2.0 CURRENT WATER SYSTEM

This section describes the District's existing potable water system. The purpose of this section is to describe the current water demands, the facilities available to meet the demands, the capacities of the existing facilities, and the identification of any deficiencies in the existing facilities that should be addressed with future projects.

There are three main components of the potable water system. The first component is the source of water. The District currently uses three main sources of raw water: groundwater pumped from a system of wells, exchange water from Monument Creek, and water from Lake Woodmoor (Lake) that is also used to store water from Monument Creek and some of the wells. The second main component is the water treatment plants that treat the raw water to meet potable standards. The last component is the distribution system that distributes the treated water to customers throughout the District. Each one of these components needs to be analyzed with respect to capacity and identify deficiencies in order to maintain a system that delivers high quality water in sufficient supply to customers.

2.1 CURRENT SYSTEM SUMMARY

The existing water system consists of 23 groundwater wells, one surface water diversion structure, one surface water/groundwater diversion structure, three abandoned wells, two centralized water treatment plants, individual treatment systems for Wells 8 and 11, raw water storage, a surface water exchange system, two booster pumping stations and three potable water storage tanks. Figure 2-1 depicts the overall system in schematic form. The water infrastructure map in Appendix G shows a map of the current overall water system. The water infrastructure map in Appendix G shows the future overall systems. The District is divided into four pressure zones as shown on Figure 2-1. Zone 1 is located at the northern end of the District and encompasses high elevations at the north end of the District. Zone 2, which is situated at lower elevations than Zone 1, lies directly south of Zone 1. Zone 3 is located southwest of Zone 2 and encompasses the lowest elevations of the three zones. Zone 4 is a small zone located to the east of the South Water Tank and encompasses elevations higher than the South Water Tank. The locations of the pressure zones are also shown in Appendix G.

The majority of the District's potable water is introduced to the District's distribution system after being treated by one of two water treatment plants. Water from Wells 9R, 10R, 12, 17, and 20 along with surface water from Lake Woodmoor and Monument Creek are treated at the South Water Treatment Plant (SWTP). Water from Wells 7, 15, 16, and 18 is treated at the Central Water Treatment Plant (CWTP). Wells 8 and 11 receive treatment at small localized treatment facilities that service each individual well. Water from Wells 2, 3A and 6, is discharged directly to the distribution system without filtration and after chlorination. Well 5 is discharged to Lake Woodmoor and there is an option to discharge Wells 7, 15, 16, and 18 to Lake Woodmoor, if desired.

The District operates 15 presently active Denver Basin wells and pumps water from Dirty Woman Creek Alluvium (DWC). The 15 Denver Basin wells include: five Dawson Aquifer Wells, two Denver Aquifer Wells, and eight Arapahoe aquifer wells. Additionally, Dawson Aquifer Wells 1, 4, 19, and Denver Aquifer 13 are drilled and could be operational if equipment was installed but they are currently offline. A summary of the District's existing and abandoned wells is presented in Table 2-1 below and Figure 2-2.

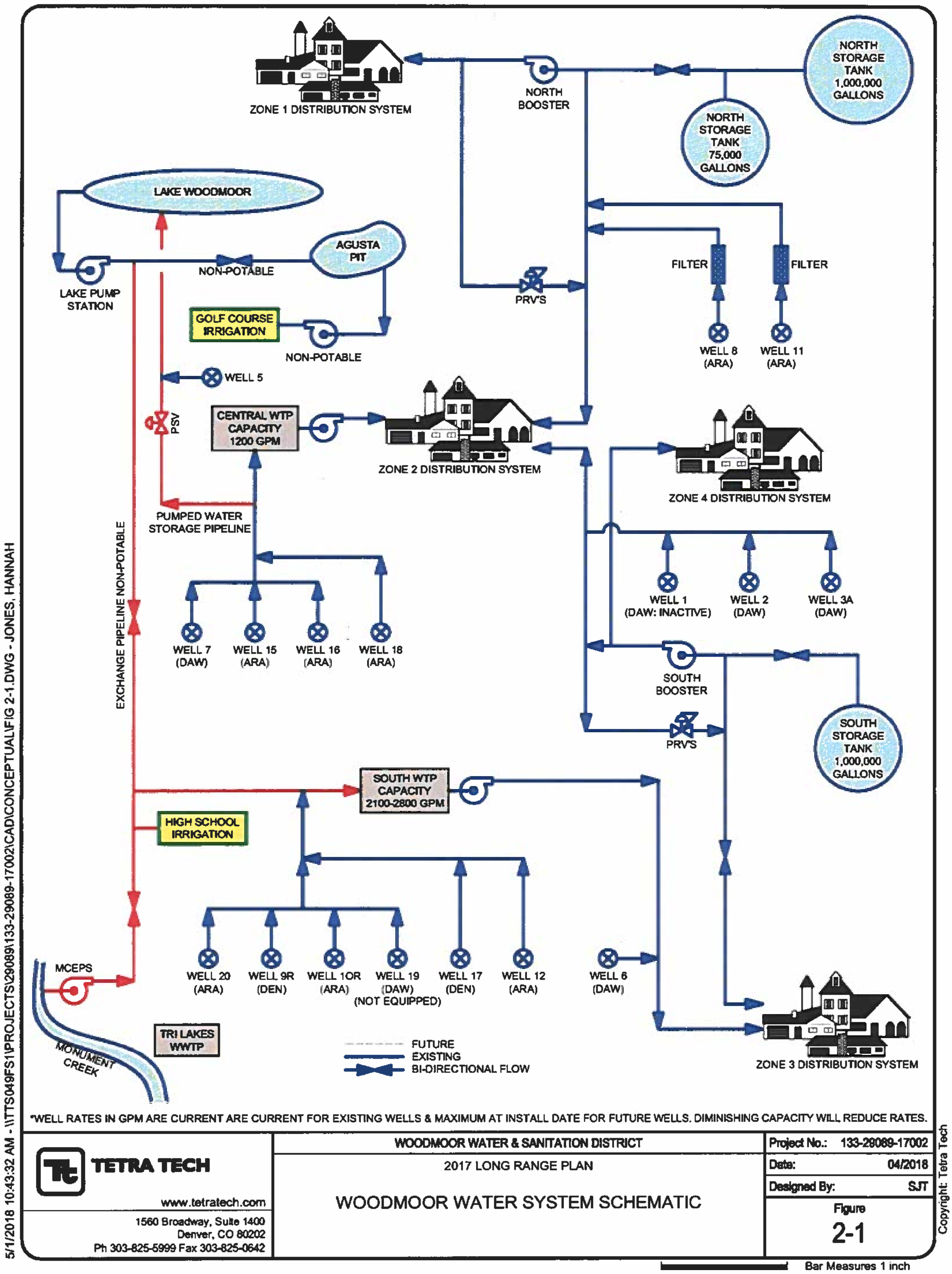


Figure 2-1 Woodmoor Water System Schematic

Table 2-1 District Well Summary

Well Number	Year Constructed	Aquifer	Operational Status	Permit Number
Qal-4	1990	Alluvium[1]	online	47155-F
Well 1	1963	Dawson	offline	4484-F
Well 2	1965	Dawson	online	9260-F
Well 3	1965	Dawson	abandoned	9259-F
Well 3A	1988	Dawson	online[2]	9259-R-F
Well 4	1965	Dawson	offline	9481-F
Well 5	1968	Dawson	online[2]	12278-F
Well 6	1962	Dawson	online[2]	3826-F
Well 7	1963	Dawson	online	4949-F
Well 8	1971	Arapahoe	online	16248-F
Well 9	1976	Denver	abandoned	21126-F
Well 9R	2001	Denver	online	21126-F-R
Well 10	1979	Arapahoe	abandoned [3]	24030-F
Well 10R	2001	Arapahoe	online	56480-F
Well 11	1986	Arapahoe	online	39116-F
Well 12	1990	Arapahoe	online	36098-F
Well 13	1992	Denver	offline [4]	40474-F
Well 14	1992	Denver	abandoned	41030-F
Well 15	1992	Arapahoe	online	41363-F
Well 16	1993	Arapahoe	online	42450-F
Well 17	1996	Denver	online	47103-F
Well 18	1998	Arapahoe	online	49574-F
Well 19	2001	Dawson	offline	55199-F
Well 20	2007	Arapahoe	online	64594-F

Notes:

1 Qal-4 pumps from DWC.

2 Wells 3A, 5 and 6 are online but reserved for emergency potable operation. Well 5 is also used to pump to Lake Woodmoor.

3 Well 10 was abandoned for production use, but was repermitted as a monitoring well.

4 Well 13 had grout in well screen upon installation.

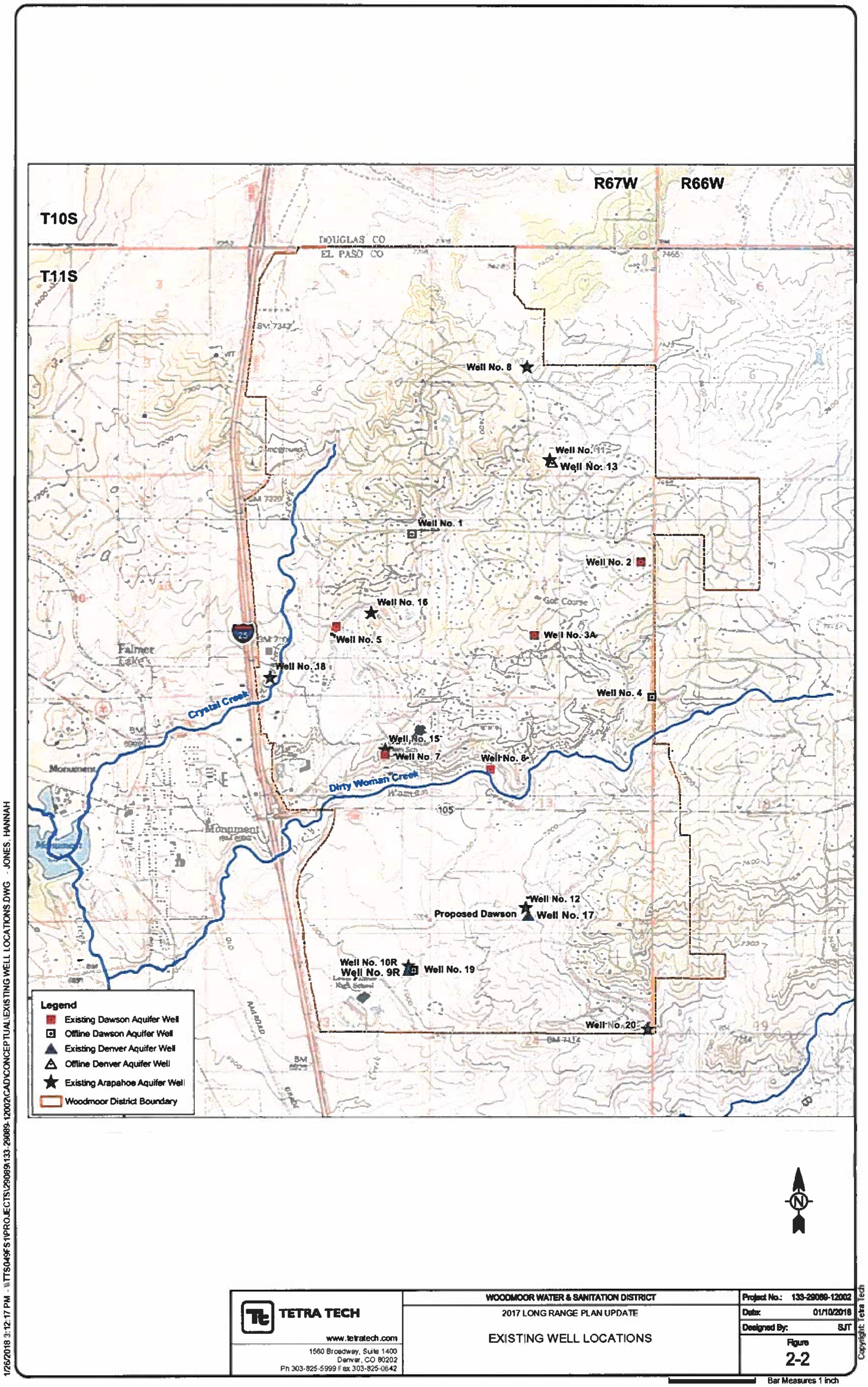


Figure 2-2 Existing Well Locations

Zones 1 and 2 mainly receive their water from the North Water Tank. Water from Wells 7, 15, 16, and 18 is delivered to the North Water Tank after treatment at CWTP. Water from Wells 8 and 11 is treated at the well site and delivered directly into the potable water distribution system. Zone 1 specifically receives water from North Tank via the North Booster Pumping Station (NBPS). In addition to receiving water from the North Water Tank, Zone 2 is fed by Wells 2 and 3A which are pumped directly into the system after chlorination at the well sites. Zone 3 is fed mainly by the south tank. Water from Lake Woodmoor, MCE, and Wells 9R, 10R, 12, 17, and 20 is treated at the SWTP and then delivered to the South Water Tank. All three zones are interconnected by pressure reducing valves (PRVs) that allow water from upper zones to feed lower zones during fire flow and peaking events. Water can also be transferred from lower zones to higher zones via the South Booster Pumping Station (SBPS) that connects the South and North Water Tanks. The SBPS also services Zone 4 via the South Booster Station; however, the large pumps used to transfer water from the south to the North Water Tanks are not used for pressure maintenance support of Zone 4, instead dedicated smaller pumps within the station are used to service Zone 4.

2.1.1 Water Demands and Water Use

The first step in evaluating the water system is to identify the water demand by the District's customers. It is essential that the water system is capable of meeting the demands of the customers now and as the District grows to its build-out population. This section analyzes the water demands since 2012 and compares the data to historical data to determine how water demand is changing over time. The current water demands are used to determine build-out water demand projections and to size future facilities.

For the 2017 Update, water usage data was analyzed from January 2012 through December 2016. The average monthly well production for each month over the period is presented in Table 2-2.

The analysis used daily usage data from the District's supervisory control and data acquisition (SCADA) system. The main goal of the analysis was to evaluate key historical parameters that can be used to predict future water demands. This analysis included evaluation of demand with and without unbilled water. Unbilled water includes; water used for backwash of treatment filters (process water), meter inaccuracies, system leaks, unmetered uses, fire hydrant flows, and any other unaccounted for water. Table 2-3 below presents the results for the data analysis to determine important water system parameters.

Table 2-2 Monthly Well Production Data

Month	2012		2013		2014		2015		2016	
	Total Production (MG)	Average Daily Demand Per SFE (gpd/SFE)	Total Production (MG)	Average Daily Demand Per SFE (gpd/SFE)	Total Production (MG)	Average Daily Demand Per SFE (gpd/SFE)	Total Production (MG)	Average Daily Demand Per SFE (gpd/SFE)	Total Production (MG)	Average Daily Demand Per SFE (gpd/SFE)
Jan	18	145	14	116	17	139	14	117	16	128
Feb	18	158	12	100	13	105	13	109	15	119
Mar	21	170	13	111	14	116	14	115	16	125
Apr	11	86	14	118	16	133	15	121	15	122
May	31	258	27	228	24	196	17	136	19	150
Jun	47	395	43	355	39	322	28	230	34	265
Jul	43	359	37	306	35	289	32	262	41	326
Aug	40	334	33	273	29	242	35	287	36	279
Sep	32	267	26	214	29	239	35	280	32	253
Oct	17	146	20	167	21	170	24	197	23	183
Nov	14	115	15	128	13	104	16	127	17	129
Dec	14	113	17	144	13	107	16	126	17	133
Total	306	212	272	188	263	180	260	176	281	184

Table 2-3 Water Demand Analysis Summary

Parameter	Total Demand With Unbilled Water		Demand Per SFE With Unbilled Water		Total Demand Without Unbilled Water		Demand Per SFE Without Unbilled Water	
January 2002 – December 2016								
Average Annual	1,023	Acre-ft/yr	258	gpd/SFE	946	Acre-ft/yr	238	gpd/SFE
Max Annual	1,273	Acre-ft/yr	362	gpd/SFE	1106	Acre-ft/yr	322	gpd/SFE
Min Annual	798	Acre-ft/yr	176	gpd/SFE	798	Acre-ft/yr	176	gpd/SFE
Max Month	187	Acre-ft/mo	653	gpd/SFE	187	Acre-ft/mo	586	gpd/SFE
January 2006 – December 2016								
Average Annual	1,000	Acre-ft/yr	237	gpd/SFE	937	Acre-ft/yr	218	gpd/SFE
Max Annual	1,273	Acre-ft/yr	310	gpd/SFE	1,106	Acre-ft/yr	270	gpd/SFE
Min Annual	798	Acre-ft/yr	176	gpd/SFE	798	Acre-ft/yr	176	gpd/SFE
Max Month	207	Acre-ft/mo	597	gpd/SFE	207.4	Acre-ft/mo	557	gpd/SFE
January 2012 – December 2016								
Peak Day	2.04	MGD	619	gpd/SFE	2.04	MGD	619	gpd/SFE

The most important number determined from this demand analysis is the system demand (demand including unbilled water) on a per SFE basis. Water use tends to fluctuate over time on a per SFE basis; therefore, for planning purposes, as much data as possible should be considered, not just the most recent data. Previous LRPs used the following rationale for determining the average water demand per SFE. The average monthly demand including all of the months from the previous LRP (in this case 2002 through 2016, 258 gpd/SFE should be used and averaged with the previous average use value in the previous LRP updates (the 2006 Update used 314 gpd/SFE and the 2012 Update used 305 gpd/SFE). **Using this rationale the planning level average annual demand per SFE is 293 gdp/SFE.**

Another goal of the data analysis was to determine how water is used throughout the District. The amount of unbilled water is a helpful indicator of how water is used by the District. The amount of unbilled water averages approximately 15% of the total water production. On average, 8% of the total water produced is used for process water and the remaining 7% is used for distribution flushing, fire hydrant use, meter inaccuracies, and other unaccounted for water loss. The 7% category of billed minus process water shows that the District has maintained good water management practices by finding and fixing leaks and optimizing distribution flushing. The District should strive to maintain this percentage as a goal in the future.

The amount of irrigation water used by the District was also evaluated by comparing the summer water demand with the winter water demand for the period of January 2012 through May 2017. The difference between summer and winter water demand is considered to be the irrigation demand. For the irrigation analysis, April and October were considered to be neither summer nor winter. During these two months, only a portion of the population uses water for irrigation which, skews the average results. The average winter water demand is considered to be equal to the average domestic water demand without outdoor irrigation. Table 2-4 summarizes the total water use for summer and winter months and Table 2-5 shows the average water use distribution throughout the year on a monthly basis. The irrigation demand does not include golf course or high school irrigation. This irrigation demand is assumed to be supplied from Lake Woodmoor and the exchange system.

The average irrigation use for the District from 2012 through 2017 is approximately 31% of the total water produced for the District throughout the year. The irrigation use has increased by approximately 1% since the 2012 Update. The irrigation demand percentage is similar or slightly less than typical values for urban areas along the Front Range of Colorado. The irrigation use can vary greatly from day to day depending on the weather conditions and day of the week. During dry periods more water is used than during wet periods.

Table 2-4 Total Water Use Evaluation Summary (2002-2016)

		Complete Year	Summer Months (May-Sept)	Winter Months (Nov-Mar)
Total Monthly Water Billed (MG)	Average	25	32.96	15
	Max Day	61	47	21
Total Monthly Water Produced (MG)	Average	27	32.96	15
	Max Day	68	47	21
Billed Water Use per SFE (gal/SFE/day)	Average	182	270	124
	Max Day	395	395	170
Total Water Use per SFE (gal/SFE/day)	Average	182	270	126
	Max Day	395	395	178

Table 2-5 Water Use Summary (2006-2016)

Month	Average Water Billed (Acre-ft/Mo)	Average Water Produced (Acre-ft/Mo)	Average Water Billed (gal/SFE/ay)	Average Water Produced (gal/SFE/day)	Average Monthly Percent of Annual Water Produced
Jan	53	62	151	177	6.06%
Feb	47	52	142	157	5.09%
Mar	51	56	143	158	5.48%
Apr	51	58	147	167	5.68%
May	83	89	237	254	8.77%
Jun	130	136	376	392	13.31%
Jul	133	134	380	382	13.16%
Aug	111	118	311	330	11.56%
Sep	104	109	294	311	10.70%
Oct	76	82	216	232	8.00%
Nov	61	68	179	198	6.63%
Dec	51	57	142	158	5.56%
Jan, Feb, Mar, Nov, Dec Average	53	57	152	170	5.76%
May, Jun, Jul, Aug, Sep Average	112	117	320	334	11.50%
Apr, Oct Average	63	70	181	199	6.84%
Average Irrigation Demand Percentage		31%			

2.1.2 Peaking Factors

The most important water system evaluation parameter is the peak day factor or the ratio of peak day water demand to average day water demand. This peaking factor is used for the design of treatment facilities, distribution system storage, water production needs, and other water infrastructure based on the peak day supply requirements.

A statistical analysis was performed on the daily demand data from 2012 through April 2017. A distribution histogram was prepared illustrating the probability distribution of peak day factors observed in the data. This analysis was performed to determine how often the District has encountered the various peak day factors over the period analyzed and to evaluate the probability of "back to back peak day events" occurring (i.e. 2-day moving average). The probability histogram is shown in Figure 2-3. The highest peak day factor observed was 2.5, which is within range of previously estimated peak day factors. More importantly, this analysis noted that this peak occurred twice within the period of analysis.

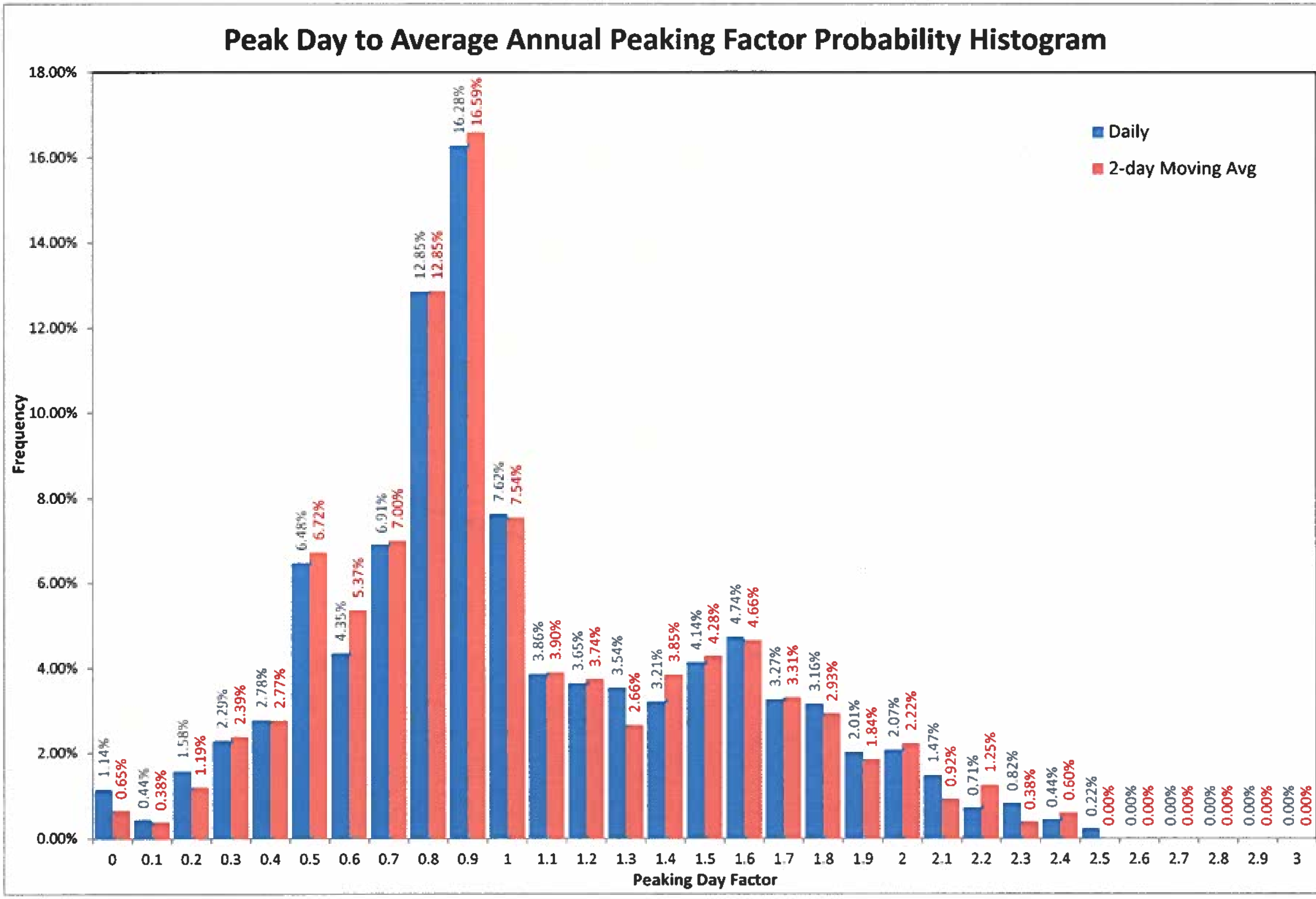


Figure 2-3 Probability Histogram

According to the SCADA data, the minimum amount of water storage in the system is 1.2 million gallons (MG., Using this information, the water storage data can be coupled with water use data to create different scenarios. For example, the maximum 30-day moving average can be coupled with the minimum storage and assumed treatment capacities to model and determine whether there is adequate treatment and storage capacity. In order to determine the design peak day factor while taking into account water storage, a scenario was derived to simulate one of the filters inside SWTP out of service, using the maximum 30-day moving average, and beginning with the minimum water storage in the system of 1.2 MG. The scenario assumed that the maximum plant capacity was available (which is the average annual demand multiplied by the peaking factor). When the actual demand was higher than the maximum plant capacity, the water level in the storage tank dropped, and when the actual demand was less than the maximum plant capacity water was added to storage until the storage tanks were full (at 2 MG). Figure 2-4 depicts the results of the water storage analysis under this scenario using various peaking factors.

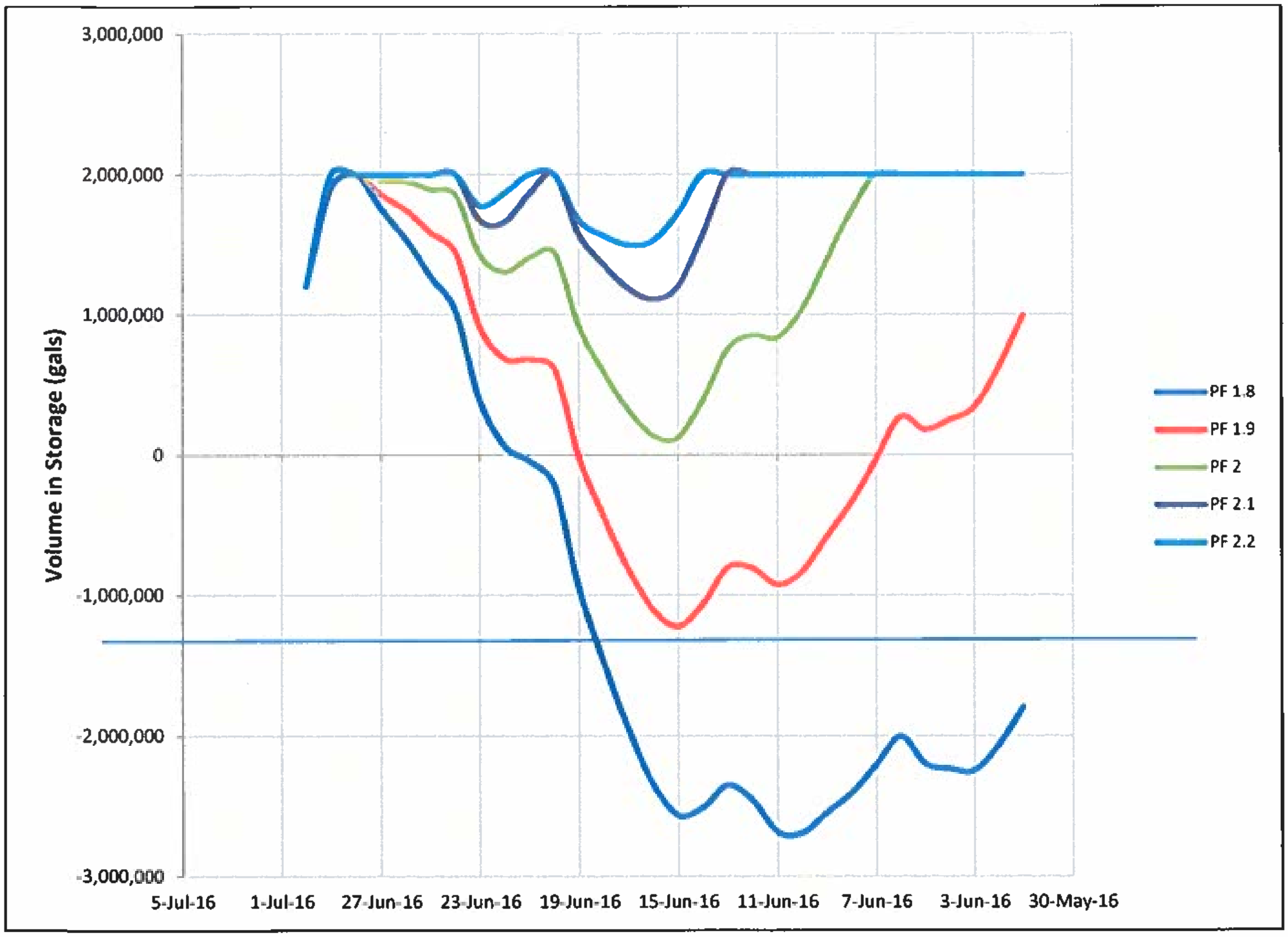


Figure 2-4 Peak Day Scenario and Water Storage to Determine Peaking Factor

As shown in the figure, the peaking factor has significant impact on the volume of water needed in storage. A lower peaking factor assumes a lower water treatment plant size; however, more storage would be required. Based on this analysis it appears that less conservative approach can be taken for choosing a peak day factor to size a water plant. A peak factor of 2 or less does not provide enough treatment capacity without adding more storage as is evident by the system dropping below or very close to zero, which would indicate the system was out of water. The peak day factor of 2.1 appears to allow a manageable (approximately 50%) dip in storage with adequate recovery. Higher peaking factors can be used to minimize the amount of storage required. **A peak day factor of 2.1 will be used for this Update, which is a reduction from the 2.2 peak day factor used in the 2012 LRP.** Future updates should perform a similar analysis to confirm that reductions in peak day continue. A goal of this Update is to develop Indirect Potable Reuse while continuing groundwater supply expansion requirements as neeped. For this LRP, the District would benefit more by building more storage than building more treatment plant capacity.

2.1.3 Water Conservation

In 2010, the District prepared and adopted a water conservation plan that identifies approaches to water conservation. The water conservation plan includes the following water conservation measures and programs:

- Rebate program for low flow and low water use fixtures and appliances
- Demonstration garden and dissemination of information regarding xeriscape landscaping
- Mandatory Outdoor Watering Schedule for customers using both days of week and hours of the day for watering during the summer
- Water metering with an increasing tiered rate structure

The majority of the District's water conservation programs are targeted for reducing peak day irrigation demand in the summer. The Mandatory Outdoor Watering Schedule set in place for June 1 through September 30 designated watering times and days when watering is acceptable as well as outlining watering type allowances. The Schedule also mandates warnings, fines and flow restrictions for violations. This allows the District to reduce peak day and regulate water use for irrigation, an area that typically consumes around 30% of water demand.

2.1.4 Peak Demand Management

As a part of the water conservation program, the District implemented a volumetric watering schedule that tells customers what days of the week they should water. One of the major impacts that a watering schedule has is that it can spread out the peak demand. Peak day demands typically occurred when customers watered on the same day (typically after a hot day). The schedule spreads out when customers water so that only half of the District's customers water on any given day (theoretically). This type of water scheduling has become popular because it is easy to implement. Most customers comply with watering schedule by simply setting their automatic irrigation controller.

Since the District implemented water scheduling for peak demand management, the peak day factor has been reduced. The peak day factor prior to the peak management program was 2.9, which has since been reduced to 2.1. This shows a large decrease in the peaking factors. The second highest peak day factor was 2.4 indicating that the one 2.5 peak day event was significantly higher than any other peak day event. It is important to monitor the occurrence distribution to measure the effect of demand management on the peaking factor. The distribution frequency of the highest peak day factors dropped from the 2012 LRPso that there is only a 1.48% chance the peak day is greater than 2.2 (as shown in Figure 2-3).

2.2 WATER RESOURCES

Currently, the District utilizes two water supply sources. First, ground water is supplied by wells from the Denver Basin Aquifers. The second supply is from surface and shallow ground water diversions on Monument Creek and Dirty Woman Creek that occur via an exchange system and reusable outdoor use return flows. The exchange system is based on the District's contribution of wastewater to the TLWWTF, where it is treated and discharged into Monument Creek. The average distribution of these water supply sources are combined to meet District water demand as shown in Figure 2-5 below:

As shown in Figure 2-5 and summarized annually in Table 2-6, the majority of the District's water is provided by the Denver Basin Aquifers. These aquifers consist of the Dawson (shallowest), the Denver, the Arapahoe, and the Laramie-Fox Hills (deepest) aquifers. The District owns water rights in each of the four aquifers and owns and operates wells in the Dawson, Denver, and Arapahoe aquifers. Of these, the Arapahoe aquifer provides the majority of the District's Denver Basin ground water.

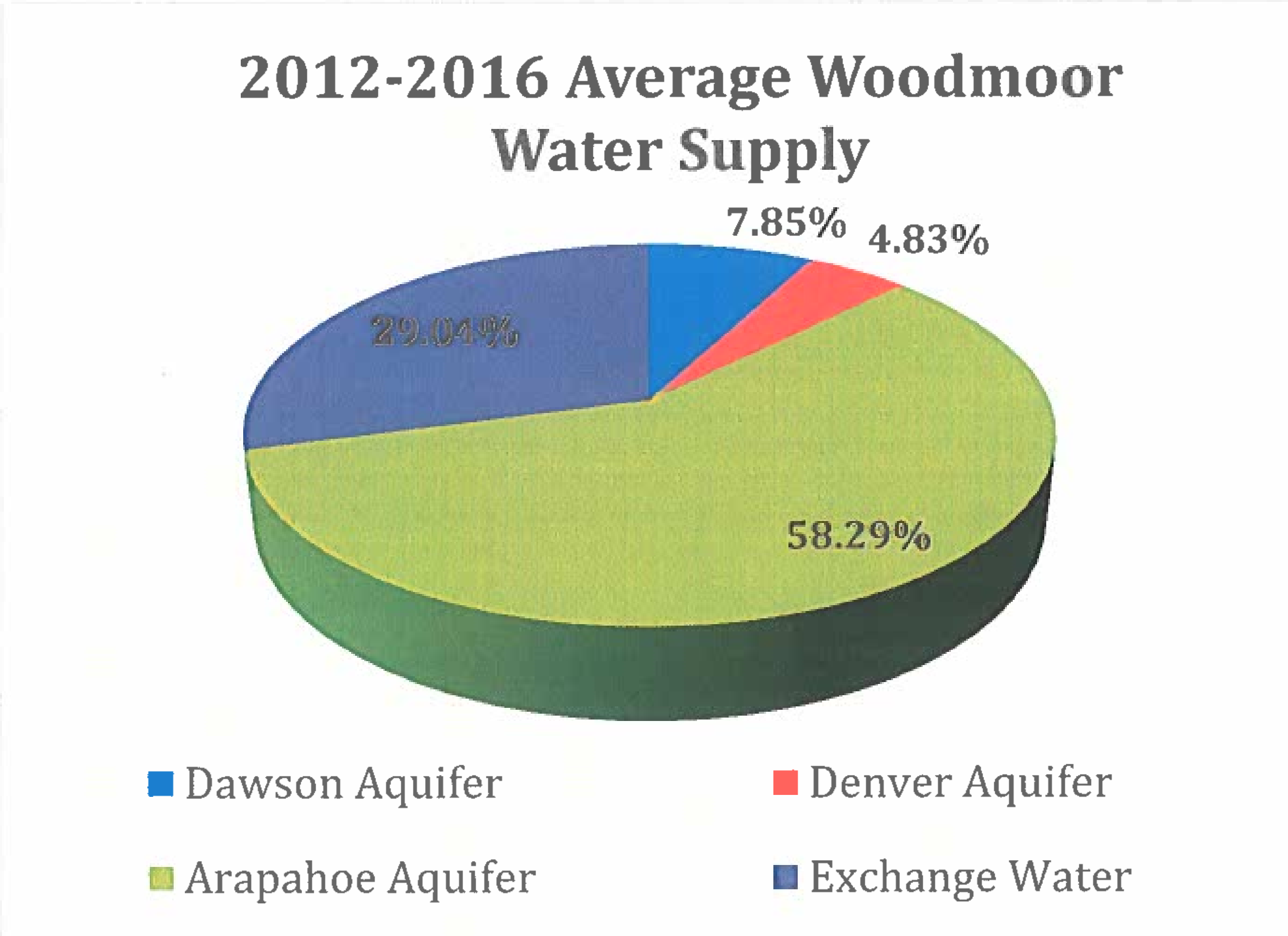


Figure 2-5 Woodmoor Water Supply

Table 2-6 Water Supply Source Summary

Year	Water Supply Source Dawson (af)	Denver (af)	Arapahoe (af)	Exchange (af)	Total (af)
2012	105	73	950	329	1457
2013	119	59	820	365	1364
2014	90	93	569	479	1231
2015	81	4	551	307	942
2016	89	69	708	312	1177

The most significant change in water supply between the 2012 LRP Update and this LRP is a reduction in average Arapahoe aquifer water level decline rates from 23 feet per year (ft/yr) in the 2012 LRP to 16 ft/yr in the 2017 LRP.

2.2.1 Existing Wells

The District has 23 Denver Basin wells: 15 are online, four are abandoned, and four are offline. The District has also constructed one shallow ground water diversion on DWC that is permitted as an alluvial well and is also online. A summary of the District's wells is presented in Figure 2-2 and Table 2-1.

The 15 online Denver Basin wells are constructed in the Dawson, Denver, and Arapahoe aquifers. Wells 2, 3A, 5, 6, and 7 withdraw water from the Dawson aquifer; Wells 9R and 17 withdraw water from the Denver aquifer; and Wells 8, 10R, 11, 12, 15, 16, 18, and 20 withdraw water from the Arapahoe aquifer. Operational pumping rates, current pump setting depths, and the date of last maintenance for the online Denver Basin wells are summarized in Table 2-7.

Table 2-7 Existing Well Pump Summary

Well Number	Top Screen (ft)	Bottom of Well (ft)	Current Pump Setting Depth (ft)	VFD Installed	Can Pump to Lake Woodmoor	Peak Pump Rate (gpm)	Last Pump Service/Maint Date
Qal-4	-	-	-	-	yes	-	-
Well 1	360	846	-	-	-	-	-
Well 2	496	1011	760 [1]	no	no	30	Oct 2006
Well 3	390	1123	-	-	-	-	-
Well 3A	620	1100	1036 [2]	no	no	-	-
Well 4	400	1126	-	-	-	-	-
Well 5	395	800	714 [2]	no	yes	30	-
Well 6	230	800	727 [2]	no	no[3]	30	Jan 2013
Well 7	275	818	605 [1]	no	yes	65	Nov 2011
Well 8	2074	2500	1945 [1]	no	no	50	May 2016
Well 9	641	1130	-	-	-	-	-
Well 9R	987	1319	1198 [2]	yes	no	120	May 2008
Well 10	1100	1765	-	-	-	-	-
Well 10R	1362	1809	1754 [1]	yes	no	325	Apr 2014
Well 11	1920	2500	2300 [1]	no	no	210	Mar 2016
Well 12	1410	1927	1756 [1]	yes	no	300	Apr 2014
Well 13	918	1438	-	-	-	-	-
Well 14	804	1349	-	-	-	-	-
Well 15	1300	1874	1794 [1]	yes	yes	200	Jul 2017
Well 16	1397	1907	1782 [2]	no	yes	200	Aug 2016
Well 17	527	1352	1296 [1]	no	no	140	Aug 2011

Well Number	Top Screen (ft)	Bottom of Well (ft)	Current Pump Setting Depth (ft)	VFD Installed	Can Pump to Lake Woodmoor	Peak Pump Rate (gpm)	Last Pump Service/Maint Date
Well 18	1374	1859	1771 [1]	yes	yes	250	Aug 2017
Well 19	200	616	-	-	-	-	-
Well 20	1300	1892	1804 [1]	yes	no	300	Oct 2014

Notes:

- Peak pump rate and date of last pump service/maintenance are current as of August 2017

[1] Pump setting depth based on pump intake depth.

[2] Pump setting depth based on airline setting depth because more specific data unavailable.
VFD = variable frequency drive.

[3] Woodmoor has plans to retrofit piping so that Well 6 can be pumped to Lake Woodmoor during the non-irrigation season and to the golf course during the irrigation season.

The abandoned Denver Basin wells include Wells 3, 9, 10 (permitted for water level monitoring only) and 14. Wells 3, 9, and 10 were redrilled as Wells 3A, 9R, and 10R, respectively. Well 14 was abandoned due to low yield.

The offline Denver Basin wells include Wells 1, 4, 13, and 19. Well 1 is constructed in the Dawson Aquifer and has a history of high iron concentrations and a yield of 20 to 40 gpm. In the future, Well 1 may be pumped to Lake Woodmoor to supplement the District's water supply and minimize water quality considerations through blending in the lake. Cleaning and rehabilitation may be necessary before operating Well 1 on a long-term basis. Well 4 is constructed in the Dawson aquifer. Current yield for Well 4 is unavailable; however, a yield of 55 gpm was reported when the well was constructed in 1965; current yield would likely be much lower. Well 13 is constructed in the Denver Aquifer and during construction cement grout entered the screened portion of the well. Despite improper construction, a yield of 50 to 75 gpm may be achieved from Well 13 based on 1992 pumping test data; however, these results are questionable. The well would need to be video surveyed, cleaned, and tested prior to equipping the well with permanent pumping equipment. Additional rehabilitation of Well 13 to remove grout from the well screens may enhance yield but may not be cost-effective. Well 19 is constructed to the Dawson Aquifer and has a yield of up to approximately 25 gpm, based on 2001 pump test data when the well was constructed. Currently, these four offline wells have no pumping equipment installed and would require installation of equipment prior to use. Additionally, down-hole video surveys and pumping tests should be completed to confirm surficial conditions of the well structure and current achievable yields. Well maintenance and rehabilitation may also be required.

Eight of Woodmoor's Denver Basin wells are beyond their expected usable lifespan of 25 to 30 years and as a result, well failure would not be unexpected. Offline Woodmoor wells that were constructed more than 30 years ago include: Wells 1 and 4. Online Woodmoor wells that were constructed more than 30 years ago include: Wells 2, 5, 6, 7, 8, and 11. Wells 3A, 12, 13, and 15 were constructed between 25 and 30 years ago.

2.2.1.1 Water Levels and Diminishing Capacity

Historical water level measurements in the District's Denver Basin wells have been collected at regular intervals to monitor changes in aquifer conditions, seasonal water level fluctuations, well performance, and well maintenance needs; and to properly size replacement pumping equipment. Based on collected water level measurements, regional water level decline rates in the Dawson, Denver and Arapahoe aquifers have been observed and quantified. These water level declines are expected because regional Denver Basin well pumping exceeds recharge. Predicting future water level changes is uncertain in the Denver Basin due to complex interbedded geology and fluctuating regional Denver Basin well pumping. For the purposes of this evaluation, future water level decline was projected to be linear. However, as the top of the aquifer transitions from confined to unconfined conditions, regional water level decline rates are expected to slow in some circumstances. The projections do not account for any decrease in regional water level decline rate as the aquifer transitions from confined to unconfined.

Peak pumping by the District and neighboring users during the irrigation season results in well-to-well impacts. These impacts result in a substantial seasonal water level decline, most of which recovers after the irrigation season. Accordingly, water levels are typically higher during the beginning of the irrigation season relative to late in the irrigation season. For this analysis, linear regional water level decline rate projections generally rely on historical beginning of irrigation season water levels and yield projections simulate additional irrigation season water level decline. The estimated regional water level decline rates were used to project the dates at which the static water level would reach the top well screen and halfway through the production zone in each of the District's online wells, presented in Table 2-8. Hydrographs for each of the District's Denver Basin wells are presented in Appendix B.

Table 2-8 Summary of Water Level Declines in the District's Basin Wells

Well Number	Estimated Ground Water Level Decline Rate	Static Ground Water Level at Top of Screen		Static Ground Water Level through Half of Production Zone	
	(ft/yr)	Date	Years from Oct 2017	Date	Years from Oct 2017
Dawson Aquifer					
Well 2	4.2	Jan 2033	15.3	Apr 2094	76.5
Well 3A	7[1]	Nov 2039	22.1	Jan 2072	54.3
Well 5	3	Apr 2074	56.5	Sep 2141	123.9
Well 6	7	Jul 2009	-8.3	Apr 2050	32.5
Well 7	11	Jul 2024	6.7	Mar 2049	31.4
Average	6.4	Mar 2036	18.5	Jun 2081	63.7
Denver Aquifer					
Well 9R	15	Dec 2017	0.2	Jan 2029	11.3
Well 17	2[2]	Dec 2033	16.2	May 2236	218.6
Average	8.5	Dec 2025	8.2	Aug 2132	114.9
Arapahoe Aquifer					
Well 8	21[3]	Dec 2032	15.2	Jan 2043	25.3
Well 10R	18	May 2028	10.6	Nov 2039	22.1
Well 11	18	Mar 2030	12.4	Jul 2043	25.7
Well 12	10	Oct 2032	15.0	Sep 2053	35.9
Well 15	18	Apr 2014	-3.5	Sep 2029	11.9
Well 16	15	Sep 2020	2.9	Jul 2037	19.7
Well 18	21	Oct 2018	1.0	Oct 2029	12.0
Well 20	12	Jun 2023	5.7	Feb 2048	30.3
Average	16.0	Feb 2025	7.4	Aug 2040	22.9

Well Number	Estimated Ground Water Level Decline Rate	Static Ground Water Level at Top of Screen		Static Ground Water Level through Half of Production Zone	
	(ft/yr)	Date	Years from Oct 2017	Date	Years from Oct 2017

Notes:

- * 2017 static ground water depth at the beginning of the irrigation season based on interpolated water level data for March 31, 2017
- * Water level decline rates based upon linear fit of historical static water level data provided by the District. Additional numbered notes provided below.
- * Years from October 2017 static water level at top screen and halfway through production zone based upon linear fit of historical water level data and do not reflect possible changes in well operation and are not based upon modeling.
- * Maximum pumping ground water depths are based upon projected ground water level at the beginning of the irrigation season, as described in the numbered notes below.

[1] Recent water level data not available; based on historical data.

[2] Based upon water level data during 2011 - 2017. Prior water level trends indicated a greater decline rate of 12 ft/yr.

[3] Limited recent water level data; not included in aquifer average.

The estimated static water level decline rate in the Dawson aquifer ranges from 3 to 11 ft/yr with an average of 6.4 ft/yr, shown in Table 2-9. The Dawson formation outcrops within the District and the surrounding area. Accordingly, the Dawson aquifer may benefit from greater recharge rates relative to the other Denver Basin aquifers beneath the District's boundary. From 2012 through 2016, the District pumped 7.9% of its ground water supply from the Dawson Aquifer. Future well yields from the Dawson Aquifer are anticipated to be near current pumping rates.

The estimated static water level decline rate in the Denver aquifer is approximately 8.5 ft/yr, shown in Table 2-9. Available water level data from Well 9R and Well 17 was relied upon to quantify the Denver aquifer static water level decline rate. The lower screens in Well 9R and Well 17 may have a hydraulic connection with the Arapahoe aquifer resulting in complex water level sensitivities. From 2012 through 2016, the District pumped 4.8% of its ground water supply from the Denver Aquifer. Future well yields from the Denver Aquifer are anticipated to decrease over time.

The estimated static water level decline rate in the Arapahoe aquifer ranges from 10 to 21 ft/yr with an average of 16.0 ft/yr, shown in Table 2-9. This average is based on available water level data from all of the District's Arapahoe Aquifer wells, excluding Well 8 which had limited water level data available. From 2012 through 2016, the District pumped 58.3% of its water supply from the Arapahoe aquifer. Due to declining water levels, future well yields from the Arapahoe aquifer are anticipated to be at or below current maximum yields.

Well yield depends upon available drawdown. Available drawdown is the difference between the static ground water level and the deepest practical pumping water level. As regional ground water levels decline, available drawdown decreases resulting in lower well yields. In addition, well-to-well impacts during the irrigation season reduce available drawdown late in the irrigation season. For example, projections indicate irrigation season well-to-well impacts may exceed 200 feet in centrally located Arapahoe aquifer wells by the end of the irrigation season in 2018. Since well-to-well impacts are cumulative, constructing additional wells in the Arapahoe aquifer will reduce yield from existing wells resulting in a diminishing return. However, based on current projections, strategically located new Arapahoe Aquifer wells will provide incremental yield increases to overall production.

Historically, well yields from the Arapahoe Aquifer have been adequate to meet peak summer demands. More recently, the District has implemented a conjunctive use program utilizing surface water from Monument Creek and storage in Lake Woodmoor to meet peak summer demands. This conjunctive use program has allowed the District to reduce stress on the Denver Basin aquifers and delay construction of additional Denver Basin wells that would otherwise be required to meet peak demands. Sustained use of surface water will continue to reduce stress on the District's Denver Basin water resources in the future, particularly to meet peak-day demands because surface water can be diverted at a higher rate from Lake Woodmoor than from the District's wells.

2.2.1.2 Monitoring

Complete records of both static and pumping water levels allow full evaluation of both aquifer water level decline rates and individual well operation. Trends identified from static water levels are used to project future well yields and plan for new District facilities. Pumping water levels are compared to pump setting depths to determine whether additional well yield could be achieved by lowering well pumps.

In 2004, the District established a minimum standard for Denver Basin water level measurements, which included pre-irrigation season and post-irrigation season static water level measurements from each well using an airline. Starting in 2006, pressure transducers connected to the District's SCADA system were installed in most of the Denver Basin wells at the time pumping equipment was pulled. Currently, seven wells are equipped with pressure transducers connected to the District's SCADA system, including Denver aquifer Well 17 and Arapahoe aquifer Wells 10R, 11, 12, 15, 16, 18, and 20. The District's SCADA system is set up to record hourly water levels and pumping rates electronically from these wells. Automated water level monitoring equipment is strongly recommended for all of the District's Denver and Arapahoe aquifer wells. Hourly pressure transducer data is of higher resolution relative to the District's manual airline measurements and allows the District to make more informed decisions regarding pump sizing, the need for new wells and optimizing existing facilities. Storing the SCADA data in a secure and retrievable place is important in order to utilize the data for future decision making.

In addition to the continued collection of SCADA ground water level and pumping rate data in the District wells that are outfitted with transducers, BBA recommends the following schedule for airline measurements of ground water levels in District wells:

- Wells 2, 3A, 5, 6, and 7 (no transducer):
  - Collect one pre-irrigation season (March through May) static (non-pumping) airline measurement after the well has been off for at least 30 days.
- Well 9R (no transducer):
  - Collect one pre-irrigation season (March through May) static (non-pumping) airline measurement after the well has been off for at least 30 days.
  - Following the static airline measurement, collect a pumping airline measurement after the well has been pumping for at least 24 hours and record the pumping rate at that time.
  - Collect one late-irrigation season (September through October) static (non-pumping) airline measurement after the well has been off for at least seven days.
- Wells 10R – 20 (if transducer is working):
  - Collect one pre-irrigation season (March through May) static (non-pumping) airline measurement after the well has been off for at least seven days.
- Wells 10R – 20 (if transducer is not working or data are suspect):
  - Collect one pre-irrigation season (March through May) static (non-pumping) airline measurement after the well has been off for at least 30 days.
  - Following the static airline measurement, collect a pumping airline measurement after the well has been pumping for at least 24 hours and record the pumping rate at that time.
  - Collect one late-irrigation season (September through October) static (non-pumping) airline measurement after the well has been off for at least seven days.

Typical peak pumping rates for Woodmoor's Denver Basin wells are summarized in Table 2-9 and range from 30 gpm for some Dawson aquifer wells to over 300 gpm for some Arapahoe aquifer wells. Recommended maximum pumping water levels are included in Table 2-9 that balance available well water level drawdown with well efficiency and pump setting depths.

Table 2-9 District Peak Operational
Pumping Rates and Maximum Pumping Water Levels

Well Number	Peak Pump Rate (gpm)	Last Pump Service/Maint. Date	Recommended Maximum Pumping Water Level: 2017 Beginning of Irrigation Season (ft)	2022 End of Irrigation Season
Well 2	30	Oct 2006	680[3]	680[3]
Well 3A	-	-	860[1]	860[1]
Well 5	30	-	598[1]	598[1]
Well 6	30	Jan 2013	542[2]	560[2]
Well 7	65	Nov 2011	525[3]	525[3]
Well 8	50	May 2016	1865[3]	1865[3]
Well 9R	120	May 2008	1118[3]	1118[3]
Well 10R	325	Apr 2014	1552[1]	1552[1]
Well 11	210	Mar 2016	2155[1]	2155[1]
Well 12	300	Apr 2014	1620[1]	1620[1]
Well 15	200	Jul 2017	1630[2]	1660[2]
Well 16	200	Aug 2016	1648[1]	1661[2]
Well 17	140	Aug 2011	885[4]	885[4]
Well 18	250	Aug 2017	1587[2]	1624[2]
Well 20	300	Oct 2014	1643[1]	1643[1]

Notes:

* Peak pump rate and date of last pump service/maintenance are current as of August 2017.

[1] Static water level is above the top well screen. Maximum recommended pumping water level is halfway between the top well screen and the bottom of the well, or halfway through the well screen if screen depths are known.

[2] Static water level is below the top well screen. Maximum recommended pumping water level dewaters 50% of the remaining saturated screens.

[3] Maximum recommended pumping water level is 80 feet above the pump setting depth.

[4] Well 17 static water level is above the top well screen. Halfway through the Well 17 screen is a depth of 786 feet. However, pumping water levels as deep as 900 feet have been operable for Well 17 in the past, and will continue to be acceptable in the future.

Historically, Woodmoor has "cycled" many of their wells with run times less than 24-hours. This practice can result in excessive pump and motor wear and sand production during start-up cycles. However, well cycling has been necessary to accommodate system demands.

2.2.2 Exchange System

The District's exchange system captures approximately 42% of the District's reusable effluent from the TLWWTF. The exchange system relies on the exchange of a percent of treated wastewater effluent from the TLWWTF for a percent of fully consumable native flow in Monument Creek and DWC. The exchange system includes the Monument Creek Exchange Pumping station (MCEPS) that diverts water from Monument Creek and pumps it to Lake Woodmoor and/or SWTP. Water can also be exchanged directly from DWC at the Augusta Pit within the limits of the District. The water from Augusta Pit can be pumped directly to the golf course for irrigation or it can flow by gravity to Lake Woodmoor. Water from Lake Woodmoor can flow by gravity to SWTP where it can be treated and sent to the distribution system for consumption. However, most of the water from Lake Woodmoor is typically pumped to the SWTP due to the siphon not working properly. Water from MCE and/or Lake Woodmoor can also be used directly for irrigation at Lewis-Palmer High School or the golf course. Lake Pump station is located near Lake Woodmoor and is intended to pump water to Augusta Pit for use at the golf course or to pump water from Lake Woodmoor to SWTP for treatment. A schematic of the exchange system is provided in Figure 2-6.

2.2.2.1 Current Operation

Currently, the reusable effluent relied upon for the exchange results from the District's use of Denver Basin groundwater, most of which can be reused and successively used to extinction. After the District pumps and uses the Denver Basin water, the water is discharged to Monument Creek via the TLWWTF. The exchanges are decreed water rights and operate in conjunction with the District's decreed augmentation plans and other decreed water rights. Pursuant to the District's water rights decrees, Woodmoor's effluent credits are limited to the daily minimum of the measured effluent discharge and 90% of calculated indoor water use (average November through March water system demand).

During the 2012-2016 period, the District averaged 845 acre-feet per year of effluent discharge from TLWWTF, of which an average of 607 acre-feet per year (72%) was claimed as fully-consumable effluent credit. (The amount of available reusable effluent credit may have been greater.) In the 2012-2016 period, an average of 358 acre-feet per year of the District's claimed effluent credit (59% of 607 acre-feet) was actually exchanged to Monument Lake or non-potable water uses via the MCEPS or exchanged via the diversion at DWC.

The exchange system is limited by the amount of natural flow in Monument Creek and DWC.During the spring and during storm events, there is typically adequate flow to exchange all of the effluent credits allowed; however, during other times of the year, the exchange can be limited by the amount of water in the stream. The MCEPS is currently another limiting factor for the exchange system. The current pumping station is capable of pumping all of the flow in the creek up to the maximum current pumping capacity of 1,000 gpm; however, there are times when the intake screens need to be backwashed or become plugged and need to be cleaned. When the intake screens are not operable the efficiency of the exchange system decreases. In addition to the mechanical efficiency of the MCEPS, the overall exchange efficiency is limited by the practical operational capacity.

BBA prepared a model of the exchange system to predict future yield as more effluent credits are available (refer to Section 3.2.4.1). To calibrate this model, the actual volume of water exchanged was compared to the amount of water available to be exchanged with limitations on available effluent credits. The District currently captures approximately 85% of the native water available for exchange. This overall system efficiency accounts for all mechanical and operational inefficiencies when native flow is available for exchange, but is not diverted.

2.2.2.2 Monument Creek Exchange Pump Station Operation

The MCEPS previously experienced limitations due to intake clogging. The previous LRP Water Capital Improvement Plan Project Sequence scheduled modification to improve efficiency for 2017, and has been completed to provide adequate intake capability to prevent future system clogging and return the pump station to normal operation.

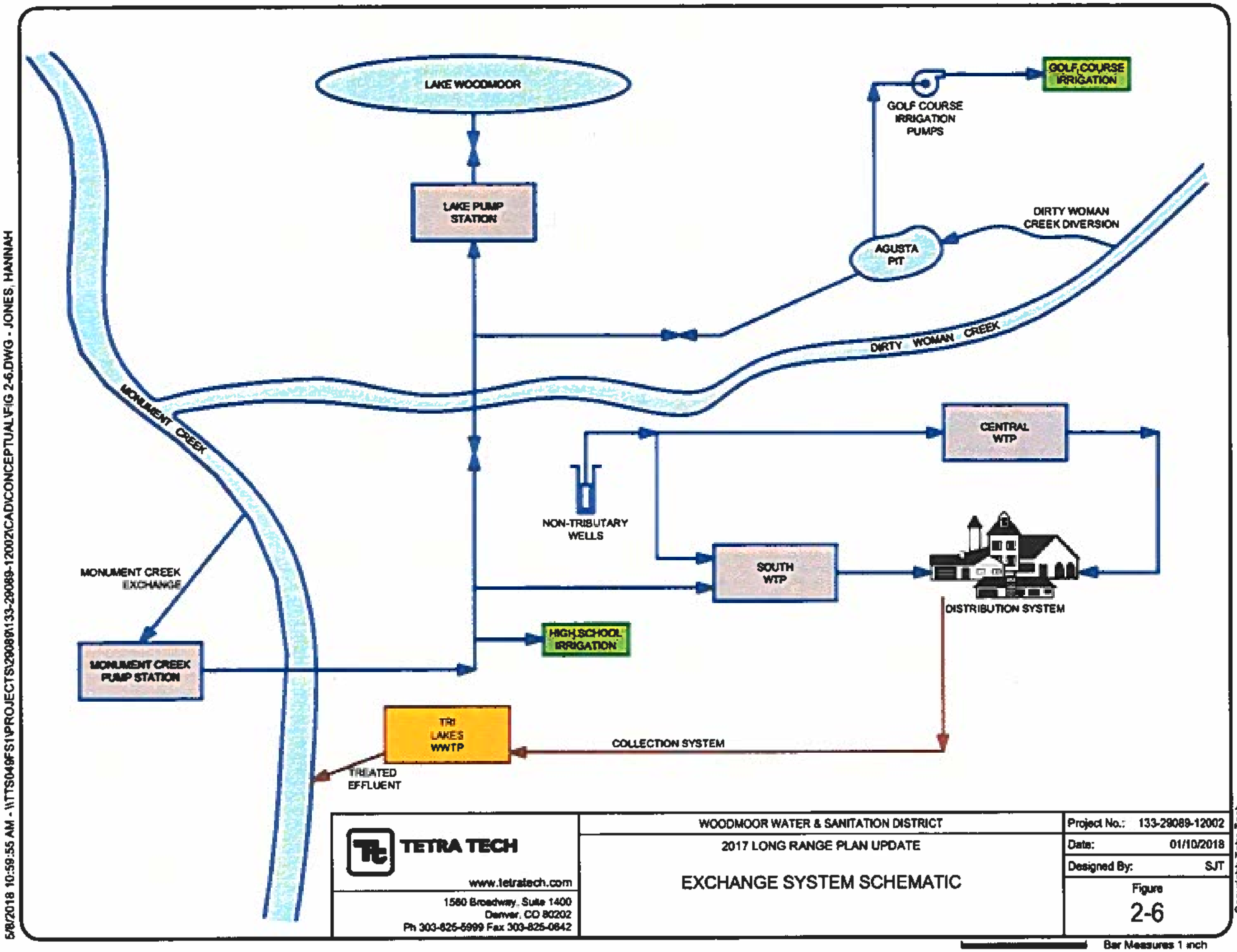


Figure 2-6 Schematic of The Exchange System

2.2.2.3 Lake Woodmoor Operation

The District currently relies on Lake Woodmoor to meet summer peak demands. The Lake is filled by the exchange system throughout the year when there is natural flow in Monument Creek or DWC. In the summer, water from the Lake is treated at SWTP and pumped into the distribution system. Raw water from the Lake is also sent directly to large irrigation customers (the golf course and Lewis-Palmer High School). It is anticipated that in general the water level in Lake Woodmoor will drop in the summer and will gain in the fall, spring, and winter. In addition to water from the exchange system, Wells 5, 7, 15, 16, and 18 can be pumped directly to the Lake to supplement exchange yield during dry years.

The District operates the Lake based on the expected loss or gain of water volume for each month. The exchange model is used to determine an "anticipated" loss or gain of water volume in the lake based on the average stream flow in Monument Creek. If the actual volume of water in the Lake for the year is higher than anticipated, no action is needed; however, if the volume in the Lake begins to fall short for the year, the operations staff can pump wells directly to the Lake to make up the difference between the actual exchange and anticipated exchange. This operation gives the District flexibility and more certainty that the Lake will have enough water to supply peak summer demands.

If there are multiple dry years in a row where the supplemental wells cannot maintain the water level in the Lake it is possible that the District will need to enact watering restrictions to curb peak demand in the summer irrigation season. By monitoring the volume in the Lake on a monthly basis, the District can predict whether watering restrictions would be required by April or May prior to the peak irrigation season. This affords the District ample time to prepare and enact watering restrictions. The modeling shows the chance of requiring watering restrictions to be approximately 5%.for any given year.

The need for additional wells is based on how many wells need to be dedicated to supplementing below average exchange yield by pumping water directly to the Lake. Tetra Tech updated the Lake Best Management Practices (BMP) Model to determine the need for new wells to ensure there is sufficient water in the Lake to handle peak summer demands. The BMP Model assumes that on average one well (15, 16, or 18) is pumped directly to the Lake on an average annual basis to supplement exchange yield during dry years. The model predicts end of summer lake levels based on the actual streamflow data from Monument Creek for a 20 year period.

2.2.2.4 Exchange Yield

The yield of the District's exchanges are subject to available native stream flows in Monument Creek and DWC. During low-flow periods, the District generates reusable effluent at a greater rate than available native stream flow. At other times, the District is unable to operate the exchange due to surface water taste and odor treatment challenges.

The historical yield of the District's exchanges is summarized in Table 2-10. The average monthly distribution of the District exchange yield is summarized in Table 2-11, and illustrates greater exchange amounts during November through May and lesser exchange amounts during the June through October irrigation season.

Table 2-10 Summary of Annual Exchange Yield 2012 - 2016

Year	Exchanged Water Available for Domestic Use (af)	Golf Course, High School Irigation, and Village Center Metro District (af)	Total Water Exchanged (af)
2012	191	138	329
2013	264	102	365
2014	367	113	479
2015	216	91	307
2016	198	114	312
Average	247	111	358

Notes:
Exchange water available for domestic use is equal to total water exchanged minus golf course, high school irrigation, and Village Center Metro District non-potable uses.

Table 2-11 Summary of Monthly Exchange Distribution (2012-2016)

Monthly Average	Monthly Average Exchange (af)	Golf Course, High School Irrigation, and Village Center Metro District (af)
Jan	41.4	0.3
Feb	42.1	0.2
Mar	46.1	0.4
Apr	48.0	1.7
May	42.2	7.5
Jun	16.9	20.4
Jul	15.2	26.8
Aug	16.0	21.9
Sep	9.2	20.6
Oct	5.8	10.4
Nov	32.4	1.0
Dec	42.9	0.0
Total	358	111

Notes:
Golf course, high school irrigation, and Village Center Metro District non-potable water uses are a subset of the monthly average exchange.

2.2.3 Supplemental Water Service

Supplemental water service is service above the District's 0.5 acre-ft/acre/year allocation policy. The total quantity of supplemental water available is derived from the difference in the District's decreed water rights and its water service commitments while maintaining compliance with both State of Colorado's 100-year rule and El Paso County's 300-year rule. It should be noted that the quantity of supplemental water projected for undeveloped land is less than the legal quantity calculated above due to practical economic considerations in the development and delivery of supplemental water service and Board policy regarding the sale of supplemental water.

As a result of the recession beginning in 2008, many supplemental water customers gave up their purchase of supplemental water. This means that there is supplemental water available compared to previous LRPs. The District's policy regarding the purchase of supplemental water has not been changed. As the District transitionsfrom a finite groundwater supply to a renewable surface water supply, the District's water allocation policies should be re-evaluated.

2.3 WATER RIGHTS

The District owns a portfolio of nontributary, not-nontributary and tributary Denver Basin water rights, a storage decree for Lake Woodmoor, and exchange rights to exchange reusable effluent and lawn irrigation return flows (LIRFS) on both Monument Creek and DWC. The District additionally has exchange rights for exchange of reusable effluent to the Monument Hills Country Club ponds and augmentation of ponds located within the District using fully consumable supplies, including LIRFs. Finally, the District owns senior direct diversion surface water rights on Fountain Creek that were changed for storage and municipal use in Case No. 12CW01 (Division 2) known as the "Ranch water rights". These senior Fountain Creek surface water rights include 58.0 shares (55%) of the Chilcott Ditch, 75% of the Liston and Love Ditch, 75% of the Lock Ditch, 75% of the Lock Ditch No. 2, and the Callahan Reservoir storage right. The Fountain Creek water rights are not yet used at the District.

2.3.1 Denver Basin Water Rights

The District's Denver Basin water rights include three statutory classifications of ground water, including tributary, nontributary and not-nontributary. The District's tributary Dawson aquifer water is replaced at 25% of pumping pursuant to a historical water rights decree. Nontributary ground water is defined as ground water that when withdrawn will not deplete the flow of a natural stream within one hundred years of continuous withdrawal "at an annual rate greater than one-tenth of one percent of the annual rate of withdrawal." Not-nontributary ground water is ground water located within the Denver Basin that does not meet the statutory definition of nontributary ground water. Decreed augmentation plans are required prior to pumping not-nontributary water in order to replace depletions both during pumping and after pumping has stopped. Prior to the statutory creation of not-nontributary water, the District decreed some of its Denver Basin water rights which resulted in a tributary classification for those water rights.

The District owns and has decreed in Water Court all of the Denver Basin water rights beneath its boundaries, except for limited reservations that account for historical wells owned by others. The District's Denver Basin water rights total approximately 7,390.5 acre-feet per year. Not all of the Denver Basin water rights are available for use, including: (1) nontributary water rights reserved for not-nontributary water rights post-pumping augmentation (POPA), and (2) not-nontributary water rights not included in a decreed augmentation plan. The POPA reserve is set aside for the District's future augmentation obligation as a result of current not-nontributary ground water pumping pursuant to Augmentation Plan II and is owed to Monument Creek and West Cherry Creek for a period of 200 years after pumping has ceased. Approximately 6,322.4 acre-feet per year of nontributary water is available to the District for use, summarized in Table 2-12. During the 2016 water year the District pumped approximately 865 acre-feet of Denver Basin ground water, or approximately 13.7-percent of Woodmoor's annual entitlement available for use.

Table 2-12 The District Decreed Denver Basin Water Rights

Item		Annual Entitlement (af/yr)
1	Tributary Water Rights	730.0
2	Not-Nontributary Water Rights	3,475.1
3	Nontributary Water Rights	3,185.4
4	**Total Denver Basin Water Rights**	**7,390.5**
5	Not-Nontributary Water Rights w/o Decreed Augmentation Plan	(625.1)
6	Nontributary Water Reserved for Post-Pumping Augmentation (POPA)	(443.0)
7	**Total Denver Basin Water Rights Available For Use**	**6,322.4**

Notes:

1 Total tributary water rights decreed in Case No. W-2647 (Division 2). The tributary water rights operate under an augmentation plan decreed in Case No. 80CW170 (Division 2).

2 Total not-nontributary water rights decreed in Case No. 81CW230 (Division 2), Case No. 02CW025 (Division 2) and Consolidated Case Nos. 07CW104 (Division 2) and 08CW263 (Division 1). The not-nontributary water rights decreed in Case No. 81CW230 (Division 2) total 2,850.0 af/yr (based upon a 100-year statutory aquifer life) and operate under an augmentation plan decreed in Consolidated Case Nos. 87CW067 (Division 2), 88CW100 (Division 2) and 88CW218 (Division 1). The District's other not-nontributary water rights are not included in a decreed augmentation plan and are not available for use.

3 Total nontributary water rights are decreed in Case No. W-2647 (Division 2), Case No. W-4544 (Division 2), Case No. 80CW169 (Division 2), Case No. 81CW231 (Division 2), Case No. 02CW025 (Division 2) and Consolidated Case Nos. 07CW104 (Division 2) and 08CW263 (Division 1).

4 Total Denver Basin water rights equals [1] + [2] + [3].

5 Not-nontributary water rights decreed in Case No. 02CW025 (Division 2) and Consolidated Case Nos. 07CW104 (Division 2) and 08CW263 (Division 1) total 625.1 af/yr (based upon a 100-year statutory aquifer life) and are not currently included in a decreed augmentation plan. Therefore, these water rights are not currently available for use.

6 Nontributary water rights totaling 443.0 af/yr (based upon a 100-year statutory aquifer life) are reserved for not-nontributary post pumping augmentation (POPA) requirements in Consolidated Case Nos. 87CW067 (Division 2), 88CW100 (Division 2) and 88CW218 (Division 1), which have been conservatively estimated based on the full use of Aug II NNT water rights. The POPA reserve is set aside for the District's future augmentation obligation as a result of current not-nontributary ground water pumping pursuant to Augmentation Plan II and is owed to Monument Creek and West Cherry Creek for a period of 200 years after pumping has ceased.

7 Total Denver Basin water rights available to the District for use equal [4] - [5] - [6]. Although the District has 6,322.4 acre-feet per year of Denver Basin water rights available for use, not all of this water can be consumed. Pursuant to the District's existing decrees, a percentage of pumped Denver Basin ground water must be relinquished to the stream system, including: 25% of pumped tributary water, 4% of pumped not-nontributary water, and 0% to 2% of pumped nontributary water, depending on the various water rights decrees. These relinquishments are typically achieved through assignment of waste water return flows.

Special provisions in some of the District's Denver Basin water rights decrees allow unused portions of the District's annual entitlement to be carried over for use in subsequent years, referred to as "banking" or "banked water"; however, the banking provision is not included in the District's older decrees. The banking provision takes effect once the Denver Basin water rights decree is signed by the water judge. After that time, any portion of the annual entitlement that is not pumped during a year is added to the "bank" of water available for pumping in any subsequent year. This banked water can be withdrawn in addition to the District's Denver Basin water rights annual entitlements discussed above. For example, through 2016 more than 22,880 acre-feet of Arapahoe aquifer water has been banked pursuant to Case Nos. 81CW231, 02CW025 and 07CW104 (Division 2), and 08CW263 (Division 1).

Despite declines in well yield, the Arapahoe aquifer is the most productive aquifer beneath the District. If all future demands are met solely with the District's decreed Arapahoe aquifer water rights, an unlikely and very conservative scenario, the decreed Arapahoe aquifer annual entitlement would be exceeded. However, Arapahoe Aquifer pumping meets less than 60% of the Distrcit's demand and there is no actual exceedance. Furthermore, banked Arapahoe aquifer water rights could meet projected District demand through at least 2049. Many new Arapahoe aquifer wells would need to be drilled to supply all of the District's demand through 2049 at considerable expense. Therefore, although the District has ample Denver Basin water rights entitlements to meet future demand, it is not cost effective to rely exclusively on this non-renewable resource as a permanent supply

2.3.1.1 County Water Supply Planning Requirements

El Paso County requires a 300-year water supply for subdivisions relying on Denver Basin ground water (300-year rule). The 300-year rule applies to subdivisions that did not have preliminary plan approval prior to November 20, 1986. The 300-year rule differs from the 100-year aquifer life period used by the State for Denver Basin water rights administration (100-year rule). Approximately 767 acres of the District's lands are subject to the County's 300-year rule. The remaining 2,816 acres of the District's lands were zoned prior to the effective date of El Paso County's 300-year rule and are subject to the State's 100-year rule. The District relies upon a planning value of 0.5 acre-feet per acre per year (af/ac/yr) for average in-district water demand. By applying a demand of 1.5 af/ac/yr to lands subject to El Paso County's 300-year rule and 0.5 af/ac/yr to lands subject to the State's 100-year rule, the estimated Denver Basin water rights annual entitlement needed to meet planning requirements totals 2,558.5 af/yr. Currently, the District's decreed Denver Basin water rights annual entitlement available for use totals 6,322.4 af/yr; therefore, even before the inclusion of banked water, the District has an excess of 3,763.9 af/yr of Denver Basin water rights annual entitlement available for future water commitments.

2.3.2 Effluent Credits

The District may use, reuse, and successively use a portion of their pumped Denver Basin ground water. Reuse water occurs as fully consumable effluent and LIRFs. Methodology to determine the District's fully consumable effluent is provided in the District's decreed augmentation plan in Consolidated Case Nos. 87CW067 (Division 2), 88CW100 (Division 2), and 88CW218 (Division 1) and equals total effluent less non-consumable effluent. Total effluent is calculated as the lesser of (1) the District's measured effluent discharged to Monument Creek through Tri-Lakes Waste Water Treatment Facility and (2) 90-percent of the District's average base monthly water use for the previous November through March period. Non-consumable effluent equals pumped Denver Basin ground water that must be relinquished to the stream system, including: 25% of pumped tributary water, variable percentages% of pumped not-nontributary water and 0% to 2% of pumped nontributary water (depending on the various decrees). From 2012 through 2016 the District averaged 654 af/yr of total effluent credit, of which, 46 af/yr was non-consumable and the remaining 607 af/yr was fully consumable, summarized in Table 2-13.

As summarized in Section 2.2.2.1, an average of 354 af/yr of the fully consumable effluent was exchanged by the District in the 2012-2016 period. Typically, the District reuses fully consumable effluent credits by operating their exchange system and for augmentation of the Golf Course ponds, discussed in more detail in Section 3.3.2.1. Less frequently, the District reuses fully consumable effluent credits by selling them to downstream entities.

2.3.2.1 Supplemental Effluent Credits

In order to exchange water at a higher rate than the District's own fully consumable effluent credit allows, the District can purchase additional effluent credits from neighboring entities whose wastewater is treated at either TLWWTP or the Upper Monument Creek Regional Wastewater Treatment Plant (UMRWWTP). These entities include the City of Monument, TriView Metropolitan District, and the Donala Water and Sanitation District. In the 2012-2016 period, the District purchased credits from other entities during two periods: January through May of 2012 and March through May of 2013. Purchased effluent credits allow the District to fill Lake Woodmoor at a faster rate than would otherwise be possible and is advised during drought recovery when there is adequate native flow in Monument Creek to support exchange.

Table 2-13 Summary of Effluent Credits

Water Year	Total Effluent Credit[1] (af)	Non-Consumable Effluent Credit[2] (af)	Fully Consumable Effluent Credit[3] (af)
2001*	474	59	415
2002	569	55	514
2003	547	54	494
2004	526	41	485
2005	564	48	515
2006	595	42	553
2007	659	35	624
2008	690	31	658
2009	648	43	605
2010	659	41	618
2011	648	42	606
2012	632	51	581
2013	634	58	576
2014	657	42	614
2015	654	37	617
2016	691	43	648
2002-2011 Average	611	43	567
2012-2016 Average	654	46	607

Total effluent and non-consumable effluent from the District's monthly Augmentation Reports.

Notes:

1 Estimated total effluent credit equals lesser of the District's measured effluent to Monument Creek through TLWWTP and 90% of the District's average base monthly water use for the previous November through March period, generally based upon "Augmentation Plan II". This column may underestimate the actual historical effluent credit due to improper calculation of available credit.

2 Non-consumable effluent credit equals pumped Denver Basin ground water that must be relinquished to the stream system, including: 25% of pumped tributary water, variable percentages of pumped not-nontributary water, and 0% to 2% of pumped nontributary water (depending on the various decrees) and augmentation obligations that the District has undertaken by lease agreement with various in-District entities.

3 Fully consumable effluent equals total available effluent minus non-consumable effluent. Equals [1] - [2].

* Incomplete data for November and December of 2001 water year. Therefore, 2001 was excluded from the average.

2.3.3 Lawn Irrigation Return Flows

The District can use reusable outdoor use return flows (also known as Lawn Irrigation Return Flows "LIRFs") as an augmentation source to replace evaporative depletions from in-District ponds by direct diversion or exchange pursuant to the decrees in Case Nos. 2010CW28 and 14CW3058. LIRFs result from outdoor lawn irrigation and equal the amount of water estimated to percolate below the lawn root zone and accrue to the stream system over time. The District quantifies LIRFs using a fixed return flow percentage equal to 15-percent of outdoor water use within identified LIRF areas. LIRF areas are located within the Crystal Creek, DWC, and Teachout Creek drainage basins in the District's boundaries that overlie alluvial or colluvial deposits outside of dense tree canopy, shown in Figure 2-7. The LIRF areas comprise approximately 760 acres out of the District's 3,898 acres, or approximately 19% of current District area. Based upon the fixed return flow percentage, total unlagged LIRF credits available to the District for augmentation use under current and build-out conditions equal 18.3 af/yr and 30.3 af/yr, respectively, summarized in Table 2-14. Those annual amounts accrue to Crystal Creek, DWC, and Teachout Creek over time.

Table 2-14 Estimated Unlagged Lawn Irrigation Return Flows (LIRF)

LIRF Areas[1]	Current Conditions within LIRF Areas		Build-Out Conditions within LIRF Areas	
	Annual Outdoor Water Use[2] (af/yr)	Annual Unlagged LIRF[3] (af/yr)	Annual Outdoor Water Use[4] (af/yr)	Annual Unlagged LIRF[5] (af/yr)
Crystal Creek	20.8	3.1	11.2	1.7
Dirty Woman Creek	32.0	4.8	91.8	13.8
Teachout Creek	69.2	10.4	99.3	14.9
Total	121.9	18.3	202.2	30.3

Notes:

1 LIRF areas include areas within the Crystal Creek, Dirty Woman Creek and Teachout Creek drainage basins in the District's boundaries that overlie alluvial or colluvial deposits outside of dense tree canopy. LIRF areas comprise approximately 760 ac out of the District's 3898 ac, or approximately 19% of current District area.

2 Current outdoor water use based upon October 2016 - September 2017 water use data for accounts located within the LIRF areas. Annual outdoor water use equals total monthly water use during the April through October period less calculated average monthly indoor water use, which equals the average monthly water use during the previous November through March period. In the LIRF areas, lawn areas tend to be much greater than other areas in the District and outdoor water use is typically 50% - 75% of total water use, which is much higher than the District-wide average percentage of outdoor water use.For this reason, in the Crystal Creek basin, current outdoor water use exceeds the projection of build-out outdoor water use.

3 Current annual unlagged LIRF equals 15-percent of current outdoor water use. Equals [2] * 15%. LIRFs currently available for augmentation purposes depend on the timing of the LIRFs accretion to the stream system. LIRFs from Crystal Creek, Dirty Woman Creek and Teachout Creek accrete to the stream system over a period of years.

4 Build-out outdoor water use calculated based on total estimated SFE units within LIRF Areas, average water use of 293 gallons per day per SFE, the District-wide current demand distribution (31% outdoor water use), and potable system losses of 6%.

5 Annual build-out unlagged LIRF equals 15-percent of build-out outdoor water use. Equals [4] * 15%. LIRFs available for augmentation purposes during build-out conditions depend on the timing of the LIRFs accretion to the stream system. LIRFs from Crystal Creek, DWC, and Teachout Creek accrete to the stream system over a period of years.

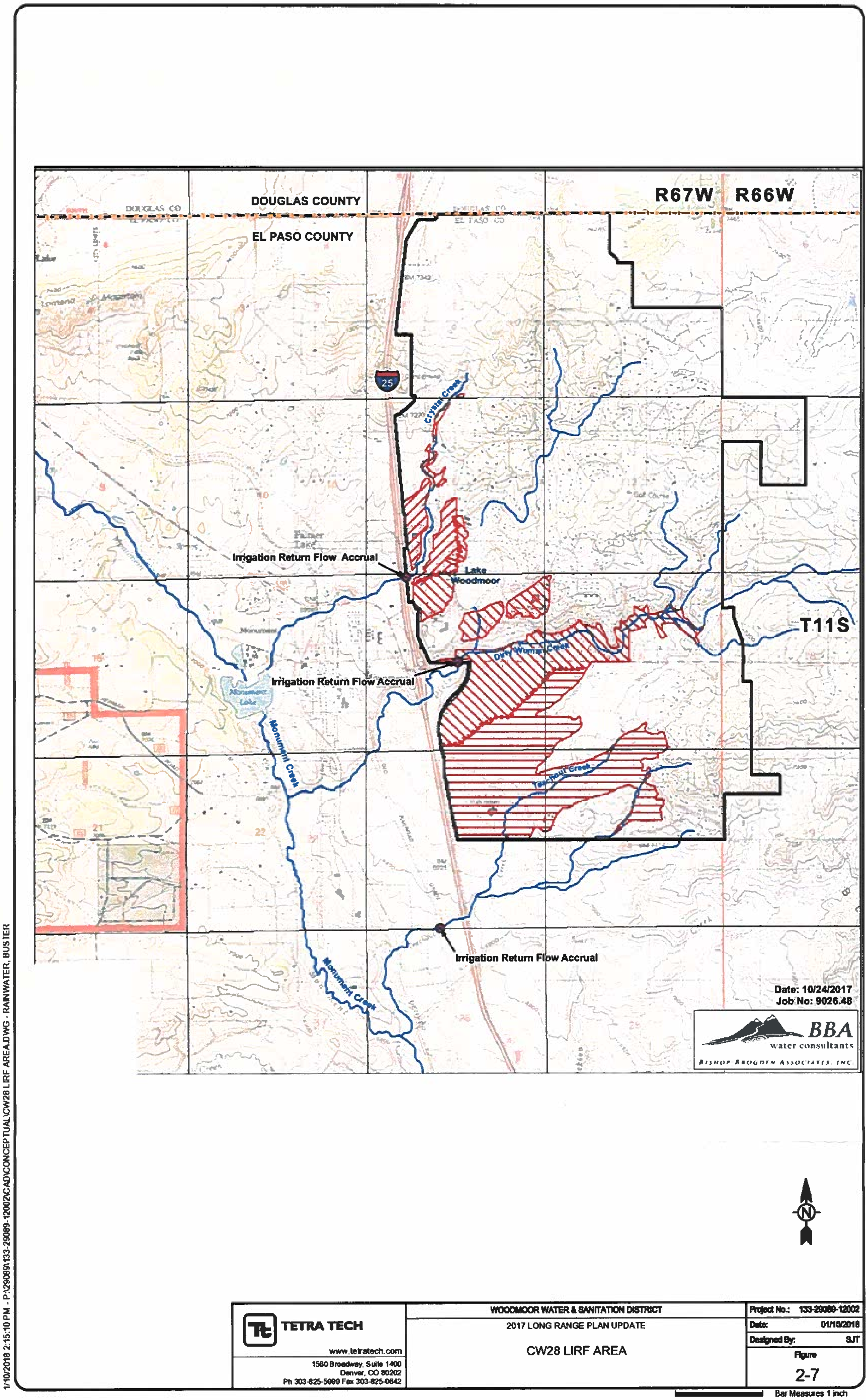


Figure 2-7 CW28 LIRF Area

LIRFs available to the District for augmentation purposes depend on the lagged timing of the LIRFs accretion to Crystal Creek, DWC, and Teachout Creek over a period of months and years. LIRFs are only available for the District's use after they have accrued to the stream. During October 2016 through September 2017 total LIRF accrual was 9.4 af, summarized in Table 2-15. The rate of LIRF accrual will increase over time and ultimately reach the build-out projection.

Table 2-15 2017 Lagged LIRF Credits

Month	Crystal Creek Basin (af)	Dirty Woman Creek Basin (af)	Teachout Creek Basin (af)	Total (af)
Oct-16	0.37	0.59	0.09	1.05
Nov-16	0.27	0.54	0.10	0.91
Dec-16	0.22	0.48	0.10	0.79
Jan-17	0.18	0.43	0.10	0.71
Feb-17	0.15	0.39	0.10	0.64
Mar-17	0.12	0.36	0.10	0.59
Apr-17	0.11	0.33	0.10	0.55
May-17	0.17	0.33	0.11	0.61
Jun-17	0.24	0.37	0.11	0.72
Jul-17	0.37	0.46	0.11	0.94
Aug-17	0.32	0.50	0.11	0.93
Sep-17	0.36	0.54	0.11	1.02
Total	2.89	5.31	1.23	9.44

The District currently uses a portion of the lagged LIRFs to augment evaporative depletions resulting from the operation of three ponds at Monument Hill Country Club totaling approximately 4.4 af/yr (evaportation from the fourth pond is accounted for by the Country Club on a daily basis through reservoir accounting). The remaining LIRFs are available for other pond augmentation purposes, exchange and other uses specified in the Case No. 10CW28 decree.

2.3.4 The Ranch Water Rights

The District acquired the Ranch water rights in 2011. The Ranch is located in El Paso County, near the City of Fountain, as shown in Figure 2-8. Approximately 2,040 acres on the Ranch were irrigated from Fountain Creek through the Chilcott Ditch using Chilcott Ditch, Liston and Love Ditch, Lock Ditch, Lock Ditch No. 2 and Callahan Reservoir water rights. The District is in the process of revegetating certain portions of the Ranch. The Ranch water right amounts and priority dates are summarized in Table 2-16.

On February 7, 2014, a decree was entered in Case No. 12CW01 (Division 2) that changed the use of the Ranch water rights from irrigation to municipal use and other uses. The change of use will allow the Ranch water rights to be diverted from Fountain Creek at their current point of diversion, stored in a reservoir and ultimately delivered to the District via pipeline to meet municipal demands. Until they are needed for municipal use, the Ranch water rights may continue to be used for irrigation on the Ranch.

Future municipal water use of the Ranch water rights will be based upon the terms of the 12CW01 decree and Woodmoor's system for diverting and storing the rights, and will vary from year-to-year with wet and dry cycles.

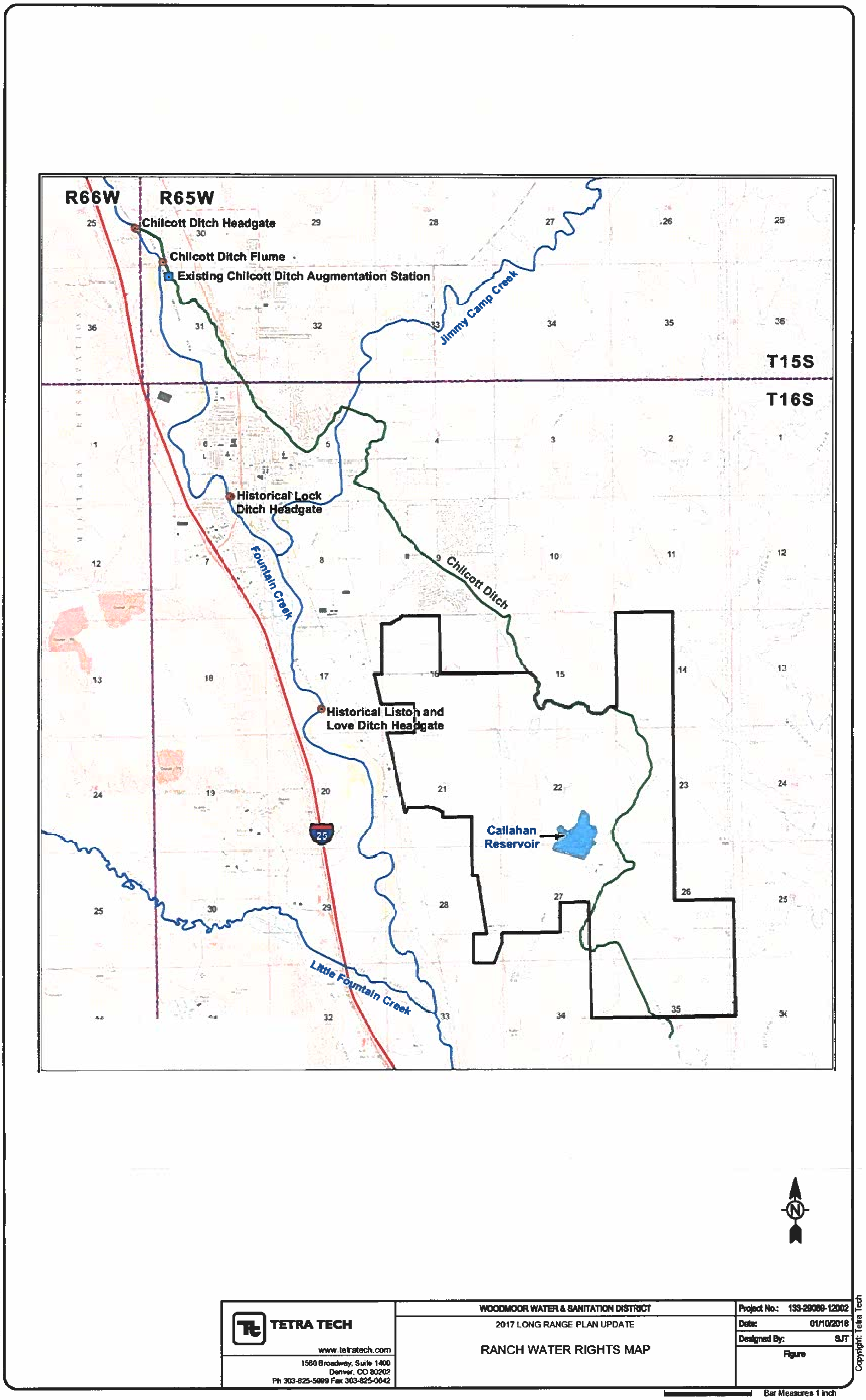
Table 2-16 Summary of Ranch Water Rights

Case No.	Fountain Creek Priority	Appropriation Date	Adjudication Date	Total Water Rights (cfs or af)	District's Water Rights (cfs or af)
Chilcott Ditch Water Rights (Woodmoor owns 58/105 shares)					
CA 751	27	March 21, 1866	February 15, 1882	27.0	14.914
CA 751	39	March 21, 1874	February 15, 1882	20.63	11.396
CA 10146	172	December 18, 1905	June 2, 1919	30.95	abandoned
Liston and Love Ditch Water Rights (Woodmoor owns 75%)					
CA 751	14	March 21, 1863	February 15, 1882	8.82	6.615
CA 751	33	December 31, 1871	February 15, 1882	3.6	2.7
Lock Ditch and Lock Ditch No. 2 Water Rights (Woodmoor owns 75%)					
CA 751	15	December 31, 1863	February 15, 1882	6.3	4.725
CA 751	22	December 31, 1864	February 15, 1882	8.38	6.285
CA 751	45	December 31, 1880	February 15, 1882	5.02	3.765
Callahan Reservoir Water Rights (Woodmoor owns 100%)					
CA 10146	51(2)	November 20, 1909	June 2, 1919	716(1)	716(1)

Notes: District's share of Chilcott Priority 172 was abandoned in Case No. 12CW1.

(1) Amount in (af).

(2) Reservoir priority



1/10/2018 2:17:31 PM - P:\29089\133-29089-12002\CAD\CONCEPTUAL\RANCH WATER RIGHTS MAP.DWG - RAINWATER, BUSTER

Figure 2-8 Ranch Water Rights Map

2.4 WATER TREATMENT CAPACITY

The District operates four WTPs, the CWTP, SWTP, and two small WTPs for Wells 8 and 11. The majority of water introduced into the distribution system is treated by one of these treatment plants. A small amount of water from Dawson aquifer wells is simply chlorinated before being introduced to the distribution system. The CWTP and the facilities for Wells 8 and 11 are equipped to treat only groundwater while SWTP is equipped to treat both groundwater and surface water. The capacities of each WTP are summarized in the sectionsbelow.

2.4.1 Groundwater Treatment Capacity

All WTPs target the removal of iron and manganese, which is commonly found in groundwater from the Denver Basin aquifers. After iron and manganese removal, the water is chlorinated before being introduced into the distribution system. The CWTP utilizes 3 filters each with a treatment capacity of 0.58 MGD each, for a total treatment capacity of 1.74 MGD and a firm capacity of 1.15 MGD. Currently, Wells 7, 15, 16, and 18 produce a maximum of 1.12 MGD leaving 0.60 MGD of capacity available for treatment of future wells. The SWTP utilizes 3 Trident Filters each with a treatment capacity of 1.1 MGD for a total treatment capacity of 3.3 MGD and a firm treatment capacity of 2.2 MGD. There is additional space in the SWTP building for one additional 1.1 MGD filter. Currently, Wells 9R, 10R, 12, 17, and 20 produce a maximum of 1.64 MGD leaving 1.66 MGD of capacity available for treatment of future wells and surface water. Wells 8 and 11 both utilize greensand pressure filters for an estimated capacity of 0.11 and 0.29 MGD respectively. The treatment systems for Wells 8 and 11 are designed to serve individual wells and it is not reasonable to construct transmission lines from new wells to these treatment systems; therefore, there is not considered to be any excess capacity in the Well 8 and 11 treatment systems.

Overall, the District has sufficient treatment capacity to grow to a peak day demand of 3.72 MGD (based on firm capacity) which will occur at 6,045 SFEs based on the 2.1 peaking factor. Based on the current projected growth rate of 3%, the District will exceed 6,045 SFEs in 2030.

2.4.2 Surface Water Treatment Capacity

The SWTP is equipped with alum and polymer feeds to enhance coagulation so it can treat groundwater, surface water, or a combination of both. CWTP does not have this capability. The SWTP treats surface water exchanged directly from Monument Creek or water that is stored in Lake Woodmoor. The exchange system and Lake Woodmoor are relied on for meeting peak irrigation season demands. The surface water treatment capacity of SWTP must be maintained to meet peak demands since the number of wells in the well field (existing and proposed) are not/will not be capable of meeting peak demands solely from the well field. The firm capacity of the surface water supply system of 2.2 MGD (the firm capacity of SWTP) plus the firm capacity of the Wells 7, 8, 11, 15, 16, and 18, which are in the northern part of the system (these wells have a firm capacity of 0.94 MGD). Wells 9R, 10R, 12, 17, and 20 feed into SWTP and cannot be treated if all capacity in SWTP is used for treating surface water. Based on this rationale, the firm capacity of the surface water supply system is 3.6 MGD (the 2.2 MGD SWTP capacity plus 0.94 MGD northern well capacity) Without further expansion, maximum capacity use will occur at 5,851 SFEs based on the 2.1 peaking factor. Using the projected growth rate of 3%, the District will exceed 5,851 SFEs in 2029 based on growth projections in Section 3.

There are two possible improvement projects to increase the surface water treatment capacity. There is space for an additional filter at the SWTP that could be installed to increase capacity by 1.1 MGD bringing the firm capacity of the SWTP to 3.3 MGD to allow for the CWTP to be taken offline while still handling demand of the district. The CWTP could be upgraded to treat surface water by replacing the media in the existing three 0.58 MGD filters. In addition, a pumping station could be added to bring surface water from Lake Woodmoor to CWTP. With these improvements, the total capacity of the system will be 4.45 MGD, allowing the district to treat demand at build-out

(3.8 MGD). In the future, an additional 0.58 MGD filter could be added at the CWTP to make the firm capacity of the whole system 5.05 MGD in order to treat ultimate build-out (4.8 MGD).

2.4.2.1 Summer Lake Woodmoor Operation

During the summer months, the District draws water from Lake Woodmoor that is then treated at the SWTP for distribution instead of relying solely on water from wells to meet demands, which typically is done in the other months. Using water from the Lake in the summer months to handle peak irrigation flows allows the wells to pump at a more constant rate throughout the year, which minimizes stress on the wells. The hydrogeologic modeling performed in the 2006 LRP Update indicated that providing peak day demands from the Lake will minimize the pumping stress on the wells and will prolong the overall life of the wells. Therefore, it has become a District practice to supply peak demands from Lake Woodmoor and not to maintain peak day capacity solely with the well system. In order to use this philosophy, it is critical that the Lake be maintained and operational during the summer months.

In the past, the District occasionally received complaints of odor in its treated water from customers when Lake Woodmoor was used as part of the raw water supply. The issues reported by customers centered on noticeable odors when the hot water was turned on, which was described as ranging from "earthy" to "fish-like" in smell. Taste and odor compounds in drinking water are typically associated with 2-methylisoborneol (MIB) and/or geosmin, which are primarily produced by cyanobacteria (blue-green algae). MIB and geosmin impart an earthy smell to water and have been linked to the smell of bottom-feeding fish, such as carp and catfish. Reports of the smell primarily causing an issue in hot water with less associated odor or taste issues in cold water, suggest that the offending compound(s) is organic and semi-volatile in nature and is consistent with MIB and/or geosmin.

In the summer of 2012, the District started sampling Lake Woodmoor to determine whether the water contained high levels of MIB and/or geosmin. Data consistently showed that geosmin is the main cause of the complaints, which has a taste and odor threshold of 10 nanograms per liter (ng/L). In 2013, geosmin concentrations were as high as 117 ng/L. Elevated geosmin concentrations over the threshold value were also seen in 2014 and 2015; therefore, the District had a number of studies performed to determine treatment options (including addition of ozone) to remove the taste and odor compounds, which will be discussed in Section 3. During two of the studies in 2016 and 2017, the District did not receive any taste and odor complaints and there was minimal geosmin found in the Lake water.

Potential reasons for the improved geosmin concentrations in the recent years may be attributed to the District's implemented BMPs for the lake operations. This includes blending with low nutrient well water, aerating with diffusers and suppressing invasive/noxious aquatic weed growth. Since the implementation of these BMPs, the District has seen a reduction in taste and odor complaints, better mixing and litte, if any, thermocline in the lake, higher dissolved oxygen levels, and minimal to non-detectable concentrations of geosmin and MIB.

Due to the following factors in the most recent study, the District received recommendations to continue the Lake BMP operations and delay the implementation of ozonation at the SWTP.

- Improved Lake operations
- A number of unknowns (such as geosmin concentrations with the implementation of Lake BMPs, bromide concentration range, etc.)
- Reduced taste and odor occurrences
- Requirement to change water chemistry
- Cost of the ozone system

However, its recommended that the District continue monitoring geosmin concentration and influent bromide level to better assess the formation of bromate if ozone treatment treatment is considered in the future for combatting taste and odor challenges.

2.5 DISTRIBUTION SYSTEM CAPACITY

The District maintains and operates a potable water distribution system comprised of approximately 450,000 linear feet of distribution piping ranging from 4-inch to 12-inch piping. The majority of the distribution system (390,000 linear feet) is 6-inch diameter pipe. The distribution system is subdivided into four pressure zones. Zone 1 encompasses the northern area of the District (north of Woodmoor Drive) and is the highest elevation pressure zone. Zone 1 is fed from the North Storage Tank by the North Booster Pumping station (NBPS), which maintains working pressure in Zone 1. Zone 2 encompasses lower elevations immediately to the south of Zone 1 and the eastern border of the District. Zone 2 is fed from CWTP and the North Storage Tank. Zone 3 is located in the southwestern portion of the District and is serviced by SWTP and the South Storage Tank. South Booster Pumping station (SBPS) supplies all water to Zone 4 which is a small pressure zone immediately above the South Storage Tank in the southeastern corner of the District. SBPS can also be used to transfer water from South Storage Tank to North Storage Tank. All of the zones are connected with PRVs to allow higher elevation pressure zones to feed lower elevation pressure zones if needed.

The District uses and maintains a hydraulic model of their distribution system to evaluate new system expansions as well as confirm system flows and available pressure. The model is currently operated using the software InfoWater by Innovyze. InfoWater is a state-of-the-art program that integrates with ArcGIS which provides a graphical representation of the distribution system and allows users to incorporate spatial data to supplement the model. A copy of the hydraulic model was provided to Tetra Tech by the District for the purpose of evaluating the existing distribution system as well as future system changes. The hydraulic model was assumed to be validated for the level of evaluation required to make recommendations to the district for system improvements.

The hydraulic model was used for the purpose of this study to evaluate whether the district has any immediate problems with pressure, fire flow, and/or capacity with existing booster pump stations. A plot of the model with pipes and junctions are shown in Exhibit 2-1.

2.5.1 DBP Formation

Disinfection byproducts (DBPs) are regulated water quality compounds (such as haloacetic acids, and trihalomethanes) that are formed in the distribution system due to residual disinfectant compounds (such as hypochlorite) reacting with residual organic matter. The formation of DBPs is a function of the amount of organic matter in the water, the disinfection dose, and the amount of time the water spends in the distribution system. The District is currently minimizing the formation of DBPs and is in compliance with the maximum contaminant levels (MCLs) for haloacetic acids and trihalomethanes, however, as the District relies more on surface water and less on groundwater in the future, the potential for DBP formation increases. When the District switches to surface water in the summer months, the formation of DBPs is greatly increased indicating that DBPs formation will be more of a concern as more surface water is used.

The distribution system water model can be used to evaluate the water age within the system to help operators balance storing enough water within the distribution system to meet demands and fire flows while minimizing DBP formation. Currently the InfoWater model is not calibrated to accurately perform water age modeling. In order to calibrate the distribution system model for water age modeling, dynamic operations data such as pumping rates, durations, fluctuations in tank levels, and PRV station operations must be incorporated into the model. The calibration for dynamic system modeling should be completed as a miscellaneous project so that the model can be used to predict DBP formation in the future.

Currently the District uses increased sampling frequency at locations within the distribution system that have a high potential for longer water age. This current approach is currently adequate and complies with CDPHE requirements; however, as the system relies more heavily on surface water in the future the potential for DBP formation will increase. The District may find that the calibrated dynamic water model is more accurate and less expensive than increased sampling as DBP formation potential increases with increased use of surface water.

2.5.2 Treated Water Storage

The District currently maintains and operates three treated water storage tanks that have a total storage volume of 2.075 million gallons. The South Storage Tank has a total storage capacity of 1 million gallons and is supplied by the South Water Treatment Plant. There are two North Storage Tanks having total storage capacities of 1 million gallons and 0.075 million gallons respectively. The two north tanks are supplied by the Central Water Treatment Plant and/or from the South Storage Tank via the South Booster Pump Station.

The overall storage volume of the three tanks serves three purposes; 1) provide operational storage volume to offset peak hour demands, 2) provide adequate fire protection volume, and 3) provide enough volume of water to supply the water system during the event of a major power failure or transmission pipe break. Typically operational storage equates to about 25% of the overall treated water storage in a distribution system (about 520,000 gallons). The volume of water necessary to provide fire protection is equal to the maximum fire flow rate the system can provide for the estimated duration that the flow would be provided for. The District's system can provide fire flow at a rate of 1,250 gallons per minute for a duration of 2-hours, which would require 150,000 gallons of fire protection storage. The remaining 1,405,000 gallons of treated water storage is available should a major power outage or transmission line failure prevent the South or Central Water treatment plants from providing water for the duration of the emergency. For the purpose of evaluating whether the District has adequate emergency storage it was assumed that the maximum duration of such an emergency would be 12-hours. Based on that assumption the system has adequate storage through build-out to provide 12-hours of average day demand with their existing storage capacity so long as the South Booster Pump Station would remain operational so that water stored in the South Tank can be distributed to the North and Central Pressure Zones.

2.5.3 Booster Pumping Stations

The NBPS and the SBPS both have adequate capacity to meet current conditions and do not require immediate improvements. The NBPS was expanded in 2004 to a firm capacity of 2,500 gpm, which added adequate capacity to meet ultimate build-out demands. The SBPS has a current firm capacity of 1,060 gpm which provides adequate capacity for the current conditions; however, it will need to be expanded to supply water from SWTP to Zones 1 and 2 as the District's population increases toward current and ultimate build-out. Refer to Section 3 for a description on the recommended improvements for SBPS.

2.5.4 Distribution Pressure and Fire Flow

The District system is comprised primarily of a network of six-inch diameter pipe with some larger pipelines that were placed with the water treatment, water storage and well infrastructure. A 6-inch piping network is not ideal in a system that has to pr ovide fire flow with a given residual pressure due to the lack of flow capacity relative to 8-inch and larger vessels. For example, at 5 ft/second, a 6-inch diameter pipe can transmit 440 gpm of water whereas an 8-inch pipe can transmit nearly double that (783 gpm). This means that for the same flow rate, water in a 6-inch pipe will need to flow almost twice as fast as in an 8-inch pipe. This increased velocity is what causes the rapid pressure loss in 6-inch pipe as compared to 8-inch. The higher pressure losses in a 6-inch pipe network also lead to increased operation and maintenance costs seen in larger pumps required to move a given flow through the system.

A typical design value for available fire flow is 1500 gpm at a residual pressure of 20 psi at all points of service in the distribution system. Given the construction of the system it has been the District's experience that this is not feasible and that a more attainable design value of 1,250 gpm at 20 psi should be set as the controlling design criterion throughout the distribution system. The modeling showed that at current conditions the minimum conditions of 1,250 gpm at 20 psi have been met at all locations showing that there is no need for immediate improvements to the distribution system.