21%

Total Current Irrigated Area (without VCC Golf Course)	565.1

Notes:
(1) Parcel acres from ACWWA land use mapping (see Figure 2-2).
(2) % irrigated area computed as the irrigated acres (3) / parcel acres (1).
(3) Irrigated acres delineated in 2018 Lawn Irrigation Return Flow Study (SWE 2018).
(4) Irrigated percentage based on random sample of parcels.

Table 3-5

Future Irrigated Area
Arapahoe County Water and Wastewater Authority

Future Irrigated Area (Estimated) - ACWWA West

Land Use	(1) Parcel Acres	(2) % Irrigated	(3) Irrigated Acres
Future Commercial	918.6	8.7%	79.9
Future Industrial/Warehouse	164.7	11.8%	19.5
Future Small SFR	9.9	29.1%	2.9
Future SFR	38.5	29.1%	11.2
Future MFR	24.0	25.0%	6.0
Total	1155.7	10.3%	119.5

Future Irrigated Area (Estimated) - ACWWA East

Land Use	(1) Parcel Acres	(2) % Irrigated	(3) Irrigated Acres
Future Commercial	11.9	8.7%	1.0
Future SFR	122.1	8.7%	10.6
Total	134.0	8.7%	11.6

Total Future Irrigated Area 131.1

Summary of Current and Future Irrigated Area - All

Land Use	(1) Parcel Acres	(4) % Irrigated	(5) Irrigated Acres	
Current - ACWWA West	2696.6	16.5%	446.1	64%
Current - ACWWA East	1405.2	8.5%	119.1	17%
Future - ACWWA West	1155.7	10.3%	119.5	17%
Future- ACWWA East	134.0	8.7%	11.6	2%
Total	5391.5	12.9%	696.2	100%
Total - Current	4101.9	13.8%	565.1	81%
Total - Future	1289.7	10.2%	131.1	19%
Total - ACWWA West (Current and Future)	3852.3	14.7%	565.5	81%
Total - ACWWA East (Current and Future)	1539.3	8.5%	130.7	19%

Notes:

(1) Parcel acres from ACWWA land use mapping (see Figure 2-2).
(2) % irrigated values are based on figures for the existing development in the ACWWA West area.
(3) Irrigated acres computed as the parcel acres (1) x % irrigated (2).
(4) Average % irrigated area computed as the irrigated acres (5) / parcel acres (1).
(5) Sum of the irrigated acres for current and future development.

Table 3-6

Annual Irrigation Water Use (1999-2017)
ACWWA West Area
Arapahoe County Water and Wastewater Authority

(1) Water Year	(2) Annual Irrigation Use (AF)	(3) Irrigated Area	(4) Annual Irrigation Use (af/ac)	(5) Annual Applic. Reqmt. (af/ac)
1999	877.3	297.6	2.95	2.33
2000	1067.4	297.6	3.59	3.32
2001	1324.8	324.2	4.09	2.94
2002	1063.3	350.9	3.03	3.64
2003	1006.8	377.6	2.67	2.96
2004	1288.7	404.3	3.19	2.70
2005	1339.1	431.0	3.11	3.09
2006	1697.5	457.6	3.71	3.63
2007	1586.6	472.6	3.36	3.25
2008	1469.4	487.5	3.01	3.28
2009	1519.9	502.5	3.02	2.27
2010	1390.8	517.4	2.69	3.37
2011	1594.3	532.4	2.99	2.89
2012	1735.5	532.4	3.26	3.84
2013	1112.2	494.5	2.25	2.59
2014	1139.0	494.5	2.30	2.60
2015	1200.9	494.5	2.43	2.45
2016	1322.5	409.9	3.23	3.27
2017	1254.6	409.9	3.06	2.94
Ave	1315.3		3.05	3.02
Max	1735.5		4.09	3.84

Notes

(1) November - October water year for water rights accounting.

(2) Irrigation water use data for 2011-2015 are limited to the accounts that were included in the 2011 LIRF Study, and water use data for 2016-2017 are limited to the accounts that were included in the 2016 LIRF Study (some outlier accounts were excluded from these studies).

(3) Irrigated area data were measured in 2000, 2006, 2011, and 2016 by SWE as part of the LIRF Studies in those years. Values in the non-study years before 2011 were estimated by interpolation. The 2011 and 2016 values are limited to the accounts included in those studies (some outlier accounts were excluded from those studies). The 2011 irrigated area was used for 2012. In 2013 ACWWA ceased supplying the Cherry Creek Soccer Fields and that irrigated area was removed. The 2013 irrigated area value was used for 2014 and 2015. The 2016 irrigated area value was used for 2017. The 2000 value was used in 1999 and the 2016 value was used in 2017.

(4) (2) / (3).

(5) Annual potential evapotranspiration for turfgrass computed using the Modified Blaney-Criddle Method minus effective precipitation divided by an average sprinkler application efficiency of 75%.

Table 3-7

Water Needs for Potential Future Service Areas
Arapahoe County Water and Wastewater Authority

	Annual Demand (acre-feet)	Peaking Factor: (3) Average Day Demand (MGD)	2.5 (4) Peak Day Demand (MGD)
(1) Potential Future Inclusions			
Arapahoe Heights	97	0.1	0.2
Chenango	396	0.4	0.9
East Valley	74	0.1	0.2
Piney Creek Ranches	216	0.2	0.5
Vermillion Creek	266	0.2	0.6
Compark 190	25	0.0	0.1
Total Demand	1,074	1.0	2.4
Total Requirement (with 10% System Loss)	1,193	1.1	2.7
(2) Service to Prosper Development	2,978	2.7	6.6
Total Requirement for Future Service Areas	4,171	3.7	9.3

Notes:

(1) Annual demands for potential inclusions provided by Alan Leak of Respec. (ACWWA) Plan.
(2) Estimated total annual water requirement provided by Prosper representatives.
(3) Annual demand converted to average daily rate.
(4) Average Day Demand x 2.5 peaking factor.

4.0 WATER SOURCES AND SUPPLIES

ACWWA has a diverse portfolio of water supplies and water rights that are integrated under a plan for augmentation that has operated successfully for almost 30 years. Descriptions of ACWWA's water supplies are provided below.

4.1 Denver Basin Ground Water

ACWWA holds ground water rights in the four deep bedrock aquifers of the Denver Basin. These aquifers are in order of descending depth the Dawson, Denver, Arapahoe, and Laramie-Fox Hills aquifers. Like most Denver Basin ground water rights, ACWWA's are based on the estimated volume of ground water within each aquifer that underlies the Cherry Creek Service Area divided by a statutorily prescribed aquifer life of 100 years. A portion of the ground water underlying the Cherry Creek Service Area had already been appropriated by the City of Aurora and others prior to AWSD's formation, and this reduced the amount of Denver Basin ground water that AWSD was able to appropriate for its own use. As additional areas were included in AWSD and later ACWWA, the unappropriated Denver Basin ground water underlying these areas was adjudicated and added to ACWWA's Denver Basin ground water rights portfolio. A listing of ACWWA's Denver Basin ground water rights is provided in Table 4-1 and a summary is provided below.

Denver Basin Annual Ground Water Rights
Arapahoe County Water and Wastewater Authority
(acre-feet per year)

Denver Basin Aquifer	Nontributary	Not Nontributary
Dawson	161.0	41.7
Denver	274.3	433.6
Arapahoe	1,633.3	0.0
Laramie-Fox Hills	1,015.9	0.0
Total	3,084.5	475.3

Most of ACWWA's nontributary Denver Basin ground water rights were decreed prior to the 1985 Senate Bill 5, and do not have a two percent relinquishment requirement that was mandated for Denver Basin ground water right appropriations starting in 1985. The ground water rights that do have a 2% relinquishment requirement are indicated in Table 4-1.

ACWWA owns not-nontributary Dawson aquifer and Denver aquifer ground water rights that are subject to a four percent or actual depletion replacement obligation as shown in Table 4-1. This water cannot be used until ACWWA obtains a judicially approved plan for augmentation to meet the replacement obligations.

Other than the limited relinquishment or replacement obligations, all of ACWWA's Denver Basin ground water is fully consumable and can be reused to extinction. Unlike surface water rights and tributary ground water rights, withdrawal of nontributary Denver Basin ground water is not administered under the priority system, and these withdrawals are limited only by decreed annual volumes.

The annual pumping entitlements for Denver Basin ground water rights that were decreed under the provisions of the 1985 Senate Bill 5 may be banked and the unused annual volumes may be withdrawn in later years effectively enhancing their potential use as a drought supply. However, most of ACWWA Denver Basin ground water rights were decreed prior to 1985 and are not entitled to the banking provision.

In general, the Arapahoe aquifer is the most productive of the Denver Basin aquifers and wells constructed in this aquifer can typically produce 300 to 500 gallons per minute. The production rates of the Denver and Dawson aquifers are much lower. Wells in the Laramie-Fox Hills aquifer can produce 200 to 300 gallons per minute, but the water is of poor quality with high total dissolved solids. Because of these factors, the majority of the Denver Basin ground water use by municipal water suppliers in Arapahoe and Douglas Counties is from wells in the Arapahoe aquifer.

In general, ACWWA may construct any number of wells to withdraw its Denver Basin ground water rights provided that the wells are located on land parcels that are contiguous to the parcels under which the ground water rights were adjudicated. While there are some exceptions to this rule, as a practical matter this means that ACWWA's Denver Basin ground water rights for the ACWWA West parcels must be withdrawn from wells located west of Parker Road and ground water rights for the ACWWA East parcel must be withdrawn from wells located each of Parker Road[4].

ACWWA presently operates six nontributary Denver Basin wells in the Arapahoe aquifer as summarized in Table 4-2. These wells produce a combined 1,560 gallons per minute ("gpm") and have a combined annual pumping entitlement of 1,633 AF/y.

[4] Due to the intervening prior Denver Basin ground water appropriations of Aurora and others, ACWWA is unable to withdraw Arapahoe aquifer water associated with parcels east of Parker Road using wells located west of Parker Road under the overlapping cylinder of appropriation provision of Rule 11.B of the Statewide Nontributary Ground Water Rules.

Denver Basin ground water is a nonrenewable supply of water. Natural recharge to the aquifers occurs very slowly and therefore virtually all water that is pumped mines the aquifers of water. As a result, many water users, including ACWWA, are pursuing renewable surface water and tributary ground water sources to reduce their reliance on Denver Basin ground water supplies.

4.2 Alluvial Ground Water

The Cherry Creek alluvial aquifer is a highly productive source of tributary ground water with wells typically yielding 800 gpm to 1200 gpm. However, alluvial ground water is conjunctively administered with surface water under the prior appropriation system and junior alluvial ground water rights are subject to curtailment when downstream senior surface water rights are short of water, which is most of the time except during periods of high runoff or low demand. Alluvial wells can be operated without curtailment under an augmentation plan whereby the out-of-priority depletions to surface flows are replaced (see Section 4.2).

ACWWA owns twenty wells in the Cherry Creek alluvial aquifer, and a list of the wells and associated tributary water rights is provided in Table 4-3. Most of ACWWA's alluvial wells were formerly irrigation wells with two or more water rights; a relatively junior water right based on construction of the well, and one or more senior surface water rights that were changed for diversion at the well. The decreed use of these irrigation water rights was changed to include municipal and other uses by ACWWA in several Water Court decrees. These cases quantified the historical consumptive use of the irrigation rights and established terms and conditions to limit their use for municipal, augmentation, and other purposes.

Table 4-3 also lists ACWWA water rights for alluvial wells and diversion structures on several tributaries to Cherry Creek. The Happy Canyon Creek Wells Nos. 1 – 3 have been constructed but are not in service. The others are proposed wells that could potentially be constructed to serve a local nonpotable irrigation use (e.g., at a nearby park).

ACWWA presently operates nine Cherry Creek alluvial wells (including four CWSD wells). Six of these wells[5] are planned to be pumped to the JWPP for treatment and delivery of potable water to ACWWA and CWSD, and the other three wells serve ACWWA's raw alluvial nonpotable irrigation system.

ACWWA's original augmentation plan covered ten Cherry Creek alluvial wells and was approved in Case No. 86CW388(A) by decree entered in 1991. Another augmentation plan that added ten additional wells and additional replacement water sources was approved in Case No. 96CW1144 by decree entered in 2016. Under these augmentation plans ACWWA may pump its tributary

[5] Of the alluvial wells in the vicinity of the JWPP, two ACWWA wells and four CWSD wells were determined through testing to produce raw water most suitable for advanced treatment.

wells out of priority provided that the computed weekly depletions to Cherry Creek are replaced. The replacement sources in ACWWA's augmentation plans include the following:

- Discharge of reclaimed effluent to Lone Tree Creek,
- Return flows from lawn irrigation within the ACWWA West portion of the service area and from land application of reclaimed effluent at the Valley Country Club golf course,
- Return flows from individual sewage disposal systems ("ISDS") from the ACWWA East portion of the service area,
- Discharges of brine concentrate from the JWPP,
- Direct discharge of nontributary ground water to Cherry Creek or its tributaries,
- Historical consumptive use credits associated with ACWWA's changed tributary irrigation water rights, and
- Releases of the above sources from storage in Chambers Reservoir,

ACWWA successfully operated its alluvial wells under the 86CW388(A) augmentation plan from 1991 to 1998. In 1998, ACWWA joined with CWSD, ECCV, the City of Aurora, and Colorado Parks and Wildlife to form the Upper Cherry Creek Water Association ("UCCWA") to develop and operate a joint plan for augmentation. The plan, which was decreed in 2007 in Case No. 01CW284, provides for pooling of the replacement supplies of the members to replace their combined out-of-priority depletions to Cherry Creek ("UCCWA Decree"). The UCCWA Decree allows greater flexibility in the use of water by the members than would be allowed under the individual augmentation plans of the members through the sharing of replacement supplies. This sharing of supplies is facilitated, in part, through operation of a storage account in Cherry Creek Reservoir. Participation in UCCWA is voluntary and any member can leave the group provided they give notice one year in advance. The UCCWA plan for augmentation has operated successfully since 1998.

4.3 ACWWA Flow Project

Development of the ACWWA Flow Project was initiated in 2009 when ACWWA entered into a contract with the United Water and Sanitation District ("United") to develop a renewable treated water supply from the South Platte River. Numerous applications were filed with the Water Court involving changes of senior irrigation water rights on the South Platte River and its tributaries. In addition, ACWWA filed applications for storage water rights, exchanges, and a plan for augmentation for the ACWWA Flow Project. These applications, some which are still pending or have yet to be filed, facilitate the delivery of alluvial ground water to ACWWA at the NWTP for treatment and subsequent delivery by pipeline to ACWWA as shown in the map in Figure 1-1. Treated water deliveries under the ACWWA Flow Project began in 2013. These deliveries are fully consumable and reusable, and ACWWA may reuse the return flows from use of the ACWWA

Flow Project water as a replacement water source in its augmentation plans. A summary of the ditch shares for the ACWWA Flow Project, the approved Water Court decrees, and the pending and future applications is included in Table 4-4.

4.4 Cherry Creek Project Water Authority

In 2005, ACWWA joined with CWSD, the Denver Southeast Suburban Water and Sanitation District (a.k.a., the Pinery), and IWSD to form the Cherry Creek Project Water Authority ("CCPWA") and to purchase the assets of the Western Water Company. These assets included over 7,100 acre-feet of Denver Basin ground water rights, approximately 2,900 acre-feet of senior and junior tributary water rights, and two gravel pit reservoir storage sites. The CCWPA water rights and storage sites are mostly located along Cherry Creek upstream of the Town of Parker. Since 2005, the CCPWA has acquired other tributary water rights and Denver Basin ground water rights in the upper Cherry Creek basin. ACWWA owns 41.25 percent of the CCPWA supply.

A plan for augmentation to facilitate delivery of the CCPWA supplies to its members was decreed in Case No. 10CW318. The CCPWA is working with the Parker Water and Sanitation District ("Parker") to facilitate delivery of water to the downstream CCPWA members (ACWWA, CWSD, and IWSD) through a proposed effluent trade agreement whereby CCPWA water will be diverted to storage in Parker's Rueter-Hess Reservoir and Parker will provide in trade reclaimed effluent discharged to Cherry Creek at the confluence with Sulphur Gulch approximately two miles upstream of the Cherry Creek Service Area. ACWWA and the other downstream CCPWA members would use the reclaimed effluent as a replacement source in their augmentation plans to support additional alluvial well pumping.

A Water Supply Master Plan for the CCWPA supply was prepared in 2014 and proposed average annual deliveries to the members totaling 1,000 AF/y to 2,000 AF/y. This would be approximately 400 AF/y to 800 AF/y for ACWWA. An alternative conceptualization of the project as a drought supply with deliveries occurring only in dry years was analyzed in an addendum report.

4.5 Reuse

With the exception of a small portion of its Denver Basin ground water, ACWWA's water sources are legally reusable and may be fully consumed to extinction. Reuse refers to use of return flows following initial and subsequent water uses and can occur directly or indirectly. ACWWA's direct reuse occurs through its nonpotable irrigation system that is supplied by reclaimed effluent from the LTCWRF.

ACWWA has been indirectly reusing its reclaimed effluent discharges and lawn irrigation return flows since it began operating its original augmentation plan in the early 1990s. Indirect reuse of return flows through an augmentation plan is an invaluable mechanism to effectively leverage reusable water sources into additional water use without impacting other water users. An idealized illustrative example of how this works is provided in Figure 4-1. In this example, 2,200 acre-feet of reusable water is leveraged into 4,000 acre-feet of total water use (initial use of 2,200 AF and reuse of 1,800 AF) resulting in a reuse factor of 1.82 (4,000/2,200). The actual reuse factor may be more or less than this figure depending on return flow amounts, system losses, reuse efficiency, and other variables.

4.6 Aquifer Storage and Recovery

Aquifer Storage and Recovery ("ASR") refers to recharging Denver Basin aquifers with treated water for subsequent withdrawal and use. ASR is regulated by the Colorado Division of Water Resources in accordance with the 1995 Denver Basin Artificial Extraction Rules ("ASR Rules"). The ASR Rules require that recharged water be fully consumable and be treated to drinking water standards. Recharged water may be banked indefinitely and may be withdrawn from the same well used to inject the water or from other wells that meet certain proximity criteria.

A permit is also required from the EPA to inject water into the Denver Basin aquifers. The EPA permit process involves two steps. First, the quality of the water proposed to be injected must be tested, and an application for a pilot testing permit must be submitted to the EPA. If the quality is determined to be adequate, the EPA will issue a permit to conduct a pilot study on specific wells. The pilot study program involves water quality testing of water before being injected and after being withdrawn from the proposed ASR well(s). After completing the pilot study, the proponent must then apply for approval of a permit to implement a full ASR program for each well based on the pilot study data.

ASR performed on a large scale has the potential to slow the decline in ground water storage and ground water levels in the Denver Basin aquifers and help maintain well production capacities. In addition, the indefinite banking provision could increase the utility of ACWWA's Denver Basin wells as a drought supply by providing banked water that could be withdrawn in addition to the decreed annual volumes. This would be beneficial even a modest scale by injecting 1,000 acre-feet or more that could be saved for withdrawal during periods of drought or interruption of delivery of ACWWA's other water supplies.

Many of the members of the South Metro Water Supply Authority, including CWSD and IWSD, are beginning the process to securing the necessary ASR permits to inject treated water delivered by Aurora Water under the WISE Project. ACWWA should monitor the testing and permitting efforts by the SMWSA members and pursue its own modest ASR project when the process of permitting and developing ASR is more mature.

Figure 4-1

Illustrative Example of Augmentation Reuse
Arapahoe County Water and Wastewater Authority

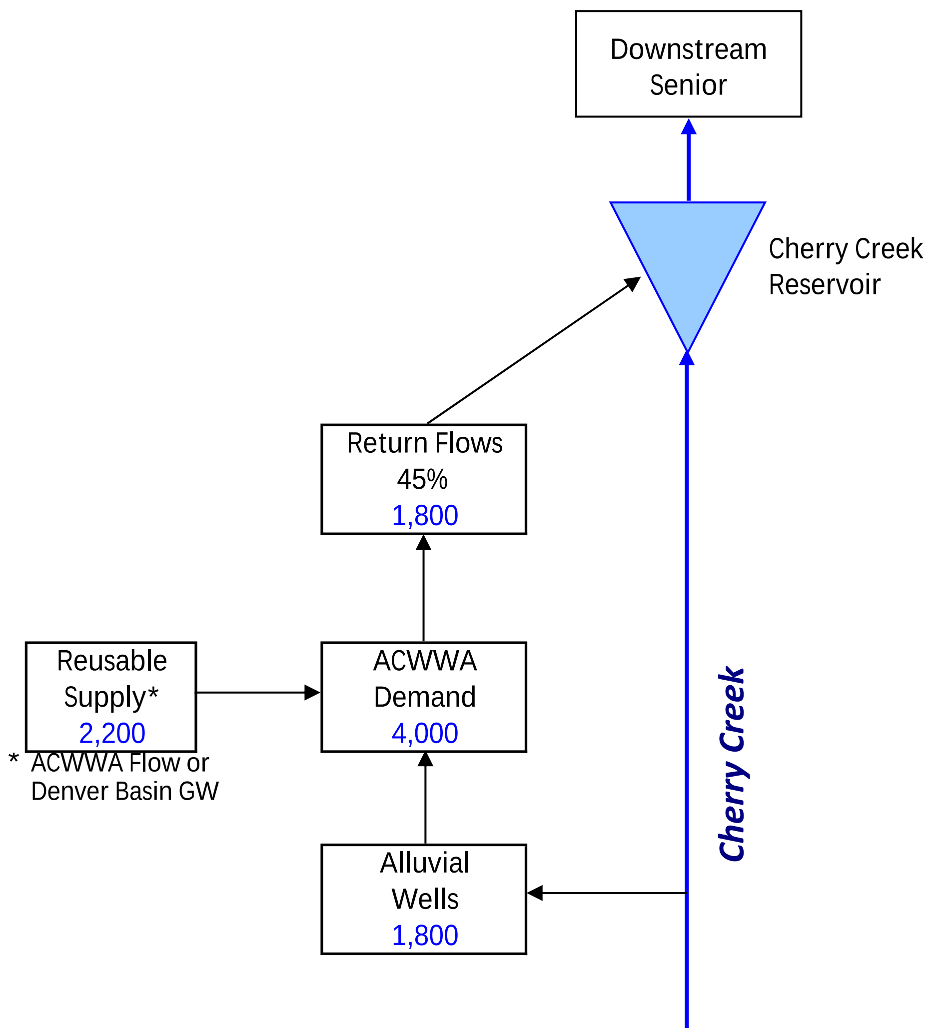


Table 4-1

Denver Basin Ground Water Rights
Arapahoe County Water and Wastewater Authority

Structure Name	Rate (cfs)	Rate (gpm)	(1) Annual Amount (AF/yr)	Relinquish %	Replacement Required	Original Case No.	Decree Date	Change Case No.
Lower Dawson Aquifer Nontributary Water Rights								
Antonoff	0.44	200	43.0			81CW065	1/13/1983	86CW388(A)
			18.0			81CW065	1/13/1983	86CW388(A)
Chaparral - Dawson			100.0			79CW367	5/6/1981	96CW1144
Total	0.44	200	161.0					
Denver Aquifer Nontributary Water Rights								
Denmark-DEN-1	0.20	90	103.0			W-9456-78	6/11/1981	86CW388(A)
Loyd-Den	0.45	200	75.3			80CW043	6/11/1981	86CW388(A)
DEN-1	0.11	50	57.0			80CW427	2/9/1983	86CW388(A)
DEN-2	0.11	50	13.0			80CW427	2/9/1983	86CW388(A)
DEN-3	0.11	50	13.0			80CW427	2/9/1983	86CW388(A)
DEN-4	0.11	50	13.0			80CW427	2/9/1983	86CW388(A)
Total	1.09	490	274.3					
Arapahoe Aquifer Nontributary Water Rights								
Airport-1	0.16	70	10.0			W-4887	3/10/1975	86CW388(A)
Airport-2	0.35	160	10.0			82CW466	12/5/1986	86CW388(A)
	0.67	300	30.0			82CW466	12/5/1986	86CW388(A)
Denmark-Arapahoe	1.11	500	180.0			W-9455-78	6/11/1981	86CW388(A)
Airport-3	0.67	300	71.5			82CW466	12/5/1986	86CW388(A)
Southeast	1.11	500	160.0			W-9428-78	4/29/1986	86CW388(A)
A-1	0.89	400	104.4			80CW428	2/9/1983	86CW388(A)
A-2	0.89	400	69.0			80CW428	2/9/1983	86CW388(A)
A-3	0.89	400	69.0			80CW428	2/9/1983	86CW388(A)
A-4	0.89	400	108.0			80CW428	2/9/1983	86CW388(A)
A-5	0.89	400	82.0			80CW428	2/9/1983	86CW388(A)
A-6	0.89	400	219.0			80CW428	2/9/1983	86CW388(A)
Antonoff A-1	0.67	300	12.0	0.02		85CW461	4/12/1991	96CW1144
Chaparral - Arapahoe			217.5	2%		79CW367	5/6/1981	96CW1144
Foxfield - Arapahoe			6.5		4%	93CW128	6/14/1994	96CW1144
Foxfield - Arapahoe			141.1	2%		00CW67	11/16/2001	96CW1144
Foxfield - Arapahoe			1.4	2%		03CW81	10/28/2003	96CW1144
Antelope - Arapahoe			84.1	2%		00CW197	5/31/2001	96CW1144
Douglas County - Arapahoe			20.85	2%		84CW237A	2/10/1989	96CW1144
Douglas County - Arapahoe			37.0	2%		09CW101	7/23/2012	96CW1144
Total	10.08	4,530	1633.3					
Laramie-Fox Hills Aquifer Nontributary Water Rights								
Denmark-LFH	0.45	200	80.0			W-9457-78	6/11/1981	86CW388(A)
Denmark-LFH			22.0	2%		85CW461	4/12/1991	
Loyd-LFH	0.45	200	82.8			80CW044	6/11/1981	86CW388(A)
LFH-1	0.33	150	119.0			80CW426	3/19/1982	86CW388(A)
LFH-1			20.3	2%		85CW461	4/12/1991	
LFH-2	0.33	150	118.0			80CW426	3/19/1982	86CW388(A)
LFH-2			22.0	2%		85CW461	4/12/1991	
LFH-3	0.33	150	118.0			80CW426	3/19/1982	86CW388(A)
LFH-3			22.0	2%		85CW461	4/12/1991	
LFH-4	0.33	150	121.0			80CW429	2/9/1983	86CW388(A)
LFH-4			22.0	2%		85CW461	4/12/1991	
Chaparral - LFH			41.0			79CW231	7/11/1980	96CW1144
Chaparral - LFH			59.0	2%		79CW367	3/28/1989	96CW1144
Foxfield - LFH			6.1		4%	93CW128	6/14/1994	96CW1144
Foxfield - LFH			8.5	2%		99CW211	8/11/2000	96CW1144
Foxfield - LFH			92.5	2%		00CW67	11/16/2001	96CW1144
Foxfield - LFH			1.2	2%		03CW81	10/28/2003	96CW1144
Antelope - LFH			60.5	2%		00CW197	5/31/2001	96CW1144
Total	2.22	1,000	1015.9					

Table 4-1

Denver Basin Ground Water Rights
Arapahoe County Water and Wastewater Authority

Structure Name	Rate (cfs)	Rate (gpm)	(1) Annual Amount (AF/yr)	Relinquish %	Replacement Required	Original Case No.	Decree Date	Change Case No.
Dawson Aquifer Not Nontributary Water Rights								
Denmark - Daw	0.89	400				W-8196-76	6/17/1977	
Douglas County - Dawson		0	7.8		actual	84CW237A	2/10/1989	96CW1144
Douglas County - Dawson		0	33.9		actual	09CW101	7/23/2012	96CW1144
Total	0.89	400	41.7					
Denver Aquifer Not Nontributary Water Rights								
Denmark-DEN-1	0.20	90	73.0		4%	W-9456-78	6/11/1981	85CW461
Denmark-DEN-2	0.17	80	73.3		4%	85CW461	4/12/1991	
DEN-1	0.18	80	74.0		4%	80CW427	2/9/1983	85CW461
DEN-2	0.12	50	74.0		4%	80CW427	2/9/1983	85CW461
DEN-3	0.12	50	74.0		4%	80CW427	2/9/1983	85CW461
			2.0		4%	85CW461	4/12/1991	
Douglas County - Denver			19.4		4%	84CW237A	2/10/1989	96CW1144
Douglas County - Denver			43.9		4%	09CW101	7/23/2012	96CW1144
Total	0.79	350	433.6					

Notes:

(1) The annual amount is less than the decred amount in situations where ACWWA did not aquire the full decreed amount.

Table 4-2

Summary of Active Wells and Current Water Supplies
Arapahoe County Water and Wastewater Authority

POTABLE WATER SYSTEM

Denver Basin Wells

Well	gpm	mgd
A-1	330	0.48
A-2	310	0.45
Airport	220	0.32
CMD A2	180	0.26
CMD D2	100	0.14
Denmark	420	0.60
Total	1,560	2.25
Planning *	1,140	1.64

Alluvial Wells (Potable to JWPP)

Well	gpm	mgd
Loyd-2	1,020	1.47
Race-1	800	1.15
CCC-4 (CWSD)	100	0.14
DD-1 (CWSD)	800	1.15
DD-4 (CWSD)	1,100	1.58
DD-7 (CWSD)	200	0.29
Total	4,020	5.79
Planning *	2,920	4.20
ACWWA JWPP	1,389	2.00

ACWWA Flow

Structure	gpm	mgd
Himalaya Vault	1,563	2.25

* 10% of total or largest well out of service.

NON-POTABLE WATER SYSTEM

Untreated Alluvial Wells

Well	gpm	mgd
Smith-2	1,000	1.44
Braun	1,000	1.44
Other (to be added)	1,000	1.44
Total	3,000	4.32

Reclaimed Effluent (Reg 84)

Limited by treated effluent production less deliveries to Valley Country Club per 1992 agreement (358 AF/y).

Table 4-3

Cherry Creek Tributary Water Rights
Arapahoe County Water and Wastewater Authority

Source	Case Nos.	Approp. Date	Rate (cfs)	(1) Annual Limit (AF)
Senior Tributary Direct Flow Water Rights				
The 59 Ditch No. 1	1883 Adjud, 80CW42	5/1/1862	1.82	24.0
The 59 Ditch No. 1	1883 Adjud, 80CW236	5/1/1862	1.82	28.425
Boss Ditch	1883 Adjud, 81CW142, 86CW388	7/30/1869	0.30	5.345
Boss Ditch	1883 Adjud, 80CW236	7/30/1869	0.28	4.989
Hawkey, Dane, & Gird Ditch	1883 Adjud, 84CW681(A)	7/30/1869	2.50	192.0
George Dane Ditch	1883 Adjud, 84CW681(A)	6/30/1874	1.80	43.0
West Cherry Creek Ditch	1883 Adjud, 84CW681(A) & (B)	2/28/1875	6.87	64.0
Cleona Ditch	1883 Adjud, 84CW681(A)	6/30/1875	2.00	38.0
Gillman Ditch	1883 Adjud, 81CW142, 86CW388	2/28/1880	0.62	5.322
Gillman Ditch	1883 Adjud, 80CW236	2/28/1880	0.57	4.894
Junior Tributary Direct Flow Absolute Water Rights				
Race Well No. 1	W-3098, 84CW681(A)	5/3/1939	2.67	124
Gillen Well	CA No. 3635, 84CW681(A)	12/31/1948	1.07	61
Race Well No. 2	W-3098, 84CW681(A)	5/12/1950	2.67	124
Smith Well No. 1	W-4396, 84CW681(A)	7/14/1950	1.67	
Smith Well No. 2	W-4396, 84CW681(A)	7/14/1950	1.44	228
Smith Well No. 2	W-4396, 84CW681(A)	1/27/1966	0.22	
Loyd Well No. 2	W-2640, 80CW042, 84CW681(A)	4/20/1953	2.74	106
Antonoff Well No. 1	W-1776, 81CW211, 84CW681(A)	4/26/1953	2.78	190
Loyd Well No. 4	W-2640, 84CW156	8/1/1954	1.56	30.64
Mee Well No. 2	W-4619, 84CW681(A)	5/12/1955	1.69	55
Race Well No. 3	W-3098, 84CW681(A)	5/19/1955	1.00	43
Mee Well No. 1	W-4619, 84CW681(A)	6/3/1958	1.10	15
Antonoff Well No. 2	W-1776, 81CW211, 84CW681(A)	6/21/1961	2.22	170
Loyd Well No. 5	W-2640, 80CW236	9/20/1962	2.67	110.992
Braun Well	W-1740, 84CW681(A)	5/7/1964	1.33	73
Ford Well No. 1	W-5541, 84CW681(A)	4/29/1964	2.67	136
Ford Well No. 2	W-5541, 84CW681(A)	5/2/1967	2.67	137
Junior Tributary Direct Flow Conditional Water Rights				
Antonoff Well No. 1	86CW388(A)	12/31/1986	2.78	1,823
Antonoff Well No. 2	86CW388(A)	12/31/1986	2.22	1,437
Deem Well	86CW388(A)	12/31/1986	1.22	883
Ford Well No. 1	86CW388(A)	12/31/1986	2.67	1,797
Ford Well No. 2	86CW388(A)	12/31/1986	2.67	1,796
Loyd Well No. 2	86CW388(A)	12/31/1986	2.74	1,854
Murdock Well No. 2	86CW388(A)	12/31/1986	1.78	1,289
Race Well No. 1	86CW388(A)	12/31/1986	2.67	1,809
Race Well No. 3	86CW388(A)	12/31/1986	1.00	681
Smith Well No. 1	86CW388(A)	12/31/1986	1.67	1,095
Loyd Well No. 4	96CW1144	12/31/1996	2.67	
Murdock Well No. 1	96CW1144	12/31/1996	2.67	
Race Well No. 2	96CW1144	12/31/1996	2.67	
Race Well No. 4	96CW1144	12/31/1996	2.67	
Smith Well No. 2	96CW1144	12/31/1996	2.67	
Braun Well	96CW1144	12/31/1996	2.67	
Gillen Well	96CW1144	12/31/1996	2.67	
Hodge Well No. 1	96CW1144	12/31/1996	2.67	
Mee Well No. 2	96CW1144	12/31/1996	2.67	
Weider Well	96CW1144	12/31/1996	2.67	

Table 4-3

Cherry Creek Tributary Water Rights
Arapahoe County Water and Wastewater Authority

Source	Case Nos.	Approp. Date	Rate (cfs)	(1) Annual Limit (AF)
Junior Tributary Conditional Water Rights on Cherry Creek Tributaries				
Cottonwood Diversion Structure No. 1	90CW201	4/23/1990	2.67	
Lone Tree Surface Diversion	90CW201	4/23/1990	2.67	
Windmill Diversion Structure No. 1	90CW201	4/23/1990	2.67	
Windmill Diversion Structure No. 2	90CW201	4/23/1990	2.67	
AWSD-CW-1 Well	90CW201	4/23/1990	2.67	
AWSD-LT-1 Well	90CW201	4/23/1990	2.67	
AWSD-LT-2 Well	90CW201	9/3/1993	2.67	
AWSD-WM-1 Well	90CW201	4/23/1990	2.67	
AWSD-WM-2 Well	90CW201	4/23/1990	2.67	
Happy Canyon Creek Well No. 1	96CW1144	12/31/1996	0.67	
Happy Canyon Creek Well No. 2	96CW1144	12/31/1996	0.67	
Happy Canyon Creek Well No. 3	96CW1144	12/31/1996	0.67	
Happy Canyon Creek Well No. 4	96CW1144	12/31/1996	0.67	
Happy Canyon Creek Well No. 5	96CW1144	12/31/1996	0.67	

Table 4-4

ACWWA Flow Project Water Rights
Arapahoe County Water and Wastewater Authority

Source	Case No. (Decree Date)	Annual Limit (af)	No. Shares
Cache La Poudre, St. Vrain, and S.Platte River Exchange	09CW283 (9/18/2014)	6,981.0	
Beebe Draw Recharge Project	10CW306 (4/2/2014)	4,400.0	
70 Ranch Plan for Augmentation and Recharge Project	10CW306 (4/2/2014)	3,600.0	
United Reservoir No. 3 (conditional storage rights)	10CW312 (10/20/2014)	1,000.0	
70 Ranch Reservoir (conditional storage right)	13CW3171(6/20/2017)	3,000.0	
Gilcrest Reservoir (conditional storage right)	13CW3173 (3/29/2016)	1,000.0	
Binder Reservoir (conditional storage right)	16CW3195	pending	
Serfer Pit (conditional storage right)	16CW3195	pending	
Highlands Reservoir (conditional storage rights)	16CW3195	pending	
Barr Lake (conditional storage right)	16CW3195	pending	
SPR 1 Water Right (conditional surface right)	16CW3195	pending	
Drouhard Recharge Site (conditional recharge right)	16CW3195	pending	
Brighton Lateral (conditional recharge right)	16CW3195	pending	
Brighton Lateral Recharge Site (conditional recharge right)	16CW3195	pending	
Fulton Ditch Company	10CW313 (2/21/2015)	308.7	182.0
Weldon Valley Ditch Company	11CW151/05CW58 (pending)	921.1	62.625
Farmers Independent Ditch Company	12CW73 (2/26/2016)	190.1	20.0
New Cache La Poudre Irr Co and Cache La Poudre Res Co	13CW3026 (10/31/2017)	430.3	108.0
Western Mutual Ditch Company	16CW3200		166.5
Lower Latham Ditch Co. and Lower Latham Reservoir Co.	not in pending case		4.0
Fort Morgan Reservoir and Irrigation Company	not in pending case		50.0
Lake Canal Company and Lake Canal Reservoir Company	not in pending case		16.0
Larimer & Weld Irrigation and Reservoir Company	not in pending case		2.75
Water Supply and Storage Company	not in pending case		40.0
Whitney Irrigation Company	not in pending case		7.0
Windsor Reservoir and Canal Company	not in pending case		7.0

5.0 ACWWA WATER SUPPLY OPERATIONS MODEL

5.1 Overview

The ACWWA Water Supply Operations Model ("Operations Model") was developed to simulate operation of ACWWA's water supply systems, including the potable water system and the nonpotable irrigation systems. Potable water requirements are simulated as being met from ACWWA Flow Project deliveries, Denver Basin ground water, and treated alluvial ground water. Nonpotable irrigation requirements are satisfied through simulated deliveries of reclaimed effluent and untreated alluvial ground water regulated through ACWWA's Chamber Reservoir. A schematic diagram of the components of the simulation model is shown in Figure 5-1.

The Operations Model simulates a user-selected sequence of dry, average, and wet years over a ten-year period using monthly stress periods. Water needs are specified as annual indoor demands, irrigated areas, and annual irrigation application depths. These demand specifications can be set as level through the study period or can be set to increase between specified starting and ending amounts. The model simulates separate demands for (a) potable use (indoor and irrigation), (b) raw water irrigation, and (c) reclaimed effluent irrigation. The annual indoor and irrigation water demands are distributed monthly based on the distribution patterns described in Section 3.4. ACWWA's augmentation plan operations are simulated on a simplified level whereby monthly alluvial well pumping is limited by the available monthly replacement supply (CU Credits + reclaimed effluent discharges + LIRFs).

Summaries of the input data, input parameters, model operation, and output are provided below.

5.2 Input Parameters

Various input parameters are specified by the model user to conduct a simulation run. These include the water demands, return flow percentages, well capacities, reservoir specifications, water supply yields, and other parameters. The following is a list of the input parameters for the Operations Model:

- Indoor Use (AF/y) – Annual indoor potable water use.
- Irrigated Area (acres) – Irrigated area for the potable system and the raw alluvial and reclaimed effluent nonpotable irrigation systems.
- Irrigation Demand (AF/y) – Dry year, average year, and wet year annual irrigation demands.
- System Loss – Portion of simulated supply that is assumed lost between water supply source(s) and delivery to meet the simulated demands.

- Augmentation Supply Loss – Portion of the simulated return flows available for augmentation that is assumed to be unavailable for augmentation due to operational and management inefficiencies.
- Potable Supply Mixing Goals – Flag to specify whether the model should attempt to meet specified water supply mixing goals for use of ACWWA Flow Project water, treated alluvial ground water, and Denver Basin ground water.
- ACWWA Flow Lease to Others (AF/y) – Annual volume of ACWWA Flow deliveries leased to others (e.g., to supply the proposed Prosper Development).
- Annual Hydrology – Sequence of dry, average, and wet years to simulated during the 10-year simulation period
- Peak Day/Month Factors – Peaking factors applied to monthly indoor and irrigation demands to compute peak day water requirements.
- Return Flow Percentages – The percentage of indoor use that returns as treated effluent (or ISDS returns), the portion of the treated effluent sent by contract to the Valley Country Club, the percentage of irrigation use that returns as LIRFs, and the portion of the return flows that are assumed lost due to augmentation plan inefficiencies.
- Denver Basin Well Limits – Denver Basin well pumping capacity for potable use and nonpotable use, and the annual pumping volume limit.
- Alluvial Well Limits – Alluvial well pumping capacity for potable use and nonpotable use, and whether to alluvial ground water may be used to meet unmet demand for the reclaimed effluent irrigation system.
- Chambers Reservoir Specifications – Storage volume, maximum rate of delivery from storage for irrigation, maximum rate of release for augmentation, and whether to limit inflows to storage to the period from November – March.
- JWPP Operations – Water treatment capacity (MGD), and the portion of the raw alluvial ground water delivered for treatment that becomes concentrate return flows.
- ACWWA Flow Delivery Rate and Schedule – The initial maximum rate of delivery from the ACWWA Flow Project, the simulation year that the delivery rate is increased, and the schedule for deliveries (municipal demand pattern, irrigation season only deliveries, or flat year around deliveries).
- ACWWA Flow Yield – The initial dry, average, and wet year yield from the ACWWA Flow Project and the simulation year that the annual yields increase. The dry year yield

decreases by 500 AF after the first year of multiple consecutive dry years.[6] (500 AF for of the dry year yield is assumed

- CU Credits – Seasonal yields in dry, average, and wet years for ACWWA's Cherry Creek basin consumptive use water rights that are used as augmentation credits.
- CCPWA Supply – Seasonal deliveries of augmentation water from ACWWA's participation in the Cherry Creek Project Water Authority.

5.3 Potable Water System Simulation

The Operations Model attempts to meet the simulated monthly potable water demands in prioritized order of use from ACWWA Flow Project deliveries, augmented alluvial ground water treated at the JWPP, and Denver Basin ground water pumping. ACWWA Flow Project water is limited by the annual yields distributed by the user-specified monthly distribution and by the specified maximum delivery rate. Alluvial ground water use is limited by the available augmentation supply (remaining reclaimed effluent after nonpotable irrigation use, LIRFs, CU credits, CCPWA deliveries, and Chambers Reservoir releases), by the JWPP treatment capacity, and by the alluvial well capacity for potable uses. Denver Basin ground water use is limited by the specified annual volume entitlement and by the specified Denver Basin well pumping capacity.

The model user can optionally specify that potable demands be met by a specified percentage mix of the three potable water sources, if possible, given the constraints on the availability and yield of these sources.

5.4 Nonpotable System Simulation

The Operations Model simulates two separate nonpotable irrigation systems. The reclaimed effluent irrigation system demands are assumed met by the amount of reclaimed effluent that remains after delivery to VCC by contract.

The raw alluvial irrigation system is simulated as untreated alluvial ground water to storage in Chambers Reservoir. Alluvial ground water pumping to storage is limited by the remaining augmentation supply, the maximum raw alluvial ground water pumping rate and the available storage capacity. Deliveries from storage for irrigation are limited by the specified maximum release rate. The user can specify that deliveries of alluvial ground water be limited to the period from November – March to increase storage retention times for settling out the high iron content in the alluvial ground water supply.

[6] Approximately 500 AF of the dry year yield is assumed to come from water stored in United Reservoir No. 3. That supply is assumed used in the first year of a drought and not available in subsequent consecutive years of drought.

5.5 Peak Day Demands

Peak day water demands for the potable and nonpotable water systems are computed by multiplying the simulated monthly demands by user-specified peak day/month factors. The computed peak day demands are compared to the combined capacities for the sources that supply each system, and any simulated shortages in the peak day supplies are tabulated.

5.6 Annual Hydrology

The following sequence of hydrologic years was selected for all of the model simulations in this report:

1	2	3	4	5	6	7	8	9	10
Dry	Avg	Wet	Dry	Dry	Dry	Avg	Wet	Dry	Dry

As described in Section 5.0, the year type affects the irrigation demand, the annual yield of the ACWWA Flow Project, the yield of the consumptive use credits for augmentation, and the yield of the CCPWA supply (when simulated).

Operation of Chambers Reservoir is the only simulated element of the model with effects that carryover to the next year (the simulated ending storage in one year is the beginning storage in the next year. Otherwise, all simulated model elements are independent from year to year.

5.7 Model Limitations and Uncertainty

The Operations Model was constructed to reasonably simulate the ACWWA water supply system at a planning level with sufficient detail to enable use of the model to assess the adequacy of ACWWA's water supply to meet demands in dry, average, and wet years. The model is also suitable for simulating what-if scenarios to assess the effects of adding new supplies and/or adding new demands. However, the performance and accuracy of the model are limited by its spatial and temporal resolution and by certain simplifying assumptions, including the following:

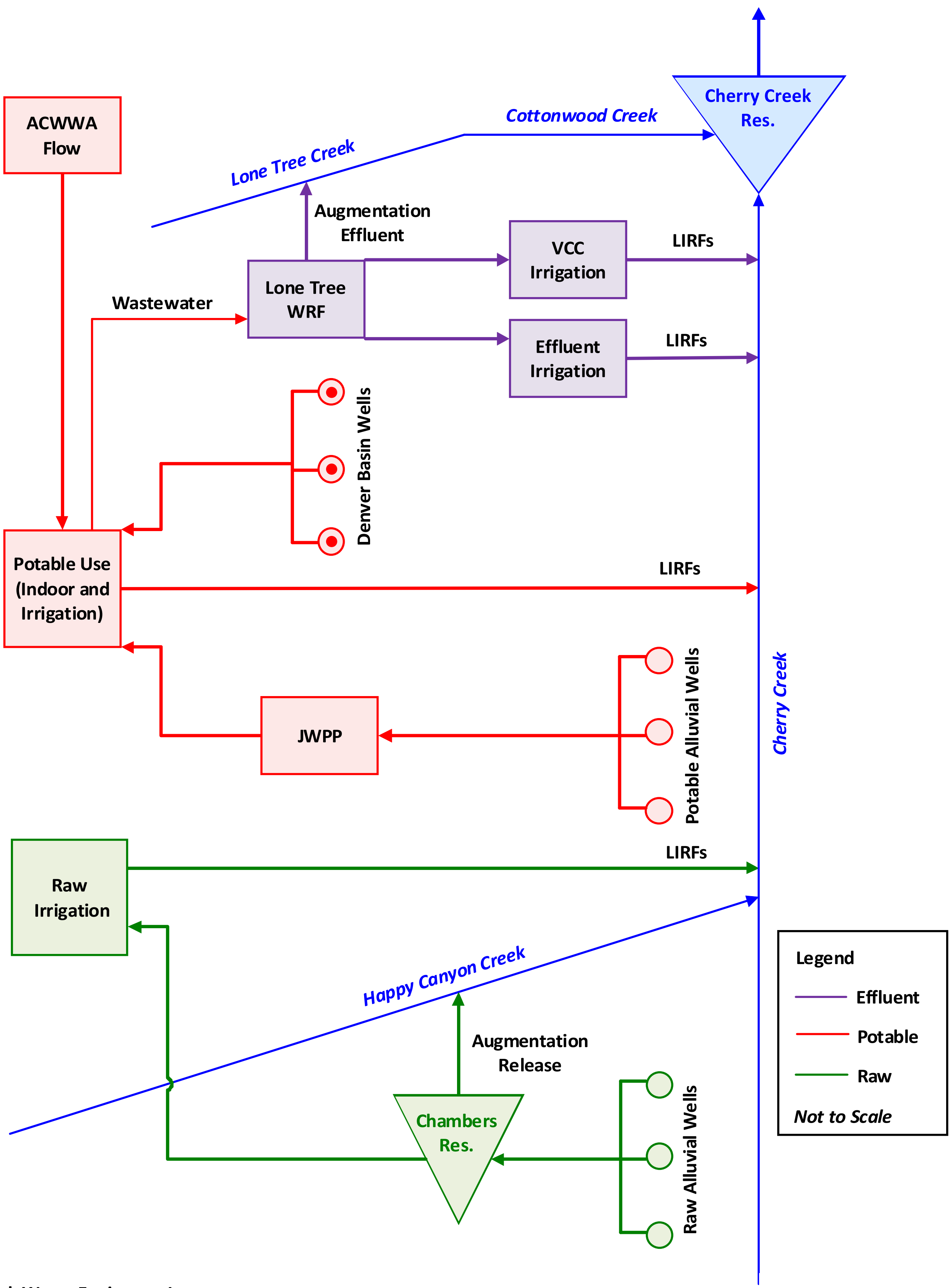
1. The monthly time-step of the model prevents consideration of the week-to-week or day-to-day variations in supply, demand, and water rights administration.
2. The simulated yield of ACWWA water supplies is limited only by legal and capacity constraints and not by physical water availability:
    a. ACWWA Flow – Limited by the obligations in ACWWA-United Water Contract and ACWWA's portion of the capacity of the Northern Pipeline.
    b. Denver Basin Wells – Limited by annual decreed entitlements and reported well capacities.

   c. Alluvial Wells – Limited by simulated augmentation supplies and reported well capacities.

3. There is no simulation of physical water availability and therefore potential physical limitations in ACWWA's alluvial wells and Denver Basin wells to deliver the simulated volumes are not considered.
4. It is presumed that the water system operators will operate the system to dynamically respond to changes in supply and demand to generally maximize the use of tributary ground water and minimize the amount of return flows and other augmentation supplies that go unused. In recognition of the inherent limitations in optimizing the operation of a complex water system such as ACWWA's the following conservative assumptions are built into the model:
   a. 10% system loss
   b. 10% augmentation supply loss
   c. No free river other than assumed wet year yield of CU credits
5. The model does not simulate the temporal lagging of stream depletions from pumping nor return flows from irrigation that can affect the ability to optimize the system operation.
6. All potable water system demands are lumped, and it assumed there are no material constraints in the distribution system that would inhibit the simulated supply from reaching the simulated demand. All nonpotable supplies and demands are similarly lumped.
7.

Figure 5-1

Schematic Diagram
ACWWA Water Supply Operations Model



6.0 WATER SUPPLY SCENARIOS AND ALTERNATIVES

The Operations Model is a useful tool for evaluating changes in municipal demands, additional raw water supplies, and alternative operating procedures. During the process of developing this Raw Water Supply Master Plan, the model has been invaluable in helping to better understand the benefits of adding water supplies, increasing facility capacities, and the tradeoffs between various operating strategies. Based the results of numerous model runs and discussions with ACWWA staff and consultants, several current and buildout demand scenarios were selected to present in this report. These example scenarios and the simulated results are described below and shown in Tables 6-1 – 6-6. A summary of key inputs and key results for the example scenarios is provided in Table 6-7.

The results for each model run are presented in a two-page table. The first page summarizes the key input parameter settings and shows the simulated annual and peak day water supplies for dry, average, and wet years. Simulated shortages are highlighted in red and surpluses in green. At the bottom of the first table are graphs summarizing the simulated monthly supplies for the potable water system, the raw irrigation system, and the reclaimed effluent system. Also shown is a graph of the simulated contents of Chambers Reservoir (when simulated). The second page lists all of the input parameter settings and summarizes average annual deliveries from the simulated water sources over the 10-year study period.

6.1 Scenario 1 - Current Demand

Scenario 1 was simulated to assess the capability of ACWWA's existing water supplies and facilities to meet the projected current planning demands for the Cherry Creek Service Area of 4,205 AF/y in a dry year (4,673 AF/y water requirement with 10% system loss). The results for this scenario, shown in Table 6-1 indicate that the current available water supplies and facilities would be insufficient to meet the simulated potable water demands in dry and average years during the peak water use months of June – September. Simulated annual shortages total 430 AF in a dry year and 90 AF in an average year. Peak day potable demand shortages range from 1.7 MGD in wet years to 3.8 MGD in dry years.

There were no simulated shortages for the nonpotable irrigation systems served by raw alluvial ground water and reclaimed effluent because these sources are simulated in the model before the potable water system. While shorting the nonpotable irrigation demands could make additional water available for augmentation, this would not result in increased alluvial ground water for potable use because the simulated JWPP treatment plant operation is at the 2.0 MGD capacity during the summer months.

The simulated potable water shortages are due to limited capacities of the existing Denver Basin wells (with the largest well assumed out of service) and ACWWA Flow delivery pipelines. The simulated shortages could be largely eliminated by drilling additional Denver Basin wells to increase the rate at which this supply can be produced and/or by increasing the rate that ACWWA Flow water can be delivered for use.

6.2 Scenario 2 - Current Demand with Increased ACWWA Flow Rate

Scenario 2 was simulated to demonstrate the benefit of increasing the delivery rate for ACWWA Flow Project water from 2.25 MGD to 5.25 MGD. The 3.0 MGD increase in the treatment capacity and delivery rate is planned as part of the Northern system expansion and construction of a separate delivery pipeline that is being jointly funded by ACWWA and ECCV and which is projected to be operable in 2019. The same current demand of 4,205 AF/y (4,673 AF/y with 10% system loss) used in Scenario 1 was simulated in this scenario.

The results for this scenario, shown in Table 6-2 show that increasing the rate of delivery of the ACWWA Flow water to 5.25 MGD would eliminate the simulated monthly potable system shortages during the summer months that were present in Scenario 1. There remains a peak day potable system shortage in dry years of 1.0 MGD in July and nearly that amount in August. This represents approximately 10 percent of the peak summer demand and could likely be managed through watering restrictions and demand management.

6.3 Scenario 3 - Current Demand with Increased ACWWA Flow Rate and Chambers Reservoir

Scenario 3 was simulated to show the utility of Chambers Reservoir to the operation of ACWWA's water supply system. The reservoir was simulated with a usable capacity 1,200 acre-feet. The reservoir is simulated primarily to regulate distribution of untreated alluvial ground water for nonpotable irrigation use (currently 49.4 acres). The temporary retention of the untreated alluvial ground water in storage in Chambers Reservoir will settle suspended iron and will reduce the sidewalk staining that currently plagues the existing raw alluvial irrigation system. Water stored in Chambers Reservoir is also released for augmentation use as needed in the model.

The results for this scenario, shown in Table 6-3, indicate that all of the current nonpotable raw irrigation demand can be met from Chambers Reservoir without emptying the reservoir. The simulated minimum reservoir content at the end of the three-year drought period is approximately 550 acre-feet. Just as for Scenario 2, there are no simulated monthly water supply shortages, and there remains a peak-day potable system shortage of 1.0 MGD.

6.4 Scenario 4 - Buildout Demand

Scenario 4 was simulated to assess the capability of the facilities in Scenario 3 to meet the projected planning demand at buildout of the Cherry Creek Service Area of 5,706 AF/y in a dry year (6,340 AF/y with 10% system loss). The results for this scenario, shown in Table 6-4 indicate that the current available water supplies and facilities are sufficient to meeting the simulated monthly water demands in dry, average, and wet years. The maximum dry year annual use of Denver Basin ground water totals 680 AF/y. No Denver Basin ground water pumping was needed to meet the monthly demands in average and dry years. This meets ACWWA's goals to ultimately become a water supply system primarily reliant on renewable water sources. There are simulated peak day potable water demand shortages of up to 1.3 MGD in dry years and 0.2 MGD in average years.

Inflows and irrigation releases from Chambers Reservoir are simulated as both occurring through the same delivery pipeline. This restriction limits the time for filling of Chambers Reservoir to the November – March non-irrigation season. While there are no non-potable irrigation shortages, the reservoir empties in average and dry years, necessitating undesirable direct deliveries of raw alluvial ground water for irrigation without storage. This could be mitigated by construction of a separate delivery pipeline to Chambers Reservoir so that water nonpotable water could be run through the approximately 200 acre-feet of operational dead storage that is expected to be maintained in the reservoir.

6.5 Scenario 5 - Buildout Demand (Chambers Inflow Pipeline)

Scenario 5 is the same as Scenario 4 with the exception that Chambers Reservoir is simulated with a separate inflow pipeline that allows it to be filled throughout the year rather than only during the non-irrigation season. The results for this scenario, shown in Table 6-5 indicate that adding the inflow pipeline to Chambers Reservoir would eliminate the summer month shortages that existed in Scenario 4. The maximum dry year annual use of Denver Basin ground water is reduced to 680 AF/y, and no Denver Basin ground water pumping is needed to meet the monthly demands in average and dry years. There remain peak day potable water demand shortages of up to 1.3 MGD in dry years and 0.2 MGD in average years.

There are no simulated nonpotable irrigation demand shortages. The simulated Chambers Reservoir inflow pipeline allows excess return flows during April – October to be stored in the reservoir through augmentation of additional alluvial well pumping. This allows almost all of the simulate raw alluvial irrigation demands to be met from storage releases. The year-round simulated delivery of water to storage in Chambers Reservoir also alleviates simulated summer month potable water shortages through storage releases for augmentation during dry years when the other replacement supplies are insufficient.

6.6 Scenario 6 - Buildout Demand with Inclusion of Nearby Areas

Scenario 6 was simulated to assess the capability of the ACWWA water system to meet additional water demands at buildout resulting from water service provided to nearby areas that potentially could be included in the Cherry Creek Service Area. As described in Section 3.7, the total buildout demand for these additional areas is estimated at 1,074 AF/y (1,193 AF/y with 10% system loss). It was assumed that roughly one-half of this demand would be for indoor use and one-half for irrigation use. It is assumed that these demands would be met from the same sources that are used to supply the present Cherry Creek Service Area.

The results for this scenario, shown in Table 6-6 indicate that the current available water supplies plus an additional Denver Basin well (300 gpm) are not quite sufficient to meet the simulated dry year potable water demand. The simulated dry year shortage totals 122 AF, or about 2 percent of the potable water demand. There is significant increased use of Denver Basin ground water in this scenario compared to Scenario 6 with use of 1,600 AF in dry years, 657 AF in average years, and 406 AF in wet years. The dry year shortage could be eliminated and Denver Basin ground water use reduced by 200 to 300 AF/y by increasing the JWPP treatment capacity from 2.0 MGD to 2.4 MGD. There are no simulated shortages to the non-potable irrigation systems in this scenario, and Chambers Reservoir is kept relatively full.

6.7 Scenario 7 - Buildout Demand with Leases to Others

Another series of runs were made assuming that treated ACWWA Flow water was delivered to supply a separate service area, such as the proposed Prosper Development, via a spur pipeline off the ACWWA Flow Northern Pipeline. Model runs were made for annual lease demands ranging from zero to 2,000 AF for a base condition and three alternative water supply scenarios, and the results of these runs are summarized in Figure 6-1. The solid lines in Figure 6-1 depict the simulated annual dry-year Denver Basin well pumping for the base run and the three alternative scenarios, and the dotted lines plot the annual shortages.

The base run is the buildout Scenario 5 without service to potential nearby inclusions. As the annual lease volume increases, the model simulates increasing amounts of Denver Basin ground water use by ACWWA to attempt to replace the increasing ACWWA Flow delivery leases. The simulated Denver Basin ground water pumping rate limits the ability to full replace the ACWWA Flow leases and this result in a steady growth in the simulated shortages as the annual lease volume is increased.

Alternative 1 increases the Denver Basin ground water pumping rate from 1,140 gpm to 2,000 gpm (green lines). This results in increased Denver Basin ground water pumping in dry years and a significant reduction in the simulated shortages.

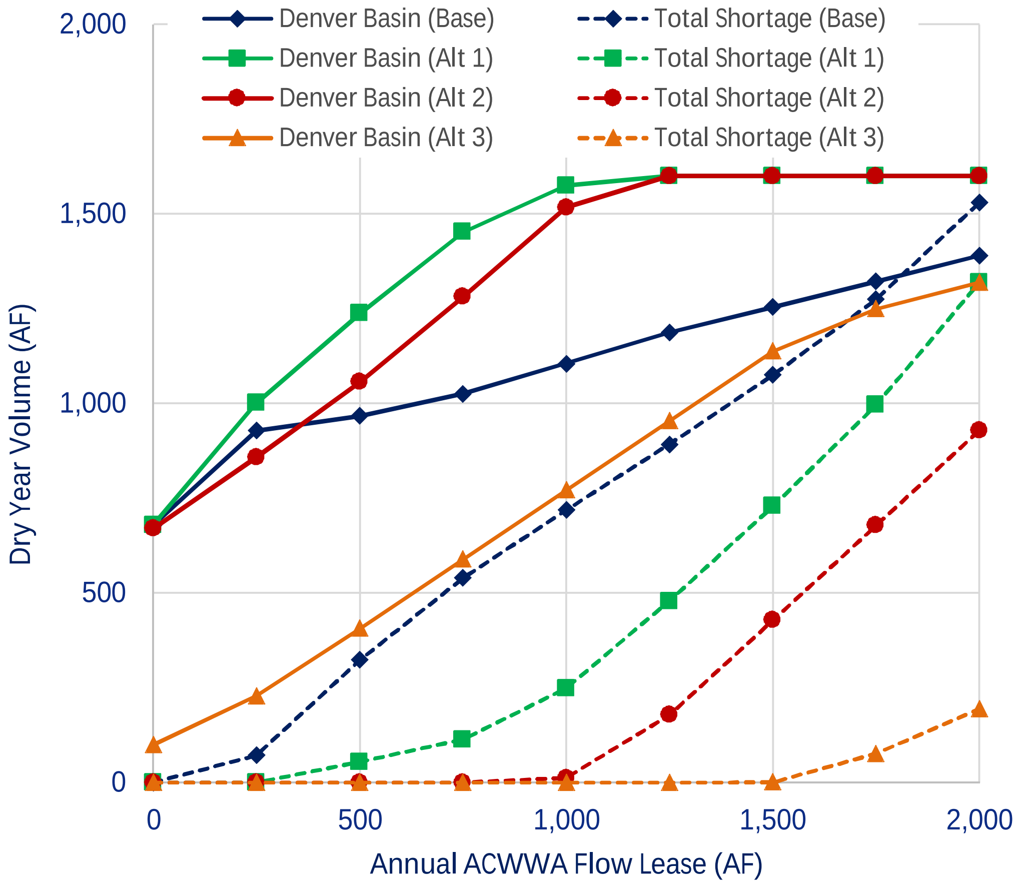
Alternative 2 adds simulated deliveries of CCPWA supply of 1,400 AF in dry years (red lines). The CCPWA deliveries further reduce the simulated dry year shortages such that there are no shortages until the annual lease volume reaches 1,000 AF.

Alternative 3 increases ACWWA's portion of the JWPP capacity from 2.0 MGD to 3.0 MGD (orange lines). The increased water treatment capacity results in additional shortage reductions and shows that 1,500 AF could be leased annually without shortages. If the Denver Basin well capacity is increased to 2,600 gpm, then the annual lease volume could be increased to 2,000 AF without shortages.

The results of the lease runs show that ACWWA has little excess water to lease to others in dry years with its current and proposed facilities. However, additional water could be made available for lease by drilling additional Denver Basin wells, developing or acquiring additional reusable water supplies such as the CCPWA supply, and by increasing the JWPP treatment capacity.

Figure 6-1

Simulated Dry Year Shortages
and Dry Year Denver Basin Ground Water Use
with ACWWA Flow Leases to Others at Buildout
Arapahoe County Water and Wastewater Authority



<u>Simulated Scenarios:</u>

Base: Scenario 5 - Buildout Demand (Chambers Inlet).

Alt 1: Increase Denver Basin well capacity to 2,000 gpm.

Alt 2: & Add CCPWA dry year delivery of 1,400 af.

Alt 3: & Increase JWPP capacity to 3.0 MGD.

ACWWA Water Supply Operations Model

Table 6-1

Model Version 0.87

Arapahoe County Water and Wastewater Authority

Water Supply Master Plan - 1 - Current Demand

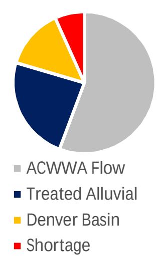
Key Inputs

Dry Year Demand	
ACWWA (AF/y)	4,673
Lease (AF/y)	0
Total	4,673
ACWWA Flow	
Rate (MGD)	2.25
Dry Year (AF/y)	3,100
Schedule	Muni
JWPP	
Rate (MGD)	2.00
Denver Basin Wells	
Rate (gpm)	1,140
Annual (AF/y)	1,600
Chambers Reservoir	
Capacity (AF)	0
Potable Mixing	
Goals On (y/n)	No
System Loss	
Loss %	10%

Dry Year Reuse Factor 1.33

Year	Type
1	dry
2	avg
3	wet
4	dry
5	dry
6	dry
7	avg
8	wet
9	dry
10	dry

Avg Potable Mix



ANNUAL Potable Supply (AF/y)

Potable	Dry	Average	Wet
Demand	4,337	3,956	3,684
Supply			
ACWWA Flow	2,282	2,309	2,305
Treated Alluvial	1,011	989	951
Denver Basin	615	565	428
Total	3,907	3,863	3,684
Shortage	430	93	0
	10%	2%	0%

ANNUAL Non-Potable Irrigation Supply (AF/y)

Raw Alluvial	Dry	Average	Wet
Demand	220	181	154
Supply	220	181	154
Shortage	0	0	0
Reg 84	**Dry**	**Average**	**Wet**
Demand	116	96	82
Supply	116	96	82
Shortage	0	0	0

ANNUAL Total Supply (AF/y)

Total Demand	4,673	4,234	3,920
Total Supply	4,243	4,141	3,920
Shortage	430	93	0

PEAK DAY Potable Supplies (MGD)

Potable	Dry	Average	Wet
Demand	9.5	8.3	7.5
Supply			
ACWWA Flow	2.1	2.1	2.1
Treated Alluvial	2.0	2.0	2.0
Denver Basin	1.6	1.6	1.6
Total	5.8	5.8	5.8
Shortage	3.8	2.6	1.7
	40%	31%	23%

ANNUAL Lease to Others (AF/y)

Lease	Dry	Average	Wet
Demand	0	0	0
ACWWA Flow	0	0	0
Shortage	0	0	0

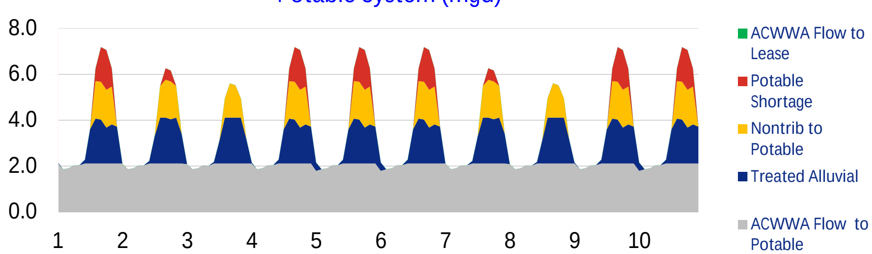
ANNUAL Augmentation Supply (AF/y)

Augmentation*	Dry	Average	Wet
Demand	1,201	1,170	1,104
Supply	1,993	2,036	3,189
Surplus	792	866	2,084

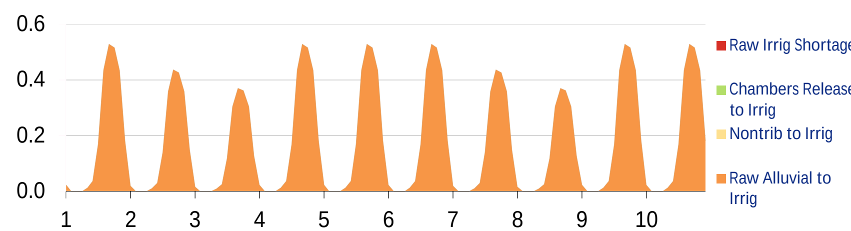
(1) In third consecutive dry year.

(2) Not including Chambers releases

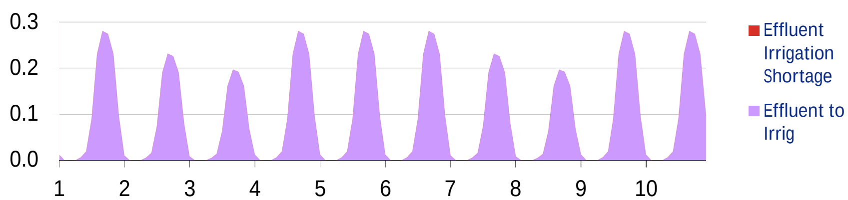
Potable System (mgd)



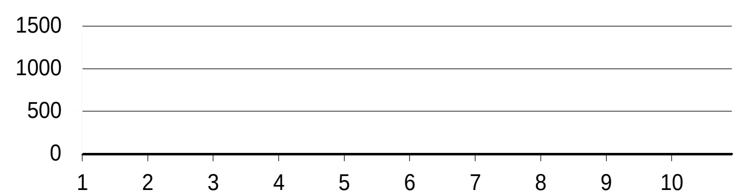
Raw Irrigation System (mgd)



Reg 84 System (mgd)



Chambers Reservoir (AF)



ACWWA Water Supply Operations Model

Table 6-2

Model Version 0.87

Arapahoe County Water and Wastewater Authority

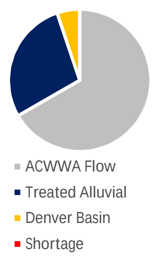
Water Supply Master Plan - 2 - Current Demand (AF 5.25)

Key Inputs	
Dry Year Demand	
ACWWA (AF/y)	4,673
Lease (AF/y)	0
Total	4,673
ACWWA Flow	
Rate (MGD)	5.25
Dry Year (AF/y)	3,100
Schedule	Muni
JWPP	
Rate (MGD)	2.00
Denver Basin Wells	
Rate (gpm)	1,140
Annual (AF/y)	1,600
Chambers Reservoir	
Capacity (AF)	0
Potable Mixing	
Goals On (y/n)	No
System Loss	
Loss %	10%

Dry Year Reuse Factor 1.54

Year	Type
1	dry
2	avg
3	wet
4	dry
5	dry
6	dry
7	avg
8	wet
9	dry
10	dry

Avg Potable Mix



ANNUAL Potable Supply (AF/y)

Potable	Dry	Average	Wet
Demand	4,337	3,956	3,684
Supply			
ACWWA Flow	2,340	3,134	3,137
Treated Alluvial	1,600	781	547
Denver Basin	397	41	0
Total	4,337	3,956	3,684
Shortage	0	0	0
	0%	0%	0%

ANNUAL Non-Potable Irrigation Supply (AF/y)

Raw Alluvial	Dry	Average	Wet
Demand	220	181	154
Supply	220	181	154
Shortage	0	0	0
Reg 84	**Dry**	**Average**	**Wet**
Demand	116	96	82
Supply	116	96	82
Shortage	0	0	0

ANNUAL Total Supply (AF/y)

Total Demand	4,673	4,234	3,920
Total Supply	4,673	4,234	3,920
Shortage	0	0	0

PEAK DAY Potable Supplies (MGD)

Potable	Dry	Average	Wet
Demand	9.5	8.3	7.5
Supply			
ACWWA Flow	4.9	4.9	4.9
Treated Alluvial	2.0	2.0	2.0
Denver Basin	1.6	1.6	1.6
Total	8.6	8.6	8.6
Shortage	1.0	0.0	0.0
	10%	0%	0%

ANNUAL Lease to Others (AF/y)

Lease	Dry	Average	Wet
Demand	0	0	0
ACWWA Flow	0	0	0
Shortage	0	0	0

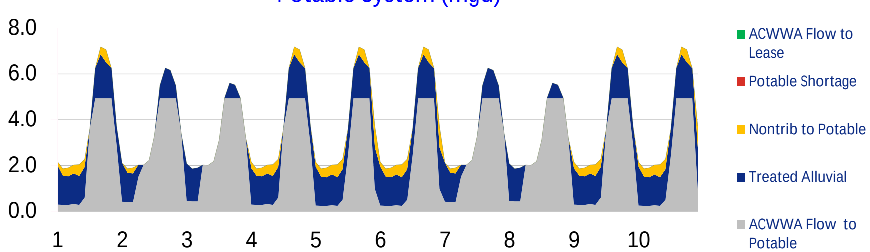
ANNUAL Augmentation Supply (AF/y)

Augmentation*	Dry	Average	Wet
Demand	1,618	962	701
Supply	1,993	2,036	3,189
Surplus	375	1,074	2,488

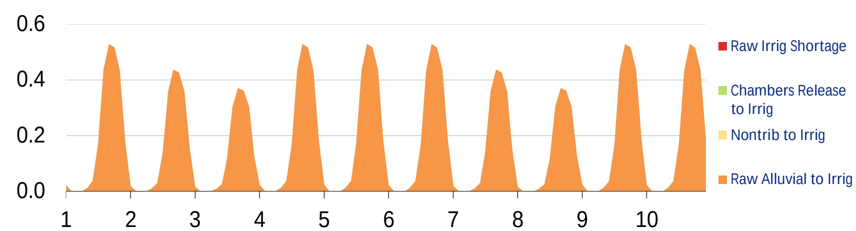
(1) In third consecutive dry year.

(2) Not including Chambers releases

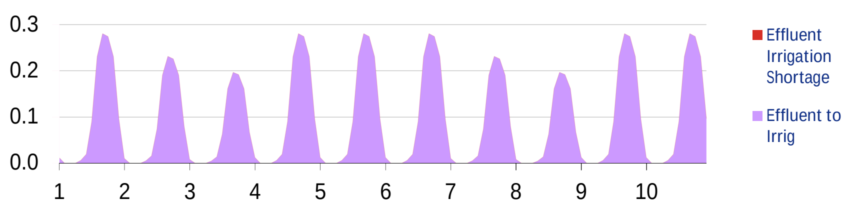
Potable System (mgd)



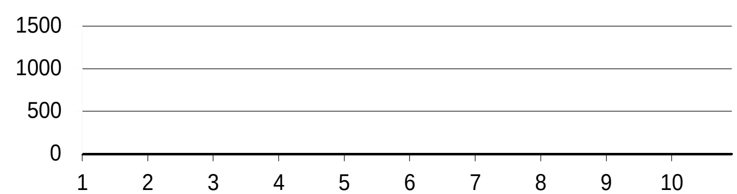
Raw Irrigation System (mgd)



Reg 84 System (mgd)



Chambers Reservoir (AF)



ACWWA Water Supply Operations Model

Table 6-3

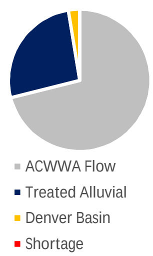
Model Version 0.87

Arapahoe County Water and Wastewater Authority

Water Supply Master Plan - 3 - Current Demand (AF 5.25, Chambers)

Key Inputs		Year	Type
Dry Year Demand		1	dry
ACWWA (AF/y)	4,673	2	avg
Lease (AF/y)	0	3	wet
Total	4,673	4	dry
ACWWA Flow		5	dry
Rate (MGD)	5.25	6	dry
Dry Year (AF/y)	3,100	7	avg
Schedule	Muni	8	wet
JWPP		9	dry
Rate (MGD)	2.00	10	dry
Denver Basin Wells			
Rate (gpm)	1,140		
Annual (AF/y)	1,600		
Chambers Reservoir			
Capacity (AF)	1,200		
Potable Mixing			
Goals On (y/n)	No		
System Loss			
Loss %	10%		
Dry Year Reuse Factor		1.61	

Avg Potable Mix



ANNUAL Potable Supply (AF/y)

Potable	Dry	Average	Wet
Demand	4,337	3,956	3,684
Supply			
ACWWA Flow	2,340	3,484	3,500
Treated Alluvial	1,733	472	184
Denver Basin	264	0	0
Total	4,337	3,956	3,684
Shortage	0	0	0
	0%	0%	0%

ANNUAL Non-Potable Irrigation Supply (AF/y)

Raw Alluvial	Dry	Average	Wet
Demand	220	181	154
Supply	220	181	154
Shortage	0	0	0
Reg 84	**Dry**	**Average**	**Wet**
Demand	116	96	82
Supply	116	96	82
Shortage	0	0	0

ANNUAL Total Supply (AF/y)

	Dry	Average	Wet
Total Demand	4,673	4,234	3,920
Total Supply	4,673	4,234	3,920
Shortage	0	0	0

PEAK DAY Potable Supplies (MGD)

Potable	Dry	Average	Wet
Demand	9.5	8.3	7.5
Supply			
ACWWA Flow	4.9	4.9	4.9
Treated Alluvial	2.0	2.0	2.0
Denver Basin	1.6	1.6	1.6
Total	8.6	8.6	8.6
Shortage	1.0	0.0	0.0
	10%	0%	0%

ANNUAL Lease to Others (AF/y)

Lease	Dry	Average	Wet
Demand	0	0	0
ACWWA Flow	0	0	0
Shortage	0	0	0

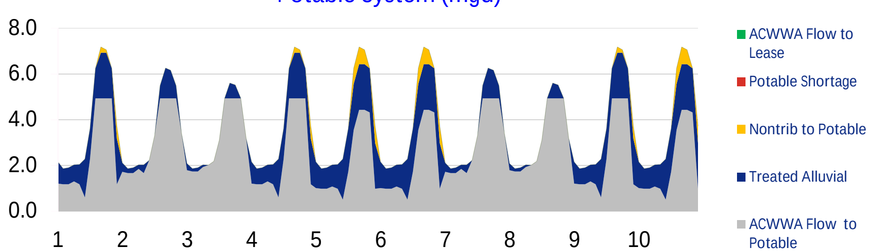
ANNUAL Augmentation Supply (AF/y)

Augmentation*	Dry	Average	Wet
Demand	1,723	974	707
Supply	1,993	2,036	3,189
Surplus	302	1,062	2,482

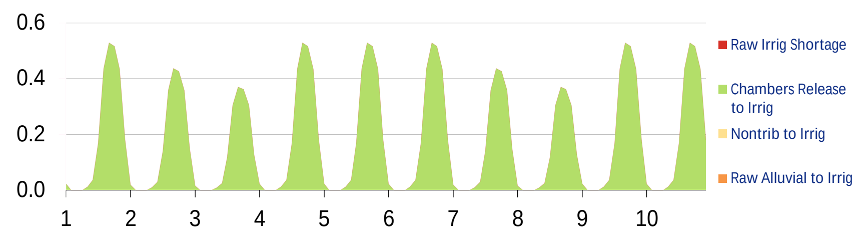
(1) In third consecutive dry year.

(2) Not including Chambers releases

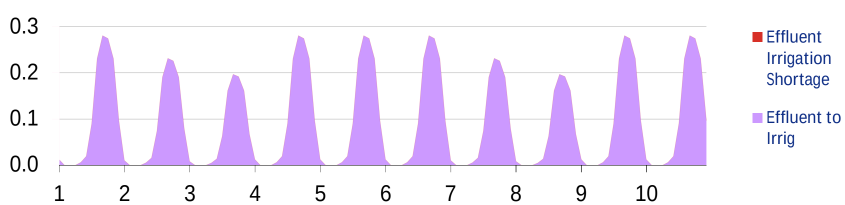
Potable System (mgd)



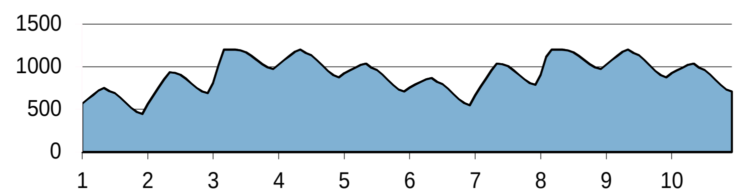
Raw Irrigation System (mgd)



Reg 84 System (mgd)



Chambers Reservoir (AF)



ACWWA Water Supply Operations Model

Table 6-4

Model Version 0.87

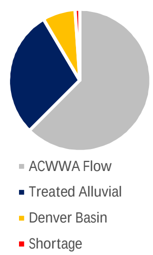
Arapahoe County Water and Wastewater Authority

Water Supply Master Plan - 4 - Buildout Demand

Key Inputs	
Dry Year Demand	
ACWWA (AF/y)	6,340
Lease (AF/y)	0
Total	6,340
ACWWA Flow	
Rate (MGD)	5.25
Dry Year (AF/y)	3,100
Schedule	Muni
JWPP	
Rate (MGD)	2.00
Denver Basin Wells	
Rate (gpm)	1,140
Annual (AF/y)	1,600
Chambers Reservoir	
Capacity (AF)	1,200
Potable Mixing	
Goals On (y/n)	No
System Loss	
Loss %	10%
Dry Year Reuse Factor	1.76

Year	Type
1	dry
2	avg
3	wet
4	dry
5	dry
6	dry
7	avg
8	wet
9	dry
10	dry

Avg Potable Mix



ANNUAL Potable Supply (AF/y)

Potable	Dry (1)	Average	Wet
Demand	5,109	4,783	4,550
Supply			
ACWWA Flow	2,340	3,806	3,918
Treated Alluvial	1,728	977	631
Denver Basin	870	0	0
Total	4,938	4,783	4,550
Shortage	171	0	0
	3%	0%	0%

ANNUAL Non-Potable Irrigation Supply (AF/y)

Raw Alluvial	Dry	Average	Wet
Demand	824	680	577
Supply	824	680	577
Shortage	0	0	0
Reg 84	**Dry**	**Average**	**Wet**
Demand	407	336	285
Supply	407	336	285
Shortage	0	0	0

ANNUAL Total Supply (AF/y)

	Dry	Average	Wet
Total Demand	6,340	5,798	5,412
Total Supply	6,169	5,798	5,412
Shortage	171	0	0

PEAK DAY Potable Supplies (MGD)

Potable	Dry	Average	Wet
Demand	9.8	8.8	8.0
Supply			
ACWWA Flow	4.9	4.9	4.9
Treated Alluvial	2.0	2.0	2.0
Denver Basin	1.6	1.6	1.6
Total	8.6	8.6	8.6
Shortage	1.3	0.2	0.0
	13%	2%	0%

ANNUAL Lease to Others (AF/y)

Lease	Dry	Average	Wet
Demand	0	0	0
ACWWA Flow	0	0	0
Shortage	0	0	0

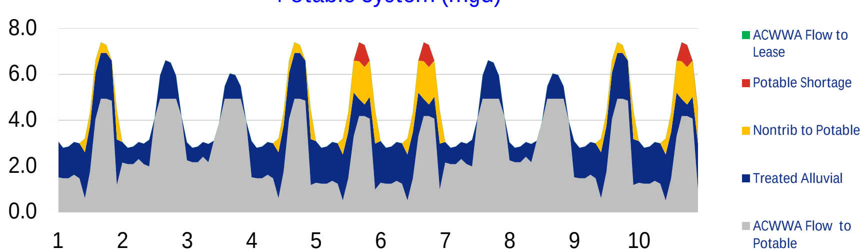
ANNUAL Augmentation Supply (AF/y)

Augmentation (2)	Dry	Average	Wet
Demand	2,342	1,701	1,845
Supply	2,631	2,702	3,873
Surplus	289	1,001	2,028

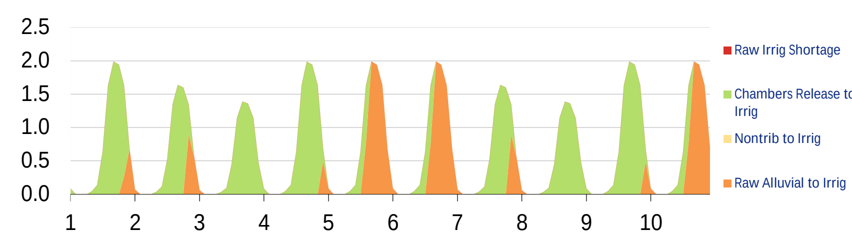
(1) In third consecutive dry year.

(2) Not including Chambers releases

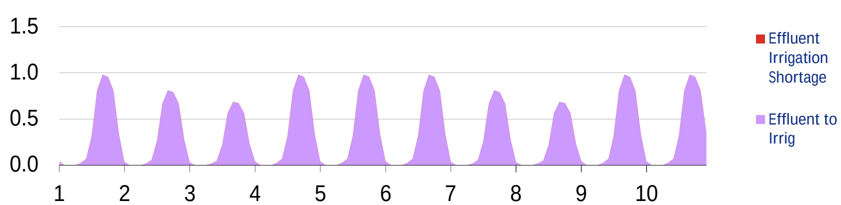
Potable System (mgd)



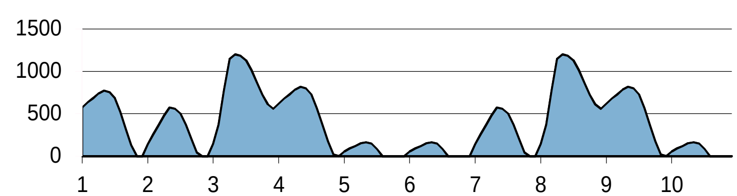
Raw Irrigation System (mgd)



Reg 84 System (mgd)



Chambers Reservoir (AF)



ACWWA Water Supply Operations Model

Table 6-5

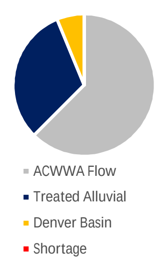
Arapahoe County Water and Wastewater Authority

Water Supply Master Plan - 5 - Buildout Demand (Chambers Inlet)

Key Inputs	
Dry Year Demand	
ACWWA (AF/y)	6,340
Lease (AF/y)	0
Total	6,340
ACWWA Flow	
Rate (MGD)	5.25
Dry Year (AF/y)	3,100
Schedule	Muni
JWPP	
Rate (MGD)	2.00
Denver Basin Wells	
Rate (gpm)	1,140
Annual (AF/y)	1,600
Chambers Reservoir	
Capacity (AF)	1,200
Potable Mixing	
Goals On (y/n)	No
System Loss	
Loss %	10%
Dry Year Reuse Factor	1.91

Year	Type
1	dry
2	avg
3	wet
4	dry
5	dry
6	dry
7	avg
8	wet
9	dry
10	dry

Avg Potable Mix



ANNUAL Potable Supply (AF/y)

Potable	Dry (1)	Average	Wet
Demand	5,109	4,783	4,550
Supply			
ACWWA Flow	2,340	3,806	3,918
Treated Alluvial	2,089	977	631
Denver Basin	680	0	0
Total	5,109	4,783	4,550
Shortage	0	0	0
	0%	0%	0%

ANNUAL Non-Potable Irrigation Supply (AF/y)

Raw Alluvial	Dry	Average	Wet
Demand	824	680	577
Supply	824	680	577
Shortage	0	0	0
Reg 84	**Dry**	**Average**	**Wet**
Demand	407	336	285
Supply	407	336	285
Shortage	0	0	0

ANNUAL Total Supply (AF/y)

Total Demand	6,340	5,798	5,412
Total Supply	6,340	5,798	5,412
Shortage	0	0	0

PEAK DAY Potable Supplies (MGD)

Potable	Dry	Average	Wet
Demand	9.8	8.8	8.0
Supply			
ACWWA Flow	4.9	4.9	4.9
Treated Alluvial	2.0	2.0	2.0
Denver Basin	1.6	1.6	1.6
Total	8.6	8.6	8.6
Shortage	1.3	0.2	0.0
	13%	2%	0%

ANNUAL Lease to Others (AF/y)

Lease	Dry	Average	Wet
Demand	0	0	0
ACWWA Flow	0	0	0
Shortage	0	0	0

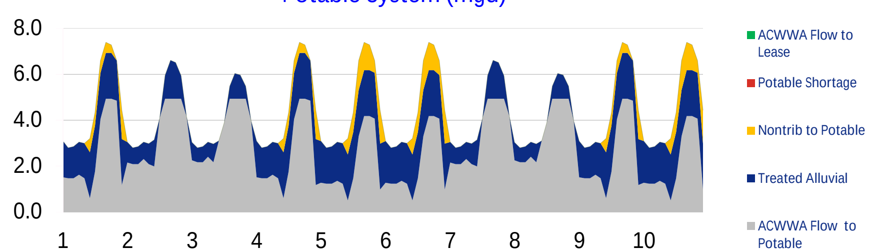
ANNUAL Augmentation Supply (AF/y)

Augmentation (2)	Dry	Average	Wet
Demand	2,631	2,661	1,301
Supply	2,631	2,702	3,873
Surplus	0	41	2,572

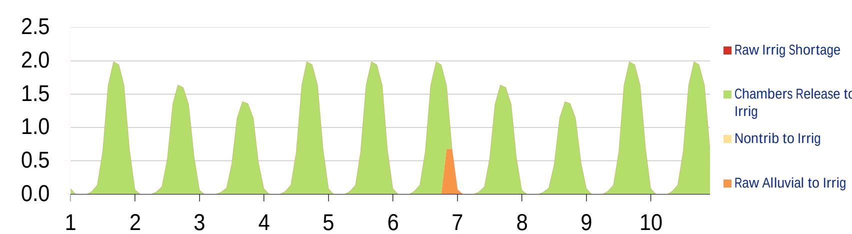
(1) In third consecutive dry year.

(2) Not including Chambers releases

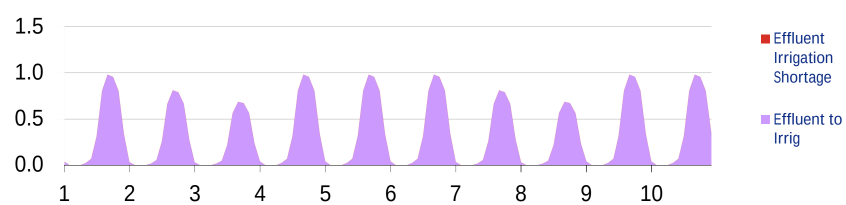
Potable System (mgd)



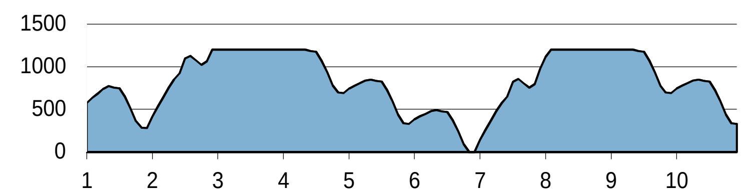
Raw Irrigation System (mgd)



Reg 84 System (mgd)



Chambers Reservoir (AF)



ACWWA Water Supply Operations Model

Table 6-6

Model Version 0.87

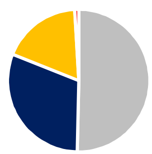
Arapahoe County Water and Wastewater Authority

Water Supply Master Plan - 6 - Buildout Demand (with inclusions)

Key Inputs	
Dry Year Demand	
ACWWA (AF/y)	7,533
Lease (AF/y)	0
Total	7,533
ACWWA Flow	
Rate (MGD)	5.25
Dry Year (AF/y)	3,100
Schedule	Muni
JWPP	
Rate (MGD)	2.00
Denver Basin Wells	
Rate (gpm)	1,440
Annual (AF/y)	1,600
Chambers Reservoir	
Capacity (AF)	1,200
Potable Mixing	
Goals On (y/n)	No
System Loss	
Loss %	10%
Dry Year Reuse Factor	1.75

Year	Type
1	dry
2	avg
3	wet
4	dry
5	dry
6	dry
7	avg
8	wet
9	dry
10	dry

Avg Potable Mix



ANNUAL Potable Supply (AF/y)

Potable	Dry (1)	Average	Wet
Demand	6,302	5,864	5,552
Supply			
ACWWA Flow	2,340	3,713	3,859
Treated Alluvial	2,240	1,505	1,302
Denver Basin	1,600	646	391
Total	6,180	5,864	5,552
Shortage	122	0	0
	2%	0%	0%

ANNUAL Non-Potable Irrigation Supply (AF/y)

Raw Alluvial	Dry	Average	Wet
Demand	824	680	577
Supply	824	680	577
Shortage	0	0	0
Reg 84	**Dry**	**Average**	**Wet**
Demand	407	336	285
Supply	407	336	285
Shortage	0	0	0

ANNUAL Total Supply (AF/y)

Total Demand	7,533	6,880	6,414
Total Supply	7,411	6,880	6,414
Shortage	122	0	0

PEAK DAY Potable Supplies (MGD)

Potable	Dry	Average	Wet
Demand	12.5	11.1	10.1
Supply			
ACWWA Flow	4.9	4.9	4.9
Treated Alluvial	2.0	2.0	2.0
Denver Basin	2.1	2.1	2.1
Total	9.0	9.0	9.0
Shortage	3.5	2.1	1.1
	28%	19%	11%

ANNUAL Lease to Others (AF/y)

Lease	Dry	Average	Wet
Demand	0	0	0
ACWWA Flow	0	0	0
Shortage	0	0	0

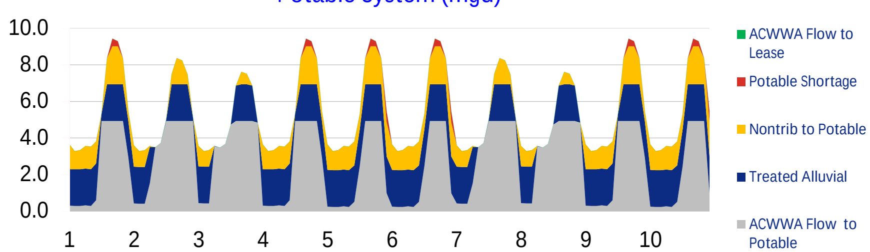
ANNUAL Augmentation Supply (AF/y)

Augmentation (2)	Dry	Average	Wet
Demand	3,155	2,802	1,972
Supply	3,155	3,207	4,363
Surplus	0	404	2,391

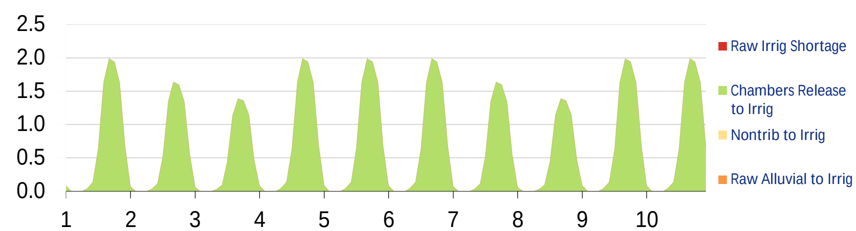
(1) In third consecutive dry year.

(2) Not including Chambers releases

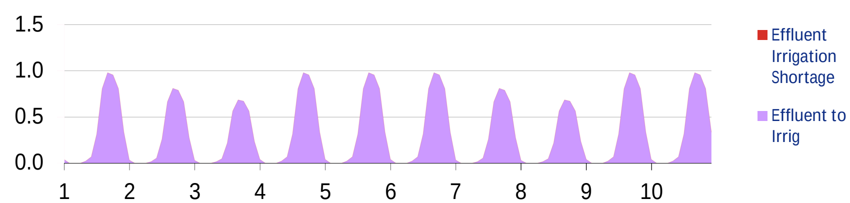
Potable System (mgd)



Raw Irrigation System (mgd)



Reg 84 System (mgd)



Chambers Reservoir (AF)

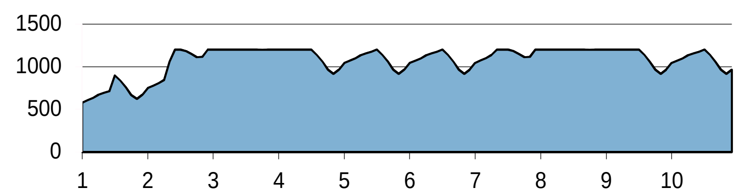


Table 6-7

Summary of Model Runs
ACWWA Water Supply Operations Model
Arapahoe County Water and Wastewater Authority

Scenario:	1	2	3	4	5	6
KEY INPUTS	Current Demand	Current Demand (AF 5.25)	Current Demand (AF 5.25; Chambers)	Buildout Demand	Buildout Demand (Chambers Inlet)	Buildout Demand (Inclusions)
Dry Year Demand						
ACWWA (AF/y)	4,673	4,673	4,673	6,340	6,340	7,533
Lease (AF/y)	0	0	0	0	0	0
ACWWA Flow						
Rate (MGD)	2.25	5.25	5.25	5.25	5.25	5.25
JWPP						
Rate (MGD)	2	2	2	2	2	2
Concentrate (%)	5%	5%	5%	18%	18%	18%
Denver Basin Wells						
Rate (gpm)	1,140	1,140	1,140	1,140	1,140	1,140
Annual (AF/y)	1,600	1,600	1,600	1,600	1,600	1,600
Chambers Reservoir						
Capacity (AF)	0	0	1,200	1,200	1,200	1,200
Inflow Pipeline (y/n)	no	no	no	no	yes	yes

KEY RESULTS	1		2		3		4		5		6	
Dry Year Demand and Supply (AF)												
Potable Demand	4,337		4,337		4,337		5,109		5,109		6,302	
Potable Supply												
ACWWA Flow	2,282	58%	2,340	54%	2,340	54%	2,340	47%	2,340	46%	2,340	38%
Treated Alluvial	1,011	26%	1,600	37%	1,733	40%	1,728	35%	2,089	41%	2,240	36%
Denver Basin	615	16%	397	9%	264	6%	870	18%	680	13%	1,600	26%
Total	3,908		4,337		4,337		4,938		5,109		6,180	
Potable Shortage	(429)	10%	0		0		(171)	3%	0	0%	(122)	2%
Peak Day Demand and Supply												
Potable Demand	9.5		9.5		9.5		9.8		9.8		12.5	
Potable Supply												
ACWWA Flow	2.1	36%	4.9	57%	4.9	57%	4.9	59%	4.9	57%	4.9	54%
Treated Alluvial	2.0	34%	2.0	23%	2.0	23%	2.0	24%	2.0	23%	2.0	22%
Denver Basin	1.6	28%	1.6	19%	1.6	19%	1.6	19%	1.6	19%	2.1	23%
Total	5.8		8.6		8.6		8.3		8.6		9.0	
Potable Shortage	(3.7)	39%	(0.9)	9%	(0.9)	9%	(1.5)	15%	(1.2)	12%	(3.5)	28%
Reuse Factor	1.33		1.54		1.61		1.76		1.91		1.76	

7.0 FACTORS THAT AFFECT ACWWA'S WATER SUPPLY

There are several factors that have the potential to affect ACWWA's long term water supplies, and these include declining Denver Basin ground water levels, low flows in Cherry Creek during drought periods, and increased water quality regulations. The potential effects of these factors on ACWWA's water supply are discussed below.

7.1 Declining Denver Basin Ground Water Levels

As described in Section 4.1, ACWWA's Denver Basin ground water supply is considered a non-renewable supply that is mined through use of ACWWA's Denver Basin wells. The Arapahoe aquifer is the most prolific of the Denver Basin aquifers and is source of most of the existing high-capacity Denver Basin wells in Arapahoe and Douglas Counties, including wells that ACWWA uses.

Much of the residential and commercial development in Arapahoe and Douglas Counties during the past 50 years has been supplied by wells in the Arapahoe aquifer, and this has resulted in substantial declines in ground water levels and well pumping capacities. Figure 7-1 shows the historical ground water level declines in one of ACWWA's well (Well A-2) and the projected decline in ground water levels in the Arapahoe aquifer that were simulated from 2004 – 2053 in a 2011 modeling effort by the U.S. Geological Survey. The rate of decline in ground water levels has slowed in recent years due to the loss of confining conditions in portions of the aquifer and as many water users including ACWWA, have or are developing renewable water sources to at least partially replace their Denver Basin ground water supplies. Nonetheless, the map in Figure 7-1 shows projected additional Arapahoe aquifer ground water level declines of 50 to 100 feet over the next 30 – 40 years.

As the ground water levels continue to decline, additional wells will need to be constructed to maintain current production rate and volumes. Future mining of the Arapahoe aquifer will likely cause well yields to decline to a level that is hydraulically and economically unsustainable.

Because of the likely long-term unsustainable nature of the Denver Basin aquifers and the increased development of renewable water supplies, many water users are treating their Denver Basin sources as a drought supply to draw on primarily in dry years when the yields of surface water and tributary ground water sources may be limited. This conjunctive use of nonrenewal Denver Basin ground water and renewable water sources should extend the usable life of the Denver Basin ground water supplies.

7.2 Low Cherry Creek Flows

ACWWA and CWSD are presently working to reconfigure the JWPP as a hybrid reverse-osmosis and micro-filtration water treatment plant with a total combined treated water capacity of 3 .0 MGD (4.65 cfs). A combination of ACWWA and CWSD alluvial wells will provide the raw water supply for treatment at the JWPP. In addition, ACWWA, CWSD, and others pump Cherry Creek alluvial ground water for non-potable irrigation use. The production capacity of these Cherry Creek alluvial wells is dependent on surface water flows and ground water underflow from upstream to periodically recharge the alluvial aquifer.

Cherry Creek occasionally dries up in places within the Cherry Creek Service Area due to a combination of low flows into the reach and substantial alluvial ground water use. The low flow periods are more prolonged during dry years when the inflows are low and the pumping is high.

Because of potential future increases in upstream alluvial ground water use and reuse of treated effluent, there are concerns about the adequacy of the Cherry alluvial aquifer to dependably sustain the pumping of the ACWWA and CWSD alluvial wells that will supply the JWPP. As a result of these concerns, a preliminary analysis was performed to estimate the frequency and duration of low flow periods on Cherry Creek in the reach of Cherry Creek containing the alluvial wells that will supply the JWPP. The analysis is described in a December 2, 2016 SWE memorandum that is attached to this report as Appendix A.

The results of the 2016 Cherry Creek flow analysis are summarized in Table 7-1 (Table 4a from the 2016 memorandum) which shows the average frequency of occurrence of various low flows for periods ranging from 1 week to 24 weeks. For example, there is a 54 percent chance that the lowest 12-week average flow (yellow line) will not exceed 1.0 MGD in any particular year, and a 16 percent chance the lowest 24-week average flow (green line) will not exceed this amount.

When the inflows to the reach are less than the pumping, the surface flow will dry up and the local alluvial ground water storage will be depleted to sustain the alluvial well production. If this situation is prolonged, at some point the alluvial ground water storage will become depleted to the extent that the alluvial well pumping capacities will decline.

A preliminary analysis of capability of the JWPP alluvial wells to pump when Cherry Creek is dry was performed by HRS Water Consultants (CWSD consultant) using analytical wellfield techniques. This analysis indicated that the alluvial aquifer could sustain a pumping rate of 3.0 MGD for approximately 45 days before a material loss of yield would occur.

Based on the results of the preliminary analyses described above, concerns about the ability of the alluvial wells to pump at a continuous rate of 3.0 MGD to supply the JWPP during a prolonged dry period are justified and warrant further analysis. It is recommended that an analysis be performed using the alluvial ground water model that was developed as a part of the Cherry Creek Aquifer Modeling Project "(CCAMP") to simulate operation of the JWPP alluvial wells during low Cherry Creek flows.

There are several alternatives to mitigate the effect of substantive reductions in the pumping capacity of the JWPP alluvial wells during low flow conditions, including the following:

- Increase use of other water sources (ACWWA Flow and Denver Basin ground water)
- Construct a reclaimed effluent return pipeline to discharge reclaimed effluent upstream of the dry reach during low flow conditions.
- Take delivery of water from upstream water sources such as CCPWA supply.
- Implement watering restrictions or other demand reduction actions.

7.3 Water Supply Risks and Uncertainties

ACWWA should continue to be vigilant in planning for risks and uncertainties associated with operating a large and complex water supply system. This risks and uncertainties include, but are not limited to the following:

- Physical and Legal Water Availability – Dry years and increased water use by upstream water users have the potential to affect ACWWA's alluvial ground water supply.
- Power Outages - ACWWA should maintain backup power supplies so that it can continue operating during power outages.
- Facility Failures – A planning policy of assuming the largest well is out of service will help ensure adequate pumping capacity is available to meet peak demands.
- Toxic Spills – Spills of gasoline or other toxic waste in the vicinity of the Cherry Creek or Beebe Draw alluvial aquifers would have the potential to impact ACWWA's alluvial ground water supply.
- Increased Regulations – Increased water quality regulations have the potential to increase treatment costs or potentially render certain supplies unusable.

7.4 Reuse Efficiency

As illustrated in Section 4.4, direct and indirect reuse are effective mechanisms for ACWWA to leverage its reusable water sources into larger water supply volumes. The potential extent of ACWWA's reuse depends on the unmeasured system losses, the amount of lawn irrigation and treated effluent return flows, and the reuse efficiency.

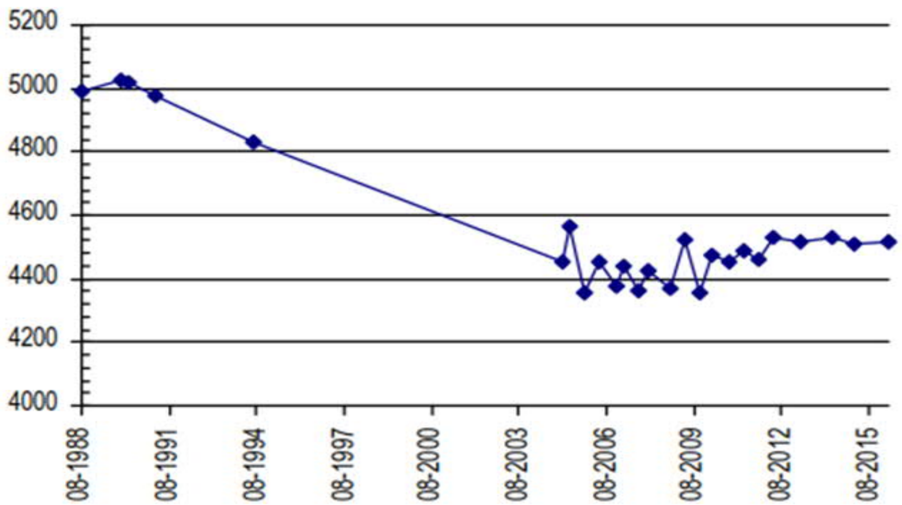
In order to maximize the reuse efficiency, ACWWA should bring into the system the minimum amount of reusable water that allows it to meet its demands from these sources combined with the concurrent reuse of return flows. Stated another way, maximizing reuse use means to minimize the amount of return flows that are not reused. For example, during the winter months when ACWWA is returning roughly 90 percent of its water use to the stream through WWTP discharges, it only needs to produce 10 percent of its water supply from reusable sources (e.g., ACWWA Flow) and the remainder of the supply can come through reuse through alluvial pumping that is augmented by the treated effluent discharges. Maximizing reuse efficiency requires vigilant operation of the system to respond to changing supply and demand conditions.

As a part of each of the model runs described in Section 6, a dry year reuse factor was computed for each model run by dividing the total water supply (potable + raw alluvial irrigation + direct irrigation reuse) by the total reusable supply (ACWWA Flow deliveries, Denver Basin well pumping, and senior consumptive use credits). The resulting dry year reuse factors ranged from 1.33 for Scenario 1 to 1.91 for Scenario 5.

Figure 7-1

Long -Term Viability of ACWWA's
Denver Basin Ground Water Supply

Historical Ground Water Level
ACWWA Well A-2 (Arapahoe Aquifer)
(1988 - 2016)



Sources:
Colorado Division of Water Resources (CDWR, 2016)
U.S. Geological Survey (Paschke, 2011)

USGS Simulated Ground Water Level Decline
Arapahoe Aquifer
(2004 - 2053)

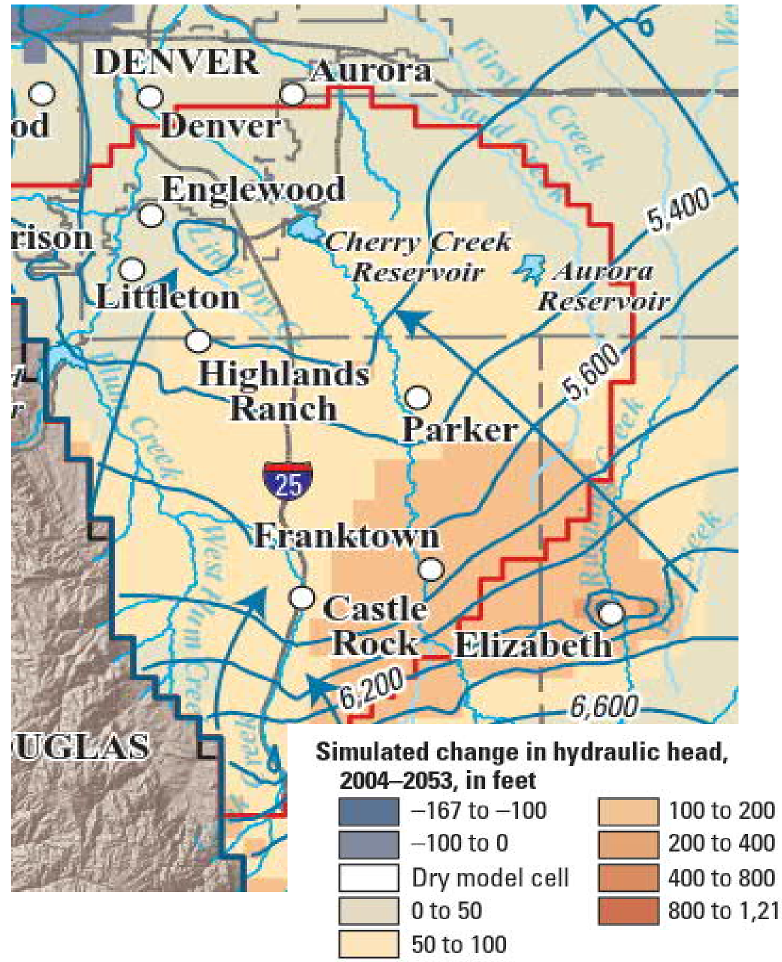
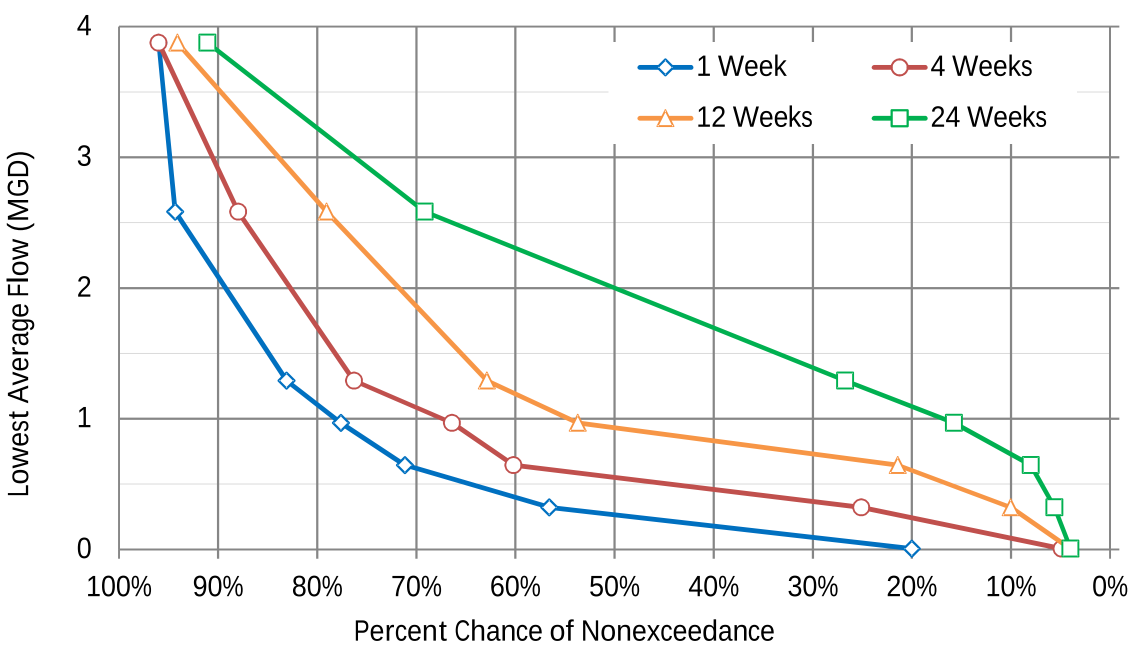


Table 7-1

Annual Low Flow Frequencies (1992-2015)
Cherry Creek at Parker Gage (Adjusted) (1)
(MGD)

(2) Lowest Avg Flow (MGD)	Annual % Chance of Nonexceedance for Weekly Periods (3)								
	1	2	3	4	8	12	16	20	24
0.0	20%	9%	6%	5%	4%	4%	4%	4%	4%
0.3	57%	48%	33%	25%	14%	10%	9%	7%	6%
0.6	71%	65%	64%	60%	39%	21%	18%	13%	8%
1.0	78%	74%	67%	66%	64%	54%	29%	21%	16%
1.3	83%	77%	77%	76%	68%	63%	53%	39%	27%
2.6	94%	94%	92%	88%	83%	79%	73%	72%	69%
3.9	96%	96%	96%	96%	96%	94%	94%	93%	91%



Notes:

(1) The adjusted Cherry Creek flow was computed as the daily flow at the Cherry Creek at Parker gage (USGS) minus the daily Parker WWTP discharge to Sulphur Gulch minus estimated free river diversions to RHR prior to March 2010.
Daily Parker WWTP discharges for 1992 - 1996 were estimated as average 1997 flow.

(2) The above values represent the percent chance that in any year the lowest average flow for weekly periods of varying duration will not exceed a specified flow in MGD.
For example, there is a 21% chance that the average 12-week low flow will not exceed 0.6 MGD.

(3) Annual probabilities are based on a climatic year from April 1 - March 31.

8.0 ELKHORN RANCH WATER SYSTEM

ACWWA operates a separate municipal water system that provides potable water to the Elkhorn Ranch subdivision in Elbert County. There are 250 single family residential lots in the subdivision of which approximately 80 percent have been developed and are being supplied water. Water supply is currently provided from two Denver Basin wells and a third well is planned to be drilled in 2019. This section provides an overview of the current and projected future Elkhorn water requirements and the current and future water supplies that will meet those requirements.

8.1 Water Requirements

Elkhorn Ranch pumping records and billing records were compiled by ACWWA staff for 2012 – 2018. The Elkhorn Ranch water supply was provided by a single Arapahoe aquifer well until the summer of 2018 when a Denver aquifer well was drilled and put into production. Total monthly pumping volumes from 2012 – 2018 are summarized in the upper table in Table 8-1. Annual pumping ranged from 55 acre-feet in 2014 to 93 acre-feet in 2018.

The billing records consist of monthly billed water use for each residential account. A summary of the total monthly billed water use data is provided in the middle table in Table 8-1. Annual billed water use ranged from 41 AF in 2014 to 77 AF in 2018. Note that watering restrictions limiting the number of days of outdoor water use were in place during portions of 2016 – 2018. The annual billed water deliveries averaged 17 percent less than the annual pumping, and therefore an average system loss of 20 percent was assumed for the Elkhorn Ranch service area for planning purposes.

The lower table in Table 8-1 shows the computed monthly average billed water use per household. To eliminate the influence of accounts that were activated in the middle of the year, the water use per account was computed for accounts with at least nine months of billed water usage in the year. Annual water use per household averaged 129,000 gallons, and ranged from 115,000 gallons in 2014 to 155,000 gallons in 2012. This equates to a daily average use of 355 gpd for each account, ranging from 315 gpd to 426 gpd.

The planning water requirement at buildout for Elkhorn Ranch was estimated by multiplying the total 250 residential lots by the maximum annual historical water use of 155,000 gallons per household resulting in an annual buildout demand of 38.8 million gallons or 119 AF. The annual buildout demand was increased to account for the estimated 20 percent system loss resulting in an estimated annual pumping requirement at buildout of 149 AF (119 AF / 0.8). This equates to a daily average pumping requirement at buildout of 0.133 MGD.

Peak day pumping requirements for the Elkhorn Ranch service area were estimated based on analysis of the weekly pumping records during 2012 – 2018. A graph showing the weekly pumping for each year is provided in Figure 8-1. For each year, the average weekly pumping and peak week pumping were tabulated as shown in the table at the bottom of Figure 8-1. The peak week / average factor ranged from 2.06 in 2012 to 2.41 in 2016.

The peak day / average factor was estimated by multiplying the peak week / average factor by 1.3. This multiplier is greater than the 1.2 multiplier used for the Cherry Creek service area to account for the greater variability in demand that would be expected in a population with much fewer accounts. The resulting maximum peak day demand factor is approximately 3.1. This factor was multiplied by the estimated average planning pumping requirement of 0.133 MGD to compute a peak day pumping demand of 0.412 MGD at buildout of the Elkhorn Ranch service area.

The current peak day pumping requirement was estimated by scaling the peak day demand at buildout by 0.8 (200 developed parcels / 250 total parcels) resulting in a current peak day demand of 0.329 MGD

8.2 Water Supply

As described above, the Elkhorn Ranch water supply is currently provided from two Denver Basin wells, and a third well is planned to be constructed in 2019. A summary of the actual and estimated capacities for these wells is shown below.

Denver Basin Well Capacities
Elkhorn Ranch

Well	Capacity (gpm)
Elkhorn Arapahoe	130
Elkhorn Denver	20
Elkhorn Arapahoe 2 (proposed)	130
Total	280

The current peak day pumping requirement of 0.329 MGD equates a pumping rate of 230 gpm which is 50 gpm less the estimated pumping capacity that will exist after the second Arapahoe aquifer well is drilled in 2019. If the largest well is out of service, then the pumping capacity would be 150 gpm which is 80 gpm less than the estimated current peak day demand.

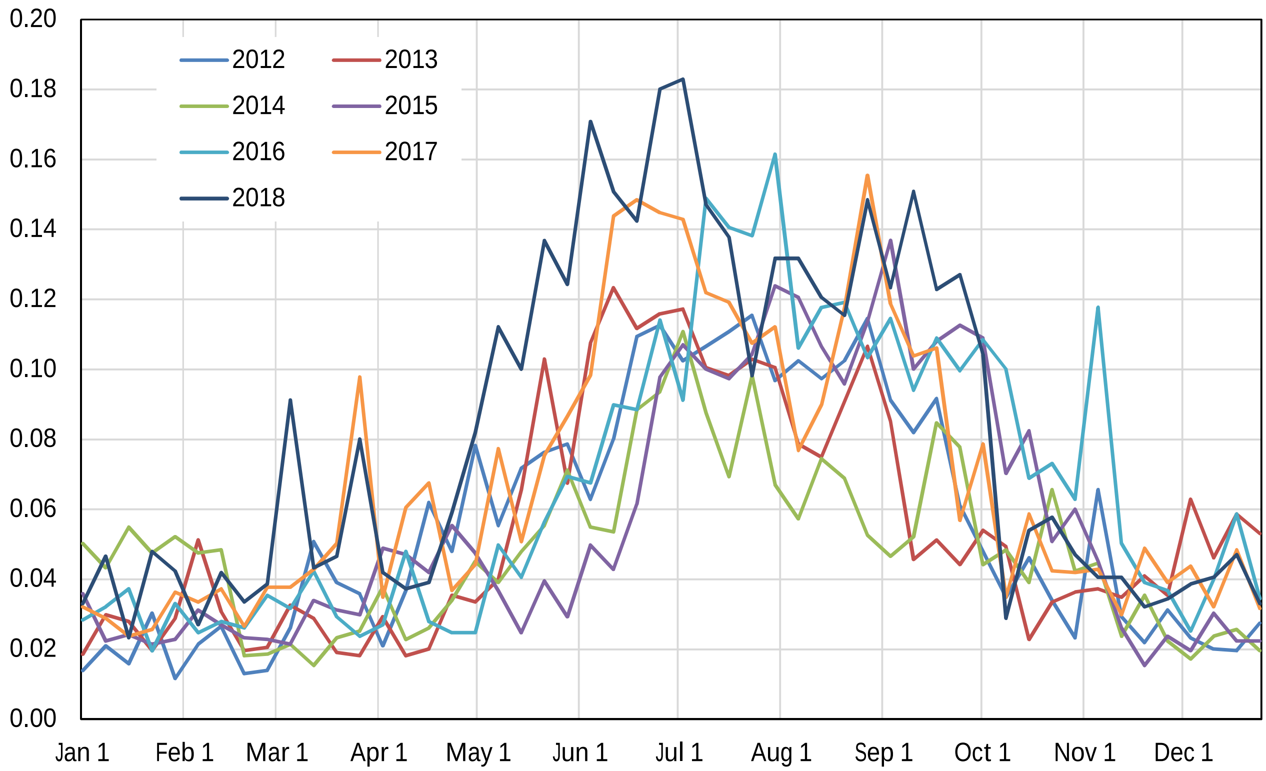
The peak day demand at buildout of 0.412 MGD equates to a pumping rate of approximately 290 gpm which is close to the 280 gpm pumping capacity with the new Arapahoe aquifer well. The pumping capacity with the largest well out of service (150 gpm) will be 140 gpm less than the peak day demand at buildout.

In order to meet the current peak pumping demand with the largest well out of service, another Arapahoe aquifer well (130 gpm) would need to be constructed. This additional well would be approximately sufficient for ACWWA to meet the peak demand at buildout (280 gpm supply vs 290 gpm peak day demand).

It will be necessary to construct additional Denver Basin wells in the future if the water levels in the Denver Basin aquifers decline to the extent that well yields are affected. There currently are no plans to develop a renewable water supply for the Elkhorn Ranch. However, a pipeline to deliver renewable water from the Cherry Creek service area could be constructed if necessary.

Figure 8-1

Weekly Pumping
Elkhorn Ranch Service Area
(2012-2018)
(MGD)



	2012	2013	2014	2015	2016	2017	2018
(1) Annual Summaries							
Average (MGD)	0.056	0.055	0.049	0.057	0.067	0.069	0.083
Peak Week (MGD)	0.115	0.123	0.111	0.137	0.162	0.155	0.183
Peak Week/ Avg	2.06	2.23	2.27	2.39	2.41	2.26	2.21
(2) Est. Peak Day (MGD)	0.150	0.160	0.144	0.178	0.210	0.202	0.238
(2) Est. Peak Day / Avg	2.68	2.90	2.95	3.11	3.14	2.93	2.87

Notes:

(1) Includes potable supplies only (Elkhorn Arapahoe and Denver wells)

(2) Peak week x 1.3 peak day/week factor.

Table 8-1

Monthly Pumping and Billed Water Deliveries
Elkhorn Ranch Service Area
(2012 - 2018)

(1) Monthly Pumping Volumes (acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2012	1.9	1.6	3.3	3.8	6.8	7.6	10.0	7.6	10.2	3.7	3.5	2.2	62.2
2013	2.3	2.7	2.4	2.4	6.0	10.3	9.9	8.4	6.2	3.7	3.3	5.8	63.5
2014	4.7	3.1	2.1	2.9	4.9	6.8	8.3	5.7	6.6	4.2	3.0	2.2	54.5
2015	2.3	2.2	2.9	4.4	3.2	6.1	10.0	10.1	10.8	6.6	2.7	2.3	63.8
2016	3.0	2.5	3.0	2.9	4.8	8.6	13.8	9.6	10.3	7.6	6.0	3.7	75.6
2017	2.8	2.8	3.8	6.0	6.0	11.5	11.9	10.0	9.8	5.0	3.7	3.6	76.8
2018	3.7	3.1	5.7	4.3	10.2	14.5	13.7	11.9	12.5	5.9	3.6	3.7	92.8
Average	3.0	2.6	3.3	3.8	6.0	9.3	11.1	9.1	9.5	5.2	3.7	3.4	69.9

(2) Monthly Billed Deliveries (acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	% Pump
2012	1.7	1.3	1.5	3.9	5.0	7.6	9.7	8.4	9.4	3.4	1.7	1.6	55.3	89%
2013	1.9	1.4	1.4	1.7	3.1	9.5	8.8	6.4	6.6	2.8	1.7	1.4	46.7	74%
2014	1.5	1.6	1.4	1.8	3.0	7.1	5.7	7.1	3.7	4.3	2.8	1.3	41.2	76%
2015	1.9	1.4	1.9	2.4	2.4	3.7	7.9	9.4	9.6	7.6	2.1	2.0	52.3	82%
2016	2.4	1.7	2.0	2.9	3.3	6.8	12.6	11.8	7.1	8.9	4.9	2.3	66.7	88%
2017	2.8	2.7	3.3	4.1	3.9	11.2	11.5	7.9	10.7	4.5	3.0	2.5	68.1	89%
2018	3.4	2.2	2.4	3.1	6.4	12.9	12.1	10.5	12.1	6.1	3.3	2.7	77.2	83%
Average	2.2	1.8	2.0	2.8	3.9	8.4	9.8	8.8	8.4	5.4	2.8	2.0	58.2	
% Pump	75%	69%	60%	74%	65%	90%	88%	97%	89%	102%	75%	59%	83%	

(3) Monthly Water Use Per Household (1,000 gallons)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Annual (gpd)	(4) No. Accts
2012	5	4	5	11	15	22	26	23	26	9	5	5	155	426	111
2013	6	4	4	5	9	27	25	18	19	8	5	4	134	367	113
2014	4	4	4	5	8	20	16	20	10	12	8	4	115	315	115
2015	5	3	5	6	6	9	19	23	23	18	5	4	126	346	129
2016	5	4	4	6	7	14	25	21	14	16	9	4	127	348	160
2017	5	5	6	7	7	20	20	14	18	8	5	4	118	324	186
2018	6	4	4	5	11	22	21	17	20	10	5	4	130	355	190
Averag	5	4	4	7	9	19	22	19	19	12	6	4	129	355	

Notes:
(1) Reported weekly pumping volumes accumulated to monthly totals (weeks spanning 2 months prorated by no. days in each month).
(2) Monthly billed water deliveries to all accounts.
(3) Monthly average water use for households with at least 9 months of billed water usage.
(4) No. of accounts with at least 9 months of billed water usage.

9.0 CONCLUSIONS AND RECOMMENDATIONS

In preparing this Raw Water Master Plan a thorough analysis of ACWWA's water requirements and water supplies was completed in close cooperation with ACWWA's staff and consultants. The result of this work is an improved understanding of the adequacy of ACWWA's current water supplies and the necessary improvements to meet ACWWA's current and projected future water demands. A summary of the major conclusions and recommendations from this planning effort follow.

9.1 Water Requirements

Analysis of ACWWA's water use records shows that approximately 55 percent of ACWWA's current water use is for indoor purposes while 45 percent is used outdoors, primarily for irrigation. Most of the annual variation in ACWWA's water use is due to irrigation water usage that increases in hot and dry years and decreases in cool wet years. For planning purposes, ACWWA's dry year water requirements were estimated based on an irrigation application rate of 4.0 feet per year, which is approximately the highest irrigation application rate indicated in ACWWA's water usage records over the past 20 years. Indoor water requirements were projected based on the current and projected future residential, commercial, office, and industrial/warehouse land uses and water usage rates derived from ACWWA's water use data and industry standard planning figures.

The following is a summary of the projected current and future demands for the current Cherry Creek Service Area and the additional demands for nearby areas that potentially may be served by ACWWA in the future. The table shows the dry year demand, the dry year water supply requirement assuming a 10 percent system loss, and the peak day potable water requirements.

Summary of Annual and Peak Day Water Needs

Service Area	Dry Year Water Demand (AF/y)	Dry Year Water Requirement (AF/y)	Peak Day Potable Supply (MGD)
CC Service Area (Current Development)	4,205	4,672	9.5
CC Service Area (Future Development)	1,501	1,667	--
Buildout of Current CC Service Area	5,706	6,340	9.8
Service to Nearby Inclusions	1,074	1,193	2.7
Buildout of Enlarged CC Service Area	6,780	7,533	12.5
Service to Prosper Development	2,978	2,978	5.8
Total Potential Buildout	9,758	10,511	18.3

9.2 Water Supply Adequacy

The adequacy of ACWWA's water supplies to meet current and projected future water requirements was analyzed using the ACWWA Water Supply Operations Model. This analysis showed that the current supplies and facilities are insufficient to meet the current dry year planning demand of 4,672 AF/y (with 10% system loss) with a projected annual shortage of 430 AF/y and a peak day potable supply shortage of 3.8 MGD.

The projected shortage in meeting the dry year water demand will be largely eliminated by completion of the expansion of the NWTP and the enlargement of the Northern Pipeline, both of which will increase the delivery capacity of the ACWWA Flow Project supply from 2.25 MGD to 5.25 MGD. While this will eliminate the annual water supply shortage, there will remain a peak day potable water shortage of approximately 1.0 MGD (10%).

The increased capacity of the NWTP and Northern Pipeline will also allow ACWWA to meet most of the dry year planning demand 6,340 AF/y (with 10% system loss) at buildout with a projected annual shortage of 171 AF/y (3%), and peak day potable water shortage of 1.3 MGD (13%). These modest shortages at buildout can be eliminated by construction of a separate inflow pipeline to Chambers Reservoir which would allow the reservoir to be filled year-around rather than only during the November-March non-irrigation season. This allows ACWWA to operate more efficiently by capturing excess return flows during the irrigation season for subsequent reuse.

ACWWA's buildout water requirements could potentially increase by almost 1,200 AF/y through water service provided to nearby areas that potentially could seek inclusion in the Cherry Creek Service Area. The resulting increased dry year water requirement of 7,533 AF/y (with 10% system loss) could be largely met through increased use of Denver Basin groundwater with a projected annual shortage of 122 AF/y. While the projected annual water shortage is only 122 AF/y (2%), the projected shortage in the peak day potable supply is 3.5 MGD (28%).

9.3 Operation of Potable Water System

There are three water sources presently available to meet ACWWA's potable water demands; ACWWA Flow Project deliveries, Denver Basin groundwater, and treated alluvial ground water. Deliveries from the ACWWA Flow Project are limited by the yield of the South Platte River water rights that supply the project, operation of the infrastructure, exchanges and augmentation plan that facilitate the project water deliveries, and by the terms of the ACWWA-United contract. Use of Denver Basin ground water is limited by ACWWA's decreed annual entitlements and by the capacity of the Denver Basin wells. Use of treated alluvial ground water is limited by the available augmentation supplies, the treatment capacity of the JWPP, and the ground water supply in the Cherry Creek alluvial aquifer.

There is some flexibility in the use of the three potable sources depending on ACWWA water supply objectives. The following are several potential operating schemes:

- <u>Maximize ACWWA Flow Project Deliveries</u> – ACWWA Flow Project deliveries are maximized when by delivering water to ACWWA at the maximum 5.25 MGD rate. During the winter, this results in unused return flows that can be stored in Chambers Reservoir to meet subsequent nonpotable irrigation demands.

- <u>Maximize JWPP Operation</u> – Operation of the JWPP to deliver treated alluvial ground water is maximized by treating this as the primary supply that is supplemented by ACWWA Flow deliveries and Denver Basin ground water and by managing the augmentation supplies so that there are sufficient replacement supplies to augment the out-of-priority depletions from pumping.

- <u>Minimize Denver Basin Ground Water Use</u> – ACWWA can minimize use of its nonrenewable Denver Basin ground water supplies by managing its use of the ACWWA Flow and treated alluvial ground water supplies to meet all or most of its potable water demands. Some use of Denver Basin ground water is necessary in dry years when yields from the other supplies are limited.

It is recommended that a projection system be developed to help guide the operation of ACWWA's potable water system. The projection system would include estimates of ACWWA's potable water demands and the supplies projected to be available to meet these demands.

9.4 Operation of Nonpotable Water System

There is limited flexibility in the operation of ACWWA's two nonpotable water systems that are supplied by treated effluent and untreated alluvial ground water. ACWWA staff need to ensure that there are sufficient supplies available to meet these nonpotable irrigation demands. In addition, the operation of the nonpotable irrigation systems has a direct effect on the replacement supply that is available to augment the alluvial wells that supply the JWPP. Demand management and conservation in operation of the nonpotable irrigation system can free up additional replacement supplies for alluvial well pumping to the JWPP.

9.5 Future Water Supply Development

Following completion of the NWTP expansion and Northern Pipeline enlargement, putting the JWPP back in operation, and completing the repairs to Chambers Reservoir, ACWWA will generally have sufficient water supplies to meet the estimated water requirements for buildout of the Cherry Creek Service Area. Construction of additional Denver Basin wells may be needed to meet the additional demands for nearby developments that may be included in the Cherry Creek Service Area.

9.6 Leases to Others

A preliminary analysis was completed using the Operations Model to assess whether ACWWA has sufficient water supplies to lease a portion of its ACWWA Flow supply to other users in Arapahoe County such as the proposed Prosper Development. The preliminary results showed that ACWWA would need to make additional improvements to its system such as drilling additional Denver Basin wells, developing its interest in the CCPWA supply or acquiring other fully consumable water supplies, and increasing the water treatment capacity at the JWPP in order to lease significant quantities to others. Additional analysis is recommended if ACWWA wants to further investigate its water leasing options.

9.7 Denver Basin Ground Water and ASR

Full development of the ACWWA Flow Project and increased reuse capabilities will reduce ACWWA's reliance on Denver Basin ground water. However, the simulated water supply simulations at buildout show that ACWWA will need to pump Denver Basin ground water to meet potable water demands in dry years when deliveries from the ACWWA Flow Project are limited. Additional Denver Basin ground water use will be necessary, including use in average and wet years, if nearby areas are included in ACWWA for water service or water is leased to others.

Because of the necessary continued limited reliance on Denver Basin ground water, ACWWA should continue to monitor Denver Basin ground water levels and the potential effect on the yields of ACWWA's Denver Basin wells. At some point in the future it may be necessary to construct additional Denver Basin wells to maintain sufficient pumping capacity to deliver the amounts necessary to meet ACWWA's potable water requirements.

ACWWA should monitor the efforts of other local water providers to implement ASR. After the process for permitting and implementing ASR has further matured, ACWWA should implement ASR at moderate level to bank water in the Arapahoe aquifer as a redundant drought year supply and for use during potential interruption of deliveries from its other water supplies Ie.g., deliveries of treated water from ACWWA Flow Project or the JWPP).

9.8 Continued Participation in UCCWA

ACWWA's participation in UCCWA provides more operating flexibility than would exist if ACWWA were operating its stand-along augmentation plan, and therefore ACWWA should continue its participation in UCWWA.

9.9 Monitoring Activities of Upstream Water Users

ACWWA's alluvial ground water use to supply water for treatment at the JWPP and to deliver water for nonpotable irrigation use depends on an adequate physical water supply in the Cherry Creek alluvial aquifer. The alluvial aquifer supply in turn depends on sufficient surface inflow from upstream to recharge the aquifer. ACWWA needs to continue to be vigilant in monitoring the activities of upstream water users and oppose actions that threaten the available aquifer recharge supply.

9.10 Use of Water Supply Yield Model

The ACWWA Water Supply Operations Model is a useful tool for evaluating how changes in water demands and water supplies affect ACWWA's water supply adequacy. The model is also useful in analyzing and comparing different operating procedures. ACWWA should continue to use and improve the model as a part of its raw water supply planning efforts.

9.11 Elkhorn Ranch Water Supply

ACWWA provides potable water service to the Elkhorn Ranch residential subdivision in Elbert County. Approximately 80 percent of the 250 lots have been developed. The water supply for Elkhorn Ranch service area is provided from two Denver Basin wells, with a third well planned for construction in 2019. To meet the current peak day pumping with the largest well out of service it is recommended that another Arapahoe aquifer well be constructed. This would provide a pumping capacity with the largest well out of service of approximately 280 gpm. This capacity would be approximately sufficient to meet the estimated peak day demand at buildout of 290 gpm. To the extent the capacities of the Elkhorn Ranch wells decline due to falling Denver Basin ground water levels, it will be necessary to construct additional wells to keep up with the peak day demand. If necessary, a pipeline could be constructed to deliver renewable water from the Cherry Creek service area to the Elkhorn Ranch.

9.12 Availability of Uncommitted Effluent

As described herein, almost all of ACWWA's treated effluent produced at the LTCWRF is legally reusable, and ACWWA reuses this supply directly and indirectly. Direct reuse occurs through delivery of treated effluent to VCC for golf course irrigation pursuant to a 1992 contract and by delivery to supply a portion of ACWWA's nonpotable irrigation system. The remainder of the effluent is discharged to Lone Tree Creek and is used as a source of replacement water in the UCCWA plan for augmentation.

The water supply modeling results described in Section 6 show that after simulation of reusable treated effluent deliveries to VCC, use of treated effluent to supply ACWWA's nonpotable irrigation system, and use of the remaining effluent as an augmentation source, there is no unused effluent that would be reliably available for other uses. This is consistent with the historical operation of the UCCWA plan for augmentation which generally uses all available reusable effluent discharged from the LTCWRF for replacement of out-of-priority depletions during times of a downstream priority call.

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APPENDIX A

2016 Cherry Creek Flow Analysis

Spronk Water Engineers, Inc.
1000 Logan Street • Denver, Colorado 80203-3011 • 303.861.9700 • www.spronkwaterengineers.com

Preliminary Draft – For Discussion Only

Memorandum

TO: Steve Witter (Arapahoe County Water and Wastewater Authority)
Pat Mulhern (Cottonwood Water and Sanitation District)

FROM: Spronk Water Engineers, Inc.; Heidi Welsh, P.H. and Gregory K. Sullivan, P.E.

DATE: December 2, 2016

RE: Cherry Creek Flow Analysis

As part of the assessment of the proposed conversion of the Joint Water Purification Plan back to Reverse Osmosis ("RO"), the physical availability of raw water in the Cherry Creek alluvial aquifer for treatment is being studied. The alluvial ground water supply available to the ACWWA and CWSD alluvial wells that are proposed to supply the JWPP is comprised of (a) ground water stored in the aquifer in the vicinity of the wells, (b) ground water underflow into the reach containing the alluvial wells, and (c) surface flow in Cherry Creek that is hydraulically connected to underlying alluvial aquifer.

The Cherry Creek alluvial aquifer is generally composed of unconsolidated sands and gravels with discontinuous clay layers at varying depths. The aquifer is generally believed to be in good hydraulic connection with the surface flow of Cherry Creek although the accumulation of fine sediments on the channel bottom and the discontinuous clay layers below the surface may result in some localized areas where the hydraulic connection between the surface flows and the ground water is somewhat impeded.

ACWWA, CWSD, and other Cherry Creek water providers recently commenced the Cherry Creek Aquifer Study ("CCAS"), which is a three-year study of the interrelationship of surface water and alluvial ground water involving data collection and analysis. The study is expected to substantially improve understanding of the interconnection of surface water and ground between Parker and Cherry Creek Reservoir.

Because there is a need for information about the physical availability of water to the JWPP prior to completion of the CCAS, ACWWA and CWSD have requested that their water consultants (Spronk Water Engineers and HRS Water Consultants) make a preliminary assessment of the physical supply. As a part of this assessment, HRS Water Consultants is going to use the MODFLOW ground water model of Cherry Creek that was developed as part of the Cherry Creek Aquifer Modeling Project ("CCAMP") to simulate pumping of ground water to supply the JWPP under various assumed flow conditions.

SWE is coordinating with HRS on the development of the model runs and will assist in review of the results. In addition, SWE is reviewing the historical flow records for Cherry Creek (a) to assess the frequency and duration of low flow periods, and (b) to help develop various inflow scenarios to simulate in the CCAMP ground water model.

This memorandum describes SWE's analysis of the historical Cherry Creek flow records.

Spronk Water Engineers, Inc.

ACWWA and CWSD have tentatively identified the following alluvial wells to supply the JWPP:

- Race 1
- Loyd 2
- DOD-1
- DOD-4
- DOD-7
- CCC-4

A map showing the location of the proposed alluvial wells and other alluvial wells in the vicinity is attached as **Figure 1**.

The USGS has operated the Cherry Creek at Parker gage (USGS Site No. 393109104464500) approximately two miles upstream of the proposed JWPP alluvial wells since 1992 ("Parker Gage"). Based on its location, historical records from the Parker Gage can be used to estimate the surface flow that is physically available to proposed JWPP alluvial wells.

Until recently, most of the wastewater treated by Parker Water and Sanitation District ("PWSD") has been discharged to Sulphur Gulch, a tributary that joins Cherry Creek a short distance upstream of the Parker Gage. Therefore, the historical flows at the Parker gage have been enhanced by the PWSD effluent discharges.

Most of PWSD's treated effluent is legally reusable because it derived from Parker's use of Denver Basin ground water and other reusable supplies. However, until recently, Parker has performed little reuse of its effluent by augmentation, exchange, or otherwise. Based on review of PWSD's water rights accounting, this changed in late-2014 when Parker began pumping some, but not all, of its reusable treated effluent to storage in Rueter-Hess Reservoir ("RHR"). Water stored in the reservoir is treated at PWSD's new water treatment plant and delivered for potable use.

Based on prior discussions with PWSD representatives PWSD plans to eventually reuse most if not all of its reusable effluent by pumping it to storage and/or by augmentation of out-of-priority pumping. As a result, the discharges of treated effluent at Sulphur Gulch that have enhanced the flows downstream of Parker during recent decades are expected to decline substantially.

In addition to the reduction in Cherry Creek flow that will result from Parker reusing its treated effluent, the flows will also be reduced by Parker's in priority diversions to storage in RHR. These diversions occur during periods when there is no call from the South Platte River (i.e., free river periods). However, PWSD is required to leave 5 cfs at the Parker Gage during times when it is diverting in-priority to storage.

Adjustment of Parker Gage Flows

Based on the foregoing discussion, the flow at the Parker Gage available for downstream pumping would have been present if RHR was in operation and PWSD was fully reusing its treated effluent was estimated for the period from 1992 – 2015 by reducing the historical daily flows by (a) the reported daily effluent discharges to Sulphur Gulch, and (b) the estimated flow available at the RHR surface diversion (Newlin Gulch Aqueduct No. 2) during free river periods, subject to maintaining a 5 cfs flow at the Parker Gage.

The flow at the RHR surface diversion was estimated as 87% of the difference between the historical Parker Gage flow and the treated effluent discharge at Sulphur Gulch. The 87% factor represents the drainage area at the RHR surface diversion divided by the drainage area at the Parker Gage. The adjustment to reduce the historical gage flows for the estimated in-priority RHR diversions was made to the records prior to the date of the first actual diversion to RHR in March 2010. After that time, the historical records already reflect the in-priority diversions to storage that actually occurred.

The daily streamflow records for the Parker Gage were obtained from the CCAMP 2.0 database and the USGS. The daily Parker WWTP discharge data were obtained from the CCAMP 2.0 database and PWSD's RHR water rights accounting. The historical daily unadjusted Parker Gage flows from 1992 – 2015 are shown as the black line in **Figure 2**. The upper limit of the vertical axis on the charts was limited to 10 cfs to better depict the low flows.

The historical monthly average <u>unadjusted</u> flows at the Parker Gage are summarized in the **Table 1** during the 1992 – 2015 period. The historical annual unadjusted flows averaged 7,977 acre-feet (11 cfs or 7.1 MGD) and ranged from 1,987 acre-feet (2.7 cfs; 1.8 MGD) in 1994 to 18,576 acre-feet (25.6 cfs or 16.5 MGD) in 1999.

The historical daily flows at the Parker Gage with the adjustments for PWSD's operations are shown in **Figure 2**. The red-shaded area shows the Sulphur Gulch effluent discharge that was assumed to be pumped to storage or otherwise reused by PWSD. The green-shaded area is the estimated in priority diversions to storage in RHR. The blue-shaded area shows the adjusted daily flow at the Parker Gage after the PWSD operations described above. Note that when PWSD is diverting in priority to storage, the adjusted flow at the Parker Gage is maintained at 5 cfs.

After PWSD began diverting to storage in RHR in 2010, it appears they were discharging treated effluent to help meet the 5 cfs flow requirement when they were diverting in priority at the RHR surface diversion. During these periods, the Parker Gage flows were not reduced to remove the treated effluent discharges. This is seen in **Figure 2** where portions of the red-shaded WWTP flows are recolored as blue-shaded flow left at the gage.

The monthly average adjusted Parker Gage flows are summarized in **Table 2.** The historical annual adjusted flows averaged 4,450 acre-feet (6.1 cfs or 4.0 MGD) and ranged from 1,154 acre-feet (1.6 cfs; 1.07 MGD) in 1994 to 9,187 acre-feet (12.7 cfs or 8.2 MGD) in 2007. The results in **Table 2** show that the adjusted flows typically peak during the spring months and reach the minimums during the summer and fall months. The monthly average flows declined to less 2.0 cfs (1.3 MGD) in 18 years out of the 24-year study period and to less than 1.0 cfs (0.6 MGD) in 11 years.

<u>Frequency Analysis</u>

The annual probability of occurrence of low flows at the Parker Gage was estimated based on a low-flow frequency analysis of the adjusted daily flows. Running average daily adjusted Parker Gage streamflow for various consecutive week periods were computed for the 1992 – 2015 study period. The minimum running average adjusted streamflow for each consecutive week period was summarized for each climatic year (April 1 – March 31) in the 24-year study period. The climatic year was used to minimize the double counting of the same dry period in the fall/winter in consecutive water years or calendar years. Running averages were reset at the end of each climatic year.

The annual low flows for various consecutive week period in each climatic year during the study period are summarized in **Table 3**. The 4-week average low flow is 1.0 cfs (0.6 MGD) or less in 15 years out of the 24-year study period. The average adjusted flow was less than 1.0 cfs for 8 weeks in 9 years, for 12 weeks in 5 years, and 20 weeks in 3 years.

The results shown in **Table 3** were used to compute annual non-exceedance probabilities for various flows of various durations as shown in **Table 4**. The results in **Table 4** show the percent chance that in any year the lowest average flow for various consecutive week periods will not exceed a specified flow in cfs. For example, there is a 21 percent chance that the average 12-week low flow will not exceed 1.0 cfs. A chart of the results is also shown below the tabular values.

A parallel set of **Tables 1 – 4** were prepared to present the results in units of MGD rather than cfs, and these table are attached as **Tables 1a – 4a**.

The results in **Table 4** show that low flows at the Parker Gage will occur relatively frequently, particularly if Parker fully reuses its treated effluent. The information in this memorandum should be used to develop proposed scenarios to analyze in the CCAMP MODFLOW model to assess the capability of the proposed ACWWA and CWSD alluvial wells to supply water to the JWPP during low flow periods of various durations.

It is also important to note that PWSD has three existing and several other proposed alluvial wells located downstream of the Parker Gage. These wells are shown in **Figure 1**. During 2012 – 2014, Parker pumped an average of about approximately 1,600 acre-feet per year from the three existing wells. Some of the pumping occurred in priority during no-call periods, and other pumping was augmented using historical consumptive use credits and lawn irrigation return flows. Review of PWSD's recent accounting shows that PWSD has approximately 100 acre-feet of senior consumptive use water rights and approximately 1,000 acre-feet of LIRFs that it can use for augmentation of these and other alluvial wells.

Based on discussions with Mark Palumbo, we propose to evaluate the potential effect of pumping by Parker's alluvial wells downstream of the Parker Gage using the CCAMP ground water model.

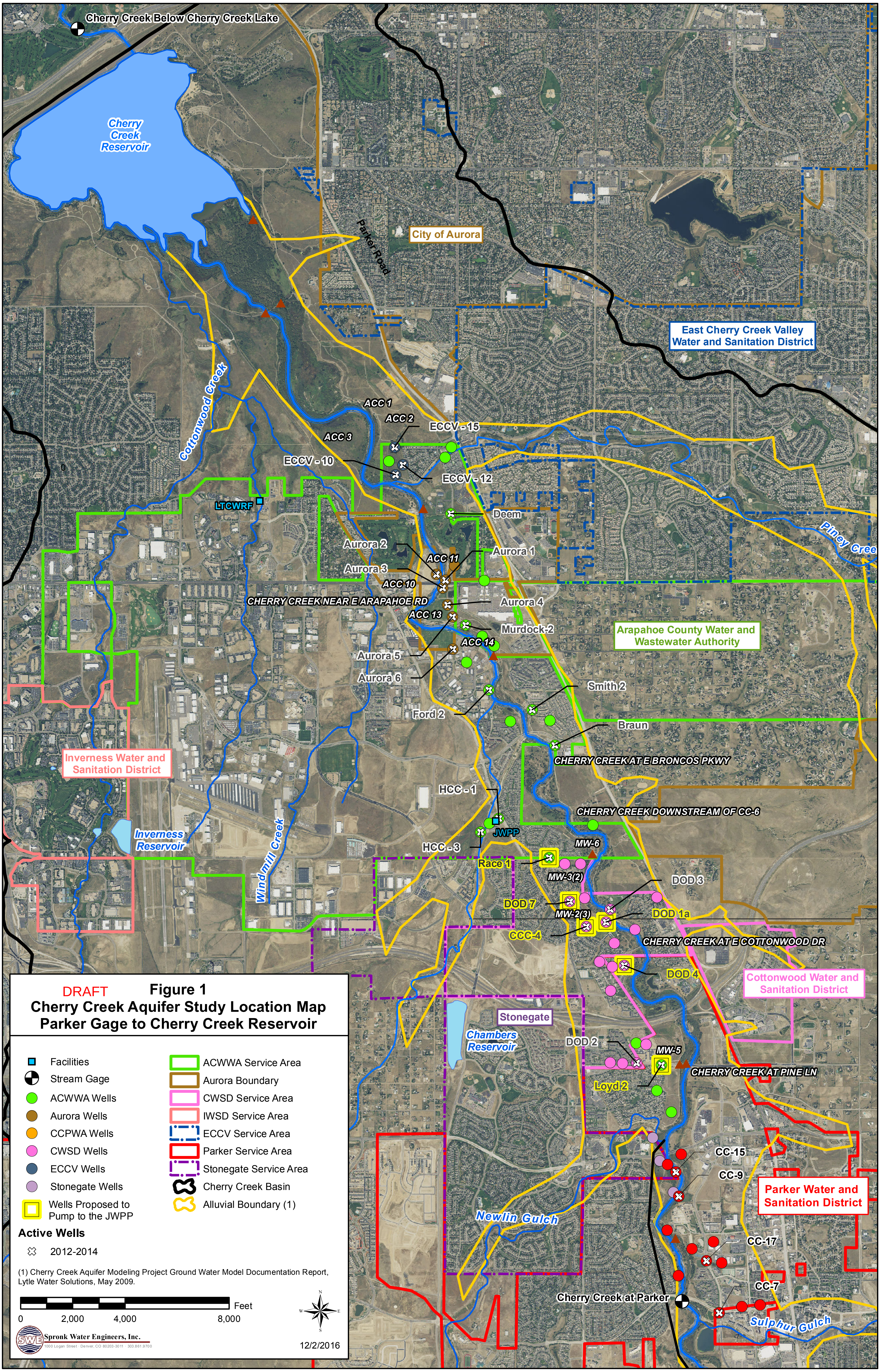
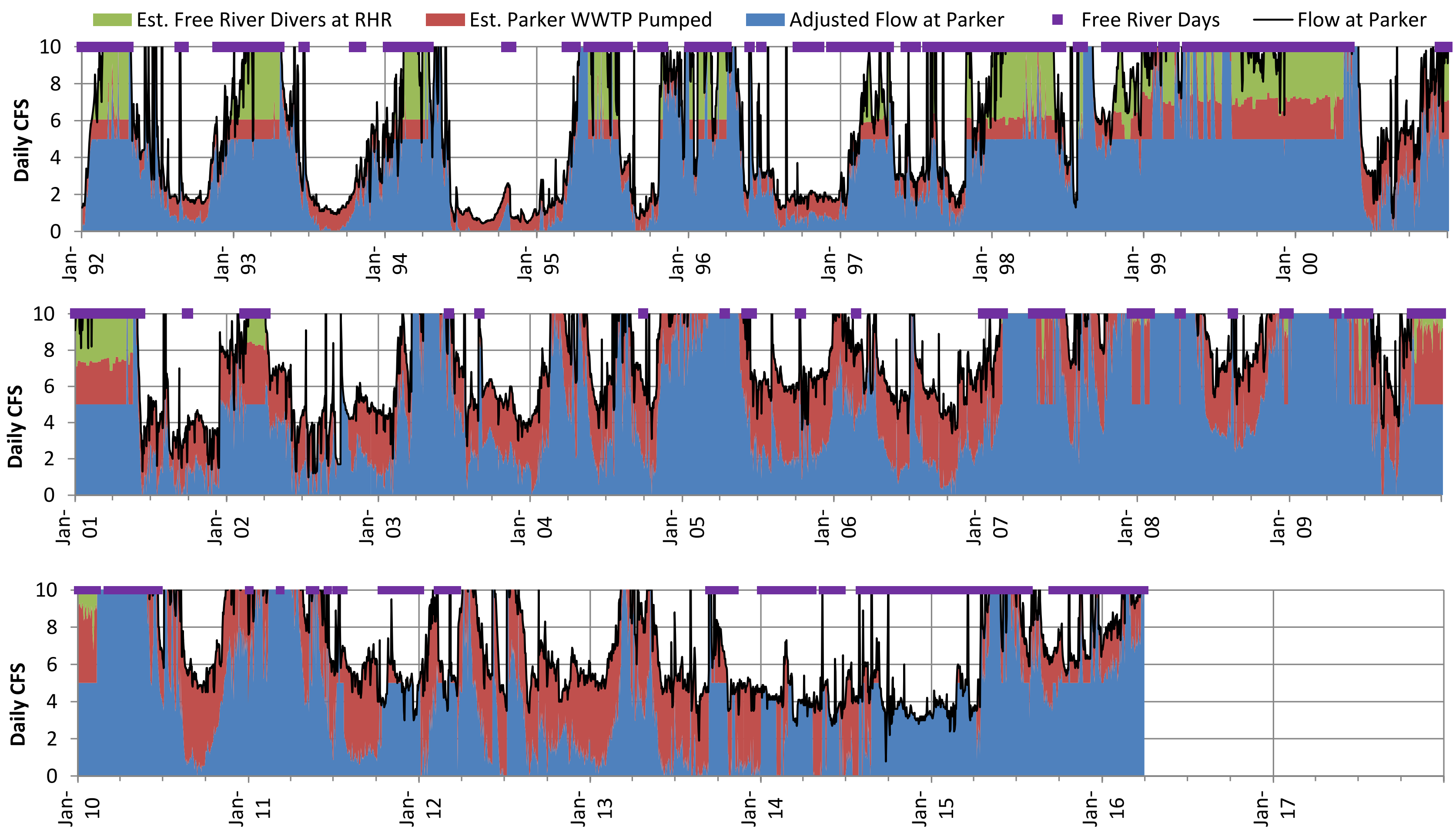


Figure 1
Cherry Creek Aquifer Study Location Map
Parker Gage to Cherry Creek Reservoir

Figure 2

Daily Cherry Creek at Parker Gage Flow, Flow Adjustments, and Parker Gage Flow (Adjusted) (1)

1992 - 2015



Notes: The adjusted Cherry Creek flow was computed as the daily flow at the Cherry Creek at Parker gage (USGS) minus daily Parker WWTP discharge to Sulphur Gulch minus estimated free river diversions at RHR prior to date of first RHR diversion (March 2010).
Daily Parker WWTP discharges for 1992 - 1996 were estimated as the average 1997 discharge.
Daily call records previously compiled (CCAMP) and updated with CDSS call records (12/6/2016).

Table 1

Monthly Average Flow
Cherry Creek at Parker Gage
1992 - 2015
(CFS)

(2) Climatic Year	Monthly CFS												Ann	Ann
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	CFS	AF
1992	20.2	5.2	11.5	4.3	3.5	1.7	1.7	4.0	5.9	7.8	14.1	16.6	8.0	5,789
1993	21.7	7.4	5.7	1.6	1.2	1.2	2.2	3.6	4.6	5.5	14.0	12.7	6.7	4,856
1994	9.9	8.3	1.9	1.0	0.6	0.7	1.9	0.8	0.8	1.5	1.7	3.8	2.7	1,987
1995	10.9	26.8	33.5	14.0	2.9	1.2	3.9	8.9	9.0	8.8	10.9	10.5	11.8	8,543
1996	10.7	5.7	4.1	3.6	4.3	1.8	1.9	1.9	1.8	3.0	5.7	7.4	4.3	3,109
1997	8.1	4.2	3.8	3.9	15.1	3.6	2.7	7.4	6.5	9.9	15.0	32.2	9.4	6,771
1998	47.4	25.0	5.6	18.3	29.1	6.4	6.7	8.4	8.1	9.7	10.9	10.4	15.5	11,237
1999	27.1	87.9	47.5	16.0	18.2	10.3	9.7	9.8	14.9	21.0	21.4	22.5	25.6	18,576
2000	25.8	17.1	4.4	3.2	3.9	5.6	5.3	8.2	9.0	10.7	15.3	16.0	10.3	7,472
2001	17.1	29.6	4.1	4.3	5.2	3.1	4.1	3.0	5.8	8.0	9.2	14.4	9.0	6,530
2002	7.9	6.6	3.9	3.7	4.5	3.4	5.0	5.3	4.8	4.3	6.6	11.8	5.6	4,088
2003	32.2	18.0	14.7	7.3	6.0	6.6	5.3	5.1	3.9	5.2	9.2	11.2	10.3	7,512
2004	10.1	9.2	5.2	8.9	26.5	6.8	5.7	10.5	11.2	12.6	12.8	16.4	11.3	8,209
2005	38.2	15.5	7.8	6.0	7.6	5.8	6.3	6.5	7.3	10.0	8.4	7.7	10.6	7,657
2006	7.8	5.8	5.1	15.0	5.8	5.0	4.9	6.4	6.7	7.6	19.2	43.0	11.0	7,975
2007	52.4	45.1	29.3	9.2	13.3	13.1	10.3	14.4	15.6	17.5	28.6	30.6	23.2	16,845
2008	21.5	15.1	9.4	6.7	13.5	7.0	8.2	10.7	13.0	15.1	15.9	15.2	12.6	9,103
2009	33.1	20.8	46.5	16.7	6.7	6.7	10.4	20.9	17.0	15.8	16.5	28.4	19.9	14,412
2010	46.8	31.3	12.0	12.7	7.6	5.0	5.9	9.6	11.3	12.1	14.9	16.5	15.4	11,184
2011	12.6	12.4	10.0	9.8	5.2	6.2	4.8	5.5	4.5	6.9	6.7	7.3	7.6	5,550
2012	12.1	6.9	17.2	10.6	6.5	6.3	5.5	5.3	5.5	5.1	6.4	11.4	8.2	5,961
2013	9.1	9.2	5.0	5.3	4.8	17.1	5.9	4.7	4.6	4.4	5.0	4.0	6.6	4,762
2014	3.9	4.5	3.7	5.3	5.7	5.0	3.8	3.4	3.2	3.8	3.8	4.9	4.3	3,090
2015	7.7	40.3	43.2	8.5	9.0	6.6	7.0	7.4	9.0	7.9	10.5	12.2	14.1	10,232
Avg	20.6	19.1	14.0	8.2	8.6	5.7	5.4	7.1	7.7	8.9	11.8	15.3	11.0	7,977
Max	52.4	87.9	47.5	18.3	29.1	17.1	10.4	20.9	17.0	21.0	28.6	43.0	25.6	18,576
Min	3.9	4.2	1.9	1.0	0.6	0.7	1.7	0.8	0.8	1.5	1.7	3.8	2.7	1,987

Notes:
(1) Climatic year is April 1 - March 31.

Color Key	Range (cfs)	
	Min	Max
	0	1
	1	2
	2	4
	4	6
	>	6

Table 2

Monthly Average Flow
Cherry Creek at Parker Gage (Adjusted) (1)
1992 - 2015
(CFS)

(2) Climatic Year	Monthly CFS Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Ann CFS	Ann AF
1992	6.3	4.2	10.5	3.3	1.4	0.7	0.7	3.0	4.4	5.0	4.9	5.0	4.1	2,961
1993	6.2	6.3	3.1	0.5	0.1	0.2	1.2	2.5	3.6	4.1	4.8	4.9	3.1	2,258
1994	6.3	7.2	0.9	0.1	0.0	0.0	0.8	0.0	0.0	0.5	0.7	2.6	1.6	1,154
1995	9.9	8.3	12.3	4.2	1.9	0.2	2.2	7.8	7.9	4.6	5.9	5.2	5.8	4,245
1996	9.5	4.2	3.0	2.5	3.2	0.8	0.8	0.8	0.7	2.2	4.3	4.9	3.1	2,228
1997	5.2	3.3	2.4	2.3	3.9	1.7	1.3	4.6	4.6	5.0	5.0	5.4	3.7	2,703
1998	6.2	5.1	4.1	11.1	20.5	5.0	4.8	5.0	4.7	6.1	7.0	6.6	7.2	5,218
1999	13.0	36.2	7.0	10.3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	8.9	6,466
2000	6.3	13.9	2.0	0.9	2.1	3.1	2.9	5.5	5.3	5.0	5.0	5.0	4.8	3,446
2001	5.0	10.4	1.6	1.6	3.4	0.9	1.6	1.1	3.3	5.3	5.0	5.0	3.7	2,670
2002	4.5	3.9	1.5	1.5	2.7	1.9	4.2	2.4	1.6	1.2	3.9	8.7	3.2	2,287
2003	29.3	14.9	10.5	4.6	2.4	4.2	2.5	2.2	1.5	1.4	5.8	7.5	7.2	5,215
2004	6.4	5.8	1.9	5.9	23.3	3.2	2.1	6.8	8.7	9.0	9.2	12.7	7.9	5,743
2005	32.9	11.9	3.4	2.2	3.5	1.8	2.9	2.5	3.5	6.2	4.8	5.5	6.7	4,883
2006	4.6	2.0	1.4	10.9	1.9	1.0	1.2	2.8	2.7	3.9	13.9	37.9	7.0	5,068
2007	29.7	5.9	14.0	4.7	8.6	7.9	6.1	9.6	8.4	7.1	24.7	26.1	12.7	9,187
2008	15.6	12.1	5.4	3.5	7.7	3.4	4.3	7.6	8.1	11.3	12.4	11.8	8.6	6,199
2009	18.0	14.2	14.2	5.8	2.6	2.8	6.1	5.0	5.0	5.0	10.5	24.6	9.5	6,848
2010	42.9	27.1	8.1	8.3	2.7	0.7	2.0	5.5	7.2	8.3	10.5	12.9	11.3	8,200
2011	8.5	7.9	5.9	6.6	1.1	1.2	3.4	4.8	4.4	2.2	4.7	5.5	4.7	3,400
2012	7.2	2.4	12.6	6.2	2.6	2.1	1.7	2.1	1.3	0.8	2.2	7.9	4.1	2,958
2013	4.7	4.7	0.8	1.2	0.9	13.7	3.7	1.4	0.5	4.4	1.8	4.0	3.5	2,509
2014	2.8	2.5	2.4	1.3	3.2	4.3	3.8	3.4	3.2	3.8	3.7	4.6	3.2	2,343
2015	5.7	37.6	40.2	6.0	6.5	4.4	5.5	5.6	6.9	5.7	8.4	9.7	11.8	8,601
Avg	11.9	10.5	7.0	4.4	4.6	2.9	2.9	4.0	4.3	4.7	6.8	9.5	6.1	4,450
Max	42.9	37.6	40.2	11.1	23.3	13.7	6.1	9.6	8.7	11.3	24.7	37.9	12.7	9,187
Min	2.8	2.0	0.8	0.1	0.0	0.0	0.7	0.0	0.0	0.5	0.7	2.6	1.6	1,154

Notes:

(1) The adjusted Cherry Creek flow was computed as the daily flow at the Cherry Creek at Parker gage (USGS) minus daily Parker WWTP discharge to Sulphur Gulch minus estimated free river diversions to RHR prior to March 2010.
Daily Parker WWTP discharges for 1992 - 1996 were estimated as the average 1997 discharge.

(2) Climatic year is April 1 - March 31.

Color Key	Range (cfs) Min	Max
	0	1
	1	2
	2	4
	4	6
	>	6

Table 3

Lowest Average Flow for Consecutive Weeks
Cherry Creek at Parker Gage (Adjusted) (1)
1992 - 2015
(CFS)

(2) Climatic Year	Lowest Average Flow for Consecutive Weeks (CFS) 1	2	3	4	8	12	16	20	24
1992	0.5	0.5	0.6	0.6	0.7	0.9	1.0	1.5	1.9
1993	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.7	1.0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2
1995	0.0	0.0	0.0	0.1	0.4	1.1	1.8	2.8	3.5
1996	0.2	0.3	0.4	0.5	0.7	0.8	0.8	0.8	1.2
1997	0.7	0.7	0.8	0.8	1.3	2.0	2.3	2.3	2.3
1998	1.6	2.5	3.2	3.5	4.2	4.8	4.8	4.9	5.4
1999	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0
2000	0.2	0.2	0.4	0.5	1.0	1.4	1.8	1.9	2.4
2001	0.2	0.4	0.7	0.6	1.0	1.1	1.1	1.6	1.7
2002	0.6	0.7	1.0	1.0	1.2	1.4	1.8	2.1	2.2
2003	0.2	0.4	0.8	1.0	1.2	1.6	1.7	2.0	2.3
2004	1.1	1.3	1.7	1.8	2.4	3.6	4.5	5.5	6.1
2005	1.4	1.7	1.8	1.8	2.0	2.4	2.4	2.6	2.6
2006	0.4	0.5	0.5	0.5	0.9	1.2	1.6	1.8	2.0
2007	2.8	3.1	3.4	4.0	5.7	6.9	6.6	7.1	7.6
2008	2.6	2.8	3.0	3.2	3.4	4.1	4.6	4.6	5.0
2009	0.1	1.3	1.6	1.9	2.3	3.1	3.9	4.1	4.2
2010	0.5	0.5	0.5	0.6	0.9	1.4	2.4	3.3	3.9
2011	0.8	0.9	1.0	1.0	1.1	1.4	2.2	2.7	2.9
2012	0.0	0.1	0.5	0.7	0.9	1.2	1.4	1.5	1.5
2013	0.0	0.1	0.2	0.2	0.6	1.0	1.0	1.8	2.5
2014	0.0	0.0	0.3	0.6	1.5	2.0	1.9	2.2	2.6
2015	2.1	2.7	4.1	4.3	4.6	5.0	5.3	5.4	5.6
Avg	0.9	1.1	1.3	1.4	1.8	2.2	2.5	2.8	3.2
Max	4.9	4.9	5.0	5.0	5.7	6.9	6.6	7.1	7.6
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2

Notes:

(1) The adjusted Cherry Creek flow was computed as the daily flow at the Cherry Creek at Parker gage (USGS) minus daily Parker WWTP discharge to Sulphur Gulch minus estimated free river diversions to RHR prior to March 2010.
Daily Parker WWTP discharges for 1992 - 1996 were estimated as the average 1997 discharge.

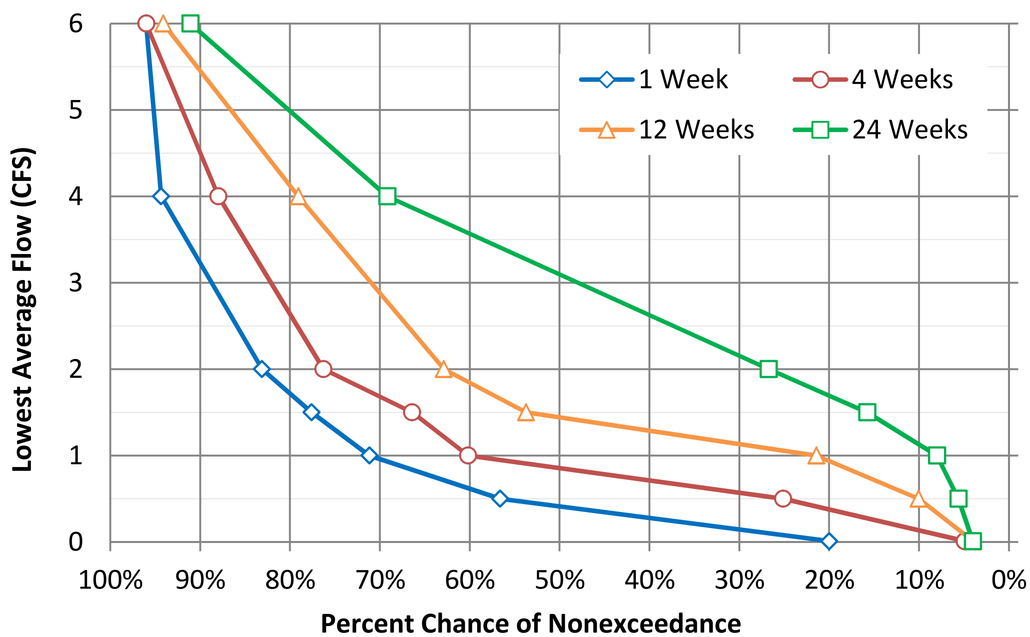
(2) Climatic year is April 1 - March 31.

Color Key	Range (cfs) Min	Max
	0	1
	1	2
	2	4
	4	6
	>	6

Table 4

Annual Low Flow Frequencies
Cherry Creek at Parker Gage (Adjusted) (1)
1992 - 2015
(CFS)

(2) Lowest Avg Flow (cfs)	Annual % Chance of Nonexceedance for Weekly Periods (3)								
	1	2	3	4	8	12	16	20	24
0.0	20%	9%	6%	5%	4%	4%	4%	4%	4%
0.5	57%	48%	33%	25%	14%	10%	9%	7%	6%
1.0	71%	65%	64%	60%	39%	21%	18%	13%	8%
1.5	78%	74%	67%	66%	64%	54%	29%	21%	16%
2.0	83%	77%	77%	76%	68%	63%	53%	39%	27%
4.0	94%	94%	92%	88%	83%	79%	73%	72%	69%
6.0	96%	96%	96%	96%	96%	94%	94%	93%	91%



Notes:

(1) The adjusted Cherry Creek flow was computed as the daily flow at the Cherry Creek at Parker gage (USGS) minus the daily Parker WWTP discharge to Sulphur Gulch minus estimated free river diversions to RHR prior to March 2010.
Daily Parker WWTP discharges for 1992 - 1996 were estimated as average 1997 flow.

(2) The above values represent the percent chance that in any year the lowest average flow for weekly periods of varying duration will not exceed a specified flow in CFS.
For example, there is a 21% chance that the average 12-week low flow will not exceed 1.0 cfs.

(0) Annual probabilities are based on a climatic year from April 1 - March 31.

Table 1a

Monthly Average Flow
Cherry Creek at Parker Gage
1992 - 2015
(MGD)

(1) Climatic Year	Monthly MGD Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Ann MGD	Ann AF
1992	13.0	3.4	7.5	2.8	2.3	1.1	1.1	2.6	3.8	5.0	9.1	10.7	5.2	5,789
1993	14.0	4.8	3.7	1.0	0.7	0.8	1.4	2.3	3.0	3.5	9.1	8.2	4.3	4,856
1994	6.4	5.3	1.2	0.7	0.4	0.5	1.2	0.5	0.5	1.0	1.1	2.5	1.8	1,987
1995	7.0	17.3	21.7	9.1	1.9	0.8	2.6	5.7	5.8	5.7	7.0	6.8	7.6	8,543
1996	6.9	3.7	2.6	2.3	2.8	1.2	1.2	1.2	1.2	1.9	3.7	4.8	2.8	3,109
1997	5.3	2.7	2.4	2.5	9.8	2.3	1.7	4.8	4.2	6.4	9.7	20.8	6.0	6,771
1998	30.6	16.2	3.6	11.8	18.8	4.1	4.3	5.4	5.2	6.3	7.1	6.7	10.0	11,237
1999	17.5	56.8	30.7	10.3	11.7	6.7	6.3	6.4	9.7	13.6	13.8	14.6	16.5	18,576
2000	16.6	11.0	2.8	2.1	2.5	3.6	3.4	5.3	5.8	6.9	9.9	10.3	6.7	7,472
2001	11.0	19.1	2.7	2.8	3.4	2.0	2.7	1.9	3.7	5.2	5.9	9.3	5.8	6,530
2002	5.1	4.3	2.5	2.4	2.9	2.2	3.3	3.4	3.1	2.8	4.3	7.6	3.6	4,088
2003	20.8	11.6	9.5	4.7	3.9	4.3	3.5	3.3	2.5	3.3	5.9	7.3	6.7	7,512
2004	6.5	5.9	3.3	5.7	17.1	4.4	3.7	6.8	7.3	8.1	8.3	10.6	7.3	8,209
2005	24.7	10.0	5.0	3.9	4.9	3.8	4.1	4.2	4.7	6.5	5.4	5.0	6.8	7,657
2006	5.0	3.7	3.3	9.7	3.8	3.2	3.1	4.1	4.3	4.9	12.4	27.8	7.1	7,975
2007	33.8	29.1	18.9	5.9	8.6	8.4	6.7	9.3	10.1	11.3	18.5	19.8	15.0	16,845
2008	13.9	9.7	6.1	4.3	8.7	4.5	5.3	6.9	8.4	9.7	10.3	9.8	8.1	9,103
2009	21.4	13.5	30.0	10.8	4.3	4.3	6.7	13.5	11.0	10.2	10.7	18.3	12.9	14,412
2010	30.2	20.2	7.7	8.2	4.9	3.3	3.8	6.2	7.3	7.8	9.7	10.7	10.0	11,184
2011	8.1	8.0	6.5	6.3	3.4	4.0	3.1	3.6	2.9	4.4	4.3	4.7	4.9	5,550
2012	7.8	4.5	11.1	6.8	4.2	4.1	3.6	3.4	3.5	3.3	4.2	7.4	5.3	5,961
2013	5.9	5.9	3.3	3.4	3.1	11.1	3.8	3.0	3.0	2.8	3.2	2.6	4.2	4,762
2014	2.5	2.9	2.4	3.4	3.7	3.2	2.5	2.2	2.1	2.5	2.5	3.2	2.8	3,090
2015	5.0	26.1	27.9	5.5	5.8	4.3	4.5	4.8	5.8	5.1	6.8	7.9	9.1	10,232
Avg	13.3	12.3	9.0	5.3	5.6	3.7	3.5	4.6	5.0	5.8	7.6	9.9	7.1	7,977
Max	33.8	56.8	30.7	11.8	18.8	11.1	6.7	13.5	11.0	13.6	18.5	27.8	16.5	18,576
Min	2.5	2.7	1.2	0.7	0.4	0.5	1.1	0.5	0.5	1.0	1.1	2.5	1.8	1,987

Notes:

(1) Climatic year is April 1 - March 31.

Color Key	Range (MGD) Min	Max
	0.0	0.6
	0.6	1.3
	1.3	2.6
	2.6	3.9
	>	3.9

Table 2a

Monthly Average Flow
Cherry Creek at Parker Gage (Adjusted) (1)
1992 - 2015
(MGD)

(2) Climatic Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Ann MGD	Ann AF
	Monthly MGD													
1992	4.1	2.7	6.8	2.1	0.9	0.4	0.4	1.9	2.8	3.2	3.2	3.2	2.6	2,961
1993	4.0	4.1	2.0	0.4	0.1	0.1	0.8	1.6	2.3	2.6	3.1	3.2	2.0	2,258
1994	4.0	4.7	0.6	0.0	0.0	0.0	0.5	0.0	0.0	0.3	0.4	1.7	1.0	1,154
1995	6.4	5.4	8.0	2.7	1.2	0.1	1.4	5.0	5.1	3.0	3.8	3.4	3.8	4,245
1996	6.2	2.7	2.0	1.6	2.1	0.5	0.5	0.5	0.5	1.4	2.8	3.2	2.0	2,228
1997	3.4	2.1	1.6	1.5	2.5	1.1	0.9	3.0	3.0	3.2	3.2	3.5	2.4	2,703
1998	4.0	3.3	2.7	7.2	13.2	3.2	3.1	3.2	3.0	3.9	4.5	4.3	4.7	5,218
1999	8.4	23.4	4.5	6.6	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	5.8	6,466
2000	4.1	9.0	1.3	0.6	1.4	2.0	1.8	3.6	3.4	3.2	3.2	3.2	3.1	3,446
2001	3.2	6.7	1.1	1.1	2.2	0.6	1.0	0.7	2.2	3.4	3.2	3.2	2.4	2,670
2002	2.9	2.5	1.0	0.9	1.7	1.2	2.7	1.6	1.0	0.8	2.5	5.6	2.0	2,287
2003	19.0	9.6	6.8	3.0	1.6	2.7	1.6	1.4	1.0	0.9	3.7	4.9	4.6	5,215
2004	4.2	3.7	1.2	3.8	15.0	2.1	1.3	4.4	5.6	5.8	5.9	8.2	5.1	5,743
2005	21.2	7.7	2.2	1.4	2.3	1.2	1.9	1.6	2.2	4.0	3.1	3.6	4.4	4,883
2006	3.0	1.3	0.9	7.0	1.2	0.6	0.8	1.8	1.8	2.5	9.0	24.5	4.5	5,068
2007	19.2	3.8	9.1	3.0	5.6	5.1	3.9	6.2	5.4	4.6	16.0	16.9	8.2	9,187
2008	10.1	7.8	3.5	2.3	5.0	2.2	2.8	4.9	5.2	7.3	8.0	7.6	5.5	6,199
2009	11.6	9.2	9.1	3.8	1.7	1.8	3.9	3.2	3.2	3.2	6.8	15.9	6.1	6,848
2010	27.7	17.5	5.3	5.4	1.8	0.4	1.3	3.5	4.7	5.4	6.8	8.3	7.3	8,200
2011	5.5	5.1	3.8	4.3	0.7	0.8	2.2	3.1	2.9	1.4	3.0	3.6	3.0	3,400
2012	4.7	1.6	8.1	4.0	1.7	1.3	1.1	1.4	0.8	0.5	1.4	5.1	2.6	2,958
2013	3.0	3.0	0.5	0.8	0.6	8.8	2.4	0.9	0.3	2.8	1.2	2.6	2.2	2,509
2014	1.8	1.6	1.5	0.8	2.0	2.8	2.4	2.2	2.1	2.5	2.4	3.0	2.1	2,343
2015	3.7	24.3	26.0	3.9	4.2	2.8	3.6	3.6	4.5	3.7	5.5	6.3	7.7	8,601
Avg	7.7	6.8	4.6	2.8	3.0	1.9	1.9	2.6	2.8	3.0	4.4	6.2	4.0	4,450
Max	27.7	24.3	26.0	7.2	15.0	8.8	3.9	6.2	5.6	7.3	16.0	24.5	8.2	9,187
Min	1.8	1.3	0.5	0.0	0.0	0.0	0.4	0.0	0.0	0.3	0.4	1.7	1.0	1,154

Notes:

(1) The adjusted Cherry Creek flow was computed as the daily flow at the Cherry Creek at Parker gage (USGS) minus daily Parker WWTP discharge to Sulphur Gulch minus estimated free river diversions to RHR prior to March 2010.
Daily Parker WWTP discharges for 1992 - 1996 were estimated as the average 1997 discharge.

(2) Climatic year is April 1 - March 31.

Color Key	Range (MGD) Min	Max
	0.0	0.6
	0.6	1.3
	1.3	2.6
	2.6	3.9
	>	3.9

Table 3a

Lowest Average Flow for Consecutive Weeks
Cherry Creek at Parker Gage (Adjusted) (1)
1992 - 2015
(MGD)

(2) Climatic Year	Lowest Average Flow for Consecutive Weeks (MGD)								
	1	2	3	4	8	12	16	20	24
1992	0.3	0.4	0.4	0.4	0.4	0.6	0.7	0.9	1.3
1993	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.6
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
1995	0.0	0.0	0.0	0.1	0.3	0.7	1.2	1.8	2.3
1996	0.1	0.2	0.3	0.3	0.5	0.5	0.5	0.5	0.8
1997	0.4	0.5	0.5	0.5	0.9	1.3	1.5	1.5	1.5
1998	1.0	1.6	2.1	2.2	2.7	3.1	3.1	3.1	3.5
1999	3.1	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
2000	0.2	0.2	0.2	0.3	0.7	0.9	1.2	1.3	1.6
2001	0.1	0.3	0.4	0.4	0.7	0.7	0.7	1.0	1.1
2002	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.4	1.4
2003	0.1	0.3	0.5	0.6	0.8	1.0	1.1	1.3	1.5
2004	0.7	0.8	1.1	1.2	1.5	2.3	2.9	3.6	4.0
2005	0.9	1.1	1.1	1.2	1.3	1.6	1.6	1.7	1.7
2006	0.2	0.3	0.3	0.3	0.6	0.8	1.0	1.1	1.3
2007	1.8	2.0	2.2	2.6	3.7	4.5	4.3	4.6	4.9
2008	1.7	1.8	1.9	2.1	2.2	2.7	3.0	3.0	3.2
2009	0.1	0.8	1.1	1.2	1.5	2.0	2.5	2.6	2.7
2010	0.3	0.3	0.3	0.4	0.6	0.9	1.5	2.1	2.5
2011	0.5	0.6	0.6	0.6	0.7	0.9	1.4	1.8	1.9
2012	0.0	0.1	0.3	0.5	0.6	0.7	0.9	0.9	1.0
2013	0.0	0.1	0.1	0.2	0.4	0.6	0.6	1.2	1.6
2014	0.0	0.0	0.2	0.4	0.9	1.3	1.3	1.4	1.7
2015	1.4	1.7	2.6	2.8	3.0	3.2	3.4	3.5	3.6
Avg	0.6	0.7	0.8	0.9	1.2	1.4	1.6	1.8	2.0
Max	3.1	3.2	3.2	3.2	3.7	4.5	4.3	4.6	4.9
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1

Notes:

(1) The adjusted Cherry Creek flow was computed as the daily flow at the Cherry Creek at Parker gage (USGS) minus daily Parker WWTP discharge to Sulphur Gulch minus estimated free river diversions to RHR prior to March 2010.
Daily Parker WWTP discharges for 1992 - 1996 were estimated as the average 1997 discharge.

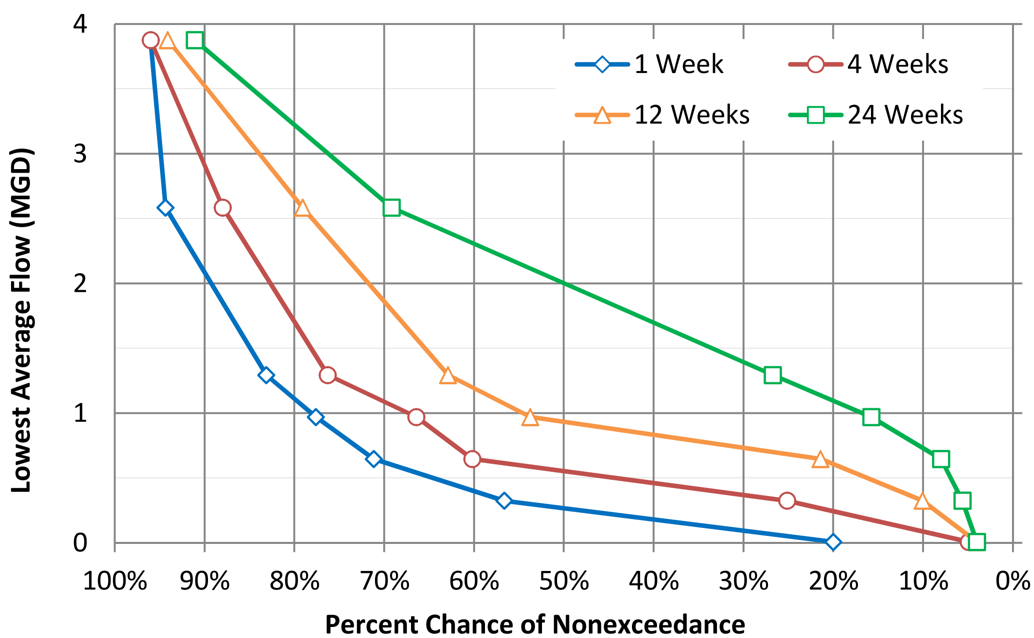
(2) Climatic year is April 1 - March 31.

Color Key	Range (MGD)	
	Min	Max
	0.0	0.6
	0.6	1.3
	1.3	2.6
	2.6	3.9
	>	3.9

Table 4a

Annual Low Flow Frequencies
Cherry Creek at Parker Gage (Adjusted) (1)
1992 - 2015
(MGD)

(2) Lowest Avg Flow (MGD)	Annual % Chance of Nonexceedance for Weekly Periods (3)								
	1	2	3	4	8	12	16	20	24
0.0	20%	9%	6%	5%	4%	4%	4%	4%	4%
0.3	57%	48%	33%	25%	14%	10%	9%	7%	6%
0.6	71%	65%	64%	60%	39%	21%	18%	13%	8%
1.0	78%	74%	67%	66%	64%	54%	29%	21%	16%
1.3	83%	77%	77%	76%	68%	63%	53%	39%	27%
2.6	94%	94%	92%	88%	83%	79%	73%	72%	69%
3.9	96%	96%	96%	96%	96%	94%	94%	93%	91%



Notes:

(1) The adjusted Cherry Creek flow was computed as the daily flow at the Cherry Creek at Parker gage (USGS) minus the daily Parker WWTP discharge to Sulphur Gulch minus estimated free river diversions to RHR prior to March 2010.
Daily Parker WWTP discharges for 1992 - 1996 were estimated as average 1997 flow.

(2) The above values represent the percent chance that in any year the lowest average flow for weekly periods of varying duration will not exceed a specified flow in MGD.
For example, there is a 21% chance that the average 12-week low flow will not exceed 0.6 MGD.

(3) Annual probabilities are based on a climatic year from April 1 - March 31.